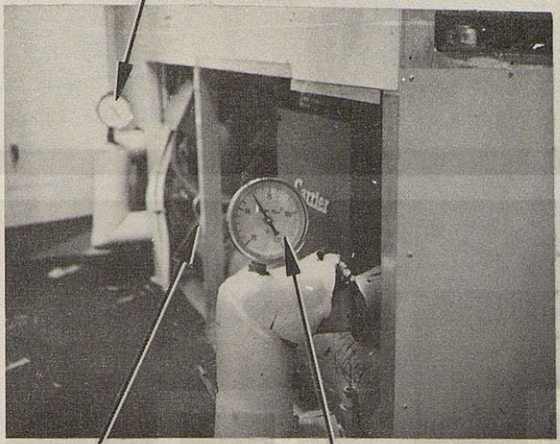


Fig. B14 - Liquid chiller which cooled the coolant fluid in the thermal control system

B3.1.4 Scuba Charging Equipment

The scuba charging equipment, shown schematically in Fig. B15 consisted of two high-pressure compressors on the support barge, a high-pressure umbilical from the compressors to the habitat, three 270-standard-cubic-foot accumulator tanks mounted external to the habitat, and associated valves, piping, and charging lines within the habitat. The air compressors maintained 2400 psi within the accumulator storage tanks. The charging line consisted of a bleed valve, shutoff valve, pressure gage, and yoke for attachment to the cylinder. When the aquanauts charged the tanks, the two compressors on the support barge were operated. The output of the compressors plus the air stored in the accumulator tanks was sufficient to maintain a satisfactory charge rate. A hookah system also drew air from the scuba charging equipment, through a stepdown pressure regulator. When an aquanaut was on the hookah, the compressors on the support barge were also operated and maintained an adequate supply of air for this open cycle system. Figure B16 shows the scuba charging and hookah panel in the wet room.

B3.1.5 Emergency Systems

The environmental control system provided several subsystems for use during possible emergencies: surface emergency air system, purge system, self-contained emergency air supply, emergency built-in breathing system, and escape air bottles. The surface emergency air system (Fig. B15) consisted of a compressed air storage tank at the support barge. In case both normal air supply compressors failed, or there was a power failure, air from the supply could be delivered to the habitat in the normal manner. The air supply was more than sufficient to last the specified 24 hours. Its use was not required during the mission.

The purge system (Fig. B6) was designed to completely change the air within the habitat should it become contaminated. The system used an engine-driven compressor and a compressed nitrogen gas storage tank on the support barge, supplying gas to the

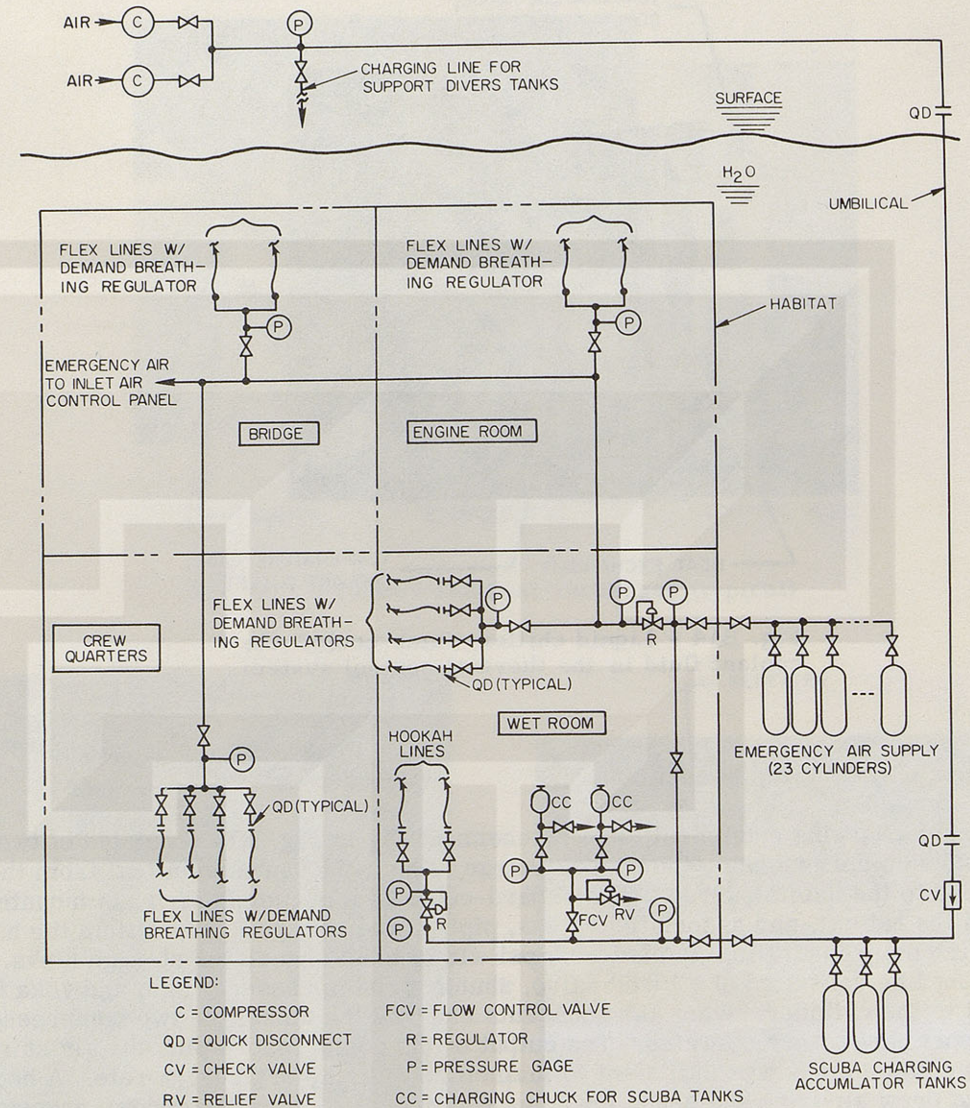


Fig. B15 - Emergency breathing and scuba charging systems

habitat via the air supply umbilical. In operation the air compressor flushed out the habitat atmosphere and replaced it with compressed air (suitable filters were used to remove any oil, CO, or other contaminants from the air that might be produced by the compressor). Then nitrogen was added to the habitat to reduce the pO_2 to a normal level. The purge system was not required during the mission. However, just prior to beginning the mission, nitrogen was added to the atmosphere within the habitat to establish the proper mixture of O_2 and N_2, and after the mission the habitat was purged with compressed air to allow a greater diving time for the support personnel. No problems were encountered with either purge.

The habitat also had a self-contained emergency air supply consisting of twenty-three 270-standard-cubic-foot compressed air cylinders in the base of the habitat (Fig. B15). This air could be used instead of the normal air supply from the surface or for supplying the emergency breathing system. This air supply was also crossconnected to

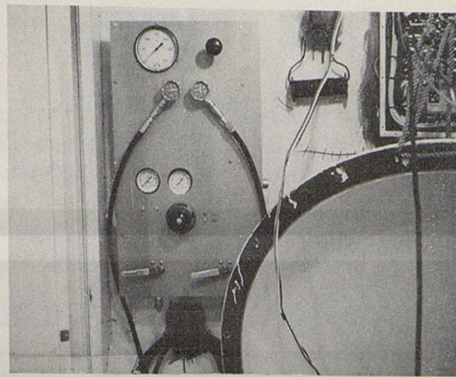


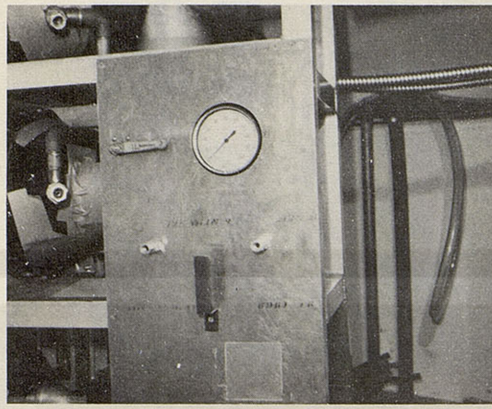
Fig. B16 - Scuba charging and hookah panel in the habitat wet room

the scuba charging system, so that it could be recharged or supplemented by the scuba charging compressors.

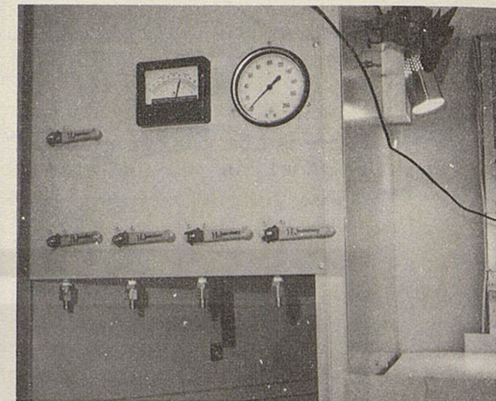
The emergency built-in breathing system (Fig. B15) provided 12 breathing stations within the habitat (four in the crew quarters, four in the wet room, two in the equipment room, and two in the bridge) to be used in case of atmosphere contamination. Each breathing station consisted of a hose of sufficient length to reach the stations in adjacent compartments, terminating with a scuba type demand breathing regulator (Fig. B17). Each breathing station, less the hose and demand regulator, is shown in Fig. B18. The line pressure to each regulator was maintained at 100 psi. If used, the aquanauts would breathe air directly from the self-contained emergency supply, which would last for 12 hours.

Fig. B17 - Hose and regulator for built-in breathing stations to be used in case of atmosphere contamination

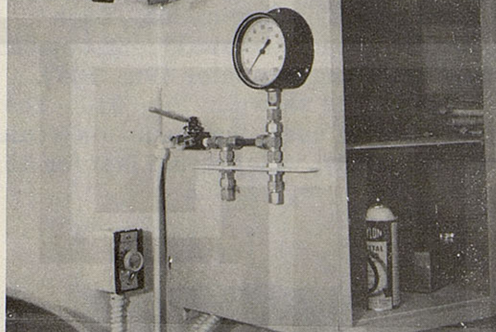
Escape air bottles (Fig. B19) complete with regulators, hoses, and mouthpieces, were located in all compartments except the wet room, where scuba equipment was available. Four were in the crew quarters, and two were in the bridge, and two were engine room. These bottles provided the capability to move about or escape from the habitat in the case of a severe emergency, such as flooding. Each bottle contained 18 standard cubic feet of air, which would provide a useful life of 7 to 8 minutes.



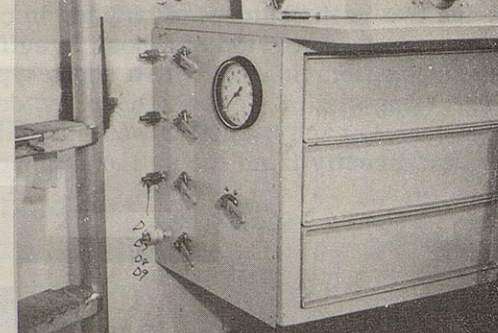
(a) Equipment room



(b) Crew quarters



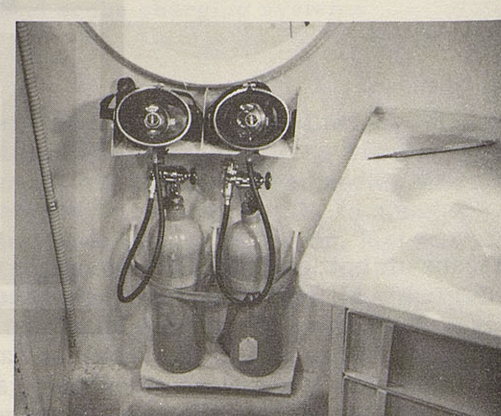
(c) Bridge quarters



(d) Wet room

Fig. B18 - Built-in breathing stations to be used in case of atmosphere contamination

(a) Crew quarters



(b) Bridge

Fig. B19 - Escape air bottles

B3.2 Atmosphere Monitoring Subsystem

B3.2.1 Background

The atmosphere monitoring subsystem served two objectives: first, and most important, the Tektite I mission made it highly desirable to automatically and continuously monitor the major life support gases with readout both in the habitat and on shore. Second, the more insidious buildup of any toxic, flammable, or obnoxious gases, vapors, or particulates had to be detected reliably and well within safety limits to the satisfaction of all concerned, especially to the isolated aquanauts. Other considerations such as logistics, calibration, maintenance, simplicity, and cost were also necessary in the selection of the instruments ultimately used in Tektite I. The subsequent sections will deal with the details of the particular package of instruments selected for Tektite I. Table 5 (chapter 4, page 38) showed this list of instruments and the location and functional priority of each in the analytical scheme.

Some discussion of analytical limits and safety limits will be presented in following sections. These are included to also more clearly explain the basis for selection of the various instruments.

Another important facet in the maintenance of a high-purity atmosphere involved choice of materials used in the habitat. All materials and components, paints, insulations, soundproofing, and various chemicals were screened to avoid contamination as much as possible. All interior painting was completed well in advance of the mission (at least 30 days). One possible source which was more difficult to control involved the scientific and personal gear of the aquanauts, such as formaldehyde for specimen preservation and various paints for specimen marking. Minor amounts of these and other possible contaminants could be easily handled by the charcoal scrubbers and by ventilation of the habitat atmosphere. Major spills would be another matter, so safety procedures allowed only small quantities to be used at any one time. Another source of concern involved the charcoal scrubbers, which could eventually be a source of contamination. This could occur if some contaminant originally adsorbed early in the mission was displaced by a more actively adsorbed contaminant generated later in the mission. This was checked by removing part of the charcoal midway in the mission and analyzing it for amounts and types of contaminants present in order to determine whether the charcoal was near the end of its useful life.

A final point in this subsystem and the Tektite I mission involved the need for rapid and precise measurement of contaminants not readily identified by the equipment available or due to equipment failure or malfunction. This was solved by arranging off-site standby facilities at Puerto Rico, where a complete analytical laboratory was available. Mainland facilities were inappropriate because of the long turnaround time involved.

B3.2.2 Discussion

The major constituents of the atmosphere were nitrogen, oxygen, carbon dioxide, and water vapor. These gases (vapors) were monitored onboard between the limits and with the accuracies given in Table 5 (page 38). Suitable backup and standby equipment was provided both on board and on shore.

Anticipated trace constituents of the atmosphere were carbon monoxide, varied hydrocarbons, ozone, particulates, Freon, etc. These gases, solids, and aerosols were monitored to insure that they did not exceed safety and comfort limits. The threshold limit values for the more likely constituents are shown in Table B-1. A complete review of all gases and compounds which were potentially harmful was made using the list provided by the American Conference of Governmental Industrial Hygienists, 1966. Tektite I

Table B1
Acceptable Threshold Limit Values* (TLV) of Objectionable Constituents in the Habitat Atmosphere

Constituent	Tektite Limit Value During Operations†	Emergency Value‡
Carbon dioxide	3,000 to 15,000	>15,000
Carbon monoxide	15 to 80	>80
Hydrocarbons (toxic)	1/4 to 5/4 of TLV	>5/4 of TLV
Hydrocarbons (obnoxious)	By smell	NA
Ozone	<0.06 to 0.30	>0.30
Particulates (inert)	5 to 25	>25
Particulates (toxic):		
Lead	0.06 to 0.30	>0.30
Mercury	0.01 to 0.05	>0.05
Freon 12	1500 to 7500	>7500
Freon 22	1500 to 7500	>7500

*These values were 1/4 the threshold limit values set for a normal 8-hour working day by the American Conference of Governmental Industrial Hygienists, 1966.
†If the contaminant level was detected in this range, steps were to be taken to locate the source and initiate the appropriate corrective action.
‡If this concentration was detected, an immediate habitat purge was to be initiated with the crew on the built-in breathing system.

mission limits were set at 1.4 the values given in this list, since the aquanauts were exposed on a full 24-hour day basis versus the 40-hour-week basis for the limits given.

B3.2.3 Monitoring Equipment

A single onboard instrument was used to continuously monitor the oxygen, carbon dioxide, water vapor, and introgen content of the habitat atmosphere. This instrument was a miniaturized mass spectrometer supplied by NASA (Langley Research Center) which allowed simultaneous subsurface and onshore readout. The concentration levels as noted onshore were logged at periodic intervals, and habitat readouts were logged by the habitat crew. The instrument was calibrated by the crew as required. Each constituent gas was indicated on an edge meter. The oxygen and carbon dioxide meters had adjustable set points connected to audible and visual alarms.

Onboard backup instruments monitored oxygen and carbon dioxide in the event of power or prime equipment failure. These instruments used reliable chemical and physical principles to analyze O_2 and CO_2 and were simple to calibrate and read out. For oxygen monitoring, a Mine Safety Appliance (MSA) Model E oxygen indicator was used in conjunction with two General Electric O_2-partial-pressure sensors. An MSA detector tube with a Universal Test hand pump was used for backup CO_2 sensing. For probable toxic gases, an MSA portable air-sampling test kit applying colorimetric chemical analytical techniques was used. The test kit was equipped with the chemical detector tubes for: ammonia, carbon monoxide, chlorine, phosgene, mercury vapor, organic nitrogen compounds, nitrogen dioxide, hydrogen chloride, unsaturated hydrocarbons, sulphur dioxide, carbon dioxide, hydrogen sulphide, halogenated hydrocarbons (Groups A, B, C, and D), hydrogen cyanide, aromatic hydrocarbon, ozone, alcohol, aldehyde, styrene, dimethyldiethyl sulfate, carbon disulfide, hydrogen fluoride, and lead.

It was not expected that all of these tests would be required during mission operations. In addition, an air-particulate sampler was also provided. These particulate samples were to be taken as required and placed in suitable dusttight polyethylene envelopes and sent topside for analysis. The need for particulate sampling never arose, so samples were taken only before and after the mission. A simple halide detector to be used only in emergencies provided Freon leak-source detection.

On the surface both a Beckman and a Servomex oxygen meter fitted with suitable valving and appropriate absorbents were used to monitor habitat O_2 concentration via a vent line. The vent line umbilical sampled the atmosphere near the CO_2 scrubber inlet in the habitat. Later in the mission a Beckman CO_2 analyzer was added to the onshore instrumentation to monitor CO_2. A gas chromatograph was also available for major gas analysis as an additional backup and could also monitor carbon monoxide or any buildup of hydrocarbon vapors whose concentrations were within detection limits of the instrument. These analyses were to be conducted using batch bottle samples taken in the habitat. Additional batch samples were taken and analyzed at the Naval Research Laboratory in Washington, D.C., for trace compounds developed during the mission. In case of equipment or power failure, a simple Orsat gas apparatus was also available in the watch director's station on the support barge to monitor oxygen and nitrogen. Arrangements were also made for emergency analytical services at the Puerto Rico Nuclear Center whereby complete, more precise chemical and instrumental analyses could be quickly provided.

Samples of particulate filtration were analyzed ashore using simple weight-change measurements and a microscope. Suitable chemicals also were available for spot tests if required. Samples were also taken of the charcoal and filters used onboard to purify the atmosphere. These samples were in airtight plastic containers for later analysis as part of postoperation analyses. Finally, an occasional sniff test was conducted on the gases from the oxygen sampling umbilical to qualitatively evaluate the habitat atmosphere, since the aquanauts sense of smell could have been deadened by constant exposure to the habitat conditions.

B3.3 Electrical Power Distribution Subsystem

B3.3.1 General

The electrical power distribution subsystem depicted by a one-line diagram in Fig. B20 was specifically defined as that which transmited, transformed, controled and distributed power to all habitat electrical loads. The power subsystem derived its electrical power from one of two identical 100-kW diesel generators mounted on the habitat support barge, which also supplied power to the surface control center van and all other barge loads. One of these generators operated while the other was on standby. The load was transferred from one generator to another manually after the standby generator was started. Power from the operating generator was fed through a distribution circuit breaker and was stepped up to 480 volts by transformers mounted on the surface support barge. The power flow then interfaced with the power distribution subsystem. The total power being transmitted to the habitat was monitored by a watt-hour demand meter before being fed through a 1000-foot-long power umbilican cable.

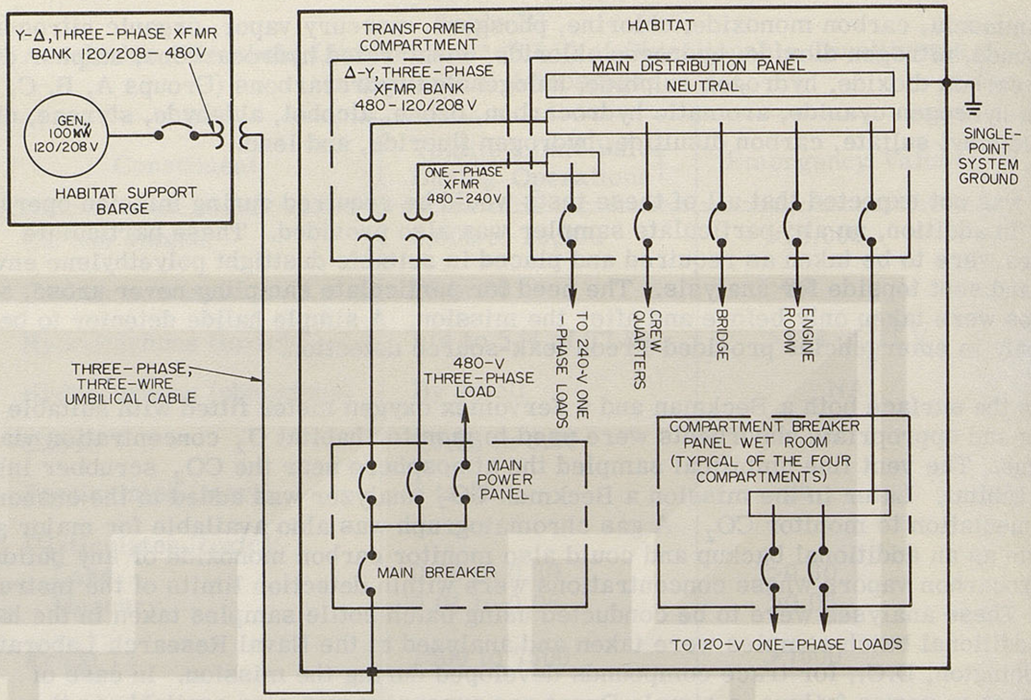


Fig. B20 - Single-line diagram of the Tektite electrical power distribution system

B3.3.2 Main Power Panel

The power umbilical cable entered the habitat through a penetration plate and was fed directly to the main power panel, which controlled all power at three different voltage levels (120, 240, and 480 volts) for electrical loads in the habitat. Power for the 480-volt load was controlled directly at the main power panel. Power at 480 volts was distributed on separate circuits to transformers which stepped down the voltage to 120 volts and 240 volts. Power was then transmitted at these voltage levels to the main distribution panel. The main distribution panel provided centralized control and distribution of power to all 240-volt loads. It also provided control for and distributed all 120-volt power to four individual compartment breaker panels, which provided centralized, local control and power distribution to all 120-volt loads in the respective compartments.

