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The European Diving Technology Committee

Technical and Human aspects of Diving and Diving Safety

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FOREWORD

Directorate E of the Directorate General for Employment and Social Affairs of the Commission of the European Communities is concerned with the promotion of improved standards of safety and health in industry. As technological changes occur in industry, new hazards arise and new problems have to be studied and resolved.

The recent growth of exploitation of petroleum and gas from sub-sea reserves has been an important factor in the economic development of several member states of the Community. This new industry has necessitated a considerable amount of diving in difficult and sometimes dangerous conditions which have exposed workers to new risks, the order of which is constantly changing, and as a result a number of accidents have already arisen.

For several years these problems have been extensively studied by both the European Undersea Bio-Medical Society and the European Diving Technology Committee. The Commission of the European Communities had been aware of the elevated accident rate in diving, and accordingly agreed with the above two organisations to jointly arrange a congress on the medical aspects of diving accidents in 1978. This congress was attended by nearly 120 doctors and specialists, and its success encouraged the Commission of the European Communities, to respond favourably to a request from the European Diving Technology Committee, to arrange jointly a further two day International Symposium on the Technical and Human Aspects of Diving and Diving Safety. The programme included material from the sports, scientific and professional fields.

230 experts who are specialists in this field, from 16 countries, attended this Symposium which was held in Luxembourg on 9th. and 10th. October 1980 ; the 16 papers presented at this congress, plus the Chairmens' summaries and the salient points of the discussion are included in the following report of the proceedings.

These papers are circulated in the hope that by the wider diffusion and discussion of their contents, they may add to the general knowledge of the subject and so help to prevent or reduce the loss of life in this dangerous occupation.

I would like to take this opportunity of thanking the authors of the papers and the two above societies for their cooperation in organising this Symposium and helping to make it the success which it was.

Jean DEGIMBE
Director general for "Employment and Social Affairs"
Commission of the European Communities

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by

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SUMMARY

Man has been diving into the sea for 6,000 years but in more recent times, time on the seabed has been extended by using diving bells and eventually the successful commercial diving helmet.

Autonomous diving equipment, free of lines to the surface, culminated in the development of the aqualung (or SCUBA) which is the standard compressed air equipment used by sports divers. Diving clubs and federations sprang up in many parts of the world after the introduction of the aqualung in the early 1950s.

Comprehensive training is provided through amateur diving clubs throughout the world and follows the use of the "basic equipment" of face mask, foot fins and snorkel tube. The diver swims horizontally, using a wet suit to keep warm and a life jacket so that he may return to the surface in an emergency. The breathing of compressed air from the aqualung brings complications which include the possibility of decompression sickness, air embolism and nitrogen narcosis. These can be avoided by training and following the rules of the sport. The aqualung itself consists of a cylinder of compressed air, a demand valve or regulator, which reduces the pressure and supplies it on demand, and a harness to fit the equipment to the diver's back.

Fatalities are generally low where comprehensive training is given and the sport of underwater swimming provides enormous opportunities to explore the seabed and take part in other activities, such as underwater photography.

Many amateur divers have worked on historic wrecks and on studies of pollution around the coasts of Europe.

TECHNICAL INTRODUCTION TO DIVING AND DIVING SAFETY (SPORT)

by

Reg VALLINTINE
Director, British Sub Aqua Club (United Kingdom)

From as early as 4500 BC, man has been diving into the sea - for mother of pearl, for sponges and for food.

The first divers were undoubtedly breath-hold divers but in their necessarily brief forays to the seabed they managed to recover pearls and even sunken treasure.

The first means of prolonging the time on the seabed was provided by diving bells and Aristotle was one of the first to describe these devices, which were merely large open inverted cup-shaped containers that trapped air inside when they were lowered into the sea. The divers could exist for quite long periods in the bells and even make brief sorties outside.

With the renaissance came new inventors designing apparatus that would allow man to walk and move on the bottom and a flood of new ideas was recorded in the notebooks of Leonardo da Vinci. Like earlier drawings, they mostly involved long simple tubes to the surface and would not have worked as the water pressure on the diver's chest would have prevented air from being drawn down more than half a metre.

Diving bells became more efficient over the centuries being fitted with glass windows and other improvements. Gradually the importance of the laws of pressure to diving was realised and one of the best known successful diving bells was produced by the astronomer Edmund Halley in 1715. The air in Halley's bell was repurified with barrels of fresh air. At the same time an Englishman, John Lethbridge, developed a resistant tube in which he was lowered to the seabed, where he could work for limited periods with his hands which were left free outside.

The biggest development was undoubtedly, however, that of the diving helmet by John Deane and Alexander Siebe in the early years of the 19th century. Air was pumped down to the helmet, which rested on the diver's shoulders and was attached to a rubberised diving suit that allowed the diver considerable mobility. The standard helmet diving suit remained until very recently the normal method used by commercial divers throughout the world.

The dangers connected with breathing compressed air were first explained by a French scientist Paul Bert in "La Pression Barometrique" published in 1878. Seventy-nine per cent of our atmospheric air is nitrogen and when compressed air was used to prevent the diver from being squeezed, Bert discovered that it began to dissolve in the fatty tissues. If the diver returned to the surface too quickly, the excess nitrogen formed bubbles that could damage the nervous system and block the circulation of the blood. The disease became known as decompression sickness or colloquially as "the bends". Bert's answer was to raise the diver very slowly so that the nitrogen would gradually escape through his system as he breathed and if bubbles had already formed, to "recompress" the diver in an air chamber to force them back into solution. Tables were developed by John Scott Haldane in England; these form the basis for the diving tables of all the world's navys.

In 1825 another Englishman, William H. James, designed a self-contained compressed air diving apparatus in which the air was held in a circular iron reservoir worn around the diver's waist. It was never used, however, and so the credit for the first autonomous walking dress should go to an American, Charles Condert, whose suit incorporated a flexible helmet with a continuous airflow from a horseshoe-shaped reservoir. Condert walked over the bottom in a suit made of gum elastic. A glass plate was fixed opposite his eyes. Unfortunately, he suffered an accident while underwater in 1832, which resulted in the breaking of the tube to the reservoir and a quick death! The first practical semi-autonomous air diving apparatus was devoloped by a French mining engineer, Rouquayrol, and Lieutenant Denayrouze of the French Navy in 1865. The diver was provided with a metal canister on his back which contained air at a pressure of forty atmospheres. Their most important development was a "regulator" between the canister and the breathing tube in which a membrane was subject to pressure on one side from the water and on the other, from the air breathed by the diver. When the diver breathes in, the air side was at a lower pressure and this caused the membrane to move and open the valve to let in more air. When the diver exhaled, the valve closed and the excess expired gas escaped from a "ducks beak" valve. This was the first demand valve which automatically adjusted the pressure between the air inside and the water outside.

Autonomous apparatus using pure oxygen was also developed in Britain and in Germany and in 1918 an apparently successful compressed air device was patented by Mr Ohgushi of Japan. It was known as Ohgushi's Peerless Respirator.

All diving equipment up until this time had been designed for use either by the inventor himself, or by professionals. The first man to envisage a large number of amateur divers taking to the sea was Yves Le Prieur, who began diving in 1905 with the French Navy. He became interested in some extremely light-weight equipment produced by another Frenchman, Maurice Fernez, and together they produced apparatus which consisted of a cylinder of compressed air attached to the diver's back. By 1933 it was being worn with a mask which covered the whole face and around which bubbles of air escaped. In 1935, he founded the first amateur diving club in Paris. In 1933, Commandant De Corlieu marketed foot flippers or fins and the diver moved from the vertical to the horizontal. In 1932, Alec Kramarenko, an expatriate Russian, used a mask with a single pane covering both eyes, which prevented the double-vision given by goggles and Maxim Forjot patented a mask which also included the nose and which thus allowed the diver to blow a little air into his mask to prevent it squeezing into his face under pressure. The first truely successful aqualung was produced by Georges Commeinhes, whose father ran a business manufacturing valves for mining equipment. His fully automatic aqualung worn with a full face mast and a demand valve (regulator) mounted between the shoulderblades was approved by the French War Office in 1937 and manufactured until Commeinhes death in the battle for the liberation of Strasbourg in 1944.

Another Frenchman had also been searching to develop an easy efficient aqualung. He was Jacques Cousteau, a French Navy Officer. In 1942 he met an engineer, Emile Ghenan, and together they produced a version of a "demand regulator" with two breathing tubes, one for inhalation and one for exhalation, linking the rear of the cylinder to the diver's mouth. The development of the aqualung opened the underwater world to millions for the first time and their enthusiasm was kindled by the books and films of Cousteau and the Austrian, Hans Hass.

The aqualung became known in America as SCUBA (for self-contained underwater breathing apparatus). The sport of underwater swimming became the fastest growing of all the sports in the 1960s and 1970s and the potentially dangerous nature of the activity lead to the production of manuals and the formation of aqualung or scuba diving clubs in which beginners could share their training and experience. The first aqualung club was formed in Cannes by Broussard in 1946 and by 1948 their were eight clubs in existence in France with over seven hundred members. The French Federation was formed in 1955 and became the recognised body for amateur diving in France. Early aqua lungs were bought in France by visiting sportsmen who often returned to form clubs in their own countries. The aqualung became available in Britain in 1950 and a number of clubs and schools sprang up. In 1953, the British Sub-Aqua Club was founded in London and soon after it was decided to form branches in other cities. The Club now has over one thousand branches in twenty-seven countries and is recognised by the Sports Council as the Governing Body for the Sport in the United Kingdom. Throughout the country, BSAC branches were helping local authorities, police and museums with projects ranging from the recovery of bodies to replacing sluice valves in reservoirs. The aqualung had become a working tool as well as a means of merely enjoying the underwater world.

In many countries in the early 1950s, divers were obsessed with the new sport of spearfishing which had developed from the early efforts of an American, Guy Gilpatric, in the French Riviera, and which was normally practised without an aqualung, the use of which was felt to be unfair to the fish. Spearfishing using just the "basic" equipment of mask, fins, breathing tube and a simple spear or speargun provided a tough and adventurous sport which gave participants stamina in the water and a unique knowledge of the sea and its larger inhabitants.

The fastest growth area for the sport was in the United States, and particularly in California, where the aqualung was introduced in 1949. By 1955, twenty-five thousand aqualungs had been sold worldwide, eighty per cent of them in California and the U.S.A. had more divers than any other country in the world.

At first the "club system" was widespread in the U.S.A. but as the sales of equipment grew, a new phenomenon the "dive shop" began to spread. Most shops had an attendant "pro" instructor whose job besides coaching, was to sell the equipment. The real force in American diving, apart from the commercial influence of the huge manufacturing and retailing companies, developed in the new instructor organisations. NAUI (the National Association of Underwater Instructors) was formed in the late 1950s as a non-profit educational corporation of professional underwater instructors, certifying its own candidates through a six day course and examination. NAUI Instructors have now trained over seven hundred thousand American divers.

The Professional Association of Diving Instructors (PADI) was formed in 1966 and membership was obtainable on the strength of other recognised instructor qualifications and through a PADI Instructors' Institute. Other instructor orientated organisations in the U.S.A. include the YMCA and the National Association of Skin Diving Schools.

All instructors in the U.S.A. are permitted to qualify basic divers and issue them with a "C" (for certification) card which they then obtain from the parent organisation. The C card is a very basic qualification and some holders may have had very little open water experience.

Since the early years of the sport, holiday diving organisations and schools have existed and provided training for beginners in the sport.

The first and largest of these is the Club Mediterranee.

Within local diving clubs, members train for qualifications and national federations provide examinations to qualify instructors. The more advanced of such instructors are considered competent to run diving schools and to instruct in them.

The World Underwater Federation or CMAS (Confédération Mondiale des Activités Subaquatiques) was founded in 1959 in Monaco by representatives of fifteen countries and with Jacques Cousteau as President. It is composed of properly constituted and recognised national federations whose representatives meet every eighteen months at a General Assembly. Between these times an elected Executive Bureau works on more pressing and immediate problems. The World Federation has three main committees: Sports, Technical and Scientific. For many years the Sports Committee dealt with the annual World Spearfishing Championships and now also covers the competitive sports of finswimming, underwater orienteering and underwater hockey. The Technical Committee deals with aqualung diving and techniques and recently established international standards through which nationally qualified divers and instructors may be provided with World Federation certificates and cards, giving evidence of their standards worldwide.

The President of the World Federation is Maitre Jacques Dumas of France and the address of the Confederation is 34, rue du Colisee, 75008 Paris.

Snorkelling and Diving Standards

Most diving clubs and federations throughout the world expect a basic swimming standard from the beginner. This swimming test generally consists of swimming certain distances in pools, use of a weight belt, floating, treading water and recovering objects from the bottom of a swimming pool.

In a diving club every member should be able to help another in an emergency. This is unlike the situation in the holiday diving school, where the professional instructor takes responsibility and so less initial ability is required and the beginner may be trained successfully under more controlled conditions. Holiday diving schools often aim to provide a quick and safe basic training course and some interesting holiday diving as an introduction to the sport. They then advise the holiday maker to return and join a diving club for further training.

Diving schools may also exist outside the holiday sphere and cater for the person who needs a full-time course leading to a national sport-diving certificate but who has not the time to go through a standard club training. "Recognised Schools" in each country can provide this elementary training and further information will be given on this question later in this Congress.

It is essential that those taking up the sport are given expert tuition, either through the recognised national federation and its clubs, or through recognised schools with qualified instructors.

The first "swimming" test is not a race but checks that the potential diver is "at home" and competent in the water. Training then usually continues in the swimming pool where the new diver gains confidence with the unfamiliar equipment.

Training is provided cheaply by local clubs or branches, who meet at pools for one or two training evenings each week. Weekend dives are then organised at the sea or inland open water areas. Film shows, lectures and other social events are usually part of the programme of every diving club and make the most enjoyable and perhaps thorough way of taking up the sport.

Equipment

After the swimming test, the diver must master the "basic equipment" of face mask, foot fins and snorkel "tube".

The fins, which are used in a wide slow crawl kick provide the propulsion, and leave the diver's hands free to be used for holding other equipment or investigating the seabed. The mask provides clear vision underwater. Without it, objects would appear blurred as the eye is designed to function in air. The mask should cover the eyes and nose, a single pane preventing the double-vision that comes with goggles and it should be possible to blow air into it through the nose when necessary. Modern masks also feature two indentations which allow the diver to squeeze the nose through the mask and thus "compensate" or equalise the pressure on the ears. The snorkel tube provides a means of easy breathing through the mouth while lying weighted on the surface without the need to turn the head to breath.

It is vital to become as competent as possible with these three items of diving equipment. When divers can swim strongly with them, they should be able to "swim their way out of trouble" whether or not they are also wearing an aqualung. Once a snorkeller goes out into open water, whether in an inland lake or in the sea, a "wet" suit will soon be needed to protect against the cold and from sharp rocks and animals. In principle, the wet suit lets in a little water but this soon warms up to body heat. In practice, with a well-fitting suit, very little water will find its way in.

"Variable volume" or "inflatable" dry suits, which are worn comfortable and dry, but are more expensive and more complicated to use, are also available. They are used by divers who are spending long periods in cold water.

The full wet suit normally includes jacket, trousers, hood, "booties" and gloves.

Once the diver has a wet suit, a weight belt and weights will also be needed to allow re-adjustment for excess buoyancy. The belt should have an easily operated "quick-release" and should be worn so that it falls away from the diver if released in an emergency.

A diver's lifejacket is a very useful, if not vital, addition. Surface lifejackets will keep a diver afloat on the surface where most initial difficulties are likely to occur, but will not operate efficiently at depth. Most experienced European aqualung divers favour the more expensive "adjustable buoyancy" lifejackets (ABLJs) which are known as "buoyancy compensators" in the United States. These contain a small bottle of compressed air which can be filled from an aqualung before a dive and will inflate the jacket to bring up a diver from depth in an emergency.

It is essential to wear a depth gauge and a diving watch when aqualung diving.

Before introducing the aqualung or SCUBA equipment and the hazards connected with it, it should be mentioned that even snorkel diving with the simple equipment described above does involve hazards.

The pain in the ears when going down is caused by water pressure distorting the ear-drum inwards. By holding the nose and blowing gently against the pressure, air can be passed through the eustachian tube to the other side of the air drum. The pressure is then equalised, the pain disappears and the diver can continue downwards.

The mask compressing on the face is due either to the pressure of the water increasing on descent or more often because a diver has inadvertently breathed in through the nose. This should be corrected by blowing a little air out through the nose to adjust the pressure.

Snorkellers may take one or two deep breaths before duck diving down but continued "forced breathing" or hyperventilation can result in light-headedness and in the warning of the 'need-to-breath' mechanism in the body being put out of action temporarily. This means that there is no warning of black-out if the breath is held for too long. Unconsciousness underwater is far more serious than on land, leading rapidly to death from drowning.

Snorkellers frequently suffer from cold as they are not limited by the amount of air that they have with them and are often engrossed with the activities of fish below. The sea, which can develop unpredictable currents and sudden squalls, must always be respected and local information should be obtained before leaving the beach.

The state of the surface should be checked regularly during the swim and, as in all sportsdiving, a companion should be taken and information left on the shore as to the planned route.

In Britain, a BSAC National Snorkellers Club for juniors exists to provide tuition in safe snorkelling for those too young to undertake aqualung training.

As previously mentioned, snorkel divers may take part in a number of competitions including spearfishing and finswimming. The latter involves surface racing using large fins and is normally organised in olympic-size pools. Underwater hockey is also played in swimming pools by breath-hold divers and in this game a lead puck is pushed along the bottom towards goals at the pool ends. Underwater rugby is also played in pools in three dimensions.

A number of specialists have set depth records without the aqualung, such as a dive to one hundred metres by yoga expert Jacques Mayol in 1976.

There is some doubt, however, as to how much pressure the human body can resist when lungs are filled with air at amospheric pressure, and for this and other reasons, such records have not been encouraged by the World Underwater Federation.

Depth records with the aqualung were also attempted in the early days of the sport, but these proved even more dangerous. Maurice Fargues, a compatriot of Cousteau, died at one hundred and twenty metres, the cause of death being almost certainly nitrogen narcosis, a form of depth drunkeness. These sort of attempts have been likened to putting one's head in a gas oven, turning on the gas, and guessing how long one can retain consciousness.

Underwater technique competitions are organised using the aqualung and involve navigation underwater. Competitors swim with a specially prepared panel of instruments which record direction, speed and distance.

Aqualung Diving

Most snorkellers, sooner or later, wish to proceed to the aqualung which has the enormous fascination of providing long periods on the bottom and the thrill of the sensation of being weightless during underwater "flight". It has been aptly described by Cousteau as the "passport to Inner Space".

To learn the techniques of aqualung or SCUBA diving, the snorkeller should be in good health and have reached the age of fourteen. A competent instructor is also needed. One of the great advantages of the aqualung is that it allows divers to breath in air at the same pressure as the water through which they are swimming. They, therefore, never suffer from the massive "squeezes" that sometimes affected helmet divers. The human body, being largely composed of water, is virtually incompressible. Pressure does, however, affect the air in the lungs, small cavities behind the ears and in the sinuses.

The breathing of compressed air brings other complications though, including decompression sickness, which has already been referred to. Little harm is caused as long as the diver takes enough time on the ascent to prevent the formation of nitrogen bubbles due to rapid change of pressure. The decompression tables, which are generally produced by the World's Navys, give an exact indication as to the length of time it is possible to stay at each depth and when it is necessary to make decompression stops near the surface to eliminate excess nitrogen. Generally, sportsdivers do not undertake decompression stops as all their dives may be undertaken within the "no-stop" curve of the tables. American Navy diving tables are widely used internationally, however, the only Navy diving tables specifically designed for amateur divers are those produced by the Royal Navy Physiological Laboratory in conjunction with the British Sub-Aqua Club.

Divers who break these rules may suffer from the "bends" which can cause pain, paralysis, or even death, depending on where the bubbles lodge in the body. The best cure is to rush the victim to the nearest recompression chamber, where they can be rapidly pressurized again in air and then very slowly "decompressed" until all the symptoms have disappeared and they can be returned to surface pressure again.

At greater depth, divers will suffer from "nitrogen narcosis", an effect on the brain resulting in slow thinking, apprehension and confusion. This is also described as depth drunkeness, and more poetically by the French as "rapture of the great depths". In the less poetic Royal Navy, it has always been referred to as "the narcs" and stiff-lipped sailors were often loath to report its symptoms and effects. Nitrogen narcosis is particularly dangerous to aqualung divers, who are dependent on keeping their breathing mouthpieces in place with their teeth, and on swimming and calculating on the bottom. The easy cure is a return to a higher level where the symptoms disappear leaving no after-effects. It is generally accepted that the use of compressed air is acceptable down to depths of fifty metres, from which depth onwards the effects of nitrogen narcosis rapidly increase.

The aqualung provides air "on demand" to the diver, each breath is thus provided at the same pressure as the surrounding water. Because of this, the diver must not hold his breath when swimming up to the surface; otherwise the air in the lungs will expand with the drop in the surrounding pressure, causing eventual rupture of the lungs. This is a serious condition generally known as Air Embolism. In the unlikely event of a complete air failure, therefore, the diver should either share another diver's aqualung or return to the surface breathing out all the way up.

In spite of these dangers, aqualung diving is one of the safest sports and the equipment is extremely reliable. The accidents that do occur are usually due to a diver's thoughtlessness or to changing weather conditions.

The Aqualung

The modern breathing set has three main components, a cylinder of compressed air, a demand valve which includes a mouthpiece for breathing, and a harness to attach them to the diver's back. In the United States, cylinders are generally known as "tanks" and the demand valve as a "regulator".

The cylinders are constructed of steel or aluminium and they are designed to contain pure breathing air at pressures of one hundred and fifty to two hundred atmospheres. They are filled from specially designed compressors, which incorporate filters to prevent impurities that could make the air toxic at depth. Each cylinder has a valve at the top end which the diver opens before diving.

The demand valve reduces the air pressure from the cylinder and supplies it on demand. The basic mechanism surrounds a rubber diaphragm which is in contact with the water. A small lever is in contact with the diaphragm and when the latter moves in with the diver's inhalation, it automatically opens another valve to let more air in. The original type of demand valve had two breathing tubes - inlet and outlet, leading from the small breathing mouthpiece round to the diver's back where the main demand valve was situated. This type is still used, however, more recently a single-hose model with a diaphragm in front of the mouthpiece has been developed.

The exhaled air rises through the water in large flattened bubbles and these can often be followed on the surface in calm weather. This is the main reason why the aqualung is not used for military operations. Every aqualung should have a system to give the diver warning when his air is getting low. This either takes the form of a gauge which shows the remaining air pressure at all times, or a device which comes into operation when the pressure drops to a certain level, giving warning that it is time to surface.

The harness consists of two shoulder straps to attach the breathing set to the diver's back and a strap round the waist or between the legs to stabilise it. A weight belt is also worn in such a way that it can be dropped and will fall free when released in an emergency.

Other necessary items of equipment include a depth gauge and diving watch or dive-timer, from which decompression and bottom time can be calculated, and a knife to be used in case of entanglement. A lifejacket or buoyancy compensator is strongly advised for the experienced diver. Special training is advisable if the more effective "ABLJ" has been bought, as this is capable of bringing the diver up from depth at potentially dangerous speeds. In tidal waters, sportsdivers often drift across the bottom holding a reel with a line to a small diver marker buoy on the surface. A light diving boat can then follow this buoy and be in position to pick up the divers wherever and whenever they surface. The buoy and the boat should show a reproduction of the international code "A" flag, which means "I have a diver down, keep clear and at slow speed". Divers operating at specific sites, such as wrecks, and with larger boats will usually anchor and descend down the anchor line to the bottom.

One of the secrets of successful diving is to be able to relax, always keeping energy in reserve for a possible emergency. Over-exertion can lead to a build-up of carbon dioxide and breathlessness. By carefully adjusting weights and other buoyancy factors, a diver can become virtually weightless, a very pleasant sensation shared with astronauts. In fact for this reason, aqualung diving is part of the obligatory astronaut training.

The trained diver can overcome most hazards and the apparatus is remarkably reliable and adaptable. If the air fails, or has been completely used up, two divers can "share" together, passing one breathing mouthpiece between them and taking two breaths each. Instructors now sometimes use a second mouthpiece which fixes directly to their demand valve for use by another diver in an emergency. This is known as an "Octopus" rig.

If water leaks into his mask, the diver turns on his back, presses his fingers against the top of his face plate and blows air through the nose. This excess air then blows away any water through the bottom of the mask.

One of the most important rules is "never dive alone". Each pair, or small group of divers, should have a recognised leader, and communication underwater is by international hand singles.

Boat-Diving

Larger diving boats are equipped with spacious ladders to allow divers to climb on board while still wearing fins, but much sportdiving is done from smaller inflatables with outboard engines. The divers then travel, facing inwards, sitting on the inflatable's sides and roll backwards into the sea for their dive. Inflatables have proved very useful for the majority of divers who are based inland, as they are easily transportable, sea-worthy, fast and manoeuvrable. On a dive, the boat-handler will stay near the divers' buoys, positioning the boat near them should another craft approach too close and threaten to run over them. Although divers may have little need to swim on the surface in these conditions - merely signalling on their return to the surface that they are ready to be picked up - they may have to surface-swim when diving from anchored boats or when an inflatable loses contact with their buoy. The diver thus always takes a snorkel tube which will allow comfortable breathing on the surface when weighed down with cylinder and weight belt and in waves.

Safety

Amateur diving accident statistics have been collected worldwide by the University of Rhode Island and in Britain, the BSAC keeps a careful record of accidents and incidents. Fatalities are generally low when their is comprehensive training. For example, BSAC fatalities as against the total membership for the last six years are as follows:

1974 - 22,150 members, 3 fatalities;
1975 - 23,204 members; 2 fatalities
1976 - 25,310 members; 4 fatalities
1977 - 25,342 members; 3 fatalities
1978 - 25,884 members; 6 fatalities
1979 - 26,531 members; 5 fatalities

The majority of those who died in recent years had become separated from their companions, whether underwater or during the ascent. The commonest cause of non-fatal accidents in recent years has been due to ignoring time and depth on the bottom, resulting in decompression sickness.

Opportunities

Underwater swimming is not just a healthy and enjoyable sport in itself, giving the diver the opportunity to explore a virtually new world, but is also a means to engage in other more specialised activities such as underwater photography, archaeology, or studies of animals and the marine environment. Not only have many ancient wrecks been located by amateur divers, but they have also subsequently been successfully excavated by them. Underwater archaeology needs responsible club divers and in Britain a diving archaeologist is usually assigned to advise such groups who are allowed to continue to survey and excavate their wreck under guidance.

The comprehensive amateur training provides a good basis for those considering entering the commercial diving scene and is accepted as such by recognised commercial diving schools.

Besides working on historic wrecks, such as the "Mary Rose", which went down in the Solent in July 1545 while sailing out with the British Fleet to intercept marauding French men of war, the British Sub-Aqua Club divers have organised their own expeditions. In 1974, a thirty-six man club expedition went into the Arctic Circle to look for the remains of HMS "X5", a British midget submarine that had disappeared while attacking the German battleship Tirpitz in 1943. Diving in near freezing conditions, they discovered the remains of an "X" craft and raised it to the surface. The remains are now in the Imperial War Museum in London, and the expedition proved that amateur divers could make unique contributions to the historical record.

Dr David Bellamy of Durham University was one of the first to realise the potential of thousands of aqualung divers and used them successfully in a number of studies of pollution round British coasts and also in

Europe. The divers collected recognisable marine animals such as starfish and mussels, which gave indications of the amount of toxic matter in the water. The specimens were sent to the University for analysis and provided the first comprehensive figures on pollution off British coasts. By 1978, amateur BSAC divers were taking part in expeditions as far afield as the Chagos Archipelago in the middle of the Indian Ocean, where a joint Forces and BSAC expedition studied these little known islands and reefs.

The future for amateur diving is bright as the younger generation looks more and more towards the new "exploration sports" and especially this one that gives opportunities for discovery in a completely new world. The work of the pioneers, Hass and Cousteau, has resulted in millions discovering for themselves the excitement of this undersea world.

INDUSTRIAL DIVING

by

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For man, the sea long represented a universe full of dangers on to which one did not lightly venture, even though in ancient times a number of attempts were made (in particular, it is said, an attempt by Alexander the Great). Later there were the activities of Arab pearl or coral divers, and during naval battles brave men sometimes slipped under the water in order to hole the hulls of enemy ships. But these were single and infrequent occasions which did not require breathing apparatus but only physical ability.

It was only after the Renaissance, particularly in the 18th century, that attempts were made by men to dive under water in barrels converted into diving bells. The French term 'scaphandre' (scaphe: ship, andros: man) was invented in 1775 by the Abbé de la Chapelle. From this time onwards hesitant steps were increasingly taken, leading, approximately a century ago, to the creation of an apparatus akin to the hard-hat diving gear with which we are familiar, and it was in this form that diving slowly developed and that the diver's equipment gradually evolved.

The invention of this apparatus meant that a new stage had been reached, because man could now enter the water and move beneath it (not without some difficulty) for short periods. But as diving depth increased new difficulties arose. Physical problems (mainly decompression incidents) deriving from the human constitution itself presented a new obstacle to underwater diving. Certain inexplicable phenomena, termed 'caisson disease' ('the bends'), were noted in workers in pressurized chambers. Paul Bert and later John Haldane pinpointed the cause of these complaints and discovered how to avoid them, thereby marking another step forward. But hard-hat diving gear did not lead to any great expansion in underwater activity because of the weight of the surface equipment and underwater equipment needed, the difficulty of moving while wearing an outfit of this kind, and the great skill needed when using such equipment in order to avoid accidents. So, we can safely say that for several decades diving vegetated. Heavy underwater work was carried out by a very few divers in shallow waters and only exceptionally at depths which would at the time be classed as great.

Certain people continued to look for a way to enable man to move freely under water without links to the surface. Between the two World Wars, Le Prieur devised a diving suit which, once the Cousteau-Gagnan demand valve was invented, became the self-contained underwater breathing apparatus (Scuba) with which we are familiar. This was the start of a wide expansion in military and scientific diving, as well as diving as a sport. From this point on, man could move freely under water.

Shortly after the Second World War a fixed-volume diving suit was perfected which might roughly be described as a compromise between the hard-hat diving gear and the Scuba since it is a dry suit in which a demand valve similar to that used in the Scuba ensures that the volume of air entering the suit is in relation to the submersion time.

This diving suit, which has the advantage, as compared to neoprene suits, of providing better heat insulation and avoiding any contact between the water and the body, enables the diver to work for long periods in colder and polluted waters.

In France this invention led to a rapid and large increase in underwater work because the equipment was easy to manipulate. This suit therefore became a much used item in civil engineering, and is now very often combined with an umbilical (gas and heating supply line) and a telephone to ensure that work on the surface and under water is properly coordinated. Professional diving thus increased and underwater techniques for civil engineering works also expanded. When discussing industrial diving, it should be borne in mind that a large portion of such activity is carried out in waters of medium depth.

At the same time attempts were being made to dive ever deeper, and a new physical barrier was encountered, that of nitrogen narcosis. Once again, having overcome equipment problems so that he could now go deeper, for longer periods and move more freely under water than ever before man suddenly found himself faced with a new barrier at approximately 60 metres depth. New gas mixtures were thus needed which did not have the same effect on the nervous system as nitrogen, and the result was that bi-mixes (He, O_2) or tri-mixes (He, O_2N_2) began to be widely used for descents beyond 60 metres.

Before the war experiments had been carried out, in particular in the United States, on helium-based synthetic mixes, which had shown that diving using such mixes was perfectly feasible.

For about 20 years experiments in diving to greater and greater depths were of interest only to research workers or to the armed forces, since it was rarely necessary for underwater work to be carried out at more than 60 or 80 metres depth. From the 1960's onwards things changed radically. The discovery and exploitation of oil deposits in shallow waters suggested to an enlightened few the need to seek ways of allowing men to work for long periods at great depths because, with the demand for energy constantly increasing, land-based oil deposits were limited, whereas large quantities of oil were surely hidden beneath the oceans. Very soon, they thought, man would have to seek his energy sources, and later on perhaps his raw materials too, on the ocean beds. Preparations had to be made, and all over the world more and more tests were carried out which rapidly led to actual operations.

The various complementary tests carried out in several countries (it would take too long to enumerate them all) improved knowledge of diving physiology, showed up the successive obstacles which had to be overcome, and made it possible to draw up decompression tables, tables for the compression process, saturation methods, and diving equipment. In France, the Physalie series of brief experiments aimed at testing procedures for going to ever greater depths, brought to light the High Pressure Nervous Syndrome (trembling, variations in EEG readings, but no behavioural disturbances) which was later subjected to closer study.

In 1968, a depth of 335 metres was reached and it was found that speed of compression influenced the appearance of HPNS symptoms.

In 1970, the 520 metres point was reached, and although HPNS symptoms were very marked, they still did not lead to physical and psychological disturbances or have any affect on the diver's health.

In 1972, a depth of 610 metres was reached.

The Physalie experiments were supplemented by the Sagittaire series of experiments (still using a chamber) aimed at testing human behaviour over long periods at a given pressure; these included physical endurance tests.

1971	300 m	25 days
1972	500 m	

During these experiments, extremely strict medical supervision produced a whole host of measurements and confirmed that after a certain time the HPNS did not further increase.

Operation Janus was more specifically aimed at testing, on an operational scale, deep-working potential and working periods.

Janus II, carried out in 1970, consisted of 34 hours of actual work by two men in one week at a living depth of 200 m, and a working depth of 250 m.

In 1975 a real operation was carried out in Labrador at 326 m depth in water at a temperature of – 2°C, with 4 actual hours work during a period of ten days.

Janus IV (1977) following a first phase of experiments and personnel selection in a chamber, involved 10 hours work at 460 m, carried out in 5 dives in teams of 3 men and one excursion to 501 m. This experiment showed that it was possible to overcome the HPNS and to carry out useful work at such depths. It also showed that only certain individuals specially chosen for their physical aptitudes can achieve a performance of this kind without thier work being impaired.

Lastly, reference may be made to the recent American experiment at 650 m using a tri-mix (7.7% nitrogen) which totally prevented the HPNS. This is clearly a great step forward.

During these experiments, progress in equipment was also made. It had already appeared to be dangerous and cumbersome to send a diver to depths greater than 90 m with only his individual equipment. It was dangerous because even the most harmless incident could lead to an extremely serious or even fatal accident, given the pressure barrier which had to be broken in order to reach the open air, and it was cumbersome because of the very long periods of decompression needed under water even for short jobs at such depths. So diving bells, including spherical bells, were developed which really guaranteed safety. As things stand, self-contained diving is still practised at depths beyond 60 m and up to 90 m using gas mixes, but these can only be very short operations, because of the small reserve gas supply. There are, however, some situations in which a very good diver may prefer to operate using a self-contained outfit rather than with an umbilical.

In most cases of short dives using a gas mix, it is more reassuring to use an umbilical which provides permanent contact with the diver. But, once again, decompression times are such that this system can only be used for short dives. This is the reason for the development of the spherical bell, which guarantees better safety and comfort to the diver, and especially for the design of the diving bell proper, since it enables the diver, when he has finished his work, to enter a dry environment immediately, and to be then transferred into a chamber where he can perform his decompression procedure.

For the diver who is linked by umbilical to his bell, which is itself supplied with gas and heated, we can safely say that whatever the depth he is working at the open air is at the end of his umbilical since, in case of accident, he only has to cover approximately 20 m to reach a dry environment. But 'bounce' diving using gas mixes is for practical reasons restricted in terms both of duration and area because of the decompression time needed (e.g. 25' at 120 m requires seven hours decompression).

There comes a stage when it is useful to have the diver live at a pressure corresponding to the working level by installing him in a living chamber. He is decompressed and brought back to surface pressure several days or even several weeks afterwards. This is called the saturation method (because the diver's body is saturated with inert gas), and the diving bell is then no more than a lift used to go from the surface to the sea bottom and to provide the diver with a dry shelter.

As the equipment became better and more sophisticated, greater knowledge became necessary. At the same time the technique of saturation in surface chambers (in contrast to underwater saturation chambers) developed, as did the equipment needed to monitor and regenerate the atmosphere, and all this required an increasing application of electronics. Other barriers, such as helium heat loss, had to be overcome and this was done by perfecting heating systems for diving suits and for breathing gases. Finally, new tools were designed which were suited to offshore petroleum work and which could operate at great pressures.

In the past, the overcoming of each obstacle was followed by long periods of development. Equipment breakthroughs were followed by phases of progress in the understanding of physiological phenomena and vice-versa. In this short period of less than twenty years, however, progress was made quickly in both areas at the same time.

Industrial deep-sea diving developed on the job by repeated trial and error, as is always the case when a new technology is born under the stimulus of adventurous and brave pioneers. This was not achieved without risks being taken, particularly since the obstacles to be surmounted were huge.

Without the bravery and innovating spirit of the first divers the offshore petroleum industry would not have been able to expand as it has, even in the notoriously difficult conditions which exist in the North Sea.

However, there are severe restrictions on the use of divers. Some of these are caused by the marine environment - currents, storms, cold. Others are due to the physical structures present: it is risky to use unwieldy heavy equipment such as diving bells around complex installations. The diver needs, in order to carry out his work, considerable surface back-up because the volume of equipment to be moved is often enormous. A barge for underwater work may in some ways be compared to an inverted pyramid. For a team of two men working at the sea bottom, approximately 60 to 80 men are needed at the surface: diving technicians, divers, barge team, crane operators, etc. This shows how well prepared the diver's work must be if expensive loss of time is to be avoided.

Deep-sea diving is no longer simply a diver's job, but that of a whole back-up team, made up of highly qualified technicians. Even if it is still the diver who must shoulder the risks involved in diving, it is no longer he who dictates his dive but the technicians who have more specific knowledge and who have come a long way from the mere diving-suit tenders they were before. As has always been the case at the inception of a new technology, the pioneers move forward inch by inch, and then the industrialists take over to organize, codify, regulate and analyse the problems.

We are still more or less at this stage. The technology exists, but it needs to be given a clear form if it is to develop. We also need rules for the protection of the divers because diving remains a dangerous activity.

As we have seen, throughout man's progress in his adventurous discovery of the sixth continent, material and physiological factors have always been closely interrelated. This means that in the safety rules which are being or will be drawn up, the following points should be taken into consideration:

- precautions for equipment manufacture, rescue procedures and periodic checks;
- methods to be used with the above equipment or with compression techniques, decompression techniques and techniques of living in saturation chambers;
- medical supervision (selection and then check-ups).

But drawing up rules on how to use equipment and on diving methods is not enough to guarantee divers' safety. For this, the latter must be perfectly trained, both as divers (ability to move under water while working), and as users of increasingly more complicated equipment (technical training).

This training also concerns, and to a very high degree, the people who are in charge of conducting the dive: the diving supervisors, chamber masters, etc. Clearly, this training must cover the topics which will be discussed during this meeting:
- equipment,
- methods,
- training.

Attention should also be given to the likely progress in human operations under water. This will be the subject of lectures to be delivered at the end of this conference.

Because rapid solutions had to be found in order to carry out certain underwater tasks in the petroleum exploration and construction industries, divers were called upon, and efforts were made to increase their deep-water operating capability. Apart from certain complicated or technical operations such as pipe-welding, however, the tasks which divers are generally asked to perform are in themselves simple:

- observing and measuring (on drilling sites, and when platforms are being positioned);
- opening and closing valves (in pipe-laying, and jacket positioning);
- placing in slings, bolting, cutting;
- checking (anodes, plate thickness, etc).

For observation and measurement tasks, manned vehicles or remotely-controlled vehicles are already widely used. A start has been made on the construction of wellheads situated within pressure-resistant enclosures in which men can work at normal atmospheric pressure.

Atmospheric diving suits (ADS) are also being perfected and normal pressure welding can be carried out in water- and pressure-resistant hulls.

If work has to be carried out at ever greater depths, and even if the technical and physiological problems posed by man-based operations are solved, the question arises as to whether divers will still be used. Certainly, as working depths increase, the diver's work will become more expensive and difficult. It is highly probable therefore, that, as has been the case in every industry, a stage will be reached at which remote control and automation will cost less than using men. Once these procedures have been perfected for use at great depth, they will become less expensive to use in shallow waters.

We should not deduce from this that the age of the diver is past. There will very certainly be fields in which preference will be given to human intervention, especially in what might today be termed medium depths (300 m). Similarly, this does not mean that the feasibility of men reaching and working at depths beyond 500 m should not be examined, because however sophisticated equipment becomes, there will always come a time when human intervention is necessary, and there is no doubt that the exploitation of the oceans will expand, even if not as soon as was once thought. Human intervention will doubtless not take the form that we are familiar with today, and it is then that we will truly be able to speak not of divers but of aquanauts.

Industrial history shows generally that any technical advance does away with certain tasks and jobs, but at the same time gives rise to other more complicated ones.

What do the pioneers of airmal services across the Andes and today's airline pilots aided by automatic pilots and a whole host of radio or radar aids to navigation and landing have in common? Do not the air traffic controllers, who bear the very heavy responsibility for regulating air traffic, remind one of the surface technicians who are responsible for supervising dives?

I think we can say that industrial diving is, comparatively speaking, at a half-way stage between the first airmail services and modern air traffic, since it still depends on personal endeavour, and I believe that it will progress towards an increasingly high level of technology which will be accompanied by efforts at international organization and coordination. This is clearly the goal pursued by the E.D.T.C.: to coordinate existing methods, whilst at the same time paving the way for the future.

DIVING ACCIDENTS

ACCIDENTS IN DIVING

by

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SUMMARY

The intention of this paper is to provide the necessary background information on diving accidents against which one can appreciate the following papers on statistics, lessons learnt, preventative measures introduced and summary of existing regulations.

It is also hoped that this paper will provide some of the reasons for the firm action that is being taken on training for the professional diver and why particular lines of research have been initiated.

The paper will contain a complete brief of all known diving fatalities involved in oil and gas operations in Northern Europe since 1971.

This paper will also describe the "serious" and "minor" accidents that occur in the offshore diving industry.

Brief coverage will also be given of the inshore diving industry accidents that have occurred in the United Kingdom and may be accepted as reflecting the problems the inshore industry throughout Europe.

The diving accidents encountered in sport diving will also be discussed.

DIVING ACCIDENTS

by

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PAPER

Details of diving accidents are not always easily obtained even in the world of professional diving. I therefore propose to concentrate on the diving fatalities that have occurred in the offshore industry between 1971 and the end of 1979 in the British, Norwegian, Irish and Dutch sectors of the North Sea.

Detailed statistics and the details of the action that has been taken as a result of the lessons learnt from investigations into these accidents are dealt with in later papers.

During the period 1971 to 1979 there were a total of 45 fatalities in the areas that I have mentioned.

In February and again in March 1971 a diver was lost in the Norwegian sector, diving to a depth of 200 feet on both occasions. Unfortunately firm details of these accidents are not known but it is certainly suspected that had the use of a diving bell been mandatory, at least one of these fatalities may not have happened.

In November of 1971 a diver was lost on the drilling ship Glomar III in the British sector diving to 275 feet. This accident occurred before there was any safety legislation covering diving in the offshore areas. The accident was investigated and a fatal accident inquiry was held but neither the diving team or the police were versed in the problems of deep diving and many of the details are lacking.

In this case the man had dived to over 250 feet for quite a long time the previous day and in less than 24 hours he dived again to 275 feet where he once again spent longer than was planned and according to the evidence, surfaced rapidly. Once again a diving bell was not employed.

In 1972, working in the British sector a diver was drowned whilst operating in 44 feet and there is every reason to suspect that he was inadequately trained and had had no experience.

We are still covering the period when there was no legislation covering these activities but already some avenues for improvement in safety coverage was showing.

In August 1973 a diver operating from a barge in the British sector and working at 320 feet using a new designed helium reclaimation equipment lost his life due to a suspected inadequate equipment design. In many ways this was an unfortunate set-back because helium is a finite source and its conservation is essential both for economy and conservantion reasons.

It is only now that we are seeing the re-introduction of much more sophisticated helium reclaimation breathing systems.

In December 1973 a diver, carrying out a comparatively simple task at a comparatively shallow depth of 60 to 70 feet, cut his life-line and communication line and was lost. At the time it was considered that although he was an experienced diver he must have panicked for some reason or other. With the experienc and the knowledge that we now have it would seem that his "illogical action" was almost certainly caused through the onset of hypothermia. He had carried out the first dive and although shivering to the extreme volunteered to do the second dive. This reflects the attitude that existed in those days. A diver had to be rough and tough. We now know some of the dangers of cold and that irresponsible behaviour can be a symptom of the onset of hypothermia.

In January 1974 two divers operating from a drilling rig in the Norwegian sector lost their lives due to an accidental surfacing of a diving bell with the bottom door open. This accident was probably caused by a failure of communication within the diving company. Details of a modification to the bell weights slipping device had not reached the actual operators.

In April 1974 a diver operating from a drilling ship in 300 feet of water lost his life due to a variety of errors. The diving team was multinational, they had been working up in preparation the actual task required, the fatal dive was in fact the first operational dive. The diver who was French was attended by a bellman who was Scandinavian. The supervisor was French and the rest of the team were English. The diver left the diving bell and went to his task and was observed on the underwater television to be working very hard. His respiratory rate also suggested that he was working too hard. It would appear, that the diver, due to over-enthusiasm worked far too hard and encountered respiratory fatigue. He then returned to the diving bell in a hurry but failed to take the clear route back and passed the wrong side of one of the bell guide weight wires. The bellman attempting to haul him into the bell by his umbilical was in fact hauling the diver under water due to the turn round the bell weight wire. A certain amount of panic occurred during which the individuals reverted to their own language and it ended up by the bellman cutting the diver's umbilical, shutting the bottom door of the diving bell and telling the surface to recover them to the surface. The diver's drowned body was found on the bell weight when it surfaced.

Diver number 10 was operating on a pipelaying barge in the British sector of the North Sea diving in 200 feet and suffered a form of decompression sickness on surfacing. Due to his obesity there was some delay in getting him into the chamber where he died. The Post Mortem result and a check back on his medical history showed that he was not only unfit to dive through obesity but that he had a history of heart problems about which he had been informed. The introduction of diving safety legislation aims to prevent persons who are unfit from diving.

Diver number 11 was a most unfortunate fatality. The man was diving to 490 feet and contracted a Pheumothorax during his decompression. This condition was recognised by the diving supervisor but the doctor who was called was inexperienced in diving medicine and failed to recognise a classic class of Pheumothorax in a pressure environment. Instead he diagnosed pneumonia. The supervisor acting on the advice of the medical officer decompressed the diver who unfortunately died.

Diver number 12 was working on or near an installation in the Norwegian sector at a depth of 300 feet but through an error in communication when ordering the gas, and the fact that the supervisor did not test the gas before use, he was fed pure helium instead of an oxy-helium mixture. He died from Hypoxia.

Fatal casualty number 13 was really a surface accident where the casualty was with another diver carrying out a task in shallow water on one of the legs of the rig. It would appear that the "swimming attendant" had problems with his breathing. It is probable that he was washed against an obstruction on the rig leg where he sustained broken ribs. Attempts to recover him onto a platform on the rig leg aggravated the situation. Whilst being towed back to the diving basket for recovery he drowned.

In October 1974 there was another fatal casualty to a diver operating on the Ekofisk Pipeline and it is suspected that he died from Asphyxia.

Casualty number 15 happened in the Irish sector. The diver was operating from a bell and had his umbilical severed, probably my the movement of the diving bell against some underwater obstruction. It is of interest to note that when the body was recovered the emergency gas supply had not been used.

In December 1974 a diver was inspecting a pipeline, which was at atmospheric pressure, in 100 feet of water. Sometime previously a valve on the pipeline had been damaged possibly by the vessel's cables or by fishing boat trawl boards and, when the diver knocked the valve, it came off the pipeline and he was trapped by suction and died.

In March 1975 a man died whilst operating at 460 feet and the only thing the Post Mortem showed was suggestions of Annoxia. The situation was that the heating system for the diver had broken down and he was diving in 460 feet without external body heating. It is known that he made himself heavy to enable himself to carry out the hard work necessary. The breathing gas contained adequate oxygen for the depth. It was extremely difficult to find the cause of this accident. The diver was certainly very cold. We know that one's oxygen uptake can double under these circumstances. The only hypothesis that can be put forward is that the diver during the onset of hypothermia overworked and the combination of high oxygen uptake for cold and the requirements for high oxygen uptake for hard work, the diver possibly beat his ability to take up oxygen although it was available in the gas.

Casualty number 18 was in fact a natural causes accident where the diver operating at 140 feet encountered Pulmonary Oedema caused by Cardiac Myopathy.

In June 1975 a diver operating from a barge in the Norwegian sector was carrying out a visual survey of the bottom which was at 69 metres from his depth of 50 metres when he slipped his lifeline and failed to surface. Almost certainly this apparantly irresponsible action was due to nitrogen narcosis and, in my opinion, lack of responsible supervision.

Casualties number 20 and 21 occurred in Scapa Flow and were caused by incorrect operations of valves on a pipeline which produced differential pressures thereby sucking both divers into the pipe.

In February 1975 a diver operating at 140 feet in Stavanger Fjord slipped his helmet and his body was not recovered. This fatality was almost certainly due to lack of training of the diver.

In September 1975 two divers had carried out a successful and comfortable dive to 390 feet and having returned to the surface, minor difficulties were encountered in locking the diving bell to the compression chamber. It was the practice in those days to concentrate on avoiding the problems of cold. The living habitat was maintained at a high temperature because, it was generally considered that cold was the worst enemy and almost invariably divers returned to the surface cold after a deep dive. On this occasion the divers were in fact quite comfortable, but due to an accumulation of errors they were shut in the living chamber which was at a very high temperature without the facilities of moving into the much cooler and damp transfer under pressure chamber. They died from over heating. This was the first incident encountered in the offshore industry where overheating was the cause of an accident. In fact it was not until the next day, after the Post Mortem, when even the possibility of hyperthermia was considered.

Fatality number 25 occurred in the Dutch sector to a diver operating in very shallow water and about to carry out some underwater welding. The body was never recovered and the reason for this accident is not really known.

Accident number 26 occurred in January 1976 to a diver operating at a depth of 480 feet. It is possible that whilst turning around in the diving bell the diver accidently switched off his own gas supply by knocking a "ball valve" into the closed position. The diver left the bell and very soon ran out of main gas, and either his neck seal inverted or he tried to remove his helmet and drowned. Once again it is of interest to note that the emergency gas supply was not used.

In the same month two divers were operating at 240 feet from a diving bell which employed the technique of underslung weights. There was a need for the bell to be moved closer to the actual diving task. The bell was moved with the bottom door open but due to "seabed suction" on the bottom weights the slings parted and the bell became buoyant and surfaced rapidly causing the death of one of one of the divers due to Pulmonary Baratrauma and caused almost complete paralysis of the other.

Casualty number 28 happened in the British sector in 120 feet of water. Once again, due to enthusiasm, the diver operated longer than he should have done in a tidal area and when his umbilical became foul he could not reach the surface and was swept away and drowned.

In May 1976 a diver died from Pulmonary Baratrauma possibly caused by too rapid ascent, lung abnormality or lung collapse.

Casualty number 30 happened in the British sector to a diver operating on the SBM at Anglesea. Death was due to drowning and it is possible that freezing in the second stage of the demand valve of his air breathing set caused the accident but it has not been possible to re-construct this incident in the laboratory.

In July 1976 a diver operating from a barge in 51 feet of water lost his life due to Cerebral Annoxia because of equipment design failure.

In November 1976 two divers were lost on the surface in very bad weather. Again in December 1976 another diver having completed his dive was unable to re-enter the diving basket because of the bad weather and, having disengaged his lifeline, was lost from sight and the body was never found. It was presumed that he died from drowning and exposure or possibly was run down by the standby vessel.

Casualty number 35 actually occurred to a bell man. The bell was at 500 feet and it would appear that for some unknown reason the bell man fainted and fell into the bell trunking and was drowned. This particular fatality is a very worrying one in as much as we do not know the reason for the man fainting.

Fatality number 36 happended to a diver operating at 75 feet working on the stinger of a pipelaying barge. He was using SCUBA equipment with a free mouth piece and whilst he was experiencing the use of deep diving equipment, he was certainly not in practice with a free mouth piece SCUBA equipment. Death was due to drowning.

Fatality number 37 occurred in the South Western Approaches of the English Channel where a diver operating at 300 feet, due to an equipment deficiency, lost his helmet and was drowned.

In October 1977 a dredging barge operating in the Dutch sector deployed a diver in 100 feet of water where his umbilical became foul and his pipeline cut. Death was due to Asphyxia. It would appear that the diver did not attempt to use his emergency gas supply.

Fatality number 39 happened in 100 feet of water and unfortunately I do not have all the details of that accident.

In January 1978 a diver lost his life whilst diving to 1000 feet in the Norwegian Fjord during a demonstration of underwater welding at that depth. The reason for and the cause of death has been extremely difficult to establish but it is possible that the casualty could have been a "CO2 retainer" if indeed there is such a person. Research is still continuing into this particular problem.

