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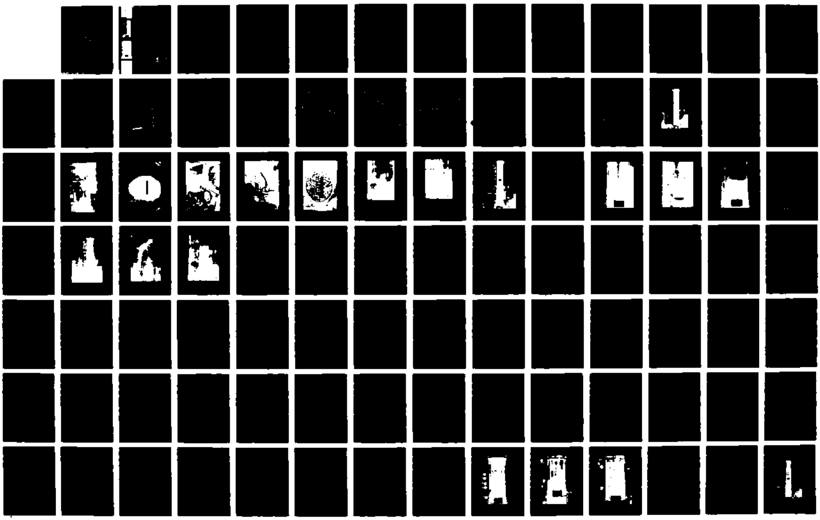

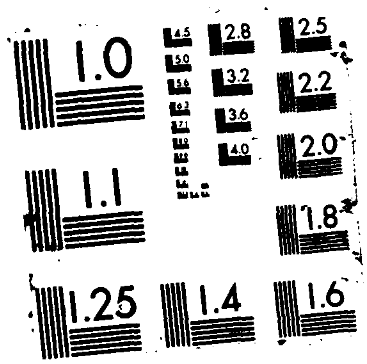
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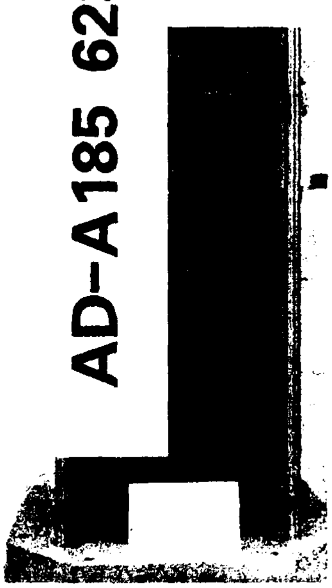

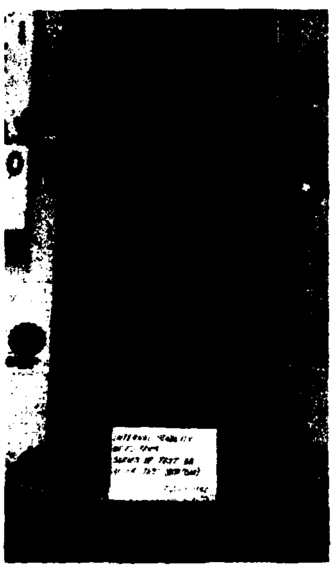

GEOTECHNICAL LABORATORY

TECHNICAL REPORT GL-87-22

LABORATORY TESTS ON GRANULAR FILTERS FOR EMBANKMENT DAMS

by

Edward B. Perry

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

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Final Report

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Present Corps of Engineer (CE) filter criterion (EM 1110-2-1901, Appendix D) dates from the early 1950's, and some uncertainty exists as to the applicability and adequacy of this criterion under various conditions. Laboratory filter tests were conducted on uniform and poorly-graded cohesionless base materials protected by various filters, and internal stability tests were conducted on various graded filter materials. Based upon the limited tests conducted, the following changes to CE filter criterion are proposed.

For a uniform (poorly-graded) cohesionless base material, the second stability ratio

$$\frac{D_{50_F}}{D_{50_B}} \leq 25$$

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19. ABSTRACT (Continued).

where

D_{50_F} = size of filter material at 50 percent passing

D_{50_B} = size of base material at 50 percent passing

should not be used, and there is no need for requiring parallelism of filter and base gradations. For a poorly-graded cohesionless base material, the second stability ratio should not be used, but the requirement for parallelism of filter and base gradations should be retained. Poorly-graded gravelly sand and sandy gravel are internally unstable and should not be used as filters when the coefficient of uniformity

$$C_u = \frac{D_{60_F}}{D_{10_F}} \geq 20$$

where

C_u = coefficient of uniformity

D_{60_F} = size of filter material at 60 percent passing

D_{10_F} = size of filter material at 10 percent passing

Segregation during placement can occur for $C_u \geq 10$.

PREFACE

This study on granular filters for embankment dams was sponsored by the Office, Chief of Engineers, US Army. This report completes CWIS Work Unit 31618, "Design and Construction of Granular Filters for Embankment Dams." Technical Report GL-83-4, "Evaluation of the Erosion Potential of Embankment Core Materials Using the Laboratory Triaxial Erosion Test Procedure" was prepared to complete an early phase of this study.

This study was conducted by Mr. Walter C. Sherman and Dr. Edward B. Perry, Research Group, Soil Mechanics Division (SMD), Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES). Dr. Kandiah Arulanandan, Department of Civil Engineering, University of California, Davis, conducted Studies on "Erosion in Relation to Filter Design Criteria for Earth Dams" and "Relationship Between Type and Amount of Fines in Filter Material Required for Vaughn's Perfect Filter, Crack Susceptibility of Filter, and Erodibility of Core Material," under WES contracts DACW39-79-M-1133 and DACW39-81-M-004, respectively. Dr. Marshall L. Silver, Department of Materials Engineering, University of Illinois at Chicago Circle, conducted studies on "Laboratory Triaxial Erosion Test Procedure for the Evaluation of the Erosion Potential of Embankment Dam Materials" and "Evaluation of the Erosion Potential of Embankment Core Materials Using the Laboratory Triaxial Erosion Test Procedure," under WES contracts DACW39-79-M-5051 and DACW39-80-M-4050, respectively. Drs. Arulanandan's and Silver's work was sponsored under this work unit. This report was prepared by Dr. Perry.

Laboratory filter tests at WES were conducted during the period from June 1979 to July 1982 by Messrs. Dave A. Ellison and William J. Harper. Soil property testing was conducted under the general supervision of Messrs. Gene P. Hale, Chief, Soil Research Center, and Jessie C. Oldham, Chief, Soil Testing Facility, SMD, GL. The work was performed under the general supervision of Mr. Clifford L. McAnear, Chief, SMD, and Dr. William F. Marcuson III, Chief, GL.

COL Dwayne G. Lee, CE, was the Commander and Director of WES during the preparation and publication of this report. Dr. Robert W. Whalin was Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees Fahrenheit	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	2.54	centimetres
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

LABORATORY TESTS ON GRANULAR FILTERS FOR EMBANKMENT DAMS

PART I: INTRODUCTION

Background

1. Present Corps of Engineers (CE) filter criteria date from the early 1950's, and some uncertainty exists as to the applicability and adequacy of the criteria under various conditions (Headquarters, Department of the Army 1986). Research by other organizations indicate that the adequacy of current CE criteria should be carefully assessed (Vaughn and Soares 1982; Sherard, Dunnigan, and Talbot 1984a and b; Kenney et al. 1984; Kenney and Lau 1984).

Objective of the Study

2. The objective of the study was to conduct laboratory filter tests on uniform and graded cohesionless base materials protected by various filters, conduct instability tests of various gradations of graded filter materials, and if appropriate, propose changes to CE filter criteria.

Scope of the Study

3. The study is limited to laboratory filter tests conducted at the US Army Engineer Waterways Experiment Station (WES) during the period from 1979 to 1982.

PART II: FILTER AND DRAIN DESIGN AND CONSTRUCTION

Introduction

4. A filter must retain the protected soil and have a permeability greater than the protected soil, but does not need to have a particular discharge capacity. Drains, however, while meeting all the requirements of filters, must have an adequate discharge capacity since drains collect seepage and carry it to a specified location. In practice, the critical element is not definition, but recognition by the designer, when a drain must collect and carry water, and then to design properly the drain for the expected flows. The objective of filters and drains is to control the movement of water within and about the embankment. In order to meet this objective, filters and drains must, for the project life and with minimum maintenance, retain the protected materials, allow relatively free movement of water, and have sufficient discharge capacity. Filters and drains are used to remove seepage water, reduce uplift pressures, protect against wave action and rapid drawdown, and prevent piping. Filter material should be durable particles which will not be altered by excavation, processing, hauling, placement, and compaction or by stresses imposed by the embankment or interaction with seepage water. Table 1 gives applications and functions for filters and drains.

Design Requirements

General

5. The design requirements for filters and drains (Headquarters, Department of the Army 1986; Headquarters, Department of the Army 1978) are as follows:

- a. Retain the protected soil (piping or stability requirement).
- b. Allow relatively free movement of water (permeability requirement).
- c. Have sufficient discharge capacity (discharge requirement).

---

* Based upon the gradation of the filter or drain material after compaction, which includes possible effects of particle crushing, surface runoff, contamination, dust, etc.

d. Prevent particle migration within the filter (internal stability). Laboratory filter tests may be required under certain conditions (see paragraph 11). Also, when used as a vertical or inclined drain downstream of a fine-grained core material, the filter material should not sustain an open crack under saturated flow. To meet this requirement, the fines (material smaller than the No. 200 sieve or 0.074 mm) should have a plasticity index equal to zero.

Piping or stability requirement

6. To prevent infiltration of the protected soil into the filter material*

$$\frac{D_{15_F}}{D_{85_B}} \leq 5 \qquad (1)$$

where

D_{15_F} = size of filter material at 15 percent passing

D_{85_B} = size of protected soil at 85 percent passing

and

$$\frac{D_{50_F}}{D_{50_B}} \leq 25 \qquad (2)$$

where

D_{50_F} = size of filter material at 50 percent passing

D_{50_B} = size of protected soil at 50 percent passing

Permeability requirement

7. To assure the filter material is much more permeable than the protected soil

---

* This criterion applies to filters and drains; for brevity, only the word filter is used.

$$\frac{D_{15_F}}{D_{15_B}} \geq 5 \qquad (3)$$

Hazen's law for the permeability of uniform clean sand (Cedergren 1977) is expressed as

$$k = 100\ D_{10}^{2} \qquad (4)$$

where

k = permeability, cm/sec

D_{10} = size of sand at 10 percent passing, cm

Hazen's law can be approximated as

$$k = 100\ D_{15}^{2} \qquad (5)$$

Equation 3 can be written as

$$D_{15_F} \geq 5\ D_{15_B}$$

$$D_{15_F}^{2} \geq 25\ D_{15_B}^{2}$$

$$100\ D_{15_F}^{2} \geq 25 \times 100\ D_{15_B}^{2}$$

Using the approximation given by Equation 5

$$k_F \geq 25\ k_B \qquad (6)$$

Thus, the permeability requirement in Equation 3 requires that filter materials have 25 or more times the permeability of the protected soil.

8. The stability and permeability requirements are applicable for all protected soils with gradation curves approximately parallel to the filter gradation curve, except CL or CH soils. When gradation curves of the

protected soil and filter material are not parallel, filter tests should be run. For CL and CH soils without sand or silt, the 15 percent size of filter material in Equation 1 may be as great as 0.4 mm (coarsest limit for concrete sand) and Equation 2 may be disregarded.

Discharge capacity

9. When drains are designed and constructed with ample discharge capacity, the line of seepage will not rise above the drain. The total quantity of seepage from all sources that must discharge through the drain is determined from a flow net for the system (i.e., dam and foundation) assuming infinite permeability for the drains. The minimum required permeability of the drain material is computed from Darcy's law:

$$k = \frac{Q}{iA} \tag{7}$$

where

k = permeability

Q = discharge determined for the flow net

i = hydraulic gradient

A = area of flow

The hydraulic gradient is equal to

$$i = \frac{H}{L} \tag{8}$$

where

H = head loss

L = length of flow over which head loss occurs

Substituting Equation 8 into Equation 7

$$k = \frac{Q}{(H/L)A} \tag{9}$$

Seepage in coarse aggregates is likely to be turbulent and a reduction factor should be applied to the permeability as shown in Figure 1. In order to provide for higher than expected flows, the permeability after placement and compaction should be at least twenty times that calculated theoretically from Equation 9 and Figure 1 (Cedergren 1977).

Gap-graded filter material

10. A gap-graded filter material (see Figure 2) should never be used since it will consist of either the coarse particles floating in the finer material or the fine material having no stability within the voids by the coarse material. In the former case, the material may not be permeable enough to provide adequate drainage. The latter case is particularly dangerous since piping of the protected material can occur through the relatively large loosely filled voids provided by the coarse material (Headquarters, Department of the Army 1978).

Laboratory filter tests

11. Laboratory filter tests should be conducted when the soil to be protected is either described as

- a. Gap- or skip-graded.
- b. Coarse broadly (or widely) graded.
- c. Dispersive.

In a gap-graded soil, the coarse material simply floats in a matrix of finer-sized material. Therefore, the scattered coarse particles will not deter the migration of finer-sized material as they do in a well-graded material. For gap-graded soils, the filter should be designed to protect the fine matrix rather than the total range of particle sizes and the design should be checked by laboratory filter tests.

12. Laboratory filter tests should also be conducted when the filter material either contains

- a. Broadly-grained sands and gravels.
- b. Crushed rock.
- c. Cohesive fines.

Broadly-graded sands and gravels may be internally unstable, and segregation during placement can occur for these types of materials. For uniform cohesionless soils, crushing of particle during compaction, with resulting decrease in permeability, occurs to a higher degree in soils with angular shapes and rough surfaces than in soils with rounded shapes and smooth surfaces. Crushing of particle during compaction leads to an increase in the amount of fines (material smaller than the No. 200 sieve or 0.074 mm) which

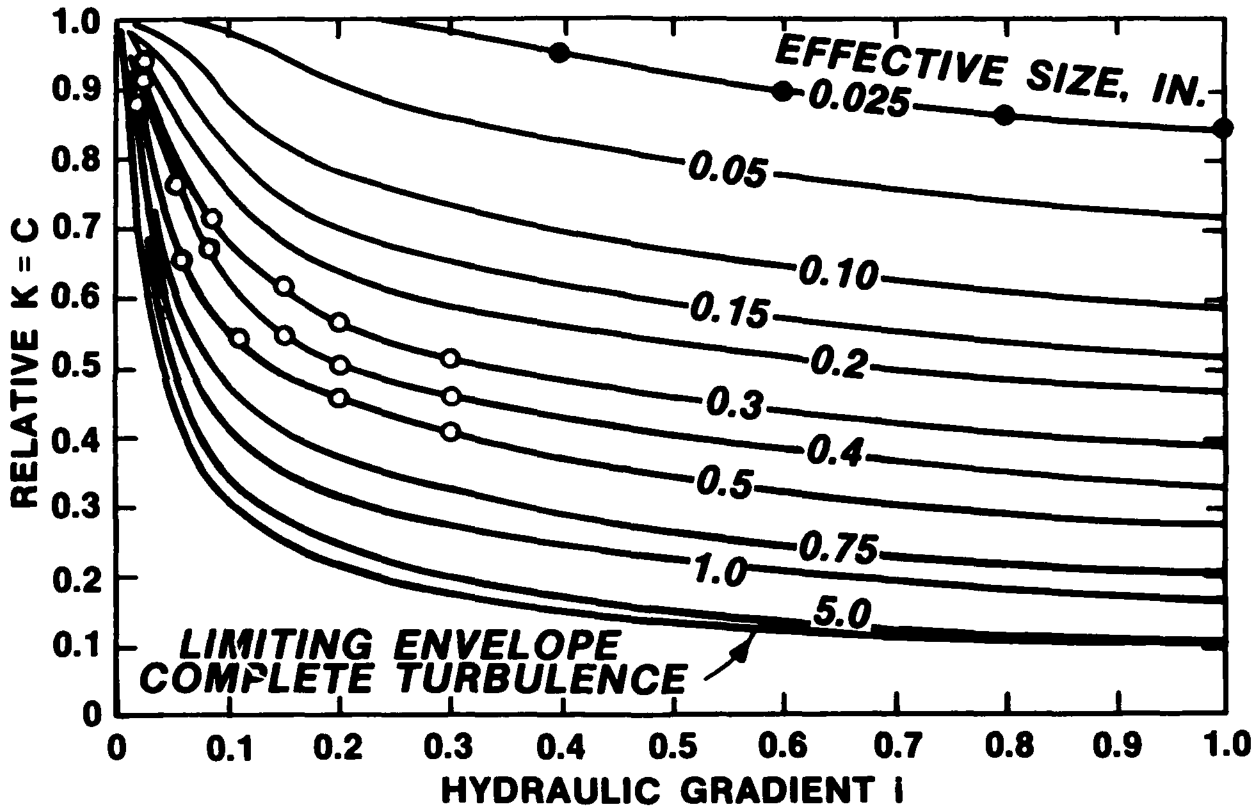

Figure 1. Approximation for estimating reduction in permeability of narrow-size range (poorly-graded) aggregate caused by turbulent flow (after Cedergren 1977)

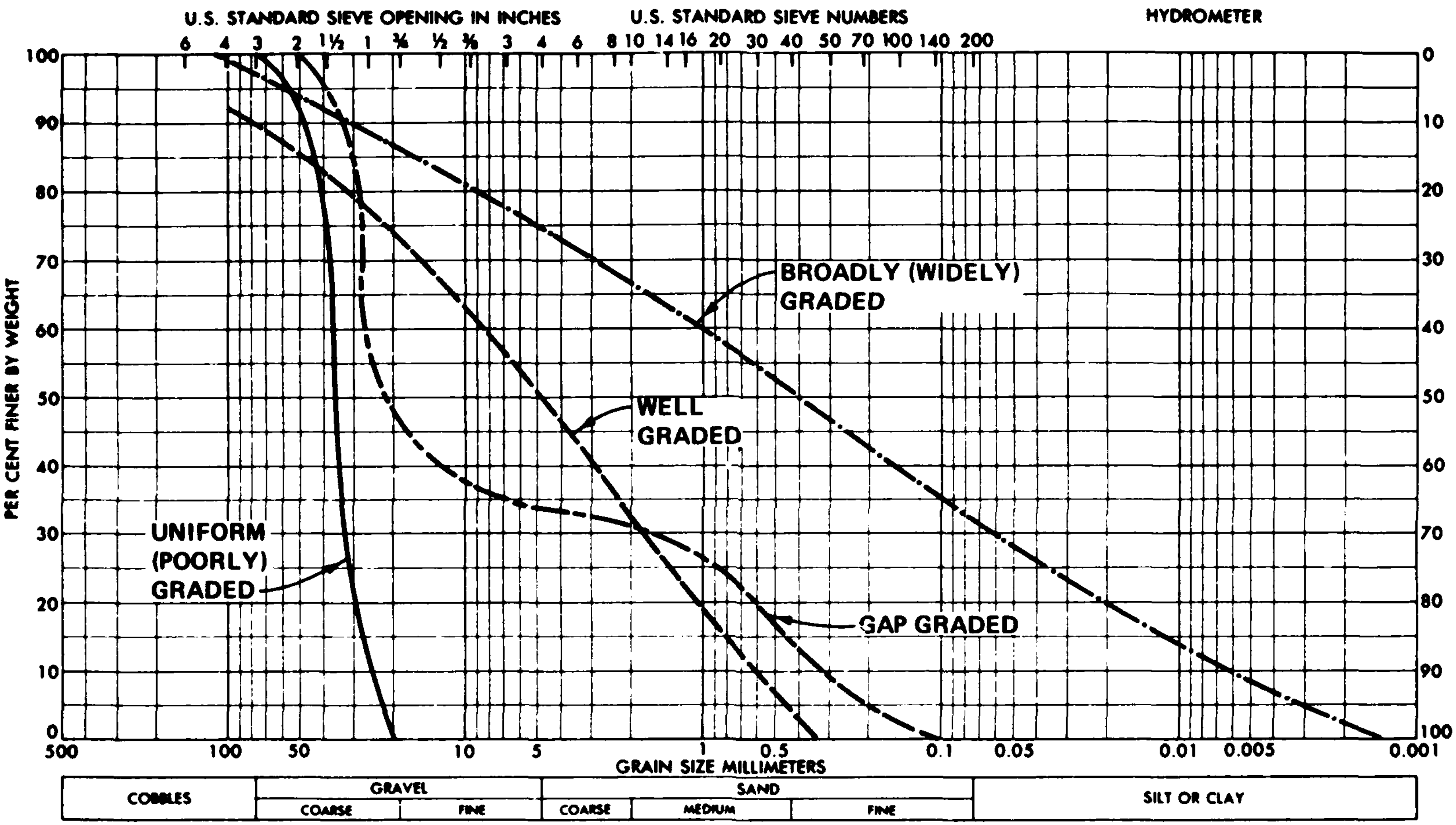

Figure 2. Typical gradation curves for gap-graded material, well-graded material, broadly-graded material, and uniform gradation

results in lower permeability. Also, cementation in limestones and arching due to particle angularity may occur when crushed rock is used for filters in earth dams. The permeability of filter materials varies significantly with the type and amount of fines present.* Even minute quantities of silt or clay can greatly diminish the permeability of filter material (Cedergren 1977). As shown in Figure 3, the addition of 2.5 percent, by dry weight, silt fines to concrete sand results in an order of magnitude decrease in permeability (Barber and Sawyer 1952). The addition of 6.5 percent silt fines to concrete sand decreases the permeability two orders of magnitude. Similar results were obtained by the addition of somewhat larger amounts of clay and limestone fines to concrete sand. As shown in Figure 4, the addition of 2.0 percent silt fines to a sand-gravel mixture results in an order of magnitude decrease in permeability (Barber and Sawyer 1952). The addition of 4.2 percent silt fines to a sand-gravel mixture decreases the permeability two orders of magnitude. Similar results were obtained by the addition of somewhat smaller amounts of clay and larger amounts of limestone, respectively, to a sand-gravel mixture. As shown in Figure 5, the addition of about 1 percent calcium montmorillonite fines to a uniform fine sand results in an order of magnitude decrease in permeability, while over 10 percent kaolinite fines would be required for a similar reduction in permeability (Fenn 1966).

Construction Considerations

13. The average in-place relative density of the filter should be at least 85 percent and no portion of the filter should have a relative density of less than 80 percent (Headquarters, Department of the Army 1971). This requirement applies to vertical (or inclined) and horizontal drains and filters under concrete structures but not to bedding layers under riprap. When the filter material is sand or contains significant portions of sand sizes, the material should be maintained in as saturated a condition as possible during compaction to prevent bulking. The filter material should pass the 3-in.

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* The amount of fines may increase due to particle crushing during field compaction, surface runoff contamination, dust, etc. The laboratory filter test should be conducted with appropriate type and amount of fines to represent conditions which will exist in the field after compaction of the filter.

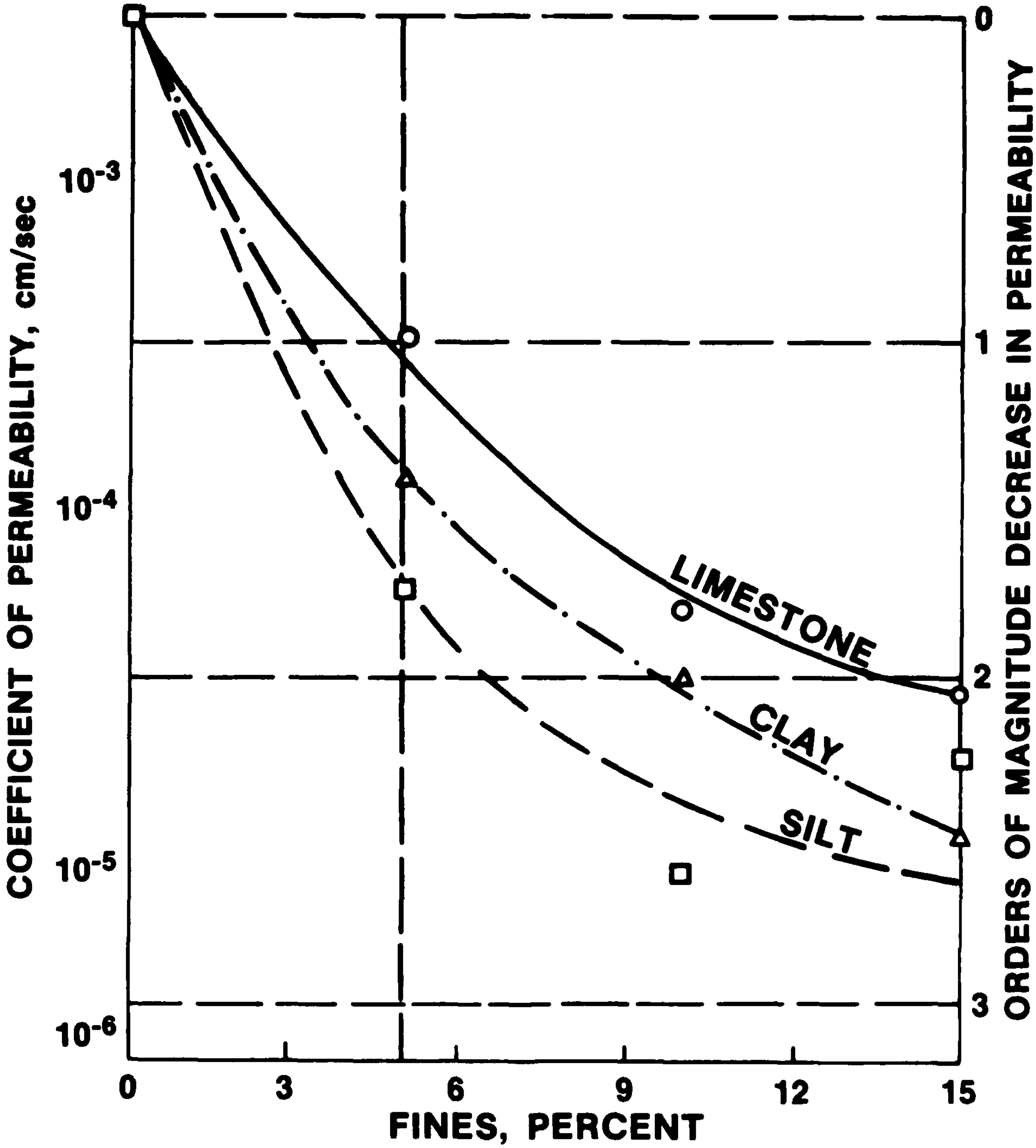

Figure 3. Influence of type and amount of fines on the permeability of concrete sand (after Barber and Sawyer (1952)

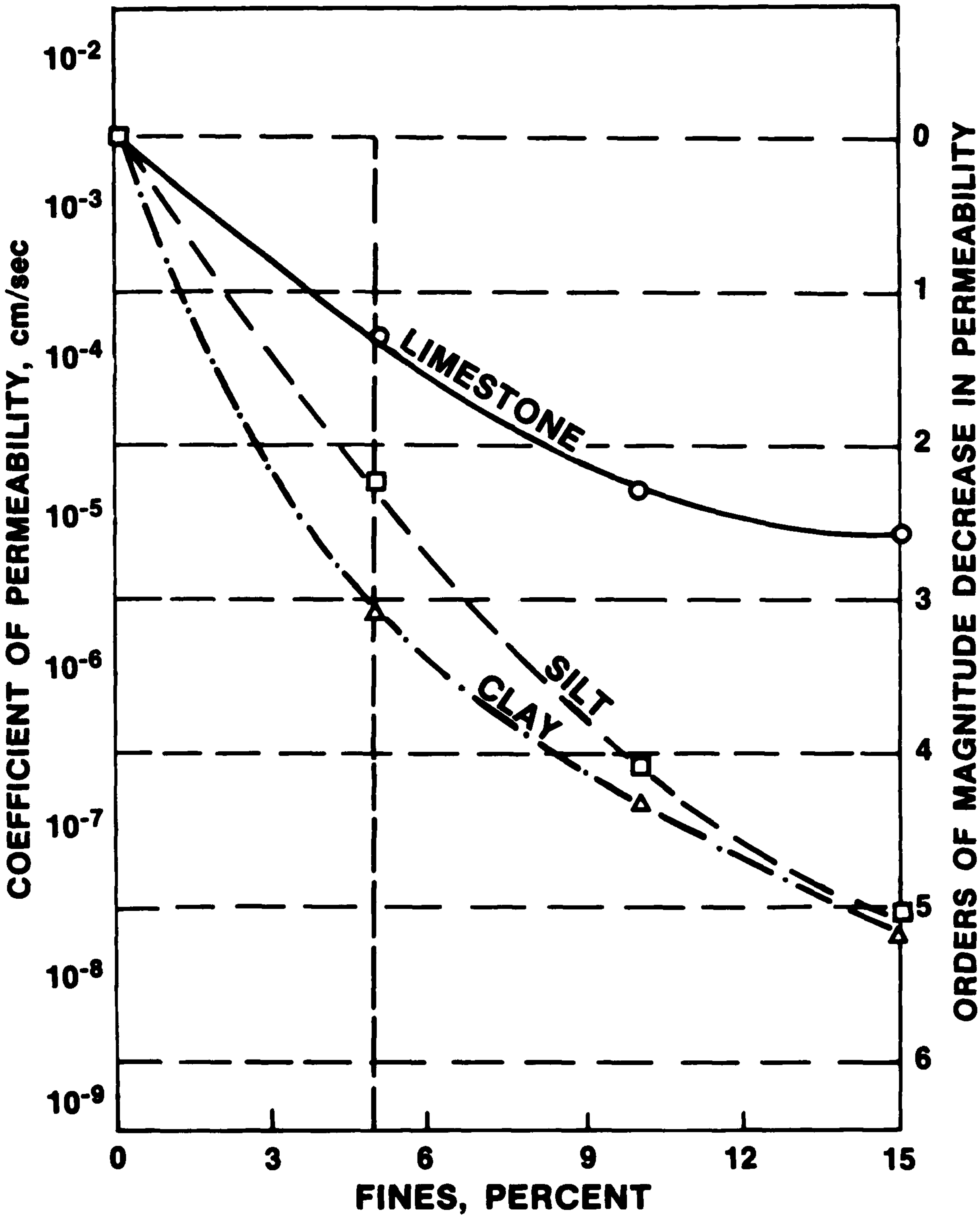

Figure 4. Influence of type and amount of fines on the permeability of a sand-gravel mixture (after Barber and Sawyer 1952)

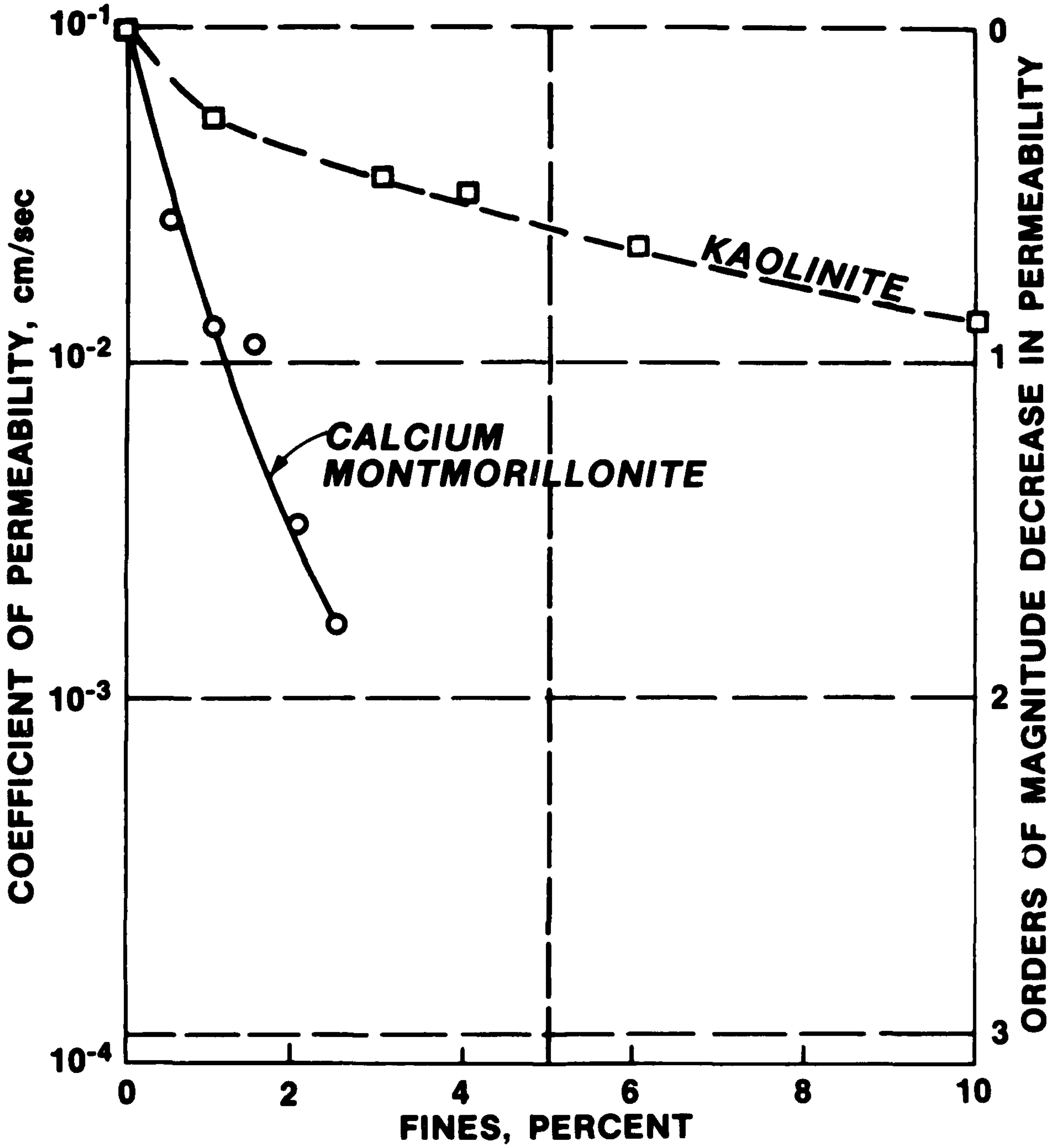

Figure 5. Influence of type and amount of clay mineral on the permeability of uniform fine sand (after Fenn 1966)

screen size for minimizing particle segregation and bridging during placement. Care should be taken during construction to prevent reduction in permeability of the filter by silt or clay carried in surface runoff, spillage of core material by hauling equipment, or degradation of filter material during compaction. Also, care must be taken to prevent coarse material from collecting (as a result of segregation during dumping and spreading) between the core and filter and forming a permeable "tube" through which core material could be lost by piping.

PART III: FILTER TESTS ON COHESIONLESS BASE MATERIALS

Introduction

14. Laboratory filter tests were conducted to check the adequacy of existing CE filter criteria. In particular, it was desired to determine whether the requirement for parallel gradations is necessary and whether supplementary stability ratios are required.

Test Equipment

15. The equipment used for conducting the filter tests is shown in Figures 6 and 7. The filter test apparatus consists of three 12-in.-diam lucite cylinders that are bolted together to form a 6-ft-high test device. Flow is downward with provision for a small back pressure to minimize air bubbles. Piezometer taps, capped with a No. 70 screen to prevent soil infiltration, were placed at intervals along the cylinder and connected to a wall-mounted manometer board to measure incremental gradients.* The quantity of flow was measured with a stop watch (nearest 0.1 sec) and graduated cylinders (100, 200, 500, or 1000 ml) at the location of the inlet to the reservoir shown in Figure 6. The temperature was measured with a centigrade thermometer, with a range of 0 to 50 deg C and accurate to 0.1 deg C, mounted inside the settling tank. (Figure 6). Ordinary tap water was used as it was not considered feasible to deair the large volume of water involved. Consequently, a decrease in permeability due to the accumulation of air in the top part of the specimen (Betram 1940) was anticipated. The influence of air segregation on the test results is discussed in Appendix A.

Test Program

16. The test program, as shown in Figures 8 and 9 and Table 2, consisted of two series of tests. The first series (Series 1A) consisted of filter tests with a uniform (poorly-graded) base protected by various filters.

