Current Practice in Soil Sampling in the United States

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This paper presents a summary of the principal types of soil samplers in common use in the United States. Each type of sampler is described and its particular applications to sampling indicated.

The one-inch retractable plug sampler developed by O. J. Porter about 1930 is shown *(Fig. 1)*. The sampler consists of an inner retractable plug and piston rod, an outer casing and master tube with brass liners, and a driving mechanism.

The steps in the operation of the sampler are as follows. With the piston and plug locked to the casing *(Fig. 1A)* the sampler is driven into the ground by lifting the 30-lb drive weight by hand and letting it fall upon the drive head.

When the sampler reaches a depth at which sampling is desired, the piston rod is rotated to unlock it from the casing, raised a distance of 2 ft, and locked to the casing again *(Fig. 1B)*. The unit is then driven 2 ft deeper to obtain a sample *(Fig. 1C)*. At the end of sampling *(Fig. 1D)* the plug is rotated further to develop a tight seal at the top of the sampler. The entire unit is then jacked out of the ground *(Fig. 1E)*.

The next sample is taken by driving the unit down the same hole, but to greater depth. Disturbed but representative samples are obtained. The sampler is used primarily for determining the thickness of surficial deposits of soft silts and clays as occur in swamps and estuaries. The unit can be operated to depths of 60 ft or more. One of its main advantages is that it can be hand-carried into swampy areas difficult of access by conventional equipment. The unit is used both for reconnaissance investigations and for mapping soft strata between more elaborate sample borings.

The split barrel sampler is the most commonly used sampler. As illustrated *(Figs. 2, 3)*, it consists of a barrel shoe, a split barrel, a solid sleeve, and a sampler head. When the shoe and sleeve are unscrewed from the

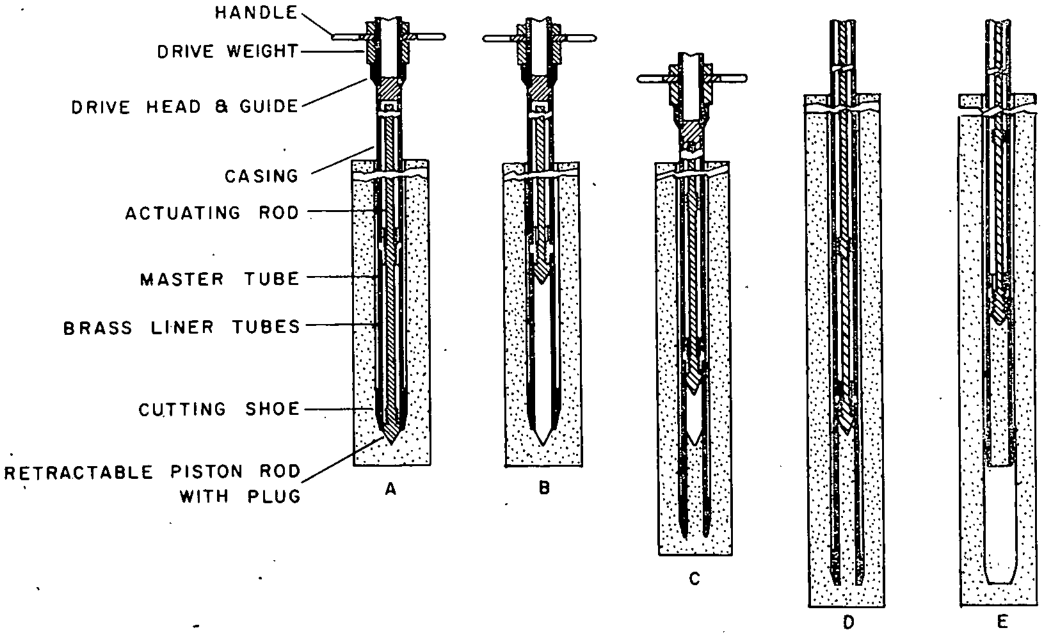
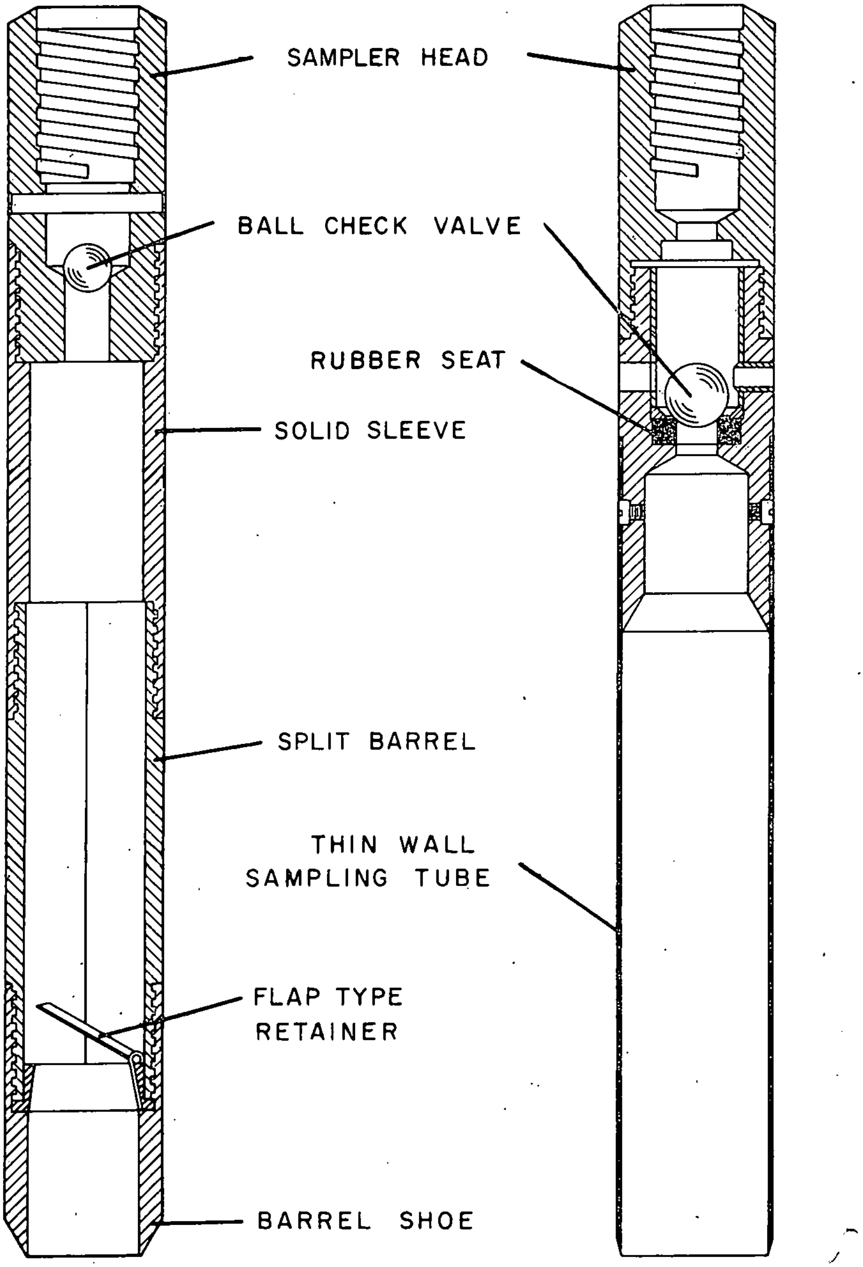


