Designation: D6914/D6914M – 16

Standard Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices[1]

This standard is issued under the fixed designation D6914/D6914M; 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 practice covers procedures for using sonic drilling methods in the conducting of subsurface exploration for site characterization and in the installation of subsurface monitoring devices.

1.2 The use of the sonic drilling method for exploration and monitoring-device installation may often involve preliminary site research and safety planning, administration, and documentation.

1.3 Soil or Rock samples collected by sonic methods are classed as group A or group B in accordance with Practices D4220. Other sampling methods (Guide D6169) may be used in conjunction with the sonic method to collect samples classed as group C and Group D. Other drilling methods are summarized in Guide D6286.

1.4 *Units*—The values stated in either inch-pound units or SI units [presented in brackets] are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Reporting of test results in units other than in-pound shall not be regarded as nonconformance with this practice.

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values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this standard.

1.6 This practice offers a set of instructions for performing one or more specific operations. It is a description of the present state-of-the-art practice of sonic drilling. It does not recommend this method as 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 practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.6.1 This practice does not purport to comprehensively address all the methods and the issues associated with drilling practices. Users should seek qualified professionals for decisions as to the proper equipment and methods that would be most successful for their site investigation. Other methods may be available for drilling and sampling of soil, and qualified professionals should have the flexibility to exercise judgment as to possible alternatives not covered in this practice. This practice is current at the time of issue, but new alternative methods may become available prior to revisions, therefore, users should consult manufacturers or sonic drilling services providers prior to specifying program requirements.

1.7 *This practice does not purport to address all the safety concerns, if any, associated with its use and may involve use of hazardous materials, equipment, and operations. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.* For good safety practice, consult applicable OSHA regulations and drilling safety guides.[2,3,4]

2. Referenced Documents[5]

2.1 *ASTM Standards—Soil Classification:*

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Exploration

[1] This practice 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.

Current edition approved Nov. 15, 2016. Published December 2016. Originally approved in 2004. Last previous edition approved in 2010 as D6914–04(2010). DOI: 10.1520/D6914_D6914M-16.

[2] "Drilling Safety Guide," National Drilling Association.

[3] "Drillers Handbook," Thomas C. Ruda and Peter Bosscher, National Drilling Association.

[4] "Innovative Technology Summary Report," April 1995, U.S. Department of Energy.

[5] 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

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock

2.2 *ASTM Standards—Drilling Methods and Installation Methods:*

D1452 Practice for Soil Exploration and Sampling by Auger Borings
D5088 Practice for Decontamination of Field Equipment Used at Waste Sites
D5299 Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities
D5791 Guide for Using Probability Sampling Methods in Studies of Indoor Air Quality in Buildings
D5782 Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5784 Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D6286 Guide for Selection of Drilling Methods for Environmental Site Characterization

2.3 *ASTM Standards—Soil Sampling:*

D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1587 Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils (Withdrawn 2016)[6]
D4220 Practices for Preserving and Transporting Soil Samples
D4700 Guide for Soil Sampling from the Vadose Zone
D6169 Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations
D6640 Practice for Collection and Handling of Soils Obtained in Core Barrel Samplers for Environmental Investigations

2.4 *ASTM Standards—Aquifer Testing:*

D4044 Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
D4050 Test Method for (Field Procedure) for Withdrawal and Injection Well Testing for Determining Hydraulic Properties of Aquifer Systems
D5092 Practice for Design and Installation of Groundwater Monitoring Wells

2.5 *ASTM Standards—Other:*

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of technical terms in this standard refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hydraulic extraction, n*—the removal of the sample specimen from the solid sampling barrel by the application of fluid.

3.2.2 *natural frequency, n*—the frequency or frequencies at which an object tends to vibrate when disturbed.

3.2.3 *resonance, n*—when one object (sine generator) vibrating at the natural frequency of a second object (drill pipe or casing) forces the second object into vibrational motion.

3.2.4 *sine wave generator, n*—a drill head that imparts forces in wave forms corresponding to single-frequency periodic oscillations to create resonance of the drill rods and casings to advance the drill hole.

3.2.4.1 *Discussion*—This drill head is referred to as a sonic drill head, or resonant sonic drill head throughout this standard. This drill head is attached to the drill rods and casings and can be used to lift rods for sample extrusion.

3.2.5 *sonic drilling, n*—the practice of using high frequency vibration as the primary force to advance drill tools through subsurface formations.

3.2.5.1 *Discussion*—While vibration is the primary force for drilling, the drilling process also requires rotation of the drill rods with applied downforce reaction from the drill

4. Summary of Practice

4.1 Sonic drilling is the utilization of high frequency vibration aided by down pressure and rotation to advance drilling tools through various subsurface formations. All objects have a natural frequency or set of frequencies at which they will vibrate when disturbed. The natural frequency is dependent upon the properties of the material the object is made of and the length of the object. The sonic drill head provides the disturbance to the drilling tools causing them to vibrate. To achieve penetration of the formation the strata is fractured, sheared, or displaced. The high frequency vibration can cause the soil in contact with the drill bit and drilling casing string to liquefy and flow away allowing the casing to pass through with reduced friction. Rotation of the drill string is primarily for even distribution of the applied energy, to control bit wear, and to help maintain borehole alignment. The use of vibratory technology reduces the amount of drill cuttings, provides rapid formation penetration, and the recovery of a continuous core sample of formation specimens for field analysis and laboratory testing. Boreholes generated by sonic drilling can be fitted with various subsurface condition monitoring devices. Numerous sampling techniques can also be used with this system including thin walled tubes, split barrel samplers, and *in-situ* groundwater sampling devices. Fig. 1 demonstrates the general principle of sonic drilling.