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* Pressure gages were used instead of a manometer board for Test 1B-A (gages 6, 8, 9, and 10).

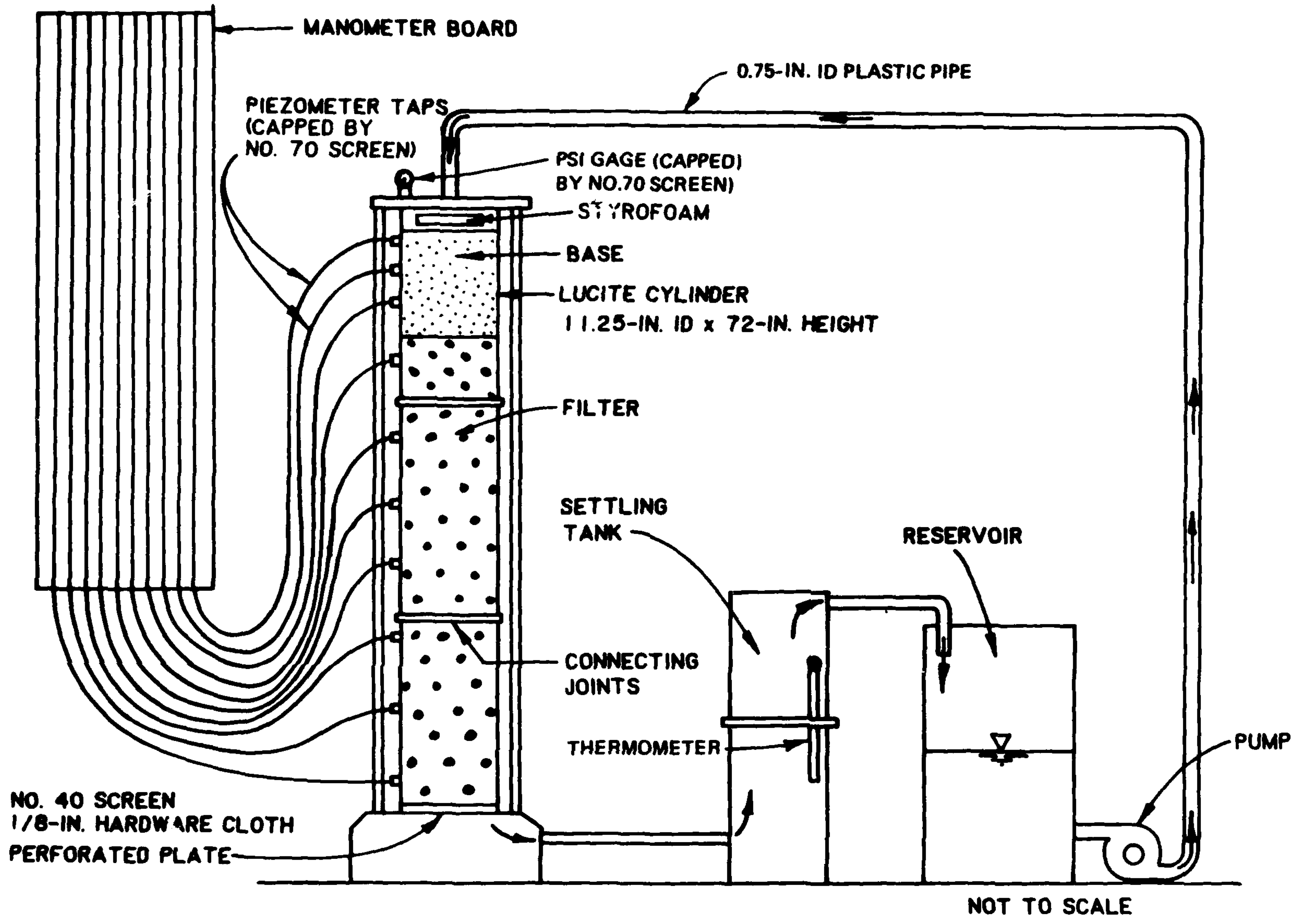

Figure 6. Schematic diagram of laboratory filter apparatus

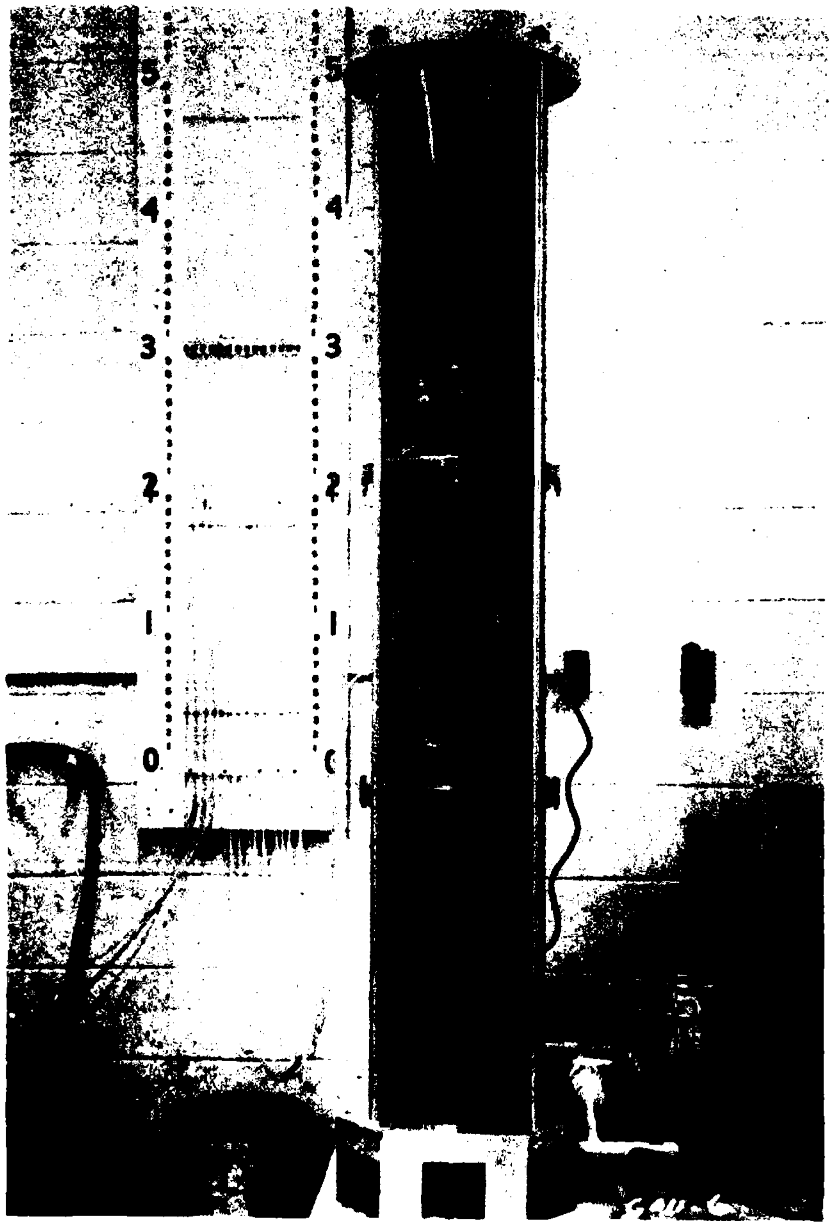

Figure 7. Laboratory filter test apparatus

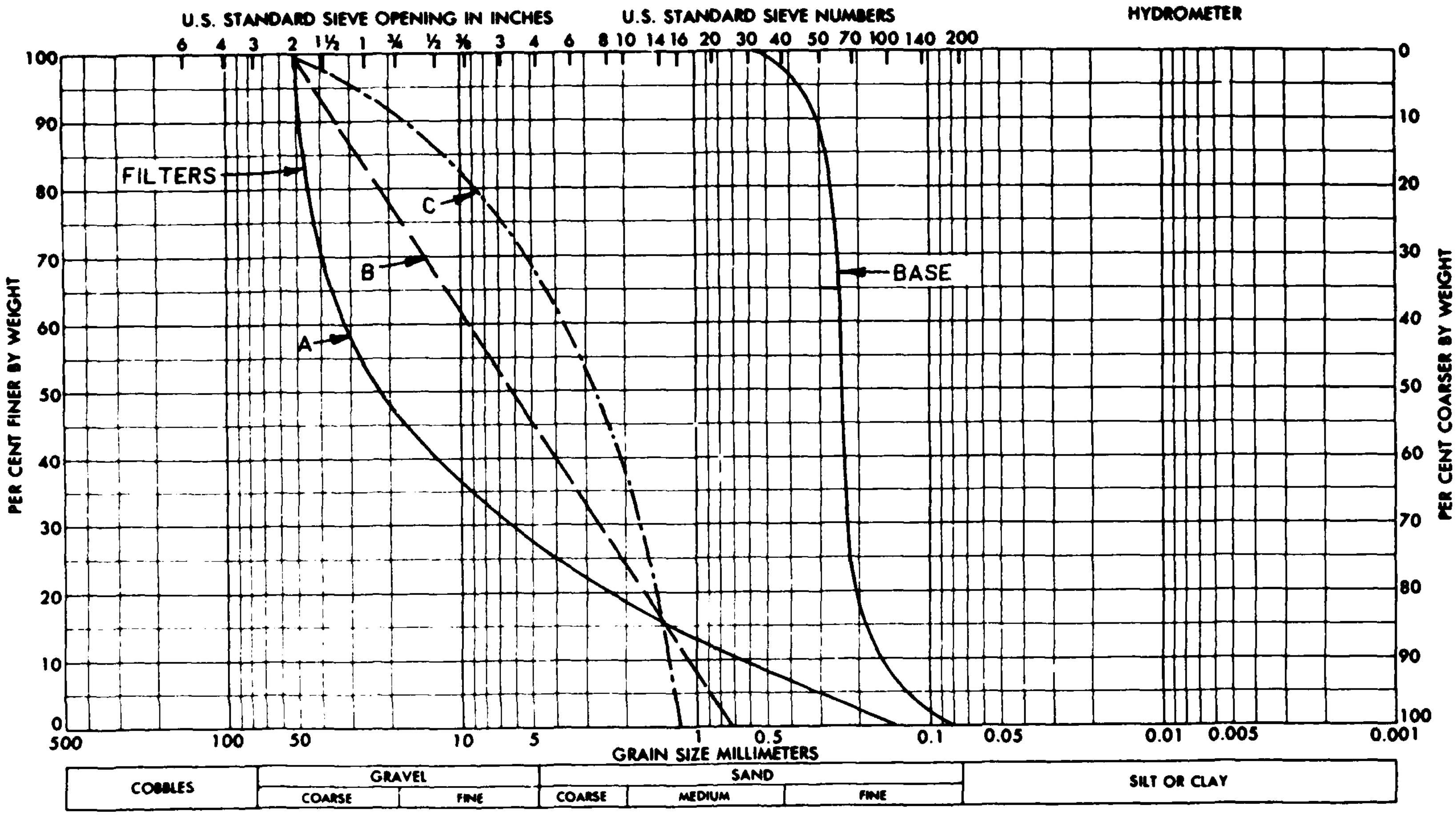

Figure 8. Gradation curves for filter tests with uniform (poorly-graded) bases (Series 1A)

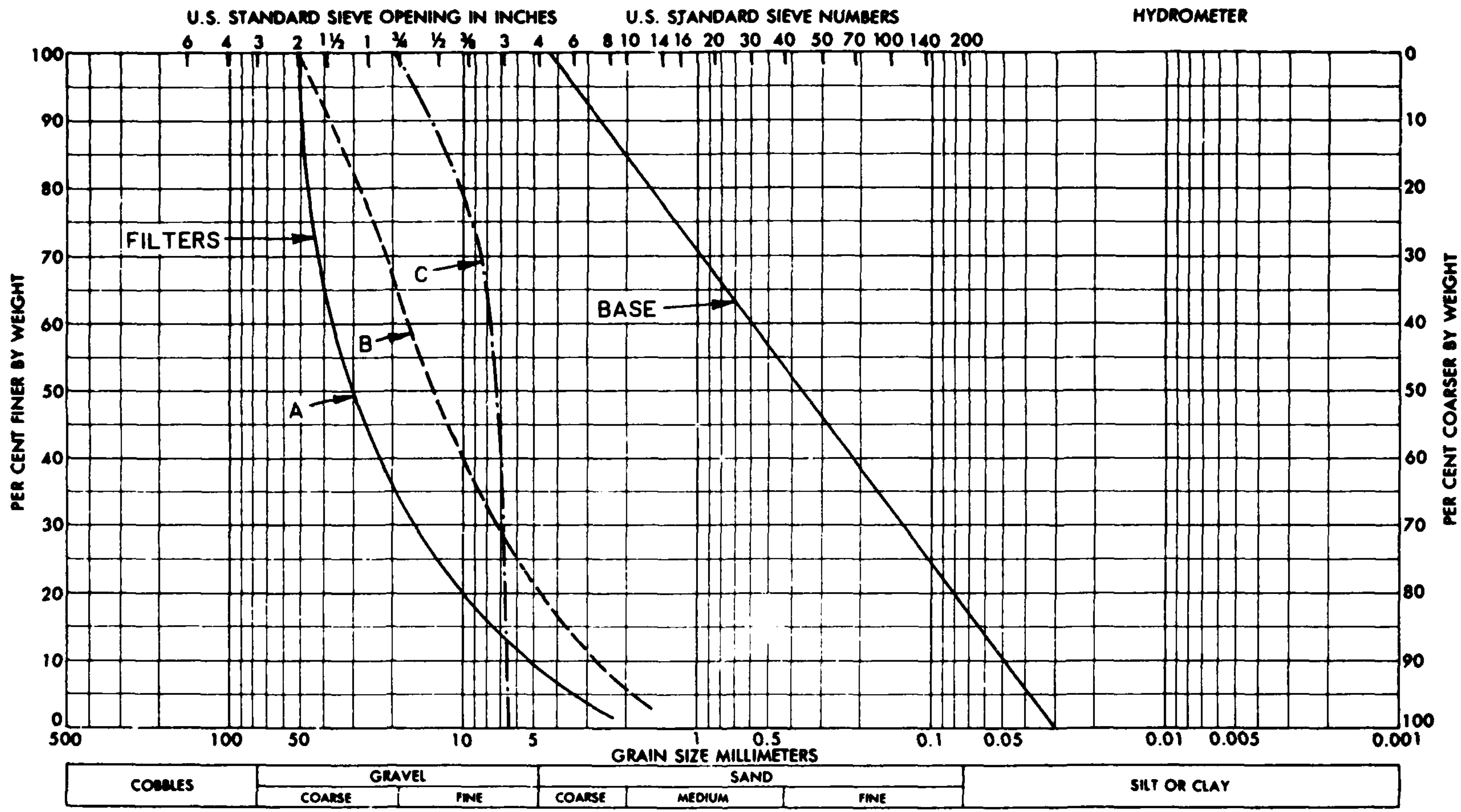

Figure 9. Gradation curves for filter tests with poorly-graded base (Series 1B)

The second series (Series 1B) consisted of filter tests with a poorly-graded base protected by various filters.

Description of Soils Tested

17. The gradations of the filter and base materials used for the Series 1A and 1B tests are shown in Appendix C and in Figures 8 and 9, respectively. The properties of the soils tested are summarized in Table 3. All materials were blended from existing stockpiles of natural sands and gravels of subrounded to subangular particles. The materials were thoroughly washed to remove dust, clay particles, and organic matter. The ratio of inside diameter of the filter test apparatus to maximum particle size of the filter was 5.6.

Specimen Construction

18. The sequence of specimen construction is illustrated in Figures 10 to 17.* The first step in construction of a specimen was to place the bottom lucite cylinder in position as shown in Figure 10. The bottom cylinder overlies a No. 40 screen, 1/8-inch hardware cloth, and perforated plate (Figure 11). The filter material was blended in 50 lb increments and mixed prior to placement (Figure 12). Using a funnel and open hose, the filter material was placed in the cylinder (Figure 13). All material was placed dry** and no compaction was used.† However, average posttest relative densities ranged from 70 to 100 percent as presented in Table 4. Following completion of construction of the bottom cylinder (Figure 14) the middle cylinder was placed in position (Figure 15) and construction continued (Figure 16). The completed specimen is shown in Figure 17. Photographs of the top cylinder of the test

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* Pressure gages were used instead of the manometer board at the time this series of photographs were taken.

** Placing material wet in an effort to avoid segregation resulted in bridging of particles and was subsequently abandoned in favor of dry placement.

† The first test (1A-A) was compacted by striking the sides of the permeameter with a rubber mallet during and after saturation of the filter material. The filter material settled from 62-in. to 59-in. (approximately 5 percent). Therefore, the results of Test No. 1A-A (not reported herein) were not considered representative. This test was superseded by Test No. 1A-A (Check).

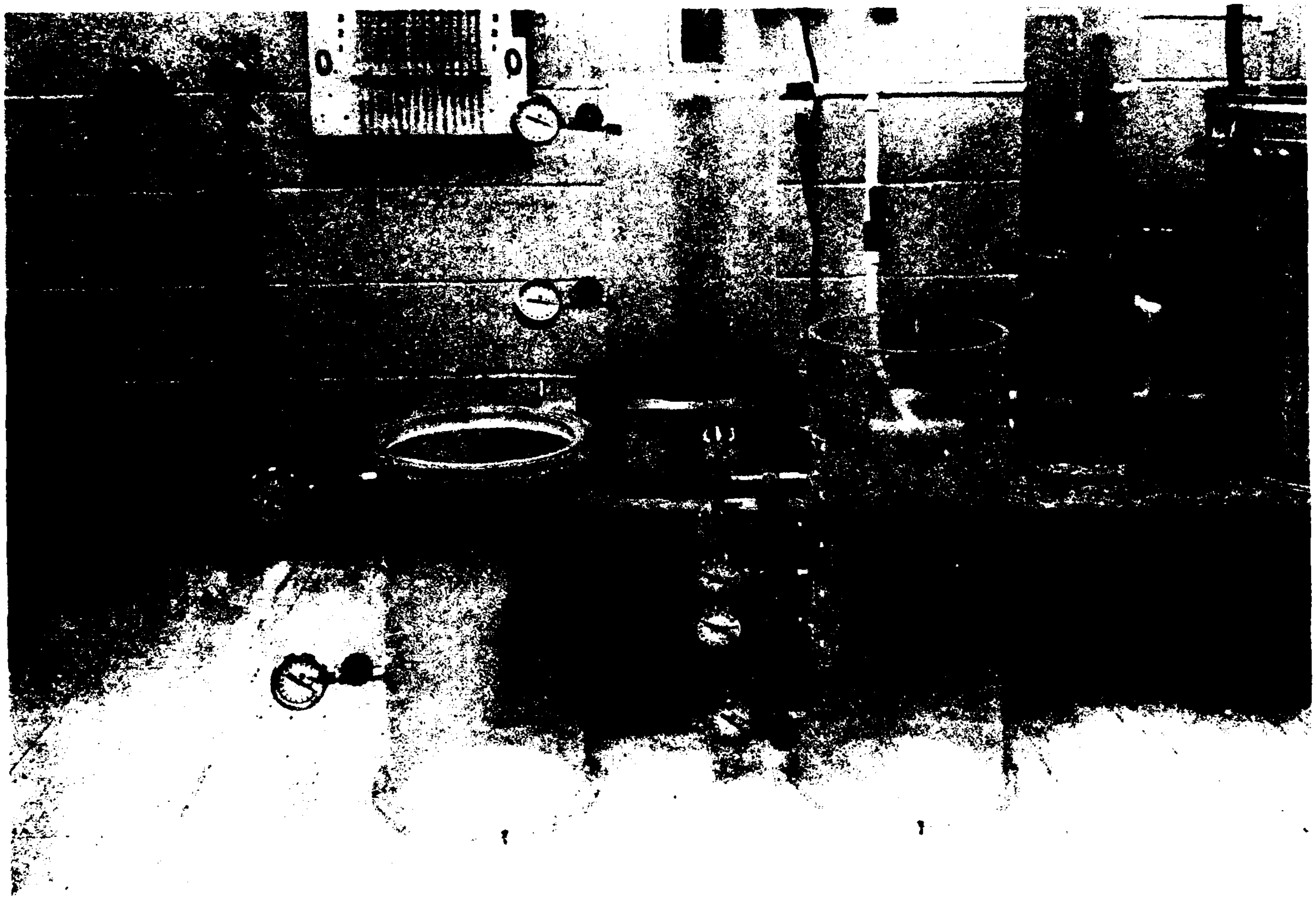


Figure 10. Lucite cylinders used to form filter apparatus

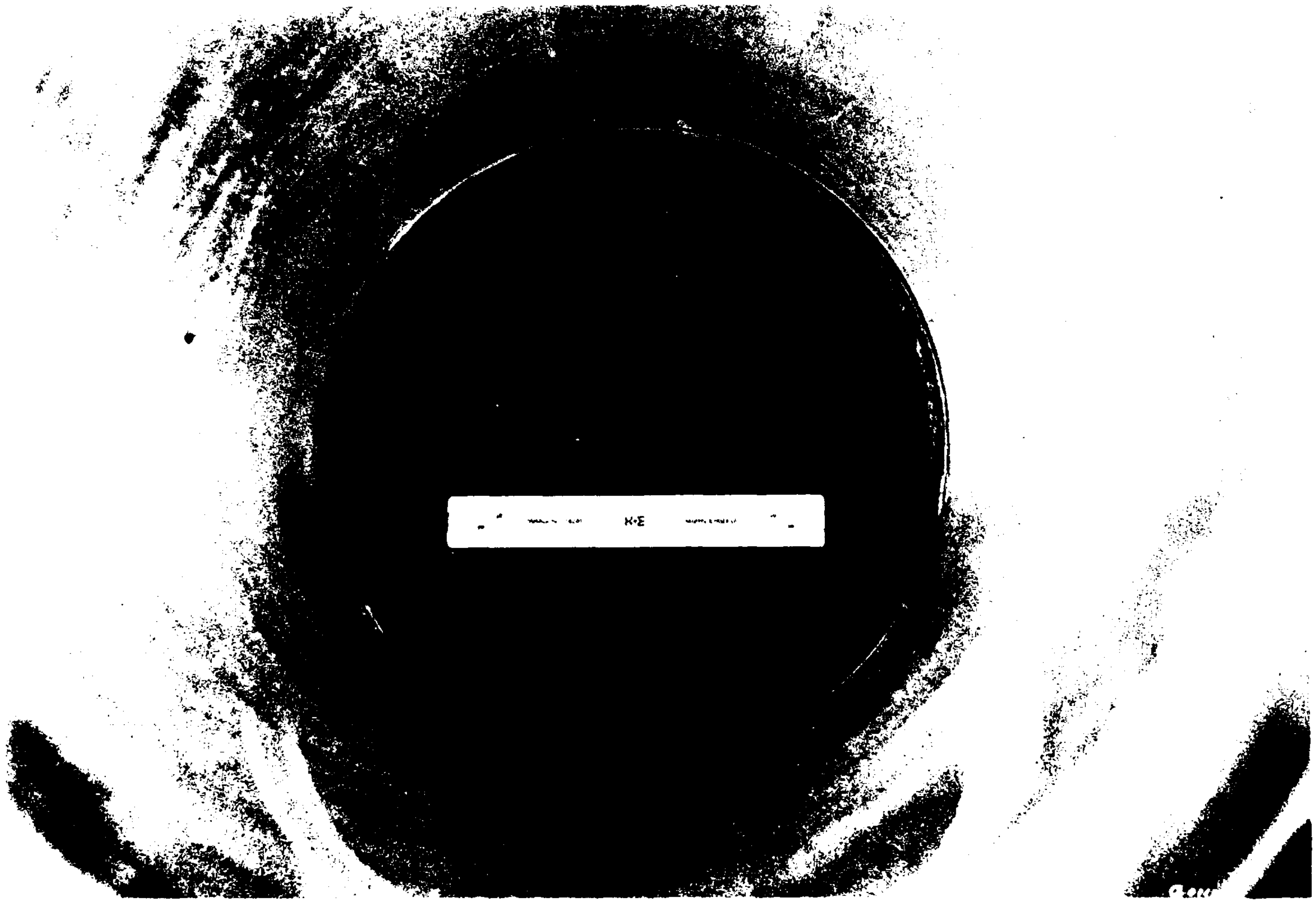


Figure 11. Bottom of filter apparatus showing screen over hardware cloth overlying perforated plate

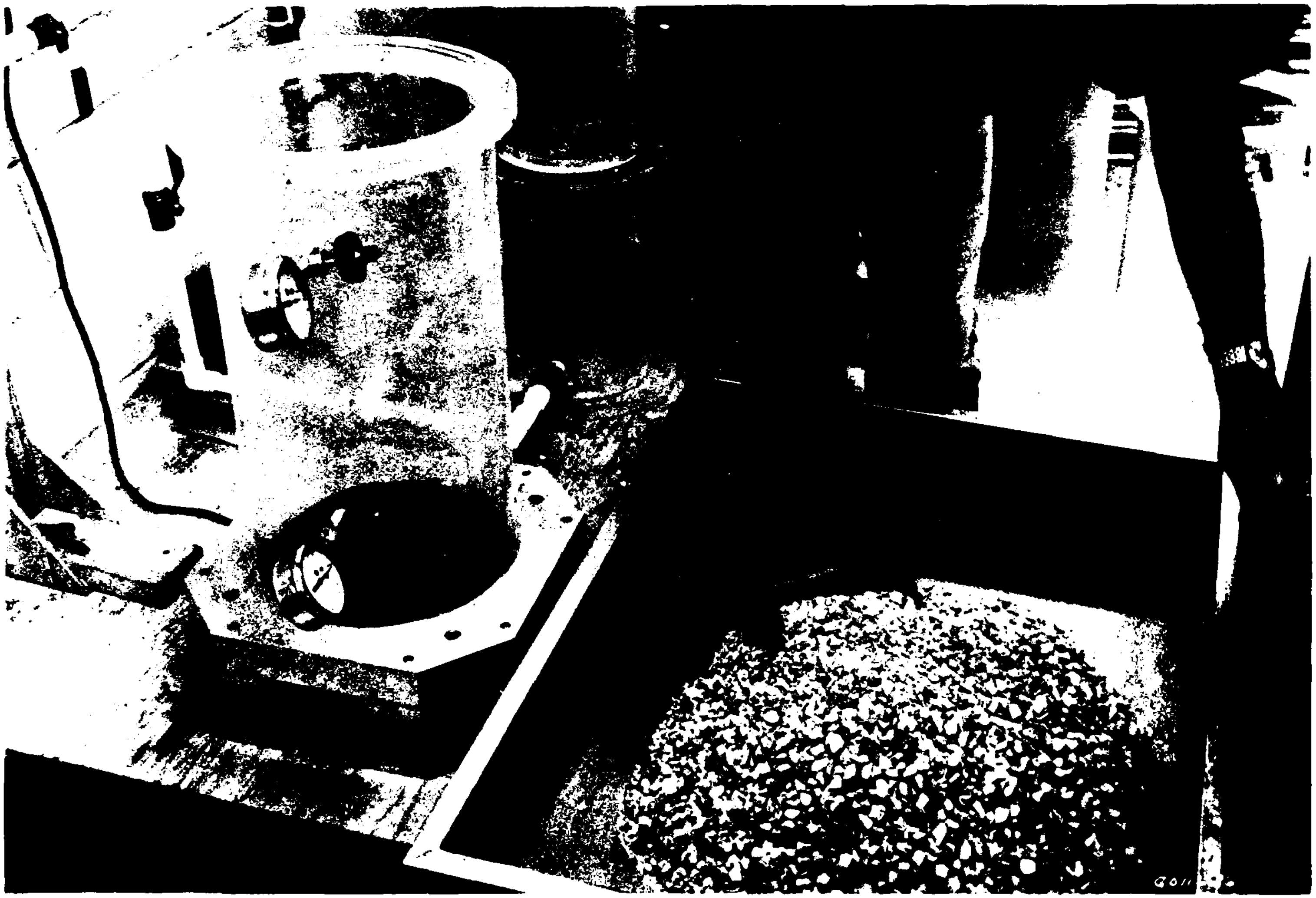


Figure 12. Mixing filter material prior to placement (Material shown is a poorly-graded sandy gravel used in Test No. 3A as discussed in Part IV.)

Figure 13. Placing filter material with funnel and open hose (Material shown is a poorly-graded sandy gravel used in Test No. 3A as discussed in Part IV.)

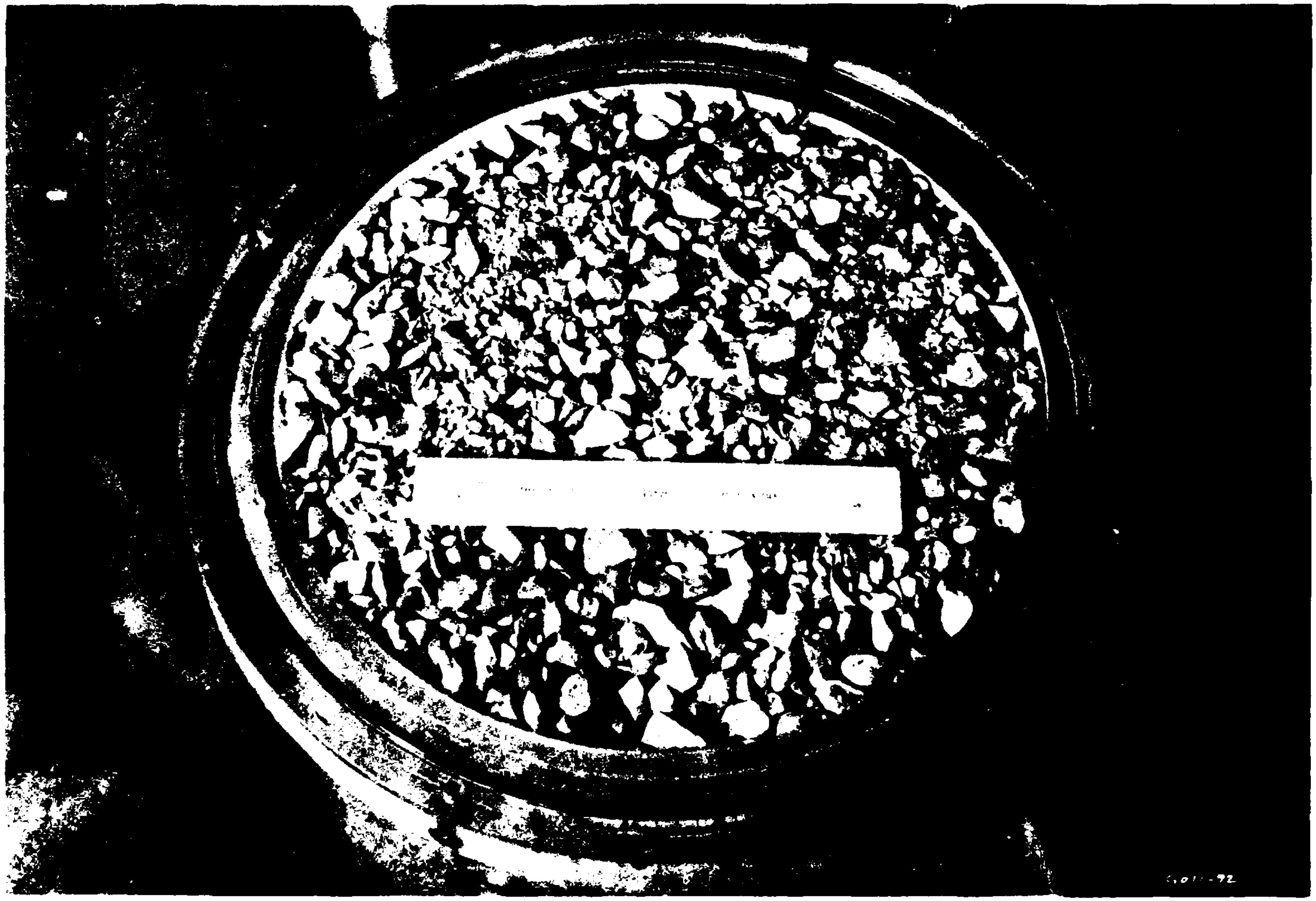


Figure 14. Bottom cylinder filled with O-ring in place (Material shown is a poorly-graded sandy gravel used in Test No. 3A as discussed in Part IV.)

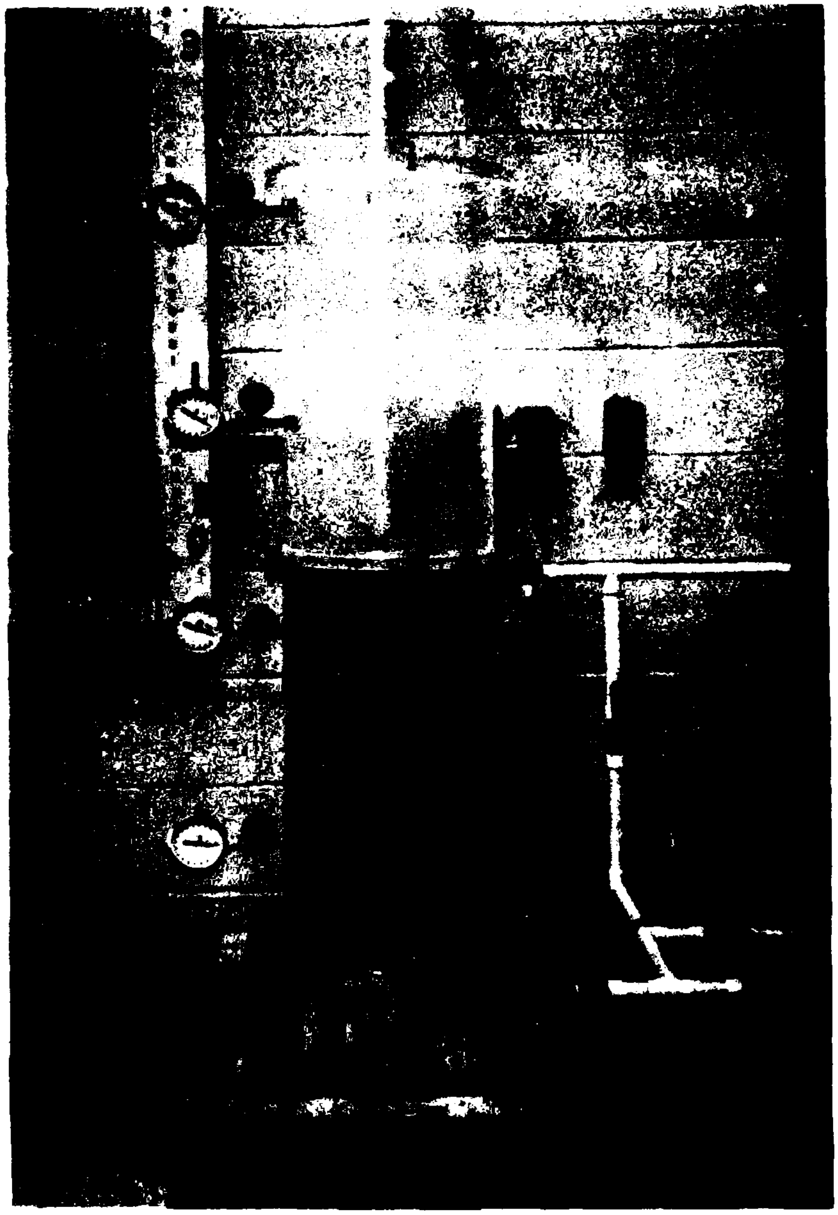


Figure 15. Middle cylinder attached prior to filling (Material shown is a poorly-graded sandy gravel used in Test No. 3A as discussed in Part IV.)

