Designation: D1587/D1587M – 15

Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes[1]

This standard is issued under the fixed designation D1587/D1587M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover intact soil samples suitable for laboratory tests of engineering properties, such as strength, compressibility, permeability, and density. This practice provides guidance on proper sampling equipment, procedures, and sample quality evaluation that are used to obtain intact samples suitable for laboratory testing.

1.2 This practice is limited to fine-grained soils that can be penetrated by the thin-walled tube. This sampling method is not recommended for sampling soils containing coarse sand, gravel, or larger size soil particles, cemented, or very hard soils. Other soil samplers may be used for sampling these soil types. Such samplers include driven split barrel samplers and soil coring devices (Test Methods D1586, D3550, and Practice D6151). For information on appropriate use of other soil samplers refer to Practice D6169.

1.3 This practice is often used in conjunction with rotary drilling (Practice D1452 and Guides D5783 and D6286) or hollow-stem augers (Practice D6151). Subsurface geotechnical explorations should be reported in accordance with Practice D5434. This practice discusses some aspects of sample preservation after the sampling event. For more information on preservation and transportation process of soil samples, consult Practice D4220.

1.4 This practice may not address special considerations for environmental or marine sampling; consult Practices D6169 and D3213 for information on sampling for environmental and marine explorations.

1.5 Thin-walled tubes meeting requirements of 6.3 can also be used in piston samplers, or inner liners of double tube push or rotary-type soil core samplers (Pitcher barrel, Practice D6169). Piston samplers in Practice D6519 use thin-walled tubes.

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this standard.

1.7 This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice 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 project'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.

1.8 The values stated in either inch-pound units or SI units presented in brackets 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 nonconformance with the 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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A513/A513M Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing

A519 Specification for Seamless Carbon and Alloy Steel Mechanical Tubing

A787 Specification for Electric-Resistance-Welded Metallic-Coated Carbon Steel Mechanical Tubing

B733 Specification for Autocatalytic (Electroless) Nickel-Phosphorus Coatings on Metal

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Evaluations.

Current edition approved Nov. 15, 2015. Published December 2015. Originally approved in 1958. Last previous edition approved in 2012 as D1587 – 08 (2012)$^{\varepsilon 1}$. DOI: 10.1520/D1587_D1587M-15.

[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**

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
D2166 Test Method for Unconfined Compressive Strength of Cohesive Soil
D2435 Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D2850 Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils
D3213 Practices for Handling, Storing, and Preparing Soft Intact Marine Soil
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils (Withdrawn 2016)[3]
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4186 Test Method for One-Dimensional Consolidation Properties of Saturated Cohesive Soils Using Controlled-Strain Loading
D4220 Practices for Preserving and Transporting Soil Samples
D4452 Practice for X-Ray Radiography of Soil Samples
D4767 Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils
D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D6026 Practice for Using Significant Digits in Geotechnical Data
D6151 Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling
D6169 Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations
D6282 Guide for Direct Push Soil Sampling for Environmental Site Characterizations
D6286 Guide for Selection of Drilling Methods for Environmental Site Characterization
D6519 Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of terms in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *area ratio, A_r, %, n*—the ratio of the soil displaced by the sampler tube in proportion to the area of the sample expressed as a percentage (see Fig. 1).

3.2.2 *inside clearance ratio, C_r, %, n*—the ratio of the difference in the inside diameter of the tube, D_i, minus the inside diameter of the cutting edge, D_e, to the inside diameter of the tube, D_i expressed as a percentage (see Fig. 1).

3.2.3 *ovality, n*—the cross section of the tube that deviates from a perfect circle.

3.3 *Symbols:*

3.3.1 A_r—area ratio (see 3.2.1).

3.3.2 C_r—clearance ratio (see 3.2.2).

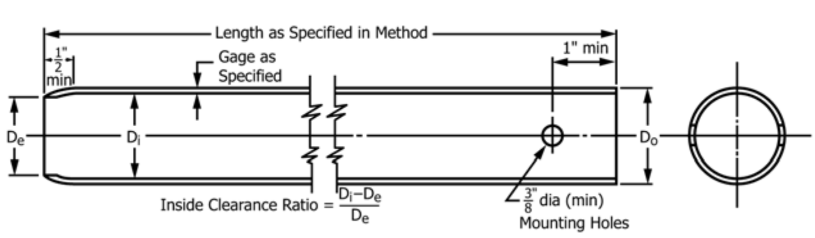
4. Summary of Practice

4.1 A relatively intact sample is obtained by pressing a thin-walled metal tube into the in-situ soil at the bottom of a boring, removing the soil-filled tube, and applying seals to the soil surfaces to prevent soil movement and moisture gain or loss.

5. Significance and Use

5.1 Thin-walled tube samples are used for obtaining intact specimens of fine-grained soils for laboratory tests to determine engineering properties of soils (strength, compressibility, permeability, and density). Fig. 2 shows the use of the sampler

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



$$\text{Area Ratio} = (D_o^2 - D_i^2)/D_i^2$$

NOTE 1—The sampling end of the tube is manufactured by rolling the end of the tube inward and then machine cutting the sampling diameter, D_e, on the inside of the rolled end of the tube.

NOTE 2—Minimum of two mounting holes on opposite sides for D_o smaller than 4 in. [100 mm]. Minimum of four mounting holes equally spaced for D_o equal to 4 in. [100 mm] and larger.