FIGURE 1
One-inch retractable plug sampler.



FIGURES 2 and 3
Split barrel sampler and thin wall "Shelby Tube" sampler.

split barrel, the two halves of the barrel may be separated and the sample easily extracted.

To facilitate recovery of samples of cohesionless type materials, a ball valve is incorporated in the head of the sampler. This valve seats when the sampler is being withdrawn from the soil and if the sample tends to slide out, a vacuum created at the top of the sample helps to retain it. At the lower end of the sampler a flap type retainer may be used. This permits soil to enter during sampling but upon withdrawal of the sampler from the ground the flap closes and retains the sample.

An alternative type of retainer consists of a crown-shaped spring. The points of the crown deflect toward the center of the sampler. As soil enters the sampler it easily pushes aside the points. If upon withdrawal of the sampler from the ground the sample tends to slide out, the points of the spring move inward and grip the sample. Generally, the sampler has an inside diameter of 1½ in., an outside diameter of 2 in., and a length of 18 to 24 in. For sampling soils which contain gravel sizes the inside diameter may be increased to 2½ in. or more. The wall thickness in all cases is about ¼ in.

Sampling is accomplished by driving the sampler into the ground with a drive hammer, the weight of which depends upon the size of the sampler. For the 1½ in. inside diameter sampler, a weight of 140 lbs is generally used; for the larger samplers larger hammers are used.

It is common practice during sampling operations to record the number of blows required for each 12 in. of penetration of the sampler; many engineers record the number of blows for each 6 in. of the 12 or 24 in. total penetration.

The number of blows required to drive the 1½ in. sampler a distance of 12 in. with a 140-lb hammer falling a distance of 30 in. is the standard penetration resistance which has been developed by Terzaghi and Peck. The correlations between standard penetration resistance and stiffness of clays and density of sands developed by Terzaghi and Peck are widely used, probably with more faith in their accuracy than can be justified.

Practically all subsurface exploration programs are initiated with split barrel sampling. Frequently foundation conditions are such that design can be made on the basis of the split barrel sample data. This is particularly the case where a minor type structure is involved. In other instances the split barrel sample borings are supplemented with sampling by one or more of the undisturbed type samplers described below.

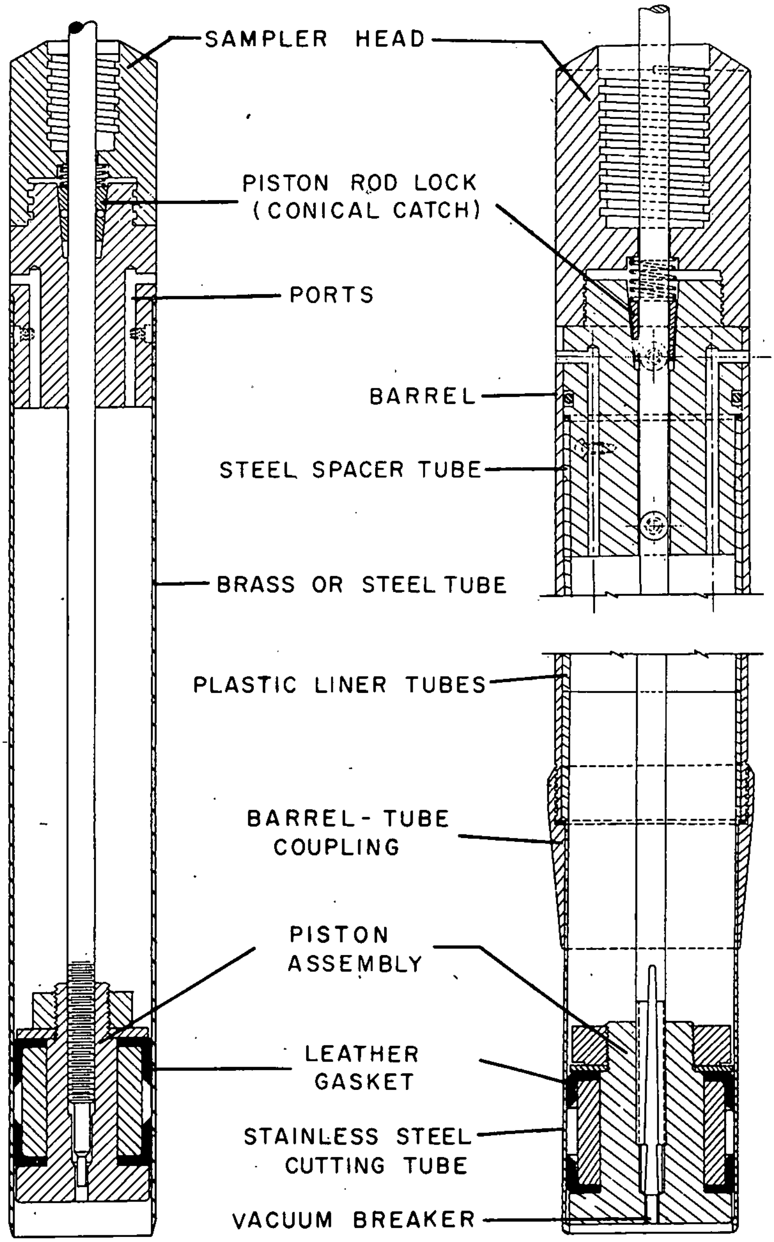
The thin-wall tube sampler (Shelby tube sampler) is the next most commonly used sampler in the United States. This sampler is illustrated in Figure 3. It consists of a thin-wall steel or brass tube and a head section. The head section is similar to that used for the split barrel sampler. The thin-wall tube is drawn in at the lower end and reamed so that the inside diameter of the cutting edge is ½ to 1 per cent less than that of the tube. The most common sizes of tube are 2-in. and 3-in. diameters. However, occasionally samples are taken with tubes 4 in. and 6 in. in diameter. The length of the sampler is generally about 30 in. Some engineers coat the inside of the tube with lacquer to minimize corrosion effects on the sample. Ports are provided in the head to permit easy escape of drilling fluid from the sample tube as the sample enters it.

