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.

Designation: D7352 – 18

Standard Practice for Volatile Contaminant Logging Using a Membrane Interface Probe (MIP) in Unconsolidated Formations with Direct Push Methods[1]

This standard is issued under the fixed designation D7352; 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 standard practice describes a field procedure for the rapid delineation of volatile organic compounds (VOC) in the subsurface using a membrane interface probe. Logging with the membrane interface probe is usually performed with direct push (DP) equipment. DP methods are typically used in soils and unconsolidated formations, not competent rock.

1.2 This standard practice describes how to obtain a real time vertical log of VOCs with depth. The data obtained is indicative of the total VOC level in the subsurface at depth. The MIP detector responses provide insight into the relative contaminant concentration based upon the magnitude of detector responses and a determination of compound class based upon which detectors of the series respond.

1.3 The use of a lithologic logging tool is highly recommended to define hydrostratigraphic conditions, such as migration pathways, and to guide confirmation sampling and remediation efforts. Other sensors, such as electrical conductivity, hydraulic profiling tool, fluorescence detectors, and cone penetration tools may be included to provide additional information.

1.4 Since MIP results are not quantitative, soil and water sampling (Guides D6001, D6282, D6724, and Practice D6725) methods are needed to identify specific analytes and exact concentrations. MIP detection limits are subject to the selectivity of the gas phase detector applied and characteristics of the formation being penetrated (for example: permeability, saturation, clay and organic carbon content).

1.5 The 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.

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this standard.

1.6.1 The procedures used to specify how data is collected/recorded and calculated in the standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analytical methods for engineering data.

1.7 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice 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 the consideration of a project's many unique aspects. The word "standard" in the title means that the document has been approved through the ASTM consensus process.*

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 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 practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

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

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D5092 Practice for Design and Installation of Groundwater Monitoring Wells

D5299 Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities

D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Groundwater (Withdrawn 2013)[3]

D5792 Practice for Generation of Environmental Data Related to Waste Management Activities: Development of Data Quality Objectives

D6001 Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization

D6026 Practice for Using Significant Digits in Geotechnical Data

D6067 Practice for Using the Electronic Piezocone Penetrometer Tests for Environmental Site Characterization and Estimation of Hydraulic Conductivity

D6282 Guide for Direct Push Soil Sampling for Environmental Site Characterizations

D6724 Guide for Installation of Direct Push Groundwater Monitoring Wells

D6725 Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers

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

E355 Practice for Gas Chromatography Terms and Relationships

E1689 Guide for Developing Conceptual Site Models for Contaminated Sites

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *carry over*—retention of contaminant in the membrane and trunkline which may result in false positive results or an increased detector baseline at subsequent depth intervals.

3.2.2 *chemical response test*—a test of the working MIP system performed by exposing the MIP membrane to an aqueous phase solution with a known contaminant of known concentration.

3.2.2.1 *Discussion*—Performed before and after each MIP log to validate the MIP system performance. Also used so that log data from different locations across a site may be compared.

3.2.3 *closed couple flow*—the trunkline carrier gas return flow with the trunkline gas lines connected together when the MIP probe is bypassed.

3.2.3.1 *Discussion*—Used during troubleshooting to determine the source of a gas leak in the MIP system.

3.2.4 *gas dryer*—a selectively permeable membrane tubing is used to continuously dry the MIP carrier gas stream before it enters the detectors by removing only water vapor.

3.2.4.1 *Discussion*—The gas dryer may need to be removed to improve detection of some analytes with high water solubility, such as MTBE, acetone, dioxane or ethanol.

3.2.5 *gas phase detectors*—heated laboratory grade detectors used for gas chromatography (Practice E355).

3.2.5.1 *Discussion*—Carrier gas effluent from the MIP probe flows through these detectors at the surface for the analysis of VOCs. Detectors most often used with the MIP include photoionization detector (PID), flame ionization detector (FID), and a halogen specific detector (XSD) (Fig. A2.2). Other, appropriate gas phase detectors may be used.

3.2.6 *membrane interface probe (MIP)*—a subsurface logging tool for detection of VOCs.

3.2.7 *parts per billion (ppb)*—the number of units of a contaminant per 1 billion units of total mass, typically measured as either µg/Kg or µg/L depending if a solid or liquid is being measured.

3.2.8 *parts per million (ppm)*—the number of units of a contaminant per 1 million units of total mass, typically measured as either mg/Kg or mg/L depending if a solid or liquid is being measured.

3.2.9 *trigger*—software icon interface between the operator and the acquisition software to initiate or terminate data collection.

3.2.10 *trip time*—the time required for an analyte to diffuse across the semipermeable membrane and travel to the gas phase detectors at the surface through a fixed length of tubing.

3.2.11 *trunkline*—a durable, protective jacketed cord containing electrical wires for the heaters in the probe block, electrical wires for other sensors, and tubing for the transport of carrier gas and the analytes to the surface detectors which is pre-strung through steel drive rods prior to logging.

3.2.11.1 *Discussion*—The trunkline connects the MIP probe containing the onboard sensors with the surface instrumentation.