In 1978 a dynamically positioned vessel was blown off station whilst 2 divers were operating at 380 feet. All connections with the diving bell was severed and 3 separate means of recovery were cut. Unfortunately both divers died during the time taken to relocate and recover the diving bell. Almost certainly the cold played a major part in this accident.

In May 1979 a diver operating in 102 feet in the Southern gas field lost his life by drowning due to his helmet either being blown off or pulled off.

The last two fatal accidents that happened in 1979 were in the Thistle Field in the British sector when 2 divers were lost when their diving bell became disconnected from surface support. This accident is still under investigation and the fatal accident inquiry has not yet been held but I can say that it did not happen from a dynamically positioned vessel and, unfortunately, cold was once again a predominant factor in the cause of death.

DIVING STATISTICS

by

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SUMMARY

Other presentations at this Symposium will be concerned with technical aspects of diving, with accidents and ways of preventing/minimising them and with the role of various Authorities.

Statistics in relation to diving have been inadequately handled in the past and it is considered important and timely to try to rectify the position.

It has been said that statistics, like politics, is the art of presenting information to show that the impossible is possible or vice versa. This is not the purpose of this paper, which is to present in an authorative manner as much pertinent information as possible on the industry/sport so that considered judgements may be made, based on facts as opposed to hypothesis.

The presentation will consider commercial, sport and scientific diving over a period of about 10 years with particular emphasis on numbers of divers in each category and the fatal accident position.

Sport diving and diving by scientists in support of scientific activities is carried out in the air diving range (to depths less than 50 metres) in all but a handful of cases and usually in the summer months under

favourable environmental conditions (either inland in lakes or rivers,or offshore). Such activities are growing in popularity and are likely to so continue in all European countries.

Commercial diving is carried out in all European countries in lakes and rivers in support of civil engineering activities and in docks and harbours in all sea-bonded (littoral) states. Apart from military operations, the vast majority of offshore diving is carried out in support of Hydrocarbon Exploration and Exploitation activities. The extent of these is obviously dependent on deposits which exist offshore particular States in their own section of the Continental Shelf.

Mixed gas diving is generally carried out in water depths in excess of 50 metres and consequently reference to this technique will only apply to those European states having deep water and commercial interests in it.

Figures are still being collected and analysed but it is planned to be able to present a comprehensive picture of the growth of commercial, sport and scientific diving in all European states and to relate this to fatal accident figures.

Tables are being prepared for presentation at the Symposium with a view to showing the present and historical position.

On the commercial side, reference will be made to the considerable growth in size of the offshore diving industry and of the steps which have been taken to improve its productivity and efficiency against a falling fatal accident position.

Finally, it is planned to relate European statistics to world wide figures, if possible, in relation to all three sectors - commercial, sport and scientific.

It is to be hoped that the figures which will be presented will not only be of interest to symposium delegates but will also help to set in perspective other more technical topics, relating to diving, which will be considered at the symposium.

PAPER

DIVING STATISTICS

Tom Hollobone
Secretary
Association of Offshore Diving Contractors

1 INTRODUCTION

This paper aims to set down some of the basic facts and figures on the subject of diving. There is no central source from which high quality data can be obtained, and this lack of basic information has arisen for a variety of reasons, not least of which has been the rapid growth of the oil related offshore diving business, the relatively small size of some of the contractors, a fluctuating pattern of employment and, particularly in the past, a relatively high movement of personnel connected with it.

This paper sets out to fill in some of the gaps. During the course of its preparation and of the very extensive background research and enquiries, it became more and more apparent that much basic information just does not exist. Much of the commercial information, particularly in relation to offshore oil and gas related diving, has been supplied by UK and Norwegian based diving contractors, but the tables which follow show an almost complete lack of information from other European sources. In order to complete the scenario, short sections have been included in this paper on sport diving, and on diving in support of scientific activities.

2 COMMERCIAL DIVING

i) Introduction - Commercial diving work is carried out in all littoral states, at inshore and inland sites, in docks and harbours, and on continental shelves of some, principally in support of offshore oil and gas operations. This paper does not consider all European countries, but aims to include all of those which bound on the North West European Continental Shelf area.

ii) Inland, Inshore, Docks & Harbours - Diving has been carried out in support of civil engineering and salvage activities in relatively shallow waters and in the air diving range for many years.

Table 1 shows the approximate number of air divers employed between 1968 and 1980 working inland, in docks and harbours, and on shallow inshore works (generally non oil and gas).

Offshore diving work tends to be concentrated during the summer months, when weather and sea conditions are most attractive. The same does not hold true, however, in relation to inland/ inshore diving activities which are carried out on a "round the year" basis, depending on local circumstances. The figures shown should

TABLE 1

Approximate Number of Air Divers Working, Inland; In Docks & Harbours; and Inshore (Non Oil & Gas)

	1968	1970	1972	1974	1976	1978	1980
Belgium	12	15	20	25	30	30	40
Denmark	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eire	N/A	N/A	N/A	N/A	20	N/A	70
France	N/A	N/A	N/A	N/A	N/A	N/A	N/A
West Germany	N/A	N/A	N/A	800	800	800	800
Italy	120	120	150	150	180	200	200
Netherlands	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Norway	250	300	300	350	400	450	500
Sweden	200	200	200	200	200	200	200
UK	700	700	700	700	700	700	700

N/A = Figures Not Available

therefore be regarded as approximations at any time in the year.

Because most of this type of diving work is carried out by relatively small diving contractors, it has been very difficult to put these figures together. They should not be regarded as authoritative, but only indicative and clearly show, if nothing else, that very poor information is available.

iii) Offshore Diving - Air & Mixed Gas - This section is concerned with diving work which is related to offshore oil and gas operations and includes diving using compressed air and mixed gas. Diving in support of offshore hydro-carbon recovery in the North West European Continental Shelf area started in the mid 60's and Table 2 gives population figures for 1968 to 1980.

As for inland/inshore diving, figures are not available from a number of littoral states and have been shown as zero for three others.

Notwithstanding the lack of information, the main activity is clearly in UK and Norwegian waters. The population for these two countries has been lumped together, principally because many diving contractors work in both sectors. It is difficult, authoritatively, to split the population on a yearly basis between the two, but as a rule of thumb, a rough division of 25-30% Norwegian/70-75% UK can be taken.

The UK and Norwegian figures have been subdivided into High and Low, representing maximum summer and minimum winter populations. It should be appreciated however that the number of divers actually working offshore at any moment in time will be less than 50% of these figures shown for a variety of reasons, including work/leave rota's; sickness; onshore or offshore support and others.

Table 3 gives a more detailed breakdown for the years 1977-1980 for air; mixed gas divers; offshore support personnel; and finally total air and mixed gas divers.

These two Tables quite clearly show the relationship between the diving population using air and mixed gas techniques, and the growth in numbers, in particular for mixed gas divers, from the early 1970's through to a peak in 1978. Since then there has been a falling off in numbers, but it is no part of this paper to discuss the reasons for this or to consider future trends.

Tables 2 and 3 do not include base personnel, offshore project management staff, management staff, and others.

iv) Export of Diving Services to Other Parts of the World - For a variety of commercial reasons, a number of UK based contractors have been developing markets for their services in other parts of the world away from the North West European Continental Shelf Area.

Table 4 shows approximate numbers of divers working out with the N.W.European area, but supported from a UK or Norwegian base for the years 1977 to 1980. These figures clearly show some considerable growth, both for air and mixed gas divers and less fluctuation between the (H)

TABLE 2

Approximate Number of Offshore Divers Working in Support of Hydrocarbon Activities (Air & Mixed Gas)

		1968	1970	1972	1974	1976	1978	1980
Belgium		0	0	0	0	0	0	0
Denmark		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eire		N/A	N/A	N/A	N/A	N/A	N/A	N/A
France		N/A	N/A	N/A	N/A	N/A	N/A	N/A
West Germany		0	0	0	0	0	0	0
Italy		70	70	90	110	130	130	140
Netherlands		N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sweden		0	0	0	0	0	0	0
UK & Norway	(H)	250	400	600	900	1500	1800	1450
	(L)	N/A	N/A	N/A	N/A	900	1050	800

Notes:

1) (H) = Maximum number "employed" at the height of the summer season

2) (L) = Maximum number "employed" during the winter period

3) N/A = Figures not available

TABLE 3

Approximate Number of Offshore Divers and Support Personnel Working in UK & Norwegian Waters

		1977	1978	1979	1980	
Air	(H)	450	500	530	450	
	(L)	230	200	210	200	EST
Mixed Gas	(H)	1100	1300	1100	1000	
	(L)	750	850	600	600	EST
Support Personnel	(H)	650	760	550	500	
	(L)	400	450	320	300	EST
Total Air & Mixed Gas	(H)	1550	1800	1630	1450	
	(L)	980	1050	810	800	EST

Notes:
1) (H) = High - Maximum number "employed" at the height of the summer season
2) (L) = Low - Minimum number "employed" during the winter period
3) Support Personnel include Supervisors; Linesmen; Life Support Technicians; Chamber Operators & Others
4) EST = Estimate for Winter 1980

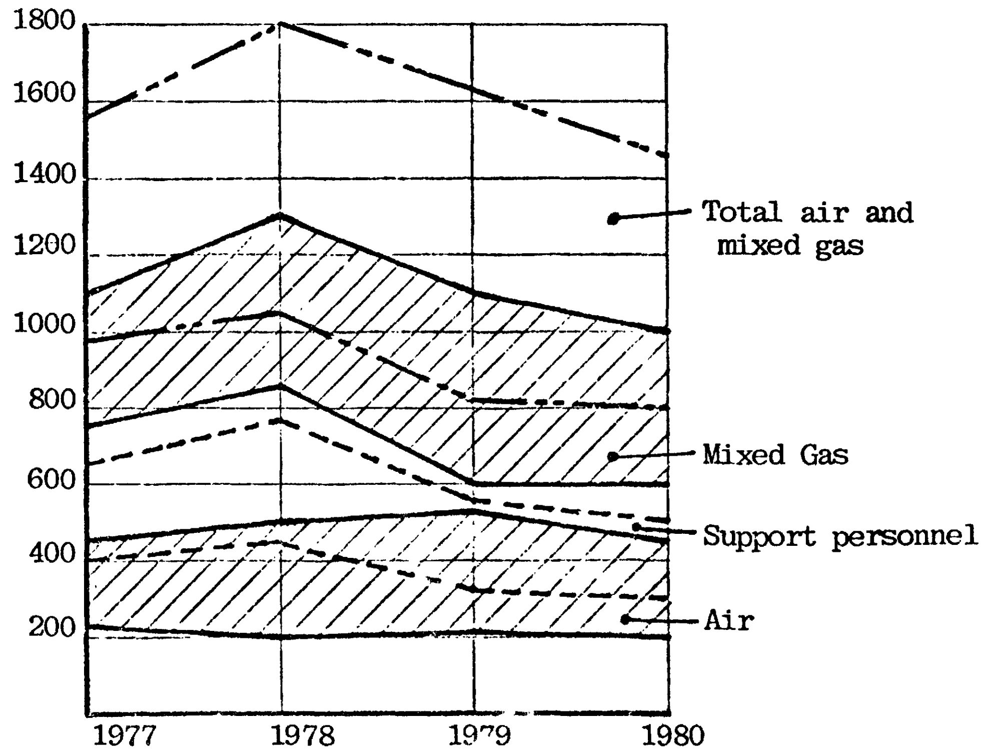
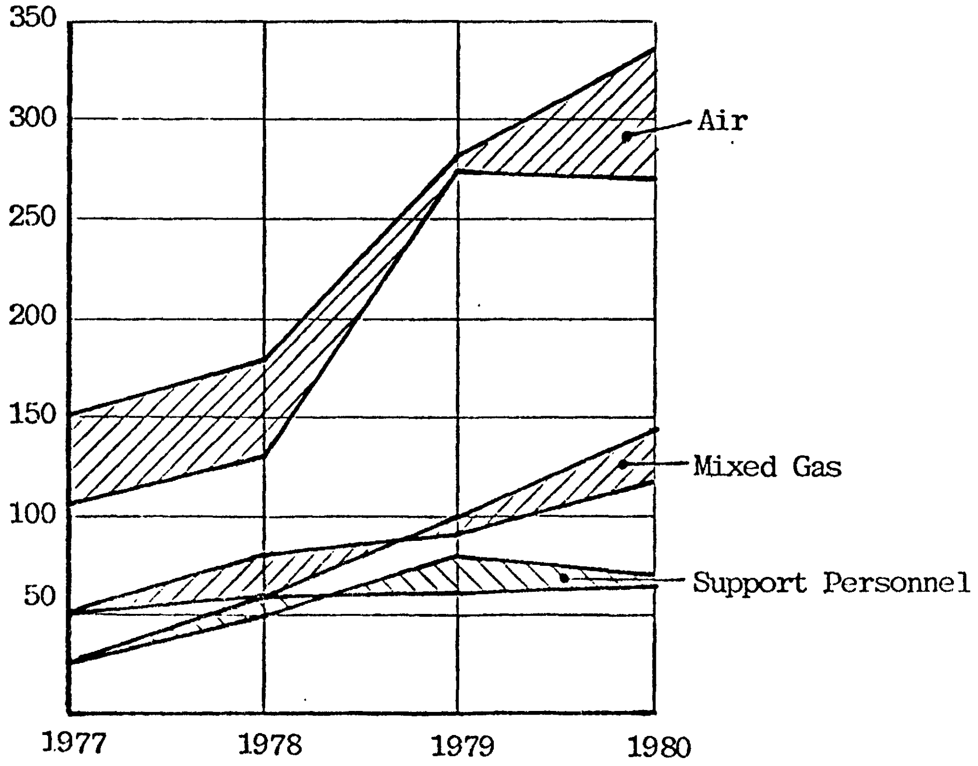


TABLE 4

Approximate Numbers of Divers Working Elsewhere in the World but Supported From a UK or Norwegian Base

	1977 (H)	1977 (L)	1978 (H)	1978 (L)	1979 (H)	1979 (L)	1980 (H)	1980 (L) (Est)
Air	150	105	178	130	280	275	333	268
Mixed Gas	50	50	60	80	100	90	144	115
Support Personnel	25	25	50	60	80	60	70	65

Notes:
1) (H) = Maximum Number
2) (L) = Minimum Number
3) Est = Estimate for Winter 1980



and (L) figures than for the "North Sea Year".

Apart from the commercial considerations, the figures indicate the high standard of the diving services being provided by these contractors and, as a consequence, their ability to seek and carry out work away from their home base.

By addition of the (H) numbers from Tables 3 and 4, we arrive at the following figures for maximum number of offshore divers employed by UK/Norwegian contractors (both air and mixed gas) in home waters and overseas.

TABLE 4 (A)

Years	1977	1978	1979	1980
Numbers	1750	2038	2010	1927

These total figures clearly show a more even overall pattern than that exhibited by Table 3.

v) Figures Available from Medical Records - As a means of checking on the population figures shown in Tables 1, 2, 3 and 4, enquiries were made regarding availability of medical records for divers. All countries in the area require commercial divers to have at least yearly medical examinations, and it was thought that an analysis of centrally stored figures would be useful. Time has only permitted a check on the UK position, and Table 5 shows a record of the number of divers' medicals carried out in the UK from 1973-1980.

At the time of writing this paper, two classes of medical examination are carried out. Those under the 1960 Factory Act Regulations essentially apply to "inland/inshore air divers" and have to be carried out at six monthly intervals. The relevant figures shown in the Table have been divided by 2 to arrive at the consequential number of divers. Records clearly show a falling off in the number of returns made by "approved" doctors under these regulations, following the introduction in 1975 of the yearly "offshore divers" medical. Many inland/inshore divers now take the offshore medical and, as far as the UK is concerned, the position will be rationalised when unified Diving Regulations are issued, probably in the latter part of 1980.

All "approved" doctors have to make returns to the UK Government, and it will also be noticed that considerable numbers of divers are given medical examinations by "approved" doctors outside the UK.

The totality of divers receiving medicals under the 1960 Regulations (Line (b)), plus those having medicals within the UK under the Offshore Regulations (Line (c)(ii)), can be compared with the estimate of the total inland/inshore air divers; offshore air divers; and offshore mixed gas divers extrapolated from Tables 1, 2 and 3, and adjusted for the UK proportion this shows.

TABLE 5

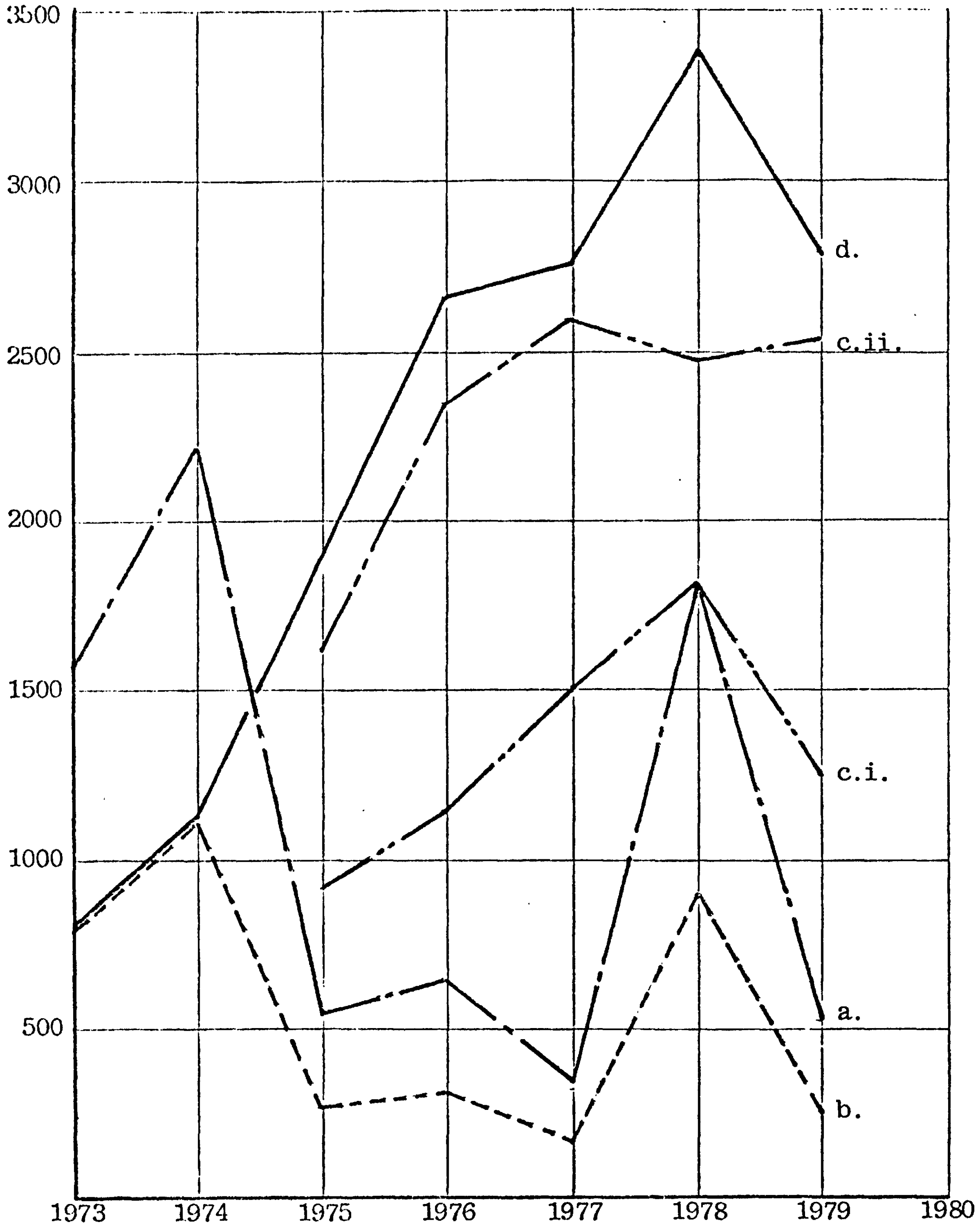
Record of Divers Medicals Carried Out in the UK

	1973	1974	1975	1976	1977	1978	1979	1980
a) No. of Inshore/Inland Medicals	(1566)	(2229)	(538)	(645)	(335)	(1829)?	(511)	N/A
b) No.of Consequential Divers	783	1114	269	322	168	914?	255	N/A
c) No.of Offshore Medicals								
i) From Outside the UK	-	-	(912)	(1144)	(1507)	(1824)	(1248)	N/A
ii) Within the UK	-	-	1625	2344	2593	2478	2535	N/A
d) Total [(b)+(c)(ii)]	783	1114	1894	2666	2761	3392?	2790	N/A

Notes:
1) Basic figures supplied by UK Health & Safety Executive
2) Figures in line a) have been divided by 2 to arrive at the number of divers shown in line b)
3) The (?) against a 1978 figure indicates an apparently anomolous return
4) N/A = Figures not available

TABLE 5

Record of Divers Medicals Carried Out in the UK



a. Number of inshore/inland medicals
b. Number of consequential divers
c. Number of offshore medicals
  i. From outside the UK
  ii. Within the UK
d. Total [(b)+(c.ii)]

TABLE 5 (A)

	1977	1978	1979	1980
Table 1 - Inland Air Divers	700	700	700	700
Table 3 - 75% of (H)	1161	1350	1220	1086
TOTAL - From Tables 1 and 3	1861	2050	1920	1786
COMPARATIVE TOTAL - From Table 5	2761	3392	2790	N/A

There clearly is little or no correlation between the two sets of figures. A number of possible explanations could be put forward for these differences, but suffice to say now that they show quite clearly the problems facing anyone trying to produce authoritative figures.

vi) Work Output - A serious attempt was made to show the considerable growth which has been achieved in work carried out in the offshore diving sector. At the time of writing this paper, relevant figures are still being studied and will be made available at a later date, if of sufficiently high quality. The trend is, however, quite clear in that the "number of hours spent in saturation" and the "number of hours spent working in the water", have both increased out of proportion to the increase in the number of divers.

3 SCIENTIFIC DIVING

There are about 10,000 scientists who dive as part of their work for Scientific Institutions on a worldwide basis. It is not part of this paper to consider the techniques and equipment which they use, but it should be noted that their diving activities are generally in support of other work, are usually in the air diving range, and are carried out at a time which is most efficient from a work output point of view. Many of these divers, therefore, conduct a relatively small number of dives in any year.

Table 6 gives approximate numbers of divers in this category. Two columns are shown representing figures obtained from two completely independent investigations.

As with the commercial diving considered in Section 2, these also show a lack of sound quantitative information, and some disparity, even when figures are available.

4 SPORT DIVING

As part of the background research which was carried out for this paper, extensive enquiries were also made regarding numbers of sport divers in the European Littoral States. The information received was so sparse that a table has not been prepared.

The British Sub Aqua Club represent the interests of many sport divers in the UK, and there are similar bodies in other countries. Not all sport divers, however, belong to such organisations.

BSAC membership has grown as shown by the Table set out below:

TABLE 6

Approximate Numbers of Divers Involved in Scientific Activities - 1980

	(A)	(B)
Belgium	N/A	N/A
Denmark	N/A	30
Eire	N/A	N/A
France	N/A	400/450
West Germany	150	200/300
Italy	180	50
Netherlands	N/A	N/A
Norway	50	50
Sweden	N/A	50
UK	N/A	450
USA	N/A	5,000
Worldwide Total	N/A	10,000

Notes: 1) Columns (A) and (B) show figures derived from two completely separate investigations

2) N/A = Figures not available

Year	Members	Branches
1956	2,097	42
1962	5,023	140
1968	9,241	250
1974	22,150	575
1979	30,569	834

5 FATALITIES

This paper would not be complete without a section on the number of fatalities to divers in all classes.

It is impossible to simply equate figures for the different commercial sectors and the sport and scientific communities, as fatal accidents arise for a variety of reasons, some of which are unique to a particular sector. The figures which follow, therefore, should not be compared sector to sector, or as a percentage of the sector population. The accuracy of the figures cannot be guaranteed, despite extensive enquiries.

Table 7 shows the number of fatalities from 1968 to 1979 for the countries considered in Section 2, and in respect of inland/inshore air diving (non oil and gas related).

Table 8 shows the number of fatalities from 1971 to 1979 for some of the countries considered in Section 2 in respect of offshore diving (oil and gas related).

It has not been possible to collect figures in respect of fatalities to sport divers, despite extensive enquiries. Certain figures have been made available, but their accuracy is so doubtful that they have not been included.

Eight fatalities have been recorded in Western Europe to scientific divers since 1960, three of which were associated with diving from a habitat.

--oOo--

It is hoped that the information given in this paper will be of interest to readers, although it is quite clear that basic information does not appear to exist in many countries.

The concentration of deep offshore diving (oil and gas related) in UK and Norwegian waters is apparent.

Sincere thanks are offered to all those who supplied information.

--oOo--

TABLE 7

DIVING FATALITIES - INLAND/INSHORE

Figures not available - Denmark, France, Netherlands.

Belgium - 1968 (1); 1971 (1); 1979 (1)

Eire - 1979 (1)

West Germany - 1979 (2)

Italy - 1974 (1); 1978 (2)

Norway - 1968 (1); 1976 (1); 1978 (1); 1979 (1)

Sweden - 1968 (2); 1974 (1)

UK - 1973 (2); 1974 (2); 1975 (4); 1976 (2); 1977 (1); 1979 (2)

TABLE 8

DIVING FATALITIES - OFFSHORE

Figures not available - Denmark, France

Eire - 1972 (1)

Italy - 1976 (1); 1978 (1)

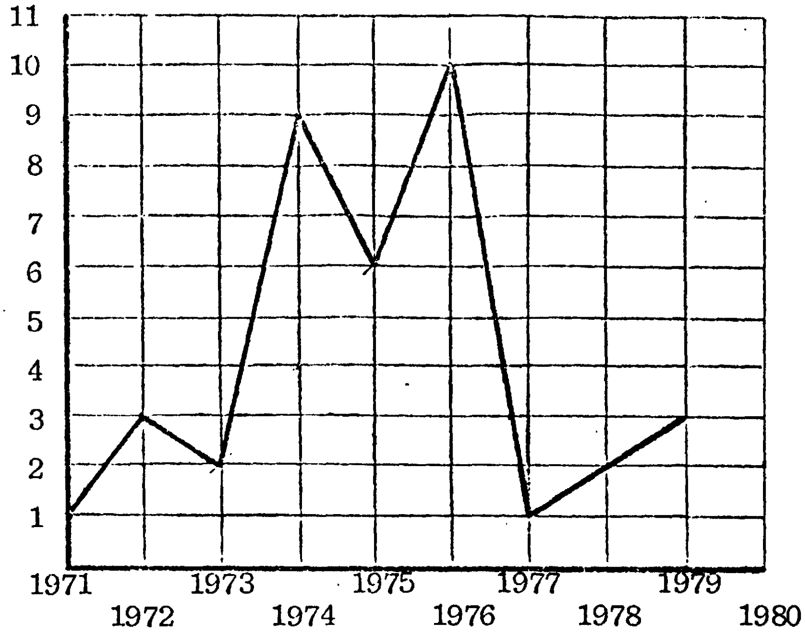
Netherlands - 1975 (1); 1977 (2)

Norway - 1972 (2); 1974 (4); 1976 (1)

UK - 1971 (1); 1972 (1); 1973 (2); 1974 (5); 1975 (6); 1976 (9); 1977 (1); 1978 (2); 1979 (3)

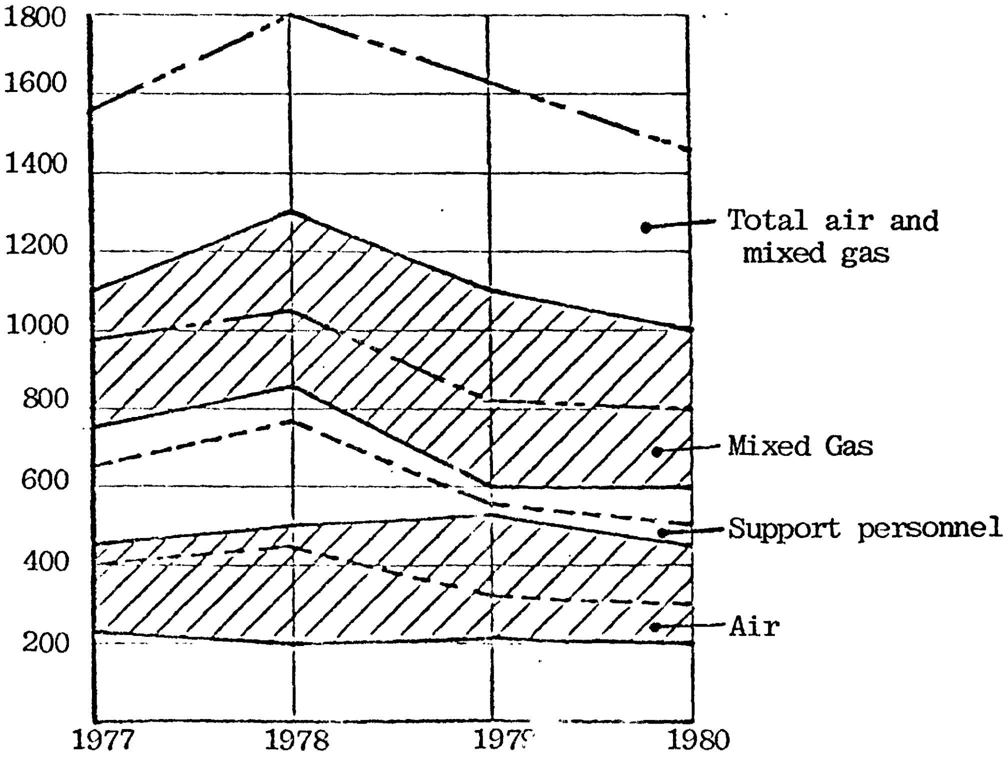
TABLE 8

Diving Fatalities - Offshore



UK and Norway

Diving Population - Offshore



UK and Norway

LESSONS TO BE LEARNED
SUMMARY

by

Per Rosengren
Section Manager - The Norwegian Petroleum Directorate - Stavanger (Norway)

SUMMARY

Diving compared to other industry is relatively young. It is also a very small industry, and up to the last years little money had been put into development of better equipment, safer procedures and training of personnel.

The divers were regarded as some sort of modern cowboys who worked hard and lived hard. To a certain extent they constructed their own equipment, made their own personal procedures and trained each other.

As the oilindustry moved offshore to deeper waters and to areas with more hostile weather conditions, the old equipment and procedures became inadequate. This resulted in an increase in the accident rate.

In the wake of the increased number of accidents, a better knowledge of the cause and thus the shortcoming of the existing system became clear.

Through investigations and analysis of the different accidents it became clear that the existing equipment had to be improved and new equipment developed. In some of the accidents it was obvious that the lack of for example a diving bell was one of the main factors that caused the accident.

As the equipment became better and more complicated the main cause for accidents seemed to swing over to

human inadequacy. Recent investigations not only into diving accidents show that the human line in the operation is very often the weakest link. With this I do not necessarily mean that it is the single individual human being who fails, but more often the whole system which manufacturers, operates and regulates the diving operation.

LESSONS TO BE LEARNED

by

Per ROSENGREN

Section Manager - Diving Section
The Norwegian Petroleum Directorate - Stavanger (Norway)

GENERAL

Diving compared to other industry is relatively young. It is a very small industry, and up to the last years little money has been put into development of better equipment, safer procedures and training of personnel. One of the causes for this may be that we do not know where to put the money in order to get an optimal increase safety.

Very few serious analysis of the accidents and incidents that have occured have been carried out. This may be because the institutions capable of initiating or carrying out such analyses do not have access to a sufficient number of incident and accident reports.

The Norwegian Petroleum Directorate's diving regulations state:

Quote: "All fatal accidents and all dangerous occurances are to be reported to the Norwegian Petroleum Directorate immediately. Further shall all cases which require first aid or medical treatment be reported........." Unquote.

We have reason to believe that most accidents which require first aid are being reported to the NPD. All reports are treated by operational and medical people in order to learn how a similar occurance may be avoided in the future.

We have been asking the diving contractors to send us accident/incident reports also for occurances which take place outside the Norwegian Continental Shelf in order to get as much material as possible available for analysis, but there seems to be a reluctance between the diving contractors to give us more information than what we are entitled to in accordance with Norwegian law.

All abnormal occurances in diving are naturally discussed within the safety organization in the diving company. But generally very little information has been made public or available to interested parties.

Some years ago AODC (Association of offshore diving contractors) established their Safety Committee, and one of their tasks was to analyse diving incidents/accidents which occure. The AODC Safety Committee's recommendations are distributed to all members and governmental agencies. However we felt the need for an independant institution to carry out an analysis and thereby suggest improvements.

In 1979 we asked the Norwegian Underwater Institute to carry out a risk assessment for diving. Unfortunately the information available to NUI for this task were limited. It should be mentioned that reports sent to NPD from the diving contractors are treated confidential, thus it was limited what information we could supply. But in our opinion this work carried out at NUI was a very important step towards a better understanding of what caused the accidents and incidents that occured.

When analysing the accident where most of the details are known, there are lots of points to be taken.

DECK CHAMBER SYSTEMS.

If we look especially on incidents/accidents which have taken place inside the deck chamber systems, the list of lessons learned may be as follows:

- only fire resistant and antistatic material is to be used inside the chamber complex,
- the O_2 percentage should be kept as low as possible,
- the use of electrical equipment inside the chambers should be kept to a minimum, and if necessary the voltage should be kept below 50 Volt,

- there should be earth error alarm and proper fuses on all electrial circuits,
- to avoid overpressurization pressure alarms for each indivudual pressurized section or chamber should be used,
- continous analysis of chamber atmosphere should be carried out in order to make sure that the atmosphere hold the desired percentage of the different gases,
- the device which clams the bell to the chamber should have visual indicators to indicate that the clamp is in the proper position. If power is lost, the clamp should be "fail to safe",
- the diving supervisor outside the chamber complex should always be able to control the pressure in the chamber, even if the divers inside have closed off all valves.

When going through all chamber accidents known to us, it becomes clear that the main danger for the divers in chambers is fire. There have been 2,7 fatalities per event.

DIVING BELL.

A high percentage of divers fatalities has taken place in the bell, or with divers operating from the bell. Some of the points we have learned may be listed as follows:

- the survival time for divers in a bell with no supply from the surface should be increased,
- the possibility to locate a lost bell by the rescue team should be improved,
- the system to make a negative bouyant bell positive should be made intrisically safe,
- the secondary bell lifting system should be improved,

- all gas from the surface to the bell should be continously analysed with high and low oxygen alarm,
- continous analysing of the atmosphere in the bell with oxygen and carbondioxyde alarms should be carried out,
- divers operating from the bell should never be positive bouyant,
- there should be a better system for the monitoring of divers condition (temperature, work load),
- all divers should carry bail-out bottles with sufficient capacity to give enough gas to return to the bell,
- the breathing equipment should be improved in order to reduce the divers breathing work.

It is of interest to observe that out of the total number of divers who have lost their lives in connection with bell diving, about half the number died inside the bell.

SURFACE ORIENTED DIVING.

A high percentage of the total number of fatal accidents offshore have taken place during surface orientated diving operations. In some of the cases the victims of the accidents had been using scuba gear. We are of the opinion that use of scuba gear in offshore diving is generally unprofessional and should be avoided if in any way possible. Therefore I will in the following mention some of the points we have learned from accidents with surface supplied equipment excluded scuba:

- the divers should use suits and equipment which gives zero bouyancy at the different depths they are operating,
- all divers should be equipped with reserve breathing gas supply,
- divers should wear high visibility/light reflecting equipment and should be equipped with light emitting

device,

- the breathing equipment should be improved in order to reduce the divers breathing work,
- the divers should be brought to and from the worksite in an open bell or similar device,
- there should be a better system for monitoring the diver's general condition,
- when diving from dynamic positioned ships, measures should be taken to avoid injury to divers from the thrusters or main propellers,
- decompression stops in the water should be reduced to an absolute minimum.

Generally speaking, surface orientated diving is very strenous on the divers. A diving bell should be used where it is possible.

SURFACE DIVE CONTROL

Some of the known accidents have been initiated by bad or faulty equipment on the surface. Others could have been reduced to a minor incident if the equipment had been better.

Lesson to be learned must be:

- proper back up gas to the divers. At least two independant sources should at all times be available,
- the gas distribution system should be designed to avoid that wrong gas is given to the divers or injected into the deck chambers,
- avoid high pressure oxygen,
- the handling system for the diving bell and the open bell should be improved,

- there should be sufficient power back up for the total diving system,
- the monitoring of the divers should be improved in order to permit a closer supervision of the dive from the surface,
- the general routines for maintenance and testing should be improved to ensure that all systems are in good working order.

What has been said till now generally, concerns equipment, but I feel that the most important lesson we have learned from all the incidents and accidents we know of, has little to do with equipment. I think it is very appropriate to keep in mind some of the finding of the Kemeny-Committee, the committee appointed to look at the nuclear power plant accident at Three Mile Island.

Quote:
" Popular discussion on nuclearpower plants tend to concentrate on question of equipment safety. Equipment can and should be improved to add further safety to nuclear-power plants, and some of our recommendations deal with this subject. But as the evidence accumulated, it became clear that the fundamental problems are people related and not equipment problems.

When we say the basic problems are people-related, we do not mean to limit this term to shortening of individual human beings, although these do exist. We mean more generally that an investigation has revealed problems with the "systems" that manufactures, operates and regulates nuclear power plants. These are structural problems in the various organizations, these are definiencies in various processes, and there is a lack of communication among key individuals and gruops.
We are convinced that if the only problems were equipment problems, this Presidential Commission would never have

been created. The equipment was sufficiently good so that except for human failures, the major accident of Three Mile Island would have been a minor incident. But whereever we looked, we found problems with the human beings who operated the plant, with the management that runs the key organization, and with the agency that is in charge with assuring the safety of nuclear power plant." Unquote.

PERSONNEL

To what degree these findings are relevant to the diving business may be discussed, but when looking at the diving accidents, it is obvious that in most of the cases there has been a human failure in at least one of the stages. Many accidents start as a minor equipment or human failure and the development into a fatal accident is often caused by wrong actions taken by the involved personnel.

I will say that in nearly all accidents we have been analysing, it becomes obvious that the personnel qualifications should have been better. Personnel qualifications are a combination of basic training and experience. The value of practical experience compared to formal training is debated the world over. In Norway we have generally been inclined to put great emphasis on formal training. We have here, I think, a question to which no clear cut answer can be given, but we must look for some sort of balance of combination. However it has become clear that both formal training and practical experience will improve personnel qualifications.

DIVING MANUALS

Although very few accidents have been caused directly by bad procedures laid down in the diving manuals, it is clear that there is lot of room for improvements. The harmonization of procedures between the different diving companies should also be mentioned as a factor which will improve safety. Many of the divers tend to change employer which means that they may have to learn completely new procedures.

CONTINGENCY PLANS

When an accident develops, it is often typical that the personnel involved are caught completely unprepared. They have not had sufficient training in how to handle an abnormal situation. The contingency plans for diving which exists are of varying quality, and generally very little training and drill have been carried out. One of the reasons for this may be that diving operations are being carried out continously and there are simply not time available to train.

Generally one may say that accidents have shown us that the contingency plans must be improved and also extended to include all situations one may have reason to believe may occure.

MAINTENANCE

The problem with proper maintenance involves both the technical and human aspects. Some of the accidents which we say have been caused by technical breakdown have in fact been caused by inadequate maintenance. Proper preventive maintenance programs are not widely used in the diving industry. Some of the accidents we have had might have been avoided if proper maintenance had been carried out.

In some cases the technical manuals have not even been sent onboard, which means that it is up to the crew onboard to find out how the equipment work and how to maintain it in a proper way. It is sad, but this can be said to have been the direct cause in an accident where two divers lost their lives.

ORGANIZATION

In our opinion no accident have been caused directly because of the organization of the diving company and the diving team. The total organization may have been undermanned, but generally it is the shortcoming of the individuals within the organization which causes the accidents.

REGULATIONS

We are of the opinion that there is a need for some sort of governmental regulations. The general impression is that we get a decrease in accidents when regulations are being introduced.

Most of the lessons learned from earlier accidents are reflected in the official regulations, but the main purpose of regulation are of preventive nature; to prevent accidents in the future by trying to foresee dangerous situations which may occure.

How the regulations should ideally be, are widely discussed, and we have not really found out if the best solution to improve safety is to have them very detailed or very general. At the moment a combination of the two seems to be widely used.

CONCLUSION

In order to learn maximum from the incidents and accidents that are occuring all over the world, the system of reporting must be improved. The diving companies should volontary submit their internal reports to interested agencies and institutions. The details which may blame certain individuals may be omitted. Our main interest is to be able to analyse the sequence of events which led to the accidents in order to learn and not to put blame on the diving company or its employees.

ACCIDENT PREVENTION

PREVENTATIVE MEASURES INTRODUCED

by

Joël GRISELIN
COMEX - Marseille (France)

Summary

Measures to prevent industrial or commercial diving accidents are generally introduced by the legislative bodies responsible for safety in these spheres, and also by the companies working in the field.

An identification of these risks, the studies which result therefrom and the quality or the existence of them, what should be done, depend to a large degree on the means available in a general sense, both to the Governments and companies concerned.

The application of these measures depends finally on the persons who in effect, will be affected by them.

***

PAPER

We cannot hope, in the time available, to cover the subject of preventive measures in operation in the field of diving in anything like exhaustive detail. I have therefore decided to restrict by remarks to those aspects which seem to me to be most important, with special reference to the application and effectiveness of the measures taken.

A brief historical review will give us some idea of the measures in effect today compared with the situation in the recent past.

We shall then go on to discuss the current system in the United Kingdom for improving safety conditions in industrial diving, set up in particular at the instigation of the DOE.

These specific examples will bring out a number of general rules which will place in perspective the problems requiring solution at various administrative levels.

Finally, examination of the situation within a private company will enable us to look at the problem from a more economically-biased point of view.

A number of specific problems will then be examined before arriving at what will inevitably be somewhat less than a comprehensive conclusion.

HISTORICAL BACKGROUND

The history of man's attempts to dive under pressure is a major success story interspersed, however. with an appalling number of serious accidents.

A whole century elapsed between Marc ISAMBARD BRUNEL's invention of the technique of diving in pressurized vessels in 1818 and the appearance of the first item of legislation on this kind of activity. During this period, the incidents of serious accidents grew steadily, culminating in a fatality rate of 25% per year on the HUDSON TUNNEL project in the USA between 1874 and 1882. These accidents are now realized to have been connected with the problem of decompression, although their true nature has still not been identified despite the fact that doctors have isolated the causes.

Definite progress on the explanation of the phenomena observed and the application of presentive measures had to wait for the work done by Paul BERT between 1870 and 1910 and by HALDANE from 1905 on.

Despite the immense progress which has been made since then, it is worth noting that an American translation of the work 'La Pression Barométrique' had to be prepared for military use in 1943, and that, even today, references to the famous paper by BOYCOTT, DAMANT and HALDANE (1908) are still often encountered.

THE SYSTEM IN OPERATION IN THE UNITED KINGDOM

The safety system in operation in the United Kingdom is exemplary in more than one respect.

It is based on a number of elements which I think are worth discussing, the most important being as follows:

- Legislation :

The number of countries in which diving goes on and where these activities are covered by appropriate legislation is much lower than is generally thought. The UK legislation is not of an excessively restrictive nature and therefore leaves the door open for improvements to be made to the system within a reasonable space of time. This is made possible by the existence of an executive authority operating under the auspices of the Department of Energy.

- The Diving Inspectorate :

This organization, which ought to be an indispensable element of any legislative system, no matter what the country is required inter alia - to :

- detect any new problems affecting safety;
- define the improvements to be made;
- introduce the most appropriate measures quickly;
- monitor the application of these measures.

The acknowledged affectiveness of the Inspectorate in this field is due in large part to the competence of its staff and the cooperation of professional or government organizations, especially the Association of Offshore Diving Contractors (AODC) and the Diving Medical Advisory Committee (DMAC).

A very rough-and-ready examination of how these various organizations carry out their work will at least bring out a number of important points.

GENERAL IMPLEMENTATION PROCEDURE

- Identification of the problem :

Almost all the preventive measures in operation have their origin in an accident or incident reported to the relevant authorities.

Once the problem has been recognized, the next step is to identify the causes, which must be done clearly isolating - as with any accident - the role played by a variety of factors.

This in turn presupposes the following conditions :

- the existence of an organization responsible for gathering information at every level: e.g. diver, place of work, company, national and international organizations. (The witholding of information at any of these levels severely restricts the range).
- the capacity at each level to take suitably modified measures (the methods differing from level to level).
- a sytematic study of corrective measures designed to ensure that no new problems are unwittingly created.

The results obtained for each of the above points depend on known factors which are not restricted simply to the field of diving.

The essential factors are as follows :

- Training :

It is always worthwhile stressing the importance of training for the prevention of accidents.

The results obtained depend on the quality of the training and the frequency of training sessions, and should enable the trainee to acquire :

- a knowledge of the risks and potential hazards and the means of preventing them;
- the ability to cope with situations where to panic would be fatal;
- the organizational flair necessary to prepare and carry out operations in maximum safety.

These considerations of course concern divers, but they also apply to all those who, directly or indirectly, have some influence of operations at the place of work.

- The existence of monitoring procedures :

The monitoring procedures adopted must increase the number of possible information channels, and should be based essentially on:

- systematic processing of diving reports;
- the production of place-of-work reports, including checklists
- systematic interviews (anonymous or otherwise) conducted with personnel, including interviews at the place of work.

THE SYSTEM WITHIN A DIVING COMPANY

The general system described above also applies within a diving-company.

There are, however, a number of factors which generally serve to complicate the work of the persons responsible in this field.

For instance, the lack of appropriate legislation in some countries may give rise to fierce commercial competition to the detriment of the safety aspect (e.g. smaller teams, use of unsuitable procedures, etc.).

By the same token, divers may be subjected to pressure from ill-advised clients where economic interests are of paramount importance.

It is therefore pleasing to note that the major oil companies are aware of the problem and are increasingly making efforts to draw up diving rules valid in all the countries in which they operate.

The efforts made at European and world level to harmonize diving rules should be applauded and encouraged.

- Preventive measures proper :

Fig. 1, taken from the "Underwater Handbook" by SCHILLING at al., sets out in diagram form all the problems a diver is likely to face.

For those whose jobs it is to introduce new techniques, it provides a resumé of the factors which should be taken into account before specific methods are applied.

The intention here is of course not to provide a general review of the preventive measures in operation; nonetheless, it is worth taking this opportunity to draw attention to a number of points which seem to me to be important at the present time.

- Decompression :

This is perhaps the subject which has given rise to the greatest number of research projects and publications in the field of diving. At any rate, it has been subjected to study over the longest period of time, and one may be forgiven for thinking that the problems are the best understood and mastered.

The facts, however, are as follows (and certain conclusions may - somewhat riskily - be drawn) :

- the multiplicity of decompression tables is a source of bewilderment, especially to users

- a large number of theories have been advanced, although only few are based on concrete findings;
- the statistics published in this field are sometimes in flagrant contradiction to the facts;
- certain publications on decompression lead one to believe that the work is not always done by the most competent people and that, all too often, the findings of the recent past are ignored.

- Chemical poisoning :

The increase in underwater techniques, the more and more frequent use of substances which are non-noxious at atmospherie pressure but which may be poisonous at higher pressures and repairs to damaged oil pipelines have substantially increased the risk of chemical poisoning.

The reduction or elimination of risks encountered in these conditions presupposes a systematic publication setting out the basic products used in the manufacture or operation of current systems.

The various noxious substances and their degree of toxicity are known; the means of detecting them and preventing them from doing harm are less well-known, while attempts to make personnel aware of the dangers are practically non-existent.

- The fire risk :

Underground welding techniques seem to have been developed without any real knowledge of the attendant risks.

These risks are not restricted simply to welding and there is no lack of examples in this field.

For instance, a case is known of a diver wearing a supposedly fire-proof diving suit having been ignited by a shower of sparks during milling operations in dry conditions, in the presence of air at a depth of 24 metres.

- Temperature problems:

The problems presented by temperature changes in diving have long been acknowledged.

However, they cannot be said to have been solved despite the fact that a great effort is now being made with respect to divers trapped in diving bells of pressure habitats.

Even more distrubing are certain points which have come to light in the course of the apparently normal sequence of operations.

For instance, if certain measurements taken under operational conditions are confirmed, it seems likely that most of the divers currently working in the North Sea are close to hypothermia, with all its known effects on the victim's psycho-sensorial and psychompoor functions.

- Individual equipment:

The heavy equipment used at the place of work is normally subject to a large number of thorough tests and checks.

This is undoubtedly due to the fact that the equipment and methods used are very similar to what is used on the surface at normal atmospheric pressure.

However, the same does not go for individual items of equipment, and, in this respect, systematic checks along the lines of those used for heavy items of equipment would be desirable.

Every item of individual equipment should conform to specific standards (e.g. respiratory resitance, heating and insulation capacity, etc.) as well as to general standards (e.g. impact-resistance, corrusion-resistance, long-term reliability, etc.).

CONCLUSION

I have endeavoured to review the problems which crop up in connection with the application of preventive measures. It has inevitably been of a limited, bitty and hasty nature, but may have served some purpose nevertheless if it generates an exchange of ideas in one of the areas under review, and may even have brought a point home to someone.

In place of a conclusion proper, there are two points I should like to raise.

The first concerns the economic aspects of safety. Quite apart from the moral aspect, experience has shown that the direct and indirect cost of accidents to the company and to their individual is much greater than the amount of money spent on improving safety.

My second point is that certain European organizations have entered into a phase of active cooperation on the prevention of the risks involved in changes of temperature and that this cooperation could usefully be extended to other fields of research and to other countries.

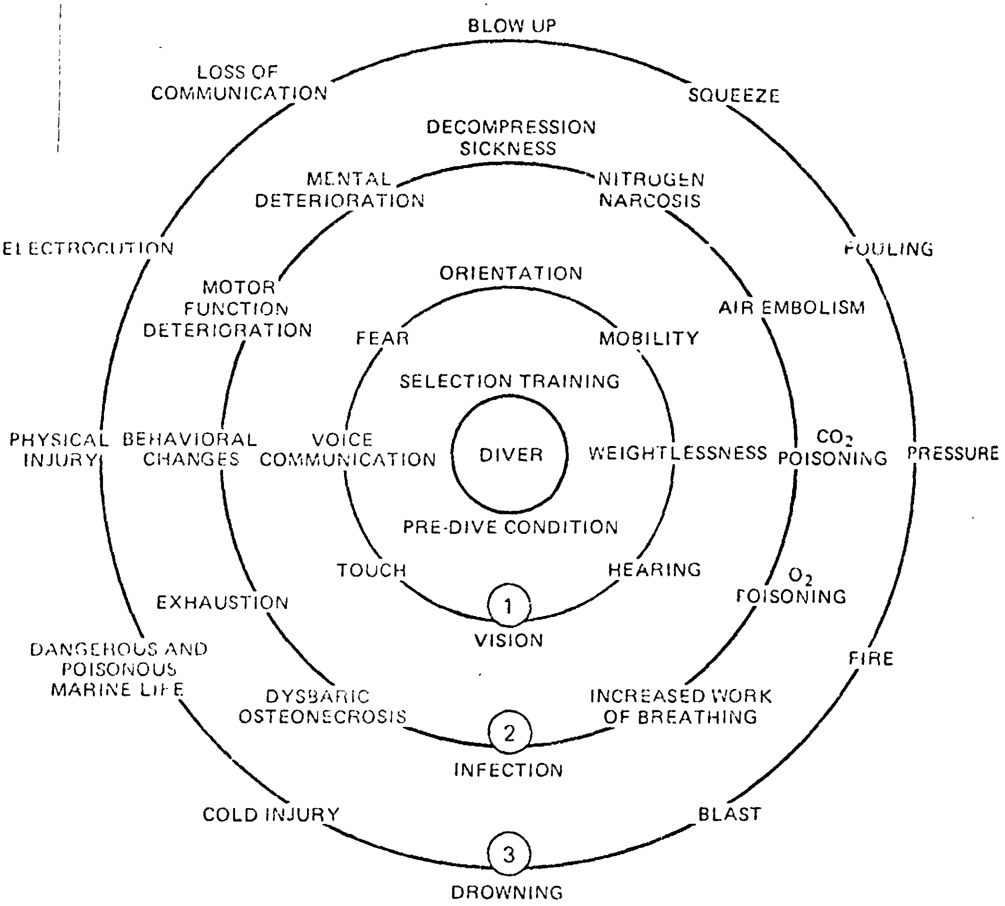


Figure 1 . Organization and planning. Accidents, illnesses, hazards, and environmental difficulties affecting performance. The diver—selected, trained, and in good condition. (1) The immediate circle of sensory awareness. (2) Physiological and psychological problems inherent in underwater work. (3) Possible environmental accidents.

A SUMMARY OF EXISTING REGULATIONS

by

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SUMMARY

It has been said that per head of working population the diving contracting industry is the most heavily legislated business in the world.

The recent rapid increase in offshore hydrocarbon exploration and production has brought an equally rapid expansion of diving and associated underwater operations.

