**SOAH DOCKET NO. 582-15-2082**
**TCEQ DOCKET NO. 2015-0069-MSW**

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| **APPLICATION OF 130** | § | **BEFORE THE STATE OFFICE** |
| **ENVIRONMENTAL PARK, LLC** | § | |
| **FOR PROPOSED PERMIT** | § | **OF** |
| **NO. 2383** | § | |
| | § | **ADMINISTRATIVE HEARINGS** |

**PROTESTANTS' EXHIBIT 7**

# PREFILED TESTIMONY OF CRAIG SCOTT COURTNEY, P.G.

## ON BEHALF OF PROTESTANTS TJFA & EPICC

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| Exhibit No. | Description | Date |
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| Exhibit 7-A | Resume of Scott Courtney, P.G. | Not dated. |
| Exhibit 7-B | ASTM D1587 Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes | Not dated. |
| Exhibit 7-C | ASTM 1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils | Not dated. |
| Exhibit 7-D | ASTM Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock | Not dated. |

## I. INTRODUCTION

Q: Please state your name.

A: Craig Scott Courtney.

Q: Please state your address.

A: 102 Woodcrest, San Antonio, TX 78209

Q: Please describe your occupation.

A: I'm the owner of Premier Hydro and the CEO and geologist for that firm. I tend not to be the hour-by-hour drill operator, but I supervise drilling activities and sometimes operate equipment. Premier Hydro is a consulting and contracting firm specializing in Water Resources, Environmental Management, Oil & Gas, and Drilling & Site Characterization.

## II. QUALIFICATIONS

Q: Please describe your educational background.

A: I have a Bachelor of Science in Geology from the University of Texas at San Antonio, which I earned in 1991.

Q: Please describe the nature of your professional work.

A: I provide expertise to clients in the fields of drilling & sampling, geology, hydrogeology, well design, well siting, well installation, and site characterization.

Q: Are you a licensed geo-scientist in the State of Texas?

A: Yes. My License Number is 6413.

Q: How long have you been a licensed geologist?

A: Since 2005.

Q: Do you have any other licenses or registrations?

A: Yes, I hold Water Well License Number 2419W 1984-2007. I recently re-applied for this license in June of 2016.

Q: Do you have experience in subsurface evaluations?

A: Yes.

Q: Please describe your experience.

A: I have 35 years of experience, education, background, and training in geology, drilling (water wells, oil & gas wells, environmental site characterization, geotechnical borings, geothermal, and mineral exploration). I have owned and operated geotechnical, environmental, water well, and oil & gas drilling rigs and businesses. I have worked for geotechnical, engineering, water well, and oil & gas companies. I have worked on and with the Department of Defense, Department of Energy, federal and state superfund sites, and private industry.

Q: Do you have experience in overseeing subsurface drilling operations?

A: Yes. In fact, I have extensive experience and expertise that is directly relevant to the investigation and determination of suitability of solid waste landfill sites.

Q: Please describe your experience as it relates to drilling soil borings and subsurface explorations.

A: My drilling career began in approximately 1982 when my family was in the water well drilling business. I worked for various drilling companies over the next 10 years including Courtney Drilling (family owned), Raba Kistner (geotechnical & environmental), IT Corporation (environmental drilling & sampling primarily at hazardous waste landfills and other environmental characterization sites), Edwards Underground Water Districts (oversite of drilling and well installation activities), and Chen Northern (geotechnical drilling & sampling).

After receiving my Geology Degree in 1991, I was employed by IT Corporation as a geologist overseeing drilling, sampling, and well installation, with company-owned and sub-contracted drilling firms, at Department of Energy sites (Hanford Reservation & PANTEX), Department of Defense sites (Kelly Air Force Base, Tinker Air Force Base, McClellan Air Force Base, and others), Federal and State Superfund sites, and many other private facilities requiring environmental drilling, sampling, and well installation.

I am well versed and experienced in virtually all types of drilling equipment and a wide range of depths and diameters of soil borings and wells. I have operated mud rotary, air rotary, casing advance, cable tool, sonic, and straight flight and hollow stem augers, in diameters ranging from 2-inches to 36-inches, and depths ranging between surface to 10,000 feet below ground level.

Q: Do you have any experience related to solid waste landfills?

A: Yes, over the years I have drilled, sampled, and set monitoring wells at over 10 solid waste landfill sites.

Q: Do you have any experience in interpreting soil boring logs related to a solid waste landfill?

A: Yes. Over the years I have prepared, reviewed and interpreted several hundred soil boring logs related to solid waste landfills.

Q: Can you identify what has been marked as Exhibit 7-A?

A: Yes. This exhibit is a representative resume summarizing my experience in various areas of practice.

Q: Is this a true and accurate copy of your resume?

A: Yes.

**PROTESTANTS OFFER EXHIBIT 7-A**

Q: What materials have you reviewed in preparation for your testimony?

A: I have reviewed Applicant's soil boring logs & geotechnical results, Protestants' soil boring logs, samples, & geotechnical results, and I have observed first-hand subsurface soils & rock during Protestants' site characterization activities.

Q: Did you visit the property of the proposed landfill site?

A: Yes in February and the beginning of March, 2016.

Q: How many times did you visit the proposed landfill site?

A: About ten to twelve times.

Q: Describe the circumstances of your site visits.

A: I was hired to assist Protestants' site examination activities including trenching, drilling, soil sampling, geophysical logging, well installation, and borehole abandonment. This required me to arrange drilling activities and participate in trenching at the proposed landfill site on behalf of Protestants TJFA and EPICC. I supported the project by arranging for the contracting of a drilling company to conduct drilling and sampling at the site and oversaw drilling operations and the mechanics of core sampling at seven locations. I also operated a backhoe for trenching that extended to a maximum depth of five feet in two locations. My trenching work was directed by Dr. Lauren Ross. For all of my work at the proposed landfill site, I functioned as part of a team of professionals retained on behalf of EPICC and TJFA, which included Dr. Lauren Ross and Michael Rubinov. To be clear, I was not present during Applicant's drilling and sampling operations in 2016.

## III. SUMMARY OF OPINIONS

Q: Have you developed any opinions regarding the application by 130 Environmental Park, L.L.C. ("130 EP" or "Applicant") for Permit No. 2383?

A: Yes.

Q: On what subjects have you developed opinions?

A: The drilling & sampling techniques employed by Applicant, the geotechnical analyses by Applicant, and the veracity of the soil borings and well logs submitted by Applicant to the Texas Commission for Environmental Quality, also known as TCEQ, and the Texas Department of License and Regulation, known as TDLR.

Q: Please summarize your opinions.

A: <u>Drilling and Sampling:</u> Applicant employed a mud rotary drilling technique to advance the geotechnical soil borings, and the majority of the soil samples were collected utilizing Shelby Tubes. Shelby Tubes were not the appropriate soil sampling apparatus for much of the sampling because of the difficult subsurface conditions encountered at the site (such as gravels and cobbles in the upper section of the boreholes, very dense sandstone and siltstone, and very hard silts and clays).

Geo-technical Analysis:_In addition, Applicant appears to have used a subjective or biased selection process for submitting soil samples for geotechnical analyses and then used those results as representative of subsurface conditions favorable for a landfill site.

Boring Logs: Lastly, the Applicant submitted unreliable and inaccurate boring logs in the application that created a misleading and unreliable portrait of the soil conditions at the landfill site.

## IV. SUMMARY OF OPINION REGARDING SAMPLING METHOD USED BY APPLICANT

Q: Ok, let's begin with the first part of your opinion. Can you explain your first concern with the Applicant's reliance on Shelby Tubes for collecting samples?