3.2.12 *working standard*—an aqueous chemical standard used in response testing the MIP system.

4. Summary of Practice

4.1 This practice describes the field method for delineation of VOCs with depth via the MIP (**1-4**).[4] The MIP is advanced through the soil or unconsolidated formations using a direct

[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.

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

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push machine for high resolution logging of volatile analytes in real time. Other sensors may be run in tandem with the MIP (e.g. electrical conductivity (EC), hydraulic profiling tool (HPT), cone penetration testing (CPT) to provide lithologic data simultaneously (**5-7**, D6067, D8037).

4.2 A semipermeable membrane on the probe is heated to a temperature of 100 to 120°C [212 to 250°F]. Clean carrier gas is circulated across the internal surface of the membrane. VOCs diffuse across the membrane under a concentration gradient into the carrier gas. The VOCs are transported in the carrier gas by the return gas line to the surface for analysis by gas phase detectors (Fig. 1).

4.3 After pre-log quality assurance tests the MIP probe is advance into the subsurface. Probe advancement is halted at predefined depth increments (for example, every 30 cm [1 ft.]) depending on the level of vertical detail required. Probe advancement is stopped for about 45 seconds at each depth. This allows time for the heater to warm the probe/formation, for VOCs to cross the membrane into the carrier gas line and travel to the up-hole detector system, and for desorption of contaminants off the membrane after passing through contaminated zones.

4.4 Detector responses and data from other sensors are observed onscreen as the log is obtained.

4.5 Detector responses and data from other sensors (such as EC, HPT, CPT) are saved in the digital logfile. The logfiles can be retrieved, after log completion, in a viewing software package. Logs may be printed for reports or viewed onscreen.

4.6 After reaching the end of the log the probe is retracted using the DP machine.

4.7 MIP bore holes must be properly sealed to meet local regulatory code.

5. Significance and Use

5.1 The MIP system provides a timely and cost effective way for delineation of many VOC plumes (for example, gasoline, benzene, toluene, solvents, trichloroethylene, tetrachloroethylene) with depth (**1, 2, 4, 8, 9**). MIP detector logs provide insight into the relative contaminant concentration based upon the response magnitude of detector and a determination of compound class based upon which detectors of the series respond of the bulk VOC distribution in the subsurface but do not provide analyte specificity (**1, 2, 7**). DP logging tools such as the MIP are often used to perform expedited site characterizations (**10, 11**, D5730) and develop detailed conceptual site models (E1689). The project manager should determine if the required data quality objectives (D5792) can be achieved with a MIP investigation. MIP logging is typically one part of an overall investigation program.

5.2 MIP logs provide a detailed record of VOC distribution in the saturated and unsaturated formations and assist in evaluating the approximate limits of potential contaminants. A proportion of the halogenated and non-halogenated VOCs in the sorbed, aqueous, or gaseous phases partition through the membrane for detection up hole (**1**).

5.3 Many factors influence the movement of volatile compounds from the formation across the membrane and into the carrier gas stream. One study has evaluated the effects of temperature and pressure at the face of the membrane on analyte permeability (**12**). Formation factors such as degree of saturation, clay content, proportion of organic carbon, porosity and permeability will also influence the efficiency of analyte movement from the formation across the membrane. Of course, the volatility, concentration, molecular size and mass, and water solubility of each specific VOC will influence movement across the membrane and rate of transport through the carrier gas line to the detectors.

5.4 High analyte concentrations or the presence of Non-Aqueous Phase Liquid (NAPL) in the formation can result in analyte carry over in the MIP log (**8, 13**). This is a result of high analyte concentrations within the membrane matrix requiring time to diffuse out of the membrane into the carrier gas stream. This effect can lead to tailing of detector peaks on the MIP log to deeper intervals. Use of appropriate detectors and detector sensitivity settings can reduce this effect (**14**). Experience with log interpretation also helps to identify analyte carryover. Of course, targeted soil or groundwater sampling (D6001, D6282)

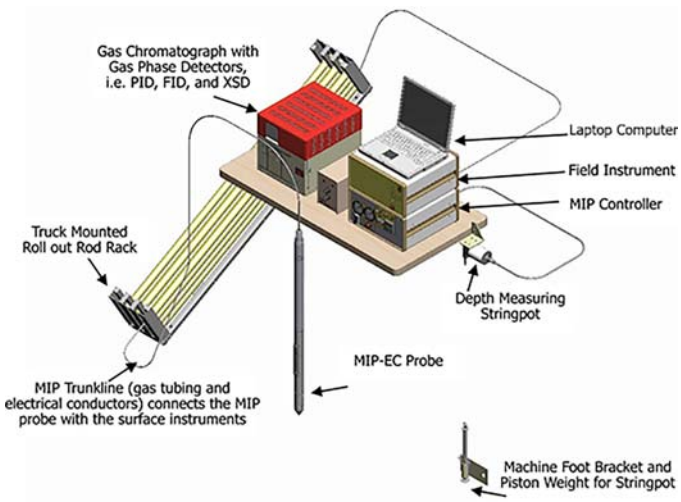

FIG. 1 The Primary Components of a Typical MIP System

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should be performed routinely to verify log results and assist with log interpretation and site characterization (subsection 1.4).

