Designation: D3385 – 09

Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer[1]

This standard is issued under the fixed designation D3385; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method describes a procedure for field measurement of the rate of infiltration of liquid (typically water) into soils using double-ring infiltrometer.

1.2 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 1.5.

1.3 This test method is particularly applicable to relatively uniform fine-grained soils, with an absence of very plastic (fat) clays and gravel-size particles and with moderate to low resistance to ring penetration.

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

1.5 This test method is difficult to use or the resultant data may be unreliable, or both, in very pervious or impervious soils (soils with a hydraulic conductivity greater than about 10^{-2} cm/s or less than about 1×10^{-6} cm/s) or in dry or stiff soils that most likely will fracture when the rings are installed. For soils with hydraulic conductivity less than 1×10^{-6} cm/s refer to Test Method D5093.

1.6 This test method cannot be used directly to determine the hydraulic conductivity (coefficient of permeability) of the soil (see 5.2).

1.7 The values stated in SI units are to be regarded as the standard.

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 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
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D5093 Test Method for Field Measurement of Infiltration Rate Using Double-Ring Infiltrometer with Sealed-Inner Ring

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *incremental infiltration velocity*—the quantity of flow per unit area over an increment of time. It has the same units as the infiltration rate.

3.2.2 *infiltration*—the downward entry of liquid into the soil.

3.2.3 *infiltration rate*—a selected rate, based on measured incremental infiltration velocities, at which liquid can enter the soil under specified conditions, including the presence of an excess of liquid. It has the dimensions of velocity (that is, $cm^3 cm^{-2} h^{-1} = cm\ h^{-1}$).

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[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.

3.2.4 *infiltrometer*—a device for measuring the rate of entry of liquid into a porous body, for example, water into soil.

4. Summary of Test Method

4.1 The double-ring infiltrometer method consists of driving two open cylinders, one inside the other, into the ground, partially filling the rings with water or other liquid, and then maintaining the liquid at a constant level. The volume of liquid added to the inner ring, to maintain the liquid level constant is the measure of the volume of liquid that infiltrates the soil. The volume infiltrated during timed intervals is converted to an incremental infiltration velocity, usually expressed in centimetre per hour or inch per hour and plotted versus elapsed time. The maximum-steady state or average incremental infiltration velocity, depending on the purpose/application of the test is equivalent to the infiltration rate.

5. Significance and Use

5.1 This test method is useful for field measurement of the infiltration rate of soils. Infiltration rates have application to such studies as liquid waste disposal, evaluation of potential septic-tank disposal fields, leaching and drainage efficiencies, irrigation requirements, water spreading and recharge, and canal or reservoir leakage, among other applications.

5.2 Although the units of infiltration rate and hydraulic conductivity of soils are similar, there is a distinct difference between these two quantities. They cannot be directly related unless the hydraulic boundary conditions are known, such as hydraulic gradient and the extent of lateral flow of water, or can be reliably estimated.

5.3 The purpose of the outer ring is to promote one-dimensional, vertical flow beneath the inner ring.

5.4 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.[3] Thus, tests made at the same site are not likely to give identical results and the rate measured by the test method described in this standard is primarily for comparative use.

5.5 Some aspects of the test, such as the length of time the tests should be conducted and the head of liquid to be applied, must depend upon the experience of the user, the purpose for testing, and the kind of information that is sought.

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.

6. Apparatus

6.1 *Infiltrometer Rings*—Cylinders approximately 500 mm (20 in.) high and having diameters of about 300 and 600 mm (12 and 24 in.). Larger cylinders may be used, providing the ratio of the outer to inner cylinders is about two. Cylinders can be made of 3-mm (⅛-in.), hard-alloy, aluminum sheet or other material sufficiently strong to withstand hard driving, with the bottom edge bevelled (see Fig. 1). The bevelled edges shall be kept sharp. Stainless steel or strong plastic rings may have to be used when working with corrosive fluids.

