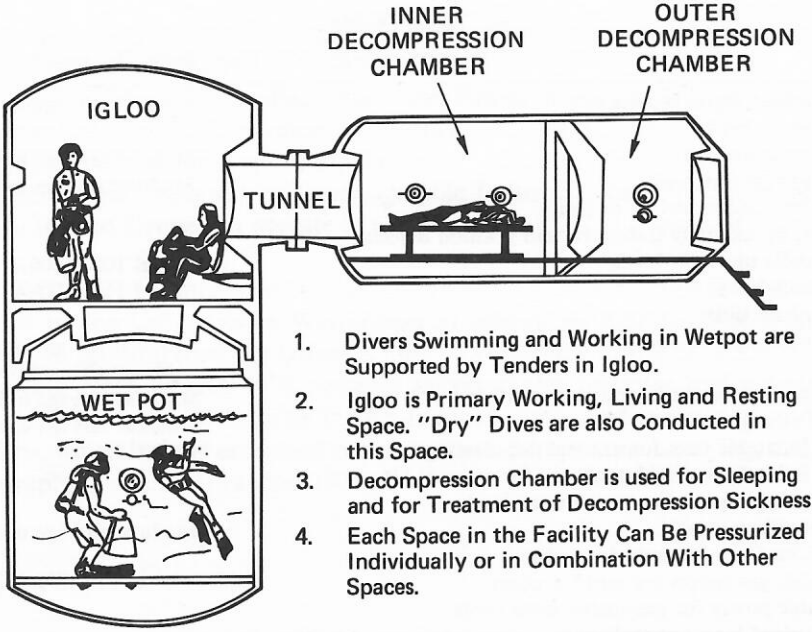

1. Divers Swimming and Working in Wetpot are Supported by Tenders in Igloo.
2. Igloo is Primary Working, Living and Resting Space. "Dry" Dives are also Conducted in this Space.
3. Decompression Chamber is used for Sleeping and for Treatment of Decompression Sickness.
4. Each Space in the Facility Can Be Pressurized Individually or in Combination With Other Spaces.

Figure IX-32. Typical experimental hyperbaric facility (Reimers and Hansen 1972).

b. Examples of Hyperbaric Chambers

(i) Navy Experimental Diving Unit. The facilities include two high-pressure chamber systems. Each system is composed of three basic units: a decompression chamber, connected to the outside of the unit by a safety chamber; an igloo, in which the diver prepares to descend; and a diving tank or "wet pot," which is 10 ft in height and approximately $9\frac{1}{2}$ ft in diameter, for simulation of deep-water excursions. The maximum working pressure of the complex is equivalent to 1000 ft of sea water (445 lb). A monitoring system is employed to measure total pressure, O_2 partial pressure, CO_2 partial pressure, temperature, and humidity. For dives deeper than 190 ft or for long-duration dives, a mixture of oxygen and helium is employed, with the oxygen content varying according to depth to prevent oxygen toxicity or anoxia. Figure IX-32 shows an artist's illustration of the facility (Reimers and Hansen 1972).

(ii) Navy Ocean-Pressure Simulation Facility. The mission of the facility is "simulation of ocean environments to a depth of 2250 ft to conduct research, develop tests, and evaluate systems involving man and/or machine with emphasis placed on the man–machine interface" (Mossbacher 1973). The high-pressure system consists of five dry chambers and one wet chamber, which is ellipsoidal, 15 ft in diameter, 15 ft high, and 30 ft long. It was designed to provide the capability to test most two- and three-man submersibles. The facility is located at the Naval Coastal Systems Laboratory at Panama City, Florida. A diagrammatic sketch of the high-pressure system is shown in Figure IX-33 and the specification are summarized in Table IX-31. Arrangement of the chambers and interconnecting lock permit use in several combinations. The dry chambers are designed as living and/or working space (Montgomery 1969).

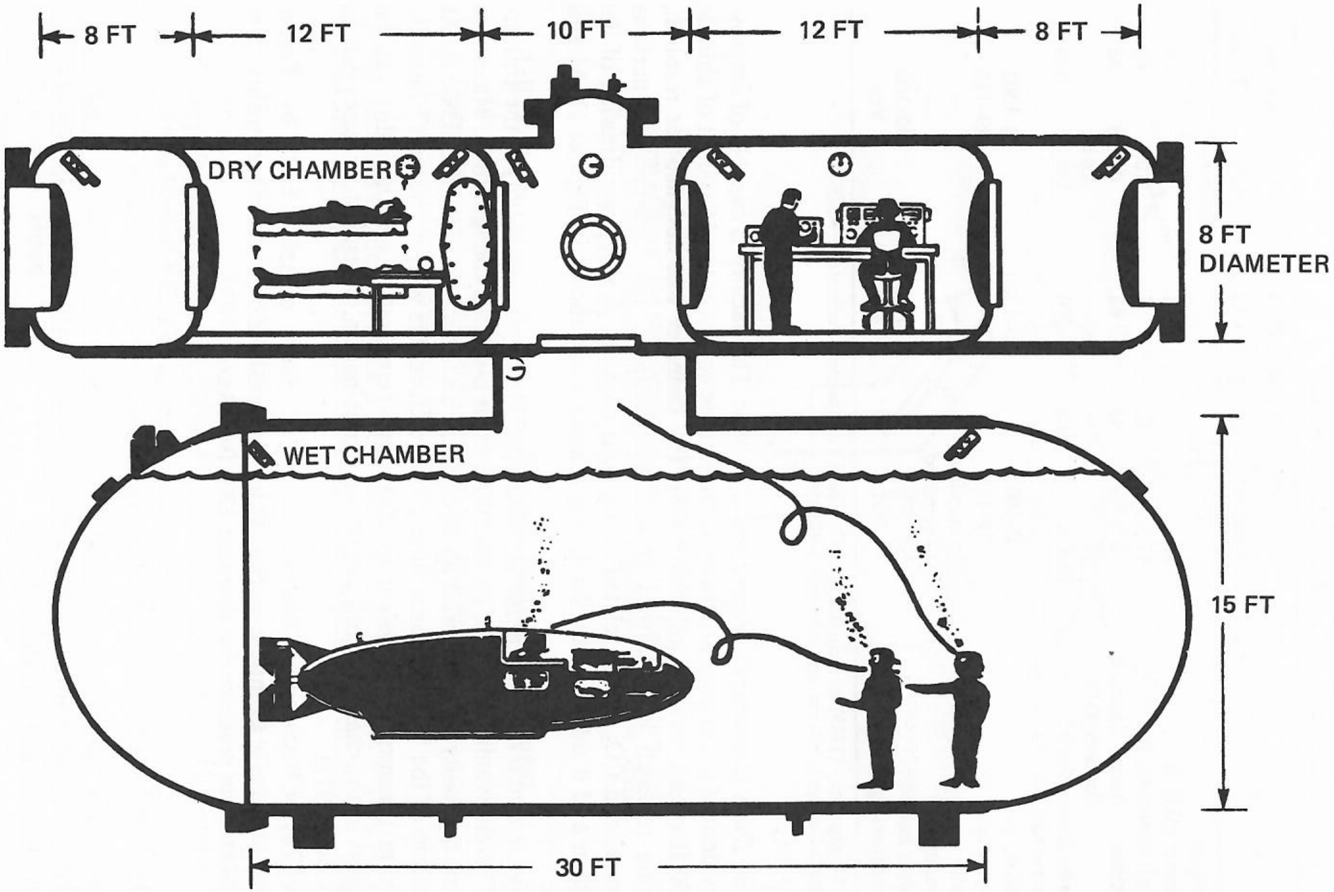

Figure IX-33. Diagram of the Navy's Ocean-Pressure Simulation Facility in Panama City, Florida. By interconnecting the OPSF to its $5 million hybrid computer complex, the Navy can simulate complete missions in real environments under laboratory conditions. [From Montgomery (1969) by permission of *Undersea Technology*.]

