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Standard Guide for
Direct Push Soil Sampling for Environmental Site Characterizations[1]

This standard is issued under the fixed designation D6282/D6282M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide addresses direct push soil samplers, which may also be driven into the ground from the surface or through prebored holes. The samplers can be continuous or discrete interval units. Samplers are advanced by static push, or impacts from hammers, or vibratory methods, or a combination thereof, to the depth of interest. Both single tube and dual (double) tube systems may be advanced for soil sampling with direct push methods. Direct push methods are most often used to collect geo-environmental soil samples. These soil samples are used for soil classification (Practice D2488) and lithologic/hydrostratigraphic logging as well as being sub-sampled for contaminant and chemical analyses.

1.2 Other drilling and sampling methods may apply for samples needed for engineering and construction applications. This guide does not address single sampling events in the immediate base of the drill hole using rotary drilling equipment that employ cuttings removal as the sampler is advanced. Other sampling standards, such as Test Method D1586, Practices D1587 and D3550, and summarized in Guide D6169 apply to rotary drilling activities (Guide D6286). The guide does not cover open chambered samplers operated by hand such as augers, agricultural samplers operated at shallow depths, or side wall samplers.

1.2.1 While Sonic Drilling is considered a direct push method this standard may not apply to larger equipment addressed in Practice D6914.

1.3 Guidance on collection and handling of samples, are given in Practices D4220 and D6640. Samples for chemical analysis often must be subsampled and preserved for chemical analysis using special techniques such as Practice D4547, D6418, and D6640. Additional information on environmental sample preservation and transportation is available in other references (**1**, **2**, **3**, **4**, **5**, **6**)[2]. Samples for soil classification may be preserved using procedures given in Practice D4220 similar to Class A. In most cases, a direct push sample is considered as Class B in Practice D4220 but is protected, representative, and suitable for chemical analysis. The samples taken with this practice do not usually produce Class C and D (with exception of thin wall samples of standard size) samples for laboratory testing for engineering properties, such as shear strength and compressibility. If sampling is for chemical evaluation in the Vadose Zone, consult Guide D4700 for any special considerations.

1.4 Insertion methods described include static push, impact, percussion, other vibratory/sonic driving, and combinations of these methods using direct push equipment adapted to drilling rigs, cone penetrometer units, and specially designed percussion/direct push combination machines. Hammers providing the force for insertion include drop style, hydraulically activated, air activated and mechanical lift devices.

1.5 Direct push soil sampling is limited to soils and unconsolidated materials that can be penetrated with the available equipment. The ability to penetrate strata is based on hammer energy, carrying vehicle weight, compactness of soil, and consistency of soil. Penetration may be limited or damage to samplers and conveying devices can occur in certain subsurface conditions, some of which are discussed in 5.6. Successful sample recovery also may be limited by the ability to retrieve tools from the borehole. Sufficient retract force must be available when attempting difficult or deep investigations.

1.6 This guide does not address the installation of any temporary or permanent soil, groundwater, vapor monitoring, or remediation devices.

1.7 The practicing of direct push techniques may be controlled by local regulations governing subsurface penetration. Certification, or licensing requirements, or both, may need to be considered in establishing criteria for field activities.

1.8 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a projects's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D3694 Practices for Preparation of Sample Containers and for Preservation of Organic Constituents
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4220 Practices for Preserving and Transporting Soil Samples
D4547 Guide for Sampling Waste and Soils for Volatile Organic Compounds
D4700 Guide for Soil Sampling from the Vadose Zone
D5088 Practice for Decontamination of Field Equipment Used at Waste Sites
D5092 Practice for Design and Installation of Groundwater Monitoring Wells
D5299 Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities
D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D6001 Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization
D6067 Practice for Using the Electronic Piezocone Penetrometer Tests for Environmental Site Characterization
D6169 Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations
D6286 Guide for Selection of Drilling Methods for Environmental Site Characterization
D6418 Practice for Using the Disposable En Core Sampler for Sampling and Storing Soil for Volatile Organic Analysis
D6640 Practice for Collection and Handling of Soils Obtained in Core Barrel Samplers for Environmental Investigations
D6724 Guide for Installation of Direct Push Groundwater Monitoring Wells
D6725 Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers
D6914 Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices
D7242 Practice for Field Pneumatic Slug (Instantaneous Change in Head) Tests to Determine Hydraulic Properties of Aquifers with Direct Push Groundwater Samplers
D7648 Practice for Active Soil Gas Sampling for Direct Push or Manual-Driven Hand-Sampling Equipment

3. Terminology

3.1 *Definitions*—For definitions of common terminology terms used within this guide refer to Terminology D653. Definitions for additional terms related to direct push water sampling for geoenvironmental investigations are in accordance with Guide D6001.

3.1.1 *assembly length, n*—length of sampler body and riser pipes.

3.1.2 *direct push sampler, n*—sampling devices that are advanced into the soil to be sampled without drilling or borehole excavation.

3.1.3 *extension rod, n*—hollow steel rod, threaded, in various lengths, used to advance and remove samplers and other devices during direct pushing boring. Also known as drive rod. In some applications, small diameter solid extension rods are used through hollow drive rods to activate closed samples at depth.

3.1.4 *incremental drilling and sampling, n*—insertion method where rotary drilling and sampling events are alternated for incremental sampling. Incremental drilling often is needed to penetrate harder or deeper formations.

3.1.5 *push depth, n*—the depth below a ground surface datum to which the lower end, or tip, of the direct-push sampling device is inserted.

3.1.6 *sample interval, n*—defined zone within a subsurface strata from which a sample is gathered.

3.1.7 *sample recovery, n*—the length of material recovered divided by the length of sampler advancement and stated as a percentage.

3.1.8 *soil core, n*—cylindrical shaped specimen recovered from a soil sampler of soil, sediments, or other unconsolidated accumulations of solid particles produced by deposition or the physical and chemical disintegration of rocks and which may or may not contain organic matter.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *closed barrel sampler, n*—a sampling device with a piston or other secured device that is held to block the movement of material into the barrel until the blocking device is removed or released. Liners are required in closed barrel samplers. Also may be referred to as a protected type sampler.

3.2.2 *impact heads/drive heads, n*—pieces or assemblies that fit to top of the above ground portion of the direct push tool assembly to receive the impact of the hammering device and transfer the impact energy to sampler extensions or drive rods.

3.2.3 *open barrel sampler, n*—sampling barrel with open end allowing material to enter at any time or depth. Also may be referred to as an unprotected type sampler.

3.2.4 *piston lock, n*—device to lock the sampler piston in place to prevent any entry of a foreign substance into the sampler chamber prior to sampling.

3.2.5 *single tube system, n*—a system whereby single extension/drive rods with sampler attached are advanced into the subsurface strata to collect a soil sample.

3.2.6 *solid barrel sampler, n*—a soil sampling device consisting of a continuous or segmented tube with a wall thickness sufficient to withstand the forces necessary to penetrate the strata desired and gather a sample. A cutting shoe and a connecting head are attached to the barrel.

3.2.7 *split barrel sampler, n*—a soil sampling device consisting of the two half circle tubes manufactured to matching alignment, held together on one end by a shoe and on the other by a connecting head.

3.2.8 *dual tube systems, n*—a system whereby inner and outer tubes are advanced simultaneously into the subsurface strata to collect a soil sample. The outer tube is used for borehole stabilization. The inner tube for is used sampler recovery and insertion.

4. Summary of Guide

4.1 Direct push soil sampling consists of advancing a sampling device into subsurface soils by applying static pressure, by applying impacts, or by applying vibration, or any combination thereof, to the above ground portion of the sampler extensions until the sampler has been advanced to the desired sampling depth. The sampler is recovered from the borehole and the sample removed from the sampler. The sampler is cleaned and the procedure repeated for the next desired sampling interval. Sampling can be continuous for full depth borehole logging or incremental for specific interval sampling. Samplers used can be protected type for controlled specimen gathering or unprotected for general soil specimen collection.

5. Significance and Use

5.1 Direct Push Soil Sampling is used extensively in environmental site characterization of soils below ground surface and can also be used for subsurface geotechnical site characterization (**3**, **7**, **8**, **9-12**, **13**). Limited early studies have been done using Direct Push Soil Sampling for environmental investigations (**14**, **15**, **16**). These methods are preferred for environmental site characterization over rotary drilling sampling methods (D6169, D6286) because they are minimally intrusive (less disruptive to the soil column) and they do not generate soil cuttings which could be contaminated and require characterization and safe disposal. Direct Push soil samplers are grouped into two categories; Single Tube and Dual (Double) Tube systems.

5.1.1 *Dual Tube Systems*—Dual tube soil sampling systems are preferred for use because the bore hole is protected and sealed by the outer casing during operations. However, in some conditions when sampling below the groundwater, a sealed single tube sampler (5.1.2) must to be used to avoid sample cross contamination. Figure 1 shows how a Double Tube system is used. The outer tube stays in place to protect and seal the borehole and prevents potential cross contamination of the boring and the soil sample. Dual tube systems allow for rapid continuous sampling both above and below the water table. When sampling is not required, a sealed inner drive point can be locked in for driving through zones not targeted for sampling or through obstructions or difficult to sample formations.

5.1.1.1 Dual tube systems facilitate deployment of other testing and sampling systems (Test Method D1586 and Practice D1587) and sensors, groundwater sampling (D6001), water testing (D7242), and even monitoring well installations (D6724, D6725). Well installations may require use of specially designed expendable tips that facilitate well construction.