Diving in a commercial mode has always traditionally been associated with danger either industrial or environmentally, with a dramatic public image of the deep sea. When therefore, during the initial rapid expansion of E & P work a number of underwater accidents did occur there was a predictable public concern and also considerable interest by governmental bodies.

Inquiries into these accidents indicated that, while the major diving contractors were operating to broad principles previously established by, in the main, military bodies, there were no recognisable civilian rules or procedures for the guidance of operators. Regulation was considered necessary by responsible governments and industrial bodies, and this in turn has become somewhat of a gowth industry in it's own right.

In European waters there is an approximate population of 2 000 professional divers of differeng nationalities at work at the height of the season. Their tasks range from the daily routine grind of dock-wall inspection and repair in 10 metres of water depth, to hyperbaric welding tie-ins on 40" pipelines in 200-250 m of water in the Northern North Sea. In addition there are an unknown number of 'scientific' divers and numerous sport divers.

There are at least 16 European and U.S. Governmental and industrial regulations, Codes of practice, Guidelines and advice documents, in addition to individual operators manuals, and military rules.

The paper will outline these, identifying the various regulatory bodies, discuss some duplications and anomalies and offer some comment on this multiplicity. A description of the industry's response to the implications and practical implementation of this documentation will be attempted together with a proposed method of applying the regulations on a world-wide basis.

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Major organisations involved in the documentation of underwater activities whose regulations, guidance notes etc. will be reviewed.

U.K. Ministry of Defence (Navy)
U.K. Dept. of Energy
U.K. Health and Safety Executive
U.K. Dept. of Trade
U.S. Dept. of Transport, Coast Guard
U.S. Navy
U.S. Dept. of Labour, Occupational Safety and Health
Norwegian Petroleum Directorate
Norwegian Maritime Directorate
British Standards Institute
CIRIA Underwater Engineering Group
European Diving Technology Committee
American Bureau of Shipping
American Society of Mechanical Engineers
Lloyds
Det Norske Veritas
Bureau Veritas

PAPER

1. SUMMARY OF EXISTING DIVING REGULATIONS

In the last 20 years the diving industry has come a very long way. In the 1960's most diving was carried out in support of civil engineering work, on sewer outfalls, harbour walls and similar work, with a hard core of professional salvage divers used to open water work. The total European workforce was then estimated at some 400 men. The majority of the equipment was still based on Siebe Gorman Standard design, now known as hard hat, but S.C.U.B.A. (Aqualung) types of gear were increasing. Most work was carried out in less than 35 m water depth and supported from a variety of vessels of opportunity. Procedures and techniques had been developed from military sources although Mr. R.A. Davis' book Diving and Submarine Operations had been published earlier in the century. With the advent of the offshore explorations and production of hydrocarbons, however, the picture dramatically changed.

Diving in support of the offshore oil industry had been carried out in the Gulf of Mexico, the Mediterranean and South East Asia for many years. In particular the Gulf of Mexico experience had initiated new developments in techniques and equipment, for example the growth in commercial oxy-helium work, and usage of lightweight equipment originated there. Control of any kind was vested in the diving contractors with little governmental involvement.

The problems of working in the North Sea, however, were a vastly different proposition and a number of fatal accidents occurred in the late 1970's. These were duly reported in the press, and, as diving has always been associated with danger a dramatic public image began to grow. Politicians responded to the public concern and in particular the United Kingdom government. Diving in U.K. had been the responsibility of the Factories Inspectorate who had originally drafted regulations to cope with the new situation. This initial draft was utilised later, when the responsibility was given to the Dept. of Energy's newly formed Diving Inspectorate under Cdr. Warner in 1973, to improve overall safety. From it a series of regulations were developed in 1974, 1975 and 1976 to cover the following areas of offshore diving operations.

Offshore Installations
Submarine Pipelines
Merchant Shipping

It should be recognised,however, that U.K. industry had taken the first innovate step with the work by the Underwater Engineering Group of the Construction Industry Research Association to develop and publish the Guidance Notes on Safe-diving Practice in 1968. These Notes gave advice on: terminology, equipment, physiology, communications, personnel, qualifications, and operations, to list but a few, and it is on those same subjects that almost all other legislation has been made.

Following the U.K. a number of other countries have produced national rules as have a number of non-legislative bodies, indeed so much documentation has been produced that the development of rules, regulations and guidance information in U/W operations has become a growth industry in its own right.

A sample of existing documentation would include, but not be limited to:

Government

U.K.		Diving Operations Special Regulations 1960 (Factories Act)
		The Offshore Installations (Diving Operations) Regulations 1974
		The Submarine Pipelines (Diving Operations) Regulations 1976
		The Merchant Shipping (Diving Operations) Regulations 1975
	*	Health & Safety at Work (Diving Operations) Regulations 1980
	*	The Merchant Shipping (Submersible Operations) Regulations 1980
	*)	In draft form only at this time
Norway		Provisional Regulations for Diving on the Norwegian Continental Shelf 1978
		Regulations for Control of Diving Systems on-board of Norwegian Flag Vessels, 1980

U.S.A. Dept. of Transportation (Coast Guard) Commercial Diving Operations
General Provisions
Dept. of Labour, Occupational Safety & Health Administration
Commercial Diving Operations
National Oceanographic and Atmospheric Administration
Diving Manual (Scientific Divers)

Australia Commonwealth of Australia, Petroleum (Submerged lands)
Act 1967 - 1974 Direction as to Diving

Industrial & Other Bodies

Commission of the European Economic Communities
European Diving Technology Committee. Guidance
Notes for Safe Diving

U.K. Construction Industry Research & Information Association
Principles of safe diving practice
U.S. Navy - Diving Manual Vol. 1 and 2
U.K. Ministry of Defence (Navy) Diving Manual

Classification Societies

Lloyds	
DNV	(Det Norske Veritas)
BV	(Bureau Veritas)
ABS	(American Bureau of Shipping)
ASME	(American Society of Mechanical Engineers)

All have regulations for the design and instructions of diving systems.

A host of documents, not necessarily compatible even in the same country, all to control the working and improve the safety of what is estimated as a working population of 5000 full time divers. Hence the saying that per head of population the diving industry is the most heavily legislated business in the world.

Comparison of these varying documents indicates differing philosophies. For example, the U.K. & Norwegian regulations are broadly comparable and are couched in fairly general terms without attempting to venture into detailed operating procedures or equipment specifications. The original OSHA regulations inhibited contractors operations so much that an injunction was sought against their introduction. The EDTC document vol. 1 contains considerable training and qualification information and the U.S. Coast Guard regulations have quite considerable detail on equipment specifications in addition to that contained in the various classification society's rules. International Association of Classification Societies itself has been unable to reach agreement among its members on standard requirements. A fuller comparison however leads to the following summary of the major legislative or advisory documentation on Commercial Diving Operations.

2. LEGISLATIVE DOCUMENTS

2.1 HEALTH AND SAFETY COMMISSION DRAFT DOCUMENT, "HEALTH AND SAFETY AT WORK (DIVING OPERATIONS) REGULATIONS"

i) General

This consultative document, the work of an Inter-Departmental Working Group on Diving Legislation, arose from a policy decision in 1976 to allocate responsibility for occupational health and safety in the offshore oil and gas industry to the Health and Safety Commission. Following an Order-in-Council in July 1977 the Health and Safety at Work Act was extended to cover diving operations in the following areas:

a) The U.K. Continental Shelf, in connection with offshore oil and gas installations.
b) The territorial waters of Great Britain.
c) Within Great Britain, where the Act has applied since it was first brought into operation.

The consultative document represents the Working Groups intentions in the production of a set of unified Diving Regulations which would form a part of the Health and Safety at Work Act legislation. Such a unified document would replace the following existing regulations:

a) The Diving Operations Special Regulations, 1960, made under the Factories Act.
b) The Offshore Installations (Diving Operations) Regulations 1974.
c) The Submarine Pipelines (Diving Operations) Regulations 1976.

It was not intended that the proposed regulations replace the Merchant Shipping (Diving Operations) Regulations 1975 which apply to diving operations carried out from British registered merchant vessels without geographical limitation. However, it is important to note that in the case of any diving operations covered by these Merchant Shipping (Diving Operations) Regulations and the Health and Safety at Work Act, the proposed unified regulations of the latter will take precedence.

Although incorporating virtually all the features of pre-existing legislation (including the Merchant Shipping (Diving Operations) Regulations 1975) the proposed unified regulations have been designed to take account of advances in all aspects of offshore work with which diving is associated.

A significant and somewhat controversial aspect of the document is its proposed application to "all diving operations carried on in the course of or in connection with any trade business or other undertaking whether for profit ot not". This clause implies inclusion of all divers apart from amateur or "sport" divers. Otherwise, it is fair to say that it has been fairly well received by the commercial diving industry which is perhaps not surprising in view of its derivation from pre-existing legislation. The main significance of the proposals to the commercial diving industry is the application to what might be termed "inland" diving and "inshore" diving. These areas, previously covered by the inadequate regulations of the Factories Act, are now to be covered by much stricter regulations.

Another innovative area in this document is the reference to various aspects of diver health and, in particular, a set of health standards to be decided upon by the Health and Safety Commission's Medical Advisory Committee. These standards, themselves the subject of a consultative document, will not be commented upon further. However, the intention to require notification of pressure related illnesses, injuries or co-incidental illness/ injury in divers under pressure, is entirely laudable.

ii) Status

After wide circulation, the initial consultation period is now over and a final draft is in preparation for submission to the Secretary of State for making and laying before Parliament.

iii) Citation

When law, the regulations will be cited as the HEALTH AND SAFETY AT WORK (DIVING OPERATIONS) REGULATIONS.

iv) Application

The wide application also applies to all diving operations undertaken outside Great Britain to which Sections 1 to 59 of the 1974 Act apply by virtue of the Health and Safety at Work Act 1974 (Application outside Great Britain)

Order 1977. Also the application extends to non-British subjects and corporations whether or not they are incorporated under the law of any part of the United Kingdom.

The proposed regulations are considered to represent reasonable legislation but have some controversial recommendations in certain areas of evacuation.

2.2 THE MERCHANT SHIPPING (DIVING OPERATIONS) REGULATIONS 1975

i) General

These regulations form part of a series designed specifically to cope with the extension of the offshore industry and associated diving which occurred in U.K. waters in the late 1960's and early 1970's.

Their role was to cover diving from craft other than covered by that legislation dealing with fixed installations (i.e. The Offshore Installations (Diving Operations) Regulations 1974). They have not been incorporated in the H & SE regulations in view of their application to British ships whatever their geographical location (similarly they apply to ships registered in the United Kingdom). Needless to say, they apply to all ships operating in U.K. waters of the U.K. Continental Shelf. In most respects these are almost identical with the H & SE regulations although not as detailed in certain areas. It is in the area of delineating the responsibilities of owners and masters of craft from which diving takes place that these regulations are of importance. They are best viewed as complimentary to the H & SE regulations and hopefully will be updated to conform with the H & SE final document.

ii) Citation

STATUTORY INSTRUMENTS, 1975 No. 116, THE MERCHANT SHIPPING (DIVING OPERATIONS) REGULATIONS 1975.

iii) Commencement

1 March 1975.

iv) Application

All diving operations, other that those to which the Health and Safety at Work (Diving Operations) Regulations apply, carried on from, on, in or near any submersible or supporting apparatus to which Part 4 of the Merchant Shipping Act 1974 applies, being diving operations carried on in the course of or in connection with any trade or business or by any person for hire or reward. They apply to all persons, whether or not British subjects, and to all companies, whether or not incorporated under the law of any part of the United Kingdom.

v) General Comments

These regulations tend to deal with the Statutory requirements for each "human component" of a diving operation (i.e. masters of craft, employers of divers, supervisors of divers etc.). On the technical side of diving practice, particularly in the area of diving equipment, they are not very detailed. They do go into considerable detail over "matters in respect of which provision is to be made in the diving manual", a diving manual being an obligatory requirement for employers of divers. In this respect they are identical to the H & SE regulations (1.4). Also, a sensible definition worthy of wider use is given for "craft under way" and allowance is made for dynamic positioning or other similar propulsion systems.
It is felt that, in general, these regulations could be updated to take account of recent advances.

2.3 DEPARTMENT OF TRANSPORTATION COAST GUARD, COMMERCIAL DIVING OPERATIONS GENERAL PROVISIONS

i) General

In its attempt to regulate commercial diving operations in those areas coming under its jurisdiction the U.S. Coast Guard initially cooperated with the Occupational Safety and Health Administration (OSHA) when that body held its informal fact finding hearing in November 1975. When OSHA published its Emergency Temporary Standard (ETS) for commercial diving in June 1976 a Memorandum of Understanding (MOU) was signed between OSHA and the Coast Guard which adopted this ETS for Coast Guard areas of jurisdiction until such time as Coast Guard regulations were produced.

During the stormy passage of the OSHA regulations proper, which were announced as proposals in November 1976, the Coast Guard supported OSHA and joined in the public hearings relating to the proposed regulations although these regulations did not ultimately apply to areas of Coast Guard jurisdiction. The final OSHA regulations were published in July 1977 and in November 1977 the Coast Guard published their own proposals. After public comment and recommendations from the Offshore Operators Associations, the final regulations (i.e. those reviewed here), were published in November 1978.

Inevitably they are similar in outline and content to the OSHA document, in fact certain sections are worded identically. In common with the OSHA regulations there is a lengthy preamble detailing all the comments taken into account in the preparation of the document. Much of this comment has resulted in clarification of ambiguous terms whereas some comment prevented or delayed what seemed reasonable action. Detailed discussion or review of this section is not necessary but it should be noted that there is no regulation in the areas of medical requirements, both health standards for divers and medical training of personnel.

ii) Citation

COAST GUARD, DEPARTMENT OF TRANSPORTATION (CGD 76-009) Part 197 - GENERAL PROVISION. COMMERCIAL DIVING OPERATIONS.

iii) Commencement

1 February 1979.

iv) Application

"Commercial diving operations taking place at any deepwater port or the safety zone thereof as defined in 33 CFR 150: from any artificial island, installation or other device on the Outer Continental Shelf and the waters adjacent thereto as defined in 33 CFR 147 or otherwise related to activities on the Outer Continental Shelf; and from all vessels required to have a Certificate of Inspection issued by the Coast Guard including mobile off-shore drilling units regardless of their geographic location, or from any vessel connected with a deepwater port or within the deepwater port safety zone, or from any vessel engaged in activities related to the Outer Continental Shelf".

This application is qualified by exclusions for research, search and rescue or public safety related diving operations

v) General Comment

Whilst quite good in the areas of duties of supervisors and equipment checks/ specifications, there are some large gaps in this legislation. No comment is made on diver qualifications or provision of emergency services. Some gaps will be filled (e.g. compression chambers at diving sites) when OSHA and Coast Guard regulations are harmonised in certain areas.

2.4 DEPARTMENT OF LABOUR, OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION, COMMERCIAL DIVING OPERATIONS, OCCUPATIONAL SAFETY AND HEALTH REQUIREMENTS

i) General

Following a petition in August 1975 by the United Brotherhood of Carpenters and Joiners of America (somewhat anachronistically, the union representing commercial divers in America), OSHA held a fact finding hearing in November 1975. It was followed in June 1976 by an Emergency Temporary Standard (ETS) which was to have been effective in July 1976. After challenge by several diving contractors a Stay was Granted by the U.S. Court of Appeals and resulted in the ETS being withdrawn in November 1976. Further proposals were made that month incorporating various corrections and with the joint participation of the Coast Guard (see 1.6). Following many representations the various hearings continued until February 1977 after which OSHA consulted again with all the major parties who had been represented at the hearings. This resulted in the production in July 1977 of the document here reviewed.

It is like the Coast Guard document in that there is a lengthy preamble outlining all the various issues raised at the public hearings and by written comment. It is prefaced by descriptive sections outlining the nature of the diving industry, the divers work environment and physiological hazards. These sections make quite interesting reading but are outside the scope of this review. Suffice to say, certain areas such as medical examinations have survived and are included in the final regulations.

ii) Citation

OCCUPATIONAL SAFETY AND HEALTH STANDARDS, PART 1910, TITLE 29, SUBPART T - COMMERCIAL DIVING OPERATIONS.

iii) Commencement

20 October 1977

iv) Application

"Every place of employment within the waters of the United States, or within any State, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, American Samoa, Guam, the Trust Territory of the Pacific Islands, Wake Island, Johnston Island, the Canal Zone, or within the Outer Continental Shelf lands as defined in the Outer Continental Shelf Lands Act (67 Stat. 462, 43 U.S.C. 1331) where diving and related support operations are performed.

This standard applies to diving and related support operations conducted in connection with all types of work and employments, including general industry, construction, ship repairing, ship building, ship breaking and long shoring".

Thereafter follows exclusions for the following:

a) instructional diving using open circuit, compressed air SCUBA within no decompression limits;
b) search, rescue or related public safety purposes by or under control of a government agency;
c) research and development involving human subjects where subject to government or federal agency control;
d) certain defined emergencies

The application, as in the case of the Coast Guard regulations (1.6) has been given very fully for the importance of the application of these two sets of regulations in the United States is clear. The OSHA regulations have a wider application and cover basically inshore and inland diving.

v) General Comment

These regulations are interesting in that they initially arose out of union concern for safety. They are on the whole concise, unambiguous and in contrast with the H & SE document (1.7) deal more specifically with pre-dive, during dive and post-dive requirements. This is a good idea.

Also SCUBA, SDDE and Mixed Gas Diving are dealt with separately. They are wider ranging than the Coast Guard regulations and, as has been mentioned, make some (albeit brief) reference to medical requirements.

2.5 PROVISIONAL REGULATIONS FOR DIVING ON THE NORWEGIAN CONTINENTAL SHELF 1978

i) These regulations, issued by the Norwegian Petroleum Directorate, are in many senses similar to the existing U.K. legislation. This is inevitable because of the close co-operation between the two countries in North Sea offshore activities but there are differences between the two countries' regulations once again, particularly with regard to evacuation.

The regulations are bi-lingual in Norwegian and English and have no introduction, preamble or general comment of any kind. As far as is known, they did not replace any previous legislation of substance which covered diving.

In general they are a comprehensive set of regulations which cover virtually the same area as the H & SE document (1.4).

ii) Citation

PROVISIONAL REGULATIONS FOR DIVING ON THE NORWEGIAN CONTINENTAL SHELF.

iii) Commencement

1 January 1978 (In fact, the document dated 1978 states "immediately").

iv) Application

"All diving operations carried out in connection with exploration, production, exploitation, storing and transportation of underwater petroleum deposits in areas covered by "Regulations relating to safe practices etc. in exploration and drilling for submarine petroleum resources" issued pursuant to Royal Decree of 3 October 1976 and "Regulations for production etc. of submarine petroleum resources" issued pursuant to the Royal Decree of 9 July 1976".

It is interesting to note the reference to petroleum deposits and wonder whether these regulations would apply to exploitation of other sea-bed resources. Also, there is no comment as to inshore diving for purposes non-related to petroleum deposits.

One feature of great importance is the reference to hyperbaric evacuation (para 2.2). Also the reference to dynamic positioning of diving vessels or platforms is of similar importance in view of the emergence of more and more dynamically positioned vessels. Similar regulations have now been proposed for use in Norwegian Flag vessels.

2.6 COMMONWEALTH OF AUSTRALIA, PETROLEUM (SUBMERGED LANDS) ACT 1967-1974 DIRECTION AS TO DIVING

i) General

These proposals, intended for introduction on an unspecified date in 1978, will replace previous general legislation of 1975 and some legislation specific to the area adjacent to Western Australia.

No details are given as to the application of these regulations and it is assumed that they apply to the Australian Continental Shelf. Whilst not as detailed as some legislative documents they do have several areas of legislation not touched on by other documents. For instance they do make reference to manned submersible vehicles although they are, for legislative purposes, linked with diving bells.

Thereare quite stringent requirements for information to be submitted in respect of diving deeper than 125 m. Also, there are some sensible restrictions on frequency of diving, therapeutic compression procedures that are acceptable and some unique comments on certain aspects of safety.

ii) Citation

COMMONWEALTH OF AUSTRALIA PETROLEUM (SUBMERGED LANDS) ACT 1967-1974, DIRECTION AS TO DIVING

iii) Commencement

1978

iv) Application

Not formally stated.

v) General Comment

These regulations are in several senses worthy of inclusion as a comparative document. Weak points are little comment as to their application and, like the Norwegian regulations, a seeming concentration on diving in connection with petroleum exploitation and production. They are, as will be seen in the comparative section, significantly different to other documents in some important areas.

3. ADVISORY OR GUIDANCE DOCUMENTS

3.1 BRITISH STANDARD INSTITUTE, DRAFT FOR DEVELOPMENT, "SAFE DIVING AND UNDERWATER WORKING" - DD 60 1978

1) General

This document was circulated for comment, a process which is now completed, but it is not known when a British Standard will be produced.

This was quite a comprehensive document, containing material from the CIRIA document "Principles of Safe Diving Practice" and other sources together with some new material. Unfortunately, it abounded with errors, some of them elementary, and was badly in need of much revision. Further, it was a strange document inasmuch as a lot of guidance was given in a form which was totally unsuited for "Standards", and areas where a British Standard could be of value have been ignored. A large medical section was generally superfluous. It will, however, probably emerge as a guidance document which has the status of being called a "British Standard" and therefore is worthy of comment as a possible source of expertise. Currently it has no status.

3.2 CIRIA, "THE PRINCIPLES OF SAFE DIVING PRACTICE" 1975 (3 Volumes)

i) General

Now in its second edition, this document is quite useful and many of the errors of the first edition have been corrected. It is quite clear in its application and whilst intended for use in world-wide diving operations as well as diving around the U.K., specifically states that where it is in conflict with local statutes or national regulations, these latter regulations must take precedence.

The document originally applied essentially to air diving but later additions (parts 2 and 3) are available to cover helium diving and diving from lock-out submersibles. The part dealing with helium diving is less valuable in that errors do occur and the subject is treated rather superficially. The diving from lock-out submersibles section deals solely with personnel (qualifications and responsibilities) and operating procedures.

The CIRIA document does have a sensible section on flying after diving and gives simple rules for diving at altitude. It also has a comprehensive medical section in which useful first-aid advice is contained as is the form of examination for commercial divers which has become virtually standard in the U.K.

3.3 COMMISSION OF THE EUROPEAN COMMUNITIES, EUROPEAN DIVING TECHNOLOGY COMMITTEE'S "GUIDANCE NOTES FOR SAFE DIVING"

i) General

Produced in May 1978 under the overall aegis of the Mines' Safety and Health Commission, these guidance notes are in the form of general recommendations.

They represent an attempt to standardize throughout member nations of the European Community those principles upon which safe and good diving practices are based.

Because of the individuals involved in its production, it is in part very similar to the CIRIA document, although the layout is somewhat different. It is a document difficult to assess in terms of its impact but it is largely non-controversial and is perhaps best regarded as basic information to be used in conjunction with legislation.

It makes useful recommendations with regard to training and classification of divers but, of course, they are only recommendations which attempt to "provide" legislation. Other volumes are in the process of development, to cover operations and medical matters.

DISCUSSION

We thus have a variety of rules, regulations, instructions and guidance, some mandatory, but all relevant. To handle this the major responsibility lies of course with the diving contractor, represented here by Mr. Hollobone of AODC, who has talked on their role in this area. Nevertheless many oil field operators have personnel experienced in underwater operations to monitor the activities of the contractors, to advise on operations and to assist in the design of structures and U/W facilities. In addition to their daily involvement many of these advisors serve on various committees with the contractors and government to monitor the industry as a whole and to recommend courses of action where necessary. For example, E.D.T.C., Oil Industry Exploration & Production Forum, Intergovernmental Maritime Consultative Organisation. The recent guidance notes on lost diving bells issued by the U.K. Association of Diving Contractors were compiled in cooperation with the Dept. of Energy and U.K. Offshore Operations Association. The U.K. O.O.A. purchased, and now fund on a permanent basis the medical hyperbaric evacuation facility based at Aberdeen.

As an example of detailed implementation of these various regulations I can perhaps describe, in broad terms, the way the Shell Group of Companies have addressed the situation on a world-wide and local operating company basis. Diving as operating advice comes from Shell Internationale Petroleum Maatschappij in The Hague. In this advice on diving and U/W operations to Operating Companies we cover diving techniques, legislation, regulations and audits, in consultation with the Environmental and Safety group. Input varies of course, in the case of Shell Expro in Aberdeen for example, the degree of advice required is less than for an operating company such as that of Shell, BP & Todd in New Zealand but a standard policy has been implemented through-out.

This is, that in areas where no local mandatory regulations exist the oil companies should still require their contractors to confirm to recognised rules of good safe diving practice, with additional advice from Central Office where necessary. By adopting this type of approach where a central organisation already maintains a close watching brief of, and involvement with, developing legislation, the field operators can be kept up date and hopefully ease their main task, that of getting the oil flowing.

In conclusion I would like to make a strong recommendation for standardisation wherever possible. While we all fully understand individual national aspirations and requirements, the majority of divers, diver supervisors, and managers, system designers and manufacturers, have developed through experience a very good understanding of the basic rules and are most anxious to apply them world wide. We all feel,however, that the development of new, differing rules, for the sake of having a national rule, is not only counter-productive, but can lead to a significantly increased safety risk rather than an improvement. The basic fact that we are assembled here because we are all primarily concerned with the safety of the diver in the water cannot be overemphasised and that any legislation should have that aim as a primary, practical function.

TRAINING THE DIVER

TRAINING THE PROFESSIONAL DIVER
FOR INLAND-INSHORE OPERATIONS

by

Mr. Z.W.S. MOERKERK

Managing Director of SMIT TAK International Bergingsbedrijf BV - Rotterdam (Netherlands)

SUMMARY

Since 5000 years mankind is looking for possibilities to stay and work underwater.

From the surface to 10 metres waterdepth the difference in pressure equals the difference in pressure from the earth to the moon. That is not to say that diving is as complicated as flying to the moon, but it certainly has its problems and its limits. My part of this session is diving related to inland-inshore jobs, that is to say shallow water diving upto 50 metres waterdepth regardless if it is inland or at sea.

It started in an era when Alexander the Great went down in a diving bell around 330 years BC to inspect the progress of his divers who were working in the harbour of Tyre - nowadays called Lebanon.
And it was about 2200 years later in 1885 when the first diver went down in our company - then called W.A. van den Tak. They were using the Siebe Gorman hard hat equipment and air was supplied to the diver by a handpump. I can imagine that these divers at that time were observed in the same manner as we observed Neil Armstrong when he touched down on the moon.

Salvage was already an established profession due to the many groundings on the Dutch coasts, especially in the South-West the approach to Rotterdam and Antwerp. It was here that the founder of the company - Mr. Willem van den Tak - saw the advantage of men working underwater. He bought some handpumps, helmets and diving dresses and looked for some volunteers under his crew-members to start diving.

These first divers - who in reality were all deckhands, skippers and the like - were all from the same family and upto a few years ago we had still members of this family working in our company.
During the years W.A. van den Tak grew bigger and bigger; more divers were required, diving went deeper and during and after the 2nd World War diving became a daily routine particularly when the doors were opened to international waters.
To-day the name of the company is SMIT TAK International Salvage Company (with the name of the founder TAK linked with the name of the founder of the well-known Dutch Tugboat company SMIT).

As I already mentioned, the early diver had the function of skipper, deckhand or engineer and specialised himself as a diver for the occasion. A long process because first of all the established divers in the company went down first when a job was to be done in order to receive their extra payment of Dfl. 2,50 for 6 hours diving, and secondly there was little demand for divingwork.

Another important factor was the protection of the trade - if you did not belong to a particular family or at least came from the same island - then it was very difficult to get yourself dressed in a diving suit for the first time.
Most of the times it started in assisting to dress the diver, keeping the signal-line, cleaning the equipment, and if you then - after some years of deckexperience and had proven to be a capable hardworking "Jack of all trades" and had shown interest in being a diver (also the foreman had to be good-humored that day, the job not too difficult, not too deep water) then you were allowed to make the first dive. Without payment of course: monies went to the diver whose turn it really was. Whenever the man diving for the first time, was a bit scared to let go the grip he had on the rungs of the ladder, the older diver would step on his hands and the new diver was sea-borne. If this first dive was not satisfactorily enough for the foreman, you could forget diving in the company for the rest of your life.

It must be clear that this way of self-selection produced the best divers. This in respect of their capabilities and craftmanship in using their imagination and ability to improvise. They were hardworking brave people and of course very healthy but had little or no notion of dangers, other than weather or currents. Safety precautions - doctors examinations, decompression, were subjects never heard of.
When I joined Van den Tak in 1954 we employed some 15 men who - apart from being skipper, deckhand or motorman - practiced diving. The equipment was still the same as at the start 70 years ago ; i.e. : Siebe Gorman hard hat diving equipment. The handpump was still in use although most of them had been replaced by compressors and the diving telephone had just been introduced, but because of the many failures one had to rely on the signal-line which system proved to work out very satisfactorily and was preferred especially by the elder men.
Diving tables were hardly heard of and the established divers thought of them as being nonsense. There was no Dutch diving manual available nor diving tables except with the Royal Dutch Navy. So my first work was to partly translate the U.S. Navy and British Navy Diving Manuals and to introduce diving tables, inwater decompression and some diving safety regulations; I also started to send divers to the doctors for examination. If I compare this with to-day's medical examinations I wonder about the effectiveness of the examination in those days, but it was a start.
The training continued more or less on the existing principle of "do it yourself" and was for the greater part based on the experience of the elder divers and the fundamentals were grounded on facts on what to do and how to do it in practice, rather than theoretical possibilities and the physiology and medicine of diving.

In the early days of oil exploration and wild catting in the North Sea a lot of wild catting also occurred in the diving industry: many young men were put in sophisticated dresses, bells and mixed gas, but quite a number of these men have never been able to tell anybody about their last experience.

By now/we have come to an almost ideal education program in order to maintain the high standard of quality divers and to keep accidents to a minimum whilst using our divers in the most economic way.
Prior to our training course we invite applicants who should meet the following requirements: not younger than 18 years of age - not older than 25, preferably in the possession of a diving licence from the Navy or Corps of Engineers, or valid certificate of a sportdiving club, secondary school or higher or a craftsman school and knowledge of the English language. Successful applicants are interviewed whereby we try to find out if the man is motivated for his new job, if he has no objection to be alone and far away from home, the languages he speaks, a general impression, if his parents or wife have any objections etc. We inform them about our terms and conditions, payment during and after the trainingperiod, inform him of the hard and irregular life, the danger of his profession which of course is higher than when being a clerk, the type of company we are and many other things.
When the twelve candidates have been selected they are sent to the doctor specialised in the physiology and medicine of diving in Holland for a medical check (both mentally and physically). Only thereafter - if successful - the diver, employed under a special contract, can start the training course.

For the last training course executed during October November and mid-December 1979 we had at our disposal one salvage vessel and a fully equipped pontoon with living quarters, a galley, classroom, toolroom, training basin, specific tools and her own mooring system. The salvage vessel was one of the bigger coastal salvage vessels, very well equipped including a double lock deco-chamber with an oxygen overboard dump system.

We had four instructors available for the divers as well as the ships crew of the salvage vessel. The complete unit was brought to the harbour of Hellevoetsluis. The harbour itself is approx. 6 metres deep, outside the harbour at a distance of 300 m., depths are found upto 32 metres and at half an hour's sailing water-currents of 1½ knots are running. In short an idea area for this course. On board of the salvage vessel as well as on board of the pontoon we had the following types of diving equipment: SCUBA-set witn wet and dry suit and face-mask; surface-demand with dry suit; Kirby Morgan band-mask or Superlite 17 and bail out bottle and the classic Siebe Gorman hard hat.

Every trainee diver had his own wet suit provided by the company. After all people had arrived on board an introduction was held with specific instructions for the following 10 weeks. Everybody remained on board from Monday-morning till Friday-afternoon. During the nights theorie, selfstudy and night-exercises were given. The twelve divers were split into two groups. Each with its own inspector, a retired diving officer of the Royal Dutch Navy; a retired diving sergeant of the Royal Dutch Navy; a salvage master of SMIT TAK (an ex-diver with 35 yeard of experience). The man in charge and responsible for all diving and safety was our chief diving officer in the SMIT TAK diving unit. Theorie was also given during the Monday- and Tuesdaymornings.

The course started first with swim-training in wet suit on the surface. In this exercise you clearly get an impression on the condition of the trainee and his swim capabilities. In the afternoon everyone got a chance to show his capabilities in the diving tank on the pontoon.

Dive for your SCUBA-set, put it on, clear your face-mask etc. were the normal exercises after which the first dives were made in open water. Work especially related to salvage and underwater construction work were instructed as far as they could be executed in a wet suit and SCUBA-set. Search methods like the circle method and Jackstay swimming for lost objects, propellor clearance of steelwires, nylon hawsers, inspection of shiphull and lockdoors. Furthermore simple jobs like cutting small size chain with hammer and chissel, constructing a wooden box, put together 6" pipes and flanges etc.

After this first week with wet or dry suit and SCUBA-set both groups started with instruction in the dry with the Siebe hard hat.

All trainees except one had no experience in this type of equipment. The first exercise is going down along the downline and getting used to his equipment already presented problems to some of the trainees. While some walked from the start on the soft harbourbottom others stayed for hours on the same spot and when they came up they could not even climb the ladder and were completely broken.

But fortunately even they moved around after some days and could start with the exercises. A special one was to raise a steel workboat which was put on the harbourbottom with holes in its hull. For this operation they had available wooden beams, steel drums to be used as camels, air-hoses, valves, rope etc. and it was up to them to work out a plan and bring the boat to the surface.
At the end of the second week we had two drop-outs and we continued the third week with 10 trainees left. The third week was spènt in deeper water upto 28 metres. The same exercises were repeated and it became clear that the similar work in deeper water created more problems for some of the divers. When during the exercises some divers were without a specific duty they got trained in boat handling, in cable- and rope splicing and making knots and in sculling. They also had to clean bathrooms and assist the cook in cleaning dishes.
There is one important law for a working salvage diver: "if he cannot use his hands on the surface, how can he use them underwater ?"

During the hours of theory and selfstudy lessons were given in underwater-physiology, physics, decompression tables and deco-methods, decompression-illnesses, tools first aid, shipbuilding, salvage methods etc. A lot of films, explaining salvage operations with sheerlegs, camels, polystyrene, combination of those, were shown in order to give the trainee some indication of their future task.
Although the hard hat equipment is not very much in use we still give 3 weeks of extensive hard hat training in muddy harbours, deep water and in currents and exercises were repeated.
Also the training with the Cox-gun, underwater cutting and welding, was done using this suit. At the end of the third week we had one more drop-out and nine trainees continued.
The last two weeks of the course were used to train the trainees in the surface demand equipment; Kirby Morgan Band-mask 10 and helmet Superlit 17B were used with the wet and dry suit and a bail out bottle.
After these weeks of extensive training and studying exams were held and questions asked about all subjects: navigation, ships-construction, diving illness, decompression, tools and equipment.
The diploma was at the end also signed by the Inspector of the

Dutch Department of Energy who is responsible for all diving on the Dutch continental shelf and who spent some time in the training school as an Observer. We feel that this way of training is very good. In total each trainee made approx. 40 water dives of approx. 45min. average bottom time, they used the same tools and vessels as later in the field; they make a team and know and depend on eachother. After the course they will be sent into the field as a apprintice diver - always accompanied by a second or first class diver. After two years the apprintice can qualify as a diver 2nd class, but only after an exam whereby the subjects for tuition are extended. After another three years and an enlarged amount of subjects and capabilities followed by an exam he can be 1st class diver, and after eight years he can become a diver foreman or a diving supervisor. For this however, he must have obtained a qualification as a paramedic from the Wolfson Institute of Occupational Health University of Dundee, Scotland, followed by a three weeks course as an advanced first aid medical helper at the University Hospital of Rotterdam.

Finally, it is not only in our own country that we do salvage or wreck clearing jobs, construction work and demolition, we work all over the world. Our gear is not as impressive and complicated as used in the deep diving industry, not so glamourous but the scope of work and the importance of what our divers are doing, the dangers they encounter, justifies that these divers are treated equal to the deep divers and that they are well-trained, equipped and looked after, and by doing so this in combination with the diving regulations increase their safety.

I hope I have given you some insight in this problem, the possibilities scope of work of the inland-inshore diving which in many cases is the hatchery for the men who want to go to the very deep.

Ladies and Gentlemen, I thank you for your attention.

TRAINING THE PROFESSIONAL DIVER FOR INLAND-INSHORE OPERATIONS

by
Z.W.S. MOERKERK
Managing Director of Smit Tak International Bergingsbedrijf BV
Rotterdam (Nederlands)

PAPER

Ladies and Gentlemen,

Since 5000 years mankind is looking for possibilities to stay and work underwater.

To start with I may draw to your attention that from the surface to 10 metres waterdepth the difference in pressure equals the difference in pressure from the earth to the moon. That is not to say that diving is as complicated as flying to the moon, but it has certainly its problems and its limits. My part of this session is diving related to inland - inshore jobs, that is to say shallow water diving upto 50 metres waterdepth regardless if it be inland or at sea, and consequently his safety.

It all started in an era when Alexander the Great went down in a diving bell around 330 years BC to inspect the progress of his divers who were working in the harbour of Tyre - nowadays called Lebanon - in removing obstacles. The story does not state what type of bell nor how deep; from what we know to-day it could not have been long nor deep. What we do know is that mankind and hundreds of inventors have tried to make a contraption to stay underwater: Leonardo da Vinci - Jules Verne - Roger Bacon, William Phipps. A Mr. John Letherbridge made a contraption that could be called a forerunner of our modern Wasp. The real breakthrough in diving came in 1840 by Mr. Augustus Siebe when he presented the first practical clossed diving dress and helmet. This apparatus is the direct ancester of the standard-dress which has been used and still is in use in all kinds of shallow water construction-, harbour and salvage work.

After 1920 the progress of new equipment went faster and faster and a major breakthrough in diving equipment came during the war, when Yves Cousteau together with Emile Gagnau invented the demand-regulator in connection with pressure air bottles and created the first really safe and efficient open circuit.
The Self Contained Underwater Breathing Apparatus - in short SCUBA.
During the first salvage operation with the Siebes diving dress and helmet, many divers who spent 6-7 hours a day under water at depths of approx. 20 metres had repeatedly attacks of what was thought to be rheumatism and cold. This occurred during the work on HMS Royal George, which vessel was fouling a major fleet anchorage just outside of Portsmouth England.
At the same time other inventors were working on improvements of the diving bell - which the French called 'caisson'.
Concurrent with the expanding use of caissons an apparently new and unexplained malady began to affect the caisson-workers.
After completing a shift and returning to the surface, they would frequently be struck by dizzy spells, difficulty in breathing or by sharp pains in the joint or abdomen. With the increasing caissonwork fatalities occurred with alarming frequency and the malady was called the 'caisson-disease'.

However, workers on the Brooklyn bridge project in New York gave the sickness a more descriptive name that has remained ever since 'the Bends'. The term may have grown out because of the similarity between the contorted posture of the suffering worker and an awkward forward leaning stance affected by fashionable ladies of that time known as the 'Grecian Bend'.

To-day 'the Bends" is the best known danger of diving, popularized by generations of adventure fiction in books, magazines and on television.

Every dive deeper than 9 metres - when not followed by a proper decompression-schedule may lead to the 'Bends'.
The actual cause of the 'Bends' was first clinically described in 1878 by the French physiologist Paul Bert. Following experiments by the English physiologist J.S. Haldane during the years

1905-1907 led to a stage method of decompression presented in diving tables. Though they have been re-studied and improved over the years, these tables remain the basis of the accepted method for bringing a diver to the surface.

It was about 15 years before the turn of last century that the first diver went down in our company - then called W.A. van den Tak. They were using the Siebe Gorman hard hat equipment and air was delivered to the diver by a handpump.
I can imagine that these divers at that time were observed in the same manner as we observed Neil Armstrong when he touched down on the moon.

Salvage was already an established profession due to the many groundings on the Dutch coasts, especially in the South-West the approach to Rotterdam and Antwerp.
Schooners, fregates barks and other sailing vessels which ran aground in bad weather were refloated by local fishermen using their fishingvessels with little draft to lighten the cargo-vessels and bring them back to open sea. Sometimes part of the vessel was flooded and underwater repairs were required prior to the refloatation. It was there that the founder of the company - Mr. Willem van den Tak - saw the advantage of men working underwater. He bought some handpumps, helmets and diving dresses and looked for some volunteers under his crewmembers to start diving.

The first divers, who in reality were skippers, deckhands and the like, were all from the same family called Sperling, and upto a few years ago we had still members of this family working in our company.
During the years W.A. van den Tak grew bigger and bigger, more divers were required and diving went deeper. It was during and after the 2nd World War that diving became a daily routine.
At the same time the doors were opened to international waters.
To-day the name of the company is Smit Tak International Salvage Company, with the name of the founder TAK linked with the name of the founder of the well-known Dutch Tugboat Company SMIT International.

SMIT TAK is one of the work companies of the Smit International Group and one of the oldest diving companies of the world.
The Smit International Group employs approx. 3500 people divided over more than 40 companies all over the world. It operates a fleet of over 310 units in harbour tugs, ocean-going tugs, salvage- and diving vessels, supply-vessels, cranes and barges.
Seven workcompanies employ divers, mainly in the salvage and cargo recovery, but also in the oil-offshore industry. The total amount of divers within the Smit International Group reaches the 100 and most of them are trained in those companies and are on a fixed payroll. and their standard of training and craftmanship can be measured with anybody else in this world.
But of course it has not always been like this and we have come a long way since 1880. In those days - as I already explained before - a diver had the function of skipper,deckhand, engineer and specialized himself as a diver for the occasion.
This was a long process because first of all the established divers in the company went down first when there was a job in order to receive their extra payment of Dfl. 2,50 for 6 hours diving, and secondly there was little demand for divingwork.

Another important factor was the protection of the trade, and if you did not belong to a particular family or at least you should come from the same island, then it was very difficult to get yourself dressed in a diving suit for the first time.

Most of the times it started in assisting to dress the diver, keeping the signal line, cleaning the equipment, and if you then - after some years of deckexperience and had proven to be a capable hardworking 'Jack of all trades' and had showed interest in being a diver (also the foreman should be in a good mood that day and the job not too difficult, not too deep water - then you were allowed to make the first dive. Without payment of course: this went to the diver whose turn it was. Whenever the man, diving for the first time, was a bit scared to let go the grip he had on the wrongs of the ladder, the older diver would step on his hands and the new diver was sea-borne.

If this first dive was not satisfactory enough for the foreman, you could forget diving in the company for the rest of your life.

It must be clear that this way of self-selection produced the best divers. This in respect of their capabilities and craftmanship in using their imagination and ability to improvise. They were hardworking brave people and of course very healthy but had little or no notion of dangers, other than weather or currents. Safety precautions - doctors examinations, decompression, were subjects unheard of. It is true people did not dive deep in those years, the ships were rather shallow drafted and harbours and waterways had not been dredged for VLCC's as to-day. An important factor why so little diver diseases occurred in those days was besides the small waterdepth the short periods one could dive because of the tides. When I joined Van den Tak in 1954 we employed some 15 men - who apart from being a skipper, deckhand, motorman - practiced diving. The equipment was still the same as during the start 70 years ago, to know: Siebe Gorman hard hat diving equipment. The handpump was still in use, although most of them had been replaced by compressors and the diving telephone had just been introduced, but because of the many failures one had to rely on the signalline which system proved to work out very satisfactorily and was much more preferred especially by the elder men. Diving tables were hardly heard of and the established divers thought of them as being nonsense. There was no Dutch diving manual available nor diving tables except with the Royal Dutch Navy.

So my first work was to partly translate the U.S. Navy and British Navy Diving Manuals and to introduce diving tables inwater decompression and some diving safety regulations I also started to send divers to the doctors for examination. If I compare this with today's medical examinations I wonder about the effectfulness of the examination in those days, but it was a start.

The training continued more or less on the existing principle of 'do it yourself' and was for the greater part based on the experience of the elder divers and the fundamentals were grounded on facts on what to do and how to do it in practice, rather than theoretical possibilities and the physiology and medicine of diving.

We trained people in the field, how to work upstream on the rivers, especially the Rhine where the constant current flows to the sea and divers can only work behind a screen put up in the river and held by anchors and a crane to protect the diver from being washed away. How to use the various tools, but all this was done in the field telling him once, and off he went for his trials - some succeeded, others never once failed, off for ever. The rivers with her tides brought forward other difficulties, running and changing tides, when was the time to go down, how to get on your work, use explosives and how and where to apply, oxy hydrogen cutting, how to clear yourself when tangled, everything to be learned was learned in the field, and it was taught the hard way.
A real breakthrough came in the early sixties. Some young divers had the chance to obtain a SCUBA-set and during some demonstrations showed the old divers the advantage of free swimming diver. Some of the old divers were suspicious of this modern equipment because they even could not swim. But gradually the SCUBA won over the old hard hat.The divers activity expanded, not in the least because of the increasing demand for divers in the offshore oil industry. And the demand was for deeper and deeper. Also the ships became larger and larger and all parts of the world and fairways to these ports had to be deepened and hundreds and hundreds of wrecks left over from World War I and II had to be removed. Van den Tak expanded and more and more divers were needed. There was no more time to engage a sailor and to wait and see if within 3 to 5 years somebody would think him big enough to perform as a diver. Also the various navies: in the U S British and French had discovered the great importance of deep-diving in relation to our life source - OIL, and started an extensive experimental deep diving program.

And with these experiments there was a requirement for new diving gear, new systems. new breathing media etc. and at last (but not least) the diving got the attention of the medical world. Underwater construction and new techniques came into practice and a new type of diver was required, the days of the barrel chested self-made boys were over and a more sophisticated better orientated, more scientific and well trained diver came on stage. Also Van den Tak realised that for inland and inshore divers, shallow water divers in general, the time had come for a change and that well trained and also theoretically well prepared divers was a necessity. So we established a company diving school in 1967.

Six youngsters - working already over a year in the company as a deckhand or engineer - got the chance to specialize themselves in diving. Instruction started first in a swimmingpool and after they had shown sufficient experience with snorkel, half-mask and flippers, they were allowed to make some test-dives with a SCUBA-set, the next step was again Siebe's hard hat.

Diving started in the harbour of Maassluis, our home port on the New Rotterdam Waterway, where waterdepth is about 5 meters. Bottom condition is soft mud and there is no visibility. It is always in this week that we had the most drop outs, mostly physical ciscumstances. With the remaining boys about 50 exercises were made in walking, working with specific tools like air lift, air hammer, impact-wrenchers, air saw, Cox-gun, how to make patches etc.

After the first week diving in the hard hat equipment in the harbour of Maassluis the training continued in deeper water: first in Europoort where waterdepth is 28 metres and lateron in the New Rotterdam Waterway where depth is less but where currents are running, The last two weeks of the training course were normally used to finish SCUBA-diving in wet and dry suits and the whole course terminated with a theoretical exam. When the trainee divers passed this exam they got a company licence to start working under water, always accompanied by a second first class diver. Basically they now know how to move underwater, in order to learn to work they needed practice. This is still the basic idea of our diver-training although a lot has improved.

In the early years of oil exploration and wild catting in the North Sea a lot of wild catting also occurred in the diving industry, many young men were put in sophisticated dresses, bells and mixed gas, and quite a number of these men have never been able to tell anybody about their last experience.

It was now the time for the governments to step in and Gt. Britain was the first nation to adopt a diving law, soon afterwards followed by Norway and the rest of the EEC-countries and although it is a pity that all these laws in different countries vary and that there is no common law, at least it has been an enormous step forward to divers safety. For also the training of men is now more or less regulated, as well as their medical examination.

In order to maintain our high standard of quality divers, to keep accidents to a minimum and to use our divers in the most economic way, we have come to an almost ideal education program. Months prior to a diver training we start collecting data of young men who do have interest in diving. Last couple of years we had about 60 applications for a training-program suitable for 12 men only. Some of our qualifications for joining are: not younger that 18 years of age, not older than 25, preferably in the possession of a diving licence from Navy or Corps of Engineers or a valid certificate of a sportdiving club, secondary school or higher or a craftsman school, and knowledge of the English language.

When the applicants fulfill to those requirements they are invited for a personal visit. During this meeting we try to find out if the man is motivated for his new job, if he has no objection to be alone and far away from home, which languages he speaks, a general impression, if his parents or wife have any objections etc. We inform them about our terms and conditions and payment during and after the training, the hard and irregular life, the danger which of course is greater than being a clerk, the type of company we are and many other things.
The next thing is to send the selected twelve to a doctor specialized in the physiology and medicine of diving in Holland until recently only the Royal Dutch Navy, for a medical check (both mentally and physically).
When they also have passed this check successfully they will be employed under a special contract and the diver training can start.
For the last training which we have executed during October, November and half-December 1979 we had one salvage vessel and one fully equipped pontoon at our disposal. The pontoon had been equipped with living quarters, a galley, classroom, toolroom, training basin, specific tools and her own mooring system. The salvage vessel was one of our bigger coastal salvage vessels, very well equipped including a double lock decor-chamber with an oxygen overboard dump system.

Four instructors were at the disposal of the divers, as well as the ships crew of the salvage vessel. The complete unit was brought to the harbour of Hellevoetsluis. The harbour itself is approx. 6 metres deep, outside the harbour at a distance of 300 metres depths are found upto 32 metres and at half an hour's sailing watercurrents of 1½ knots are running. In short an ideal area for this course. On board of the salvage vessel as well as on board of the pontoon we had the following types of diving equipment: SCUBA-set with wet and dry suit and face mask; surface-demand with dry suit; Kirby Morgan bandmask or Superlite 17 and bail out bottle and the classic Siebe Gorman hard hat.

Every trainee diver had his own wet suit provided by the company. After all people had arrived on board an introduction was held with the specific instructions for the following 10weeks. Everybody remained on board from Monday-morning till Friday-afternoon. During the nights, theorie, selfstudy and night-exercises were given. The twelve divers were divided into two groups. Each with its own instructor, a retired diving officer of the Royal Dutch Navy; a retired diving sergeant of the Royal Dutch Navy; a salvage master of SMIT TAK (an ex-diver with 35 years of experience). The man in charge and responsible for all diving and safety was our chief diving officer in the SMIT TAK diving unit.
Theorie was also given during the Monday and Tuesdaymornings.

The course started first with swim-training in wet suit on the surface. Normally this shows no problems because everybody floats in a wet suit without weight-belt. In this exercise you clearly get an impression on the condition of the trainees and their swim capabilities. In the afternoon everyone got a chance to show his capabilities in the tank on the pontoon. Dive for your SCUBA-set, put it on, clear your face mask etc. were the normal exercises after which the first dives were made in open water. Work especially related to salvage and underwater construction work were instructed as far as they could be executed in a wet suit and SCUBA-set.
Search methods like the circle method and Jackstay swimming for lost objects, propellor clearance of steelwires, nylon hawsers, inspection of shiphull and lockdoors. Furthermore simple jobs such like cutting small size chain with hammer and chissel, constructing a wooden box, put together 6" pipes and flanges etc. After this first week with wet or dry suit and SCUBA-set both groups started with instruction in the dry with the Siebes hard hat. All trainees except one had no experience in this type of equipment. The first exercise going down along the downline and to get used to his equipment already presented problems to some of the trainees. While some walked from the start on the soft harbourbottom others stayed for hours on the same spot and when they came up they could not even climb the ladder and were completely broken.

But fortunately even they moved around after some days and could start with the exercises.
Some of the same exercises made the first week were repeated and with much interest we have observed the inventiveness of some trainees specially when they received the 6 boards at one time of which they had to make a box with nails and hammer. They received instruction in various tools like airdrills, air-saw and Cox-gun.
A special exercise was to raise a steel workboat which was put on the harbourbottom with holes in its hull. For this operation they had available: wooden beams, steel drums to be used as camels, air-hoses, valves, rope etc. and it was up to them to work out a plan and bring the boat to the surface.
At the end of the second week it became clear that two of the youngest trainees were unable to cope with the difficulties of this program and were told to leave this training course.
Some others got a warning that their results were not satisfactory and that they got another week chance to improve this. With 10 trainees left, the third week was spent in deeper water upto 28 metres. The same exercises were repeated and it became clear that the similar work in deeper water created more problems for some of the divers. When during the exercises some divers were without a specific duty they got trained in boat handling, in cable- and rope splicing and making knots and in sculling. They also had to clean bathrooms and assist the cook in cleaning dishes.
There is one important law for a working salvage diver:"if he cannot use his hands on the surface, how can he use them underwater?"

During the hours of theory and selfstudy, lessons were given in underwater-physiology, physics, decompression tables and deco-methods, decompression illness, tools first aid, shipbuilding, salvage methods etc. A lot of films, explaining salvage operations with sheerlegs, camels, polystyrene, combination of those were shown in order to give the trainee some indication of their future work.