A: Yes. Take for instance the log of Soil Boring No. BME-01 prepared by Biggs and Mathews, dated Technically Complete 2014, drilled in 2013, and submitted in the Application. Sample designated A1 is illustrated as covering the entire interval from 0-2 feet below ground surface (bgs). However pertinent information regarding actual interval achieved (pushed) and actual length of sample recovered (recovered) is missing leaving a reviewer with the impression of 100 % success rate in both length pushed and length recovered. Under the Material Description Sample A1 is described as CLAY, SILTY, dark brown, very stiff to hard, with pebbles, dry (CH). On the bottom of the log under Remarks Column there is a note titled – Sampling Method that states "Thin Wall Tube/Split Barrel, and an accompanying note that states: "Where a split barrel sampler was used to obtain the sample, the standard penetration test was not performed because the soils are cohesive." The Reviewer has no way to tell which sample method was used, and since no standard penetration test was conducted, if they used a split barrel sampler you have no information with respect to length driven with the 140 hammer, the blow counts, or the amount recovered. Yet the Applicant applied the (CH) designation over the entire 0-2 interval. This process was repeated on all logs submitted with the Application. An additional note under the Remarks column states: "Groundwater was not observed prior to the introduction of drilling fluids at a depth of 55 feet". This is inconsistent with the Wet Rotary Drilling Method. If Wet Rotary was utilized to advance the boring from surface to the total depth then drilling fluid would have been utilized throughout the entire drilling and sampling process, which could have masked the presence of groundwater at the location. Particularly if a bottom discharge drill bit was used which is not recommended by ASTM Standard D-1586. Applicant's predominant reliance on Shelby Tubes is inconsistent with ASTM standards. ASTM standards are the preeminent standard for the geotechnical and geo-environmental industries in the United States and internationally. There are ASTM standards that govern proper geotechnical soil sampling and analyses. ASTM D-1587 covers Shelby Tube sampling, which is a thin-walled sampler.

Q: Can you identify what has been marked as Exhibit 7-B?

A: Yes, this is a true and correct copy of ASTM D-1587.

**PROTESTANTS OFFER EXHIBIT 7-B INTO EVIDENCE.**

Q: Can you explain how Applicant's reliance on Shelby Tubes is inconsistent with ASTM standards?

A: Section 5.5 of ASTM D1587/1587M states, "The thin-walled tube sampler can be used to sample soft to medium stiff clays". The majority of soil samples extracted at the site were very stiff to hard (4.0 to 4.5+ on a pocket penetrometer). Thus for this reason, the use of the Shelby Tubes in this context was inconsistent with professional geotechnical standards.

Section 5.5 of the ASTM standard adds another reason why Shelby Tubes are not the appropriate sampling tool in this context: "gravely soils cannot be sampled and gravel will damage the thin-walled tubes." Gravely soils were encountered in the shallow subsurface and at depth in several locations sampled by the Protestants that were within 10 to 20 feet of Applicant's borings. In addition, siltstone and sandstone lenses were encountered, which are not suitable for sampling with Shelby Tubes.

I was informed by geologist Mike Rubinov and engineer Dr. Lauren Ross that on several occasions in 2016, while they were able to observe Applicant drill 11 borings, they witnessed Applicant's drillers experience difficulty with Shelby Tubes that resulted in damaged and bent tubes. During my presence on the proposed landfill tract, we also encountered subsurface conditions that were not suitable for collection using a Shelby Tube.

Q: What type of drilling and sampling method was used by Protestants during their site investigation?

A: We chose to utilize a rotary core method with hollow stem augers. The sample barrel was 4-inches inside diameter by 5-feet length. The larger barrel combined with the pressure applied by the drill rig was able to collect representative samples of the gravels, gravely clay, siltstone, and sandstone that could not be collected using Shelby Tubes.

There is a natural and recognized progression in geotechnical soil sampling. When subsurface conditions are too hard or stiff for using Shelby Tubes, split spoons (governed by ASTM D-1586) are driven with a 140-pound hammer repeatedly dropped over a 30-inch free fall to collect soil samples.

Q: Please identify what has been marked as Exhibit 7-C.

A: Exhibit 7-C is a true and correct copy of ASTM D-1586.

**PROTESTANTS OFFER EXHIBIT 7-C INTO EVIDENCE.**

Q. Can you further explain the natural and recognized progression of tools used in soil sampling?

A: Split spoons are utilized until subsurface conditions are such that a sufficient amount of penetration (less than 6 inches for 50 blows with the 140-pound hammer) cannot be achieved due to the density, firmness, and/or grain size of the subsurface soils. When split spoons are ineffective, you go to larger diameter rotary core methods. Rotary coring can be accomplished using air rotary, mud rotary, and hollow stem augers to advance the core barrel. Protestants' soil sampling followed this progression of soil sampling protocol. Applicant's did not.

Q: Applicant's geologist John Michael Snyder asserts, in his prefiled testimony, that your equipment and methods resulted in "sample recovery" problems. These problems he defines as "a large percentage of the samples" being "significantly disturbed." Do you agree with his assessment?

A: No. His statements are misleading and not true. It is important to distinguish between engineering and geologic perspectives when considering the use of "disturbed" samples. A "disturbed" sample is not a deficient sample. A disturbed sample does not diminish the quality or the value of the information that can be obtained from the sample. Whether an undisturbed sample is necessary (versus a disturbed sample) depends on the purpose of the sampling and the type of analysis that will be conducted.

Engineering analyses typically revolve around construction and properties of soils that can and do affect design. Geological analyses and investigations focus on the in situ state of subsurface conditions. The term "disturbed" versus "undisturbed" from an engineering perspective can be significant depending on the type of testing the engineer needs to evaluate. The term "disturbed" versus "undisturbed" may not be significant, at all, depending on the information a geologist needs to evaluate. A sample may be considered "disturbed" and be perfectly suitable for both an engineer and a geologist.

For our purposes, we considered permeability to be an important factor in determining the suitability of subsurface condition for a solid waste landfill, due to the potential for leachate migration and groundwater pollution potential. Undisturbed samples are more suitable for permeability analysis. So, we ran permeability analyses only on soil samples collected with Shelby Tubes in accordance with ASTM D-1587. In other words, the samples collected for permeability testing were "undisturbed."

The samples we collected using the 5' x 4-inch continuous split barrel were collected for geologic description, lithology (visually observing different layers of material based on grain size, color, consistency, grading, sorting, moisture) and geotechnical analyses other than permeability. None of these properties are modified, changed, or significantly altered using the 5' x 4-inch continuous split barrel. In other words, undisturbed samples are not necessary for these purposes. In fact, due to difficulties encountered attempting to collect ASTM-compliant soil samples utilizing Shelby tubes, we switched to a more reliable method of sampling both coarse grain and fine grain unconsolidated soil types encountered at the site. The larger diameter opening was better able to accommodate the coarse grain gravel and fine grain siltstone and sandstone layers of rock.

In addition, we were able to both collect and document much larger sample recovery and more representative quantities of soil for geologic descriptions and geotechnical analyses than the Applicant's consultants were able to with their mis-application of the Shelby Tube methods.

## V. OPINION REGARDING APPLICANT'S SOIL SELECTION PROCESS

Q: What about your second criticism or opinion? Can you summarize what you've described as Applicant's subjective sample selection process?

A: Yes. My concerns can be summarized as follows:

Applicant's consultants appear to have used a very subjective selection process for submitting soil samples for geotechnical analyses and then used those results as representative of subsurface conditions favorable for a landfill setting. By that, I mean it appears they only submitted soil samples that exhibited a high clay content for geotechnical analyses, thereby skewing the overall results to indicate the site was underlain by predominantly impermeable clays and therefore appropriate for a landfill site. By contrast, even the limited sampling and geotechnical analysis performed by Protestants' experts revealed highly variable subsurface conditions.

## VI. OPINION REGARDING APPLICANT'S BORING LOGS AND WELL REPORTS

Q: Similarly, can you summarize what you describe as the unreliability and incompleteness of Applicant's soil boring logs and well reports submitted to the TCEQ and TDLR?

A: Yes. ASTM Standard 5434 "Guide for Field Logging and Subsurface Exploration of Soil and Rock" provides guidance for professional standards in documenting information on field exploration procedures, which is used in concert with soil boring logs to provide a complete record of the subsurface investigation.. Applicant's boring logs, included in the application, fail to comply with these professional standards as described below.

Q: Please identify Exhibit 7-D.

A: Exhibit 7-D is a true and correct copy of ASTM Standard 5434.

**PROTESTANTS OFFER EXHIBIT 7-D INTO EVIDENCE.**

Q: Please describe how the Applicant's boring logs and well reports failed to comply with this ASTM standard and are otherwise unreliable and misleading.

