Measurement of liquid flow in open channels —

Part 10: Sediment transport —

Part 10 C: Guide to methods of sampling of sand-bed and cohesive-bed materials

Committees responsible for this British Standard

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Contents

Foreword

This Part of BS 3680 has been prepared by Technical Committee CPL/113. It supersedes BS 3680-10C:1980 which is withdrawn.

This revision of BS 3680-10C has been prepared in order to bring the techniques and equipment described up to date. The scope has been extended to include cohesive-bed materials, and details of the construction and deployment of all the major types of sampler are presented.

This standard is one of a series of Parts of BS 3680-10 on sediment transport. The other Parts are as follows.

— *Part 10B: Measurement of suspended sediment;*

— *Part 10D: Methods for determination of concentration, particle size distribution and relative density of sediment in streams and canals;*

— *Part 10E: Sampling and analysis of gravel bed material.*

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 28, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Introduction

Bed-material samplers are used to obtain samples of sediment from the bed of a watercourse. They are not to be confused with bed-load discharge samplers which are used to determine the discharge of sediment as bed load.

The particle size data derived from bed samples, together with hydraulic data, are necessary for the computation of bed material load and for flow estimation.

This standard covers methods for sampling both non-cohesive and cohesive bed material. Sediment composed of material with a particle size finer than 30 µm is cohesive. However, coarser material can also be cohesive if it contains a small proportion of this finer fraction.

1 Scope

This Part of BS 3680 gives guidance on methods for sampling of both non-cohesive sand-bed material and cohesive-bed material (both of which may contain some fine gravel) principally for the purpose of determining the grain size frequency distribution of the bed material in open channels.

NOTE Other publications of relevance to samplers and sampling techniques are listed in the bibliography in Annex A.

2 References

2.1 Normative references

This Part of BS 3680 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this British Standard only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This Part of BS 3680 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this Part of BS 3680, the definitions given in BS 3680-1:1991 apply, together with the following.

3.1
sand

sediment having a particle diameter between 0.0625 mm and 2 mm

4 Sampling procedure

Ideally, the size composition of the bed material should be determined for various stages of flow, as composition can change due to scour and fill activities.

In cases where information is required on the composition of layers located more than approximately 0.05 m below the surface of the bed, the use of core-type samplers is recommended.

Precautions should be taken to prevent fine particles escaping from the sample.

5 Selection of site

The site for sampling bed material for the purpose of computing bed material load or for flow estimation should be located as near as possible to the site where hydraulic measurements are made or need to be estimated. Equations for estimating bed load transport and flow resistance usually need measurements from a straight uniform section of channel. Site conditions should be selected that are suitable for the estimating equations which are to be used.

When estimates of total load are to be made, it is also essential that the site conforms to the conditions specified for the measurements of suspended sediment loads in BS 3680-10B.

For investigations of bed material transport rates it is recommended that as a minimum a sample should be taken at each vertical in the cross-section where sediment transport is to be measured.

6 Selection of sampler

In order to sample successfully, the sampler and the sampling method need to be chosen for their suitability for the particular circumstances. Results obtained using different methods may not necessarily be comparable.

When bed material is sampled, the sample inevitably suffers some form of disturbance. This can result in loss of fines, in which case the sample is referred to as "disturbed", or in loss of fabric, which is referred to as "structural disturbance". Structural disturbance of the sample does not affect the assessment of the erodability of non-cohesive sediments, whereas it does affect the results of tests on the erodability of cohesive sediments.

The construction and use of different types of samplers are described in clauses **7**, **8** and **9**.

7 Hand-held samplers

7.1 General

Hand-held samplers are lightweight devices which can be operated by an individual while wading or, in deeper water, by a Scuba diver. Hand-held samplers include bed surface samplers and core samplers.

7.2 Bed surface samplers

7.2.1 *Sampling cylinders*

7.2.1.1 *Construction*

A sampling cylinder comprises a metal cylinder which encloses the area of bed to be sampled, and which is heavy enough to resist the flow. If practicable, the cylinder should break the water surface.

7.2.1.2 *Deployment*

Digging tools are used to remove samples from within the enclosed volume. The cylinder helps to minimize the washout of fines.

7.2.1.3 *Sample type*

This method yields disturbed samples. The top 0.1 m approximately of the bed is sampled.

7.2.2 *Pipe scoops*

7.2.2.1 *Construction*

A pipe scoop comprises a pipe, one end of which is closed and the other end of which is bevelled to form a cutting edge, attached to a wading rod. A hinged cover plate, held closed by a spring, is mounted over the open end. The plate is opened by a rope (see Figure 1).

7.2.2.2 *Deployment*

The pipe is pushed along the bed into the current. The plate is opened to sample then immediately closed, thus minimizing washout.

7.2.2.3 *Sample type*

This method yields disturbed samples. Samples of mass up to 3 kg can be obtained. The top 0.05 m approximately of the bed is sampled.

7.2.3 *Bag scoops*

7.2.3.1 *Construction*

A bag scoop comprises a metal ring with an attached flexible bag, mounted on a wading rod (see Figure 2).

7.2.3.2 *Deployment*

The ring is forced into the bed and dragged upstream until the bag is full [see Figure 2 a)]. As the sampler is raised the bag seals automatically [see Figure 2 b)].

7.2.3.3 *Sample type*

This method yields disturbed samples. Samples of mass up to 3 kg can be obtained. The top 0.05 m approximately of the bed is sampled.

7.3 Core samplers

7.3.1 *Push or hammer corers and boxes*

7.3.1.1 *Construction*

These include metal or plastics corers up to 150 mm in diameter and boxes of up to 0.25 in side.

7.3.1.2 *Deployment*

The cylinder or box of the corer is pushed or hammered into the bed and dug or pulled out. Sample retention can be ensured by use of one or more of the following methods.

a) A plate is slid beneath the corer and the cylinder or box is dug out.

b) A partial vacuum can be created above the sample.

   1) After the insertion of the cylinder or box, the water-filled space above the sample can be sealed off by means of a screw cap, thus forming a partial vacuum when the sampler is withdrawn (see Figure 3).

   2) Alternatively, in the case of cylinder samplers, the cylinder can be fitted with a piston which rises on the surface of the sample and is locked when the sampler has been pushed or hammered to the desired depth. A partial vacuum develops below the piston and helps to hold the sample in the cylinder as it is withdrawn from the bed (see Figure 4).

c) In the case of cylinder samplers a core catcher (sphincter) of flexible stainless steel petals can be located at the bottom opening of the cylinder (see Figure 5).

7.3.1.3 *Sample type*

This method disturbs the texture and structure of the sample, although the gross particle population may be preserved. Maximum penetration is approximately 0.5 m.

7.3.2 *Freeze-core samplers*

7.3.2.1 *Construction*

A freeze-core sampler comprises a thin walled copper or mild steel tube with a hardened steel tip. A probe, through which liquid carbon dioxide, liquid nitrogen or solid carbon dioxide mixed with acetone can be injected, is inserted into the tube. In the case of liquid carbon dioxide, delivery is from a pressurized cylinder via fine nozzles in the probe (see Figure 6).

7.3.2.2 *Deployment*

The outer tube is hammered into the bed and the probe, connected to the coolant, inserted into it. After a suitable period, which depends on the sediment properties and the ambient temperature, the tube is pulled out of the bed with the adjacent sediment frozen to it.

7.3.2.3 *Sample type*

This method yields a spindle-shaped frozen "core" up to 0.5 m in length and with a maximum diameter of approximately 0.3 m. Sedimentary structures are disturbed but recognizable.

7.3.2.4 *Limitations*

The method is not suitable for Scuba use or for water depths in excess of 3.5 m.

8 Lightweight remotely-operated samplers

8.1 General

These samplers can be hand-operated and can be deployed from small boats. They include bed surface samplers and core samplers.

8.2 Bed surface samplers

8.2.1 *Pipe scoops and bag scoops*

8.2.1.1 *Construction*

Pipe scoops and bag scoops are constructed as described in **7.2.2.1** and **7.2.3.1**, respectively. The scoop is attached to a pole up to 4 m in length.

8.2.1.2 *Deployment*

The scoops are deployed as described in **7.2.2.2** and **7.2.3.2**, respectively. Normally it is necessary for the boat to be anchored.

8.2.1.3 *Sample type*

This method yields disturbed samples. Samples of mass up to 3 kg can be obtained. The top 0.05 m approximately of the bed is sampled.

8.2.1.4 *Limitations*

Use of this method is limited to water depths of less than 4 m and velocities of less than 1.0 m s^{-1}.

8.2.2 *Drag buckets*

NOTE These are also known as dredges.

8.2.2.1 *Construction*

The sampler comprises a weighted bucket or cylinder with a flared cutting edge at one end and a sample collecting receptacle at the other. A drag rope is attached to a pivoting bridle towards the cutting end of the cylinder (see Figure 7).

8.2.2.2 *Deployment*

The device is lowered to the bed and dragged along it from a boat moving slowly into the current. To ensure contact of the cutting edge with the bed a streamlined weight can be attached to the rope.

8.2.2.3 *Sample type*

This method yields disturbed samples. Samples of mass up to 1 kg can be obtained. The top 0.05 m approximately of the bed is sampled.

8.2.2.4 *Limitations*

Samples are liable to be affected by washing-out of material.

8.2.3 *Grab samplers with 90° closure*

8.2.3.1 *Construction*

Two quarter-cylinder shaped buckets are hinged to each other, forming a half-cylinder when closed. Arms are attached to each bucket to which a rope and pulley system is fastened. A latching system holds the buckets open until the grab reaches the bed. The slackening of the rope releases the latch, and the tightening of the rope as the grab is retrieved closes the buckets (see Figure 8).

8.2.3.2 *Deployment*

The grab is latched open and lowered slowly to the bed from a slowly drifting or anchored boat. The rope is allowed to slacken momentarily then a steady pull is applied and the grab retrieved.

8.2.3.3 *Sample type*

The samples obtained are often relatively undisturbed. Samples of mass up to 3 kg can be obtained. The top 0.05 m approximately of the bed is sampled.

8.2.3.4 *Limitations*

This method is not suitable for use in sand when amounts of coarse gravel are present, as stones can wedge open the jaws allowing the sample to wash out.

The grab may be too light to use when water velocities exceed 1.0 m s^{-1}.

8.2.4 ***Grab samplers with 180° closure***

8.2.4.1 *Construction*

A half-cylinder shaped bucket is pivoted and spring-mounted within a streamlined housing with a flat base. The spring is tensioned when the bucket is rotated into the housing. A latching system keeps the bucket in this position until the bed is reached and the tension goes out of the support rope, at which point the bucket snaps shut enclosing the sample. The sampler has a mass of approximately 15 kg (see Figure 9).

8.2.4.2 *Deployment*

The bucket is rotated into the housing and, keeping a steady tension on the rope, the grab is lowered slowly to the bed. The rope is slackened to close the bucket, then the grab is retrieved.

WARNING. This device can maim if accidentally triggered whilst it is being handled.

8.2.4.3 *Sample type*

This method yields disturbed samples. Samples of mass up to 1 kg can be obtained. The top 0.05 m approximately of the bed is sampled.

8.2.4.4 *Advantages and limitations*

This equipment can be used to sample sediment containing stones up to approximately 30 mm in diameter without serious wash-out of material. However, stones caught between the bucket and the body of the sampler, keeping the bucket wedged open, can allow some material to fall out. The sampler has been observed to bounce off the bed on hard-packed sands.

8.3 Corer samplers

8.3.1 ***General***

The samplers are as described in **7.3**, but are restricted to push or hammer corers (see **7.3.1**) 100 mm or less in diameter.

8.3.2 ***Push or hammer corers***

8.3.2.1 *Construction*

The sampler comprises a corer up to 100 mm in diameter attached to a pole up to 4 m in length, with a vacuum or core-catcher sample retention mechanism as described in **7.3.1.2** b) and **7.3.1.2** c), respectively.

8.3.2.2 *Deployment*

The sampler is deployed from a boat which needs to be anchored fore and aft.

