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WOODS HOLE OCEANOGRAPHIC INSTITUTION

Reference No. 64-1

DEEP SUBMERGENCE RESEARCH

conducted during the period
1 November 1962 -- 31 December 1963

Prepared under Contract Nonr-3484(00)

WOODS HOLE, MASSACHUSETTS

Woods Hole Oceanographic Institution

Woods Hole, Massachusetts

Reference No. 64-1

Deep Submergence Research

conducted during the period
1 November 1962 - 31 December 1963

Submitted to Undersea Programs
Office of Naval Research

Prepared under Contract Nonr- 3484(00)

February 1964

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Paul M. Fye, Director

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Abstract

Deep Submergence Research

1 November 1962 - 31 December 1963

During the above period the Deep Submergence Research program at the Woods Hole Oceanographic Institution has centered around the procurement of ALVIN, a two man submersible designed for a 6,000 foot depth, and the necessary adjuncts to the same. The progress of the design and construction of this craft is given with emphasis on the testing and inspection rather than engineering details. An outline of the acceptance testing planned for the completed vehicle is included. The instrument system to be used with the vehicle is discussed, as is the necessary support equipment. Reports on model tests performed during this time, including a collapse test of a one-sixteenth scale model of the ALUMINAUT, are referenced but not discussed in detail.

Reports

The following technical reports contain detailed information:

1. WHOI Ref. No. 62-41 -- "Deep Submergence Research conducted during the period 1 November 1961 - 31 October 1962". November 1962
2. WHOI Ref. No. 63-17 -- "Preliminary Report on Pressure Test of One-Sixteenth Scale ALUMINAUT Model" by Joseph B. Walsh, dated May 1963.
3. Southwest Research Institute Project No. 1206-3 -- "Experimental Stress Analysis of a Model of the ALVIN Hull" by D.J. Bynum and R.C. DeHart, dated 3 April 1963.
4. Southwest Research Institute Project No. 1206-3 -- "Experimental Stress Analysis and Leak Test for ALVIN Hull Number 1" by E.M. Briggs and R.C. DeHart, dated 18 September 1963.
5. WHOI Technical Memorandum No. TM-DS-9 -- "The Mechanical and Chemical Properties of the HY 100 Pressure Hulls of the Submarine ALVIN" by James W. Mavor, Jr., dated November 1963.

Papers

The following technical papers were prepared and presented during this period:

1. "Structural Design of a 6,000 foot Submergence Manned Oceanographic Research Vehicle" by James W. Mavor, Jr., presented at the Deep Submergence Vehicle Workshop at David Taylor Model Basin on December 3, 1962, CONFIDENTIAL.
2. WHOI Contribution No. 1394 -- "ALVIN, An Oceanographic Research Submarine" by Joseph B. Walsh and W.O. Rainnie, Jr., presented at the American Society of Mechanical Engineers Annual Winter Meeting, Philadelphia, Pennsylvania on November 21, 1963.

Introduction

The Woods Hole Oceanographic Institution believes that man's understanding and knowledge of physical oceanography, marine geology and geophysics, marine biology and underwater acoustics will benefit from the use of manned undersea research vehicles. A very positive step to further this type of research was taken in 1962, when a design and construction subcontract was let to General Mills Electronics Group (now Applied Science Division of Litton Systems) for a 6,000 foot depth submersible (ALVIN). The prime contract was between the Office of Naval Research (Code 466 Nonr 3484(00) and the Woods Hole Oceanographic Institution. Prior to this time a nucleus of a deep submersible group had been formed at Woods Hole in the anticipation of the possible use of the ALUMINAUT.

General

The Deep Submergence Research Vehicle Group (DSRVG) of the Woods Hole Oceanographic Institution (WHOI) has continuously followed and inspected the design, manufacture and fabrication of the ALVIN vehicle (Figures 1 and 2) during this period. The most important components have been the pressure hulls (three in total number) which were machined and welded in accordance with the Navy's most recent procedure for submarine hulls, at Hahn & Clay in Houston, Texas.

Various components and systems of the vehicle were designed, reviewed and approved. A number of conferences were held, both at General Mills (now the Applied Science Division of Litton Industries) and in Washington at the Bureau of Ships (BuShips) and Bureau Laboratories, on the many technical problems involved in this project. Appreciable time was expended in specifying and ordering the instrument suite for the vehicle and orders were placed for all of the major components. Additional personnel were employed for the staff and operating crew. A major activity has been the review and approval of the drawings for the vehicle. On important design problems, close liaison was maintained with ONR and BuShips. Model tests of both the structural properties and hydrodynamic characteristics of the vehicle have been conducted or are in progress. A support craft, a catamaran, is being investigated, ONR-WHOI having acquired two 96' floats as Navy surplus from BuShips. A model of this craft is being constructed.

