

Technical Report

Sediment Core Samplers

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May, 1988

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Env. Eng. Report No. 102-88-1

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Submitted to the

Massachusetts Department of Environmental Quality Engineering
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Division of Water Pollution Control
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ACKNOWLEDGEMENT

This study was supported by Research and Demonstration Program funds from the Massachusetts Division of Water Pollution Control (MDWPC: Project Number 87-01-5).

EXECUTIVE SUMMARY

Sampling of river bottom material is most often performed to determine particle size distribution and density to aid in sediment transport studies. For this purpose, disturbed samples are often adequate, and these may be easily obtained with either a drag, grab, or rotating bucket. These are the most readily available commercial samplers.

However, where detection of contaminants is desired, undisturbed core samples must be brought to the surface. A variety of such samplers have been developed. Variations in design reflect differences in the environment and characteristics of the deposits, the required depth of the sample core, the mass of sample required, and the propensity of the sediment under study to compact and smear during the sampling process.

This report presents a brief survey of the unique characteristics of predominant core samplers available, and assesses their applicability to sampling for halogenated organics in Lampson Brook in Belchertown, Massachusetts.

The Federal Inter-Agency Project has developed a coring device (BMH-53) for use in wadable streams in which the bed material is finer than medium gravel. The collecting end of the hand held corer consists of an 8 inch long stainless steel cylinder 2 inches in diameter and fitted with a brass piston. The piston creates a partial vacuum above the sample, thus helping to overcome resistance to withdrawal. This device is used primarily to sample only the top two or three inches of sediment.

For soft muddy sediments, a thin walled transparent corer was developed by York Wastewater Consultants. The device creates minimal sediment disturbance and permits inspection of the sample immediately after withdrawal.

An improvement on the BMH-53 was developed by Soilmoisture Equipment Corp. in which removeable brass liners hold the samples intact for transportation to the laboratory. The addition of a slide hammer to drive the corer into the sediment further reduces distortion.

Where vertical resolution is of the utmost importance and for use in sediments which tend to smear, the Swedish Foil sampler provides the best results. This device feeds thin

strips of foil into the cutting assembly of the corer as it is driven into the sediment in such a way as to eliminate friction between the sample core and the sampling tube. This device cannot be hand held, but it can provide undisturbed samples over ten feet in length in slow moving water several tens of feet deep. The U.S.G.S. has developed a large coring device for use in rapidly moving water which has provided satisfactory results in water 20 meters deep moving at a rate of 1.5 meters per second.

The study site is a small wadable stream with nonhomogeneous sediments ranging from fine silt to coarse gravel. Because the targeted pollutant may preferentially associate with different grain sizes, it is desirable to view the cored sample prior to analysis. Fine vertical resolution at depths of up to eighteen inches are also desired, as is minimal sidewall smearing. Additionally, analytical techniques require that sufficient mass be taken at each horizon of interest to insure detection in significant amounts.

The above constraints warrant a core sampler with the following recommended design parameters:

- Hand held corrosion resistant rigid tube sampler.
- Twenty inch long coring cylinder with a 2 inch ID.
- Transparent plastic cylinder liner.
- Fingered basket-type sample retainer.
- Water tight piston.

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INTRODUCTION

The most common purpose for sampling sediment deposits is to obtain information on the character of sediment particles that are subject to movement. In streams this material is commonly called the bed material. Ordinarily, bed material samples are collected at or near the bed surface to define the particle size distribution and density available for transport. For such purposes, disturbed samples are often adequate provided that the samples components accurately reflect the required characteristics of the deposits under study. For this reason the bulk of sediment samplers commercially available will produce samples which are disturbed. They include the drag bucket or scoop, the grab bucket or clamshell, and the rotating bucket.

However, for studies in which the detection of pesticides, trace metals, or other contaminants is desired, sediment samplers such as those mentioned above are inadequate. In order to obtain suitable samples, the sampler should enclose a volume of the bed material and then isolate the sample from water currents while being lifted to the surface. For this purpose, a variety of vertical pipe or core samplers and piston core samplers have been developed. Variations in design reflect differences in the environment of the deposits, the characteristics of the deposits, the required depth of the sample core, the mass of sample required, and the propensity of the sediment under study to compact and smear during the sampling process (U.S.G.S., 1977).

In the following section, a brief survey of the predominant types of sediment sample corers in use is presented, along with the precipitating factors which led to certain unique aspects of their design. The ultimate purpose of this presentation is to select or devise the most appropriate sediment core sampler for use in a study of the fate of halogenated non-volatile organic discharges from industrial and municipal wastewater effluents at selected sites in Massachusetts. A brief description of the pertinent analytical requirements and probable site conditions will then be presented to serve as a basis for selection of proper core sampler characteristics. The final section will then include design recommendations.

SEDIMENT CORE SAMPLERS

There have been a great many sediment core samplers used to obtain samples of various characteristics from an array of different environments. Many are available commercially, and a few have been developed specifically to deal with unique sampling requirements. Although the range of design is large, a review of the various models reveals a set of components which, in various configurations, comprise the most important corer characteristics of each model. The following is not an attempt to list the many models available, but rather is a brief outline of representative examples of the major types. The primary features which designers have chosen for their models should become evident. Each feature was designed to handle a different environmental or analytical constraint. Given a set of unique sampling requirements, the proper choice of sampler characteristics from among this group of corer components ought to provide satisfactory results.

Piston Type Corers

The Federal Inter-Agency Project has developed three types of instruments for sampling the bed material of streams where most of the material is finer than medium gravel (Guy & Norman, 1970). One of the three, the US BMH-53 (see Figure 1) is a hand-held corer designed to sample the bed of wadable streams. The instrument is 46 inches in total length and usually is made of corrosion resistant materials. The collecting end of the sampler is a stainless steel thin-walled cylinder 2 inches in diameter and 8 inches long with a tight fitting brass piston. The piston is held in position by a rod which passes through the handle to the opposite end. The piston creates a partial vacuum above the material being sampled and thereby compensates for some of the frictional resistance required to push the sampler into the bed. This partial vacuum also retains the sample in the cylinder while the sampler is being removed from the bed. The piston also serves to force the sample from the cylinder in a manner that results in a sample column with a minimum of distortion from which material at different depths from the surface may be inspected and subsamples obtained. The U.S.G.S. uses this coring device in studies which require samples from only the top two or three inches of sediment, although an extended barrel is available which will yield a longer sample core. However, as the barrel is lengthened, the potential for sample distortion upon removal is increased.

