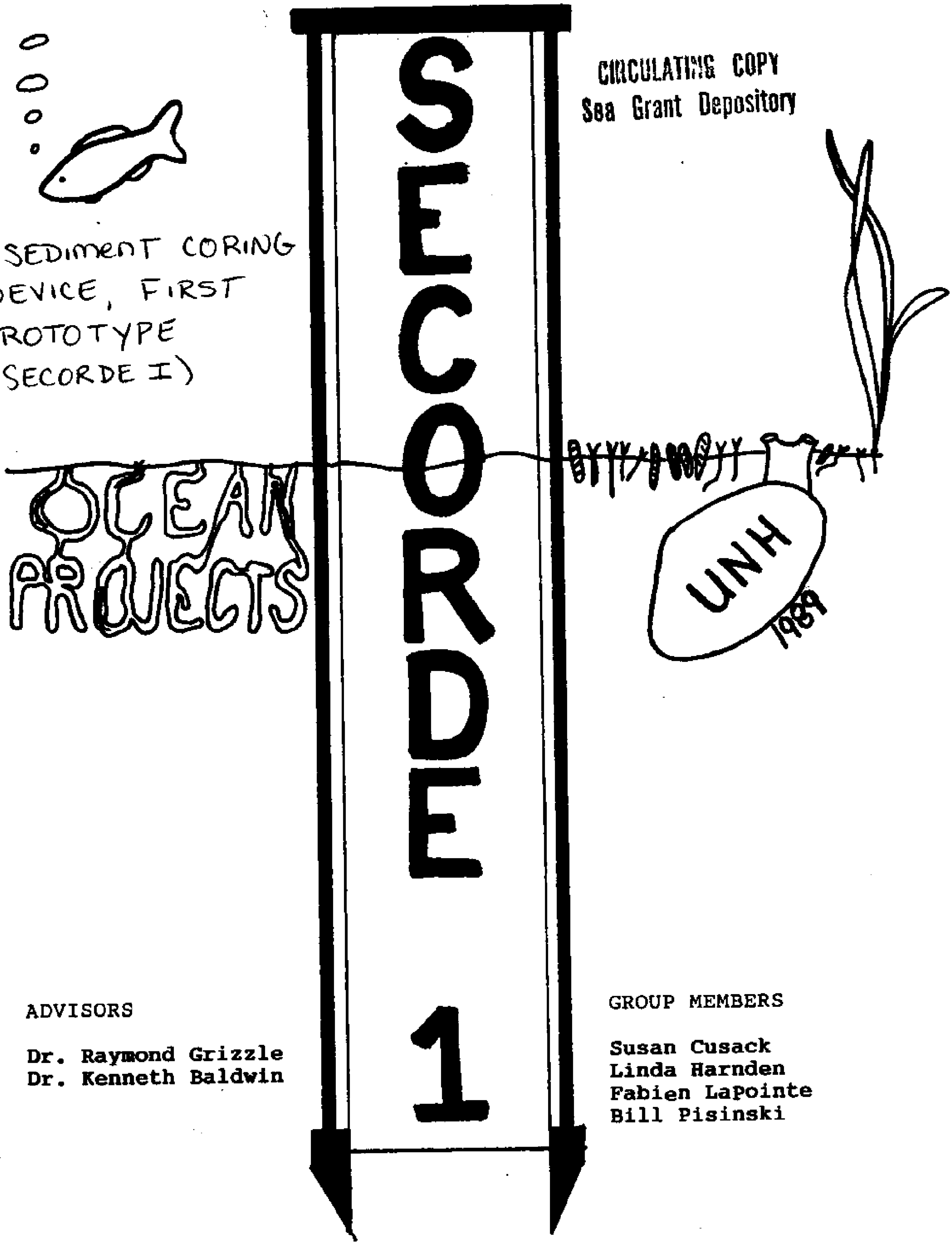
SEDIMENT CORING DEVICE, FIRST PROTOTYPE (SECORDE I)



ADVISORS

Dr. Raymond Grizzle
Dr. Kenneth Baldwin

GROUP MEMBERS

Susan Cusack
Linda Harnden
Fabien LaPointe
Bill Pisinski

UNHMP-AR-SG-89-10 $3.70

ABSTRACT

The design of the Sediment Coring Device, first prototype (SECORDE I), combines some components of existing core samplers with some original, experimental components. It resembles traditional core samplers in that it has a standard size core tube which can extract a sample of sediment from shallow marine environments where there is a muddy bottom. The unique features of SECORDE I are its reduced weight, hydraulic cylinder, suction anchors, and optically clear core tube. Some other advantages are the reduced number of moving parts and the relatively low cost of production.

INTRODUCTION

The oceans cover two-thirds of the earth's surface, yet in many respects they are still considered an unexplored frontier. Recently, much attention has been focussed on ocean research concerned with the effects of pollutants. Not only is the open ocean affected by various pollutants, but the waters near shore in many areas are being seriously impacted by organic pollutants, debris, and toxic chemicals. These pollutants and measurement of their effects are major topics of concern for biologists, ecologists, environmentalists, and others. One method of determining the impact pollution has on the environment is examining the seabed and associated organisms (benthos). Sediment/benthos samples contain information about how pollutants affect the marine environment.

Many approaches to collection and interpretation of benthic data have been used. Even a cursory examination of reviews such as Bouma (1979) or Holme and McIntyre (1984) might cause one to wonder why another type of bottom sampling device is needed. The primary motivation for development of the new sampler described herein was the need for a device that would allow collection of sediment profile imaging data in a more effective manner than is currently available, while also providing a sediment sample for benthic and/or physicochemical analyst. Benthic data from pollution surveys are usually obtained using what may be called "traditional" techniques where a sediment sample is removed from the seabed, identified, and further processed. Such traditional approaches are time-consuming and expensive.

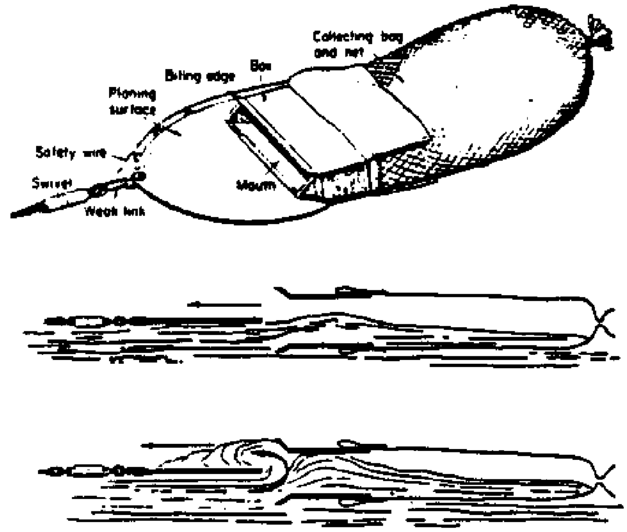
One approach that offers substantial potential for improving upon traditional benthic sampling methodology is sediment profile imaging using the Remote Ecological Monitoring Of The Seafloor (REMOTS) apparatus developed by Dr. Donald C. Rhodes and associates of the Science Applications International Corporation. The REMOTS apparatus is a large frame supporting an optical prism with camera that is pushed into the sediment where photographs of the sediment/water profile are taken. Such photos provide information on kinds of organisms present, vertical variations in sediment characteristics, etc. This approach is certainly much faster than traditional methods, but at present it is felt that REMOTS suffers from three major drawbacks. (1) REMOTS only obtains imaging data; i.e., it does not remove a sediment sample. (2) Because of its size it requires substantial vessel and winching capabilities for deployment. (3) It is apparently too expensive for most research laboratories.

SUMMARY OF EXISTING SAMPLERS

The new sampler, SECORDE I (Sediment Coring Device, first prototype), was designed to address the above three drawbacks with REMOTS. As part of the design process, available samplers were reviewed and evaluated with respect to their potential for possible modification as sediment profile imaging and quantitative sampling device, or with respect to possible use of some of their features in the design of a new sampler. Existing sampling devices can generally be categorized as dredges, grabs, or corers (see review by Holme and McIntyre, 1984).

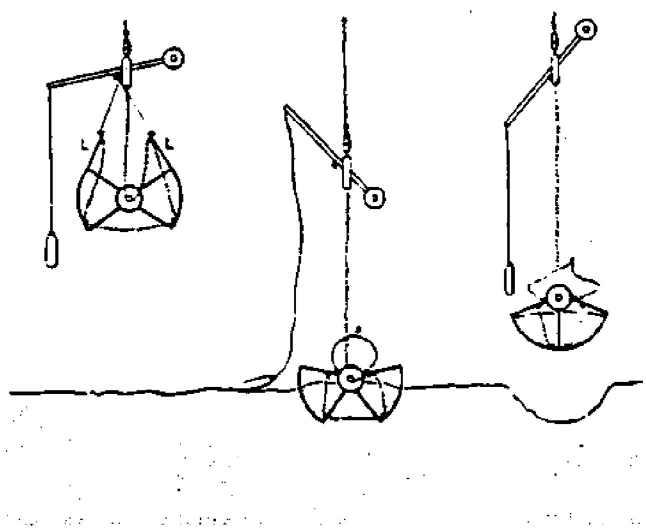
A dredge consists of a collecting bag and net attached to a frame which is towed, by a boat, along the seabed (Figure 1-A). A dredge can be used to get an approximation of species diversity and abundance in the top layers of sediment, and can be deployed in rough sea conditions when more complicated samplers, such as grabs or corers, may be damaged. The dredge provides a semi-quantitative sample of animals living on or just above the sea bottom, but it does not retain the sample of sediment, nor does it have characteristics useful for obtaining sediment profile information.

