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REFERENCE NO. 69-32

HAND TOOLS AND MECHANICAL ACCESSORIES
FOR A DEEP SUBMERSIBLE

by

Clifford L. Winget

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Frontispiece: Drilling a Dolomite Rock Sample at 1200 Foot Depth

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Woods Hole, Massachusetts

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FOR A DEEP SUBMERSIBLE

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Clifford L. Winget

May 1969

TECHNICAL REPORT

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Department of Ocean Engineering

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FOREWORD

The hand tools and mechanical accessories covered in this report were constructed for use with a manned deep submersible. They represent the first phase of a program devoted to the development of tools specifically designed for deep ocean use. The various phases of tool development, both successful and unsuccessful, have been included to illustrate a few of the difficulties encountered while working in deep water. Hopefully, the problems will improve the second phase of tool development, providing the user with more productive bottom time and a wider variety of sampling devices for gathering deep ocean geological data and biological specimens.

In keeping with the single tool-single job concept established at the start of the program, the majority of tools and devices illustrated are of simplified design and inexpensive construction. Consequently, the occasional loss of a tool does not constitute a major monetary catastrophe. Piece parts used in the construction of the various devices are considered as off the shelf items readily available at local supply houses or easily fabricated in a moderately equipped machine shop.

Artist sketches have been included in those areas where bottom photographs of operational devices were not available, or, the proposed apparatus had not been completed and tested by the deep submergence section of the Woods Hole Oceanographic Institution.

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In conclusion, the project's success has been largely due to the persistent efforts of Messrs. W. Schultz, P. O'Malley, G. Gibson, P. Kallio, T. Spencer and J. Sullivan, whose technical knowledge and novel fabrication techniques have kept the program rolling.

Figure 1. Emergency Release of A) Mercury; B) Manipulator; C) Battery Boxes

EMERGENCY SPHERE &
SAIL RELEASE

Figure 2. Emergency Release of Personnel Sphere

1.0 Submersible Safety Devices

Personnel safety is a primary feature of the ALVIN submersible. An example of this is the pilot's ability to select, and electrically release various emergency weight reduction devices in the event the submersible becomes snagged on an underwater obstacle. Figure 1, plates A, B and C illustrate three options open to the pilot for increasing the buoyancy of the vehicle:

- a. He may release approximately 600 pounds of pitch control mercury;
- b. Drop the mechanical manipulator, which increases his buoyancy by an additional 285 pounds; or
- c. He may select to release any or all of the three main battery boxes, which increase his total buoyancy to approximately 3400 pounds.

As the ultimate safety step, the pilot can mechanically release the entire forebody of the vehicle, consisting of the personnel sphere and buoyancy ring, as illustrated in Figure 2. The positive buoyancy of the sphere (1800#) will float the personnel capsule to the surface. A battery power pack, located within the sphere, provides the necessary energy to operate the life support system as well as the internal emergency lighting during the ascent.¹

1.1 Release Mechanisms for Externally Mounted Science Apparatus

In keeping with the personnel safety concept, the attachment of all externally mounted science apparatus has been designed to provide the operator with the means of releasing them while the vehicle is submerged. Depending on the apparatus to be mounted, several release mechanisms have been used with the vehicle.

Figures 3 and 4 illustrate the first of a series of prototype release devices tested on the submersible. From experience gained through their use, the improved electro-mechanical release illustrated in Figure 5 was developed.² Basically, its construction is a mousetrap mechanism controlled by the plunger of an electrically actuated solenoid.

1.1.1 Solenoid Actuated Release Assembly

Figure 6 illustrated the operation of the electro-mechanical release. The apparatus, descent weight, or science tray, Item 1, is fitted with an attachment bolt, Item 2. The

Figure 3. Prototype, Vertical Solenoid, Weight Dropper

Figure 4. Prototype, Horizontal Solenoid, Weight Dropper

Figure 5. Solenoid Operated Release Mechanism

Figure 6. Pictorial View of Solenoid Operated Release Mechanism

apparatus is positioned against the base of the release mechanism, in direct contact with the stop pads 3. The hook, Item 4 of the latch mechanism, is placed under the head of the bolt as shown, and the lever mechanism cocked. The bolt is tightened slightly to pre-load the apparatus against the pads. The pre-load assures the snap action of the release, as well as preventing excessive movement of the apparatus due to the sea swell motion, while on deck or entering the water.

1.1.2 Operation of the Solenoid Release

To operate the release mechanism, the operator actuates the solenoid, Item 5, drawing plunger 6 into the coil cavity and rotating the release pivot arm Item 7. Intermediate lever 8 is free to move up, rotating latch pin 9 clear of latch lever, Item 10. As the pin releases the latch lever, the bolt pre-load and spring 11 snaps the latch lever around its pivot pin Item 12 releasing hook 4 from the base of the attachment bolt. The apparatus is free to fall, provided of course, it has sufficient negative buoyancy to drop away from the release mechanism.

To facilitate the release of the attachment bolt, the underside of the mounting plate Item 13 has been machined to a conical configuration. It provides clearance for the bolt-head, improving the drop-away characteristics even with the vehicle in pitch and roll angles as great as 30 degrees.

A safety pin Item 14 can be inserted into the drilled block as illustrated. The lock pin effectively prevents the vertical motion of the latch lever Item 10, in the event of inadvertent electrical actuation. The lock pin, however, should have a good size red flag attached to it, to draw the crew's attention that it must be removed prior to the dive.

The triangular plate welded to the top of latch pin Item 9 was added at the conclusion of the first year of operation. While the pin did not fail, it did exhibit a slight upward bending at the butt weld, due to the load applied by the latch lever. Subsequent operation has been satisfactory, with no indication of deformation.

Science trays as light as 15 pounds water weight and lead descent weights as great as 300 pounds air weight (280 pounds water weight) have been released as a daily routine, with no malfunctions reported during any of the last 120 dives. In

Figure 7. Multi-Contact Electrical Disconnect

the cocked position, the release mechanism does not require power. The momentary solenoid current drain at release is approximately 10 amperes at 30 volts D. C.

The release mechanism illustrated is a simple reliable assembly, quite tolerant to dirt, although the plunger should be kept clean if sluggish action is to be prevented. Judicious use of Lubri-Plate grease at all rubbing points will enhance the action of release.³ However, keep in mind that only a thin film is required, large amounts of grease become stiff at the 4 to 5° C temperatures encountered at operational depths.

The material used in the construction of the assembly is 17-4pH steel. It has been left unpainted, and has not exhibited any tendency to rust, corrode, or show other detrimental surface reaction due to salt water immersion. The solenoid is capable of operating at depths as great as 20,000 feet.

1.2 Construction of a Multi-Contact Electrical Disconnect

In addition to the pilot's ability to release mechanical components when additional buoyancy is required, it is equally important to maintain the capability of releasing electrical science apparatus. An example of this would be protruding temperature probes that could become entangled while operating on the bottom.

The electrical disconnect illustrated in Figure 7 provides a means of externally attaching various pieces of electrical apparatus to the power source of a deep diving submersible. When used with the mechanical release, it provides the pilot with a quick release capability in the event of entanglement while the vehicle is submerged. The device provides for 16 separate electrical leads, each capable of carrying 10 amperes at 28 volts direct current. Electrical contacts within the assembly may be wired in parallel if increased current carrying capacity is required.

The use of an oil medium to fill the internal cavity assures against electrical shorting due to the sea water, as well as protecting the device against the external hydrostatic pressures encountered as the vehicle descends below the surface. Pressure compensation is accomplished by separating the external sea water from the internal oil through the use of a flexible rubber diaphragm.⁴ The diaphragm transmits the water pressure directly to the oil, equalizing the pressure

Figure 8. Pictorial Cross-Section of Multi-Contact Electrical Disconnect

Figure 9. Typical Installation of a Multi-Contact Electrical Disconnect

within the chamber. The equalization of pressure facilitates the separation of the two sections, and allows the use of thin wall materials in the construction of the disconnect housing.

A standard ribbon type multi-contact electronic plug⁵ is internally mounted in the assembly. On separation of the two shell sections, the electronic plug opens, disconnecting the electrical circuits wired to the science apparatus. Complete oil immersion of the electrical contacts tends to decrease arcing at separation. However, it should be standard practice, if time permits, to de-activate the circuits prior to releasing the mechanism. The oil quickly dissipates into the salt water and vehicle mounted wiring could be damaged if shorting occurred at the contacts of the assembly.

Figure 8 illustrates the various piece parts of the assembled disconnect. It consists of an upper housing Item 1, and a lower housing Item 2. The two sections may be constructed of any material not adversely effected by exposure to water.

The upper housing contains the male half of a multi-contact electronic plug Item 4. The plastic gland nut assembly 3 provides an entry point for the electrical leads 7, which are wired directly to the contacts of the plug. At the top of the housing assembly is a pressure compensating device consisting of a top hat shaped rubber diaphragm Item 6, and a plastic oil filler connection and cap Item 10.

The upper housing mates with the lower housing 2. An "O" ring type seal Item 9 is located between the mating flange of both housings. The lower housing has provisions for mounting the female or mating half of the electronic plug 5. The male and female plug assemblies are provided with a restricted, free floating motion, to prevent binding, and to assure proper alignment of their contact points during assembly. The disconnect housings are keyed to assure proper mating of the electrical circuits, as well as to assist in the alignment of the "O" ring seal. A plastic gland nut assembly Item 11 is mounted in the lower housing, providing an entry point for the electrical leads.

A captive compression spring Item 12 and its retainer assembly consisting of guide shaft 16, nut 15, and washer Item 14 are located at the base of the lower housing. When properly assembled on the vehicle, compression spring 12 maintains a constant compression force between the two assemblies.

Figure 9 illustrates a typical installation of the electrical disconnect assembly. In use the upper housing of the disconnect is firmly mounted to the submersible. The lower housing is attached to a bracket secured to the droppable rack or science tray, which is latched to the electro-mechanical release mechanism. The electronic apparatus is wired through the connector, and attached to the science tray.

The lower mounting bracket for the electrical disconnect is located in a manner that compresses the captive spring at its base. The compression spring acts both as a restricted motion universal joint, as well as assuring the sealing properties of the "O" ring sandwiched between the two housings.

To release the rack mounted apparatus in the event of submerged entanglement, the pilot actuates the electro-mechanical release mechanism used to attach the science tray to the vehicle. The tray, lower half of the disconnect, spring, nut, washer and guide shaft, as well as the lead wires and science apparatus drop away from the vehicle, freeing the submersible.

1.2.1 General Design Features of a Multi-Contact Disconnect

The materials used in the construction of the disconnect assembly are not critical due to the pressure compensation feature. The housing may be constructed of plastic, fibre glass, or metal. It may be machined or molded depending on the quantity required. Machining tolerances are not critical.

The use of a ribbon type electrical disconnect is not mandatory and a pin or strip type contact assembly may be used, provided it fits into the internal cavity and does not require excessively high pull-apart loads. The quantity of lead wires is determined by the apparatus and the accommodation provided by the electrical plug. The plastic gland nut feed through bushings are manufactured in various sizes and are off the shelf hardware.⁶

During the initial stages of development, and on vehicle testing, it was determined that the original semi-rigid spring loaded universal joint at the base of the assembly did not provide sufficient freedom of motion. Consequently, any side or rocking action of the science basket allowed the disconnect to open at the separation point. The compensating oil would "burp", sea water would enter, and short out the electrical contacts.

Figure 10. Exploded View of Disconnect Components

Figure 11. Filling Disconnect with Pressure Compensation Oil

Figure 12. Plastic Filler Disconnect With Spring Loaded Check Valve

A longer spring and stem assembly provided greater flexibility, allowing additional science basket movement without opening the disconnect. Some minor compensation oil "weepage" at the separation point was cured through the use of a lower durometer "0" ring. Pressure compensation oil may be obtained from several sources. Hoover submersible fluid #2, Tellus #15, Univolt #35 and 36, as well as Royal C-141, are all satisfactory for use with electrical circuits.⁷

Figure 10 is an exploded view of the disconnect, illustrating the major components. All hardware used in the assembly is considered as off the shelf, and may be purchased from local suppliers. Plastic nuts, bolts,⁸ and fittings have been used to decrease the possibility of electrolytic corrosion due to dissimilar metals. The PVC⁹ spacers prevent direct contact between the stainless steel spring and the aluminum shell housings. As an added corrosion preventative measure, the aluminum components were hard coated and painted before final assembly.

1.2.2 Pressure Compensating Oil, Filling Procedure

Figure 11 illustrates the filling of the quick disconnect with pressure compensating oil just prior to a dive. Filling is accomplished by removing the filler cap, and injecting an oil with good dielectric properties into the assembly until it overflows. The flexible nature of the rubber top hat diaphragm provides direct transmission of the external sea water pressure to the compensating oil. It also provides a means of continually compensating for the slight compressibility of the oil as the submersible descends to its operational depth.

Figure 12 is an all plastic quick disconnect with a spring loaded check valve.¹⁰ It may be used as an alternate means of attaching the filler assembly to the pressure compensated electrical disconnect. The female portion of the filler disconnect contains the check valve portion of the assembly, and must be mounted in the base of the electrical disconnect as shown in Figure 13. The male section of the disconnect is attached to a filler hose and oil reservoir as shown. Filling is accomplished by removing the cap plug on the diaphragm, inserting the male disconnect into its mating half, then raising the oil reservoir until bubble free oil flows from the vent hole.

Figure 13. Reservoir Fill Assembly for Pressure Compensating Oil

Figure 14. Clamp Assembly for Removing Disconnect from Science Rack

When the male half of the plastic disconnect is removed, the oil is trapped within the electrical disconnect cavity by the spring loaded check valve in the filler disconnect. The clamp shown on the rubber hose cuts off the flow from the reservoir when the disconnect is removed. It is a standard compression type hose clamp found in most chemical laboratories.

The electrical disconnect, being a pressure balanced assembly, allows the use of inexpensive pressure molded plastic fittings such as the one illustrated.

In the event the complete disconnect assembly must be removed from the submersible, the fork type clamp shown in Figure 14 may be used to retain the upper and lower disconnect sections without loss of compensating oil.

1.2.3 Operational Advantages Provided by Disconnect

In addition to its safety features, a connector of this type provides the deep diving submersible with the capability of quickly and simply attaching and/or removing externally mounted electrically powered apparatus. The wiring may be accomplished with a minimum of difficulty and without stringing them through a guillotine type cutter. It also provides the means of rapidly performing wiring circuit changes to conform to new apparatus. "In Circuit" testing of the disconnect may be performed without mechanical or electrical damage to the lead wires or apparatus. The disconnect assembly is readily filled with pressure compensating fluid at installation, or after release drop tests have been performed.

In using an electrical disconnect of this type, the operator is not limited to wire bundles or sizes that must fit into the throat of a guillotine type mechanism. He has complete freedom of wire and cable bundle size and is not hampered by the available shear energy stored in the cutting head of the guillotine.

1.3 Low Cost High Current Multi-Contact Disconnect

Figure 15 illustrates the design of a simple disconnect using PVC material for the shell, modified panel type fuse holders, and simple turned brass pins that mate with the spring loaded contact on the inside of the fuse holders.

Figure 15. Exploded View of Low Cost High Current Disconnect

Figure 16. Exploded View of "Quickie"-Disconnect

Pressure compensation was provided by compensating oil and the plastic bellows obtained from a meat baster procured from the local variety store. The release mechanism and spring loaded universal joint is identical to the one used with the previous assembly.

The lead-in wires were potted into the shell with Flexane putty.¹¹ The two part potting compound is a catalyst type room temperature curing material with a rubber consistency. In the cured state, it has demonstrated a good resistance to the pressure compensation fluids normally used.

1.4 "Quickie" Electrical Disconnect

Figure 16 illustrates a simple but extremely successful disconnect that may be fabricated from components usually available to any crew chief's "bag of tricks".

Basically it consists of a length of automotive radiator hose, two plastic Danco feed-through bushings, and a commercial electronic pin/socket type connector. The hose may be filled with any oil available at the time. Motor oil or transmission fluid is satisfactory in any emergency. However, new oil should be used to prevent high resistance leakage due to carbon particles or moisture that may be suspended in "used" oil.

A disconnect of this type works satisfactorily primarily due to the collapse ability of the hose. If the hose did not collapse during separation, the negative pressure created by the removal of the Danco connector, plus the high external ambient water pressure, would make the release cycle extremely difficult if not impossible.

The Danco bushings are modified by machining off the flange at the base of the connector. Figure 17 illustrates a standard assembly at the top left, a modified smooth wall and two with beaded sealing surfaces. Either modification is satisfactory, depending primarily on the inside diameter of the rubber hose that is available. The diameter of the flange should be a snug fit into the I. D. of the hose when both surfaces are dry. Do not machine for a hard press fit. A dry-snug fit provides good pull apart qualities when the surfaces are wetted, with sufficient restraint to prevent inadvertant separation when in use.

Figure 17. Danco Connector Modification

Figure 18. Cross-Section of Tubeless Tire Filler Plug Assembly

Figure 19. Mechanical Pull-Pin — Release Assembly

Note that an "O" ring has not been used between the Danco and I.D. of the hose. The modified Danco flange provides a satisfactory seal between the two assemblies. For best results, the hose length to inside diameter should be a 5 to 1 ratio, which provides sufficient reserve oil to assure a satisfactory collapse capability when separation occurs. Do not use hose clamps to restrain the Danco connectors; at least one end must remain free to slip out of the hose as break-away occurs.

To facilitate filling the device with compensating fluid, the filler plug illustrated by the cross-sectioned hose in Figure 18 may be used. Basically it consists of a tubeless tire repair plug¹² inserted into a hole punched in the wall of the radiator hose. The plug is inserted from the inside, with the pig-tail on the outside. The assembled quick-disconnect may be filled with oil from a plastic squeeze bottle, or completely immersed in a container of fluid. When filled, the repair plug is pulled through until the mushroom head seals against the inner wall of the hose.

The plug provides a convenient method of "burping" any entrapped air that may remain in the assembly after filling. It also eliminates the hydraulic ram effect that occurs within the oil filled tube during the final assembly and insertion of the Danco connector bushings.

1.5 Mechanical Pull-Pin Release Assembly

The pull-pin mechanism illustrated in Figure 19, was devised as a back-up release for a bottom moored beacon assembly. The release is operated by grasping either of the two loose footed pull rings with the claw of the mechanical manipulator. On retracting the manipulator, or backing the vehicle, the cotter pin pulls free releasing the beacon from the bottom anchor. Figure 20 is a deep water photograph illustrating the pull pin assembly¹³ attached to the base of a beacon string.

The operation of the release is simple, reasonably fool proof, and has been successfully used in 6000 feet of water. Figure 21 is an artist sketch of the pull pin release attached to a beacon deployed on the ocean bottom. As a note of interest, a liberal film of Lubri-Plate grease will enhance the release capabilities of the mechanism.

Figure 20. Bottom Photograph of Pull-Pin — Release

Figure 21. Artist Sketch of Bottom Mooring and Pull-Pin — Release

Dimensions and materials of construction are dependent on the buoyancy characteristics, the weight of the bottom anchor, and the expected time-on-the-bottom. Brass or stainless steel may be used for the pull release rings and cotter pins. The main body may be aluminum, stainless, or brass, depending on the load applied by beacon and its float.

For long term salt water submergence, and where the release will be attached to dissimilar metals, plastic insulator bushings must be inserted between the release and the attachment shackles as shown in the illustration. Past experience has proven that cathodic corrosion can be quite severe in the shackle area. Damage due to this local action can result in the loss of a bottom beacon, or the inability of the submersible to release the corroded assembly due to the "growth" that occurs on the release.

The orientation of the two pull pins should be 180° as illustrated. This allows the submersible to approach from either direction, saving considerable time for the operator. The dual approach concept allows the operator to circumnavigate the hazards of local currents and bottom obstructions, as well as tending to lighten the pilot's task of maneuvering an unwieldy vehicle in close quarters.

Note the hook shape rod at the lower left of the photograph. It was installed on the science rack as an experiment to determine the feasibility of releasing the pull-pin mechanism without the aid of a mechanical manipulator. The test was successfully accomplished. However, the time required to maneuver the submersible into proper alignment was considered excessive.

As a point of interest, the pull rings should be sized by doubling the diameter that feels comfortable to your hand. The operation of the manipulator is difficult under the best conditions, and what may appear excessively large on the surface becomes a very small target for a pilot operating at great depths and limited lighting conditions.

To aid the pilot in visually sighting the pull rings, white paint tends to stand out fairly well in areas having a dark background. In light, sandy background, the use of red fluorescent spray paint has been found quite satisfactory.

Figure 22. Pinger and Release Mechanism

1.6 Pinger Release Mechanism

Figure 22 illustrates a solenoid actuated pinger release mechanism.² The device is externally mounted on the submersible, providing the operator with a means of releasing a water actuated pinger on command.

Figure 23 is a simplified cross sectional drawing of the release mechanism. The pinger Item 6 is shown in the latched position. Surfaces "A-B", at the base of the pinger, are the electrodes that must be in contact with the sea water, in order to actuate the pinger transmitter. Installed as shown, electrode plate "A", is shielded from water contact, while electrode "B" is free flooded. The pinger will not operate until both electrode plates are wetted.

To operate the pinger release mechanism, solenoid 1 is energized, plunger 7 is drawn into the solenoid cavity, moving latch arm 8 about pivot 9. Latch pin 10 releases the pinger, which drops away from the release housing assisted by spring 5.

In order to shield pinger electrode plate "A" from water contact, the rubber diaphragm Item 4 has been positioned to rest flat against it when the pinger has been inserted into the release mechanism. As the vehicle descends, ambient sea water pressure is sensed through vent hole 3, and applied to diaphragm 4, which forms on wall of cavity 11. The pressure applied to the diaphragm seals the activator surface "A" until the pinger is released.

As originally installed, some difficulty was experienced with hang-up of the pinger and spring assembly. On release, the pinger began its ejection through the I. D. of the spring. Hang-up occurred as the last coil caught in the notch at the pinger base. The second malfunction resulted when the coil spring slipped down over the pinger body, preventing a full release of the transmitter. The ejection spring was removed from the release and the pinger allowed to free fall. No malfunctions have been noted since the ejection spring was removed.

The release does not require power to retain the pinger. It is a spring loaded mechanical latch that requires power only at release. The solenoid operates at 30 V. D. C., drawing approximately 9.5 amperes when actuated.

$\frac{3}{4}$ SCALE

Figure 23. Cross-Section Sketch of Finger Release Mechanism

The device may also be used to release other light weight items of equipment. Depending on the weight of the apparatus, the mechanism may be positioned as illustrated, or turned upside down to release objects having a positive buoyancy. The device is not position sensitive.

The apparatus to be released requires a cylindrical boss 1 1/4" in diameter, at least 2" in length. A 1/4" groove must be machined 3/8" in from the end in order to provide the necessary locking action when mated with the solenoid release latch.

Some difficulty has been experienced with salt deposits collecting in the pressure sensing cavity, Item 11. The sensing port Item 3 will be modified to provide a means of flushing the entire cavity and preventing salt incrustation of the rubber diaphragm.

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A. Devcon Corporation, Danvers, Mass.
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Figure 24. Prototype Science Tray

2.0 Science Tray Development

One important capability of a manned deep submersible is the ability to provide an in-situ direct view observation platform for the science observer. Having observed bottom life as it exists in its native habitat, the science observer's next objective is to obtain specimens and data pertaining to his area of interest.

To accomplish this, a means of retrieving and storing the specimen becomes the next requirement. The present deep submersible, however, has not been constructed to provide this convenience or capability. In view of this, some means of externally storing tools are required, as well as providing an area for the safe storage of specimens retrieved from the bottom.

Due to the many variations of vehicles presently in operation, no one set of science racks or baskets would be satisfactory for all. The science racks and other hardware illustrated in this section were designed for use with the ALVIN vehicle. The methods of attachment, design, and construction, however, are adaptable to most other vehicles.

2.1 Design and Fabrication of Science Tray Structures

Figure 24 illustrates the first science tray fabricated for use with the ALVIN vehicle. It provided a storage space for both tools and specimens, as well as having a quick release capability. Construction materials were inexpensive, consisting of expanded metal, aluminum angle framing, and two pre-form wire baskets for tool and specimen storage.

The large flat surface of the tray somewhat restricted the pilot's vision. Its primary fault, however, was the reduced area of operation available to the manipulator.

As additional bottom time and experience was gained, the design of science trays continuously improved. Figure 25 illustrates the modified milk basket approach. It provided a wide clear working area for the manipulator and presented a minimum visual obstruction to the pilot. Its storage space was small, which limited both the tools and specimens carried by the vehicle. Unfortunately, it protruded forward of the vehicle in an unprotected zone, and was prone to major damage when working on or close to the bottom. Its simplicity, however, could not be beaten.

Figure 25. Milk Basket Science Rack

As each series of dives progressed, the design of science trays continued. New ideas were discussed and if considered as an improvement, they were incorporated in the existing tray. After many modifications, some satisfactory and some questionable, the following design parameters were established as the ideal science tray for the ALVIN vehicle.

2.1.1 Science Tray Design Criterion

1. The frame should have sufficient strength to accept an occasional bumping of the bottom, while still retaining a fail safe characteristic that would protect the submersible if the tray was accidentally crushed in a collision.
2. Be constructed in a manner that would not obstruct the pilot's view while operating the manipulator or driving the vehicle.
3. Have sample storage space and strength to accept a reasonable pay load of tools and specimens without being excessively heavy.
4. Be capable of being released at the pilot's command in the case of bottom entanglement.
5. Provide the pilot with the means of scooping into the bottom, or holding against an outcrop, while simultaneously retrieving a heavy specimen with the manipulator.
6. The overall dimensions should not restrict the motion of the manipulator, or prevent the easy withdrawal and return of tools after their use.
7. Be capable of being removed by divers while in the water.
8. Be constructed in a way that the temporary installation of science apparatus and mechanical tools may be accomplished at sea with a minimum of equipment.
9. Have provisions for installing individual, coded, carrying bins or pouches for specimens obtained during the dive.
10. Be constructed in a way that provides protection from wash-out and physical damage to the specimen when the vehicle returns to the surface.

Figure 26. Sled Runner Science Rack

2.2 Sled Runner Science Rack

Figure 26 illustrates one version in the family of science trays developed along the proposed guide lines. Box type construction and the liberal use of expanded metal¹ provides the necessary strength and minimum visual obstruction to the pilot. The use of aluminum tubing² keeps weight to a minimum, as well as providing a structure that will crush if inadvertently rammed into a solid object.

The curved sled runners furnish the pilot with a rack that will slide up and over minor obstructions while cruising slowly over the bottom. When resting on the bottom, the vehicle can be positioned in a nose down attitude by pumping mercury trim. As trim ballast changes, the submersible rocks or pivots on the curved runners. In the bow down position, and with the forward edge of the basket resting on the bottom, the pilot can scoop large objects into the tray, using the manipulator. With this method of retrieval, the operator is capable of recovering specimens of a size and weight that is greater than the grasp and life capabilities of the mechanical manipulator.

The tubular sled type structure illustrated blocks out a small portion of the bottom directly below the pilot's window; however, it is minimal and does not affect the safety of the vehicle. Figure 27 represents the approximate area of obstruction as viewed by the pilot. The actual view shown was taken looking down from the bow, about 3 feet above the pilot's forward view port.

Assembly of the various tubular sections may be accomplished by welding or through the use of cast aluminum scaffolding joints. A composite tray assembly, using both the aluminum scaffolding attachments as well as welded joints, is shown in Figure 28.

The structural joints³ are available in commercial pipe sizes ranging between 3/4 inch to 2 inches, have high strength and are reuseable. If welded structures are used be sure to drill vent holes to equalize the pressure in any dead ended sections of the frame.

2.3 Triangular General Purpose Science Rack

Figure 29 represents a second type of tubular tray that has evolved from the guide lines originally established.

Figure 27. Pilot's View of Science Rack Obstruction to View

Figure 28. Composite Welded and Scaffolding Joint Science Rack

Figure 29. Triangular General Purpose Science Rack

Figure 30. Triangular Science Rack with Bottom Ski

Similar to other trays, it is constructed from welded 6061 tubular aluminum stock. Its geometric form, however, is triangular rather than the sled runner box type construction previously illustrated. The triangular structure provides the pilot with an improved view of the bottom, as well as additional maneuvering room for the manipulator. Science apparatus and specimen containers are easily attached to the basic frame using hose clamps or the cast aluminum structural fittings.

2.4 Ski Attachment for General Science Tray Use

Figure 30 illustrates an adaptation of the basic triangular tray. The installation of a fibre glass ski provides the pilot with a means of gliding across the bottom, while maintaining a constant altitude. Bottom tracks, incidentally, furnish the submersible's crew with a built-in road map when returning to a specific point. Past pilot experience has shown that in areas where bottom current velocities are low, ski tracks have remained visible guide lines for periods of time as long as one year.

The ski device illustrated is of solid construction. It was fabricated by the wet lay up method, using fibre glass mat and cloth impregnated with polyester resin.⁵ The wear rate on the ski is quite high and a protective sheath should be included to protect the bottom surface as well as the edges.

As an item of interest concerning the use and protection of fibre glass structures operating in deep ocean environments, it is considered as mandatory to reseal any areas of outer-skin that have been penetrated due to a machining operation or damage. All exposed raw edges must be sealed with an unbroken coat of resin before the device is exposed to elevated hydrostatic pressure. If repairs are not performed the sea water is forced into the edges of the unsealed fibre glass, where it wicks along the material, breaking the bond between the resin and glass fibres. Once separation has occurred it is difficult to repair and could result in structural failure due to the loss of strength that occurs.

2.5 Safety Release of a Typical Science Tray

In keeping with the design goals requiring the ability to release the science tray in the event of entanglement, Figure 31 illustrates the mechanics of a typical release.

$\frac{1}{6}$ SCALE

FIG

Figure 31. Mechanics of a Typical Science Rack Release

The science tray Item 1 is attached to the submersible by a three point suspension. The two pivot type attachment points Item 2 are located at the forward end of each vehicle skid, with the third attachment being the electro-mechanical release mechanism Item 3.

On command, the release mechanism unlatches, the tray begins to drop, pivoting around the pins until the rack drops free. Actual drop tests have shown that a "free" tray glides away from the submersible after being released. In the event the tray is entangled, the pilot actuates the release, rises slightly and backs away, performing the same mechanics of release as shown in the illustration.

While no special surface finishes or preparations have been applied to the 6061 aluminum science trays, corrosion, both internal and external has been minimal. There have been no structural failures due to corrosion over the last two years of operation. Corrosion preventative finishes or oil filled pressure compensated structures are not recommended for science trays of the type used on the ALVIN vehicle. Their free flooding characteristics, low cost of construction, and the high probability of loss or damage make protective coatings a high cost item for the small benefit gained.

Past experience tends to substantiate that a fresh water wash down will effectively clear the salt deposits from the tubular surface appreciably extending the life of the structure.

2.6 The Science Tray as a Mechanical Tool

As a point of interest, the science tray may be considered as a working tool capable of performing a mechanical function. To illustrate this, the mechanical manipulator used on the ALVIN vehicle was lost in 4800 feet of water as a result of a rough sea landing collision with its support vessel.

In order to recover the manipulator, several devices were designed to perform a "no hands" retrieval. One method proposed was to modify a science tray with the hook shown in Figure 32.

With the modified "hook" tray attached to the vehicle, the operator descended to the bottom and made a preliminary run on the manipulator. Figure 33 illustrates the furrow dug by

Figure 32. Triangular Science Rack with Retrieval Hook

Figure 33. Recovery Photograph of ALVIN Manipulator on the Bottom

Figure 34. Typical Geological Sled Runner Science Rack

the hook on the first pass. The second attempt placed the hook under the manipulator elbow joint. Mercury trim was then pumped aft to compensate for the added weight of the arm, and to provide a definite bow up angle in order to prevent the manipulator from slipping off the hook.

The remaining ascent and on deck retrieval of the manipulator was uneventful. Repair costs to the manipulator were \$4700 and the replacement cost would have been in excess of \$80,000.

2.7 Geological Science Trays

In general, no single science tray design will fulfill the requirements imposed by a variety of geological missions. Past experience indicates that a wide operational overlap can exist between so-called geological and biological science trays.

Figure 34 illustrates a geological science tray in its basic form. It represents the typical rectangular sled runner construction with specimen storage space, coring tools, and bottom sediment samplers. The tools are positioned along both sides of the rack, within easy reach of the mechanical manipulator.

2.7.1 Science Rack with Bottom Scoop and Flapper Door

Figure 35 represents the overlap that can exist between the biological and geological science trays. As shown, the basic sled runner has been modified to include a sediment scoop and fish net located at the base of the assembly. Figure 36 illustrates the hinged flapper door that is actuated by the mechanical manipulator, and used to close the mouth of the trap. As originally designed, the scoop net was used to gather small biological specimens living in the bottom sediment.

To operate the collection device, the mechanical manipulator opens the trap by raising the pull-rod located at the top center of the scoop. The vehicle moves slowly over the bottom, skimming the top layer of sediment into the net. The net "catch" is viewed by the operator looking through the forward port. After sufficient specimens have been collected, the operator closes the trap with the mechanical manipulator.

The net and scoop configuration has proven to be quite satisfactory in obtaining both biological and geological specimens

Figure 35. Typical Biological Sled Runner Tray, with Net and Scoop Entry

Figure 36. Scoop Entry Closure of Typical Biological Rack

ENTRY DOOR IN CLOSED POSITION

ENTRY DOOR IN OPEN POSITION

Figure 37. Artist Sketch of Scoop Closure Latch Mechanism

FIG.

from deep ocean sediments. The flapper door assembly safely prevents specimen wash-out and loss as the vehicle passes through the wave action at the surface. The trap door is a straight forward device, capable of being operated by two simple motions of the manipulator. Figure 37 is an artist sketch of the pull-rod mechanism. As shown, it acts as both the operating and locking device when the door is in either the open or closed position.

To prevent mechanical damage to delicate objects, the net is usually constructed using a resilient synthetic or fibre material. Originally, a metal mesh was used. However, it is excessively stiff and does not "give" with the wave action as the vehicle passes through the interface. In some cases, it may be advisable to have divers retrieve the more delicate items while the vehicle hovers 50 to 75 feet below the surface.

Figure 38 illustrates a bowed metal scoop designed to dig selected areas of bottom sediment. The scoop aids in the collection of small creatures by breaking the bottom sample into small pieces that are easily eroded by the water flowing through the net. Unfortunately, the sediment in some areas has a tendency to lift off the bottom in large flat sections, similar to the surface heaving of a macadam road on a hot day. On passing into the collection net, the sediment layers pile-up in a glutinous mass, and fail to wash through the net openings.

In an attempt to prevent overloading the submersible with unnecessary mud ballast, the saw tooth scoop illustrated in Figure 39 was designed. Its purpose is to break the sediment into smaller pieces, making it more susceptible to erosion. It did not improve the situation to any great degree, and either configuration may be used depending on the operator's preference.

2.7.2 Furnishing a Geological Science Rack

Figure 40 illustrates a typical science rack rigged for a geological mission. Fulcrum pry-bars are shown across the front of the rack, with brass sediment core tubes mounted in the side quivers. On some bottom missions, the science observer requires the collected specimens to be stored in their order of retrieval. To provide this capability, the canvas collection sacks⁶ shown in the photograph have been lettered with an ink marking pen. Each sack provides a

Figure 38. Bowed Sediment Scoop at Entry of Collection Net

Figure 39. Toothed Sediment Scoop at Entry of Collection Net

Figure 40. Geological Rack with Specimen Bags, Core Tubes, and Fulcrum Tools

Figure 41. Science Rack with Prototype Hard Rock Coring Device and Specimen Bags

coded storage space for the specimens collected. The sacks and their individual numerical code are clearly visible to the inside observer peering through the view port.

For small object retrieval, the butterfly nets, slurper, and sampling sacks illustrated in section 9.0 are provided. They furnish the operator with an additional means of obtaining both biological and geological bottom specimens.

2.7.3 Basic Equipment Rack for Hard Rock Sampling

Figure 41 illustrates a science rack rigged to obtain both hard rock as well as soft sediment cores. The hard rock core drill is retained in its receptacle by gravity. It is of sufficient weight to prevent wash-out when the vehicle enters the water. The canvas sack located at the side of the drill is used to store the rock core specimens.

Operating the drill, while simultaneously engaged in driving the submersible, is a very tedious affair requiring all the skill the pilot can muster. To assist the operator and to decrease unproductive bottom time as much as possible, tools and tool holders should be designed for simplified operation. For example, on completing the hard rock coring operation, it requires approximately 3 to 4 minutes to return the drill to its original storage receptacle. This is a time consuming operation that requires considerable skill with the manipulator controls. It is unproductive bottom time and should be reduced or eliminated if at all possible.

In the case of the rock coring device it was an easy matter to make the specimen storage sack sufficiently large to accept the complete drill assembly. The coiled power lead has sufficient flexibility and length to allow the manipulator to deposit the drill in the canvas receptacle. The power lead being fully pressure compensated will accept the bending stress without cracking.

As a point of information, it is important to pressure compensate all electrical wires connected to a device that must have freedom of motion. The pressure compensation keeps the cable in a flexible state by preventing the external sheath from squeezing around the internal lead wires. Uncompensated cables form a dense tightly packed "rod" of rubber that will rapidly fail if subjected to any twist or bending stresses while operating in deep water.

2.8 Biological Science Trays

The deep submersible provides the science observer with a means of collecting biological specimens at precise pre-selected depths and bottom locations.

Early deep ocean biological sampling from the submersible was accomplished using the drag nets illustrated in Figure 42. The cot end of the nets are tied to the aft end of a flat basket tray, with the mouth entry hinge located at the front. The net is held in the open position by stretching a bungee cord⁷ with the fingers of the mechanical manipulator. When released, the rubber bungee snaps the hinge frame to the flat or closed position, as illustrated in Figure 43.

By controlling the operation of the net, the scientist is provided with a means of determining the quantity of specimens contained in a specific volume of water. Knowing the area of the net opening and the forward velocity of the submersible, he can calculate the time the net must remain open in order to pass the required quantity of fluid. Under normal operation, the net remains in the closed position until the vehicle descends to the area of interest. The net is opened at the selected site, and the vehicle cruises for the required period of time.