Table IX-31
Summary of Specifications for Navy Ocean-Pressure Simulation Facility[a]

	Wet chamber	Dry chambers		Center section	
		Main (2)	Locks (2)	Lock	Trunk
Dimensions					
Diameter (ID), ft	15	8	8	8	8
Length (internal), ft	47	12	8	10	6½
Diameter: Access doors, in.	48	42	42	42 (2)	48
Hatches, ft	15	—	—	48 in.	—
Volume (internal), ft³	7000	600	300	520	330
Environmental control ranges					
Pressure, psig	0–1000	0–1000		0–1000	
Temperature, °F	29–110	29–110		29–110	
Salinity	As required	—		—	
Turbidity	As required	—		—	
Relative humidity, %	—	10–100		10–100	
Atmospheric gas control[b]	Yes	Yes		Yes	

[a] From Montgomery (1969) by permission of Compass Publications, Arlington, Virginia.

[b] Mixtures of oxygen, helium, and nitrogen available.

(iii) Duke University's Hyperbaric Chamber. This facility is capable of employing any desired gas at pressures ranging from those equivalent to 150,000 ft of altitude to 1000 ft of sea water (Linderoth 1973). The chamber was designed for research, including research on acoustics speech modifications, the high-pressure nervous syndrome, and CO_2 effects related to inert-gas narcosis. A schematic drawing of the floor plan and a side view of the diving chambers are shown in Figures IX-34 and IX-35.

(iv) Institute for Environmental Medicine. The hyperbaric facility at the University of Pennsylvania consists of six chambers in an L-shaped configuration. Maximum pressure capability is 90 psi with an equivalent maximum altitude of 150,000 ft. At the bottom of the "L" are three high-pressure chambers with a "wet pot" beneath. Maximum pressure is equivalent to 2000 fsw. Temperature and humidity can be controlled in the chambers and almost any combination of respiratory gases can be used (Covey 1971).

(v) Taylor Hyperbaric Complex. A high-pressure complex built by Taylor Diving and Salvage Company of New Orleans consists of three chambers with a "wet pot." Maximum pressure can simulate 2200 fsw (Anon. 1970).

c. Current Research Facilities

Combined facilities for clinical medicine, biomedical research, and diving research are listed below. Those with "wet pot" facilities are marked with an asterisk (Penzias and Goodman 1973):

* Duke University, Durham, N. C.
Kantonsspital, Zurich, Switzerland

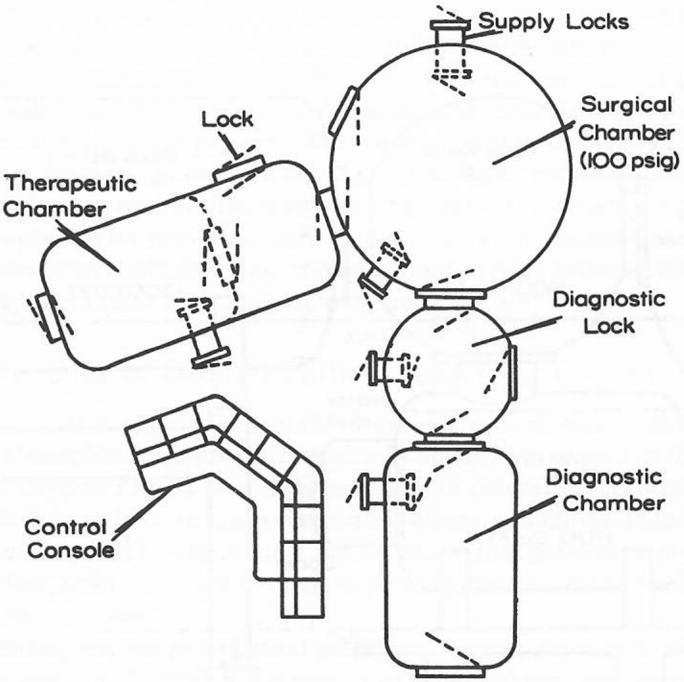

Figure IX-34. Plan view of the main chamber floor showing the arrangement of five of the chambers in an interconnected Vee formation. Scale, 1 in. = 10 ft. [From Linderoth (1973) by permission of the Marine Technology Society, Washington, D. C.]

* Karolinska Institut, Aviation & Nautical Medical Department
Ohio State University, Columbus, Ohio
* State University of New York at Buffalo, Buffalo, N. Y.
* University of Pennsylvania, Philadelphia, Pa.

Current facilities for development of equipment and procedures as well as for diving research and training can be found at the following locations (Penzias and Goodman 1973):

* Compagnie Maritime D'Expertise, Hyperbaric Research Center, Marseille, France
* Deep Trials Unit—Royal Naval Physiological Laboratory, Alverstoke, U. K.
* Defense Research Establishment, Toronto, Ontario, Canada
* Diving Medical and Technical Centers, Royal Netherlands Navy, Den Helder, The Netherlands
Diving Medical Research Laboratory, Japanese Maritime Self-Defense Force, Yokosuka, Japan
* Experimental Diving Unit, Panama City, Fla.
* Groupe d'Etudes et de Recherches Sous-Marines, Toulon, France
* Institute of Aviation Medicine (of D.V.L.R.) Bad Godesberg, West Germany

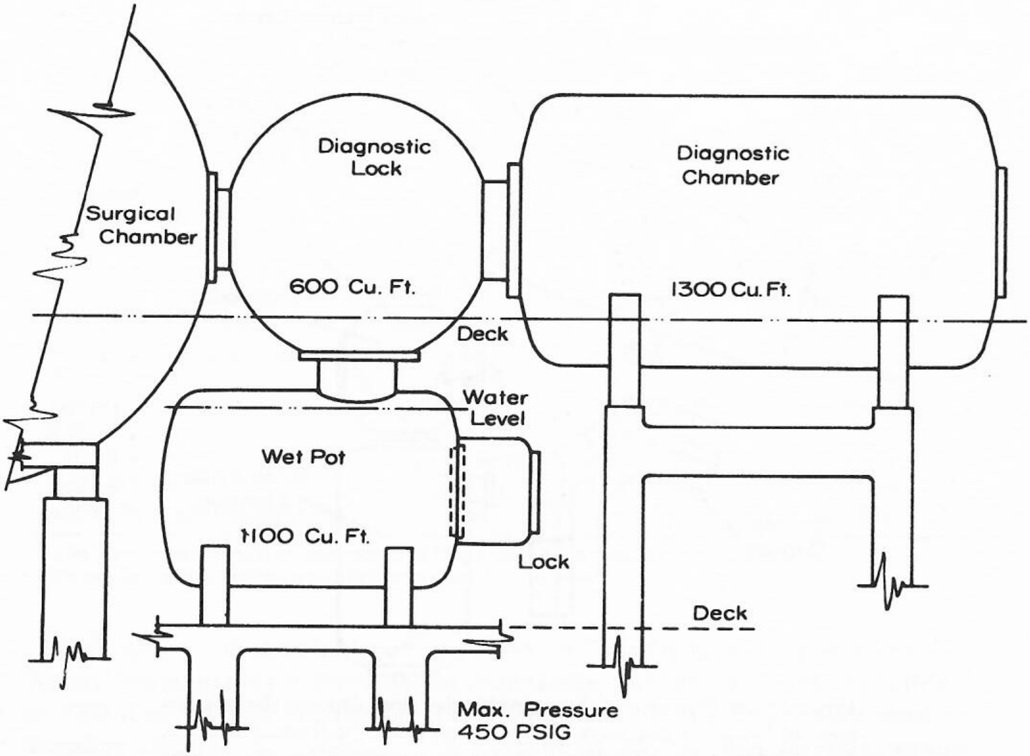

Figure IX-35. Side view of the diving chamber including the wet pot below the smaller sphere. Scale, $\frac{1}{4}$ in. = 1.0 ft. [From Linderoth (1973) by permission of the Marine Technology Society, Washington, D. C.]