A grab sampler provides a more quantitative sample of benthic organisms than does a dredge. The grab sampler is used to extract a known quantity of sediment based on the grabs volume and depth of penetration (see Figure 1-B). The grab will not penetrate more than 15 cm (6 inches) below the sediment surface and therefore may



1-A. Deep-sea anchor dredge. Above, general view; centre, movement of sediment into dredge before clogging; below, movement of sediment after clogging. (Redrawn from Sanders et al., 1965.)

(Holme and McIntyre, 1984)



1-B. Operation of the Okean grab. Note the counterweight release and the lids (L) of the two buckets, which are open during the descent. (Redrawn from Lisitsin & Udintsev, 1955.)

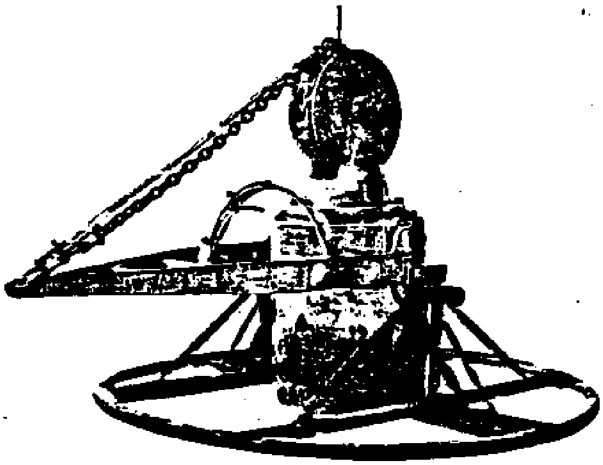
(Holme and McINtyre, 1984)

Figures 1-A and 1-B are examples of a typical dredge and a typical grab sampler, respectively. Figures 1-C through 1-F and 1-H show different types of coring devices. Figure 1-G illustrates the free-fall mechanism used to deploy most gravity corers.

not reach the deep burrowing animals. Some other drawbacks of grabs are the tendency to distort a sample at the edges (obscuring sediment profile information) and the bow wave created when the device is lowered to the seabed. This bow wave may disturb the flocculent surface sediments and blow away the small organisms and particle reactive pollutants present at the sediment/water interface. There is also the dangerous possibility that the grab may be triggered prematurely, closing before reaching the seabed. Grabs generally do not have characteristics suitable for a sediment profile imaging device.

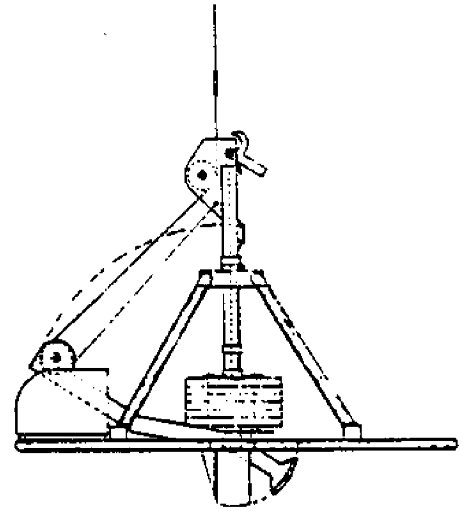
Core samplers avoid some of the complications of the grabs because of their simplified design (i.e. fewer moving parts). In addition, most corers can be made with clear tubes which would allow sediment profile imaging. Core samplers are generally of four types: 1) hydrostatically actuated samplers, 2) box corers, 3) gravity corers, and 4) piston corers.

Hydrostatically actuated corers use evacuating pumps and hydrostatic pressure to do work. One of the most efficient samplers of this type is the Knudsen sampler which uses a pump to suction a coring tube into the sediment (see Figure 1-C). One disadvantage of this device is that it may dig itself in so deep that it can not be removed. The Mackereth core sampler uses this powerful suction to its advantage (see Figure 1-D). It has an anchor chamber below the core tube which contacts the sediment first. A pump on the surface evacuates the water from under the chamber allowing the hydrostatic pressure surrounding the anchor



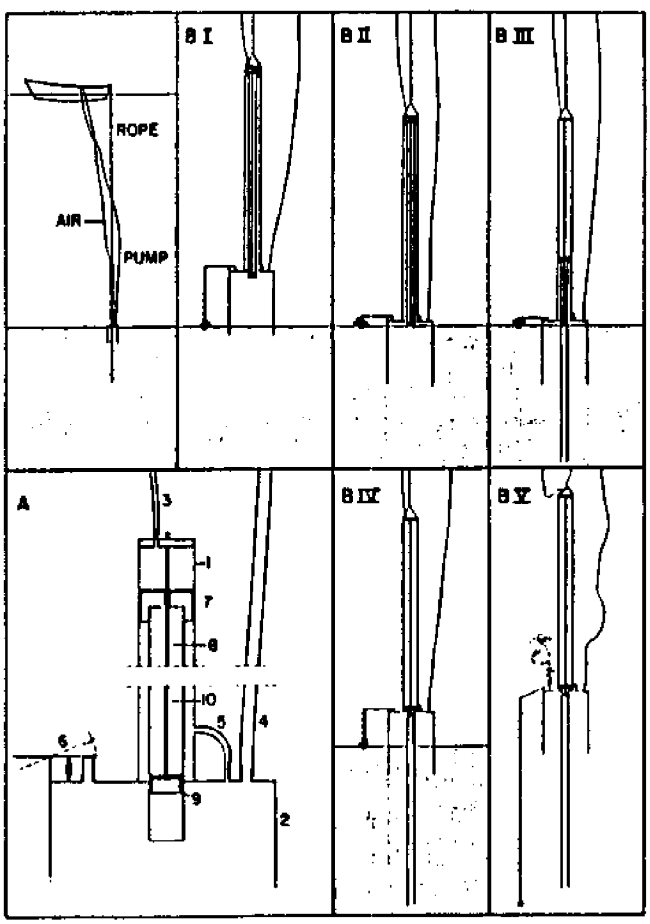
1-C. . Knudsen sampler fitted with framework to keep it upright on the sea bed (Barnett, 1969). The sampler is operated by unwinding cable from the drum at the top. This operates a pump which sucks the wide coring tube down into the sediment. When hoisted off the bottom, strain on the wishbone arm causes the sampling tube to invert as it comes out of the sediment. (Photograph E. Elliott.)

(Holme and McIntyre, 1984)



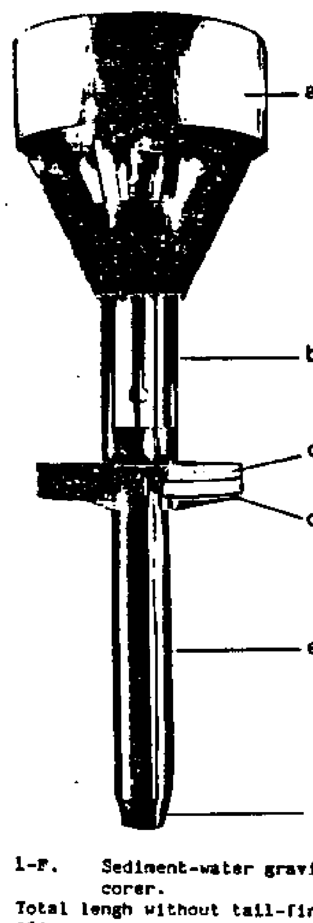
1-E. Reineck box sampler. The rectangular coring tube is closed by a knife edge actuated by pulling up on the lever on the left. An attachment can be fitted to show the inclination and compass orientation of the core. (Redrawn from Reineck, 1963.)

(Holme and McIntyre, 1984)



1-D. Diagram of the main features (A) and operational sequence (B(I-V)) of the Mackereth core sampler. The usual working position is indicated in the upper left-hand drawing. (A): (1) outer chamber or anchor chamber; (2) outer tube; (3) air pressure hose; (4) hose running to pump; (5) short pipe for air escape from the outer tube into the anchor chamber; (6) air release valve; (7) piston; (8) inner tube; (9) fixed piston; (10) tube. The operation sequence I-V is explained in the text. (Courtesy A. J. Smith, Univ. College, Univ. of London, England; redrawn from Smith, 1959.)