NOTE 3—Tube held with hardened set screws or other suitable means.

FIG. 1 Thin-Walled Dimensions for Measuring Tube Clearance Ratio, C_r (approximate metric equivalents not shown)

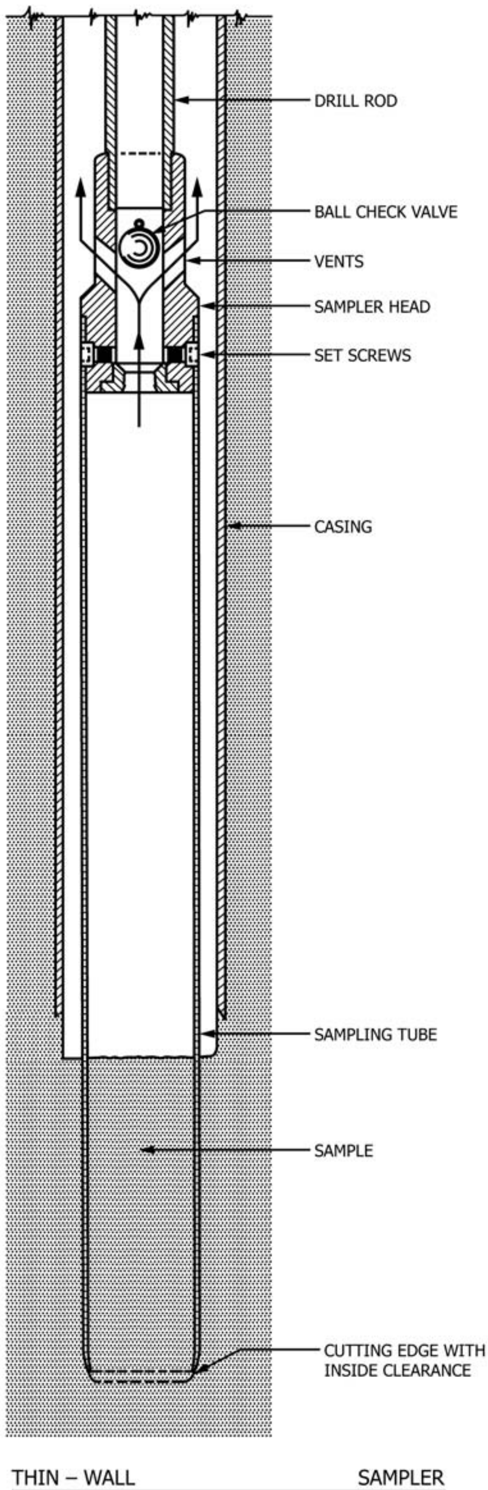


FIG. 2 Thin-Walled Tube Sampler Schematic and Operation (1)

in a drill hole. Typical sizes of thin-walled tubes are shown on Table 1. The most commonly used tube is the 3-in. [75 mm] diameter. This tube can provide intact samples for most laboratory tests; however some tests may require larger diameter tubes. Tubes with a diameter of 2 in. [50 mm] are rarely used as they often do not provide specimens of sufficient size for most laboratory testing.

TABLE 1 Suitable Thin-Walled Steel Sample Tubes[A]

Outside diameter (D_o):			
in.	2	3	5
mm	50	75	125
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.25	1.65	3.05
Tube length:			
in.	36	36	54
m	1.0	1.0	1.5

[A] The three diameters recommended in Table 2 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions. Wall thickness may be changed (5.2.1, 6.3.2). Bwg is Birmingham Wire Gauge (Specification A513/A513M).

5.1.1 Soil samples must undergo some degree of disturbance because the process of subsurface soil sampling subjects the soil to irreversible changes in stresses during sampling, extrusion if performed, and upon removal of confining stresses. However, if this practice is used properly, soil samples suitable for laboratory testing can be procured. Soil samples inside the tubes can be readily evaluated for disturbance or other features such as presence of fissures, inclusions, layering or voids using X-ray radiography (D4452) if facilities are available. Field extrusion and inspection of the soil core can also help evaluate sample quality.

5.1.2 Experience and research has shown that larger diameter samples (5 in. [125 mm]) result in reduced disturbance and provide larger soil cores available for testing. Agencies such as the U.S Army Corps of Engineers and US Bureau of Reclamation use 5-in. [125-mm] diameter samplers on large exploration projects to acquire high quality samples (**1, 2, 3**).[4]

5.1.3 The lengths of the thin-walled tubes (tubes) typically range from 2 to 5 ft [0.5 to 1.5 m], but most are about 3 ft [1 m]. While the sample and push lengths are shorter than the tube, see 7.4.1.

5.1.4 This type of sampler is often referred to as a "Shelby Tube."

5.2 Thin-walled tubes used are of variable wall thickness (gauge), which determines the Area Ratio (A_r). The outside cutting edge of the end of the tube is machined-sharpened to a cutting angle (Fig. 1). The tubes are also usually supplied with a machine-beveled inside cutting edge which provides the Clearance Ratio (C_r). The recommended combinations of A_r, cutting angle, and C_r are given below (also see 6.3 and Appendix X1, which provides guidance on sample disturbance).

