Designation: ~~D4491/D4491M – 17~~ D4491/D4491M – 20

Standard Test Methods for Water Permeability of Geotextiles by Permittivity[1]

This standard is issued under the fixed designation D4491/D4491M; 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 These test methods cover procedures for determining the hydraulic conductivity (water permeability) of geotextiles in terms of permittivity under standard testing conditions, in the uncompressed state. Included are three procedures: the constant head and falling head methods using a water flow apparatus, and the air flow method using an air flow apparatus.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.3 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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]

D123 Terminology Relating to Textiles

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D4439 Terminology for Geosynthetics

D5199 Test Method for Measuring the Nominal Thickness of Geosynthetics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ASTM Adjuncts:*[3]

Detailed Drawings and Materials List for Construction, 10 Drawings

3. Terminology

3.1 *Definitions:*

3.1.1 *geotextile, n*—a permeable geosynthetic comprised solely of textiles.

3.1.2 *permeability, n*—the rate of flow of a liquid under a differential pressure through a material.

3.1.2.1 *Discussion*—

The nominal thickness is used as it is difficult to evaluate the pressure on the geotextile during the test, thereby making it difficult to determine the thickness of the fabric under these test conditions.

3.1.3 *permeability, n—of geotextiles*, hydraulic conductivity.

[1] These test methods are under the jurisdiction of ASTM Committee D35 on Geosynthetics and are the direct responsibility of Subcommittee D35.03 on Permeability and Filtration.

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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] Detailed drawings and a materials list for construction are available from ASTM International Headquarters. Order Adjunct No. ADJD4491.

3.1.4 *permittivity, (ψ), (T−1), n—of geotextiles*, the volumetric flow rate of water per unit ~~cross-sectional~~ cross-sectional area per unit head under laminar flow conditions, in the normal direction through a geotextile.

3.1.5 For the definitions of other terms relating to geotextiles, refer to Terminology D4439. For the definitions of textile terms, refer to Terminology D123. For the definition of coefficient of permeability, refer to Terminology D653.

4. Summary of Test Method

4.1 *Water Flow Test Methods*—These test methods describe procedures for determining the permittivity of geotextiles using constant head or falling head test procedures with a water flow apparatus:

4.1.1 *Method A – Constant Head Test*—A head of 50 mm of water is maintained on the geotextile throughout the test. The quantity of flow is measured versus time. The constant head test is used when the flow rate of water through the geotextile is so large that it is difficult to obtain readings of head change versus time in the falling head test. The constant head test is the referee method for this standard.

NOTE 1—Data has shown agreement between the falling and constant head methods of determining permittivity of geotextiles.[4] Selection of the test method, that is, constant or falling head, is left to the technician performing the test.

4.1.2 *Method B – Falling Head Test*—A column of water is allowed to flow through the geotextile and readings of head changes versus time are taken. The flow rate of water through the geotextile must be slow enough to obtain accurate readings.

4.1.3 *Method C – Air Flow Test*—A geotextile specimen is subjected to increasing air flow while the flow rate and differential pressure are measured. Two flow rate data points are obtained at pressures of 250 and 500 ~~Pascals,~~Pa, which are used to determine the ~~Characteristic Flow Equation~~characteristic flow equation of the specimen. The water permittivity at ~~50-mm~~ 50 mm water head is then calculated using the conversion algorithm described in this standard.

5. Significance and Use

5.1 These test methods are considered satisfactory for acceptance testing of commercial shipments of geotextiles since the methods have been used extensively in the trade for acceptance testing.

5.1.1 In case of a dispute arising from differences in reported test results when using these test methods for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens that are as homogeneous as possible and that are from a lot of material of the type in question. The test specimens should then be randomly assigned in numbers to each laboratory for testing. The average results from the two laboratories should be compared using Student's ~~*t-test*~~-test for unpaired data and an acceptable probability level chosen by the two parties before the start of testing. If a bias is found, either its cause must be found and corrected, or the purchaser and the supplier must agree to interpret future test results in light of the known bias.