* Institute of Navigation Medicine, Kiel-Kronshagen
J. and J. Marine Diving Company, Pasadena, Texas
Life Support Systems Division of U. S. Divers, Santa Ana, California
Naval Medical Research Institute, Bethesda, Maryland
* Naval Research and Development Laboratory (formerly Mine Defense Laboratory), Panama City, Florida
* Office Francais de Recherches Sous Marines, Marseille, France
* Royal Norwegian Navy, Haakonsvern, Norway
* Rushcutter, H.M.A.S., Sydney, Australia
* Submarine Medical Research Laboratory, New London, Connecticut
* Taylor Diving and Salvage Company, New Orleans, Louisiana
* Westinghouse Ocean Research and Engineering Center, Annapolis, Maryland

8. *Environmental Control*

Control and maintenance of a livable environment are of the utmost importance in all the systems discussed above. Internal environments of deep-submergence research vehicles and fleet-type or nuclear submarines are controlled at 1 atm to allow operation at any desirable depth with the capability of rapid descent or ascent without the need for pressurization or decompression. Deep-submergence saturation-diving habitats and deep-diving systems control internal environments at pressures equivalent to the ambient underwater pressure. This allows divers to exit into the surrounding area for work tasks or research. In either case strict environmental conditioning and control systems are required. These systems must provide for maintaining the oxygen partial pressure and for removal of carbon dioxide and other contaminants; they must control temperature, humidity, and circulation and provide extravehicular support to divers if they are to make excursions from the unit.

a. Maintenance of Desired Partial Pressure of Oxygen

Oxygen is necessary to maintain the metabolic requirements of man. At sea level or normal atmospheric pressure, air consists of about 21% oxygen or 0.2 atm partial pressure of oxygen. Anoxia (low oxygen supply to tissues) occurs when the oxygen content falls below about 16% at normal atmospheric conditions. Pulmonary oxygen toxicity (see Chapter IV) can occur if the oxygen partial pressure is increased to 0.6 atm. Therefore, strict control of the oxygen partial pressure must be maintained in any diving system.

Determining the desirable partial pressure of oxygen depends to some extent on the type of mission. Nuclear submarines and other vehicles that maintain a 1-atm environment would maintain the normal 0.2 atm oxygen partial pressure. A high oxygen partial pressure around 1.2 atm is desirable for deep nonsaturation dives because it reduces the decompression time by decreasing the inert-gas partial pressure (Parker and Burt 1970). For normal diving operations and long-term saturation dives, pressures are generally maintained between 0.21 atm (160 mm Hg) and 0.33 atm (250 mm Hg). Oxygen partial pressure is maintained at the proper level as depth increases by increasing the amount of diluent gas. Nitrogen is generally used down to 150–200 ft, and helium or a helium–nitrogen mixture is used for greater depths. Figure IX-36 shows the decrease in the percentage of oxygen and the increase in the percentage of diluent gas, in this case helium, as depth, shown as atmospheric pressure, increases (Gussman *et al.* 1971).

For habitats and other surface-supported vehicles, the simplest means of maintaining oxygen partial pressure is by an air-supply system and venting of the vehicle. This type of system was used on the TEKTITE project, where compressed air was continually supplied by low-pressure air compressors located on the surface-support center. It was supplied to the habitat via an umbilical to maintain an oxygen partial pressure between 151 and 165 mm Hg. The flow rate was manually controlled, based on measured P_{O_2} (partial pressure of oxygen) levels and was approximately 16–24 SCF/hr. A continual outflow of the habitat atmosphere was provided through vents to the sea. This continuous inflow and outflow of air maintained the total atmospheric pressure of the habitat in equilibrium with the water-depth pressure. A Servomex O_2 sensor was used in the habitat to monitor the P_{O_2} and a Servomex A0150 O_2 analyzer was used on the surface. As backup equipment, an MSA O_2 meter was used in the habitat and a Beckman F3 O_2 analyzer was used on the surface. A schematic diagram

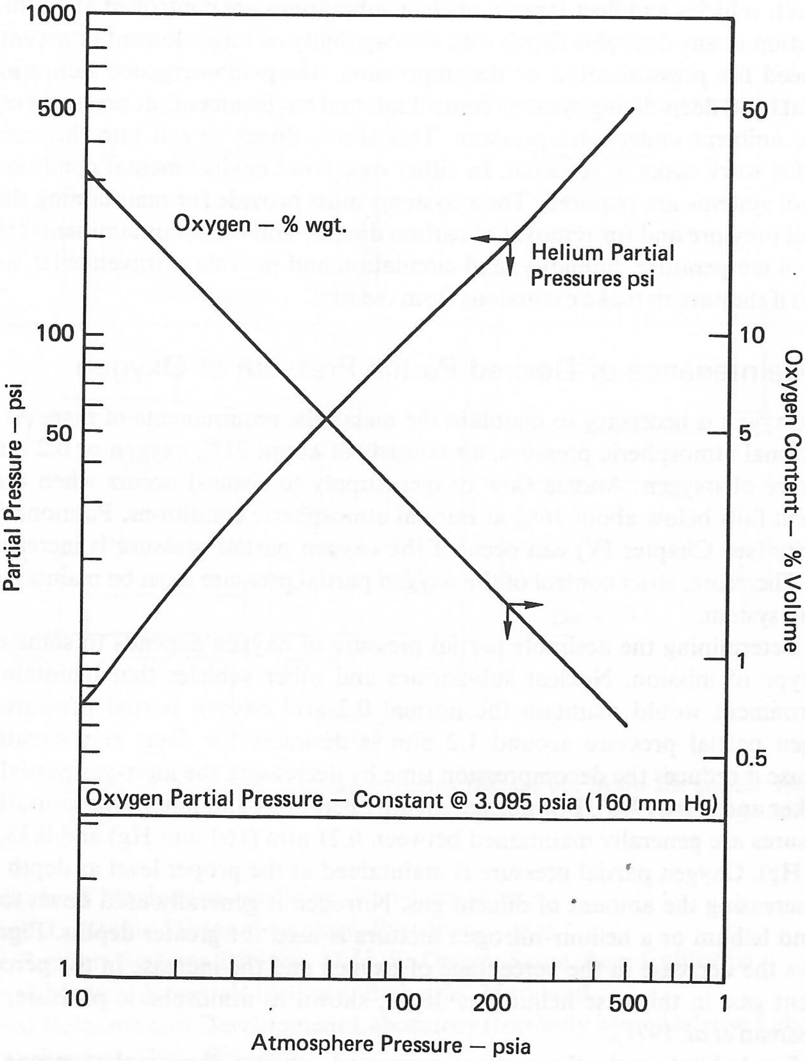

Figure IX-36. Oxygen–helium atmosphere pressure vs. composition. P_{O_2} = 160 mm Hg; T = 20°C (Gussman *et al.* 1971).

of the habitat gas-supply systems used on TEKTITE I is shown in Figure IX-37 (Pauli and Cole 1970).