5.2.1 A_r should generally be less than 10 to 15 %. Larger A_r of up to 25 to 30 % have been used for stiffer soils to prevent buckling of the tube. Tubes of thicker gauge may be requested when re-use is anticipated (see 6.3.2).

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

5.2.2 The cutting edge angle should range from 5 to 15 degrees. Softer formations may require sharper cutting angles of 5 to 10 degrees, however, sharp angles may be easily damaged in deeper borings. Cutting edge angles of up to 20 to 30 degrees have been used in stiffer formations in order to avoid damage to the cutting edges.

5.2.3 Optimum C_r depends on the soils to be tested. Soft clays require C_r of 0 or less than 0.5 %, while stiffer formations require larger C_r of 1 to 1.5 %.

5.2.3.1 Typically, manufacturers supply thin-walled tubes with C_r of about 0.5 to 1.0 % unless otherwise specified. For softer or harder soils C_r tubes may require special order from the supplier.

5.3 The most frequent use of thin-walled tube samples is the determination of the shear strength and compressibility of soft to medium consistency fine-grained soils for engineering purposes from laboratory testing. For determination of undrained strength, unconfined compression or unconsolided, undrained triaxial compression tests are often used (Test Methods D2166 and D2850). Unconfined compression tests should be only used with caution or based on experience because they often provide unreliable measure of undrained strength, especially in fissured clays. Unconsolidated undrained tests are more reliable but can still suffer from disturbance problems. Advanced tests, such as consolidated, undrained triaxial compression (Test Method D4767) testing, coupled with one dimensional consolidation tests (Test Methods D2435 and D4186) are performed for better understanding the relationship between stress history and the strength and compression characteristics of the soil as described by Ladd and Degroot, 2004 (**4**).

5.3.1 Another frequent use of the sample is to determine consolidation/compression behavior of soft, fine-grained soils using One-Dimensional Consolidation Test Methods D2435 or D4186 for settlement evaluation. Consolidation test specimens are generally larger diameter than those for strength testing and larger diameter soil cores may be required. Disturbance will result in errors in accurate determination of both yield stress (5.3) and stress history in the soil. Disturbance and sample quality can be evaluated by looking at recompression strains in the One-Dimensional Consolidation test (see Andressen and Kolstad (**5**)).

5.4 Many other sampling systems use thin-walled tubes. The piston sampler (Practice D6519) uses a thin-walled tube. However, the piston samplers are designed to recover soft soils and low-plasticity soils and the thin-walled tubes used must be of lower C_r of 0.0 to 0.5 %. Other piston samplers, such as the Japanese and Norwegian samplers, use thin-walled tubes with 0 % C_r (see Appendix X1).

5.4.1 Some rotary soil core barrels (Practice D6169-Pitcher Barrel), used for stiff to hard clays use thin-walled tubes. These samplers use high C_r tubes of 1.0 to 1.5 % because of core expansion and friction.

5.4.2 This standard may not address other composite double-tube samplers with inner liners. The double-tube samplers are thicker walled and require special considerations for an outside cutting shoe and not the inner thin-walled liner tube.

5.4.3 There are some variations to the design of the thin-walled sampler shown on Fig. 2. Figure 2 shows the standard sampler with a ball check valve in the head, which is used in fluid rotary drilled holes. One variation is a Bishop-type thin-walled sampler that is capable of holding a vacuum on the sampler to improve recovery (**1, 2**). This design was used to recover sand samples that tend to run out of the tube with sampler withdraw.

5.5 The thin-walled tube sampler can be used to sample soft to medium stiff clays[5]. Very stiff clays[5] generally require use of rotary soil core barrels (Practice D6151, Guide D6169). Mixed soils with sands can be sampled but the presence of coarse sands and gravels may cause soil core disturbance and tube damage. Low-plasticity silts can be sampled but in some cases below the water table they may not be held in the tube and a piston sampler may be required to recover these soils. Sands are much more difficult to penetrate and may require use of smaller diameter tubes. Gravelly soils cannot be sampled and gravel will damage the thin-walled tubes.

5.5.1 Research by the US Army Corps of Engineers has shown that it is not possible to sample clean sands without disturbance (**2**). The research shows that loose sands are densified and dense sands are loosened during tube insertion because the penetration process is drained, allowing grain rearrangement.

5.5.2 The tube should be pushed smoothly into the cohesive soil to minimize disturbance. Use in very stiff and hard clays with insertion by driving or hammering cannot provide an intact sample. Samples that must be obtained by driving should be labeled as such to avoid any advanced laboratory testing for engineering properties.

5.6 Thin-walled tube samplers are used in mechanically drilled boreholes (Guide D6286). Any drilling method that ensures the base of the borehole is intact and that the borehole walls are stable may be used. They are most often used in fluid rotary drill holes (Guide D5783) and holes using hollow-stem augers (Practice D6151).

5.6.1 The base of the boring must be stable and intact. The sample depth of the sampler should coincide with the drilled depth. The absence of slough, cuttings, or remolded soil in the top of the samples should be confirmed to ensure stable conditions (7.4.1).

5.6.2 The use of the open thin-walled tube sampler requires the borehole be cased or the borehole walls must be stable as soil can enter the open sampler tube from the borehole wall as it is lowered to the sampling depth. If samples are taken in uncased boreholes the cores should be inspected for any sidewall contamination.