(Bouma, 1979)



1-F. Sediment-water gravity corer.
Total lengh without tail-fins: 960 mm; total weight, with 6 lead rings: 90 kg; weight without lead masses: 15 kg.
(a) tail-fins;
(b) loading mechanism
(c) anular lead masses (12.5 kg each);
(d) mass-bearing disk;
(e) core tube;
(f) "Sphincter" core nose

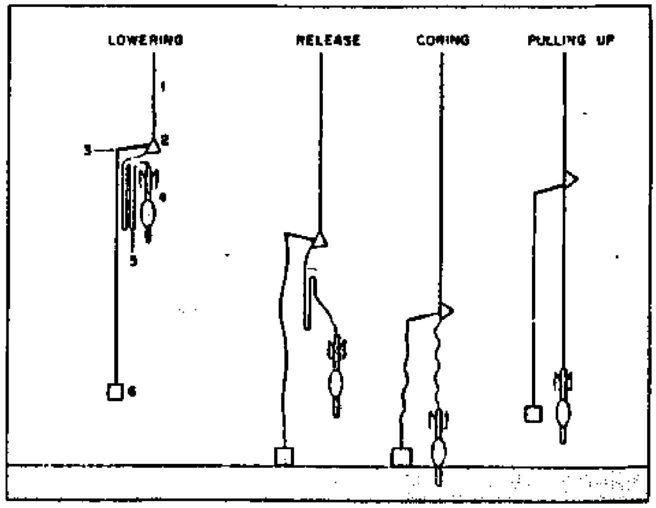
(Busatti et al., 1988)

to push it into the sediment . This holds the device in place while a pneumatic piston forces the core tube into the sediment. The use of the anchor chamber and the pneumatic piston avoids the heavy weights used by many other core samplers.

A box corer is one such device which uses heavy weights instead of suction to force a rectangular corer into the sediment (see Figure 1-E). After penetration the corer is closed off by a hinged cutting blade, thus preventing loss of the sample. A box corer is very effective for obtaining relatively undistorted samples, and it can penetrate deeply enough, (18 to 24 inches or 45 to 60 cm), to capture deep burrowing organisms. However, devices of this type are expensive, and can be dangerous to use in rough water because of their weight and size.

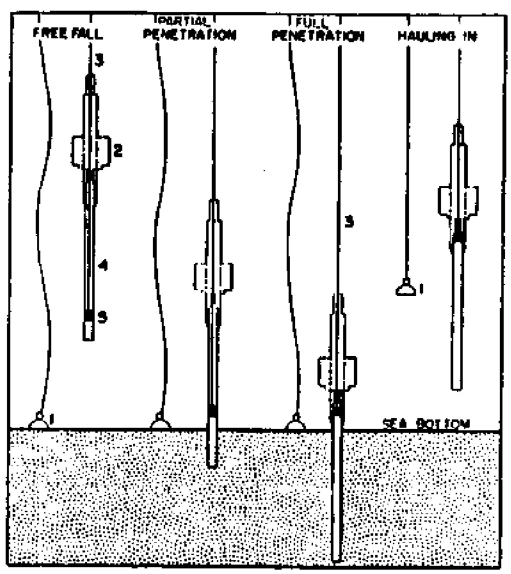
Gravity corers are also heavy (300 - 500 pounds) and not very useful in rough conditions, but their mechanism is even simpler than a box corer. A gravity corer uses heavy weights to drive a cylindrical core tube into the sediment (see Figure 1-F). Many gravity corers require the use of a free-fall device (Figure 1-G) to achieve terminal velocity on impact for maximum penetration. The cylinder typically has a one-way valve at one end to allow water to flow through it during descent, thus minimizing the disturbing effects of a bow wave. Varying the mount of weight used allows one to take samples of variable depth.

A sample obtained using a gravity corer is not as compacted as those obtained using a piston corer. A piston corer works much like a hypodermic needle. It has a snug fitting piston inside the



1-G. Principle of free-fall in coring devices that are lowered on a cable: (1) lowering cable; (2) release mechanism; (3) release lever arm; (4) corer; (5) loops of wire of equal length as the free fall; (6) trigger weight. (Redrawn from Cochran, 1959.)

(Bouma, 1979)



1-H. Principle of operation of piston cores. As soon as the trigger weight (1) hits bottom, the corer (2) is released and free fall starts. The lowering cable (3) has reserve length, similar in length to the free fall, between the release mechanism and the top of the corer (see Fig. 6.9). As soon as the core barrel (4) hits bottom, the free loop in the lowering cable is gone and the piston (5) stays stable above the sea bottom, while the corer penetrates. (Redrawn from Cochran, 1959.)

(Bouma, 1979)

core tube which remains fixed relative to the seabed while the core tube slides past it and penetrates the mud (see Figure 1-H). Heavy weights are used to drive the corer into the sediment. The whole assembly is then removed from the bottom by hauling on the piston cable.

SECORDE I is essentially a combination of the features of some of the corers described above. The process by which the final design criteria were settled upon is described below.

SECORDE I DESIGN APPROACH

Three characteristics were used as guidelines in the design of SECORDE I.

1. capable of easily providing sediment profile imaging data on board the vessel

2. capable of removing a quantitative sediment sample to a depth of at least 25 cm (10 inches)

3. light enough so that it can be deployed from a small outboard-powered research vessel

SECORDE I is a corer that uses a hydraulic pump to drive an acrylic core tube into the sediment. In reverse mode the core tube with sediment/water sample is removed from the bottom. The acrylic tube allows the operator to obtain sediment profile imaging data after the corer is returned to the surface, as well as providing a sediment sample for further processing if desired. Suction anchors mounted at the foot of each leg of the frame eliminate the need for heavy weights necessary to hold most coring devices (including REMOTS) on the seabed while the sample is being taken. SECORDE I weighs 85 lbs. and is five feet two inches tall.

The design of SECORDE I was divided into four major components:

(1) the coring tube/valve

(2) the driving system

(3) the anchoring system

(4) the frame

Each member of the design group was responsible for one of the above components.

I. CORE TUBE/VALVE

Holme and McIntyre (1984) described the most efficient corer as one, "which takes relatively undisturbed samples, penetrates deeply, and shows the smallest loss of surface layers." The achievement of these ideals is related largely to the design of the core tube itself. For example, to obtain undisturbed samples it is necessary to use a core tube with a diameter of four inches (10 cm.) or greater. With corers smaller than this the sample tends to become compacted due to wall friction of the tube. When samples are compacted the sediment profile becomes distorted and imaging data is inaccurate. Sediment profile may also be distorted because of the shape of the corer. Traditional box corers are rectangular but cylindrical corers are becoming more popular. The lesser surface to volume ratio of the cylinder allows easier penetration into the sediment and avoids the distortion of corners in the box corer. The design of the core tube is also very important when considering depth of penetration. Obviously a longer core tube will penetrate farther and will be able to capture deep dwelling animals. A penetration depth of 11 inches (approx. 30 cm.) is an acceptable distance, even though many animals are reported to live below 20 inches (approx 50 cm.) . While it is important to be able to reach the burrowing animals, a corer must also be able to capture the small animals that live on the very top layers of sediment. To avoid or at least decrease the problem of the bow wave (see discussion of grab samplers) the core tube can be made with a one-way valve at the top which allows water to flow freely through the tube during descent. After the corer has been inserted into the sediment this valve can be closed, creating a suction which helps to hold the sample in the tube.

In addition to the characteristics described above, it was decided that the core tube of SECORDE I would be optically clear so that sediment profile imaging data could be obtained in the field by photographing the sample just after it was taken. In this way SECORDE I would give the same sort of imaging data as provided by the REMOTS system (described earlier), as well as obtain a sediment sample for further processing.

The stipulation that the core tube must be clear limited the choice of materials. Some of the options considered were polyvinyl chloride (PVC), stainless steel, and clear cast acrylic. Because the problem of optical clarity eliminating the first two as options it was decided that clear cast acrylic would be used. The problem then faced was that the acrylic would be likely to crack if subjected to the anticipated forces (500 -800 pounds of force could be encountered if the corer hit a rock or other immovable object). This seemed to indicate that it would be necessary to brace or somehow reinforce the acrylic. One way this could be done would be to use stainless steel rods to brace the acrylic. The acrylic liner could be removed and the sample photographed. The problem with an assembly such as this is that the stainless steel is heavy, difficult to machine, and is expensive. A more practical solution to the problem is to use a stainless steel cutting edge that is only 2.5 inches long and fits over the penetrating end of the tube. Three stainless steel support rods brace the cutter against another piece of stainless steel which is attached to the power source. The purpose of the cuff and bracing is to decrease the magnitude of force applied directly to the acrylic.

It was previously stated that the core tube of SECORDE I would have a one way valve on one end to minimize the bow wave during descent and to help retain the sample (by suction) during extraction. There are several types of one-way valves available. Frithsen et al. (1983) compared a modified flap valve with a ball-type check valve and found the flap valve to give more consistent results. With this in mind the SECORDE I design group investigated a few different types of flap valves. One of the valves considered was a component of a gravity corer used by Benthos, Inc. This was the most suitable and was purchased from manufacturer and modified for SECORDE I.