B3.3.3 System Ground

The electric power distribution subsystem was a grounded system except for the 480-volt circuit, which was ungrounded. This provided selective, positive operation of a circuit breaker to deenergize and completely isolate any circuit or load on which a fault had occurred. An equipment grounding system was also utilized to hold all electrical equipment enclosures at hull ground potential to prevent dangerous electrical shock. Each piece of electrical equipment had a grounding strap bolted to it for this purpose. Grounding straps were also used to hold the floor structures, cabinets and bunk frames at hull ground potential, since all of these structures had electrical equipment mounted on them. Mechanical mounting interfaces were not relied on to assure proper grounding.

B3.3.4 Power Umbilical Cable

The power umbilical cable, which transmitted 480-volt three-phase power from the surface support barge to the habitat, was armored between strain termination fittings, with an unarmored section beyond the strain termination fittings.

The 1000-foot cable assembly was composed of three waterproof, insulated, size 1/0 copper conductors with No. 8BWG polyethylene-coated galvanized steel wires wound around them. This outside armor protected the conductor insulation from abrasion and provided strain relief by supporting the weight of the cable. At both ends of the cable the armor wires were circumferentially clamped by a steel cable support fitting (O-Z Electrical Mfg. Co. Part FS0830). This cable support was bolted to the base structure of the habitat at one end and the surface support barge on the other end.

The waterproof connector plug at the habitat end (Burton Electrical Engineering Co. Part 5801-3804) was a four-pin connector with the umbilical cable conductors molded to its shell. The connector was supplied with a protective cap, which when mated to the connector provided a waterproof seal to 3000 psi. A mating cable and connector inside the habitat carried power from the umbilical plate to the main breaker panel.

The bulkhead connector mounted to the umbilical plate under the cabinets in the wet room. A nut screwed onto the connector shell from the water side secured the connector O-ring flange against the umbilical plate to provide a watertight seal. This connection was done on the water side; however since it was required that connectors be dry, it was necessary to lift the umbilical plate when mating them. Although the connector fittings were pressure resistant and watertight, after the connection was made the umbilical trunk was blown dry and remained dry during the mission.

B3.3.5 Power Distribution Sequence

All distribution panels in the power subsystem were of heavy-gauge steel construction and painted with a corrosion resistant nonflammable paint. Molded-case circuit breakers provided control and overcurrent protection for all circuits in the subsystem. A wiring shield prevented access to all internal wiring when the front door was open.

The main power panel in the engine room contained four 480-volt, three-pole molded-case circuit breakers and three current-limiting fuses. The main power panel provided a door-on-door feature. The 125-ampere main breaker controlled all electrical power being fed to the habitat by the power umbilical cable. It had an external operating lever at the top of the full-front-panel door. This operating lever was interlocked such that the main breaker had to be opened to secure all electrical power to the habitat before the full door could be opened. Wired in series with each pole of the main breaker was a 600-ampere current-limiting fuse. A voltage-sensing element wired across each fuse tripped the three-pole main breaker to prevent damaging a three-phase load had any one fuse burned out. The combination of the main breaker and the current-limiting fuses provided adequate overcurrent protection and selectivity with the remaining three circuit breakers in the panel.

The main distribution panel in the engine room (upper right in Fig. B20) provided overcurrent protection and distributed power for all the 120-volt and 240-volt circuits in the habitat. The main distribution panel obtained 120/208-volt power from the stepdown transformer bank on a three-phase, four-wire circuit and 120/240-volt power from the stepdown transformer on a single-phase, three-wire circuit. A simplified one-line schematic of the main distribution panel is shown in Fig. B21.

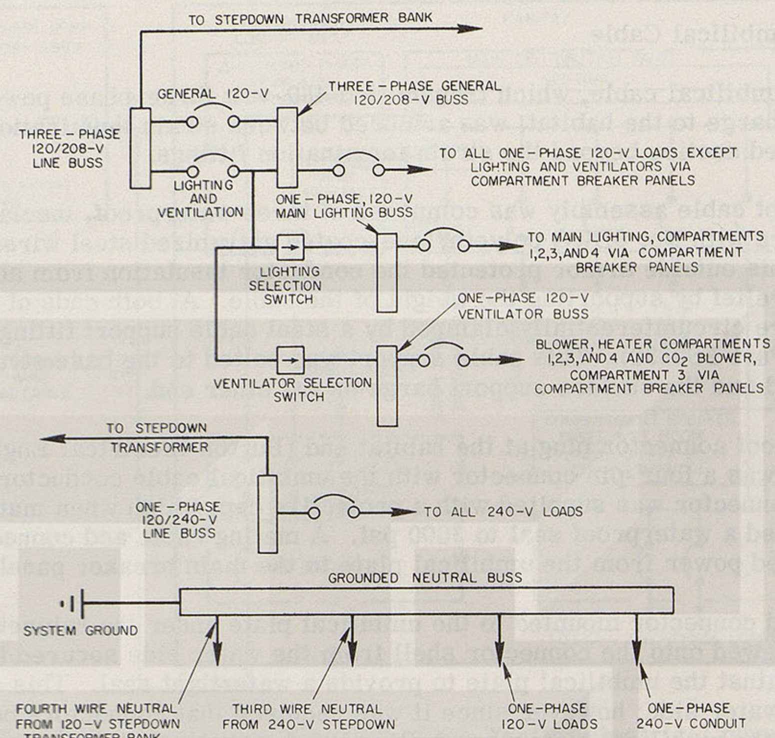


Fig. B21 - Single-line diagram of the main distribution panel. All 120-volt power from this panel is distributed on multiple one-phase, three-wire circuits to the individual compartment breaker panels. All 240-volt power from this panel is distributed on multiple one-phase, three-wire circuits directly to 240-volt loads.

A grounded neutral buss was provided to pick up the neutral and ground wire on all 120-volt and 240-volt circuits on both the line and load side. The system was grounded to the hull by a ground strap fastened to the neutral buss.

The compartment breaker panels, one in each compartment, obtained 120-volt power from the main distribution panel in the engine room on multiple, single-phase circuits which were enclosed in conduit. Each compartment breaker panel was identical in construction except for the number of circuit breakers which it contained. Table B2 indicates the breakers and ratings for each compartment and indicates the types of 120-volt services provided to the habitat.

Four 25-kVA 120/240-43/450/460/480/500/510-volt single-phase transformers (General Electric Model 9T21Y9615) were mounted in a ventilated enclosure behind the freezer in the engine room. Three of these transformers, wired in a delta-wye bank, stepped down the three-phase, three-wire, 480-volt power obtained from the main power panel to 120/208-volt power which was transmitted on a three-phase, four-wire circuit to the main distribution panel. The fourth transformer stepped down the one-phase, two-wire, 480-volt power obtained from the main power panel to 120/240-volt power which was transmitted on a one-phase, three-wire circuit to the main distribution panel.

Table B2
Breaker Panel Circuits

Breaker Number	Bridge		Crew Quarters		Equipment Room		Wet Room	
	Function	Rating (amp)	Function	Rating (amp)	Function	Rating (amp)	Function	Rating (amp)
1	Main lighting	15	Main lighting	15	Main lighting	10	Main lighting	15
2	Gen. outlet	20	Heater blower 1	20	CO_2 blower	15	Heater blower 4	20
3	Gen. outlet	20	Heater blower 2	20	CO_2 blower	15	Gen. outlet	20
4	Communi-cations panel	15	Gen. outlet	20	Heater blower 3	20	Gen. outlet	20
5	Biomedi-cal panel	5	Gen. outlet	20	Gen. outlet	20	Spare	–
6	Environ-mental control system panel	5	Spare	–	Gen. outlet	20	Exterior lighting	20
7	Reheater	50	Spare	–	Freezer/ toilet blower	15	Exterior lighting	20
8	Spare	–	Refrig.	10	Toilet	10	Exterior lighting	20
9	Spare	–	Stove	40	Spare	–	Exterior lighting	20
10	–	–	Reheater	50	Reheater	50	Reheater	50
11	–	–	Conden-sate pump	5			Sump/ bilge pumps	15
12	–	–	Spare	–			Spare	–

B3.3.6 Lighting and Assorted Fixtures

The interior lighting system contained four ceiling fixtures in each compartment to provide area illumination. These lighting fixtures could be continuously controlled from maximum to zero intensity with a dimmer switch in each compartment.

Supplementary lighting fixtures were used to provide additional illumination over countertops, bunks, and sinks. A shallow lighting fixture was mounted under all the wall cabinets to provide added illumination on the countertops. A swiveled lighting mixture was mounted at the head of all the bunks to provide individual lighting for each aquanaut.

Three 500-watt quartz iodide external lighting fixtures (Hydro Products Part LQ-10) were mounted on the habitat. The lighting fixtures were provided with a short three-wire waterproof lead which was terminated with an underwater connector. An extension cord, which was provided with a mating underwater connector on the water end, and a conventional three-prong (grounding) plug on the dry end carried power to each external lighting fixture. The extension cord entered the wet room through a 12-inch-diameter trunk and plugged into the special external-light-receptacle panel. This panel provided seven, three-prong (grounding) single receptacles (Hubbel No. 5261) rated for 15 amperes at 125 volts ac, each with a weatherproof lift cover plate. The maximum power available on any one circuit was 2000 watts.

Small rubber-bladed fans were mounted at the head of each bunk and in the cupola to provide additional ventilation.

Three-prong (grounding) duplex utility receptacles with a weatherproof lift cover plate were provided in each compartment for general-purpose portable loads. These receptacles were rated for 15 amperes at 125 volts ac.

B3.3.7 Alarms

An alarm was provided at the bridge alarm panel to provide visual and audible indication if power were lost on any one or more of the phases on the three-phase, 120/208-volt line buss in the main distribution panel. A functional schematic diagram of this alarm is shown in Fig. B22. If power were lost at the line buss, the amber alarm and the bridge buzzer would be energized. The buzzer was secured during an alarm condition by moving switch S1 to the "disable" position. Immediately the white disable light was energized. When the alarm condition was over, switch S1 would be reset to the "on" position. A "test" position was provided on switch S1 to test the function of the buzzer. Both the amber alarm light and the white disable light were provided with a "press to test" feature.

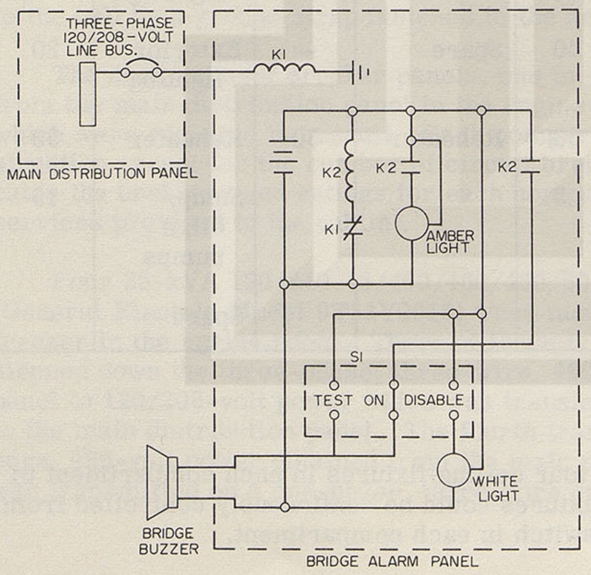


Fig. B22 - Power loss alarm. Relay K1 is one of three identical relays, each of which receives power from one phase of the three-phase buss. The normally closed K1 contacts of these relays are wired in parallel.

An alarm and control function was located in the habitat and the surface control center van to provide audible and visual indication and to secure all electrical power to the habitat if major flooding occurred in the wet room. A functional schematic diagram of this alarm and control function is shown in Fig. B23.

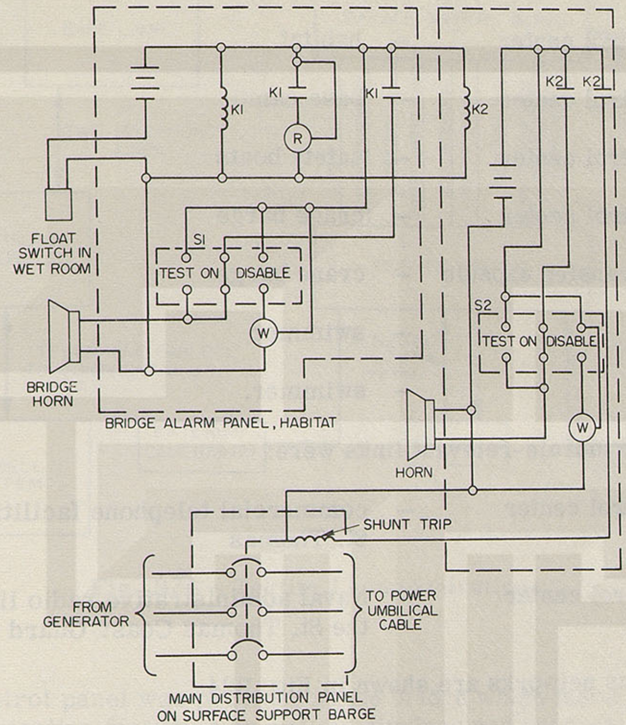


Fig. B23 - Wet room flood alarm

The float switch for the wet room flood alarm was mounted on the pressure hull in the wet room. Had the water level risen within the compartment to submerse the float switch, the following events would have taken place simultaneously:

- All power to the habitat would be secured through the operation of a trip device to open the three-pole circuit breaker feeding the power umbilical cable.

- A red alarm light in the bridge alarm panel would be energized.

- The bridge horn would be energized.

- The horn in the surface control center van would be energized, indicating that the habitat was flooding.

B3.4 Communications Subsystem

B3.4.1 General

The Tektite I communication plan required that voice communication be provided between the following locations or activities. The safety-relevant links were:

Surface control center	—	habitat
Surface control center	—	base camp
Surface control center	—	safety boats
Surface control center	—	crane barge
Personnel transfer capsule	—	crane barge
Habitat	—	swimmer
Swimmer	—	swimmer.

The Administrative or morale-relevant links were:

Surface control center	—	commercial telephone facilities via St. Thomas
Surface control center	—	Naval administrative radio links via the St. Thomas Coast Guard Station.

Elements of the various networks are shown in Fig. B24.

B3.4.2 Control Center-Habitat Communications

The communications system provided voice and visual control communication between the surface control center van and the habitat. The communication link from the van to the habitat was a 1000-foot high-quality submarine cable which contained 51 shielded twisted-pair and 12 triaxial video circuits. All audio, video, and data signals flowed through this link. These elements are shown schematically in Fig. B25.

B3.4.3 Umbilical Communications Cable

The communications umbilical was an armored submarine cable containing 51 shielded 22-gauge twisted-pair and 12 triaxial video cables which were RG 59/U equivalents in electrical characteristics. The cable cross section is shown in Fig. B26. The nominal air weight of the cable was 2.79 lb/ft, and the weight of the cable in water was 0.92 lb/ft. Both ends of the cable were terminated in multipin connectors for ease in field deployment and recovery. The habitat end used three 51-pin, high-density, subminiature connectors to terminate the 51 shielded pairs in a volume small enough to pass through the communication umbilical stuffing tube after being given a waterproof wrapping. Each end of the cable was connected to a set of mating connectors at a communication cable junction box.

B3.4.4 Communication Centers

The bridge functioned as the communication center for the habitat, and the watch director's station in the van functioned as the surface communications center.

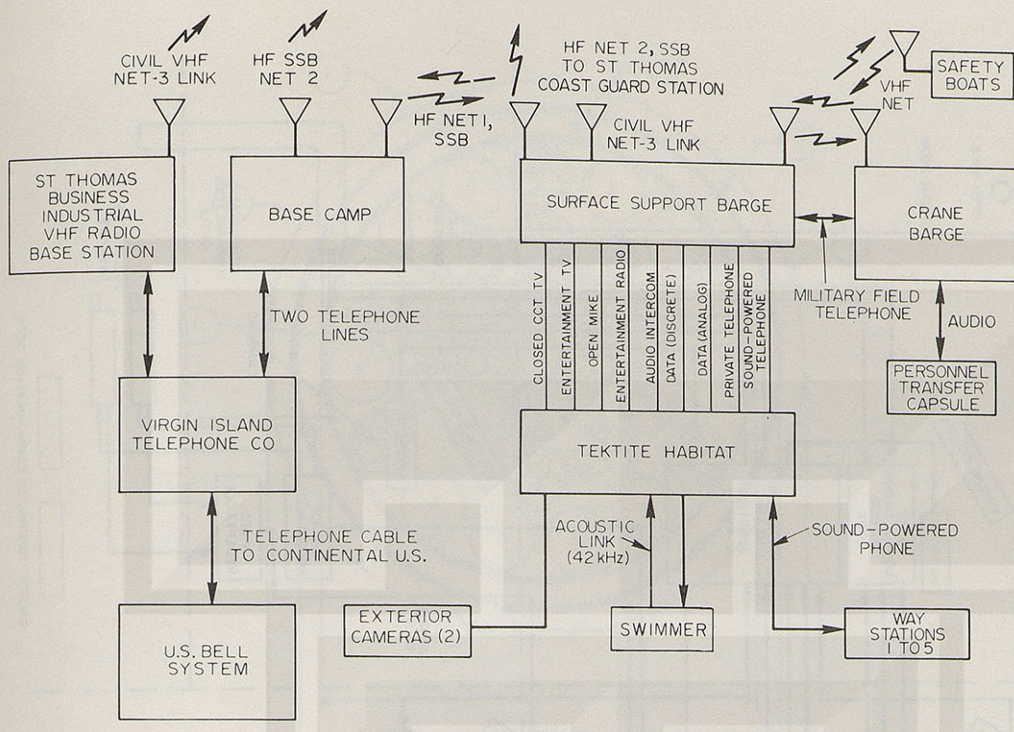


Fig. B24 - Tektite I communications

A technical control panel was provided at the bridge which featured a convenient grouping of communication facilities as well as displays and readouts pertaining to environmental control and crew safety. Displayed information included pN_2, pH_2O, pO_2, pCO_2, water level in the entry trunk, flooding, and power loss. The partial pressures of the three important atmospheric gases were displayed on meters. The pCO_2 and the pO_2 meters incorporated solid-state relays controlled by movable set points to permit crew adjustment of alarm actuating values. The data essential to crew safety and for mission control was displayed at and controlled from the habitat and from the watch director's station of the van.

The behavioral observation station was located in a closed-off area of the van. Here the television monitors, audio facilities, video and audio recorders, and associated technical control consoles were conveniently and compactly arranged for the behavioral staff. The television monitors were six 14-inch studio-type monitors with video recording capability. The behavioral station could not communicate directly with the habitat.

B3.4.5 Communication Modes

B3.4.5.1 Open Microphones

One cardioid microphone centrally located in each of the four habitat compartments fed one of a set of four audio amplifiers on the bridge which raised the audio level sufficiently to overcome umbilical cable losses and minimize other distortion and noise effects incidental to wire distribution. At the surface additional amplifiers and attenuators were employed to permit high-quality sound distribution in the behavioral monitor station.