8.3.2.3 *Sample type*

Samples of non-cohesive material are undisturbed. Samples of cohesive material suffer structural disturbance. The corer has a maximum penetration of approximately 0.5 m, and yields samples of up to 1.5 kg mass per 0.1 m penetration.

8.3.2.4 *Limitations*

This type of sampler is difficult to use if water velocities exceed 1.5 m s^{-1}.

9 Remotely-operated samplers requiring handling machinery

9.1 General

To obtain larger samples, either in terms of surface area or depth of penetration of the bed, or for sampling under conditions with high flow velocities (> 1.5 m s^{-1}) heavier equipment has to be deployed. Derricks and winches need to be mounted on a reasonably sized vessel (> 5 m length), the draft of which generally makes it impracticable to work in water depths of less than 1.2 m.

9.2 Bed surface samplers

9.2.1 ***Anchor dredges***

9.2.1.1 *Construction*

An anchor dredge comprises a cylindrical or rectangular-section open-ended box of up to 0.5 m diameter or length of side. A large heavy-duty flexible bag is laced to one end, and the other end is flared to provide a cutting edge. A bridle spans the open end, pivoted from the centre of the box, to which a tow line is fastened (see Figure 10).

9.2.1.2 *Deployment*

The dredge is deployed as described in **8.2.2.2**.

9.2.1.3 *Sample type*

This method yields disturbed samples. Samples of mass up to 0.5 t can be obtained. The top 0.1 m approximately of the bed is sampled.

9.2.1.4 *Limitations*

Considerable power is needed to pull the equipment.

9.2.2 ***Grab samplers with 90° closure***

9.2.2.1 *Construction*

A variety of designs are in use, ranging from larger versions of the simple grab described in **8.2.3.1** to devices where the buckets are mounted in a frame and triggering is effected via contact plates protruding below the grab base. One type uses a spring system to force the open buckets partially into the bed prior to the jaws being wound shut. The mass of the grabs is of the order of 0.5 t, but can be doubled by the addition of lead. An example is shown in Figure 11.

9.2.2.2 *Deployment*

The grabs are deployed as described in **8.2.3.2**.

Grabs with trigger plates protruding from the base need special tables to land upon.

9.2.2.3 *Sample type*

The samples obtained are often relatively undisturbed. This equipment can take samples of up to 0.1 m^2 to a depth of approximately 0.15 m.

9.2.2.4 *Limitations*

This equipment is not effective in sand if amounts of gravel are present, as stones can wedge open the jaws allowing the sample to wash out.

9.2.3 ***Grab samplers with 180° closure***

9.2.3.1 *Construction*

These grabs are larger versions of the grab described in **8.2.4.1**. Examples are shown in Figure 12 and Figure 13. One design does not employ a spring but uses the suspension cable to wind the bucket shut prior to retrieval (see Figure 13). On striking the bed, the gripping claw is released. When the suspension cable is tensioned, the sleeve is raised. The bucket, which is connected to the sleeve by the bucket cable, is then closed prior to the grab being raised from the bed.

9.2.3.2 *Deployment*

Deployment is as described in **8.2.3.2**.

9.2.3.3 *Sample type*

The samples obtained are disturbed. This equipment can take samples of up to 0.05 m^2 to a depth of approximately 0.1 m.

9.2.3.4 *Advantages and limitations*

See **8.2.4.4**.

9.3 Core samplers

9.3.1 ***Free fall gravity corers. Circular barrel corer***

9.3.1.1 *Construction*

A barrel of 50 mm to 100 mm internal diameter and up to approximately 2 m in length is attached at one end to a structure fitted with the following:

a) a system for attaching lead weights;

b) a flap valve connecting the interior of the barrel to the outside environment;

c) a swivel for the attachment of a heavy rope or wire.

A hardened steel cutting shoe is screwed onto the other end of the barrel, where provision may also be made for the fastening of a core-catcher (see Figure 5).

The mass of the weights which it is necessary to attach in order to obtain reasonable penetration depends largely upon the hardness of the substrate, and may be up to 1.0 t. (See Figure 14.)

9.3.1.2 *Deployment*

The corer is lowered until the cutting shoe lies approximately 3 m above the bed, then it is allowed to free fall. The corer is then winched out of the sediment, sample retention depending upon both the core-catcher and the vacuum set up under the flap valve. During retrieval the pull has to be vertical; thus it is essential that the boat is anchored.

9.3.1.3 *Sample type*

Fine layers can be lost. Penetration rarely exceeds 1 m. Samples can be obtained of mass up to 1.5 kg per 0.1 m penetration.

9.3.1.4 *Limitations*

This equipment usually cannot be used to sample hard-packed sand or material with an appreciable stone content.

9.3.2 ***Free fall gravity corers. Square barrel corer***

9.3.2.1 *Construction*

Construction is similar to that of the circular barrel corer (see **9.3.1.1**) except that the barrel corer and sample retention systems have a square cross-section and are typically 150 mm long.

The corer barrel has a square cross-section and is divided longitudinally into two halves. Each half comprises two sides of the square and they are joined by overlapping flanges held together by clips and bolts (see Figure 15).

At the top of the barrel is an adaptor which connects to the weight chassis above it and to the square section barrel below. Weights can be added to the weight chassis as required.

At the bottom of the barrel is a cutting shoe with two spring loaded closure flaps. These flaps are folded back and held against release levers during the coring exercise (see Figure 15).

9.3.2.2 *Deployment*

The square barrel type corer is deployed in the same way as the circular barrel type (see **9.3.1.2**). As the corer is withdrawn from the bed the release levers are activated and the closure flaps close to retain the core.

9.3.2.3 *Sample type*

The cores obtained are relatively undisturbed. Samples can be obtained of mass up to 4 kg per 0.1 m penetration. The sampled area is 0.0225 m^2.

9.3.2.4 *Limitations*

Penetration in mud is limited by barrel length and the mass of the corer. This type of corer cannot be used to sample sand.

9.3.3 ***Frame-guided gravity corers. Circular barrel corer***

9.3.3.1 *Construction*

The basic construction is the same as for a free-fall gravity corer (see **9.3.1.1**), with the addition of a frame guide consisting of a tapered vertical frame and a circular horizontal frame (see Figure 16), which rests on the bed prior to core penetration, thus guiding the barrel squarely into the sediment.

The barrel and the unit consisting of lead weights and a hinged sealing cover, gimbal and slide freely within the frame guide. The barrel length is usually restricted to less than 1 m. Additional features can be a triggered ball or plate closure which seals the base of the barrel immediately after withdrawal from the sediment, and a hydraulic system controlling the rate of barrel penetration (see Figure 16).

9.3.3.2 *Deployment*

The corer is deployed in the same way as a free-fall gravity corer (see **9.3.1.2**) except that the corer is lowered slowly all the way to the bed, then the rope allowed to remain slack whilst penetration occurs solely as a result of the deadweight of the corer.

9.3.3.3 *Sample type*

See **9.3.1.3**.

9.3.3.4 *Limitations*

See **9.3.1.4**.

9.3.4 ***Frame-guided gravity corers. Square barrel corer***

9.3.4.1 *Construction*

The construction is similar to the circular barrel corer (see **9.3.3.1**) except that the barrel has a square cross-section. A cutting blade is mounted on a pair of arms pivoted at the level of the top of the barrel. The arms are operated by a pulley system involving the hoisting cable, and come into action when the latter slackens and activates a release mechanism. The cutting blade is winched down to seal off the sample before the barrel is pulled from the sediment. The barrel is 0.3 m deep (see Figure 17).

9.3.4.2 *Deployment*

See **9.3.3.2**.

9.3.4.3 *Sample type*

This equipment yields undisturbed samples. Samples of mass up to 25 kg can be obtained. Up to 0.05 m^2 of bed is sampled.

9.3.4.4 *Limitations*

This type of sampler gives poor penetration in hard sands. Blade action often tilts the barrel before closure is complete.

9.3.5 ***Vibrocorers***

9.3.5.1 *Construction*

A vibrocorer has the same construction as a frame-guided barrel corer, with the addition of an electric vibrator motor at the top of the barrel to aid penetration into sands and gravels. An electrical umbilical is necessary for connecting the corer to the power supply and control unit on board the boat. Small vibrocorers have been constructed with a core barrel diameter of 15 mm and a length of 0.3 m. Longer corers are commonly in use with a core barrel diameter of 100 mm and core barrel lengths of 3 m or more. A penetrometer (e.g. an echo-sounder attached to the barrel top) is usually employed to monitor coring progress (see Figure 18).

9.3.5.2 *Deployment*

The boat needs to be anchored. The corer is lowered slowly to the bed and the vibrator switched on, keeping power at a minimum.

9.3.5.3 *Sample type*

Relatively undisturbed samples can be obtained from non-cohesive sediments, unless over vibrated, but samples of cohesive sediments can suffer severe structural disturbance.

9.3.5.4 *Advantages*

This method gives the best penetration in sands and gravelly sands of all coring techniques.

10 Subsurface sampling

If an armour layer of gravel overlies a bed of finer material, then it may be possible to sample the armour layer by surface sampling techniques (see BS 3680-10E). The underlying material can be sampled by routine bulk sampling techniques.

11 Choice of sampler for muds

Samplers used for taking samples of mud should maintain, as far as possible, the structural integrity of the sample and its pore water content. To achieve this a sampler should be selected which has a minimum surface area: volume ratio for a given diameter and which closes effectively to minimize pore water drainage. Introduction of the sampler into the mud inevitably destroys the structure near the walls and so a subsample which discards the 5 mm to 10 mm nearest the walls should be the final portion used for testing or analysis.

The most serious disturbance to the sample is produced by the use of petal type core catchers which are fitted to most cylindrical barrel corers. Flap type retainers as are fitted to square barrel free-fall gravity corers cause less disturbance and externally closing cutting blades, as are fitted to square barrel frame-guided corers, cause the least disturbance.

Cylindrical samplers are generally unsuitable and square barrel samplers without a guiding frame can also have unacceptable effects. The most appropriate sampler appears to be a frame-guided square barrel sampler. In soft sediments the sampler needs to be supported by a frame to prevent tilting during sampling unless sufficient penetration is achieved to support the driving weight of the sampler.

The two most suitable devices which provide minimal structural disturbance and effective closure, and permit subsampling are:

a) a free fall gravity square barrel corer (see **9.3.2**);

b) a frame-guided gravity square barrel corer (see **9.3.4**).

12 Determination of sample mass and number of samples

12.1 General

The mass of an individual bulk sample that needs to be taken at a single location needs to be determined. Much larger samples are needed for sand than for silt and clay and these materials need to be considered separately.

As the bed material is likely to vary spatially, it is also necessary to determine the number of similar sized bulk samples that are needed to enable accurate assessment of the grain size characteristics of the reach or area under investigation.

12.2 Mass of individual bulk sand samples

12.2.1 In general, the sample mass needed depends on the acceptable error.

If p_i is the proportion of the bulk sample, by mass, of a particular fraction having a grain diameter of D_i, in millimetres, and r_{pi} is the acceptable relative error in p_i, then the mass m, in kilograms, of the bulk sample to be analysed should be:

$$m > f(D_i) \times r_{pi}^{-2} \times p_i^{-1} \qquad (1)$$

where

$f(D_i)$ is a specified function of D_i as given in equation (2);

in order to reproduce the coarse tail of the particle size distribution with sufficient accuracy.

Using a $\sqrt{2}$ series of sieves and assuming a specific gravity of 2.65, the function $f(D_i)$, in kilograms, has been determined to be:

$$f(D_i) \approx 2.2 \times D_i^3 \times 10^{-6} \qquad (2)$$

where

D_i is the grain diameter (in mm)

For particle sizes less than D_i the error is less than r_{pi}, the acceptable relative error.

D_{84} (i.e. the particle diameter which 84 % by mass of the sample falls below) is often used to characterize the coarse tail of the particle size distribution. It is often appropriate to use this diameter in the determination of the required sample mass. To determine the sample mass required to estimate p_i for a particular particle diameter (e.g. D_{84} or D_{50}) that particle diameter should be substituted for D_i in equations (1) and (2).