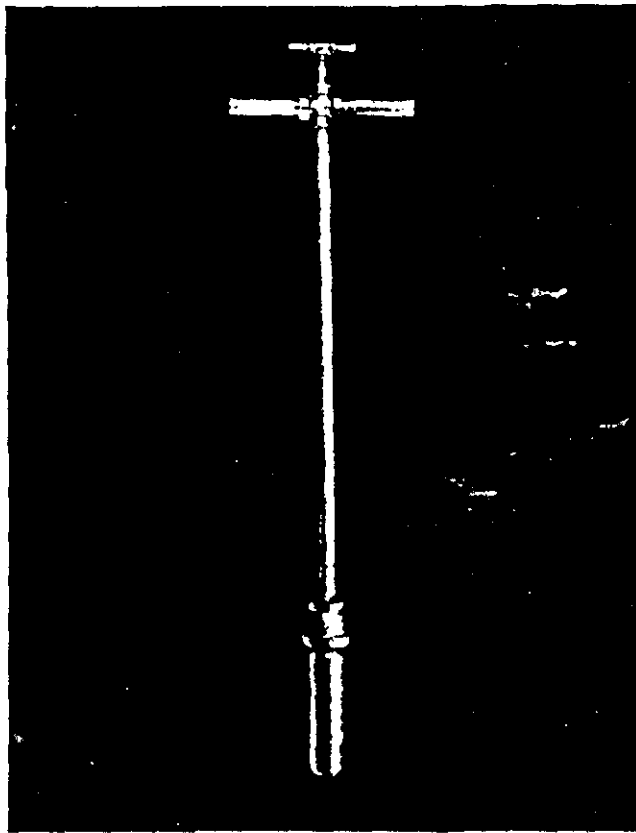


Figure 1: U.S. BMH-53 hand held piston corer
(Guy, 1970)

For certain sampling conditions, much simpler equipment will suffice. In an effort to determine the quantities of lead, aluminum, and other contaminants in Mill Pond, Fairfield, Connecticut, York Wastewater Consultants, Inc. (Kellogg, 1985) fabricated a simple coring tube which suited their purposes quite well. Mill Pond may best be characterized by very slow moving water and a soft muddy bottom. A sediment core sampler was constructed of polyvinyl chloride (PVC) pipe and clear cellulose acetate butyrate (CAB) tubing. The actual coring section of the sampler was a six foot long section of the CAB tubing which was 2-1/2 inches OD with a wall thickness of 1/16 inch. CAB was chosen because it is clear, allowing inspection of the core before it is removed from the sampler. It was also chosen because the thin wall allowed penetration into the sediment without disturbing the sediment, and because it resists fracture when torsional or lateral forces are applied (see Figure 2). PVC was used as a handle for the sampler because of its high strength, low weight, and relative ease with which it can be cut and glued. An eye-bolt with two tapered rubber stoppers was used to form a suction on the sediment sample to keep samples that were fluid in nature from falling out of the sampler during withdrawal. A rope was attached to the eye-bolt so that the stopper could be pulled up through the CAB tubing as the sample was being taken. The nature of the study required a high degree of resolution of pollutant concentration gradient in the sediment core, so sample deformation needed to be kept to a minimum. Field tests indicated that the samples obtained maintained spatial relationships between the sediment horizons which were within one inch of their actual in situ placement.

Simple Tube Type Corers

A variation on the US BMH-53 sampler is offered by Soilmoisture Equipment Corp. Its model 200-A Soil Corer Sampler (see Figure 3) provides a few distinct advantages to the government model. Ease of handling samples is facilitated by the addition of brass sample-retaining cylinders of various lengths which fit into the barrel of the corer. After a sample has been taken, the retaining rings can be pushed out of the barrel with a slotted core extractor with negligible distortion of the sample. A second improvement is the means by which the barrel is driven into the ground. The sampler is driven into the bed material by slipping the small diameter rod of a cylindrical slide hammer down into the hollow handle of the sampler. The large end of the slide hammer is then simply lifted and dropped to drive the barrel into the bed. This method minimizes the torque on the barrel and the pivoting about the cutting-shoe which often accompanies sampling in medium to

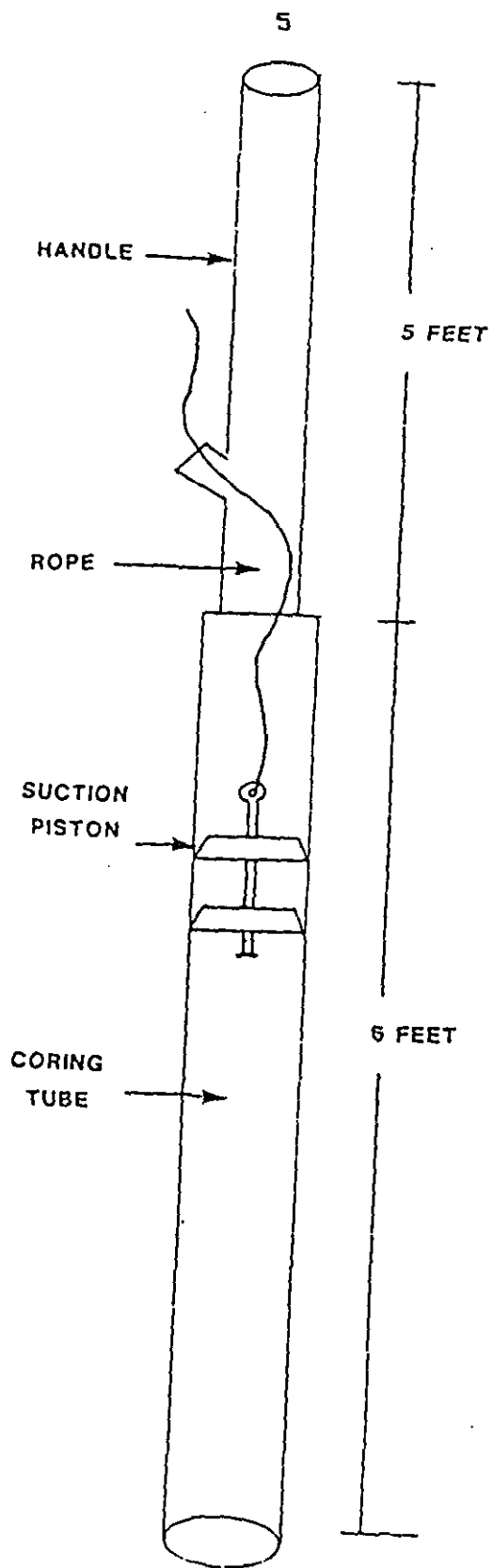
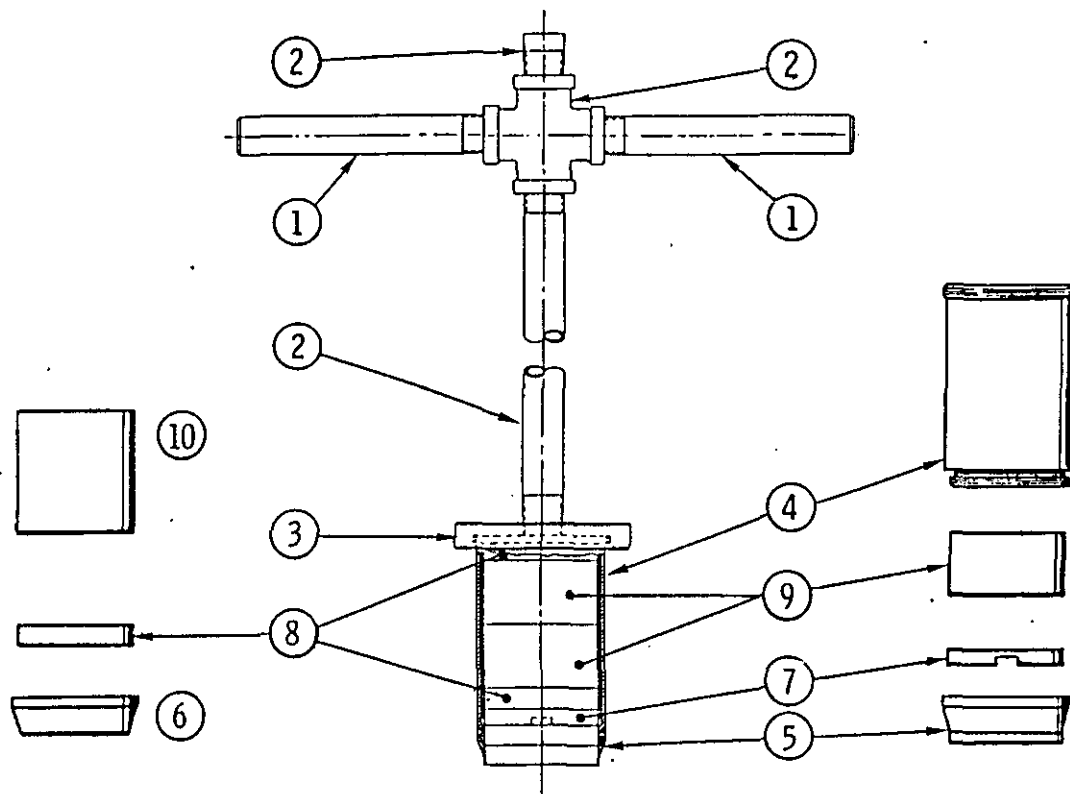


