Designation: D8152 – 18

Standard Practice for Measuring Field Infiltration Rate and Calculating Field Hydraulic Conductivity Using the Modified Philip Dunne Infiltrometer Test[1]

This standard is issued under the fixed designation D8152; 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 describes a procedure for field measurement of the infiltration rate of liquid (typically water) into soils using the modified Philip Dunne (MPD) infiltrometer. The data from the field measurement is then used to calculate the field hydraulic conductivity. Soils should be regarded as natural occurring fine or coarse-grained soils or processed materials or mixtures of natural soils and processed materials, or other porous materials, and which are basically insoluble and are in accordance with requirements of 5.1.

1.2 This practice may be conducted at the ground surface or at given depths in pits, on bare soil or with vegetation in place, depending on the conditions for which infiltration rates are desired. However, this practice cannot be conducted where the test surface is at or below the groundwater table, a perched water table, or the capillary fringe.

1.3 This practice is for soils within a range of infiltration rate range defined in 5.1, as long as an adequate seal can be made between the MPD Infiltrometer base and the soil being tested. In highly permeable soils, readings can be taken at shorter intervals, to ensure that enough data are collected to determine the infiltration rate.

1.4 The field measurement is a falling head test that can be performed relatively quickly (30 to 60 minutes) in silty sand or clayey sand soils suitable for stormwater infiltration practices. It is suitable for testing several locations across a site, to characterize the spatial variability of the infiltration rate throughout the site.

1.5 The field measurement can be used to measure the infiltration rate, which can be used to calculate the field hydraulic conductivity. The field hydraulic conductivity can be used as an index to compare the suitability of soils for use in the development of surface drainage applications (for example, rain gardens or stormwater fills).

1.6 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are to be included in this standard.

1.7 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.8 The procedures used to specify how data are collected/recorded or calculated in this 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 this standard to consider significant digits used in analytical methods for engineering design.

1.9 *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.*

1.10 *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:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.04 on Hydrologic Properties and Hydraulic Barriers.

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[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.

D2937 Test Method for Density of Soil in Place by the Drive-Cylinder Method
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D5879 Practice for Surface Site Characterization for On-Site Septic Systems
D5921 Practice for Subsurface Site Characterization of Test Pits for On-Site Septic Systems (Withdrawn 2019)[3]
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data
D6938 Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

3. Terminology

3.1 *Definitions:*

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

3.1.2 *gravimetric water content, n*—the ratio of mass of water to mass of solid particles in a soil matrix.

3.1.3 *volumetric water content, n*—the ratio of the volume of water to volume of solid particles in a soil matrix.

3.1.4 *infiltration, n*—the downward entry of liquid into a soil layer.

3.1.5 *infiltration rate, n*—a selected rate, based on measured incremental infiltration velocities, at which liquid can enter the soil under specified initial and boundary conditions; it has the dimensions of velocity.

3.1.6 *incremental infiltration rate, n*—the quantity of flow per unit area over an increment of time; it has the same units as the infiltration rate.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *field hydraulic conductivity* K_{fs} *n*—the rate of discharge of water under laminar flow conditions through a unit cross-sectional area of a porous medium under a unit hydraulic gradient.

4. Summary of Practice

4.1 The infiltration rate of the soil is measured using the MPD infiltrometer by measuring the change in water level over time in a reservoir initially filled with 3.5 L of water. An iterative solution to the Green-Ampt equation is used to calculate the field hydraulic conductivity and the matric suction at the wetted front by matching the solution to the measured water level data.

5. Significance and Use

5.1 This practice shall only be used on soils having infiltration rates ranging from 2.5 mm/h (field hydraulic conductivity of 6.9×10^{-7} m/s) to 15000 mm/h (field hydraulic conductivity of 4.0×10^{-3} m/s).