Support equipment, consisting of a power van, electronic shop van, and a machine shop van have been designed and ordered. Tools, test equipment and spare parts have been ordered. A small support craft, a "Boston Whaler", has been received and modified to provide transport facilities and SCUBA support. All crew members are undergoing or have completed SCUBA training. Three staff members and five operating crew members have been added to the DSRVG during this period. Several summer

students assisted on the project during the past summer, two as employees and one as a Summer Student Fellow.

Most of the above subjects are discussed in more detail below. This report does not purport to be the final report on any of these subjects -- such as hull and materials inspection -- but does give a summary of the work.

The 16 mm. movie camera has been used extensively by project personnel to record significant steps in the manufacture, inspection, test and assembly of the vehicle. These will be edited, and a documentary film made for showing to interested groups and persons. In like manner, still photographs are being taken by project personnel when appropriate.

Drawing Approval and Program Monitoring

All of the drawings of the vehicle have been submitted by GMI/Litton for WHOI review and approval. As these drawings are the design of the vehicle, they were studied in detail and modified until a satisfactory design was obtained. Fabrication and test procedures have been reviewed and conferences held to establish the steps to be followed. Important items in this category have been the hull design and fabrication, component design and assembly, and the pressure and operational testing program, the hull test and strain gaging program.

In addition, the assembly and testing programs have been monitored in considerable detail. The hull fabrication at Hahn & Clay, Houston, Texas, was covered by Mr. O.N. Johnsrud, WHOI representative, and Mr. Englin, INSMAT, Dallas, and additional staff members as required. The testing schedule for the hulls at Southwest Research Institute and the assembly of same there and at Hahn & Clay have recently required constant attention.

The early testing program and assembly of the vehicle at Litton was monitored as necessary, and became a continuous operation by WHOI personnel in mid-September. WHOI has established a field office in Minneapolis, furnished by Litton.

The major instrument contracts have been followed also, and tests observed by WHOI personnel. These include the mechanical arm at Litton the TV at Oceanographic Engineering Corporation (OEC), the photographic equipment at Edgerton Germeshausen & Grier, Inc. (E G & G), the U/W telephone at Naval Electronics Laboratory (NEL) and the scanning sonar at Straza. In regard to the latter system, we wish to acknowledge the invaluable assistance given by Mr. Robert Waldie and his associates at NEL in the test and evaluation program conducted by NEL on this important system.

Pressure Hulls

Following the detailed specifications of the Bureau of Ships (Special Provisions for the Design and Construction of a Research Submarine for operation to a depth of 6,000 feet), three hulls have been constructed.

Six hemispheres (Figure 3) were spun by Lukens Steel Corporation, Coatesville, Penna., from HY 100 plate. Chemical analysis and sonic inspection were performed on the plate. The hemispheres were then heat treated to the desired properties. Ultrasonic inspection of the hemispheres indicated some possible small laminations in several of the hemispheres and these were paired so as to keep the suspect ones together.

At Hahn and Clay (H & C), Houston, Texas, the hemispheres were machined inside, and welded around the equator (Figure 4). All welding was conducted and inspected during the process in accordance with NavShips 250-637-3. Holes were cut for the window and hatch inserts. These inserts (Figure 5) were made from HY 100 forgings by Isaacson Iron Works, Seattle, Washington. The spheres were machined on the outside to final dimensions, (Figure 6) and the inserts welded in by H & C. The holes were placed so as to include some of the flaws detected on the hemispheres and these flaws were examined. Apparently the flaws were incipient laminations and/or inclusions of very small dimensions. All three hulls were again ultrasonically inspected as the machined surfaces were more suitable for this than the surfaces of the hemispheres as spun and roughly hand-ground. As designated No. 1 hull had several indications of flaws, No. 2 had only a few quite small ones, and No. 3 had none.

The choice of hulls for collapse, operation and spare was carefully considered. WHOI and David Taylor Model Basin made circularity measurements on all three hulls to aid in determining the collapse depth. Circularity was well within drawing tolerance and BuShips requirements. Thus the asphericity was not considered to be a major factor in the choice of the hulls.

Figures 7, 8 and 9 show the hulls at various stages of fabrication and assembled for testing.

One of the interesting developments during this procedure was the result of the stress relieving process which took place after all the welding. During stress relief of the No. 2 hull, samples of base metal from all three hulls were placed in the oven with it and subsequently, physical test specimens were obtained. It became apparent that although the tensile strength or ductility had not changed significantly as compared with the pre-stress relieved samples, the impact strength (Charpy V-notch) had undergone a significant reduction. A completely satisfactory explanation of this phenomenon is as yet unknown. It is uncertain

whether or not the benefit of stress relief overbalances the loss of impact strength when considering fatigue strength. Based upon known flaws and reduced "Charpy V-notch" data, No. 1 hull was chosen for the collapse tests to be conducted at the newly constructed Southwest Research Institute (SWRI) tank. No. 2 hull was considered to be second best and No. 3 hull to be the best based upon all of the known data; namely, circularity, physical specimens, "Charpy V-notch" values, flaws, and the shape of the stress-strain curve. Discussion with pressure vessel specialists in and out of the Navy gave assurance that flaws of the magnitude detected were very unlikely to affect the characteristics of the hulls for cycling or collapse, but the flaws were one criterion for choice. It was therefore planned to attempt to collapse hull No. 1 and to test the other two hulls to 2/3 of their calculated collapse depth based upon the collapse depth of hull # 1. These collapse depths have been estimated by DTMB to be as follows, ignoring stress concentrations, strength of weld material, and toughness of base and weld metals.

