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NOLTR 62-174

AN INCREMENTAL HYDROBAROPHONE (U)

27 FEBRUARY 1963

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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ABSTRACT: A Wein bridge type hydrobarophone capable of measuring incremental pressure fluctuations as low as 1/10 of an inch of water in the presence of a static head as high as 300 feet of water is described. A frequency response of 0-200 cps is attainable. Special features include:

a. An incremental pressure sensitivity independent of static head. This is accomplished by pressure equalization through a system of an air-pressure bag and valves.

b. An acoustic filter inserted between the pressure equalization system and the active portion of the hydrobarophone permits pass band operation. The low frequency end of the band can be easily adjusted for any desired period less than an hour.

c. Enclosure of the hydrobarophone in a fiberglass container for shielding it from undesirable temperature changes.

d. An attached temperature indicator, instrumental in obtaining an accurate hydrobarophone.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

This report presents the design, development and fabrication of a Wein bridge type hydrobarophone from a simple variable inductance type to the unit presently used. Assembly, calibration, planting and recovery procedures are detailed. This work was done by the Electrical Evaluation Division of the Underwater Evaluation Department under Task Assignment RUME 2E000/031.

The authors wish to acknowledge the contributions of the following people. Mr. Robert R. Tobin has given technical assistance through the entire program. Assistance in the preparation of the report was given by Mr. James R. Miller and Mr. Henry Gerber.

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By direction

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (CONT'D)

TABLES

Chapter 1

INTRODUCTION, SYSTEM DEVELOPMENT, AND OPERATIONAL CHARACTERISTICS OF HYDROBAROPHONE

Introduction

1. Various types of hydrophones exist for measuring and recording low frequency underwater signals from static pressure to low audio ranges. Some of these are listed as follows:

a. Swell Recorder (Wiancho Gauge) - A recorder of this type converts variations in sea pressure, caused by swells, into analogous impedance variations which causes an unbalance in a bridge circuit and produces an electrical signal proportional to the swell amplitude. This system essentially produces an unbalance of pressure between two chambers by a fluid flow with a resultant impedance change.

b. Variable Inductance Type (Mark 1 Acoustic System) - The pressure-sensitive element is essentially an inductance which is varied by applied pressure. This element, with its associated cable, is in one arm of an A.C. bridge located on shore. The bridge is balanced and a change of inductance is recorded as a change of current.

c. Piezoelectric Crystals - Certain crystals, when compressed in particular directions, develop positive and negative charges on certain portions of their surfaces which are proportional to the pressure. These charges disappear when the pressure is released. Piezoelectric crystals and electrostrictive ceramics are used as elements for underwater sound receivers. Depending upon their construction these can be developed for either ultra low-frequency measurements or high-frequency measurements.

2. Various other hydrophones are available of which the magnetostrictive principle is well known. No attempt will be made to explain their operational characteristics in this report.

3. The hydrobarophone is a refined hydrophone of the variable inductance type. It is capable of measuring incremental pressure fluctuations as low as 1/10 of an inch of water in the presence of a static head of water of as much as 300 feet. This pressure sensitivity is made independent of the static head by a pressure equalization system. The unit has a frequency response of 0-200 cps but is primarily designed for use in measuring pressure signals from 0-1 cps. An additional feature of the unit is an acoustic filter which permits pass band operation and therefore adjustments for desired time periods.

4. A hydrophone sitting on the bottom of a body of water is subjected to water pressures which are continually changing. These pressures arise from many causes. Those that concern the designer of a hydrobarophone are listed as follows:

a. Static pressure - This is the pressure head proportional to the mean water depth.

b. Those caused by tides and swells - Swells and tides create bottom pressure fluctuations with periods ranging from 0.2 second to many hours and have amplitudes which may be of the order of magnitude of several feet of water.

c. Those caused by moving ships, waves, seiches and fish - These are pressure fluctuations with amplitudes measured in inches of water and of short duration, and are referred to as pressure signals.

5. The purpose of this report is to give developmental, operational, assembly and maintenance details of the hydrobarophone.

Hydrobarophone System Development

6. The measurement of water pressure changes can be accomplished in a straightforward manner through the use of a pressure controlled variable inductance. In its simplest form this consists of a sealed compartment of which one face is a movable diaphragm with a permalloy armature attached to it. An immovable inductance coil is located adjacent to the diaphragm and permalloy armature. Any change in external pressure causes a deflection of the diaphragm with a resultant change in coil inductance. Such an instrument could be lowered to the sea bottom and connected to one arm of a Wein bridge by underwater cables. The bridge is then balanced. Subsequent bridge unbalance, caused by an inductance change, is then a measure of pressure caused by a difference in the head of water acting on the diaphragm. Changes of pressure caused by tidal difference or swells can run to several feet of water and would be measured by the instrument. Small variations as might be caused by the passage of a ship, in the order of inches of water, are also measured by the instrument, but with limitations. First, the sensitivity is a function of depth, and secondly the operational depth is limited by the pressure which the diaphragm can withstand. It is therefore necessary to know the depth and to calibrate the instrument for that depth. Thirdly, for continuous recording of the system output, the gain is largely determined by the large tidal amplitude, acting over a long period, making accurate measurements of small variations difficult. Thus for the measurement of small variations of pressure caused by a change in the head of water of less than 1/2 inch it would be desirable to develop an instrument whose sensitivity is independent of depth and which does not respond to those larger variations of tides and swells.

7. The first experimental model of the hydrobarophone was designed, fabricated and planted at Fort Lauderdale, Florida. A variable inductance type system was used with the additional features listed below:

a. The unit was modified so that the sensitivity was independent of the static head due to depth. The internal volume of the hydrobarophone is connected to a pliable, gas filled, rubber bag through a length of small diameter plastic tubing. If the rubber bag is inflated, but not stretched, prior to planting, the internal pressure of the hydrobarophone will equalize to the static head after planting. Thus there is no fixed diaphragm deflection and the sensitivity is independent of water depth and equal to the sensitivity at atmospheric pressure.

b. An acoustic filter was inserted between the rubber bag and the active portion of the hydrobarophone to equalize long term tidal variations. This consists of the small diameter plastic tubing which acts as a resistance, and the volume of the hydrobarophone which acts as a capacitance. The higher frequency wave background fluctuations are not passed by the filter. The frequency response of the acoustic filter is dependent upon the absolute gas pressure and therefore the water depth. This presents a problem; but if the water depth is approximately known, the filter can be designed to yield the required cutoff characteristics. For a mathematical treatment of the filter see Appendix A.

8. A hydrobarophone of this design has a very short life due to the nature of the rubber bag. The diffusion of water and gas through the surface will soon exhaust the gas and collapse the bag or short the electronic equipment. The unit planted lasted for four days, but proved useful in that it showed that with improvements the system is feasible.

9. In order to increase the hydrobarophone life a second experimental model was designed and fabricated which replaced the rubber bag with a system of bellows, valves, and an air-pressure plastic beach ball. A soluble washer control valve, normally open during planting, bypasses the bellows and connects the gas-filled plastic bag with the hydrobarophone during planting. The internal pressure is then equalized to the static head as before. A valve was installed to bypass the filter to avoid damage to the diaphragm before equalization through the filter can take place. After one hour the soluble washer dissolves and closes the valve. Gas and water passage through the bag surface is then immaterial. Tidal variations are transmitted through the bag to the bellows which compresses or expands the gas in the bellows chamber. These changes are transmitted through the acoustic filter as before. This experimental unit was planted at Fort Lauderdale, Florida, in 100 feet of water in December 1957; it operated successfully until it was retrieved.

10. This improvement in the pressure equalization system of the hydrobarophone permitted an increase in sensitivity. This sensitivity is dependent primarily upon the thickness of the moving part of the diaphragm and the spacing between the diaphragm armature face and the inductance coil. While keeping the spacing the same, a new sandwich type diaphragm was developed using a thin metal piece of shim stock sealed between two metal rings. This increased the sensitivity by a factor of 12. This third experimental unit was planted at Fort Monroe, Virginia.

11. With increased hydrobarophone sensitivity, it became apparent that the unit responded to water temperature variations; the lower the bottom ambient water temperature the higher the sensitivity, or the higher the bottom ambient water temperature the lower the sensitivity. A more undesirable condition noted was that rapid water temperature changes in the order of 1°F

to 2°F over a period of 15 to 20 minutes produced a drift in the system. It was extremely difficult to distinguish between this and pressure variations. To eliminate calibration errors due to ambient water temperature requires only that the water temperature be measured by some type of temperature recorder. By using a temperature versus sensitivity curve for the hydrobarophone, it is possible to determine the sensitivity for any water temperature. To eliminate rapid changes of temperature due to currents, etc. required that the hydrobarophone be enclosed within a fiberglass cylinder which essentially puts an insulated pocket of water around the unit. This would then keep the unit operating at ambient water temperature which is measured by a temperature recorder.

12. The hydrobarophone with its associated fiberglass shield is being used for the purposes of the Underwater Evaluation Department at Fort Monroe, Virginia and Fort Lauderdale, Florida. Unless unforeseen difficulties arise, the effectiveness of this design is now well established.

Hydrobarophone Operational Characteristics

13. The operational details of the hydrobarophone will be explained for the sake of clarity. A cross sectional assembly drawing of the hydrobarophone is shown by Figure 1. Each individual component is numbered to correspond with the associated figure which shows close-up views of the component, and a detailed drawing sheet number. Table 1 is a complete list of the component drawings which are available. The fabrication and assembly of these components will be detailed in Chapter 2 of this report.

14. In preparing the unit for planting, the compliant plastic air bag (Figure 2) must be inflated to atmospheric pressure and installed. It assumes the position shown in Figure 1, not completely filling the metal cylinder due to the bag retaining ring shown in Figure 3 and the restrictions of the top and sides. The two flood plugs (Figure 2) with the soluble cores are in position. These close the upper portion of the bellows chamber (Figure 4) to sea water. A soluble washer (Figure 5) must also be installed to hold the pop-off valve in valve port 2 open to the air pressure of the copper tubing (Figure 6) which flows through the upper portion of the bellows chamber and the air bag stem (see Figure 2) into the compliant plastic air bag. A shore cable connects the unit with the shore instrumentation and the instrument is ready for planting.

15. Upon entrance into the water, the bellows chamber cover plate (Figure 2) is flooded through the openings in the casting. The compliant air bag is compressed in accordance with the static head of water at any instant. The air pressure within the air bag is transmitted through the air bag stem, the upper portion of the bellows chamber, the tee joint (Figure 6) and copper tubing to valve ports 1 and 2. The pressure in the tube to valve port No. 1 (Figure 7) has no effect as the pop-off valve opens outward. The pressure in the tube to valve port No. 2 is transmitted through the pop-off valve (Figure 5). This valve is held open by a bellows-operated rod assembly (A) (Figure 5). It admits pressure to the lower portion of the bellows chamber,

and through the acoustic filter assembly (Figure 8) to the coil compartment of the body casting (Figure 9). Thus pressure is exerted on the inside face of the diaphragm (Figure 10) to balance the pressure of the static head of water acting on the exterior face of the diaphragm. For a pressure differential of 3 pounds per square inch, the pop-off valve (see insert - Figure 11) will function to by-pass the acoustic filter and equalize the pressure on the inward side of the diaphragm. Thus, the continuing static pressure change as the unit is being lowered in the water is balanced out; and the unit remains in a balanced condition for any workable water depth.

16. At some fixed time after planting, the soluble washer and the boric acid cores of the flood plugs will dissolve. When the soluble washer dissolves, the bellows of assembly A expands and the rod is withdrawn from the pop-off valve. This has the effect of closing the pressure equalization passageway between the interior of the pliable plastic air bag and the lower portion of the bellows chamber. Pressure changes are now transmitted from the pliable air bag, through the air bag stem, to the upper portion of the bellows chamber, Figure 12. Pressure changes are transmitted by this route through the acoustic filter to the coil compartment and the interior face of the diaphragm. When the cores of the flood plugs are dissolved sea water enters directly onto the upper portion of the bellows chamber. In this situation, the pliable plastic air bag is eliminated from the pressure equalization system. The bellows is filled with Tricresyl Phosphate to prevent the sea water from corroding the corrugations. For planting operations, the opening of the bellows is covered with a pure rubber latex diaphragm to prevent the Tricresyl Phosphate from causing a malfunction by being driven through the instrument. Within a few days this diaphragm will dissolve due to contact with Tricresyl Phosphate and the sea water will be in direct contact with the bellows.

17. For gradual pressure changes such as those caused by seiches or tides, the pressures on the interior and exterior faces of the diaphragm remain the same due to the action of the acoustic filter, and there is no movement of the diaphragm. For changes of pressure of short duration such as waves and ship signatures, the acoustic filter serves as a barrier due to the small orifice in the tubing; and a difference of pressure on the interior and exterior faces of the diaphragm occurs. This causes a deflection of the diaphragm which moves the armature relative to the coil (Figure 13) and varies the inductance. The resulting signal can then be measured and recorded, and represents the signature desired.

Chapter 2

HYDROBAROPHONE FABRICATION AND ASSEMBLY

A. Fabrication Processes

18. Diaphragm - The sensitivity of the hydrobarophone is inversely proportional to the cube of the thickness of the moving part of the diaphragm. Accuracy and uniformity are critical in diaphragm construction. Great care must be exercised. The moving part of the diaphragm is fabricated from perfectly flat, stress-relieved, and controlled thickness shim stock. The other components required for a sandwich-type diaphragm require normal machining. When all parts are available, the diaphragm must be assembled and ground until satisfactory. These procedures are detailed as follows:

19. Adhesive - The parts to be cemented together should be prefit so that reasonably good contact will occur. All surfaces to be bonded must be free of grease. If necessary, they should be cleaned with trichlorethylene. The adhesive used is Type 1-A, activator "A", manufactured by Armstrong Products Company, Argonne Road, Warsaw, Indiana. For best results the following instructions in its use should be followed:

a. Mixing

(1) Add 4 parts of activator "A" to 100 parts (by weight) of adhesive.

(2) Mix thoroughly by stirring. Good mixing is important.

(3) The reaction of activator "A" with the adhesive is exothermic. Only a small quantity of the adhesive should be mixed at one time.

b. Bonding

(1) Spread a thin layer of adhesive evenly on each of the surfaces to be bonded and press together gently. Only contact pressure is required.

(2) Assemble parts immediately after spreading the adhesive.

(3) Air dry overnight at room temperature (70°F - 75°F). Do not move after assembly. For maximum hardening allow a curing time of one week.

20. Assembly - Assemble the diaphragm sections as shown in Figure 1 and Figure 10. Clean the permalloy armature and cup thoroughly with trichlorethylene and dry. Place a small amount of A-1 adhesive in the cup and on the

surface of the armature. Place the armature into the cup and, using finger pressure, squeeze together to assure an even seating contact between the surfaces. Clean the bottom of the assembly plus the shim stock with trichlorethylene and dry. Place the adhesive jig fixtures on the diaphragm as shown in Figure 14. Spread A-1 adhesive on the bottom of the cup assembly and place the assembly through the hole in the adhesive jig. Using the forefinger and a small amount of finger pressure rotate the cup assembly clockwise and counter-clockwise to assure an even surface contact. Allow to dry overnight before removing the adhesive jig and allow two or three days curing time before grinding.

21. Diaphragm Grinding - In order to assure flat and parallel surfaces across the complete face of the diaphragm the following grinding procedure is followed. A Thompson Grinding Machine with a #32A46K-8 type wheel, and equipped with a magnetic chuck is used. Before grinding, it is recommended that the grinding wheel be diamond dressed. The recommended sweep of the cross speed is 0.015" per pass with no coolant being used. The first set-up as shown by Figure 15, is to position the diaphragm with the assembly screws facing up. The magnetic parallel blocks hold the diaphragm up off the magnetic chuck so that the permalloy armature does not sit directly on the magnetic chuck. The grinding wheel is brought in contact with the screws holding the diaphragm together and a sufficient amount of material is removed to insure a true 8-point flat surface. The diaphragm is then turned right side up, as shown, and placed directly on the magnetic chuck with steel parallel blocks holding it in position. The grinding wheel is then brought in very light contact with the permalloy armature which, it should be noted, is always higher than the surface of the diaphragm base plate. Once contact is made between the wheel and the armature, each wheel pass removes metal in measured increments of 0.0005". Make as many passes as necessary to reduce this surface to that of the diaphragm base plate. When the grinding wheel touches the diaphragm base plate surface each wheel pass should be set to remove only 0.0001" of metal. Two or three passes should be made to insure a flat and parallel surface across the diaphragm. The surfaces can then be checked with an indicator as shown in Figure 16.

22. Coil - Due to the fact that the hydrobarophone is a variable inductance device, the driven coil in the body casting (Figure 9) must be accurately wound and measured before installation. Fifty coils are usually manufactured, measured on an inductance bridge, and placed in groups which measure plus or minus one percent of an average mean. For use in a group of hydrobarophones, it is required that the inductance of these groups be very close to one another. Preparation of these coils in the body casting is accomplished in two steps as follows:

23. Coil Assembly and Potting - The coil assembly consists of the coil form, coil insulating spacer, coil, permalloy core and terminal posts. As shown in Figure 17, the terminal posts are pressed into the coil insulating spacer and the spacer is pressed into the coil form. The coil form is then turned over and the permalloy core is pressed into the coil insulating spacer. The coil is then inserted into the permalloy core and the 2 leads passed through to the back side of the coil form and a lead wound around each

terminal post. The complete coil assembly is now ready for potting in a thermosetting epoxy resin.

24. Before proceeding to the potting procedures, some information on the epoxy resin should be noted. Thermosetting Epoxy Resin (Scotch Cast #5), made by Minnesota Mining and Manufacturing Company, St. Paul 6, Minnesota, is used. It is a 100% solid thermosetting epoxy resin, which has been compounded to obtain excellent physical and electrical properties. The resin offers good shock resistance and quick reaction time and has excellent resistance to moisture vapor penetration. The following instructions for its use are noted:

a. Mixing

Resin #5 is furnished in parts A and B. Mixing proportions are as follows: 2 parts, by weight Part A to one part by weight Part B. The two parts should be thoroughly mixed by a mechanical means. Avoid excessive whipping, as it introduces air into the mixture.

b. Pot Life

3/4 to 1-1/2 hours.

c. Casting

Pour into molds at room temperature. After pouring the mixture, a vacuum is recommended to promote impregnation. The recommended cycle is 25-28" of vacuum, hold for one minute. Release slowly, and repeat 2 or 3 times.

d. Curing Time

The resin will cure at room temperature in about 24 hours. The maximum properties can be achieved more quickly by allowing the resin to gel for 2-4 hours at room temperature followed by 2 hours at 140°F.

25. For pouring, a polyethylene cap is installed to cover and seal the coil components as shown in Figure 17. The coil assembly is then turned over and placed within a vacuum jar. The resin is then poured in the cavity to cover the permalloy core. A vacuum is pulled, released, and resin again poured until it is level with the top edge of the coil form. A vacuum is again pulled, and released; and the resin is allowed to cure the recommended time. After curing, the polyethylene cap is removed, and the coil side is potted in the same manner as the opposite side.

26. Coil Grinding - Figure 18 shows a drawing of the spacing tolerance between the diaphragm and the coil of the hydrobarophone. The 0.003" air gap that exists is accurately maintained by a series of grinding techniques as this is one of the most critical mechanical phases of the hydrobarophone construction. It not only regulates the sensitivity but linearity as well. A similar grinding technique, using the same equipment as that used to grind the

diaphragm, is used for the coil. One difference is that a coolant is used during this grinding operation.

27. When the potting and curing of the coil assembly is completed, the coil assembly is installed with a 0.003" shim between the coil assembly and the body casting. Fastening is provided by three screws as shown in Figure 19. The coil assembly and casting is placed directly on the magnetic chuck bed and secured by parallel blocks as shown. The grinding wheel is positioned to just lightly touch the epoxy resin covering the coil. In wheel increments of 0.001" per pass, the resin is removed until the permalloy core is exposed. Then in increments of 0.001" per pass, the wheel is passed over the total surface including the body casting until all surfaces are flat and parallel. The coil assembly is then removed from the casting and the shim removed. The coil assembly is then reassembled without the shim. This lowers the coil assembly by 0.003" below the surface of the body casting, and provides the necessary 0.003" air gap between the diaphragm armature face and the coil as shown in Figure 18.

Chassis

28. The electronic chassis consists of a linen-base, bakelite base plate (Figure 20), machined to fit into a very limited space in the body casting. A hole is drilled in the base plate for access to the Fusite connector terminals in order that the coil leads may be connected. Two stand-off terminals are screwed into the base plate as close to the edges as possible between the stuffing gland and the coil lead access hole. A 50-ohm wire wound noninductive 5-watt resistor is soldered across these two terminals. The calibrating inductor (Communications Accessories Corporation #76009321, 1500 microhenries ±1%) is mounted with a 6-32 brass screw that is threaded into the bushing in the center of the coil. A brass nut and lock washer are placed on the bottom side of this screw and the screw turned into a threaded hole in the base plate. This screw must not project beyond the base of the base plate. The nut is turned down until there is a tight contact with the base plate thereby holding the coil rigidly in place. The high impedance relay (Sigma 4F 10000 S Sil) is positioned on the board and two mounting holes, 3/8-inch center-to-center, are drilled through the base plate, using a number 25 drill. These two holes are counterbored from the bottom of the base plate to one-half the thickness of the base plate. From the bottom of the base plate, two 6-32 round head nylon screws are used to fasten the relay. Nylon screws are used here because the mounting bracket forms one of the contacts of the relay. It is imperative that this be insulated from the body casting. After the screws are inserted, the heads will not be quite flush with the surface of the base plate. They must be filed flat. The thermal time delay relay (Spencer Thermostat Company No. DA29) is supplied with a copper plated clip not suitable for mounting. A small piece of flat brass with clearance holes for a 4-40 screw is fabricated and soldered to the clip of the relay so that a mounting hole is provided at either end. The relay is then fastened to the base plate by this method. Finally the terminals for the resonating capacitor are installed and the circuit wired as shown on the electrical circuit (Figure 21). The placement of parts is not detailed because of many variables, but a general idea is given in Figure 22.

Filter

29. The filter is made of polyethylene plastic having an inside diameter of 0.011" and an outside diameter of 0.024". The catalog number is PE 10 and the tubing is purchased in 100 foot rolls from Clay-Adams, Incorporated, 141 East 25th Street, New York 10, New York. The tubing adapter, catalog A-2627, Size A, used to connect the tubing to the back volume of the hydrobarophone, is purchased from the same Company. The stock adapter is modified as shown in Figure 8 for this particular application.

30. Before winding the filter, the approximate operating depth should be known. Once this is known the correct filter length can be determined from the curve shown in Figure 23. For further derivation of the filter theory, see Appendix A. The tubing is then wound on a thin paper mandrel whose diameter is approximately one inch and length approximately 3 inches as shown in Figure 24. About 3 inches of tubing is left exposed on the end for attaching the tubing adapter. When winding, care should be used so that very little tension is applied to the tubing. When the final lap is completed, the coil of tubing is secured by thin nylon twine in three or four places to prevent the layers of tubing from unwinding. After tying, the coil is removed from the mandrel by compressing the thin paper inward as shown in Figure 24.

31. The male and female pieces of the modified Luer-Lock fitting are shown in Figure 8. The end of the top layer of filter tubing is threaded into the female piece of the adapter. A match is lighted and held near the end of the tubing, the end will form into a flare. Care must be used as too much heat will melt the tubing. The male end is then screwed into the female end with the plastic flared joint between them. Hand tight pressure is sufficient to seal the tubing to the fitting.

32. To leak test the unit, obtain any source of air pressure, regulated to 2 or 3 pounds per square inch, and apply pressure through the threaded end of the male section of the adapter. With the open end of the plastic tubing immersed in a volume of water, air bubbling into the water can be observed. No visible air bubbling should be observed when the female of the adapter is immersed completely in the water. When installing, a rubber gasket should be put over the threaded male section and the assembly screwed into the bellows chamber as shown in Figure 8.

Copper Tubing

33. A four foot length of copper tubing with an outside diameter of 3/16", and a wall thickness of 0.030" is used. For bending, the tubing is secured by the two holding clamps as shown in Figure 25. The tube forming jig used in forming the complete coil and the forming technique is also illustrated.

Rubber Diaphragm

34. The material for the rubber diaphragm is Magic-Vulc, manufactured by Magic Chemical Company, 121 Crescent Street, Brockton 2, Massachusetts.

Magic-Vulc is a 100% pure latex rubber in liquid form. A paint brush, 3 inches wide, can be used as the applicator. Three coats of Magic-Vulc should be applied to the platen shown in Figure 26. This material is water soluble and an 8 hour drying period is required between coats. When removing the latex film from the platen it should be coated thoroughly with talcum powder to prevent the latex from sticking to itself. After the film is removed, the engraved circles from the platen will be visible. With scissors the outlines can be cut out to obtain a diaphragm of the correct diameter.

Flood Plug Packing

35. Before packing the flood plug, the hardware should be degreased in a solution of trichlorethylene. The compression jig for packing the flood plug is shown in Figure 27. With the rod removed and the flood plug installed in the jig, 3 grams of powdered boric acid is placed into the hole and the rod installed. The complete assembly is then placed into the press and one thousand pounds per square inch of pressure is applied upon the rod to compress the boric acid powder into the hole of the plug. This compressed plug forms a water tight seal which is soluble when exposed to water. After planting, this seal will last from three to seven days before dissolving depending upon water temperature and other water conditions.

Soluble Washer

36. Two types of soluble washers are used for the hydrobarophone, with the only difference being in the chemical mixture. In order to obtain these a suitable mold must be constructed to press the washer into the detailed size. Details of the two washers are as follows:

a. One Hour Dissolving Time

Material - 60% boric acid (H_3BO_3)

40% potassium nitrate (KNO_3)

Material must be mixed thoroughly and free from lumps. Weight of material required for one washer is about 7.85 grams. Mold material dry with a load of 10,000 pounds.

b. Two Hour Dissolving Time

Material - 85% powdered boric acid (H_3BO_3)

15% potassium nitrate (KNO_3)

Materials must be mixed thoroughly and free of lumps. Weight of material required for one washer is about 7.35 grams. Mold material dry and with a load of 10,000 pounds.

B. Assembly Procedures

37. In assembling the hydrobarophone, the work is better done by assembling sections and attaching the sections together. The assembly procedures will therefore be described in this way.

Bellows Chamber

38. The tee joint is soft-soldered into the bellows chamber. Care must be taken that an excessive amount of solder does not close the hole between the tee joint and the hole provided in the bellows chamber. Valve bodies for valve ports 1 and 2 are temporarily screwed into the bellows chambers without the O-rings. One coil of copper tubing is then hand shaped for one end to fit into one end of the tee joint, and the other end to fit into the valve body for valve port #2. The other coil of tubing is shaped in the same manner to accommodate the valve body for valve port #1, as shown in Figure 28. Solder the ends of the tubing into the valve bodies and leave the other ends unsoldered. This procedure must be followed to prevent the burning of the O-rings in the valve bodies and pop-off valves. The valve body for valve port #1 plus the tubing is now unscrewed from the bellows chamber and the pop-off valve plus the necessary gaskets and O-rings installed (see Figure 29). The valve assembly is then screwed into the bellows chamber and the relief valve cap installed. Place the open end of the copper tubing into the tee joint and solder. Install the pop-off valve in the valve body for valve port #2 with the necessary gaskets and O-rings, bellows assembly A, soluble washer and valve cover cap, as shown in Figures 5 and 11. Solder the copper tubing as before.