To obtain bottom specimens, the operator first positions the vehicle at the proper depth above the bottom. He opens the net entry and slowly skims over the top layer of silt. The silt agitation resulting from contact with the aluminum frame causes the bottom specimens to flow back into the net. At the completion of the run, the operator closes the entry, trapping the specimens within the net.

As additional bottom experience was gained, three deficiencies were found to exist in the basic assembly:

- 1) The net closure method was unsatisfactory as it allowed extraneous contamination to enter the net, both during ascent and descent.
- 2) The pilot had extreme difficulty in maintaining a constant distance off the bottom which resulted in either digging-in or skipping-over various areas of bottom sediment.
- 3) The calculation of water volume passing through the net was under the best conditions frequently open to question.

Figure 42. Vehicle Mounted Bottom Sediment Drag Nets, Shown in Open Position

Figure 43. Bottom Sediment Nets in Released and Closed Position

2.9 Mid-Water Plankton Net with Flow Totalizer

Figure 44 illustrates a plankton net⁸ with an improved closure mechanism, as well as a flow meter⁹ to measure the amount of water passing through the net. The mouth of the net is attached to a pivot on the science tray and is actuated by the mechanical manipulator. The flow meter is equipped with stoppers to prevent rotation of the recording vanes when the net is closed.

The net is normally left in the closed position as the vehicle descends through the water. At the proper depth, the operator opens the net with the mechanical manipulator, positioning it as illustrated in Figure 45. The vehicle cruises along the pre-selected course at a known forward velocity for a specified period of time. At the conclusion of the time interval, the manipulator closes the net to the position illustrated by Figure 46. A rubber bungee cord provides a positive retention force, holding the net in the closed position. A draw string is pulled tight around the net to secure the specimens, as well as to reduce the possibility of contamination as the vehicle ascends.

Figure 47 is an artist sketch illustrating the draw string operation. A length of bungee cord is formed in a noose and positioned around the net slightly aft of the swivel frame. After closing the net, the operator grasps the pull loop in the bungee cord, using the manipulator fingers. The bungee stretches and draws tight around the net, pinching off the entry. The alligator jaws provide a lock for the bungee, allowing the manipulator to release the cord without loosening the tension in the noose.

While the draw string closure appeared satisfactory, the science observer was never positive that contamination had not occurred. Based on further discussions, a decision was made to design a positive closure net. The device would assure the science observer that an uncontaminated specimen had been obtained.

2.10 Bottom and Mid-Water Specimen Net Improvement

Biological specimen retrieval, both on the bottom and in mid-water, continued to illustrate the need for an improved positive closure net. The problem was considered to be a

Figure 44. Mid-Water Plankton Net and Flow Totalizer

Figure 45. Open Position of Mid-Water Plankton Net

Figure 46. Mid-Water Plankton Net in Closed and Faired Position

Figure 47. Artist Sketch of Plankton Net Draw String Safety Closure

Figure 48. Experimental Vertical Gate Plankton Net Closure Model

major one, and as such, it was decided to undertake a complete re-design of the net closure as well as the operational procedures.

Several proposed methods were investigated, and the following models constructed to evaluate the proposed designs.

2.10.1 Vertical Gate Plankton Net Closure

Figure 48 illustrates a model of a vertical gate plankton net. It consists of a flat plate that slides in two "U" shaped channels mounted on each side of the net frame. In view of its simplicity, it appeared to have considerable merit. Further evaluation, however, revealed a few operational problems would be encountered, especially during surface operation of the vehicle.

With a proposed 2 square foot entry, the fixed flat-surface frontal area of two vertically mounted nets would present a vehicle handling problem as a result of surface wave action. In addition, the "U" shaped channel guides did not provide the positive closure necessary to prevent contamination of the internal surfaces of the net.

The design investigation was discontinued as it did not appear to satisfy all the requirements previously established. The basic approach, however, could be modified to do a satisfactory job and will in all probability be investigated at a later date.

2.10.2 Rack and Pinion Flapper Door Closure

Figure 49 illustrates a working model constructed to evaluate a flapper door plankton net closure. It consists of a flat plate hinged to the net frame and actuated by a link connected to a rack and pinion.

Similar to the previous model, it also presents a large "sail" area that creates a vehicle handling problem when exposed to surface wave action. The main difficulty, however, appears to be in obtaining a positive closure seal along the edges of the flapper door. To assure this positive closure, the construction of the door must be of sufficient strength to resist warpage and twisting during the operation.

Figure 49. Rack and Pinion Flapper Door Closure Model

Neither problem is considered insurmountable and can be corrected with a minimum of effort. The basic design is considered satisfactory and will be carried over into other equipment fabricated for the vehicle.

2.10.3 Positive closure Plankton Net

Figure 50 illustrates the third model constructed to evaluate the proposed plankton net designs. The device illustrated is a flapper type closure actuated by a gear drive mechanism. The door is hinged at the top with sealing provided by a rubber gasket cemented to the aluminum frame. The device is shown in the full open position.

The upper illustration in Figure 51 represents the closed position of the device, while the lower illustration shows it in the closed and faired position. The three positions illustrated in Figures 50 and 51 are a sequence type operation, occurring as the drive gear is rotated through its operational cycle.

The ability of the operator to position the plankton net door in the faired position is of great importance to the pilot of the submersible. By reducing the frontal area of the two closures, it substantially decreases the possibility of surf-boarding when operating on the surface, especially in following seas.

Figure 52 is an artist sketch illustrating the construction details of the positive closure plankton net assembly. The top sketch shows the flapper door Item 1 in the full open position. The drive gear Item 4 is secured to the flapper. It drives the door rotating it around the pivot point until the positive stop bracket Item 2 contacts the frame Item 3.

To close the door, the direction of gear rotation is reversed until the door reaches the position illustrated by the center sketch. At this point the door and frame are in direct contact. Sealing at the contact surfaces is provided by a section of weather stripping as well as a flat rubber gasket.

Continued rotation of the drive gear pivots the flapper door and the plankton net frame to the closed and faired position, as illustrated in the bottom sketch. The plankton net is normally secured to the lip which forms

Figure 50. Positive Closure Flapper Door Plankton Net Model, Open Position

Figure 51. Closed and Faired Position of Positive Closure Plankton Net Model

Figure 52. Operational Sequence Sketch of Positive Closure Door Assembly

the back edge of frame 3. It is not shown in this sketch in order to provide a clear view of the closure pivot mechanism.

2.11 Construction of a Full Scale Positive Closure Plankton Net Assembly

Figure 53 illustrates a full scale positive closure net based on the flapper door design. It consists of a riveted aluminum frame and hinged trap door. The door is actuated by a gear box driven by the wrist rotate drive mechanism of the mechanical manipulator. Positive sealing of the mating surfaces is assured through the use of a soft strip of weather stripping. The material is cemented to the frame using a commercial bonding agent.¹⁰

Figure 54 is a close up of the net closure, illustrating the gear box¹¹ and the universal tee handle drive that mates with the mechanical manipulator.

The net is attached to the frame using a stainless steel banding strip¹² spot welded to a screw type hose clamp and four wood forms as illustrated by the upper sketch in Figure 55. The banding and wood segments provide a tight "contamination free" seal between the net and the frame. It is, however, exceedingly difficult to remove and re-assemble when recovering the captured specimens. The level of difficulty was sufficiently high so that the science observer finally settled on rinsing the specimens out of the assembled net rather than remove it. Future net designs will be fabricated to eliminate this difficulty.

As a temporary fix, the device was modified by attaching the four wood segments to the stainless steel band with wood screws. A lever type latch¹⁴ has been included to secure the assembly to the net and frame as illustrated in the lower sketch. The 3 screw type hose clamps¹⁵ provide sufficient adjustment to assure proper positioning of the net and the clamp when assembled to the positive closure frame. Future assemblies will be attached through the use of a positive seal zipper mechanism.¹⁶

2.11.1 Installation and Operation of a Flapper Door Plankton Net.

Figure 56 illustrates the two nets installed on a science tray. The net at the right is shown in the open position, the one at the left is closed and faired.

Figure 53. Full Scale Plankton Net, Full Open Position

Figure 54. Flapper Door Gear Box Drive Mechanism

Figure 55. Artist Sketch Illustrating the Attachment of Plankton Net

Figure 56. Vehicle Mounted Positive Closure Plankton Nets

Figure 57. Rigid Tee Handle Drive for Flapper Door Plankton Net

The two bungee loaded latch levers located between the nets are used to lock the assemblies in the closed and faired position. The net and frame assemblies can be released one at a time by nudging the latch levers with the mechanical manipulator.

Figure 57 is a close up of the tee handle used to operate the gear box assembly. One of the bungee loaded release levers is shown at the upper right center. The tee handle illustrated is considered as a rigid design and in actual use was found to require precise alignment between the tee handle and the fingers of the mechanical manipulator. Any misalignment, regardless of how small, exerts excessive side loading on the manipulator joints when the wrist rotate motor is actuated.

To correct this deficiency, the tee handle was modified as illustrated in Figures 58 and 59. The fix consists of inserting a semi-rigid universal joint, with self-aligning features, between the tee handle and the gear box assembly. The universal joint¹⁷ provides 360° rotational alignment, while the hose provides a semi-rigid structure which keeps the handle in an upright position. The device has been extremely satisfactory. In addition to eliminating the side loading, it has substantially decreased the time required to assure proper alignment between the tee handle and manipulator fingers.

Figure 60 illustrates a typical science tray specifically rigged to obtain biological specimens close to the bottom. Its design is based on the improvements provided by the closure model investigation, as well as the bottom experience gathered during previous operations.

The two nets are controlled by the mechanical manipulator. They are positioned close to the bottom, and have a positive, contamination free closure. The ski shown in the lower left furnishes the pilot with a device that establishes a fixed "off the bottom" altitude, as well as preventing inadvertent ramming of the nets into the bottom. At the completion of the mission the nets can be rotated to the faired position, substantially reducing frontal resistance. To assure the safety of the vehicle and its personnel, the net assemblies are directly attached to the science rack, which may be dropped in the event of entanglement.

Figure 58. Universal Joint Assembly of Modified Tee Handle Drive

Figure 59. Assembled Semi-Rigid Universal Joint

Figure 60. Typical Plankton Net and Ski-Mounted Science Rack Installation

References and Manufacturing Vendors
Section 2, Science Tray Development

1. Expanded metal (perforated aluminum)
 - A. Edgcomb Steel of New England, Fall River, Mass.
 - B. Hawridge metals, Malden, Mass.
2. Aluminum tubing (6061)
 - A. Aluminum Company of America, Alcoa Building, Pittsburgh, Pa.
 - B. J. T. Ryerson & Sons, Inc., New York, N. Y.
3. Aluminum scaffolding attachments
 - A. Hollaender Manufacturing Co., Cincinnati, Ohio
 - B. Kee Klamps, North American Limited, Buffalo, N. Y.
4. Fibre glass cloth/mat
 - A. Allied Resin Products Corporation, East Weymouth, Mass.
 - B. Owens-Corning Fibreglas Corporation, New York, N. Y.
5. Polyester resin (Polylite ED-524)
 - A. Allied Resin Products Corporation, East Weymouth, Mass.
 - B. Catalyst Hardener (Mek-Peroxide)
6. Canvas collection sacks
 - A. Soiltest Inc., Evanston, Illinois
7. Bungee cord
 - A. John G. Shelly, Wellesley Hills, Mass.
 - B. C. G. Edwards Co., South Boston, Mass.
8. Plankton nets (custom fabricated on order)
 - A. Mrs. Ernest Cass, Box 45 Andover, New Jersey
 - B. W. C. Schroeder, Falmouth, Mass.
9. Flow meters
 - A. C M Squared Inc., Mountain View, California
 - B. Hydro Products, San Diego, California
 - C. Braincon Corporation, Marion, Mass.
 - D. Geodyne, Waltham, Mass.
10. Bonding agent (weather strip adhesive, Black #8011)
 - A. 3M Adhesive and Sealer Division, St. Paul, Minnesota
11. 90° Spiral bevel gear drive
 - A. Crown Gear Division, Harrington & Richardson, Inc.
Worcester, Mass.

12. Stainless steel banding
 - A. Band-It Company, Denver, Colorado
13. Portable hand held spot welders
 - A. Twentieth Century Manufacturing Co., Minneapolis, Minn.
14. Lever type latch
 - A. Acroquip Corporation, Marman Division, Los Angeles, California
15. Screw type hose clamps (aero seal)
 - A. Wittek Manufacturing Co., Chicago, Illinois
 - B. Breese Corporation, Union, New Jersey
16. Positive seal zipper assemblies (pressure tight closure)
 - A. B. F. Goodrich Aerospace & Defense Products Division, Akron, Ohio
 - B. Talon Inc., Meadville, Pennsylvania
17. Universal joint, 1/2" shaft bore
 - A. Boston Gear Works, Inc., Quincy, Mass.
 - B. Curtis Universal Joint Co., Inc., Springfield, Mass.

Figure 61. Typical Photograph of Mechanical Manipulator Performing Bottom Science Task

3.0 Mechanical Manipulator

The electro-mechanical manipulator shown in Figure 61 illustrates the primary method for gathering science specimens from a deep submersible. The manipulator is operated by an electrical control box within the personnel capsule.

The arm has six degrees of motion. It simulates the action of the human arm except for (1) its lack of lateral movement at the wrist, and twisting movement at the shoulder socket; (2) its continuous wrist rotation; (3) its finger configuration. Figure 62 provides a close-up of the manipulator, illustrating the elbow, finger rotate, and wrist motions available to the operator.

The manipulator is a reasonably rugged device having a maximum reach of 62 inches, and the capability of being able to lift 50 pounds (in water). It is pressure compensated, with all the D.C. drive motors, gear trains and slip clutches fully immersed in the compensating oil.

A quick acting snap latch, electrically activated on command, provides the pilot with a jettison ability in case of entanglement.

3.1 Manipulator Terminal Devices

The finger/hand arrangement of the mechanical manipulator is a multi-purpose mechanism. It has been designed for both grasping and retrieving samples, as well as a tool holder for bottom implements.

3.1.1 Finger and Tool Handle Development

Figure 63 illustrates the finger and wrist design of the mechanical manipulator originally installed on ALVIN. The parallel motion of the fingers limits the grasp ability of the manipulator, as well as the maximum size of the object that may be retrieved.

Figure 64 illustrates the tool handle configuration used with the original parallel fingers. Note the complexity of construction, which required a variety of machining operations for each handle fabricated. In view of the high possibility of tool loss, and the time required to fabricate handles, the original fingers were not considered as ideal for use with a deep submersible.

Figure 62. Overall View of Manipulator Joint Construction

Figure 63. Original Parallel Finger Design

Figure 64. Tool Handle Design for Use with Parallel Motion Fingers

Figures 65 and 66 present a close-up of the present tee handle and manipulator finger design. Note that when the tee handle cross nests into the half circle milled at the base of the finger yoke, and the fingers close about the tee handle shank, the tool is rigidly restrained against both torque and leverage forces. The use of standard stock size rod, as well as the assembly technique of silver braze, provides an inexpensive method of fabricating the universal tool handles used with the various devices.

In addition to providing a simplified universal tool holder, the curved finger design provides the operator with a mechanism capable of retrieving objects up to 8 inches in diameter. Figure 67 illustrates the ability of the modified fingers to retrieve a large geological specimen from the bottom. Figure 68 illustrates the operator's ability to grasp and retain, with a minimum of damage, irregular shaped biological specimens.

As a point of interest, the present manipulator design is toggle switch operated; there is no feed-back for the pilot to adjust his finger grasp or squeeze. All motions, up-down, left and right, are straight line operations, each controlled by its own spring loaded toggle located on a control panel.

To improve the operation of the manipulator, a new control console is being developed. It will provide the operator with a joy-stick control with a natural motion sequence. For example, twist left, move left, push down move down, etc.

As a point of interest, the manipulator fingers are fixed in a plane of motion that is parallel with the elbow and wrist action; they do not rock from side to side. This lack of side to side rocking action has presented the operator with a few problems in orientation and grasping. An example of this is the plankton net closure discussed in section 2.11.1. As originally designed, the operator had difficulty in obtaining precise alignment between the fingers and the tee handle drive mechanism. To alleviate this condition, a flexible joint was added to the rigid tee handle, which in effect provided the missing wrist rocking motion.

Figure 65. Modified Manipulator Finger Design, Open Position

Figure 66. Modified Manipulator Fingers Grasping Implement Tee Handle

Figure 67. Bottom Photo of Fingers Holding Large Irregular Shape Object

Figure 68. Manipulator Fingers Grasping Octopus

3.1.2 General Design Notes for Manipulator Tools and Apparatus

In view of the time required to perform even the simplest of manipulator maneuvers, it is strongly urged that considerable thought be given to the design of apparatus that is powered or maneuvered by the device. Based on past experience of ALVIN operators, the following suggestions are submitted as a guide in designing manipulator hardware:

1. Handles, pull rings, and release mechanisms should be of sufficient physical size to provide the operator with a good "grasping target".
2. Handles should be painted with a color that stands out from the background. White, black, and fluorescent orange have been considered as satisfactory by the ALVIN operators.
3. Release mechanisms should be positioned in a manner that allows the vehicle to approach the device from more than one direction.
4. Knobs, cranks, and handles that must be turned by the manipulator should be provided with a semi-rigid universal joint. This will help alleviate any alignment problems between the fingers and the driven apparatus.
5. Mechanical devices that are tripped or actuated by pedals should be designed to use a single spring loaded seesaw device rather than two separate levers.
6. Two position devices should make liberal use of spring return mechanisms, rather than requiring the manipulator to grasp the mechanism and mechanically reposition the device.
7. Actuation handles should be sufficiently rugged to accept an occasional bumping by the manipulator, without damage to the mechanism.
8. Plastic bags, tubes, or containers have a habit of becoming "invisible" in the high intensity lighting. They should be outlined with a black painted cross-hatch or other design that makes them stand out.

Figure 69. Manipulator Operated Hawser Knife

9. Tool holders and receptacles should be of simple design. They should hold the tools in a position that provides an "easy grasp" for the manipulator. Laying tools flat on the storage basket adds considerably to the time normally required to pick them up. Arrange the handles in a position that is "natural" to the manipulator motion.
10. If at all possible, specimen storage receptacles should be designed to accept both the specimen and the hand tool. This saves the time that would normally be lost in returning the tool to its own storage bin. This procedure should be accomplished only with those specimens that will not be damaged by contact with the tools. In some cases, a large open mouth sack can be used to drop the used tools into, rather than trying to return them to their individual containers.
11. For those tools that are light enough to be washed off the storage rack as the vehicle enters the water, rubber bands, small magnets,¹ or Plas-Dux putty² can be used to restrain them until grasped by the manipulator.

3.2 Manipulator Tools and Mechanical Implements

In addition to the manipulator tools developed to support the ocean sciences, various other special devices are available for bottom operations.

3.2.1 Manipulator Knife

Figure 69 is a knife or saw type device designed to cut through heavy hawser. It will not cut stranded steel cable or wiring. It is for use on manila or synthetic stranded material, webbing, or light weight cargo nets. For severing steel cable, tag lines, or stays, the true shearing action of a powered guillotine type tool is recommended.

3.2.2 Permanent Magnet Probe

Figure 70 is a magnetic "catch all", utilizing a permanent magnet attached to a non-magnetic probe handle. It was designed for use on a deep water salvage program. The elongated handle provides the mechanical manipulator with an extended reach, permitting it to grasp magnetic objects in a confined area.

Figure 70. Permanent Magnet Fish-Pole

Figure 71 is a close-up of the magnet head, illustrating the swivel neck which assures flat contact between the magnetic poles and the object to be retrieved. It is capable of swiveling approximately 45 degrees each side of center. The device will pick up a flat surface object having an air weight as great as 50 pounds.

3.2.3 High Strength Lifting Bridle

The snap-hook³ retrieval cable illustrated in Figure 72 provides a submersible with the capability of attaching a high strength lifting bridle to a bottom object.

The universal tee handles required by the manipulator are secured to the lift hooks with hose clamps. Welding, brazing, drilling, or other machine operations that could damage the structural strength of the hooks must not be used to attach the handles. The spring loaded safety latches, illustrated in the photograph, are a desirable feature to prevent inadvertent loss of the object being retrieved. However, once they have been attached to the object, they are not easily removed if a change in procedures becomes necessary.

Figure 73 is an artist conception of the high strength bridle being attached to the lift rings of a submerged structure. Figure 74 illustrates how the bridle may be snapped onto itself to form a lifting noose, when lift rings are not part of the structure.

3.2.4 Ice-Tong Retriever

The ice-tong retrieval device illustrated in Figure 75 includes a simple trigger mechanism. The hook on the right is in the cocked position, the hook at left has been tripped and will close around the object when a pull is exerted on the top linkage.

To cock the device, the notch in the trip bar is hooked on the lock pin as illustrated. To retrieve an underwater object, the manipulator lowers the tongs until the trigger bar is released. The legs of the device close around the object. As the device is lifted, the pincers tighten, holding the object securely until retrieved at the surface.

If the device has been inadvertently tripped, the manipulator may re-cock the device under water. The operator places

Figure 71. Close-Up of Fish-Pole Magnetic Head Assembly

Figure 72. High-Strength, Snap Hook Lifting Bridle

Figure 73. Lift Bridle Attached to Bottom Object

Figure 74. Lift Bridle Noose Attached to Object

Figure 75. Ice-Tong Life Mechanism

Figure 76. Snap Action Retrieval Grab

the tips of the pincers on a flat surface, exerting a downward pressure. The pincers slowly open until the trigger latches on the lock pin. The device is cocked and ready for a second attempt at retrieval.

Heavy lifts are not normally attempted with the manipulator. A lifting line would be attached to the ice-tong grab, providing the necessary pull to lift the salvaged equipment from the bottom.

3.2.5 Snap-Action Grab Hook

Figure 76 is a snap action grab hook. It is shown in the triggered or closed position. To cock the device, the two pincer arms are opened and latched. The latch is similar to a mouse-trap release, being actuated by a trip wire spread between the pincers. After tripping, the device cannot be re-cocked by the manipulator. It must be returned to the surface or re-set in shallow water by a diver.

For lifting heavy objects, a hawser or light cable is attached directly to the grab. The manipulator serves only as a guidance and trip device. After positioning and latching the hook, the submersible clears the area to prevent fouling in the lift lines.

3.2.6 Guillotine Line Cutter

Figure 77 illustrates a deep ocean solenoid actuated spring loaded guillotine cutter, specifically designed for use with a mechanical manipulator. The mechanism is shown in the cocked position, with the line to be severed resting in the throat of the cutter anvil.

The mechanism is a modification of an original design provided by the Naval Underwater Sound Laboratories, New London, Connecticut.⁴ Figure 78 is an artist conception of the mechanical manipulator positioning the cutter around a bottom cable in preparation to severing the line. The device illustrated has an open cutter throat, which provides the submersible with the capability of attaching the device to any underwater line within reach of the manipulator. The cutter has successfully severed synthetic, manila, and hemp lines up to 1 1/2 inches in diameter.

Figure 77. Overall View of Guillotine Line Cutter

Figure 78. Artist Conception of Submersible Severing Anchor Line

Figure 79. Close-up of Cutter Blade and Anvil Throat

Figure 79 is a close up of the anvil head and 431 stainless steel cutter, which was heat treated to a Rockwell 42 condition. 5,6 Note the cutter blade guide slot machined into the anvil head. The slot assures the straight line travel of the blade, providing a clean cross-section cut as the blade severs the line. A clean cut is important as it helps to prevent the formation of straggler-strands that do not cut completely through, especially when the cable is in an unloaded condition.

Figure 80 is an exploded view of the piece parts that make up the complete assembly. The solenoid used to control the trigger mechanism is a 30 volt D.C. device designed for deep ocean use. The trigger consists of a mechanical latch assembly that is released only when the solenoid is actuated. It does not need power to retain the mechanism in the cocked position. When triggered by the operator, the solenoid requires a momentary power pulse of 8 amperes at 30 volts D.C. to release the cutter blade mechanism.

Figure 81 is a simplified cross section sketch of the complete assembly. To cock the device, jam nut 1 is screwed down until it rests against thrust washer 2. As nut rotation is continued, it exerts pressure on the thrust washer and housing Item 3, and begins to compress spring 4. The cutter blade assembly 5 is drawn into the cavity at the base of the guide tube. When the full extent of travel has been reached, the trigger latch, Item 6, is free to position itself in preparation for the arming cycle.

The trigger release sleeve Item 7 is rotated approximately 10 degrees to lock the trigger latch as shown by the position of lever 8. The solenoid plunger Item 9 locks the sleeve in the armed position.

For clarity, latch lever 6 is shown in the released position, while lever 8 is shown in the cocked position. Figure 79 illustrates the slotted section in the trigger release sleeve. When unlatched by the solenoid plunger, the sleeve rotates approximately 10 degrees to allow the release levers to enter the milled slots in the side wall of the housing.

The torque necessary to rotate the trigger release sleeve is obtained from the shallow angle machined on the inside edge of each slot, as well as the generous radius at the outer surface of each release lever.

Figure 80. Exploded View of Assembly Piece Parts

Figure 81. Cross Section Sketch of Cutter Mechanism

Figure 82. Guillotine Cutter with Modified Anvil and Notched Blade

The acme thread cocking screw Item 10 has a positive stop to prevent the cutting edge of the blade from making actual metal to metal contact at the base of the anvil Item 11.

Caution: The shearing action of the cutter is sufficiently strong to sever a finger. This is not a piece of equipment to be carelessly handled. It should be stored in the unloaded condition.

As a safety precaution when the cutter has been armed, jam nut Item 1 should be run down the threads until it makes contact with the top of spring housing 3. This will prevent the cutter from being actuated even when the solenoid has been tripped. The jam nut, however, should have a red flag or other indicator to assure the removal of the safety before the vehicle enters the water.

The air weight of the complete assembly is 24 pounds. The water weight is 20 pounds. In its present form, the device is a single shot mechanism. With minor modifications it can be readily adapted as a repeating device that can be cocked underwater.

The cutter blade and anvil in the existing mechanism is not considered as adaptable to cutting steel cable. The device will be modified to accept a redesigned blade and anvil specifically fabricated for shearing stranded metal line. The modification will consist of a replaceable blunt edge blade having metal to metal contact with the anvil. The cutting edges will be formed in the shape of a commercial cold chisel, which will accept the shock load with a minimum of edge chipping.

Figure 82 is a photograph illustrating the PVC mock-up of the proposed attachment. It is designed as a replacement insert that will convert the existing anvil into a cutter assembly capable of severing stranded steel cable.

Note the shape of the insert throat; it has been designed to restrain the cable at exact center of the anvil, which helps reduce side loading on the cutter blade.

The notched configuration prevents the cable from jumping out of the anvil as the blade starts its penetration. This is a common occurrence with shear type cable cutters that do not physically restrain the cable during the shearing operation.

References and Manufacturing Vendors
Section 3, Mechanical Manipulator

1. Magnets
 - A. Edmund Scientific Co., Barrington, New Jersey
 - B. Dings Magnetic Separator Co., Milwaukee, Wisconsin
 - C. Eriez Magnetics, Erie, Pennsylvania
2. Plas-Dux adhesive compound (putty)
 - A. Babbit Chemical Co., Mattapoisett, Mass.
3. Snap hooks
 - A. American Forge & Manufacturing Co., Pittsburgh, Pa.
 - B. Chicago Hardware & Fixture Co., Franklin Park, Illinois
 - C. Crosby-Laughlin, Fort Wayne, Indiana
4. Underwater Sound Laboratories, New London, Connecticut
Original Design by Mr. E. P. April: Blue Print Reference
Number SKR47615
5. Cutter blade material, 431 stainless steel
 - A. Carpenter Steel Co., Union, New Jersey
6. Heat treating facilities
 - A. Industrial Heat Treating, Quincy, Mass.
7. Solenoids, deep ocean
 - A. Benthos, Inc., North Falmouth, Mass.
8. Compression spring
 - A. Hunter Spring Division, Amtek Inc., Hatfield, Pa.
 - B. Lee Spring Co., Brooklyn, New York

Figure 83. Typical Geological Pay-Bar Tools Used with Manipulator

4.0 Geology Hand Tools

The fabrication of non-powered hand tools is dictated by the characteristics of the ALVIN mechanical manipulator. In general, the manipulator is not to be considered as a tool for heavy prying, hammering, or breaking off of rock specimens with the fingers. Its motion, by design, is a slow deliberate action, with slip clutches limiting the forces available to the operator.

4.1 Geology Pry Bars and Rock Splitters

To make the greatest use of the manipulators unhurried motion, the majority of non-powered tools have been designed to take full advantage of the added force supplied by a fulcrum point. Figures 83 and 84 are examples of typical geological manipulator tools designed to pry small fragments of rock specimens from bottom outcrops. Note that each tool illustrated provides the necessary rocking action, or fulcrum, to enhance the manipulator's limited strength.

4.2 Geologist Pick

Figure 85 illustrates the standard geologist pick¹ modified for use by the ALVIN vehicle. The picks shown are not used to hammer or spit rock specimens as normally accomplished during surface sampling. The manipulator's rate of motion does not provide the inertia necessary to split the rock with a hammering type blow. The operator, therefore, must insert the sharp pick end into a fissure, prying or flaking off a specimen of the material.

4.3 Snag Hook Cutter Bar

Figure 86 illustrates a tool not normally used for prying. It was designed for breaking off specimens of stem type coral, although when properly sharpened it will cut through the smaller synthetic and manila lines.

4.4 Clam Rake Assembly

Urchins, clams, sponges, and other small objects can be easily scooped up and deposited in specimen containers by using the clam rake illustrated in Figure 87. The three tangs are spring steel wire secured into drilled holes with

Figure 84. Fulcrum Type Rock Splitter Hand Tools

Figure 85. Geologist Picks Modified for Manipulator Use

Figure 86. Hook Cutter for Coral or Light Line

anaerobic resin.² The security of the tangs have been excellent with no loosening due to external hydrostatic pressures. However, it is advisable to drill a small vent hole at the bottom of each spring wire mounting hole. If a vent is not provided, a small bubble may become trapped at the bottom of the hole when the spring wire is inserted. Subsequent deep dives with its high hydrostatic pressures may result in loosening of the wire tangs due to cracking of the resin cement as it collapses around the trapped bubble.

The hand tools illustrated have been fabricated from inexpensive off the shelf automotive and hobby shop devices. Each tool has been attached to a universal tee handle, which simplifies its construction, and provides interchangeability between the numerous geological and biological devices available to the scientist. The tools shown represent a small cross section of various configurations that may be constructed from locally available hardware.

Figure 87. Clam Rake

References and Manufacturing Vendors
Section 4, Geology Hand Tools

1. Geologist pick
 - A. Soiltest Inc., Evanston, Illinois
2. Anaerubic resin
 - A. Loctite Corporation, Newington, Connecticut
3. Fulcrum pry-bars, splitters, hooks, tire irons
 - A. Robert A. Main & Sons, Inc., Wyckoff, N. J.
 - B. H. K. Porter, Inc., Somerville, Mass.
 - C. Mac Tools Inc., Sabina, Ohio
 - D. J. H. Williams & Co., Buffalo, N. Y.
 - E. Sears & Roebuck Co.

Figure 88. Assembled View of Free Fall Bottom Marker Beacon

5.0 Bottom Marker and Acoustic Accessories

The items of hardware illustrated in this section provide the operator of a deep submersible with a means of navigating in and marking a search area. The bottom markers are of inexpensive construction and are considered as expendable. The devices are used in conjunction with the submersible mounted sonar system which provides the operator with a visual cathode ray tube display of the return echo obtained from the bottom markers.

5.1 Expendable Free Fall Bottom Marker Beacon

The expendable free fall bottom marker beacon illustrated in Figure 88 was designed to provide a navigational aid for deep diving submersibles. The beacon is compact self-contained assembly that may be quickly released from a surface vessel to mark a pre-determined position on the ocean floor.

When deployed, a single free fall marker provides a homing beacon or target for the sonar equipped submersible. The use of multiple units surface-dropped in a pre-planned pattern provides widely separated reference points or targets, between which a search pattern may be performed.

Figure 89 is an artist conception of the deployed beacon. The separable lead nose cone anchor and syntactic foam¹ sonar/pinger² target are tethered through the use of a length of nylon line. The ability of the pinger and passive sonar target to float some predetermined distance above the bottom improves the beacon's ability to be detected by a deep submersible, especially when operating in hilly terrain.

Figure 90 more clearly illustrates the point of separation between the nose cone anchor and the target float, as well as the drum storage area with its pre-wound nylon tether line.

5.1.1 Construction and Assembly Details of Marker Beacon

Figure 91 is an exploded view of the free fall bottom marker, showing the various piece parts comprising the complete assembly. As a point of interest, the small cylindrical component just to the left of the stabilizing tail cone is a self-contained pinger that commences its pulsed transmission on contact with the water. The pinger has a 21 day continuous service life, with a 37 KHz pulse every 25 milliseconds and an off time of approximately 700 milliseconds.

Figure 89. Artist Sketch of Beacon Deployed on Bottom

Figure 90. Nose Cone Anchor and Float Tether Line

Figure 91. Exploded View of Beacon Assembly

The acoustic output is approximately 1500 dynes/cm² at one meter.

Figure 92 is a cross-sectional view of the bottom marker which consists of a cylindrical float Item 1 constructed of syntactic foam. The foam consists of a mixture of micro-sphere hollow glass beads mixed into a resin material. The formation of the syntactic foam and the beads are such that the material formed is less dense than water. It has a compressive strength sufficiently high to prevent collapse at the sea water pressures encountered in deep sea environments. The material may be obtained in various densities depending on its anticipated use.

A stabilizing fin Item 2 is attached to the float section. The purpose of the fin is to stabilize and restrict the free fall velocity of the assembly, as well as to act as a passive sonar reflector when the electrically operated pinger transmitter Item 3 has depleted its built-in power supply.

5.1.2 Operational Details of Beacon Assembly

A ball detent nose cone release mechanism, consisting of a number of balls Item 4, detent plunger release 5, pressure actuated bellows 6, and ball cage assembly 7, provides a means of separating the lead nose cone anchor 8 from the float and sonar targets, Items 1, 2 and 3. In operation, the free fall bottom marker beacon is released from a surface vessel at some predetermined point. As it descends through the water, the bellows Item 6 begins to collapse due to the increasing external water pressure. The bellows are restrained at one end by retainer clamp Item 9. The opposite end is free to move and is attached to the detent plunger release 5.

As the bellows collapses the detent plunger retracts and slides free, allowing the retainer balls 4 to fall into the cavity left by the detent plunger, unlocking the ball cage Item 7 from the float assembly 1. On separation, the float assembly trails out behind the nose cone, unwinding the tether line from its storage spool. On contact with the bottom, the float and sonar target remain anchored to the nose cone, floating above the bottom a distance equal to the length of the tether line Item 10. To facilitate assembly of the ball detent mechanism, the nose cone plunger pin Item 11 has been included. It provides a means of mechanically collapsing

Figure 92. Cross Sectional Drawing of Beacon

the bellows to allow the insertion of the detent balls.³

The nose cone plunger pin also provides a secondary or back-up mechanism for the mechanical release of the ball detent separation assembly. On contact with the bottom, the pin contacts the bellows⁴ causing it to collapse and releasing the ball detent lock. The float assembly is now free to float above the bottom on its tether line.

The dry storage life (on deck) of the free fall bottom marker beacon is limited only to the shelf life of the self-contained batteries installed in the pinger. The free fall beacon has been successfully deployed as a bottom marker. However, the existing expanded metal stabilizing tail cone is an unsatisfactory sonar reflector and will be replaced with a tri-plane sonar reflector of the type shown in Figure 94.

5.2 Passive Bottom Sonar Targets

The use of the submersible sonar system provides the pilot with a terrain or target profile presentation on a cathode ray tube (P.P.I.) mounted within the vehicle. Depending on the target size and acoustic conditions, the sonar has an effective range of 500 yards. Based on this range and relative bearing information and the pilot's ability to differentiate between return echoes, the sonar provides a means of homing-in on a specific target.

One method employed to provide a bottom target is to use a corner reflector similar to the one illustrated in Figure 93. The reflector shown was designed specifically for the sonar frequency of the system installed aboard the ALVIN submersible. It consists of three 1/8 inch thick steel plates, fabricated and assembled in a manner shown in the close-up view of Figure 94. To assure satisfactory sonar reflections, all vertical plane surfaces should be kept within ± 1 degree.

The geometric design illustrated provides sufficient flat surfaces to reflect a major portion of an approaching sonar pulse back to its point of origin, where it is presented as a strong blip on the P.P.I. scope.

Figure 95 is an artist's conception of the tri-plane being used as a sonar reflector. In actual use, the reflectors would not normally be within range of the vehicle, as

Figure 93. Illustration of a Typical Tri-Plane Bottom Marker

Figure 94. Close-Up of Reflector Head Construction

BOTTOM POSITION LOCATION
USING SONAR REFLECTORS

Figure 95. Artist Conception of Tri-Plane Reflectors on the Bottom

indicated by the sketch. The actual field and range of view available to the deep submergence pilot, even under ideal illumination and turbidity conditions, may be considered as being not greater than 100 feet. With this limited visibility it becomes important for the pilot to have a homing or navigation reference if he is to return to an area previously explored.

As a point of interest, the 6 inch tri-plane illustrated has a reflective range of approximately 150 yards, provided, of course, that line of sight conditions exist between it and the vehicle. Its usefulness is also dependent on having minimum back scatter reflections from hilly terrain in the area of operation. For long range homing, the tri-plane will not replace an electronic bottom marker beacon tethered above the ocean floor. However, it is a useful and inexpensive means of providing close-in sonar reference points for a deep submergence pilot.

5.2.1 Deployment of Passive Bottom Markers

Figure 96 illustrates two tri-planes installed on a science tray in preparation for a bottom survey mission. In use, the pilot sets the vehicle on the bottom, maneuvers the mechanical manipulator to a position where he may grasp the tee handle of the reflector. Removing the reflector from the tray, he places the sharpened end of the probe against the bottom, pushing the shaft into the sediment with the manipulator.