Figure 2: York Wastewater Inc. soft sediment coring tube
(Kellogg, 1985)



STANDARD PARTS BREAKDOWN

ITEM NO.	PART NO.	DESCRIPTION	ITEM NO.	PART NO.	DESCRIPTION
1	201-6	HANDLE	6	201-2	WEDGE CORING TIP
2	201-100	STEM ASSEMBLY	7	201-9	SLOTTED EXTRACTOR RING
3	201-4	CAP	8	208	CYLINDER 1 CM. LONG
4	201-3	BARREL	9	207	CYLINDER 3 CM. LONG
5	201-1	BLADE CORING TIP	10	206	CYLINDER 6 CM. LONG

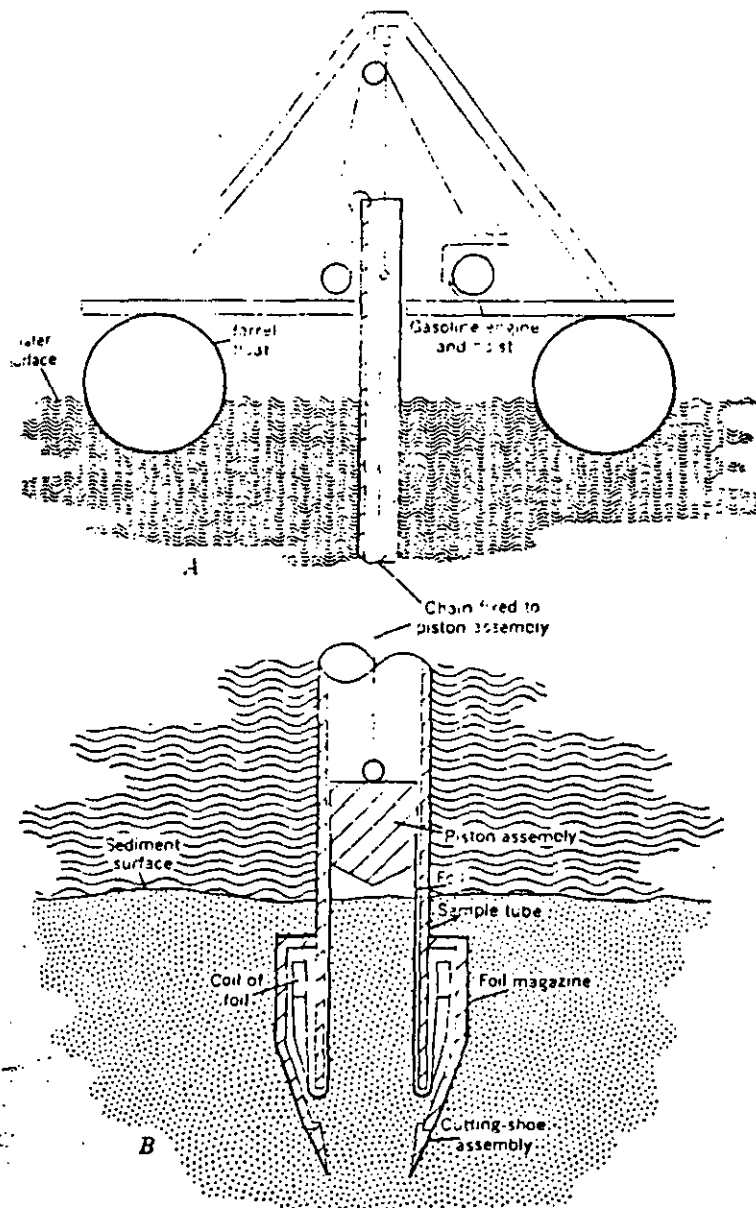
Figure 3: Soilmoisture Equipment Corp. 200-A soil corer
(Soilmoisture Equip. Corp.)

coarse grained sediments with hand-driven corers. With this method of penetration, the integrity of the sample is maintained to a greater degree. Like the BMH-53, the 200-A is equipped with a short core barrel (about 5 inches), but may also be extended to 8 inches or more with a longer modified barrel (Soilmoisture Equipment brochure).