Although the hard hat equipment is not very much in use we still keep the principle that when the divers feel themselves comfortable in this piece of equipment and move around easily they are able to

dive and control any other type of equipment.
Therefore 3 weeks of extensive hard hat training in the muddy harbours, deep water and in currents were given and exercises were repeated. Also the training with the Cox-gun - an underwater gun for shooting bolts in steel plates - was done using this suit. At the end of the third week we had one more drop out, and nine trainees continued.
The last two weeks were used to train the trainees in the surface-demand equipment. Kirby Morgan Bandmask 10 and helmet Superlit 17B were used with the wet and dry suit and a bail out bottle.
As they all got experience with the hard hat now it was much easier for them to work with the surface demand equipment.
This equipment is the most ideal for our work. A dry hat with communication, a warm body and a back-up air supply when hose is out or supply of gas fails. It will be used on almost every job and when the dry suit is not sufficient enough to keep the diver warm a hotwater suit will replace this one. All the exercises done with SCUBA and/or hard hat were repeated.

After eight weeks of extensive training and studying an exam was held, and questions were asked about all subjects: navigation, shipconstruction, diving-illness, decompression, tools and equipment and the diploma was also signed by the Inspector of the Dutch Department of Energy, who is responsible for all diving on the Dutch continental shelf and who also spent some time in the training school as an observer. Each trainee diver made approx. 40 water dives with an average bottom time of 45 minutes.
We believe that this way of training is a good one. During the training they work already with the same vessels and tools as later in the field. They form a team and know eachother and depand on eachother. Now they have finished the training course they will be sent into the field as an apprintice diver always accompanied by a second or first class diver in order to get accustomed to the very wide scope of work.

After two years an apprintice diver with a certain amount of diving hours has to qualify as diver 2nd class, again after an exam whereby the subjects for tuition are extended.
Diver 2nd class for three years and again of course after an exam with an enlarged amount of subjects and capabilities he can be 1st class diver.
After eight years he then can become a diver foreman or a diving supervisor. This is a promotion by choice of the company: no exam for this rank. He must however, have obtained a qualification as a para-medic from the Wolfson Institute of Occupational Health University of Dundee (Scotland), followed by a three weeks course as an advanced first aid medical helper at the University Hospital in Rotterdam.

Why such an extensive training program and skill for inland water divers.
As perhaps you will know 1/3 of my country lies below sea-level and is protected by dikes and a complicated system of ditches, canals, rivers, waterways and sea arms penetrate deeply into its soil.
Currents can run up to 4 and 6 knots, no visibility.
Other problems with so many waterways are the many many crossings of power-cables, telephone cables, pipelines for oil, gas, chemical potable water etc.

Another area where divers are required are the many harbours in Holland, like Rotterdam, Amsterdam, Delfzijl, Terneuzen, Vlissingen.
Maintenance and repair works on jetties, mooring dolphins, locks, shipyards, slipways, tunnels as well as the many ships that enter those harbours.

With all the river traffic going from those harbours to Germany, Belgium, France, Switzerland, accidents often happen and in all cases where vessels sink they should be removed.

On those rivers the current is always running one way and can reach speeds of 5 knots and higher. In such cases specially developed screens as used to give divers more protection against the current but there is always a moment when the diver has to fight those currents. Not only on the river accidents happen. On the coast and at sea vessels ground due to bad weather, collision or other reasons and the salvage or removal of those objects we can consider as inland/inshore.
During the project divers are extensively involved in cargo-recovery, underwater burning, repairs etc. and most of the time under difficult circumstances, with high seas, current and no visibility. When a shipscrew leaves their vessel, salvors go on board and try to salve the vessel. When an oil tanker is laying sunk and oil escapes from various tanks our divers go down and try to stop the leakage in order to avoid further pollution.

The last area where divers are involved in is the underwater construction business, mainly in the southern province Zeeland where the biggest hydraulic works of the world are in progress. After the floods of 1953 - when nearly 2000 people were drowned - the Dutch government made the decision to close all estatuaries by damms and locks, raise dikes. This work is now in its final stage and divers are involved in all kinds of underwater jobs. Some jobs are carried out by divers in a divingbell, under bottom pressure condition and they collect undistorted ground samples. Others make TV and visual inspection surveys of willow matting anchorpiles etc. Others are busy with underwater grouting. In short, diving work inland-inshore is very versatile and although depths commonly are not greater than 50 metres and gas mixtures not used, the environment can be very hostile, decompression stops have to be made and accidents happen.

And it is not only in our own country that we do salvage or wreck clearing jobs, construction work and demolition, we work all over the world. Our gear is not as impressive and complicated as used in the deep diving industry, not so glamorous but the scope of work and the importance of what our divers are doing, the dangers they encounter, justifies that these divers are treated equal to the deep divers and that they are well-trained, equipped and looked after, and by doing this in combination with the diving regulations increase their safety.
I hope I have given you some insight in this problem, the possibilities scope of work of the inland-inshore diving which in many cases is the hatchery for the men who want to go to the very deep.

Gentlemen, I thank you for your attention.

TRAINING THE PROFESSIONAL DIVER FOR OFFSHORE OPERATIONS

SUMMARY

by

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SUMMARY

At the time of preparation of this abstract there is underwater industrial activity taking place on an increasing scale world wide. Offshore installations and projects requiring divers and diving support personnel are currently taking place in Australia, Borneo, Brazil, Canada, Chile, Egypt, Great Britain, India, Indonesia, Iran, Israel, Korea, Malaysia, Mexico, New Zealand, Nova Scotia, Norway, China, Saudi Arabia, Singapore, Syria, Taiwan, Trinidad, the United States and Venezuela.

The equipment the offshore diver is required to use and the technological advances in the field of deep diving are such that today specialised training has become even more important than in the past.

The predictions made in the 60's and early 70's regarding the requirements for trained personnel have long since been made obsolete by fact. One prediction still exists; that it is vital to provide adequately trained commercial divers if the safety record in this dangerous occupation is to be improved.

My paper is concerned with the training given to prepare commercial divers in the United Kingdom for work as mixed gas divers for offshore operations.

Historically these men were recruited from the UK Services or from countries who had "expertise" in the field. This did not always produce the calibre of person required to meet the needs of an ever expanding industry.

The need for professional divers to be able to work safely and competently in their specific areas of operation, be it in the air range, or with additional training and experience as mixed gas divers has not altered, only the method by which this is achieved.

The systematic approach to diver training advocated in the United Kingdom lays great emphasis on the selection process by which suitable personnel are chosen.

National standards both for air training down to 50 metres and for mixed gas/saturation training have been established and practised since 1975/76.

These standards specify the terminal objectives to be met in the United Kingdom by divers attending schools if courses are to be approved by government. They define the nature and therefore scope of air and mixed gas diving training and have consequently led to a standardised system within the United Kingdom.

The Training Standards are continually kept under review, for example the mixed gas standard has recently been reviewed, the terminal objectives altered and a pilot course held to evaluate the proposed new syllabus. The air standard is under review at present to meet the continuing but changing demands of industry.

In the United Kingdom there are four distinct phases in the training of a commercial diver for offshore operation:

1. Formal training as a basic commercial air diver including the use of underwater tools.
2. On site experience as an air diver gained after completing a basic air course.
3. Formal mixed gas/saturation training.
4. Planned experience gained in the field.

I consider that if the need is to be met, a commercial diver must undertake all of these training phases before he can be considered to be a competent and professional diver.

TRAINING FOR THE PROFESSIONAL DIVER FOR OFFSHORE OPERATIONS

by
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PAPER

1. Introduction

In 1972/73 the requirement for divers or skilled underwater technicians to work offshore in the British Section of the North Sea was seen as being between 500 - 600. The majority of these men were operating mainly in shallower water with little saturation being required. Forecasts at that time indicated that there would be a need for a further 200 - 400 divers each year up to 1980. The resources that existed in 1972/73 and the traditional method of "poaching" personnel could not meet this need. As operations in the North Sea moved progressively further North on the Continental shelf the requirement for bounce and saturation capabalities increased considerably. Similarly the exploration and exploitation worldwide of underwater resources increased, and still increases steadily.

In 1976 there were estimated to be 2000 + commercials divers working offshore in the North Sea, with a proportionate increase worldwide. This number remained fairly constant until early 1978 when a decrease in the overall numbers become apparent and still coninues.

In 1972/73 the demand and subsequent high pay scales drew in some cases inadequately trained personnel to the work, and the increase in fatalities and injuries testify to this.

It was seen that a vital need existed to provide adequate training for commercial divers particularly in order to increase the safety record in this dangerous occupation.

The harsh conditions of the North Sea, and the increased depths at which work is undertaken emphasised the need for special commercially orientated training, particularly in depths below 50 metres, ie. Oxy Helium bounce and saturation diving.

It was considered that part of this requirement could be met by the establishment of a National Commercial Diver Training School: Hence the foundation in 1975 of the Underwater Training Centre.

2. Historical Background

Historically it can be seen that the diver training was undertaken either by the services or by an informal "apprenticeship", where coaching was given on site by divers who had learned "the hardway". During the 60's and early 70's the marjority of commercial divers working offshore in British waters learned their trade in this manner.

At this time the skilled underwater technician came mainly from overseas, from America and France, having gained oil field experience in the Gulf of Mexico or in the Middle East. Ex-service divers particularly from the Royal Navy accounted for a considerable proportion of the underwater work force who learned specific skills by experience on site.

The demand for skilled trained personnel was however overtaking the supply. It bacame apparent during this time that a training method was required if experienced divers were to be found in sufficient numbers to meet the requirement.

4. The Need

In order to establish a training method to meet the continuing requirement for trained underwater personnel it is important to define the need.

It is obviously impossible to specify in one sentence the needs which exist throughout every facit of the diving industry, however in general terms I feel the need can be defined as follows:

That proffessional divers be able to work safely and competently in their specific areas of operation, be it in the air range, or with additional training and experience as mixed gas divers.

5. Training to meet the Need

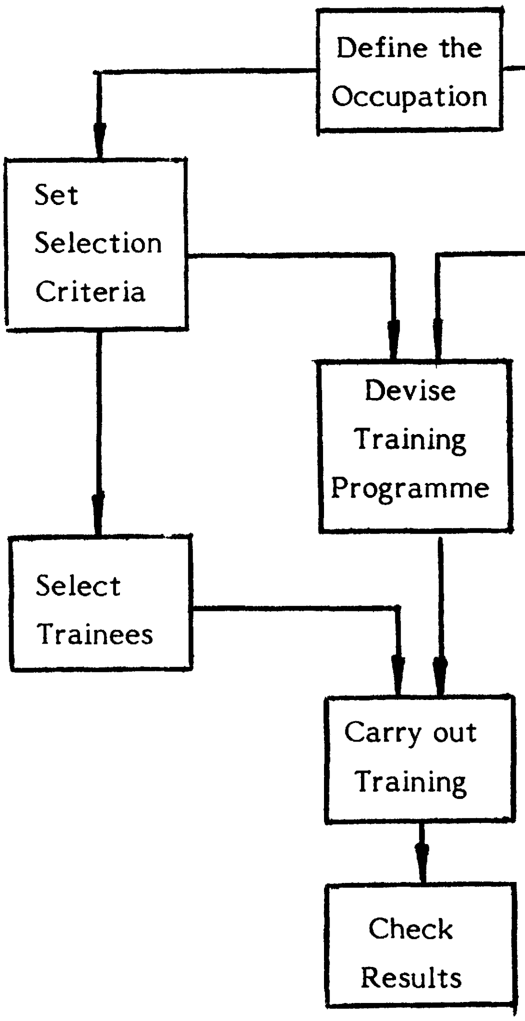
The need defines two areas of operation, air and mixed gas. These can be described as "shallow work" and "deep work". It follows therefore that there are two different training requirements. It is not unknown for mixed gas to be used at relatively shallow depths where in other circumstances air would be the breathing gas: we therefore use the term "air diving and "mixed gas diving" in preference to "shallow" and "deep". I must stress that this division of requirements for air diving and mixed gas diving does not imply that training should be to two different standards but that the nature and scope of the training programmes should be different. In the past "air diving" has meant dock, river, canal work and the like. To this is now added offshore work in water depths of less than 50 metres.

The first phase of training must concern itself principally with the task of enabling a man to operate in the underwater enviorment safely while breathing air. It is generally agreed that this limit should be 50 metres, mainly because of the effects of nitrogen and decompression requirements.

Training for work below 50 metres will concern itself with the nature of diving operations generally in more exposed conditions. Although it should be reasonable to assume that the diver progressing into deeper work still has instilled into him from his earlier air training a continuing and over-riding awareness of the need for safety throughout the diving operation. Obviously the additional safety requirements for this deeper diving must be continually stressed during the period of training.

Training for divers and underwater workers is expensive, particularly mixed gas training. At the same time training has to be effective. It is considered that the most efficient use of training resources can be achieved if a systematic approach is adopted.

Figure 1 shows schematically how the system used in the United Kingdom functions.



6 The Systematic Approach to Training

This systematic approach to training applies equally to air or mixed gas, although naturally the requirements for the two types of diving differ.

The overall aim of training is to enable a person to work underwater safely and efficiently. The skills involved fall into two very clearly defined areas:

a) Diving Skills
b) Working/task skills.

The training programme must recognise that these are two quite distinct objectives. The first aim of training is to enable a diver to dive safely without endangering others in whatever equipment is relevent to the depth range for which the training has been formulated. Secondly the diver must be employable, the person must therefore be trained to carry out a range of useful underwater tasks.

In the United Kingdom, air training, including training in the use of tools and techniques likely to be required by the industry is undertaken in 12 weeks. This is considered to be an adequate length of course to prepare a novice for employment in the industry at the basic grade. Once there he must gain "on the job" experience under close supervision before he can be considered to be a fully qualified and competent Air Diver.

The majority of offshore diving work however falls within the "Mixed Gas" range. It is of this type of training that I propose to devote the remainder of this paper.

As already outlined the systematic approach is basically the same for "air" and "mixed gas".

The definition of occupation, selection criteria and terminal objectives for mixed gas training within the United Kingdom are produced by Government. The training plan and syllabus, the selection of students and the carrying out of this training is undertaken by the UTC or by company in-house training if approval is granted by Government. Both Government and UTC check the results by validation and assessment.

The range of working conditions for a commercial mixed gas diver are wide. For example, it could involve working on an exploration oil rig, undertaking a bounce dive when required, or being subjected to long periods of saturation diving while working on a pipelinge in say 150 metres of water. In addition there are a wide range of equipment designs, configurations and operating proceedures.

At the UTC we concentrate on the skills of mixed gas diving both for bounce and for saturation, leaving the detailed underwater working skills so essential to the successful completion of the job, to be developed during either the individuals pervious experience as an air diver or by specialist underwater working training, probably undertaken "in house".

7 Defining the Job

The occupational description given in the UK Training Services Division training standard for mixed gas diving describes what a competant person should be able to do in diving and diving operations. Two points need to be made regarding this occupational description. Firstly it does not cover every aspect of every job. The particular requirements of each diving employer varies and it is not possible to produce occupational descriptions which would apply in every case in respect of all needs.

Secondly, not all commercial mixed gas divers have had the training and experience to be fully competant in every aspect. Where this is the case the occupational description does not imply that they are in any way imcompetent or unexperienced. Quite clearly in setting out to train people for an occupation it is of the utmost importance for that occupation to be defined.

The definition of a Mixed Gas Diver is given as being:
Able to dive and work competently and safely in depths greater than 50 metres, using mixed gas techniques and working from a submersible compression chamber in both bounce and saturation modes.

It will be immediately apparent that this definition of mixed gas diver corresponds directly to the need as specified earlier in this paper.

8 Training Requirements and Terminal Objectives

If you ask yourself the question - what must I teach this man in order to make him a safe competent mixed gas diver, the training requirement becomes obvious. In the United Kingdom the requirement for mixed gas divers is:

a Understand and apply relevant section of statutary regulations and British Standard codes of Practice, which are pertinent to diving operation, to the health and safety of the diver and the use of safe working practices.

b Dive safely and competently to depths greater than 50 metres using mixed gas techniques.

c Dive from SCC both by day and night under various water conditions and visibility.

d Act as a bell man to other divers and take emergency measures to ensure their safety.

e Carry out routine user maintenance of mixed gas commercial diving equipment and diver communication systems; also the repair and testing of diving suits.

f Operate a DDC under supervision.

g Prepare gas mixtures and apply compression and decompression schedules under supervision.

h Undertake, under supervision, the planning preperation and conduct of diving operations.

i Recognise the signs and symptons of typical divers illnesses associated with mixed gas diving.

j Apply first aid under hyperbaric conditions, the method of expired air resuscitation and external cardiac massage.

The terminal objectives or what the trainee will be able to do on completion of a mixed gas course are derived from the training requirements. The working of the terminal objectives and their interpretation is very important for they are used to produce the topics to be included in the training programme and indicate the extent to which each one is to be covered.

For mixed gas training the terminal objectives have been grouped under three headings:

1 Deck decompression chamber operation.

2 Submersible compression chamber operation

3 Diving theory, Physiology and First Aid.

These three headings cover a number of subjects each of which has a number of objectives.

Terminal objectives can be classified broadly into two groups:

a Objectives whose purpose is to develope some degree of competance in the trainee. ie. Control gases on line to chamber BIBS (Built in Breathing System).

b Objectives which are limited to developing in the trainee an appreciation of, or acquaintance with a piece of equipment or proceedure ie. describe the working of inspired gas and diver heating.

9 Selection Criteria

The overall selection criteria for mixed gas training has in the United Kingdom been set by Government as part of the overall systematic approach to diver training.

The selection criteria were set taking into account:

1 The minimum acceptable attributes, for example normal vision without glasses, minimum level of numeracy.

2 Other attributes which could be taught within the training programme but which would be desirable as pre-entry qualifications, for example competancy as an air diver and underwater worker.

The selection criteria are intended to select individuals who after completing a mixed gas training course together with planned experience on the job, will be competent deep divers, and to minimise wastage in diving training.

The selection criteria are based on:

Legal requirements

Informed opinion.

There are three mandatory requirements which candidates must have achieved before they can be selected for mixed gas training.

a They must hold an in date British Offshore Medical certificate issued by an approved doctor. The certificate must not contain a depth restriction of less than 300 metres.

b Must be a competent commercial air diver and underwater worker.

c Must be at least 18 years of age.

For guidance the selection criteria further states that "It is unlikely that an individual could build up sufficient experience and competance as a commercial air diver and underwater worker in less than 12 months after completing a basic course and hence the majority of trainees will be significantly older than the minimum age requirement".

In my experience, gained after interviewing and selecting numerous candidates for mixed gas training, it is of the utmost importance to ensure that any mixed gas candidate must have achieved this minimum level of industrial experience.

It is beyond doubt that the potential mixed gas divers air range experience must have been gained at a varity of depths under real working conditions.

The selection criteria stipulates "12 months after completing a basic course". It is possible for an air diver to spend 12 months on an offshore installation and yet dive relatively infrequently. I personnally feel that real experience and competance as an air diver is required. The man therefore must have completed 12 full months while employed and working as a commercial air diver. These 12 months real experience could well take 24 calendar months or more to achieve. In addition, the experience built up by potential mixed gas candidates should show dives to representitive depths within the air range, not be confined to very shallow depths achieved say in a harbour or canal. The importance of the students experience cannot be over emphasised - it is the basis on which all further training will be built.

Although no specific educational standard is laid down as a prerequisit for mixed gas training it is suggested in the selection criteria, that candidates for mixed gas training,should he is in possession of formal educational certificates for English language (or equivalent) and for mathematics. These certificates should be of a standard approximating to GCE 'O' Level.

This is particularly important on a course which is short but intensive. The student must be able to grasp from day one the formula and theory apertaining to mixed gas diving. There is no time available or for that matter scheduled to allow students to catch up on basic subjects during the course.

In view of the demanding nature of underwater work particularly that involved in deep diving, special care is taken when considering applications for training from those over 30 years of age. This most definitely does no exclude over 30's from undertaking training but I would suggest that only candidates with considerable commercial air diving experience be considered if they have reached their 30th birthday.

The mandatory requirements and those suggested aspects covered by the selection criteria concerning candidates for mixed gas training can only be fully checked at interview. No amount of documentary "proof" will or can dispence with eyeball to eyeball interview. It is important to gain a "gut feeling " for a candidate to support - or otherwise - his documentary application.

The job definition, training requirements, terminal objectives and training programme are all extremely important functions in the overall systematic approach to diver training.

10 The training programme

As already mentioned the overall training plan has two distinct phases.

a Formal course training

b Planned experienced gained on the job.

Phase two, the planned experience is the direct responsibility of the diving employer. It is particularly important that those sponsoring trainees see these two phases as interdependent and complementary in the development of the trainee into a competend mixed gas diver.

11 Formal Training

Any teaching system whether for academic study, trade skills or the professions starts with a period of formal training which is used as the base for experience gained actually practicing the trade or profession.

In my view professional diving is no different.

When a man decides he wishes to become a professional diver he applies initially for air training. If successful in his application he attends a course of formal training, 12 weeks in duration, before entering the real world of the commercial diver to gain on-site experience. After a period of on site work gaining experience, the next step toward competence as a mixed gas diver must be a further period of formal training to re-emphasise the basic theory learned as an air diver. The student must then also be taught the additionals skills required for mixed gas diving. This I suggest can best be done in a "classroom" or training school environment, as a prelude to planned experience gained on the job.

Five years ago the UK authorities realised that this initial period of formal training for mixed gas diving did present the best method of preparing divers to work offshore.

It must be emphasised that during formal training, particularly at UTC conditions are real - students do dive to 100 metres and do undertake saturation in conditions exactly equal to those found offshore. There are differences and the important difference is that while undergoing this training students are completly divorced from any commercial pressure. This would most certainly not be the case if initial training was undertaken offshore.

Nothing in this industry remains static. Training requirements change and emphasis shifts to other aspects of training. The mixed gas syllabus originally produced in 1975 has recently been amended to conform to a revised set of Terminal objectives stipulated by the UK Manpower Services Commission.

These revised terminal objectives were distributed for comment and discussion to all interested parties within the industry and Government. They are seen to best meet the requirements of the commercial diving inudstry at this present time.

The training syllabus was rewriten by the UTC at the request of the Government to conform to the revised terminal objectives. A pilot course was run on behalf of the Government by the UTC in April 1980. The revised formal mixed gas syllabus for this training is attached a Annex A to this paper.

12 Methods of Assessment

There are several methods which can be used to assess the performance of trainees. The main problem is deciding on which to apply to particular tasks and topics. The two most usual methods are:

a Continuous assessment throughout the course of practical work and theoretical studies: this may include an end of course examination.

b Assessment confined to a terminal examination which could include practical tests and written or oral examinations.

The UTC utilises the system of continuous assessment together with phase exams and final examinations covering mandatory subjects. The methods of assessment used for the Mixed Gas Pilot course are attached to Annex B to this paper.

Annex A

TRAINING THE PROFESSIONAL DIVER FOR OFFSHORE OPERATIONS

MIXED GAS/BELL DIVING TRAINING SYLLABUS

Day No	Period	Subject
1	am 1	Arrival at UTC. Check documents and log books.
	am 2	Introductory lecture
	pm 1	Tour facilities and chamber dip
	pm 2	Theory examination
2	am 1	Basic Diving theory, Resume, Maths
	am 2	First Aid No 1 - Resuscitation, E.A.R., E.C.M.
	pm 1	DDC familiarisation
	pm 2	Handling of gases, compressors
	pm 3	Maintenance of personal equipment. Monitoring systems, Draeger tubes.
3	am	SCC Checks, Timekeeping and Records, Control Van, Gas and Electrical, communications and T.V.
	pm	Doctor's lecture "Medical Aspects of Deep Diving".
4	am 1	Hazards and control of mixed gas diving, ECU's
	am 2	Emergency Procedures
	pm 1	O^2 cleaning methods, filters, environmental control systems, maths resume.
	pm 2	Physics films
5	am	Physiology No 1 Basic Anatomy, Physiology and Hygiene.
	pm	Decompression schedules, therapeutic treatment, abort schedules, saturation excursions.

Day No	Period	Subject
6	am	<u>Physiology No 2</u> Decompression sickness, Henry's Law, Barotrauma, Embolism.
	pm	Free
7	All day	Free
8	am	Dry bell instruction, set up surface dive station, combined surface dives and shallow bell lockouts.
	pm	Instruction on bell lockout procedures combined with surface diver to bell operation.
9	All day	Instruction on emergency procedures. Shallow bell lockouts and re-entry. 2 students plus instructor in bell.
10	All day	Shallow bell lockouts and re-entry. 2 students plus instructor in bell.
11	All day	Shallow bell lockouts and re-entry. Unconscious diver recovery, E.C.U., E.A.R. No instructor in bell.
12		Shallow bell lockouts and re-entry. Unconscious diver recovery, E.C.U., E.A.R. No instructor in bell.
13	am	<u>Physilolgy No 3</u> Gas toxicity, HPNS Thermal extremes.
	pm 1	Gas and safety lecture, o^2 cleanliness.
	pm 2	<u>First Aid no 2</u>
14		Free
15		
16		
17		Shallow bell lockouts and re-entry
18		
19		

Day No	Period	Subject
20	am 1 am 2 pm 1 pm 2	First Aid No 3 First Aid No 4 Doctors lecture. Physiology examination. Phase examination
21		Free
22 23 24		Shallow bell lockouts and re-entry
25	All day	50 metre bounce dives on air
26	am 1 am 2 pm	Physics Physics First Aid No 5
27	am 1 am 2 pm	Physics ad associated maths Diving legislation Demand valves, regulators, helium reclamation.
28		Free
29 30 31		75 metre bell excursion from 55 metre saturation. (HeO2) Saturation period for 6 students (ABCDEF)
32 33 34		75 metre bell excursion from 55 metres saturation. (HeO2) Saturation period for 6 students (GHJKLM)
35	am pm	Bend watch Free
36	am 1 rest of day	Prepare and tow barge to dive site. 75 metre bounce diving (HeO2)

Day No	Period	Subject
37	All day	Practical assessments and First Aid Examination.
38	am om	Diving Theory Examinations. Free
39	All day	100 metre bounce diver (HeO2)
40	All day	100 metre bounce dives (HeO2)
41	All day	100 metre bounce dive decompression and bend watch. Return diving equipment.
42		Results and presentation of certificates.

MIXED GAS/BELL DIVER TRAINING SYLLABUS

Diving Requirements to Meet Revised Terminal Objectives

The following table details the number of dives to be achieved by each student attending MixedGas/Bell Divig training at UTC.

The number of dives in each depth range meets the Revised Terminal Objectives for this type of training. The Mixed Gas Working Party agreed these numbers during a meeting at UTC Fort William on 29th April, 1980.

1.	Shallow Bell Lockouts	25 - 30
2.	50 metre Bounce Dives on Air	one
3	75 metre Bounce Dives	one
4	100 metre Bounce Dives	one
5	55 metre Saturation with Excursion to 75 metres	one

Total number of students per course 12. This number was agreed by the working partly as being "ideal".

If courses of 16 students are undertaken there will be penalties to pay with reagrd to the overall length of the course, probably in the region of 6 extra days.

Annex B

B

TRAINING THE PROFESSIONAL DIVER FOR OFFSHORE OPERATIONS

Revised Mixed Gas/Bell Diving Training Standard

Pilot Course

METHODS OF ASSESSMENT

1. To be awarded a certificate the trainee must achieve the required standard in (i) the practical work: (ii) the two written examinations: (iii) the first aid practical and oral examinations.

2. The trainee is warned that if in the opinion of UTC he is a danger to himself or others he will be taken off the course and no certificate will be issued.

3. Practical Work

The trainee is assessed for practical ability out of a total of 10 marks, The overall pass mark is 73 or more, ie. 66%. Assessment is in two parts:

a.	Five Weekly assessments	- total 50 marks
b.	Diving Equipment Oral/Practical Examination	- total 60 marks
		110 marks

3.1 Weekly assessments

In addition to general and potential ability, performance as a team member, and progress, the trainee is assessed weekly on the main topics covered by the syllabus.

Weekly marks are out of 10 to the following standards.

10 Outstanding

All work done to a high professional standard. Confident and competent paying particular attention to detail Could work without supervision.

9 Very Good

Always checks equipment and undertakes all preparatory work without being instructed to do so. Anticipates problems and takes corrective action. Capable of working without supervision.

8 - 7 Satisfactory

Carries out all work in a satisfactory manner but requires guidance and minimum supervision.

6 Below Standard

Work done incorrectly, or with numerous errors. Over/under confident and/or disregards some safety precautions. Requires constant supervision. Does not always work as a member of a team.

5 Unsatisfactory

Performance well below standard. Ignores safety rules. Requires constant supervision.

Marks awarded for the first week of the course only count towards the overall pass mark. Any trainee awarded 6 marks of less during weeks two to five is warned about his inadequate performance. If he is awarded 5 marks or less in weeks two to five he is taken of course as having failed to achieve the required practical standard.

3.2 Diving Equipment Oral/Practical Examination

This examination will be conducted by an instructor who assesses each individual trainee. The examination is in four sections as follows:

Compression chamber

Carry out before use checks, showing an understanding of the basic working of:

i Environmental Control

ii Gas Networks (BIBS, Gas Sample, compression and Decompression Systems).

(15 marks)

Bell

Show an understanding of the basic principals of:

i Gas Control Networks
ii Temperature Control
iii Gas Analysis
iv Emergency Procedures (15 Marks)

Control Van

i Put gases on line to Bell, Compression Chamber, BIBS.
ii Calibrate 0^2 and $C0^2$ monitors
iii Control-of-chamber environment (15 Marks)

General

i Show an ability to use booster compressors, (starting, running stopping).
ii Show an understanding of the operation and maintenance of KMB 10 and Superlite helmet.
iii Show an understanding of the operation and principles of helium reclamation. (15 Marks)

4 Written Examinations

The trainee sits two written examinations at the end of the course. A paper on physiology is marked out of a total of 60 marks, and the final written examination, set on a selection of the subjects listed below, is assessed out of a total of 140 marks.

The overall pass mark for two examinations is 120 marks or over out of a total of 200 ie. 60%.

A trainee who fails theory but has attained a practical pass mark may be re-examined orally at the discretion of the Diving Manager in consultation with the MSC representative.

4.1 Physiology

This is taken as a separate examination because of the amount of writing required to give full answers to the questions. The questions are designed to give an indication of the trainees understanding of physiology, an understanding which is necessary if he is to give a thorough report of the symptons or injuries of a sick diver to a Doctor outside the compression chamber. The Doctor may base his initial diagnosis and subsequent actions on such a report.

4.2 Final Written Examination

Questions are selected from the following subjects:

Boyles Law, Daltons Law, Natural Gas Law, Archimedes Principle, mixing of gases, reasons for oxygen cleanliness, environmental control, emergency procedures, methods used to clean gas systems, diving legislation.

Questions on Boyles, Daltons and the Natural Gas Laws and Archimedes Principle are set to test the trainees understanding of their practical application.

5 First Aid Practical and Oral Examination

The examination is in two parts. An approved Medical Doctor gives the oral examination. The second part consists of practical tests and an oral examination carried out by a qualified member of the UTC staff.

The assessment of the two parts are based on a total of 15 marks. The pass mark is 9 marks or over, ie. 60%. A UTC First Aid Certificate is awarded if the students successfully passes this phase of training.

TRAINING FOR DIVING AS A SPORT

by

Claude ARZILLIER
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If one analyzes the title of this paper, one immediately realizes the need to take account of the link between two words. The last relates to the first and really defines how "training" should be interpreted and carried out. Diving is also a technique suited to the vast and varied medium in which it takes place.

There are two types of underwater activity :

- lake or fresh-water diving ;
- sea or salt-water diving.

If he is too far away from a natural environment suitable for diving, or simply wishes to wait for more favourable climatic conditions, the diver has a useful alternative - the swimming-pool. There, in sheltered conditions and at times which fit in with city life, the diver can learn, perfect his style or keep himself in condition, without of course forgetting that all this is only a means and not an end in itself.

The various types of diving have one thing in common - the need for safety to be ensured by confirming and maintaining medical fitness, by observing rules issued by the diving federations, and through gradual and well-planned training.

TRAINING IN THE SWIMMING-POOL

Such training is and always will be an important and effective way of preparing divers (whether beginners or experienced) for dives in a natural medium.

The basis of swimming-pool training is swimming in all its forms - the sporting aspect of diving. For far too long people thought of diving as synonymous with underwater adventure, for which there was no need to be able to swim ("The surface ? Never heard of it."). There were too many cases of so-called fatal diving accidents which were in reality simply surface drownings, in which no accident specific to diving took place, and which were caused only by lack of training and by unfamiliarity with the medium. Apart from sport, technique also plays an important part in this preparation. All the basic exercises which can be carried out at the shallow end (emptying the mask, releasing the mouthpiece, more than one diver breathing from a single cylinder, removal and re-fitting of equipment, etc.) are studied and repeated so that the divers become relaxed underwater and acquire a sound technical knowledge which will ensure their safety when they begin diving.

PHOTO n. 1

FRESH-WATER TRAINING

Motivation will play a large part in this type of diving. Those whose interest in diving has been aroused by the magnificent colour films shown in the cinema or on television do not find lake or quarry waters as warm or as luxuriant as those of their dreams. The water is cold or even very cold, and murky rather than clear. In spite of these disadvantages, thousands of fresh-water divers meet every weekend or during the holidays to practise their favourite sport.

Faced with such a hostile medium, training can only succeed by gradual acclimatization. Special equipment is used to combat the cold (especially for winter dives), and because of the poor visibility movement is disciplined very strictly and in a different way from movement in sea diving. However, there is little or no difference with respect to the exercises to be carried out and the tests set by the federations, for which divers are awarded certificates recognized by the World Underwater Federation.

PHOTO n. 2

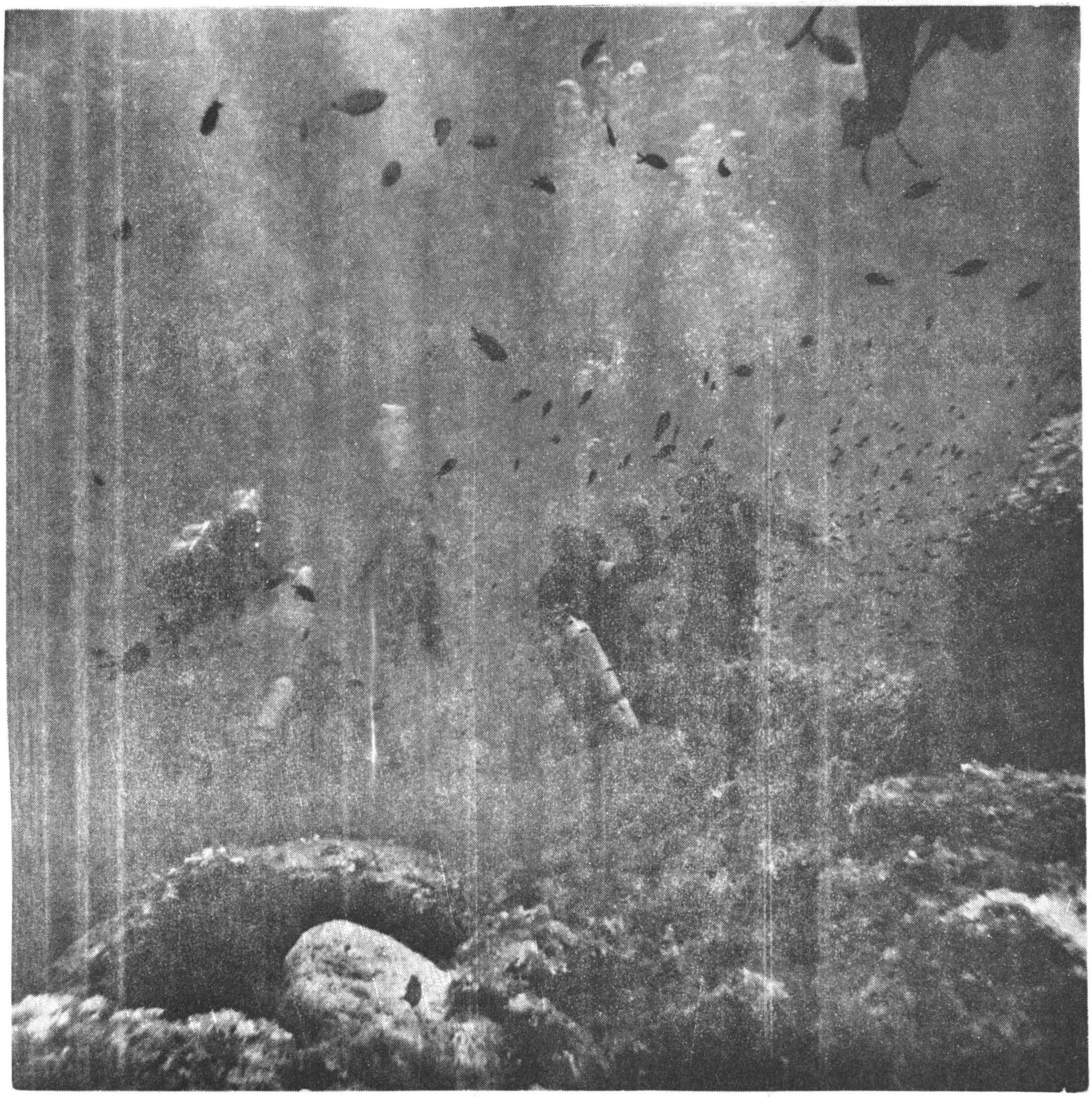


PHOTO n. 3 SALT WATER TRAINING

Photograph from Serge de SAZO - 33 rue de Rivoli PARIS IV (France)
Archives 0258

SALT-WATER TRAINING

'The eternal sea, eternally renewed ...'. The sea must be approached on a basis of knowledge ; one must not fight it but cooperate with it. It is therefore essential to be physically fit and to have undergone suitable surface training in order to respond to its moods, which sometimes change rapidly. The currents, tides, storms, cold and sometimes also poor visibility are all important factors. In recent years a knowledge of the ocean deeps and the life-forms found there has also been necessary in order to understand better that unfortunately the sea will not be able to renew itself eternally without help from human beings.

CERTIFICATES

These are perhaps a reward, but they are essentially and must remain a means of discovering one's own potential and then maintaining one's standard by continued training.

The standard of divers is determined by four levels and three certificates. Above these levels are the instructors, who organize training and award the various certificates.

Level 1 : The basic training, preparing for dives by means of swimming (suitable distances and speeds), movements on the surface and breath-holding diving using the essential equipment (fins, mask, snorkel, plus isothermic suit and ballast belt according to the temperature of the medium).

Level 2 : 'ONE-STAR DIVER' - a diver qualified to move about in shallow water under supervision. This represents an apprenticeship in the basic exercises and the first safety rules - preparation and knowledge of diving equipment, knowledge of the international communication code, emptying the mask and releasing the mouthpiece. Depending on the country and the pace of training, additional exercises may be carried out.

Level 3 : 'TWO-STAR DIVER' - an experienced diver able to move about at medium depths accompanied by one or more divers of the same standard, but remaining under supervision during 'deep' dives (40 metres or more). Training aims to achieve complete physical preparation to ensure totally safe movements at medium depths, - though basic exercises carried out without hesitation, two divers breathing on one mouthpiece, controlled surfacing, etc. In parallel with this training, simple theoretical instruction makes possible a better understanding of the problems posed by diving and an adaptation of physical behaviour to deal with them.

At present, in most of the countries visited by large numbers of tourist divers, this is the minimum level required for participation in exploration dives without being subject to supervision (which would tend to take the fun out of discovery). Indeed, diving as a sport or leisure activity must continue to be practised in total freedom, but this can be experienced to the full only if the participants are physically fit and have adequate knowledge.

Level 4 : 'THREE-STAR DIVER' - a practised diver whose training and knowledge enable him to move about in total safety, accompanied by one or more divers of the same standard, even at a considerable depth, and to provide support for divers of a technically lower standard nearer the surface. The training uses the same exercises as those required for the 'two-star diver' certificate, and gradually increases the depth. The concept of 'practised diver' implies not only the need for a thorough training but also the development of a first-aid capability - underwater and surface rescue, and the use of lifesaving procedures (resuscitation, first aid for decompression sickness, etc.), are part of the practical training.

Theoretical instruction is given in parallel, covering physical laws and their physiological consequences, diving tables and their uses and operation and maintenance of equipment.

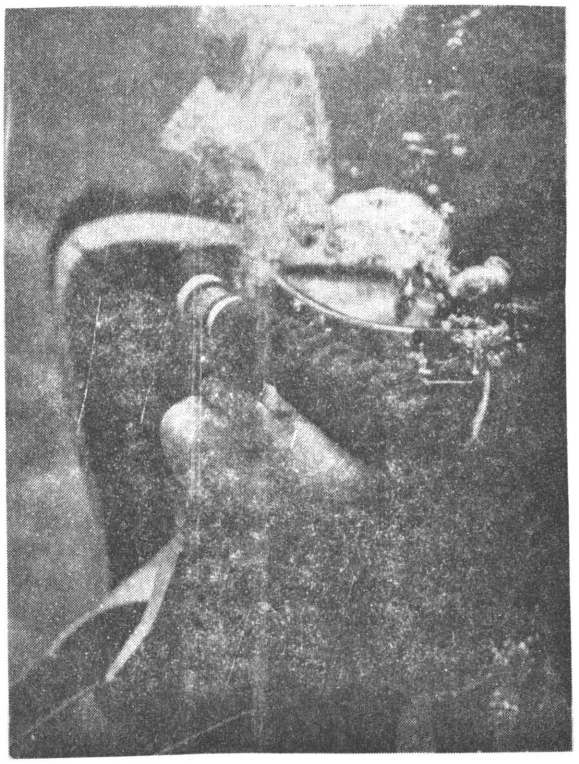
ORGANIZATION OF TRAINING

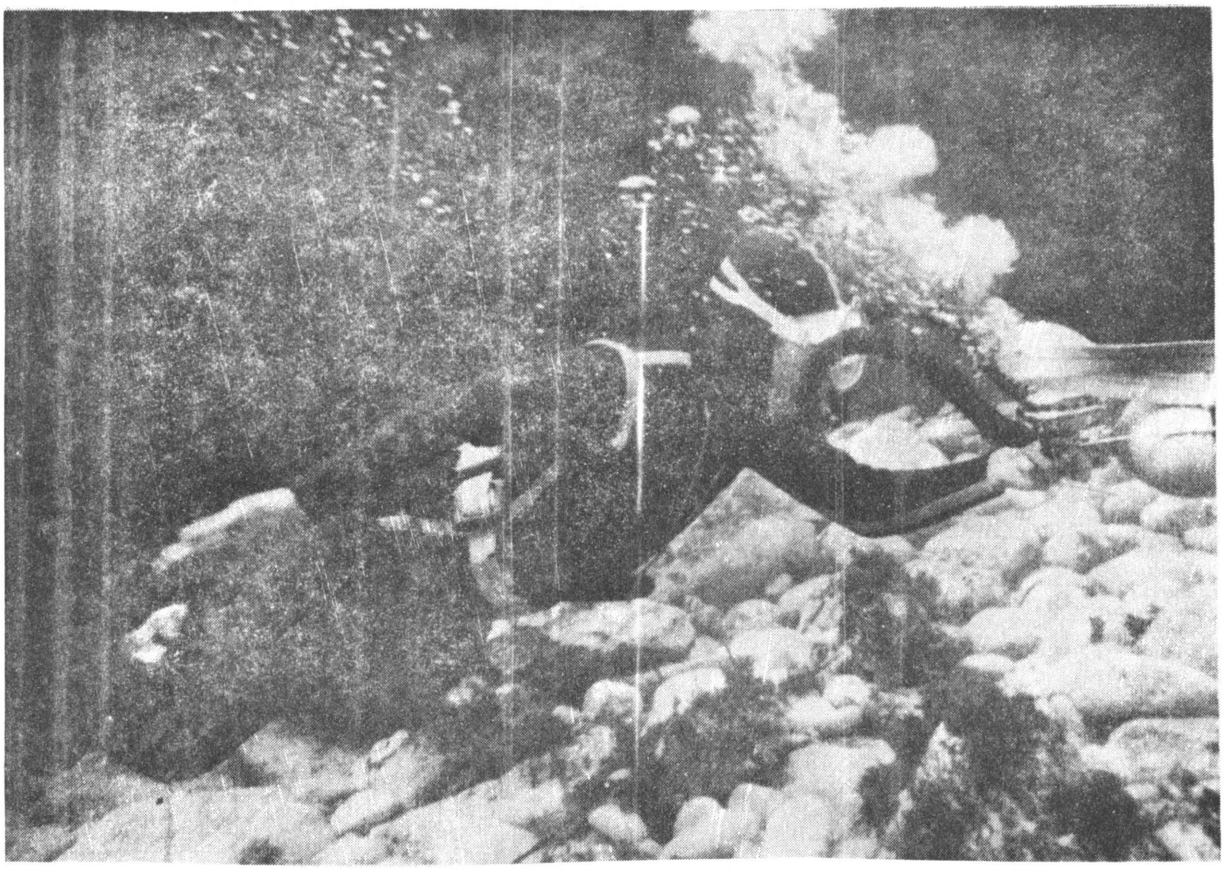
Diving training needs to be perfectly organized and run, precisely because diving takes place in a medium where the human body has to adapt to abnormal living conditions. The size of a group moving about underwater is related to the technical standard of the divers. Thus a beginner will be alone with his instructor, whereas two- or three-star divers may be in a group as large as four or five. It is not feasible (as in some sports) for an instructor to teach ten or fifteen pupils at once. Considerations of safety forbid it, and instruction would be much less effective in those conditions. But the small numbers involved should not lead one to think that one can dive alone. As one of our diving doctors frequently says, the diving unit is two.

The instructors have the difficult task of keeping physically and mentally fit while adopting a flexible approach to the teaching of a strict technique in which mistakes cannot be tolerated. Motivation - a factor which has already been mentioned - is even more important for the instructor. There can be no worthwile instruction or training without interest in and enthusiasm for the liquid medium and the diving which is a part of it.

CONCLUSION

The sport of diving can be the fulfilment of a wonderful dream, but no-one can achieve this completely and in total safety without fully developing his physical and mental resources and learning to control his land-dweller reflexes by carefully guided preparation. DIVING HAS TO BE LEARNT.





SAFETY PROCEDURES AND TRAINING FOR THE SCIENTIFIC DIVER

by

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SUMMARY

There are about 10,000 scientific divers world-wide, excluding the communist bloc. Diving training for scientific divers has developed in an evolutionary fashion during 25 years. Universities and research institutes have adopted sports-diving methods of diving, which give them an adequate depth range, mobility, safety, efficiency, and low costs. Training methods have been adapted from commercial, naval, and sports experience. These produce an excellent supply of well-trained students and graduates, at minimum cost to the research institutions. The fatality rate for scientific divers is low, but efforts should always be made to reduce accident rates wherever possible. Legislation in many countries is now being introduced which will be applicable to scientists and university teachers and graduate students for the first time. This paper urges that, where regulations and laws have to be applied for the first time, maximum attention should be paid to the existing system which already works and has produced a good safety record. Wherever possible the regulations should confirm the best existing practice. The present system of training is highly flexible, and continues to adapt to new equipment, new medical knowledge, and new work requirements. Any radical or mandatory changes will tend to produce increased costs, avoidance, inflexibility, and even increased risks due to the possible attempt to apply unsuitable equipment or techniques in certain situations. Improved optional courses are required to provide scientific divers with the opportunity to learn more about underwater techniques such as data-logging, acoustic positioning, video-systems, sampling equipment, etc.

INTRODUCTION

The total number of scientific divers including professional research workers, post-graduate research students, students, research technicians, and amateur scientists participating on a regular basis is of the order of 10,000 worldwide (excluding Russia, China, and Eastern Europe), and well over 2,000 in Western Europe. Diving in the course of scientific research started in the late 19th century, if not earlier (Dugan, 1960; and Wojtusiak, 1973). All forms of diving equipment, standard, self-contained, air, oxygen, mixture, bell, and habitat, have been used at one time or another for scientific work, although SCUBA is by far the most common (Roberts, 1971; NOAA, 1975; Müller, 1977). Diving is now used regularly in several hundred institutes, laboratories, universities, and polytechnics (Flemming, 1973; Gamble and Yorke, 1978; Gamble and George, 1979). The fatality rate in scientific diving is uniformly low, less than 2 per 10,000 at risk per year, in Europe and probably worldwide. A significant proportion of the accidents associated with European divers has been associated with habitat experiments. Training methods used for scientific divers are similar to, or identical to, those used for sports divers where SCUBA is concerned. Where other systems are used, the training is usually at a commercial school or with an appropriate commercial or navy diving operator or diving school. There is a standard CMAS (Confederation Mondiale des Activites Subaquatiques) certificate of Scientific Diver Qualification, which is recognised in the 55 countries with CMAS federations, and is probably accepted in many more. However, the laws, if any pertaining to scientists who dive vary greatly from country to country.

Scientific diving is completely international. Individual scientists visit other countries to work in laboratories where they dive; groups of diving scientists from several countries make up teams to work in one country, or in the open sea; teams of scientific divers from one country conduct marine scientific research in other countries. The discussion in this paper will concentrate on the EEC countries, but will include frequent references to non-EEC countries in Western Europe, and to other countries with advanced diving technologies. It is essential that the freedom and ability for scientific divers to work in different countries should be preserved.

DEFINITIONS

A scientific diver for the purposes of this paper is a person who is a qualified scientist, engineer, or archaeologist, who is employed primarily to use his or her technical skills, and who chooses to dive with breathing equipment in order to further the research project. The contract of employment usually does not require the scientist to dive, although in a few institutes the Senior Diving Officer or Chief Diver may have such a contract.

The most obvious example of a scientific diver is the scientist or archaeological research worker on a marine project whose research requires frequent diving on a week-by-week and year-by-year basis. However, these people are a minority. More typically the scientific diver conducts less than 20-30 dives per year, either concentrated into a few weeks of intense fieldwork, or spread out as seasonal sampling and observations. The remaining time is devoted to teaching, laboratory research, library study, computer analysis, and interpretation of results, etc.

A survey conducted by the CMAS Scientific Committee of scientific divers in 8 countries, of which 6 were West European, showed that the professional qualifications of scientific divers were distributed as follows: professional research workers and university lecturers, 17%; post-graudate research students, 40%; students and volunteers, 43%. A more detailed study of the percentages with different qualifications in British institutions produced the following figures: (N = 300)

TABLE 1	%	
. Professional post-graduate researchers diving regularly in their work	10	) 28
. Professional post-graduate researchers diving occasionally in their work	18	
. Research students working for a higher degree and diving in their research	11	
. Qualified teachers, graduates, and instructors diving in the course of work	7	
. Qualified technicians, instrument and equipment personnel diving at work	12	
. University undergraduates diving in connexion with study or assisting research	17	

CONT'D

	%
. Other students and pupils diving in connexion with their study	11
. Other, usually technical assistants, undergraduates, trainees, pupils, etc.	14
	100

The great majority of scientific divers learn to dive as a sport whilst coincidentally undergoing education as scientists, archaeologists or engineers. As they gain experience in both fields, the value of using diving techniques to further research becomes apparent to them. They are thus highly motivated volunteers who are practising two activites which fascinate and involve them professionally. A small number of qualified research workers take up diving training as a deliberate step towards increasing their research capabilities; similarly, a small number of sports divers who are not scientifically qualified, volunteer for further education in marine subjects, or apply for academic research posts, after sports diving has made them interested in the underwater world.

Physiological and psychological experiments upon divers are not included in this paper, with the exception of those cases (e.g. Miller et al, 1971; Baddeley and Flemming, 1967) where a significant number of working scientific divers were used as guinea-pigs in experiments under normal sea going conditions.

SCIENTIFIC DIVING METHODS

In order to appreciate the existing training and safety methods used by scientific divers it is necessary to understand what scientific divers typically do in the course of their work, and why they choose certain types of equipment. Ideal examples of underwater science are the various experiments in which electronic measuring devices have been attached to benthic fauna in situ by Earll and others (1975), the measurements of internal breaking waves using dye tracers by Woods and others (Woods & Fosberry, 1966), or the measurements of energy flow in kelp forests by Zoutendyk and others (Zoutendyk, 1975; Field, 1975; Greenwood, 1980), or the observation and mapping of coralline algae outcrops and oxygen depletion in the northern Adriatic by Stefanon

(Stefanon, 1977), and the work of Anger et al (1977). Scientific diving teams are usually small, and extreme mobility is needed in transport from the laboratory to the coast, from the coast to the dive site, and underwater at the work site. In consequence, the equipment has to be light and transportable. SCUBA meets all these requirements, and the diving methods adopted are those developed by sports diving training organisations over the last three decades.

The result is that scientific diving usually shares with sports diving the equipment and diving methods, whilst it shares with commercial diving the responsibilities and obligations of employment. These relationships are illustrated by Figure 1, a, and b. The figure is intended to illustrate a concept, and does not necessarily imply that scientific divers are always classified as employed divers in all countries.

