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EFFECTS OF THE DEEP-OCEAN ENVIRONMENT ON MATERIALS - A PROGRESS REPORT

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U. S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

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Task Y-F015-01-001(c)

Type C

by

Kenneth O. Gray

OBJECT OF TASK

To develop systems and techniques for construction in deep-ocean areas. The task envisages obtaining all necessary data to permit engineers to design, construct, and install required structures and equipment in deep-ocean areas.

ABSTRACT

A research program to determine what materials are suitable for use in the construction of deep-ocean structures and facilities is delineated. The program, initiated in August 1959, involves (1) the exposure of a wide variety of constructional materials in deep-ocean environments, and (2) the exposure of companion specimens in laboratory-simulated deep-ocean environments.

A Submersible Test Unit carrying 1318 specimens of 301 different materials was placed on the ocean floor on 29 March 1962 in 5300 feet of water for an exposure period of 6 months. Five additional units are proposed, one each for 12 and 24 months submersion at 6000 feet and one each for 6, 12, and 24 months submersion at 12,000 feet on the ocean floor.

A system of medium sized (9-inch ID) pressure vessels capable of simulating various aspects of the deep-ocean environment, with a pressure range from zero to 20,000 psi, has been fabricated and will be in operation early in FY-63. A large (18-inch ID) pressure vessel with similar capabilities is under procurement and is expected to be in operation in FY-63.

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INTRODUCTION

Subtask Y-F015-01-001(c), "Effects of Deep-Ocean Environment on Materials," is part (c) of Task Y-F015-01-001, "Deep Ocean Studies," assigned to NCEL by the Bureau of Yards and Docks.

The object of the basic task is to develop systems and techniques for construction in deep-ocean areas. The purpose of this report is to describe the program for the execution of that part of the task related to the effects of the deep-ocean environment on materials and to summarize the progress made in this program since the issuance of the preceding progress report, TN-380, published 23 March 1960.[1]

SCOPE OF DEEP-OCEAN MATERIALS INVESTIGATION

While no specific structures or equipment are delineated in the scope of the investigation, it is reasonable to assume that they will eventually include the following types, as well as other more exotic types of submerged facilities:

- Structures on which to mount antisubmarine warfare gear
- Fuel caches
- Supply depots
- Refueling stations
- Submarine repair facilities
- Nuclear weapon shelters
- Utility (water, air, heat, electricity, etc.) systems for underwater habitation
- Heavy mobile construction equipment
- Power-generating stations

It is apparent that most known significant types of engineering materials may be involved and that eventually they should be evaluated for deep-ocean applications. It is also clear that this is a monumental task which could easily involve the concerted efforts of a large number of engineers and scientists for many years. It is therefore necessary to place limitations on any list of materials to be tested in the first phases of this program. Another reason for limiting the initial materials list is that it is always possible that the proposed experiments may show that the information already available concerning the behavior of materials in shallow marine environments is applicable with only slight modifications to similar materials in a deep-ocean environment. For these reasons the selection of materials for inclusion in the first phases of this program has been limited to a representative sampling of various material types rather than directed toward the systematic coverage of each variety of each type of material. However, through the cooperation of certain industrial research laboratories, a wide variety of small "screening specimens" of various alloys has been included in the specimen load of the first Submersible Test Unit (STU).

Although time-dependent changes in engineering properties of materials may occur, chemical deterioration and corrosion are expected to be the major processes of deterioration in the deep-ocean environment. For purposes of this report the term corrosion is defined as "... a gradual chemical or electrochemical attack on a metal by its surroundings, such that the metal is converted into an oxide, salt or some other compound."[2] These major processes of deterioration will be influenced by the physical environment (high hydrostatic pressure and low temperature) and the biological environment. Since the rate and degree of deterioration are also influenced by specimen configuration and by the mechanical and physical structure of the metals, it will be necessary, in the case of metallic specimens, to include variations in these factors as well as variations in the alloying elements.

The first materials to be extensively tested for suitability for use in the deep-ocean environment will be those commonly used in conventional construction and available through normal supply channels. If it is determined that these materials are not satisfactory for deep-ocean structures, then the less commonly used, exotic, and unusual materials will also be studied.

When constructing in a medium of relatively high density (compared to air) such as sea water, there is immediately available a unique technique of building virtually weightless structures and thus regulating the dead-load pressure such a structure will exert on the ocean bottom. This technique is based on the use of low-density structural plastics, foamed materials, and/or the incorporation of buoyancy through the use of either voids or spaces filled with a buoyant fluid or other material. For this reason, and also because of their resistance to sea-water corrosion, plastic materials take on great importance. These include acrylics, polyvinyl chlorides, polypropylene, polyethylene, polyeurthane, teflon, nylon, rubber (both natural and synthetic), glass-fiber laminates, and others. Samples of many of these materials will be included in this program.

Ceramic and glass materials are important to provide electrical insulation, view ports, and transparent closures for light sources, cameras, and television; they are also used as structural elements in some electrical lead-through systems. Some of these types of materials will be tested.

Cables for lowering and raising loads in deep water, for mooring buoys and ships, for guying structures, and cables for general-purpose work are important to the deep-ocean program and will be tested. Included in this program will be galvanized steel, electrogalvanized steel, aluminized steel, uncoated steel, and polyvinyl-chloride-coated steel cables. Stainless steels and other alloys will be included. Specimens of some electrical cables will also be included.

The suitability of concrete for use in deep-ocean structures will be investigated. Experiments will be set up to evaluate the effect of this environment on its permeability, water absorption, volume change, and durability. The types of reinforcing material for this use will also be investigated.

EXPERIMENTAL ENVIRONMENTS

If the results of experiments conducted in deep-ocean environments differ materially from what would be expected of similar materials exposed in shallow-water environments (judged on the basis of data published in the literature), it will then be necessary to conduct similar experiments using identical specimens in shallow water to insure that the anomalous results were in fact due to the environmental differences and not due to some variable in the particular specimens used or to the experimental technique. In the event that such shallow-water exposure seems desirable, Port Hueneme Harbor will probably be used. Various pressurized and unpressurized laboratory-simulated deep-ocean environments will also be used to isolate and study the contribution of individual factors to the deterioration of materials exposed in the deep ocean.

Deep-Water Environments

The environments with which this task is primarily concerned are those of the water near the ocean bottom (at depths beyond normal engineering construction practices; i.e., depths in excess of 2000 ft),[3] the water-bottom interface, the sediments adjacent to the water-bottom interface, and to a somewhat lesser extent, the intervening water mass between the ocean bottom and the surface.

This study concentrates on these environments because the effects of the near-surface (shallow-water) environment on materials have been and are under intensive study by many other agencies. Also it is believed that the greater part of most deep-ocean structures of interest to BuDocks will be on the ocean bottom or in its immediate vicinity.

The intervening water mass between the bottom and surface will be considered primarily as an environment for mooring cables and small suspended structures such as underwater buoys and arrays.

In order to appreciate the potential effects of the deep-sea environment and the necesssity for evaluating materials while exposed to it, the following example of physical data describing the actual environment as measured at the bottom in the Romanche Deep of the Atlantic Ocean,[4] is presented:

Depth - 25,000 feet
Ambient pressure - 11,000 psi
Temperature - 1.45° C
Salinity - 34.75 o/oo
Oxygen - 5.1 ml/L
pH - 7.7
Currents - probably on the order of 0.1 knot or less

While these are the conditions which prevail at this depth, it must be remembered that anything being placed on the bottom must pass through the upper portions of the sea where strong currents, wave action, sunlight, relatively high oxygen content, and a very active biological environment prevail. In addition to these factors, the object being lowered would go through a pressure gradient ranging from atmospheric pressure at the surface to many thousands of psi hydrostatic pressure at the bottom.

Factors contributing to changes in and/or the deterioration of materials exposed to the deep-ocean environment are summarized as follows:

Low ambient temperature
Biological environment
High hydrostatic pressure
Stress
Chemical environment
Electrochemical effects of immersion in an electrolyte
Water movement

These factors, separately or in combination, may operate to produce one or a combination of the following effects which may change certain properties of the materials exposed to this environment:

Creep
Mechanical failure
Physical deterioration
Chemical deterioration
Biological deterioration
Electrochemical deterioration
Volume change
Water absorption

Laboratory-Simulated Environments

One of the early objectives of this task has been the investigation of means of reproducing the deep-sea environment in the laboratory under controlled conditions. Toward this end the literature has been studied to determine the state of the art in this field. Visits have been made to various government, university, and industrial laboratories throughout the country to examine high-pressure research facilities and to determine what work has been done on this problem. As an outgrowth of these searches, which disclosed a lack of the desired facilities, various high-pressure laboratory vessels and facilities have been designed and are being fabricated.

NCEL's high-pressure laboratory, which will be described in detail later in this report, will, when fully developed, be used to reproduce the following aspects of the deep-ocean environment:

Hydrostatic pressure to 20,000 psi
Temperature down to 0°C
Sea-water chemistry as found in situ at great depth

Shallow-Water Environments

In order to study the differences in deterioration processes and rates of deterioration in deep and in shallow water and to determine if observed differences are in fact due to the environmental differences and not differences in specimens or experimental technique, it may be necessary to expose duplicate specimens of certain of the materials under study in both environments for similar periods of time. Because of its proximity, Port Hueneme Harbor has, for some years, been used as a site for corrosion and protective coating studies by NCEL. The harbor waters are relatively unpolluted and are monitored weekly for pH, salinity, and solid content.

Specimens exposed in this environment would be prepared from the same lots of material used in the deep-water tests. The essential difference in the exposure conditions, other than the environment, would be the spacing of specimen plates. Due to the high fouling rate in the harbor, it would be necessary to provide more separation between adjacent specimen plates than is believed necessary for deep-ocean exposure.

MATERIALS TO BE INVESTIGATED

Since this is a continuing program it is not feasible to provide a complete list of all the materials to be tested. The Appendix contains a list of all the materials contained in the specimen load of the first Submersible Test Unit placed in FY-62. Selections of materials to be included in the tests have been based on gleanings from the literature and from the records of meetings held by various naval activities and scientific groups. The major producers of metals, as well as nonmetals, have been requested to supply their recommendations. In most instances the producers have provided advice, and in some cases have supplied samples of production materials for test.

The Naval Air Material Center at Philadelphia, Pennsylvania, the U. S. Naval Engineering Experiment Station at Annapolis, Maryland, the U. S. Naval Underwater Ordnance Station at Newport, Rhode Island, the Naval Ordnance Test Station at China Lake, California, the Navy Electronics Laboratory at San Diego, California, and some industrial laboratories, as well as NCEL, have contributed specimens for inclusion in this program.

EXPERIMENTAL METHODS

Unstressed Specimen Experiment

Unstressed materials will be utilized as the primary type of specimens to be exposed in the experimental environments. Where it is feasible (generally a matter of having a sufficient quantity of the test material), rigid sheet materials have been cut to 6 inches by 12 inches in size and mounted in racks. The purpose of utilizing specimens of this size is to reduce the possibility of edge effects obscuring the effects of the environment on normal flat surfaces. Sixteen such plates are shown in Figure 1 in a exposure rack designed for specimen exposure above the water-bottom interface. Similar racks are used for exposure of specimens in the environment of the sediments below the water-bottom interface. As may be noted in Figure 1, each 6-inch by 12-inch specimen is in contact with nothing except porcelain insulators and each set of four specimens is separated from adjacent dissimilar materials by a vinyl separator plate. In this illustration, four replicate sets, each containing four plates of a single material, are shown.

The arrangement of the four specimens is such that the two outside specimen plates of each set are separated from the adjacent vinyl plate by about 1/2 inch and from the closest of the inside pair of specimen plates by about 1 inch. The inside pair of specimen plates are separated one from another by about 3/4 of an inch. This arrangement is designed to test the effects of the spacing of the plates (from each other and from adjacnet materials) on the rate and on the degree as well as type of deterioration of the plates.

In each set of four replicate specimens, one plate has a 1-inch by 1-inch square "patch" of the same material bolted to it (as shown in Figure 1) by a nylon bolt. The purpose of this procedure is to investigate the susceptibility of the material to crevice corrosion.

Specimen identification code numbers are applied to all rigid 6-inch by 12-inch specimens by a combination of two edge notches and two 1/8-inch holes which are drilled through the specimen at specific "grid points."

When the quantity of material available is insufficient for the fabrication of 6-inch by 12-inch plates, a specimen size of 1-inch by 6-inches is used. These specimen strips are fastened to a 1/2-inch-thick polyethylene strip by means of 1/4-inch-diameter nylon machine screws. The specimens are spaced about 1/8 inch from the polyethylene strips by means of an acrylic washer. By using this method, both rigid and nonrigid materials are mounted for exposure. Figure 2 shows two sets of the 1-inch by 2-inch racks installed on the Submersible Test Unit.

Short pieces of wire, cable, and rodlike specimens are held in plastic mounting clips fastened to 1/2-inch-thick polyethylene strips by means of 1/4-inch-diameter nylon machine screws. The polyethylene strips are held in their racks by means of mild-steel bolts.