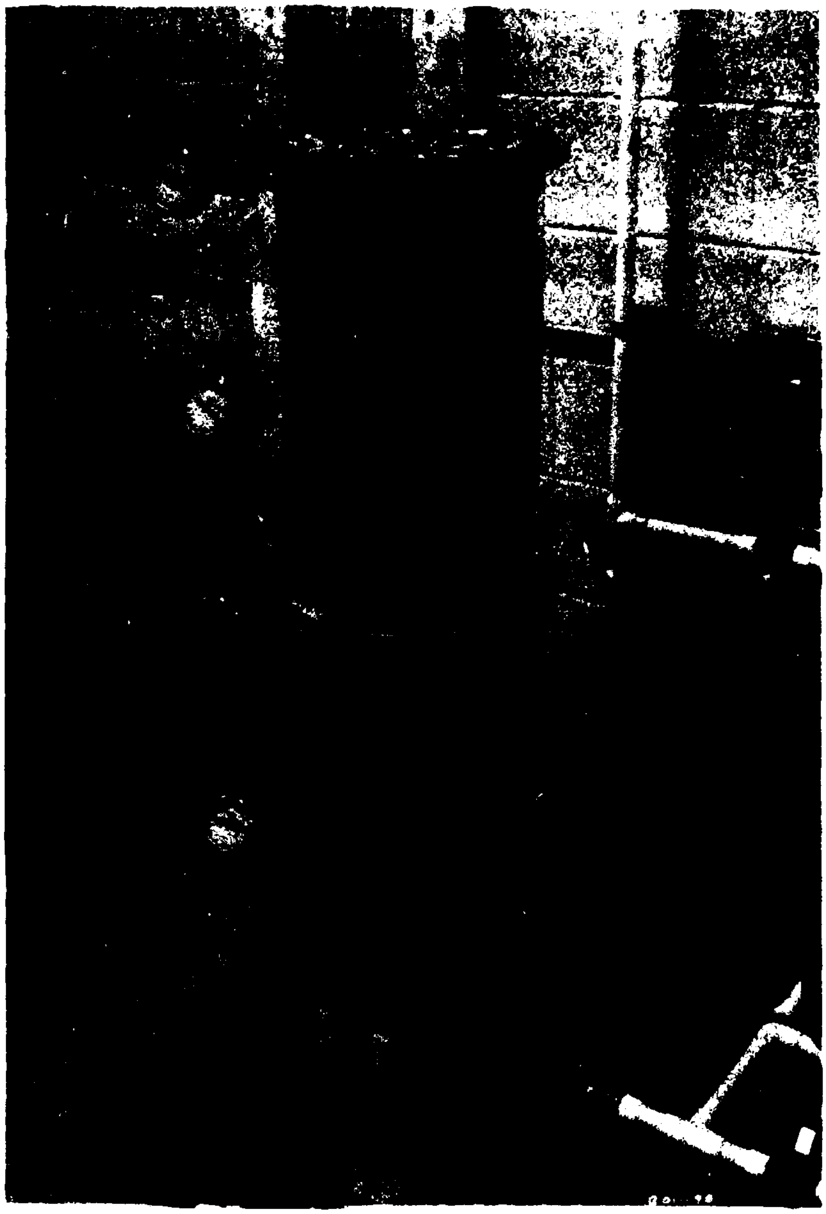


Figure 16. Bottom and middle cylinders filled (Material shown is a poorly-graded sandy gravel used in Test No. 3A as discussed in Part IV.)

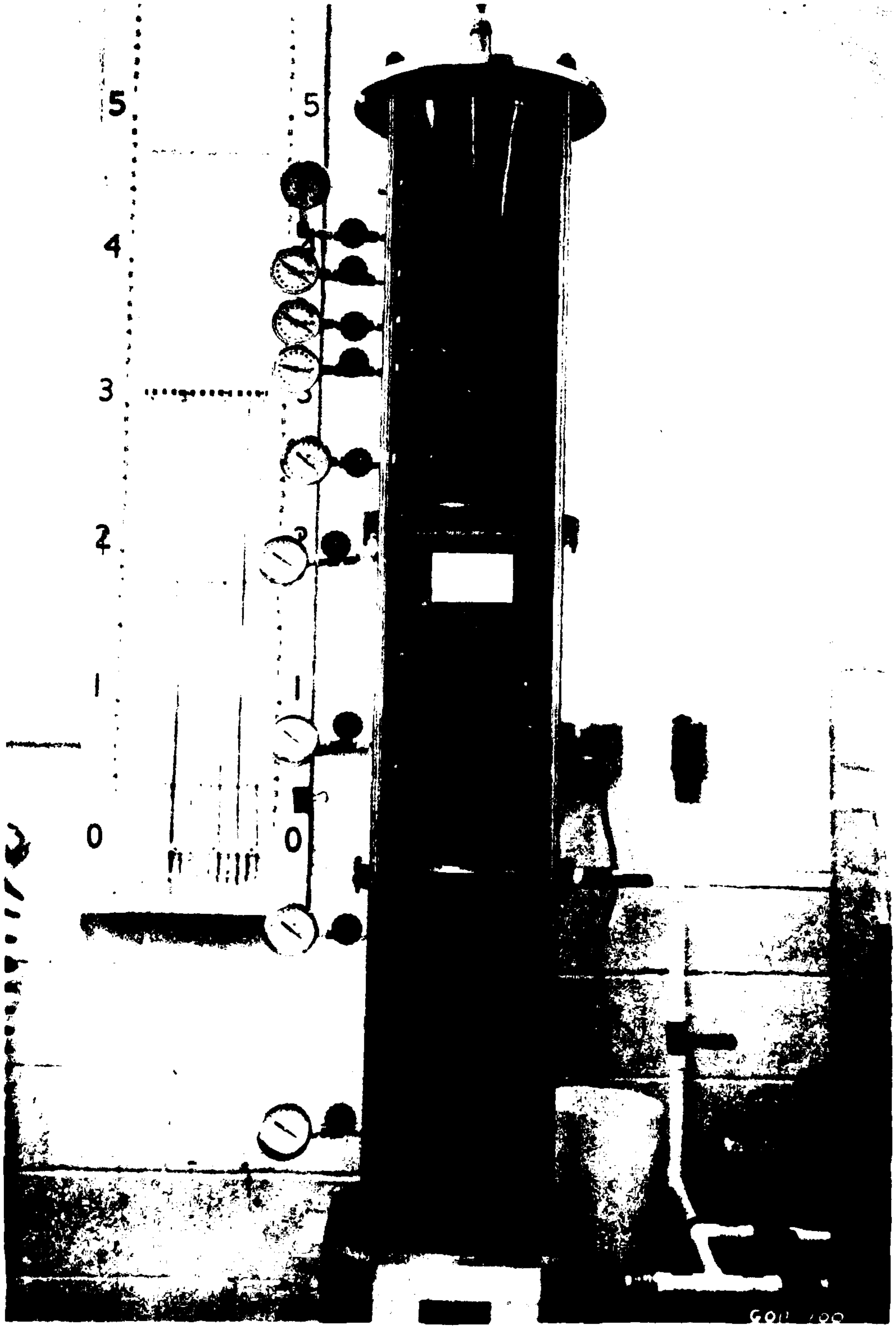


Figure 17. Specimen construction completed with no base material for this test (Filter material shown is a poorly-graded sandy gravel used in Test No. 3A as discussed in Part IV.)

apparatus showing the base filter interface with a grid overlay were made for Test No. 1B-A (Figures 18 and 19) and Test No. 1B-C (Figure 20). Following completion of the permeability test on the filter material (described in paragraph 19), the filter specimen was drained slowly over about 15 hours. The top plate of the test device was then removed and base material was placed on top of the filter material using a small scoop. The base material was placed dry and no compaction was used.

Test Procedure

19. A permeability test was conducted on the filter material prior to placing the base material (Table 5). A low vacuum was applied as water was slowly introduced from the bottom of the test device. The time required for saturation of the filter material was about 15 hours. In conducting the permeability test, a relatively low hydraulic gradient was applied across the filter material, and piezometric heads along the filter (see Figure 21 for location of piezometer taps), rate of flow through the specimen, and water temperature were measured. Readings were taken until the rate of flow became relatively constant with time. Then the hydraulic gradient was increased and the measurements were repeated. This sequence was continued until the maximum hydraulic gradient was obtained. The purpose of the permeability test was not to document a property of the soil (turbulent flow conditions existed in the filters for some tests as shown in Table 5) but rather to compare the relative permeabilities of the filter and the base.

20. Following completion of the permeability test on the filter material, the test device was drained slowly under gravity flow over about 15 hours and the base material placed as described in paragraph 18. The saturation process for the filter presented in the previous paragraph was repeated for the filters and base. In conducting the filter test, a relatively low hydraulic gradient was applied across the base material (Table 5), and piezometric heads along the base and filter, rate of flow through the specimen, and water temperature were measured. Readings were taken until the rate of flow became relatively constant with time. This procedure was continued until the maximum hydraulic gradient was obtained. Piezometer, flow, and water temperature readings are given in Appendix B.

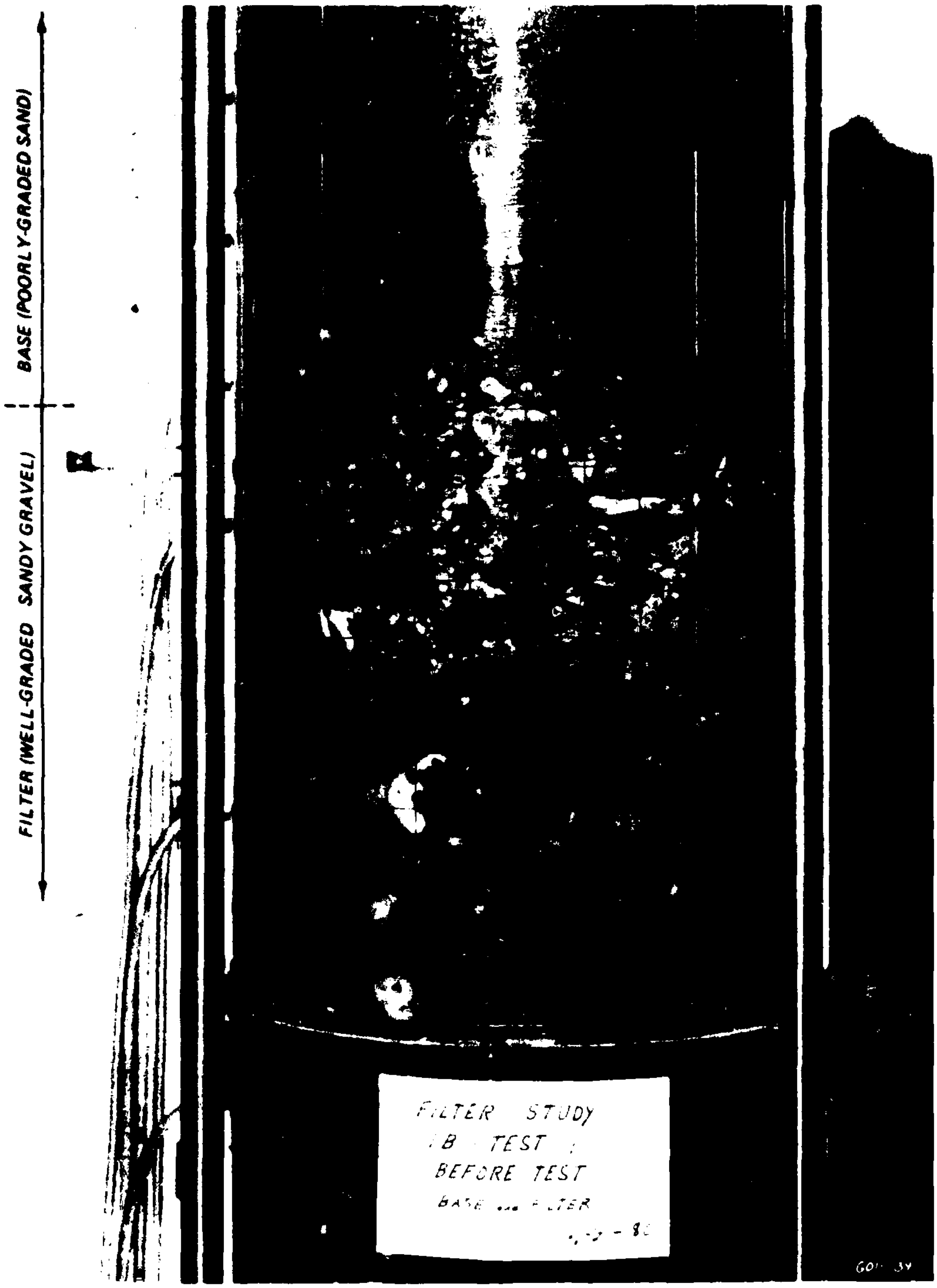


Figure 18. Top cylinder with grid before test for Test No. 1B-A

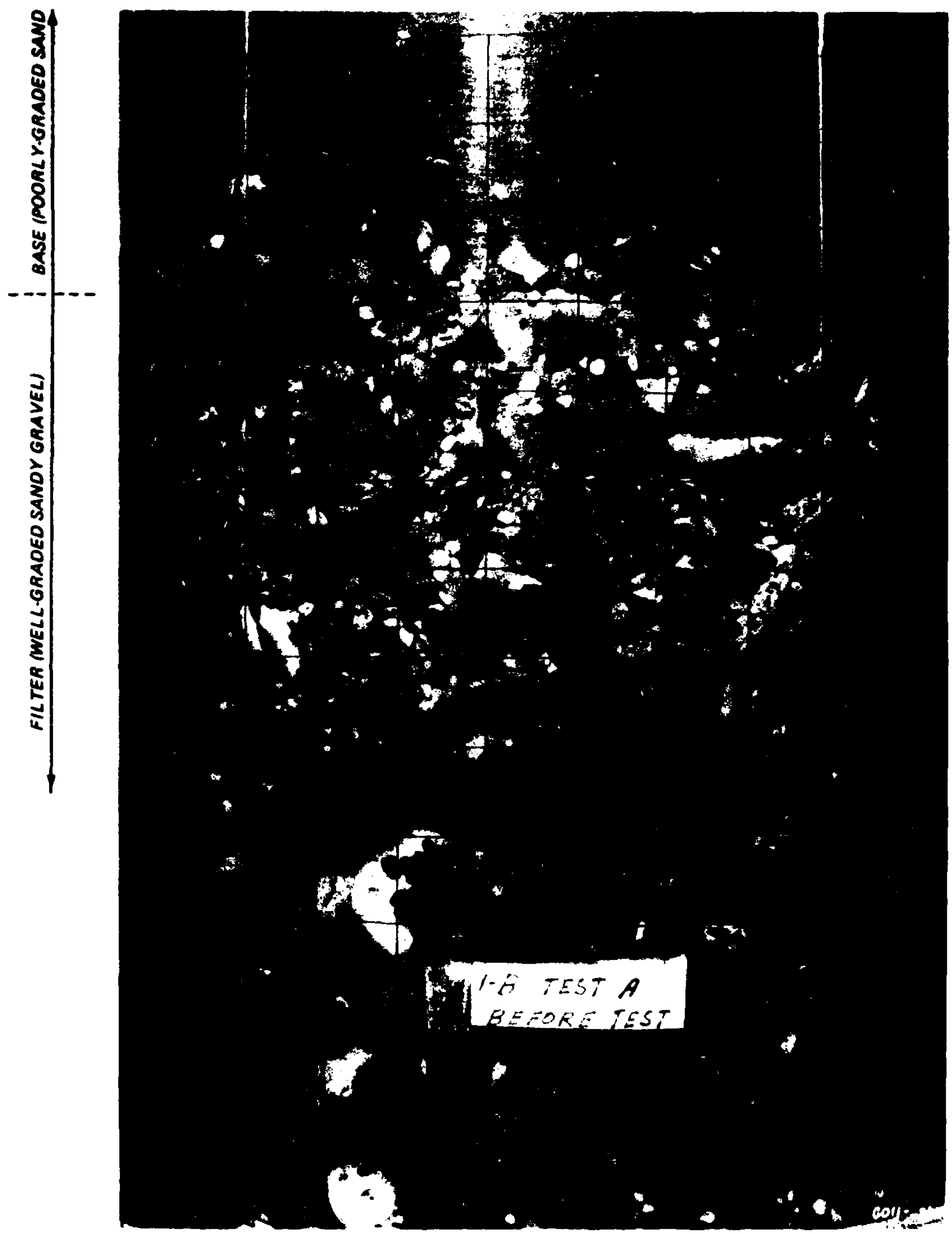


Figure 19. Close-up of top cylinder with grid before test for Test No. 1B-A

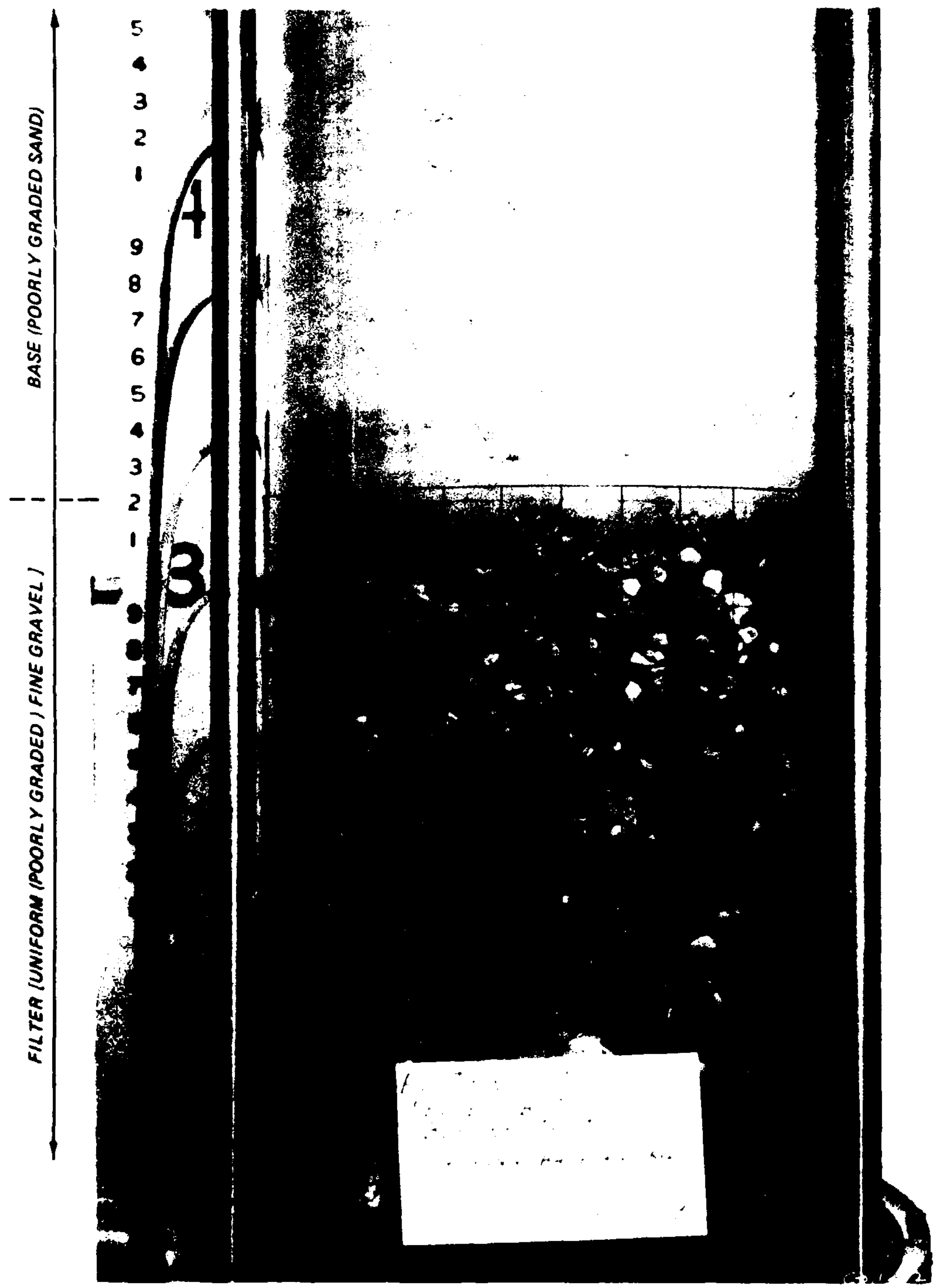


Figure 20. Top cylinder with grid before test for Test No. 1B-C

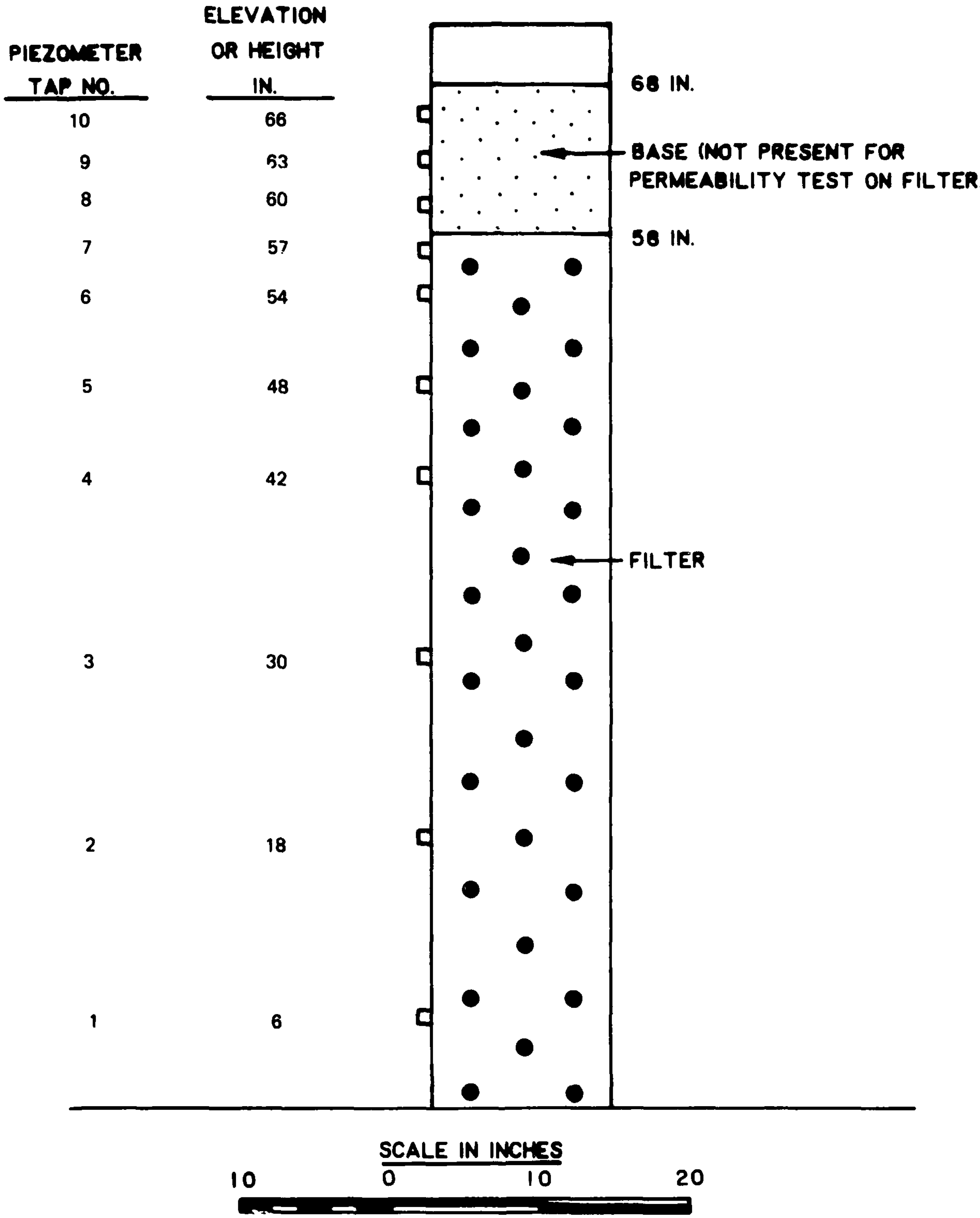


Figure 21. Schematic diagram showing location of piezometer taps

Posttest Sampling

21. Upon completion of the filter test, the water was drained from the specimen under gravity flow over a 15-hour period. The specimen was marked vertically into 6-in. increments (Figure 22). Each increment was removed, as shown in Figures 23 and 24, for determination of dry unit weight* and gradations (see Appendix D).

Test Results

Methods used to evaluate filter performance

22. Filter requirements. As previously mentioned in Part II, the design requirements for filters are to retain the protected soil, allow relatively free movement of water, have sufficient discharge capacity, and prevent particle movement within the filter. The discharge capacity of the filter is calculated based upon the total quantity of seepage determined from a flow net assuming infinite permeability for the filter (Cedergren 1977). The fulfillment of the remaining design requirements may be determined by the filter test.

23. Migration of base into filter. Filter failure may occur because of migration of a significant quantity of base material into the filter. Some migration of the base is needed to develop filter action. The required thickness is (Sherard 1981)

$$t = 2\left(\frac{D_{85_B}}{0.15}\right) \qquad (10)$$

where

t = required base migration to develop filter action

D_{85_B} = size of base material at 85 percent passing

---

* This method for determining dry unit weight can be in error because the measurement of the height of each increment is rather approximate. For example, a 1/4-in. error in height of the increment would change the dry unit weight about 5 lb/cu ft. However, the profile of dry unit weight versus specimen height is capable of showing trends in the data.

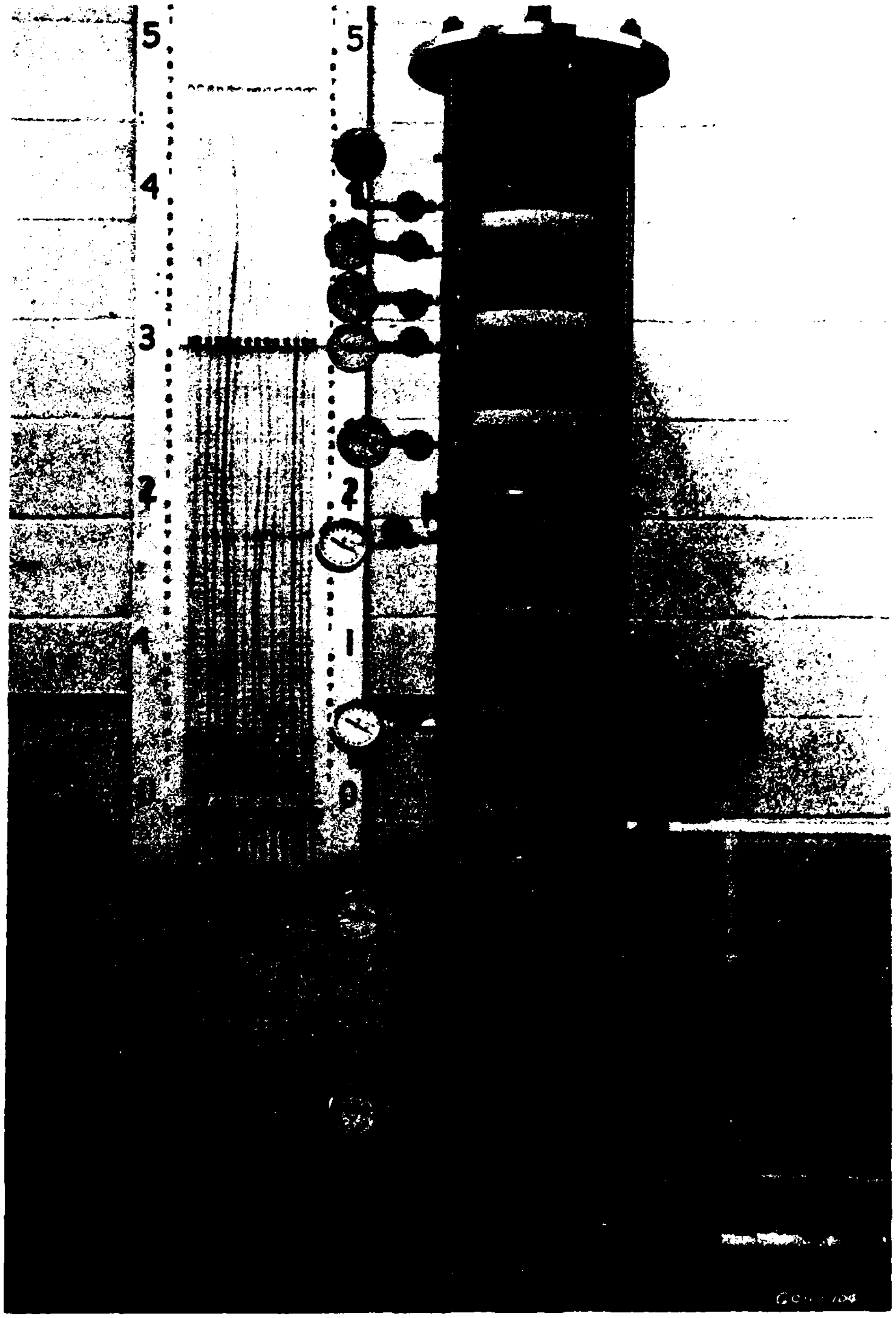


Figure 22. Overall view of specimen prior to posttest sampling (no base material for this test)

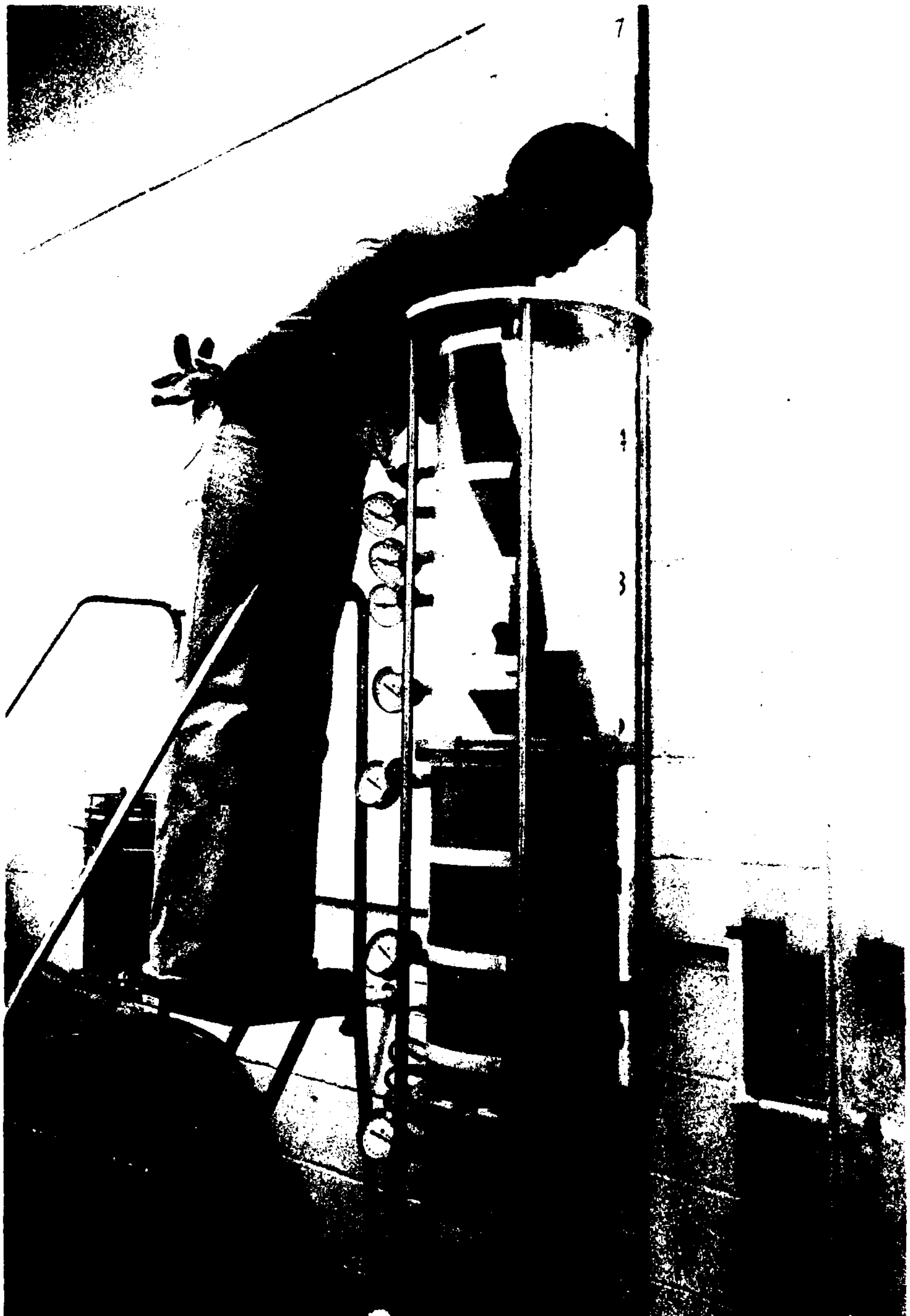


Figure 23. Removal of last increment of filter material during posttest test sampling (no base material for this test)

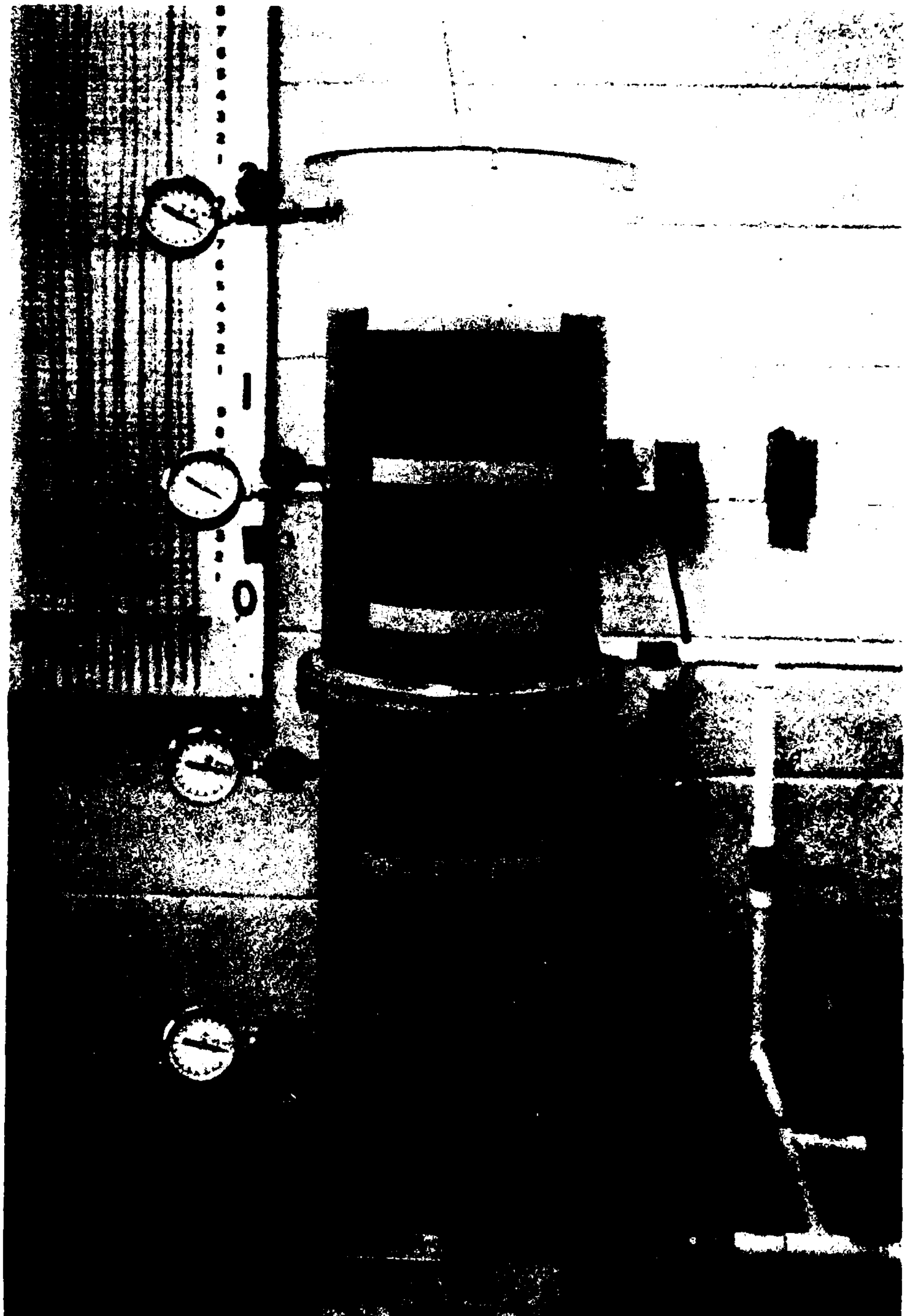


Figure 24. First increment of filter material removed from middle cylinder during posttest sampling (no base material for this test)

Migration of the base into the filter in the interior of the specimen was not determined directly, but was rather inferred from visual observation through the lucite cylinder of penetration of the base around the periphery of the filter specimen, comparison between posttest gradations of the filter and the filter material blended for the test for various heights, and changes in permeability for the upper part of the filter with time. Various limitations are present in the techniques used to determine base migration. The interface between the filter and the cylinder wall results in larger pore channels within the filter, as compared to the interior of the filter, with resulting abnormally high base migration around the periphery of the specimen.* Migration of the base into the filter was possible during construction and/or saturation of the specimen. This pretest migration adds a degree of uncertainty to inferences concerning base migration drawn from the posttest dry unit weight profile of the filter, comparison between posttest gradations of the filter and the filter material blended for the test for various heights, and changes in permeability for the upper part of the filter with time. Also, as shown in Appendix A, air segregation (accumulation of air in the voids of the soil) or base migration occurred in the uppermost portion of the filter (54- and 57-in.) in each of the filter tests analyzed (5 of 6 tests conducted). Since air segregation would lower the permeability, this would add to the degree of uncertainty of using changes in permeability of the upper part of the filter with time to determine base migration into the filter.

