APPENDIX XIII:

PINHOLE EROSION TEST FOR IDENTIFICATION OF DISPERSIVE CLAYS

1. CHARACTERISTICS OF DISPERSIVE CLAYS. a. Nature of Dispersive Clays. Dispersive clays are a particular type of soil in which the clay fraction erodes in the presence of water by a process of deflocculation. This occurs when the interparticle forces of repulsion exceed those of attraction so that clay particles are detached and go into suspension. If the water is flowing, as in a crack in an earth dam, the detached clay particles are carried away and piping occurs. Problems involving dispersive clays include piping failure of earth dams, rainfall erosion on slopes of earth dams, erosion of shoreline on reservoirs due to wave action, and erosion of channels (both unlined and lined) constructed in dispersive clays.

b. Influence of Clay-Sized Particles† and Plasticity. Soils with the fraction finer than 0.005 mm $\leq$ 12 percent and with a plasticity index $\leq$ 4 generally do not contain sufficient colloids to support dispersive erosion.††,‡ However, such soils are known to have low resistance to erosion,‡‡ and the dispersion characteristics would add little to the

† 0.005 mm is American Society for Testing and Materials (ASTM) designation for clay-sized particles (see ASTM D-422-63).

†† J. L. Sherard, L. P. Dunnigan, and R. S. Decker, "Identification and Nature of Dispersive Soils," Journal of the Geotechnical Engineering Division, Vol 102, No. GT4, Apr 1976, pp 287-301.

‡ N. L. Ryker, "Encountering Dispersive Clays on SCS Projects in Oklahoma," Dispersive Clays, Related Piping, and Erosion in Geotechnical Projects, ASTM Special Technical Publication No. 623, American Society for Testing and Materials, May 1977, pp 370-389.

‡‡ H. J. Gibbs, "A Study of Erosion and Tractive Force Characteristics in Relation to Soil Mechanics Properties," Soils Engineering Report No. EM-643, 23 Feb 1962, U. S. Department of the Interior, Bureau of Reclamation, Denver, Colo.

known field performance of the soils.

2. IDENTIFICATION OF DISPERSIVE CLAYS. a. Introduction. Identification of dispersive clays may be required for earth structures not yet constructed, for existing earth structures, and for natural soil deposits. Positive identification of dispersive clays is by observed performance of the soil in the field.* Dispersive clays cannot be identified by conventional index tests such as particle size distribution, Atterberg limits, and compaction characteristics.

b. Laboratory Tests Used to Identify Dispersive Clays. Four laboratory tests commonly used to identify dispersive clays are the Crumb test, Soil Conservation Service (SCS) dispersion test, soil pore water chemistry correlation, and the pinhole erosion test.††

(1) The Crumb test (procedure given in Plate XIII-1) is often used as an adjunct to other tests for identifying dispersive clays. However, the Crumb test is a useful indicator only in one direction. If the Crumb test indicates dispersion (Crumb reading 3 or 4), the soil is probably dispersive; however many dispersive soils, particularly kaolinitic soils, do not react to the Crumb test (i.e., give Crumb readings of I or 2).‡

(2) The SCS dispersion test has been used to identify

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* P. Forsythe, "Experience in Identification and Treatment of Dispersive Clays in Mississippi Dams," Dispersive Clays, Related Piping, and Erosion in Geotechnical Projects, ASTM Special Technical Publication No. 623, American Society for Testing and Materials, May 1977, pp 135-155.

†† J. L. Sherard et al., "Pinhole Test for Identifying Dispersive Soils," Journal of the Geotechnical Engineering Division, Vol 102, No. GT1, Jan 1976, pp 69-85.

Sherard, Dunnigan, and Decker, op. cit.

‡ G. G. S. Holmgren, and C. P. Flanagan, "Factors Affecting Spontaneous Dispersion of Soil Materials as Evidenced by the Crumb Test," Dispersive Clays, Related Piping, and Erosion in Geotechnical Projects, ASTM Special Technical Publication No. 623, American Society for Testing and Materials, May 1977, pp 218-239.

dispersive clays. Available results indicate for soils with SCS dispersion < 35 percent, dispersive erosion will not be a problem; for soils with SCS dispersion from 35 to 50 percent, dispersive erosion may or may not occur; and for soils with SCS dispersion > 50 percent, dispersive erosion will be a problem.†,††,‡ The SCS dispersion test has about 85 percent reliance in predicting dispersive performance (about 85 percent of dispersive soils show more than 35 percent SCS dispersion).††

(3) Sherard et al.,‡‡ have obtained a relationship between dispersion and soil pore water chemistry based on pinhole erosion tests and observed dispersion erosion in nature, as shown in Figure 1. The soil pore water correlation has about 85 percent reliance in predicting dispersive performance.††

(4) The pinhole erosion test is the most reliable test for identifying dispersive soils.†,‡‡ Figure 2 shows a schematic representation of the pinhole erosion test. In conducting the test, distilled water under a low hydraulic head is caused to flow through a small diameter hole in the soil specimen. For dispersive soils, the flow emerging from the soil specimen is cloudy and the hole rapidly enlarges. For nondispersive soils, the flow is clear and the hole does not enlarge. The pinhole erosion test was developed for the purpose of identifying dispersive soils and is not intended to be a geometrically scaled model of an actual prototype structure. Since the theory of similitude was not used in the design of the test, quantitative data

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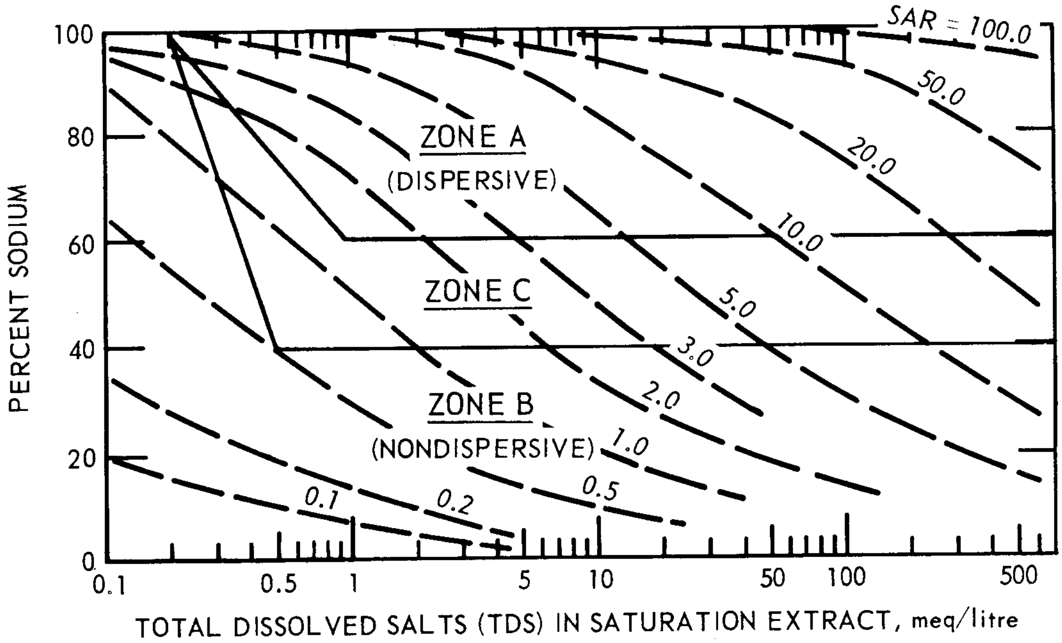
† Sherard, Dunnigan, and Decker, op. cit.

†† R. S. Decker and L. P. Dunnigan, "Development and Use of the SCS Dispersion Test," Dispersive Clays, Related Piping, and Erosion in Geotechnical Engineering Projects, ASTM Special Technical Publication No. 623, American Society for Testing and Materials, May 1977, pp 94-109.

‡ N. L. Ryker, op. cit.

‡‡ J. L. Sherard et al., op. cit.



NOTE: RELATIONSHIP SHOWN IS VALID ONLY WHEN ERODING WATER IS RELATIVELY PURE.

$$\text{PERCENT SODIUM} = \frac{\text{Na}\ (100)}{\text{TDS}} = \frac{\text{Na}\ (100)}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}}$$

$$\text{TDS} = \text{Ca} + \text{Mg} + \text{Na} + \text{K}$$

$$\text{SAR} = \frac{\text{Na}}{\sqrt{0.5\ (\text{Ca} + \text{Mg})}}, \text{ ALL IN meq/litre}$$

Figure 1. Relationship between dispersion and soil pore water chemistry based on pinhole erosion tests and experience with erosion in nature (after Sherard et al.)

