E. *Environmental Equipment*

With increased knowledge of the underwater environment, man has endeavored to accomplish more work and more detailed scientific research for longer periods of time. This has resulted in an ever-increasing demand and supply of support equipment, such as swimmer vehicles, manned and unmanned submersibles, and habitats which allow man to actually live on the sea floor. When a diver is supported by additional equipment, many of the burdens imposed by the underwater environment are alleviated. For example, the diver is no longer required to carry all the tools he might need. Long, heavy umbilical or gas-supply cylinders may be eliminated by a gas storage system carried on support equipment. A power source, though sometimes quite limited, may aid in lighting, supplying heat to the diver, and providing power for his tools. Communication is simpler with an on-the-site support subsystem than with the surface, and the diver can be provided a place for resting, protected from extreme cold and hostile marine life.

Obviously, the type of work being done, whether it is pipeline inspection, salvage, or experimental research, determines the type of support equipment desired and, many times, several different types of support equipment are used as subsystems to an entire complex system. Actual design of this support equipment has not been well coordinated with the main goal of developing a piece of equipment that will accomplish a particular task. Insufficient attention has been paid to diver safety in many instances. At the other extreme, some equipment has been designed around diver safety, with the result that the equipment is only marginally useful to the diver because his task requirements were not extensively considered. In the future, engineers, scientists, and divers will have to work together in order to develop the ultimate in underwater support equipment that not only will help the diver to perform the particular task necessary, but will also allow for the greatest diver safety and provide the diver with the most comfortable surroundings and support possible. Safety considerations as regards the various types of environmental conditions are discussed in Chapter VIII. Here we are principally concerned with design and function.

Although design and development of each type of support equipment have been extremely varied, there are basic underlying principles. An attempt is made in this section to explain these and to give specific examples of actual hardware in use.

The three basic types of working equipment for underwater tasks are diving systems, habitats, and submersibles. Where a platform or surface ship is available, and the task is localized, the diving system is the ideal choice. With the development of saturation-diving techniques, the habitat is becoming more frequently used as a base for scientific operations, since it permits a more continuous and flexible approach to the research project. When a large area is to be covered, the requirement is better met by the submersible, either manned or unmanned, lockout or 1 atm, depending on the nature of the task (Baume 1972).

1. *Diving Systems*

The term *diving system* is used very broadly to cover many different systems used for diving. In general, it implies the use of three basic components:

1. *A surface ship* or platform serves as a support center.
2. *A deck decompression chamber* (DDC), easily monitored, large and comfortable enough for several divers, is located on board the surface ship or platform.
3. *A transfer chamber*, which can be either a personnel transfer capsule (PTC) or a submersible decompression chamber (SDC), transports divers between surface and underwater work site and can be mated to the DDC.

These basic components can be used in a wide variety of different combinations, depending upon the task to be performed.

Diving systems may be divided into two general types. The first is the advanced diving system (ADS), which was developed commercially and is also used by the U. S. Navy. The basic unit is the SDC, a tethered pressure chamber which provides divers a warm, dry environment while they are transported between the surface ship or platform and the underwater work site. It also provides an underwater refuge for the diver and serves as a dry, warm decompression area. This greatly reduces the time a diver must spend in an uncomfortable, alien environment.

The second type of diving system is the deep-diving system (DDS) developed by the U. S. Navy. This type of system was designed to provide the capability of making observation dives, bounce dives, or long-term saturation dives. The basic unit of the DDS is the PTC. This capsule is a type of submersible decompression chamber, permitting dry decompression under water, and can also be used to transfer personnel under pressure. This provides the capability of using saturation-diving techniques. This capability differentiates it from an SDC. Although an SDC can be used for saturation-diving techniques, the chamber is usually too small to be comfortable for more than short-term decompressions. When used for saturation diving, the PTC is used to transfer personnel from the surface ship to the underwater work area while maintaining the pressure to which they are saturated. In this type of diving the DDC then becomes the surface habitat for the divers, in which they sleep and eat. The PTC can also be used as an observation chamber and in this case it is maintained at 1 atm of pressure.

a. Advanced Diving System

The ADS II was the first of its type developed. The SDC for this system has two chambers, which allows an observer to remain at 1 atm in the upper chamber, while the lower chamber can be pressurized to ambient underwater pressure. On descent both chambers remain at 1 atm and, once at the work site, the lower chamber is pressurized. One diver then exits from the bottom hatch using an umbilical from the SDC to provide breathing gas and communications. A second diver remains in the SDC to monitor the umbilical and is available for emergency assistance. This type of chamber is extremely useful in that an engineer can be present right at the work site to supervise the work and it also gives the working diver more flexibility and safety than he would have diving with a long, vertical umbilical from a surface support. When the work is completed, the diver reenters the lower chamber and decompression begins immediately. The chamber can then be removed from the water and decompression continues with the SDC aboard ship.

The ADS III utilizes the same type of SDC but also incorporates a deck decompression chamber, which can be mated to the lower chamber of the SDC. This allows for a second crew of divers to be transported to the work site while the first crew is decompressing in the DDC. The ADS III can also work with an underwater habitation, which can be used as a dry working area or a dry refuge at the work site. Figure IX-24 shows a diagrammatic sketch of the ADS III.

The ADS IV incorporates a single-chamber SDC, which can be mated to the deck compression chamber. It can be used both as a submersible decompression chamber or it can be lowered at 1 atm of pressure for observation tasks. The advantage of this system over the others is that it is of smaller size and weight and has a much less complicated support system.

b. Deep Diving Systems

The U. S. Navy used the ADS IV (now termed the SDS-450) for its deep diving operations up until the development of their own Mark I Deep Dive System. Although the SDS-450 has been used for deep saturation diving, the chamber is so small that it is unsuitable for long decompressions. The Mark I deep diving system was designed to meet the following specifications of the Navy (Milwee 1970):

1. A diving capability for work to depths of 850 ft.
2. A diving capability for observation dives at 1 atm pressure, bounce dives of short-term nonsaturation, and long-term saturation dives.
3. Air transportability for rapid deployment.
4. The capability to use a variety of surface support ships or platforms, the most frequently used of which is the ARS class salvage ship.