The sampler is used primarily for sampling soft to stiff cohesive soils. For such soils, the wall thickness of the tube is about $\frac{1}{16}$ in. and the sampler is pushed into the soil at a rate of ½ to 1 ft per second.

At times the sampler is used for obtaining undisturbed samples of hard cohesive soils or sand. In such instances the wall thickness is about ⅛ in. and the sampler is driven into the soil. After the sample has been taken and the thin-wall tube has been removed from the head, the ends of the sample may be coated with petro wax or paraffin, covered with metal caps and shipped to the laboratory.

At the laboratory the sample tube is cut into 6- to 9-in. lengths by means of a saw or a thin abrasive wheel, and the sample is ejected from the sections of tube. Occasionally the sample is ejected in the field, cut into 6- to 9-in. lengths and placed in cylindrical waxed containers somewhat larger than the sample. The space between the sample and container is filled with petro wax or paraffin. Samples from 2-in. diameter tubes are suitable for unconfined compression and triaxial compression tests. Samples from no less than 2¾-in. diameter tubes are required for consolidation tests.

The thin-wall stationary piston sampler is the thin-wall tube sampler plus a piston and piston rod. The sampler is illustrated *(Figs. 4, 5)*. The piston rod is ½ in.



FIGURES 4 and 5
Thin wall stationary sampler and thin wall stationary piston sampler with liners.

in diameter and fits easily inside the hollow drill rod. Joints in the piston rod are displaced about 6 in. from joints in the drill rods.

The unit may be lowered on the drill rod since a conical ball-bearing catch, termed the piston rod lock on the figure, prevents the piston rod from slipping downward with respect to the head of the sampler. To prevent upward movement of the piston as the sampler is lowered into the bore hole, the piston rod has a short section of left-handed threads which engages a matching section of threads in the sampler head.

By rotating the piston rod counter-clockwise, the rod is threaded into the sampler head and the piston is locked at the bottom of the sampler; to release the piston from the sampler, the piston rod is given several clockwise turns. This method of locking the piston during the lowering of the sampler into the bore hole is required for sampling deep below ground water or in bore holes filled with heavy drilling fluid in order to prevent the piston from rising under the fluid pressure.

The procedure used to obtain a sample is as follows. The sampler, with its piston located at the base of the sampling tube, is lowered into the bore hole. When the sampler reaches the bottom of the hole, the piston rod is held fixed relative to the ground surface and the thin-wall tube is pushed into the soil. The fixed piston tends to prevent excess soil from entering the thin-wall tube at the beginning of sampling and too little soil from entering near the end of sampling. It also acts more positively to retain the sample than the ball valve of the thin-wall tube sampler. After sampling, the vacuum between the piston and the top of the sample is broken, using a device provided for this purpose in the piston; the piston is then removed from the sampler.

The stationary piston sampler is used for sampling soft to stiff cohesive soils. It is jacked into the soil at a rate of ½ to 1 ft per second; it is never driven. The most frequently used size is 2.8 in. inside diameter.

A thin-wall stationary piston sampler with liners, developed by the author together with the Acker Drill Company, is shown in Figure 5. The piston and piston rod, the lower 6 in. of the sampler and the head section, are all very much the same as in the standard stationary piston sampler. The lower tube is made of stainless steel, and is connected to a barrel containing liners. Originally, the liner tubes were made of brass but now are made of laminated phenolic resin-impregnated paper.

The liners are 6 in. and 9 in. in length and 0.1 in. in wall thickness. They are inert chemically and electrolytically; therefore samples can be stored in them for long periods of time without corrosion effects. The liners are watertight and tough. Because of their short lengths, the liner tubes do not have to be cut in the laboratory and disturbance to the sample from this operation is eliminated. The liners are reusable and light in weight for shipment.

Because the lower portion of the sampler consists of a 6-in. long thin-wall tube and a 3-in. long tapered coupling, the effect of the thicker walled barrel section on sampling is believed to be negligible. The sampler is used to sample soft to stiff cohesive soils. However, because of the high penetration resistance of the barrel section the sampler requires greater thrust than the standard thin-wall piston sampler when used in sands and very stiff cohesive soils. The sampler with plastic liners has been in use more than two years and has proved entirely satisfactory.

In the author's laboratory the sample is ejected from the liner as illustrated *(Fig. 6)*. A close fitting piston is brought in contact with the lower end of the sample. As the piston is jacked upward the liner is held stationary by the restraining plate. The sample is ejected from the liner and into a specimen cutting punch which in effect is a miniature thin-wall tube sampler. Excess material is trimmed away as the sample moves into the punch.

Jacking is continued until soil reaches the top of the punch. Then the ends of the specimen are trimmed by sliding a wire across the ends of the punch. Alternatively, the full 2.8-in. diameter sample is used; this is frequently the case in triaxial tests. Other laboratories generally use turntables and wire saws for trimming less than full diameter specimens from ejected samples.

Samplers somewhat similar to the thin-wall stationary piston sampler with liners have been developed by the firm of Dames & Moore and by Prof. Housel at the University of Michigan. Generally, 1-in. brass rings are used as liners in the latter two samplers.