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

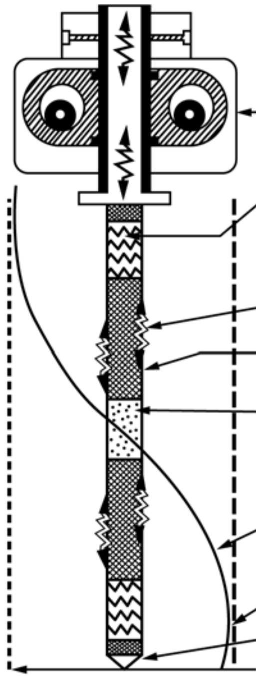

FIG. 1 General Principle of Sonic Drilling

5. Significance and Use

5.1 Sonic drilling is a rapid, primarily dry drilling method (see 5.2), used both in geotechnical applications to avoid hydraulic fracturing, and in environmental site exploration. Geotechnical applications include exploration for tunnels, underground excavations, and installation of instrumentation or structural elements. Sonic drilling methods are used in rocky soils with large diameter casing to obtain continuous samples in materials that are difficult to sample using other methods. It is well suited for projects of a production-orientated nature with a drilling rate faster than most all other drilling methods (Guide D6286). Sonic drilling is used for environmental explorations because sonic drilling offers the benefit of significantly reduced drill cuttings, a major cost element, and reduced drill fluid use and production. Sonic drilling offers rapid formation penetration thereby increasing production. It can reduce fieldwork time generating overall project cost reductions. The continuous core sample recovered provides a representative lithological column for review and analysis. Sonic drilling readily lends itself to environmental instrumentation installation and to *in-situ* testing. The advantage of a clean cased hole without the use of drilling fluids provides for increased efficiency in instrumentation installation. The ability to cause vibration to the casing string eliminates the complication of monitoring well backfill bridging common to other drilling methods and reduces the risk of casing lockup allowing for easy casing withdrawal during grouting. The clean borehole reduces well development time. Pumping tests can be performed as needed prior to well screen placement to allow for proper screen location. The sonic method is readily utilized in multiple cased well applications which are required to prevent aquifer cross contamination. The installation of inclinometers, vibrating wire piezometers, settlement gauges, and the like can be accomplished efficiently with the sonic method.

5.2 The cutting action, as the sonic drilling bit passes through the formation, may cause disturbance to the soil structure along the borehole wall. The vibratory action of directing the sample into the sample barrel and then vibrating it back out can cause distortion of the specimen. Core samples can be hydraulically extracted from the sample barrel to reduce distortion. The use of split barrels, with or without liners, may improve the sample condition but may not completely remove the vibratory effect. When penetrating rock formations, the vibration may create mechanical fractures that can affect structural analysis for permeability and thereby not reflect the true *in-situ* condition. Sonic drilling in rock will require the use of air or fluid to remove drill cuttings from the face of the bit, as they generally cannot be forced into the formation. Samples collected by the dry sonic coring method from dense, dry, consolidated or cemented formations may be subjected to drilling induced heat, which could be a concern if core sampling for volatile organic compounds using Practice D6640. Heat is generated in these dry formations by the impact of the bit on the formation and the friction created when the core barrel is forced into the formation. The sampling barrel is advanced without drilling fluid whenever possible. Therefore, in very dense formations, drilling fluids may have to be used to remove drill cuttings from the bit face and to control drilling generated heat. In dry, dense formations precautions to control drilling generated heat may be necessary to avoid affecting contaminant presence. The effects of drilling generated heat can be mitigated by shortening sampling runs, changing vibration level and rotation speed, using cooled sampling barrels, collecting larger diameter samples to reduce effect on the interior of the sample, and using fluid coring methods or by using alternate sampling methods such as the standard penetration test type samplers at specific intervals. Heat generated while casing the borehole through dense formations after the core sample has been extracted can be alleviated by potable water injection and/or by using crowd-in casing bits that shear the formation with minimal resistance. Should borehole wall densification be a concern it can be alleviated by potable water injection, by borehole wall scraping with the casing bit, by using a crowd-in style bit, or by injecting natural clay breakdown compounds.

5.3 Other uses for the sonic drilling method include mineral investigations. Bulk samples can be collected continuously, quite rapidly, in known quantities to assess mineral content. Aggregate deposits can be accurately defined by using large diameter continuous core samplers that gather representative samples. A limited amount of rock can be effectively penetrated and crushability determined. In construction, projects include freeze tube installations for deep tunnel shafts, piezometers, small diameter piles, dewatering wells, foundation anchors with grouting, and foundation movement monitoring instrumentation. Sonic drills can be used to set potable water production wells. However, production may not equal more conventional potable well drilling techniques because of the need to transport drill cuttings to the surface in short increments. Sonic drill units presently in use are in various sizes and most are truck mounted. Sonic drills can be skid or all-terrain vehicle mounted to access difficult areas.

5.4 Sonic drills can be adapted to such other drill methods as conventional rotary (Guide D1583, Guide D5782), down hole air hammer work (Guide D5782), diamond bit rock coring; conventional and wireline (Practice D2113), direct push probing (Guide D6001, Guide D6286), thin wall tube sampling (Practice D1587), and standard penetration test split barrel sampling (Practice D1586). The sonic drilling equipment offers more adaptability than most existing drilling systems. However, it is important to keep in mind that the technique the machine is designed for is the one at which it will be the most efficient. Long term use of sonic drills for other drilling methods may not be cost effective.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors. Practice D3740 was developed for agencies engaged in the testing and/or inspection of soils and rock. As such, it is not totally applicable to agencies performing this practice. However, user of this practice should recognize that the framework of Practice D3740 is appropriate for evaluating the quality of an agency performing this practice. Currently there is no known qualifying national authority that inspects agencies that perform this practice.

6. Criteria for Selection

6.1 Important criteria to consider when selecting the sonic drilling method include the following:

6.1.1 Diameter of borehole,

6.1.2 Sample quality (Class A, B) for laboratory physical testing (Refer to Practices D4220),

6.1.3 Sample handling requirements such as containers, preservation requirements,

6.1.4 Subsurface conditions anticipated: soil type or rock type/hardness,

6.1.5 Groundwater depth anticipated,

6.1.6 Boring depth,

6.1.7 Instrumentation requirements,

6.1.8 Chemical composition of soil and contained pore fluids,

6.1.9 Available funds,

6.1.10 Estimated cost,

6.1.11 Time constraints,

6.1.12 History of method performance under anticipated conditions (consult experienced users and manufacturers),

6.1.13 Site accessibility,

6.1.14 Decontamination requirements,

6.1.15 Grouting requirements, local regulations, and

6.1.16 Amount of and disposal costs for generated drill cuttings and drilling wastes.

7. Apparatus

7.1 *Sonic Drill Head*—The sonic drill head contains a sine wave generator, sine generator drive mechanism, lubrication system to reduce friction and control heat in the head, vibration isolation device, drill string rotating mechanism, and a connection to the drill string. The sine wave generator must be capable of producing sufficient energy to force movement in the drill string to accomplish the fracturing, shearing or displacement necessary for the borehole to be advanced as shown in Fig. 1.

