INTERNATIONAL

Designation: D6169/D6169M − 21

Standard Guide for Selection of Subsurface Soil and Rock Sampling Devices for Environmental and Geotechnical Investigations[1]

This standard is issued under the fixed designation D6169/D6169M; 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 covers guidance for the selection of soil and rock sampling devices used for the purpose of characterizing in situ physical and hydraulic properties, chemical characteristics, subsurface lithology, stratigraphy and structure, and hydrogeologic units in geotechnical and environmental investigations.

1.2 This guide should be used in conjunction with referenced ASTM Guides D420 and D5730, and individual practices for sampling devices referenced in 2.1. Soil and rock samplers are most often used in drilled/pushed boreholes using various drilling methods/technologies in Guide D6286 and it addresses ability to use these samplers.

1.3 Refer to Practice D6640 and Guide D4547 for handling of samples for environmental investigations. Practices D4220/D4220M and D5079 are used for preserving and transporting soil and rock samples.

1.4 This guide does not address selection of sampling devices for hand-held soil sampling equipment (Guide D4700) and soil sample collection with solid-stem augering devices (Practice D1452/D1452M), or collection of grab samples or hand-carved block samples (D7015/D7015M) from accessible excavations. Refer to X1.2 for additional guidance on use of soil and rock sampling devices for both environmental and geotechnical applications.

1.5 This guide does not address devices for collecting cores from submerged sediments or other sampling devices for solid wastes. Refer to Guides D4823 and D6232 for these materials.

1.6 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.

1.7 *This guide offers an organized collection of information or series of options and does not recommend a specific course of action. This document cannot replace education and experience and should be used in conjunction with professional judgment. The word "Standard" in the title of this document means that the document has been approved through the ASTM consensus process.*

1.8 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D420 Guide for Site Characterization for Engineering Design and Construction Purposes

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D1452/D1452M Practice for Soil Exploration and Sampling by Auger Borings

D1586/D1586M Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

D1587/D1587M Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes

D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Exploration

D3550/D3550M 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

[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

Current edition approved Nov. 1, 2021. Published December 2021. Originally approved in 1997. Last previous edition approved in 2013 as D6169 – 13. DOI: 10.1520/D6169_D6169M-21.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

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/D4220M Practices for Preserving and Transporting Soil Samples
D4452 Practice for X-Ray Radiography of Soil Samples
D4547 Guide for Sampling Waste and Soils for Volatile Organic Compounds
D4700 Guide for Soil Sampling from the Vadose Zone
D4823 Guide for Core Sampling Submerged, Unconsolidated Sediments
D5079 Practices for Preserving and Transporting Rock Core Samples (Withdrawn 2017)[3]
D5084 Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
D5088 Practice for Decontamination of Field Equipment Used at Waste Sites
D5608 Practices for Decontamination of Sampling and Non Sample Contacting Equipment Used at Low Level Radioactive Waste Sites
D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Groundwater (Withdrawn 2013)[3]
D5778 Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils
D6001/D6001M Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization
D6151/D6151M Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling
D6232 Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities
D6282 Guide for Direct Push Soil Sampling for Environmental Site Characterizations
D6286 Guide for Selection of Drilling and Direct Push Methods for Geotechnical and Environmental Subsurface Site Characterization
D6519 Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler
D6640 Practice for Collection and Handling of Soils Obtained in Core Barrel Samplers for Environmental Investigations
D6914/D6914M Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices
D7015/D7015M Practices for Obtaining Intact Block (Cubical and Cylindrical) Samples of Soils
D8170 Guide for Using Disposable Handheld Soil Core Samplers for the Collection and Storage of Soil for Volatile Organic Analysis

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of general technical terms used within this standard, refer to Terminology D653.

3.1.2 *intact, adj—in soil and rock*, material obtained by a process following the state of practice (or standard of care) intended to preserve in-situ structure, water content, density, and other properties to a level consistent with the intended purpose for testing.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *borehole grab sampler*—a sampling device with a cutting head that advances by rotation and collects a sample by scraping side or bottom rather than coring. (See Section 8.1.)

3.2.2 *chemically intact core sample*—a soil or rock core sample in which the sampling device, collection and handling procedures result in preservation of the chemical properties to a degree that satisfies the purpose for which the sample was taken.

3.2.2.1 *Discussion*—For nonsensitive chemical constituents, representative samples (3.2.15) will generally provide chemically intact samples. Nonrepresentative samples may also be chemically intact, but are generally not suitable for analysis because of their uncertain integrity, location or origin. For sensitive chemical constituents, special sample collection and handling procedures are generally required to obtain chemically intact samples as discussed in 6.4 and 6.4.3. Physically intact samples (3.2.13) will generally provide chemically intact samples provided that sampling technique, and materials for sampling devices and containers are selected to avoid chemical alteration.

3.2.3 *clearance ratio (inside)*—the difference between inside diameter of the sampling tube and inside diameter of cutting edge or shoe divided by the inside diameter of the cutting shoe or edge.

3.2.3.1 *Discussion*—Refer to D1587/D1587M, Hvorslev (**1**),[4] and Paikowsky et al. (**2**) for appropriate formulas for calculating clearance area ratio.

3.2.4 *core—for the purposes of this guide*, a cylindrical sample of soil or rock obtained by means of a thick-wall, thin-wall, or rotating core sampler.

3.2.5 *direct push (DP) method, v*—a subsurface investigation method by which drive rod, casing tube, sampling, and logging devices are pushed, driven, or vibrated into soils or unconsolidated formations to be sampled or logged without rotary drilling and removal of cuttings (D6001/D6001M, D6286).

3.2.5.1 *Discussion*—For the purposes of this guide, a subsurface investigation method that uses hand-held percussion driving devices, or hydraulic percussion, quasi static push, or vibratory drive systems that are mounted to a truck, van, all-terrain vehicle, trailer, skid, or drill rig.

3.2.6 *drill rig—for the purposes of this guide*, a land-based wheeled, ATV, or skid-mounted assembly or offshore or barge mounted assembly capable of drilling boreholes and collecting soil or rock samples with a diameter generally greater than 50 mm [2 in.] using rotary, drive, push, or vibratory advancement methods.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] The boldface numbers given in parentheses refer to a list of references at the end of the text.

3.2.7 *Group A*—samples for which only general visual identification or profile logging is necessary (see Practice D4220/D4220M).

3.2.8 *Group B*—samples for which only water content, classification tests, compaction, and/or bulk samples for laboratory prepared test specimens is required (see Practice D4220/D4220M).

3.2.8.1 *Discussion*—Group B samples are disturbed, remolded samples used primarily for engineering properties tests.

3.2.9 *Group C*—intact, natural formed or field fabricated, samples for density determination; or for swell pressure, percent swell, consolidation, hydraulic conductivity, and shear testing with or without stress-strain and volume change measurements, to include dynamic and cyclic testing (see Practice D4220/D4220M).

