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Introduction

In the fall of 1982 The Mississippi Mineral Resources Institute undertook to build an airlift drill/dredge system based on earlier designs by Woolsey for use in the exploration and evaluation of subsurface marine mineral deposits off the Mississippi Gulf Coast. Limited theoretical information concerning airlift operation was obtained through The University of Mississippi library's computer search system which referenced related articles as a result of keyword input. The design study consisted of three phases which were; Preliminary, Research, Design and Construction, and Field Testing. The final system was designed by Anthony B. Wilson, Staff Engineer, under the direction of James R. Woolsey, Director. Construction of the dredge was done in The University of Mississippi's engineering shop by Bob McCain, Russell Pinion, and Anthony Wilson in July of 1983. The dredge was tested in August of 1983 off the Mississippi Gulf Coast on the research vessel ''Tommy Munro", before being shipped for further testing to a United Nations survey off the west coast of Africa, involving phosphate exploration and evaluation.

Once the preliminary information gathering on dredge systems had been completed, the basic airlift system developed by Woolsey (1974) (Figure 1) was selected for the M.M.R.I. design because of its simplicity, low cost, and relative efficiency. Airlift system operation is based on the pressure differential between the water surface and the ocean floor or point of intake. Air is injected at the lower end of the unit via a manifold and a flow is set up which entrains the unconsolidated sediment to be recovered. This is aided by the addition of a variable pressure water jet at the cutting shoe of the drill/dredge system. By adjusting the air-water ratio, the specific gravity of the slurry is varied resulting in a suction effect. The greater the water depth the larger the pressure differential, and therefore the greater the lift. Since the only mechanical equipment involved is an air compressor and water pump, located on the surface, there is very little wear and very little maintenance required. The energy requirements are determined by the water depth in the area of interest as air pressure must be sufficient to overcome the hydrostatic pressure at the base of the system. Once the sample material is delivered at the surface, it can be processed, making various size cuts and separations as required.

The M.M.R.I. system was designed with certain objectives to facilitate the upkeep and operation of the system. The system was to operate in both a drilling and dredging configuration. Water depths to be encountered varied from 10 to 60 m and therefore the device was to have sufficient weight for sampling at these depths. Also, it should be of a convenient length for handling and transport. This was accomplished by building a 24′ system in 8 and 6 foot sections with a 2′ manifold and filling each casing annular jspace with lead for added weight (Figure 2) . This was an alternative to previous designs in which the system was made of a single 20′ pipe, making it difficult to transport. The sections also allowed different weight and length combinations for differing depths, sea conditions and applications. The manifold section was designed to have interchangable air introduction segments for various sediment conditions (Figure 3).

Flow inside an airlift depends on a number of variables which include mixture, depth of air injection, depth of intake, height of eductor out-flow above water surface, and the specific weight and size of the particles to be lifted. An evaluation of the Bernoulli & Momentum equations as related to this system demonstrates the principles involved.

The major portion of the airlift is constructed using a 4", 100 mm, I.D. galvanized jacket pipe, schedule 80, with a 3", 76 mm, I.D. slurry transport pipe, schedule 80, centered inside. Spacer rings of 3 1/2", 89 mm, I.D. schedule 80 pipe are used to maintain a consistent centering of the inner pipe. The annular space between the jacket and slurry pipe, .326", is filled with lead to add weight to the system. The total weight of the dredge is 750 lb., 34.09 kg. The individual segments are fitted together using an overlap system with standard 4" pipe flanges which bolt together (Figure 4).

A water jet is attached to the base of the dredge where a 50-100 psi stream of water aided in cutting the sedimentary material. Water supply is furnished by a 1.5", 38 mm, I.D. double braid general purpose hose. Air is injected via a one-way check valve entering the 3" slurry eductor pipe, through a manifold Which has been selected for the sediment encountered. Air is usually supplied by the ship's onboard compressor, and specific requirements vary with water depth. An air supply of 50-80 psi with 30-50 cfm will be sufficient for water depths up to 160 ft. Exact air requirements may be calculated using the following formulas ;

(1) $$Q = \frac{H}{K \log_{10} (W_{VT} / s+34)}$$

Where:

Q = quantity of air required in ft/gal (water)

H = total lift in ft from water surface to discharge point

S = vertical distance in ft between point of intake and water surface

K = constant from table 1

S/S+h = submergence ratio

S/SHi (%)	40	45	50	55	60	65	70	75	80	85	90
K	246	272	296	318	335	348	358	366	372	377	380

The average slurry velocity may be calculated using the formula below:

(2) $$V = \frac{A\ I}{Q\ 66}$$

Where:

V = average velocity in ft/sec

A = free air capacity of air compressor in ft/min

I = linear ft/gal capacity of drill pipe

3 in ϕ - 2.72   4 in ϕ - 1.53   5 in ϕ - .98   6 in ϕ - .68

Q = derived from (1)

And finally, the volume capacity of air coirpress or for a given system and submergence ratio:

$$A = \frac{V\ Q\ 60}{I}$$ V Q & I from (1) and (2)

The air supply was delivered through a 1/2" double braid general purpose air hose.