No. 1	-	16,000 feet
No. 2	-	16,100 feet
No. 3	-	15,100 feet

The reason that the DTMB predicted collapse pressure for hull No. 3 is lower than the other two is entirely due to lower compressive strength of the base metal. Physical test results of specimens from sample qualifying welds indicate a compressive strength equal to that of the base metal in hull No. 3. Failure is expected to occur at one of the major relatively flat regions on the hulls and all of these are located at welds. Therefore, no distinction can be made between the hulls as far as the effect of sphericity and strength of physical specimens. The Charpy V-notch impact strength of the base metal in hull No. 1 was lower than that of hulls No. 2 or 3. The choice of hulls was thus made primarily on the basis of flaws and toughness, all other things being considered equal.

During this period the hulls have been final machined for attachments and all of the hardware has been manufactured and fitted to hull No. 1 and is presently being fitted to hull No. 2. Hull No. 3 has been set aside pending a decision on whether a deeper vehicle capability should be acquired.

In December, the pressure tank was completed and installed at SWRI and No. 1 hull was strain gaged with 400 gages and the stress data taken for pressures up to 3300 psi. This data is being analyzed and will be available in the near future. To date, preliminary information indicates that the predicted collapse depths are very reasonable. Approximately one hundred fifty strain gages will be installed on No. 2 hull complete with all hardware and windows, and it will be tested to 3300 psi. It will then be shipped to Minneapolis for installation in the rest of the vehicle, which is proceeding concurrently. The decision to test hull No. 2 to 3300 psi rather than two-thirds of collapse depth was made on the basis that the collapse data from hull No. 1 would not be available

prior to test of hull No. 2; therefore, 2/3 of the design collapse depth was used for the test of this hull.

Model Testing and Structural Analysis

Analyses of the stresses in the thickened hatch and window insert areas were conducted by Litton and WHOI during the early part of this period that aided in establishing the design of these features. A 3 1/2 inch thick window was chosen for the main windows.

A 0.2867 scale aluminum model (Figure 10) was constructed and pressure tested at SWRI (See Report No. 3) to aid in the final design. The results of this test were very encouraging and the final design was established for both the window and hatch inserts.

The hatch area stress pattern was analyzed on the full scale model, hull No. 1. Results may be seen in Report No. 4. Again, the stress pattern appeared to be very good.

The 1/16th scale ALUMINAUT model was pressure tested to collapse, the results of which are reported in Report No. 2.

Hydrodynamic Analysis and Model Testing

Towing of the 1/12 scale model referred to in Report No. 1 was conducted and the results were considered representative of full scale behavior. It appears that the tow point should be as low on the vehicle as possible, and towing in reasonable sea states (State 3 to 4) should be practical.

Drag data was taken on this small model in the tank at Massachusetts Institute of Technology but the scale effects were such as to cast doubt on the results. Therefore, a 1/4 scale model study was initiated with the Illinois Institute of Technology and this program is currently in progress.

The static vertical performance characteristics were investigated using the 1/12 scale model at a tank at Harvard University by one of the summer students. The performance appears to be acceptable from these tests, a report of which is in preparation.

Design, Fabrication and Assembly

The design of all of the remaining components and systems has been determined and manufacture has been completed in almost all of these. Assembly is well along.

Buoyancy Material

A special machine for mixing and pouring the epoxy-glass micro-balloon buoyancy material has been set up at Litton. Litton is in the process of pouring the mixture into molds for the various configurations required. Samples from each pour are being taken for testing purposes.

Propulsion, Ballast and Trim Systems

The components of these systems are being "breadboarded" for bench and pressure testing in the pressure tank (Figure 11) recently installed at Litton. The first sub-system operating test at 5,000 psi indicated that, as expected, these systems are not sensitive to pressure effects, at least to 5,000 psi which is well above the intended operating pressures. All components and systems will be tested in a similar manner prior to assembly in the vehicle, except those things that are not pressure sensitive (frame, fiberglass outer shell) and the large buoyancy material configurations for which samples will be tested (See Appendix "A" for detailed test program).

Buoyancy and Variable Ballast Spheres

These spheres (Figure 12) are nearing completion of machining and final assembly. Some difficulty was experienced due to close tolerance between the as forged dimension and the desired final machine dimensions. This necessitated ordering some new forgings.

