INTERNATIONAL

Designation: D4647/D4647M – 13 (Reapproved 2020)

Standard Test Methods for Identification and Classification of Dispersive Clay Soils by the Pinhole Test[1]

This standard is issued under the fixed designation D4647/D4647M; 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 test method presents a direct, measurement of the dispersibility and consequent colloidal erodibility of clay soils by causing water to flow through a small hole punched in a specimen. The results of the tests are qualitative and provide general guidance regarding dispersibility and erodibility. This test method is complemented by Test Method D4221.

1.2 This test method and the criteria for evaluating test data are based upon results of several hundred tests on samples collected from embankments, channels, and other areas where clay soils have eroded or resisted erosion in nature (**1**).[2]

1.3 Three alternative procedures for classifying the dispersibility of clay soils are provided as follows:

1.3.1 Method A and Method C, adapted from Ref (**1**), classify soils into six categories of dispersiveness as: dispersibility (D1, D2), slight to moderately dispersive (ND4, ND3), and nondispersive (ND2, ND1).

1.3.2 Method B classifies soils into three categories of dispersiveness as: dispersibility (D), slightly dispersive (SD), and nondispersive (ND).

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

1.5 *Units*—The values stated in either SI units or inch-pound units 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 non-conformance with the standard.

1.6 *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.*

1.7 *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:*[3]

D422 Test Method for Particle-Size Analysis of Soils (Withdrawn 2016)[4]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))

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

D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedures)

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

D4221 Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer

D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D6026 Practice for Using Significant Digits in Geotechnical Data

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.06 on Physical-Chemical Interactions of Soil and Rock.

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[2] The boldface numbers in parentheses refer to the list of references at the end of these test methods.

[3] 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.

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

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

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms in these test methods, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dispersive clays*—clays that disaggregate easily and rapidly in water of low-salt concentration, and without significant mechanical assistance. Such clays usually have a high proportion of their adsorptive capacity saturated with sodium cations.

3.2.1.1 *Discussion*—Such clays generally have a high shrink-swell potential, have low resistance to erosion, and have low permeability in an intact state.

4. Summary of Test Method

4.1 The test method is started with distilled water flowing horizontally under a hydraulic head of 50 mm [2 in.] through a 1.0-mm [0.04-in.] diameter hole punched in the soil specimen. The nature of the solution emerging from the specimen under the initial 50-mm [2-in.] head provides the principle differentiation between dispersive and nondispersive clays. Flow from dispersive clays will be distinctly dark and the hole through the specimen will enlarge rapidly, with a resultant increase in the flow rate. Flow from slightly to moderately dispersive clays will be slightly dark with a constant hole size and flow rate. Flow from nondispersive clays will be completely clear with no measurable increase in the hole size.

4.2 Test results are evaluated from the appearance of the flowing solution emerging from the specimen, the rate of flow, and the final size of the hole through the specimen. These observations provide the basis for classifying the soil specimen.

5. Significance and Use

5.1 The pinhole test provides one method of identifying the dispersive characteristics of clay soils that are to be or have been used in earth construction. The piping failures of a number of homogeneous earth dams, erosion along channel or canal banks, and rainfall erosion of earthen structures have been attributed to the colloidal erosion along cracks or other flow channels formed in masses of dispersive clay (**2**).

5.2 This test method models the action of water flowing along a crack in an earth embankment. Other indirect tests, such as the double hydrometer test (Test Method D4221), the crumb test (**3**, **4**), that relates the turbidity of a cloud of suspended clay colloids as an indicator of the clay dispersivity, and chemical tests that relate the percentage of sodium to total soluble salt content of the soil are also used as indicator tests of clay dispersibility (**2**). The comparison of results from the pinhole test and other indirect tests on hundreds of samples indicates that the results of the pinhole test have the best correlation with the erosional performance of clay soils in nature.

5.3 Method A and Method C of the pinhole test require the evaluation of cloudiness of effluent, final size of the pinhole, and computation of flow rates through the pinhole in order to classify the dispersive characteristics of the soil. Method B requires only the evaluation of the cloudiness of effluent and final size of the pinhole to classify the dispersive characteristics of the soil. The computation of flow rates through the pinhole in Method A serves primarily as a guide to the proper equipment and specimen performance under sequential pressures applied during the test. All methods produce similar results and any method can be used to identify dispersive clays.