5.5 Some volatile contaminants are composed of multiple analytes of different molecular mass, size and volatility (e.g. gasoline). A detailed study was performed using a gas chromatograph (GC)-mass spectrometer system to assess the delay in movement of several components of gasoline from the membrane face, up the trunkline, to the MIP detectors (**15**). The larger, more massive analytes were found to be delayed in reaching the detectors. This effect means that some analyte mass will be graphed on the MIP log at a depth below where it entered the membrane. This "dispersion" effect is difficult to overcome. However, knowledge of the site-specific analyte(s) and experience with log interpretation can help the user assess these effects on log quality and contaminant distribution. Of course, targeted soil or groundwater sampling (D6001, D6282) should be performed routinely to verify log results and assist with log interpretation and site characterization (subsection 1.4).

5.6 One of the important benefits of MIP logging is that the number of samples and laboratory analyses required to effectively characterize a VOC plume and source area can be greatly reduced, thus reducing investigative time and costs. Reduction of the number of samples required also reduces site worker exposure to hazardous contaminants. The data obtained from the MIP logs may be used to guide and target soil (D6282) and groundwater sampling (D6001) and the placement of long-term monitoring wells (D6724, D6725, D5092) (**2, 7, 8**) to more effectively characterize and monitor site conditions.

5.7 Typically, only VOCs are detected by the MIP system in the subsurface. Use of specialized methods and/or detector systems may allow for detection of other gaseous or volatile contaminants (for example, mercury). Detection limits are subject to the selectivity and sensitivity of the gas phase detectors applied, the analytes encountered, and characteristics of the formation being penetrated (for example permeability, saturation, sand, clay and organic carbon content).

5.8 Correlation of a series of MIP logs across a site can provide 2-D and 3-D definition of the of the primary VOC contaminant plume (**7, 8**). When lithologic logs such as EC, HPT, or CPT are obtained with the MIP data, contaminant migration pathways (**7, 8**) as well as storage and back diffusion zones (**16**) may be defined.

5.9 Some investigations (**8, 17-21**) have found the MIP can be effective in locating zones where dense nonaqueous phase liquids (DNAPL) may be present. However, under some conditions, especially when inappropriate detectors and methods are used (**22, 23**), analyte carryover (**15**) can mask the bottom of the DNAPL body (**9, 13, 24**). These limitations can be minimized by use of appropriate methods and detectors (**14, 23**).

5.10 While the conventional MIP system does not provide quantitative data or analyte specificity some researchers have modified the system with different sampling or detector systems in attempts to achieve quantitation and specificity (**21, 25, 26**). These methods typically reduce the speed of the logging process in order to provide improved quantitation and analyte specificity for a limited group of analytes.

5.11 MIP data can be used to optimize site remediation by knowing the vertical and horizontal distribution of VOCs as well as obtaining information on the soil type and permeability where contaminants are held by using tandem lithologic sensors such as EC, HPT, or CPT. For example, materials injected for remediation are placed at correct depths in the formation based upon the detector responses of contaminants and the proper type of injection is performed based upon the formation permeability.

5.11.1 This practice also may be used as a means of evaluating remediation performance. MIP can provide a cost-effective way to evaluate the progress of VOC remediation. When properly performed at suitable sites, logging locations can be compared from the initial pre-remedial investigation to logs of the VOC contaminants after remediation is initiated.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Practitioners that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc.. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors. Practice D3740 was developed for agencies engaged in the testing and/or inspection of soils and rock. As such, it is not totally applicable to agencies performing this practice. However, users of this practice should recognize that the framework of Practice D3740 is appropriate for evaluating the quality of an agency performing this practice. Currently there is no known qualifying national authority that inspects agencies that perform this practice.

6. Apparatus

6.1 *General*—The following discussion provides descriptions and details for the MIP and system components (Fig. 1).

NOTE 2—The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

6.2 *Membrane Interface Probe*—The membrane is the interface between the bulk formation and the gas phase detectors up hole.

6.2.1 The membrane is set in a removable insert for easy replacement if damaged or worn. It is constructed of a polymer coating impregnated into stainless steel wire mesh set in a stainless-steel mount. (See Annex A1 for membrane removal/replacement instructions.)

6.2.2 The membrane is inserted into a heater block. The elevated temperature of the heater block is used to speed the diffusion of contaminants out of the bulk formation and through the membrane (Fig. 2). This heater block has a regulated temperature typically set at 121°C [250°F]. Temporary cooling, especially in saturated formations, will occur as the probe is advanced incrementally to the next depth.