The actual diving system has a mode of operation similar to that described under advanced diving systems. However, two decompression chambers are available for use, so that two diving crews can be decompressed simultaneously, even if the decompression times are not the same. An entry lock connects the two DDC's and is the transfer area between the DDC and the PTC. The PTC will accommodate three men. Each DDC will accommodate two men comfortably but can accommodate three. The deck decompression chambers are equipped with sleeping bunks, shower, sanitation facilities, and a complete life-support system. The PTC has a special cable carrying power, communications, and instrumentation wiring. The gas supply for the PTC is surface supplied, but it also carries its own on-board emergency gas supply. Umbilicals used by divers for excursions from the PTC are located inside the chamber. A diagrammatic sketch of the Mark I Deep Dive System is shown in Figure IX-25 (Milwee 1970).

The Mark II Deep Dive System was designed to provide a depth capability of 1000 ft for eight divers to make either conventional dives or saturation dives for periods up to 14 days. It is quite similar in principle to the Mark I DDS but the Mark II system incorporates two PTC's, two main-control consoles (MCC), and two DDC's. The Mark II Deep Dive System is capable of operating in six modes, each with a different type of control requirement (Hall 1973):

1. Saturation diving.
2. Hydrostatic diving with the PTC maintained at 1 atm.

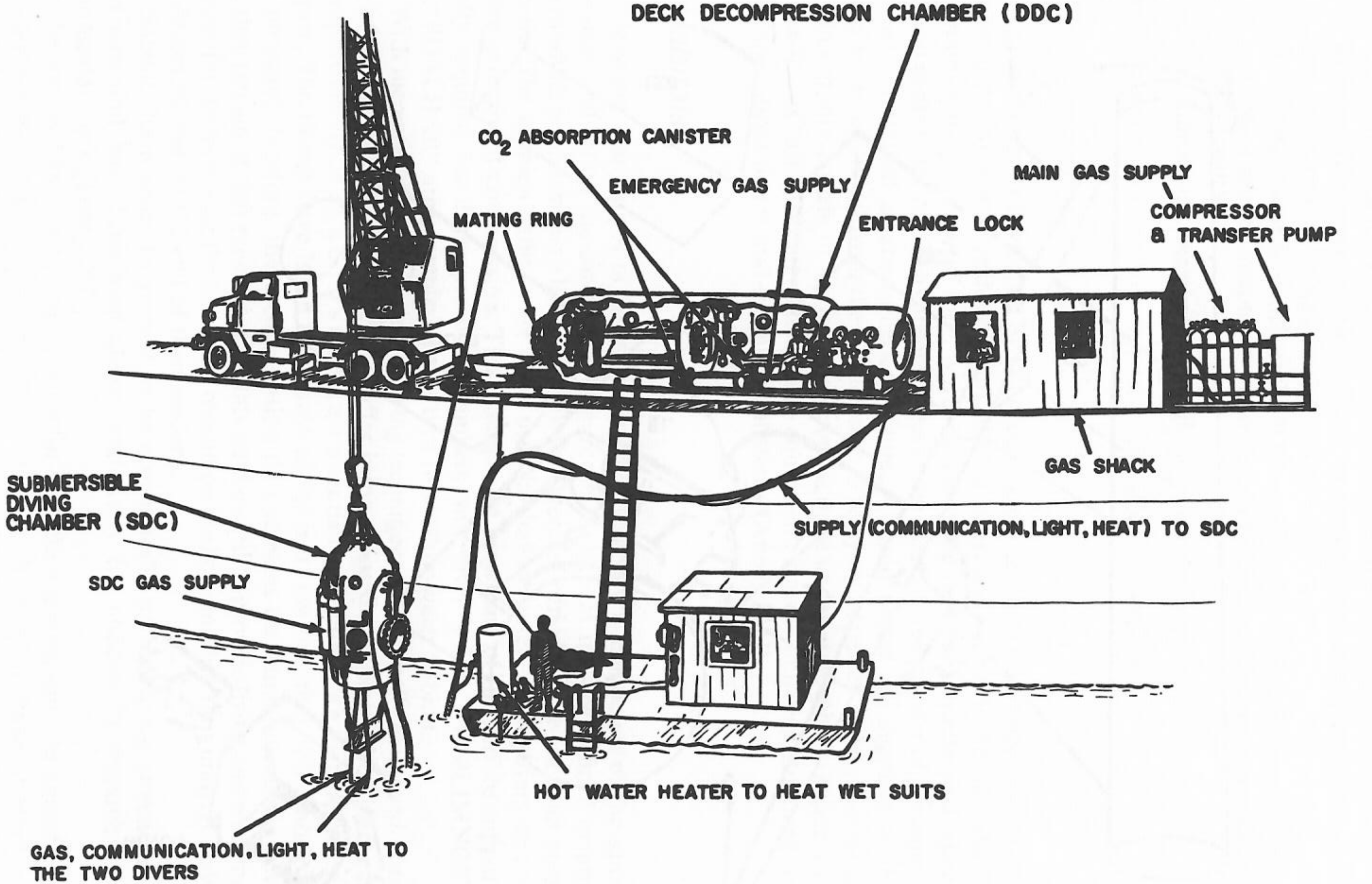

Figure IX-24. ADS III shown here includes deck decompression chamber with which the submersible chamber can mate through a special fitting. Divers can then decompress in safety and comfort ashore. [From Kowal (1967) by permission from *Sea Frontiers*.]

