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The Bathyscaph TRIESTE

Technological and Operational Aspects, 1958-1961

LT Don Walsh, USN

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PREFACE

The TRIESTE program is presently administered under BUSHIPS problem number S-R004 03 01, Task 0528 (NEL L4-2). Support for fiscal year 1960 was provided by the Office of Naval Research, and for fiscal years 1961 and 1962 jointly by ONR and BUSHIPS. The technical and operational control of the program was assumed by BUSHIPS in August 1959.

The report covers work until the end of calendar 1961, and was approved for publication 27 July 1962. In the future, it is planned to issue annual reports to cover successive fiscal years.

The author wishes to thank Dr. G. H. Curl, Dr. A. B. Rechnitzer, CDR R. D. Plunkett, and LT L. A. Shumaker for their assistance and for critical review of this manuscript.

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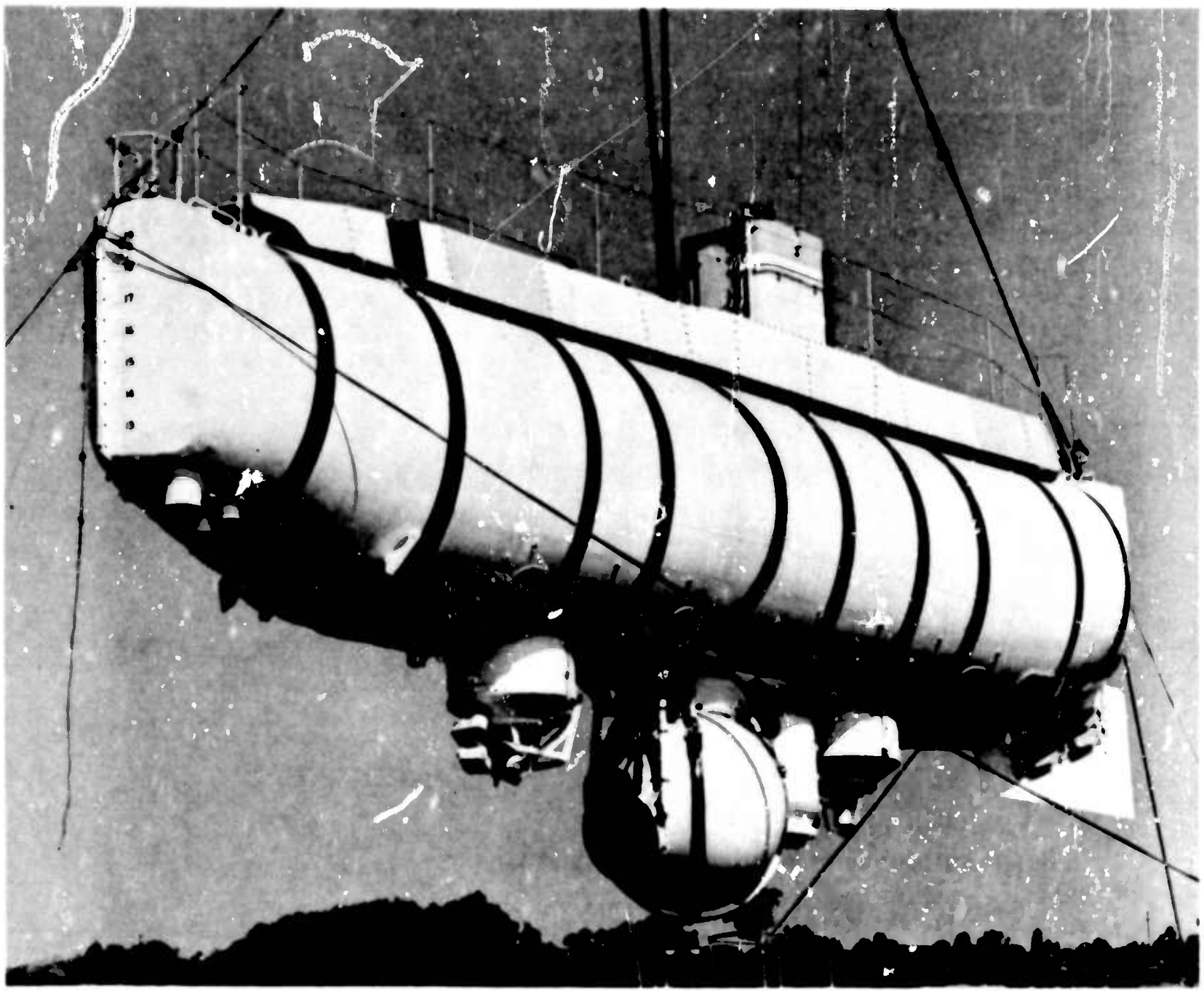


Bathyscaph TRIESTE 1961

INTRODUCTION

A deep sea diving program with a vehicle such as the Navy's first true submersible, the bathyscaph TRIESTE, can provide three basic "products":

1. Scientific information

2. Technological information

3. Operational information and techniques

The quantity and quality of each of these will vary with the design and mission of the particular vehicle. The bathyscaph TRIESTE is primarily a scientific vessel, and its scientific product has already been covered by various publications many of which are cited in the Bibliography at the end of this report. The major purpose of the present report is to cover the other two products of the TRIESTE program, namely the technical and operational information that the deep sea diving program has yielded. This report deals with the period 1958 to 1961; it includes a technical description of TRIESTE, a summary of the 1960-1961 reconstruction, an outline of the personnel organization and support facilities that were found necessary for operation of the vessel and, as appendixes, a chronology of the TRIESTE program and a diving log.

It is hoped that the information given here, particularly the techniques developed and the lessons learned at sea, will be of help to those charged with developing the next generation of research submersibles, for nothing else can replace the experience obtained while working deep in the ocean in such a craft.

OPERATIONAL PRINCIPLES OF TRIESTE

The principle of the bathyscaph TRIESTE is basically the same as that of a free balloon operating in air. The two major assemblies of the bathyscaph, the float and the sphere, are analogous to the balloon (gas bag) and the cabin of the free balloon. The differences in construction of the submersible and the airborne balloon arise only from the different environments in which the vehicles operate.

The balloon (float) of the bathyscaph is filled with a buoyant substance that is considerably heavier than the helium or hydrogen normally used in the aeronautical free balloon. Because the bathyscaph has to function in an environment where pressure increases with depth, the buoyant substance must have low compressibility; thus, helium or hydrogen are totally unsuitable. Also, the buoyant substance must not add so much on-board weight that it would be impossible to lift the craft out of water and, preferably, it should be a liquid that can be pumped from the balloon casing. The fluid used in TRIESTE and, for that matter, all bathyscaphs at present is aviation gasoline, a liquid with a specific gravity of approximately 0.7, which is readily obtainable almost anywhere in the world and can be easily handled and stored.

With the gasoline removed, TRIESTE's weight is a manageable 50 tons; with the gasoline aboard, the craft weighs some 150 tons. Because of its weight, even in the unloaded (50 ton) condition, it is not feasible to transport the craft to the diving site on shipboard as few ships have sufficient lifting capacity. Instead, the craft must be towed and, in fact, it must remain waterborne at all times when it is operational. Therefore, the bathyscaph's balloon was made sausage-shaped to provide a streamlined body for towing. If it were possible to take the craft to the diving site on board a ship and there lower it into the water, a spherical shape would provide better streamlining for the diving operation.

Since the bathyscaph must be towed at sea and moored alongside piers in port, the rubberized fabric used for construction of the conventional airborne balloon is not satisfactory for its float. Instead, the float of TRIESTE is made of thin steel (0.2 inch thick), which provides a lightweight but strong shell and prevents loss of its contents from abrasion against the pier or towing strain.

The use of aviation gasoline does pose some problems in that it is more compressible than water. Since its steel shell is rigid, the float has to be pressure-compensated to avoid its being crushed as the gasoline is compressed during descent. As the craft descends into the sea, a two-way "breathing" valve fitted in the float opens inward and allows sea water to enter the float. The sea water, being more dense than the gasoline, sinks to the bottom of the float. As the craft returns to the surface and the outside pressure decreases, the valve opens outward and the expanding gasoline forces the sea water back out through the valve. In this way, the thin-shelled balloon is pressure-compensated at all times. The compressional loss of buoyancy is of such a magnitude that approximately 1 ton of ballast must be dropped for every 3000 feet of descent to maintain equilibrium.

The cabin (sphere) suspended beneath the balloon of the bathyscaph is quite similar to the cabin of an airborne balloon. The prime difference is that the latter is designed to maintain atmospheric pressure inside as the external pressure decreases, while the former is designed to maintain atmospheric pressure as the external pressure increases (up to 16,000 psi at 35,800 feet). The sphere has thick enough walls to maintain atmospheric pressure at all times irrespective of depth. The sphere is the only pressure-resistant assembly on TRIESTE; all the other devices are pressure-compensated. The reason for pressure-compensating the other devices is as follows. In TRIESTE, all buoyant force is derived from the lift generated by the fixed quantity of gasoline; this lift decreases (through compression) with the depth. Subtracting the constant (structural) weight of the craft from the variable lift, we are left with a variable payload. Therefore, any reduction of the structural weight will be repaid in ability to carry more payload.

For diving, it is necessary to make the craft only slightly negatively buoyant, which is done by flooding the two small ballast tanks, one located at each end of the float. These tanks operate in a similar fashion to ballast tanks on submarines.

Prior to going to sea, the bathyscaph is given an equilibrium test to determine its exact buoyancy trim. An actual test dive is made alongside a pier to determine how much negative buoyancy the craft will have when the end tanks are flooded. The trimming of the craft is accomplished through external addition or subtraction of lead

pigs and the addition or subtraction of water ballast inside the float. The water ballast in the gasoline tanks permits varying the loading of TRIESTE to compensate for addition or subtraction of large amounts of weight. For example, if the float were full of gasoline and the craft in its light load condition with no scientific equipment aboard other than its basic instrumentation suit, the craft would require a topside loading of several tons of ballast to enable it to dive. This variable load arrangement allows the craft to carry a wide range of external equipment for various operations.

The diving procedure is simple. When the bathyscaph has been cast loose from the towing vessel, the handling crew and the pilot go aboard and rapidly go through the predive checks. When these are satisfactorily completed, the pilot and observer enter the sphere, closing the heavy door behind them. When the topside handling crew receives information from the men in the sphere that they are ready to dive, the handling crew floods the entrance tube with water and then floods the end tanks by opening the topside vents at each end of the float. The entrance tube is flooded because it is of no use to the crew during the dive, while the alternative of making it pressure-resistant would result in a tremendous structural weight penalty. The flooded entrance tube actually acts as a third ballast tank. Upon surfacing, the pilot can blow the water out of the entrance tube by compressed air, and can let himself and the observer out.

With all three "tanks" flooded, the bathyscaph begins its slow descent into the depths. As soon as it sinks beneath the surface, the spring-loaded breathing valve goes into action and begins to admit sea water to the float as the gasoline is compressed. The deeper it goes, the more sea water flows into the float and the heavier it becomes. To moderate the craft's speed, it is necessary in some fashion to get rid of weight. It is not feasible to blow sea water out of the end tanks because very high pressure air would be required. One can imagine the size of the air bottles that would be needed to blow the end tanks against an ambient pressure of 8 tons per square inch! Therefore, the ballast system employs the dropping of mass weights from two ballast tubs located in recesses at the bottom of the float. Each tub contains 8 tons of steel shot ballast, the same material that is used in industrial establishments for scaling steel, etc. The steel is hard and has good magnetic properties. At the bottom of each tub is a funnel-like orifice surrounded by a coil winding. When the coil is electrically

energized, a magnetic field is created in the orifice and the shot cannot drop. When the circuit is opened, the magnetic field no longer exists and the ballast drops. By means of these magnetic valves, careful control can be maintained of the ballast dropping process. Because of its fine particle size (about the size of a "BB"), the ballast in water acts much as a dense fluid rather than as a collection of individual weights. At the rate of 1 ton per 3000 feet, the 16 tons of steel shot ballast carried by the bathyscaph is more than enough for even the deepest dives, and provides an adequate safety factor. In addition, should the orifices become clogged in some way, the ballast tubs can be jettisoned by throwing a switch inside the sphere. Switches are fitted to the magnetic valve and the tub holding circuits, permitting reversal of polarity in these circuits to obviate problems caused by residual magnetism. To date, it has not been necessary to employ either of these emergency measures.

To maintain stability of the bathyscaph at a midwater point, it is necessary to alternately drop ballast and release gasoline. At a depth of 1000 feet, for example, the craft gradually becomes heavier due to slow cooling of the gasoline. The pilot, therefore, has to continuously meter out ballast to maintain his position; should he meter out slightly too much ballast, the craft would begin to ascend and, as it headed for the surface, the expanding gasoline would cause an increase in speed and, finally, the dive would be aborted. To prevent this happening, the float is fitted with a separate 1200 gallon gasoline tank called the maneuvering tank from which the pilot can release gasoline. This tank has a magnetically activated valve that permits the gasoline to flow out and sea water to displace it. Also, it is isolated from the rest of the system so that, if the valve should fail, the craft could not lose all its gasoline load and become too heavy to come back to the surface. With all the gasoline evacuated from this small tank, the bathyscaph is 3000 pounds negatively buoyant. Thus, even if the valve should jam open, only 3000 pounds of buoyancy would be lost, and this would not be a problem as the empty ballast tubs weigh more than 1500 pounds each.

An additional maneuvering feature was added during the recent reconstruction. Vertical motors were fitted, one in each of the two ballast tanks at the ends of the float. These vertical motors operate in a tunnel or tube and exert a vertical thrust of some 200 pounds in either direction. Activation of these motors assists in maintaining the bathyscaph in a hovering position. By combined use of these

devices (ballast, gasoline, and motors), the bathyscaph can be maintained in a midwater position within 10 or 15 feet of the intended depth. However, much still depends on the proficiency and experience of the pilot.

Landing on the sea floor is accomplished easily through the use of a Fathometer which gives some 200 fathoms of warning before actual contact with the sea floor. The pilot can watch the Fathometer and gauge his rate of descent so that, as he approaches the sea floor, he can slow down to a rate of a foot or so per minute and make a smooth landing. Normally, at about 200 feet from the bottom, the outside lights are turned on, and at 60 feet the pilot is able to see the back reflection of the bottom through the front window. At 30 feet, he will see the bottom. With this slow rate of descent, he can easily abort the landing by the control method described in the previous paragraph if the presence of a large rock structure or some other undesirable terrain feature should make landing unfeasible. He would then turn on his propulsion motors, move to another area, and try the landing again.

Another device borrowed from aerial balloon operations and used for the landing is a guide rope consisting of an 80-foot steel cable that is suspended beneath the bathyscaph. If the craft is trimmed so that it is only a few pounds heavy as it approaches the sea floor, it should attain equilibrium riding on the end of its guide rope through the loss in negative buoyancy as the cable gains support from the sea floor. This equilibrium, of course, is not permanent because cooling of the gasoline will eventually make the craft heavy and cause it to settle to the bottom. The pilot, by manipulating the shot valve, can counteract this effect. The guide rope also tends to provide a lateral stabilizing effect, if there is any current at the bottom, by acting as a sort of "sea anchor." Finally, the pilot can throw a switch and jettison the guide rope by means of a magnetic release, if it should become fouled on the bottom.

Upon completion of observations at the bottom, the pilot releases ballast, watching the Fathometer and the sea floor. As the craft starts to leave the bottom, he stops dropping ballast. The craft will become lighter once the ascent is started, gradually accelerating as it goes upward. Release of only a modest amount of ballast is normally required for ascent. There is no control over the ascent, and this part of the operation is normally not scientifically useful. The only way the bathyscaph could actually be slowed would be to release gasoline from the main tank

system, which would, of course, lead to obvious problems if the pilot were not careful. The release of gasoline from the small maneuvering tank, which is dependent on displacement by sea water, is insufficient to appreciably slow the craft's ascent once it starts to accelerate toward the surface.

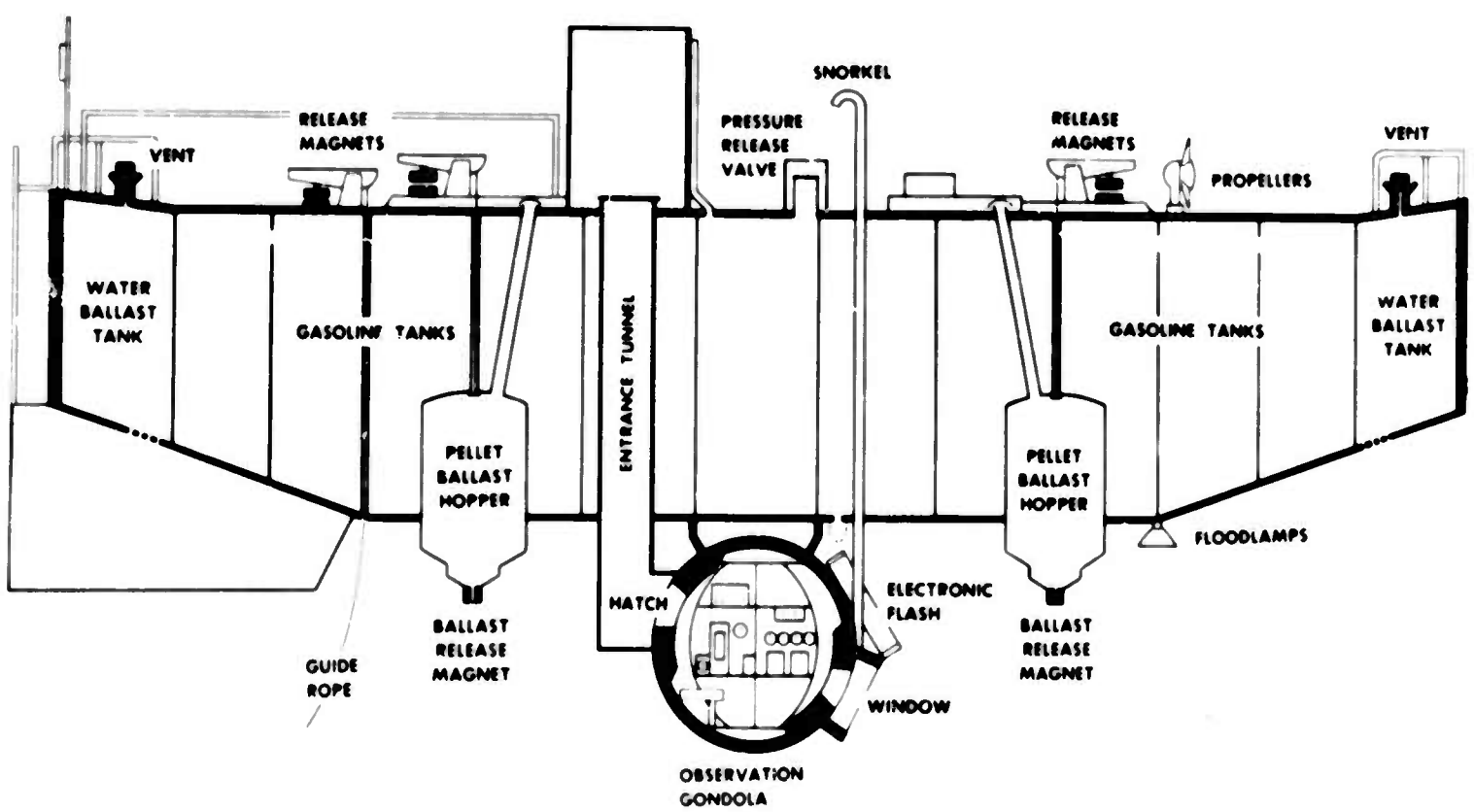
The uncontrolled ascent is perhaps the most dangerous part of the bathyscaph operation and the prime reason why the surface ships must remain well clear of the diving point. Standard procedure for the surface ships is to stay at least 4000 yards from the diving point to avoid collision with the ascending TRIESTE. It is hoped that, at some time in the future, a portable sonar may be fitted to the project work boat to allow it to "see" TRIESTE as it ascends. Present procedure calls for keeping the work boat at the diving point to maintain underwater telephone communications with the bathyscaph. The intensity of the underwater telephone signal is a fairly good gauge of the proximity of the bathyscaph and, if the latter appears to be too close, the work boat can move away from the diving point.