The time required to set the vehicle on the bottom, place a reflector, and move off is approximately 5 minutes. On some occasions, depending on bottom contour and currents, the pilots have inserted the reflectors while hovering above the bottom.

However, under the best conditions, the insertion of a tri-plane reflector is time consuming and wasteful of bottom time. To off-set this and to improve the usefulness of the vehicle while marking a search area, the sling-shot tri-plane dispenser illustrated in Figure 97 has been proposed. It will provide the pilot with a means of dispensing tri-plane reflectors while cruising above the bottom.

Under present conditions, the normal tri-plane load has never exceeded a quantity of four on any one dive period. The proposed dispenser will carry 6 reflectors for bottom

Figure 96. Tri-Plane Reflectors on Science Rack

deployment. The assembly will be loaded and cocked while the vehicle is on the support vessel and will not interfere with the launching or recovery of the submersible. The storage rack will be mounted on the vehicle using a release mechanism similar to the device illustrated in Figure 31. In case of bottom entanglement, the rack can be released at the command of the operator.

In areas having rock or relatively impenetrable bottom conditions, the tri-plane reflector can be fabricated as illustrated in the exploded view shown on Figure 97. The pie shape segments of syntactic foam provide sufficient buoyancy to assure the device will remain in a vertical position. For all practical purposes the syntactic foam acts as a window to the sonar energy transmitted by the submersible. The floatation material does not block or attenuate the energy received or reflected by the tri-plane corner reflector.

The mushroom anchor is constructed with a swivel ring which connects to the tri-plane mounting rod. This simple universal joint provides sufficient freedom of motion to compensate for the most irregularities of the bottom terrain.

5.3 Expendable Water Activated Finger Assemblies

Figure 98 illustrates the typical 37 KHz water activated pinger devices² used with the ALVIN submersible. Both devices are capable of functioning at the operational depth of the submersible and are considered as expendable items. The normal "in use" life expectancy of the assemblies are considered as 14 and 21 days respectively. The electrical and acoustic parameters may be varied by the manufacturer depending on the user's requirements.

The pingers are used to mark a search area, bottom science equipment, or as a sonar guide for returning to some predetermined position at a later date. Figure 99 illustrates a fish trap and pinger installed on the submersible. The trap was lifted from the science tray and deposited on the bottom with the manipulator. The cylindrical pinger shown at the top of the trap was used as a navigation aid to return to the trap the following day.

Figure 100 illustrates a typical pinger retainer quiver used for on vehicle storage. To prevent pinger operation when the vehicle enters the water, an oil filled thin

Figure 97. Artist Sketch of Proposed Tri-Plane Sling Shot Dispenser

Figure 98. Water Activated, Expendable Fingers

Figure 99. Water Activated Pinger Marker on Bottom Fish Trap

rubber sheath was rolled over the activator plates at the base of the assembly. The pinger is inserted in the quiver and a small pin or other cutter device clipped to the top of the quiver rim. When the pinger is withdrawn from the quiver, the pin ruptures the rubber, releasing the oil, and exposing the activator plates to the sea water. Experience has shown that the rubber sheath is quite reliable and lasts for approximately 72 hours before self-deterioration takes place in the oil.

The large pinger illustrated may be installed in and released by the pinger dropper shown in Figure 22. The small pinger is not adaptable to this release mechanism and is normally used with the rubber sheath or allowed to free run when the vehicle enters the water.

Figure 100. Pinger Storage Quiver Mounted on Typical Science Rack

References and Manufacturing Vendors
Section 5, Bottom Markers and Acoustic Accessories

1. Syntactic Foam
 - A. 3M Reinforced plastics Department, St. Paul, Minnesota
(Scotch Ply XP-241)
 - B. Emerson & Cuming Inc., Canton, Mass. (Stycast 1090)
2. Pingers
 - A. Burnett Electronics Laboratory, Inc., San Diego,
California
 - B. Clevite Ordinance, Cleveland, Ohio
3. Detent balls (stainless steel or plastic)
 - A. Industrial Tectonics Inc., Ann Arbor, Michigan
 - B. Ace Plastic Co., Industrial Division, Jamaica, N. Y.
 - C. Hartford Universal Co., Rocky Hill, Connecticut
4. Bellows
 - A. Nagle Company, Rochester, N. Y. (Plastic)
 - B. Metal Bellows Corporation, Sharon, Mass.
 - C. Cagne Associates, Binghamton, N. Y.

Figure 101. Deep Water Bottom Flood Lamp Assembly

6.0 Deep Water Illuminating Devices

The mechanical hardware illustrated in this section has been designed primarily to experiment with various lighting techniques, using commercially available hardware. The devices are all considered to be deep water mechanisms.

The materials, components, and designs have been tested either through actual use or in a hydrostatic test chamber. The test depth or pressure exposure, is considered as 6000 feet, the operating limit of the submersible.

6.1 Deep Water, Bottom Flood Lamp

Figure 101 illustrates a deep water, pressure compensated flood lamp, fabricated for use with a bottom salvage operation. The device was designed to be "flown" to the bottom by a submersible and placed in the operating area. The lamp is provided with a simple on-off control switch that may be actuated by the mechanical manipulator. The dual flood lamp assembly pivots about its axis, providing directional control of the light beam.

The basic structure consists of a 55 gallon drum to which is attached a bottom anti-tip skirt, lift brackets, switch, and the two flood lamp assemblies. A total of nine lead acid, 12 volt 150 ampere hour storage batteries are installed within the drum cavity. The batteries are wired in series, providing 1350 ampere hours of power to operate the flood lamps.

As a point of interest, the battery package may be used as a deep ocean power source. The ampere hour capacity of the device is sufficient to operate a variety of experimental devices requiring a source of direct current. The simplified rotary switch assembly provides a means of controlling the power applied to the apparatus.

6.1.1 Electro-Mechanical Construction Features

The battery storage drum is filled with Tellus #15, an oil having good dielectric qualities, as well as being immiscible with the battery electrolyte. The fluid is used as the pressure compensating medium and is separated from the sea water by the 1/8 inch thick neoprene diaphragm¹ stretched over the top of the drum. The diaphragm is secured to the drum through the use of two oversize screw type hose clamps.² To prevent the worm screw tightening mechanism from cutting into the neoprene, a small shim of teflon or

1. Diaphragm is 1/8" thick neoprene: 32 inch diameter.
2. Use two hose clamps to secure diaphragm to drum.
3. Do not use adhesive or sealant between diaphragm or drum side wall.
4. Use plastic shim between hose clamp screw mechanism and diaphragm to prevent cutting.

1. Apply a wash coat of flexane around drum bead, and area under hose clamps.
2. Allow to dry thoroughly before installing diaphragm.
3. Stretch diaphragm over drum end, attach clamps loosely.
4. Work out creases while tightening clamps.

Figure 102. Artist Sketch of Diaphragm and Clamp Assembly

other plastic sheet stock³ is inserted between the clamp screw and the diaphragm. Construction details of the clamp and diaphragm assembly are illustrated in Figure 102.

The flood lamp is series connected, with one lead routed directly to the lights, the other being connected to a tilt type mercury switch.⁴ Figure 103 is an exploded view of the mercury switch and its pressure resistant housing. Miniature mecca electrical connectors⁵ are used to penetrate the two end plugs of the assembly.

Figure 104 is a simplified cross sectional drawing of the switch mechanism, showing the mercury switch and its PVC holder. To facilitate assembly of the switch, the "O" ring sealed bleed screw⁶ vent illustrated in the drawing should be included. While the assembly can be put together without it, it does facilitate the operation if the air can be vented during insertion of the end plug assembly.

The bottom sketch illustrates the simple spring loaded swivel mechanism used to apply a load to the switch rotate pivot. At assembly, the springs and cavity should be packed with Lubri-Plate grease to decrease corrosion.

Figure 105 illustrates the oversize aluminum extensions attached to the switch housing. The extensions provide an easy mechanism for the manipulator to operate. A positive stop is provided for both the on and off position. To operate the switch, the manipulator need only rotate the mechanism 180 degrees.

The manipulator does not have to grasp the switch; it may be turned by nudging or jogging the assembly to its on or off position. The color coded extensions are important if the power package is to be used for purposes other than a bottom flood lamp. It provides the operator with a simple visual indication of the switch position.

A 0.2 to 0.5 PSI plastic relief valve⁷ is installed at the center point of the diaphragm. As the lead-acid cells gas, the diaphragm becomes distended. The gas pockets at the high spot in the dome, popping through the relief valve as it reaches its crack pressure.

A check valve⁸ is also installed in the diaphragm to provide a "topping-off" fill point for additional pressure compensating oil. It may be located at any point on the diaphragm,

Figure 103. Exploded View of Mercury Tilt Mechanism, Switch, and Pressure Housing

Figure 104. Cross Sectional Sketch of Mercury Switch and Swivel Assembly

Figure 105. On-Off Mercury Tilt Switch

but must permit flow into the drum. About 3 gallons of Tellus is used to "top off" the assembly. The additional oil provides make-up to accommodate for compressibility, and any gas pockets that may have remained at the top of the batteries when they were originally filled.

Figure 106 illustrates a typical cross-section of the PVC spacer assemblies used to penetrate the neoprene diaphragm. The material is 3/8" stock, with the machine screws spaced approximately 1 inch apart. No sealant or gasket seal compound is used between the plates and the diaphragm. It is important to assemble the piece parts in a dry condition, as "wetting" of the PVC or neoprene will result in the diaphragm slipping as the PVC plates are bolted together. If spreading occurs, the diaphragm thickness is decreased to a point where oil begins to leak from the assembly.

The electrical penetrators are Mecca single pin type. They are supplied with an "O" ring at the base and require only a drilled and tapped hole. They are quite tolerant to misalignment of the vertical axis, especially in pressure balanced systems. However, for best results and in all cases where the system is not pressure balanced, a skin cut counterbore at the "O" ring sealing surface is a must.

The flood lamp assembly, reflector cones, and glass pressure housings⁹ are identical to those used with the expendable battery light discussed in section 6.2. The lamps are standard 50 candle power 6 volt automotive type. They are wired in series in order to make use of the slight increase in light that appeared to be developed, although two 12 volt lamps wired in parallel would provide some measure of redundancy. The current drain for the two series connected lamps is 7 amperes.

Figure 107 illustrates the spring loaded swivel joint used to provide flood lamp positioning. It is identical to the assembly used on the tilt switch handle and should be packed with grease to prevent corrosion.

6.1.2 Flood Lamp Buoyancy Characteristics

In order to meet the requirements for negative buoyancy condition "not to exceed 50 pounds," the balloon floatation illustrated in Figure 108 was provided. Six glass spheres¹⁰ were tethered to the flood lamp, providing 288 pounds of

Figure 106. Cross-Section Sketch of Diaphragm Penetrators and Relief Valve Assembly

$\frac{3}{8}$ SCALE

Figure 107. Cross-Section Drawing of Flood Lump Swivel

Figure 108. Balloon Floatation Assembly for a Deep Water Flood Lamp

positive buoyancy. The total water weight of the oil filled package was 328 pounds, resulting in an approximate negative buoyancy of 40 pounds. The spheres have an operational depth of 10,000 feet, and are commercially available. Figure 109 illustrates the balloon assembly prior to its being mated with the lift bridle and flood lamp.

In use, the submersible grasps either the top lifting eye or the pelican hook just above the "A" frame, flying the assembly to the site of interest. On reaching the bottom, the vehicle positions the light as close as possible to the area to be illuminated. The drop link on the pelican hook is released allowing the 6 floatation spheres to rise to the surface. The negative buoyancy of the assembly becomes approximately 330 pounds, holding the lamp solidly on the bottom.

If the flood lamp must be moved about frequently, it might be more advantageous to provide two pelican hooks. The second hook should be placed between the two sets of spheres. In this way, the upper set could be released, making the assembly approximately 85 pounds heavy. The added weight would hold the lamp firmly on the bottom, but still be within the lifting capabilities of the manipulator and the vehicle.

Figure 110 is an artist sketch illustrating the flood lamp assembly positioned to illuminate the area of a typical salvage operation.

6.2 Externally Mounted Vehicle Flood Lamp with Expendable Battery

Figure 111 illustrates a lead acid storage battery attached to the base of an ascent weight and connected to an externally mounted flood lamp. The main purpose of the assembly was to provide the science observer with an external light source that could be used during descent, without draining the main battery system. The light was designed primarily to provide illumination for visual observation only, and not for mid-water photography.¹¹

The battery is rigged at the base of the ascent-descent weights with a simple angle iron structure. Figure 112 illustrates a descent weight "hanging" from the standard electro-mechanical release mechanism. The weights are

Figure 109. Deep Water Glass Floatation Spheres

Figure 110. Artist Sketch of Lamp and Beacon Assemblies Deployed on Bottom

Figure 111. Expendable Battery Assembly for Deep Water Vehicle Lamp

Figure 112. Ascent/Descent Weight Dropper Mechanism

Figure 113. Dual Bulb Flood Lamp Assembly

installed prior to each dive and are dropped at the pilot's command. They are considered as non-recoverable support equipment. The battery water weight approximates that of a single lead block. It is an inexpensive lead acid cell, and does not have to be new. If it will hold a charge for at least 2 hours it is satisfactory for use as an expendable power pack.

6.2.1 Operational Details

Operation of the lamp is automatic, having a water pressure actuated switch connected in series with the battery/lamp assembly. At approximately 200 feet the pressure switch automatically turns on the lamps. They remain on until the battery is exhausted, the vehicle returns to a depth of less than 200 feet, or the pilot jettisons the ascent weight and battery package.

The light assembly operated successfully on its first test and while the entire dive lasted only two hours, it provided sufficient illumination to make mid-water observations during the descent as well as on the bottom. The pilot reported that the illumination level of the lamps just prior to being jettisoned tends to indicate that an estimated 4 hour life may be expected from the 12 volt automotive battery power package and its two series connected 6 VDC 50 C.P. lamp assemblies.

Two modifications were discussed after the initial dive. The first was to modify the pressure switch to actuate at approximately 1000 feet, which is a compromise depth established as the darkness area requiring external illumination. The second suggested improvement was to add an external on-off switch actuated by a simple push-to-operate motion of the mechanical manipulator. The switch provides the pilot with complete control of the lamp and assures the observer a period of total darkness during a descent, during which he may observe such items as mid-water phosphorescence. The switch mechanism, however, does add to the complexity of the original design goal for a simplified expendable self-contained external lighting system.

6.2.2 Construction and Assembly of Hardware

Figure 113 illustrates the two 6 volt automotive type lamps, the glass pressure resistant housings and a spring loaded piston actuated pressure switch. Figure 114 is an exploded view of the pressure switch and lamp components used in the complete assembly.

Figure 114. Exploded View of Flood Lamp and Pressure Switch Assembly

The 12 volt D. C. storage battery is a conventional automotive type, with the fill vents topped off with a dielectric type oil¹² that is immiscible in the battery electrolyte. Isolation of the battery posts and the lead wires from contact with the salt water was accomplished by a "wash-coat" of 2 part catalyst type rubber compound that air cures to a thin rubber film.¹³ The vent holes in the top of the cell filler caps were plugged with a dab of silicone rubber caulking¹⁴ compound to prevent the compensating oil from floating out when the battery became submerged.

Although no trouble was experienced with flooding, it is suggested that the battery be thoroughly burped in order to eliminate as much of the gas as possible that may have been trapped at the top of the case. Last minute burping would assure that sufficient pressure compensating oil was available above the electrolyte to prevent the entrance of salt water during the vehicle descent.

The battery used in this experiment was considered as expendable. It is not recommended that the battery be returned to the surface. From a safety stand point, it is best to release the battery before ascent, if only to preclude the possibility of case rupture from the expansion of the trapped gasses within the battery shell.

6.3 Moored Deep Water Flashing Beacon

Figure 115 is a pictorial sketch of the deployed beacon, illustrating the various assemblies used to construct the device. Figure 110 illustrates an artist conception of a moored deep water beacon deployed on the bottom. The flashing light was developed to provide a visual aid that would act as a homing beacon for a deep submersible operating in a fixed area. The electronic flasher and battery package has a service life of 3 weeks, with a flash rate of approximately once every 3 seconds. It is a commercially available electronic assembly.¹⁵

6.3.1 Deployment and Operation of a Flasher Beacon

Figure 116 illustrates the complete assembly ready for use. It has an air weight of 85 pounds, a water weight of 23 pounds, and may be easily handled by a submersible by grasping the large carrying ring and bridle. On reaching the bottom, the vehicle sets the assembly at the site of operation.

Figure 115. Moored Deep Water Flashing Beacon Assembly

Figure 116. Assembled Self Contained Bottom Flasher Beacon

Figure 117. Self Contained Bottom Flasher Beacon in "Triggered" Condition

The manipulator grasps the trigger ring at the side of the basket, pulling it free. On release, the bungee loaded top cover slides off and to the side as illustrated in Figure 117. The syntactic float¹⁶ and flasher rise from within the container, paying out the 125 feet of polypropylene line used to secure the flasher to the basket. On reaching the full extension of the tether line, the magnet switch is pulled out of a bracket mounted on the flasher ball, actuating the flasher circuit. The expanded metal basket becomes the bottom anchor, having an approximate water weight of 30 pounds.

6.3.2 Component Assembly

Figure 118 illustrates the major components used in the assembly of the self-contained flasher beacon. From left to right, the syntactic foam floatation block¹⁶ is tethered to the flasher assembly. The upper sphere contains the battery pack, the lower sphere the flasher circuit and strobe lamp. The free loop of tether line and the magnet release loop can be seen at the base of the second sphere. The deployed top cover is at the upper left. The spring tension restrained polypropylene line is shown ready for release.

Note the tether line has been installed in a way that assures the top lay will always come off first. The top cover release pin is shown in the lower center, with the carrying ring and bridle located at the far right. At the completion of the mission, the submersible can release the flasher spheres, recovering the electronic portion of the package. The release is a simple pull-pin device that is actuated by the mechanical manipulator on the submersible.

The initial design study revealed the flasher had a positive buoyancy on the surface; its characteristics at depth were unknown. To assure sufficient reserve buoyancy to overcome any sticking during the paying out of the line, and to provide proper operation of the magnetic switch, the syntactic float was added. Submerged operational tests have verified the assembly will deploy and operate as designed.

The glass spheres used to enclose the battery pack and electronic strobe circuits were pressure tested to an external hydrostatic pressure of 5000 PSI. Syntactic foam,

Figure 118. Flasher Beacon Assembly Partially Deployed to Illustrate Components

similar to that used to construct the floatation block has been tested and found satisfactory for use at the operational depth of 6000 feet. The density of the foam used for this application was approximately 38.0 pounds per cubic foot.

6.4 Extendable Lighting Boom for a DSRV

Figure 119 illustrates an extendable boom light mounted on the DSRV ALVIN. In the stowed position the retracted boom is located in a fore and aft position as illustrated in the upper sketch. When activated by the pilot, a hydraulic pump pressurizes sea water which extends and rotates the boom 90° as illustrated by the lower sketch.

6.4.1 Operational Characteristics of a Typical Extend/Retract Cycle

The sea water flow in a typical operational cycle is illustrated by the simplified schematic shown in Figure 120. On command of the pilot, sea water pressure is piped from the pressure side of the pump directly into the priority valve inlet port. As the pressure builds up, the spring loaded cylinder lock unlatches the index pin, which releases the turn table. The fluid flow continues through the passages in the priority valve, simultaneously entering control cavities "A" and "B".

In cavity "B" the check valve is unseated and the full flow of fluid passes into the boom rotate cylinder. As the pressure rises, the actuator rotates the boom 90°, positioning it as illustrated in the lower sketch of Figure 119.

The check valve in cavity "A" prevents fluid flow from passing directly through the control center and prematurely extending the boom until it has completed its rotate function. Once the boom is in the proper position, the fluid flow through the restrictor-orifice increases, extending the boom to its full 10 foot length.

To retract and reposition the boom in its stowed position, the operator reverses the direction of water pump flow. The ball check in control cavity "A" unseats, allowing the boom to retract as the sea water is withdrawn from behind the extended boom piston. When complete retraction has

Figure 119. Artist Sketch of Extendable Light Boom on DSRV

Figure 120. System Diagram of Sea Water Fluid Flow

Figure 121. Boom Extend and Retract Cycle

been accomplished, the boom rotate cylinder drives the turn-table to the stowed position as sea water is drawn through the restrictor-orifice "B". At the completion of the cycle, the pilot deactivates the sea water pump. As the system pressure decreases the spring loaded latch pin engages the boom rotate turn-table, locking the assembly.

6.4.2 Construction of the Telescoping Boom Structure

Figure 121 illustrates the plastic tubular sections used to construct the boom. The upper photograph illustrates the boom in the retract position, while the lower illustration shows it in the fully extended state. As point of information, the boom can be adjusted on the surface through several steps ranging from a horizontal position to a 20° up angle. Figure 122 clearly illustrates the adjustment range provided by the 4 notches machined into the front surface of the boom mounting plate. The plastic piston assembly at the front of the photograph is the boom rotate assembly.

The tubular plastic sections are manufactured by a centrifugal casting process. The material is basically a syntactic core, with the internal and external wall or shell formed from epoxy resin. The vendor manufactures the tubing in several densities and in various sizes ranging between 9/64 inches through 2.0 inches outside diameter.¹⁷

The material has a reasonably good bending strength, provided the side walls are not drilled or notched. Drilled penetrations as small as 1/8 inch in diameter will substantially reduce the strength of the material at the area of penetration. Experience has shown that any bending stresses put on the tube will result in a circumferential crack that shears the drilled section as clean as a saw cut. Mixing of filler fibres with the syntactic foam material would in all probability increase the bending strength considerably, especially in the areas of drilled holes.

6.4.3 Pressure Compensated Coiled Power Lead

Figure 123 illustrates the coiled plastic tubing¹⁸ that encases the electrical leads used to power the lamp assembly. It is an oil filled, fully pressure compensated device, and includes a simplified electrical disconnect of the type discussed in section 1.4 of this report. The

Figure 122. Top View of Boom Turn Table and Positioning Rack

Figure 123. Coiled Power Lead and Quick Disconnect

Figure 124. Assembled View Modified Quartz Iodide Lamp

tubing is positioned around the outside of the two telescoping tubes, as illustrated in Figure 121. The flexible nature of the coiled device allows it to stretch and retract as the boom is actuated. Being restrained by the boom structure that runs down the center of the coiled tube, it doesn't drop or tangle the way a single hanging cable would as the boom length is varied.

The 4 power leads are commercial grade vinyl hook-up wire that is snaked through the coiled tubing. If the tube fitting is clamped in a vise and the hose stretched out straight, the lead wires can be pushed through without too much difficulty. If trouble is experienced, use shop air to blow a piece of marlin through the tube, then attach the lead wires to the marlin and draw them through. After releasing the plastic tubing, it will return to its original coiled form.

6.4.4 Modified Quartz Iodide Boom Lamp

Figures 124 and 125 illustrate a modified quartz iodide flood lamp specifically constructed for use with the extendable boom. It was originally a commercially available high intensity deep water light having dual D. C. illuminating elements.¹⁹ The internal components are protected from external hydrostatic pressure through the use of a glass pressure resistant housing. As received from the vendor, the assembly had an air weight of 9.0 pounds. By reducing the diameter of the corrosion resistant base, and replacing all other metallic parts with components fabricated from PVC and nylon, the total air weight was reduced to 3.0 pounds.

In addition to reducing the total weight, the liberal use of plastic has substantially decreased the possibility of corrosion. The device has been successfully hydrostatically tested to 6000 P.S.I. without deformation, leakage or other damage.

As originally received, the corrosion resistant metal base plate was thought to be an important factor involving heat transfer between the illuminating elements and the sea water. Subsequent operational evaluation tends to support the fact that the smaller modified base will still provide sufficient heat transfer capability. The efficient transfer of lamp heat to the external sea water is an important

Figure 125. Exploded View of Lamp Assembly

factor in preventing damage to the insulator material in the penetrator assemblies.

Note that all drilled and tapped holes are machined straight through to pressure balance both ends of the plastic bolts. The two corrosion resistant machine screws at the lamp swivel fork are vented at the bottom of the blind hole in the PVC boss. The vent eliminates compression damage that could occur from hydrostatic pressure jamming the bolt into an unvented cavity.

6.4.5 Sea Water Actuator Pump

Figures 126, 127 and 128 illustrate the original sea water pump assembly used to actuate the boom mechanism. It consists of a peristaltic pump²⁰ that squeezes a plastic tube to move the fluid, a D. C. drive motor²¹ and a simple pressure compensation chamber constructed from the appropriate sections of a plastic bottle. Conventional "O"-ring seals and screw type hose clamps are used to provide a leak tight seal at the mating surfaces.

The chamber is completely filled with a pressure compensating fluid and the bottle cap replaced. The plastic side walls have sufficient resiliency to provide pressure compensation, provided both the upper and lower chambers are completely filled with fluid. All entrapped bubbles must be removed to prevent excessive collapse of the chamber walls as the external sea water pressure rises during the descent.

The motor is a standard 30 volt D. C. permanent magnet device, with a gear reduction assembly that drives the peristaltic pump at approximately 60 RPM. The pump operation was reasonably successful, as it satisfactorily extended and retracted the boom mechanism without difficulty. As additional tests were performed the motor was found to be under powered due to a hardening action that occurred in the neoprene tube installed in the pump housing. Several different tubing materials were tested and all seemed to stiffen somewhat after an overnight exposure to the pressure compensating oil.

A conventional rubber impeller pump with a reversible D.C. motor was used as a substitute pump and found to work satisfactorily.²² No additional work was accomplished on the original peristaltic pump, and the impeller pump will be used for the final installation.

Figure 126. Pressure Compensated Peristaltic Motor/Pump

Figure 127. Disassembled View of Pump Assembly

Figure 128. Close-Up View of Peristaltic Pump

As a point of interest, most inexpensive fractional horse power D. C. motors will operate quite well as pressure compensated drive mechanisms. In the lower price field, the manufacturer doesn't pot the armature or field windings and uses inexpensive punched and formed sheet metal cases. Off the shelf motor windings that free flood are less prone to shorting than potted assemblies sold for commercial or aviation use. The potting of field and armature windings for deep water application is a complicated art requiring considerable knowledge of plastic flow characteristics, de-gassing, and pressurization of the potting compound if it is to be successful.

Considerable structural deformation and shorted windings can occur in potted assemblies and die cast frames that have not been specifically designed for deep submergence use. In view of this, it is strongly urged that inexpensive motor assemblies that have free flooding windings and stamped metal housings and frames be used for any experimental apparatus requiring a fractional horse power drive mechanism.

6.4.6 Turn Table Assembly

Figure 129 is a bottom view of the turn table that is attached to the side of the submersible. The rotating mechanism is mounted on a large diameter bearing obtained from a variety store lazy-susan. It is constructed of compression molded plastic with glass rollers. It is quite rugged as well as being completely corrosion resistant.

The rolling diaphragm²³ and turn table lock pin assembly can be seen mounted beneath the bearing mounting plate. It is a spring loaded device with a neutral center position. It automatically unlocks the turn table whenever the pump is operational, regardless of the pumping mode. The lock will disengage with either a positive or negative pressure.

The top view of the turn table in Figure 130 illustrates the piston rotate actuator, release solenoid, and the 4 step boom position mechanism that can be pre-set on the surface. For clarity, the hydraulic quick-disconnect²⁴ that separates automatically when the boom is released has not been included in the illustration. Similar to

Figure 129. Bottom View of Turn-Table and Index Lock Assembly

other externally mounted apparatus, the boom has been designed to provide the operator with the means of releasing the device while the vehicle is submerged. In view of the break-away characteristics of the syntactic/epoxy composite boom material, the release device is considered only as an added safety feature. However, in the case of a structure fabricated from telescoping metal tubing, the release mechanism would be a mandatory safety mechanism.

Figure 130. Solenoid Safety Release and Boom Angle Plate

References and Manufacturing Vendors
Section 6, Deep Water Illuminating Devices

1. Neoprene sheet stock
 - A. Globe Rubber Works, Quincy, Mass.
 - B. Ray Bestos-Manhattan Inc., Packing Division
Passaic, New Jersey
2. Hose clamps (Aero Seal)
 - A. Breeze Corporation, Union, New Jersey
 - B. Wittek Manufacturing Co., Chicago, Illinois
3. Plastic sheet stock
 - A. Laminated Sheet Products Inc., Norwood, Mass.
 - B. National Plasti Fab Inc., Burlington, Mass.
4. Mercury switch
 - A. Micro-Switch, D. H. Honeywell Inc., Freeport, Ill.
5. Mecca electrical connectors
 - A. Mecca Cable & Service Inc., Houston, Texas
6. Sealant head machine screws
 - A. Long-Lock Corporation, Los Angeles, California
 - B. APM Hexseal Corporation, Englewood, New Jersey
7. Plastic relief valves
 - A. Nuculear Products Co., Cleveland, Ohio
8. Plastic check valves
 - A. Nuculear Products Co., Cleveland, Ohio
9. Glass pressure resistant lighting domes (conical pipe joints)
 - A. Corning Hydrospace Products, Corning, New York
 - B. Termal American Fused Quartz Co., Montville, N. J.
10. Glass floatation spheres (3" to 16" diameter)
 - A. Corning Hydro Space Products, Corning, New York
11. Light housings for deep submergence applications,
Parts I and II. Naval Civil Engineering Laboratory,
Port Hueneme. J. Stachiw and K. Gray.
12. Pressure compensating oils
 - A. See Section 1 references.

13. Flexane sealant (#95 liquid)
 - A. Devcon Corporation, Danvers, Mass.
14. Silicone rubber caulking compound
 - A. G. E. Silicone Products Department, Waterford, N. Y.
15. Electronic flasher spheres
 - A. Designed and fabricated by Benthos Inc., North Falmouth, Mass.
16. Syntactic foam
 - A. 3M Reinforced Plastics Division, St. Paul, Minn. (Scotch Ply XP-241)
 - B. Emerson & Cuming Inc., Canton, Mass. (Stycast 1090)
17. Syntactic/Epoxy Tubing
 - A. Resdel Corporation, Rio Grande, New Jersey
18. Coiled plastic tubing (Synflex self storing hose)
 - A. Samuel Moore & Co., Manua, Ohio
19. Quartz iodide lamps
 - A. Hydro Products Division, San Diego, California
20. Peristaltic pump
 - A. Cole-Parmer Instrument & Equipment Co., Chicago, Ill.
21. D. C. motors
 - A. Globe Industries, Division of TRW, Dayton, Ohio
 - B. Vernitron Corporation, Farmingdale, New York
 - C. Pittman Corporation, Sellersville, Pennsylvania
 - D. General Electric, Morrison, Illinois
22. Pump/motor assembly
 - A. Benthos Inc., North Falmouth, Mass.
23. Rolling diaphragm
 - A. Chicago-Allis Manufacturing Corporation, Chicago, Ill.
 - B. RKL Controls Inc., Hainesport, New Jersey
24. Hydraulic disconnect
 - A. Hansen Manufacturing Co., Cleveland, Ohio
 - B. Snap-Tite Inc., Union City, Pennsylvania

Figure 131. Prototype Hard Rock Drill and Laboratory Core Specimens

Figure 132. Close-Up of Prototype Drill Structural Details

7.0 Hard Rock Specimen Retrieval

The electrically powered drill, illustrated in the frontispiece, provides a manned deep submersible with the means of obtaining a hard rock core from the ocean depths. The photograph was taken in Lydonia Canyon and illustrates the cutting of the first selected hard rock core ever obtained by a manned deep diving submersible.

Previous methods of obtaining hard rock specimens from the deep ocean relied on the use of a ship board drag or dredge towed along the bottom by the surface vessel. After the development of the manned deep diving submersible, small rock specimens could be selectively picked from the bottom for further scientific evaluation at the surface. However, science personnel were never sure the rock specimen had actually come from the rock formations in the area, or had been deposited there after rolling from a formation located higher on the slope. In order to assure themselves of having a true specimen that represented the rock in the area, it became necessary to obtain an actual core sample from the basic outcrop. To provide this requirement, a rotary diamond tipped core drill was developed.

7.1 Operational Characteristics of a Rotary Hard Rock Coring Drill

Figure 131 is a photograph of the prototype drill and a selection of rock core specimens obtained during the development phase of the coring device.

The prototype rock drill is capable of obtaining a 4 inch long by 3/4 inch diameter hard rock core specimen. Its drilling capacity is approximately 1/4 inch per minute in Dolomite material, with the best drilling rate obtained at a constant 30 pound down thrust or load on the drill. The operator of the drill "feels" the proper drilling characteristics by maintaining a 7 to 9 ampere current drain and by observing the rotation rate of the candy stripe painted on the diamond bit.

7.1.1 Construction and Test of a Rotary Core Device

Figure 132 provides a close-up of the laboratory instrumented drill, illustrating the copper cooling coil for

the pressure compensating fluids and the oil filled tubular container which provides pressure compensation for the spiral power lead. The various Tygon tubes attached to the drill were used for pressure sensing at the water pump inlet and discharge chambers. The round aluminum disc at the drive end of the tubular diamond drill contains four magnets used to activate a magnetic sensing device connected to a tachometer assembly.

As a point of interest, the housing and attachments of the prototype drill were constructed of PVC.¹ The plastic was selected in order to provide a construction material that could be easily fabricated and modified with a minimum of machine shop tooling. The material is an excellent low cost stock, providing the designer with a means of quickly fabricating "Tinker Toys", without tying up expensive machine tools at the initial stages of development. Its resistance to sea water and high ambient pressure conditions are satisfactory; although its use as a pure pressure resistant chamber is very limited.

As expected, the heat transfer qualities of the PVC were quite poor. At the start of the laboratory tests on the drill assembly, it became obvious that a method would be required to dissipate the heat generated by the motor. Operating under loaded conditions, the compensating oil was unable to dissipate the heat through the PVC case into the surrounding water as rapidly as it was generated. Fortunately, a separate coolant pump was not required as a pumping action was found to exist at the spur gears in the speed reduction assembly² and at the commutator end of the electric motor.³

In an attempt to make use of this fluid flow, holes were drilled in the PVC case and a copper cooling coil mounted on the outside of the drill.

The tube openings were positioned in a way that the pumping action of the spur gear and commutator augment each other, resulting in a flow of pressure compensating oil through the cooling coil. Additional laboratory tests revealed sufficient cooling was obtained in 70° F. water to prevent the compensation oil temperature from exceeding 138° F. The second generation drill will be constructed with a metal housing, eliminating the cooling coil requirement.

Figure 133. Exploded View of Prototype Drill Components

The plastic cylinder⁴ at the mid-section of the drill is the pressure compensator for the coiled power lead. In use, the bottle is filled with compensating fluid having good dielectric qualities. The fluid wicks into the power lead until it reaches the dead ended section at the quick disconnect attached to the vehicle. When submerged, the flexibility of the plastic container provides pressurization of the power lead by maintaining an internal oil pressure equal to the external sea water pressure. Compensation of the power lead assures the flexibility of the coiled cord,⁵ decreasing the possibility of sheath cracking due to the stiffening action normally encountered with uncompensated leads.

7.1.2 Construction Details of the Prototype Drill Mechanism

Figure 133 is an exploded view of drill assembly. The PVC tubular shell, copper cooling coil and end cap are self explanatory. The threaded tee at the upper right is the universal handle used with all tools developed for the ALVIN vehicle. The motor is a 28 volt D. C. shunt wound assembly, operating at 6000 RPM with a torque of 1.1 inch pounds. It is reversible and rated for continuous service. The motor is direct coupled to a 6:1 gear reduction assembly, a universal joint, and a reversible water pump, which is shown as the round disc and hollow threaded shaft at left center. The diamond tipped core drill⁶ is at the lower left.

Figure 134 is a simplified drawing of the rotary rock drill, consisting of the tubular shell Item 1, within which are housed the following components. A direct current motor Item 2 is directly coupled to a gear reducer 3. A spline type universal joint 4 provides a simplified means of separating the gear box/motor assembly from the flexible impeller water pump 5 and the diamond tipped core drill 6.

The device is fully pressure compensated and, as such, may be constructed of light weight thin wall enclosures. The cavity used to house the electric drive motor and the gear box assembly is filled with a pressure compensating oil having good dielectric characteristics. The oil prevents electrical shorting of the drive motor and provides a means of compensating for the external sea water pressure as the device descends beneath the surface.

PUMP DETAIL, ITEM 5.

Figure 134. Simplified Cross Sectional Sketch Core Drill Major Component Assembly

The oil is separated from the sea water through the use of an "O" ring sealed floating piston. As the sea water enters the free flooding cavity through passage 8, the force exerted by the sea water is directed against piston 7 which forms one wall of the oil filled motor/gear box cavity. As external pressures increase, the force is transmitted, effectively balancing the internal and external pressures.

Under load, the D. C. motor rotation is reduced to approximately 650 RPM at the output shaft of the gear reducer. The gear reducer is coupled to the drive shaft Item 9 of the rubber impeller pump. The pump draws in sea water through passage 10, discharging its flow through port 11, into the water plenum chamber 12. The water contained in the plenum chamber flows into the oblong port 13 of the pump shaft. The flow continues through the hollow core of the diamond drill 6, passing out through the drill tip. As the core drill penetrates the rock surface, the mud generated by the cutting action of the drill is flushed away by the water flow. The flushing action effectively prevents jamming or drill seizure.

At the normal drilling RPM, the pump discharge is approximately 2.3 liters per minute, with a discharge pressure of 1.5 to 2.5 PSI depending on the drill depth and the material being cored. Pressures and flow rates in excess of these limits tend to push the drill out of the core hole, decreasing the rate of drill penetration.

7.1.3 Drilling Procedure for Hard Rock Material

Figure 135 illustrates the rock drill and mechanical manipulator in their mated position. Note the nesting of the drill tee handle into the notched section of the base plate and the overlapping grasp of the fingers. In the position shown, the drill is firmly restrained, resisting both lateral motion and rotary torque resulting from the drilling action.