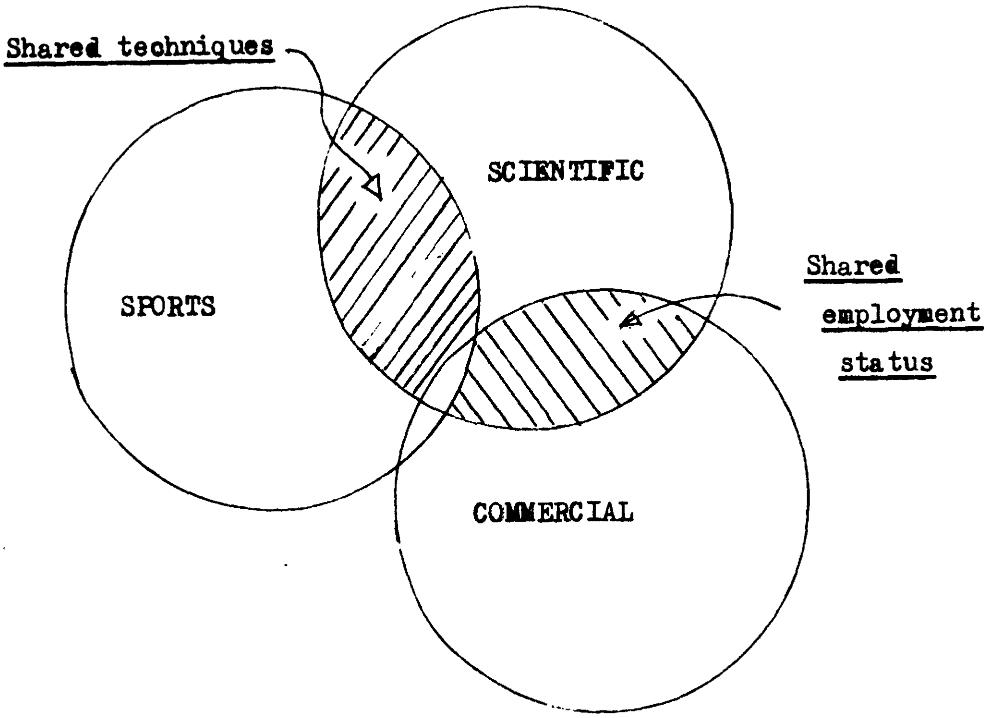
Because of the speculative and non-profit nature of most marine research it usually is conducted with small diving teams, no overheads, and short lead times. When the weather is right, or further samples are required, a research worker needs to be able to gather three or four colleagues, and plan a dive within a few days, or even the same day.

Equipment must be transportable and portable in one-person loads. On site the gear must be portable in small vessels or inflatable boats. Equipment must be highly reliable, and must not require a staff of engineers and technicians to operate it. Sports diving equipment is highly reliable in practice, for the same reason that a domestic television receiver is designed to be reliable. Although it is a complex piece of equipment, successful selling depends upon ownership by people who are not technical experts, and minimum maintenance of the equipment. In practice, accidents in sports diving and scientific diving are very seldom caused by equipment failures (Schenk & McAniff, 1975; BSAC, 1979; Underwater Association, 1978). Most scientific diving (with the exception of archaeological excavation on a wreck of small dimensions) requires extensive movement both in horizontal area and vertically during the dive. Track lengths of 500 metres are

FIG.1

RELATIONS BETWEEN DIVING ACTIVITIES

A. Sports diving, Commercial diving, and Scientific diving have certain factors in common, shown by the overlap of the circles.



B. This diagram stresses the fact that most scientific divers use sports diver techniques, but many have the status of employment.

Status → Technique ↓	EMPLOYED "AT WORK"	NOT EMPLOYED NOT "AT WORK"
HEAVY AND MIXED GAS SYSTEMS	COMMERCIAL	N.A.
SELF-CONTAINED AIR DIVING	SCIENTIFIC	SPORTS

not uncommon. Since the purpose of the dive is to get the trained scientist as close as possible to the objective of the research, it follows that the choice of direction and speed of movement on the seabed must rest with the diver. That is, the dive management is, as far as possible, within the control of the diver, not top-side. The surface Dive Supervisor will only override the Dive Leader underwater in the interests of safety.

The following table is a very rough estimate of the proportion of man hours dived by scientific divers using different techniques:

TABLE 2

Scuba	over 95%
Surface demand, air	1% - 5%
Mixed gas	Less than 1%
Bell diving	Less than 0.1%
Habitat	Less than 1%

There are several modes in which basic SCUBA equipment can be used. These modes are variously suitable to different diving conditions and tasks. However, it can be dangerous to mix the modes of diving on the same site, or to switch divers who are unfamiliar with one mode to the other, without very careful planning. In some circumstances it can be positively dangerous to have divers in different modes working together, since they cannot provide reciprocal safety support to each other in the water. At opposite poles are the two following modes:

(a) Full-face mask, double tanks with decant taps, no snorkel, no contents gauge, no life-jacket, life-line to surface tender, buddy-line to companion diver.

(b) Separate face mask and breathing tubes, any tank combination but no decant taps, snorkel, adjustable buoyancy life-jacket, depth gauge, cylinder contents gauge, buddy diver within visual contact, float-line to surface, diving watch, life-line to surface tender optional.

The advantages and disadvantages of the two modes of self-contained diving are as follows:

(a) Advantages

- topside monitoring and control of the divers
- communications with the divers
- recall and recovery of the divers in case of underwater emergency
- recovery of an unconscious or dead body
- double-decant method of monitoring breathing gas consumption
- possibility of diver continuing to breathe even if he becomes unconscious underwater

Disadvantages

- limited mobility to range of life-line
- risk of entanglement of life-line and buddy-lines
- drag of life-line through the water, and in currents
- inability of divers to buddy-breathe, or share breathing systems
- inability of divers to breathe for a long time or swim for a long distance on the surface when their breathing gas is exhausted
- poor flotation on the surface
- no control of buoyancy when picking up heavy objects on the bottom
- no control of buoyancy for assisted or emergency ascents
- no control of buoyancy for lifting an injured buddy diver

(b) Advantages

- extreme mobility
- no drag from life-lines or buddy-lines
- safety factor of buddy-breathing
- the diver can continuously monitor and calculate the desired dive profile

- the diver can breathe indefinitely on the surface in a relaxed position
- the diver can float indefinitely on the surface
- the diving breathing system can be ditched by the diver, and he still has the capacity to float and breathe indefinitely on the surface

Disadvantages

- lack of communications with surface control
- an unconscious diver would lose the breathing mouth-piece
- in the event of surfacing at a considerable distance from the surface support, the diver cannot be easily pulled to safety in the absence of a life-line
- an unconscious or dead body has to be searched for without the contact of a life-line

On balance scientific divers have almost universally adopted mode (b), which is that developed by sports diving organisations and sports diving schools. This method of diving is taught to several million sports divers around the world, and this ensures that volunteer divers working on archaeological or scientific projects underwater, have identical training to that of the scientists with whom they are working. When scientific divers wish to use a life-line or buddy-lines, for safety reasons, or for direct communications, the system is usually adopted with the existing breathing system of separate face-mask and breathing tubes. A full face-mask is usually only used when the diver is likely to be exposed to extremely polluted or corrosive waters.

Because of the need for mobility, often associated with long swims before and/or after the dive, most scientific divers choose to use SCUBA with separate face-mask and snorkel. Since many universities and colleges have sports diving clubs for their students, it is logical and convenient that the methods of diving learnt by the students as sports divers should be compatible with that used when they graduate to research.

The methods used by sports divers, and the training standards, are codified in recognised manuals such as the NAUI (National Association of Underwater Instructors) Manual, the BSAC (British Sub-Aqua Club) Diving Manual, and equivalent publications in many other countries. The CMAS Commission for Equivalence has carefully examined the documentation produced by the sports diving federations of more than thirty countries in order to establish the equivalence of diving grades internationally, regardless of the actual name given to each grade within a country. The grades of sports diving training and sports diving instructor are codified by CMAS as 1-Star, 2-Star, 3-Star and 4-Star diver; and 1-Star, 2-Star, 3-Star and 4-Star instructor (see Appendix 1 for a summary of the qualifications of each grade). Internationally recognised certificates and cards, of a credit-card type, are issued for each grade by CMAS in Paris. The divers carry the cards, and are thus entitled to hire diving equipment, diving boats, compressed air, etc., in over 55 countries.

Whilst self-contained air diving and sports diving methods are very widely used by scientific divers, there are many aspects of diving organisation which are not covered routinely by sports diving manuals. Accordingly scientific diving associations in several countries have produced technical manuals and codes which are used in conjunction with the diving training manuals. Such documents include the NOAA Research Divers Manual (USA), the Underwater Association Code of Practice for Scientific Diving (Great Britain), the Code of Practice for Scientific Diving (South Africa), and the Code of Practice for Scientific Diving (Italy), and the Richtlinien für Forschungstauchen (Germany). These codes cover such topics as medical standards, diving laws and obligations, qualifications for Diving Supervisor, responsibilities of employing institutions, conflicts of interest, diving in extreme and special conditions, insurance, etc. Several universities produce their own Codes; e.g. Scripps Institution of Oceanography, San Diego; University of Delaware; University of Florida; etc.

RECOGNITION OF SCIENTIFIC DIVING

Underwater research groups have been formed in many European countries at regional or national level over many years. The Centro Italiano Ricercatori Subacquei was formed in Italy at least as early as 1956, though it soon became defunct, and was later superseded by the Comitato Italiano di Ricerche Studi Subacquei (CIRSS). The Underwater Association for Scientific Research was formed in Britain in 1965; an Underwater Marine Biological Research Association was established in Scandinavia in the mid-1970s, and an Underwater Archaeological Research Organisation. In Germany the Unterkommission Forschungstauchen der Senatskommission für Ozeanographie was formed in the mid-1970s; and in France the Society Colympha was set-up early in 1979 to unite scientific divers. Holland and Belgium have active scientific divers within their sports diving federations, and some independent of the federations. The same is true of Denmark. These various associations and societies are all in frequent communication with each other, and exchange scientific newsletters and publications. There is considerable cross-membership, since an Irish geologist may wish to work with French geologists on the coast of France, or an Italian marine biologist may be interested in working with German divers in the Baltic. These are both real examples.

Most scientific diving groups are represented on the Scientific Committee of CMAS, both within Europe, and from many other countries. An international Code of Practice for Scientific Diving is in preparation with cooperation from the Scientific Committee of Oceanic Research of UNESCO. CMAS has introduced a Scientific Diver Brevet or Identity Card, which is issued to those divers who already possess the CMAS 3-Star Diver Certificate, who can also produce proof of employment or study in a place of research or learning where they dive in the course of their work, and who can also prove that they are entitled to dive in the course of their scientific work in their country of origin.

TRAINING AND SAFETY

The training options open to a potential scientific diver are;

(a) Join a general sports diving club
(b) Join a university or college sports diving club
(c) Attend a course at a commercial sports diving school
(d) Attend an in-house training course at the institute or university designed for scientific diving
(e) Attend a commercial course for industrial diving
(f) Attend a navy or army self-contained diving course
(g) Attend a government authorised and supervised course
(h) Attend a course at a commercial diving school offering training specifically for scientific divers

At the moment, initial training in most cases is obtained by option (a), (b) or (c). A relatively small number use options (d) and (f), and very few indeed use option (e), on account of the inappropriateness of the equipment and the high cost. In Germany in particular, option (g), is recommended by the authorities. As far as I know, option (h) does not yet exist, although it would be very useful. In particular, courses of one or two weeks might be valuable in order to improve and up-date the training of people who had learnt first through sports diving clubs, and then had gained a little practical experience.

Whilst there is a gradual and steady increase in the technical level and proficiency of scientific diving, it can be said that the present ad hoc training methods continue to provide sound basic training on the following criteria:

(i) very low fatality rate (less than 2 per 10,000 at risk per year)
(ii) ample supply of talented young scientific divers, and a continuous increase in membership of scientific diving associations
(iii) low cost of training
(iv) training does not interfere with study schedules

(v) varied training options to suit individual requirements
(vi) training is progressive and intersperses the course with experience over several months or years
(vii) training qualifications are internationally recognised
(viii) the system is equally suitable for men and women divers
(ix) training is available at many hundreds of centres and clubs throughout Europe so that travel and delays are minimal

It would be difficult to find an alternative system which scored so positively on all these counts. Any radical change in the existing system, for all its apparent ad hoc evolution, would certainly result in a loss of efficiency. The most useful changes could be made in the following areas:

(i) advanced SCUBA courses to raise standards of divers with 1-Star, or 2-Star, CMAS grades
(ii) modular courses in specific scientific diving techniques, underwater photography, surveying, data recording, acoustics, etc.
(iii) modular courses in non-SCUBA diving techniques
(iv) optional courses in peripheral techniques such as recompression chamber operation, para-medical training, navigation, equipment repairs, etc.

The existing training options used by scientific divers have grown up originally to fulfil other purposes, sport, military, or commercial. The scientific fraternity has simply used or adapted existing training schemes in the most efficient way. The principle shortcomings arise from certain aspects of non-standardization, particularly in the severity and frequency of medical examinations. All sports diving organisations which issue credentials at national level require the diving trainee to undergo an initial medical examination, but this is not as detailed or as expensive as the commercial diving medical. A standard medical examination is recommended by the Medical Commission of CMAS (see Appendix 2).

Medical and fitness standards required for industrial courses are relevant to exposure to depths of 100-600 metres, and industrial work with heavy machinery. Whilst most scientific divers are young and relatively fit, they tend to dive at irregular intervals, and so fitness is not necessarily maintained at a continuous level. It is standard practice to include work-up dives and fitness training prior to diving operations after a long spell away from diving. There is no evidence that an unacceptable level of accidents is being caused in either sports diving or scientific diving by inadequate medical standards. The accident rate in scientific diving is so low that, so far as I know, no single accident in the last 20 years has been caused by medical illness, heart-attack, etc., either in Europe, America, or elsewhere. In sports diving there have been a small percentage of the total number of accidents caused by heart-attack, and, before 1973, by diabetes. Diabetes is now not admissible for sports divers in most countries, and definitely unacceptable for scientific divers.

The emphasis on physical fitness, (as opposed to lack of medical contra-indication), and sheer physical strength, in commercial diving courses for industrial diving is much less appropriate to scientific diving. Whilst safety must be maintained, and the diver must be a competent swimmer and capable of surviving in adverse sea conditions, the primary requirement of the scientific diver is a trained mind. The mental training and academic skills may have taken anything from 3-7 years of expensive courses to acquire. A scientist with the best academic training and perfectly reasonable physical fitness may not be capable of passing the more Tarzan-like tests of some commercial and military diving courses. This is particularly true of women divers, who make up 15-20% of scientific divers. The physical rigour of training courses should be appropriate to the work envisaged. Detailed accident statistics are published by Hilbert Schenk (1975), and by BSAC annually, and there is no evidence that a disproportionate number of accidents in either sports diving or scientific diving is caused by lack of physical strength or stamina in either men or women.

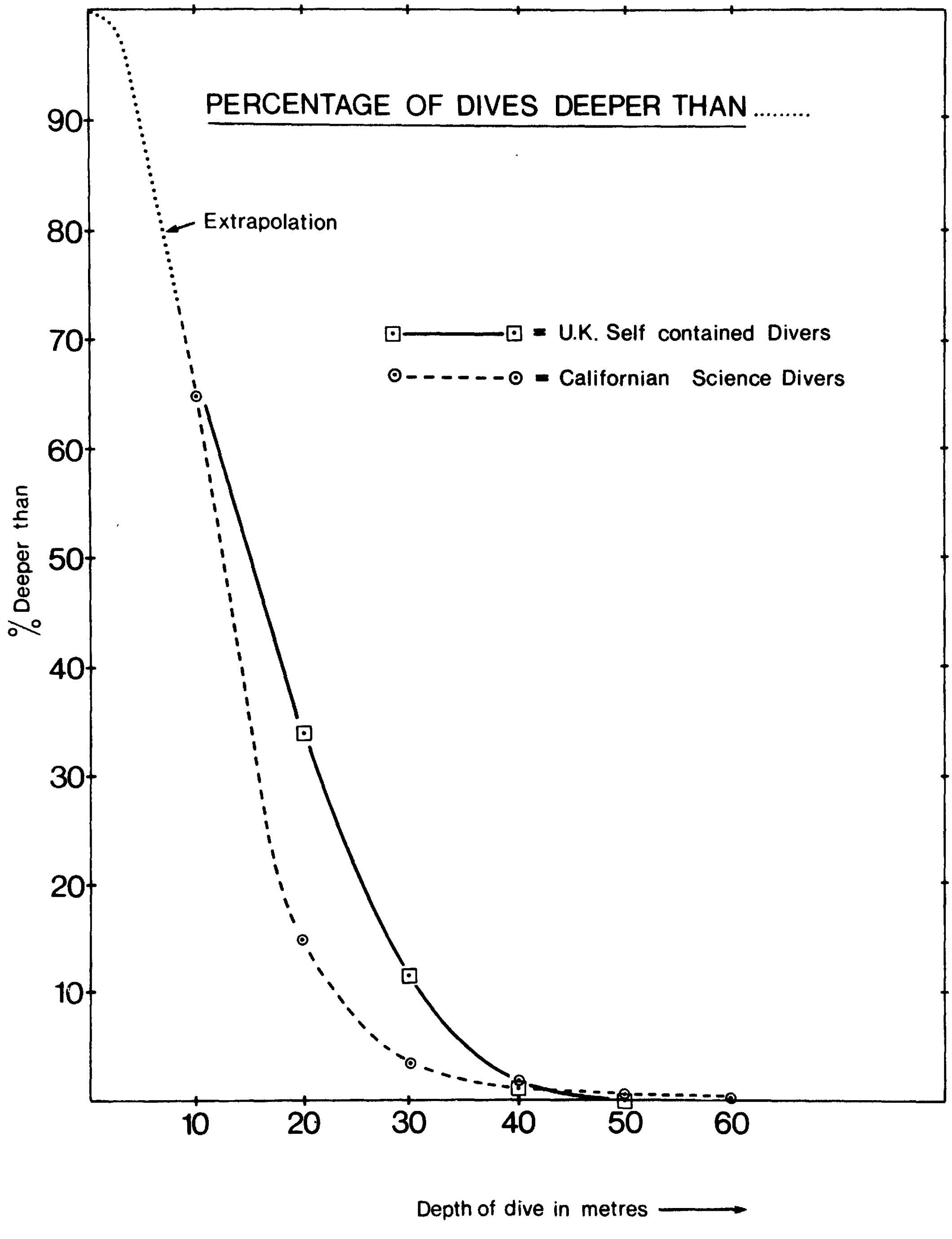
It follows that the initial medical examination, and the physical fitness required in the training course should be appropriate to the normal work load of scientific divers, and should be suitable for both men and women divers. Since scientific divers are employed or quasi-employed they have greater responsibilities to their colleagues, to their superiors, and to the general public, than sports divers. Their medical fitness to dive should therefore be checked annually. The strictness and detail of the medical examinations might be increased for deep diving, say below 40 metres, and for divers over 35 years of age.

The new British Diving Regulations drafted by the Health and Safety Executive propose a category of diver described as Class IV. This category has training qualifications suitable for self-contained air diving to depths and durations which do not require the presence of a compression chamber on-site. This qualification would permit diving on air to a depth not exceeding 50 metres, and dives which did not require decompression in the water exceeding 20minutes. This category of diving qualification is exactly suited to the requirements of most scientific divers. It seems reasonable to propose that the diving training requirements, and medical requirements, for this class of diver should be less rigorous than those for commercial divers who may work to depths of several hundred metres on mixed gases, and in saturation for days or weeks.

PROFILE OF SCIENTIFIC DIVES

In Britain at least there has been considerable official discussion as to whether the approved or required training for a scientific diver should be restricted to basic diving techniques and safety, or should include a range of vocational elements relating to biology, acoustics, sampling methods, sedimentary geology, survey techniques, etc. A survey of ten different marine scientific institutions showed unanimously that establishments only wanted courses to provide their trainees with adequate diving training, not scientific skills. The logic is simple. Most scientific

Figure 2.


PERCENTAGE OF DIVES DEEPER THAN ....
Extrapolation
U.K. Self contained Divers
Californian Science Divers
% Deeper than
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
Depth of dive in metres

establishments are places of teaching, or are associated with places of teaching. There is no point in a scientific establishment releasing staff from work, and paying for them to attend a diving school, where they will be taught half-baked botany, acoustic physics or archaeology. They can learn these subjects much more professionally in their normal academic institutions. During the same survey of marine scientific institutions it was also established unanimously that the diving standard required was CMAS 3-Star, using self-contained equipment, and not the commercial/industrial standard. It is uniformly considered that standard diving, hard-hat, surface demand, band-mask, mixed gas diving, and bell diving, are not relevant to the basic training for scientific divers, and nor is the use of hydraulic or pneumatic powered tools.

The previous paragraph refers to strictly basic initial training. It is extremely important that institutions and diving schools should offer voluntary options in techniques of underwater photography, video-systems, underwater geological sampling, etc. But these skills should not be parts of the compulsory basic training, since they would force up initial costs, be irrelevant to many of the trainees on one course, and would deter recruitment.

Figure 2 shows a comparison of the percentage of dives to different depths carried out by British and American scientific divers. The same overall profile probably applies to northern Europe, but the Mediterranean countries probably conduct a larger proportion of the dives at greater depths because of the greater clarity and warmth of the sea. Scientific divers from all European countries also sometimes conduct work in the Mediterranean, or in waters further afield, such as the Red Sea, Caribbean, or Indian Ocean. Provided that recompression facilities are available, it is again probable that there will be a tendency towards deeper and longer dives.

It has occasionally been suggested that scientific diving training standards should be based on no-decompression diving, on the basis that only a small percentage of scientific dives are in the decompression zone. This proposal is unnecessarily restrictive and much more damaging than appears at first sight. Although most scientific dives are not deep, almost all scientific divers dive in the 30-50 metre range from time to time. Thus the idea of a two-tier qualification, say 0-25 metres, and 25-50 metres, would be largely unworkable. Either everybody would need to take the deep qualification, or almost everybody would have to curtail some aspect of their research. The system proposed by the British Health and Safety Executive is highly practicable, allowing scientific divers to conduct dives not exceeding 50 metres in depth, and not requiring more than 20 minutes decompression in the water.

Scientific divers are likely to work anywhere in the world, and to have to work in unusual conditions, such as absolute silence, inside caves, in mid-ocean more than 1,000 kms from land, in mountain lakes, in warm mineral springs, in sewage farms, etc. The general parameters for maintaining safety in such varied conditions are laid down in the Code of Practice for Scientific Diving. It is not possible for basic training to include instruction on all possible diving conditions from the tropics to the poles, quite apart from the fact that many conditions are not reproducible in training. Thus an essential element of training is to alert the scientific diver to the implications of diving in different climates and oceanic conditions, to provide references, and to provide contacts with individuals and organisations which can help in each country. Such assistance is provided through the Code, and through the CMAS Scientific Committee.

THE SAFETY RECORD

The purpose of diving training is to enable the scientific diver to conduct the necessary work safely and efficiently. Whilst total safety is an ideal to strive after, it has to be accepted that diving is potentially hazardous, and that there is an inevitable trade-off between perfect safety and practical efficiency. If any changes in the past training system are being considered it is important to check the past safety record to see whether there is any evidence that inadequate training is causing accidents. If so, how much money should research institutes be required to pay to obtain improved training?

I have not been able to acquire complete statistics from all European countries, but the records from all countries with active scientific diving programmes show that the practice of scientific diving is probably the safest class of diving that anyone could be involved with. The following table shows the fatal accidents to scientific divers in Western Europe which I have been able to identify over 20 years:

TABLE 3

1960	a Bristol University undergraduate
1960	Conrad Limbaugh, Chief Diver of the Scripps Institution of Oceanography, California, diving in a cave off the South of France
1968	one German diver in BAH-I habitat
1969	two German divers in the Helgoland habitat
1972	Per Svensen - Norway, University of Bergen
1975	two divers in the Helgoland habitat, diving off the coast of the USA
1975(?)	a Norwegian university diver (?)
1977(?)	a Swedish biological diver

This makes a total of 8 fatalities in Western Europe, in 20 years, of which one was to an American citizen. Assuming that the total number of diving scientists has grown from about 500 to about 3,000 linearly, then the total number of diver-years is 35,000. Eight fatalities in 35,000 diver years is 2.3 per 10,000, which is identical with the sports diver population, using the same techniques. Three of the west European deaths were associated with diving from a habitat, and one was to a non-European. If these are excluded, the SCUBA deaths are 1.1 per 10,000 per year at risk.

In Britain during the last 20 years three non-fatal decompression accidents have occurred, and no fatal ones. All occurred shallower than 30 metres, and on dives being conducted according to the tables. In sports diving in Britain, out of a diving population of 40,000, there are usually 20-30 decompression accidents per year, and no decompression accident has ever been fatal to a sports diver. Whilst there have probably been similar incidences of decompression accidents in other European countries, I have not received a single report of a fatal decompression accident either to a sports diver or a scientific diver in an EEC country.

It follows that there is no evidence that deep diving by scientific divers is causing accidents or unacceptable risks. The established methods of diving in the 30-50 metre depth zone, and decompression procedures, as used by sports divers of CMAS 3-Star grade, are adequate and safe for scientific divers.

The accident record is therefore very creditable. On a person at risk per year basis it is much better than oil-field diving, and even on a person at risk per hour of diving it is comparable or better. There is therefore no case for radically altering the present training system on the grounds of a need for improved safety. Whilst gradually introduced improvements in training and supervision will improve safety, there is evidence that radical changes in safety legislation cause confusion and actually lead to a reduction in safety. The existing training system has evolved with scientific diving over the last 20 years, and this evolution should be continued in a gradualistic manner.

COMPARISON WITH NON-EUROPEAN COUNTRIES

The only countries which are known to have government established training standards for scientific divers are Germany and South Africa. In all other Western European countries, both within the EEC, and without, and in all Mediterranean countries, in the USA, Australia, Canada, and New Zealand, sports diving training standards are accepted for scientists who dive in the course of their work. In many of these countries there is an additional Code of Practice for Scientific Diving. In Italy a new Code was introduced in 1980; in South Africa there is a National Code for Scientific Divers; in New Zealand the Underwater Association Code of Practice for Scientific Divers is officially recognised. The official standards in South Africa are based on those of sports diving combined with the Underwater Association Code of Practice, and the South African Factories Legislation. Germany is unique in recommending navy-style life-line surface control diving for scientists, combined with a lengthy and mandatory training course. The existence of a different technique for scientists and sports diving probably acts as an obstacle to recruitment from university sports diving clubs, and increased costs to departments.

LEGAL STATUS OF SCIENTIFIC DIVERS

Laws pertaining to the activity of diving may be drafted as subsections or regulations within general laws in any of the following categories:

(a) Laws applicable only to offshore oilfields or pipelines
(b) Laws applicable to the construction industry
(c) Laws applicable to factories (however defined)
(d) Laws applicable to ships and the safety of craft at sea
(e) Laws applicable to all employers and their employees
(f) Laws concerning safety at work, whether employed, self-employed, or activities not for gain or reward
(g) Laws concerning safety at work which apply only when the work is carried out for gain or reward

In addition, such laws may be applicable or inapplicable depending as to whether the diving is carried out in inland water-ways and lakes, docks, within territorial limits near fixed offshore structures, within the 200 mile economic zone, or from a ship flying the national flag. A commercially employed diver working in the construction or offshore oil industries will certainly be included by any laws of the types (e), (f), (g) above, and any of (a)-(d) depending upon the diving location. Thus in one way or another the conditions of industrial employed diving are constrained by law. A scientific diver, by comparison, is on much less certain grounds. Categories of students, research students, and even lecturers, do not count as "employees" in many institutions. The diver may in effect be a partner, an associate, self-employed, a volunteer, or even a member of the public, as defined by the laws in that country or institution. If the scientific diver is technically "employed" he will be covered by some laws; if he is technically not employed he may be covered by no laws specifically designed for diving.

In Britain, the Health and Safety at Work Act (1974) applies to all persons "at work", whether employed or self-employed, and whether working for direct financial reward or not. Indeed, the full implications of the definition of "at work" have not yet been tested in the highest courts. The Diving Regulations which will come into force in 1981 will apply to all divers "at work", and will therefore apply to many scientific divers, though probably not to students and research students on grants. The Regulations will stipulate that training should be of an approved standard, though this standard is not itself defined in the Regulations. Training standards will be established and monitored by a committee set up especially for the purpose.

When the new HSE Regulations come into force, Britain will become the second EEC country, after Germany, to stipulate training standards which will apply to scientific divers. Unlike the German regulations, the British training standards for self-contained air divers are based on the more mobile sports diving systems, preferred and used by almost all diving scientists throughout the world.

In view of the widely varying nature of the enabling legislation within which diving regulations are promulgated in different countries, it is unlikely that a set of training methods and certificates could be devised which would indicate identical training and legal status in all countries, or even all EEC countries, and in all diving locations. What is important is that a scientific diver who is entitled to dive at work or in employment in a scientific institution in his homeland should also be entitled to do so in another country, even if the method of obtaining diving training differs in the two countries, and the legal status of the individual with regard to safety legislation may also differ. As explained above, since all scientific diver training in all countries is to CMAS standards, with the exception of Germany, the diving standard obtained will be the same in practice already.

From the point of view of the institution or diving team in country "A" which is joined by a scientist from country "B", most of the uncertainty will relate to employers' responsibilities and insurance liability. It seems relevant therefore that a diver who is qualified to undertake scientific diving in the course of his work in country "B" should carry an identity card to indicate his status. The scientists and administrators of country "A" thus know that the diver is entitled to dive as a scientist in his country of origin, and have reasonable grounds for granting him or her equivalent status.

This system already exists in the CMAS Scientific Diver Certificate. All holders of this card must already hold the CMAS 3-Star diving qualification, and the government approved diving certificate for a scientific diver if it is required in his or her country of origin. In addition, the holder must be a member of a place of learning or research, and must be authorised to dive in the course of work at that institution. The card is a plastic credit-card style card, with a unique number, and the name and signature of the holder. A complete record of the issue of the cards is held by CMAS in Paris and by the Scientific Committee of CMAS. The cards are recognised in more than 55 countries.

CONCLUSIONS

Scientific diving has developed in an ad hoc but highly efficient and adaptive manner over the last 20 years. The present system of training and regulation can be summed up by the following characteristics:

(a) The diving method used by scientific divers is predominantly SCUBA equipment used in the sports diving mode.

(b) Training is generally to the CMAS 3-Star level, but training may be obtained by various routes.

(c) The present system of training provides an adequate supply of highly motivated young scientists and archaeologists who use SCUBA diving in the course of their research, and training costs are minimal.

(d) The fatality rate amongst scientific divers is zero in many countries, and probably averages in the range 1.1 - 2.0 per 10,000 at risk per year for the whole of Western Europe over the last 20 years.

(e) University and marine science institutes are generally satisfied with the wide range of optional training methods and different routes available by which divers can obtain training.

(f) University and marine research institutes regard the syllabus and standard of CMAS 3-Star as adequate and relevant for scientific diving.

(g) It would be damaging to introduce an inflexible system of mandatory training based on specified courses and standards to be obtained in a specified course duration.

(h) University and marine research institutes do not want mandatory courses which would include vocational training.

(i) There is a need for an increased range of optional specialised courses in scientific diving technical skills, such as underwater photography, video-systems, underwater surveying and navigation, acoustics, data-logging, measurement of sediment properties, light transmission, etc.

(j) The CMAS 3-Star qualification should be preserved as a single qualification without division into two or more depth ranges.

(k) The CMAS Scientific Diver Certificate is already established, and provides a suitable basis for the mutual recognition of scientific diving standards between countries.

(l) Scientific diving training standards should be relevant to the work, and should be specifically for both male and female divers.

(m) Scientific diving qualifications do not and should not entitle a diver to undertake commercial or industrial construction or oil-field diving.

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APPENDIX I

Federations whose certificates have been recognized as equivalent to the international certificates issued by CMAS should send to CMAS, on special forms which will be supplied on request, the list of divers who have successfully passed all the tests or examinations for these certificates and for which the Federation is now requesting issue of international certificates as equivalents.

The CMAS will issue the certificates in question and send them to the National Federation who will present them to its nationals.

AIM OF INTERNATIONAL CERTIFICATES

This system will allow CMAS, without any interference in the affairs of National Federations, who will continue to issue their own certificates, to aim for standardization of the number of standards and tests or examinations to be passed in respect of each particular certificate. The fact that a diver is the holder of a CMAS certificate will be taken to mean that he has the knowledge and qualifications which go with that certificate.

TEMPORARY PROVISIONS

Divers who have received certificates from their National Federations before CMAS admits the validity of equivalence of the certificates issued in their respective countries may request the issue of CMAS certificates through the medium of their own National Federations.

EXPLANATION OF STANDARDS

Diver Grade 1. A diver with elementary knowledge of equipment and methods of use. May only dive under strict supervision of an instructor.

Diver Grade 2. A diver with more experience of the underwater medium as Diver Grade 1. May dive in company with a small group under supervision and control of an instructor, or in company with at least two divers Grade 3.

Diver Grade 3. A diver able to dive in company with a group of divers of same grade without supervision or control by instructors. May technically assist in the training of diver Grade 2 in conditions laid down above.

Instructor Grade 1. A diver Grade 3 having thorough knowledge of practical teaching, and elementary ideas of theoretical teaching.

Instructor Grade 2. An Instructor Grade 1 having acquired further knowledge of practical teaching and thorough knowledge of theoretical teaching.

Instructor Grade 3. An Instructor Grade 2 having exhaustive knowledge of both practical and theoretical teaching.

Instructor Grade 4. An Instructor Grade 3 having acquired sufficiently wide experience in practical and theoretical teaching, to be able to take part in national or international work concerning diver training and to take part also in the work of the Supreme Judges' Panels for both federal or national certificates.

Properly speaking, this is not a certificate in the ordinary sense of the word, but rather an acknowledgement of the worth and qualities of the holder. All Instructors Grade 4 have a consultative voice within the CMAS Technical Committee.

Note: This classification takes into account the decisions agreed upon by the Technical Committee of CMAS at Tangier in 1961 and London in

1962. It has nevertheless seemed right to update these and to add the new grades 2 and 3 for Instructors, as well as that of Instructor Grade 4.

This classification reflects the actual situation existing within numerous Federations.

EQUIVALENCE BETWEEN STANDARDS AND CERTIFICATES

Diver Grade 1	equals:	Diver's Certificate, One Star
Diver Grade 2	equals:	Diver's Certificate, Two Star
Diver Grade 3	equals:	Diver's Certificate, Three Star
Instructor Grade 1	equals:	Instructor's Certificate, One Star
Instructor Grade 2	equals:	Instructor's Certificate, Two Star
Instructor Grade 3	equals:	Instructor's Certificate, Three Star

The Instructor Grade 4 card will bear the title of "Instructor" followed by four stars.

AGE LIMITS

The age limits are as follows:

Certificate One Star:	14 years	
Certificate Two Star:	15 years	**Divers Certificates**
Certificate Three Star:	17 years	
Certificate One Star	18 years	
Certificate Two Star:	19 years	**Instructors Certificates**
Certificate Three Star:	21 years	
Instructor Grade 4:	25 years	

The age applicable shall be that on the date of the examination.

Minors must furnish written authorisation from a parent or guardian.

TIME SCALES BETWEEN CERTIFICATES

Apart from the age limits laid down, for reasons based on intellectual maturity and self-control, it is also necessary to lay down a minimum time limit between the issue of the different certificates so ensuring that the candidate has sufficient practical and technical training time.

During the time limit laid down a minimum number of dives will have to be carried out; from this it follows that every diver must have a diving log.

MEDICAL EXAMINATION

In order to graduate from one certificate to another there must be evidence supplied that a medical examination has been undergone, this for preference being carried out by a doctor approved by the organizing Federation.

DIVING LOGBOOK

The diving logbook may be that issued by the CMAS, or that issued by the National Federation. In the latter case, it will have to be submitted to the CMAS Technical Committee for approval.

Must have carried out, since issue of the latter, at least 30 dives (excluding those for training or refresher purposes) as shown in the diving logbook, of which at least 10 are to a depth of approximately 40 metres.

Must submit a medical certificate.

Organization:

Certificate examinations may be organized on Regional or National basis.

The organization must advise the President of the National Technical Commission or any person so accredited by him at least one month before the examinations take place. The Commission may delegate a representative to take part in the work of the jury.

Jury:

This should be made up of at least two instructors holding three-star instructor certificates, and, where required, of the representative of the National Technical Commission.

Examinations:

Without any equipment:

1. After swimming 200 metres freestyle in less than 8 minutes and without landing, dive to bring up dummy of 1.5 kgs. apparent weight from a depth of 3 metres and hold it on surface for 2 minutes without difficulty.
2. Undergo two periods of underwater breath-holding of 20 seconds each with an interval of 10 seconds between.

With fins, mask and tube, weight belt and suit:

3. Swim 800 metres with a group.
4. "Duck" dive to 10 metres.

Equipped with aqualung and equipment stated above:

5. Swim 500 metres with aqualung fitted using snorkel tube.
6. Bring up fellow diver from 20 metres depth, hold him on surface for 2 minutes and remove his equipment without difficulty.
7. Dive straight down "in the blue" to a depth of 40 metres.
8. At 40 metres signal, receive and interpret diving signals.
9. At same depth, carry out mask and mouthpiece tests.
10. Ascend from 30 metres without use of mouthpiece.
11. Swim approximately 30 metres at 5 metres depth without mask.

Seamanship:

12. Know how to tie the knots for:
    berthing/mooring boat.
    tie-up boat alongside quay.
13. With help of boat (no engine) follow fellow diver by towing and help him to remove equipment and come aboard.

Theory:

14. Find solution to a problem using decompression tablets.
15. Symptoms and emergency drill for diving accidents.
16. Lifesaving and resuscitation drill.
17. Practical knowledge on aspects of physics in diving.
18. Practical knowledge on aspects of physiology in diving.
19. Practical and theoretical knowledge concerning equipment used.

NOTE:

Examinations on theoretical knowledge will be written, except for the part concerned with lifesaving and equipment.

At this level, it would be desirable for the candidate to be in possession of a driving licence for power boats issued by the country concerned. In this case, extra points will be awarded.

Issue of certificates:

Certificates will be issued under the signatures of the Instructors acting as members of the jury, and countersigned by the President of the Federation's Technical Commission, or his representative.

It will comprise at least:

a. a sheet bearing details of the diver's identity, with a photograph, and proof of his membership of a club;
b. a sheet bearing details of his curriculum vitae as a diver, and listing the various certificates obtained;
c. a sheet for use as a medical record;
d. a reminder of the safety measures laid down by the CMAS;
e. prescribed signals from the code of communication in diving;
f. sheets recording dives carried out and stating:
    date;
    place;
    depth reached;
    duration of dive;
    senior divers/officers present;
    observations recorded during dive.

All dives carried out must be certified by an instructor holding at least a two-star Grade.

The CMAS diving logbook will be in two separate parts bound together in a plastic folder. The first part, which will hold the sheets referred to above in paragraphs a. to e., will make up the "passport" ("international diving passport") of the holder; the second part, which will hold sheets referred to above in paragraphs a. and f., will make up the dive record.

The records and logs may be overprinted with the insignia of the member Federations.

METHOD OF MARKING EXAMINATIONS

Experience has shown that in the field of diving certificates straightforward marking is difficult to apply, since the majority of tests or examinations are simply judged, and cannot be marked since they are not measurable.

It is therefore recommended that a marking system (so many marks out of a total of 10 or 20, for example) should be replaced by a wider and more just "value judgement" system, for example:

assessment A:	examination carried through at a high standard and with ease;
assessment B:	examination carried through at a high standard;
assessment C:	examination carried through at an average standard and without especial brilliance;
assessment D:	examination carried through with difficulty by the candidate, but without any serious faults or mistakes; the candidate could improve;
assessment E:	examination carried through at a low standard. This assessment does not mean automatic elimination of the candidate if it only appears once in his record;
assessment F:	examination not completed, or carried through at a very low standard; this assessment means automatic elimination.

It will be possible, using the method outlined above, to establish a candidate's "record" and so more objectively to judge his value.

PROGRAMME FOR DIFFERENT CERTIFICATES

For each of the following different certificates we shall examine:

1. Conditions of admission.
2. The organization of the examination.
3. The examination jury.
4. The minimum requirements of the tests.
5. Issue of certificates.

CERTIFICATE FOR ONE-STAR DIVER

The tests laid down for obtaining this certificate should be such as to allow a check to be made on the snorkel diving ability of the candidate as well as his knowledge of elementary facts on diving equipment and its use.

This certificate should be obtained under conditions which will develop a liking for diving as well as the desire to persevere on the part of the candidate.

Conditions:

Must be qualified by a Federation affiliated to CMAS.
Must be at least 14 years old.
Must submit a medical certificate.

Organization:

At club level.

Jury:

Diploma issued by an instructor holding at least a One-Star Instructor's certificate.

Minimum tests:

1. Swim at least 200 metres without fins.
2. Swim at least 15 metres underwater with fins, mask and tube.
3. Know how to equip himself with aqualung apparatus properly.
4. Know how to clear his mask underwater.
5. Swim 50 metres in full equipment breathing through snorkel tube, submerge and return to starting point in aqualung without landing (maximum depth 10 metres).
6. Know all compulsory diving signals laid down by CMAS.
7. Reply to several oral questions on elementary diving theory (equipment, safety rules, basic knowledge).

Issue of certificate:

The certificate will be issued by the Club under the signature of the instructor carrying out the examination.

CERTIFICATE FOR TWO-STAR DIVER

The tests under this heading should be such as to allow a check to be made on the diving capacities of the candidate, and in order not to compromise the safety of the team of which he is part; the team diving under the supervision of a two-star instructor, and at least in the sight of a one-star instructor, or of two three-star divers.

This certificate should be awarded under conditions which will develop in the candidate the idea of individual responsibility for a group.

Conditions:

Must be qualified by a Federation affiliated to CMAS.
Must be at least 15 years old.
Must have held a one-star certificate for at least one year.
Must have carried out, since issue of the latter, at least 15 dives which are recorded in the diving logbook, of which at least 5 are to a depth of 20 metres or more.

The validity of "training" dives counting towards the above mentioned dives will be left to the discretion of the instructor who will approve these as full dives if the conditions under which they took place qualifies them and will mark the log accordingly.

Must submit a medical certificate.

Organization:

At local or regional level.

Jury:

The certificate will be issued on the authority of an instructor holding at least a two-star instructors certificate.

Tests:

Wearing fins, mask and tube, suit and weight belt:

1. Swim 500 metres freestyle.
2. "Duck" dive to 5 metres.
3. With aqualung:
   Swim 250 metres on the surface wearing aqualung but breathing with snorkel tube.

   At a depth of 5 metres:
4. Remove mask and refit
   Remove mouthpiece and refit } tests of control.
5. Fit aqualung after leaving surface with fins, mask and tube (test of familiarity with equipment).
6. Exchange equipment with fellow diver.
7. Breathe using same mouthpiece for 2 minutes with second diver ("sharing").

   At 20 metre depth:
8. Dive or enter water with mask in the hand, fit under water and go down;
   At bottom, remove mask and refit;
   At bottom, remove mouthpiece and refit.
9. Signal, receive and interpret CMAS diving signals.

   Theory:
10. Examination (oral or written) on elementary theory.

Issue of certificate:

The certificate is presented by the club under the signature of the instructor organizing the examination.

CERTIFICATE FOR THREE-STAR DIVER

This certificate constitutes the highest qualification of a sport diver who is not intending to undertake the teaching of diving.

The jury must pay the greatest attention to the candidate's knowledge: elements of individual and team safety, as well as rescue work and in conditions where self-control is vital.

This certificate allows the holder to dive with one or more fellow divers of the same grade, without the necessity of having an instructor present, each of the divers being responsible for his own safety as well as that of the others.

Conditions:

Must be qualified by a Federation affiliated to the CMAS.

Must be at least 17 years old.

Must have held a two-star certificate for at least one year.

APPENDIX 2

CONFÉDÉRATION MONDIALE DES ACTIVITÉS SUBAQUATIQUES

WORLD UNDERWATER FEDERATION

FICHE MÉDICALE DE PLONGÉE
MEDICAL EXAMINATION FOR DIVING

MODÈLE 1976

Ce document est soumis au secret professionnel. L'attestation d'examen médical est délivrée séparément.

This document is subject to the rules of professional secrecy. Results of the medical examination are given on a separate sheet

Nom : ____________________ **Prénom :** ____________________
Name: ***Christian Name:*** ☐ 1

Adresse : ____________________ **Date de naissance :** ____________________
Address: ***Date of birth:*** ☐ 2 ☐

Profession : ____________________ **Club :** ____________________
Occupation: ***Club:*** ☐ 4

Sports pratiqués habituellement : ____________________
Sports currently practised:

____

Accidents sportifs : ____________________
Sports accidents: ☐ 5

____

Brevets : ____________________ **Date du premier examen :** ____________________
Diving qualification: ***Date of the first examination:*** ☐ 6

Ne rien inscrire dans les marges.

Do not write in the margin.

Commission Médicale et de Prévention:
Medical Comittee and Prevention
CMAS, 34, rue du Colisée - 75008 Paris, Tél. 225 60 42

Antécédents médicaux et état actuel
Medical history

Système cardiovasculaire :
Cardiovascular system: ☐ 7

Système respiratoire :
Respiratory system: ☐ 8

Système digestif :
Digestive system: ☐ 9

Système urogénital : **Grossesse :**
Urogenital system: ***Pregnancy:*** ☐ 10 ☐ 11

Système neurologique :
Neurological system: ☐ 12

ORL
ENT: ☐ 13

Maladies endocriniennes et métaboliques :
Glandular or metabolic disorders: ☐ 14

Antécédents chirurgicaux :
Surgical operations undergone: ☐ 15 ☐

Maladies actuelles :
Present illnesses: ☐ 17

Usage de médicaments et/ou traitements actuels :
Drugs taken and/or medical treatments: ☐ 18 ☐

Divers :
Miscellaneous: ☐ 19

Je déclare prendre l'entière responsabilité des conséquences d'une déclaration erronée.
I hereby declare that I take full responsibility for the consequences of false statement in the above declaration.

Signature du titulaire :
Signature of holder:

Examen
Examination

Taille : / ***Height:*** — **Poids :** / ***Weight:*** ☐ 20 ☐ ☐ 22 ☐

Etat général : / ***General condition:*** ☐ 23

Tête : / ***Head:*** — **Yeux :** / ***Eyes:*** ☐ 24 ☐ 25

Oreilles : / ***Ears:*** — **Tympans :** / ***Eardrums:*** ☐ 26 ☐ 27

Perméabilité tubaire : / ***Valsalva test - Eustachian patency:*** ☐ 28

Nez : / ***Nose:*** — **Sinus :** / ***Sinuses:*** ☐ 29 ☐ 30

Cavité buccale : / ***Oral cavity:*** — **Pharynx :** / ***Pharynx:*** ☐ 31 ☐ 32

Cou : / ***Neck:*** ☐ 33

Thorax : / ***Thorax:*** — **Ampliation thoracique :** / ***Chest expansion:*** ☐ 34 ☐ 35

Poumons : / ***Lungs:*** — **Spirométrie :** / ***Spirometry:*** ☐ 36 ☐ 37 ☐

Cœur : / ***Heart:*** — **Tension artérielle :** / ***Blood pressure:*** ☐ 38 ☐ 39 ☐ ☐

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Etat neuropsychique : / ***Neurological findings, psyche:*** ☐ 47

Divers : / ***Miscellaneous:*** ☐ 48

Test de Ruffier

1. Une minute de repos
2. Pouls/min (P) après ce repos
3. 30 accroupissements sur 45 sec
4. Pouls/min. (P_1) aussitôt après.
5. Pouls/min. (P_2) après une minute

(Le pouls est toujours compté sur 15 sec.)

Ruffier test

1. *One minute rest.*
2. *Pulse/min. (P) after this rest.*
3. *30 kneebends in 45 sec*
4. *Pulse/min. (P_1) immediately after.*
5. *Pulse/min. (P_2) after one minute*

(Pulse measured over a period of 15 sec. each time)

Normal : Index 0-10
(0-3 très bon, 3-5 bon,
5-10 moyen, 10 insuffisant)
(0-3 very good, 3-5 good,
5-10 average, 10 inadequate)

☐ 49 ☐

Index .

$$\frac{P:\qquad + P_1:\qquad + P_2:\qquad - 200}{10} =$$

Test de Flack : / ***Flack test:*** — **mmHg :** — **sec. :** — **pouls/*pulse*:** ☐ 51 ☐

(sert surtout pour déceler des dysrégulations circulatoires – Après inspiration forcée maintenir 40 mmHg en soufflant dans un manomètre Hommes 40 sec , femmes 30 sec , enfants 14 ans 20 mmHg, 20 sec , on prend le pouls au cours de l'exercice durant 5 sec , son élévation ne doit pas dépasser plus de 10 pulsations par 5 sec)

(mainly to reveal circulatory irregularities – After breathing in as deeply as possible maintain a pressure of 40 mmHg when blowing into a sphygmo manometer for a period of men 40 sec , women 30 sec , children under 14 20 mmHg 20 sec The pulse count taken over a period of 5 sec during the exercise must not exceed 10/5 sec).

Examens complémentaires : / ***Supplementary examinations:***

ECG : / ***ECG:*** — **EEG :** / ***EEG:*** ☐ 53 ☐ 54

Laboratoire : / ***Laboratory:*** — **Radio:** / ***X Ray:*** ☐ 55 ☐ 56

Groupe sanguin : / ***Blood group:*** — **Rhésus :** / ***Rhesus factor:*** ☐ 57 ☐ 58

Audiogramme : / ***Audiogram:*** — **Examens cochléo-vestibulaires :** / ***Cochleo-vestibular examinations:*** ☐ 59 ☐ 60

Divers : / ***Miscellaneous:*** ☐ 61

Conclusion : / ***Conclusion:*** ☐ 62

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Lieu et date / ***Place and date*** — **Cachet** / *Stamp* — **Signature** / *Signature*

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Follow-up medical examinations

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Perméabilité tub. *Valsalva test*					☐ 74
Nez *Nose*					☐ 75
Sinus *Sinuses*					☐ 76
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Thorax					☐ 78
Poumons *Lungs*					☐ 79
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Système nerveux *Nervous system*					☐ 89
Etat neuropsychique *Neurological findings, psyche*					☐ 90
Examens complémentaires *Other examinations*					☐ ☐ 91
Conclusion/*Conclusion*					☐ 93
Signature/*Signature*					

COMMISSION MÉDICALE
MEDICAL COMMITTEE

CONFÉDÉRATION MONDIALE DES ACTIVITÉS SUBAQUATIQUES
WORLD UNDERWATER FEDERATION

ATTESTATION

Je soussigné Docteur ____________________ certifie avoir examiné ____________________
I the Undersigned Doctor *certify that I have examined*

Nom : ____________________ Prénom : ____________________
Name : *Christian Name :*

Né : ____________________ Adresse : ____________________
Born : *Adress :*

selon les recommandations de la Commission Médicale et de Prévention de la CMAS
according to the recommendations of the Medical Committee of the CMAS

Conclusion de l'examen : ____________________
Results of the examination :

Examen à refaire avant le : ____________________
Examination to be repeated before the :

Lieu et date ____________________ Cachet
Place and date *Stamp*

Signature

WRITTEN COMMENTS
on the paper of M.C. FLEMMING
Scientific Diver, Safety and Training

received from

Dr. Justus HOLTHAUS,
G.K.S.S. Research Center (West Germany)

I would like to make some factual observations on Mr. Flemming's paper:

1) Fatalities in scientific diving: West Germany

None of the fatalities was due to failure of the habitat.

1968 Shallow water accident. Burst lung. Not in the habitat. Not in saturation.

1969 CO_2 intoxication. Not in the habitat. Not in saturation. German regulations on scientific diving were made after these three accidents happened.

1975 Professional diver. Burst lung from keeping to a fixed structure in rough seas. Not in the habitat. Not in saturation.

2) Methods of Diving:

Full face mask, guideline and so on. None of the disadvantages described, apply : the following are my comments -

- low mobility: lack of training.
  (exemptions from diving with guideline are possible in rare circumstances, e.g.
    - high visibility underwater
    - pinger
    - blub
    - verbal communication
- fouling of guidelines: lack of training
- problems with currents: thin guideline, no guideline results in high risk for the diver
- buddy breathing: potentially dangerous and unnecessary (guideline, reserve, double breathing system, emergency ascent)

- low buoyancy at surface: not true
- no regulation of buoyancy when lifting heavy objects from the bottom: lifting dangerous, forbidden with the buoyancy equipment of the diver.
- no regulation of buoyancy in an emergency ascent: not true
- no regulation of buoyancy when at rescue of an injured diver: not true.

3) Of course most of the scientific divers like to use Version (b) of diving. due to low cost, but it does of course carry a higher risk.

4) Training. Version(g): governmental course in Germany not only recommended but the only possibility.

5) Facultative course: Handling of hyperbaric chambers and Training in First aid are notperipheral skills, but essential topics in the basic training of divers.

6) Physical and medical qualifications in Diving: can not to be divided into a professional and mixed gas diving type and a lower qualifications type for scientific divers.

Nota bene : The most dangerous area in diving is the shallow 10 m area. See: Fatality analysis: Seemann. The following are the main factors.

1) Human error / irrespective of depth
2) Too high risk / sports diving
3) Personality defects of divers / sports diving
4) Diving with medical defects / sports diving
5) Equipment failure / sports diving

The high risk groups derive from the sports type of diving; see statistics on sports diving accidents.