Finally, it must be remembered that the bathyscaph is not a submarine. It has neither the mobility nor the controllability of a submarine. Whereas a submarine may be regarded as analogous to a dirigible or a blimp, the bathyscaph may be considered to be a lighter-than-water free balloon. The craft is at the mercy of currents and is limited mostly to "elevator" type operations, such as investigations of the water column from the surface to the sea floor and detailed studies of the sea floor at the base of the water column. The bathyscaph type of configuration does not lend itself to survey work.

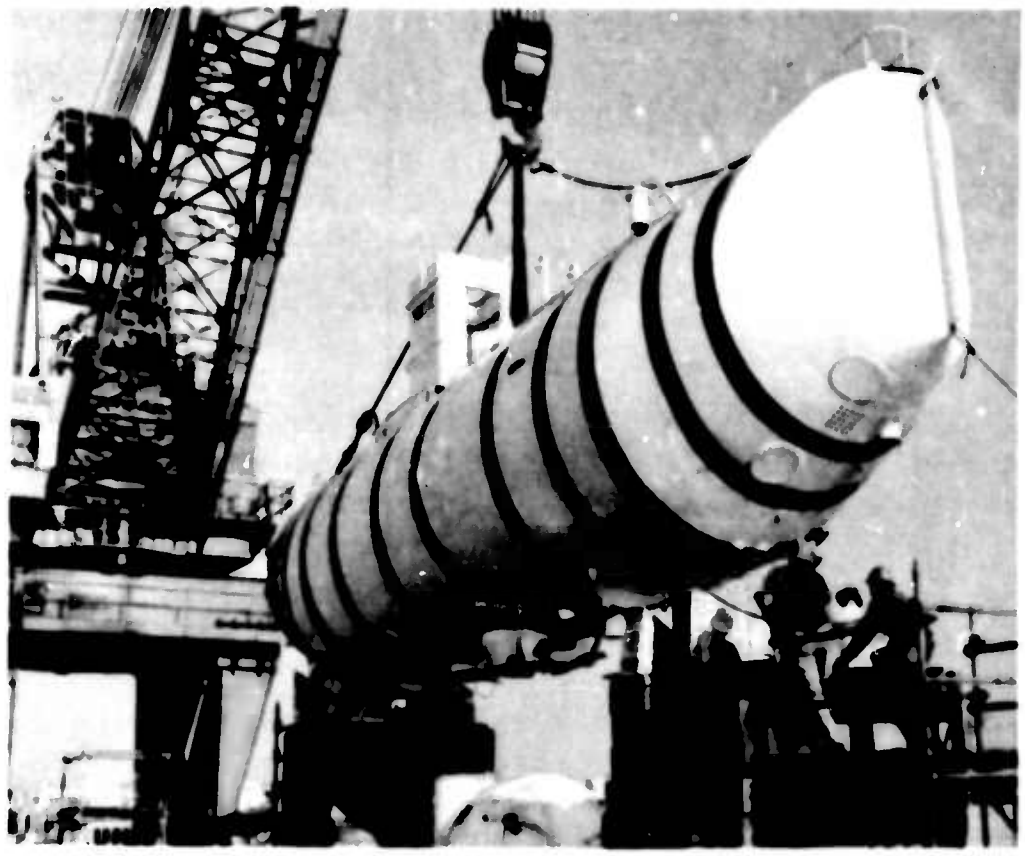
TECHNICAL DESCRIPTION OF TRIESTE

DIMENSIONS AND WEIGHTS

Length	60 feet
Diameter	11 feet 6 inches
Draft (Loaded)	18 feet
Freeboard	2 feet
Weight, without buoyant substance aboard	50 tons
Weight with buoyant substance aboard	150 tons
Maximum towing speed	4 knots maximum
Buoyant substance	34,000 gallons of 115/145 aviation gasoline (less water ballast)
Ballast material	16 tons of steel shot



Cutaway of TRIESTE



Assembly at Naval Repair Facility, San Diego, 1958

THE FLOAT*

The float functions as the "balloon" structure of TRIESTE. It also serves as a platform for several of the bathyscaph's systems to be described later. When filled with aviation gasoline, the float exerts a lifting force of several tons from which may be subtracted the structural weight of the craft to give the craft's useful payload.

The float has the shape of a cylinder with tapered ends (sausage). It is made of 0.2-inch-thick mild steel plate in the cylindrical section and 0.12-inch-thick steel plate in its extreme end sections (the ballast tanks). It is divided into twelve different compartments internally, through the use of transverse bulkheads made of 0.12-inch-thick mild steel plate. Its weight empty is 16 tons.

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*The repetition in this report is the result of an attempt to make the major sections self-contained.

At each end of the float there is a water ballast tank that is separate from the gasoline tank system. The ballast tanks provide a negative buoyancy for the craft when they are flooded at the time of diving. The forward ballast tank is internally reinforced to withstand the stresses of towing. In addition, these end tanks serve as "bumper" protection for the gasoline tanks; the rupture of one of them through accident would not cause loss of the craft or of any of its gasoline.

The nine main gasoline tanks in the float are fitted with a compensating system so that it is possible to pressure-equalize the entire tank system by means of a single valve located in the center tank. Also located inside the center tank is a tenth tank called the maneuvering tank, that serves three vital purposes: (1) it is an independent reservoir for some 1200 gallons of gasoline that may be slowly released by the pilot to control buoyancy; (2) with a wall thickness of 0.33 inch it is a strength member, and provides at its bottom the mounting pad for the cabin of the craft; and (3) it supports, at its top, the lifting pad to which the crane hook is attached for raising TRIESTE out of the water. Since this tank is disconnected from the rest of the gasoline system, inadvertent release of the gasoline from this tank by the pilot or failure of its release valve would cause the loss of only 1200 gallons of gasoline and not of the entire contents of the float.

At the bottom of the float are located two recesses, one forward of the sphere and one aft of the sphere, for the shot ballast tubs. In addition, the float provides a generous area for the attachment of instrumentation and various other fixed and temporary devices.

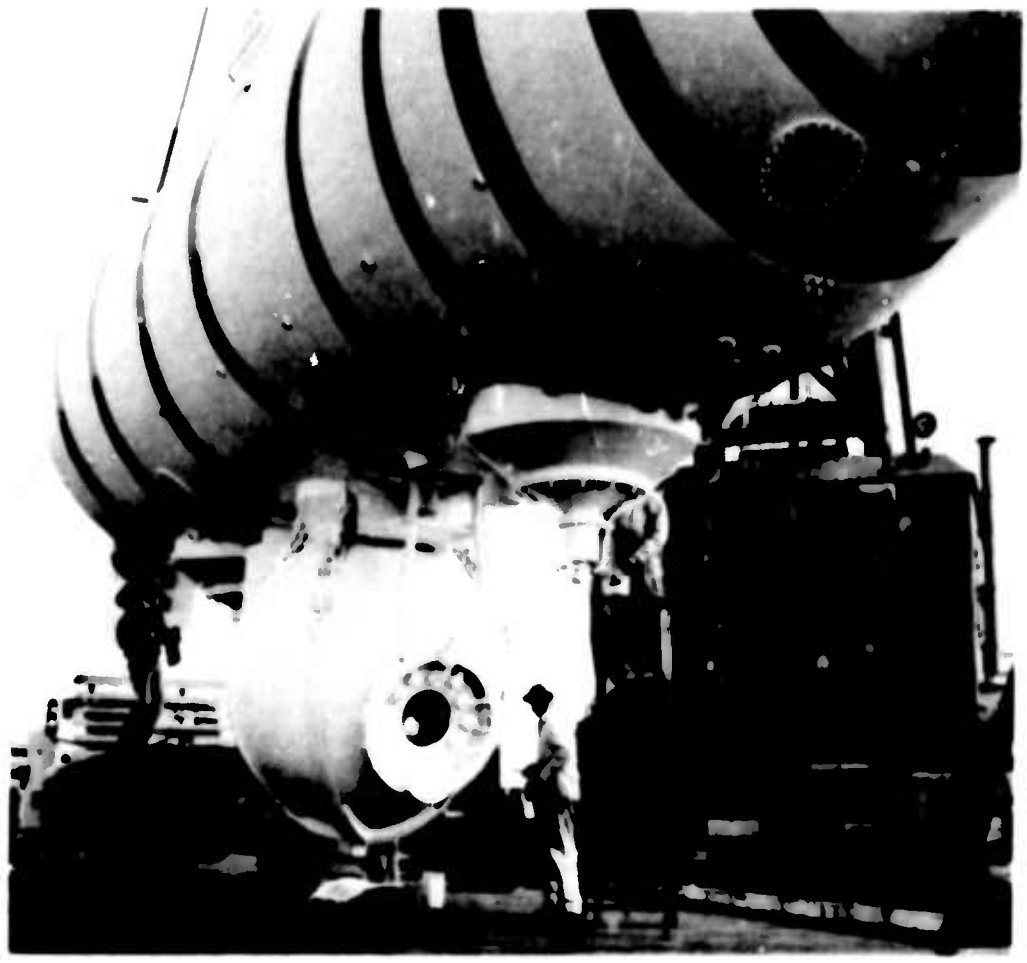
A free-flooding superstructure on top provides adequate working room for the handling crew and also provides protection for equipment located beneath.

THE SPHERE

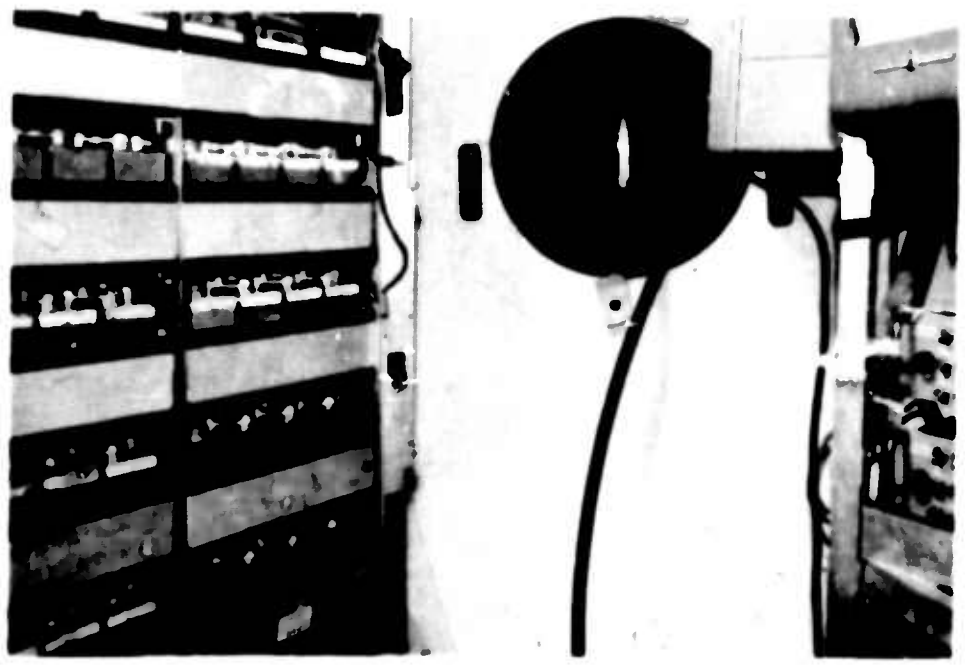
The sphere functions as the cabin of the craft. It contains all the controls and instrumentation readouts necessary for operation of the craft and for performance of its scientific mission. The two-man crew of the craft maintain their diving station inside the sphere. When all the operating controls, instrumentation, and power supplies are installed, a little over 17 cubic feet of working space remains for the crew.

Before describing the sphere's systems in detail, it is desirable to indicate the interior layout. The inside of the sphere is divided into six bays. Bay No. 1 includes the entrance to the sphere, the hatch, and the seat for the scientific observer. Bay No. 2 houses instrumentation, some power supplies, and the underwater telephone. Bay No. 3 is the pilot's operating panel with most of the controls and instruments necessary for operation. Bay No. 4 contains the primary observation window, the camera mounts, the manometer pressure gauge system, and the air revitalization system. Bay No. 5 contains, in one half, operational controls such as lighting circuits and Fathometer and, in the other half, scientific instrumentation. Bay No. 6 is entirely free for scientific instrumentation.

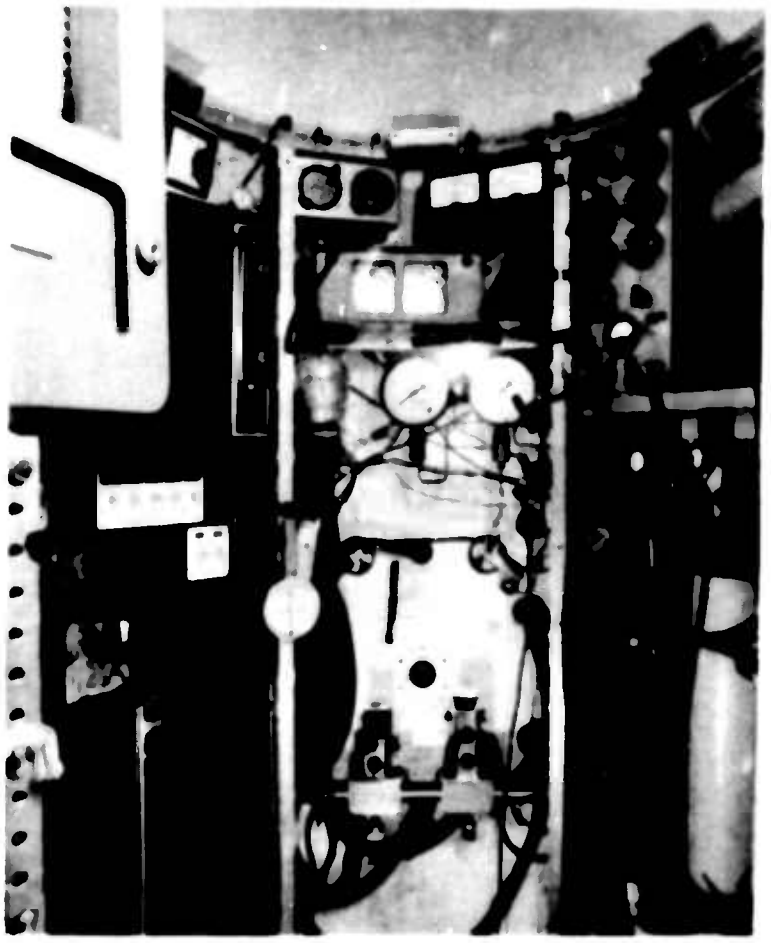
The bathyscaph is actually equipped with two spheres: (1) the original or Terni sphere which was part of the craft as originally delivered, and (2) the Krupp sphere which was purchased a few months after the craft had been received in the United States. The Terni sphere can withstand



Sphere, exterior view



Sphere, interior entrance



Sphere,
pilot panel and window

Sphere,
batteries and air supply

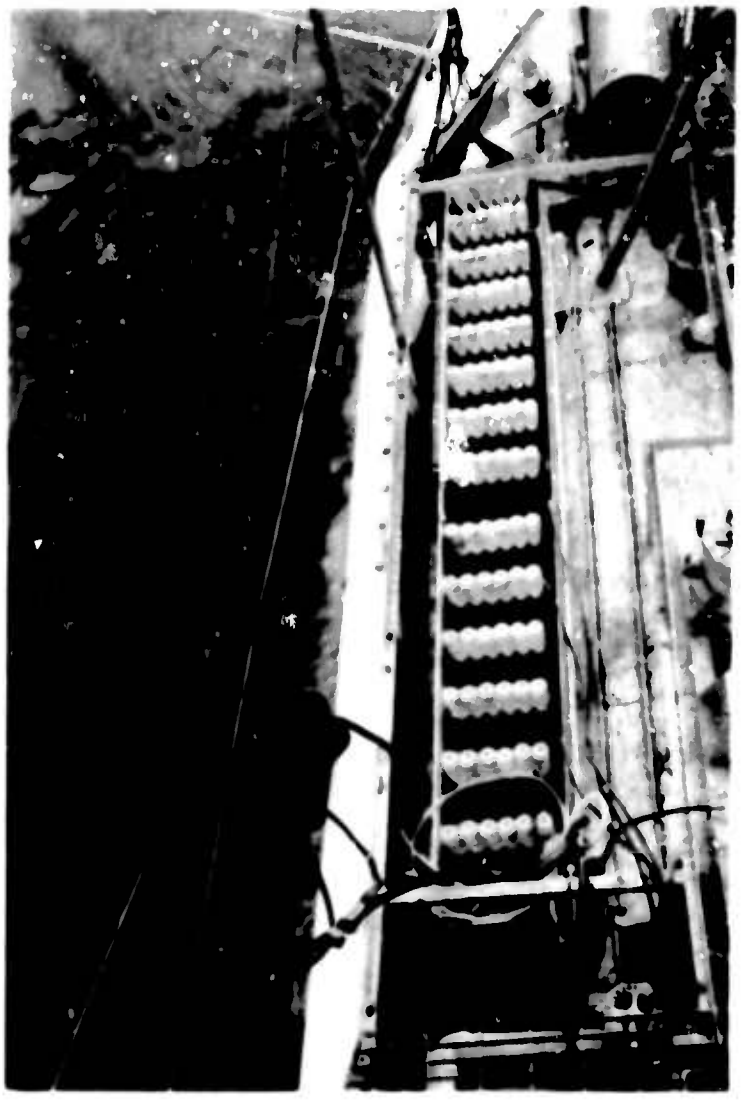
depths down to 20,000 feet, while the Krupp sphere has no depth limits and was the one used for the deep dives off Guam. The essential differences between the two spheres are: (1) the method of assembly and (2) the wall thickness. The Terni sphere consists of two hemispheres that are joined together at a flange. The Krupp sphere is in the form of a central ring with two end caps joined to it. On the Krupp unit the original joint was made with an epoxy glue; however, during one of the dives this joint failed and it became necessary to secure these two sections with a mechanical fastening system. Wall thickness of the Terni sphere is approximately from 3½ to 6 inches and of the Krupp sphere from 5 to 7 inches. The greatest thickness in both cases occurs at the reinforcement around the window and the entrance hatch. In order to be interchangeable, both spheres have an external diameter of 7 feet 2 inches. The steel used in each is a nonfatiguing chrome-nickel-molybdenum alloy which is forged and machined to exact size. Each sphere has two diametrically opposite openings: the primary observation window with the 12 hull penetrators arranged around it, and the entrance hatch which is also fitted with a window. The windows are Plexiglas cones laminated to the correct thickness. Access to the sphere is via an entrance tube (antechamber) starting at the top of the float at the conning tower and ending below the float with an elbow that is attached to the sphere. The weight of the Terni sphere is 11 tons while the Krupp sphere weighs 14.25 tons, the additional 3.25 tons being the result of the greater wall thickness.