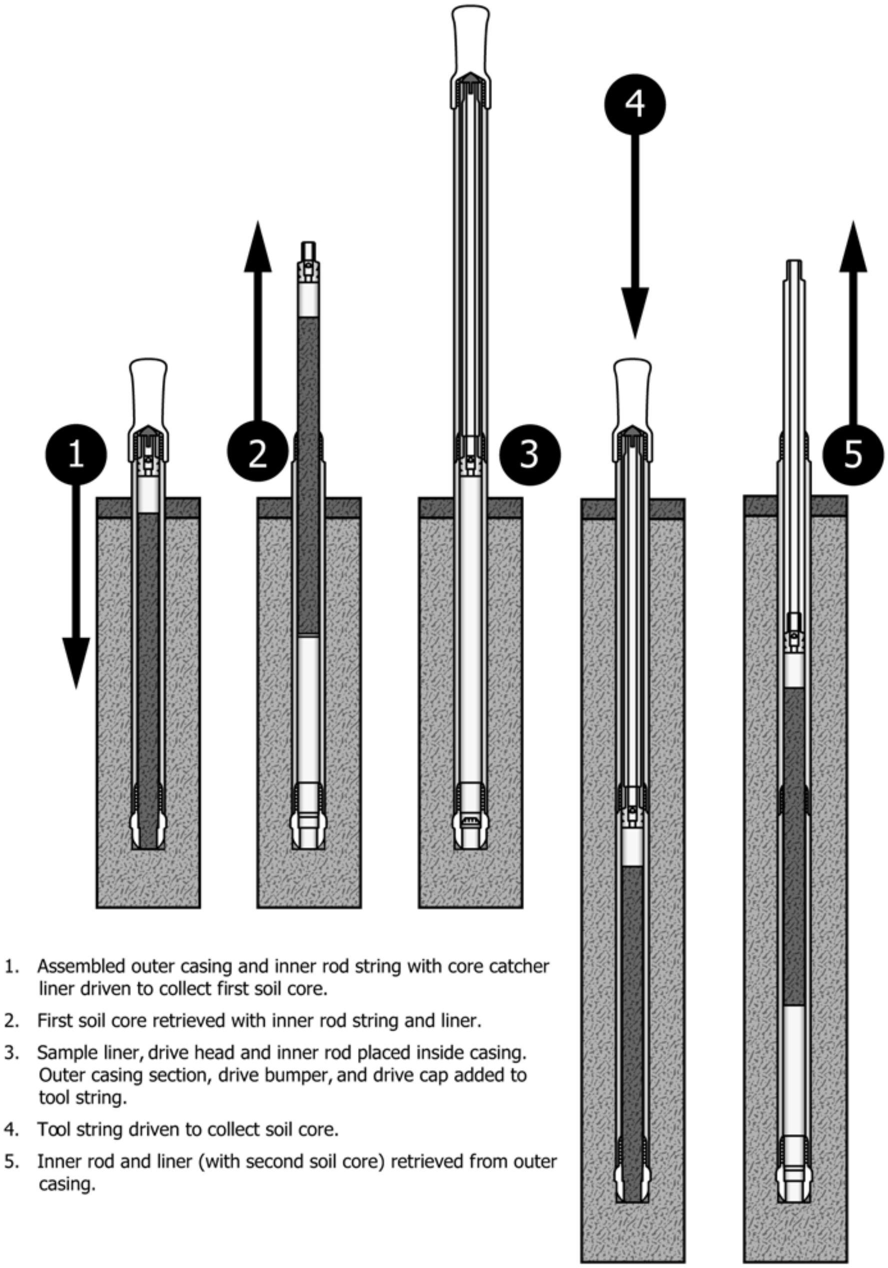
5.1.1.2 In larger Dual Tube systems with inside diameters of at least 75 mm the Standard Penetration Test (D1586) is often conducted in the bottom of the boring. Reliable SPT N values can be obtained in most soil formations that are not disturbed by the driving of the casing. Cohesionless sands and very soft clays may be disturbed during advancement of the Dual System to the test depth and should be evaluated or flagged if suspect. Reliable N values may not be obtained if there is evidence of heave or borehole instability from the base of the borehole to the inside the casing.

5.1.1.3 Dual tube systems are easily grouted and sealed for completion because the outer casing keeps an open sealed borehole for insertion of grout tubes.

5.1.1.4 As shown on Fig. 1, continuous sampling is done with an opening left at the bottom of the outer casing during the sampling process. This is fine as long as the formation is stable between sampling events. If there are heaving conditions into the outer casing the outer casing may be retracted to set the sampler barrel in position. The instability can be improved by maintaining a water level balance in the outer casing and using slower retraction of the sampler string during withdraw. If the material stability ids a problem then one must deploy a sealed single tube piston sampler (5.1.2) into the boring to retrieve samples.

5.1.1.5 A constant outer tube diameter of the Dual Tube system generally has more friction than some Single Tube rod driven samplers so may require larger equipment capable of higher more percussion and push forces. Dual Tube systems approaching 100 to 150 mm outside diameter have been developed and require larger direct push equipment.

5.1.2 *Single Tube Systems*—Sealed single tube samples assure that the soil sample is not cross contaminated by other soils or fluids inside the bore hole so they are preferred sampling method to use below groundwater. Single tube soil



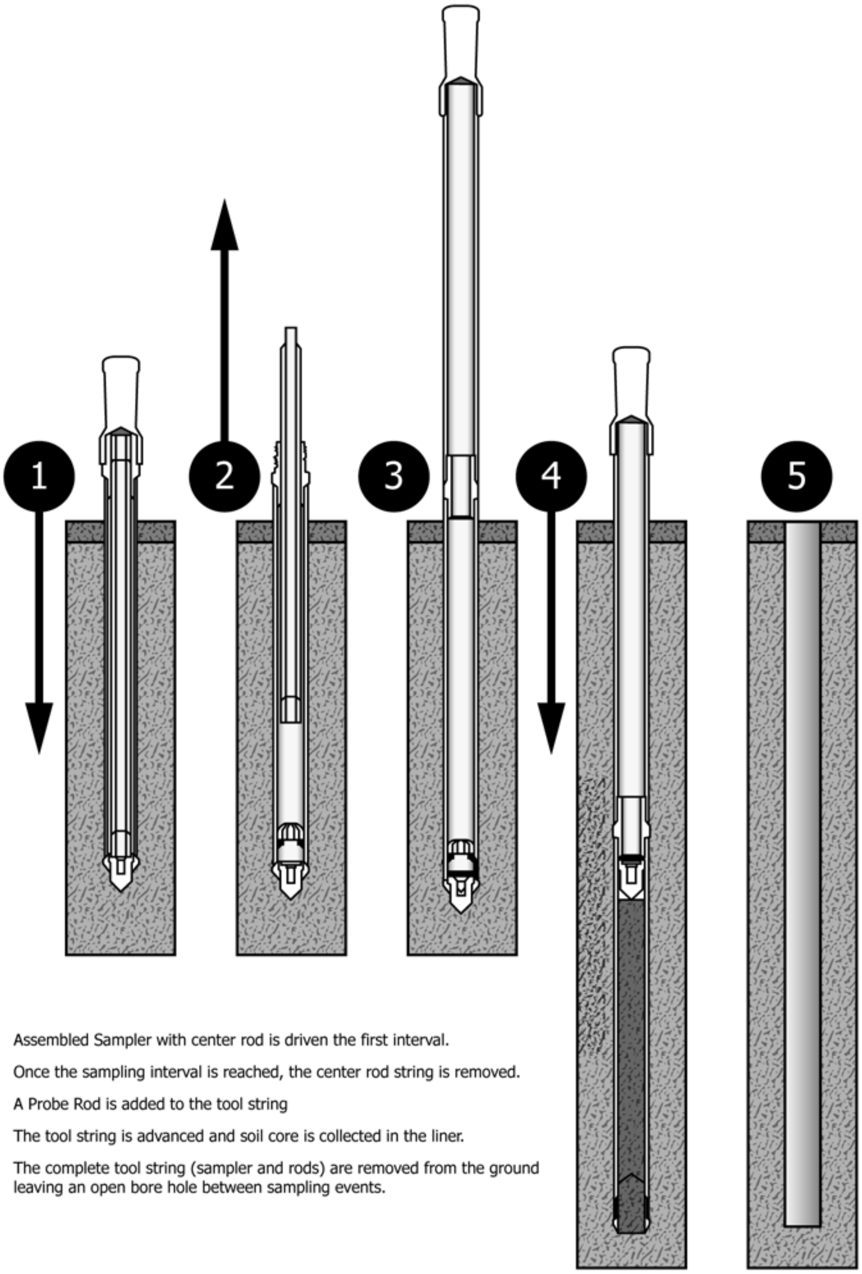
1. Assembled outer casing and inner rod string with core catcher liner driven to collect first soil core.
2. First soil core retrieved with inner rod string and liner.
3. Sample liner, drive head and inner rod placed inside casing. Outer casing section, drive bumper, and drive cap added to tool string.
4. Tool string driven to collect soil core.
5. Inner rod and liner (with second soil core) retrieved from outer casing.

FIG. 1 Dual Tube Direct Push Soil Sampler Operation

sampling systems are most often used for single incremental discrete soil sampling events but can also be used in continuous sampling modes with limitations listed below. Sealed piston type samples assure the best preservation of sample and assure no cross contamination of the soil. Figure 2 shows the basic operation of a single tube sampler. The sampler includes a sealed piston point to prevent soil intrusion during advancement to the target sample depth. The piston is then unlocked using various mechanisms and the sample is pushed to the design length. The complete sampler tube and drive rods are removed from the ground to retrieve the sample leaving an open hole after sampling.

5.1.2.1 The disadvantage to single tube sampling is that the hole left in the ground may not stay open and it would be difficult to grout if required. If positive proof of grouting is required it may be necessary to push a re-entry grout tube to the sample depth to grout the hole (D6001). Another disadvantage is possible travel of contaminants down the open hole. If cross contamination is a concern than a dual tube sampler system should be used.

5.1.2.2 Many single tube systems use drive rods of smaller diameter than the sampler body. The use of smaller diameter drive rods raises two concerns when sampling. First the soil above the sampler body may cave on the sampler and cause



1. Assembled Sampler with center rod is driven the first interval.
2. Once the sampling interval is reached, the center rod string is removed.
3. A Probe Rod is added to the tool string
4. The tool string is advanced and soil core is collected in the liner.
5. The complete tool string (sampler and rods) are removed from the ground leaving an open bore hole between sampling events.

FIG. 2 Single Tube Direct Push Soil Sampler Operation

retraction problems. Second, if chemical analysis is required and the sampler will penetrate and cross contaminated zones there is concern that fluids from layers up above may run down the open annulus above the sampler causing cross contamination.

5.1.2.3 Single tube piston samplers are sometimes used in conjunction with Cone Penetrometer Testing (CPT) (D6067) and can be used in other geotechnical drilling (D6169) in the base of a drill hole.

5.1.2.4 Continuous Sampling operations may be conducted in the same hole with limitations. Using the sealed piston sampler, consecutive samples can be obtained in the same hole by re-driving the sealed piston sampler to a deeper target depths.

5.1.2.5 Open tube samplers without a piston (Fig. 3) should not be used except in rare cases. Use of an unsealed open barrel sampler without a sealed piston multiple times in the same sampling hole will result in cross contamination of samples from the hole wall, cave, and heaving. Continuous soil sampling using an open barrel is sometimes performed above the water table where boreholes are very stable. This sampling mode should never be used below the water table. A sealed sample is required to assure no cross contamination.