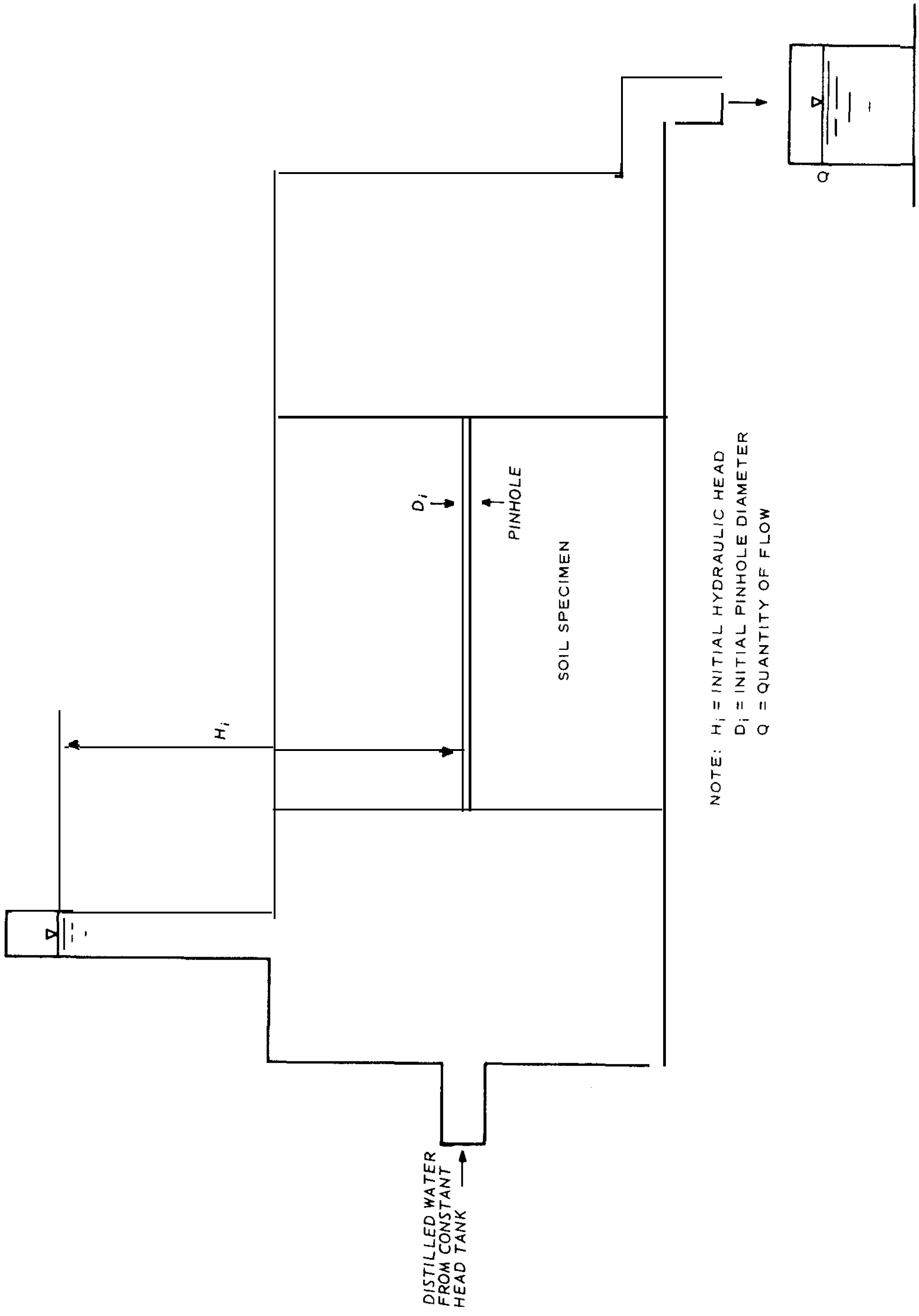


Figure 2. Schematic representation of WES pinhole erosion apparatus

are not obtained on the quantity of flow through the pinhole, amount of soil erosion, or rate of soil erosion. Two limitations of the pinhole erosion test for identifying dispersive soils have been observed. Undistrubed soil samples of high sensitivity (ratio of the peak undrained strength of the soil in a natural state to the peak undrained strength after it has been remolded without change in water content) may be classified as dispersive from the pinhole erosion test, while in nature the soil may be resistant to erosion.† Apparently, the natural structure of the soil is destroyed by punching the pinhole in the undisturbed soil specimen and a reaction analogous to dispersion is obtained in the pinhole erosion test. Soils with high sodium (>80 percent) and low total dissolved solids (< 0.4 meq/ℓ) in the soil pore water may show nondispersive in the pinhole erosion test, while the soil may exhibit dispersive performance in the field.†† This may occur because a decrease in the concentration gradient between the soil pore water and eroding fluid (distilled water ≃ 0.0 meq/ℓ for pinhole erosion test) results in a decrease in the erosion rate for soils.‡ However, available data from case histories indicate very few soils with total dissolved solids < 1.0 meq/ℓ for which dispersive performance has been observed in the field.‡‡

c. Field Tests Used to Identify Dispersive Clays. Four field tests that have been used to identify dispersive clays are the Crumb test (also used as a laboratory test), the ultraviolet light, the modified

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† 0. Dascal, G. Pouliot, and J. Hurtubise, "Erodibility Tests on a Sensitive, Cemented Marine Clay (Champlain Clay)," Dispersive Clays, Related Piping, and Erosion in Geotechnical Projects, ASTM Special Technical Publication No. 623, American Society for Testing and Materials, May 1977, pp 74-93.

†† Forsythe, op. cit.

‡ A. Sargunam, "Influence of Mineralogy, Pore Fluid Composition and Structure on the Erosion of Cohesive Soils," Ph.D. Dissertation, June 1973, University of California, Davis, Calif.

‡‡ Sherard, Dunnigan, and Decker, op. cit.

hydrometer or Dilution-Turbidity test, and determination of soil pore water chemistry by sodium electrode and chemical reagents or Wheatstone bridge.

(1) The Crumb test, which may be used in the laboratory or field, has been described previously.

(2) The ultraviolet light has been used to indicate the presence of sodium in the soil.* Uranyl acid is mixed with the soil and the intensity and amount of fluorescence under ultraviolet light is observed The ultraviolet light has shown about 40 percent reliance in predicting dispersive performance of soils in Mississippi.

(3) The modified hydrometer or Dilution-Turbidity test has been used to identify dispersive clays.†,†† Prior to using the modified hydrometer test to identify dispersive clays in a particular area, the test results must be correlated with laboratory tests to establish a range of values. For example, test data from the Bluff Hills region of Mississippi indicate for a turbidity ratio < 4, dispersive erosion will be a problem; for a turbidity ratio 4-9, dispersive erosion may or may not occur; and for a turbidity ratio > 9, dispersive erosion will not be a problem.*

(4) Two methods have been developed for determination of soil pore water chemistry in the field to use with the correlation shown in Figure 1 and to identify dispersive clays.‡ The first method involves a sodium electrode and chemical reagents to determine the percent sodium and total dissolved cations (calcium, magnesium, and

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* Forsythe, op. cit.

†† Ryker, op. cit.

‡ C. P. Flanagan and G. G. S. Holmgren, "Field Methods for Determination of Soluble Salts and -Percent Sodium From Extract for Identifying Dispersive Clay Soils," Dispersive Clays, Related Piping, and Erosion on Geotechnical Projects, ASTM Special Technical Publication No. 623, American Society for Testing and Materials, May 1977, pp 121-134.

sodium). This method does not determine potassium, which exists in small quantities ($\leq$ 1.0 meq/ℓ) in most soils. The second method uses a Wheatstone bridge to determine the percent sodium and total dissolved cations (calcium, magnesium, sodium, and potassium).

d. Recommended Procedure for Identification of Dispersive Clays. Soils with the fraction finer than 0.005 mm $\leq$ 12 percent and with a plasticity index $\leq$ 4 generally do not contain sufficient colloids to support dispersive erosion. The pinhole erosion test is the recommended laboratory test for identifying dispersive clays. A Crumb test (procedure given in Plate XIII-I) should be run on each soil tested in the pinhole erosion apparatus. There is no generally reliable field test for identifying dispersive clays.

(1) To identify dispersive clays for earth structures not yet constructed, pinhole erosion tests will be conducted on compacted soil samples taken from proposed borrow areas.

(2) To identify dispersive clays in existing earth structures or natural soil deposits, pinhole erosion tests will be conducted on undisturbed soil samples.

3. WES PINHOLE EROSION APPARATUS. Detailed drawings for the U. S. Army Engineer Waterways Experiment Station (WES) pinhole erosion apparatus are given in Plates XIII-2 to XIII-4. The apparatus, shown schematically in Figure 2, is a simplified version of a laboratory erosion test apparatus constructed previously at WES.† The apparatus is designed to accommodate three different size specimens: (a) compacted specimens 1.312 in. in diameter by 2.816 in. high (Harvard miniature compaction mold), (b) compacted specimens 4.00 in. in diameter by 4.59 in. high (standard compaction mold), and (c) undisturbed

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† E. B. Perry, "Piping in Earth Dams Constructed of Dispersive Clay; Literature Review and Design of Laboratory Tests," Technical Report S-75-15, Nov 1975, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

specimens encased in Shelby-tube 3.125 in. in outside diameter by 4.60 in. high. Accessory equipment needed includes: (a) de-aired distilled water; (b) graduated cylinders of 10-, 25-, 50-, 100-, and 250-ml capacity; (c) stopwatch reading to 0.1 sec; (d) centigrade thermometer with range 0 to 50C and accurate to 0.1C; (e) modeling clay,† plus 1/8- and 1/4-in. circular hardware cloths cut to fit inside the specimen tube; (f) pea gravel, 1/4- to 3/8-in. size; and (g) 1/16-in.-diameter steel welding rod.

