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Standard Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices¹

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1. Scope

1.1 This guide covers cable-tool drilling and sampling procedures used for geoenvironmental exploration and installation of subsurface water-quality monitoring devices.

1.2 Several sampling methods exist for obtaining samples from drill holes for geoenvironmental purposes and subsequent laboratory testing. Selection of a particular drilling procedure should be made on the basis of sample types needed and geohydrologic conditions observed at the study site.

1.3 Drilling procedures for geoenvironmental exploration often will involve safety planning, administration and documentation. This guide does not purport to specifically address exploration and site safety.

NOTE 1—This guide does not include considerations for geotechnical site characterizations that are addressed in a separate guide.

1.4 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

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 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 This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

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2. Referenced Documents

2.1 ASTM Standards:

- D 420 Guide for Site Characterization for Engineering Design and Construction Purposes²
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids²
- D 1452 Practice for Soil Investigation and Sampling by Auger Borings²
- D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils²
- D 1587 Practice for Thin-Walled Tube Geotechnical Sampling of Soils²
- D 2113 Practice for Diamond Core Drilling for Site Investigation²
- D 2487 Test Method for Classification of Soils for Engineering Purposes (Unified Soil Classification System)²
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²
- D 3550 Practice for Ring-Lined Barrel Sampling of Soils²
- D 4220 Practices for Preserving and Transporting Soil Samples²
- D 4428/D4428M Test Methods for Crosshole Seismic Testing²
- D 4700 Guide for Soil Sampling from the Vadose Zone²
- D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)²
- D 5079 Practices for Preserving and Transporting of Rock Core Samples²
- D 5088 Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites²
- D 5092 Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers²
- D 5299 Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities²
- D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock²

² Annual Book of ASTM Standards, Vol 04.08.

- D 5521 Development of Ground Water Monitoring Wells in Granular Aquifers²
- D 5730 Guide for Site Characterization for Environmental Purposes³
- D 5782 Guide for the Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices³
- D 5783 Guide for the Use of Direct-Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices³
- D 5784 Guide for the Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices³

3. Terminology

3.1 Terminology used within this guide is in accordance with Terminology D 653 with the addition of the following:

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bailer*—a long, narrow bucket, made from a piece of large-diameter pipe with a dart valve in the bottom, used to remove cuttings from the borehole.

3.2.2 *bentonite*—the common name for drilling-fluid additives and well-construction products consisting mostly of naturally occurring montmorillonite. Some bentonite products have chemical additives which may affect water-quality analyses.

3.2.3 *bentonite granules and chips*—irregularly-shaped particles of bentonite (free from additives) that have been dried and separated into a specific size range.

3.2.4 *bentonite pellets*—roughly spherical- or disc-shaped units of compressed bentonite powder (some pellet manufacturers coat the bentonite with chemicals that may affect the water-quality analysis).

3.2.5 *coefficient of uniformity*— $C_u(D)$, the ratio D_{60}/D_{10} , where D_{60} is the particle diameter corresponding to 60 % finer on the cumulative particle-size distribution curve, and D_{10} is the particle diameter corresponding to 10 % finer on the cumulative particle-size distribution curve.

3.2.6 *collar*—the section of a drill tool between the wrench square and the pin or box joint.

3.2.7 *dart valve*—a type of valve used on a bailer, that opens when the bailer drops through the cuttings at the bottom of the borehole.

3.2.8 *drill bit*—the steel tool on the lower end of the string of tools which does the actual drilling; shaped to perform the operations of penetration, reaming, crushing, and mixing.

3.2.9 *drill hole*—a cylindrical hole advanced into the subsurface by mechanical means. Also known as a borehole or boring.

3.2.10 *drill stem*—a steel tool composed of a round bar of steel with a pin joint at its upper end and a box joint at its lower end that is placed below the jars in a string of drilling tools to furnish the necessary weight to the tool string.

3.2.11 *drill string*—the complete cable-tool drilling assembly including bit, drill rods and connector assemblies (subs).

The total length of this assembly is used to determine drilling depth by referencing the position of the top of the string to a datum near the ground surface.

3.2.12 *drive shoe*—a forged- or machined-steel collar either a threaded- or drop-type attached to the upper joint of casing to protect the casing threads during driving operations.