3.2.9.1 *Discussion*—Group C samples are physically intact samples used primarily for geotechnical engineering properties tests. Some of these tests, such as bulk density and permeability are useful for environmental investigations. Additional physical and hydrologic properties that require Group C type samples are identified in Table 1.

3.2.10 *Group D*—samples that are fragile or highly sensitive for which tests in Group C are required (see Practices D4220/D4220M).

3.2.11 *liner*—cylindrical tubes or rings made of metal or plastic placed inside a core sampling device to facilitate sample retrieval and handling.

3.2.12 *nonrepresentative sample*—a soil sample that consists of drill cuttings of uncertain integrity, location or origin, or other incomplete or contaminated portions of subsurface materials; generally not suitable for testing or analysis (**3**).

3.2.13 *physically intact core sample*—a soil or rock core sample in which the sampling device, collection and handling procedures result in preservation of the in situ physical and hydraulic properties (such as, structure, density, and moisture content) to a degree that satisfies the purpose for which the sample was taken.

3.2.13.1 *Discussion*—Group C and D core samples are physically intact. Generally, collection of intact samples may require use of thin-wall or double-tube rotating core sampling devices, but as discussed in 6.2, thick-wall samplers may be satisfactory for some objectives.

3.2.14 *piston core sampler*—a thin-wall or, less commonly, thick-wall sampling device in which the inner piston is held in a fixed position and the cutting head and outer barrel is advanced mechanically or hydraulically into the soil. (See 7.5.)

3.2.15 *representative soil sample*—a soil sample from a known subsurface interval in which some structural features do not survive but other properties, such as moisture content, grain size and gradation and chemical characteristics of the sample interval are preserved; suitable for mechanical and chemical analysis for non-sensitive chemical constituents, and lithologic logging. (See discussion in 6.3.) **Adapted from U.S. Geological Survey, 1980 (3)**

3.2.15.1 *Discussion*—This definition follows general usage in the geologic profession, and differs from the definition of representative sample in the statistical sense. The sample is only representative of the subsurface material encountered by the sampler and is not necessarily representative of the formation being sampled. Sample representativeness in the latter sense needs to be addressed in the sample design that defines the specific location of sampling.

TABLE 1 General Sample-Type Requirements for Determination of Physical and Chemical Properties

Tests to be Performed	Physically Intact	Chemically Intact	Representative
Physical/Hydrologic Properties			
Hydraulic Conductivity	X	. . .	. . .
Specific Yield	X	. . .	. . .
Pressure Head (Matric Potential)	X	. . .	. . .
Moisture Characteristic Functions[A]	X	. . .	X
Water Content	. . .	. . .	X
Particle Size Distribution	. . .	. . .	X
Bulk Density/Porosity	X	. . .	. . .
Strength Properties	X	. . .	. . .
Compressibility	X	. . .	. . .
Mineralogy			
Gross Mineralogy	. . .	. . .	X
Soil Thin Section Micromorphology	X	. . .	. . .
Surface Properties			
Ion Exchange Capacity	. . .	X	. . .
Sorption (Batch Tests)	. . .	X	. . .
Sorption (Flow-Through Tests)	X	. . .	. . .
Sorption Site Density	. . .	X	. . .
Surface Area	. . .	. . .	X
Non-sensitive Chemical Constituents[B]			
Most Total Elemental Concentrations	. . .	. . .	X
Carbonate	. . .	. . .	X
Soil Organic Carbon	. . .	. . .	X
Sensitive Chemical Constituents[C]			
Microbiology	. . .	X	. . .
Volatile and Semi-volatile Organics	. . .	X	. . .
Nitrogen- and Sulfur-Containing Species	. . .	X	. . .
Redox-Sensitive Species (As, Cr, Fe, Mn, Se)	. . .	X	. . .
Other Sensitive Inorganics (Hg, cyanides)	. . .	X	. . .
Per-Polyfluoroalkyl Substances (PFAS, PFOS,PFOA)	. . .	. . . X	. . .

[A] Physically intact sample preferred, but repacked representative sample may be adequate.
[B] Chemical constituents that are sufficiently stable that no special attention need to be given to sample device/container compatibility, or sample handling, transport, and storage if analyzed within a few months.
[C] Special consideration of sample device/container compatibility, sample collection, handling and transport required to obtain chemically intact samples.

3.2.16 *rotating core sampler*—a rotating cylindrical sampler with a coring bit that cuts away soil or rock material from around the core. (See 7.6.)

3.2.17 *sensitive chemical constituents*—chemical species or compounds for which the composition or concentration in soil may change rapidly in soil in response to disturbance, or interaction with sample container materials, due to processes such as volatilization, degassing, microbial action or abiotic oxidation-reduction reactions.

3.2.18 *thick-wall sampler*—a core sampler that does not satisfy the requirements for collection of intact Group C and D samples.

3.2.18.1 *Discussion*—Generally, samplers with a wall area ratio greater than 15 percent (see 6.2.2 for additional specifications). Typical thick wall samplers are found in Test Method D1586/D1586M and Practice D3550/D3550M. (See 7.3.)

3.2.19 *thin-wall sampler*—a sampler that meets the specifications in Practice D1587/D1587M. (See 7.4.)

3.2.20 *vibratory core sampling*—a sample process in which a thick-wall or thin-wall sampler is advanced using high frequency vibrations rather than hydraulic or percussion forces.

3.2.21 *wall area ratio*—the ratio of gross wall area due to thickness divided by the inside opening of the sampler.

3.2.21.1 *Discussion*—Refer to D1587/D1587M, Hvorslev (**1**) and Paikowsky et al. (**2**) for appropriate formulas for calculating wall area ratio.

3.2.22 *wireline core sampling*—a sampling process in which rotating or pushed core samplers are raised and lowered inside drill rods with a wireline and attached for coring or pushing with an overshot latching mechanism.

4. Significance and Use

4.1 Direct observation of the subsurface by the collection of soil and rock samples is an essential part of investigation for geotechnical and environmental purposes. This guide provides information on the major types of soil and rock sampling devices to assist in selection of devices that are suitable for known site geologic conditions, and provide samples that meet project objectives. This guide should not be used as a substitute for consulting with professional experience in sampling soil or rock in similar formations before determining the best method and type of sampling.

4.2 This guide should be used in conjunction with Guide D6286 on drilling methods and sampling equipment, and diamond drilling Guide D2113. Drilling and sampler specific practices and guides listed throughout this guide are used as part of developing a detailed site investigation and sampling plan. The sampling plan should start with development of a site conceptual model and phased investigations to locate sampling sites (D420, D6286). The selection of sampling equipment and sampling devices goes hand-in-hand. In some cases, soil sample requirements may influence choice of drilling method, or conversely, types of available sampling equipment may influence choice of sampling devices.

4.3 Samples should be handled in accordance with Practice D4220/D4220M, for preserving and transporting soil samples, Practice D5079 for preserving and transporting rock core samples for geotechnical purposes. For environmental work sample handling procedures should be in accordance with Practice D6640 for collection and handling of soils obtained in core barrel samplers for environmental investigations, Practice D3694 for preparation of sample containers and for preservation of organic constituents, and Practice D5088 for decontamination of field equipment used at waste sites.