39. The bellows is now placed into the bellows chamber, and filled with Tricresyl Phosphate to prevent sea water from corroding the corrugations. It will remain in the bellows after planting as its specific gravity is greater than water. The rubber diaphragm is placed over the opening of the bellows and sealed with the spacer ring shown in Figure 28. The filter is then screwed into the bellows chamber and the planting relief valve shown in Figure 11 installed. The bellows chamber is now ready for attachment to the body casting of the hydrobarophone containing the electronic compartment and diaphragm.

Body Casting

40. Before assembly of the diaphragm and the body casting, it is necessary that the coil assembly (Figure 9) be connected. The coil assembly has two terminals, projecting from the plastic potting compound, to which leads of Number 22 stranded wire are carefully soldered. Because there is very little clearance between the back of the coil assembly and the body casting, great care must be exercised to prevent shorting to the case or interference with the proper setting of the coil assembly. The coil assembly is placed near its final position and the two leads soldered to the Fusite terminals leading through the body casting. These Fusite terminals are the threaded type - No. 104T13-FP manufactured by Fusite Corporation, Cincinnati, Ohio and are shown in Figure 30. To obtain an air tight seal between the

casting and terminals, each terminal is coated with "Locktite Sealant", which is a liquid seal for metal parts against high pressures. It is manufactured by the American Sealant Company, Hartford, Connecticut. The coil assembly may now be fastened into place.

41. After installation of the coil assembly, the diaphragm is installed to avoid damage to ground surfaces. The coil assembly is now ready for the determination of its resonant capacity. This may be derived by placing a variable capacitor in series with one side of the main coil and a stable 1000 cycle generator (accuracy of ±1 cycle per second). The capacitor is varied until the A.C. meter across the supply voltage reads a minimum null which indicates a resonant condition of the inductive, capacitance circuit. A capacitor of the same value as that required on the variable capacitor can now be installed in the electrical chassis.

42. The electrical chassis is fastened to the bottom casting with two 6-32 screws. It is very important that there be no projection above the machined surface of the body casting as this can lead to a short or improper seating of the bellows chamber casting. The inductance coil leads are now soldered into place with one lead going to the unconnected side of the resonant capacitor, and the other lead going to the opposite side of the line. The "pigtail", a six foot length of two-conductor unshielded rubber-covered cable, is passed through the stuffing gland on the side of the casting and the leads soldered to either side of the 50-ohm resistor across the stand-off terminals. The outside jacket of the cable must appear inside the casting at the end of the stuffing gland to assure a good water tight seal.

Overall Hydrobarophone Assembly

43. Place the bellows chamber casting on top of the body casting, using care that the acoustic filter is not pinched while being placed in the acoustic filter well. Install and secure the eight 1/4-20 bolts joining the two castings. Apply pipe dope to the threads of the flood plugs and air bag stem, and install them into the bellows- chamber cover plate. Bolt the bellows-chamber cover plate to the bellows chamber, and bolt the retaining ring to the cover plate. The function of the retaining ring is to prevent the air bag and miscellaneous debris (as shown in Figures 31 and 32) from blocking the flood plugs. Fill the plastic bag with air. The correct volume of air should be measured by placing the bag into the air-volume cylinder and compressing it until the bag is approximately 2-1/2 inches to 3 inches below the top of the cylinder. Maintain this volume of air and push the bag onto the bag stem and tie the bag to the stem with a rubber band by wrapping it around several times and tying. Place the air-volume cylinder over the plastic bag, retaining ring, and bellows-chamber cover plate, and attach this with screws. Secure the cylinder top plate to the air volume cylinder.

Assembly into Temperature Shield and Anchor

44. After the hydrobarophone is assembled, it is installed into the fiberglass temperature shield and mounted to the concrete anchor. Bolt the four mounting brackets to the air-volume cylinder, as shown in Figure 33.

Bolt the complete assembly to the fiberglass cylinder lid of the temperature shield as shown. Assemble the fiberglass cylinder, except for the lid and hydrobarophone, and bolt it to the concrete anchor with three nuts as shown in Figure 34. Place into the anchor cradle shown in Figure 35. The top lid with the hydrobarophone can now be secured to the fiberglass cylinder with the necessary bolts. The cable clamp assembly (Figure 36) is bolted to the concrete anchor and the "pigtail" connected to the underwater cable that runs from the hydrobarophone to the underwater distribution box. All loose lines are lashed down and the unit as shown in Figure 37 is ready for planting.

Chapter 3

HYDROBAROPHONE CALIBRATION, PLANTING, AND RECOVERY

Calibration

45. Pressure changes in the field are recorded as an electrical unbalance of the hydrobaric recording system. To convert this unbalance into a usable term (inches of water versus output current), it is necessary to calibrate the hydrobarophone with a known change of water pressure. A simple method of creating a known change of water pressure is to move the hydrobarophone through a measured depth of water, for instance, six inches and measure the change in output current of the inductance bridge with a very accurate (±one-half percent) milliammeter. Another, more complicated, method of determining the sensitivity of the hydrobarophone is the application of a known pressure to the face of the diaphragm. Both methods are used in the laboratory calibration of the hydrobarophone and will be discussed in detail.

Applied Pressure to Diaphragm

46. The method of applying pressure to the face of the diaphragm is the first step in the calibration procedure and is considered to be the more accurate method of calibration. The calibrating system consists of an air pot, a very accurate manometer capable of reading to 24 inches and a source of controlled air pressure (see Figures 38 through 40). Another view showing the test console with the vacuum pump, oven and leak detecting equipment is shown in Figure 41. It has been found that the sensitivity of the hydrobarophone is dependent upon water temperature. Consequently, the air pot, with the lower unit of the hydrobarophone, is placed in an American Instrument Company controlled temperature chamber; and all connections brought out through appropriate ports. Calibrations are made at temperatures of 35°, 45°, 55°, 60°, 70° and 75°F. The calibration factor is plotted as a function of temperature as shown in Figure 42. During calibration, the following procedures for assembly and electrical line up must be followed:

47. The body casting of the hydrobarophone containing the diaphragm, coil assembly, and the electrical chassis is placed in an air pot with the diaphragm sealed in the air tight enclosure by an "O" ring around the side of the unit. See Figure 38.

48. A rubber covered cable, containing two electrical conductors and commonly called a "pigtail", is brought out of the side of the body casting through a stuffing gland. These conductors are connected to the input terminals (marked Hydrobarophone) of the Mark 1 Mod 4 A.C. Bridge.

49. The bridge power supply and the 1000 cps secondary frequency standard are turned on. At least one hour is allowed for the electronic components to warm up, and to reach stability.

50. After warm-up and with the "A" gain at zero, the output milliammeter of the bridge should read zero. If it does not, the "Electrical Zero Adjustment" potentiometer should be adjusted so that the output reads zero. It is marked P-9, and is located in the upper left-hand corner of the bridge.

51. Before balancing the bridge, place an accurate high impedance A.C. voltmeter across the terminals marked J and K on the bridge. With the voltmeter set for the 0.1 volt scale, the voltage reading should be 0.07 volts. If not, adjust the potentiometer P-1 until the reading is correct. This potentiometer is located on the lower right-hand side of the bridge.

52. The bridge is now ready for balancing. A balanced state exists when the output current of the bridge, with no signal or pressure applied to the diaphragm of the hydrobarophone, reads zero for any "A" gain setting. The bridge is balanced by adjusting controls which are designated coarse and fine "R" balance, and the coarse and fine "L" balance. It is necessary to have the Operate switch, located in the middle of the front panel of the bridge, in the "R" balance position when adjusting the "R" balance controls, and in the Operate position when adjusting the "L" balance controls. Place the coarse "R" and coarse "L" balance controls in the center of their mechanical travel. Connect a decade (adjustable) capacitor across terminals G and H, and a decade (adjustable) resistor across terminals C and D.

53. Turn the "A" gain to step number one and observe the milliammeter. Adjust the decade capacitor until the meter reads zero with the switch in the "Operate" position. Place the switch in the "R" balance position, and adjust the decade resistor until the meter reads zero. It may be necessary to readjust the decade capacitor slightly at this point. The decade capacitor, in this case, has balanced out the capacitive reactance of the hydrobarophone-cable combination, and the decade resistor has balanced out the direct current resistance of the combination. From this point on, it is necessary to use only the balance control knobs while advancing the "A" gain in steps of 3, and balancing the meter to zero each time. At step 10 or 11 on the "A" gain, the bridge has become sensitive enough to use the fine "L" and "R" balance adjustments. Continue this balancing until step 20 is reached.

54. Set the "A" gain as noted in the table below for the specified changes of water pressure on the hydrobarophone.

Pressure Changes (Inches of Water)	"A" Gain Setting	Approximate Meter Reading
3	16	0.283
6	14	0.283
10	13	0.360

NOTE: The milliammeter reading is approximate because it depends upon the sensitivity of the unit under test.

The milliammeter reading should not exceed 1.0 milliamperes either in the positive or negative polarity. The bridge output is designed for a one milliampere full scale reading.

55. To arrive at a calibration term for the hydrobarophone, a known inductance change must be made in one of two physical locations in the bridge and hydrobarophone circuit. The first method is designated the shore calibration and consists of placing either a 100 microhenry or a 1500 microhenry inductor in series with one arm of the bridge circuit at the bridge end. The second method is designated the underwater calibration and consists of placing a 1500 microhenry inductor in series with the coil of the hydrobarophone directly at the hydrobarophone. The 100 microhenry inductor may be used in the laboratory. With wave background, as found in the field, it is necessary to step down in gain. The 100 microhenry inductance is then too small to give a suitable deflection on the meter. Using the 100 microhenry inductor, the "A" gain control should be at Step 14. From the table in paragraph 56, it can be seen that Step 14 is also the gain step used for a pressure change of six inches. If the hydrobarophone were calibrated at a pressure change of six inches and a 100 microhenry inductor could be used, the calculations would be simplified in that no voltage ratio figure is needed in the calculation.

56. When calibrating a unit, at least three readings of the current caused by the calibrating inductor, and three readings caused by the pressure step on the face of the diaphragm should be made. There should be a negligible difference in these readings. If this is not the case, there is likely to be a cause of drift somewhere in the system which should be investigated. The current, indicated by the meter, corresponds to specific pressure on the diaphragm. This current is recorded, and used in the final calculation.

57. The formula for determining the sensitivity is as follows:

$$Z = L\, I_p/_\rho\ PI_L = \text{Sensitivity in microhenries per inch of pressure} = Z$$

Where:

L = Calibrating inductor in microhenries

I_L = Current caused by introducing L

ρ = Voltage ratio of the difference between the "A" gain setting for the inductance calibration and the "A" gain setting for a Pressure Step at 3 decibels per step

I_p = Current caused by Pressure Step

P = Pressure applied to diaphragm in inches of air or water

For a typical example, consider that the "A" gain setting for a six-inch pressure change is Step 14. The meter reading of this pressure is 0.282.

The "A" gain setting for the 100 microhenry calibrating inductor is Step 14. The meter reading is 0.480. Then the calculation is as follows:

$$\frac{100 \text{ microhenries}}{0.480 \text{ milliamperes X } 1} \times \frac{0.282 \text{ milliamperes}}{6 \text{ inches of pressure}} = \begin{array}{l}11.3 \text{ microhenries per}\\ \text{inch of pressure}\end{array}$$

If a 1500 microhenry inductor had been used, the numerical values for the computation would be the following:

The "A" gain setting for the 1500 microhenry inductor is 6. The meter reading of this pressure is 0.394. The "A" gain setting for a six-inch pressure change is Step 14. The decibel difference of Step 14 and Step 6 is equal to 24 db (8 steps at 3 db per step). The voltage ratio for 24 db is 15.85. These values indicate the following value for the hydrobarophone sensitivity.

$$\frac{1500 \text{ microhenries}}{0.394 \text{ Ma X } 15.85} \times \frac{0.282 \text{ Ma}}{6} = \begin{array}{l}11.3 \text{ microhenries per inch}\\ \text{of pressure}\end{array}$$

58. Now that the sensitivity of the hydrobarophone is known, it is converted to a "inches of water" calibration value for field use. A deflection or calibration is made in the field by inserting a known inductance in one arm of the bridge exactly as was accomplished in the laboratory. This deflection may be reproduced as a voltage change on a magnetic tape recorder or the deflection of a pen on an electric oscillograph. This deflection will be accomplished at a particular "A" gain step on the bridge and the following calculation will convert it to inches of water.

$$\Delta P = L/\rho Z = \text{Equivalent value of calibration deflection in inches of water}$$

L = 1500 microhenry inductor

Z = Laboratory sensitivity of the hydrobarophone in microhenries per inch of water

ρ = Voltage ratio of the difference between the "A" gain of the recording and the "A" gain of the calibration

EXAMPLE: If the calibration gain is at Step 5 and the recording gain is Step 18, there are thirteen (13) steps between 5 and 18 at 3 decibels per step and this is equal to 39 decibels. The voltage ratio of 39 decibels is equal to 89.0. If, for example, the voltage caused by the calibrating inductor were 0.624 and the sensitivity of the hydrobarophone were 11.76 microhenries per inch of water, the calculated value of the calibration deflection in inches of water would be as follows:

$$\frac{1500}{11.76 \times 89} = \text{1.135 inches of water for a calibration deflection of 0.624 volts at Step 18}$$

A typical calibration sheet is shown in Figure 43.

59. For underwater calibrations the 1500 microhenry inductor is inserted in series with the hydrobarophone coil by a method which uses two relays. One relay is a high impedance across the line and the second is a thermal delay relay. A direct current power supply with a capacity of 1000 milliamperes supplies the necessary power to actuate these relays. The hydrobarophone cable is disconnected from the bridge input and placed across the output of the power supply for approximately twenty seconds. This actuates the high impedance relay which in turn applies voltage to a heating element in the time delay relay. The heating element expands a bi-metallic strip which opens a short circuit across a 1500 microhenry inductor in series with the main hydrobarophone coil. The series resonant capacitor prevents the direct current from damaging the main coil. When this inductor is in the circuit, it appears, of course, as a change of 1500 microhenries and causes an equivalent deflection or change in output voltage of the bridge circuit.

60. For any hydrobarophone calibration to apply for a range of expected pressure changes, the hydrobarophone response must be linear over this range. The flexible diaphragm detects both a positive and negative water pressure as it moves through its zero mechanical position due to the rise and fall of water pressure in the field, caused by waves and seagoing vessels. In the laboratory, sensitivities are measured for various pressures up to ±24 inches of water (corresponding to a wave having an amplitude of four feet) in both the positive and negative directions. Care must be taken to insure that the bridge gain is set so that the 24-inch pressure step gives an output which does not exceed 1 milliampere. The pressure applied to the face of the diaphragm closes the air gap and causes an increase in inductance indicating a positive pressure. For a negative pressure it is necessary to apply pressure to the back of the diaphragm and open the air gap thereby decreasing the inductance. (See Figure 38 for mechanical connections for negative pressure step).

Movement of Hydrobarophone through a Measured Depth of Water

61. This is the second step in the calibration procedure, and is done for the primary purpose of obtaining the frequency response of the acoustic filter with the sensitivity figure being of secondary value. A frequency response must be made on each individual filter because the inside diameter of the tubing varies and causes a difference in characteristic with corresponding different operational characteristics of each hydrobarophone. The characteristics of this filter are calculated so that the time constant allows a relatively fast signature such as wave background and ship signatures to be recorded with absolute fidelity but attenuates very slow signals such as tides and seiches These conditions, if not attenuated, would drive the

bridge completely out of balance in a period of minutes. The Mine Test Tank (Building 409) is used for these tests, but is limited to 100 feet. Filters for greater depths must be obtained by extrapolation. This response is determined in the following manner.

62. The hydrobarophone is suspended on a steel cable. The length of this cable is adjusted to immerse the unit at the approximate depth at which the unit is to be used in the field. The steel cable is attached to a variable-speed, revolving arm mounted on a platform above the water. The arrangement is shown in Figure 44. The two-conductor electrical cable of the hydrobarophone is spliced to a long electrical cable which leads to the bridge input. This splice is enclosed in a water tight splicing gland.

63. After the hydrobarophone has been lowered to the proper water depth, a waiting period of about two hours is necessary so that the soluble washer in the pop-off valve of the unit may dissolve. While the washer is dissolving, the hydrobarophone inductive balance will be continually shifting and no valid measurements can be made.

64. The bridge is adjusted as mentioned before except that a recording milliammeter is used for this test rather than a laboratory type instrument. The recording milliammeter is balanced, by the bridge controls, to the center of the recording chart. The attenuator or "A" Gain Control of the bridge is set at a point where the six inches of water change will not overdrive the recording milliammeter. The rotating arm must be in the horizontal position so that the hydrobarophone passes through zero with three inches of water on either side of zero.

65. After balancing, the speed control of the rotating arm is set for the fastest speed. At this setting the period for a complete revolution is 62 seconds. A timer starts when power is applied to the driving motor and the arm is rotated for about twenty revolutions. The resulting sine wave output is recorded on the milliammeter chart. Within twenty revolutions transients in the system will have vanished, and the recording pen will trace a smooth sine-wave. The double-amplitude of the sine wave is measured in divisions of the chart. The measurement is the reference level from which the percent of the input signal lost for a single-cycle field is calculated.

66. It is necessary to describe a single-cycle field. This pulse form closely resembles target signature signals, and is useful for comparison. Single-cycle fields of various periods are recorded in the following manner.

a. The arm of the rotating device is placed exactly in a vertical position with the hydrobarophone at the extreme bottom of travel. Allow at least ten minutes for the back pressure device to equalize in the hydrobarophone.

b. The pen of the recording milliammeter is inductively off-balanced by the "L" balance controls of the bridge. In order to center the recorded single-cycle field on the chart, the pen should start its motion from a position approximately two large divisions from the right. The resistive or "R" balance of the bridge must be at the zero center line.

c. The speed control of the rotating device is set again at the fastest speed, power is applied, and the arm is allowed to rotate through one complete cycle. It is stopped when the pen has exactly the same displacement as the start. The percent of the input signal lost is the ratio of the deflection of the single-cycle peak from the zero line to the deflection of the steady state value of the sine-wave.

d. Change the speed control of the rotating arm for various periods ranging from one minute to ten minutes, and repeat the procedure for recording the single-cycle field. The results can then be plotted on a fall off curve as shown in Figure 45.

Planting Procedures

67. After the hydrobarophone is mounted on the concrete anchor, the hydrobarophone "pigtail" leading out of the stuffing gland is ready to be spliced to a unit cable. The unit cable is normally a four-conductor armored cable containing size 14 conductors, and having a length of approximately 400 to 600 feet. Polarity of the conductors from the pigtail need not be observed. The unit cable has a "TURKSHEAD" retainer worked onto the armor and this retainer is fastened to a cable clamp on the side of the anchor. Two of the four conductors of the unit cable (opposite pairs 1 and 3 or 2 and 4) are spliced to the "pigtail". The two remaining conductors are used for the temperature indicating probe which is mounted inside the temperature shield. The lead from this probe is also brought out of the shield through a stuffing gland and a water tight splice made. The probe cable and its splice, and the "pigtail" and its splice, are now wrapped individually with nine thread line. This wrapping is covered with a piece of the outer jacket from a 21-conductor cable or any similar material, to protect the cable and splices from abrasion. The entire assembly is then lashed down to a convenient place on the lowering cradle.

68. After the splice is made, the conductors in the unit cable are identified as to their connection, either hydrobarophone or probe. By using an ohmmeter the hydrobarophone leads are checked for resistive continuity and leakage to ground. The resistance reading is the 50-ohm harmonic suppression resistor plus the few units of resistance in the unit cable. The leakage reading should read infinity from each conductor to ground.

69. The units are loaded aboard the planting vessel along with their unit cables and moved into position for planting operations. The shore cable is retrieved by using the distribution box recovery system. The shore cable is usually a 21-conductor armored cable. It is made up of four quads plus a spare quad laid at the outside circumference of the cable. The twenty-first conductor is laid in the center. It is normally used to fire a distribution box recovery buoy. After the sea end of the cable has been retrieved, the water tight joints are opened. The several quads are separated according to

a colored binding encircling each quad. Individual conductors are stripped back and played out. Continuity and insulation measurements are made from the shore station. Opposite conductors of each quad are chosen for the hydrobarophone leads. The electrical parameters of the cable must be measured so that suitable matching networks can be installed at the bridges to eliminate undesirable phase shift of the 1000 cps driving voltage.

70. The values are measured with a General Radio Impedance Bridge Type 650-A, or the most recent Type 1650-A. The procedure follows:

Loop Resistance

a. At the shore end of the cable, set the impedance bridge for D.C. resistance measurements.

b. Instruct the cable vessel to twist the opposite conductors in the quad of interest, making certain that a good connection is made.

c. Connect the impedance bridge to the pair of conductors of interest. (WARNING - DO NOT CONNECT BRIDGE TO LEADS UNTIL THEY HAVE BEEN TWISTED TOGETHER AT THE SEA END. FAILURE TO OBSERVE THIS PROCEDURE WILL RESULT IN AN UNPLEASANT ELECTRICAL SHOCK TO PERSONNEL WORKING ON THE CABLE).

d. Adjust the dials of the impedance bridge to obtain a perfect null on the galvanometer.

e. Read the resistance value and record this value.

Loop Inductance

f. Change the impedance bridge from D. C. resistance measurement to inductance measuring.

g. Adjust the dials of the impedance bridge to obtain a null.

h. Read the dial settings and record the measured inductance at 1000 cycles.

Open Circuit Capacitance

i. Disconnect the impedance bridge from the cable to avoid unpleasant electrical shock to personnel.

j. Instruct the cable vessel personnel to untwist the conductors of interest; and make sure that the leads are not grounded.

k. Connect the impedance bridge to the shore ends of the cable and set for capacitance measurements.

l. Adjust dials to obtain a null; and record the corresponding value of capacitance.

71. Each of the four quads will measure approximately the same values. The fifth or spare quad will be slightly different because of the greater spacing between leads and a slightly longer lay. After the measurements have been completed on all conductors of interest, watertight splices may be made at the distribution box. When conditions permit, it is advisable to insert temporary values of the cable balancing network in the bridge, and to check the operation of the hydrobarophones before concluding the planting operation.

72. In the past it has been the practice to parallel opposite conductors in a quad to minimize the electrical length of the cable. This may be done only if there are enough conductors available for the hydrobarophones and the temperature indicating probe. In a range such as Fort Lauderdale, Florida, five hydrobarophones are planted; and all of the available quads are used. With temperature probes installed, it would be impractical to parallel conductors. In this circumstance it is necessary to use two conductors in a quad for the hydrobarophones, and the remaining two for the temperature probe.

73. The length of the unit cables will have negligible effect on the overall electrical measurements of the shore cable. Any slight changes of phase shift can be corrected by a phase shifting network installed in the shore equipment for the hydrobarophones.

74. The temperature shield around the hydrobarophone must be filled completely with water, and all air exhausted from inside the shield. This is accomplished by lowering the top of the shield just below the surface of the sea. When air bubbles no longer appear from the filling hole, a flood plug is installed and the units may be planted.

75. Approximately two hours is required for the soluble washer to dissolve. After this has occurred, the units may be checked from shore for proper operation. Temporary cable-balancing networks are set up at the bridges on shore. The phase-shift network is adjusted to balance the bridge.

76. To be certain that a known change of inductance at the hydrobarophone and a similar change at the shore equipment are equal, it is necessary to remotely insert a 1500 microhenry inductance in series with the main hydrobarophone coil. This is designated the underwater system calibration. It is accomplished in the following manner.

77. To actuate the calibrating circuit in the hydrobarophone, it is necessary to disconnect the shore cable from the bridge and pulse the cable with a direct current of about 600 milliamperes for about 30 seconds. This current immediately actuates the high impedance relay, which in turn actuates the thermal time-delay relay. The open time of the thermal time-delay relay is directly proportional to the time of the applied current. While the delay relay is open, the 1500 microhenry calibrating coil is inserted in series with the main coil of the hydrobarophone. When the hydrobarophone leads are reconnected to the bridge, the relay stays open for approximately 20 seconds. This arrangement produces a step function whose amplitude on the recording device is equivalent to a change of 1500 microhenries. This step function

is compared to a 1500 microhenry change at the shore end. The deflections will be equivalent if no error has been introduced by the circuitry. This step is included in a computation as a final calibration of the system. After establishing that the phase shift is negligible and that the hydrobarophone is operating properly, fixed values of resistance, inductance and capacitance are placed across terminals C, D and E of the bridge.

Recovery

78. Malfunction of the pressure recording system is indicated by excessive drift of the reference line on the recording tape, excessive noise or transients suddenly appearing, or complete loss of ability to balance the bridge. These troubles are usually caused by one of three factors. The first thing to investigate is the resistance of the cable to ground and the resistance across the hydrobarophone leads. The leads must be disconnected from the bridge for these measurements. Do not use a megger as the high voltage may damage the hydrobarophone. It is recommended that either a Simpson Meter or a Voltohmyst be used. Set these instruments on the OHMS scale; readings to ground should indicate infinite resistance. If resistances are very low in the order of 100 to 1000 ohms, switch the meter to volts D. C. on the lowest scale setting. If a voltage is indicated on the meter, it is reasonable to assume that water has leaked into either the hydrobarophone, or the cable, setting up a electrolytic action. The unit should be recovered, checked, and replaced if flooded. If it is determined by resistance measurements that the cable is at fault, a good pair of conductors in the cable should be substituted.

79. When it is determined that the cable and hydrobarophone are not at fault, it is recommended that the bridge be checked. This is done simply by placing a 25-ohm resistor across the input terminals and attempting to balance the bridge. If the bridge does not balance, conventional electronic troubleshooting methods are applied to discover the difficulty.

80. In recovering the unit from the water, the power to the bridge should be off to prevent damage to the recording media. Recovery techniques will not be discussed here. When the unit has been raised, reverse assembly procedures down to removing the bellows chamber cover plate. Check the rubber diaphragm covering the bellows. Be sure it is intact. If not, replace. Reassemble as before, and replant.

