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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 Devices[1]

This standard is issued under the fixed designation D 5875; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 420 Guide for Site Characterization for Engineering Design and Construction Purposes[2]
D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]
D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]
D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils[2]
D 1587 Practice for Thin-Walled Tube Geotechnical Sampling of Soils[2]
D 2113 Practice for Diamond Core Drilling for Site Investigation[2]
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 Soils[2]
D 4220 Practices for Preserving and Transporting Soil Samples[2]
D 4428/D4428M Test Methods for Crosshole Seismic Testing[2]
D 4700 Guide for Soil Sampling from the Vadose Zone[2]
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 Samples[3]
D 5088 Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites[3]
D 5092 Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers[3]
D 5299 Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities[3]
D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D 5730 Guide for Site Characterization for Environmental Purposes
D 5521 Development of Ground Water Monitoring Wells in Granular Aquifers

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

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[2] *Annual Book of ASTM Standards*, Vol 04.08.
[3] *Annual Book of ASTM Standards*, Vol 04.09.

D 5782 Guide for the Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

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 Devices

D 5784 Guide for the Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

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.

3.2.20 *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

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

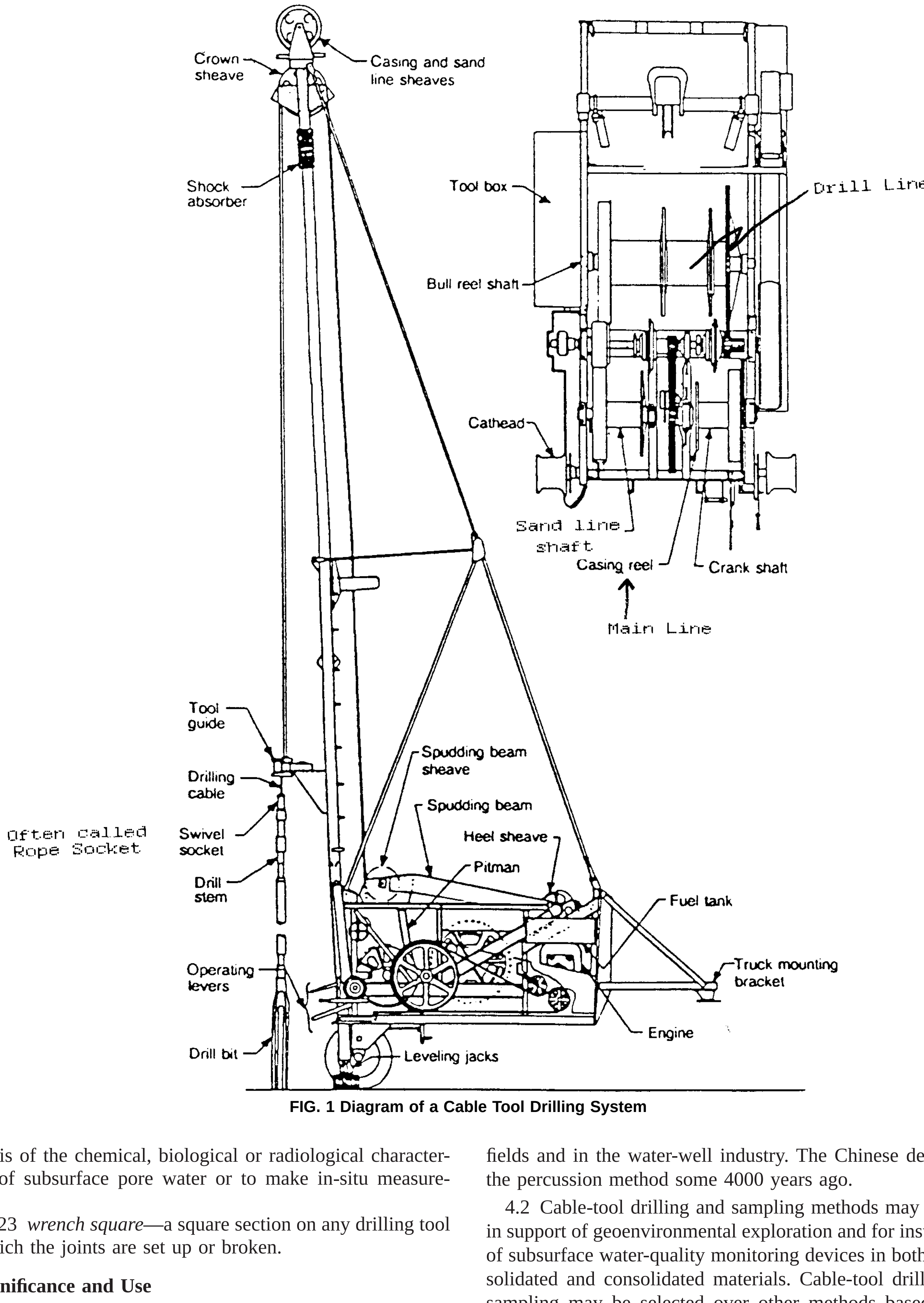


FIG. 1 Diagram of a Cable Tool Drilling System

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

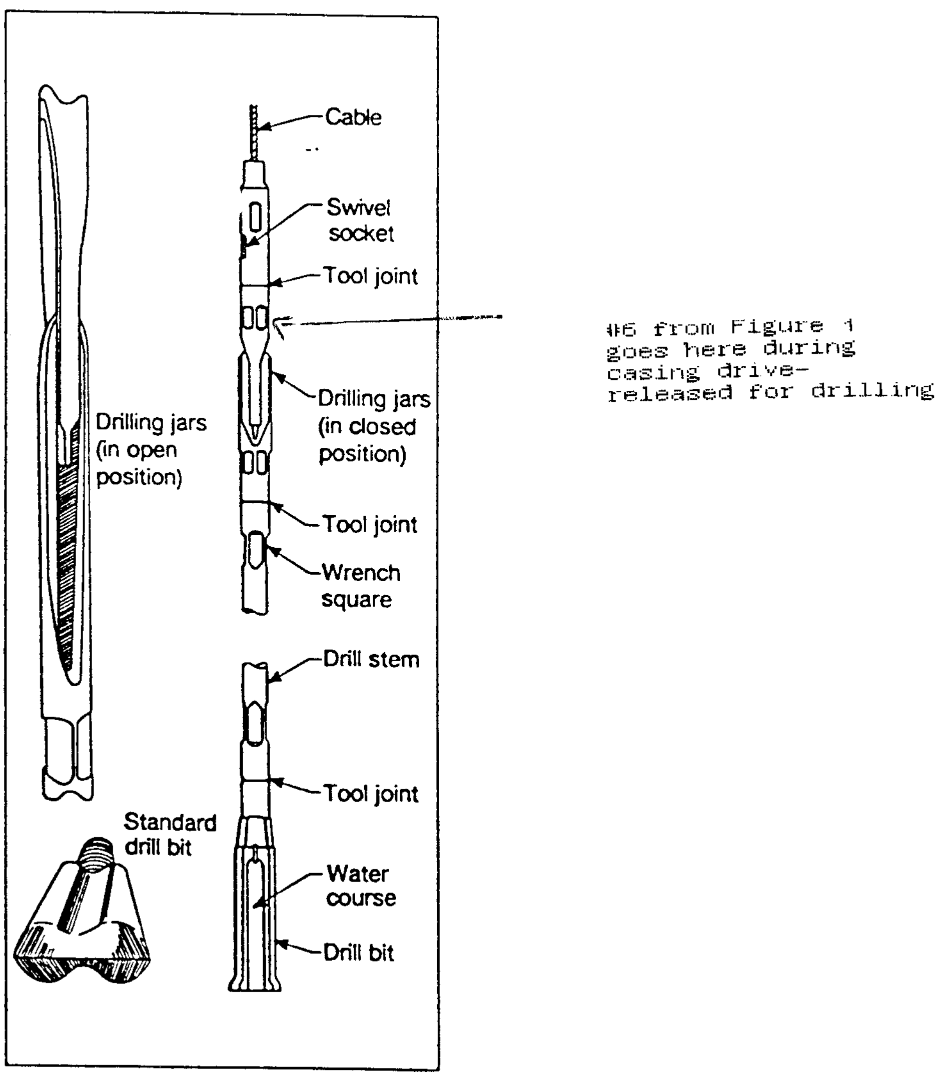


FIG. 2 A Full String of Cable Tools Consists of Five Components That are Necessary for Drilling

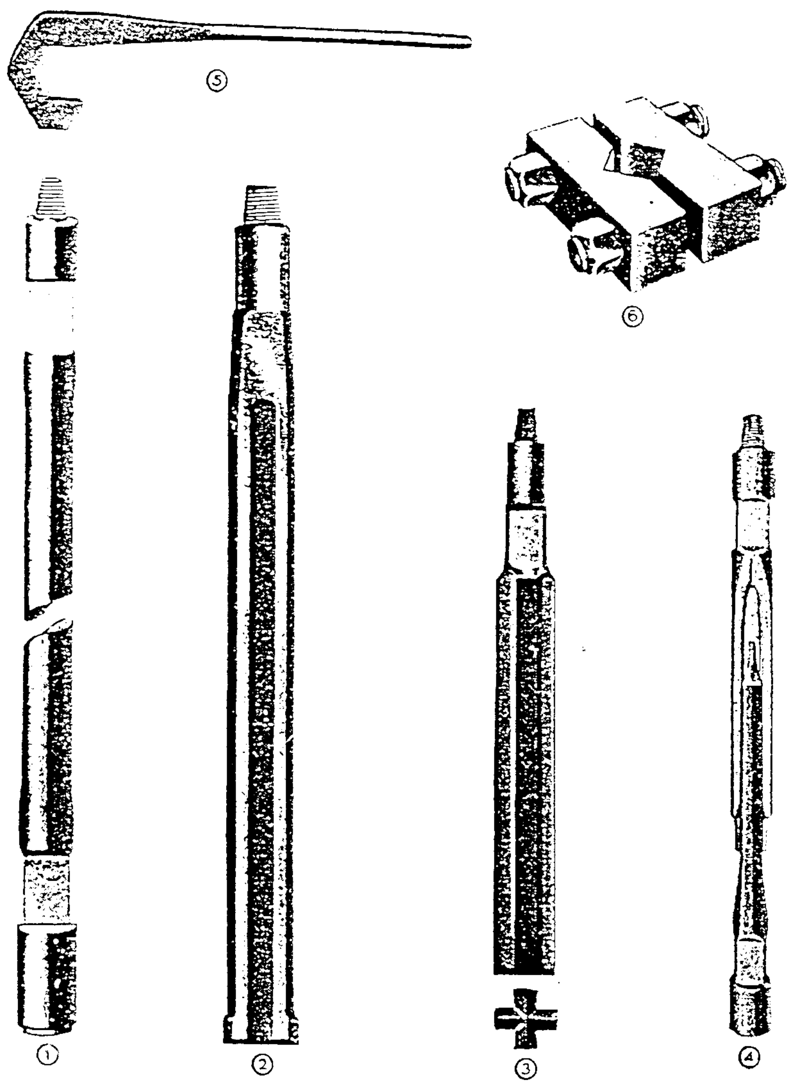
drilling either by crushing the material or by drive sampling. The spudding beam, commonly referred to as the walking beam, that is driven by the pitman and crank, imparts a reciprocating motion to the drilling line (see Fig. 3 **(6)**).

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)



1. Drill Stem.
2. Regular pattern bit.
3. Star or four-wing bit.
4. Jars.
5. Wrench for tightening drive clamps.
6. Drive clamps.

