Designation: ~~D6167 – 11~~ D6167 – 19

Standard Guide for Conducting Borehole Geophysical Logging: Mechanical Caliper[1]

This standard is issued under the fixed designation D6167; 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*~~Scope

1.1 This guide covers the general procedures necessary to conduct caliper logging of boreholes, wells, access tubes, caissons, or shafts (hereafter referred to as boreholes) as commonly applied to geologic, engineering, groundwater, and environmental (hereafter referred to as geotechnical) investigations. Caliper logging for mineral or petroleum exploration and development are excluded.

1.1.1 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

1.2 This guide defines a caliper log as a record of borehole diameter with depth.

1.2.1 Caliper logs are essential in the interpretation of geophysical logs since ~~they~~ geophysical results can be significantly affected by borehole diameter.

1.2.2 Caliper logs provide useful information for borehole completion and testing and are commonly used to ~~measure~~assess borehole diameter, shape, roughness, and stability; calculate borehole volume; provide information on borehole construction; and delineate lithologic contacts, fractures, and solution cavities and other openings.

1.2.2.1 Borehole-diameter information is essential for calculation of volumetric rate from flowmeter logs.

~~1.2.2.2 Caliper logs provide useful information for borehole completion and testing.~~

1.2.2.2 Caliper logs are used to locate the optimum placement of inflatable packers for borehole testing. Inflatable packers can only form an effective seal within a specified range of borehole diameters, and can be damaged if they are set in rough or irregular parts of the borehole.

1.2.2.3 Caliper logs are used to estimate the volume of borehole completion material (cement, gravel, etc.) needed to fill the annular space between borehole and casing(s) or well screen.

1.2.2.4 Caliper logs may be applied to correlate lithology between boreholes based upon enlargements related to lithology. The measured borehole diameter may be significantly different than the drilled diameter because of plastic formations ~~extruded~~expanded into the borehole and friable formations enlarging the borehole. A series of caliper logs may also show increases or decreases in borehole diameter with time.

1.3 This guide is restricted to mechanically based devices with spring-loaded arms, which are the most common calipers used in caliper logging with geotechnical applications.

1.4 This guide provides an overview of caliper logging, including general procedures, specific documentation, calibration and standardization, and log quality and interpretation.

~~1.5 To obtain additional information on caliper logs see Section 9 of this guide.~~

1.5 This guide is to be used in conjunction with Guide D5753.

1.6 This guide should not be used as a sole criterion for caliper logging and does not replace professional judgment. Caliper logging procedures should be adapted to meet the needs of a range of ~~applications and~~ applications. Information in this guide is stated in general terms so that flexibility or innovation is not suppressed.

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[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Characterization.

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***A Summary of Changes section appears at the end of this standard**

1.7 *Units*—The ~~geotechnical industry uses English or SI units. The caliper log is typically recorded in units of inches, millimetres, or centimetres.~~values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units, which are provided for information only and are not considered standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.8 *This guide does not purport to address all of the safety and liability problems (for example, lost or lodged probes and equipment decontamination) associated with its use.*

1.9 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D5088 Practice for Decontamination of Field Equipment Used at Waste Sites

D5608 Practices for Decontamination of Sampling and Non Sample Contacting Equipment Used at Low Level Radioactive Waste Sites

D5753 Guide for Planning and Conducting Geotechnical Borehole Geophysical Logging

3. Terminology

3.1 *Definitions:*

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

3.2 ~~*Definitions:*~~*Definitions of Terms Specific to This Standard:*

~~3.1.1 Definitions shall be in accordance with Terminology D653, Section 12, Ref (1),[3] or as defined below:~~

~~3.1.2 *accuracy, n*—how close a measured log values approaches true value. It is determined in a controlled environment. A controlled environment represents a homogeneous sample volume with known properties.~~

3.2.1 *depth of investigation, n*—the radial distance from the measurement point to a point where the predominant measured response may be considered ~~centered, that is not to be confused with borehole depth (for example, distance) measured from the surface.~~centered.