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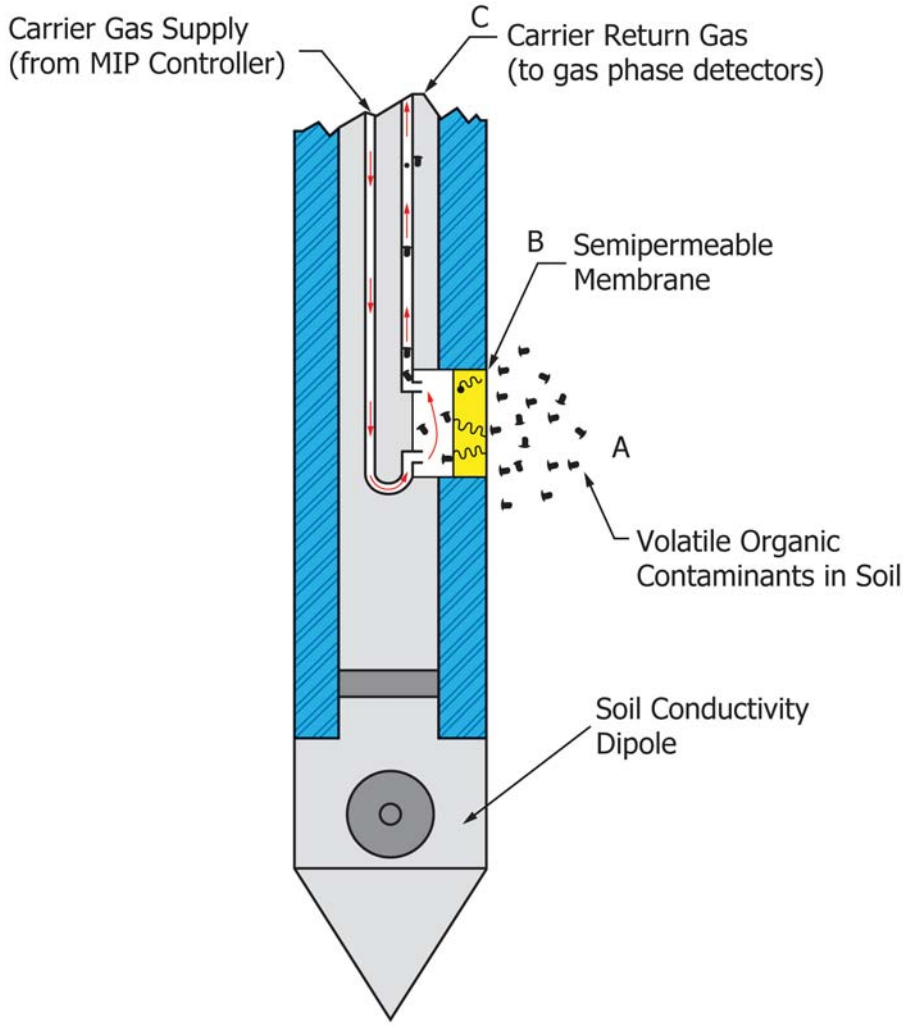

NOTE 1—The schematic of the membrane interface probe depicts the movement of VOCs in the bulk formation (A) diffusing through the semipermeable membrane (B) into the carrier gas (C) to be swept to the surface detectors.

FIG. 2 Schematic Diagram of the Membrane Interface Probe

6.2.3 The MIP probe is typically configured with a soil conductivity dipole for simultaneous collection of bulk formation EC data. At many sites the EC can be correlated with soil and sediment lithology and used in real time to locate test zones.

6.2.4 The MIP probe may be configured with an HPT injection port (D8037) for the simultaneous collection of soil permeability measurements (Appendix X1).

6.2.5 Alternately the MIP probe may be coupled to a CPT probe at its lower end for simultaneous collection of CPT data (Fig. X2.1).

6.3 *MIP Trunkline*—Standard MIP trunklines operate at ambient temperatures to transport analytes to the surface detectors through gas line tubing. The heated trunkline (Appendix X3) option operates at an elevated temperature – approximately 100°C [212°F] for enhanced transport of analytes to the detectors.

6.3.1 Tubing is used for the gas lines to supply a continuous flow of carrier gas to and from the membrane. Two tubes are used in the standard trunklines: a Teflon supply tube brings clean carrier gas from the MIP controller source to the membrane and PEEK (polyether ether ketone) tubing returns carrier gas from the membrane to the gas phase detectors at the ground surface. PEEK tubing is used as the return line due to is lower sorptive capacity for many VOC analytes. If using the heated trunkline system, the gas lines are constructed from stainless steel tubing.

6.4 *MIP Controller*—The MIP controller is used to control the gas flow delivered to the membrane cavity and the voltage delivered to the heater block and EC dipole electrode. The primary features of the MIP controller include:

6.4.1 Primary pressure regulator to control the pressure of carrier gas to the flow regulation circuit of the MIP controller.

6.4.2 A mass or electronic flow controller is used to regulate the flow of carrier gas through the MIP system. The flow rate is typically set to 40 mL/min but can range from 20 to 60 mL/min in the operation of the MIP.

