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SAND CORING IN THE HALEKULANI SAND CHANNEL WITH THE BEACHCOR 67 CORING SYSTEM

By

FREDERICK M. CASCIANO and ROBERT Q. PALMER

MAY 1970

Prepared under the
National Science Foundation
SEA GRANT PROGRAM
(Grant No. GH-28)

DEPARTMENT OF OCEAN ENGINEERING

UNIVERSITY OF HAWAII

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Co-Principal Investigators:

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Approved by Charles L. Bretschneider
Chairman, Dept. of Ocean Engineering

Date June 30, 1970

FOREWORD

As part of the National Sea Grant Program, the University of Hawaii began receiving federal funds in September 1968 to conduct an inventory and recovery study of offshore sand deposits surrounding the Hawaiian Islands. The Department of Ocean Engineering and the Hawaii Institute of Geophysics are working jointly on this project.

The study required that representative core samples be taken of identified deposits. A survey of methods and devices for use in obtaining core samples was conducted; and a commercial coring device, priced within the limited means and compatible with operational capabilities of the project, was purchased (the Beachcor 67 Coring System).

During the period January to April 1969, project personnel field tested this apparatus while coring in the Halekulani Sand Channel off Waikiki Beach. These investigations were partially funded by the Harbors Division of the State of Hawaii, Department of Transportation; and carried out through facilities of the Look Laboratory of Oceanographic Engineering, Department of Ocean Engineering.

Results of the field tests, and laboratory sieve analyses of the core samples, are presented in this report.

ACKNOWLEDGEMENTS

The authors are grateful for the diving and operations assistance of Richard Luthy, Anthony Fallon, David Kern, Henry Koenig and Milton Soo of the Department of Ocean Engineering and of Fris Campbell of the Hawaii Institute of Geophysics, who also rendered advice and technical assistance in the operation and modifications of the corer.

They also acknowledge assistance from James Roy of the U.S. Army Engineering District, Honolulu, Hawaii, who provided sieve analyses of the core samples. Harbors Division, Department of Transportation provided partial funding.

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I. SAND CORING

A. Introduction

Many methods are available for taking core samples of the ocean floor. Welling and Cruickshank [1] classify sub-bottom sampling systems into seven categories by their method of penetration: impulsive, percussive, vibratory, rotary, oscillatory, jetted and combination. The authors list 36 different commercial corers available in 1966; undoubtedly, many others are on the market at this time.

The most common examples of impulsive corers, which penetrate in a single motion, are of the gravity and piston types. These consist of a weighted barrel which is lowered to the bottom on a cable; and, near the bottom, a releasing device which is tripped to allow the corer to fall free for the remaining distance and drive into the sediment. Both the gravity-type and the piston-type corers achieve their penetration from free-fall kinetic energy. The piston corer differs from the gravity corer in that it has a movable piston inside the core barrel, which reduces the pressure in the tube above the sample to obtain longer and less disturbed cores. A common type of gravity corer is the Phleger; Kullenberg and Ewing are common piston corers. A free-fall corer has been developed which eliminates use of a lowering cable. A float brings the core to the surface when the outer barrel and weights are expended [2], [3].

Percussive types of corers use repetitive impulses to hammer the device into the bottom. These have been used mainly for blast hole drilling [1].

Vibratory corers use hydraulic, pneumatic, or electric power to drive the core tube into the sediment. The natural frequency of vibration of the material, which is related to the velocity of sound in it, controls the optimum frequency to achieve best penetration. These have experienced good results in sand and unconsolidated sediments [1]. The "Vibracore," by Alpine Geophysical Associates, Inc. (65 Oak St., Norwood, New Jersey 07648); the "Vibro-corer," by Ocean Science and Engineering, Inc. (4905 Del Ray Ave., Washington, D. C. 20014); and the Vibratory corers by Marex, Ltd. (High St., Isle of Wight, Cowes, England, 3906) and Oceanoics, Inc. (6204 Evergreen, Houston, Texas 77036) are examples of this type.

Rotary drilling techniques, combined with a drive sampler, are used to sample deeper sediments as exemplified by the Glomar Challenger's work on project JOIDES [2]. This type of coring is usually carried out from drilling ships or platforms. Oscillatory methods are similar to rotary drilling and are not frequently used.

The jetting technique uses high pressure water or air to dig into the bottom. The Beachcor 67 System (American Underseas Company) removes cores by pumping water down between an inner and outer tube, thus acquiring cores as deep as 10 ft. in the inner tube. The hydraulic mole corer, as described by Rosfelder [4], is capable of burrowing into the sediment and can acquire intermittent cores from deeper layers.

Of these methods, gravity and piston corers are probably the most rapid and least expensive methods of coring the ocean bottom, when the sediments are soft. However, when cores are required in the stiff sediments of the continental shelf (sand, gravel, clay), these methods are unsatisfactory. The ability of sand to resist penetration from impact, best illustrated by the use of sand bags to stop bullets, generally precludes the use of impulsive devices [5].

Dr. Douglas Inman, Scripps Institute of Oceanography, and Dr. David Duane, Chief Geology Branch, Coastal Engineering Research Center, recommended a vibratory corer for use in sand [6], [7]. Reports of sand inventories along the East Coast of the United States disclose the use of the "Vibracore" to obtain cores up to 16 feet long [8].

Although these vibratory type devices appear to be best for sand coring, they are expensive and extremely heavy, requiring a relatively large ship and attending crew. The Alpine Vibracore, Model 270, sells for $13,962 FOB, New Jersey, without compressor, weighs 2,500 lbs., and requires a crew of four to six men to operate with the assistance of a crane.

The Ocean Science and Engineering models M-30,000 and K-365 appear to be similar in size and operational requirements; however, a somewhat-smaller, diver-operated model (1136) is available for which only general descriptive information has been received. The Marex and

Oceanonics models appear to be about the same size as the Alpine Model 270. Based on the figures quoted for the Alpine model, the vibratory type of corer (possibly with the exclusion of the O.S.E. model 1136) was beyond the scope of monetary, and other support capabilities, of the present Sand Inventory Program [9], [10].

In light of the above, a "Beachcor 67" coring system was purchased jointly by the Ocean Engineering Department and the Hawaii Institute of Geophysics, at an approximate cost of $3,400 from CM^2 Inc. (193 Constitution Drive, Menlo Park, California).

B. Beachcor 67 Coring System

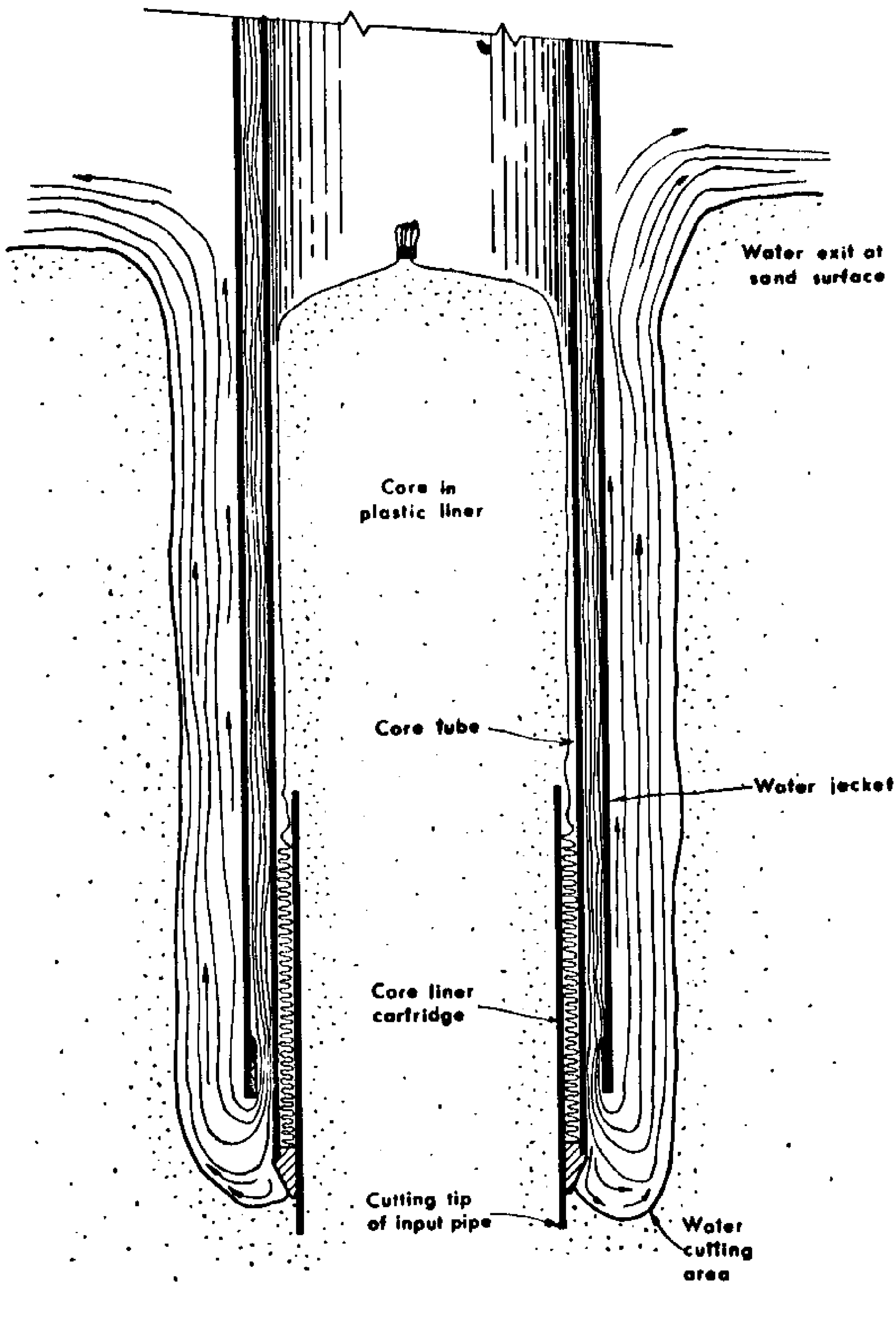
The Beachcor 67 system was designed by the American Undersea Co. for the purpose of taking cores in sand, especially from beach areas. The working end of the corer consists of two, 10 ft. pieces of galvanized steel tube, one inside the other, concentrically fitted. The outside diameters are 3 1/2" and 4". A pre-packaged polyethylene core liner is slipped over a cylindrical stainless steel input pipe (core catcher and cutting tip assembly, 2 7/8" x 6") and inserted in the cutting end of the inner or "core tube." The core liner, or core case, is .004" thick by 3 1/8" diameter by about 8' long extruded polyethylene tubing and is folded accordion style on a thin sleeve.

