



Designation: D8571 – 24

Standard Practice for Detection of Hydrocarbon Liquids in Soils by Fluorescence with an Optical Imaging Profiler Using Direct Push Methods¹

This standard is issued under the fixed designation D8571; 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 presents a method for delineating the subsurface presence of nonaqueous phase liquids (NAPLs) consisting of petroleum hydrocarbons, coal tars, and similar waste materials using an optical image profiler (OIP) system. The OIP probe is advanced into waste materials, soils, and unconsolidated formations using direct push (DP) methods. The OIP system provides data approximately each 15 mm (0.05 ft) of log depth to support high-resolution site characterization.

1.2 OIP logging is limited to wastes, soils, and unconsolidated formations that can be penetrated with the available direct push equipment. The ability to penetrate materials is based on carrying vehicle weight, density of soil/materials, and consistency of soil/materials. Penetration may be limited or damage to sensors or tooling can occur under certain ground conditions. DP tools are not designed to penetrate consolidated rock (Guides [D6001/D6001M](#) and [D6282/D6282M](#), Practices [D7352](#) and [D8037/D8037M](#)).

1.3 *Units*—The values stated in SI units are to be regarded as standard, however, inch pound units are indicated for information within parentheses as they are in common use for many users. 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.

1.4 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice [D6026](#), unless superseded by this standard.

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

1.6 *This international standard was developed in accordance with internationally recognized principles on standard-*

ization 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](#)

[D5092/D5092M Practice for Design and Installation of Groundwater Monitoring Wells](#)

[D5299/D5299M Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities](#)

[D5681 Terminology for Waste and Waste Management](#)

[D5778 Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils](#)

[D6001/D6001M Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization](#)

[D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data](#)

[D6187 Practice for Cone Penetrometer Technology Characterization of Petroleum Contaminated Sites with Nitrogen Laser-Induced Fluorescence](#) (Withdrawn 2019)³

[D6282/D6282M Guide for Direct Push Soil Sampling for Environmental Site Characterizations](#) (Withdrawn 2023)³

[D6724/D6724M Guide for Installation of Direct Push Groundwater Monitoring Wells](#)

[D6725/D6725M Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers](#)

[D7352 Practice for Volatile Contaminant Logging Using a Membrane Interface Probe \(MIP\) in Unconsolidated Formations with Direct Push Methods](#)

¹ This practice is under the jurisdiction of ASTM Committee [D34](#) on Waste Management and is the direct responsibility of Subcommittee [D34.01.05](#) on Screening Methods.

Current edition approved May 1, 2024. Published May 2024. DOI: 10.1520/D8571-24.

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.

³ The last approved version of this historical standard is referenced on www.astm.org.

D8037/D8037M Practice for Direct Push Hydraulic Logging for Profiling Variations of Permeability in Soils

3. Terminology

3.1 For definitions of common technical terms used in this standard, refer to Terminologies **D653** and **D5681**.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *CMOS camera, n*—complementary metal-oxide semiconductor used by the OIP system to capture images in the visible or IR light range.

3.2.2 *fluorophore, n*—a substance that gives off light (fluoresces) when exposed to light of a particular color or wavelength.

3.2.2.1 *Discussion*—Fluorescence occurs at longer wavelengths than the incident light; this is called the Stokes shift. Aromatic molecules such as benzene, naphthalene, anthracene, and other polynuclear aromatic hydrocarbons (PAHs) fluoresce. Some anthropogenic materials, naturally occurring organic materials, and inorganic, naturally occurring minerals also fluoresce (for example, calcite).

3.2.3 *green wavelength light, n*—green light is usually defined by a wavelength range of 495 nm to 570 nm.

3.2.3.1 *Discussion*—The green laser diode used to induce fluorescence with the OIP has a primary wavelength emission of 520 nm.

3.2.4 *infrared (IR) light, n*—typically defined as light with a wavelength range between 700 nm to 1 mm. The OIP uses an IR LED with primary wavelength of 940 nm.

3.2.5 *optical image profiler (OIP), n*—in groundwater, geohydrology, a steel probe equipped with viewing window that is advanced into the subsurface at a constant rate, or pauses in testing, where either UV or green light is sent into the soil and the reaction of the soil to light (fluorescence) and visible images are recorded by a CMOS camera, viewed, and recorded to a data acquisition system at the surface.

3.2.5.1 *Discussion*—A steel probe about 50 mm (2 in.) in diameter and 61 cm (2 ft) in length that is equipped with a sapphire window on one side is included in an OIP. Two different light sources are mounted inside the probe to illuminate the formation outside the window. One of the light sources (either ultraviolet or green wavelength) is used to induce fluorescence of hydrocarbon nonaqueous phase liquids in the formation. A second light source (either visible or infrared light) is used alternately to illuminate the formation to observe color and/or texture. A CMOS camera mounted inside the probe and behind the window captures images of the illuminated formation or fluorescing hydrocarbon contaminants. Images are transmitted up-hole by a trunkline for viewing and analysis. One image at every 15 mm (0.05 ft) depth increment is saved to file.