PRIMARY SYSTEMS

Electrical

The primary 24 volt electrical system of TRIESTE is powered by 56 twelve-volt, 48 ampere-hour, lead-acid batteries located in four aluminum saddle tanks fastened to the top of the float beneath the superstructure. Each of the four battery tanks or boxes is pressure-compensated through the use of transformer oil and, therefore, during submergence the batteries themselves are subjected to full depth pressure.[1] Three of the boxes are allotted for

[1] Navy Electronics Laboratory Report 1063, Evaluation of External Battery Power Supply for Bathyscaph TRIESTE, by L. A. Shumaker, 18 August 1961



Topside battery box

powering the craft's five 3-horsepower electrical propulsion motors and for providing power to the lighting systems. The fourth box is the power supply for the sphere and its equipments. The external battery system is so organized that it can be charged in place from a single point charging connection. The following additional power supply systems are also installed:

1. 110 volt ac, 1000 watts converted from 24 vdc main power available for instrumentation and scientific equipment.

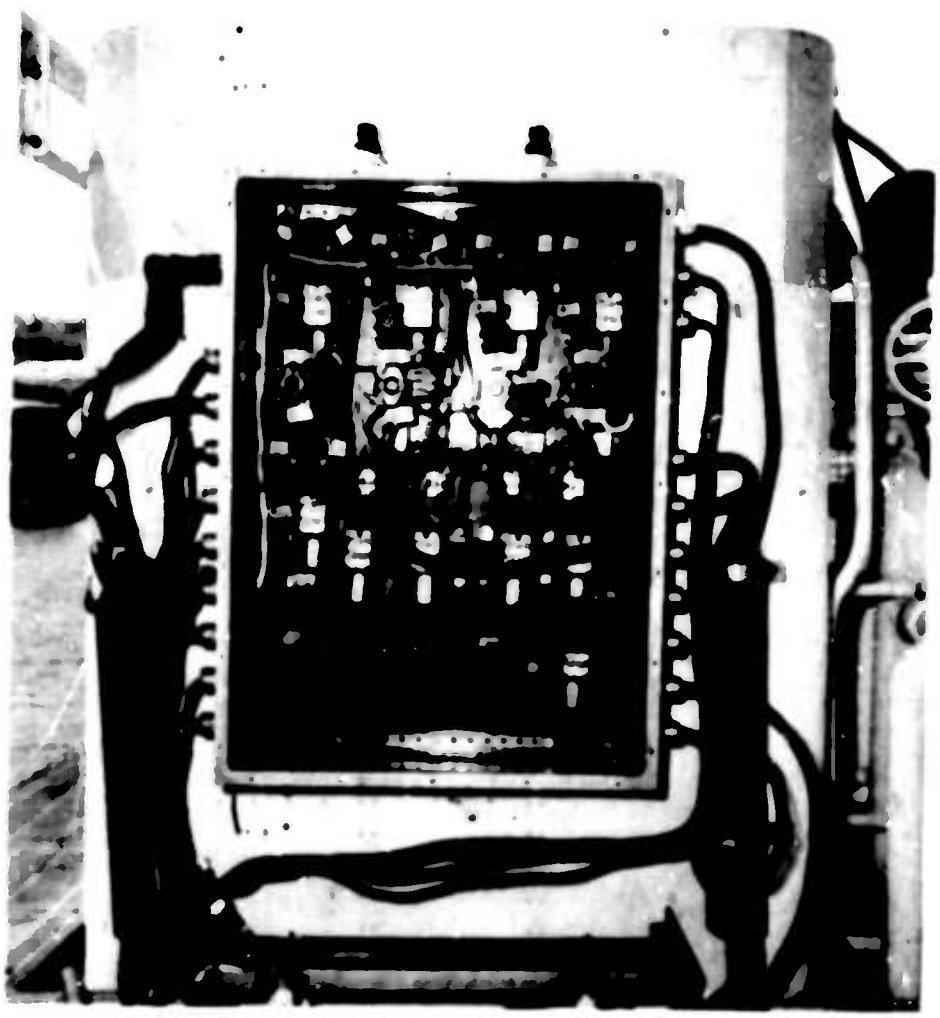
2. 110 volts ac, 400 cycle converted from 24 vdc main power for operation of the directional gyro.

3. 12 volts dc provided by silver-zinc batteries carried internally, for operation of the ballast release system.

4. 15 volts dc provided by internally carried silver-zinc batteries for operation of the ballast tub holding system.

All external wiring of the electrical system is heavy duty and is protected from direct water impingement by use of wire runs made of plastic pipe. As much as possible, all external circuit components are tested under pressure in the project's 40,000 psi pressure pot. All topside connections in the primary operating circuits such as lights, motors, and ballast are made up, spliced, and then potted in plastic, to avoid any water damage or hosing through the splices. Some 98 spare wires are provided for scientific equipment. These wires, because of the need for interchangeability, are provided with rubber high-pressure plug-type connectors that allow rapid assembly and disassembly with a high degree of reliability against pressure failure.

The heavy current demands of the motor and lighting circuits require that these circuits be controlled via a relay system since the wires which pass through the hull connectors are only capable of carrying a maximum load of 10 amperes. These control relays operate in a pressure-compensated, oil-filled control box located just aft of the conning tower.



Relay control box

The control circuits located in the sphere, when activated, in turn activate relays making and breaking the circuits concerned with motors and lighting. This system has proved to be reliable and efficient. The hull connectors themselves are located radially around the primary observation window at the front of the sphere. There are 12 hull connectors; however, only nine of these are concerned with electrical wiring. Three types of hull connectors are installed:

1. Six 30-wire connectors with No. 17 polyethylene insulated solid conductor wire.

2. Two 12-wire connectors with the same conductors as above but with thicker insulation.

3. The 24 volt dc power cable (No. 0) from No. 4 battery box that supplies the sphere power.

The hull connectors themselves are plastic-filled steel cones potted with epoxy material that adjusts itself to increasing pressure at depth.

Lighting

TRIESTE is fitted with two lighting systems. One system consists of NEL-developed 150-watt incandescent lamps, of which there are 15 located in clusters of five each beneath the float. All three clusters are located forward of the primary observation window. These lamps operate on 24 volts at 6 amperes. The second system is the Edgerton lighting system consisting of five 300-watt incandescent lighting units that provide intensification of lighting where needed. Four of these units are located forward of the primary observation window, and one in the vicinity of the television camera which is aft and beneath the entrance tube. Additional lighting may be added or the existing units may be moved to suit varying requirements. The limit is determined by the number and rating of the control relays in the relay box. Investigations are now being carried out to develop improved lighting; however, at present it appears that pressure-encapsulated incandescent lamps are the only solution for reliability in long periods of use.[2]

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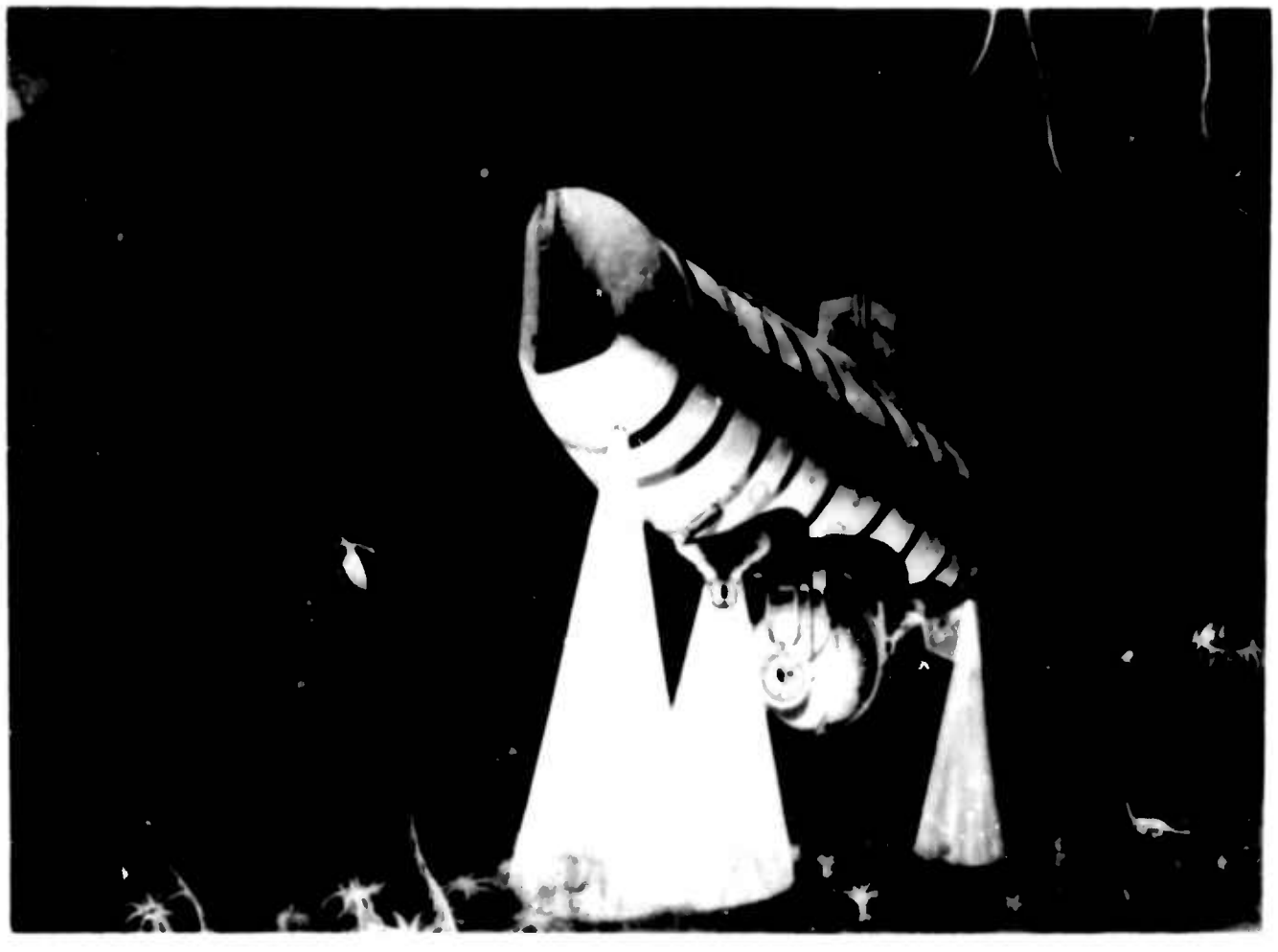
[2] Navy Electronics Laboratory Report 1094, Evaluation of External Lighting Systems for the Bathyscaph TRIESTE, by L. A. Shumaker, 21 December 1961

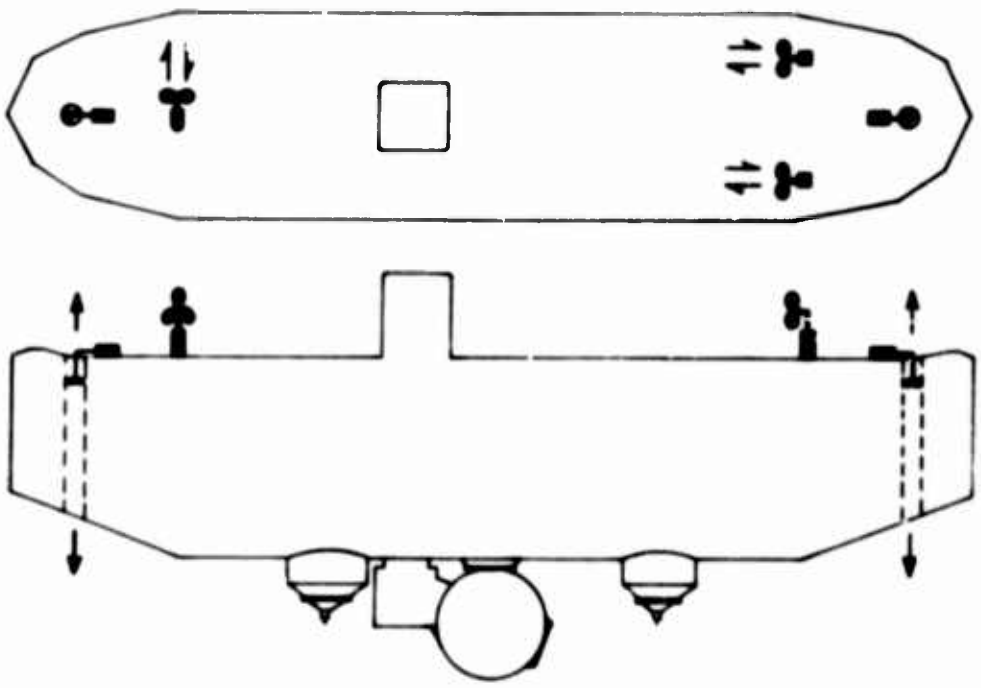


Artist's concept of TRIESTE landing upon the sea floor

Propulsion

The propulsion system consists of five special General Electric 3-hp dc motors. These motors are designed to operate in inert fluid (silicone oil) and are subjected to full ambient pressure during diving operations. The motors themselves are in five different locations. Two of them provide horizontal motion forward and backward, two

provide vertical motion either ascending or descending, and one is installed athwartships for turning. The motors all drive propellers through gear boxes. Special features of the motors include epoxy coating of the armature to lessen windage losses, and helical grooving of the commutator to provide a wiping action on the carbon brushes to prevent excessive buildup of an insulating oil film between brushes and commutator. As mentioned before, motor control is effected via control circuitry from the sphere to the topside control box.



Motor locations

Ballast

The ballast system of the bathyscaph consists of two steel ballast tubs located in recesses in the bottom of the float. Each tub is held in place by a chain that passes up through the float and is attached to a large electromagnet on the topside of the float. This system gives the operator the opportunity, in case of emergency, of jettisoning the

Aft ballast tub and light for TV cameras

complete tub by opening the holding magnetic circuit. The tubs are each filled with 8 tons of steel shot. Located at the bottom of each tub is an orifice surrounded by an electromagnet. When the magnetic circuit is energized, the shot is held in the orifice and cannot flow. When the circuit is turned off, the shot is no longer magnetized and is able to flow. The magnetic valve in each of these circuits is double-wired to prevent accidental loss of the tubs through wire failures. An arrangement of pins, turnbuckles and gates mechanically secures the system during nonoperating periods.

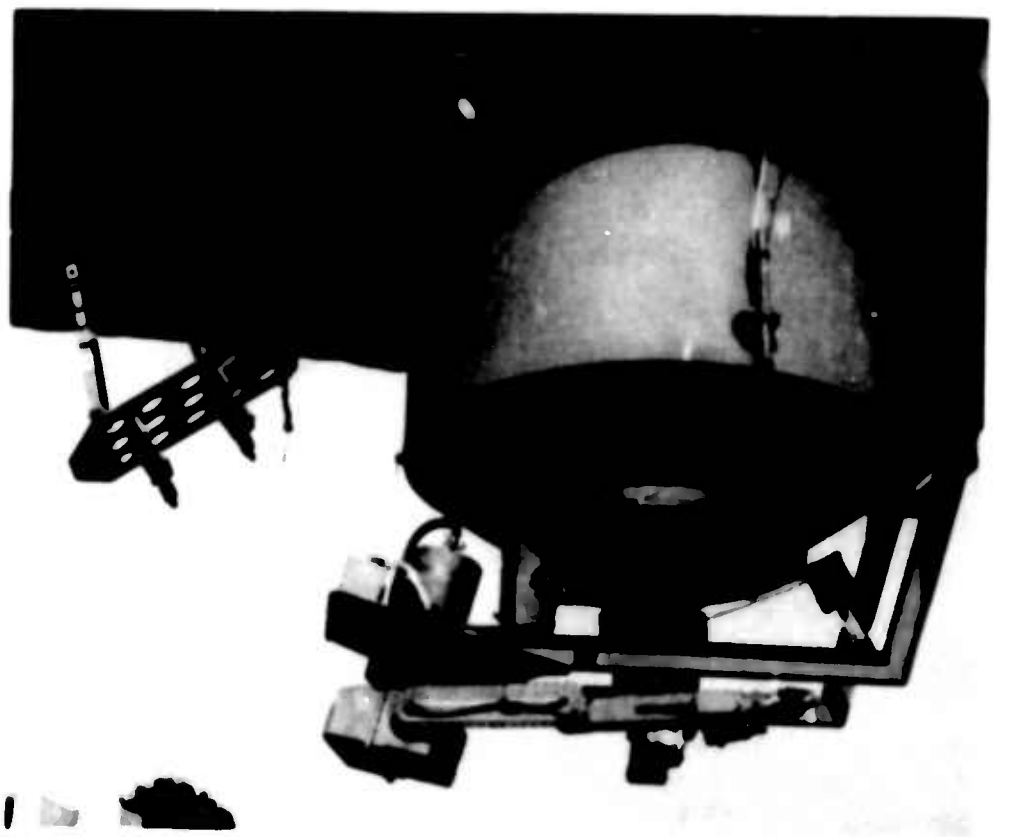
Closed-Circuit Television

The closed-circuit television system allows an expansion of the viewing area at both the sea floor and in midwater. The vidicon tube camera unit, designed to withstand over 16,000 psi, is located beneath the entrance tube of the

bathyscaph looking in a rearward direction. The monitoring unit is inside the sphere and can be equipped with a small robot-type camera so that pictures can be taken directly from the viewing scope. The primary advantage of this particular closed-circuit system is that it works with a very low power supply (24 volts dc). The camera functions well with a single 300-watt Edgerton lamp illuminating the sea floor in the vicinity of the camera. A pan and tilt head is planned for this unit in the future.

