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Open-sea Diving Techniques

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Man may descend into the ocean as the occupant of a submarine, or as a mobile diver. In the former he is protected by a shield of unyielding armour, and in the latter he is directly exposed to ambient pressure and its effects. In both modes he is severely constrained by the harsh laws of his temporary environment.

Open-sea diving techniques are the special arrangement of skills that allow an individual to descend safely and work effectively as a free-diver beneath the sea. The return journey is also critical, and frequently the most important and demanding operational techniques are necessary to allow safe transport back to the surface.

It is evident that any diving technique involves critical interactions between the diver and his diving equipment. Whatever its nature, this equipment (or system) is used to minimize exposure to the stresses of the sea such as cold, wetness and pressure; and to maximize the control of life-supporting factors, such as oxygen, temperature, carbon dioxide and pressure. Therefore, the successful diver must have extensive knowledge of the physical and chemical laws of the sea related to diving; the medical consequences of disregarding these laws; and the principles and skills necessary to operate his surface and underwater equipment. These three avenues of knowledge are the foundation of effective open-sea diving techniques.

PRIMARY CONSIDERATIONS

Fundamental laws

Awareness of the laws covering diving, and the result of disobedience, has fostered the development of a combination of systems and techniques that today allow men to safely submerge to increasingly greater depths. The laws are:

Ideal Gas Law	(behaviour of gases at low pressures)
Boyle's Law	(volume inversely proportional to pressure)
Charles's Law	(volume directly proportional to temperature)
Real Gas Law	(behaviour of gases at high pressures)
Dalton's Law	(law of additive partial pressures)
Graham's Law	(diffusion rate proportional to molecular rate)
Amagat's Law	(law of additive partial volumes)
Thermal Laws:	specific heat; conductive and convective; heat transfer
Acoustical Laws:	conduction, diffraction and speed of sound
Density Laws:	Archimedes' Principle
Optical Laws:	curvature of light, absorption of colour

It is important to recognize that a direct line can be drawn from any existing technique to at least one of these fundamental laws. Another important fact is that all of these laws and their physiological relationships and implications are under constant scrutiny by a large group of laboratory investigators. Thus, any success in an open-sea system or technique has its genesis in the hours spent in laboratories and on the design board.

Dive profile

There are countless diving techniques currently used in the open sea. Their relevance and application are better understood if a typical dive is examined (Table 3.1). In this table, a deep commercial dive is used to illustrate the essential elements. Short duration dives are the most common deep underwater activity today. At least 10 000 such dives are made each year by divers working for oil exploration companies.

For example, two men descend in a diving bell to about 100 m (11 ATA) to work briefly at an oil well-head. Normally the average time at maximum pressure is less than 30 min, and the task involves light or moderate effort. Only one diver exits to the work site, while the other monitors his activity and stands by to assist.

Since compression rates are normally in the range of 30 m/min (3 ATS/min), this phase of the dive is of extremely brief duration. Life-support requirements and their attendant techniques reach a peak at maximum pressure and during decompression.

It can be seen that each phase of the dive has its major human stresses, vital life-support requirements, and critical mechanical sequences. Each of these is interdependent and must flow along a carefully planned and coordinated time frame.

Underwater tasks

Some of the major underwater work tasks conducted by commercial and scientific divers will now be outlined. It has been estimated that about four-fifths of manned underwater work in excess of 30 m (4 ATA) is carried out by commercial divers. The remainder is accomplished by military and scientific divers. Although considerable exertion sometimes accompanies their activities, sport divers are not included in this work estimate. Each different work task requires its own assortment of tools or other work support system and each device has its own technique of utilization. It is important to recognize that as demands enlarge, and confidence increases, all three groups of divers will be required to expand their work into deeper and colder waters. Supporting tool systems and techniques will have to develop accordingly.

Commercial tasks

1. Fixed structures. Work on fixed structures such as oil drilling and production platforms, towers, bridges, intakes, outfalls, reservoirs, tunnels, pulp mills, saw mills, and dams (including inspection and photography of damage by impact or corrosion; construction, repair, cleaning, removal, replacement of damaged elements). Work on mobile structures such as ships, barges and small vessels (including inspection and photography of damage; repair, cleaning, removal, replacement of damaged elements).

2. Cables and pipelines. Work on cables and pipelines including inspection and photography for damage and fouling. Location and repair of cable loops and suspensions. Burying by jetting, blasting, air-lifting, mechanical digging, hydraulic dredging. Construction and repair by underwater welding and joining. Installation and monitoring of cathodic protective devices.

3. Search and recovery. Work on search and recovery involving ships, aircraft, missiles, submersibles, transducers.

4. General tasks. These include repair and maintenance of valves and transducers, patching of leaks, placing, bolting, welding of parts, attaching of life devices, locating buried objects, placing explosive charges, site selection surveys, cutting, inducing buoyancy, rigging, excavation, erosion control, berth dredging, coating, grouting, core-drilling, scour control, data acquisition, damage surveys, logging, mining, and fish farming.