A: The "soil boring logs" submitted by the Applicant in support of its Permit Application to TCEQ appear to be drafted in such a manner as to indicate the site was almost entirely underlain by highly plastic clays (CH). They present a subsurface picture of a homogeneous and isotropic clay formation when in fact that is not the case. Take for instance Applicant's soil boring log BME -32, long sections of boring logs (10-48 feet) are classified as entirely CH. We drilled MP-1 and MP-1A adjacent to BME – 32 and observed variability in the same nearby sections, including silts (ML), sandy Clays (CL), Clayed Gravels (GC), and siltstone and sandstone.

Moreover, critical information is missing from the Applicant's boring logs. Typical professionally prepared boring logs consistent with ASTM Standard 5434 include depth and sample interval attempted, length of interval successfully accomplished, and amount of recovery. For example, a typical log will state "push Shelby Tube from 10-12 feet bgs, recovered 18-inches." The Applicant's boring logs present the appearance of 100% success at all intervals with 100% recovery – something extremely unusual if not unprecedented in my 35 years of observing and conducting soil boring operations. My experience, background, education, and training along with our own soil sampling experience at the site lead me to believe the Applicant's boring logs are unreliable and misleading.

The State Well Reports submitted by Applicant to the TDLR for the permanent piezometers are false and misleading as well as they show the same oversimplified geology.

## V. CONCLUSION

Q: What opinion do you have of the reliability of the representations made by the Applicant of the subsurface conditions at the proposed landfill site?

A: For the reasons stated above, the representations made by the Applicant regarding subsurface soil conditions are not in agreement with site conditions I observed, are inconsistent with professional standards, and as such are not reliable. The Applicant's predominant reliance on Shelby Tubes was inconsistent with ASTM standards and obscured and missed soils containing gravel, sand, and other non-clay conditions. The soil samples submitted by the Applicant for analysis do not appear to be representative of subsurface soil conditions at the site. And the soil boring logs contain representations of subsurface conditions that are contradicted by the sampling I observed on behalf of Protestants. These boring logs omit information contained in a standard boring log and contain representations that are so insufficient as to not be credible.

Q: Does this conclude your testimony?

A: Yes, although I reserve the right to supplement this testimony.

# SCOTT COURTNEY, PG-TX
San Antonio, TX

Over 30 years professional experience in water resource management, environmental consulting, business development, and public relations/community involvement. Specializing in consulting related to: business development & program management; water resources & waste water management; environmental & regulatory compliance; and community relations.

Previous roles and responsibilities included; program management, business development, teaming & partnering, geologic consulting, strategic planning, environmental management, performance based strategies for environmental restoration, technical support for public affairs, providing technical review of document, written and oral presentations at public meetings, supporting negotiations with State and Federal regulators, assist in development of technical and regulatory legal defense in support of litigation, document review, field oversight, project planning and coordination, and data evaluation & management.

## Detailed Experience

**January 2001 to Present, Owner Premier Hydro –** Drilling and geologic consulting services related to the oil and gas, environmental, and water resources industries for both government and private entities. Support services include; technical, regulatory, public affairs, project management, strategic planning, and business development. Past performance includes water resource evaluation, environmental compliance, drilling & completion, well abandonment, permits & regulatory submittals, and all waste disposal activities including handling, storage, waste water treatment, waste profiling, manifesting, and disposal.

**January 2010 to January 2011 – Marcellus Shale Business Development –** Various Business Development/Program Management positions for engineering firms including FPM, Groundwater & Environmental Services, and SCE. Participating member of the Marcellus Shale Coalition and served on the Public relation subcommittee. Provide testimony during EPA Frac Study Workshop. Focused on Frac water sourcing, permitting, and delivery. In addition vetted numerous water treatment technologies and initiatives.

**October 2005 to JANUARY 2008, SRA GEITA05 Deputy/Program Manager**
Program Manager of $2M annual contract providing advisory & assistance services to AFCEE. Responsible for program management, task order management, business development, personnel oversight, client interface, budget development and tracking, monthly status reporting, invoicing, and technical support.

**October 1999 to 2004, Booz Allen Hamilton, San Antonio TX, Hydrogeologist, Level III**
Providing on site Advisory and Assistance support to the Air Force Real Property Agency (AFRPA) at former Kelly AFB. Duties and responsibilities included: directly supporting AFRPA in strategic planning; government procurement services, evaluation of environmental liabilities associated with realignment of former Kelly AFB facilities and infrastructure to Lackland AFB; development of performance based strategies for environmental restoration; providing technical support for public affairs documents at Kelly AFB; providing technical review of document; written and oral presentations at public meetings; supporting negotiations with State and Federal regulators; assist in developing technical and regulatory legal defense in support of litigation,

performing document review, field oversight, project planning and coordination, and data evaluation.

**July 1996 to October 1999, Waste Policy Institute, San Antonio TX, Hydrologist.** Technical consultant supporting the Air Force Center for Environmental Excellence. On-site technical support to Environmental Management Restoration East Kelly at Kelly AFB. Duties include performing document review, field oversight, project planning and coordination, data evaluation, regulatory interface, and technical presentations. Responsible for providing technical support on all Zone 4 activities associated with the Compliance Plan, Basewide Groundwater Remedial Assessment, and modeling. Also responsible for coordinating Zone 4 environmental restoration project Peer Reviews. Primary projects responsibilities included the investigation and remedy determination for off-Base chlorinated solvents plume and construction of 6600 linear feet of hydraulic control around the perimeter of East Kelly, AFB.

Previously served as point of contact for K. I. Sawyer AFB, Gwinn, Michigan. Responsible for determining final remedy for large fuel spill. Compiled and evaluated pertinent site data, developed conceptual site model and identified data gaps, and prepared Work Plan which led to final remedial action plan accepted by Michigan Department of Environmental Quality and EPA.

**June 1991 to June 1996, IT Corp., Austin TX, Geologist.** Performed various duties including but not limited to well site geologist, field supervisor, field manager, and task manager. Prepared procurement documents, work plans, technical reports, proposals, and performed technical presentations. Participated in domestic and international business development. Provided services to DOE, DOD, COE, multi-state, and local government entities as wells as commercial and industrial clients. Awarded IT National Quality Award, 1994 for participation as Field Manager of Burning Grounds RCRA Facility Investigation, DOE, Pantex Facility.

**December 1990 to June 1991, Williams Co., San Antonio TX, Consulting Geologist.** Duties and responsibilities included geophysical log interpretation, geologic mapping and cross-section development, and well site geologist in support of horizontal well drilling in the Austin Chalk-Pearsall field.

**September 1990 to December 1990, United States Geological Survey, San Antonio TX, Student Intern/Hydrologist.** Duties included geophysical log interpretation and filing, populating water well database, and various field activities.

**July 1990 to August 1990, Envirodrill, Houston TX, Driller.** Licensed driller responsible for operating drilling rigs and supervising crew. Duties included drilling, soil sampling, monitoring well design and installation, well plugging and abandonment, well development, and groundwater sampling.

**September 1988 to May 1990, Edwards Underground Water District, San Antonio TX, Student Intern/Hydrologic Technician.** Duties included performing geophysical well logging, log interpretation; collecting, interpreting, and recording monthly water level data; locating abandoned Edwards aquifer wells, identifying ownership, providing technical assistance in plugging and abandoning wells; and monitoring aquifer recharge facilities.

**September 1987 to September 1988, Chen Northern, San Antonio, TX, Driller.** Licensed driller responsible for operating drilling rigs and supervising crew. Duties included drilling, soil sampling, monitoring well design and installation, well plugging and abandonment, well development, and groundwater sampling.

**July 1986 to September 1987, IT Corporation, Austin TX, Driller.** Licensed driller responsible for operating drilling rigs and supervising crew. Duties included drilling, soil sampling, monitoring well design and installation, well plugging and abandonment, well development, and groundwater sampling.

**July 1985 to July 1986, Raba Kistner Corp., San Antonio TX, Driller.** Licensed driller responsible for operating drilling rigs and supervising crew. Duties included drilling, soil sampling, monitoring well design and installation, well plugging and abandonment, well development, and groundwater sampling.