Mechanical Arm

The electromechanical arm used on TRIESTE was constructed by General Mills Corporation, Minneapolis, Minnesota. This arm is capable of all motions of the human arm, but has only two fingers. It can cover an area 4 feet in diameter on the sea floor and is capable of lifting 50 pounds. The arm is intended for picking up selected samples from the sea floor. It is mounted beneath the forward shot tub where the operator of the craft can easily see it through the forward observation window. The control box for the arm is in the sphere and consists of a



Mechanical arm stowed under forward ballast tub

series of switches controlling each of the motions of the arm. One of the Edgerton 300-watt lamps is mounted on the arm itself, enabling the operator to concentrate light upon the area from which he wishes to take samples. Various sampling tools and containers can be provided.

Air Revitalization

This system is designed to provide the proper atmospheric mixture within the sphere. Since the breathing process removes oxygen from the air and replaces it with carbon dioxide (CO_2), it is necessary to again add oxygen (O_2) to the atmosphere and remove the CO_2. This is accomplished through the installation of a 38-cubic-foot oxygen bottle at an initial pressure of 2000 lb per square inch. Oxygen is manually metered from this bottle through the use of a constant flow regulator. A spare bottle is carried in the sphere. Carbon dioxide absorption is accomplished through the use of a chemical absorbent system consisting of three canisters attached to a manifold through which air is pulled by use of a small electrically driven fan. In the future, this manifold will be fitted with a suction tube leading to the Fathometer, which is a partially sealed unit, to draw off any ozone (O_3) that is generated by the electric stylus of the Fathometer. A heated wire catalyzer for the ozone will be located in this suction line between the Fathometer and the suction manifold on the CO_2 device. The atmosphere in the sphere is regulated manually through observation of instrumentation, consisting of an aircraft altimeter that indicates positive or negative (vacuum) pressure in the sphere, and a CO_2 and O_2 sensing device that reads in percentages.

External Camera

The bathyscaph is equipped with two external pressure-encapsulated Edgerton cameras. These cameras are capable of taking several hundred 35-mm still pictures per loading. The cameras operate in conjunction with two externally carried stroboscopic light units that are also pressure-encapsulated. The "A-camera" is located at the bow of the bathyscaph and is aimed vertically at the bottom. The "B-camera" is located midway between the bow and the forward ballast tub and is aimed at the same bottom area as the A-unit, but at an oblique angle. Both

cameras are controlled through a pushbutton switch located inside the sphere. The frequency of operation is of the order of one photo cycle every 15 seconds. The bathyscaph is also fitted with a timing device that allows four pictures per minute to be taken automatically, and counts the number of pictures taken. This arrangement relieves the busy crew of the craft from manually operating the equipment and timing the sequences.

Hydraulic Pressure

The hydraulic pressure system is used to sense the depth and to take *in situ* water samples in the sphere. The system consists of pressure tubing that enters the sphere through one of the hull connectors and then is connected to a manifold system for gauges, transducers, and sampler. The sampler ("aquatap") for taking *in situ* samples is located in the water-filled section of the manifold. The operator can take water samples at any point by merely opening the valve and filling a container. The system is fitted with a surge check so that, if the valve should fail, a free-floating check would automatically secure the line. The hydraulic depth-sensing system operates through water pressure that is admitted to one side of a free piston that operates on the other side against hydraulic fluid. The water pressure operating on the piston pressurizes the hydraulic fluid; the pressure is then transmitted to the direct-reading depth (pressure) gauges and to the strain-gauge-type pressure transducers that drive the pen recorder located in the sphere.

Air Blow

The function of this system is to evacuate the entrance tube of the bathyscaph after surfacing. The system utilizes four pressure-resistant air flasks located outside and beneath the entrance tube; they carry air at 3000 lb per square inch and contain a total volume of 550 cubic feet at atmospheric pressure. The blow valve is actuated from the interior of the sphere by means of a switch which starts a small electric motor located inside a pressure-resistant case in the entrance tube. As the valve opens, it gradually uncovers the blow line allowing the high pressure air to escape into the entrance tube and force out the water. It takes six minutes to blow the antechamber.

Ballast Tank Flood

This system vents the air from the end ballast tanks to make the bathyscaph negatively buoyant. It is actuated by manually operated valves located at each end of the float. The valve consists of two parts: a mechanical stop and a plunger-depressed valve disk. First, the stop is opened and, when all diving preparations have been made, upon command from the crew in the sphere the spring-loaded plunger is depressed allowing air to vent from the end tanks. The plungers are constructed with a cork wedge that allows them to stay open until the buoyancy of the cork overcomes the friction with which it is wedged into place, and the valve closes. By this time the tanks have been completely vented. Each ballast tank is fitted with a blow line which is connected to a central manifold in the conning tower. After surfacing from a dive, an air hose from the work boat is connected to the manifold to blow these tanks; the antechamber, also, can be blown by this system.

Cathodic Protection

The purpose of this system is to retard corrosion of the metals of the float and its associated equipments. As a result of its experimental mission, the craft utilizes many metals and is therefore highly susceptible to corrosion due to galvanic action. Any loss of thickness of the thin metal of the float would involve great reduction in strength. Therefore, a protection system more efficient than a paint film is essential. The system now installed on TRIESTE is a passive one that uses a series of 40-pound magnesium Cathanodes.* These Cathanodes gradually deteriorate, depending on the amount of galvanic activity that occurs. However, the set that was installed originally on TRIESTE during the spring of 1959 has provided continuous protection, is still in good order, and is still in use. The system roughly corresponds to the circuit of a battery in that the Cathanode may be considered as one plate of a battery, the bathyscaph and its associated equipments as the other plate, and sea water as the electrolyte. In the Cathanode circuit is a variable resistance that can be "tuned" to the required values. The values of current and voltage can be read out on instruments inside the sphere. This system has virtually prevented all external galvanic deterioration of the craft below the waterline during the past three years.

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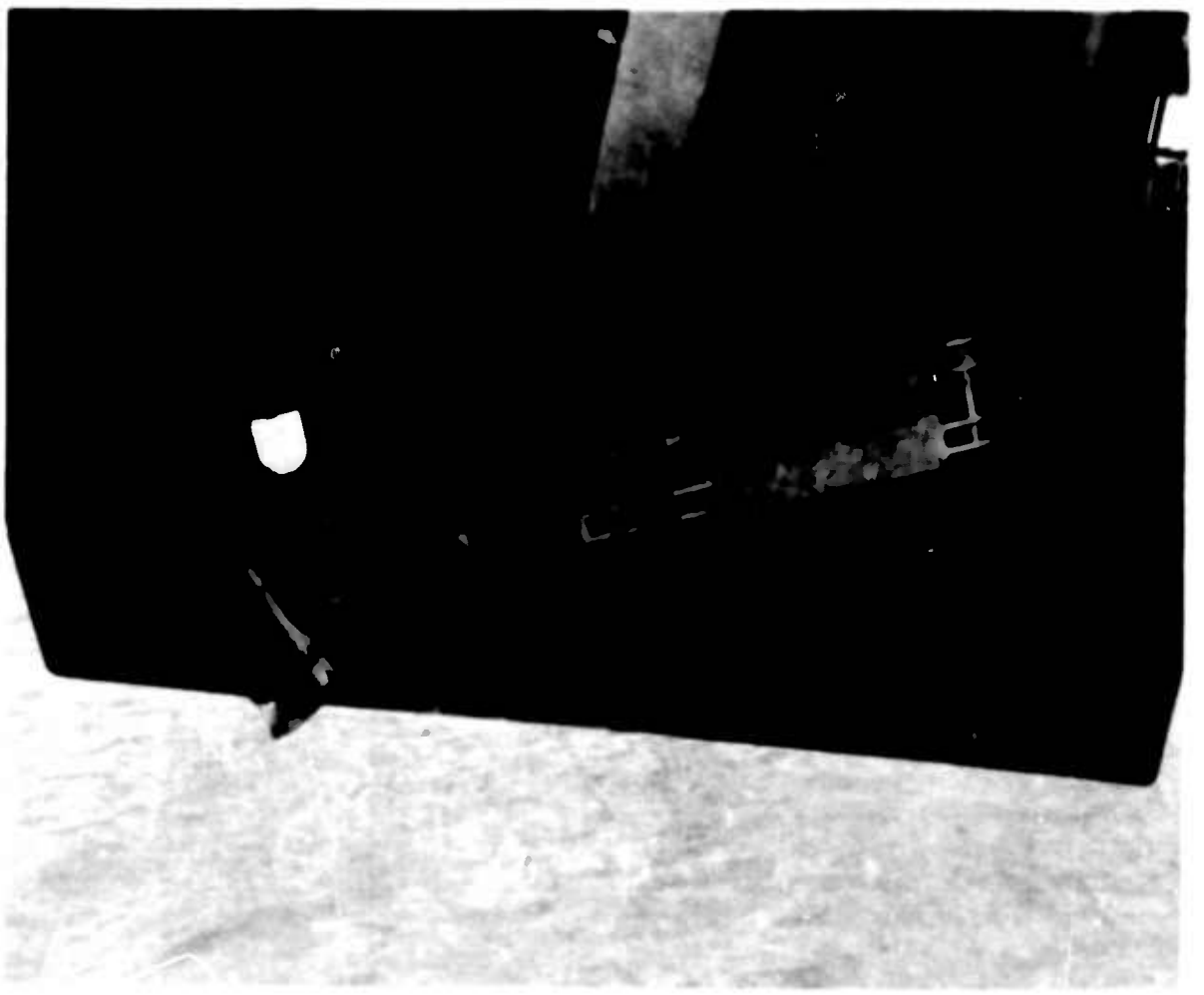
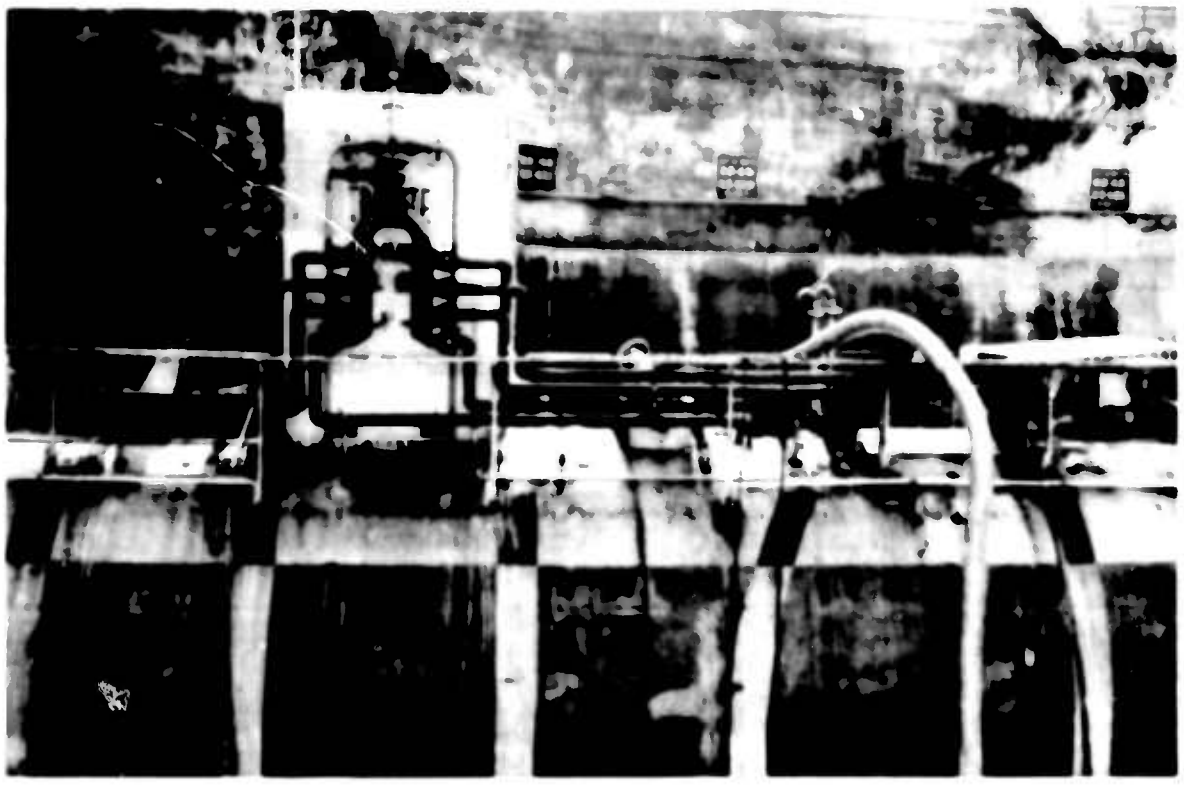
*Patented name.



Cathode protection Cathanodes

Fueling

The function of this distribution system is to provide rapid and safe handling of the aviation gasoline load of the bathyscaph. The system consists of a central manifold located on the conning tower with a 4-inch opening leading into it, a master stop valve for the manifold, and a master stop valve on the manifold for each line to each fuel tank. The lines from the manifold to each fuel tank run beneath the superstructure of the craft and into the top of each tank. At the junction of the fuel line and the tank, a second stop valve is fitted. With this system, the time required to fuel or defuel the bathyscaph can be cut by three-fourths. In addition, the system has the advantage of a single-point fueling arrangement, whereas in the past up to five different hoses were required for each operation.



Fuel distribution installation

CONTROL AND INSTRUMENTATION SYSTEMS

Fathometer

The echo-sounder used on the bathyscaph is an adaptation of a small boat commercial Fathometer. It has a depth capability of 200 fathoms, and the readout is on electrosensitive paper. The Fathometer enables the pilot of the craft to "see" the sea floor at some distance before it becomes visible to the eye. Its usage is analogous to the use of an altimeter by the pilot of an aircraft. The only modification made to the unit was to its transducer. The original transducer was unable to withstand the great pressures of the depths, and the beamwidth was too wide.

Ballast Quantity Indication

This system allows the pilot of the bathyscaph to read the approximate quantity of ballast in each ballast tub, in

fractions such as half or three-fourths full, etc. The system operates through a series of three induction coils, one coil in each ballast tub and a reference coil in the conning tower. Comparison of the coil immersed in steel shot with the reference coil which is relatively free of any inductive influence permits the quantities to be read on an instrument within the sphere for each of the tubs.

Vertical Speed Indicator

This device is a variable resistance with a spring-loaded vane attached to it. The vane is located on an arm fixed to the conning tower at right angles to the path of travel of the bathyscaph. As the bathyscaph goes up or down, the vane is deflected in one direction or another, varying the resistance in the circuit. This resistance appears on a dial inside the bathyscaph as either ascent or descent, on an empirical scale.

Directional Information

Directional information is provided by the use of an electrically driven aircraft gyro. This unit requires 400-cycle ac power, and it was necessary to build a small solid state 400-cycle ac inverter for this purpose. Directional information is important on every dive of the bathyscaph. The steel mass of the sphere and the proximity of operating electrical equipment made the utilization of a magnetic compass entirely out of the question.

Underwater Telephone

The underwater telephone on TRIESTE allows its crew to communicate with the surface craft. This unit basically is a voice-modulated sonar. The frequency of the unit is comparable with that of the underwater telephones used in ASW vessels and submarines. The present unit is the second of this type to be designed and built by the Navy Electronics Laboratory for TRIESTE. It operates on 24 volts and has a power output of 150 watts (from transducer). Two transducers are fitted to this system, one located on top of the conning tower and the other beneath the float. Transmission may be accomplished either through voice

or through cw. A second, lightweight portable unit with transducer is available for the supporting surface vessel. A third and more powerful unit (300 watts) is now being constructed which will provide not only greater transmission range but also distance ranging information not now available to the bathyscaph crew. In this way the bathyscaph operator will be able to tell how far away the transmitting station is located, though he will not know its bearing.

Topside Telephone

While on the surface, communications between the sphere and the conning tower are maintained through a telephone circuit. The topside unit is located in a waterproof box in the conning tower and consists of the phone handset, buzzer switch, and buzzer. Inside the sphere, there is essentially the same equipment. Prior to diving, the topside unit is unplugged and taken to the supporting vessel. The unit in the sphere remains in place at all times. Through the use of this unit, rapid communication can be made while surfaced between topside and the personnel in the sphere even after the sphere door has been closed.

Motor Control

This system consists of a panel containing the controls for all five propulsion motors. The switching arrangement for each motor consists of an energizing switch for the circuit, a switch that removes the starting resistance from the circuit, a rheostat used for building up motor speed and, finally, a reversing switch.

Lighting Control Panel

This panel controls all the external lighting except for the Edgerton stroboscopic lights which are controlled through the external camera panel. The lighting panel is so arranged that each light cluster of five NEL lamps and each Edgerton 300-watt unit can be controlled separately. In this way, maximum flexibility is afforded.

Ballast Control Panel

The ballast control panel consists of the necessary switches to energize the ballast tub holding magnets for control of the dropping of ballast. In addition, switches are provided to reverse the polarity in both circuits in the case of failure due to residual magnetism. The flow of shot is measured by use of two electrically activated stop-watches. When the spring-loaded switch is depressed to drop ballast from a tub, the stopwatch automatically turns on and remains on as long as the switch is depressed. In this way, a cumulative time count is obtained, and it is an index of the amount of ballast that is dropped from each tub. The ballast falls roughly at a rate of 25 pounds per second per tub.

Electrical Checkout Panel

The function of this panel is to permit the pilot of the bathyscaph to check the current and voltage in each of the key control and instrumentation circuits. Through use of rotating switches, each circuit may be read to ascertain its exact state.