Scientific tasks

1. Biology. Observation and photography of animals and plants of the sea floor and water column. Measurements of living resource inventories, productivity, bio-scattering population density, influence of foreign objects, biological fouling, response to physical and chemical stress, bio-luminescence, bio-acoustics.

2. Physics and chemistry. Measurement of dissolved gases and solutes, gravimetric and magnetic data, acoustic data, pollution time and location distributions, pollution impact on available gases and solutes. Study of formation, configuration, aging, movement, and break up of ice.

3. Geology. Observation and photography of

TABLE 3.1

Phases of a deep, short-duration dive

Phases	*Pre-dive*	*Observation*	*Compression*	*On-the-bottom*	*Decompression*	*Post-dive*
Pressure status	Sea-level	Sea-level	Rapidly increasing	Maximum	Decreasing	Sea-level
Mechanical sequences	Prepare the diving system and subsystems	Lower bell to work site and maintain bell at work site	Maintain bell at work site	Diver(s) open hatch and exit to work site Monitor diver performance Diver(s) enter and secure hatch	Maintain seal Lift bell from work site and mate to surface decompression chamber Diver(s) transfer to decompression chamber	Inspect diving system
Psycho-physiological stresses	(Non-specific stress and tension)	(Non-specific stress, e.g. confinement)	(Non-specific stress) Noise hazard Heat Ambient pressure rise	(Non-specific stress) Cold Breathing gas density Exertion of work Urgency of the task	(Non-specific stress) Gas wash-out Rewarming Cold	Any task failure imposing a greater urgency to the next dive
Life support	General physical and mental condition Fluid balance	O_2 CO_2 elimination Temperature Humidity Communications	O_2 CO_2 elimination Inert gas Cooling Communications	O_2 CO_2 elimination Inert gas Heat Monitor for toxic contaminants Communications Helium voice processing	O_2 CO_2 elimination Decompression schedule Communications Fire prevention Monitor for toxic contaminants Heat	Rest Diet Fluid balance

sediments and outcrops of the sea-floor and slopes. Recovery by grab and core samples of sediments and outcrop material. Measurement of slope angles, surface dynamics, bearing strength, stability, sheer strength, density, thickness layering, change with depth, chemistry, scouring effects, sound velocity and mass physical properties.

4. Archaeology. Observation, measurement and recovery of artifacts from shipwrecks and former land sites.

Bio-engineering and human performance

1. Study of the performance of new non-diving equipment such as mass-spectrometers, cameras, hand coring devices and fish traps.
2. Study of the performance of new diving equipment such as closed circuit breathing systems, heated suits, mobile laboratories, navigation systems, and diver tools.
3. Study of new underwater salvage and construction techniques such as airlifts, water jets, buoyant spheres, and hydraulic systems.
4. Confirmation of hyperbaric laboratory studies.
5. Measurement of human performance under various stress conditions.

OPERATIONAL DIVING SYSTEMS

Since other chapters in this book describe specific systems, such as breathing and life support, no mechanical or physiological detail is given here. This section illustrates only the vital and complex interaction between open-sea diving systems and their technique of operation.

Breathing apparatus

Breathing systems offer a variety of operational options, which in turn reflect the complexity of manned diving. Each type of breathing system used has its own technique. Some, like open circuit SCUBA, are simple to use and maintain while at sea. Others, like semi-closed and closed circuit, are complex, and operationally difficult. For example, some closed circuit systems require a full-time technician to support their use in open-sea operations.

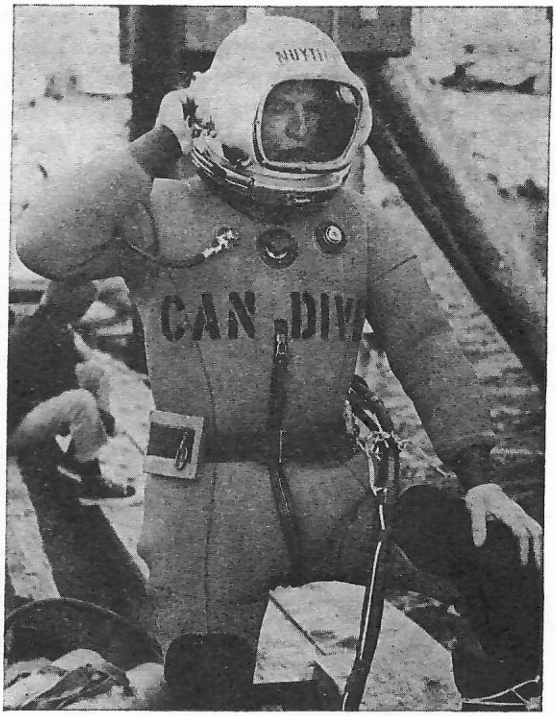

FIG. 3.1. A commercial diver checking out his helmet and suit prior to the dive

Thermal protection

Cold is probably both the most common and insidious of all the factors contributing to diving accidents. Attempts at thermal protection of the skin are as old as diving itself; but even the available diving dress of today has a definite time span of effective protection (Fig. 3.1). Beyond a certain period, cold begins to exert its rapidly debilitating and often unrecognized effects. The only readily available diving suit which offers an exception to this time limit is the open circuit hot water suit. This device provides an endless source of heat energy in the form of hot water which continuously bathes the skin of the diver. All the diving suits described require maintenance, but fortunately the techniques of their open-sea use are usually quite simple.