The corer functions through the action of water which is pumped down between the core tube and outer tube, or water jacket, to jet away the sand just above the cutting tip. As the sand is washed away around the periphery of the tip, the weight of the corer causes it to drop over the center cylinder of sand forcing it up into the input pipe and against the top end of the polyethylene liner. As the corer continues downward, the core liner unfolds permitting the sample to move into it, thus providing a carrier which eliminates friction between the sand and the inside of the core tube. The core, in its plastic container, moves up through the core tube with negligible friction [11]. See Figure 1.

Upon achieving full penetration (10 ft.) the trap-door-type core catcher is closed manually by a cable extending up to a lever on the top of the core tube. The corer is then easily withdrawn since the action of the continued stream of water emanating at the tip keeps sand from packing against the outside of the water jacket. The core is then removed from the core tube, neatly packaged in its plastic casing.

Cores taken with the Beachcor 67 system are not "undisturbed" in the strict sense of the word. Since the inside diameter of the input tube is less than that of the core liner, cores are shortened by 25% as they expand into the liner. Thus, lines drawn on the liner at 9" intervals represent one foot of penetration. According to the manufacturer natural layering and horizons retain their relative location and thickness in spite of diameter change [11].

The corer comes equipped with a small gasoline-powered pump, four 50 ft. lengths of 2 inch diameter plastic hose, and a small hand-operated winch.



CUTAWAY VIEW OF CORER IN ACTION (From ref. 11)

FIGURE 1

As mentioned previously, the Beachcor 67 system was designed primarily to operate on dry beach or in ankle to knee deep water; however, the company implies that the device can be operated successfully by divers for coring underwater. Unfortunately, instructions were not furnished by the supplier for operation in this mode. To modify the corer for this purpose a weight stand was welded to the top end of the core tube, by the manufacturer; and an adapter was supplied, at additional cost, to be fitted into the end of the plastic core liner, which is otherwise taped closed. The adapter, a cylindrical section 3 1/4" dia. x 1" long made of thin brass sheet metal, is essentially a filter which allows water to pass but not sand.

The purpose of this adapter apparently is to prevent the plastic liner from unfolding prematurely when lowering through the water. The purpose of the weight stand is to permit the addition of weight to make up for loss due to buoyancy. (Weight on the corer is necessary to force the sand through the input pipe and into the liner.)

C. Underwater Field Testing the "Beachcor 67" System

From January to April 1969, coring operations were carried out in the Halekulani Sand Channel off Waikiki Beach. The purpose of this undertaking was to obtain 15 cores of at least 8 ft. in length from various depths in the channel ranging from 20 to 80 ft. Analysis of these cores assisted the Harbors Division, Hawaii Department of Transportation, to evaluate the potential of this sand channel as a source of sand for the proposed

Kuhio Beach restoration project. The request from the State for assistance in this project provided an excellent opportunity to field test the acquired coring system.

The following details of our experience with the "Beachcor 67" are presented to assist the small Hawaiian contractors considering exploitation of offshore sand, who cannot afford expensive equipment and who, therefore, might benefit from these results. Little or no guidance, on the diver-operated use of the system, is supplied by the manufacturer.

The corer weighs approximately 85 lbs. and is difficult to handle when operating from a small boat. The Look Laboratory boat, an 18 ft. fiberglass skiff powered by an inboard/outboard unit, was modified by adding a small davit with a manual winch to facilitate lowering and recovery of the corer. Photo (a) in Figure 2 shows the boat with corer, pump, and hose on board.

After several trials the handling problem at and near the interface was overcome. The corer was lifted from its horizontal stowed position on the boat gunwale, and lowered into the water with the winch cable attached to a rope strap around the corer at the center of gravity. It was lowered away until the weight was borne by a tagline attached to a shackle on the top of the corer, thus "hanging it off" in the vertical position. The winch cable was then shifted to this shackle by a swimmer, the tagline disconnected, and the corer lowered to the bottom. Retrieval was accomplished by the same procedure in reverse.

Figure 2 (a) 18' Boat with Davit, Corer, Pump and Hose

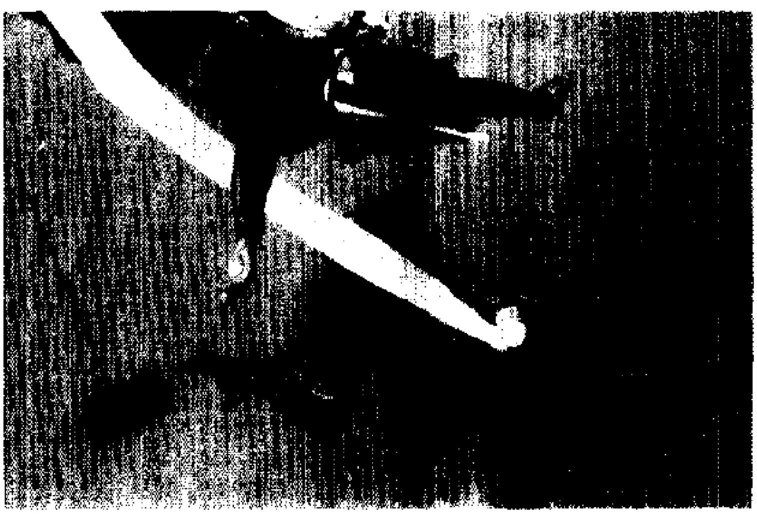


Figure 2 (b) Attempt to Capture Jetted Sand with Core Tip and Liner Removed (Unsuccessful)

Initial attempts at obtaining cores were only occasionally successful. Some of the difficulties and symptoms encountered are listed below:

1. Incomplete penetration in sand. (The problem was frequently traced to coral fragments lodged in tip assembly.)

2. After 10 ft. penetration, no core was obtained because the polyethylene liner had not extended and was still folded in place.

3. After 10 ft. penetration, liner completely or partially extended but with only a 1 to 3 ft. core retained.

4. At commencement of coring, corer would topple over into horizontal position on bottom, and two divers would be unable to right it.

5. The core catcher would not close fully allowing part of the core to wash out as the corer was being raised to the surface. (Generally the problem was traced to coral fragments wedged in the catcher.)

6. The core catcher and tip assembly, core liner, and adapter were lost in sand when corer was extracted. (Only one occurrence.)

During the two months of coring, attempts were made to resolve these difficulties in order to increase the probability of acquiring of an 8-10 ft. core with each try.

Referring to the numbers above, problem (1) was not particularly bothersome, and could not be corrected as it depended upon the amount of large coral fragments in the sand.

Problems (2) and (3) were the major sources of difficulty encountered when using the Beachcor system. That is, after complete penetration (and with high hopes) when the corer was brought back aboard, either the liner was not extended or the liner was completely extended with only a short core or no core retained. It was assumed in the first case that either:

a) The liner cartridge was being squeezed too tightly when inserted in the core tube so as to prevent its being pulled off the liner cylinder, or

b) The underwater adapter (brass filter) was jamming inside the core tube.

In the second case (problem 3), several possibilities existed:

a) The heave and roll motion of the boat, transmitted to the corer when lowering, resulted in waterflow through the tube which caused the liner to extend prematurely.

b) Air pockets trapped in the liner caused premature extension when lowering.

c) In the process of taking the core either incorrect throttling of waterflow, incorrect setting of the length of cutting tip beyond the water jacket, incorrect downward force of corer (weight), or the rocking motion used by divers to help penetration was causing the jetting water to extend the liner.

In an attempt to correct both problems, a device as shown in Figure 3 was fabricated to hold the liner in the packaged position until coring started, and to guide its extension rate as the corer penetrated the bottom. Although the device appeared sound in principle, the addition of this extra apparatus severely complicated the already difficult handling task for the divers, it was abandoned after one unsuccessful and frustrating attempt.

Other corrective action was taken:

a) The throttling valve, fitted at the corer instead of at the pump, was carefully regulated by the divers to provide only enough flow to sustain downward motion.

b) The cutting tip extension was varied from 1" to 2 1/2" on separate trials.