7) A high standard of physical fitness is necessary, especially for the scientific diver. (Long surface swims.)

8) Medical examinations in two versions

   a) for shallow diving
   b) for deep diving

   have no rationale. There cannot be a lower standard examination for scientific divers.

   Nota bene: The dangers of the sea don't ask, whether you are professional or a scientific diver !

9) It is impossible and thus unfair to compare the safety already achieved in the complex, problematic, deep,mixed gas oil related offshore diving to shallow simple scientific scuba diving.

10) I believe, that universities and research institutions do have the opinion, that CMAS training is adequate for scientific diving: Lack of money, possibly no responsability, No means for better training, No regulations,

11) Documentation of medical fitness by any doctor,CMAS.

    Medical fitness of scientific divers must be the same as of professional divers. Doctors should be approved examining doctors, well aware of the problems in the field. See list of approved doctors,EDTC Guidelines, Vol. II.

12)	CMAS	Scuba diving from age of 14
		second degree from age of 15
		third degree from age of 17

EUBS, EDTC and other relevant institutions have agreed upon, that diving must not commence before the age of 18. Reasons: Cardiovascular lability of the adolescent. Development of pulmonary tissue incomplete. Reasoning and judgement imperfect. Psychologic lability.

The safety philosophy report of N.C. Flemming is in my opinion in almost complete contradiction to the reasoning of the experts in the field and doesn't comply with the safety philosophy laid down in the EDTC guidelines.

Litterature:

GKSS report 79 E 40
English version
GKSS training course for scientific divers,
German report of experience,
J. Holthaus

J. Holthaus
Approved Diving Doctor,Germany, UK, Norway.
Member UMS / EUBS.
German representative in the EDTC.

Note; The above comments are published following a specific request from Dr. Holthaus. They do not necessarily represent the views of the above organisations of which Dr. Holthaus is a member.(Editor)

RESEARCH AND DEVELOPMENTS IN DIVING

RECENT DEVELOPMENTS IN DIVING

by
Dr. W. LUBITZSCH
Drägerwerk AG - Pressure chamber Engineering Works,
Lübeck-Travemünde (West Germany)

1. Historical summary

The long history of diving can be traced back as far as Alexander the Great. Modern diving is found in its most complete form in a mixed-gas diving system.

Although many principles of present-day diving have a long tradition behind them, it is mainly in the last 15 years that the modern technique has taken shape.

2. Notes on individual developments

2.1. Diving equipment

A diver's equipment can be broken down (cf. Fig. 1) essentially by the following component headings :

- breathing gas supply
- communications
- energy supply for heating
- orientation
- others.

A central aspect here is the various sub-systems for the supply of breathing gas, and these systems will be discussed in more detail in the following chapters by reference to specific examples.

2.1.1. Helmet outfit

The standard personal diving equipment for many decades was the helmet outfit, which was developed even before 1910 in the form still frequently found today. It can operate on either a compressed-air or a mixed-gas supply, and in physiological terms it combines very significant advantages.

This system is distinguished by good head mobility, no hydrostatic or other resistance to breathing in the upright position, the possibility of preheating the breathing gas on the surface, good heat insulation ensured by thick woollen clothing, etc.

However, new developments were made necessary by the cumbersome dressing of the diver, lack of flexibility in operation, in short the need for a more efficient method of work.

Modern materials, together with new construction standards, have led to the development of helmet outfits which meet the most stringent practical and medical requirements for heavy duty use by divers over long periods. **Fig.** 2 shows a new type of outfit incorporating a telephone link to the diver using a conference circuit.

2.1.2. Compressed air outfit

The SCUBA-type breathing-air supply, in an open system from the surface, or from pressurized containers carried by the diver, gradually became the preferred system for sporting, exploratory and commercial diving where rapid and relatively short operations are required.

Time and again systems were developed which, by reclaiming the breathing gas and processing it in a half-closed or closed circuit, were intended to reduce operating costs by lessening air consumption (cf. Fig. 3). It was not possible to use them for compressed air diving because of their complicated construction and relatively high maintenance and operating costs, and last but not least their high price. Such systems only became topical again very much later under the influence of other constraints. This will be discussed later.

The development of the modern compressed air outfits has the following aims : simplicity of construction, ease of maintenance, operating safety, high air output and low resistance to breathing even at depths of 50 m or more.

Fig. 4 shows a compressed air SCUBA outfit using high-grade synthetic materials and corrosion-resistant materials such as special steel, aluminium and high-grade plastics.

2.1.3. Systems for testing operating safety

Together with the diving equipment and the emergence of guidelines for testing, the question of systems to ensure operating safety throughout the life of the equipment has come increasingly into prominence.

Test benches were developed on which the user could periodically test the most important functions of the equipment and detect faults in the system at an early stage. (cf. Fig. 5).

The need to keep the breathing air free of CO, CO_2, oil and water is - especially for the diver - of paramount importance. The aim is to prevent physiological damage to the diver caused by breathing in toxic gas components as well as damage caused by equipment failure due to corrosion or the icing-up of important functional components as a result of an excessive level of water in the compressed air.

Analysis of the quality of the air in breathing-air compressors required costly laboratory processes, and was rarely done in practice. Information on pollution with oil, water, CO_2, CO, etc. was unusual. However, the values for these were not allowed to exceed a certain limit. In 1976 this problem was solved by the development of a very simple device which can be used easily and cheaply even in field conditions. (cf. Fig. 6).

2.2. Deep-sea diving technique

Diving at depths of more than 50 m requires periods of decompression which, for physiological and safety reasons, cannot take place in the water itself.

Decompression therefore takes place on the surface in fixed deck decompression chambers (DDCs), with a transportable submersible diving chamber (SDC) being used as a pressure-resistant lift and working base for the diver. Under depth pressure, the SDCs are brought to the surface and transferred into the DDC (cf. Fig. 6). In the case of diving accidents, direct treatment by a doctor can be provided within a short time.

Air can no longer be used as a breathing gas at depths greater than 50 m, at which depth N_2 begins to have a narcotic effect, as does O_2. Moreover, the density of the air becomes so great that lungs can no longer be adequately supplied with air because of airway resistance (especially in strenuous work). For that reason, a synthetic mixture of helium and oxygen is used with a modified level of O_2.

The move into sub-50 m depths was also difficult for the following reasons :

a) New decompression tables had to be developed and tested in costly parallel series of experiments.

b) Investment costs for diving operations exceeding the 50 m threshold made a leap of at least one order of magnitude. The mainly small onshore diving enterprises could not, and still cannot, meet these costs, so that safe inland diving in depths greater than

50 m remains a largely unsolved economic and technical problem.

2.2.1. Bounce diving

This deep-diving technique involves decompression between each dive. The technique is worthwhile for dives of short duration at depths of between 100 and 150 m. However, it becomes highly uneconomic at greater depths or for dives of longer duration because of the progressively extending decompression times in relation to the effective working time.

2.2.2. Saturation diving

It was particularly the offshore activities in the North Sea which made dives of long duration at considerable depths (of far more than 100 m) necessary. They became possible with the help of the saturation dive procedure. After compression, the divers live and work for days or even weeks in a helium/oxygen atmosphere under the pressure of the working depth. Once the body tissue is saturated with the inert gas of the breathing mixture, the decompression time is no longer dependent on the duration of the dive but only on the depth.

Many problems were of course connected with this diving method and with operation under high pressure in a helium/oxygen atmosphere. A final solution to these problems has not yet been found.

a) High costs of helium, and supply problems in remote offshore areas, necessitate :

- helium reclamation and purification systems with :
  - . purification and conditioning of the atmosphere of deck decompression chambers in a closed circuit;
  - . reclamation and purification of gases breathed out by divers during underwater operation ;

  . helium-reclaim systems for reclamation and purification of chamber gas during decompression ;
  . purification of the atmosphere of underwater welding chambers ;
- high airtightness of the whole system, i.e. low helium leak rates.

b) Speech distortion while breathing mixed gases containing helium :
- speech correction systems.

c) High thermal conductivity of helium and high density of the breathing gas at great depths lead to increased heat losses by expiration and through the skin. Heating systems are necessary for :
- breathing gases ;
- diving suit.

d) Good protection, against uncontrolled sudden falls in pressure in the system or the exceeding of permitted levels for all vital parameters in the system, requires :
- high operational safety of components ;
- back-up systems for the vital pieces of equipment.

e) The design of diving bells and personal diving equipment must conform to ergonomic and diving medicine standards.

f) The need for external service personnel to relieve the diver of checking, servicing and maintaining his equipment requires as far as possible :
- simple design and construction of the equipment ;
- external systems for operational conditioning of diving bell gases and diver's breathing gases, etc.

Fig. 8 shows in diagram form the components of a modern saturation diving system, which was built up to a great extent on the basis of the above problems.

2.2.3. Life support systems

Entirely externally arranged, hermetically sealed systems for conditioning of the atmosphere of the deck compression chamber (DCC) up to helium/oxygen pressures of 50 bars or more have been developed and put into service.

They contain filter systems for carbon dioxide absorption, in which the filters can be changed without interrupting operation.

The automatic moisture regulation mechanism operates e.g. with the help of a cooling condenser and keeps the desired moisture level constant within narrow parameters.

The comfortable temperature in a helium atmosphere is between 28°C and about 32°C according to the pressure level. The range between too hot and too cold decreases as the pressure increases, so that very exact temperature regulation is necessary. According to the temperature of the chamber's surroundings, its insulation and the pressure within it, etc., either heating or cooling may be necessary.

The necessary quantity of circulating gas for the ventilation of the chamber is determined less by the quantity of carbon dioxide produced than by the quantity of heat to be taken off during cooling. In this connection not only the thermal capacity of the helium, but also, and to a much greater extent, that of the chamber wall need to be taken into account.

Moreover, an adequate intermixing of the chamber gas must be ensured to avoid too rapid increases in temperature, carbon dioxide concentration, etc.

2.2.4. Personal diving equipment with closed circuit

The successful reclamation and processing of the diver's breathing gas is of the greatest economic importance.

Offshore diving concerns did not have much interest in such systems as long as the oil companies supplied the helium, or at any rate helium supplies were available.

In this respect a change seems to be coming about in that more diving contracts are being awarded at fixed prices and diving operations off Brazil are becoming as much a matter of course as those off New Zealand, in both of which places helium is extremely difficult to come by.

There are many ideas for such systems, but only a few have been developed to the production stage and tested.

The oldest version is in the form of an independent system with fully closed circuit. Carbon dioxide is removed with the help of quickline. The partial oxygen pressure regulation system and the necessary phosphorus dioxide measurement system are technically very demanding. Circulation in the system is ensured by the diver.

The investment costs are relatively low. Supervision of operation etc. has to be carried out mainly by the diver.

In extended circuit systems the diver, using a closed system, is supplied with gas from the submersible decompression chamber (SDC). Circulation is effected with the help of pressure and suction pumps attached to the SDC.

Perhaps the most technically demanding principle is applied in the system in which the gas processor, phosphorus dioxide regulation system, carbon dioxide absorber, compressor for gas circulation and control are all arranged on the surface. The breathing gas circuit is entirely separate from the chamber atmosphere. Diver and SDC are equipped with emergency gas supply systems. (Fig. 8 cf.)

A whole system can be almost entirely serviced, maintained and repaired from the surface by suitably qualified staff. Incorporation in existing systems is usually possible without serious problems.

2.2.5. Communication system

Although good communication between divers and operator is of the greatest importance, not least for reasons of safety, and much pioneering work has been done, development in this field is still largely in its infancy.

The cost of the further development needed is great, and the market limited. Thus better systems will not become available unless the importance of good communication is recognized and the will exists on the part of the users to invest more.

3. Conclusion

The very rapid development of deep-sea diving in the pioneering stage at the start of offshore development in the North Sea in 1973 to 1974 is being followed by development on more scientific lines. This is largely controlled by guidelines laid down by experienced standards authorities.

The manufacture will increasingly have to gear himself to delivering systems which are ready for use and fully conform to the standards laid down.

The development and production process already involves strict quality control under realistic conditions, and extensive analyses of cases of malfunctioning. These provide information on whether, in the case of breakdown of components of the system, the damage limits laid down have not been exceeded, or back-up systems, which permit continued safe operation for a specified time are available.

List of illustrations

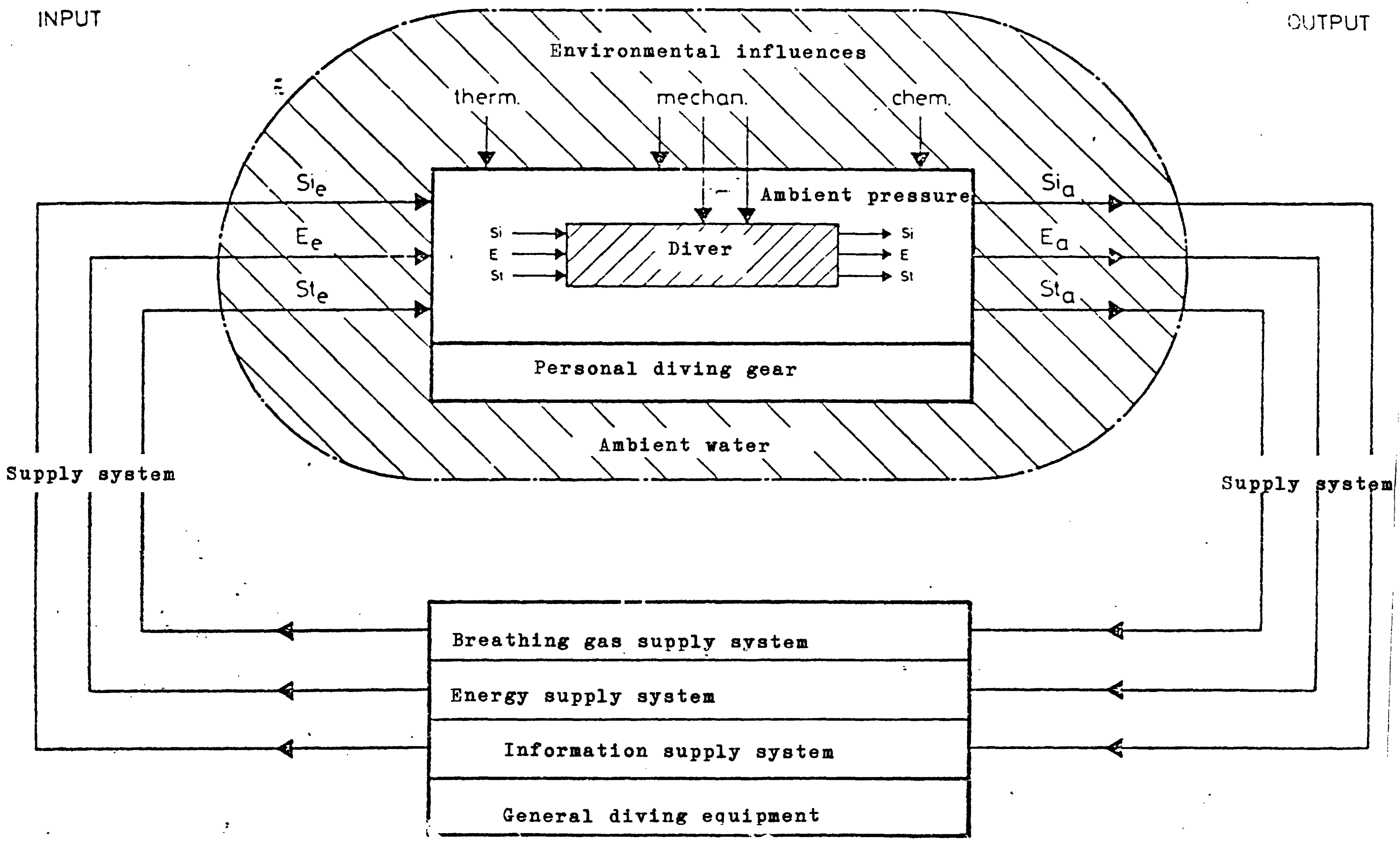
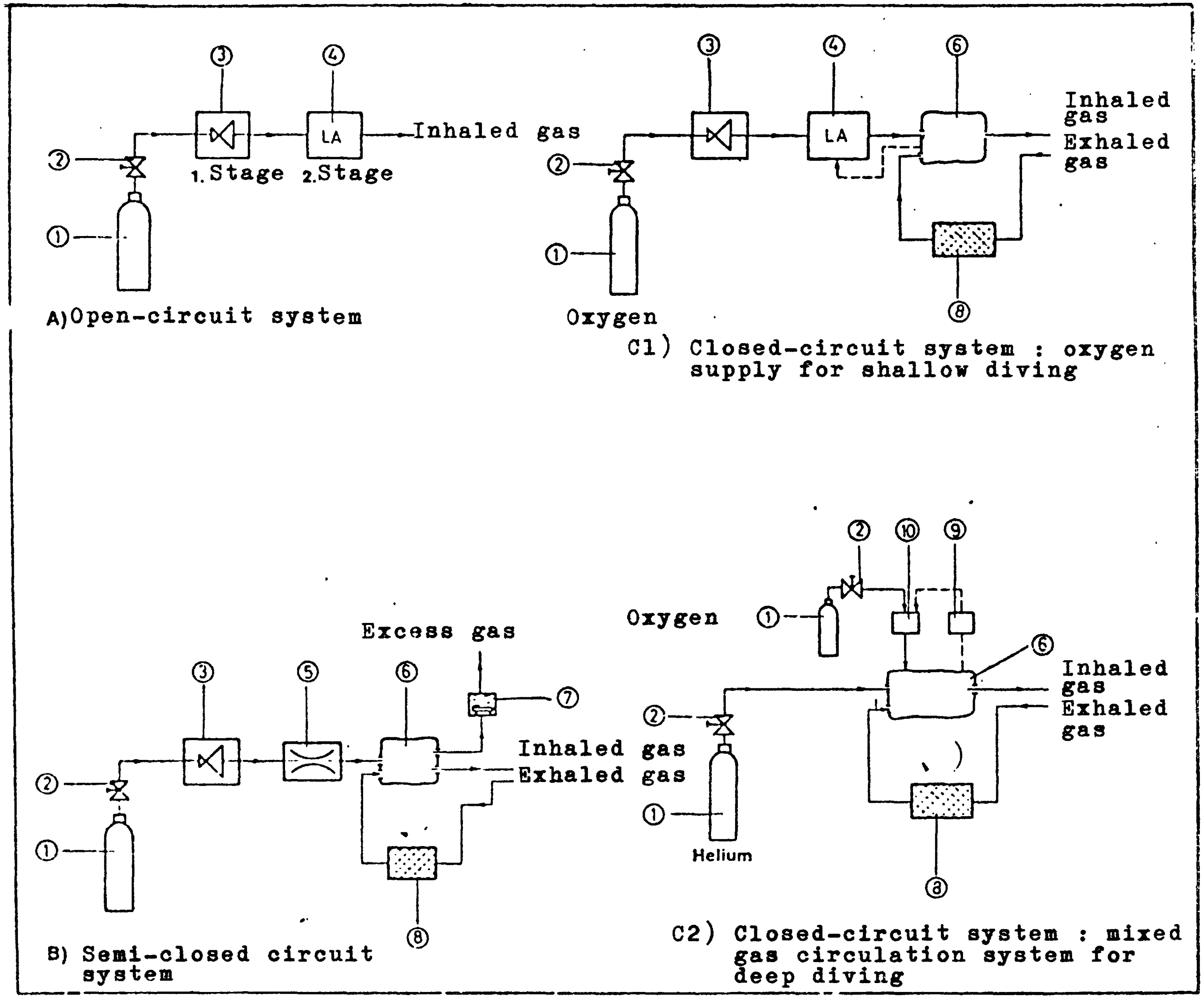


Fig.1 : Diving equipment system

Fig. 2 : Modern helmet outfit with diver's telephone on a conference circuit



A) Open-circuit system

C1) Closed-circuit system : oxygen supply for shallow diving

B) Semi-closed circuit system

C2) Closed-circuit system : mixed gas circulation system for deep diving

1. Pressurized gas bottle
2. Valve
3. Pressure reducing valve controlled by the ambient pressure
4. Aqualung
5. Constant dosage valve
6. Breathing bag (counterlung)
7. Relief valve
8. CO_2 absorber
9. O_2 partial pressure filter
10. O_2 dosage device (controlled by partial pressure)

Fig. 3 : Forms of breathing gas circuits in diving equipment

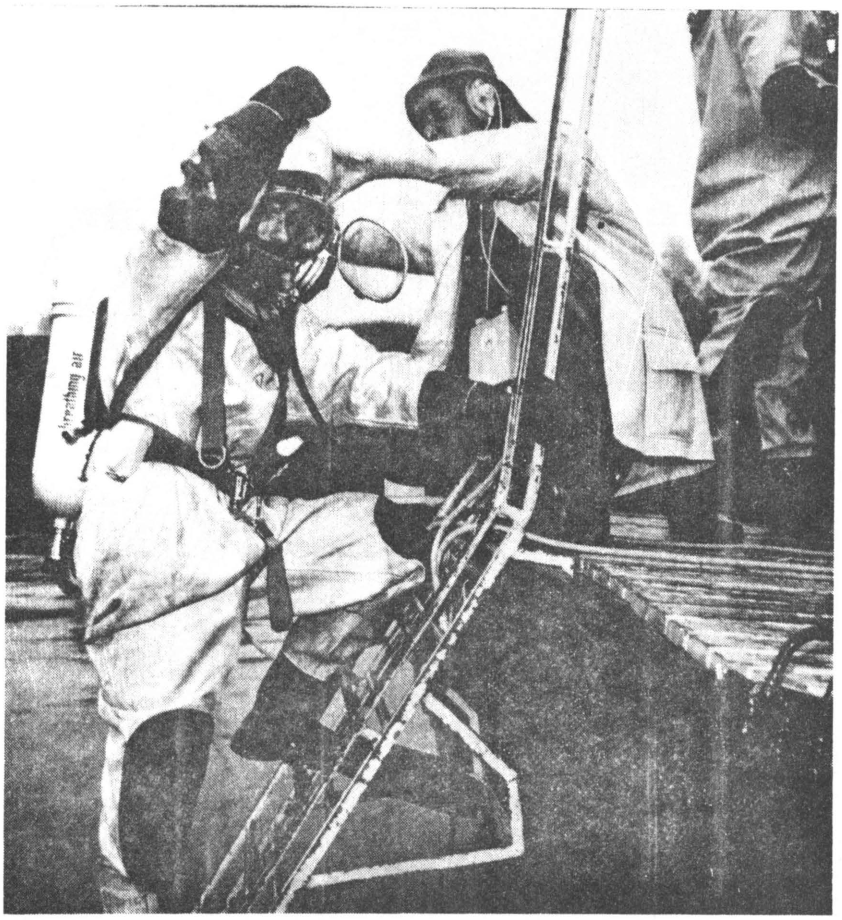


Fig. 4 : Compressed air SCUBA outfit

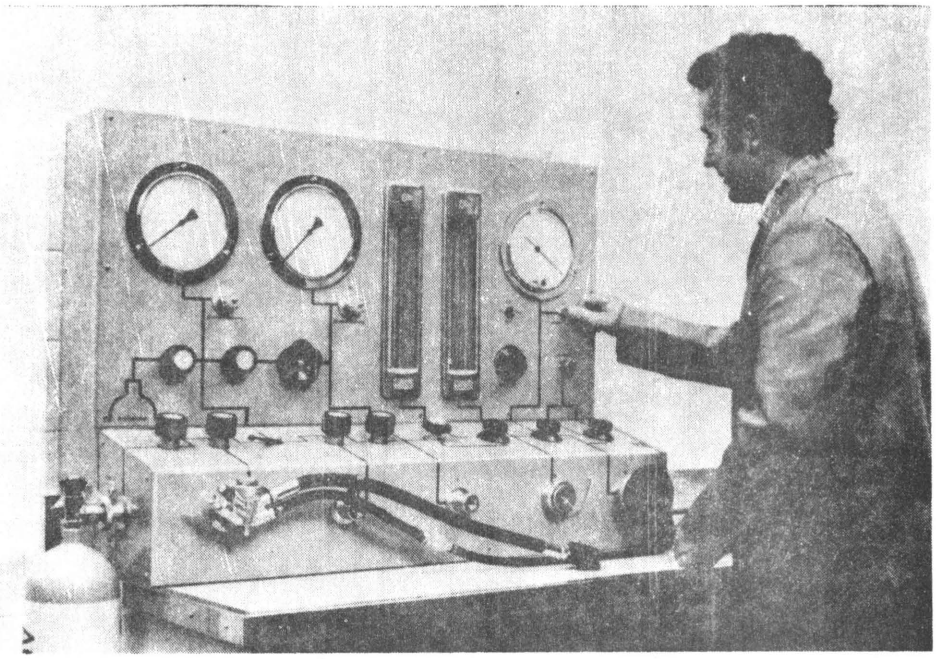


Fig. 5 : Test bench for the functional testing of SCUBA diving geer

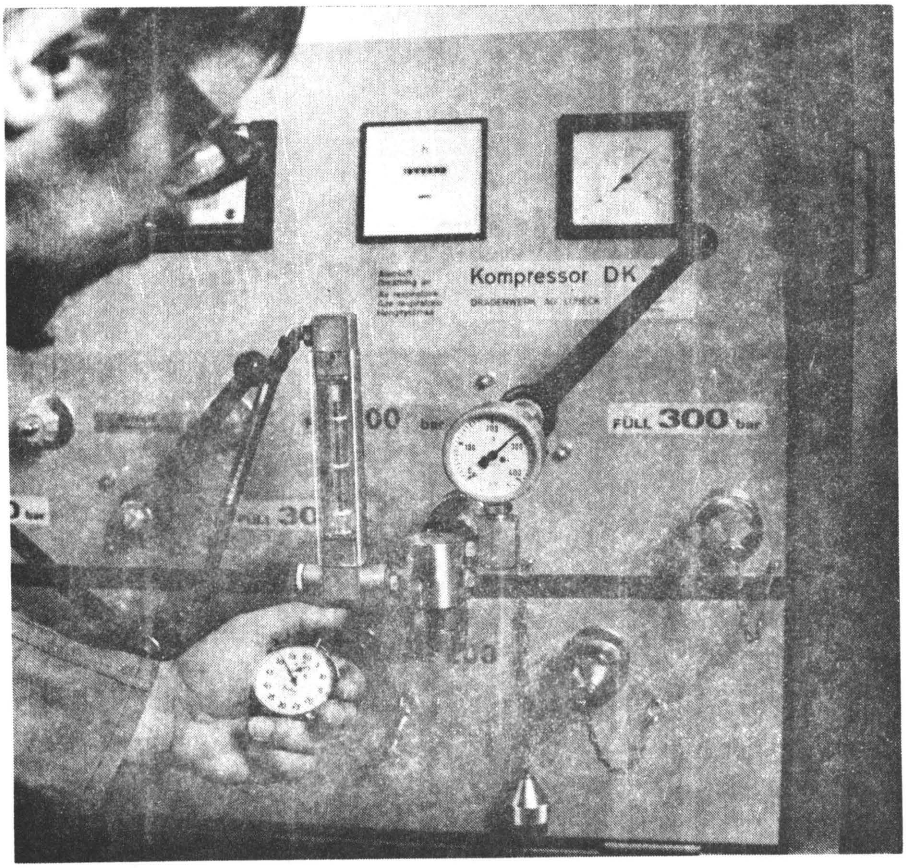
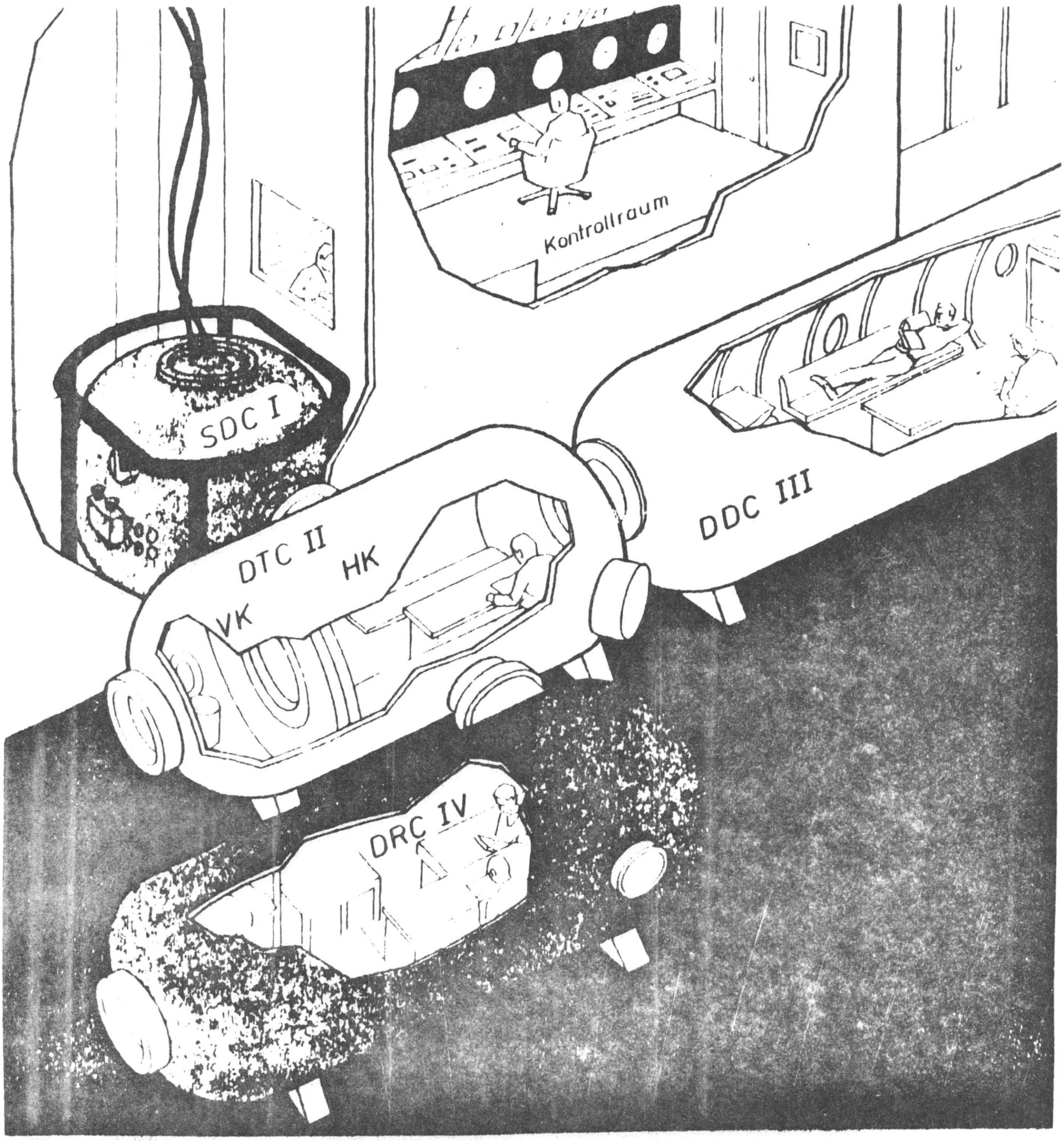


Fig. 6 : Apparatus for the operational analysis of CO, CO_2, H_2O and oil in the breathing air in the immediate vicinity of the compressor



SDC I = Submersible decompression chamber I

DTC II = Deck transfer chamber II (VK = ante-chamber ;
HK = main chamber)

DDC III = Deck decompression chamber III

DRC IV = Deck rescue chamber IV

Fig. 7 : Deep diving system for saturation diving on a diving ship

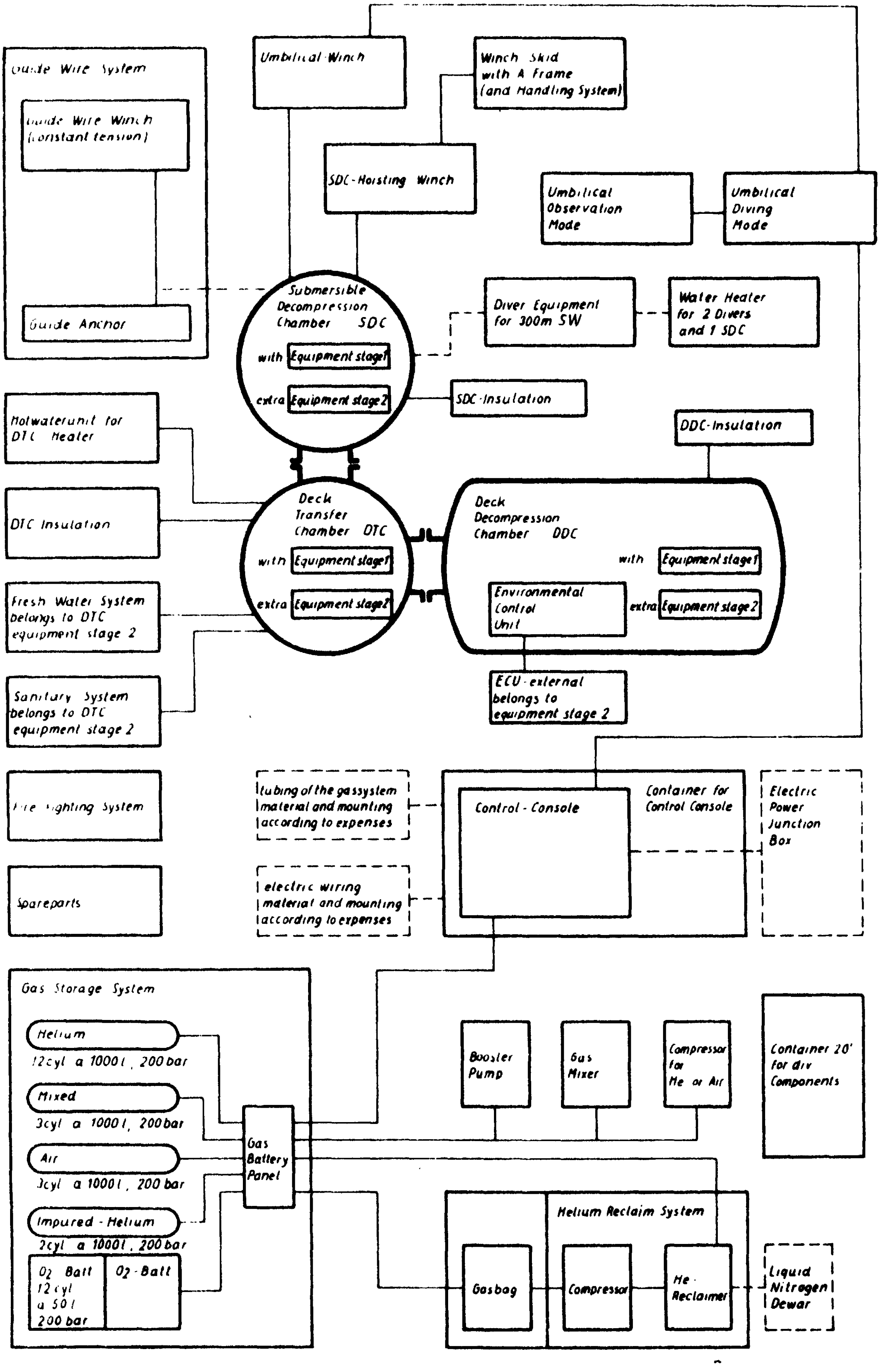


Fig. 8 : Deep diving system

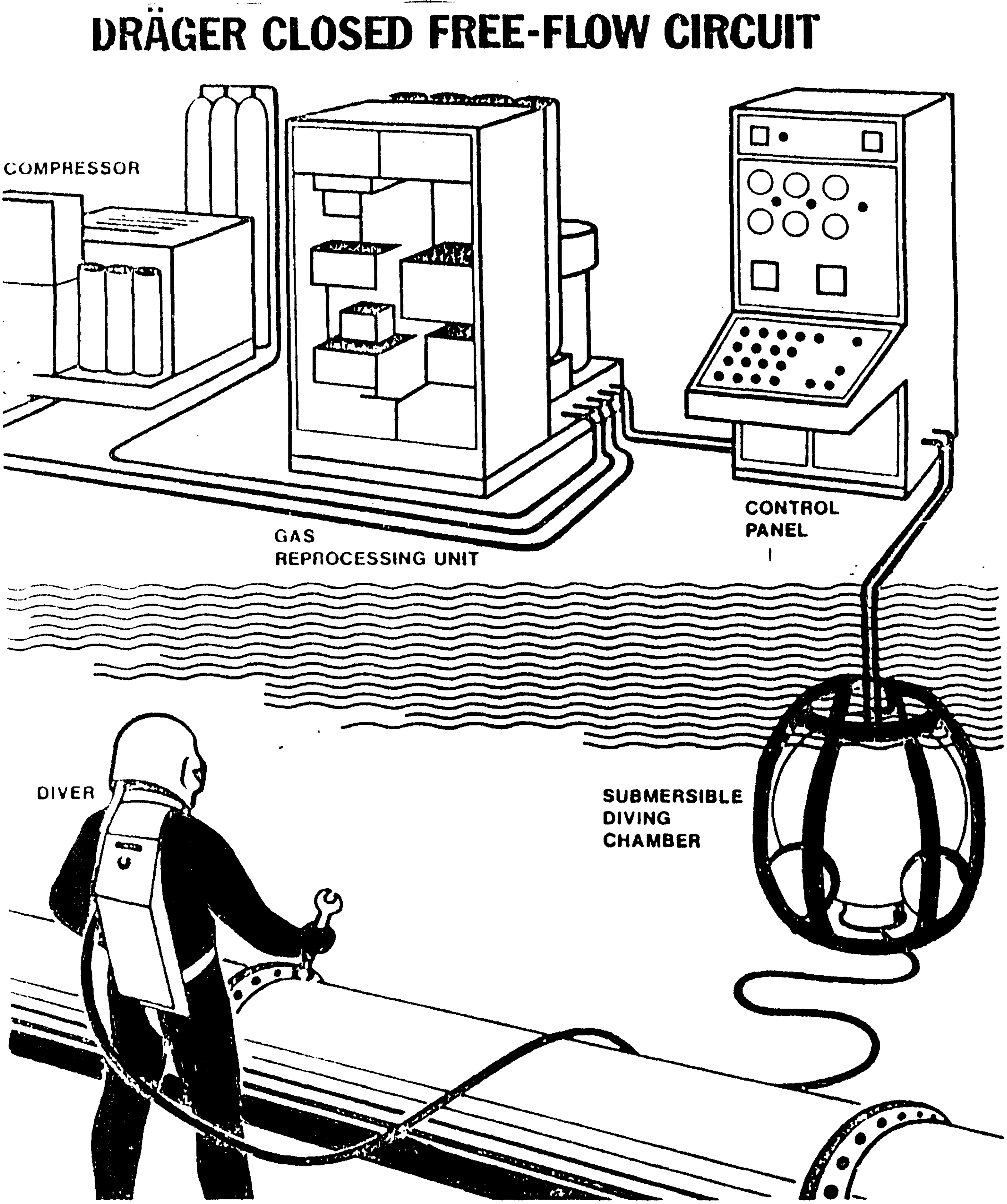


Fig. 9 : Deep diving equipment (closed circuit) with gas processing on the surface

DIVING RESEARCH

by

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1. RESUME

This paper highlights the tasks, means and results of "Diving Research".

With the basic objective of finding the limits to man's performance at raised pressure, under water, the tasks are found in the following fields:

- Biology of diving
- Methods of diving
- Technology of diving

In addition to the basic objective referred to above, the introduction of national laws and regulations in diving operations challenges the research worker with two additional objectives:

- To assist industry in complying with existing regulations.
- To prove to relevant authorities that some particular regulation is irrelevant, too restrictive or too permissive.

"Diving Research" is an expensive form of research, and therefore adequate funding must exist to make it feasible. Much money must be spent on investments and consumables (hyperbaric chambers and gas), and because "Diving Research" is not a traditional university subject, special training programs must be established to cultivate the personnel resources.

It is important in "Diving Research", as in any other field of applied research, to present the results as quickly and understandable as possible, so that the industry and the authorities can benefit from it directly. Operational introduction of the results may be difficult in several cases, and the participations of the research worker in that process will often prove useful.

2. INTRODUCTION

The state of the art in modern diving is a direct result of extensive research with roots back in the eighteenth century. Nevertheless, it was not until the mid 1960's, with the prospects of deepwater oil exploration, that diving industry and with it "Diving Research" really flourished.

"Diving Research" is an unorthodox" area of applied science destined to solve the problems related to "man in the sea". Since there are obviously going to be both men and hardware involved, "Diving Research" is calling upon mutual cooperation between scientific workers from biological and technological sciences. There are not many areas where this constellation has had success, but in "Diving Research" it has always been a necessity due to the nature of the problems. I dare say that in no other area of research would the medical doctor be so helpless without the engineer and vice versa.

The objective of "Diving Research" has always been and continues to be , to find the limits of man's performance at raised pressure, underwater. But although the "world record" for high pressure exposure at 650 msw was set in a US laboratory early this year, very little operational experience exists for diving deeper than 200 msw. And there is serious evidence that the industry may encounter problems if routine operations are simply extrapolated into, say 400 msw, using existing equipment and known methods.

Several countries have by now established laws and regulations relevant to diving in their territorial waters, and thus the tolerated hazards to the people involved have been defined for those countries. As a consequence, new objectives for the research worker has been given, either to help the industry comply with the laws and regulations in force, or to prove to the relevant authority that some particular regulation is irrelevant, too restrictive or too permissive.

"Diving Research" has been in existence in various places throughout the world, but not until 1976, when the Norwegian Underwater Institute (NUI) was established, were these problems given much attention in Norway. Since I represent NUI in this context, the following must, therefore, be taken as the thoughts and ideas of the needs in "Diving Research" formed over the last few years in Norway. But most of it has been based on international contacts and literature and, therefore, the main lines will be indications of the global needs.

A good example of this is that the report of a British Government committee on offshore safety, the Burgoyn-report /5/ has got parallel views on several aspects treated in this paper.

3. TASKS

As a supplement to the above-stated general objective of "Diving Research", it is important to define its specific tasks. Such tasks must be based on aims of a more practical nature, and for the first five years period, four such aims can be listed:

- To make operational diving to 400 meters available to the oil industry. The diving companies in question must by then be able to work at such depths well within existing rules and regulations.

- To make the working environment for the divers as safe as technicaly and economicaly possible.

- To improve the underwater contractors' ability to comply with rules and criterias implemented by the authorities.

- To assist the authorities in their efforts to further improve existing rules and criteria.

These aims require work in three specific fields; namely:

- Biology of diving
- Methods of diving
- Technology of diving

But it must be stressed that the lines between these three fields are not sharp and clear-cut. Since there is a surplus of interesting material in all three fields, a hard selection is needed to give priority to the most important programs.

3.1. Biology of diving

Manned intervention under the sea surface involve problems of medical, physiological, biochemical, ergonomic, phsychological and psychosocial nature.

The highest priority should be given to medical, physiological and ergonomic problems. Hyperbaric medicine and physiology research must include animal experimentation and subsequent follow-up with humans. Underwater ergonomic is best attacked directly in connection with specific tools and equipment development.

In hyperbaric medicine and physiology we have found it necessary to give high priority to four different programs These programs will be discussed in the following.

Divers work capacity

Exposure to high pressure causes many stresses on mammalian systems and these stresses, in turn, may compromise the ability of that system to function in an ordinary or competent manner. The broad objective of this program, therefore, is to determine in what ways and to what extent exposure to diving conditions affects and limits man's capacity to do work.

All aspects of work "capacity" are of concern. The primary goals of the program have been related to exercise capacity while using underwater breathing apparatur, however. Man's ability to perform physical activity is critically linked to his ability to obtain oxygen and eliminate carbondioxide. These funtions are greatly influenced by the ambient pressure, the inert gas composition and oxygen content of the breathing gas and the imposition of an external breathing resistance. Current research has been designed to determine the relationships between these factors and the physical work output of the diver. In addition, the impact of compression and exercise on mental and psychmotor functions at high pressure will be studied; and such variable factors as the diver's thermal state, physical condition, smoking habits, state of rest are of concern.

The results of this program are expected to contribute to our knowledge of what can be expected from a diver under a broad range of environmental conditions, proper engineering design criteria and safety standards for underwater breathing apparatus, and operational approaches for work under extreme conditions.

Long term effects of diving on the human body

Available information indicates that there are three main problem areas in the diver's work environment that may lead to long-term effects on the individual diver. Three organ systems need to be followed in a long-term program:

i) Lung function and ventilation control

A survey of a population of divers has shown that deep diving may lead to changes in lung functions, such as Functional Vital Capacity (FVC) and internal breathing resistance measured with Forced Expiration Volume (FEV). This is beneficial to the diver, and we shall try to find the reason for this development, how long a periode of time it takes before such changes occur and if they are of a permanent nature.

Another important problem in deep diving is whether or not, the body is able to sufficiently eliminate metabolic carbon dioxide (CO_2). Increased CO_2 contents of the blood stimulates the respiration centre in the Central Nervous System (CNS) to increased activity, but above a certain level of CO_2 concentration, poisoning accurs. It has been shown that experienced divers may develope a breathing pattern which predisposes CO_2 accumulation in the body without giving raise to increased breathing stimulation from the CNS. This is a dangerous development because when CO_2 concentration in the body increases towards poisonous levels, the diver is more vulnerable to oxygen poisoning and nitrogen narcosis and the body heatloss is accelerated. We shall try to find the reasons for this, how long it will take to develop such changes in lung functions and if the changes are of a permanent nature.

ii) The inner ear (labyrinthine)

The inner ear includes the organs for balance and hearing (the vestibular apparatus and cochlea together make up the labyrinthine). Earproblems in diving were studied early in history; in the diver's situation there are many factors that may damage the fragile organs in the ear, and frequently dives are aborted due to acute ear damage. Factors such as barotrauma, head injury, noise, decompression illness, poisonous pollution of the breathing gas, oxygen poisoning and asphyxia have lead to ear damages. But it has not been shown if divers as a group are more vulnerable to chronic ear damage than the normal population when no acute damage has been diagnosed. We shall endeavor to find answeres to these problems and shall work for elimination of the risk of ear damage in divers.

In particular, we will aim at a better work environment for divers who are using equipment giving off strong acoustical noises. Criteria for tolerable noise exposure will be established and necessary noise-reduction measure will be proposed.

iii) Central Nervous System (CNS)

Through retrospective and prospective investigations in neurological, neurophsychological and psychosocial matters, groups of divers and diver trainees are compared to control groups of non-diving personel. The methods that are being used, are based on extensive and well-accepted test "batteries". The results og these investigations may have an impact on diver selection in the future.

It is inherent in the nature of the problems that prospective investigations of long-term effects of diving must be carried on for several years to obtain relevant and significant data.

Physiological and biochemical effects of gases at pressure

It is of significant interest to maintain a relatively high oxygen partial pressure in the diver's breathing gas. For example, oxygen breathing will shorten the total decompression time needed after any dive. But this method of course adds the risk of oxygen poisoning. Today there are no safe limits of oxygen partialpressures established, partially due to the complexity of the problem.

It is our aim to define safe partial pressures for oxygen. Another part of this program, addresses itself to the effect that pressure seems to have on blood circulation in the body organs and the antagonistic effect of pressure to anaesthetics.

The nature of the problems dealt with in this program are of a fundamental character. Initially they must therefore be approached through studies of biochemical and animal models.

Thermal problems in diving

A man's physical and mental performance can only be obtained when he is in thermal balance. Should this thermal balance be only slightly disturbed, death may quickly become the result. Diving in cold water implies loss of body heat if proper protection is not maintained. Problems of heat loss in a hyperbaric environment increase with increasing pressure and with the use of helium-oxygen breathing mixtures. They are not limited to the divers stay in the water, but extend to his stay in the diving bell or the decompression chamber. Calculations of the divers thermal balance are based on knowledge of his body temperature and heat loss. These calculations are difficult to compare, because the said variables are dependent on the measuring technique and extent of heat loss.

This program can be subdivided into three main problem areas:

i) Deep diving with active thermal protection should be investigated thourough realistic inwater dives down to 400 - 500 meters, where water temperature is maintained at North Sea level. This will provide information on the efficiency of today's thermal protection devices, such as hot water systems and breathing gas heaters. Existing information on this is based on dry chamber dives and mathematical models.

ii) Diving with passive thermal protection in cold water may result in serious thermal problems for a diver at any depth, and the percentage of cold water deaths that can be traced back to excessive heat loss is open to speculation. By increasing the information available on heat loss at different temperatures and different passive thermal protection, the safety of coldwater diving will be directly affected.

iii) A prolonged stay in a cold hyperbaric helium atmosphere will lead to excessive heat loss much faster than in an air atmosphere at the same temperature. Comfortable ambient temperature in a helium atmosphere is around 30 °C. Current knowledge of thermal balance in a cold helium atmosphere is inadequate. A diving bell cut off from its power supply represents an extreme situation in this respect, and further investigations should be made to set firm criteria for the design of diver survival systems.

3.2. Methods of diving

The methods used in the execution of dive-operations are normally written in procedures, manuals, tables, contingency plans and maintenance schemes. This is the field where the biologists, technologists and operational people are working closely together.

Three programs should be focused upon in this field:

Compression- and decompression procedures

Changes in breathing gas and/or ambient gas and pressure can cause unfavorable changes in the body of a diver. These can lead to an acute depressed medical condition, varying from discomfort to severe pain and possible death. There may also be chronic health damage. Implications of these problems are increased risk, reduced work output and increased costs for diving operations.

As a consequence, the goal of this program is to learn more about when and how such problems develop and how to avoid them.

Work will be carried out on the following topics:

1) Investigate aetiology of decompression sickness (bubble formation, consequences of bubbles in the body, and their resolution). At NUI this effort will primarily consist of a follow-up of what has been done elsewhere and what can be learned from operational data. We will also carry out theoretical and experimental work ourselves.

2) Causes for "High Pressure Nervous Syndrome" (HPNS) associated with compression to high pressure (150 - 500 meters depth). For the near future, at NUI this part of the program will consist of following up work carried out in other laboratories.

3) Develop practical decompression procedures based on known principles and experiments. This is to be done both to replace current therapeutic and operational procedures with better ones and to facilitate new types of operations. In this program procedures will be tested under controlled and safe conditions in NUI's chamber system. We will also follow-up and modify these procedures when they are used.

4) Monitoring and diagnosis.
Work to improve the ultrasound detection of bubbles in the bloodstream is in progress at NUI, also work on the electromagnetic detection of gasphases in tissue has been started. Both methodes will be further developed.
Other methods for decompression sickness and HPNS-detection will be studied and developed if promising.

Databank and analytical tools for dive operations

Modern computer technology and field data processing should be used as tools to increase and maintain a high level of safety in dive operations. Present regulations in the North Sea area have made it mandatory for the dive companies to log and store vital information from each individual operation. Examining doctors shall also complete extensive forms for each individual diver on the annual medical examination. Until now, these sources of information have rarely been exploited, one reason being, of course, that the reliability of handwritten data is expected to be fairly low. Future practice will lead to introduction of a "black box" type dive recorder which will be ideally suitable for computer analysis.

Data banks and analytical tools for field data processing will be of mutual benefit to both operations and research.

Contingency functions

A number of situations exist where divers are more vulnerable with less chance of rescue than regular offshore workers. It is therefore necessary to look into rescue possibilities for divers and to try to establish an optimal system for diver rescue. This program must address itself to the following list of problems:

- Risk evaluations
- Diver's heatloss and rewarming in emergency
- Emergency gas cleaning procedures
- Emergency power sources

The state of the art in this respect calls for practical types of experiments where known or proposed systems are being evaluated.

3.3. Technology of diving

Technology of diving represents both the technical aspects of bringing the diver safely to his worksite and the technology needed to make him perform useful work. The problems related to this are of physical, electrical, chemical and mechanical natures, and must be solved by application of good engineering practice.

This field of research and development at NUI involves three programs:

Communication_and_monitoring_techniques

This program addresses itself to problems related to

- Diver communication
- Monitoring of physiological and techical parameters

These problems can be solved only by application of fundamental principles of electron-optics, acuostics, digital signal processing and general instrumentation.

Conrete work tasks under this program are:

- Development and operational introduction of special diver lexicon for use in diver training programs.

- Development of hardware such as improved unscrambles for helium-voice, emergency communication devices etc.

- Development and operational introduction of suitable sensors for diver and equipment monitoring.

Gas_supply_systems

An important task that must be performed before deep diving is extended operationally to 400 - 500 meters, is to improve existing individual breathing equipment. Environmental control systems must also be improved to some extent, and oxygen supply systems must be made safer with respect to explosion hazards.

Therefore, this program is designed to:

- Test existing and new concepts for gas delivery to a diver in the water. The use of a breathing simulator is quite essential here. Parameters such as breathing resistance, temperature stability and humidity stability in equipment for use down to 400 - 500 meters must meet the criteria established in the Diver Work Capacity program described above.

- Test out new concepts for environmental control in hyperbaric welding habitats.

- Develope safe criteria for components in oxygen-supply circuits.