Recent investigations confirm the need to provide supplementary heat to the respiratory system of the diver when oxygen–helium is breathed at depths in excess of 200 m (22 ATA). Since these findings hold true for temperate waters, similar protection will also be necessary for shorter and shallower dives in polar waters. Several devices are under development to solve this problem and prototypes of both active and passive breathing gas heaters have been successfully used operationally in both deep and arctic seas.

Support platforms

There are many varieties of surface and underwater platforms used to support open-sea diving (Table 3.2). Surface platforms are critically important because their operation directly influences the use of whatever manned diving system is on board. For example, the techniques of mechanically operating a diving bell are quite different on an ad hoc rescue vessel, than on a semi-submersible drilling rig. However, the procedures used to support physiological requirements are usually the same. Underwater platforms range from a simple two-man diving stage to complex manned stations or lock-out submersibles. Each underwater platform has its own technique of employment. However, many of the life-support and mechanical subsystems are similar.

TABLE 3.2

Open-sea diving platforms—operational alternatives

	Description	*Operational examples*	*Primary users*	*Approximate number in use*	*Maximum depth (m)*
Surface					
Monohull	Conventional surface ship	Offshore supply boat	All groups	Many hundreds	
Catamaran	Twin hull vessel	USN–ASR's 21 and 22	Military	3	
'SPAR'	Long submerged columns with centre of gravity below centre of buoyancy	FLIP	Scientific	3	
'SWATH'	Small water plane area twin hull platforms which are semi-submerged on station	Semi-submersible oil drilling rig	Oil explorations companies	225	
Underwater					
Stage	Open two-man platform which is lowered to work site	USN deep dive stage	Military		100
Diving bell	Closed two-man pressure chamber which is lowered to work site	ADS–IV MK–4 Seachore	Commercial	200	330
Lock-out submersible	Twin-chambered small submarine. Forward chamber carries pilot and observer. Aft chamber similar to a diving bell	Deep diver Shelf diver SDL–I Johnson (Sea-Link) (VOL–I)	Scientific	6	300
Manned station	Large semi-permanent sea-floor dwelling maintained at ambient pressure. Usually life-support tethered to surface	SEATOPIA Helgoland	Scientific	10	200
Manned workshop	Small semi-portable sea-floor structure maintained at ambient pressure. Surface tethered	SUBIGLOO	Scientific	4	10
Welding chamber	Portable structure placed over pipelines for welding	Submerged pipeline repair system (SPRS)	Commercial	10	150

Diving bells

Tethered diving chambers, or diving bells, originated in the 1930s with the invention of the Davis submersible decompression chamber in Great Britain. Although this chamber and its several international counterparts had a transfer-under-pressure capability, they were normally used to pick up divers who had reached the work