12.2.2 The mass, m, of the bulk sample to be analysed, as a function of the characteristic diameter D_i, can therefore be derived using equations (1) and (2), leading to design curves as shown in Figure 19.

If a value of p_i is chosen, this value can be combined with various values of r_{pi} to give different levels of accuracy, as shown in Table 1.

Table 1 — Examples of combinations of r_{pi} and p_i

r_{pi} %	$r_{pi}^2 \times p_i$	Accuracy
1	10^{-5}	High
3	10^{-4}	Normal
10	10^{-3}	Low

The accuracy required depends on the circumstances. In cases where the composition of the bed material differs considerably from location to location, there may be little benefit in pursuing high accuracy.

If the composition of the bed material is more homogeneous normal accuracy can be taken.

12.2.3 In the example illustrated in Figure 19, it was known from samples taken previously that the composition of the bed material differed substantially from place to place.

From analysis of previous samples, it was known that D_{84} was approximately 5 mm.

This gives a sample mass, m, of approximately 0.2 kg for low accuracy and of approximately 2 kg for normal accuracy.

12.2.4 The size of the samples taken with most of the conventional samplers varies between 0.2 kg and 1 kg. From Figure 19 it can be seen that, especially for coarse bed material, the analysis of large samples is needed. If necessary, a number of bulk samples, taken at the same location, should be aggregated to obtain a total sample of the required mass.

12.3 Mass of individual bulk silt and clay samples

For sediments consisting entirely of silts and clays the sample size need not exceed 10 g.

12.4 Number of bulk samples

12.4.1 If bed material size appears to be the same everywhere within the reach under investigation, a single bulk sample from any location should be representative. However, in many channels bed material size is not spatially uniform and it is necessary to take bulk samples from more than one location.

12.4.2 If the bed material size varies spatially, the number of bulk samples required depends on the variability of the bed material and the desired accuracy.

To calculate the required number of bulk samples it is first necessary to take a number (x) of equal volume bulk samples from within the reach. The D_i value, in millimetres, for each bulk sample is determined by sieving and the standard deviation s_b, in millimetres, of the sample D_i values is calculated using the following equation:

$$s_b = \sqrt{\frac{\sum_1^x (D_i - \overline{D}_i)^2}{(x-1)}} \quad (3)$$

where

D_i is the mean of the x sample D_i values (in mm).

12.4.3 Where the variability is relatively low, the number of bulk samples (N_b) required to obtain an acceptable level of accuracy for the sample D_i value for the reach, at the 95 % confidence level is given by:

$$N_b = \left(\frac{ts_b}{d}\right)^2 \quad (4)$$

where d, the acceptable error, is the difference between the sample and population D_i values, in millimetres, for the reach and t is Student's t, obtained from Table 2 for the particular number of initial bulk samples (x).

Table 2 — Student's t values at the 95 % confidence limit for different numbers of initial bulk samples (x)

Number of initial bulk samples (x)	Student's t value
2	12.71
3	4.30
4	3.18
5	2.78
10	2.26
20	2.09

13 Errors

13.1 General

When bed material sampling is used in the determination of the particle size distribution of bed material, errors in the final results can arise from the sources detailed in **13.2** to **13.4**.

13.2 Inadequate sampling

The loss of fine particles results in a systematic uncertainty, the magnitude of which depends on the operating system and the characteristics of the particular sampler employed.

The influence of this uncertainty, which cannot be expressed quantitatively, can only be minimized by careful sampling and by excluding that part of the sample which could have lost some of its material during retrieval.

13.3 Sample mass (sand samples)

While the sample mass needed depends on the acceptable error (see **12.2.1**), for a given sample mass, m, (in kg) the relative error, r_{pi}, associated with that sample mass can be expressed by:

$$r_{pi}^2 = \frac{1}{p_i m}\left\{f(D_i) - \frac{p_i}{\sum p_i / q(D_i)}\right\} \quad (5)$$

For sand, using a $\sqrt{2}$ series of sieves and assuming a specific gravity of 2.65, the functions $f(D_i)$ and $q(D_i)$ have been determined to be as follows:

$$f(D_i) = 2.2 \times D_i^3 \times 10^{-6}$$

$$q(D_i) = 1.69 \times D_i^3 \times 10^{-6}$$

where

D_i is the grain diameter (in mm).

For the coarser fractions the $f(D_i)$ term dominates the expression for r_{pi}^2, but for the finer fractions the

$\dfrac{p_i}{\Sigma\, p_i / q(D_i)}$ term dominates.

13.4 Particle size analysis

The particle size analysis (for example by sieving) can introduce errors.

To minimize these errors the analysis should be carried out in accordance with one of the methods described in BS 3680-10D.

