A Lightweight Pneumatic Coring Device: Design and Field Test

by

Jonathan A. Fuller and Edward P. Meisburger

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A lightweight pneumatic coring device for use from relatively small research vessels was developed and field tested. The device consists of an aluminum frame supporting a core barrel surmounted by a pneumatic industrial vibrator. Tests of a number of paired ball-type and piston-type vibrators revealed that a piston-type vibrator with a 3-inch-diameter piston provided the best penetration and was capable of obtaining cores from 0.6 to 2.4 meters long from a variety of unconsolidated sediments. A description of the tests and drawings of the final design are presented.

PREFACE

This report presents the results of a joint research effort by the U.S. Army Coastal Engineering Research Center (CERC) and the Lake Erie Section, Ohio Department of Natural Resources (ODNR) Division of Geological Survey (DGS). The objective of the research effort was to devise and test lightweight vibratory coring devices which could be deployed from a small vessel, 9.1 to 18.3 meters long, characteristic of the type generally available to Corps of Engineers District agencies and to other organizations engaged in sediment studies of coastal and inland waters. The work was carried out under CERC's Barrier Island Sedimentation Studies work unit, Shore Protection and Restoration Program, Coastal Engineering Area of Civil Works Research and Development.

The report was prepared by Jonathan A. Fuller and Edward P. Meisburger, geologists of DGS and CERC, respectively, under the general supervision of Dr. C. Carter, Chief, Lake Erie Section (DGS), Dr. C.H. Everts, Chief, Engineering Geology Branch, and Mr. N. Parker, Chief, Engineering Development Division, CERC. The design and the laboratory testing of the coring device were done by Meisburger at CERC. Field testing and modifications were done by Fuller in Lake Erie using the DGS research vessel *GS-1*.

The authors acknowledge the assistance of the following people: C.D. Puglia, CERC, who assisted in designing the coring frame; J.D. Jackson, CERC, who built the coring device; D.L. Liebenthal, DGS, who skippered the boat and assisted in the coring; C.L. Hopfinger, DGS, who assisted in the boat work; and T.C. Welch, ODNR, Division of Wildlife, who provided most of the PVC core tubes.

Technical Director of CERC was Dr. Robert W. Whalin, P.E., upon publication of this report.

Comments on this publication are invited.

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TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

A LIGHTWEIGHT PNEUMATIC CORING DEVICE: DESIGN AND FIELD TESTS

by
Jonathan A. Fuller and Edward P. Meisburger

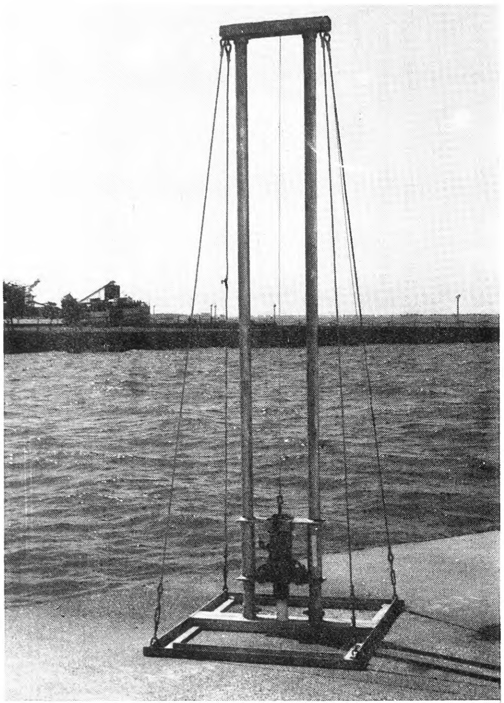
I. INTRODUCTION

Sediment coring devices powered by a pneumatic vibrator or hammer have been widely used during the past two decades for obtaining continuous sediment cores up to 15.2 meters long in coastal marine, Continental Shelf, and lake sediments. These vibratory coring devices usually provide much deeper penetration in typical coastal, shelf and lacustrine sediments than gravity coring devices which are most effective in deep-sea sediments of relatively low shear strength. Because they are free standing on the bottom and have no rigid connection to the support vessel, vibratory corers are also more practical for open-water locales than standard barge-mounted, soil-boring equipment.