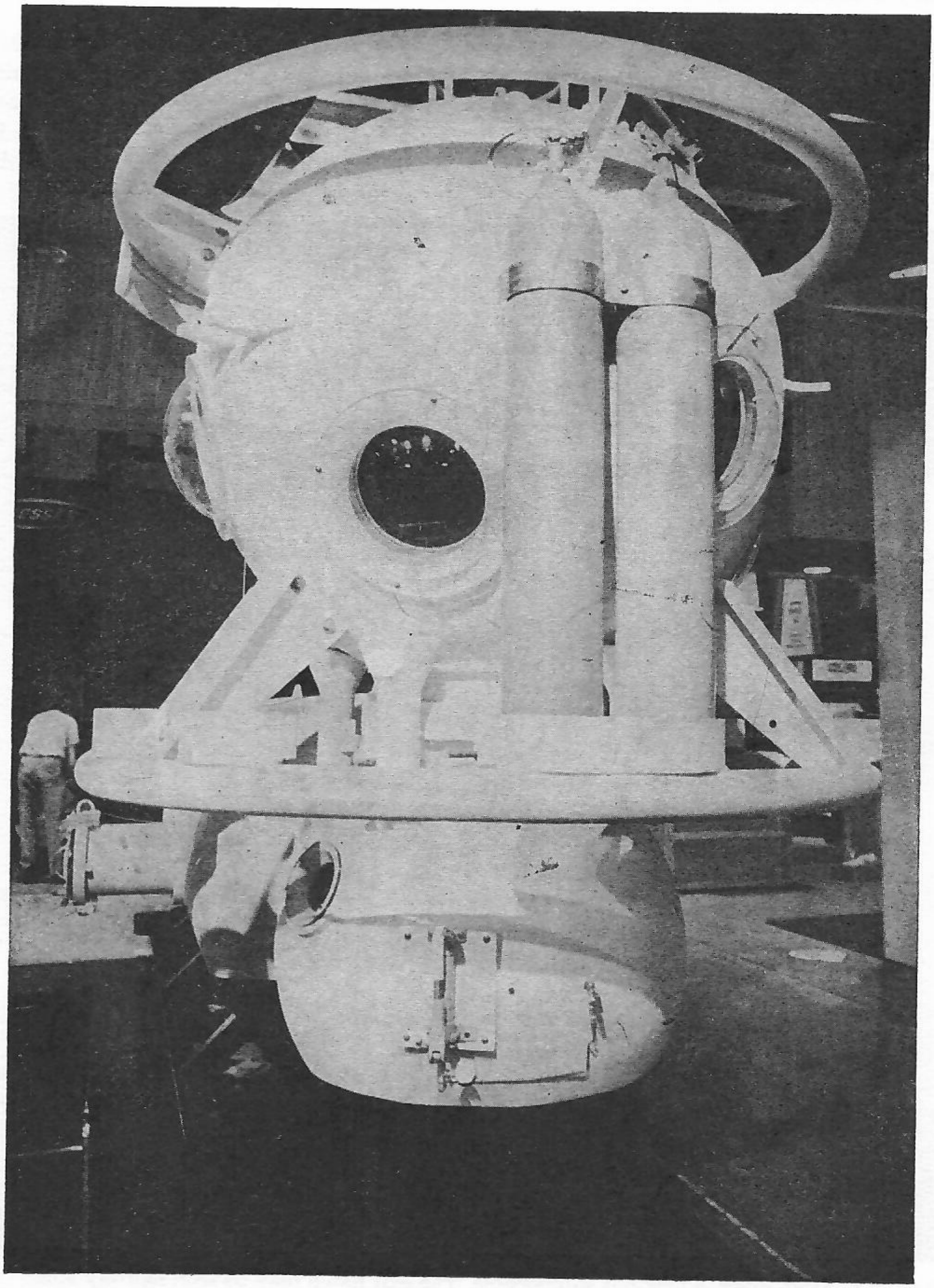

Fig. 3.2. 950 ft diving bell for 950 ft system, resting on deck chamber

site by conventional means. Current bell systems with internal and external pressure integrity began their most recent phase of evolution with Edwin Link's 1960 invention. His submersible decompression chamber was constructed of aluminum and was used for the first open-sea saturation dive in 1962. Since then, diving bell design has considerably advanced, and several hundred of these systems are currently operational. Most diving bells are used by commercial companies, and almost all are mated with deck-mounted decompression chambers for the decompression phase of the dive (Fig. 3.2). In 1972 the US Navy conducted the deepest open-sea dive to date, 1010 ft (31·5 ATA) using their DDS (Deep Diving System) MK II system.

Submersibles

Lock-out submersibles are three-dimensional extensions of diving bell capability. Instead of being tethered, the submersible and its lock-out chamber carries its divers directly to any location.

