



Designation: **D6274 – 10 D6274 – 18**

## Standard Guide for Conducting Borehole Geophysical Logging - Gamma<sup>1</sup>

This standard is issued under the fixed designation D6274; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This guide covers the general procedures necessary to conduct gamma, natural gamma, total count gamma, or gamma ray (hereafter referred to as gamma) 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. Spectral gamma and logging where gamma measurements are made in conjunction with a nuclear source are excluded (for example, neutron activation and gamma-gamma density logs). Gamma logging for minerals or petroleum applications are excluded.

1.2 This guide defines a gamma log as a record of gamma activity of the formation adjacent to a borehole with depth (See Fig. 1 and Fig. 2).

1.2.1 Gamma logs are commonly used to delineate lithology, correlate measurements made on different logging runs, and define stratigraphic correlation between boreholes (See Fig. 23).

1.3 This guide is restricted to gamma logging with nuclear counters consisting of scintillation detectors (crystals coupled with photomultiplier tubes), which are the most common gamma measurement devices used in geotechnical applications.

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

~~1.5 To obtain additional information on gamma logs, see Section 13.~~

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

1.6 Gamma logs should be collected by an operator that is trained in geophysical logging procedures. Gamma logs should be interpreted by a professional experienced in log analysis.

~~1.7 The geotechnical industry uses English or SI units. The gamma log is typically recorded in units of counts per second (cps) or American Petroleum Institute (API) units; values stated in either SI units or inch-pound units [given 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 nonconformance with the standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.~~

~~1.7.1 The gamma log is typically recorded in units of counts per second (cps) or American Petroleum Institute (API) units. The gamma ray API unit is defined as 1/200 of the difference between the count rate recorded by a logging tool in the middle of the radioactive bed and that recorded in the middle of the nonradioactive bed” recorded within the calibration pit. A calibration facility for API units currently exists at the University of Houston and is the world standard for the simple Gamma Ray tool, however the validity of the calibration pit has been called into question in recent years.~~