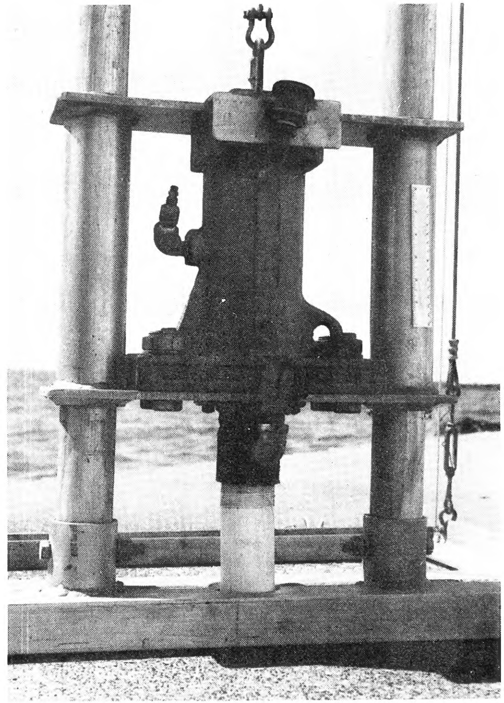
Most commercial vibrator/hammer-type coring devices are large and require the use of a vessel at least 18.3 meters long to accommodate the equipment and to safely extract the core barrel from the sea floor. The larger devices are usually necessary to obtain cores 3 meters or more long; however, many sediment studies could probably be accomplished with shorter cores using smaller devices. Also, many surficial sampling programs could be supplemented by coring if economical means were available. The usefulness of a small vibratory corer was recently demonstrated during the Coastal Engineering Research Center's (CERC) Inner Continental Shelf Sediment program (ICONS). Out of more than 1,500 cores from coastal and Great Lakes areas collected as part of ICONS, about 48 percent exhibited significant lithologic changes in the first 1.8 meters; 31 percent showed changes in the first 1.0 meter.

As a result of these findings, in 1979 CERC undertook an investigation of the feasibility of constructing a lightweight 2.4-meter-long vibrator/hammer-type coring device. The major criterion was that the device could be deployed from a relatively small, 9.1- to 18.3-meter-long coastal vessel of the type customarily employed by Corps of Engineers Districts, which would provide an in-house capability for securing cores in coastal and lake deposits. Two prototype models were designed and constructed by CERC in 1979.

The Lake Erie Section, Ohio Department of Natural Resources (ODNR) Division, Division of Geological Survey (DGS) which had a parallel interest in developing a coring device for their research vessel, the *GS-1*, joined CERC in a common effort to test and further develop a suitable device. After the design, construction, and laboratory testing of the two prototype models, extensive field testing was carried out from the *GS-1* in various areas of Lake Erie during the summer of 1980. The most suitable frame and vibrator/hammer device was then determined and important modifications were made based on these tests (see Fig. 1). The results of the tests, design drawings, and a description of the coring apparatus considered most usable are presented in this report.



a. Overall view.



b. Closeup of slide section.

Figure 1. Photos of the lightweight corer.

II. TEST PROCEDURE AND RESULTS

1. Equipment.

The equipment tested during development of the lightweight pneumatic corer consisted of two support frames, 2.4 and 4.3 meters long, and five industrial vibrators. The frames were designed and constructed at CERC. Both were of the same basic design, which closely approximated the final frame design shown in Figures 2, 3, and 4. The criterion for design and materials was to keep the frame as compact and as light as possible commensurate with the intended use. Also, the frame assembly was constructed in sections for easily disassembling and packing for transport in a panel van or pickup truck. During the early phases of testing it was determined that the small frame, which could be readily extended to any desired length by lengthening the guide pipes, was capable of supporting the largest vibrator to be tested. All field tests were made with this frame after modification to an overall length of 3.0 meters.