**January 1984 to July 1985, Courtney Drilling, San Antonio TX. Owner/Operator.** Water well drilling contractor operating in San Antonio area.

**Education**
Bachelor of Science Degree, Geology, University of Texas at San Antonio, 1991

**Training & Registrations**
**State of Texas Professional Geoscientist License No. 6413**
**Texas Water Well Drillers License No. 2419 1984-2005**
**OSHA 40-Hour HAZWOPER Training**
**OSHA 8-Hour HAZWOPER Supervisor Training**
**OSHA 8-Hour HAZWOPER Refresher Training, 2008**
**DOE RAD Worker II Training**
**US Government Procurement Integrity Training**
**NGWA Short Course: Understanding Migration and Remediation of Non-Aqueous Phase Liquids**

**Chairman of 2013/14 South Texas Wildcatters Host Committee** under the Texas Alliance of Energy Producers.. Member and contributing author of the **SHALE Oil & Gas Magazine** Advisory Board 2013/2014.

**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

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[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).

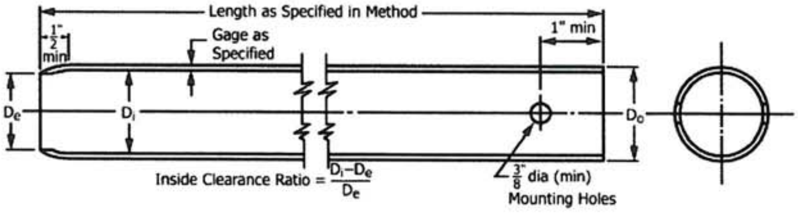
3.3.2 $C_r$—clearance ratio (see 3.2.2).

## 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



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

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)**

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

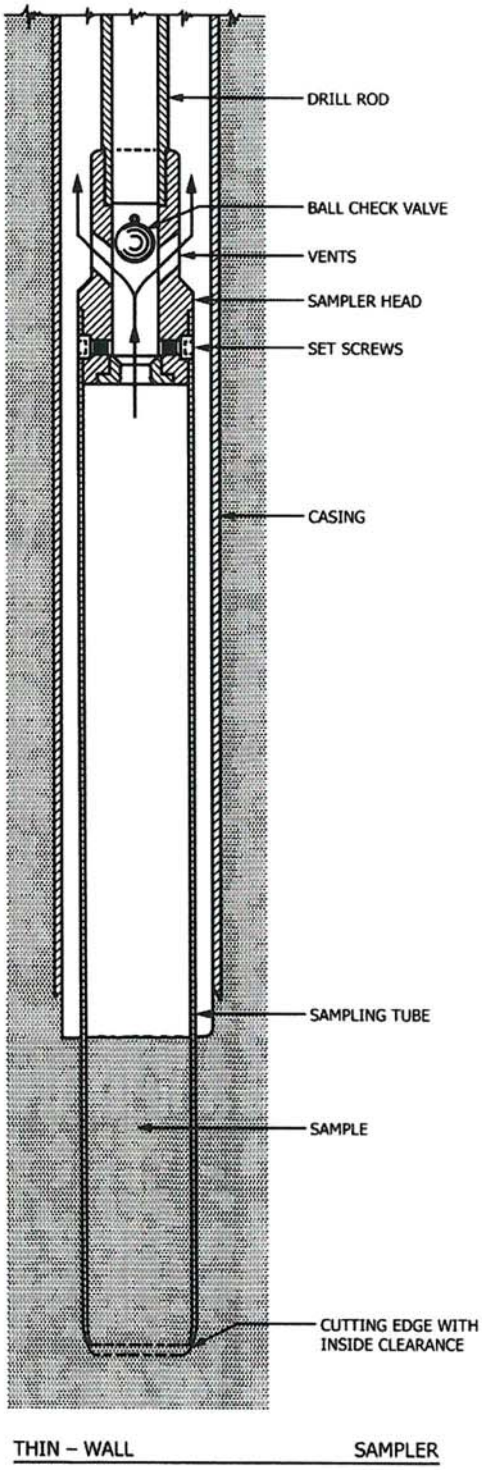

**FIG. 2 Thin-Walled Tube Sampler Schematic and Operation (1)**

**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).

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.

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).

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[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).

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[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<br>-0.000 | +0.179<br>-0.000 | +0.010<br>-0.000 | +0.254<br>-0.000 | +0.015<br>-0.000 | 0.381<br>-0.000 |
| Inside diameter, $D_i$ | +0.000<br>-0.007 | +0.000<br>-0.179 | +0.000<br>-0.010 | +0.000<br>-0.254 | +0.000<br>-0.015 | +0.000<br>-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

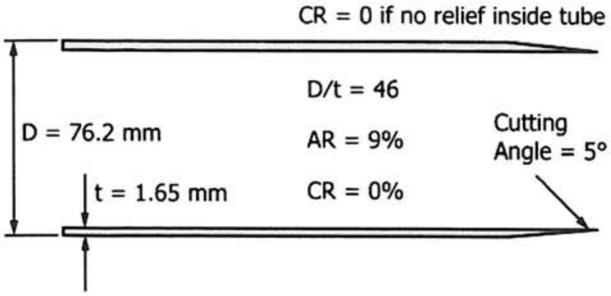

**FIG. 3 Schematic of Standard 3-in. [75-mm] Thin-Walled Tube Modified by Removing the Beveled Cutting Edge and Machining a Five-Degree Cutting Angle (DeGroot and Landon (6)).**

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

**Designation: D1586 – 11**

# Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils[1]

## 1. Scope*

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative disturbed soil sample for identification purposes, and measure the resistance of the soil to penetration of the sampler. Another method (Test Method D3550) to drive a split-barrel sampler to obtain a representative soil sample is available but the hammer energy is not standardized.

1.2 Practice D6066 gives a guide to determining the normalized penetration resistance of sands for energy adjustments of N-value to a constant energy level for evaluating liquefaction potential.

1.3 Test results and identification information are used to estimate subsurface conditions for foundation design.

1.4 Penetration resistance testing is typically performed at 5-ft depth intervals or when a significant change of materials is observed during drilling, unless otherwise specified.

1.5 This test method is limited to use in nonlithified soils and soils whose maximum particle size is approximately less than one-half of the sampler diameter.

1.6 This test method involves use of rotary drilling equipment (Guide D5783, Practice D6151). Other drilling and sampling procedures (Guide D6286, Guide D6169) are available and may be more appropriate. Considerations for hand driving or shallow sampling without boreholes are not addressed. Subsurface investigations should be recorded in accordance with Practice D5434. Samples should be preserved and transported in accordance with Practice D4220 using Group B. Soil samples should be identified by group name and symbol in accordance with Practice D2488.

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

1.8 The values stated in inch-pound units are to be regarded as standard, except as noted below. The values given in parentheses are mathematical conversions to SI units, which are provided for information only and are not considered standard.

1.8.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs.

1.9 Penetration resistance measurements often will involve safety planning, administration, and documentation. This test method does not purport to address all aspects of exploration and site safety. *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.* Performance of the test usually involves use of a drill rig; therefore, safety requirements as outlined in applicable safety standards (for example, OSHA regulations,[2] NDA Drilling Safety Guide,[3] drilling safety manuals, and other applicable state and local regulations) must be observed.

## 2. Referenced Documents

2.1 *ASTM Standards:*[4]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

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[1] This method 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.

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[2] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, http://www.osha.gov.

[3] Available from the National Drilling Association, 3511 Center Rd., Suite 8, Brunswick, OH 44212, http://www.nda4u.com.

[4] 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**

D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4220 Practices for Preserving and Transporting Soil Samples
D4633 Test Method for Energy Measurement for Dynamic Penetrometers
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
D6066 Practice for Determining the Normalized Penetration Resistance of Sands for Evaluation of Liquefaction Potential
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
D6286 Guide for Selection of Drilling Methods for Environmental Site Characterization
D6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

## 3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of terms included in Terminology D653 specific to this practice are:

3.1.2 *cathead, n*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods, n*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *N-value, n*—the blow count representation of the penetration resistance of the soil. The *N*-value, reported in blows per foot, equals the sum of the number of blows (*N*) required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.5 *Standard Penetration Test (SPT), n*—a test process in the bottom of the borehole where a split-barrel sampler having an inside diameter of either 1-1/2-in. (38.1 mm) or 1-3/8-in. (34.9 mm) (see Note 2) is driven a given distance of 1.0 ft (0.30 m) after a seating interval of 0.5 ft (0.15 m) using a hammer weighing approximately 140-lbf (623-N) falling 30 ± 1.0 in. (0.76 m ± 0.030 m) for each hammer blow.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *anvil, n*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.2.2 *drive weight assembly, n*—an assembly that consists of the hammer, anvil, hammer fall guide system, drill rod attachment system, and any hammer drop system hoisting attachments.