External Camera Panel

This panel contains the necessary equipment for manual and automatic operation of the external Edgerton cameras and stroboscopic light units. In addition, it permits the synchronization of the interior still cameras with the external stroboscopic lights. The manual mode is operated by pressing a small switch. The automatic feature is operated by a low speed motor which automatically makes and breaks the contact in the circuit at approximately 15-second intervals.

Temperature Recording

The temperature recording system consists of a Varian dual-pen recorder which is capable of printing a continuous temperature profile from the surface of the ocean to the sea floor in two modes. The coarse mode

measures between 0 and 30 degrees centigrade, while the fine mode presents with greater accuracy any 10 degree section of this wide range selected by the operator. The water temperature is sensed by a small element attached to the outside of the sphere near the observation window.

Oxygen Content of Sea Water

Oxygen content may be read directly from the panel containing the O_2 -CO_2 indicator. The system is equipped with an external sensor located near the sphere window.

Tape Recording

The sphere may be fitted with a 22-channel FM type tape recorder that was developed for use in TRIESTE. While this recorder is not presently mounted, it may be put in at times when additional data-gathering facilities are required. Also, voice tape recording may be accomplished through the use of a small portable recorder that is normally used to record the pilot's log during the course of a dive. This tape provides the basic information for preparing the report of the dive upon completion. A portable dictaphone is available for the use of the scientific observer in recording his data.

Current Measuring Equipment

This system permits measurement of horizontal direction and velocity and vertical velocity of current flow. Accuracy is to 1/100 knot. Recording is through a pen recorder.

Plankton Sampler

This externally mounted unit can collect up to 10 samples on 4-inch-diameter screen disks. Control is through push-buttons in the sphere.

Depth Recording

The pressure transducers provide depth inputs to the Varian dual-pen recorder, which also usually records the temperature trace.

MODIFICATIONS MADE DURING THE 1960-61 RECONSTRUCTION

This section summarizes the major additions and modifications made to TRIESTE during the 1960-1961 reconstruction. A brief explanation of the reason for each particular change is included. The over-all basis for the reconstruction was, of course, the lessons and experience of the preceding three years of operation.

It should also be noted that, in addition to the TRIESTE reconstruction, a considerable amount of work was done on the supporting facilities both ashore and afloat. The second shop building was completed, and both shop buildings were finished on the inside. Both project boats received complete overhauls and some modification. While not all of this work was directly accomplished by project personnel, it was planned and supervised by them.

1. FUEL DISTRIBUTION

In the past, TRIESTE was fueled through individual hoses to each of the ten tanks in the float. This system was inefficient in that most of the time spent in fueling was actually used for shifting connections, making preparations for fueling, and controlling the fuel flow to the individual tanks. The defueling process was time-consuming because of the considerable loss of suction resulting from the numerous fittings that were employed.

It was decided to install a centralized manifold fuel system on board TRIESTE in spite of the slight weight penalty and consequent reduction in over-all payload. The centralized manifold system allows quick connection and disconnection and high rates of fuel flow. The rate of flow through the 4-inch main supply line to the manifold is about 1000 gallons per minute. The lines to each of the tanks have two stop valves, one at the tank and one at the manifold. Thus, one man can control the entire fueling operation from the manifold. The time required to fuel the bathyscaph has been reduced from over 4 hours to a little less than 1 hour. Also, this system is designed to be compatible with the proposed mother ship system in that the bathyscaph can be fueled and defueled rapidly from a single point. Small

improvements were also made in the internal fuel piping, such as replacement of bad sections and improvement of low point drains.

2. NITROGEN INERTING SYSTEM

This system provides an inert atmosphere inside the float prior and subsequent to fueling and defueling operations. It is so constructed that nitrogen gas (N_2) under pressure, is admitted to the float through the high point vent holes in each tank. In the case of fueling, the rising liquid level displaces nitrogen preventing creation of dangerous explosive vapor concentrations within the float. In the defueling operation, as the liquid level decreases, the empty space created is filled by nitrogen, also reducing explosive vapor concentration within the float. The flow of the nitrogen is manually regulated from a central control point topside. The nitrogen system and improved fuel handling procedures for the bathyscaph were the result of NEL requested consultation by the aircraft carrier aviation gas specialists from the San Francisco Naval Shipyard and the Mare Island Naval Shipyard.[3]

3. SUPERSTRUCTURE

The present superstructure design on TRIESTE resulted from the difficult working conditions experienced by the TRIESTE crew during the sea operations off the island of Guam. In the past, TRIESTE had only a 20-inch freeboard which was actually the top of the float. Working on top of this rolling cylinder at sea posed considerable problems for the topside crew in making their post-towing inspections and preparations for the dives. In fact, it was not unusual for crew members to be swept over the side. With these experiences in mind, a light-weight free flooding superstructure was designed for TRIESTE. This structure is made of stainless steel supporting members, with Fiberglas side panels and aluminum gratings at the top. The superstructure covers about 90 per cent of the length of the float, is 6 feet wide, and stands approximately 18 inches

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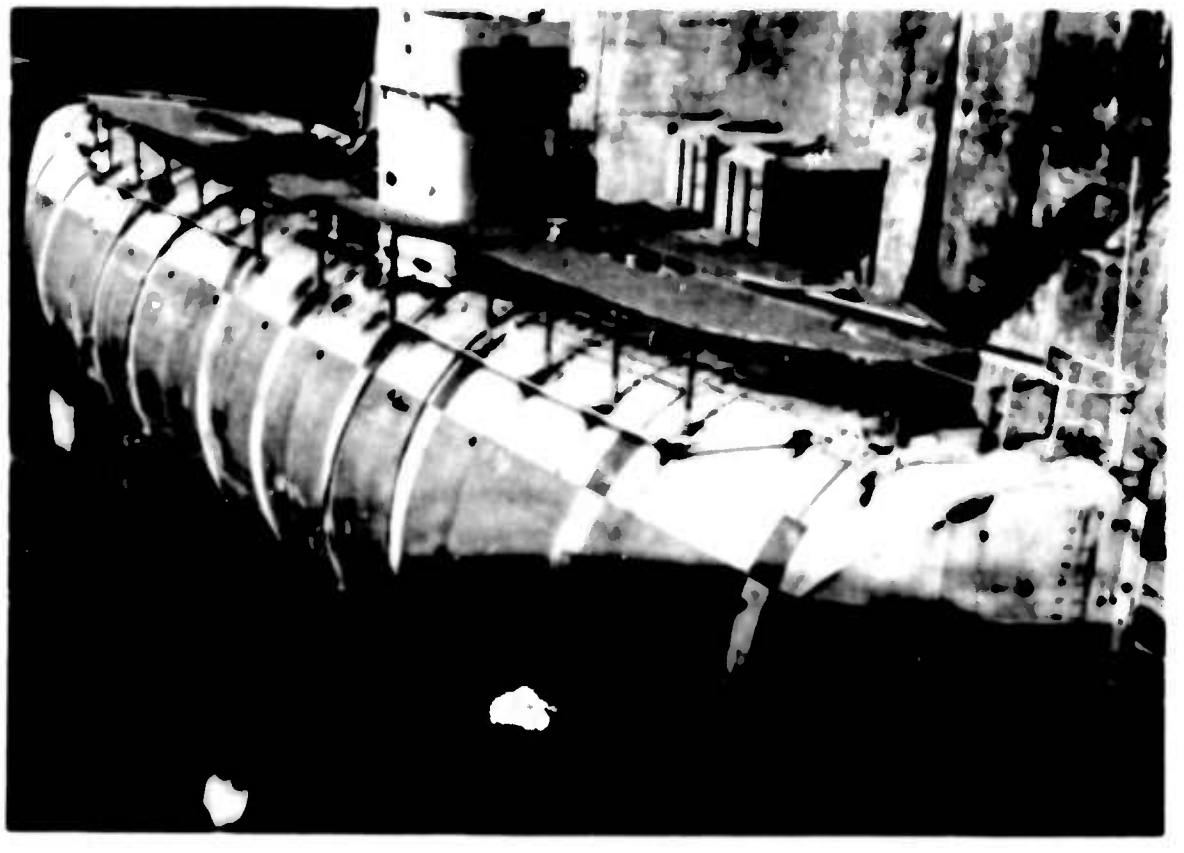
[3] San Francisco Naval Shipyard Report, Operational Safety for the Gasoline System on Bathyscaph TRIESTE, by A. C. Wong, 23 April 1961



Installation of superstructure

above the top-center of the float. The gratings are in small removable sections for ease of access.

The superstructure also prevents direct wave impingement on the delicate equipments located on top of the float. Several times off Guam, equipment was either damaged by wave action or carried over the side, and it was merely good fortune that no dives had to be aborted through loss of vital equipments.

Recent sea tests with the new superstructure have proved it to be entirely satisfactory. An additional advantage is that it provides an ideal surface for the small boat to come alongside for transfer of personnel and equipment. In the past, the round hull configuration of the float, which tends to lie broadside to the prevailing seas, made this extremely difficult. With the new superstructure and with life lines rigged to prevent personnel from being carried over the side, the sea operations are considerably safer.

4. CONNING TOWER DOOR

The conning tower door was installed on the forward side of the tower to protect the interior from direct wave impingement. In the past, this area was open and, during towing, the seas which broke over the bathyscaph rolled into the conning tower, causing damage.

5. REPLACEMENT OF THE EXTERNAL ELECTRICAL SYSTEM

The entire electrical system of TRIESTE was replaced during the reconstruction. Though part of the system had been replaced in early 1959, the material delivered by the contractor was not of good quality and caused severe problems. The primary control systems for lighting, motors, and balla ' still used the original wiring installed in TRIESTE in early 1953 when the craft was built in Italy. It was considered prudent to replace all this wiring, as it was beginning to fail due to aging. In addition to replacing substandard and aging wire, the wiring system was improved by protecting all wire runs with plastic tubing and pipe.

Several changes were made in the design of the electrical system in consideration of the new power system and the many new equipments that were to be put aboard TRIESTE. The new power system basically is a 24-volt dc system supplied by four external battery boxes. It reduces the possibility of an electrical failure associated with high voltages and high pressure. Thus, it was found, with the previously used 500-volt lighting circuits and the 250-volt motor circuits, that the smallest pinhole in the insulation of the wire would cause immediate failure of that wiring circuit. Of course, the high current requirements of the motors and lights now dictate the use of an external relay control box, as the hull connectors can only carry a maximum of 10 amperes.

6. PROPULSION MOTORS

TRIESTE had two horizontal pressure-compensated propulsion motors, each of which developed less than 2 hp. In the three years preceding the reconstruction they had given intermittent service and had become a continuous

source of maintenance "headaches." It was decided to substitute a better designed motor and to increase their number. Since the craft is not steerable at its low speeds, it was also decided that it would be better to maneuver it by force or thrust component rather than by trying to "twist," i.e., going ahead on one motor and backing on the other. Some difficulty was experienced in finding a U. S. contractor willing to build suitable motors, but finally the General Electric Company constructed six 3-hp, inert, fluid-filled motors, five of which were mounted on the bathyscaph. These motors are special 24-volt dc motors, with rotors potted in epoxy plastic to reduce windage losses and helical-cut commutators that provide a wiping action at the brushes to prevent formation of insulating film at that area. The motors operate in silicone oil.

In service, the motors have proved to be efficient and they provide excellent maneuverability for the craft at low speeds. For maximum flexibility, two motors are mounted in vertical tubes, one in each end tank to provide vertical thrust, two are mounted as propulsion motors allowing forward and aft movement, and one motor is mounted athwartships for turning purposes. The motors drive geared propellers, at approximately 300 rpm maximum speed for the propulsion and turning motors and at 600 rpm for the vertical thrust motor. A rheostat controller allows regulation of the motor speed over about half of its rpm range and, in addition, all motors can be reversed.

7. LIGHTING

The original lighting system on TRIESTE consisted of four miniature mercury vapor lamps. One unit was located forward, two above the sphere, and the fourth aft near the fixed rudder. Each unit was designed to operate at 500 volts; however, many times in service the lamps would not light with this voltage owing to their extreme temperature sensitivity. The lamps were made by the Phillips Company of Holland and were difficult to replace. The only readily available mercury vapor lamps in the United States operate at 1000 volts, thus causing wiring problems.

Investigations made to solve the lighting problem are the subject of a NEL report.[4] Two types of lighting were

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[4] See footnote reference 2, page 19

finally installed on TESTE. The first is a lamp developed at NEL which consists of a small General Electric 150-watt incandescent bulb designed for use in wingtip lights of high performance aircraft. The lamps are housed in a pressure-resistant case with a Plexiglas window and are designed on a unit basis so that they can be rapidly replaced by a SCUBA diver. The lamp bulbs have a life of approximately 100 hours and are arranged in clusters of five units to a cluster. The plastic window is protected by a thin layer of water and a piece of heat resistant glass between the bulb and the window, so that heating of the window is not a problem. The second type of lighting is an Edgerton 300-watt unit which is an ordinary projection lamp bulb enclosed in a Pyrex sock, with an external reflector behind the whole unit. These lamps proved extremely useful in the early test dives and it is anticipated that more will be installed. In addition, investigations are still being carried out to develop a more efficient, higher intensity lighting system.

8. CONTROL SYSTEM

To achieve a 24-volt basic power system, the motor and lighting circuits had to accept larger currents. Since the hull connectors were only capable of handling a maximum of 10 amperes per wire, an external control system operating through a system of relays was constructed. This system is contained in a pressure-compensated, oil-filled box located just aft of the conning tower. The relay system is actuated by control circuits from inside the sphere and, thus, the heavy current demands are met without high currents being carried by the hull connectors themselves. In operations, the relay control box proved to be efficient and reliable.

9. FLOAT STRUCTURE

Several of the tubes and pipes within the float were found to be in deteriorated condition during overhaul of the float and were replaced at the Naval Repair Facility in San Diego. In addition, the end tank of the float, where the towing force is applied, needed additional internal bracing to distribute towing stresses more equally. The internal bracing was installed and some deteriorated metal replaced, achieving considerably more strength in this area. The

float was completely stripped of paint, carefully inspected, and then coated with Demetcoat paint in the interior and Laminar polyurethane paint on the exterior. These coatings were chosen to provide maximum protection of the metal surfaces of the float. In addition to renovation most of the metric standard hardware and fittings were replaced by U. S. standard material for ease of maintenance.

10. CATHODIC PROTECTION

The cathodic protection system installed on the float was modified slightly by the substitution of an improved control box topside. The original control box proved unsatisfactory, as the inert fluid within it was lost several times during operations owing to poor construction. The new control box is a completely sealed unit containing a flexible diaphragm for pressure compensation. In addition, the circuit wiring was revised to provide better control of the system.

11. VERTICAL SPEED

The original vertical speed transmitter was inoperative more often than not. The unit was completely redesigned, but using the same basic principle. The redesigned unit has performed very well so far.

12. AIR BALLAST BLOW SYSTEM

The air ballast blow system used to blow the end tanks and the antechamber subsequent to the dive was badly deteriorated. Therefore, all the piping was replaced with stainless steel piping, and a better type control valve system was installed.

13. HULL CONNNECTORS

The hull connectors that were constructed for the Terni sphere, while actually new assemblies, were of the same design as the original Piccard hull connectors. The

differences were in the plastic pressure barrier, the types of wires, and the fabrication method. Tests were made to find an epoxy bonding agent more satisfactory than the material formerly used. The older material had a tendency to crack internally after a period of time, and tended to pull away from the metal sides of the hull connector creating a possible water leakage path. To compensate for this fault, M. Piccard put a layer of synthetic beeswax on top of the epoxy casting, so that if any cracking or pulling away occurred, the beeswax would flow into the resultant gap and seal it. It was considered, however, that the primary epoxy barrier itself should withstand full pressure without developing any leakage paths. The search for suitable materials and improved fabrication methods was time consuming; however, eventually, a hull connector system was developed using improved epoxy that was capable of withstanding over 16,000 psi for a period of 24 hours without developing any leakage. After each of the connectors had passed this test, the synthetic beeswax material was poured on top of the epoxy as a further safeguard.

An additional hull connector was acquired for use as a wire passage. Formerly, this connector had been used as a passage for a single blow line for the antechamber. By converting to the electrically operated blow system located external to the sphere, this connector, instead of carrying one piece of high-pressure tubing, was used for one heavy duty copper buss that provides 24-volt power to the inside of the sphere from the external battery boxes.

14. FATHOMETER

The first Fathometer was capable of giving height information only for some 40 fathoms above the bottom. In the same sized package, the new Fathometer gives a 200 fathom trace, thus providing the pilot with earlier warning of the approach of the bottom. In addition, the Fathometer transducer was modified to make the beamwidth slightly smaller so that the representation of the bottom beneath would be more accurate.

15. MECHANICAL ARM

This unit, built by General Mills Corporation, is basically their Model 150 mechanical arm modified for use under high ambient pressures. The arm is located in the forward field of vision beneath the forward ballast tub. It is capable of operating in several axes in a circle 4 feet in diameter on the sea floor and can pick up 50 pounds of weight. The unit allows the scientists diving in TRIESTE to obtain selected samples from the sea floor. The arm is controlled by a pushbutton switch box inside the sphere.

16. CLOSED CIRCUIT TELEVISION

The purpose of this system is to increase the field of vision at the sea floor. The vidicon camera unit is located beneath the entrance tube facing aft, and the monitor unit is inside the sphere. The scientist can, by looking at the monitor, determine the characteristics of the bottom behind the sphere and also observe biological activity. The monitor will be fitted with a small automatic camera to provide scope photographs. Since the TV camera has a light sensitivity better than that of the human eye, it requires minimum illumination of the sea floor. A switch-operated focusing arrangement permits detailed inspection. Provisions have been made for a pan and tilt unit, though it is not presently on board.

17. SPHERE

The Terni sphere was completely gutted, re-treated for preservation, and rewired. This 20,000-foot sphere is more than adequate for the projected, local (San Diego) diving program. The Krupp sphere was also stripped and then sent to Mare Island Naval Shipyard for reconditioning.

In the Terni sphere overhaul, emphasis was on a more functional layout of the controls for the pilot to leave more room available for the scientist. Also emphasized was standardization of panel size and power supply, so that the various equipments needed by scientists with different specialties could be interchanged rapidly. The

previous layout of the sphere can only be described as chaotic. As with the rest of the craft, most of the dimensions of fittings and dial units were in the metric system, so that replacement parts, even as simple as nuts and bolts, had to be metric and specially procured. Replacement of switches and other electrical assemblies was almost impossible, since they were of European manufacture and very hard to procure in this country on an "off the shelf" basis.

The new interior layout of the sphere has over three times as much space for scientific equipment as before. In addition, all the wiring parts and assemblies are standard stock readily available on short notice from local suppliers. The layout of the operational panels is more functional, to provide ease of operation for the pilot, and several new systems have been added.