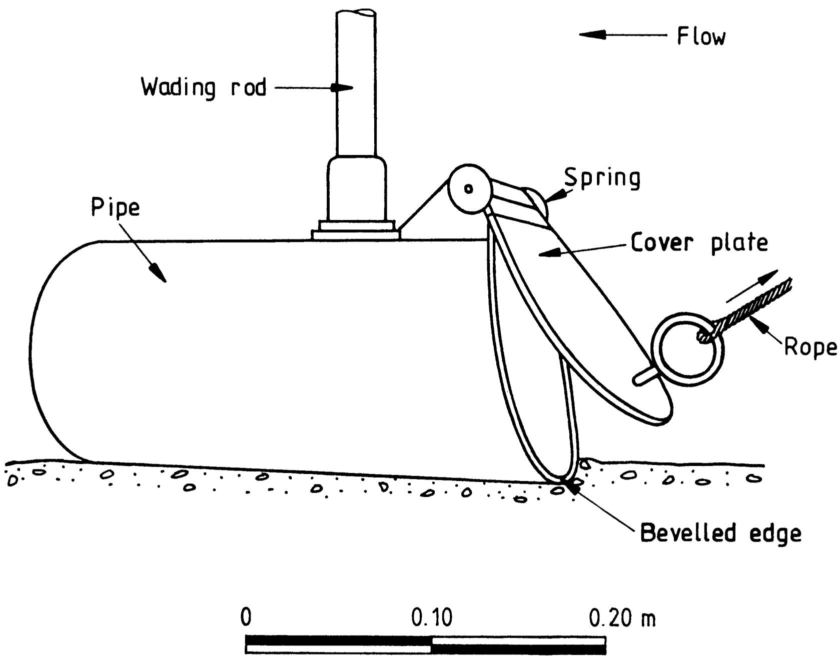


Figure 1 — Pipe scoop sampler with hinged cover

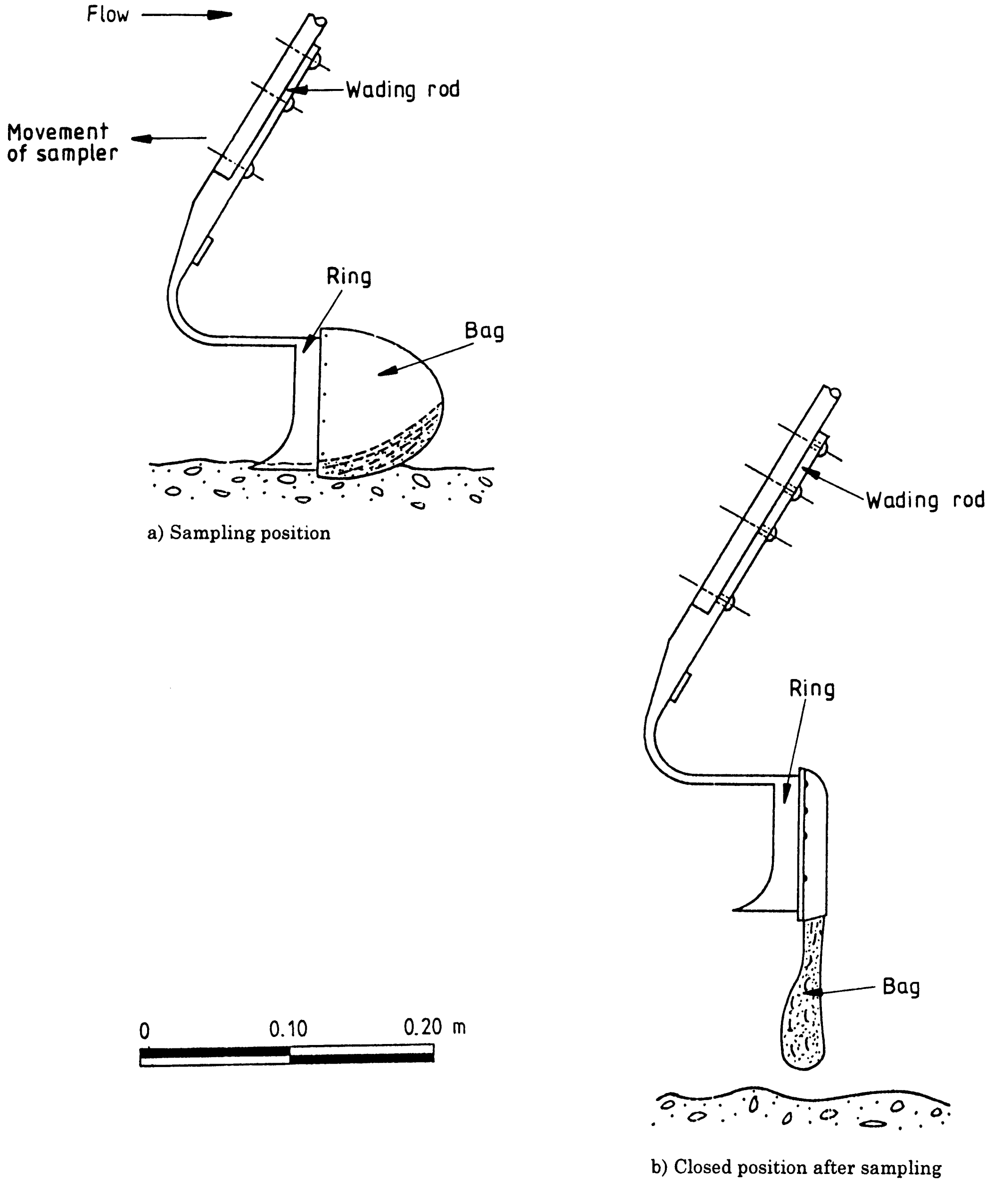


Figure 2 — Bag scoop sampler with canvas bag

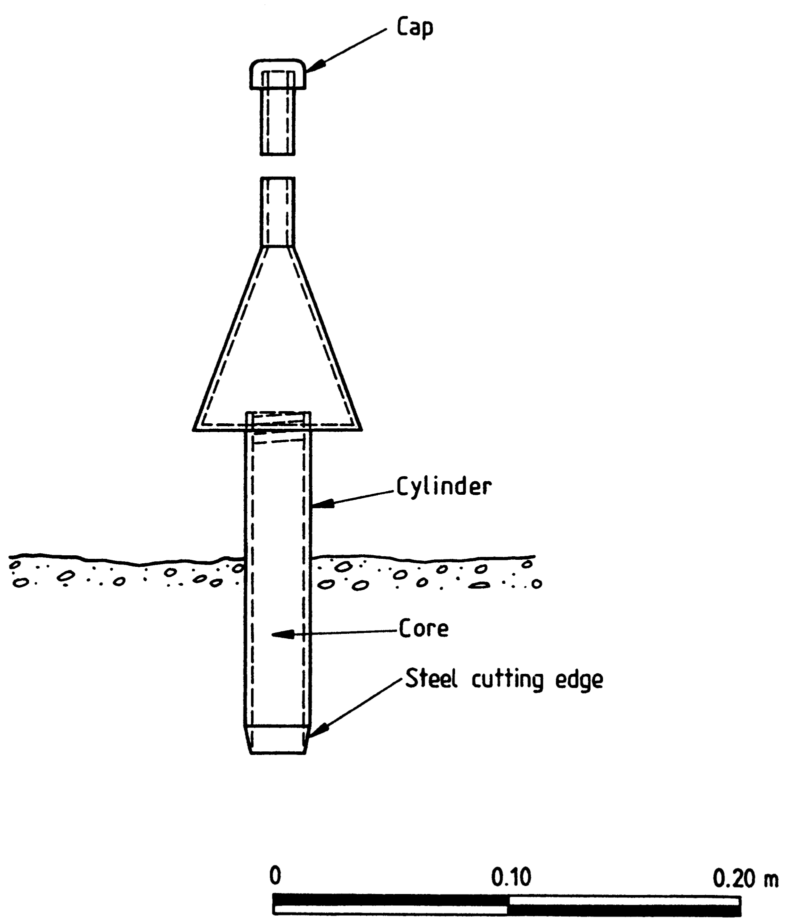


Figure 3 — Push or hammer corer sampler

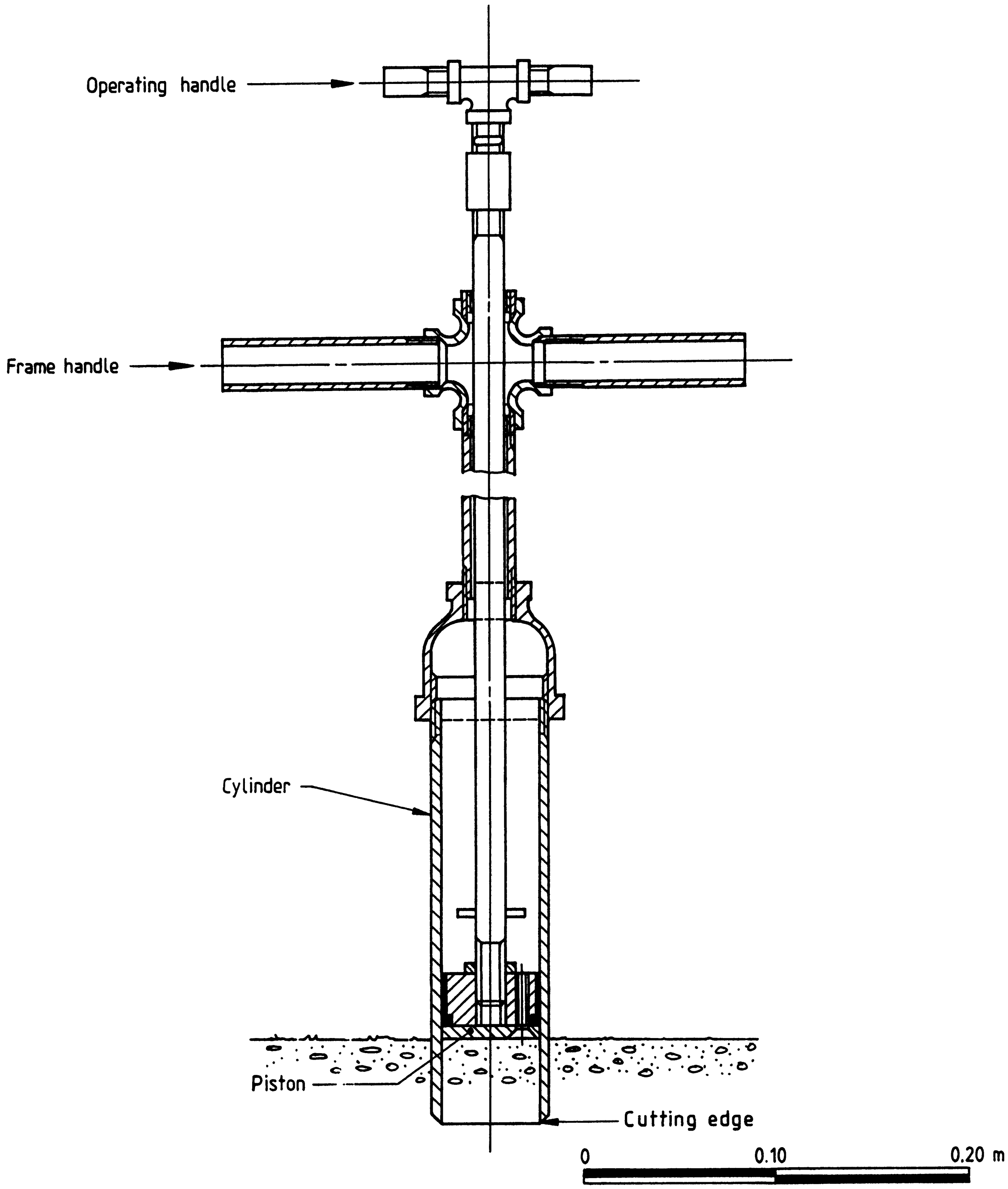
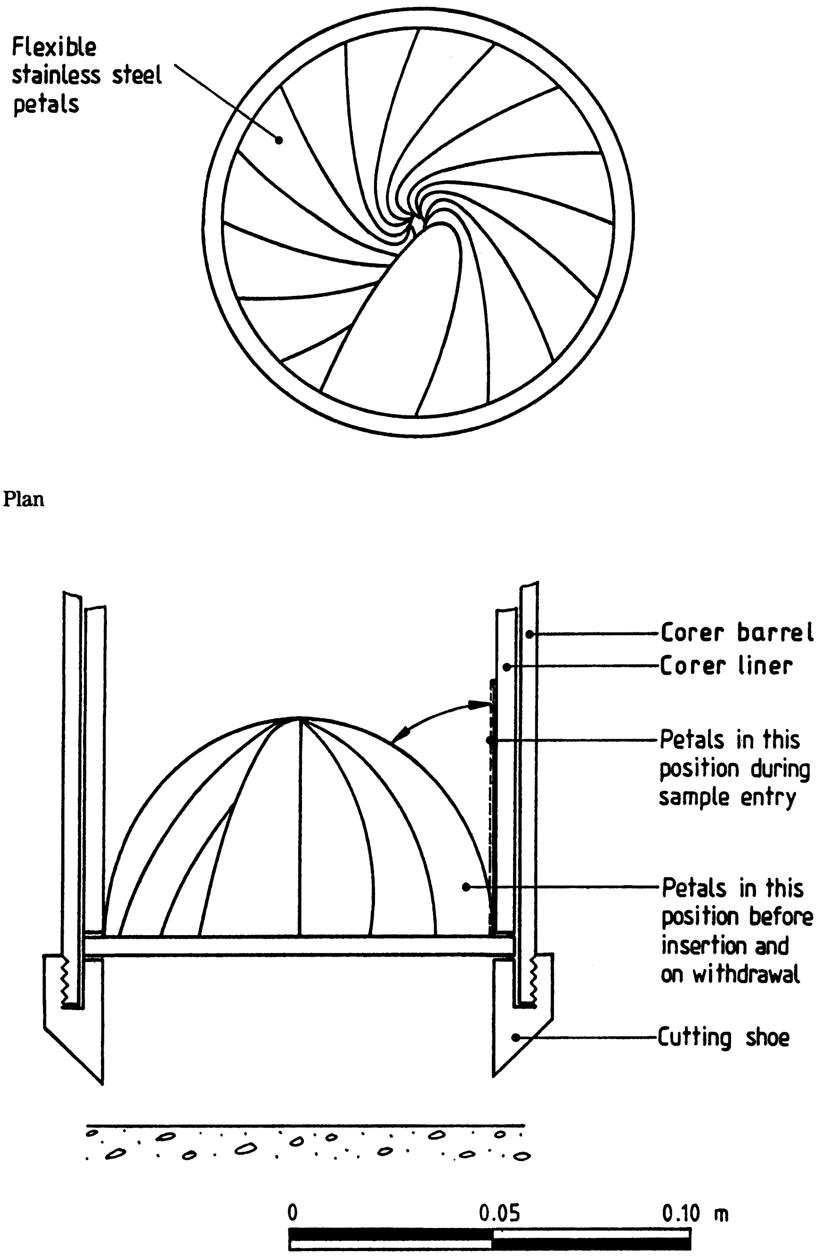


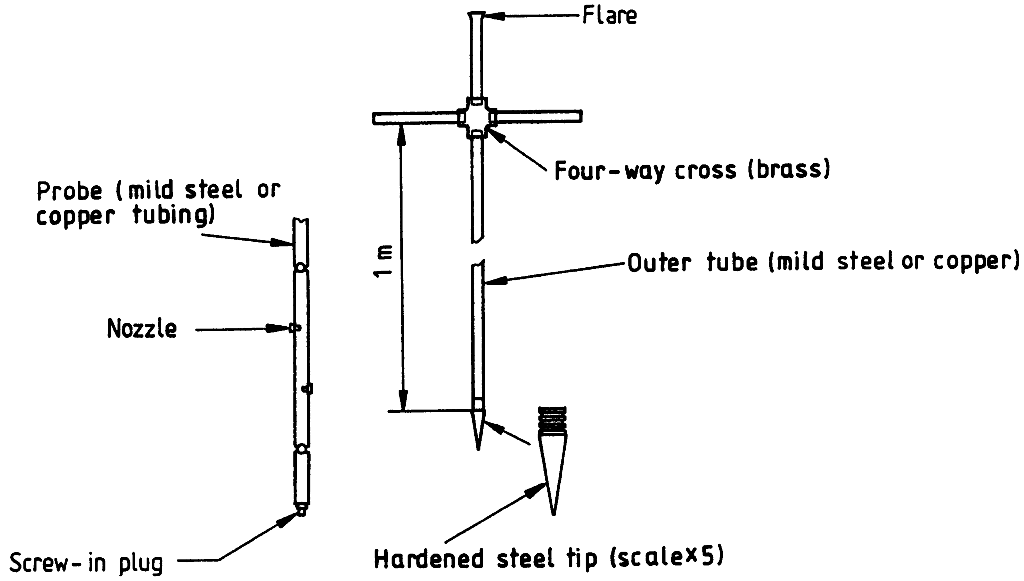
Figure 4 — Push or hammer cylinder corer sampler with piston