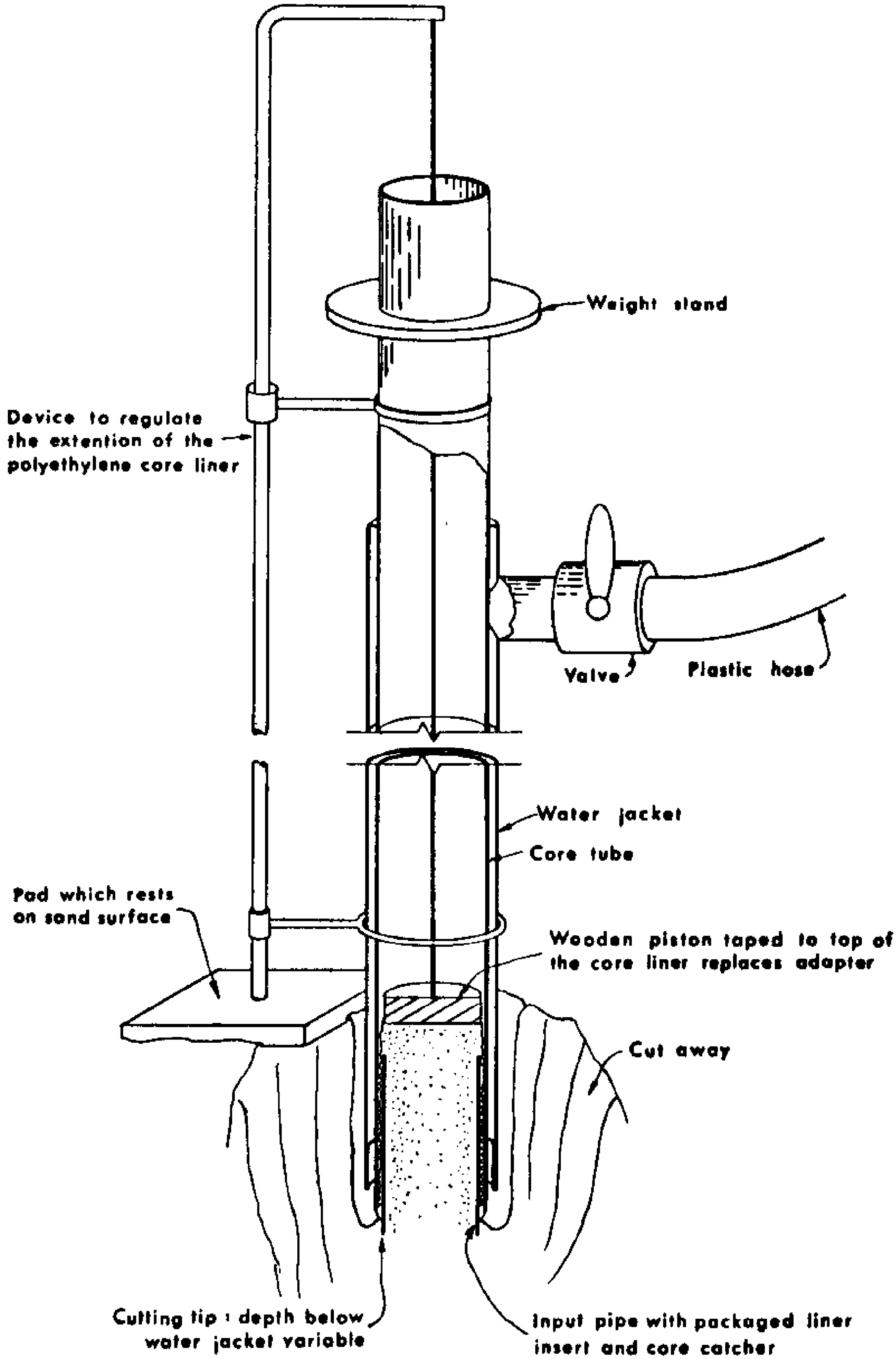
c) Care was taken to avoid rocking the corer during operation as it was theorized that this might result in simply excavating a cavity into which the corer would fall without taking a core.

d) Upon placing the corer in the water, the cutting end was held above the top end for several seconds to allow trapped air to escape from around the liner before lowering to the vertical position.

Despite the above precautions, the corer continued to be unreliable.

A standard 50 lb. core weight was then added at the weight stand. (None had been used previously.) The added weight appeared to increase the length of cores obtained (up to 8'); however, the percentage of successful core recoveries was not improved. Also, the additional weight made the corer top heavy and the chance of it toppling, as the winch cable was slacked, was increased (problem 4). The tendency for the boat to swing at anchor and aggravate this difficulty was alleviated somewhat by use of two-point moor to hold the boat approximately above the corer.

Because an additional 50 lbs. seem to help, a second 50 lb. weight was added. The corer now became so top heavy that it was very difficult for the divers to hold it erect long enough to allow the cutting tip to penetrate the bottom sufficiently to improve stability. (See photograph (b) Figure 4.) Until this point the procedure has required the two divers to follow the corer



DEVICE TO IMPROVE CORING (UNSUCCESSFUL)

FIGURE 3

down; immediately as it touched bottom, the winch tender would slack the line so that the core operators were unhindered by connections to the surface. With the 100 lbs. of added weight, it became necessary to pay out line gradually, after touching bottom, until the corer had penetrated several feet, to avoid toppling. This required a third swimmer in the water, snorkling on the surface, to instruct the winch tender. Because this procedure depended upon good underwater visibility, and also subjected the corer to the boat motions during the initial phase of coring, it was concluded that 50 lbs. of weight was preferable.

At this point, the input pipe (tip and core catcher), core liner, and underwater adapter were lost upon extraction of the core tube (problem 6). The input pipe is held snugly, when first inserted into the core tube, by the packaged liner cartridge which fills the void space. When the liner is extended, the input pipe and core are held in the tube only by the core-catcher trip cable. As the cable is attached to the catcher arm by simply slipping a ball-end fitting into an open ended slot, it apparently can work free as easily. This was prevented by the addition of a safety wire secured at one end to the input tube and the other to the water jacket.

During the interim awaiting replacement parts, several other methods of using the basic device without the polyethylene liner or proper cutting tip were tried. In one case a standard clear plastic core pipe was inserted into the core tube and secured so that one end protruded two inches below

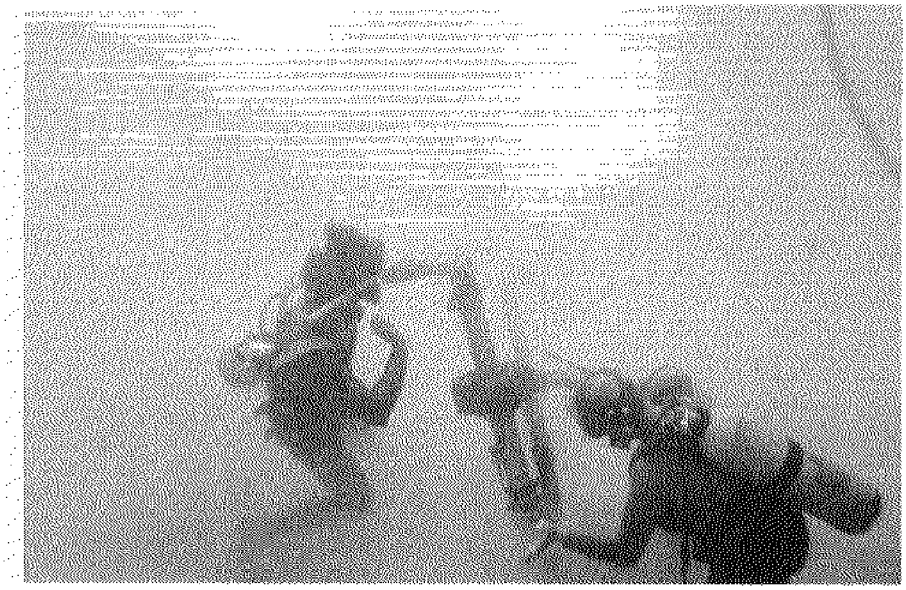


Figure 4 (a) Corer at 10' Penetration into Sand

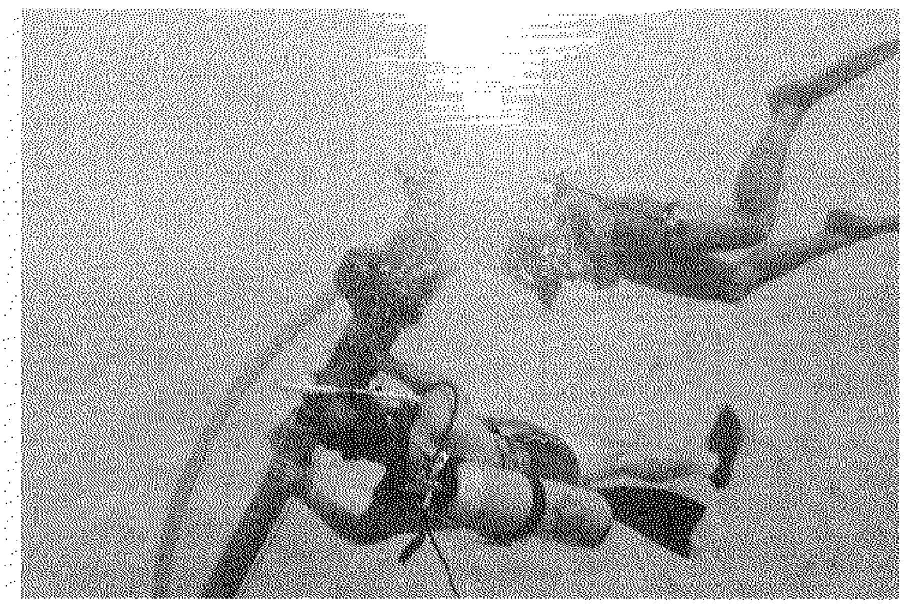


Figure 4 (b) Corer Toppling at Commencement of Operation--
Two 50 lb. Weights Attached

the water jacket. This was tried with and without a core catcher installed in the top; in most instances 2 to 4 ft. cores were obtained. An attempt to simply capture a representative amount of the core, with no concern about maintaining the shape or layering of the core, is shown in Photo (6) of Figure 2. Here a cloth bag was affixed to the top of the core tube with the remainder of the tube empty. Water flow was throttled maximum to attempt to force the flow up the tube and into the bag carrying the sand with it. This was unsuccessful.

Upon receipt of the new tip assembly and adapter, efforts were renewed to insure proper extension of the polyethylene core liner; that is to prevent jamming and failure to extend, or premature extension. The underwater adapter, which fitted into the end of the liner, was lengthened with brass rod to prevent canting and wedging in the core tube. This made no noticeable improvement. A new adapter then was fabricated from 2" PVC pipe (2 3/8" outside diameter) by 7 inches in length and fitted with a screen inside. The adapter was tied off to the core tube, during lowering, to hold it in place and released just before touching bottom. Unfortunately, the surge running through the pipe, caused by wave effects, induced the liner to extend around the periphery of the adapter because of the diameter difference of about 1 inch between the adapter and the core tube.