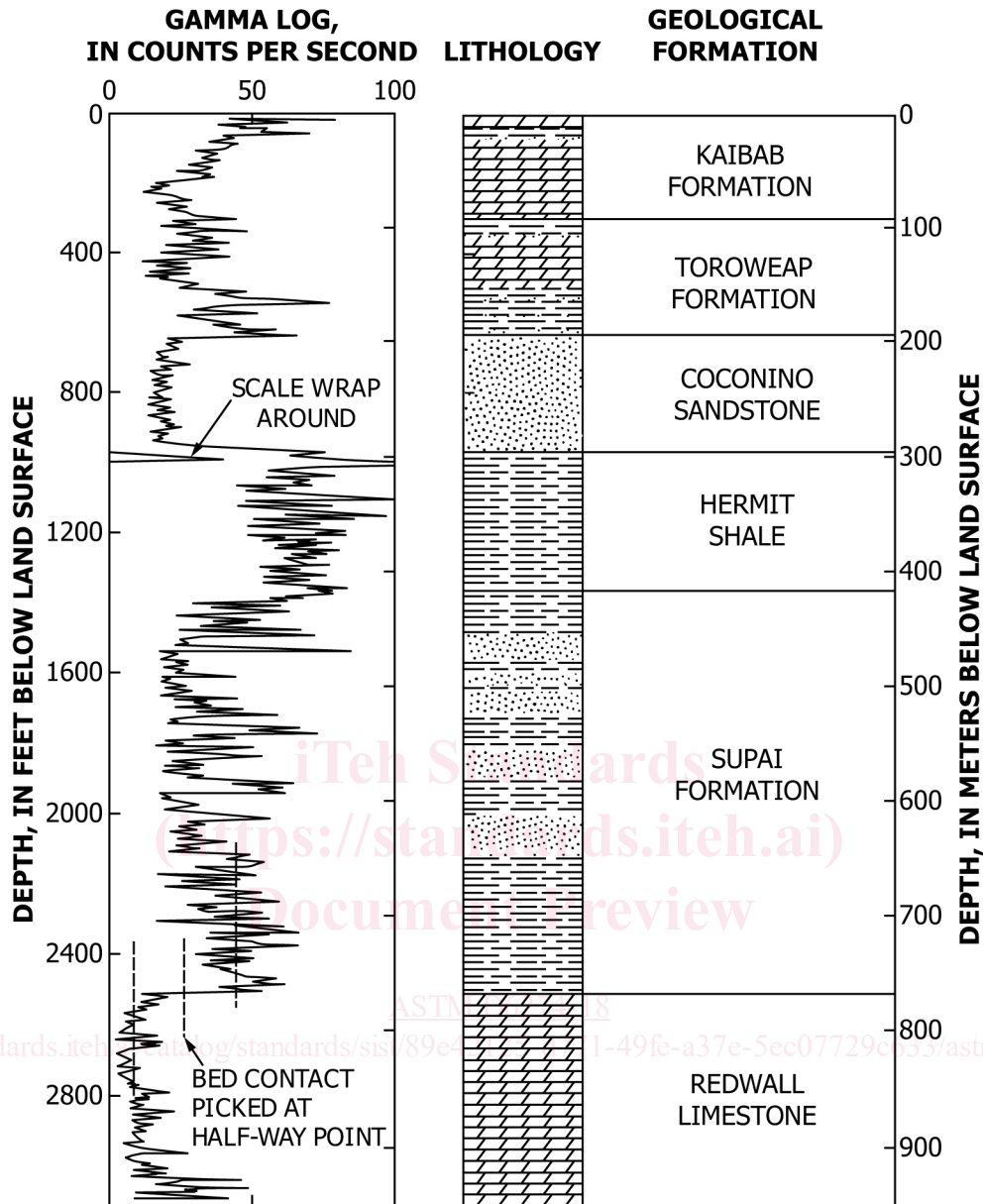
~~1.9 This guide does not purport to address all of the safety and liability problems (for example, lost or lodged probes and equipment decontamination) associated with its use.~~

1.8 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.

1.9 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

<sup>1</sup> 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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NOTE 1—This figure demonstrates how the log can be used to identify specific formations, illustrating scale wrap-around for a local gamma peak, and showing how the contact between two formations is picked to coincide with the half-way point of the transition between the gamma activities of the two formations.

FIG. 1 Example of a Gamma Log From Near the South Rim of the Grand Canyon in the USA (in cps)

*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.*

*1.10 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:<sup>2</sup>

[D653 Terminology Relating to Soil, Rock, and Contained Fluids](#)