Foil Sampler

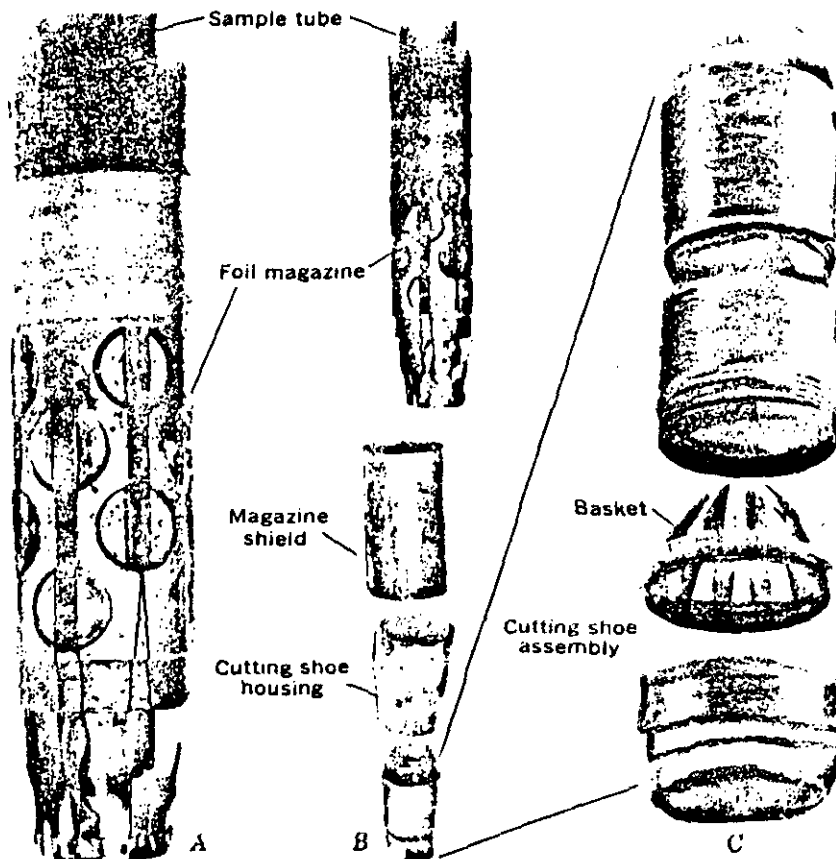
The collecting of undisturbed core samples of fine, somewhat fluid sediment is hampered by the tendency of the sediment to adhere to the interior of the sampling tube and thus cause compaction and preferential coring of certain sediment layers. For a study of the fate of radionuclides released to the Clinch River in Tennessee conducted by the U.S. Geological Survey and the Oak Ridge National Laboratory in 1960, undisturbed core samples of river bottom sediments were required for phases of the joint study pertaining to the vertical distribution of fission products in the sediments. Preliminary coring tests with several tools showed that the simple tube-type samplers were unsatisfactory for use in the relatively fine bottom sediment of the Clinch River. Analysis revealed the sediment to be composed of approximately 15-20 percent clay, 25-30 percent sand, and 50-60 percent silt. Conventional tube-type corers yielded preferential coring of certain sediment layers and excessive compaction of most of the core sample. Larger diameter thin walled corers produced better results, but better control of compaction was necessary. Further tests resulted in the selection of the Swedish Foil Sampler for sampling bottom sediments of the Clinch River. The Foil Sampler is a piston type sampler in which thin axial metal strips (foils) are used to eliminate friction between the sediment core and the sample tube while the coring is proceeding (see Figure 4). Cores two and a half inches in diameter and as much as fourteen feet in length were obtained in water as much as forty-five feet deep with the Foil Sampler mounted on a barrel equipped with a drilling tower and gasoline engine and hoist.

In loading the sampler, steel foils, fed from coils in the foil magazine, are attached to the piston assembly. As the sampler is pushed into the sediment, the foils unroll and form a sheath that encloses the core and prevents its contact with the interior of the sampling tube. The core does not move relative to the foil strips, and the only friction in the sample tube is the metal to metal friction between the foils and the interior of the tube. Compaction and blocking of the core in the tube due to friction between the sediment and the tube is prevented.



A, Float with hoisting engine and rigging for driving and raising the sampler. B, Swedish Foil Sampler; piston is held in place by chain as tube is pushed down through the sediment; end of each foil strip is attached to piston and the strips of foil unroll from the magazine and envelope the sediment core as the sampler is pushed into the sediment.

Figure 4: Swedish Foil Sampler; schematic
(Pickering, 1966)



A, Magazine in head of sampler showing coils of steel foil.
 B, Top to bottom, sampler head, magazine shield, cutting-shoe housing, and cutting-shoe assembly. C, Cutting-shoe assembly pulled apart to show basket-type core retainer used to retain cores that have a high tendency to slump.

Figure 5: Swedish Foil Sampler; cutting-shoe and foil assembly
 (Pickering, 1966)

Sidewall smearing is effectively eliminated and the integrity of the sample is maintained.

Under most conditions, satisfactory samples were obtained with the sampler. However, in some circumstances, the lower 6 to 18 inches of the sample was lost. To decrease core loss, a modification of the cutting-shoe assembly was made. A basket-type core retainer was designed for the sampler, and upon request, was fabricated by the drilling contractor. The basket, which consisted of curved closely spaced flexible spring steel fingers attached to a steel ring, was inserted near the base of the cutting shoe (see Figure 5). Above the basket was fixed a thin plastic sleeve that was slit at the top so it would collapse over the basket when the sediment began to slide out of the shoe and thus partially, and at times completely, seal the opening at the base of the sample tube (Pickering, 1966).

Samplers for Use in Deep Rapidly Moving Water

In 1963 the U.S.G.S., in cooperation with the Atomic Energy Commission, began an investigation of radioactivity in the Columbia River estuary. The bed of the estuary is mainly sand, although fine-grained deposits are not uncommon. Sampling sites may reach depths below the water's surface of up to 70 feet, and may reach velocities of 5 feet per second. Because medium to coarse grained sediments offer greater resistance to corer penetration than do finer grained sediments, the problem of obtaining deep cores was compounded, particularly in deep swift water.

To overcome these problems, the U.S.G.S. developed a core sampler which performed effectively in almost all of the desired sampling sites. The sampler is designed to collect cores 4.75 cm in diameter and up to 180 cm long in sandy beds under water depths up to 50 meters and flow velocities up to 2 meters per second. In addition, portability was stressed so that the sampler could be used from small craft or from structures such as bridges. To achieve penetration, the device utilizes vibration together with axial force and suction. Vertical stability and resistance against overturning in flowing water are achieved with a cable and puller suspension system arranged so that tension on the suspension cable produces a downward thrust on the core barrel and also provides support against horizontal forces.