Dril·l System Components

Air Compressor

The specific air compressor required is determined by the water depth and material to be lifted, each of which vary considerably. The main point of concern is that sufficient pressure be supplied to overcome hydrostatic pressure at the deepest point of penetration and the system used being able to maintain this supply. The ship selection for a project should include consideration of the onboard air supply, however, a portable system may be obtained. An important part of the compressed air system is a suitable tank of at least 30 cubic feet with reliable pressure gauges and relief valves. An easily accessible 90 shut-off valve should be included for instantaneous on-off selection, as well as a gate valve.

Water Pump

The water pump in the system supplies a jet for both cutting the material to be sampled and aid in delivery to the intake ports. Most ships have on-board water pumps which are capable of supplying sufficient pressure, 150 psi or less, at 100 GPM, however a portable pump will suffice. If stiff clays are encountered, a higher pressure system may be required.

Hose

The slurry eductor hose should be a good quality, light weight pressure suction type. For this project a 3" I.D. Uniroyal 1196 hose was selected. This is a slightly heavier design of the plastic, spiral reinforced type, however the market price and durability make it a good choice.

The water (1 1/2" I.D.) and air (1/2" I.D.) supply hoses were red general purpose 2 braid hose. All hoses were made up in 25 and 50 foot lengths with Quik coupling fittings, with the exception of the air hose, where Dixon fittings were used.

Deck Handling/Hoist System

Drill Suspension/Hoist System

Suspension of the drill pipe is best handled by an a-frame or boom with a hoist block height of 7-8 m from the water's surface and a plumb line within arm's reach of the ship's rail for retrieving the system. The structure should be capable of supporting 2 tons dead weight. Both the a-frame and boom have been used satisfactorily, although the a-frame is generally preferred. The system may be located on the stem or beam. The stem is the preferred location provided a minimum of 35 m^2 of working space is available. Placing the a-frame along the longitudinal axis minimizes the effects of the ship's roll. In practice a little roll is beneficial to drilling by providing a "churn drill effect", however, excessive tool motion (exceeding .5 m) makes it difficult to start the hole.

Drill Hoist Winch and Cable

The drill hoist should have a minimum line pull of 2 tons for drill pipe handling and casing extraction from the hole. It should have a capacity for a sufficient quantity of 7/16" (11 mm) or 1/2" (13 inn) drill cable to accommodate all rigging and reach the maximum desired sampling depth with 30 m of additional cable. The cable should be marked with braided color codes in approximately 1 m increments to enable the hole depth relative to the surface to be determined. Marks every 3 m are sufficient for dredging operations.

Any comfortable retrieval rate is satisfactory; a speed of 1 m/second is a good average which most standard systems can maintain. The only requirement is a reliable braking system for stopping and holding the drill at desired levels.

Anchors

The anchor system used in a survey is dependent on the vessel's capabilities, prevailing current and wind directions, and hole depth. In relatively calm seas, a bow thruster is desirable to hold the vessel on station during sampling, particularly in water deeper than 30 m. If dynamic positioning is available, this is certainly capable of holding on site, however, the cost is usually prohibitive for most surveys. Bow and stem anchoring is the simplest and most positive method in water depths less than 30 m and is typically all that is available on most vessels available for hire.

Operating Procedures

Positioning and Anchoring

A significant advantage of the airlift system is that some ship movement is permissible since all connections from the drill to the surface are flexible. This permits a less rigid mooring system, resulting in a considerable saving of time and expense.

The mooring system consists essentially of a sling between two fixed points, a bow and stem anchor, and a third flexible point effected by the dominant drift or wind or current.