6.2 *Driving Caps*—Disks of 13-mm (½-in.) thick hard-alloy aluminum with centering pins around the edge, or preferably having a recessed groove about 5 mm (0.2 in.) deep with a width about 1 mm (0.05 in.) wider than the thickness of the ring. The diameters of the disks should be slightly larger than those of the infiltrometer rings.

6.3 *Driving Equipment*—A 5.5-kg (12-lb) mall or sledge and a 600 or 900-mm (2 or 3-ft) length of wood approximately 50 by 100 mm or 100 by 100 mm (2 by 4 in. or 4 by 4 in.), or a jack and reaction of suitable size.

6.4 *Depth Gage*—A hook gage, steel tape or rule, or length of steel or plastic rod pointed on one end, for use in measuring and controlling the depth of liquid (head) in the infiltrometer ring, when either a graduated Mariotte tube or automatic flow control system is not used.

6.5 *Splash Guard*—Several pieces of rubber sheet or burlap 150 mm (6 in.) square.

6.6 *Rule or Tape*—Two-metre (6-ft) steel tape or 300-mm (1-ft) steel rule.

6.7 *Tamp*—Any device that is basically rigid, has a handle not less than 550 mm (22 in.) in length, and has a tamping foot

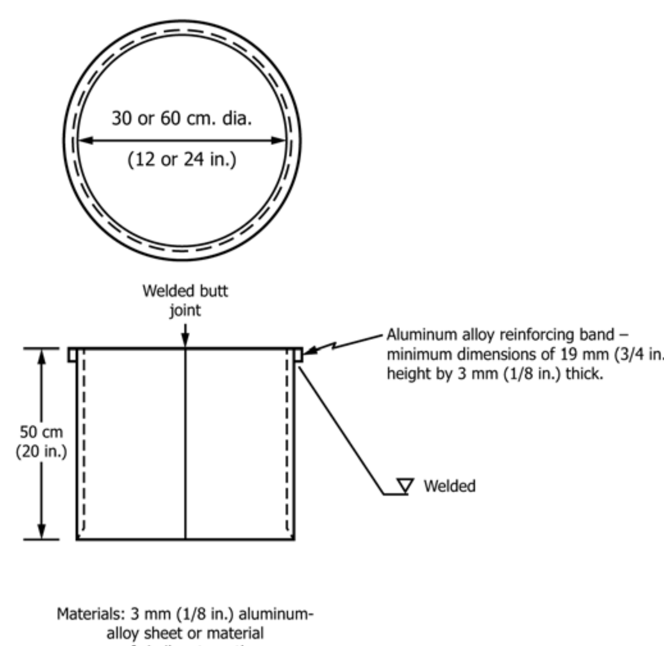


FIG. 1 Infiltrometer Construction

[3] Discussion of factors affecting infiltration rate is contained in the following reference: Johnson, A. I., *A Field Method for Measurement of Infiltration*, U.S. Geological Survey Water-Supply Paper 1544-F, 1963, pp. 4–9.

with an area ranging from 650 to 4000 mm^2 (1 to 6 in.^{2}) and a maximum dimension of 150 mm (6 in.).

6.8 *Shovels*—One long-handled shovel and one trenching spade.

6.9 *Liquid Containers:*

6.9.1 One 200-L (55-gal) barrel for the main liquid supply, along with a length of rubber hose to siphon liquid from the barrel to fill the calibrated head tanks (see 6.9.3).

6.9.2 A 13-L (12-qt) pail for initial filling of the infiltrometers.

6.9.3 Two calibrated head tanks for measurement of liquid flow during the test. These may be either graduated cylinders or Mariotte tubes having a minimum volume capacity of about 3000 mL (see Note 2 and Note 3 and Fig. 2).

NOTE 2—It is useful to have one head tank with a capacity of three times that of the other because the area of the annular space between the rings is about three times that of the inner ring.