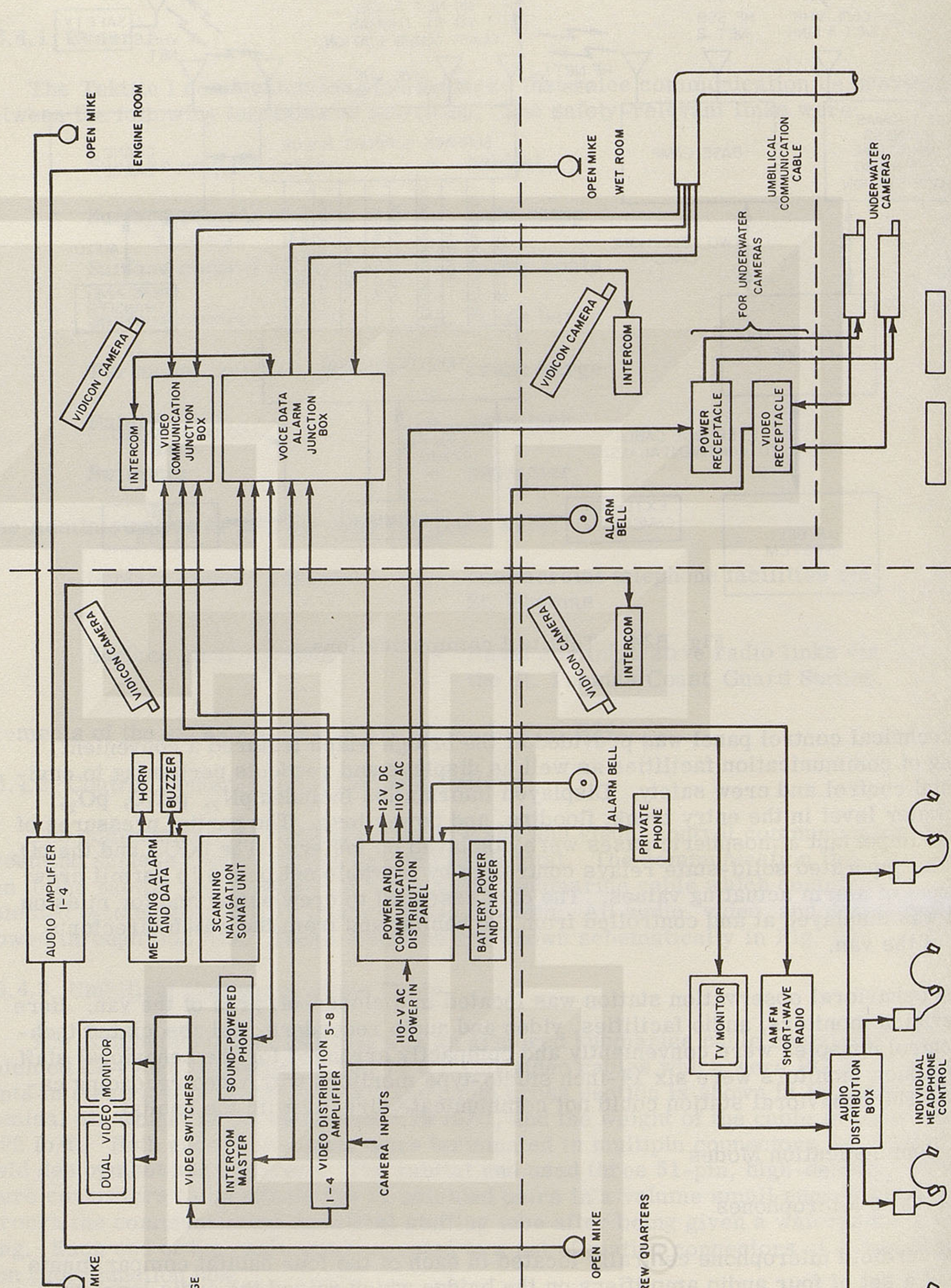


Fig. B25 - Elements of the communication links between the control center and the habitat

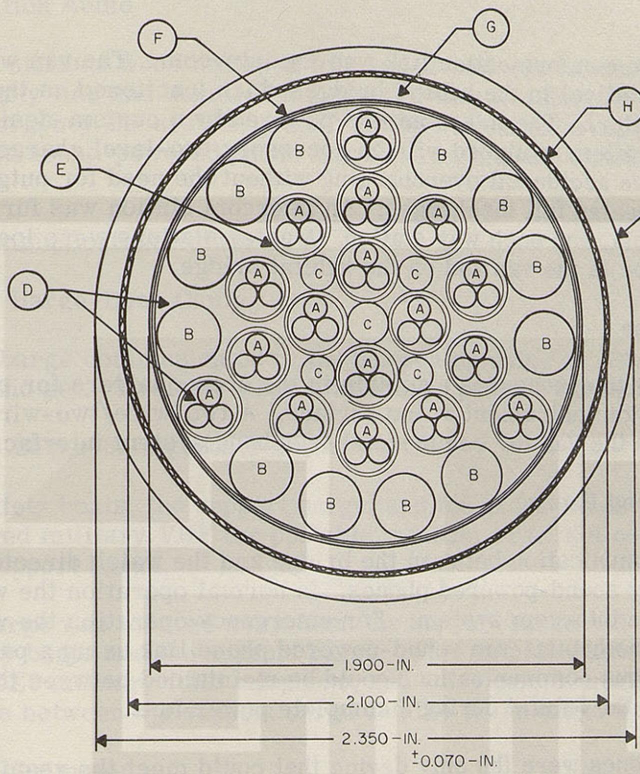


Fig. B26 - Communications umbilical cable: A -- 102 No. 22 AWG 7/0.0.010 T.C., BIW (Boston Insulated Wire and Cable Co.) E-08 insulation, BIW N-01 jacket of 0.052-in. O.D. (51 pairs), BIW T-31 tape binder, No. 36 AWG T.C. shield, BIW T-34 printed tape, and BIW N-06 jacket of 0.145-in. O.D.; B -- twelve 75-ohm triaxial, No. 22 AWG 6-30 T.C. over 1-30 T.C. WLD, BIW P-02 insulation, No. 36 AWG T.C. shield, BIW E-08 insulation, BIW N-06 jacket, No. 36 AWG T.C. shield, and BIW E-08 jacket of 0.288-in. O.D.; C -- BIW HF rubber core and fillers; D -- BIW AF-17 blocking compound; E -- BIW T-34 printed tape binder; F -- BIW T-39C tape binder; G -- BIW E-09 belt; H -- BIW A-44 flat SST armor; I -- BIW V-19 PVC jacket

B3.4.5.2 Closed Circuit TV

Four TV cameras, one in each habitat compartment, fed a video distribution system similar to the open microphone audio system. Two more cameras were available for use outside the habitat. The video system was used for mission operations and control as well as for behavioral observations, and for this reason dual monitors with separate video switches were furnished in the watch director's station in the van and also on the bridge for aquanauts. The TV cameras in the compartments were commercial videcon types provided with wide-angle lenses to permit a large compartment viewing area and to avoid crew distraction from pan and tilt camera motion.

B3.4.5.3 Intercom

The primary voice communication link was the intercom. The van was connected via the communication umbilical to the habitat bridge (which functioned as the habitat communication control center). The intercom was powered by a custom-designed sealed 12-volt nickel-cadmium battery equipped with an accessory two-level charger. The battery was designed to survive accidental overcharging without the need for outgassing ports. It could also survive repeated full discharges. An intercom station was furnished in each compartment, the cupola, and each way station. Master stations were located at the watch director's station in the van and on the habitat bridge.

B3.4.5.4 Private Phone

A common battery telephone was available in the crew quarters for private conversations with a companion instrument at the surface. A two-wire/two-wire telephone repeater was provided in the van for commercial telephone system interfacing.

B3.4.5.5 Sound-Powered Phones

Backup voice communication between the bridge and the watch director's station or the way stations was by sound-powered phones. In normal operation the way stations were connected into the intercom system. For emergency operation the way stations could be patched into the habitat-van sound-powered phone link using a patch cord provided at the bridge. Thus communications could be maintained between the surface and crew inside or outside the habitat during a complete power loss.

Sound-powered phones were the only device that could meet the requirements for a voice communication instrument that would function in the event of a power loss, would be economical, survive the marine environment, and integrate into the intercom system with minimum interface impact. The unit selected had provisions for plug-in transducer elements, since this was the part most likely to fail. The sound-powered handsets in the way stations were stored in dry boxes, which were merely inverted containers designed to trap air to protect the handsets from immersion when the way stations were flooded after use. The dry boxes were provided with underwater pluggable connectors permitting easy removal of the boxes and at the same time permitting closure of the party-line link by joining the mating line connectors.

B3.4.5.6 Links

Analog output voltages in the 0-to-V-dc range from the mass spectrometer were fed to the surface for meter display at the watch director's station through isolation amplifiers. The same displays were available on the bridge. Discrete voltages were also fed to the van over the umbilical cable to furnish records for behavioral accounting of selected housekeeping and other activities. These were recorded by a Franklin printer located in the behavioral monitor's station.

B3.4.5.7 Entertainment

Entertainment radio and TV sets were provided in the crew quarters. The signals were transmitted from the surface antenna to the habitat using triaxials in the umbilical.

B.3.4.5.8 Morale Telephone

A morale telephone link was provided in the field by adapting the intercom to a rented VHF mobile communications system. This system had interface capabilities with the local Virgin Islands Telephone Company.

B3.4.5.9 Way Station Audio

The five way stations were equipped with sound-powered handsets. Each station was connected as a party line and then tied into the van-habitat intercom to boost the line levels. In an emergency the system could function without external power. It could also be patched into the sound-powered phone link between the habitat and the watch director's station.

B3.4.6 Other Communication Networks

B3.4.6.1 Support Barge-Base Camp

The support barge communicated to the base camp using an AN/PRC-47 HF single-sideband field radio set. Two sets were available to provide for backup operation.

B3.4.6.2 Support Barge-Safety Boats-Crane Barge

The diver safety boats, the support barge, and the crane barge were linked in a VHF net which employed military VHF for portable transceivers. Net control was the watch director on the support barge.

The crane barge was moored away from the support barge and operated in the VHF net with the safety boats and the support barge. Wire communications were a secondary means using an EE8 military field telephone, and voice communication was also possible since the distance between the support barge and the crane barge was in tens of yards.

B3.4.6.3 Habitat-Swimmer

An Aquasonic 420 acoustic communicator was provided for habitat-diver and diver-diver communications. This unit operates using AM modulation on a 42 kHz carrier.

B3.5 Ancillary Equipment

B3.5.1 Transfer Pots

Two sizes of transfer pots were used during the Tektite I mission to make dry transfer of materials between the surface and the habitat. Two of the smaller size and one of the larger size were used; an intermediate size was available but not used because of the greater handling ease of the smallest pot.

The small pots were commercial paint tanks of 3-gallon capacity. A valve was installed in the lid to permit pressure equalization after each transit. The lid was secured with four T-bolts having large wing nuts that were tightened to effect a seal. The lid also incorporated a wire-rod handle. Lead weights were added inside the pot as required so that it was close to neutral buoyancy. The small pots proved to be extremely useful and saw much service during the startup and checkout phase as well as during the mission. The only difficulties encountered were procedural problems. After several occasions when the pot was flooded, a more thorough check procedure was adopted before each transfer; the wing nuts and equalization valve were verified as secure.

The larger pot (Fig. B27) was fabricated from 2-foot-diameter steel pipe and incorporated a standard hinged closure, secured by T-bolts. A pressure equalization valve was installed in the closure. The inside height of the pot was approximately 3 feet, sized to take the largest replaceable component in the habitat. The pot was intended to be neutrally buoyant but was made overweight in error. As a result the pot was awkward to

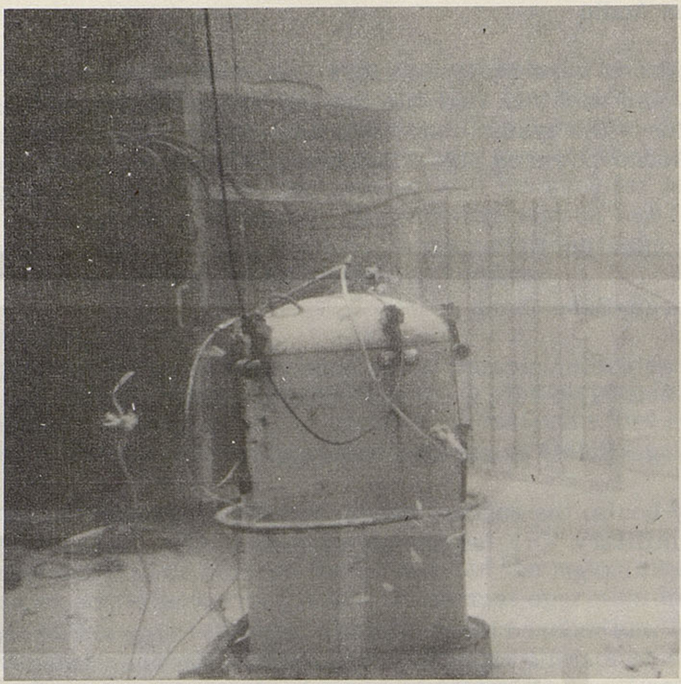


Fig. B27 - The large dry-transfer pot used; two small pots were also used

handle in the water. To facilitate handling, a raft was moored on the surface near the habitat so that the pot could be lowered on a line. The pot was then manhandled by divers into the entry trunk, where it was lifted by the chain hoist installed over the hatch in the wet room.

Despite its awkwardness the large pot proved to be invaluable, and saw almost daily use during the mission. Its most significant role was enabling the mass spectrometer to be returned to the surface for repairs during the early part of the mission. As with the small transfer pots it became necessary to adopt a rigid procedure of checking the bolts and equalization valve before each transfer to prevent accidental flooding of the pot.

B3.5.2 Way Stations

Each of the five way stations provided as part of the ancillary equipment for the habitat consisted of a base structure, cage enclosure and Plexiglas dome (Fig. B28). Inside the dome a sound-powered phone was mounted.

The base structure consisted of a square steel plate, 1-1/4 inch thick, providing sufficient ballast to maintain negative buoyancy of the way station when the dome was filled with air. The cage structure was fabricated from 1/2-inch-diameter steel rods, welded to 4-foot-diameter rings and bolted to the base structure. A section of the cage structure was hinged to swing outward as a door. A stainless-steel-bar latch on the door was located so that it would be easily operated from either side of the door. The hinges for the door consisted of simple stainless steel pins. On the door was mounted a plate with a number, from 1 to 5, identifying the particular way station.

Fig. B28 - One of the five way stations, which served as shark cages and as rest and communication stations. The spare scuba tanks were maintained by surface support divers.

The dome was clamped to the upper ring of the cage enclosure at its flange. The dome was 4 feet in diameter, free blown from 1/4-inch-thick acrylic sheet (Plexiglas G). Inside the dome was mounted an inverted box that enclosed the sound-powered phone. This enclosure trapped air to keep the handset dry when the dome was flooded with water. This approach was chosen as being more economical than providing a phone designed to withstand immersion in the water. The phones in the five way stations were wired into a patch panel in the habitat in such a way that they tied in with the intercom system and hence to the surface support barge, and yet they could be operated independently of habitat power. A small brass valve was located inside the dome of the way station at the apex, so that the air in the dome could be vented.

All steel parts of the way station were painted with a nonmarine anticorrosive paint, the finish coat being a black enamel to provide a visible contrast with the sandy bottom. Because the steel parts did not receive the appropriate surface preparation prior to painting, it was not possible to apply the same anticorrosive, antifouling paint system that the habitat received. The Plexiglas domes received no special treatment prior to emplacement, other than a strippable protective coating that was removed at the last possible opportunity.

The way stations were used as a temporary shelter by the aquanauts when working outside the habitat. One way station was located near the habitat and the other four were located in the most frequently visited work sites remote from the habitat. During the Tektite I mission the way stations were used by the aquanauts to rest, converse, and adjust breathing equipment. Spare scuba bottles were kept at the way stations to extend the excursions of the aquanauts and to fill the dome of the way station with air before each use. The spare bottles were delivered and the empties returned by surface support divers. The way stations provided emergency protection from sharks and a means of calling for assistance for an injured diver. Fortunately no such emergency conditions occurred during the mission.

The way stations performed satisfactorily during the mission. Difficulties that were encountered with the sound-powered phones were in most instances procedural problems. On one occasion the phones were removed from all five way stations and returned to the surface for inspection. Two of the phones showed indications of damage due to accidental immersion, and the other three were in proper operating condition. The vent valve in a dome was replaced on one occasion because of a missing handle.

Postmission inspection of the way stations revealed that they were coated with an easily removable marine growth. No attempt had been made during the mission to clean the way stations, with the result that the domes were clouded with marine growth.

B4 SUPPORT BARGE

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B4.1 Introduction

The support barge supplied the habitat with breathing gases, electrical power, and potable water. It provided for several forms of audio and visual communications between the aquanauts and personnel located at the support barge, the crane barge, the base camp, and the outside world. It provided for readout of scientific, engineering, and operational data from the habitat. It served as a center for monitoring and controlling all primary mission operations and safety.

B4.2 Design Conditions

A set of conditions was preselected which had to be met in the design of the support barge and its systems. The design conditions were divided into the following categories:

1. Vertical loads, movable as well as static, which included the weight of the structure, equipment, facilities, and supplies. A list of the design vertical loads is given below:

Weight of structure	85,120 lb
Generators, transformers, and distribution panel	13,440 lb
Control van with instrumentation and TV	13,440 lb
Two main-supply air compressors	224 lb
Purge air compressor	3,000 lb
Purge air aftercooler	896 lb
Two scuba-charging air compressors	448 lb
Bank of five nitrogen bottles and one emergency air bottle	31,360 lb

Control console	291 lb
Fresh-water pillow tank (full)	29,120 lb
Two fresh-water pumps	224 lb
Fuel tanks (full)	4,480 lb
Piping and valves	2,240 lb
Outfitting	8,960 lb
Gear	2,240 lb
Personnel	2,240 lb
Total vertical load	197,723 lb

2. Lateral loads, which included wind, waves, hydrostatic pressure, currents, tides, earthquake forces, berthing impacts by support vessels, and other lateral loads due to operating equipment. Environmental data for the site were meager. The historic weather data collected for the months of operation involved, January through May, were: maximum wind velocity, 10 to 15 knots; predominant wind direction, east; average tides, 1 foot; maximum tides, 2 feet; maximum current, 1 knot; and predominant sea state, 0 to 1. The parameters used for design were: maximum wind velocity, 20 knots from any direction; maximum wave height of wind-generated surface waves, 3 feet; maximum period of wind generated surface waves, 6 seconds; maximum height of swells, 6 feet; maximum period of swells, 15 seconds; hydrostatic pressure, from 0 to 10 feet in depth; currents, 1 knot; tides, 2 feet; earthquake zone, 1; and berthing impact, 500 pounds per linear foot. The disturbance generated by the swells close to shore line presented acute problems during the site preparation. The day before the emplacement of the support equipment center the tide was approximately 2 feet. During the emplacement of the support barge the maximum swell observed was 2 feet with a period of 15 seconds, and the wind velocity was 8 knots in the bay with gusts up to 12 knots. Outside of the bay the wind velocity was between 20 and 25 mph.

3. Ocean bottom soil and topography. The near-shore ocean bottom in the vicinity of the habitat site was predominantly coral and rock, with many outcroppings of each and some limited areas of coral sand.

4. Water temperature. The average surface temperature of the water was 75 to 80°F; the average bottom temperature was 70 to 75°F.

5. Underwater visibility. The visibility was 20 to 40 feet.

6. Surface topography. In the vicinity of the habitat site nearly vertical rock cliffs lined the shore. Farther into the bay the land became flat and low. This area was filled with an overgrowth of large and small trees, shrubs, and plants.

B4.3 Site and Structural Concept Selection

During the selection of the site for the support equipment center various functional requirements, specific conditions, and specific constraints had to be taken into consideration. The functional requirements included ample space for equipment and personnel, berthing of support boats for transfer of personnel and supplies, and replenishment of water and fuel. Some of the specific conditions which had to be dealt with were wave action, wind action, surface and subsurface currents, the soil conditions, and the bottom and shore topography.

Three alternatives were possible for the support center: an onshore platform, an offshore floating platform, or an offshore elevated platform. Two constraining factors led to dropping the floating platform from further consideration. These were stability considerations and noise and vibration. An elevated platform would provide a more stable platform for the control van with all its instrumentation. It would also keep the noise and vibration transmitted into the water to a minimum and thus prevent any gross disturbances to the ecology of the reef which the aquanauts wanted to study, and it would be less disturbing to the aquanauts themselves.

There were other conditions and constraints which affected the final choice of site and type of platform. Procurement of umbilicals had to be initiated in advance of site selection due to a long lead time. The specified 1000-foot length of the umbilicals made it mandatory to locate the support equipment center within 900 feet of the habitat. The Tektite I operation was in a U.S. National Park. To preserve the natural beauty of the area, no clearing of sites of their natural vegetation could be done without the consent of the Park authorities.

Three sites were investigated (Fig. B29). On each site the possibilities of using an onshore platform or an elevated platform above the water were considered. To make a sound decision, the following evaluation was necessary:

At site 1 the advantages of an onshore platform were that it would be outside the influence of waves, swells, and current; construction would be easier out of the water; and it would be within the limit of 900 feet from the habitat site (450 ft). The disadvantages were a rough terrain, expensive construction, and problems in transferring equipment and personnel. The advantages of an elevated platform were the availability of an elevated platform, ample area to work, accessibility by boats and platforms for transfer operations, and a location within the limit of 900 feet (400 feet). The disadvantages were construction problems in water, a rough ocean bottom, requirement of mooring, and exposure to wind, waves, swells, and current.

At site 2 the terrain was too rough for an onshore platform, and the approaches were blocked by large rocks. The advantages of an elevated platform were that the area seemed to be protected by a natural breakwater and the platform would be within the limit of 900 feet (750 feet). The disadvantages were a rough ocean bottom; requirement of mooring; construction problems in water; swells that were chaneled into a smaller opening resulting in their magnification; a longer distance from the habitat site than site 1; and hazardous conditions for small-boat operations.

At site 3 the advantage of an onshore platform was a level terrain. The disadvantages were that the distance from the habitat was greater than 900 feet and that clearing of trees and plants from the site was not allowed by Park authorities. The advantages of an elevated platform were a smooth bottom and small waves and swells. The disadvantage was that the distance from the habitat was greater than 900 feet.

Site 3 was ruled out completely, since it was outside the 900-foot radius from the habitat. At site 2 there was no possibility of an onshore platform due to the rough terrain. There were more disadvantages and fewer advantages for an offshore elevated platform at site 2 than at site 1; therefore site 1 was chosen. The next problem was to choose between the onshore platform and the offshore platform at site 1.

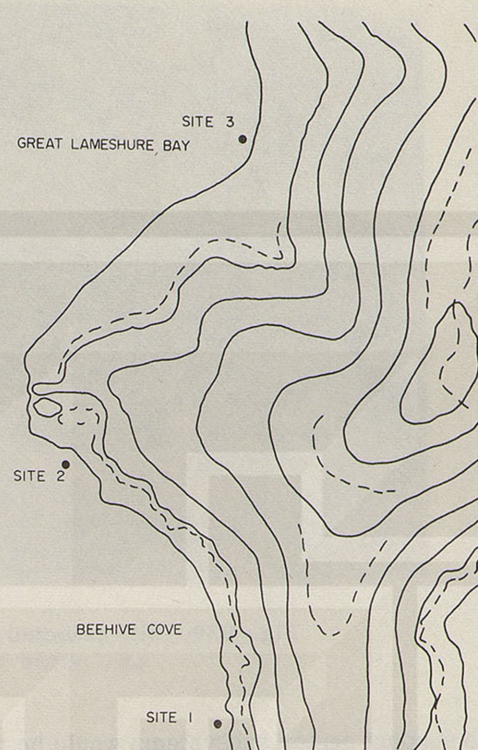

Fig. B29 - Three sites investigated in selecting the site of the support barge

The site for the onshore platform was at the mouth of a draw which ended in Beehive Cove. This spot offered the only relatively flat area in the vicinity, the remaining area being the steep rock cliffs mentioned. After a further on-site survey of the area it was determined that at least one leg of any platform built there would have to be out in the water in order to have the estimated deck area required for all of the support equipment.

To make a final choice the time element had to be taken into account. There were 6 months at the maximum in which to do all design work, site layout, procurement, assembly, and on-site construction. This time frame was not just for the habitat support center but for all of the support systems for the project. This time limit made for very tight scheduling of all phases of the project. It was, therefore, mandatory in the design stage to go to off-the-shelf or all-ready-built items as much as possible. The time element would not allow time for the proper testing of new or improved hardware or construction methods.

Another problem was logistics. The location of the project was in an isolated area with access by ship only. There were no wholesale or retail distributors of most materials for fabrication in the area. The closest naval base was at Roosevelt Roads, Puerto Rico. For all practical purposes all materials and hardware would have to be procured in the continental United States.