4. CALIBRATION OF PINHOLE EROSION APPARATUS. a. Concept. To interpret the results of the pinhole erosion test and to develop a classification system containing intermediate grades between dispersive and nondispersive clays, it is necessary to determine the relationship between quantity of flow and initial hydraulic head as a function of the size of the pinhole, as shown in Figure 3. This relationship is determined by substituting aluminum cylinders with varying pinhole diameter (Plate XIII-4) for the soil specimen and measuring the quantity of flow for various hydraulic heads. Two calibrations are required: (1) 4.60-in.-long aluminum cylinders with varying pinhole diameter, and (2) 2.82-in.-long aluminum cylinders with varying pinhole diameters. These calibrations should be conducted for each pinhole erosion apparatus used.

b. Assembly of Apparatus. To calibrate the pinhole erosion apparatus, the temperature of the distilled water is recorded both before and after the test. The 4.60-in.-long aluminum cylinder with the 1/16-in.-diameter pinhole is pushed into the specimen tube and positioned longitudinally in the center of the specimen tube as shown (for a soil specimen) in Plate XIII-2. The 1/4-in. hardware cloth is placed next to the exit end of the aluminum cylinder (away from the distilled water entrance) and positioned so that the pinhole is centered in an opening in the hardware cloth. The 1/8-in. hardware cloth is

† Clayola modeling clay, Binney and Smith, Inc., 380 Madison Avenue, New York, N. Y. 10017.

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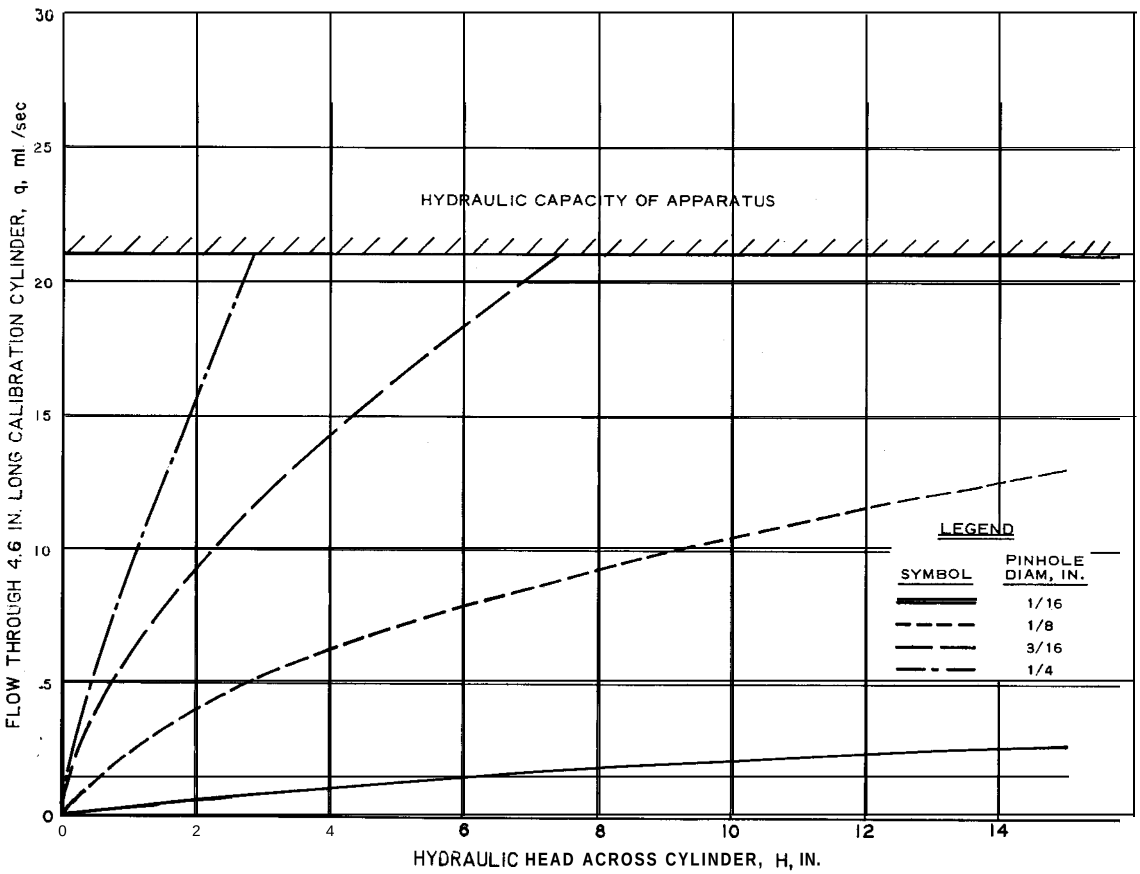

Figure 3. Typical calibration curve for pinhole apparatus using 4.6-in.-long specimen

placed next to the 1/4-in. hardware cloth. Modeling clay is placed around the perimeter of the hardware cloths to hold them in place. Pea gravel (1/4- to 3/8-in. size) is placed next to the hardware cloths, and the drain plate (Plate XIII-3) is attached to the exit end of the specimen tube. The 1/4-in. hardware cloth is placed next to the entrance end of the aluminum cylinder and pusitioned so that the pinhole is centered in an opening in the hardware cloth. The 1/8-in. hardware cloth is placed next to the 1/4-in. hardware cloth. Modeling clay is placed around the perimeter of the hardware cloths to hold them in place and to provide a watertight seal between the beveled edge of the aluminum cylinder and the inside of the specimen tube. Pea gravel (1/4- to 3/8-in. size) is placed next to the hardware cloths and the pressure plate (Plate XIII-31 is attached to the entrance end of the specimen tube, completing the assembly of the pinhole erosion test apparatus.

c. Test Procedure for Calibration. Distilled water from the constant head tank is caused to flow through the pinhole in the aluminum cylinder under a hydraulic head of 1 in. for a period of 2 to 4 min (until the quantity of flow becomes constant). The quantity of flow is measured continuously with a stop watch (nearest 0.1 sec) and graduated cylinders (10, 25, 50, 100, or 250 ml) and recorded on the data sheet (Plate XIII-5). The quantity of flow is measured for hydraulic heads of 1, 2, 3, 5, 7, 9, 11, 13, and 15 in. This process is then repeated using the aluminum cylinders with 1/8-, 3/16-, and 1/4-in.-diameter pinholes. The hydraulic capacity (maximum quantity of water which will flow through the pinhole erosion apparatus for a given hydraulic head and pinhole diameter) of the pinhole erosion apparatus may be reached with the 1/4-in.-diameter pinhole at less than 15 in. of hydraulic head. This completes the calibration for the 4.60-in.-long aluminum cylinders. A similar calibration will then be conducted using the 2.816-in.-long aluminum cylinders with 1/16-, 1/8-, 3/16-, and 1/4-in.-diameter pinholes.

d. Presentation of Calibration Results. The results of the calibration test for the 4.6-in.-long aluminum cylinders are plotted in a manner similar to that shown in Figure 3. The measured quantities of flow from the calibration test are used to prepare a classification of test results for the pinhole erosion test using 4.6-in.-long specimens (see Fig. 4). The classification shown in Figure 4 is depicted graphically in Figure 5.

5. PREPARATION OF COMPACTED SPECIMENS FOR PINHOLE EROSION TESTING. To identify dispersive clays for earth structures not yet constructed, pinhole erosion tests will be conducted on

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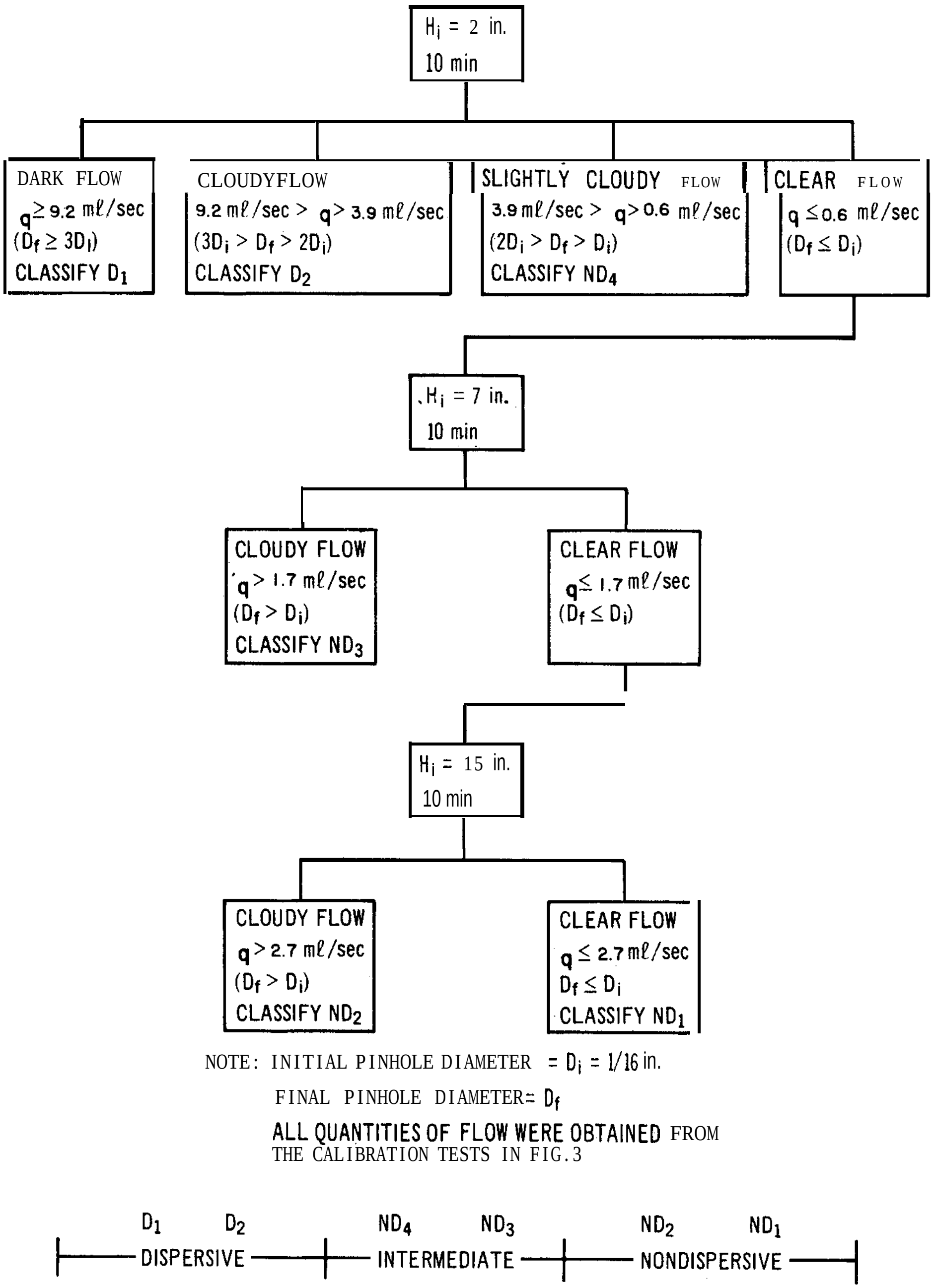