II. DRIVING SYSTEM

Most coring devices use lead weights to push the core tube into the sediment. Because of this they are heavy, awkward to maneuver on the boat, and require a large boat with a substantial winch for deployment. As stated previously, one of the desired characteristics of SECORDE I is that it be lightweight. This characteristic gives rise to the problem of how to push the core tube into the sediment without the use of weights. The design group of SECORDE I proposed to solve this problem by using a remotely operated power source that could be mounted on the frame of the coring device. Analysis of the bearing capacity of mud (see Appendix II-B) indicated that approximately 200 pounds of force would be required to push the core tube into the sediment.

Once the tube is in the sediment the problem is how to get it out. Removal of the sediment filled core tube can require more force than required for insertion, depending largely on sediment properties. Most coring devices rely on the winch of the vessel from which they were deployed to remove the core tube from the sediment. Suction created between the fine mud or clay and the corer can require a force of up to 200 pounds (Appendix V) to remove the tube. This means that for a factor of safety of five, the power source of SECORDE I must be able to exert a force of 1000 pounds to ensure that the core tube could be removed successfully from the mud.

In addition to the criteria mentioned above there are other characteristics that the power source of SECORDE I must meet. 1) It must be corrosion resistant, 2) It must push the core tube straight in without twisting (twisting would distort the sample), 3) the power source must be able to push the tube in at least 30 cm (11 inches), 4) The rate of tube insertion must be controllable, and 5) Also as a general principle it was felt that minimization of the amount of moving parts would be desirable.

The first type of power source considered was an electric motor. The favorable characteristics of this are that it is easy to control the rate of penetration and that a power supply is usually accessible. However, the necessity of a power supply (generator) means additional cost. Another drawback is that the motor would need to be encased in a water-tight housing. Also, the use of an electric motor would require complex gears and several moving parts. Furthermore, there is always a danger of electicution with an AC current source. Clearly an electric motor would not be the best choice for SECORDE I.

An alternative power source that was considered was an air motor which uses pneumatics to do the work. One advantage to a system like this is that it does not need to be absolutely water-tight. However, a major disadvantage is that it would require a pneumatic pump and a generator on deck to create the force needed to push the core tube into the sediment. It would also require complex gears and it would have several moving parts.

Another type of power source that would eliminate submerged electric cables is a hydraulic system. A dual action hydraulic cylinder provides linear motion in both a forward and a reverse mode. This eliminates all gears and makes the motion as simple as possible. The hydraulic cylinder can be driven with mechanical advantage using a simple hand pump, thus eliminating the need for an electric generator. The shortcomings of this system are the possibility of a leak in the hydraulic lines and the necessity of having two hydraulic lines to the surface. In spite of these drawbacks it was decided that SECORDE I would use a dual action hydraulic cylinder as its power source.

III. ANCHORING DEVICE

As mentioned previously, most coring devices use lead weights to push the core tube into the sediment and for this reason they are heavy, difficult to maneuver, and require a large boat with a winch for deployment. To keep SECORDE I light weight it was decided to eliminate lead weights. This presents the problem of how to secure the complete device to the seabed as the tube is being pushed into the sediment. Bearing capacity calculations showed that almost 200 pounds of force are required to push the core tube into the muddy sediments (see Appendix II-B). The design group of SECORDE

I proposed to design an anchoring device that would provide an equally resistant force.

One option considered was to use augers which would be mounted on each of the legs. Each of the augers would be powered by a separate motor which would be mounted on the frame and encased in a protective material. Field tests performed by the design group, (Appendix V) showed that the augers would be quite successful in anchoring. Another advantage to using the augers is that they could each be separately operated to ensure that the device is level on the seabed. They are also easily extracted by running the motors in the reverse mode. The motion of the augers is somewhat complex (translational and rotational), hence, gearing is required in the motors and also a power source is needed for the motors. Because of this requirement augers are an unattractive alternative due to the amount of moving parts and problems with motors as discussed above.

Muddy sediments create excellent suction. This was discovered upon examining the forces needed to insert the coring tube and, more dramatically, removing the coring tube. Where this a problem when removing the core tube, it can be used to an advantage here by using this required force as anchoring. Large cylinders mounted on the ends of each leg of the frame could be sunk into the sediment acting as anchors. Tubing would be connected from the top of the cylinders to a hand pump on the boat. The water within the cylinder would then be sucked up the hose and surrounding water pressure on the evacuated cylinders would push them into the sediment. This principle is the same used in hydrostatically actuated corers (see discussion on existing coring devices above). By creating suction within the cylinder, a resistance is produced which provides enough holding force to keep the coring device on the seafloor while the core sample is being taken. The advantages to using this system are its extreme simplicity, experimental success (see Appendix V), and a minimum number of moving parts. Other benefits to this system are the minimized weight, there is very little that can break, and ease of removal from the sediment. One disadvantage to this system is the cylinders size. Carrying the complete device with the three cylinders on the legs would be somewhat cumbersome. This could be overcome be designing the anchors so they can easily be removed for transport. Due to these advantages this was the option chosen in the design of SECORDE I.

IV. FRAME

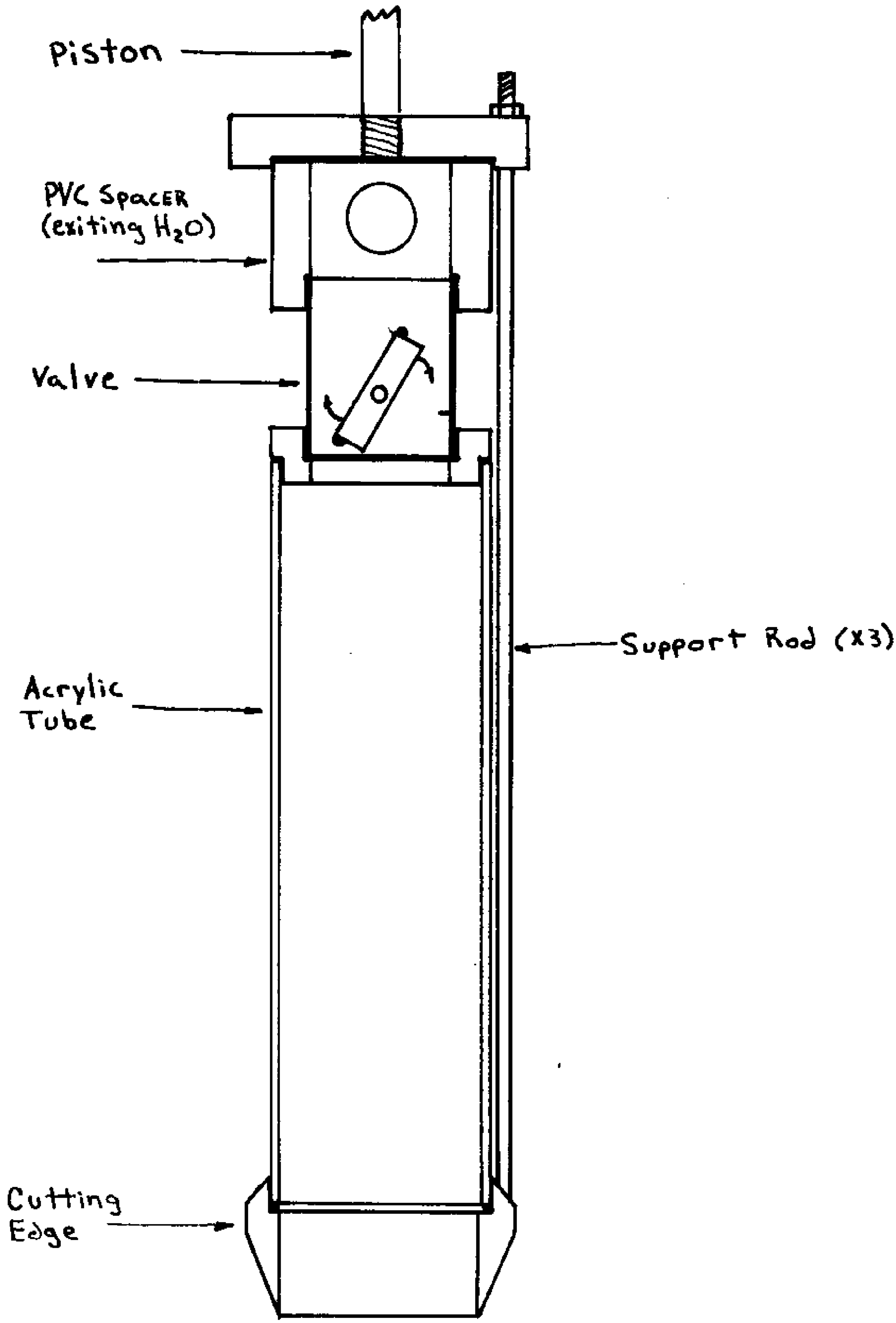
To ensure an undistorted sample it is important that the core tube be inserted into the sediment properly. This means that the core tube must be perpendicular to the sediment surface before penetration. Maintaining the core tube in this position depends largely on the frame of the corer. The frame must be balanced in order to land on the sea floor in such a way that the core tube is properly oriented. In addition to being balanced, the frame of SECORDE I must be strong enough to withstand up to 1000 pounds of force. This is the maximum amount of force required to free the anchoring from the sediment and to pull the complete device to the surface. The frame must also meet the same criteria as the other components with regard to its weight and affordability. If all of these specifications are met the frame will provide support for the power supply, core tube, and anchoring device, with maximum stability and minimum weight.