Consideration of the time element, tight scheduling, and logistics problems and other problems involved in building an onshore platform on site and transferring all of the machinery, the control van, and other support items to the platform discouraged use of this scheme. It was decided to use an offshore elevated platform at site 1 with all support systems preassembled in the continental United States. This site (Fig. B1) was approximately 400 feet from the habitat site, near shore in Beehive Cove. Figure B30 shows the site as photographed during the initial site survey.

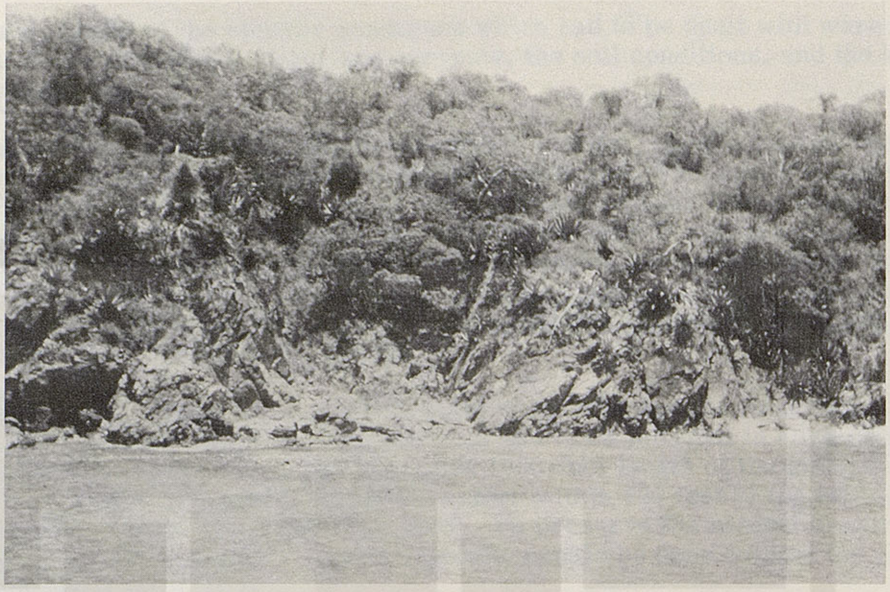

Fig. B30 - Site selected for the support barge

The support center subsystems would be mounted on an Ammi pontoon and would be assembled at the Philadelphia Naval Shipyard, where adequate facilities and logistics were available. The whole barge-mounted system could be transported to St. John, Virgin Island, in an LSD and then towed to its final site and hoisted up on piles.

The final position of the support barge was determined in the following manner: The Ammi pontoon has six 24-inch-I.D. spudwells in it. These are holes through the pontoon, top to bottom, through which pile legs can be placed. The four corner spudwells would be used on the support barge. A template was made using four inflated inner tubes with connecting lines. The inner tubes were spaced the same distances apart (length, beam, and diagonal) as the four corner spudwells of the Ammi pontoon. The template was floated over the site and manipulated by swimmers until a position was found at which all four pile legs would be sitting on a relatively flat surface amid the rocks and coral outcroppings on the bottom (Fig. B31). Markers (plastic-bottle floats) were then placed at the pile leg spots for future reference in positioning the support barge.

A topography of the bottom was obtained by Seabee divers using elevations of the tops of large rock and coral outcroppings. This was done to be sure that the support barge would not come in contact with any obstruction while floating over its site and suffer possible damage. The divers also marked with plastic floats the rock outcroppings in the vicinity which would be hazardous to small-boat operations.

B4.4 Barge Structure

The support barge platform was a 90-foot-long by 22-foot-wide by 4-foot-deep Ammi pontoon. It weighed 38 tons, drew 9 inches of water unloaded, and was capable of supporting 172 tons with 10 inches of freeboard. This pontoon, one of a family of sizes, is named after its principal designer, Dr. Arsham Amirikian of the Naval Facilities Engineering Command. The Ammi pontoon was conceived as a cargo offloading functional component for use in advance base areas lacking deep-water port facilities. This pontoon furnishes the Navy's Seabees with a unique component for rapid port construction.

Fig. B31 - Template for locating the positions of the support barge legs

The shell and interior bulkheads are 1/4-inch steel plating. The framing members (Fig. B32) of the Ammi pontoon are unique sections formed of 3/16-inch steel plate serrated along both edges and bent to form a U shape. This configuration gives high strength while decreasing the total weight of the structure. Spudwells are provided in the pontoons through which pipe piles can be driven into the ocean bottom to provide secure anchoring of the pontoon. The pontoon may also be raised on the pile legs by the use of hoisting pile caps and a tackle arrangement and winching the pontoon up.

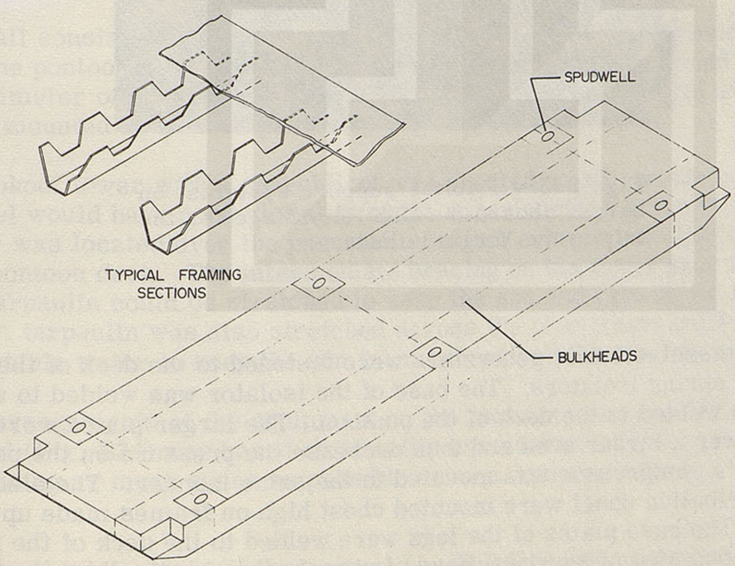

Fig. B32 - Typical Ammi pontoon

Mounted on the pontoon were all of the subsystems required for the support and monitoring of the habitat and its occupants. Supports, connection methods, and tiedowns were designed for all pieces of equipment or subsystems, piping, and other appurtenances. These supports were designed not only to withstand the on-site design load but also to withstand the forces during transit from Philadelphia Naval Shipyard to St. John, Virgin Islands (Fig. B33). Typical support types used were skid mounts, bolted bases, column bases and vibration isolators. All connections made between base plates and pontoon deck were by welding.

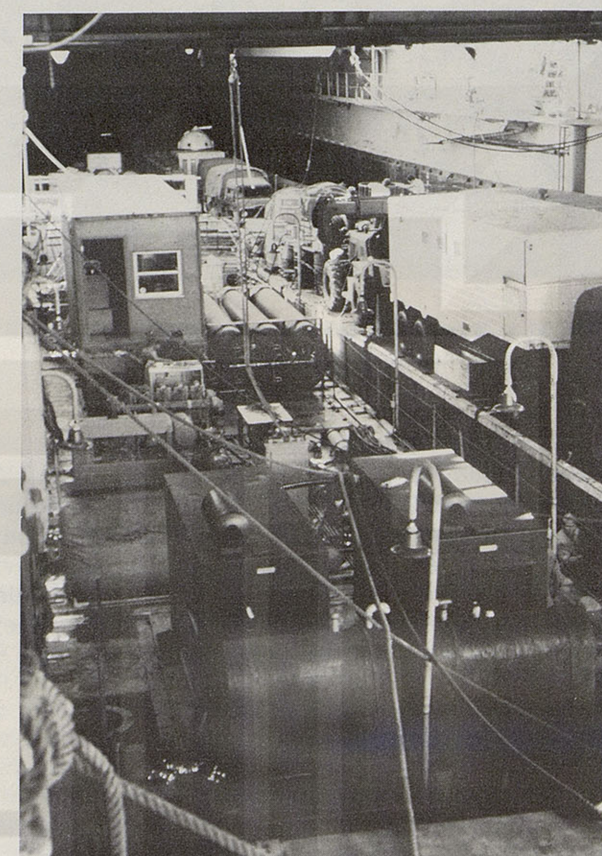

Fig. B33 - Habitat support systems on barges aboard the USS Hermitage for the trip to the Virgin Islands

The 100-kW diesel-electric generators were fastened to the deck of the pontoon through vibration spring isolators. The base of the isolator was welded to a larger plate, which in turn was welded to the deck of the pontoon. The larger plates were used to distribute the load over a larger area and thus decrease the pressure on the pontoon decking. The purge air compressor was mounted in the same manner. The electric transformers and distribution panel were mounted chest high on frames made up of braced steel-pipe legs. The base plates of the legs were welded to the deck of the pontoon. The antenna support consisted of short sections of pipe, to receive the three legs of the antenna, welded to a base plate, which was welded to the deck of the pontoon.

The 275-gallon fuel tanks were elevated on their usual steel-pipe legs. For transportation, flat steel bar braces were used across the legs. The bases of the pipe legs were welded to the deck of the pontoon. The 3000-gallon fabric pillow tank for fresh water was placed on the pontoon deck with no supports required, since the tank was empty during transit.

The support van was tied down using wire rope and turnbuckle guys. Both vertical and diagonal tiedowns were designed. The guys consisted of 3/8-inch-diameter wire rope and 5/8-inch jaw-ended turnbuckles. Each guy was connected to the van through a 1/2-inch anchor shackle to an eyebolt connected to a girder of the van's deck framing. At the other end of the guy the jaw end of the turnbuckle was connected to a padeye welded to the pontoon deck.

All other equipment used one of the typical skid, bolted, or column bases. Equipment having a bolted base was bolted to I-beams welded to the deck. All piping and conduit were raised off the deck to decrease corrosion. The piping was clipped onto short pieces of channel welded to the pontoon deck. Sanitary facilities were provided on the barge by a portable, skid-mounted chemical toilet.

All tiedowns and supports were either designed for or analyzed using forces developed by a 15-degree roll with a period of 2.091 seconds. Capability of the supports was also analyzed for the forces from the wind and wave loadings on site.

Strain reliefs for the umbilicals were provided on the side of the pontoon. For the power umbilical the armor was peeled back and clamped between two collars in turn bolted to the fuse. The pneumatic umbilicals were secured to the side of the support barge with hose clamps. An alternate method designed for the strain reliefs, but not used, was a method incorporating woven cable grips.

Other appurtenances included towing padeyes, mooring bitts, chocks, and cleats. The chocks were placed at the ends of the pontoon with the towing padeyes in line behind them. The mooring bitts were placed along the sides of the pontoon at intermediate distances from the ends. These hardware items were used during towing, for mooring the pontoon in position, for mooring two barges together, and for use in mooring small boats to the pontoon. They were all welded to the deck of the pontoon.

A guard rail consisting of pipe stanchions and fiber ropes was provided around the perimeter of the pontoon for safety. Lighting for the barge was provided by light poles around the perimeter of the pontoon. For fire protection dry-chemical and water extinguishers were mounted at various places on the barge.

A steel lookout tower with a searchlight was erected on site on the barge so that the watch personnel would have good visibility of the water surface in the vicinity of the habitat. The tower was located over the pneumatic control console with its leg base plates welded to the pontoon deck. The intermediate bracing on the tower provided a framework over which a tarpaulin could be stretched to keep the sun and rain off of the console and its operator. A tarpaulin was also stretched across the pipe frame built around the pillow tank for potable water to keep the sun from excessively heating the water.

Various arrangements of the equipment on the pontoon were studied. The final arrangement used (Fig. B34) was based on stability considerations, minimizing list and trim, and providing as much space as possible around equipment for operation and maintenance.

The measured total weight of the support barge with a full load of water and fuel was 88.27 tons. The pontoon had an average draft of 1 foot 8 inches, 3.68 inches of trim, and

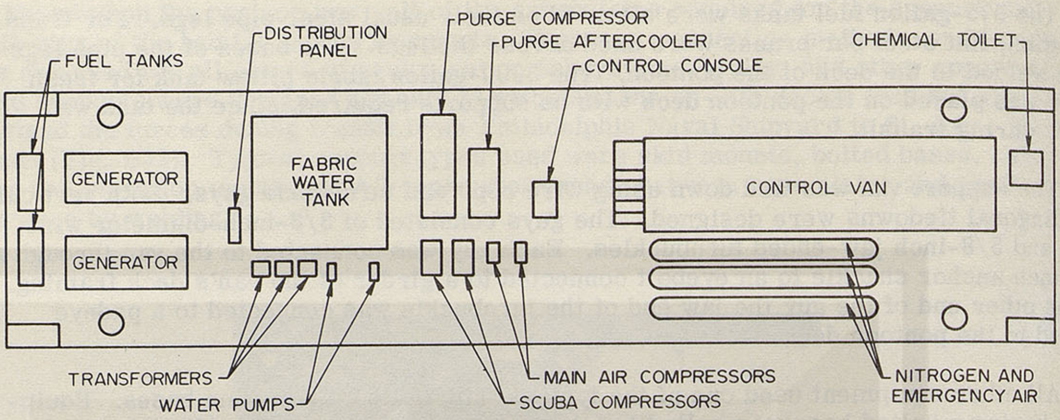

Fig. B34 - Support barge layout

a list of 1.7 inches. With no water or fuel aboard, which was the condition most of the time while afloat on site, the total weight of the barge was 70.47 tons. In this condition the mean draft was 1 foot 4 inches, the average trim was 3 inches, and the average list was 10 inches.

B4.5 Foundation and Elevating Mechanism

The Ammi pontoon contains six 24-inch-I.D. spudwells through which pipe piles can be inserted, and since the support platform was to have legs at only the four corner spudwells, the remaining two were covered over with plate for safety. Moments, shears, and deflections of the pontoon were analyzed based on the four leg supports, and all stresses were within allowable working strength limits.

The legs to be used were 20-inch-O.D. pipe piles with a 3/8-inch wall thickness. Normally the piles for the Ammi pontoons (and for most nonfloating ocean platforms) are driven into the bottom, but at the support barge site the ocean bottom was hard rock. Since the legs would be sitting on the bottom, a bracing arrangement was designed to hold the legs plumb while the pontoon was being winched up. Out of seven methods of support investigated, a guy cable system was chosen for ease of fabrication and assembly. Each leg was to have three guys 120 degrees apart. The guy cables were made up of 1/2-inch 6 by 19 wire rope and 3/4-inch shackle-end turnbuckles. Three-quarter-inch anchor shackles were used on the ends to make the connections. With the bottom being rock, the bottom connection point for the guys would incorporate rock bolts. The three holes per pile leg would be drilled in the bottom rock by divers. Rock bolts were to be inserted in the holes, and bent plates, with holes burned in them to receive a shackled end of the guy, would be bolted to the bottom (Fig. B35). For the pile-leg connection of the guys, a connecting ring (two half rings) was designed to fit around the pipe leg. The rings were made of 1-inch plate. Padeyes were welded on the rings to take the guy-connecting shackle. The two half rings would be bolted around the pile legs by divers after the piles had been inserted through the spudwells. To keep the rings from sliding down the piles, four stopper plates would be welded on the pile at the proper elevation for the ring to rest on.

The elevating mechanism for the support barge consisted of a pile cap, a ten-part line assembly, a winch, and safety chains (Fig. B36). There was a complete mechanism on each pile leg. The pile caps were made up of 18-inch-O.D. pipe and 1/2-inch steel plate. Reinforced holes were provided for sheave and chain connections. The winches

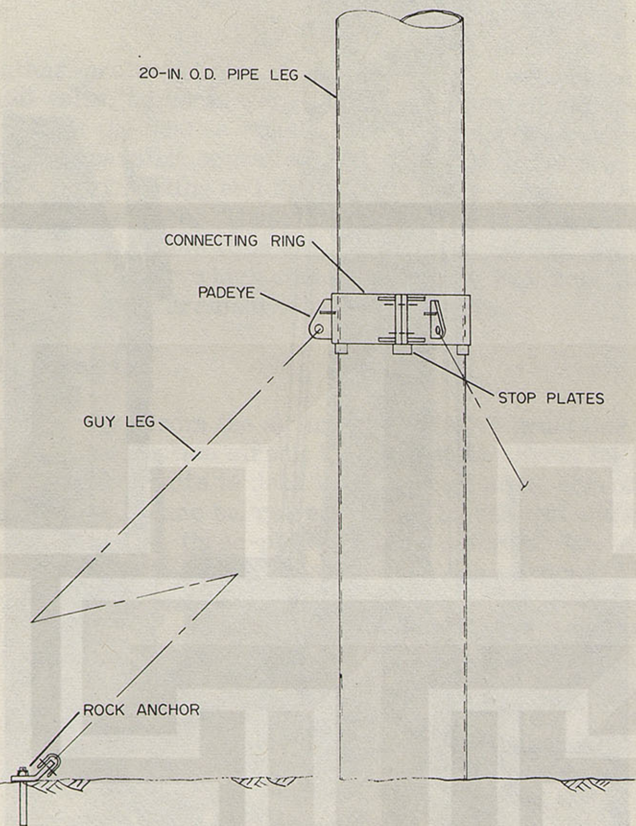

Fig. B35 - Bracing for the legs of the support barge

were 10-kip, hand-operated gear winches welded to the pontoon deck in such a position that they would be in line with the wire rope coming off the last sheave. Single, double, and triple 8-inch heavy-duty blocks were used to make the ten-part line system. Some of the blocks were connected to the pile caps and the others to the pontoon through reinforced eyes provided around the outside of the spudwells. The line for the hoisting arrangement was 1/2-inch 6 by 19 wire rope reeved through the blocks to form the ten-part line. This arrangement provided a mechanical advantage of about 10 to 1, not considering friction. The line loads were calculated to be about 6 kips. To check this during lifting, a tensiometer was placed in the system on one of the legs. Two 3/4-inch safety chains were connected to the pile cap on opposite sides of a leg, were run through an anchor shackle connected to the pontoon, and were attached to themselves by grab hooks. During the lifting operation the chains were designed to hold the pontoon and keep it from falling if one of the elevating mechanisms failed.

Welding rings with wedges were provided to make a more permanent structure. The plate rings, with wedges attached, could be placed around the pile at the barge deck and bottom, with the pontoon at its final elevation, and welded to both the pipe legs and the pontoon to form a rigid structure.

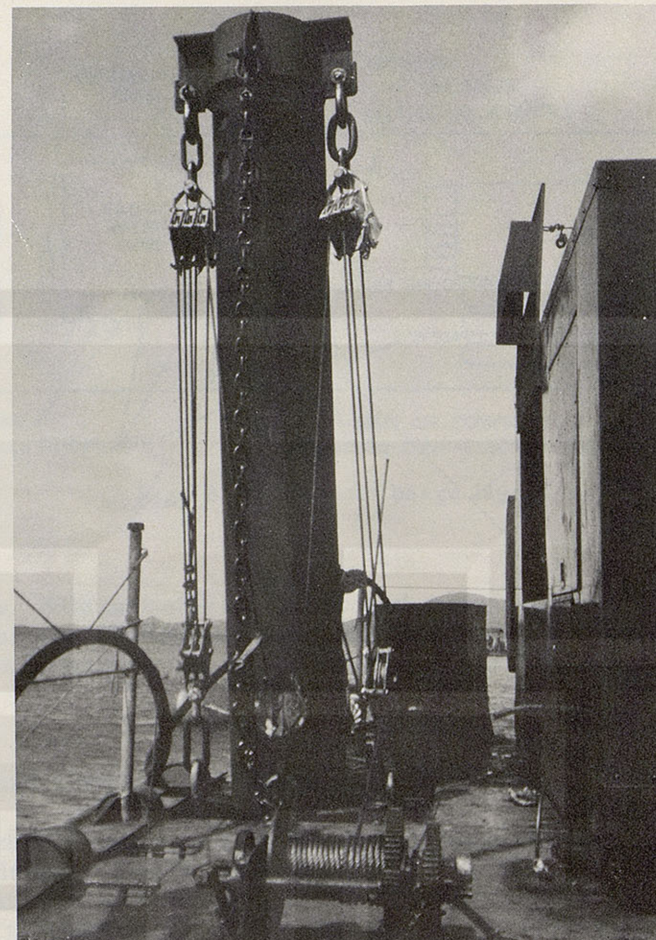

Fig. B36 - Hoist, with safety chains, at each of the four legs to lift the support barge out of the water

B4.6 Electrical Power Subsystems

B4.6.1 Design Conditions

The peak electrical load for the habitat, support barge, and crane barge was expected to be in excess of 50 kilowatts. The habitat demanded a 480-volt three-phase supply at the support barge end of the 1000-foot, three-wire power cable. Provisions existed in the habitat for voltage transformation for those systems requiring lower voltages. The support barge and crane barge systems required 208-volt and 115-volt supply, all at 60 hertz. Habitat power consumption was to be monitored. The loads were to be balanced, insofar as practicable, across the three phases of the generator supply. The generator regulation was not to exceed ±1%.

Penetrations of the support barge were not permitted; therefore, all electrical installations were above deck and exposed to the marine atmosphere. Normally the materials and installations would have been the types suitable for exposure to this environment. However, due to the limited time schedule for procurement, construction, and operations the majority of the materials specified were weatherproof commercial types.

B4.6.2

B4.6.2 Power Source

Two portable weather-protected diesel-engine generator sets rated 100 kW at 0.8 power factor, 208Y/120 volts, 60 hertz were specified for installation on the support barge. These units, part of the Seabee Functional Component System, contain synchronizing equipment to permit parallel operation or transfer of loads from one to the other. Normally one set was to be operating and the other used as a standby for unscheduled outages and preventive maintenance. These functions were interchanged between the units on a 66%-33% time basis. This time sharing tends to prevent simultaneous failure of the same part on each generator which could result from 50% time sharing and, thereby, provides for timely procurement of unstocked parts.