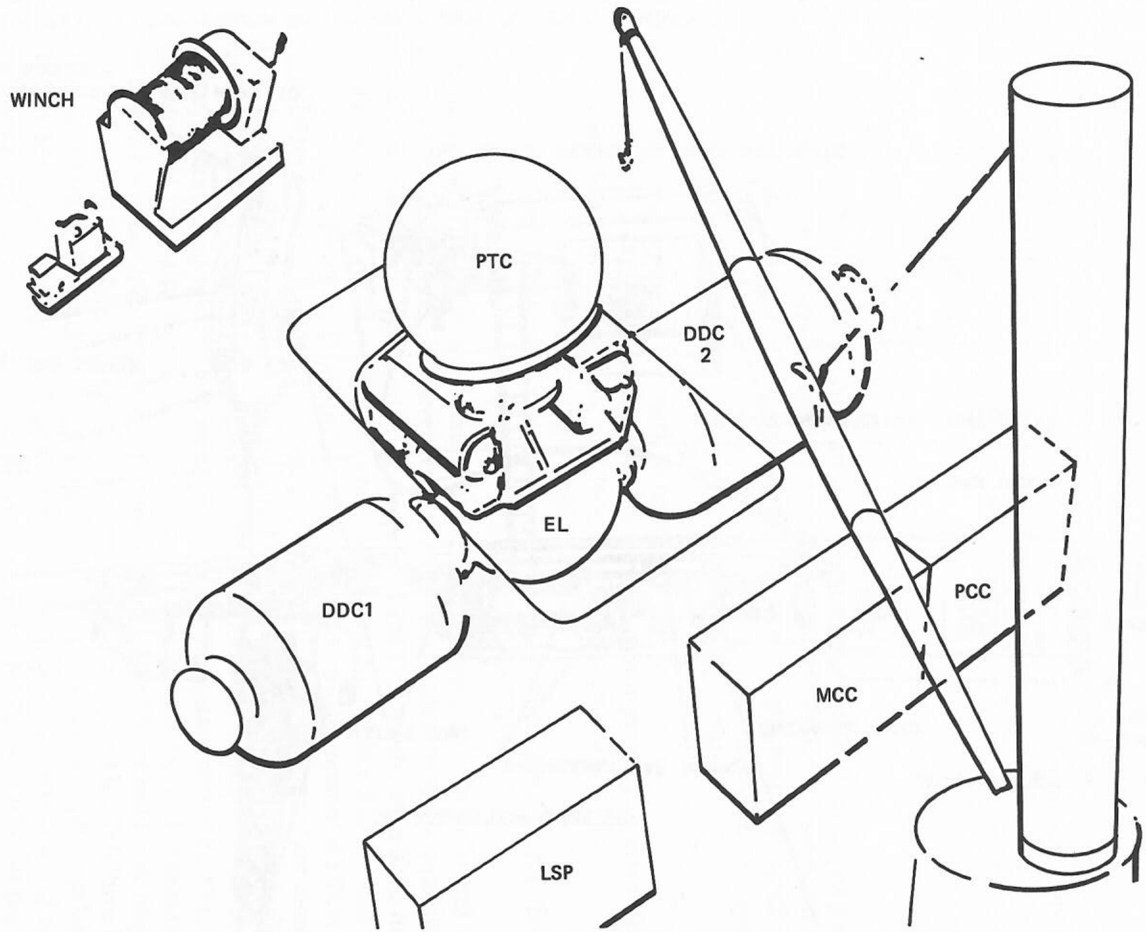

Figure IX-25. Mark I deep dive system. [From Milwee (1970) by permission of the Marine Technology Society, Washington, D. C.]

3. Air diving with the PTC pressurized from surface-supplied air hoses.
4. Routine diver support with the DDC being used as an emergency decompression chamber if a diving casualty should occur.
5. Submarine rescue in which each DDC could accommodate 34 men at 5 atm and with a mating adapter to allow mating to the Deep Submergence Rescue Vehicle (DSRV).
6. Decompression, whereby saturated divers are decompressed at 1 atm.

This diving system was used in support of the SEALAB Project.

c. The 1-atm Work System

A system recently developed by Lockheed for the Shell Oil Company consists of a chamber installed over a wellhead, marked by a buoy, and a service capsule capable of accommodating a crew of four, which contains the necessary operational equipment and control devices. The capsule mates to the chamber for transfer of personnel; both are maintained at atmospheric pressure. Air and power are supplied to the capsule by an umbilical from the surface ship. The system appears to be economical and efficient, due largely to the fact that work is done under atmospheric pressure in dry conditions, using ordinary tools and equipment, thus eliminating the need for highly specialized divers and supply installations (Anon. 1973).

2. *Habitats*

There are many types of habitats, but each basically is composed of the same subsystem and serves the same general purpose. A habitat may be defined as any system which permits men to live and work for extended periods in the sea at ambient pressure. The simplest habitats are those used in shallow water, where divers do not require extensive decompression. This eliminates a large part of the surface support usually required for decompression chambers and diver safety. "SUBLIMNOS" and "EDALHAB" are examples of this type of shallow-water habitat.

With increased depth, saturation diving techniques are normally employed. This type of diving is based on the fact that after being exposed to a pressurized inert gas for approximately 24 hr, a diver's tissues are essentially saturated with that gas at that pressure. The tissues have taken up almost all the inert gas that they will absorb at that pressure; therefore, the decompression time remains the same, no matter how long they remain at that pressure. Habitats can be used to provide living and working quarters for divers during the time they remain on the bottom; they then undergo only one decompression at the end of their sojourn.

Habitats have generally proven to be economically unfeasible for commercial operations and have been used almost exclusively for underwater research and experimental work (Tenny 1971).

The total habitat system, particularly for saturation diving, must be considered as a complex made up of a surface support ship or shore-based center, a sea-floor habitat/living area, and a transfer device such as a PTC to transport personnel and supplies between the habitat and the surface ship. A habitat contains its own

Table IX-26
Classification of Underwater Habitats[a]