Stressed Specimen Experiment

Exposure to the experimental environment under stressed conditions is accomplished in either of two ways according to the type of material. Cables exposed in a stressed condition are placed in tension jigs patterned after similar devices developed by the American Steel & Wire Company. Figure 3 shows a jig containing two specimens of cable under tension. In use, the cable is threaded through the jig end-plates and tensioning screw; mild-steel end stops are swaged in place and the tension screw is then adjusted using a cable tension indicator (see Figure 4) in order to stress the wire to 20 percent of its ultimate strength. All metal-to-metal contact between the cable specimens and the tension jig is eliminated by means of fiber-reinforced plastic washers and plastic sleeves.

Four cable-tensioning jigs containing specimens of eight different materials are included in the test program for the first deep-sea tests. The cable materials are as follows:

Bright plow steel
Bright Monitor
Galvanized plow steel
Electrogalvanized plow steel
Type 316 stainless steel
PVC over Amgal
USS Tenelon
Aluminized steel

Two specimens are mounted in each of the four jigs. The jigs are located on the STU so that each cable specimen crosses the water and sea-floor interface and is partially embedded in the sea floor.

Stress-corrosion testing of appropriate metallic materials may be conducted by utilizing the method illustrated in Figure 5 and described by Phelps.[5] In this method, the specimen, which is prepared in the form of a strip 1 inch wide and 0.050 inch thick, is placed in flexure in a rigid jig. The jig holds the ends 7.000 ± 0.001 inches apart. The tensile stress induced in the outer fibers of the mounted specimen is a function of the length of the specimen; the length is calculated for a desired stress level. In order to assure that there are no bimetallic electrical currents between the metal specimen under test and the metallic jig, an insulating film is placed between the jig and the specimen. To prevent complete loss of a broken or displaced specimen, a hole is drilled through each end of each specimen and a thin plastic cord is used to tie it to the jig.

Specimen Handling

The following procedure for treating the specimens which were mounted on the first Submersible Test Unit (see Ocean Environment Experiments) is planned for all deep-ocean exposure tests.

Following the degreasing, the metallic specimens were handled with clean cotton gloves and immediately placed in sealed canisters which contained silica-gel desiccant. All materials, both metallic and nonmetallic, were then taken to a workroom where the humidity was maintained at approximately 20 percent relative humidity. The specimens were then weighed and placed in the racks in which they were to be exposed to the deep-ocean environment. The individual racks were then wrapped in polyethylene and transferred to the assembly room where they were attached to the STU, which is shown in Figures 6 & 7 with the complete specimen load. The assembly room consisted of a large plastic-covered, humidity-controlled chamber (see Figure 8) which was erected in a warehouse-type building. The humidity in this chamber was controlled at approximately 35 percent relative humidity.

When the STU was removed from the assembly room for transporation to the ship and the sea-installation site, it was wrapped in a polyethylene cover with desiccant included. The cover and desiccant were removed about an hour before the actual placement of the STU in the water.

Evaluation of Specimens After Exposure to Test Environment

Immediately after removal of specimens from the ocean environment they will be photographed with color film and then examined by a biologist who will collect, for identification, specimens of any organisms which may be attached. For a discussion of the biological aspects of materials deterioration see NCEL Technical Report R-182, The Effects of Marine Organisms on Engineering Materials for Deep Ocean Use.[6]

Following the collection of biological specimens, the STU and its contents will be washed off with fresh water, and the test racks and jigs will be removed and dried and cleaned so as to permit examination of the surfaces of the specimens. Pitting depth, edge deterioration, and loss of plate thickness and weight will be recorded.

Other tests to determine changes in properties such as durometer, hardness, moisture content, resistivity, tensile strength, chemical composition, and elasticity will be conducted as appropriate for the individual materials.

OCEAN ENVIRONMENT EXPERIMENTS

Deep-Water Experiments

Submersible Test Unit (STU). The STU (Figures 6 & 7) is designed for placing specimens and/or instruments on or near the ocean bottom, exposing its load to the effects of the deep-ocean environment for extended periods of time, and recovering its load at the end of the exposure period.

The STU is a towerlike structure 14 feet high with a 30-inch by 30-inch cross section supported on a 13-foot by 13-foot square base to assure stability on soft or sloping bottoms. The structural members are fabricated from A-7 structural steel and are protected with a vinyl paint. This particular paint was selected to inhibit corrosion of the structure and at the same time not to inhibit fouling activity. It was felt that the introduction of a fouling inhibitor would interfere with the effects of the experimental environment (including the resident organisms) on the various specimens under test.

The tower portion of the STU is provided with adjustable shelves, each consisting of a steel grating fastened to an angle-iron framework. The weight of the loaded STU is approximately 7000 pounds in air and 6000 pounds in sea water.

Program. The STU provides a means for exposing a large number of specimens of various materials to the effects of the deep-ocean environment. The initial program, as presently envisioned, is divided into two phases. In the Phase I program three STU's are to be placed at a depth of 6000 feet for periods of 6, 12, and 24 months respectively. In Phase II, three STU's are to be placed at a depth of 12,000 feet for periods of 6, 12, and 24 months respectively. The extent of this program beyond Phases I and II will depend entirely on the results obtained from these first experiments.

The first STU of Phase I has been fabricated and was emplaced in 5300 feet of water on 29 March 1962 for a 6-month exposure. Emplacement of the next STU is planned for late in FY-63.

Operational Testing. Tests at sea in 1200 and 6000 feet of water, which involved the placement of the STU with a 1600-pound simulated specimen load on the bottom, were conducted with the YFU-48 during November and December 1961. These tests revealed the following facts:

1. The YFU-48, a 116-foot converted LCU, is adequate for the STU placement operation at the 6000-foot-depth site in favorable weather.

2. The standard Navy UQN-1E depth sounder is not adequate for tracking the STU during placement in 6000 feet of water using the standard recording equipment.

3. The two devices designed and constructed at NCEL to sense any departure of the STU's attitude from a normal vertical position during lowering and placement on the bottom worked satisfactorily.

4. A lowering rate of 200 feet per minute for the STU was found to produce no yawing. A rate of 300 feet per minute produced yawing of as much as 10 degrees.

5. The STU sank about 12 inches into the bottom sediments, upon which it rested for about one-half hour.

Further operational tests were successfully conducted early in 1962 during which a rehearsal of the placement of the STU and portions of its mooring and recovery system was conducted in 6000 feet of water in the Santa Cruz Basin.

STU Instrumentation. The first STU was equipped with an electronic instrument to assist in placing it gently on the bottom in a stable upright position. This instrument is an orientation-sensing device which is designed to sense any departure of the STU from a vertical attitude and to indicate the number of degrees at which its vertical axis is inclined from the true vertical. The signal of the attitude sensor is used to control the ping rate of the pinger attached to the STU. When the axis of the STU is vertical it emits pings at a rate of 100 per minute. With each degree of inclination from the true vertical the sensing mechanism causes the pinging rate to be decreased by one ping per minute. By this means the attitude of the STU was determined to be 6 degrees from the vertical at the time it was placed on the bottom for the 6 months exposure period at 5300 feet. The attitude signal was monitored for about 4 hours after placement and no change was observed.

It would be desirable to instrument the STU to periodically sample and record information concerning local temperature, salinity, oxygen content, pH, and oxidation-reduction potential during its entire period of submergence. At present, reliable, automatic, self-contained instrumentation capable of collecting and storing such information over a 6-month period is not available. For this reason conventional oceanographic methods will be used to collect this kind of information. At such time as suitable automatic instrumentation becomes available at a "reasonable cost," it is expected that it will be added to this program.

An automatic self-contained recording device to measure the velocity and direction of the currents in the vicinity of the STU during the 6-month submersion period was attached to the STU retrieval system at the time of placement.

Placement and Recovery System. A special "mooring" system, as shown in Figure 9, has been used to assure the relocation and recovery of the STU at the end of the test period. Relocation and recovery relies on the use of precision electronic surveying equipment to place the retrieval vessel directly over the emplacement site. Actuation of the acoustic command link, noted in Figure 9, will cause the sinker to be jettisoned and will allow the submerged buoys to float up to the surface for attachment of lifting gear. A number of alternative recovery methods have been incorporated in the mooring and retrieval system.

This installation does not use a surface marker because: (1) sea conditions at the site would probably cause it to be swept away; (2) past experience has indicated that irresponsible mariners would very likely sink or remove it; (3) it would provide a hazard to navigation; and (4) since the site is in international waters, a surface buoy would provide a marker for hostile investigators.

A complete description of the installation procedures, the rigging, and the equipment involved in the placement of the first STU will be published in a separate report by NCEL.

Test Sites. The primary considerations in the selection of test sites for the initial program of deep-ocean testing were to select a site at which circulation, sedimentation, and bottom conditions were more or less "normal." Just what constitutes a "normal" environment is open to discussion; however, in order to arrive at acceptable sites for these first exploratory experiments, certain practical limitations were established. First, the sites had to be within reasonable operating range of Port Hueneme and converted LCU with which the Laboratory conducts its work; second, the site should not be located in an area of restricted circulation such as a silled basin; third, the bottom should be reasonably flat; and fourth, the site should be located so that use could be made of the best available precision location techniques for positioning the recovery vessel, preferably those techniques using line-of-sight reference points.

The 6000-foot-depth Site. The site chosen for 6000 feet of water depth is in a broad submarine valley southwest of San Miguel Island. This site is open to the effects of the prevailing coastal ocean currents and is as nearly "normal" a location as there is to be found within a reasonable distance from Port Hueneme. Environmental conditions at the bottom at a depth of 5647 feet at a site about 5 miles northwest of the actual STU placement site were determined to be as follows:

Temperature	2.53°C
Salinity	34.584 °/oo
Oxygen	1.29 ml/L

The complete oceanographic station record of these parameters as measured at this location by the Scripps Institution of Oceanography ship HORIZON on January 12, 1962 is shown in Table I.

The 12,000-foot-depth Site. The site tentatively chosen for 12,000 feet of water depth is located in the area near the San Juan Seamount about 120 miles southwest of Port Hueneme. Investigation of this site and alternative sites is planned to be conducted in FY-63.

Shallow-Water Experiments

For purposes of comparison, specimens identical to certain of those exposed in the first STU may be exposed in the Port Hueneme Harbor for similar periods of time. This environment is well known; corrosion investigations have been conducted there for many years.

LABORATORY-SIMULATED DEEP-OCEAN ENVIRONMENT EXPERIMENTS

Program

One of the objectives of this subtask is to develop laboratory techniques, equipments, and test procedures which will make possible laboratory evaluation of materials under consideration for deep-ocean service. These methods will be developed by comparing and correlating results obtained in a laboratory-simulated deep-ocean environment with those obtained in an actual deep-ocean environment.

In addition to the chemical, biological, and other laboratory facilities which exist at NCEL, a new deep-ocean laboratory has been established specifically for this investigation of deep-ocean environmental problems. This new facility is being equipped with unique sea-water pressure-vessel systems and associated equipment, designed to simulate the chemical and physical aspects of the deep-ocean environment.

The deep-ocean laboratory will make available facilities to perform the following general type of investigations, tests, and experiments:

1. Proof-testing of deep-ocean equipment, devices, and components.

2. Calibration of instruments for use in the deep ocean.

3. Investigation of the effects of high hydrostatic pressure (sea water or fresh water) on materials, devices, electrical equipment, instruments, and other equipment.

4. Investigation of the effects of variations in sea-water chemistry, pressure, and temperature on corrosion, and possibly other deep-sea deterioration processes.

5. Investigation of the effects of a high hydrostatic-pressure sea-water environment on structural joining systems.

6. Investigation of the effects of a high hydrostatic-pressure sea-water environment on cathodic protection systems.

7. Investigation of the effects of a high hydrostatic-pressure sea-water environment on protective coatings.

Deep-Ocean Laboratory Equipment

Pumps. Sea water is supplied to the pressure vessels by two types of high-pressure pumps. One of these is an air-operated pump capable of supplying and automatically maintaining sea water at any pressure up to 20,000 psi for an indefinite period. The other pump is an electrically driven, reciprocating, manually regulated unit capable of delivering sea water at pressures up to 30,000 psi.

Small (1-1/2-inch-ID) Pressure Vessel (see Figure 10). This vessel, constructed of chrome-vanadium steel, has an inside length of 10-1/2 inches and a maximum operating pressure of 15,000 psi. It is provided with two closures; one closure has one fluid inlet and the other (shown in Figure 10) has one fluid inlet plus six electrical lead-in connections. This vessel is used for evaluating the effects of hydrostatic pressure on materials, small devices, and components. Figure 11 shows the safety-housing cabinet for this vessel and its pump. Figure 12 illustrates the interior of the cabinet and shows a test in progress. The reciprocating, adjustable-stroke, electric-motor-driven pump appears in the center foreground. All valves are hand-operated through an indirect chain-drive so that in the event of a valve stem "blowout" the valve stem will be confined within the cabinet and not create a missile type of hazard. In Figure 12 a lead-through test bomb holder is shown resting on the bracket used to hold the 1-1/2-inch-ID vessel while in use.