3.2.3 *hammer, n*—that portion of the drive-weight assembly consisting of the 140 ± 2 lbf (623 ± 9 N) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.2.4 *hammer drop system, n*—that portion of the drive-weight assembly by which the operator or automatic system accomplishes the lifting and dropping of the hammer to produce the blow.

3.2.5 *hammer fall guide, n*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.2.6 *number of rope turns, n*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by 360° (see Fig. 1).

3.2.7 *sampling rods, n*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

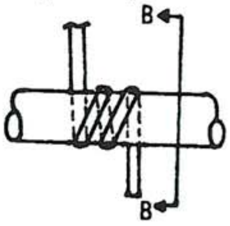
## 4. Significance and Use

4.1 This test method provides a disturbed soil sample for moisture content determination, for identification and classification (Practices D2487 and D2488) purposes, and for laboratory tests appropriate for soil obtained from a sampler that will produce large shear strain disturbance in the sample such as Test Methods D854, D2216, and D6913. Soil deposits containing gravels, cobbles, or boulders typically result in penetration refusal and damage to the equipment.

4.2 This test method provides a disturbed soil sample for moisture content determination and laboratory identification. Sample quality is generally not suitable for advanced laboratory testing for engineering properties. The process of driving the sampler will cause disturbance of the soil and change the engineering properties. Use of the thin wall tube sampler (Practice D1587) may result in less disturbance in soft soils. Coring techniques may result in less disturbance than SPT sampling for harder soils, but it is not always the case, that is, some cemented soils may become loosened by water action during coring; see Practice D6151, and Guide D6169.

4.3 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate blow count, or *N*-value, and the engineering behavior of earthworks and foundations are available. For evaluating the liquefaction potential of sands during an earthquake event, the *N*-value should be normalized to a standard overburden stress level. Practice D6066 provides methods to obtain a record of

(*a*) counterclockwise rotation
approximately 1¾ turns



(*b*) clockwise rotation
approximately 2¼ turns

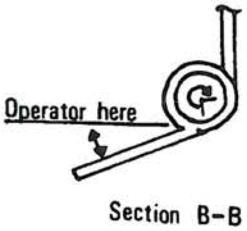


**FIG. 1 Definitions of the Number of Rope Turns and the Angle for (*a*) Counterclockwise Rotation and (*b*) Clockwise Rotation of the Cathead**

normalized resistance of sands to the penetration of a standard sampler driven by a standard energy. The penetration resistance is adjusted to drill rod energy ratio of 60 % by using a hammer system with either an estimated energy delivery or directly measuring drill rod stress wave energy using Test Method D4633.

NOTE 1—The reliability of data and interpretations generated by this practice 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 generally are considered capable of competent testing. Users of this practice are cautioned that compliance with Practice D3740 does not assure reliable testing. Reliable testing depends on several factors and Practice D3740 provides a means of evaluating some of these factors. Practice D3740 was developed for agencies engaged in the testing, inspection, or both, of soils and rock. As such, it is not totally applicable to agencies performing this practice. Users of this test method should recognize that the framework of Practice D3740 is appropriate for evaluating the quality of an agency performing this test method. Currently, there is no known qualifying national authority that inspects agencies that perform this test method.

## 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitable borehole before insertion of the sampler and ensures that the penetration test is performed on intact soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions:

5.1.1 *Drag, Chopping, and Fishtail Bits,* less than 6½ in. (165 mm) and greater than 2¼ in. (57 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits,* less than 6½ in. (165 mm) and greater than 2¼ in. (57 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers,* with or without a center bit assembly, may be used to drill the borehole. The inside diameter of the hollow-stem augers shall be less than 6½ in. (165 mm) and not less than 2¼ in. (57 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers,* less than 6½ in. (165 mm) and not less than 2¼ in. (57 mm) in diameter may be used if the soil on the side of the borehole does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod that has an outside diameter of 1-5/8 in. (41.3 mm) and an inside diameter of 1-1/8 in. (28.5 mm).

5.3 *Split-Barrel Sampler*—The standard sampler dimensions are shown in Fig. 2. The sampler has an outside diameter of 2.00 in. (50.8 mm). The inside diameter of the of the split-barrel (dimension D in Fig. 2) can be either 1½-in. (38.1 mm) or 1⅜-in. (34.9 mm) (see Note 2). A 16-gauge liner can be used inside the 1½-in. (38.1 mm) split barrel sampler. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The penetrating end of the drive shoe may be slightly rounded. The split-barrel sampler must be equipped with a ball check and vent. Metal or plastic baskets may be used to retain soil samples.

NOTE 2—Both theory and available test data suggest that *N*-values may differ as much as 10 to 30 % between a constant inside diameter sampler and upset wall sampler. If it is necessary to correct for the upset wall sampler refer to Practice D6066. In North America, it is now common practice to use an upset wall sampler with an inside diameter of 1½ in. At one time, liners were used but practice evolved to use the upset wall sampler without liners. Use of an upset wall sampler allows for use of retainers if needed, reduces inside friction, and improves recovery. Many other countries still use a constant ID split-barrel sampler, which was the original standard and still acceptable within this standard.

5.4 *Drive-Weight Assembly:*

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lbf (623 ± 9 N) and shall be a rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting an unimpeded fall shall be used. Fig. 3 shows a schematic of such hammers. Hammers used with the cathead and rope method shall have an unimpeded over lift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged as shown in Fig. 3. The total mass of the hammer assembly bearing on the drill rods should not be more than 250 ± 10 lbm (113 ± 5 kg).

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

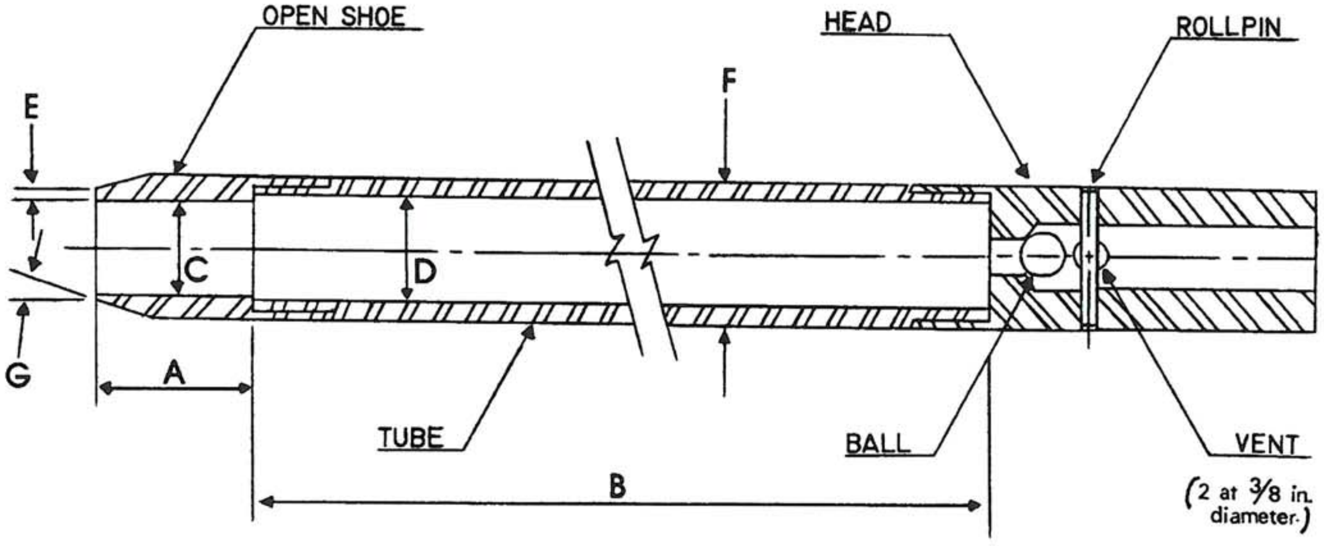
5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

## 6. Drilling Procedure

6.1 The borehole shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata. Record the depth of drilling to the nearest 0.1 ft (0.030 m).