The vibrators tested consisted of a 2-inch and a 3-inch long-stroke, flange-mounted piston vibrators and three paired ball-type vibrators with ball sizes of 25, 38, and 64 millimeters. All vibrators were commercial off-the-shelf items. During testing, the piston vibrators were mounted on a shelf section bolted to a slide plate. The paired ball vibrators were mounted directly to the slide plate with the bases opposed and the long axis of the flanges in a vertical position with the inlet ports up. In this configuration the forces generated by the two vibrators become linear in the vertical plane and cancel each other in the horizontal plane. In the final design the slide plate was modified to more effectively support the piston vibrator.

2. Testing.

Preliminary tests of the vibrators in a sandfilled barrel, 2.4 meters deep, were conducted at CERC during the winter of 1979-80. From these tests it was concluded that the 2-inch piston vibrator and the 25-millimeter ball vibrators were not large enough for their intended purpose. Only the three larger vibrators were tested in the field.

Field tests were conducted in Lake Erie from the DGS research vessel *GS-1* (Fig. 5), a steel hull vessel 14.5 meters long and a 4.3-meter beam with a normally loaded draft of 1.4 meters. The *GS-1* was moored over the coring site by two 12H Danforth anchors emplaced fore and aft. The corer was deployed over the stern (Fig. 6) by a 3.3-meter derrick crane with an electric winch which has a lifting capacity of about 454 kilograms. The system was strong enough to extract the core tube from the sediment. No significant problems were encountered in holding the vessel within tolerable excursion distances with the two point mooring in seas 0.6 to 1 meter high. Deploying and recovering the corer with the help of the derrick crane and two persons were carried out without difficulty.

Field tests were conducted throughout the summer months of 1980 by DGS; a total of 181 coring sites were occupied. The results of the tests are