5.2 Direct push methods of soil sampling are used for geologic investigations, subsurface soil matrix contamination studies, and water quality investigations. Examples of a few types of investigations in which direct push sampling may be

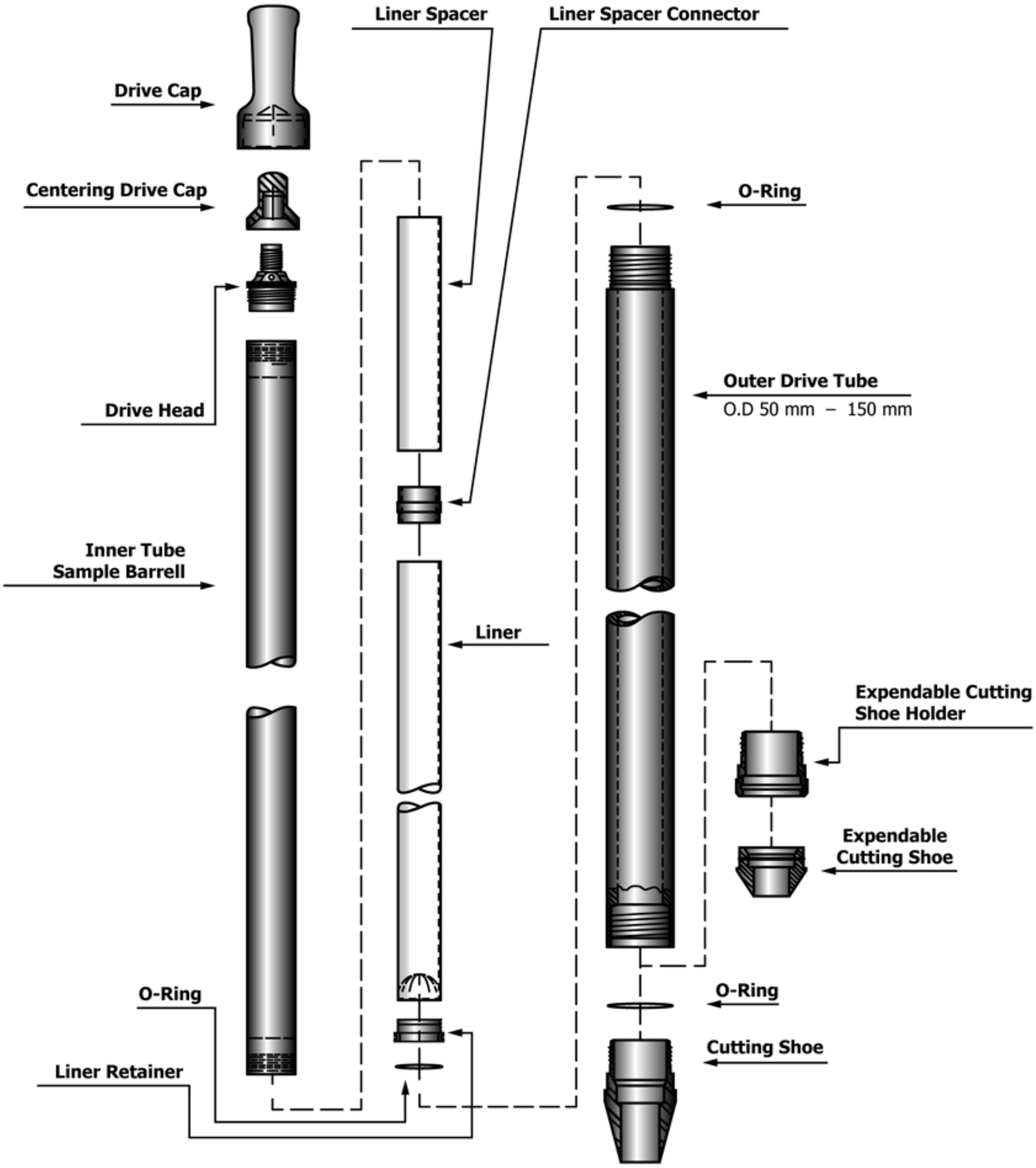


FIG. 3 Dual Tube Soil Sampler with Solid Inner Barrel and Liner

used include site assessments, underground storage tank investigations, and hazardous waste site investigations (17-19). Continuous sampling is used to provide a lithological detail of the subsurface strata and to gather samples for classification and index tests or for chemical testing. These investigations frequently are required in the characterization of hazardous waste sites. Samples, gathered by direct push methods, provide specimens necessary to determine the types and concentration of contaminants in soils and sediments, and in most circumstances, the contained pore fluids (7, 8, 9, 10, 11, 12, 13). Procedures for soil core handling for chemical testing are given standard D6640. Sampling for Volatile Organic Compounds (VOC) is addressed in Guide D4547 and often the core may be rapidly subsampled on site using other methods such as D6418 or other similar small hand core samplers. Samples for other chemical characterization generally require subsampling into glass or plastic jars or vials and preserved with refrigeration (See EPA test methods in SW-846 (4)). Verify containers and preservation requirements meet the data quality objectives as specified by the lead regulatory agency, in the project work plan, and with the selected analytical laboratory.

5.3 Direct push methods can provide accurate information on the characteristics of the soils encountered and of the chemical composition if provisions are made to ensure that discrete samples are collected, that sample recovery is maximized, and that clean decontaminated tools are used in the sample gathering procedure. For purposes of this guide, “soil” shall be defined in accordance with Terminology D653. Using sealed or protected sampling tools, cased boreholes, and proper advancement techniques can assure good representative samples. Direct push boreholes may be considered as a supplementary part of the overall site investigation or may be used for the full site investigation if site conditions permit. As such, they should be directed by the same procedural review and quality assurance standards that apply to other types of subsurface borings. A general knowledge of subsurface conditions at the site is beneficial.

5.4 Soil strata profiling to shallow depths may be accomplished over large areas in less time than with conventional drilling methods because of the rapid sample gathering potential of the direct push method. More site time is available for actual productive investigation as the time required for ancillary activities, such as decontamination, rig setup, tool handling, borehole backfill, and site clean-up is reduced over conventional drilling techniques. Direct push soil sampling has benefits of smaller size tooling, smaller diameter boreholes, and minimal investigative derived waste.

5.5 The direct push soil sampling method may be used as a site characterization tool for subsurface investigation and for remedial investigation and corrective action. The initial direct push investigation program can provide good soil and sediment stratigraphic information depending on the soil density and particle size, determine groundwater depth, and provide samples for field screening and for formal laboratory analysis to determine the types and concentrations of chemical contaminants in the soil or sediments and contained pore fluids. The method does not provide samples for laboratory test if engineering properties (Class C and D D4220).

5.6 This guide may not be the correct method for investigations in all cases. As with all drilling methods, subsurface conditions affect the performance of the sample gathering equipment and methods used. Direct push methods are not effective for solid rock and are marginally effective in partially weathered rock or very dense soils. These methods can be utilized to determine the rock surface depth. The presence or absence of groundwater can affect the performance of the sampling tools. Compact gravelly tills containing boulders and cobbles, stiff clay, compacted gravel, and cemented soil may cause refusal to penetration. Certain cohesive soils, depending on their water content, can create friction on the sampling tools which can exceed the static delivery force, or the impact energy applied, or both, resulting in penetration refusal. Some or all of these conditions may complicate removal of the sampling tools from the borehole as well. Sufficient retract force should be available to ensure tool recovery. As with all borehole advancement methods, precautions must be taken to prevent cross contamination of aquifers through migration of contaminants up or down the borehole. Regardless of the tool size, the moving of drilling and sampling tools through contaminated strata carries risks. Minimization of this risk should be a controlling factor in selecting sampling methods and drilling procedures. The user should take into account the possible chemical reaction between the sample and the sampling tool itself, sample liners, or other items that may come into contact with the sample (**3, 4**).

5.7 In some cases this guide may combine water sampling, or vapor sampling, or both, with soil sampling in the same investigation. Guides D6001 and D4700, D7648 can provide additional information on procedures to be used in such combined efforts. D3740 provides evaluation factors for the activities in this standard.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Criteria for Selection

6.1 Important criteria to consider when selecting sampling tools include the following:

6.1.1 Size of sample.

6.1.2 Sample quality (Class A,B,C,D) for physical testing. Refer to Practice D4220.

6.1.3 Sample handling requirements, such as containers, preservation requirements. Refer to Practice D6640.

6.1.4 Soil conditions anticipated.

6.1.5 Groundwater depth anticipated and perched water tables.

6.1.6 Boring depth required.

6.1.7 Types and concentrations of contaminants in the soil or sediments and contained pore fluids.

6.1.8 Probability of cross contamination.

6.1.9 Available funds.

6.1.10 Estimated cost.

6.1.11 Time constraints.

6.1.12 History of tool performance under anticipated conditions (consult experienced users and manufacturers).

6.2 Important criteria to consider when selecting direct push equipment include the following:

6.2.1 Site accessibility.

6.2.2 Site visibility.

6.2.3 Soil conditions anticipated.

6.2.4 Boring depth required.

6.2.5 Borehole sealing requirements.

6.2.6 Equipment performance history.

6.2.7 Personnel requirements.

6.2.8 Decontamination requirements.

6.2.9 Equipment grouting capability.

6.2.10 Local regulatory requirements.

7. Apparatus

7.1 *General*—A direct push soil sampling system consists of a sample collection tool, hollow extension rods for advancement, retrieval, and transmission of energy to the sampler, and an energy source to force sampler penetration. Auxiliary tools are required to handle, assemble and disassemble, clean, and repair the sample collection tools and impact surfaces. Necessary expendable supplies are sample containers, sample container caps, sample liners, sample retainers, appropriate lubricants, and personal safety gear. The following text and subsequent figures tell and show the overall intent of this standard; however, if the exact configuration and dimensions vary in a particular tooling configuration, yet the intent is still met, that particular tooling configuration is acceptable to be used as a part of complying with this standard.

7.2 *Direct Push Tool Soil Sampling Systems*—Direct push soil samplers are described in two groups; Dual Tube and Single Tube Systems.

7.2.1 *Dual Tube System*—Figures 3 and 4 are examples of typical Dual Tube direct push soil samplers. The Outer Drive Tube which is generally the same diameter. Diameters range from 50 to 150 mm [2 to 6 inches]. The outer drive tube is sometimes referred to as Probe rod in the drawings. Outer drive tube friction can be reduced by using oversized cutting shoes or other friction reducers. The Outer drive tube stays in the ground and seals and protects borehole collapse as the sampling progresses to depth.

7.2.1.1 *Sampler*—Figure 3 shows a sampler with a solid inner barrel with a liner inside the barrel. Figure 4 shows just an inner liner without the solid barrel. The solid barrel may be required in situations where liner damage may occur. The length of sample ranges from 2 to 6 ft [0.5 to 1.5 m] and diameters range from 50 to 125 mm [2-5 inches]. The sampler is normally held in place with a series of inner rods that fit inside the outer tube and connect to the drive cap so both the outer rods and inner rods are advanced together. The inner rods are used to place and remove the sampler barrels during sampling events. There are other means of locking the sample barrel in place besides inner rods such as wire line latching systems.