5.6.3 Do not use thin-walled tubes in uncased fluid rotary drill holes below the water table. A piston sampler (Practice D6519) must be used to ensure that there is no fluid or sidewall contamination that would enter an open sampling tube.

5.6.4 Thin-walled tube samples can be obtained through Dual Tube Direct Push casings (Guide D6282).

[5] Soil Mechanics in Engineering Practice, Terzaghi, K. and R.B Peck, (1967) Second Edition, John Wiley & Sons, New York, Table 45.2, pg. 347.

5.6.5 Thin-walled tube samples are sometimes taken from the surface using other hydraulic equipment to push in the sampler. The push equipment should provide a smooth continuous vertical push.

5.7 Soil cores should not be stored in steel tubes for more than one to two weeks, unless they are stainless steel or protected by corrosion resistant coating or plating (6.3.2), see Note 1. This is because once the core is in contact with the steel tube, there are galvanic reactions between the tube and the soil which generally cause the annulus core to harden with time. There are also possible microbial reactions caused by temporary exposure to air. It is common practice to extrude or remove the soil core either in the field or at the receiving laboratory immediately upon receipt. If tubes are for re-use, soil cores must be extruded quickly within a few days since damage to any inside coatings is inevitable in multiple re-use. Extruded cores can be preserved by encasing the cores in plastic wrap, tin foil, and then microcrystalline wax to preserve moisture.

5.7.1 Soil cores of soft clays may be damaged in the extrusion process. In cases where the soil is very weak, it may be required to cut sections of the tube to remove soil cores for laboratory testing. See Appendix X1 for recommended techniques.

NOTE 1—The one to two week period is just guideline typically used in practice. Longer time periods may be allowed depending on logistics and the quality assurance requirements of the exploration plan.

NOTE 2—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 sampling. Users of this practice are cautioned that compliance with Practice D3740 does not in itself ensure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Drilling Equipment*—When sampling in a boring, any drilling equipment may be used that provides a reasonably clean hole; that minimizes disturbance of the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler (Guide D6286). Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

6.2 *Sampler Insertion Equipment,* shall be adequate to provide a relatively rapid continuous penetration force.

6.3 *Thin-Walled Tubes*—The tubes are either steel or stainless steel although other metals may be used if they can meet the general tolerances given in Table 2 and have adequate strength for the soil to be sampled. Electrical Resistance Steel welded tubing meeting requirements of Specification A513/A513M are commonly used but it must meet the strict the SSID (Special Smooth Inside Diameter) and DOM (Drawn Over Mandrel) tolerances. Table 2 is taken from older versions of this standard, and is in general agreement with Specification A513/A513M with tubes meeting SSID and DOM requirements. Seamless steel tubing (Specification A519) meeting requirements of Table 2 may avoid problems associated with welded tube, such as improper or poor quality welds, and will have better roundness (ovality). Tubes shall be clean and free of all surface irregularities including projecting weld seams. Other diameters may be used but the tube dimensions should be proportional to the tube designs presented here. Tubes may be supplied with a light coating of oil to prevent rusting in storage. Measure the inside and outside diameters, and diameter of the cutting edge to check for ovality and C_r (6.3.2) with micrometers to ascertain that tubes meet these general tolerance requirements.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Nominal Tube Diameters from Table 1[A] Tolerances						
Size Outside Diameter	2 in.	[50 mm]	3 in.	[75 mm]	5 in.	[125 mm]
Outside diameter, D_o	+0.007 -0.000	+0.179 -0.000	+0.010 -0.000	+0.254 -0.000	+0.015 -0.000	0.381 -0.000
Inside diameter, D_i	+0.000 -0.007	+0.000 -0.179	+0.000 -0.010	+0.000 -0.254	+0.000 -0.015	+0.000 -0.381
Wall thickness	±0.007	±0.179	±0.010	±0.254	±0.015	±0.381
Ovality	0.015	0.381	0.020	0.508	0.030	0.762
Straightness	0.030/ft	2.50/m	0.030/ft	2.50/m	0.030/ft	2.50/m

[A]Intermediate or larger diameters should be proportional. Specify only two of the first three tolerances; that is, D_o and D_i, or D_o and Wall thickness, or D_i and Wall thickness.

6.3.1 *Length of Tubes*—See Table 1, 7.5.1 amd Appendix X1. Use tubes at least 3 in. [75 mm] longer than the design push length to accommodate slough/cuttings.

6.3.2 *Wall Thickness of Tubes*—Table 1 shows typical wall thickness for the different diameter tubes. For heavy duty or anticipated re-use, the wall thickness can be increased. For example, a 3 in. [75 mm] tube may be increased from Bwg 16 (0.065 in.) to Bwg 14 (0.083 in). If tubes are to be re-used, they must be thoroughly cleaned and inspected prior to each re-use. Do not re-use tubes that are bent or out of round, or have damaged cutting edges, inside corrosion or corrosion coating damage. Repair re-used tube damage to the cutting edges that would disturb or obstruct passage of the core using a file to maintain a sharp cutting edge.