Program or habitat name	Weight	Dimensions	Ballast	Operations	Crew	Depth, m	Duration	Atmosphere	Mode of supply		Comments
									Power	Gas	
ADELAIDE (Australia)	—	—	—	1967–68	—	—	—	—	Pontoon, barge	—	—
AEGIR (Habitat II) (USA)	200 t	$L = 2 \times 4.6$ m, $D = 2.8$ m, Ball $D = 3$ m, Total $L = 15.2$ m	—	Hawaii, 1969	4–6	147	14 days	Variable	Ship	Autonomous	Can ascend and descend by completely internal control
AQUATAT I	—	—	—	—	—	—	—	—	—	—	—
AQUATAT II (USA)	—	—	—	—	3–5	—	—	—	—	—	Six viewports 1.8 m² viewing area (shallow water)
BACCHUS	—	—	—	—	—	—	—	—	—	—	—
BAH I (Germany)	—	$L = 6$ m, $D = 2$ m	—	Baltic Sea, Sept. 1968	2	10	11 days	Air	Ship	Ship	—
				Ost Sea, June 1970	2	10	14 days, 2–5 mo	—	—	—	—
CARIBE I (Cuba)	—	$L = 3$ m, D = 15 m	—	1966	2	15	3 days	—	Ship	Partly autonomous	—
CHERNOMOR I (USSR)	—	$L = 8$ m, $D = 3$ m	—	Gelendehuk, Black Sea	4	5 14	30 days	—	—	—	—
CHERNOMOR II (USSR)	70 t	—	—	Design	4	25, 35	4 weeks	—	—	—	—
EDALHAB (USA)	—	$L = 3.7$ m, $D = 2.4$ m	5.5 t	Alton Bay, New Hamps.	4	7.6	36 h	Air	Land	Land	—
GLAUCUS (UK)	—	—	—	1965	—	9	1 week	—	—	—	—
HEAVY DUTY SEA BED VEHICLE (UK)	—	$L = 12$ m, $W = 7$ m $H = 4.2$ m	—	Design	4+	180	5 days	—	Surface	—	—
HEBROS I (Bulgaria)	—	$L = 5.5$ m, $D = 2$ m	—	Bay of Warna, July 1967	2	10	—	—	—	—	—
HEBROS II (Bulgaria)	—	$L = 6.7$ m, $D = 2.5$ m	—	Cape Maslenos, 1968	2	30	10 days	—	Surface	—	Effective volume of 30 m³; depth can be controlled autonomously by crew (about 64 t)
HELGOLAND (Germany)	75 t	$L = 9.0$ m, $D = 2.5$ m $H = 6$ m	—	North Sea, July 1969	4	23	10 days	Air	Buoy	—	Capable of depths to 100 m; numerous occupations since 1966
HYDROLAB	—	$L = 4.9$ m, $D = 2.4$ m	40 t	July 1966 continuous to 1970	—	12	—	—	—	—	Transfer from submersible at either ambient or atmospheric pressure possible
ICHTHYANDER 66 (Idctiandr) (Ikhtiandr) (USSR)	600 kg	$L = 22$ m, $W = 1.6$ m $H = 2$ m	—	Crimean Coast, Black Sea, August 1966	1–2	11	7 days	Air	Land	—	Single-chambered lab, 6.8 m³, four viewports
ICHTHYANDER 67	4.5 t	$W = 8.6$ m $H = 7.0$ m	27 t	Crimean Coast, Black Sea, August 1967	2–5	12	2 weeks each	Air	Surface	—	Three chambers

ICHTHYANDER 68	—	—	—	Crimean Coast, Black Sea, Sept. 1968	Several crews	20	8 days total	—	Land	—	15 m^3 displacement
ICHTHYANDER 69	—	—	—	Design	—	20	—	—	—	—	—
KARNOLA (Czechoslovakia)	—	—	—	1968	5	8–15	—	—	—	—	—
KITJESCH (USSR)	—	L = 5.6 m, D = 2.6 m	—	Crimean Coast, Summer 1968	4	15	—	—	Shore	—	Volume = 30 m^3, three chambers (converted railway tank car)
KOCKELBOCKEL (Netherlands)	—	D = 1.9 m, H = 4.6 m	9.5 t	Sloterplas 1867	2–4	15	Short period	Air		Autonomous	—
KRAKEN (UK)	—	L = 2.6 m, W = 1 m, H = 2.3 m	—	Firth of Lorne, Oban Argyle, Scotland	2	30	Several weeks	7% O_2, 93% N_2	—	—	Proposed; two compartments
MALTHER I (East Germany)	14 t	L = 4.2 m, D = 1.8 m, H = 3.5 m	(1.4 m^3 of iron) 11 mp	Malther Dam, Nov.–Dec. 1968	2	8	2 days	Air	Land	Autonomous	Volume = 10 m^3
MAN-IN-SEA I	1.9 t	L = 3.2 m, D = 0.9 m	—	Villefranche, Mediterranean, Sept. 1962	1	61	1 day	3% O_2, 97% He	—	Ship	Aluminum cylinder
MAN-IN-SEA II (SPID) (USA)	—	L = 2.4 m, D = 1.2 m	—	Great Stirrup Cay, Bahamas, June 1964	2	142	2 days	4% O_2, 96% He	—	Ship	Flexible rubber tent (submersible, portable, inflatable dwelling)
MEDUSA I (Poland)	3 t	L = 2.2 m	—	Lake Klodno, July 1967	2	24	3 days	37% O_2, 63% N_2	—	Land	—
MEDUSA II (Poland)	—	L = 3.6 m, W = 2.2 m, H = 1.8 m, total H = 2.5	—	Baltic Sea, July 1968	3 3	30 26	14 days 7 days	Air	—	Ship	Autonomous operation up to 50 hr
MINITAT (USA)	4.5 t	H = 3.5 m, D = 2.4 m	—	Design	2	50	—	—	—	—	Four view ports
OKTOPUS (USSR)	—	—	—	Crimean Coast, Black Sea, July 1967	3	10	Several	Air	—	—	—
PERMON II (Czechoslovakia)	—	L = 2 m, W = 2 m	—	Split, Yugoslavia, Adriatic Sea, July 1966	2	3	Discont.	—	—	Autonomous	Displacement 5 m^3; discontinued; decompression within habitat possible
PERMON III	1.5 t	—	5 t	Czech. Lake March 1967	2	10	4 days	—	Land	Autonomous	—
PRECONTINENT I (CONSHELF I) (France)	—	L = 5.2 m, D = 2.5 m	—	Marseille, Mediterranean, Sept. 1962	2	10	1 week	Air	—	—	—
PRECONTINENT II (CONSHELF II) (France)	—	—	—	Shaab-Rumi Reef, Red Sea, July 1963	5 2	11 27	30 days 1 week	Air 5% O_2, 20% N_2, 75% He	Ship	—	—
PRECONTINENT III (CONSHELF III) (France)	130 t	L = 14 m, sphere D = 7.5 m, H = 8 m	70 t	France, Mediterranean, Sept 1965	6	100	22 days	1.9–2.3% O_2, 1% N_2, balance He	Surface	Autonomous	—