NOTE 3—In many cases, the volume capacity of these calibrated head tanks must be significantly larger than 3000 mL, especially if the test has to continue overnight. Capacities of about 50 L (13 gal) would not be uncommon.

6.10 *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.

NOTE 4—To obtain maximum infiltration rates, the liquid should be free from suspended solids and the temperature of the liquid should be higher than the soil temperature. This will tend to avoid reduction of infiltration from blockage of voids by particles or gases coming out of solution.

6.11 *Watch or Stopwatch*—A stopwatch would only be required for high infiltration rates.

6.12 *Level*—A carpenter's level or bull's-eye (round) level.

6.13 *Thermometer*—With accuracy of 0.5°C and capable of measuring ground temperature.

6.14 *Rubber Hammer (mallet).*

6.15 *pH Paper,* in 0.5 increments.

6.16 *Recording Materials*—Record books and graph paper, or special forms with graph section (see Fig. 3 and Fig. 4).

6.17 *Hand Auger*—Orchard-type (barrel-type) auger with 75-mm (3-in.) diameter, 225-mm (9-in.) long barrel and a rubber-headed tire hammer for knocking sample out of the auger. This apparatus is optional.

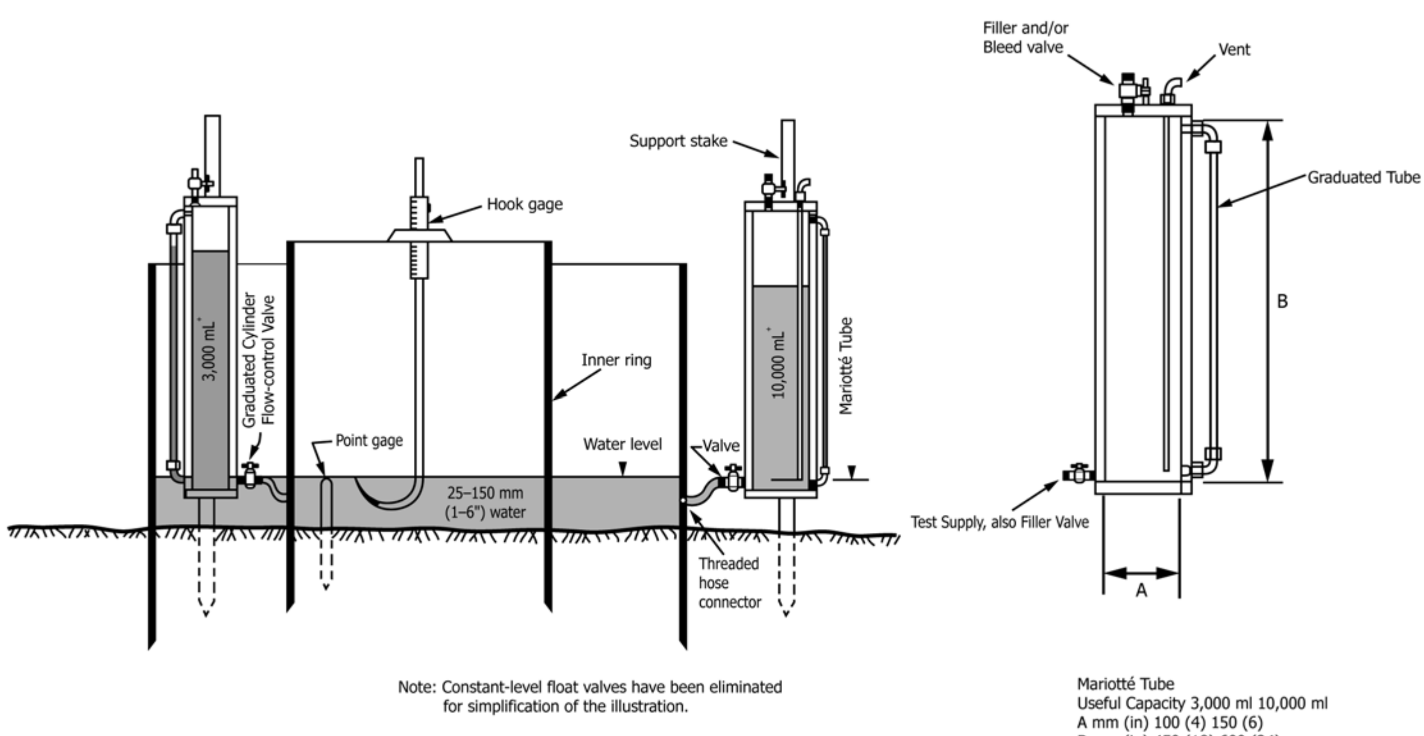
6.18 *Float Valves*—Two constant level float valves (carburetors or bob-float types) with support stands. This apparatus is optional.