FINAL DESIGN

I. CORE TUBE/VALVE

SECORDE I uses a steel reinforced acrylic tube to obtain a sediment sample (refer to Figure 2). The tube is made of optically clear acrylic that is 15 inches long, has a four inch inside diameter, and a 3/16 inch wall thickness. The stainless steel cutting edge also has an inside diameter of four inches. It is approximately 0.77 inches thick to allow room for three stainless steel rods. The rods are 1/4 inch thick and threaded at both ends to make disassembly easier (see Appendix I for buckling calculations). The rods are attached to a mounting plate on the top of the valve. This plate is threaded onto the end of the piston rod. The stainless steel cutting edge, rods, and plate act as braces to minimize the force acting directly on the acrylic. Between the cutting edge and the acrylic is an O-ring which provides a water-tight seal. Another O-ring is located on the top of the acrylic tube, between it and the valve. The valve consists of a spring loaded plate inside a cylinder. The plate is held open by a pin during the corer's descent to allow water to flow through the core tube. When the tube has been fully inserted into the sediment a tether attached to the pin and to the frame becomes taught. The tension on the tether pulls the pin out of the plate, allowing the valve to close. The length of this tether can be easily changed so

Figure 2. Schematic diagram of the core tube/valve assembly showing cutting edge and bracing.



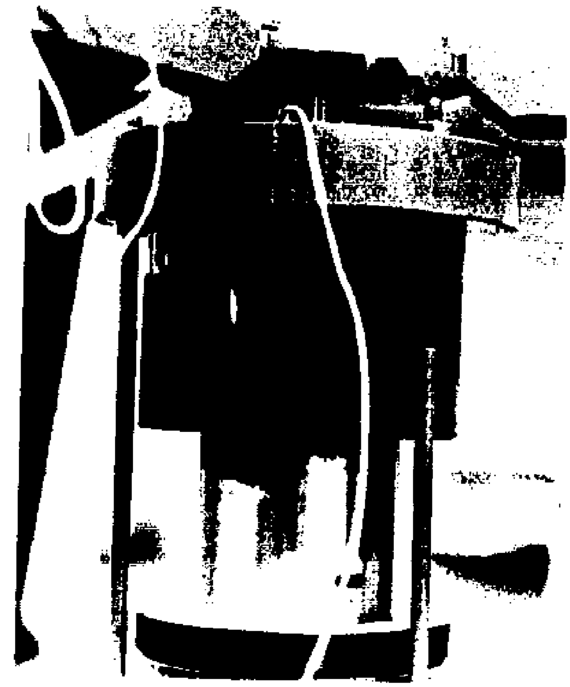
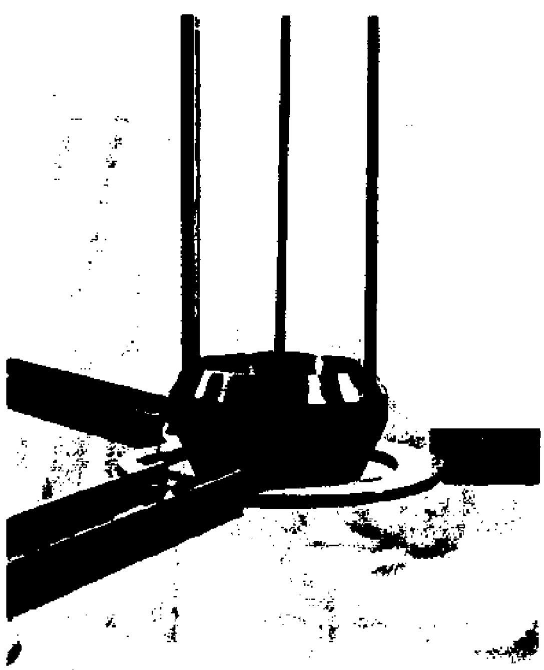


Figure 2-A. Completed core tube/vlave assembly (above left). Close-up of cutting edge (below left). Close-up of valve (above right) note tether attached to pin.



that the ratio of water to sediment obtained can be accurately controlled. An O-ring on the plate makes a water-tight seal which creates suction to hold the sample in the core tube. Figure 2 is a schematic diagram of the core tube/valve assembly showing cutting edge and bracing. Figure 2-A is a composite of photographs showing the completed core tube/valve assembly.

II. DRIVING SYSTEM

The core tube of SECORDE I is pushed into the sediment by a dual action hydraulic cylinder (see Figure 3). It is mounted on the top plate of the frame and is stabilized at its base by braces attached to the frame. The cylinder has a bore diameter of 1 1/2 inches and a rod diameter of one inch. It has an 18 inch stroke to ensure penetration to the desired depth (11 inches). The cylinder can exert a maximum force of 1000 pounds. This is an approximation of the forces to be encountered when sampling in silts and clays (based on bearing capacity of clay, see Appendix 2-B). The dual action of the cylinder makes it possible to insert and extract the core tube at a controlled rate. The rate of penetration is controlled by a hand pump operated on the boat.

III. ANCHORING DEVICE

To hold the coring device on the seafloor during sampling, a suction anchoring system is used (see Figure 4).

Figure 3. Dual action hydraulic cylinder (1/3 scale).