The Swedish foil sampler has been introduced into the United States in the last two years. Sprague & Henwood, Inc. have the franchise for its use in the eastern part of the country and International Engineering

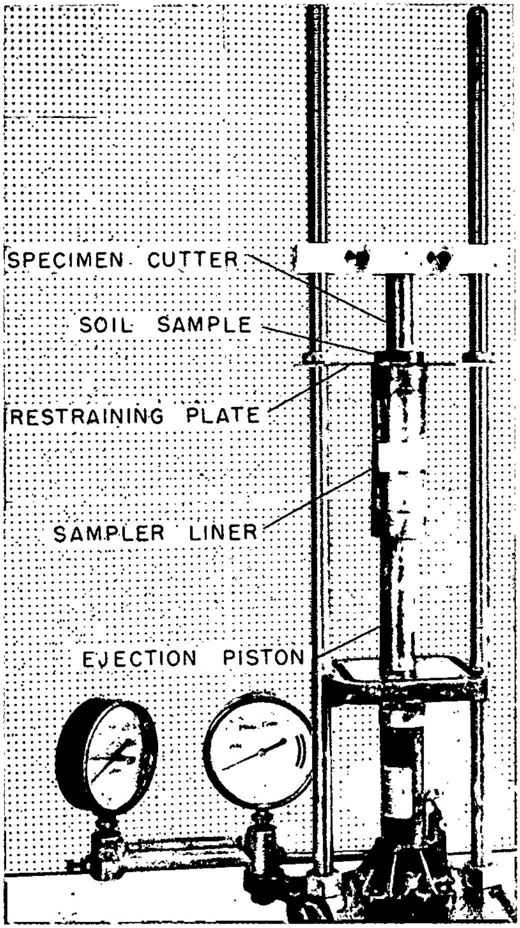


FIGURE 6
Sample ejector and specimen cutter.

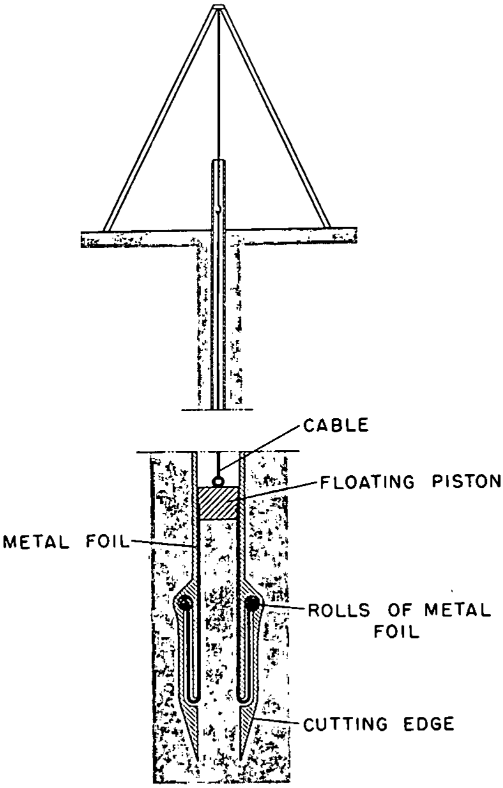


FIGURE 7
Schematic drawing, principle of Swedish foil sampler.

in the western. The basic principle of the sampler is illustrated *(Fig. 7)*.

The sampler consists of a sampling tube containing rolls of metal foil and a more or less fixed piston to which the ends of the foil strips are attached. As the sampling tube is pressed into the ground the strips of foil unwind and encase the sample. Thus, friction between the sample and the inside of the sampling tube is eliminated. Friction does develop, however, between the foils and the inside of the sampling tube and the tensile strength of the foils must be adequate to carry the friction accumulated over the extended length of the foils.

Longitudinal and transverse sections of the sampler are shown *(Fig. 8)*. They illustrate how 16 rolls of foil are incorporated into the sampler and are arranged to completely encase the sample.

Because of the elimination of friction, continuous samples up to 75 ft long may be taken. The sampler is uniquely adapted for sampling of thinly stratified soils and for sampling of very soft and semiliquid soils which frequently occur at harbor bottoms. By sampling through the very soft surficial layers and into somewhat stiffer layers below, enough friction can be developed between the foil and the stiffer soil to hold both the lower layers and the overlying very soft layers in the sampler during withdrawal from the ground. It is anticipated that use of this sampler will increase in the United States.

The Osterberg piston sampler is a recent modification of the thin-wall stationary piston sampler. The operation of the sampler is illustrated *(Fig. 9)*. The new feature is a second piston, termed the actuating

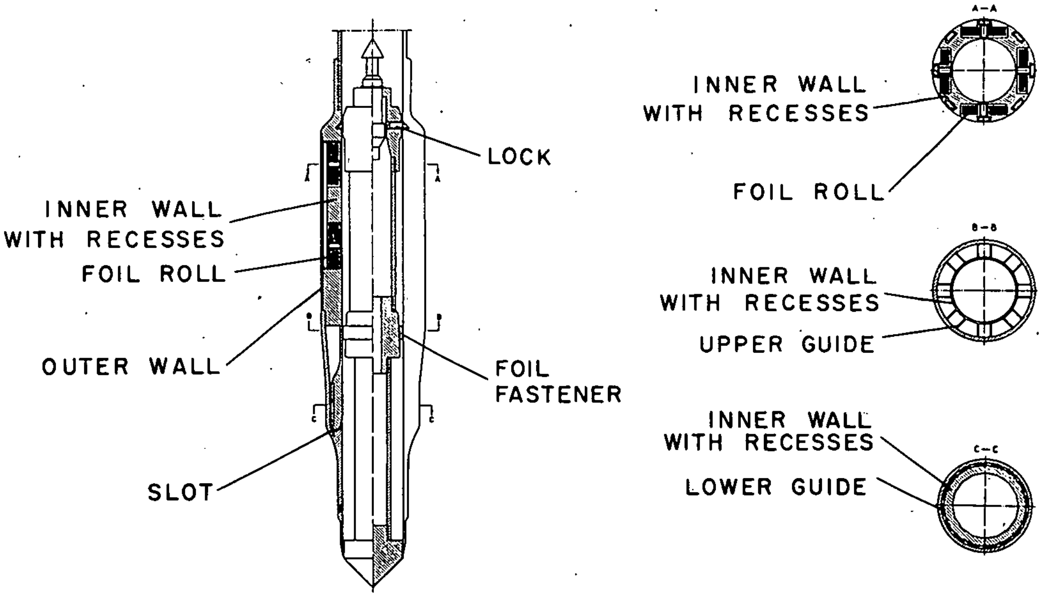


FIGURE 8
Swedish foil sampler head.

piston, and a pressure cylinder. To take a sample, fluid pressure is brought to the top side of the actuating piston. The pressure forces the actuating piston and the sampling tube to move down. At the end of sampling the actuating piston comes in contact with the stationary piston; thus the sampler cannot be over-pushed.