24. Relative permeability of filter. As given previously in Part II, Equation 6, the filter material should have 25 or more times the permeability of the base. This requirement is determined from the filter test by comparing the ratio of the permeability of the filter to the permeability of the base.

25. Particle movement within the base and filter. Internal movement of particles within the base or filter was determined by visual observation of the specimen through the lucite cylinder during the test. Also, as shown in Appendix A, air segregation (accumulation of air in the voids of soil) or migration of base occurred in the upper portion of the base (63- to 60-in.) in each of the filter tests analyzed (5 of 6 tests conducted). Since air

* A unique way to eliminate this problem using an annulus of side material, coarser than the base and finer than the filter, between the filter and the cylinder wall has been developed (Sherard, Dunnigan, and Talbot 1984).

segregation would lower the permeability, this would add to the degree of uncertainty of using changes in permeability within the base in determining internal movement of particles within the base. Possible base migration into the filter limited the application of posttest dry unit weight profiles, posttest gradations, and changes in permeability in determining internal movement of particles within the filter.

Filter tests with a
uniform (poorly-graded base

26. Migration of base into filter. The calculated base migration to develop filter action (Equation 10) ranged from 0.1- to 0.2-in. as shown in Table 6. Visual observations of the specimen through the lucite cylinder indicated that migration of the base around the periphery of the filter occurred to a depth of about 4 in. during construction in Test No. 1A-A (check), to a depth of about 3 in. during Test No. 1A-B, and just slightly during Test No. 1A-C (Table 7).

27. Posttest dry unit weight profiles of the filter for Test No. 1A-A (check), 1A-B, and 1A-C are given in Figures 25, 26, and 27, respectively. As shown in Table 7, for Test No. 1A-A (check), the posttest dry unit weight for the top 6 in. of the filter is 24 percent denser than the remaining portion of the filter because of migration of base into the filter during construction prior to conducting the filter test. Test No. 1A-B and 1A-C did not show any significant changes in the posttest dry unit weight for the top 6 in. of the filter.

28. The posttest grain size of fine particles (5, 10, and 15 percent fines) profile of the filter for Test No. 1A-A (check), 1A-B, and 1A-C, are given in Figures 28, 29, and 30, respectively. Base migration would be indicated by a smaller particle size at the top of the filter. No indication of migration of base into the filter is apparent. Comparison among posttest gradation of the top, middle, and bottom 6 in. of the filter are given in Appendix E and summarized in Table 7. Base migration would be indicated by an increase in the percent of finer particles at the top of the filter. No evidence of migration of base into the filter is present.

29. Changes in permeability with time for various heights within the base and filter for Test No. 1A-A (check), 1A-B, and 1A-C are given in Figures 31 to 36, respectively. For these plots, the permeability at zero time was taken as the final permeability measured on the filter during the

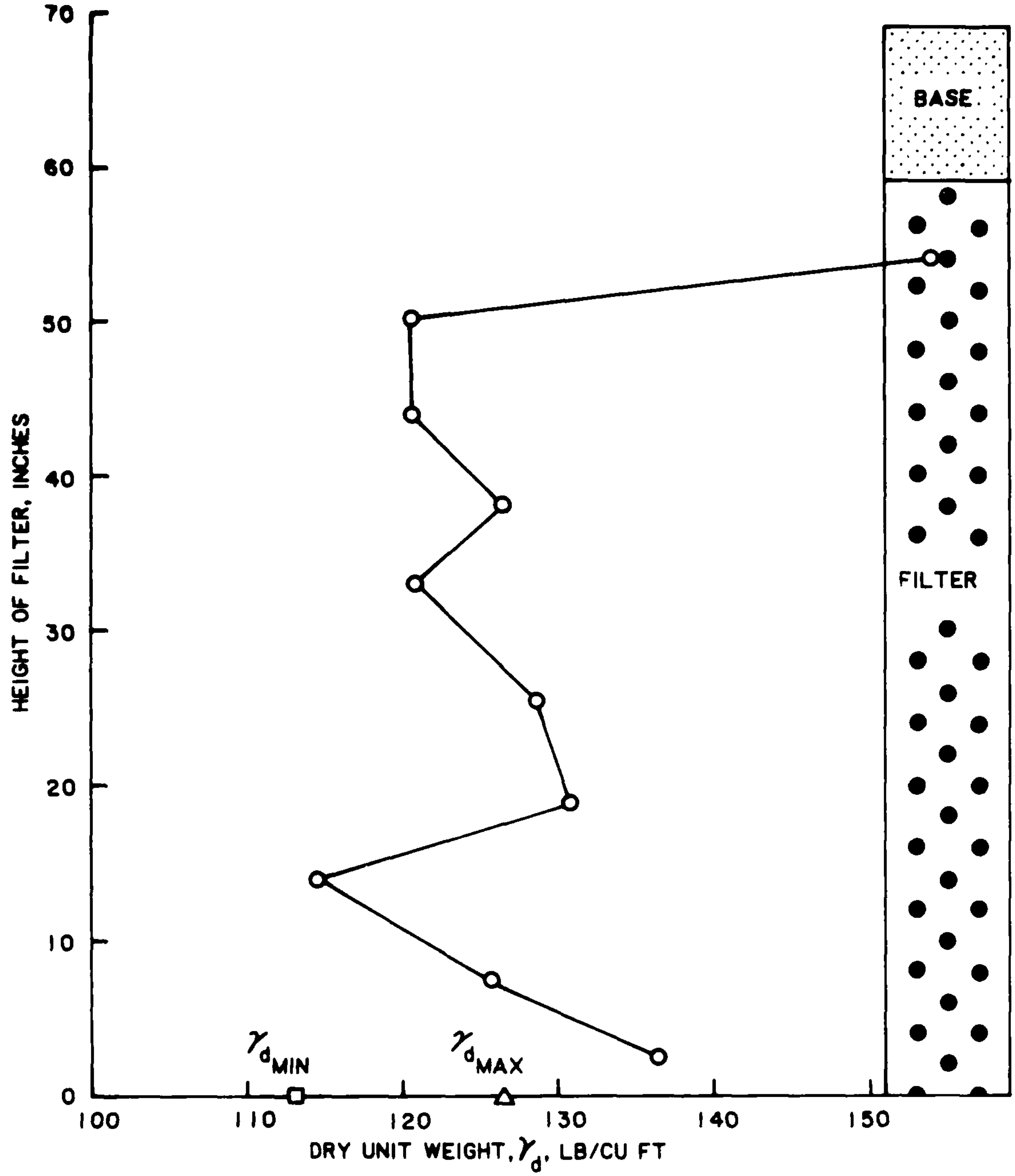


Figure 25. Posttest dry unit weight profile of filter for Test No. 1A-A (check)

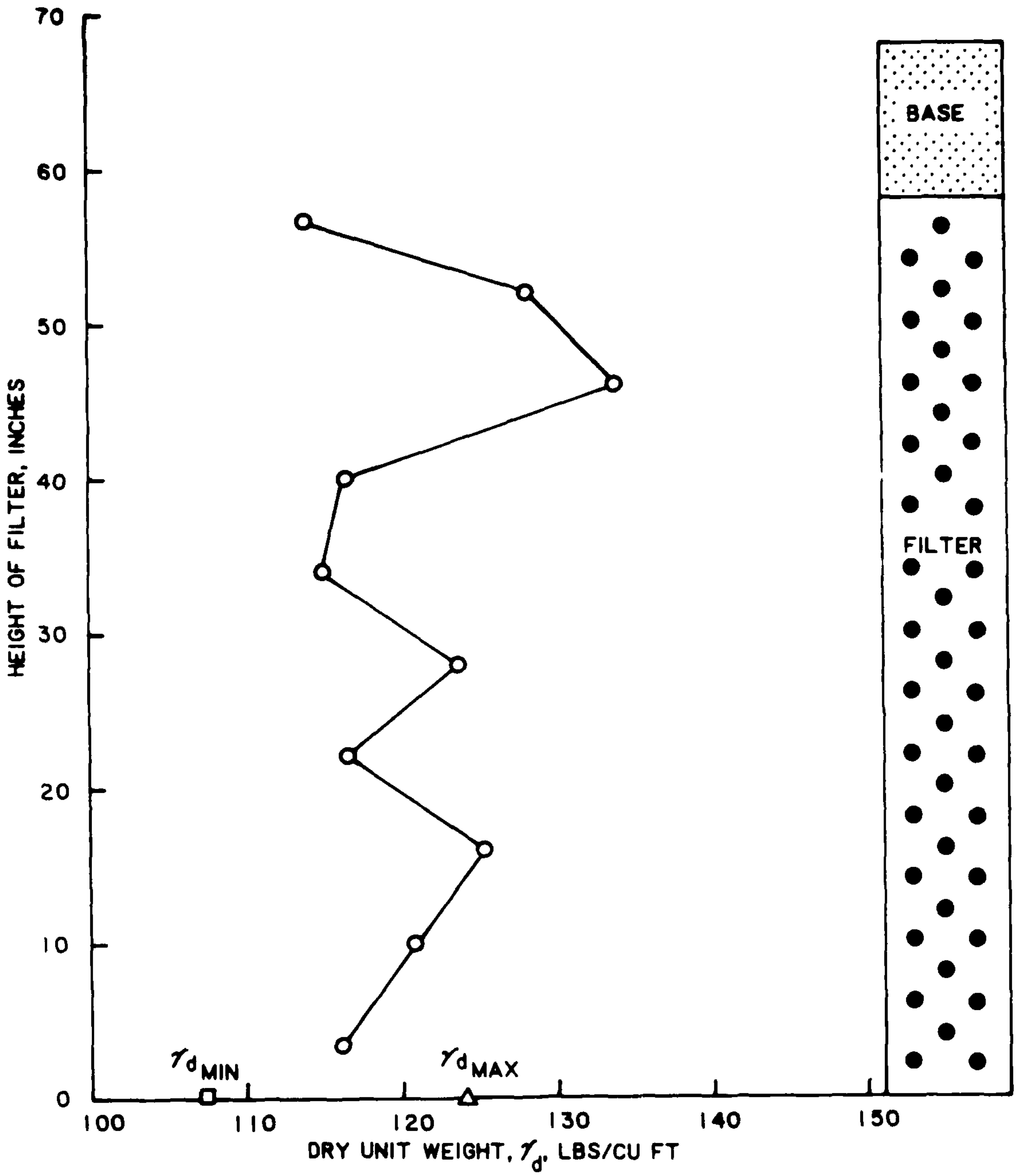


Figure 26. Posttest dry unit weight profile of filter for Test No. 1A-B

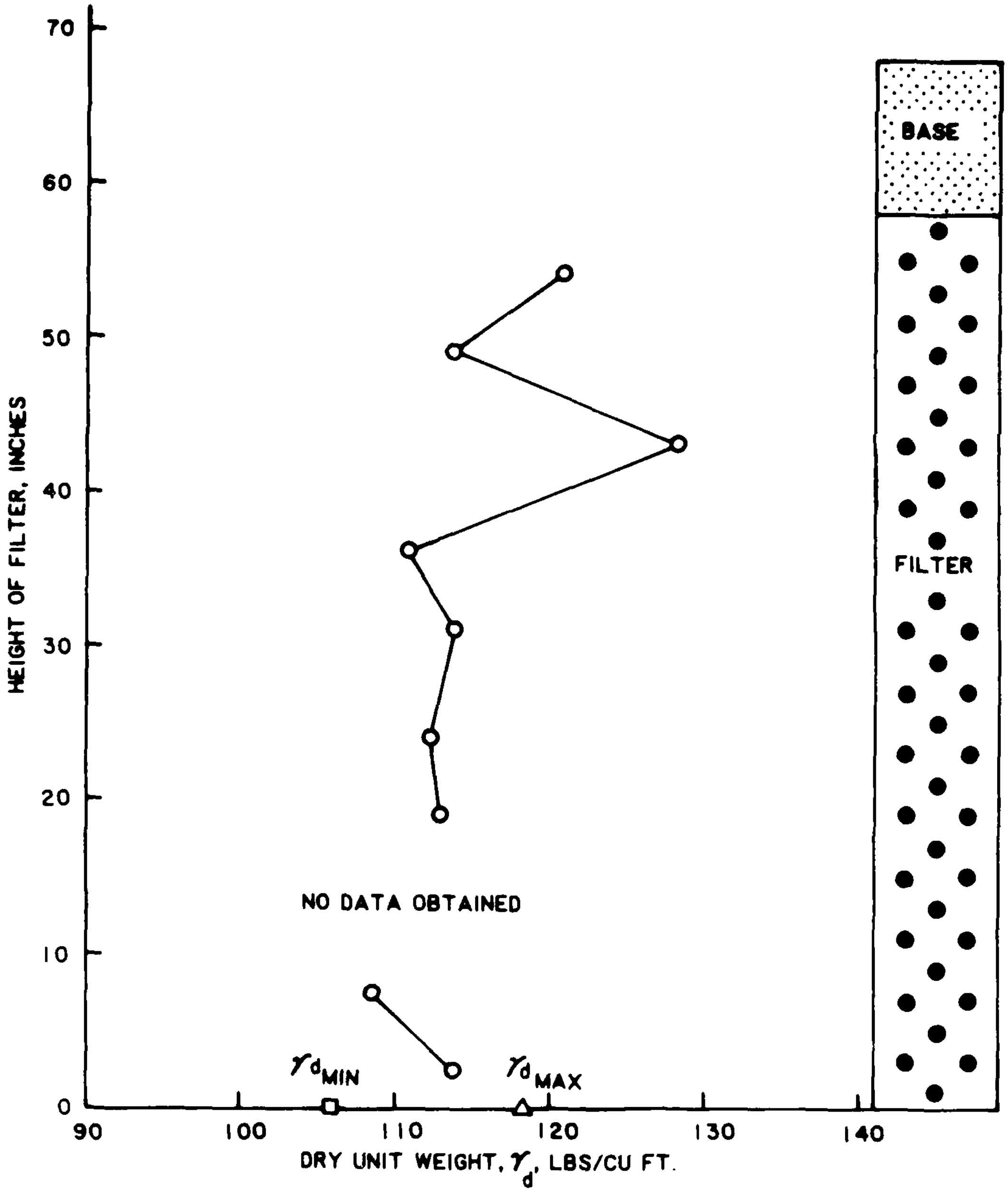


Figure 27. Posttest dry unit weight profile of filter for Test No. 1A-C

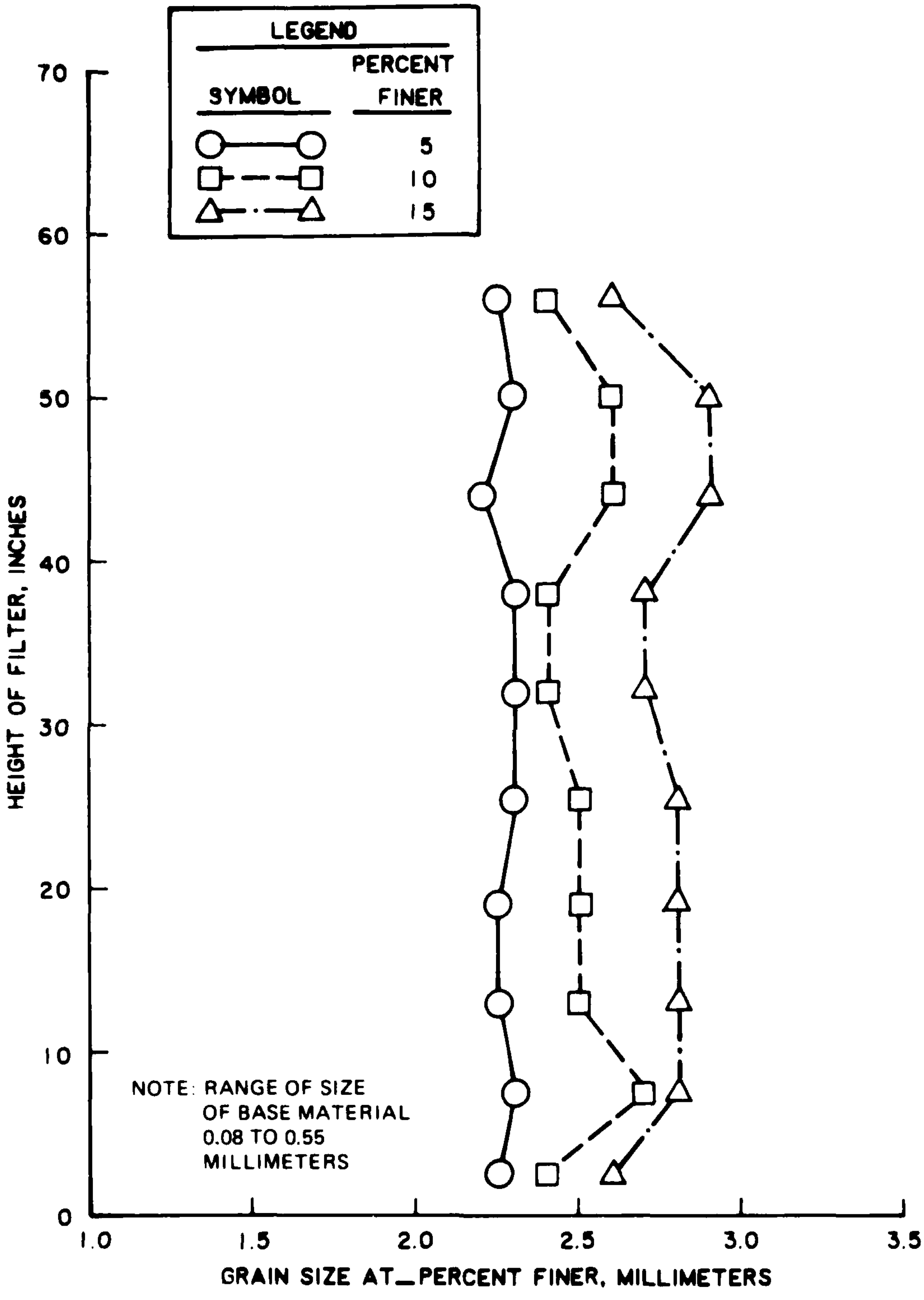


Figure 28. Posttest grain size of fine particles profile of filter for Test No. 1A-A (check)

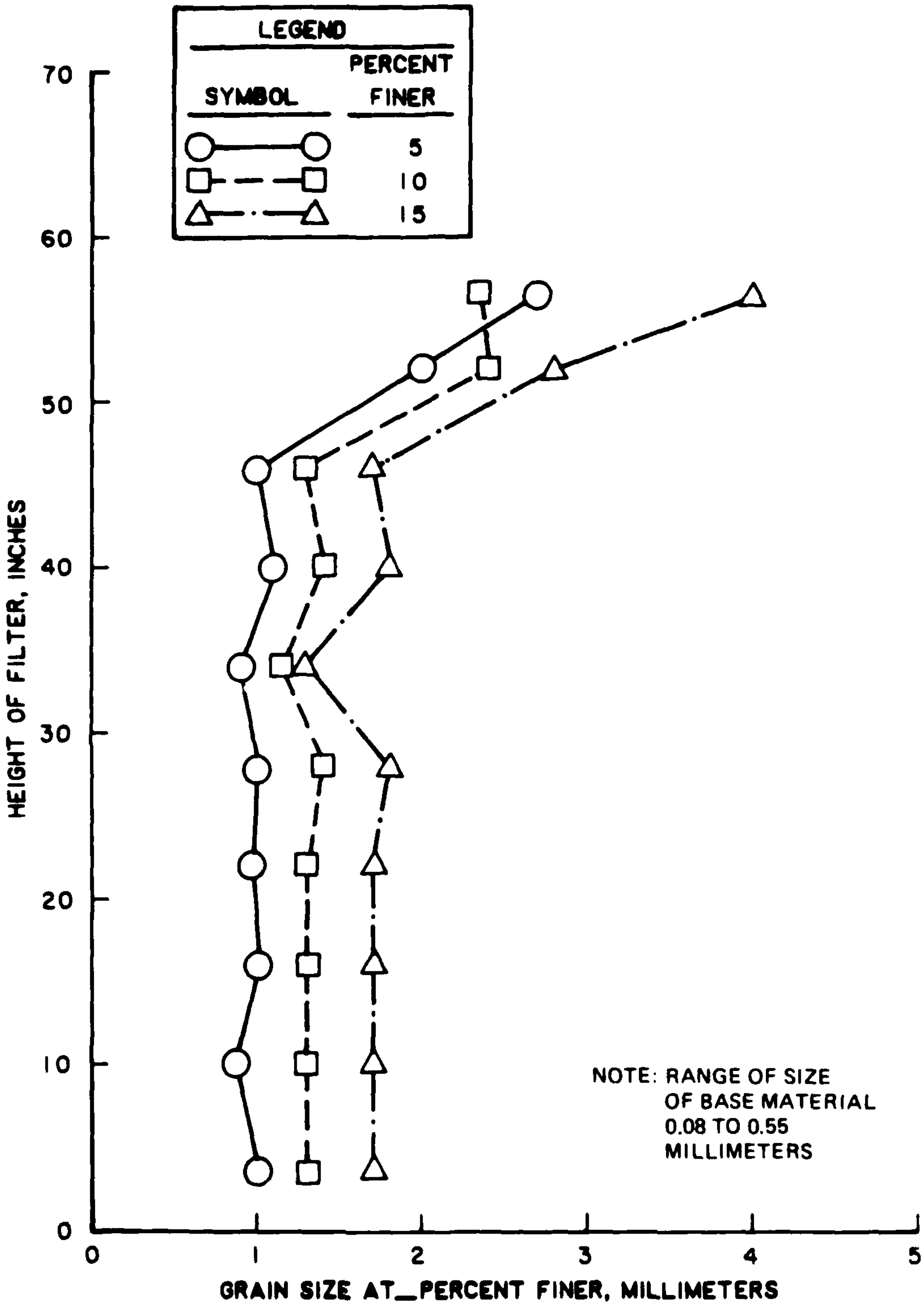


Figure 29. Posttest grain size of fine particles of profile of filter for Test No. 1A-B

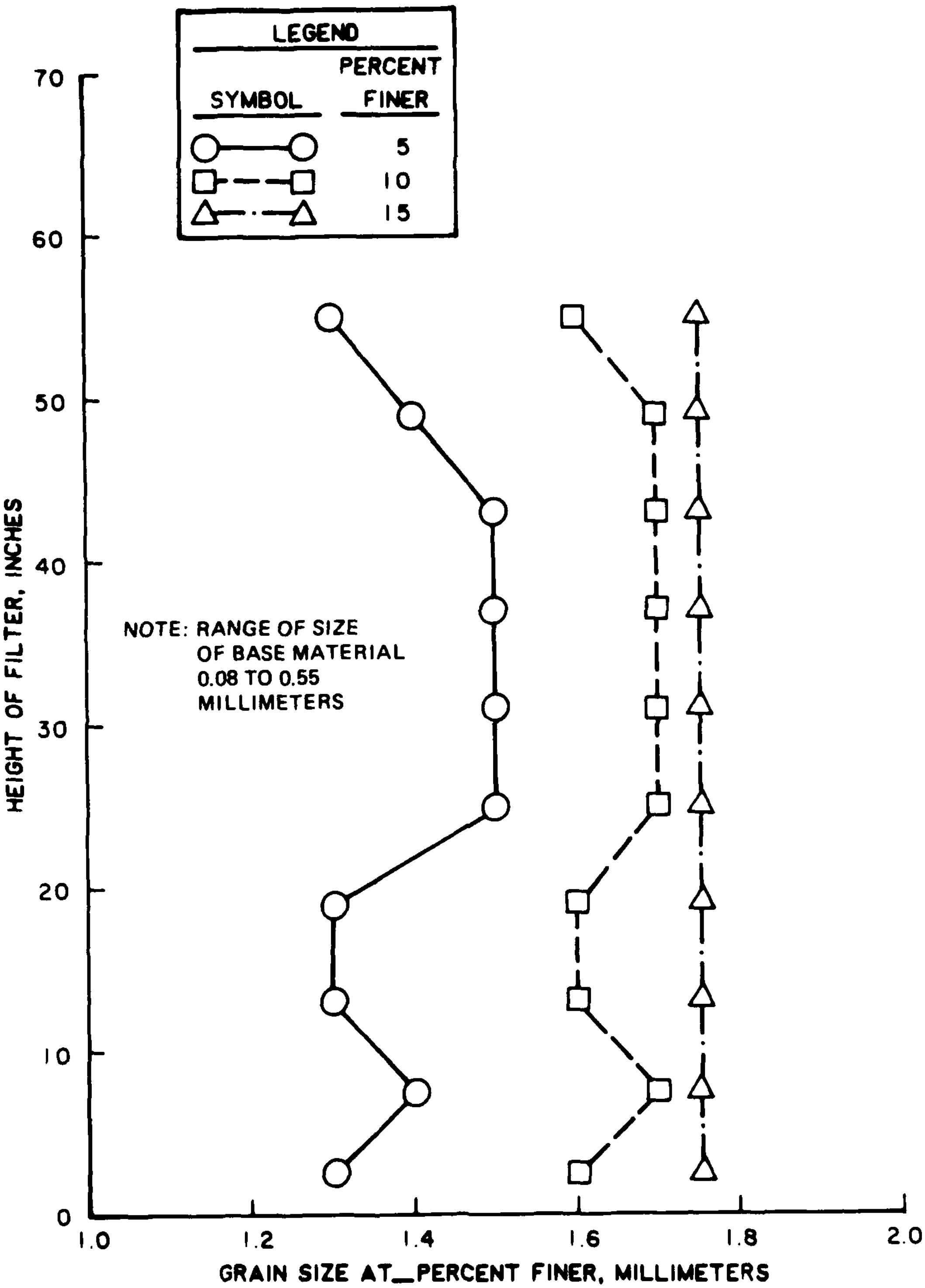
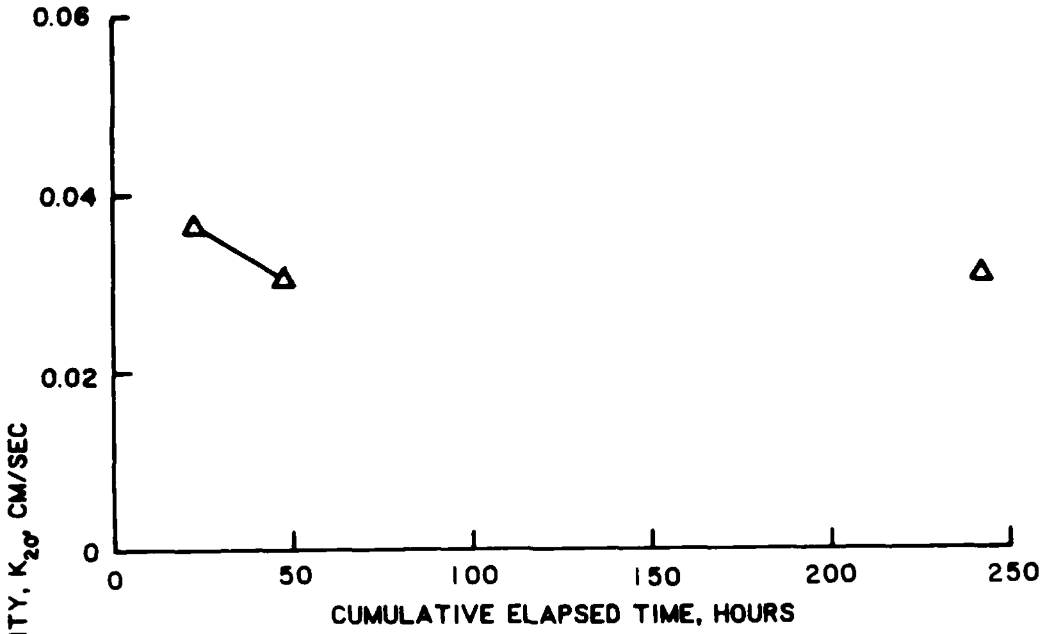
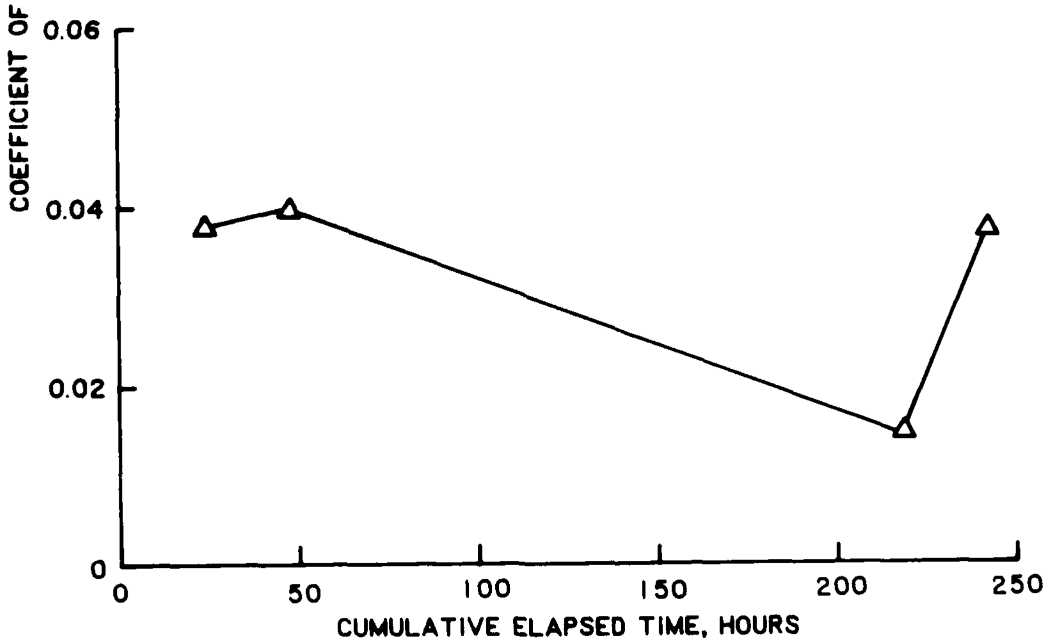


Figure 30. Posttest grain size of fine particles profile of filter for Test No. 1A-C

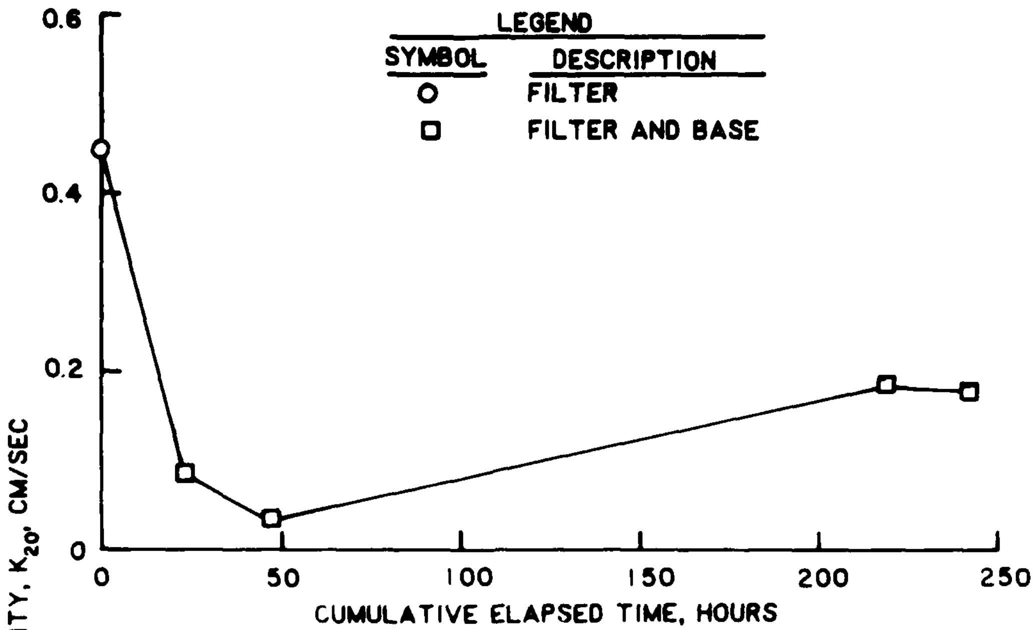


a. Piezometer taps 9 and 10 (63- and 66-in. elevation, respectively)

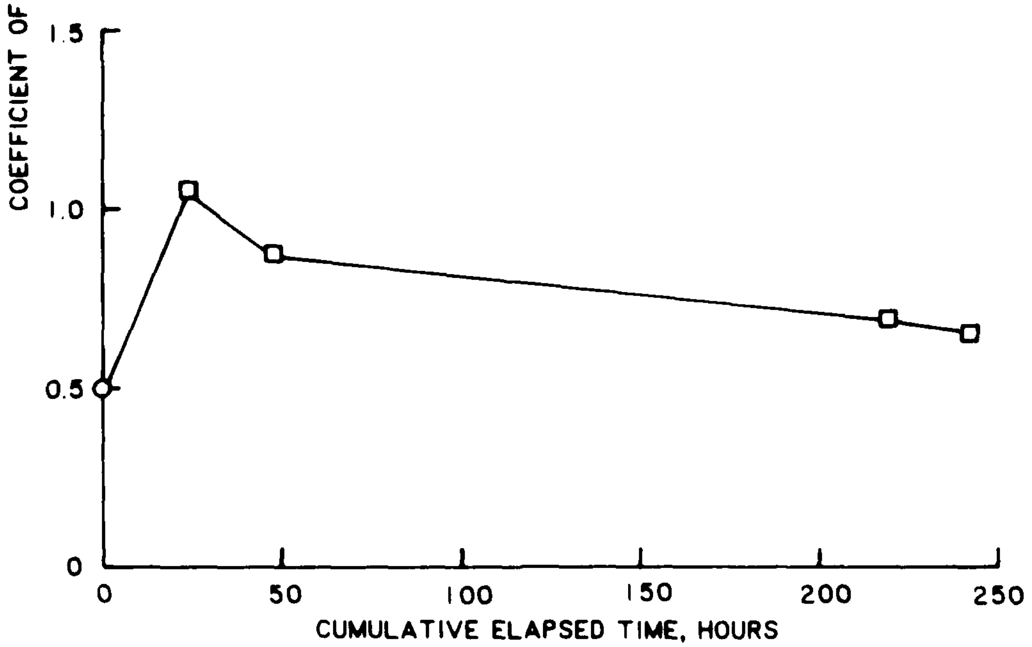


b. Piezometer taps 8 and 9 (60- and 63-in. elevation, respectively)

Figure 31. Permeability versus time for base of Test No. 1A-A (check)