Medium (9-inch-ID) Pressure Vessel. The system in which these vessels are used utilized modified, surplus, 16-inch, high-capacity naval shells as pressure vessels. These shells serve as vessels with a usable inside cylindrical cavity 9.47 inches in diameter by 28.25 inches long. The cavity extends beyond the cylindrical portion an additional 18 inches and tapers to 3.36 inches in diameter, providing a total inside length of about 46 inches.

These vessels will be equipped with inlets and outlets to permit the internal circulation of sea water at adjustable rates of flow at any pressure up to 20,000 psi (see Figures 13, 14, 15, and 16 for details).

The vessels will be provided with an electrical feed-through unit which includes eight entries. The number and types of entries in the feed-through unit can be varied to meet new requirements as they arise.

Since the vessels are fabricated from a steel alloy susceptible to attack by sea water, the sea water will be isolated from the steel vessel wall by a pliable bag supported in a stainless-steel mesh with a noncorrosive fluid occupying the space between the bag and the vessel wall.

As shown in Figure 16, a number (12 shells available) of these vessels is planned for fabrication to provide enough facilities for conducting both long-term and short-term tests. All will be supplied with pressurized sea water from a chemically controlled storage tank connected to a manifold distribution system.

The prototype vessel of this system has been fabricated in the NCEL shops and will be tested in FY-63. Following the testing of the prototype vessel and the accomplishment of any necessary design modifications, it is planned that up to two more such vessels will be fabricated in FY-63. It is expected that this pressure-vessel system will be operational early in FY-63.

Large (18-inch-ID) Pressure Vessel. A pressure vessel with the following general specifications is presently under procurement:

1. The vessel will have a usable inside diameter of 18 inches and a usable inside length of 36 inches.

2. A removable end closure will be provided at one end. This closure will be provided with three fluid entries, a top vent, three 220-volt 10-amp electrical entries, and 18 electrical instrumentation entries.

3. The bottom, which may or may not be removable, depending on the final design, will have four fluid entries.

4. The vessel operating pressure will be 20,000 psi at any temperature between $0^{o}C$ and + $40^{o}C$.

Depending on the costs involved in lining the vessel and the end closures with a material which is unaffected by sea water, this vessel may be provided with a pliable bag and basket system similar to that used in the 9-inch vessel and shown in Figure 14.

The vessel will be provided with an air-operated circulating sea-water supply system similar to that used with the 9-inch vessel. It is planned that this vessel will ultimately be provided with a refrigeration system and an automatic pressure-control and pressure-cycling system.

The procurement, installation, and development of this system has been planned as follows:

Phase I - FY-62

a. Design and procurement of the vessel.

b. Alteration of an existing building to accommodate the vessel system. (Completed)

Phase II - FY-63

a. Installation of the vessel.

b. Fabrication and installation of a controlled sea-water supply system.

c. Procurement of refrigeration equipment.

d. Procurement of temperature-control equipment.

e. Installation of a cooling system.

Phase III - FY-64

a. Procurement and installation of an electronic salinity and oxygen monitoring system.

b. Procurement and installation of pressure-cycling pumping and control equipment.

The vessel should be available for initial use late in FY-63.

Sea-Water Supply System. Sea water will be supplied to the pressure-vessel systems from two large plastic-lined, covered tanks. The chemical and physical properties of this water will be adjusted and monitored so as to duplicate as nearly as possible the environment of the ocean as determined to exist in the waters at any selected deep-ocean test site. Natural sea water will be used as the raw material for simulating deep-ocean sea water.

Atmospheric-Pressure Sea-Water Exposure Tank. In order to permit the evaluation of the contributions of high hydrostatic pressure to any of the effects observed in laboratory pressure-vessel experiments, a small closed plastic-lined tank, supplied with "controlled" sea water, will be available for exposing specimens at sea-level ambient pressures.

Miscellaneous Test Fixtures and Devices. Various special-purpose devices have been designed and fabricated as the need for them occurred. These include:

Pressure lead-through - 15,000 psi. A miniaturized version of the lead-through system used on the Marine Physical Laboratory's RUM vehicle was developed to provide electrical entries into the 1-1/2-inch pressure vessel. See Figure 17.

Lead-through proof-test bomb. In order to proof-test various proprietary lead-through devices, a small bomb assembly was designed. Various lead-throughs were tested to 15,000 psi with this device. See Figure 18. A room-temperature vulcanizing silicone rubber was used to seal the threaded joint between the connector and the holder. No leaks developed at pressures of 15,000 psi during test periods as long as 30 hours. The test bomb in its safety shield is shown attached to the high-pressure pump in Figure 14.

Stress corrosion rack. A special fixture fabricated from stainless steel and polyetheylene is shown in Figure 19. This fixture will hold 16 stress-corrosion jigs of the type illustrated in Figure 5. By means of this rack, these jigs and specimens can be exposed to a high-pressure sea-water environment in either the 9-inch or 18-inch pressure vessels.

Tensile stress corrosion jig. A stainless-steel and plastic tensile-stress jig is shown in Figure 20. This jig is designed to place tensile-test specimens under stress for exposure in pressure vessels. Figure 21 is an exploded view of this jig showing the plastic sleeves and washers which provide electrical insulation between the specimen and the jig.

DEEP-OCEAN BIBLIOGRAPHY FILE

The deep-ocean studies bibliography file contains over 2000 entries which include books, reports, articles from scientific journals, and papers presented at various symposia and congresses. The subject matter of this bibliography covers the entire spectrum of the sciences and arts involved in deep-ocean work.

Of these 2000 entries approximately 750 have been entered into a manual keyword information-retrieval system. This system is based on the assignment to each reference of a number of keywords which describe the content of the reference. These terms or keywords are selected by an examination of the reference, an abstract, a table of contents, or in some cases where none of these are available, the title of the reference.

Each reference entered into this bibliography is assigned an accession number. After analysis for keywords, the accession number is posted to all of the appropriate keyword cards in the keyword file. It is then possible, by consulting the keyword file, to discover any reference which contains information on the subject described by a keyword or combination of keywords.

In addition to the keyword file, which contains only 750 accession references at present, all 2000 entries are indexed by author and issuing agency.

An intensive effort has been made to contact all known suppliers of equipment and devices for high-pressure research, oceanographic measurements, and deep-sea investigations. This effort has resulted in the accumulation of an extensive reference file concerning equipment and instruments for these applications.

FUTURE PLANS

Ocean Environment Research Facilities

The second STU (24 months exposure at a depth of 6,000 feet) is scheduled for placement late in FY-63. It is anticipated that subsequent STU's will be placed at a rate of one per year unless an urgent need for this type of research develops.

On the basis of experience with the first STU and the problems presented by its loaded weight (about 7000 pounds), it is anticipated that future STU's will be constructed of a lightweight, corrosion-resistant material such as plastic reinforced with glass fiber. It should be possible by this means to reduce the gross weight by about 30 percent.

The placement and retrieval system used with the first STU will be further developed and simplified. It is believed that development of a highly reliable, remotely actuated or time-delay actuated anchor-release system will do away with the necessity for the complex retrieval "back-up" system used with the first STU. Such a release system will be considered for development and use with future STU's.

Redesign of specimen racks will be undertaken to reduce weight and eliminate materials requiring protective coatings. For example, the end plates of the rack shown in Figure 1 which are now vinyl-coated mild steel could be replaced by reinforced plastic, and the long mild-steel bolts passing through the insulators could also be replaced by reinforced plastic or by a more corrosion-resistant metal. Results from exposure tests conducted in the first STU should provide the necessary information for selecting appropriate materials.

Investigation into problems of measuring and recording the environmental parameters of the actual STU site will continue; the ultimate objective being to provide a compact instrument package which will measure and record (for periods of 6, 12, and 24 months) the current direction and velocity, salinity, temperature, oxygen content, oxidation-reduction potential, and pH of the surrounding sea water.

Laboratory Research Facilities

It is expected that the first of the medium (9-inch-ID) pressure vessels will be operational early in FY-63. Work on providing for a continuous supply of sea water will be completed early in FY-63. During FY-63 the problems of monitoring and controlling the physical and chemical properties of the sea water supplied to the vessels should be resolved. Until these problems are solved the vessels will be useful primarily for short-term experiments.

Delivery of the large (18-inch-ID) pressure vessel should be made in mid FY-63. This vessel will be provided with a controlled sea-water supply and a cooling system. It is anticipated that this will be completed late in FY-63.

Ocean Environment Research

STU's for the 24- and 12-month's exposure periods at a depth of 6000 feet will be designed, fabricated, and placed in FY-63 and FY-64 respectively.

During the second quarter of FY-63 (October) the first STU will be retrieved from a 6-month exposure period in 5300 feet of water. Following its retrieval a maximum effort will be made to evaluate the environmental effects on the STU specimen load and to publish preliminary results at as early a date as possible.

A literature study will be made to disclose possible effects of ocean-bottom sediment composition, sediment transport, sedimentation processes, and bottom topography on materials and bottom-mounted structures.

It is believed that accurate knowledge of the pertinent oceanographic parameters - i.e., current velocity, salinity, oxygen content, temperature, oxidation-reduction potential, and pH - will be essential for predicting the relative corrosiveness of potential deep-ocean construction sites. Information concerning these parameters will also be necessary for the accurate simulation of deep-ocean environmental conditions in laboratory high-pressure systems. For these reasons an intensive study of the methods and devices necessary to conduct in-situ measurement of these parameters will be conducted. In the event that suitable instrumentation is not commercially available to fulfill these requirements, the necessary instruments may be developed either through in-house research or by contract.

Laboratory-Simulated Ocean Environment Research

As soon as pressure vessel facilities with chemically controlled sea water are available, laboratory research will commence on the problem of laboratory simulation of the deep-ocean environment in order to compare corrosion rates obtained in laboratory pressure vessels with results observed to have taken place in the STU during the 6 months submersion in 5300 feet of water.

Methods of measuring and monitoring corrosion of specimens contained in pressure vessels while under high hydrostatic pressure will be investigated and adapted to the needs of this program. It is believed that methods which utilize measurement of changes in electrical resistance with metal loss may be adaptable to this requirement.

REFERENCES

1. U. S. Naval Civil Engineering Laboratory. Technical Note N-380, Properties of Materials in Deep-Ocean Environment - A Progress Report, by Kenneth O. Gray. Port Hueneme 1960.

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3. U. S. Naval Civil Engineering Laboratory. Technical Note N-400, Outline for an Engineering Handbook for Construction in Deep Ocean Areas, by W. F. Burkart. Port Hueneme, 1961.

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5. Phelps, E. E., and A. W. Loginow. "Stress Corrosion of Steels for Aircraft and Missiles," Corrosion Magazine, Vol. 16, No. 7 (1960), p.325t-335t.

6. U. S. Naval Civil Engineering Laboratory. Technical Report R-182, The Effects of Marine Organisms on Engineering Materials for Deep-Ocean Use, by James S. Muraoka. Port Hueneme, 1962.