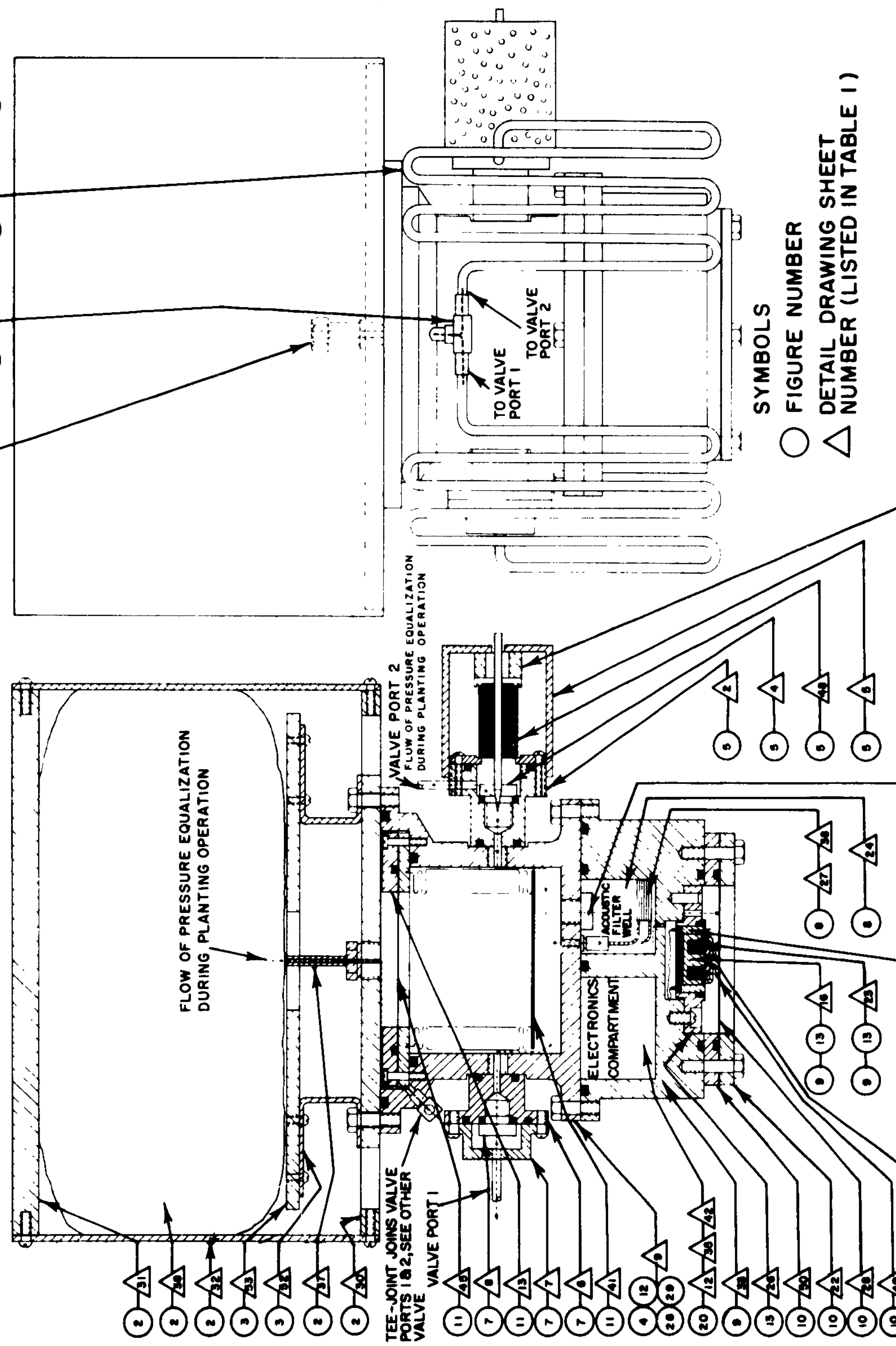


FIG. I CROSS-SECTIONAL ASSEMBLY DRAWING OF THE HYDROBAROPHONE

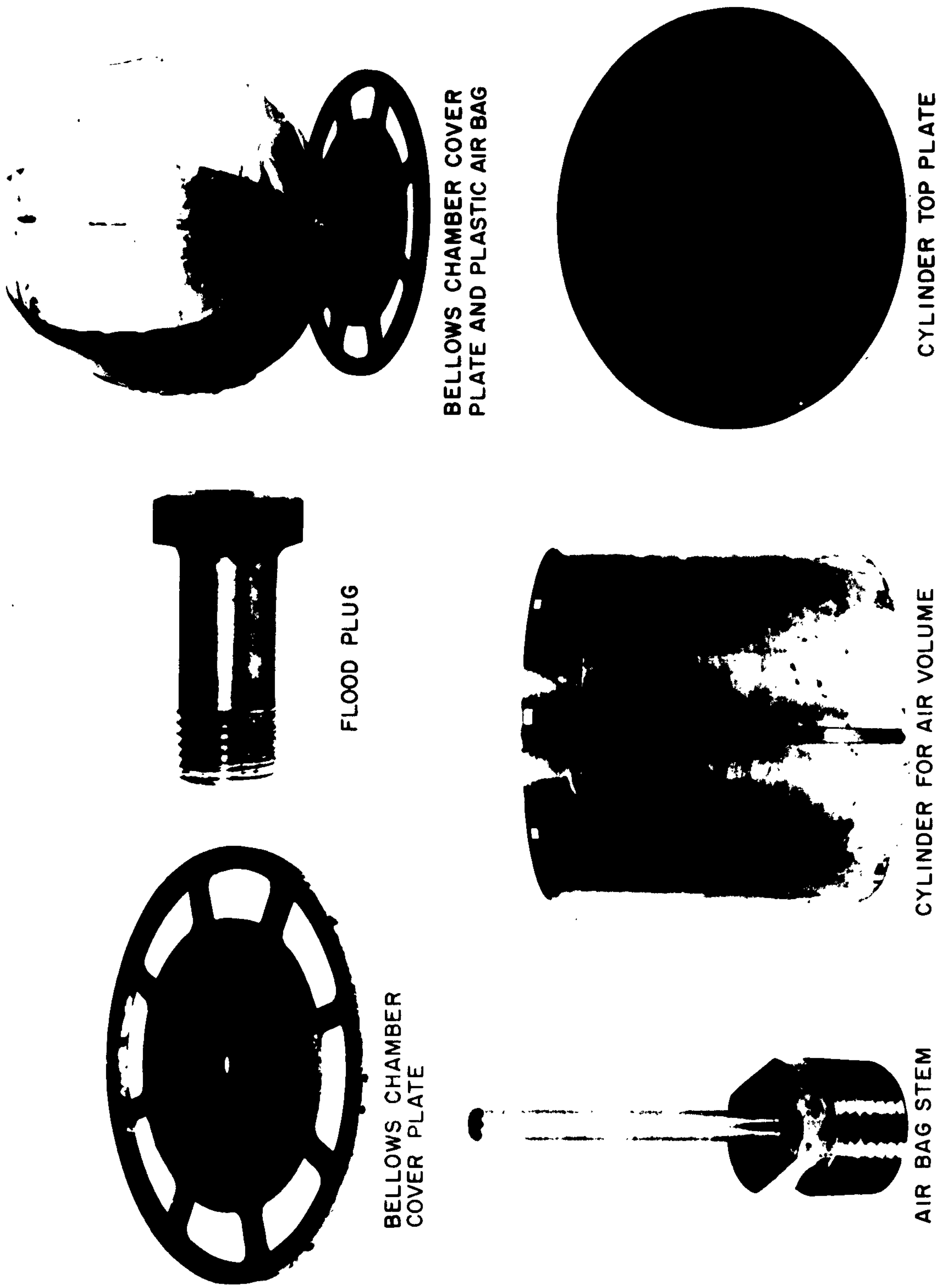


FIG. 2 PRESSURE EQUALIZATION ASSEMBLY

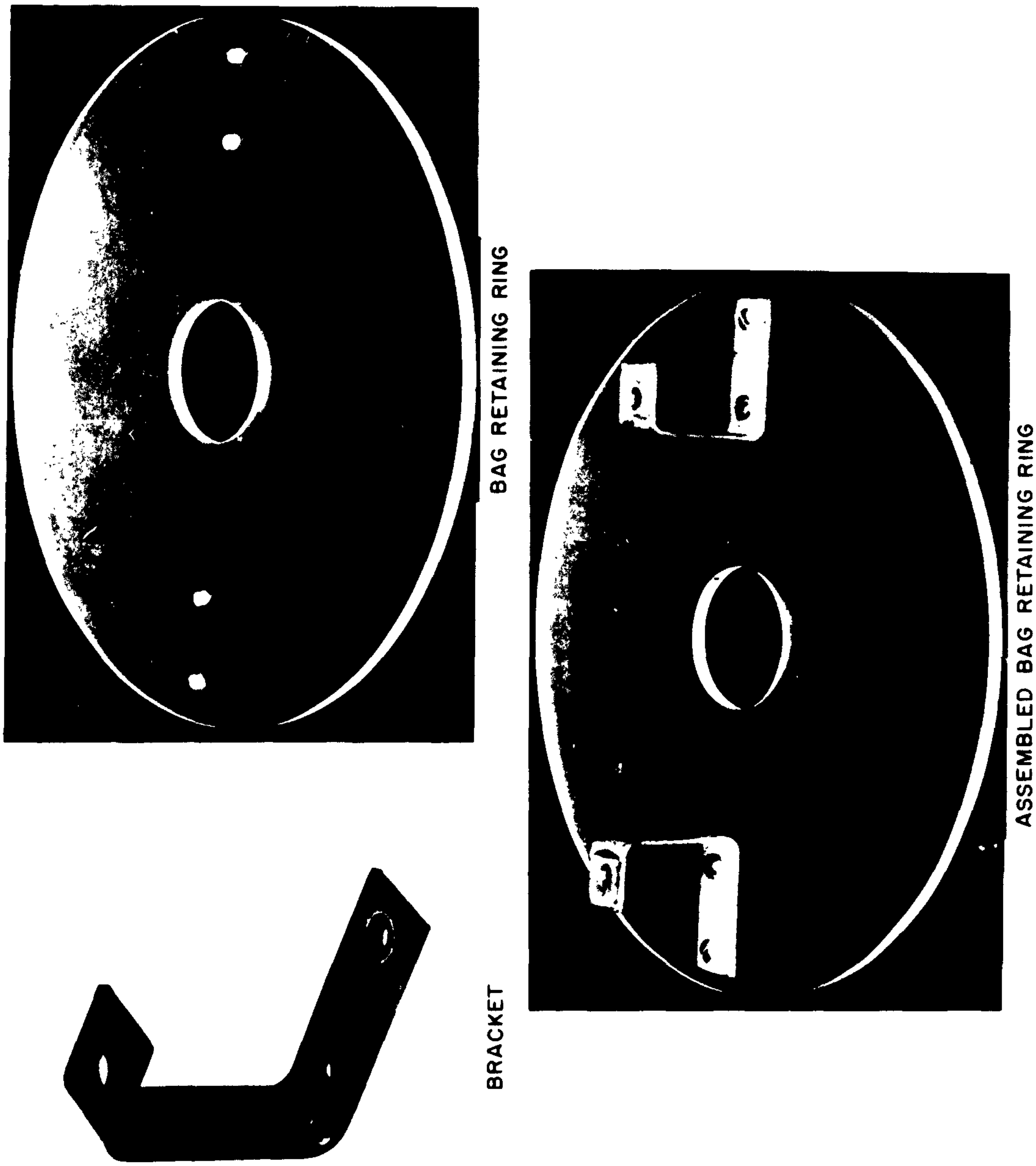


FIG. 3 ASSEMBLED BAG RETAINING RING AND COMPONENTS

FIG. 4 UPPER BELLOWS CHAMBER SHOWING BELLOWS CAVITY, RELIEF VALVE & FILTER PORT

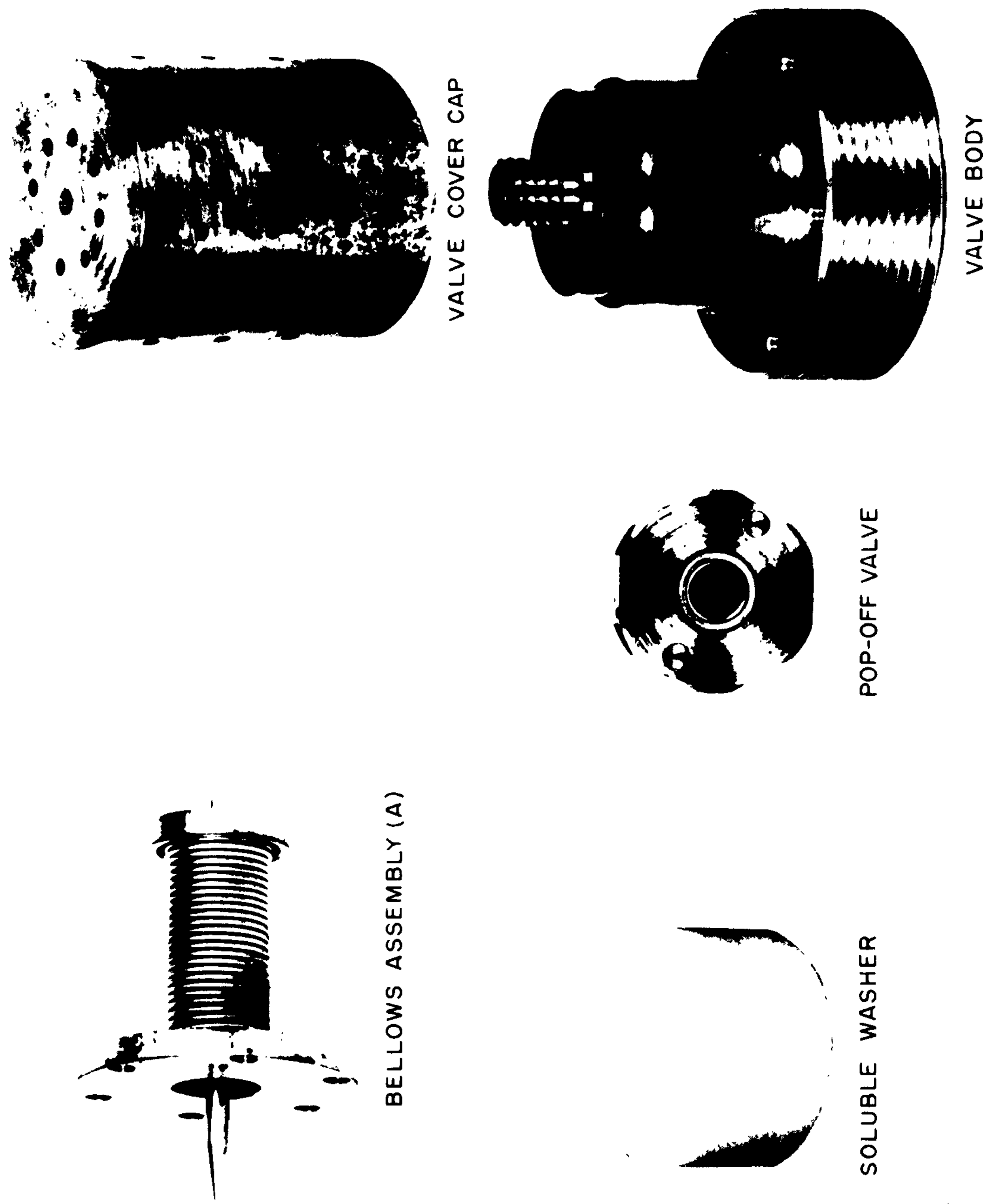


FIG. 5 CUT-OFF VALVE ASSEMBLY

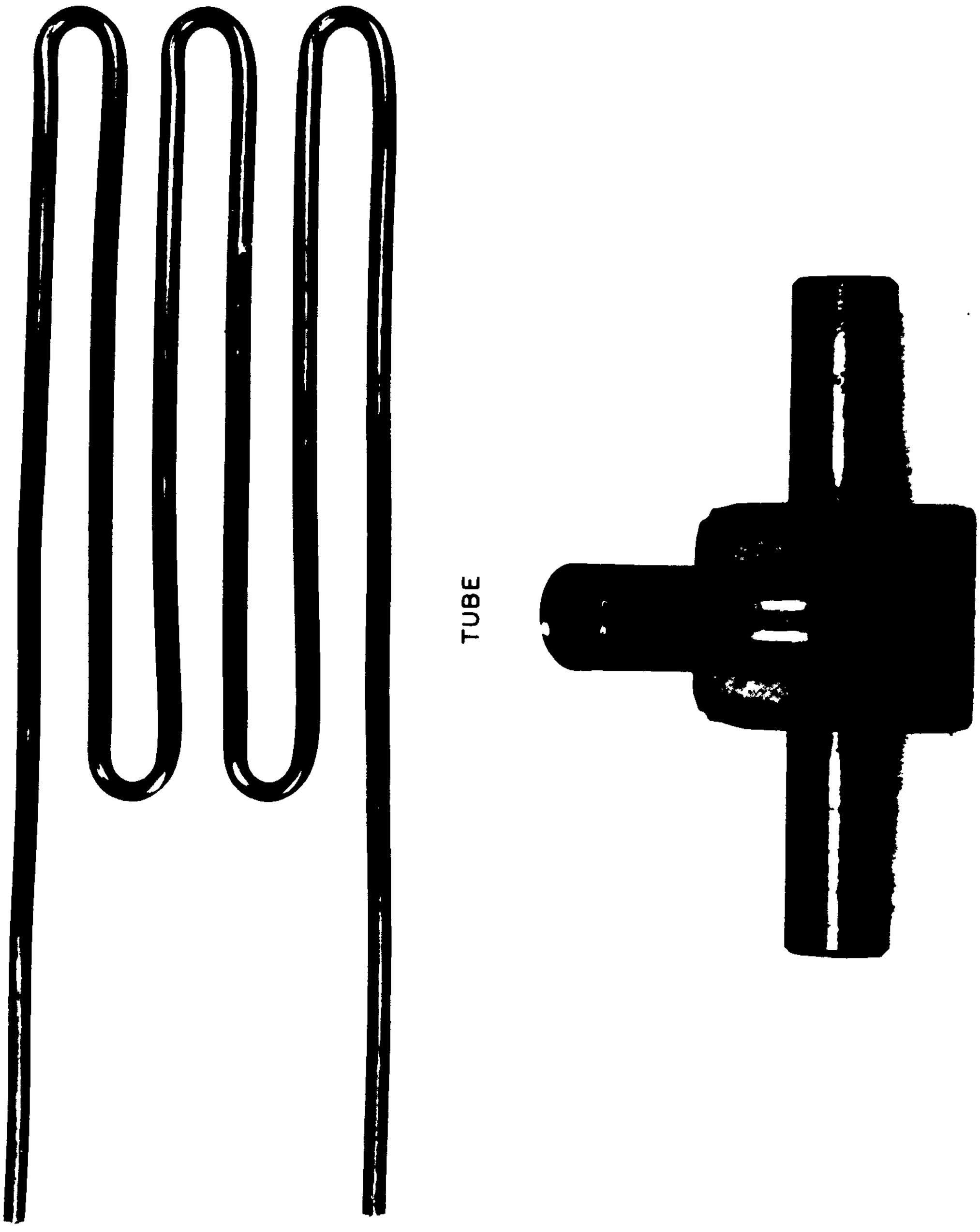
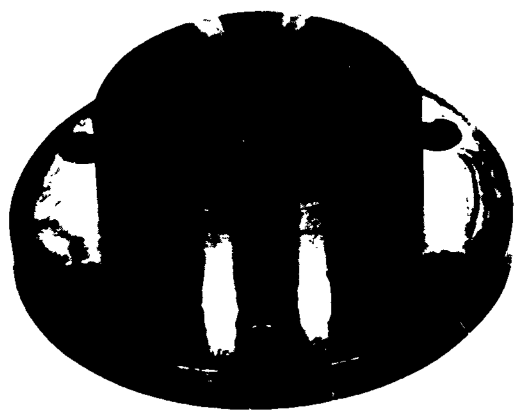
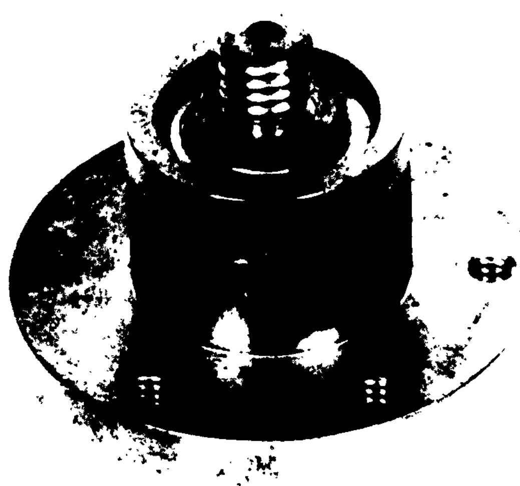