3.2.6 *still image*—with respect to OIP logging, sharper images of subjects may be obtained by halting advancement of the OIP probe and clicking an icon on-screen to acquire images by both light sources; these images are saved as “still” images in the log file at the depth captured.

3.2.6.1 *Discussion*—Images captured and saved as the probe is being advanced may be blurry due to probe movement. To

obtain sharper images of features of interest, the operator may halt probe advancement and acquire “still” images which are labeled and saved as “still” images in the log file at the depth captured. These images may be valuable for review and analysis of product fluorescence and/or formation texture/color.

3.2.7 *ultraviolet (UV) light, n*—ultraviolet light is typically defined by a wavelength range from 10 nm to 400 nm.

3.2.7.1 *Discussion*—For the OIP system, a UV light emitting diode (LED) with primary wavelength emission in the range of 265 nm to 275 nm is used for the UV source to induce fluorescence.

3.3 Acronyms:

3.3.1 *BTEX*—benzene, toluene, ethylbenzene, and xylenes

3.3.2 *CMOS*—complementary metal-oxide semiconductor

3.3.3 *CPT*—cone penetrometer

3.3.4 *CVOC*—chlorinated volatile organic compound

3.3.5 *DNAPL*—dense nonaqueous phase liquid

3.3.6 *DP*—direct push

3.3.7 *EC*—electrical conductivity

3.3.8 *EPA*—Environmental Protection Agency

3.3.9 *FPS*—frames per second

3.3.10 *GPS*—global positioning system

3.3.11 *HPT*—hydraulic profiling tool

3.3.12 *LED*—light emitting diode

3.3.13 *LIF*—laser induced fluorescence

3.3.14 *LNAPL*—light nonaqueous phase liquid

3.3.15 *MIP*—membrane interface probe

3.3.16 *NAPL*—nonaqueous phase liquid

3.3.17 *OIP*—optical image profiler

3.3.18 *PAH*—polynuclear aromatic hydrocarbon

3.3.19 *QA*—quality assurance

3.3.20 *TarGOST*—tar-specific green optical screening tool

3.3.21 *UVOST*—ultraviolet optical screening tool

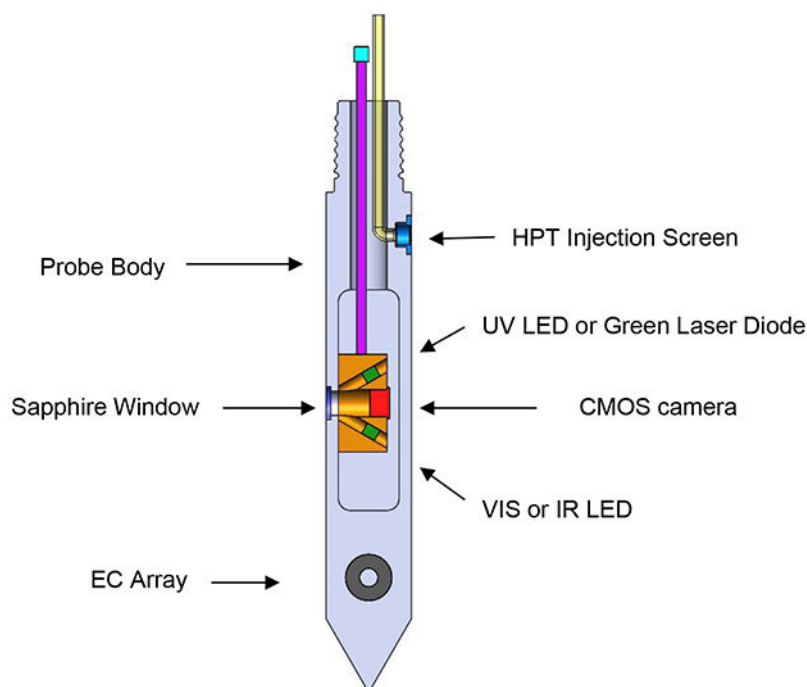
3.3.22 *VIS*—visible wavelength light

4. Summary of Practice

4.1 This practice describes a field method for screening nonaqueous phase petroleum fuels, oils, coal tars, creosote, and other similar hydrocarbon products and wastes with depth using an OIP probe⁴ (**Fig. 1**) **(1)**.⁵ The OIP is run in combination with an electrical conductivity (EC) array sensor, and can

⁴ The optical image profiling probe is covered by a patent (US010371637B1). Interested parties are invited to submit information regarding the identification of an alternative(s) to this patented item to the ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend. The sole source of supply of the apparatus known to the committee at this time is Geoprobe Systems Inc, Salina, KS. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

⁵ The boldface numbers in parentheses refer to a list of references at the end of this standard.