6.19 *Covers and Dummy Tests Set-Up*—For long-term tests in which evaporation of fluid from the infiltration rings and unsealed reservoirs can occur (see 8.2.1).

7. Calibration

7.1 *Rings:*

7.1.1 Determine the area of each ring and the annular space between rings before initial use and before reuse after anything has occurred, including repairs, which may affect the test results significantly.



NOTE 1—Constant-level float valves have been eliminated for simplification of the illustration

FIG. 2 Ring Installation and Mariotte Tube Details

Project Identification: NRTS
Test Location: IDAHO - Lost River Alluvium
Liquid Used: River water pH = 8.0
Tested by IJA CWJ Liquid level maintained using: Mariotte Tube
Depth to water table: 5.2 m Penetration of rings -- Inner: 7.5 cm ; Outer: 17.5 cm Date: 10/14/1982

Constants	Area (cm^2)	Depth of Liquid (cm)	Liquid No.	Containers Vol/ΔH (cm^2/cm)
Inner Ring	707	4.0	1	78.54
Annular Space	2106	4.1	2	176.7

Trial No.		Time (hr:min)	Elapsed Time: Δ/total (min)	Flow Readings: Inner Reading: Reading (cm)	Inner Reading: Flow (cm^3)	Annular Space: Reading (cm)	Annular Space: Flow (cm^3)	Liquid Temp (°C)	Incremental Infiltration Rate: Inner (cm/h)	Incremental Infiltration Rate: Annular (cm/h)	Ground Temperature = 14°C at depth of 30 cm Remarks: Weather Conditions, etc.
1	S	10:00	15	30	114	2.2	389	15	0.64	0.74	Cloudy, slight wind
	E	10:15	(15)	4.45		4.4		"			
2	S	10:15	15	4.45	212	4.4	795	15	1.2	1.5	
	E	10:30	(30)	7.15		8.9		"			
3	S	10:30	15	7.15	263	8.9	848	15	1.5	1.6	
	E	10:45	(45)	10.5		13.7		"			
4	S	10:45	15	10.5	306	13.7	945	15	1.7	1.8	
	E	11:00	(60)	14.4		19.05		15.5			
5	S	11:00	30	14.4	758	19.05	2324	15.5	2.1	2.2	
	E	11:30	(90)	24.05		32.2		16			
6	S	11:30	30	24.05	848	32.2	2580	16	2.4	2.45	
	E	12:00	(120)	34.85		46.8		16.5			
7	S	12:10	60	3.5	1944	2.2	5902	16.5	2.75	2.8	Refilled tubes
	E	13:10	(180)	28.25		35.6		17			
8	S	13:20	60	2.4	1877	3.2	5690	17.5	2.65	2.7	" "
	E	14:20	(240)	26.3		35.4		"			
9	S	14:30	60	4.3	1696	4.7	5054	17.5	2.4	2.4	" "
	E	15:30	(300)	25.9		33.3		18			
10	S	15:40	60	2.2	1586	4.5	4842	18	2.2	2.3	" "
	E	16:40	(360)	22.4		31.9		"			Cloudy, slight wind

FIG. 3 Data Form for Infiltration Test with Sample Data

7.1.2 Determine the area using a measuring technique that will provide an overall accuracy of 1 %.

7.1.3 The area of the annular space between rings is equal to the internal area of the 600-mm (24-in.) ring minus the external area of the 300-mm (12-in.) ring.

