Standard Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices[1]

This standard is issued under the fixed designation D 5872; 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 casing-advancement drilling and sampling procedures may be used for geoenvironmental exploration and installation of subsurface water-quality monitoring devices.

1.2 Different methods exist to advance casing for geoenvironmental exploration. Selection of a particular method should be made on the basis of geologic conditions at the site. This guide does not include procedures for wireline rotary casing advancer systems which are addressed in Guide D 5786.

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

1.4 Casing-advancement drilling methods for geoenvironmental exploration and monitoring-device installations will often involve safety planning, administration and documentation. This guide does not purport to specifically address exploration and site safety.

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 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 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 Practice 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 Ground Water Monitoring Wells in Aquifers[3]
D 5254 Practice for Minimum Set of Data Elements to Identify a Ground-Water Site[3]
D 5299 Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities[3]
D 5408 Guide for the Set of Data Elements to Describe a Ground-Water Site; in manuscript: Part 1—Additional Identification Descriptors[3]
D 5409 Guide for the Set of Data Elements to Describe a Ground-Water Site; in manuscript: Part 2—Physical Descriptors[3]

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

D 5410 Guide for the Set of Data Elements to Describe a Ground-Water Site; in manuscript: Part 3—Usage Descriptors[3]

D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock

D 5474 Guide for Selection of Data Elements for Ground-Water Investigations[3]

D 5521 Guide Development of Ground Water Monitoring Wells in Granular Aquifers[3]

D 5730 Guide for Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone and Ground Water

D 5781 Guide for the Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[3]

D 5782 Guide for the Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[3]

D 5783 Guide for the Use of Direct-Rotary Drilling with Water-Based Drilling Fluid Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[3]

D 5784 Guide for the Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[3]

D 5876 Guide for the Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices[3]

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

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

3.2.3 *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).

3.2.4 *cleanout depth*—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).

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

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

3.2.8 *drill string*—the complete 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.

3.2.9 *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 selected 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, act as a formation stabilizer when the aquifer is suitable for natural development.

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

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

3.2.11 *in-situ testing devices*—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 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.

3.2.12 *mast*—or derrick, on a drilling rig is used for supporting the crown block, top drive, pulldown chains, hoisting lines, etc. It must be constructed to safely carry the expected loads encountered in drilling and completion of wells of the diameter and depth for which the rig manufacturer specifies the equipment.

3.2.12.1 *Discussion*—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.

3.2.13 *piezometer*—an instrument placed below ground surface to measure hydraulic head at a point.

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

4. Significance and Use

4.1 Casing advancement may be used in support of geoenvironmental exploration and for installation of subsurface water-quality monitoring devices in both unconsolidated and consolidated materials. Casing-advancement systems and procedures used for geoenvironmental exploration and instrumentation installations consist of direct air-rotary drilling utilizing conventional rotary bits or a down-the-hole hammer drill with underreaming capability, in combination with a drill-through casing driver.

NOTE 1—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.

4.1.1 Casing-advancement methods allow for installation of subsurface water-quality monitoring devices and collection of water-quality samples at any depth(s) during drilling.

4.1.2 Other advantages of casing-advancement drilling methods include: the capability of drilling without the introduction of any drilling fluid(s) to the subsurface; maintenance of hole stability for sampling purposes and monitor-well installation/construction in poorly-indurated to unconsolidated materials.

4.1.3 The user of casing-advancement drilling for geoenvironmental exploration and monitoring-device installations should be cognizant of both the physical (temperature and airborne particles) and chemical (compressor lubricants and possible fluid additives) qualities of compressed air that may be used as the circulating medium.

4.2 The application of casing-advancement drilling to geoenvironmental exploration may involve soil or rock sampling, or in-situ soil, rock, or pore-fluid testing. The user may install a monitoring device within the same borehole wherein sampling, in-situ or pore-fluid testing, or coring was performed.

4.3 The subsurface water-quality monitoring devices that are addressed in this guide consist generally of a screened- or porous-intake device 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 low-permeability backfill to deter the movement of fluids or infiltration of surface water between hydrologic units penetrated by the borehole (see Practice D 5092). 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 and integrity of the installation to include the quality of materials that will contact sampled water or gas. Both water-quality monitoring devices and piezometers should have adequate casing seals, annular isolation seals and backfills to deter communication of contaminants between hydrologic units.