7.1.1 *Sine Wave Generator*—The sine wave generator uses eccentric, counter rotating balance weights that are timed to direct 100 percent of the vibration at 0 degrees and at 180 degrees (Figs. 2 and 3). The sine wave generator is powered hydraulically and generally operates at frequencies between 0 and 185 Hz delivering a full range of energy outputs for advancement of up to 12 in. [300 mm] drill casing.

7.1.2 *Lubrication System*—The lubrication system is fitted with oil coolers of sufficient capacity to keep the hydraulic fluid at an allowable operating range as recommended by the oil supplier.

7.1.3 *Vibration Isolation System*—In order to transmit the maximum vibratory energy to the drill string and not damage the drilling rig the vibration applied to the drill tools must be isolated from the drill rig as shown in Figs. 2 and 3. This can be accomplished by using air charged springs, manual disk springs, or such other methods as will meet that goal.

7.2 *Drilling Tools*—A significant variety of tooling is necessary to accomplish the sonic drilling program. The tools consist of drill rods, drill casing, sampler barrels, sampler bits, casing bits, direct push sampling probes, borehole water sample collection systems, etc. Individual drillers and companies have in-house tooling designed for specific purposes and projects. If these specialized tools provide high quality sampling and efficient drilling processes they are acceptable to the practice.

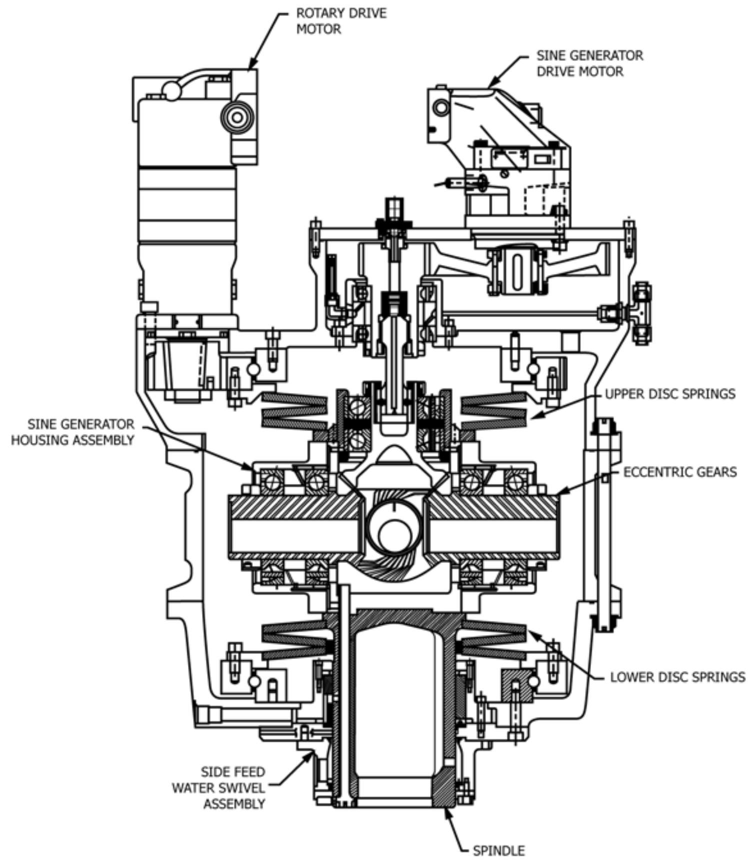

FIG. 2 Typical Sonic Drill Head with Disk Spring Form of Isolation System

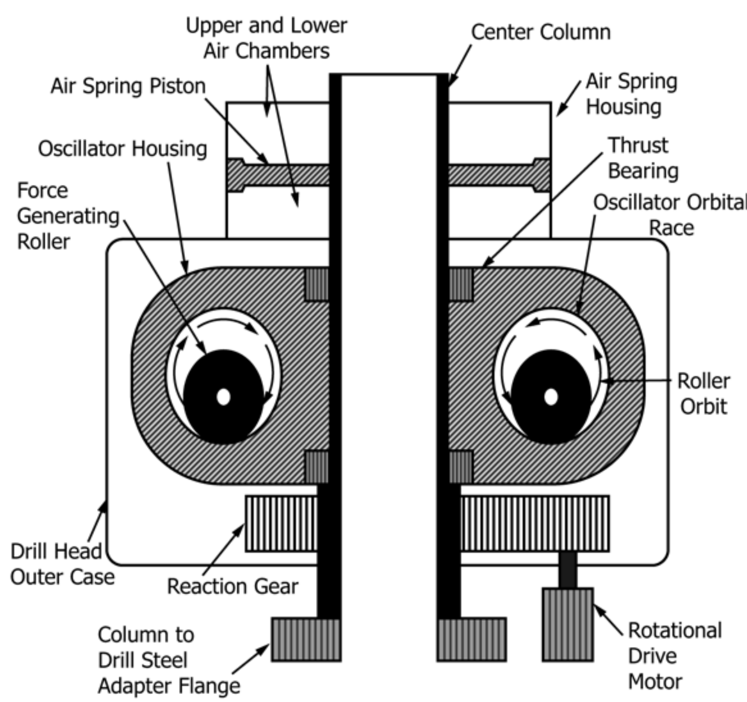

FIG. 3 Typical Sonic Drill Head with Air Spring Form of Isolation System

7.2.1 *Drilling Rods and Casing*—Drilling rods are used to propel and recover the sampling barrels. Drill rods are the most handled tools. The common sizes are 2 in. [50 mm] to 4 in. [100 mm] diameter by 2 ft [0.5 m], 5 ft [1.5 m], 10 ft [3 m], and 20 ft [5 m] lengths. Annular space between casing and rod is not critical allowing the same sized drill rod to be used with various sized sampling barrels. Current sonic drilling technology can be used to set drill casing in various sizes from 4 in. [100 mm] up to 12 in. [300 mm] nominal outside diameter depending on project requirements.

7.2.2 *Sampler Barrel*—Sampler barrels (a.k.a. core barrels) are used to recover formation specimens and to clean the inside of the drill casing. Sampler barrels are either solid tubes or split barrels of various diameters and lengths. The sampling barrels are generally sized to match the inside diameter of the various sizes of drill casing and to fulfill project requirements. The barrel is fitted with a drill bit/cutting shoe that holds the borehole alignment as it passes through the outer casing into the formation.