It was determined after an experimental study, to conventionally weld the variable ballast spheres (6061 aluminum) and mechanically join the buoyancy spheres (7178 aluminum). Two of each of these kinds of spheres will be cycled and collapsed to establish their safe test and operating depths. It is expected that these will exceed the specification requirements.

Cabin Instruments and Arrangements

A conference was held at Litton to determine the cabin arrangement and location of instruments using the full scale mock-up and full scale models of the various components. Based on this conference, the two occupants will sit side by side just aft of the centerline with the pilot normally to starboard and the observer to port. Racks for standard 19" electronic chassis will be located both in front of and behind the occupants. Instruments and controls associated primarily with either the pilot or observer are appropriately located. Access is provided to each of the four observing windows.

Instruments

When ALVIN is delivered to WHOI for deep sea trials, the vehicle will contain a skeleton set of instruments and instrument systems. The basic set of instruments will be installed by WHOI prior to the deep sea trials and are intended to permit safely conducting these trials. This same set of instruments will give ALVIN a research capability including survey, underwater inspection, photographic and light underwater sampling missions.

Concurrently with the first missions of the vehicle, and taking advantage of the experience gained during the evaluation of the vehicle, the basic set of instruments will be refined and expanded to give an increased research capability.

The set of instruments and controls purchased as part of the basic vehicle includes:

- a) Battery controls and monitors
- b) Propulsion controls and indicators
- c) Ballast and trim controls and indicators
- d) Life support system including CO₂ and O₂ monitors
- e) Gyro-compass and backup magnetic compass
- f) Water speed indicator
- g) Attitude inclinometers
- h) Mounting provisions for the mechanical arm
- i) Depth indicating pressure gages

These systems will be installed by Litton Systems and delivered as part of the vehicle.

All additional instrument systems have been or are being procured separately and will be installed by WHOI upon receipt of the vehicle. This basic set of instruments includes:

- a) Scanning sonar set continuous transmission frequency modulated (CTFM)
- b) Underwater telephone set
- c) Underwater closed loop television set
- d) Altitude and depth pulse sonar set
- e) Mechanical arm
- f) Doppler navigating set
- g) DC to AC power inverters
- h) 35 mm underwater cameras
- i) Ship to ship radio
- j) Underwater incandescent lights

It is planned to purchase in the immediate future:

- a) Strobe lights
- b) Sonar directional receiver
- c) Mother ship to ALVIN simplified tracking set

The most complex instrument system will be the CTFM sonar set (Figure 13 and 14). This unit has been specially packaged to meet the space and weight requirements for use on a small manned vehicle. The set operates at a center frequency of 80 KC and has a maximum range of 800 yards. The projector and hydrophone are mechanically trained in the horizontal plane. There are both a PPI and aural presentation available to the operator. In addition to the normal search mode of operation, there is a Classify mode which permits detailed presentation of a target area with range resolution improved by a factor of five. The primary use of the set will be in obstacle avoidance and in search. It is anticipated that the set will also prove invaluable as a navigational aid, particularly when used with a variety of bottom markers. The set has been assembled and is currently being operated at NEL, San Diego, California for 'debugging' and acceptance testing.

The underwater telephone set (Figure 15) is an improved version of the TRIESTE system. This set is fully transistorized and operates on the standard U.S. Navy underwater telephone frequency. The set permits either voice or code communication with the mother ship. This set has been received at WHOI.

The underwater T.V. system consists of two cameras and one monitor. One of the cameras will be mounted on the sail of ALVIN and be used as a periscope. This is required since all of the observation windows in ALVIN are underwater when ALVIN is surfaced and high seas may preclude safely opening the hatch for surface navigation. The second camera will be mounted on the nose of ALVIN, looking down and will be used in conjunction with the mechanical arm. It will also supplement the observation windows.

The altitude and depth pulse sonar set consists of two pingers, one looking up and one looking down. The readout is printed on a helix recorder similar to that used at WHOI as a Precision Graphic Recorder (P.G.R.). This system will give a precision record of the depth and altitude of ALVIN. It will also be used for other purposes such as scattering layer studies, detailing of shallow sediments in the bottom, etc. The pulse system is a modification of the Inverted Echo Sounder in current use at WHOI.

A mechanical arm (Figure 16) is being built for use on ALVIN. This arm has a 63 inch reach and is capable of lifting 50 pounds at that lever arm distance. Normally the arm will be operated thru the port viewing window. The arm has six degrees of freedom and is powered with small DC motors running submerged in oil.

A doppler navigation set has been purchased. The set will be operative when ALVIN is near the bottom, i.e., within approximately 100 feet. The set gives a readout of speed and distance traveled over the bottom, and should be quite accurate over smooth bottoms. The drift angle of the craft is also presented. The set is a low cost unit built commercially for small boats with a modified transducer-receiver head. We will evaluate its utility as applied to small manned submersibles.