Table IX-26—*Cont.*

Program or habitat name	Weight	Dimensions	Ballast	Operations	Crew	Depth, m	Duration	Atmosphere	Mode of supply: Power	Mode of supply: Gas	Comments
ROBIN II (Italy)	—	—	—	Genoa, Mediterranean, March 1969	1	17	7 days	—	—	—	Light, permeable plastic hull
ROBINSUB I (Italy)	—	$L = 2.5$ m, $W = 1.5$ m $H = 2$ m	—	Ustica Is., Mediterranean, July 1968	1	10	—	Air	Land	—	Wire cage, plastic tent, volume 5 m^3
ROMANIA LSI (Romania)	—	—	—	Bicaz Lake 1968	2	—	—	—	Ship	—	—
SADKO I (USSR)	—	Sphere $D = 3$ m	8.5 t	Caucasian Coast, Black Sea, Oct. 1966	2 2 2	45 40 25	6 days 6 hr 1 month	—	(Capable of volume 14 m^3 ship or land)		—
SADKO II (USSR)	—	Twin spheres, $D = 3$ m	21 t	Caucasian Coast, Black Sea, Summer 1967	2	25 (50–60)	6 days	—	Land ship	Autonomous	Buoyancy 12 t
SADKO III (USSR)	—	—	—	Zukhumy Bay, Black Sea	6	25	6 days	—	—	—	—
SD-M 1 (UK)	—	$L = 2.7$ m, $W = 1.5$ m, $H = 2.1$ m	—	Malta, Mediterranean	—	9.1	—	Air	Autonomous	Resupply tanks from surface	Discontinued
SD-M/2 (UK)	—	—	—	Malta, Mediterranean	1–2	6.1	10 man-days	Air	Autonomous	Resupply tanks from surface	—
SEALAB I (USA)	—	$L = 12.2$ m, $D = 2.7$ m, $H = 4.5$ m	—	Argus Is., Bermudas, July 1964	4	59	11 days	4% O_2, 17% N_2, 79% He	Ship	—	Double chamber
SEALAB II (USA)	200 t	$L = 17.4$ m, $D = 3.7$ m	—	LaJolla, Calif. Pacific Ocean	28	60	10 days	4% O_2	Ship	Autonomous	Three teams, ten days each plus one man, 29 days
SEALAB III (USA)	—	—	—	—	5–12	183	—	2% O_2, 6% N_2, 92% He	—	—	Suspended
SUBLIMNOS (Canada)	—	$H = 2.7$ m, $D = 2.4$ m	9 t	Little Dunks Bay, Tobermory, L. Ontario installed June 1969 to date	2–4	10	Up to 24 hr	Air	Land	—	Designed for "day-long" occupation—overnight accommodations feasible for short periods
TEKTITE I (USA)	—	Twin cylinders, $H = 5.5$ m, $D = 3.8$ m	79 t	Lameshur Bay, U. S. Virgin Is. 1969	4	12.7	59 days	—	Ship	—	—
TEKTITE II (USA)	—	Twin cylinders, $H = 5.5$ m, $D = 3.8$ m	79 t	Lameshur Bay, April–Nov. 1970	10–5	12.7	14–21 days	—	Land	—	—

[a] From Parrish *et al.* (1972) by permission of IPC Science and Technology Press.

life-support system, food preparation area, sanitation facilities, and waste disposal system. It can be mobile or stationary, but is seldom self-propelled and must be towed by the surface ship. Life-support gas can be supplied to the habitat either from its own high-pressure cylinders or from the surface ship via an umbilical. Likewise, power may be derived from a source at the habitat or from a power supply line from the surface ship (Garnett and Achurch 1969).

A tabulated list of design features of habitats is presented in Table IX-26. Since each habitat is a unique system, reference should be made to a report on a particular habitat for detailed system analysis.

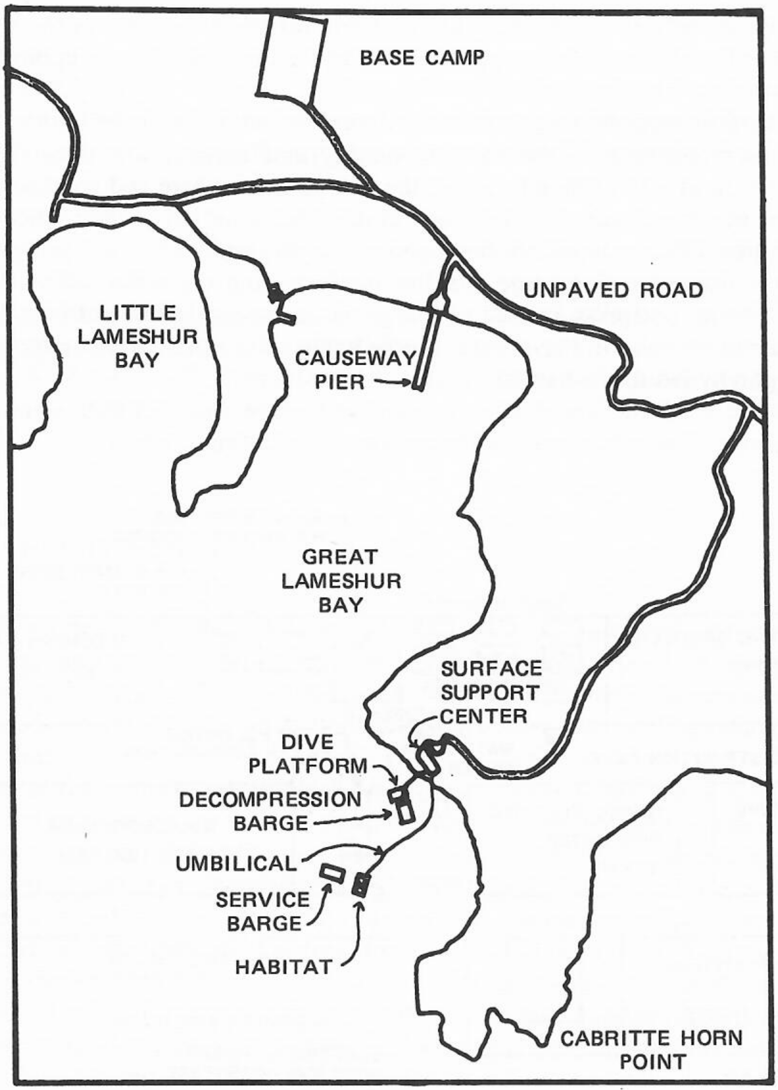

Figure IX-26. TEKTITE II operational site at St. John, U. S. Virgin Islands (Miller *et al.* 1971).

Although each habitat has different characteristics and design features, TEKTITE II is a good representative system. The operational facilities of TEKTITE II consisted of a base camp, a causeway pier, a shore-based surface-support center, a dive platform, a towable decompression barge, a service barge, and an underwater habitat. These are shown in Figure IX-26 at the operational site.

The base camp served as the principal accommodation facility for support personnel. It consisted of 13 tropical huts, which served various purposes, such as kitchen-dining area, office-dispensary, toilet and shower facilities. Power was supplied by electricity from the local power company with diesel generators as a backup system.