3.2.13 *filter pack*—also known as a gravel pack or primary filter pack in the practice of monitoring-well installations. The gravel pack is usually granular material, having specified grain-size characteristics, that is placed between a monitoring device and the borehole wall. The basic purpose of the filter pack or gravel envelope is to act as: a non-clogging filter when the aquifer is not suited to natural development or, a formation stabilizer when the aquifer is suitable for natural development.

3.2.13.1 *Discussion*—Under most circumstances a clean, quartz sand or gravel should be used. In some cases a pre-packed screen may be used.

3.2.14 *grout shoe*—a drillable “plug” containing a check valve that is positioned within the lowermost section of a casing column. Grout is injected through the check valve to fill the annular space between the casing and the borehole wall or another casing.

3.2.14.1 *Discussion*—The composition (or mix) of the drillable “plug” should be known and documented. A grout shoe would probably only be installed in a cable-tool drilled hole if the hole was to be continued on by a rotary-type drilling rig.

3.2.15 *grout packer*—a reusable inflatable or expandable annular plug that is attached to a tremie pipe, usually positioned immediately above the discharge end of the pipe.

3.2.16 *intermittent sampling devices*—usually barrel-type samplers that are driven below the bottom of a borehole with drill rods or with a wireline system to lower, drive, and retrieve the sampler following completion of an increment of drilling. The user is referred to the following standards relating to suggested sampling methods and procedures: Practice D 1452, Test Method D 1586, Practice D 3550, and Practice D 1587.

3.2.17 *in-situ testing devices*—sensors or probes, used to obtain mechanical- or chemical-test data, that are typically pushed, rotated or driven below the bottom of a borehole following completion of an increment of drilling. However, some *in-situ testing devices* (such as electronic pressure transducers, gas-lift samplers, tensiometers, and etc.) may require lowering and setting of the device(s) in pre-existing boreholes by means of a suspension line or a string of lowering rods or pipes. Centralizers may be required to correctly position the device(s) in the borehole.

3.2.18 *jars*—a tool composed of two connected links or reins with vertical play between them (see Fig. 1 (4)).⁴ Drilling jars have a stroke of 9- to 18-in. whereas, fishing jars have a stroke of 18- to 36-in. (7 mm). Jars permit a sudden upward load or shock to loosen a string of tools stuck in the borehole.

3.2.19 *sand pump*—bailer made of tubing with a hinge-flap valve and a plunger that works inside the barrel. It is used in sand and gravel where the dart-valve bailer will not pick up the materials adequately.

³ Annual Book of ASTM Standards, Vol 04.09.