7.2.1.2 The outer drive tube is equipped with a Cutting Shoe on the end the is designed specifically for the sampler system such that the liners, o-rings, and core catchers all fit in place correctly and the shoe cuts the core to slides into the sampler liner with minimal disturbance. There are different cutting

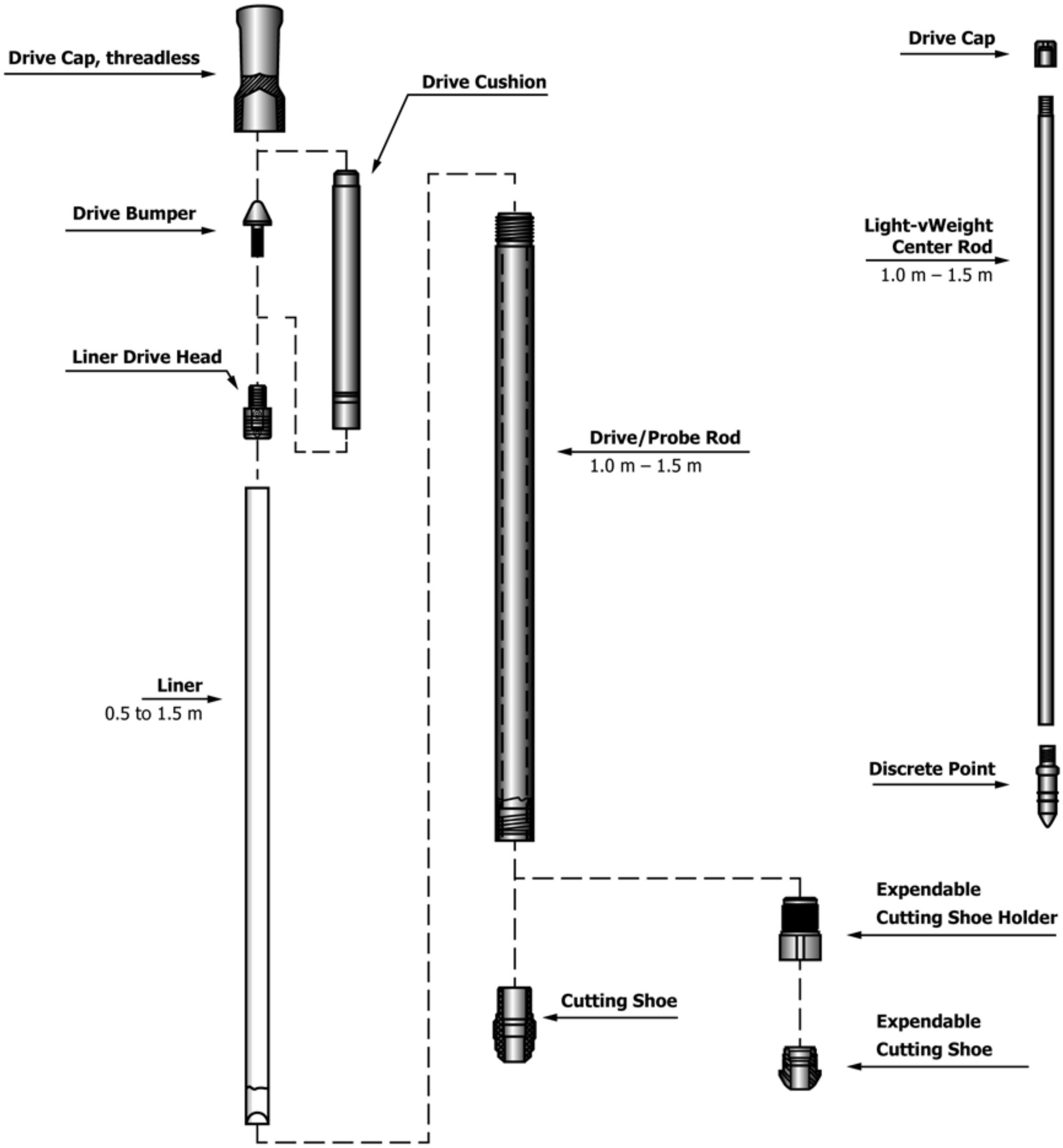


FIG. 4 Dual Tube Sampler with Inner Liner and Inner Rods

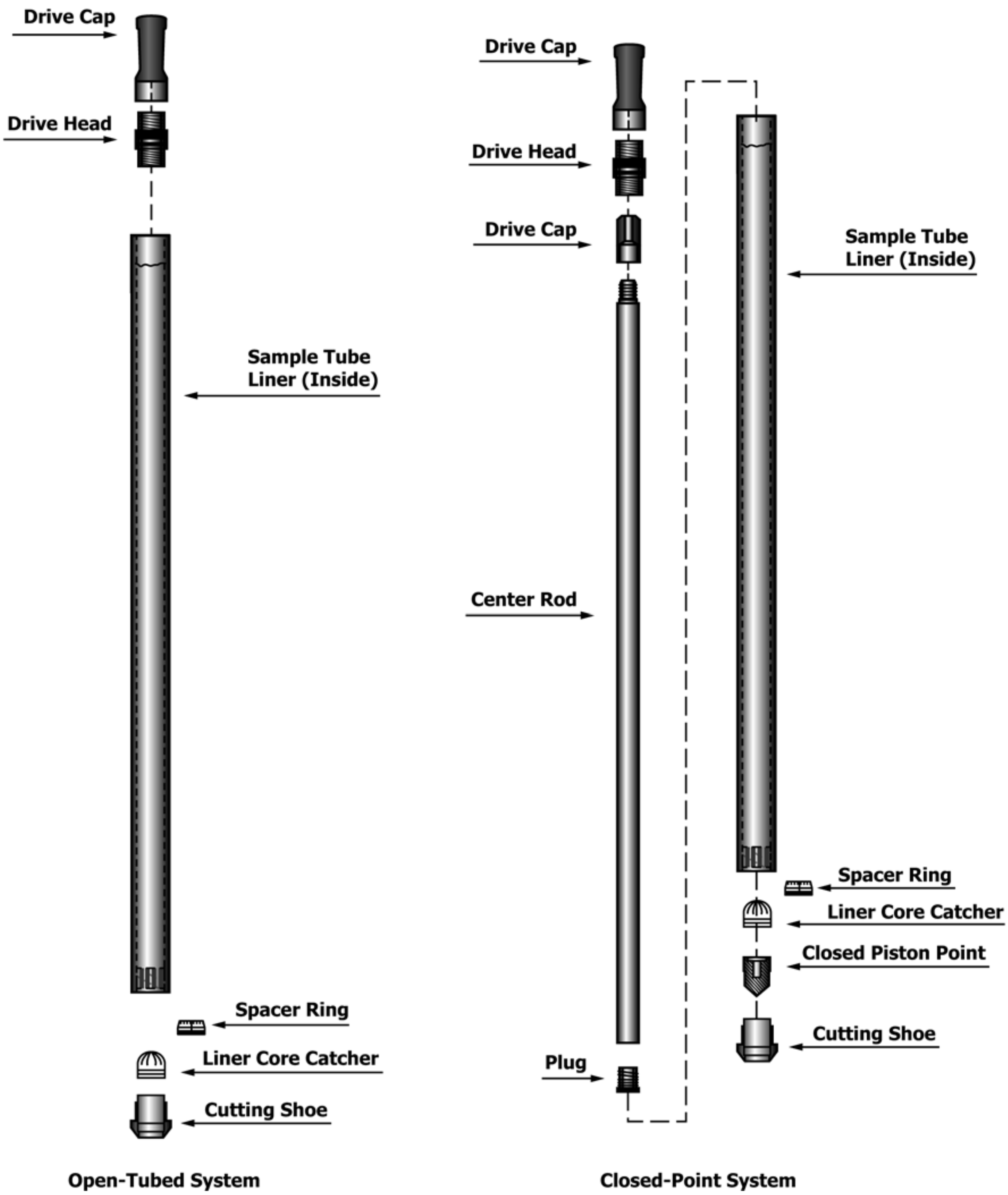


FIG. 5 Typical Single Tube Sampling System Used in Either Open Tube or Sealed (Closed) Piston Point

shoes for differing soil conditions (see Appendix X1) so the correct design must be used in the soils to be sampled. The Cutting Shoe is the most important feature that effects soil core recovery or quality. General purpose cutting shoes are successful in a wide range of soil deposits but if the recover is poor one should change the cutting shoe design for the soils to be sampled. Special expendable cutting shoes (Figs. 4 and 5) can be used when the planned investigation requires post sampling installations such as monitoring wells (D6724, D6725).

7.2.1.3 Core catchers can be used to help the soil recovery by preventing loss of core. Figure 3 shows a core catcher built into the sample liner. Core catchers should be used in most all soil conditions. The catcher does not disturb the soil except in very soft soils. The use of a catcher assures that if clean sands are encountered they can be recovered without running/falling out of the liner.

7.2.1.4 Figure 4 shows a discrete point with inner rods that can be inserted into the dual tube system in place of the sampler barrel to advance the system without sampling. It can be used to drive through difficult formations and intervals where sampling is not required.

7.2.2 *Single Tube Samplers*—Figures 5 and 6 show some single tube sampler systems. Figure 5 shows a Single Tube system used in either an open or sealed mode. Sample lengths