For deeper operations where surface support is not practical and for free, self-propelled submersibles and vehicles, the atmosphere must be controlled using stored gas. Two modes are in general use today—high-pressure gas cylinders and cryogenic-gas storage. Adequate sensors must be used to monitor the P_{O_2}. The sensor should be able to cover the range of P_{O_2} from 0.1 to 2.0 atm with 5% accuracy and a response time of 10 sec (Reimers 1972). More than one sensor should be used in order to

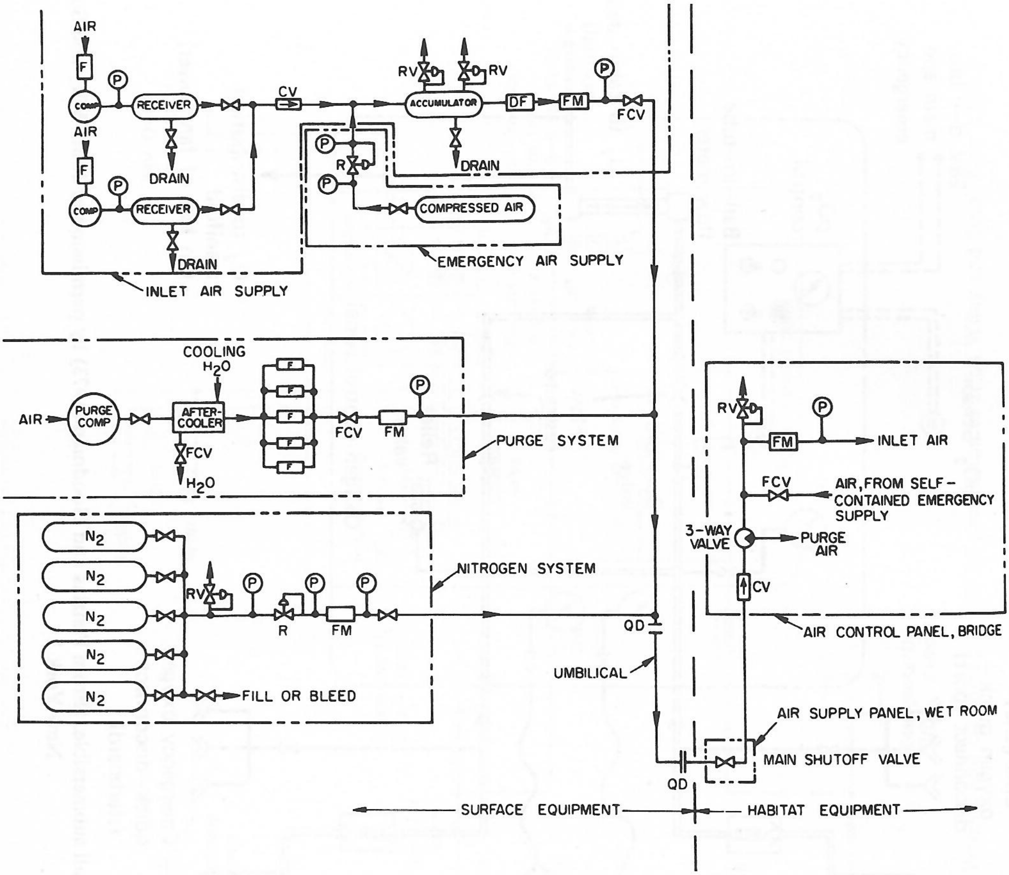

Figure IX-37. Habitat gas supply systems. F = filter, P = pressure gauge, CV = check valve, RV = relief valve, FCV = flow control valve, R = regulator, DF = desiccant filter, FM = flowmeter, QD = quick disconnect. (Pauli and Cole 1970.)

provide both a check system and a redundancy backup system in case of failure. Both galvanic and polarographic sensors are small and inexpensive (Parker and Burt 1970). A simple method of controlling a desired oxygen level is with a flow-limited solenoid valve. When the oxygen level falls below the set point by a fixed amount, the valve opens; when the level rises above the set point by a fixed amount, the valve closes. Audible and visible alarms, activated when the sensor reading deviates from the control point, should be incorporated in the system.

A schematic diagram of a self-contained oxygen supply system using high-pressure gas cylinders is shown in Figure IX-38, and one using cryogenic gas storage is shown in Figure IX-39. A third method of supplying oxygen is impractical except on large, nuclear-powered submarines because the power requirement is too high. This method utilizes water electrolysis to generate oxygen (Penzias and Goodman 1973).

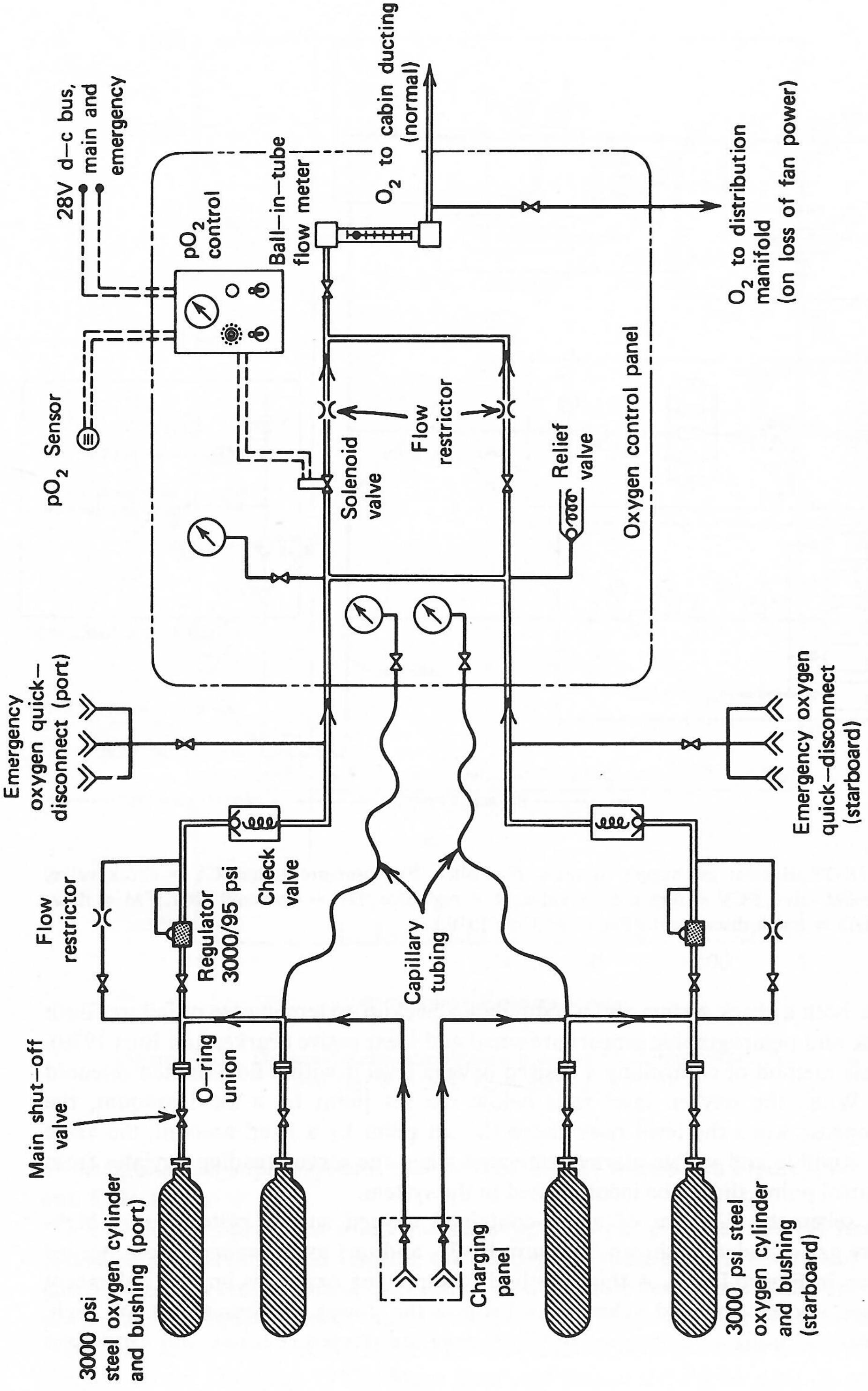

Figure IX-38. Metabolic oxygen system schematic for small submersible. [From Penzias and Goodman (1973) by permission of John Wiley and Sons, New York.]