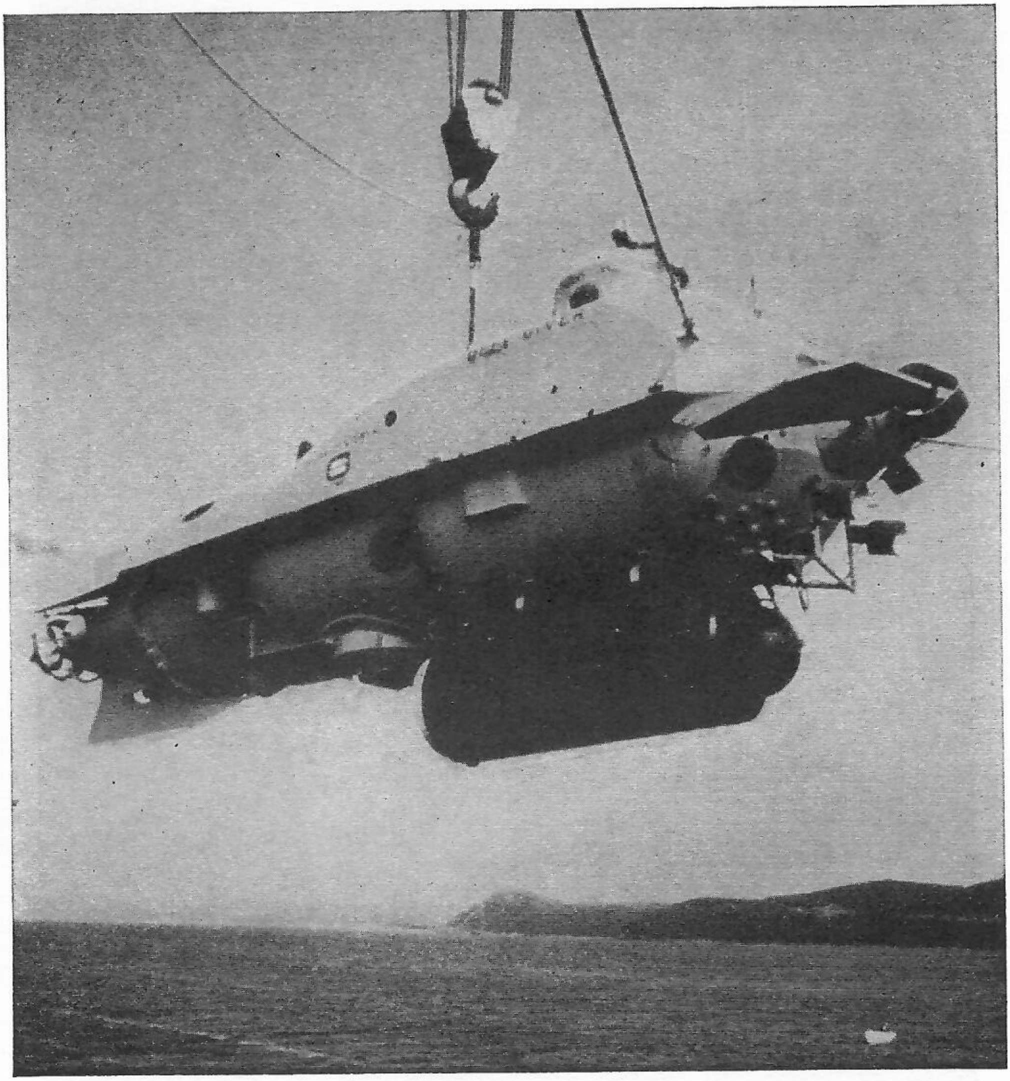

Fig. 3.3. Deep diver, a lock-out submersible. The exit hatch may be seen halfway along the underside

At the work site, the submersible is negatively ballasted, and the divers pressurize and control their chamber by techniques similar to those required to operate a diving bell (Fig. 3.3).

Two basic disadvantages of a diving bell are that its surface supporting platform requires a semi-permanent anchorage, and the bell itself is strictly limited to vertical dives. Attempts to provide tethered bell systems with propulsive motors have resulted in only a limited degree of horizontal movement and a high entanglement potential. Lock-out submersibles avoid the surface vessel anchoring requirement, and permit horizontal as well as vertical excursions. For these and other reasons, it appears that these types of submersibles, even with their current limitations on payload and gas storage capability, will be increasingly used in future deep diving operations.

Underwater stations

Since Cousteau's Conshelf I habitat, almost 50 manned underwater stations and workshops have been built and utilized. Due to high operating costs these systems are normally operated on a periodic basis and a number are presently stored and inactive. Table 3.3 shows the small number of manned stations that were operated in 1972–73. The most frequently used was Hydrolab which saw almost continuous occupation beneath Bahamian waters during 1972 (Fig. 3.4). The first nitrogen–oxygen saturation excursion dives were carried out to 180 ft (6·5 ATA) from La Chalupa during its 1973 operations off the coast of Puerto Rico.

Underwater workshops

Manned underwater workshops are smaller seafloor structures that are not designed for overnight accommodation. Their normal function is to provide a base for the storage, refuge, and communication elements of shallow dives. They are most frequently used by small teams of scientist divers studying and working at a specific site. Manned workshops are particularly useful in shallow polar seas where ice cover is a serious operational hazard. They extend the effective bottom-time and increase the safety of such open-sea dives.

Support equipment

The greatest variety of operational possibilities is found in the work-support equipment and

TABLE 3.3
Operational underwater stations: 1972–1973

Name	*Country*	*Owner*	*Operational depth (m)*	*Atmosphere*	*Crew*
Hydrolab	US Bahamas	Bahamas Undersea Research Foundation	13	Air	3
Chernomor	USSR	USSR	15	O_2He	4
Edalhab	USA	University of New Hampshire	15	Air	3
Sadko	USSR	USSR	25	O_2He	6
Kraken	UK	UK	30	O_2N_2	2
Seatopia	Japan	Marine Science Centre	100	O_2He	10
SDM Two	UK	UK	6	Air	2
La Chalupa	USA	Puerto Rico Marine Science	30	O_2N_2	4
Helgoland	W. Germany	Dräger	23	Air	5
		Operational underwater workshops			
Sublimnos	Canada	MacInnis Foundation	10	Air	2–4
Lora I	Canada	Memorial University	10	Air	3
Subigloo	Canada	MacInnis Foundation	10	Air	2–4
Lakelab	USA	University of Michigan	10	Air	2–3
Uriuh	USA	University of Rhode Island	10	Air	2