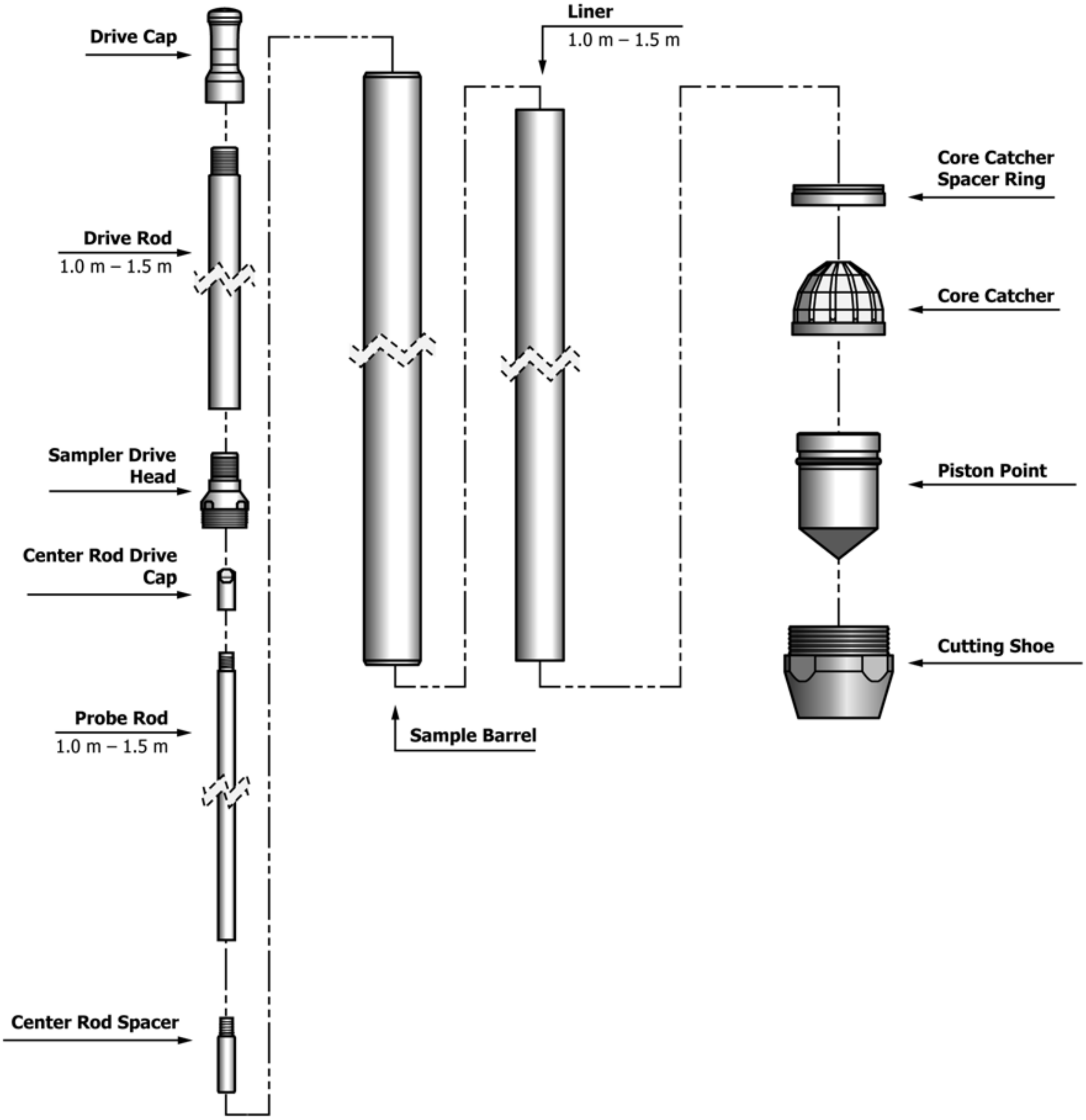


FIG. 6 Sealed Single Tube Piston Sampler

range from 0.5 to 1.5 m [2 to 5 ft]. Typical sample diameters range from 30 to 100 mm [1 to 4 inches]. Figure 6 shows the Sealed single tube sampler with solid barrel, inner liner, piston point, and cutting shoe. The sealed system includes the piston and inner rod are locked inside the liner and the sampler is advanced to the sampling depth. The piston is unlocked using rods or other methods prior to the sampling push. The sample barrel is equipped with a cutting shoe which is specifically designed to cut the core for optimal recovery.

7.2.2.1 Figure 7 shows a typical piston sampler deployed on CPT rigs (D6067) (**20**). It uses a simple ball system to unlock the piston when the sampling depth is reached.

7.2.2.2 A Core Catcher is sometimes used to add in recovery of sands and low plasticity silts. This catcher is reusable and is not built into the liner. In many cases the catcher is not required as the piston system creates a vacuum to hold the sample in the liner.

7.2.2.3 Figure 5 shows the single tube sampler use without the piston in an open sampling mode. As discussed in section 5.1.2.5, the use of an open sampler for consecutive sampling events is extremely limited.

7.3 *Sampler Extension/Drive Rods*—Sampler extension/drive rods are lengths of rod or tube generally constructed of steel to withstand the pushing or percussion forces applied. Inner rods used with Dual Tube systems can be made with thinner walls to provide lightweight tooling to minimize manual effort in sampling. Extension drive rods lengths range from 1.0 to 1.5 m [3 to 5 ft] but are available in various lengths. Rod lengths should be mated with casing and sampling equipment used. Thread types and classes vary between equipment manufacturers. Rod joints can be sealed to prevent fluid intrusion with “O” rings. TFE-fluorocarbon washers or TFE-fluorocarbon tape. Because of the percussive effort, joint

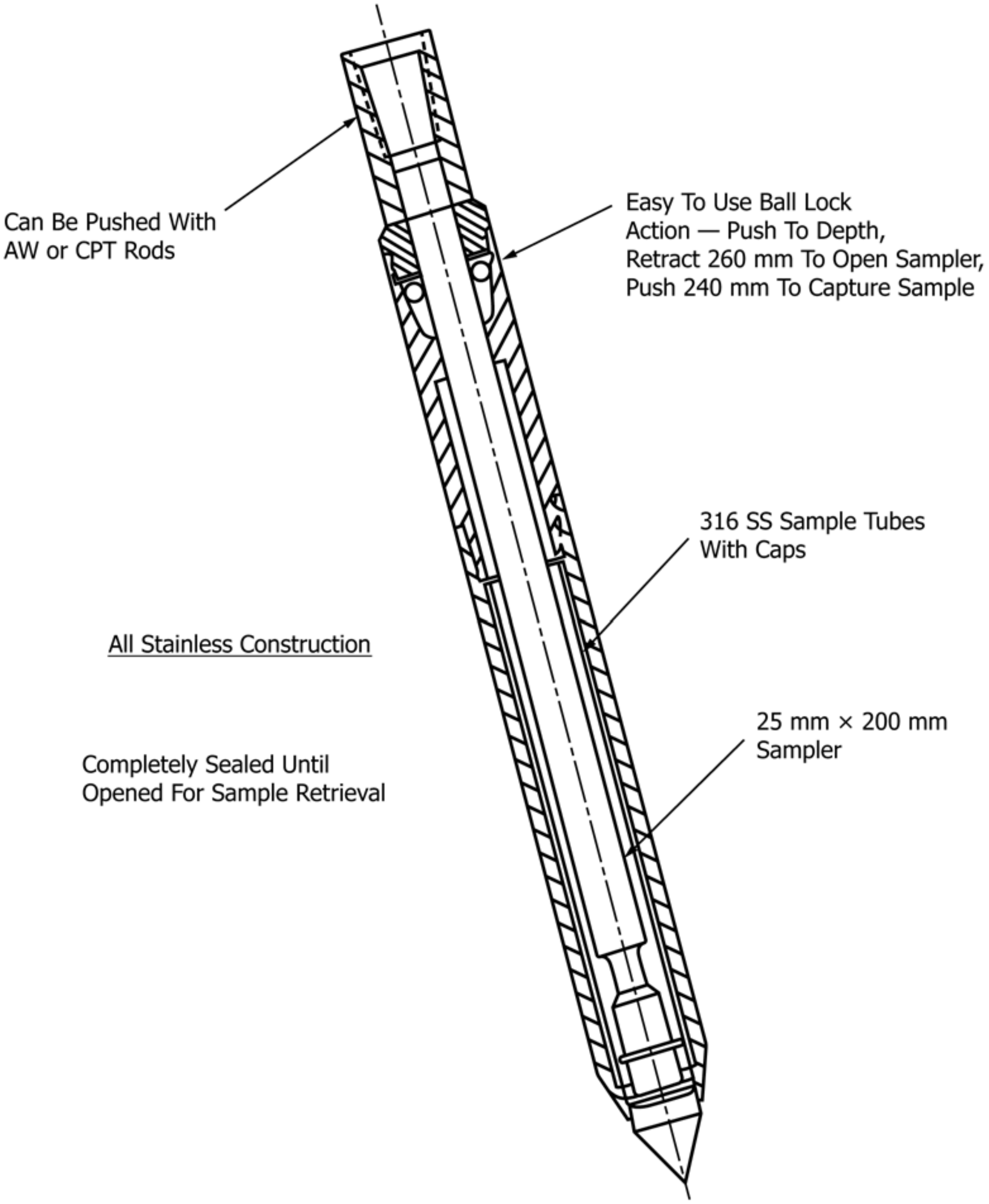


FIG. 7 Single Tube Piston Sampler Used on CPT and Drilling Operations

seals should be checked for each sampling effort. Dual Tube outer rods should have sufficient inside diameter to accommodate the equipment necessary to perform the desired action. For Direct Push monitoring well installation (D6724, D6725) research has shown **(21)** that the minimum nominal 100-mm [4-inches] inside diameter requirement normally specified for rotary drilled monitoring wells (D5092) is not required for the installation of smaller diameter direct push wells.

7.4 *Sampler Liners*—Sampler liners are used to collect and store samples for shipment to laboratories, for field index testing of samples and for removing samples from solid barrel type samplers. Most chemical testing of the soil core, if performed, requires rapid or immediate sub-sampling, containerization, and preservation of samples (see 5.2) for testing and therefore the material of the liner and interaction of the liner with chemicals is not a major concern. Liners are only used to retain soils for long term for classification and geotechnical index properties testing. Liners are available in lengths from 150 mm [6 in.] to 1.5 m [5.0 ft]. Liners should be sealed in accordance with Practice D4220 or sealed subsamples taken when samples are collected for moisture content physical testing. Liners generally are split in the field for subsampling. Individually split liners are available in some sizes for field use. The liner should have a slightly larger inside diameter than the soil specimen to reduce soil friction and enhance recovery (see 7.5). When a slightly oversized liner is used, the potential for air space exists around the sample. Certain chemical samples may be affected by the enclosed air. Liners having less tolerance may be required and a shortened sampled interval used to reduce friction in the liner. Metal liners can be reused after proper cleaning and decontamination. Plastic liners should be disposed of properly after use.

7.4.1 The most predominant liner material in used is clear medical grade Polyvinyl Chloride (PVC). The clear liner has the advantage of exposing the soil core to visual examination after recovery. Smearing of soil in the liner does occur and liners should be opened and examined and required subsamples taken. Liners are available in plastics, TFE-fluorocarbon, brass, and stainless steel. Other materials can be used as testing needs dictate, however, since there is limited concern when immediate subsamples are taken on chemical test results, there may be no need for more expensive non-reactive liner materials such as TFE-fluorocarbon or brass. Verify that liner materials meet local regulatory requirements and specifications in the project sampling plan and quality assurance plan.

7.5 *Cutting Shoes*—The Cutting Shoe is one of the most important parts affecting the quality and Recovery (9.5.4) of the soil specimens. General purpose cutting shoes work well in most formations but if core recovery is poor, then one should change the cutting shoe and liner design to optimize the sample recovery and quality. The Clearance Ratio (Ratio of ID of Cutting Shoe to ID of Liner) is the most important parameter for optimizing sample recovery and quality. In general higher clearance ratios are required in dense soil formations while lower ones can be used in softer formations. The cutting angle of the shoe also influences the sample quality. Sharper cutting shoes work better in fine grained formations but they are not as durable. Appendix X1 gives additional information on Cutting Shoe design. Contact your manufacturer if you have questions regarding recovery and quality issues.

7.6 *Sample Containers*—Sample containers should be prescribed according to the anticipated use of the sample specimen. Samples taken for chemical testing may require clean containers with specific preservatives (see 5.2). Practice D3694 and EPA SW-846 (**4**) provides information on some of the special containers and preservation techniques required for these containers generally will be cleaned to specific criteria. Samples for geotechnical testing require certain minimum volumes and specific handling techniques. Practice D4220 offers guidance for sample handling of samples submitted for geotechnical physical testing.