7.2 *Liquid Containers*—For each graduated cylinder or graduated Mariotte tube, establish the relationship between the change in elevation of liquid (fluid) level and change in volume of fluid. This relationship shall have an overall accuracy of 1 %.

8. Procedure

8.1 *Test Site:*

8.1.1 Establish the soil strata to be tested from the soil profile determined by the classification of soil samples from an adjacent auger hole.

NOTE 5—For the test results to be valid for soils below the test zone, the soil directly below the test zone must have equal or greater flow rates than the test zone.

8.1.2 The test requires an area of approximately 3 by 3 m (10 by 10 ft) accessible by a truck.

8.1.3 The test site should be nearly level, or a level surface should be prepared.

8.1.4 The test may be set up in a pit if infiltration rates are desired at depth rather than at the surface.

8.2 *Technical Precautions:*

8.2.1 For long-term tests, avoid unattended sites where interference with test equipment is possible, such as sites near children or in pastures with livestock. Also, evaporation of fluid from the rings and unsealed reservoirs can lead to errors in the measured infiltration rate. Therefore, in such tests, completely cover the top of the rings and unsealed reservoirs with a relatively airtight material, but vented to the atmosphere through a small hole or tube. In addition, make measurements to verify that the rate of evaporation in a similar test configuration (without any infiltration into the soil) is less than 20% of the infiltration rate being measured.

Project Identification: NRTS
Project Location: IDAHO – Lost River Alluvium
Liquid Used: River water
Prepared by: IJA Date of Test: Start 10/14/82 ; Finish 10/14/82
Remarks: Ground temp. = 14°C
pH = 8.0 ; Ave Temp. = 16 ± 1°C