5.2 This practice is useful for field measurement of the infiltration rate and calculation of field hydraulic conductivity of soils. It was initially developed for stormwater treatment applications, and has been used to design, verify the construction of, and perform annual testing on surface drainage applications such as rain gardens or storm water collection systems (**1**). Other suitable applications include evaluation of potential septic-tank disposal fields (ASTM D5879 and D5921), leaching and drainage efficiencies, irrigation requirements, erosion potential, forestry, agriculture, and water spreading and recharge, among other applications. This test is not intended for use in hydraulic barriers/seals such as landfill liners, nuclear waste repositories, or the core of a dam. This test is also not intended for use in soils that experience changes in volume during infiltration, such as collapsible or expansive soils.

5.3 Field hydraulic conductivity can only be calculated when the hydraulic boundary conditions are known, such as hydraulic gradient and the extent of lateral flow of water, or these can be reliably estimated.

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. Agencies 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.

5.4 A mathematical analysis has been developed for this test that follows the Green-Ampt analysis that assumes a relationship between the volumetric water content and the depth of the wetting front, in that volumetric water content profile at the wetting front is represented by a sharp transition between the initial value in the ground and that of saturated soil, that is, the porosity (**1**), (**2**).

5.5 Many factors affect the infiltration rate, for example the soil structure, soil layering, condition of the soil surface, degree of saturation of the soil, chemical and physical nature of the soil and of the applied liquid, head of the applied liquid, temperature of the liquid, and diameter and depth of embedment of rings. Thus, tests made at the same site are not likely to give identical results and the rate measured by the practice described in this standard is primarily for comparative use.

6. Test Method

6.1 *Scope*

6.1.1 This test method describes a procedure for field measurement of the infiltration rate of liquid (typically water) into soils using the modified Philip Dunne (MPD) infiltrometer.

6.1.2 This test method may be conducted at the ground surface or at given depths in pits, on bare soil or with vegetation in place, depending on the conditions for which infiltration rates are desired. However, this practice cannot be conducted where the test surface is at or below the groundwater table, a perched water table, or the capillary fringe.

6.1.3 This test method is for soils within a range of infiltration rate range defined in 5.1, as long as an adequate seal can be made between the MPD Infiltrometer base and the soil being tested. In highly permeable soils, readings can be taken at shorter intervals, to ensure that enough data are collected to determine the infiltration rate.

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

6.1.4 The test method is a falling head test that can be performed relatively quickly (30 to 60) minutes in silty sand or clayey sand soils suitable for stormwater infiltration practices. It is suitable for testing several locations across a site, to characterize the spatial variability of the infiltration rate throughout the site.

6.1.5 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are to be included in this standard.

6.1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

6.1.7 *This standard does not purport to address all 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.*

6.1.8 *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.*

6.2 *Referenced Documents*

6.2.1 *ASTM Standards:*

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2937 Test Method for Density in Place by the Drive-Cylinder Method
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D6026 Practice for Using Significant Digits in Geotechnical Engineering
D6938 Test Method for Density in Place by Nuclear Method

6.3 *Terminology*

6.3.1 *Definitions*—For definitions of common technical terms used in this standard, refer to Terminology D653.

6.3.1.1 *gravimetric water content, n*—the ratio of mass of water to mass of solid particles in a soil matrix.

6.3.1.2 *volumetric water content, n*—the ratio of the volume of water to volume of solid particles in a soil matrix.

6.3.1.3 *infiltration, n*—the downward entry of liquid into a soil layer.

6.3.1.4 *infiltration rate, n*—a selected rate, based on measured incremental infiltration velocities, at which liquid can enter the soil under specified initial and boundary conditions; it has the dimensions of velocity.

6.3.1.5 *incremental infiltration rate, n*—the quantity of flow per unit area over an increment of time; it has the same units as the infiltration rate.

6.4 *Summary of Test Method*

6.4.1 The infiltration rate of the soil is measured using the MPD infiltrometer by measuring the change in water level over time in a reservoir initially filled with 3.5 L of water.