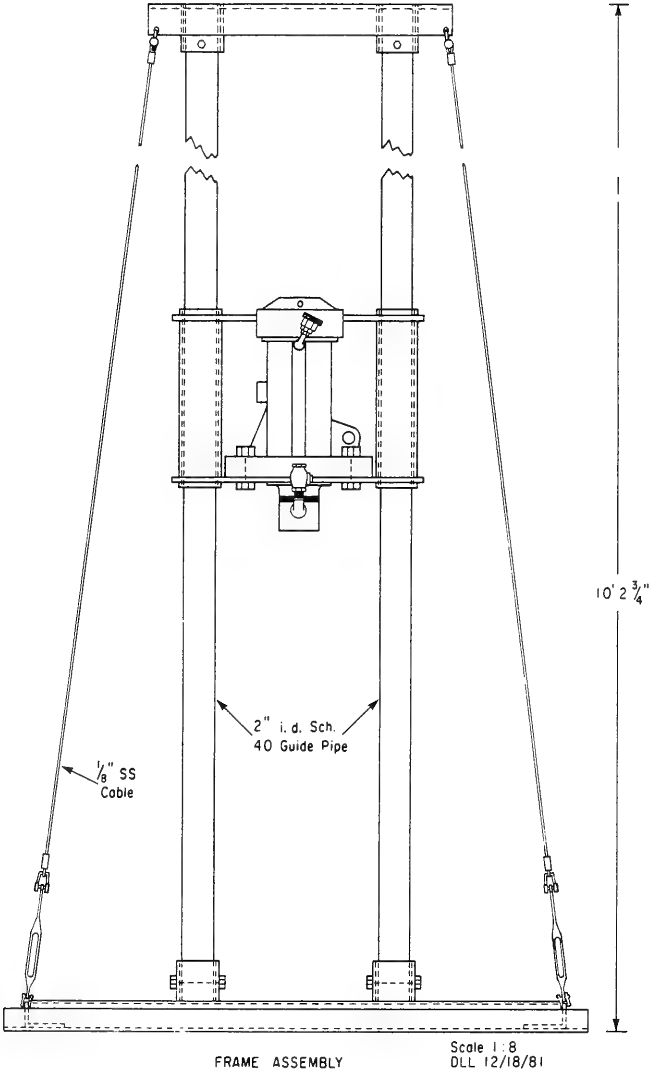


Figure 2. Overall front view of the lightweight corer with slide section midway down the guide pipes.

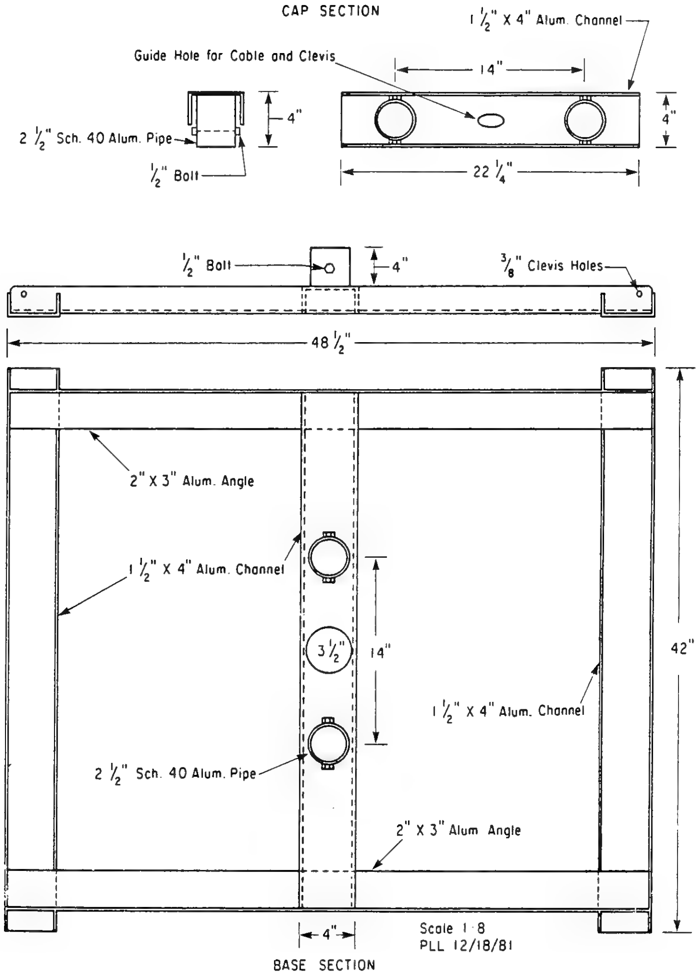


Figure 3. Details of the cap and base sections of the lightweight corer.