3.2.1.1 *Discussion*—

The depth of investigation for borehole logging is a radial distance from the borehole and is not to be confused with borehole depth or any depth measured from the surface.

3.2.2 *measurement resolution, n*—the minimum change in measured value that can be detected.

~~3.1.5 *repeatability, n*—the difference in magnitude of two measurements with the same equipment and in the same environment.~~

3.2.3 *vertical resolution, n*—the minimum thickness that can be separated into distinct units.

3.2.4 *volume of investigation, n*—the volume that contributes 90 % of the measured response. ~~It is determined by a combination of theoretical and empirical modeling. The volume of investigation is non-spherical and has gradational boundaries.~~

3.2.4.1 *Discussion*—

It is determined by a combination of theoretical and empirical modeling. The volume of investigation is non-spherical and has gradational boundaries.

4. Summary of Guide

4.1 This guide applies to borehole caliper logging and is to be used in conjunction with Guide D5753.

4.2 This guide briefly describes the significance and use, apparatus, calibration and standardization, procedures, and reports for conducting borehole caliper logging.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

5. Significance and Use

5.1 An appropriately developed, documented, and executed guide is essential for the proper collection and application of caliper logs. This guide is to be used in conjunction with Guide D5753.

5.2 The benefits of its use include the following: improving selection of caliper logging methods and equipment, caliper log quality and reliability, and usefulness of the caliper log data for subsequent display and interpretation.

5.3 This guide applies to commonly used caliper logging methods for geotechnical applications.

5.4 It is essential that personnel (see the Personnel section of Guide D5753) consult up-to-date textbooks and reports on the caliper technique, application, and interpretation methods.

6. Interferences

6.1 Most extraneous effects on caliper logs are caused by instrument problems and borehole conditions.

6.2 Instrument problems include the following: electrical leakage of cable and grounding problems, temperature drift, wear of mechanical components including the hinge pins and in the linear potentiometer (mechanical hysteresis), damaged or bent arms, and lack of lubrication of the mechanical components.

6.3 ~~Borehole~~ Problematic borehole conditions include heavy drilling mud, borehole deviation, and drilling-related borehole irregularities.

7. Apparatus

7.1 A geophysical logging system has been described in the general guide (see the Apparatus section of Guide D5753). A variety of caliper logging equipment is available for geotechnical investigations. It is not practical to list all of the sources of potentially acceptable equipment.

7.2 Caliper logs may be obtained with probes having a single arm, three arms (averaging or summation), multiple independent arms (x-y caliper), multiple-feeler arms, bow springs, or gap wheels. Single-arm and three-arm averaging probes are most commonly used for geotechnical investigations.

7.2.1 A single-arm caliper commonly provides a record of borehole diameter while being used to decentralize another type of log, such as a side-collimated gamma-gamma probe (see Fig. 1). The caliper arm generally follows the high side of a deviated hole. The single-arm ~~decentralizing~~ caliper may not have the resolution needed for some applications.

7.2.2 The three-arm averaging or summation caliper has arms of equal length oriented 120° apart (see Fig. 2). All arms move together, which provides an average diameter measurement. This caliper provides higher resolution than the single-arm caliper measurement (see Fig. 3).

7.2.3 Multiple independent arm calipers generally have three or four equally spaced, independent arms of equal ~~length; these arms are sometimes oriented.~~ length. Horizontal resolution, ~~that~~which provides accurate borehole-diameter measurement regardless of borehole shape, is related to the number of independent arms. In general, calipers with four or more independent arms will have higher resolution than a three-arm averaging caliper (see Fig. 3). The four independent-arm caliper log may show borehole elongation (elliptical borehole shape) and better indicates the actual irregularity of the borehole.