7.7 *Direct Push Power Sources*—Soil probing percussion driving systems, penetrometer drive systems, and rotary drilling equipment may be used to drive casings and direct push soil sampling devices. The equipment should be capable of applying sufficient static force, or dynamic force, or both, to advance the sampler to the required depth to gather the desired sample. The system must have adequate retraction force to remove the sampler and extension/drive rods once the selected strata has been penetrated. Rotation of the drill string can be added during insertion, as well as during retraction if the drive system can impart rotation.

7.7.1 *Retraction Force*—The retraction force can be applied by direct mechanical pull back using the hydraulic system of the power source; line pull methods using mechanical or hydraulic powered winches, or cathead and rope windlass type devices. Winches used with direct push technology should have a minimum of 900 kg [2000 lb] top layer rating capacity and a line speed of 120 m/min [400 ft/min] to provide effective tool handling. Direct push sampling tools can be retracted by back pounding using weights similar to those of standard penetration testing practices. Backpounding to recover samples can affect recovery and cause disturbances to the sample. Other forms of extraction, such as jacking, that do not cause undue disturbance to the sample, are preferable.

7.7.2 *Percussion Devices*—Percussion devices for use with direct push methods are hydraulically-operated hammers, air-operated hammers, and mechanically-operated hammers. Hydraulically-operated hammers should have sufficient energy to be effective in moving the samplers through the subsurface strata. The maximum energy application is dependent on the tools used. Hammer energy that exceeds tool tolerance will result in tool damage or loss and will not achieve the goal of collecting high quality samples. Air-operated hammers should be capable of delivering sufficient energy, as well. Hammer systems utilizing hydraulic oil or air should be operated in the range specified by the manufacturer. Manually-operated hammers can be used to advance direct push tools. These hammers can be operated mechanically or manually using cathead and rope. These systems generally involve using 63.5 kg [140 lb], standard penetration (see Test Method D1586) hammers, which can work well for direct push sampling. In operation, these hammers tend to be slower than hydraulic hammers and can cause tool damage if direct push tools are not designed to take the heavy blows associated with these hammers. The hydraulic- and air-operated hammers strike up to 2000 blows/min. In addition to the energy transferred, the rapid hammer action sets up a vibratory effect, which also aids in penetration. This vibratory effect, along with the percussive effort, may disturb some soil samples.

7.7.3 *Static Push Systems*—Cone penetrometer systems are an example of static push systems. They impart energy to the sampler and extension rods by using hydraulic rams to apply pressure. The pressure applied is limited to the reactive weight of the drive vehicle. Some portable systems use screwed in augers to anchor the machine for CPT testing (D6067). The earth augers provide the reaction force to advance the CPT probe. Retraction of the sampler and extension rods is by static pull from the hydraulic rams.

7.7.4 *Vibratory/Sonic Systems*—Sonic systems (D6914) utilize a vibratory device, which is attached to the top of the sampler extension rods. Reactive pressure and vibratory action are applied to the sampler extensions moving the sampler into the formation. In certain formations, sample recovery and formation penetration is expedited; however, all formations do not react the same to vibratory penetration methods.

7.7.4.1 *Sonic or Resonance Drilling Systems*—These are high powered vibratory systems that can be effective in advancing large diameter single or dual tube systems. They generally have depth capabilities beyond the smaller direct push systems.

7.7.5 *Rotary Drilling Equipment*—Direct push systems are readily adaptable to rotary drill units (D6286). The drill units offer a ready hydraulic system to operate percussion hammers, as well as reactive weight for static push. Drill units with direct push adaptations also offer drilling techniques should obstacles be encountered while using direct push technology. Large drill units may have reactive weights that can exceed the tool capacity, thereby resulting in damaged tools. Typical rotary drilling equipment is larger and more massive than smaller direct push equipment which can lead to limitations with site access and slower relocation times.

8. Conditioning

8.1 *Decontamination*—Sampling equipment that will contact the soil to be sampled should be cleaned and decontaminated before and after the sampling event (D5088). Extension rods should be cleaned prior to each boring to avoid the transfer of contaminants and to ease the connecting of joints. Thread maintenance is necessary to ensure long service life of the tools. Sample liners should be kept in a sealed or clean environment prior to use. All ancillary tools used in the sampling process should be cleaned thoroughly, and if contaminants are encountered, decontaminated before leaving the site. It should not be assumed that new tools are clean. They should be cleaned and decontaminated before use. Decontamination should be performed following procedures outlined in Practice D5088 along with any site safety plans, sampling protocols, or regulatory requirements.

8.2 *Tool Selection*—Prior to dispatch to the project site an inventory of the necessary sampling tools should be made. Sample liners, containers, sampling tools, and ancillary equipment should be checked to ensure its proper operation for the work program prescribed. Sampling is expedited by having two or more samplers on site. Since samples can be recovered quite fast, a supply of samplers will allow a boring to be completed so other functions can be performed while samples are being processed. Various Cutting Shoes and Liners should be available to optimize soil sampling Recovery and quality on site. A backup tool system adaptable to and within the capabilities of the power source should be available should the original planned method prove unworkable. Materials for proper sealing of boreholes should always be available at the site (D6011 section 9 Completion)

9. Procedure

9.1 While procedures for direct push soil sampling with two common direct push methods are outlined here, other systems may be available. As long as the basic principles of practice relating to sampler construction and use are followed, other systems may be acceptable.

9.2 *General Set-Up*—Select the boring location and check for underground and overhead utilities and other site obstructions. Establish a reference point on the site for datum measurements, and set the direct push unit over the boring location. Stabilize and level the unit, raise the drill mast or frame into the drilling position, and attach the hammer assembly to the drill head if not permanently attached. Attach the anvil assembly in the prescribed manner, slide the direct push unit into position over the borehole, save a portion of the sliding distance for alignment during tool advancement, and ready the tools for insertion.

9.2.1 *Tool Preparation*—Inspect the direct push tools before using, and clean and decontaminate as necessary. Inspect drive shoes for damaged cutting edges, dents, or thread failures as these conditions can cause loss of sample recovery and slow the advancement rate. Where permissible, lubricate rod joints with appropriate safe products, but clean water only may be the best option. Many organic lubricants can result in interferences with analytical tests to be performed on the collected samples (**22**). Verify that any lubricants used will not cause analytical interference or result in false positives before applying to the tools. Check impact surfaces for cracks or other damage that could result in failure during operations. Assemble samples and install where required, install sample retainers where needed, and install and secure sampler pistons to ensure proper operation where needed.

9.2.2 *Sample Processing*—Sample processing should follow a standard procedure to ensure quality control requirements are met (5.2). View sample in the original sampling device, if possible. Open the sampling device with care to keep disturbance to a minimum. When using liners or thin wall tubes, protect ends to prevent samples from falling out or being disturbed by movement within the liner. Measure recovery accurately, containerize as specified in the work plan or applicable ASTM procedures, and label recovered samples with sufficient information for proper identification. When collecting samples for volatile chemical analysis, sample specimens must be contained and preserved as soon as possible to prevent loss of these components. Follow work plan instructions or other appropriate documents (see Practice D6640) when processing samples collected for chemical analysis.

9.3 *Dual Tube System*—Assemble the outer casing with the cutting/drive shoe on the bottom. Assemble the sampler and liner, if used, and attach the sampler to the extension rods. Connect the drive head to the top of the sampler extension rods, and insert the sampler assembly into the outer casing. Position the outer casing and sampler assembly under the drill head, and move the drill head downward to bring pressure on the tool string. If soil conditions allow, advance the sampler/casing assembly into the soil at a steady controlled rate slow enough to allow the soil to be cut by the shoe and move up inside the sample barrel. If advancement is too rapid, it can result in loss of recovery because of soil friction and plugging in the shoe. Occasional hammer action during the push may help recovery by agitating the sample surface. If soil conditions prevent smooth static push advancement, activate the hammer to advance the sampler. Apply a continuous pressure while hammering to expedite soil penetration. The pressure required is controlled by subsurface conditions. Applications of excessive down pressure may result in the direct push unit being shifted off the borehole causing misalignment with possible tool damage. Stop the hammer at completion of advancement of the measured sampling barrel length. Release the pressure and move the drill head off the drive head. Attach a pulling device to the extension rods or position the hammer bail and retrieve the sampler from the borehole. At the surface remove the sampler from the extension rods and process. Soil classification is accomplished easily using split barrel samplers as the specimen is available readily for viewing, physical inspection and subsampling when the barrel is opened. However, unnecessary exposure of the sample to the atmosphere will lead to loss of volatile contaminants. If Liners are used they should be split of sections removed for soil classification and subsampling. Clean, decontaminate, and reassemble the sampler. Reattach the sampler to the extension rod, add the necessary extension rod and outer casing to reach the next sampling interval, and sound the borehole for free water before each sample interval. If water is present, it may be necessary to change sampling tools and select a sealed Single Tube sampler . Unequal pressure inside the casing may result in blow-in of material disturbing the soil immediately below the casing. Lower the sampler to its proper position, add the drive heads, and repeat the procedure. If it is desired that the pass through certain strata without sampling, install an extension drive point in lieu of the sampler (see Fig. 5). When the sampling interval is reached, remove the point and install the sampler. Advance the sampler as described. Upon completion of the borehole, remove the outer casing after instrumentation has been set or as the borehole is sealed as described in Section 10.

9.3.1 *Dual Tube System—Other Samplers:*

9.3.1.1 *Thin Wall Tubes*—Thin wall tubes (Practice D1587) can be used with the dual tube system. Attach the tube to the tube head using removable screws. Attach the tube assembly to the extension rods and position at the base of the outer casing shoe protruding a minimum of 6.25 mm [0.25 in.] to contact the soil ahead of the outer casing. Advance the tube, with or without the outer casing, at a steady rate similar to the requirements of Practice D1587. At completion of the advancement interval, let the tube remain stationary for 1 min. Rotate the tube slowly two revolutions to shear off the sample. Remove the tube from the borehole, measure recovery, and classify soil. The thin wall tube can be field extruded for on-site analysis or sealed in accordance with Practice D4220 and sent to the laboratory for processing. Samples for environmental testing generally require the subsampling and preservation of samples in controlled containers. Soil samples generally are removed from the sampling device for storage and shipping. Thin wall tubes should be cleaned and decontaminated before and after use.

9.3.1.2 *Sealed Single Tube Piston Sampler*—A Sealed Single Tube piston sampler can be used inside the Dual Tube system. This type of sampler may be required when 1.) there is water level inside the Dual Tube and a chemical testing requires virtually no possibility of cross contamination, or 2.) when the borehole becomes unstable and the continued use of the open tube sampling system cannot assure a sample of the native soils without other slough or heave in the recovered sample. Follow the section 9.4 for operation of Single Tube samplers inside of the Dual Tube.