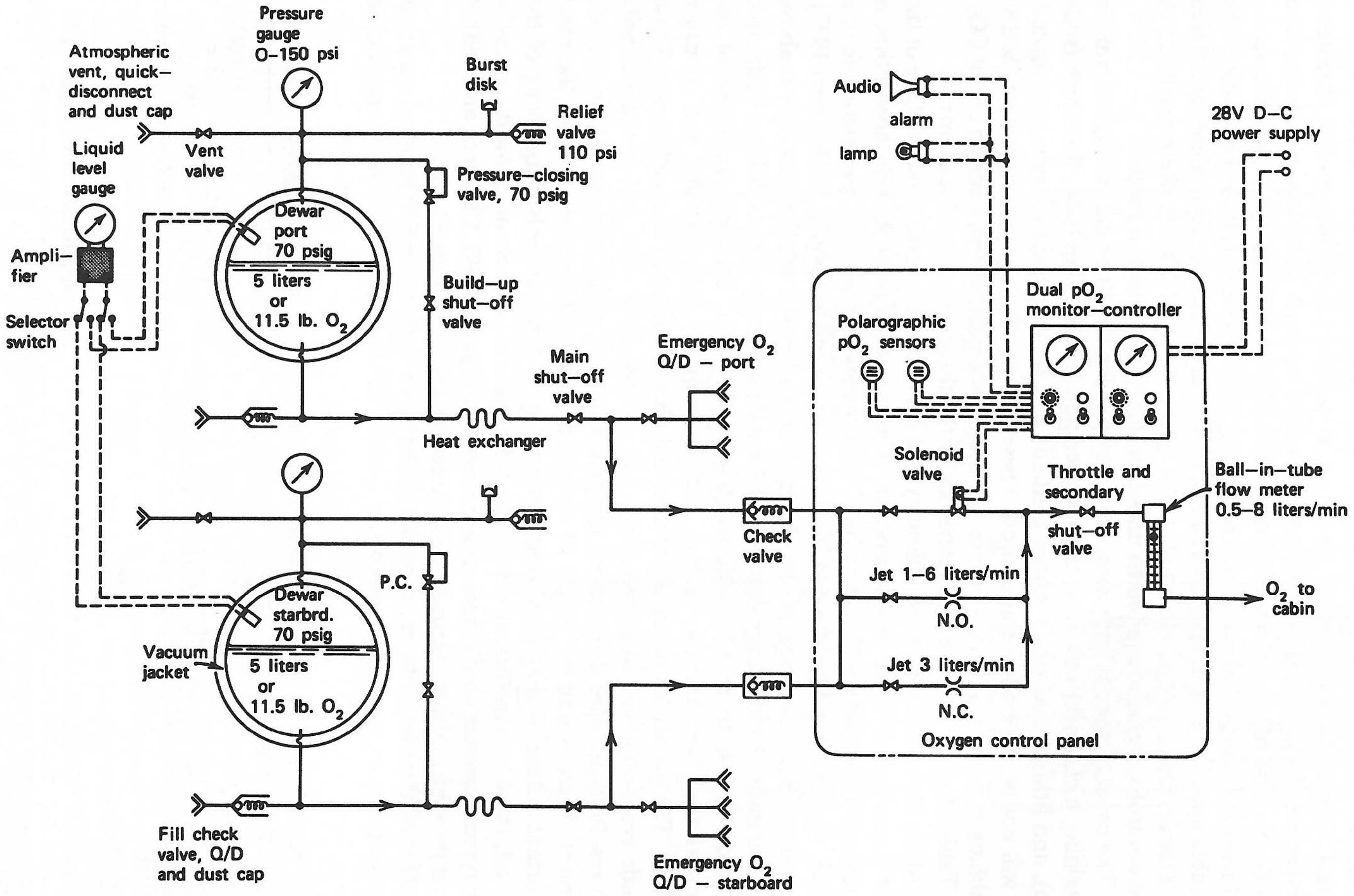

Figure IX-39. Cryogenic oxygen system. [From Penzias and Goodman (1973) by permission of John Wiley and Sons, New York.]

b. Removal of Carbon Dioxide and Trace Contaminants

Removal of CO_2 is one of the prime requirements of most environmental control systems. Rebreathing of expired air or gas is common in decompression chambers, submersibles, habitats, underwater vessels, and submarines. Therefore, exhaled carbon dioxide must be removed to avoid toxic effects. Carbon dioxide's physiological action is a function of its partial pressure, and toxicity depends on duration of exposure. The desirable upper limit is usually set at 0.5% by volume of surface equivalent, or 3.8 mm Hg. This decreases to approximately 0.014% at a depth of 1000 ft (Reimers 1972). A good control system is required to maintain the P_{CO_2} at this low level.

The usual method of removing CO_2 is by passing the air or gas through a canister containing a chemical absorber, the most common being Baralyme, Sodasorb (soda lime), and lithium hydroxide. Other methods and techniques have been investigated, but will not be covered in this section. These include the monoethanolamine (MEA) scrubbing system used on submarines, the use of molecular sieves, freezing out of CO_2, etc. Table IX-32 shows the characteristics of the three common absorbents.

Many factors influence the efficiency of a chemical absorption system. One of the more important of these is temperature. The rate of carbon dioxide absorption is considerably lower at 40°F than at 70°F. This means that, at 40°F, the useful life of a canister designed for 4 hr of use at 70°F may be reduced to about 2 hr (Reimers 1972). Also, maximum absorption can be obtained only when the relative humidity is above 70%. Chemical absorbers are deactivated when they become wet and lithium hydroxide and soda lime both form caustic solutions with water. Physical properties of the chemical absorbers are also factors, such as granular size, porosity, and moisture content. The properties of the absorbent bed also contributed to its efficiency. These include cross-sectional area, bed depth and volume, flow rate, and packing density with resulting pressure drop across the bed, and total pressure under which the bed operates. There is a great variety of absorbent bed configurations. One of the most important criteria is that a uniform distribution of flow prevents channelling of the gas and, therefore, inefficient use of all of the chemical absorbent. Flow diagrams of four typical canister configurations are shown in Figure IX-40. Chamber air is either forced through or drawn through by a blower or fan.

One of the most important considerations in a carbon dioxide removal system is to provide for an adequate monitoring system. This becomes extremely important at

Table IX-32

Characteristics of Three Carbon Dioxide Absorbents[a]

Absorbent	Density, ft^3	Theoretical efficiency, lb CO_2/lb: Weight basis	Theoretical efficiency, lb CO_2/lb: Volume basis	Water generated, lb/lb CO_2	Theoretical heat of absorption, BTU/lb CO_2
Lithium hydroxide	28	0.92	25.6	0.41	875[b]
Baralyme	65.4	0.39	25.5	0.41	670[c]
Sodasorb	55.4	0.49	27.2	0.41	670[c]

[a] From Lower (1970) by permission of Marine Technology Society, Washington, D. C.