The primary instrument power on ALVIN comes from the 30 volt Science Batteries. A solid state inverter system will be carried to provide AC power for the instrument system. A master precision frequency unit will drive power modules producing 60 cycle and/or 400 cycle 115 volt power. The power modules permit sizing the overall inverter in 200 watt increments of 60 and/or 400 cycle power depending on the particular mission requirements. This technique was adopted to permit flexibility and minimum weight.

Two 35 mm still underwater cameras have been purchased. These can be operated separately or tied together for stereo. The cameras provide 500 frames per loading. The cameras are controlled remotely from inside the vehicle.

Two underwater incandescent lights will be used for illumination. Each light contains three 400 watt elements, separately controlled, for a total of 1200 watts per light. The lights are controlled remotely by the operators.

A small boat marine radiotelephone has been purchased for surface communication between ALVIN and the mother ship. This is a 65 watt, six channel set.

During the testing of the directional hydrophone for the scanning sonar set, it was discovered that the hydrophone has a useful response from its design frequency of 80 KC all the way down to 5 KC. To take advantage of this and to delete other directional listening systems, it is proposed to obtain the necessary amplifiers, filters, etc. in order to use the scanning sonar hydrophone for lower frequency directional listening.

We have under consideration several systems to be used on the mother ship to track ALVIN when she is submerged. We hope to incorporate our sonar and/or telephone equipments into this in order to reduce weight.

The design payload weight allowance for ALVIN's instruments is 1200 pounds. This allowance requires constant effort to reduce the weight of all instruments. The latest tabulation of the weight budget is given below:

SystemWeight in Water

1. Scanning Sonar Set	225 lbs
2. DC to AC Inverter (800 watts)	165
3. Mechanical Arm	300
4. Pulse Sonar	75
5. Pulse Sonar Recorder	110
6. UW Telephone	67
7. UW TV System	40
8. Radio	26
9. Lights (2 ea.)	9
10. 35 mm Cameras (2 ea.)	37
11. Doppler Navigation Set	35
12. Wiring & Mounting Racks	100

Total 1189 lbs

Support EquipmentPortable Vans

The acquisition of ship or shore based equipment has progressed rapidly during this period. Three support vans which are portable have been received and are in the final stages of completion and testing. These include the Power Van which has two (2) 30 KW diesel generators (208 V, 60 cycle, 3 phase AC) and associated solid state rectifiers for charging batteries, and switchboards to supply power to the other two vans (either self generated or from shore power), and to portable tools, etc. Also included in this van are two (2) 5000 psi Worthington air compressors for charging the main ballast blow system, SCUBA bottles and air driven tools (through appropriate reducers). The Machine Shop Van contains an 11" lathe, a drill press, grinder, assorted portable and bench tools, bench space and storage for spare parts. The Electronics Van includes instrument racks, bench and test equipment and instruments, storage for spare parts, and certain "household" items such as a water system, washer, stove and refrigerator. The latter are for use when operating remotely from support bases, or large ships with such facilities. Basic equipment for developing and printing film will also be available in this van.

Submarine Mother Ship and Lifting Devices

Various means of handling ALVIN at sea have been studied over the past year, and a catamaran seemed to offer the most attractive approach for the funds required of any system considered. Subsequent to this decision, two (2) 96' long heavy steel floats (Figure 17) became available as BuShips surplus equipment and these have been assigned to ONR for use as the basic hulls of a towed catamaran to be designed, modified and operated by WHOI. In addition, three (3) surplus P-6-M Beaching Vehicles have been made available if required for this project.

The design requirements are in preparation by WHOI for the purpose of taking bids on the design and construction phases of this Deep Sea Research Vehicle Tender (DSRVT) for completion by next summer.

In the interim WHOI has put together twelve of the 370 cu. ft. seal bin containers acquired as surplus and tested out the feasibility of using them to lift ALVIN or other small ships or submarines out of the water alongside the dock. The tests run to date indicate that this method provides us with a back-up means of performing this function. It will be used until the catamaran is available, if necessary.

Miscellaneous Support Equipment

A Boston Whaler with a 65 HP outboard motor has been procured as a tender for the submarine and as a work boat for SCUBA diving. A two (2) man and six (6) man rubber life raft are on hand for emergency use.

A Branson Sonaray (for ultrasonic material inspection) was added to our instruments in order to inspect the pressure hulls and other pressure resistant vessels both prior to installation and at regular intervals in service. Operator training in the use of this device is proceeding. This equipment has been used in our inspection of components.

The necessary mechanical, electrical and electronic measuring devices and meters are on hand and being used for monitoring the construction, assembly and testing of both the vehicle and instruments, as well as shop tools and other equipments including a portable welding machine.