5.1.2 When the dispute involves test results produced with either the Method B falling head test or the Method C air flow test, the Method A constant head ~~test,~~test performed with a ~~50-mm~~ 50 mm head should be used as the referee method.

5.1.3 When the dispute involves Method C, the actual water temperature used for the water flow tests must be recorded and the viscosity of water at the test temperature must be used in the conversion from the air flow to water flow as described in Section 16, without the application of the temperature correction.

5.1.4 Permittivity is an indicator of the quantity of water that can pass through a geotextile in an isolated condition.

5.1.5 As there are many applications and environmental conditions under which a geotextile may be used, care should be taken when attempting to apply the results of these test methods to the field performance of a geotextile.

5.2 Since there are geotextiles of various thicknesses in use, evaluation in terms of their Darcy coefficient of permeabilities can be misleading. In many instances, it is more significant to evaluate the quantity of water that would pass through a geotextile under a given head over a particular cross-sectional area; this is expressed as permittivity.

5.3 If the permeability of an individual geotextile is of importance, a nominal coefficient of permeability, as related to geotechnical engineering, may be computed. By multiplying permittivity times the nominal thickness of the geotextile, as determined by Test Method D5199, the nominal coefficient of permeability is obtained.

NOTE 2—The nominal thickness is used as it is difficult to evaluate the pressure on the geotextile during the test, thereby making it difficult to determine the thickness of the fabric under these test conditions.

6. Apparatus

6.1 *Water Flow Apparatus*—The apparatus for performing the water flow tests shall conform to one of the following arrangements:

6.1.1 The apparatus must be capable of maintaining a constant head of water on the geotextile being tested, or

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D35-1007. Contact ASTM Customer Service at service@astm.org.

6.1.2 The apparatus must be capable of being used as falling head apparatus.

6.1.3 The location of the manometer for measuring the head loss in either constant head or falling head methods shall be located directly beneath the specimen. For the device shown in Fig. 1, this may be accomplished by drilling and tapping a small ~~(3-mm)~~ (3 mm) diameter hole in the top plate of the bottom reservoir tank directly beneath the specimen, and attaching the manometer to this plate.

6.2 In addition, the apparatus must not be the controlling agent for flow during the test. It will be necessary to establish a calibration curve of volumetric flow rate versus head for the apparatus alone in order to establish compliance with this requirement (see 11.7).

FIG. 1 Constant and Falling Head Permeability Apparatus

6.3 Refer to Fig. 1 for a schematic drawing of a device that conforms to all of the above requirements. The device consists of an upper and lower unit, which fasten together. The geotextile specimen is positioned in the bottom of the upper unit. There is a standpipe for measuring the constant head value. The rotating discharge pipe allows adjustment of the head of water at the bottom of the specimen. See ADJD4491.[3]

6.4 *Air Flow Apparatus*—The apparatus for performing the air flow tests shall conform to the following specifications:

6.4.1 *Clean Gas Pressure Source,* with regulation (filtered air).

6.4.2 *Pressure Sensor*—Pressure measurements must be obtained with a digital pressure transducer with an accuracy of ±5 ~~Pascals.~~Pa.

6.4.2.1 The head (upstream) pressure manometer tap must be installed immediately upstream, within 10 ~~mm,~~mm of the test specimen surface.

6.4.2.2 The tail (downstream) pressure sensor must be installed 25 mm or more from the geotextile test specimen, and within the ~~25-mm~~ 25 mm diameter section.

6.4.3 *Closed Specimen Holder:*

6.4.3.1 Specimen holder for the test specimens that fully confines the perimeter of the specimen to prevent any lateral pressure losses.

6.4.3.2 The specimen flow area shall be ~~25- to 50-mm~~ 25 mm to 50 mm diameter. Smaller diameter devices are not acceptable.