The core sampler consists of (a) a core barrel on top of which is mounted an electro-mechanical vibrator in a waterproof housing (see Figure 6); (b) a 250 lb streamlined body (see

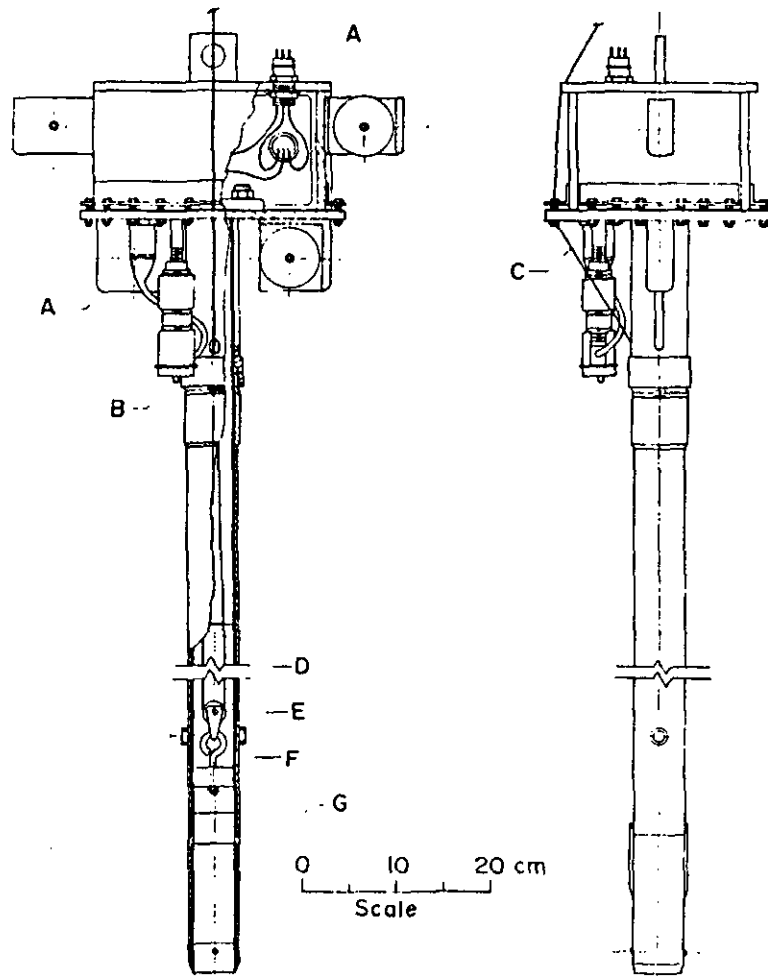
Figure 7); and (c) an interconnecting cable system with a scissors clamp which allows tension at the upper end of the cable to impart either upward or downward force on the coring barrel (see Figure 8). The core barrel is a 2-1/8 inch OD stainless steel tube into which fits a 1-7/8 inch ID plastic liner that is 6 feet long. A tightly fitting piston slides inside the plastic liner. The piston is suspended from a pulley on a light cable and remains stationary with respect to the bed during coring.

During operation, the entire unit is lowered through the water column (see Figure 9) and the coring barrel is kept from descending through the streamlined body by a pair of locking pins (see Figure 7). Upon reaching the streambed surface, the mechanical vibrator is turned on, and the locking pins are released, allowing the barrel to begin penetration through the body and into the sediment. Once the locking pins are released, any further tension on the upper end of the suspension cable results in a downward axial thrust transmitted to the barrel transmitted through the pulley system (see Figure 8). For this purpose, the weight of the streamlined body is essential to provide the necessary anchoring reaction to the upper cable tension. When sufficient penetration of the sampler barrel is achieved, a weighted messenger is sent down the upper cable, triggering the scissors clamp to allow retraction of the sampler barrel with further tension applied to the suspension cable. At this point the piston is raised along with the barrel, providing additional suction lift to the cored sample.

Field tests demonstrate that the sampler operates satisfactorily in bottom sediments ranging from silty clay to medium sand. It probably is not satisfactory, however, for coring hard-packed clay. Although the sampler has been used only in water depths of up to 20 meters and in mean flow velocities of up to 1.5 meters per second, satisfactory performance is anticipated at the design limitations. The lengths of the cores correspond closely to the depths of penetration; hence, very little compaction occurs except for that which results from material displaced by the tube walls. Stratification is not disrupted except for intermittent warping, and the vibration does not appear to have any adverse effect (Prych & Hubbell, 1966).

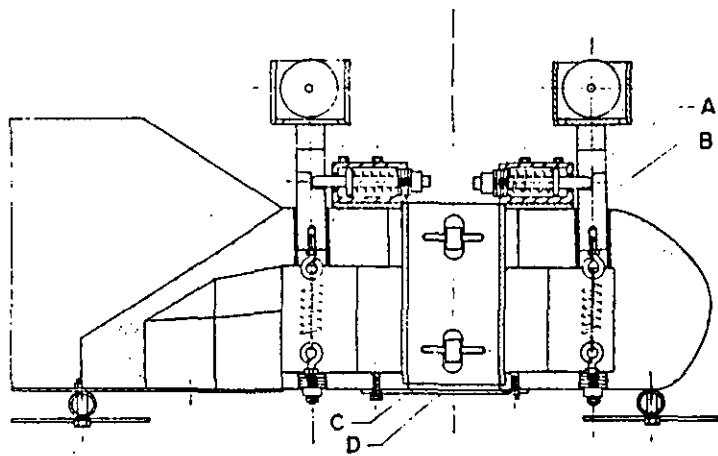
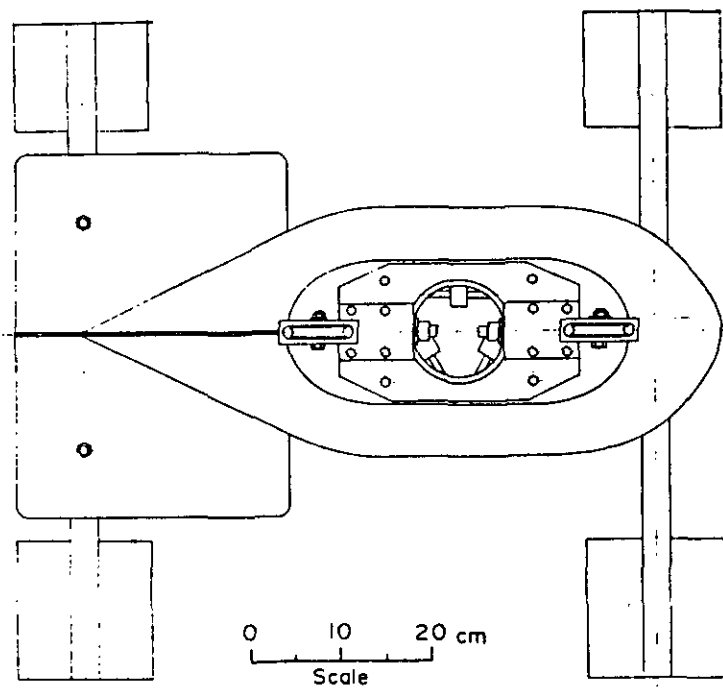
Other means by which to obtain samples from deep moving water have been developed as well. In a 1981 EPA study on the fate of PCB's in the Hudson River, a nonuniformly weighted corer was dropped from a helicopter to obtain bottom samples. The coring barrel consisted of one and two foot brass tubes containing 1-1/2 inch diameter plastic liners. The sampling

procedure was as follows: the helicopter would alight over the prospective sampling site and the corer would be lowered until it was just below the water's surface. The sampler would be released to impact the sediment surface at its own free fall velocity. The corer would then be winched back into the helicopter for sample removal. This method yielded satisfactory cores ranging in size from six to twelve inches in length from water as much as 40 feet deep (Johnson, 1982).