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.

5. Objectives of Sampling Soil and Rock

5.1 Samples of soil and rock can be collected for three major purposes: testing of engineering and hydraulic properties on intact samples, measurement of in situ chemical and biological characteristics, and identification and classification of geologic and hydrogeologic characteristics of the subsurface. Table 1 identifies general sample-type requirements for measurement of physical, hydrologic and chemical properties of the subsurface. Most coring devices (see Section 7) provide good to excellent samples for all three purposes. Borehole grab samplers and drill cuttings (see Section 8) are unsuitable for measurement of in situ physical and hydrologic properties and are only useful to get basic information on geologic and hydrogeologic properties of the subsurface.

5.2 *Laboratory Testing for Engineering and Hydraulic Properties Intact Samples*—Laboratory measurements of physical properties, such as bulk density, porosity, shear strength, consolidation of clays, hydraulic conductivity, and thin-section analysis of sediments require intact cores that retain the in situ properties of the sample. Intact samples should best preserve bulk density and porosity, which is important for both geotechnical and environmental purposes. Hydraulic properties of permeable materials are generally best measured using in situ aquifer tests (see Table A1.1 of Guide D5730, for list of ASTM standards on aquifer tests), but collection of intact samples for laboratory permeameter tests may provide useful information on vertical changes in hydraulic properties depending on the preservation and transport of the intact sample prior to testing. Impermeable materials, such as clays, are generally best measured in the laboratory using intact cores (see Test Method D5084). However, it should be recognized that laboratory measurements generally do not consider preferential flow or secondary porosity effects which can significantly affect the field permeability of a material. Table 1 lists parameters that require intact samples.

5.3 *Chemical and Biological Characteristics for Groundwater Quality Evaluations*—Samples for measurement of stable chemical constituents generally do not require physically intact samples, but do require discrete representative samples that are not subjected to cross contamination. Samples for measurement of sensitive chemical constituents, such as volatile organic compounds require special handling procedures (D6640). Whenever chemical analysis of samples is an objective of the investigation, sampling devices that result in chemical alteration should be avoided. Chemical alteration is most problematic with devices in which borehole groundwater or drilling fluids come in direct contact with the sample and when sensitive constituents such as volatile organic chemicals and redox sensitive elements (iron, manganese, arsenic, chromium, selenium), or microorganisms below the water table are to be sampled. In contaminated soil and groundwater, casing advancement methods such as dual tube direct push or sonic drilling should be used to prevent cross-contamination of samples. Sampling for such constituents requires use of samplers and sampling procedures that avoid or minimize contact with drilling fluids, the atmosphere, other contaminated soil or groundwater, and sample containers made of nonreactive materials (see 6.4 and 6.4.3). Intact samples are preferred when column leaching or sorption tests are to be performed in the laboratory, although representative disturbed samples can be used in unstructured soil materials if the bulk density is known. Table 1 identifies types of samples required for specific chemical and biological properties.

5.4 *Geologic Classification, Lithology, and Hydrogeologic Properties*—Samples for geologic properties, such as lithology, stratigraphy, and structure should generally be representative. There are many drilling methods that can continuously sample formations with disturbed but representative samples and these are preferred for the best information on the subsurface materials. With some drilling methods that do not produce cores, nonrepresentative samples combined with observations of drilling advancement rates may provide some information on changes in lithology if it is not feasible to collect representative samples (see 8.3). The quality of definition of geologic units will be a function of the quality of lithologic, stratigraphic, and structural interpretations from sampling and supplemented by water level data and aquifer tests.

6. Specific Criteria for Selection of Sampling Devices

6.1 When the specific objectives of sample collection have been defined (see 4.2), the applicable criteria described below should be identified and the sampling device or devices that will best fulfill the sampling objectives selected for use. When a sampling device has been selected, at least two should be procured, along with appropriate spare parts. Two samplers may be used in alternation if this enhances efficiency of field operations and sample collection, or the second sampler serves as a backup in the event the first one becomes damaged.

6.2 *Sample Physical Disturbance*—The degree of physical disturbance of a soil or rock sample is primarily a concern when in situ physical and hydraulic properties are to be measured by laboratory tests. Geotechnical engineers need intact samples on large projects where the compressibility and shear strength must be determined in laboratory tests. Geotechnical engineers often use thick wall drive samplers for additional penetration resistance data and to obtain representative samples on most all projects. Environmental engineers dealing with subsurface contamination are primarily concerned with hydraulic properties that are best measured by field tests (see 5.2). The degree of disturbance also affects the quality of borehole log descriptions and subsequent interpretations derived from laboratory and/or field testing. Disturbed soil cores allow logging of primarily textural and density/consistency changes. Intact soil cores allow description of soil morphologic features that are valuable for developing interpretations concerning the potential for contaminant movement in the subsurface (**4**). Collection of oriented intact rock cores allow assessment of fracture location and orientation in the subsurface (see 7.9.4).

6.2.1 *Discussion of Physically Intact*—There is no such thing as an "undisturbed sample because the sampling process inevitably results in some degree of disturbance as a result of factors such as stress relief or dilation or compression from insertion. Committee D18 has adopted the term *intact sample* (3.1.2) to designate that the sample is taken with traditional/industry standard samplers using a good, accepted practice for standard of care. Intact samplers are usually thin wall tubes or large diameter soil core samplers. Practice D1587/D1587M on the thin wall tube has an extensive discussion of evaluation of the sample quality. By evaluation recompression behavior in laboratory consolidation tests of clays, sample quality can be evaluated, and quality classifications have been proposed (D1587/D1587M, Appendix). Geotechnical engineers recognize that in clean, drained, sands it is difficult to obtain a suitable and Intact sample by insertion of thin wall tube alone, which leads to reliance on penetration resistance data such as D1586/D1586M or other insitu tests such as the cone penetrometer (D5778). In the past, the only intact sampling of clean sands was possible by expensive insitu freezing followed by soil coring but there are new polymer gel injection samplers (see 7.5.1 and 7.9.2.1) that are being used. The factors that affect physical sample disturbance are numerous and complex enough that professional judgment is still required to determine whether a sample is physically intact for the intended proposed use of the sample.