6.4.3.3 The filter holder should be checked for leaks by placing an impermeable membrane in the holder and increasing the pressure to the maximum capacity of the pressure sensor and holding it for a period of ~~one minute.~~1 min. The flow rate measured during this period must be zero, indicating a leak-free seal.

6.4.4 *Metal Punch,* used to cut a suitable size geotextile from the test sheet to fit the test specimen holder.

6.4.5 *Flow Rate Measurement Sensors*—The apparatus should be equipped with a digital flow meter to measure the flow rates at the two desired pressures. The flow meter must have an accuracy of at least ±0.5 lpm or 1.0 % of the measured value, whichever is larger.

6.4.6 *Flow Section*—The geometry of the air flow apparatus at the section where the test specimen is located shall have a uniform pipe diameter equal to the flow area, both upstream and downstream of the test specimen, for a minimum distance of two diameters.

7. Sampling

7.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of rolls of geotextile directed in an applicable material specification or other agreement between the purchaser and the supplier. Consider rolls of geotextile to be the primary sampling units. If the specification requires sampling during manufacture, select the rolls for the lot sample at uniformly spaced time intervals throughout the production period.

NOTE 3—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between rolls of geotextile and between specimens from a swatch from a roll of geotextile so as to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.2 *Laboratory Sample*—Take for the laboratory sample a full ~~roll width~~ roll-width sample extending a minimum of 1 m along the selvage from each sample roll such that the requirements of Section 9 can be met. Take a sample that will exclude material from the outer wrap of the roll or the inner wrap around the core unless the sample is taken at the production site, at which point inner and outer wrap material may be used.

8. Test Water Preparation – Water Flow Tests

8.1 To provide reproducible test results, the test water used for the water flow tests shall be de-aired to bring the dissolved oxygen content down to a maximum of six parts per million. The dissolved oxygen content may be determined by either commercially available chemical kits or by a dissolved oxygen meter.

NOTE 4—The de-airing system may be either a commercially available system or one consisting of a vacuum pump capable of removing a minimum of 150 L/min of air in connection with a non-collapsible storage tank with a large enough storage capacity for the test series, or at least one specimen at a time.

8.2 Allow the de-aired water to stand in a closed storage tank under a slight vacuum until room temperature is attained.

8.3 The test water must be maintained at the standard atmosphere for geosynthetic testing, which is 21 ± 2 °C.

9. Specimen Preparation

9.1 To obtain a representative value of permittivity, take four specimens from each ~~full width~~ full-width laboratory sample as described below.

9.2 Referring to Fig. 2, select four specimens, A, B, C, and D, as follows:

9.2.1 Select four specimens equally spaced across the width of the sample. For woven geotextiles, take the test specimens along a diagonal line extending from the lower left-hand corner to the upper right-hand corner of the laboratory sample. None of the test specimens shall be closer to the corner of the laboratory sample than 200 mm [8 in.].

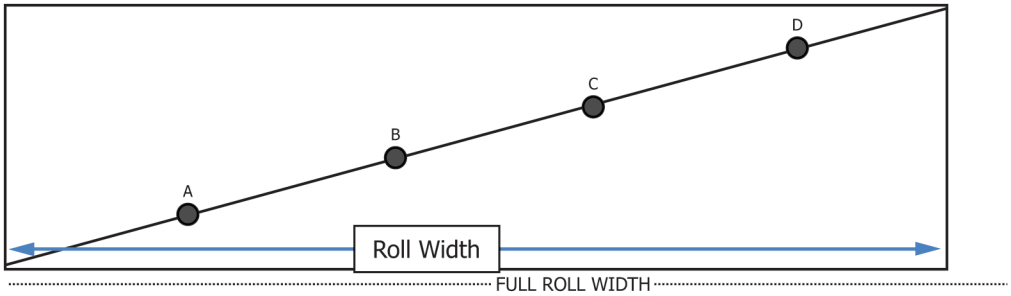

FIG. 2 Specimen Locations for Woven Geotextile Water Flow Tests

9.2.2 For the Method C air flow tests, take ten test specimens equally spaced across the width of the sample. For woven geotextiles, take the ten test specimens equally spaced along a diagonal line extending from the lower ~~left hand~~ left-hand corner to the upper ~~right hand~~ right-hand corner of the laboratory sample. None of the specimens shall be closer to the edge of the laboratory sample than 200 mm [8 in.].