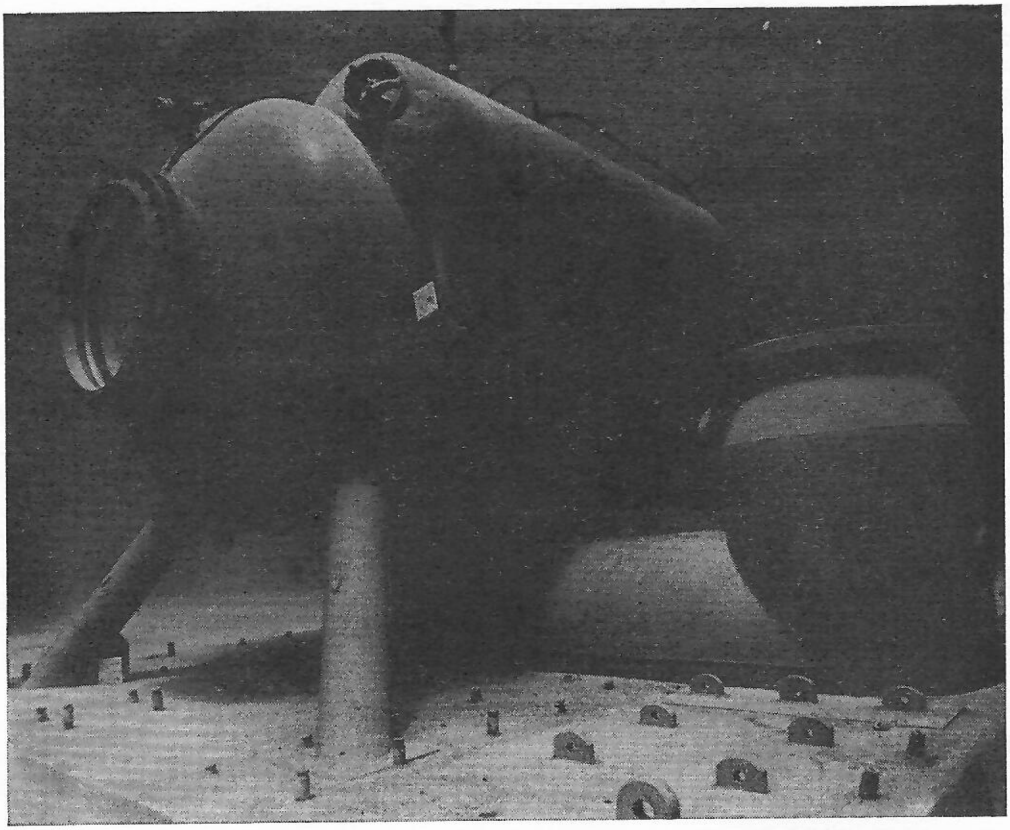

FIG. 3.4. The Hydrolab manned station in the waters off Freeport, Grand Bahama

systems outlined in Table 3.4. These range from simple hand tools to complicated propulsion vehicles. These technical devices are essentially non-life supporting, but strongly influence diver performance and safety. Consequently the technique of their use is an important component in dive management.

CHARACTERISTIC MODES OF OPEN-SEA DIVING

There are four generic types of mobile divers: military, industrial, scientific, and sport. The basic objective of the first three is work, while the primary aim of the sport diver is pleasure. There is constant overlap and interchange between all four types. One of the most impressive aspects of free-diving activity today is its growth in complexity and participation. Both these elements appear to be on a steady increase. On a world basis there are several thousand commercial, scientific, and military divers, and at least two million sport divers. Members of the former group make daily excursions to increasingly greater depths, use intricate systems, and breathe manifold and complicated gas mixtures. One vital key to their survival, success and performance effectiveness is the equipment they use. Even more important is the wide variety of open-sea diving techniques that they employ.

It is evident from the previous discussion that a great number of system and technique options are available to conduct free-diving activities. This, plus the continuously changing nature of the ocean, ensures that no two open-sea dives are identical. However, study of the four generic dive types reveals frequently repeated pressure–time profiles and recurring use of certain systems

TABLE 3.4
Work-support systems operational alternatives

Type of support	*Sub-type*	*Basic use*
Communication	Hand	SCUBA hand signals
	Wired intercom	Surface-to-diver
	Wireless	Diver-to-diver-to-surface
Navigation	Magnetic	Direction
	Acoustic	Target finding
Propulsion	One-man Two-man	Diver delivery systems for extending operational range
Work-tools	Hydraulic	Rotary power
	Compressed air	Impact tools
	Electric	Welding
	Manual	Multiple uses
Documentation	Visual	Inspection and action recording
	Audio	Voice recording

and techniques. Table 3.5 displays some of these essentially average features of typical open-sea dives.