6.4.3 Temperature controller regulates the voltage supplied to the heater block to maintain an elevated temperature in the subsurface. The temperature controller has two inputs for a

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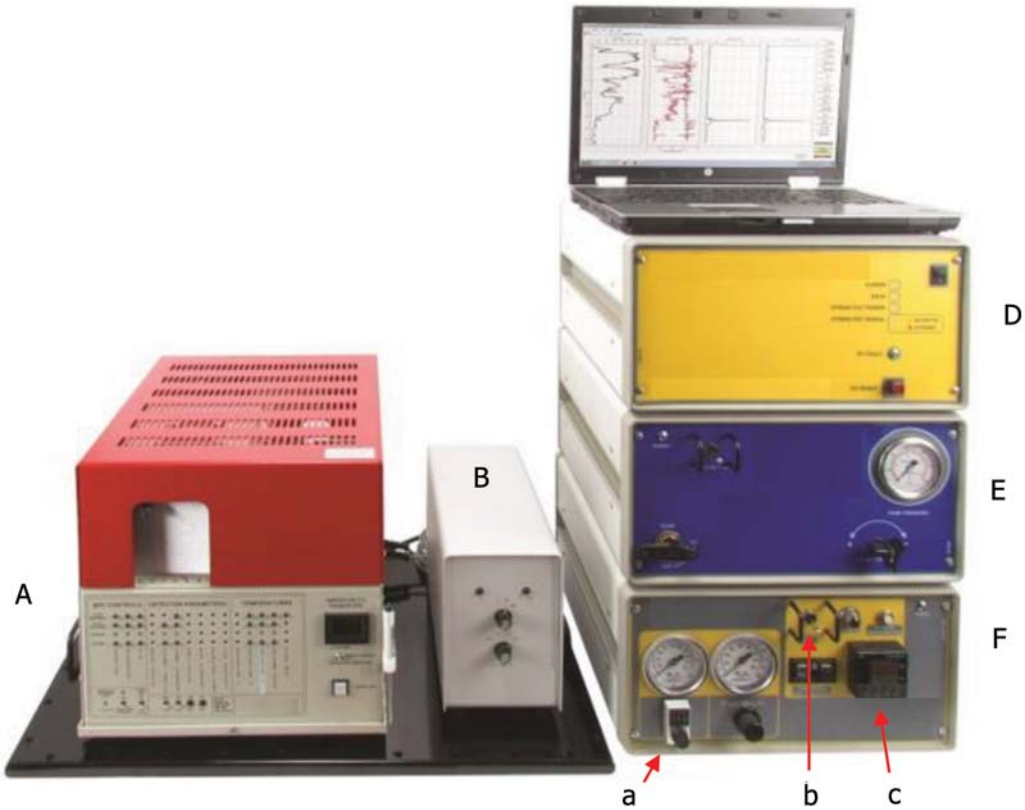

(A) The Gas Chromatograph, contains the PID, FID and XSD detector cells. Other appropriate GCs and detectors may be used.

(B) XSD Control Box for the detector heater circuit and signal amplification and output.

(C) Laptop computer with acquisition and viewing software installed.

(D) Field instrument: data acquisition for the computer also controls the EC output voltage and signal input.

(E) HPT Controller: pump and flow control for the injection of water for the hydraulic profiling system. (Only required within a MIP system when operating MiHPT.)

(F) MIP Controller: temperature control of the MIP probe and carrier gas flow regulation of MIP trunkline.

a. Mass (or electronic) flow controller to regulate MIP trunkline carrier flow rate.

b. Heater switch for MIP probe heater block.

c. Temperature display for MIP probe heater block temperature.

FIG. 3 Instruments Typically Required for MIP Operation

liquid crystal display (LCD). The top output is the temperature of the membrane in the heater block. The bottom output is the set temperature of the controller; the manufacturer sets this temperature at 121°C [250°F].

6.4.4 Analog signal input from the detector system. The analog outputs from the gas phase detectors are connected to the controller for conversion to digital formats to be transferred to the data acquisition system.

6.5 *Field Instrument*—The primary purpose of this component is to acquire analog data from the MIP probe, controller and detector system in real time. The data saved by the acquisition system are: depth; soil EC; rate of probe penetration into the subsurface; temperature of the probe; flow and pressure of the carrier gas supply at the flow controller; and four possible gas phase detector inputs. The primary components of the field instrument include:

6.5.1 Circuitry for the EC system. A voltage output of 0.75VAC is used to measure electrical conductance of the soil. The input connections for EC are located on the rear of the Field Instrument.

6.5.2 Universal serial bus (USB) output connection located on the rear of the field instrument to communicate with the acquisition software on a laptop computer.

6.5.3 Global positioning system connections for acquiring latitude and longitude locations of logging location and storage of this data directly to the log file.

6.6 *Detector System*—Laboratory grade, gas phase detectors are needed for the detection of VOCs in the carrier gas stream (Annex A2). Detectors are typically mounted on a gas chromatograph. Figs. A2.1 and A2.2 show a GC configured with an XSD, FID and PID however, other model gas chromatographs and detectors can be used with the MIP system.

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6.7 *Stringpot*—A depth measuring potentiometer (Fig. 4) mounted to the direct push machine, transfers a voltage to the data acquisition system for accurate depth measurement below ground surface.

6.8 *EC Dipole Tester*—A small device with two different resistors located between two sets of electrical poles. Used to test the EC array on the MIP probe to verify the array and EC system are operating properly.