9.3.1.3 *Open Barrel Samplers*—Use Open Single Tube barrel samplers (Figure 5 a) in advance of the outer casing where the soil conditions could cause swelling of split barrel samplers, or where friction against the outer casing precludes its advancement and sampling must still be accomplished. The sampler requires the use of liners for removal of the sample. The sampler must be cleaned and decontaminated before use.

9.3.1.4 *Standard Penetration Test Split Barrel Sampler (D1586)*—Attach the split spoon to an extension rod or drill rod. Using a mechanical or hydraulic hammer drive the sampler into the soil the desired increment, as long as that increment does not exceed the sampler chamber length. Remove the sampler from the borehole, disassemble, and process sample. Standard split barrel samplers can be used, as long as borehole wall integrity can be maintained and the additional friction can be overcome. If caving or sloughing occurs, the sampler tip should be sealed or other sampling tools used

9.4 *Single Tube System—*

9.4.1 *Sealed Sampler (see Figs. 3-7)*—Insert or attach the sample liner to the shoe, and insert the assembly into the solid barrel sampler. Install sample retaining basket if desired. Attach the latch coupling or sampler head to the sampler barrel, and attach the piston assembly with point and "O" rings if free water is present, to the latching mechanism or holder. Insert the piston or packer into the liner to its proper position so the point leads the sampler shoe. Set latch, charge packer, or install locking pin, and attach assembled sampler to drive rod. Add drive head and position under the hammer anvil. Apply down pressure, hammer if needed, to penetrate soil strata above the sampling zone. When the sampling zone is reached, insert the piston latch release and recovery tool, removing the piston, or insert the locking pin removal/extension rods through the drive rods, turn counterclockwise, and remove the piston locking pin so the piston can float on top of the sample, or release any other piston holding device. Direct push or activate the hammer to advance the sampler the desired increment. Retrieve the sampler from the borehole by withdrawing the extension/drive rods. Remove the shoe, and withdraw the sample liner with sample for processing. Clean and decontaminate the sampler, reload as described, and repeat the procedure. Extreme stress is applied to the piston when driving through dense soils. If the piston releases prematurely, the sample will not be recovered from the correct interval, and a resample attempt must be made. The piston sampler can be used as a re-entry grouting tool for sealing boreholes on completion if it is equipped with a removable piston.

9.5 *Quality Control:*

9.5.1 *Quality Control*—Quality control measures are necessary to ensure that sample integrity is maintained and that project data quality objectives are accomplished. By following good engineering principles and applying common sense, reliable site characterizations can be accomplished.

9.5.2 *Water Checks*—Water seeping into the direct push casing or connecting rods from contaminated zones may influence testing results. Periodically check for groundwater before inserting samplers into borehole or into outer casings in the two tube system. If water is encountered, it may be necessary to switch to the sealed piston type samplers to protect sample integrity. Sealed piston type samples may not always be water tight. Sealing of rod or casing joints can prevent groundwater from entering through the joints.

9.5.3 *Datum Points*—Establishment of a good datum reference is essential to providing reliable sample interval depths and elevators. Select datum reference points that are sufficiently protected from the work effort, and that can be located for future reference. Field measurements should be to 0.1 ft (3.05 mm). Measure extension rods as the bore advances to locate sample depth. Mark rods before driving each sample interval to determine accurate measurement of sample recovery and to accurately log borehole depth.

9.5.4 *Sample Recovery*—Record and report sample recovery for every sampling event. The Recovery is defined as the recovered sample length divided by the push/drive length as a percent. Sample recovery should be monitored closely and results documented. Poor recovery could indicate a change in sampling method is needed, that improper sampling practices are being conducted, or that sampling tools are incorrect. Adjust Cutting Shoes and liners to optimize sample recovery in the field (see 7.5 and Appendix X1). Sample recovery involves both volume and condition. Poor sample recovery should cause an immediate review of the sampling program.

9.5.5 *Decontamination*—Follow established decontamination procedures. Taking shortcuts may result in erroneous or suspect data.

9.5.6 *Equipment Rinsate Samples*—Equipment rinsate samples should be collected from decontaminated samplers Periodically during the sampling program in accordance with the quality assurance plan requirements. Clean water of known quality is poured over and through the assembled or partially assembled sampler so that all surfaces having potential sample contact, including liners, are rinsed. The rinse water is collected in the appropriate clean sample containers and preserved for analysis. The rinsate samples should be analyzed for the same analytes as the soil and sediment samples or groundwater samples. The rinsate samples will provide documentation that decontamination procedures are adequate and that cross contamination is controlled. For high priority sites and large projects it may be prudent to have rinsate samples analyzed on a quick turn-around basis to verify that sample integrity is maintained during the sampling program.

9.5.7 *Replicate Borings*—It is recommended that at a minimum one in twenty borings be replicated to provide some basic quality control on the repeatability of the boring and sampling process. Spacing between replicate borings should be on the order of 3 to 5 ft [1 to 1.5 m]. The same sampling techniques and tooling should be used in the replicate boring. This practice also will provide insight into: 1) lateral variability of soil and sediment strata and 2) heterogeneity of contaminant distribution for geo-environmental investigations.

10. Completion and Sealing

10.1 *Completion*—For boreholes receiving permanent monitoring devices, completion should be in accordance with Practice D5092, Guide D6724 or Practice D6725, site work plan, and or regulatory requirements.

10.2 *Borehole Sealing*—Seal direct push boreholes to minimize preferential pathways for containment migration. State regulations will generally prescribe acceptable grout mixtures and placement techniques; refer to local regulations for the state or county where the work is conducted. Additional information and guidance on borehole sealing can be found in Guide D5299, D6001 and Practice D6725. Recent work (Lackey et al., 2009 (**23**), Ross 2010 (**24**)) have found that bentonite slurries often will dessicate and crack when emplaced in the vadose zone, especially in semi-arid to arid settings. When sealing boreholes in the vadose zone it was found that neat cement, cement-sand mixtures or bentonite chip provided the best seal to minimize fluid movement along the borehole (Lackey et al., 2009 (**23**)).Regulations generally direct bottom up borehole sealing as it is the surest and most permanent method for complete sealing. High pressure grouting is available for use with direct push technology for bottom up borehole sealing.

10.2.1 *Sealing by Slurry, Two Tube System*—Sound the borehole for free water. If water exists in the casing, place the appropriate tremie tube or extension rods, open-ended, to the bottom of the outer casing. Mix the slurry to standard specifications prescribed by regulation or work plan. Pump slurry through the tremie tube or extension/drive rod until it appears at the surface of the outer casing. Slowly retract the outer casing and tremie tube while maintaining a head of grout in the borehole. Keep the grout level inside the outer casing as the tools are retracted to prevent borehole wall collapse and poor integrity seal. If no free water exists in the borehole, the slurry can be placed by gravity. Top off the borehole as the outer casing as it is removed.

10.2.1.1 *Slurry Mixes*—Slurry mixes used for slurry grouting of direct push boreholes may be of lower viscosity when small diameter tremie pipes are required. Usable mixes are 6 to 8 gal [22.7 to 30.28 L] of water/94-lb (42.64-kg) bag of cement with 5 lb [2.27 kg] of bentonite or 24 to 36 gal [90.84 to 136.28 L] of water to 50 lb [22.68 kg] of bentonite.

10.2.2 *Sealing by Gravity—Dual Tube System*—Measure the cased hole to ensure it is open to depth. Slowly add bentonite chips or granular bentonite to fill the casing approximately 2 ft. Withdraw the casing 2 ft and recheck depth. Hydrate the bentonite by adding water. Repeat this procedure as the outer casing is withdrawn. The bentonite must be below the bottom of the casing during hydration. Wetness inside the rods may affect the flow of granular bentonite to the bottom of the casing. A tremie tube may be used to add water for hydration of dry bentonite. Fill the top foot of the borehole with material that is the same as exists in that zone.

10.2.3 *Borehole Sealing Single Tube System:*

10.2.3.1 *Gravity Sealing from Surface*—If the soil strata penetrated has sufficient wall strength to maintain an open hole, and the borings ends at or above the local water table, then it may be possible to add sealing materials from the surface. Dry bentonite chips or granular bentonite can be placed by gravity. The borehole depth and volume should be determined and the borehole sounded every 5 ft [1.5 m] to ensure bridging has not occurred. The bentonite should be hydrated by adding approximately 1 gallon [1.0 L] of clean water for each 5 ft of filled borehole. Seal the surface with native material.

10.2.3.2 *Wet Grout Mix Tremie Sealing*—Tremie sealing methods can be used with single tube systems when borehole wall strength is sufficient to maintain an open hole or when extension rods with an expendable point are used to reenter the borehole. The grout pipe should be inserted immediately after the direct push tools are withdrawn or through the annulus of the extension rods that have been reinserted down the borehole for grouting. Care must be taken to not plug the end of the grout pipe. Side discharge grout pipes also can be used to prevent plugging.

10.2.4 *Re-Entry Grouting*—If the borehole walls are not stable, the borehole can be re-entered by static pushing grouting tools, such as an expendable point attached to the extension/drive rods to the bottom of the original borehole. Pump a slurry through the rods as they are withdrawn. High pressure grouting equipment may be beneficial in pumping standard slurry mixes through small diameter gravity pipes. Care must be taken to ensure the original borehole is being sealed.

11. Reports: Test Data Sheets/Forms

11.1 Fields records must be kept for each soil sampling event. These records are documented on field data sheets to show the depths of drilling and sampling events to the nearest 5 cm (0.1 ft), recovery in percent to 2-3 significant digits, and records on sample processing, subsampling locations, and visual soil classification. Soil samples can be classified in accordance with Practice D2487 and/or D2488 or other methods as required for the investigation. Prepare the final report log in accordance with standards set in Guide D5434 listing the parameters required for the field investigation program. List all contaminants identified, instrument readings taken, and comments on sampler advancement. Record any special field tests performed and sample processing procedures beyond those normally used in the defined investigation. Record borehole sealing procedures, materials used, and mix formulas on the boring log. Survey or otherwise locate the boring site to provide a permanent record of its replacement.

11.2 *Backfilling Record*—Record the method of sealing, materials used, and volume of materials placed in each borehole. This information can be added to the field boring log or recorded on a separate abandonment form.

12. Keywords

12.1 decontamination; direct push; groundwater; sealing; soil and sediment sampling

APPENDIX

(Nonmandatory Information)

X1. FACTORS INFLUENCING SAMPLE RECOVERY IN DIRECT PUSH SOIL SAMPLING

X1.1 The major factors influencing sample recovery in Direct Push Soil Sampling are the Cutting Shoe inside diameter and shape, and the Liner inside diameter and length. The other major factor is to soil formation to be sampled including the soil type, particle size, cohesiveness, and stress history. The combination of Cutting Shoe and Liner should be optimized and matched to the soil formations to be sampled. It is important that prior to sampling that different equipment be available to match the soil formation in the field.