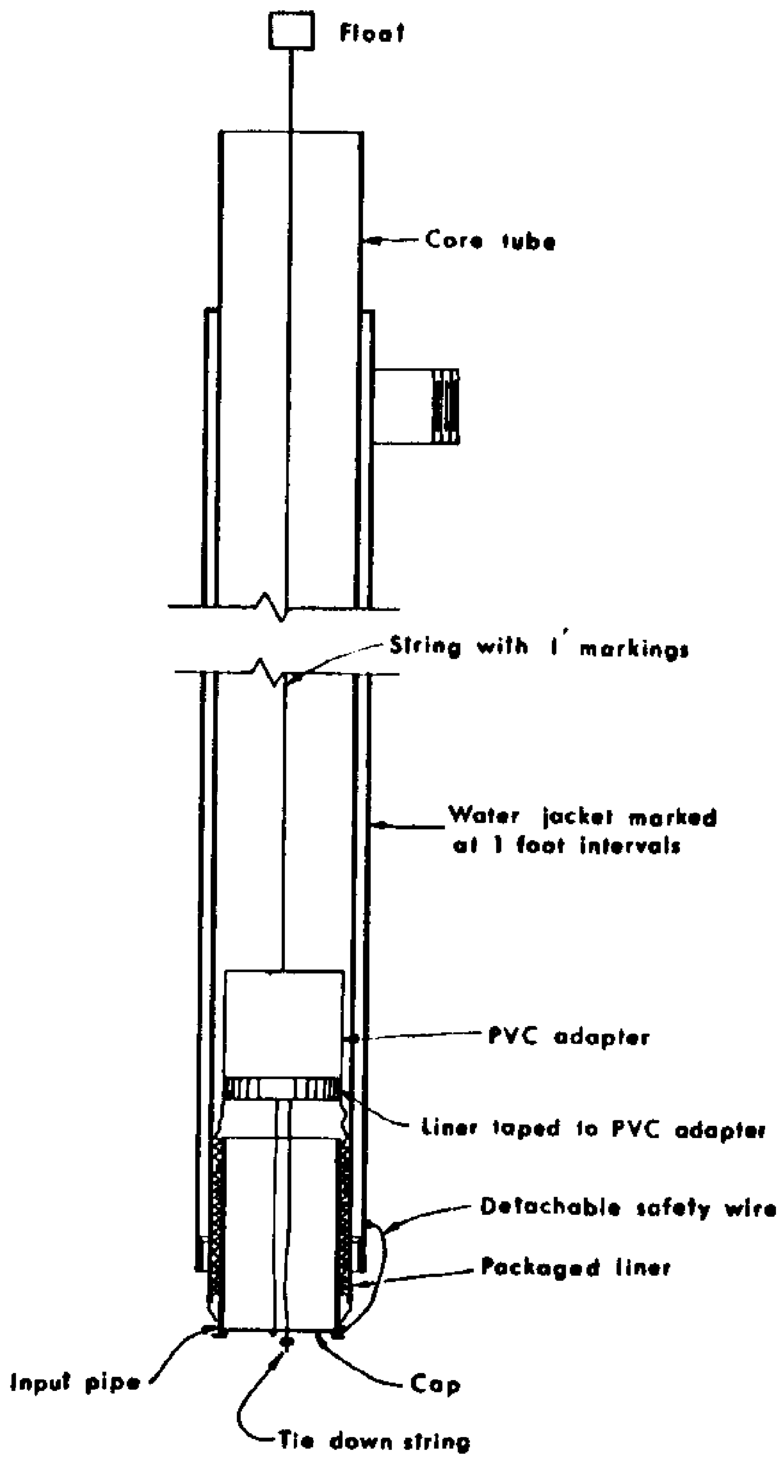
A third adapter was made from 2 1/2" PVC (2 7/8" outside diameter) 6 1/2 inches long. The adapter was tied down to a plastic cap (used to seal standard plastic core tubes) inverted and fitted in the end of the cutting tip.

See Figure 5. Just prior to the corer reaching bottom the cap was removed by a diver, in turn freeing the adapter. The cap provided additional protection against surge through the tube as well as a convenient means for securing the tie down.

Two measures were taken to ensure proper extension of the liner. First the inside of the core tube was machined smooth over the first six inches of the lower end--this to decrease the squeeze on the packaged liner. Each liner was also sprayed with silicone oil before insertion. Also, a string and float was attached to the upper end of the PVC adapter. The string was marked in one foot increments and the length was such that the float just appeared at the corer top when coring commenced. The string, of course, passed up the center of the core tube. The water jacket was also marked in one foot increments.

As the corer penetrated the bottom, comparison of the penetration depth with the marks on the float string gave an immediate indication of the extension of the liner. If the liner became jammed, it could be freed by a gentle tug on the string. The float would also signal a premature extension of the liner so coring could be halted. See Figure 5.

Loss of sand caused by incomplete closure of the core catcher (Problem 5) was partially alleviated by having the divers lash a piece of cloth over the bottom of the corer when it cleared the hole upon extraction. This, however, did not prevent loss during the exit from the hole.



FINAL SCHEME TO IMPROVE CORER RELIABILITY

FIGURE 5

D. Conclusions and Recommendations

The following techniques and modifications were found to be helpful and should be followed during underwater use of the Beachcor 67:

1. Use the new adapter for the top of the liner (as described in Paragraph 3 on page 16 and shown in Figure 5) with the tie-down string and cap, the marked string and float, and the one foot markings on the water jacket.

2. Ensure that the first six inches of the inner surface of the core tube is smooth, by machining if necessary, and spray the liners with silicone oil before insertion.

3. Use a safety wire to prevent loss of the input pipe and liner.

4. Set the cutting tip extension at 1 1/2" beyond the collar.

5. Use one 50 lb. core weight.

6. Remove the plastic cap and release the adapter tie-down just before the corer touches bottom.

7. Slack away the lowering line as soon as the corer touches bottom.

8. Throttle the water flow so as to just sustain penetration.

9. Avoid rocking the corer during operation.

10. Cover the cutting tip with cloth when it exits the hole to prevent loss of fines.

Near the end of coring operations, cores of 8 to 10 ft. were acquired intermittently; however, the final resolved combinations of methods and modifications listed above was only tried one time because of termination of the Halekulani coring work. Thus, the reliability of the corer employing these methods is not yet proved over a series of trials.

If future testing shows that the device can reliably extract 8-10 ft. cores using the procedures described, then it would be concluded that this corer could be used successfully for the Hawaii Sand Inventory Program for coring on a limited basis. That is, viewing the program with reference to the overall objective--to inventory offshore sand around all the Hawaiian Islands--the corer could be used to get a few representative cores from certain areas or deposits. It would not be reasonable to assume that extensive coring could be carried out with this device. This in part is because of limitations imposed upon the divers. In most cases our divers (non-professional) are limited by no-decompression bottom time in deeper waters or physical exhaustion caused by repeated entry and exit in shallow water. In shallow water, say 15 ft., as many as five or six cores could be taken in a day. As water depth increases the possible number of cores decreases to one per day in about 75 ft. of water. The increased depth reduces bottom time per tank to about 20 minutes. With the increase in descent and ascent time, this is about the time required to take one core.

At depths much greater than 75', this coring system is not feasible if decompression dives are to be avoided. If further trials with the Beachcor show no satisfactory improvement in effectiveness using these modifications and techniques, serious consideration will be given to the purchase of another device.

In either case, if extensive coring is to be accomplished, i.e., numerous cores in a variety of depths, a more effective and efficient coring system should be used. This apparently will require the service of a larger vessel and attending crew.

With respect to the performance of the Beachcor 67 system on land, it should be pointed out that trials made in this mode were satisfactory.

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II. LOCATION AND ANALYSIS OF CORE SAMPLES

A. Core Locations

(1) Three markers were placed along the sand channel, approximately in the center, to provide reference points.

(2) Horizontal sextant angles were used to fix all positions on the chart. The following reference points were used for the sextant angles:

Left: KKUA Radio Tower

Center: Ala Moana Tower Restaurant (La Ronde)

Right: Royal Hawaiian Hotel cupola

(3) The following is a tabulation of core positions and depths:

Core Number	Approx. Depth of Water-ft.	Left Angle		Right Angle	
1	22	34°	08'	69°	50'
2	28	34°	02'	67°	03'
3	28	34°	00'	67°	18'
4	28	25'	Diamond Head of Core #3		
5	30	34°	14'	66°	16'
6	45	35°	00'	63°	55'
7	36	34°	35'	64°	57'
8	35	34°	30'	65°	14'
9	43	34°	10'	62°	10'
10	20	34°	00'	69°	03'
11	34	34°	10'	64°	33'
11A	34	10'	Inshore from #11 core		
12	58	34°	06'	58°	12'
12A	55	35°	00'	58°	25'
13	50	35°	39'	64°	13'

Core Number	Approx. Depth of Water-ft.	Left Angle		Right Angle	
14	42	34°	50'	64°	32'
15	63	34°	25'	58°	03'
17	35	34°	10'	65°	33'
18	72	33°	47'	54°	45'
Marker C	45	34°	28'	61°	52'
Marker D	30	34°	00'	65°	00'
Marker E	20	33°	50'	69°	30'

(4) A chart of the area showing the location of the Halekulani Channel and the core positions is shown as Figure 6.

B. Sieve Analysis

Cores were divided into sections depending upon their length. A gradation analysis was performed for each section by the Materials Testing Laboratory of the U.S. Army Corps of Engineers, Honolulu District. Gradation curves as shown as Figures 7(a) - 7(i) are representative of the 45 samples analyzed from the 19 cores acquired. The complete set of curves is not presented. Those given are representative of the entire set which vary only slightly. The entire set is available upon request. Median particle size varied from about 0.15 to 0.35 mm.

The grey color of all but surface samples was initially thought to result from basaltic constitutents in the sand. Chemical analyses showed minor percentages of basalt in both surface and deep samples with actually a greater amount in the surface sample (3.7%-surface, 1.5%-deep). The cause of the grey color is still in question, although it is likely the result of staining of the calcareous grains by decomposing organic material. Exposure of a sample to sun and rain for more than three months has failed to produce significant bleaching.