Once the drill site has been established it should be marked by a buoy and the direction of dominant drift noted. The vessel is then maneuvered to a point down drift of the buoy for a distance that will allow sufficient scope on the stem anchor, also it should be offset enough to permit a run that will pass abeam the buoy (up drift) on a course that will quarter the drift component. The stem anchor is dropped and the run commenced. An equal or greater distance is run out in the updrift quadrant (beyond the buoy) to insure sufficient scope for the bow anchor. After the bow anchor is in place the bow cable is played out while the stem cable is hauled in. As the vessel approaches an abeam position with the buoy, the bow anchor winch is braked while the stem winch continues to haul in until both bow and stem cables become taunt. This insures proper setting of the anchors as well as eliminating excessive slack.

The purpose of quartering the drift is to place the major strain on the bow anchor system, for which it was designed. This permits the use of a stem anchoring system of lighter capacity since a smaller force vector is involved; its main purpose being to prevent the inevitable swing of a single anchor moor.

If bow thrusters or Dynamic Positioning are used, the site is merely located and the ship is held on site without anchoring until sampling has been completed.

Drill Crew

The drilling crew for a typical shallow to moderate depth operation (less than 60 m) should ideally consist of 5 men assigned as follows:

1. Driller - controls drill positioning and drilling rate through hand signals to the Winchman - keeps track of drill depth.
2. Winchman - coordinates anchor winch operation, operates drill hoist and monitors water pump and air compressor.
3. Sampler - takes samples as directed by the Party Chief - aids Driller with hose handling.
4. Party Chief - responsible for the coup lete operation, including drill site selection, positioning, anchoring and drilling - maintains log of all pertinent aspects of operation, i.e. position, time, water depth, tide (if applicable) sample descriptions and depth, etc.
5. Deck Hand - assists in handling of hose, drill, and sample storage - should be able to fill in at any position when needed.

NOTE: In a typical operation members of the vessel's crew may serve on the drill crew, particularly in the position of Winchman and possibly Driller and Sampler as well. This is possible due to the simplicity of operation of the airlift, ameanable to a short crew break-in time, which is another important advantage of the system.

Drilling Procedure

Starting the Hole

Once the vessel is securely moored the position and water depth are checked. The drill pipe is lowered over the side and held at a convenient level permitting attachment of the hoses. Generally, for water depths less than 10 m, a 7.5 m section is used initially; for depths of 10-18 m, a 15 m section, etc. (drill = 4.5-6 m). When the hoses are secure the drill is lowered to the bottom and then retrieved about 1m. In this position the compressor is started. Once the pumping action is established the drill is lowered to the bottom. As soon as a bottom surface sample has been collected the water jet is actuated and drilling begins.

Sampling

As drilling proceeds the Driller should continually monitor the hole depth relative to the water surface by means of the cable markings. It is the responsibility of the Party Chief to note the time drilling commences and terminates in order that any tidal adjustments to mean sea level can be made, if applicable.

Sanpies are normally taken at 1 m intervals, during which time the drill is held by the hoist break. In addition to these, the sampler should sample any significant change in lithology.

Samples are taken from the processing system which varies from survey to survey.

In addition to interval sampling, bulk sampling for heavy minerals can be accomplished by the use of a suitable sluice box and/or jig (designed for the minerals of interest) for concentration and some means of volume computation of tailings. The latter may be done through the use of bins of measured capability or a self-dumping tailing wheel and counter attached to the sluice.

Addition of Hose

Through careful monitoring of the hole depth, the need for additional hose sections can be anticipated. At this time the drill is raised off the hole bottom by 1 m, water and air are shut off, hoses disconnected from the pump, compressor and sluice as required, and additional sections added. Drilling is resumed when air and water are turned on.

Drilling Techniques

The smoothness of the drilling operation and accuracy of the depth keyed to a given sample is largely dependent on the ability of the Driller. It is essential that the Driller acquire a "feel" for the drill through the taut drill cable. With a little experience one can determine the gross lithology encountered by the drill. Hard rock transmits an unmistakable ringing jar through the cable on drill inpact; dense clay, a dull thud; sand and gravel, a grinding crunch; and mud, a soft yield.

The Driller should also be attentive to the drilling rate. This is particularly true in mud or loose sand where too rapid penetration will increase the percent solids to the point of slurry stall. The condition is noted by excessive hesitation of slurry flow or complete stoppage. It may be easily corrected by retrieving the drill a few feet and proceeding at a slower rate of penetration. It should be noted that a pulsating slurry flow is normal with solids ranging between 20 to 70 percent (for loosely packed material). Restriction or complete stoppage may also result from jamming of elongate material in the pipe or hose. This may be remedied by momentarily closing the shut-off valve at the tank which in turn allows the slurry column to collapse, freeing the jam. Pressure is commonly allowed to build to a maximum in the tank before reopening the valve, thus providing an extra volume burst, inducing an initial accelerated flow rate.