7.2.2.1 *Solid Barrels*—Solid sampler barrels are a solid length of tubing with thread sections on each end. They are available in various sizes and lengths. Typical sampling runs are 10 to 20 ft [3 to 5 m] in length. Sampling run length can be adjusted to provide the most optimum sample recovery. Sampler barrels can be joined to increase the length of sampling increment. In some formations there is a tendency to lose recovery with longer core run lengths while in others longer core runs may improve recovery. Samples of loose unconsolidated granular formations can be consolidated by the vibratory action. In loose or soft formations the inability of the soil structure to support the force necessary to move the material into the barrel can cause that material to be forced into the formation.

7.2.2.2 *Split Barrel Samplers*—Split barrel samplers are tubes that are split lengthwise with thread sections on both ends. The split sections utilize a tongue & groove feature that interlocks to prevent lateral movement between the two halves of the tube. Split barrel samplers are available in various diameters and lengths. While split barrel samplers provide a better format to view the specimen and may subject it to less disturbance, they do receive vibratory action during penetration. Depending on the method of construction, split barrels have a tendency to spread open in hard formations. They are quite heavy when fully loaded and may require special handling techniques. Liners, clear butyl or polyethylene based plastic, or stainless steel are available for use with split barrel and solid barrel samplers.

7.2.2.3 Standard formation sampling devices can be used in conjunction with the sonic drill rig for geotechnical applications. The standard penetration test D1586 can be performed if the unit is equipped with a cathead or an automatic-hammer 140 lb [63.523 kg]. The hydraulically activated, D6519, as well as manual, fixed piston, thin wall tube samplers D1587 can be used if the unit is equipped with a fluid pump of sufficient capacity. Sonic drills are generally equipped with winch lines for using sampling tools in geotechnical drilling programs.

7.2.3 *Casing Drill Bits*—Drill bits are attached to the leading section of drill casing. Their function is to provide a cutting edge to assist in moving the casing through the various formations encountered and to direct the movement of formation materials during the making of the boring. The face of the drill bit follows one of three basic directional designs: (*1*) “Crowd-in” move most of the material encountered at the drill face into the borehole or casing as it is advanced. This style of bit face provides the best service in dense, dry, or cohesive formations as it helps reduce formation compaction and friction; (*2*) “Crowd-out” moves most of the material encountered at the drill face into the borehole wall. This design works better in softer and more granular, sands, gravels, and silt formations; and (*3*) “Neutral” allows the bit face material to choose the path of least resistance. Different bit face configurations are used to effectively penetrate different formations. The general-purpose bit face is fitted with carbide buttons spaced equally across and around the bit face. Fig. 4 shows a typical carbide button faced bit. The carbide buttoned bit works well in most formations and is considered a general-purpose bit. Carbide buttons are well suited for the impact action that occurs in sonic drilling. Other configurations include welded carbide chips and blocks in a matrix, saw tooth shapes both hard surfaced and plain, and tearing shoe designs with large irregular carbides for working in construction debris and penetrating refuse in landfills. Each of these designs has a useful purpose and can be quite effective at penetrating their respective formations.

7.2.4 *Sample Barrel Bit*—The sample barrel bit is designed to both penetrate the formation and to shape the sample so it will pass through the bit into the sample barrel with the least amount of friction or compression. The bit may be constructed with serrated, carbide buttoned, or some other form of roughened inside diameter surface, or with a machined space for a retainer basket to assist in the retention of the sample. The interior of the sampler bit should have a minimum inside diameter ⅛ in. [3 mm] less than the inside diameter of the sampling barrel to allow the passage of the sample into the core barrel with the least amount of resistance so as to not impede recovery or create unnecessary disturbance to the sample. The cutting face of the bit used should be the design best suited to the formation being penetrated. For dense formations with cobbles and boulders a bit face with carbide buttons may be used. For soft formations a serrated face, sharpened to force the

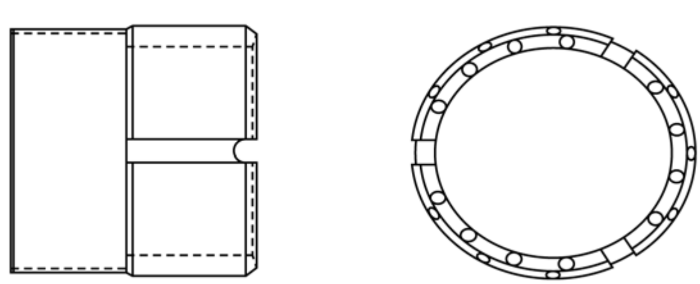

FIG. 4 Sonic Casing Bit

cuttings away from the bit, works well. The choice of bit face type and sample retention method is governed by the characteristics of the formation and should be optimized as the borehole progresses to obtain the highest recovery percentage with the least possible sample disturbance.

7.2.5 *Direct Push Water Sampling Tools*—Sonic drilling is a direct push drilling method as well. Therefore, other sampling tools similar to those used in the direct push industry are also available to the sonic drilling practice. *In-situ* water sampling tools are constructed using a screened inner stem attached to a point that is surrounded by an outer drive pipe. The point is the same diameter as the outer drive pipe to prevent the creation of an enlarged annular space that could provide an avenue for cross contamination between aquifers. The inner screen assembly is sealed from the formation during installation by an outer drive pipe fitted with "o" rings. With the friction of the soil holding the point in place while being driven to depth, the screen section is then exposed to the formation by pulling back on the outer drive pipe. The inner tube can have an inside diameter of 2 to 4 in. [50 to 100 mm] or larger to allow for larger capacity sampling pumps. Using higher capacity pumps accelerates the purging process and allows for rapid sampling from deep formations. The water sampling probes can be fitted with disposable points to allow for pressure grouting or installation of small diameter monitor wells. There are also water sampling probes driven in advance of the boring that have inflatable packers that seal inside the sonic casing.