6.3.3 *Inside Clearance Ratio (C_r)*—Sample tubes are manufactured with the inward rolled end and machine cut inside diameter, De, to clearance ratios ranging from 0.5 to 1.0 % (Fig. 1). Special order tubes of less than 0.5%. Select the proper C_r for the soil to be tested when ordering tubes based on site conditions. Clearance ratio ranges from 0 % for very soft clays to 1.5 % for stiff soils as discussed in 5.2 and Appendix X1. In the field, if there is evidence of soil disturbance such as loose soil within the tube, samples falling out, compressed or expanded sample lengths, etc., change the C_r or push length.

6.3.3.1 A recommended tube for very soft clays with 0% C_r for 3-in. [75-mm] sample tubes is shown on Fig. 3 showing the recommended cutting angle. These special order tubes do not require the end rolling process.

6.3.4 *Corrosion Protection*—Subsection 5.7 recommends prompt extrusion of soil cores with no corrosion resistant coating. Corrosion, whether from galvanic or chemical reaction, can damage both the thin-walled tube and the soil sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating, unless the soil is

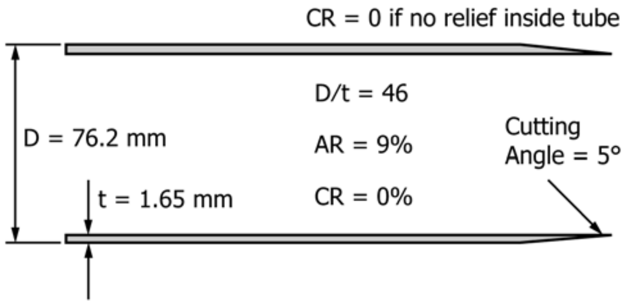


FIG. 3 Schematic of Standard 3-in. [75-mm] Thin-Walled Tube Modified by Removing the Beveled Cutting Edge and Machining a Five-Degree Cutting Angle (DeGroot and Landon (6)).

to be extruded in less than seven days. Organic or inorganic lubricants like penetrating oil and non-stick cooking spray have been used to lubricate the tube prior to sampling and also aid in extrusion and reduce friction. Tubes have been coated with lacquer or epoxy for reuse, but lacquer may not be suitable for longer storage periods and must be inspected for inside wear.

6.3.4.1 *Corrosion Resistant Tubing and Coatings*—Stainless steel and brass tubes are resistant to corrosion. Other types of coatings to be used may vary depending upon the material to be sampled. Plating of the tubes or alternate base metals may be specified. In general the coating should be of sufficient hardness and thickness to resist scratching that can occur from quartz sand particles, Nickel Electroless plating (Specification B733) has been used with good results. Galvanized tubes are often used when long term storage is required.

6.4 *Sampler Head,* serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a venting area and suitable ball check valve with the venting area to the outside equal to or greater than the area through the ball check valve. In some special cases, a ball check valve may not be required but venting is required to avoid sample compression. Fluid ports shall be designed to pass drill fluid or water through with minimal back pressure for push rates up to 1 ft [0.3 m] per second (fast push rate, 7.5).

7. Procedure

7.1 Remove loose material from the center of a casing or hollow stem auger as carefully as possible to avoid disturbance of the material to be sampled. If groundwater is encountered, maintain the liquid level in the borehole at or above groundwater level during the drilling and sampling operation.

7.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted.

NOTE 3—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

7.3 Prepare and inspect the sampling tube and secure to the sampling head and drill rods. If desired or required, lubricate the inside of the tube just prior to sampling (see 6.3.4). Attachment of the head to the tube shall be concentric and coaxial to ensure uniform application of force to the tube by the sampler insertion equipment.

7.4 Lower the sampling apparatus so that the sample tube's bottom rests on the bottom of the hole and record depth to the bottom of the sample tube to the nearest 0.1 ft [0.03 m].

7.4.1 The depth at which the tube rests should agree with the previous depth of cleanout using the drill bit to within 0.2 to 0.4 ft [50 to 100 mm], indicating a stable borehole. If the depth is less than the cleanout depth there could be excessive cuttings, slough/cave, or heave of the borehole and the borehole must be re-drilled, re-cleaned and stabilized for sampling. If the depth is deeper than the cleanout depth this may be normal because the thin-walled tube will penetrate partially under the weight of the rods. If the sampler penetrates significantly while resting at the base of the boring, adjust (shorten) the push length.

NOTE 4—Using a piston sampler (D6519) may alleviate many of the problems listed above. It is useful if there is excessive slough collected in the open thin wall tubes in unstable boreholes. With the piston locked in place, the sampler can generally be pressed through slough or cuttings to the cleanout depth without sample contamination with disturbed soil.

7.4.1.1 Keep the sampling apparatus plumb during lowering, thereby preventing the cutting edge of the tube from scraping the wall of the borehole.

7.5 Advance the sampler without rotation by a continuous relatively rapid downward push using the drill head and record length of advancement to the nearest 1 in. [25 mm] or better. The push should be smooth and continuous. It should take less than 15 seconds to push a typical 3-ft [1-m] sample tube. Note any difficulties in accomplishing the required push length.

7.5.1 Determine the length of advance by the resistance and condition of the soil formation. In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. [75 mm] for sludge and end cuttings.

7.5.2 If the drill equipment is equipped with a pressure gauge that reads the reaction to pushing at a smooth rate, this pressure can be recorded and noted during the sampling process. The noting of the difficulty or ease of pushing could be valuable to select samples for lab testing. Low pressure pushes may indicate softer or weaker soils.