Sport divers

The population of sport divers is over a million in North America alone and they carry out tens of thousands of dives each year. By far the most common breathing system is open circuit SCUBA delivering compressed air. A short jacket of neoprene is often used to ward off the chill of long or repeated dives even in tropic waters. Most sport diving descents are usually shallow, and last for less than half an hour since almost all sport divers attempt to avoid decompression stoppages. Work on the bottom is usually a light activity such as photography or spear fishing.

Scientific divers

Scientific divers are the most active group in the use of lock-out submersibles, and manned stations and workshops (see Fig. 3.4). However, all of the systems currently operational are only utilized on a periodic basis. For most of the year these devices are under repair, being modified, or being prepared for the next expedition.

Naval divers

Although naval divers constitute the largest single group of military divers, deep oxygen–helium diving is rare and is restricted to critical search, salvage and rescue tasks. For example, in spite of the fact that the US Navy has three diving bell systems, normal manned operations are confined to depths less than 100 m (11 ATA). Heavy equipment and the traditional diving stage are used for depths down to this level for some tasks; self-contained free-swimming is necessary for other tasks.

Commercial divers

Most commercial divers work in water depths less than 30 m (4 ATA). The vast majority carry out construction and repair work during exposures of about 40 min. Most breathe surface supplied air, although SCUBA is commonly used for some tasks. A typical deep dive for commercial work is outlined in Table 3.5. Such an exposure normally involves the use of a diving bell and surface decompression chamber, and is usually conducted from an offshore supply vessel or oil drilling rig.

TABLE 3.5

Some basic features of typical open-sea dives

Generic type	*Breathing gas*	*Breathing system*	*Thermal protection*	*Typical depth/time (m/min)*	*Approximate decompression time (minutes)*	*Usual support platforms*	*Comments*
Commercial	Air	Tethered Open circuit demand	Neoprene wet suit	20/30	60	Vessel Surface chamber	Usually construction, repair, or well-head maintenance
	Oxygen–helium	Tethered Open circuit demand or semi-closed circuit	Variable volume dry suit	70/30	150	Vessel Diving bell Surface chamber	Diving bells, normally used for well-head operations
Military	Air	Tethered Open circuit demand	Neoprene wet suit	15/30	40	Vessel Surface chamber	Ship repair or search and salvage
	Oxygen	Closed circuit: constant flow or demand	Neoprene wet suit or dry suit	6/90	None	Vessel	Mine clearance
	Oxygen–helium	Tethered Open circuit demand or semi-closed circuit	Variable volume dry suit	60/30	120	Vessel Stage Surface chamber	Diving bell is used only occasionally
Scientific	Air	SCUBA Open circuit demand	Neoprene wet suit	15/30	30	Small boat	Observations, photography or sample collection
Sport	Air	SCUBA Open circuit demand	Neoprene wet suit	15/20	Usually none	Small boat	Observations, photography or spear fishing

TECHNIQUE SELECTION

The most important first step in any open-sea dive is careful definition and planning of the mission. The basic elements of this decision process are: water depth, nature of the work, and the time estimated to complete the work.

Water depth is the critical factor which determines the type of breathing gas and its delivery system. If oxygen–helium is used, further consideration is then given to the use of a support system such as a diving bell. The water temperature at depth forces the choice of thermal protection, while the nature of the work to be performed dictates the use of a specific work-support system. The estimated time required to complete the task is often the most important of the three basic decision elements. It influences the kind of decompression, the support system required and the total technique approach. It is important to recognize that an operational dive can vary from a simple breath-hold swim from a sea-floor station to a diving bell, or can be a deep multi-week pipeline repair task.

Field supervisors have long recognized that the ideal technical solution to an undersea task almost never exists. Even if all decision elements point to a specific set of systems and techniques, the work is usually completed using the personnel and equipment on hand. Ocean remoteness and weather factors always impose severe constraints on time, money, and system availability. In the past this has led to the unwritten principle of open-sea compromise: 'the job gets done with what's available'. Obviously this approach to dive management can reduce safety and is not to be recommended. Fortunately it is an axiom rapidly receding from the foreground of free-diving operations today.

Once there is a systems and subsystems decision, a new planning stream begins and careful consideration is given to system alternatives, and operational time requirements. The latter is divided into periods of mobilization, dive operations, demobilization, and possible contingencies.

Every successful ocean dive depends upon the skills and experience of the operating personnel. Early attention must therefore be given to the number of men required, their qualifications and responsibilities, and their physical and mental condition. Diving accident studies show that the latter factor is the one most often ignored, and that fatigue is its commonest element.

SAFETY TECHNIQUES

Theoretically all the techniques used in open-sea diving support safety. However, some are more obvious and specific than others, and will be described in this section.