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

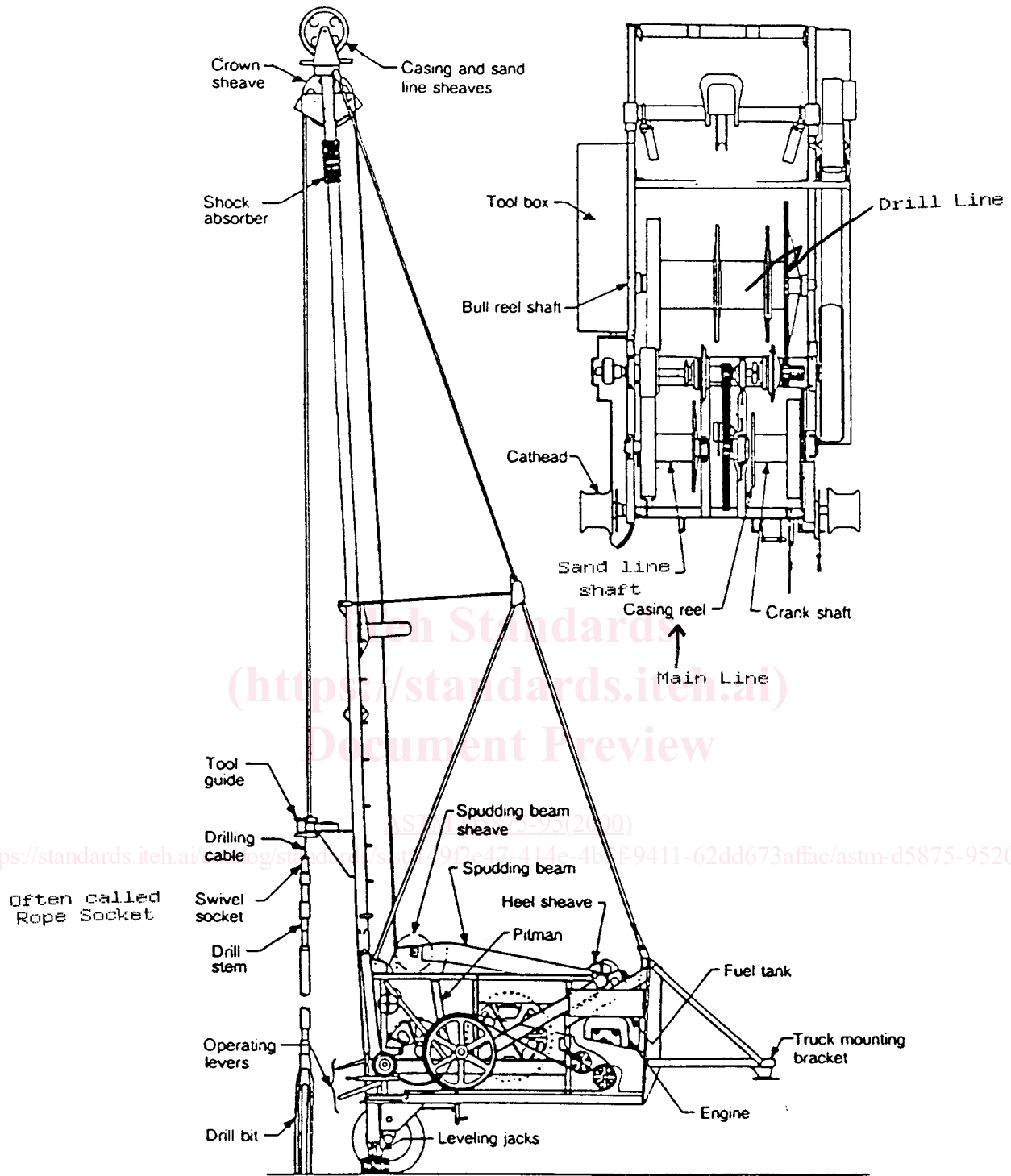


FIG. 1 Diagram of a Cable Tool Drilling System

3.2.20 *spear*—a fishing tool used when the drilling line or sand line breaks leaving the drilling tools or bailer in the hole with the line on top of the lost tools.

3.2.21 *swivel socket*—a socket that permits the tool string to spin or turn during the drilling action (sometimes referred to as a “rope socket”).

3.2.22 *subsurface water-quality monitoring device*— an instrument placed below ground surface to obtain a sample for analysis of the chemical, biological or radiological characteristics of subsurface pore water or to make in-situ measurements.

3.2.23 *wrench square*—a square section on any drilling tool by which the joints are set up or broken.

4. Significance and Use

4.1 Cable-tool rigs (also referred to as churn rigs, water-well drilling rigs, spudders, or percussion rigs) are used in the oil fields and in the water-well industry. The Chinese developed the percussion method some 4000 years ago.

4.2 Cable-tool drilling and sampling methods may be used in support of geoenvironmental exploration and for installation of subsurface water-quality monitoring devices in both unconsolidated and consolidated materials. Cable-tool drilling and sampling may be selected over other methods based on its advantages, some of which are its high mobility, low water use, low operating cost, and low maintenance. Cable-tool drilling is the most widely available casing-advancement method that is restricted to the drilling of unconsolidated materials and softer rocks.

4.2.1 The application of cable-tool drilling and sampling to geoenvironmental exploration may involve sampling unconsolidated materials. Depth of drill holes may exceed 3000 ft (914 m) and may be limited by the length of cable attached to the bull reel. However, most drill holes for geoenvironmental exploration rarely are required to go that deep. Rates for cable-tool drilling and sampling can vary from a general average of as much as 25 to 30 ft/h (7.6 to 9 m/h) including setting 8 in. (2.4 m) diameter casing to considerably less than that depending on the type(s) of material drilled, and the type and condition of the equipment and rig used.

NOTE 2—As a general rule, cable-tool rigs are used to sample the surficial materials, and to set surface casing in order that rotary-core rigs subsequently may be set up on the drill hole to core drill hard rock if coring is required.