7.3 *Sonic Drill Rig*—The sonic drill rig is similar to other drilling rigs in that it is a machine attached to a frame mounted on some form of carrier. The unit can be driven by a power take off assembly from the carrier engine or by an auxiliary engine. The unit has a feed frame for moving the drill head up and down to apply feed and retract pressure to the drill string and a mast for tool handling. Some units are equipped with automated tool handling devices. The sonic drill head is powered hydraulically. In addition to the sonic head, the feed system, drill fluid pumps, rod handling systems, and other auxiliary equipment demand power as well. Therefore, the power supply must be capable of providing the horsepower necessary to drive the system. The horsepower requirement is based on the desired productive capacity of the drill. The carrying vehicle must have sufficient gross vehicle weight to support the drill structure, rod handling equipment, fluid pumps, air compressors, and such tool storage as deck space allows.

7.3.1 *Drill Tower*—The drill rig may have a tower for extracting tools from the borehole. Tower lengths can vary, however, higher towers allow for longer tool pulls. The drill rig should have sufficient retraction power to lift a full-length string of the largest rated diameter drill tools from the deepest rated depth plus an additional 50 % or more of that total weight.

7.3.2 *Tool Handling*—Sonic drills traditionally use several different sizes of tooling. The units are generally equipped with some form of tool handling devices. Some units are equipped with a pivotal sonic head. This allows the head to tilt up 90 degrees to vertical so drill rod or casing can be aligned to the spindle for mechanical attachment. The length is then raised and rotated back to vertical for attachment to the drill string. Other units use mechanical rod loaders, which position drill rods or casing for hook up. Wire rope winches can be used for drill rod tripping. Units using the winch method are generally fitted with a slide tray that can accommodate up to 20 ft [5 m] lengths of drill rod for reducing sample barrel retrieval time.

7.3.2.1 *Tool Joint Wrench and Rod Holder Table*—A key component of the sonic drill is the tool joint make-up, breakout, and rod holding table. The upper vice of the tool joint should be capable of bi-directional rotation to both close and open the tool joints. The throat of the joint wrench must be large enough to accommodate the largest rated O.D. tooling of the drill. The throat clearance may be accomplished by jaw retraction or by installing different sized jaws. The lower jaw assembly and its supporting members should be capable of supporting the total weight of the maximum O.D tooling at the maximum depth rating of the machine. The upper jaw may include some form of high-speed rod spinning device to expedite rod disconnection.

7.3.3 *Auxiliary Equipment*—Sonic drill units require a fluid pump or pumps depending on the anticipated work program. The pumps serve many purposes; to push drilling fluids down the bore hole for lubrication and bit face cuttings removal while advancing the outer casing over core barrels in certain formations, when rock drilling to assist in the removal of cuttings, for bit cooling and cuttings removal while diamond bit rock coring, for mixing of drill fluids and grouts, for grouting of instrumentation, to grout (backfill) bore holes, and for equipment cleaning. Drill fluid injection is generally more predominate when installing casing in saturated granular formations to maintain pressure equalization than when drilling more cohesive formations. The primary purpose of injecting fluids is to keep the inside of the drilling casing clean as it is advanced over the sampling barrel. Normally drill fluids are not recycled during sonic drilling so volume generated is generally small. As the sonic drilled borings can go to considerable depth it is recommended that the unit have a least one positive displacement type pump. If a second fluid pump is desired, it should be capable of supplying 200 psi [1400 kN/m^2] for mixing and for cleaning. Progressive cavity, or peristaltic pumps, work well for this purpose. All fluid pumps should be equipped with pressure indicating gauges and pressure relief valves set at the necessary level to protect the pumps from damage and to prevent fracturing of the formation. Air compressors are sometimes used in conjunction with sonic drilling. They are utilized when operating down hole hammers or other air drilling methods to penetrate formations not conducive to penetration by sonic methods. Air pressure requirements are governed by tool requirements, depth, and bore diameter, see Guide D5782. General tools needed to operate the sonic drill unit include rod lifting tools, pipe wrenches, fluid swivels, and handtools for general maintenance and repair. Other useful equipment would include portable or hydraulic powered arc welders, acetylene torches, steam cleaners, and portable generators. Portable fluid pumps and tanks are also useful for fluid containment and transfer.

7.4 *Expendable Supplies*—Expendable supplies are items such as monitor well materials, bentonite, cement, and their proper uses are described in referenced ASTM standards. They are not addressed in this practice.

8. Conditioning

8.1 *General*—Preparation of the sonic rotary drill unit for project work starts with a thorough check of the drill's operating system. This includes the inspection, testing, and repair of all emergency shutdown switches and other safety devices. The performance of regular routine maintenance procedures including fluid level checks, lubrication, hydraulic hose inspection, leakage repairs, and the checks of the physical components with necessary repairs completed. A thorough cleaning of the drill unit is also recommended. Operating tools should be checked, repaired if necessary, and inventoried, so that that an adequate supply is on hand for the project. Drilling tools, casing, rods, bits, etc., should be checked for proper repair, and loaded in sufficient quantities to complete the project. It is recommended that additional tooling, beyond that required for the project, be taken to the site to reduce down time from breakage or damage, and to allow for increases in work effort that may occur because of site conditions.

NOTE 2—The items in Section 8 regarding inspection, cleaning, inventory, repair, storage, transportation, decontamination, equipment checks, and necessary supplies are primarily related to contractor efficiency. This is only a partial list of activities that are considered good drilling practice to prepare for drilling and are offered for consideration by users. It is recognized that strict conformance with these items is not imperative for sonic drilling and does not necessarily correlate to the quality of the work.

8.1.1 *Equipment Movement*—All tools, materials, and equipment needed for the project should be loaded in a safe manner and secured in compliance with U.S. Department of Transportation, state, and local regulations. The drilling rig, support vehicles, and auxiliary equipment should be brought to the project site fully fueled and ready for operation. Extra tooling, instrumentation installation supplies, and other expendables should be stored in a central location in a safe and secure manner. The materials should be stored in a clean dry area in their original containers until transported to the decontamination area for cleaning if necessary or to the actual drill site for installation. All packaging debris, damaged or contaminated materials, and miscellaneous trash accumulate during drilling operations should be containerized and disposed of properly.

8.2 *Decontamination*—If the drilling rig and tooling are to be used on a chemically contaminated site, site specific decontamination procedures must be followed. For general decontamination information refer to Practice D5088 for recommended procedures.

8.3 *Sampling Barrels*—The sampling barrels are in various lengths, generally 5, 10, and 20 ft [1.5, 3, 6 m]. Barrels should be in equal increments to facilitate the accuracy of borehole depth measurements. Sampling barrels are either solid or split styles.

