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Standard Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[1]

This standard is issued under the fixed designation D5782; 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 how direct (straight) air-rotary drilling procedures may be used for geoenvironmental exploration and installation of subsurface water-quality monitoring devices.

NOTE 1—The term direct with respect to the air-rotary drilling method of this guide indicates that compressed air is injected through a drill-rod column to a rotating bit. The air cools the bit and transports cuttings to the surface in the annulus between the drill-rod column and the borehole wall.

NOTE 2—This guide does not include considerations for geotechnical site characterizations that are addressed in a separate guide.

1.2 Direct air-rotary drilling for geoenvironmental exploration will often involve safety planning, administration, and documentation. This guide does not purport to specifically address exploration and site safety.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

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

1.5 All observed and calculated values are to conform to the guidelines for significant digits and rounding established in Practice D6026. The procedures used to specify how data are collected/recorded or calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objective; and it is common practice to increase or reduce the significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis method or engineering design.

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.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D1586 Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1587 Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes
D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Exploration
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils

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

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[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**

D4428/D4428M Test Methods for Crosshole Seismic Testing
D5088 Practice for Decontamination of Field Equipment Used at Waste Sites
D5092 Practice for Design and Installation of Groundwater Monitoring Wells
D5099 Test Methods for Rubber—Measurement of Processing Properties Using Capillary Rheometry
D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D5608 Practices for Decontamination of Sampling and Non Sample Contacting Equipment Used at Low Level Radioactive Waste Sites
D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions*—For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bentonite, n—in drilling*, 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.

3.2.2 *cleanout depth, n—in drilling*, the depth to which the end of the drill string (bit or core barrel cutting end) has reached after an interval of cutting. The cleanout depth (or drilled depth as it is referred to after cleaning out of any sloughed material in the bottom of the borehole) is usually recorded to the nearest 0.1 ft (0.03 m).

3.2.3 *drawworks, n—in drilling*, a power-driven winch, or several winches, usually equipped with a clutch and brake system(s) for hoisting or lowering a drilling string.

3.2.4 *drill hole, n—in drilling*, a cylindrical hole advanced into the subsurface by mechanical means. Also known as a borehole or boring.

3.2.5 *drill string, n—in drilling*, the total rotary-drilling assembly under rotation including bit, sampler/core barrel, 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.

3.2.6 *air rotary drill string, n—in drilling*, the total direct air-rotary drilling assembly under rotation including bit, sampler/core barrel, 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.

3.2.7 *filter pack, n—in drilling*, also known as a gravel pack or a 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: (*1*) a nonclogging filter when the aquifer is not suited to natural development or, (*2*) act as a formation stabilizer when the aquifer is suitable for natural development.

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

3.2.8 *hoisting line, n—in drilling*, or drilling line, is wire rope used on the drawworks to hoist and lower the drill string.

3.2.9 *in-situ testing devices, n—in drilling*, sensors or probes, used for obtaining 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 so forth) may require lowering and setting of the device(s) in a preexisting borehole by means of a suspension line or a string of lowering rods or pipe. Centralizers may be needed to correctly position the device(s) in the borehole.

3.2.10 *intermittent-sampling devices, n—in drilling*, usually barrel-type samplers that are driven or pushed below the bottom of a borehole following completion of an increment of drilling. The user is referred to the following ASTM standards relating to suggested sampling methods and procedures: Practice D1452, Test Method D1586, Practice D3550, and Practice D1587.

3.2.11 *subsurface water-quality monitoring device, n—in drilling*, 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.

4. Significance and Use

4.1 The application of direct air-rotary drilling to geoenvironmental exploration may involve sampling, coring, in situ or pore-fluid testing, installation of casing for subsequent drilling activities in unconsolidated or consolidated materials, and for installation of subsurface water-quality monitoring devices in unconsolidated and consolidated materials. Several advantages of using the direct air-rotary drilling method over other methods may include the ability to drill rather rapidly through consolidated materials and, in many instances, not require the introduction of drilling fluids to the borehole. Air-rotary drilling techniques are usually employed to advance drill hole when water-sensitive materials (that is, friable sandstones or collapsible soils) may preclude use of water-based rotary-drilling methods. Some disadvantages to air-rotary drilling may include poor borehole integrity in unconsolidated materials without using casing, and the potential for volitization of contaminants and air-borne dust.