Personnel

As the scope of the project increased, personnel were added with appropriate backgrounds to meet the requirements. As of 31 December 1963 the following people are presently or have been employed on the project during this period:

Full Time -

Engineering and Support:

Earl E. Hays
James W. Mavor, Jr.
William O. Rainnie, Jr. (also Chief Pilot)

Henry M. Horn
O. N. Johnsrud (detached in 1963)
William M. Marquet
Mabel M. Reese (secretary)

Operations:

William O. Rainnie, Jr. }
Marvin J. McCamis } Pilots
Henry H. Learnard }

Russell G. Graham
Karl R. Krueger
Orrin L. Swinhart

Part Time

Howard A. Gaberson
David M. Owen
Jess H. Stanbrough
Allyn C. Vine
Joseph B. Walsh

Summer

William Lane
Cary Rea
John Wilska
Richard C. Brower (Summer Fellowship)

Visitors

A total of over 250 persons visited personnel on this project to discuss submarines, instruments, equipments and potential use of the vehicle for research. Since these are too numerous to mention by name, suffice it to say that they came from other laboratories, government activities, foreign nations, industry, consulting services and schools.

Future Program

The immediate future will be a busy time as final testing programs and vehicle assembly will have to be monitored continuously, as well as testing programs for all of the instruments. Several openings in the operating crew are yet to be filled. Training of the crew is also a major activity in the near future.

Participation in the shallow water evaluation and deep manned dive will be required as vehicle delivery becomes a reality, presently scheduled for early spring.

With the uncertainties in delivery date and efficiency of the craft (number of dives per week, etc.), no specific schedule has been made. A general plan is to go to Bermuda for the deep dives, spend several months there on a survey for ONR Code 467 (H.A. O'Neal), and return to Woods Hole waters in the fall.

Illustrations

- Figure 1 - ALVIN - An Artist's Conception (Courtesy of General Mills)
- Figure 2 - Cross Section of the ALVIN Vehicle (Courtesy of General Mills)
- Figure 3 - Hot Spinning of An HY 100 Hemisphere for an ALVIN Pressure Hull at Lukens Steel Company, Coatesville, Pennsylvania
- Figure 4 - Equator Welding of Two Hemispheres at Hahn & Clay, Houston, Texas
- Figure 5 - Window Insert Forged and Machined at Isaacson Iron Works, Seattle, Washington
- Figure 6 - Sphere Machined on the O.D. prior to Cutting Holes for the Insert Welding
- Figure 7 - Hulls No. 1, 2 and 3 in Various Stages of Fabrication
- Figure 8 - Hull No. 1 at Completion of Fabrication and Sandblast
- Figure 9 - Hull No. 1 Assembled prior to Pressure Testing
- Figure 10 - 0.286 Scale Aluminum Model for Obtaining the Stress Pattern in the Window Insert Area
- Figure 11 - 5,000 psi Pressure Tank at Litton Systems, Minneapolis, Minnesota
- Figure 12 - Buoyancy Spheres
- Figure 13 - Straza Electronics Training Mechanism (Courtesy of Straza Industries)
- Figure 14 - Straza Electronics Sonar Display, Receiver, Analyzer and Power Supply (Courtesy of Straza Industries)
- Figure 15 - Underwater Telephone (Courtesy of U.S. Naval Electronics Laboratory, San Diego, California)
- Figure 16 - Underwater Remote Controlled Mechanical Arm
- Figure 17 - 96' Steel Float - One Pontoon of Proposed Catamaran Barge

Figure 1 - "ALVIN" - AN ARTIST'S CONCEPTION (Courtesy of
General Mills)

Figure 2 - CROSS SECTION OF THE "ALVIN" VEHICLE
(Courtesy of General Mills)

Figure 3 - HOT SPINNING OF AN HY 100 HEMISPHERE FOR AN
"ALVIN" PRESSURE HULL at Lukens Steel Company,
Coatesville, Pennsylvania

Figure 4 - EQUATOR WELDING OF TWO HEMISPHERES at
Hahn & Clay, Houston, Texas

Figure 5 - WINDOW INSERT FORGED AND MACHINED at Isaacson Iron Works, Seattle, Washington

Figure 5a WELDING INSERT INTO THE HULL

Figure 6 - SPHERE MACHINED ON THE O.D. PRIOR TO CUTTING HOLES FOR THE INSERT WELDING

Figure 7 - HULLS NO. 1, 2 and 3 IN VARIOUS STAGES OF FABRICATION

Figure 8 - HULL NO. 1 AT COMPLETION OF FABRICATION AND
SANDBLAST

Figure 9 - HULL NO. 1 ASSEMBLED PRIOR TO PRESSURE TESTING

Figure 10 - 0.286 SCALE ALUMINUM MODEL FOR OBTAINING THE
STRESS PATTERN IN THE WINDOW INSERT AREA

Figure 11 - 5,000 PSI PRESSURE TANK at Litton Systems,
Minneapolis, Minnesota

Figure 12 - BUOYANCY SPHERES

Figure 13 - STRAZA ELECTRONICS TRAINING MECHANISM
(Courtesy of Straza Industries)