7.3 Caliper probes using arms are typically spring loaded. The arms are retracted and opened with an electric motor and retention spring. The arms and gears are lubricated. Caliper probes closed by hand are held closed with an electric solenoid or weighted retention ring that is released with a sudden drop. Typically, the caliper arms are mechanically connected to a linear or

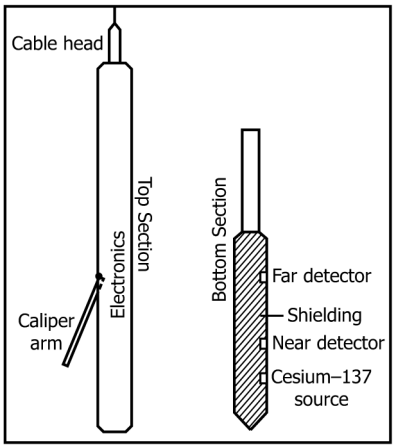

FIG. 1 Probe for Making Side-Collimated Gamma-Gamma Logs with Single-Arm Caliper (21)

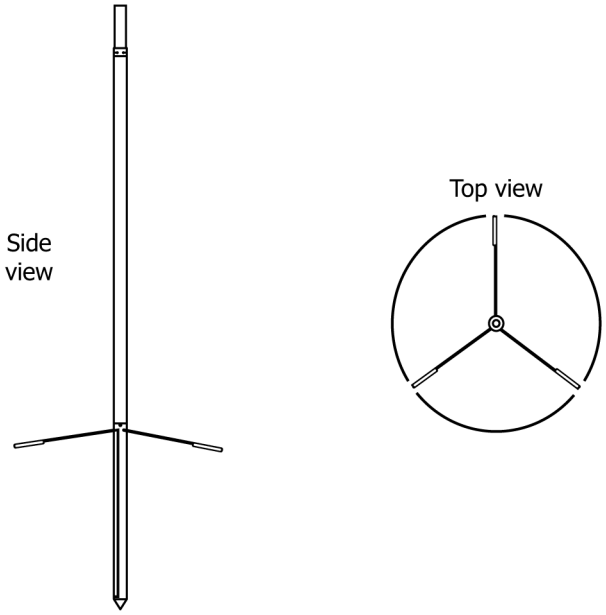

FIG. 2 Three-Arm Averaging Caliper

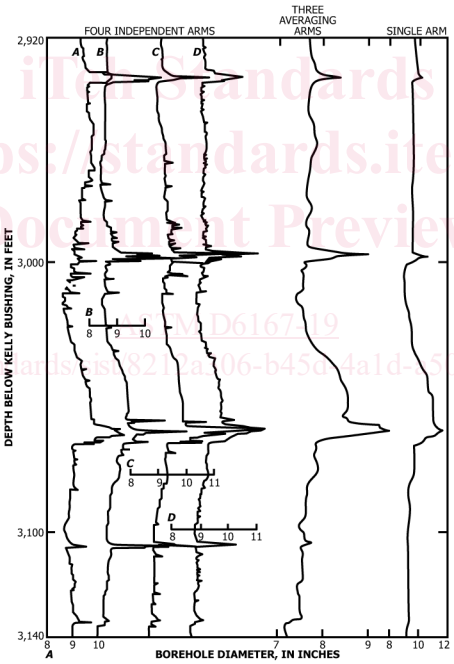

FIG. 3 Caliper Logs From Probes Having Four Independent Arms, Three Averaging Arms, and a Single ~~Arm,~~Arm; Madison Limestone Test Well 1, Wyoming (~~2~~1)

rotary potentiometer such that changes in the angle of the arms causes changes in resistance. These changes in resistance are proportional to average borehole diameter. In some probes, the voltage changes are converted to a varying pulse rate or digitized downhole to eliminate or minimize cable transmission noise. Different arm length can be used to optimize sensitivity for the borehole-diameter range expected.

7.4 The concepts of volume of investigation and depth of investigation are not applicable to caliper logs since it is a surface-contact measurement.

7.5 Vertical resolution of caliper measurements is a function of the size of the contact surface (arm tip or pad), the response of the mechanical and electronic components, and digitizing interval used. The theoretical limit of vertical resolution is equal to the width of the caliper pad or tip. Selection of arm lengths and angle, and tip diameter will affect sensitivity. Shorter arms generally