Appendix

SPECIMENS ON STU PLACED 29 MARCH 1962

Metallic Specimens

Aloyco 20 (1)*
Aluminum 1100 (1)
Aluminum 1100-0 (2)
Aluminum 2004 (1)
Aluminum 2014 (2)(3)
Aluminum 2024-T3 Clad (2)
Aluminum 2219-T81 (2)(3)
Aluminum 3003 (1)
Aluminum Alclad 3003 (1)
Aluminum ALC 3003-H12 (2)(3)
Aluminum 3003-H14 (2)(3)
Aluminum 3003-H24 (2)
Aluminum 5052 (1)
Aluminum 5052-H22 (2)
Aluminum 5086-H34 (2)(3)
Aluminum 5254-0 (4)
Aluminum 5254-H34 (4)
Aluminum 5456-H34 (2)(3)
Aluminum 5456-H321 (2)(3)
Aluminum 5456-H343 (2)(3)
Aluminum 6061 (2)
Aluminum 6061-T6 (2)(3)(5)
Aluminum 7075-Q (2)
Aluminum 7075-T6 (2)(3)
Aluminum X-7178-0 (2)
Aluminum 7178-T6 (2)(3)
AM 350 (1)
Armco 17-14 Cu, Mo (1)
Brass, 1% Aluminum (1)
Brass, Arsenical Admiralty (1)
Brass, Commercial (2)
Brass, Naval (2)(5)
Brass, Nickel (1)
Brass, Red (1)(5)
Brass, Yellow (1)(2)
Bronze, Aluminum (2)
Bronze, 5.5% Aluminum (1)
Bronze, 7% Aluminum (1)
Bronze, 9.5% Aluminum (1)
Bronze, 11% Aluminum (1)
Bronze, 13% Aluminum (1)
Bronze, Commercial (1)
Bronze, Al-Ni (1)
Bronze, "G" (Gunmetal) (1)
Bronze, "M" (1)
Bronze, Leaded-Sn (1)
Bronze, Manganese (1)(2)
Bronze, Mn-Si (1)
Bronze, Ni-Al (1)
Bronze, Ni-Vee "A" (1)
Bronze, Ni-Vee "B" (1)
Bronze, Ni-Vee "C" (1)
Bronze, Phosphor (1)(2)
Bronze, Silicon (1)
Carpenter 20 cb (1)(2)(3)
Chlorimet 2 (1)
Chlorimet 3 (1)
Constantan (1)
Copper (1)(2)(5)
Copper-Nickel 62/25, 8Zn, 5Pb (1)
Copper-Nickel 70/30 (1)(5)
Copper-Nickel 80/20 (1)
Copper-Nickel 90/10 (1)(5)
Duranickel 301 (1)
Durimet 20 (1)
Hastelloy "B" (1)
Hastelloy "C" (1)(2)(3)
Hastelloy "D" (1)
Hastelloy "F" (1)
Hastelloy "X" (1)
Haynes-Rene 41 (2)
Incoloy 800 (1)
Incoloy 804 (1)
Incoloy 901 (1)
Inconel AMS 5542D (2)
Inconel Mil-N-6840 Cond. A (2)
Inconel 600 (1)
Inconel Cast 610 (1)
Inconel 700 (1)
Inconel X-750 (1)

*See notes at end of list of metallic specimens

Iron, Armco (1)
Iron, Cast, 1% Ni, 0.35% Cr (1)
Iron, Cast, 3% Ni, 1% Cr (1)
Iron, Ductile (1)
Iron, Ductile, Ni Free (1)
Iron, Gray (1)
Iron, Ni Cast (1)
Iron, Silicon (Duriron) (1)
Iron, Silicon + Mo (1)
Iron, wrought (2)
Kanigen plated steel (1)
Lead (2)
Lead, Antimonical (1)
Lead, Chemical (1)
Lead, Tellurium (1)
Magnesium AZ31 (2)(3)
Magnesium Dow "FS-1" (1)
Magnesium Dow "M" (1)
Monel (annealed) (2)
Monel 60 (1)
Monel 400 (1)(2)(3)
Monel 402 (1)
Monel 406 (1)
Monel, cast, 410 (1)
Monel K-500 (1)
Monel, cast 505 (1)
Muntz metal (1)
Nickel, Electrolytic (1)
Nickel 200 (1)(2)(3)
Nickel 201 (1)
Nickel, Cast, 210 (1)
Nickel 211 (1)
Nickel-chromium 65/15 (1)
Mickel-chromium 80/20 (1)
Nickel Silver (18% Ni) (1)
Nimonic 75 (1)
Ni-o-nel 825 (1)
Ni-o-nel 825 sensitized (1)
Ni-o-nel cb (1)
Ni-Resist Type-1 (1)
Ni-Resist Type-2 (1)
Mi-Resist Type-3 (1)
Ni-Resist Type-4 (1)
Ni-Resist D-2 (1)
Ni-Resist D-2b (1)
Ni-Resist D-3 (1)

*High-strength, low-alloy.

Ni-Resist hardenable (1)
Renzoni Alloy (1)
RL 35-100 Alloy (1)
Solder 75 Pb, 33 Sn (1)
Steel, Copper (.2 min. Cu) (1)
Steel, AISI Type 201 (1)
Steel, AISI Type 202 (1)
Steel, AISI Type 301 1/2 hard (2)(3)
Steel, AISI Type 302 (1)
Steel, AISI Type 304 (1)(2)(3)(5)
Steel, AISI Type 304L (1)(2)(3)
Steel, AISI Type 304 Sensitized (1)
Steel, AISI Type 309 (1)
Steel, AISI Type 310 (1)
Steel, AISI Type 311 (1)
Steel, AISI Type 316 (1)(2)(3)
Steel, AISI Type 316 Sensitized (1)
Steel, AISI Type 316L (1)(2)(3)
Steel, AISI Type 317 (1)
Steel, AISI Type 321 (1)(2)(3)
Steel, AISI Type 325 (1)
Steel, AISI Type 329 (1)
Steel, AISI Type 330 (1)
Steel, AISI Type 347 (1)
Steel, AISI Type 405 (2)(3)
Steel, AISI Type 410 (1)
Steel, AISI Type 430 (1)(2)(3)
Steel, AISI Type 446 (1)
Steel, AISI Type 502 (1)(2)(3)
Steel, AISI C1010 (1)(2)(3)
Steel, AISI 4130 (2)(3)
Steel, ASTM A36 (2)
Steel, mild (5)
Steel, 1.5% Ni (1)
Steel, 3% Ni (1)
Steel, 5% Ni (1)
Steel, 9% Ni (1)
Steel, HSLA* (Cor-Ten) (1)(2)
Steel, HSLA (HY-80) (2)
Steel, HSLA (Inland Hi-Steel) (1)
Steel, HSLA (Lymore) (1)
Steel, HSLA (Mayari-R) (1)
Steel, HSLA (Republic double strength) (1)
Steel, HSLA (USS T-1) (1)(2)(3)

Steel, HSLA (USS T-1 Type A) (2)(3)
Steel, HSLA (Yoloy E) (1)
Steel, Plastic clad (2)(3)
Steel, USS Tenelon (1)(2)(3)
Steel, Stainless Type "W" (2)(3)
Steel, Stainless Type AM 350 (5)
Steel, 15-7 PH Mo Condition A (2)
Steel, 15-7 AMV (2)(3)
Steel, 15-7 AMV 150,000 psi (2)(3)
Steel, 15-7 AMV 220,000 psi (2)(3)
Steel, 17-7 PH (2)(3)
Steel, 17-7 PH Condition A (2)
Tin (1)
Titanium (1)(2)
Titanium Alloy Ti-140A (2)
Titanium Alloy Ti-4AL-3Mo-1V (2)(3)
Titanium Alloy Ti-6Al-4V (2)
Waukesha 23 (1)
Waukesha 88 (1)
Worthite (1)
Zinc (1)
Cable, Amergraph Type 1-H-4
Cable, Amergraph Type 2-H-1
Cable, Amergraph Type 4-H-0
Cable, Amergraph Type 6-H-1
Cable, special 4 conductor Polaris submarine antenna
Cable, special variable depth sonar tow
Chain, cast steel, open link, black, 3/4-inch diameter
Chain, cast steel, A-link, black, 3/4-inch
Wire rope, Polyvinylchloride over 1/8" - 7 x 7 Amgal
Wire rope, 1/8" - 7 x 7 Type 316 steel
Wire rope, 5/16" bright monitor
Wire rope, 5/16" bright plow steel
Wire rope, 5/16" - 1 x 19 Electrogalvanized (C1085 Si)
Wire rope, 5/16" galvanized plow steel
Wire rope, 5/16" - 1 x 7 Aluminized Steel
Wire rope, 3/8" - 7 x 19 Tenelon

NOTES:
(1) 2.23-inch-diameter disc-shaped "spool" specimen
(2) 1 x 6-inch flat bar-type specimen
(3) 6 x 12-inch flat plate-type specimen
(4) U. S. Naval Underwater Ordnance Station specimen
(5) U. S. Naval Engineering Experiment Station specimen

Nonmetallic Specimens

Acrylic, cast rod
Acrylic, extruded rod
Acrylic, (plexiglas) sheet
Cellulose Acetate rod
Cellulose Acetate sheet
Cellulose Acetate Butyrate sheet
Concrete, high strength
Concrete, low strength
Cotton rope
Delrin rod
Delrin sheet
Epoxy resin impregnated glass-fabric sheet
Fluorocarbon (TFE) fibre felt sheet
Fluorocarbon (TFE) impregnated glass-fabric sheet
Fluorel sheet
Glass, optical
Jute burlap cloth
Kel-F sheet
Kel-F 81 sheet
Manila rope
Melamine resin impregnated glass-fabric sheet
Nylon fabric sheet
Nylon rod
Nylon rope
Nylon sheet
Phenolic resin impregnated cotton-fabric sheet
Phenolic resin impregnated fabric rod
Phenolic resin impregnated nylon-fabric sheet
Phenolic resin impregnated paper sheet
Polycarbonate rod
Polyethylene rod
Polyethylene sheet
Polypropylene rope
Polystyrene rod
Polystyrene sheet
Polyvinyl chloride tubing Type I
Polyvinyl chloride tubing Type II
Porcelain insulators
Rubber, Buna N black sheet
Rubber, Buna N coated cotton-fabric sheet
Rubber, Buna N coated nylon-fabric sheet
Rubber, Butyl sheet

Rubber, Butyl coated nylon-fabric sheet
Rubber, (Hypalon) sheet
Rubber, (Hypalon) coated nylon-fabric sheet
Rubber, natural, black sheet
Rubber, natural, hose
Rubber, (Neoprene) coated cotton-fabric sheet
Rubber, (Neoprene) coated nylon-fabric sheet
Rubber, (Silicone) sheet
Rubber, (Silicone) coated glass-fabric sheet
Rubber, (Viton A) sheet
Rubber, (Viton A) coated teflon-fabric sheet
Saran film
Silicone resin impregnated glass-fabric sheet
Teflon rod
Teflon sheet
Texin 192A (Polyurethane) sheet
Vinyl (rigid), clear sheet
Vinyl, black sheet
Vinyl, electrical tape
Vinyl, gray sheet
Vinyl, gray Type I sheet
Vinyl, white Type II sheet
Wood, pine
Wood, greenheart

Table 1. Oceanographic Data Summary From a Site About 5 Miles Northwest of the Placement Site for STU I-1

Depth Meters	Temperature °C	Salinity °/oo	Oxygen Ml/L
1	13.73	33.461	5.88
10	13.70	33.460	5.86
27	13.58	33.471	5.88
36	13.48	33.475	5.83
50	13.00	33.514	5.74
63	11.98	33.504	4.81
86	10.28	33.549	4.21
103	9.84	33.676	3.58
119	9.54	33.759	3.23
136	9.07	33.828	3.13
161	8.66	33.908	2.93
191	8.26	33.978	2.53
217	7.98	34.013	2.24
262	7.90	34.132	1.51
311	7.29	34.121	1.33
387	6.68	34.183	1.00b
467	6.30	34.245	0.69b
549a	5.98	34.307	0.49b
538a	5.84	34.324	0.28
643	5.48	34.354	0.21
741	5.02	34.396	0.24
839	4.60	34.429	0.29
937	4.22	34.453	0.31
1084	3.76	34.490	0.49
1231	3.42	34.517	0.72
1377	3.15	34.536	0.83
1525	2.90	34.559	1.01
1672	2.68	34.575	1.19
1722	2.53	34.584	1.29

Note:

a. Overlapping casts

b. Samples bubbled when drawn, doubtful values

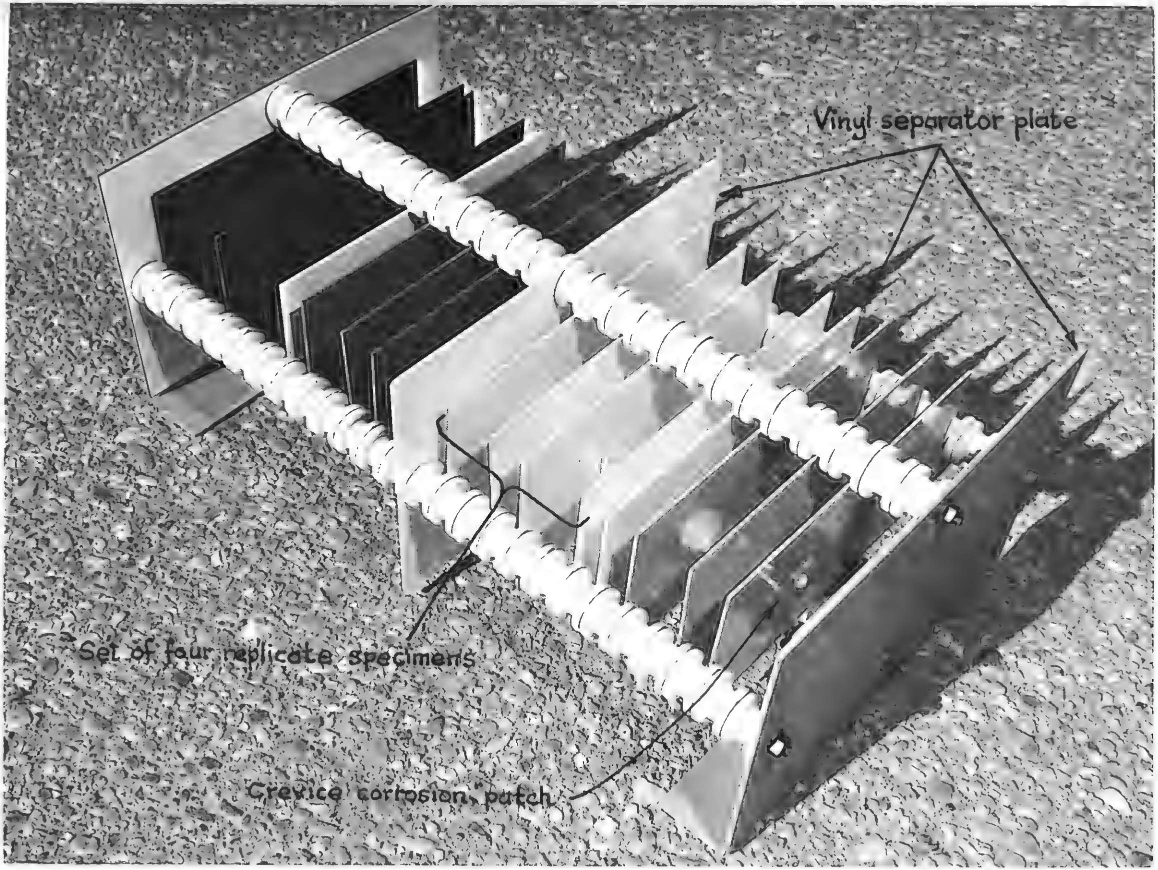


Figure 1. Rack for the exposure of unstressed 6- by 12-inch rigid specimens to the deep-ocean environment in the Submersible Test Unit.