The size of a typical OIP probe is about 50 mm (2 in.) in diameter and 61 cm (2 ft) in length. The UV LED and VIS LED are used together in the UV probe, while the green laser diode and IR LED are used together in the green wavelength probe. All OIP probes include an EC array and HPT sensor system to assess lithology and permeability.

FIG. 1 Schematic of the OIP Probe

be run in combination with a hydraulic profiling tool (HPT) (see Fig. X1.1) or with cone penetration testing (CPT) (see Fig. X1.2) for collecting lithological data simultaneously. This practice is intended to reduce the amount of sampling required for characterization and to optimize the location of borings and monitoring wells needed for site characterization. The OIP logs provide high-resolution data to support development of high-quality conceptual site models (2).

4.2 Depending on the contaminant of concern, either a UV or green light source is directed through a sapphire window in the side of the optical probe onto the bulk formation or waste materials. The UV or green light induces PAHs as well as some man-made and naturally occurring materials to fluoresce.

4.3 Pre-log quality assurance testing is performed on the probe before advancing it into the subsurface to verify the probe is operating correctly. Probe advancement is typically 1 to 2 cm/s (2 to 4 ft/min).

4.4 Log data and images are collected in real time and plotted or displayed on-screen. The graphed log data are viewed in data acquisition software during advancement of the probe into the subsurface. Images of the fluorescence are collected by the camera inside the OIP probe and viewed live-time on-screen. The data acquisition system analyzes each image for percent area in that image with light typical of hydrocarbon fluorescence. When there is no fluorescence, the images are dark.

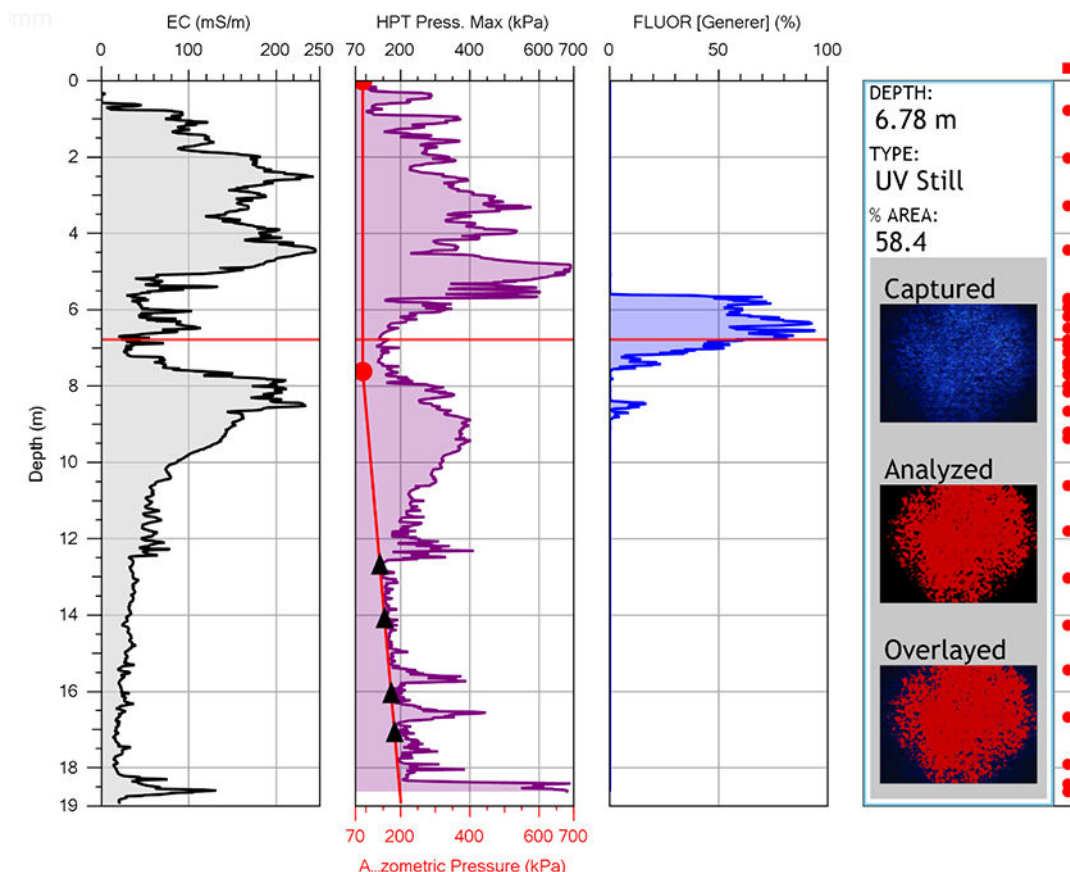
4.5 After reaching the predetermined depth or further depth penetration refusal, the probe is extracted using a direct push machine.