5. Apparatus

5.1 Casing-advancement systems and procedures used for geoenvironmental exploration and instrumentation installations include: direct air rotary in combination with a drill-through casing driver, and conventional rotary bits or down-the-hole hammer drill with or without underreaming capability. Each of these methods requires a specific type of drill rig and tools.

NOTE 2—In North America, the sizes of casings bits, drill rods and core barrels are standardized by American Petroleum Institute (API)[4] and the Diamond Core Drill Manufacturers Association (DCDMA). Refer to the DCDMA Technical Manual[5] and to published materials of API for available sizes and capacities of drilling tools equipment.

5.1.1 Direct air-rotary drill rigs equipped with drill-through casing drivers have a mast-mounted, percussion driver that is used to set casing while simultaneously utilizing a top-head rotary-drive unit. The drill string is generally advanced with bit being slightly ahead of the casing. Fig. 1 shows the various components of the drill-through casing driver system. Other mechanical components include casings, drill rods, drill bits, air compressors, pressure lines, swivels, dust collectors, and air-cleaning device (cyclone separator).

5.1.1.1 *Mast-Mounted Casing Driver*, using a piston activated by air pressure to create driving force. Casing drivers are

[4] American Petroleum Institute, "API Specifications for Casing, Tubing, and Drill Pipe," *API Spec 5A*, API, Dallas, TX 1978.

[5] *DCDMA Technical Manual*, Drilling Equipment Manufacturers Association, 3008 Millwood Avenue, Columbia, SC 29205, 1991.

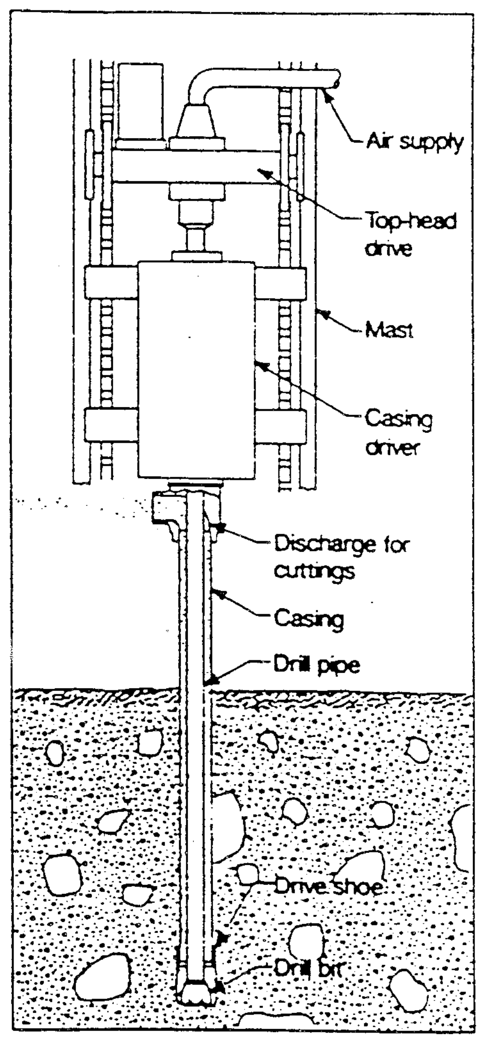


FIG. 1 Casing Drivers can be Fitted to Top-Head Drive Rotary Rigs to Simultaneously Drill and Drive Casing

devised to principally drive casing down while drilling but they can also be used to drive the casing upward for casing removal.

5.1.1.2 *Standard Casings*, driven with the casing driver. The bottom of the casing is equipped with a forged or cast alloy drive shoe. The top of the casing fits into the casing driver by means of an anvil. In hard formations casings may be welded at connections for added stability. The casing size is usually selected to provide a drill hole of sufficient diameter for the required sampling or testing or for insertion of instrumentation device components such as the screened intake and filter pack and installation devices such as a tremie pipe.