As a point of interest, the photograph illustrates the correct position of the drill when starting a rock core. To initiate a core, the operator tilts the drill to the position illustrated, holding it at this angle until a slight moon shaped groove is cut in the rock. The depth of the groove does not have to be deep, 1/16 to 1/8 inch is satisfactory. With the drill still rotating, the

Figure 135. Core Drill Mated with Mechanical Manipulator Hand

assembly is slowly brought to the vertical position and the cut continued until the required core length has been reached.

Starting the initial cut is not normally accomplished by placing the cutting edge of the diamond bit flat on the specimen surface. If this is attempted, the drill wanders off the initial point, making it extremely difficult if not impossible to control or even start the drilling action.

At the proper depth of penetration, the operator reverses the direction of motor rotation, which reverses the pump impeller and consequently the direction of water flow. The drilling action will continue with the drill rotating in the opposite direction, but the mud will not be flushed out of the hole. The mud generated begins to thicken at the base of the core hole. The drill assembly may then be rocked slightly to assist in seizing and breaking off the core specimen. The core specimen is retained in the hollow core of the diamond drill by the slight suction created by the reverse water flow action of the rubber impeller pump.

The operator removes the core drill from the hole. The rock core is deposited in a receptacle by again reversing the motor rotation, which reverses the water pump flow, ejecting the rock core from the hollow barrel of the diamond drill. Additional hard rock cores may be obtained by repeating the drilling procedure.

Actual deep water operation of the drill indicates that the restraining force necessary to counteract the torque generated by the motor was not quite as difficult to control as originally thought. In this case, however, the low level of torque, 23 inch pounds at locked rotor, as well as the propeller, rudder and lift prop configuration of the ALVIN vehicle were probably the main reason for the excellent control observed during the drilling.

Larger rotary drills or side wall sampling while the vehicle hovers at the side of a vertical outcrop will undoubtedly require the use of a holding device such as a suction pod or a driven piton.

7.2 Construction of a Rotary Hard Rock Coring Drill

Figure 136 illustrates the final design of the rotary drill assembly. The two external aluminum housings are protected from both abrasion and corrosion through the use of an

Figure 136. Assembled View of a Deep Ocean Hard Rock Core Drill

electro-chemical coating of aluminum oxide.⁷ It is commercially known as hardcoat.

When the tee handle is depressed by the operator, the stainless steel compression spring⁸ provides a constant 30 pound downward thrust on the drill bit. The constant load assures the operator of the optimum bit performance throughout the drilling cycle and tends to smooth out the spasmodic motion of the mechanical manipulator. The linear travel of the constant load spring is 3 inches.

Both the coiled power cord and the motor/gear box assembly are fully pressure compensated. The oil reservoir is located within the drill housing and has sufficient capacity to assure complete compensation of the power cord. Without compensation, the power cord becomes stiff and unmanageable when exposed to the elevated hydrostatic pressures encountered at the operational depths of the vehicle.

It is well to keep in mind that uncompensated leads have a definite tendency toward stress cracking of the external sheath, especially when subjected to twisting or bending during the pressure cycle. Once the crack has started, it provides an easy point of entry for the external sea water.

Moisture penetration of this type is sometimes very difficult to locate until total failure of the lead has occurred. Past experience has shown that high resistance short indications occur as the vehicle descends, clearing up as the vehicle returns to the surface. Intermittent indications such as these are very difficult to locate and repair.

The 28 VDC motor, gear box assembly and water pump are similar to the hardware used to construct the prototype drill. Figure 137 is an exploded view of the components. The rubber top hat diaphragm⁹ used as the pressure compensation reservoir is located to the left of the drive motor/gear box assembly.

Twisting between the inner and outer shell is prevented by a connector housing that is secured to the inner tube and free to slide within a slotted guide machined in the side wall of the outer tube. The assembly permits straight

Figure 137. Exploded View of Piece Parts Used in Final Version of Core Drill

line motion as the constant load spring is depressed, while preventing rotary motion as a result of motor torque. The photographs of the drill assembly clearly illustrate the slotted guide configuration.

Figure 138 is a cross-sectional drawing of the drill. As a point of interest, the sliding outer shell is guided by the 6 nylon buttons equally spaced around the inside diameter of the tube. They act as friction free guides, preventing abrasion between the two moving members.

The grease fitting located in the end cap provides lubrication for the thrust bushing Item 23. It also furnishes a means of "flushing" the bearing surfaces with a light weight grease. The flushing is considered as a point worth discussing in a little more detail.

When drilling under water, the pump fluid flow is discharged into the plenum chamber located just to the rear of the front bearing cap. It is then directed out through the hollow drive shaft Item 14, where it passes through the drill. When in drilling mode, the water flow is reasonably clean and free of sediment. On breaking off the core and reversing the pump flow,¹⁰ the mud and sediment is sucked up into the plenum chamber and out through the pump discharge.

To assure the mud residue does not penetrate the shaft seal¹¹ and enter the bearing assembly, it is recommended that a shot of grease be injected into the bearing at the completion of each dive. To facilitate the flushing procedure, the cup seals located at the clamp ring Item 13 and the shaft thrust collar Item 14 have been positioned to provide free-flow out of the bearing area when grease is injected through the fitting. The shaft seals were purposely installed in this manner to assure against rupture or blow-out when the grease is injected.

The oil compensation diaphragm Item 16 is shown in the fully extended or empty position. Under normal conditions, the oil cavity is pressure filled, compressing the spring Item 12, and collapsing the bellows into an accordion pleated configuration. The total volume of oil contained within the drill is 760 cc.

The air weight of the assembly including compensation oil and the coiled power lead is 13.6 pounds. The water weight is 9.7 pounds.

USE BAL. SALL. LAMBRACALIF. N500-012
 " " " " " 300-014
 " " " " " 300-012

ITEM	DESCRIPTION	UNIT
1	DRIVE MECHANISM	WHOI
2	CASE	"
3	SPRING	"
4	SHUTTER, UPPER	WHOI
5	END CAP, LOWER	WHOI
6	END CAP, UPPER	WHOI
7	PUMP ASSEMBLY	WHOI
8	CLAMP PLATE, FLANGE	WHOI
9	COUPLING, N5 FA 75-8	WHOI
10	FLANGE, BELLOW	WHOI
11	SPRING, BELLOW	WHOI
12	CLAMP RING	WHOI
13	CLAMP RING	WHOI
14	SHAFT, OUTPUT	WHOI
15	LOCK RING	WHOI
16	DIAPHRAGM, N5 1-275-275-DOJ	WHOI
17	COVER, PUMP	WHOI
18	END CAP, OUTER SHELL	WHOI
19	TEE HANDLE	WHOI
20	CLAMP, ELEC. CONNECTOR	WHOI
21	INSERT, TAPLOCK, 1/4-13 x 1/2-13 x 1/2	WHOI
22	WASHER	WHOI
23	BUSHING, N5 FB-012-6	WHOI

WOODS HOLE OCEANOGRAPHIC INSTITUTION		DEEP RESEARCH PROGRAM	
DATE: 11-3-60		DRIFT: T.B.A.	
MATERIAL:		APP: SCALE: FULL	
CORE DRILL MECHANISM		DWS: MDS-199	
DATE: 11-3-60		DWT: 11-3-60	

Figure 138. Cross Section Drawing of Deep Ocean Core Drill

The power requirements, drilling rate, water pressure, flow and motor RPM remain identical to the operating data obtained during the evaluation test of the prototype drill. With the exception of the pressure compensation diaphragm and the use of an aluminum housing and constant load spring, all the major mechanical assemblies remain identical to the prototype device.

As a design improvement several methods are being investigated to provide a means of marking the magnetic orientation on the core specimen prior to its removal from the parent material. Impact rotary and resonant coring devices are also being reviewed as a possible means of improving the science of obtaining both sediment and deep ocean hard rock cores from a deep submersible.¹²

7.3 Investigation of a Resonant Hard Rock Coring Drill

Figure 139 illustrates a hard rock coring drill designed by OCRA, Inc.¹³ It is an electrically powered resonant coring tool developed expressly for torque free operation from a submersible. The configuration illustrated has been fitted with a universal tee handle to mate with the ALVIN manipulator. The handle is removable and can be modified to accommodate a variety of manipulator attachment points.

The corer is torsionally resonant at around 65 Hertz. It may be driven from a D. C. source by using a solid state alternative power conditioning device. At 60 volts D. C. input, the power drive requires an average of 15 amperes. Using a motor-alternator power drive, the average input is estimated as approximately 8 amperes rms. at 110 volts A.C.

The coring drill, including a pressure resistant housing capable of withstanding 5000 psig external pressure, has an air weight of 152 pounds. It is 10 inches in diameter and 23 1/2 inches in length.

The tubular diamond tipped bit is capable of cutting a 2 inch diameter core, 12 inches long. The manufacturer states he has performed laboratory drilling tests with the device, obtaining core specimens in granite and other consolidated materials. Using longer core tubes, he states the device has obtained core specimens of unconsolidated sediment.

Figure 139. Resonant Hard Rock Core Drill Assembly

References and Manufacturing Vendors
Section 7, Hard Rock Specimen Retrieval

1. PVC (Polyvinyl Chloride Type I)
 - A. Comco Plastics Inc., Richmond Hill, N. Y.
 - B. General Tire and Rubber Co., Lawrence, Mass.
2. Gear reduction assembly (custom design)
 - A. Insko Corporation, Groton, Connecticut
3. Electric motors
 - A. Hoover Electric Co., Los Angeles, California
 - B. Franklin Electric Co., Inc., Bluffton, Indiana
 - C. Globe Industries, Dayton, Ohio
 - D. EMD Components Inc., Wickliffe, Ohio
4. Plastic containers
 - A. Nagle Company, Richester, N. Y.
 - B. Cole-Parmer Instrument & Equipment Co., Chicago, Ill.
5. Preform coiled power cords
 - A. Koiled Cords Inc., New Haven, Connecticut
 - B. Belden Corporation, Chicago, Illinois
6. Diamond core drills
 - A. Diamond Tool Research Co., Inc., New York, N. Y.
 - B. J. K. Smit & Sons, Murray Hill, New Jersey
7. Hard coat--aluminum oxide: (Sanford or Martin Process)
 - A. Duralectra Inc., Natuck, Mass.
 - B. General Magnaplate Corporation, Linden, New Jersey
 - C. Service Hard-Chromium Company, Union, New Jersey
8. Stainless steel compression spring
 - A. Hardware Products, Boston, Mass.
 - B. Lee Spring Company, Brooklyn, New York
9. Diaphragm (Rolling Bellows)
 - A. Bellofram Corporation, Burlington, Mass.
 - B. Chicago-Allis Manufacturing Corporation, Chicago, Ill.
10. Impeller pump
 - A. Jabsco Pumps, Costa Mesa, California (basic pump)
 - B. Benthos Inc., North Falmouth, Mass. (pump/motor assembly)
11. Shaft seals
 - A. Bal-Seal Engineering Co., La Habra, California

12. Coring and sediment sampling
 - A. Diamond Drill Hand Book, J. K. Smit & Sons, Toronto Canada, by J. D. Cumming.
 - B. A Deep Sea Rock Core Drill by J. Brooke and R. Gilbert. Atlantic Oceanographic Laboratory, Bedford Institute, Dartmouth, Nova Scotia, Canada
 - C. Drillability Studies, Impregnated Diamond Bits. U.S. Department of Interior, Bureau of Mines #6776, by J. Paone and D. Madson
 - D. Design Study for Lunar Exploration Hand Tools Martin Marietta Corporation, Baltimore Division. D. S. Crouch
 - E. Earth Manual, U.S. Department of Interior, Bureau of Reclamation
 - F. A Hand Operated Undisturbed Core Sampler, by C. W. Hayden and W. H. Heinemann, Jr. U.S. Department of Agriculture, 1967
13. Resonant hard rock coring drill.
 - A. Ocean Recovery Corporation of America, Cambridge, Mass.

Figure 140. Sediment Core Sampler Using Brass Specimen Tube

8.0 Bottom Sediment Sampling

The collection of deep water marine sediment involves the use of various sampling devices. Depending on the study being undertaken, the scientist may use a dredge, grab, snapper or core type device. The selection of the mechanism depends on the area of investigation, bottom characteristics, and the soil disturbance that can be tolerated.

8.1 Sediment Core Sampler

Figure 140 illustrates a typical core tube assembly that is operated by the mechanical manipulator and capable of obtaining either unconsolidated or semi-consolidated sediment samples. Depending on the sediment characteristics, the specimen tube may be constructed of either brass¹ or plastic.² The tubes are interchangeable with the diaphragm valve and tee handle mechanism. However, the change can not be performed at depth; it must be accomplished by surface personnel.

The serrated brass tube is used when sampling hard clay type sediments. To enhance its penetration rate, it is rotated by the wrist rotate motor of the manipulator. The approximate rotation rate is 7 1/2 RPM. The slip clutch on the wrist rotate mechanism is capable of exerting 115 inch pounds of torque, which is sufficient to penetrate most clay type deposits found on the bottom.

As a point of interest, the thin wall (.035") brass tube is a standard stock item readily available at most mill supply houses. The wall thickness and material was selected due to its availability, cost, strength factor, and ease of fabrication. The serrated teeth at the base of the tube are easily cut to shape with a pair of tin snips.

The plastic core tube has been very successful when used in unconsolidated sediments. Figure 141 illustrates the device in use during a typical deep water geology mission. The black stripe along the longitudinal axis of the tube assists the operator in orientating the coring tool. When exposed to high intensity lighting and sandy bottom conditions, the plastic tube becomes almost transparent to the operator, which presents an orientation problem. The transparent quality, however, provides the scientist with the ability of visually checking his specimen to assure it is satisfactory before returning to the surface. In the event the

Figure 141. Sediment Core Sampler, with Plastic Specimen Tube

specimen is unsatisfactory, the core may be washed out of the tube and another specimen obtained.

8.1.1 Flapper Valve Mechanism

Figure 142 is a close up of the tee handle flapper valve mechanism. The "O" ring at the base provides a water tight seal between the core tube and the valve cylinder. It also simplifies the sealing mechanism that provides interchangeability between the brass and plastic sampling tubes. The body of the valve mechanism is constructed of PVC³ material. The 3 sliding guide pins are stainless steel to reduce corrosion and subsequent sticking.

Figure 143 is a cross sectional drawing of the assembly, illustrating the major components. In use, the manipulator grasps tee handle 1, exerting a downward push on the assembly. On contact with the sediment, spring 3 compresses allowing valve 4 and rubber gasket 7 to uncover vent hole 5. As the sediment enters the open end of core tube 2, the trapped water exits through valve block 9 and vent hole 5.

After completing the insertion, the manipulator begins to withdraw the assembly. The tee handle shaft 12 moves up, assisted by spring 3 acting against stop block 11. The rubber gasket 7 seals the vent holes. A slight negative pressure is created within the tube as the sediment attempts to slide out. The assembly is capable of lifting and retaining a full core length of wet building sand when the valve mechanism is properly sealed. A seal is considered as satisfactory when an assembly may be oriented with the tube opening up, filled with water, and allowed to set overnight. No weepage is permitted at the rubber gasket seat⁴ or at the "O" ring⁵ seal, Item 8. The closure force exerted by the spring⁶ must be sufficient to assure a satisfactory seal. It must not, however, be so stiff that it prevents venting of the core tube when it is inserted into soft sediments.

Pin 6 is a free sliding fit into valve block 9 and is securely attached to stop block 11 and tee handle shaft 12. The pins act as a drive mechanism to transfer the twist action of the wrist rotate motor directly to the core tube when penetrating clay or other hard sediments.

Figure 142. Tee Handle and Valve Mechanism

Figure 143. Cross Sectional Drawing of Coring Assembly

Figure 144. Typical Science Tray Rigged for Obtaining Sediment Core Samples

8.1.2 Specimen Storage Protection

A typical vehicle science tray rigged for a geology mission is shown in Figure 144. Note that each core device sets into its own quiver or storage container. Figure 145 represents a close up of the core tube and the fibre glass quiver.

Figure 146 is an exploded view of the assembly, illustrating the rubber stopper used to seal the core tubes. Past experience has shown that open end core tubes frequently lose a major portion of their samples by the time the vehicle reaches the surface. The loss ratio increases to almost 100% when the vehicle and core sample pass through the water/air interface while being retrieved.

To prevent specimen loss, the arrangement illustrated in Figure 147 was developed. In use, the stopper is inserted into the quiver and restrained by the screw and wing nut passing through the base of the quiver. The wing nut is tightened sufficiently to spread the rubber stopper, which provides a light friction fit into the open end of a core tube. The tube is then inserted into the quiver and pushed lightly over the stopper.

With both ends of the core tube blocked, the tube is unable to vent as the vehicle enters the water. If the specimen tube does not vent, the assembly could float out of the quiver, or possibly collapse as the rubber stopper is forced into the end of the tube by the increasing pressures experienced as the submersible descends.

Figure 148 illustrates one means of holding the diaphragm valve open until flooding occurs. The circular soluble release mechanism provides sufficient time to allow full flooding before it dissolves and allows the valve to close. It leaves no objectional residue, is inexpensive, and readily available.

On reaching the area of interest, the manipulator removes the sampler from its storage container, obtains a sediment sample, then replaces the core tube into its mating quiver. The stopper effectively prevents wash-out during the ascent. On reaching the surface, the science observer need only remove the valve mechanism from the upper end, inserting a second stopper into the opening. By carefully tightening

Figure 145. Core Tube Assembly and Storage Quiver

Figure 146. Exploded View of Core Tube, Quiver, and Closure Stopper

Figure 147. Close Up of Core Tube Stopper and Quiver Assembly

Figure 148. Vent Mechanism for Core Tube Chamber

Figure 149. Close Up View of Typical Water/Silt Samplers

both wing nuts, the specimen is kept intact, with a minimum of separation, migration, and loss of moisture.

The quiver receptacles are constructed by the wet lay-up method, using wood, plaster, or foamed urethane⁷ as the mold. To assure release of the cured fibre glass the mold is well coated with a parting agent⁸ or heavy wax.⁹ The fibre glass mat¹⁰ is formed over the mold and thoroughly impregnated with polyester resin.¹¹ Be sure to use sufficient parting agent or wax to assure the release of the quiver. A drilled hole in the closed end will break the vacuum that is created between the two piece parts as the completed quiver is removed from the mold. For stubborn cases, the gentle application of air at the drilled hole will help to remove the molded quiver.

8.2 Weighted Flapper Door Water and Silt Samplers

Figure 149 illustrates a set of typical plastic silt or water samplers used with the mechanical manipulator. They consist of plastic tubes² and weighted flap valves to provide the end closure. The larger of the two is shown with the weighted flap valves in the open position.

In use, the sampler is rotated to open the lead weighted doors, then purged by moving through the water. After obtaining a water specimen, the sampler is rotated with the wrist rotate drive on the manipulator. The doors fall closed, sealing the sample within the chamber. Bottom organisms, silt, and unconsolidated sediment may be safely transported to the surface. The "O" ring seal located on each flapper valve effectively seals the specimen from the effect of wash-out, external contamination, and agitation as the vehicle moves to other areas of interest, or returns to the surface.

If uncontaminated samples are required, the containers may be constructed of materials capable of being autoclaved. To maintain sterile conditions, the assembly is placed in a plastic bag,^{12,13} filled with pure distilled water and sealed. The closure prevents contamination during the descent and maneuvering of the submersible. The protective plastic closures are easily removed by simple cutter devices when a specimen is ready to be placed within the chamber.

Figure 150. Flapper Valve and Tee Handle Mechanism

The flapper doors are attached to the chamber body through the use of piano type hinges. The hinges are quite restrictive and require a very critical alignment to assure against leakage. Future models will be fabricated with a semi-floating hinge in order to provide additional motion for self-alignment.

Sealing surface contamination due to silt and sand granules has not shown itself to be a problem. The sealing surfaces, "O" rings, and their mounting grooves are all kept free of grease, oil or other lubricants to assure that fine silt particles do not adhere to the surfaces.

Figure 150 is a close-up of the chamber assembly. Note the construction of the tee handle and saddle. It is basically a split section of aluminum tubing, welded to a simple tee handle. It is secured to the plastic tube with conventional hose clamps.

The chamber and flapper valves are clear plexi-glass material² to provide the scientist with a visual means of checking the specimen. This is an important feature as it provides the observer with "selectivity" of specimens.

The plexi-glass material is readily machined, drilled, taped, or cemented, using adhesives¹⁴ recommended by the plastics manufacturer. Both the plexi-glass and adhesives have demonstrated satisfactory characteristics even after repeated exposure to deep ocean environment. Repeated exposures as long as 6 hours, at sea water hydrostatic pressures as great as 3000 psi, have not resulted in any noticeable degradation of the materials.

Figure 151 illustrates the silt sampler mounted on a typical science tray. The universal tee handle is positioned vertically to provide accessibility for the mechanical manipulator. Normally, the sampler is mounted in a permanent receptacle provided by the science tray. In this case, however, the specimen chamber has been attached with several rubber bands. The photograph was included in order to illustrate the elementary mounting approach that can be used, while still achieving satisfactory results.

Figure 151. Sampler Chamber Mounted on Science Rack

References and Manufacturing Vendors
Section 8, Bottom Sediment Sampling

1. Brass core tube (thin wall .035")
 - A. Millard Metals, Braintree, Mass.
 - B. Admiral Brass & Copper Co., Somerville, Mass.
 - C. Bridgeport Brass Co., Cambridge, Mass.
2. Plastic core tube
 - A. Rohm & Hass (Plexi-Glass), Washington Square, Philadelphia, Pennsylvania
 - B. National Plasti Fab Inc., Burlington, Mass.
 - C. BUSADA Manufacturing Corporation, Flushing, N. Y.
3. PVC (polyvinyl chloride type I)
 - A. Como Plastics Inc., Richmond Hill, N. Y.
 - B. General Tire & Rubber Co., Lawrence, Mass.
4. Neopreen sheet gasket
 - A. Ray Bestos- Manhattan, Inc., Packing Division, Passaic, New Jersey
 - B. Globe Rubber Works, Quincy, Mass.
5. "O" Ring Seals
 - A. Parker Rubber Products Division, Cleveland, Ohio
 - B. Precision Rubber Products, Dayton, Ohio
6. Stainless steel springs
 - A. Hardware Products Inc., Boston, Mass.
 - B. Lee Spring Company, Brooklyn, N. Y.
7. Foamed urethane (mold and pattern fabrication)
 - A. Atlas Insulation, Inc., West Concord, Mass.
 - B. Hysol Division, Dexter Corporation, Lean, N. Y.
8. Parting agent (water soluble)
 - A. Plasti Lease #512B, Ram Chemical Co., Gardena, Calif.
9. Mold release wax
 - A. Butcher Polish Company, Malden, Mass. (paste)
 - B. S. C. Johnson & Son, Racine, Wisconsin (paste)
10. Fibre glass mat
 - A. Allied Resin Products Corporation, East Weymouth, Mass.
 - B. Owens-Corning Fibreglas Corporation, New York, N.Y.

11. Polyester resin (Polylite ED-524)
 - A. Allied Resin Products Corporation, East Weymouth, Mass.
 - B. Catalyst Hardener (Mek-Peroxide)
12. Plastic bags
 - A. Stone & Forsyth Company, Cambridge, Mass.
 - B. American Cellophane & Plastic Films, Jamaica Plain, Mass.
13. Plastic material heat sealing devices
 - A. Harwil Company, Santa Monica, California
(1/2 - 10 ml. thickness capacity)
 - B. Chemical Rubber Company, Cleveland, Ohio
 - C. Packaging Aids Corporation, New York, N. Y.
14. Acrylic plastic cement
 - A. Methylene (Dichloromethane)
Allied Chemical, General Chemical Division,
Morristown, New Jersey

Figure 152. Cloth Specimen Pouch and Tee Handle Frame

9.0 Small Object Sampling

The selection and retrieval of the smaller samples, such as sand, silt, rock chips or deep sea benthic fauna, requires some means to scoop and retain the sample. The universal finger and hand configuration of the manipulator, does not lend itself to the efficient retrieval of the tiny granules, or the grasping and retention of delicate forms of bottom life.

The tools necessary to collect these specimens, fall into three basic categories: scoops, suction retriever and grab devices. The selection and use of the proper device, depends on the bottom condition as well as the specimen to be retrieved.

9.1 Sampling Sacks

Figure 152 is a typical cloth pouch that may be used for scooping sand, silt, small rocks or other specimens from the bottom. The frame is of welded steel construction, painted with red insulating varnish to prevent rusting. The frame may be constructed of stainless steel if corrosion or rust is a contamination problem.

The cloth sample bags are commercially available,¹ and may be obtained in 10" X 18" and 17" X 32" sizes. The size most easily handled by the manipulator is 10" X 18". Plastic lined sample bags are also available from the manufacturer. Each pouch has a printed tag attached, providing the science observer with a place to record any pertinent information concerning the specimen. The frame has been sized to allow the open end of the bag to be pulled over the flange. It is secured by tying it with the draw string sewn into the cloth.

In use, the manipulator scoops the selected specimen from the bottom, the operator actuates the wrist rotate motor, winding the pouch and its specimen about the frame. Figure 153 is an underwater view of the manipulator in the process of wrapping the specimen within the pouch. Figure 154 is a typical science tray rigged for obtaining geological specimens. Note that each pouch has been rolled then secured with a rubber band to prevent loss as the vehicle enters the water.

On grasping the tee handle, the manipulator withdraws the specimen pouch, stretching the rubber bands, and freeing the assembly. The science rack illustrated does not have provisions to hold the specimen pouches when they are returned.

Figure 153. Underwater View of Specimen Bag and Manipulator Hand

Figure 154. Typical Science Tray Rigged with Specimen Pouches

Figure 155. Science Rack with Canvas Storage Sacks and Sediment Core Tubes

Normally, the weight of the rock specimens are sufficient to allow the operator to lay the rolled pouches on the tray without loss. The science racks are constructed with an upturned lip around the edges, which helps to prevent the specimen bags from sliding off the tray.

For those specimens considered as light weight, the tray configuration illustrated in Figure 155 may be used. After retrieving the specimens, the operator rolls the pouch around the tee handle frame, inserting it into one of the cloth storage sacks attached to the rack. To save time during some bottom operations, the operator will drop the geology tools shown fastened across the front of the rack, into an unused specimen sack.

To prevent the storage sacks from floating and turning inside out as the vehicle is lowered into the water, some weighted object such as lead or rock must be placed at the bottom of the bag. The punched holes located in the side walls of each sack, provide a drainage system when the vehicle is retrieved from the water. To assure the proper logging and storage of the specimens, the sacks may be coded with a felt tip ink pen. The identifying mark must be positioned to be visible to the operator of the manipulator.

9.2 Fish Nets Scoops

In addition to the cloth pouches used to retrieve bottom specimens, the fish net device shown in Figure 156 has been very successful. The course mesh provides a free flow of water through the net, permitting the operator to retrieve water borne specimens floating in the area. When using close knit cloth pouches, the water has a tendency to "pile-up" in front of the container, pushing the light weight objects out of the way.

The net pouches are readily available in various openings.² The type of specimen to be retrieved is the deciding factor concerning the mesh dimensions. For example, the mesh size illustrated has been found satisfactory for the retrieval of numerous light weight water borne objects, as well as some gelatinous specimens. The extremely soft or wispy type however, requires a smaller mesh to prevent the specimen from oozing through the openings.

Specimen retrieval and scoop storage, is identical to the method used for the cloth pouches. Figure 157 illustrates a typical science rack rigged with fish net scoops in preparation for a biological mission.

Figure 156. Butterfly Net Fish Scoop

Figure 157. Typical Science Rack Rigged with Butterfly Net Retrieval Scoop

Figure 158. Mechanical Manipulator Butterfly Net and "Specimen Size" Reference Marks

Figure 158 has been included to illustrate the butterfly net being grasped by the manipulator, and to show the one inch reference marks painted on the side of the manipulator forearm. The reference marks provide the operator with a means of estimating the size of various mid-water specimens as they are collected. Without a background reference, it is almost impossible for the operator to estimate the true size of mid-water objects when viewed through the observation port of the vehicle.

Most deep water submersibles are constructed with truncated, 90° cone view ports, fabricated from a clear acrylic plastic. The inner and outer faces of the port light, are machined and polished into a plane-parallel optical flat. The very nature of this "lens" construction, provides image distortion and magnification of the viewed object. When on the bottom, or using a reference of known size, the pilot subconsciously compensates for the apparent size difference, by cross-referencing between other bottom objects.

In mid-water, or without the background reference supplied by the scale on the manipulator arm, the magnification effect of the planar air-plastic-water interface, causes the operator to misjudge the true size of the object.

9.3 Powered Retrieval Slurper

Figure 159 illustrates a proposed fish slurper or small object retrieval device designed for operation with the mechanical manipulator. It provides the operator with the capability of a "soft" retrieval and storage of either gelatinous objects, tiny bottom life, or small pebble type deposits.

The mechanism consists of a pressure compensated D. C. motor/pump³ assembly, identical to the device used with the suction pod. In operation, the sea water discharge from the pump, is directed through an aspirator. The pressure reduction produced at the VENTURI,⁴ results in a flow of water into the bell mouth inlet. When the entry is directed at a small object, it is ingested, moving slowly through the flexible tube,⁵ then deposited in the specimen pouch.

The use of an aspirator device provides a mechanism that does not pass the specimen through the gears or blades of a conventional suction pump. Its flow may be regulated by varying the speed of the motor, providing a soft flow for delicate specimens, or a high velocity flow for retrieval of

ASPIRATOR-TYPE FISH "SLURPER"

Figure 159. Aspirator Type Fish "Slurper"

small rocks, clams, or other hard surface objects.

The reversing capability of the pump may be used to vacuum or wash away sedimentary deposits, exposing bottom objects for closer observation. The discharge of the pump however, should be directed down stream to prevent clouding of the area due to suspended silt.

The device may also be used in conjunction with the high pressure specimen retrieval capsule. By inserting the discharge duct of the aspirator into the mouth of the capsule, the specimen may be selected and deposited within the chamber, with a minimum of manipulator movement.

The device illustrated by the artist sketch, depicts a single pouch for specimen storage. It is intended, that the final version will provide multiple storage sacks to assure specimen segregation.

References and Manufacturing Vendors
Section 9, Small Object Sampling

1. Sample Sacks
 - A. Soil Test Inc., Evanston, Ill.
 - B. Size LT-90, 10" X 18", Size LT-92 17" X 32"
2. Fish Net Pouches (Nylon-Polyethylene)
 - A. Parisi Plastic Fishing Gear Inc., Gloucester, Mass.
 - B. Clarks Marine Equipment, Guilford, Conn.
 - C. Russell Feed Co., Andover, Mass.
 - D. Hope Fish Netting Mills Inc., Hope, Rhode Island
 - E. Stocked by Local Sporting Goods Stores
 - F. Sears, Roebuck and Co.
3. D. C. Motor/Pump
 - A. Benthos Inc., North Falmouth, Mass.
 - B. Franklin Electric Co. Inc., Bluffton, Indiana
 - C. Jabsco Pumps, Costa Mesa, Calif.
 - D. Hoover Electric Co., Los Angeles, Calif.
4. Venturies
 - A. Fox Valve Development Co. Inc., Hanover, N. J.
 - B. Air-Vac Engineering Co., Milford, Conn.
5. Flexible Tubing
 - A. Flexaust Co. Div. Callahan Mining Co., New York, N. Y.
 - B. Penn Tube Plastics Co. Inc., Clifton Heights, Pa.
 - C. Automation Industries Inc., Guilford, Conn.

Figure 160. Simplified Sediment Shear Vane Apparatus

10.0 Deep Ocean Sediment Testing

The vane shear test apparatus illustrated in this section, provides a means of determining the in-place shear resistance of soft saturated fine grain bottom sediments.

The vane shear mechanism is a device to measure torque. It consists of a four bladed paddle attached to a spring steel drive rod. At the top of the rod is an indicator which reads the amount of torsional force applied to the paddle. The device is inserted into the bottom sediment, and a slow steady torsional force applied to the rod. Depending on the shear resistance of the sediment, the spring rod attempts to twist. The amount of twist is registered on the indicator.

The range of torque depends on the size and strength of the spring steel. The device can be constructed and calibrated to read torque directly in inch-ounces, inch-pounds, foot-pounds, etc.

10.1 Simplified Vane Shear Test Device

Figure 160 is a view of a shear vane apparatus, illustrating the removable probe and the tee handle adapter. It is constructed from a commercially available torque wrench or screw driver attachment.¹ The tee handle provides a means of grasping the device with the fingers of the mechanical manipulator. The rotary drive is provided by the wrist rotate motor, which is capable of exerting a torque of 115 inch-pounds.

The normal rate of wrist rotation is approximately 7 1/2 revolutions per minute, or 45 degrees per second. The accepted rate of rotation to perform a sediment shear test is 0.1 degree per second.² To provide the necessary speed reduction, a gear reducer must be installed between the wrist drive mechanism and the vane shear device illustrated.

Figure 161 is a close-up view of the pointer and circular torque indicator at the top of the vane shear device. The model shown has a range of zero to 24 inch-ounces. Figure 162 is an artist conception of the device in use with the ALVIN submersible.

In actual applications, the vane shear device illustrated, would be extremely difficult to read due to the small size as well as the horizontal position of the torque indicator scale. Based on the problems uncovered during the evaluation of the simplified vane shear apparatus, the following improved version was designed and constructed.

Figure 161. Shear Vane Tee Handle Drive and Indicator Read-Out Drum

TRIAXIAL SHEAR VANE
BOTTOM SEDIMENT TESTER

Figure 162. Artist Sketch of Vehicle Using-Bottom Sediment Vane Test Device

Figure 163. Torsional Spring Shear Vane Test Apparatus

10.2 Torsional Spring, Vane Shear Test Apparatus

The device illustrated in Figure 163, was designed to be driven by the wrist rotate motor of the ALVIN mechanical manipulator. The tee handle drive is directly connected to a pressure compensated gear reduction assembly.³ The output shaft drives a torsional spring¹ connected to the shear vanes. The torque indication from the spring, is read directly off the scale on the indicator drum. The drum and pointer assembly are located just below the gear housing. The indicator also provides the number of degrees of rotation traversed by the paddle vanes, as they shear the soil specimen.

10.2.1 Operations and Construction Characteristics

Figure 164 is an exploded view of the apparatus. The rectangular PVC⁴ oil reservoir, and the 1/16 inch thick neoprene⁵ diaphragm illustrated in the photograph, provide pressure compensation⁶ for the gear reduction housing. The "O" ring⁷ sealed pressure transfer port connecting the two assemblies, is visible at the base of the gear reduction housing. The reduction ratio of the gear box assembly has been selected to provide an output shaft rotation of 0.1 degree per second, when driven by the 7 1/2 revolution per minute rate of the wrist rotate mechanism on the manipulator.

The load capacity of the reduction assembly is well above the maximum torque that can be applied by the manipulator wrist rotate motor. Safety slip clutches or shear pins are not provided in the vane shear apparatus. The 115 inch-pound clutch setting of the wrist rotate motor is used to provide a safety in the event of overload.

The indicator drum is of sufficient size to provide a satisfactory read-out of the torque levels obtained. The indicator pointer that provides the degrees of paddle rotation, is clearly marked, and can be read from within the vehicle. Figure 165 is a cross sectional drawing of the device, illustrating the location of the various components.

Initial testing of the apparatus indicated a floating zero point. Additional tests revealed that side loads on the indicator drum and the vane drive shaft, were having a detrimental effect at the zero and low torque read-out points. At the higher ranges, repeatability was considered as satisfactory. To assure repeatability of shear values throughout the complete range of the apparatus, it was decided to

Figure 164. Exploded View of Torsional Spring Shear Vane

Figure 165. Cross Sectional Drawing of Shear Vane

Figure 166. Cross Section of Improved Shear Vane Apparatus

modify the assembly.

10.3 Modified Vane Shear Test Mechanism

The apparatus was re-worked to "beef-up" the bearing mechanism at both the input and output shafts. Figure 166 is a cross-section view of the modified device. The gear reduction housing, which is located between the input and output assemblies, has not been included in the sketch in order to provide greater detail of the drive mechanism. The 4 needle bearings⁸ provide sufficient side load restraint to eliminate the original problem. Generous clearances are provided between all possible rubbing points at the indicator drum and pointer areas.

Figure 167 is an exploded view of the modified assembly. Pressure compensation has been increased to include the needle bearings and to eliminate any seawater end loading of the various shafts. The torsion spring, which transmits the load to the four vane paddle assembly, is located in the center of the photograph. The housing used to incase the torsion spring, has been modified to be either grease or oil filled, depending on the water temperatures that may be encountered. The original model was free flooding, and the sea water had a detrimental effect on the spring steel.

10.3.1 Calibration of Shear Vane Assembly

The assembled vane shear device illustrated in Figure 168 has a torque range of zero to 12 inch-pounds. Calibration of the mechanism is accomplished by connecting a standard torque wrench back-to-back with the vane shear apparatus. The load applied by the master torque wrench will register on the slave, or vane shear indicator. If equally spaced indicator marks are engraved on the shear vane drum, rather than actual torque values, a calibration curve must be provided for the apparatus.

The use of separate calibration curves, provides the option of varying the operating range of the device by changing the master torsion spring. This provides the operator with a complete new range of shear values to accommodate various soil consistencies. A separate calibration curve must be determined for each variation of basic assembly. Changing paddles will not normally require re-calibration. However, depending on sediment strength, it will move the torque read-out to a new level on the curve.

Figure 168. Assembled View of Improved Shear Vane Apparatus

Figure 169. Construction Features of Typical 4 Blade Shear Vane Probes

With the exception of the beefed-up needle bearings installed at the input and output shafts, the modified vane shear device maybe considered as being similar to the assembly illustrated in Figure 163. Pressure compensation, gear reduction ratio, interchangeable four bladed shear probes, and the method of calibration are the same as the former model.

Figure 169 covers the dimensions and construction details of the interchangeable four bladed shear vane probes. The original probes were constructed from stainless steel to reduce the effect of corrosion. Mild steel or brass is satisfactory if a corrosion resistant material is not available. The thickness of the material used to construct the shaft and the vanes however, must be sufficient to resist the torque exerted by the drive mechanism, without bending or twisting. As an aid to the operator as well as the science observer, the vane drive rod should be graduated with several depths of penetration marks. The subdivision should stand-out clearly against the background sediment, and not fade or lose their distinctive appearance when illuminated by the high intensity flood lamps on the submersible.