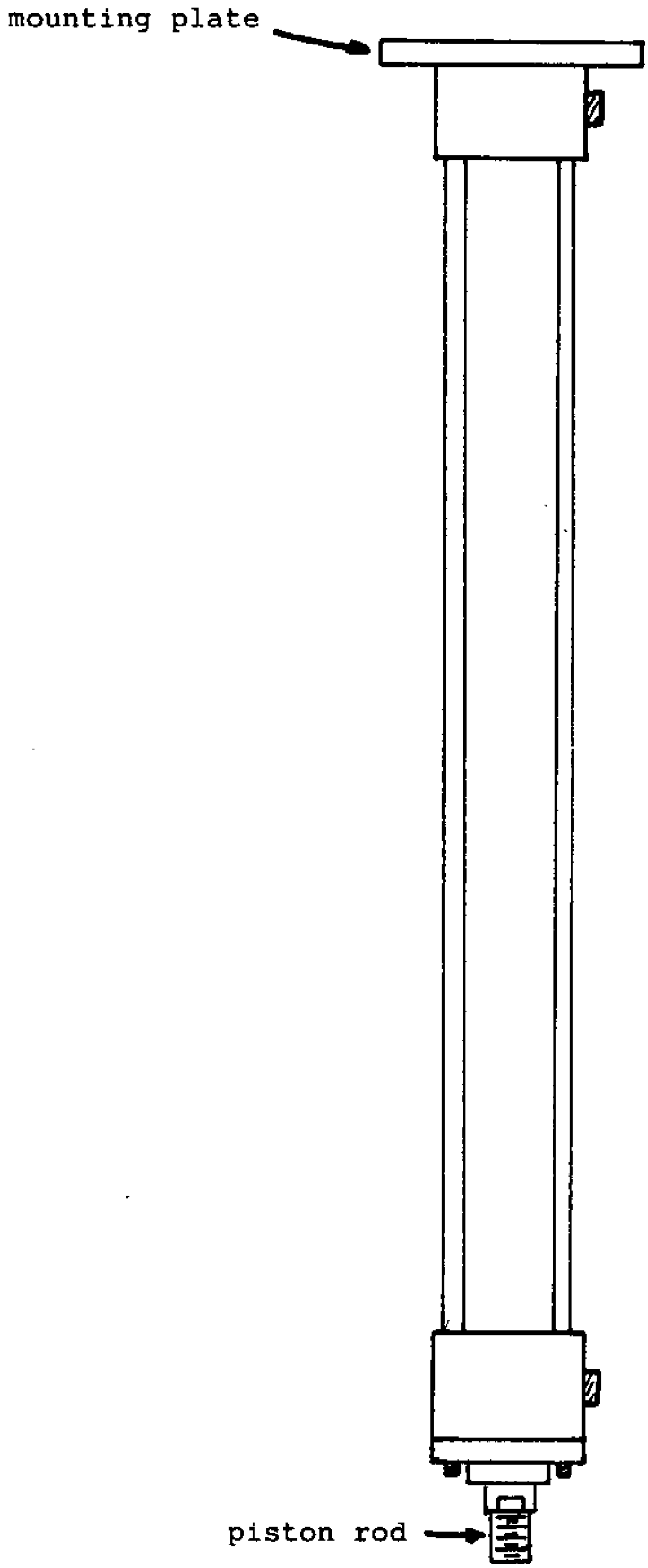
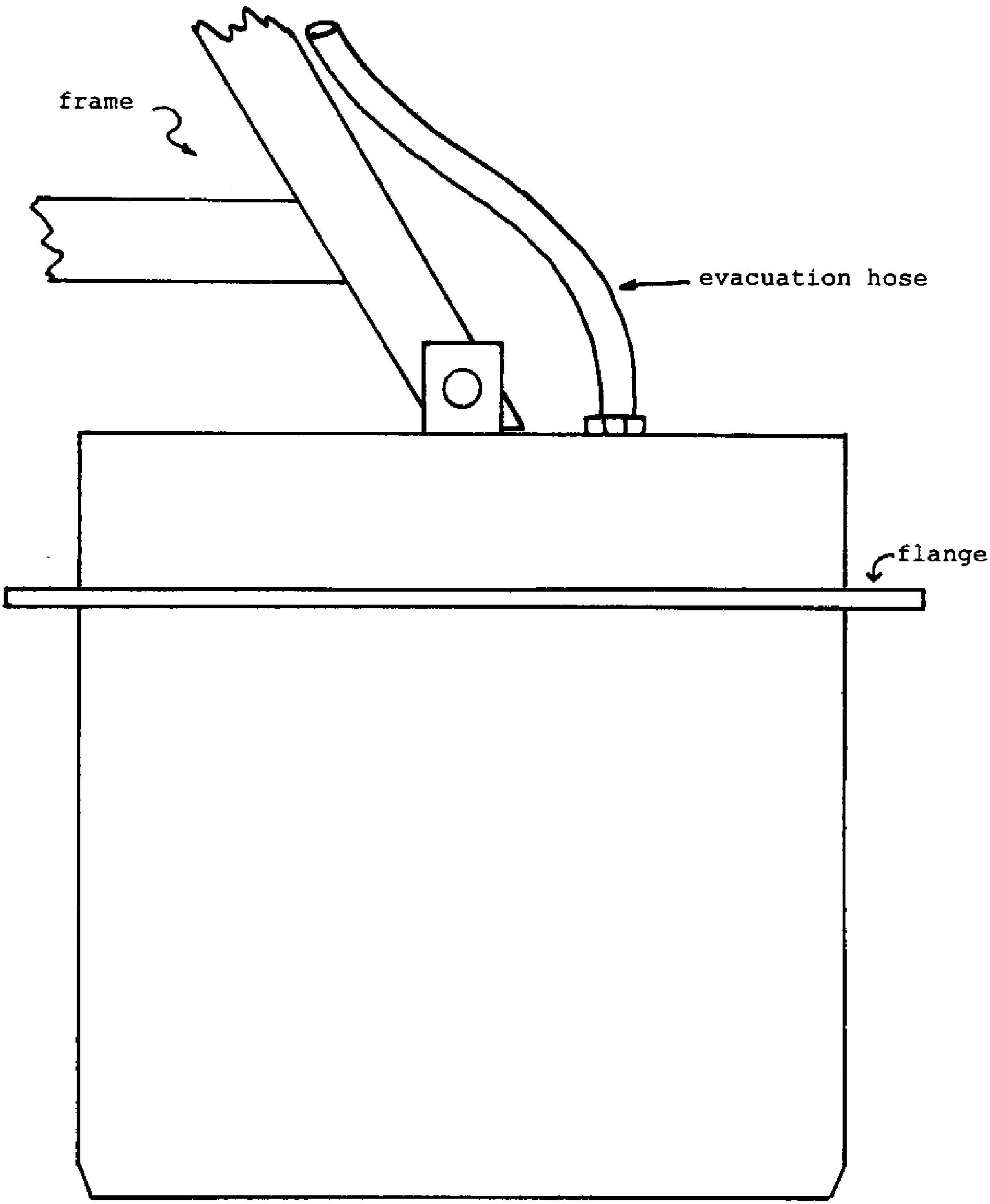


Figure 4. Schematic diagram of suction anchor showing attachment of evacuation hose (½scale).



One suction anchor consists of a cylinder closed on one end which has an outside diameter of ten inches and a wall thickness of 1/4 inch (dimensions based on field tests, Appendix V). The penetrating edge of the cylinder is beveled for easy insertion into the sediment. At a height of eight inches from the bottom of the anchor is a flange that is two inches wide and 1/4 inch thick. This flange serves to prevent the anchor from burying itself completely in the sediment. The top of each anchor is equipped with a fitting for the tube used to evacuate the water from within it. The tube from the anchor is attached to a pump on the boat which will draw water from beneath the cylinders, creating a vacuum, and will work in reverse mode to force water under the cylinders when they are to be removed from the sediment. There is one cylinder on each leg of the frame. Upon landing on the seabed 29.9 pounds of force is required to push one cylinder in eight inches. Together the three anchors require a force of 89.71 pounds (see Appendix II-A). This is amply provided by the weight of the complete system. Approximately 200 pounds of force is required to push the tube into the sediment. An equal resisting force is necessary to ensure that the whole device will not be lifted off the sediment during insertion of the core tube. As mentioned above the field test results provided the information on the appropriate diameter cylinder for this resisting force.

IV. FRAME

The frame holding all of the components of SECORDE I together consists of three legs of one by two inch aluminum channel. The legs are situated at an angle of 30 degrees from the vertical. At the top, the legs are welded onto an aluminum plate that is eight inches in diameter. Each leg is four feet 8 inches long and is angled at the lower end. The angles at the lower end allows the anchors to move. A photograph of the suction anchor showing its' range of movement is shown in Figure 5. This is to compensate for irregularities in the surface of the sediment. The frame is braced at the top and bottom by one inch by two inch aluminum channel (see Appendix III for buckling calculations). The top braces also serve to limit lateral motion of the hydraulic cylinder. The bottom braces not only provide reinforcement for the legs but converge on a ring which acts as a guide to limit lateral motion of the core tube.

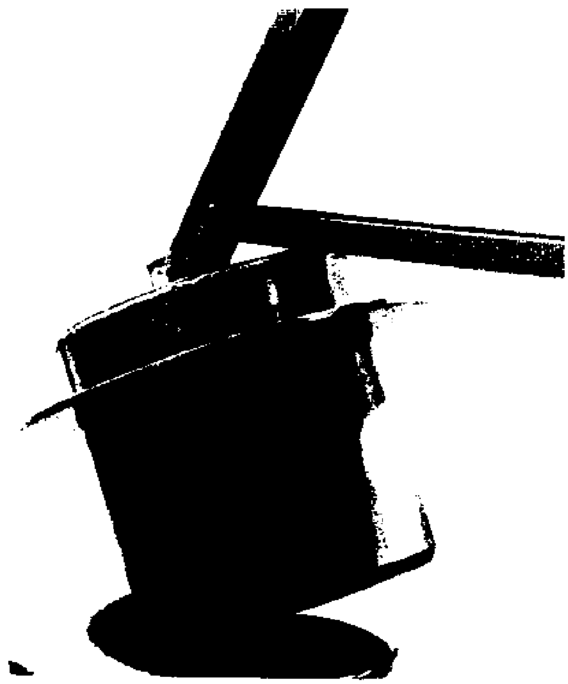


Figure 5. Photograph of one of the suction anchors of SECORDE I showing its range of movement.

OPERATION/HANDLING

Some preparation is required before deploying the sampler. The length of the sediment core must be established by adjusting the length of the tether connected to the valve. The shackle on the coring device is then hooked to a winch or to a cable which can be used to retrieve the device. The pump hoses must be primed before submerging the system. Once this is done the sampler is ready to be deployed. After the sampler has landed on the seabed a hand pump is used to evacuate the anchoring cylinders. Once the anchors are set, a pump connected to the hydraulic cylinder is activated and the core tube is pushed into the sediment. When the core tube is fully extended the valve is activated by the tether in order to trap the sample in the tube. Once this is done the hydraulic cylinder is run in reverse mode to remove the core tube and sample. The hand pump used to evacuate the anchor cylinders can also be run in reversed mode to force water back into them. This will break the suction and free the device from the sediment. The system is then ready to be retrieved. Figure 6 shows the corer: A) after it has landed, B) in the ready position with cylinders anchored, C) after the tube has been inserted into the sediment, and D) with the removed sample. Figure 7 shows photographs of SECORDE I with the coring tube retracted (left) and extended (right) without hydraulic tubing or evacuation tubing.