8.3.1 *Solid Sampling Barrels*—Check the barrel thread section for thread condition, dents, kinks, or excessive wear that could result in the loss of the barrel or the sampling shoe, or in improper assembly that will result in a reduction of energy transfer. The barrel body should be straight, without dents or wrench burrs that could cause injury. The inside of the barrel should be clean, free of any debris, rust build-up, or any obstructions.

8.3.2 *Split Sampling Barrels*—Check barrel thread section for thread condition, dents, kinks or excessive wear that could result in the loss of the barrel or sampling shoe, or in improper assembly that will result in a reduction of energy transfer. The barrel body sections should be straight, without dents, kinks, or wrench burrs that could cause injury. The split tongue and grooves must be clean and free from dents, kinks or burrs. The split barrels halves should fit together snugly without bowing or spreading. The inside of the barrel halves must be clean and free of any obstructions.

8.3.3 *Sampler Barrel Heads and Bits*—Sampler barrel heads should be checked for thread condition for proper assembly to facilitate energy transfer. Sampler barrel bits are constructed in different configurations for use in the various formations encountered. The proper bit should be selected for the anticipated formation to be encountered. The cutting face should be free of dents, without cracks, non-manufactured grooves, or indentations. The interior of the bit should be free of obstructions that would impede the movement of the sample in the barrel. Designs in the bit to aid in recovery are permitted. Bits designed for use with basket retainers should have clean undamaged shoulders for receiving basket retainers. Check to see that the required tolerance is present.

8.3.4 *Drilling Without Sampling*—When sonic drilling without sampling is desired the solid sampling barrel bit can be modified to incorporate a drive point. When the maximum boring depth is reached, the sampling barrel is over drilled with the casing to depth and the sampling barrel is removed before setting instrumentation. If a disposable drive point is used, the sampling barrel is withdrawn the length of the point and the point knocked out. Then borehole activities such as water sampling and setting monitor wells or other devices can be accomplished.

8.3.5 *Tool Selection*—Prior to dispatch to the project site, an inventory of the necessary tooling in the proper sizes, expendable items, and instrumentation supplies should be made. Drilling is an inexact science and as such planning should include provisions for possible contingencies that may arise based on the knowledge one can gather about the project and the geology of the site. Routinely used supplies such as drill casing and sample barrel bits, rod lifters, environmentally safe thread lubrication, sampler barrel couplers, and project specific materials should be available so work can proceed unimpeded. If using split barrels or thin wall tubes a sufficient number should be on hand so sample examination does not delay drilling. Expendable supplies such as sample retainer baskets, sample storage bags, or other containers, and other project specific materials should to be available in sufficient quantities so work can progress smoothly. Specialized sampling tools, necessary for project specific requirements, should be checked, cleaned and available in the required number. Refer to Guide D6169 for additional information on soil sampling tool selection. Materials for proper sealing of boreholes should always be available at the site.

9. Procedure

9.1 *General Set Up*—A safety meeting and site/project information meeting is held. A complete set of job safety analyses procedures is reviewed. Utility clearance information is reviewed. The drill crew puts on the required personal protective safety gear. The drill foreman makes a general site reconnaissance and specifically reviews the borehole location before moving any equipment onto the site. All underground and overhead utilities locations are checked and all members of the drill crew receive knowledge of their whereabouts. Any overhead obstructions that may impede drill rig setup and operation are noted. The travel path to the boring location is evaluated for the safe movement of the equipment. Move the drill rig and service vehicles to the borehole location. Unload any auxiliary equipment or supplies from the drill that would interfere with the rig setup. Level the drill unit. The leveling jacks should have sufficiently sized ground contact pads to spread the load and prevent settling during drilling that can cause misalignment of the drill tools. Once the drill is level, raise and secure the mast. If drilling fluids are to be collected position a fluid containment vessel. Position the service vehicles as necessary for efficient tool handling and drilling support. Hook up any pumps, hoses, and position working tools as necessary.

9.1.1 *Drilling Methods*—Sonic drilling can be performed wet, using a drilling medium, or dry. The choice of method is determined by project requirements, formations to be penetrated, and the depth to be achieved. In sonic drilling, the sampling barrel is advanced dry except for those occasions when actual rock or concrete penetration is occurring and drill-cutting removal is necessary to prevent tool lockup. Bouldery formations and weathered bedrock can be drilled dry as long as they will allow the cuttings at the bit face to be forced into the formation without friction causing excessive heat or impeding penetration of the formation. If sonic drilling is to be followed with rock core drilling, the criteria for sonic refusal in terms of drill rate and length of time should be specified in advance. Drilling progresses by fracturing, shearing, or displacement. Fracturing occurs when drilling through formations with cobbles, boulders, or rock formations. Shearing occurs when penetrating dense silt, clay, or soft shale. Displacement occurs in granular formations when the material is liquefied and moves away from the bit and casing, or up the casing or sampling barrel. In sonic drilling, as in other drilling practices, a combination of methods may be necessary to complete the project.

9.1.2 *Tool Preparation*—Attach the proper bit for the formation anticipated to the sampling barrel. Connect the sampling barrel to the drill head and tighten the drill bit and the sampling barrel to the drill head. Check the plumb of the casing in relation to the drill rig. The pre-torquing, or tightening of rod joints is essential to the transmission of energy through the rod string when using sonic technology. All drill rod and casing joints should be pre-torqued to the manufacture's rated capacity and/or to a level equal to the maximum amount of force that the sonic head can impart. Failure to do so can result in a loss of energy as well as damage to the threaded joint and/or loss of tooling. It is generally necessary to rotate the drilling casing to provide for even bit wear, control borehole alignment, and to facilitate removal of the casing and samplers from the borehole on completion. Slow rotation speed is satisfactory as speed is not a controlling factor in advancing the tools. In certain formations rotation of the sampling barrel during core sampling may be necessary.

9.2 *Sample Barrel Insertion*—Advance the sample barrel into and through the topsoil, pavement, or other surface material. Withdraw the sampler from the borehole and remove initial penetration material. Reinsert the sampling barrel, apply down pressure, activate the sonic drill head, and began rotation if needed. Note bottom limit of penetration and adjust as needed by using various rod lengths to achieve desired sampling increment end point. Record drilling increments to the nearest 0.1 ft [0.3 m] or better. It is desirable to end sample increments at the even foot [meter], or 0.5 ft [0.1 m] increments for ease of bore hole measurements. Accurate measurements are critical to determine recovery, locate strata changes, and determine proper instrumentation location in the borehole.