5.1.1.3 Other considerations for selection of casing size are borehole depth and formation type. The casing size should allow for adequate annulus between the casing and the drill rod for upward discharge of cuttings. Also, consideration should be made when difficult formations are expected to require telescoping from larger to smaller casing diameters.

5.1.1.4 *Drill Rods*, used inside the casing for rotary air drilling. The rods extend through the casing driver and are connected to a top-head drive motor for rotation and transfer of rotational force from the drill rig to the bit or core barrel. Drill rod and casing are usually assembled as a unit and raised into position on the mast. Individual drill rods should be straight so they do not contribute to excessive vibrations or "whipping" of the drill-rod column. All threaded connections should be in good repair and not leak significantly at the internal air pressure required for drilling. Drill rods should be made up securely by wrench tightening at the threaded joint(s) at all times to prevent rod damage. Drill pipes usually require lubricants on the threads to allow easy unthreading (breaking) of the connecting 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 pipe-thread lubricants on chemical analyses of samples should be considered and documented when using casing-advancement 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.

5.1.1.5 *Rotary Bit*, attached to the bottom of the drill rod and provides material-cutting capability. Core barrels may be used to obtain sample cores and during this operation the casing can be advanced up to the length of the core barrel. Numerous bit types can be selected depending on the formation properties. Some types successfully used include roller-cone rock bits and drag bits. In hard formations down-the-hole hammers can be substituted for rotary drill bits. Bit selecton can be aided by review of referenced literature or consultation with manufacturers, or both.

5.1.1.6 Perform coring of rock in accordance with Practice D 2113. Soil sampling or coring methods, some of which are listed in 2.2 can also be used to obtain samples and advance the hole. Simultaneously coring and advancing the casing with the casing driver would normally be considered incompatible.

5.1.1.7 Direct-rotary bits have discharge ports that are in close proximity with the bottom of the hole. When these are used in loose cohesionless materials, jetting or excessive erosion of the test intervals could occur.

5.1.2 Casing-advancement drill rigs may be equipped with either standard or underreaming down-the-hole hammers. Standard down-the-hole hammers can be used in unconsolidated deposits to break up highly abrasive particles such as cobbles and boulders. Underreaming down-the-hole hammers operate by drilling and underreaming the drill hole using an air-activated down-the-hole percussion hammer so that the casing falls or can be pushed downward directly behind the hammer bit. Cuttings are removed from the drill hole by air exiting the down-the-hole hammer. In stable rock formations casings may not be required. Down-the-hole hammers may also be used with direct air-rotary drilling procedures discussed in Guide D 5782.

5.1.3 *Down-the-Hole Hammer*, is a pneumatic drill operated on the end of the drill rods. The bit at the end of the hammer is constructed of alloy steel and tungsten-carbide inserts to provide cutting or chipping surfaces. The pneumatic hammer impacts the rock surface while the drill pipe is slowly rotated. Rotation of the bit helps ensure even penetration and straight holes in rock. Proper rotational speed is 10 to 30 rpm with lower speeds used in harder rock. Down-the-hole hammers require air pressures ranging from 100 to 200 lb/in.^{2} and volumes of 100 to 300 cfm.

5.2 *Air Compressors*, required to operate the casing driver and the down-the-hole hammer and to provide air to circulate the drill cuttings out of the borehole.

5.2.1 *Air Compressor and Filter(s)*, providing adequate air without significant contamination, for removal of cuttings generated at the bit. Air requirements for casing drivers can be evaluated from manufacturers' literature. Air requirements for rotary drilling bits or down-the-hole hammers will depend upon the drill rod and bit configuration, the character of the material penetrated, the depth of drilling below ground-water level, and the total depth of drilling. The flow-rate requirements are usually based on an annulus upflow velocity of about 1000 to 1300 m/min (about 3000 to 4000 ft/min) even though upflow rates of less than 1000 m/min (about 3000 to 4000 ft/min) are often adequate for cuttings transport. Guidance for design of air-pressure circulation systems can be found in referenced literature.

5.2.1.1 The quality of compressed air entering the borehole and the quality of air discharged from the borehole and air-cleaning devices must be considered. If not adequately filtered, the air produced by most oil-lubricated air compressors can introduce some oil into the circulation system. High-efficiency, inline, air filters are usually required to minimize contamination of the borehole. Air-quality monitoring may be required and, if performed, results should be documented.

