



Designation: D6187 – 97 (Reapproved 2003)

Standard Practice for Cone Penetrometer Technology Characterization of Petroleum Contaminated Sites with Nitrogen Laser-Induced Fluorescence¹

This standard is issued under the fixed designation D6187; 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 the method for delineating the subsurface presence of petroleum hydrocarbons and other hydrocarbons using a fiber optic based nitrogen laser-induced fluorescence sensor system.

1.2 The petroleum hydrocarbon sensing scheme utilizes a fluorescence technique in which a nitrogen laser emits pulsed ultraviolet light. The laser, mounted on the cone penetrometer platform, is linked via fiber optic cables to a window mounted on the side of a penetrometer probe. Laser energy emitted through the window causes fluorescence in adjacent contaminated media. The fluorescent radiation is transmitted to the surface via optical cables for real-time spectral data acquisition and spectral analysis on the platform.

1.3 This sensor responds to any material that fluoresces when excited with ultraviolet wavelengths of light, largely the polycyclic aromatic, aromatic, and substituted hydrocarbons, along with a few heterocyclic hydrocarbons. The excitation energy will cause all encountered fluorophores to fluoresce, including some minerals and some non-petroleum organic matter. However, because the sensor collects full spectral information, discrimination among the fluorophores may be distinguished using the spectral features associated with the data. Soil samples should be taken to verify recurring spectral signatures to discriminate between fluorescing petroleum hydrocarbons and naturally occurring fluorophores.

1.4 This practice is used in conjunction with a cone penetrometer of the electronic type, described in Test Method [D5778](#).

1.4.1 The direct push LIF described in this practice can provide accurate information on the characteristics of the soils and contaminants encountered in the vadose zone and the saturated zone, although it does not make a distinction between dissolved and sorbed contamination in the saturated zone.

1.5 This practice describes rapid, continuous, in-situ, real-time characterization of subsurface soil.

1.6 Direct push LIF is limited to soils that can be penetrated with the available equipment. The ability to penetrate strata is based on carrying vehicle weight, density of soil, and consistency of soil. Penetration may be limited; or, damage to sensors can occur in certain ground conditions.

1.7 This practice does not address the installation of any temporary or permanent soil, ground water, soil vapor monitoring, or remediation devices; although, the devices described may be left in-situ for the purpose of on-going monitoring.

1.8 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.9 Direct push LIF environmental site characterization will often involve safety planning, administration, and documentation. This practice does not purport to address the issues of operational or site safety.

1.10 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

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

[D1129 Terminology Relating to Water](#)

[D3650 Test Method for Comparison of Waterborne Petroleum Oils By Fluorescence Analysis](#)

[D4657 Test Method for Polynuclear Aromatic Hydrocarbons in Water](#)³

[D5088 Practice for Decontamination of Field Equipment Used at Waste Sites](#)

[D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Ground Water](#)

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 Ground Water and Vadose Zone Investigations.

Current edition approved Oct. 10, 1997. Published March 1998. DOI: 10.1520/D6187-97R03.

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

- D5778** Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils
- D6001** Guide for Direct-Push Ground Water Sampling for Environmental Site Characterization
- D6067** Guide for Using the Electronic Cone Penetrometer for Environmental Site Characterization
- E131** Terminology Relating to Molecular Spectroscopy
- E169** Practices for General Techniques of Ultraviolet-Visible Quantitative Analysis
- E275** Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers
- E388** Test Method for Wavelength Accuracy of Spectral Bandwidth of Fluorescence Spectrometers
- E578** Test Method for Linearity of Fluorescence Measuring Systems
- E579** Test Method for Limit of Detection of Fluorescence of Quinine Sulfate in Solution
- E924** Guide for Quality Assurance of Laboratories Using Molecular Spectroscopy³
- E1614** Guide for Procedure for Measuring Ionizing Radiation-Induced Attenuation in Silica-Based Optical Fibers and Cables for Use in Remote Fiber-Optic Spectroscopy and Broadband Systems

3. Terminology

3.1 *Definitions*—Terminology used within this practice is in accordance with Terminologies **D653**, **D1129**, and **E131**, and Practice D3415 with the addition of the following:

3.1.1 *calibration*—the process by which the relationship of instrumental response to changes in the nature and concentration of reference materials is determined.

3.1.2 *Fluorophore*—a material that produces, undergoes, or exhibits fluorescence.