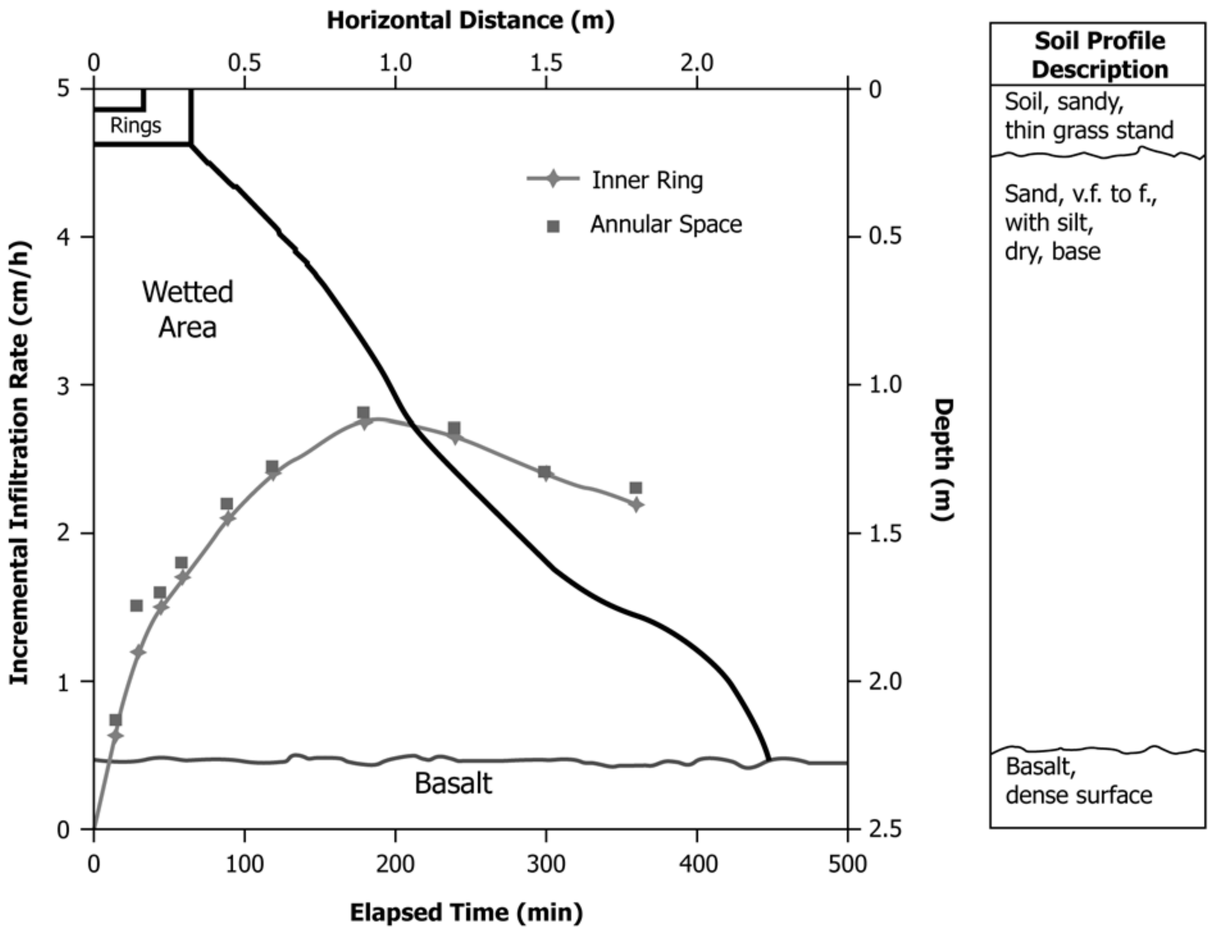


FIG. 4 Report Form for Infiltration Test With Sample Data

8.2.2 Make provisions to protect the test apparatus and fluid from direct sunlight and temperature variations that are large enough to affect the slow measurements significantly, especially for test durations greater than a few hours or those using a Mariotte tube. The expansion or contraction of the air in the Mariotte tube above the water due to temperature changes may cause changes in the rate of flow of the liquid from the tube which will result in a fluctuating water level in the infiltrometer rings.

8.3 *Driving Infiltration Rings with a Sledge:*

NOTE 6—Driving rings with a jack is preferred; see 8.4.

8.3.1 Place the driving cap on the outer ring and center it thereon. Place the wood block (see 6.3) on the driving cap.

8.3.2 Drive the outer ring into the soil with blows of a heavy sledge on the wood block to a depth that will (*a*) prevent the test fluid from leaking to the ground surface surrounding the ring, and (*b*) be deeper than the depth to which the inner ring will be driven. A depth of about 150 mm (6 in.) is usually adequate. Use blows of medium force to prevent fracturing of the soil surface. Move the wood block around the edge of the driving cap every one or two blows so that the ring will penetrate the soil uniformly. A second person standing on the wood block and driving cap will usually facilitate driving the ring, and reduce vibrations and disturbance.

8.3.3 Center the smaller ring inside the larger ring and drive to a depth that will prevent leakage of the test fluid to the ground surface surrounding the ring, using the same technique as in 8.3.2. A depth of between about 50 and 100 mm (2 and 4 in.) is usually adequate.

8.4 *Driving Infiltration Rings with Jacks:*

8.4.1 Use a heavy jack under the back end of a truck to drive rings as an alternative to the sledge method (see 8.3).

8.4.2 Center the wood block across the driving cap of the ring. Center a jack on the wood block. Place the top of the jack and the assembled items vertically under the previously positioned end of a truck body and apply force to the ring by means of the jack and truck reaction. Also, tamp near the edges or near the center of the ring with the rubber mallet, as slight tamping and vibrations will reduce hang-ups and tilting of the ring.