FIG. 3 Drilling Tools

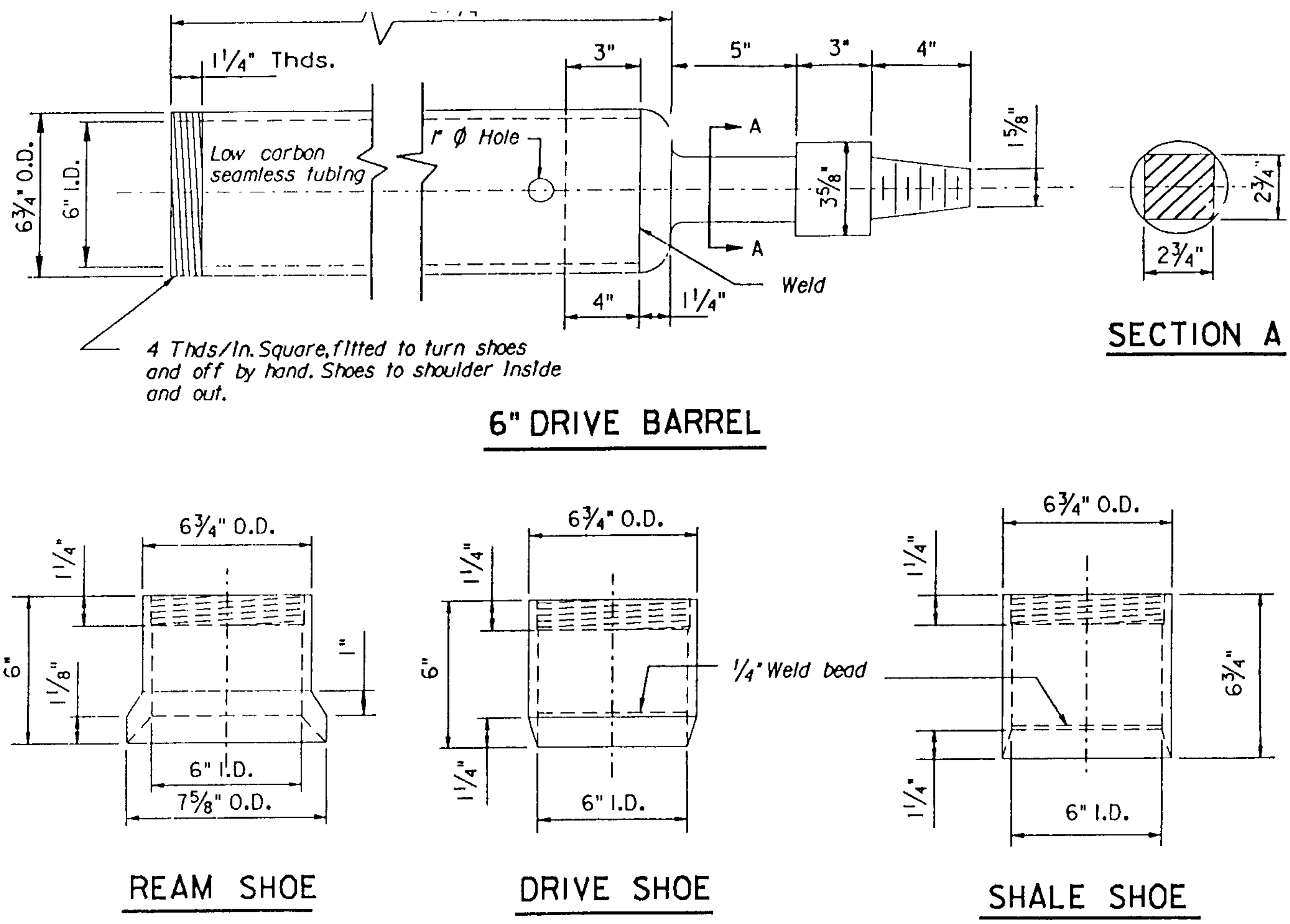


FIG. 4 Schematic Showing a 6-in. Drive Barrell and Three Shoe Configurations

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 for sand line (on smaller cable tool rigs only), and the drive pinion for the drill-line reel are all mounted on the same shaft assembly.