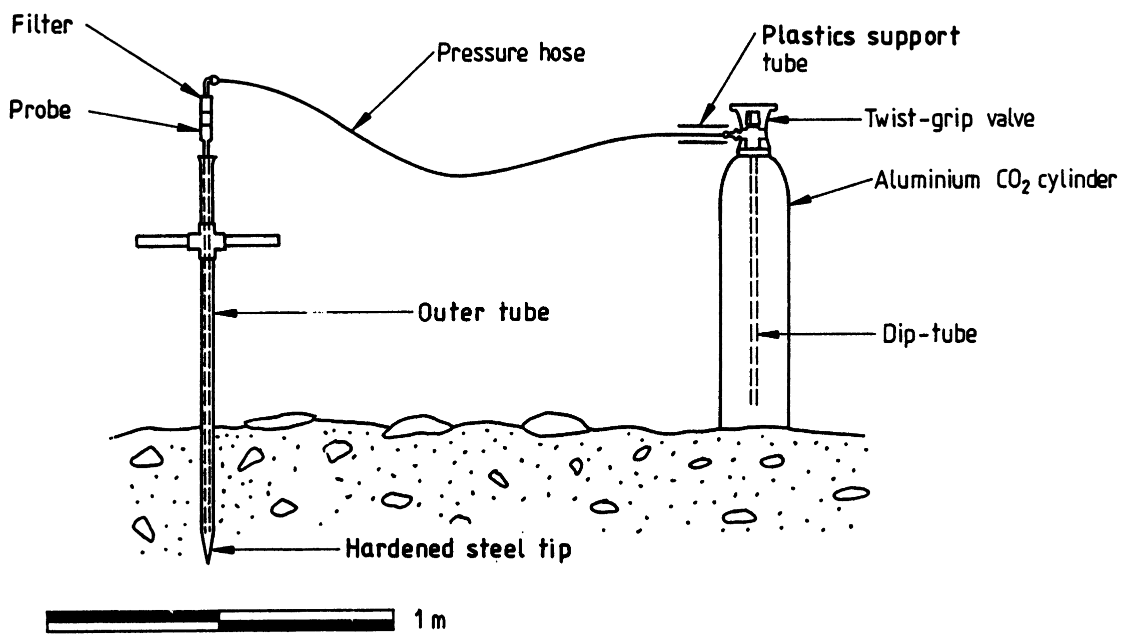
a) Plan

b) Section

Figure 5 — Core catcher

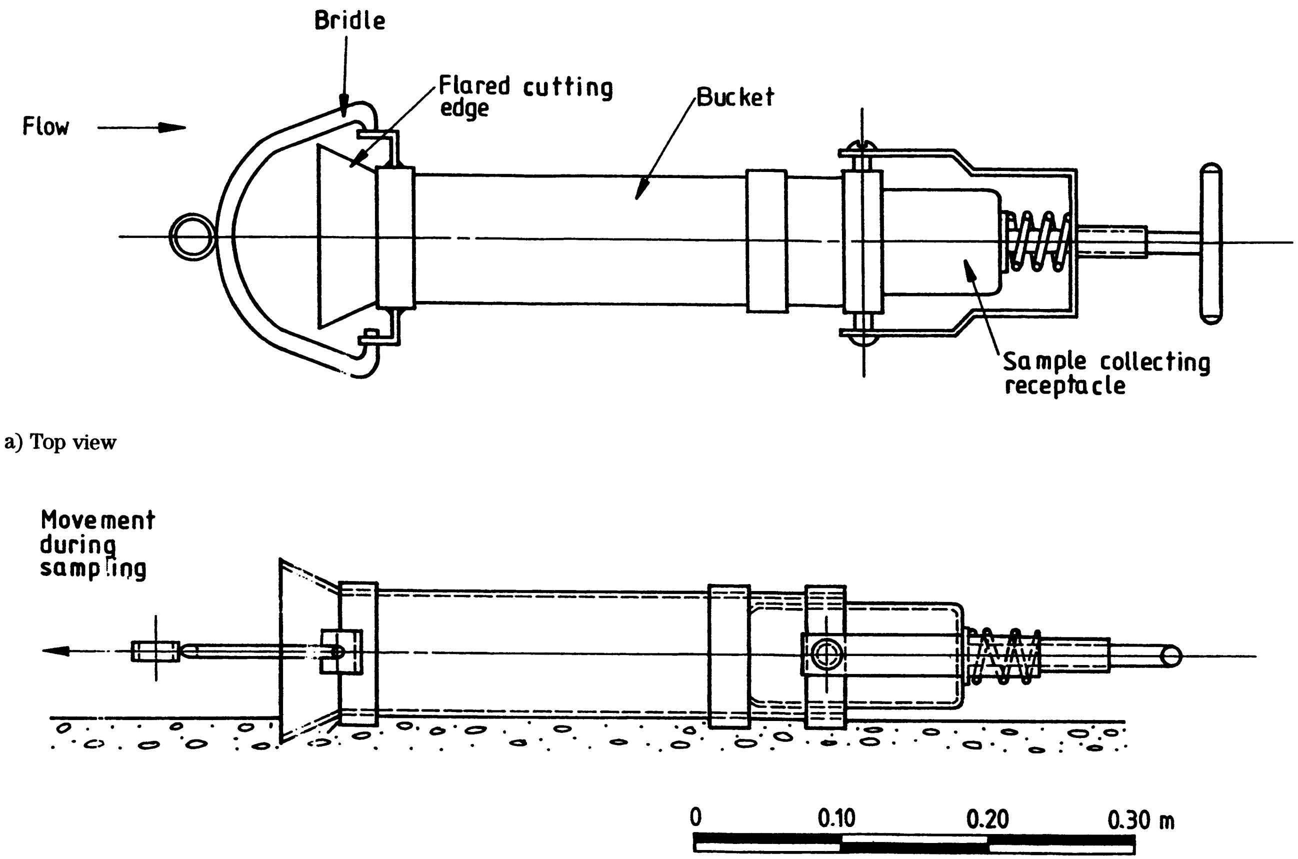


a) Detail of probe and outer tube



b) Sampling system in use in streambed

Figure 6 — Liquid carbon dioxide freeze-core sampler



a) Top view

b) Section

Figure 7 — Drag bucket sampler

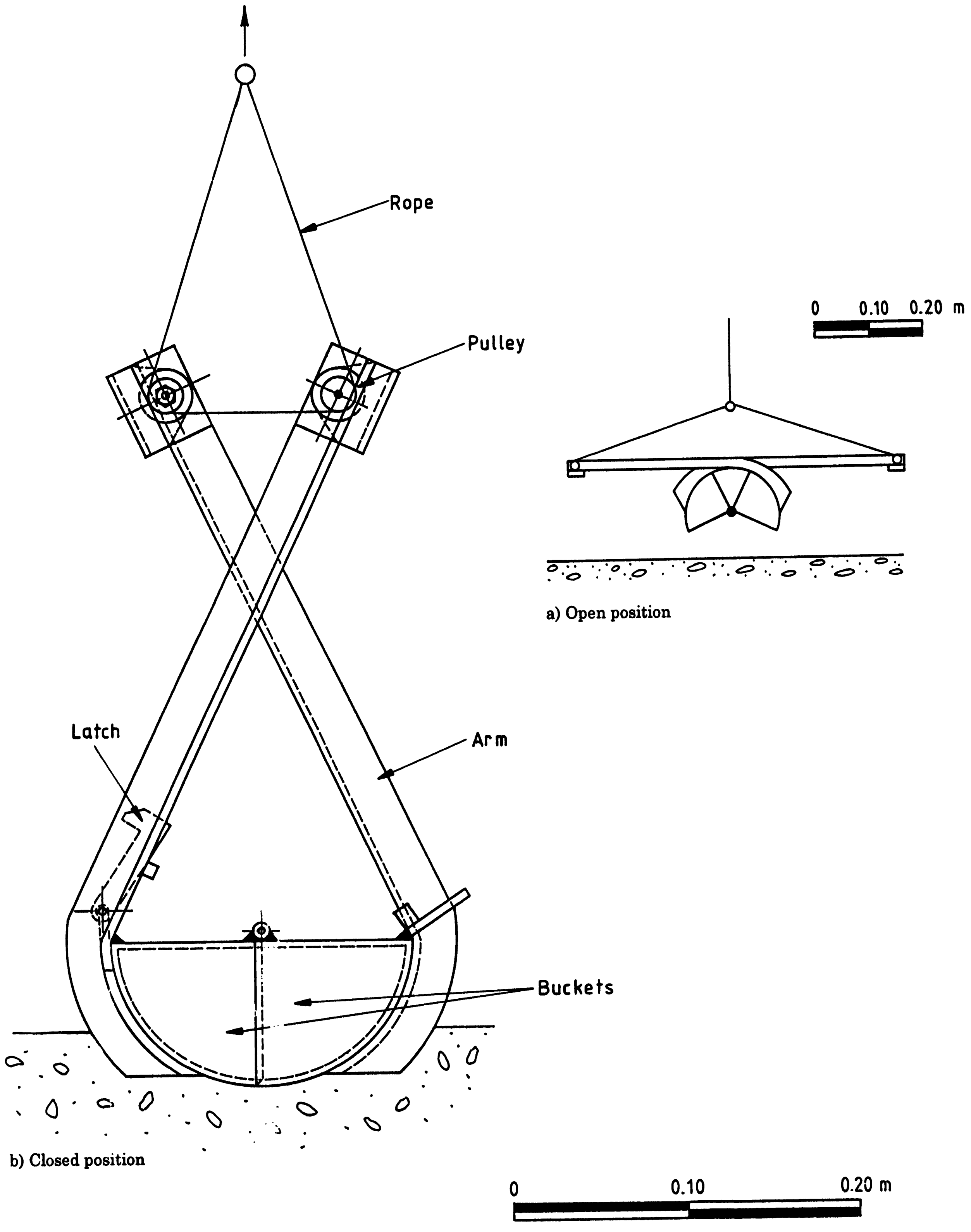
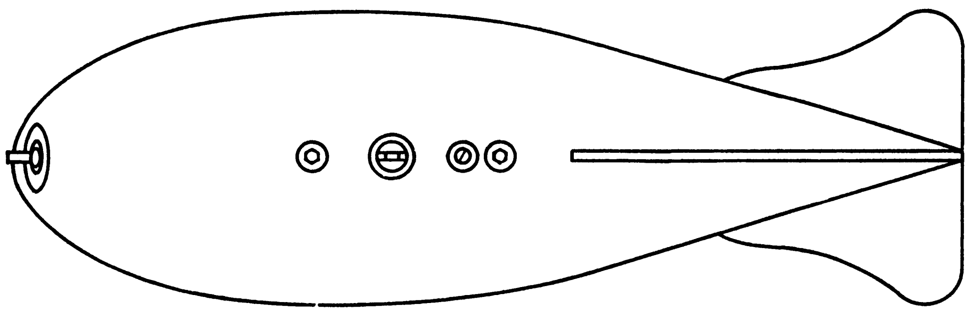
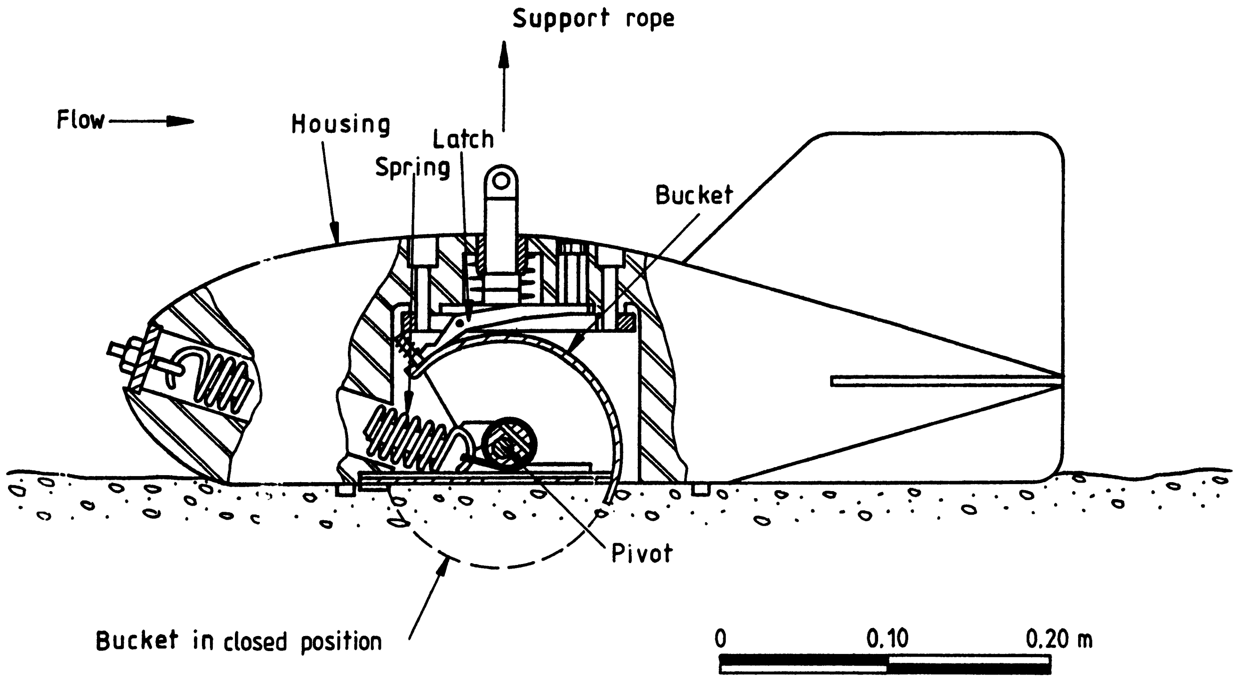