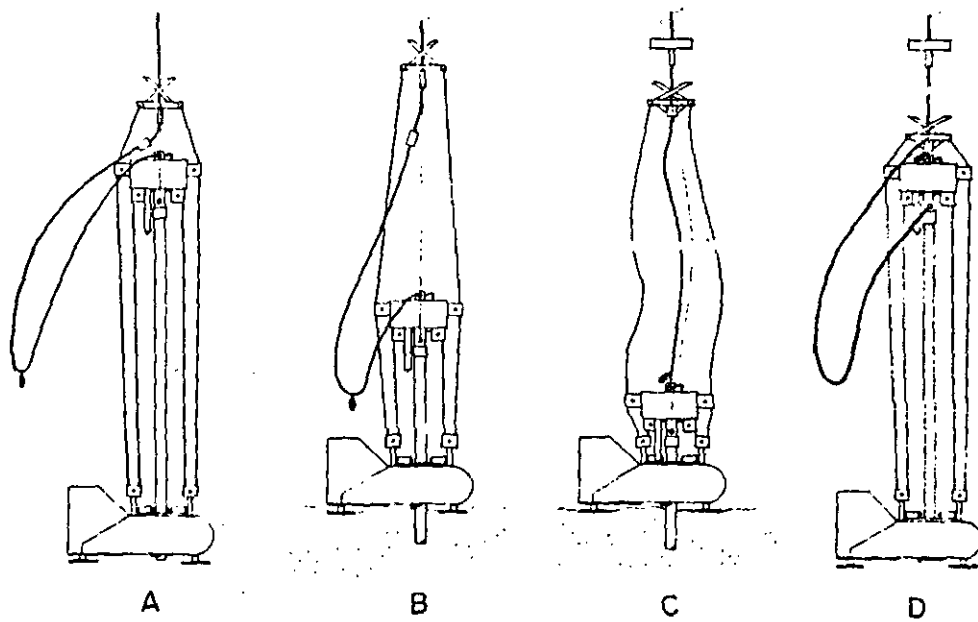
Assembly drawing of vibrator housing and core barrel.
 A, electrical connector; B, switch; C, plastic liner;
 E, locking pin socket; F, piston; G, removable filler.

Figure 6: River Sampler; core barrel
 (Prych, 1966)



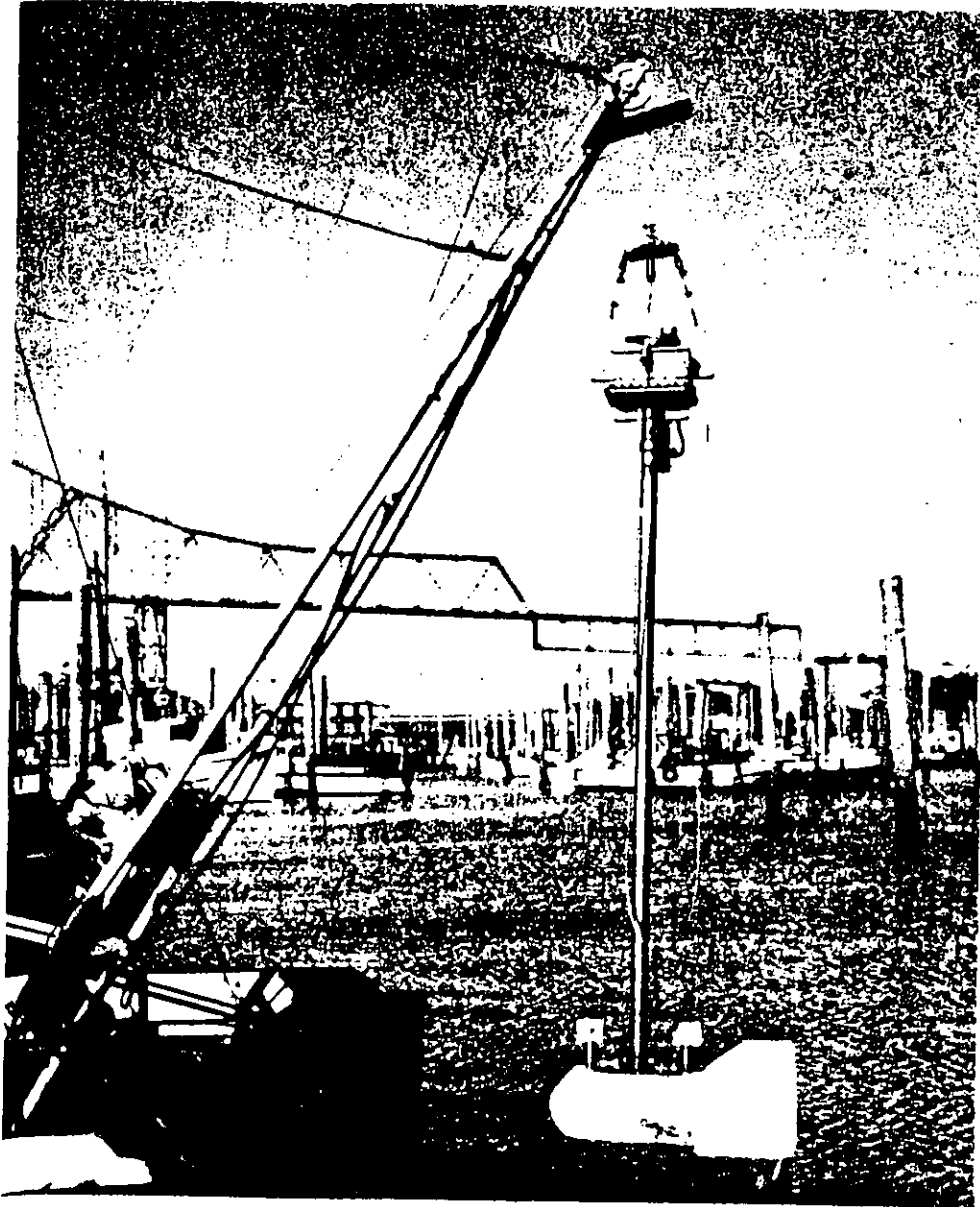
Assembly drawing of streamlined body.
A, locking pin; B, vertical piston; C, rubber roller;
D, cover plate.

Figure 7: River Sampler; streamlined body
(Prych, 1966)



A, Descending; B, Sampling; C, Withdrawal; D, Ascending

Figure B: River Sampler; cable-pulley assembly
(Prych, 1966)



SAMPLER PREPARED FOR CORING

Figure 9: River Sampler in operation
(Prych, 1966)

SAMPLING REQUIREMENTS

As mentioned in the preliminary project description, this study entails the modelling of the fate of total organic halides (TOX) in river water downstream from chlorinated municipal and industrial wastewater discharges. There are certain analytical constraints which limit the choice of the study site, and place requirements on the mode of sampling. Accuracy in detection of TOX quantities at low concentrations will be adversely affected by a large dilution factor if effluent is discharged into streams of flows much greater than about 50 cfs. For this reason, the study area will most likely be a small wadable stream, and sediment corers may accordingly be designed to be hand-held.