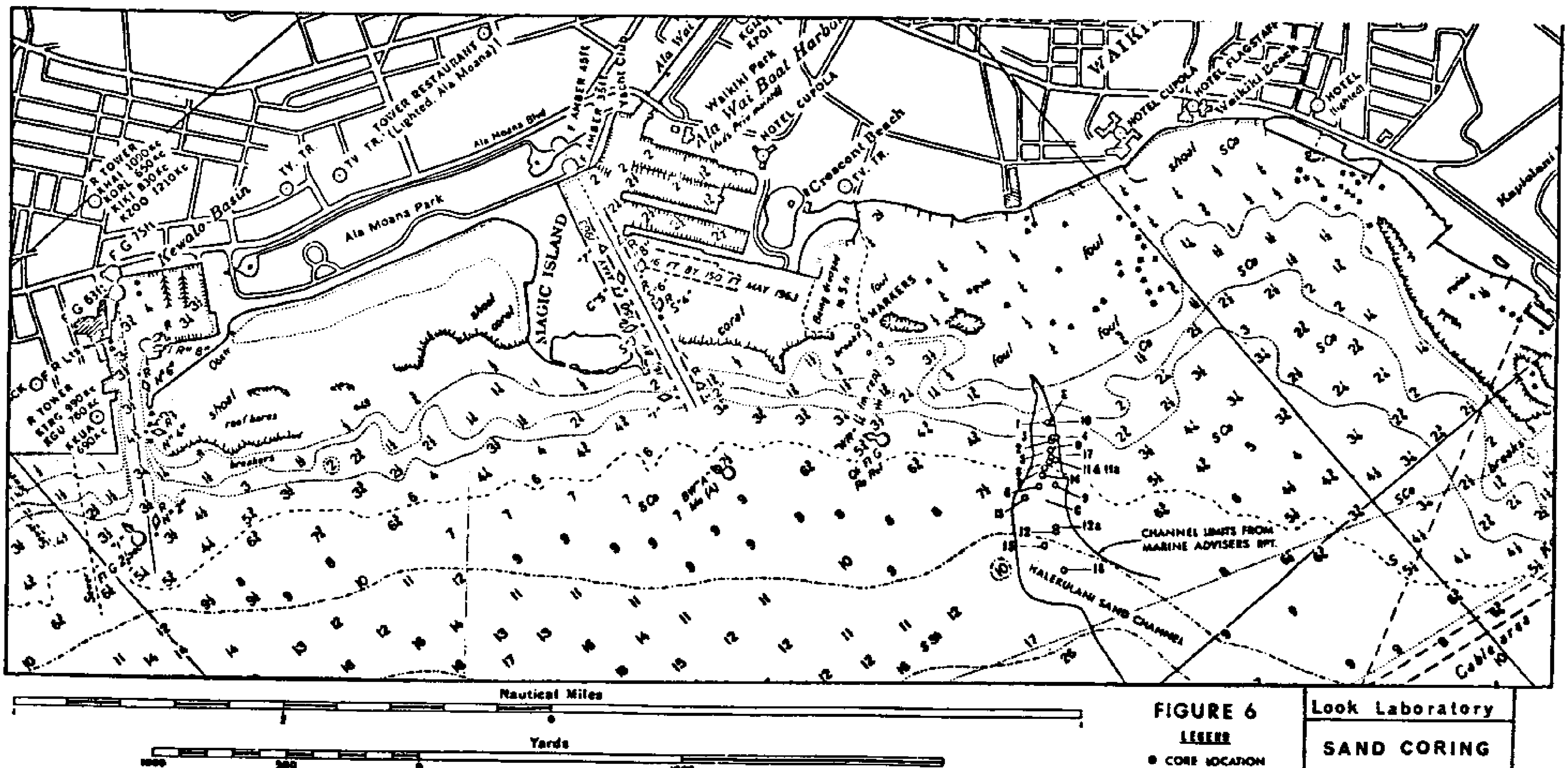

FIGURE 6

LEGEND

- ● CORE LOCATION
- · MARKER LOCATION

Look Laboratory

SAND CORING

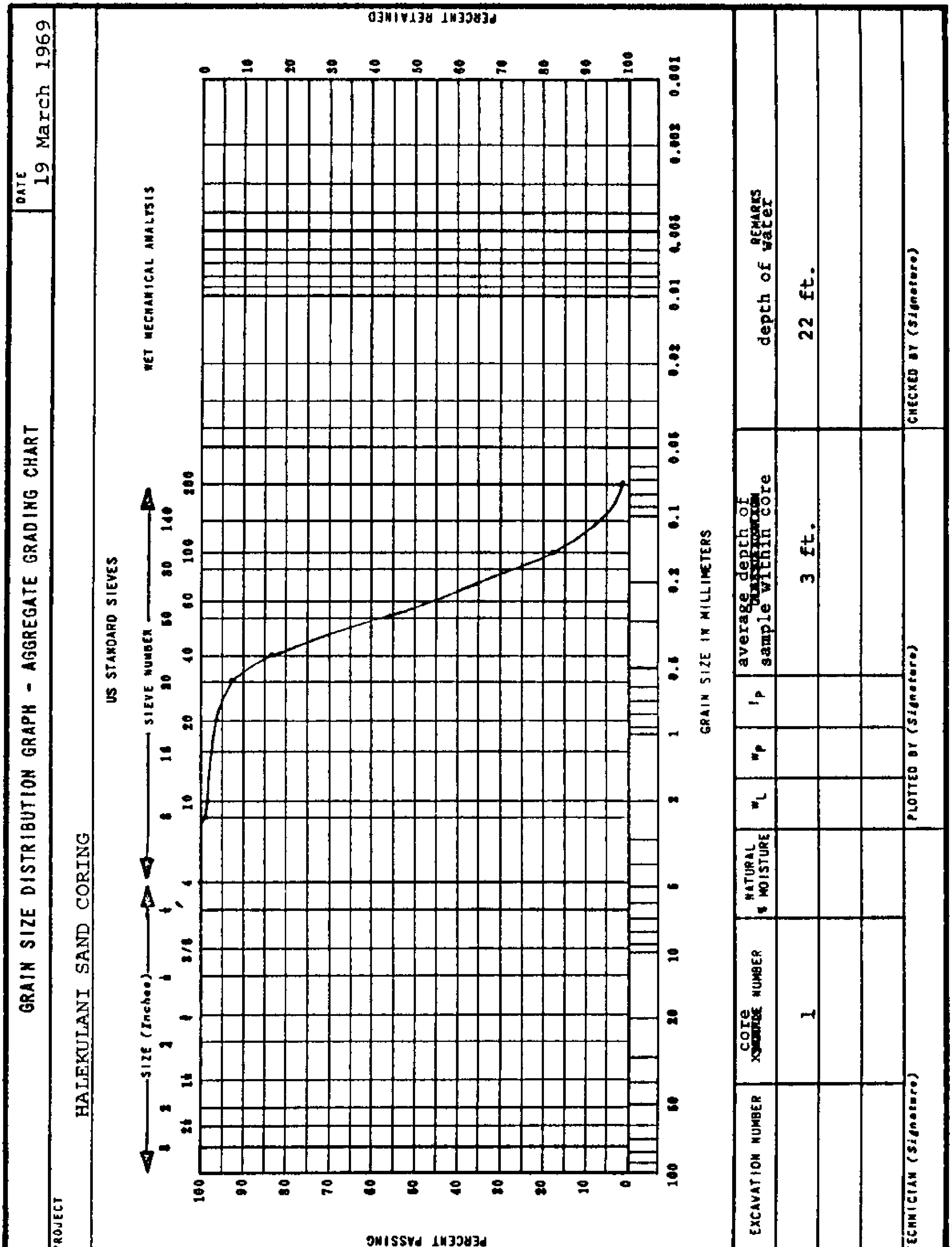
GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART
PROJECT
HALEKULANI SAND CORING
DATE
19 March 1969
US STANDARD SIEVES
SIZE (Inches)
SIEVE NUMBER
WET MECHANICAL ANALYSIS
PERCENT PASSING
PERCENT RETAINED
GRAIN SIZE IN MILLIMETERS
EXCAVATION NUMBER
core NUMBER
1
NATURAL % MOISTURE
average depth of sample within core
3 ft.
REMARKS
depth of water
22 ft.
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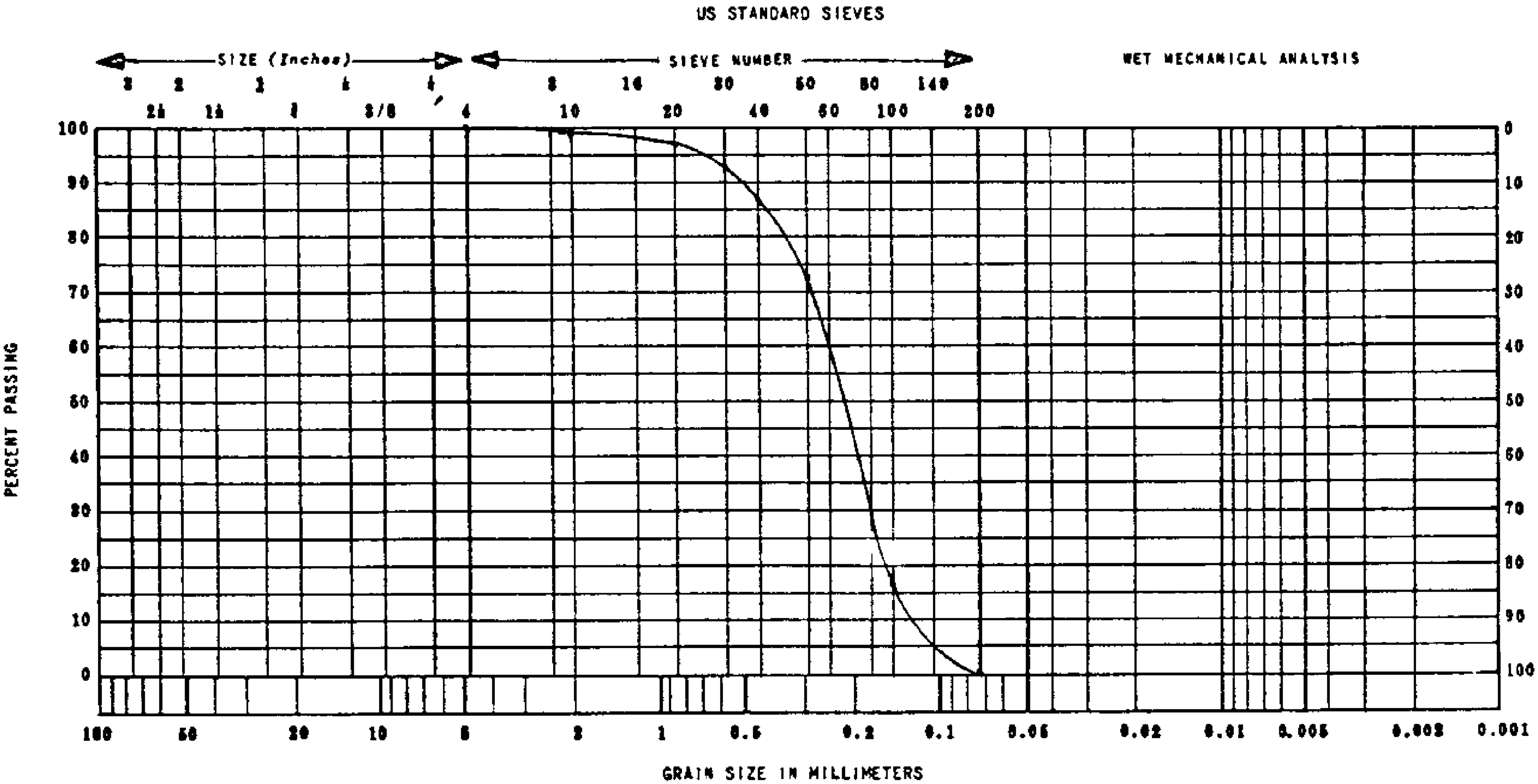
FIGURE 7(a)

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 19 March 1969

PROJECT: HALEKULANI SAND CORING



EXCAVATION NUMBER	core SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	average depth of sample within core	REMARKS depth of water
	3					surface	28 ft.