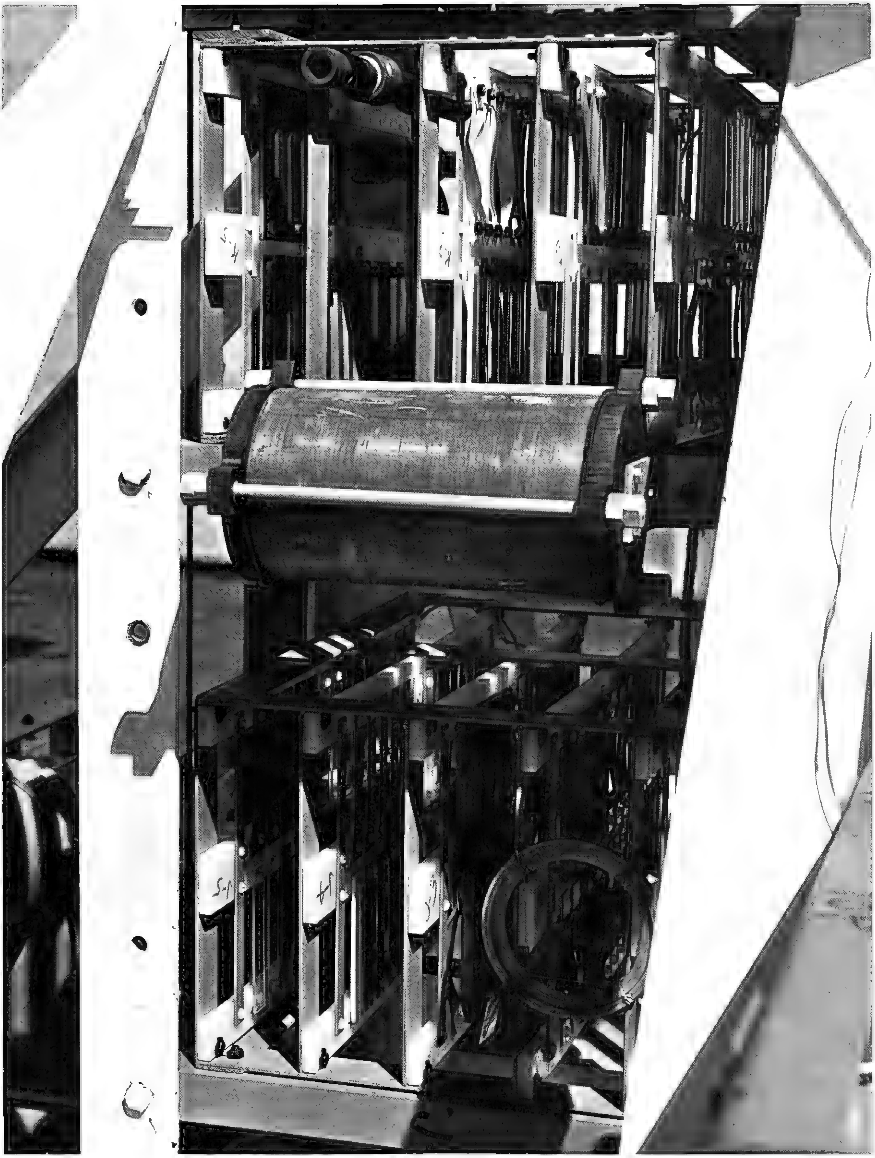
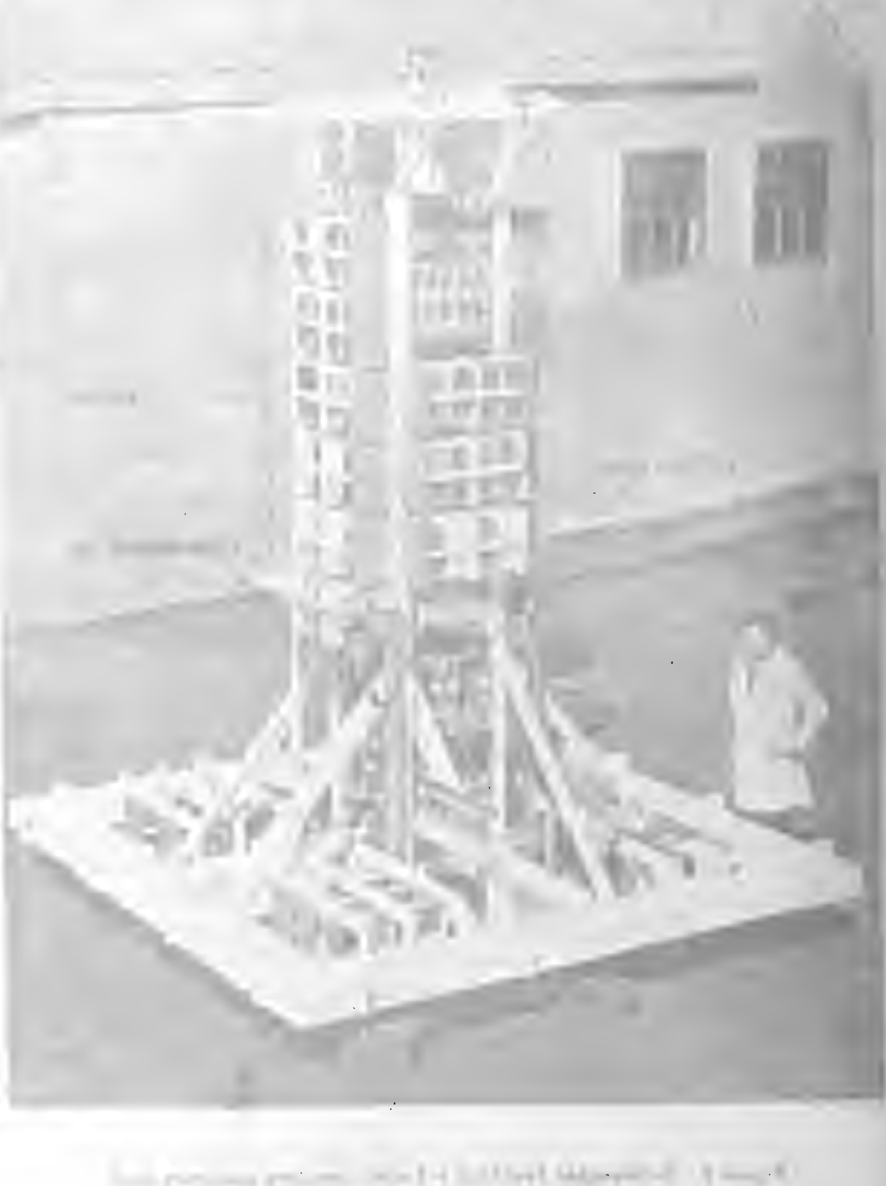


Figure 2. Arrangement of 1- by 6-inch specimen racks in the Submersible Test Unit.

Figure 3. Cable tensioning jig for the exposure of wire rope and cable specimens to the deep-ocean environment while under load.

Figure 4. Cable specimen in a tensioning jig being loaded to a predetermined stress level.

Figure 5. Stress corrosion jig with a specimen.



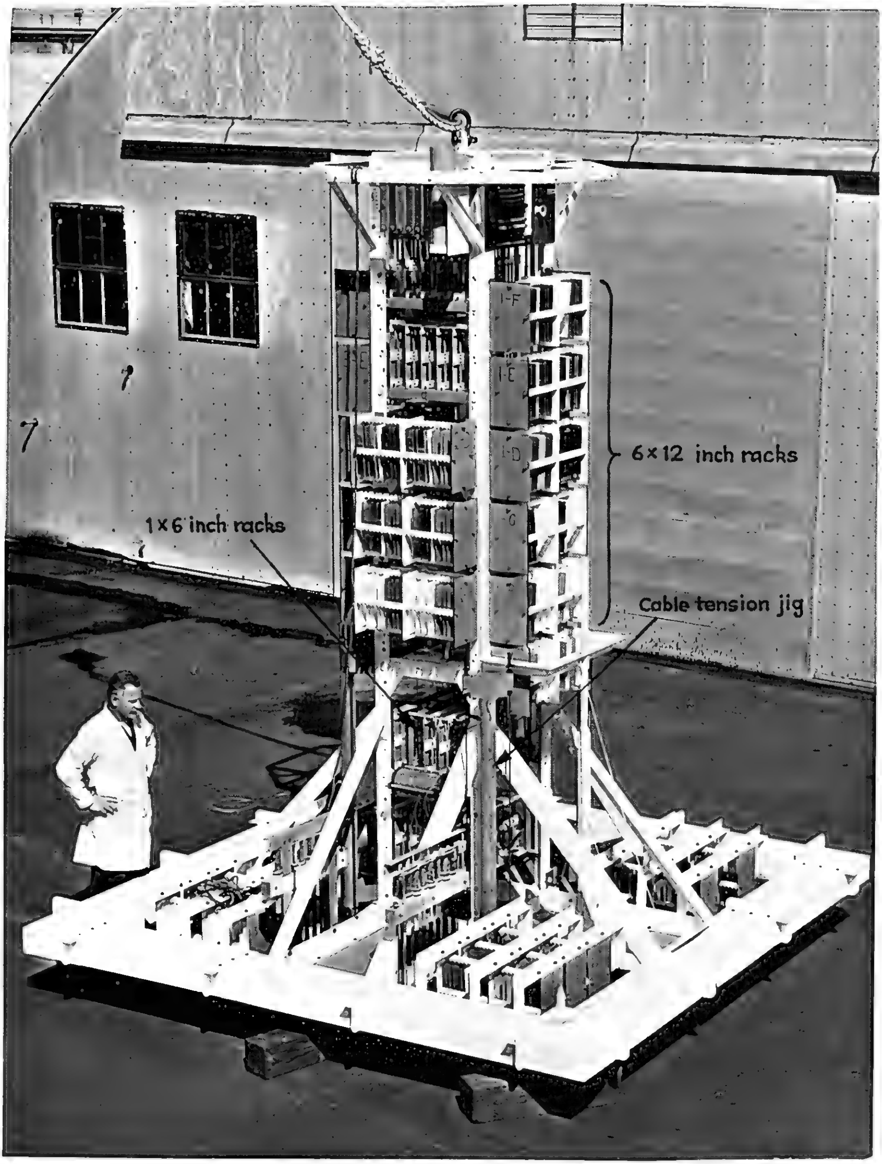


Figure 6. Submersible Test Unit I-1 with complete specimen load.

Figure 7. Bottom of Submersible Test Unit showing racks for the exposure of specimens to the effects of the sea-floor sediment environment.

Figure 8. Humidity-controlled plastic enclosure used to protect the Submersible Test Unit and specimens from atmospheric corrosion during assembly.