X1.2 Soil recovery (9.5.4) in direct push sampling is rarely close to the ideal 100% desired. The predominant use of long sample drive lengths of 1 to 1.5 m (3 to 5 ft) often results in less than desirable recovery. Shortening sample lengths will improve the recovery but that is rarely done. Recoveries of more than 100 % often occur in Direct Push Soil Sampling because of the large clearance ratios between the cutting shoe and liner. Extremely high recoveries can occur in heavily over consolidated clays that tend to expand. Conversely, recoveries of less than 100 % can occur in low density and low plasticity soils. Clean sands silts below groundwater may liquefy and run or fall out of the sampling tube during retraction of the sampler and as it clears water level. In cases of running sands the basket retianers should be used to help retain the soil.

X1.3 The Cutting Shoe is the most important feature that controls the sample recovery. Cutting Shoes are designed to have a smaller diameter opening than the Liner to help reduce the friction of the core inside the Liner. The ratio of inside diameter of the cutting shoe to the inside diameter of the liner is called the Clearance Ratio. If sample recovery in a soil formation is poor the operator should change the Cutting Shoe to match the formation.

X1.4 Research on intact soil sampling indicates the angle of the cutting shoe (Sharpness) should be less than 10 degrees for intact sampling. Most direct push cutting shoes are blunt with much flatter cutting angles and rounded cutting angles because they need to be very strong and durable to withstand the impact forces of Direct Push. These blunt surfaces transmit shock waves and possible bearing capacity failure in from of the cutting shoe edge and cause disturbance to the soil before it enters the shoe and barrel. In some dense plastic soils this can cause extreme expansion of the cores. If these symptoms occur in fine grained formations a sharpened cutting shoe may result in higher quality cores.

X1.5 Manufactures provide differing styles of cutting shoes that can be used in difficult soil deposits. Figures X1.1 through X1.6 show some examples of the Cutting Shoe designs for different formations. Consult your manufacturer for advice on cutting shoes for the soils to be tested.

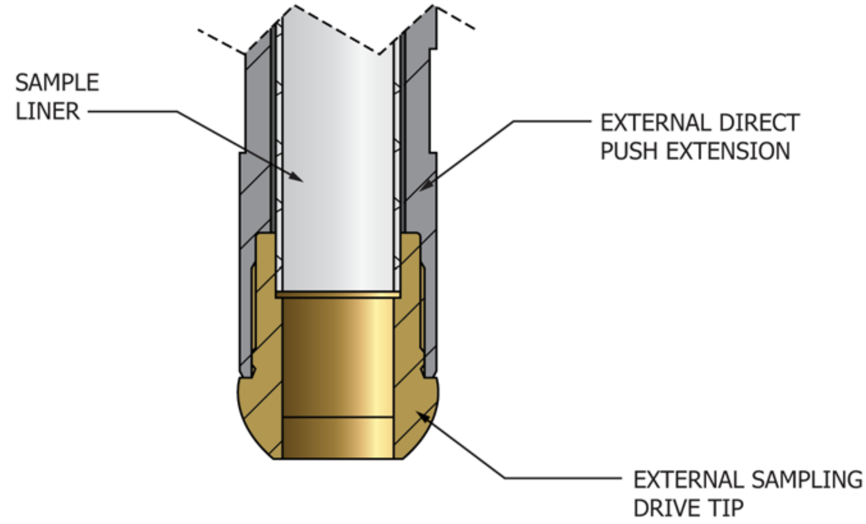


FIG. X1.1 Typical Sand and Silt Cutting Shoe

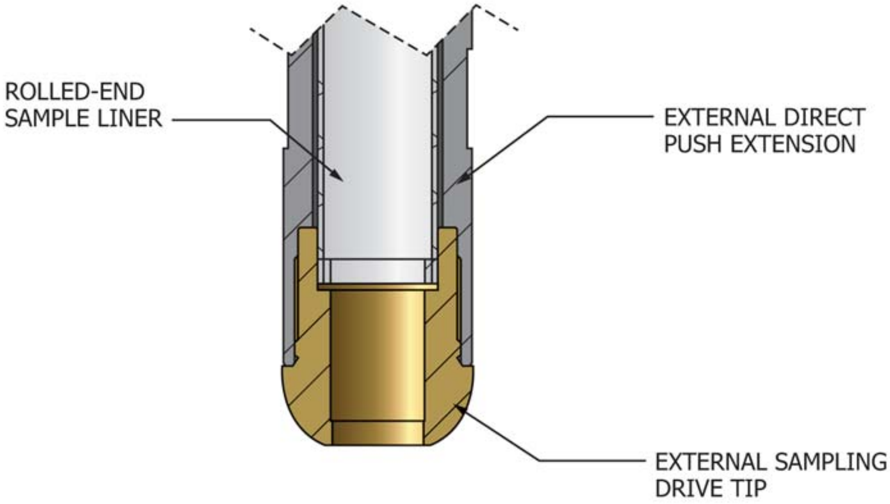


FIG. X1.2 Typical Clay Cutting Shoe

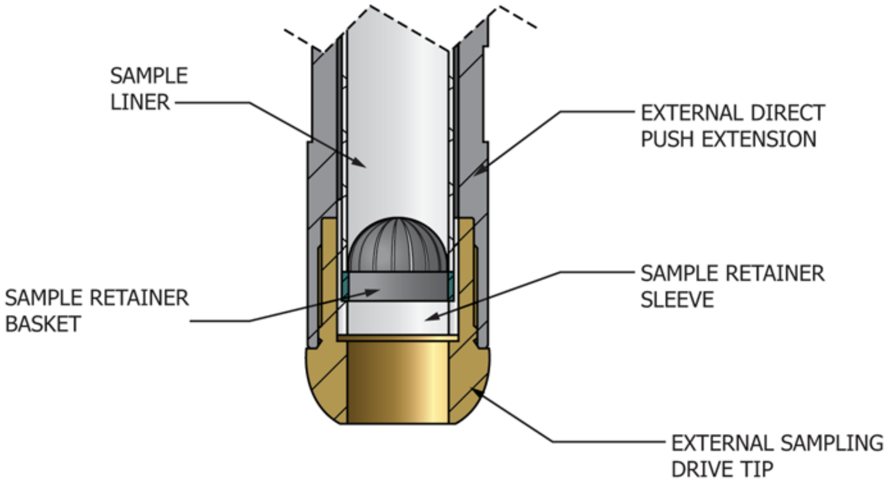


FIG. X1.3 Cutting Shoe for Loose Sand and Silts—Note Basket Retainer

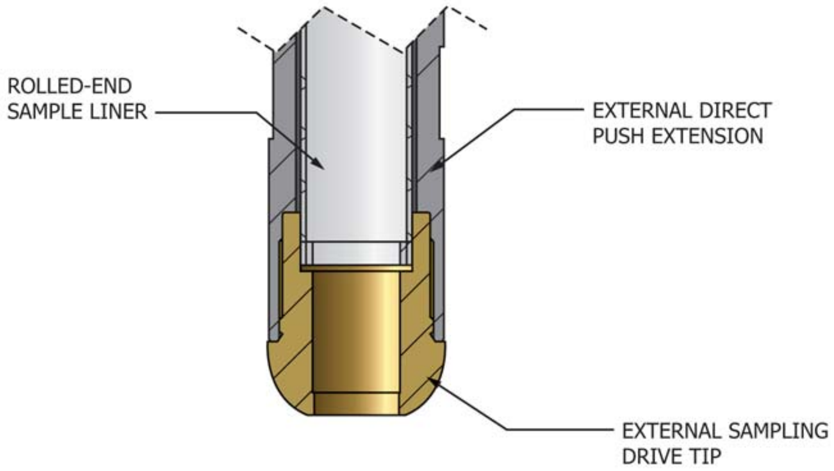


FIG. X1.4 Cutting Shoe for Very Loose Sands and Silts

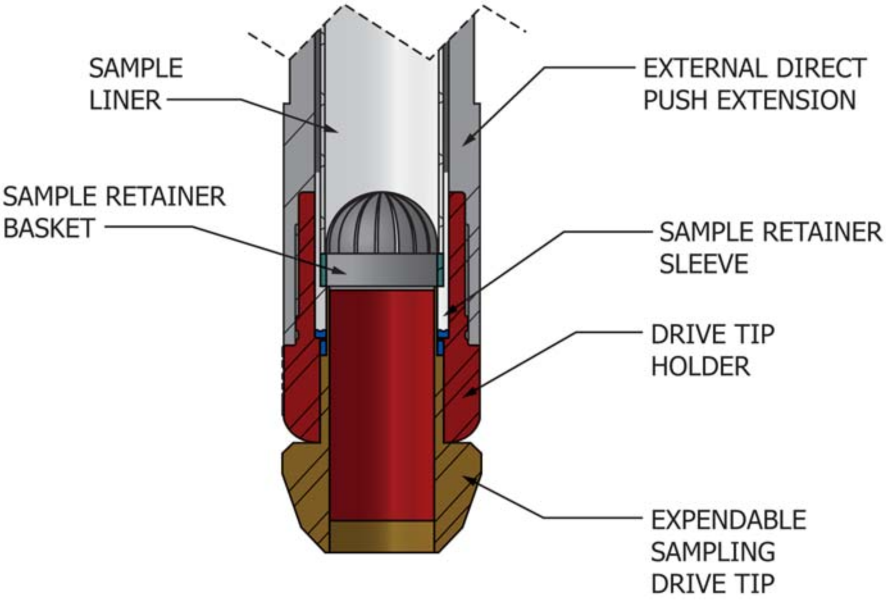


FIG. X1.5 Cutting Shoe for Stiff Over-Consolidated Clays

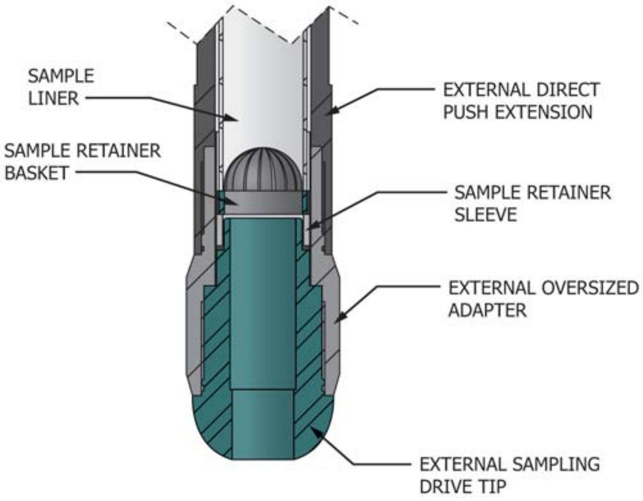


FIG. X1.6 Expendable Cutting Shoe Design for Stiff Clays

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