FIG. 6 COPPER TUBING AND TEE-JOINT

POP-OFF VALVE

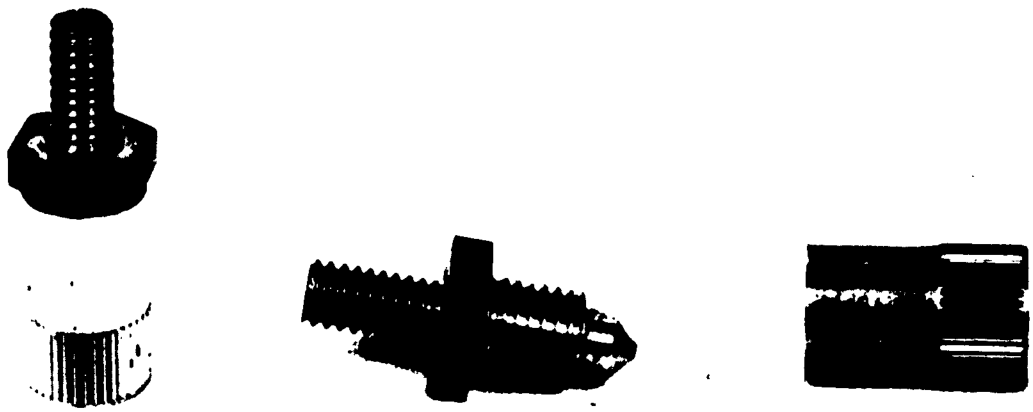


RELIEF VALVE CAP



RELIEF VALVE BODY

FIG. 7 PRESSURE RELIEF VALVE ASSEMBLY

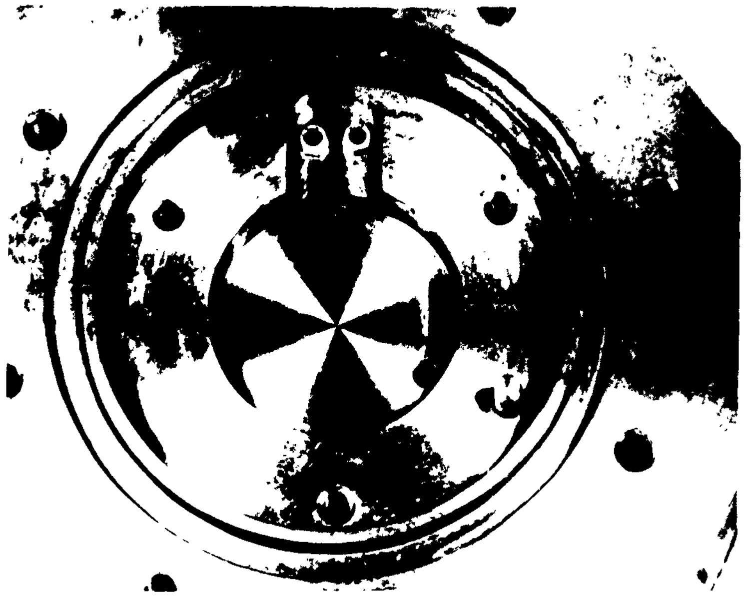


ASSEMBLED
LUER-LOCK FITTING

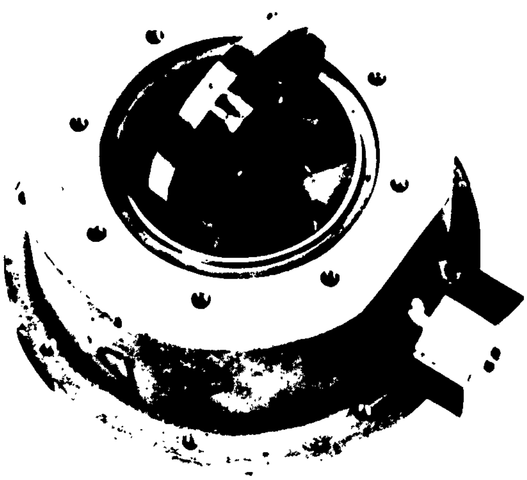
MODIFIED LUER-LOCK FITTING

FILTER ASSEMBLY

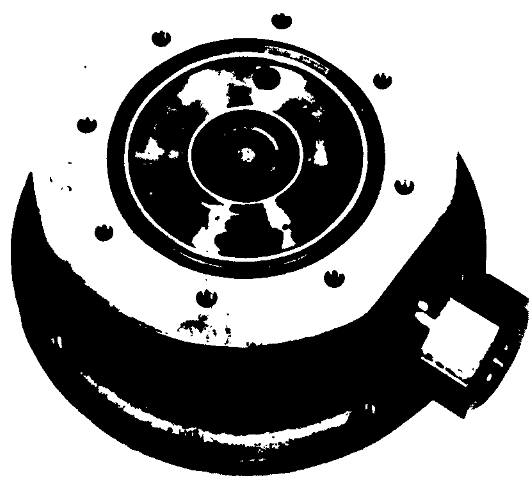
FIG. 8 ACOUSTIC FILTER COMPONENTS & ASSEMBLY



BODY CASTING WITH ASSEMBLED FUSITE CONNECTORS



COIL ASSEMBLY SOLDERED TO FUSITE CONNECTORS



COIL ASSEMBLY SET IN BODY CASTING

FIG. 9 BODY CASTING & ASSEMBLED COIL

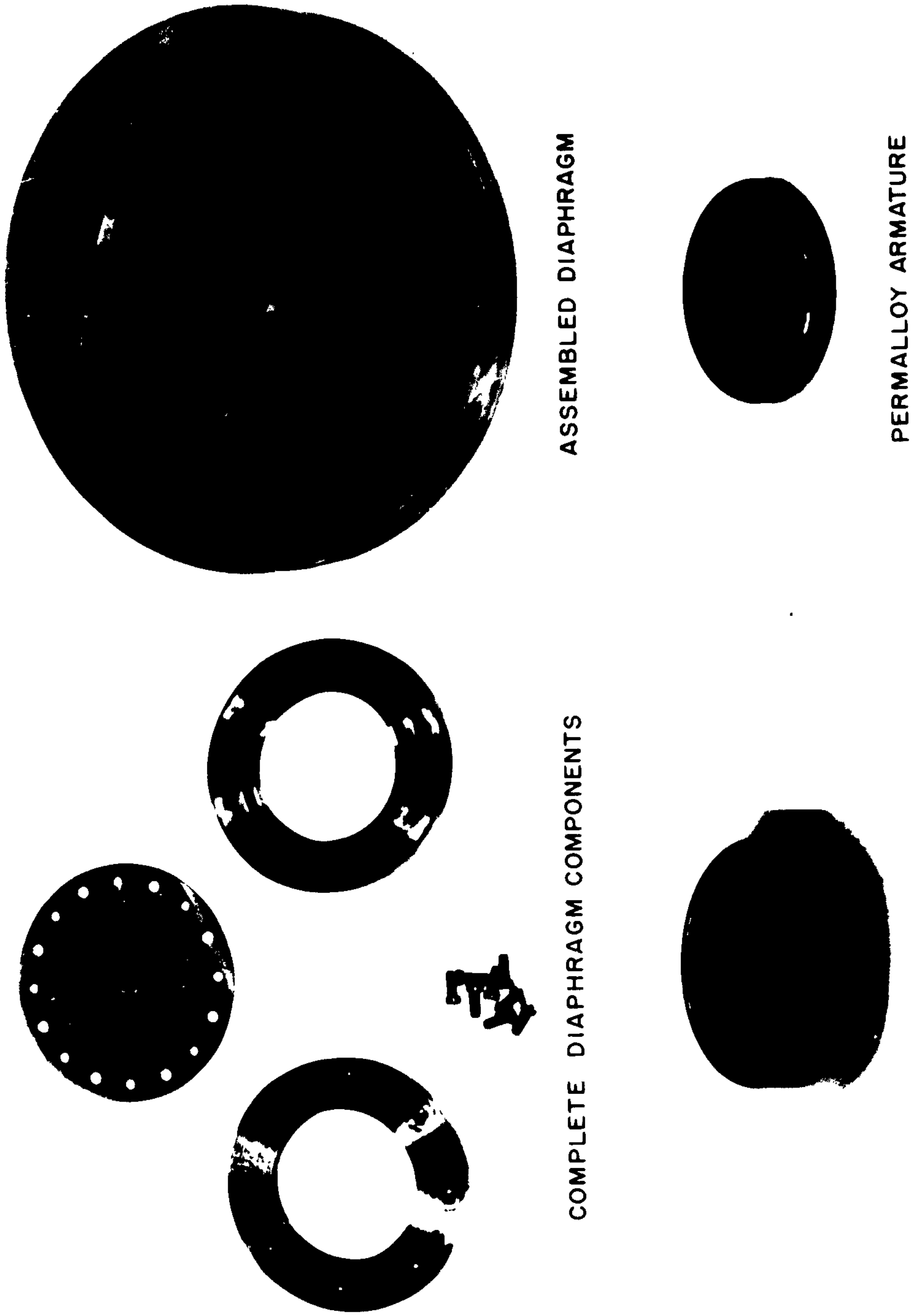


FIG. 10 DIAPHRAGM ASSEMBLY

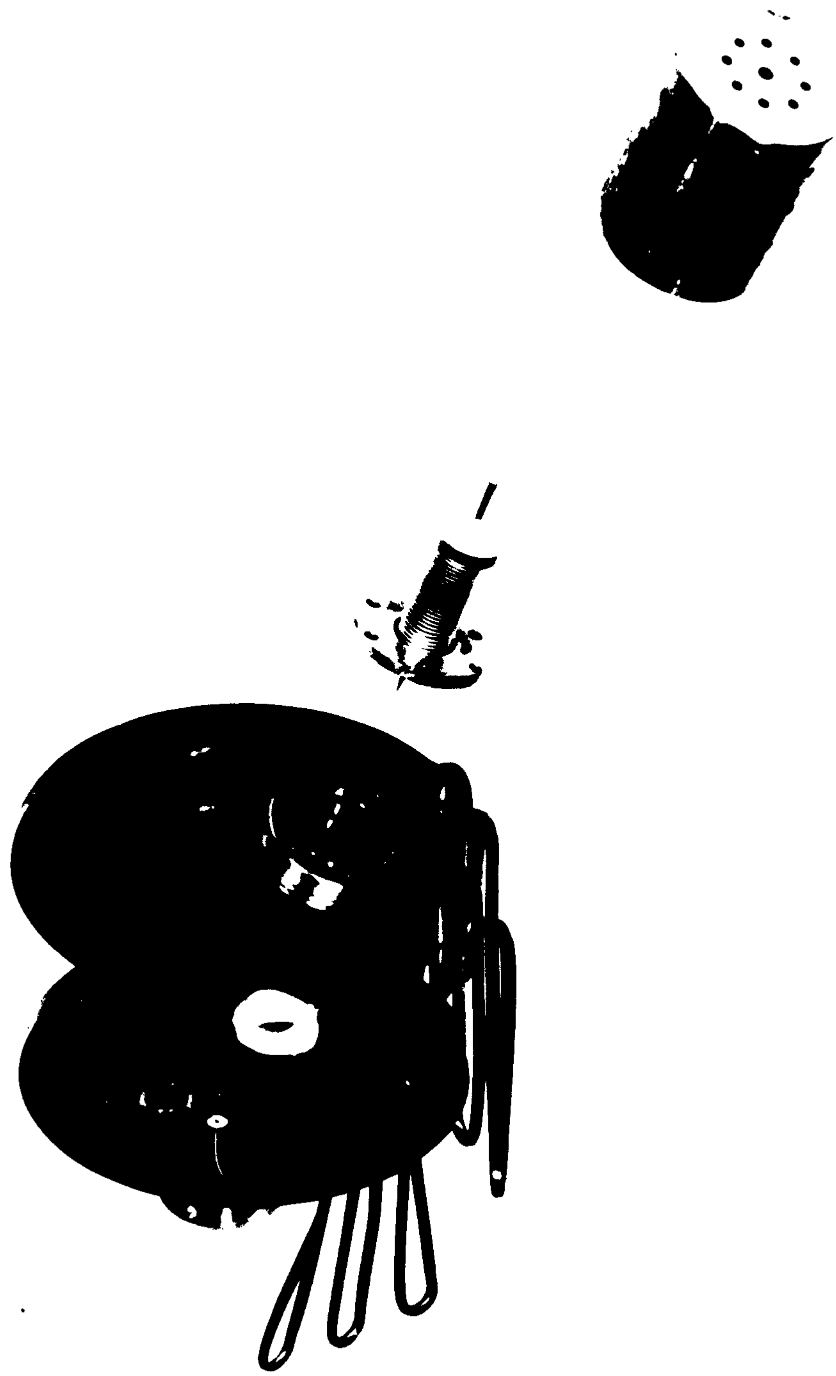
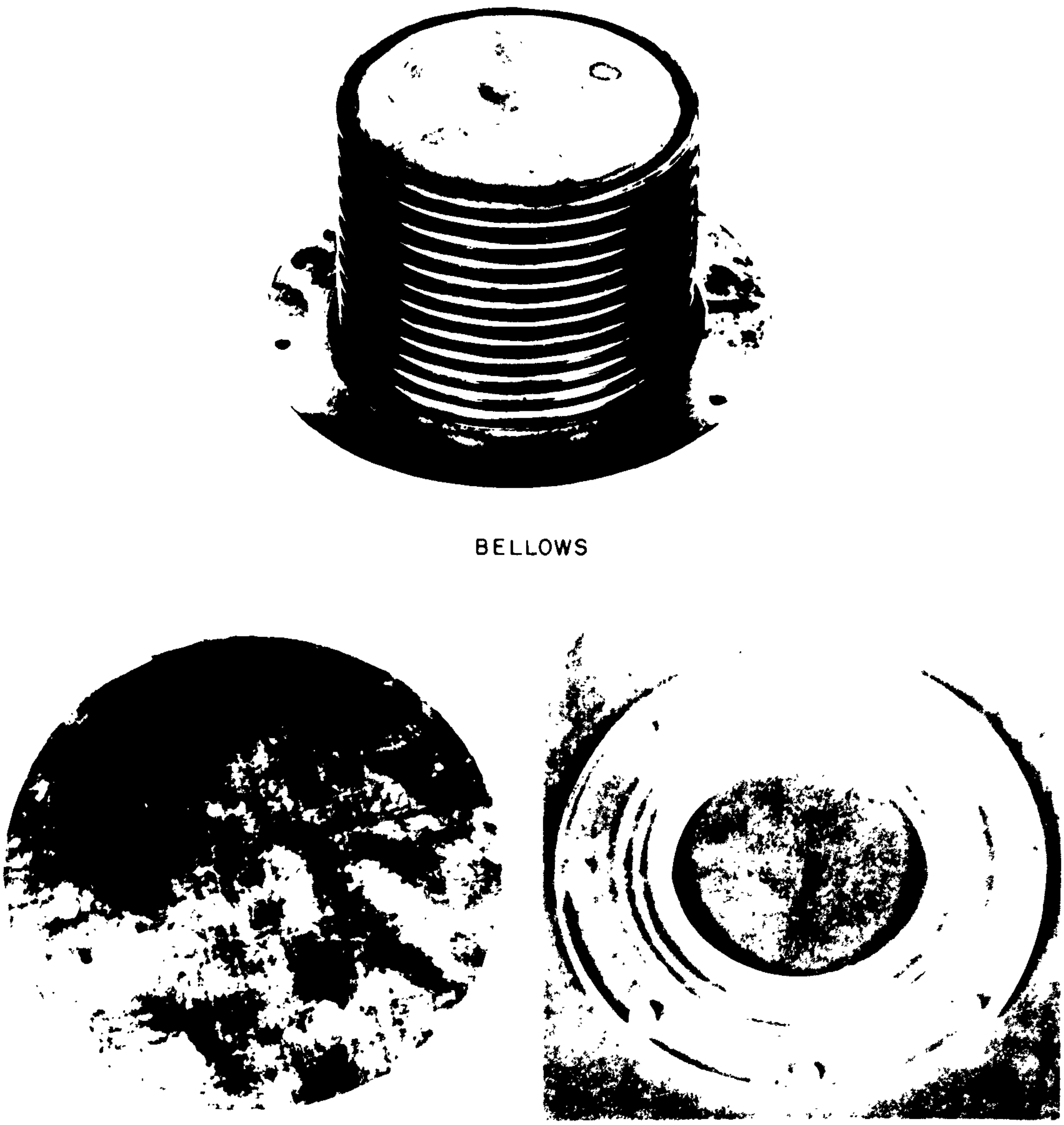


FIG. 11 ASSEMBLY OF BELLOWS CHAMBER SHOWING VALVE PORT NO.2, & RELIEF VALVE PLUS ACOUSTIC FILTER



BELLOWS

RUBBER DIAPHRAGM

SPACER

FIG 12 BELLOWS AND ASSOCIATED COMPONENTS

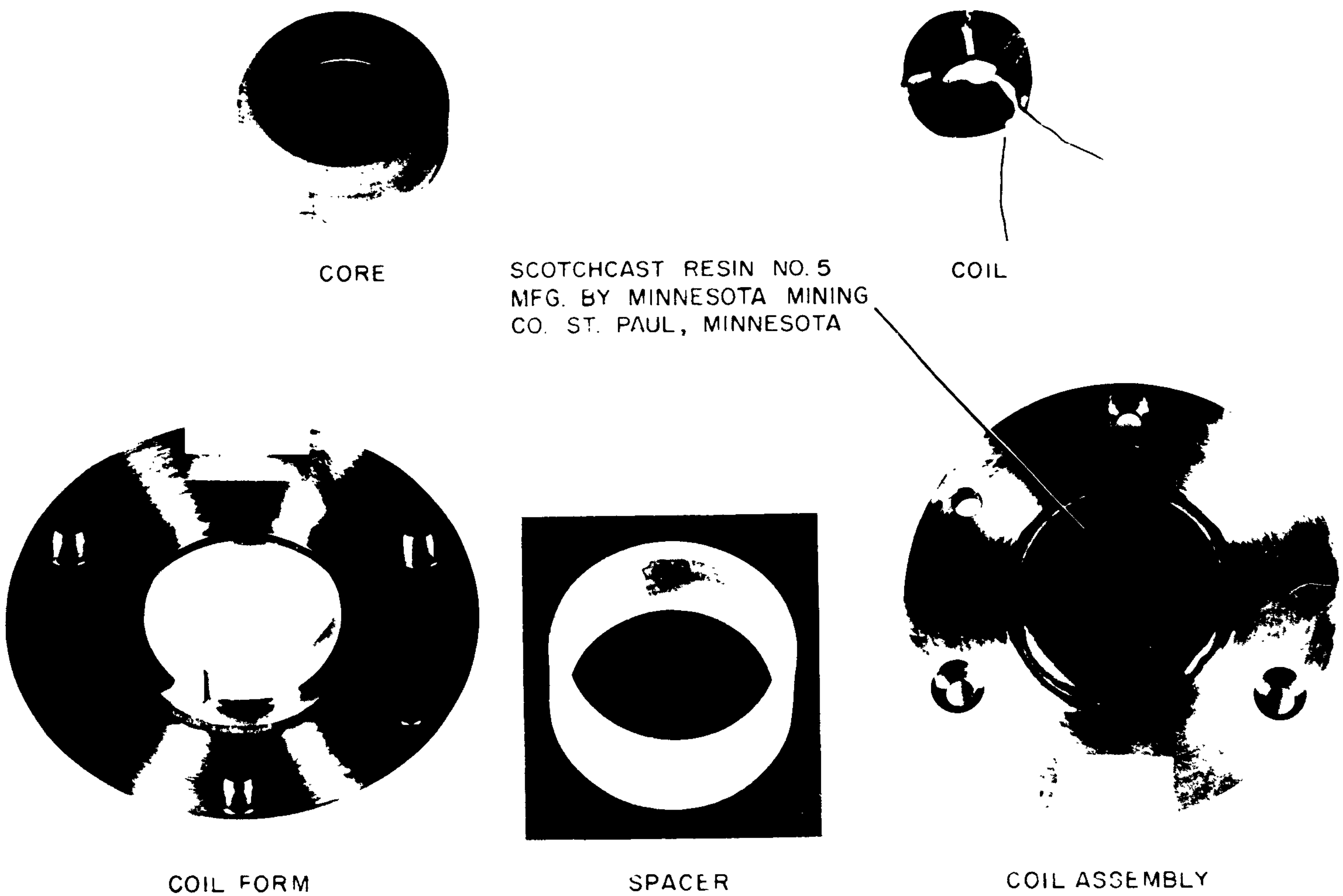
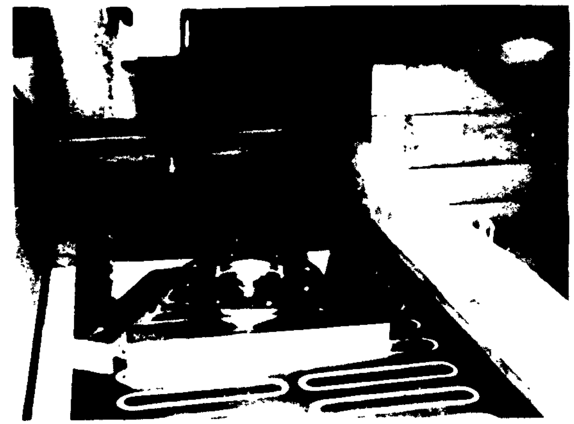


FIG. 13 COIL ASSEMBLY AND COMPONENTS

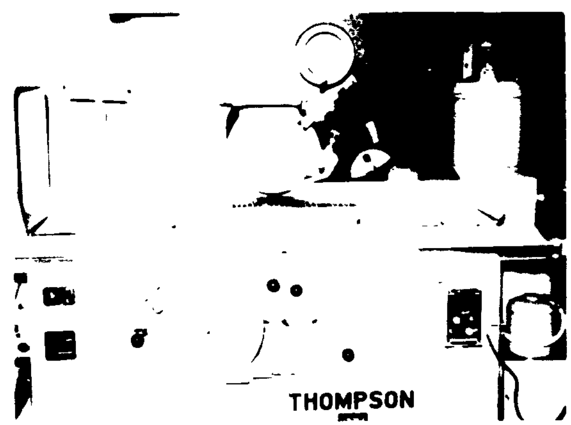
FIG. 14 ADHESIVE FIXTURE

FIRST POSITION OF DIAPHRAGM ON GRINDING WHEEL



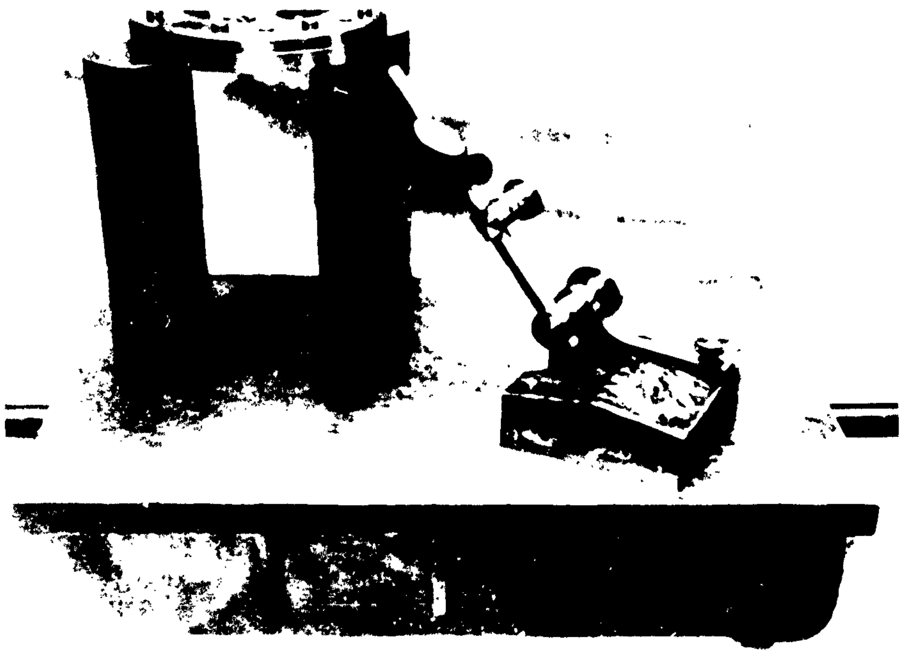
DIAPHRAGM TURNED RIGHT SIDE UP

DIAPHRAGM BEING GROUND

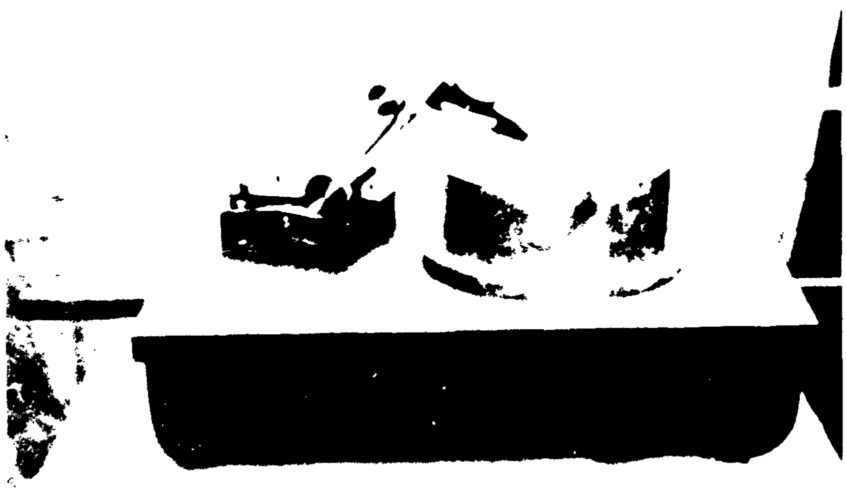


THOMPSON GRINDING MACHINE

FIG. 15 DIAPHRAGM GRINDING POSITION



INDICATING SURFACE OF GROUND ARMATURE



INDICATING SURFACE OF GROUND COIL

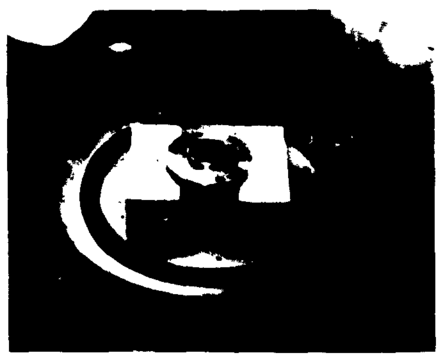
FIG. 16 INDICATOR METHOD OF CHECKING GROUND SURFACES

TERMINAL POSTS SHOWN PRESSED INTO THE COIL INSULATING SPACER

CORE PRESSED INTO THE COIL INSULATING SPACER

COIL INSERTED INTO CORE

POLYETHYLENE CAP COVERING COIL COMPARTMENTS



POLYETHYLENE CAP REMOVED AFTER EPOXY RESIN HAS CURED

COIL ASSEMBLY PLACED IN VACUUM JAR FOR POTTING STEP 2

FIG. 17 COIL ASSEMBLY AND POTTING PROCESS

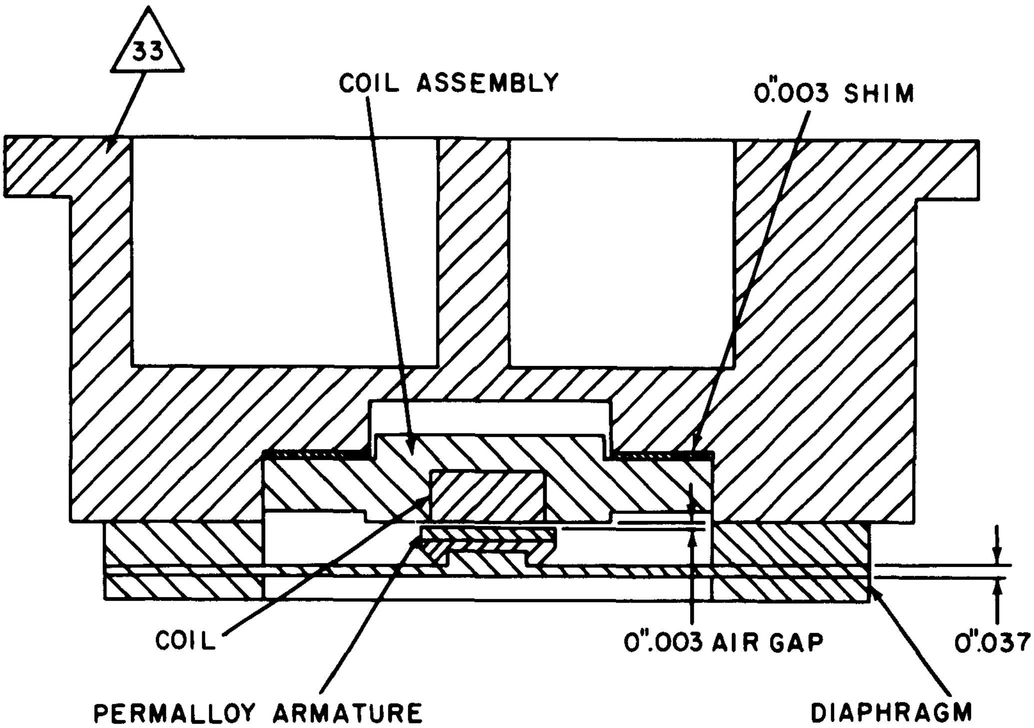
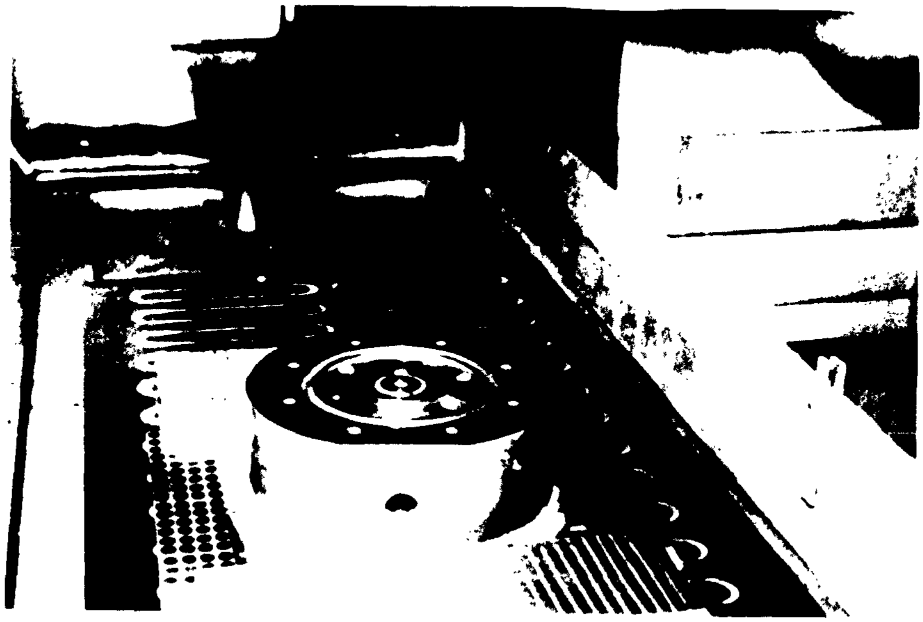
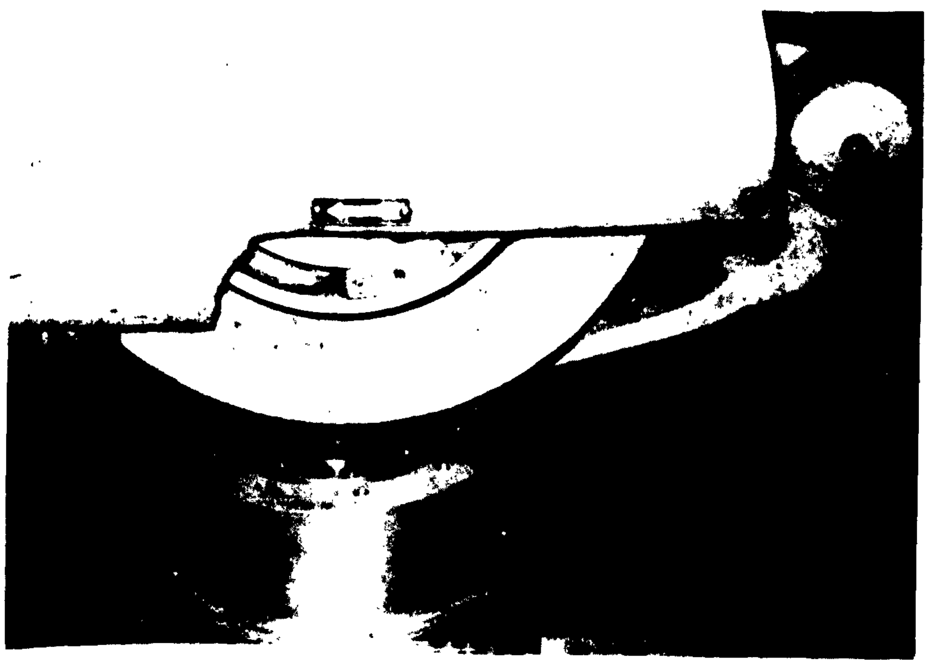


FIG. 18 SPACING TOLERANCE BETWEEN DIAPHRAGM AND THE COIL

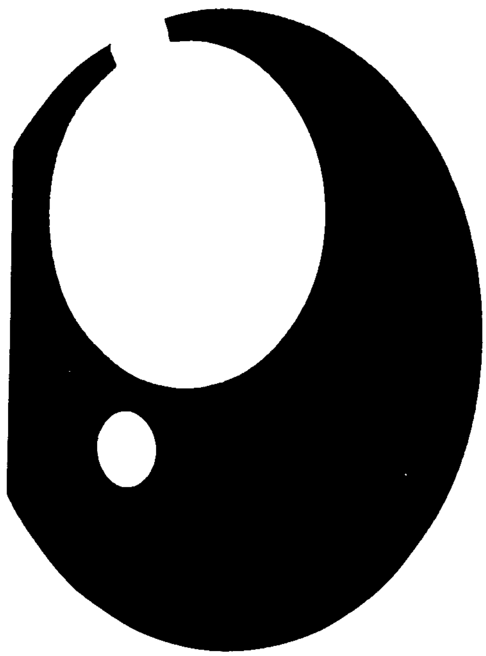


BODY CASTING AND ASSEMBLY POSITIONED ON
BED OF GRINDING MACHINE



GRINDING WHEEL IN POSITION

FIG. 19 COIL GRINDING

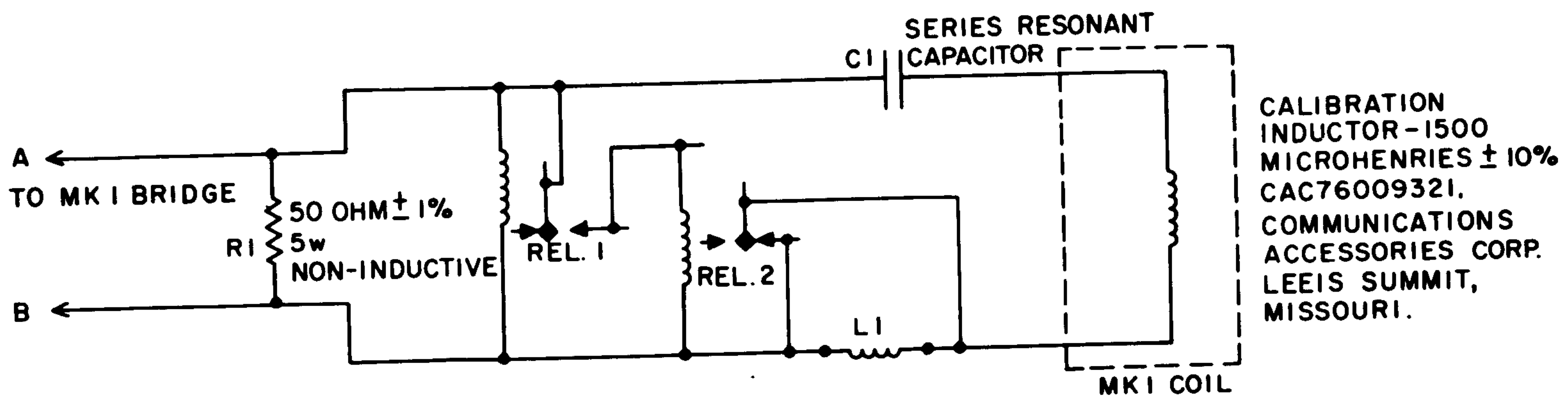


ELECTRONIC BASE PLATE

BODY

ASSEMBLED ELECTRONIC CHASSIS

FIG. 20 BODY CASTING & ELECTRONIC CHASSIS ASSEMBLY



REL. 1 - SIGMA 4F-10000-S - SIL SPDT
REL. 2 - SPENCER THERMOSTAT CO. DA29
R1 - SPRAGUE KOOLOHM TYPE 5 NIT 50 OHM 5W NON-INDUCTIVE ± 5%.
C1 - NOMINAL - CHOSEN BY RESONATING CIRCUIT AT 1000 CPS
L1 - 1500 MICROHENRY ± 0.005%.