6.2.2 *Effects of Sampling Device on Degree of Physical Disturbance*—The following three general characteristics of samplers affect the degree of physical disturbance of the sample: increasing wall thickness increases disturbance, increasing tube diameter decreases disturbance, and increasing tube length increases disturbance. Thin wall push samplers and piston samplers with thin-walled tubes are used for intact sampling. Thick wall push or drive samplers cannot provide intact samples unless the used specialized thin wall cutting shoe designs (7.4.2.4). Larger Diameter samplers provide better intact samples as discussed in the thin wall standard Practice D1587/D1587M where 125 mm [5-in.] samplers are preferred to the smaller minimum diameter of 75 mm [3 in.] sample tubes. In the thin wall standard 125 mm [5-in.] samplers can obtain longer samples. The sample diameter rule applies to other samplers with diameters of 100 to 150 mm [4 to 6 in.] are preferred. The same sampler may cause different degrees of disturbance, depending on the material being sampled, with highly plastic and compressible soils and well sorted noncohesive sands being most susceptible to disturbance. Driving the same sampler can disturb a sample more than pushing the sampler. Thin-wall samplers (see 7.4) generally provide the highest quality cores in terms of minimizing sample disturbance in fine-grained cohesive materials. Piston samplers (see 7.5) may be required for collecting cores in cohesionless materials, with thin-wall types creating less disturbance than thick-wall types). Rotary core samplers, such as the Denison sampler (see 7.6.2), or vibratory/sonic sampling methods (see 7.2.4 and 7.3.3) may be required to collect intact samples in firm to stiff cohesive soils and dense sands. In extreme cases, such as critical liquefaction studies in clean sands, intact cores can be obtained by freezing or injection of stabilizers using rotary soil core barrels (7.9.2). Depending on the sampler and soil material, thick-wall samplers may also be satisfactory for measurement of in situ physical and hydraulic properties (see 6.2.3). Shuter and Teasdale (**5**) and most of the geotechnical references (**6 and 7**) identified in the appendix provide further discussion of considerations and techniques for collecting intact cores.

6.2.3 *Criteria for Evaluating Degree of Physical Disturbance in Push and Drive Samples*—Table 2 identifies the main sampler characteristics that determine whether a sample is physically intact for Group C and D samples as defined in Practice D4220/D4220M. Although the definition of these groups has a primarily geotechnical focus, intact samples for hydrogeologic analysis and testing have the same requirements (Refer to Shuter and Teasdale (**5**) for a detailed discussion of requirements for intact soil samples for hydrogeologic analysis and testing). Groups C and D samples will also provide high quality samples for visual logging of soil morphologic and sedimentary features that are sensitive to disturbance by thick-wall samplers. Table 3 gives a number of indicators that can be used to evaluate the degree of disturbance in core collected using a thick-wall sampler. X-ray radiography (see Practice D4452) may also be useful for evaluating the quality of Group C and D cores.

6.2.4 *When to Collect Physically Intact Soil Samples—Environmental Investigations*—Intact physical soil samples in cohesionless soils (sands and gravels) are generally more costly in time and money than disturbed samples, and in environmental investigations the decision to obtain intact samples should be based on a judgment that the added information obtained from intact cores outweighs the added costs. Examples of when high-quality intact samples (Groups C and D) in environmental investigations might be appropriate for environmental investigations include: determination of laboratory hydraulic conductivity and porosity for calibration of geophysical logs in an area, thin section examination of sediments for mineralogy and microstructural features, engineering properties for fill/cut slope stability, slurry walls and backfill design for design of waste disposal facilities and remediation of contaminated soil and groundwater, collection of spatially oriented cores to establish strike and dip of formation layering and evaluate potential contaminant pathways in joint and fracture systems (see 7.9.4).

6.3 *Sample Representativeness*—Group B soil samples as defined in Practice D4220/D4220M are physically representative of the sampled interval and are primarily used for soil/rock classification and subsurface logging for lithology evaluation. Soil samples from a known subsurface interval that do not preserve in situ structural properties, but for which other physical properties such as water content and particle size distribution or chemistry, or combination thereof, are unaltered, are representative samples. Geotechnical engineers often use incremental thick wall drive samplers (D1586/D1586M, D3550/D3550M) with added benefit of using penetration resistance data to estimate engineering properties. In environmental work, continuous representative sampling using direct push methods (7.3.2), sonic core (7.3.3), or hollow-stem augers (7.6.3) are used since drilling/sampling methods are preferred since no fluids are used in the drilling process. When drilling methods involve drilling fluids, sample moisture content and chemistry may be altered. Drill cuttings or auger-flight samples are inadequate for most investigations (8.3). Borehole grab samples and drill cuttings may be representative if the sample collection method allows precise determination of the sample interval, measures are taken to prevent mixing of material from other intervals, and the drilling method does not alter sample characteristics (see 8.4).

6.4 *Sample Chemical Integrity*—Soil samples collected for chemical analysis usually do not need to preserve in situ structural characteristics of the sample but must be representative of the sampled interval. Relatively stable chemical properties, such as mineralogy, organic matter content (excluding recent organic residue) and many inorganic constituents can be collected using any device that gives a representative

TABLE 2 General Sampler Specifications Defining Intact Samples for Group C and D Samples[A]

Sampler Characteristics	Intact (Thin-Wall sampler)[B]	Disturbed[C] (Thick-Wall sampler)	Source
Wall thickness/OD ratio	< 2.5 %	> 2.5 %	Hvorslev (**1**)
Wall area ratio	< 15 %	> 15 %	Hvorslev (**1**) and Paikowsky et al. (**2**)
Clearance ratio (inside)			Shuter and Teasdale (**5**) and Practice D1587/D1587M. See also Table 7.
Nonplastic soils	0.5 to 1 %	NA	
Intermediate plasticity	1 to 2 %	NA	
Plastic soils (clays)	0 to 3 %	NA	
Length			Practice D1587/D1587M
Sands	< 10 diameters	> 10 diameters	
Clays	< 15 diameters	> 15 diameters	
Diameter			Shuter and Teasdale (**5**)
Compressible soils	> 75 mm [3 in.]	< 75 mm [3 in.]	
Less compressible soils	> 50 mm[D] [2 in.]	< 50 mm[D] [2 in.]	

[A] Group C samples include samples for the following geotechnical tests: density, percent swell, consolidation, permeability testing and shear testing with or without stress-strain and volume change measurements. Group D samples are fragile or highly sensitive for which test in Group C are required. Group C samples collected for environmental testing purposes would include laboratory measurement of hydraulic conductivity, and flow-through core tests for sorption and leachability.

[B] Thin-wall samplers cannot get intact samples of all soil materials. For denser soils, Pitcher (see 7.6.1) or Denison samplers (see 7.6.2) may be required.

[C] Samples collected with thick-wall samplers may qualify as representative samples for the purpose of description of in situ morphologic properties and for the purpose of chemical characterization. Thick-walled samplers equipped with thin sharp cutting shoes extensions can be designed to acquire intact samples (6.2).

[D] 50 mm [2-in.] samples for Group C samples for engineering tests are not recommended.