5.6 Another drum, called a casing reel, frequently is added to the basic machine assembly. The casing reel is capable of exerting a powerful pull on a third cable, the casing- or main-line. This cable is used for handling heavy casing, tools, and pumps, or other heavy hoisting. It may be used to pull a string of casing when the cable is reeved with blocks to make two-, three-, or four-part lines **(7)**.

5.7 Another commonly used hoisting device on a cable-tool rig is called a cathead. Use of this drum requires that a heavy line of manila rope be carried on a separate sheave at the top of the derrick. This line may be used for handling light loads at shallow depths (usually 10 ft (3 m) or less) and alternately lifting and dropping tools such as a drive block or bumper, spears, heads for driving casing, and individual lengths of casing so they may be stood on end and joined to the last piece in the ground **(7)**. The cathead and line is often used to shake the sample from large-diameter drive barrels. Should standard-penetration tests be required for specific geoenvironmental studies, standard rotary drill rods and drop hammer can be manipulated using the cathead and line.

5.8 Depending on the length of the drive barrels, the drive of the sampling is usually 2 ft (6 m). A schematic showing a 6-in.

drive barrel and three shoe configurations is shown in Fig. 4. Prior to any drilling all tools must be measured and the measurements recorded. Drive samples are usually disturbed. Therefore, laboratory testing is normally limited to obtaining only Atterberg Limits, mechanical analysis or chemical analysis of the disturbed samples. Poly(methyl methacrylate) or plastic liners can be inserted within the drive barrel, and the complete sample can be reexamined in the laboratory. In addition, sampling with the drive barrel provides the user with a complete geological sequence and field classification of the sampled materials at the time of drilling. When cohesionless materials are reached, and if sampling is required, the recovery is best while sampling is conducted from inside the casing. Attempts to sample below the bottom of the casing, especially when these materials are below the water table or the materials totally saturated, are usually futile. (When such conditions are observed the drive barrel acts analogous to a piston and creates a suction when the bottom of the casing has been knocked out. The drive barrel will "suck" in the sand and can pull it nearly to the top of the casing; subsequent cleanout is very slow and expensive.) When using a drive barrel in cohesionless soil, casing is required. Cohesionless materials may also be sampled using a dart-valve bailer, sand-pump bailer, or a flat-bottomed bailer attached to the sand line when sampling below the water level in the drill hole. Other bailers are available and this guide is not restrictive as to the trade name or type(s) of bailers that may be used. The unconsolidated samples obtained by bailing are usually dumped into a bucket, a small barrel (drum), or onto a piece of plywood and the water decanted in order that the sample can be placed in a sample container or bag. The use of drilling fluids (bentonite, etc.) as a substitute for casing may be used, but usually with limited success. If drilling fluids or other additives are used in lieu of casing, the type(s), compositions, quantities, depths, and other pertinent information to the occurrence(s) should be fully documented.

5.9 Standard body diameters and jaws showing nominal stroke lengths are shown in Table 1. The jars are normally run on the drilling string between the swivel socket and the drill stem except where used for fishing out lost tools. Jars should never be included in the drill string when starting the borehole **(8)**. The function of the jars is to create a jarring action when needed to loosen tools from a formation in which they have a tendency to stick while drilling. The stroke of the rig should be controlled and sufficient tension maintained on the wire to keep the jars extended when in operation. A loose drilling line permits the jars to open and close on each stroke and results in faster wear and metal fatigue on the jars.