Figure 4. Typical sequence of testing and classification of test results for pinhole erosion test using 4.6-in.-long specimens

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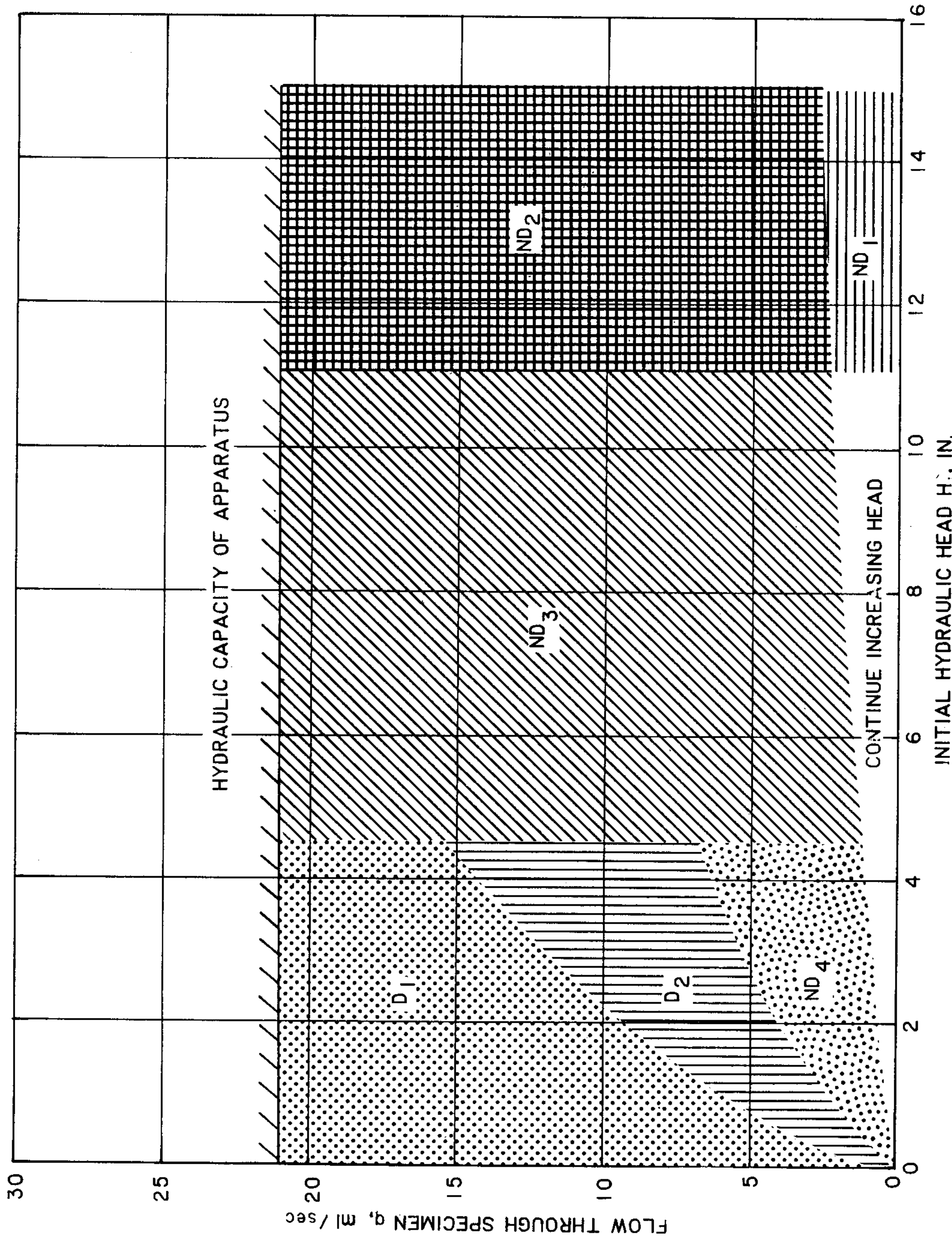

Figure 5. Typical graphical illustration of classification of pinhole erosion test results using 4.6-in.-long specimens

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compacted specimens from soil samples taken from proposed borrow areas. The soil sample shall be maintained at natural water content prior to testing.† If the soil sample contains gravel-size particles, they will be removed by pushing the material through the No. 4 sieve (0.187-in. Opening). The soil specimen tested in the pinhole erosion apparatus shall be compacted at the same water content and dry density as those proposed for the earth structure in the field. If the natural water content is greater than that proposed for construction, the soil shall be air-dried to the construction water content. If the natural water content is less than the proposed construction water content, distilled water shall be added to bring the soil to the construction water content. The type of compaction (kneading, dynamic, or other) used in the laboratory to prepare the soil specimens for pinhole erosion testing shall simulate the field compaction. Where the soil is to be compacted in the field with a sheepsfoot roller, the soil specimens for pinhole erosion testing shall be compacted with a laboratory kneading compaction apparatus (see Appendix X, TRIAXIAL COMPRESSION TESTS, pp X-14 and X-15).†† When the soil is to be compacted in the field with hand-operated tampers, such as in the vicinity of an outlet conduit, the soil specimens for pinhole erosion testing shall be compacted with a laboratory dynamic (impact) compaction apparatus (see Appendix VI, COMPACTION TESTS, p VI-13). Following compaction, the soil specimen for pinhole erosion testing shall be tested immediately (the soil specimens shall not be allowed to cure following compaction) in the pinhole erosion apparatus.

6. PREPARATION OF UNDISTURBED SPECIMENS FOR PINHOLE

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† Sherard, et al., op. cit.

†† S. D. Wilson, "Suggested Method of Test for Moisture-Density Relations of Soils Using Harvard Compaction Apparatus," Proceedings for Testing Soils, American Society for Testing and Materials, 4th Edition, Dec 1964, pp 160-162.

EROSION TESTING. To identify dispersive clays in natural deposits or existing compacted earth structures, the pinhole erosion test will be conducted on undisturbed soil samples. The soil sample is not removed from the Shelby tube. A 4.6-in.-long section is cut from the Shelby tube using a horizontal band saw, and the soil specimen encased in the Shelby tube is placed in the pinhole erosion apparatus for testing. If undisturbed block samples are available, a 4.6-in.-long section of Shelby tube with a sharp cutting edge can be pushed into the block sample to obtain a soil specimen for pinhole erosion testing.

7. PINHOLE EROSION TEST PROCEDURE. a. General. The identifying information for the soil specimen is recorded on the data sheet (Plate XIII-5 is a suggested form). The temperature of the eroding fluid (distilled water) is recorded both before and after the test. The curing time (time lapse between compaction and pinhole erosion testing) is recorded for remolded specimens. Although zero curing time is specified for the pinhole erosion test, some time will be consumed in assembling the apparatus, punching the pinhole in the soil specimen, etc.

b. Assembly of Apparatus. To assemble the pinhole erosion apparatus, the soil specimen is positioned longitudinally in the center of the specimen tube as shown in Plate XIII-2 for a compacted specimen 4.00 in. in diameter by 4.60 in. high. The same procedure is employed when testing an undisturbed soil specimen or a compacted soil specimen 1.3125 in. in diameter by 2.816 in. high (these soil specimens encased in adapters (Plate XIII-3) are positioned longitudinally in the center of the specimen tube). The pinhole punch guide assembly (Plate XIII-4) is attached to the exit end of the specimen tube (away from the distilled water entrance), and a 1/16-in.-diameter steel welding rod is pushed through the pinhole punch guide until the rod just touches (marks) the exit end of the soil specimen. The pinhole punch guide is removed from the exit end of the specimen tube, and the 1/4-in. hardware cloth is placed next to the exit end of the soil specimen and positioned so that the pinhole mark is centered in an opening in the hardware cloth. The 1/8-in. hardware cloth is placed next to the 1/4-in. hardware cloth, and modeling clay is placed around the perimeters of the hardware cloths to hold them in place. Pea gravel (1/4- to 3/8-in. size) is placed next to the hardware cloths and the drain plate (Plate XIII-3) is attached to the exit end of the specimen tube. The pinhole punch guide assembly is attached to the entrance end of the specimen tube, and a 1/16-in.-diameter steel welding rod is used to punch a pinhole longitudinally through the center of the soil specimen. The pinhole punch guide assembly is removed, and the 1/4-in. hardware cloth is placed next to the entrance end of the soil specimen and positioned so that the pinhole is centered in an opening in the hardware cloth. The 1/8-in. hardware cloth is placed next to the 1/4-in. hardware cloth, and modeling clay is placed around the perimeter of the hardware cloths to hold them in place and to provide a watertight seal between the soil specimen and the inside of the specimen, tube, as shown in Plate XIII- 2. When the soil specimen is encased in an adapter, modeling clay is used to provide a watertight seal between the beveled edge of the adapter (Plate XIII-3) and the inside of the specimen tube. Pea gravel (1/4- to 3/8-in. size) is placed next to the hardware cloths, and the pressure plate (Plate XIII-3) is attached to th.e entrance end of the specimen tube completing the assembly of the pinhole erosion test apparatus.