Drilling is most efficient when ship-induced motion imparts a "chum-drill" effect to the drill pipe. In order to take full advantage of this, the Driller should play his cable so that it comes taut on mid-up-heave, lifting the drill pipe through top-heave and allowing hold bottom impact on mid-down-heave with sufficient cable slack through bottom-heave for penetration. When drilling in calm water, the same effect can be achieved through the use of some standard form of cable tool, tripping device attached to the drill cable. One of the more simple devices is a line rigged normal, attached to the drill cable by a suitable snatchblock (one that will not sling open on tension release) . The line is manually worked on a cat-head winch by alternately applying tension for haul down (raising drill) and releasing.

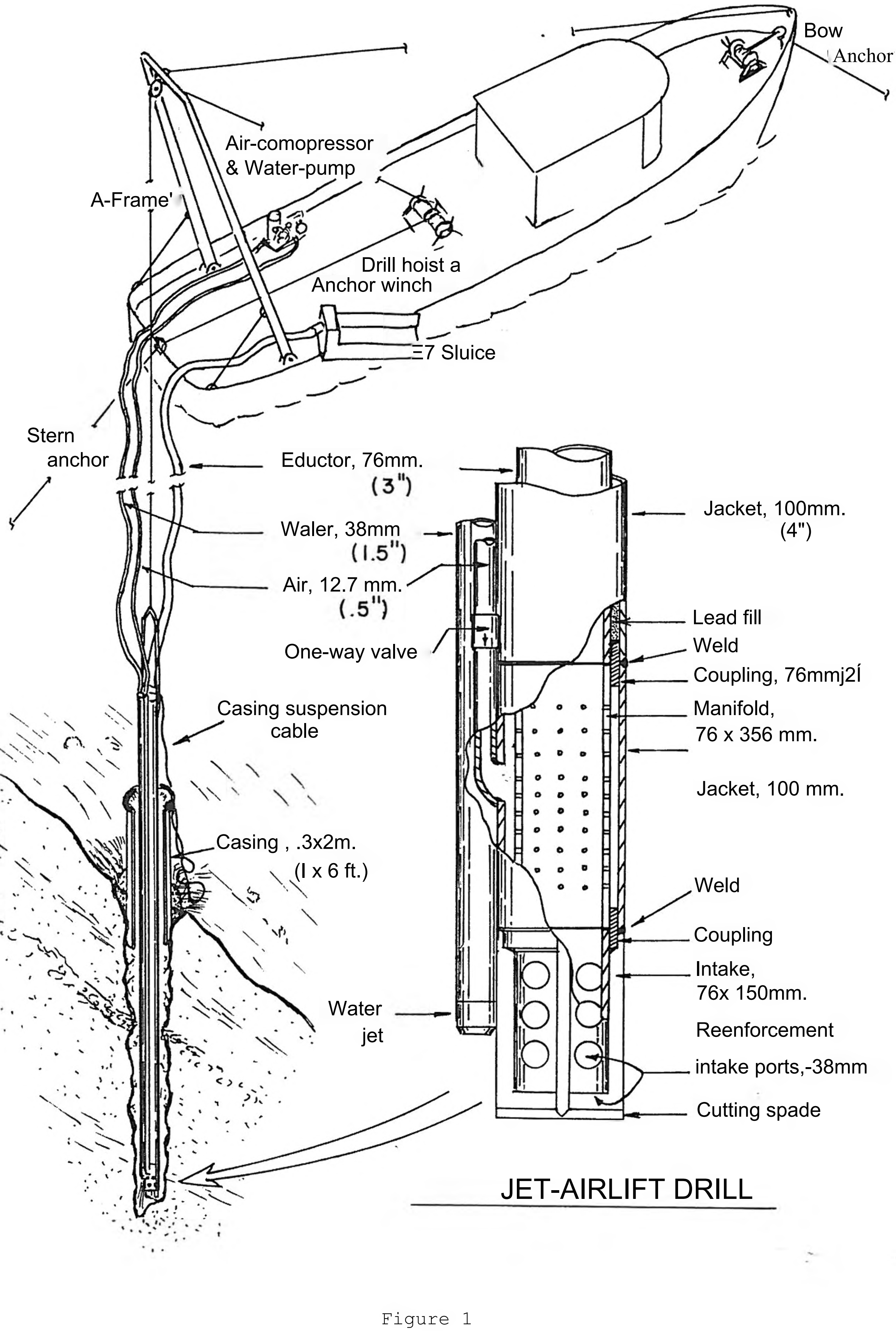
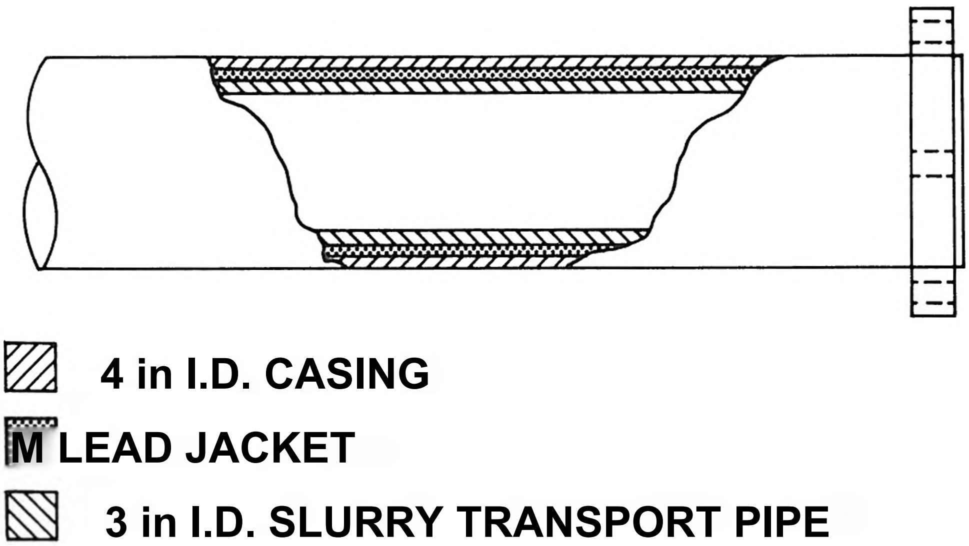
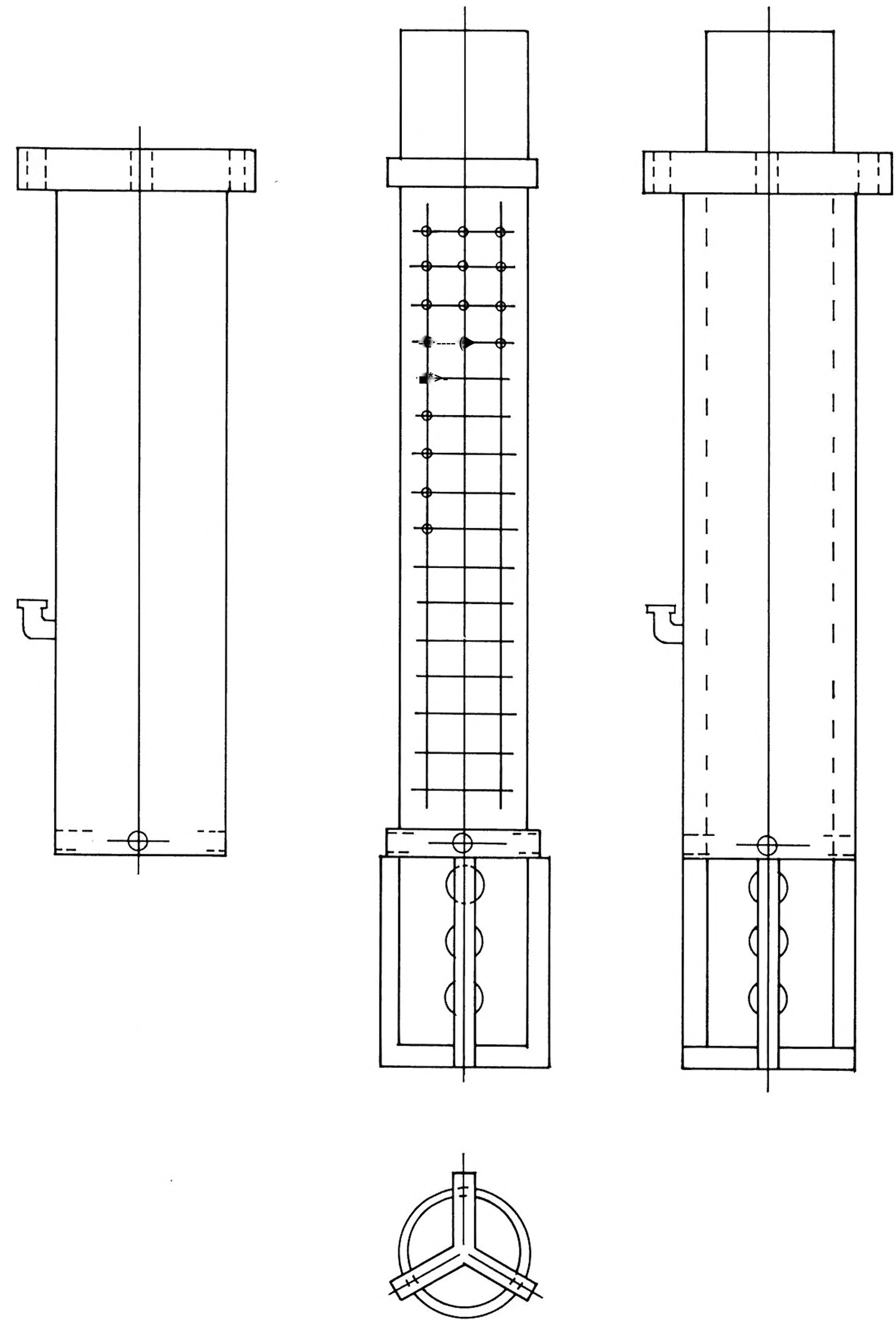