TABLE 1 Weldless Jars for Cable-Tool Drilling

Body Diameter, in.	API Joint Size	Weight 4.5 in. Stroke	Weight 8 in. Stroke	Weight 12 in. Stroke	Weight 18 in. Stroke	Weight 24 in. Stroke	Weight 36 in. Stroke
3.25	2¼	100	103	107	114	121	135
3.625	2⅝	140	145	149	158	167	185
4.375	3	237	248	256	275	294	332
4.75	3¼	285	296	312	339	366	420
5.5	3.5 to 3.75	400	421	442	474	506	570
6.5	4	605	630	650	685	720	790
6.5	4.25 to 4.5	670	694	718	754	790	862
7	5	770	808	840	890	960	1080
7	6	960	998	...	...	...	...

6. Drilling Procedures

6.1 As a prelude to and throughout the drilling process stabilize the cable-tool drill rig and raise the mast. If air-monitoring operations are performed the prevalent wind direction relative to the exhaust from the drill rig should be considered. Connect the drive barrel to the drill stem and jars. Reference the top of the drill hole to the survey stake that reflects its elevation and location. Put the drill in motion and begin the drive sampling. Drill the upper 2 to 8 ft (0.6 to 2.4 m) rather slowly until the top of the drive barrel is below the top of the ground surface. Perform drive sampling on a continuous basis and at 2-ft (0.6-m) intervals. Select samples at the direction of the design team, and perform the appropriate testing. Perform drilling and sampling to a predetermined depth. The reference datum is established (usually by a licensed surveyor) then the elevation (or location data) is transferred to a reference at the top of the drill hole or to the" deck" of the drill rig. Document these data. Most cable-tool drill rigs do not have a drill platform from which the drilling operations are performed, and the drilling and reference elevations are referenced to land-surface elevation.

NOTE 6—The drill rig, drive barrel, drill stem, cable(s), jars, and all drilling and sampling components above the drilling axis should be decontaminated according to Practice D 5088 prior to commencing drilling and sampling operations. The user of the cable-tool drilling method for geoenvironmental work should be aware that the decontamination of this type of equipment could be difficult to accomplish perhaps, making it a less desirable method to employ for a particular study.

NOTE 7—The user must locate and advise the drill crew about the location of overhead utilities as well as underground utility lines and a safety plan formulated in order to establish a safe drilling and working distance from them.

6.2 In conjunction with drive sampling it is often necessary to first set casing. To better facilitate obtaining "uncontaminated" drive samples, casing can first be driven to seal off "contaminated zones" prior to hole advancement and further sampling operations. Decontaminate all casing used according to Practice D 5088 prior to use. Set the appropriate size casing (nominal 5-ft lengths (1.5-m)) with the drive shoe attached to the bottom of the casing. (Remove the drive barrel prior to driving any casing so that it does not unscrew and fall to the bottom of the drill hole.) Set a heavy, machined drive head over or threaded on the top of the casing, and the stem goes inside the casing. Attach the drive clamp to the jars, and the percussion of the drill stem drives the casing to the required depth. When the casing has reached the required depth, remove the drive, reattach the drive barrel, and resume drilling and sampling. Repeat this procedure until the predetermined depth is reached. The driller marks the drive barrel and drill tools, and the cable in 2-ft (0.6-m) increments, so that the drilling depths may be recorded. At the discretion of the responsible person on site, measure the bottom of the hole with a tape to verify the drillers' depth. For depth-measurement reliability, the degree of precision required and measuring tool should be considered and compatible. Document this information.

6.2.1 Drilling with cable-tool methods for geoenvironmental exploration and the installation of subsurface water-quality monitoring devices require that accurate measurements be made and documented using a steel surveyors' chain, marked in 0.01-ft (or 0.003 mm) increments. Tenths of a foot (or millimetres) may be measured using a typical engineering rule.