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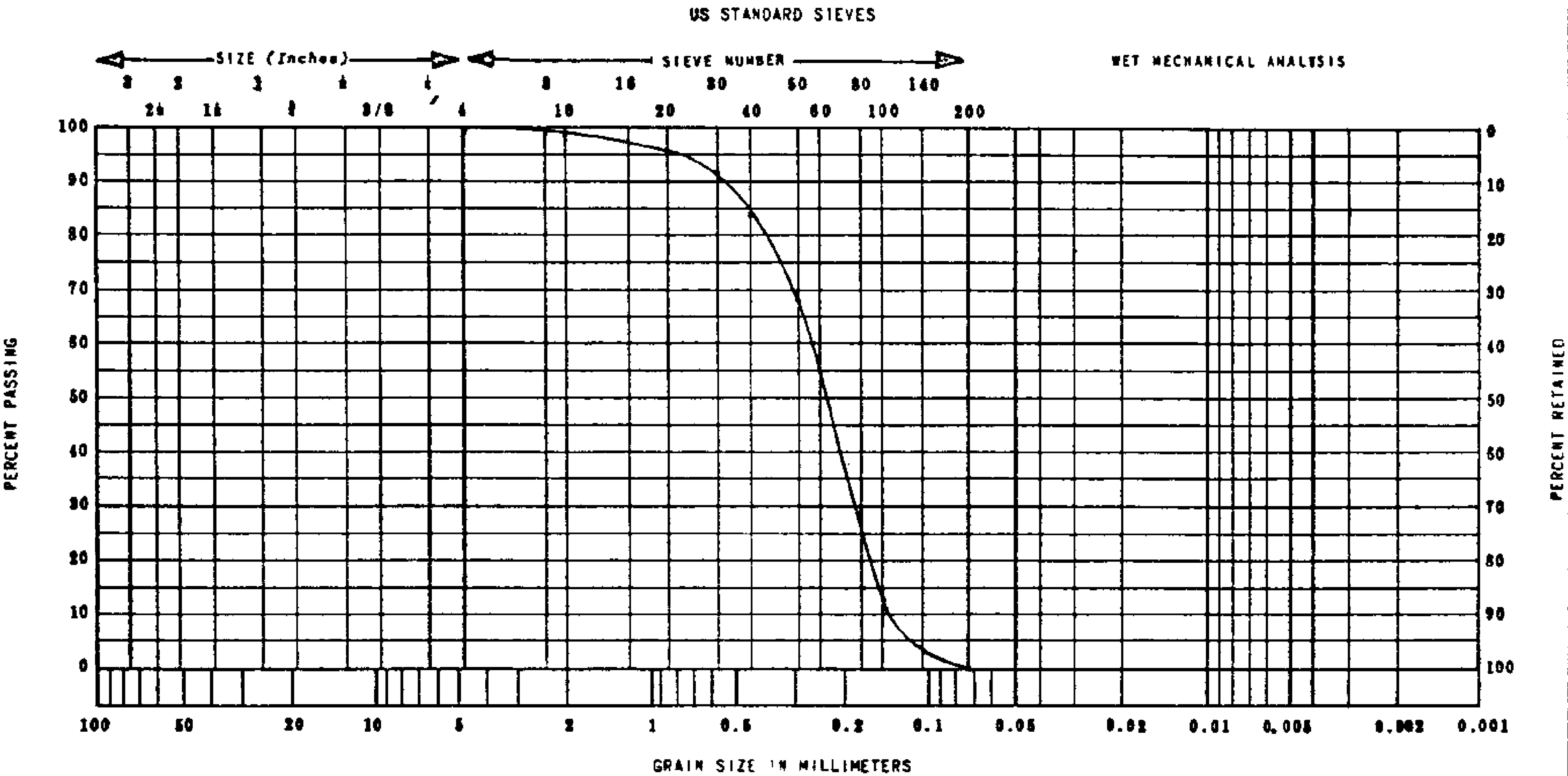
NAVY—PEARL HARBOR, T H

FIGURE 7(b)

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 19 March 1969

PROJECT: HALEKULANI SAND CORING



EXCAVATION NUMBER	core NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	average depth of sample within core	depth of water REMARKS
	3					2.5 ft.	28 ft.

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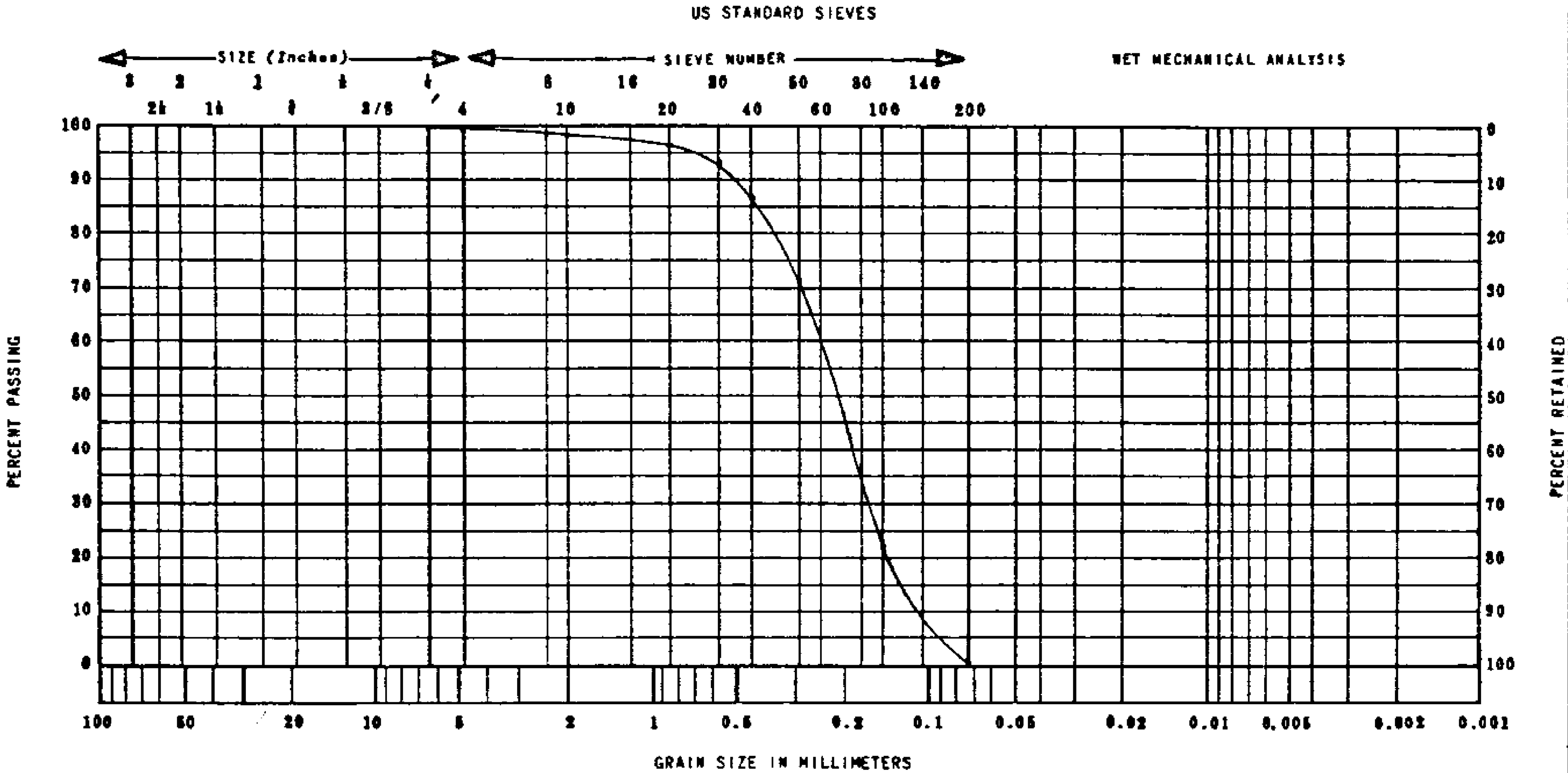
FIGURE 7(c)

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE 19 March 1969

PROJECT HALEKULANI SAND CORING



EXCAVATION NUMBER	core NUMBER	NATURAL % MOISTURE	w_L	w_P	a I_P	average depth of sample within core	depth of water REMARKS
	3					7 ft.	28 ft.