TABLE 3 Indicators of Degree of Core Disturbance in Driven Samples[A]

Indicator	Intact/Less Disturbed	More Disturbed/Disturbed
Advancement Method	Pushed	Driven
Core Recovery	Core length = sample interval	Core length < or > sample interval
Soil morphology/sedimentary structures[A]	No or little observable deformation	Moderate to extensively deformed
Core length (indicator of expansion or compaction)[B]	Length of core equal to sampled interval	Length of core > or < sampled interval
Partings at intervals equal to the distance of each drive impact (driven samples only)	Absent	Weakly to strongly evident
Practice D1586/D1586M blow count (*N*)	*N* <30	*N* >30
Core shoe (soil with course fragments)	No visible damage to cutting shoe	Cutting shoe nicked or bent
Gravel fragments or large roots in core	No evidence of grooving along core	Core has been grooved by rock or root fragments inside the core
Borehole condition	Cased or stable borehole with no caving	Unstable, uncased borehole
Drilling fluid	Not used, or not visible	Drilling fluid coats core top, bottom and sidewalls

[A] Based on visual observation of split cores or X-ray radiography using Test Method D4452.
[B] Also indicator for pushed thin-wall samples.

sample. Sensitive chemical constituents, such as redox-sensitive metals, volatile organic chemicals, and other organic chemicals that are subject to biodegradation may require collection of intact or relatively intact samples using stainless steel or brass liners or clear plastic (typically PVC) liners that are immediately sealed for transport or special coring, paring, or sub-coring devices that allow rapid placement or transfer of samples into containers for onsite analysis or preservation and transport to a laboratory.

6.4.1 Sampling equipment must be cleaned a decontaminated prior to and in between sampling events. Consult practices D5088 and D5608 for methods to decontaminate sampling equipment and perform in accordance with the site sampling plan. New samplers should be cleaned prior to use to remove any manufacturing chemicals left on the equipment. Sampling equipment may require decontamination when moved between sampling sites and when leaving the project. In hole drill rods, augers, and casings should be decontaminated when removed from the sampling site.

6.4.2 Storage of samples in liners are not recommended and most soil cores require immediate sub-sampling. 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 sub-sampled on site using other methods such as Guide D8170 or other similar small hand core samplers. Samples for other chemical characterization generally require sub-sampling into glass or plastic jars or vials and preserved with refrigeration. 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.

6.4.3 *Prevention of Cross Contamination*—Open thin-wall and thick-wall samplers may cause cross-contamination of soil samples by including material from a higher interval. Casing advancement methods (including continuous sampling with a hollow-stem auger, double-tube direct push, or vibratory/sonic drilling), or stable boreholes where the drilling method has a larger diameter than the sampler help minimize cross-contamination of sample from above the water table. Temporary seals for the barrel shoe that are pushed aside when the sampler enters the soil interval being sampled will prevent contact of the inside of the sampler with contaminated soil, soil gas or groundwater as it advances through an open borehole. Piston samplers results in less cross-contamination than open thin-wall and thick-wall samples both above and below a water table. Piston samplers used below the water table in contaminated aquifers should have good seals (O-rings or leather packing) to prevent water from entering the sampler before it is in position. A common problem with soil sampling is groundwater cross contamination below the water table. Most drilling and direct push methods using open boreholes and casing will have standing groundwater below the water table in the borehole that has the potential to cross contaminate subsequent deeper sampling. In cases where there is standing water in the borehole, the sampling procedure should be changed to using sealed sampler like the single tube direct push sampler (D6282) or a sealed piston sampler if cores are adversely affected.

6.4.4 Lewis et al. (**8**) and Turriff and Klopp (**9**) describe special sampling devices, preservation and handling procedures for minimizing loss of volatile constituents from soil samples. Chapelle (**10**) and Leach et al. (**11**) describe procedures and equipment for collecting soil samples that preserve anaerobic, reducing conditions. Some sampler materials or liner materials may be incompatible or possibly interfere with analysis of some chemical parameters. For example, stainless steel samplers or liners generally should not be used when chromium is one of the primary analytes of interest. Selecting the appropriate sample and liner materials before beginning field work.

6.5 *Nature of Geologic Materials*—The type of geologic material to be sampled is a primary consideration in selection of sampling devices, and the ease or difficulty in obtaining an intact sample. Table 4 provides some general ratings on suitability of core sampling devices for different geologic materials. In geotechnical investigations soils are often classified as cohesive (clays) and cohesionless (silt, sand, and gravel), with the basic types differentiated based on density or consistency (**12**). Table 5 provides criteria used to define density/consistency classes based on *N* values for standard penetration test (see Practice D1586/D1586M) and unconfined compressive strength. Saturation increases the difficulty in sampling of all unconsolidated materials, but especially sands. Cohesionless well graded sands and sensitive, soft, low plasticity clays and silts pose the greatest difficulties for collection of intact samples. Where only representative samples are

TABLE 4 Suitability of Core Sampling Devices for Different Geologic Materials[A]

NOTE 1—Key: Ratings: E = excellent; G = good; F = fair; P = poor; NA = not applicable. Other: FD = face discharge; RBD = recessed bottom discharge.

Sampler Type	Soil/Unconsolidated Material[B]						Rock[C]	
	Fine-Grained		Coarse, Cohesive		Cohesionless[D]			
	Soft-Stiff	Stiff-Hard	Sand	Gravel	Loose	Dense	Soft	Hard
Drive/Push Samplers								
Thick-Wall	E-G	G-P	E-G	F-P	F-P	G-P	NA	NA
Thin-Wall	E	F-P	G-F	NA	F-P	P	NA	NA
Piston[E]	E	F-P	G-F	NA	E-P	P	NA	NA
Direct Push	F-G	G-F	F-P	NA	F-P	F-G	NA	NA
Sonic Core	G-P	G-E	F-E	G-E	G-F	F-E	G-E	F-G
Rotating Soil Core Samplers								
Hollow-Stem Auger	G-F	E-G	E-G	F-P	F-P	G-P	NA	NA
Pitcher	G-F	E-G	E-G	G-P	G-P	E-P	NA	NA
Denison[F]	G-F	E-G	E-G	G-P	F-P	G-P	NA	NA
Rotating Rock Core Samplers[G]								
Single Tube, FD	NA	NA	NA	NA	NA	NA	F-P	E-P
Double Tube RBD	P	P	NA	F-P[H]	NA	G-P	E	E
Triple Tube	P	P	NA	P	NA	G-P	E	E

[A] Ratings are for general guidance only. Performance of specific sampling devices can vary depending on the type of drill rig, diameter of the sampler and nature of the geologic material.
[B] Refer to Table 5 to density/consistency terminology.
[C] Soft rock includes shales, siltstone, and weakly cemented sandstone. Hard rock includes limestone, dolomite, and most igneous and metamorphic rocks.
[D] Loose cohesionless soils are difficult to recover with most drive/push sampling devices unless retainers are used, especially when saturated. Materials in this category include saturated sensitive clays, silts and sands, sensitive organic silts, soft clays, unsaturated loose sands and silty sands. Very dense soil material is also difficult to penetrate with most drive/push sampling devices. Examples of dense materials would include compact tills and weakly cemented soil/rock.
[E] Numerous types of piston samplers have been developed, but only a few are commercially available; many are effective in sampling saturated, cohesive soils, but have varying effectiveness for sampling cohesionless soils.
[F] Denison sampler ratings are for soil sampling configuration with inner barrel advanced ahead of outer rotating core barrel. In the rock coring configuration ratings are same as for double tube RBD sampler.
[G] Numerous types of single- and double-tube rotating core samplers are available, with specific designs and cutting heads selected based on rock hardness and degree of jointing and fracturing.
[H] Only if gravels are very dense or cemented.