References and Manufacturing Vendors
Section 10, Deep Ocean Sediment Testing

1. Screw Drive Torque Wrench (Torsional Springs)
 - A. Apco Mossberg Co., Attleboro, Mass.
2. Earth Manual by U. S. Department of Interior, Bureau of Reclamation; and Diamond Drill Handbook by J. D. Cumming, Published by J. K. Smit & Sons, Ltd.
3. Gear Reduction Assemblies
 - A. Metron Instruments Inc., Denver, Colorado
 - B. Insco Corp, Groton, Mass.
4. PVC (Polyvinyl Chloride) Bar Stock
 - A. Como Plastics Inc., Richmond Hill, N. Y.
 - B. General Tire & Rubber Co., Lawrence, Mass.
5. Neoprene Sheet Gasket
 - A. Raybestos - Manhattan Inc., Packing Div., Passaic, N. J.
 - B. Globe Rubber Works, Quincy, Mass.
6. Pressure Compensation Fluids
 - A. See Section 1 References
7. "O" Ring Seals
 - A. Parker Rubber Products Div., Cleveland, Ohio
 - B. Precision Rubber Products, Dayton, Ohio
8. Needle Bearings
 - A. Torrington Bearing Co., Torrington, Conn.

Figure 170. Deep Water Benthic Retrieval Capsule

11.0 Deep Water Benthic Retrieval Capsule

The retrieval of living benthic animals from their deep sea habitats, requires a transfer capsule for returning them to the surface, and a high pressure aquarium in which they may be placed on arrival at the surface. The following devices and system concepts have been developed to establish the feasibility of the operation, and to provide the basic components which will become the nucleus of the proposed system.

11.1 Retrieval Transfer Capsule

Figure 170 illustrates a transfer capsule or pressure chamber, having a wide mouth entry, snap action closure, and a pressure make-up accumulator to assure a constant internal pressure during ascent. The chamber is shown with the closure plug in the locked position, simulating the appearance of the capsule when transferring a specimen from the bottom.

Figure 171 is a view of the capsule in the open position showing the hinge and ball lock mechanism of the closure plug.¹ In order to reveal the construction features of the capsule, the external form fitting syntactic insulating foam, necessary to maintain a constant internal temperature, has not been included.

The capsule illustrated has been hydrostatically tested to an internal pressure of 4500 psig without deformation. During the initial test, some fluid leakage was noted in the area of the "O" ring seal² at the mouth of the capsule. Investigation revealed that the clearance between the closure plug and the pressure chamber entry was of sufficient magnitude to allow the "O" ring to extrude. The chamber entry had been bored out to be on the high side of the recommended dimensions, in order to provide for some misalignment of the closure plug during entry.

To retain the plug clearance, and still prevent "O" ring extrusion, the ring groove was modified to include a split teflon back-up ring.² The teflon ring provided a semi-rigid wall "for the "O" ring to work against, substantially decreasing the clearance between the plug and the chamber bore as "seen" by the "O" ring. Additional pressure tests indicate the modification was effective in preventing the extrusion previously encountered.

Figure 171. Retrieval Capsule Illustrating Plug Valve in Open Position

11.2 Operational Characteristics of the Transfer Capsule

Figure 172 is a simplified sketch of the capsule. Item 1 is the universal tee handle used with all underwater tools developed for the ALVIN vehicle. It is the only handle required to close and lock the chamber when using the mechanical manipulator. The ball lock closure plug 2, is attached to hinge 3, with a loose sliding fit between the tee handle and hinge collar. The hinge maintains the plug in the proper plane to assure entry into the capsule. It also provides an open position stop point for the plug.

After positioning the closure plug over the capsule entry, a downward push on the tee handle is all that is required to close and lock the capsule.

Depressing the tee handle compresses spring 4, allowing the lock balls to enter the detent cavity at the base of the tee handle. The plug slips into the capsule, with the bullet shaped nose passing through the "O" ring seal Item 5. On release of the downward pressure, the tee handle returns to its spring loaded position locking the balls into the mating groove in the capsule neck.

Items 6 and 7 are the stainless steel chamber shells, with a total internal volume of 0.8 liters. The neck entry of shell 6, has an inside diameter of 2 1/4 inches. Item 8 is a pressure gage³ to indicate the chamber pressure after its return to the surface. It is incased in an oil filled chamber⁴ only as a means of protecting the gage mechanism from mechanical damage and corrosion. Being pressure balanced by the oil contained within the plastic shell,⁵ it does not indicate total pressure within the chamber until the capsule has been returned to the surface.

The pressure gage also provides the operating personnel with a reminder that the chamber is pressurized and to handle it with care. On returning to the surface, the air backed accumulator Item 9, becomes a storage volume for gaseous kinetic energy at a pressure of approximately 3000 psig when closed at 6000 foot depths. At this pressure, the closure plug could become a lethal projectile if inadvertently released. In the prototype model shown, the closure plug does not have provisions for a safety mechanism. Future models will be provided with an interlock to prevent the release of the closure plug while the chamber is pressurized.

Figure 172. Cross Sectional Drawing of Retrieval Capsule Assembly

In use, the capsule closure is in the open position, the accumulator is empty of fluids and at ambient atmospheric pressure. When the vehicle and capsule descend beneath the surface, water enters, filling the specimen chamber. As the pressure increases, water enters the accumulator through the capillary tube Item 10, compressing the air Item 11, within the spherical volume. The curved capillary tube prevents the air from bubbling out of the accumulator as the capsule descends through the water. Valve,⁶ Item 12, is used to bleed the chamber pressure to assure personnel safety.

On reaching the area of interest, the science observer selects his specimen, retrieving it with the mechanical manipulator or small suction pump probe, placing it within the capsule chamber. The operator closes the capsule, securing the plug by the locking action of the ball detent mechanism. The capsule and its specimen may now be returned to the surface with a minimum change in the temperature and pressures normally encountered in its natural habitat.

The air backed accumulator⁷ was installed as a simple pressure make-up device to provide a constant chamber pressure in the event of "O" ring weepage during the ascent. Without the accumulator, any weepage of the "O" ring seals in a "pure" hydrostatic chamber, would result in a rapid decrease in chamber pressure that could be catastrophic to the specimen.

In addition, the air backed accumulator provides the necessary soft-cushion to allow the complete insertion of the closure plug. Without the cushion, the operator would encounter a hydraulic ram condition once the "O" ring seal made contact with the plug. The pure hydraulic pressure generated by the plug (piston) and the seawater (fluid) would immediately raise the chamber pressure to a level greater than the push capability of the manipulator.

Figure 173 is an exploded view of the piece parts comprising of the retrieval capsule. The closure plug assembly is in the upper left hand corner. Note the drilled nose cone holes to accommodate the six steel locking balls, and the clearance groove machined into the detent plug used to back-up the locking balls. The detent spring, steel balls and tee handle, are located at the left center of the photograph.

Figure 174 illustrates the complete assembly, including the mounting stand used to maintain the capsule in the vertical position. The stand provides a means of mounting the device

Figure 173. Exploded View of Retrieval Capsule Piece Parts

Figure 174. Retrieval Capsule and Mounting Frame

Figure 175. High Pressure Aquarium Flow Schematic

to a science rack, as well as furnishing a safety device to prevent damage to the specimen and/or the external hardware when the chamber is removed from the vehicle.

11.3 Uncontaminated Specimen Retrieval

As a point of interest, the material used in the construction of the retrieval capsule will accept autoclaving, gaseous, or chemical cleaning in preparation for bacteriological exploration of bottom specimens. If the chamber is to be autoclaved as an assembly, the oil filled pressure gage and its plastic cap must be removed, and the tapped boss in the threaded adapter plugged.

After autoclaving, the chamber may be packaged in a water filled plastic bag,⁸ and the bag ends heat sealed. The distilled water and plastic bag act as a self pressure compensating sea water barrier preventing contamination of the chamber surfaces during the descent to the bottom.

On arrival at the site being investigated, the manipulator fingers severs the bag, exposing the capsule chamber. The specimen is deposited in the chamber, the closure plug inserted and locked. The specimen may be returned to the surface without being exposed to any external contamination enroute. If the slurper pump illustrated in section 9 is used to collect the specimen, it will simultaneously purge the chamber as it pumps the seawater. If the device is not used, the specimen chamber must be left open for a sufficient length of time to disperse the distilled water within the chamber cavity.

11.4 High Pressure Aquarium System

Figure 175 is a schematic of a proposed high pressure aquarium for use with the specimen transfer capsule. The aquarium provides the science investigator with a means of maintaining a deep ocean specimen at the same temperature and pressure condition found in its natural environment. The mechanical components of the system, provide a pulsation free constant pressure condition in the specimen chamber. Fluid flow through the chamber is continuous, providing an uninterrupted flow for the removal of toxic materials. The system however, may be dead-ended if necessary, providing a constant chamber pressure at no-flow conditions. The system maybe set and maintained at any pressure up to 4500 psig.

The piping configuration has been designed to maintain the high pressure conditions only in the area of the specimen. All other areas have been kept at atmospheric pressure to allow the use of off the shelf apparatus such as flow meters, salinity and oxygen concentration indicators, temperature read-out devices, filters, aeration pumps, etc. The use of a low pressure section also provides easy access to the system fluid when the research being conducted requires the addition of chemical compounds, radiation, or other fluid treatments requiring commercially available apparatus.

The specimen chamber illustrated, does not include the transfer portion of the assembly, which is required to mate with the proposed aquarium system. The prototype capsule was designed only to test the air back-up accumulator, the feasibility of the ball lock plug closure, and the ability of the submersible's mechanical manipulator to maneuver the closure plug and lock the assembly while operating in the deep ocean.

References and Manufacturing Vendors
Section 11, Deep Water Benthic Retrieval Capsule

1. Ball Lock Plug
 - A. Space Loc. Inc., Burbank, Calif.
2. "O" Rings/Teflon Back-Up Rings
 - A. Parker Rubber Products Div., Cleveland, Ohio
 - B. Precision Rubber Products, Dayton, Ohio
 - C. Industrial Retaining Rings, Irvington, N. J.
3. Pressure Gage (0-3000 meters)
 - A. American Standard, Advanced Technology Div., Monrovia, Calif.
 - B. Ametek/U.S. Gage Inc., Sellersville, Pa.
4. Pressure Compensating Oil
 - A. Mineral Oil, Local Drug Store
 - B. Kerosene, Local Purchase
5. Plastic Tubing (Acrylic)
 - A. BUSADA Mfg. Corp., Flushing, N. Y.
 - B. National Plasti Fab. Inc., Burlington, Mass.
6. Bleed Valve, High Pressure
 - A. Hoke Mfg. Co., Cresskill, N. J.
 - B. Parker Hannifin Corp., Ostego, Mich.
7. Air Storage Accumulator
 - A. Walter Kidde & Co., Belleville, N. J.
 - B. Matheson Co. Inc., East Rutherford, N. J.
 - C. Pressed Steel Tank Co., Milwaukee, Wisc.
8. Plastic Bags
 - A. Stone and Forsyth Co., Cambridge, Mass.
 - B. American Cellophane & Plastic Films, Jamaica Plain, Mass.

References and Manufacturing Vendors
High Pressure Aquarium System

1. Pressure Vessels
 - A. American Instrument Co., Super Pressure Div., Silver Springs, Maryland.
 - B. Parr Instrument Co., Moline, Illinois
 - C. Local Fabrication
2. Valves (Hi-Pressure Shut-off Control)
 - A. American Instruments Co., Silver Springs, Maryland
 - B. Hoke Valve Inc., Cresskill, New Jersey
 - C. Republic Mfg. Co., Cleveland, Ohio
 - D. Hex Valve Co., Long Beach, California
 - E. Airmatic Valve Inc., Cleveland, Ohio
 - F. Imperial Eastman Corp., Chicago, Ill.
 - G. Combination Pump & Valve Co., Philadelphia, Pa.
3. Thermo-Regulators (Temperature Control)
 - A. American Instrument Co., Silver Springs, Maryland
 - B. E. H. Sargent & Co., Chicago, Ill.
 - C. U. S. Gage Co., Sellersville, Pa.
 - D. Bristol Co., Waterbury, Conn.
 - E. Elliott Controls, Brooklyn, N. Y.
 - F. West Instrument Corp., Shiller Park, Illinois
 - G. Melabs, Scientific Inst. Div., Palo Alto, Calif.
4. Conductivity Indicators
 - A. American Instrument Co., Silver Springs, Md.
 - B. E. H. Sargent Instrument Co., Chicago, Ill.
 - C. Industrial Instruments Inc., Cedar Grove, N. J.
5. P. H. Indicators
 - A. American Instrument Co., Silver Springs, Md.
 - B. E. H. Sargent & Co., Chicago, Ill.
 - C. Bristol Co., Waterbury, Conn.
 - D. Analytical Measurements Inc., Summit, N. J.
6. Heat Exchangers
 - A. American Instruments Co., Silver Springs, Md.
 - B. Young Radiator Co., Racine, Wisc.
 - C. Whitlock Manufacturing Co., West Hartford, Conn.
 - D. Dennison, Div. Abex Corp., Columbus, Ohio
 - E. Borg-Warner Corp., Detroit, Mich.
 - F. United Aircraft Products, Inc., Dayton, Ohio

7. Rotameters (Flow Meters)
 - A. American Instrument Co., Silver Springs, Md.
 - B. Cox Instrument Div., Detroit, Mich.
 - C. Rambo Instrument Co., Bloomingdale, N. J.
 - D. National Instrument Labs., Rockville, Maryland
 - E. F. W. Dwyer Mfg. Co., Michigan City, Ind.
 - F. Fisher Porter Co., Warminster, Pa.
 - G. Brooks Instrument Div., Hatfield, Pa.
8. Temperature Measurement (Thermocouples/Probes)
 - A. American Instrument Co., Silver Springs, Md.
 - B. Rosemount Engineering Co., Minneapolis, Minn.
 - C. U. S. Gage Co., Sellersville, Pa.
 - D. James G. Biddle Co., Plymouth Meeting, Pa.
 - E. Thermo Electric, Saddle Brook, N. J.
 - F. Lewis Engineering Co., Naugatuck, Conn.
9. Recorders (Strip/Circular)
 - A. American Instrument Co., Silver Springs, Md.
 - B. Baldwin-Lima-Hamilton, Waltham, Mass.
 - C. U. S. Gage Co., Sellersville, Pa.
 - D. Bristol Co., Waterbury, Conn.
10. Relief Valves (Adjustable/Burst Disc.)
 - A. American Instrument Co., Silver Springs, Md.
 - B. Circle-Seal Products, Co., Pasadena, California
 - C. Ben Bow Mfg. Corp., Hawthorne, California
 - D. Manatrol, Elyria, Ohio
 - E. Enerpac, Applied Power Industries, Butler, Wisc.
 - F. Pressure Products Industries Inc., Hatboro, Pa.
 - G. Ametek, Inc., Calmec Div., Los Angeles, Calif.
11. Filters
 - A. American Instrument Co., Silver Springs, Md.
 - B. Parker-Hannifin, Des Plaines, Illinois
 - C. Fluid Dynamics, Inc., Morristown, N. J.
 - D. Microporous Filters, Div. Circle Seal, Anaheim, Calif.
 - E. Schroeder Brothers Corp., McKees Rocks, Pa.
 - F. Cuno Engineering Corp., Meriden, Conn.
12. Pressure Regulators
 - A. American Instrument Co., Silver Springs, Md.
 - B. Victor Equipment Co., San Francisco, California
 - C. Robert Shaw Controls, Knoxville, Tenn.
 - D. Volumetrics, Inglewood, California
 - E. Ben Bow Mfg. Co., Hawthorne, California
 - F. Parker-Hannifin, Des Plaines, Illinois

13. Back Pressure Regulators
 - A. American Instrument Co., Silver Springs, Md.
 - B. Victor Equipment Co., San Francisco, California
 - C. Robert Shaw Instruments, Knoxville, Tenn.
 - D. Fluid Controls Inc., Mentor, Ohio
 - E. Manatrol, Elyria, Ohio
14. Pressure Sensing (Gages/Probes/Indicators)
 - A. American Instrument Co., Silver Springs, Md.
 - B. Rosemount Engineering Co., Minneapolis, Minn.
 - C. U. S. Gage Co., Sellersville, Pa.
 - D. E. W. Dwyer Mfg. Co., Michigan City, Indiana
 - E. Helicoid Gage Div., Bridgeport, Conn.
15. Hydrostatic Pumps (Electrical)
 - A. American Instrument Co., Silver Springs, Md.
16. Hydrostatic Pumps (Air Operated)
 - A. Sprague Engineering Corp., Gardena, Calif.
 - B. S. C. Hydraulic Engineering Corp., Los Angeles, Calif.
 - C. Hasket Engineering & Supply Co., Glendale, Calif.
 - D. Greer Hydraulics, Inc., Los Angeles, Calif.
 - E. Carter Controls, Inc., Lansing, Ill.
 - F. Harwood Engineering Co., Inc., Walpole, Mass.
 - G. Miller Fluid Power Div., Bensenville, Ill.
17. Hi-Pressure Penetrators (Electrical/Temperature/Pressure)
 - A. American Instrument, Co., Silver Springs, Md. (T)
 - B. Conax Industrial Products, Div., Buffalo, N. Y. (T)
 - C. Auto-Control Laboratories, Los Angeles, Calif.
 - D. Aero Research Instrument, American Std. Chicago, Ill. (T)
 - E. Advanced Products Co., North Haven, Conn. (T)
 - F. Mecca Cable & Service Co., Houston, Texas (E)
 - G. Marsh & Marine Mfg. Co., Houston, Texas (E)
 - H. Electro-Oceanics, Inc., Santa Monica, Calif. (E)
18. Tubing/Fittings/Pipe
 - A. American Instrument Co., Silver Springs, Md.
 - B. Superior Tube, Norristown, Pa.
 - C. Imperial Eastman, Chicago, Ill.
 - D. Cajon Co., Solon, Ohio
 - E. Republic Steel Corp., Cleveland, Ohio
 - F. Ohio Steel Tubing, Shelby, Ohio
 - G. Parker-Hannifin, Cleveland, Ohio
 - H. Lenz, Co., Dayton, Ohio
 - I. Aeroquip Corp., Los Angeles, Calif.

19. O₂ Analyzers
 - A. Mine Safety Appliances, Pittsburgh, Pa.
 - B. Lockwood & McLorie, Inc., Horsham, Pa.
 - C. Beckman Instruments, Inc., Brighton, Mass.
 - D. Cole-Parmer Co., Chicago, Illinois
20. CO₂ Analyzers
 - A. Mine Safety Appliances, Pittsburgh, Pa.
 - B. Varian Associates, Vacuum Products Div., Waltham, Mass.
21. Sight Glass (Pressure Resistant)
 - A. Esco Products, Inc., Oak Ridge, New Jersey
 - B. General Electric, Lamp Glass Dept., Willoughby, Ohio
 - C. Pfaudler Co., Rochester, N. Y.
 - D. Thermal American Fused Quartz Co., Montville, N. J.
 - E. Tube Turns, D. W. Chemetron Corp., Louisville, Ky.
22. Salinity Indicator
 - A. Industrial Instruments, Inc., Cedar Grove, New Jersey
 - B. Bissett-Berman Corp., Santa Monica, Calif.
23. Check Valves
 - A. Circle-Seal Products, Co. Inc., Pasadena, California
 - B. Manatrol, Elyria, Ohio
 - C. Ful-Flo Specialties, Co., Inc., Blanchester, Ohio
24. Pressure Accumulators (Piston/Diaphragm)
 - A. Hale Fire Pump Co., Conshohocken, Pa.
 - B. Hydrodyne Industries, Inc., New York, N. Y.
 - C. Superior Hydraulics, Div., Cleveland, Ohio
 - D. Greer-Olfier Products, Los Angeles, California
 - E. Pulsation Controls Corp., Santa Paula, California
 - F. Superior Hydraulics, Cleveland, Ohio
25. Oil Free Aeration Pumps
 - A. Gast Manufacturing Corp., Benton Harbor, Mich.
 - B. Cole Parmer Co., Chicago, Illinois
26. Temperature Conditioning Mechanisms (Thermo-Electric Cooling)
 - A. Laboratory Supplies Co. Inc., Hicksville, N. Y.
 - B. Cole-Parmer, Chicago, Illinois

Figure 176. Prototype Suction Pod Bottom Anchor Assembly

12.0 DSRV Bottom Suction Pod Anchor

The purpose of the motorized bottom suction anchor is to provide a simple, rapid, light weight means of anchoring a deep diving submersible to various bottom configurations. Its holding ability provides a restraining force to counteract the opposite forces generated during the use of rotary tools. It will also resist the reaction produced when pushing core or sediment probes into the bottom. The design furnishes the operator with a simple method of releasing the anchor from the bottom, by reversing the motor discharge into the plenum chamber. Figure 176 illustrates the laboratory prototype developed to test the feasibility of the bottom suction anchor. Figure 177 is an artist conception of the suction pods in use during a bottom coring operation.

Present methods of anchoring a deep submersible requires the pilot to pump ballast until the vehicle becomes heavy. When sufficiently negative, the submersible descends until it rests on the bottom. This method is time consuming and could be hazardous if the vehicle is allowed to settle too deeply into the sediment. Experimental data indicates that the suction and/or friction forces set up between the vehicle skin and the sediment, could be of sufficient magnitude to impede the release of the submersible when the pilot attempts to ascend.¹ In addition to the static forces set up between the skin and sediment, past experience has shown that soft sediments can ooze through openings in the vehicles fairing, appreciably increasing the gross weight. If the weight increase becomes greater than the variable ballast and ascent weight release can overcome, the vehicle may have considerable difficulty returning to the surface.

A secondary method of bottom anchoring, would be through the use of either a marine anchor and mooring line arrangement, or by releasing one end of a length of chain, and dragging it along the bottom. The chain method is similar to the balloonist practice of dragging a line along the earth's surface to maintain a constant altitude. Although either of these single point tether methods will work, they are not practical due to sediment agitation, payload weight penalty, and the constant weather-cock movement of the vehicle due to the current actions. Normally, this slow undulating motion will not effect an observer taking bottom photographs, however, it does present a difficult if not impossible condition when attempting to obtain a sediment or hard rock core.

Figure 177. Artist Sketch of Proposed Suction Anchor in Use on a Submersible

To be practical, a deep submersible bottom anchor must be of minimum weight, be of small volume, have good holding power, on a variety of surfaces result in minimum sediment disturbance, in use and be capable of rapid deployment as well as having quick release capabilities.

12.1 Prototype Suction Pod Assembly Details

Figure 178 is a sectional view of the laboratory prototype bottom anchor, constructed from cemented and welded PVC plastic.² The side walls Item 4, were formed by heating PVC flat stock, forming the material around a mandrel, cementing and welding the butt joint with the approved bonding agent supplied by the plastic manufacturer.³ The cylindrical section becomes the base or bottom plenum chamber for the suction pod.

The underside or bottom of the plenum chamber is open, and as such the internal and external seawater pressure maybe considered as balanced. The top of the base or bottom chamber is closed with a plastic disc Item 6, upon which is mounted a direct-current, permanent-magnet reversible motor Item 1.

The motor is entirely immersed in a pressure compensating oil that is mechanically coupled to, and physically separated from the seawater.

The pressure compensating oil balances the seawater pressures between the inside and outside surfaces of the motor case Item 7. The pressure compensation allows the motor to be operated at great ocean depths without the use of a heavy pressure housing. A rubber impeller pump 2, of the type that reverses its flow when the direction of drive rotation is reversed, is directly coupled to the drive shaft of the motor.⁴

The internal and external pressures applied to the pump by the ambient seawater pressure maybe considered as balanced, and as such, the pump housing may be of any light weight material not adversely effected by the seawater.

The shaft seal separating the motor pressure compensating oil and the seawater within the pump housing maybe a simple lip seal type as it is considered to be installed between two pressure balanced systems. One port, Item 3 of the pump, is directly connected to the suction pod plenum chamber. The other pump port is open to the seawater. Power to operate the motor as well as lead wires to control its direction of rotation, are coupled to the deep submersible through electrical connector Item 5 and lead wires Item 8.

SEC. A-A

Figure 178. Cross Sectional Sketch of Suction Pod

12.2 Operational Characteristics

In use, one or more of the motorized bottom anchor suction pods are mechanically attached to the base of a deep diving submersible. They are positioned in a location that permits them to contact the ocean bottom before the hull or skids of the submersible. The vehicle is directed toward the ocean floor until the suction pods contact the bottom.

At this point the pilot applies power to the motor/pump assembly, rotating the pumps in a suction mode, which extracts water from the suction pod plenum chamber Item 4. On initial contact with the bottom sediment, a low pressure area is established within the plenum chamber. This low pressure condition pulls the plenum chamber into the bottom. As the sides of the chamber sink into the sediment, the water seepage under the chamber walls decreases to a minimum quantity, depending on the sediment density.

After plenum chamber settling has ceased, the pilot may turn the pump/motor assemblies to the off position. The design and construction of the rubber impeller pump, provides a check valve type action, preventing back flow into the plenum chamber.

Figure 179 illustrates the suction pod in the test tank as it burrows itself into the simulated coarse sand bottom. Note the channeling that occasionally occurs under the lip of the plenum chamber. The channeling condition or wash-out has a detrimental effect on the holding ability of the suction pod. Increasing the suction capacity of the pump tends to aggravate the channeling.

When imbedded evenly, and with a minimum of channeling, the suction pod plenum chamber remains firmly attached to the bottom with a force similar to that obtained by trying to remove a full, inverted glass, up through the surface of a liquid. Tests indicate that in some bottom conditions, the motor must be pulsed to maintain satisfactory anchoring of the suction pod.

To extract the bottom anchor suction pod the pilot applied power to the motor/pump assembly, reversing the rotation of the pump in order to force the suction pod surface area into a low pressure hydraulic piston, pushing the assembly out of the bottom sediment and freeing the submersible.

In areas having a flat hard rock surface, a thin flexible rubber skirt⁵ Item 10, may be attached to the suction pod. With the

Figure 179. Suction Anchor Partially Buried in Sandy Bottom

motor/pump assembly operating in the suction mode, the rubber skirt conforms to the varying contours of the rock surface restricting the free flow of water into the suction pod plenum chamber. The restriction of free flow results in a low pressure area within the plenum chamber, holding the submersible against the rock surface. When operating on smooth rock surfaces, the pump must remain operating in order to maintain the low pressure condition within the chamber.

When operating in very soft silty sediment, the use of the thin flexible skirt assists in preventing channeling or break through of a passage in the silt sediment. This channeling condition prevents the pump from maintaining a low pressure condition within the plenum chamber, as water is continually sucked through the channeled section. Figure 180 illustrates the rubber skirt and suction pod resting on a simulated sand bottom. Note the conformity of the rubber to the bottom contour.

The prototype model shown in the preceeding illustrations, had one square foot of surface area and a plenum chamber wall height of 4 inches. With a measured suction pressure of 0.7 inches of water, the steady vertical breakaway pull in clean brown building sand was 50 pounds. The pump was not operating during the steady force pull-out test. Based on the initial performance, the submersible bottom suction anchor is considered feasible, and will be investigated further.

12.3 Assembly of Full Scale Anchor

Figure 181 is a full scale suction pod designed for use with the ALVIN vehicle. It is 19 inches in diameter, and has 2 square feet of suction working area. The calculated holding power, as well as some preliminary tests with sand, indicate a bottom holding power of approximately 2700 pounds could be expected. The shell is constructed of 1/4 inch thick PVC, with strength gussets cemented and welded to the mounting pivot and top plate. The air weight of the suction pod and swivel assembly is 16.5 pounds, the motor and pump assembly weigh 7.2 pounds.

Simulated bottom tests performed in the wet tank, indicated the assembly is capable of withstanding an internal negative pressure of at least 19 inches of mercury without damage. The maximum inward deflection at the center of the upper plate was less than 1/32" during this evaluation. Figure 182 illustrates the full scale suction pod undergoing negative pressure deflection tests.

Figure 180. Suction Anchor With Rubber Skirt

Figure 181. Full Scale Deep Submersible Bottom Suction Anchor

Figure 182. Laboratory Test of Full Scale Suction Anchor

The deep water pump that mates with the suction pod, is capable of maintaining a negative pressure of 19 inches of mercury without excessive cavitation. The pump is a commercially available multi-vane rubber impeller type. Replacement impellers⁵ for the pump, are available at most marine distributors. The pump/motor assembly operates on 24 volt D. C. at 8 amperes, and will pump 320 GPH against a 10 foot head. The motor is wired to provide rotation in either direction, depending on the mode selected by the operator. The multi-vane impeller will operate in either direction, depending on motor rotation.

The universal joint illustrated in Figure 181 provides the suction pod with a self-leveling capability. The assembly is attached at the center point of the device, is free to swivel and will allow the suction pod to conform to most bottom conditions.

In addition to its use with a deep submersible, the device is capable of anchoring a surface vessel. The mechanism could be controlled by a simple float mechanism that actuates the pump when the internal water level reaches some predetermined point.

If designed to utilize the high pressure gas generated by a hydrazine decomposition chamber,⁸ the bottom anchor could be operated as a self-contained assembly. In operation, the decomposed fuel would be directed through an aspirator or venturi attached to the plenum chamber. The aspirator would evacuate to the plenum chamber, establishing the pressure differential which holds the device to the bottom. Control of the decomposition chamber fuel flow, would be a simple bang-bang valving system, controlled by either the water level within the chamber, or by sensing the differential pressure between the outside ambient and the plenum.

References and Manufacturing Vendors
Section 12, DSRV Bottom Suction Pod Anchor

1. Forces Required to Extract Objects from Deep Ocean Bottom, NONR #3363(00) FBM Sept. 14, 1967
2. PVC (Polyvinyl Chloride Type I)
 - A. Comco Plastics Inc., Richmond Hill, N. Y.
 - B. General Tire & Rubber Co., Lawrence, Mass.
3. PVC Bonding Agent
 - A. Cabot Solvent Cement, Cabot Piping Systems Div., Burlington, Mass.
 - B. Tri-angle Conduit & Cable Co., New Brunswick, N. J.
4. Motor/Pump Assembly
 - A. Benthos Inc., North Falmouth, Mass.
 - B. Franklin Electric Co. Inc., Bluffton, Indiana
 - C. Jabsco Pumps, Costa Mesa, Calif.
5. Neopreen Sheet Stock
 - A. Raybestos - Manhattan Inc., Packing Div., Passaic, N. J.
 - B. Globe Rubber Works, Quincy, Mass.
6. Pump Impellers
 - A. Jabsco Pumps, Costa Mesa, Calif.
7. Suction Anchor for Hard Bottom Surfaces, by C. A. Gongwer, Aero-Jet General Corp., Azusa, Calif.
8. Hydrazine Gas Generators for Undersea Systems 66R54, Rocket Research Corp., Seattle, Washington.

Figure 183. Dark Room Photograph of Chemiluminescent Fluid

13.0 Chemiluminescent Light Source Solutions

No actual deep water observations have been performed using Chemiluminescent fluids, however future plans for deep submergence research on new materials, includes the evaluation of these fluids. The manufacturer supplies the base fluid and the activator liquid¹ separately packaged in plastic nylon containers. The shelf life and temperature storage limitations are not known at this time. Low temperature, however, tends to inhibit the light producing ability of the present material. The manufacturer is investigating this area, and will try to improve the low temperature characteristics of the fluid.

High ambient pressures do not appear to have any detrimental effect, although additional evaluation will be necessary to determine its value in the deep ocean environment. A preliminary test was performed on one liquid specimen.² When placed in the hydrostatic chamber, the light appeared to increase slightly as the pressure was initially increased. It remained at the same intensity level as the pressure was raised to 12,000 psi. The chamber pressure was held at 10,000 psi for a two hour period. The light intensity slowly diminished at approximately the same rate of decay observed at sea level conditions.

Figure 183 is an actual photograph obtained with the light produced by a 17 milliliter engineering sample of the fluid. It was a 15 second time exposure at F-16 and was obtained in a dark room. The light emitted is of a decided greenish tinge. The film used in the illustration was Polaroid black/white type 55 PN.

As a point of information, the manufacturer explains the light output of the fluid, using the following comparisons; a 6 watt and a 25 watt light bulb generate light energy at a rate of 30 lumens and 250 lumens respectively. One liter of the Chemiluminescent fluid produces approximately 180 lumens at the start, and 60 lumens per liter after 30 to 45 minutes.

Actually, it is extremely difficult to provide a comparison between the two light sources. The normal light source is usually a point source, such as a candle. However, one liter of the Chemiluminescent fluid will produce 180 lumens regardless of whether it is spread out over a large area or in one container.

The manufacturer is capable of formulating the fluid in a wide variety of densities, providing the user with a material that maybe less dense, of greater density, or of equal density as the

seawater, depending on the requirements. This interesting characteristic lends itself to the investigation of mid-water and bottom current patterns.

Figure 184 is an artist sketch of one proposed deepwater program, consisting basically of a plastic floatation umbrella,³⁻⁴ sequence camera,⁵ and a fish trap.⁶ The primary purpose is to observe and photograph bottom life while they are exposed to lighting conditions not normally found in the deep ocean.

Other uses might include such items as emergency light sources in hazardous atmospheres, small emergency light beacons for skin divers that would provide a visual homing device for rescue personnel. Or, if compounded to a density that was greater than seawater, it could be poured on the bottom to provide illumination in an area undergoing search by a submersible, as well as providing "wide area" background illumination during recovery and/or rescue operations.

The material is considered by the manufacturer to be relatively non-toxic to humans, its effect, on other forms of life is unknown. It is strongly recommended that the manufacturer's instructions concerning its use and its limitations be closely followed.

Figure 184. Artist Sketch of Chemiluminescent Light Source and Deep Water Fish Trap

References and Manufacturing Vendors
Section 13, Chemiluminescent Light Source Solutions

1. Produced by American Cyanamid, Wayne, N. J.
2. Benthos, Inc., North Falmouth, Mass.
3. Plastic Sheet Material (Heat Sealable)
 - A. Stone and Forsyth Co., Cambridge, Mass.
 - B. Dewey & Almy Chemical Div., Cambridge, Mass.
 - C. American Cellophane & Plastic Films, Jamaica Plains, Mass.
4. Plastic Sheet Heat Sealing Devices (1/4 to 10 mill thickness)
 - A. Packaging Aids Corp., N. Y., N. Y.
 - B. Harwil Co., Santa Monica, Calif.
5. Sequence Camera
 - A. E. G. & G. Div. Geodyne, Waltham, Mass.
 - B. Local Fabrication
6. Fish Trap/Netting (Nylon-Polyethylene-vinyl Clad)
 - A. Local Sporting Goods Store, or Local Fabrication.
 - B. Hope Fish Netting Mills, Inc., Hope, Rhode Island
 - C. Parisi Plastic Fishing Gear Inc., Gloucester, Mass.
 - D. Clarks Marine Equip., Guilford, Conn.
 - E. Russell Feed Co., Andover, Conn.

Figure 185. 35mm Strip Film Projector

14.0 Accessory for the Review of 35MM Film Strips

Bottom and mid-water photographic records are obtained with the deep diving submersible ALVIN, through the use of two model 204B E. G. & G. 35 mm cameras.

Each camera has a capacity of taking about 500 frames of 35 mm photographs. The cameras are controlled from within the sphere, and may be tripped singly or together to obtain stereo pictures. Automatic repeated firing maybe obtained at intervals ranging from 4 to 14 seconds.

Post dive film reviews, consisting of approximately 1000 feet of developed film, illustrated the need for a rapid review projector similar to a film editor. To accommodate this requirement, Figure 185 illustrates a slide projector¹ that has been modified to accept the 35 mm strip film.

Figure 186 shows the strip film guide which replaces the standard 35 mm slide holder. Figure 187 is a close-up of the strip film guide, illustrating the under cut rollers which prevent scratching of the emulsion. Note that the film is restrained only at the area of sprocket perforations, with liberal clearance in all areas where emulsion damage could occur.

The film holder was constructed of PVC,² with the rollers constructed from stainless steel.³ The device is a simple machine operation, easily fabricated in the average small shop. The modification is inexpensive, and has been successfully used to review many thousands of feet of processed film obtained with the ALVIN submersible.

Figure 186. 35mm Strip Film Passing Through Guide Assembly

Figure 187. Film Guide for 35mm Strip Projector

References and Manufacturing Vendors
Section 14, Accessory for the Review of 35 MM Film Strips

1. Slide Projector (Signet 500)
 - A. Eastman Kodak Co., Rochester, N. Y.
2. PVC (Polyvinyl Chloride Type I)
 - A. Como Plastics, Inc., Richmond Hills, N. Y.
 - B. General Tire & Rubber Co., Lawrence, Mass.
3. Corrosion Resistant Steel
 - A. Republic Steel Co., Cleveland, Ohio
 - B. P. A. Frasse & Co., Lyndhurst, N. J.

15.0 Vehicle Position and Attitude Indicators

The direct observation of deep ocean topography, frequently requires the use of a known position reference. For example, the science observer viewing the sand ripples illustrated in Figure 188 would like to determine the direction of the ripples with reference to a known standard. When photographing the scene for later evaluation, he requires some means to determine the vehicle altitude as well as the camera tilt at the time of the photograph.

To supply this information, the following devices have been installed on the ALVIN vehicle. Figure 189 illustrates a circular bulls-eye or spirit level which provides the observer with a visual tilt angle reference. The compass assemblies illustrated in Figure 190, provides the observer with a directional indication with reference to magnetic north.

Both devices are mounted on the science rack. They are positioned in the field of camera view, providing a permanent record of the vehicle attitude and direction at the time of the photograph. To assure proper operation, the compass must be mounted far enough from the steel personnel sphere, to prevent magnetic interference.

The spirit level is unaffected by external fields, and maybe positioned to satisfy the camera field of vision. If vibration is a problem, it may require the use of a more viscous fluid to assure proper dampening.