Another advantage of the sampler is the fact that only one set of drill rods is required. These rods are used for holding the stationary piston. The actuating rods used in the standard stationary piston sampler are eliminated by the use of the actuating piston. Pressure to operate the actuating piston is brought from ground surface to the sampler through the hollow drill rods. To date the sampler has been used primarily in the 5-in. diameter size to procure samples of clay for consolidation tests.

A variation of this sampler has been developed by McClellan. In the McClellan

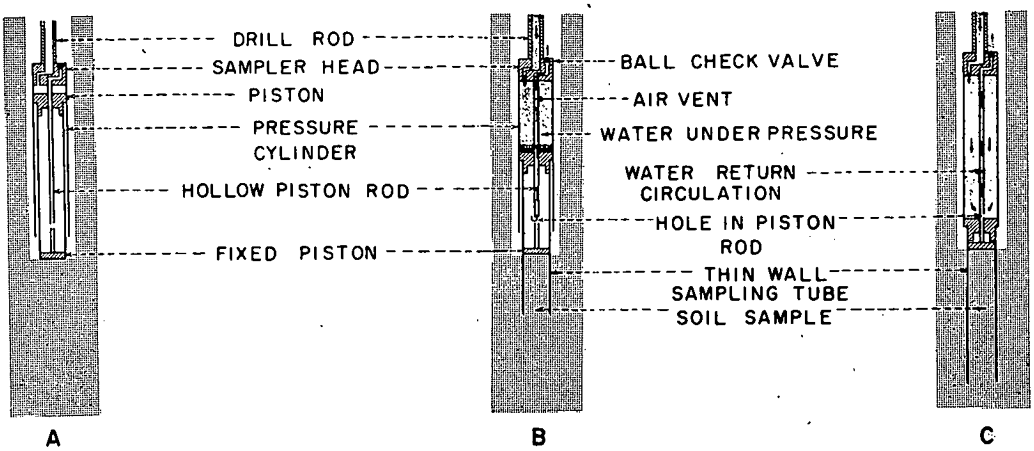


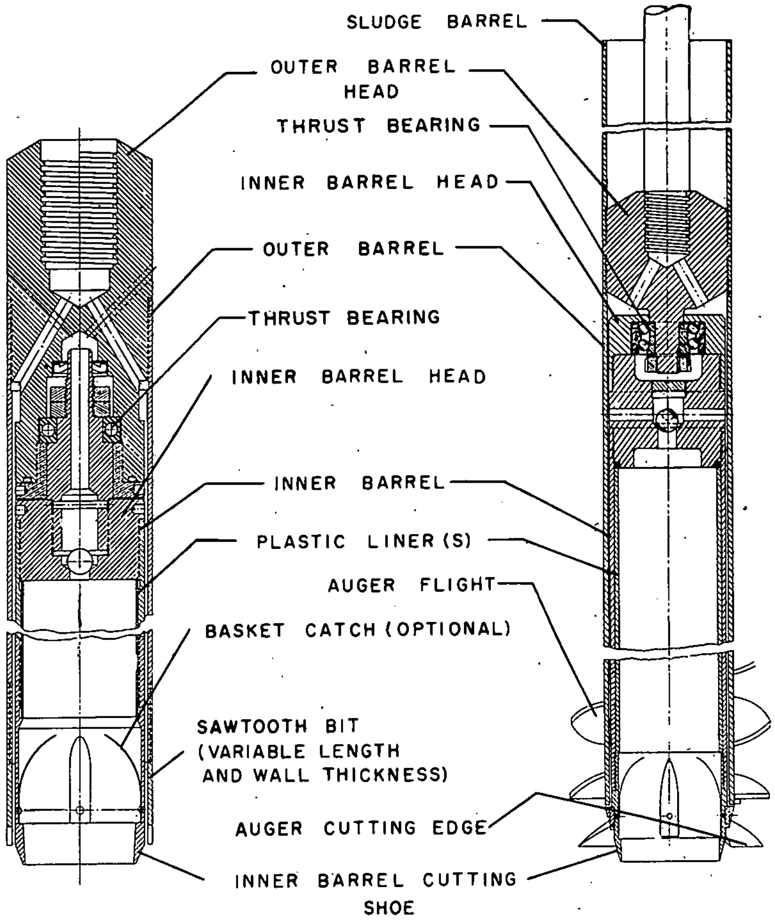
FIGURE 9
Osterberg piston sampler.

variation the actuating piston is held in position with a shear pin while pressure is built up above it. When sufficient pressure has been developed, the pin shears and the sampler moves rapidly into the soil. The purpose of this variation is to permit a quick jacking of the sampler into the soil.

The Denison double tube core barrel soil sampler *(Fig. 10)* was developed by H. L. Johnson about 1939 for the Denison Dam project in Texas.

The sampler is different in operation from the samplers previously described. It consists of an outer rotating core barrel with bit and an inner non-rotating sample barrel with liners and cutting edge. Either a carbide insert bit or a hardened steel sawtooth bit may be used depending on the material to be sampled. The cutting edge of the sample barrel may be set 0 to 2 in. ahead of the leading edge of the coring bit, depending on soil conditions. A basket type sample catcher may be inserted behind the cutting edge of the sample barrel to help retain the sample upon withdrawal from the ground. The inner head contains ports for the escape of drilling fluid and a check valve for the closing of the ports while raising the sampler.

In operation the outer core barrel is rotated as the sampler is pressed downward. Drilling fluid, generally drillers' mud, is circulated downward between the two barrels, through and under the bit and then upward between the outer barrel and the sides of the bore hole. The cuttings of the bit are removed by the circulating fluid.



FIGURES 10 and 11
Denison double-tube core barrel soil sampler and Tams double-tube auger sampler with liners.

The sampler was originally constructed for taking 6-in. diameter soil cores and this is still a frequently used size. At the present time the sampler is available also in 2¾- and 4-in. diameter sizes. The author was instrumental in developing the 2¾-in. size which fits inside the standard 4-in. pipe casing often used for borings in the United States. The author's sampler uses a 24-in. long, $\frac{1}{16}$-in. thick liner tube made of phenolic resin-impregnated laminated paper. This tube can be cut easily by saw in the laboratory for removal of the soil core.