TABLE 5 Soil Terminology Related to Sample Device Selection[A]

Basic Soil Types	Density or Consistency	Range of Standard Penetration Resistance[B]	Range of Unconfined Compressive Strength[C]
Cohesionless	Very loose	Less than 4	Not applicable
	Loose	4 to 10	Not applicable
	Medium dense	10 to 30	Not Applicable
	Dense	30 to 50	Not applicable
	Very dense	Greater than 50	Not Applicable
Cohesive	Very soft	Less than 2	Less than 0.25 kg/cm^2
	Soft	2 to 4	0.25 to 0.5
	Medium stiff	4 to 8	0.5 to 1.0
	Stiff	8 to 15	1.0 to 2.0
	Very stiff	15 to 30	2.0 to 4.0
	Hard	Greater than 30	Greater than 4.0

[A] Source: Adapted from USACE **(12)**.
[B] *N* value (numbers of blows to advance standard split barrel 0.3 m [1 ft] using Practice D1586/D1586M.
[C] Kg/cm^2 ≈ tons/ft^2. Unconfined compressive strength (q_u) may also be approximated using a pocket penetrometer or Torvane shear apparatus.

required, retainers (7.9.1) may improve sample recovery, especially in cohesionless soils. If other methods fail in clean sand, freezing or polymer gel injection piston (7.5) and rotary samplers can be used to obtain intact samples of cohesionless sediments (see 7.9.3). In very dense unconsolidated materials (stiff to hard clays, glacial tills), specially designed rotary core samplers such as the Denison and Pitcher sampler, or a large-diameter rotary core may be required (see 7.6).

6.6 *Sampling Equipment Characteristics*—All drill rigs and direct push equipment do not have the same capabilities (D6286). Site geologic conditions and sampling needs should be well enough defined beforehand that a rig capable of deploying the full range of appropriate sampling and backup tools are selected. Procedures for collecting core samples using some drilling methods such as cable tool and solid stem auger are relatively cumbersome compared to sonic, direct push, hollow-stem augers, and rotary drilling methods. Open hole sonic, dual tube direct push, hollow-stem augers, and other rotary drilling methods (with and without casing advancement) are generally flexible in the types of sampling devices that can be used as the open hole allows for insertion of different samplers. Where deep holes are to be sampled, wireline sampling capabilities should be considered (see 7.2.5).

NOTE 2—Refer to Shuter and Teasdale **(5)** for a description of coring procedures using cable tool and solid stem augers.

6.7 *Sample Continuity*—Continuous coring provides the highest quality samples for lithologic logging of boreholes. Rapid continuous soil coring is commonly performed with hollow stem augers (see 7.6.3), direct push dual tube (D6282), vibratory/sonic drilling and sampling (D6914/D6914M). Wireline rock coring systems are used ways for collecting continuous rock cores more rapidly than incremental sampling with conventional core barrels. Intact soil sampling and penetration resistance drive sampling are done incrementally in discrete, targeted zones. Both discrete and continuous sampling may be appropriate in the same borehole. For example, when investigating a deep layer or zone of concern, discrete sampling may be adequate above the zone. If the same cores are used for both logging and testing, the full core should be described first.

6.7.1 *Effects of Sampling Intervals*—Unless continuous samples are taken, a thin critical weak layer, confining layer, or other geologic feature may be missed. Geotechnical engineers using thick wall drive samplers, such as the SPT (D1586/

D1586M) for blow counts, require some spacing for the next penetration test. The traditional practice of performing SPT at 5 ft intervals or change of materials based on cuttings (8.3) may miss a critical geologic feature. Fig. 1 shows the probability of finding a critical low permeability confining layer of given thickness versus sampling interval. SPTs can be taken at shorter intervals of 2.5 ft spacings allowing 1 ft cleanouts between tests. For environmental sampling it is best to use continuous sampling methods for the best logging which requires detailed evaluation of complex hydro-stratigraphic facies (**13**).

6.8 *Sampler Materials*—Soil and rock samplers are made from steel to withstand driving, push, and rotational forces. Thick wall drive shoes are often hardened by carburization to withstand rugged driving conditions. Rotary core bits use carbide, diamonds, or polycrystalline inserts for cutting.

6.9 *Liners*—Liners facilitate sample handling and storage. Key considerations in the selection of liners include type (split or solid) and liner materials. Liners should be cleaned and decontaminated prior to use (6.4.1).

6.9.1 Split liners are recommended for use when logging and sampling for representative sampling logging and sub-sampling in the field. Split liners allow for easy handling and inspection of samples. Most samplers with exception of the thin-wall tube can be designed to accommodate split liners. Direct push samplers using solid plastic liners have special liner splitting tools that rapidly open solid tubes for logging. Split liners are recommended for environmental sampling using Practice D6640 to access the soil sample in the field for chemical sub-sampling activities.

6.9.2 Solid liners are often used when samples must be preserved for later laboratory analysis or stored for later logging. When samples are being preserved for physical testing they should be sealed and stored using methods in Practice D4220/D4220M for shipment to the laboratory. Examples of samplers with solid liners include ring-lined sampler (see 7.3.1), pitcher (see 7.6.1), Denison (see 7.6.2), and rock core barrels (see 7.7). A thin-wall tube functions as a liner if the ends are to be sealed for shipment. Sealing of liners should normally be performed by trimming away loose soil and inserting moisture proof plugs or by cutting the liner flush to the soil and capping the ends with moisture-proof material. Liners should be strong enough to support the core during shipment. Liners should be round and matched to the tolerances of the sampler. The best tolerance is achieved when the core fits in the liner without an air gap, but also without excessive core friction. If the core is over cut by a clearance ratio that is too large, oxidation and biological growths may occur with sustained storage even if the ends are sealed since an air gap exists between the core and solid liner inside. It is especially important to use correct clearance ratios for coring, so the soil core fits snugly in the liner with no air gap.