Figure 8 — Lightweight grab sampler with 90° closure



a) Top view



b) Section

Figure 9 — Lightweight grab sampler with 180° closure

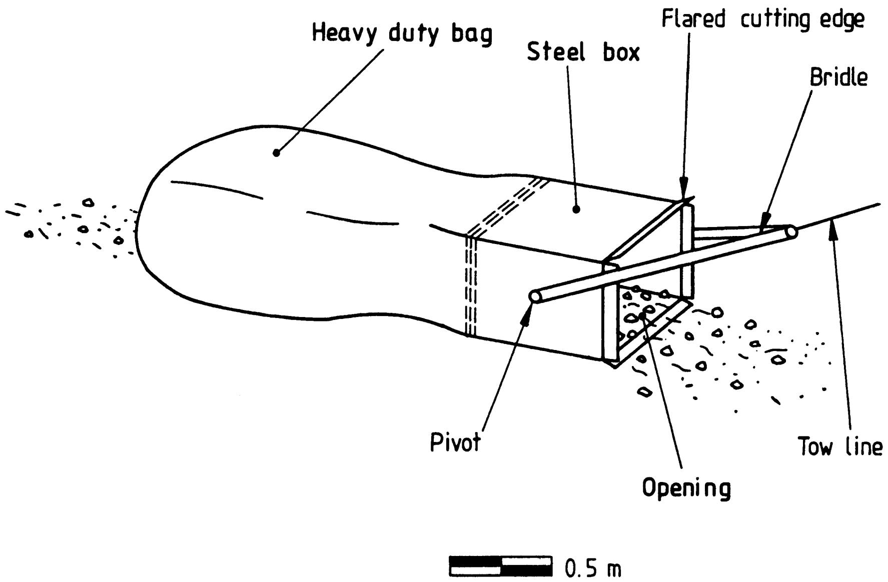
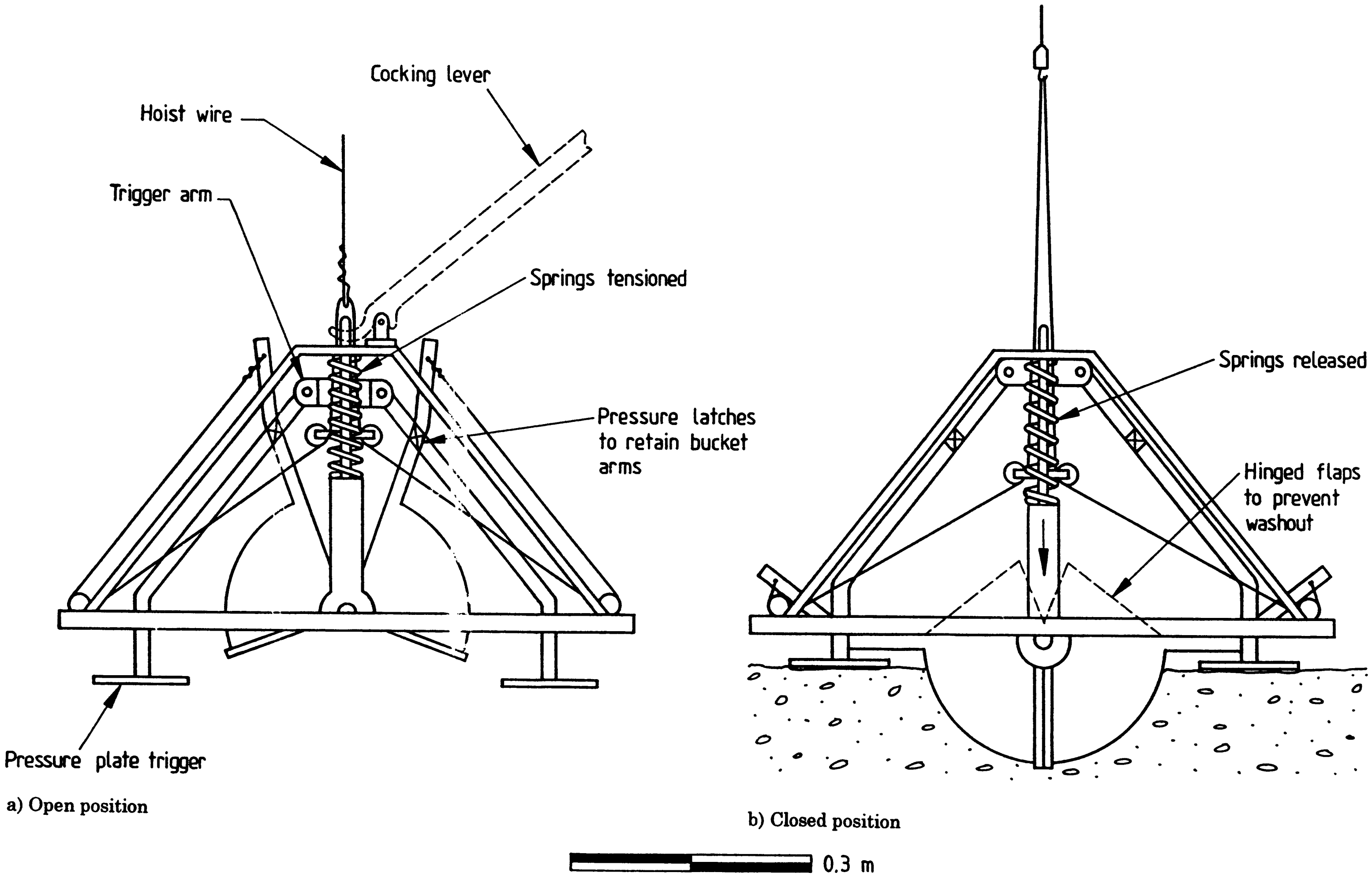


Figure 10 — Anchor dredge



NOTE Mass of sampler is approximately 0.5 t.