One essential safety step, taken well in advance of any dive, is the engineering certification of the system to be used. In the case of diving chambers this can be as formal as adherence to American Bureau of Shipping or other Standards. With less critical equipment such as diving suits it can be as informal as knowing that a reliable manufacturer's product has been used successfully many times under identical circumstances.

There must be similar confidence in the quality of the dive methods and procedures. For example, no working dive should be carried out unless there has been extensive laboratory verification of the decompression schedules. However, at present there is a growing problem of standards for open-sea diving procedures. Although men can agree on engineering criteria for diving systems, they cannot agree on the appropriate methods of use. Much of the problem stems from industrial competition and resultant proprietary information. However, it is a situation which cannot be tolerated for long.

In complex dives the personnel are divided into a surface support team and a dive team. However, for most sport and scientific dives no such division takes place, and frequently all functions are carried out by the same men. This is another situation which contains the seeds of its own destruction.

Each diving system or subsystem has its specific mode of operation. The complete collection, known as standard operating procedures, is functionally shared by the surface and dive teams. For example, the surface team operates the life-support systems of a deck decompression chamber, but the divers operate the same systems in the diving bell. The same division of labour should occur when emergency procedures are initiated.

However, there is often the problem that the resolution of serious accidents requires co-ordinated actions that are poorly understood and rarely practised. Commitment to the pre-dive check list is an essential safety element as is a critical status evaluation of ocean and weather factors, system and procedure readiness, and personnel fitness and condition.

One of the most neglected aspects of open-sea diving is accident management and prevention. A recent survey of active participants in all four generic groups confirms that insufficient time is spent in anticipation, study and rehearsal of possible accidents. Repeated success can lead to carelessness and over-confidence; two characteristics of many diving accidents. It is an obvious truism that diving accidents are too frequent. Most deaths occur in the sport group and are related to the large number of participants and their inexperience with the exacting laws of the sea. However, each of the other groups has had its own share of fatal accidents which unfortunately tend to attract local and even international headlines. Many deep diving accidents could probably be avoided if there is adequate preparation for system or personnel failure and adequate real-time information about physiological and environmental conditions available to the surface team.

The most frequent, and often only channel of information, from the diver to the surface, is voice communication. Divers are usually quiet when working in the water and their respiratory rate and depth can be heard distinctly. The alert surface crew recognizes each diver's normal breathing profile, and voice pattern, and urges caution when they change significantly. Diver monitoring systems are able to provide much post-dive physiological information. It is unfortunate that these instruments are rarely used in open-sea dives and most are in various stages of development or are used only for special scientific missions. However, the NASA life-support rationale is equally applicable to man-in-sea. Thus each participant in a deep or prolonged dive should have vital sign information relayed to a competent interpreter on the surface support team; although before this goal is attained more reliable and economic monitors will have to be developed.

There has now been sufficient experience with various deep diving systems to allow the evolution of certain operational stratagems. These are learned supporting actions which the operators have discovered to make the system or technique run more smoothly or safely. Some are known to be essential, such as diver physical fitness and helium conversion. Others are thought to be helpful, such as audio-visual distractions, e.g. television, during long decompressions.

Each diver inevitably assembles a portfolio of skills to bring into play within the dive profile. These skills are his personal adaptation to the specific work and pressure environment. Included among these skills are techniques of ear clearing, descent through water, and wordless anticipation of buddy needs. This type of activity must rest on firm practical ground or serious problems can occur. In the early days of helium–oxygen use, many commercial dives modified the USN decompression schedules on an ad hoc basis. Many were successful; others were not.

Open-sea diving technology has expanded rapidly in the past two decades. Previously there was a significant time lag between an invention and widespread user adaptation. For example, it took 10 years, and the development of the wet suit, before the aqualung became popular in the mid-1950s. Today, an advance such as the open circuit hot water suit is in production within months of its invention. Manned underwater activities are expanding rapidly. There is a continuous search for new technological solutions.

There still remain many unexplored relationships between man and the under-ocean environment. One of the most important of these is the combination of drugs and diving. Use of 'consciousness-expanding' drugs now involves more than a small number of divers. While general incompatibility is certain, little is known about the acute or chronic effects as they relate to diving. However, there is the certainty that neither cigarette smoking, nor the taking of cannabis and harder drugs, improves diver performance and safety.

Trends indicate an increasing number of open-sea diving systems and techniques being employed in the future. World factors will assure that more scientific and military divers take to the water. Recreational diving is certain to increase as more leisure time is available. The result will be deeper and colder dives as the search for energy expands into polar seas. More diving systems will be needed to support the 600 mobile drilling rigs expected by 1980. Lock-out submersibles and manned stations will also increase as basic and applied marine science activities expand.

The next two decades will see a growing need for improved techniques and consolidation of the information which is extended from the laboratory through simulation and open-sea trials. This is the only way to ensure safe and effective open-sea work.

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