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Standard Guide for Planning and Conducting Geotechnical Borehole Geophysical Logging[1]

This standard is issued under the fixed designation D5753; 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 *Purpose and Application:*

1.1.1 This guide covers the documentation and general procedures necessary to plan and conduct a geophysical borehole logging program as commonly applied to geologic, engineering, groundwater, and environmental (hereafter referred to as geotechnical) site characterizations.

1.1.2 This guide applies to commonly used logging methods (see Tables 1 and 2) for geotechnical site characterizations.

1.1.3 This guide provides an overview of the following:

(1) the uses of single borehole geophysical methods,

(2) general logging procedures,

(3) documentation,

(4) calibration, and

(5) factors that can affect the quality of borehole geophysical logs and their subsequent interpretation. Log interpretation is very important, but specific methods are too diverse to be described in this guide.

1.1.4 Logging procedures must be adapted to meet the needs of a wide range of applications and stated in general terms so that flexibility or innovation are not suppressed.

1.1.5 To obtain detailed information on operating methods, publications (for example, **1**, **2**, **3**, **4**, **5**, **6**, **7**, **8**, and **9**)[2] should be consulted. A limited amount of tutorial information is provided, but other publications listed herein, including a glossar y of terms and general texts on the subject, should be consulted for more complete background information.

1.2 *Limitations:*

1.2.1 This guide is not meant to describe the specific or standard procedures for running each type of geophysical log, and is limited to measurements in a single borehole.

1.2.2 Surface or shallow-depth nuclear gages for measuring water content or soil density (that is, those typically thought of as construction quality assurance devices), measurements while drilling (MWD), cone penetrometer tests, and logging for petroleum or minerals are excluded.

1.2.3 *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.*

1.3 *Precautions:*

1.3.1 If the method is used at sites with hazardous materials, operations, or equipment, it is the responsibility of the user of this guide to establish appropriate safety and health practices, and to determine the applicability of regulations prior to use.

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

1.5 *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.*

[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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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

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

TABLE 1 Common Geophysical Logs

Type of Log (References)	Varieties and Related Techniques	Properties Measured	Required Hole Conditions	Other Limitations	Typical Measuring Units and Calibration or Standardization	Brief Probe Description
Spontaneous potential **(7, 8, 12)**	differential	electric potential caused by salinity differences in borehole and interstitial fluids, streaming potentials	uncased hole filled with conductive fluid	salinity difference needed between borehole fluid and interstitial fluids; needs correction for other than NaCl fluids	mV; calibrated power supply	records natural voltages between electrode in well and another at surface
Single-point resistance **(7)**	conventional, differential	resistance of rock, saturating fluid, and borehole fluid	uncased hole filled with conductive fluid	not quantitative; hole diameter effects are significant	Ω; V-Ω meter	constant current applied across lead electrode in well and another at surface of well
Multi-electrode resistivity **(7, 8, 13)**	various normal focused, guard, lateral arrays	resistivity and saturating fluids	uncased hole filled with conductive fluid	reverses or provides incorrect values and thickness in thin beds	Ω-m; resistors across electrodes	current and potential electrodes in probe
Induction **(10, 11)**	various coil spacings	conductivity or resistivity of rock and saturating fluids	uncased hole or nonconductive casing; air or fluid filled	not suitable for high resistivities	mS or Ω-m; standard dry air zero check or conductive ring	transmitting coil(s) induce eddy currents in formation; receiving coil(s) measures induced voltage from secondary magnetic field
Gamma **(5, 7, 22)**	gamma spectral **(44)**	gamma radiation from natural or artificial radioisotopes	any hole conditions	may be problem with very large hole, or several strings of casing and cement	pulses per second or API units; gamma source	scintillation crystal and photomultiplier tube measure gamma radiation
Gamma-gamma **(23, 24)**	compensated (dual detector)	electron density	optimum results in uncased hole; can be calibrated for casing	severe hole-diameter effects; difficulty measuring formation density through casing or drill stem	gs/cm^3; Al, Mg, or Lucite blocks	scintillation crystal(s) shielded from radioactive source measure Compton scattered gamma
Neutron **(7, 14, 25)**	epithermal, thermal, compensated sidewall, activation, pulsed	hydrogen content	optimum results in uncased hole; can be calibrated for casing	hole diameter and chemical effects	pulses/s or API units; calibration pit or plastic sleeve	crystal(s) or gas-filled tube(s) shielded from radioactive neutron source
Acoustic velocity **(5, 26, 27)**	compensated, waveform, cement bond	compressional wave velocity or transit time, or compressional wave amplitude	fluid filled, uncased, except cement bond	does not detect secondary porosity; cement bond and wave form require expert analysis	velocity units, for example, ft/s or m/s or µs/ft; steel pipe	1 or more transmitters and 2 or more receivers
Acoustic televiewer **(28, 7)**	acoustic caliper	acoustic reflectivity of borehole wall	fluid filled, 3 to 16-in. diameter; problems in deviated holes	heavy mud or mud cake attenuate signal; slow logging speed	oriented image, 3 axis-magnetometer , 3 axis-accelerometer	rotating transducer sends and receives high-frequency pulses
Optical televiewer **(28, 7)**		optical reflectivity of borehole wall	air or clear water filled, uncased 3 to 16-in. diameter; possible problems in highly deviated holes	cannot use in mud, slow logging speed	oriented image, 3 axis-magnetometer , 3 axis-accelerometer	digital camera with hyperboloidal mirror images unwrapped borehole wall
Borehole video	axial or side view (radial), discontinuities, voids	visual image on tape	air or clean water; clean borehole wall	may need special cable	NA[A]	video camera and light source
Caliper **(29, 7)**	oriented, 4-arm high-resolution, *x-y* or max-min bow spring	borehole or casing diameter, borehole breakouts	any conditions	deviated holes limit some types; significant resolution difference between tools	distance units, for example, in.; jig with holes or rings	1 to 4 retractable arms contact borehole wall
Temperature **(30, 31, 32)**	differential	temperature of fluid near sensor	fluid filled	large variation in accuracy and resolution of tools	°C or °F; ice bath or constant temperature bath	thermistor or solid-state sensor
Fluid conductivity **(7)**	fluid resistivity	most measure resistivity of fluid in hole	fluid filled	accuracy varies, requires temperature correction	µS/cm or Ω-m; conductivity cell	ring electrodes in a tube
Flow **(12, 33, 7)**	impellers, heat pulse	vertical velocity of fluid column	fluid filled	impellers require higher velocities. Needs to be centralized.	velocity units, for example, ft/min; lab flow column or log in casing	rotating impellers; thermistors detect heated water; other sensors measure tagged fluid.
Deviation **(4, 7, 47)**	magnetic, gyroscopic, or mechanical	horizontal and vertical displacement of borehole	any conditions (see limitations)	magnetic methods orientation not valid in steel casing	degrees and depth units; orientation and inclination must be checked	various techniques to measure inclination and bearing of borehole