6.2 Any drilling procedure that provides a suitably clean and stable borehole before insertion of the sampler and assures that the penetration test is performed on essentially intact soil shall be acceptable. Each of the following procedures has proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 – 0.00 in. (38.1 ± 1.3 – 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 – 0.00 in. (50.8 ± 1.3 – 0.0 mm)
G = 16.0° to 23.0°

**FIG. 2 Split-Barrel Sampler**

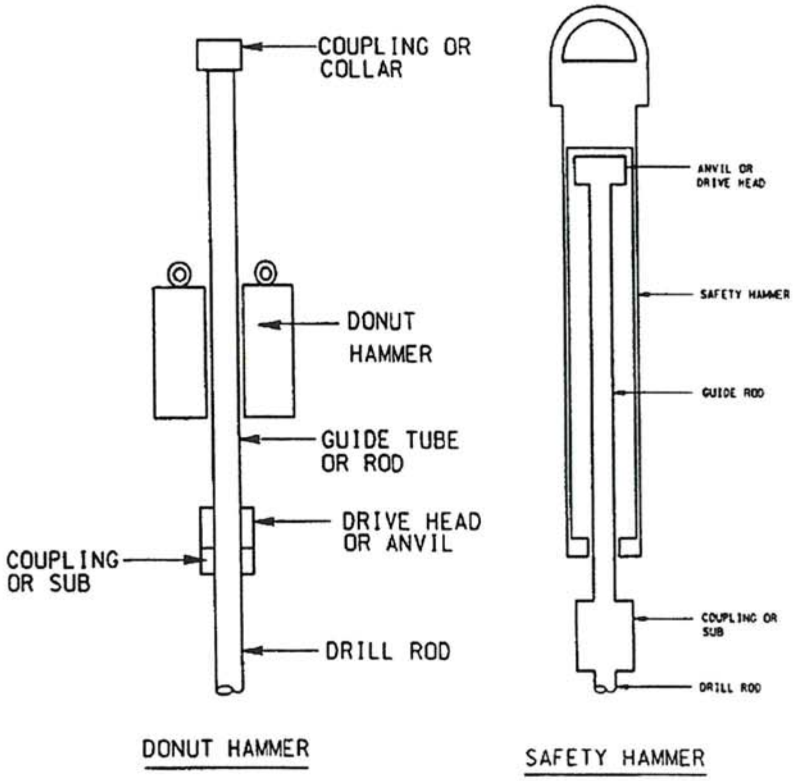


**FIG. 3 Schematic Drawing of the Donut Hammer and Safety Hammer**

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable boreholes. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the borehole below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a borehole with bottom discharge bits is not permissible. It is not permissible to advance the borehole for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the borehole or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

## 7. Sampling and Testing Procedure

7.1 After the borehole has been advanced to the desired sampling elevation and excessive cuttings have been removed, record the cleanout depth to the nearest 0.1 ft (0.030 m), and prepare for the test with the following sequence of operations:

7.1.1 Attach either split-barrel sampler Type A or B to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the borehole. Record the sampling start depth to the nearest 0.1 ft (0.030 m). Compare the sampling start depth to the cleanout depth in 7.1. If excessive cuttings are encountered at the bottom of the borehole, remove the sampler and sampling rods from the borehole and remove the cuttings.

7.1.4 Mark the drill rods in three successive 0.5-ft (0.15 m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 0.5-ft (0.15 m) increment.

7.2 Drive the sampler with blows from the 140-lbf (623-N) hammer and count the number of blows applied in each 0.5-ft (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 0.5-ft (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 1.5 ft. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.2.5 If the sampler sinks under the weight of the hammer, weight of rods, or both, record the length of travel to the nearest 0.1 ft (0.030 m), and drive the sampler through the remainder of the test interval. If the sampler sinks the complete interval, stop the penetration, remove the sampler and sampling rods from the borehole, and advance the borehole through the very soft or very loose materials to the next desired sampling elevation. Record the *N*-value as either weight of hammer, weight of rods, or both.

7.3 Record the number of blows (*N*) required to advance the sampler each 0.5-ft (0.15 m) of penetration or fraction thereof. The first 0.5-ft (0.15 m) is considered to be a seating drive. The sum of the number of blows required for the second and third 0.5-ft (0.15 m) of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 1.5 ft (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 0.5-ft (0.15 m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 0.1 ft (0.030 m) in addition to the number of blows. If the sampler advances below the bottom of the borehole under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lbf (623-N) hammer shall be accomplished using either of the following two methods. Energy delivered to the drill rod by either method can be measured according to procedures in Test Method D4633.

7.4.1 *Method A*—By using a trip, automatic, or semi-automatic hammer drop system that lifts the 140-lbf (623-N) hammer and allows it to drop 30 ± 1.0 in. (0.76 m ± 0.030 m) with limited unimpedence. Drop heights adjustments for automatic and trip hammers should be checked daily and at first indication of variations in performance. Operation of automatic hammers shall be in strict accordance with operations manuals.

7.4.2 *Method B*—By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM.

7.4.2.3 The operator should generally use either 1-3/4 or 2-1/4 rope turns on the cathead, depending upon whether or not the rope comes off the top (1-3/4 turns for counterclockwise rotation) or the bottom (2-1/4 turns for clockwise rotation) of the cathead during the performance of the penetration test, as shown in Fig. 1. It is generally known and accepted that 2-3/4 or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be stiff, relatively dry, clean, and should be replaced when it becomes excessively frayed, oily, limp, or burned.

7.4.2.4 For each hammer blow, a 30 ± 1.0 in. (0.76 m ± 0.030 m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

NOTE 4—If the hammer drop height is something other than 30 ± 1.0 in. (0.76 m ± 0.030 m), then record the new drop height. For soils other than sands, there is no known data or research that relates to adjusting the *N*-value obtained from different drop heights. Test method D4633 provides information on making energy measurement for variable drop heights and Practice D6066 provides information on adjustment of *N*-value to a constant energy level (60 % of theoretical, N60). Practice D6066 allows the hammer drop height to be adjusted to provide 60 % energy.

7.5 Bring the sampler to the surface and open. Record the percent recovery to the nearest 1 % or the length of sample recovered to the nearest 0.1 ft (30 mm). Classify the soil samples recovered as to, in accordance with Practice D2488, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 0.5-ft (150-mm) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel. Samples should be preserved and transported in accordance with Practice D4220 using Group B.

## 8. Data Sheet(s)/Form(s)

8.1 Data obtained in each borehole shall be recorded in accordance with the Subsurface Logging Guide D5434 as required by the exploration program. An example of a sample data sheet is included in Appendix X1.

8.2 Drilling information shall be recorded in the field and shall include the following:

8.2.1 Name and location of job,

8.2.2 Names of crew,

8.2.3 Type and make of drilling machine,

8.2.4 Weather conditions,

8.2.5 Date and time of start and finish of borehole,

8.2.6 Boring number and location (station and coordinates, if available and applicable),

8.2.7 Surface elevation, if available,

8.2.8 Method of advancing and cleaning the borehole,

8.2.9 Method of keeping borehole open,

8.2.10 Depth of water surface to the nearest 0.1 ft (30 mm) and drilling depth to the nearest 0.1 ft (30 mm) at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.2.11 Location of strata changes, to the nearest 0.5 ft (150 mm),

8.2.12 Size of casing, depth of cased portion of borehole to the nearest 0.1 ft (30 mm),

8.2.13 Equipment and Method A or B of driving sampler,

8.2.14 Sampler length and inside diameter of barrel, and if a sample basket retainer is used,

8.2.15 Size, type, and section length of the sampling rods, and

8.2.16 Remarks.

8.3 Data obtained for each sample shall be recorded in the field and shall include the following:

8.3.1 Top of sample depth to the nearest 0.1 ft (30 mm) and, if utilized, the sample number,

8.3.2 Description of soil,

8.3.3 Strata changes within sample,

8.3.4 Sampler penetration and recovery lengths to the nearest 0.1 ft (30 mm), and

8.3.5 Number of blows per 0.5 ft (150 mm) or partial increment.

## 9. Precision and Bias

9.1 *Precision*—Test data on precision is not presented due to the nature of this test method. It is either not feasible or too costly at this time to have ten or more agencies participate in an in situ testing program at a given site.