FIG. 21 ELECTRICAL CIRCUIT FOR HYDROBAROPHONE

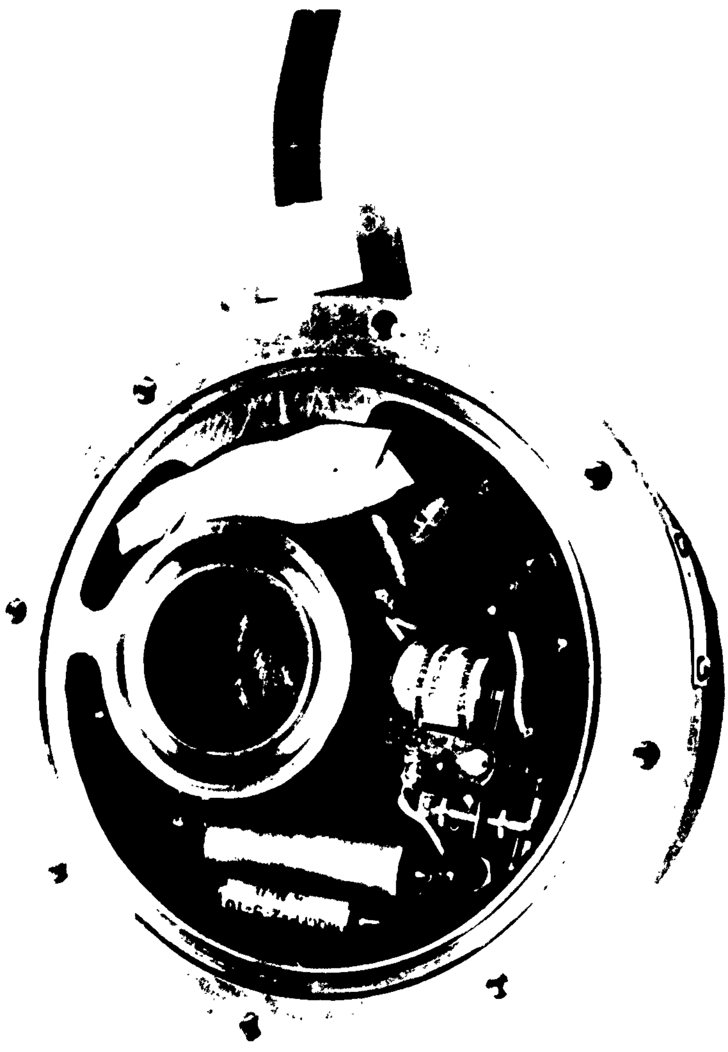


FIG. 22 ASSEMBLED BODY CASTING AND ELECTRONIC CHASSIS

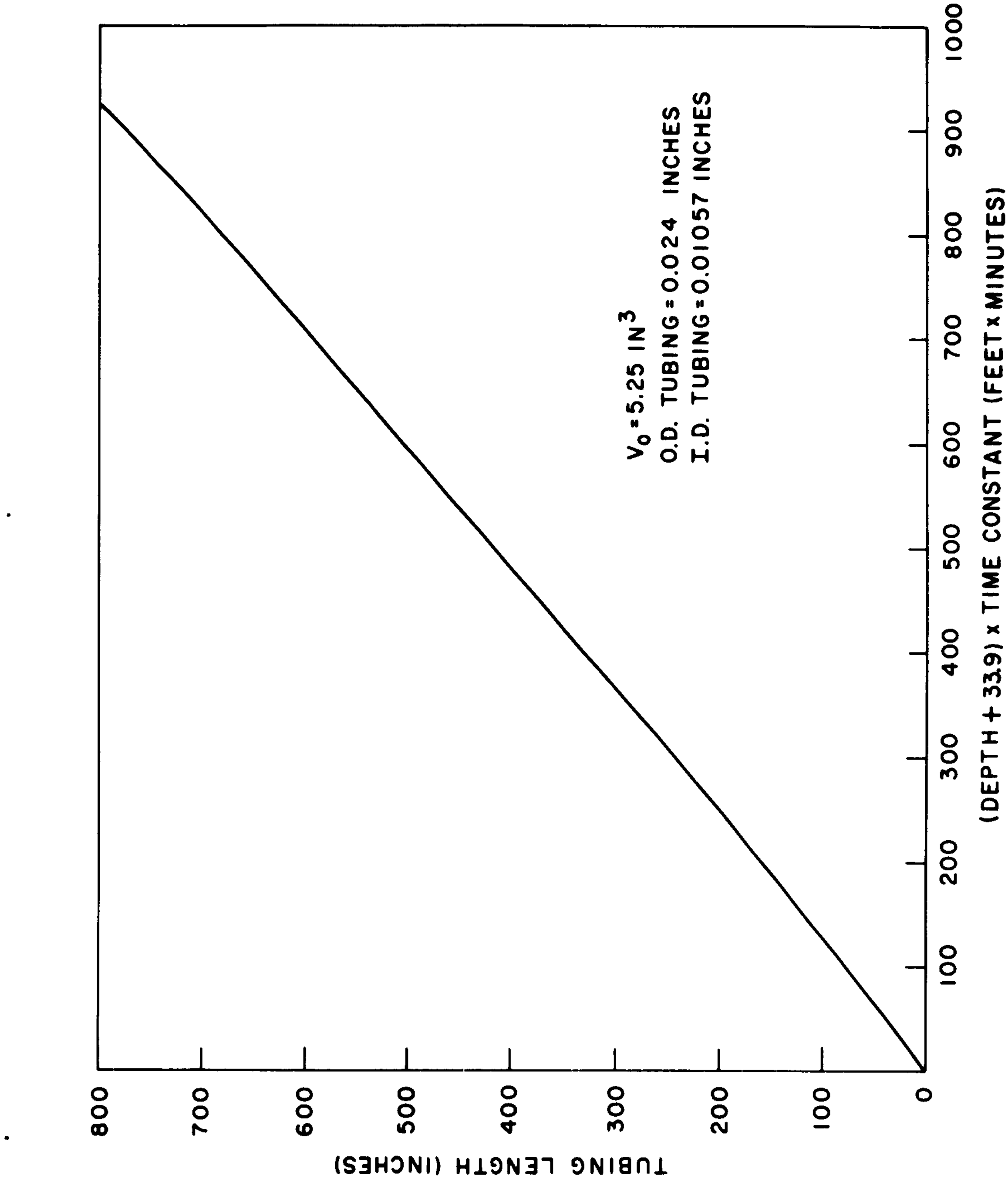


FIG. 23 TUBING LENGTH VERSUS (DEPTH + 33.9) x TIME CONSTANT

FILTER BEING WOUND

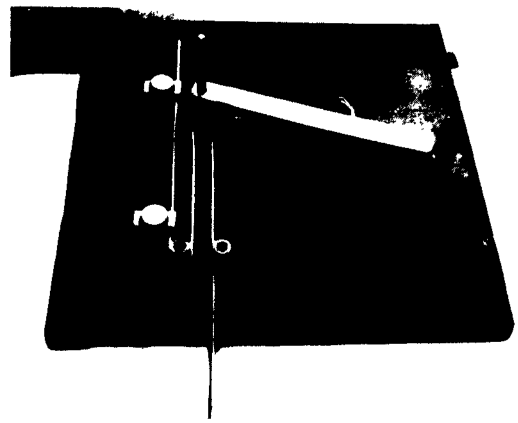
SECURING FILTER

FILTER REMOVAL FROM MANDREL

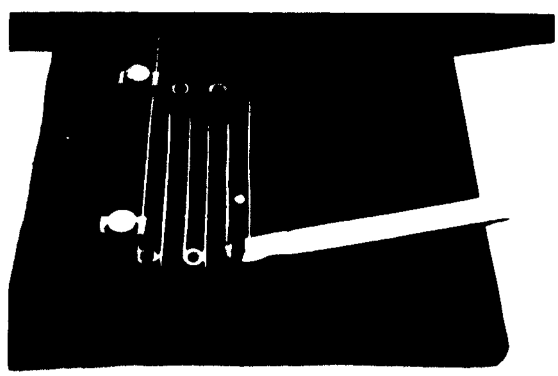
FILTER FLARING

FIG. 24 ACOUSTIC FILTER ASSEMBLY

HOLDING CLAMPS OF TUBE FORMING JIG

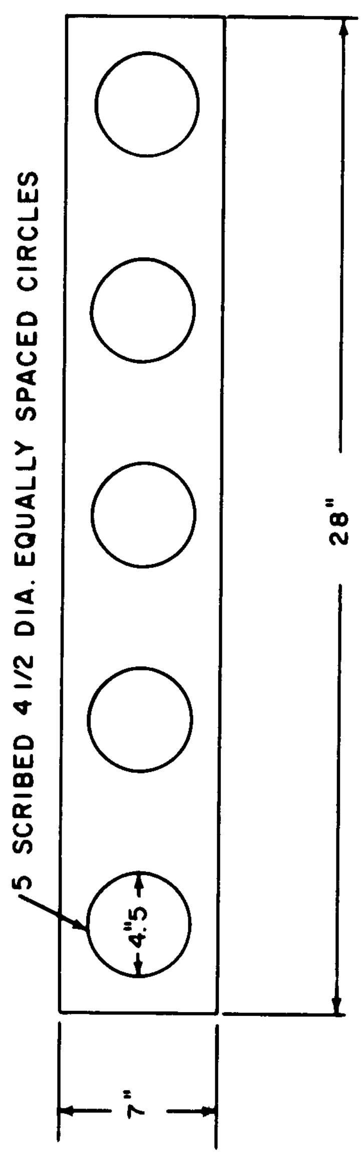


TUBE FORMING JIG



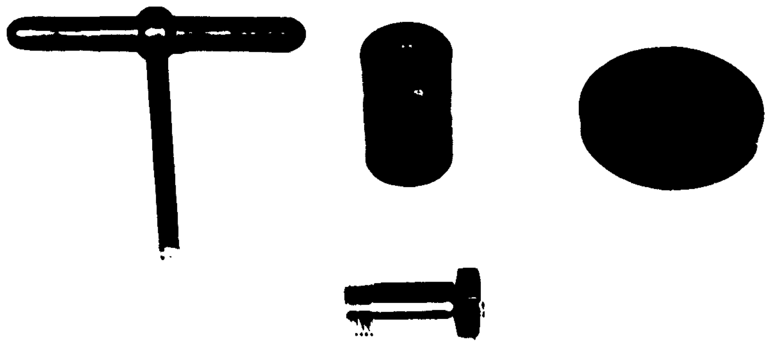
TUBE FORMING JIG

FIG. 25 TUBE FORMING JIG

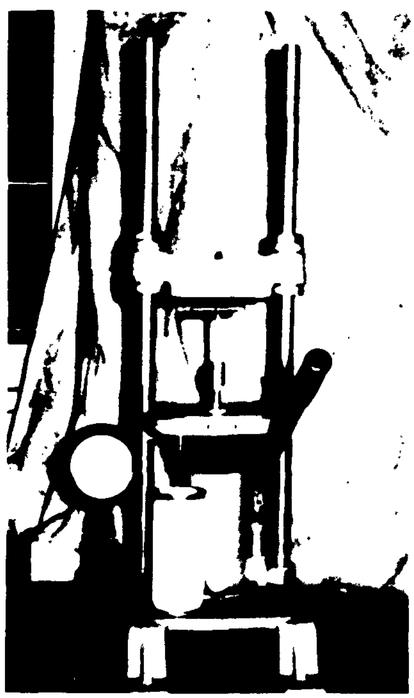


MATERIAL: ALUMINUM
1/8" THICK

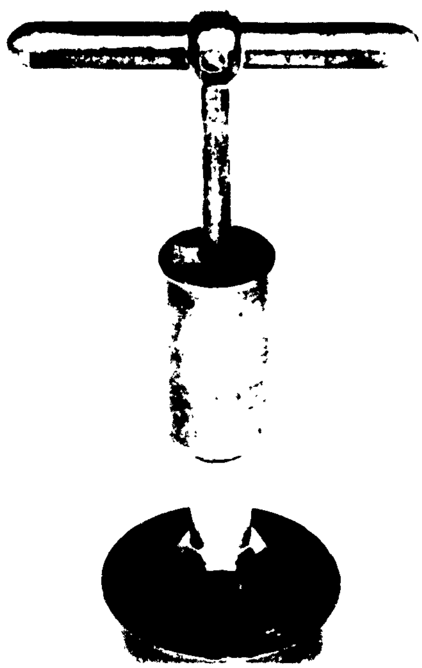
FIG. 26 ALUMINUM PLATEN FOR FABRICATING RUBBER DIAPHRAGMS



JIG COMPONENTS



PRESS



ASSEMBLED JIG

FIG. 27 COMPONENTS AND PRESS FOR THE MANUFACTURE OF THE SOLUBLE CORE FOR THE FLOOD PLUGS

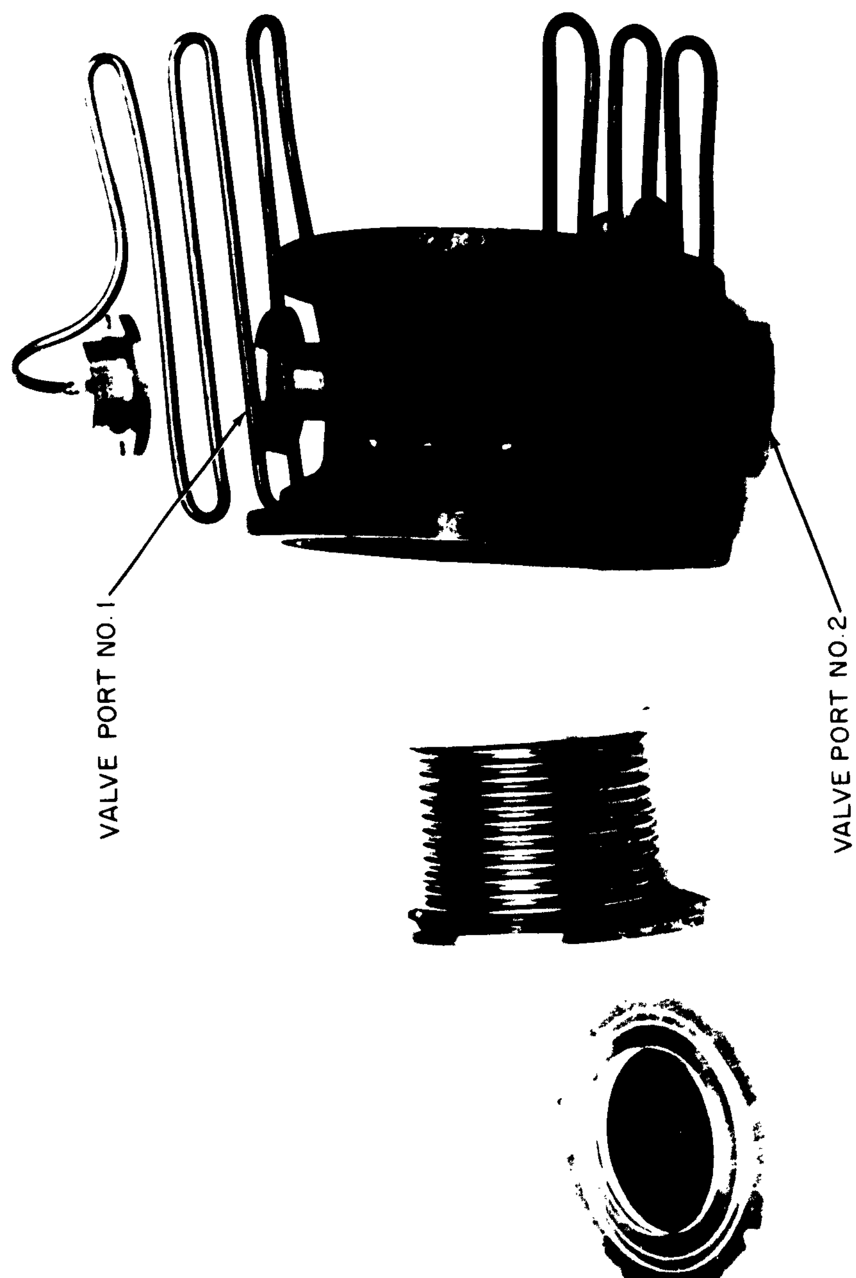


FIG. 28 BELLOWS CHAMBER SHOWING BELLOWS, RUBBER DIAPHRAGM & SPACER READY FOR INSTALLATION

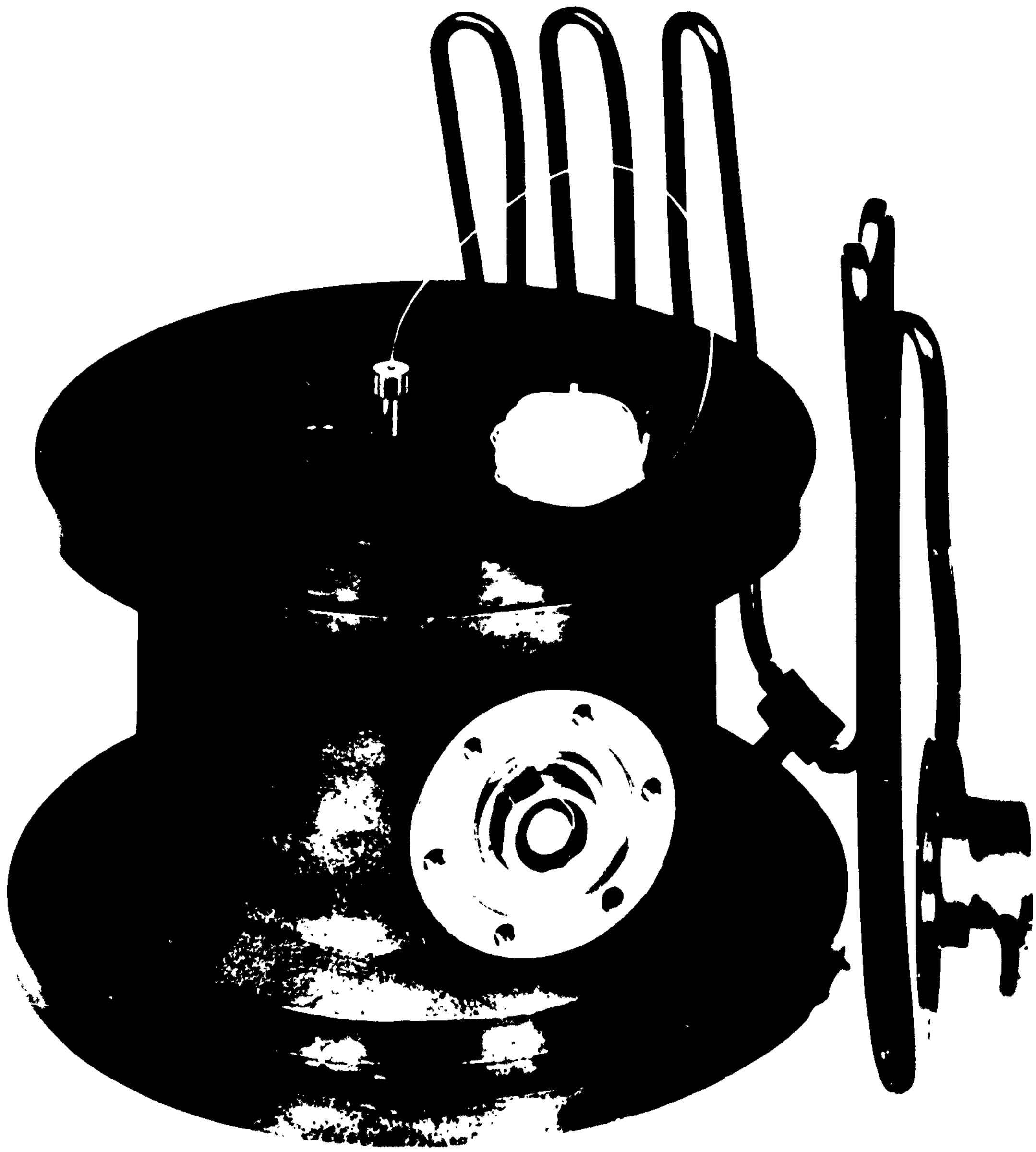


FIG. 29 ASSEMBLY OF BELLOWS CHAMBER SHOWING VALVE PORT NO. I & RELIEF VALVE PLUS ACOUSTIC FILTER

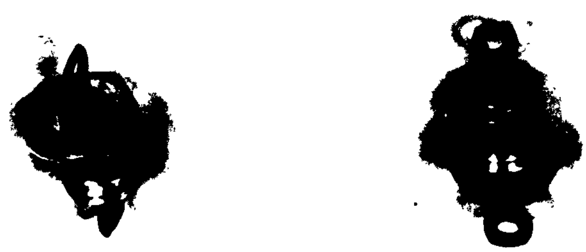


FIG. 30 FUSITE CONNECTOR

FIG. 31 RECOVERED HYDROBAROPHONE ILLUSTRATING BLOCKAGE OF FLOOD PLUGS DUE TO MISCELLANEOUS DEBRIS

FIG. 32 RECOVERED HYDROBAROPHONE ILLUSTRATING BLOCKAGE OF FLOOD PLUGS DUE TO MISCELLANEOUS DEBRIS

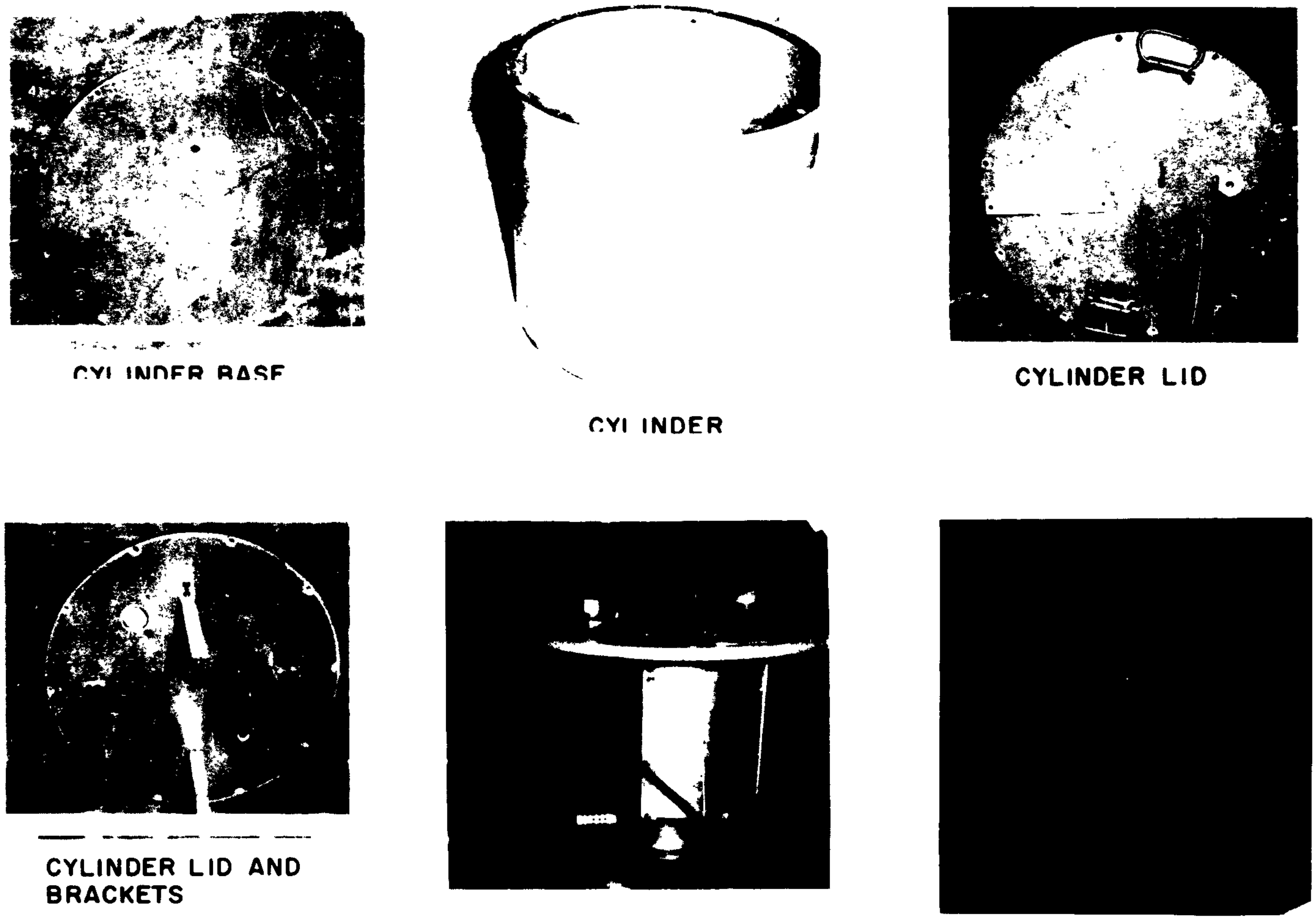
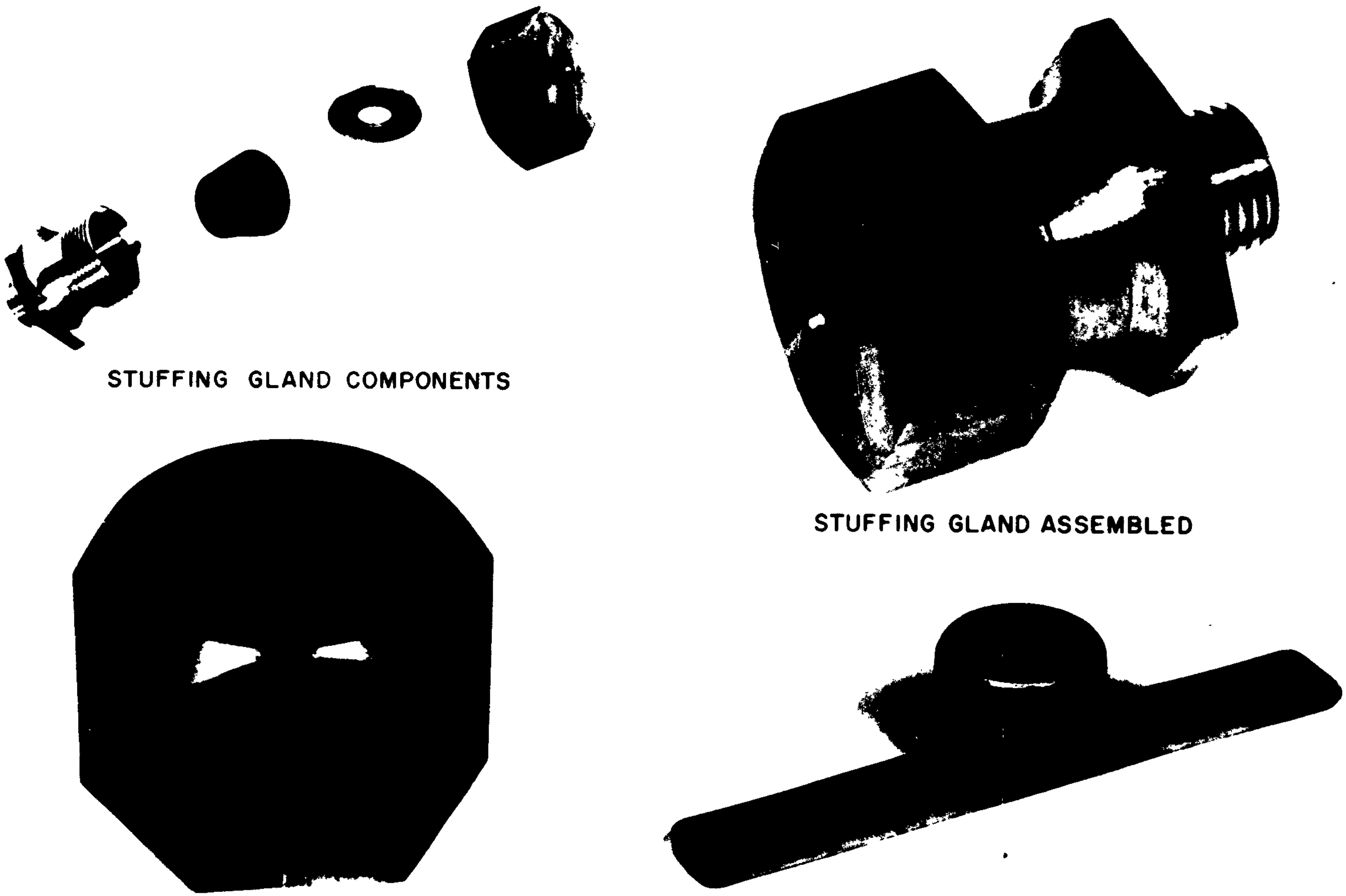


FIG. 33 FIBERGLASS CYLINDER COMPONENTS AND HYDROBAROPHONE MOUNTING



STUFFING GLAND COMPONENTS

STUFFING GLAND ASSEMBLED

CAP NUT FOR FIBERGLASS CYLINDER

FLOOD PLUG FOR FIBERGLASS CYLINDER