6.9.3 *Liner Materials*—With split liners, the core is exposed to the material for short periods of time, so the material of manufacture is not as critical. If solid liners will be stored for a long period of time, the material of manufacture for the liner is important for potential chemical interactions. Laboratory tests should be scheduled and promptly performed to minimize storage time. The thin wall tube standard Practice D1587/D1587M has detailed information on types of tubing and

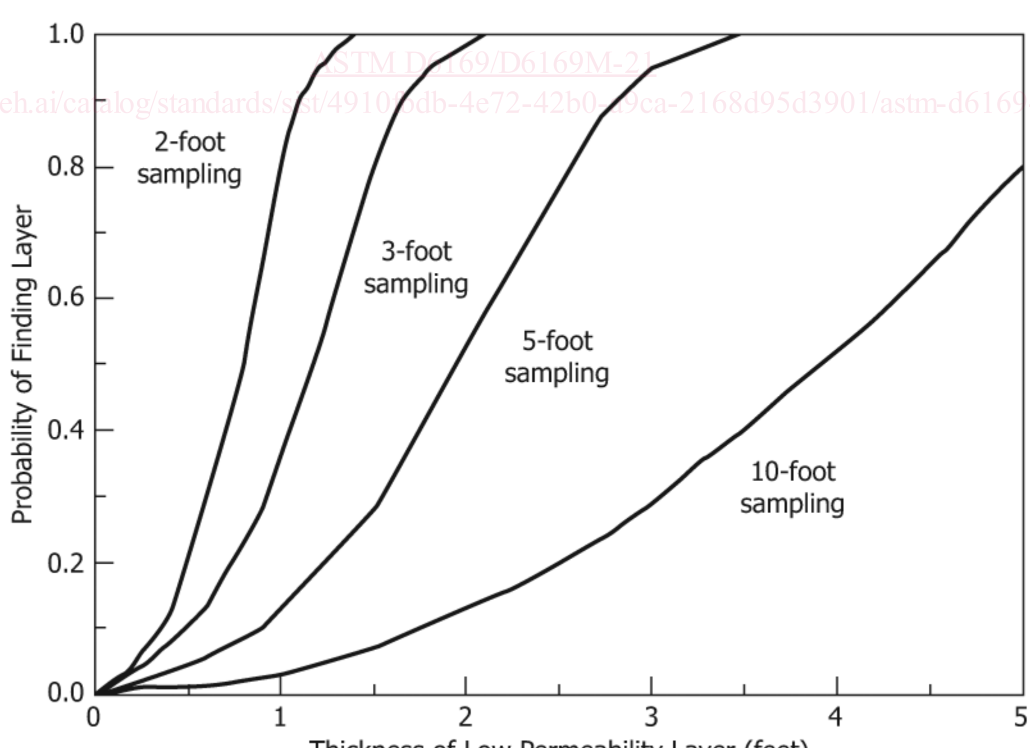

FIG. 1 Sampling at intervals can save money, but the practice creates a risk of missing important geologic units. Continuous sampling is advisable in complex geologic environments (14).

liners. Core materials may adversely age with duration of storage and undergo oxidation/reduction effects from metals and microbial growth from exposure of cores to air. In many cases, cores are extruded into other non-reactive plastic split liners and half rounds and waxed for preservation (D4220/D4220M). Metal liners are frequently made of steel or brass but can be made of aluminum or other metals. Stainless steel tube liners are difficult to machine and cut open and are more expensive. Steel tubes could be selected for samples to be extruded in the laboratory. All steel liners rust to some extent with time, so iron oxides will be present. Coating materials for steel (zinc oxides or lacquers) are not effective at preventing rust in soils containing sands and gravels because the grains scratch through the material, but they may be effective in clay soils (see Practice D1587/D1587M). The best new coating material is performed by applying Nickel Electroless plating which prevents metals reactions with thin wall tubes (Practice D1587/D1587M). Aluminum liners will oxidize, but the tendency is to develop a thin protective coating as opposed to iron which can be more mobile in the samples. Plastic liners are normally PVC or acrylics. Chemically inert materials such as Teflon should only be required for highly reactive mixed wastes and must not be used for sampling of polyfluorinated alkyl substances (PFAs).

6.10 *Experience and Skill of Driller/Sampler*—Sampling equipment, even when appropriate for the type of materials and type of sample desired, can be damaged or fail, or sample integrity compromised if the personnel collecting the sample are inexperienced, or use inappropriate procedures or methods. Conversely, skilled personnel may be able to obtain adequate samples using equipment that may not be optimal for the material being sampled.

7. Core Sampling Devices

7.1 This guide classifies core sampling devices into four major categories thick-wall samplers (see 7.3), thin-wall samplers (see 7.4), rotating soil core samplers (see 7.6), and rotating rock core samplers (see 7.7). Piston samplers are a special type of thick-wall or thin-wall samplers in which the sampler is held in a fixed position and the cutting head is advanced mechanically or hydraulically into the soil (see 7.5). Thick-wall samplers can in turn be broadly classified as solid or split barrel. Rotating core samplers are broadly classified as single-tube and double-tube. Table 6 summarizes general characteristics of these samplers (available advancement methods and availability of liners). Many specific sampler designs have been developed and adapted over the years. Names applied to the same sampling device may vary regionally and the same name may be applied to entirely different sampling devices. When evaluating a specific sampler, specification drawings or the sampler itself should be examined to determine its type. Subsections 7.8 and 7.9 discusses some specialized samplers.

7.2 *Sampler Advancement Methods*—Method of advancement is an important consideration when selecting a sampling device. Four major methods for advancing samplers are push, drive, rotation, and vibration.

TABLE 6 Classification and Examples of Core Sampling Devices

Sampler Type	Advancement Method						Liner
	Drive	Push	Rotate	Vibrate	Drill Rod	Wire-line	
Thick-Wall Samplers							
Solid	X	X	. . .	X	X	X	X
Split	X	X	. . .	. . .	X	X	X
Piston	X	X	. . .	. . .	X	X (rare)	X
Thin-Wall Samplers							
Standard	X	X	. . .	X	X	. . .	X
Piston	. . .	X	. . .	. . .	X	. . .	X
Rotating Soil and Rock Core							
Single Tube	. . .	. . .	X	. . .	X	X	X
Double Tube	. . .	X	X	. . .	X	X	X
Triple Tube	. . .	X	X	. . .	X	X	X

7.2.1 *Push Soil Sampling*—Push sampling involves application of sufficient steady force to overcome soil resistance so that the sampler advances in a continuous motion. Push samplers are usually hydraulically driven but mechanical application using sufficient weight to advance the sampler is also possible. Push sampling is the method most commonly used for thin-wall samplers, but thick-wall samplers may also be advanced this way in soft materials. Push advancement results in the least disturbance of most soil materials and is the most common method used to obtain intact core samples in soft materials. Highly plastic and compressible soil materials such as wet clays and organic silts are susceptible to disturbance even with push sampling. Push advancement is often not feasible in gravelly and very dense soil materials.

7.2.2 *Drive Soil Sampling*—Drive sampling advances the sampler by a series of discrete blows to the drill rods to which the sampler is attached. The standard weight drive assembly defined in Practice D1586/D1586M consists of a 63.5-kg [140-lb] weight, a driving head and a guide permitting a free fall of 0.75 m [30-in.] and is required whenever a standard penetration test (SPT) is being conducted. Use of drive assembly that departs from this standard is used for thick wall ring lined drive samplers using Practice D3550/D3550M. Use of SPT may be acceptable for environmental investigations (see Note 3) but is incremental and is more expensive. Thick-wall samplers are most commonly used with drive sampling, but thin-wall samplers can be driven in materials that are too dense for push advancement provided that the driving force does not damage the sampler (generally up to $N = 30$). An advantage of drive sampling is that the blow count (number of blows required to advance the sampler 0.30 m [1 ft] or fraction thereof with 100 blows) is a useful indicator of variations in lithology and density. Drive samples are almost always disturbed and not suitable for Group C and D samples.