9.1.1 The Subcommittee 18.02 is seeking additional data from the users of this test method that might be used to make a limited statement on precision. Present knowledge indicates the following:

9.1.1.1 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent boreholes in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.1.1.2 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

## 10. Keywords

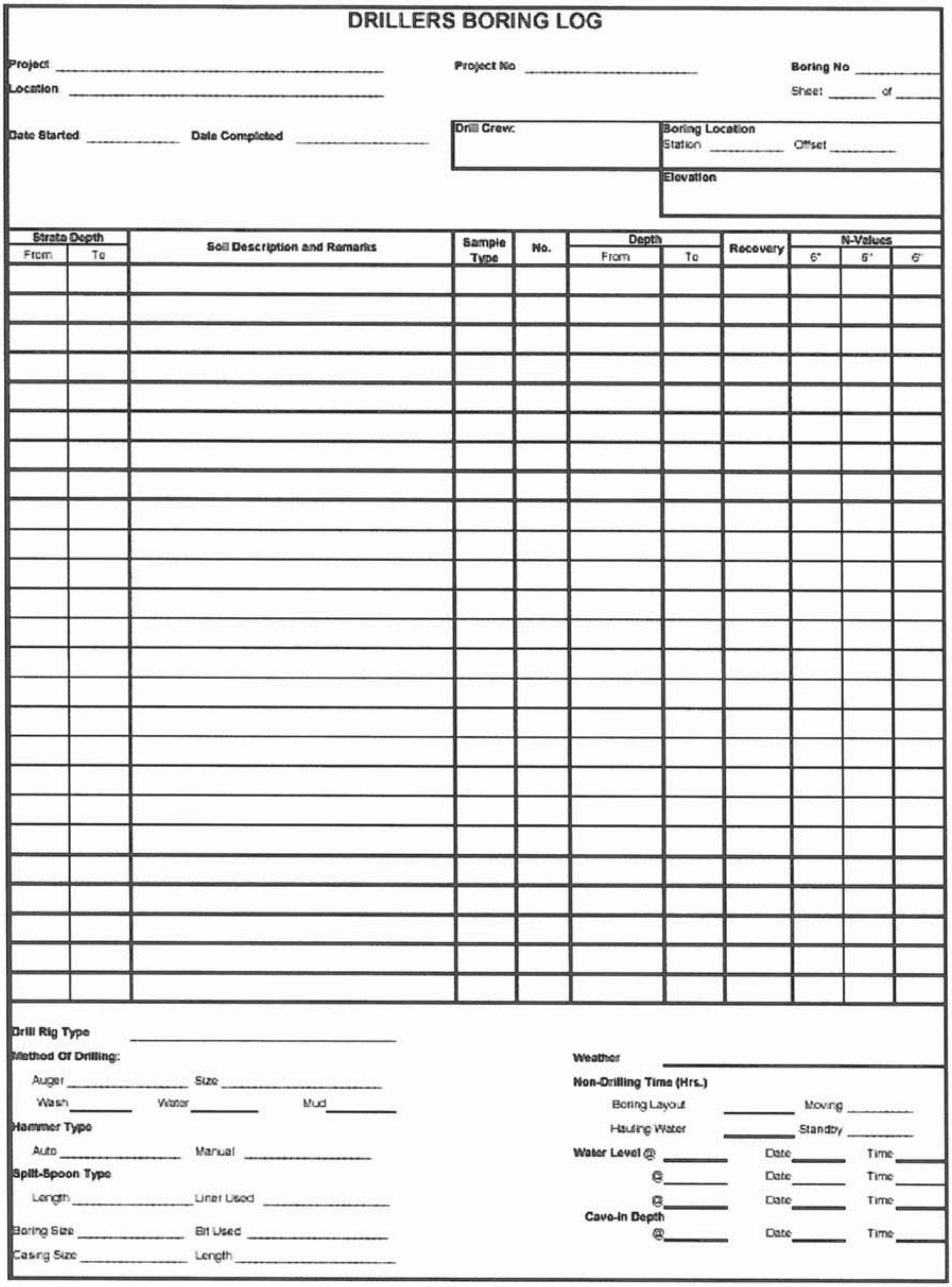
10.1 blow count; in-situ test; penetration resistance; soil; split-barrel sampling; standard penetration test

## APPENDIX

### (Nonmandatory Information)

### X1. Example Data Sheet

X1.1 See Fig. X1.1



## DRILLERS BORING LOG

**Project** ______________________ **Project No** ______________ **Boring No** ________

**Location** ______________________ Sheet ______ of ______

**Date Started** __________ **Date Completed** __________

**Drill Crew:**

**Boring Location**
Station __________ Offset __________

**Elevation**

| Strata Depth | | Soil Description and Remarks | Sample Type | No. | Depth | | Recovery | N-Values | | |
|---|---|---|---|---|---|---|---|---|---|---|
| From | To | | | | From | To | | 6" | 6" | 6" |
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**Drill Rig Type** ______________________

**Method Of Drilling:**
Auger __________ Size __________
Wash ______ Water ______ Mud ______

**Hammer Type**
Auto __________ Manual __________

**Split-Spoon Type**
Length __________ Liner Used __________

Boring Size __________ Bit Used __________
Casing Size __________ Length __________

**Weather** ______________________

**Non-Drilling Time (Hrs.)**
Boring Layout ______ Moving ______
Hauling Water ______ Standby ______

**Water Level** @ ______ Date ______ Time ______
@ ______ Date ______ Time ______
@ ______ Date ______ Time ______

**Cave-In Depth**
@ ______ Date ______ Time ______

FIG. X1.1 Example Data Sheet

## SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this test method since the last issue, D1586–08a, that may impact the use of this test method. (Approved November 1, 2011)

(*1*) Corrected misuse of significant digits.

Designation: D5434 – 12

# Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock[1]

This standard is issued under the fixed designation D5434; 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 describes the type of information that should be recorded during field subsurface explorations in soil and rock.

1.2 This guide is not intended to specify all of the information required for preparing field logs. Such requirements will vary depending on the purpose of the investigation, the intended use of the field log, and particular needs of the client or user.

1.3 This guide is applicable to boreholes, auger holes, excavated pits, or other subsurface exposures such as road side cuts or stream banks. This guide may serve as a supplement to Guide D420.

1.4 This guide may not be suited to all types of subsurface exploration such as mining, agricultural, geologic hazardous waste, or other special types of exploration.

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

1.6 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care of 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.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D420 Guide to Site Characterization for Engineering Design and Construction Purposes (Withdrawn 2011)[3]
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D2573 Test Method for Field Vane Shear Test in Cohesive Soil
D3441 Test Method for Mechanical Cone Penetration Tests of Soil
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)
D4220 Practices for Preserving and Transporting Soil Samples
D4403 Practice for Extensometers Used in Rock
D4544 Practice for Estimating Peat Deposit Thickness
D4623 Test Method for Determination of In Situ Stress in Rock Mass by Overcoring Method—USBM Borehole Deformation Gauge

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[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of D18.02 onIdentification and Classification of Soils.

Current edition approved Feb. 1, 2012. Published March 2012. Originally approved in 1993. Last previous edition approved in 2009 as D5434–09. DOI: 10.1520/D5434-12.

[2] For referenced ASTM standard, 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 of the ASTM website.

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

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

D4633 Test Method for Energy Measurement for Dynamic Penetrometers

D4645 Test Method for Determination of In-Situ Stress in Rock Using Hydraulic Fracturing Method

D4719 Test Methods for Prebored Pressuremeter Testing in Soils

D4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well) (Withdrawn 2010)[3]

D4879 Guide for Geotechnical Mapping of Large Underground Openings in Rock

D5079 Practices for Preserving and Transporting Rock Core Samples

D6032 Test Method for Determining Rock Quality Designation (RQD) of Rock Core

## 3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *field log*—a record prepared during subsurface explorations of soil and rock to document procedures used, test data, descriptions of materials and depths where encountered, ground water conditions, and other information.