3.1.3 *Laser-induced fluorescence (LIF)*—the rapid emission of light from an atom or molecule after it has absorbed radiation from collimated and polarized monochromatic light source.

3.1.4 *TPH*—total petroleum hydrocarbons.

3.1.5 *TRPH*—total recoverable petroleum hydrocarbons.

3.1.6 *vadose zone*—the hydrogeological region extending from the soil surface to the top of the principal water table; commonly referred to as the “unsaturated zone” or “zone of aeration”. However, these alternate names are inadequate as they do not take into account locally saturated regions above the principal water table (for example, perched water zones).

3.2 Definitions:

3.2.1 *in-situ testing devices*—are sensors or samplers, used for obtaining mechanical or chemical test data, that are typically pushed, rotated or driven from the surface or below the bottom of a borehole following completion of an increment of drilling.

3.2.2 *push depth*—the depth below a ground surface to which the tip of the direct push water sampling device has penetrated.

3.3 *Definitions*—Definitions in accordance with Test Method **D6067**:

3.3.1 *cone penetrometer*—a penetrometer in which the leading end of the penetrometer tip is a conical point designed for penetrating soil and for measuring the end-bearing component of penetration resistance.

3.3.2 *electronic cone penetrometer*—a friction cone penetrometer that uses force transducers, such as strain gauge load cells, built into a non-telescoping penetrometer tip for measuring, within the penetrometer tip, the components of penetration resistance.

3.3.3 *penetrometer*—an apparatus consisting of a series of cylindrical push rods with a terminal body (end section), called the penetrometer tip, and measuring devices for determination of the components of penetration resistance.

3.3.4 *penetrometer tip*—the terminal body (end section) of the penetrometer which contains the active elements that sense the components of penetration resistance. The penetrometer tip may include additional electronic instrumentation for signal conditioning and amplification.

3.3.5 *push rods*—the thick-walled tubes or rods used to advance the penetrometer tip.

4. Summary of Practice

4.1 This practice is based on a cone penetrometer deployed fiber optic-based, nitrogen laser-induced fluorescence sensor system. It is an in situ field screening technique for characterizing the subsurface distribution. This practice is not a replacement for these traditional methods; but is a means of reducing the number of borings and wells required to achieve site characterization. See **Fig. 1** and **Fig. 2**

4.2 This practice provides semi-quantitative data on the subsurface distribution of POL products from the fluorescence response induced in the polycyclic aromatic hydrocarbon compounds that are components of petroleum products. It makes use of a laser excitation source that targets polycyclic aromatic hydrocarbons with three or more fused aromatic rings and detects them in the bulk soil matrix throughout the vadose, capillary fringe, and saturated zones. When the sensor is used in conjunction with an industry-standard 20 ton penetrometer push vehicle and subsurface conditions are favorable, measurements have been made to depths greater than 150 ft (45.7 m). The depth of push is influenced by many geological factors (that is, properties of soil) and may vary widely from site to site.

4.3 The spectral data provides a means of confirming that observed fluorescence events are consistent with the spectra from known petroleum products. It provides a field screening capability that is proportional to contamination concentration and relative to a specified detection limit derived for a specific fuel product on a site specific soil matrix.

4.4 Although under ideal conditions detection limits are in the ppm range, the same contaminant in various matrices will have different levels of detection due to the influences of these matrices.

5. Significance and Use

5.1 Direct push LIF is used for site investigations where the delineation of petroleum hydrocarbons and other fluorophores is necessary. Generic terms for these investigations are