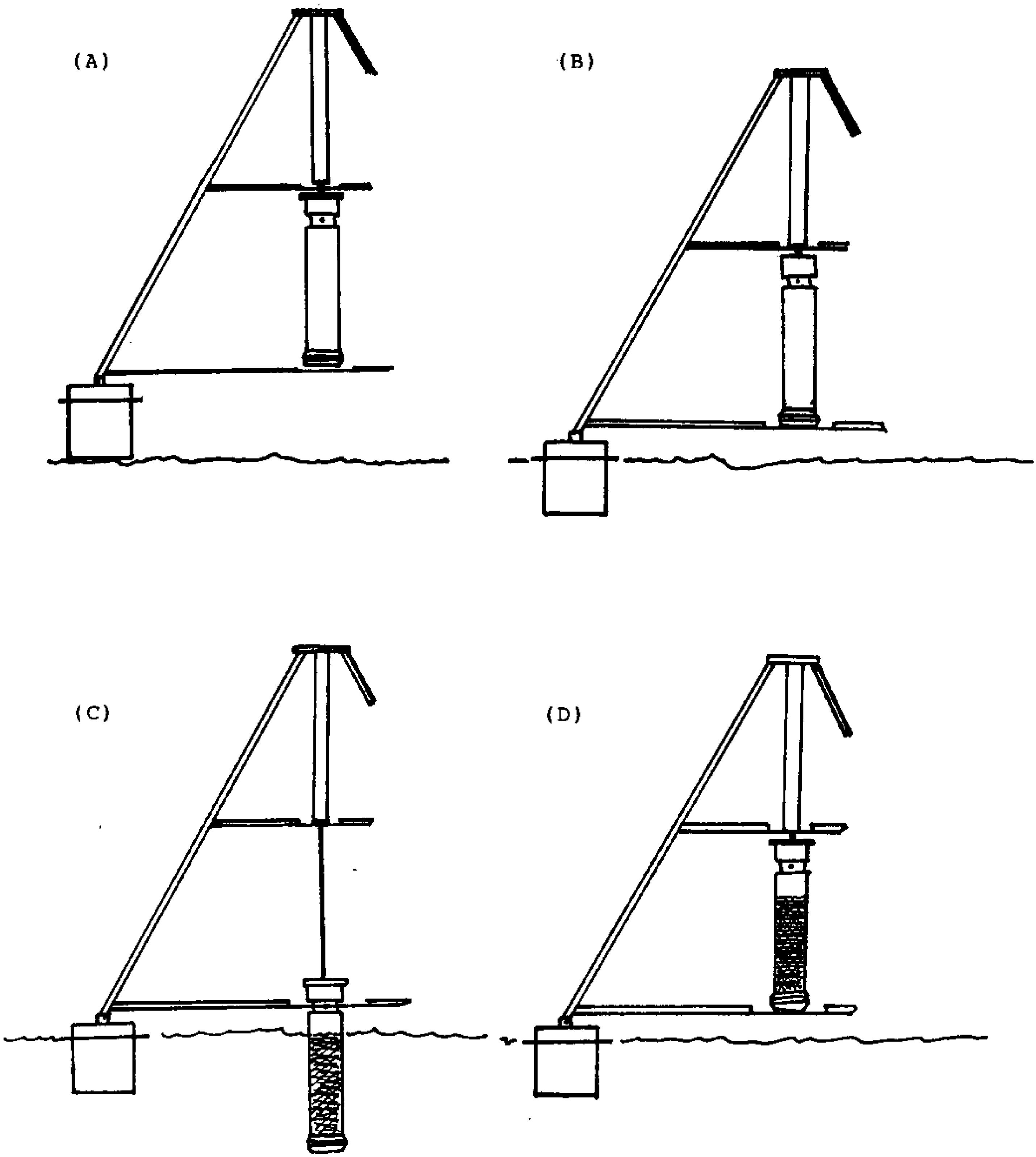


Figure 6. (A) Corer has just landed on the seafloor. (B) Cylinders anchored; tube in ready position. (C) Tube inserted into the sediment. (D) Core tube with sample removed from the sediment.

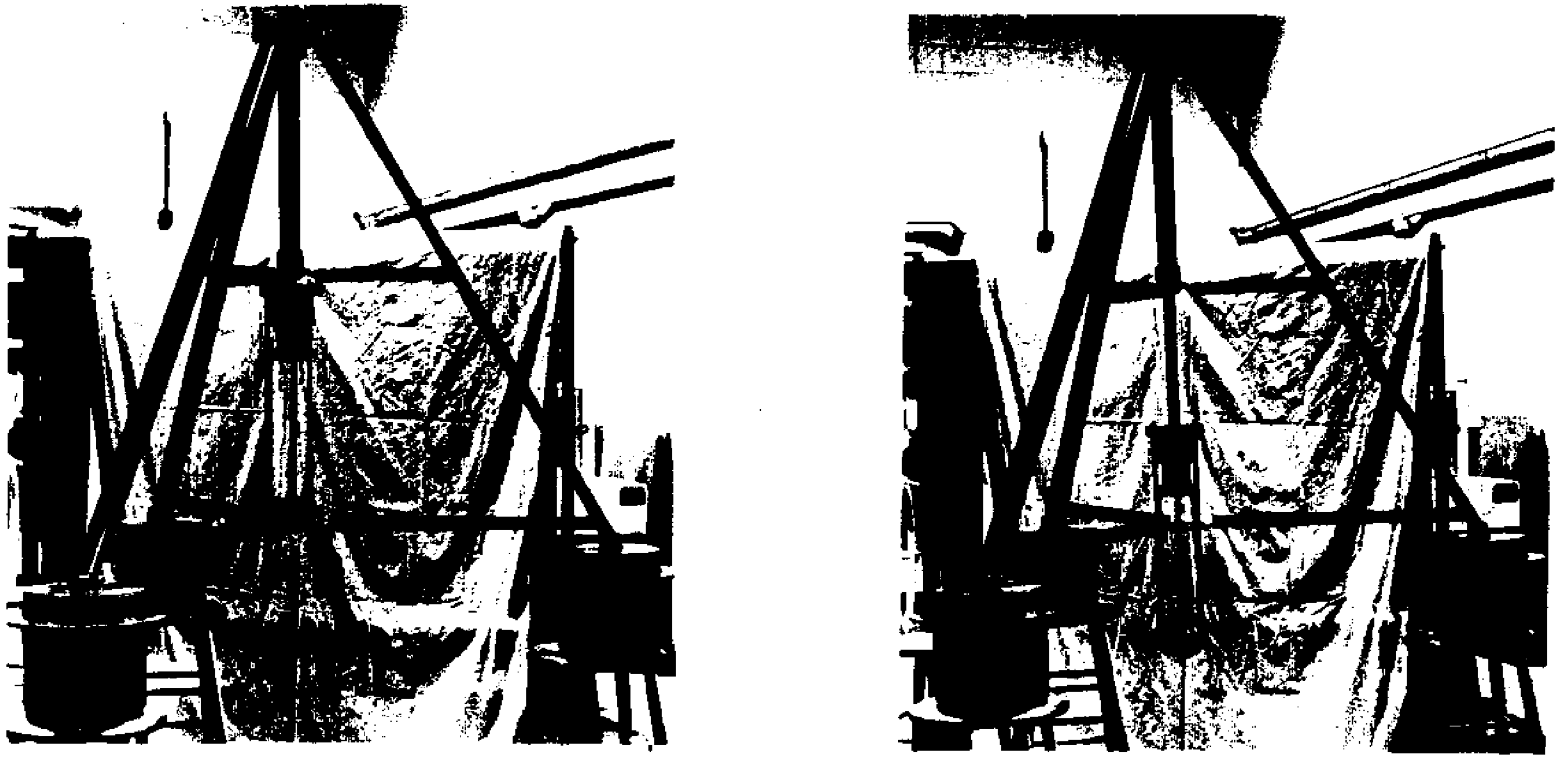


Figure 7. SECORDE I with acrylic core tube retracted (left). With the core tube extended (right).

APPENDIX

I. Buckling of Stainless Steel Braces.

$P_{crit} = cEI/L^2$

P_{crit} = Critical Force (Maximum Force)
c = constant = $4\pi^2 = 39.5$
E = 27.6×10^6 psi
I = $D^4/64 = 1.9175 \times 10^{-4}$ in^4
L = Length of Rod = 22.3 inches

$P_{crit} = 39.5(27.6 \times 10^6)(1.9175 \times 10^{-4})/(22.3)^2$
$= 419.89$ lbf

$3 \times P_{crit} = 1259.68$ lbf

II. Calculation of bearing capacity of a support of a single pile (Lamb and Whitman)

$Q = Q_p + Q_s$

Q_p = Point Resistance = $A_p(S_uN_c + \sigma vo)$
A_p = Point Area (looking from bottom)
S_u = Undrained Shear Strength of Sediment
N_c = Bearing Capacity Factor for Footing on Clay
σ_{vo} = Stress due to the Compacting of Sediment While Driving in Core

Q_s = Shaft Resistance = $\Delta L * A_s * S_a$

ΔL = Length in Contact With Sediment
A_s = Area of Pile Surface in Length in Contact with Sediment
Su = Taken for Midpoint = 1/2 S_u at Tip

Calculations:

A) Anchors:

$A_p = \pi((5/12)^2 - (4.75/12)^2) = 0.053$ ft^2
σ_{vo}= Penetration Depth(Density of Clay - Density of Water)
$= 8/12(120 - 62.4) = 38.4$ lbf/ft^2
S_u at tip = $1/3\, \sigma_{vo} = 12.8$ lbf/ft^2
N_c = 9(from Figure 32.4 - assumed worst case)
$\Delta L = 8/12 = 0.667$ ft

$A_s = 2\pi(5/12) + 2\pi(4.75/12) = 5.1\ ft^2$
S_u at midpoint = 1/2 S_u at tip = 6.4 lbf/ft^2

$Q = (0.053)((12.8)(9) + 38.4) + (0.67)(5.1)(6.4)$
$= 8.14 + 21.8 = 29.9$ lbf

Q for 3 anchors = (3)(29.9) = 89.71 lbf.