FIG. 34 MISCELLANEOUS ACCESSORIES FOR HYDROBAROPHONE & FIBERGLASS INSULATED CYLINDER ASSEMBLY

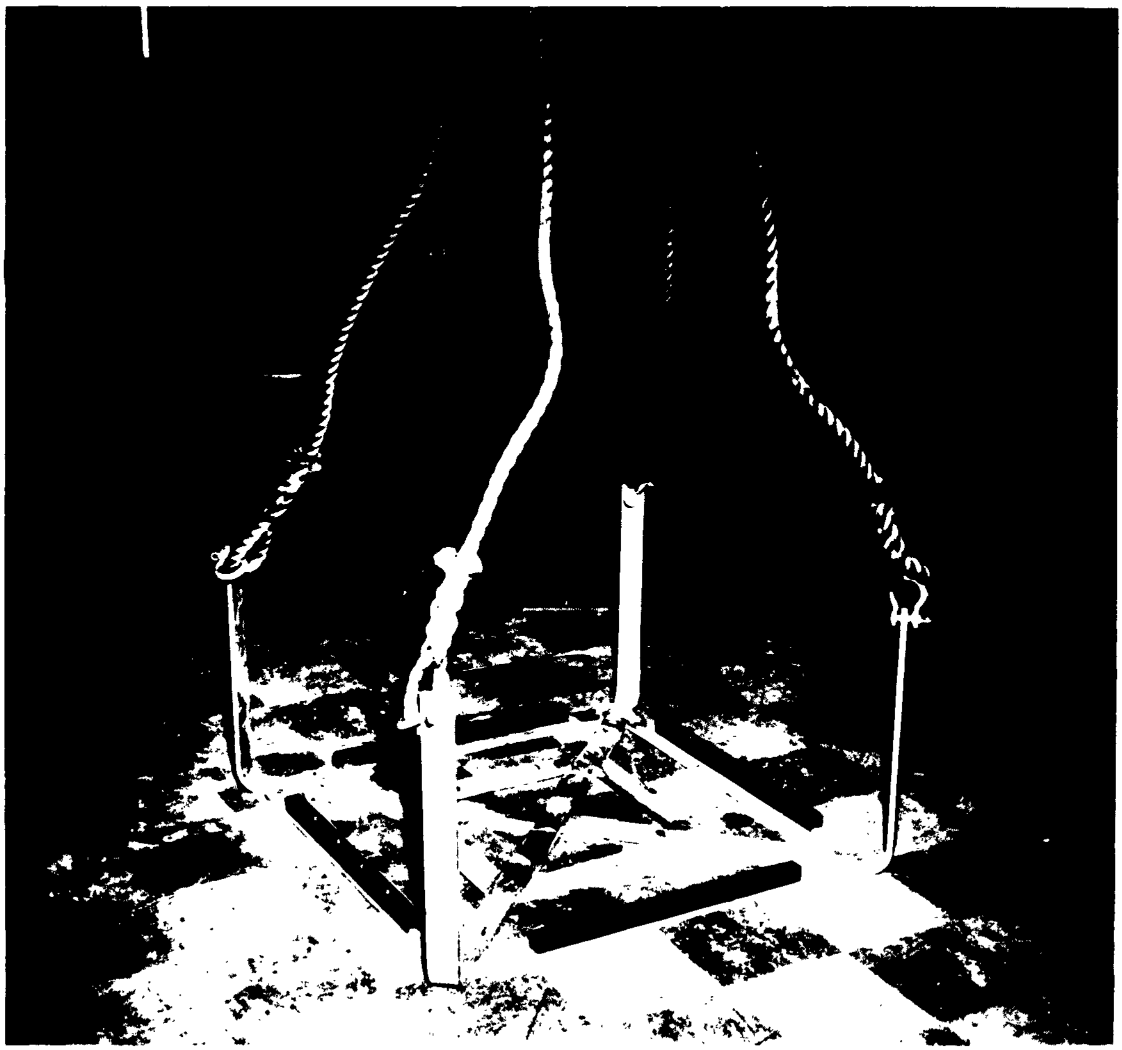


FIG. 35 ANCHOR CRADLE

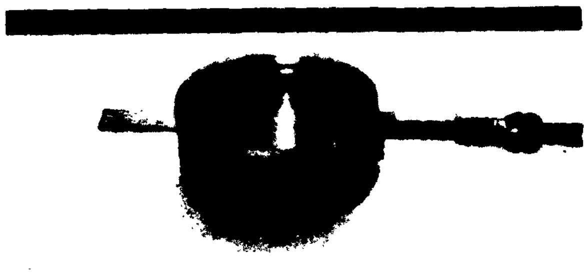
BASE FOR CABLE CLAMP

CABLE CLAMP

CABLE CLAMP ASSEMBLY

FIG. 36 METHOD OF ASSEMBLING CABLE CLAMP

FIG. 37 HYDROBAROPHONE, FIBERGLASS CYLINDER AND ANCHOR ASSEMBLY READY FOR PLANTING



AIR POT

BODY CASTING OF HYDROBAROPHONE INSERTED INTO AIR POT, POSITIVE PRESSURE STEP

BODY CASTING OF HYDROBAROPHONE ASSEMBLED FOR NEGATIVE PRESSURE STEP

HYDROBAROPHONES BEING TEMPERATURE SATURATED FOR CALIBRATION

FIG. 38 STATIC CALIBRATION CHAMBER BEING PLACED INTO TEMPERATURE CONTROL BOX

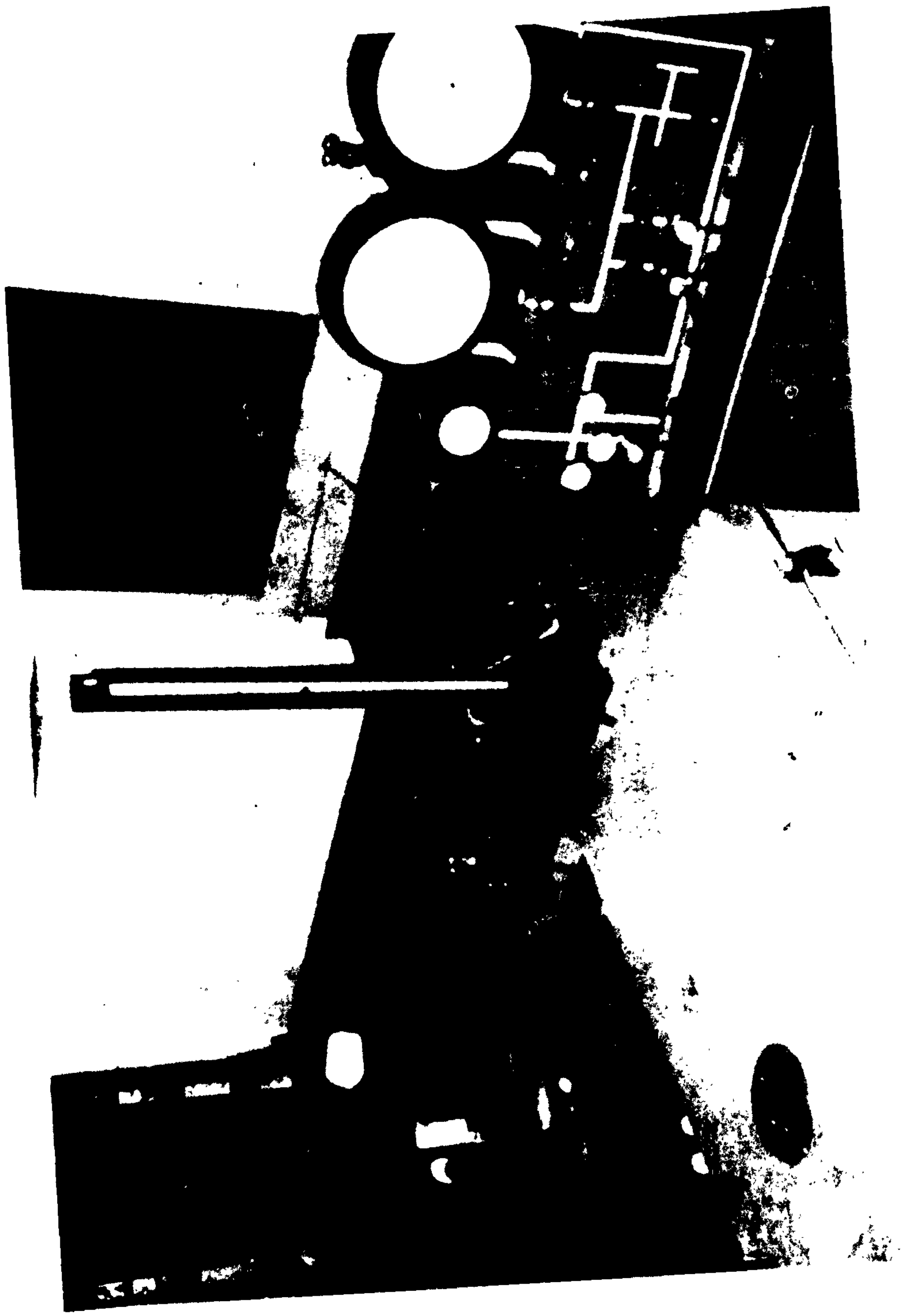


FIG. 39 STATIC CALIBRATION SYSTEM IN BLDG. 205

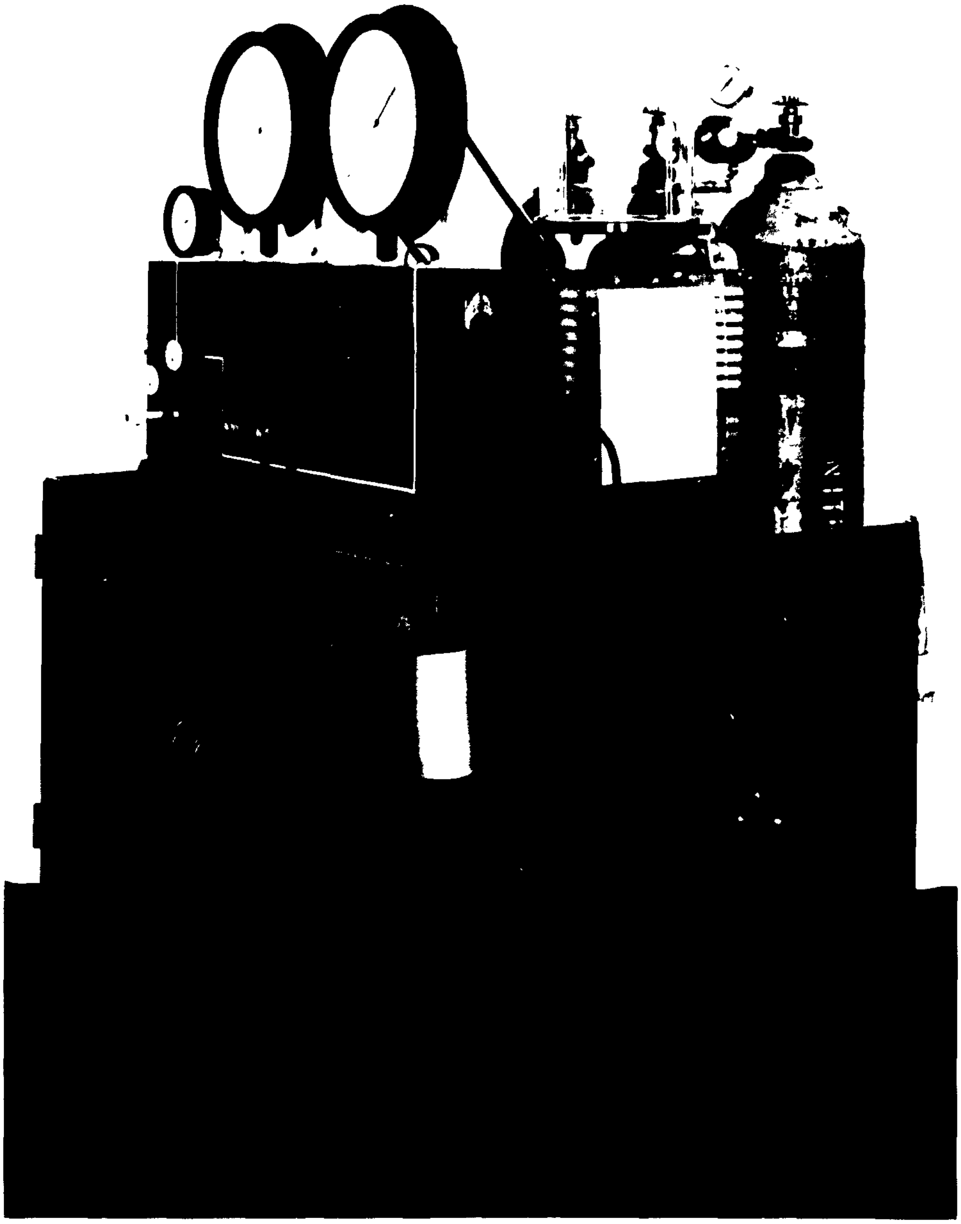


FIG. 40 TEST CONSOLE

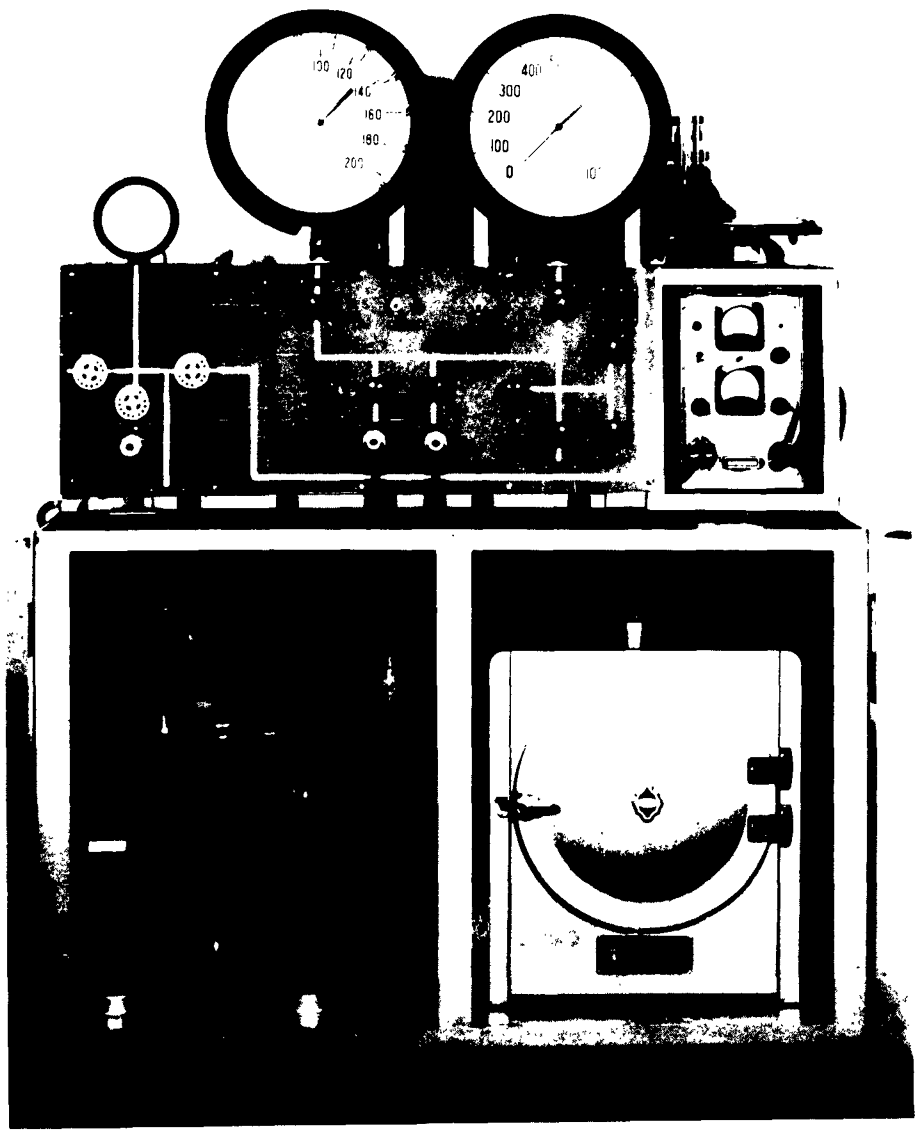


FIG. 41 TEST CONSOLE SHOWING VACUUM PUMP, OVEN AND LEAK DETECTING EQUIPMENT

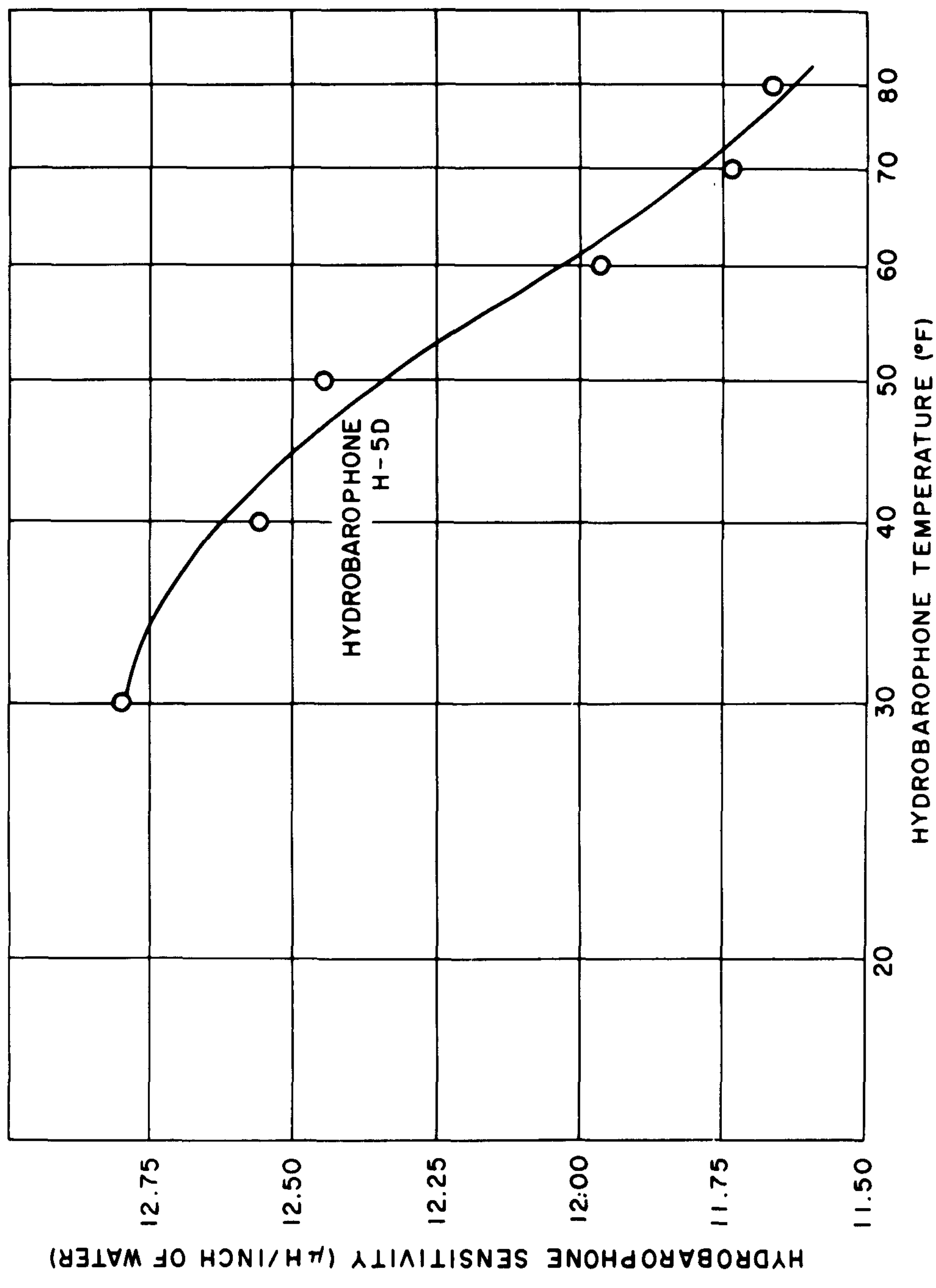


FIG. 42 HYDROBAROPHONE CALIBRATION VS TEMPERATURE

FIGURE 43

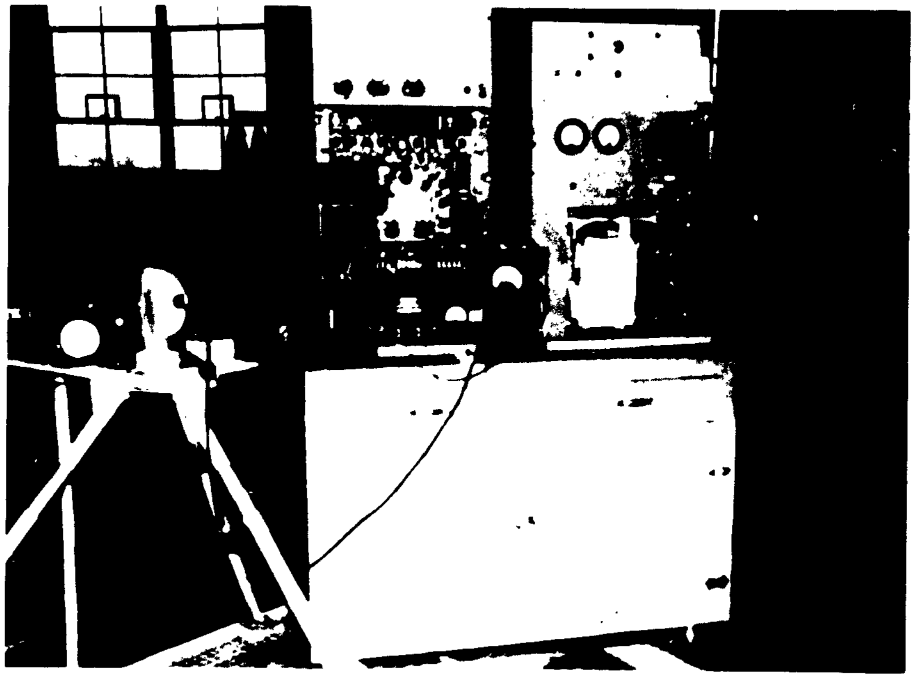
CALIBRATION VALUES FOR A HYDROBAROPHONE

Hydrobarophone Sensitivity = 11.76 microhenries per inch of water

Calibrating Inductor is 1500 microhenries

Calibration "A" Gain Step 6 Recording "A" Gain Step	Decibel Difference 3X Record "A" Gain - Cal. "A" Gain	Voltage Ratio	Magnetic Tape and Recording Oscillograph Calibration inches of water
20	42	125.9	1.12
19	39	89.0	1.43
18	36	63.0	2.24
17	33	44.6	2.86
16	30	31.6	4.48
15	27	22.4	5.72
14	24	15.9	8.96
13	21	11.2	11.40
12	18	7.94	17.90
11	15	5.62	22.80
10	12	3.98	35.80
9	9	2.82	45.60
8	6	2.00	71.80
7	3	1.41	91.20

NOTE: "A" Gain Step refers to the 3 db per step attenuator in the Mark 1 Bridge.