The depth below streambed surface at which TOX may be expected to be found in detectable concentrations will depend upon a great many factors, among them the partitioning coefficients and relative amounts of the various types of TOX compounds present, ground water baseflow, and the physical and chemical characteristics of the sediments carried by the stream. TOX contaminated sediments were found at a depth of 15 cm more than 5 km downstream of a Finnish pulping mill (Salkinoja-Salonen, et al., 1981). In a study of 13 polychlorinated dibenzodioxins and dibenzofurans found in sediment from Siskiwit Lake in Michigan, concentrations were either virtually undetectable or very small for all but one of the compounds at depths of 9 cm below the surface (Czuczwa, et al., 1985). In an EPA study of PCB's in Hudson River sediments (Johnson, 1982), appreciable amounts of contaminants were found at depths of up to 13 inches, but they exhibited a very strong affinity for certain sediment types. Fine grained sediments high in organic content retained the bulk of the PCB's, regardless of their depth.

The depositional characteristics of any given stream will naturally control to a large degree the amount and spatial extent of TOX found in the streambed. To insure adequate sampling under a variety of conditions, a sampler with the capability of obtaining a long core (18 inches or more) is desired. Additionally, where contaminants may be selectively associated with certain sediment types, it is advantageous to produce a cored sample which can be viewed prior to sectioning. Transparent sample retainers would suit this purpose. Many of the streams in New England run through unconsolidated material of glacial origin, and as such may have several distinct bedded horizons in a sediment profile. It would not be entirely surprising to find a wide range of grain size distribution.

Therefore, even though TOX may be expected to be found associated with fine grained sediments, coarser grains may easily be found in the same profile. This warrants a rigid corer with a metal cutting-shoe assembly, as penetration into coarser sediments is much more difficult than sampling fines.

Should TOX exist at depth, it is of great interest to ascertain concentration gradients where possible. Therefore, a coring device is desired which will yield an undisturbed sample with minimal compression and sidewall smearing. For this reason, a piston to provide suction upon extraction seems warranted. A piston would also contribute toward alleviating another possible source of analytical error by ridding the sediment sample of water from the water column above. It is thought that extended contact between the sediment and the water column in contained conditions might lead to erroneous TOX readings in the interstitial pore water.

Additionally, the core diameter must be large enough to supply an adequate sample mass for TOX analysis so that a high degree of concentration gradient resolution can be achieved. A large diameter will also contribute toward maintaining overall sample integrity by reducing the percentage of the sample volume that is deformed by drag along the sidewalls during coring.

RECOMMENDED DESIGN

Based on the analytical constraints and the set of primary coring sampler characteristics available, it is recommended that the following features be incorporated into the sampler design:

1. Hand-held, rigid tube: With sampling to be done in a wadable stream, a hand-held, hand driven corer will be sufficient, and its portability will facilitate frequent sampling. A corrosion resistant rigid tube and cutting-shoe assembly will be required because of expected resistance in sampling at sites with significant amounts of coarse grained sediments.

2. 20 inch long coring cylinder with 2 inch ID: Where sampling conditions permit, obtaining samples of this length will ensure that if appreciable amounts of TOX exist at depth, it will be found. The two inch diameter will provide sufficient sample mass for analysis at small (less than 1 inch) sectioning increments without inordinately increasing resistance to sampler penetration into the sediment.

3. Transparent plastic cylinder liner: Where fines or organics are distinctly interbedded with coarser sediments, this information is extremely useful for determining optimum sectioning strategies. This can only be accomplished with transparent liners. These liners will also allow one to make a reasonable estimate of the extent of sample deformation, and provide a convenient means of storing samples in the field.

4. Fingered basket-type sample retainer: Since it may be expected that bed-material may vary greatly in grain size, it is also expected that sample cohesiveness will vary greatly from site to site. To insure that sample loss upon withdrawal is kept to a minimum, a plastic fingered basket retainer will be installed prior to each sampling operation. (The basket will be very similar to that described in the operation of the Swedish Foil Sampler).

5. Water tight piston: The piston is one of the most important design features for the purposes of this study. First, the piston will provide the necessary suction during sample withdrawal so that the integrity of the sample may be retained to the fullest extent possible. Second, the volume of fluid from the water column above the sampling site must be eliminated from the sampling device so as to deter TOX site exchange during stored conditions. This can be accomplished quite easily by overturning the device after sampling while the

piston remains snug up against the sediment surface. The piston will have to be fitted with a simple valve to allow removal from the tube after sampling without deforming the upper levels of the sediment sample with undue suction. The valve will allow the partial vacuum that exists between piston and sediment to be broken and the piston to be removed easily for use in the next operation.

The final design is shown in schematic form in Figures 10 and 11. Figure 10 shows the 30 inch hollow brass coring tube with cutting-shoe assembly and piston-rod assembly. Figure 11 shows a detail of the base of the corer, including cutting shoe, plastic basket retainer, and the piston head with valve. The piston head is made of a tough, flexible polystyrene cylinder of diameter slightly smaller than the inside diameter of the plastic liner. This piston core is clamped on either side by nuts which tighten on a threaded rod which penetrates the core. As the nuts are tightened, the core deforms outward slightly to form a fit of adjustable snugness in the plastic liner. In this way, the desired fit may be obtained to compensate for wear on the piston and to achieve the optimum suction for various sampling conditions. The valve is made of a weighted tapered rubber stopper attached to a cord with a small eye-bolt. As the sampler is lowered into the stream, the cord is kept slack and the valve open to allow the water column fluid to pass through the piston head. As the sampler strikes bottom, the cord is tightened and the valve is closed. While the sampler barrel penetrates the sediment, the piston head remains stationary with respect to the streambed surface. After the core has been withdrawn, the sampler is overturned to rid the barrel of the water column fluid. The valve is then released to break the suction between the piston head and the sediment, and the piston is withdrawn from the plastic liner. The piston head is cleaned and inserted into a new plastic liner in preparation for sampling at the next site.

All known analytic and site requirements have been met. The current design is subject to modifications arising from unforeseen sampling circumstances.