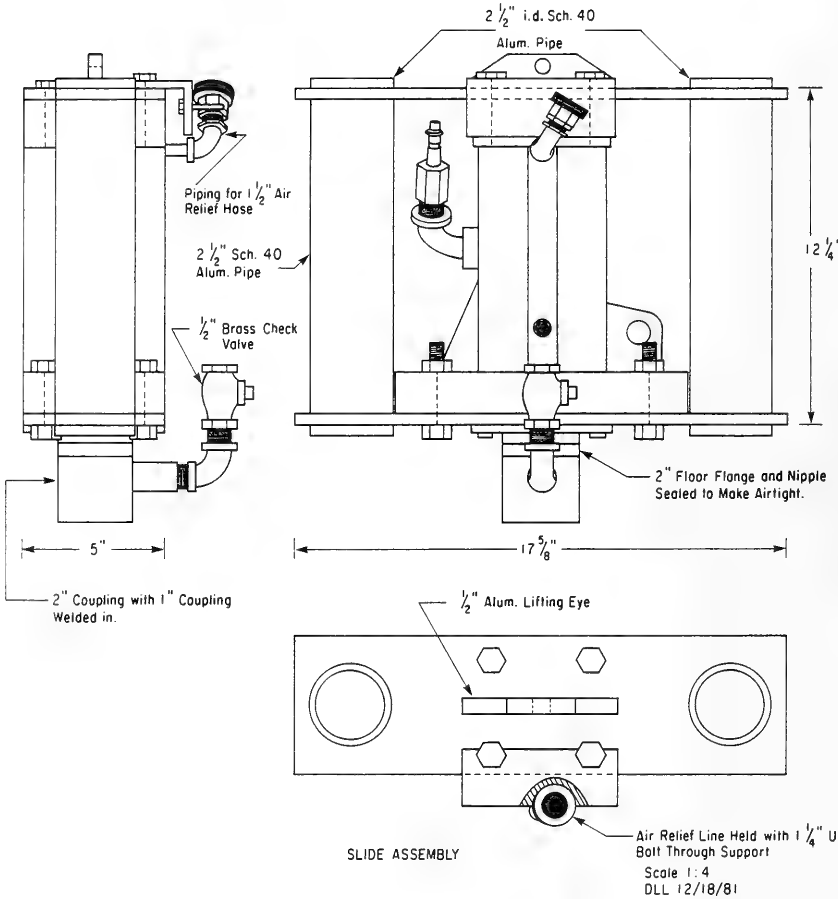


Figure 4. Details of the slide section of the lightweight corer.

Figure 5. Photo of the OGS research vessel *GS-1*.

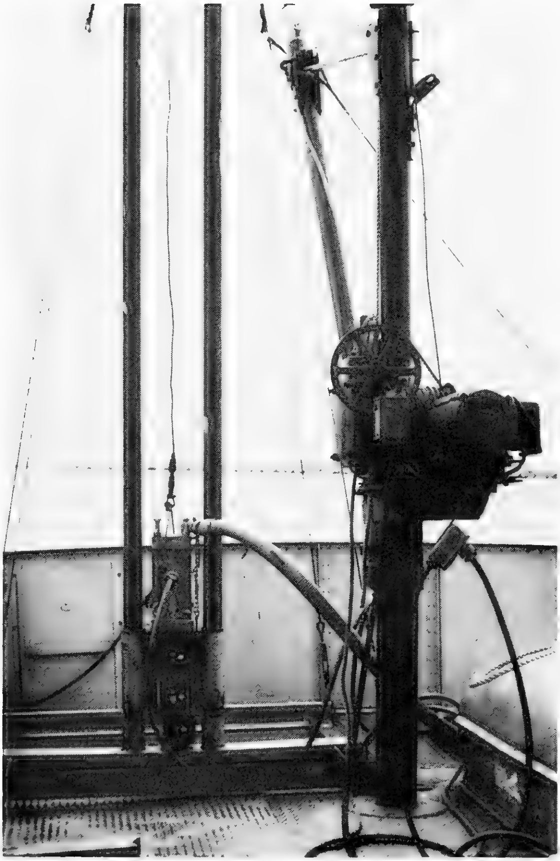


Figure 6. Photo of the afterdeck of the *GS-1* showing the lightweight corer and the small derrick crane.

summarized in Table 1. In the initial test series the 38-millimeter ball vibrators were found to be inadequate and the remaining tests were conducted with the 64-millimeter ball vibrators and the 3-inch piston vibrator. In general, the deepest penetration with the larger vibrators were obtained in fine-grained sediments such as mud, silt, and clay. The corer penetration was least in areas underlain by glacial till. Results in sand varied, but most of the cores recovered 1 to 2 meters of sediment. The cores that were split for detailed examination showed little disturbance or distortion of thin-bedded sequences.