Underwater tools

This program is aimed at increasing the efficiency of dive operation in general. In offshore operations, it often happens that several million dollars worth of equipment and vessel are standing by while one diver single-handedly performs work with his hands. It is, therefore, important that the tools he uses are adapted to his needs and limitations. The following subprojects will be handled under this program:

- Functional testing of underwater tools

- Measurement of performance in different work tasks under water

- Evalutation of safety aspects linked to the operation of underwater tools

- Improvment and development of new types of underwater tools

The program will develope and use standardized system of work tasks. ("Performance Test Rig") put together in a pattern so that objective measures of performance can be established. Efficiency criteria for underwater tools will be settled.

4. MEANS

To perform the tasks referred to above, two basic resources are needed, facilities and personnel. The latter is definitely the most important, but also the most difficult to obtain. Technical facilities can be built or simply purchased on the open market. Expertise must be cultivated.

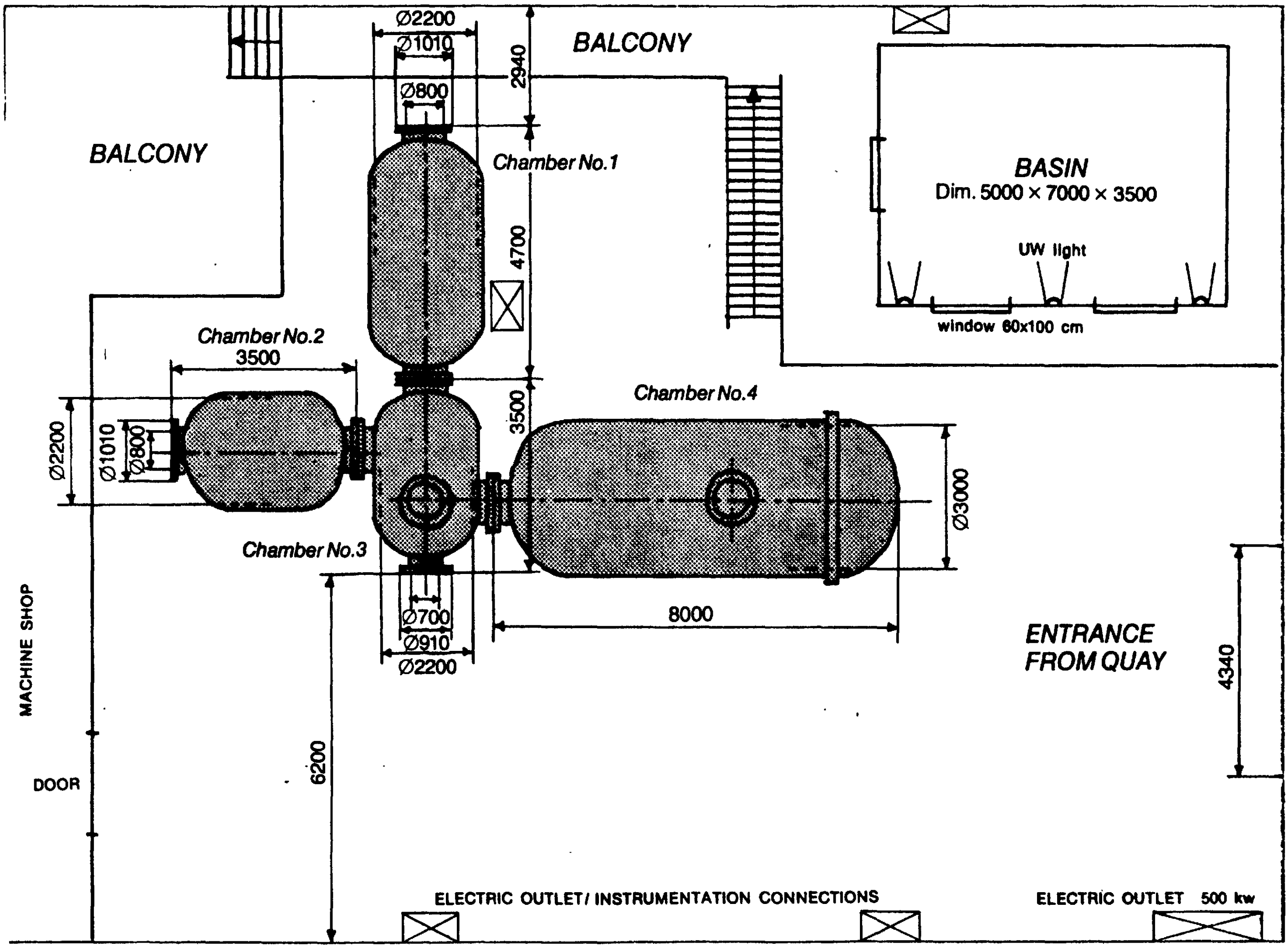


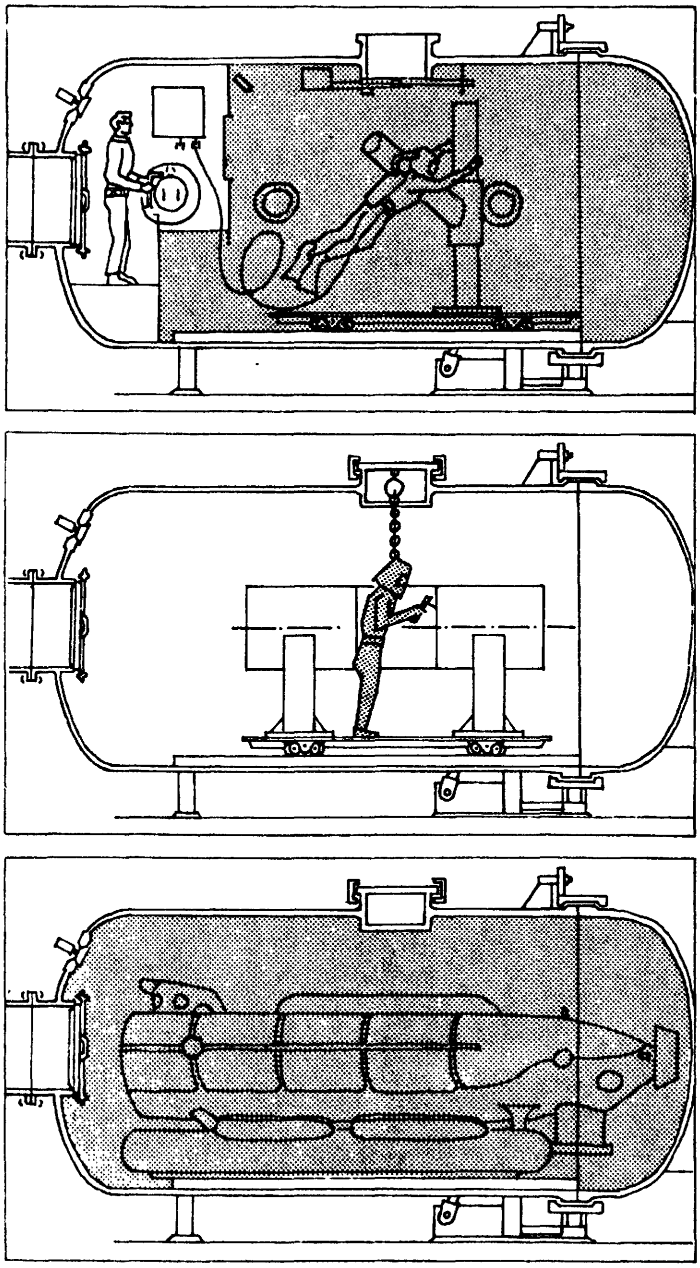
Figure 4.1. The lay-out of the existing research chamber unit at NUI

4.1. Facilities

The most important piece of equipment in a research establishment dedicated to "Diving Research" is the hyperbaric chamber unit. Such a laboratory can be situated anywhere on land, but in addition to the features needed for research purposes it must also have built-in all the safety features demanded by the local diving regulations and perhaps a bit more.

The features needed to make a hyperbaric chamber system a good tool for research can be summarized as follows:

- Modular construction (i.e. at least 3 or 4 separate but connected chamber units)



1: Diving bell/water environment
— Simulated bell excursions down to 650 MSW
— Arctic or tropic seawater conditions
— Job-training in controlled environment
— In water physiological experiments
— Hyperbaric wet welding

2: Dry Habitat
— Hyperbaric welder performance testing
— Hyperbaric welding procedures qualifications
— Dry pressure testing
— Medical care of divers under pressure — equipped with special surgical equipment
— Rescue of divers from rescue vessels (TUP) with or without mating equipment
— Dry physiological experiments

3: Wet pressure testing
— External and internal static pressure testing
— Dynamic forces during pressure testing
— Effects of temperature on pressure stability

Figure 4.2. Operational modes of the work chamber at NUI

- One of the chambers in the unit must be dedicated to work and experiments. It must therefore have -
  - . Wet and dry operational modes
  - . Water temperature control within a fairly large range (0^{o} C - 30^{o} C)
  - . As many throughull penetrators as possible. Preferably, this should be a modular system so that penetrators can be changed out quickly
  - . Possibilities to get large and heavy objects into the chamber without too much trouble
  - . Much available space around the chamber for instrumentation purposes
- Reliable and accurate environmental control system
- Depth capacity at least 650 meters of seawater equivalent dive depth
- Standard instrumentation of high accuracy
- Good visual monitoring facilities (View ports and closed cirquite TV)

All these features have been incorporated into the existing NUI system. The total cost of a hyperbaric facility as described when operationally tested and accepted, will be in the order of Nkr 20 - 25 mill. today. (US $ 4 - 5 mill.)
Even though a very expensive unit, the hyperbaric chamber system remains only one of the tools of the research worker in "Diving Research". Laboratory equipment,

computers, special instrumentation and software must also be parts of the total facility and a minimum cost today for such equipment will be in the range of Nkr 10 - 15 mill. (US $ 2 - 3 mill.)

And during the actual experiments in the hyperbaric facility a high turnover of consumables must be expected. In particular, the helium gas costs are significant. As an example can be mentioned that if the NUI chamber at maximum helium pressure is vented to the surroundings, the net cost is approx. Nkr. 0,25 mill. (US $ 5.000).

4.2. Personnel

As stated earlier in this paper, there are not many competent research workers available within "Diving Research". Therefore, one of the main problems connected to the establishment of a "Diving Research" laboratory is to get the right people and to develope them into competent "Diving Research" workers.
In the author's opinion, when a decision is made to establish a "Diving Research" laboratory, an amount of money equal to the hardware costs should be set aside as "investment" in the personnel resource. Training programs should be set up so that engineers, doctors, physiologists and other cathegories can develope themselves and get good understanding for the scientific parts as well as the practical parts of "Diving Research". To understand the requirement of the diver, the reserach worker should also be encouraged to do some diving himself. The problems met upon when

submerged in water are impossible to fully appreciate without getting wet. Some times the research worker can also learn more by being the experimental subject himself inside the chamber or in the water.

"Diving Research" opens a large field for application of more traditional subjects, and established research workers in other relevant fields, should be encouraged to apply their methods in "Diving Research". Thus bringing in the competence of the universities, hospitals and other research institutions, who themselves have not got the expensive hyperbaric chamber unit needed.

In fact, Professor Christian Lambertsen of University of Pennsylvania, one of the pioneers in "Diving Research", once said /1/ that no "Diving Research" laboratory will fully succeed in their efforts, if not closely linked to a university somehow.

5. RESULTS

The dilemma of the applied research worker is to balance between how quick a requested result shall be given out to the public and how long to continue work to get a proper job done. In "Diving Research" this is accentuated, because not only do the industry's prosperity depend on the results, but also human safety.

Scientific results are normally published through renowned scientific journals. "Diving Research" has even got a few of its own, one for biology and methods of diving called Undersea Biomedical Research /2/ and one more technically related, called Equipment for the Working Diver /3/. The scientific journals are good for getting constructive scientific criticism on a paper. But it may take long before some results become known to the industry and the divers that way, because of the time lag to get the paper accepted and subsequently published. Feedback to the research worker from the operational people is very important in "Diving Research" and therefore we at NUI have decided to pusblish a newsletter /4/ free of charge that gives shorter information on ongoing projects. The readers are asked to give comments, critisicm, advice and new ideas.

Introduction of the results from research into the real world - operational diving, may be a problem. Some problems may be related to physical limitations on the work sites, but the more important ones are those of inherited conservatism and scepticism in the operational diver.

It has, therefore, many times proved useful and sometimes necessary, that the research worker or inventor follows up the operational application of his results or products. This is particularly true when introducing new operational procedures or tables. Written guidelines are never so useful as are physical presence and oral and practical demonstrations.

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DIVING MEDICINE

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SUMMARY

The most important aspects of diving medicine for the layman are described.

Those diseases associated with diving which can be considered as true 'diving diseases' and are not attributable to other circumstances during diving (e.g. injuries or hypothermia) are divided into three groups:

- conditions occurring during descent, or 'barotrauma', due to inadequate pressure equalization in air-filled cavities of the body such as the middle-ear or lungs,
- conditions occurring during diving work such as hypercapnia, hyperoxia, narcosis, etc.
- conditions occurring during ascent or thereafter. Particularly common ones are: caisson disease (also referred to as decompression sickness) and over-expansion of the lungs.

Firstly the causes of these diseases will be outlined, the symptoms will be explained and the secondary and delayed damage will be described.

This demonstrates the significance and necessity of comprehensive medical check-ups for divers and the importance of adhering to safety regulations. These precautions help to limit the number of diving accidents.

The most important treatment for the above-mentioned diseases is recompression, i.e. subjection to increased pressure in a special pressure chamber. In this connection some technical and practical details are given, the requisite 'treatment tables' are discussed and attention is drawn to the danger of relapse.

Finally, some general statistical data are given on the frequency of diving accidents and the causes and types of accidents occurring.

DIVING MEDICINE

by

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PAPER

As the diver operates in an non-physiological environment, the health hazards are greater than in other types of occupation. The aim of this paper is to give a brief outline of the main aspects of diving medicine for the layman; no claim is made to exhaustiveness. The paper does not discuss disorders which are only indirectly connected with the stay under water, such as injuries and hypothermia, nor the specific problems occurring only in special cases such as mixed-gas or saturation diving. For systematic reasons divers' diseases are divided into three groups:

A) Affections during descent are known collectively as 'barotrauma'. This occurs when there is no pressure equalization in an air-filled cavity in (or on) the body. The eardrum and middle ear are most frequently affected, because the Eustachian tube is blocked (or partially blocked) as a result of a cold or some sort of anomaly. It can lead to earache, loss of hearing - and even perforation of the eardrum - and hydrotympanum (discharges from the middle ear). The sinuses are also endangered if the air passages are blocked. Other possibilities are barotrauma of the teeth (air bubble under a filling or crown) or of the external auditory canal (as a result of hermetic sealing by a hood). Air trapped in the rigid folds of a dry suit leads at greater depths to barotrauma of the skin.

The most dangerous form is pulmonary barotrauma, which affects a full-suit diver who suddenly changes his depth ('crash dive'). The air in the helmet and suit is forced upwards and the relative vacuum thus created in the rigid upper part has a suction effect on the face and neck (cyanosis) and continues into the lung, resulting in pulmonary oedema, right ventricular strain and hypoxia in the general circulation. Because of the large change in volume in relative terms, a crash dive just under the surface is more dangerous than at greater depths.

B) Diseases during diving include:

- rapture of the depths, a sort of nitrogen narcosis, which is similar to alcoholic intoxication and with air respiration at depths over 40 m leads to light-headiness and slow reactions and over 60 m to poor coordination and rash actions;
- carbon dioxide poisoning, which can be caused by faulty ventilation in helmet outfits or by deliberate 'economy breathing', by damage to the absorbent in self-contained breathing apparatus, by the intake of CO_2-polluted air (compressor exhaust gases) or by too much dead space in front of the respiratory passages;
- oxygen poisoning with diving equipment which operates with a higher O_2 concentration;
- anoxia owing to lack of an air reserve or of using the wrong air mixture; and
- unconsciousness due to many causes, e.g. fainting, hypoglycemia, following an infection or as a result of undetected heart disease or tendency to epileptic or other types of attacks.

In all cases the diver - especially the snorkeller - runs the risk of drowning if action is not taken in good time.

C) The main diseases during ascent or thereafter are caisson disease and overdistention of the lung. The former, also known as decompession sickness, occurs if the decompression rules are not observed after a period spent in water more than 10 m deep. It is caused by nitrogen bubbles in the blood or tissues, as the nitrogen which does not take part in the metabolic process is released in increasing quantities during the dive as a result of its high partial pressure and cannot be eliminated in sufficient quantities via the lungs if the ascent is too quick. While the nitrogen bubbles in the tissue cause pains in the muscles and joints ('bends'), in the blood vessels they lead to gas embolisms, the symptoms differing depending on location. The severity of the disease depends on pressure and time.

If there is not sufficient exhalation during rapid decompression e.g. a snorkeller's 'emergency ascent', so that the air expanding in the lungs as a result of the falling ambient pressure cannot escape, the lung becomes overdistended and air may enter the vascular system as a result of alveolar rupture or even through undamaged alveolar walls. The same happens as a result of obstructions in the respiratory passages or hereditary 'weaknesses' of the lung tissue if the pressure falls abruptly. A few metres' difference in depth covered quickly is sufficient during diving to cause a pneumothorax, emphysema or air embolism of the brain (sometimes of the coronary vessels as well). Unconsciousness almost always occurs, accompanied - as in the case of caisson disease - by paralysis, loss of central functions, and sensory disorders of varying degrees as a result of the embolic blockage.

Incapacity of more than temporary duration, which can occur after all the above-mentioned affections, is caused by virtually only the secondary damage or residual conditions after caisson disease, which may be neurological, sensory-physiological or mental. In recent years aseptic osteonecrosis with arthrotic changes of the large joints - especially in the upper arm in the case of divers - has been observed as a result of inadequate decompression.

As a rule, incapacity of older divers is caused by diseases which are only indirectly connected with diving, such as various types of rheumatic diseases, arthrosis and kidney affections.

Because of the constant health hazards, physical fitness is of prime importance. Particular emphasis must be placed on normal functioning of the heart and circulatory system and the lungs and respiratory system. The ear-nose-throat area, too may not show any pathological changes. In addition, there should not be any affections which can be aggravated by increases in pressure (e.g.

hernia, cranial trauma, malignant mypoia), or chronic diseases which can suddenly become acute again (e.g. lithiasis, gastro-intestinal ulcers, convulsions, etc), thus necessitating an immediate ascent, which is not always possible. The main criteria of suitability are physical fitness and mental stability.

An exhaustive inventory of all the pathological conditions which rule out diving is not within the scope of this paper. Reference should be made to the relevant literature. An overstandardized assessment serves no purpose; each individual case must be judged on it merits. A balanced judgement can be made only on the basis of all the findings.

A restriction of diving activity on health grounds to certain types of equipment, methods or depths has no point, it being impossible to monitor observation of the restriction; this may be invalidated by unforeseeable occurrences and because the strains and stresses are greatest at shallow depths (doubling of pressure between 0 and 10 m !).

The best medical prophylaxis against diver's diseases is a thorough, regular examination of the diver and the scrupulous observation of all safety regulations.

In order to prevent barotraumata of the tympanic cavity and sinuses, a person suffering from diseases of the upper respiratory passages must not be allowed to dive. A crash dive can be avoided by proper roping of the full-suit diver. The prevention of caisson disease involves precise observation of the decompression rules. The prophylaxis against overdistention of the lung requires training in the emergency ascent.

The health hazard of diving can be reduced but not eliminated by the above-mentioned prophylactic measures, an initial examination by a qualified consultant in diving medicine, regular check-ups and observation of industrial safety and accident prevention regulations.

The only effective treatment of decompression diseases is recompression. It must begin immediately after the appearance of a symptom and take place at an adequate pressure and for a sufficient length of time. Provision must be made for this when a diving operation is being planned.

As recompression by further diving is always unsatisfactory, entails fresh risks and frequently makes the complaints even worse, a pressure chamber is required. A distinction is made between 'transfer chambers', which are used at the point where the dive takes place and enable treatment to begin immediately, and 'treatment chambers', which are found only in certain diving medicine centres (or also on board a ship). The former can in most cases accommodate only the victim, sometimes an assistant as well.

In serious cases, however, the presence of a doctor is required in the treatment chamber. Until the doctor arrives, an attendant instructed by him should take care of the diver (both the doctor and the attendant must be physically fit for work in overpressure).

In slight cases, additional therapy with other physical measures or drugs is often not necessary. On the other hand, in serious cases (e.g. circulatory failure) drugs, infusions or resuscitation may be required. Such treatment is possible only in a treatment chamber with more than one seat. As a rule, treatment begins immediately in a transfer chamber at the point where the dive took place, and the patient is transported to a treatment chamber and transferred at the same pressure.

Recompression treatment with oxygen respiration cuts down the treatment time and reduces the danger of a relapse. Treatment chambers should therefore always be equipped with an oxygen respirator.

For treatment of divers there are 'treatment tables', which, although differing from country to country, are based on standard, internationally recognized principles. A distinction is made between

- slight forms of caisson disease (pain in the joints and limbs, cutaneous symptoms);
- severe forms (central nervous disorders, circulatory failure, respiratory and abdominal symptoms); and

- air embolism.

Irrespective of the original diving depth, the tables give information about the initial pressure required, the length of time to be spent at specified pressure intervals during the return to normal pressure, and periods with oxygen respiration.

If complaints persist after recompression treatment or recur after the treatment is ended, further recompression is the best treatment. In addition, drugs can be used to stimulate the microcirculation.

The frequency of diving accidents is discussed elsewhere. However, statistics of fatal diving accidents in America (Schenk, 1975) seem fairly representative: of 163 diving fatalities analysed, 81% involved amateur divers using breathing equipment, 9.2% amateur divers without equipment, 9.2% professional divers and 0.6% military divers. (Half of the professional divers had equipment supplied from the surface and half had independent equipment.)

Comparison of the statistics on causes of accidents gives the following frequencies in decreasing order:

- inadequate safety measures or failure to comply with safety regulations ('human error');
- undue risk (especially in the case of amateur divers);
- personality defects of the diver;
- diving despite physical defects;
- in last place only: equipment failure.

The types of accidents have the following frequencies:

- caisson (decompression) disease;
- asphyxia, anoxia (oxygen deficiency);
- unconsciousness, collapse;
- overdistention of the lung;
- barotraumata (especially of the ear);
- poisoning (carbon dioxide, rapture of the depths, oxygen);

- after-effects of diseases ;
- injuries under water.

Many of these accidents can be avoided by more careful medical examination, improved training and monitoring of compliance with safety regulations.

Editors Note :

In October 1978 an international Congress on the "Medical Aspects of Diving Accidents" was held in Luxembourg by the Safety and Health Commission for the Mining and other Extractive Industries, and the European Undersea Biomedical Society.

Dr Seemann was one of the Chairmen for the 1978 Congress and for a fuller treatment of this subject, reference should be made to the procedings of the Medical Congress. Copies of these can be obtained from the Secretariat of the Safety and Health Commission for the Mining and other Extractive Industries, Commission of the European Communities, Bâtiment Jean Monnet, Kirchberg - Luxwembourg.

THE "PH-PHOENIX" PROJECT - A MULTIPURPOSE SUBMERSIBLE

A major improvement in safety, operational capability and economy in underwater manned operations with the introduction of the "close-cycle diesel engine" concept.

SUMMARY

by

Dr. G.G. SANTI

General Manager - Sub Sea Oil Services S.p.A. - Milan (Italy)

It is generally accepted that diving from dynamically positioned vessels still involves a higher risk than diving from a traditionally moored vessel.

Furthermore, the deployement of a bell from a D.P. vessel in the vicinity of a structure allowing diver intervention with a standard length of umbilical, is very seldom accomplished with full work results owing to the various interferences affecting this type of operation. Weather conditions and specifically wind and current direction too often come from the wrong side in relation to the ship-structure position.

Traditional lock-out submersibles have limited power autonomy relating to the diving endurance in saturated conditions. For example, the thermal balance of divers in a deep oxyhelium atmosphere, in operational condition,and the power supply for the survival systems to cope with an emergency situation on the sea bed is pratically non existant.

Hyperbaric rescue chambers or lifeboats actually used to evacuate divers in saturation conditions have still to show effectiveness in heavy weather conditions whilst a multipurpose submersible craft could rapidly dive and navigate underwater, move away unaffected by the surface weather conditions, avoid collision with the ship and/or platform, and steam away from dangerous positions during blow-outs, fire on board or fire on the sea surface.
Furthermore, divers exposed to wave action in a small hyperbaric surface lifeboat could seriously be affected by seasickness with consequent dehydration and this matter has not been sufficiently investigated yet.

Based on this type of consideration and by individuating many other potential fields of application, in 1973 S.S.O.S. began the in house study of an autonomous submersible unit inclusive of a diver lock out system capable of excursions to 1000 metres and whose main characteristic is the "close-cycle diesel engine".

The "close-cycle" diesel engine

This unique engine developed by Sub Sea Oil Services S.p.A. is the heart of the whole system allowing both surface and underwater navigability.
Various types of diesel engines with power levels between 10 and 150 HP, have been modified and tested in our laboratories in the past seven years to make them suitable for application in a submerged craft without the use of the traditional snorkel.

We carried out our trials taking into consideration previous experiences accomplished by other nations on the same technical application and in particular those of U.S.A., Japan, Germany and England.

A conventional diesel engine intakes air, that is a mixture of nytrogen (79%) and oxygen (21%).
By mixing the air with the diesel oil and passing through the phases of compression, combustion and expansion, the mechanical work is produced.

Exhaust gases, mainly CO_2 and water vapour with impurities and solid particles, are exhausted and dispersed in the atmosphere.
In our"close-cycle diesel engine", which must operate in a confined space without external links, the exhaust gases are recycled to the engine intake, consequently the following problems must be solved :

a) Oxygen burnt in the combustion phase must be injected in a quantity proportional to the combustible.

b) The exhaust gases must be cooled, purified and recycled to the engine inlet.

c) The excess of gas in the closed circuit must be instantaneously expelled to avoid overpressurized conditions in the circuit itself.

d) The engine is part of the submersible and any change of the initial loads of oxygen and diesel oil must be instantaneously compensated to avoid trimming and buoyancy changes.

These and other problems have been identified and solved with unique patented methods and Sub Sea Oil Services is, at the moment, producing the first operational submersible to be operated with the close-cycle diesel engine for commercial operations. This will include diver lock-out, salvage and rescue applications and atmospheric deep interventions with relevant manipulators working capability.

The state of the art - April 1980

Sub Sea Oil Services began the research project "PHOENIX" in the early seventies and in 1973 laboratory simulation of various parameters began and the real project commenced.

In 1976 the close-cycle diesel engine was installed for the first time on board a submersible unit, the PH - X02, which was suitably converted to cope with this particular application. This experimental prototype, on which all the "wet" trials have been accomplished, has today summarized 3200 hours of "close-cycle" submerged navigation, while four laboratory engines have produced a total of 6000 hours of work with peaks of 500 hours of continuous engine running in the close-cycle mode at 10% overload over maximum power indicated by manufacturer.

The engine has also logged several thousand hours of surface navigation which is not even worth mentioning due to the fact that the engine itself is "born" for surface application.

The "PH - 1000/1", the first lock-out submersible for commercial operations powered with two close-cycle engines of 90 HP each, is one of the S.S.O.S.'s 1980 targets and the construction phase will be accomplished by December 1980.

How the "PH - PHOENIX" programme is laid down

The "PH - PHOENIX" programme includes the production and commercialization of two classes of submersibles and one class of submarine, all being powered with the S.S.O.S. close-cycle diesel engine.

Class "PH - 1" will include the short range submersible capable of operating in conjuntion with a saturation system installed on board the support vessel, able to provide 24 hours continuous lock-out services at maximum power output, to a maximum depth of 500 metres without compulsing the mother ship on location in D.P..
This class will also include observation and atmospheric working submersibles with a working autonomy of 250 miles underwater navigation at full power and 250 miles at surface, plus a 24 hours period of sea-bed sitting, during which time the diving lock-out work will be carried out.
In addition 72 hours of survival time are considered, as a minimum standard, for any emergency situation, with the craft steady on the sea bed.

The maximum manning level of this class will include three atmospheric pilots and ten saturated divers. Working capability to 1000 metres.

Class "PH - 2" will include the middle range submersible capable of operating as an autonomous saturation unit with a range of action of 250 miles at 14 knots speed to a maximum diving depth of 500 metres and observation/atmospheric working depth of 2000 metres.
A survival time of 72 hours is considered relating to the maximum number of people on board which is 15 for this class. This includes four atmospheric pilots and supervisors/technicians. This class will be tended by a tug or supply vessel to provide continuous communications and positioning.

Class "PH - 3" will include the long range "submarine" with an intervention capability of 500 miles and a diving working autonomy of 24 days to 500 metres and to 2000 metres in the atmospheric mode. The crew will reach the maximum level of 22 men, to include divers, pilots, technicians and possibly rescued crew from a distressed submarine.

Safety consideration relating to the "PH - PHOENIX" programme

The safety of diving operations are greatly improved with the introduction of the "PHOENIX" concept.

a) Diving in dynamic positioning will be simply eliminated with the deployment of the "PH - 1000/1" lock-out submersible assisted with communications and positioning system by the support vessel.

b) The multipurpose "PH - 1000/1" system will accomplish any kind of inspection and maintenance on a long distance self-contained autonomy which undoubtly also means a considerable improvement in safety for the occupants of the underwater vehicle.

c) The "PH - 1000/1" of the class PH-1 will also represent a new efficient way to evacuate divers under pressure whenever an emergency situation arises on board the ship or platform.
In fact the "PH - 1000/1" will be normally connected to the saturation unit in substitution of an SCC and the

handling system will include a passive mean to lower it at sea and to disengage it from the lifting wire to cope with the eventual installation total black-out.

d) The middle range class "PH-2" will provide a substantially different working tool for those applications within 250 miles from the shore base. Diving operations and inspections or atmospheric intervention will result unaffected by surface weather conditions still maintaining the highest level of safety.

e) Diving safety will also be improved as the "PH - 1000/1" lock-out submersible will find its position very close to the diver's intervention place and the supervisors will have the possibility to "see" the diver while he is working.
The major improvement of safety in these circumstances consists in having a supervisor who, at atmospheric pressure, can intervene to advise the diver of possible existing danger or starting during his operation.

f) Geophysical and seismic exploration will be practically carried out without meteorological limitations and with a great safety factor introduced in relation to weather working conditions.

g) Powered tools will be activated from the lock-out submersible and, safetywise, a great advantage is envisaged by the elimination of surface umbilicals which too often produce problems of primary importance mainly due to the movements of the surface vessel and current.

h) A semisubmersible or vessel operating in D.P. close to a fixed structure always represents a very high potential risk of collision. The "PH" approach eliminates this type of risk.

Some economical and commercial considerations

Today the estimated day rate for a D.P. vessel ranges between 90.000 and 30.000 U.S. dollars while the specific day cost for the bunker consumed to maintain the vessel in D.P. for launching the SCC and for keeping it in position could approximatly range between 40.000 and 15.000 U.S. dollars. It is evident that the "PH - 1000/1" application could represent a major investment saving in substitution of a traditional saturation diving bell.

The PH-2 PH-3 classes will similarly represent, in their multipurpose applications, a substantial cost reduction of the offshore underwater inspection, maintenance and repair combined with a sensible increase of the operational diving work outcome and with a great improvement of safety in diving and in submersible operations.

It is worth considering that in the near future the "PH" autonomous underwater vehicles, operating together with a fire fighting vessel, will represent the safest and most economical alternative to semisubmersibles and other production support vessels in the oil and gas offshore industry.
The "PH" "submersibles" and "submarines" will also represent an important working tool in the deep sea mining venture, with particular reference to manganese nodule fields.

THE "PH-PHOENIX" PROJECT - A MULTIPURPOSE SUBMERSIBLE

A major improvement in safety, operational capability and economy
in underwater manned operations with the introduction of the "close-cycle diesel engine" concept

by
Dr. G.G. SANTI
General Manager - Sub Sea Oil Services S.p.A. - Milan (Italy)

PAPER

A major improvement in safety, in operating range and in economy of underwater manned operations, utilizing the "closed-cycle diesel engine" concept.

This is the first time that we present our new multipurpose lock-out submersible at an international symposium. The unique and revolutionary propulsion system of our PH type submersible constitutes a major improvement in the safety of underwater manned operations, combined with a considerable increase of operating range whether in the atmospheric mode or for the hyperbaric operations of saturation divers.

Before going into the technical aspects of this new underwater tool, we wish to make some practical remarks on present offshore activities which will help to explain the reasons why, eight years ago, we decided to venture into this expensive and difficult research project, anticipating the need in the eighties for a more powerful and safer multipurpose underwater vehicle.

Recent North Sea development has called for the construction and installation of a large number and wide variety of structures, all of which require underwater inspection for various reasons.
We refer particularly to fixed steel and concrete platforms, subsea completions and wellheads, loading buoys, buoyant towers for wading and flaring, pipelines, etc.

Underwater inspection requirements are usually decided either by the operator of the installation for specific circumstantial reasons or by the certifying authority under safety requirements.

Today routine certifications and underwater inspections in the North Sea alone account for approximately 75% of the total workload, the remainder being associated with construction and repair. The estimated expenditure in the North Sea on all inspections underwater, including structures and pipelines, will be between 60 and 70 million pounds in the year 1980 while the forecast for the mid 1980's is expected to rise to 85-105 million pounds.

The present submersibles cannot meet the ever increasing operational range or they operate uneconomically due to one characteristic which is common to all submersibles today operating worldwide: the limited power capacity of storage batteries.

Furthermore, if we consider the application from a safety point of view we can easily see that the existing underwater vehicles are less and less able to cope with the increasing demand for absolute operational safety.

We particularly refer to diving operations from dynamically positioned vessels, where to the diving risk itself we have to add the intrinsic risk of the positioning system of the ship or platform from which the dive is carried out. In fact the deployment of bells from a D.P. vessel or rig in the vicinity of fixed structures very often represents a risk due mainly to the sea state, currents, wind direction which give rise to peculiar operational situations with regard to diving. These situations are usually considered within the operational diving limits when judged by traditional standards but a careful 'post accident' analysis usually shows there was undervaluation of interrelated causes and therefore increased risk to the divers.

Traditional lock-out submersibles have limited power capacity as regards their diving endurance in saturated conditions. For example, the thermal balance of divers in a deep oxyhelium atmosphere for long working exposures in cold water, and surplus power supply for operating 100% effective survival systems in an emergency condition, are both almost non existent on current manned underwater vehicles.

No hyperbaric rescue chamber or lifeboat presently used to evacuate saturated divers from a ship or platform in distress, has yet shown full effectiveness in adverse weather conditions and in particular contingency situations such as a blow-out. We have serious doubts with regard to the practical operating capability of such systems, although it is easy to recognize their effectiveness at a psychological level. Furthermore, divers exposed to wave action in a small hyperbaric surface lifeboat could seriously be affected by sea-sickness with resulting negative effects, such as dehydration, which have not been sufficiently investigated yet.

A multipurpose submersible vehicle with greater working range is in our opinion the most reliable system to cope with this type of emergency, when provided with a mid-water system of disengaging from the mother ship, combined with a passive means of lowering it through a cursor to that position.

A submersible rescue vehicle engaged in a rescue operation of saturated divers could rapidly dive and navigate underwater at maximum speed, then move away unaffected by the surface weather conditions, to avoid collision with the ship or platform, and steam away from dangerous positions during blow-outs, fire on board or fire on the sea surface.

Further to the above we now wish to point out that today the average bell-run with two or three saturated divers has a duration of 8 hours while a traditional submersible lock-out keeps an uncomfortable diver out for 3 to 4 hours only, due to limited operating range. Our

PH submersible brings the lock-out time up to 24 hours with a considerably increased safety level. Considering these problems and by identifying many other potential field of application, in 1973 Sub Sea Oil Services began the in-house study of a self-powered submersible unit to include a diver lock-out system, capable of excursions to 1000 metres of depth and whose main characteristic is the "closed-cycle diesel engine".

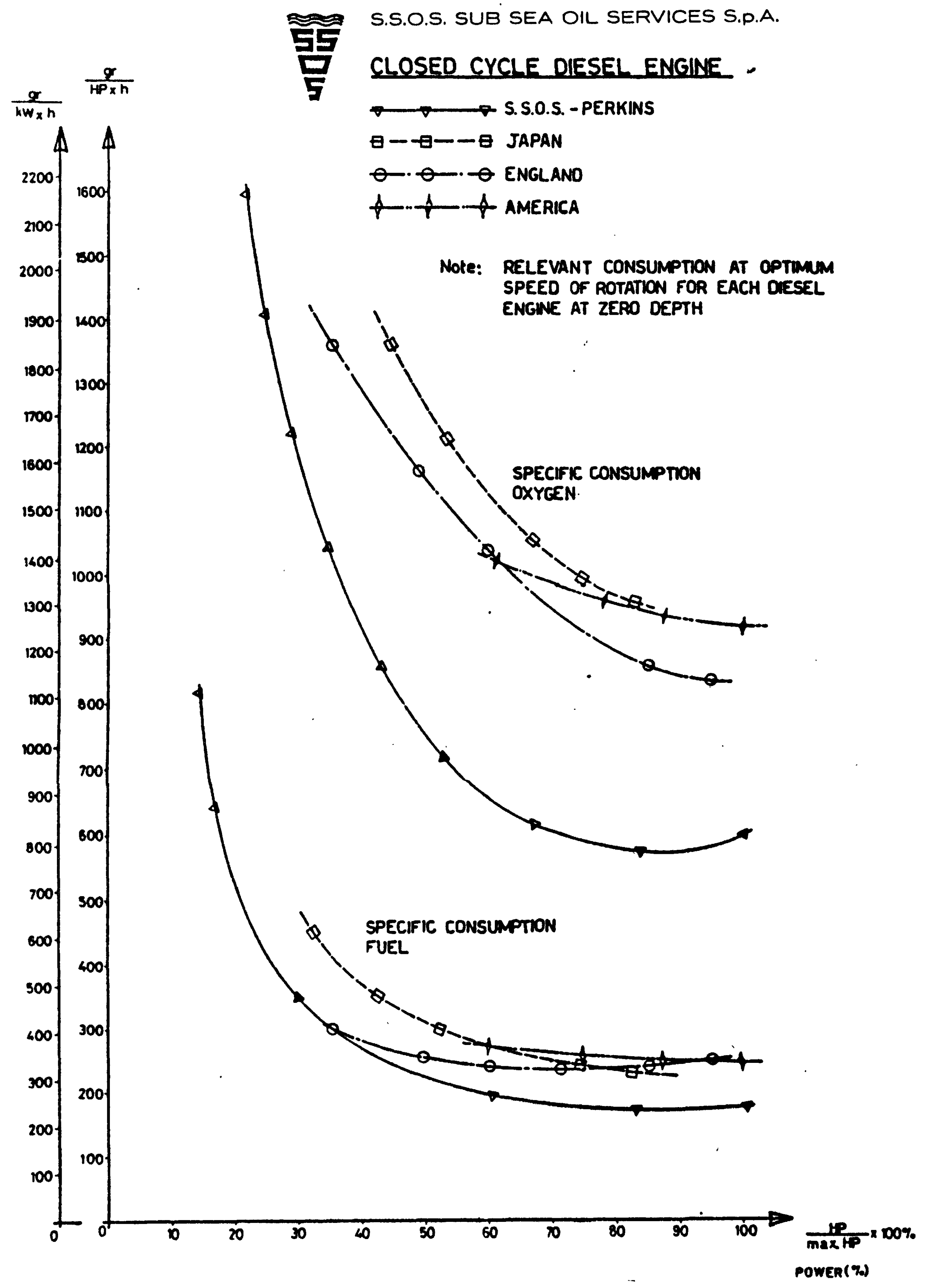
THE "CLOSED-CYCLE DIESEL ENGINE"

This unique engine developed by SUB SEA OIL SERVICES S.p.A. is the heart of the whole system and was designed for both surface and underwater navigation. Various types of diesel engine with power rating between 10 HP and 150 HP have been modified and tested in our laboratories in the past seven years, to make them suitable for utilization by submerged craft without the traditional snorkel breathing tube.

We carried out our trials making allowance for the previous experiments of other nations on the same application and in particular those of U.S.A., France, Japan, Germany, England and Sweden.

The following comparative diagrams indicate the specific consumption of fuel and oxygen relating to the various experimental prototypes produced in the last 20 years in the same countries. The comparison brings to light the optimization of fuel consumption by the S.S.O.S. closed-cycle diesel engine.
(TABLE/SLIDE No. 1)

A conventional diesel intakes air, that is a mixture of nitrogen (79%) and oxygen (21%) then by mixing the air with the diesel oil and passing through the phases of compression, combustion and expansion, the mechanical work is produced. The exhaust gases, mainly CO2 and water



TABLE/SLIDE NR.1

vapour with impurities and solid particles, are exhausted and dispersed in the atmosphere.

Our closed-cycle diesel engine must operate in a confined space without any external atmospheric links, the exhaust gases are recycled to the engine intake and therefore the following problems must be solved:

a) Oxygen burnt in the combustion phase must be injected in a quantity proportional to the fuel.

b) The exhaust gases must be cooled, purified and recycled to the engine intake.

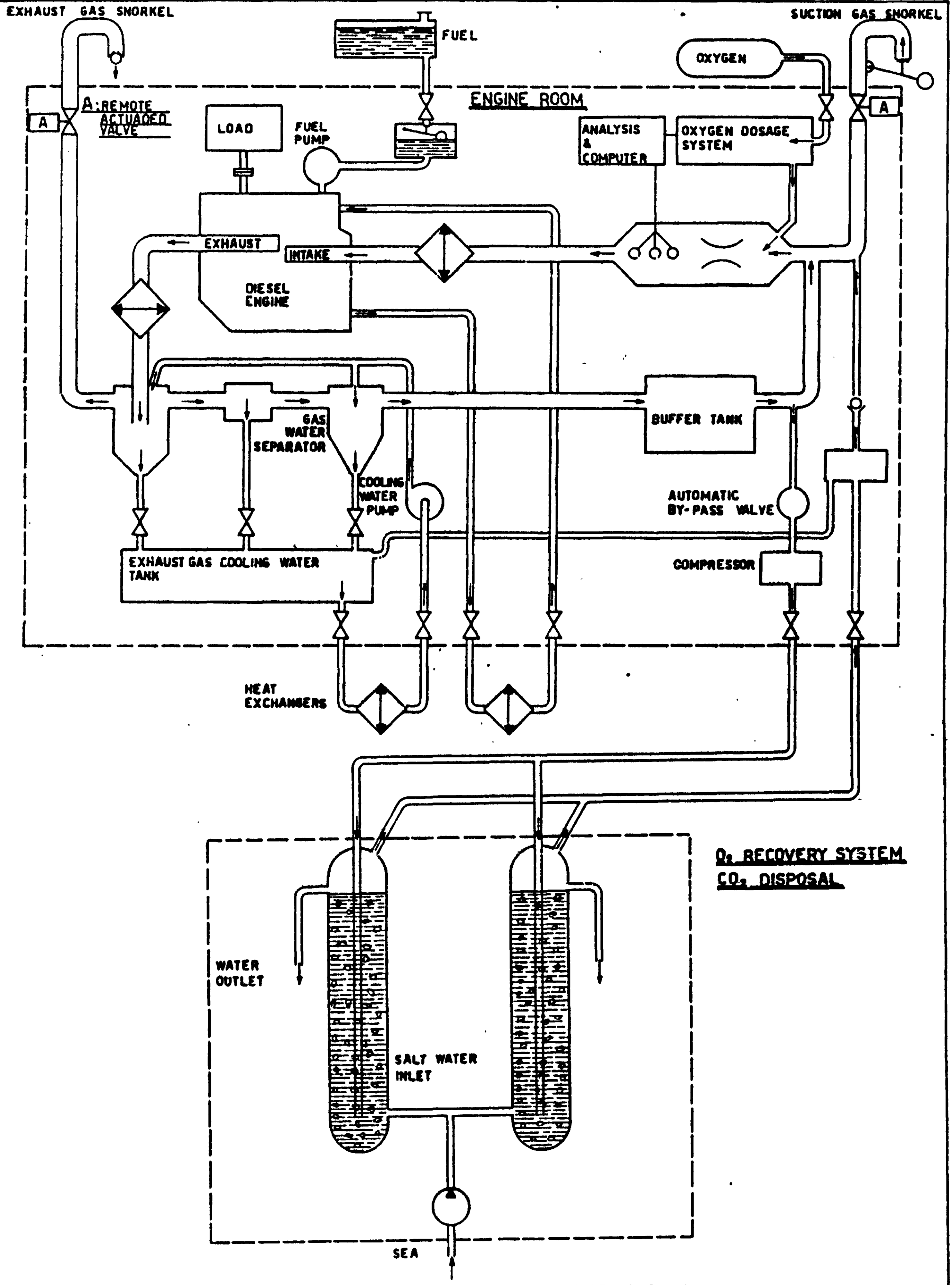
c) The excess of gas in the closed cycle must be instantaneously expelled to avoid over-pressurized conditions.

d) The engine is part of the submersible and any change from the initial loads of oxygen and diesel oil must be instantaneously compensated to avoid trimming and buoyancy changes.

TABLE/SLIDE No. 2 shows the schematic layout of the closed-cycle diesel engine designed by SUB SEA OIL SERVICES.

These and other problems have been identified and solved through research application and unique patented methods and SUB SEA OIL SERVICES has designed for manufacture the first operational submersible in the world to be operated with a closed-cycle diesel engine specifically intended for offshore operations.

The new submersible will include a lock-out hyperbaric compartment sufficiently large for 4 saturated divers, and as an atmospheric manned device it will have the most advanced equipment for routine underwater inspections and manipulator working capability, that is practically without power limits.



S.S.O.S. SUB SEA OIL SERVICES S.p.A.

BIVALENT CLOSED CYCLE DIESEL ENGINE

SCHEMATIC LAYOUT FOR SURFACE AND SUBSURFACE CONDITIONS

TABLE/SLIDE NR.2

The research programme carried forward in our laboratories is aimed at two principal objectives:

1) to develop a reliable engine and ancillary equipment for producing power both on the surface by intaking air and underwater with pure oxygen injection, in the closed-cycle mode.

2) to reach the lowest possible specific consumptions of fuel and oxygen and obtain the highest operating range.

Today we have reached unexpected results in both objectives, having achieved 4000 hours of closed-cycle submerged navigation, while 4 laboratory engines have produced a total of 6000 hours of work, with peaks of 5oo hours of continuous engine running in the closed-cycle mode at 10% overload in relation to the maximum power indicated by manufacturer (TABLE/SLIDE No 3) .

All our wet trials were carried out on board the 'PH-X02', a submersible unit modified to carry on, at various depths, all the scheduled operations including repeated equipment reliability tests and testing materials prepared and supplied by our laboratories.

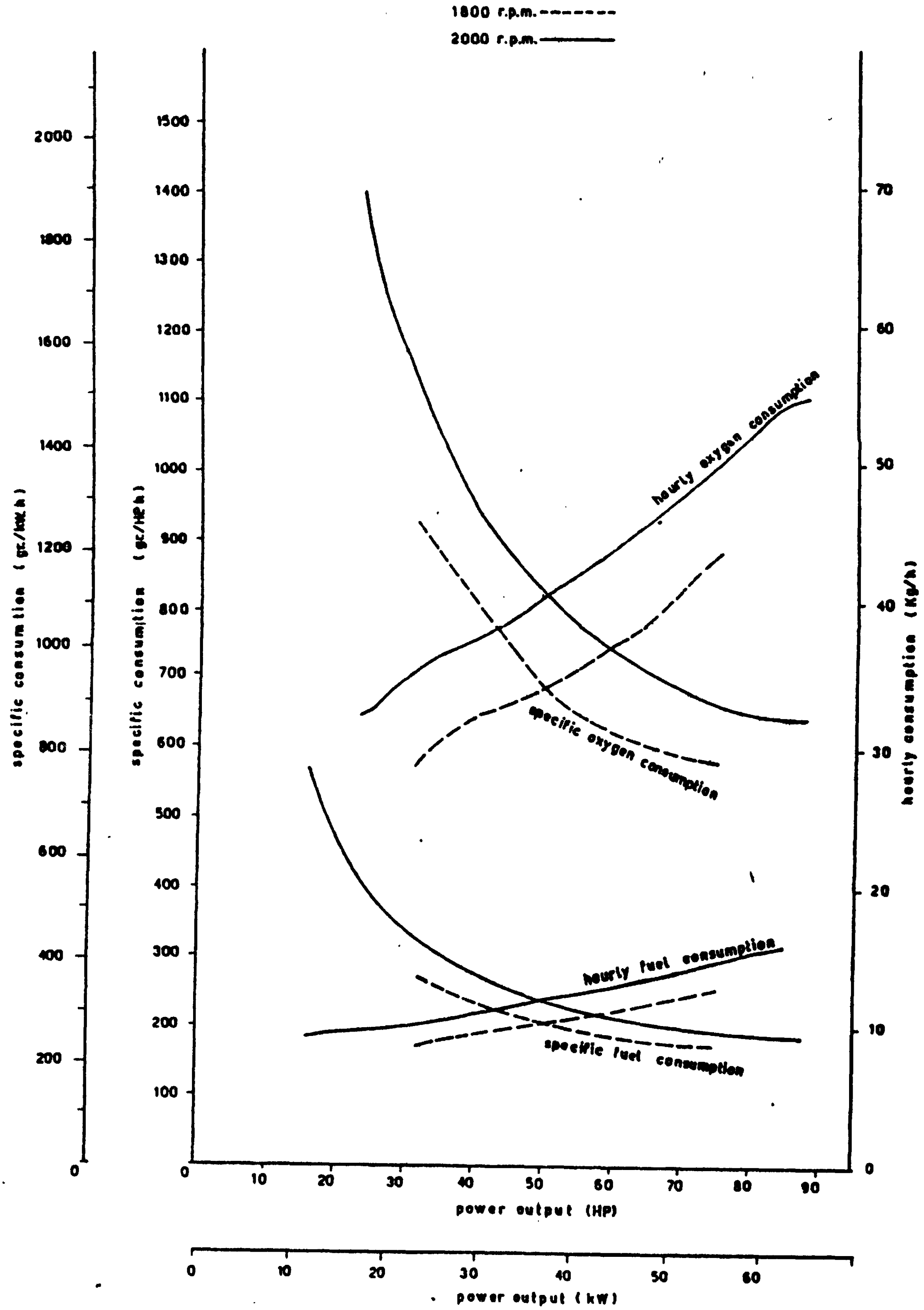
The 'intrinsically safe' principle has been a must in all engineering solutions, and simultaneously a group of 8 pilots has been specially trained to cope with the need for particular operating knowledge, as this type of submersible is slightly more sophisticated than the usual battery operated ones, and is furthermore an underwater vehicle operating at much higher speeds than the traditional ones.

The 'PH-1000/1' will be launched in December 1980, the first lock-out submersible for commercial operations powered with two closed-cycle diesel engines of 90 HP each. This craft will incorporate fully redundant systems to cope with any degree of mechanical failure, in order to ensure

S.S.O.S. SUB SEA OIL SERVICES S.p.A.

S.S.O.S.
PH-X-03
FIAT AIFO C.P.3M OPEN AND CLOSED CYCLE DIESEL ENGINE

SPECIFIC FUEL CONSUMPTION AND HOURLY FUEL CONSUMPTION AT:-



TABLE/SLIDE NR.3

the highest level of safety for the occupants and the maximum degree of operational reliability.

The power supplied from two diesel engines will be either used to obtain unusual inspection work speeds on the seabed or to supply power to any type of underwater working tool, whose traditional application would require power umbilicals from the surface.

The passive thermic energy provided by the cooling system of the engines will be used, through heat exchangers, to supply hot water to the divers and to ensure the most suitable temperature level in the compartments of the submersible.

A reserve of power, supplied by battery pods, will always be ready for 72 hours survival requirements of the atmospheric crew and the team of hyperbaric divers.

THE 'PH-PHOENIX' PROGRAMME

The 'PH-PHOENIX'programme includes the manufacture and marketing of the two classes of submersibles and one class of submarine, all powered by the S.S.O.S. closed-cycle diesel engine:

Class "PH-1"	Short range submersible
Class "PH-2"	Medium range submersible
Class "PH-3"	Long range submarine

The Class "PH-1" - short range submersible capable of operating in conjunction with a saturation system installed on board the tender vessel which also provides the submersible itself with support during the diving operation.

This includes launching the vehicle, constant communications and position monitoring of the vehicle during the dive, assistance during surfacing and recovery on board, relocation of submersible on seabed and possibly bell diving in real emergency conditions such as entanglement and flooding of compartments. It goes without saying that submersibles of this class are also suitable for atmospheric work such as inspections, TV and photography surveys, manipulator work, seabed sampling etc. The maximum lock-out capability will be 500 metres while the maximum attainable depth will be 100 metres. The navigation aids of this class will be 250 miles in the submerged condition plus 250 miles on the surface, plus 24 hours continuous lock-out service with the submersible sitting on the seabed.

For safety reasons a minimum survival time of 72 hours is ensured in terms of heat, oxygen, carbon monoxide scrubbing, oxyhelium mixture supply, water, food and waste bags.