c. Test Procedure. The 1/4-in. pipe plug, located on top of the specimen tube next to the manometer (Plate XIII-2) is removed, and the entrance end of the specimen tube containing the pea gravel is filled with distilled water. The 1/4-in. pipe plug is placed back into position, and distilled water from the constant head tank is caused to flow through the pinhole in the soil specimen under a hydraulic head of 2 in. for 10 min (if no flow occurs under the 2-in. hydraulic head, remove the pressure plate, pea gravel, and hardware cloths, attach the pinhole punch guide assembly to the entrance end of the specimen tube, and repunch the pinhole in the soil specimen). The quantity of flow is measured continuously with a stopwatch (nearest 0.1 sec) and graduated cylinders (10, 25, or 50 ml) and recorded on the data sheet (Plate XIII- 5). The color of the water in the flask (clear, cloudy, or dark) is observed and recorded on the data sheet. At the end of the 10-min flow under the 2-in. hydraulic head, the quantity of flow (ml/sec) is computed. If the quantity of flow under 2-in. hydraulic head increases with time showing a cloudy or dark color and after a 10-min flow is greater than the measured quantity of flow obtained when the pinhole erosion apparatus was calibrated using the aluminum cylinder with the 1/16-in.-diameter pinhole, i.e., $D_f > D_i$, the test is concluded. If the quantity of flow under 2-in. hydraulic head does not increase with time and remains clear and after a 10-min flow is approximately equal to or less than the measured quantity of flow obtained when the pinhole erosion apparatus was calibrated using the aluminum cylinder with the 1/16-in.-diameter pinhole, i.e., $D_f \leq D_i$, the hydraulic head is raised to 7 in., and the quantity of flow is measured continuously for 10 min. If the quantity of flow under a 7-in. hydraulic head increases with time showing a cloudy color and after a 10-min flow is greater than the measured quantity of flow obtained when the pinhole erosion apparatus was calibrated using the aluminum cylinder with the 1/16-in.-diameter pinhole, i.e., $D_f > D_i$, the test is concluded. If the quantity of flow under 7-in. hydraulic head does not increase with time and remains clear and after a 10-min flow is approximately equal to or less than the measured quantity of flow obtained when the pinhole erosion apparatus was calibrated using the aluminum cylinder with the 1/16- in. -diameter pinhole, i.e., $D_f \leq D_i$, the hydraulic head is raised to 15 in., and the quantity of flow is measured continuously for 10 min; then the test is concluded.

8. PRESENTATION AND ANALYSIS OF PINHOLE EROSION TEST RESULTS. a. Presentation of Test Results. Plates XIII-6 to XIII-9 present the test results from the pinhole erosion test. These plates are obtained from the calibration of the pinhole erosion apparatus (see Fig. 3). Typical test results for a dispersive clay and a nondispersive clay are also shown in these plates.

b. Analysis of Test Results. The primary differentiation between dispersive and nondispersive clays is given by the pinhole erosion test results under a hydraulic head of 2 in.† For dispersive clays, the quantity of flow under a hydraulic head of 2 in. continuously increases and may reach a maximum value that is limited by the hydraulic capacity of the pinhole erosion apparatus, in less than 10 min. For nondispersive clays, under a hydraulic head of 2 in. the flow will be clear or slightly cloudy. As shown in Figure 4, the pinhole erosion test results are classified as D_1, D_2, ND_4, ND_3, ND_2, or ND_1.† Dispersive clays are classified as D_1 or D_2, intermediate clays as ND_4 or ND_3, and nondispersive clays as ND_2 or ND_1.

9. POSSIBLE ERRORS WITH PINHOLE EROSION TEST. As discussed previously, undisturbed soil specimens of high sensitivity (ratio of the peak undrained strength of the soil in a natural state to the peak undrained strength of the soil after it has been remolded without change in water content), may be classified as dispersive from the pinhole erosion test, while in nature the soil may be resistant to erosion.†† Soils with high sodium (> 80 percent) and low total dissolved solids (< 0.4 meq/ℓ) in the soil pore water may show nondispersive in the pinhole erosion test while the soil may exhibit dispersive performance

† Sherard et al., op. cit.

†† Dascal, Pouliot, and Hurtubise, op. cit.

in the field.† However, available data from case histories indicate very few soils with total dissolved solids < 1.0 meq/ℓ for which dispersive performance has been observed in the field.††

† Forsythe, op. cit.

†† Sherard, Dunnigan, and Decker, op. cit.

Crumb Test

1. The Crumb test is run using distilled demineralized water. Small (5-10 g) crumbs of soil at natural water content are carefully placed on the bottom of a 100-ml clear glass beaker filled with distilled demineralized water. The behavior of the soil crumb is observed and readings are taken after 10 and 30 min.

2. Dispersion is detected by the formation of a colloidal cloud, which appears as a fine misty halo around the soil crumb. The Crumb test is rated for reaction or colloidal cloud formation as follows:

1 = no sign of cloudy water caused by colloidal suspension.

2 = bare hint of colloidal cloud formation at surface or soil crumb.

3 = easily recognized colloidal cloud covering one fourth to one half of the bottom of the glass container.

4 = strong reaction with colloidal cloud covering most of the bottom of the glass container.

3. Since the Crumb test involves a small quantity of soil, several tests should be run on each soil sample before making an evaluation. The Crumb test may be used as an indicator of field performance of dispersive soils using the following evaluation of soil crumb reaction:

No dispersion problem	= 1
Possible dispersion problem	= 2
Definite dispersion problem	= 3 or 4

4. The Crumb test is a useful indicator only in one direction. If the Crumb test indicates dispersion (Crumb reading 3 or 4), the soil is probably dispersive; however, many dispersive soils, particularly kaolinitic soils, do not react to the Crumb test (i.e., give Crumb reading of 1 or 2).