18. GAS VALVE

The gas valve formerly used on TRIESTE was not satisfactory owing to faulty seals around the valve assembly which created a considerable gas leakage problem. The valve was modified and rebuilt, and the leakage difficulties eliminated.

19. BATTERIES

The original system consisted of silver-zinc batteries carried within the sphere. While these batteries had high capacity and a small volume they required an extraordinary amount of servicing in addition to being expensive to replace. The annual expenditure on batteries could be as much as $60,000 for this type. Therefore, an external battery system consisting of 12-volt, lead-acid batteries from standard stock sources was installed instead. This system contained in four external battery tanks on the topside of the float provides approximately two-and-one-half times as much power as the old system, and the annual battery replacement cost is now of the order of $1,000. The batteries are easily serviced in place and can be rapidly charged from the pier, as opposed to the old method of having to move all the battery trays to the battery shop for recharging. Some weight penalty was, of course,

imposed in substituting heavier lead-acid batteries; however, it was regarded as worthwhile in view of the gain in simplicity in supporting the system, in low cost, and in ease of maintenance. The new battery system is the subject of a NEL report.[5]

A newer type lead-acid battery is now available which will add 50 per cent more power with only a slight increase in weight. These will be installed in the near future.

20. UNDERWATER TELEPHONE

The previous underwater telephone designed and built by the Navy Electronics Laboratory, while an excellent unit, was completely redesigned and rebuilt, resulting in improved output power and reduced internal noise. In addition, the unit was repackaged to fit the standard 19-inch rack mount inside the sphere. Several new features were added which make it more useful and efficient than in the past.

21. SONAR

A high resolution sonar unit designed and built by NEL will be "chin" mounted on the bottomside of the bow of the float. The pilot of the bathyscaph will be able to "see" up to 150 feet in any direction while on the sea floor. With the craft's increased maneuverability, the sonar unit is highly desirable to prevent collision with obstructions on the sea floor.

22. GYRO DIRECTION SYSTEM

Previously the bathyscaph had no directional reference other than a magnetic compass, which was unsatisfactory owing to magnetic disturbance inside the sphere. The directional system used now is a converted aircraft-instrument directional gyro. It is fitted with a separate, solid-state 400-cycle ac power converter to provide the necessary

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[5] See footnote reference 1, page 16

driving power. The rate of precession of this unit is acceptable over the short duration of the average dive. As this unit is not a gyrocompass but a gyrodirectional indicator, the heading must be set prior to diving so that a true heading reference is available while operating.

23. EDGERTON CAMERA SYSTEM

The Edgerton cameras now fitted to the bottom of the float are of improved design compared with those originally used. The interior circuitry, the design of the case, and the design of the front window have all been modified in light of recent experience with these units. Two cameras, one oblique and one vertical, are now carried instead of the one that was formerly used. In addition, two Edgerton stroboscopic units are fitted to provide lighting for these cameras. These stroboscopic lights can be synchronized with the internally carried Hasselblad camera so that it also can utilize the external flash units.

24. AIR REVITALIZATION SYSTEM

The original air system consisted of an oxygen bottle from which metered oxygen was used to operate a Venturi device. The vacuum caused by the oxygen flow was used to pull air from the sphere through carbon dioxide absorbent arranged in flow-through containers. This method did not permit the flexibility that was required, and the apparatus was bulky.

The new air system consists actually of two basic systems. The oxygen is supplied by a 38-cubic-foot oxygen bottle with a pressure of 2000 psi. The oxygen is metered manually through a regulator valve and pressure gauge arrangement on the bottle. The carbon dioxide absorbent system consists of three absorbent canisters attached to a manifold through which air is drawn by a small electric fan. The chemical canisters themselves are of the same flow-through design. Oxygen/carbon dioxide ratio is maintained by manually operating the regulator on the oxygen bottle and the suction motor on the carbon dioxide absorbent manifold. Percentages of the two gases are determined from an indicator panel.

25. OXYGEN-CARBON DIOXIDE SENSING SYSTEM

This system allows direct reading of the oxygen percentage inside the sphere. The concentration of carbon dioxide inside the sphere is shown on a second direct-reading dial. This system is similar to the one used in nuclear submarines. This unit can also measure O_2 in the water when an external sensor is fitted.

26. PRESSURE MANIFOLD

The entire pressure manifolding system has been concentrated into one panel which includes not only the two direct-reading depth gauges, the shallow gauge and the deep gauge, but also the three pressure transducers for the recording depth gauges. An "aquatap" is fitted to this manifold allowing direct sampling of the water outside the sphere. This special high-pressure valve is fitted with a floating piston such that, if a surge in the line should occur due to breakage of the valve or tubing, the surge check would be pushed shut and the system would be secured. The arrangement was tested to 24,000 psi after installation, and has been successfully used without any sign of leak.

27. AC POWER SUPPLY

In the past, the ac power supplies for different investigations had to be furnished by the investigator. The bathyscaph now has 1000 watts of 110-115 volt "built-in" ac power available, provided by two solid-state 500-watt inverters permanently inside the sphere. In this way, the scientist has a full choice of power supplies with which to operate his equipment.

Electrical noise from this and other power units has not yet been eliminated. The main nuisance is high background noise in the underwater telephone circuit. The external cameras and flash units are particularly guilty in this respect.

28. TOPSIDE TELEPHONE

Primary communication between topside and the sphere while on the surface is through a two-way telephone system which, in the past, was unreliable. The system was completely re-engineered, and has proved successful in recent use.

29. CAMERA BRACKETS

Mounting the cameras in the sphere was difficult owing to the makeshift arrangement. The new camera arrangement consists of a trolley that holds both movie and still cameras with tripod steadiness. When not in use, the trolley can be moved well away from the window without disassembling either camera. The two cameras presently in use are a 16-mm Arriflex movie camera with a 400-foot magazine and a 120-size Hasselblad camera with a 12-picture magazine.

THE USNEL SUPPORT FACILITY FOR TRIESTE

The present support facility for the bathyscaph TRIESTE is located at the NEL waterfront area and consists of four major components:

1. Administrative spaces

2. Shop and indoor storage areas

3. Pier and outdoor work spaces

4. Afloat equipment

1. ADMINISTRATIVE SPACES

The administration of the TRIESTE program includes the management of the program funds, planning of operations, and maintenance planning. In addition, since the program largely uses what may be termed "nonstandard" procedures and procurement, considerably more time than usual must be devoted to simplest details. Full time administrative help is not presently assigned to this program, with the result that the program managers are also their own secretaries. The present administrative spaces consist of:

a. Private office space (156 square feet) for the Deep Submergence Research Program Coordinator.

b. Private office space (143 square feet) for the Officer-in-Charge and the Assistant Officer-in-Charge.

c. Conference room (234 square feet) equipped for use of visual aids.

d. Lobby area (143 square feet) also equipped as secretary's office.

e. Study room/library (221 square feet) situated for maximum privacy, used for preparing reports and program proposals, and also for analyzing data from operations. This space contains all technical and diving information related to TRIESTE.

f. Visiting scientists' office (163 square feet), for use of visiting scientists working with TRIESTE.

g. Drafting room and engineering library (130 square feet), used for preparing technical drawings of new equipments and components for TRIESTE. This room also serves as a library for industrial product brochures and catalogues.

2. SHOP AND INDOOR STORAGE AREAS

Since mobility is an essential element of the TRIESTE program, many skills must be represented to some degree within the project organization. Technicians needed include machinist, electrician, electronics technician, welder, diver, photographer, sonarman, boatswain, engineman, general mechanic, and draftsman.

The resulting self-sufficiency manifests itself in the diversity of shop capabilities maintained. At present the bathyscaph project has the following shop facilities located in two large buildings arranged in an "L":

a. Machine shop (341 square feet). A nonproduction experimental shop capable of building experimental equipments, maintenance, and making special parts for TRIESTE.

b. Electrical shop (156 square feet). Used for the construction, test and maintenance of TRIESTE's electrical system and components.

c. Electronics and instrumentation shop (169 square feet). Used for construction, test, and maintenance of TRIESTE's on-board electronics and instrumentation suit.

d. Mechanical systems shop (228 square feet). Used for repair and maintenance of mechanical equipments such as valves, gear boxes, and hydraulics.

e. High pressure shop (299 square feet). Contains 40,000-psi pressure pot and associated equipments. Used for experimental testing of high pressure components prior to installation on TRIESTE.

f. Electrical/electronics storeroom (60 square feet).

g. Darkroom (117 square feet). Ultimately to be used by personnel from NEL photo lab for loading and unloading bathyscaph cameras and for special processing as needed (not completed).

h. Experimental equipment shop (130 square feet). Used for research into, and development of, new instrumentation systems for TRIESTE.

i. Shop stowage area (1620 square feet). Protected storage for spare parts and equipment.

j. Floor work area (2175 square feet). Doors of both shop buildings are of sufficient size for the whole sphere of TRIESTE to be brought inside for overhaul.

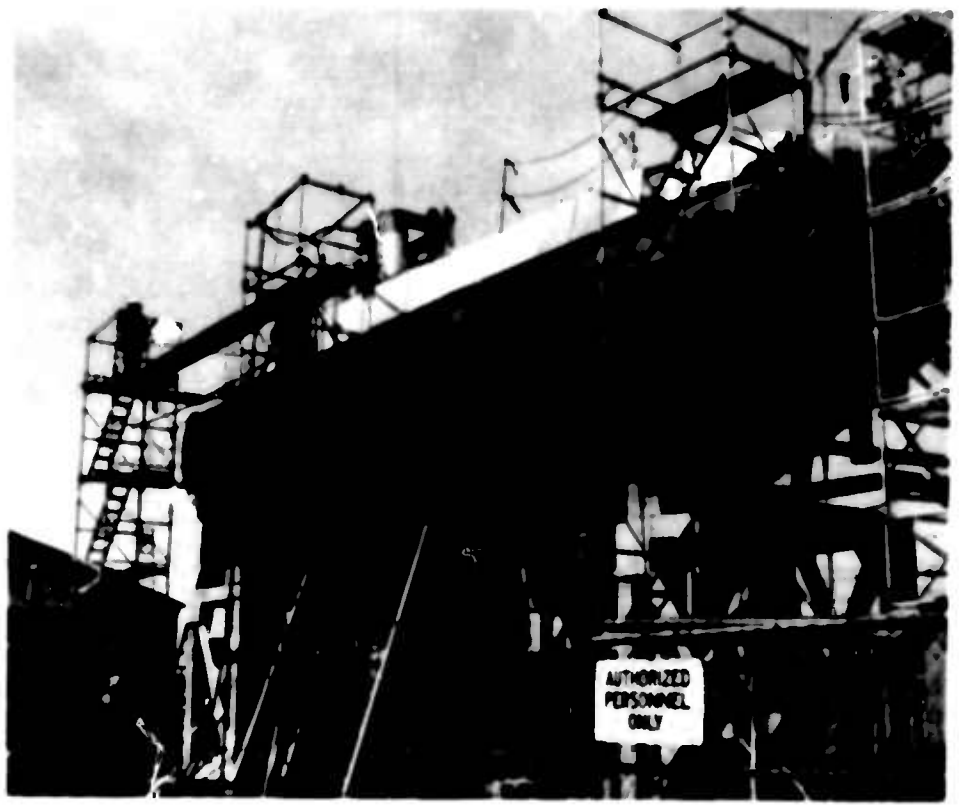
3. PIER AND OUTDOOR WORK SPACES

These areas consist of:

a. Concrete work pad (4067 square feet) adjacent to the shop buildings, completely fenced for drydocking TRIESTE and for outdoor storage of larger equipments.

b. Pier space with two 20 by 40 feet work floats. Water depth alongside is 25 feet. Located between NEL finger piers.

c. Outdoor stowage area located at NEL waterfront open stowage yard. For storage of seldom-used large equipments and assemblies.



TRIESTE drydocked at NEL

4. AFLOAT EQUIPMENT

a. A 53-foot work boat. A converted LCM equipped to handle TRIESTE during harbor operations and to support it during coastal diving operations.

b. A 17-foot outboard motorboat. An open commercial type lobster skiff used for carrying personnel and equipment between TRIESTE and other supporting craft while at sea.

c. Two 7-man rubber boats powered by outboard motors. Used when sea conditions prevent use of the small motorboat.

TRIESTE, tug, and skiff at sea, 1962

In addition to the foregoing, the project has a considerable capital investment in instrumentation, tools, and support equipments. The material involved ranges from screwdrivers to outboard motors, and from the high-pressure test tank to oscilloscopes. The net worth of this material is estimated at about $200,000; however, virtually all of it can be employed by other vessels, as very little is peculiar to TRIESTE requirements alone.

Planned expansion for the near future includes the installation of a precision high-pressure test facility using a converted 14-inch naval gun barrel. This facility will permit accurate calibration of deep submergence instruments and equipments under carefully controlled conditions of pressure, temperature, and time.

Other major additions will include:

1. Head and shower facilities for TRIESTE crew. At present only one head and one wash basin are available for nearly twenty people. Also there is no provision for shower facilities, which are required owing to the frequent late working periods of the project SCUBA divers and crew.

2. Power transformer and air system. The rapid growth of the bathyscaph project has taxed the power system supplying the project buildings, necessitating the installation of an additional transformer in this area. The air system will be installed to provide continuous air services for the project as the regular NEL waterfront machine only operates during normal working hours. The continuous air supply is particularly important for maintaining low humidity inside the sphere.

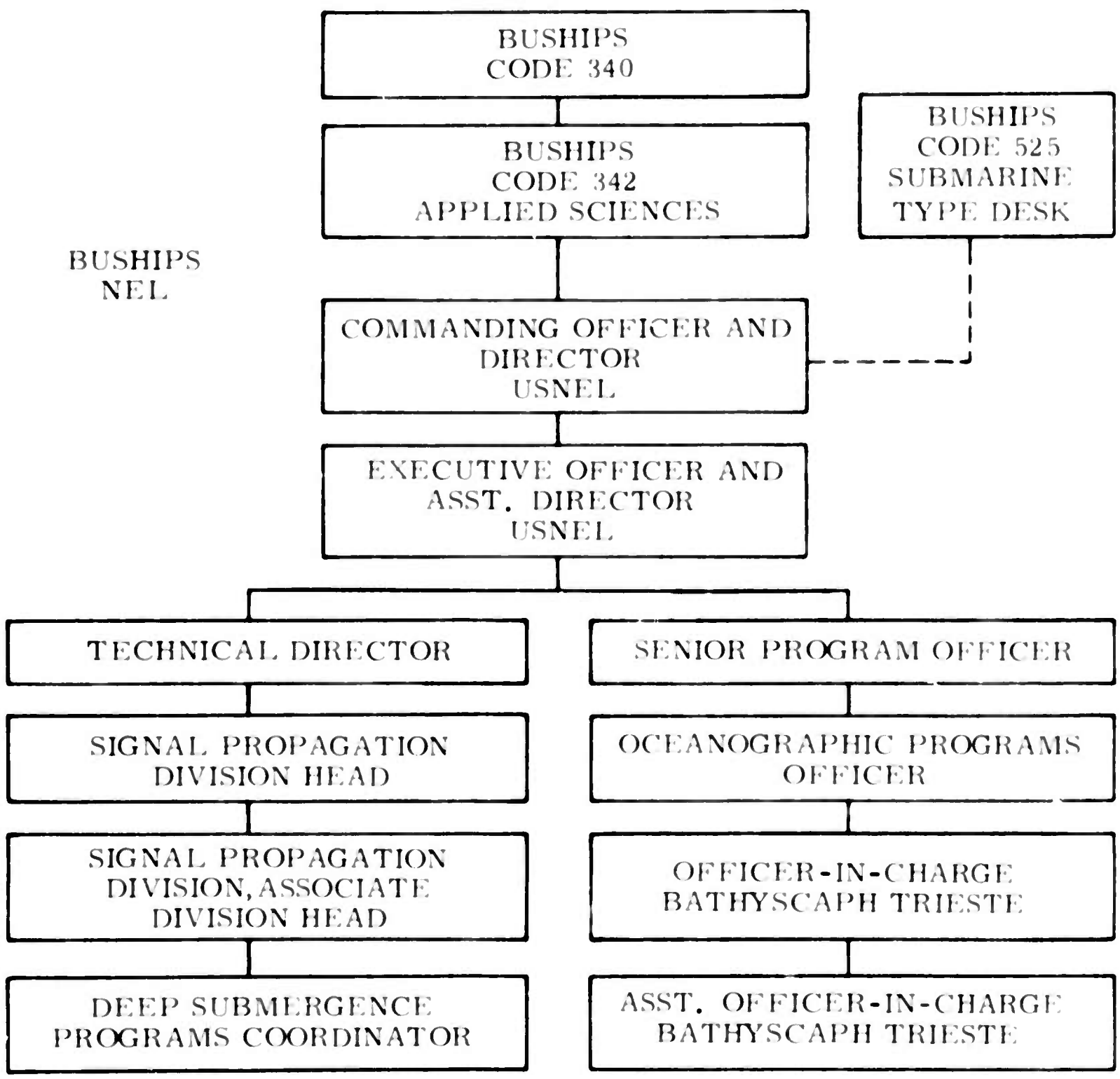
3. "Carport" for project engine-driven equipments. At present over 16 different engine-driven equipments are maintained by the project. These range from outboard motors to heavy duty portable air compressors. The carport will allow them all to be assembled at one point, for ease of routine periodic maintenance.

4. Modification of 53-foot work boat. Recent local operations have shown the desirability of fitting the project work boat with basic habitability features such as bunks, head, and galley. Limited facilities on most of the towing vessels require that from four to six project personnel live aboard the work boat for periods up to 30 hours.