5.2.2 *Pressure Hose*, conducting the air from the air compressor to the swivel.

5.2.3 *Swivel*, directing the air to the drill-rod column.

5.2.4 *Discharge Hose*, conducting air and cuttings from the drill-hole annulus to an air-cleaning device.

5.2.5 *Air-Cleaning Device*, generally called a cyclone separator—separates cuttings from the air returning from the drill hole via the discharge hose. A properly-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. In special cases, the cyclone separator can be combined with a HEPA (high-efficiency particulate air) filter for removing dust particles that might be radioactive. In other special situations, the cyclone separator may be used in conjunction with a charcoal-filtering arrangement for removal of organic volatiles. Samples of drill cuttings can be collected for analyses of materials penetrated. If samples are obtained, the depth(s) and interval(s) of sample collection should be documented.

5.2.6 Compressed air alone can often transport cuttings from the drill hole 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. Under other circumstances, for example if the drill hole starts to produce water, the injection of a foaming agent may be required. If changes to the circulating medium are made, such as addition of water, the depth(s) or interval(s) of these changes should be documented. It is important to observe the quantity and quality of return air and cuttings. Zones of low air return as well as zones of no air return should be documented. If circulation is lost and input air pressure is allowed to increase, the possibility of fracturing the geologic materials exists. In order not to raise pressures excessively the compressor can be equipped with pressure relief valves.

6. Drilling Procedures

6.1 As a prelude to and throughout the drilling process stabilize the drill rig and raise the drill-rig mast and position the cyclone separator. 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 separator relative to the rig exhaust since air-quality monitoring will be performed at the cyclone-separator discharge point. Establish and document a datum for measuring hole depth. This datum is normally the top of the surface casing or the drilling deck. If the hole is to be later surveyed for elevation, record and report the height of the datum to the ground surface.

6.1.1 Clean and decontaminate the drill rig, drill rods and bits, and hoisting and sampling tools according to Practice D 5088 prior to commencing drilling and sampling operations and at periods during the drilling operation when deemed appropriate such as when the drill string is removed from the hole to permit intermittent sampling.

NOTE 3—It is extremely important to check above the drilling rig for overhead obstructions or hazards, such as power lines, prior to lifting the mast. In most cases it is required to perform a survey of underground and all other utilities prior to drilling to evaluate possible hazards.

6.2 Drilling is usually done as follows:

6.2.1 Attach an initial assembly of a bit, often with a single section of drill rod and casing, to the top-head drive unit.

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

6.2.3 Drill through casing driver.

6.2.3.1 Several drilling methods can be used with direct air-rotary drill rigs equipped with drill-through casing drivers: the drill bit and casing are advanced as a unit, in unconsolidated materials the casing is driven first and then the plug in the casing is drilled out, and the drill bit advances beyond the casing, and then is withdrawn into the casing and then the casing is driven. Air exiting the bit removes the cuttings uphole. Separate cuttings from the return air with an air-cleaning device such as a cyclone separator. Air pressures at the bit should be as low as necessary to maintain circulation in order to minimize hydraulic fracturing or excessive erosion of the surrounding materials. Monitor air pressures during drilling. Changes in cuttings return and circulation pressures may indicate occurrence of excessive erosion. Should excessive erosion occur, note and document the depth(s) of the occurrence(s). Duly note and document any abrupt changes or anomalies in the air pressures including the depth(s) of occurrence(s).

6.2.3.2 In most operations the casing and bit are advanced as a unit. The drill bit or down-the-hole hammer generally protrudes out through the bottom of the casing usually not more than 50 cm (12 in.). Bit-lead distance is adjusted according to drilling conditions. In loose unstable formations it may be necessary to keep the bit near the end of the casing to prevent excessive erosion of the formation. Occasionally, casing advance is stopped, the bit is retracted inside the casing and circulation is maintained to clear cuttings.