PLATE XIII-1

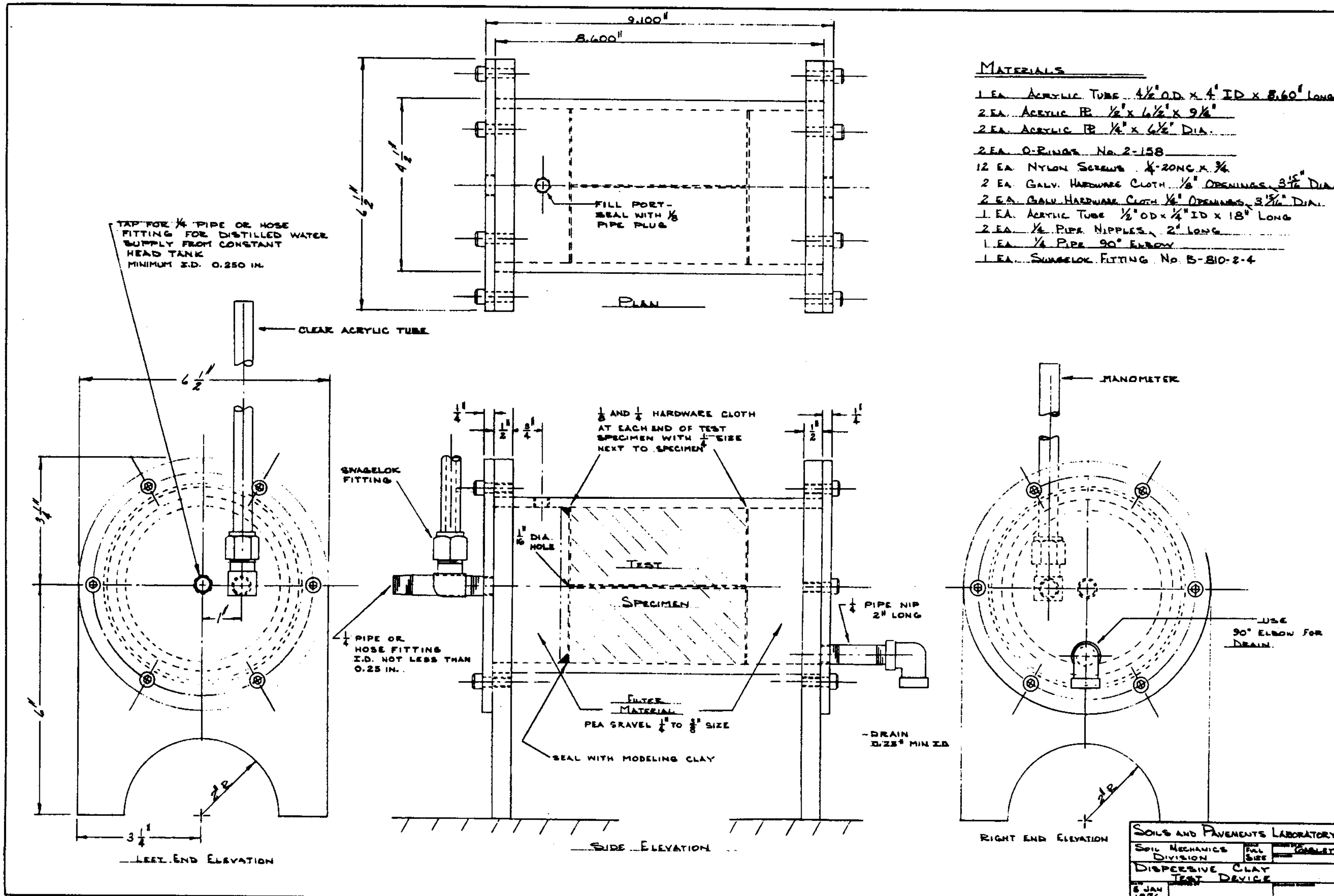
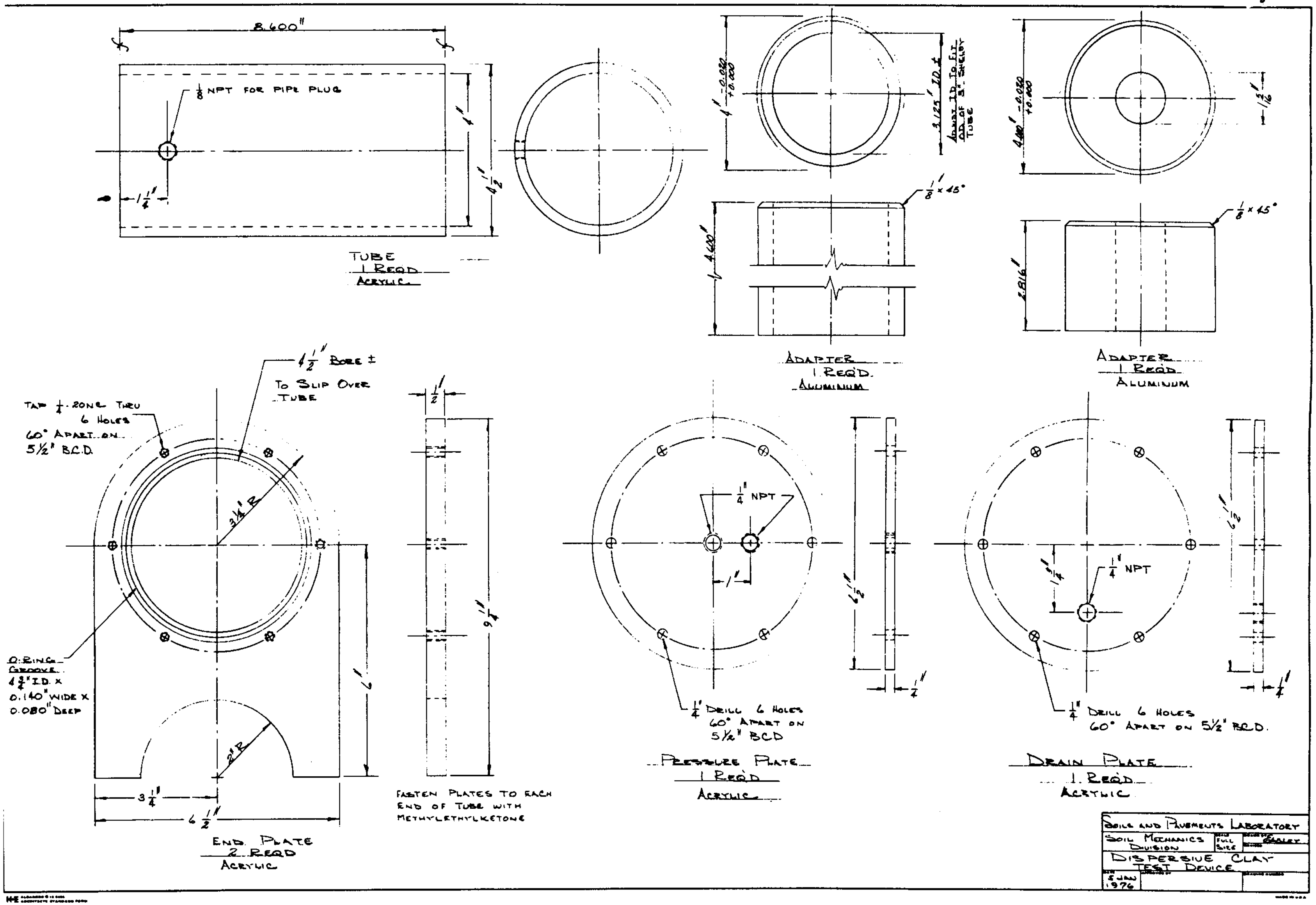

9.100"
8.600"
MATERIALS
1 EA. ACRYLIC TUBE 4½" O.D. x 4" ID x 8.60" LONG
2 EA. ACRYLIC PL ½" x 6½" x 9⅛"
2 EA. ACRYLIC PL ¼" x 6½" DIA.
2 EA. O-RINGS No. 2-158
12 EA. NYLON SCREWS ¼-20NC x ¾
2 EA. GALV. HARDWARE CLOTH ⅛" OPENINGS 3 15/16" DIA.
2 EA. GALV. HARDWARE CLOTH ¼" OPENINGS 3 15/16" DIA.
1 EA. ACRYLIC TUBE ½" OD x ¼" ID x 18" LONG
2 EA. ¼ PIPE NIPPLES, 2" LONG
1 EA. ¼ PIPE 90° ELBOW
1 EA. SWAGELOK FITTING No. B-810-2-4
4½"
6½"
FILL PORT-SEAL WITH ⅛ PIPE PLUG
PLAN
TAP FOR ¼ PIPE OR HOSE FITTING FOR DISTILLED WATER SUPPLY FROM CONSTANT HEAD TANK
MINIMUM I.D. 0.250 IN.
CLEAR ACRYLIC TUBE
6½"
3¼"
6"
1"
2R
3¼"
LEFT END ELEVATION
SWAGELOK FITTING
¼ PIPE OR HOSE FITTING I.D. NOT LESS THAN 0.25 IN.
¼"
½"
¾"
⅛ AND ¼ HARDWARE CLOTH AT EACH END OF TEST SPECIMEN WITH ¼" SIZE NEXT TO SPECIMEN
1/16" DIA. HOLE
TEST
SPECIMEN
FILTER MATERIAL
PEA GRAVEL ¼" TO ⅜" SIZE
SEAL WITH MODELING CLAY
½"
¼"
¼ PIPE NIP 2" LONG
DRAIN 0.25" MIN I.D.
SIDE ELEVATION
MANOMETER
USE 90° ELBOW FOR DRAIN
2R
RIGHT END ELEVATION
SOILS AND PAVEMENTS LABORATORY
SOIL MECHANICS DIVISION
FULL SIZE
DISPERSIVE CLAY TEST DEVICE
8 JAN 1976

PLATE XIII-2


8.600"
1/8 NPT FOR PIPE PLUG
1 1/4"
4"
4 1/2"
TUBE
1 REQD
ACRYLIC
4" -0.020 +0.000
3.125" I.D. ±
ADJUST I.D. TO FIT O.D. OF 3" SHELBY TUBE
4.600"
1/8 x 45°
ADAPTER
1 REQD.
ALUMINUM
4.00" -0.020 +0.000
1 5/16"
2.816"
1/8 x 45°
ADAPTER
1 REQD
ALUMINUM
4 1/2" BORE ±
TO SLIP OVER TUBE
TAP 1/4-20NC THRU
6 HOLES
60° APART ON
5 1/2" B.C.D.
3 1/4" R
2" R
O-RING GROOVE
4 3/4" I.D. x
0.140" WIDE x
0.080" DEEP
6"
3 1/4"
6 1/2"
END PLATE
2 REQD
ACRYLIC
1/2"
9 1/4"
FASTEN PLATES TO EACH END OF TUBE WITH METHYLETHYLKETONE
1/4" NPT
1"
1/4" DRILL 6 HOLES
60° APART ON
5 1/2" BCD
6 1/2"
1/4"
PRESSURE PLATE
1 REQD
ACRYLIC
1 1/4"
1/4" NPT
1/4" DRILL 6 HOLES
60° APART ON 5 1/2" B.C.D.
6 1/2"
1/4"
DRAIN PLATE
1 REQD
ACRYLIC
SOILS AND PAVEMENTS LABORATORY
SOIL MECHANICS DIVISION
FULL SIZE
DISPERSIVE CLAY TEST DEVICE
5 JAN 1976