Figure 14 - STRAZA ELECTRONICS SONAR DISPLAY, RECEIVER,
ANALYZER AND POWER SUPPLY (Courtesy of
Straza Industries)

NOTE: FRONT PANEL REQUIRES 2" CLEARANCE

Figure 15 - UNDERWATER TELEPHONE (Courtesy of U.S. Naval Electronics Laboratory, San Diego, California)

Figure 16 - UNDERWATER REMOTE CONTROLLED MECHANICAL ARM

Figure 17 - 96' STEEL FLOAT - ONE PONTOON OF PROPOSED CATAMARAN BARGE

APPENDIX A

ALVIN Test Program

1. Introduction - One of the important phases of design, construction, and assembly of a vehicle of this kind, is a comprehensive test program. Tests fall under several different categories depending on the component, system and type of test. The planned testing for ALVIN is comprehensive and will tend to insure the discovery of defects beforehand and make subsequent testing of the whole vehicle a safer and more successful operation. This note gives the general outline of the testing programs, but not all of the details of inspection.

2. Hull Testing -

a) Pressure - The pressure hull that houses the pilot and observer is the most important single pressure resistant component in the vehicle and it follows that the design, construction and test program for it has been most exhaustive.

Three (3) pressure hulls were constructed for this purpose, the least perfect of which from physical inspection would be cycled and collapsed if possible, in a tank at Southwest Research Institute, San Antonio, Texas. Hulls No. 2 and No. 3, of which No. 2 will be installed in the vehicle, will be assembled completely with all of the pressure resistant components and other hardware, and pressure tested to 2/3 of the collapse depth obtained from the engineering data and from the data on the collapsed hull test if possible.

(Note: Hull No. 2 is to be the first installed in the vehicle until the question of a deeper vehicle is settled.)

The tank pressure testing of the hulls is summarized as follows:

	Hull No.1	Hull No.2	Hull No.3
Cycles	500	3	3
Cycling Pressure	2,700 psi (6000')	3,300 psi (7500')	{ Not deter- mined as yet
Test Pressure	3,300 psi (7500')	3,300 psi (7500')	
Collapse	yes, if possible	No	No
Est.Collapse Pressure	7,100 psi	7,100 psi	6750 psi

(Note: Hull No.1 is considered the poorer hull, and No.3 the best.)

b) Physical Properties - Physical specimens were taken from the plate as rolled, the hemispheres as spun, the final hulls as stress relieved and sample welds. At least five tensile and five compression tests have been obtained and a similar number of Charpy V-notch sets obtained from each hemisphere. In addition all three hulls have been 100% ultrasonically inspected and known flaws located. The small flaw (probably a lamination) in Hull No. 1 was ultrasonically monitored during the cycling tests, and no changes were noted as predicted. Each weld was 100% radiographed and magnafluxed, both immediately after welding and at least 7 days after final welding to check for post weld cracking. None was found.

3. Other Pressure Vessels -

a) Pressure Testing - All external components which must resist full operating pressures such as the variable ballast spheres, buoyancy spheres, instrument cases, M.B. Air Tanks, etc. will be pressure tested as follows when possible:

No. Collapsed	2 of each kind
No. Cycles	2,000
Cycling Pressure	2,700 psi (Design operating pressure)
Test Pressure	2/3 collapse based on collapse data

The following testing in this category is anticipated or has been conducted:

	<u>Number</u> <u>Used</u>	<u>Collapsed</u>	Est. Collapse	Collapse <u>Pressure</u>	Test <u>Press.</u>
Main Ballast Air Tank	1	2	6000 psi	6100 psi	3,300psi
6061 Al.Var. Ballast Spheres	6	2	5000	Not completed	3,300
7178 Al. Buoy Spheres	9	2	5000	" "	3,300
Instrument Case	1	0	5000	" "	3,300
*Echo Sounder Instr. Case	1	1	8000	8350	5,000
*U/W TV Cameras Case	2	0	7000	Not to be done	5,000
*U/W Cameras Case	2	0	7000	" " "	5,000
*U/W Lights	2	0	7000	" " "	5,000
*Scanning Sonar Transducer Assy.	1	0	13000	" " "	10,000
her Sonar Transducer- receiver assemblies	5	0	5000	" " "	3,300

(*WHOI furnished equipment)

Physical samples similar to the pressure hulls are to be taken on items that are collapsed, and in addition, in the case of the variable ballast and buoyancy spheres, from excess material cut from the forgings of each hemisphere. These will also be sonically inspected.