4.6 The log data and images are stored in a digital log file after the log has been completed. The completed log file can be opened in a viewing software program for review or printing of the log for reports (Fig. 2). The viewing software also allows for review of stored images. Stored images and log data may be exported for use in reports or presentations.

5. Significance and Use

5.1 Subsurface contamination of soil and groundwater by nonaqueous phase liquids and wastes of various hydrocarbons is widespread in the industrialized world. In 2004, the U.S. EPA estimated there were about 680 000 active underground storage tanks (USTs) in the United States. They also estimated that approximately 96 % of these contained petroleum products and more than 443 000 releases had been confirmed (3). This indicates that there are many facilities and locations where LNAPLs may be present in subsurface soil. Often, subsurface hydrocarbon contamination may consist of common petroleum oils or fuels (diesel, gasoline, jet fuel, etc.), or crude oil and associated wastes. However, creosote used at wood treating facilities (4) or coal tars generated at historical manufactured gas plants (5) and other similar waste materials are also of concern. These products and related wastes contain aromatic and/or PAHs that will fluoresce under certain wavelengths of incident light (6).

5.2 Laser induced fluorescence (LIF) (Practice D6187) was initially developed in the 1990s for the detection of many types of hydrocarbon NAPLs in subsurface soils (7). This system uses a laser mounted above ground with a fiber-optic cable to transmit laser light down-hole and out a top of the hole.



The bulk formation electrical conductivity (EC) log is shown on the left. The injection pressure log is plotted on the middle graph. In this log, higher EC and higher pressure indicate lower permeability (higher clay content), while lower EC and pressure indicate sandy, higher permeability materials. The average percent area of the images displaying fuel fluorescence is plotted on the right graphical column. Note that above ~5.5 m and below ~9 m, no fluorescence was observed. The red bar across the log indicates the depth of the image shown on the image display at right. The top image on the right is a still image of the actual fuel fluorescence observed at a depth of 6.78 m in this log. The bottom image on the right is the analysis of the fluorescence image by the OIP software. This shows the area of the image (in red) determined by the OIP software to be representative of fuel fluorescence. The depth and percent of the image area displaying fuel fluorescence (58.4 %) is reported in the upper right corner of the log. Each image saved in the log file may be viewed on-screen. An optional window in the viewing software allows for multiple images to be plotted at one time. Other log parameters are saved during the logging process (speed, optical power, and camera frame rate) and may be plotted to assess log quality. Additional parameters may be calculated in post processing and plotted with the log (water level, corrected HPT pressure, estimated hydraulic conductivity, etc.).

FIG. 2 Combined OIHPT-UV Log Run in an Alluvial Aquifer with Unleaded Gasoline Contamination, Plotted with the Log Viewing Software

illuminate the formation. Resultant fluorescent light is transmitted back up-hole with a second fiber-optic cable to a spectroscopy system for analysis. These systems have been successfully deployed using both a cone penetrometer truck or with a direct push percussion probing machine to locate hydrocarbon NAPLs and associated wastes in the subsurface at many sites (8). Comparable systems for hydrocarbon detection using lasers are still available such as the UVOST and TarGOST systems (9).

5.3 The OIP system cannot directly detect dense nonaqueous phase liquids (DNAPLs) composed of chlorinated volatile organic compounds (CVOCs). However, if the CVOC DNAPL contains greases or oils from degreasing operations, they may be detectable with the OIP system. Alternate methods for detection of CVOC DNAPL include the dye-LIF system (10) and the MIP system (Practice D7352). The MIP system also can detect dissolved phase CVOCs and dissolved phase petroleum groundwater plumes (11).

5.4 In place of a large up-hole laser and associated fiber-optic cables, the OIP system uses a small UV LED or a small green laser diode down-hole inside the probe to illuminate the formation through a sapphire window to induce fluorescence. Additionally, a small CMOS camera mounted behind the sapphire window inside the probe is used as the detector for the emitted visible range fluorescent light (Fig. 1). The OIP has been successfully deployed under both cone penetrometer vehicles or with a direct push percussion probing machine to locate hydrocarbon NAPLs and associated wastes in the subsurface at many sites (2).

5.5 The CMOS camera takes images of the visible light fluorescence at approximately 30 frames per second (FPS) as the probe is advanced at approximately 2 cm/s. Images collected by the CMOS camera are sent to the instruments and computer system. The computer software analyzes the color in the pixels of the collected images. Pixels are analyzed for specific ranges of color typical of UV