9.2.2.1 Five test specimens may be obtained in lieu of ten if the air flow device has a flow area of ~~50-mm~~ 50 mm diameter, provided the test result complies with the Method A result in accordance with 16.7.

9.2.3 Cut specimens shall fit the testing apparatus, for example, 73 mm [2.87 in.] in diameter for the device illustrated in Fig. 1.

NOTE 5—If the illustrated device is used for the water flow tests, the specimens are attached to the specimen ring by contact cement.

9.3 Condition the water flow test specimens by soaking in a closed container of de-aired water, at room conditions, for a minimum period of 2 h. The minimum specimen diameter is to be 50 mm [2 in.].

10. Apparatus and Operator Process Control

10.1 ~~*Water Flow Apparatus:*~~ *Option 1 – Water Flow Apparatus Methods A and B via No. 200 Sieve Mesh:*

10.1.1 Prepare ~~four specimens~~one specimen of a No. 200 standard U.S. ~~mesh~~ sieve mesh to fit the test apparatus.

10.1.2 ~~Following Section~~Perform Test ~~11~~Method A or ~~Section~~B ~~13, depending on the method to be used for the geotextile specimens, perform testing on each~~ on the No. 200 mesh specimen.

10.1.2.1 The tests may be performed with a 25 mm [1.0 in.] diameter flow opening in lieu of 50 mm.

10.1.3 Based on an interlaboratory ~~test,~~test involving seven laboratories, the permittivity of No. 200 standard U.S. mesh sieve material has been determined to be 5.00 s^{-1}, with a standard deviation of ~~0.65~~0.65 s^{-1}.

10.1.3.1 New apparatus and operator process control ~~shall be performed until it is demonstrated that the operator is proficient in test performance as demonstrated by obtaining the value of permittivity~~ test results should not deviate from the mean value stated in 10.1.3, plus or minus two standard deviations.

~~10.1.3.2 Following initial proficiency testing, the operator shall perform process control testing on a semi-annual basis.~~

10.2 ~~*Air Flow Apparatus:*~~ *Option 2 – Permittivity Apparatus Methods A, B, and C via Reference Screen:*

10.2.1 The reference screen[5] is a 0.76 mm thick, stainless steel sheet that is photochemically etched with 500 ± 20 µm diameter round holes, evenly spaced, for a percent open area of 10 %.

10.2.2 ~~Using a reference orifice plate that has been calibrated for flow rate and pressure over the range that the flow meter is used for the testing, perform the dry air flow test at the ramp rate used for the permittivity testing.~~The reference screen may be used as an alternative to the No. 200 U.S. mesh sieve for Methods A and B, and shall be used for Method C.

10.2.3 Prepare one specimen of the reference screen to fit the apparatus.

10.2.4 Based on an interlaboratory test program involving nine laboratories, the mean permittivity of the reference screen was determined to be 1.47 s^{-1}, with a reproducibility standard deviation of 0.133 s^{-1}.

10.2.5 The resulting ~~flow rate versus pressure curve~~ permittivity value for process control of the apparatus, as well as the operator(s), should not deviate from the ~~reference disc plot by~~mean value stated in 10.2.4~~more than 0.50 % at any point along the plots where flow rate values are obtained for this test method.~~, plus or minus two standard deviations.

10.2.6 ~~New operator process control tests shall be performed on an annual~~The reference screen could be used for interim checks of the apparatus on a weekly basis.