4. Systems and Components external to the pressure hull - All of the systems and components subject to ambient pressure will be tested as follows prior to assembly in the vehicle in the sequence shown below, except where the component is too large to fit in the pressure tank:

1. <u>Cycle Test Pressure</u>	0 psi - 5,000 psi - 0 psi
No. of Cycles	3
Time at 5000 psi	10 min.
Operating during test	yes
2. <u>Endurance Test Pressure</u>	5000 psi
Time	24 hours on first of a kind, 4 hours on identical components
Operating	occasionally during test
3. <u>Test Pressure</u>	0
Operate	yes

If a complete system is too large for the pressure test tank, sub-assemblies will be subjected to the above testing. No single component that is too large for the test tank is considered to be pressure sensitive. This includes such items as the fibreglas skin, shrouds, propellers, battery cases, etc.

The following systems will be subjected to the above test schedule:

- a) Main ballast blow
- b) Variable ballast
- c) Main propulsion
- d) Mercury trim
- e) Miscellaneous items

5. Operational Testing

a) Preliminary Evaluation - Shallow water trials will be held for the purpose of testing the performance of the craft. It is planned to obtain the following performance characteristics:

<u>Item</u>	<u>Specification Requirement</u>
(1) Speed, Max.	6 - 8 knots
(2) Speed, Continuous	3.5 knots
(3) Endurance, Power Supply	2.5 knots for 10 hr.
(4) Endurance, Life Support	24 hours
(5) Maneuverability @ 4 knots:	
turn dia., max.	100 feet
stopping distance, max.	100 feet
fore and aft trim	± 30°
overall trim	±600#
dive/ascent rate	200 ft/min
(6) Flood & Blow Main Ballast	
(7) Flood & Drain Conning Tower	
(8) Drop Batteries	
(9) Release Sphere	

continued)

Item

- (10) Drop Mechanical Arm
- (11) Maximum Safe Astern Speed
- (12) Calibration of
 - Depth Indicators
 - Gyro
 - Magnetic Compass
 - Underwater Log
- (13) Hovering Capability
- (14) Compressibility of vehicle vs. water
- (15) Surface Sea State Limitations
- (16) Towing
- (17) Battery and Air Charge Afloat

b) Manned Deep Dive - The final evaluation and acceptance of the vehicle will consist of operating it manned in a series of progressively deeper dives to 6,000 feet, the design operating depth, or a shallower depth if the prior pressure testing so indicates.

To meet the requirements of the contract the following must be done at the operating depth:

- 1) Remain at depth for at least ten (10) minutes, and take strain gage readings
- 2) While at depth test, operate:
 - propulsion
 - steering
 - variable ballast
 - fore and aft trim
 - check sensors and instruments

Satisfactory completion of the deep dive and a successful return to the surface will constitute cause for acceptance of the vehicle.

APPENDIX B

Meetings, Presentations and Visits

Personnel of this group have participated in a variety of meetings, made several presentations concerning the subject of their major interest and have made an increasing number of visits and field trips during this period.

Technical Meetings Attended have been as follows:

- NAS/NRC, Materials Advisory Board, Sub Panel on Deep Diving Submarines
- NAS/NRC, Mine Advisory Committee
- Underwater Acoustic Symposium
- Fifth Conference on the Naval Minefield
- Society of Experimental Stress Analysis
- American Society for Testing of Materials
- Society Naval Architects and Marine Engineers, Annual and local section
- Institute of Aerospace Sciences Symposium
- David Taylor Model Basin Deep Submergence Vehicle Workshop
- Society for Non-destructive Testing
- American Ordnance Association
- Instrument Society of America
- American Society of Mechanical Engineers
- Northeast Electronics Research and Engineering Meeting
- THRESHER Advisory Group
- Underwater Society of America

Presentations have been made to the following groups or organizations:

- WHOI Journal Club
- WHOI Staff Luncheon
- MIT Lecture Series
- Several groups of visiting students
- WHOI Summer Course in Oceanography
- American Society for Testing of Materials - local section
- American Ordnance Association
- Rotary Club
- Visiting Industrial Groups
- Northeastern University Mechanical Engineering Dep't., Lecture
- American Society of Mechanical Engineers
- DTMB Deep Submergence Vehicle Workshop
- Boy Scouts of America, Cape Cod Council
- Underwater Society of America

Visits have been made by project personnel to the following:

Bureau of Ships
Office of Naval Research
National Academy of Sciences
Defense Research Laboratory, University of Texas
Applied Physics Laboratory, University of Washington
Naval Electronics Laboratory
Naval Ordnance Laboratory
Naval Research Laboratory
Naval Engineering Experimental Station
Portsmouth Naval Shipyard
General Mills/Litton Systems, Inc.
World Tool and Engineering Company
Electric Boat Division of General Dynamics Corporation
Hahn & Clay, Inc.
Sciaky
Mechtronics
Massachusetts Institute of Technology
David Taylor Model Basin
Oceanographic Engineering Corporation
Straza Industries
Janus
Loral
Northeastern University
Boston Naval Shipyard
Naval Ordnance Test Station, China Lake, Calif.
Naval Submarine Base, New London, Conn.
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