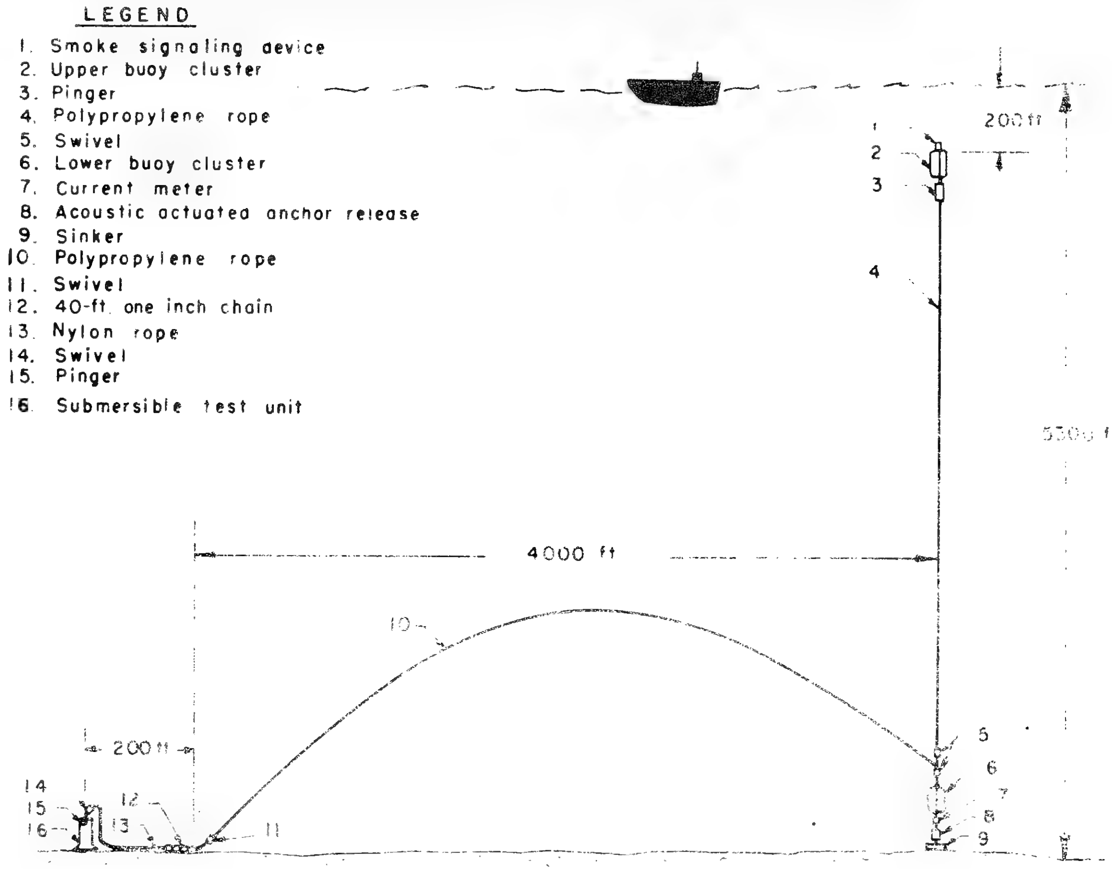


Figure 9. Complete Installation of Submersible Test Unit and retrieval system.

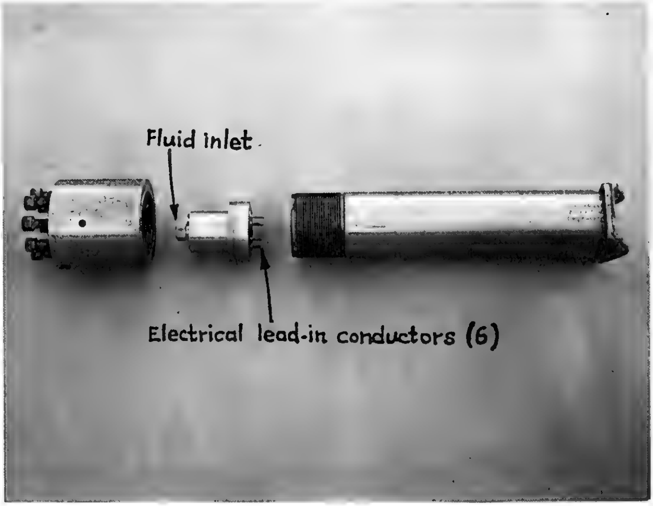


Figure 10. Small (1-1/2-inch i.d.) pressure vessel with the modified closure.

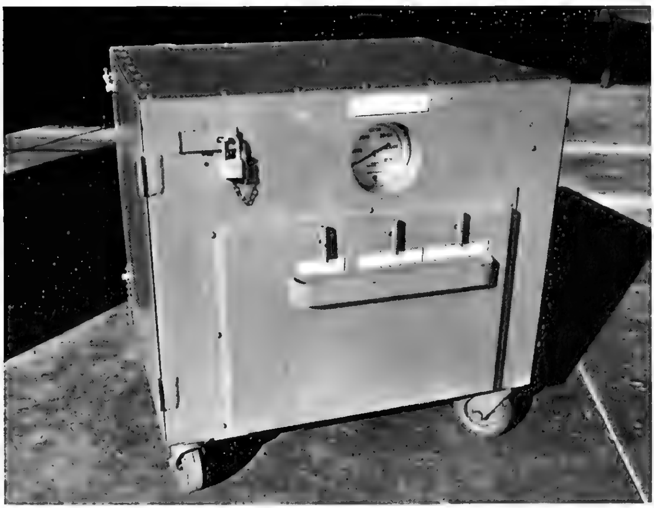


Figure 11. Small pressure vessel safety housing.

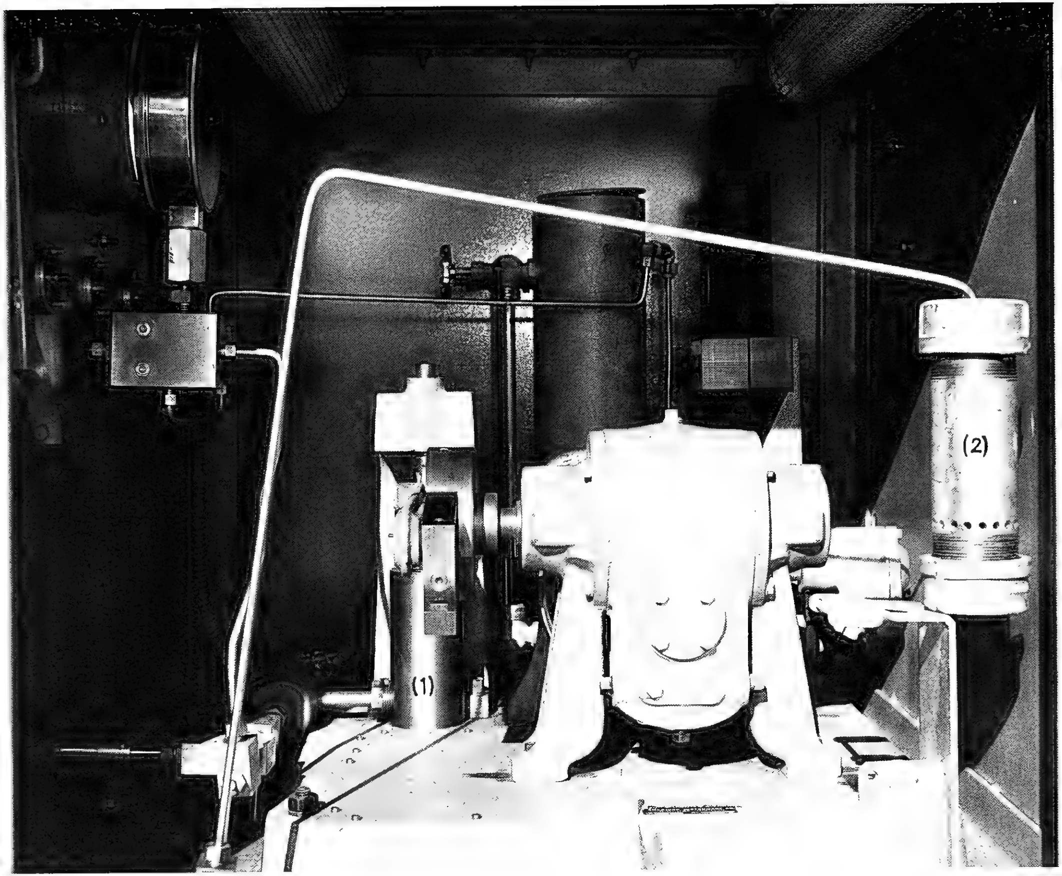


Figure 12. Interior view of small pressure vessel safety housing showing (1) electrically driven, reciprocating, adjustable stroke pump and (2) a lead-through test bomb under test.

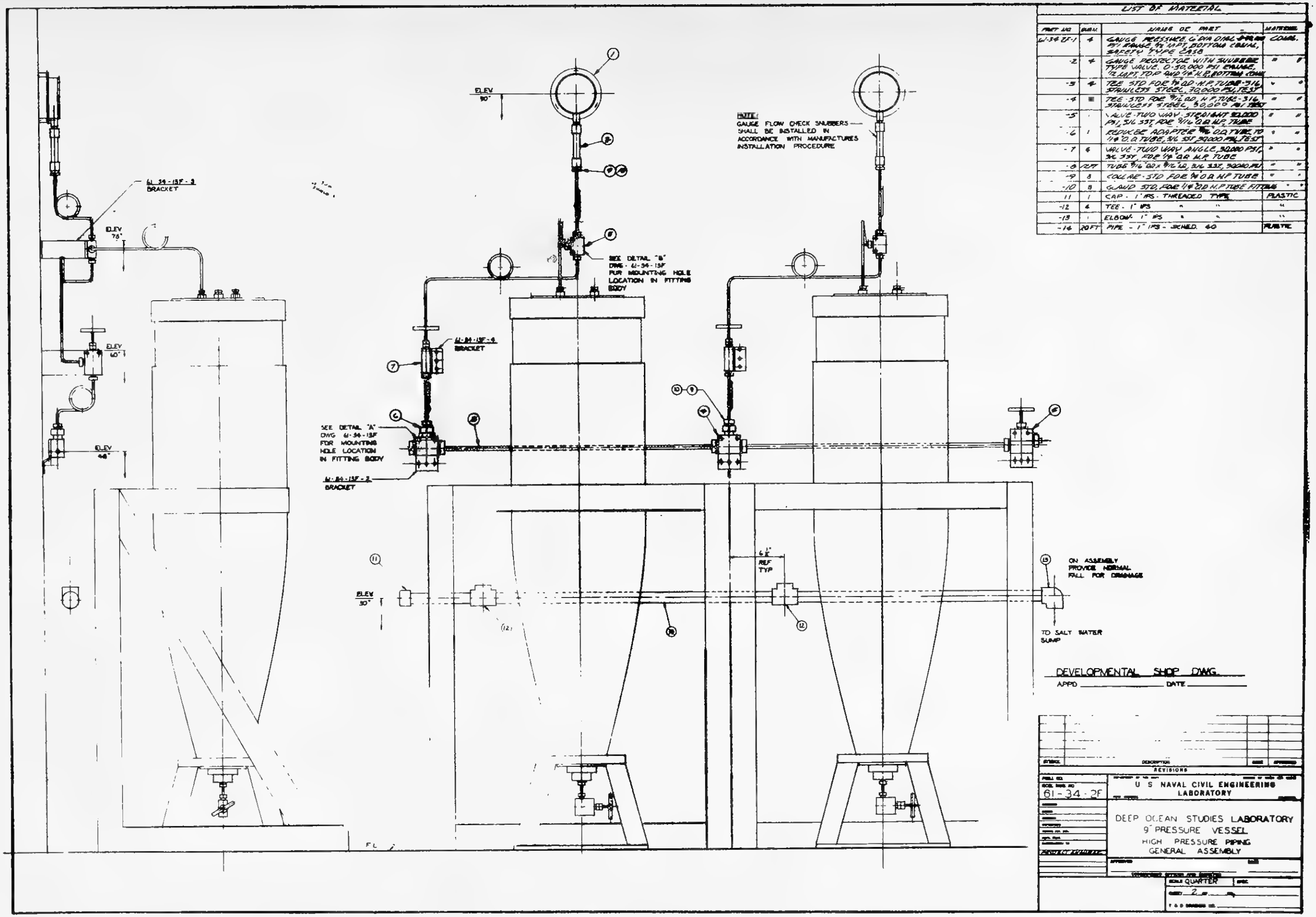

LIST OF MATERIAL
NOTE: GAUGE FLOW CHECK SNUBBERS SHALL BE INSTALLED IN ACCORDANCE WITH MANUFACTURES INSTALLATION PROCEDURE
SEE DETAIL "A" DWG 61-34-13F FOR MOUNTING HOLE LOCATION IN FITTING BODY
SEE DETAIL "B" DWG - 61-34-13F FOR MOUNTING HOLE LOCATION IN FITTING BODY
BRACKET
ELEV 90"
ELEV 78"
ELEV 60"
ELEV 48"
ELEV 30"
REF TYP
ON ASSEMBLY PROVIDE NORMAL FALL FOR DRAINAGE
TO SALT WATER SUMP
DEVELOPMENTAL SHOP DWG.
APPD
DATE
REVISIONS
U S NAVAL CIVIL ENGINEERING LABORATORY
61-34-2F
DEEP OCEAN STUDIES LABORATORY
9' PRESSURE VESSEL
HIGH PRESSURE PIPING
GENERAL ASSEMBLY
QUARTER

Figure 13.