NOTE 5—The mass of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

7.5.3 When the soil formation is too hard for push-type insertion, use rotary soil core barrels for stiff to hard deposits for obtaining intact samples. If a tube must be driven then record the driving method and label the tube "driven sample."

7.6 Withdraw the sampler from the soil formation as carefully as possible in order to minimize disturbance of the sample. There is no set requirement for removing the tube. The process used should avoid the loss of core and recover a full sample. Typical practice uses a waiting period of 5 to 15 minutes after sampling before withdraw. This is to both dissipate excess pore pressures from the push and to build some adherence/adhesion of the soil core inside the tube. Where the soil formation is soft, a delay before withdraw of the sampler may improve sample recovery. After the waiting period, typical practice is to rotate the sampler one revolution while in-place to shear off the bottom of the sample and relieve water or suction pressure prior to retraction. The waiting period and the shearing process may not be practical in some cases, such as deep marine sampling, and the sample can be removed without these steps as long as sample recovery is good.

7.6.1 Sometimes lower plasticity soils will fall out of the tube when the tube clears the water level inside the casing. If this occurs use a piston sampler (D6519) and/or reduce the C_r of the thin-walled tube. A lesser desired alternative is to maintain the borehole fluid level as the sample is retracted, and use a steel sheet plate or plywood to try to catch the soil core when the tube clears the fluid.

7.7 *Tube Re-Use*—If tubes are to be re-used, the soil cores must be extracted promptly and the tubes should be thoroughly cleaned using a high pressure washer or hand held cleaner that can reach fully inside the tube. Inspect the tubes for damage and discard any damaged tubes and repair the cutting edge if damaged (6.3.2).

8. Sample Measurement, Sealing and Labeling

8.1 Upon removal of the tube, remove the drill cuttings in the upper end of the tube using an insider diameter cutting tool and measure the length of the soil sample recovered to the nearest 1 in. [25 mm] or better in the tube. Recovery may be recorded, but may not be reliable due to uncertainty in removal of the upper slough, but it is important to note core loss and slippage. Seal the upper end of the tube. Remove at least 1 in. [25 mm] of material from the lower end of the tube. Use this material for soil description in accordance with Practice D2488. Measure the overall sample length to the nearest 1 in. [25 mm] or better. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube.

NOTE 6—If the tubes are mass tared and their inside diameters are known, the mass of tube and soil can be determined and using the diameter and length for volume, the wet density of the soil core can be calculated. Further, the dry density can be determined using water content from the bottom trimmings. This extra information can be valuable in assisting lab selection of tubes for testing. The procedure is outlined in the Earth Manual (**3**).

8.1.1 *Sealing Tubes*—Seal and confine the soil in the tubes using either expandable packers or waxed wood discs inside the tube. Tubes sealed over the ends are generally poor quality, as opposed to those sealed with expanding packers, and should be provided with spacers or appropriate packing materials, or both prior to sealing the tube ends to provide proper confinement. Packing materials must be nonabsorbent and must maintain their properties to provide the same degree of sample support with time.

8.1.2 Samples of soft or very soft clays may require tube cutting in the laboratory for removal as opposed to extrusion (Appendix X1).

8.1.3 *Extruded Cores*—Depending on the requirements of the exploration, field extrusion and packaging of extruded soil samples can be performed. This allows for physical examination, photographing, and classification of the sample. Samples are extruded in special device equipped which includes hydraulic jacks with properly sized platens to extrude the core in a smooth continuous speed. In some cases, further extrusion may cause sample disturbance reducing suitability for testing of engineering properties. In other cases, if damage is not significant, cores can be extruded and preserved for testing (Practice D4220). Bent or damaged tubes should be cut off before extruding. Preservation of intact sections of core is normally accomplished with a layer of plastic wrap and several layers of tin foil and wax to support the soil core. The extruded cores can be placed in PVC half rounds to aid in stability. Do not seal damaged portions of the extruded cores, generally the end sections, if they are not suitable for testing.

8.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample (see Section 9). Ensure that the markings or labels are adequate to survive transportation and storage.

9. Report: Field Data Sheet(s)/Log(s)

9.1 The methodology used to specify how data are recorded on the test data sheet(s)/log(s), as given below, is covered in 1.6.

9.2 Record the following general information that may be required for preparing field logs in general accordance with Guide D5434. This guide is used for logging explorations by drilling and sampling. Some examples of the information required include;

9.2.1 Name and location of the project,

9.2.2 Boring number,

9.2.3 Log of the soil conditions,

9.2.4 Location of the boring,

9.2.5 Method of making the borehole,

9.2.6 Name of the drilling foreman and company,

9.2.7 Name of the drilling inspector(s),

9.2.8 Date and time of boring-start and finish,

9.2.9 Description of thin-walled tube sampler: size, type of metal, type of coating,

9.2.10 Method of sampler insertion: push or drive, and any difficulties in accomplishing the required push length,

9.2.11 Push pressures if recorded,

9.2.12 Label any driven samples (7.5.3),

9.2.13 Method of drilling, size of hole, casing, and drilling fluid used,

9.2.14 Soil description in accordance with Practice D2488,

9.2.15 For each sample, label tubes with drill hole number and depth intervals at top and bottom and for extruded preserved cores, label the "top" and "bottom" for orientation along with the depths.