6.9 *Drive Rods*—Steel rods having adequate strength to sustain the force required to advance the MIP into the subsurface. The rods must be secured together to form a rigid column of drive rods.

6.10 *Direct Push Machine*—A machine with hydraulic rams supplemented with vehicle weight and may include a high frequency hydraulic hammer to advance drive rods into unconsolidated formations.

6.11 *Syringes*—A reciprocating pump with a plunger inside of a barrel used to measure volumes of liquid.

6.12 *Graduated Cylinder*—A measuring cylinder with marked lines on the cylinder to represent an amount of liquid that has been measured.

6.13 *Analytical Balance*—A class of balance designed to measure small mass in the sub-milligram range.

6.14 *Volumetric Flask*—A piece of laboratory glassware, calibrated to contain a precise volume of liquid.

7. Reagents and Materials

7.1 *Carrier Gas*—A non-reactive (inert) gas is used for the transportation of the volatile compounds from the membrane to the up-hole detector system. Examples of gases used for MIP logging include: ultra high purity (UHP) grade Nitrogen and UHP grade Helium. Nitrogen is mainly used for the carrier gas because it is readily available, is a stable gas, and is inert to hydrocarbons.

7.2 *Methanol*—CH_3OH, reagent grade, for use in the dilution of stock standards.

7.3 *Neat Volatile Organic Standards*—Pure product standards (99+% reagent grade) are used for the preparation of stock standards. The neat product chosen should correlate to the contaminant of concern at the investigation site. If specific contaminants are known (for example, TCE, benzene), standards of those compounds may be used. Some contaminants are composed of multiple compounds (e.g. gasoline) and an appropriate neat standard (e.g. benzene in the case of gasoline) should be used for preparation of standards.

7.4 *Gas Tight Syringes*—Graduated syringes are a measurement device used for the preparation of the stock and working standards. Recommended sizes include: 10 µL, 25 µL, 100 µL and 500 µL.

7.5 *Stock Standards*—Neat reagent grade standards are first diluted with methanol at the desired concentration. This is

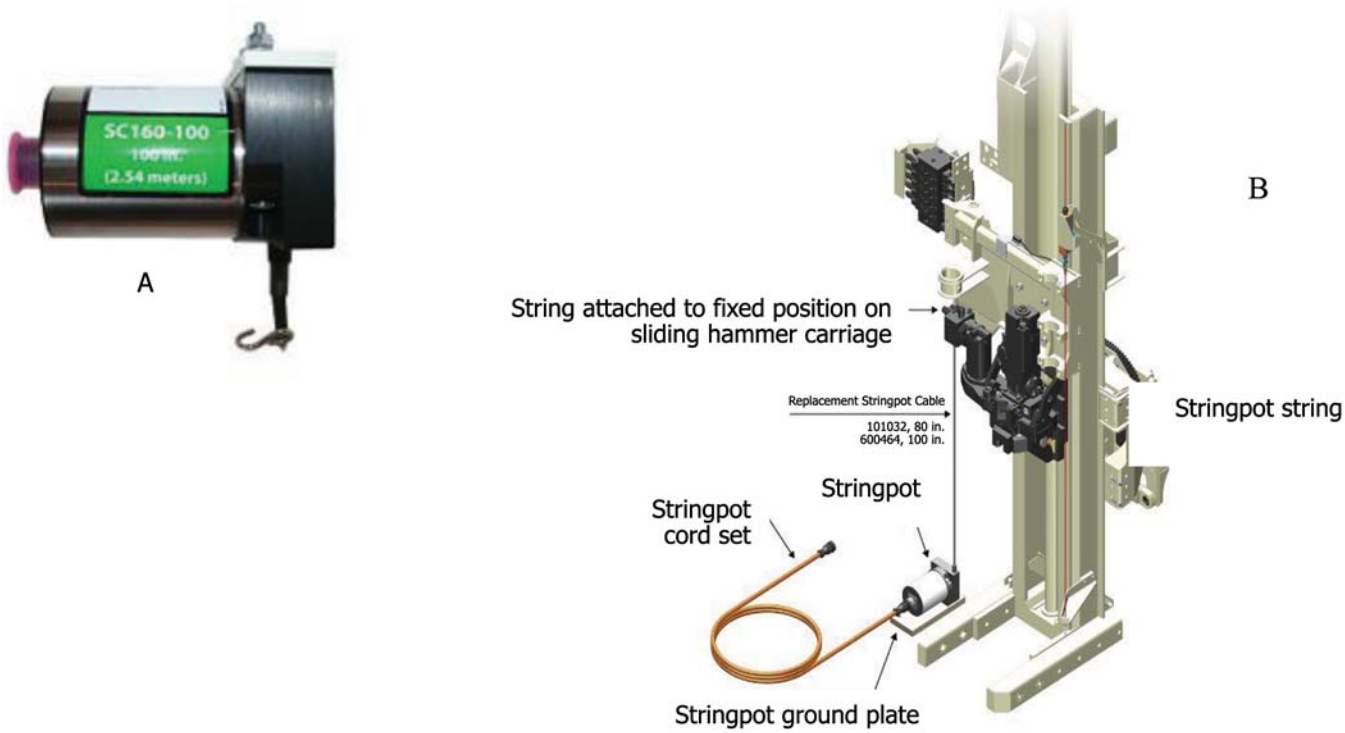

FIG. 4 The Stringpot Used to Track Probe Depth—(A) Stringpot assembly. (B) Anchoring the stringpot at ground surface and attaching the string to the sliding hammer carriage on the mast of the direct push machine to track depth as the probe is advanced into the subsurface.