6.5 *Significance and Use*

6.5.1 This test method shall only be used on soils having infiltration rates ranging from 2.5 mm/h (field hydraulic conductivity of 6.9×10^{-7} m/s) to 15000 mm/h (field hydraulic conductivity of 4.0×10^{-3} m/s).

6.5.2 This test method is useful for field measurement of the infiltration rate. It was initially developed for stormwater treatment applications, and has been used to design, verify the construction of, and perform annual testing on surface drainage applications such as rain gardens or storm water collection systems (**1**). Other suitable applications include evaluation of potential septic-tank disposal fields (ASTM D5879 and D5921), leaching and drainage efficiencies, irrigation requirements, erosion potential, forestry, agriculture, and water spreading and recharge, among other applications. This test is not intended for use in hydraulic barriers/seals such as landfill liners, nuclear waste repositories, or the core of a dam. This test is also not intended for use in soils that experience changes in volume during infiltration, such as collapsible or expansive soils.

6.5.3 Many factors affect the infiltration rate, for example the soil structure, soil layering, condition of the soil surface, degree of saturation of the soil, chemical and physical nature of the soil and of the applied liquid, head of the applied liquid, temperature of the liquid, and diameter and depth of embedment of rings. Thus, tests made at the same site are not likely to give identical results and the rate measured by the practice described in this standard is primarily for comparative use.

6.6 *Apparatus*

6.6.1 *Infiltrometer Graduated Cylinder*—A cylinder made of clear acrylic or PVC, 357 ± 1 mm long, 101.5 ± 1 mm inside diameter, with a wall thickness of 6 mm. The cylinder shall have a measuring gauge permanently attached to the inner wall and oriented vertically, with zero reading at the bottom of the cylinder. The gauge shall have millimeter and centimeter markings extending the full height of the cylinder. The cylinder is attached to the infiltrometer base (described below), with a watertight O-ring seal between the infiltrometer tube and infiltrometer base. See Fig. 1.

NOTE 2—The apparatus in Figs. 1 and 2 was developed in the United States and is based on a 4 in. inside diameter, 4.5 in. outside diameter clear acrylic tube. The stainless steel base is machined from a 5 in. outside diameter, 4 in. inside diameter hollow stainless steel tube.

6.6.2 *Infiltrometer Base*—A stainless steel collar, 82 ± 1 mm long and machined to fit around the bottom of the infiltrometer tube. The bottom edge of the base is beveled to provide a cutting edge where it is pushed into the soil. Critical dimensions of the infiltrometer base are shown below in Fig. 2.

6.6.3 *Stopwatch*—A dedicated time piece capable of measuring to 0.1 second or greater sensitivity. Do not use a nondedicated device that could be interrupted by some other function (that is, a smart phone app).

6.6.4 *Rubber Mallet*—Rubber mallet with a mass of about 9 kg.

6.6.5 *Soil Dielectric Probe*—A probe capable of inferring the volumetric water content through correlation with the dielectric permittivity of the soil.

6.6.6 *Soil Core with Drive Cylinder*—To obtain the volumetric water content from the gravimetric water content, use the soil core with drive cylinder (ASTM D2937) to obtain an undisturbed sample of the soil from the test location and measure the soil's dry density. This is not needed if the method provides a direct measurement of volumetric water content.