B. Tube:

$A_p = 0.196\ ft^2$
$\sigma_{vo} = 15/12(120 - 62.4) = 72\ lb/ft^2$
$S_u = 24$
$N_1 = 9$
$\Delta L = 15/12$
$A_s = \pi(5/12) + \pi(4/12) = 2.356$
$S_u = 12\ lb/ft^2$

$Q_{in} = 0.196(24)(9) + 15/12(2.356)(12)$
$= 91.34$ lbf

$Q_{out} = 0.545(24(9) + 72) + (15/12)(1.31)(12)$
$= 175.65$ lbf

III. Frame Leg Buckling Calculations

$Pcrit = 20.2EI/L^2$

P_{crit} = critical load
E = Modulus of Elasticity = 10×10^6
$I = (2)(1)3/12 - (1.75)(0.875)^3/12$
$= 0.069\ in^4$
L = 56.46 inches

$P_{crit} = (20.2)(10 \times 10^6)(0.069)/(56.46)^2$
$= 4372.3$ lbf

Maximum Resultant Force on One Leg = 1000 cos 30°
= 866 lbf

IV. Maximum Allowable Force for Each Bolt

Bolt Diameter = 1/2 inch
Area = $\pi(0.25)^2 = 0.196\ in^2$

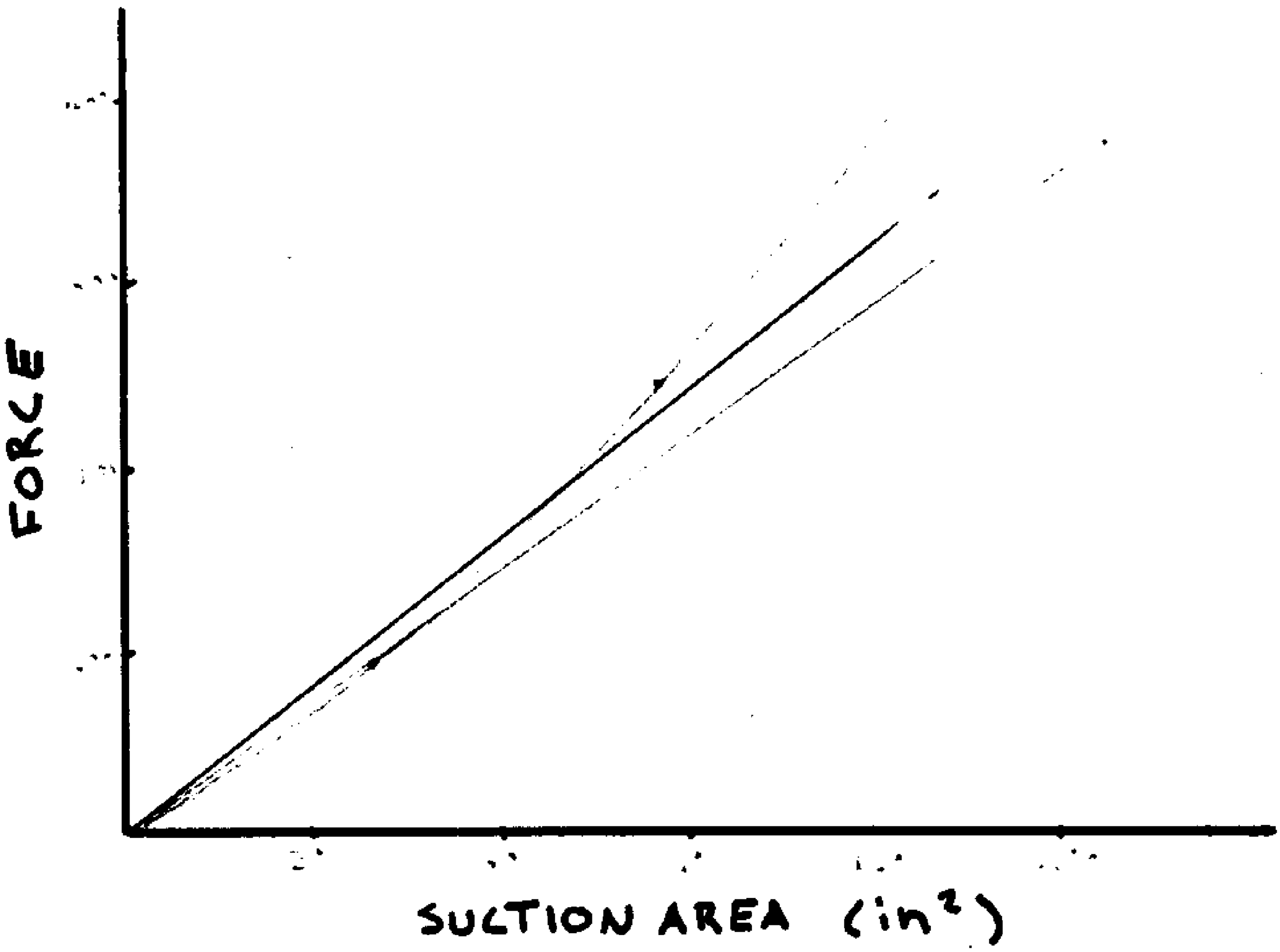
Yield Strength for 1/2 inch stainless steel bolt
= 30 kpsi

τ_{max} = (0 + 30,000)/2 = 15,000 psi

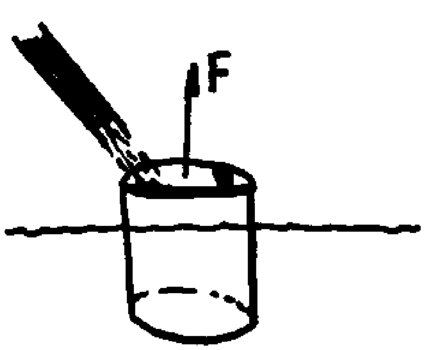
F_{max} = (15,000)(Area) = 15,000(0.196) = 2940 lbf

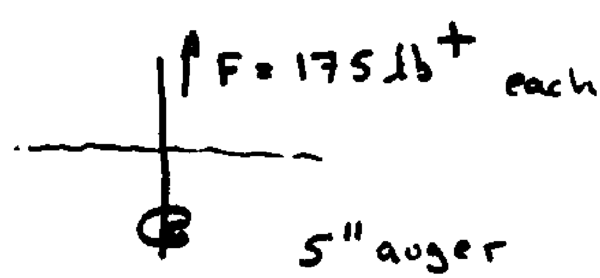
Maximum force per bolt is 2940 lbf, therefore there is a factor of safety of 8.8 for each bolt.

Appendix V. Results of field testing cylinders and augers for use as anchors.



	Diam.	Total Area	Total Force
3 cans @	4"	38 in²	195 lb
	6"	84 in²	495 lb
	8"	150 in²	~700 lb minimum





REFERENCES

Bussatti. G., A. Magagnoli, M. Mengoli, and S. Guerzoni, "A Sediment-Water Core Sampler for Coastal Pollution Studies," Environmental Technology Letters, Vol. 9, 1988, pp. 375-378.

Chase, Thomas J., "Troxler Nuclear Density Probe," (promotional material), Science Applications International Corporation, Newport, R.I.

Crandall, Dahl, and Lardner, An Introduction to the Mechanics of Solids, Second Edition, 1976.

Frithsen, Jeffrey B., David T. Rudnick, and Ragnar Elmgren, "A New, Flow-through Corer for the Quantitative Sampling of Surface Sediments," Hydrobiologia 99, 1983, pp. 75-79.

Holme, N.A., and A.D. McIntyre, Methods for the Study of Marine Benthos, Blackwell Scientific Publications, 1984, pp. 151-219.

Lamb and Whitman, Soil Mechanics, pp. 486 - 503.

Shigley, Joseph Edward, Mischke, Charles R., Mechanical Engineering Design, Fifth Edition, 1989.

ADDITIONAL REFERENCE

Bouma, Arnold H., Methods for the Study of Sedimentary Structures, Robert E. Krieger Publishing Company, New York, 1979, pp.301-354.