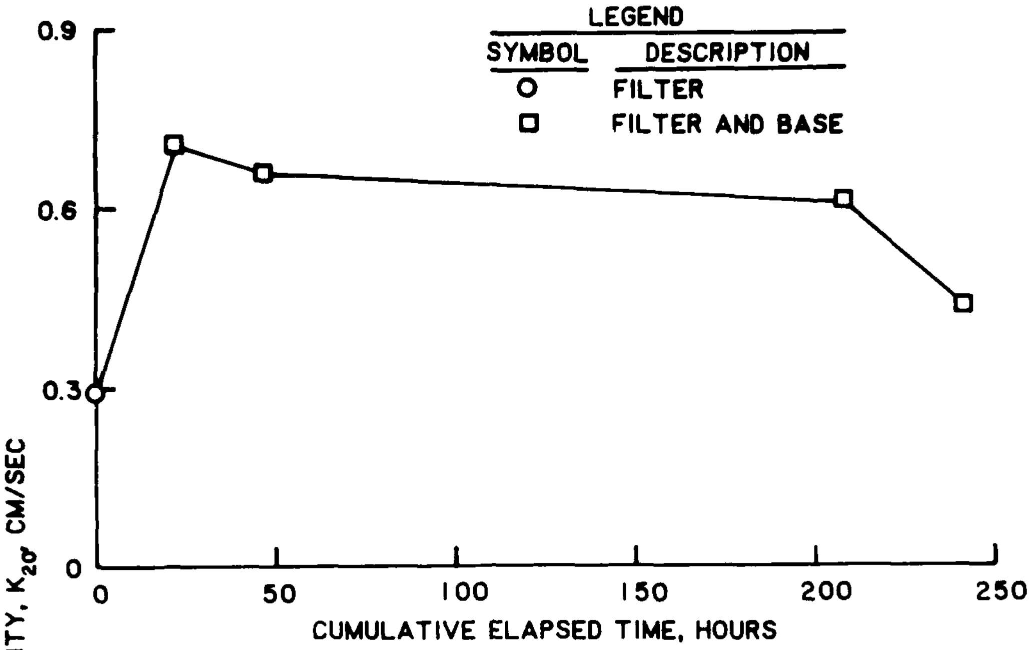


a. Piezometer taps 6 and 7 (54- and 57-in. elevation, respectively)

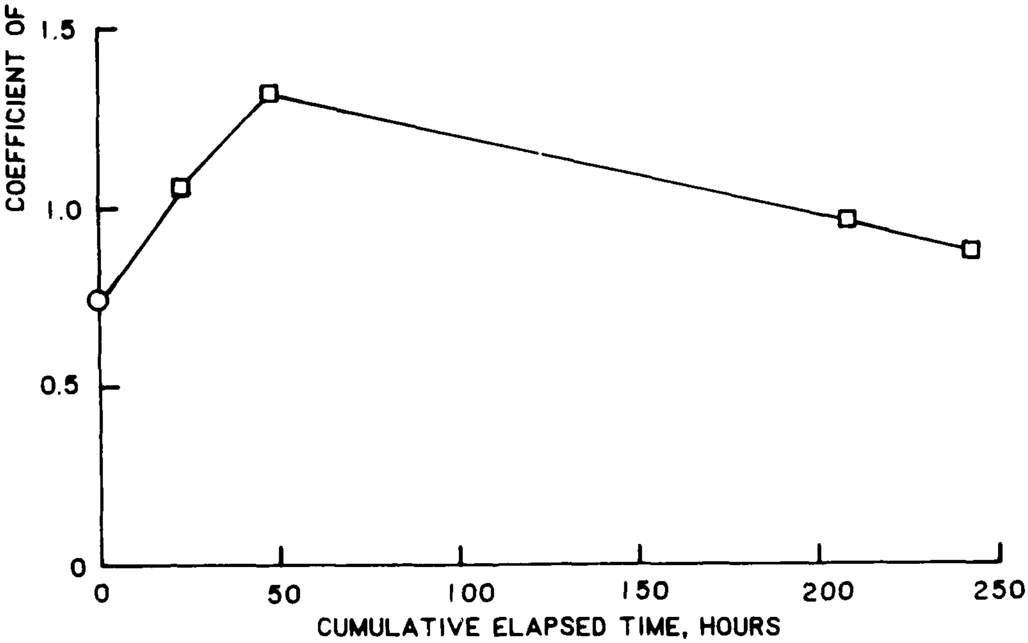


b. Piezometer taps 5 and 6 (48- and 54-in. elevation, respectively)

Figure 32. Permeability versus time for filter of Test No. 1A-A (check) (Sheet 1 of 3)

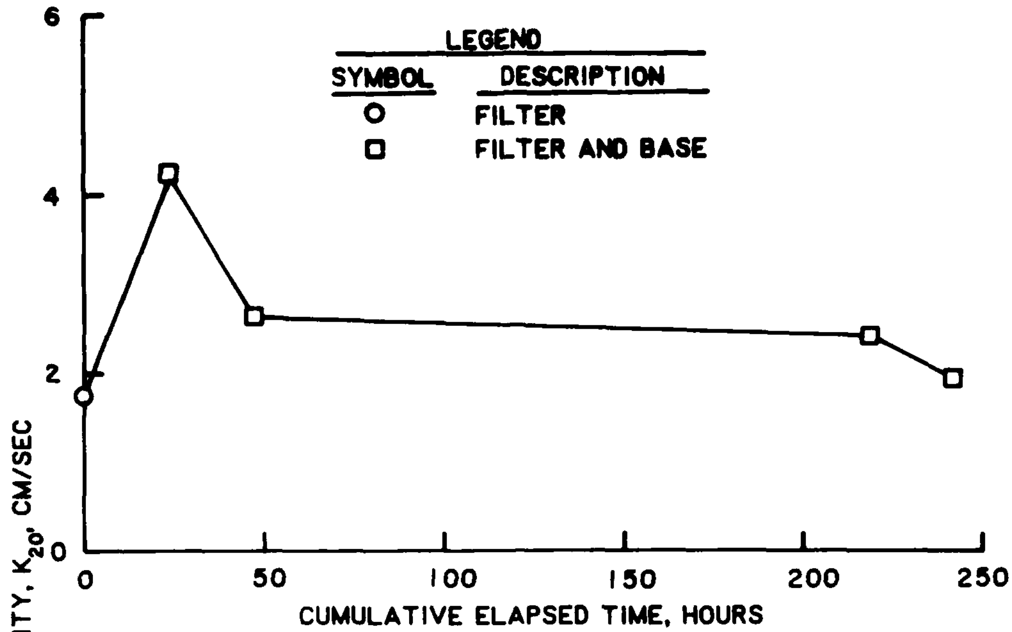


a. Piezometer taps 4 and 5 (42- and 48-in. elevation, respectively)

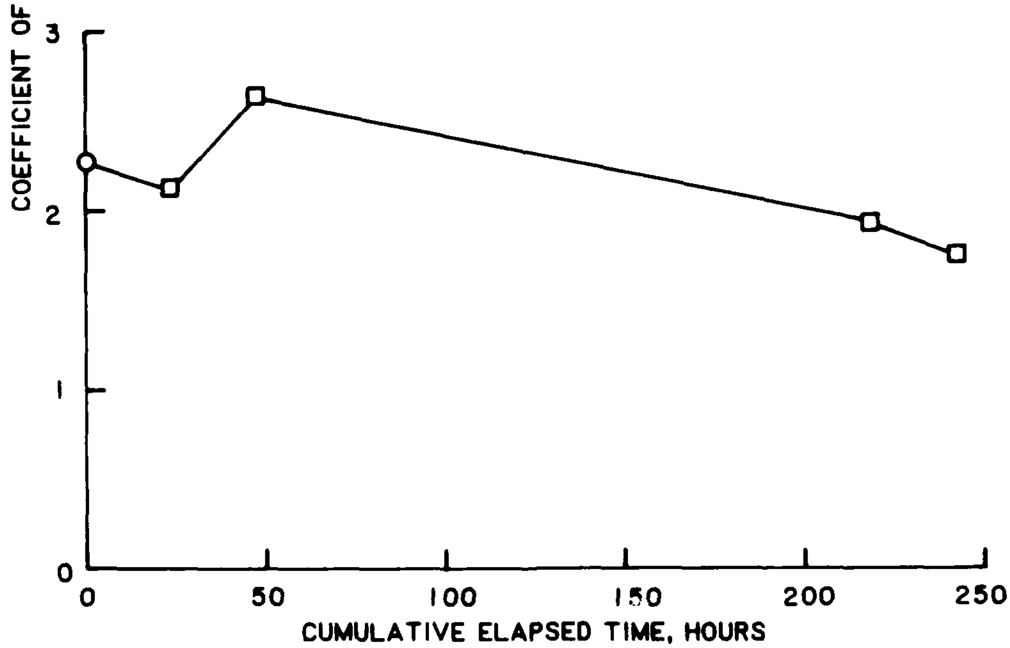


b. Piezometer taps 3 and 4 (30- and 42-in. elevation, respectively)

Figure 32. (Sheet 2 of 3)

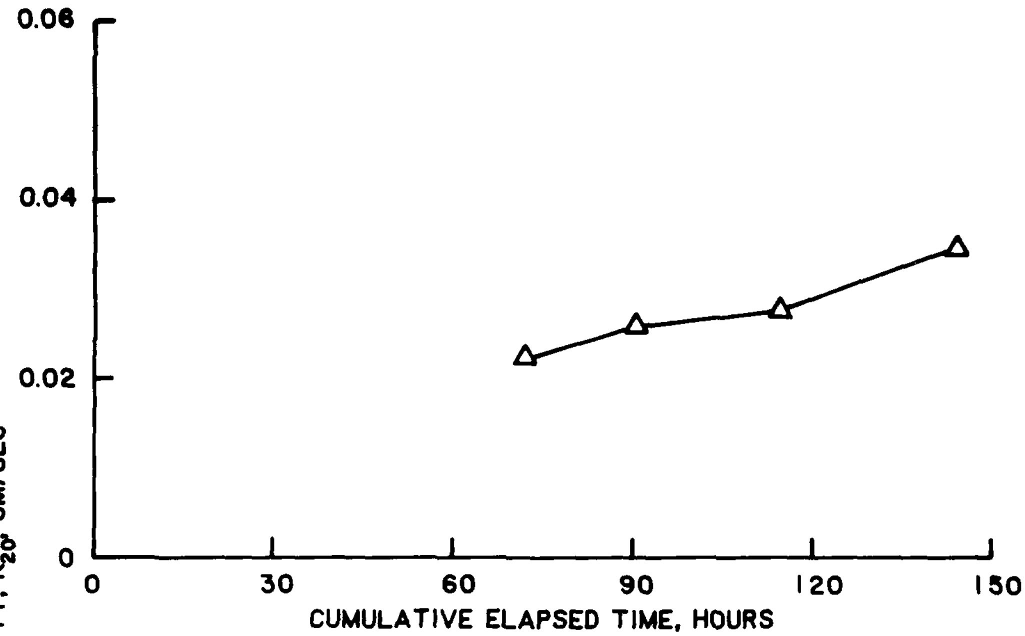


a. Piezometer taps 2 and 3 (18- and 30-in. elevation, respectively)

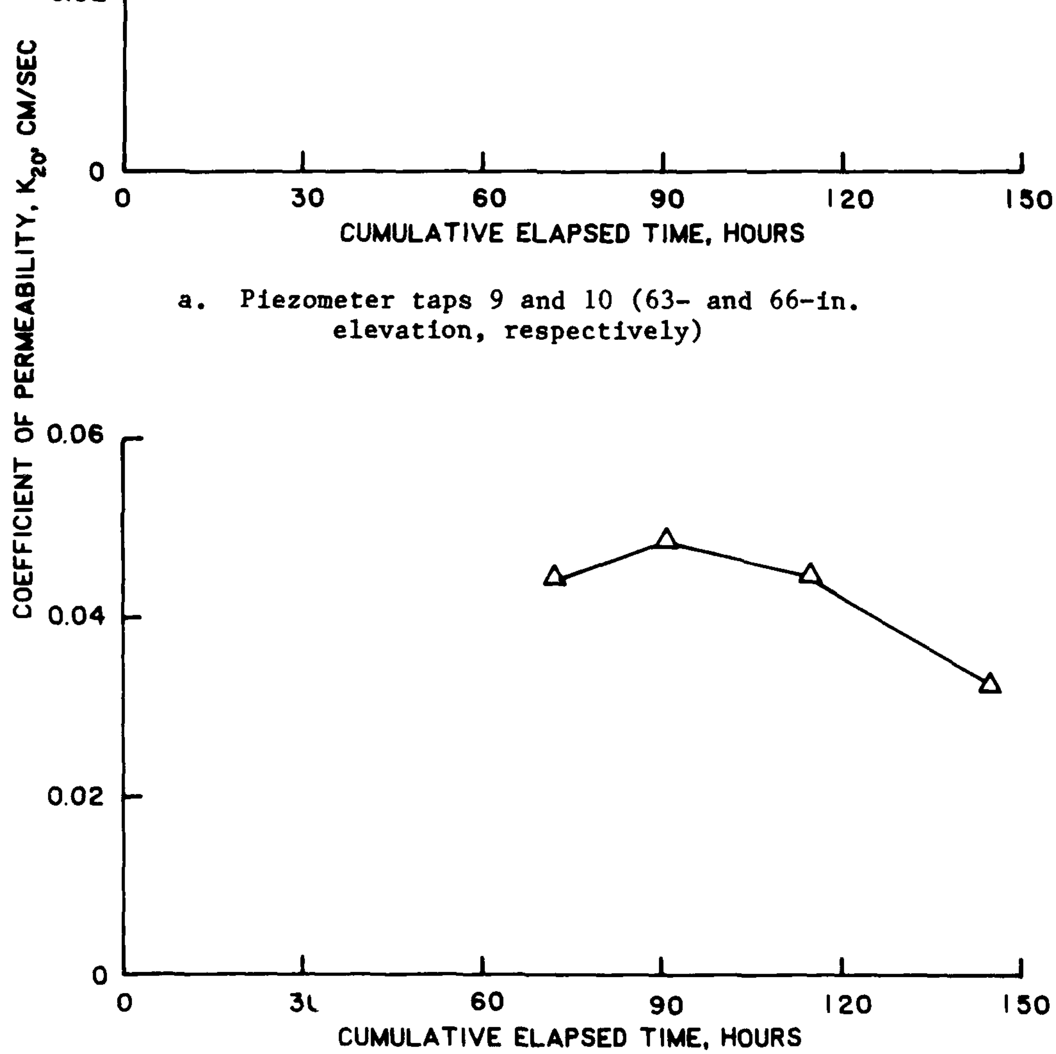


b. Piezometer taps 1 and 2 (6- and 18-in. elevation, respectively)

Figure 32. (Sheet 3 of 3)

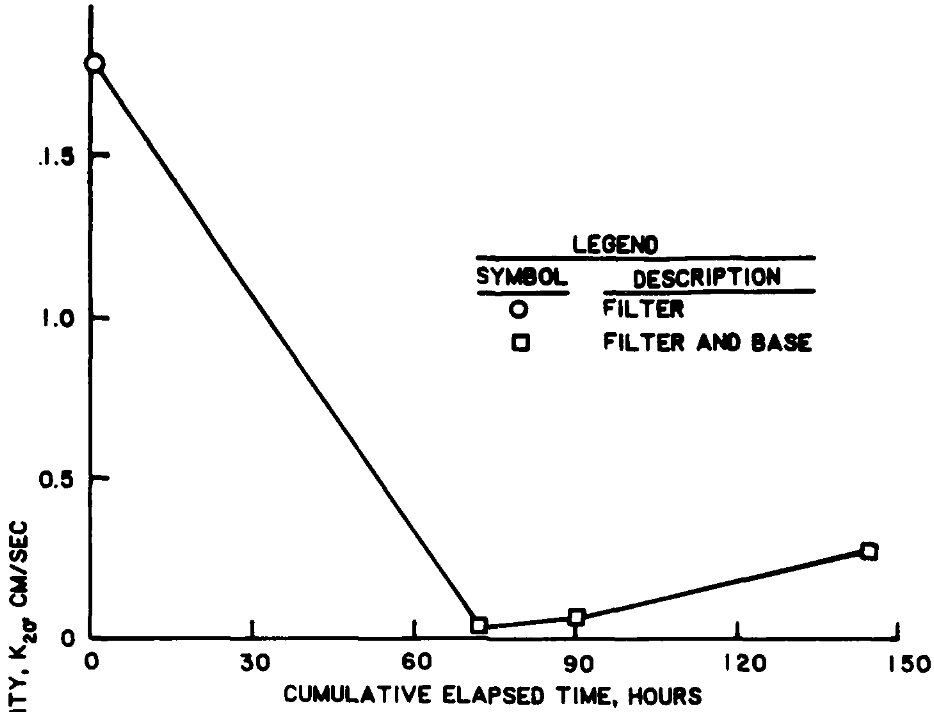


a. Piezometer taps 9 and 10 (63- and 66-in. elevation, respectively)

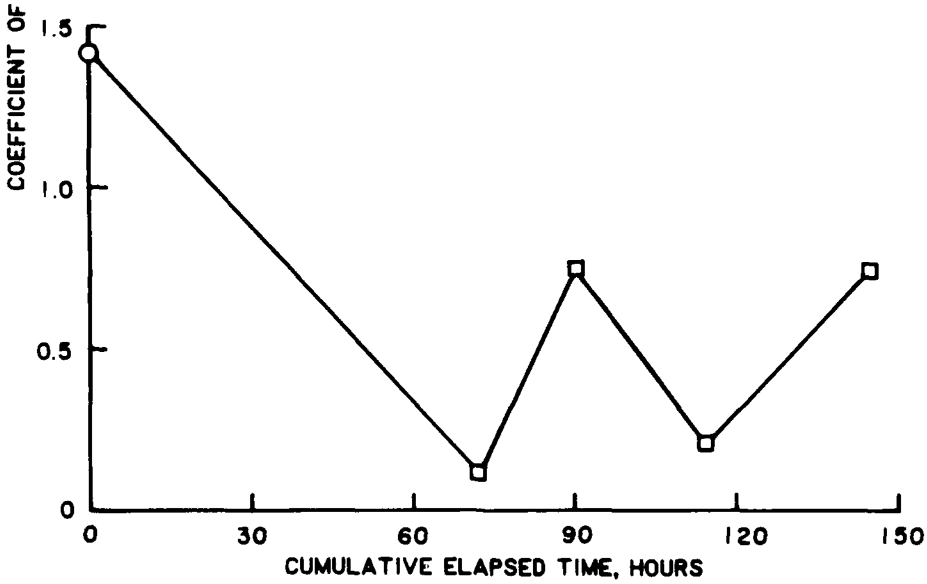


b. Piezometer taps 8 and 9 (60- and 63-in. elevation, respectively)

Figure 33. Permeability versus time for base of Test No. 1A-B

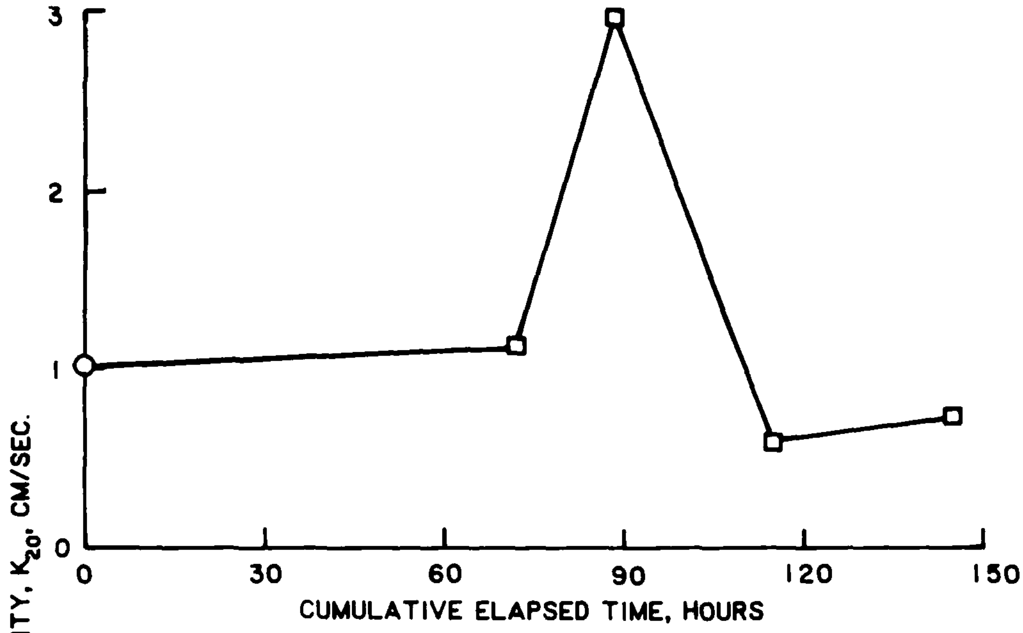


a. Piezometer taps 6 and 7 (54- and 57-in. elevation, respectively)

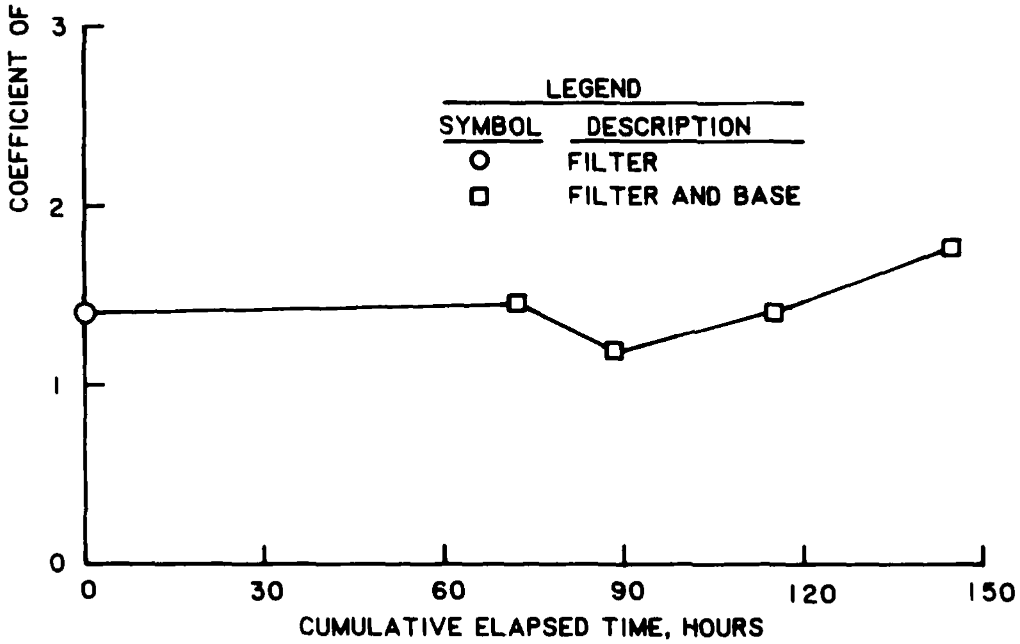


b. Piezometer taps 5 and 6 (48- and 54-in. elevation, respectively)

Figure 34. Permeability versus time for filter of Test No. 1A-B (Sheet 1 of 3)

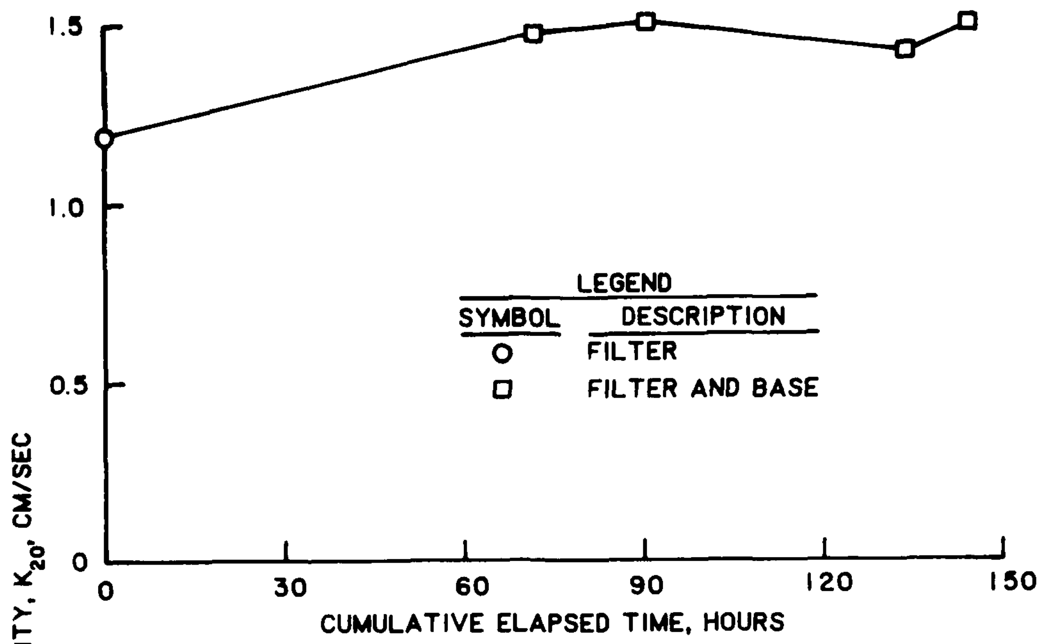


a. Piezometer taps 4 and 5 (42- and 48-in. elevation, respectively)

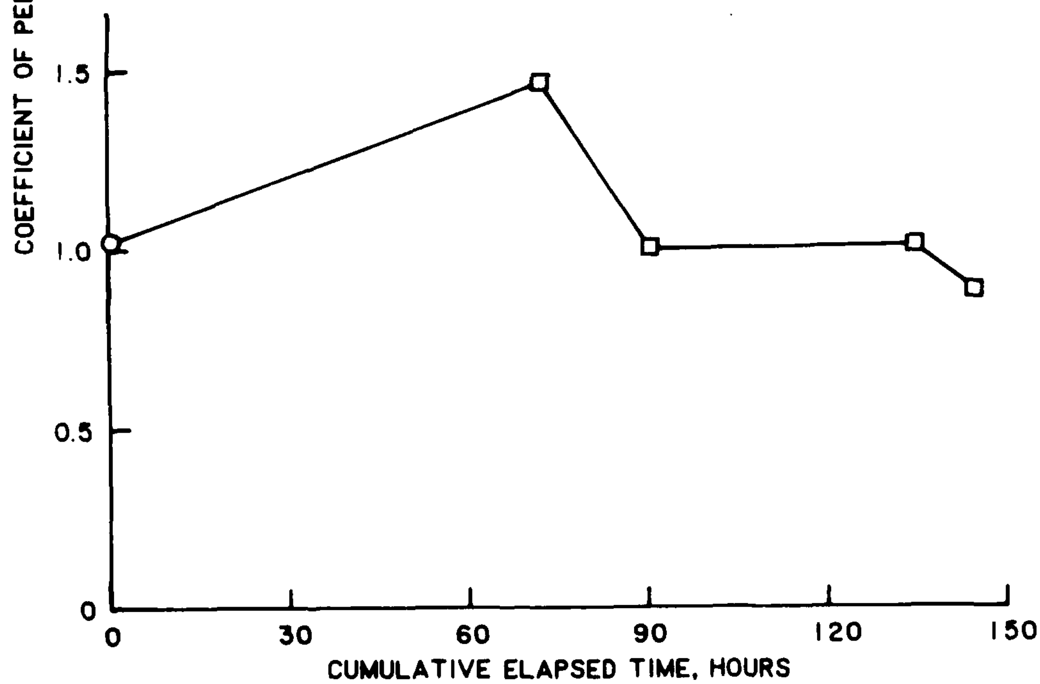


b. Piezometer taps 3 and 4 (30- and 42-in. elevation, respectively)

Figure 34. (Sheet 2 of 3)

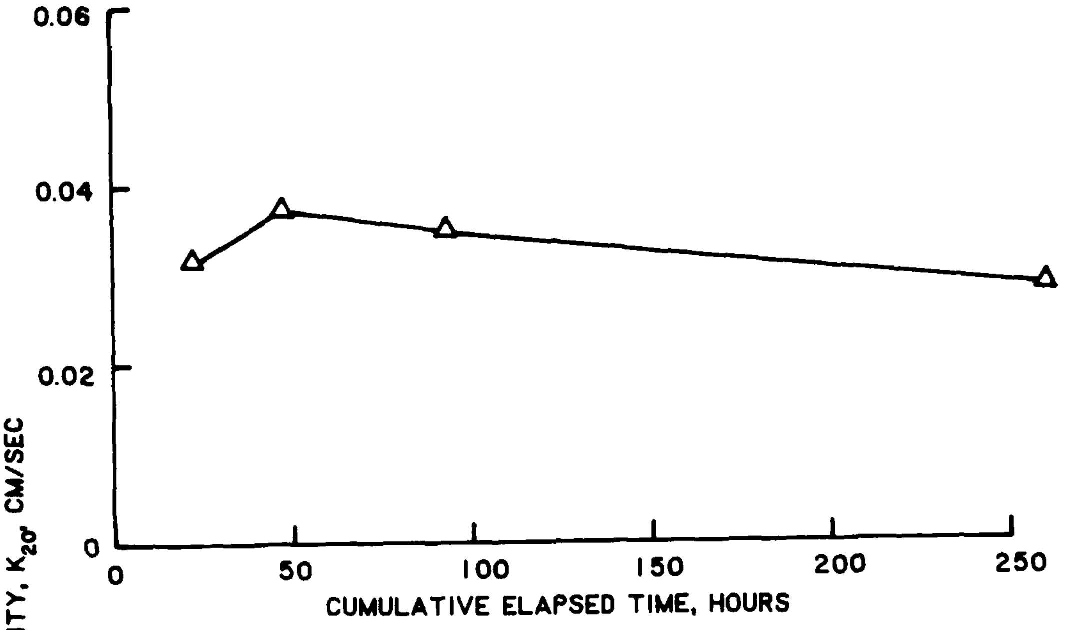


a. Piezometer taps 2 and 3 (18- and 30-in. elevation, respectively)

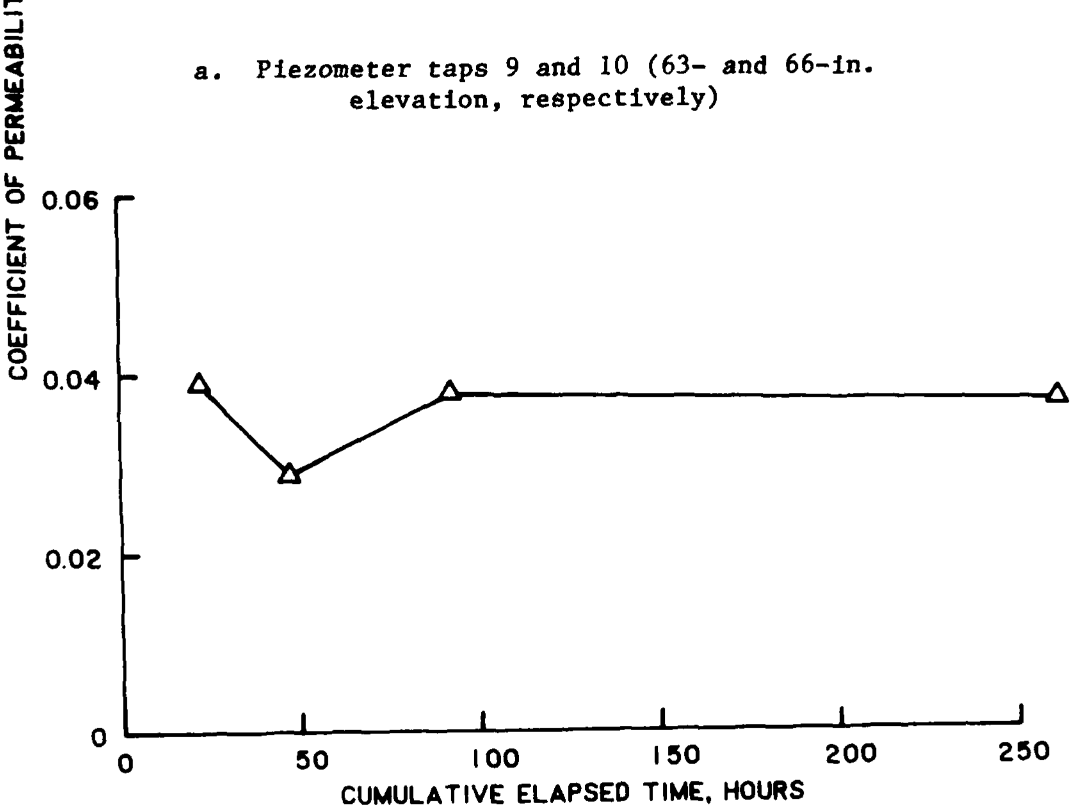


b. Piezometer taps 1 and 2 (6- and 18-in. elevation, respectively)

Figure 34. (Sheet 3 of 3)

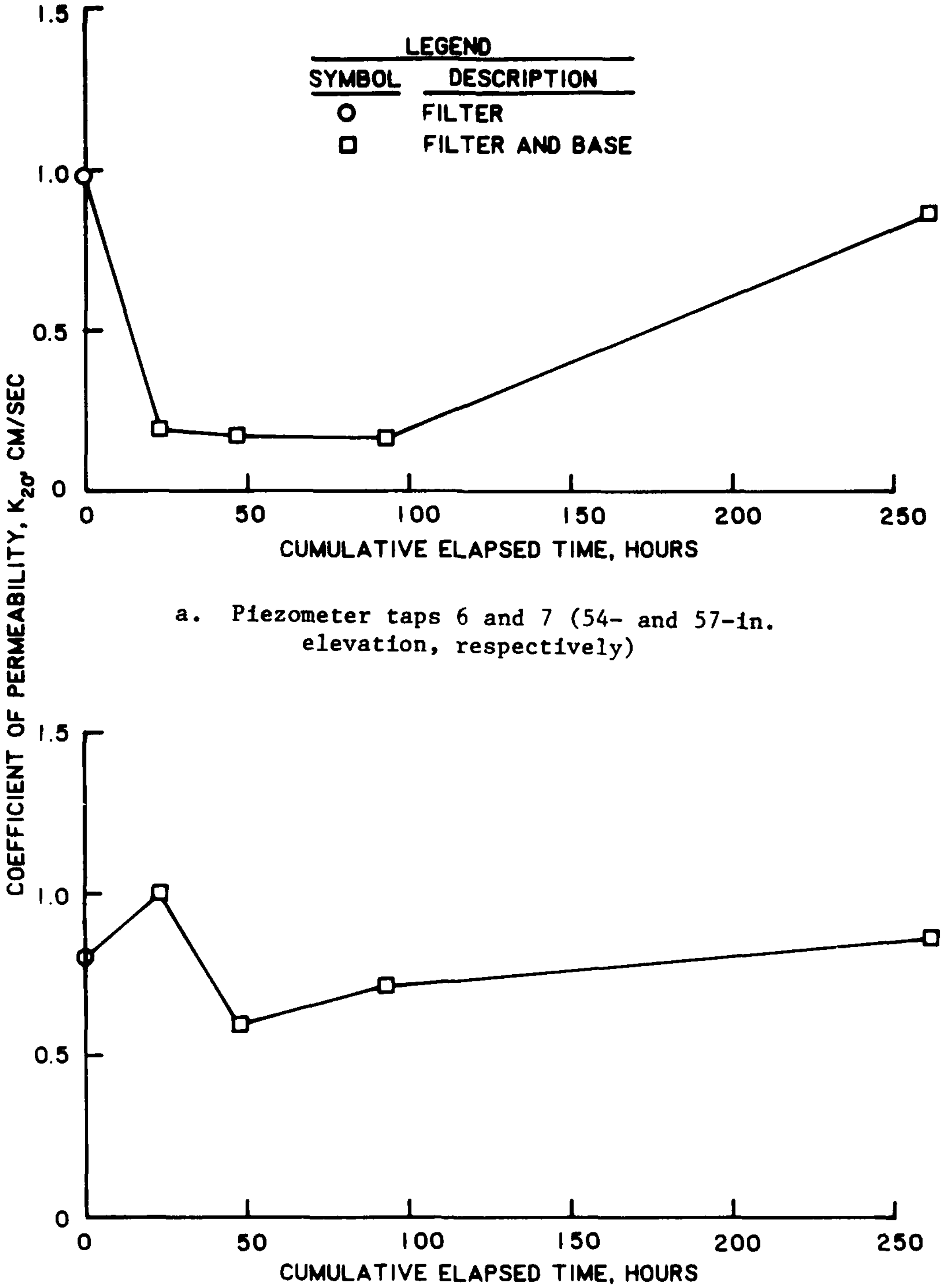


a. Piezometer taps 9 and 10 (63- and 66-in. elevation, respectively)



b. Piezometer taps 8 and 9 (60- and 63-in. elevation, respectively)