B4.6.3 Distribution System

The 208Y/120-volt service from the switch-gear of each generator was connected to the main lugs of the main distribution circuit breaker panel. From this panel, circuits were installed in rigid steel conduits to deck lights, receptacles, searchlight, air compressors, fresh-water pumps, crane barge receptacle, instrument and control van, and stepup transformers for 480-volt, three-phase service to the habitat. The habitat service was provided via a three-connector submarine-type cable from 3-25-KVA, one-phase, 120/240-480-volt, dry transformers connected wye-delta. The circuit breaker in the main distribution circuit breaker panel for this bank of transformers was provided with a 12-volt dc shunt trip with the trip energy supplied from the instrument and control van. This trip was energized when a signal from the habitat indicated flooding. All three-phase motors on the support barge were provided with a combination magnetic motor starter and disconnect. A watt-hour meter was provided at the support barge terminus of the habitat power cable.

B4.6.4 Assembly and Testing

The installation of electrical equipment aboard the support barge was in accordance with the design and applicable portions of the National Electric Code. Prior to operating, the following system tests were performed: (a) a check to assure that the system and equipment were properly grounded, (b) a check for circuit continuity and insulation integrity, (c) a check to assure that the circuiting, loading, wire sizes and protective devices are in accordance with the design, (d) a check to assure that the proper motor starters are installed for the motors involved, (e) a check of the generator phase rotation, lead connections, and synchronizing equipment to assure proper operation for paralleling or transfer of loads, (f) a check of the phase rotation at three-phase motors to assure proper operation, (g) energizing of the system and check of all components for proper operation, and (h) paralleing of the generators, under load conditions, to assure proper operations.

B4.7 Breathing Gas Subsystems

B4.7.1 Introduction

Breathing gases were provided to the habitat under controlled conditions to (a) purge the habitat with pure air after inadvertent contamination, (b) dilute the habitat atmosphere to approximately 9% oxygen with pure nitrogen, (c) supply the habitat with low-pressure air to compensate for metabolic oxygen consumption and volume decreases due to temperature and tide, and for surge-caused pressure changes, (d) make up habitat atmosphere volume for emergency compensation of rapid leakage, and (e) provide high-pressure air to storage bottles in the habitat used for scuba bottle charging, tethered breathing systems, and emergency supply. All gas systems were cleaned with detergent and hot water and dried with oil-free air. All systems were open-flow checked for obstructions and leak checked with liquid detergent.

B4.7.2 Purge Air Supply

Habitat purge air was supplied by a diesel-driven Ingersoll Rand compressor (IR-105). To compensate for the high oil contamination associated with this compressor, a water-cooled trap, dessicant filter assembly was installed (Fig. B37). From the filter, purge air was routed through a pneumatic control console, designed and fabricated by General Electric. The console monitored and manually controlled flow rate to the habitat. Standard 3/4-inch, schedule-40 galvanized piping and 150-psi fittings were used between the purge compressor and the console. The line from the console to the low-pressure umbilical was also fabricated from these materials.

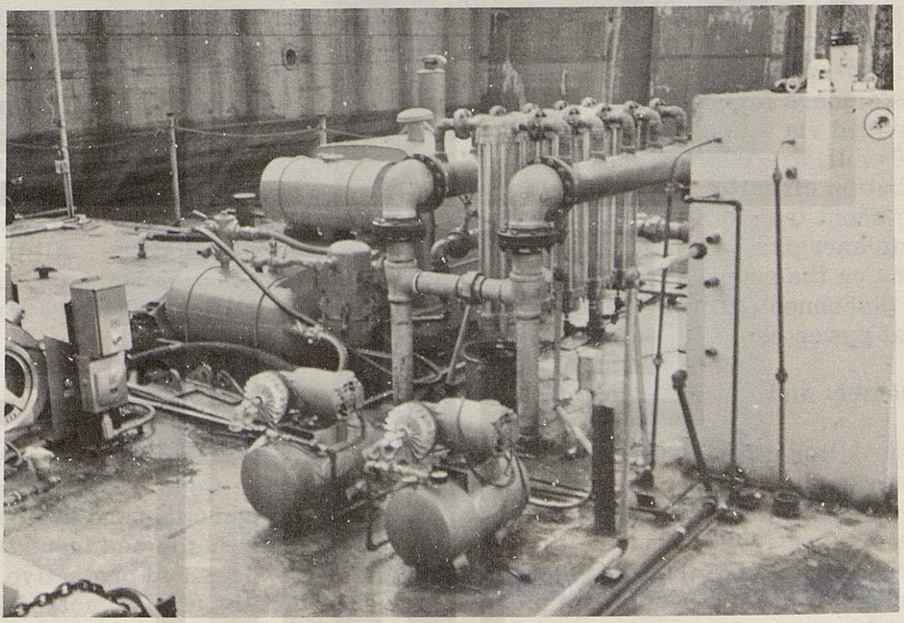

Fig. B37 - Purge air after-cooler and filter

B4.7.3 Nitrogen Supply

Nitrogen for habitat atmosphere dilution was provided by five flasks which contained 8500 standard cubic feet at 2450 psi. The flasks were manifolded as shown in Fig. B6. Schedule-160, 3/4-inch steel pipe and 3000-psi fittings conducted the nitrogen to the pneumatic control console. A regulating valve reduced the pressure of the nitrogen, which then passed through a flowmeter, manual control valve, the common low-pressure line, and the low-pressure umbilical to the habitat. Through use of the nitrogen supply system the habitat atmosphere was reduced to approximately 9% oxygen. With the habitat ambient pressure at 43 feet of water this percentage corresponded to an oxygen partial pressure of approximately 160 torr, considered suitable for long-duration, saturation exposure.

B4.7.4 Low-Pressure Air

To replenish oxygen consumed in the habitat, and to compensate for water level rises in the entry trunk due to habitat temperature and pressure changes, low-pressure air was supplied to the habitat under controlled conditions. The source was two electric-driven Johnson Model M600 78F-RE, low-pressure, diaphragm compressors, each capable of 3.1 cfm at 50 psi (Fig. B6). Each compressor was equipped with a volume tank which additionally served as a moisture trap. Air was conducted from one of these pumps through 3/8-inch, schedule-40, black steel pipe and 150-psi fittings to the pneumatic control console. In the console, air passed through a regenerable dessicant filter to a volume tank. Flow was controlled by a manual valve and flowmeter. Pressure was also monitored, so that umbilical leakage could be detected. The common low-pressure line and umbilical conducted flow to the habitat. A weather cover was provided for the compressors, since their motors were not weatherproof.

B4.7.5 Emergency Air Supply

An 8500-standard-cubic-foot, 2450-psi flask, identical to the nitrogen flasks, supplied the emergency air supply to the habitat (Fig. B6). This supply backed up the low-pressure compressor supply. With a high flow capability it could be used to prevent flooding in the habitat in the event of a large leak. Air from the flask passed through a manual pressure regulating valve and flowed to the pneumatic control console through 3/8-inch, schedule-40, black steel pipe. A manual pressure-regulating valve in the console reduced its pressure to the desired level. The low-pressure line and umbilical carried emergency air to the habitat as shown in Fig. B15.

B4.7.6 Scuba Air Supply

Volume tanks in the habitat base were used to charge scuba bottles. These bottles were supplied with 2600-psi air from two scuba compressors on the support barge. This same system was used to charge an emergency air bank in the habitat base. This bank provided makeup air to prevent flooding or terminations of operations in event of temporary interruption of the surface, low-pressure supply. This bank also supplied air for tethered, open-circuit diving apparatus.

The scuba compressors were electrically driven Mako Model K14.85E1 units of 8-cu-ft/min capacity at 3200 psi. They supplied high-pressure air through flexible pigtails, stop valves, and a brass high-pressure manifold to the high-pressure umibilical.

B4.8 Potable Water Subsystem

B4.8.1 Design Conditions

Potable water was required at a maximum flow rate of 10 gallons per minute with a total capacity of 280 gallons per day. The water pressure at the umbilical was to be 100 ± 10 psi. Habitat water consumption was to be monitored.

B4.8.2 The System

The reservoir was chosen to be the 3000-gallon fabric, collapsible pillow tank, an element in the Seabee advanced-base functional component system. It was positioned on the support barge and filled approximately every 10 days from shore with potable water. Two Colt Industries Model BR615-AB-6830, K2N3-476331 pumps were provided to take suction from a common pipe header connected to the bottom of the water tank by a 2-inch hose. Each pump had a capacity of 10 gallson per minute against a total dynamic head of

250 feet (107.5 psi). Because the pumps cavitated under no-flow conditions, a small flow of water was continuously discharged back to the water tank through a throttling valve on the bypass line. Water flow was routed through a filter unit, water meter, stop valve, and water umbilical to the habitat. A deck outlet was provided ahead of the water meter.

The habitat was furnished potable water at a maximum rate of 10 gallons per minute at the 43-foot back pressure. Only one pump was operated at a time, and the pumps were alternated on a 66%-33% time sharing.

B4.8.3 Assembly and Testing

The system was assembled according to standard practice. It was cleaned with detergent and hot water and flushed with fresh water. All fittings and external seams were covered with soapsuds and the tank examined for leaks. The piping system was tested for 1-1/2 times the working pressure of 125 psi, or 180 psi, from the discharge of the pumps to the fixtures in the habitat.

B5 CONTROL VAN

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B5.1 Introduction

The surface support barge served as the control center for the entire Tektite I project. The control functions were performed in a standard 30-foot trailer which had been outfitted for this purpose, called the surface control center van. Figure B38 shows the general location of equipment in the surface control center. An artist's rendering of this van was shown in Fig. 30 on page 41.

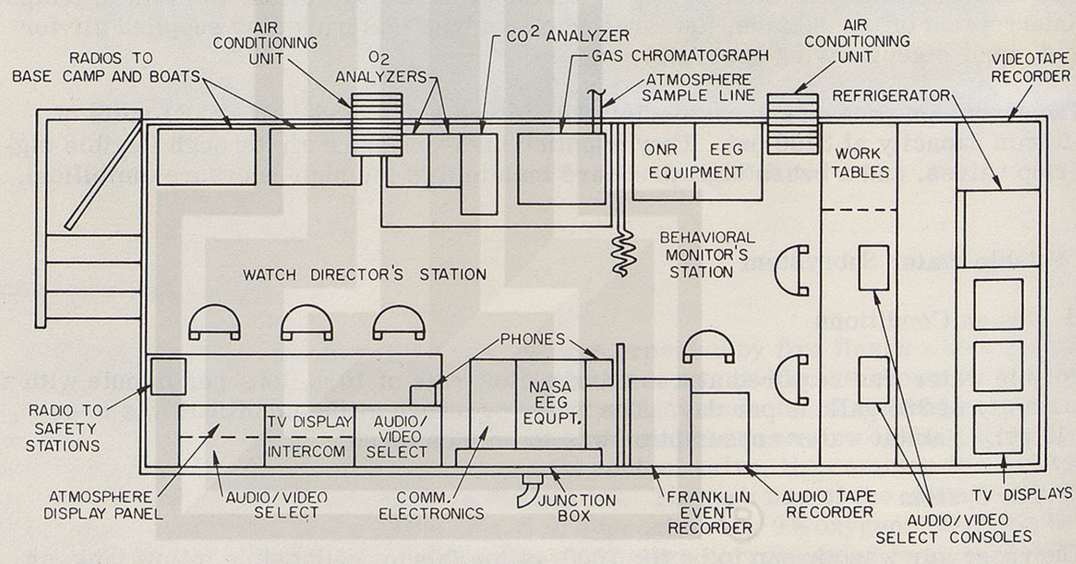

Fig. B38 - Floor plan of the surface control center van

The surface control center van was divided into two compartments: the watch director's station and the behavioral monitor's station.

B5.2 Watch Director's Station

The watch director's station was equipped to provide continuous monitoring of aquanauts and their environment. The following equipment was provided for this purpose.

B5.2.1 TV Monitors

Two TV monitors were used in conjunction with selector switches to display the video on the camera in each compartment of the habitat and on the outside camera. Two monitors proved quite adequate to cover the activity of four men at four primary (habitat) stations and one secondary (outside) station.

B5.2.2 Meter and Alarm Panel

The meter and alarm panel provided continuous remote readout from the mass spectrometer covering partial pressures of N_2, O_2, CO_2, and H_2O. For this purpose four edge meters, driven from the panel in the habitat, were provided. The panel, in addition, was equipped with a two-way intercom station which could communicate with each compartment of the habitat or with all compartments at once. This intercom was the primary link between the surface watch and the aquanauts.

A speaker was located in the panel and could be cut in to any one or all open microphone circuits using a selector switch on the panel. This speaker normally was cut out to preserve the privacy of the aquanauts. It was used on occasion as an alternate to the intercom for receipt of messages from the habitat.

B5.2.3 Alarms

The panel was equipped with switches to sound a bell in the bridge and wet room, a buzzer in the bridge, and a horn on the exterior of the van.

B5.2.4 Telephones

Adjacent to the panel was a sound-powered phone connecting to the bridge in the habitat. This phone was used for communications between surface personnel in communicating with aquanauts without interference with operational communications over the intercom.

On the wall behind the NASA EEG was a private phone connecting to the living compartment in the habitat. This phone was used for private and semiprivate communications between the surface and the habitat.

B5.2.5 Communications Electronics

Between the NASA EEG and the meter and alarm panel was the communications electronics rack for the audio and video circuits. This rack contained all electronic components used on the surface to condition signals coming in from the umbilical. These components were in replaceable modules to facilitate maintenance or repair.

At the bottom of the communications electronics rack was a voltmeter to indicate potential in the battery which furnished backup power to the instrumentation in the habitat.

B5.2.6 NASA EEG

The NASA EEG was used during the first and last 10 days of the mission to record the sleep characteristics of one aquanaut. It was operated by NASA personnel.

B5.2.7 Gas Analysis Equipment

The control room was equipped with the following instrumentation to monitor habitat breathing atmosphere: a gas chromatograph, a Lira CO_2 analyzer, a Beckman O_2 analyzer, and a General Electric O_2 analyzer. The instruments received gas from a 1/2-inch atmosphere sample line from the habitat. The accuracy of the instruments was checked using samples bottled in the habitat and analyzed in a chemical laboratory.

B5.2.8 Communications Equipment

The watch director's station was equipped with the following voice communications equipment: For surface operations, VHF/FM equipment (Navy PT 200 Handi-Talkies) was used to communicate with the crane barge, diver boats, the base camps, and the control van. For local operations, 3HF single-sideband equipment (Navy AN/PRC-47 SSB transceivers) was used to communicate with the base camp and the control van. For administration, local marine radio was used to communicate with St. Thomas control and the control van. This equipment was used for telephone calls until the telephones were installed at the base camp. It was then connected to the intercom so that aquanauts could use it for telephone contact to families.

B5.3 Behavioral Monitor's Station

B5.3.1 Introduction

The behavioral monitor's station of the support van contained a variety of electronic monitoring equipment in the 8 by 15-foot area occupying the back half of the van (Fig. B38). These devices for maintaining visual, audio, and automated monitoring of the aquanauts included TV monitors, video and audio tape recorders, dynagraphs, and a digital printer.

B5.3.2 Bioelectric Monitoring

Immediately to the left as one entered the behavioral section was the Navy Medical Neuropsychiatric Research Unit's bioelectrical monitoring and recording system equipment. This system monitored two aquanauts, Edward Clifton and John Van Derwalker, and was divided into two distinct subsystems, one in the support van and one in the habitat.

Sensor signals were accepted by in-habitat equipment (Tektronix Differential Amplifiers type 2A61) which magnified the brain-wave, eye-movement, and heartbeat signals and then channeled them topside through the power communication umbilical. The topside system served primarily to record the incoming information. Two Beckman Type-R dynographs (with type-9806A dc/ac couplers and dual amplifiers type 482M8) reconditioned and rerouted the incoming signals to two folded-chart drives and two Hewlett-Packard Model 3917B seven-channel FM magnetic tape recorders. An IRIG compatible time code translator/generator (Astrodata Model 5400) insured later synchronization of paper and tape recordings by coding both in clock time. Other instruments were available to assure system calibration and maintain FM tape recorders.

B5.3.3 Behavioral Monitoring

The remainder of the equipment in the behavioral monitor's station supported the Naval Medical Research Institute's behavioral observation program.

B5.3.3.1 Video and Audio Monitoring

Six 14-inch Conrac CKD TV monitors were mounted on the far wall of the van in a three wide by two deep configuration. These screens provided real-time displays of incoming signals from four habitat TV cameras as well as from two, usually unoperative, underwater TV cameras positioned near the habitat. Three of the four compartment cameras were individually fitted with a wide-angle lens with 96 degree horizontal by 76 degree vertical coverage. Trained Navy enlisted personnel seated at a working table systematically recorded a selected variety of aquanaut activity using an on-line data card punching system described in detail in section A4. The majority of data was derived from the closed circuit TV display of on-going observable crew behavior as well as the crew conversations. Such conversations were monitored through the use of a centrally located supercardiod microphone in each compartment; each microphone was connected to a central, high-fidelity, audio distribution network.

Two observer control consoles at the working table provided selector switching access to any habitat microphone, with separate volume controls for headphone output and an external speaker. The console also supplied remote controls for the Ampex PR10-2 (two-channel) audio tape recorder and backup, located in equipment racks behind the observers. These recorders tapped back into the consoles and incoming signals from the habitat microphones. While samples of aquanaut conversation were recorded on one channel of the audio recorder, the parallel channel was recording tones generated by a bank of tuned solid-state audio oscillators (B.R.S. Electronics Model AO-201), controlled and routed to the recorder by pushbutton switching located in a small, separate control box. Each unique tone identified a different aquanaut. Only during his actual speech was that aquanaut's tone recorded. Such a record first coded by an elapsed time device allows computer evaluation of the duration and sequencing of each aquanaut's conversational contribution. An observer's desk microphone allowed on-line identifying comments to be placed on the conversation channel.

During data collection the observers used Penwood Model 100 real-time digital readout clocks set atop the consoles for time placement of each record. Also for permanent visual records a Sony video tape recorder (Model TCV 2110), with remoted video switcher, permitted selection of desired source camera input and provided video recording as well as playback capability.

B5.3.3.2 Automated Electronic Monitoring

An event-recording subsystem, in a rack alongside the audio recorders, allowed automated monitoring and recording of individual aquanaut diving time and bunk headphone usage as well as crew usage of the entertainment facilities and the stove. Habitat switches, topside logic modules, and a digital printer maintained an around-the-clock record.

Near the rim of the ingress-egress hatchway in the habitat each aquanaut had a personal switch to push when entering the water and another when leaving. Each bunk was provided with a private headphone tapping into the radio and TV in the crew quarters. An attached microswitch activated when the headband was stretched. The stove, radio, and TV were each modified with a relay switch on the power line. Onset of the respective relay indicated which appliance was on. Finally an operator switch controlled by the topside observer served as a real-time stopwatch for timing aquanaut work performance.

Each switch was wired to close a -12-volt dc line to a separate buffer module, which in turn produced a shaped trigger pulse for each circuit (-12 V dc to ground, 1 microsecond wide).

Topside a package of B.R.S. Electronics (Series 200) solid-state logic modules was used as central control system of all switch lines. Each separate line triggered unique binary information, which the digital printer (Franklin Model 1200) with its logic circuitry converted to a decimal printout. The paper-tape printout provided a continuous record of each switch modification in the form of 12 digits worth of coded information indicating an individual switch being on or off; the operator aquanaut when possible; the date; and the real time to the nearest second, derived from a B.R.S. Electronics (Series 200) binary clock.

B5.3.3.3 Support Accessories

The primary storage area allowed a space for boxes and other large items, a cupboard for storage of recording materials, and two small drawers for incidentals. A small elevated desk immediately to the right and behind the observer team with matching stool provided a supervisory position for over-the-shoulder viewing of recordings, especially during the observer training phase. The behavioral section of the van was kept cool and dry by an 18,000-BTU wall air conditioner. The incandescent, 30-ft-candle illumination of the station was usually dimmed to fairly low levels to insure optimum television viewing. Finally a small refrigerator below the TV monitors allowed temporary food storage for watch-standing personnel.

B5.4 Discussion and Recommendations

The consensus of the behavioral investigators is that the behavioral monitoring section provided, on the whole, reasonable accommodations. The location of the section away from the entry door insured in most cases no unauthorized entries during monitoring hours, thus maintaining the conversational privacy of the aquanauts. Having no windows in this section proved to be of considerable value. Interested visitors and reporters peering into the van would have distracted the observers. The heat of the afternoon sun streaming through such windows would have greatly elevated the interior temperatures. The only price paid was having an observer, during low-density crew activity, momentarily leave the somewhat claustrophic environment.

Hooded overhead van lighting would have prevented considerable reflectance off the TV monitoring screens, a difficult situation when the TV signals were somewhat less than optimal. Appreciable dimming of the lights was not practical, since the observers needed to see and read the recording they were accomplishing at the work table. Habitat camera controls remoted to topside would have allowed adjustment by topside technicians and have prevented requesting aquanaut adjustment of a camera drifting off optimal settings.

Safety monitoring for the watch-director personnel could be implemented by adding cue lights topside responding to signals from the habitat dive panel. Such an aid would provide excellent backup monitoring in the future if the dive panel is configured properly. During the actual mission the aquanauts punched in and out on dives less than 50% of the time. For the most part this was due to an unusual disregard for panel design on the part of the contractor. Separate pushbutton switching for each aquanaut (an in and out button with an adjoining cue light which lit up upon punched out into the water and reminded the incoming aquanaut to punch back in) had been specified but was omitted. Independently the aquanauts commented while in the habitat on the difficulty of knowing what the status of their buttons was, since no cue light had been provided and the push-buttons immediately returned to a full-out status after being punched.

The other switching problem encountered was a spurious number of stove switch signals being printed topside, the result of either a short or the actual stove setting switch being multidirectioned.

The section had a capacity for only three working personnel; often six individuals were required in the space. The present configuration and amount of equipment in a wider van would have eased the space shortage considerably. Storage areas were relatively inadequate. The tops of equipment racks proved to be favorite places for storage, since accessibility to available storage was difficult.

Overall, however, the station and instrumentation therein combined to form an outstanding system. Other than the space problem this complete environment provided an excellent base for collecting behavioral data – much beyond that hoped for.

B6 ASSEMBLY OF TEKTITE HABITAT

L. Goldstein, C. Lorenz, and C. C. Meigs, General Electric Company, Missile and Space Division, Philadelphia, Pennsylvania

B6.1 General

The assembly of the Tektite habitat consisted of two major phases: (phase A) Assembly of tank 1 (crew quarters and bridge), tank 2 (wet room and engine room), and the control van from April 15, to November 15, 1968, in General Electric facilities at Valley Forge, Pennsylvania, and (phase B) mating of the tanks to the base and the interconnection of the habitat systems to the control van and support barge from November 13, 1968, to January 5, 1969, in the Philadelphia Naval Shipyard. The schedule is outlined in Table B3.