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

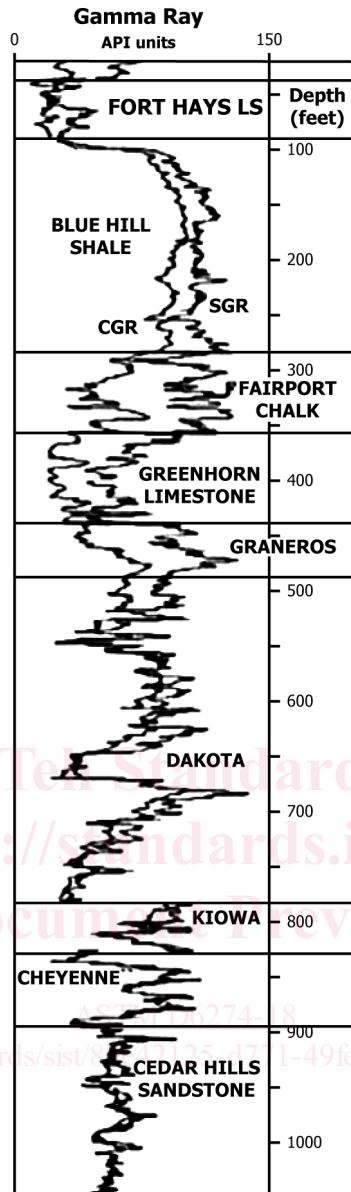


FIG. 2 Example of a Gamma Log for the Hydrologic Observation Well KGS #1 Braun located near Hays, Kansas in the USA (in API units whereby SGR reflects the derived total gamma ray log (the sum of all the radiation contributions), and CGR reflects the computed gamma ray log (the sum of the potassium and thorium responses, leaving out the contribution from uranium).

[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](#)

[D6167 Guide for Conducting Borehole Geophysical Logging: Mechanical Caliper](#)

### 3. Terminology

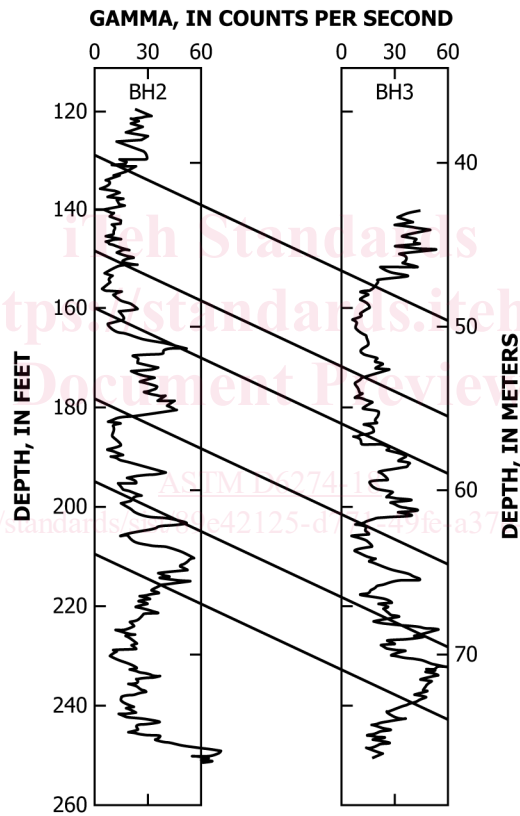
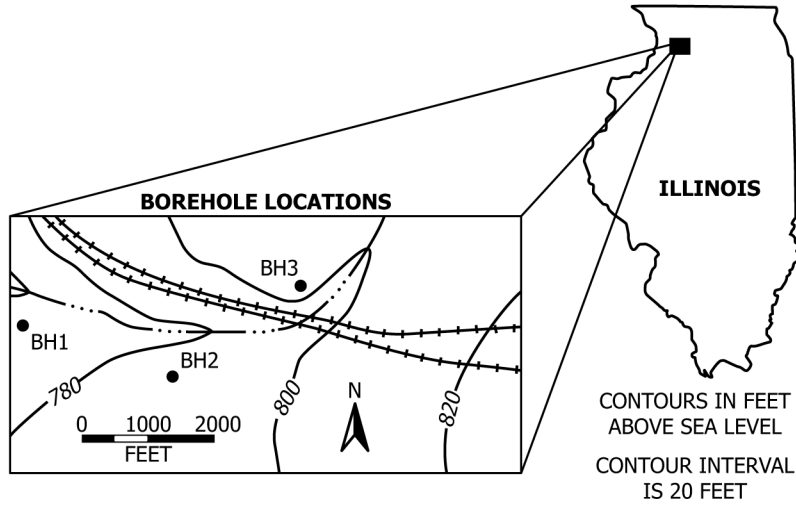
#### 3.1 Definitions:

3.1.1 Definitions shall be in accordance with For definitions of common technical terms used in this standard, refer to Terminology D653, Ref. (1), or as defined below.

#### 3.2 Definitions of Terms Specific to This Standard:

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

3.2.1 dead time, *n*—the time after each pulse when a second pulse cannot be detected.