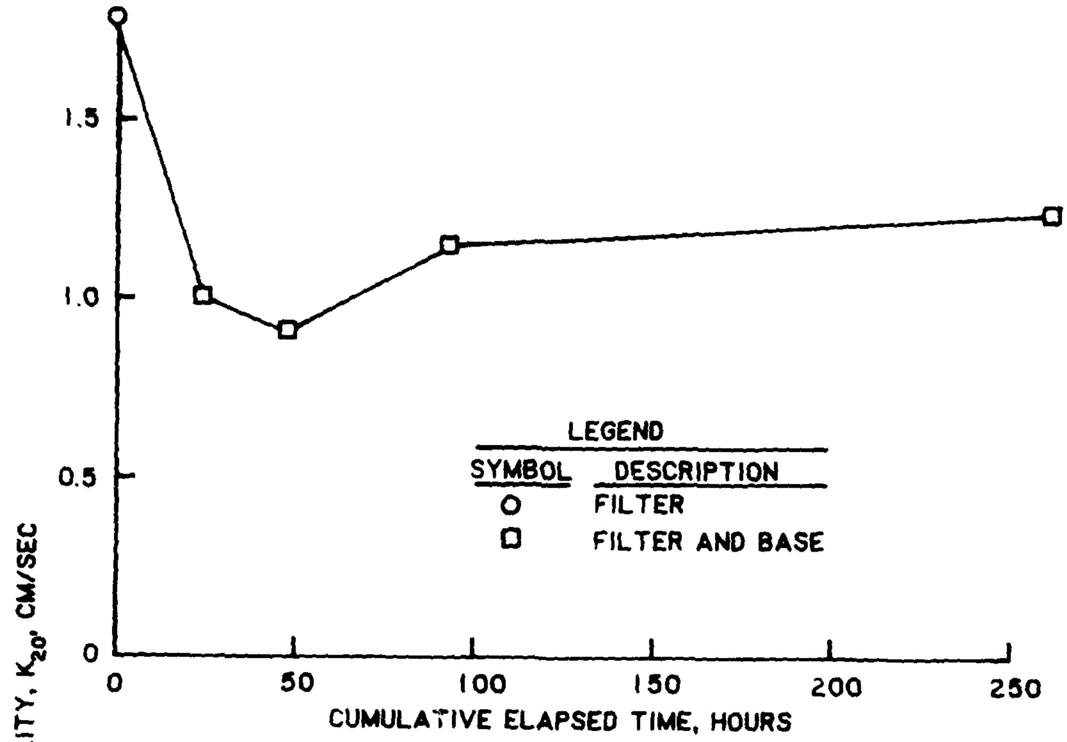
Figure 35. Permeability versus time for base of Test No. 1A-C



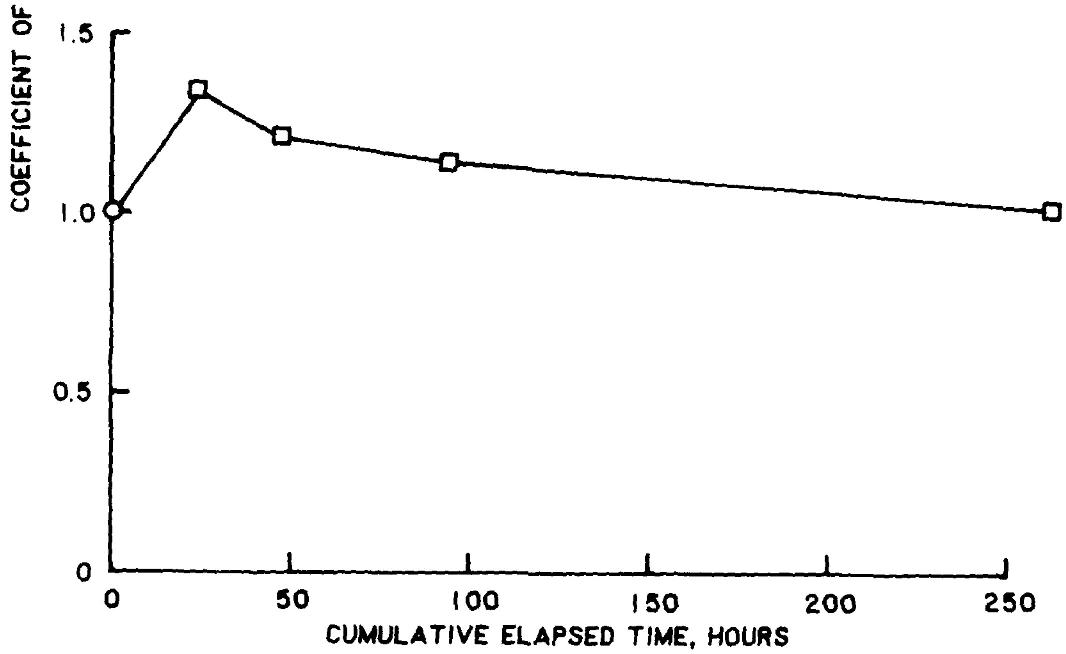
a. Piezometer taps 6 and 7 (54- and 57-in. elevation, respectively)

b. Piezometer taps 5 and 6 (48- and 54-in. elevation, respectively)

Figure 36. Permeability versus time for filter of Test No. 1A-C (Sheet 1 of 3)

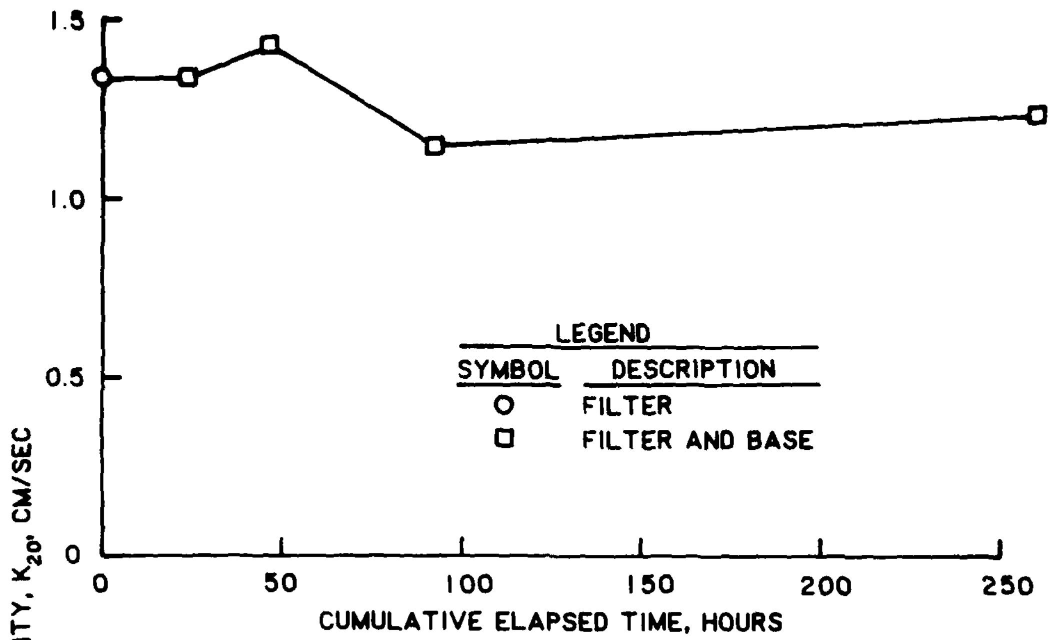


a. Piezometer taps 4 and 5 (42- and 48-in. elevation, respectively)

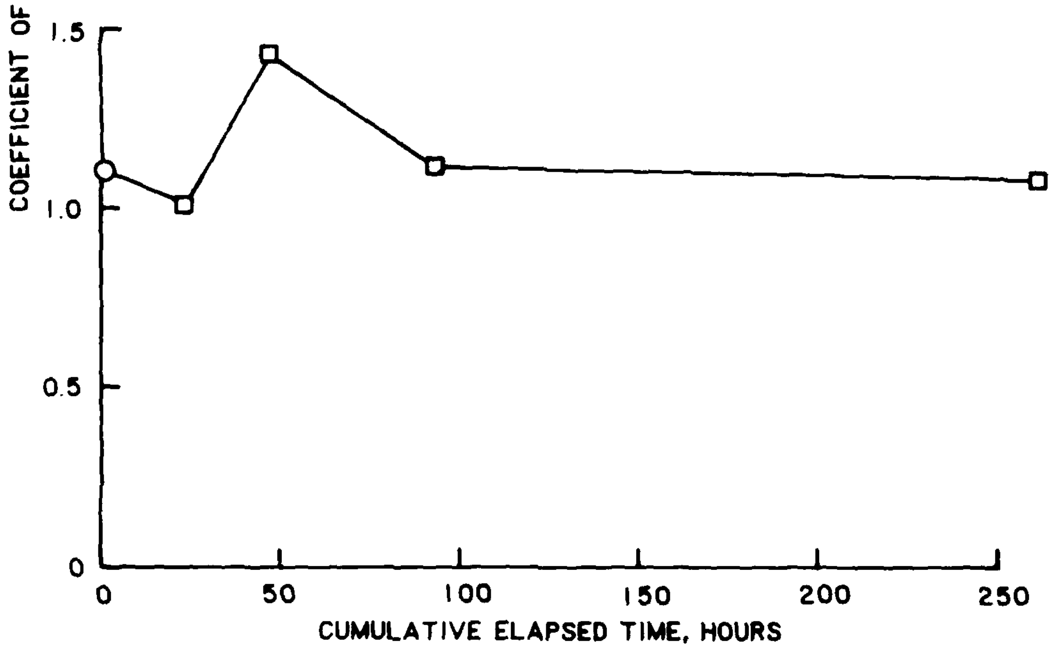


b. Piezometer taps 3 and 4 (30- and 42-in. elevation, respectively)

Figure 36. (Sheet 2 of 3)



a. Piezometer taps 2 and 3 (18- and 30-in. elevation, respectively)



b. Piezometer taps 1 and 2 (6- and 18-in. elevation, respectively)

Figure 36. (Sheet 3 of 3)

permeability test. Figures 32a, 34a, and 36a indicate a reduction in permeability at the top of the filter (54- to 57-in. level) equal to 80, 98, and 80 percent (Table 7) occurred for Test No. 1A-A (check), 1A-B, and 1A-C, respectively. This reduction in permeability was due to air segregation (Appendix A) and/or migration of base material into the filter during either construction and/or saturation or filter testing.

30. Relative permeability of filter. As stated previously, from Part II, Equation 6, the filter material should have 25 or more times the permeability of the base. Table 5 shows that the ratio of the permeability of the filter to the permeability of the base averaged 35, 31, and 32 for Test No. 1A-A (check), 1A-B, and 1A-C, respectively.

31. Particle movement within the base and filter. No internal movement of particles within the base was observed for Test No. 1A-A (check), 1A-B, or 1A-C (Table 5). No significant change in permeability is evident when comparing the permeability of the lower part of the base (60- to 63-in. level) with the permeability of the upper part of the base (63- to 66-in. level) as shown in Figures 31a and 31b, 33a and 33b, and 35a and 35b for Test No. 1A-A (check), 1A-B, and 1A-C, respectively. The ratio of permeability of the lower part of the base to the upper part of the base ranged from 1.0 to 1.5 for Test No. 1A-A (check), 1A-B, and 1A-C (Table 7). The smaller permeability of the upper part of the base may have been due to air segregation (Appendix A). Internal movement of sand within the filter at 38-in. and 49-in. elevation immediately following application of the highest gradient was visually observed in Test No. 1A-A (check) during the filter test as given in Table 5. The posttest grain size of fine particles profile (Figure 29) and comparison among posttest gradations of the top, middle, and bottom 6 in. of the filter (Appendix E and Table 7) indicate internal movement within the upper quarter (46- to 58-in.) of the filter for Test No. 1A-B either during construction and/or saturation or filter testing.

Filter tests with a poorly-graded base

32. Migration of base into filter. The calculated base migration to develop filter action (Equation 10), was 1.0 in. as shown in Table 6. Visual observations of the specimen through the lucite cylinder did not indicate that migration of the base around the periphery of the filter occurred (Table 7).

33. Posttest dry unit weight profiles of the filter for Test No. 1B-A, 1B-B, and 1B-C are given in Figures 37, 38, and 39, respectively. As shown in

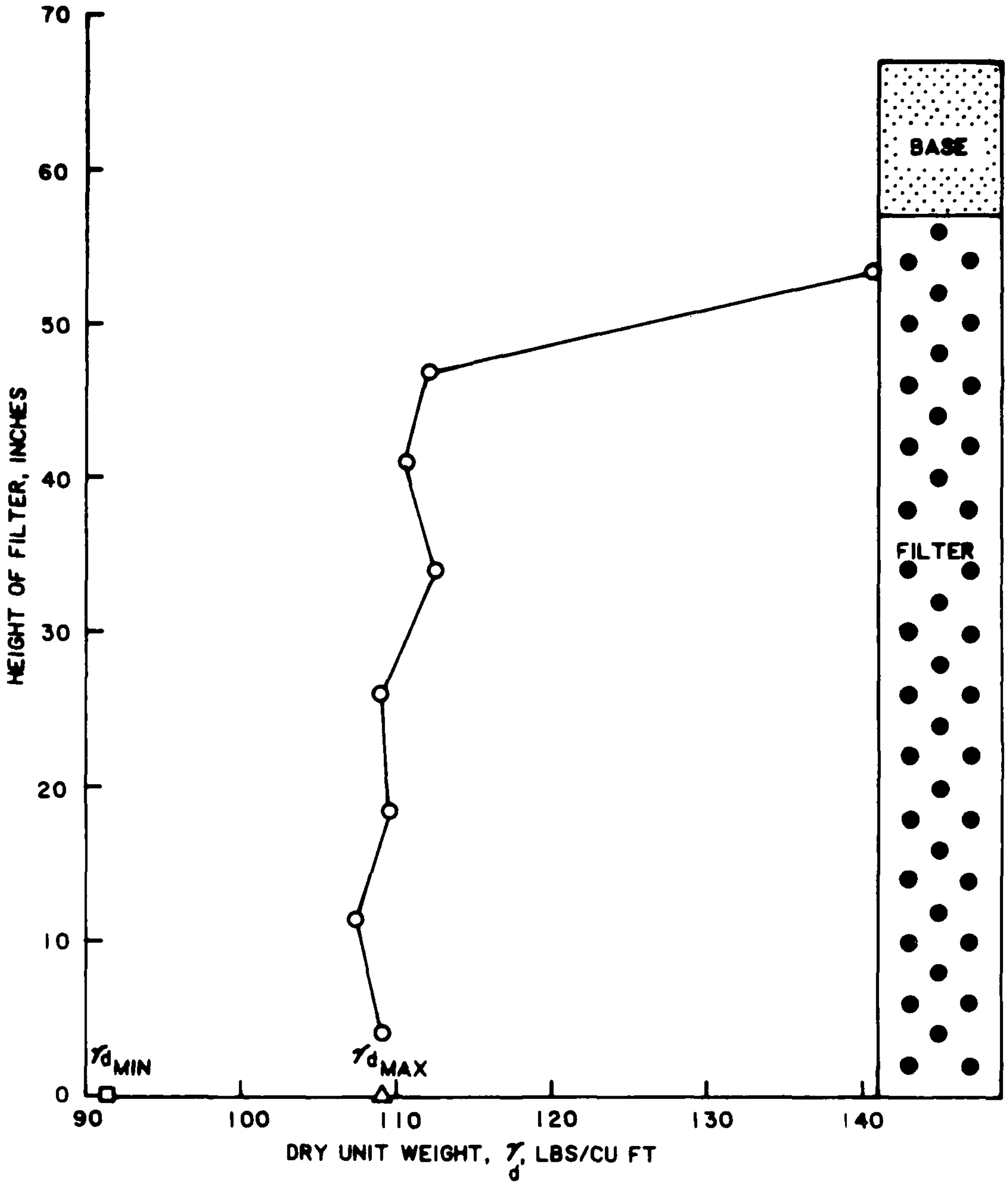


Figure 37. Posttest dry unit weight profile of filter for Test No. 1B-A

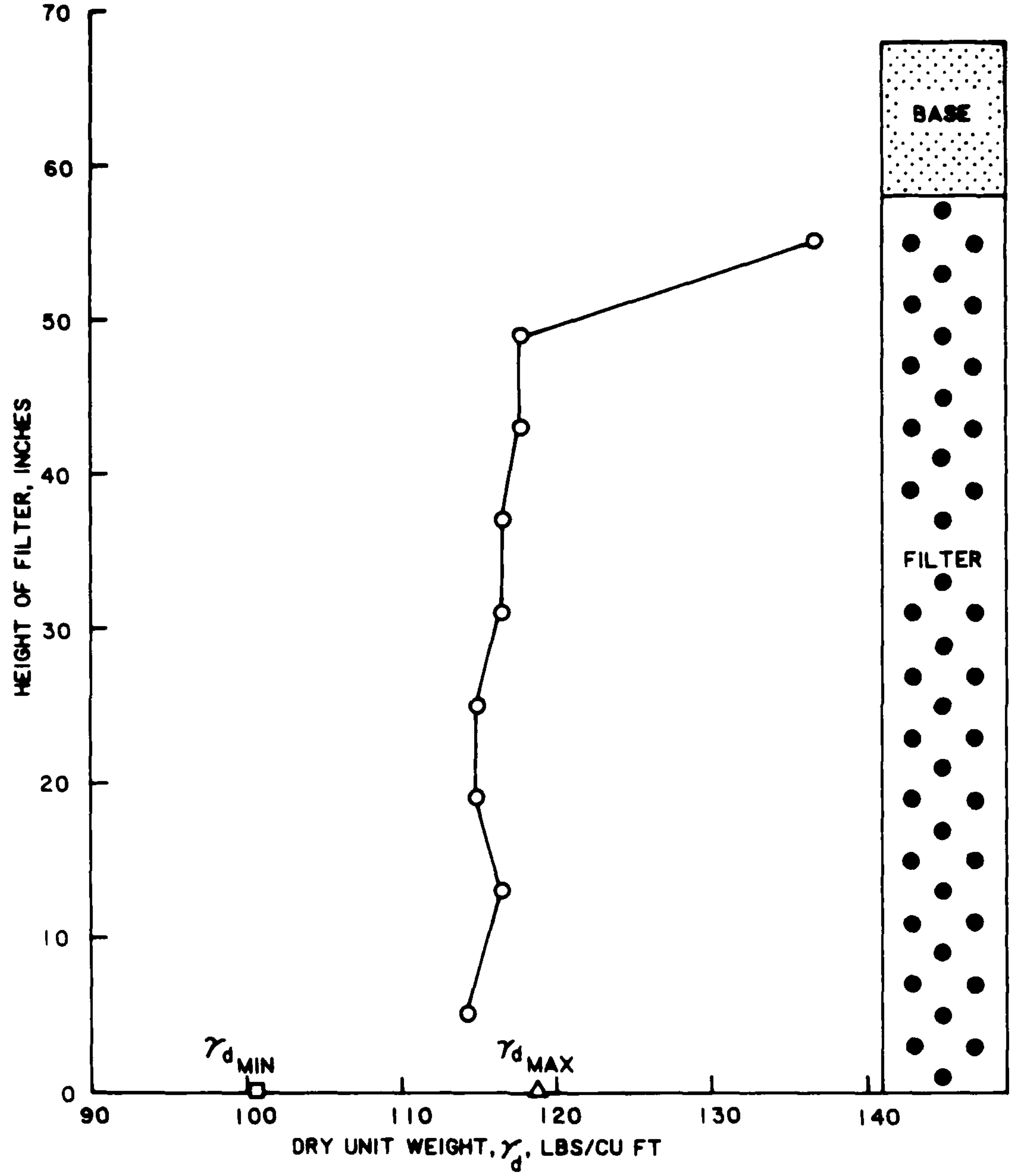


Figure 38. Posttest dry unit weight profile of filter for Test No. 1B-B

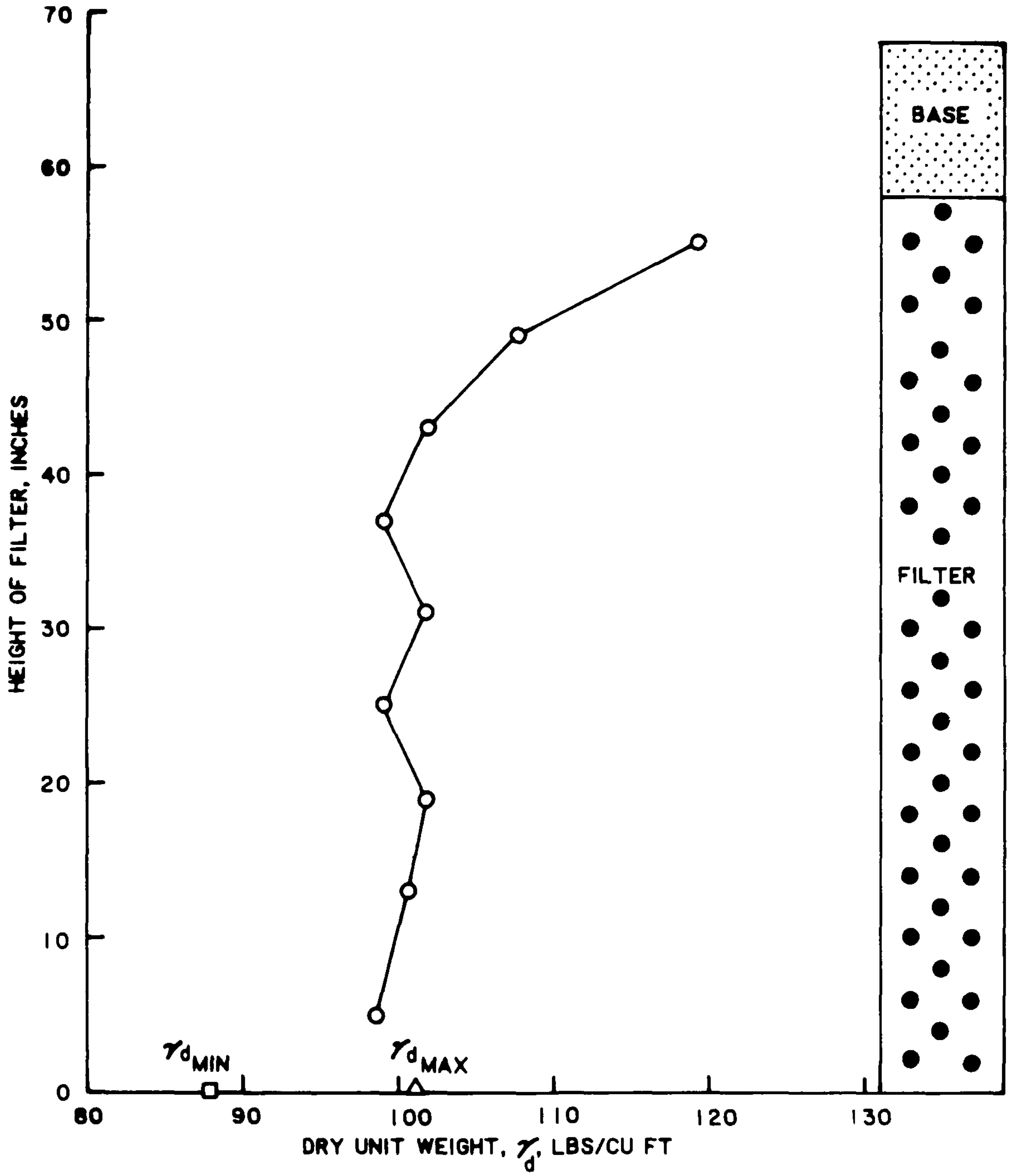


Figure 39. Posttest dry unit weight profile of filter for Test No. 1B-C

Table 7, the posttest dry unit weight for the top 6 in. of the filter is 28, 18, and 18 percent denser than the remaining portion of the filter for Test No. 1B-A, 1B-B, and 1B-C, respectively, because of migration of the base into the filter during either construction, saturation, and/or filter testing. For Test No. 1B-C (Figure 39), there is a profile of increase in posttest dry unit weight from the 42-in. height to the top of the filter indicating a deeper migration of the base into the filter.

34. The posttest grain size of fine particles (5, 10, and 15 percent fines) profile of the filter for Test No. 1B-A, 1B-B, and 1B-C are given in Figures 40, 41, and 42, respectively. Migration of base into the filter is evident for Test No. 1B-A, 1B-B, and 1B-C. Comparison among posttest gradations of the top, middle, and bottom 6 in. of the filter are given in Appendix E and summarized in Table 7. Test No. 1B-A and 1B-B were finer in the top 6 in. of the filter indicating possible migration of base into the filter during either construction, saturation, and/or filter testing.

35. Changes in permeability with time for various heights within the base and filter for Test No. 1B-A, 1B-B, and 1B-C are given in Figures 43-48, respectively. The permeability at zero time was taken as the final permeability measured on the filter during the permeability test. As shown in Table 5, the average permeability of the base material for Test No. 1B-A and 1B-B was relatively low (2.9×10^{-4} cm/sec and 1.2×10^{-3} cm/sec, respectively) such that no measurable head loss occurred across the filter during the filter test. For Test No. 1B-C, the average permeability of the base material (0.9×10^{-1} cm/sec) was 2 to 3 orders of magnitude higher than for Test No. 1B-A and 1B-B. Permeability values were obtained for the filter material during Test No. 1B-C. No data were obtained from piezometer taps 2, 3, 4, or 5 during the permeability test on the filter prior to placing the base Test No. 1B-A and 1B-C. Therefore, there is no zero (baseline) permeability for the 54- to 57-in. level of the filter, a fact of particular interest with respect to migration of base material into the filter (Figure 48a) but of no consequence for Test No. 1B-A and 1B-B since the permeability of the filter was largely undefined during both tests. However, inferences concerning migration of base material into the filter (Figure 48a) but of no consequences for Test No. 1B-A and 1B-B since the permeability of the filter was largely undefined during both tests. However, inferences concerning migration of base material into the filter for Test No. 1B-C where permeability data was

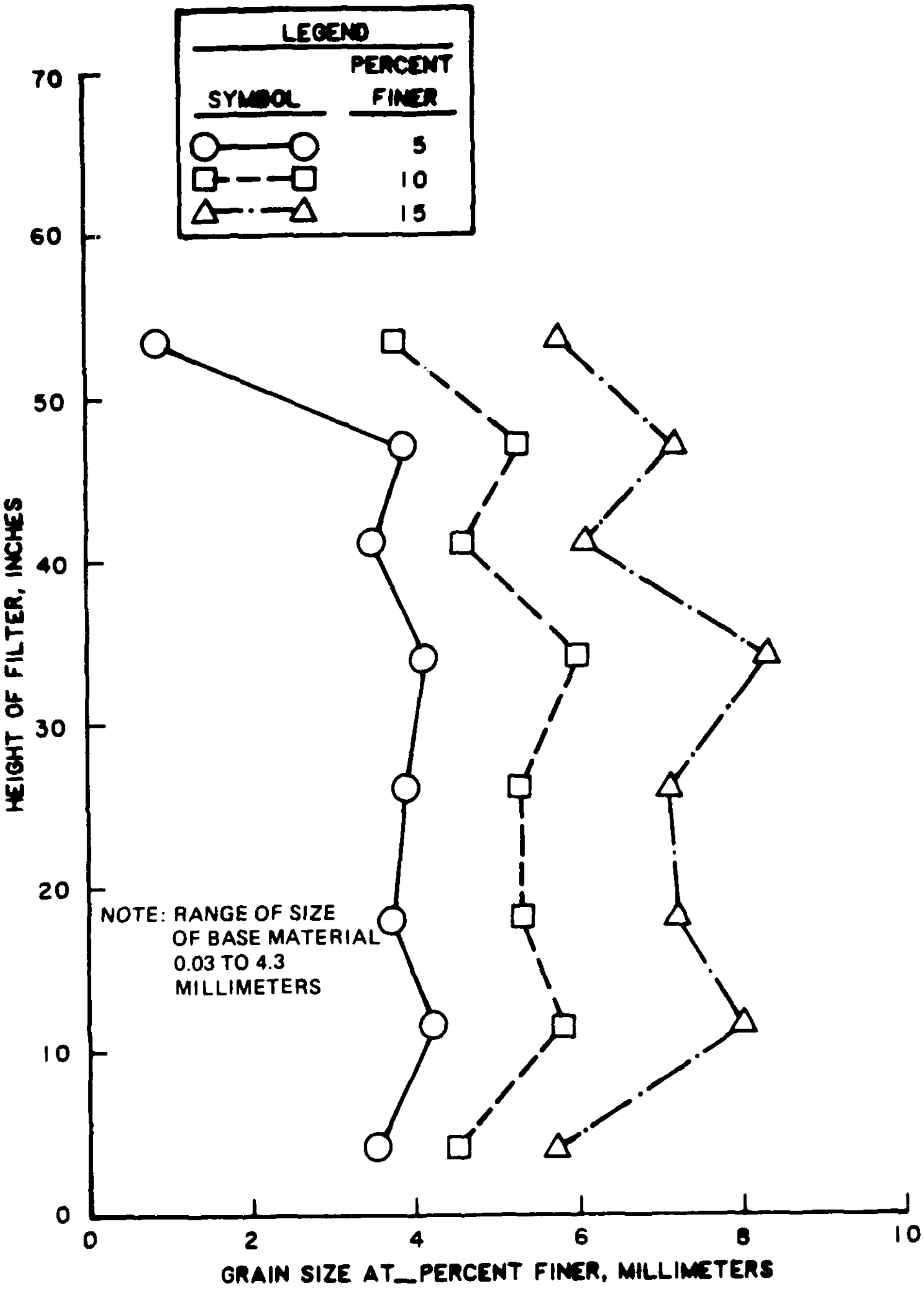


Figure 40. Posttest grain size of fine particles profile of filter for Test No. 1B-A

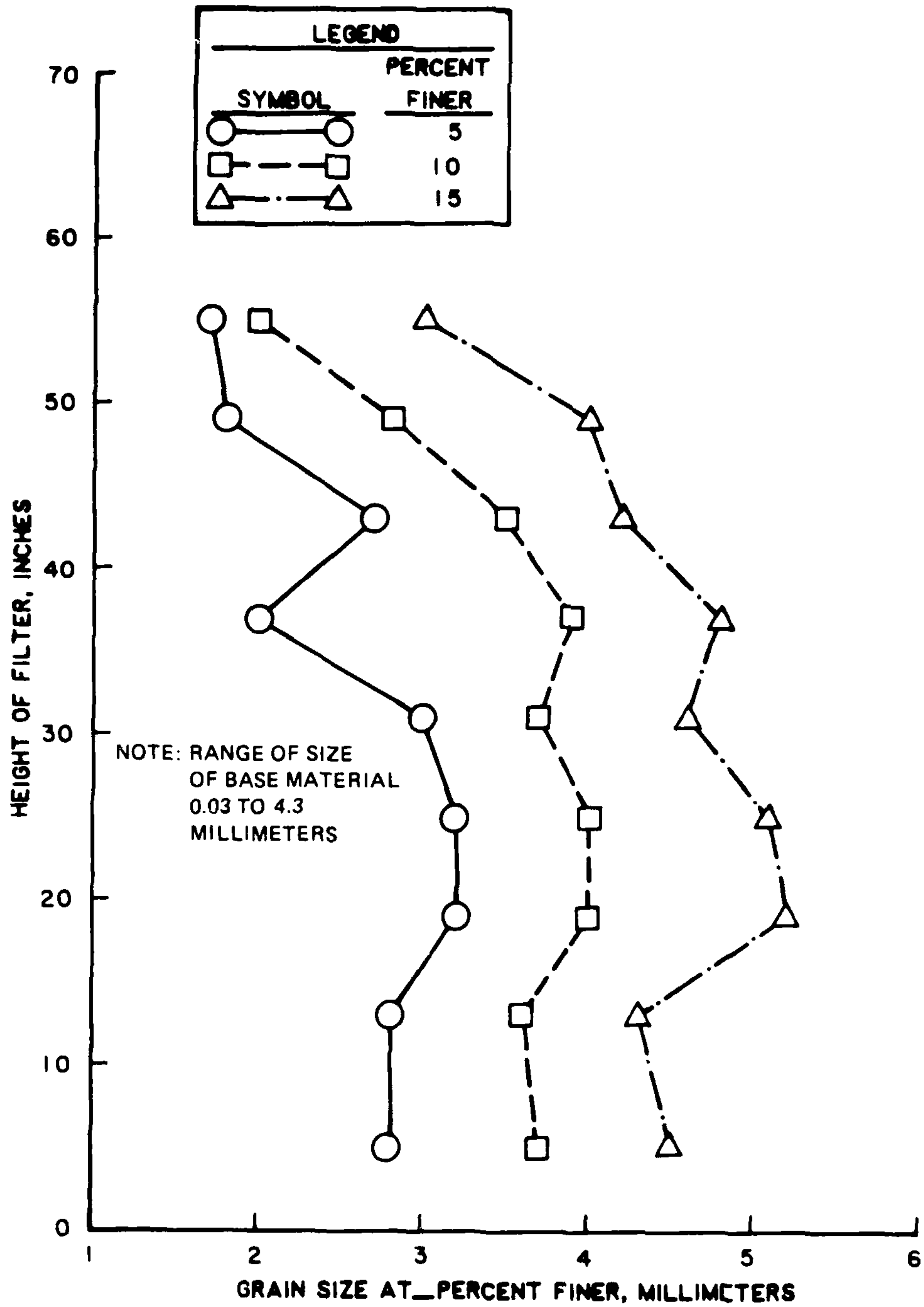


Figure 41. Posttest grain size of fine particles profile of filter for Test No. 1B-B