B6.2 Phase A

Phase A started with fabrication of a full-size mockup consisting of lumber and cardboard. The visualization and familiarization gained with this mockup aided considerably in getting the hardware portion of the program off to a fast start.

The tanks used for the habitat were purchased from a local steel fabricator and hydrostatically tested prior to delivery to General Electric. In parallel with the tank fabrication, in-house activity was devoted to the prefabrication of cabinets, bunks, countertops, shower, and a variety of brackets, ducts, etc.

Tank 1 arrived on May 25, 1968. As received the tank had been assembled with the legs, the three port flanges, the entry scuttle flange, and the tunnel mounting flange, all of which had been sandblasted and painted with one coat of red lead vinyl primer. From this point the logical sequence of assembly would be very similar to building a house once the framing and enclosing was complete, that is, install the services (plumbing, heating, wiring, wall covering, and finish work). Unfortunately, due to schedule requirements, design completion date, and material availability, a logical assembly sequence was often not possible. There were continual decisions regarding schedule versus cost and schedule versus esthetics, without compromising quality and reliability. For example, cabinetry was installed prior to plumbing and wiring, because the cabinets were available several weeks ahead of wiring and plumbing information and material. Another assembly planning problem was to schedule manpower to keep personnel fully utilized without losing work continuity. Although this is a natural assembly problem, it was

Table B3
Fabrication and Assembly Schedule, 1968-1969

Schedule Element	Time Stay During Which Work Was Accomplished								
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan
Phase A — Assembly in GE Facility at Valley Forge									
Receive tank 1	Δ								
Weld bracketry to walls	—	—							
Paint interior walls		—							
Fabricate and install floors		—							
Install cabinetry		—	—						
Plumbing			—						
Wiring			—	—					
Environmental control system		—	—						
Communications and alarm				—	—				
Ceiling and trim parts				—	—				
Paint interior cabinets, etc.			—	—					
Changes, modification, rework	—	—	—	—	—	—	—		
Paint exterior					—				
Receive tank 2			Δ						
Fabricate and install floors			—						
Install cabinetry			—	—					
Plumbing				—					
Wiring				—	—				
Environmental control system				—	—				
Install ceiling					—				
Communications and alarms				—	—				
Paint interior					—	—			
Paint exterior					—	—			
Join tanks 1 and 2 together					Δ				
Interconnections					—				
Receive van				Δ					
Insulation, floor, ceiling				—	—				
Install equipment, and wire					—	—			
Test all subsystems					—	—	—		
Pack for shipment							—		
Ship to Philadelphia Navy Yard							—		
Phase B — Assembly at the Philadelphia Navy Yard									
Reinstall equipment removed							—		
Check out habitat subsystems							—	—	
Paint base and assemble ballast tanks							—		
Mount base on barge and tanks on base								—	
Interconnect all systems								—	—
Test and training							—	—	—
Changes, modification and rework							—	—	—
Leave Philadelphia Navy Yard							—	—	— Δ

magnified during the early assembly stages, as a 12-1/2-foot-diameter tank provides a limited work area. It was advantageous to keep a small group of people throughout the program with overtime rather than crash some phase of the work by applying additional manpower unfamiliar with the habitat and the prior work effort. As the work progressed, few prefabricated components fitted as planned and most required on-the-scene modifications. In most cases, sheet metal work and fabrication of panels, drawers, sliding doors, etc., was best done on a make-to-fit basis rather than prefabricated-to-print dimensions. Ready access to shop equipment and facilities was a necessity.

Tank 2 was received on July 2, 1968, and work progressed more smoothly. The majority of material had been received, the lessons learned from tank 1 were not lost, and more work space was available.

By early September both tanks had been essentially assembled as individual components. On September 5, 1968, the tanks were joined together with the crossover tunnel installed as shown in Fig. B39. The necessary power, plumbing, and communication connections between the two tanks were then made so the various subsystems could be tested.

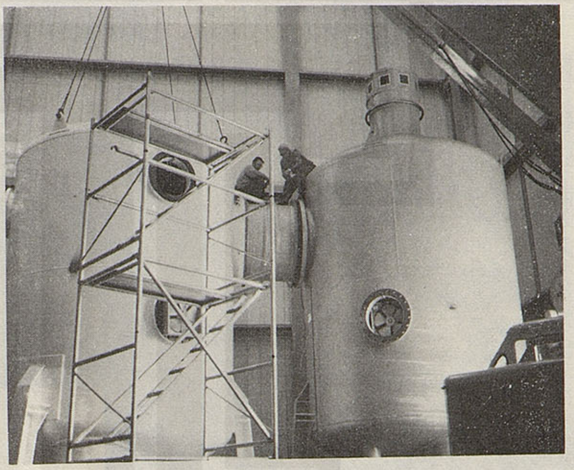

Fig. B39 - The tektite habitat under construction at the General Electric plant in Valley Forge. This view shows the crossover tunnel being positioned between the habitat cylinders.

The final assembly task at General Electric was outfitting the control van, interconnecting the van with the habitat, and testing the complete system. The van as received was a standard 8-by-30-foot trailer van. The first step was to insulate it and furnish the interior, since the van would be occupied continuously for the period of the mission, and the general comfort level of the occupants was of some importance. As a consequence some thought was given to layout, decor, and work volume to provide the best conditions within the constraints of cost and space.

On October 24, 1968, a 4-hour live-in was conducted with tasks assigned similar to those performed by the aquanauts. Based on the live-in minor modifications were suggested: removal of locking pins from the drawers in the crew quarters; mounting of towel bars, paper-cup dispensers, tooth-brush holder, and paper-towel dispensers; installation of a fan in the cupola; mounting of a curtain between the engine room and the bridge; replacement of the cooking unit.

After removing some of the electronics, disconnecting the two tanks, and shoring some of the heavier items such as the freezer, and the refrigerator, each tank was laid on its side and moved by truck to the Philadelphia Naval Shipyard. Figure B40 shows one tank being lifted prior to loading on a trailer, and Fig. B41 shows the cabin on the trailer.

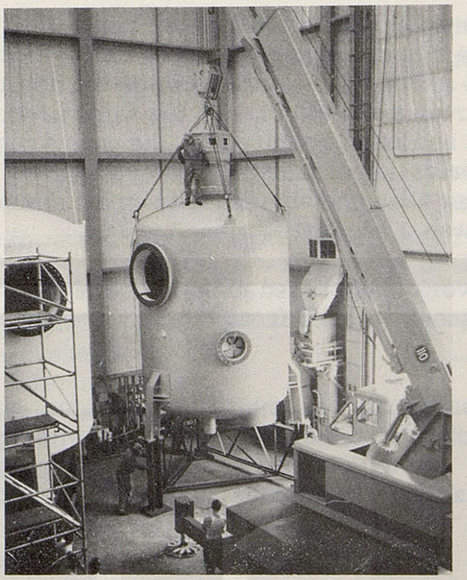

Fig. B40 - Habitat cylinder being lifted aboard a truck for transportation to the Philadelphia Naval Shipyard

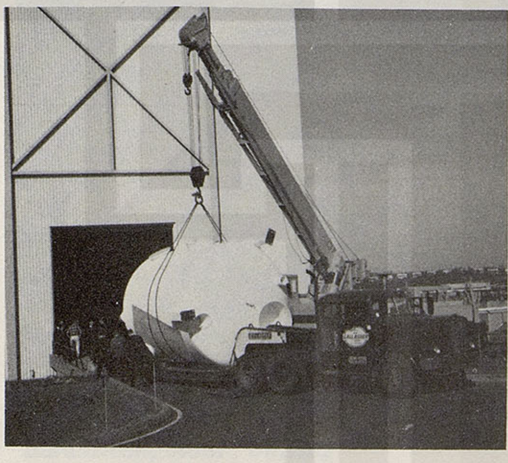

Fig. B41 - Habitat aboard a truck ready for transportation to the Philadelphia Naval Shipyard

B6.3 Phase B

Upon arrival at the shipyard the habitat tanks were set up on stands at the east side of drydock 5. The trailers (control van, storage van, and office trailer) were located nearby. The habitat and trailers were unloaded, the crates were unpacked, and outfitting of the habitat was resumed. Major installations at this stage were the mass spectrometer and all view ports.

While the tanks were being outfitted, the base and ballast were brought to the shipyard. The base was sandblasted and painted in drydock 5. At the same time,the Ammi barges (launch barge and support barge) were located on keel blocks in the drydock. Upon completion of painting, the base was weighed and placed on the launch barge and secured with turnbuckles. Chocks were used to compensate for irregularities in the deck of the support barge. Once the base was located on the barge it was loaded with steel ballast punchings. The total weight of punchings, 113,280 pounds, was distributed in the base to compensate for unbalance between tanks. Next the deckplates were welded in place over the ballast holds.

Tanks 1 and 2 were lifted, weighed, and placed on the base, held by clamps on the feet. The crossover tunnel was attached to tank 1. Tank 2 was attached to the crane using four chain falls and was lifted just enough to keep a slight load on the feet. It was then rotated (by chain falls) around the axis of the crossover tunnel to align bolt holes in tunnel and tank flanges and rotated around the tank axis for parallelism of flanges using chain falls attached between tank legs and base. When flange face alignment was correct, the flanges were bolted together.

The position of the tanks had been maintained temporarily by steel chocks under the feet when crane and chain falls were removed. It now was necessary to attach the tanks permanently to the base in the alignment and position existing at conclusion of attachment of the crossover tunnel. This was done by shoring the tanks in position, cutting off the feet (Fig. B42), adjusting leg length, and rewelding tank legs to feet. The tanks were now secured firmly to the base with their axes perpendicular to the base. The entire assembly weighed 277,240 pounds divided as follows: tank 1, 34,760 pounds; tank 2, 40,020 pounds; base, 69,180 pounds; and ballast, 133,280 pounds.

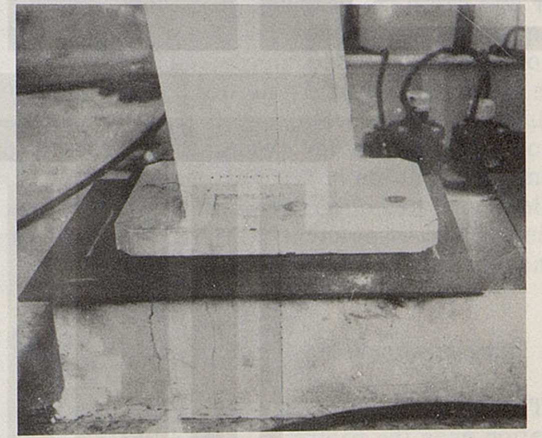

Fig. B42 - Temporary feet of the habitat. These were cut off according to the scribe marks and rewelded to the proper length for permanent attachment to the base.

As soon as the crossover tunnel was in place, the plumbing and wiring between tanks was connected, making the habitat ready for test. It was connected to yard services for air and water, and the first test was a pneumostatic pressure test of the structural envelope.

While the habitat was being assembled, the support barge was outfitted by technicians from Amphibious Construction Battalion Two, and the control van outfitting was completed by G.E. technicians. The diesel generators on the support barge were connected to the habitat using a short section of the power umbilical (the umbilical itself could not be used as it was on a reel and inductive heating would have resulted). The communications umbilical was partly unreeled and connected to the habitat and control van. After the pressure test was completed, each subsystem was given an operational performance test and minor deficiencies were corrected.

Upon arrival of the *USS Hermitage* (LSD 34) the habitat on the launch barge and the support barge were floated in the drydock and towed to pier 4, where they were loaded into the ship. The storage van, house trailer, umbilicals, extra ballast, and other miscellaneous gear were loaded onto pontoon causeways and into the ship. Food for the aquanauts was purchased at the commissary store and delivered to the ship, frozen food being placed in the reefer.

During the voyage from Philadelphia to St. John the first 2 days were mainly occupied in securing equipment in the control van and habitat against heavy rolling. Although some equipment received rough treatment, none was damaged. The habitat and control van were connected to ship power for lighting and for operation of equipment.

Work continued in readying the habitat for emplacement. Food was inventoried and stored, habitat equipment and lockers were labeled, the intercom system was checked out, and subsystems were rechecked.

B7 CRANE BARGE

W. J. Eager and D. H. Potter, Naval Facilities Engineering Command, Washington, D.C.

B7.1 Introduction

The crane barge was the safety and decompression center but was called the crane barge, since its 35-ton crane was used in support of underwater construction and to lower and raise the personnel transfer capsule. A system was required to respond to the aquanaut-related emergencies of (a) atmospheric contamination in the habitat, (b) injury or disease, (c) decompression sickness or air embolism, (d) inadvertent excursion above the upward depth limit, (e) shark attack, (f) loss of scuba air, and (g) loss of bearings. The corresponding action may have been removal, treatment, and decompression of the aquanauts for events (a) through (e), dispatch of filled scuba bottles for event (f), and presentation of direction and guidance for event (g). The system used for this function consisted of qualified safety divers, specific operational procedures, and facilities to support these divers. The system had also to provide for decompression of the aquanauts at the end of their mission.

B7.2 Mooring Conditions

The crane barge (safety diving and decompression center) was required to remain on station near the habitat site throughout the operational phase of the project except under severe storm. Under severe storm the habitat was to be evacuated and the aquanauts placed in the decompression chamber; then the crane barge was to be moved to a protected location. Under normal conditions the crane barge was to be moored in water about 26 feet deep, which was the minimum depth for avoiding risk of decompression sickness as the aquanauts moved from the habitat to the personnel transfer capsule.

The equipment was to be securely mounted on the barge to withstand the environmental conditions, and a mooring system was to be designed which would hold the crane barge secure under these conditions. From historic weather data the environmental conditions for the months of operation involved, January through May, were as follows: maximum wind velocity, 10 to 15 knots; predominant wind direction, east; average tides, 1 foot; maximum tides, 2 feet; current, less than 1 knot; and predominant seastate, 0 to 1. The design of the mooring was based on loading from a 20-knot wind and 4-foot wave height.

The mooring configuration used was a four-leg spread mooring with each leg coming off a corner of the barge at 45 degrees. The legs were made up of anchors, chain, buoys and wire rope. The two legs off the shoreward end of the barge used 500-pound anchors. These were positioned on the rocky bottom by divers to insure that they were placed in a position to develop their capacity. Between the anchor and the barrel buoy, was one shot of 1-inch chain. One-half-inch wire rope was used from the buoy to the barge; it was passed through a chock on the end of the barge and connected to a cleat. Five-inch nylon had been tried for the buoy-to-barge connection, but after excessive rubbing and chaffing was noted, the nylon line was replaced by wire rope. The seaward legs were identical to the shoreward legs except that 1500-pound Danforth anchors were used. The ocean bottom at these anchor locations was sand.

B7.3 Safety Center

The crane barge (Fig. B43) was an Ammi pontoon measuring 90 feet by 28 feet by 5 feet deep. Mounted on the crane barge as part of the safety center was a diving system consisting of a deck decompression chamber, a personnel transfer capsule, a control console van, a base collar for mating the personnel transfer capsule to the deck decompression chamber, an air compressor, banks of oxygen and air bottles, a spare parts chest, and an air conditioning unit. An air line was run from the purge compressor on the support barge as a backup to the diving system compressor.

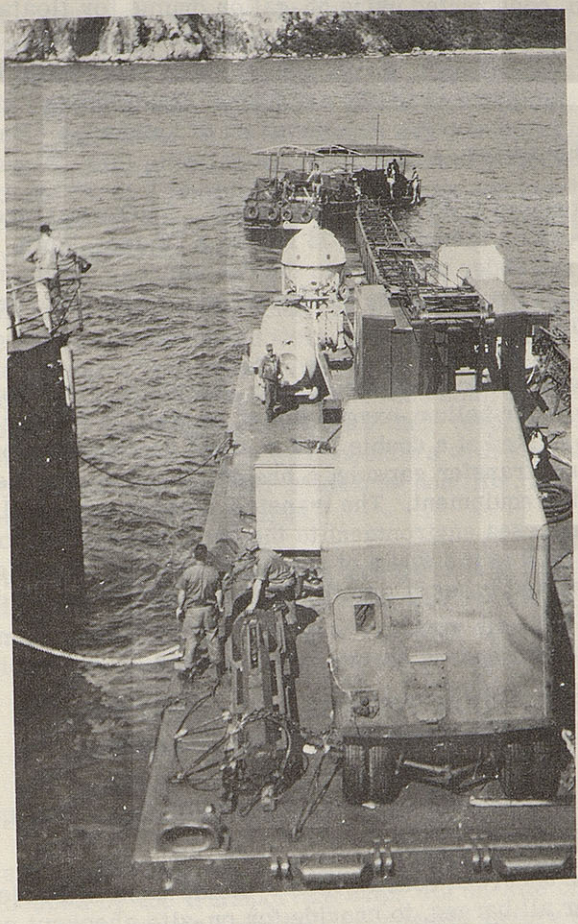

Fig. B43 - Crane barge prior to mooring

Mounted on the crane barge was a 35-ton P&H 640 crawler crane with an 80-foot boom. The crane, used in the construction operations, was used on the safety center for handling the personnel transfer capsule. A van was mounted on the barge for storing safety diving equipment, first aid equipment, and spare parts. It also provided a suitable maintenance space. A 15-kW generator was provided as an emergency backup to the power line from the support barge.

To provide for mooring and moving the crane barge and to provide for docking boats up to the size of an LCM-6, mooring bitts, chocks, cleats, and rubber-tire fenders were installed on the barge. Equipment installed on the crane barge was arranged to insure a positive stability, to keep list and trim to a minimum, and to provide compatibility between the components of any particular system such as the decompression complex. The total weight of the barge with installed equipment was 116 tons.

Maintained at the crane barge were two 18-foot outboards used by the safety divers to follow the aquanauts on all excursion dives from the habitat.

A wooden platform, constructed using 55-gallon drums for floatation and propelled manually with lines, provided transportation between the crane barge and the support barge.

B7.4 Decompression Facilities

The aquanauts, saturated at 43 feet on the 92% N_2, 8% O_2 mixture, were limited to an upward no-decompression excursion of 23 feet to a 20-foot depth. From this depth, they had to be transferred under pressure to the decompression chamber for either a 19-hour decompression at the end of the 60-day project or an emergency decompression under the conditions stated.

The system used was the Ocean Systems, Inc., advanced diving system (ADS IV), which is rated to 600 feet for helium-oxygen diving as well as for air diving to shallow depths. The ADS IV consisted of a double lock surface decompression chamber with medical lock, a personnel transfer capsule, a breathing gas compressor, air conditioner, a control van, and related equipment. The transfer capsule was used to transfer the aquanauts from their undersea environment to the deck decompression chamber, under bottom pressure. The P&H crane would pick up the personnel transfer capsule from its cradle on the barge deck and lower it into the 26-foot depth of water over the port side of the barge.

B8 UNDERSEAS CONSTRUCTION SYSTEMS AND OPERATIONS

Cdr. W. J. Eager, Naval Facilities Engineering Command,
Washington, D.C.

B8.1 Introduction

The functions of the undersea construction systems used in Project Tektite I were: to emplace moorings for all barges, to provide for on-site checkout of surface support barge systems prior to submerging the habitat, to submerge or launch the habitat to its buoyant position, to prepare a foundation for the habitat at its operational site, to move the submerged habitat to this site and emplace it securely on the foundation, to prepare foundations for the support barge, to emplace and secure the support barge on its foundations, to emplace, anchor, and connect the habitat-support barge umbilicals, to emplace and connect the habitat sewer outfall, to emplace the way stations, to install cable for and connect the way station sound-powered phone system, and to inspect for damage or malfunction.

These functions were performed by a detachment of Seabees from Amphibious Construction Battalion Two augmented by 12 Seabee construction divers from Atlantic and Pacific mobile construction battalions. They were directed by a Naval Facilities Engineering Command Officer in Charge of Construction (Cdr. W. J. Eager).

Lt. Cdr. N. Monney was responsible for the initial site engineering survey. M. Yachnis and D. H. Potter, who contributed to facilities design, served as on-site as technical observers and engineering assistants. Lt. (jg) Scott Stevenson was on-site as a technical observer for the Naval Civil Engineering Laboratory and acted as the assistant diving officer for certain operations. Lt. (jg) C. J. Fucillo supervised the base camp construction and operations, and power and communications cable laying. Lt. (jg) T. M. Fusby was a general assistant. Senior Chief R. G. Miller was the construction diving supervisor for Project Tektite I. Numerous other personnel of the Naval Facilities Engineering Command and Amphibious Construction Battalion Two contributed to design and procurement efforts.

The undersea construction systems were designed by the Naval Facilities Engineering Command and fabricated, tested, and assembled by personnel of Amphibious Construction Battalion Two under direction of the Naval Facilities Engineering Command. The crew was trained intensively prior to operations. Construction and integration checkout was completed as originally scheduled within an extremely limited, 30-day period. Meeting optimistic schedules is an uncommon event in undersea operations. This success resulted from: careful planning for equipment and material requirements, good forecast of contingencies, careful critical-path scheduling and rescheduling of equipment and personnel for simultaneous operations at the habitat-launch, support-barge, habitat, and way-station sites, and good fortune.

The only problems with marine life occurred when exceptionally large (6-foot) remoras, which resemble sharks, interrupted work operations by persistently trying to attach to the construction divers. Unloaded bang sticks, which were maintained at each site for protection from sharks, were used to prod the remoras away. Occasionally very large baracuda momentarily interrupted work until their ferocity was determined to be subordinate to curiosity. Although two close encounters with sharks were experienced during the construction operations, neither evidenced hostility, and no interference with construction operations resulted from sharks.

Except for ear infections no sickness or accidents caused lost time. All diving was accomplished on no-decompression tables, and work was scheduled to obtain efficient and safe use of the small crew. Officer engineers closely directed and supervised all underwater work; officer and design engineers carefully inspected all work.