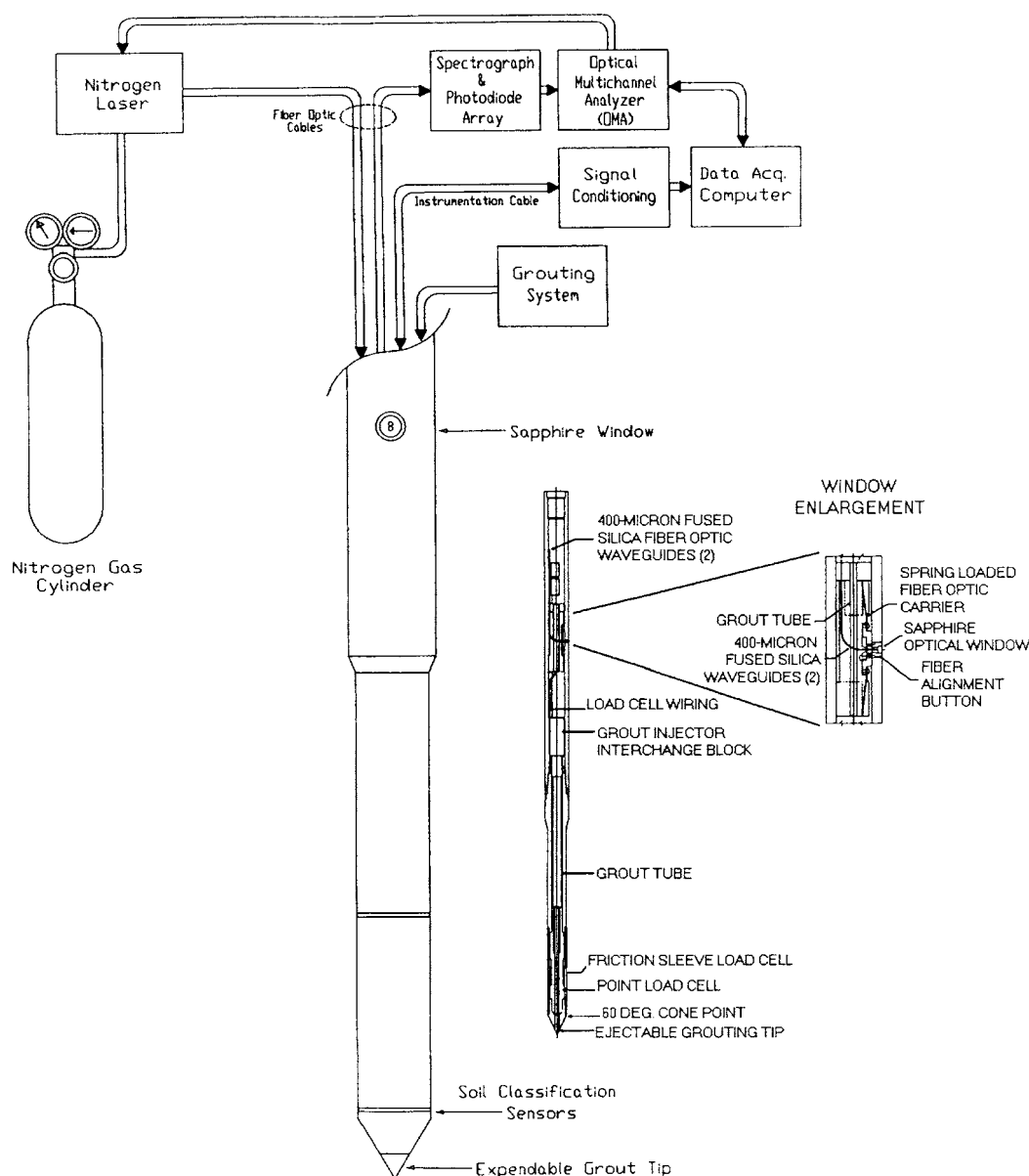


FIG. 1 Laser-Induced Fluorescence Petroleum, Oil, and Lubricant Sensor

assessments and hazardous waste site investigations. Continuous LIF is used to provide information on the relative amounts of contamination and to provide a lithological detail of the subsurface strata. These investigations are frequently required in the characterization of hazardous waste sites.

5.2 This technology provides preliminary results within minutes following the completion of each test. This allows the number, locations, and depths of subsequent tests to be adjusted in the field. Field adjustment may increase the efficiency of the investigation program.

5.3 The rapid fluorescence data gathering provided by direct push LIF provides information necessary to assess the presence of contamination in soils and associated pore fluids in the field. This method allows for immediate determination of relative amounts of contamination. This allows the number, locations,

and depths of subsequent activities to be adjusted in the field. Field adjustment may increase the efficiency of the investigation program.

5.4 With appropriate sensors, the direct-push investigation program can provide information on soil stratigraphy and the distribution of petroleum and other fluorophores in the subsurface. This method results in minimum site disturbance and generates no cuttings that might require disposal (1).⁴

5.5 This practice is confirmed using soil samples collected at given depths to confirm the fluorescence readings using a field deployed EPA Method 418.1 (2), EPA method 8015-modified, and a modified EPA 8270 Method (3), or equivalent

⁴ The boldface numbers given in parentheses refer to a list of references at the end of the text.