PERSONNEL ORGANIZATION AND JOB DESCRIPTIONS

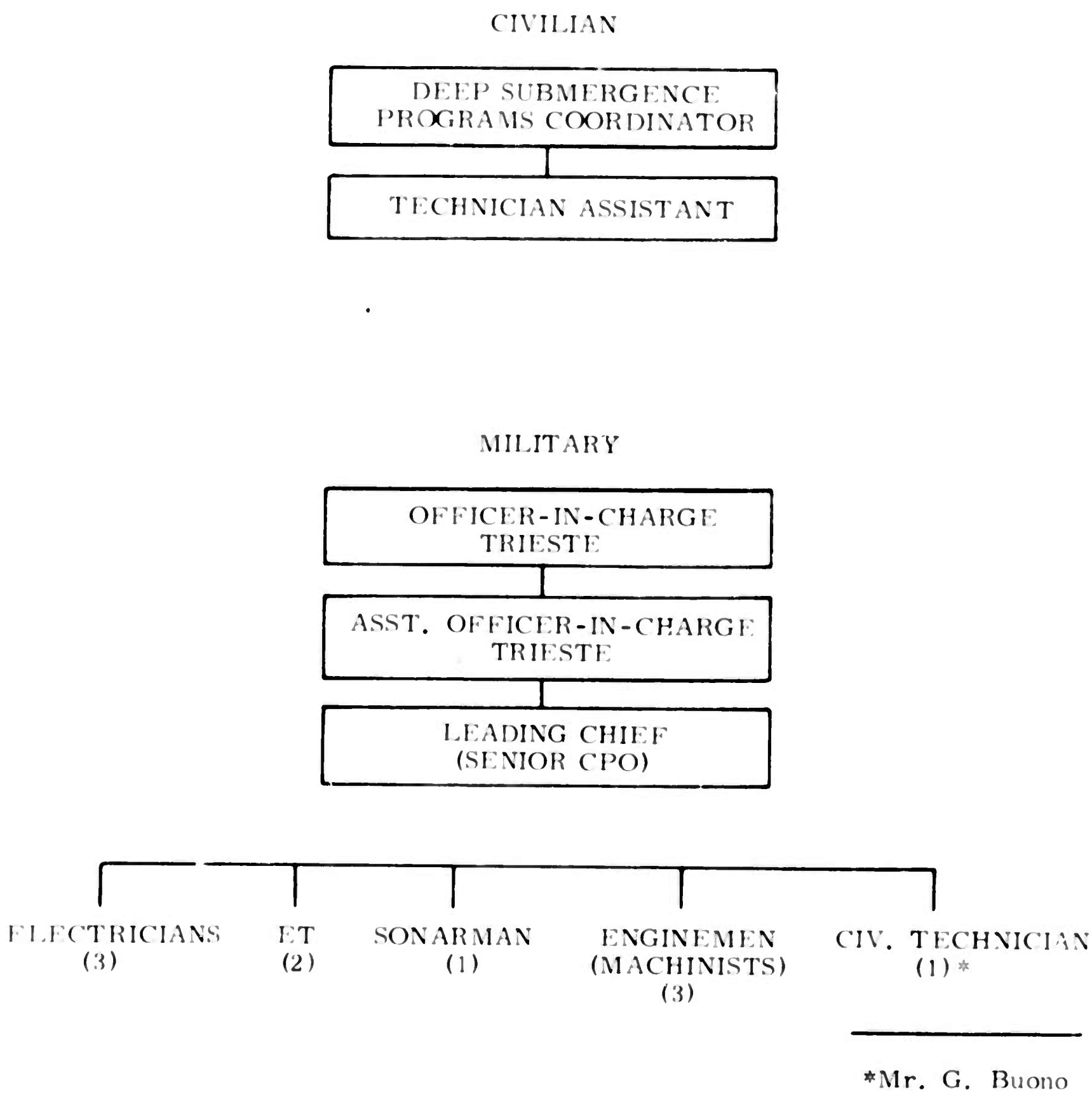
The following diagrams list and interrelate the personnel concerned with the TRIESTE project.

1. BUREAU OF SHIPS - NEL RELATIONSHIP



(AS OF 12/61)

2. NEL - TRIESTE PROGRAM RELATIONSHIP



JOB DESCRIPTIONS

Civilian

DEEP SUBMERGENCE RESEARCH PROGRAM COORDINATOR. Coordinates and plans the scientific program for the bathyscaph TRIESTE. In addition, is responsible for the development and purchase of new instrumentation systems for the craft. When TRIESTE is on extended field operation, the coordinator normally performs the additional duty of Chief Scientist for that operation.

ASSISTANT TO DEEP SUBMERGENCE RESEARCH PROGRAM COORDINATOR. Either an instrumentation or electronics technician who is assigned for the purpose of assisting in the design, coordination, acquisition, and installation of instrumentation systems for use on TRIESTE.

Military

OFFICER-IN-CHARGE, BATHYSCAPH TRIESTE. Either a lieutenant or a lieutenant commander qualified in submarines. The Officer-in-Charge is responsible for the operations, maintenance, and overhaul of the bathyscaph TRIESTE. In port he supervises the upkeep of the craft, and at sea he acts either as pilot or as director of the operation. The basic administration of project military matters and assigned military personnel is his responsibility. In addition, he maintains liaison with operating forces and the technical bureaus through the Program Officer, to insure proper flow of technological and operational information as pertinent new techniques are developed.

ASSISTANT OFFICER-IN-CHARGE, BATHYSCAPH TRIESTE. This officer is also qualified in submarines and is a lieutenant. He assists the Officer-in-Charge in performing his duties and acts as the alternate pilot of the craft during sea operations.

LEADING CHIEF PETTY OFFICER. The senior chief of the assigned military personnel. He assists the two officers in the administration of the military aspects of the program.

ELECTRICIANS. The following electricians are assigned to the program: Two electricians first class and one electrician third class. The electricians install, maintain, and repair both external and internal wiring on the bathyscaph. In addition, they maintain all electrical operating machinery, such as motors and lighting.

ENGINEMEN. The following enginemen are assigned to the program: Two chief enginemen and one engineman second class. These personnel are responsible for the maintenance of the engine-driven equipments and the mechanical systems on board TRIESTE. Their work includes machine shop work and maintenance of hydraulic systems and other devices classed as nonelectric and nonelectronic.

ELECTRONICS TECHNICIANS. One ET first class and one ET second class are assigned. They are responsible for the installation and maintenance of the instrumentation and electronic equipment on board the bathyscaph.

SONARMAN. A sonarman second class is assigned for maintaining and installing acoustic equipment, including underwater telephone, sonar, and Fathometers. In addition, he assists the electronics technicians in the performance of their duties.

CIVILIAN TECHNICIAN. A civilian technician is assigned to the military group. He is Mr. Giuseppe Buono, a member of the original Piccard group that built the bathyscaph in the early 50's. He was recruited by NEL in 1960. His duties include maintenance of the craft's operating systems and consultation work in design changes and operation of the vehicle, and he acts as the senior topside handler during diving operations.

SPECIAL QUALIFICATIONS OF PERSONNEL

The personnel assigned to this program have additional

capabilities as follows:

1. Qualified SCUBA and Second Class Divers

Four of the project personnel are qualified Navy SCUBA divers. These qualifications are needed since a great deal of the in-the-water maintenance of TRIESTE involves diving.

2. Welding Capability

One member of the project team is qualified in arc and acetylene welding. The NEL support facility has complete equipment for light welding work.

3. Seamanship

In addition to their repair, maintenance, and supporting functions at NEL, the TRIESTE military team supervises the sea operations. These include operations with small boats, acting as topside handlers and divers, and maintenance of communications between the bathyscaph group and NEL. As there are no separate maintenance and operating crews, the tempo of operations of TRIESTE is necessarily limited more by the human factor than by the mechanical factor.

APPENDIX A: CHRONOLOGY OF TRIESTE PROGRAM 1958-1961

2 September 1958. Bathyscaph TRIESTE arrived in San Diego, California, on board the commercial steamship, ***P&T Leader***.

20 December 1958. Bathyscaph TRIESTE made first ocean dive for U. S. Navy.

3 March 1959. Lieutenant Don Walsh, USN, reported aboard NEL as Officer-in-Charge TRIESTE.

11 March 1959. TRIESTE was drydocked at its new drydock facility at NEL Waterfront Area.

22 April 1959. TRIESTE was waterborne after a five-week overhaul period.

12 May 1959. TRIESTE commenced spring diving series with a dive to 50 feet during the post-overhaul harbor test dive.

19 May 1959. First ocean dive of the spring diving series was made to a depth of 720 feet. (For dates and details of dives, see Appendix B of this report.)

5 June 1959. Final dive of the spring diving series was completed.

18 June 1959. TRIESTE again drydocked at Navy Electronics Laboratory for modifications prior to deployment to the Guam area.

June through September 1959. TRIESTE underwent modification at Naval Repair Facility, San Diego, and Navy Electronics Laboratory, San Diego. Alterations involved lengthening of float to increase gasoline capacity, increasing the size of the ballast tubs to increase droppable ballast capacity, and installation of the new deep (Krupp) sphere on the float.

July 1959. Proposal for Project NEKTON submitted to OPNAV for approval.

29 July 1959. Lt Shumaker reported aboard NEL as Assistant Officer-in-Charge of TRIESTE.

8 September 1959. TRIESTE was again launched at NEL.

11 September 1959. First harbor dive of the new configuration was made in 62 feet of water.

15 September 1959. Ocean test dive made with modified TRIESTE; water depth, 4900 feet.

2 October 1959. TRIESTE and its supporting equipment were loaded aboard the American President Line ship, *SS Santa Mariana*, at San Diego, California, for transportation to Guam.

10 October 1959. The advance party of the Project NEKTON team arrived on the island of Guam to establish the supporting facilities for the bathyscaph and its auxiliary equipment.

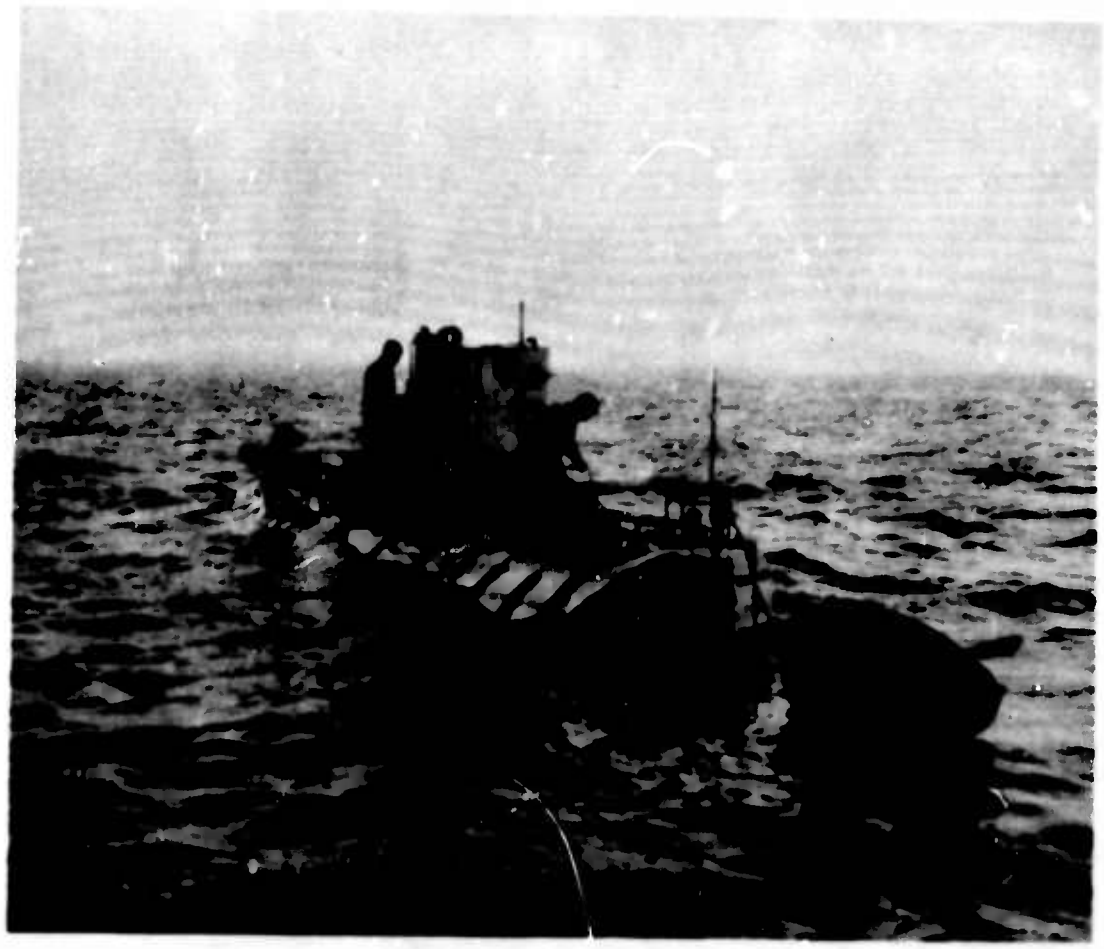
22 October 1959. *SS Santa Mariana* arrived at Guam. TRIESTE and its equipment were unloaded for Project NEKTON. Project headquarters and berthing for TRIESTE were located at Ship Repair Facility, Apra Harbor, Guam.

4 November 1959. TRIESTE was waterborne upon completion of reassembly. First harbor dive was made in Apra Harbor to a depth of 70 feet.

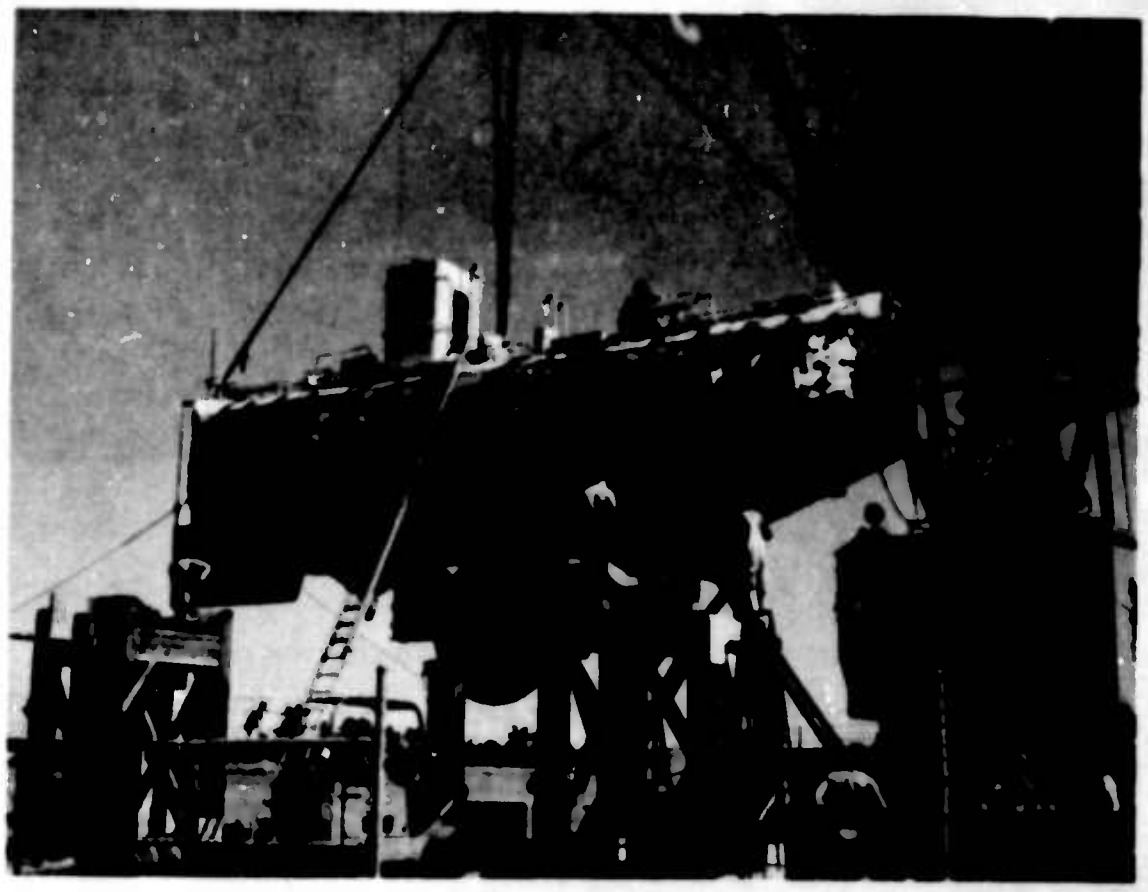
10 November 1959. First progressive ocean test dive of Project NEKTON took place 3 miles off Apra Harbor, Guam. Depth 4900 feet.

15 November 1959. The world's depth record was broken by TRIESTE with a dive to 18,150 feet at a point 30 miles southeast of Guam. Failure of the epoxy bonding in the sphere joint during surfacing of TRIESTE required craft to be drydocked upon return to SRF, Guam.

18 November 1959. Bathyscaph drydocked at SRF, Guam for the purpose of making repairs to the sphere joints. Repair equipment available on Guam was not appropriate for dismantling the sphere, machining and rebonding the joints. Therefore, the three sphere segments were aligned through the use of hydraulic jacks and the sphere was secured through the use of steel bands and attachment rings for proper alignment. The joints were covered with a rubber gasket which was glued in place to prevent additional water seepage.