The sampler is designed for use in stiff to hard cohesive soils and in sands. By using drillers' mud, a vacuum valve, and a basket catch, samples of clean sands may be recovered. The sampling action is ideal in that the cutting edge of the inner barrel easily displaces soil into the annular space cut by the bit on the outer barrel. In soft soils the cutting edge leads the bit by as much as two in.; in very hard soils the cutting edge is located approximately flush with the bit.

The Tams double tube auger sampler with liners *(Fig. 11)* operates on a principle similar to that of the Denison double tube core barrel soil sampler except that a helical conveyor rather than circulating drilling fluid is used to remove cuttings made by rotation of the outer barrel.

The sampler has a stationary inner barrel with plastic liners and is equipped with a ball valve at the top and a basket catch at the bottom. The inner barrel is forced into the ground without rotation by means of a thrust bearing incorporated in the head of the sampler. The sampler was developed by the author in 1951 for sampling sandy silt above groundwater table. Excellent results were obtained in the determination of the natural unit weight and water content of the material. The sizes of the liners is 2¾ in. inside diameter. To date the sampler has not been used extensively; however, the author feels that it offers good possibilities particularly when constructed in a larger and stronger version.

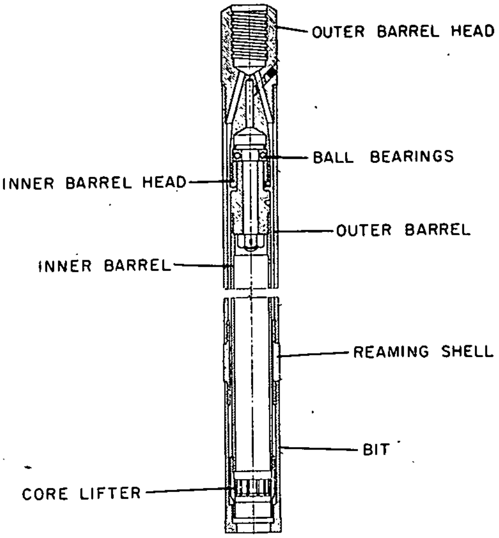


FIGURE 12
Series M double-tube core barrel.

A Series M double tube core barrel is illustrated *(Fig. 12)*. This core barrel is used for sampling soft rocks which would be eroded by the flow of drilling fluid. The core barrel is similiar to the Denison double tube core barrel except that the inner barrel does not have a cutting edge projecting beyond the bit of the outer barrel nor does it have a liner. Also, a standard rock core lifter is used instead of the basket catch used in the Denison sampler.

The Vane Shear Apparatus is used extensively in the United States for determining the in-situ shear strength of soft cohesive materials *(Fig. 13)*. Several variations of the apparatus are available. The essential features are as follows. The vane is mounted on a small diameter rod which permits the vane to be pushed below the bottom of the drill hole into undisturbed material. Ball bearings are provided along the drill rod to minimize friction between the drill rod and the casing of the bore hole. A torque wrench which rests on a thrust bearing at the top of the casing is used to measure the torque required to rotate the vane. Shown *(Fig. 14)* is this portion of the apparatus.

Vanes have been developed which can be used in connection with the 1-in. retractable plug sampler. In this case, the sampler with the vane adjacent to the plug is driven into the ground to desired elevation, then the vane is pushed ahead of the plug and the shear test performed. Next the plug sampler

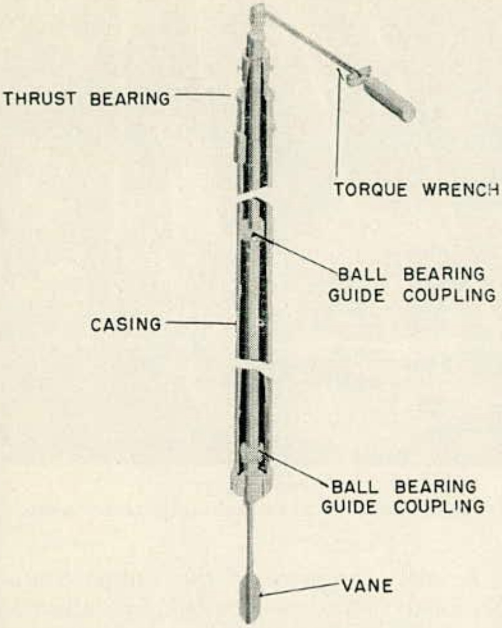


FIGURE 13
Schematic drawing, vane shear apparatus.

is driven down to contact the vane again, and the two are driven as a unit to the next elevation for testing.

Drill rigs used for putting down bore holes and samplers are available in a wide variety of sizes and types. A hand-operated rig, known as the Packsack, is shown *(Fig. 15)*. This is a rotary unit of 5.5 horsepower which weighs only 32 lbs and can be held in position by two men. It is particularly well adapted for reconnaissance work in rough country.

A light rig which is popular for general foundation investigation work is the Acker Teredo. This rig can be operated by its own power unit or by power take-off from a vehicle such as a jeep. The power units generally used consist of diesel engines, gasoline engines and electric motors whose power ratings range from 15 to 30 horsepower. Shown *(Fig. 16)* is a jeep-mounted Teredo operated by power take-off; shown *(Figs. 17, 18)* are trailer-mounted and skid-mounted Teredo rigs with their own power units.

A skid-mounted Sprague & Henwood 40C rig is shown *(Fig. 19)*. This is a 20.2 horsepower unit which is also popular for foundation investigaton programs. The hydraulic head is shown in open position in the figure and the gears of the drill head may be seen. A larger Sprague & Henwood rig, the 142, with 30 horsepower is shown *(Fig. 20)*. A still larger rig which has been developed recently is the Acker Presidente shown *(Fig. 21)*. The latter two rigs are used only in large diameter and deep foundation exploration work. Failing rigs comparable in size to the latter two rigs are also quite popular in the United States.