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typically prior to mobilization to the field. These standards must be stored on ice or under refrigeration until used to prepare working standards.

7.6 *Working Standards*—These standards are made from the stock standard solutions by diluting them to the desired concentration in tap or deionized water to use for pre-log and post log quality assurance testing. For specific standard preparation instructions see Annex A4.

8. Pre- and Post-Log Preparation and Conditioning of the Apparatus

8.1 *General*—Quality assurance tests of the MIP logging system are performed prior to each log to verify that the system components are operating properly so that good quality data is obtained during the logging process. Chemical response tests are performed to verify that the MIP membrane, trunkline, gas supply and detector systems are operating correctly. If lithologic logging sensors such as EC, HPT or CPT are run in tandem with the MIP probe, those sensors should be tested before each log according to manufacturer's requirements to verify their performance.

8.2 *Chemical Response Testing* is an integral part of ensuring the quality of data from the MIP system. A chemical response test must be performed before deploying the system in the field as well as before and after each log. To conduct a response test, a stock standard is prepared. The selected stock standard(s) used for a site needs to be determined based on the site contaminants of concern. Preparation of the stock standard is critical to the final concentration of the response test.

8.2.1 *Preparation of Stock Standards*—A 50mg/mL stock standard is typically sufficient for a stock standard concentration. At this concentration, only a small amount (~25mL) in a 40mL vial is needed in the field. Stock standards have a shelf life of 30 days when appropriately handled and stored on ice or in a refrigerator. For additional information see Annex A4.

8.2.1.1 *Mass of Solute, M_s*—This parameter is the mass, in milligrams, of solute needed to prepare the stock standard and is defined as:

$$M_s = V_m \times C_{final} \tag{1}$$

where:

V_m = volume of solvent (methanol) in milliliters, and
C_{final} = final concentration of stock standard in mg/mL.

8.2.1.2 *Volume of Solute in Microliters, V_s*—This parameter is the volume of solute needed for the stock standard prepared to equal a concentration of 50 mg/mL. By using the density (Table A4.2) of the compound and the result in 8.2.1, a volume of the solute is obtained.

$$V_s = \frac{M_s}{d_s} \tag{2}$$

where:

M_s = definition in 8.2.1.1, and
d_s = density, in mg/µL, of the solute.

8.2.1.3 Label the vial with the date the standard was prepared, initials of the one who prepared the standard, the concentration and the analyte contained within the standard.

8.2.1.4 Handle and store standards appropriately. VOC standards should be handled with appropriate gloves in a well-ventilated area or under a fume hood. Some standards are carcinogens and a safety data sheet (SDS) should be consulted before handling. Some VOCs (for example, benzene) will degrade in sunlight and standards should be stored in a refrigerator or freezer or with ice in a cooler in the field. When storing, replace damaged septa or lids on vials.

8.2.2 *Performing Chemical Response Tests*—Response testing must be conducted before and after each log. This will validate the data and the integrity of the system. Response testing also provides for comparison of data for later MIP logs at the same site. Results of the response test may change due to membrane wear from soil contact and abrasion. Additional information on performing chemical response tests is located in Annex A5.

8.2.2.1 Choose an appropriate compound for the chemical response test which is similar to what is expected to be encountered on the field site.

8.2.2.2 Run the response test by exposing the membrane to the prepared working standard for 45 seconds. There are two acceptable methods exposing the membrane to the chemical response test standard: The first method is to pour the working standard into a nominal 5.08 × 61 cm [2 × 24 in.] PVC or steel pipe and insert the probe into the tube (Fig. A5.2). The second acceptable method is performed by pouring the working standard into a vial (approximately 40 mL) and invert onto the membrane (Fig. A5.3).

8.2.2.3 From the chemical response seen on the computer screen determine the contaminant trip time, which is the time it takes the contaminant to travel through the trunkline from the MIP membrane to the detectors. The software will ask for this value and is needed to correctly plot the depth a detector response came from.

9. MIP Logging Procedure

9.1 *General Requirements:*

9.1.1 Prior to driving the MIP into the subsurface, make sure that the proper clearance for direct push equipment has been provided to avoid any hazards from underground and overhead utilities.

9.2 *MIP System Start Up:*

9.2.1 Turn on carrier gases. Typically, nitrogen or helium compressed cylinders are equipped with a 2-stage gas regulator that is typically set to output 75 kPa [40 psi] for MIP operation.

9.2.2 Power on the detector system, data acquisition system and MIP controller box.

9.2.3 Set the nitrogen or helium carrier flow to approximately 40 mL/min trunkline flow (20-60 mL/min is acceptable).

9.2.4 Verify that there are no leaks in the MIP probe and trunkline circuit by measuring the return trunkline flow. This must be within 3 mL/min of the MIP supply flow if it is more than this there is a leak in the system, do not proceed until this is resolved.