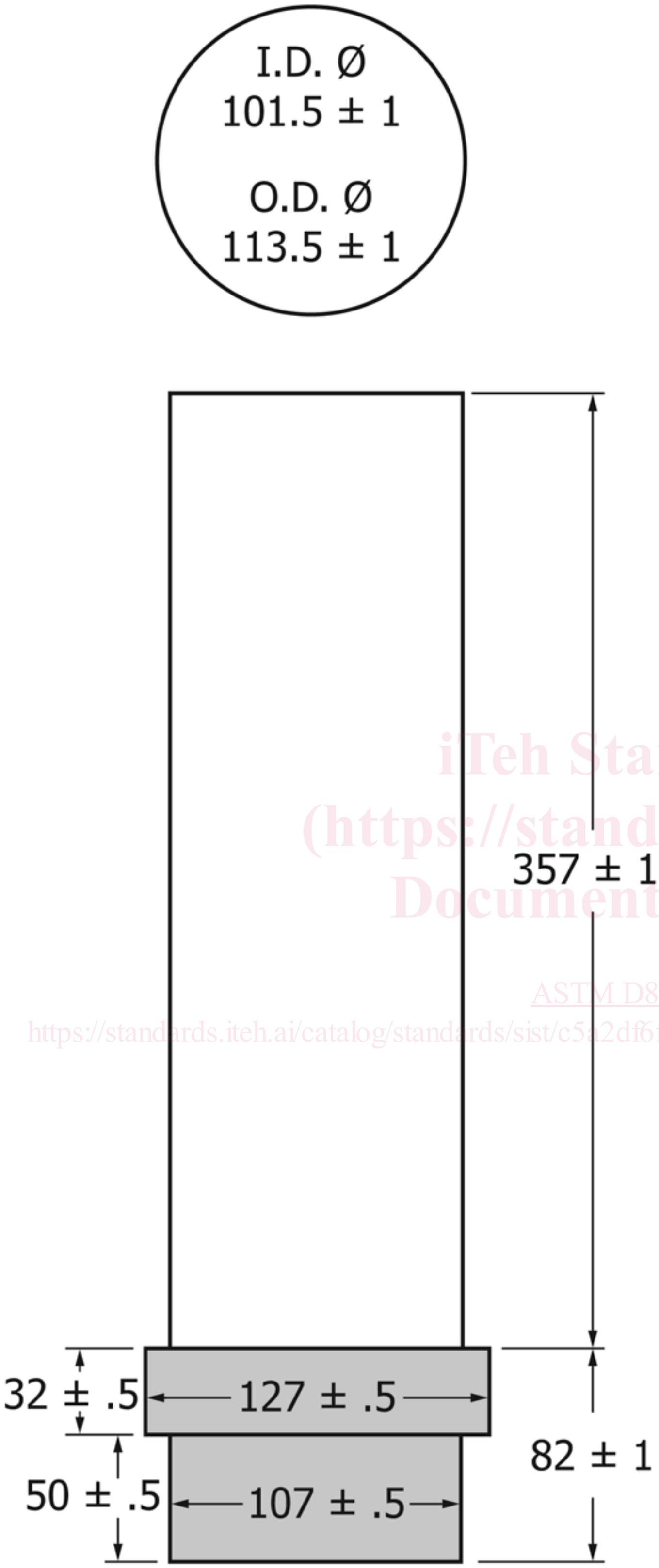

FIG. 1 Infiltrometer Tube with Steel Base Attached—Dimensions in mm

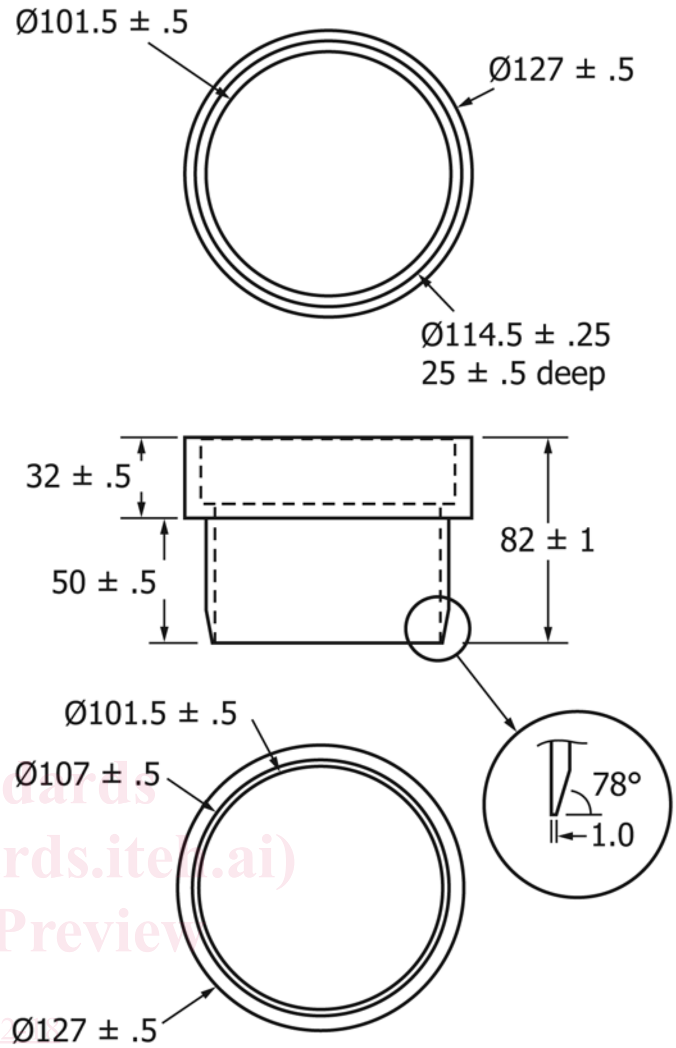

FIG. 2 Infiltrometer Stainless Steel Base—Dimensions in mm

6.6.7 *Wooden Block*—When driving the clear cylinder and base into the soil, place the wooden block on the top of the clear cylinder and strike the top of the wooden set with the rubber mallet. The wooden block protects the clear cylinder from damage when driving the infiltrometer into the soil. The wooden block shall be large enough to completely cover the top of the clear cylinder. See Appendix X4 for an example of a machined wooden set that can be used for this purpose.

6.6.8 *Liquid Container*—A container that holds enough water to run the anticipated number of tests, at 3.5 L per test. The container must have an opening or spout that allows the liquid to be poured into the infiltrometer cylinder without spilling the liquid outside of the cylinder.

6.6.9 *Liquid Supply*—Water, or preferably, liquid of the same quality and temperature as that involved in the problem being examined. The liquid used must be chemically compatible with the infiltrometer rings and other equipment used to contain the liquid.

6.6.10 *Thermometer*—A thermometer capable of reading a range of 0 to 55°C or greater and readable to at least 1°C.

6.6.11 *Scale*—A commercially available scale for reading water level shall be marked in mm, with the 0 mark at the bottom of the infiltrometer cylinder.

6.7 *Test Site*