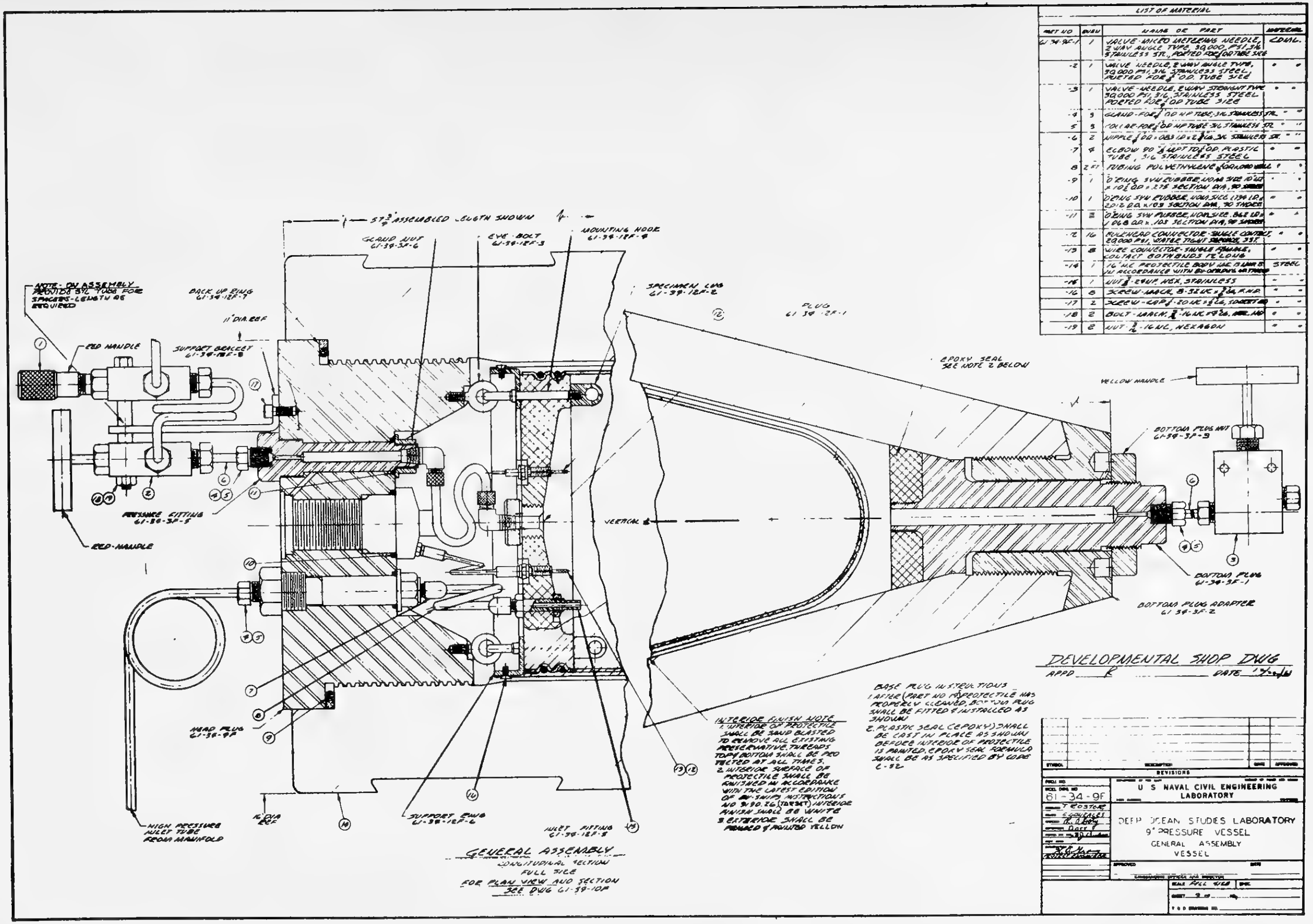

DEVELOPMENTAL SHOP DWG
GENERAL ASSEMBLY
LONGITUDINAL SECTION
FULL SIZE
LIST OF MATERIAL
U S NAVAL CIVIL ENGINEERING LABORATORY
DEEP OCEAN STUDIES LABORATORY
9" PRESSURE VESSEL
GENRAL ASSEMBLY
VESSEL
61-34-9F

Figure 14.

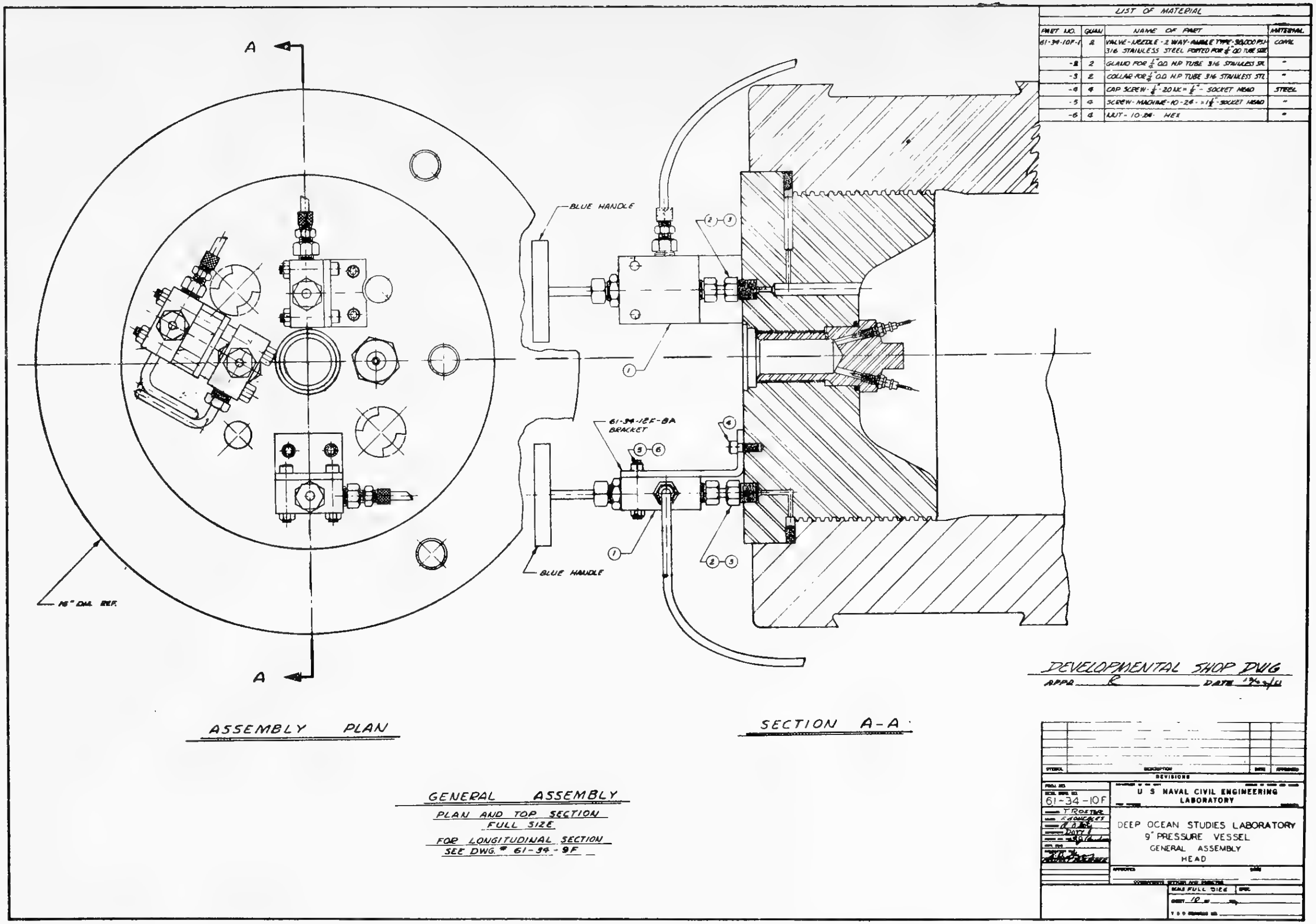
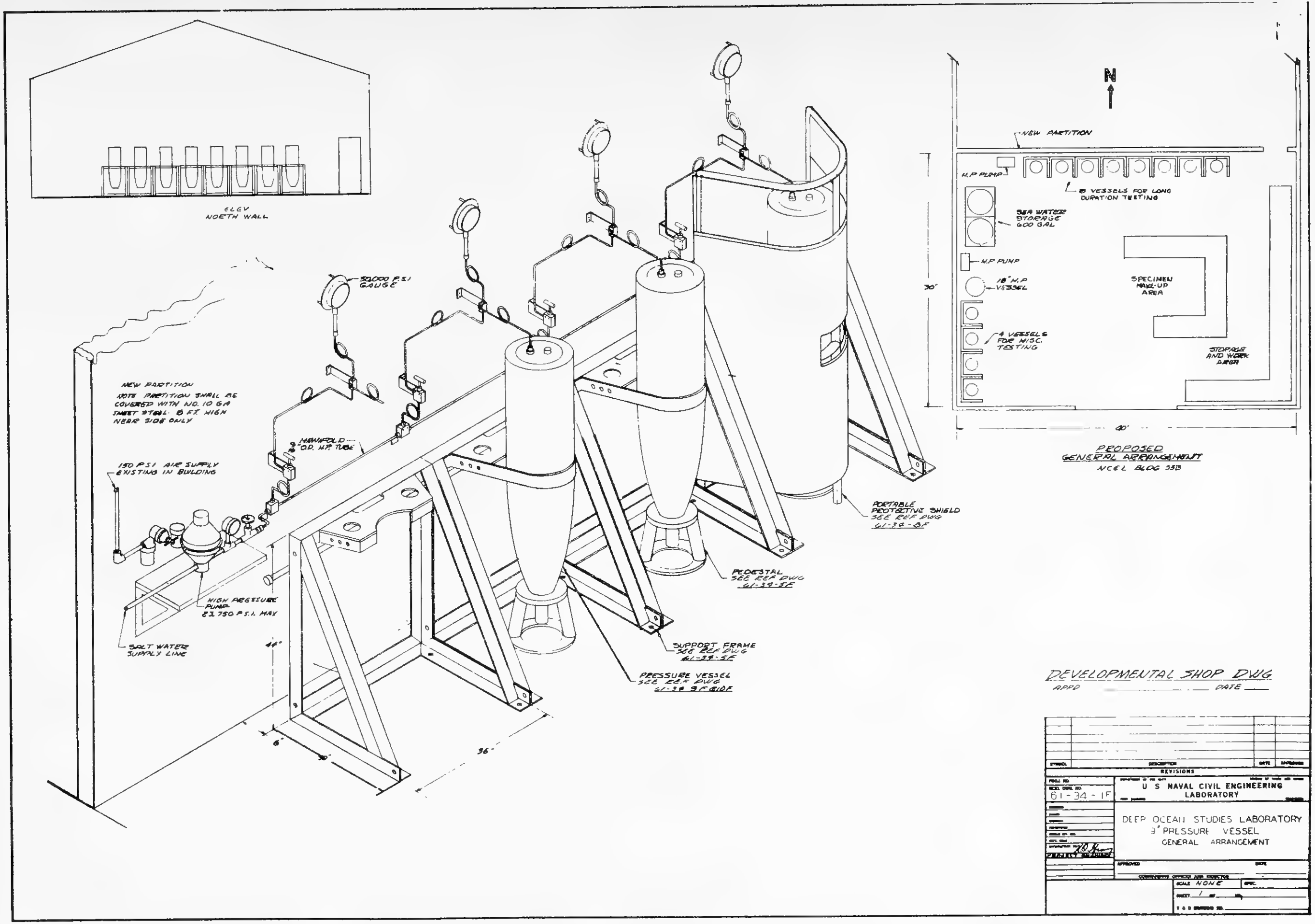

LIST OF MATERIAL
PART NO. | QUAN | NAME OF PART | MATERIAL
61-34-10F-1 | 2 | VALVE - NEEDLE - 2 WAY - ANGLE TYPE - 30,000 PSI - 316 STAINLESS STEEL PORTED FOR 1/4" OD TUBE SIZE | COML
-2 | 2 | GLAND FOR 1/4" O.D. H.P. TUBE 316 STAINLESS STL | "
-3 | 2 | COLLAR FOR 1/4" O.D. H.P. TUBE 316 STAINLESS STL | "
-4 | 4 | CAP SCREW - 1/4" - 20 NC × 1/2" - SOCKET HEAD | STEEL
-5 | 4 | SCREW - MACHINE - 10-24 × 1 1/2" - SOCKET HEAD | "
-6 | 4 | NUT - 10-24 - HEX | "
A
A
BLUE HANDLE
BLUE HANDLE
61-34-12F-8A BRACKET
16" DIA. REF.
ASSEMBLY PLAN
SECTION A-A
GENERAL ASSEMBLY
PLAN AND TOP SECTION
FULL SIZE
FOR LONGITUDINAL SECTION
SEE DWG. # 61-34-9F
DEVELOPMENTAL SHOP DWG
APPR. R
REVISIONS
U S NAVAL CIVIL ENGINEERING LABORATORY
61-34-10F
T ROSTER
DEEP OCEAN STUDIES LABORATORY
9" PRESSURE VESSEL
GENERAL ASSEMBLY
HEAD
FULL SIZE

Figure 15.