6.2.3.3 Compressed air from the drilling system, when allowed to enter geologic zones to be monitored or sampled, may not be easily developed out and may, in turn, affect the chemistry of water samples obtained. Take care in the drilling process to minimize introduction of air into the formation by not allowing the drill bit to advance beyond the casing shoe in unconsolidated formations where it may be possible to do so.

6.2.3.4 In drilling extremely unstable deposits it may be necessary to use the second method of driving casings without rotary drilling. Intermittently remove the plug in the casing by rotary drilling performed inside the casing.

6.2.3.5 In drilling stable deposits, such as when drilling with down-the-hole hammers, it may be possible to use the method of advancement mentioned above that entails drilling ahead of casing advancement. However, if circulation is lost and input air pressure is allowed to increase, the possibility of fracturing the geologic materials exists when the bit is below the casing.

NOTE 4—Consideration should be given to the speed of drilling so that the borehole can be maintained as close to vertical as practicable.

6.2.4 Underreaming down-the-hole air hammers:

6.2.4.1 Use direct air-rotary drill rigs equipped with underreaming down-the-hole air hammers to advance a casing without applying percussion forces to the casing.

6.2.4.2 Special down-the-hole air hammers open a hole slightly larger than the outside diameter of the casing so that the casing will fall, or can be pushed downward, immediately behind the bit. After advancing the casing, retract the radial dimension of the drill bit to facilitate removal of the down-the-hole air hammer and drill tools from inside the casing.

6.2.4.3 Cuttings are removed from the drill hole with the air that operates the hammer and can be separated from the discharged air with a cyclone separator. While the drilling proceeds, downfeed pressure, cuttings returned, and ease of drilling as it relates to the geologic strata being penetrated should be monitored.

NOTE 5—Discharge of the cuttings from the cyclone separator affords an excellent point for collection and logging of the cuttings during the drilling process.

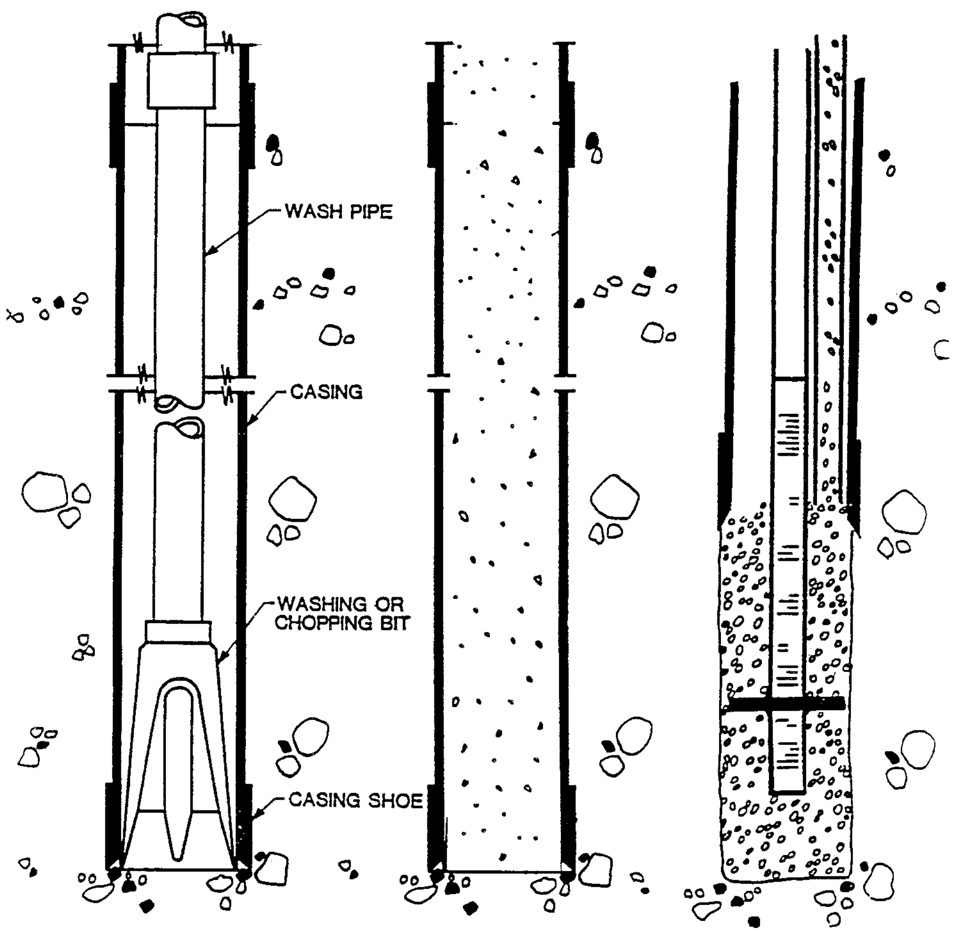
6.2.5 Continue air circulation and rotation of the drill-rod column until drilling progresses to a depth where sampling or in-situ testing will be performed or until the length of the drill-rod section limits further penetration. Then, stop rotation and lift the bit slightly off the bottom of the hole to facilitate cuttings removal while air circulation is continued for a short time until the drill cuttings are removed from the drill-hole annulus. If a check of the hole quality is required, stop circulation and rest the bit on the bottom of the hole. If hole cave or other instability of the boring is suspected, check the depth at which the bit rests against the previous maximum cleanout depth.