5.4 The use of Method A or Method C results in the accumulation of data relative to sequential flow rates through the pinhole and consequent enlargement or erosion of the hole. The pinhole erosion test was developed for the purpose of identifying dispersive soils and is not intended to be a geometrically scaled model of a prototype structure. Since the theory of similitude was not used in the design of the pinhole test, quantitative data are not obtained. The quantity of flow through the pinhole, amount of soil erosion, or the rate of soil erosion should not be extrapolated to actual field conditions (**3**). However, such data may be useful in performing qualitative evaluations of the consequences of such erosion in terms of dam failure, loss of life and property. They also may be used in considering the cost effectiveness of defensive design measures necessary to minimize the effects of failure due to dispersive clays. For example, the amount of colloidal erosion that will occur in a soil classed as ND2 (very slightly dispersive) will be very small for a relatively long period of time. Such erosion may not be significant in evaluating the cost-benefit relationships in projects where public safety is not involved or where normal maintenance procedures will handle the problem. In such cases, classifying the soil as ND (nondispersive) using Method B of the pinhole test should be adequate.

5.5 Pinhole tests that result in classifying soil as slightly dispersive (ND3 by Method A or Method C or SD by Method B) indicate high uncertainty about the existence of significant problems to be considered in the design or stability of a structure. In such cases, it is advisable to resample and test a number of other soils from the same area to generate an adequate statistical sample for problem evaluation. The original slightly dispersive sample may come from an area on the edge of a more highly dispersive soil.

5.6 In a few physiographic areas or geoclimatic conditions, or both, neither the pinhole test nor the other indicator tests provide consistent identification of dispersive clays (**5**, **6**, **7**). In such cases, the results of the tests (**8**, **9**) should be evaluated in terms of cost effectiveness and design judgment (**7**).

5.7 For some projects, it may be desirable to perform the pinhole test using eroding fluids other than distilled water (**8**, **10**). In such cases, Method A, Method B, or Method C may be used to identify the dispersive characteristics of the soil and compare the results with those obtained using distilled water.

NOTE 1—Notwithstanding the statement on precision and bias contained in these test methods: The precision of these test methods is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies which meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of these test methods are cautioned that compliance with Practice D3740 does not in itself assure reliable testing. Reliable testing depends on several factors; Practice D3740 provides a means of evaluating some of those factors.

6. Limitations

6.1 Development of the test procedure to provide reproducible results that differentiate between clay soils that were known to be erodible (dispersive) and nonerodible (nondispersive) in the field indicates the following limitations in the use of this test:

6.1.1 This test method is not applicable to soils with less than 12 % finer than 0.005 mm and with a plasticity index less than or equal to 4 (**2**, **11**). Such soils generally have low resistance to erosion regardless of dispersive characteristics.

6.1.2 The most consistent results are produced when the natural water content of the sample is preserved during the sampling, shipping, storage, and testing operations.

6.1.3 A few instances have been reported in which the pinhole test did not identify some dispersive clays in which the pore water contained less than 0.4 meq/L total soluble salts that were more than 80 % sodium salts.

6.1.4 This test method was developed to test specimens of disturbed soil that are compacted into the test cylinder. This test method can also be used to test intact specimens when they are properly trimmed and sealed into the test cylinder; however, some investigators (**6**) have found that these test methods are not applicable in evaluating the dispersive characteristics of intact specimens of highly sensitive clays. Such clays may be classed as dispersive from the pinhole test results but perform as nondispersive materials in nature.

6.1.5 This test method is performed with distilled water, at a pH of 5.5 to 7.0, as the eroding fluid. The use of water with various ionic concentrations and combinations will alter the results of the test (**8**, **10**).

7. Classification

7.1 The observations of these test methods provide the basis for classifying the soil specimen into a category of dispersiveness according to the following general criteria:

7.1.1 *Method A:* D1, D2—Dispersive clays that fail rapidly under 50-mm [2-in.] head.

ND4, ND3—Slightly to moderately dispersive clays that erode slowly under 50-mm [2-in.] or 180-mm [7-in.] head.

ND2, ND1—Nondispersive clay with very slight to no colloidal erosion under 380-mm [15-in.] or 1020-mm [40-in.] head.