B8.2 Habitat Launch

B8.2.1 Design and Operations Conditions

The habitat was a new development, and concern existed over the effects of vibration and dynamic forces induced by the transporting ship. An on-site checkout of the systems on the habitat and support barge was considered necessary before submerging the habitat. The habitat was therefore mounted on a barge for movement to and from the well deck of the transporting landing ship dock (LSD) and remained on this platform during on-site checkout. To avoid the high cost of a floating crane to lift the 310,000-pound habitat from the barge into the water, an Ammi pontoon barge was used and the Ammi lift dock concept was employed for launching. The barge was progressively sunk through controlled compartment flooding, thereby lowering the habitat into the sea. Cylindrical steel piles were inserted through spudwells in the barge and driven into the seafloor. Winch mechanisms attached to the piles maintained stability during lowering operations.

Other conditions which influenced launch systems design, site selection, and launch operations were: weights (habitat with punching ballast installed, 310,000 pounds; launch barge, 120,000 pounds; support barge, 198,000 pounds; crane barge, 259,000 pounds), environmental loading, visibility (20 to 40 feet), and the minimum sediment depth required for piles (15 feet).

The habitat draft when floating was about 24 feet. The launch barge depth was 5 feet. Therefore, a bottom depth of about 32 feet was required for the launch to provide a separation of 3 feet. To prevent the barge from jamming on the piles at the bottom, the ocean bottom pile pattern had to be within ±1 inch of the barge spudwell pattern. These tolerances resulted from spudwell diameters of 22-1/2 inches and pile diameters of 20 inches.

Because Greater Lameshure Bay is part of a National Park all construction had to be such that all launching foundations and structures could be removed and the seafloor returned to its original condition at the end of the project.

B8.2.2 Site Selection and Preparation

Site survey and selection for launch operations was accomplished during advanced party operations before the facilities construction operations commenced. A prospective 32-foot-deep, level site was located in the approximate center of Greater Lameshure Bay (Fig. B1) using standard diver depth gauges and confirmed by surveyor tape measurements to the surface. The prospective location was selected for its approximate equal distance between rock outcropping and coral reefs in the bay, suggesting maximum depth of sand for pile emplacement. The launching site was about 1/3 mile from the operational site.

The barge spudwell pattern was laid out and marked on the ocean bottom using a steel surveyor tape. The pattern was directionally oriented so that prevailing waves would be taken on a corner of the launch barge. The sediment bottom was proved at each pile penetration print, using a water-jet-driven lance. A lance could be driven to the required 15-foot depth and was left in place to mark each pile point at the confirmed site. Surface sediment samples were taken and analyzed to be well-graded coral sand, suitable for pile driving and retention. Bottom obstructions were removed, and a standard Seabee four-point moor was set using 1500-pound Danforth anchors, chain, and mooring cans. Five-inch nylon line was used between the cans and the barges.

B8.2.3 Launch Facility and Operations

Upon completion of the prelaunch systems checkout the habitat hatches were sealed, the habitat pressurized to 20 psi, and a check made for pressure loss in preparation for launch. Using the concept called the Ammi lift dock the barge was lowered under controlled conditions to the seafloor, permitting the habitat to float free.

Cylindrical piles of 20-inch diameter and 3/8-inch wall thickness were inserted by the crane on the crane barge through the four corner spudwells of the launch barge (Fig. B44). The piles were lowered to within 1 foot of the 32-foot ocean bottom. Construction divers placed a 1/4-inch rectangular steel plate with a 22-inch-diameter hole (Figs. B45 and B46) over the end of each pile, and the pile was lowered to the bottom. The four plates were connected by 1/2-inch wire ropes with turnbuckles. Hand winches attached to jetted anchors at one end and the plates at the other spread the four plates and the piles with them into a rectangular pattern which matched that of the barge spudwells. The piles were oriented vertically using a spirit level and then driven to approximate refusal depth

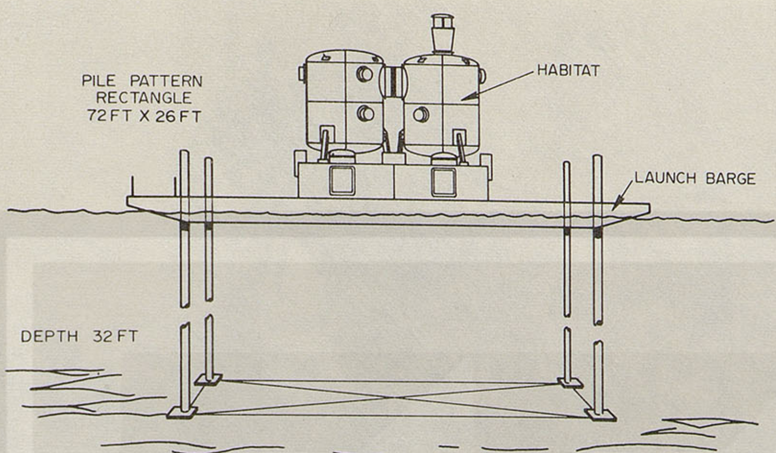

Fig. B44 - Placement of the piles for the habitat launching

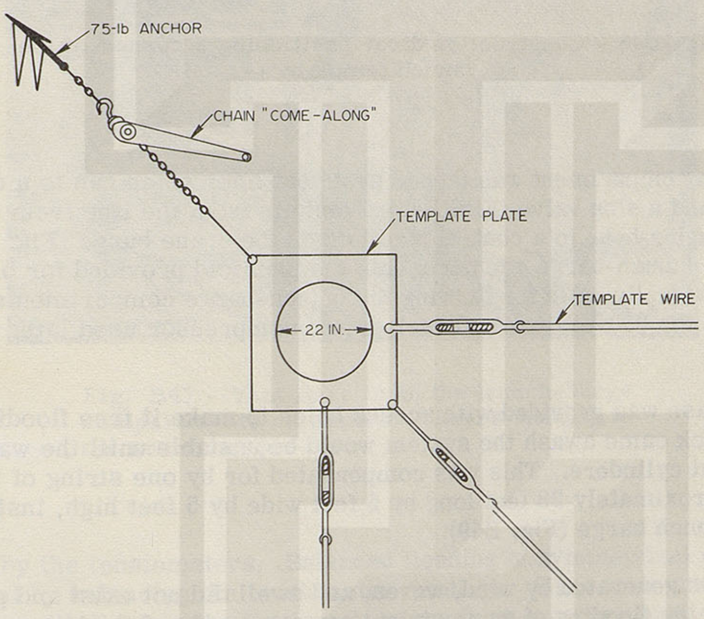

Fig. B45 - One of the four corners of the template for the four piles to launch the habitat

of 17 feet using a diesel-driven pile driver. Using this technique the piles were emplanted within ±1 inch of the ideal pattern of the barge spudwells and within 1 foot in 100 in vertical position.

The interior of the barge was divided into 12 individual airtight compartments. Two 10-inch-diameter holes through the bottom skin into each of the major compartments and one 6-inch-diameter hole into each small end compartment were provided for flood-water access. Gasketed plates covering these holes were removed just prior to launch. To vent air from each compartment so that water could enter through the flood holes the

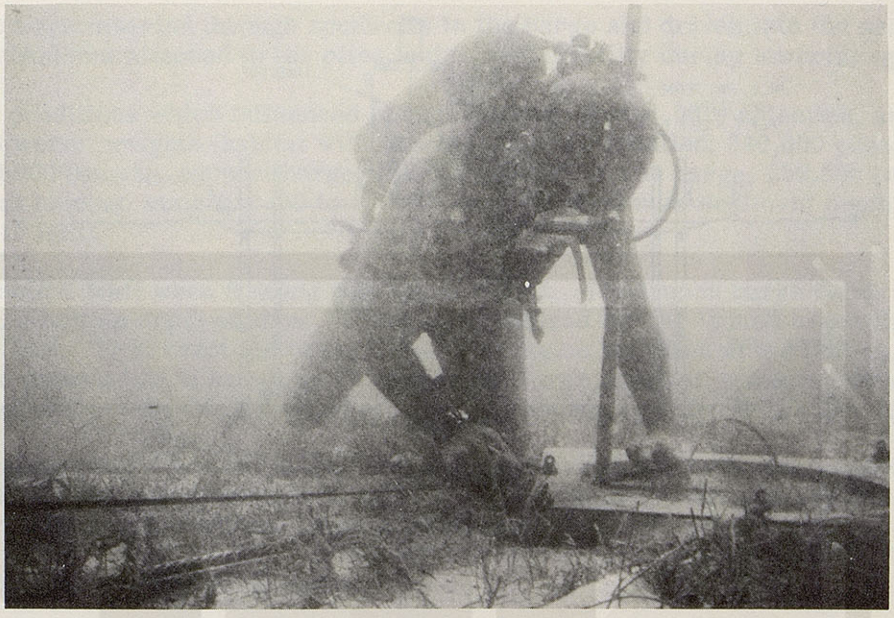

Fig. B46 - Construction diver positioning a corner of the launch template

upper skin of each compartment was tapped by a vent line, which ran to a common side of the launch barge and a stop valve (Fig. B47). Vent air from the line from each compartment passed through a hose to a control manifold on the crane barge (Fig. B48). In addition to venting the launch-barge compartments the manifold provided for blowing each compartment individually. Air for blowing the launch-barge compartments was supplied to the manifold by the 600-cu-ft/min diesel-driven compressor used later for pile extraction.

The habitat base was provided with access holes to make it free flooding. Therefore when the barge deck came awash the system would be unstable until the water line reached the habitat cylinders. This was compensated for by one string of 5-by-5-by-7-foot pontoons, approximately 28 feet long by 5 feet wide by 5 feet high, installed across each end of the launch barge (Fig. B49).

If small forces generated by wind, waves, and swell did not exist and great care was taken in balancing the flooding of symmetrical compartments of the barge, the system described to this point could be used to launch the habitat. However, such forces cause differential motion of the sides, ends, or corners of the barge. Once the barge and pontoon strings are submerged, the habitat cylinders alone could not have produced the necessary restoring moments to correct this motion. The water within the large compartments would have moved to produce additional differential motion and the barge sputwells would have jammed on the piles.

To overcome the small initiator forces and thereby maintain the launch barge in a horizontal position, the mechanisms shown in Fig. B50 were used. A manual 4000-pound winch was mounted on top of each pile. One-half-inch wire rope from each winch was routed down through a block attached to the deck of the barge and to a tensiometer attached to the pile cap. As air was vented from selected, symmetrical compartments, water entering flood holes in the barge bottom produced forces on the wire rope that

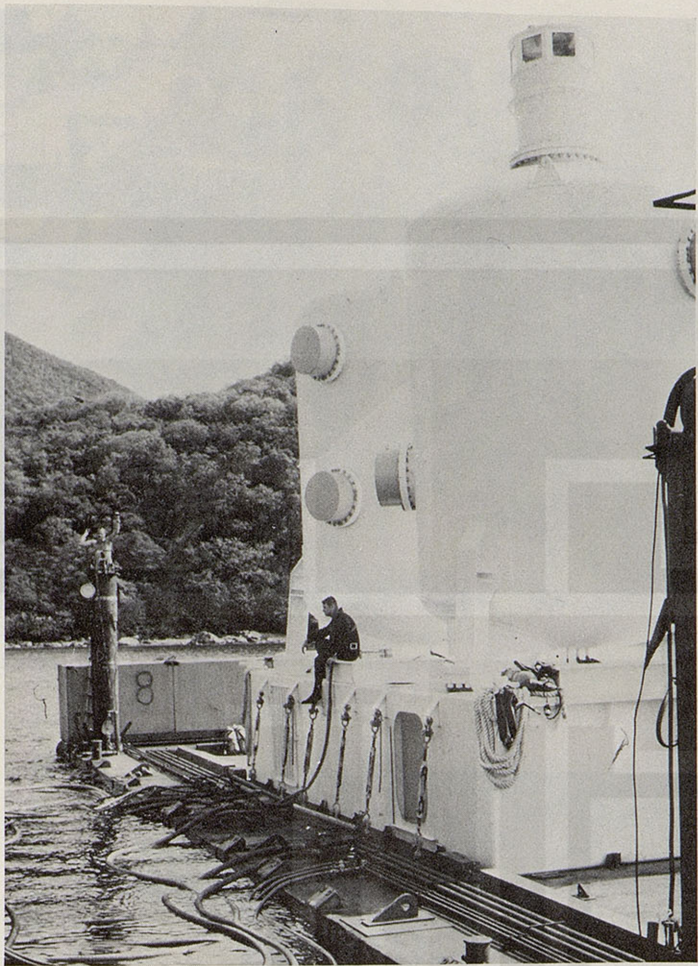

Fig. B47 - Vent lines from the launch-barge compartments connected to hoses running to the crane barge

were measured by the tensiometers. Balanced flooding of symmetrical compartments could be achieved by balancing the tensiometer readings. Since wave and swell forces were producing oscillations in the tensiometers readings, average forces had to be observed. When average forces on all tensiometers approached 3000 pounds, operators on command winched out equal amounts of wire rope, and the barge would be moved to a lower horizontal position (Fig. B51).

To ascertain that the barge was advancing equally on all four corners, depth-marking-tape readings were observed and compared before flooding was repeated. Differential elevation of the corners was corrected by winch adjustment. The process was repeated until the habitat approached its buoyant draft (Fig. B52). At this point 12 1-inch turnbuckles holding the habitat to the launch barge were released, and constraining lines were attached from the habitat to the piles. The launch barge was then lowered to rest on the ocean bottom, allowing the habitat to float free. Observations of habitat pressure loss was made throughout launch and emplacement operations.

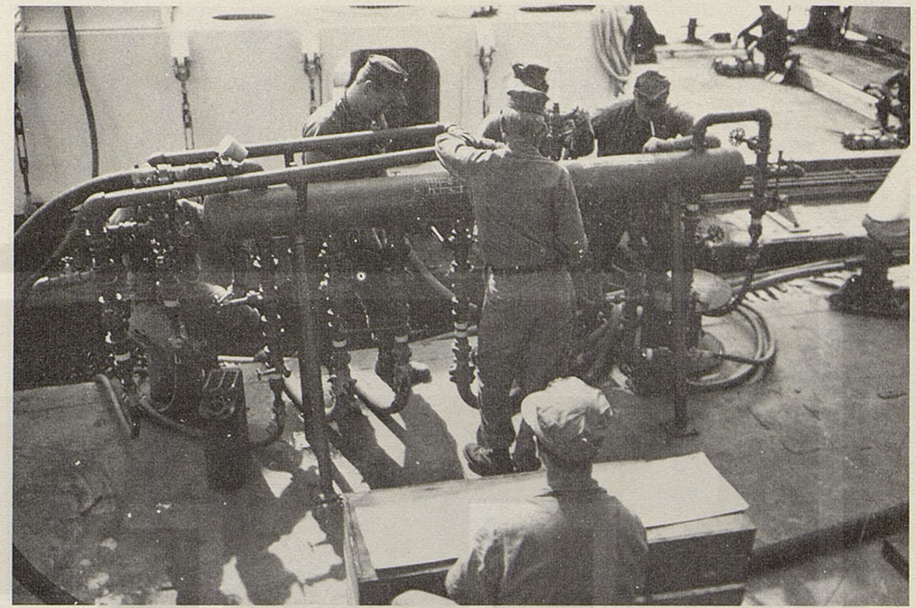

Fig. B48 - Vent control manifold on the crane barge connected to the hoses shown in Fig. B47

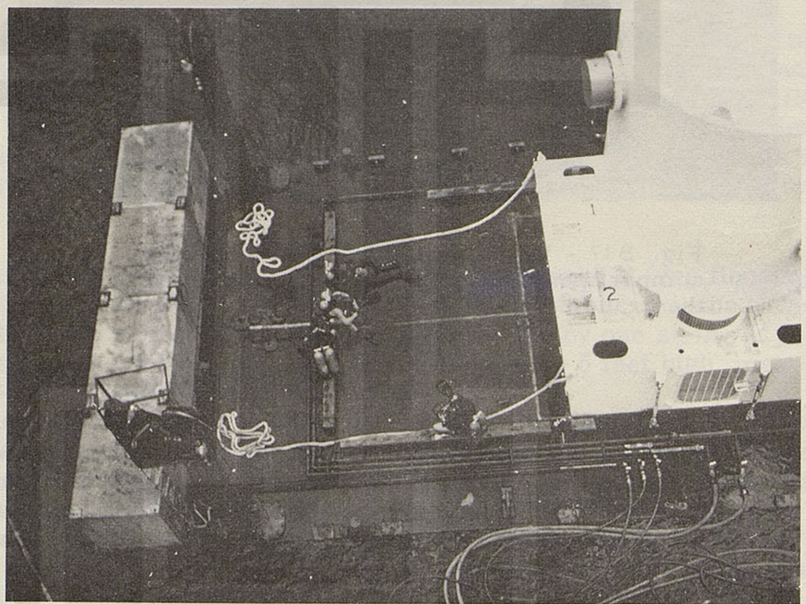

Fig. B49 - String of stabilizing pontoons along one end of the launch barge

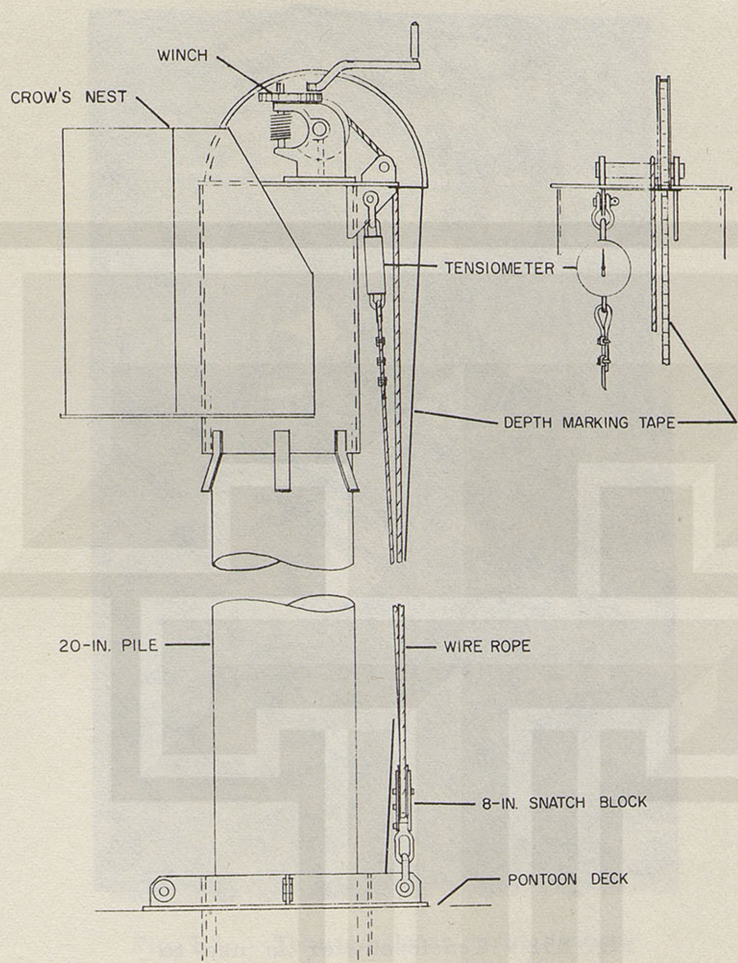

Fig. B50 - Launch system mechanism

The self-propelled diving barge was used to tow the habitat from the launch site to a position over the habitat site (Fig. B1). A personnel boat was attached by tow line to trail the habitat. Thus fore and aft control of its motion was provided. The tow path had been checked by construction divers, who again scouted for obstruction during the tow.

B8.2.4 Performance Evaluation

Environmental data on Greater Lameshure Bay was sparse. All observations and reports indicated calm conditions. With trade winds and waves blocked by high land masses, 5-foot swells with 30-second period were not expected until the summer months. However, such conditions worked against the assembled 400 tons of barges and equipments over a 5-day period to produce fatigue failure of the first set of launch system pilings a few inches below the sea floor. The natural period of the system approximated the long period swells. Pile failure was produced by a combination of inadvertent stress raisers in the piling, delayed delivery of 1/2-inch wall piling, and unexpected delays in completing the prelaunch habitat system tests, and the unexpected sea conditions. Spare piling sections on hand were welded into the required 60-foot lengths in the field with superior alignment. Stress raisers were eliminated, and the replacement piles were driven the day prior to predictable completion of systems checkout and during a predicted

Fig. B51 - Tensionometer in use to control the descent of the launch barge

period of good weather. The result was a successful and timely launch of the habitat at a cost substantially lower than for known alternatives.

Minor difficulties were encountered with winch cables jamming in pulley blocks of the lowering mechanism when waves caused cables to go slack. Brackets to hold the blocks in their inverted vertical positions were installed to correct the problem. One jam-up of the barge on the piling was experienced as a result of an avoidable operator error. This was corrected by applying a force to the jammed corner with the 35-ton crane.

Good information was not available on wave-imposed barge dynamics. In spite of timing the launching with relatively calm seas, transient loads were experienced in excess of 4000-pound ratings of the lowering winches. Occasionally these dynamic forces reached 10,000 pounds. This did not produce problems in launch operations. However, a system for repetitive use would suffer. This could be overcome by increasing the winch capacity.

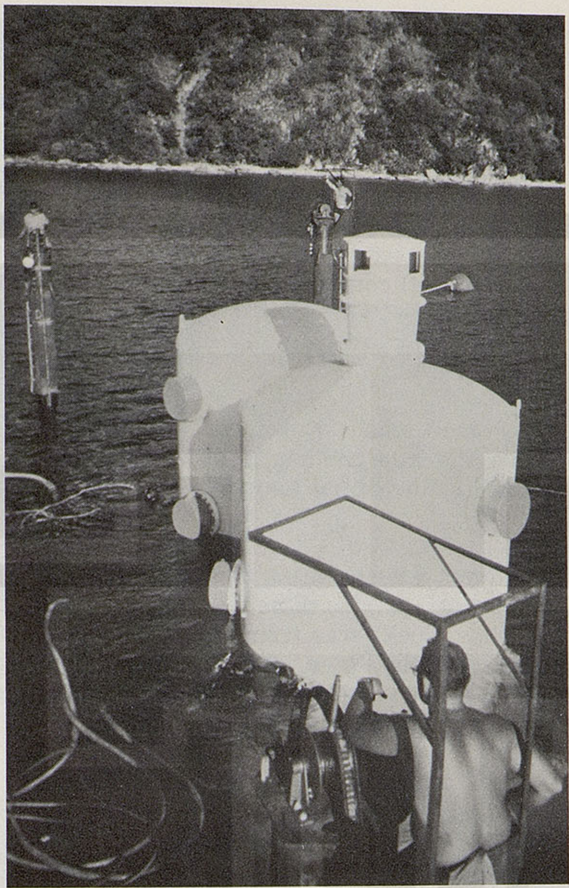

Fig. B52 - Tektite habitat during launch

B8.3 Habitat Emplacement

B8.3.1 Emplacement Conditions and Site Selection

To satisfy the requirements of the marine biology program the habitat was to be located within or adjacent to a biologically active, coral reef structure. The location was to permit saturated diver access to a broad expanse of reef at a depth below 20 feet. Biomedical requirements for saturated divers set a 23-foot upward excursion dive limit from the saturation depth (internal habitat pressure). These two requirements uniquely determined that the water surface in the habitat access trunk had to be at a 43-foot depth. Since the midheight of the trunk was 6 feet above the bottom of the habitat base, the habitat was placed on the seafloor at an approximate 49-foot depth. A site at this depth, in a narrow U-shaped valley between very abundant reefs, satisfied engineering requirements as well.