7.2.2.1 *Direct Push Drive Sampling*—Direct Push soil samplers are driven by high frequency hydraulic hammer systems for rapid sampling using longer thick wall drive tubes. This is a preferred method for environmental sampling since no drill cuttings are generated. Sample recovery is highly variable but can be improved by using different drive shoes (Practice D6282).

NOTE 3—The standard penetration test in Test Method D1586/D1586M was developed primarily to determine penetration resistance (N) of soils for geotechnical engineering purposes. If N values are not essential for the purposes of geoenvironmental investigations, use of other continuous methods such as direct push sampling are recommended.

7.2.3 *Rotation Sampling*—Rotating core sampling advances the sampler by cutting soil or rock material away from around the core using a circular cutting shoe. Advantages and disadvantages of rotating core sampling are discussed further in 7.6. Rotational core samplers can be used for intact sampling, but the sampler configuration must be adjusted to the formation to be sampled. In soil sampling the key combination of interior cutting shoe clearance ratio and the lead distance (for example, the amount the interior shoe is in advance of the outer cutting teeth) must be adjusted. The Pitcher sampler (7.6.1) adjusts lead distance automatically by spring loading, but other samplers like the Denison barrel (7.6.2) or hollow-stem auger (7.6.3) require manual adjustments for best sample quality. Rotary diamond drilling of rock cores employs a wide array of bit designs and fluid discharge ports to optimize the core quality. Recovery of poor quality fluid sensitive rock will like require face discharge bits, triple tube liners, and even retainers, while high quality rock can employ standard interior fluid discharge ports.

7.2.4 *Vibratory/Sonic Sampling*—Vibratory/sonic drilling methods use variable frequency vibrations in some cases coupled with hydraulic force or rotation to advance a thin-wall or thick wall sampler into the ground, followed by an outer casing which maintains the borehole wall, prevents cross contamination and allows for the installation of monitoring wells and various borehole testing devices. (See Note 4.) Vibratory core sampling is a well-established technique for sampling soil and rock (see 7.3.3, Practice D6914/D6914M). Although the basic technology for sonic or vibratory soil and rock sampling was developed in the 1950s, relatively recent improvement in design, application, and reliability make it an attractive drilling method for environmental investigations (**15, 16, 17**). Sonic/vibratory drilling is an effective method of collecting continuous or intermittent large or small diameter core samples in all types of soil and rock, including thick unconsolidated gravel formations with cobbles and boulders, and saturated sand and gravel below water table. Rock core samples that require use of air or water to remove cuttings, can be collected to depths in excess of 150 m [500 ft] in most bedrock formations. Continuous cores can be taken in increments of 1.5 to 6 m [5 to 20 ft] or longer. In a drilling mode, vibratory/sonic rigs cause disturbance of soil material, as a result of material being pushed outward into the borehole wall or inward into the core barrel, depending upon the formation, sampling criteria and bit face design. Such samples are representative of the formation and many structure features survive, especially at the center portion of the core sample. The degree of sample disturbance can be reduced by reducing vibration frequency, reducing or eliminating rotation, and use of thinner wall sample barrels and bits or cutting shoes that are tapered outward. Intact soil samples can be collected by pausing drilling and using a thin-wall sampler to collect a core in advance of the cutting head of the outer casing.

NOTE 4—Most soil sampling using vibratory drilling methods involves use of specially designed drill rigs which can be converted for many other types of drilling and sampling methods, such as: hydraulic thin-wall samples, hydraulic and/or vibratory advancement of thick-wall samplers, hydraulic piston samplers, air hammer, rotary drilling, wireline hard rock core drilling, tri-cone rotary drilling (see Guide D6286). With the appropriate equipment, sonic/vibratory rigs can also perform standard penetration tests.

7.2.5 *Drill-Rod Versus Wireline Sampling*—For shallow investigations (generally less than 45 m [150 ft]) sampling devices are most commonly attached to a sufficient number of drill rods to place the sample at the bottom of the hole. Once the sampler has been advanced a distance equal to the sampler length, it is retrieved by pulling and disassembling the drill rods. As the depth of the hole increases, the amount of time required to pull and replace the drill rod assembly increases. Wireline rock sampling is the most common method used for rock coring operations over conventional core barrels (see 7.7). In wireline rock sampling, an inner barrel is raised and lowered inside drill rods with a wireline and attached to the outer rotating casing/rod bit with an overshot latching mechanism (see Fig. 2). Some wireline rock core systems can be converted for soil sampling where a spring provides the tension to keep a thin-wall tube some 150 mm [6 in.] in front of the rotating bit. If an obstruction is encountered the spring retracts to allow the bit to drill through or displace the obstruction, similar to a pitcher sampler (see 7.6.1). Retrieval and reinsertion of a sampler with a wireline system is faster than using a drill-rod assembly. The main disadvantage of wireline systems is that the coring devices are more complex than conventional thick-wall and thin-wall samplers and hence are more expensive. Use of wireline systems to sample sands below the water table may require special drilling techniques and extra care in managing drilling fluids to prevent jamming of the latching mechanism by sand in the water column. The depth at which wireline core sampling becomes more cost effective than drill-rod sampling typically ranges between 15 to 45 m [50 to 150 ft]. Wireline systems have been developed for sonic drilling equipment which changes the sampling procedure to advance the outer casing and inner core barrel together.

7.3 *Thick-Wall Samplers*—A thick-wall sampler is any type of open tube or, less commonly, piston sampler that is advanced by push, drive or vibratory methods, where the wall thickness or wall area to outer diameter ratio, inner clearance ratio, length exceed specifications for a thin-wall sampler (see Table 2). Samples collected with thick-wall generally do not qualify as physically intact core samples.

7.3.1 *Geotechnical Thick-Wall Drive Samplers*—The most common type of thick-wall samplers is the 50 mm [2 in.] OD split barrel SPT sampler (D1586/D1586M) widely used with the 63.5 kg [140 lb] drive hammer for penetration resistance data shown on Fig. 3. This small diameter sampler most always results in a disturbed sample. Larger diameter split barrel samplers of 75 to 100 mm [3 to 4 in.] inches are often used to improve recovery and sampler quality. Fig. 4 shows the split barrel ring lined sampler described in Practice D3550/D3550M where the 75 mm [3 in.] OD barrel being used. The ring lined sampler is often used in unsaturated soils. The rings are useful for wetting consolidation tests but the sample quality is always questionable and is often used as an index test. Fig. 5 shows the 100 mm [4 in.] diameter U100 drive sampler used in Europe and discussed in ISO standards. The larger diameter U100