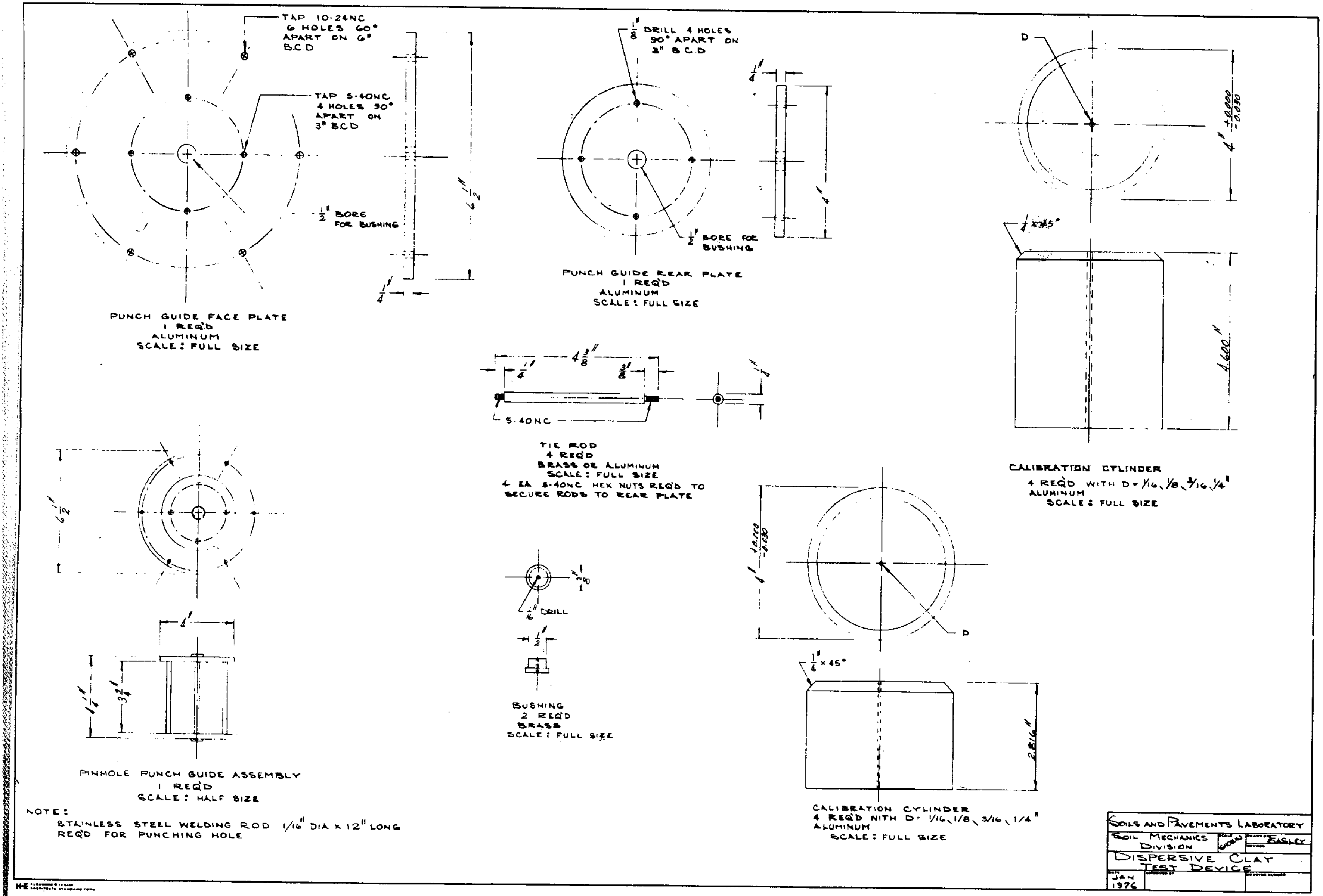

TAP 10-24NC
6 HOLES 60° APART ON 6" B.C.D
TAP 5-40NC
4 HOLES 90° APART ON 3" B.C.D
1/2" BORE FOR BUSHING
6 1/2"
1/4"
PUNCH GUIDE FACE PLATE
1 REQ'D
ALUMINUM
SCALE: FULL SIZE
1/8" DRILL 4 HOLES 90° APART ON 3" B.C.D
1/2" BORE FOR BUSHING
1/4"
4"
PUNCH GUIDE REAR PLATE
1 REQ'D
ALUMINUM
SCALE: FULL SIZE
D
4" +0.000 -0.030
1/4" x 45°
4.600"
CALIBRATION CYLINDER
4 REQ'D WITH D = 1/16, 1/8, 3/16, 1/4"
ALUMINUM
SCALE: FULL SIZE
4 3/8"
1/4"
3/8"
5-40NC
TIE ROD
4 REQ'D
BRASS OR ALUMINUM
SCALE: FULL SIZE
4 EA 5-40NC HEX NUTS REQ'D TO SECURE RODS TO REAR PLATE
6 1/2"
4"
1 1/4"
3 3/4"
PINHOLE PUNCH GUIDE ASSEMBLY
1 REQ'D
SCALE: HALF SIZE
NOTE:
STAINLESS STEEL WELDING ROD 1/16" DIA x 12" LONG REQ'D FOR PUNCHING HOLE
1/16" DRILL
1/2"
BUSHING
2 REQ'D
BRASS
SCALE: FULL SIZE
1" +0.000 -0.030
D
1/4" x 45°
2.816"
CALIBRATION CYLINDER
4 REQ'D WITH D = 1/16, 1/8, 3/16, 1/4"
ALUMINUM
SCALE: FULL SIZE
SOILS AND PAVEMENTS LABORATORY
SOIL MECHANICS DIVISION
EASLEY
DISPERSIVE CLAY TEST DEVICE
JAN 1976

PLATE XIII-4

PINHOLE EROSION TEST

DATE

PROJECT

SAMPLE NO.