7.1.2 *Method B:* D—Dispersive clays that erode rapidly under 50-mm [2-in.] head.

SD—Slightly dispersive clays that erode slowly under 180-mm [7-in.] head.

ND—Nondispersive clays that show very slight or no colloidal erosion under 380-mm [15-in.] head.

NOTE 2—Method B for classifying dispersiveness of clay soils combines the categories of Method A as follows: D = D1, D2, ND4; SD = ND3; and ND = ND2, ND1.

7.1.3 *Method C:* D1, D2—Dispersive clays that fail rapidly under 50-mm [2-in.] head.

ND4, ND3—Dispersive clays that erode slowly under 50-mm [2-in.], 180-mm [7-in.], or 380-mm [15-in.] head.

ND2, ND1—Nondispersive clay with very slight to no colloidal erosion under 380-mm [15-in.] head.

8. Apparatus

8.1 *Pinhole Test Apparatus*—Typical pinhole test apparatus is shown in Fig. 1, Fig. 2, and Fig. 3. Various other types and sizes of specimen molds or containers and top and base plates may be used provided the test specimen is 38 mm [1.5 in.] long, the pinhole is 1.0 mm [0.04 in.] in diameter, and the hole through the truncated cone centering guide or other centering device is 1.5 mm [0.059 in.] in diameter.

8.1.1 It is important that the outlet drain be large enough to accommodate the maximum inflow without creating a partial vacuum in the system. Partial vacuum may develop when small diameter outlet drains flow at full capacity and when long segments of flexible tubing are attached to the outflow pipe.