NOTE 1—From a study site showing how the gamma logs can be used to identify where beds intersect each of the individual boreholes, demonstrating lateral continuity of the subsurface geology.

**FIG. 23 Example of Gamma Logs From Two Boreholes**

3.2.2 *dead time effect, n*—the inability to distinguish closely-spaced nuclear counts leads to a significant underestimation of gamma activity in high radiation environments and is known as the “dead time effect”.

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

3.2.3.1 *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.

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

~~3.2.6 *repeatability, n*—the difference in magnitude of two measurements with the same equipment and in the same environment.~~

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

~~3.2.6 *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.~~

3.2.6.1 *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 gamma 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 gamma logging.

#### 5. Significance and Use

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

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

5.3 This guide applies to commonly used gamma 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 gamma technique, application, and interpretation methods.

#### 6. Interferences

6.1 Most extraneous effects on gamma logs are caused by logging too fast, instrument problems, borehole conditions, and geologic conditions.

6.2 Logging too fast can significantly degrade the quality of gamma logs. Gamma counts originating at a given depth need to be averaged over a time interval such that the natural statistical variation in the rate of gamma photon emission is negligible (see [Fig. 34](#)).

6.3 Instrument problems ~~include~~ include: a) electrical leakage of cable and grounding problems, b) degradation of detector efficiency attributed to loss of crystal transparency (fogging) or fractures or breaks in the crystal, and c) mechanical damage causing separation of crystal and photomultiplier tube.

6.4 Borehole conditions ~~include~~ include: a) changes in borehole diameter (especially in the fluid-filled ~~portion~~); ~~portion~~, b) casing type and ~~number~~; ~~number~~, c) radioactive elements in drilling fluid in the borehole, or in cement or slurry behind casing; ~~and casing~~, d) steel casing or cement in the annulus around casing, and e) thickness of the ~~annulus~~; ~~annulus around casing~~.

6.5 Geologic conditions include high levels of radiation which can degrade the efficiency of gamma counting through the dead time effect, energy level of emitted gammas, formation density, and lithologic bed geometry.