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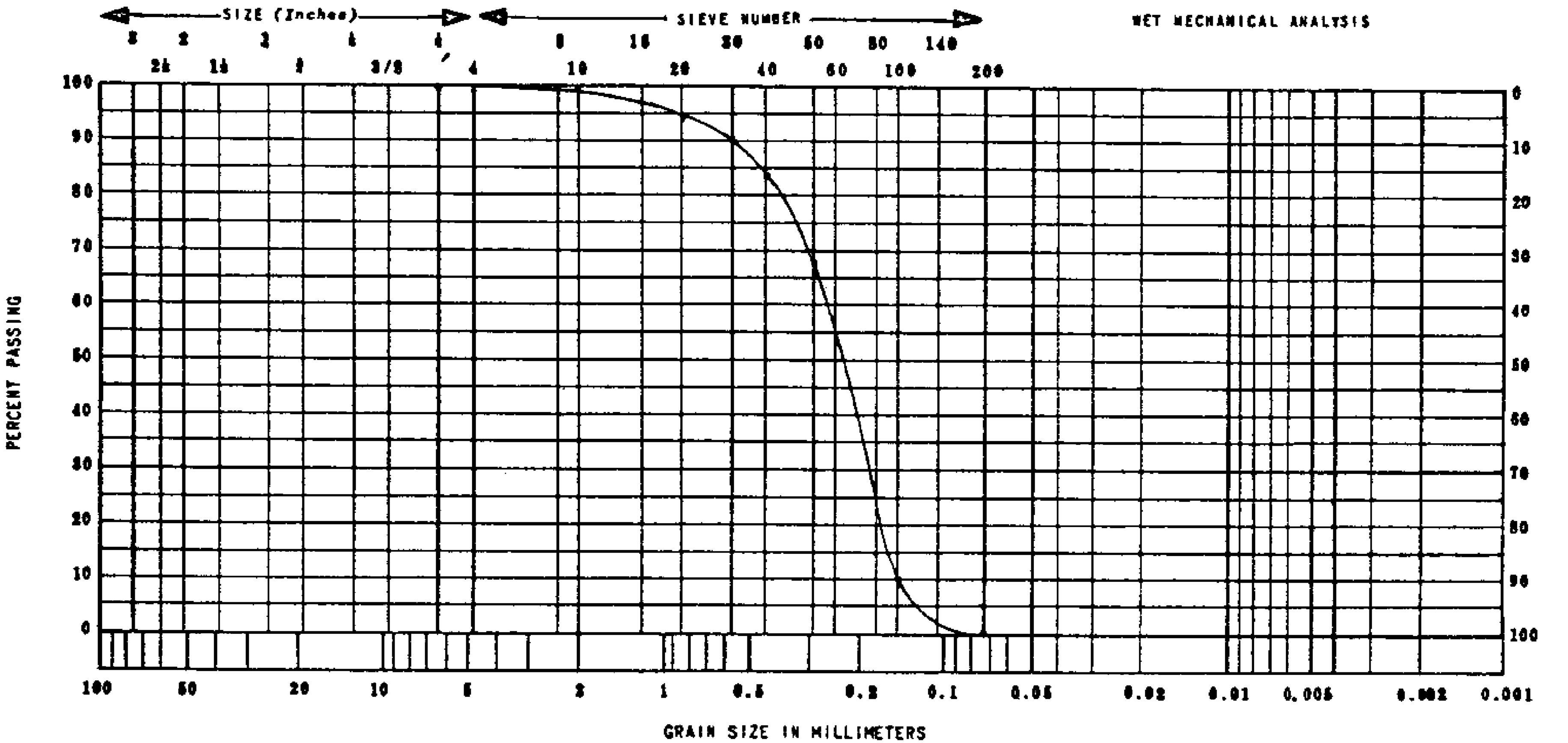
NAVY—PEARL HARBOR, T. H.

FIGURE 7(d)

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 19 March 1969

PROJECT: HALEKULANI SAND CORING



EXCAVATION NUMBER	core ~~SAMPLE~~ NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	~~CLASSIFICATION~~ average depth of sample within core	REMARKS depth of water
	5					1 ft.	30 ft.

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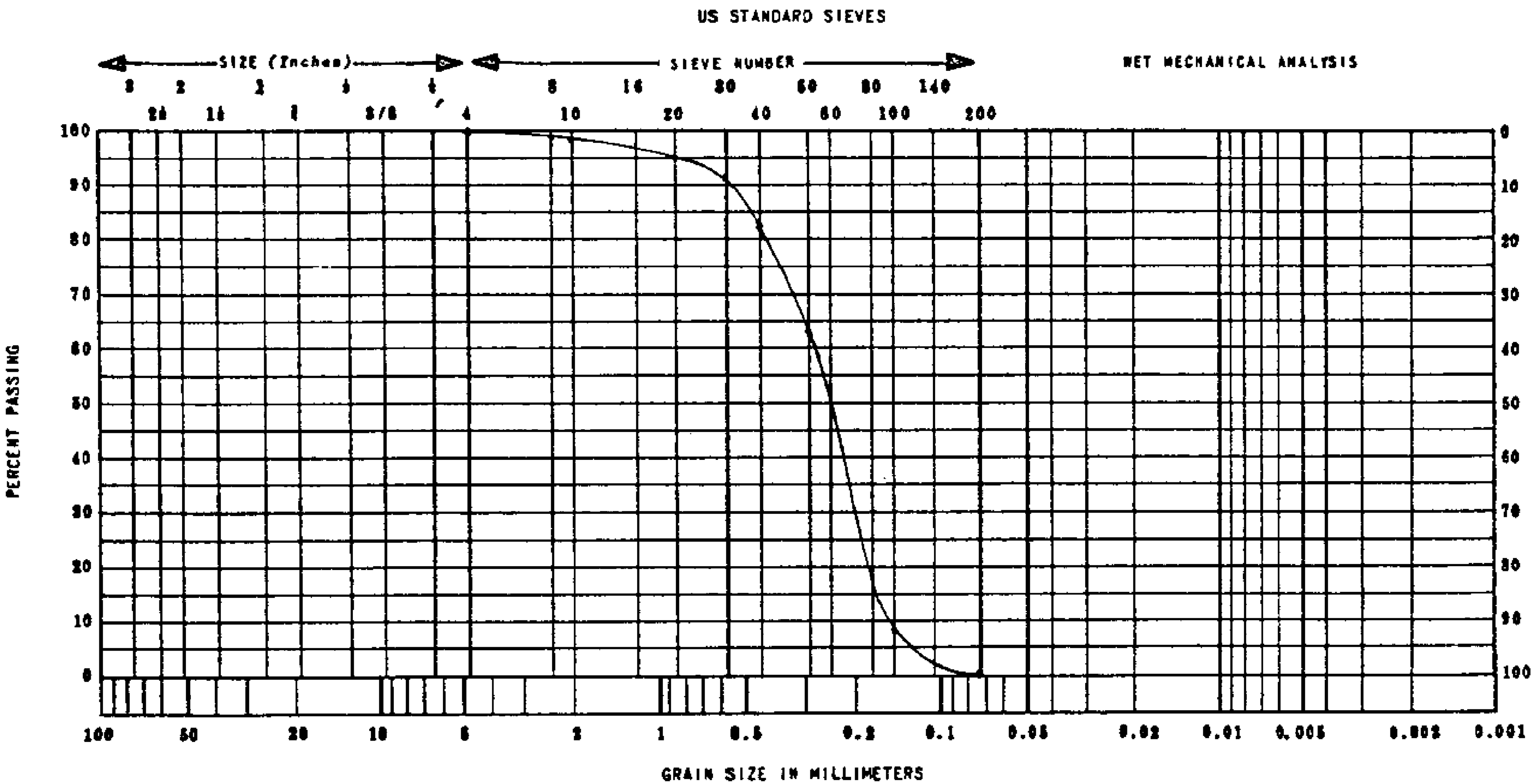
NAVY—PEARL HARBOR, T. H.

FIGURE 7(c)

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 19 March 1969

PROJECT: HALEKULANI SAND CORING



EXCAVATION NUMBER	core NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	average depth of sample within core	depth of water REMARKS
	9					2 ft.	43 ft.

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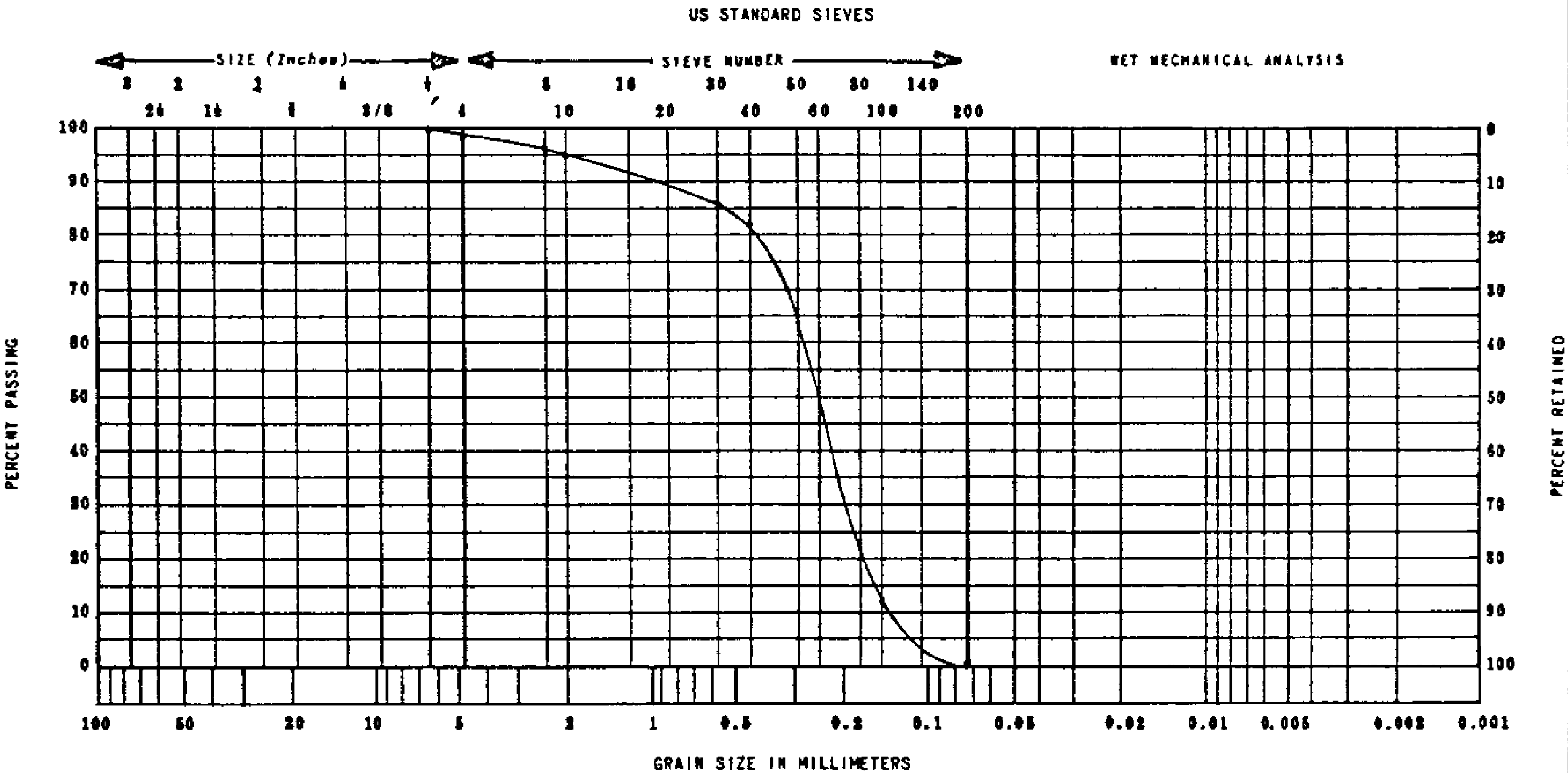
NAVY—PEARL HARBOR, T.H.