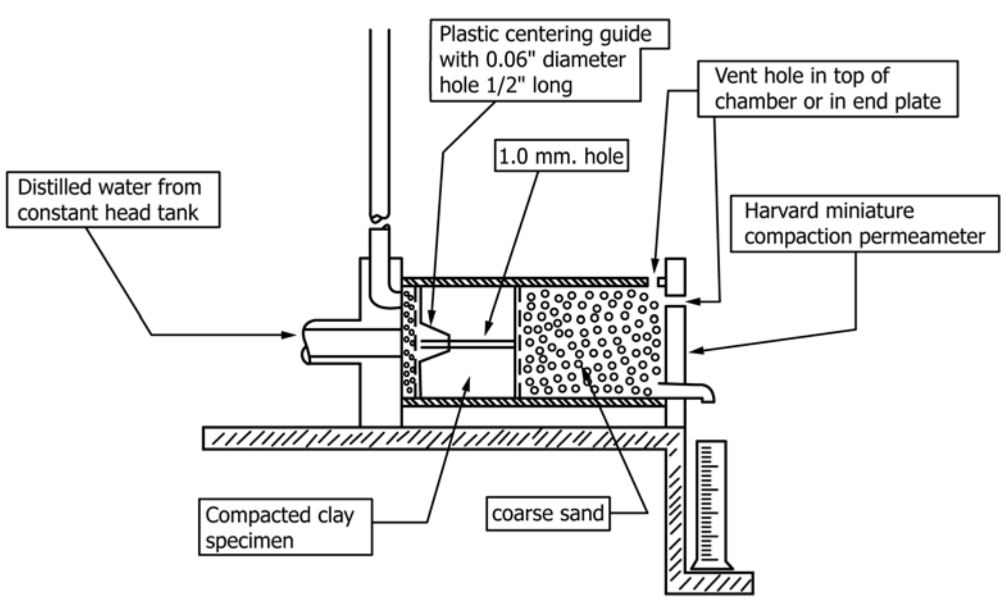

FIG. 1 Schematic Drawing of the Pinhole Test Equipment

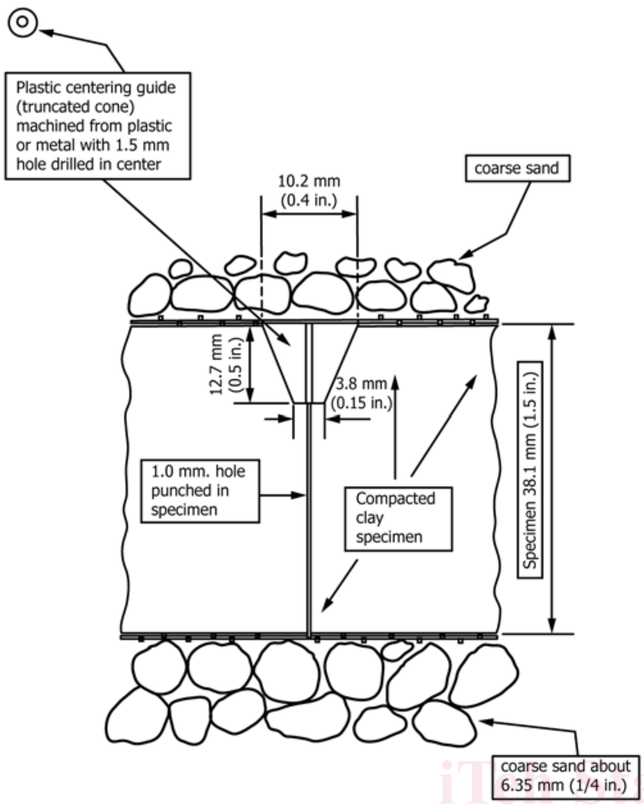

FIG. 2 Schematic Drawing of Pinhole Test Specimen

8.1.2 The development of partial vacuum in the system produces hydraulic heads greater than those specified for the test in Section 10 and following.

8.1.3 The installation of a 1.6-mm [0.063-in.] to 3-mm [0.12-in.] diameter breather hole in the center of the base plate, as shown in Fig. 1, generally assures discharge from the system at atmospheric pressure without partial vacuum.

8.2 *Constant Head Tank,* to supply distilled water with a pH of 5.5 to 7.0.

8.3 *Graduated Cylinders,* of 10, 25, 50, and 100-mL capacity.

8.4 *Wire Screen,* with holes smaller than 2 mm [0.08 in.], cut in circular shape to fit inside the specimen tube.

8.5 *Wire Punch,* 1.0 mm [0.039 in.] in diameter by 50 to 75-mm [2.0 to 3-in.] punch. [No. 19 veterinarian hypodermic needle or 1-mm drill bit or stiff wire length.]

8.6 *Centering Guide*—Truncated cone centering guide with 1.5-mm [0.059-in.] diameter hole (plastic, brass, steel, or other suitable material).

8.7 *Coarse Sand,* that has been washed and sieved through 2 to 6 mm diameter sieves [No. 10 to ¼ in.].

8.8 *Stop Watch,* reading to 0.1 s.

8.9 *Manometer,* pressure transducer, standpipe, or similar device to measure hydraulic head to within 5 % of value.

8.10 *Compaction Equipment,* Harvard miniature compaction apparatus or similar device to compact the specimen into the pinhole test cylinder.

8.11 *Balance,* meeting the requirements of Class GP2 in Specification D4753.

9. Preparation of Samples

9.1 *Disturbed Soil at Natural Water Content:*

9.1.1 Remove from the sample sand and gravel particles larger than 2 mm [No. 10 sieve] in diameter.

NOTE 3—This sieving process generally involves hand forcing materials through the No. 10 sieve. Separation on a finer screen may be necessary if medium sand particles tend to clog the pinhole.

9.1.2 Determine the water content using procedures in Test Method D2216, and adjust the moisture by adding distilled water or air drying to within two percentage points of the water content for compaction to be used in construction.

9.2 *Disturbed Soil, Pulverized and Air-Dried:*

9.2.1 Remove sand and gravel particles larger than 2-mm [No. 10] sieve.

9.2.2 Add distilled water to bring the soil to within 2 percentage points of the specified water content for compaction to be used in construction.

9.2.3 Compact the soil using equipment and procedures of Test Method D698.

9.2.4 Extrude the compacted specimen from the compaction mold and store the compacted specimen in moisture-resistant containers (plastic bags) for a period of 24 to 48 h prior to performing the pinhole test. (The specimen may be compacted and stored for curing in the test cylinder sealed in plastic to maintain water content.)

9.2.5 The cylinder of compacted soil should be broken up and screened through a 2-mm [No. 10] sieve prior to proceeding with the preparation of the pinhole specimen as described in 10.1.1.

NOTE 4—The compaction and rescreening of the disturbed soil has been found effective in facilitating the even distribution of water content through the specimen. Other methods may be used provided the water content is uniformly distributed.