The causeway pier extended about 270 ft into the bay and served as the principal landing site for shuttle boats, supply vessels, and other small boats supporting the program.

The surface-support center contained the command van and the utilities trailer. Continuous monitoring of the habitat, visually and aurally, was done from the command van, as well as monitoring of the habitat atmosphere and trunkway water level. The command van also provided communications equipment. The utilities trailer (Figure IX-27) contained diesel generators to supply electrical power to the habitat, the decompression barge, the dive platform, and the command van. It also contained the air compressors used to charge the scuba equipment and to supply the makeup air to the habitat. Fresh water for the habitat was stored at the support center and was gravity-fed to the habitat via the umbilical bundle.

The dive platform served as an equipment storage area and a duty station for support divers. It also had a scuba-charging compressor and air bank.

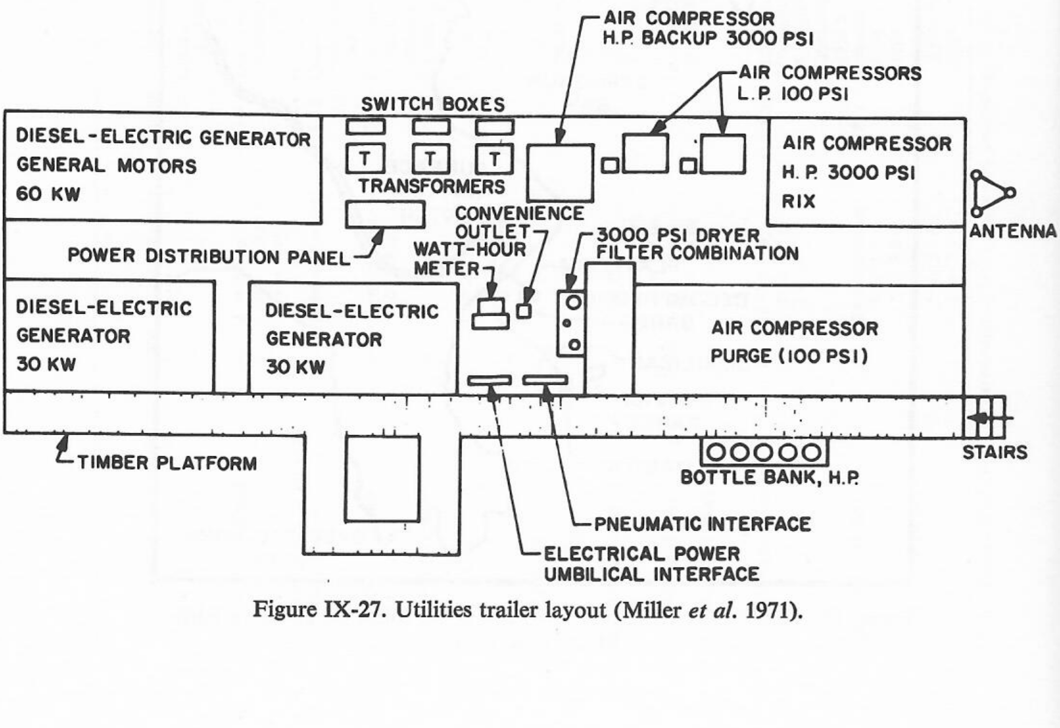

Figure IX-27. Utilities trailer layout (Miller *et al.* 1971).

The decompression barge was the primary decompression facility, mounted on a pontoon catamaran to make it towable. The decompression complex consisted of the decompression control console, a deck decompression chamber, and a personnel-transfer capsule. The decompression console contained gas-monitoring equipment, temperature probes, valves and gauges to control the pressure in the personnel-transfer chamber and the deck decompression chamber, as well as the master communications unit for the chambers. The deck decompression chamber was a double-lock chamber with a 5-ft entry lock and a 12-ft main chamber. Four bunks were available in the main chamber and a small pressure-flushing commode and fresh-water shower were located in the entry lock. The personnel-transfer capsule was a sphere, 66 in. in diameter, which could be mated to the main chamber of the DDC. A side double-door hatchway was used for mating and surface entry and a bottom double-door hatchway was used for diver lock-in and lock-out. An umbilical bundle contained compressed-air lines, communication cables, and gas-sampling lines. High-pressure bottles mounted on the exterior were available for on-board oxygen and air supply.

The service barge, 45 by 18 ft, served for equipment transport, work platform, and site evacuation. It was a staging site for transfer of material, equipment, and personnel to and from the habitat.

The underwater habitat was made up of two vertical cylinders, each divided into two compartments attached to a steel base. Diagrammatic layouts are shown in Figures IX-28 and IX-29. Two entry trunks were located at the base. One gave access to the open ingress–egress wetroom hatchway, while the other gave access to the normally closed emergency hatch located beneath the crew quarters.

3. *Swimmer Vehicles*

Many types of swimmer vehicles, towing-type or self-powered, are available to aid the free-swimming scuba diver. Towed vehicles, which depend on a surface ship for propulsion, are usually of simple design with some degree of directional control. Their use is limited by drag restrictions imposed on the diver and by reliance on the surface craft.

One of the simplest towed vehicles is the aquaplane—a board which, when tilted downward or sideways, provides a dynamic thrust to counter the corresponding pull on the towing cable. The addition of a broom handle seat and proper balancing of the towing points permit one-handed control of flight path. With this device, a diver may be towed at speeds of 2 or 3 knots by a rubber boat, the maximum speed being limited by the hydrodynamic forces that tend to tear off the diver's mask. There are several modifications of this basic design available, which incorporate improved controls and a face shield in order to increase maneuverability and pilot comfort. Aberdeen Marine Laboratory has developed the "MOBEL," which has excellent maneuverability, and the Russians are reported to have a complex towed submersible, the "ARLANT I BATHYPLANE," now being used in trawl net observations.