[A] NA = not applicable.

TABLE 2 Log Selection Chart for Geotechnical Applications Using Common Geophysical Borehole Logs[A]

Information Desired	Acoustic		Electric and Induction					Fluid Logs				Radioactive or Nuclear				Other Methods		
	Acoustic Tele-viewer	Acoustic Velocity, Δt, CBL, VDL, FWS	Induced Polari-zation	Multi-electrode Resistivity, Normal, Lateral, Micro Guard Resistivity	Single-Point Resis-tance	Sponta-neous Poten-tial	Induc-tion (Conduc-tivity)	Flow Meter	Fluid Resistivity	Fluid Sampler	Temper-ature, Dffer-ential Temper-ature	Gamma-Gamma Density	Gamma	Neutron	Spectral Gamma	Borehole Video	Caliper	Deviation
Lithology and Correlation																		
Bed/aquifer thickness; correlation, structure	●	●		●	●	●	★					Δ	✓	Δ	✓	◇	✓	
Lithology—depositional environment	?	●		●	●	●	★					Δ	✓	Δ	✓	◇	✓	
Shale or clay content			●	●		●	★					Δ	✓	Δ	✓			
Bulk density												Δ						
Formation resistivity				●			★											
Injection/production profiles				?			?	□	□		□	Δ		Δ				
Permeability estimates		●						□	□		□		✓					
Porosity (amount and type)	●	●		●			★					Δ		Δ				
Mineral identification			●									Δ			✓			
Potassium-uranium thorium content (KUT)															✓			
Rock Mass Parameters																		
Strike and dip of bedding	●															◇		✓
Fracture detection (number of fractures), RQD	●	●		●	●											◇	✓	
Fracture orientation and character	●															◇		✓
Thin bed resolution	●			?	●											◇	✓	
In situ stress data	●	●														◇	◇	
Fluid Parameters																		
Borehole fluid characteristics								?	□	□	□							
Fluid flow						●		□	□		□					◇		
Formation water quality				●		●	★			□								
Moisture content—water saturation				?			?					Δ		Δ				
Temperature		?									□							
Water level and water table	●	●		●	●	●	?		□		□	Δ		Δ		◇		
Borehole Parameters																		
Casing evaluation integrity, leaks, damage, screen location	■	■					?	■			■					♦	✓	
Deviation of borehole																		✓
Diameter of borehole	●																✓	
Examination behind casing		●					★					Δ		Δ				
Location of debris in wells	●															♦	✓	
Well completion evaluation, for example, cement bond, seal location, grout location	?	■					★					Δ	✓	Δ				

[A] Required hole conditions: ■ = cased fluid-filled hole, ✓ = clear fluid or dry cased hole, □ = screened or open fluid-filled hole, ✓ = clear fluid or dry open hole, ✓ = steel casing only, Δ = active nuclear log to be run in stable holes, ★ = open or nonconductive cased holes, dry or fluid filled, ✓ = no restrictions, ● = open fluid-filled hole only, and ? = possible applications.