Figure 191 illustrates the circular spirit level mounted at the front of the vehicle. It provides the pitch and roll attitude of the submersible, with reference to a simulated horizontal plane. Figure 192 is a bottom photograph illustrating one example of the orientation information, provided by the compass and spirit level cluster mounted on the science rack. The compass in the photograph clearly indicates the wing of the aircraft is positioned in a North-South direction. It also provides the submersible operator with a simple guidance device for "driving" from the window of the vehicle, without constantly moving his eyes to an indicator mounted within the personnel sphere.

15.1 Construction Details for a Pressure Compensated Spirit Level

The spirit level illustrated, was constructed from the plastic base,¹ glass hemisphere,² mineral oil,³ and a chemically

Figure 188. Bottom Photo of Sand Ripples

Figure 189. Assembled View of Pressure Compensated Bulls-Eye Spirit Level

Figure 190. Deep Water Pressure Resistant Magnetic Compass Assemblies

Figure 191. Bulls-Eye Spirit Level Mounted on Science Rack

Figure 192. Bottom Photograph of Rack Mounted Magnetic Compass

Figure 193. Exploded View of Pressure Compensated Bulls-Eye Spirit Level

blackened⁴ brass ball.⁵ Figure 193 is an exploded view of the various parts used in the assembly. The base was constructed by machining a shallow concave radius on the front face of a plastic disc. The curvature or depth of cut is determined by the full scale deflection (number of degrees of tilt) that is required. The spirit level illustrated, had a full scale deflection of eight degrees, four degrees each side of center. The inked circle,⁶ or half scale point was located at two degrees.

An "O" ring groove is machined in the front face to mate with the base of the glass dome. Sealing should be at the bottom surface of the hemisphere to provide a cushion for the glass. Figure 194 is a cross-section of the level, illustrating the major points of construction. The "O" ring sandwiched between clamp ring 1 and dome 2, helps to cushion and prevent fracture of the glass during handling.

After machining, the concave surface is lightly hand lapped to obtain a fine grain mat finish. Hard felt or leather, impregnated with a mixture of water, tooth powder or scouring powder, will give satisfactory results. A mat surface is necessary to assure clean ink lines. If a polished surface is used, the plastic marking ink puddles in small droplets. It will not run a clean cut line.

A pressure transfer hole Item 3 is drilled between the upper and lower chambers. A thin plastic diaphragm, 1/32 to 1/16 inch thick, is cemented⁷ in the base of the assembly. An "O" ring seal head screw⁸ is used to prevent leakage at filler port 5. To prevent hydrostatic pressure from crazing or cracking the plastic base, the blind tapped holes used to mount the clamp ring, must be vented as shown by Item 6.

Depending on the vibration and period of motion expected, the viscosity of the compensating fluid maybe varied to fit the requirements. Clear colorless light grade mineral oil was found to be satisfactory fluid for the device illustrated. It is available in various grades, ranging between light, heavy, and extra heavy. Kerosene or compass oil⁹ maybe used for those applications requiring a rapid or undampened motion.

The plastic diaphragm located in the base, has sufficient resiliency to accommodatethe slight compression effect of the oil when operating on a deep dive. It also provides sufficient compensation to minimize the effect of small bubbles left in the oil. For best results, complete venting and bubble removal

Figure 194. Cross Sectional Sketch of Bulls-Eye Level

is considered advisable. When mounting the tilt indicator, the vessel must be level. The lubber lines are positioned along the longitudinal and athwartship axis of the vessel.

15.2 Magnetic Compass

The magnetic compass assemblies illustrated in Figure 190 are commercially available devices.¹⁰ To facilitate mounting, the bases are drilled and tapped for conventional machine screws. Similar to the spirit level, the glass enclosures are liquid filled hemispherical sections, which provide good visibility and magnification of the magnetic needle when viewed underwater.

The lower compass assembly does not have a true pressure compensation feature, it depends partially on its structural strength, and the complete void-free filling of the internal cavity with dampening fluid. The device is extremely reliable and will withstand considerable rough usage.

The upper compass assembly is a true pressure compensated device having a diaphragm built into the bottom of the plastic base. Due to the construction of its indicator card, its best field of view is from a vertical position.

If the compass must be positioned some distance from the observer, the wide indicator needle illustrated by the lower compass is considered to be superior. If better accuracy is desired, and the compass can be mounted close to the observer without interference from magnetic structures, the upper compass maybe used.

15.3 Mechanical Altitude Indicator

Figure 195 is an artist sketch of a "Mechanical feeler" altitude mechanism, used to determine the height of the vehicle from the bottom. Basically, the device consists of a indicator dial and pointer assembly, which is attached to the vehicle within the operators field of view. The pointer is driven by a small rack and pinion mechanism¹¹ mounted at the rear of dial. The rack is connected to a length of flexible "push-pull" armored cable.¹² Figure 196 is a photograph of the dial and pointer assembly, with the push-pull flexible cable extending to the right of the illustration. The cable turns downward in a gentle loop, and is shown attached to the feeler mechanism.

Figure 197 is a close-up of the "feeler" lever mechanism

Figure 195. Artist Sketch of Mechanical Altitude, Feeler Rod Mechanism

Figure 196. Altitude Indicator Dial and Pointer Assembly

Figure 197. Feeler Lever Mechanism

illustrating the method of attachment to the motion transmitting push-pull cable. To assure the smooth transmission of linear motion, the core of the flexible cable was removed and a light film of Lubri-Plate grease applied to all rubbing surfaces.

In use, the operator flies the vehicle to the bottom until the extended feeler contacts the ocean floor. As the submersible slowly cruises along the ocean bottom, the feeler measures the distance between the base of the vehicle skids and the bottom sediment. The distance is mechanically transmitted to the indicator pointer. The operator reads the true vehicle altitude above the bottom, by observing the indicator read-out scale through the vehicle port light.

Deep water vehicle operation indicated the original mechanism had excessive "slop" in the bearings, gears, and transmission cable. It was difficult to zero-out and calibrate. Once in the water, the altitude reading would not repeat due to the excessive clearances between operating components. Some "stickiness" was also noticed between the motion transmitting cable and its outer protective sheath.

In view of the simplicity of the device, it would appear that it could be made to operate satisfactory with some minor re-design to the mechanical components. One item however, should be kept in mind if the operator intends to apply this mechanical measurement principle. With the present design, the vehicle is unable to back-down without digging the feeler probe into the bottom sediment.

The device is a fairly delicate mechanism and is unable to withstand the compression and bending loads applied to the feeler as the vehicle moves backward. As illustrated by the sketch, any bending of the feeler probe would immediately change the read-out accuracy of the device. One possible fix however, might be to attach a small wheel at the end of the feeler.

References and Manufacturing Vendors
Section 15, Vehicle Position Attitude Indicators

1. Plastic (Acrylic)
 - A. Rohm & Hass "Plexi-Glass", Washington Square, Philadelphia, Pa.
 - B. National Plastifab Inc., Burlington, Mass.
2. Glass Hemispheres
 - A. Corning Hydrospace Products, Corning, N. Y.
 - B. Thermal American Fused Quartz, Co., Montville, N. J.
3. Mineral Oil
 - A. Local Purchase
 - B. E. R. Squibb & Sons, N. Y., N. Y.
4. Chemical Brass Blackening Fluid
 - A. Birchwood Casey Co., Minneapolis, Minn.
5. Solid Brass Spheres (Balls)
 - A. Industrial Tectonics, Inc., Ann Arbor, Mich.
6. Plastic Marking Ink
 - A. Makepeace Inc., Boston, Mass. (Pelican type 9120K, Black)
 - B. Phillips Process Co. Inc., Rochester, N. Y.
7. Acrylic Plastic Cement
 - A. Methylene Chloride (Dichloromethane)
Allied Chemical, General Chemical Div., Morristown, N. J.
8. "O" Ring Seal Pan Head Screws
 - A. Long-Lok Corp., Los Angeles, Calif.
9. Compass Fluid
 - A. Robert E. White Instruments Inc., Boston, Mass.
10. Compass Assemblies, Deep Water Devices
 - A. E. G. & G., Div. Geodyne, Waltham, Mass.
 - B. Taylor Instrument, Asheville, N. C.
11. Rack and Pinion Gears
 - A. Boston Gear Works, Quincy, Mass.
12. Armored "Push-Pull Cable"
 - A. C. E. Beckman, New Bedford, Mass.

B. American Chain & Cable, Automotive & Aircraft Div.,
Detroit, Mich.

13. Lubri-Plate Grease (130-AA-L-702)

A. Fiske Brothers Refining Co., Newark, N. J.

Figure 198. Savonius Current Meter Mounted on Sail of Deep Submersible

16.0 Current Observations from a Deep Submersible

Bottom and mid-water current patterns, can be measured or observed by science personnel operating with a deep submersible. Current patterns are provided by using dye materials, while current velocity measurements can be obtained using mechanical measuring devices.

Initial bottom current observations from the ALVIN vehicle, were accomplished using a savonious current meter.¹ Figure 198 illustrates the rotor sensor mounted on the top forward section of the sail, just above the flood light. The electrical read-out, or current velocity indicator is located within the vehicle. It provides current measurements between a span of 0.05 to 7.0 knots.

When setting on the bottom, the vehicle must face into the current to decrease turbulence. The sensor being mounted on the sail, is somewhat effected by the disturbed water flow around the sail. The rotor sensor, being several meters off the bottom, does not provide a true indication of the actual bottom current.

16.1 Mechanical Device for Bottom Current Measurement

To provide true bottom current measurements, the device illustrated in Figure 199 is used. It is placed on the bottom in the area of interest. A simple trip latch at the base of the rotor is activated by the manipulator fingers, allowing the rotor to revolve. The vehicle backs off, positioning the indicator up-current of the submersible.

A strip of scotchlite reflective tape² is attached to the rotor. The reflected flashes from the vehicle lights, representing the revolutions of the rotor, are counted against a stopwatch. The device indicates current flow, but not the direction of flow.

Figure 200 is an artist conception of a bottom current meter having the following advantages. A magnetic compass card,³ housed in an oil filled pressure compensated plastic chamber, provides a direct indication of magnet north. The weather vane and pointer at the top of the assembly, indicate the direction of current flow. To prevent bearing damage while out of water, the trip latch at the base of the assembly provides a positive rotor lock. It prevents excessive rotor velocities due to deck and surface wind currents.

The savonious rotor, like other rotative devices having

Figure 199. Savonius Current Meter Modified for Bottom Use

Figure 200. Savonius Meter with Magnetic Compass and Current Direction Indicator

Figure 201. Photograph of Simulated Manipulator Finger Squeezing Plastic Dye Container

inertia, does not respond to rapidly changing water flow. The device smooths out turbulence and other minor variations, providing the observer with an average current velocity.

To visually observe rapidly changing current patterns, a mechanism having low inertia is required.

16.2 Dye Trace Current Indicators

To provide a low inertia device for the investigations of bottom and mid-water current patterns, a solution containing fluorescein dye⁴ is used.

The mixture is placed in a plastic squeeze bottle,⁵ and attached to the mechanical manipulator. Fluorescein ejection is provided by squeezing the manipulator fingers. Figure 201 illustrates the mechanics of discharging the dye from a plastic squeeze bottle. The finger assembly illustrated in the photograph, represents the squeeze action applied by the mechanical manipulator fingers.

Figure 202 illustrates the first assembly employed on the submersible. The plastic squeeze bottle is shown mounted between the fingers. The two thermistor probes are used to determine the water temperature at the area of dye ejection. They are mounted in the same horizontal plane as the discharge nozzle.

The dye mixture consists of a saturated solution of water and fluorescein. The specific gravity of the solution is adjusted to be equal to the specific gravity of the seawater. The plastic bottle must be completely filled to prevent collapse as the vehicle descends. A small dab of wax or thick water pump grease on the nozzle tip, prevents "Bleeding" of the fluid until the container is actually squeezed.

In addition to acting as a non-inertial indicator to illustrate current patterns, the dye trace can be used to measure velocity. The dye is injected into the current stream in spurts, and the time for each puff to move between two known points is accurately measured.

Figure 203 illustrates a bottom current investigation using a fluorescein saturated solution, a metal container, and a tubular chimney. It was not a controlled discharge, it represents the dense cloud that can be obtained using a fluorescein material.

Figure 202. Squeeze Bottle with Dye Mounted on Vehicle Manipulator

Figure 203. Bottom Photograph of Dye Cloud Swirling from Generator Can

Figure 204. 3 Barrel Tubular Dye Pellet Dispenser

16.3 Tubular Dye Trace Pellet Dispenser

To perform meaningful experiments, a means of dispensing controlled quantities of dye is required. Figure 204 represents a tubular pellet dispenser. Each rod is capable of releasing 5 dye pellets. The dispenser is mounted on the science rack of the submersible as illustrated in Figure 205.

The dispensers are swivel mounted to provide a self-alignment when the manipulator grasps the pull-ring on each pellet rod. The individual rods are drilled to accept a preformed, compressed fluorescein powder pellet.

To charge the assembly, the pellets are inserted into the drilled cavities. The rod is slowly inserted into the external tube, while simultaneously filling the tube with kerosene. An "O" ring at each end of the pellet rod retains the kerosene within the sheath, preventing the seawater from contacting the pellets. The outer tube is open at both ends to prevent pressure lock. Circular white stripes are painted at each pellet rod cavity. They establish a visual withdrawal stop for the operator.

Normally the pellets are released individually. As they descend through the water they produce a visible dye trace representing the current pattern in the vertical water column. When used with the submersible, the dye provides the science observer with the opportunity of observing both mid-water and bottom current patterns.

Figure 206 illustrates a dye pellet mold used to form the individual tablets. A small quantity of fluorescein powder, type 8015 is poured into the dye cavity. The ram is inserted and used to compress the powder into a pellet form. The compressed pellet is shown between the dye and the striker plate.

The pellets molded in the original cavity, are of greater density than seawater. They slowly sink when released. To provide the science observer with a more versatile tool, provisions have been included to mold pellets that may be either positive or neutrally buoyant.

Figure 207 illustrates the split mold used to form the buoyant pellets. The teflon pin shown at the lower center of the photograph, is inserted into the split striker plate base. The powder is compression molded around the pin, firmly imbedding it into the fluorescein material.

The tablet and pin assembly is removed and inserted in the molding fixture illustrated in Figure 208. Liquid paraffin⁶

Figure 205. Science Rack with Dye Pellet Dispenser for Mid-Water Current Investigation

Figure 206. Dye Pellet Compression Mold

Figure 207. Split Compression Pin Mold for Buoyant Dye Pellets

Figure 208 Split Mold for Paraffin Float

Figure 209. Rotary Dye Pellet Dispenser Mounted on Science Rack

is poured into the cavity, forming a buoyancy float. On cooling, the teflon pin is firmly embedded in the paraffin. Buoyancy variations are achieved by shaving or slicing sections off the paraffin, until the desired conditions are obtained.

16.4 Rotary Dye Trace Pellet Dispenser

Figure 209 illustrates an improved dye pellet release mechanism. It will dispense up to 30 trace tablets. In use, the mechanical manipulator alternately depresses the two round pedals. One releases a single pellet, and the other rotates the drum to position a new pellet in the drop position.

Figure 210 illustrates the operational functions of the various assemblies. Item 1) The index roller, engages the triangular notches machined in the outer edge of the dispenser drum. It establishes a fixed stop every 12 degrees of drum rotation. 2) The dye pellet ejector pin, is actuated by depressing the forward pedal. It is shown in the depressed, (eject) position. 3) The pawl latch at the upper right, mates with the milled slots in the drum. It rotates the assembly 12 degrees, which is one pellet cavity, each time the back pedal is depressed.

Figure 211 is a back view of the rotary dispenser, illustrating the simple lever actions used to operate the device. To prevent collapse at depth, note the liberal use of vent holes in the welded tubular structure.

Figure 212 is a cross-sectional sketch of the rotary drum, Item 1. The upper dye pellet Item 2, represents a typical fluorescein tablet that is heavier than seawater. It will descend in the water column when ejected. To protect the pellet from seawater contact as the vehicle descends, a plastic cap plug Item 3 is snapped over the exposed notch of pin 4. The plug and pellet assembly is pressed into the rotary drum as shown, and the cavity filled with kerosene. Filling should be complete, as the fluid also provides pressure compensation.

To seal the assembly and prevent fluid loss, cap-plug 5 is pressed into the opposite end of the cavity. Note the flange has been removed from around the base of the cap plug.⁷ If the flange is not removed, the ejection pin will be unable to push the dye pellet and plug through the drum when the pedal is depressed.

The lower dye pellet illustrates an assembly having either a neutral or positive buoyancy, depending on the volume of the

Figure 210. Disassembled View of Rotary Dye Pellet Dispenser

Figure 211. Back View of 30 Pellet Rotary Dispenser

Figure 212. Cross Sectional Sketch of Drum, with Pellets positioned in Dispenser Cavities

paraffin float, Item 6.

The paraffin float and cap plug 7 are molded to the nylon pin and dye pellet as a single assembly. When inserted in the dispenser drum, the cavity is filled and sealed exactly as the previous trace pellet.

Compressed fluorescein tablets maybe stored in a container filled with kerosene. Tablets have been fluid-stored for periods as long as 1 year, without mechanical degradation.

16.5 Sea Bed Drifters

Figure 213 illustrates an all plastic sea bed drifter used to investigate the movement of sea bed currents.⁸ Figure 214 is a typical science tray rigged to perform bottom current investigations. The mushroom shaped drifters "floating" above the tray, are secured to the frame using rubber bands.

At the selected site of release, the mechanical manipulator frees the drifters.⁹ A small weight at the lower end of the stem provides a slight negative buoyancy to the device. The drifters move over the sea bed with the "tail" just touching the bottom. The science observer visually follows the drift pattern from the submersible.

Figure 213. Plastic Sea-Bed Drifters

Figure 214. Typical Science Tray Rigged to Dispenser Sea-Bed Drifters

References and Manufacturing Vendors
Section 16, Current Observations from a Deep Submersible

1. Current Meters
 - A. Hydro Products, San Diego, Calif.
 - B. Braincon Corp., Marion, Mass.
 - C. Marine Advisors Inc., La Jolla, Calif.
 - D. Geodyne, Waltham, Mass.
2. Reflective Pressure Sensitive Tape (Scotch-Lite Silver, #3270)
 - A. Minnesota Mining & Manufacturing, St. Paul, Minn.
3. Magnetic Compass Accessories
 - A. Robert E. White Instruments Inc., Boston, Mass.
 - B. M. Low Inc., New York, N. Y.
4. Fluorescein Dye (Powder Type #8015)
 - A. New York Color & Chemical Co. Div., American Dyewood Co., Belleville, N. J.
5. Plastic Containers
 - A. Agile Div. Nalge/Ritter Pfaudler Div.
Rochester, N. Y.
 - B. Cole-Parmer Instrument and Equipment Co., Chicago, Ill.
6. Paraffin (Preserving Wax)
 - A. Local Hardware
 - B. Gulfwax, Gulf Oil Corp., Gulf Building, Pittsburgh, Pa.
 - C. Scientific Glass Apparatus Co. Inc., Bloomfield, N. Y.
7. Cap Plugs (Plastic)
 - A. Caplug Division, Protective Closure Co. Inc., Buffalo, N. Y.
 - B. Sinclair & Rush Inc., St. Louis, Missouri
8. The Sea Bed Drifter, by A. J. Lee, Dean Bumpus, L. M. Lauzier, International Commission for Northwest Atlantic Fisheries, Research Bulletin #2, 1965
9. Sea Bed Drifters
 1. Insultag Inc., Woburn, Mass.

Figure 215. Solenoid Actuated Reversing Thermometers

17.0 Temperature Measuring Devices

Temperature measurements during the majority of deep water missions performed by the ALVIN vehicle, have been provided by a Hydro Products model 403 Thermistor Sensor, and a model 401 Read-out Indicator located within the personnel sphere. The accuracy of the device is considered as $\pm 1.6^{\circ}\text{C}$ throughout the range of 0° to 40°C .

On several occasions, science personnel have required greater accuracy while performing a particular phase of an investigation. To accommodate this, a solenoid actuated reversing thermometer mechanism was devised.

17.1 Solenoid Actuated Reversing Thermometer Assembly.

The device illustrated in Figure 215 provides a science observer with the means of obtaining an accurate temperature reading at some exact location and depth of his own choosing. The device consists of two reversing thermometer frames actuated by solenoids. ¹ Either of the two pairs of frames maybe tripped from within the submersible, on command of the operator.

The trip mechanism consists of a simple solenoid release mechanism. Figure 216 is an artist sketch of the device. Actuating the solenoid, draws the spring loaded plunger into the winding cavity, releasing the thermometer frames which fall by gravity.

The device requires an impulse of 30 volts D. C. to trigger the release. The current drawn at release is approximately 9.5 amperes. It does not require power except when actuated.

To prevent possible damage to the glass thermometers,² a piece of soft sponge rubber is cemented to the frame. The rubber bumper cushions the device as it reaches the end of its reversing cycle.

17.2 Thermistor Temperature Profile Probe

Figure 217 is an artist conception of a proposed sediment temperature probe designed for operation with a deep submersible. The concept consists of 5 thermistor beads isolated from, and attached to, a hollow stainless steel probe. The instrumentation housing, and read-out device is attached at the top of the probe.

In use, the ALVIN manipulator grasps the tee handle at the top of the housing, inserting the probe into the bottom sediment.

Figure 216. Cut Away Sketch of Reversing Device

Figure 217. Artist Sketch of Bottom Sediment Probe

Figure 218. Plastic Probe for Use with Resistivity Sonde

The 5 thermistors are automatically sequenced from 1 through 5, each reading the temperature at its particular level in the sediment. Temperature read-out is provided by a self-contained nixie tube circuit located in the instrument housing at the top of the probe. The outer case of the instrument housing is a glass cylinder, which provides direct viewing of the indicators by the science observed within the submersible.

Five pilot lamp assemblies are positioned vertically within the glass instrument housing, adjacent to the nixie tube indicator. As each thermistor bead is sequenced to provide a temperature reading, a corresponding pilot lamp assembly is illuminated, indicating the thermistor that is in the circuit.

17.3 Sediment Resistivity Sonde

Figure 218 illustrates the probe assembly of the Woods Hole-Schlumberger resistivity sonde. The device is attached to the base of a deep submersible, and provides a means of locating anomalous bottom waters and pore waters. The device is capable of measuring the electrical resistivity of sediment to a maximum depth of penetration of approximately 30 cm. Figure 219 illustrates the plastic probe positioned between the skids of the ALVIN vehicle.

The probe is attached to a leaf spring assembly which exerts a positive downward pressure, holding the apparatus firmly in contact with the bottom sediment. Varying temperatures and/or the seepage of fresher waters moving through the bottom sediments, provide a direct indication on a sensitive A. C. read-out device located within the personnel sphere.

The device performed satisfactory throughout the dive series. However, soft sediment adhering to the bottom of the plastic probe did result in some erroneous readings toward the end of several dives. This is considered as a minor problem, and will be corrected by directing a stream of water over the bottom face of the probe. The water jet will remove any residue mud or sediment that remains after completing a resistivity measurement. The water jet will be controlled by the operator, and will be turned off before positioning the "clean" probe on a new sediment area of interest.

Figure 219. Resistivity Probe Mounted on Deep Submersible

References and Manufacturing Vendors
Section 17, Temperature Measuring Devices

1. Solenoids
 - A. Benthos, Inc., North Falmouth, Mass.
2. Reversing Thermometers
 - A. Richter & Wiese, Berlin, Germany
 - B. Kahl Scientific Instrument Co., El Cajon, Calif.
 - C. Negretti & Zambra Ltd., London, England
3. W. H. O. I. - Schlumberger Resistivity Sonde
 - A. Read-out Device: Type EMT-D
Schlumberger Well Surveying Corp., Houston, Texas
4. W. H. O. I. Publication 67-80 ALVIN Dives on the Continental Margin off the Southeastern, United States,
J. D. Milliman, F. T. Manheim, R. M. Pratt, E. F. K. Zarudzki.

Figure 220. Slant Range Circular Slide Rule

18.0 Slant Range Circular Slide Rule

The slide rule illustrated in Figure 220, provides the surface controller of a deep submersible, with a simple and rapid means of computing the horizontal distance between the tender and a submerged vehicle.

18.1 Operation of the Distance Determining Device

Figure 221 illustrates the typical navigational triangle that exists between the deep submersible and its tender. In its simplified form, the surface controller determines the length of leg "C", by measuring the time required for a sound pulse to travel from the submersible to the tender. The base of the triangle "A", is determined by the depth gage on the submersible. It is transmitted to the surface controller by the pilot of the submersible on the underwater telephone.

The data is dialed into the slide rule, which automatically solves for altitude "C" on the slant range triangle. The relative bearing of the submersible from the tender, is provided by a trainable line hydrophone located below the two hulls of the tender. With the information provided, the surface controller can accurately plot the relative position of the submersible from the tender.

Figure 221. Navigation Tri-Angle of a Typical Submerged Vehicle

19.0 Design Data for Pressure Resistant Housings¹

The information presented in this section, will furnish the user with sufficient design data to fabricate a variety of pressure resistant instrument housings. Depending on the housing diameter and material selected, the design curves will provide the wall and end cap thickness necessary to withstand the external pressure at the selected depth of operation.

To assure accuracy, separate curves are presented for end cap closures and housing fabrication from 302, 304 and 316 series stainless;² 6061-T6, 2024-T3, and 7075-T6 aluminum alloys,³ as well as the titanium series 6AL-4V.⁴ A separate design curve has been included for end caps or windows constructed of acrylic plastic.⁵

Curves for determining the displacement of spheres and cylinders, provides the user with a ready reference in determining the approximate water weight of the completed instrument housing.

Several rule of thumb curves provide information on the compressibility of fluids. The data furnishes the user with a simplified means of determining the quantity of additional fluid that must be added to a system to compensate for the "apparent fluid loss" due to compressibility.

A simple working example concerning fluid compressibility, would be the bottom flood lamp described in Section 6, Deep Water Illuminating Devices. If additional oil was not used to "top-off" the compensation chamber, the neoprene diaphragm could depress to a concave condition, as a result of the hydrostatic pressure encountered at 6,000 feet. The concave distortion would force the diaphragm against the tops of the batteries and their connecting cables, possibly resulting in a rupture of the neoprene material.

19.1 Collapse Depths of Long Tubes

The following pages of curves give the collapse depths of long cylindrical tubes in terms of the thickness - diameter ratio for various materials. A long tube is defined as one whose length is greater than

$$L = 4.90 r (r/t)^{1/2} \text{ inches} \quad (\text{Ref. 6})$$

Where

r = tube radius, inches

t = wall thickness, inches

In general, each curve is in two parts, representing the two possible modes of failure. For lower values of the t/D₀ ratio, the mode of failure is elastic buckling, while for higher t/D₀ values, failure is one of yielding of the material. It should be noted that in two of the curves presented here (Aluminum 7075-T6 and Titanium 6AL-4V) the elastic buckling mode of failure governs throughout the range of ocean depth values considered.

The curves presented here are based on the following equations:

A. Elastic Buckling

$$p' = \frac{2E}{1-\mu^2} (t/D_0)^3 \quad (\text{Ref. 6})$$

Where

p' = elastic buckling pressure, p.s.i.

E = modulus of elasticity, p.s.i.

μ = Poisson's ratio

B. Inelastic Failure (Yielding)*

$$(S)_{\max.} = \left(\frac{2 b^2}{b^2 - a^2} \right) p$$

Where

(S)_{max.} = Maximum stress at inner surface, p. s. i.

p = external pressure, p. s. i.

b = outer radius of tube, inches

a = inner radius of tube, inches

*Note: In this case failure is considered to occur when (S)_{max.} is equal to the yield strength of the material.

The present curves are intended to serve as a guide to designing

(or predicting collapse depths of) cylindrical pressure cases. The actual collapse depth of a tube depends upon several factors not considered here, such as out-of-roundness, variations in wall thickness, flat spots, and flaws or lack of homogeneity in material. These defects are usually small in magnitude and may be expected to decrease collapse strengths slightly from those values given by the curves.

19.2 Collapse Depths of Flat End Caps

Cylindrical pressure cases commonly use flat circular plates as end closures. These plates usually contain some type of seal, such as an o-ring, and some means of attachment to the cylinder. For practical design purposes the equation for a flat circular plate, simply supported around its edge, can be used. The diameter used in the equation is the diameter of the unsupported plate in the actual case.

This equation is

$$(S)_{\max.} = \frac{3pa^2}{8mt^2} (3m+1) \quad (\text{Ref. 6})$$

Where

(S) max. = Maximum stress at center of plate, p.s.i.

p = external pressure (pressure uniformly distributed over plate surface) p.s.i.

a = radius of unsupported plate, inches

t = thickness of unsupported plate, inches

m = reciprocal of Poisson's ratio.

Note: Failure of plate is considered to occur when (S) max. is equal to the yield strength of the material.

The following curves for flat end caps are based on the above equation. They are arranged to present collapse depths as a function of the thickness - diameter ratio d/D_i

19.3 Illustrative Examples of Instrument Housing Design Procedures.

The following sample problems will demonstrate the procedure to be followed in using the curves included in this section.

Example 1

Determine the collapse depth of a cylindrical instrument case having an outside diameter of 6 inches, an inside diameter of 5 inches and flat end caps 1 1/8 inches thick. Material is 6061-T6 aluminum.

Solution:

- A. Tube wall thickness $t = \frac{6-5}{2} = .5$ inch
- b. Wall thickness/outside diam. ratio $t/D_o = \frac{.5}{6} = .083$
- c. In Figure 222, for $t/D_o = .083$ the collapse depth of the tube is 13,700 ft. Mode of failure is plastic yielding of the material.
- d. For the end caps, the ratio of thickness to unsupported diameter $t/D_i = \frac{1.125}{5} = .225$
- e. In Figure 227, for $t/D_i = .225$ the collapse depth of the cap is 14,400 ft. Thus, failure will occur in the tube itself at 13,700 ft.

Example 2

It is required to design a cylindrical pressure housing with flat end caps to have an operating depth of 4,500 ft. with a factor of safety of 2.0. Type 304 stainless steel is to be used, and the case must have an outside diameter of no more than 6 inches.

Solution:

- A. Applying the factor of safety, the collapse depth of the case must be $4500 \times 2 = 9,000$ ft.
- B. Using Figure 225, the t/D_o ratio for 9,000 ft. is 0.061

The wall thickness t can be found from

$$t/6 = .061$$

$$t = .061 \times 6 = .366 \text{ in.}$$

- C. A standard tube having a 6 in. outside diameter and a 0.375 in. wall thickness would probably be used. This would have a collapse depth slightly greater than required.
- D. Using Figure 230, the t/D_i ratio for the end caps is 0.188 for 9,000 ft.

The cap thickness can be determined from

$$t/5.25 = 1.88$$

$$t = .188 \times 5.25 = .987 \text{ in.}$$

End caps of 1 inch thickness would be practical to use here.

19.4 Collapse Depths of Flat Acrylic Windows

Deep-sea instrument cases, such as those which house cameras or lights, often must contain transparent windows. Commonly these are in the form of flat circular plates of clear acrylic plastic material (Plexiglas). They are of simple design, easy to manufacture, and probably only slightly less efficient than the windows of conical design which are used as observation ports in many deep-diving submarines.

Flat disc windows are usually inserted into a flange type of mounting similar to that shown in Figure 233. The window itself fits into the recess having diameter D_o , while the smaller opening of diameter D_i provides a supporting shoulder for the window and determines the window's effective size.

The curve in Figure 232 gives the depths of collapse or fracture of flat disc acrylic windows of various thickness - diameter ratios. This curve is based on the same equation as that used for the curves for flat end caps for cylindrical pressure housings (Figures 227 through 231).

The flat disc window is considered to be a flat circular plate resting on a simple support having a diameter D_i . It is expected that the curve in Figure 232 will give conservative predictions for flat acrylic windows for the following reasons:

- A. The assumption of a simply - supported plate is conservative, since the outer edge of the plate is forced against the shoulder, which tends to produce a clamped-edge condition.

- B. Recent experimental results (Ref. 7) indicate that flat acrylic windows have substantially higher strength values than those given by Figure 232. Tests show that the mechanism of failure is fairly complex and occurs in several stages over a range of increasing pressures. The curve in Figure 232 is based on simple tensile failure on the low pressure face, which corresponds roughly to the first stage of failure as observed in the tests.

The tests of Reference 7 were performed under conditions of short term pressure application with a pressurization rate of 600-700 p.s.i. per minute. Tests using other conditions of loading have not been completed. Because of this, it has been recommended that a factor of safety of at least four be used in designing flat acrylic windows.

19.5 Displacement of Spheres and Cylinders in Seawater

In the design of underwater housings for devices such as cameras, lights, current meters, etc., it is almost always desirable to have information concerning weights and displacements for the various geometric shapes used. If this information is known, the weight in water (or the net lifting force) of an instrument case can be calculated. Since housings for deep-ocean use are usually spherical or cylindrical in shape, displacement curves for these configurations are included in this section. The curves illustrated in Figures 234 and 235 are based on the well-known volume equations for sphere and cylinder. Arranged to express displacements in terms of outside diameters, these equations are

$$D_{\text{sph}} = \frac{d^3}{162} ,$$

and

$$D_{\text{cyl}} = \frac{d^2}{9} \text{ per foot of length.}$$

In both cases the units for D are pounds of displaced seawater, and those for d, inches of outside diameter.

In use, the net buoyancy B can be found by subtracting the air weight W of the package from the displacement D as found from the curves.

19.6 Compressibility of Liquids

Although in some applications liquids are said to be "practically incompressible", in most oceanographic and deep-submersible work the compressibility (roughly speaking, the change in volume for a given change in pressure) of liquids must be taken into account. Compressibility values are useful in determining, for example, the amount of additional fluid which must be added to a pressurized system to compensate for the apparent loss due to the reduction in volume of the liquid. Thus, in a pressure-compensated deep ocean housing, such as an oil-filled battery case, enough excess oil must be provided initially so that the required volume of oil will be available under conditions of higher pressure.

The curves in Figures 236, 237, and 238 present data on compressibility of hydraulic oil (Ref. 8) and fresh and salt water (Ref 9)

If great accuracy is not essential and if a reasonable estimate of volume change is sufficient, the following "rule of thumb" maybe used:

- A. For hydraulic oil, average reduction in volume is $1/2$ percent per 1000 p.s.i.
- B. For water, average reduction in volume is $1/3$ percent per 1000 p.s.i.

19.7 Hydrostatic Test Requirements for Implodable Containers.¹⁰

To assure the safety of the submersible and the operating personnel, all pressure resistant instrument housings must be hydrostatically tested. Each housing must demonstrate its ability to satisfactorily resist an external pressurization 1.5 times the maximum anticipated operating depth.

The test cycle is performed in the following sequence:

1) Nine (9) pressure cycles from zero to 1.5 times the maximum external operating pressure, holding each cycle at the peak pressure for a 10 minute period. 2) One (1) pressure cycle from zero to 1.5 times the maximum external operating pressure, holding the peak pressure for a 60 minute period.

No physical distortion of the case, end closures, windows, or electro-mechanical penetrators is permitted. At the completion of a satisfactory test series, all pertinent data must be documented for inclusion with the submersible's operation dive file. Instrument housings that do not have a certified pressure test document, are not considered acceptable for use with a manned deep water submersible.

Theoretical calculations have been performed on the implosion effect resulting from the failure of a 10 inch diameter spherical container, exposed to a hydrostatic pressure equal to a 6,000 foot depth. The potential energy attained during the failure could reach peak values as great as 119,000 foot pounds. While the pulse is of short duration, the shock wave created by a failure of vehicle mounted equipment, could conceivably damage the submersible. In view of the damage potential, the need for careful handling and pre-dive testing should be considered as an item of considerable importance.

Figure 239 is a conversion curve for determining the seawater pressure at various operating depths. It has been included as an aid in determining the proper test range for pressure resistant instrument housings.

Figure 222. Collapse Depth of Long Cylindrical Tubes Aluminum Alloy 6061-T6
Yield Strength 40,000 psi

Figure 223. Collapse Depth of Long Cylindrical Tubes Aluminum Alloy 7075-T6
Yield Strength 73,000 psi

Figure 224. Collapse Depths of Long Cylindrical Tubes Aluminum Alloy 2024-T3
Yield Strength 50,000 psi

Figure 225. Collapse Depth of Long Cylindrical Tubes Stainless Steel Types 302, 304, 316 Yield Strength 35,000 psi

Figure 226. Collapse Depths of Long Cylindrical Tubes Titanium Alloy 6AL-4V
Yield Strength 125,000 psi

Figure 227. Collapse Depth of Flat Circular End Caps Aluminum Alloy 6061-T6
Yield Strength 40,000 psi

Figure 228. Collapse Depth of Flat Circular End Caps Aluminum Alloy 7075-T6
Yield Strength 73,000 psi

Figure 229. Collapse Depth of Flat Circular End Caps Aluminum Alloy 2024-T3
Yield Strength 50,000 psi

Figure 230. Collapse Depth of Flat Circular End Caps Stainless Steel Type 302, 304, 316 Yield Strength 35,000 psi

Figure 231. Collapse Depth of Flat Circular End Caps Titanium Alloy 6AL-4V
Yield Strength 125,000 psi

Figure 232. Collapse Depth of Flat Acrylic Windows Material: Grade "G"
 Acrylic Tensile Strength 10,000 psi

Figure 233. Mounting Configuration for Flat Acrylic Windows

Figure 234. Displacement of Spheres in Sea Water Pounds Displacement vs. Diameter in inches

Figure 235. Displacement of Cylinders in Sea Water. Pounds Displacement per Foot of Length vs. Diameter in Inches

Figure 236. Compressibility of Sea Water Percent Reduction in Volume at Various Pressures

Figure 237. Compressibility of Fresh Water Percent Reduction in Volume at Various Pressures

Figure 238. Compressibility of Hydraulic Fluid Percent Reduction in Volume at Various Pressures

DEPTH - PRESSURE CONVERSION CHART

Figure 239. Conversion Curve for Determining Sea Water Pressure at Various Operating Depths

How to use : Place straightedge connecting center of circle and known value on one of the scales. Straightedge then indicates desired values on other scales.