6.3 When drilling by the cable-tool method, the rock is broken up and pulverized by the percussive drill action of the bit. However, when drilling unconsolidated materials the bit primarily loosens the materials. In both instances, the reciprocating action of the tools mixes the crushed or loosened particles with water to form a slurry or sludge at the bottom of the borehole. If water is not present in the borehole, add water to form the slurry. As slurry accumulation increases as the drilling progresses it eventually reduces the impact of the drill tools. It is then removed from the borehole either by a sand pump or bailer **(7)**. If water is added to form the slurry, document the source of the water, quantity of water added, chemical makeup of the water, and depth added. If necessary, cuttings are decanted, in order to be examined by the responsible person on site. Set and pull casing according to 6.2. The sand line or main line is often used to expedite pulling the casing. Decontaminate all tools used in this drilling procedure according to Practice D 5088.

7. Borehole Completion and the Installation of Subsurface Monitoring Devices

7.1 Monitor ground-water levels periodically and document the water levels both during drilling and after the predetermined depth has been reached. If ground water is not present or if the measurement of the ground-water level is of doubtful reliability, document that also.

7.2 Subsurface water-quality monitoring devices are generally installed in boreholes drilled by cable-tool rigs using a four-step procedure. The four steps are: (*1*) drilling without sampling, (*2*) temporarily leaving the casing in the drill hole to support the sidewalls after the predetermined sampling depth has been reached, (*3*) inserting the monitoring device to the desired depth, and (*4*) the simultaneous extraction of the casing (using the cathead and a drive block or drive clamp to bump the casing back) with addition of completion materials (that is, filter pack, bentonite pellets, bentonite granules and chips, annular seals and grout added either above or below the bottom of the casing).

7.3 *Other Completion Methods*—Depending on the purpose of the investigation(s) it may be necessary to perform special completion(s) with protective casing(s) or other method(s) of backfilling. An example of other completions is the seismic crosshole test (see Test Method D 4428) that requires grouted PVC casings. These completions are also performed using those methods in 7.2. Document the completion method(s) used.

8. Field Report and Project Control

8.1 The field report should include all information and identified as necessary and pertinent to the needs of the exploration program. Information normally required for the project include: exploration type and execution, drilling equipment and methods used, subsurface conditions encountered, groundwater conditions, sampling events, and type of installations made in the borehole(s) including well-completion techniques used.

8.2 Additional information should be considered as follows:

8.2.1 *Drilling Methods*:

8.2.1.1 Description and documentation of the rig/system including weight of drill stem and jars, sizes of drive barrels used and size of casing set, if any. Record when drive barrels are changed to smaller diameters as well as the depth obtained for each drive barrel and the casing set. Document reasons why changes were made.

8.2.1.2 Note and document type, quantities, and locations in the drill hole of use of additives such as water or drilling fluids added.

8.2.1.3 Description of cuttings.

8.2.1.4 Descriptions of drilling conditions and general ease of drilling as related to subsurface materials encountered should be noted and documented.

8.2.2 *Sampling*—Document conditions of the bottom of the drill hole prior to sampling and report any slough or cuttings present in the recovered sample.

8.2.3 *In-situ Testing*:

8.2.3.1 For devices inserted below the bottom of the drill hole document the depths below the bottom of the hole and any unusual conditions during testing.

8.2.3.2 For devices testing or seating at the borehole wall, document any unusual conditions of the borehole wall such as inability to seat borehole packers.

8.2.4 *Installations*—Document a description of well-completion materials and placement methods, approximate volumes placed, depth intervals of placement, methods of confirming placement, and areas of difficulty of material placement or unusual occurrences.

8.2.5 *Site Conditions*:

8.2.5.1 *Site Description*—Description of the site and any unusual circumstances,

8.2.5.2 *Personnel*—Documentation of all personnel at the site during the drilling process; driller, helpers, geologist or logger, engineer, and other monitors or visitors,

8.2.5.3 Weather conditions during drilling, and

8.2.5.4 Working hours, operating times, breakdown times, and sampling times. Report any unusual occurrences that may have happened during the investigation.

9. Keywords

9.1 cable-tool drilling; drilling method; geoenvironmental exploration; ground water; vadose zone

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