6.7.1 For testing an existing infiltration practice, the test is typically performed at the ground surface within the infiltration practice. For new construction, or for septic drainfields, it is necessary to determine the soil strata to be tested. This is determined beforehand and is based on a geotechnical exploration (soil borings or test pits). If the strata to be tested is below the existing ground surface, it will be necessary to excavate a pit. Perform tests at the proposed elevation where water will infiltrate into the soil.

6.7.2 At the test location, prior to setting up the MPD infiltrometer, obtain the initial volumetric water content. This can be measured directly, using a capacitance probe **(3)**. Push the probe 50 to 70 mm into the soil, wait 30 seconds, and record the inferred volumetric water content. Another method that can be used is the nuclear density test (ASTM D6938). The gravimetric water content typically inferred by this device will need to be converted to volumetric water content. Multiply the dry density by the gravimetric water content and divide by the density of water to get the volumetric water content. The third method is the oven drying method. This is described in ASTM D2216. If this method is used, it is also necessary to obtain a soil core with drive cylinder (ASTM D2937). Use the dry density determined from the soil core to calculate the volumetric water content from the gravimetric water content. When using the nuclear density test or oven drying method, the initial sample for determination of the gravimetric water content must be obtained at least 350 mm (three infiltrometer cylinder diameters) from the test location. This is to ensure that sampling of the soil or hole from the nuclear density probe does not influence the test.