4.2.2 The cable-tool rig may be used to facilitate the installation of a subsurface water-quality monitoring device(s) including in-situ testing devices. The monitoring device(s) may be installed through the casing as the casing is removed from the borehole. The sand line can be used to raise, lower, or set in-situ testing device(s), or all of these. If necessary, the casing may also be left in the borehole as part of the device.

NOTE 3—The user may install a monitoring device within the same borehole wherein sampling, in-situ, or pore-fluid testing, or coring was performed.

5. Apparatus

5.1 Cable-tool rigs have a string of drill tools with a drive clamp (see Fig. 1 (6)) on the drill string connected by wire rope that periodically can be hoisted and allowed to “fall” for percussion drilling in unconsolidated and consolidated materials and for driving/retrieving casing. The full string of drilling equipment consists of drill bit (see Fig. 1 (2)—bit used for all-around general drilling and, (3)—bit used for chopping and breaking hard materials and rock), drilling jars (optional), and a drill stem (see Fig. 1 (1)), with a swivel socket (see Fig. 2) connected by a wire rope fastened to a drum called a bull reel that raises and lowers the drilling tools and permits percussion drilling either by crushing the material or by drive sampling. The spudding beam, commonly referred to as the walking

beam, that is driven by the pitman and crank, imparts a reciprocating motion to the drilling line (see Fig. 3 (6)).

NOTE 4—All cable-tool rigs have the capacity to lift and drop heavy drive clamps for installing large-diameter casing in unconsolidated materials.

5.2 Water-well drilling rigs have been converted (for the purpose of geoenvironmental-engineering explorations) by replacing the jars and stem, and replacing the chopping bit (see Fig. 1 (3)) with a drive barrel, (see Fig. 4) that is used for sampling purposes. If the bit becomes stuck in the borehole it can normally be freed by upward blows of the drilling jars (jars can also be used in the same mode to extract casing). The primary function of the drilling jars is to transmit the energy from the bull wheel to the drill stem and the sample barrel. The stroke of the drilling jars is 9 to 18 in. (0.23 to 0.46 m) and distinguishes them from fishing jars that have a stroke 18 to 36 in. (0.46 to 0.91 m). Jars are often not used when hard-rock drilling (6, 7).

5.3 The swivel socket connects the drill string to the cable and, in addition, the weight of the socket supplies part of the weight of the drill tools. The socket also imparts part of the upward energy to the jars when their use becomes necessary. The socket transmits the rotation of the cable to the tool string and bit (drive barrel) so that the drive is completed on the downstroke, thereby assuring that a round, straight hole will result. The elements of the tool string are coupled together with right-hand threaded tool joints of standard API (American Petroleum Institute) design and dimension (7).

5.4 The wire cable that carries and rotates the drilling tool is called the drill line. It is a 5/8-in. (16-mm) to 1-in. (25-mm) left-hand lay cable that twists the tool joint on each upward stroke to prevent it from unscrewing. The drill line is reeved over a crown sheave at the top of the mast, down to the spudding sheave on the walking beam, to the heel sheave, and then to the working-line side of the bull-reel (see Fig. 3). The stroke of the cable-tool rig should be controlled and sufficient tension maintained on the wire cable to keep the jars open or extended when in operation (often referred to as “tight-line drilling”). Bull reels generally are set-up with a separator on the drum to provide a working-line and a storage-line side (7).

NOTE 5—The mast must be constructed safely to carry the required loads for drilling, sampling, and completion of boreholes of the diameter and depth for which the rig manufacturer specifies the equipment. To allow for contingencies it is recommended that the rated capacity of the mast should be at least twice the anticipated weight load or normal pulling load.

5.5 The characteristic up and down or spudding action of a cable-tool rig is imparted to the drill line and drilling tools by the walking beam. The walking beam pivots at one end while its out end, which carries the sheave for the drill line, is moved up and down by a single or double pitman connected to a crankshaft. The vertical stroke of the walking beam, and thus the drill tools, can be varied by adjusting the position of the pitman on the bull gear and the connection to the walking beam. The number of strokes per minute can be varied by changing the speed of the driveshaft. The bull gears are driven by a pinion mounted on a clutch. This clutch, the friction drive