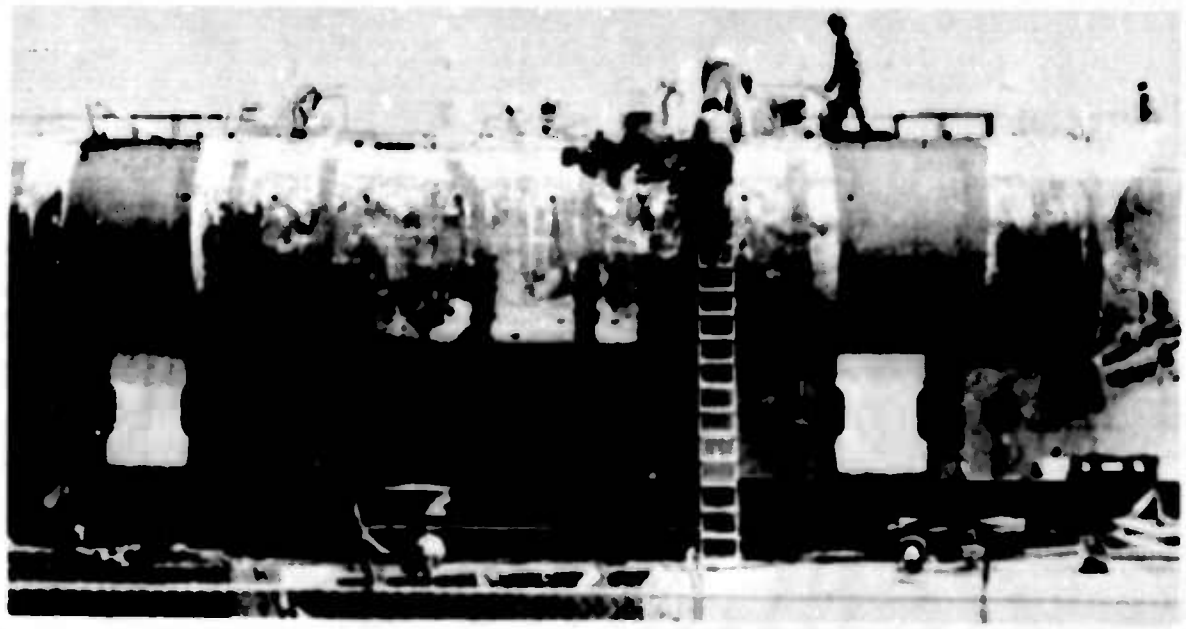


TRIESTE's first USN dive, 20 December 1958

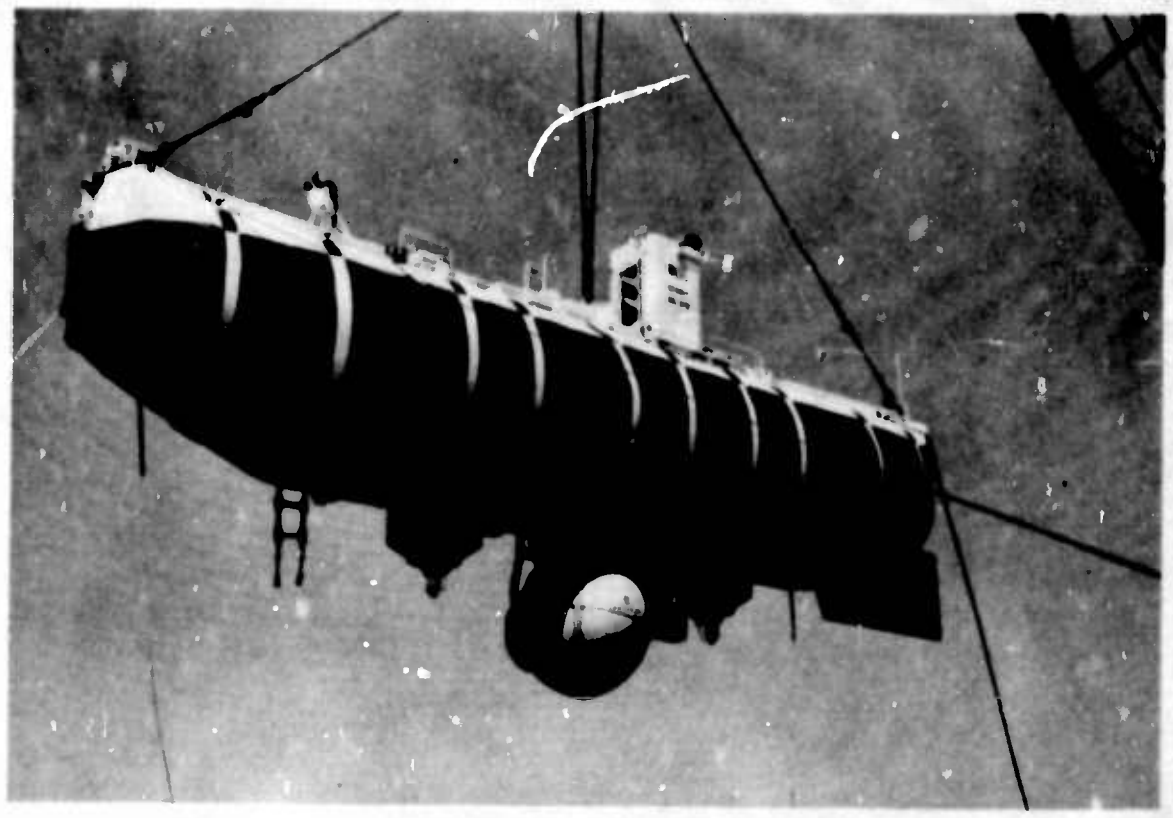


First haul-out at NEL, 11 March 1959. Note marine growth on float.

Sea floor at 4200 feet, dive 55, 29 May 1959



Lengthened float in its cradle



Modified TRIESTE launched at NEL, 8 September 1959, with long float, new sphere, and larger ballast tubs.

14 December 1959. TRIESTE was launched with the new sphere modifications in place. It was found that the weeping had not been completely arrested even though the sphere segments were in approximate alignment. A harbor dive was made on this date to test the repair of the joint.

18 December 1959. First ocean test dive of the repaired sphere was made to a depth of 5700 feet. No significant amount of water entry was noted at the joint. The weeping did continue and gave evidence of creating some corrosion problem at the joint surfaces. Upon completion of this test dive, M. Piccard returned to the United States.

29 December 1959. Three harbor dives were made for training bathyscaph operators. LT Walsh, LT Shumaker, and Dr. A. B. Rechnitzer each made solo dives to a depth of 100 feet in Apra Harbor, Guam.

30 December 1959. Training dives were continued in 100 foot depths at Apra Harbor; two dives were made.

2 January 1960. M. Piccard returned. Work commenced on preparing the bathyscaph for the next progressive deep dive.

8 January 1960. Dive No. 69 of the bathyscaph took place in the Marianas Trench to a depth of 23, 070 feet. This was the final deep test dive prior to diving in the Challenger Deep.

23 January 1960. Successful deep dive was made in the Challenger Deep 200 miles southwest of Guam in a water depth of 35, 800 feet.

30 January 1960. Drydocked TRIESTE at SRF for inspection.

1 February 1960. Dr. A. B. Rechnitzer, M. J. Piccard, LT D. Walsh, USN, and LT L. A. Shumaker, USN, the principals involved in the NEKTON diving operations, departed Guam for official ceremonies in Washington, D. C.

19 February 1960. Principals returned to Guam (with the exception of M. Piccard who terminated his association with the project) where it was determined that further operations for Project NEKTON were no longer possible

due to the potential loss of the supporting ships for towing and escorting services, the continuance of unfavorable weather for diving operations, and the necessity to return the majority of the project's temporary personnel to their original assignments at NEL. It was decided to leave the bathyscaph on its cradle at SRF, Guam, and to leave all equipment in place at the project headquarters at SRF while the crew returned to NEL, San Diego, for reorganization and formulation of plans for additional diving operations.

March-May 1960. TRIESTE crew at NEL prepared plans for Project NEKTON II, implementing permanent staff with additional military and civilian personnel prior to returning to Guam for the second series of diving operations.

18 May 1960. Advance group of Project NEKTON II personnel arrive at Guam to establish operations base. Local supporting ships were available. Weather was suitable for operations.

12 June 1960. The bathyscaph was launched after completing some minor repair work and installation of equipment.

15 June 1960. Two harbor dives were made for material test and operating review for the two pilots, LTs Walsh and Shumaker.

21 June 1960. Dive Nos. 73 and 74 were made to depths of 1070 feet and 1455 feet, respectively. First solo ocean dives for LTs Walsh and Shumaker. These dives marked the commencement of Project NEKTON II, a program to measure sound velocity profiles at various depths from ocean surface to sea floor. The original intention was to culminate this diving series with a second dive to 35, 800 feet to obtain a sound velocity profile in the deepest known spot in the ocean.

25 June 1960. Third dive of NEKTON II series was made to a depth of 8530 feet.

1 July 1960. LT L. A. Shumaker, USN, and Dr. A. B. Rechnitzer made the deepest dive of Project NEKTON II to a depth of 18, 900 feet in the Marianas Trench. It was decided that a deep dive in the Challenger Deep would not be possible during this diving series because of the

continued weeping of the sphere joint and the possibility that the strength of the sphere had been substantially reduced due to corrosion within the joint. Therefore, it was arbitrarily established that the bathyscaph would only dive to two-thirds of its working depth. The dive on this day marked an operation to this specified depth and the deepest dive of this program.

6 July 1960. A dive was made to 1040 feet for making sound velocity measurements.

9 July 1960. The final dive of Project NEKTON II was made to a depth of 7500 feet. Project NEKTON II operations were then terminated. The primary reason for termination of this program was the loss of all external lighting on the craft through the shortage of the specially constructed light bulbs that were used for this purpose. Since these special bulbs were made in Europe, it was felt that the long delay in procuring additional bulbs would force eventual termination of the program in any case. The bathyscaph and its equipment were then prepared for return to NEL, San Diego.

13 July 1960. Bathyscaph was drydocked and disassembly commenced.

19 July 1960. All project material was packed ready for shipment. First increment of personnel left Guam for return to NEL.

2 August 1960. Bathyscaph and all support equipment were loaded aboard USNS PENDLETON for shipment to San Diego, California.

3 August 1960. Last increment of personnel left Guam. Project NEKTON II terminated.

28 September 1960. USNS PENDLETON arrived at San Diego. TRIESTE and equipment offloaded.

September 1960 through June 1961. The bathyscaph underwent a comprehensive reconstruction involving replacement, repair, and modification of various systems, assemblies, and equipments. (Initial step was a thorough physical examination of the craft to determine the feasibility of investing funds in a reconstruction program.) The objective of the reconstruction was to apply the experiences of the past two years of Navy operation of the craft so as to equip it better for its scientific mission. Emphasis

was put on utilizing the locally ava.lable (U.S.) materials in lieu of foreign and specialized offshore procured items. In addition, sufficient time was to be available to establish liaison with various instrumentation contractors to supply expanded instrumentation capabilities for the bathyscaph, such that it would be able to gather the maximum amount of information on any given dive.

26 June 1961. The modified TRIESTE was launched and prepared for a resumption of diving operations. Some delay was incurred in the supply of propulsion motors, but it was decided that limited operations could commence without the availability of these motors.

7 September 1961. First harbor test dive of the modified craft was made.

12 September 1961. Second harbor test dive was completed successfully with all discrepancies being corrected.

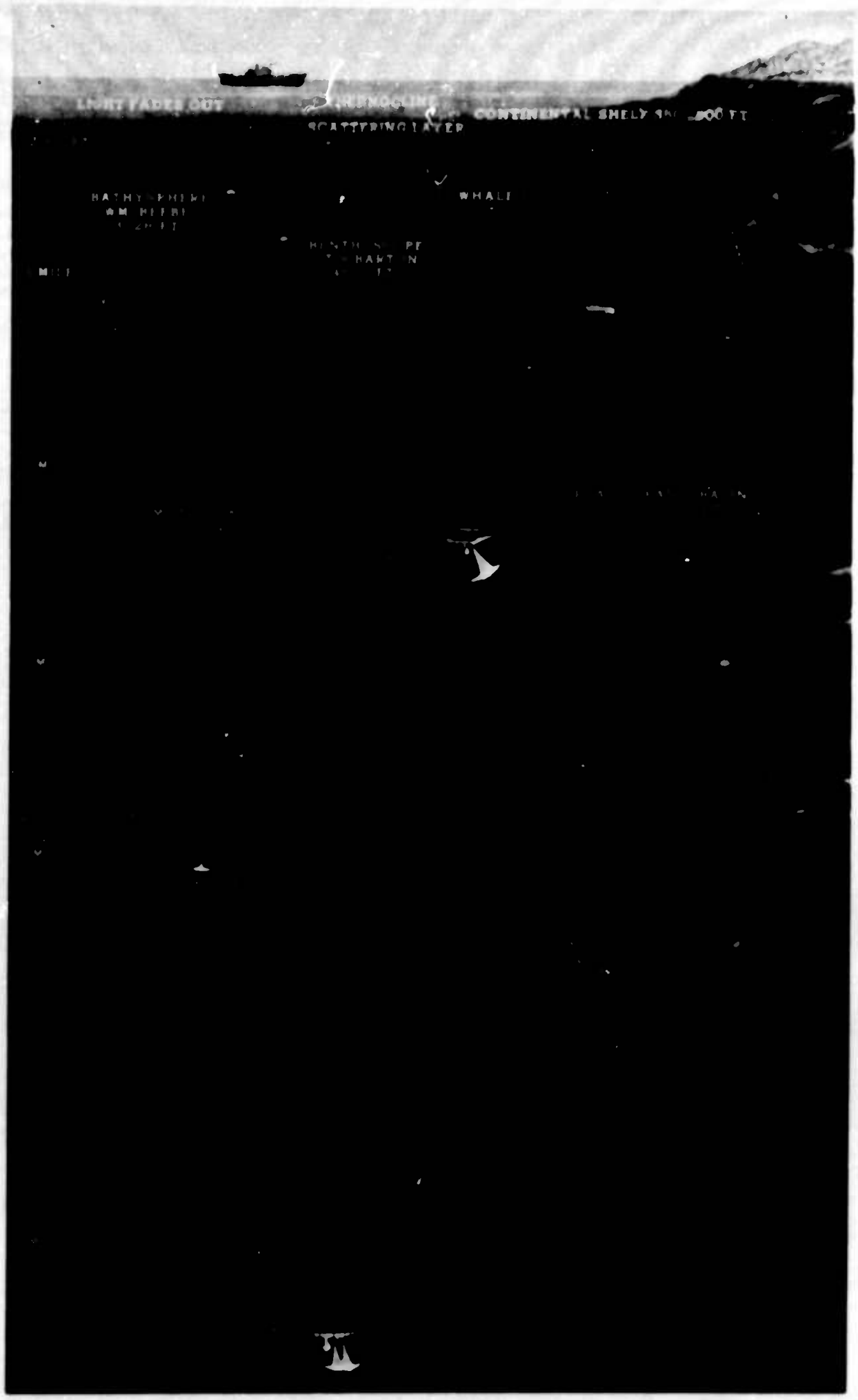
14 September 1961. First ocean test dive of modified craft was made to a depth of 492 feet off San Diego, California.

11 October 1961. A satisfactory harbor test dive was made after correcting deficiencies of prior ocean test dive.

13 October 1961. First scientific ocean dive of fiscal year 1962 diving program was made; this was a geological measurement dive to a depth of 1920 feet.

25 October 1961. A dive was made to a depth of 3870 feet for deep current studies.

7 December 1961. A test dive was made in San Diego Harbor to test completion of certain items; this was the final dive of calendar year 1961.



Pictorial summary of deep submergence dives

APPENDIX B: DIVING LOG OF THE TRIESTE 1958-1961.

Dive	Date	Location	Depth (feet)	Crew	Support Ship(s)	Purpose
49	12/17/58	San Diego Harbor	70	Piccard Rechnitzer		Test
50	12/20/58	San Diego 32-39.5N 117-23.0W	860	Piccard J. Light	YFU-45 (NEL)	Photography
51	5/12/59	San Diego Harbor	50	Piccard Walsh		Test
52	5/19/59	San Diego 32-40.2N 117-23.1W	720	Piccard Rechnitzer	MATACO (ATF-86)	Biological observations
53	5/22/59	San Diego 32-37.6N 117-29.7W	4100	Piccard Walsh	MATACO	Technical
54	5/28/59	San Diego Harbor	60	Piccard Mackenzie		Equipment check for acoustic dive
55	5/29/59	San Diego 32-33.2N 117-27.0W	4200	Piccard Mackenzie	KOKA (ATA-185)	Acoustic measurements
56	6/5/59	San Diego 32-37.6N 117-22.2W	770	Piccard Rechnitzer	TAWASA (ATF-92)	Biological observations
57	9/11/59	San Diego Harbor	62	Piccard Shumaker		Test of new (Krupp) sphere
58	9/15/59	San Diego 32-40.2N 117-23.1W	590	Piccard Rechnitzer	GEAR (ARS-34)	Biological & test of sphere
59	11/4/59	Apra Harbor, Guam	70	Piccard Shumaker		Test after assembly
60	11/10/59	Guam 13-29.5N 144-38.2E	4900	Piccard Rechnitzer	WANDANK (ATA-204)	Test and oceanographic
61	11/15/59	Guam 12-52.8N 145-10.2E	18150	Piccard Rechnitzer	WANDANK LEWIS (DE-535)	Test and oceanographic
62	12/14/59	Apra Harbor, Guam	65	Piccard J. Cawley		Test of repair of sphere joint

APPENDIX B: (Continued)

Dive	Date	Location	Depth (feet)	Crew	Support Ship(s)	Purpose
63	12/18/59	Guam 13-30.1N 144-37.1E	5900	Piccard Walsh	WANDANK	Deep test of sphere repair
64	12/29/59	Apra Harbor, Guam	100	Walsh Jensen		Pilot training
65	12/29/59	Apra Harbor, Guam	100	Shumaker DeGood		Pilot training
66	12/29/59	Apra Harbor, Guam	100	Walsh Rechnitzer		Pilot training
67	12/30/59	Apra Harbor, Guam	100	Walsh Michel		Pilot training
68	12/30/59	Apra Harbor, Guam	100	Shumaker Rechnitzer		Pilot training
69	1/8/60	Marianas Trench 12-40.0N 145-21.5E	22560	Piccard Walsh	WANDANK LEWIS	Test dive
70	1/23/60	Challenger Deep 11-18.5N 142-15.5E	35800	Piccard Walsh	WANDANK LEWIS	Record dive
71	6/15/60	Apra Harbor, Guam	102	Walsh Winkler		Test dive
72	6/15/60	Apra Harbor, Guam	100	Shumaker Kennedy		Test dive
73	6/21/60	Guam 13-30.7N 144-37.0E	1070	Walsh Rechnitzer	WANDANK	Sound velocity measurements
74	6/21/60	Guam 13-30.3N 144-36.4E	1455	Shumaker Kennedy	WANDANK	Training
75	6/25/60	Guam 13-26.0N 145-31.0E	8530	Walsh Rechnitzer	WANDANK	Sound velocity measurements
76	7/1/60	Guam 12-44.5N 144-53.5E	18900	Shumaker Rechnitzer	WANDANK HAVERFIELD (DER-393)	Sound velocity measurements

APPENDIX B: (Continued)

Dive	Date	Location	Depth (feet)	Crew	Support Ship(s)	Purpose
77	7/6/60	Guam 13-28.2N 144-24.5E	1140	Shumaker Rechnitzer	WANDANK	Sound velocity measurements
78	7/9/60	Guam 13-27.0N 144-32.1E	7500	Walsh Rechnitzer	WANDANK	Sound velocity and gravity measurements
79	9/7/61	San Diego Harbor	40	Walsh Adams		Test
80	9/12/61	San Diego Harbor	69	Shumaker Devoe		Test
81	9/14/61	San Diego 32-37.8N 117-20.9W	492	Walsh Shumway	TAWASA	Geology & ocean test
82	10/11/61	San Diego Harbor	48	Walsh Chandler		Test
83	10/13/61	San Diego 32-55.3N 117-20.9W	1920	Shumaker Dill	CHICKASAW (ATF-83)	Geological measurements
84	10/25/61	San Diego 32-37.0N 117-30.0W	3870	Walsh La Fond	MOLALA (ATF-106)	Deep current studies
85	12/7/61	San Diego Harbor	40	Shumaker Beagles		Test

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