6.2.6 Increase drilling depth by attaching an additional drill rod and casing section to the top of the previously advanced drill rod column and resuming drilling operations according to 6.2.2-6.2.5. In some cases, it may be necessary to remove the rotary drill string to change bits. If the string is removed and replaced, check the depth to the base of the boring where the end of the string rests and compare to the clean out depth to evaluate hole quality. As the drilling progresses, note and document drilling procedures such as circulation rates or losses, intervals where equipment is changed, intervals where casing is installed or drilling method is changed.

6.2.7 Sampling or in-situ testing can be performed at any depth by interrupting the advance of the bit and casing, stopping air circulation, and removing the drill rod column from the drill hole. Compare the sampling depth to the cleanout depth if the sampler is attached to rods. This comparison is accomplished by resting the sampler at the bottom of the hole and comparing the apparent depth with the cleanout depth. If the samples taken appear to have been contaminated and contain sloughed materials from the bottom of the hole, the apparent amount of contamination in the sample(s) and the depth of occurrence should be documented. In-situ testing can be performed at the base of the drill hole or at shallower depths if the hole is uncased. If in-situ testing is performed at the base of the drill hole performed, perform similar depth checks to accurately document the location of the test.

7. Installation of Monitoring Devices

7.1 Subsurface water-quality monitoring devices are generally installed in boreholes drilled by casing advancement methods using the three-step procedure shown in Fig. 2. The three steps are as follows: (1) casing advancement in increments, with or without sampling; (2) removal of the drill rods and the attached drill bit while the casing is temporarily left in place to support the borehole wall; and (3) insertion of the



NOTE 1—The method shown is with using the wash boring method. Drilling procedures and tools other than those shown may be used.

FIG. 2 Basic Three-Step Procedure for Installation of Instrumentation Devices Using Casing Advancement Methods

monitoring device through the inside of the casing, and followed by addition of well-completion materials (that is, filter packs, annular seals and grouts) as the casing is withdrawn from the borehole. (Under some circumstances, part of the casing may be left in the drilled hole.)

7.2 Assemble water-quality monitoring devices with attached fluid conductors (risers) and insert them into the borehole with the least possible addition of contaminants.

7.2.1 Some materials, such as screens and risers, may require cleaning or decontamination at the job site, or both (see Practice D 5088).

7.2.2 Prior to installation, store all monitoring-device materials undercover and place upwind and well away from the drill rig and any other sources of contamination such as electrical generators, air compressors, or industrial machinery.

7.2.3 Clean and decontaminate hoisting tools, particularly wire rope and hoisting swivels according to Practice D 5088 before using.

7.3 Select and install filter materials, bentonite pellets, bentonite granules and chips and grouts, according to subsurface monitoring or instrumentation requirements.