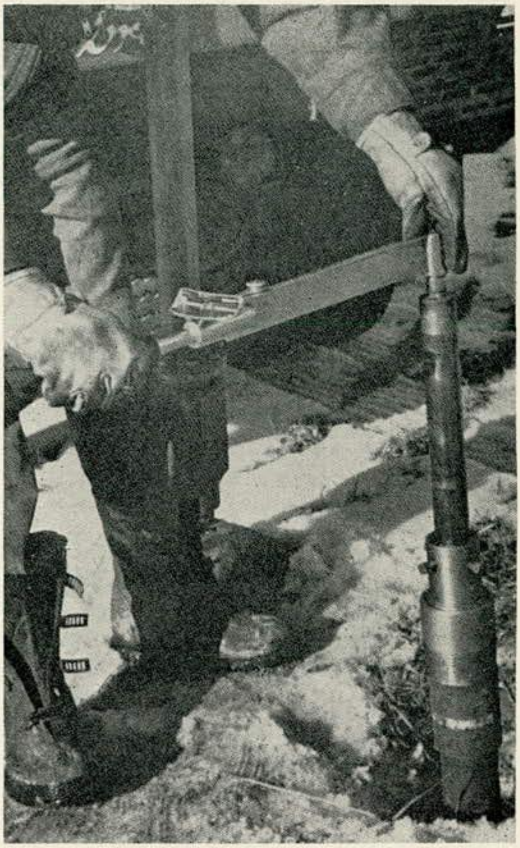


FIGURE 14
Vane shear apparatus torque wrench and thrust bearing.

In the previous discussion of samplers and drilling rigs the author has endeavored to include the more commonly used sampling and drilling equipment and to point out the more recent developments in such equipment in the United States. The list cannot help but be influenced by the author's particular viewpoint.

FIGURE 15
Acker Packsack portable diamond core drill.

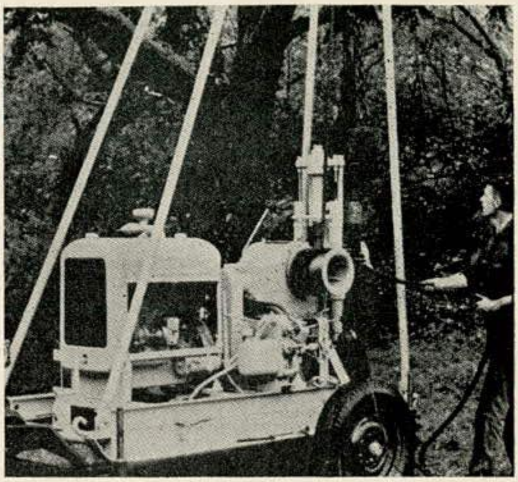


FIGURE 17
Trailer-mounted Acker hydraulic feed Teredo.

A task committee of the United States National Committee for the International Society of Soil Mechanics and Foundation Engineering plans to circulate a questionnaire to all engineers and contractors in-

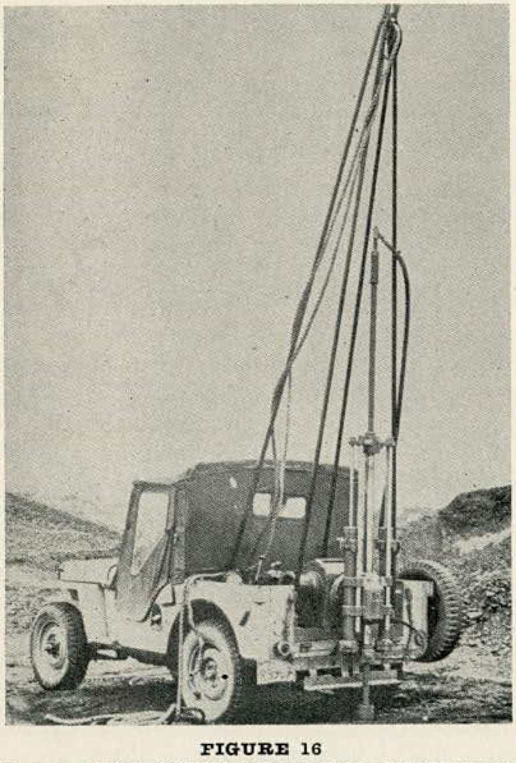


FIGURE 16
Jeep-mounted Acker hydraulic feed Teredo power take-off drive.

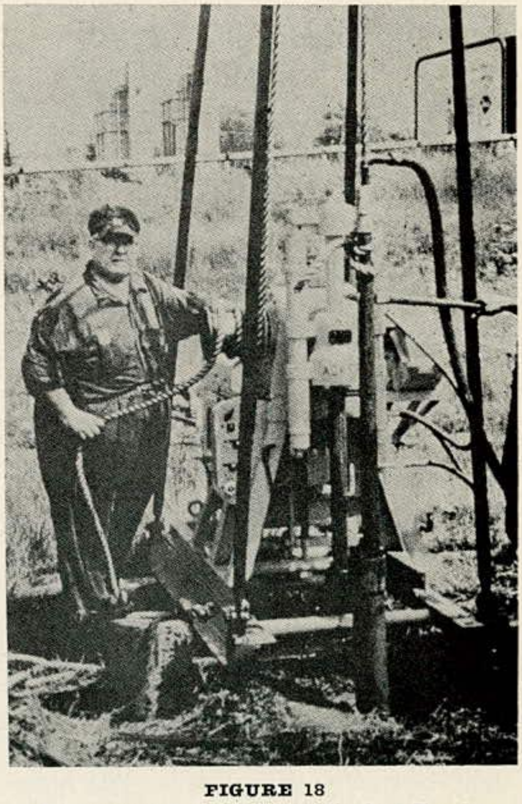


FIGURE 18
Skid-mounted Acker hydraulic feed Teredo.