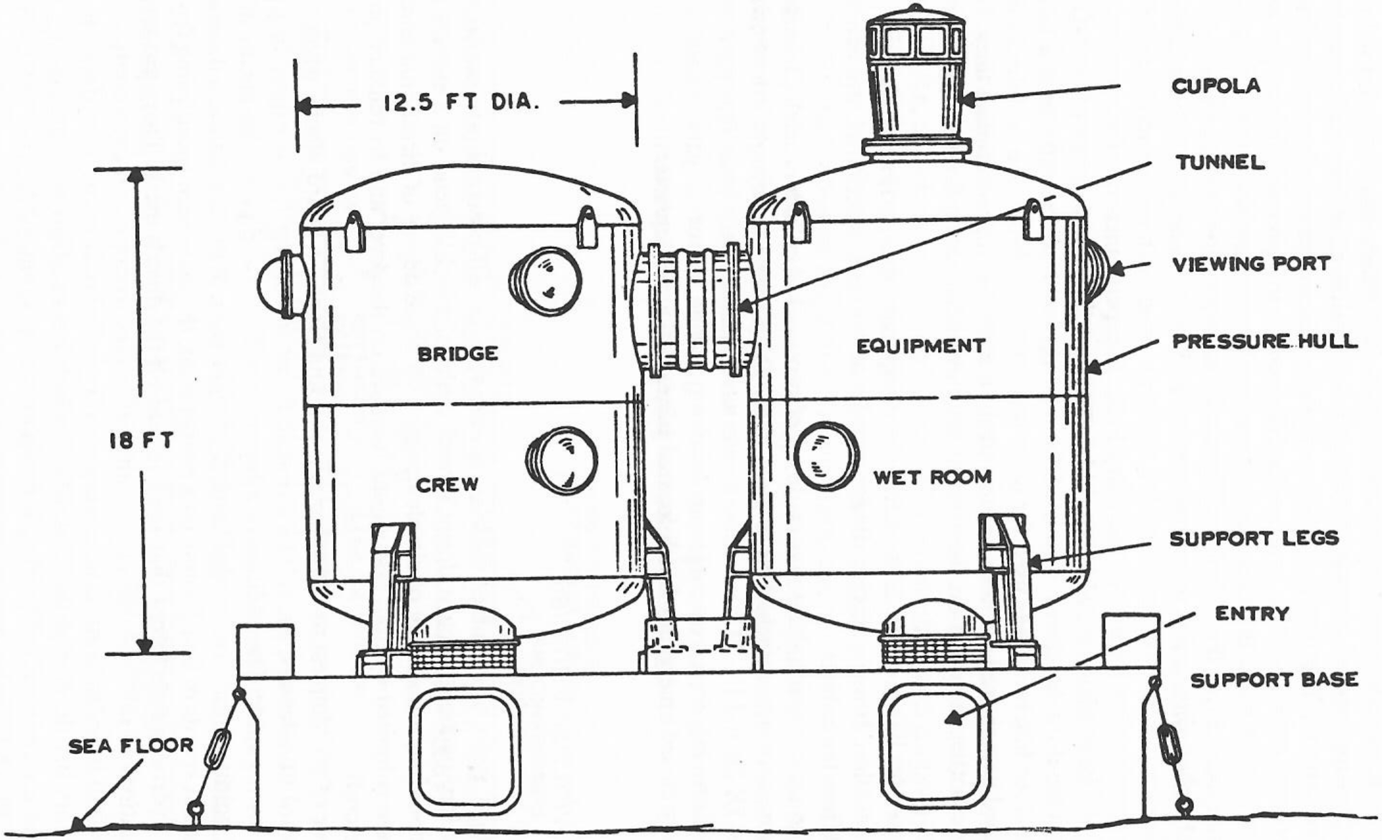

Figure IX-28. Side view of the TEKTITE II habitat (Miller *et al.* 1971).

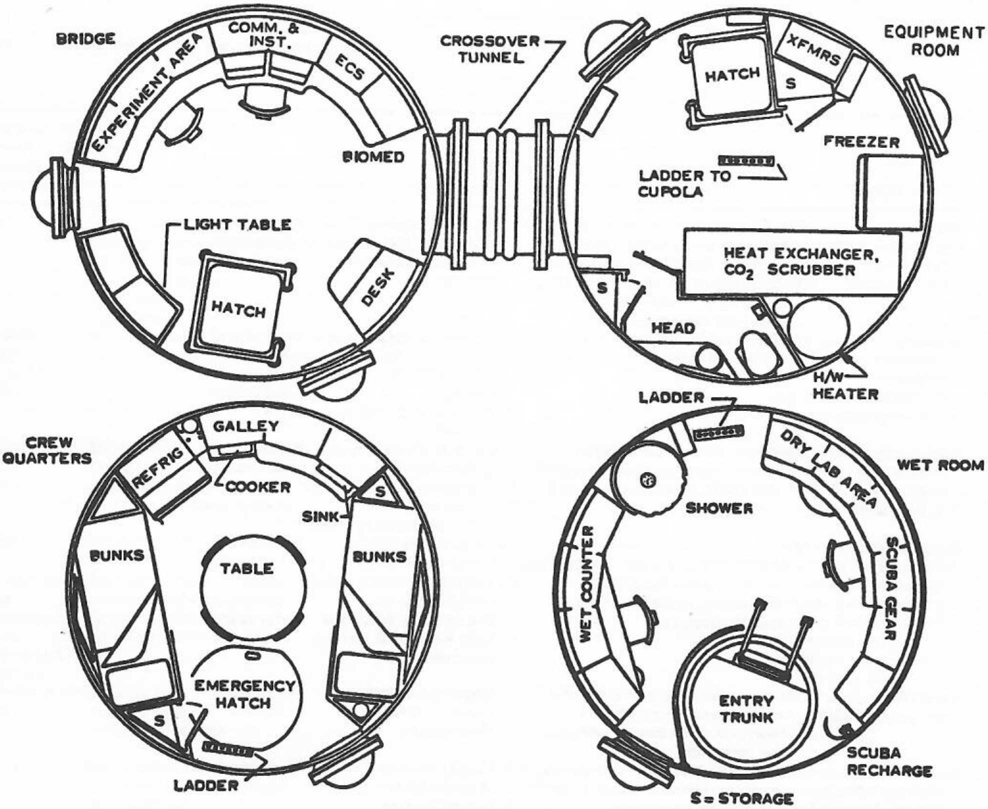

Figure IX-29. Plan views of the habitat compartments (Miller *et al.* 1971).

Even more helpful are self-powered craft. These generally provide some degree of shielding for the diver so that faster speeds may be attained. There is some confusion of terminology in this type of equipment, as indeed there is in the entire field of environmental and working equipment. Two terms frequently used are swimmer delivery vehicle (SDV) and diver propulsion vehicle (DPV). The larger vehicles are sometimes referred to as wet submersibles.