NOTE 3—Direct-air rotary drilling uses pressured air for circulation of drill cuttings. In some instances, water or foam additives, or both, may be injected into the air stream to improve cuttings-lifting capacity and cuttings return. The use of air under high pressures may cause fracturing of the formation materials or extreme erosion of the borehole if drilling pressures and techniques are not carefully maintained and monitored. If borehole damage becomes apparent, consideration to other drilling method(s) should be given.

NOTE 4—The user may install a monitoring device within the same borehole in which sampling, in situ or pore-fluid testing, or coring was performed.

4.2 The subsurface water-quality monitoring devices that are addressed in this guide consist generally of a screened or porous intake and riser pipe(s) that are usually installed with a filter pack to enhance the longevity of the intake unit, and with isolation seals and a low-permeability backfill to deter the movement of fluids or infiltration of surface water between hydrologic units penetrated by the borehole (see Practice D5092). Inasmuch as a piezometer is primarily a device used for measuring subsurface hydraulic heads, the conversion of a piezometer to a water-quality monitoring device should be made only after consideration of the overall quality of the installation to include the quality of materials that will contact sampled water or gas.

NOTE 5—Both water-quality monitoring devices and piezometers should have adequate casing seals, annular isolation seals, and backfills to deter movement of contaminants between hydrologic units.

5. Apparatus

5.1 Direct air-rotary drilling systems consist of mechanical components and the drilling fluid.

5.1.1 The basic mechanical components of a direct air-rotary drilling system include the drill rig with rotary table and kelly or top-head drive unit, drawworks drill rods, bit or core barrel, casing (when needed to support the hole and prevent wall collapse when drilling unconsolidated deposits), air compressor and filter(s), discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator).

NOTE 6—In general, in North America, the sizes of casings, casing bits, drill rods, and core barrels are usually standardized by manufacturers according to size designations set forth by the American Petroleum Institute (API) and the Diamond Drill Core Manufacturers Association (DCDMA). Refer to the DCDMA technical manual and to published materials of API for available sizes and capacities of drilling tools equipment.

5.1.1.1 *Drill Rig,* with rotary table and kelly or top-head drive unit should have the capability to rotate a drill-rod column and apply a controllable axial force on the drill bit appropriate to the drilling and sampling requirements and the geologic conditions.

5.1.1.2 *Kelly,* a formed or machined section of hollow drill steel that is joined to the swivel at the top and the drill rods below. Flat surfaces or splines of the kelly engage the rotary table so that its rotation is transmitted to the drill rods.

5.1.1.3 *Drill Rods,* (that is, drill stems, drill string, drill pipe) transfer force and rotation from the drill rig to the bit or core barrel. Drill rods conduct drilling fluid to the bit or core barrel. Individual drill rods should be straight so they do not contribute to excessive vibrations or "whipping" of the drill-rod column. Threaded connections should be in good repair and not leak significantly at the internal air pressure needed for drilling. Drill rods should be made up and kept secure by wrench tightening at the threaded joint(s) to prevent rod damage.

NOTE 7—Drill rods used for air drilling jointed to make sure that the cutting's-laden return air will not be deflected to the borehole wall as it passes the return air were deflected against the borehole blasting and erosion of the borehole wall would occur.

NOTE 8—Drill rods usually require lubricants on the thread to allow easy unthreading (breaking) of the drill-rod tool joints. Some lubricants have organic or metallic constituents, or both, that could be interpreted as contaminants if detected in a sample. Various lubricants are available that have components of known chemistry. The effect of drill-rod lubricants on chemical analyses of samples should be considered and documented when using direct air-rotary drilling. The same consideration and documentation should be given to lubricants used with water swivels, hoisting swivels, or other devices used near the drilling axis.

5.1.1.4 *Rotary Bit or Core Bit,* provides material cutting capability for advancing the hole. Therefore, a core barrel can also be used to advance the hole.