[b] Based on gaseous H_2O generation.

[c] Based on calcium hydroxide reaction only.

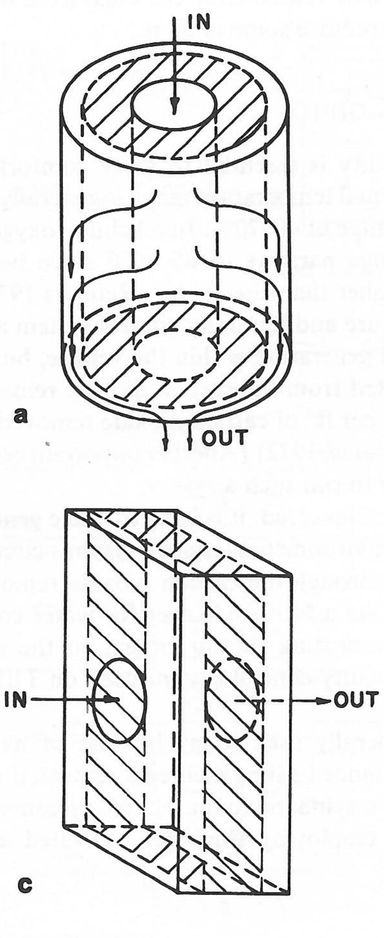

Figure IX-40. Channelling surface areas for four types of canisters. (a) Annular flow (b) flat, transverse flow (c) flat, longitudinal flow (d) solid cylinder. (Lower, 1970.)

increased depths because of the very small percentage of carbon dioxide that is permissible to avoid toxic effects. An adequate sensor should be capable of detecting carbon dioxide in the range of 0–7.6 mm Hg (0–1.0 surface equivalent by volume) with an accuracy of 5% and a 30-sec response time (Reimers 1972). To date there is not an adequate analyzer to meet all the needs of every diving system. Some systems merely employ a method to determine whether the CO_2 content has risen above a certain maximum value. TEKTITE II used a Lira CO_2 sensor in the habitat and a Varian gas chromatograph on the surface. As backups, a detector tube was used in the habitat and a Beckman 1R215 infrared sensor (Miller *et al.* 1971).

Except in the case of long-duration dives, as in nuclear submarines, the trace contaminants result chiefly from construction materials, lubricants, etc. These are usually removed with the carbon dioxide or vented from the area, as in the case of a habitat. Charcoal filters are also used to remove some of them.

c. Temperature and Humidity Control

Control of temperature and humidity is essential to diver comfort and work efficiency. In an air environment, the normal temperature range is generally considered to be 68–80°F with a relative humidity range of 40–70%. In a helium–oxygen environment, the comfortable temperature range narrows to 85–89°F since helium has a thermal conductivity about six times higher than that of air (Reimers 1972). Factors which must be considered in a temperature and humidity control system are ambient water temperature, heat dissipation and generation within the vehicle, humidity gain from the crew, and water vapor generated from the carbon dioxide removal system. [About 1 ft^3 of water vapor is produced per ft^3 of carbon dioxide removed by lithium hydroxide, Baralyme, or soda lime (Canty *et al.* 1972).] Another important consideration is the amount of power that is available to run such a system.

Because of the many different factors involved, it is hard to make generalizations about specific designs. However, many environmental-control systems circulate gas or air from the vehicle cabin or chamber through the carbon dioxide removal system, then reduce the temperature of the gas via a heat exchanger for water condensation and humidity control, and follow by reheating the air or gas to the appropriate temperature. The temperature- and humidity-control system used on TEKTITE I is shown in Figure IX-41.

Electrical resistance heating is generally used today because of its simplicity. Smaller submersibles use electrical resistance heating elements cemented on the outside of the hull, which is insulated with a syntactic foam. Humidity can also be controlled by a chemical adsorption unit employing silica gel, activated alumina, or molecular sieves (Canty *et al.* 1972).

d. Maintenance of Air Circulation and Extravehicular Support

Although they are important factors to be considered in an environmental-control system, maintenance of air circulation and extravehicular support are so dependent upon the overall design and function of a particular underwater vehicle or habitat that they are not described here. The most important factors to consider are the additional power that will be consumed and the additional breathing gas necessary to support excursion divers.

9. *Instrumentation*

In the last two decades the military, economic, and scientific demands to know more about the oceans has reached a high pitch. Electronics is playing a very large role in carrying man into the ocean, but electronic instrument designers need to appreciate the problems of working underwater.

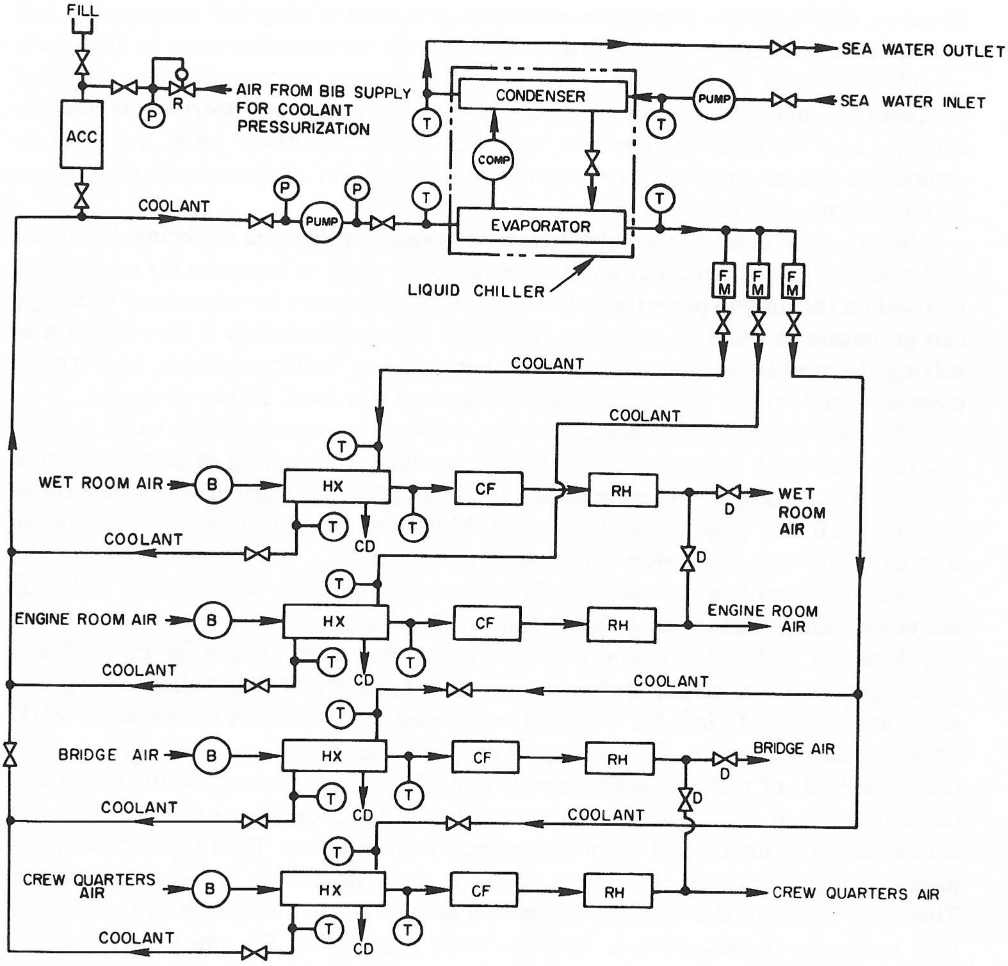

Figure IX-41. Thermal control system. P = pressure gauge, T = temperature, R = regulator, ACC = Accumulator, FM = flowmeter, B = blower, Hx = heat exchanger, CF = charcoal filter, RH = reheater, D = diameter, CD = condensate drain. (Pauli and Cole 1970.)