9.3 *Intact (Core or Block) Specimens:*

9.3.1 Trim or cut a specimen 38-mm [1.5-in.] long to fit snugly in the test cylinder and position the specimen on top of the screens and pea gravel as shown in Fig. 1.

9.3.2 Seal the perimeter of the top of the specimen with molding clay or other moisture-resistant sealant to prevent flow of water between the specimen and the wall of the test cylinder.

9.4 *Use of Larger Test Specimens:*

9.4.1 The procedures and interpretations in this test method were developed using the apparatus and dimensions listed in Section 8. Results using larger test specimens (either compacted, remolded, or intact) should be correlated and compared with the results obtained using these test methods to ascertain their validity. ASTM Committee D18 is unaware of any published documentation on the use of test specimens with dimensions different from those specified in these test methods.

10. Method A Procedure

10.1 *Compacted Specimen:*

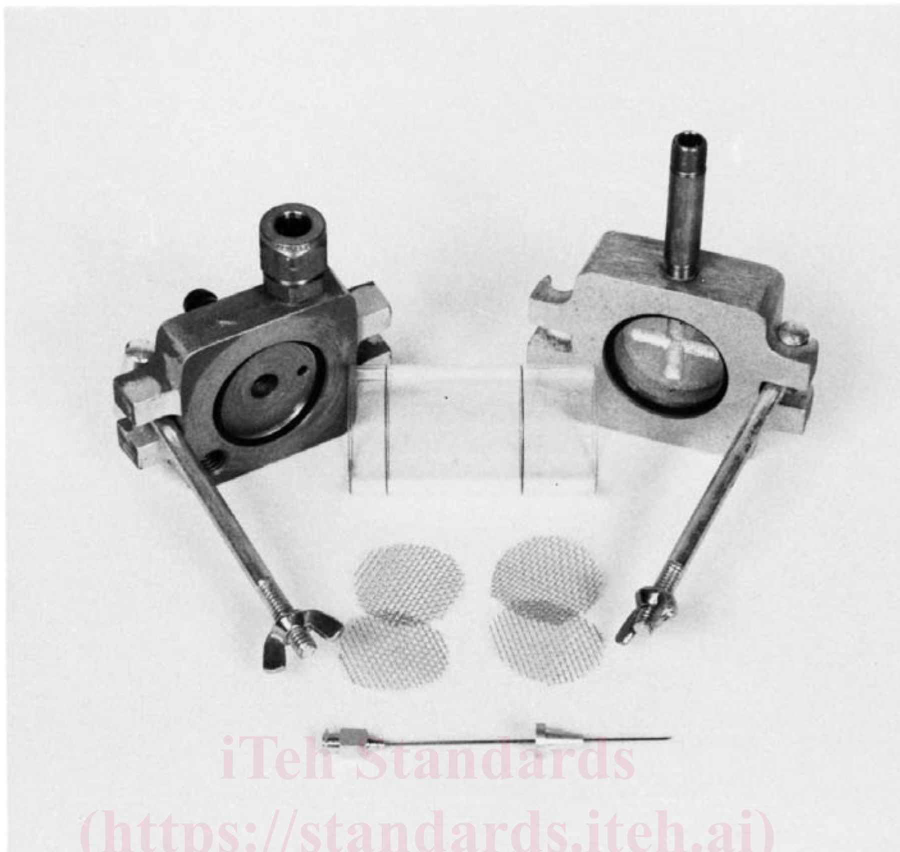

FIG. 3 Pinhole Test Mold, Screens, Nipple, and Needle

10.1.1 Compact the 38-mm [1.5-in.] long specimen into the pinhole test cylinder on top of the coarse sand and wire screen, which have been previously placed in the cylinder.

10.1.1.1 The dry unit weight and water content of the compacted specimen should correspond to those specified for the proposed earth construction.

10.1.1.2 When using the Harvard compaction and permeability equipment **(1, 12)** , approximately 95 % of maximum standard (Test Method D698) dry unit weight can be achieved by compacting the specimen in five lifts with 16 tamps on each lift using a 6.8-kg [15-lb] spring on the Harvard compaction test tamper.

10.1.2 Insert the truncated cone centering guide with the 1.5-mm [0.059-in.] diameter hole into the center of the top of the specimen using finger pressure.

NOTE 5—Take care that the nipple is inserted vertically with the top of the nipple flush with the top of the soil specimen so that the pinhole is normal to the specimen surface.