Bow
Anchor
Air-comopressor
& Water-pump
A-Frame'
Drill hoist a
Anchor winch
7 Sluice
Stern
anchor
Eductor, 76mm.
(3")
Waler, 38mm
(1.5")
Air, 12.7 mm.
(.5")
One-way valve
Casing suspension
cable
Casing , .3x2m.
(I x 6 ft.)
Water
jet
Jacket, 100mm.
(4")
Lead fill
Weld
Coupling, 76mmj2Í
Manifold,
76 x 356 mm.
Jacket, 100 mm.
Weld
Coupling
Intake,
76x 150mm.
Reenforcement
intake ports,-38mm
Cutting spade
JET-AIRLIFT DRILL

Figure 1



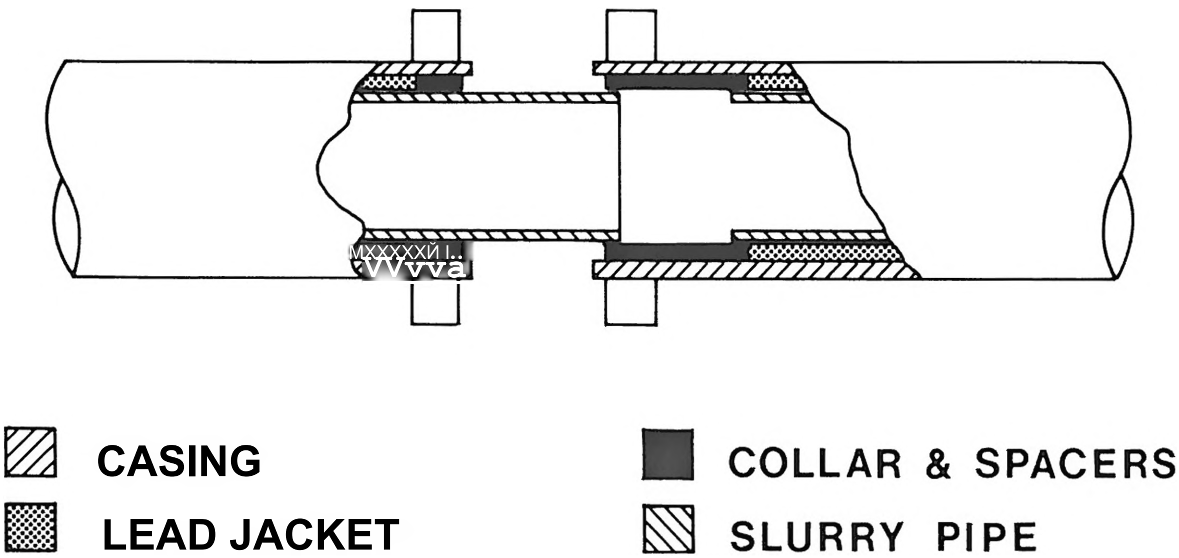
Lead Jacket

Figure 2



Manifold

Figure 3



Sleeve Connection

Figure 4