As a result of the field tests, a final design was selected which consisted of the small frame extended to an overall length of 3 meters to allow for a 2.4-meter core barrel. The 3-inch piston vibrator was chosen over the 64-millimeter ball vibrators because at a given location it gave nearly the same results while requiring significantly less air, allowing the use of a smaller compressor and two instead of four hoses (see Table 2). Drawings and a description of the final design are provided in the following section. The slide section was modified after the field test to eliminate the plate used to attach the ball vibrators, thus allowing for a longer core barrel. The figures and drawings herein show the device after final modification.

III. DESCRIPTION OF CORING ASSEMBLY

1. Frame.

The frame of the lightweight pneumatic corer is constructed of standard-size structural aluminum and consists of four main sections: the base, the cap, the slide, and the upright guide pipes. The overall length, and thus the length of the core tube, can vary by using shorter or longer guide pipes. The design drawings show 3-meter-long guide pipes.

The base section (Fig. 4) is 48.5 inches square and constructed of aluminum channel and angle. The central crossmember is an aluminum channel with a centered 3.5-inch hole to allow passage of the core tube. On either side of the hole are 4-inch pieces of nominal 2.5-inch aluminum pipe, welded in an upright position to serve as sockets for the guide pipes. The guide pipes are equal lengths of nominal 2-inch aluminum pipe of the desired length.

The guide pipes are surmounted by a cap section (Fig. 3) consisting of a length of channel with two 4-inch-long pieces of nominal 2.5-inch aluminum pipe welded to the inside to serve as the upper sockets for the guide pipes. A central hole in the cap allows passage of the retrieving cable. The base, guide pipes, and cap are held together and braced by four pieces of nominal 0.25-inch steel cable attached with clevises and turnbuckles extending from the four corners of the cap section to the four similar corners of the base section (Fig. 2).

The slide section (Fig. 4), which holds the vibrator and the core barrel, consists of two vertical 13-inch pieces of 2.5-inch aluminum pipe joined by two 17.5- by 5-inch pieces of 0.25-inch aluminum plate. The vibrator is sandwiched between the two plates. The vertical pipes at either end slide up and down the guide pipes. Bolted to the bottom of the slide plate is a nominal

Table 1. Summarized results of field tests in various bottom sediments.

Sediment type	Vibrator Ball (mm)	Vibrator Piston (in)	Water depth (m)	Core length (cm) Max.[1]	Core length (cm) Min.	Core length (cm) Avg.	No. of tests
Sand	38		1.8 to 3.7	137.2	3.4	91.2	18
Sand	64		6.1 to 6.4	203.2	47.0	114.0	15
Sand		3	1.5 to 12.8	243.8	35.6	152.4	38
Mud over clay	64		8.2 to 9.4	138.4	38.5	102.1	2
Mud over clay		3	4.6 to 15.5	243.8	83.8	197.9	27
Sand over till		3	2.1 to 8.8	243.8	21.6	100.8	14
Mud over till	64		7.3	-----	-----	55.9	1
Mud over till		3	6.4 to 10.4	243.8	31.8	148.8	15
Mud over silt	64		7.9 to 9.1	144.8	35.6	79.5	5
Mud over silt		3	7.9 to 15.8	243.8	146.1	191.0	4
Mud with sand	38		9.4	57.2	33.0	49.3	3
Mud with sand	64		8.5	-----	-----	72.4	1
Mud with sand		3	4.6 to 15.2	243.8	24.1	188.0	17
Silt with clay	38		3.4 to 11.3	243.8	4.0	87.9	13
Silt with clay	64		4.0	201.9	96.5	146.1	4
Silt with clay		3	8.8 to 107	243.8	170.2	205.5	4
Total							181

[1]Maximum possible length is 243.8 centimeters.

Table 2. Field results of comparison tests at two locations between 3-inch long-stroke piston vibrator and paired 64-millimeter ball vibrators.