The valley was relatively level with a coral-sand overburden about 2 feet deep, suitable for site grading. A continuously downward sloping path was available for routing the sewer outfall. An inverted U in the line would collect sewer gases which would back up to the habitat under certain circumstances.

The habitat with water ballast tanks dry, when totally submerged, displaced 5000 pounds more than its weight. With the ballast tanks flooded it was 5000 pounds negative. An additional 25,000 pounds of pig iron ballast was available to secure the habitat to the bottom. The bottom of the habitat base was a heavy flat steel plate, so no problems with the bearing capacity of the coral-sand bottom were encountered.

The environmental conditions at the site were approximately those cited in section B4.2. The visibility at the habitat site was a minimum of 30 feet. Even during severe storms significant currents were not experienced at the habitat site. Since the operational site was in a National Park, all construction techniques had to provide for easy restoration of the natural conditions at the end of the project.

B8.3.2 Site Preparation

During the advance party operations in November 1968, two 1000-pound concrete clump anchors were placed 75 feet from the center of the habitat site at opposite ends. They were to be used for mooring the habitat temporarily, while down-haul equipment was being attached.

For use in leveling the bottom a rectangular aluminum frame was entrenched in a level orientation. The frame, which had the dimensions of the habitat base, was fabricated from 4-inch square tubular stock. The tubular frame was provided with flood and blow fittings to facilitate handing in the water. The sand bottom was graded by moving a bar over the frame much as a concrete flood is leveled during pouring (Fig. B53). The frame was removed before habitat emplacement.

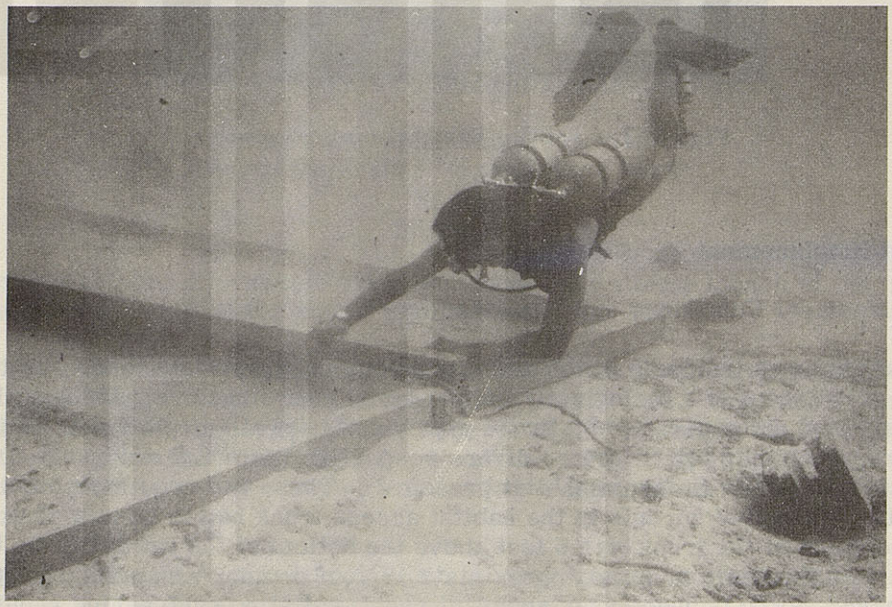

Fig. B53 - Habitat site being leveled by moving a screed bar along a level frame

Immediately adjacent to the frame four anchor clumps fabricated from steel plate were emplaced. They were used to haul the habitat to the bottom and became part of the foundation. Each weighed approximately 2500 pounds and were provided with two pad-eyes for attachment (Fig. B54). They were lowered to the bottom by the crane barge and were moved into position by construction divers using six 500-pound lift bags. Stakes cut from 1/2-inch pipes were driven through holes in the plates to hold them in lateral position during habitat winch down.

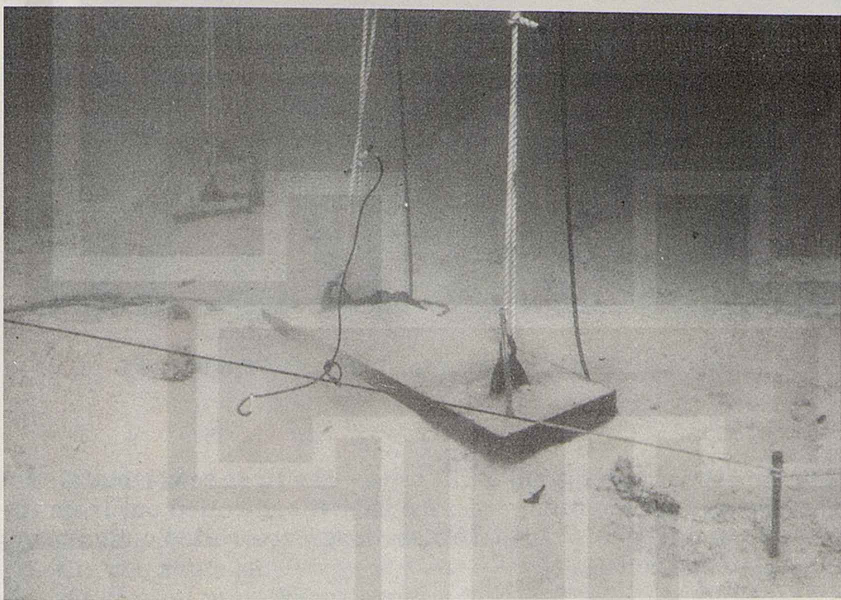

Fig. B54 - Anchor clump used to haul the habitat to the bottom

B8.3.3 Emplacement Operations

With the habitat in its moor and floating at the surface, pig ballast was placed in habitat ballast trays to adjust its orientation and to give it a 5000-pound buoyancy when wholly submerged. Upon completion of trimming operations, eight 3000-pound chain falls were symmetrically attached and moused to shackles on the habitat base. The hook end of the chain falls were attached and moused to shackles on the steel anchor clumps through nylon leaders. The latter were used to reduce surge forces on the chain falls. As shown in Fig. B55, eight construction divers hand-winched the habitat 20 feet to the bottom while spirit levels were used to ascertain level submergence.

When the habitat reached the bottom, vent and flood valves on the ballast tanks were opened. The habitat went from 5000 pounds positive to 5000 pounds negative buoyancy. Winches were replaced one by one with turnbuckles. Steel (25,000 pounds in approximate 10-pound pigs) was lowered to the top of the habitat base and distributed in the ballast trays. At first pallets of pigs were lowered to the habitat ballast trays from the diving barge. Difficulties in this method were overcome through the use of a chute constructed of 4-inch steel pipe (Fig. B56).

The habitat was periodically repressurized and checked for leakage using the Bolstad Lister breathing air compressor on the diving barge. The shark cage and three doors

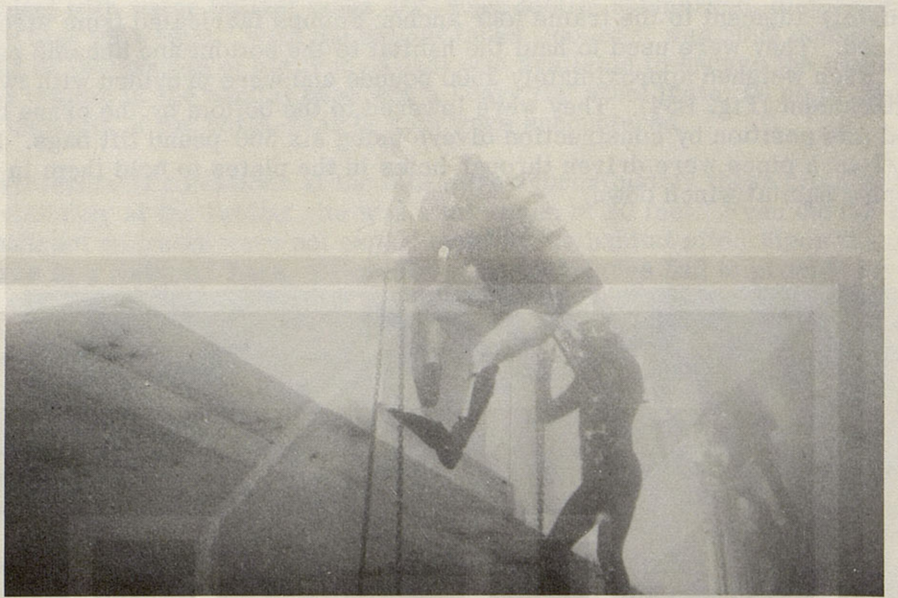

Fig. B55 - Divers winching the habitat to the bottom

were attached to the habitat with the aid of lift bags. The first sewer outfall hose section was connected to the appropriate fitting from the habitat and rolled out from its reel along the course shown in Fig. B1. Additional sections were rolled out and connected at the bottom to complete the outfall.

B8.3.4 Performance Evaluation

The simple and low-cost site preparation and habitat emplacement systems worked quite effectively. By using this haul-down technique the motion of the habitat was coupled with the bottom while it was still at the surface, thereby avoiding impact forces with the bottom as is the case with objects lowered from the surface. Surface conditions were very calm, which simplified the lowering operations.

B8.4 Support Barge Emplacement

B8.4.1 Introduction

The 22-by-90-foot support barge with all habitat support systems except the TV and radio antennas, installed and checked out was to be emplaced as an elevated platform about 15 feet offshore in Beehive Cove. Large boulders and coral which came within a foot of the surface were immediately adjacent to the area where the barge was to be emplaced. A few coral heads approached the surface in the area where the support barge was to lie. Two-foot swells moved into this protected region. Prevailing open-sea waves, swells, and wind were blocked by a high land mass. The bedrock and boulders had the hardness and strength of granite and were grown over with fire coral. This stinging material forced construction divers to clothe in wet suits and gloves for protection in spite of high water temperatures.

Fig. B56 - Ballast being placed on the habitat base

B8.4.2 Site Preparation

During advance party operations a template was made using four inflated inner tubes spaced by lines in the same pattern as the four-corner spudwells of the support barge. The template was floated over the proposed site until a position was found at which all four piles would be sitting on a relatively flat bedrock surface and the barge would avoid interaction with the rock and coral outcroppings. Markers were then placed at the pile points for future reference in placing rock bolt anchors and in positioning the support barge.

To stabilize the pile legs of the support barge for hoisting, the guying system of Fig. B35 was to be used. Three rock bolts were installed in the bedrock surrounding each pile location. The rock was a metamorphosed lava and pyroclastic deposit with great strength and hardness. An electric underwater rotary tool, developed by the Battelle Memorial Institute, was used with tungsten carbide masonry bits to drill the holes for 3/4-inch bolt expansion jackets. A sample of the installed bolts was tested with a specially fabricated tripod tensiometer to 5000 pounds without evidence of pullout.

Two coral heads which would have interacted with the bottom of the support barge were broken off with a sledge hammer on approval of the National Park Service's representative.

Two 1500-pound anchor-surface can moors were emplaced to constrain the seaward end of the support barge during emplacement operations. To constrain the shoreward end a 75-pound anchor with a wire-rope leader, was emplanted between boulders on shore. For the other corner of the barge a wire rope was wrapped around and secured to a 30-ton boulder.

B8.4.3 Emplacement Operations

The support barge was moved into and connected to its moor by a causeway tender boat. This is a modified landing craft mechanized (LCM-6) used by the Seabees in amphibious operations. It has a shallow draft, twin screws, and adequate power for moderate surf operations. A standard LCM-6 assisted in positioning the barge. The crane barge was then moved into a position adjacent to the support barge. Steel pilings, 20 inches in diameter, were inserted through the support barge spudwells using the 35-ton crane. Swells caused substantial movement in the support barge. The mooring lines were adjusted until the spudwell lined up with the pile point marked on the bottom. The pile was dropped. This was repeated until all piles were in place.

The surge produced sufficient barge motion that installation of the guying system (Fig. B35) on the shoreward piles for hoisting would have endangered the construction divers. This plan was abandoned on the shoreward piles, although guys were installed on the seaward piles. The barge elevation mechanism (Fig. B36) was installed. In normal operations the piles are driven into a sediment bottom, which constrains them to a vertical position when the barge is winched up. Tektite I was the first application in which the piles were set on a rocky ocean bottom. Without pile guys on the shoreward piles, it was decided to jack the barge out of the water on the canted piles and attempt to erect the assembly by pushing with the tender boats. Sleeves were to be welded in the spudwells to maintain the vertical orientation.

The barge was jacked out until the lower side was 6 inches out of the water and the high side 20 inches. At this point, binding in the spudwells became excessive. Attempts to force the piles into an erect position were not successful. The bedrock possessed a fracture plane at approximately the same angle as the pile cant and piles penetrated approximately a foot into the ocean bottom along this plane. Observations and calculations showed that the support barge was in a stable configuration with the 4-foot-long spudwells capable of balancing the moments caused by surf and wind conditions in this protected cove. It was decided not to attempt to correct the cant or raise the barge higher. Four safety chains were attached between barge padeyes and the pile caps at each pile. The winch cables were slacked to approximately a half load. The support van was shimmed to a level position compensating for the 4-degree lateral cant of the barge's deck, to complete the support barge emplacement as shown in Fig. B57.

B8.4.4 Performance Evaluation

Preassembling the support system on a barge at a suitable fabrication facility rather than attempting to assemble them in a remote area on a land-mounted platform was unquestionably advantageous to operational schedules and construction costs. Also advantageous was the elevation of the platform even apart from the requirements for minimizing noise in the water. Continuous checking and adjustment of the moors and motion of the operational platform was thereby avoided.

Development of the Ammi lift dock concept for use on rocky ocean bottoms is required. The value of such development is in the large cost savings over drilling the piles in. Increasing the diameter of the piles or decreasing the spudwell diameter, providing a bearing plate or shoe for the pile to set in and guying of the pile tops are to be considered in the development effort.

Techniques and equipment used for drilling into hard rock underwater were not adequate. A minimum of 1 hour of hard work by three construction divers was required on each hole drilled.

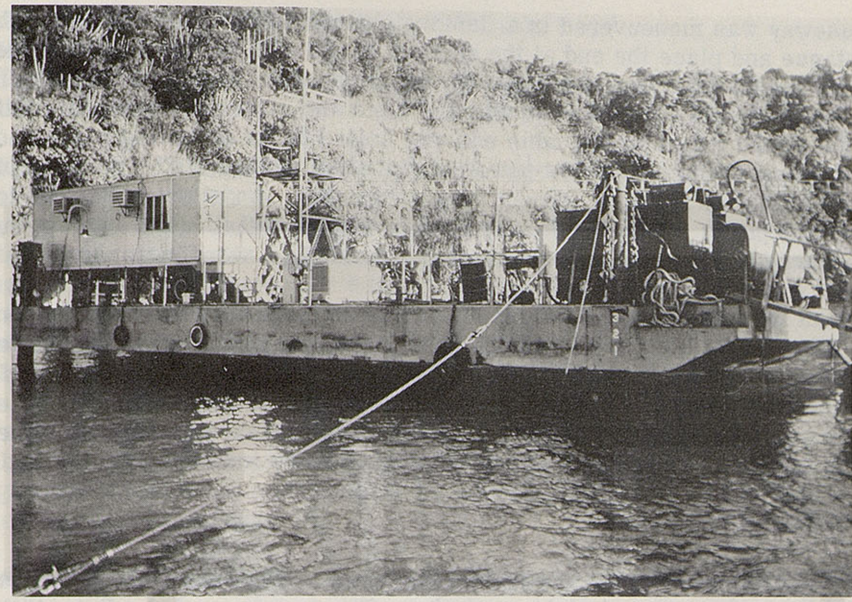

Fig. B57 - Support barge in its final position

The tripod tensiometer developed specially by the Seabees for testing the static pullout strength of water jetted anchors works very well for that purpose. In shallow water, however, it was difficult to position. For use on rock surfaces the forces do not require spread footings, and a more compact unit could be developed.

B8.5 Umbilical Emplacement

B8.5.1 Introduction

The umbilicals consisted of two heavy armored cables and four air and water hoses which float in water. The 1000-foot armored cables were to be laid on the bottom over the 400-foot distance between the support barge and the habitat. To prevent navigational difficulties and risk of severing hoses the air and water hoses, which could be swum out on a straight path at the surface, had to be anchored to the bottom.

B8.5.2 Emplacement Operations

The electrical power cable and the communications cable were provided on their reels with the habitat ends free. The reels were mounted on two reel stands by means of a pipe shaft through the reel center. The reel stands were welded to the deck in the center of a causeway section. A standard Naval Facilities Engineering Command fairlead was modified to suit and welded at one end of the causeway. A reel brake was to have been provided with each reel but was not. Rather than delay the project, and in view of the shallow water into which the cables were to be laid, a crude brake was devised from a piece of timber. The causeway was maneuvered into a position adjacent to the strain relief mounts on the habitat. The habitat end of the power cable was payed out to construction divers. The strain relief had been previously connected to the armor on the cable and the unarmored end had been waterproofed with shrink tubing. Seabee construction divers bolted the strain relief to the mount on the habitat base and threaded the unarmored end up through the cable trunk into the habitat.

The causeway was maneuvered in a flanking pattern to lay the 1000-foot cable over a 400-foot distance and place the end at the support barge with no substantial excess. The bottom throughout the area was composed of very rugged bedrock and coral formations. An error in laying would have taken substantial time and effort to correct. At the support barge the strain relief on the cable end was bolted to its mounting plate and the unarmored end connected to the habitat power distribution system. The communication and signal cable was laid in the same way as the power cable. An attempt was made to avoid crossing over the power cable, which may have produced signal interference, but once crossover occurred. It was compensated for by installing a wooden separator.

The ends of the air and water hoses were secured in strain reliefs and connected at the habitat. They were swum out individually in a straight path at the surface to the support barge, secured in strain reliefs there, and connected to the support barge fittings. They were then married into a bundle every 20 feet, swum to the bottom, and tied with manila line to coral heads and to the power and communication cables where they crossed them. During systems integration checkout the hoses were inspected for leaks.

B8.5.3 Performance Evaluation

Umbilical laying operations were totally successful. No damage to hoses or cable occurred, and the ends came out right on station. The presence of a substantial reel brake or reel drive, such as was used to recover the umbilical, would have reduced the overactivity of the adrenal glands of construction personnel. Under the conditions of having to flank two heavy 1000-foot cables over a 400-foot distance, a crossover was virtually unavoidable but was easily remedied.

B8.6 Way Station Installation

B8.6.1 Introduction

The way stations (Fig. B28) were to provide a refuge for the aquanauts if they became threatened by predators while on excursion dives from the habitat and also allowed aquanauts to communicate by voice with each other while diving and with aquanauts in the habitat. Each way station was equipped with a bang stick loaded with a 12-gauge shotgun shell, and twin 72-cubic-foot scuba tanks for displacing the water in the plastic dome.

B8.6.2 Emplacement Operations

The way stations were lowered to the bottom using a sling and the crane barge. The units, with air in the domes, were positioned on the bottom by swimming them into position using a lift bag.

Sound-powered phones were installed in each way station. Phone wire was spooled off along the bottom from the farthest way station around the loop (Fig. B1) to the habitat and connected by construction divers.

B8.6.3 Performance Evaluation

Construction equipment and techniques were straightforward and adequate.

B9 INSTALLATION, INTEGRATION AND CHECKOUT OF THE HABITAT SYSTEM

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At 9:00 p.m. on January 27, 1969, the Tektite habitat floated clear of the Ammi barge used to transport and launch it. The habitat was sealed, internally pressurized to 20 psig, and positively buoyant by 15,000 pounds. On the following day the Tektite habitat was towed to its emplacement site at Beehive Cove, where it was secured to preplaced bottom anchors made from steel plates. At this point, cast-iron ballast pigs were added by Seabee construction divers to reduce the reserve buoyancy by 10,000 pounds. With the habitat positively buoyant by 5000 pounds it was winched to the bottom, where ballast tanks in the base were flooded to reverse the buoyancy to 5000 pounds negative.

Additional ballast pigs were added and the habitat was secured to the bottom anchors using turnbuckles. At 10:30 a.m. on January 30 General Electric divers opened the habitat and began the installation and checkout procedures that were completed on February 14. The mission began on February 15.

All integration and checkout tasks were accomplished in accordance with prepared checklists that reflected careful study of experience in Sealab II. Checkout tasks during various conditions of the habitat, both above and below the surface, required close cooperation between all of the participating agencies.

The checklist for when the habitat was on the deck of the Ammi barge with its base secured to the barge, had been removed from the well deck of the LSD, was in its shipping configuration including protective coverings on the windows, did not have the power line connected, and had the shark doors and screens in place but did not have the cage at the entrance to the wet room attached was as follows:

1. Tow the Ammi barge and the habitat to the launch site.

2. Moor the Ammi barge on preplaced moors.

3. Locate the template.

4. Thread and drive the four piles.

5. Inspect the piles for depth and perpendicularity.

6. Connect temporary lights inside the habitat.

7. Transfer to the habitat all spares not transferred at the Philadelphia Naval Shipyard, all dry goods (excluding frozen food), all tools, and all expendables (e.g., linens, towels, baralyme, charcoal, and colorimetric tubes).

8. Check the pressure on all emergency scuba bottles and secure the bottles to wall brackets.

9. Check the pressure on all habitat fire extinguishers and secure them in the habitat.

10. Stock spare coolant.

11. Install all charcoal in the filters of the environmental control system.