One example of a craft with its own electric propulsion unit is the "PEGASUS." Self-powered devices offer maneuverability to the diver free from a surface support vehicle and are equipped with comprehensive navigational equipment, but the costly batteries used in these vehicles make them too expensive for most research purposes (Woods and Lythgoe 1971). A complete coverage of the variable designs and configurations is beyond the scope of this chapter; however, the following three types are illustrative.

1. The *ECOR*-1 from East Coast Oceanic Research Inc. (Anon. 1972*a*) is a two-man unit, operated by a $1\frac{1}{2}$ hp electric motor, capable of maintaining an underwater speed of 4 knots for $2\frac{1}{2}$ hr with a depth limit of 300 ft. The hull is constructed of polyester fiberglass.

Table
Comparison of Wet Submersibles
(Black and

Description	General function	Diver support functions	Propulsion system	Maximum submerged speed, knots	Operational time at maximum speed
Buoyancy transport vehicle—experimental	Designed to prove concept of free-swimming vehicle that provides forklift or yard crane functions at an underwater site; i.e., transport and position relatively large payloads	1. Transport and position payloads (on bottom) 2. Power tools (limited capability)	Vertical, horizontal, surface, hover	1.3	1 hr
Buoyancy transport vehicle—(projected data) prototype	Underwater forklift/yard crane; move and position relatively large payloads	1. Transport and accurately position large (multi-thousand pound) payloads 2. Provide hydraulic power for tools	Vertical and horizontal, surface and submerged	1.5	Unlimited on umbilical, 1 hr on batteries
Construction assistance vehicle—experimental	Designed as an experimental diver support platform equipped with tools, power sources, and cargo area	1. Carry tools and cargo underwater 2. Power tools 3. Transport divers 4. Stable bottom platform	Vertical, horizontal, surface, hover, turn-in-place	2.5	4 hr
Construction assistance vehicle prototype	Extension of experimental model to include interchangeable work modules for drilling, excavating, cable installation, stabilization, etc.	Same as above plus: 5. Crawl on bottom 6. Translate through mild surf (3–4 ft) 7. Heavy work functions such as drilling, coring, excavating	Vertical, horizontal, surface, bottom crawl, dry land, surf zone	1–2	4 hr
Swimmer propulsion units	Designed for transportation of a single diver; commercially available units mostly designed for recreation	1. Transport divers 2. Visual survey or photography	Horizontal, surface	2–3	1–4 hr
Swimmer delivery vehicle; "Shark Hunter," commercial	Designed to transport two divers, tools, and limited cargo to and from underwater sites	1. Carry divers and tools to underwater work site 2. Survey bottom	Horizontal, surface	2–4	1–3 hr
Swimmer delivery vehicle	Several commercial models available; military models provide increased speed, endurance, cargo, and cost	—	—	—	—
Surface support platform	Ship or other moored platform with compressors, generators, etc., mounted on deck	1. Support working diver 2. Tools and lifting and positioning limited by sea state 3. Divers burdened by umbilicals	Surface and possibly a sled towed under water for survey	NA	NA

2. The *Farallon DPV MK-1* (Anon. 1971) combines a diver propulsion unit with a light source. It will operate to a depth of 300 ft while pulling one or more divers at a speed up to three times normal swimming speed. It is powered by two 12-V dc batteries.

3. The *CAV* or Construction Assistance Vehicle was developed for the Naval Civil Engineering Laboratory (Black and Elliott 1972). It can maintain a maximum speed of 2½ knots for 4 hr with a depth limit of 120 ft. The electrohydraulically powered craft is capable of delivering up to 1500 lb of wet-weight cargo.

A comparison of some of the wet submersibles for supporting scuba divers is presented in Table IX-27.

IX-27
for Supporting Scuba Divers
Elliott 1972)

Navigational capability	Maintainability	Payload capability	Tool power	Dry wt., lb	$L \times B \times H$, ft	Operating depth, ft	Comments
Visual	One technician full time (large part of effort is maintenance of surplus silver–zinc batteries)	1000 lb on cargo hook	6 gpm at 1800 psi (oil hydraulic)	1,800	8 × 6 × 6	850	Steering and depth control by propulsion; buoyancy control by dewatering sphere
Visual plus limited compass	Low man-hour requirements	3000 lb can be supplemented by modular buoyancy packages	10 gpm at 2000 psi	2,500	8 × 8 × 8	130	Steering and depth control by propulsion motors; automatic buoyancy or depth control system incorporated into design
Visual and limited compass	During operational period requires one skilled technician half time	1300 lb in 4 × 7-ft cargo bed or slung underneath	12 pgm at 1200 psi (oil hydraulic) 20 cfm pneumatic	18,630	26 × 9½ × 7½	130	Variable speed control; steering and depth control by propulsion; fabrication cost: $75,000
Visual compass; adaptable to future developments, such as transponders and pingers	Designed for compatibility with fleet, low maintenance: performed in the field by fleet personnel	2000 lb in cargo bed or lift	Total power to vehicle ~20–50 hp; power can be directed to diver tool (hydraulic)	10,000–15,000	—	Diver-limited	All specifications preliminary; derived for interpolation with performance of existing vehicle; both land and underwater final specifications will follow preliminary design
Usually direct visual	Relatively low maintenance because of simplicity of vehicle	None	None supplied	50–100	3 × 1 × 1	150	Primarily designed as a propulsion device; cost: $400 and up
Visual	Low maintenance because of simplicity of structure and components	Usually inside vehicle	None supplied	1,200–2,500	16 × 8 × 5	150–300	Step speed control; steering and depth controlled by planes and rudders; cost: $5,000–$500,000
—	—	100–300 lb; 5–10 ft³	—	—	—	—	—
Standard surface ship techniques	Standard ship maintenance; performed by regular diver	Ship lift capacity	Limited only by size of umbilical diver can carry	NA	NA	NA	Support of diver limited by safety factors relating to sea state and umbilicals

4. *Manned Submersibles*

A submersible is sometimes defined as an underwater diving vehicle that requires surface support; it is thus differentiated from a submarine, which is autonomous and requires no surface support. However, some of the larger submersibles are virtually autonomous, so that a better distinction might be the somewhat arbitrary one of differentiation by function. A large submersible vessel designed for military use is generally termed a submarine, and does not come within the scope of this handbook. Most submersibles could be defined as dry, 1-atm vehicles in which the pilot and observers are protected from the outside pressure by a pressure hull or cabin. The shape of the hull can be spherical, ellipsoidal, cylindrical, etc. The spherical design is