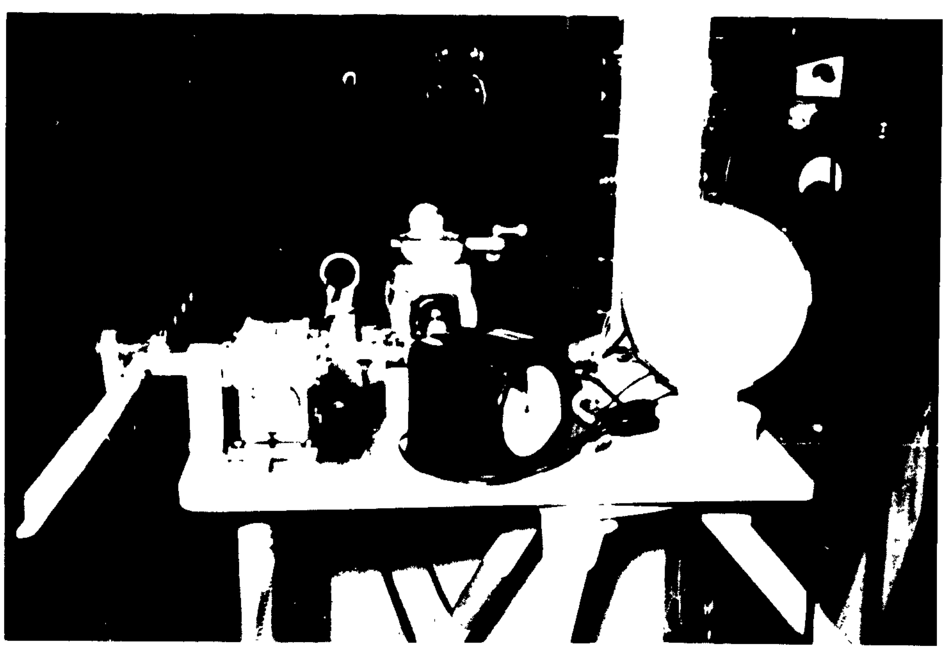


FIG. 44 CALIBRATION SYSTEM IN BLDG 409

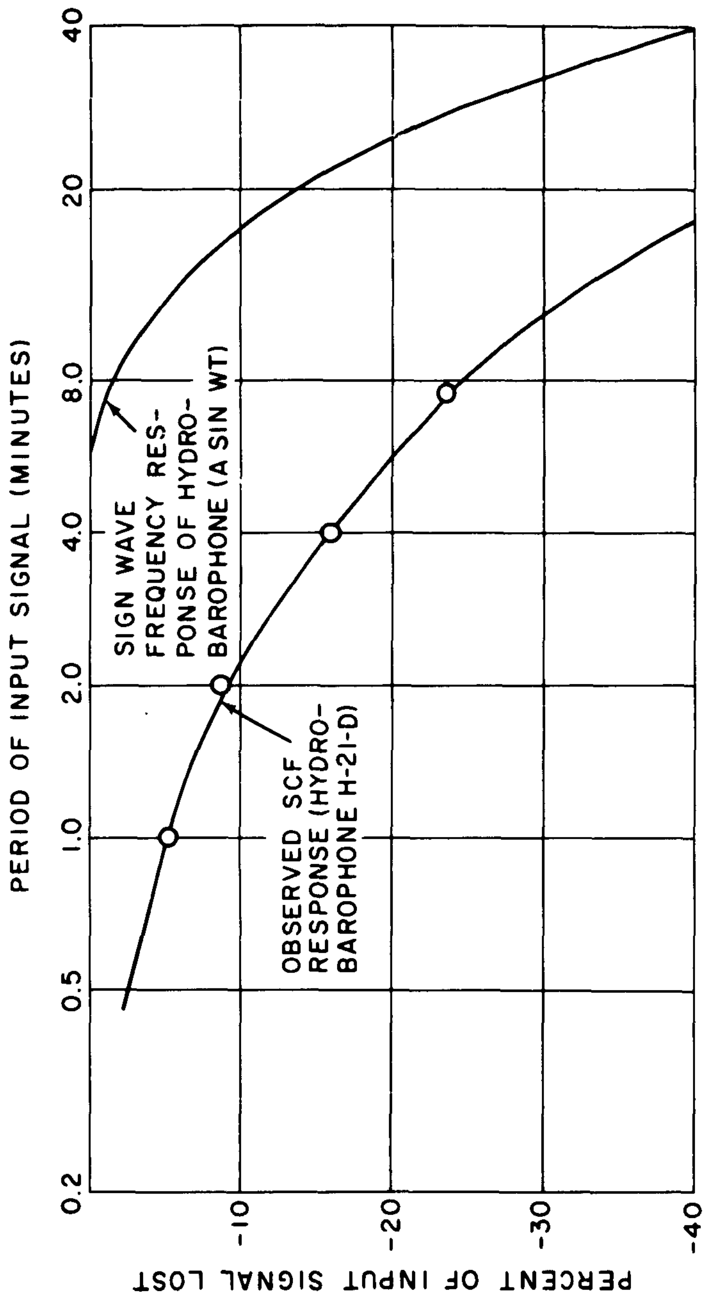


FIG. 45 FREQUENCY RESPONSE TO SINE WAVES AND SINGLE-CYCLE FIELDS OF A HYDROBAROPHONE (SINGLE-STAGE FILTER WITH A TIME-CONSTANT OF 300 SECONDS)

TABLE 1

LIST OF DETAIL DRAWINGS AVAILABLE FOR HYDROBAROPHONE FABRICATION

Drawing No.	Title
1	Valve Bellows Base
2	Valve Body
3	Salt Water Washer Stem
4	Cut-Off Valve Assembly
5	Valve Cover Cap
6	Relief Valve Body
7	Relief Valve Cap
8	Relief Valve Assembly
9	Bellows Chamber
10	Bellows
11	Dowel
12	Electronic Base Plate
13	Spacer
14	Shim
15	Armature
16	Core
17	Packing Nut
18	Washer
19	Rubber Packing
20	Stuffing Box
21	Stuffing Gland Assembly
22	Diaphragm Top Plate
23	Coil
24	Modifications of Luer-Lock Fittings
25	Flood Plug
26	Coil Form
27	Filter Mandrel
28	Monel Diaphragm
29	Sandwich Type Diaphragm (Assembly)
30	Bellows Chamber Cover Plate
31	Cylinder Top Plate
32	Cylinder for Air Volume
33	Body
34	Coil Spacer
35	Hydrobarophone Electronic Circuit
36	Tube
37	Air Bag Stem
38	Hydrobarophone Assembly
39	Tee Joint
40	Luer-Lock Gasket
41	Bellows Assembly
42	Electronic Components
43	Cable Clamp Assembly

TABLE 1 (CONT'D)

Drawing No.	Title
44	Soluble Washer
45	Diaphragm
46	Bellow Head
47	Plate
48	Bellows Assembly (A)
49	Cup
50	Diaphragm Base Plate
51	Process for Cleaning Hydrobarophone Brass Components
52	Bracket
53	Bag Retaining Ring
54	Cylinder
55	Gasket
56	Lids
57	Cap Nut for Fiberglass Cover
58	Anchor Lifting Cradle
59	Cable Clamp
60	Cylinder Plug
61	Cylinder Bracket
62	Cylinder Assembly
63	Anchor for Hydrobarophone
64	Stud Ring for Anchor

APPENDIX A

FREQUENCY RESPONSE OF THE HYDROBAROPHONE

A-1. The single stage filter can be represented by the simplified electrical analogue shown by Figure A-1. For the purposes of discussion, let

P = Sinusoidal pressure acting on the outside of the diaphragm

p = Actual pressure difference across the diaphragm

C = Compliance of the volume between the tubing and the back of the diaphragm

R = Acoustical resistance of the filter tubing

ω = $2\pi/T$

T = Period

v = Volume velocity of the gas

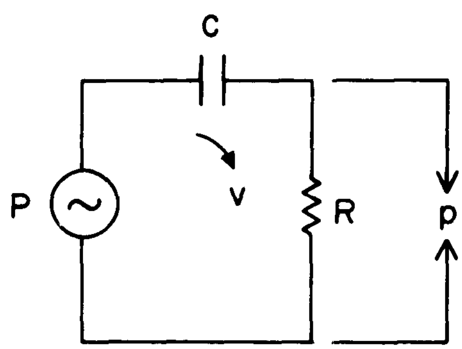


Figure A-1. Equivalent Acoustic Circuit of Hydrobarophone

The sinusoidal pressure, P, is given by the relationship

$$P = vR + v/i\omega C \qquad \text{(A-1)}$$

Solving Eq. (A-1) for v gives

$$v = \left(\frac{i\omega C}{1+i\omega RC} \right) P \tag{A-2}$$

Ohm's law for an acoustic circuit states that

$$p = vR = \left[\frac{i\omega RC}{1+i\omega RC} \right] P \tag{A-3}$$

The absolute value, $|p| = (pp^*)1/2$

$$\frac{|p|}{P} = \frac{\omega RC}{\sqrt{1+(\omega RC)^2}} \tag{A-4}$$

Upon dividing the numerator and denominator by (ωRC), it becomes apparent that the normalized pressure at the diaphragm is

$$\frac{|p|}{P} = \frac{1}{\left[1+1/(\omega RC)^2\right]^{1/2}} \tag{A-5}$$

This relation may be expressed in decibels by performing the following operations:

$$20 \log_{10} |p|/P = -10 \log_{10} \left[1+1/(\omega RC)^2 \right] \tag{A-6}$$

When ω is replaced by its value $2\pi/1$, the normalized pressure at the diaphragm is

$$\frac{|p|}{P} \text{(in decibels)} = -10 \log_{10} \left[1+0.02533 \left(\frac{T}{RC} \right)^2 \right] \tag{A-7}$$

It will be noted that the time constant of the analog circuit is $T_c = RC$

Thus

$$|p|/P \text{ (in decibels)} = -10 \log_{10} \left[1+0.02533 \; (T/T_c) \right]^2 \qquad \text{(A-8)}$$

A-2. The attenuation of sine waves with short and long periods is shown in Figures A-2 and A-3 respectively. These curves are computed from Eq. (A-8). The use of the curves is illustrated by the following examples:

Examples

Given a filter with a time constant of 5 minutes. What is the attenuation of sine waves with the following periods?

a. 10 minutes

b. 500 minutes

Solutions

a. $T/T_c = 10/5 = 2$. From Figure A-2 for $T/T_c = 2$

DB = - 0.42

b. $T/T_c = 500/5 = 100$. From Figure A-3 for $T/T_c = 100$

DB = 23.9

These results may be confirmed directly by using Eq. (A-8) for the computation.

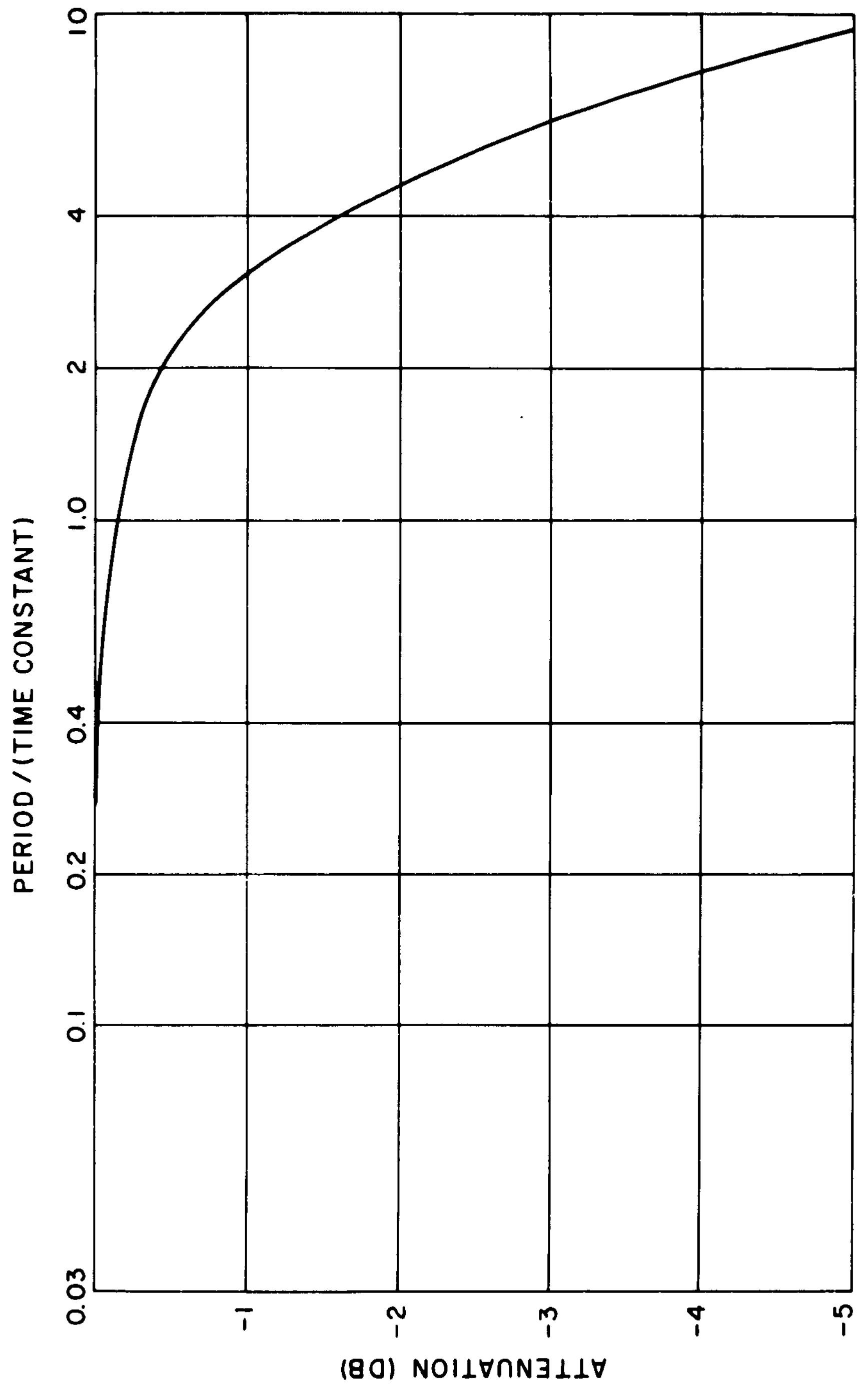


FIG. A-2 ATTENUATION OF SINE WAVES BY A SINGLE STAGE RC FILTER VS (PERIOD / TIME CONSTANT) WITH PERIOD FROM 0.03 TO 10 TIME CONSTANTS

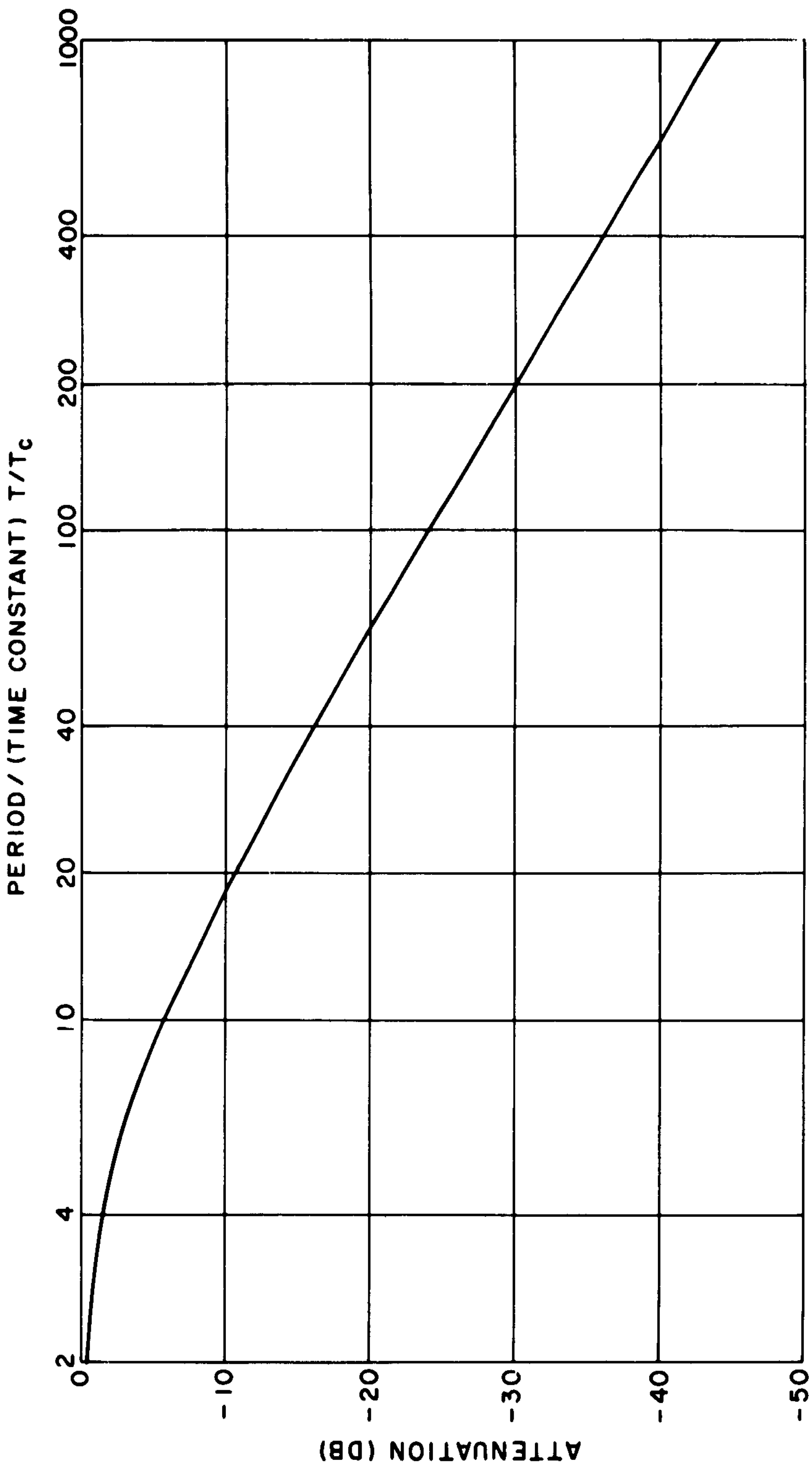


FIG. A-3 ATTENUATION OF SINE WAVES BY A SINGLE STAGE RC FILTER VS (PERIOD/TIME CONSTANTS) WITH PERIOD FROM 2 TO 1000 TIME CONSTANTS

APPENDIX B

CONSTANTS OF THE HYDROBARIC FILTER

B-1. The hydrobarophone is made sensitive to pressure changes of reasonably long periods only by a filter which is designed to eliminate high frequency fluctuations. The filter consists essentially of a tube which is long relative to the diameter of its cross section. The properties of the filter can be computed in terms of quantities represented by the following symbols:

Let: L = length of tubing

D_i = inside diameter of tubing

D_o = outside diameter of tubing

V_o = volume in back of diaphragm without tubing

$V_T = \frac{D_o^2 \pi L}{4}$ = outside volume of tubing

$V_e = V_o - V_t$ = effective volume in back of diaphragm

μ = viscosity of air

γ = ratio of specific heats

P_o = absolute static pressure

T_c = time constant of the filter

R = acoustic resistance of the tubing

C = compliance of the back volume

The formulas for acoustic resistance and capacitance are

$$R = \frac{128 \mu L}{\pi D_i^4} \quad ; \quad C = \frac{V_e}{P_o} \qquad \text{(B-1)}$$

Therefore, the time constant T_c is given by the expression

$$T_c = RC = \left[\frac{128\mu L}{\pi Di^4}\right]\left[\frac{V_e}{\gamma P_o}\right]$$

$$= \left(\frac{128\mu L}{\pi Di^4}\right)\left[V_o - \frac{D_o^2 \pi L}{4}\right]\left[\frac{1}{\gamma P_o}\right]$$

$$T_c = \left(\frac{128\mu}{\pi\gamma}\right)\left(\frac{L}{Di^4 P_o}\right)\left(\frac{4\ V_o - D_o^2 \pi L}{4}\right) \qquad (B\text{-}2)$$

Rearrangement of Eq. (B-2) yields:

$$L^2 \pi D_o^2 - 4\ V_o L + \frac{4\pi\gamma T_c Di^4\ P_o}{128\mu} = 0 \qquad (B\text{-}3)$$

Eq. (B-3) is a quadratic equation in L. The solution of Eq. (B-3) is:

$$L = \frac{2\ V_o}{\pi D_o^2}\left[1 \pm \sqrt{1 - \frac{\pi^2 \gamma D\ i^4 D_o^2 P_o T_c}{128\mu\ V_o^2}}\right] \qquad (B\text{-}4)$$

Eq. (B-4) shows that there is a maximum value of $P_o\ T_c$ for a given filter. The equation for $P_o\ T_c$ max. is as follows:

$$P_o T_c\ \text{max} = \frac{128\mu V_o^2}{\pi^2 \gamma Di^4 D_o^2} \qquad (B\text{-}5)$$

The critical length corresponding to $P_o T_c$ max is given by the relation

$$L\ \text{critical} = \frac{2\ V_o}{\pi D_o^2} \qquad (B\text{-}6)$$

At a given depth, the time constant has a maximum value when the tubing length has the critical value. If the tubing is longer than the critical value, then the time constant decreases. The numerical expression for L will now be derived: Since for practical purposes, a tubing having a length less than the critical length is desired, only the minus sign of Eq. (B-4) will be retained. Thus:

$$L = \frac{2\,V_o}{\pi D_o^2}\left[1 - \sqrt{1 - \frac{\pi^2 \gamma}{128\,\mu\,V_o^2}\; D_i^4\; D_o^2\;(P_o\;T_c)}\;\right] \tag{B-7}$$

For the present hydrobarophone, the following constants apply:

$$V_o = 5.25 \times 16.387 = 86.032\ cm^3$$

$$D_o = 2.40 \times 10^{-2} \times 2.54 = 6.096 \times 10^{-2}\ cm$$

$$D_o^2 = 3.7161 \times 10^{-3}\ cm^2$$

$$D_i = 1.0571 \times 10^{-2} \times 2.54 = 2.685 \times 10^{-2}\ cm$$

$$D_i^2 = 7.2094 \times 10^{-4}\ cm^2$$

$$D_i^4 = 5.1975 \times 10^{-7}\ cm^4$$

$$V_o^2 = 7.4015 \times 10^{-3}\ cm^6$$

$$\pi 2 = 9.8696$$

$$\gamma = 1.403$$

$$\mu = 1.83 \times 10^{-4}\ \frac{9\ ms}{cm \times sec}$$

Inserting the above values in Eq. (B-7) gives the following relationship for the length of capillary tubing:

$$L = 5803\left[1 - \sqrt{1 - 2.7665 \times 10^{-4}(F+33.9)T_c}\;\right] \tag{B-8}$$

where:

L = length of capillary tubing ... (inches)

F = water depth .... (feet)

T_c = time constant of filter ...... (minutes)

33.9 feet of water = 1 atmosphere

Eq. (B-8) is plotted in Figure 23. The use of Figure 23 in determining the length of capillary tubing is shown in the following example:

Example: water depth = 50 feet

time constant = 5 minutes

Find the length of capillary tubing:

Solution:

$$F + 33.9 = 50 + 33.9 = 83.9$$

$$(83.9)(5) = 419.5$$

From Figure 23, the length corresponding to 420 (feet-minutes) is seen to be 347 inches.

APPENDIX C

SHIELDING OF HYDROBAROPHONE FROM QUICK CHANGING WATER TEMPERATURES

C-1. Not only is the hydrobarophone sensitive to tides and pressure steps, but it responds to changing water temperatures also. This is undesirable since it is extremely difficult to distinguish between the two types of response. The water temperature changes may be in the order of 1°F or 2°F over a period of 15 to 20 minutes. Thermal changes of this kind have been recorded by a thermistor mounted near the hydrobarophone. They have been observed by divers also reading thermometers on the bottom at the actual hydrobarophone location. When changes of this magnitude were generated in the laboratory, the hydrobarophones were observed to drift off scale. Thermal changes of this sort are caused by the motion of large masses of water. Thermal expansions or contractions in the diaphragm changes the gap spacing, and thus unbalances the bridge circuit. Hence, it becomes necessary to devise a means of shielding the hydrobarophone.

C-2. In order to determine the effects of changes in water temperature upon the hydrobarophone (temperature) changes were simulated in the laboratory. A cylindrical, wooden tank, six feet in diameter by six feet high, was purchased for the purpose. (See Figures C-1 and C-2). To drain the tank a small valve was installed in the bottom. Steam was used to change the temperature of water in the tank without changing the static water head. Copper tubing, 1/2" in diameter, was formed into a spiral to cover the bottom of the wooden tank; and a helix was formed from this tubing to cover the walls of the tank. This arrangement produces a fairly uniform heat transfer through the water. Steam under pressure was forced through the coils of copper tubing, and the supply was controlled by valves (see Figure C-3). Two electric stirring paddles, rotating at 60 RPM, were mounted on top of the tank as shown in Figure C-2 to stir the water gently. With the stirrers and thermocouples mounted in strategic spots, a series of trials were made until the best valve combinations were set to obtain the desired temperature gradient.

C-3. A fiberglass cylinder was used as an insulating shield for the hydrobarophone. The fiberglass material is Bonate #C-0019-14, with the following physical properties: Thermal expansion, 1.49×10^{-5} per °C; thermal conductivity, approximately 2.5 BTU/hr/ft^2/°F/in, and the water absorption is 0.17% weight increase for a pressure of 500 psi over 24 hours at a temperature of 65°F. The battery section was modified as shown in Figures C-4, C-5 and C-6. The shield is 20 inches long, and 21 inches in outside diameter. The wall thickness of the cylinder, as well as the bottom and top lids, is 3/4-inch. A lucite flute, 6 inches long, 1 inch in diameter, and with a 5/16-inch I.D. hole, is inserted through the fiberglass shield. This deters sea life from entering the shield (see Figure C-4). The hydrobarophone is attached to the lid as shown in Figure C-5; and it is placed into the shield as shown in Figure C-6. This complete assembly was installed in the wooden tank for test of its effectiveness in providing insulation for the hydrobarophone.