8.4.3 Add additional weight to the truck if needed to develop sufficient force to drive the ring.

8.4.4 Check the rings with the level, correcting the attitude of the rings to be vertical, as needed.

8.5 *Tamping Disturbed Soil:*

8.5.1 If the surface of the soil surrounding the wall of the ring(s) is excessively disturbed (signs of extensive cracking, excessive heave, and the like), reset the ring(s) using a technique that will minimize such disturbance.

8.5.2 If the surface of the soil surrounding the wall of the ring(s) is only slightly disturbed, tamp the disturbed soil adjacent to the inside and outside wall of the ring(s) until the soil is as firm as it was prior to disturbance.

8.6 *Maintaining Liquid Level:*

8.6.1 There are basically three ways to maintain a constant head (liquid level) within the inner ring and annular space between the two rings: manually controlling the flow of liquid, the use of constant-level float valves, or the use of a Mariotte tube.

8.6.2 When manually controlling the flow of liquid, a depth gage is required to assist the investigator visually in maintaining a constant head. Use a depth gage such as a steel tape or rule for soils having a relatively high permeability; for soils having a relatively low permeability use a hook gage or simple point gage.

8.6.3 Install the depth gages, constant-level valves, or Mariotte tubes as shown in Fig. 2, and in such a manner that the reference head will be at least 25 mm (1 in.) and not greater than 150 mm (6 in.). Select the head on the basis of the permeability of the soil, the higher heads being required for lower permeability soils. Locate the depth gages near the center of the center ring and midway between the two rings.

8.6.4 Cover the soil surface within the center ring and between the two rings with splash guards (150-mm (6-in.) square pieces of burlap or rubber sheet) to prevent erosion of the soil when the initial liquid supply is poured into the rings.

8.6.5 Use a pail to fill both rings with liquid to the same desired depth in each ring. Do not record this initial volume of liquid. Remove the splash guards.

8.6.6 Start flow of fluid from the graduated cylinders or Mariotte tubes. As soon as the fluid level becomes basically constant, determine the fluid depth in the inner ring and in the annular space to the nearest 2 mm (1⁄16 in.) using a ruler or tape measure. Record these depths. If the depths between the inner ring and annular space varies more than 5 mm (1⁄4 in.), raise the depth gage, constant-level float valve, or Mariotte tube having the shallowest depth.

8.6.7 Maintain the liquid level at the selected head in both the inner ring and annular space between rings as near as possible throughout the test, to prevent flow of fluid from one ring to the other.

NOTE 7—This most likely will require either a continuing adjustment of the flow control valve on the graduated cylinder, or the use of constant-level float valves. A rapid change in temperature may eliminate use of the Mariotte tube.

8.7 *Measurements:*

8.7.1 Record the ground temperature at a depth of about 300 mm (12 in.), or at the mid-depth of the test zone.

8.7.2 Determine and record the volume of liquid that is added to maintain a constant head in the inner ring and annular space during each timing interval by measuring the change in elevation of liquid level in the appropriate graduated cylinder or Mariotte tube. Also, record the temperature of the liquid within the inner ring.

8.7.3 For average soils, record the volume of liquid used at intervals of 15 min for the first hour, 30 min for the second hour, and 60 min during the remainder of a period of at least 6 h, or until after a relatively constant rate is obtained.

8.7.4 The appropriate schedule of readings may be determined only through experience. For high-permeability materials, readings may be more frequent, while for low-permeability materials, the reading interval may be 24 h or more. In any event, the volume of liquid used in any one reading interval should not be less than approximately 25 cm^3.

8.7.5 Place the driving cap or some other covering over the rings during the intervals between liquid measurements to minimize evaporation (see 8.2.1).

8.7.6 Upon completion of the test, remove the rings from the soil, assisted by light hammering on the sides with a rubber hammer.