10.2.6.1 Once the average permittivity result has been determined for a particular reference screen over several different test days or different operators, the control chart standard deviation should be on the order of 2.3 % of the grand average.

10.3 *Frequency of Apparatus and Operator Qualifications:*

[5] The reference screen can be obtained from TRI Environmental, Inc., 9063 Bee Caves Road, Austin, TX 78733. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

10.3.1 Process control of the apparatus and each operator should be performed annually, unless the apparatus is adjusted or modified in any way, such as replacement of or adjustments to the pressure transducer or the flow rate measurement mechanism.

METHOD A – CONSTANT HEAD TEST

11. Procedure A – Constant Head Water Flow Test

11.1 Assemble the apparatus with the specimen in place.

11.2 Open the bleed valve and backfill the system through the standpipe or discharge ~~pipe,~~pipe with de-aired water. Backfilling in this manner forces any trapped air out of the system and the geotextile.

NOTE 6—For the water flow apparatus shown in Fig. 1, the water should be at the bottom level of the specimen at the time of specimen installation.

11.3 Close the bleed valve once water flows from it. Continue to fill the apparatus with de-aired water until the water level reaches the overflow.

11.4 With water flowing into the system through the water inlet, adjust the discharge pipe along with the rate of water flowing into the apparatus to obtain a ~~50-mm [2-in.]~~ 50 mm [2 in.] head of water on the geotextile. This is the head (h) under which the test will be performed initially.

11.5 Submerge a tube attached to a source of vacuum to just above (10 mm [0.5 in.]) the surface of the geotextile, moving the tube gently over the surface while applying a slight vacuum in order to remove any trapped air that may be in or on the specimen. If necessary, readjust the head to 50 mm [2 in.] after removing the vacuum.

11.6 Record the values of time (t), quantity of flow (Q) as collected from the discharge pipe, and water temperature (T), holding the head at 50 mm [2 in.]. Make at least five readings per specimen and determine an average value of permittivity for the specimen.

NOTE 7—The quantity of flow may be measured in millilitres and then converted to cubic millimetres for the computation of permittivity (1 mL = 1000 mm^3).

11.7 After the first specimen has been tested under a ~~50-mm [2-in.]~~ 50 mm [2 in.] head, using the same specimen, start with a ~~10-mm~~ 10 mm [~~⅜-in.~~] in.] head and repeat the procedure. Increase the head by 5 mm [3⁄16 in.] after every five readings. Increase the head until a ~~75-mm [3-in.]~~ 75 mm [3 in.] head is reached. Use this data to determine the region of laminar flow. Plot volumetric flow rate, v (where v equals Q/At, values defined in 12.1), versus head. The quantity of flow (Q) should be corrected to 20 °C [68 °F]. The initial straight line portion of the plot defines the region of laminar flow. If the ~~50-mm [2-in.]~~ 50 mm [2 in.] head is outside the region of laminar flow, repeat the test procedure using the head of water in the mid-region of laminar flow.

11.7.1 Compare the data from 11.7 with the apparatus calibration curve referred to in 6.2. The apparatus calibration plot of volumetric flow rate versus head should plot well above the same plot for the geotextile specimen (see Fig. 3). If the specimen curve intersects the calibration curve, the apparatus is controlling the flow through the geotextile rather than the structure of the geotextile itself. In such an instance, modify the apparatus by enlarging the discharge pipe so that the device does not control the flow.