Since volume considerations are extremely important, miniaturization of instruments is vital. Every kilogram inside the hull means an overall increase in 2–3 kg because of the need for additional external buoyancy material. Instrument volume is important to the efficient use of space in a submersible, a factor critical to mission effectiveness. Instrument power consumption should be as low as possible since demands of propulsion leave very little for other purposes. Waste heat is not so often a problem as in other environments because of the excellent heat sink properties of water.

Some limitations of weight and volume can be negated by placing instrumentation in pressure-tight or pressure-balanced compartments external to the pressure hull;

however, this technique introduces additional problems of electrical cable glands and difficult access for maintenance. Instrumentation for submersibles must be absolutely reliable because of the difficulty of repair or maintenance tasks underwater. Carrying of spares is limited by the lack of space. The close proximity of instruments leads to acoustic and electrical interference between circuits. Electrical plugs and sockets external to the pressure hull can result in many pieces of equipment flooding if not carefully designed (Haigh 1971).

Some of the most important methods of ocean investigation are being developed in the field of acoustic technology. The extraordinary role of acoustics for oceanology is based on the unique properties of acoustic waves in water; no other form of energy can propagate in water to such long distances. This methodology is very effective in solving the problems of acoustic vision, telemetering, communication, and remote control of underwater systems that arise in underwater work and/or research.

Another significant advancement is the single-wire communication cable (especially the electrically isolated wire). When an acoustic telemetering or communication link is too expensive or too complicated in design, the thin isolated wire (with multichannel electronic system) should be used. Multiwire cables will find no place in the coming technology for reasons of reliability and weight.

New noncorrosive materials are the underwater materials of the future, including alloys with an aluminum base and plastics such as acrylic.

A review of the developing trends in instrument modification for physical and main hydrochemical measurements is shown in Table IX-33 (Mikhaltsev 1971). The last column characterizes the information processing techniques for research work. There are several reasons for the importance of these techniques. First, the observational methods of making measurements and physical experiments in the ocean and the high demand for the quantitative reliability of the data allows too little time for determining the final result from the collected information. Results from measurements obtained while an experiment proceeds make immediate corrections possible. This can sometimes show a considerable economy, by avoiding the need for a return visit to repeat the experiment. Second, there is the need for precise quantitative analysis of the characteristics of ocean processes, impossible without comprehensive computer facilities onboard. The need for the best and most explicit form for the final results of the analysis demands a prompt assessment by the scientist. Third, the economy of automatic information processing and the elimination of human labor from routine operations must be considered. One important example is reduction of the number of auxiliary personnel required on research vessels on long oceanic voyages.

The present state and trends in the development of techniques used in biological geological, and chemical oceanography are shown in Table IX-34. "The active role of the scientist-operator in gathering material, fulfilled by remote devices, will characterize the methods of work in this group of ocean sciences in the 1970s" (Mikhaltsev 1971). A topical outline of certain aspects of the hyperbaric chamber environment as related to instrumentation is given in Table IX-35. Not indicated, but of particular significance, are the many interactions involved. For example, minimum decompression time calls for breathing high-oxygen concentrations and this increases the fire hazard (Hamilton *et al.* 1970).

Table IX-33

Technical Means for Ocean Research in Hydrophysics[a]

	Methods widely used in the 1960's	Possible methods for use in the 1970's	Possible 1970's methods for information processing and analysis
Currents	Self-recording current meters from moored surface buoys; pinger-buoys of neutral buoyancy	Autonomous moored buoys (AMB) with radiotelemetering and self-contained memory; current–temperature–electroconductivity-meters, local optical and acoustical characteristics, acoustical noise and meteorology in the air–sea interaction layer	—
Temperature	Reversing mercury thermometers; thermographs with stylo- or photo-recording	Towed systems (TS) with temperature, electroconductivity, and other measuring gauges	Input of all the data in the information-memory and processing computer; processing in accordance with given programs and printing results in the form of drawings, charts, plans, etc.
Electroconductivity (salinity); fluctuations in turbulence, temperature, electroconductivity, sound velocity, and flow speed	Bathymetric samples with laboratory analysis	Sondes (S); temperature, salinity, depth, optical, and local acoustical characteristics; thermoanemometers, acoustical meters of velocity and flow; galvanic and electromagnetic conductivity meters (on AMB, TS, and S)	—
Fluctuations in atmospheric layer (see surface interaction zone), humidity, wind speed, and heat flow		Conductivity thermometers, thermoanemometers, optical meters of wind fluctuations	—
Surface state: waves and level	Quasistatic pressure gauges; string gauges	Acceleration meters, strain gauges on buoys; radar and stereophotogrammeters	—
Less common characteristics: propagation velocity, damping and scattering for electromagnetic (radio and optic) and acoustical waves, radiation characteristics	—	Special instrumentation and probes for mass measurements on AMB and from ships	Computer processing to special programs

[a] From Mikhaltsev (1971) by permission of IPC Science and Technology Press.

Table IX-34
Technical Means for Ocean Research in Biology, Geology, and Chemistry[a]

Type of research	Methods widely used in the 1960's	Possible methods for use in the 1970's	Possible 1970's methods for information processing and analysis
Biology			
Ecology, biogeography, systematica: mass fauna collection (pelagic, bottom)	Plankton and ichtyo-nets for vertical movement; pelagic trawls, bottom trawls	Trawls and nets for multihorizontal catch with thermo- and bathystats; photo and introscopic tools for viewing in the waters; sonar with object-quantity-defining systems; sound–vision systems; bioluminescence counters; volume and surface counters; isotopic counters; IR spectrophotometry; standard instrumentation for chemical and physical experiments and for methods of treating live samples	Special counting systems (television microscopes, counters, filter particle counters, microphotometers, etc.)
Productivity experiments	—		Automation of analysis
Biochemistry, biophysics, biotechnics (bionics)	—		—
Geology			
Bottom surface	Echosounders, deepwater photography	Narrow-beam echosounder with digital indicator and digit-code output Towed deepwater side-bottom-sonar and photo-television systems	See Table IX-33
Surface layer sediments, rock material	Samplers and specimen corers, dredges, grab samplers; bottles for suspension gathering	Echosounders or determination of mechanical characteristics of surface layers with adequate technique of sample gathering (piston- and vibrocorers, rotation dredges, drills, etc.) Deep drilling equipment; manned and unmanned submersibles with automatic manipulators; deep-water (towed or sonde) filtering techniques	Automation of optimum methods of physical-chemical analysis: plasma, X-ray structure, mass-spectrometer, radiation-energy, and other types of analysis

Deep crust layers	Geophysical surveys using ship seismo-profiling systems with radio-buoys, towed hydrophone lines, towed sparkers, boomers, etc., and hydrophone lines; ship-towed proton, ferrosonde, or quantum magnetometer; ship gravity-meters; heat flow measurements with thermogradientometer	Towed systems of the full geophysical survey complex with digital output Automatic self return-to-surface systems for complex measuring of: seismic waves, heat flow, near-bottom currents, magnetic variations, with built-in digital recording system	See Table IX-33
Chemistry			
Geochemistry	Same as geology of surface layer and sediments		
Hydrochemistry	Bottles	Microprobes with automatic synchronous line analysis of all important chemical elements and structures; technical and chemical methods of monitoring all chemical elements of sea water	Standardizing of all chemical analysis of water for automatic printing and storage of information

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[a] From Mikhaltsev (1971) by permission of IPC Science and Technology Press. The above information concerns only the main aspects of ocean research.