The crew will include a maximum number of 4 pilots/operators/ surveyors in the atmospheric compartment, 4 divers in routine lock-out conditions or 10 saturation divers in emergency rescue conditions in the hyperbaric compartment.

The "PH-1" class submersible will also be capable of assisting other submersibles in distress and its high operating range combined with the most efficient lock-out facilities will be decisive in this type of application.

At present S.S.O.S. is building the first model of the generation of the PH-1 class whose main characteristics are as follows :

- Length	11.45 mt
- Breadth	3.00 mt

- Height	3.00	mt
- Fore pressure hull diameter	1.90	mt
- Aft pressure hull diameter	1.50	mt
- Length pressure hull	8.35	mt
- Operational depth	350	mt
- Dry weight	25	tons
- Displacement (submerged)	31	tons
- Maximum submerged speed (2 engines)	12	knots
- Maximum surface speed (2 engines)	7.5	Knots
- Submerged endurance at maximum output of 1 engine	24	Hours
- Surface endurance at maximum output of 1 engine (in addition to the above endurance)	24	Hours
- Main engine	2 x 90 HP	
- Oxygen capacity	1780	Kgs
- Fuel capacity	960	Kgs

The application of our design of prime mover to an improved conventional lock-out submersible provides a tool capable of performing 75% of offshore maintenance and inspection requirements.

The vehicle belonging to the "PH-1" class has the following advantages when compared to a traditional battery-powered submersible or to a conventional bell:

- Greater on bottom working time, 20 hours/day.
- Accurate positioning of divers on site, due to much greater power of its thrusters.
- Unlimited heat source, therefore no divers heating problems.

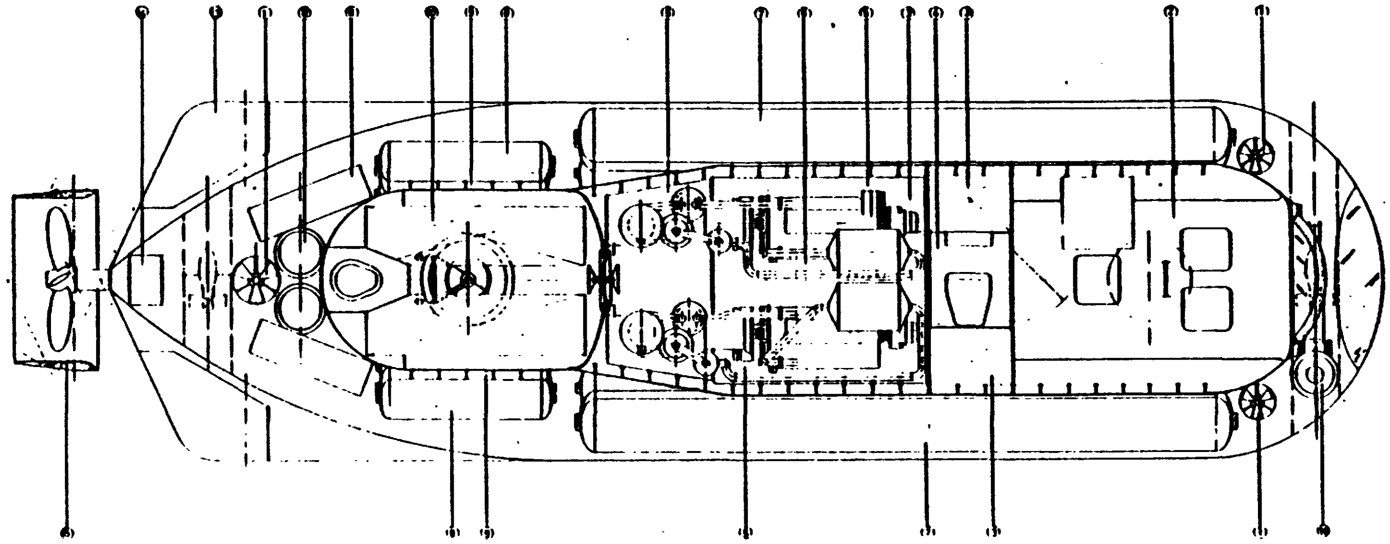
- Mobile bell, therefore more efficient.
- Support craft does not need to anchor near the structure.
- Support craft does not need to hold station on D.P.
- Much greater efficiency in maintenance and inspection work.
- No power limitation on the seabed.
- Total freedom from the surface spread, no umbilicals or power cables.
- Capability of carrying engineers and client representatives to inspect diver's work, due to increased range of survival systems.
- Capability of using vehicle as hyperbaric rescue device instead of the hyperbaric rescue chamber or lifeboat.

Other advantages of this underwater vehicle equipped with the closed-cycle diesel engine are outlined in the following comparative descriptions of the S.S.O.S. submersible CCDE at present under construction and of a conventional submersible of similar weight and displacement but equipped with a very efficient battery produced power source.

	S.S.O.S. CLOSED-CYCLE DIESEL ENGINE	CONVENTIONAL BATTERY POWERED SUBMERSIBLE
Power supply	2 x 90 HP	25 HP
Power density (by weight)	7 HP/TON	1 HP/TON
Max Speed	12 knots	3 Knots
Time at survey speed	48 Hours	8 Hours
Divers bottom time	20-24 Hours	4- 6 Hours
Accommodation: Pilots	4	2- 3
Divers	4- 6	3
Comparative efficiency levels		
a) Survey:		
Launching & diving to seabed	1 Hour	1 Hour
Working	48 Hours	8 Hours
Surfacing & recovery	2 Hours	2 Hours
Power refuelling	4 Hours	10 Hours
TOTAL	55 Hours	21 Hours
Efficiency : $\frac{48}{55}$ = 87%		$\frac{8}{21}$ = 38%
b) Lock-out:		
Launching & diving to work location	1 Hour	1 Hours
Working	24 Hours	6 Hours
Surfacing and recovery	2 Hours	2 Hours
Power refuelling	4 Hours	8 Hours
TOTAL	31 Hours	17 Hours
Efficiency: $\frac{24}{31}$ = 77%		$\frac{6}{17}$ = 35%

Tables/slides no. 4 and 5 show general layouts of the submersible under construction.

TABLE/SLIDE NR. 4



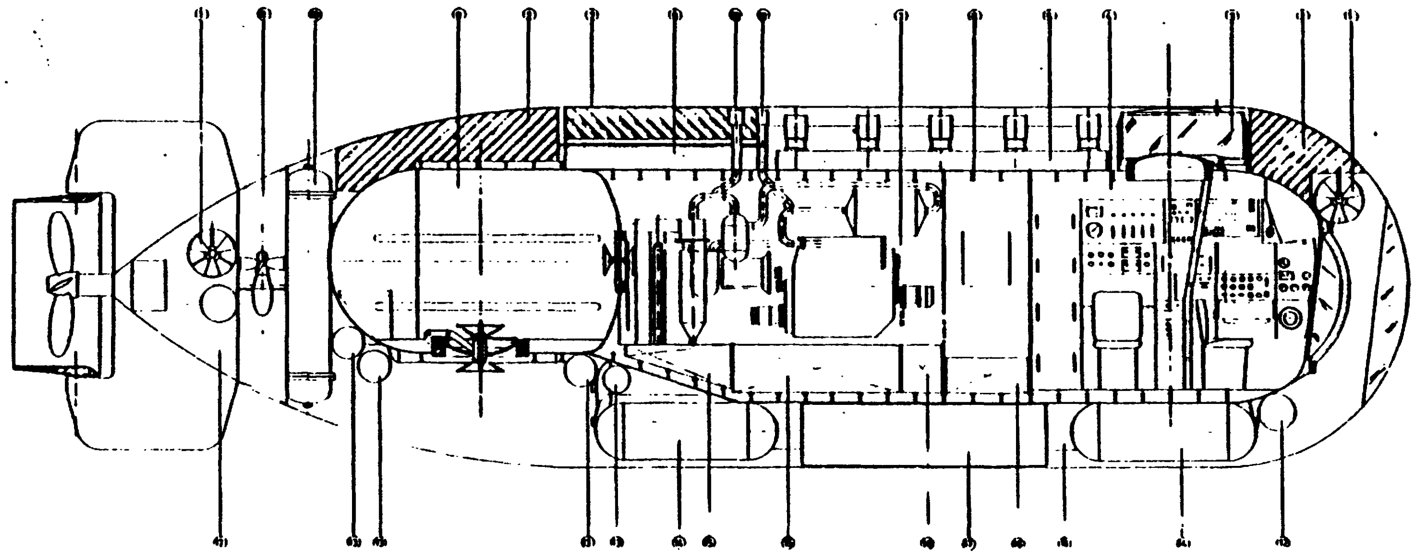
1	VERTICAL THRUSTER
2	CREW COMPARTMENT
3	COMPENSATION TANKS
4	TOILET
5	EXHAUST GAS CLEANING AND CONSUMABLE COMPENSATION TANK
6	ENGINE ROOM
7	OXYGEN PLANT
8	GAS MIXTURE VESSEL
9	AIR COMPRESSED VESSEL
10	DIVERS COMPARTMENT
11	BATTERY POD
12	OXYGEN REGENERATOR PLANT
13	HORIZONTAL RUDDER
14	PROPELLER HYDRAULIC MOTOR
15	PROPELLER STEERABLE NOZZLE
16	MANIPULATOR

SUB SEA OIL SERVICES
MILANO

PH - 2350/ 2250 GENERAL ARRANGEMENT
(horizontal section)

5054 - 03

TABLE/SLIDE NR. 5



1 HORIZONTAL THRUSTER
2 BUOYANCY MATERIAL
3 TELESCOPIC TOWER
4 CREW COMPARTMENT
5 FORCEPS
6 TURRET
7 ENGINE ROOM
8 HYDRAULIC POWER DISTRIBUTION UNIT
9 DIVERS COMPARTMENT
10 OXYGEN REGENERATION PLANT
11 VERTICAL THRUSTER
12 MERCURY TRIM TANK
13 HEAT EXCHANGER
14 BALLAST [illegible] TANK
15 EXHAUST GAS CLEANING AND CONSUMABLES COMPENSATION TANK
16 COMPENSATION UNIT
17 SOLID BALLAST
18 OXYGEN PLANT
19 AIR INTAKE
20 EXHAUST

SUB SEA OIL SERVICES
MILANO

PH 2350/2250 GENERAL ARRANGEMENT
(longitudinal section)

[illegible]	[illegible]	1:20	5054 - 02

Our future programme:

CLASS 'PH-2'

The submersibles belonging to this class do not substantially differ from the above class except that they have a greater range, with a higher power rating for two closed-cycle diesel engines; furthermore sizes and volumes are considerably greater.

The lock-out diving capability of this class will be to 500 metres with 11 saturated divers whilst the maximum depth attainable by the vehicle at atmospheric pressure will be 2000 metres with 4 to 6 pilots-operators - surveyors.

The main differentiating characteristic of this class will be its range in total saturation. In fact no hyperbaric equipment will be kept on board the supporting surface craft, which will be a tug or supply vessel, required as a continuous communication link and for positioning the submersible. The tender vessel will also provide towing services whenever needed. The range of action of vehicles belonging to this class will be 250 miles at maximum speed 14 knots.

Survival time will be 72 hours considering a maximum manning level of 15 persons. The 'PH-2' submersible will sail from the harbour or shelter for medium range intervention and will return to the harbour only when the task is finished. Expressed in time the range will be 10 days including the survival time to cope with emergency situations.

CLASS "PH-3"

During the final stage of our programme we shall develop class 'PH-3' which will include "submarine" type vehicles capable of working offshore with a 500 miles navigation range and 24 days saturation endurance. The maximum crew will be 22 persons including pilots, technicians, diving supervisors and the rescued crew of a distressed submersible, when required.

The survival time will be 72 hours also for this class and the submarine will be tended at all times, for safety reasons, by a surface craft such as a tug or supply vessel capable of continuous communications and position monitoring of the underwater craft.

Maximum lock-out diving capability will be 500 metres, whereas in the atmospheric mode the "PH-3" submersible will be able to reach 2000 metres depth.

Finally, we wish to outline the great safety improvements included in our PH project:

a) Diving in dynamic positioning will simply be eliminated by the development of the PH lock-out submersible. The tender ship will stand by at anchor or on thrusters in the vicinity of the working site in order to ensure continuous communications and position monitoring of the underwater vehicle.

b) Submersibles belonging to the "PH-1" class will consitute an efficient and realistic method of evacuating divers under pressure in emergency situations.

c) The medium range "PH-2" will provide a substantially different working tool for applications within 250 miles of the shore base. Diving operations and inspections or atmospheric operations will be unaffected by surface weather conditions with a major improvement in safety standards.

d) The diving work will be more closely and better supported from the

"PH" lock-out submersible and at last the diver will be able to rely upon a support habitat, the submersible, which cannot either shift away because of D.P. failure, or pull away umbilicals or power cables due to surface shifts or current changes. The diving supervisor will be able to "see" the diver working outside the submersible control habitat, and in our opinion this represents a major safety improvement when we consider that the diving supervisor is able to intervene at any moment during the dive to correct anomalous situations or to advise the diver or divers of possible risk arising in the working area.

e) The "PH-2" and the "PH-3" classes will also ensure a much higher factor of safety when we consider how a submersible operation carried out nowadays, particularly referring to weather conditions and weather changes during dive. These classes will really be unaffected by weather conditions as we consider to be extremely critical the recovery onboard of a submersible craft in worsening weather conditions.

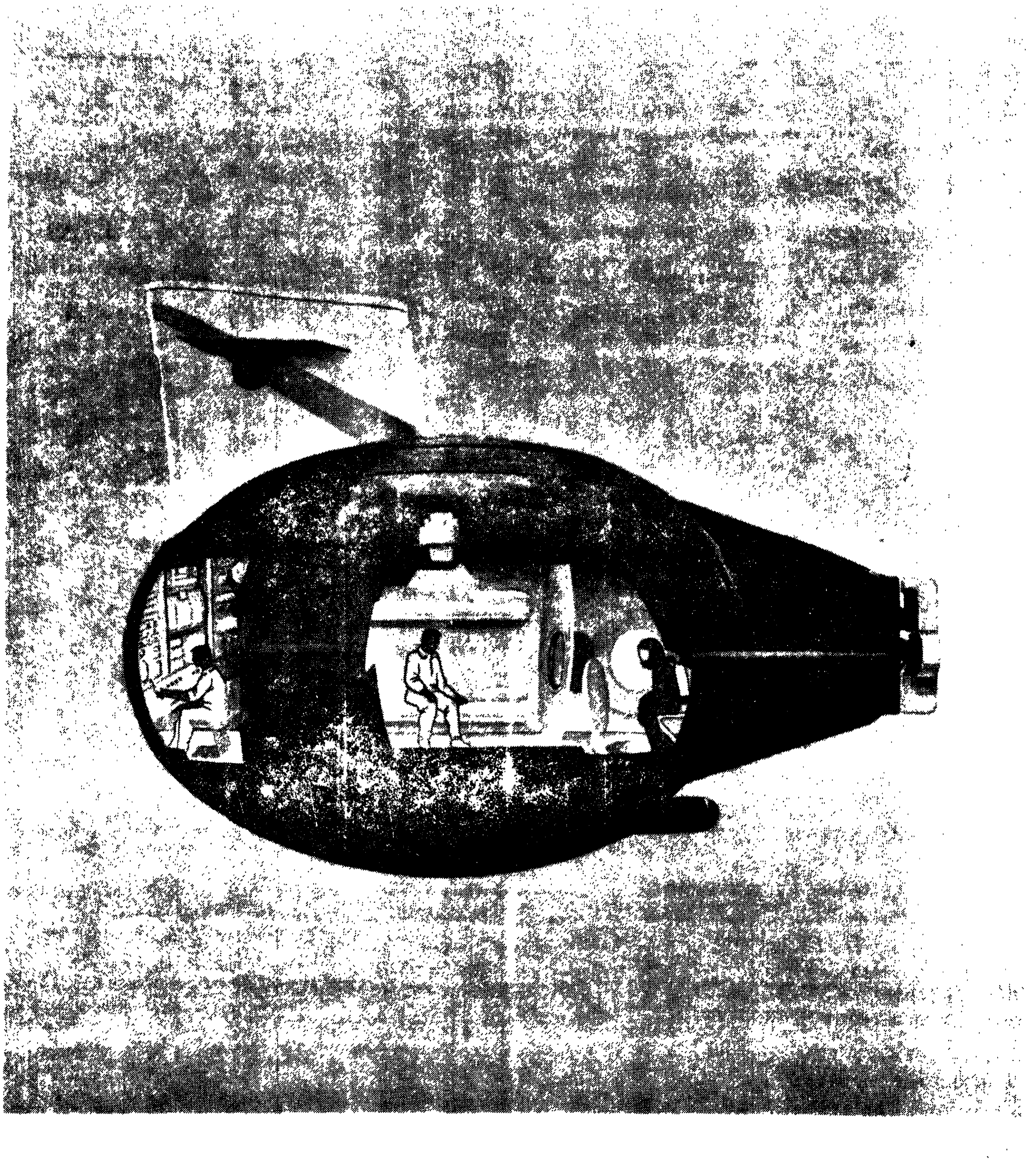
f) The risk of collision between a D.P. positioned support vessel employed to launch a bell and a fixed structure is totally eliminated under the PH approach. Furthermore, this solution represents a major cost saving when we consider that the daily cost of fuel required to operate a D.P. vessel today varies between 15.000 and 40.000 US dollars.

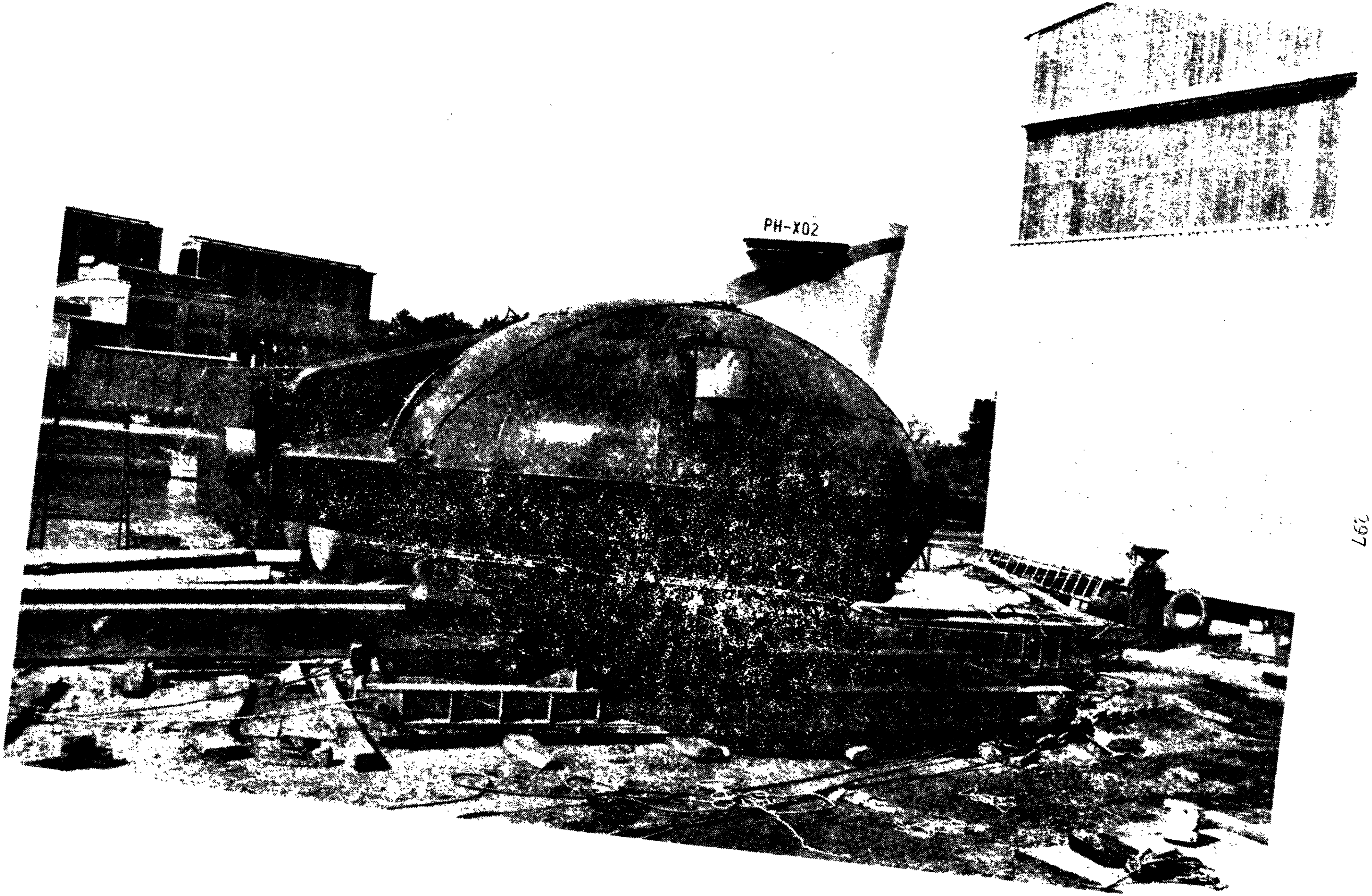
It is worth considering that in the near future the PH self-powered submersible and submarine , operating together with a tender or fire fighting vessel, is the safest and most economical alternative to existing semisubmersibles and other production support vessels presently employed by the offshore industry.

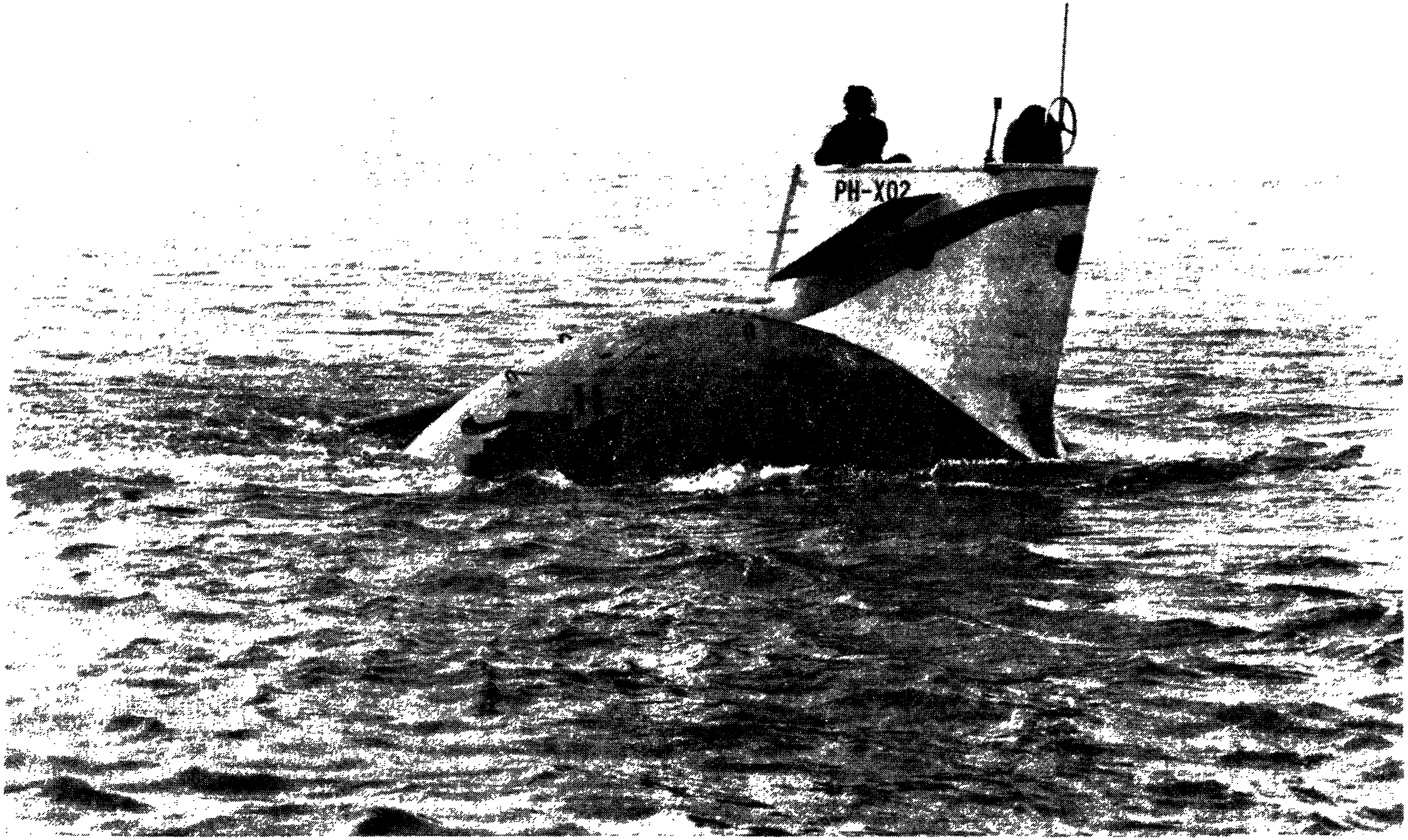
One of the PH vehicles could satisfactorily cover maintenance and routine inspection requirements of a complete field with many fixed structures and pipelines.

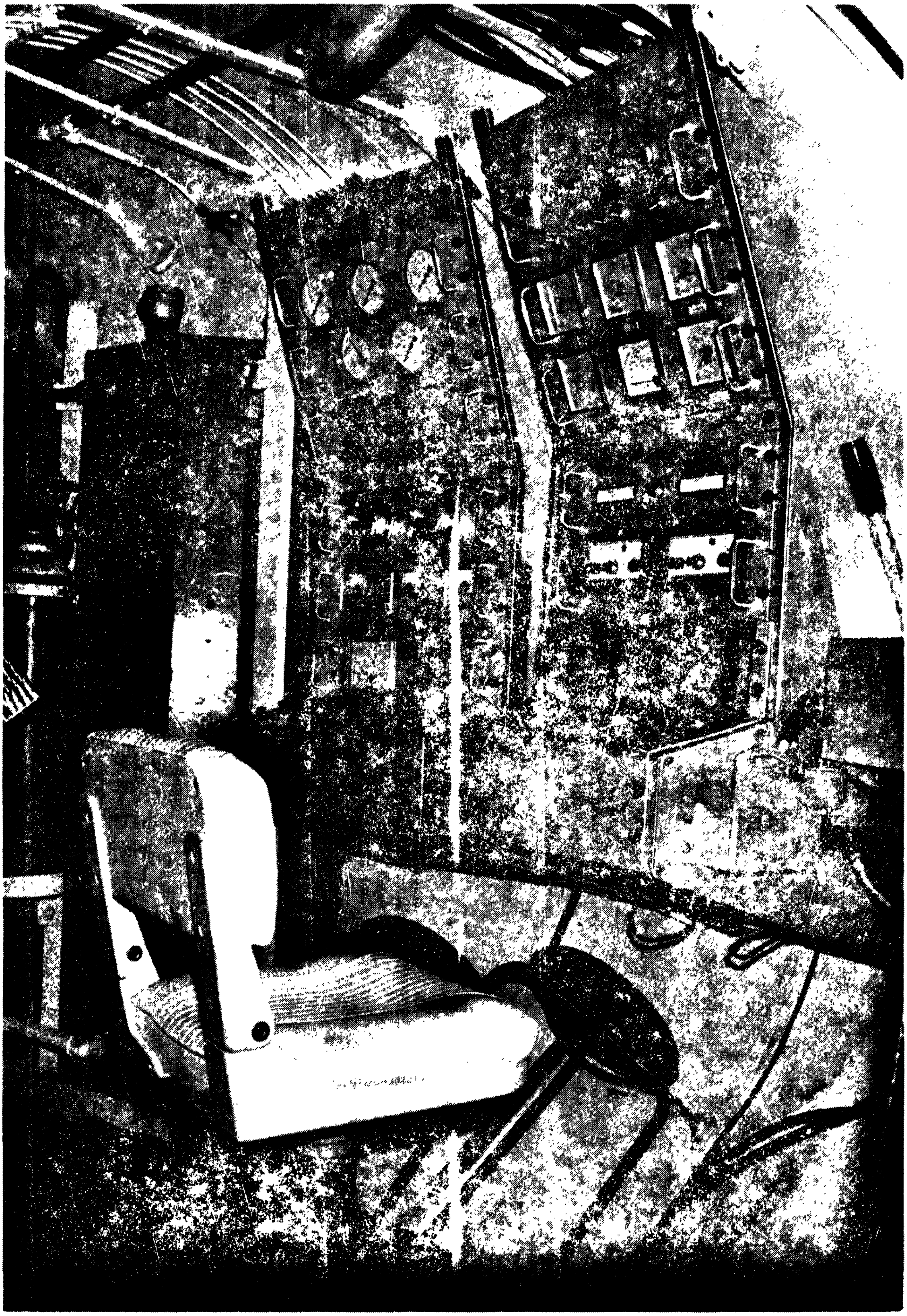
The submersible could easily be launched and recovered from the fixed platform itself and supported during the dive by the platform and/or a supply vessel.

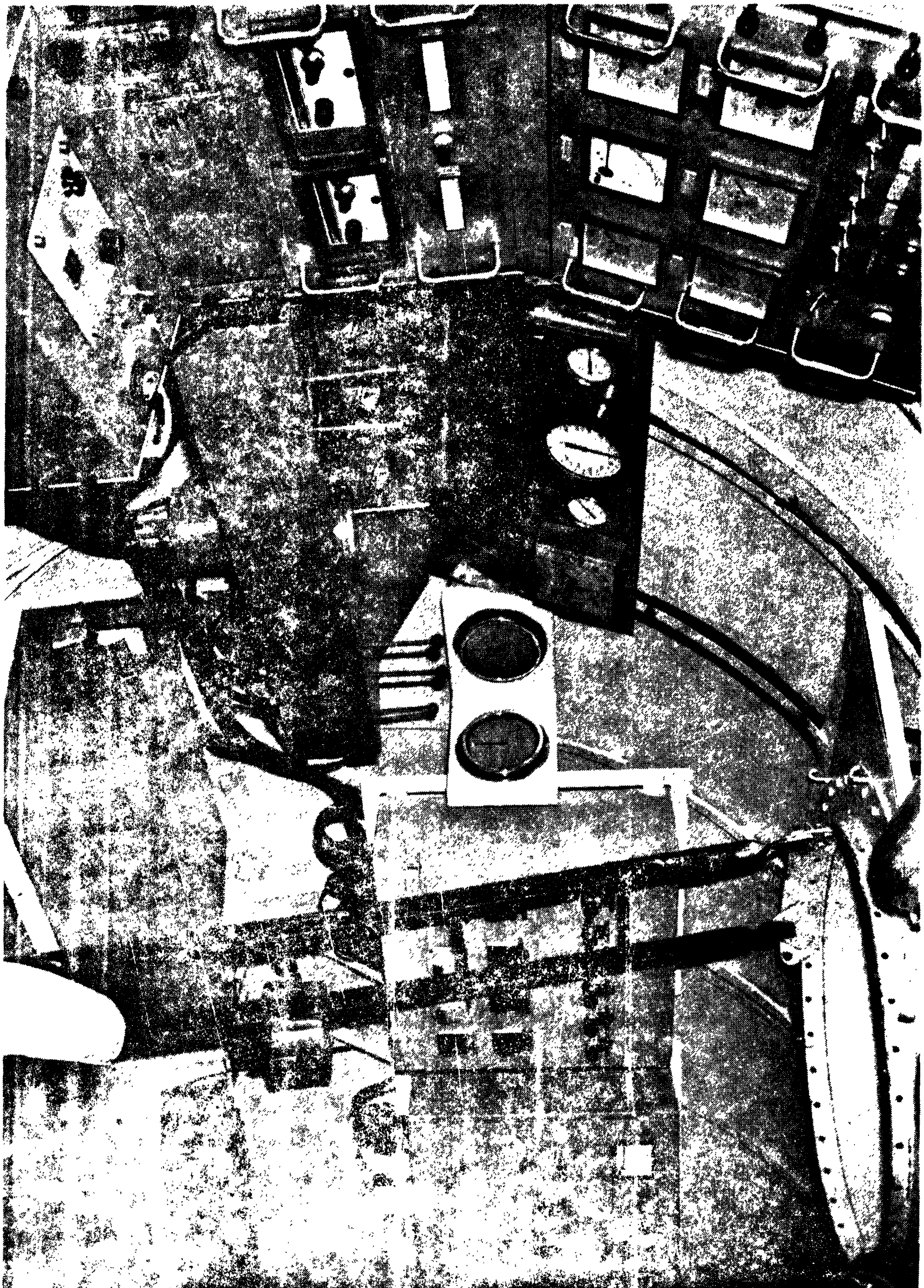
Ocean mining projects, with particular reference to manganese nodules in deep sea fields, also represent a very interesting and profitable field of application for our FH programme, and to complete the presentation of our PH submersibles we now wish to show you some slides of the experimental PH-X02 vehicle on which most of the wet trials were carried out, beginning in 1976.




PH-X02


PH-X02





THE ALTERNATIVES TO DIVING

by

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SUMMARY

At present most tasks can be carried out by divers, though the cost increases markedly with depth, while the effectiveness of the diver decreases, and it may be expected that before long significant demands will arise below the practical limit of diving. Meantime it is unlikely that alternatives will be used unless they can demonstrably work more effectively than divers and at lower cost. Such diver alternatives include manned submersibles, one man-one atmosphere tethered submersibles, atmospheric diving suits and remotely operated vehicles.

The case for having the operator at the worksite or in some remote location is discussed. It is concluded that, since remote viewing systems are possible which give better performance than the unaided eye, remote operations with the operator removed from the psychological pressures of working underwater are to be preferred providing that an acceptable man/machince interface can be achieved. Thus, remotely operated systems appear to have the greatest potential for development.

Areas where there is considerable scope for improvement are highlighted, including: deployment, station keeping, navigation, viewing, manipulation and overall system reliability.

PAPER

DEVELOPMENT BACKGROUND

Until recently the first reaction to the need to carry out engineering work underwater has been to use divers wielding some kind of hand tool or a simple adaption of it. This is a natural reaction to a situation where it has been very difficult to specify each and every task in advance and where the number of tasks required is very large. This is in direct contrast to other branches of engineering where man acts as an operator or supervisor of machinery sometimes having a high degree of sophistication. One can therefore conclude that underwater engineering is at a fairly early stage of its development where most of the work is done by skilled or unskilled manual labour. Thus there would seem to be considerable scope for technological advance - such a view is somewhat fascile.

It is relatively easy for the technologist to get carried away with his enthusiasm for doing expensive technological development in the underwater area. However when the commercial framework of the industry is examined it is clear that his enthusiasm needs to be tempered by the realisation that such aspirations are laudable provided the companies working in the industry can use these developments to generate sufficient work to earn the funds to pay for them.

When the functions of the diver are examined the range and diversity of the tasks he performs are very large. He is a universal and flexible tool. Although with the advent of offshore oil and gas the market for underwater engineering has increased markedly, the market for each individual specialist task that the diver performs remains quite small in terms of the numbers of each specialist equipment required. The development costs are also high especially if an extended period of offshore testing is required. Consequently high technology equipment manufacturers are reluctant to carry out developments on their own account as they fear the numbers sold will be insufficient for them to recoup their investment. In addition the major concern of most underwater engineering companies is to stay alive commercially. Most have had a difficult period as there have been times when there has been insufficient work available to keep the industry fully employed. Capital equipment costs are large, the rate of obsolescence are high and qualified experienced manpower is scarce. With such a background it is hardly surprising that the underwater engineering industry is reluctant to embark on long term integrated development programmes and to employ the necessary specialist staff.

DIVING

Advances can be stimulated by economic or technical pressures. It maybe seen that a job can be done more economically on a cost per unit of work basis or it maybe impossible to carry out a particular task with existing equipment. In the underwater environment the pressure to work at greater depth has both economic and technical implications. The cost of getting the diver down to and maintaining him at the work site increases with depth and the effectiveness with which the diver can work decreases with the increasing physiological and psychological pressures. Although diving technology to date has been largely successful in keeping pace with the technical requirements placed upon it, it is generally accepted that there must be a depth below which divers cannot work at all.

There is also a sociological aspect. Danger at the place of work becomes increasingly unacceptable as society develops. Diving is undoubtedly dangerous and the reaction to this is usually to create even more stingent safety requirements. This increases the costs of diving and provides further economic pressures to seek alternatives which are cheaper than putting man under pressure.

Before examining alternatives to divers it is useful to examine the advantages and disadvantages of a diver as a work system.

The main advantages are:-

(i) Ability to attach himself to structures at all levels within his operating depth and get good physical contact with the work.

(ii) Ability to use all the senses particularly the combination of sight and touch.

(iii) The flexibility and judgemental capability of man at the work site.

(iv) Great dexterity enhanced by working in a buoyant medium.

The disadvantages are:-

(i) All work is done under severe physiological and psychological pressure.

(ii) Total reliance has to be placed on bulky life support systems.

(iii) There is a very limited range of operation away from the life support system.

(iv) A continuous working period is limited to about 4 hours between rest periods.

(v) A return to a normal atmosphere and pressure involves long decompression times.

(vi) Very great limitations in providing power and in handling heavy objects.

(vii) Use of electrical tools is hazardous and requires considerable care and attention to detail.

(viii) Limited in range of vision compared with low light cameras.

(ix) The divers equipment as used below the surface has the appearance of being relatively cheap.

Summarising, man is flexible, highly adaptable and by being able to make adaptive decisions can use a combination of relatively cheap and simple hand tools to do a very wide range of functions. It is not easy to produce the same flexibility at the man/machine interface, retain man in the decision making loop and at the same time produce a universal machine. But nevertheless it is hardly surprising that for a large majority of the functions carried out by a diver that the alternatives which have so far emerged are general purpose systems attempting to duplicate many of the divers abilities.

Although most people are probably familiar with these alternatives it is necessary to briefly survey them here.

THE MANNED SUBMERSIBLE

The conventional free swimming manned submersible displacing between 5 and 10 tons and carrying a crew of 2 or 3 has the longest history of any diver alternative. Its capabilities are now well understood. It is most suited to inspection and survey work in open water. There always has understandably been a great reluctance to use these vehicles in or near structures due to the risk of collision or of being trapped but now some operators seem willing to take them inside steel jacket structures.

The advantages are:-

(i) Ability to carry expert personnel who are experienced in engineering and oil field operations to the work site.

(ii) Ability to carry a wide range of instruments and equipment including lock out divers.

(iii) Vehicles exist that can go beyond current diver operating depths and no insurmountable engineering problems exist in extending existing maximum depths of operation.

The disadvantages are:-

(i) The high cost of operating the submersible and its mother ship which usually has to be special purpose.

(ii) Reliant on internal battery power which limits the duration of dives and particularly places severe limits on work requiring high power consumption.

(iii) Large size makes access to restricted work sites difficult and often impossible. Attaching vehicles to structures to enable them to work at a particular site has proved very difficult.

(iv) Their size and weight are such that they have in the past had to depend on special purpose mother ships.

Use of manned submersibles seems to be on the decline. The high capital cost of the equipment which particularly includes the mother ships together with the seasonal nature of the work has resulted in commercial difficulties for all manned submersible operators. None of the operators entering the North Sea market have survived in their initial form: of 5 entrants only one is now operating.

THE ATMOSPHERIC DIVING SUIT

The concept of enclosing a man in a pressure suit which still gives him freedom to move his limbs retains some of the advantages of divers whilst removing the problem of pressurized gas. It is a very old concept, however the new generation of suits/vehicles are much more flexible, they are lighter and better engineered than those that appeared before the advent of offshore oil and gas. The resulting atmospheric diving suit (ADS) has to date not been used extensively for oil field activities in North West Europe although the situation would change as a result of trials being conducted by oil companies.

These suits have one over-riding advantage in that an operator can step into one and go straight to work and then simply step out when he returns. Thus they are a cheap alternative for providing manned subsea intervention for the odd unscheduled job as the suit operator does not need to be maintained at pressure. However there are a number of disadvantages:-

(i) Dexterity, the sense of touch and mobility are all severely restricted compared to the diver.

(ii) The articulated limbs are fairly tiring to operate as none have servo assisted limbs as yet.

(iii) Operations are limited to the seabed or to preplaced staging. They do not have the same unique ability of the diver to be able to attach and work in almost any position at any depth above his maximum.

THE ONE-MAN ATMOSPHERE VEHICLE

One of the disadvantages of the ADS is its lack of manoeuverability and lack of mid water capability. To overcome this disadvantage the concept of the one atmospheric suit has been modified to provide propulsion.

There are two main forms:-

(a) The pilot standing upright using articulated arms as in Wasp and Spider.

(b) With the pilot lying prone using manipulators as in Mantis.

These vehicles like the ADS have the advantage that the unique abilities of man are available at the work site but he is remote from it by virtue of the pressure hull required to maintain him at atmospheric pressure. The disadvantages of a greatly reduced sense of touch and manipulative capability immediately follow as to date it has not been possible to take the manipulative dexterity of man with its sophisticated tactile sensors through a solid barrier without a great deal of limitation. However provided the underwater engineering company can live with this disadvantage it does appear that these vehicles are relatively inexpensive to build and operate, they can be used from a non specialised ship, power is from an umbilical and the limitation is the endurance of the pilot. They are also relatively small compared with a manned submersible but big and awkward compared to a diver.

One man vehicles are coming to be accepted as being capable of doing useful work underwater and are claimed to be beginning to erode the markets for both divers and manned submersibles. They appear to be particularly useful for support of exploration drilling where they can be deployed at depth quickly on the relatively few occasions when underwater intervention is required.

MOBILE BELLS

These vehicles are typified by the Oceaneering Arms vehicles and the Comex MOB series. They can probably be regarded as tethered manned submersibles linked to their surface support by a cable that lowers them to depth. Some limited lateral mobility is provided by thrusters. Internal batteries and life support are carried and they are usually equipped with manipulators. Their main use has been exploration drilling support at great depth: a capability of 3,000ft is common. The most complex implementation of the concept is the mobile diving unit (MDU) for the Occidental Maintenance Support vessel. This bell incorporates diver lock out facilities.

The mobile bell suffers from the advantages and disadvantages of one-man and free swimming one atmosphere submersibles. Compared with latter the support cable allows greater case of deployment and recovery while restricting mobility. It is therefore probably an economic solution to the engineering problem of providing a pressure hull of sufficient strength for a free swimming submersible while retaining sufficient bouyancy to enable batteries and a payload to be carried. With new materials it is possible that one man vehicles could be developed to have a greater depth capability and could then duplicate all the capabilities of a mobile bell at lower cost. The future of mobile bells seems at the present time to lie in providing manned access at depths to which currently divers cannot go.

REMOTELY OPERATED VEHICLES

Oil company customers are now beginning to accept that remotely operated vehicles (ROVs) are capable of doing some useful work at a lower cost than competing systems including divers. ROVs so far employed for offshore use are linked to the surface with an umbilical carrying power, data and control signals. The ROV has a number of advantages many of which have not yet been fully realised in practice.

(i) Ability to operate continuously by rotating operating crews at the surface.

(ii) Ability to operate in areas hazardous or inaccessible to man and the simple camera carrying versions can be made cheap enough to risk losing them.

(iii) Small size and weight of most vehicles allows deployment from small ships of opportunity or platforms.

(iv) Has the potential to carry a wide range of payloads, tools and instrumentation.

The disadvantages of present vehicles include:-

(i) In common with all other vehicles they lack dexterity and the tactile sensing abilities of the diver.

(ii) Viewing systems although having a greater range in low light conditions than the unaided human eye omit to give many of the cues such as perspective range etc normally available to the eye. The also do not give the same detail as the eye.

(iii) The drag of the umbilical cable can absorb much of the power of the vehicle when fully deployed; the cable is also prone to snag on obstructions and as the pilot is not in the vehicle his senses have difficulty in detecting a snag until it hampers vehicle movement. Some of these difficulties can be alleviated by deploying the vehicle from an underwater garage.

(iv) Current vehicles are prone to unreliability and certainly have a reputation for it.

These vehicles have had their greatest success in tasks like pipeline inspection and in carrying a camera and lights to some chosen spot where it is expensive or difficult to deploy divers and where the market for these repetitive tasks is fairly large.

AUTONOMOUS SUBMARINES

A further method which has been proposed but not so far used for underwater engineering work is the large submarine operating autonomously from a shore base free from the effects of weather and thus capable of year round operation. A surprisingly large number of designs have emerged, mostly from military submarine designers or builders. A study commissioned by the DEn suggests that the concept is feasible and that a wide range of underwater tasks could be performed by or from such a submarine, but analysis of the economics shows very little advantage compared with the conventional methods of systems launched from large surface vessels such as the MSVs which are not unduly affected by weather and which are required anyway for other functions. However if manned habitats on the seabed are used in very deep water to produce oil something akin to an autonomous submarine will be required to ferry considerable numbers of personnel and materials to the habitats.

DISCUSSION

It is very difficult to determine quantatively whether any of the alternatives to divers that have evolved so far have made any serious in-roads to the divers market because many carry out functions that the diver seldom did. However it is clear that when the task requires dexterity, choice, close proximity to the work site and tactile capability there is no acceptable alternative to the diver. This becomes clear when tasks like a welded repair to a pipeline at 2,000ft are contemplated. Such consideration generates thought about the alternative means of solving the problem which is to break it down into its components and then design it so that it can be done by present day submersibles. Such activity is usually extremely expensive in development terms and is normally out of reach financially for most underwater engineering and diving companies. However it does illustrate one of the problems in that there is a generation of offshore equipment installed in which very little if any attention was given inthe design process to the needs of the submersible or diver.

It is perhaps significant that in the 2 areas where the RCV has penetrated the market to the greatest extent, pipeline inspection and visual inspection in general that these are fairly specialised activities where the remote system can be tailored to suit a widely required task. For pipeline inspection, first the manned submersible and more recently the ROV equipped with specialist instrumentation have proved capable of working efficiently. For visual inspection the small easily transportable and comparatively simple vehicles used have demonstrated their capability to do simple visual inspection at depth considerably cheaper than saturation divers.

Visual inspection is now being extended to other simple tasks such as taking cathodic protection readings and at last questions are being asked about NDT systems at the outset of their development to determine their probable compatibility to operation from a submersible or RCV.

Tethered manned vehicles seem to have a role to play when a quick intervention is required for a non routine task. In such circumstances the customers still perceive an advantage in having a skilled engineer in direct visual contact with the work site to make decisions. These vehicles are also a most economical method of taking man to depths where divers cannot operate. To a certain extent this is an admission that the technology of unmanned systems is not yet advanced sufficiently to make the operator feel he is present at the work site even when removed from it.

There are arguments abroad that the role of the conventional manned submersible is rapidly diminishing and that in the future a combination of RCVs and manned tethered vehicles will carry out all the work that in the past has been performed by manned submersibles. The final choice however at any one time is an economic one which takes into consideration the costs of development and the work done per unit price. In other allied fields like space and hazardous nuclear zones it has not proved economic or technically possible to remove man completely from the work site to date. There are increasing signs that this can be cone technically but it will require a far greater understanding of man's sensory perception than currently available. Man in the unforeseen situation is unique and his combination of intelligence, manipulative and sensory perception has proved to be extremely cost effective.

FUTURE DEVELOPMENT

The use of manned alternatives to diving will always be subject to some restriction due to the potential hazard to the life of the crew and the use of these vehicles in potentially dangerous areas will always be subject to increasingly sophisticated safety requirements. The size and cost of these vehicles is largely governed by the size of the crew and their life support systems. Their main advantage is the pilots direct visual contact with the work site. In theory there is no reason why all the tools, instrumentation etc that can be carried by a manned vehicle could not be carried by an unmanned vehicle. The pilot also gets tired in a manned vehicle while an ROV if engineered correctly should be able to work 24 hours a day with operators working in shifts. This argument leads to the view that the diver alternative with the greatest potential for development is the ROV but it is only valid on the basis that a cost effective technical solution can be found to providing the operator of the vehicle with the visual and sensory perception required and at the same time providing an acceptable means of transposing his manipulative skills and responses to the vehicle and hence to the work piece. This process is not going to be easy by any means nor is it going to be cheap. The problem has a lot in common with that of aerospace technology and it is clear that there is much to be learned from that technology that could be applied relatively quickly underwater.

The other somewhat simpler problem with diver alternatives, particularly ROVs, has in the past, been lack of reliability. Again the techniques to produce more reliable systems are available in other industries particularly nuclear and aerospace. There is no inherent reason why these techniques cannot be applied to underwater vehicles Modern electronics is highly reliable so it is probably best to concentrate sophistication into electronic and computing elements of a system while keeping electro mechanical elements, which always prove troublesome, as simple as possible.

In the short term it is suggested that the ROV will continue to make inroads on the market if future designs are concentrated on either single tasks which arise frequently or on a small range of such tasks. The development of a reliable technique for underwater NDT that could be applied by a vehicle would open up a large market. Cleaning of structures seems another possibility.

An activity which causes concern now is the repair of installations in deep water. Already in the Mediterranean pipelines are being installed in water depths where repair is atpresent not possible. A number of methods which are potentially capable of being applied by remotely controlled systems have been proposed but in most cases the basic technology has not yet reached a satisfactory stage of development let alone its remote application. Methods discussed in the literature and debated in the industry include mechanical connectors, explosive welding, welding in dry environments either under hyperbaric or one atmospheric pressure and even automatic orbital welding. This example serves in part to illustrate the wide diversity of solutions and the very difficult problem facing the technologist in defining exactly what is required, when it is required, what price the market will pay and in obtaining quantative data on which to substantiate the choices made in writing a specification. There is an unfortunate aspect in this industry to only consider such issues after the invention and development process as the large numbers of commercially unsuccessful manned and unmanned vehicles around the world goes to show.

CLOSING ADDRESS

by

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Ladies and Gentlemen,

In the opening address, it was suggested that the main benefit of a meeting such as this should be to exchange information on an informal basis, and to establish personal contacts on an international plane between the various bodies involved in diving both for sport, scientific and professional purposes, so that a common approach to the various problems encountered could be developed.

It is my impression that this is exactly what has happened, and I hope that you agree. But perhaps the most useful thing to do at this time is to try to sum up ; to pick out some general points which have emerged and to draw them together in a concise form.

- first we heard that accident experience had emphasised the need for proper training of the diver, no matter if he were a sport, scientific or professional diver.

- second the diver must operate within a system which ensures that he does not exceed the limits of his personal equipment, the back-up facilities or his training.

- thirdly, considerable progress has already been made in the reduction of the accident rate in all three spheres of diving activity; to put it more constructively, the level of safety has been raised.

- legislation is one of the factors responsible for this, but safety codes worked out as a result of accident experience are equally important. From the standpoint of cost, there is a good case for trying to eliminate conflicting standards, but harmonisation must not result in inflexibility in an industry where technology is in the process of developing at a very rapid rate.

If I can express a personal view for a moment, evaluation of the accident rates in similar activities, shows that safety improvement, like all other processes of development is subject to the law of diminishing returns. Thus the first steps that one takes to improve safety bring about a very big return in the reduction of accidents, for relatively simple measures, at low cost. In the diving sphere one of the first steps is training of the diver. But it must be accepted that each progressive step will cost correspondingly more.

After the first steps of training and simple equipment modification, we have to look elsewhere. Again, industrial accident experience can be a guide. Looking at the mining industry for a moment as a typical example ; in the year after the Safety and Health Commission was formed (1958) there were 770 fatalities in the coal mining industry of the Community of Six. The corresponding figures for 1979 for the Community of Nine, with approximately the same output was 131 fatalities. And if one considers the period prior to 1958, the comparison is even more marked. How has this been achieved ? In the first instance, it was by better training and better standards of supervision. But latterly, it has been by the removal of men from the source of danger, by the use of new technologies ; principally mechanisation.

It is my view that this also applies in the case of diving. Gradually as there is a need to work in more and more difficult conditions, at greater depths and in colder waters, we shall be forced to consider alternative systems such as the use of machines or submersibles to keep the man out of danger. This was exactly what Dr. Miles was saying.

Looking now to the future : two symposia have been organised by the Commission of the European Communities in liaison with the European societies competant in this field. On each occasion there has been a fruitful exchange of information ; what happens next ? I would like to suggest that it is for the various societies such as the European Diving Technology Committee, E.U.B.S., C.M.A.S., etc.. , the government organisations and companies, to reflect on what has been discussed. It is to be hoped that arising out of these deliberations, will come proposals which can be brought to the international organisations, so that they can continuously update their codes of practice and establish common guidelines which will lead to a general advancement towards safer diving on an international basis.

It is to be hoped that this procedure will allow the establishment of further guidelines for safe Diving by European Diving Technology Committee ; and then perhaps this type of symposium can be held some time in the future at an appropriate place and an appropriate time to assess what progress has been made since 1980 and what other steps are then required.

And now it is my final duty on your behalf and on behalf of the Director of the Directorate for Health and Safety of the Commission of the European Communities to thank the European Diving Technology Committee for their help in organising this International Symposium for without their aid it would have been extremely difficult for the Commission to organise such a meeting as this ; to thank the authors of their papers for their hard work and their interesting presentations, and last but not least to thank you all for attending, and making this Symposium the resounding success that it has been. Thank you all.

I now declare the Symposium closed.

END OF THE SYMPOSIUM

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