## 4. Summary of Guide

4.1 This guide describes the type of information that should be recorded during the execution of field subsurface explorations in soil and rock. The information described relates to the project, personnel, methods of investigation and equipment used, visual description of subsurface materials and ground water conditions, in-situ testing, installation of monitoring equipment, and other data that may be appropriate.

## 5. Significance and Use

5.1 The preparation of field logs provides documentation of field exploration procedures and findings for geotechnical, geologic, hydrogeologic, and other investigations of subsurface site conditions. This guide may be used for a broad range of investigations.

5.2 The recorded information in a field log will depend on the specific purpose of the site investigation. All of the information given in this guide need not appear in all field logs.

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

## 6. Summary of Work

6.1 Soil and rock field logs should include the following written information:

6.1.1 Project information should include:

6.1.1.1 Name and location of the project or project number, or both,

6.1.1.2 Name of personnel onsite during the exploration, such as drilling crew, supervisor, geologist, engineer, and technicians,

6.1.1.3 Names and addresses of organizations involved,

6.1.1.4 Name of person(s) preparing log,

6.1.1.5 Reference datum for project if available and description of datum, and

6.1.1.6 General remarks as appropriate.

6.1.2 Exploration information should include:

6.1.2.1 Exploration number and location (station and coordinates if available and applicable, position relative to a local permanent reference which is identified, or markings of exploration location),

6.1.2.2 Type of exploration, such as drill hole, auger hole, test pit, or road cut,

6.1.2.3 Date and time of start and finish,

6.1.2.4 Weather conditions including recent rain or other events that could affect subsurface conditions,

6.1.2.5 Depth and size of completed exploration,

6.1.2.6 The condition of exploration prior to and after backfilling or sealing, or both, and

6.1.2.7 Method of backfilling or sealing exploration, or both.

6.1.3 Explorations by drill hole or auger hole should include the following drilling information:

6.1.3.1 Type and make (manufacture and model if known) of drilling machine or description and name of contractor,

6.1.3.2 Method of drilling or advancing and cleaning the borehole. State if air, water, or drilling fluid is used. Describe type, source of water and additives, concentration, and tests performed on fluid,

6.1.3.3 Size, type, and section length of drilling rods (rod designations should conform with Table 3 of Method D2113) and drilling bits used.

6.1.3.4 Dates and times of each stage of operation and time to complete intervals,

6.1.3.5 Size of hole (diameter and depth),

6.1.3.6 Ground elevation at top of borehole,

6.1.3.7 Orientation of drill hole, if not vertical (azimuth or bearing and angle),

NOTE 2—Even with careful drilling, the actual subsurface path of both vertical and inclined drill holes may be different from the intended direction of drilling. Deflection of the drill bit due to inclined bedding and hard boulders are some of the many reasons a drill hole might deviate from the intended direction. Drill holes that deviate from the intended direction can give erroneous data if not corrected. This can lead to significant interpretation errors of subsurface conditions and geologic structure. Depending on intended use of the data, it may be prudent to perform a borehole survey so the borehole spatial data can be corrected.

6.1.3.8 Size and description of casing, if appropriate, method of casing installation (driven, drilled, or pushed) and depth of cased portion of boring (casing size designations should conform with Table 2 of Method D2113), hollow-stem augers,

6.1.3.9 Methods used for cleaning equipment or drilling tools, or both, when required, and

6.1.3.10 Describe and state depth of any drilling problems such as borehole instability (cave in, squeezing hole, flowing sands), cobbles, lost drilling fluid, lost ground, obstruction, fluid return color changes, and equipment problems.

6.1.4 Exploration by test pit, road cut, stream cut, etc., should include:

6.1.4.1 Method of exploration,

6.1.4.2 Equipment used for excavation,

6.1.4.3 Type of shoring used, and

6.1.4.4 Excavation problems: instability of cut (sloughing, caving, etc.), depth of refusal, difficulty of excavating, etc.

6.1.5 Subsurface information should include:

6.1.5.1 Depth of changes and discontinuities in geologic material and method used to establish change (such as Practice D4544).

6.1.5.2 Description of material encountered with origin or formation name, if possible, and type of samples used for description. The system or method of soil (such as Practices D2488 and D4083) or rock description should be referenced.

6.1.5.3 Description of nature of boundary between strata (gradual or abrupt, as appropriate) and other relevant structural features such as breccia, slickensides, solution zones, discolorations by weathering or hydrothermal fluids, and other stratigraphic information.

6.1.6 Soil or rock sampling and testing information should include:

6.1.6.1 Depth of each sample and number (if used),

6.1.6.2 Method of sampling (reference to appropriate ASTM standard, for example, Practice D1452, Test Method D1586, Method D1587, Practice D3550, or other method).

6.1.6.3 Description of sampler: inside and outside dimensions, length, type of metal, type of coating, and type of liner,

6.1.6.4 Method of sampler insertion: pushed, cored, or driven,

6.1.6.5 Sampler penetration and recovery length of sample. For each rock sample (core run), record the rock quality designation (RQD) in accordance with Test Method D6032, and the rate of coring,

6.1.6.6 Method of sample extrusion. Mark direction of extrusion,

6.1.6.7 Method of preserving samples and preparing for transport (refer to Practices D4220 or D5079),

6.1.6.8 Mark top and bottom of samples and orientation, if possible,

6.1.6.9 Depth and description of any in-situ test performed (reference to applicable ASTM standard, for example, Test Methods D1586, D2573, D3441, D4623, D4633, D4645, D4719, or other tests if applicable),

6.1.6.10 Description of any other field tests conducted on soil and rock during the exploration such as pH, hydraulic conductivity, pressuremeter geophysical, pocket penetrometer, soil gas/vapor analysis, or other tests, and

6.1.6.11 Destination or recipient of samples and method of transportation.

6.1.7 Ground water information should include:

6.1.7.1 Depths and times at which ground water is encountered, including seepage zones, if appropriate,

6.1.7.2 In the case of drilling using drilling fluid, depth of fluid surface in boring and drilling depth at the time of a noted loss or gain in drilling fluid,

6.1.7.3 Depth to ground water level at the completion of drilling and removal of drill steel and description of datum (note condition of borehole, for example, cased or uncased). Date and time measured,

6.1.7.4 Depth to ground water level at some reported time period following completion of drilling and description of datum, when possible.

6.1.7.5 Method or equipment used to determine depth of ground water level, such as Test Method D4750,

6.1.7.6 Method and depth of ground water samples obtained, including size of samples taken and description of sampler, and

6.1.7.7 Description of any field tests conducted on ground water samples such as pH, temperature, conductivity, turbidity, or odor.

6.1.8 Information regarding installation of instrumentation or monitoring equipment should include:

6.1.8.1 Type of equipment installed, for example, piezometers, monitoring well screens, inclinometer, including sizes and types of materials,

6.1.8.2 Depth and description of equipment installed (reference to applicable ASTM standard, for example, Practice D4403, or other standards or procedures),

6.1.8.3 Methods used for installation of equipment and method used for sealing annular space, and

6.1.8.4 Methods used to protect equipment (casing cap or locks).

6.2 Soil and rock field logs should include the following pictorial information:

6.2.1 Maps, drawings, or sketches of area of exploration and subsurface surfaces observed. Include pertinent surface information such as neighboring outcrops, as appropriate. Describe system of mapping, such as Guide D4879 for rock, or legend for symbols of materials. Include dimensions, directions, and slopes, and

6.2.2 Photographs of activities, surfaces, or core. Describe sequence, dates and time, direction, objects used for scale, and subject.

## 7. Keywords

7.1 drilling; explorations; geologic investigations; ground water; logging; preliminary investigations; sampling; soil investigations; subsurface investigations

## SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this guide since the last issue, D5434–09, that may impact the use of this guide. (Approved February 1, 2012)

(*1*) Revised 6.1.6.5.