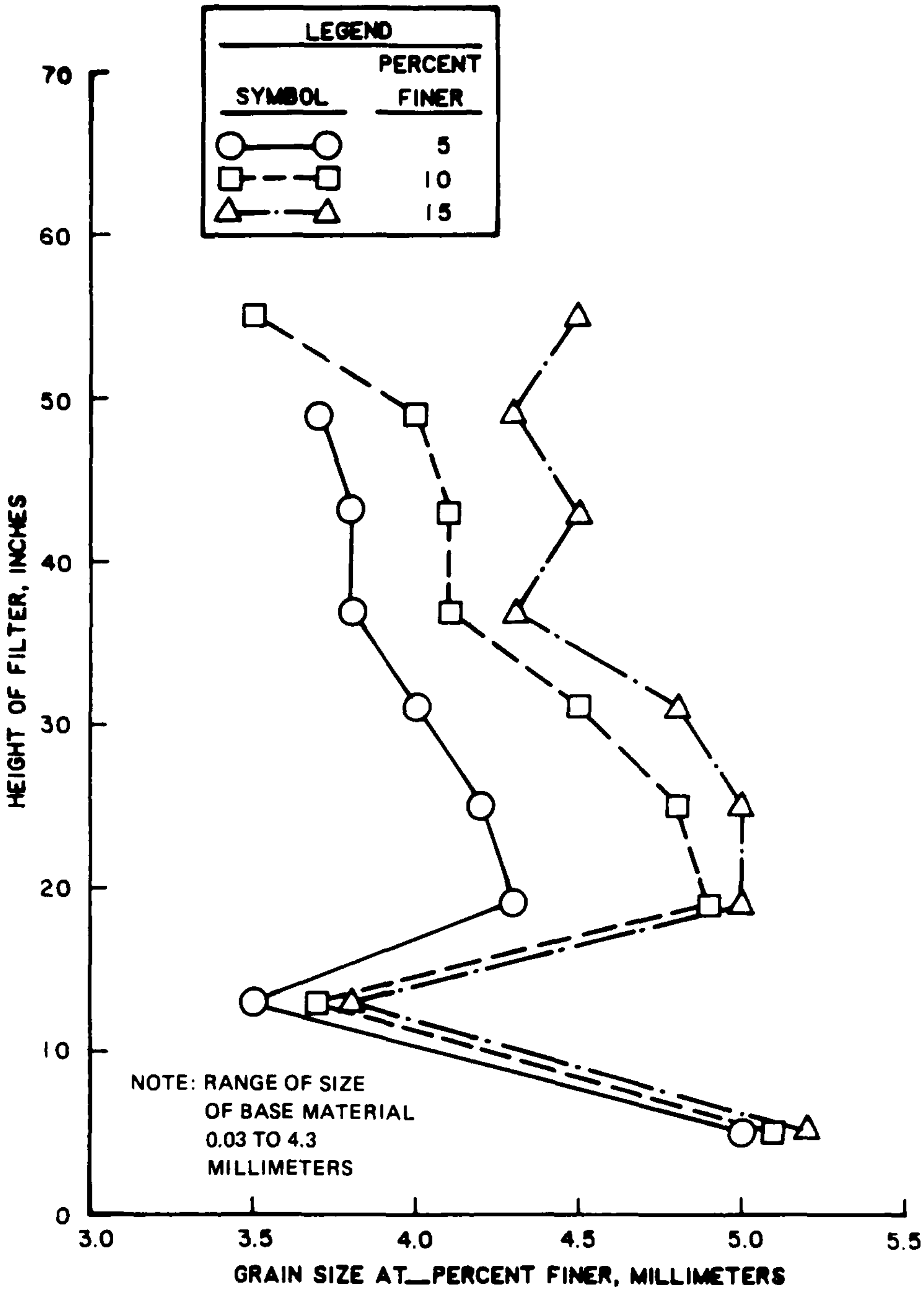
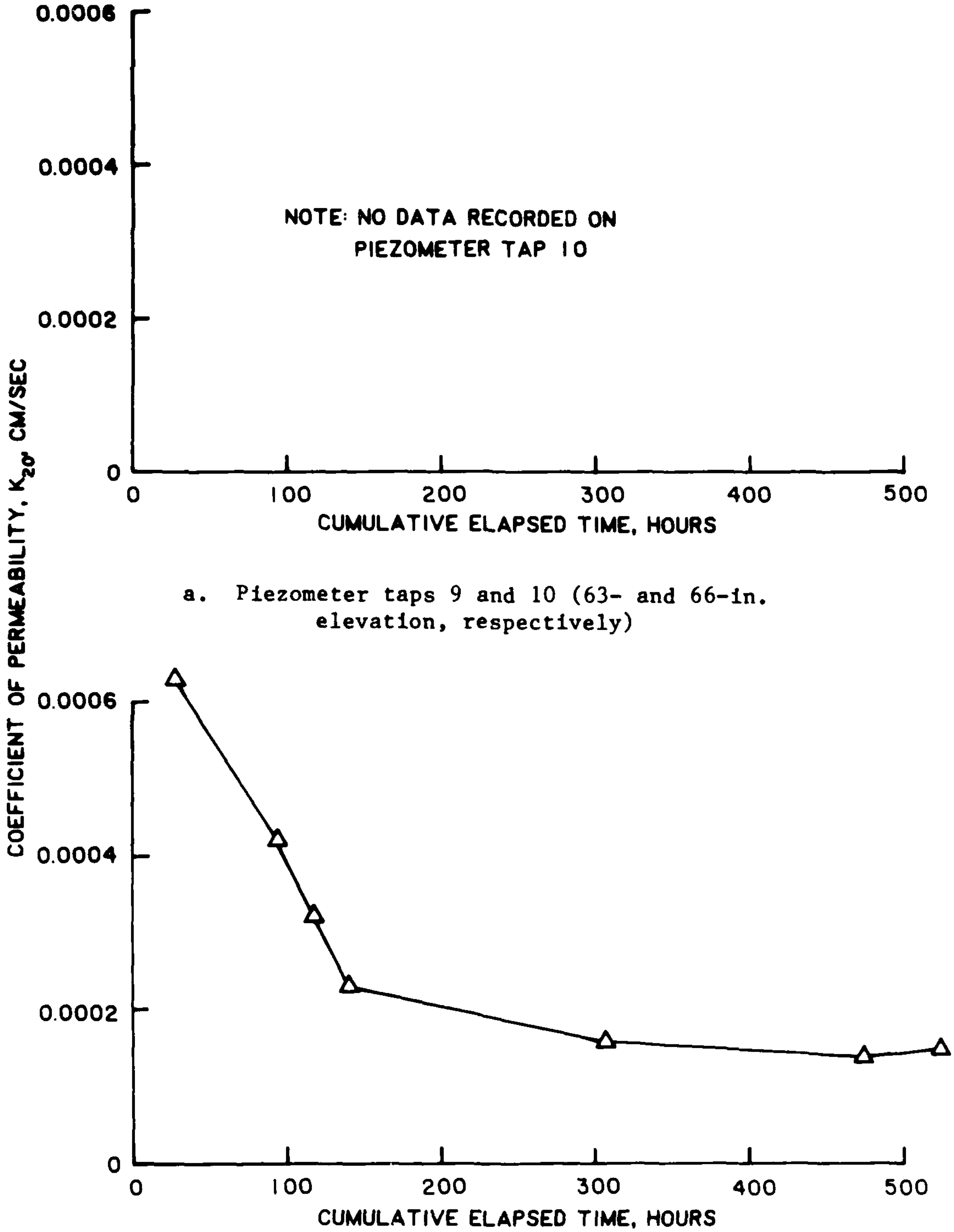


Figure 42. Posttest grain size of fine particles profile of filter for Test No. 1B-C



a. Piezometer taps 9 and 10 (63- and 66-in. elevation, respectively)

b. Piezometer taps 8 and 9 (60- and 63-in. elevation, respectively)

Figure 43. Permeability versus time for base of Test No. 1B-A

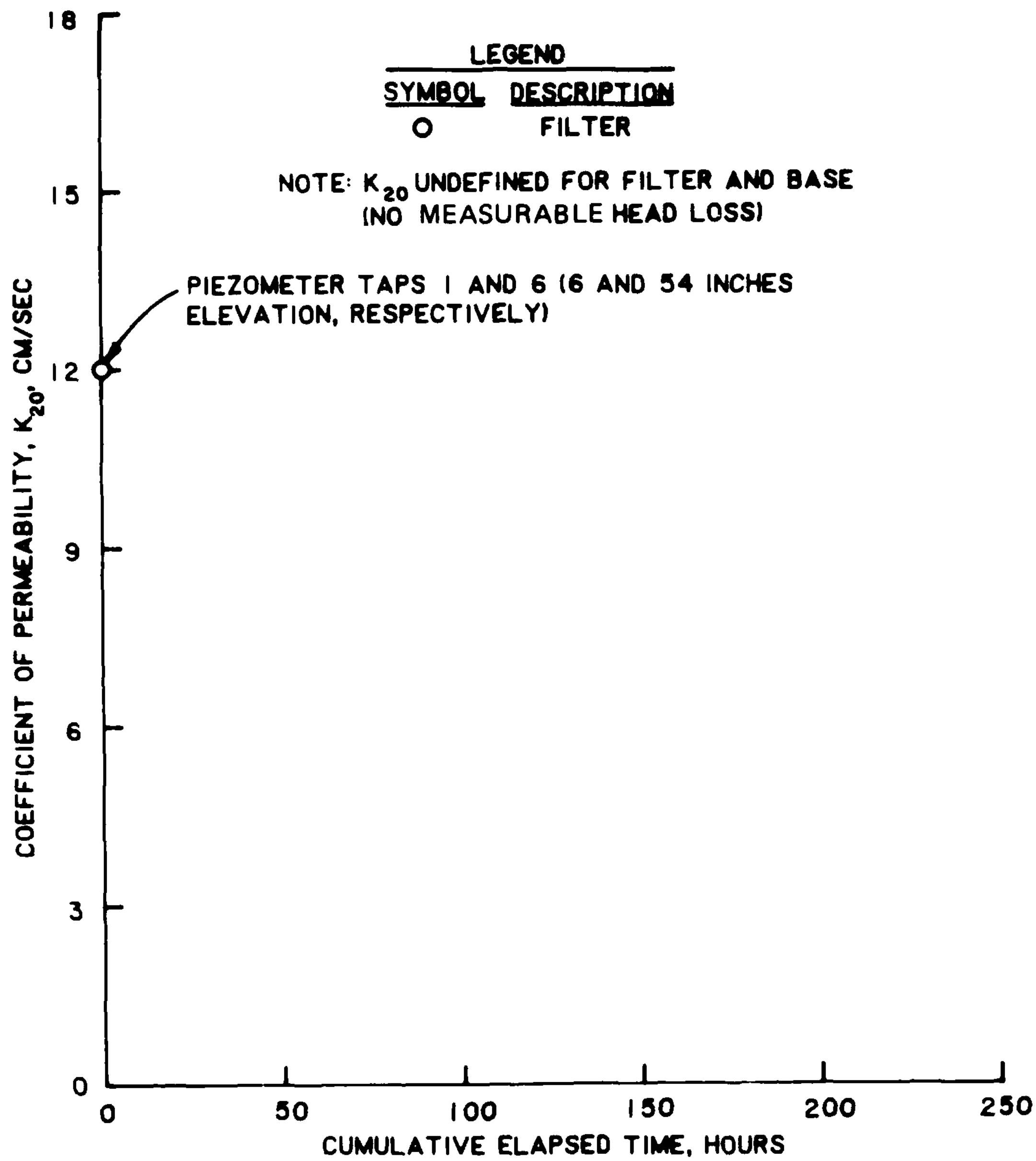
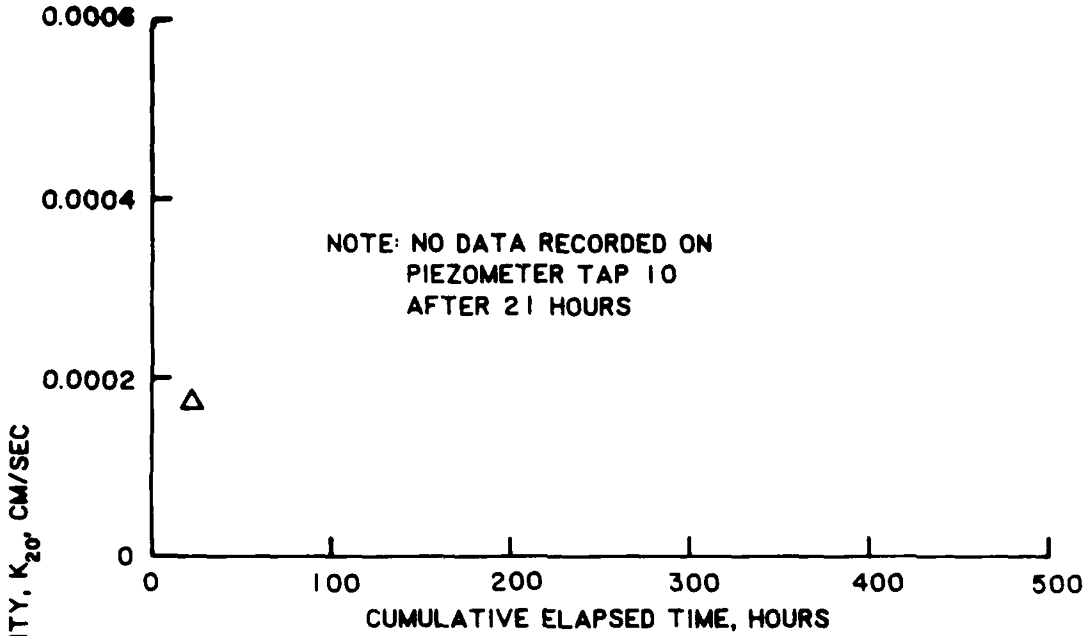
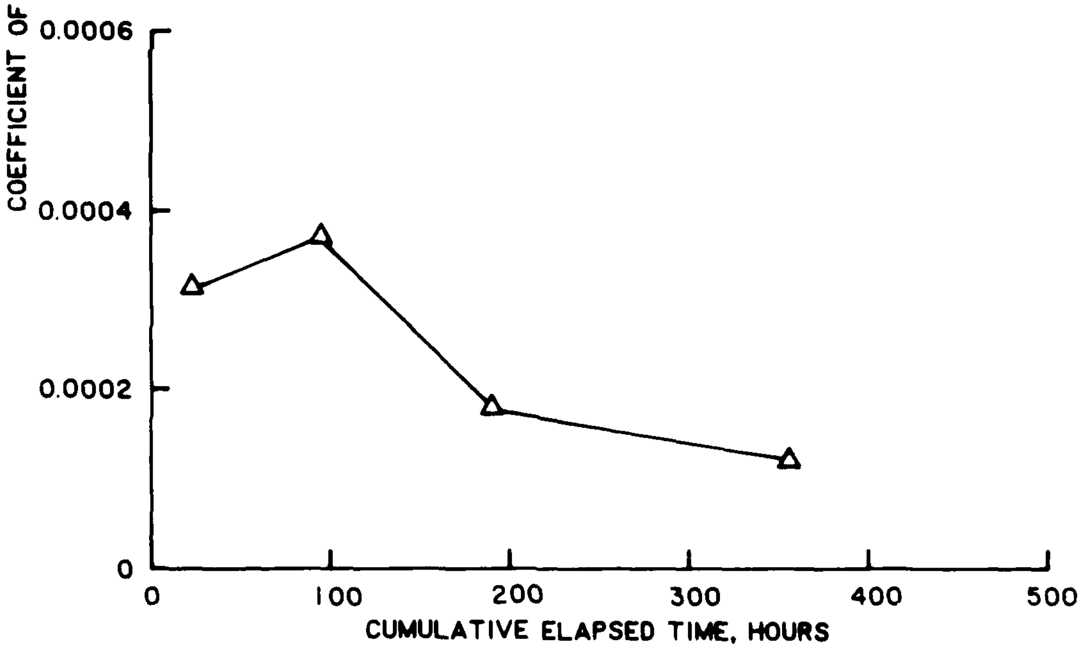


Figure 44. Permeability versus time for filter of Test No. 1B-A

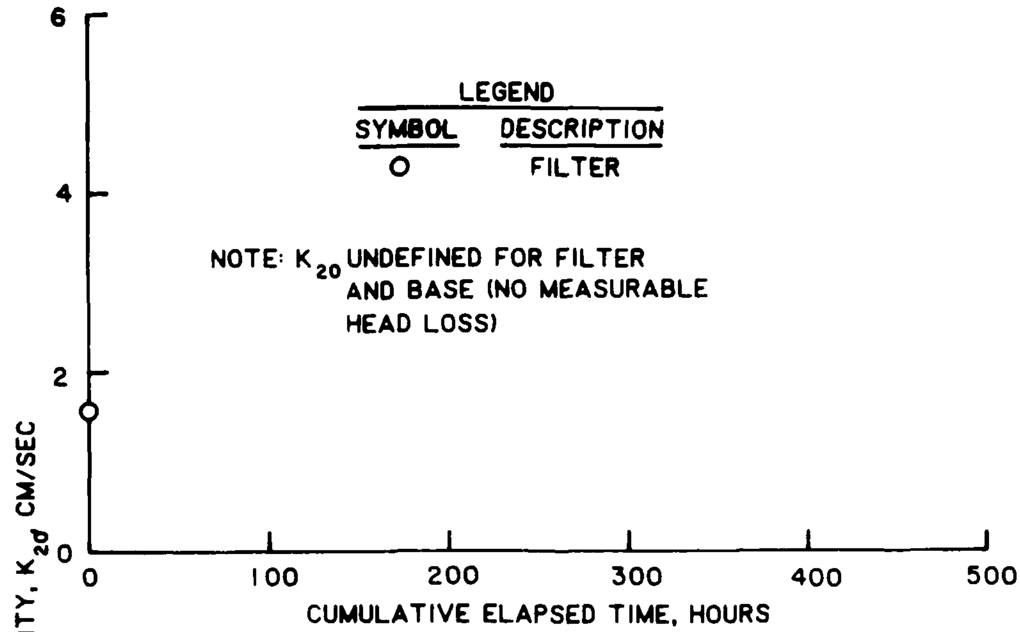


a. Piezometer taps 9 and 10 (63- and 66-in. elevation, respectively)

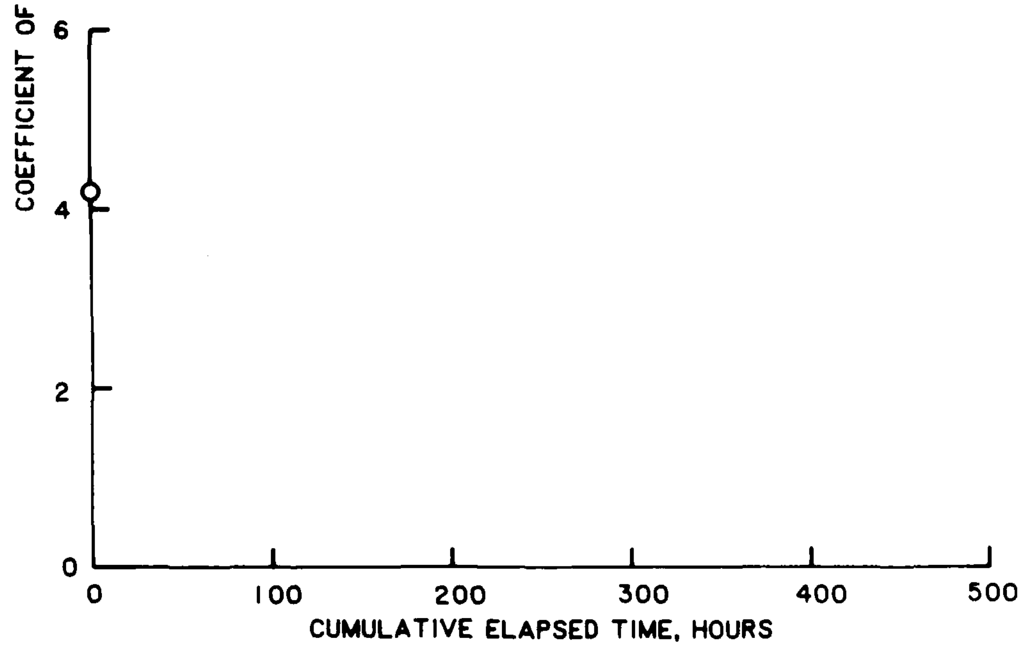


b. Piezometer taps 8 and 9 (60- and 63-in. elevation, respectively)

Figure 45. Permeability versus time for base of Test No. 1B-B

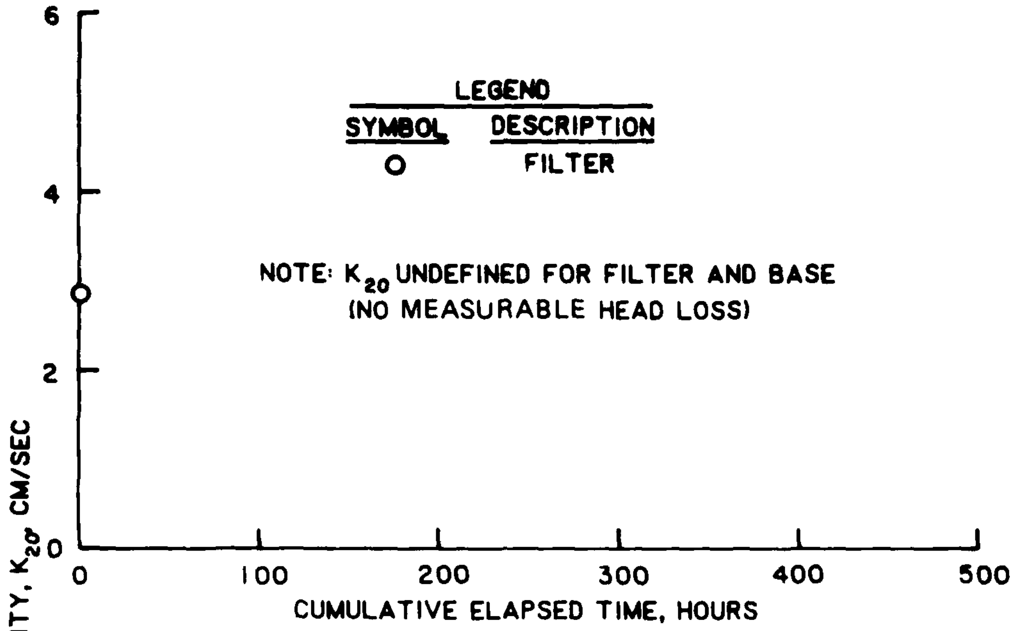


a. Piezometer taps 6 and 7 (54- and 57-in. elevation, respectively)

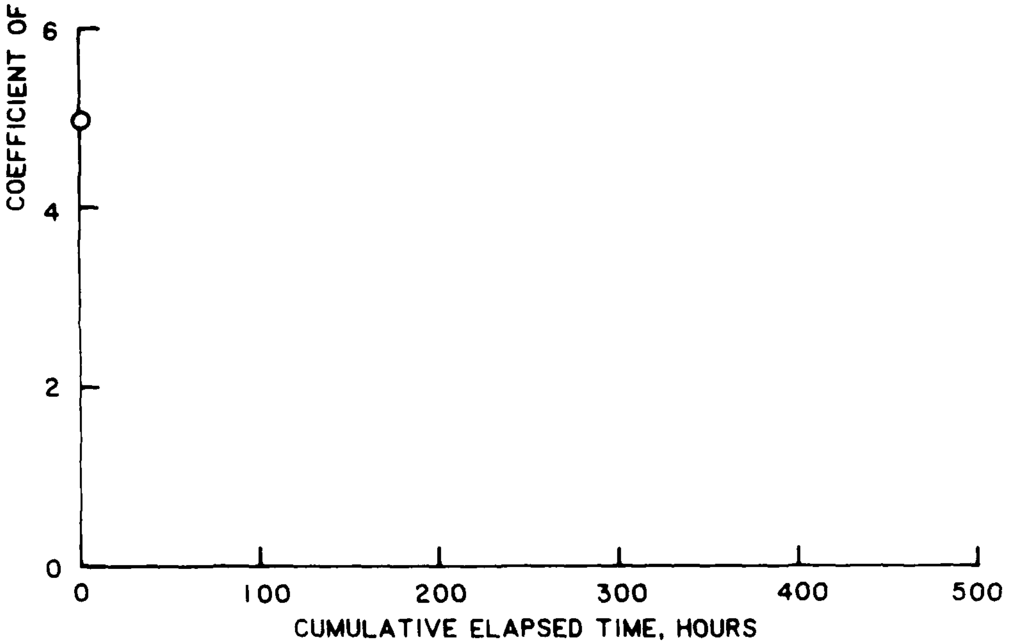


b. Piezometer taps 5 and 6 (48- and 54-in. elevation, respectively)

Figure 46. Permeability versus time for filter of Test No. 1B-B (Sheet 1 of 3)

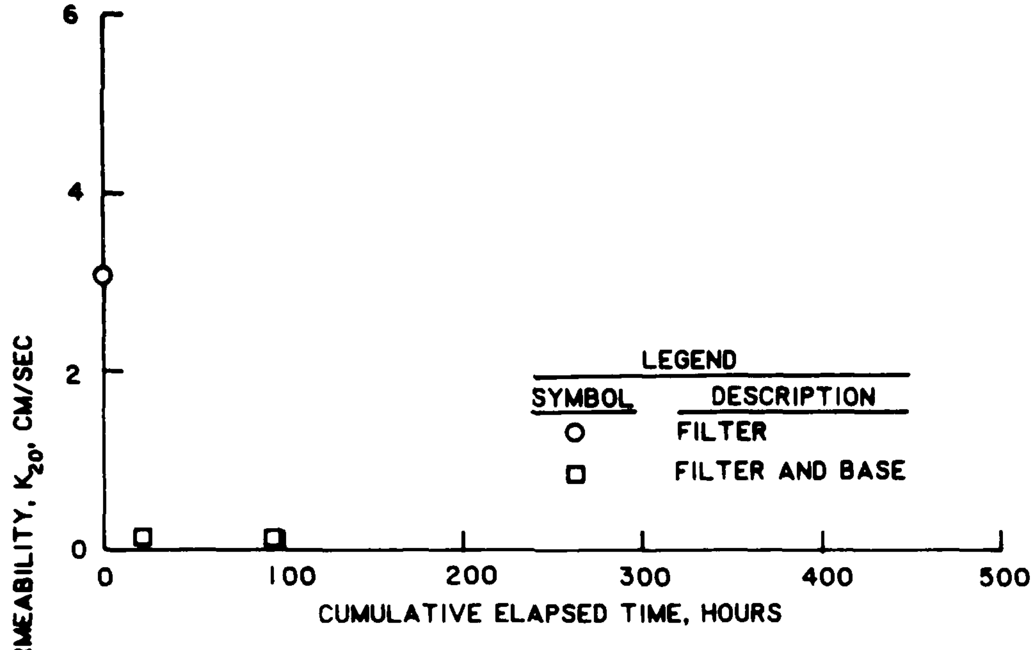


a. Piezometer taps 4 and 5 (42- and 48-in. elevation, respectively)

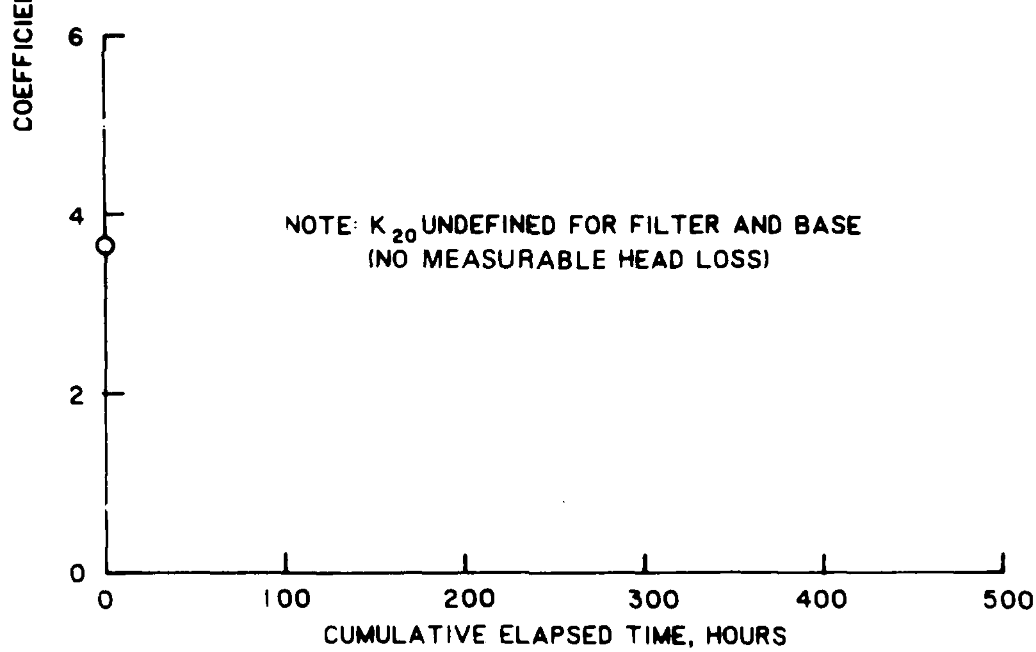


b. Piezometer taps 3 and 4 (30- and 42-in. elevation, respectively)

Figure 46. (Sheet 2 of 3)

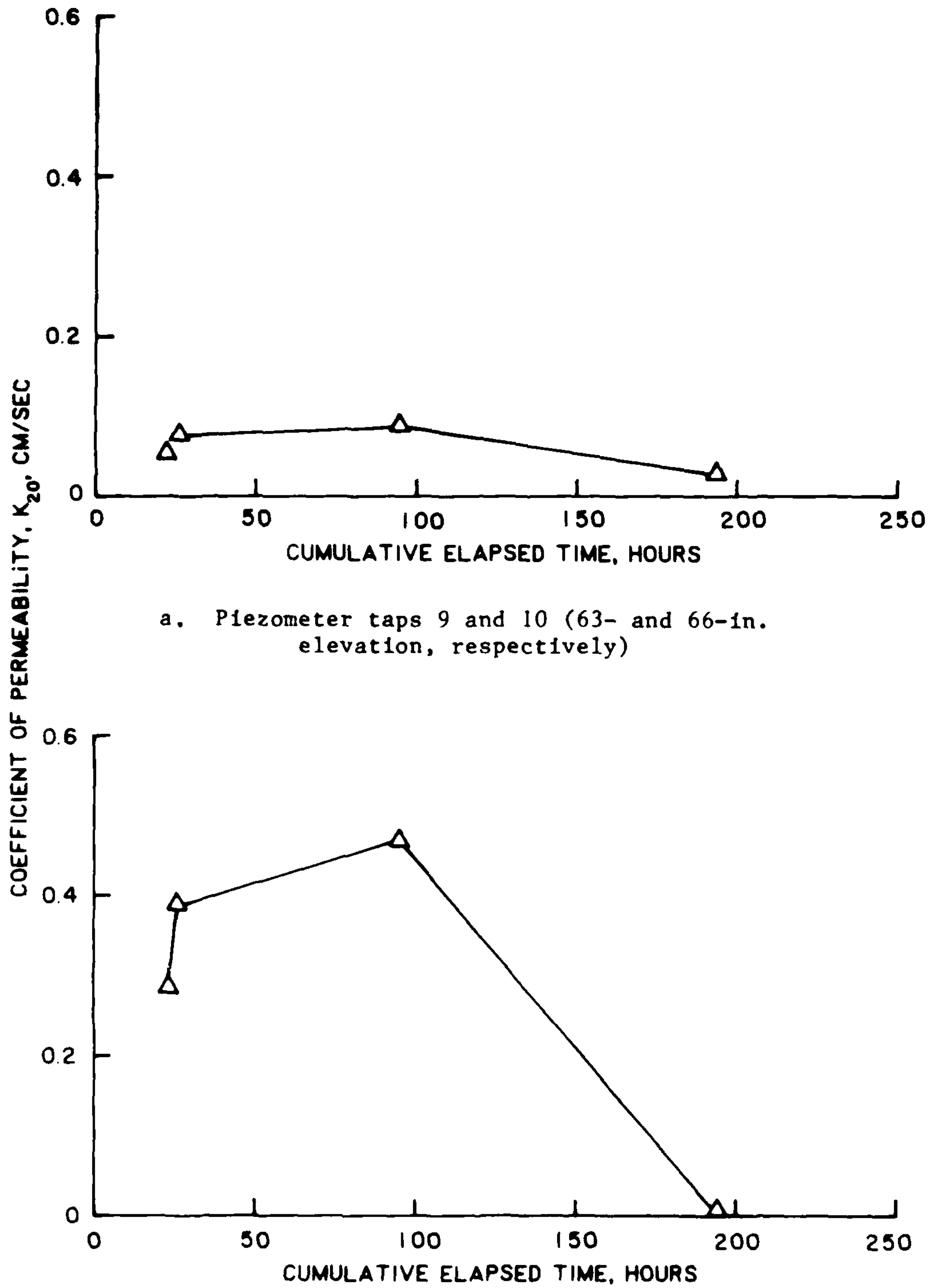


a. Piezometer taps 2 and 3 (18- and 30-in. elevation, respectively)



b. Piezometer taps 1 and 2 (6- and 18-in. elevation, respectively)

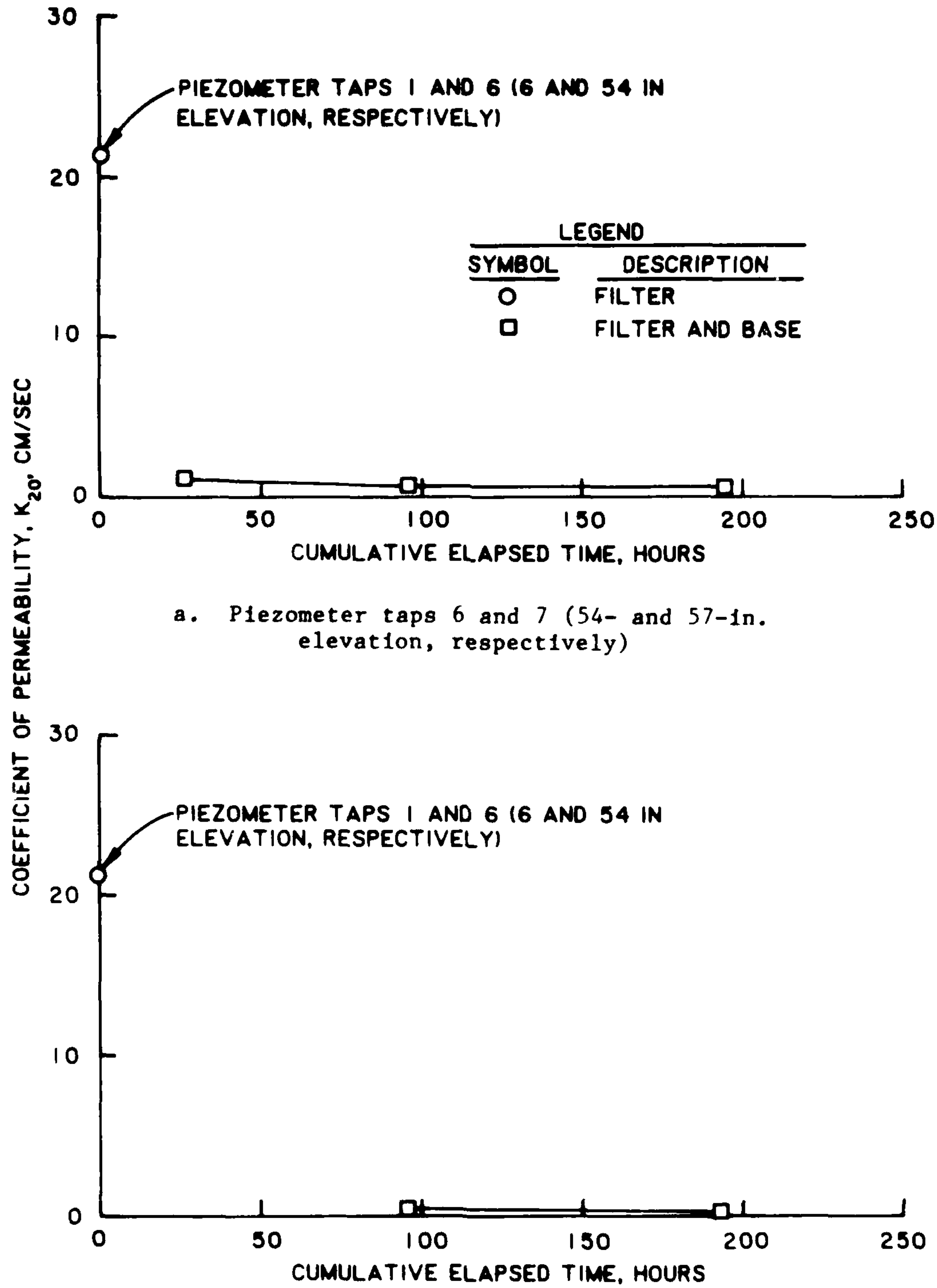
Figure 46. (Sheet 3 of 3)



a. Piezometer taps 9 and 10 (63- and 66-in. elevation, respectively)

b. Piezometer taps 8 and 9 (60- and 63-in. elevation, respectively)