Vibrator	Compressor required (m^3/min)	Hoses required	Core length (cm)
Location 1 Bottom material: sand Water depth: 6.4 meters			
3-in piston	~0.7	2	109.2 177.8 180.3 101.6
64-mm ball	~2.8	4	203.2 129.5
Location 2 Bottom material: silt and clay Water depth: 4.0 meters			
3-in piston	~0.7	2	92.7 96.5
64-mm ball	~2.8	4	108.0 96.5

2-inch pipe floor flange. A short nipple and a nominal 2- by 2- by 0.75-inch pipe tee are threaded to the floor flange to receive the core barrel. A nominal 0.75-inch check valve is installed in the side opening of the tee by way of an elbow which places the valve in a vertical position. The floor flange and all joints are sealed, which creates a vacuum in the core tube during retrieval and holds the cored sediments in place.

2. Core Tube.

Nominal 2-inch polyvinyl chloride (PVC) pipe was used as core tube because it is reasonably inexpensive, readily available, and acts as both core barrel and disposable liner. This size pipe is also easy to handle and is large enough in diameter to show internal sediment stratifications. Two wall thicknesses of PVC were tested: SDR 26 (thin wall) and Schedule 40 (thick wall). These were tested with both blunt and sharpened ends. Of the two, the Schedule 40 with a sharpened end appeared to be the best. A pipe adapter can be used to thread the core tube to the floor flange, or in the case of the Schedule 40, the pipe can be threaded. No cutterhead or core retainer was used and in most cases the check valve was adequate to retain the core during recovery.

3. Vibrator.

The 3-inch vibrator used was a piston-type industrial vibrator model BH3 Long-Stroke, Impacting, manufactured by the National Air Vibrator Company, Houston, Texas. The vibrator weighs 33 kilograms and consumes 14 standard cubic feet per minute at 50 pounds per square inch. A 0.37-inch hose was used to supply air at 60 pounds per square inch to the vibrator and a 1.5-inch exhaust hose was used to return the air to the surface. Similar vibrators are available from other commercial firms. A direct impact-type vibrator with a hole in the base plate opening to the piston chamber should not be used unless an adequate seal can be made between the base of the vibrator and the mounting plate.

4. Field Operation.

For field use the vibrator is connected by hose to a suitable size compressor with a second hose of larger diameter connected to the exhaust port to exhaust the air above the water surface. The hoses should have sufficient wall strength to resist collapsing under the water pressure at normal coring depth. In order to keep air in the system at all times when the vibrator is underwater, an air valve is connected to the exhaust hose side. Pressure is thus kept in the system without activating the vibrator. If difficulty occurs in starting the vibrator underwater, vibration can be commenced before lowering. When the corer is on the bottom the lifting cable is slackened and coring commences. Vibration can be continued for a specified time (e.g., 10 to 15 minutes was used during the tests) or a tag line connected to the slide section can be payed out as the core is driven to roughly indicate when penetration is stopped or near refusal is attained. After penetration the vibrator is stopped, then pullout and recovery are commenced. When the corer is retrieved the core tube is removed, any excess empty tubing cut off, the ends capped and sealed with tape, and the core tube marked to identify it and indicate top and bottom.

IV. SUMMARY

A lightweight pneumatic coring device intended for use from relatively small research vessels was designed and tested. Results of field tests showed that the corer, when powered by a 3-inch piston vibrator, was capable of recovering 1- to 2-meter-long cores in nominal 2-inch Schedule 40 PVC pipe from a variety of sediments with recovery in some cases of up to 2.4 meters which was the maximum length of core tube used. The lightweight corer was found to be relatively easy to deploy and recover in seas from 0.6 to 1 meter high, with the 14.5-meter support vessel secured by anchors fore and aft. Additional support equipment required included a boom with winch and a 25-cubic-feet-per-minute air compressor.

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