6.7.3 Drive the infiltrometer graduated cylinder and steel base into the soil to a depth of 50 mm. Place the wooden set on top of the clear cylinder and hit the wooden set with the rubber mallet to accomplish this.

6.7.4 Fill the graduated cylinder with 300 mm of water. Flow starts immediately when water is poured into the cylinder.

6.7.5 When performing the test in silty soils, care must be taken to avoid scouring the silt when pouring water into the cylinder. This can cause the scoured silt to re-settle and reduce the measured infiltration rate. A screen can be placed on the soil surface, prior to pouring the water, to avoid scouring the soils.

6.7.6 Start the stopwatch and record the water level at time zero (called H_0). Take the second reading of the stopwatch when the water level drops 10 mm. Take all subsequent readings at regular intervals, the length of which is determined by Table 1.

6.7.7 Read the water level at the bottom of the meniscus. The water must be clear when taking readings.

6.7.8 Typically, at least 16 readings for a location are desired for an accurate calculation of hydraulic conductivity. A large water level drop will incorporate more soil depth into the hydraulic conductivity calculation and is recommended. If the water level drop is slow, head versus time data should be taken until the water level is at least 100 mm from H_0.

6.7.9 When enough readings have been taken, end the test and measure the final (after-test) volumetric water content. This must be done at the test location, within the footprint of the infiltrometer base. (Depending upon the method used to measure the volumetric water content, this may require removing the infiltrometer from the soil first.) Use one of the methods described in 6.7.2.

6.8 *Technical Precautions*

6.8.1 The MPD Infiltrometer test and the dry density sample collection (if the drive cylinder method, ASTM D2937 is used to measure bulk density), should not be done at the same time if these two locations are very close to each other. Driving the sampler through the soil might disturb surrounding or nearby soil, which can affect the MPD Infiltrometer test. The collection of the dry density sample should be performed 3 m to 5 m away from the MPD test location.

6.8.2 Observe the ground surface around the outside of the MPD Infiltrometer for water pooling above the ground surface. This is an indication that the MPD Infiltrometer steel base is not adequately sealed against the soil. If water pools above the ground surface outside of the MPD infiltrometer base, discontinue running the test and extract the MPD Infiltrometer base/cylinder. Move to a new location at least 500 mm away and re-test.

6.8.3 Inspect the cutting edge on the MPD Infiltrometer base prior to beginning any test. If the cutting edge is dull or damaged, replace the base or sharpen the cutting edge to restore it to its original functionality.

6.8.4 Take precautions not to bump or otherwise disturb the MPD Infiltrometer once the test has started. This can cause the seal between the stainless-steel base and the soil to break. If the loss of this seal goes unnoticed, it will result in an artificially high calculated value of the hydraulic conductivity.

6.8.5 A version of the MPD Infiltrometer test automated with sensors, a datalogger, and software is considered to be in compliance with this standard, provided that the automated procedures and calculations match those described in this standard.

6.9 *Measurements*

TABLE 1 Time Interval for Water Level Readings

Initial time required to drop 10 mm	<10 s	10 s	20 s	40 s	1 min	2 min	5 min	>10 min
Time interval between two subsequent head measurements	20 s – 30 s	40 s	1 min	2 min	4 min	6 min	10 min	30 min

6.9.1 Record the ambient air temperature to the nearest degree and barometric pressure to the nearest 0.01 kPa at the start of the test.

NOTE 3—The barometric pressure is typically obtained from records at a nearby weather station, for the day the test was performed. This is obtained from various internet sites, for example, http://www.wunderground.com.

6.9.2 Record the initial volumetric water content at the test location to the nearest percent.

6.9.3 Record the water level H_0 at the beginning of the test (time = 0 second) to the nearest mm.

6.9.4 Record the time for the water level to drop 10 mm.

6.9.5 Record the water level at each time interval determined in 6.7.6 to the nearest mm.

6.9.6 Record the final volumetric soil water content at the test location to the nearest percent.

NOTE 4—See Appendix X1 for an example MPD Infiltrometer test form.