Table IX-35
Constraints of Instrumentation in Hyperbaric Chambers[a]

Condition	Remarks
Pressure	Protection is required for some equipment, or modification Special penetrations needed for electrical wiring, etc. Special techniques are required for external gas sampling, and gas analysis is complicated Pass-through "lunch" locks can be used for handling samples, etc. Subject, investigators, samples, and equipment are subject to "decompression sickness" Inadvertent loss of pressure or failure of lines or vessels may be catastrophic; consequences of failure should be a planning factor Wall tension in a tube, at a given pressure, is proportional to radius, so small tubes can safely hold high pressures; this permits topological manipulations of the actual pressure domain
Isolation	To contain an experimental high-pressure environment involves a wall of up to 5 in. of steel; huge, heavy hatches; only a few small thick windows; not nearly enough space and, inevitably, too few penetrations Information, things, and energy must be transmitted through the chamber wall; if pressure is high, transmission of power and mechanical movements may require special techniques; one is by means of a sealless magnetic drive A communication system is required, even if it is only banging with a leather (sparkless) mallet, or shouting When communication is impossible due to helium speech, the subjects in the chamber are in some ways as isolated as if in an orbiting spacecraft Some things will not fit into the lock or even into the chamber Mechanical isolation and decompression obligation may complicate rescue of sick and injured persons inside
Atmosphere	Oxygen causes a special fire hazard Helium may distort speech Helium permeates equipment Helium conducts heat readily, disturbing some equipment and measurements [e.g., tympanic (ear) temperatures are not usable in helium]; fans designed for air may not provide sufficient flow in helium, causing overheating Helium as a background gas may upset gas analyzers (e.g., infrared carbon dioxide analyzer and nitrogen analyzer) General toxicological problems of a captive atmosphere are present
Electricity	Main aspect of electrical safety is fire Shock is a special hazard because people inside are generally well grounded, crowded, and confined; in case of severe shock, rescue is difficult or impossible Sea water and perspiration increase shock hazard and electrical leakage Chamber itself is a superb electrostatic and electromagnetic shield, but only from interference outside the chamber Some instrumentation may shock subjects via internal defects and intentionally applied electrodes
Fire	Use of oxygen-enriched atmospheres or compressed air under pressure has high fire risk "Zone of no combustion" may eliminate risk People are "trapped" inside; in case of fire, extinguishing and rescue are difficult Very few materials will not burn in high-oxygen atmospheres Electric power is the most likely source of ignition

[a] From Hamilton *et al.* (1970) by permission of *Transactions of the New York Academy of Sciences.*

Terminology

The following definitions have been used in this chapter to describe various underwater operational equipment. Many times, different names are used for the same basic piece of equipment and assigned according to the function of the equipment. An example of this is a pressure chamber. This term implies an enclosed space which can withstand pressure. This can then be divided into three categories: (1) a chamber that can withstand internal pressure only; (2) a chamber that can withstand external pressure only; and (3) a chamber that can withstand both internal and external pressure. An example of the first is a hyperbaric chamber. This is designed to withstand internal pressure while the outside remains at 1 atm of pressure. An example of the second type is an underwater observation chamber, such as a bathysphere, which is designed to withstand the internal pressure imposed by the ambient underwater pressure while maintaining an internal pressure of 1 atm. An example of the third type is a submersible decompression chamber. This is designed to withstand the external pressure imposed by the ambient underwater pressure as well as being able to withstand internal pressurization. A pressure chamber is also named for its function. Thus, a hyperbaric chamber implies that it is used to simulate high pressures. A decompression chamber implies that it is used to gradually decrease the pressure to which a diver has been exposed. A recompression chamber implies that it is used to increase the pressure to return a diver to the exposed depth, such as when treating a case of the bends.

There are many combinations of basic terms which are used together to define equipment. Thus, a swimmer delivery vehicle is used to describe a transport device that will carry a swimmer for limited distances. A swimmer propulsion unit is used to define a small device that will aid in propelling a swimmer through the water.

Many times several basic pieces of equipment are used together to form a total system. When one uses the term SDC/DDC (submersible decompression chamber/deck decompression chamber), this implies a total diving system with no need to include mention of the support ship or platform and also implies that the system includes the capability of mating the SDC to the DDC.

New combinations of basic terms constantly appear in the literature. An example of this is the personnel transfer submersible, used to describe search and rescue vehicles such as the Deep Submergency Rescue Vehicle (DSRV). Since a submersible implies an underwater vehicle that requires surface support, the terminology is self-descriptive, even though sometimes confusing.

Therefore, as an aid to understand the many terms used when describing underwater operational equipment, or land-based equipment used in support of underwater diving projects, the following terms are presented with their conventional definitions or functional definitions.

Bathyscaph. A navigable submersible ship for deep-sea exploration having a spherical, watertight cabin attached to its underside; an example is TRIESTE.

Bathysphere. A tethered, strongly built diving sphere for deep-sea exploration; an example is CACHALOT.

Mesoscaph. The same as a bathyscaph except for depth of operation; an example is BEN FRANKLIN.

Diving system. A system composed of three basic subsystems which can be used in various combinations; the subsystems are (1) a surface support ship or platform; (2) a deck decompression chamber used to decompress divers on the surface; (3) a tethered capsule, which is used to transport divers from the surface ship to the underwater work site. The capsule is capable of being pressurized internally and can be used to transfer divers under pressure, whereby it is called a personnel transfer capsule, or it can be used to decompress divers, whereby it is called a submersible decompression chamber. An example of a complete diving system is the ADVANCED DIVING SYSTEM IV and the U. S. Navy DEEP DIVE SYSTEM MARK II.

Submersible. A dry, 1-atm vehicle where the operator and crew are protected from outside by a pressure hull and which requires surface support although it can operate autonomously for short periods of time; it may have diver lockout facility. An example is ALVIN.

Submarine. A propelled underwater vehicle, used primarily for military missions, which can operate autonomously for a long period of time.

Habitat. A life-support system of limited mobility, capable of providing functional living and working space in the underwater environment; highly dependent upon land- or sea-based support equipment; has an internal pressure equal to the pressure of the ambient underwater pressure; it has free access to enter and leave it through an open hatch in the bottom. An example is SEALAB.

Fixed bottom stations. Underwater work sites that are maintained at 1 atm of pressure; highly dependent upon land- or sea-based support equipment. An example is an underwater welding chamber.

Vessel. A hollow structure designed for carrying or transporting something underwater.

Vehicle. The same as a vessel.

Wet pot. One chamber of a hyperbaric facility capable of being filled with water and pressurized to simulate a given underwater depth.

Swimmer vehicle. Any one of a number of devices used to aid the swimmer in attaining swim speeds greater than he could accomplish using fins.

Hyperbaric facility. The entire group of systems and subsystems used to support a high-pressure chamber or chambers, used to simulate high pressures; may include a wet pot to simulate an actual underwater environment.

Lock out capability. A vehicle, usually maintained at a dry 1 atm pressure; has a chamber which can be pressurized to the ambient underwater pressure to allow egress of a diver or divers; if necessary, it can be used to decompress the divers back to 1 atm of pressure.

Decompression chamber. An enclosed space used to gradually decrease the pressure to which a diver is exposed from the ambient underwater pressure back to 1 atm.

Recompression chamber. An enclosed space used to rapidly increase the pressure to which a diver has been exposed to return him to the ambient underwater pressure; especially used when treating a diver with the bends.