9.2.1 *Sampling-Solid Barrel*—At the completion of the sampling run, stop down pressure, stop the sonic drill head and any rotation of the sampling barrel. If necessary disconnect from the sampling barrel and install casing over the sampling barrel. Extract the sampling barrel from the borehole using the drill head or such other method as will expedite the movement of the sampling barrel to the surface. At the surface, reattach the sampling barrel to the sonic drill head and position the sampling barrel to remove the sample. Remove the bit, protecting the bottom of sampling barrel to prevent any material from dropping out. Remove any material in the sampling bit and place it in the sample receiving bag in the correct orientation. Slide the sample bag over the sampling barrel the full remaining length of the bag so the sample does not fall. Allow the sample to flow into the bag by activating the sonic drill head as needed to vibrate the sample from the barrel. Keep the sample bag as close to the bottom of the sample barrel as possible while it fills to reduce sample dropping distance causing as little disturbance as possible. Samples are generally deposited in 2 to 5 ft [1 to 2 m] length plastic bags for review, logging and analysis. Sample bag length should not exceed 5 ft [2 m] as the weight of the specimen collected becomes very difficult to handle without causing excessive disturbance. Longer sample bags greater than 5 ft [2 m] can be used if disturbance is not an issue affecting exploration objectives. Change sample bags as needed until all sample is removed from the barrel. It is important that all material collected be contained for recovery measurements and for disposal. Accurate measurements of sample recovery are achievable with the solid barrel sampling method of sample collection if certain practices are followed. In some formations more precise measurements of recovery can be made using clear plastic sampler liners. Hydraulic extraction of the sample from the solid barrel sampler can also be utilized in some formations. The nature of sonic vibration and bit face displacement can cause some disturbance in granular and in other soils. This should be kept in mind when measuring recovery and examining core samples. Such measurements are best judged by experienced equipment operators and knowledgeable field logging personnel who are knowledgeable in recognizing the differences in disturbed verses non-disturbed formation materials. Clean the sampling barrel by flushing with clean water or decontaminating as necessary. If project needs require full decontamination remove the used sampling barrel to the decontamination area, attach a cleaned sampling barrel to the drill head, add the drill bit and tighten it, and reinsert the sample barrel into the borehole to the depth of the previously sampled increment. Repeat the sampling process. It may be advantageous to rotate the sampling barrel as is withdrawn from the borehole to aid in extraction. However, rotation during extraction should only be used when necessary to retrieve the sampling tools to avoid disturbing the sample or causing it to fall from the sampling barrel. In some formations it may be necessary to activate the sonic drill head to facilitate withdrawal of the sample barrel. Once the sample is collected however, any action applied could cause disturbance to the sample. All such actions should be avoided wherever possible.

9.2.2 *Sampling-Split Barrel*—The procedure for using split barrel samplers is the same as solid barrel samplers except that the split barrel design it is not able to accept heavy down pressure or high friction resistance rotation. The limits of the split barrel are easily exceeded and caution must be exercised when utilizing these tools. Split barrel samplers offer the potential for reducing sample disturbance as the sample is removed from the core barrel. Sample removal and cleaning follow the procedures in referenced ASTM standards. Measuring sample recovery may be more accurate with the split barrel as result of generally shorter run length and the ability to visibly observe the material being measured in the barrel before it is removed.

9.3 *Drilling with Casing*—It is generally necessary to stabilize the borehole with an outer casing to control caving or slough, to facilitate sample collection, to protect against aquifer cross contamination, to provide a controlled environment for well or instrumentation installation, and to provide proper bottom up grouting. Casing is either installed using drilling fluid or installed dry depending on the formation being penetrated. Casing is available in a variety of lengths and diameters common to the drilling industry to fit a range of project requirements. The casing is either advanced over the sampling barrel when using drilling fluid or after the sample barrel has been removed from the borehole when drilling dry. Proportional sizing of the sampling barrel to the casing is required so that the casing is properly cleaned.

9.3.1 *Drilling Casing Wet*—Various drilling fluids can be used to advance the casing ranging from clean potable water to specialized drilling fluids. The choice of fluid is dictated by the formation and the project requirements. There is generally no recirculation of the drilling fluid during sonic drilling. The drilling fluid serves several functions. It helps keep debris and drill cuttings from entering the casing; it provides a lubrication film between the outside of the casing and the formation materials; it removes drill cuttings from the face of the bit and from the borehole annulus; and the fluid helps to keep the sample barrel and the casing from becoming sand locked as the casing passes over the barrel. It is important that the annular space between the sampler barrel and the casing bit be kept to a minimum. This prevents material from moving into the annular space, reduces the amount of drilling fluid needed, and helps maintain borehole alignment. The drilling fluid is also used to maintain a pressure equalization head inside the casing to prevent any inflow of formation materials.

9.3.1.1 *Casing Insertion Wet*—The sampling barrel is advanced to the target depth increment as described previously. The drill head is disconnected from the sampling rod string. A plug is placed in the drill rod box to protect the threads and prevent any drill fluid from entering the sampling rod string. An equal length of drill casing is attached to the drill head and hoisted into position over the sampling rod string. As the casing is advanced using downpressure, rotation and vibration, drilling fluid is pumped into the casing string. The casing is advanced to the base of the sampling barrel shoe. Advancement is stopped. The drill head is disconnected from the casing and reconnected to the sampling barrel tool string. The sampling barrel is then removed and the sample extracted. The sampling barrel is cleaned and then reinserted, additional drill string added, and the sample barrel advanced to the next increment. Then the casing installation procedure is repeated. There is a slight amount of contact between the top of the sampling increment and the drilling fluid when the sample barrel is withdrawn. However, as no drilling fluid is recycled, the composition of the drilling fluid remains known and controlled. As soon as the sample specimen begins to enter the barrel the fluid in the barrel is pushed upward and the sides of the sample barrel are sweep clean by the friction of the passing soil.

9.3.1.2 *Bore Hole Slough or Cave-In*—As with all drilling methods there are times when special techniques are needed to maintain control of the bore hole. In certain formations, if the head pressure in the borehole is not equalized, the groundwater will carry formation materials in as it equalizes in the borehole. If project constraints do not allow the adding of compensating fluids other techniques must be employed. To provide room for the deposited material a second sampling barrel can be added on top of the first. As the materials are essentially liquefied along the barrel surface there is relatively little influence exerted on the lower portions of the sample from the upper portions. However, to provide sample quality and integrity every effort should be made to eliminate as much cave-in as possible.