10.1.3 Insert the 1.0-mm [0.039-in.] diameter wire punch into the centering guide and punch or force it through the soil specimen. Force the punch in a continuous motion through the soil specimen; it should penetrate into the underlying sand. Take care that the punch completely penetrates through the soil specimen and 6 to 10 mm [0.24 to 0.4 in.] into the coarse sand under the specimen and screens. A few rotations of the punch after it has passed through the soil specimen will assist penetration through the screen and into the sand.

10.1.4 Remove the wire or punch from the specimen.

NOTE 6—Rotating the punch four or five times during the extraction operation generally assures a clean, open hole through the specimen.

10.1.5 Carefully place the wire screen on top of the specimen (with centering guide in place) and fill the remaining void in the top of the test cylinder with coarse sand.

NOTE 7—The sand should be carefully screened and leveled across the top of the cylinder so a watertight seal can be provided between the test cylinder and the test plate.

NOTE 8—If the pinhole centering guide is included as an integral part of the cylinder head plate, the truncated cone centering guide (10.1.2) and the top screen and gravel (10.1.5) can be eliminated **(13, 14)**.

10.1.6 Assemble the top plate; connect the head (distilled water) source, and the head measuring device (standpipe or manometer). Place assembled apparatus in horizontal position as shown in Fig. 1. At this stage of the test, the valve for the head source should be closed and the valve for the head measuring device should be open (if valves are used).

10.1.7 Start the test by introducing distilled water into the apparatus so that a hydraulic head at the level of the pinhole is 50 mm [2 in.]. If flexible tubing is used to connect either the apparatus with the water source or to the head measuring device, care should be taken to ensure that all air bubbles are expelled from the water supply and head measuring tubes when the test is started.

10.1.8 Record the time at start of test (or start the stop-watch).

10.1.9 Take measurements of the quantity of effluent flow with an appropriate graduated cylinder as it emerges from the specimen. If no flow occurs when the test is started, stop the test, dismantle the top of the apparatus, and repunch the hole (or seal the first hole and punch a new hole).

10.1.9.1 The first two or three measurements of discharge should be made in units of the time in seconds required to collect 10 mL of effluent. Subsequent measurements may consist of recording the time interval required to collect 25, 50, or 100 mL of effluent.

10.1.9.2 It is also acceptable to select a time interval, such as 60 s, and measure the volume of effluent collected during that interval. This method allows sufficient sensitivity to determine the rate of change of flow rates and observation of hydraulic capacity (example, constant flow rate).

10.1.10 Observe the cloudiness of the effluent for each measured discharge by looking both through the side of the cylinder and vertically through the column of fluid in the cylinder. Record the cloudiness of the effluent in the cylinder as very dark, dark, moderately dark, slightly dark, barely visible, or completely clear, Fig. 4.

10.1.11 Continue the test under the 50-mm [2-in.] head for 5 min. If, at the end of 5 min, the effluent is very dark and flow rates have gradually increased to 1.0 to 1.4 mL/s, the test is complete.

10.1.12 Dismantle the apparatus and extrude the soil specimen from the cylinder. Break or cut open the specimen, transversely and longitudinally, and measure the size of the hole by comparing against the needle used to punch the hole, Fig. 5.

10.1.13 If the final hole size is greater than twice the needle punch diameter, classify the soil as highly dispersive, D1. Otherwise, the flow rate and hole size are inconsistent and the test should be done again.

NOTE 9—Extensive experimental data (**13**) indicate that the hydraulic capacity of the system using a nipple with a diameter equal to 1.5 mm [0.06 in.] is 1.2 to 1.3 mL/s under a 50-mm hydraulic head. If flow rates exceed these amounts, the outlet system is operating under a partial vacuum or the initial head reading is higher than 50 mm.

10.1.14 If the effluent from the 50-mm [2-in.] head is distinctly dark and the flow rate does not exceed 1.0 mL/s at the end of 5 min, continue the test an additional 5 min for a total of 10 min. At the end of 10 min, if the effluent is still dark,

NOTE 1—Comparison of cloudy colloidal appearance of water flowing through dispersive clay specimen (left cylinder) with perfectly clear water from a nondispersive clay specimen (right cylinder).

FIG. 4 Comparison of Appearance