FIGURE 7(f)

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 19 March 1969

PROJECT: HALEKULANI SAND CORING



EXCAVATION NUMBER	core NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	average depth of sample within core	REMARKS depth of water
	12					10 ft.	58 ft.

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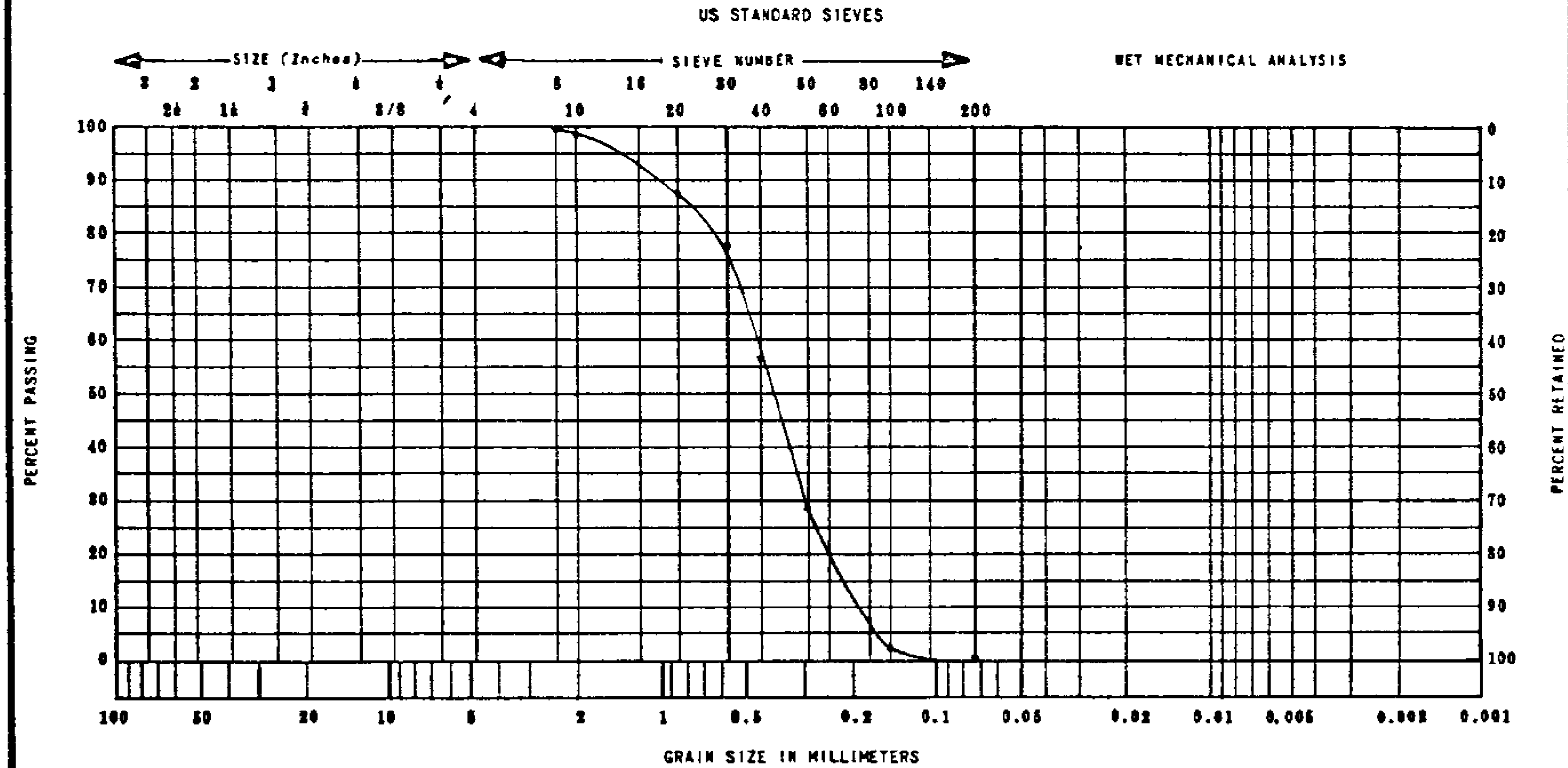
NAVY—PEARL HARBOR

FIGURE 7(g)

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 19 March 1969

PROJECT: HALEKULANI SAND CORING



EXCAVATION NUMBER	core NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	average depth of sample within core	depth of water REMARKS
	15					6 ft.	63 ft.

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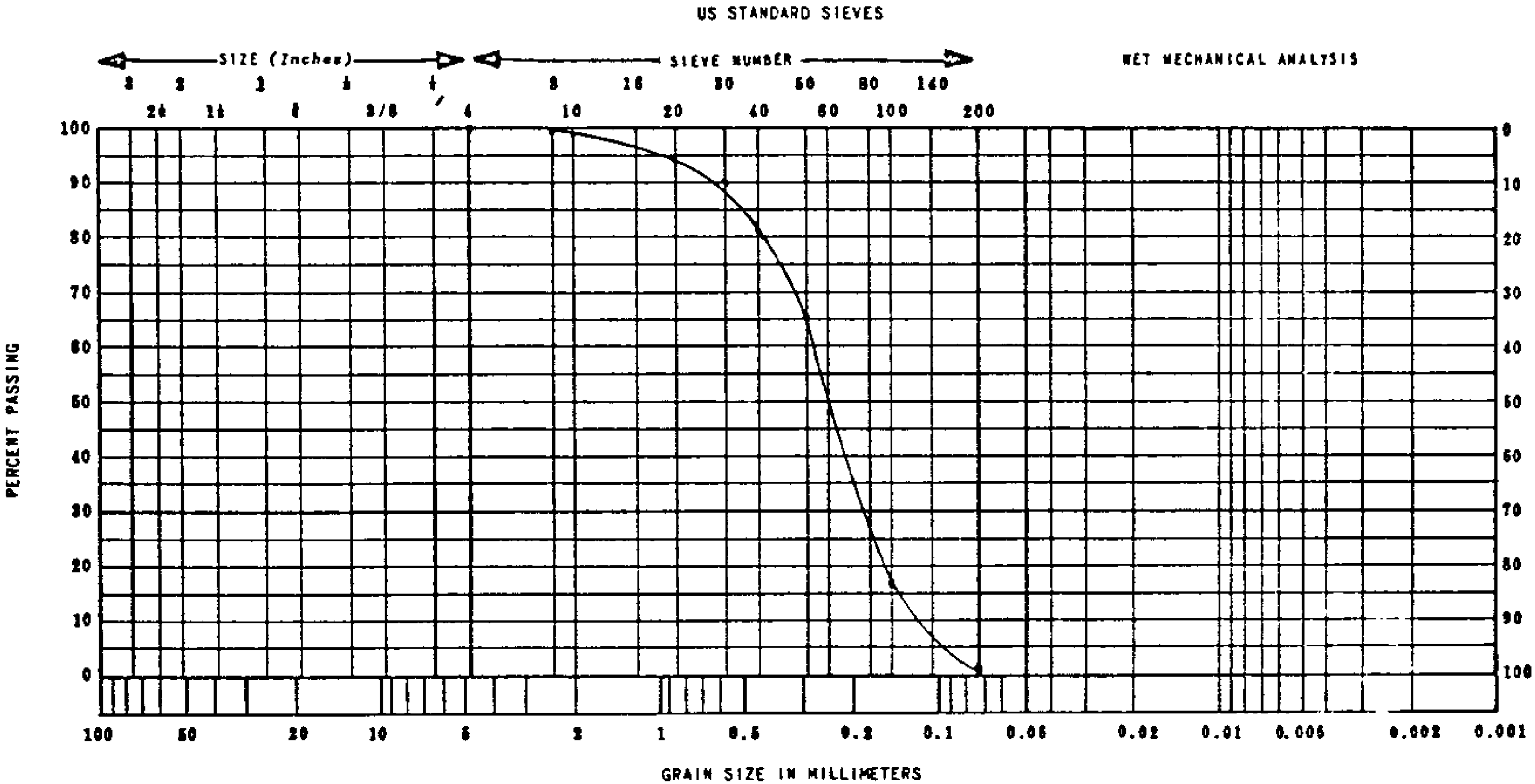
NAVY—PEARL HARBOR, T. H.

FIGURE 7(h)

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 19 March 1969

PROJECT: HALEKULANI SAND CORING



EXCAVATION NUMBER	core NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	average depth of sample within core	REMARKS depth of water
	18					7 ft.	72 ft.

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NAVY—PEARL HARBOR, T. H.

FIGURE 7(i)