9.3 Record at a minimum the following sample data:

9.3.1 Surface elevation or reference to a datum to the nearest 0.1 ft [0.3 m] or better,

9.3.2 Drilling depths and depth to the nearest 0.1 ft [0.3 m] or better,

9.3.3 Depth to groundwater level: to the nearest 0.1 ft [0.3 m] or better, plus date(s) and time(s) measured,

9.3.4 Depth to the bottom or top of sample to the nearest 0.1 ft [0.03 m] and number of sample, 9.3.5 Length of sampler advance (push), to the nearest 0.05 ft [25 mm] or better, and

9.3.6 Recovery: length of sample obtained to the nearest 0.05 ft [25 mm] or better.

10. Keywords

10.1 geologic explorations; intact soil sampling; soil sampling; soil exploration; subsurface explorations; geotechnical exploration

APPENDIX

X1. INFORMATION REGARDING FACTORS AFFECTING THE QUALITY OF THIN-WALLED TUBE SOIL SAMPLING

(Nonmandatory Information)

X1.1 The most complete early study of soil sampling was performed by J.M. Hvorslev in 1949 (**1**) for the US Army Corps of Engineers (USACE). This study was comprehensive and reviewed all sampling methods including intact soil sampling. In this study he traces the origins of the thin-walled tube sampling practice and details regarding the design of thin-walled tubes to minimize disturbance of soils sampled for laboratory testing. This classic work is no longer available in print, however the USACE revised their Engineer Manual EM-1101-1-1804 in 2001 and it provides an excellent summary of this work.

X1.2 Either operator or mechanical factors affect the quality of thin-walled tube samples. Of course, the operator should use due care to properly drill the boreholes to ensure the soil is not disturbed at the base and to push the sampler at a smooth steady rate for proper sampling. Generally drilling too fast or pushing too fast can result in damage to the resulting sample.

X1.3 Mechanical factors include the sample diameter, sample push length, area ratio, Clearance Ratio, and edge cutting angle. It was clear in Hvorslev's work that large diameter samples 5 in. [125 mm] provided higher quality samples. The majority of soil sampling practice prefers the use of the smaller 3-in. [75-mm] tubes. When using these smaller tubes, more attention needs to be given to the factors listed above. If there are problems with sample quality, one should first consider going to a larger diameter sampler.

X1.4 Hvorslev defined and evaluated the Clearance ratio, C_r, of the sampler. Hvorslev suggested that C_r of 0 to 1 % may be used for very short samples, values of 0.5 to 3 % could be used for medium length samples, and larger may be needed for longer samples. If limited to a certain clearance ratio, the length of push can be shortened if there appears to be sample quality problems.

X1.5 For most soils, a C_r of 0.5 to 1.0 % can be used. C_r should be adjusted for the soil formation to be sampled. In general softer soils require lower C_r and stiffer soils require a higher C_r as they have a tendency to expand. Cohesive soils and slightly expansive soils require larger C_r, while soils with little or no cohesion require little or no clearance ratio.

X1.6 Piston samplers are designed to sample difficult to recover non-plastic or low plasticity soils and soft to very soft clays and thus require use of C_r of 0 to 0.5 %. Use of commercially supplied tubes with 1 % clearance ratio will result in complete core loss in low plasticity soils. A smaller clearance ratio of 0 to 0.5 % must be used or piston samplers can be used. Thin-walled tubes for rotary soil core barrels such as the Pitcher Sampler used in stiff soils generally require higher C_r of 1-2 % (**2**). Use of a larger C_r allows for larger push lengths. The US Army Corps of Engineers uses 5 in. [125 mm] diameter piston sampler tubes pushed 4 ft [1.2 m] with commercially available 0.5 to 1 % C_r with good success in soft normally consolidated clays. Having the larger diameter core allows one to tolerate some core annulus disturbance with good specimens still in the central portion of the core. Core annulus disturbance can be evaluated in lake deposits by allowing sections of cores to dry and evaluating the lake bed layering with attention to the damage at the annulus of the sample.

X1.7 Manufacturers supply thin-walled tubes with premade C_r of 0.5 to 1.0 %. You must custom order other clearance ratios. If you are going to sample a soft formation you need to custom order tubes with lower clearance ratios.

X1.8 Table X1.1 below shows some recommended C_r for various soil types and moisture conditions and was included in ASTM D6169 (Table 7). These are estimates from experienced drillers and may be used as a guide but the estimates are based on large diameter samples 5-in. [125 mm] with short push lengths (2.5 ft [0.8 m]) and may not apply to smaller diameter tubes.