6.10 *Precision and Bias*

6.10.1 Test data on precision is not presented due to the nature of this test method. It is either not feasible or too costly at this time to have ten or more agencies participate in an in situ testing program at a given site.

6.10.1.1 The subcommittee D18.04 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

6.10.2 There is no accepted reference value for this test method, therefore, bias cannot be determined.

7. Field Hydraulic Conductivity Calculation

7.1 Variables.

7.2 Initial and final volumetric soil water content:

If a capacitance probe was used for this measurement, no calculation is required as this value is read directly from the probe. If oven-drying is used, calculate the gravimetric water content as follows:

$$w = [(M_{cms} - M_{cds})/(M_{cds} - M_c)] \times 100 = (M_w / M_{ds}) \times 100 \quad (1)$$

where:

w = gravimetric water content, %
M_{cms} = mass of container and moist specimen, kg,
M_{cds} = mass of container and oven dry specimen, kg,
M_c = mass of container, kg,
M_w = mass of water, kg, and
M_{ds} = mass of oven dry specimen, kg.

If a nuclear density test (ASTM D6938) is used, this produces a gravimetric soil moisture content and step 7.3 is used to calculate volumetric soil water content.

7.3 Dry density is determined using the core method (ASTM D2937). Follow the procedures in this standard to obtain the dry density of the soil. Use the dry density to convert the gravimetric water content to the volumetric water content, as follows:

$$\theta = w \times \rho_d / \rho_w \quad (2)$$

where:

θ = volumetric soil water content,
w = gravimetric soil water content,
ρ_d = dry density of the soil in kg/m^3, and
ρ_w = 1000 kg/m^3 (standard density of water).

Perform this calculation on both the initial and final values of the gravimetric water contents.

7.4 Calculate the time at the midpoint between each set of readings.

$$t^* = (t_n + t_{n-1})/2 \quad (3)$$

where:

t_n = time at current reading (seconds) and
t_{n-1} = time at last reading before current reading (seconds).

7.5 Calculate the water height midway between each set of readings, as follows:

$$h = (h_n + h_{n-1})/2 \quad (4)$$

where:

h_n = water level of current reading (mm) and
h_{n-1} = water level at last reading before current reading (mm).

7.6 Calculate incremental infiltration velocity (q) between each set of readings, as follows:

$$q = (h_{n-1} - h_n)/(t_{n-1} - t_n) \quad (5)$$

7.7 Calculate minimum R(t). R(t) is the distance to wetted front as shown in Fig. 3.

$$R(t) > \sqrt{r^2 + L_{max}^2} \quad (6)$$

where:

r = inside radius of the infiltrometer apparatus and
L_{max} = depth of embedment of the infiltrometer into the soil.

These are illustrated in Fig. 3. Dimensions are mm.

7.8 For each measurement of head [H(t)] compute the distance to the wetted front R(t), by solving the following equation:

$$[H_0 - H(t)] r_1^2 = \frac{(\theta_1 - \theta_0)}{3}\left[2\,[R(t)]^3 + 3[R(t)]^2 L_{max} - L_{max}^3 - 4r_0^3\right] \quad (7)$$

where:

H_0 = height of water above the ground surface at the beginning of the test, as shown in Fig. 3. Dimensions are in mm.
$H(t)$ = height of water above the ground surface at time (t), as shown in Fig. 3. Dimensions are in mm.
θ_1 = final volumetric water content (decimal form),
θ_0 = initial volumetric water content (decimal form), and
r_0 = $r_1/2$. This is the radius to the wetted front at the beginning of the test, according to the Modified Philip-Dunne test methodology (1). It is shown in Fig. 3. Dimensions are in mm.

See Fig. 3 for the definition of r_1, R(t), and L_{max}. Dimensions are in mm.

Continue on steps given in 7.9 through 7.12 only for readings where R(t) is greater than the minimum value