References and Manufacturers
Section 19, Pressure Resistant Housing Design

1. Unpublished Notes on Instrument Housing Design, A. G. Sharp, Research Associate, Woods Hole Oceanographic Institution.
2. Corrosion Resistant Alloys: Bar, Sheet, Tubular, Rod
 - A. International Nickel Co., N. Y., N.Y.
 - B. AMSCO Div. Abex Corp., Chicago Heights, Ill.
 - C. Janney Cylinder Co., Philadelphia, Pa.
 - D. Latrobe Steel Co., Latrobe, Pa.
 - E. Ohio Steel Foundry Co., Springfield, Ohio
3. Aluminum Alloys, Bar, Sheet, Tubular, Rod
 - A. Aluminum Co. of America, Alco Bldg., Pittsburgh, Pa.
 - B. Edgecomb Steel & Aluminum Corp., Hillside, N. J.
 - C. Pfister Alum. Tubing Corp., Paterson, N. J.
 - D. Reynolds Metals Co., Richmond, Va.
4. Titanium: Bar, Sheet, Tubular, Rod
 - A. Titanium Metals Corp. of America, N. Y., N. Y.
 - B. Minerals Research Corp., Orangeburgh, N. Y.
 - C. Kennametal Inc., Latrobe, Pa.
 - D. Alloy Metals Inc., Detroit, Mich.
 - E. United Mineral & Chemical Corp., N. Y., N. Y.
5. Plastic (Acrylics) Bar, Sheet, Tubular, Rod
 - A. Polymer Products, Co., Oakland, Calif.
 - B. Ace Plastic Co., Inc., Jamaica, N. Y.
 - C. American Cyanamid Co., Wakefield, Mass.
 - D. Union Carbide Corp., Plastic Div., N. Y., N. Y.
 - E. Gering Plastics Co., Kenilworth, N. J.
6. Roark, Raymond J., "Formulas for Stress and Strain", McGraw-Hill Book Co., 1965.
7. Stachiw, J. D., Dunn, G. M., and Gray, K. O., "Windows for External or Internal Hydrostatic Pressure Vessels, Part II: Flat Acrylic Windows Under Short-Term Pressure Application", Technical Report R527, U. S. Naval Civil Engineering Laboratory, Port Hueneme, California, May, 1967.
8. Fluid Power Data Book, Womak Machine Supply Company, Dallas, Texas, 1967.
9. Wilson, W., et al, "Specific Volume, Therman Expansion, and Isothermal Compressibility of Seawater", Technical Report NOLTR66103, U. S. Naval Ordnance Laboratory, White Oak, Maryland, June 1966.

10. A Technical Guide to the Deep Submergence Research Vehicle (DSRV) ALVIN for Use in Planning Scientific Missions, Woods Hole Oceanographic Reference 67-67, C. L. Winget, M. J. McCamis.

20.0 Construction Kinks and Materials of Fabrication

The hardware, materials, and construction procedures covered in this section, have been successfully used to assemble the various mechanical tools and accessories designed for the deep submersible ALVIN.

The hardware, as well as material vendors, have all demonstrated satisfactory performance in deep ocean environments. However, other "like-items" are commercially available, and, if carefully selected they should perform as well as the original components.

20.1 Fluids and Greases for Use with Deep Water Apparatus.¹

Several types of fluids and greases maybe used as compensating media. A few that have been successful on the deep submersible will be covered in this section. Other fluids are undoubtedly satisfactory but have not been mentioned due to the lack of operational data.

1. Hoover² submersible fluid #2 has good dielectric properties, reasonably good lubrication for operation of electric motors with ball bearing mounted shafts, and appears to stand up fairly well when used with immersed relays. The switching of high currents however, does appear to break down the fluid as the arc is quenched. The exact mechanism of the breakdown is not known but will probably be investigated. Diode arc suppression helps considerably when switching high density currents. As a note of caution, close-coupled relay contacts may form carbon pellets or granules as spark quenching occurs and could prevent proper circuit operation as the build-up continues.
2. Royal Lubricants³ compensating fluid C-141 has been undergoing laboratory tests with fractional horsepower D. C. motors. Based on the preliminary testing, it appears to have satisfactory dielectric qualities. Additional tests will be performed to evaluate its characteristics under deep ocean environment, as well as its ability to provide efficient lubrication for sleeve and roller bearing assemblies.
3. Univolt oil⁴ series 35 and 36 are both satisfactory for general pressure compensation. They are manufactured by Esso for use as a transformer cooling medium, and have excellent dielectric strength. Univolt 36 does appear to cause a slight softening of polyethylene after prolonged exposure, but the softening is minor and should not present

any difficulty. The lubrication qualities of Univolt oil for gear train or bearing assemblies is unknown.

4. Tellus #15, manufactured by the Shell⁵, is satisfactory for use with lead-acid batteries, medium duty gear trains, and as a general pressure compensating fluid. Relays and contacts prone to arcing during operation however, have a tendency to break down the oil, forming carbon pellets or granules that frequently adhere to the contacts, decreasing the circuit reliability due to the high resistance of the carbon.
5. Silicon greases,⁶ Dow-Corning #33 and DS-4, are satisfactory for filling voids in the conventional off-the-shelf electrical connectors made specifically for deep submergence use. They do have some tendency over a period of time to form a green soap-like material around brass and copper electrical contacts. Its degradation effect on the dielectric properties of the Dow-Corning grease is not known.
6. Lubriplate⁷ grease #130AA, L-7027, is an excellent lubricant for threaded components such as nuts and bolts, as well as sleeve bearings and lip seal closures used with rotating or sliding shafts. It does not break down appreciably or wash-out after repeated exposures to saltwater and high pressures. It is an excellent seawater barrier material and is considered as the best general purpose grease available for deep submergence use. Its use, however, should be restricted to those areas having limited motion. If used as a gear box lubricant at the low temperatures normally experienced in deep water operation, it stiffens sufficiently to hamper normal operation of the component, and may overload the drive motor.
7. One final note of caution concerning the use of pressure compensating oils exposed to spark, or arc-producing devices within a closed container. Reports have been received that serious explosions have taken place during the testing of apparatus that had been previously drained of its compensating fluid. While the majority of the fluids have a high flash point, the vapors remaining within the chamber apparently have ignited as a result of commutator or relay arcing. Flushing or purging with an inert medium should be performed before an operational test is made on an "empty" container.

20.2 Syntactic Foam Buoyancy Material⁸

Items of science apparatus that require buoyancy for recovery, or floatation ability for tethering above the bottom, can use blocks of syntactic foam similar to the material used in the deep water submersibles.

The material is commercially available and consists of an epoxy resin, filled with hollow glass micro-sphere balloons.⁹ In its cured condition, the foam has good strength, high resistance to water absorption, and is capable of withstanding high hydrostatic loads. Depending on the operational depth selected, the material is commercially available in various densities ranging between 16 to 50 pounds per cubic foot.

It can be precast to the desired form, or block material maybe procured and machined to the required dimensions with conventional power tools. Machining however, is a dusty job and tools require frequent sharpening.

20.2.1 Machining, Forming and Coating of Syntactic Material

The following hints have been included to aid the operator who has not had previous experience working with syntactic floatation materials:

1. When grinding or cutting the material with power equipment, it is strongly urged that a filter mask be used to protect the lungs. For adequate protection, it should completely cover both the nose and mouth area.
2. While not considered dangerous to the skin, the dust generated by grinding does act as an irritant. It causes itching and redness after prolonged contact especially if the operator has been perspiring heavily. If at all possible, protective clothing should be worn over the normally exposed parts of the body.
3. A barrier type skin cream has been found to be quite effective in preventing irritation from the grinding dust.¹⁰
4. For long term exposure to high hydrostatic pressure, a surface sealant coat is suggested to help seal any "raw" areas exposed by the machining operation. Normally, when poured into a mold, the surface in contact with the side walls, develops a skin of resin which effectively seals

the surface. While there is some discussion both pro and con concerning the necessity of surface sealing, experience with the ALVIN vehicle tends to confirm the fact that deterioration is substantially reduced when the material has been adequately protected.

5. Imperfections such as cracks, air pockets, or cavities in the floatation material provide an entry point for seawater. After a period of time, the resin binder begins to deteriorate from the effects of seawater bacteria that feeds on the resin. Rotted foam quickly loses its strength, as well as its floatation ability as a result of the entrapped moisture. In view of this it is strongly urged that a sealant coat of some type, be used as a water barrier for all exposed surfaces.
6. Several sealants have been successfully used as the surface protective medium.¹¹ Thiolutex, Flexane, Laminar X-500, or a wash coat of resin that is compatible with the bonding agent, will adequately seal the floatation material. Keep in mind however, that excessively thick coatings add to the weight, and decrease the floatation ability of the basic material.
7. The sealant must be applied carefully as pin hole surface imperfections, or small bubbles entrapped during the mixing process, are weak points in the coating and could provide an entry point for the seawater. The elevated hydrostatic pressures encountered as the apparatus descends, ruptures the weak areas, allowing the seawater to seep between the sealant coat and the syntactic foam. On returning to the lesser pressures, the moisture trapped behind the sealant coat, puffs up or bubbles in the area of damage.
8. Several thin coats of sealant are superior to a single heavy application, as each successive coat tends to heal any imperfections in the previous coating.

20.3 Inexpensive Deep Water Floatation Devices

Oil filled plastic bottles and automotive inner tubes can be used as inexpensive throw-away floats. The devices are readily available and are reasonably easy to fill with kerosene or other inexpensive fluid.

To facilitate the back filling of the inner tube, it is suggested that a second valve be installed to aid in the complete venting of air.

Air-water filler valves¹² are commercially available for filling tractor tires with calcium chloride liquid. They are inexpensive, easily installed, and allow fluids to be injected directly into the tube.

Complete venting of all entrapped air is mandatory, if any bubbles remain within the tube, it is compressed as the external pressure increases during the descent to the bottom. Depending on the size of the original bubble, the volume change could be sufficient to cause a substantial loss of buoyancy.

20.4 Commercially Available Spherical Floatation Devices

Spherical Floatation Housings similar to those illustrated in Figure 109, maybe used separately or in groups depending on the buoyancy required. Attachment of instrumentation devices to the individual spheres, is simplified by using a fish net fabricated of strong marlin or synthetic light weight line.

The flexibility and strength of the net has the advantage of eliminating any possible build-up of stress in the float walls, which sometimes occur when using a tight metallic girth band. The net also acts as a cushion or bumper, dampening the initial contact during deck handling and while passing through the interface.

20.4.1 Glass Floatation Spheres¹³

Deep water floatation spheres fabricated from either pyrex type glass or polyethylene, are available for use at external hydrostatic pressures as great as 15,000 lbs/sq. inch. They may be obtained as complete spheres or as hemispherical sections from 3 inches to 16 inches in diameter.

The approximate buoyancy of the spherical containers ranges from 0.34 lbs. for the 3 inch size, to as high as 48 lbs. for the 16 inch diameter spheres.

20.4.2 Spherical Aluminum Instrument Floatation Housings¹⁴

Spherical Aluminum Housings are commercially available with penetrators and quick acting clamps at the girth. Sealing is provided by conventional "O"-Rings. The working depth of the spherical container is considered as 10,000 feet. The outside diameter is 10 3/4 inches, with a usable inside diameter of 9 1/2 inches.

Standard Aircraft Hydraulic Pressure Accumulators having a heavy wall aluminum construction can also be used as a pressure resistant housing for various pieces of experimental gear. The accumulators are available from most surplus houses, and can be converted with little effort. Their main drawback is the sealing area and their method of closure. Most assemblies have approximately 36 closure bolts around the firth flange. They were constructed to restrain high internal pressures, while simultaneously preventing the firth from opening and releasing the rubber diaphragm separating the two sections. With some minor machine work, the flange can be modified to accept an

"O"-Ring seal in place of the original diaphragm. The assembly maybe held together with approximately 6 to 8 bolts after being modified, or by using the clamp mechanism illustrated in Figure 245 Sketch "C".

20.5 Installation of Penetrators in Glass Pressure Resistant Housings.

The drilling of penetrator holes in glass instrument housings can be readily accomplished by the careful machinest. It does not require special skills or tools to be successfully performed. With light drilling pressures, low spindle speeds, and adequate cooling, satisfactory penetrator holes can be obtained.

Several methods have been used successfully, and will be covered in this section. It is strongly urged however, that a few practice holes be drilled in scrap glass before the actual attempt is made. The drilling is a matter of "feel", and can not be explained as concisely as the information gained by one practice drill session.

20.5.1 Core Drill Grinding of Penetrator Holes

Depending on the diameter of the hemispherical section, a cut-out plywood centering jig is clamped to the drill press. The center line of the spindle is aligned with the polar axis of the glass hemisphere. Figure 240 illustrates the mechanical set-up, including the Silly Putty¹⁵ dam used to retain the kerosene/carborundum¹⁶ slurry. 80 to 100 grit material has been found to be a satisfactory grinding agent for use with the brass coring tool.

In addition to its abrasive cutting action, the fluid acts as the cooling medium. Be generous and use atleast a cup full of liquid as it is the only means of keeping the glass cool during the drilling cycle. To prevent excessive heat generation at the cutting edge, the spindle speed must be rotated at a very low rate. Experience tends to indicate that 80 r.p.m. or less works out quite well for holes 1/2 inch or less in diameter. It also prevents splattering and loss of the slurry mix, as it is picked up by the cutter during the drilling cycle.

Using light pressures, the operator allows the cutter to grind its way into the glass. Frequent backing off of the cutter, clears the drilled hole and allows a fresh charge of carborundum to enter the penetration. The glass is drilled approximately half way through the total wall thickness. Don't try to penetrate more than half way, as the bottom of the hole will fracture.

The hemisphere is turned upside down, and inserted in an alignment jig with a fixed pilot that assures the two cuts will coincide. Slurry is again used as the cutting and cooling

Figure 240. Core Grinding of Penetrator Holes in Glass Housings

medium. The procedure is continued until complete penetration is achieved.

20.5.2 Cutting Penetrator Holes with a Standard Twist Drill

Conventional metal twist drills have also been used to cut penetrations in glass instrument housings. A plywood centering jig, Silly Putty dam, back-up strain relief pad, and turpentine coolant fluid are required. For best results, the twist drill should be of the high speed steel type. The conventional point angle and lip relief provided by the drill manufacturer is satisfactory. Spindle speeds should be maintained at about 80 r.p.m., and feed pressures should remain light. Sufficient turpentine must be maintained within the dam to assure adequate cooling. Figure 241 illustrates a typical set-up for drilling glass hemispheres.

Depending on the required hole size, a good start can be obtained with a 1/4 inch diameter drill. The initial depth of penetration should be slightly less than 1/2 the wall thickness of the hemisphere. This will assure against fracturing the back side of the shell, as it requires slightly more drilling pressure than the previous grinding method.

The hemisphere is turned over, and repositioned on a wood centering pin and rubber back-up pad. The jig provides proper hole alignment and strain relief during the final drilling cycle.

The 1/4 inch drill is replaced with one that is approximately 1/64 of an inch larger than the initial penetration on the opposite side. The reason for the size increase is to prevent the drill from jamming as the final break-through occurs between the two holes. Perfect alignment is almost impossible, and the larger drill will help prevent fracturing the glass. The procedure is repeated until the proper size penetrator hole is obtained. The maximum practical hole size that can safely be cut using conventional twist drills, is considered as 1/2 inch diameter.

20.6 Hardware for the Fabrication of Mechanical Structures

The cast aluminum fittings illustrated in Figure 242, provide a rapid means of constructing a variety of vehicle science racks for deep ocean research. The versatility of the fittings enables the deep submergence operator to mate most items of science apparatus to the vehicle with a minimum of difficulty. A typical rack constructed with the mechanical fittings can be seen in Figure 28.

The fittings are commercially available in various pipe sizes ranging from 3/4 inch to 2 inch¹⁷. They are re-usable, and with a limited inventory of aluminum pipe, they eliminate the time consuming welding previously required to construct new science racks.

Figure 241. Drilling of Penetrator Holes in Glass Housings

Figure 242. Cast Aluminum Structural Fittings

Figure 243. Corrosion Resistant Stamped Tube Saddle Clamp Assemblies

Figure 243 illustrates a tube clamp saddle that maybe used to modify or add additional hardware and technical apparatus to the deep submersible or its science rack. Its simplicity and versatility of design, make it readily adaptable to general shipboard use. The saddles are fabricated from corrosion resistant steel, and will fit a wide variety of pipe or tubing diameters.¹⁸ As shown by the photograph, the saddle can be used separately or mated into a swivel assembly. The wide variety of applications are limited only by the ingenuity of the user.

20.7 Installation of Fasteners in Syntactic Material

Figure 244 illustrates several methods used to provide structural attachment points in syntactic foam. If high strength is required, the composite insert method illustrated in sketch "A" is preferred.¹⁹ The body of the insert can be aluminum rod stock, knurled on the outside to provide a good bonding surface for the adhesive. When fabricating the inserts, it is important to provide the drilled hole and slotted vents as illustrated. They assure proper venting as well as adhesive distribution when the device is cemented into the syntactic material.

Insert type "B" is a commercially available piece part,²⁰ that can be obtained in various internal thread sizes ranging from 8 - 32 through 5/8-11. It has no provisions for venting, and when inserted and cemented into the syntactic foam a drilled vent must be provided as illustrated. The attachment bolt should be of the slotted or drilled vent configuration, to provide a release for the Lubri-Plate⁷ grease during final assembly. An insert of this type has excellent strength in the lateral direction. In the axial direction, its resistance to pull-out is fair. Unfortunately the insert does not have a knurled section on the outside shell, which would greatly improve the axial holding power in syntactic.

Sketch "C", illustrates a typical internal-external threaded insert that is manufactured in various sizes and materials.¹⁹ A bottom vent hole should be provided when cementing this type insert into syntactic. If the foam configuration is such that a drilled vent can not be properly positioned as illustrated, a drilled machine bolt can be used. It will help vent the air pocket that forms behind the insert as it is pushed into the drilled hole. Be sure to grease the threaded bolt before screwing it into the insert. The epoxy adhesive must not be allowed to ooze into the internal threads, as it would be almost impossible to remove the bolt after the resin has cured. The pull-out strength of this type insert is fairly good, however it should not be used for structural attachment points or tie pads exposed to shock or snap type strains such as those generated by handling lines.

20.7.1 Construction of a Typical High Strength Insert

Past experience with the ALVIN vehicle, has shown that a

Figure 244. Artist Sketch of Typical Metallic Inserts in Syntactic Foam.

satisfactory long-life attachment point can be expected from composite insert assembly illustrated in Sketch "A". The following fabrication and assembly procedures have been successfully used, and are submitted as guide lines for the operator:

1. The aluminum rod stock for the outer shell, can be either 7075 or 6061. Both have demonstrated high strength and long life in syntactic foam materials.
2. Depending on the pull out and shear strength requirement, the outside diameter of the rod stock is determined by the wall thickness necessary for the stainless steel threaded insert. Don't skimp on wall thickness, a little extra meat on the diameter of the aluminum rod provides a better bearing area in the syntactic.
3. To assure proper adhesive distribution, as well as venting of the area behind the bolt, it is suggested that both the slot and drilled hole be machined as a standard part of each aluminum body.
4. The external knurl assures a good footing between the insert, adhesive, and the syntactic. Its geometric configuration is not important, and a diamond or cross hatch pattern is satisfactory.
5. The stainless steel threaded insert is a commercial item, and is available in various bolt thread sizes.
6. On completing the necessary machine work, the aluminum body should be thoroughly de-greased and painted with a wash coat of phos-pho-neal primer.¹¹ After the prime coat has air dried, the stainless steel insert is coated with an anaerobic resin and inserted into the aluminum fitting. Note the shallow countersink at the front face of the aluminum body in sketch 3. This serves two important purposes:
 - a. It eliminates the sharp edges and burrs thrown up on the aluminum as the external threads of the corrosion resistant insert are forced into the material. By eliminating the feather edges, the second coat of corrosion preventative paint forms a smooth even film, rather than thinning and skipping as it normally does on burred surfaces and sharp corners.
 - b. The pocket formed by the shallow countersink, provides a grease seal area behind the mounting plate that is used to attach the apparatus to the insert. It helps to prevent corrosion that could result from seawater collecting in the cavity.

20.7.2 Installation of a High Strength Insert

In preparation for installing the composite insert assembly, a hole is drilled in the syntactic foam. It should be of a size that provides a light tap fit for the aluminum insert. It should not be drilled too deep, about 1/8 to 1/4 inch greater than the overall length of the insert is considered satisfactory.

1. A well greased bolt is screwed into the fitting. If the aluminum insert was constructed as a tapped blind hole, the threaded cavity should be filled with grease before the bolt is inserted into the assembly. The excess grease will extrude out the vent hole effectively preventing any adhesive from entering and blocking the passages.
2. Thoroughly wipe all grease from the external surfaces. Removing any remaining residue with a cloth dipped in acetone, lacquer thinner, or other commercial solvent. It is important to remove all the oily film, as it acts as a parting agent and prevents a good bond between the adhesive and the metal insert.
3. The two part epoxy adhesive is mixed and inserted into the drilled hole in the syntactic.¹¹ Make a concerted effort to eliminate any trapped air bubbles, as they could collapse at depth, substantially weakening the bond strength of the adhesive.
4. If the assembly is to be installed in a vertical surface, hold the insert with one of the vent slots at the top. Slowly insert the insert into the cavity, protecting your face and eyes, as the excess resin extrudes out of the slots cut in the sides of the insert. The trapped air behind the insert becomes entrained with the resin, and will ooze out the top slot.
5. It is important to insert the aluminum assembly flush or slightly above the outside surface of the syntactic as illustrated. If it is below the surface, the mounting pad that attaches to the insert will apply a jacking load as the bolts are snugged up tight. The excessive shear loads applied to the composite insert, could break the adhesive bond between the syntactic and the aluminum surface.
6. When reassembling hardware to embedded inserts, it is important to keep the threaded cavity filled with grease. Complete filling of the bolt hole assures a pressure balanced condition in the area, as well as preventing the entry of sea water. The drilled vent passage also provides a release mechanism for the excess grease. Without some means of providing a free flow exit for the grease, a hydraulic ram effect will be set-up as

the bolt is screwed into the insert. Sufficient hydraulic ram pressure can be generated to break the adhesive bond and jack the insert out of the syntactic.

7. In areas that cannot be readily vented by the methods previously shown, either of the two bolt configurations illustrated in sketches B and C can be used. For short length bolts, a small drilled center hole will not appreciably decrease the strength of the bolt. For longer bolts, a slotted section along the sides of the bolt threads has been found to be satisfactory. Slotted self locking machine bolts are commercially available,²¹ they are supplied with a nylon insert which runs along the side of the thread. The nylon strip is easily removed, leaving a ready made vent slot.
8. In addition to providing a release mechanism for the grease, it is of equal importance to use the proper length bolt. If the bolt thread is too long, it will bottom in the drilled hole. Continued twisting could force the insert out of the syntactic due to the mechanical jack-screw effect.

20.8 Chemical Coatings, Treatments, and Protective Finishes

The chemical treatments and surface coatings discussed in this section have been successfully used with the DSRV ALVIN. They have demonstrated their corrosion preventative effectiveness over a period of several years of deep submergence operation.

20.8.1 Polyurethane, Coatings (Paints and Primers) 11

Laminar X-500, a two-part polyurethane glossy finish coat, has been very successful as a corrosion deterrent. It is used in conjunction with a two-part catalyst base surface treatment, a primer, and an intermediate coating that may be brushed or sprayed, depending on the users preference.

When applied in accordance with the manufacturer's instructions, the finish shows excellent resistance to salt water exposure, abrasions, and blistering due to moisture penetrating beneath the sub-surface coatings. The superior adhesion and sealant characteristics have frequently been demonstrated on a variety of materials. Syntactic, HY-100, Aluminum Alloys, and Aluminum Oxide (Hardcoat) have been successfully coated and protected by the Laminar X Material.

To assure a smooth unbroken paint film on metallic surfaces, all sharp edges must be rounded with a generous radius. Any burrs, nicks, or digs in the material must be blended in with a file and emery. Drilled and tapped holes must be slightly countersunk. If these precautionary measures are not observed, the paint film thins out in the areas having sharp edges,

decreasing the corrosion protection supposedly provided by the paint.

20.8.2 Aluminum-Oxide Surface Treatment (Sanford Hardcoat/or Martin Process)²²

Hardcoat, an Electro-Chemical Surface Treatment, forms an Aluminum-Oxide coating on Aluminum. The oxide is extremely hard and has reasonably good resistance to corrosion. As the conversion coating forms in the Electro-Chemical bath, it builds up on the surface as well as penetrating into the base material. For example, a total oxide thickness of .002 inch, penetrates into the Aluminum .001 inch and builds up .001 inch, for a total of .002 inch.

20.8.2.1 Thickness of Aluminum Oxide Coating

The conversion process can be applied to a wide variety of Aluminum. The maximum practical thickness however, varies somewhat, and is listed next to each of the basic alloys.

- 1100 Series .0025 inch.
- 2000 Series .004 to .006 inch.
- 3000 Series .002 inch.
- 5000 Series .004 inch.
- 6000 Series .0025 to .003 inch.

The chemical process requires a direct electrical connection with the piece part being processed. The conversion coat is not formed at the point of contact, and if an unbroken surface coat is required, a threaded hole should be used as the connection point. The processing vendor should be advised of the areas that require an unbroken coating. In some cases, he can make the connection at an inside surface where a slight imperfection can be tolerated without jeopardizing the corrosion resistant qualities of the complete assembly.

To prevent the normal dimensional surface growth that occurs during processing, from changing the dimensions of machined areas, the vendor should be advised to mask all sections considered as critical. Both internal and external threads are effected, and masking should include the two areas. If external threads must be hard coated for abrasion and/or corrosion resistance, the vendor can advise the designer concerning thickness and dimensional variations he may expect in the threaded area. The vendor can normally hold to a close dimensional tolerance, and can provide a satisfactory fit between two threaded hard coated surfaces.

20.8.2.2. Surface Sealing of Aluminum Oxide Coating

The conversion coating is considered as porous, and if good corrosion resistant characteristics are necessary, a boiling water/dichromate dip is required to seal the pores. If the

component is to be processed with a surface preparation such as paint or lubricant, the conversion coat should be left un-sealed. The open pores will improve the adhesive bond between the aluminum-oxide and the applied surface material.

20.8.2.3 Spot Removal of Aluminum Oxide Coating

The aluminum-oxide conversion coat is extremely hard and can not be machined with conventional tools. If the hard coat must be removed to rework a damaged area, it can be readily removed by dipping or swabbing with one of several solutions.

Nitric acid, sodium hydroxide, or a solution of phosphoric and chromic acid have all been successful in removing the aluminum-oxide finish.²⁵ Keep in mind however, that if the component is dipped in solution, the external growth as well as the oxide penetration will be removed. The stripping operation could result in the component being undersized by the amount equal to the sub-surface hardcoat penetration.

20.8.3 Chemical Paint Removing Solutions

Polyurethane coatings may be removed from Aluminum surfaces through the use of a chemical paint stripper solution, commercially known as "Vis-Strip".²³ The material is a viscose fluid, having excellent cohesive properties, which allows it to be used on vertical surfaces.

The solution is readily removed by flushing with potable water, and does not require the use of a neutralizer to halt the stripping action. Excellent stripping has been observed on various aluminum test pieces having a sand blast, rolled or extruded mill surface, as well as an aluminum-oxide hardcoat. The stripped surfaces have been sufficiently cleaned to allow T.I.G. welding to be performed in the areas of paint removal, without further surface preparation. In the case of the hard-coated specimen, no visual surface or sub-surface deterioration was visually observed when viewed with a 40X microscope.

20.8.4 Aluminum Oxidation and Corrosion Removers

Regardless of the surface preparation, aluminum alloys exposed to sea water and slat laden atmospheres, eventually exhibit some form of surface oxidation or corrosion. Maintenance data gathered from equipment operating with the DSRV ALVIN, illustrated the need for a means of removing and inhibiting these corrosion deposits.

Several solutions have been successfully used to "clean" various items of hardware having mild to severe corrosion. Manganed Phospholene #MP-7 and B3240 Aluminum Oxidation and Corrosion Remover,²⁴ have been used satisfactorily on aluminum, stainless, and ferrous materials. Corrosion removal has been performed using both the bath and brush application method. Both solutions have chemically cleaned severe aluminum corrosion, without

damaging the Laminar X-500 polyurethane paint and aluminum oxide hardcoating directly adjacent to the corrosion pocket.

Either of the chemicals may be removed by flushing with potable water. After a thorough drying, the clean area can be primed and painted using one of the finishes covered earlier in this section. Excellent adhesion, as well as good corrosion inhibiting action has been observed in the chemically cleaned area.

20.8.5 Testing the pH Level of Chemically Treated Surfaces²⁵

In view of the various chemical treatments used to clean, strip, and prepare metallic surfaces prior to painting, it is suggested that the following tests be performed to assure the complete removal of any chemical residue. It is important that all residue be removed from the cleaned area. If contamination is "locked-in" by subsequent painting, the foreign material could result in continued corrosion, blistering or peeling of the painted surface.

The pH indicating papers can be used while the surface is still wet from the potable water rinse. Methyl red paper is used to test for the lower pH limit, while red litmus paper is used for the upper limit. When touched to the wetted area there should be no color change noted. If there is any indication of a color change, an additional water rinse will be required.

To assure that the potable rinse water is within the required neutral range, it should be tested separately, and should fall within a range of 6.4 and 8.3 to be considered satisfactory.

20.8.6 Self-Curing Flexible Urethane Coatings¹¹

The availability of a flexible room temperature self-curing urethane material, has proven to be very useful in the deep submergence field. It is supplied in either a liquid or putty consistency. The material has a wide variety of use, and has successfully demonstrated its ability to withstand continued exposure to elevated hydrostatic pressures.

It has been used to surface coat and cement syntactic foams, mold special gaskets, and form a wide variety of special shapes. The material has shown excellent resistance to the electrolyte contained in the lead-acid storage batteries, as well as the various pressure compensating fluids covered in Section 20.1.

20.9 Use of Polyvinyl Chloride Plastics (PVC)²⁶

PVC has been successfully used in a wide variety of structures fabricated for the DSRV ALVIN. Considerable use has been made of cemented and welded pressure compensated electrical junction box assemblies, as well as attachment structures requiring reasonably good mechanical strength.

PVC is commercially available in a wide variety of stock sizes and shapes, ranging from tubing, flat sheet, rod and bar, as well as angle, tee, and hex configurations. It is readily cemented and welded using the manufacturer's recommended solvent cements, welding rod and hot air welding guns.

It is a corrosion resistant material that may be put in direct contact with aluminum, titanium, stainless steel, or syntactic foam, as well as painted or hard coated surfaces without difficulty. A liberal coat of Lubri-Plate grease forms an excellent water barrier between the two materials, substantially decreasing the possibility of surface damage due to stagnate water films.

The material is easily machined, filed, drilled, and heat formed. It provides the designer with an excellent hobby-lobby material to work out his ideas without tying up the valuable talent of a machinist. Figures 132 and 181 are typical items of deep submergence hardware that illustrate the versatility of the material.

In view of the success the PVC material has had, it is not to be considered as a panacea for the construction of deep water apparatus. It has several inherent characteristics that could present a problem. The material has a slight tendency to cold flow after machining. Drilled and tapped holes close-up slightly, making it difficult to insert the threaded mating parts.

Drilled clearance and pilot holes must be machined with greater than normal clearance to prevent binding with their mating piece parts. Set screws used to restrain collars, gears, and shafts, have a tendency to loosen slightly as the PVC material relaxes under the stress of set screw tension. They do not however, loosen sufficiently to cause failure of the mechanism.

The heat transfer characteristics prevent the material from being used as motor housings, unless a separate means of cooling is provided. Considerable heat transfer difficulty was experienced with the prototype hard rock core drill discussed in Section 7.1 of the report.

This lack of heat transfer ability however, can be used to good advantage with proper equipment design. For example, if specific items of equipment require a heat stabilized environment for proper operation, the PVC material can be used as an insulating interface between the device and the outside seawater.

The PVC material has a unique characteristic of softening at temperatures ranging between 165° and 360°F. It may be easily shaped and molded when in the pliable state,²⁷ and if clamped or restrained in a jig until cool, it will retain the desired preform. Past experience tends to indicate that immersion in any of the pressure compensating fluids covered in Section 20.1, will not adversely effect the physical characteristics of the PVC material.

Best results have been obtained with structures and instrument housings that are pressure compensated. The material has insufficient collapse strength to resist the effects of deep ocean pressure, and is not considered as satisfactory for pure pressure resistant housings.

20.10 Recommended Construction Practice for Instrument Housings and End Cap Closures

The various sketches illustrated in Figure 245 and 246, are considered as the more commonly used designs for cylindrical housing end cap closures. Each design has a particular area of operation where it is best suited. When selecting a design, the operator should give considerable thought to the following parameters as they effect the operational characteristics, cost, and construction complexity as much as the assembly hints covered later in this section.

20.10.1 Instrument Housing Design Hints

1. Try to design around commercially available stock size tubing. The sizes listed in the brochures supplied by various vendors, do not always reflect the actual inventory carried by the mill. Check with the vendor before proceeding with the final design.
2. Will the case be exposed to saltwater atmosphere for long periods, as well as actual deep water hydrostatic pressure. Is it a device that can be rinsed with potable water after each operation, or will its mounting location prevent ready access once its installed. Questions such as these are important, as they dictate the type of mechanical attachment that should be used to secure the end caps, the corrosion resistant finish required, as well as "O"-Ring locations.
3. Will the operational conditions contribute to possible galling and hang-up of threaded sections due to dirt or suspended silt in the area. Keep in mind that O-Rings positioned as illustrated in sketch "F" will move toward the low pressure side as external hydrostatic pressure is applied. Water and entrained silt actually move into the threaded area, and could result in damage during disassembly.
4. The size, quantity, and type of electrical penetrators have a large bearing on the type of locking closure that can be used to secure the end cap. Sketches "G and J" illustrated how some latch mechanisms limit the space available for the installation of these feed through devices. If the design dictates the use of saddle clamps, be sure to leave sufficient clearance for the removable outer shell of the mating connector. Depending on the manufacturer, the mating section could increase the

Figure 245. Typical End Cap Closures for Pressure Resistant Housings

actual connector diameter sufficiently to cause interference with the saddle bar.

20.10.2 Assembly Procedure for Pressure Resistant Instrument Housings

For long term exposure to saltwater conditions, the "O" ring seal should be positioned in an area that will keep the most internal surface from being wetted. The O-Ring location illustrated in sketches "D, G, H, and J" would be the most effective, as they prevent water from penetrating into threaded areas and blind cavities.

Keep in mind that under most conditions you are not trying to contain internal pressure within the instrument housing, and that the external seawater pressure can assist in sealing the chamber. This allows the designer to use lightweight tie bars, plastic threaded bolts, as well as grooved segmented sections and hose clamps as illustrated in sketch "C" of Figure 245.

One word of caution when using plastic threaded belts for closure assemblies such as those illustrated in sketches "A and B". The blind end of the tapped hole must be vented to the seawater side, to prevent the external pressure from extruding the plastic into the cavity. To prevent corrosion due to salt water entry, fill the tapped cavity with Lubri-Plate grease. The excess will extrude from the vent hole as the plastic bolt is inserted. The grease effectively pressure compensates the cavity, as well as preventing the entry of seawater.

Depending on the size of the hold down bolt, pressure compensation can also be provided by drilling the bolt as illustrated in sketch "B" of Figure 245. The use of plastic machine bolts substantially reduces corrosion in instrument housings and end cap closures fabricated from aluminum alloys. If plastic attachments are not practical, and the design requires the use of corrosion resistant machine bolts, the following assembly procedure is recommended.

20.10.3 Installation of Corrosion Resistant End Cap Fasteners

Depending on the housing wall thickness, and the expected depth of operation, the ends of the housing can be drilled and tapped to accept corrosion resistant threaded inserts of the selected size.¹⁹ When installing the insert, the liberal use of an anaerobic resin²⁸ will seal the threaded surfaces, effectively preventing corrosion between the aluminum housing and the corrosion resistant steel. Keep in mind that if the instrument housing is to be processed with aluminum-oxide, the hard coat must be accomplished before the inserts are installed. The vendor will not process an assembly having mixed materials as it will "kill" the processing bath.

The entry to the drilled hole must be countersunk slightly to assure the removal of all sharp corners. If the burrs are not removed, and the housing is painted to provide an additional

Figure 246. Typical End Cap Closures for Pressure Resistant Housings

corrosion barrier, an adequate paint thickness will not form on the sharp edges or burrs. The shallow cavity formed by the countersink, also provides a pocket to retain a small quantity of grease, which aids considerably in reducing the possibility of corrosion from entrapped seawater.

As an added precaution, and to prevent water leaking past the threads and remaining trapped behind the bolt, small vent holes should be drilled at the base of the insert cavity. To assure complete filling of the void, the insert should be packed with Lubri-Plate grease before inserting the hold down screws.

20.10.4 Construction of Composite Flanges for Attachment of End Cap Closures

The circular flange illustrated in sketch "C" provides the designer with a method of attaching flat end caps without the necessity of procuring extra heavy wall tubing or using welded flanges. As shown by the illustration, the composite assembly does not have to be machined as an integral part of the housing. It can be cemented to the outer surface using a rubber compound having a firm but slightly resilient characteristic.¹¹ The low level of flexibility takes care of any minor movement in the outer shell due to pressure or temperature variations at depth. The use of hard setting epoxy resins have not been tried, as the general feeling seems to be that the adhesive bond might not have sufficient flexibility to ride with the shell movement without cracking. The "V" shape band clamps are available in corrosion resistant material, and may be obtained in a wide variety of sizes.²⁹

20.10.5 Sealing of End Cap Closures without the Use of Mechanical Attachments.

In line with the thought of ocean pressure assisting in the sealing mechanism, sketch "D" illustrates how the application of a slightly negative internal pressure can be used to provide initial sealing. The O-Ring seal plug shown in the illustration, provides positive sealing of the check valve, preventing leakage into the chamber if the check seat should fail. As the chamber descends beneath the surface, the force exerted by the external hydrostatic pressure, completes the sealing that was initially provided by the reduced internal pressure.