X1.9 Research has been conducted comparing the ASTM D1587 thin-walled tubes to other samplers used around the world. Tanaka, et al. (**7**) compared the ASTM thin-walled tube to other samplers including the Japanese Piston sampler, Laval Sampler and NGI samplers. The results of this research showed very poor results with ASTM 3-in. [75-mm] tubes with very low Unconfined Compression test results (D2166). There are other studies on sample quality comparing the ASTM thin-walled tube to other samplers, but all these studies neglected

TABLE X1.1 General Recommendations for Thin-Wall, Open Push-Tube Sampling

Soil type	Moisture condition	Consistency	Length of push, cm [in.]	Bit clearance ratio, %	Push tube sampler recovery	Recommendation for better recovery
Gravel			Thin-wall, open push tube samplers not suitable			
Sand	Moist	Dense	46 [18]	0 to ½	Fair to poor	
Sand	Moist	Loose	30 [12]	½	Poor	Recommend piston sampler
Sand	Saturated	Dense	45 to 60 [18 to 24]	0	Poor	Recommend piston sampler
Sand	Saturated	Loose	30 to 45 [12 to 18]	0	Poor	Recommend piston sampler
Silt	Moist	Firm	45 [18]	½	Fair to good	
Silt	Moist	Soft	30 to 45 [12 to 18]	½	Fair	
Silt	Saturated	Firm	45 to 60 [18 to 24]	0	Fair to poor	Recommend piston sampler
Silt	Saturated	Soft	30 to 45 [12 to 18]	0 to ½	Poor	Recommend piston sampler
Clay and shale	Dry to saturated	Hard	Thin wall, open push tube sampler not suitable			Recommend double-tube sampler
Clay	Moist	Firm	45 [18]	½ to 1	Good	
Clay	Moist	Soft	30 to 45 [12 to 18]	1	Fair to good	
Clay	Saturated	Firm	45 to 60 [18 to 24]	0 to 1	Good	
Clay	Saturated	Soft	45 to 60 [18 to 24]	½ to 1	Fair to poor	Recommend piston sampler
Clay	Wet to saturated	Expansive	45 to 110 [18 to 44]	½ to 1-½	Good	

the determination of C_r of the thin-walled tubes used. Thin-walled tubes were likely purchased from manufacturers with the typical 0.5 to 1 % clearance ratio which is not recommended for soft clays.

X1.10 Lunne, et al., (**8**) published a study of samplers where the clearance ratios were noted. The study confirms that larger push lengths can be used successfully with higher C_r in the larger diameter the NGI sampler uses this.

X1.11 DeGroot and Landon (**6**) published recommendations for thin-walled tube sampling of soft clays. The recommendations stress the lower clearance ratios required for thin-walled tubes that are incorporated into this revision of the standard. Also contained in this report are recommendations by Ladd and DeGroot (**4**) that detail how to remove sections of the thin-walled tube without extrusion of the core.

X1.12 Evaluations of sample quality

X1.12.1 Soil samples inside the tubes can be readily evaluated for disturbance or other features such as presence of fissures, inclusions, layering or voids using X-ray Radiography (D4452) if facilities are available. The X-ray method is excellent for checking for badly disturbed specimens and also very advantageous to locate where to cut specimens for laboratory testing. Field extrusion of soil cores and also show any indications of excessive disturbance. When performing field extrusion and preservation, do not preserve areas that are excessively damaged, only seal and wax the most intact sections of the core.

X1.12.2 In the laboratory disturbance of the soil cores and overall sample quality can be evaluated using the One-Dimensional Consolidation test (D2435) using methods proposed by Andressen and Kolstad (**5**). The amount of recompression up to the estimated pre-stress or existing ground stress should be small in high quality samples. Recompression in consolidated shear strength tests can also be used.

(1) Hvorslev, M.J., 1949, Subsurface Exploration and Sampling of Soils for Engineering Purposes, report of a research project of the Committee on Sampling and Testing, Soil Mechanics and Foundations Division, American Society of Civil Engineers, Waterways Experiment Station, US Army Corps of Engineers, Vicksburg Mississippi, re-published by Engineering Foundation 1960

(2) Engineer Manual 1101-1-1804, 2001, Geotechnical Investigations, US Army Corps of Engineers, Washington D.C. http://140.194.76.129/publications/eng-manuals/

(3) Bureau of Reclamation, 1990, Earth Manual, 3rd Edition, Part 2, Test method USBR 7105 on Undisturbed Sampling of Soil by Mechanical Methods, Bureau of Reclamation, Denver CO.

(4) Ladd, C.C., and D.J., DeGroot, "Recommended Practice for Soft Ground Site Characterization: Arthur Casagrande Lecture," 12th Pan-American Conference on Soil Mechanics and Geotechnical Engineering, Massachusetts Institute of Technology, Cambridge, MA, June 22-25, 2003, revised May 9 2004.

(5) Andressen, A. AA., and Kolstad, P., 1979, "The NGI 154-mm Samplers for Undisturbed Sampling of Clays and representative Sampling of Coarser Materials," State of the Art on Current Practice of Soil Sampling, Proceedings of the International Symposium of Soil Sampling, The Subcommittee on Soil Sampling, International Society for Soil Mechanics and Foundation Engineering.

(6) DeGroot, D., J., and Landon, M., M., "Synopsis of Recommended Practice for Sampling and Handling of Soft Clays to Minimize Sample Disturbance," Geotechnical and Geophysical Site Characterization, Huang & Mayne (eds), Taylor and Francis Group, London, 2008

(7) Tanaka, H., Sharma, P., Tsuchida, T., and Tanaka, M., "Comparative Study on Sample Quality Using Several Types of Samplers," Soils and Foundations, Vol. 36, No. 2, 57-68, June 1996

(8) Lunne, T., Berre, T., Andersen, K.H., Strandvick, S., and M. Sjursen, (2006), "Effects of Sample Disturbance and Consolidation Procedures on Measured Shear Strength of Soft Marine Norwegian Clays, Can. Geotech. J 43: 726-750