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9.2.5 Measure the detector flow rates to verify proper flows and operation of the detectors. For more information on detector flow rates see the detector manufacturer's operating manual.

9.2.6 Set the MIP pressure on the secondary pressure gauge to 69 kPa [10 psi]. This may result in a trunkline flow rate <40 mL/min perhaps 25-30 mL/min which is fine. Detector sensitivity is improved at lower trunkline pressures. Make sure an accurate trip time is measured and used in the software.

9.3 Perform chemical response test (see section 8.2.2 and Annex A5).

9.4 Test the EC dipole according to the manufacturer's specifications. If the EC array does not pass the QA test refer to manufacturer's guidance for trouble shooting and corrective measures.

9.5 The HPT reference test is performed when operating MiHPT to verify that the HPT pressure sensor is in working order and to evaluate the condition of the HPT injection screen and HPT system. Refer to ASTM Practice D8037 for guidance on operation of the HPT probe and system.

9.6 Position the MIP probe under the direct push machine at the cleared location after successful QA tests are completed. Level the DP machine as appropriate for the logging operation. Place a slotted drive cap on the top of the probe to protect the trunkline from damage during advancement. Attach the stringpot cable to the direct push machine (Fig. 4B) and the field instrument.

9.6.1 Zero the depth of the MIP probe by driving the tip into the subsurface aligning the MIP membrane with the ground surface.

9.6.2 Turn on the trigger located in the acquisition software (a typical acquisition software example, other similar software may be used). The data acquisition system is now ready to acquire data. Any downward movement of the machine mast will now be recorded as log depth.

9.6.3 The MIP tool string is driven into the subsurface incrementally. The length of the increments depends on the level of vertical resolution required. Typically, 30cm [1ft] increments are used to obtain good resolution of the VOC plume. Example: Take 15 seconds to advance the MIP 30cm [1ft], then wait 45 seconds before advancing to the next interval.

9.6.4 Rods are added to the tool string as needed to advance the probe to the desired depth or until refusal is encountered.

9.6.5 During the logging process significant changes in analyte concentrations in the subsurface may require the operator to adjust detector gain settings. For details on detector gain adjustment refer to Annex A3 or the manufacturer's operating manual. When high level contaminant concentration is an issue or low volatility compounds are being logged a heated trunkline system may be used to minimize carryover in the system see Appendix X3. When attempting to track lower concentration contamination a low-level MIP system may be used see Appendix X4.

9.7 MIP logs are displayed on computer screen as the probe is advanced to depth (Fig. 5). Data points saved by the acquisition software are all in reference to depth from surface. The MIP log may be printed in the field or viewed onscreen with the viewing software for on-site decision making. Other data saved in the MIP log file includes rate of advancement, temperature of the probe, and carrier gas flow and pressure (Fig. 5). This additional data may be plotted with the log to assist with log review and interpretations at the operator's discretion.

9.8 Record in the field notes any observations of bore hole irregularities, pressure differences of the carrier gas, temperature fluctuations and any detector anomalies. Also note if the probe was stopped at any depth for an extended period of time.

9.9 If the MIP log is to be advanced through a confining layer or into an area of very high contaminant concentration (perhaps NAPL) the operator may choose to use a grout sub (Appendix X5) for immediate, post-log abandonment of the boring. The grout sub is operated with the 5.71cm [2.25in.] MIP probe and tool string.

9.10 An example MIP-HPT (MiHPT) log is shown in Appendix X6.

9.11 *Removal from the Subsurface:*

9.11.1 Before removing the MIP from the subsurface, pause at the terminal depth for a period equal to two times the measured trip time. This allows data from the final probe position to be recorded to the appropriate depth in the data acquisition system.

9.11.2 Stop the log and use the direct push machine to remove the MIP from the subsurface.

9.11.3 Turn off the probe heater when the log is finished before removing the probe from the soil to allow for the cooling of the membrane and minimizes diffusion of contaminants through the membrane.

9.11.4 Retract the MIP probe using the rod grip system or a slotted pull cap. Trunkline management is important during removal so the tool string is ready for advancement at the next location.

9.11.5 Upon complete removal of the probe, wash the probe and membrane with water and detergent, turn on the heater. Heating will accelerate the cleanup if any contaminants have sorbed onto the membrane during retraction. Wait until the detector baselines return to near pre-log level before performing the post log chemical response test.

9.11.6 Record baseline readings and complete another chemical response test with a fresh working standard as outlined in section 8.2.2. Compare the results of the response tests, noting any major differences in trip time or peak response.

9.11.7 Properly abandon open borehole by grouting as per Guide D5299 or as required by local regulations.

10. Report: Test Data Sheet(s) Form(s)

10.1 The methodology used to specify how data are recorded is covered in section 1.5.

10.2 Record as a minimum the following general information (data): Additional information can be entered in a notes section of the log and saved in the file.

10.2.1 Facility name, location and site contacts,

10.2.2 Date and Time the log is obtained,

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