Figure 11 — Grab sampler with 90° closure

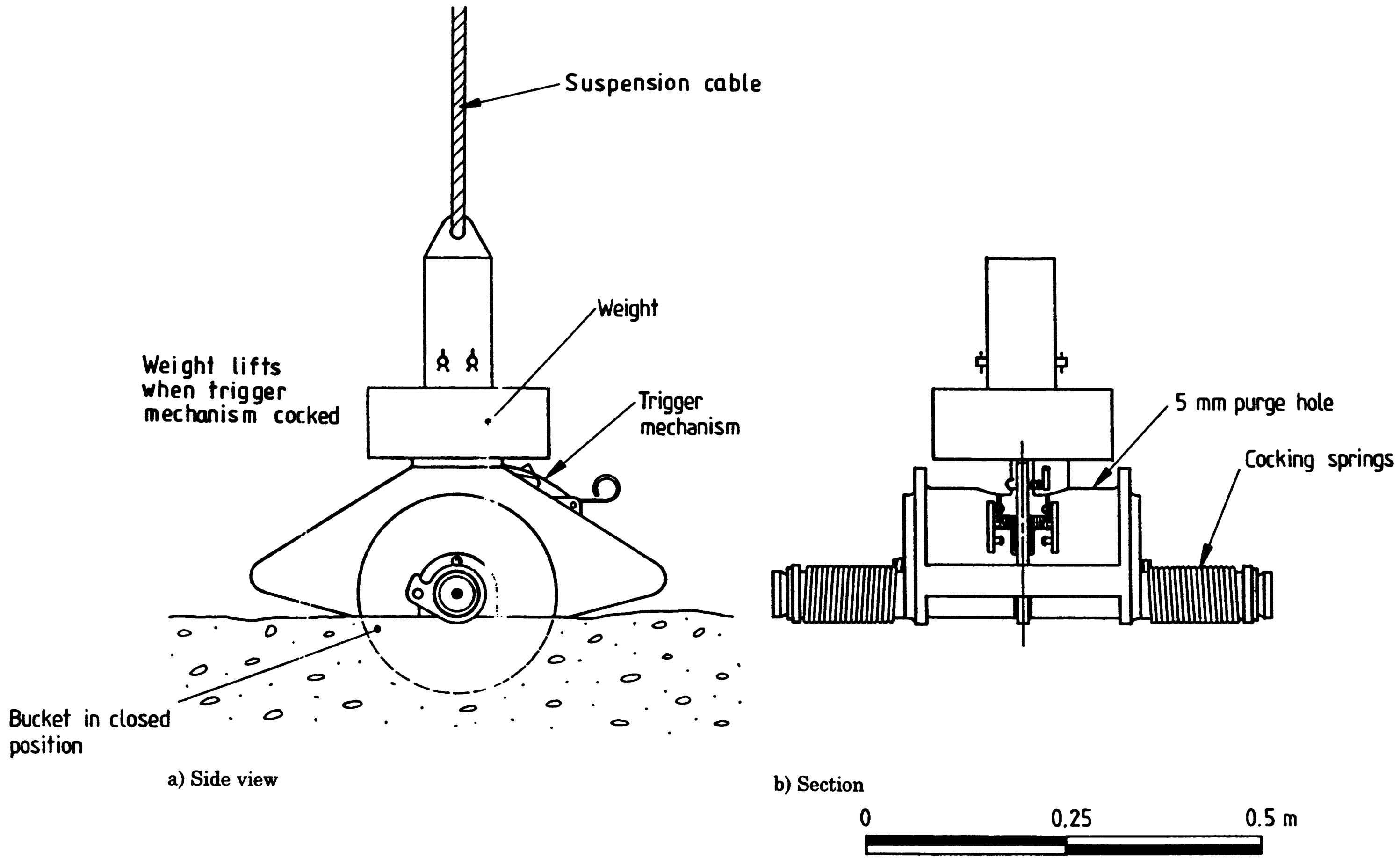


Figure 12 — Heavyweight grab sampler with 180° closure

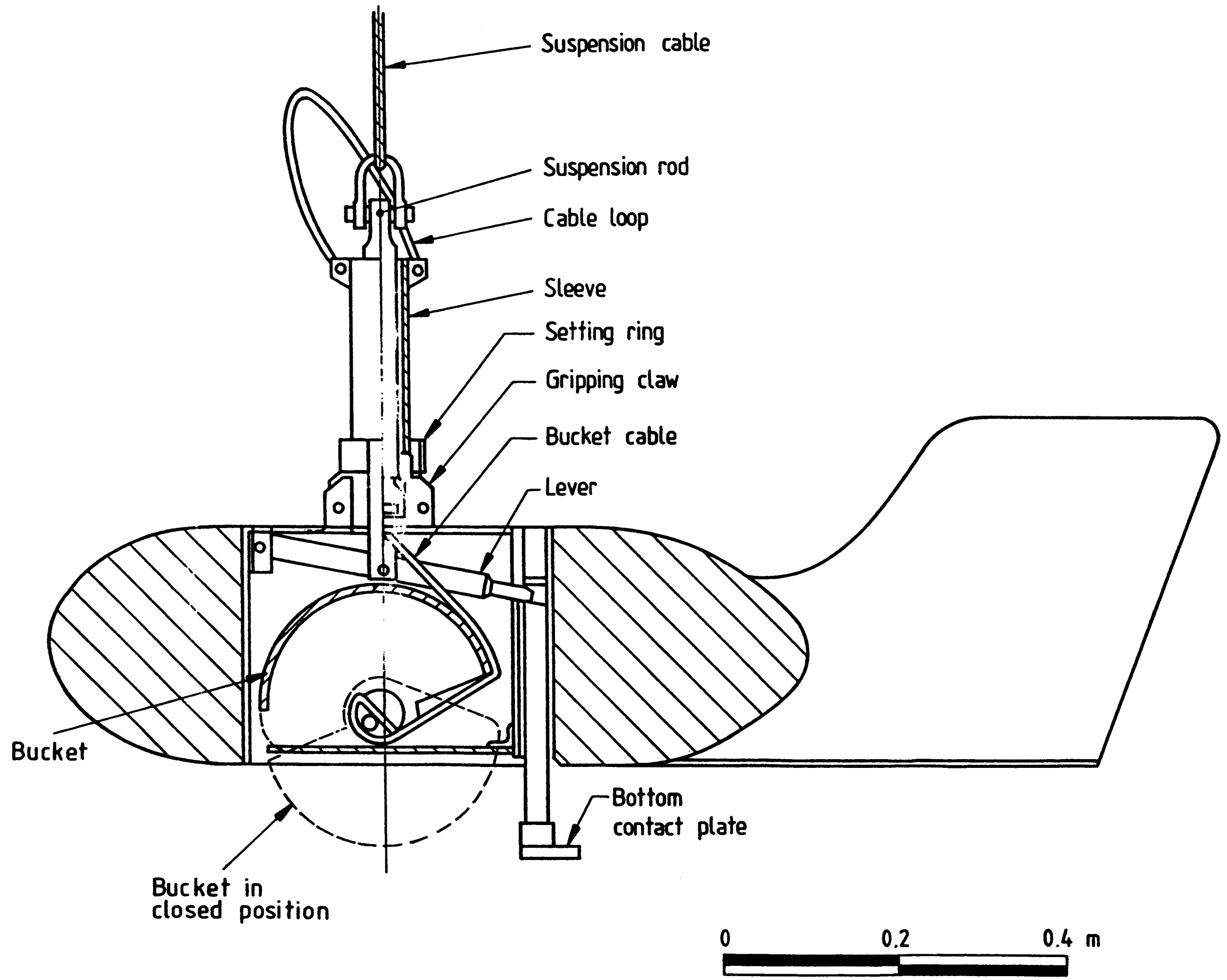


Figure 13 — Heavyweight grab sampler with 180° closure

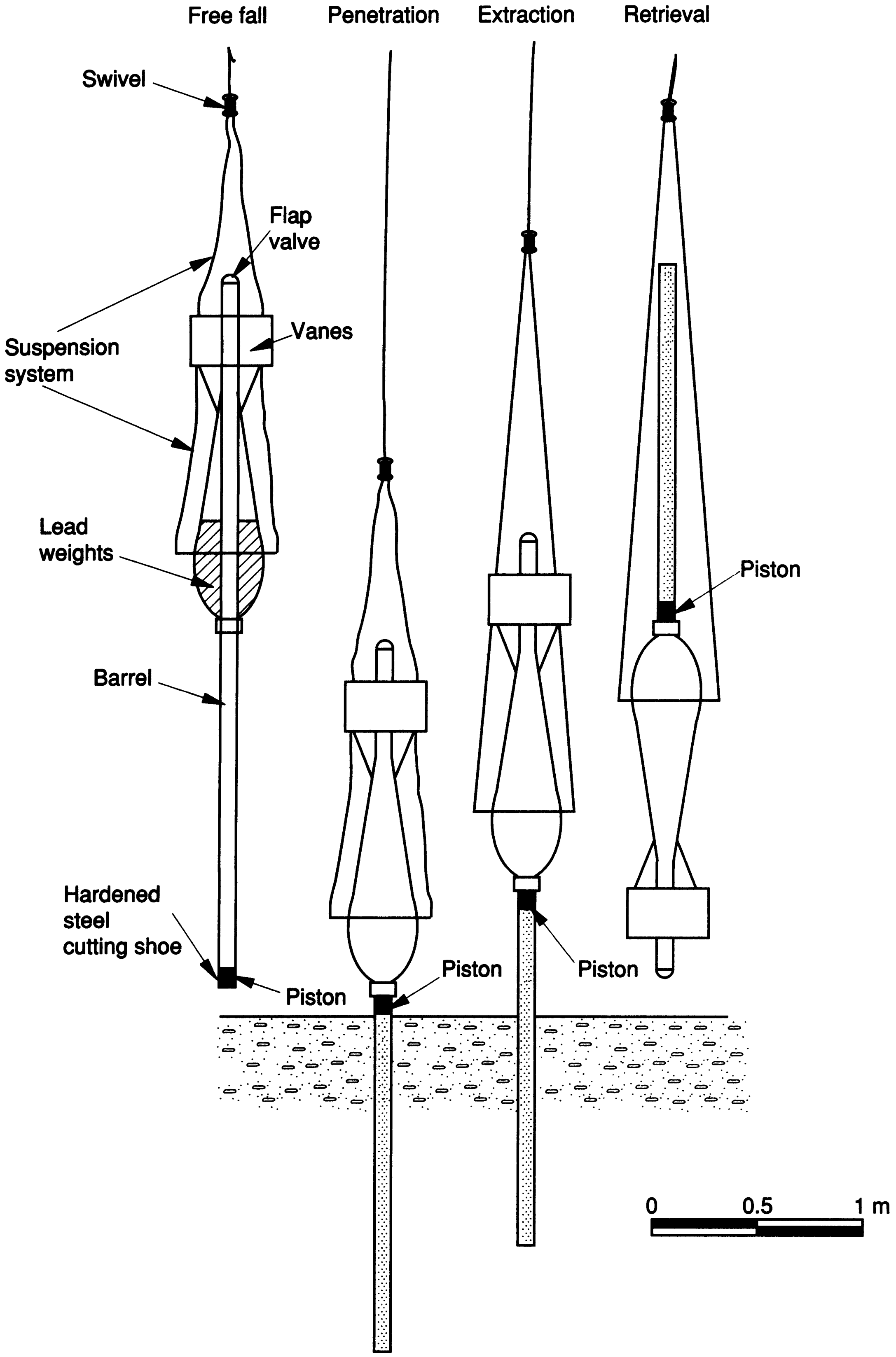


Figure 14 — Free fall gravity corer. Circular barrel corer

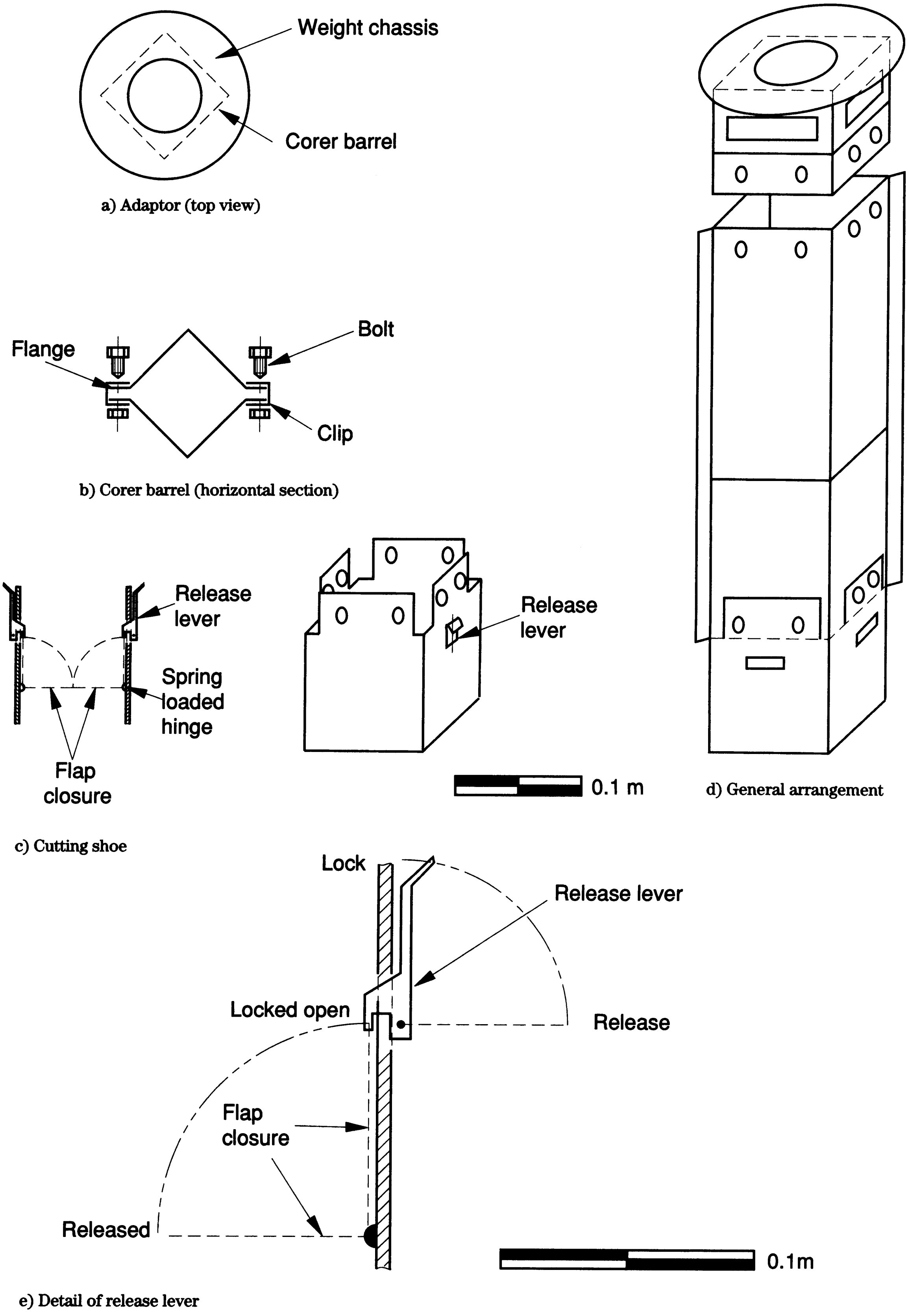


Figure 15 — Free fall gravity corer. Square barrel corer

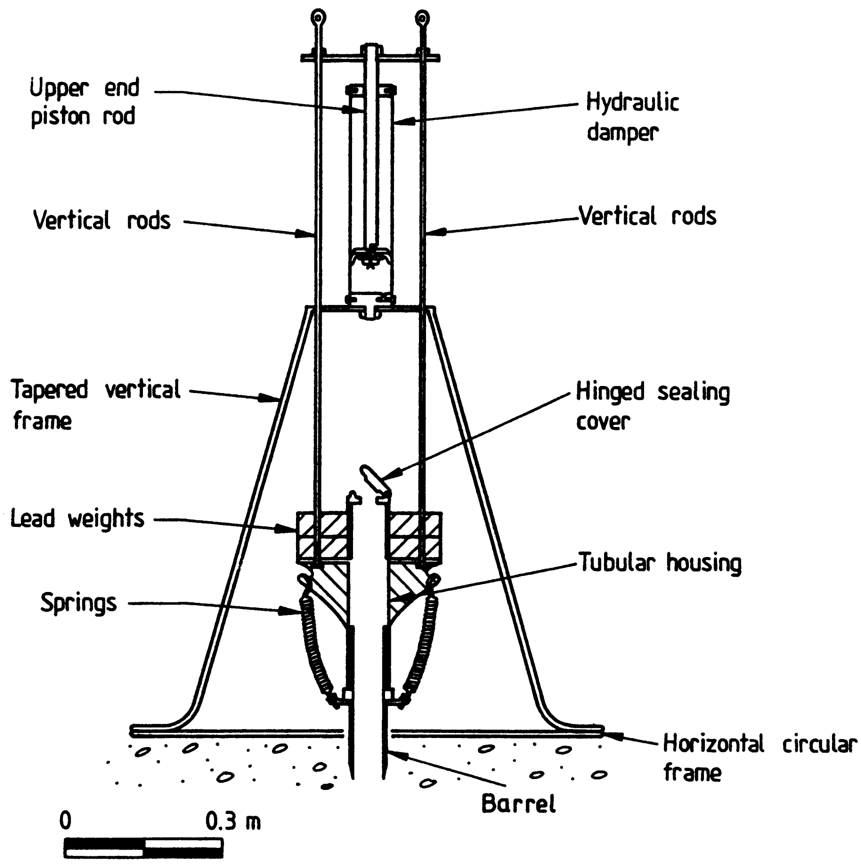
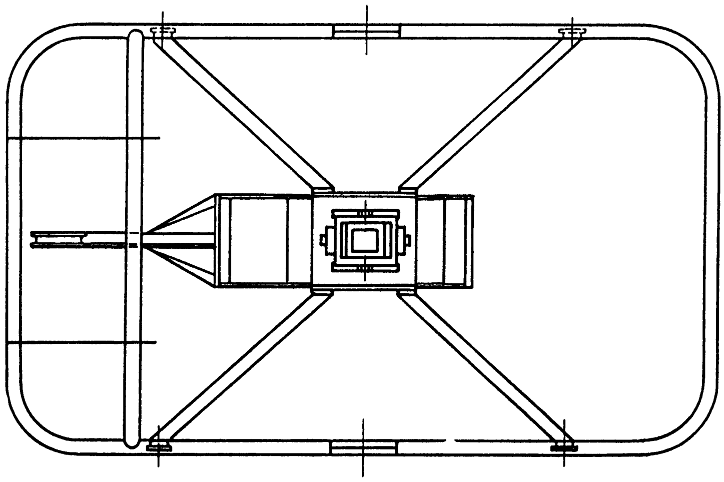
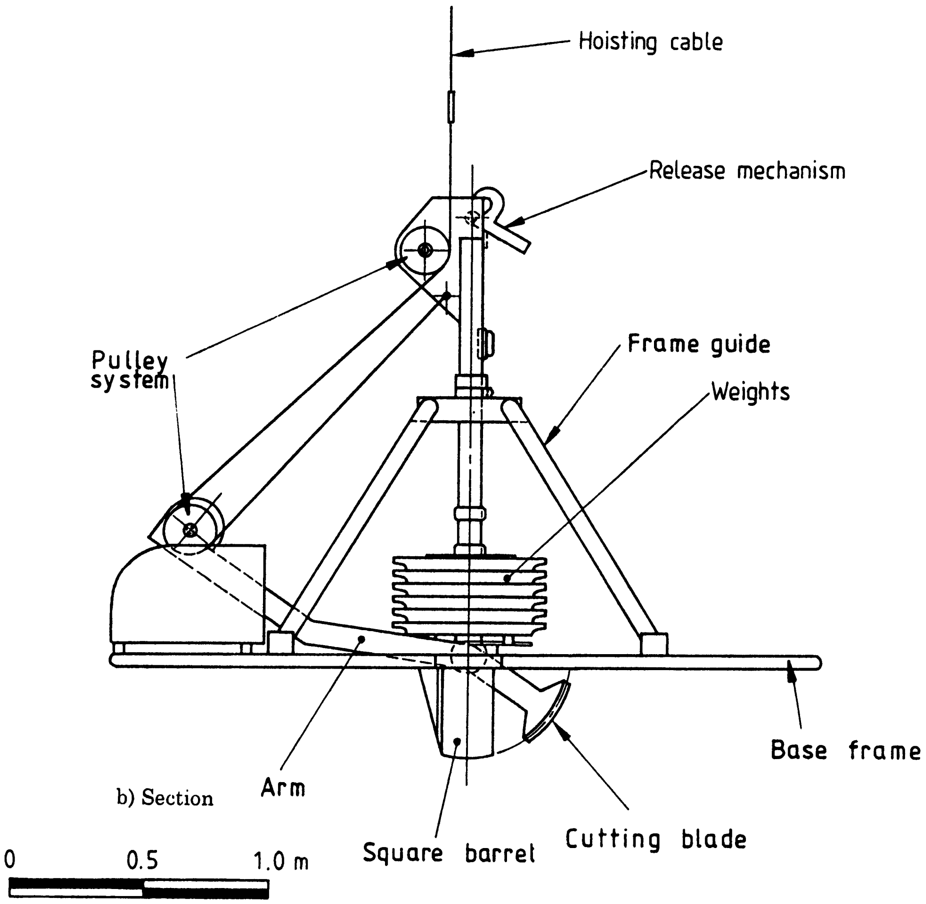