NOTE 9—The bit is usually selected to provide a borehole of sufficient diameter for insertion of monitoring-device components such as the screened intake and filter pack and installation devices such as a tremie pipe. It should be noted that if bottom-discharge bits are used in loose cohesionless materials, jetting or erosion of test intervals could occur. The borehole opening should permit easy insertion and retraction of a sampler, or easy insertion of a pipe with an inside diameter large enough for placing completion materials adjacent to the screened intake and riser of a monitoring device. Core barrels may also be used to advance the hole. Coring bits are selected to provide the hole diameter or core diameter needed. Coring of rock should be performed in accordance with Practice D2113. The user is referred to Test Method D1586, Practice D1587, and Practice D3550 for techniques and soil-sampling equipment to be used in sampling unconsolidated materials. Consult the DCDMA technical manual and published materials of API for matching sets of nested casings and rods if nested casing are to be used for drilling in incompetent formation materials.

5.1.1.5 *Air Compressor,* should provide an adequate volume of air, without significant contamination, for removal of cuttings. Air requirements will depend upon the drill rod and bit configuration, the character of the material penetrated, the depth of drilling below groundwater level, and the total depth of drilling. The airflow rate requirements are usually based on an annulus upflow air velocity of about 1000 to 1300 m/min (about 3000 to 4000 ft/min) even though air-upflow rates of less than 1000 m/min are often adequate for cuttings transport. For some geologic conditions, air-blast erosion may increase the borehole diameter in easily eroded materials such that 1000 m/min may not be appropriate for cuttings transport. Should air-blast erosion occur, the depth(s) of the occurrence(s) should be noted and documented so that subsequent monitoring-equipment installation quality may be evaluated accordingly.

NOTE 10—The quality of compressed air entering the borehole and the quality of air discharged from the borehole and the cyclone separator should be considered. If not adequately filtered, the air produced by most oil-lubricated air compressors inherently introduces a significant quantity of oil into the circulation system. High-efficiency, in-line air filters are usually needed to prevent significant contamination of the borehole.

5.1.1.6 *Pressure Hose,* conducts the air from the air compressor to the swivel.

5.1.1.7 *Swivel,* directs the air to the rotating kelly or drill-rod column.

5.1.1.8 *Dust Collector,* conducts air and cuttings from the borehole annulus past the drill rod column to an air-cleaning device (cyclone separator).

5.1.1.9 *Air-Cleaning Device,* (cyclone separator) separates cuttings from the air returning from the borehole by means of the dust collector.

NOTE 11—A correctly sized cyclone separator can remove practically all of the cuttings from the return air. A small quantity of fine particles, however, are usually discharged to the atmosphere with the "cleaned" air. Some air-cleaning devices consist of a cyclone separator alone; whereas, some utilize a cyclone separator combined with a power blower and sample-collection filters. It is virtually impracticable to direct the return "dry" air past the drill rods without some leakage of air and return cuttings. Samples of drill cuttings can be collected for analysis of materials penetrated. If samples are obtained, the depth(s) and interval(s) should be documented.

NOTE 12—Zones of low air return and also zones of no air return should be documented. Likewise, the depth(s) of sampled interval(s) and quality of samples obtained should be documented.

NOTE 13—Compressed air alone can often transport cuttings from the borehole and cool the bit. For some geologic conditions, injection of water into the air stream will help control dust or break down "mud rings" that tend to form on the drill rods. If water is injected the depth(s) of water injection should be documented. Under other circumstances, for example, if the borehole starts to produce water, the injection of a foaming agent may be needed. The depth when a foaming agent is added should also be recorded. When foaming agents are used, a cyclone-type cuttings separator is not used and foam discharge accumulates near the top of the borehole. When contaminants are encountered during drilling and returning from the borehole at geoenvironmental-exploration sites, special measures should be taken to contain the foam and protect personnel and the environment. Therefore, added water and some available foaming agents could affect water-quality analyses. The need for chemical analysis of added water or foaming agents should be considered and documented.

6. Drilling Procedures

6.1 As a prelude to and throughout the drilling process, stabilize the drill rig and raise the drill-rig mast. Position the cyclone separator and seal it to the ground surface. If air-monitoring operations are performed consider the prevalent wind direction relative to the exhaust from the drill rig. Also, consider the location of the cyclone relative to the rig exhaust since air-quality monitoring will be performed at the cyclone separator discharge point.