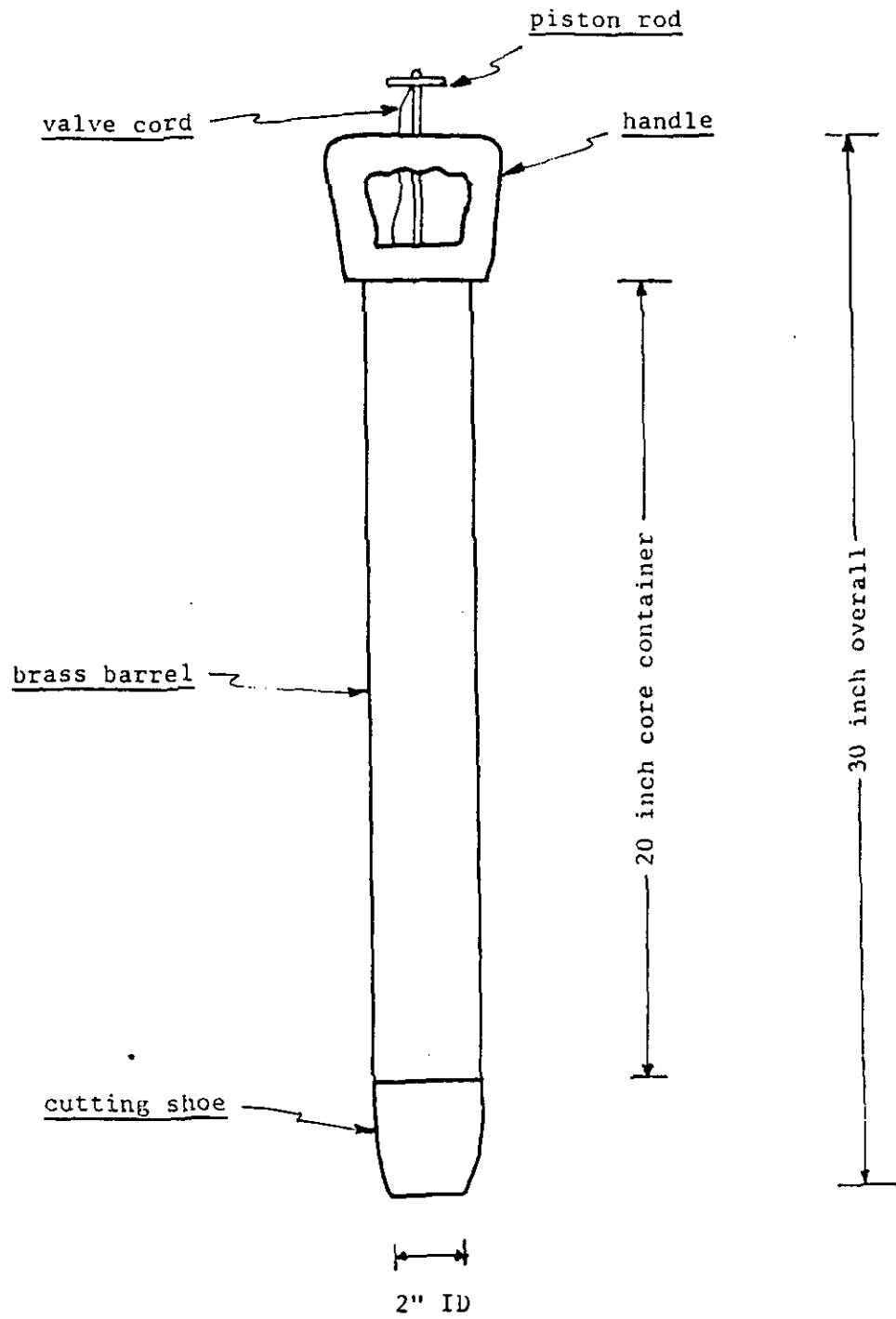


Figure 10: Recommended Design

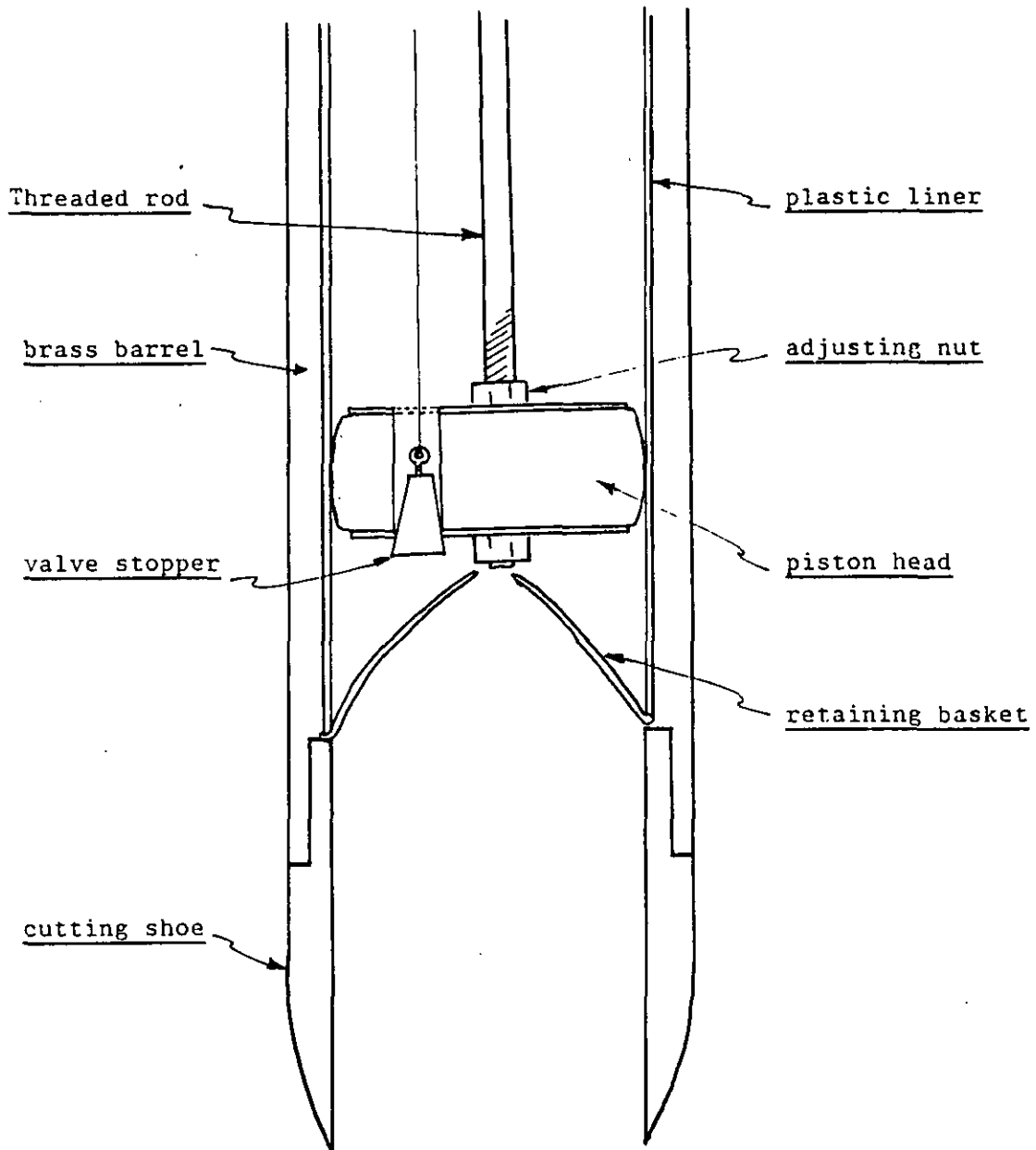


Figure 11: Recommended Design; detail

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