TYPE OF SPECIMEN: ☐ UNDISTURBED ☐ COMPACTED

CURING TIME FOR COMPACTED SPECIMEN

ERODING FLUID

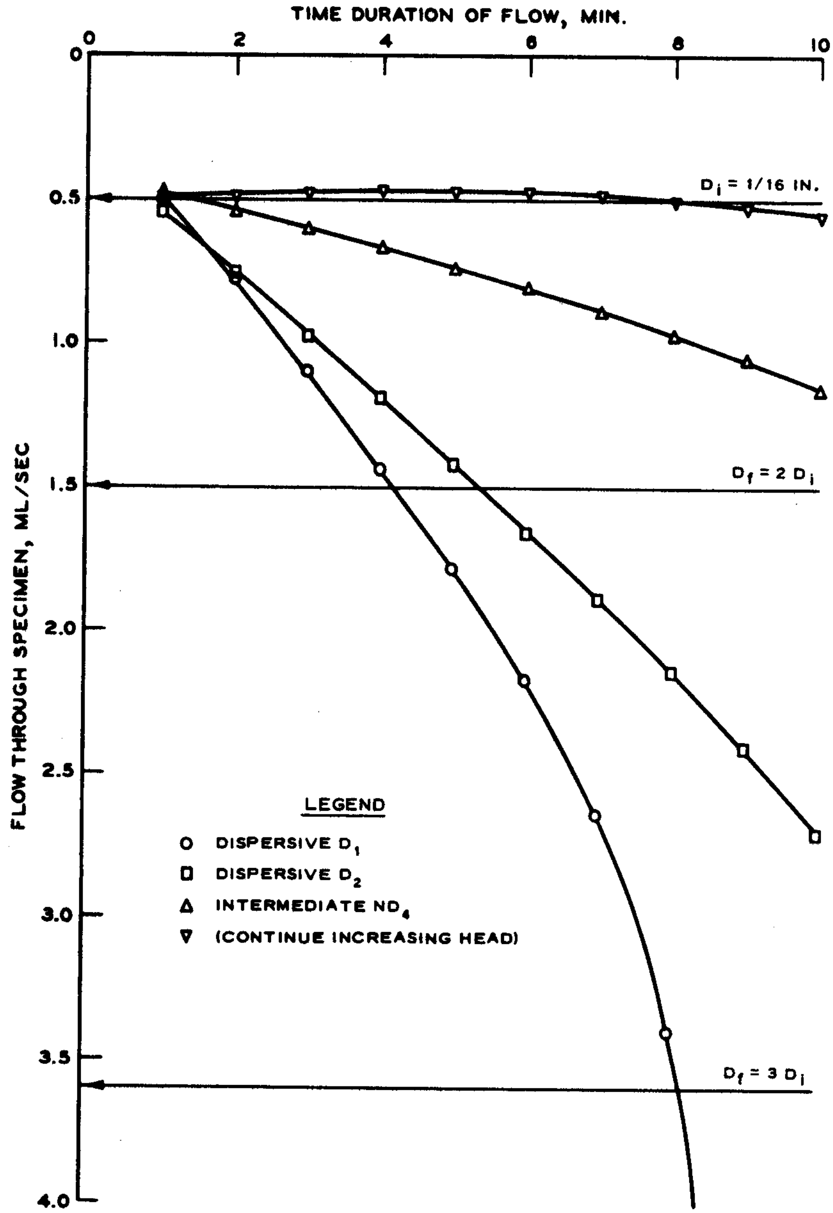
TEMPERATURE: BEFORE TEST END OF TEST

TECHNICIAN

TIME	HEAD IN.	FLOW THROUGH SPECIMEN		COLOR OF FLOW			REMARKS
		ML	SEC	CLEAR	CLOUDY	DARK	

ENG FORM 4668 -R
1 APR 80

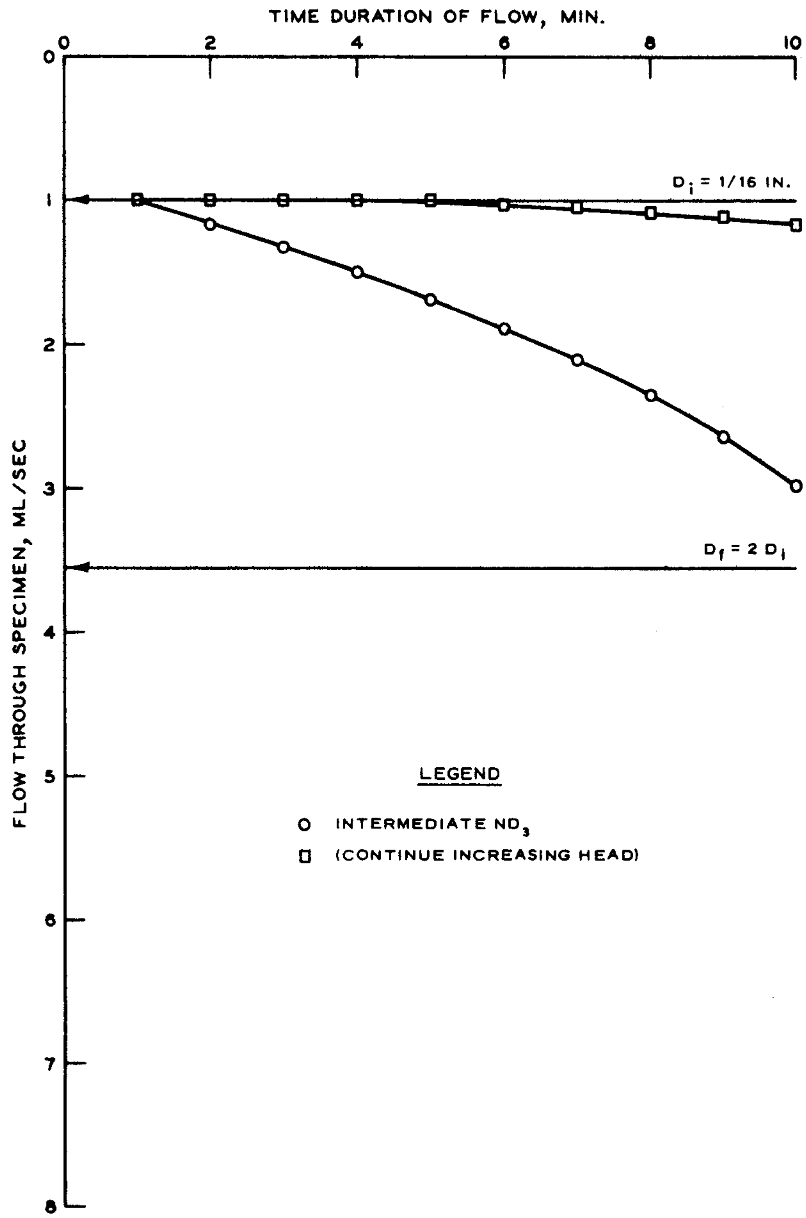
PLATE XIII-5



TYPICAL PINHOLE EROSION TEST RESULTS

FLOW THROUGH SPECIMEN
VERSUS TIME FOR
INITIAL HYDRAULIC HEAD OF 2 IN.

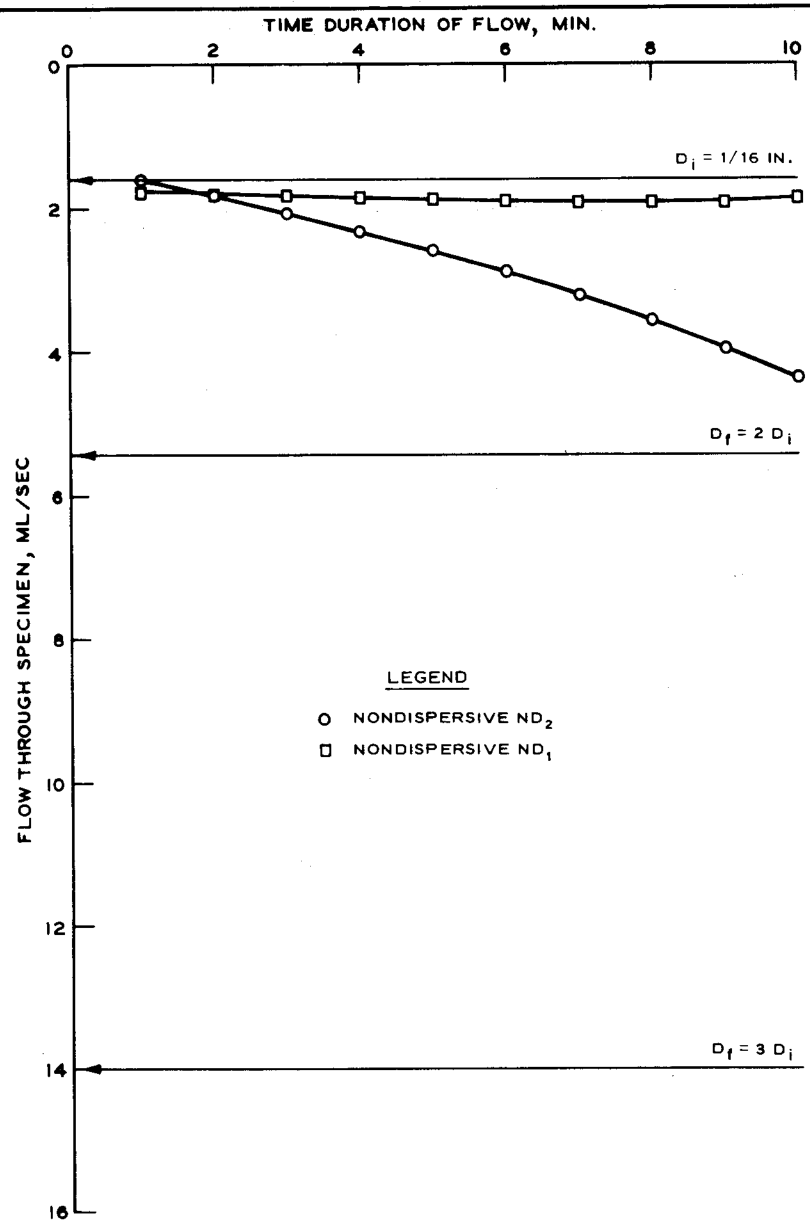
PLATE XIII-6



TYPICAL PINHOLE EROSION TEST RESULTS

FLOW THROUGH SPECIMEN
VERSUS TIME FOR
INITIAL HYDRAULIC HEAD OF 7 IN.

PLATE XIII-7



TYPICAL PINHOLE EROSION TEST RESULTS

FLOW THROUGH SPECIMEN
VERSUS TIME FOR
INITIAL HYDRAULIC HEAD OF 15 IN.

PLATE XIII-8

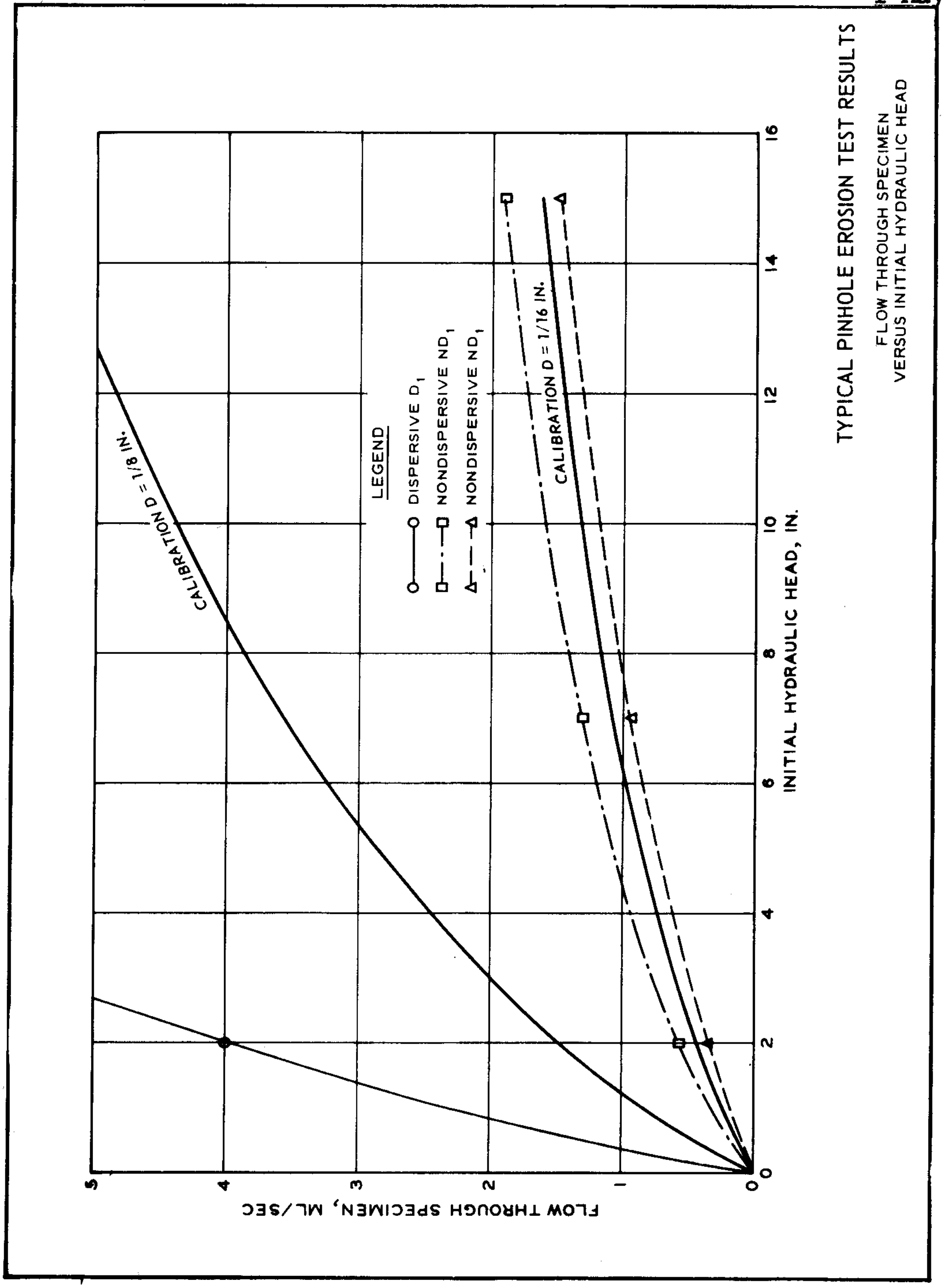


PLATE XIII-9

*U.S. GOVERNMENT PRINTING OFFICE: 1991--524-634/40509