To open the device, the check valve is vented, allowing external ambient pressure to enter the chamber, freeing the end caps. The internal negative pressure does not have to be excessive to provide the initial sealing. In fact, if the instrument housing is used to encase electrolytic capacitors, dry cells, or other items that might out gas or boil-off fluids, the negative pressure must be kept at a level that will not damage the components. To assure against possible damage, it is suggested that a test program be established to determine the safe level of reduced pressure that can be tolerated by the various assemblies.

20.10.5 Mechanical Alignment of End Cap Closures

Flat end closures that do not depend on integral threads to provide proper positioning, must have some type of pilot to assure the alignment between the cap, "O" ring, and housing. The designs illustrated by G, H, J, are piloted closures that assure proper alignment, as well as preventing side slip of the end plate. When using an external saddle clamp or tie rods as shown, the closure cap is quite prone to physical displacement due to mishandling. Without the alignment pilot, the possibility of leakage is greatly increased.

20.10.6 Permanently Mounted Closure Mechanisms

Latch mechanisms that are permanently attached to the instrument housing and end caps, are not recommended. Sketch "H" illustrates several typical assemblies that are attached with drive screws or roll-pins. Severe corrosion has been noted in the general area, becoming quite severe at the point of direct contact between the two metals, especially when dissimilar metals are used to construct the assembly.

Other than suggesting that clamp/latch assemblies be constructed from the identical material as the instrument housing and end cap closures, or be liberally coated with Lubri-Plate grease prior to each dive, no constructive recommendations will be given concerning this type of closure mechanism. Past experience with these attachment devices has been unsatisfactory.

20.10.7 Assuring Against "O"-Ring Leakage

One closing word of caution concerning threaded end caps. When assembling the piece parts, a liberal film of Lubri-Plate grease is recommended between all rubbing surfaces. Particular attention should be paid to the "O" ring and its mating surfaces.

Threaded assemblies, such as those illustrated in sketches D, E, and F, must be assembled carefully. If there is insufficient lubricant on the O-ring, or if the device is rotated too rapidly, the O-ring has a tendency to wrinkle and twist within its retaining groove. If the wrinkle is sufficiently severe, it could result in failure of the seal at high pressure. At the shallow depths, the twist could prevent the O-ring "seating" or assuming a natural position within the cavity, with the end result being considerable low pressure leakage into the instrument chamber.

20.11 Use of "O" Ring Seals

For the majority of applications, sufficient detailed design data has been developed by the "O" ring manufacturer to provide the designer with all the information required for both static and dynamic sealing. The information has been compiled in several catalogs or hand books, any of which can be readily

obtained through the local distributor.³⁰

The actual information is quite voluminous, and will not be covered in this report. Numerous compounds are available, and, depending on the operating medium the proper selection may be obtained from the vendors compatibility list.

For those O-ring sizes that are special, a sealant splicing kit #0112 is available.²⁸ It supplies the user with several lengths of stock diameter elastomer material, and a quick setting adhesive. Satisfactory seals may be custom fabricated to the exact size required by the apparatus. Excellent results have been obtained with static seals fabricated by this method, however, dynamic seals have not been attempted.

References and Manufacturers

Section 20, Construction Kinks and Materials of Fabrication

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2. Hoover Submersible Fluid #2
 - A. Hoover Electric Co., Los Angeles, Calif.
3. Royal Lubricants Compensating Fluid C-141
 - A. Royal Lubricants Inc., Hanover, N. J.
4. Univolt #35 and #36
 - A. Esso Oil and Refining Co., U. S. A.
5. Tellus #15
 - A. Shell Oil Company, U. S. A.
6. Silicone Grease, Dow Corning #33 and #DS-4
 - A. Dow Corning Corp., Midland, Mich.
7. Lubri-Plate Grease #130AA, L-702
 - A. Fiske Brothers Refining Co., Newark, N. J.
8. Syntactic Foams
 - A. 3M Reinforced Plastic Div., St. Paul, Minnesota
 - B. Emerson & Cumming, Inc., Canton, Mass.
9. Micro-Sphere Balloons
 - A. Emerson & Cumming, Inc., Canton, Mass.
 - B. 3M Reinforced Plastic Div., St. Paul, Minn.
10. Protective Skin Creams (Kerodex #71)
 - A. Ayerst Laboratories, Inc., N. Y., N. Y.
11. Surface Sealants
 - A. Thio-Tuck (Polysulfide Sealant)
 1. Electrocoat Co., Minneapolis, Minn.
 - B. Flexane (#95 Putty or Liquid)
 1. Devcon Corp., Danvers, Mass.
 - C. Laminar X-500 (Primer and Urethane Paints)
 1. Magna Coatings & Chemical Corp., Los Angeles, Calif.
 - D. Catalyst Resins
 1. Boatex Fibre Glass, Needham, Mass.
 2. Durez Plastic Div., Hooker Chemical, North Tonawanda, N. Y.
 3. Allied Resin Products Corp., East Weymouth, Mass.

12. Air-water Inner Tube Filler Adapters
 - A. Dill Div., Eaton Mfg. Co., Cleveland, Ohio
13. Spherical Glass Floatation Devices
 - A. Corning Hydrospace Products, Corning, N. Y.
14. Spherical Aluminum Instrument/Floatation Housings
 - A. Hydro Products, Div., Dillingham Corp., San Diego, Calif.
15. Silly Putty (SS-91 Silicone Speciality)
 - A. Local Toy Store
 - B. General Electric, Silicon Products Div., Waterford, N. Y.
16. Carborundum
 - A. Clover Mfg. Co., Norwalk, Conn.
 - B. Time Saver Products Co., Chicago, Ill.
 - C. Mitron Research & Development Corp., Waltham, Mass.
17. Cast Aluminum Structural Hardware
 - A. Holleander Manufacturing Co., Cincinnati, Ohio
 - B. Kee Klamps, Buffalo, N. Y.
18. Tube Clamp Saddles
 - A. Universal Saddle Clamp Inc., West Harwich, Mass.
19. Internal-External Threaded Inserts (Corrosion Resistant Material)
 - A. Tap-Lok Groove-Pin Corp., Ridgefield, N. J.
 - B. Newton Insert Co., Los Angeles, Calif.
 - C. Heli-Coil Corp., Danbury, Conn.
20. Internal Long Stem Threaded Inserts (Corrosion Resistant Material)
 - A. KSM Weld Pads Products, Inc., Moorestown, N. J.
21. Nylon Strip Lock Screws
 - A. Nylok Corp., Precision Fastener Div., Jenkintown, Pa.
 - B. Long-Lok Corp., Los Angeles, Calif.
22. Aluminum-Oxide Hard Coating
 - A. Duralectra Inc., Natick, Mass.
 - B. General Magnaplate Corp., Linden, N. J.
 - C. Service Hard-Chromium Co., Union, N. J.
23. Strippers for Polyurethane Coatings (Oakite Vis-Strip Liquid)
 - A. Oakite Products Inc., N. Y., N. Y.
24. Aluminum Oxidation and Corrosion Remover #B3240, and Manganese Phospholene #MP-7

- A. Arnett Associates, Gardena, Calif.
 - B. Bellflower Chemical Mfg. Corp., Bellflower, Calif.
25. pH Indicator Papers/Chemicals
- A. Scientific Glass Apparatus Co., Inc., Bloomfield, N. J.
 - B. Fisher Scientific, Medford, Mass.
26. Polyvinyl Chloride Plastics (PVC Type I)
- A. Comco Plastics Inc., Richmond Hill, N. Y.
 - B. General Tire and Rubber Co., Lawrence, Mass.
27. Hot Air Heat Guns (Electric Blower)
- A. Ace-Sycamore Inc., Sycamore, Ill.
 - B. Master Appliance Corp., Racine, Wisc.
28. Anaerubic Resins, "O"-Ring Splicing Kits
- A. Loctite Corp., Newington, Conn.
29. "V" Retainer Clamps
- A. Specialty Products Corp., Wickliffe, Ohio
 - B. Aeroquip Corp., Marman Div., Los Angeles, Calif.
30. "O"-Ring Manufacturers
- A. Parker Seal Co., Culver City, Calif. (Catalog #OR5700)
 - B. Precision Rubber Products, Dayton, Ohio
 - C. Industrial Retaining Ring, Irvington, N. J.

21.0 Future Investigations Necessary to Improve the Operational Capability of a Deep Submersible.

There has been sufficient success in the design and fabrication of the tools and apparatus discussed in this report, to warrant the continuation of new areas of investigations. The following section is devoted to several proposed items of hardware considered as necessary to improve the usefulness of a deep water submersible. The suggested areas of interest pertain primarily to the engineering and scientific disciplines performed at the Woods Hole Oceanographic Institution.

21.1 Portable Hydraulic Power Package and Associated Hand Tools

Design and build a portable hydraulic power package consisting of a hydraulic pump, electric motor, valving, and fluid storage sump. The pressure compensation fluid should be used as the power transfer medium. The electric motor drive should be pressure compensated, and be powered by the D. C. source on the submersible. It should have a depth capability of 10,000 feet. The operator of the vehicle must have positive on-off control from within the vehicle.

If the package is mounted on the vehicle, it must be provided with hydraulic quick disconnects to release any tools that may have become entangled on the bottom. If mounted on the science tray, it must be provided with an electrical quick disconnect to allow separation of the assembly from the vehicle in the case of entanglement. The hydraulic power source should include the following tool accessories:

1. Chain Saw - Metal and Wood
2. Drill - Metal and Rock
3. Chippers
4. Cable Shears
5. Rock Splitters
6. Suction Dredge
7. Rivet Gun Hammer
8. Impact Wrench
9. High Velocity Water Jet Trencher
10. Rock Core Drill

21.2 Surface Drop Free Fall Tool Messenger

Provide a means of dropping tools and equipment to a submersible working on the bottom. The messenger should be controlled by a single self-contained rudder device that would provide a reasonably vertical descent. The terminal velocity of the device should be variable. The messenger should free fall throughout the major portion of descent. As it approaches the bottom, it automatically reduces its rate of descent. The final descent velocity is reduced sufficiently to assure a soft landing on the bottom.

The messenger should have the capability of being tracked during descent, or at least have the provisions to visually and/or acoustically be located by the submersible after landing on the bottom. The construction of the device, should provide easy access to the tools or equipment carried in the messenger storage bin. It should be a self recoverable item, returning to the surface on actuation by the submersible.

21.3 Free-Ascent Specimen/Equipment Retrieval Apparatus

The device may be designed around the free-fall messenger. It should provide the deep submersible with a means of retrieving bottom objects and specimens, that are too large to be stored or carried on the vehicle science racks. The device should provide a means of attracting attention to its general recovery area, after it has returned to the surface.

21.4 Powered Knife with Oscillating Serrated Blade

The manipulator held knife should be capable of operating at depths as great as 10,000 feet. It should be self powered and be fully pressure compensated. The blade should be capable of cutting synthetic as well as manila rope and canvas webbing.

In its basic form, the device would be similar to an oscillating carving knife or the cutter mechanism of a hedge trimmer. The power source could be a package of several miniature high current density batteries. The service life of the batteries, before requiring recharge, should be sufficient to sever a minimum of 6 eight inch synthetic or manila lines. If additional cutting power was required, the mechanism could be powered by using the energy of deep ocean pressure as it flows through a motor into an evacuated chamber.

21.5 Stun-Gun for Retrieval of Ichthyological Specimens

Develop a squirt-type stun-gun directed and actuated by the mechanical manipulator. The device would be used to stun selected mid-water or bottom specimens, through the use of a slug or cloud of commercially available stupefying fluid.¹ The device should be charged at the surface with approximately 2 liters of fluid. The discharge or ejection of the fluid slug, would be accomplished by a valve connected to a spring loaded accumulator, with one end open to the ambient sea pressure. The open ended accumulator, provides the stun-fluid with an ejection pressure that is always some pre-determined value above the sea water pressure, regardless of the operating depth.

21.6 Underwater Yard Stick

Develop a simple measuring device that will provide the science observer with a means of accurately determining the linear size of an object.

The majority of observation ports in existing deep submersibles are in the form of truncated 90° cones, with the inner and outer optical faces being plane parallel surfaces. When observing objects in the water, they appear nearer and larger than they actually are. If the observer turns his head slightly and looks through the port at an oblique angle to the center axis of the cone, the objects appear both larger and distorted.

The proposed measuring device will not correct the distortion or the magnification of the object, but it will provide a closer size approximation than is possible without the known visual reference.

21.7 Bottom Slope Measurement

Develop a accurate means of measuring canyon wall and bottom slope angles. The design may be optical, mechanical or electrical. It must not be of a size that would present a handling problem to the operator, or the vehicle.

One suggested method is a hand held optical device, similar to a pair of wide angle field glasses. Superimposed on the field of view would be a zero bubble to assure the device is level at the time of reading. A protractor, indicator, and base line are also superimposed on the field of view.

The operator views the slope area he wishes to measure, then by rotating the protractor he places the base line along the average slope of the terrain. The level indicator bubble must be at zero while setting the protractor base line. The angle of slope may be read directly from the protractor angle indicator line. Several optical devices have been constructed by NASA for use as visual attitude orientation aids for space flight crew members.² With some modification, they could be adapted for use in deep submersible survey missions.

21.8 Vertical Water Column Sampling Device

Develop a high velocity free fall net assembly that will sample a vertical water column. The device should be self-controlled to assure a vertical drop with a minimum of side drift. The control vanes or fins should provide sufficient stability to prevent toppling during the free fall.

On reaching a pre-selected depth, the device should automatically close to prevent loss of the trapped specimens. Depending on the depth of free fall, and the ocean depth at the sampling site, the assembly should be capable of either making a soft landing on the bottom, or automatically returning to the surface.

In either case, the sampler should provide some visual, audible, or sonar transmission source to guide either a submersible or surface vessel to the recovery site.

Figure 247. Isobaric Altimeter Sketch

21.9 Low Level Altitude Indicator

Devise a means of accurately measuring the height of the submersible from the bottom. The device should operate over a 1 to 10 foot range. It can be electronic or optical, with the read-out capable of being superimposed on a photographic film of the bottom.

The device would not normally be used for navigation purposes, although in areas of restricted visibility it could be a definite safety factor. The primary purpose of the short range altitude indicator, is to provide an accurate measurement between the ocean bottom and the lens of bottom scanning cameras. The exact altitude data provides the science observer with a method of determining the size of bottom objects.

One suggested method is to measure the overlap or separation between two beams of light set to intersect on the bottom. At a pre-set altitude, the two beams overlap forming one spot, if the vehicle moves up or down, the spot separates. The distance between the spots would be an indication of the vehicles altitude off the bottom.

The second proposed system was to modify a commercial shallow water depth finder for use at the operational depth of the vehicle. The read-out indicator would be installed within the personnel sphere, with the transducer mounted in a downward looking mode to measure the vehicle altitude above the bottom. The transducer could be liquid filled to provide pressure compensation.

21.10 High Accuracy Level Flight Indicator

Design and test an inexpensive mechanism that is capable of providing the deep submersible pilot with an accurate fixed altitude or level flight indicator. The device may be hydraulic, electronic, or pneumatic. It should provide an accuracy of ± 1 foot. The indicator mechanism can be located outside the pressure hull, with read-out provided by observing through the portlight. The device should be automatic in operation.

The indicator scale should be zero center, with a span of 10 feet either side of center. Off scale excursions as great as 50 feet should not result in damage to the indicator or the measuring device. One suggested method is to use a differential pressure gage and a pressure accumulator chamber. Pressure variations resulting from vehicle movement above or below the level flight condition, are presented as altitude variations on the indicator mechanism. A device operating on this basic principle was constructed and used with the Asherah³ vehicle. Figure 247 illustrates an artist conception of the Isobaric Altimeter system.

Figure 248. Artist Conception of Fortune Cookie Drop Pattern

21.11 "Fortune Cookie" Surface Dropped Bottom Survey Markers

Perform sufficient tests to evaluate and improve the technique of marking the bottom by surface dropping coded plastic sheets attached to descent weights.

As a simplified explanation of the system, it consists of dropping individually coded and weighted vinyl tiles along a north-south axis, at the area to be searched. A second set of coded tiles are dropped in a east-west direction, intersecting the first drop at the center of the drop zone. The "X" formed by the targets is theoretically within the search area. The submersible uses the coded vinyl tiles as "street signs" to perform the search pattern. The upper sketch in Figure 248 illustrates the drop pattern established by the surface vessel.

The tiles should be brightly colored, and if the bottom material is known, they should be of a contrasting color. Past experience indicates that a good grade of tile should be used, as the bargain type have a tendency to curl-up, making them difficult to find as well as impossible to read. The descent sinker consists of a sash weight attached to each tile as illustrated by the lower sketch. Figure 249 is a deep water photograph showing a fortune cookie resting on the bottom.⁴ The marker in the illustration was released at the site over a year prior to the photograph, attesting to the usefulness of these deep ocean street signs.

21.12 Manipulator Controlled Vibration Generator for use with Short Core Sediment Tubes.

Develop a simplified vibration generating device that can be mounted between the manipulator fingers and the hand held coring tools previously discussed in Section 8.1, Sediment Core Samplers.

The device may be mechanical or electrical, and generate sufficient vibratory force to break down the cohesion between the bottom sediment and the core recovery tube. A device of this type would provide the science observer with a more rapid means of penetrating the bottom sediment, using the existing short core sampling tubes. It would also allow the use of longer specimen core tubes, as the force required to penetrate the bottom sediment would be substantially reduced, decreasing the load on the manipulator mechanism.

When operating in hard sediment areas with the present sampling device, the pilot usually sets the vehicle on the bottom in a negative buoyant condition. The negative buoyancy is required in order to provide sufficient mass to overcome the reaction generated by pushing the sampling tube into the bottom. Operating the vehicle in this manner is time consuming and puts excessive strain on the manipulator mechanism as the core tube is pressed into the sediment.

Figure 249. Deep Water Photograph of Fortune Cookie on the Bottom

The proposed device would allow the acquisition of core samples in most any sediment configuration encountered. The sampling time would be substantially decreased, and the disturbance of the core material kept to a minimum.

21.13 Long Core Sediment and Hard Rock Coring Mechanism for a Deep Submersible.

Figure 250 illustrates an artist sketch of a proposed self-contained drilling platform for a deep submersible. The design is based on the present state of the art, as well as existing hardware and operational procedures that have been successfully used in other deep submersible programs.

Basically, the drill rig is a lightweight structure as illustrated in Figure 251, with a cradle for attachment to the deep submersible. When mated to the platform, the submersible becomes the propulsion and guidance package for the assembly. The operator flies the rig to the selected area of interest, landing the platform on the bottom. The bottom suction pod anchors, which are an integral part of the platform, are actuated to anchor the assembly at the drilling site.

The power to operate the suction anchors, hard rock drill, and sediment coring apparatus, is obtained from a series of lead acid batteries located within the base of the platform structure. The battery package is fully pressure compensated, and would be capable of operating at any depth within the diving limitations of the vehicle.

Several methods have been proposed for obtaining the long sediment cores. One proposal is based on an existing design that uses an electro-mechanical vibratory device which effectively decreases the cohesion between the sampling tube and the sediment.⁵

The core drive mechanism is guided and controlled by the mechanical manipulator. In use, the manipulator raises and lowers the drive tube assembly, locking it to the core retrieval tube with hydraulic piston clamps. On starting the vibratory drive, the soil cohesion decreases and the core tube moves into the bottom sediment until the drive tube reaches its lower limit of travel.

At this point the hydraulic locks are released and the manipulator again raises the drive mechanism to its upper position. The piston clamps are actuated to lock on a new section of core tube, and the vibratory process repeated until the full length of the core assembly has been inserted into the bottom sediment.

The core tube is retrieved by the combined effect of the vibratory action, and a latching jack which assists in retracting the tube from the bottom sediment.

Figure 250. Self Contained Deep Submergence Drill Platform and DSRV

A second method of core tube excitation has been proposed, and consists of extracting the energy from the deep ocean sea water as it passes through a motor enroute to an evacuated chamber.⁶ The rotary motor drives an eccentric device which generates the vibratory action. The chambers are emptied at the surface, providing a rapid turn-around capability. One draw-back however, is the decrease in platform buoyancy that occurs after the chambers have become water logged. This loss of buoyancy must be made up by either the control vehicle or by a ballast system on the platform. Either way, the system complexity is increased.

For hard rock sampling, the sediment probe would be replaced by either a rotary or resonant drive mechanism, similar to the two devices covered in Section 7.0 of this report. The power to operate the device would be obtained from the platform power package, with guidance and control provided by the submersible operator.

To assure the safety of the vehicle and its personnel, the entire coring platform can be released from the submersible on command of the operator. The pilot controlled release also provides the operator with the option of leaving the platform on the bottom at the end of a normal dive period, or due to inclement weather conditions in the area. On returning to the platform at a later date, the pilot lands on the cradle and resumes the operation. When operating in areas of soft sediment, the release of the platform from the bottom, is assured by reversing the flow of water in the suction anchor assemblies. The low pressure water pumped into the suction pods will "pop" the platform out of the sediment, freeing the vehicle from the suction and friction forces that exist between the bottom surface of the drill rig and the sediment.⁷

Based on existing deep submersible operating capabilities, and the present state of deep water tool development, the proposed self-contained sediment-hard rock core platform could be constructed on a moderate budget. Being a platform, it readily adapts itself to the elevator type launch and retrieval of a deep submersible.

Figure 251. Artist Sketch of Basic Drill Platform

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Development funds provided under National Sea Grant
College Act.
6. A Deep Sea Rock Core Drill, by J. Brooke and R. Gilbert,
Atlantic Oceanographic Laboratory, Bedford Institute,
Dartmouth, Nova Scotia, Canada.
7. Forces Required to Extract Objects from Deep Ocean
Bottom, R. C. DeHart, C. R. Ursell, South West Research
Institute, San Antonio, Texas. Contract ONR 3363(00)
FBM.

22.0 Proposed System Improvements Pertaining to the Operation and Safety of a Deep Submersible Vehicle.

The items covered in this Section are areas of engineering research that will improve the state of the art for deep submersible operation. Several of the proposed areas are considered as system improvements essential to the safety of the vehicle and its personnel.

22.1 Level Flight Automatic Pilot

Devise a simple automatic pilot that could relieve the pilot while cruising in reasonably level terrain for extended periods. Depending on the mode of operation selected by the pilot, the device should maintain either a level flight condition in relation to the surface, or maintain a parallel path in relation to the bottom terrain.

The mechanism should maintain a straight line course as selected by the operator. It must be a fail safe device, with the pilot having complete control at all times. The system must provide the operator with the capability of being able to immediately override the operation of the device to avoid an obstacle, or in the case of a system malfunction.

22.2 Obstacle Detection Beacon

Design and construct a proximity warning device with both visual and audible indicators. The device would warn the operator that the submersible was on a collision course with a fixed obstacle. The device should have a range adjustment that can be set to actuate when the object is approached within some pre-determined distance. The alarm trigger distance should be established to provide the pilot with sufficient space to either avoid the obstruction, or stop the vehicle. The beam width of the device should be sufficiently narrow to detect only those obstacles directly ahead and on a plane with the vehicle.

22.3 Evaluation of Radar Reflective Paints¹

Establish a test program to determine the return echo characteristics of various radar reflective paints. The material would be applied to test panels or to the conning tower of a deep submersible. Detection tests would be performed using the shipboard radar installed on the support vessel. The tests should be performed with varying sea states as well as atmospheric conditions.

While not as active as an electronic beacon, the radar reflective paint would assist in locating a surfaced deep submersible under inclement weather conditions. Its fail safe, requires a minimum of maintenance, and would have a long service life.

22.4 Apparent Lead-Acid Battery Power Loss During Deep Water Operation.

Investigate the mechanics of reducing the apparent power loss that occurs in a deep submersible lead-acid battery system, while operating in a pressure compensated deep ocean environment. It is generally agreed that temperature is an important factor in determining the capacity that can be provided by a lead-acid storage cell. Considerable work has been accomplished in this area, and sufficient information is available to aid the user in determining the percentage of power loss that he may expect as varying degrees of cold-soak.

The proposed program pertains primarily to new areas of investigation, such as the effects of propulsion battery gassing during deep water discharge conditions. Under high pressure conditions the bubbles forming on the battery plates, are of insufficient size to break their cohesive bonds, and float to the top of the electrolyte. As gassing continues, the bubble blanket isolates the plates from the electrolyte, causing an apparent battery power loss.

As the vehicle ascends, the bubbles increase in size and finally break away from the plates, this re-establishes the electro-chemical cycle between the plates and the electrolyte. The scrubbing or bubble removal, results in an appreciable increase in the power that may be drawn from the battery.

Due to its complexity, the scrubbing of battery plates by means of a mechanical device, does not appear to be a satisfactory answer to bubble removal. The use of chemical agents that decrease the cohesive level between bubbles and the plates, as well as allowing the bubbles to unite to form a larger more buoyant volume, may be one area for investigation. Acoustically, a short controlled pulse of energy from a transducer located at the base of the battery box, may provide a means of shearing the bubbles from the plates. The power level would have to be controlled as there is a possibility the mechanical "thump" may loosen the paste from its grid structure.

22.5 Multiplexing Device for Shared Use of a Hull Penetrator

Devise a multiplexing device that will provide for the multiple use of a single penetrator lead wire. One model of the device should provide a means of separately switching relay circuits without energizing or de-energizing any other circuit as it sweeps to the required step. The operator control console should be a push button or switch device with telltale lights to indicate the mode-of the various circuits.

A separate device should be considered for gathering instrumentation data. It should provide a means of feeding multiple data bits through a hull penetrator for use within the vehicle. The proposed multiplexer should have a minimum of

cross talk between the data bits and other systems on the vehicle, and should be capable of data transmission with a minimum of attenuation and distortion. Low signal levels may require the use of an amplifier or voltage booster right at the point of data transmission.

22.6 Improving the Viewing Characteristics of Deep Submersible Windows²

The investigation should not be geared toward the development of exotic optical systems, or the re-design and relocation of viewports. It should be directed more toward improving the existing windows, possibly through the use of simple attachments. The device should be easily attached to either the inside or outside of the window. It should decrease distortion, correct for the magnification of an object, as well as providing a wider field of view.

22.7 Reducing Strobe Light Flash Reflection

Investigate the possibility of providing the pilot with an automatic or manually controlled polarizing filter, to reduce the reflected strobe light glare associated with sand bottom.

When operating with a sequence strobe light, the high intensity flash temporarily disrupts the vision of the vehicle operator, as well as the science observer. A manually controlled light filter could reduce the momentary flash glare, while still providing a sufficient level of visibility for safe vehicle operation. An automatically controlled light level lens however, would block the flash only at the time of greatest flash intensity, providing unrestricted visibility at all other times. The complexity of the mechanism may however, become greater than the benefit derived.

One product of interest is "photogray glass,"³ developed for use in sun glasses. Unfortunately the present material changes slowly both during excitation and recovery. In its present state of development, it does not appear to have the rapidly changing characteristics necessary to reduce the high intensity glare from the photo flash assembly.

Considerable work is being done concerning the ability of transparent electrically conductive coatings to reduce light transmission when electrically activated.³ The device could be attached to the pilots port light, and with appropriate circuitry it could be triggered by the discharge mechanism of the high intensity photo flash. By monetarily decreasing the light transmission at the instant of photo flash discharge, the submersible operator would not be inconvenienced by the continual back scatter flash.

Figure 252. Sonar Search Using Low Power Pinger Target

22.8 Low Power Long Life Marker Beacon

Design, build and test a small self-contained, low power, free running acoustic transmitter for use as a bottom marker beacon. It should be of a physical size and shape that it can readily be attached to a deep submersible, towed camera, manipulator, instrument package, or other deep ocean exploratory device.

The purpose of the low power beacon is to provide a small long life homing device for items of equipment that have been inadvertently dropped during an oceanographic program. The low output power should extend the operating life of the device as well as keeping its physical size, cost, and weight to a minimum.

For the most part, the precise position of an item lost on the bottom is not generally known. The general area however, can usually be obtained from the position plots normally taken by the surface vessel. Based on this knowledge, a low power transmitter attached to the lost hardware, could be located by a receiver towed close to the bottom by a search ship. Figure 252 is an artist sketch of the proposed search operation being conducted by a surface vessel. On locating the device, a larger beacon assembly would be free dropped to mark the exact location. The second beacon would have sufficient sensitivity to receive and answer an interrogation signal from the surface vessel, with an output energy level of sufficient strength to be received by the search ship.

To assure system compatibility, and to improve the possibility of recovery, the transmitted frequency of both beacons should be one that is readily received by the search sonar of a deep submersible. As an added refinement, it may be possible to add a transmitter delay mechanism to the low power beacon. For example, when operating a submersible or other deep water device having a normal 6 hour mission, the low power beacon could have a delay of 12 hours before it began its transmission. The built-in delay would assure that the device would not interfere with other equipment being operated during the normal 6 hour program. The delay mechanism should be a simple device that can be re-set at the completion of each mission.

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23.0 Science Apparatus for Improving the Ocean Technology Performed by a Deep Submersible Vehicle

The suggestions covered by this section, pertain to various areas of investigation that would be of interest to deep submergence and science personnel. They are not considered essential at this time, and are proposed as a means of opening new areas of investigation for the engineer, scientist and the deep submersible operator.

23.1 Mineral Discovery Using Black Light Devices¹

Investigate the feasibility of surveying the bottom using the fluorescent qualities of minerals. The device would require a pressure resistant housing, as well as a glass port light that would permit the ultra-violet transmission from the lamp to the specimens. If successful, it may be possible to fabricate the quartz lamp with sufficient strength to resist the direct exposure to sea water. This would enhance the viewing characteristics, as it would eliminate the attenuation effect of the glass port light required by the pressure resistant instrument housing.

23.2 Extruded Plastic Blanket for Sediment Control

Investigate the feasibility of controlling sediment agitation by extruding a thin plastic sheet on the bottom. The device would provide the submersible with the capability of extruding overlapping sheets in the area of a wreck or piece of equipment to be salvaged. The plastic blanket would prevent the formation of sediment clouds which substantially decreases the operator's vision.

In deep water operations, some locations have very little active current flow to clear the area of these sediment clouds. The blanket coverage would permit the operator to continue his mission with a minimum of visual interference from suspended silt. As a safety feature, the plastic sheet must be capable of being ingested by the lift and propulsion mechanisms without stalling or damaging the propeller. It may be possible to have the plastic material disintegrate or dissolve after a specified period of time on the bottom.

23.3 Hardware and Structure Attachment Using Adhesive Materials²

Evaluate the possibility of using self-contained packages of adhesive to attach or assemble various lifting devices, or structural hardware, to items of salvage located in the deep ocean.

The cement or glue may be of the contact variety, or of the catalyst mix configuration. It should be capable of "curing" at a temperature range between 38 to 45°F, and at the ambient pressures found at depths as great as 10,000 feet.

Figure 253. Rubberized Tubular Inflatable Boom Structure

23.4 High Resolution Viewing Systems for Submersible Use³

Establish a program to investigate low light level image intensifier and laser viewing devices for use with a deep submersible. The proposed deep ocean investigations would be performed as a joint effort between W. H. O. I. and interested vendors. The evaluation program should include NASA as well as Military oriented devices.

23.5 Suction Pod Salvage/Retrieval Apparatus

Investigate the feasibility of using a suction pod device, similar to the bottom anchor, as attachment points on objects to be raised from the bottom. The use of a flexible diaphragm around the base of the suction pod chamber, would assure proper sealing of the device, especially when attached to an irregular surface. Multiple small suction cups attached to a flexible harness, would conform to both irregular surfaces and shapes, enhancing the lift capability of the device.

23.6 Hydrostatically Inflated Structures and Boom Assemblies

Investigate the feasibility of using extendable tubular structures as light booms, construction and hoisting apparatus, beacon towers, or as framing for a deep ocean protective closures. Figure 253 illustrates a tubular rubberized fabric boom that can be inflated on the bottom by pumping sea water into the structure. The device illustrated has demonstrated its ability to operate out of water by lifting a 19 pound air weight while pneumatically pressurized to 15 lbs./sq. inch. Its ability to lift or provide an underwater boom structure would not be diminished if it used the surrounding sea water as its pressurizing medium.

The device was constructed of rubberized fabric formed into a tapering tubular boom. A nylon mesh surrounds the tube and is attached to both end plates located at the tube extremities.

As the device is pressurized, the tube expands and stretches. The outer mesh acts as a "chinese finger puzzle" i.e. The greater the tube expansion and elongation, the tighter the mesh constriction around the tube, resulting in a rigid tubular stress member. As shown by the illustration, the simple device is capable of lifting a considerable load.

As a point of interest, the device has a built in safety factor. When overloaded, the tube gradually distorts into a collapsed condition. It recovers its original shape and position as well as its strength when the overload is removed.

23.7 Thru-Hull Telemetry

Investigate the feasibility of transmitting voice intelligence and/or vehicle operating commands, directly through either the

walls of the personnel sphere or a small pressure resistant window.

A device of this type could substantially lower the ever increasing load put on the existing wire type through hull penetrators. It would also decrease the need for machining additional holes in the pressure hull to accommodate added penetrators.

When used with an optical window, the device might consist of a coded light transmitter that could be pulsed or modulated to transmit the command. The receiver would be constructed to make use of small photo diodes at the command pick-up point. The receiver section would de-code the pulsed light, selecting and actuating the circuit corresponding to the transmitted data.

Audio transmission might be transmitted through the port light by using modulated light waves. The light wave intelligence could be converted to ultra-sonic energy for final transmission to another submersible or surface vessel.

Direct transmission through the metal pressure hull might be provided by pulsed magnetic energy waves for radio frequencies. External pick-up coils placed in close proximity to the hull, would interpret the transmitted data, selecting and actuating the proper circuit.

23.8 Ocean Current Investigation Using Temperature Sensitive Dyes

Develop a temperature sensitive dye that can be used as a low inertia device to measure both temperature⁴ and current distribution simultaneously. The temperature/current pattern would be recorded on film as a continuous motion picture or as sequence shots.

The dye material should retain its basic characteristics as long as possible, and not dissipate into the surrounding water too rapidly. The material should continue to provide an accurate temperature pattern as it dissipates. Submersible flood lamps would be used to illuminate the dye cloud, providing sufficient light to photograph the display.

23.9 Self-Contained Extendable Tubular Structure⁵

Figure 254 is a model of a self-erecting tubular structure called Stacer. As shown in the lower photograph, the device consists of a preformed ribbon of metal. In the retracted state, the ribbon is wound on a storage drum in a flat condition. When released, it reverts back to its preformed coiled state, forming the semi-rigid structure illustrated in the upper photograph.

Figure 254. Preformed Metal Strip Extendable Boom Device

Figure 255. Typical Motions Required for Simplified Mechanical Manipulator

When properly designed, the device is capable of resisting considerable bending and side loads before total collapse takes place. To assure compatibility with ocean environments, the ribbon strip could be fabricated from a corrosion resistant steel, and possibly coated with teflon to reduce the friction during retraction. The retract drive can be housed within the storage drum, which can be readily adapted to be either a pressure compensated device or a true pressure resistant structure.

23.10 Simplified Inexpensive Manipulator Mechanisms⁶

Design and fabricate an inexpensive simple motion manipulator. The device may be electrical or hydraulic, and be capable of at least the 5 motions illustrated in Figure 255. The mechanism should be designed for the retrieval of lightweight specimens such as mollusks, small geological specimens, and shell fish. The maximum extension should be established by the vehicle configuration. In the case of ALVIN, SEA CLIFF, and TURTLE, an extension of approximately 72 inches is considered satisfactory.

The maximum water weight lift capability should be sufficient to retrieve objects having a weight no greater than two pounds. The finger configuration should be a simple pincer grasp, capable of holding an object at least 3 inches in diameter.

The artist sketches in Figures 256 and 257, illustrate several conceptions of simplified retrieval and grasp mechanisms that could be adapted to provide the bases of the proposed manipulator.

23.11 Light Seeking Servo Controlled Manipulator Mechanism

Develop an electro-mechanical manipulator that is guided by a light sensitive photo diode positioned at the tip of the finger appendages. In use the operator of the vehicle directs a pencil light beam on the bottom object to be retrieved. The detection device on the manipulator is actuated, and the manipulator moves directly to the spot of light reflected from the object. Once locked in on the reflected spot, the operator would close the finger mechanism to retrieve the selected specimen.

23.12 Cryogenic CO₂ Temperature Stabilized Specimen Retrieval Chamber.

Develop a specimen retrieval chamber that is temperature stabilized by a cryogenic refrigeration device. The proposed device would be used to retain bottom specimens at a $4^{\circ}\text{C} \pm 1^{\circ}\text{C}$ temperature range during the return trip to the surface.

PLUMBER'S SNAKE EXTENSION MECHANISM

Figure 256. Simplified Manipulator Mechanisms

The device would use the cooling characteristics of CO₂ as it expands in a heat exchanger attached to the specimen chamber. When operating at depth, a thermostat device would maintain the refrigerant mechanism in a quiescent state due to the 4°C ambient temperature water surrounding the device.

As the chamber begins its ascent and the water temperature increases, the thermostat control permits the flow of liquid CO₂ into the heat exchanger mechanism. The expanding CO₂ gas is exhausted into a hard volume container in order to eliminate the back pressure of the sea water at depth. When the chamber temperature stabilizes at the required setting, the thermostat cuts off the refrigerant flow. The device remains off, until the thermostat indicates additional cooling is required.

The evacuated CO₂ exhaust storage tank is provided with a relief valve that allows the expanding gasses to vent to ambient whenever the external pressure reaches a level slightly less than the gas within exhaust tank. On reaching the surface, the exhaust tank would vent directly to atmospheric.

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from a Deep Submersible.

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 - A. Edmond Scientific Co., Barrington, N. J.
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 - B. Improvements in Surgical Adhesives, G. A. Grode,
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 - A. Laser Diode Labs. Inc., Methuchen, N. J.
 - B. Raytheon Co., Submarine Signal Div., Portsmouth, R. I.
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Figure 257. Simplified Manipulator Mechanisms

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