ELEV
NORTH WALL
NEW PARTITION
NOTE PARTITION SHALL BE COVERED WITH NO. 10 GA SHEET STEEL 8 FT. HIGH NEAR SIDE ONLY
150 P.S.I AIR SUPPLY EXISTING IN BUILDING
HIGH PRESSURE PUMP 23,750 P.S.I. MAX
SALT WATER SUPPLY LINE
32,000 P.S.I GAUGE
MANIFOLD 9/16 O.D. H.P. TUBE
PORTABLE PROTECTIVE SHIELD SEE REF DWG 61-34-8F
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36"
6"
44"
N
NEW PARTITION
H.P PUMP
8 VESSELS FOR LONG DURATION TESTING
SEA WATER STORAGE 600 GAL
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Figure 16.

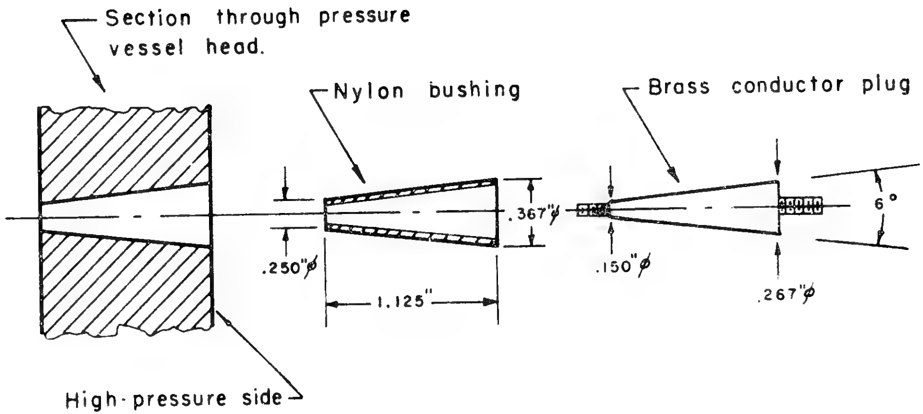


Figure 17. Electrical lead-through device for 15,000-psi service.

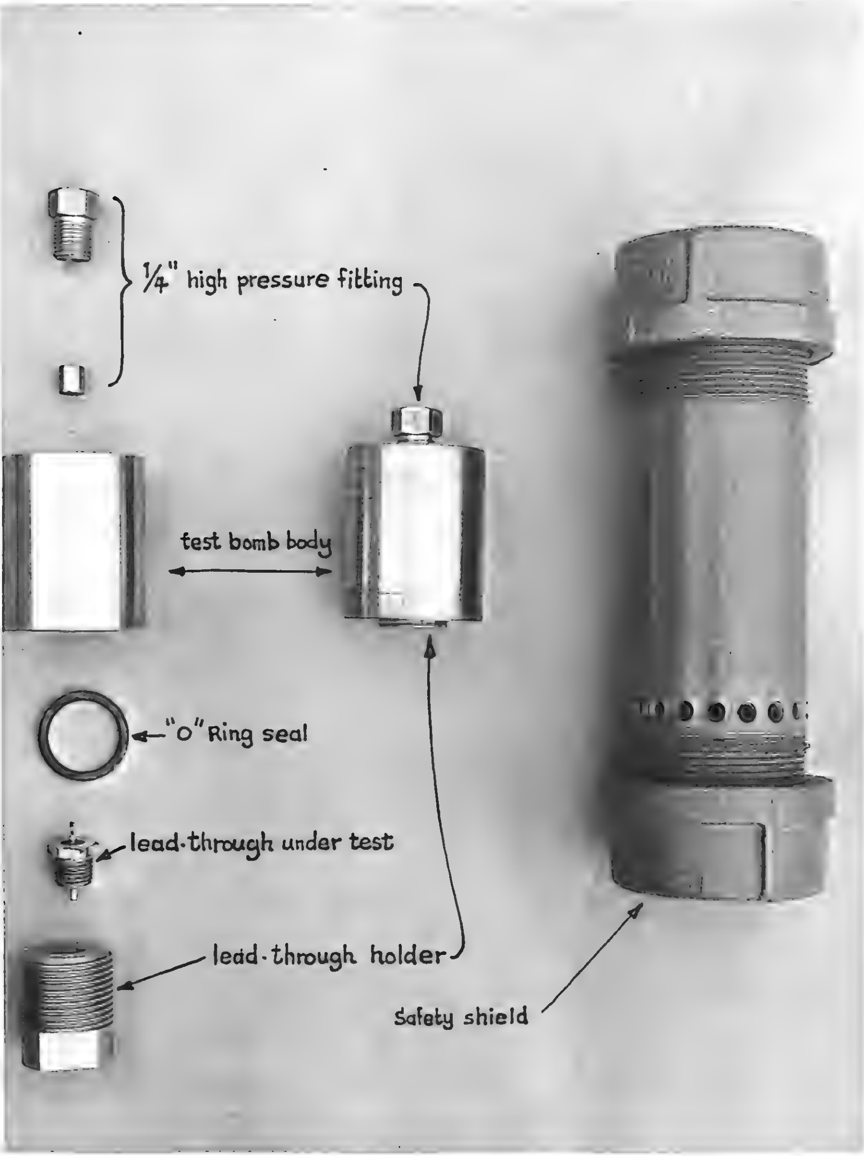


Figure 18. Electrical lead-through test bomb assembly and safety shield.

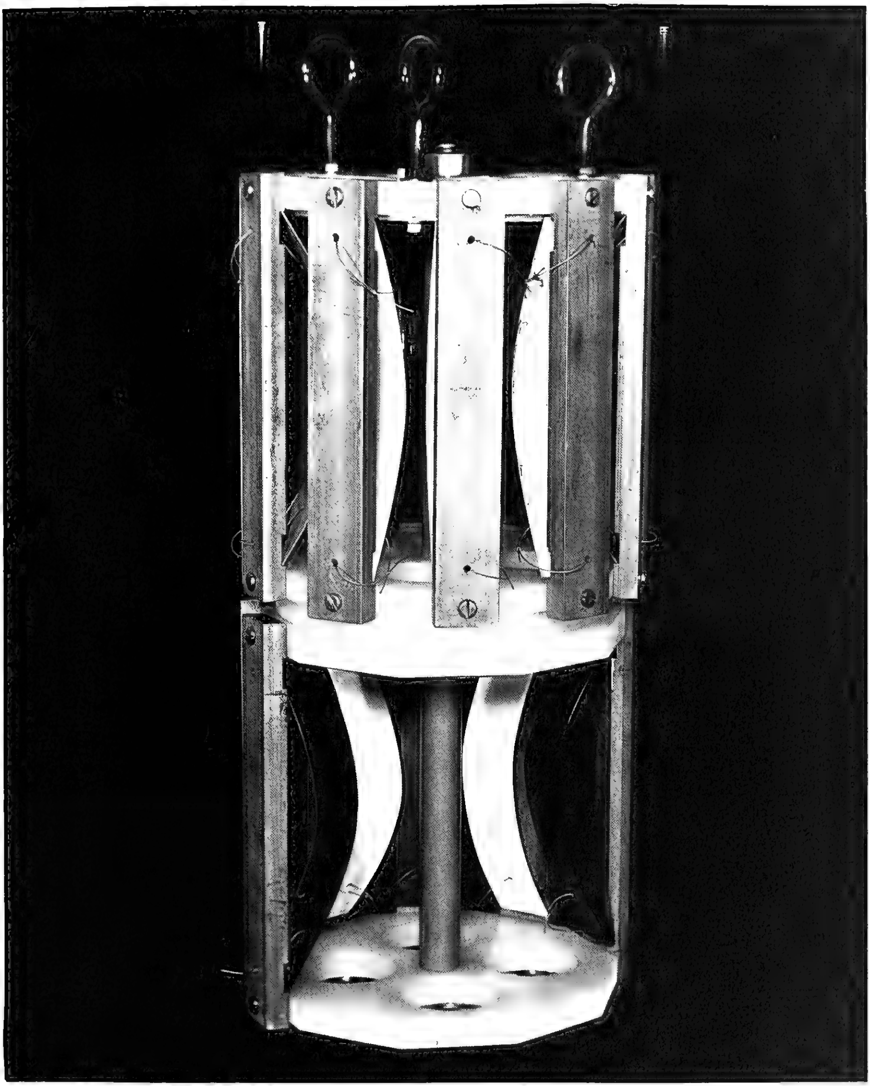
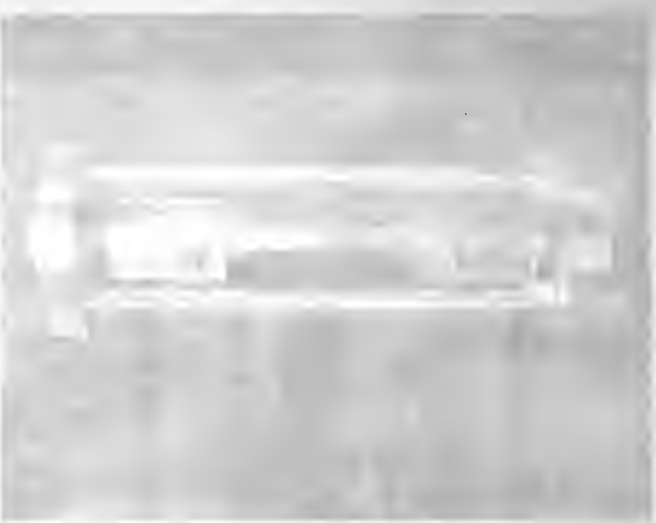
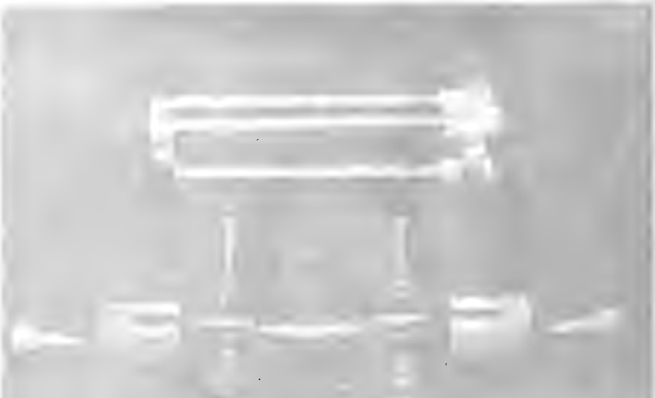


Figure 19. Stress corrosion jig rack for the exposure of 20 stress corrosion jigs in either a medium or large pressure vessel.





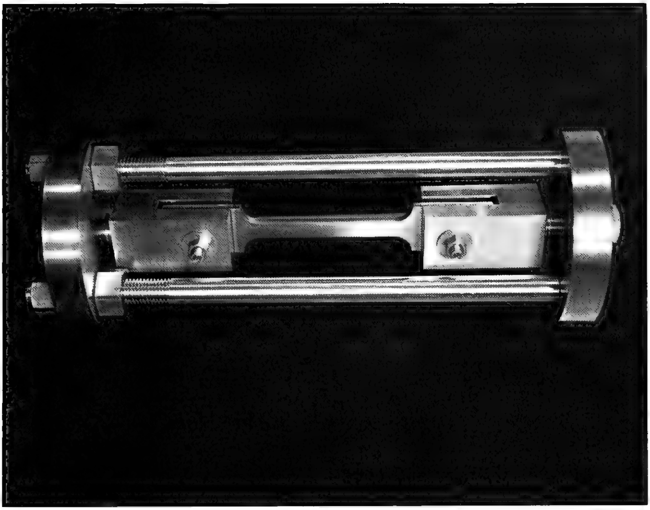


Figure 20. Tensile stress corrosion jig with a specimen under tension. Jig is designed for use in either a medium or large pressure vessel.

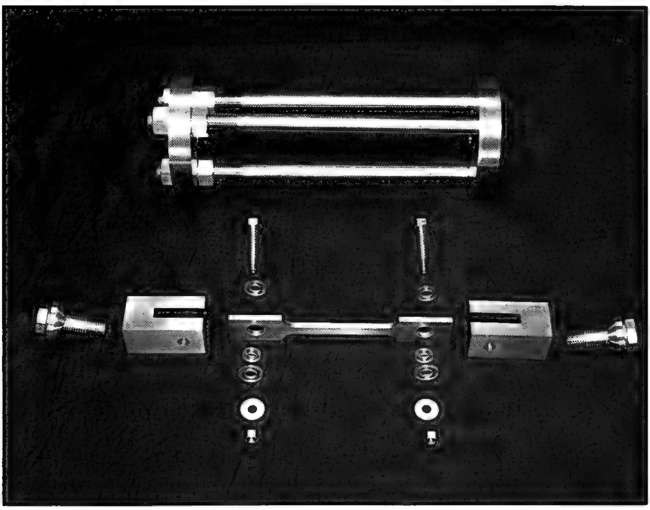


Figure 21. Tensile stress corrosion jig disassembled to show component parts.

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