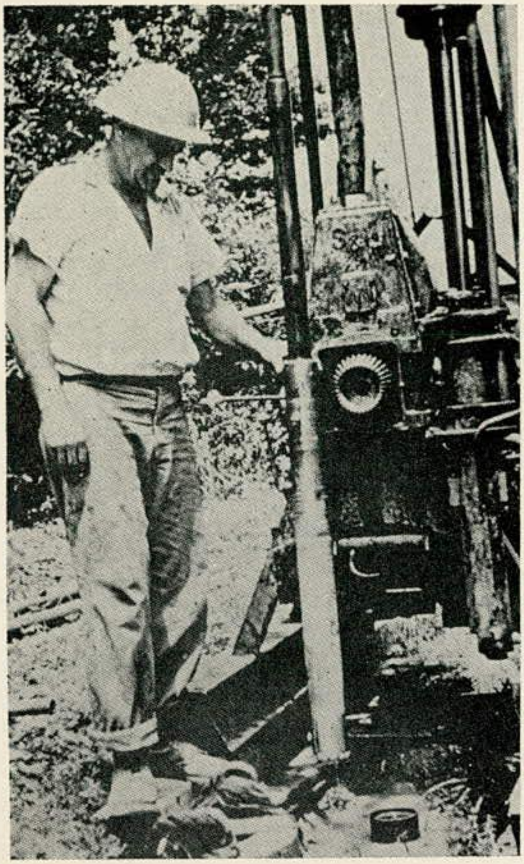


FIGURE 19
Sprague and Henwood 40C hydraulic feed.

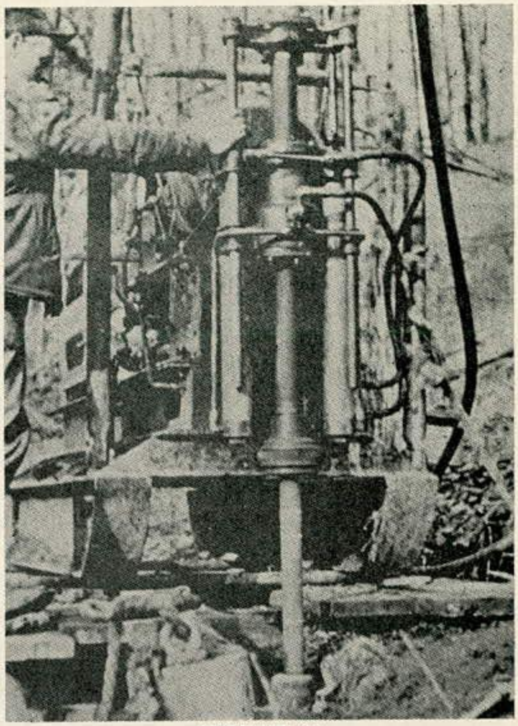


FIGURE 20
Sprague and Henwood 142 hydraulic feed.

volved in site investigations in the United States to determine more accurately current practices in sampling. It is hoped that the results of the questionnaire will be available for the next International Conference. The United States National Committee also has a task committee which is part of the International Society's committee on investigation of the standard penetration test.

The author is indebted to the owners of the Acker Drill Company and Sprague & Henwood, Inc., for supplying several of the drawings and photographs.

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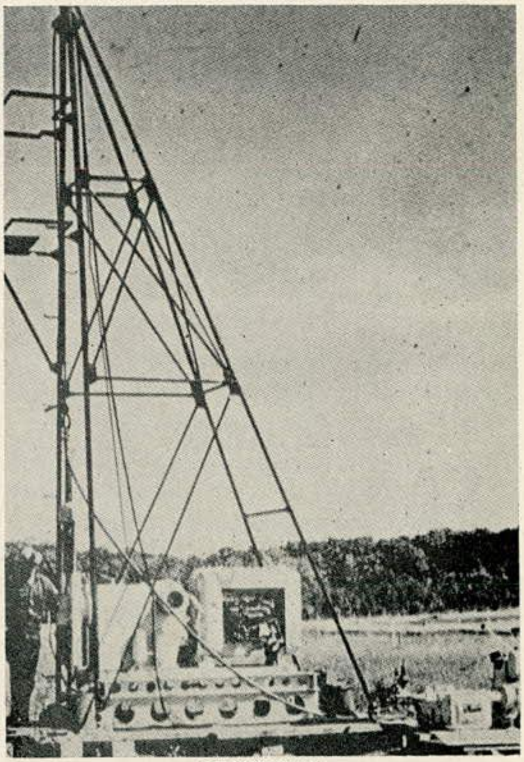

FIGURE 21
Acker Presidente high-capacity hydraulic feed drill.

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Certain Features of Lateral Pressures of Soils

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In my paper I intend to give a brief review of experimental investigations of two types of retaining structures carried out in recent years in the United States and in England.

In the first part of my report I shall describe special features of lateral pressures on inclined struts of wide open braced cuts. In the second part, I shall outline some aspects of the design of anchored sheet pile bulkheads.

In both cases, the interaction between the retaining structure and the soil is so complex that up to now it has not permitted rigorous mathematical analysis thereof. Observations and measurements on construction sites have invariably preceded even approximate theoretical explanations of corresponding modern methods of design proposed by various investigators. Therefore, both in the first and in the second parts of my paper I shall at first briefly touch upon preceding studies of this kind.

(1) Lateral Pressures of Sandy and of Silty Soils Against Inclined Struts of Sheet Pile Walls

The practical experiences during the construction of the first New York subways during the first decade of our century already showed that the lateral pressures of soils against the upper rows of struts exceeded appreciably the values obtained from design diagrams of the customary triangular shape.

Measurements performed during the following quarter of a century on subway construction sites in New York, Berlin and Munich confirmed that in such cases the actual lateral pressures of sandy soils have a parabolic form *(Fig. 1)*.

On the basis of these measurements, Terzaghi *(Ref. 1)* proposed in 1941 a design diagram which had the form of a trapezoid. This diagram was established in a purely empirical manner as an envelope of pressure diagrams obtained by measurements on various sections of the Berlin subway.

Other studies showed that the increase of the lateral pressures on the upper struts of braced cuts is related to the nature of the deformations of the sheet pile wall as shown diagrammatically on Figure 1.

A rigorous theoretical solution of the problem has not yet been obtained and is greatly hindered by the fact that at different depths in the soil two physically different phenomena, i.e., wedging and slipping, develop simultaneously.

In its lower part, the soil behind the sheeting expands; its density decreases and surfaces of sliding develop in it. In the upper part, however, under normal conditions of deformations of the braces of the cut, a densification of the soil takes place and a wedging of its hard particles, i.e., the so-called "arching action" *(Ref. 2)*.

In spite of the absence of a mathematically rigorous justification, Terzaghi's design trapezoid *(Fig. 1)* fully justified itself in practice when cuts were braced by horizontal struts. However, experience with inclined struts proved to be somewhat different in certain cases.

When the width of a cut is very large, the bracing of its walls by horizontal struts *(Fig. 1)* is not practical. For that reason, one frequently uses the method shown *(Fig.*