7.3.1 Filter packs, for monitoring devices are usually installed in borings drilled with casing advancement methods by placing the materials through the casing-riser annulus. This annular area then serves the same function as a separate tremie pipe for placing the annular materials. In some cases, it may be appropriate to use a tremie pipe inserted in the annulus between the inner pipe and the monitoring-device riser, provided it is sufficiently large. Monitoring devices installed in a saturated zone ordinarily have sand size filter packs that are selected primarily on the basis of the grain size characteristics of the hydrologic unit adjacent to the screened intake. The coefficient of uniformity of the filter-pack sand is usually less than 2.5. Filter packs for monitoring devices installed in a vadose zone may be predominantly silt sized. These filter materials are often mixed with water of known quality, inserted through a tremie pipe, and tamped into place around the device. Take care when adding backfill or filter material(s), or both, so that the materials do not bridge. However, if bridging does occur during the installation procedure, tamping rods or other tamping devices may be used to dislodge the “bridge”.

7.4 Sealing materials, consisting of either bentonite pellets, chips, or granules, are usually placed directly above the filter pack of a monitoring device. It may be effective, when granular filter packs are used, to install secondary filter of thin, fine sand either below the annular seal or both above and below the seal. These secondary filters protect both the monitoring-device filter and the seal from intrusion of grout installed above the seal.

7.5 The backfill that is placed above the annular seal is usually a bentonite or cement-based grout. Grouts should be designed and installed in consideration of the ambient hydrogeologic conditions. Select the constituents according to specific performance requirements and these data documented. Typical grout mixtures are given in Practice D 5092 and Test Methods D 4428.

7.5.1 Clean and decontaminate grouting equipment prior to use according to Practice D 5088. Also, the equipment used for grouting should be constructed from materials that do not “leach” significant amounts of contaminants to the grout.

7.5.2 Control the initial position of the tremie pipe and grouting pressures to prevent materials from being jetted into underlying seal(s) and filter(s). Consider use of a tremie pipe having a plugged bottom and side-discharge ports to minimize bottom-jetting problems.

7.5.3 When it is appropriate to use a grout line, discharge the grout at a depth of approximately 1.5 to 3 m (5 to 10 ft) below the grout surface within the annulus (after the initial 1.5 to 3 m (5 to 10 ft) of grout has been deposited above the uppermost filter or seal). Document the need for chemical analysis of samples of each grout component and the final mixture. Also, it should be noted that if cements are used for grouting, they generate hydroxides and heat, thereby causing a localized increase in the alkalinity and temperature of the surrounding ground water.

7.5.4 Using a tremie install the grout from the bottom of the borehole to the top of the borehole so as to displace fluids in the borehole.

8. Development

8.1 Most monitoring-device installations should be developed to remove any air that may have been introduced into the formation by the drilling method, suspended solids from drilling fluids, and disturbance of geologic materials during installation and to improve the hydraulic characteristics of the filter pack and the geohydrologic unit adjacent to the intake. For suggested well-development methods and techniques the user is referred to Guide D 5521. The methods(s) selected and time expended to develop the installation and the changes in water quality discharged at the surface should be carefully observed and documented. Under most circumstances, development should be initiated as soon as possible following completion however, time should be allowed for initial setting of grout.

9. Field Report and Project Control

9.1 The field report should include all information and identified as necessary and pertinent to the needs of the exploration program.

9.2 Other information in addition to Guide D 5434 should be considered if deemed appropriate and necessary to the needs of the exploration program. Additional information should be considered as follows:

9.2.1 *Drilling Method*:

9.2.1.1 Description of the casing advancement method system,

9.2.1.2 Type, quantities, and locations in the borehole of use of additives added to the circulation media,

9.2.1.3 Description of circulation rates, cuttings return, including quantities, over intervals used,

9.2.1.4 Description of the lithology of the cuttings that are returned, and

9.2.1.5 Descriptions of drilling conditions related to drilling pressures, rotation rates, and general ease of drilling as related to subsurface materials encountered.

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

9.2.3 *In-situ Testing*:

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

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

9.2.4 *Installations*—A description of well-completion materials and placement methods, approximate volumes placed, depth intervals of placement, methods of confirming placement, and areas of difficult of material placement or unusual occurrences.

10. Keywords

10.1 casing-advancement drilling method(s); direct air rotary drilling; down-the-hole hammer (DTH); drill through casing hammer; drilling; ground water

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