#### 7. Apparatus

7.1 A geophysical logging system has been described in the general guide (the Apparatus section of Guide [D5753](#)).

7.2 Gamma logs are collected with probes using scintillation detectors.

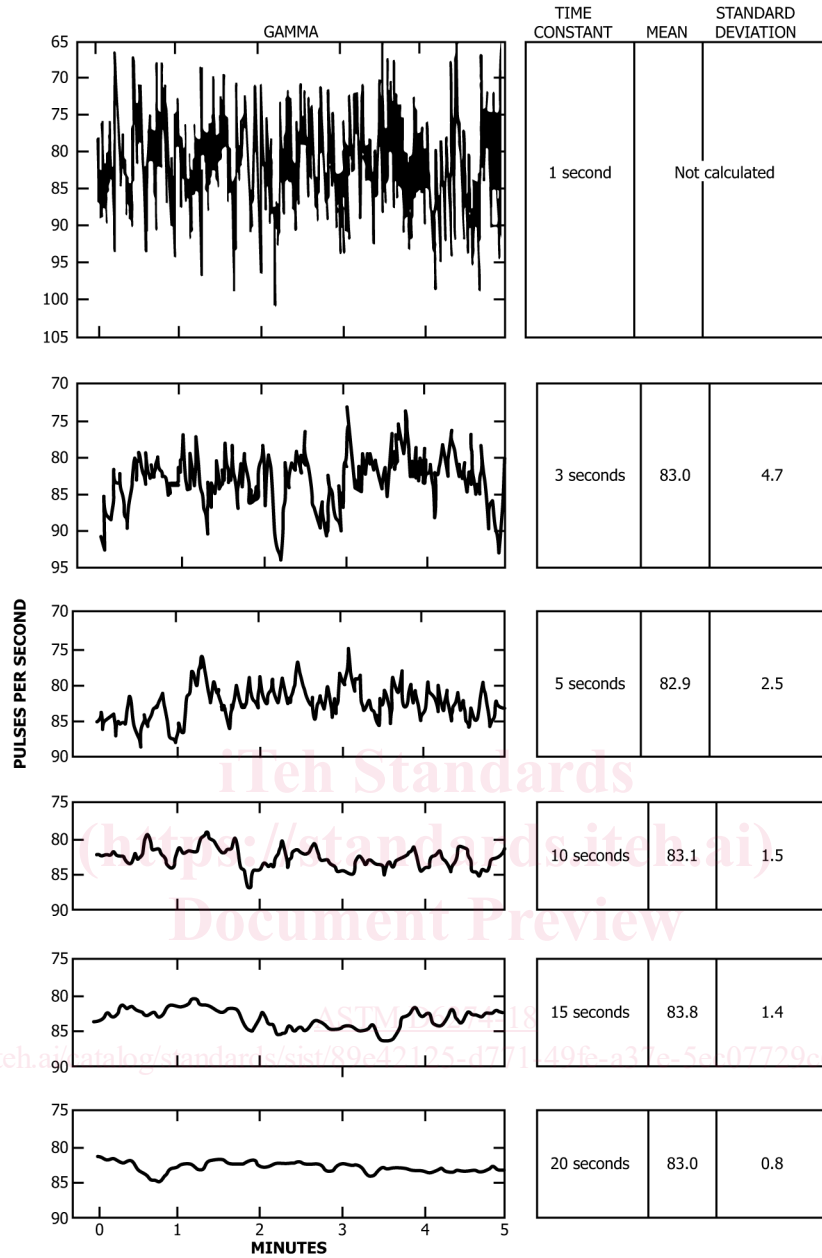
7.2.1 The most common gamma detectors are sodium iodide (NaI).

7.2.2 Other gamma detectors include cesium iodide (CsI) and bismuth germanate (BGO).

7.3 Gamma probes generate nuclear counts as pulses of voltage that are amplified and clipped to a uniform amplitude.

7.3.1 Gamma probes typically used for geotechnical applications can be logged inside boreholes as small as ~~2-in. (5-cm)~~ 5 cm [2-in.] in diameter.

7.4 The volume of investigation and depth of investigation are determined by the density of the material near the probe, which controls the average distance a gamma photon can travel before being absorbed.



NOTE 1—The fluctuations in gamma activity in counts per second is shown to vary by progressively smaller amounts as the averaging period (time constant) is increased from 1 to 20 s.

FIG. 34 Example of Natural Statistical Fluctuation of Gamma Counts From a Test Source of Given Strength

7.4.1 The volume of investigation for gamma logs is generally considered spherical with a radius of 0.5 to 1.0 ft (15 to 30 cm) to 30 cm [0.5 to 1.0 ft] from the center of the detector in typical geological formations. The volume becomes elongated when detector length exceeds approximately 0.5 ft (15 cm); 15 cm [0.5 ft].

7.4.2 The depth of investigation for gamma logs is generally considered to be 0.5 to 1.0 ft (15 to 30 cm); 15 to 30 cm [0.5 to 1.0 ft].

7.5 Vertical resolution of gamma logs is determined by the size of the volume from which gammas can reach a nuclear detector suspended in the borehole. In typical geological formations surrounding a fluid-filled borehole, this is a roughly spherical volume about 1 to 2 ft (30 to 60 cm) 30 to 60 cm [1 to 2 ft] in diameter. Excessive logging speed can decrease vertical resolution.

7.6 Measurement resolution of gamma probes is determined by the counting efficiency of the nuclear detector being used in the probe. Typical measurement resolution is 1 cps.

7.7 A variety of gamma logging equipment is available for geotechnical investigations. It is not practical to list all of the sources of potentially acceptable equipment.