9. Calculations

9.1 Convert the volume of liquid used during each measured time interval into an incremental infiltration velocity for both the inner ring and annular space using the following equations:

9.1.1 For the inner ring calculate as follows:

$$V_{IR} = \Delta V_{IR}/(A_{IR} \cdot \Delta t) \tag{1}$$

where:

V_{IR} = inner ring incremental infiltration velocity, cm/h,
ΔV_{IR} = volume of liquid used during time interval to maintain constant head in the inner ring, cm^3,
A_{IR} = internal area of inner ring, cm^2, and
Δt = time interval, h.

9.1.2 For the annular space between rings calculate as follows:

$$V_A = \Delta V_A/(A_A \cdot \Delta t) \tag{2}$$

where:

V_A = annular space incremental infiltration velocity, cm/h,
ΔV_A = volume of liquid used during time interval to maintain constant head in the annular space between the rings, cm^3, and
A_A = area of annular space between the rings, cm^2.

10. Report

10.1 Report the following information in the report or field records, or both:

10.1.1 Location of test site.

10.1.2 Dates of test, start and finish.

10.1.3 Weather conditions, start to finish.

10.1.4 Name(s) of technician(s).

10.1.5 Description of test site, including boring profile, see 10.1.12.

10.1.6 Type of liquid used in the test, along with the liquid's pH. If available, a full analysis of the liquid also should be recorded.

10.1.7 Areas of rings and the annular space between rings (nearest 1 cm^2 or better).

10.1.8 Volume constants for graduated cylinders or Mariotte tubes (nearest 0.01 cm^3 or better).

10.1.9 Depth of liquid in inner ring and annular space (nearest 2 mm or better).

10.1.10 Record of ground and liquid temperatures (nearest 0.5°C), incremental volume measurements (nearest 1 cm^3 or better), and elapsed time (nearest 1 min. or better).

10.1.11 Incremental infiltration velocities (use 3 significant digits) for inner ring and annular space. The rate of the inner ring should be the value used if the rates for inner ring and annular space differ. The difference in rates is due to divergent flow.

10.1.12 If available, depth to the water table and a description of the soils found between the rings and the water table, or to a depth of about 1 m (3 ft).

10.1.13 A plot of the incremental infiltration rate versus total elapsed time (see Fig. 4).

10.2 An example field records form is given in Fig. 3.

10.3 See Appendix X1 for information on the determination of the moisture pattern.

11. Precision and Bias

11.1 No statement on precision and bias can be made due to the variability in soils tested and in the types of liquids that might be used in this test method. Because of the many factors related to the soils, as well as the liquids that may affect the results, the recorded infiltration rate should be considered only as an index value.

12. Keywords

12.1 coefficient of permeability; hydraulic conductivity; infiltration rate; infiltrometer; in-situ testing; Mariotte tube

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF MOISTURE PATTERN

X1.1 Although not considered a required part of the test method, the determination of the moisture pattern in the moistened soil beneath the infiltration rings commonly provides information useful in interpreting the movement of liquid through the soil profile. For example, horizontal liquid movement may be caused by lower-permeability layers and will be identified by a lateral spreading of the wetted zone. Thus, the exploration of the soil moisture pattern below an infiltration test in an unfamiliar area may identify subsurface conditions that may have affected the test and later applications of the data.

X1.2 If the investigator wishes to make such a study, dig a trench so that one wall of the trench passes along the center line of the former position of the rings. Orient the trench so that the other wall is illuminated by the sun, if the day is sunny. If feasible, dig the trench large enough to include all of the newly moistened area. Collect samples from the shaded wall of the trench for determination of water content. If preferred, an auger, such as the orchard barrel type, may be used to determine the approximate outline of the moistened area below the rings and to collect samples for water content.

X1.3 Plot the visibly moistened area on graph paper or on the cross-section part of the report form (see Fig. 4). If samples were collected and water contents were determined, contours of water content also can be plotted on the graph.