9.3.1.3 *Drilling Casing Dry*—When installing casing dry, advance the sampling barrel through the scheduled interval. Remove the sample barrel and process the sample. Connect the drill head to the casing and advance the casing to the bottom of the previously sampled increment. Disconnect from the casing. Insert the sample barrel and vibrate through the borehole material in the casing to the top of the next scheduled sampling increment. Remove the sampling barrel and clean it in accordance with project requirements. Reinsert the sampling barrel and advance it to the end of the next sampling increment. Then repeat the procedure. In certain formations a double length sample barrel can be utilized to both remove the borehole material and to continuously sample the next increment in one tool trip. Whenever slough is encountered in the borehole it should be measured and properly noted on the boring log.

Determining the need for cleanout runs with the core barrel is primarily a driller skill.

9.4 *Bore Hole Testing*—The sonic drilling method lends itself well to many forms of borehole testing in most formations primarily because of the clean cased hole provided and from the versatility of the machine. Actual procedures for water and aquifer testing, or other formation properties exploration procedures are given in referenced ASTM standards and will not be individually addressed here. The very high level of energy that can be imparted to the drill bit by the sonic drill gives it the ability to advance casing and core barrels into very dense formations. In these dense formations, when drilling dry, the borehole wall may be affected by the forcing of soil particles into it. Should this condition be of concern it can be alleviated by using potable water injection while advancing the casing, by using a crowd in style bit that directs materials sheared from the borehole wall into the casing, by borehole wall scraping with the casing bit, or by injecting natural clay breakdown compounds.

9.4.1 Pump testing to determine aquifer characteristics, Test Method D4050, is easily accomplished because of the clean hole and the minimal disturbance that is caused to the formation. This results in a rapidly clearing formation that reaches its maximum production rate quickly. Minimum turbidity with rapid production results in less development water for disposal and expedited test results. This is especially significant when setting smaller diameter wells, which can only accommodate low volume pumps. Slug tests, Test Method D4044, can also readily be performed because of the clean borehole wall. Constant head and falling head tests can also be performed.

9.4.2 *Well Installation*—Wells, Practice D5092, of various sizes can be set using the sonic method. Advantages are that in many formations the casing in the screened zone can be set without fluid to keep the formation clean and to reduce development and/or pumping time. The vibratory effect can be used to good advantage to settle filterpack material around the screen and eliminate bridging of backfill materials as the casing is removed.

9.4.3 *Other Instrumentation*—Any type of instrumentation that can be set with any other drilling method can be set with sonic drilling. *In-situ* borehole tests such as pressure meters D4719, vane shear devices D2573, permeability testing using packers can be used with the sonic method as long as the borehole wall is prepared properly. When utilizing these types of testing methods it may be necessary to advance the casing into the borehole using water injection and a crowd in bit to reduce sonic drilling's effect on soil pore pressure.

9.5 *Incorporating Other Drilling Practices*—The sonic drill rig easily accommodates other drilling methods should they be needed to satisfactorily complete projects. Rock coring adaptations can be incorporated to do diamond bit coring (D2113) either wireline or conventional. Sonic drills generally have low rotary rpm ratings. Adequate speeds for rock coring can be acquired through a gear driven speed multiplier, a high-speed coring head, 2-speed rotation motors, or if available, adjustment to the rotational output of the sonic drill head. Downhole hammers can be readily adapted to the sonic drill with the incorporation of a compressed air source. The low rpm rating works very well with downhole hammer. As the sonic drill offers all basic drill functions air or fluid rotary techniques can be easily adapted as well. Standard soil sampling techniques can be utilized with the sonic drill. Split barrel sampling with standard penetration tests (D1586), thin walled tubes (D1587), and the like can be easily incorporated.

10. Completion and Sealing

10.1 Information on the sealing of boreholes and installations can be found in Practice D5092 and Guide D5299 for wells, and in Guides D5791, D5782, D5783, and D5784 for drilling methods. Local regulating agencies or organizations may control both the method and the materials for borehole sealing.

11. Report: Test Data Sheet(s)/Form(s)

11.1 The methodology used to specify how data are recorded is covered in 1.5.

11.2 Record as a minimum the following general information (data):

11.2.1 *Field Report*—The field report may consist of boring log or a report of the sampling event and a description of the sample. Soil samples can be classified in accordance with Practice D2488 or other methods as required for the exploration. Prepare the log in accordance with Guide D5434, which lists the parameters required for the field exploration program. Report the dates of drilling and the personnel performing the drilling. List all information related to drilling and the sampling event, including depths, fluid injection, drilling parameters (drilling rate), sampling intervals, recovery, strength index readings such as pocket penetrometer, classification of soil, and any comments on sampler or casing advancement. If a computer collects drill performance data, add identifying marks to log so correct information can be downloaded and incorporated into the final log as necessary.

11.3 Record as a minimum the following sampling data as follows;

11.3.1 Record all drilling and sampling measurements to the nearest 0.1 ft. [0.3 m] or better.

11.3.2 *Sampling*—Report depth interval sampled, sample recovery lengths to the nearest 0.1 ft. [0.3 m] or better and percent recovery, classification, and any other tests performed,

11.3.3 *In situ Testing*—Report the depths and types of insitu tests performed. For devices that were inserted below the base of the drill hole, report the depths below the base of the hole to the nearest 0.1 ft. [0.3 m] or better, and any unusual conditions during testing.

12. Keywords

12.1 drilling; resonance; soil and rock sampling; sonic drilling; subsurface exploration

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2004(Reapproved 2010)) that may impact the use of this standard.

(1) The revision in 2016 included editorial revisions required by Committee D18. The units were converted to in.-lb with rationalized SI units. The original version used exact metric values from rationalized US sizes, for example, it was really and in-pound primary standard. Reference was made to several new standards including D6640 on sampling soil in core barrels for environmental purposes.

(2) Terminology—unused terminology was deleted and the terminology for defining the drill head to include the sine wave generator.

(3) Significance and Use—Use of sonic drilling has expanded into the geotechnical field. When this standard was first written it was centered on environmental explorations. Throughout the standard, typical geotechnical use is recognized.