Figure 16 — Frame-guided gravity corer. Circular barrel corer

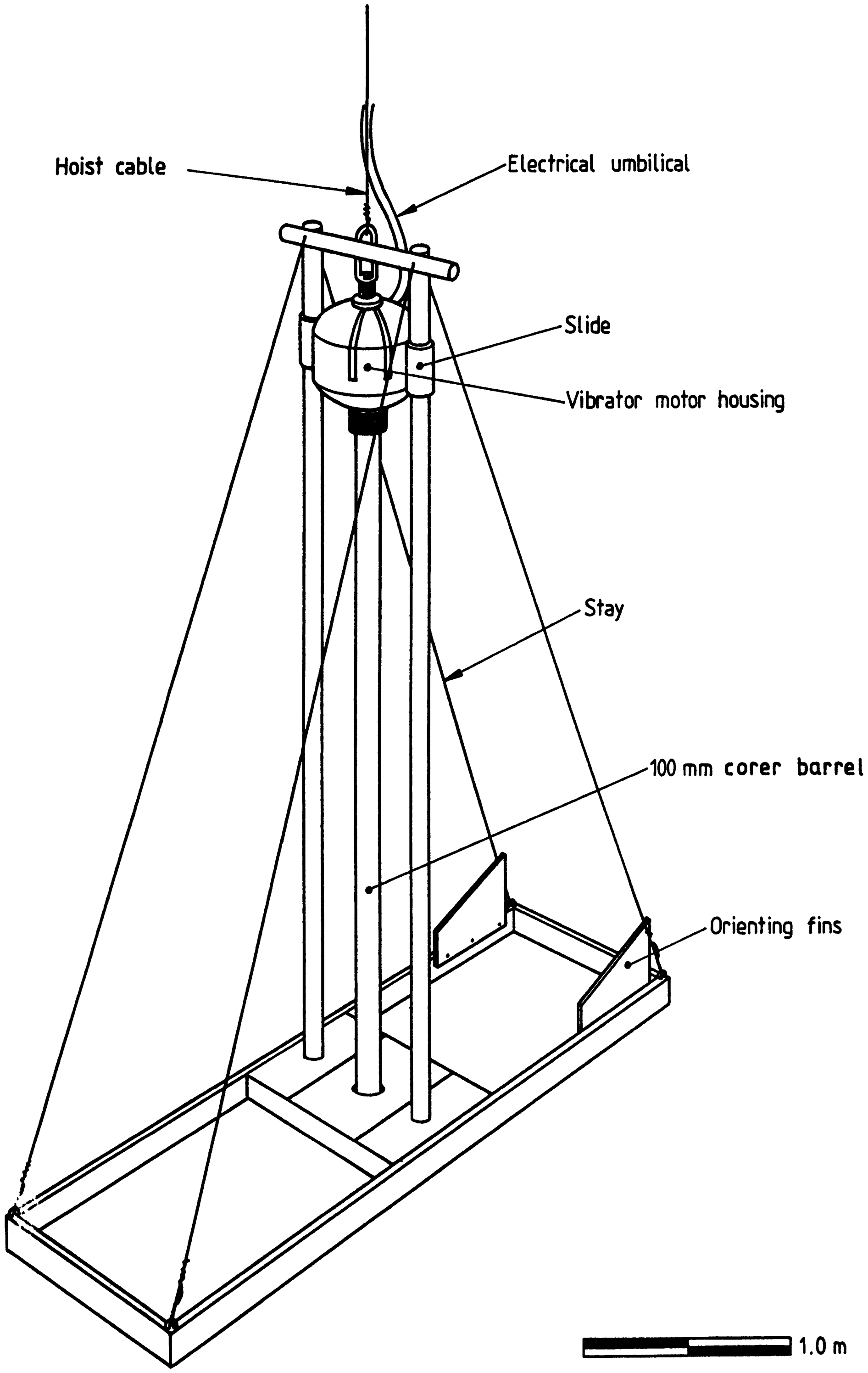


a) Top view



b) Section

Figure 17 — Frame-guided gravity corer. Square barrel corer



NOTE The mass of the equipment is approximately 0.75 t.

Figure 18 — Vibrocorer

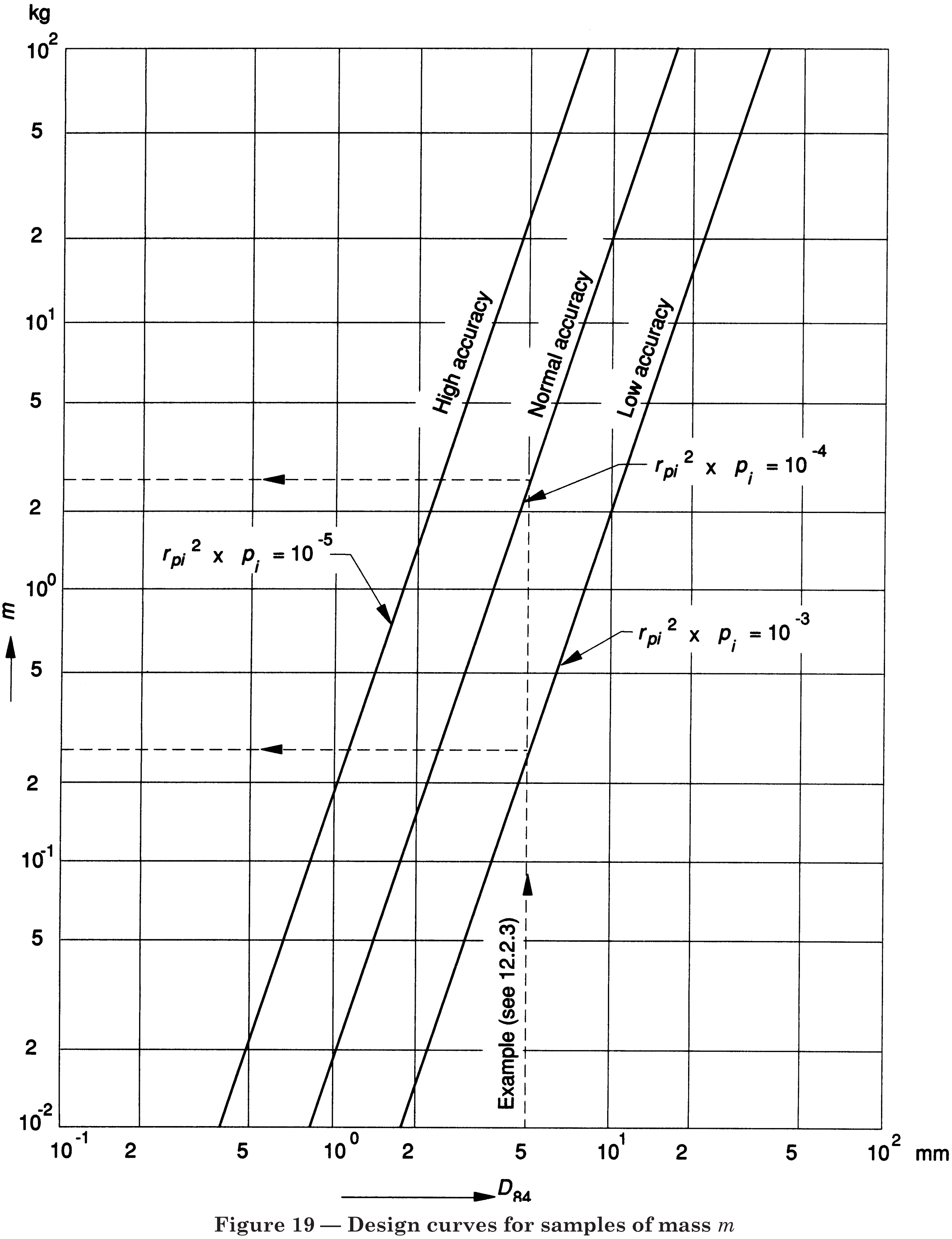


Figure 19 — Design curves for samples of mass *m*

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NOTE The method described uses liquid carbon dioxide.

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NOTE The method described uses liquid carbon dioxide.

RYAN, P. *Design and operation of an in situ frozen core gravel sampler* Canadian Department of Fisheries, Forest Fish Service Pacific Region, Technical Report 12, 1970.

NOTE The method described uses a solid carbon dioxide/acetone mixture.

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NOTE The method described uses liquid nitrogen.

THOMAS, M.C. A comparison of grab- and freeze-sampling techniques in the collection of gravel-bed river sediment. *Sedimentary Geology*. 1992, **78**, 191–200.

NOTE This paper deals with the statistics of sampling.

[1] Available from the Institute of Oceanographic Sciences, Wormley, Godalming, Surrey GU8 5UB.

[2] Available from the Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research, Fisheries Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 0HT.

List of references (see clause 2)

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 3680, *Measurement of liquid flow in open channels.*

BS 3680-1:1991, *Glossary of terms.*

BS 3680-10, *Sediment transport.*

BS 3680-10B:1980, *Measurement of suspended sediment.*

BS 3680-10D:1986, *Methods for determination of concentration, particle size distribution and relative density of sediment in streams and canals.*

Informative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 3680, *Measurement of liquid flow in open channels.*

BS 3680-10, *Sediment transport.*

BS 3680-10E, *Sampling and analysis of gravel bed material.*

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