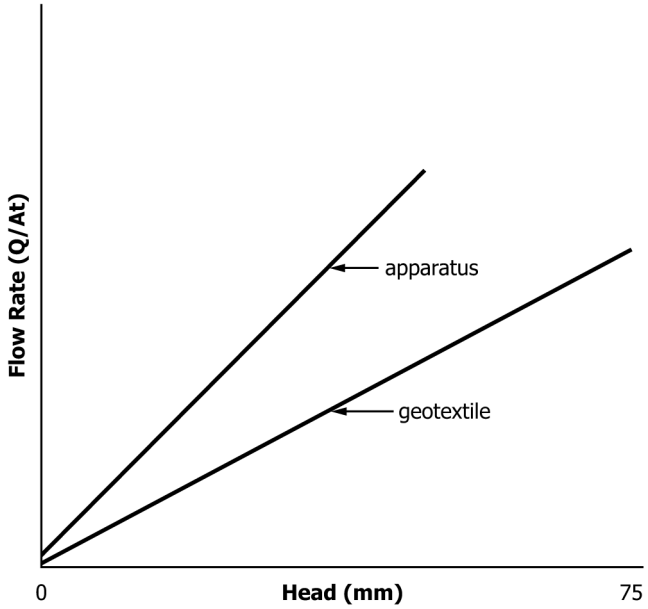

FIG. 3 Calibration Curve

11.8 Repeat 11.1 – 11.6 with the remaining specimens.

12. Calculation – Constant Head Water Flow Test

12.1 Calculate the permittivity, ψ, as follows:

$$\psi = QR_t/hAt \quad (1)$$

where:

ψ = permittivity, s^{-1},
Q = quantity of flow, mm^3,
h = head of water on the specimen, mm,
A = cross-sectional area of test area of specimen, mm^2,
t = time for flow (Q), s, and
R_t = temperature correction factor determined using Eq 2.

$$R_t = u_t/u20_c \quad (2)$$

where:

u_t = water viscosity at test temperature, millipoises, as determined from Table 1, and
$u20_c$ = water viscosity at 20 °C, mP.

12.2 Calculate the permittivity for the five sets of readings per specimen at the 50 mm [2 in.] head.

12.3 Determine the average permittivity for the individual specimen tests.

METHOD B – FALLING HEAD TEST

13. Procedure – Falling Head Water Flow Test

13.1 Proceed as in ~~11.1~~11.1 – 11.5 ~~through 11.5~~. (**Warning—**The falling head procedure should not be performed for geotextiles with a permittivity greater than 0.05 ~~sec~~s^{-1}, unless the system is equipped with an automated data acquisition system that would measure elapsed time for the drop in head from 80 to 20 mm on the manometer.)

13.2 For the water flow apparatus shown in Fig. 1, adjust the discharge pipe so that its outlet is slightly above the level of the specimen.

13.3 By increasing the flow from the water supply, adjust the water level to 150 mm [6 in.]. Once the water is at this level, shut off the water supply and allow the water level to fall to 80 mm [3.2 in.]. At this point, start the ~~stop watch~~ stopwatch and determine the time for the water level to fall to the ~~20-mm~~ 20 mm [~~⅘-in.~~] in.] level. Record the inside diameter (d) of the upper unit, the diameter (D) of the exposed portion of the specimen, and the water temperature (T). Make at least five readings per specimen. All measurements in 13.3 are in relation to the outlet water.

13.4 Repeat the procedure on the remaining specimens.

14. Calculation – Falling Head Water Flow Test

14.1 Calculate the permittivity, ψ, as follows:

$$\psi = [(a/At)\ 1n\ (h_0/h_1)]R_t \quad (3)$$

where:

A = $\pi D^2/4$—cross-sectional test area of specimen, mm^2,
a = $\pi d^2/4$—cross-sectional area of standpipe above specimen,
t = time for head to drop from h_0 to h_1, s,
h_0 = initial head (80 mm),
h_1 = final head (20 mm), and

TABLE 1 Viscosity of Water Versus Temperature

Temperature, °C	Viscosity (×10^{-3} ~~kg/s·m~~)kg/s·m)	Correction Factor, R_t [A]
19	1.027	1.025
20	1.002	1.000
21	0.978	0.976
22	0.954	0.952
23	0.932	0.931

[A] Alternatively, the correction factor, R_t, can be calculated with: R_t=1.4751 −0.0237*T, where T is in degrees centigrade.