C-4. The instrumentation shown in Figure C-7 was used in a series of six tests. Thermocouples were located both inside and outside the hydrobarophone. Table C-1 giving the average values observed in the six tests. It will be noted that the diaphragm, which is the critical area of the hydrobarophone, experienced a temperature change of only +0.15°F during a period of 60 minutes, while the areas outside the fiberglass shield experienced temperature changes as great as 21.2°F. The magnitude of the outside temperature is much greater than any observed, or expected in the field. The test was made even more severe in that the gain setting of the Mark 1 Bridge was higher than that normally used in field operations. It was therefore concluded that the shield is wholly satisfactory as a temperature shield for the hydrobarophone.

TEMPERATURE MEASURING SYSTEM

C-5. As previously mentioned, the hydrobarophone sensitivity and calibration is dependent upon the ambient water temperature at the time of recording. Due to seasonal weather changes and various recording locations throughout the world, ambient water temperatures vary. Therefore, it is necessary to know, at the time of recording, what the ambient water temperature is in order to obtain the correct sensitivity and calibration. The Oceanographic Engineering Corporation of San Diego, California has developed a temperature measuring system that will indicate the water temperature at the time of recording. The temperature sensing element is mounted within the fiberglass cylinder that houses the hydrobarophone; and the temperature indicator is mounted in a relay rack on shore. The complete system specifications are as follows:

a. The temperature sensing element is contained in a brass box (4" x 4" x 4").

b. The temperature indicating unit reads direct in degrees F.

c. The electrical connection between the sensor and indicator is provided by one pair of leads from the existing shore cable used to transmit response from the hydrobarophone.

d. The range of temperature measurement is from +35°F to 85°F with an accuracy of ±1°F or better.

e. The housing in which the sensor is contained will withstand a maximum depth of 300 feet of water.

f. Maximum time lag between a change in sea temperature changes and its indication by shore-based unit is two minutes.

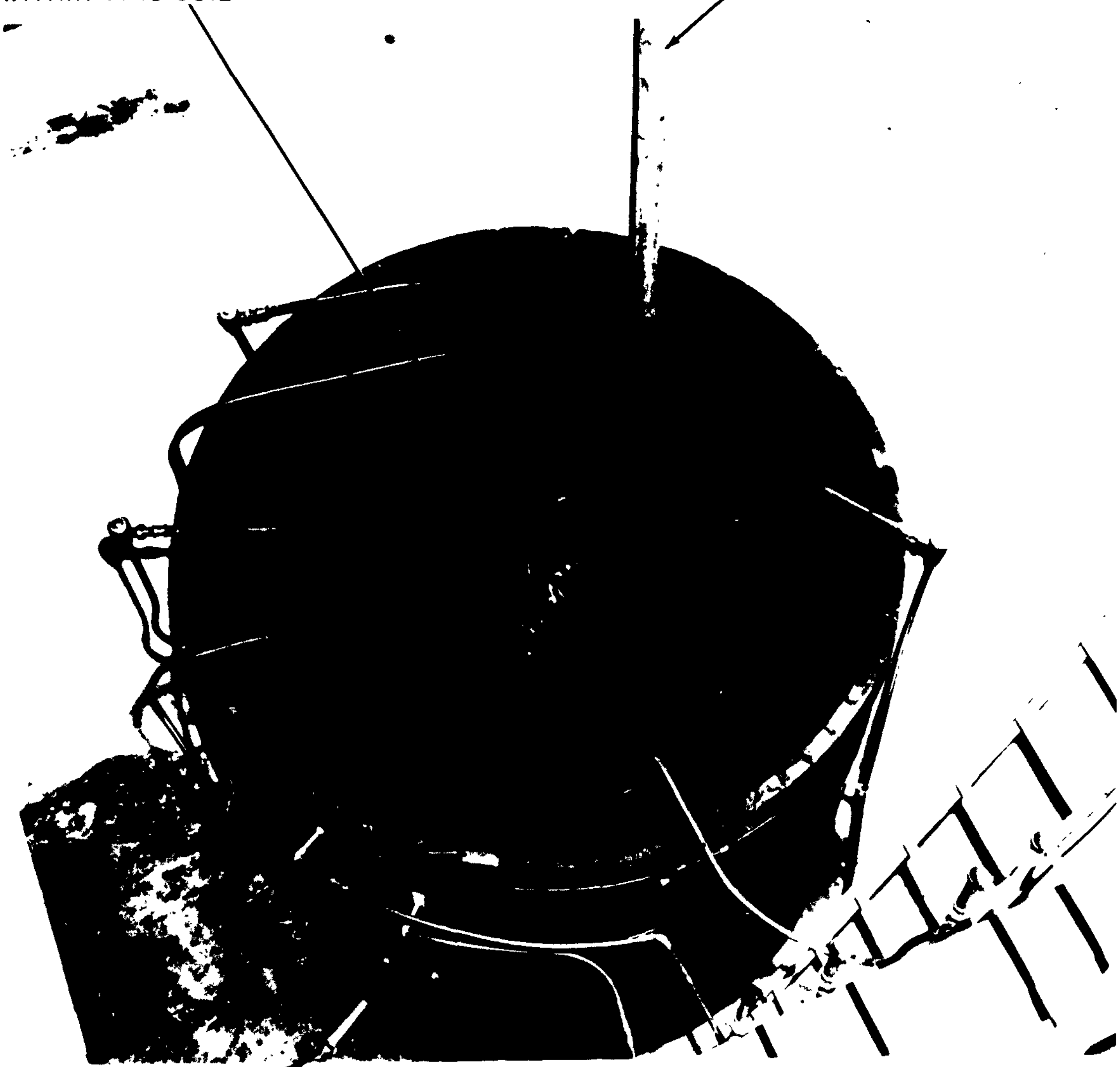


FIG. C-1 WOODEN WATER STORAGE TANK WITH STEAM COILS, WITHIN CONCRETE WATER TANK (BLDG 201)

FIG. C-2 WOODEN TANK WITH ELECTRIC STIRRERS

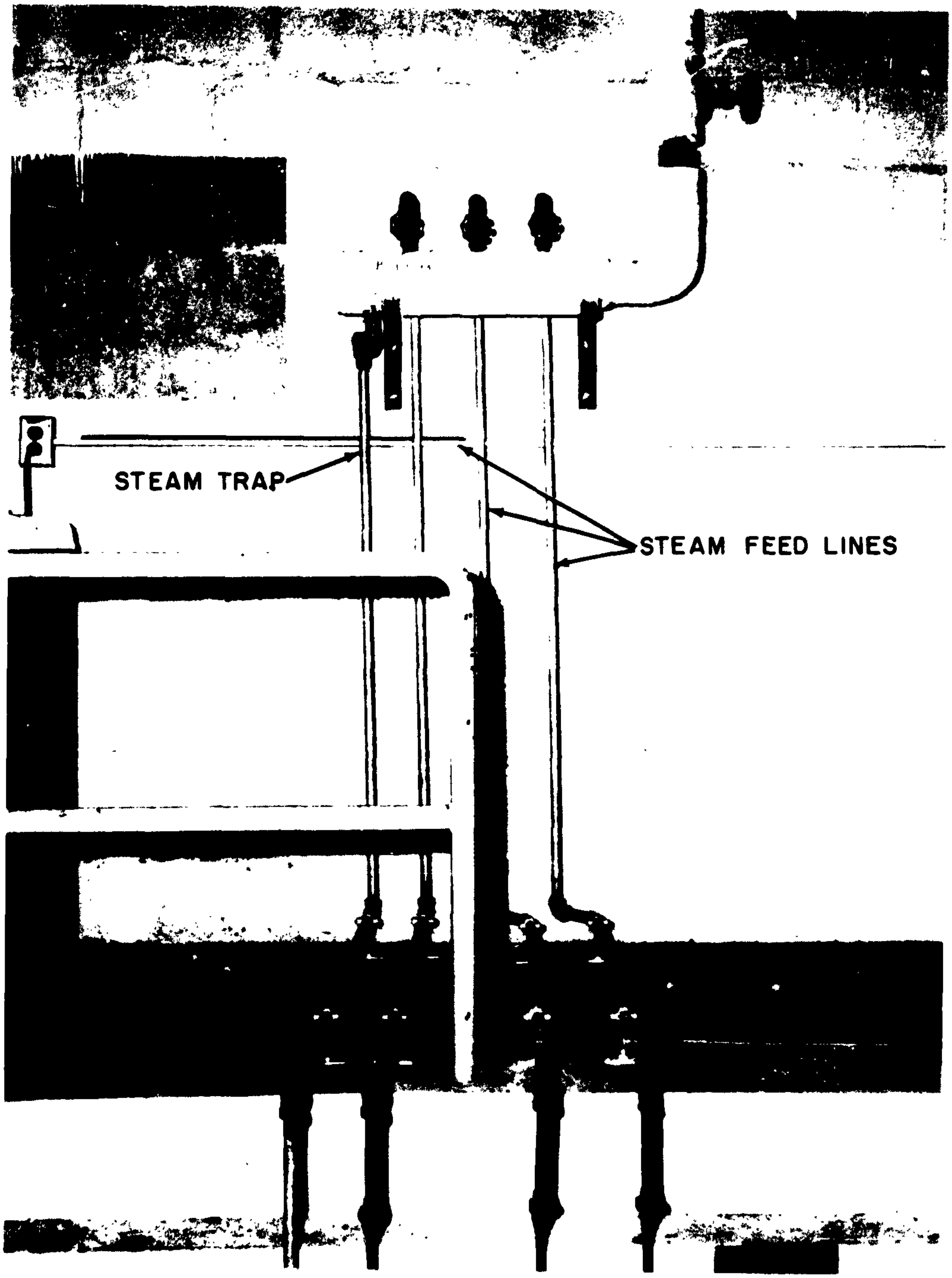


FIG. C-3 STEAM VALVE CONTROL SYSTEM

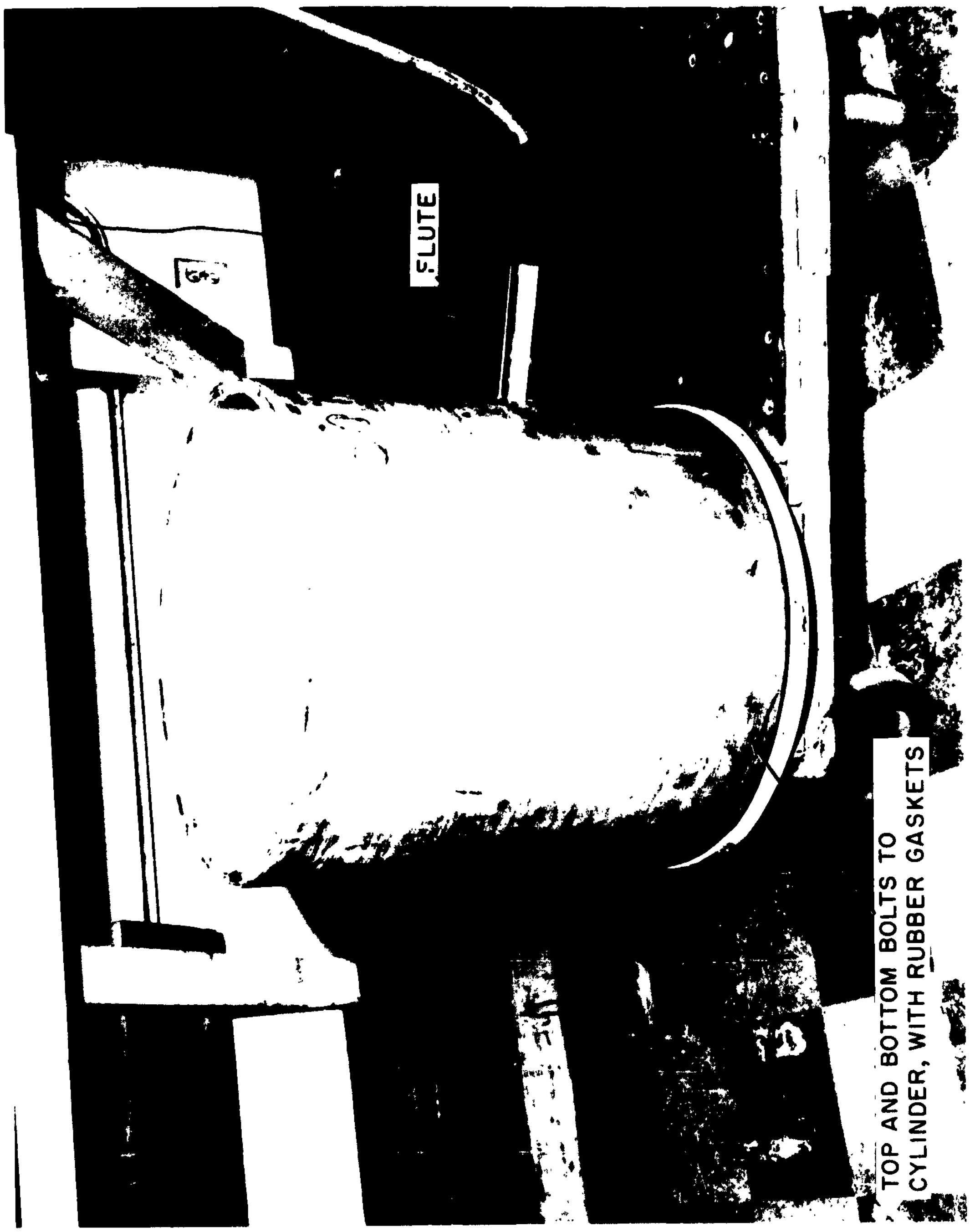


FIG. C-4 FIBERGLASS CYLINDER WITHOUT LID

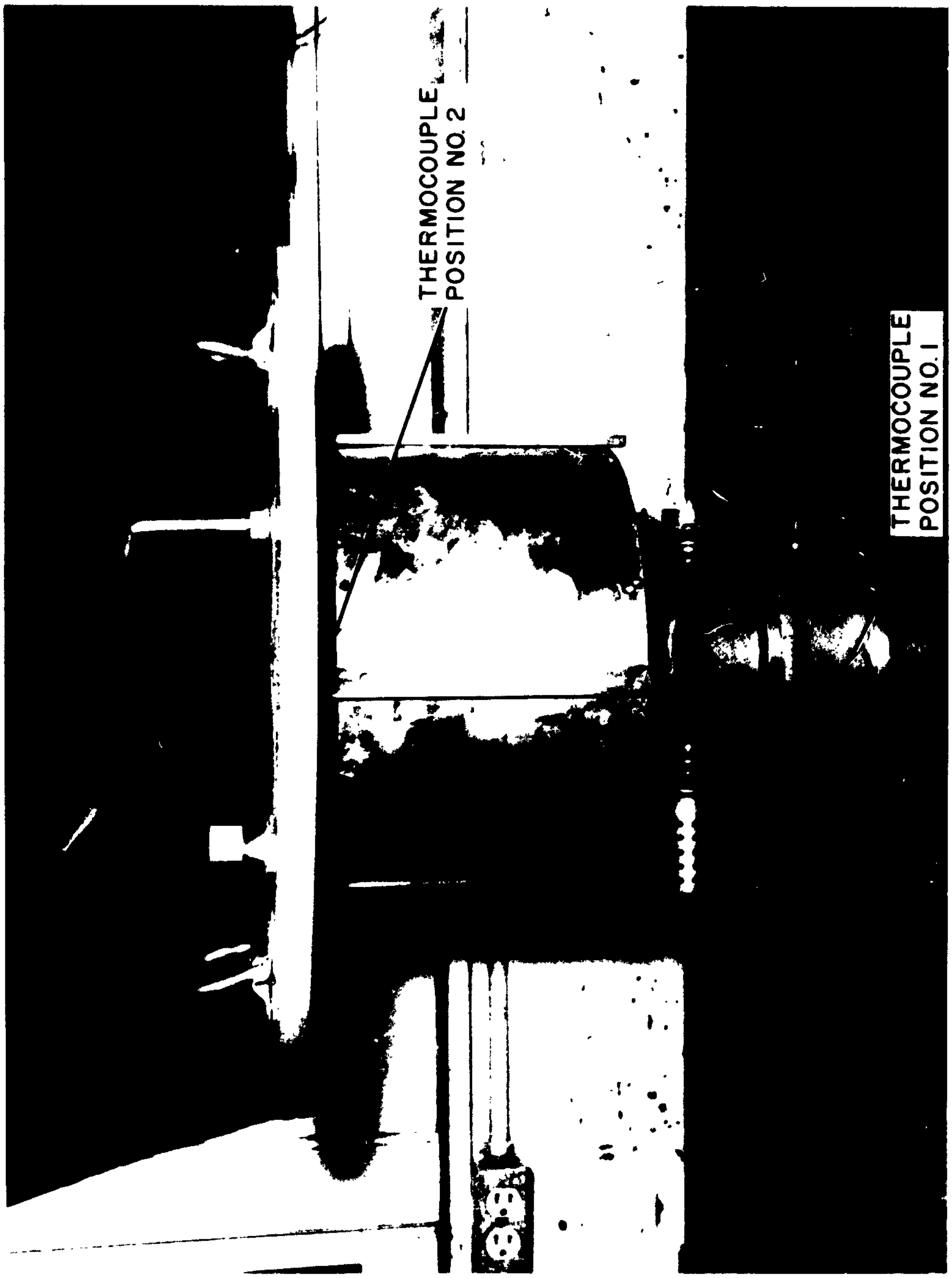


FIG. C-5 HYDROBAROPHONE ATTACHED TO FIBERGLASS LID

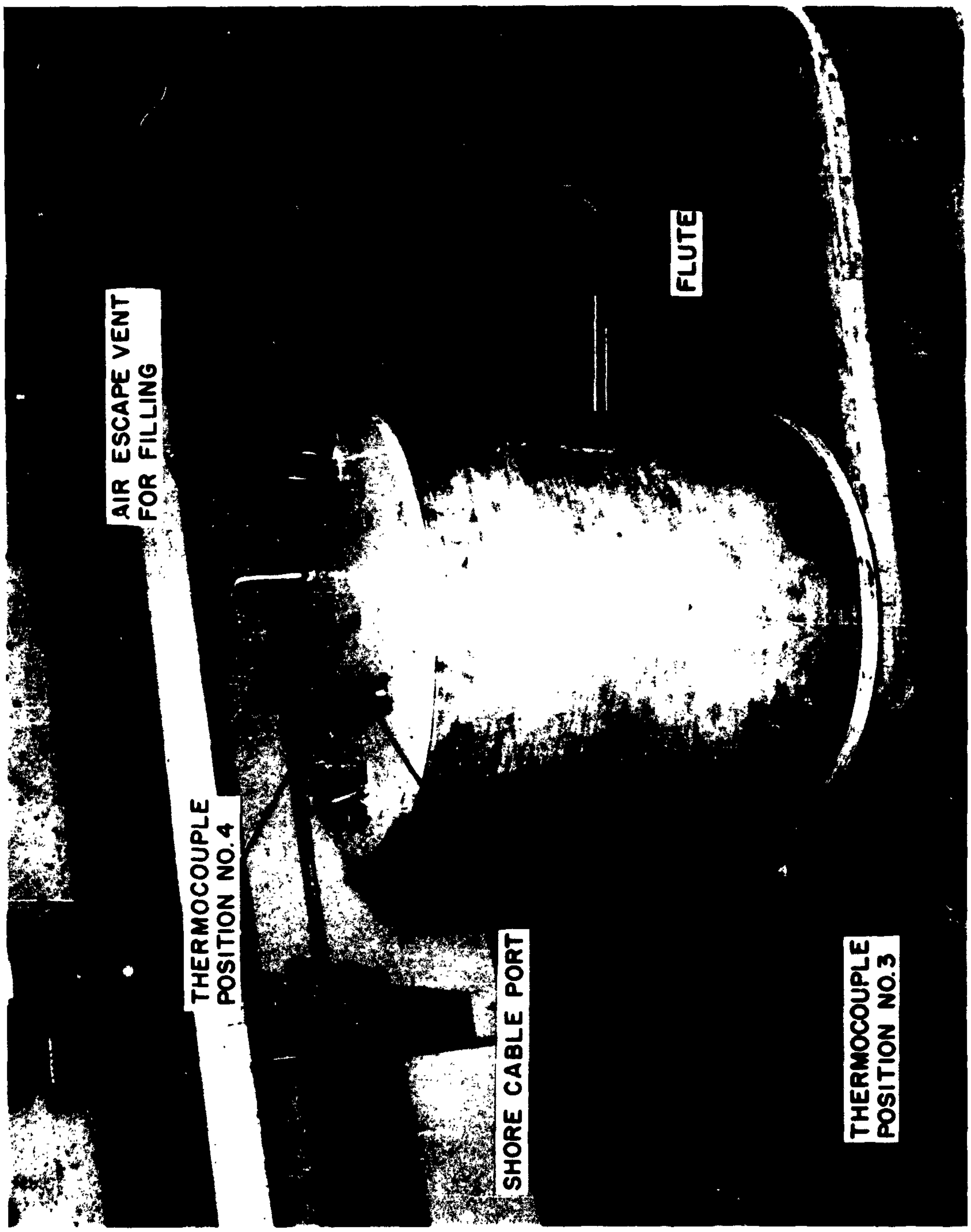


FIG. C-6 FIBERGLASS SHIELD WITH THERMOCOUPLES INSTALLED

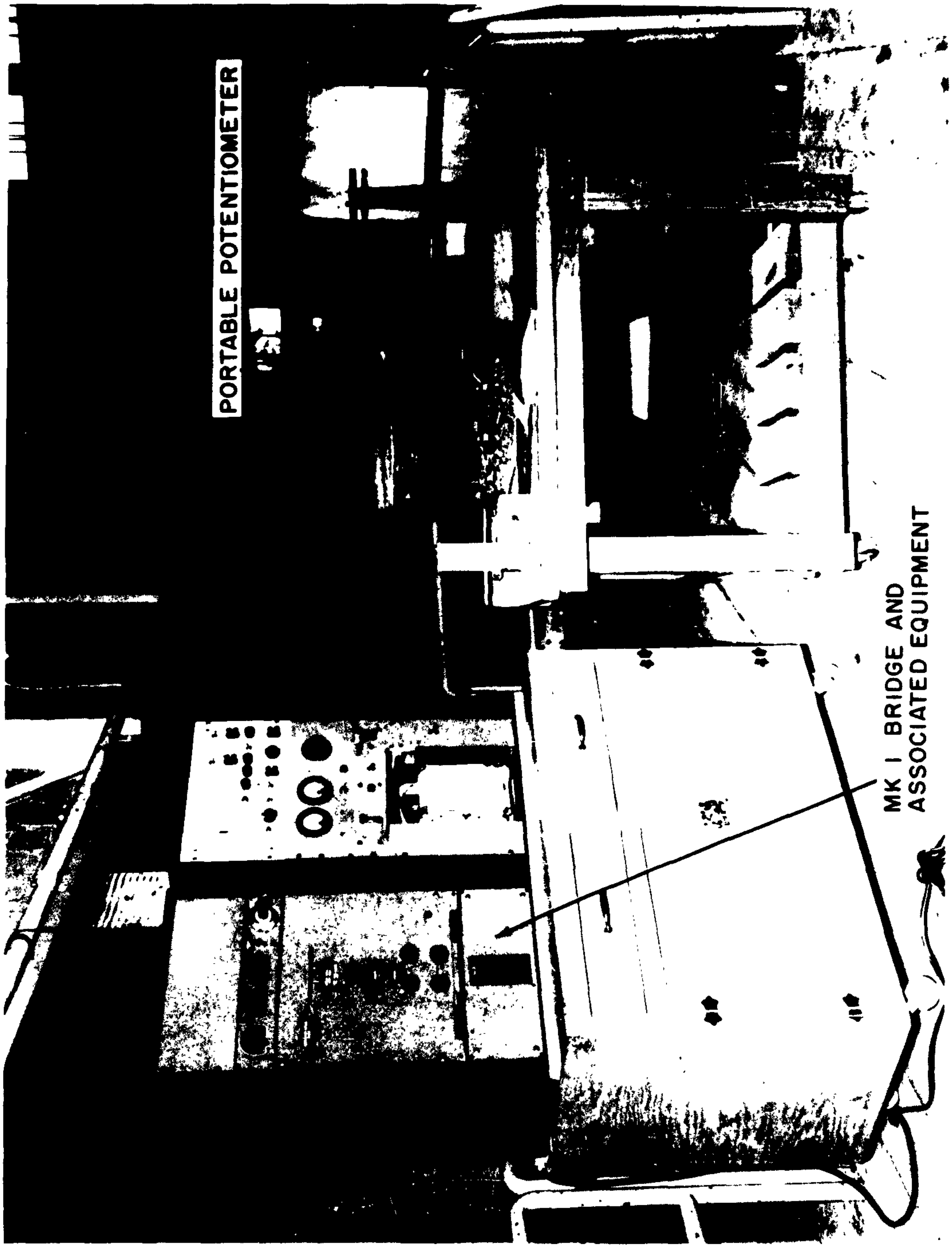


FIG. C-7 INSTRUMENTATION USED IN TEMPERATURE TESTS

TABLE C-1

AVERAGE VALUES FROM SIX TESTS

Test	Thermocouple #1 Inside (Near Hydrobarophone) Degrees F	Thermocouple #2 Inside (Near Plastic Bag) Degrees F	Thermocouple #3 Outside (At Bottom Of Cylinder) Degrees F	Thermocouple #4 Outside (At Top Of Cylinder) Degrees F
7	.1	1.5	16.5	21.0
8	.2	1.9	17.6	21.9
9	.1	1.4	15.3	21.0
10	.1	1.4	17.2	21.6
11	.1	2.0	13.8	19.0
12	.3	2.6	18.4	22.9
Average	+ .15°F	+ 1.8°F	+ 16.4°F	+ 21.2°F

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REPORT DATE	27 February 1963	Ø263	CIRCULATION LIMITATION OR BIBLIOGRAPHIC		
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SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Incremental	ICRE	Acoustic	ACOU	Hydrophone (Design)	HYDRD
Hydrophone	HYDR	Filter	FILT	Hydrophone (Development)	HYDRL
Wein	WEIN	Pass	PASG	Hydrophone (Fabrication)	HYDRF
Bridge	BRID	Band	BAND	Assembly	ASSM
Measurement	MEAU	Operation	OPER	Calibration	CALB
Pressure	PRES	Fiberglass	GLAC	Planting	LAYE
Fluctuations	FLUC	Container	CNTA	Recovery	RECV
Frequency response	FREN	Water	WATR	Hydrophone (Operation)	HYDRI
Sensitivity	SENV	Temperature	TEMP		
Equalization	EQAL	Shielding	SHIL		
Bags	BAGS	Indicator	INDC		
Valves	VALV	Accuracy	ACCU		

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AN INCREMENTAL HYDROBAROPHONE (U), by
Edward L. Peters and Charles H. Marshall.
27 Feb. 1963. v.p. illus., diagr., tables.
Task Assignment RUME 2E000/031.

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