NOTE 14—Under some circumstances a surface casing may be needed to prevent hole collapse. Deeper casing(s) (nested casings) may also be needed to facilitate adequate downhole air circulation and hole control. Casing used should be decontaminated according to Practices D5088 or D5608 prior to use.

6.2 Drilling usually progresses as follows:

6.2.1 Attach an initial assembly of a bit or core barrel, often with a single section of drill rod, below the rotary table or top-head drive unit with the bit placed below the top of the dust collector.

NOTE 15—The drill rig, drilling, hoisting and sampling tools, drilling rod and bits, the rotary gear or chain case, the spindle, and other components of the rotary drive above the drilling axis should be cleaned and decontaminated according to Practices D5088 or D5608 prior to commencing drilling and sampling operations.

6.2.2 Activate the air compressor, causing compressed air to circulate through the system.

6.2.3 Initiate rotation of the bit.

6.2.4 Continue air circulation and rotation of the drill-rod column until drilling progresses to a depth where sampling or in-situ testing will be performed or until the length of the drill-rod section limits further penetration. Air pressures at the bit should be low to prevent fracturing of the surrounding material. Monitor air pressures during drilling. Note and document abrupt changes or anomalies in the air pressure including the depth(s) of occurrence(s). Air-quality monitoring may be needed. If air-quality monitoring is performed document the sampled intervals and air-quality data.

6.2.5 Stop rotation and lift the bit slightly off the bottom of the hole to facilitate drill-cuttings removal, and continue air circulation for a short time until the drill cuttings are removed from the borehole annulus. If sampling is to be done, stop air circulation and rest the bit on the hole bottom to determine hole depth. Document the hole depth and amount of caving that occurred. If caving is apparent, set decontaminated casing to protect the boring.

6.2.6 Increase drilling depth by attaching an additional drill-rod section to the top of the previously advanced drill-rod column and resuming drilling operations according to 6.2.2 through 6.2.5. Record drilling behavior as drilling progresses. This recorded information should include: air-circulation pressures, depth(s) of low or lost circulation, depth(s) of water-/foam-additive injection(s), air-quality data, drill-cuttings description, depths of and type of sample(s)/core(s) taken from the hole, and other data identified as necessary and pertinent to the needs of the exploration program.

NOTE 16—Drilling rates depend on many factors such as the density or stiffness of unconsolidated material and the existence of cobbles or boulders, the hardness or durability of the rock, or both, the swelling activity of clays or shales encountered in the borehole, and the erosiveness of the borehole wall. Drilling rates can vary from a few millimetres (less than an inch/minute) to about 1 m (3 ft)/min, depending on subsurface conditions. Other factors influencing drilling rates include the weight of the drill string, collar(s) weight and size of drill pipe, and the rig pulldown or holdback pressure. These data and other drilling rate information should be recorded.

6.2.7 Sampling or in-situ testing can be performed at any depth in the hole by interrupting the advance of the bit, cleaning the hole of cuttings according to 6.2.5, stopping air circulation, and removing the drill-rod column from the borehole. Drill-rod removal is not necessary when a sample may be obtained or an in-situ test can be performed through the hollow axis of the drill rods and bit. Compare the sampling depth to the cleanout depth. Verify the depth comparison data by first resting the sampler on the bottom of the hole and comparing that measurement with the cleanout-depth measurement. If bottom-hole contamination is apparent (determined by comparing the hole-cleanout depth with the sampling depth) it is recommended that a minimum depth below the sampler/bit be at least 18-in. for testing. This should be done before every sampling or in-situ testing is performed in the hole. Record the depth of in-situ testing or sampling as well as the depth below the sampler/bit for evaluation of data quality. Decontaminate sampling and testing devices according to Practices D5088 or D5608 prior to testing.

6.3 When drilling progress through material suspected of being contaminated occurs, installation of single or multiple (nested) casings may be needed to isolate zones of suspected contamination. Isolation casings are usually installed in a predrilled borehole or by using a casing advancement method. A grout seal is then installed, usually by applying the grout at the bottom of the annulus with the aid of a grout shoe or a grout packer and a tremie pipe. The grout should be allowed to set before drilling activities are continued. Document the casing and grouting records, including location(s) of nested casings for the hole.