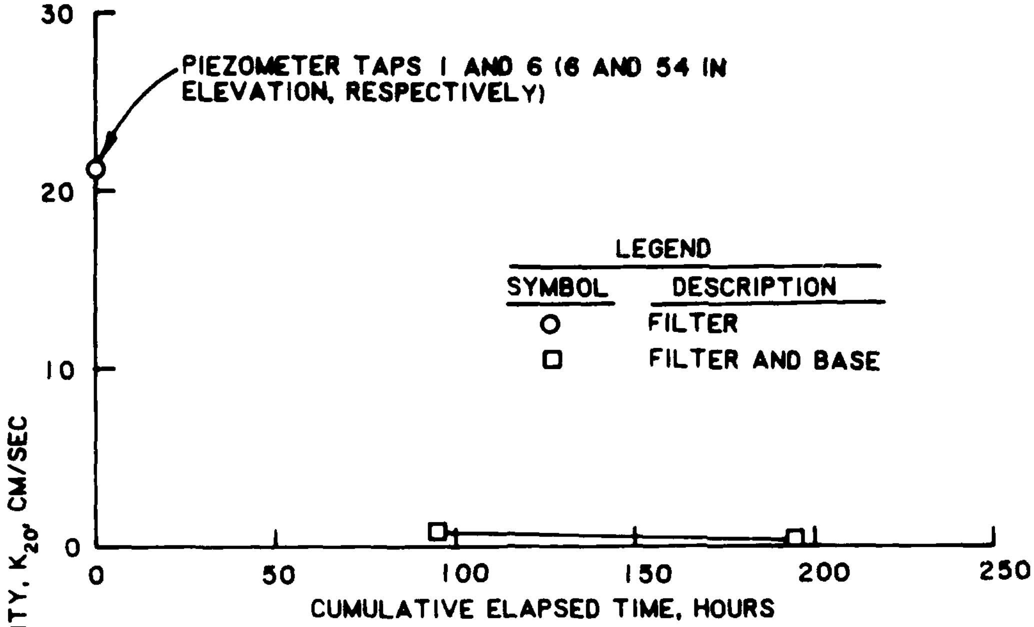
Figure 47. Permeability versus time for base of Test No. 1B-C



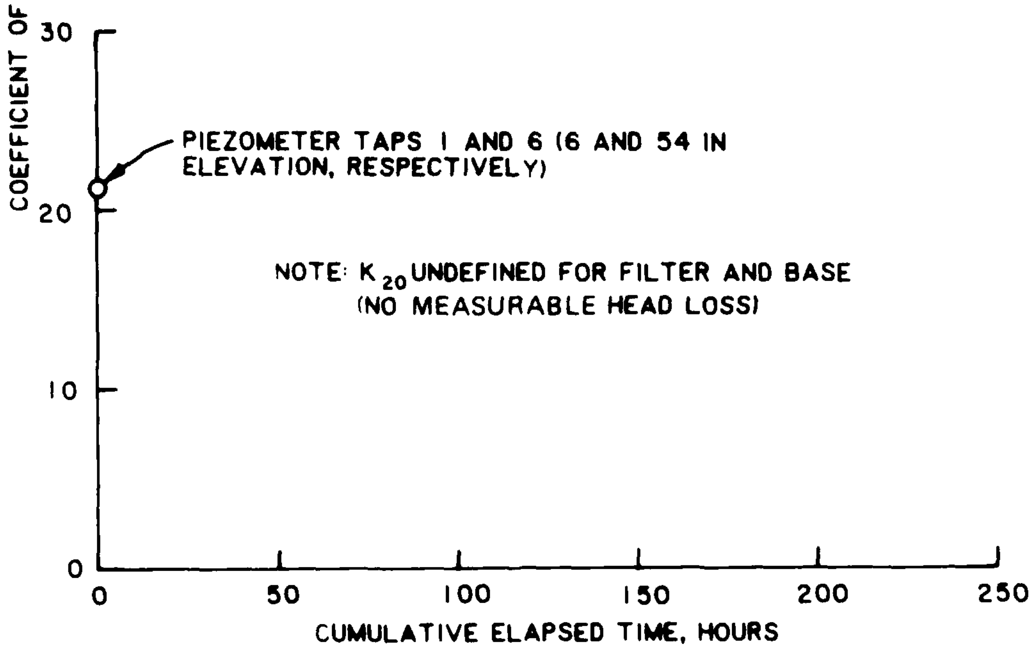
a. Piezometer taps 6 and 7 (54- and 57-in. elevation, respectively)

b. Piezometer taps 5 and 6 (48- and 54-in. elevation, respectively)

Figure 48. Permeability versus time for filter of Test No. 1B-C (Sheet 1 of 3)

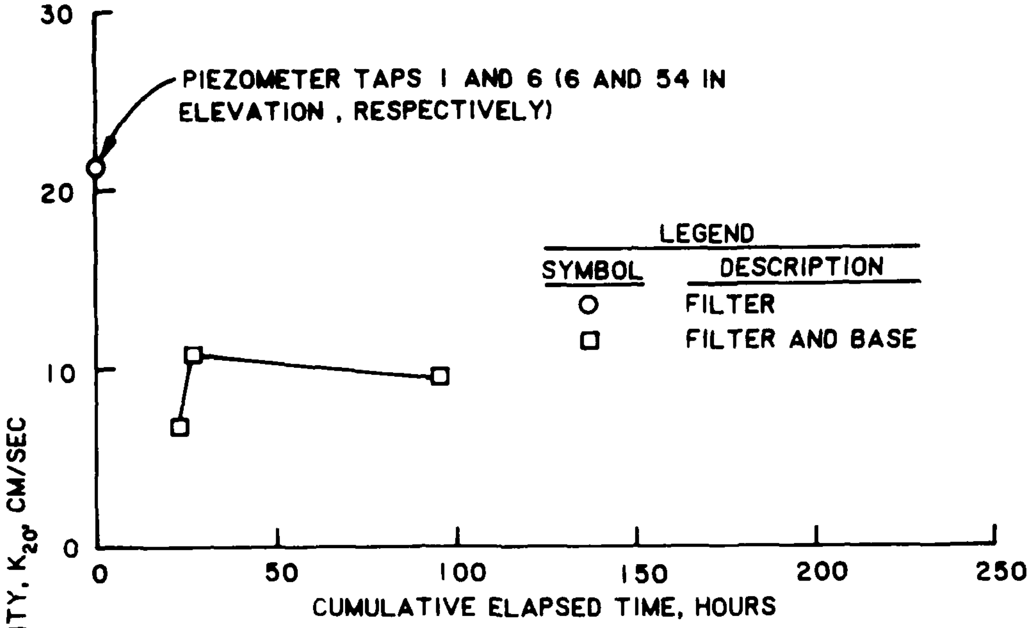


a. Piezometer taps 4 and 5 (42- and 48-in. elevation, respectively)

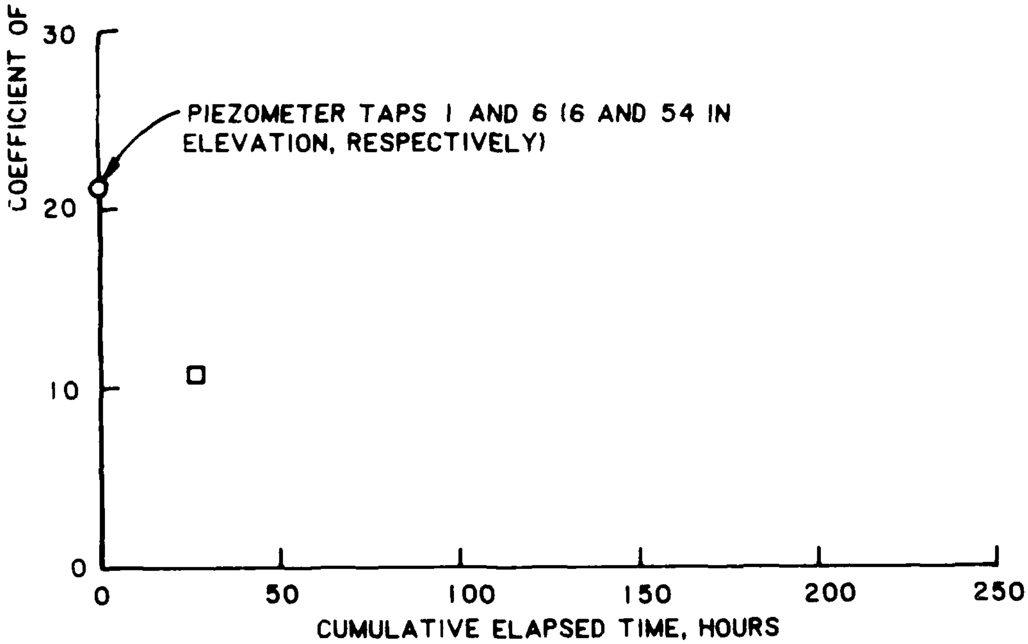


b. Piezometer taps 3 and 4 (30- and 42-in. elevation, respectively)

Figure 48. (Sheet 2 of 3)



a. Piezometer taps 2 and 3 (18- and 30-in. elevation, respectively)



b. Piezometer taps 1 and 2 (6- and 18-in. elevation, respectively)

Figure 48. (Sheet 3 of 3)

obtained were restricted (Figure 48a). For Test No. 1B-C, Figures 47a and 47b show that the permeability of the lower part of the base was 5.4 times the permeability of the upper part of the base (Table 7). This difference in permeability was due to air segregation (Appendix A) and/or migration of the lower part of the base downward into the filter during either construction and/or saturation or filter testing.

36. Relative permeability of filter. As previously stated, the filter material should have 25 or more times the permeability of the base (Part II, Equation 6). As shown in Table 5, the ratio of the permeability of the filter to the permeability of the base averaged 1861 and 157 for Test No. 1B-B and 1B-C, respectively.

37. Particle movement within the base and filter. No internal movement of particles within the base or filter was observed for Test No. 1B-A, 1B-B, or 1B-C. As noted in Table 5, during the last 12 hours of Test No. 1B-B, a cavity (3-3/4-in. by 3/4-in.) appeared in the base material near the top. For Test No. 1B-C, a cavity was blown out in the top of the sand base by an air bubble during saturation. Once the test began, the base became dry under low gradient.

Analysis of Test Results

Filter tests with a uniform (poorly-graded) base

38. Movement of a significant quantity of base material into the filter did not occur in Test No. 1A-A (check), 1A-B, or 1A-C. No internal movement of particles was observed within the base for Test No. 1A-A (check), 1A-B, or 1A-C. Internal movement occurred within the upper quarter of the filter, either during construction and/or saturation or filter testing, for Test No. 1A-B.

Filter tests with a poorly-graded base

39. Movement of a significant quantity of base material into the filter occurred either during construction and/or saturation or filter testing for Test No. 1B-A, 1B-B, and 1B-C. No internal movement of particles within the base or filter was observed for Test No. 1B-A, 1B-B, or 1B-C.

Comparison with CE filter criteria

40. Table 8 gives a summary of the soils, CE filter criteria, and test results. The filter tests with a uniform (poorly-graded) base met the CE filter criteria for permeability (Equation 3, Part II) and the first stability requirement (Equation 1, Part II)

$$\frac{D_{15_F}}{D_{85_B}} \leq 5$$

where

D_{15_F} = size of filter material at 15 percent passing

D_{85_B} = size of base material at 85 percent passing

One of the three filter tests with a uniform (poorly-graded) base Test No. 1A-A (check) did not meet the second stability requirement (Equation 2, Part II)

$$\frac{D_{50_F}}{D_{50_B}} \leq 25$$

where

D_{50_F} = size of filter material at 50 percent passing

D_{50_B} = size of base material at 50 percent passing

Two of the three filter tests (Test No. 1A-A (check) and 1A-B) with uniform (poorly-graded) base did not meet the criteria for grain size curve of the filter approximately parallel to grain size curve of the base. However, as shown in Table 8, movement of a significant quantity of base material into the filter did not occur for the filter tests with a uniform (poorly-graded) base. Internal movement occurred within the poorly-graded sandy gravel filter for Test No. 1A-B where the C_u of the filter was 8.

41. The filter tests with a uniform (poorly-graded) base, though limited, suggest that the second stability ratio (Equation 2, Part II) should not

be used and that there is no need for requiring parallelism of filter and base gradations.* The tests indicate that problems with internal stability may occur with poorly-graded sandy gravel filters.

42. As shown in Table 8, the filter tests with a poorly-graded base met the CE filter criteria for permeability (Equation 3, Part II) and the first stability requirement (Equation 1, Part II). Two of the three filter tests with a poorly-graded base (Test No. 1B-A and 1B-B) did not meet the second stability requirement (Equation 2, Part II). One of the three filter tests with a poorly-graded base (Test No. 1B-C) did not meet the criteria for grain size curve of the filter approximately parallel to grain size curve of the base. Movement of a significant quantity of base material into the filter occurred for all three filter tests with a poorly-graded base.

43. The limited filter tests with a poorly-graded base indicate that the second stability ratio (Equation 2, Part II) should not be used. Filter Test No. 1B-C with a uniform (poorly-graded) base indicated movement of a significant quantity of base material into the filter may occur with a uniform (poorly-graded) filter because of a lack of parallelism of base and filter gradations when the first stability requirement (Equation 1, Part II) has been satisfied.

---

* This is in agreement with laboratory filter tests results obtained by Sherard (1981) and co-workers on very uniform ($C_{u_{avg}} = 1.1$, $1.0 \le C_u \le 1.4$) sand bases and very uniform ($C_{u_{avg}} = 2.3$, $1.1 \le C_u \le 9.3$) sand and gravel filters (Sherard, Dunnigan, and Talbot 1984). Figure 49 indicates that Test No. 1A-A (check), 1A-B, and 1A-C all fall into the stable category for filter tests with a uniform base.

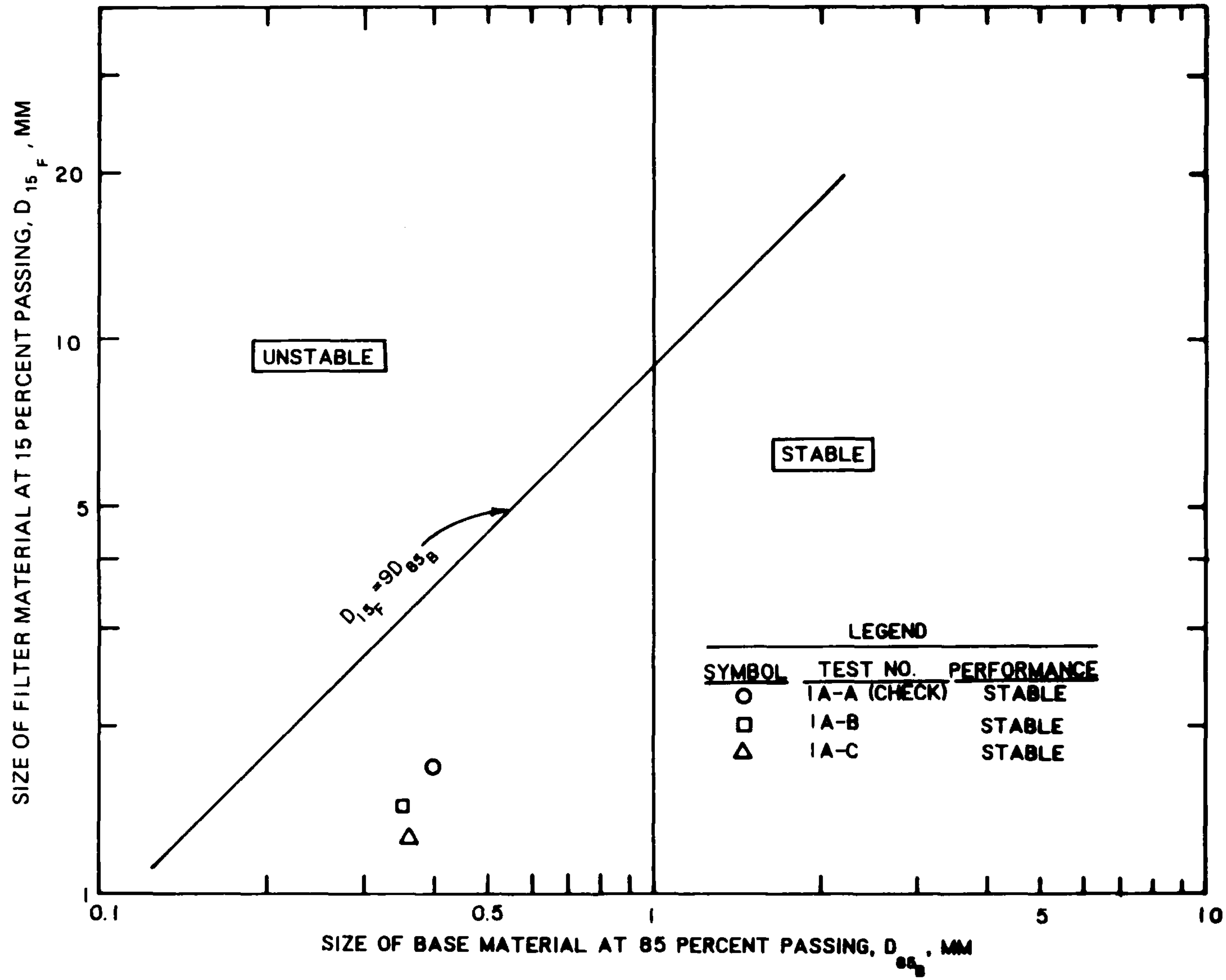


Figure 49. Filter stability for very uniform ($C_{u_{avg}}$ = 1.1, 1.0 ≤ C_u ≤ 1.4) sand bases (after Sherard, Dunnigan, and Talbot 1984)

PART IV: INTERNAL STABILITY OF FILTER MATERIALS

Introduction

44. Laboratory tests were conducted to investigate the internal stability of well-graded and poorly-graded gravelly sands. In particular, it was desired to determine whether an upper limit should be placed upon the coefficient of uniformity of the filter

$$C_u = \frac{D_{60_F}}{D_{10_F}} \tag{11}$$

where

C_u = coefficient of uniformity

D_{60_F} = size of filter material at 60 percent passing

D_{10_F} = size of filter material at 10 percent passing

to maintain internal stability of filters.

Test Equipment

45. The equipment used for conducting the internal stability tests was the same as that used for the filter tests described in Part III. However, prior to conducting the internal stability tests, a new pump and connecting water lines were installed as shown in Figure 50. Flow was downward and ordinary tap water was used as it was not considered feasible to deair the large volumes of water involved. Therefore, a decrease in permeability due to the accumulation of air in the top part of the specimen (Bertram 1940) was anticipated. The influence of air segregation on the tests results is discussed in Appendix A. Pressure gages were used to measure incremental gradients.*

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* Manometer board readings were used for Test 1 (gages 1, 2, 3, 4, 5) at hydraulic gradients of 0.9 and 1.2.

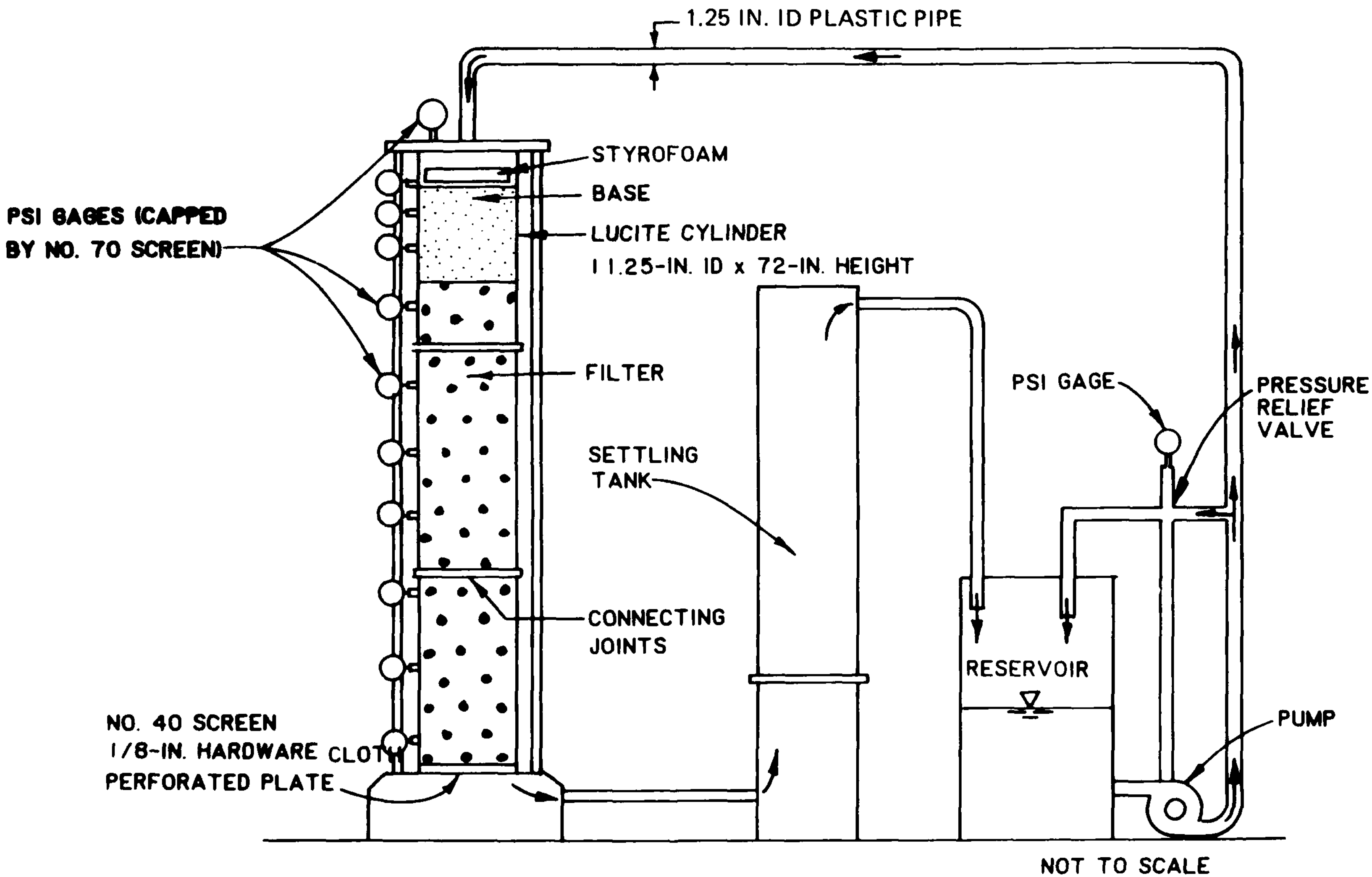


Figure 50. Schematic diagram of test apparatus used for internal stability of filters

Test Program

46. The test program consisted of six tests conducted on well-graded and poorly-graded gravelly sands with coefficient of uniformity values of 10, 20, and 40 as illustrated in Figure 51.

Description of Soils Tested

47. The gradations of the filter materials used are shown in Appendix C and in Figure 51. The properties of the soils are summarized in Table 9. All materials were blended from existing stockpiles of natural sands and gravels of subrounded to subangular particles. The materials were thoroughly washed to remove dust, clay particles, and organic matter. The ratio of inside diameter of the filter test apparatus to maximum particle size of the filter material tested (Test No. 3) was 5.6.

Specimen Construction

48. The procedure used to construct the specimen for the internal stability tests was essentially the same method used to construct the filter described in Part III and illustrated in Figures 10 to 17. During construction, the dry unit weight was measured for each of the three cylinders used to form the specimen. Test No. 1 was compacted by striking the permeameter with a rubber mallet. No compaction was used for any subsequent tests. The average pretest relative density ranged from 0 to 24 percent for Test No. 1A, 2, 2A, 3, and 3A as shown in Table 10. The average pretest relative density for Test No. 1 was 58 percent. Following completion of the specimen construction, photographs of each cylinder of the test apparatus with a grid overlay were made as shown in Figures 52 to 54.

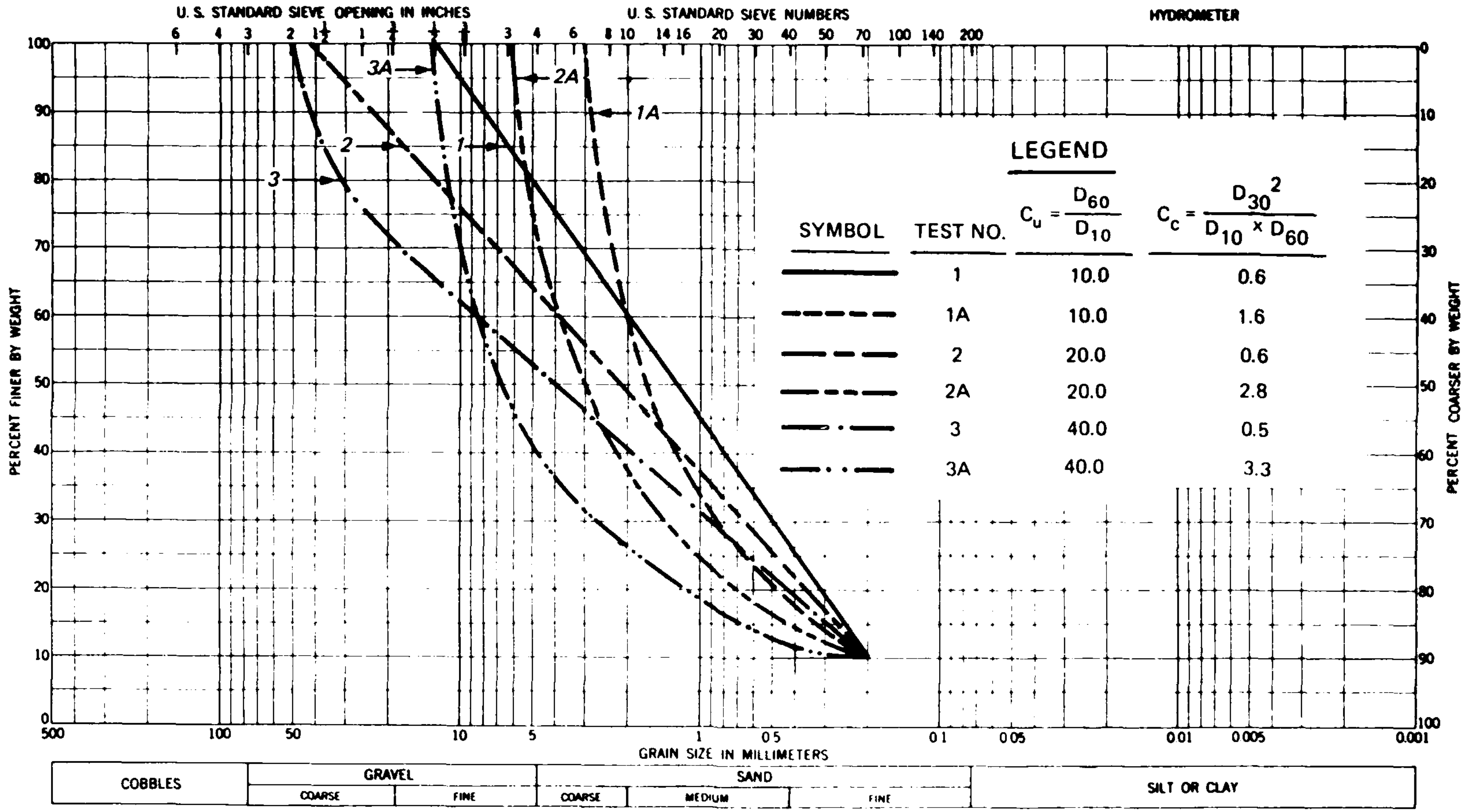


Figure 51. Gradation curves for internal stability tests

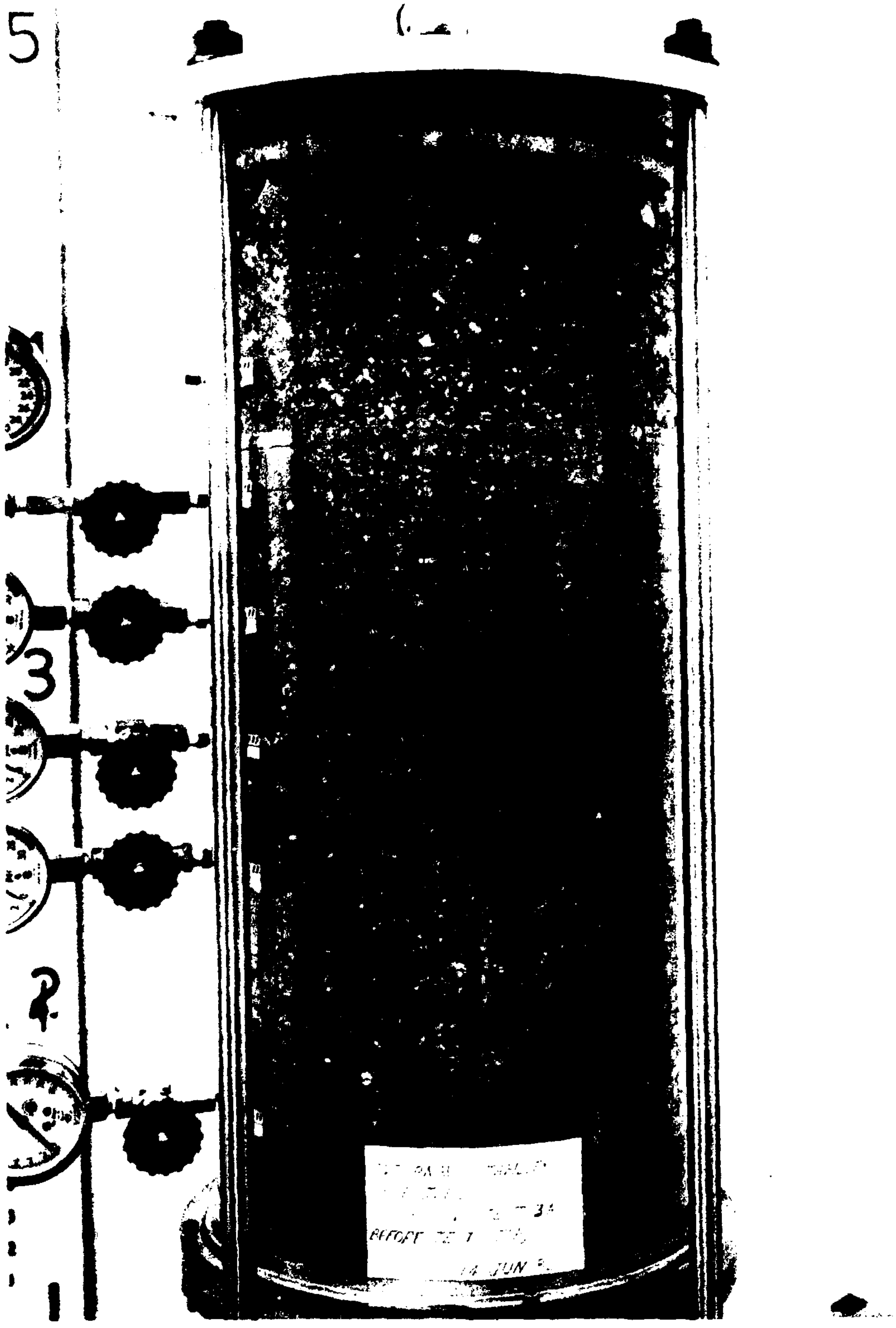


Figure 52. Top cylinder with grid before test

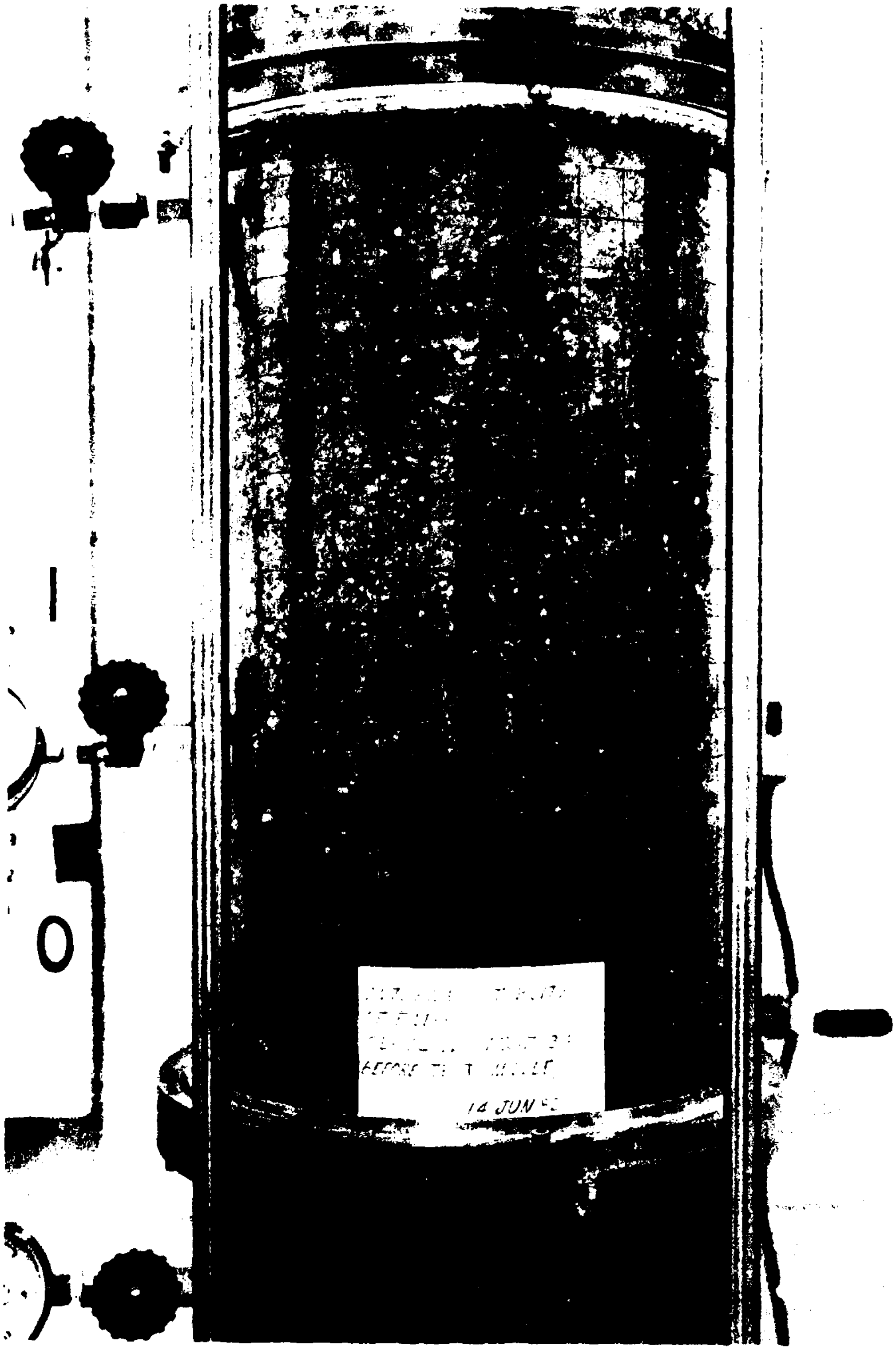


Figure 53. Middle cylinder with grid before test

Figure 54. Bottom cylinder with grid before test

Test Procedure

49. Prior to conducting the internal stability test, the filter material was saturated in the same manner as that previously described for the filter tests in Part III. In conducting the internal stability test, a relatively low hydraulic gradient was applied across the specimen* (Table 11), and piezometer heads along the filter (see Figure 55 for location of piezometer taps), rate of flow through the specimen, and water temperature were measured. Readings were taken until the rate of flow became relatively constant with time. Then the hydraulic gradient was increased and the measurements were repeated. This sequence was continued until the maximum hydraulic gradient was obtained. Piezometer, flow, and water temperature readings are given in Appendix B.

Posttest Sampling

50. Upon completion of the internal stability test, the water was drained from the specimen under gravity flow over a 15-hour period. Photographs were made of the test apparatus, including each cylinder with a grid overlay, as shown in Figures 56 to 59. The specimen was sampled, as previously described for the filter tests in Part III, for determination of dry unit weight and gradations (see Appendix D).

Test Results

51. Methods used to determine internal movement. As previously mentioned in Part II, one of the design requirements for the filter is to prevent particle movement within the filter or internal movement. Internal movement of the filter was not determined directly, but was rather inferred from comparison between pretest and posttest dry unit weight profiles of the filter, comparison between posttest gradations of the filter and the filter material blended for the test for various heights, and permeability profiles of the filter. As shown in Appendix A, air segregation (accumulation of air in the

* The hydraulic gradient across piezometer taps 7 and 9 (57- and 63-in. elevation, respectively) was used as a control.

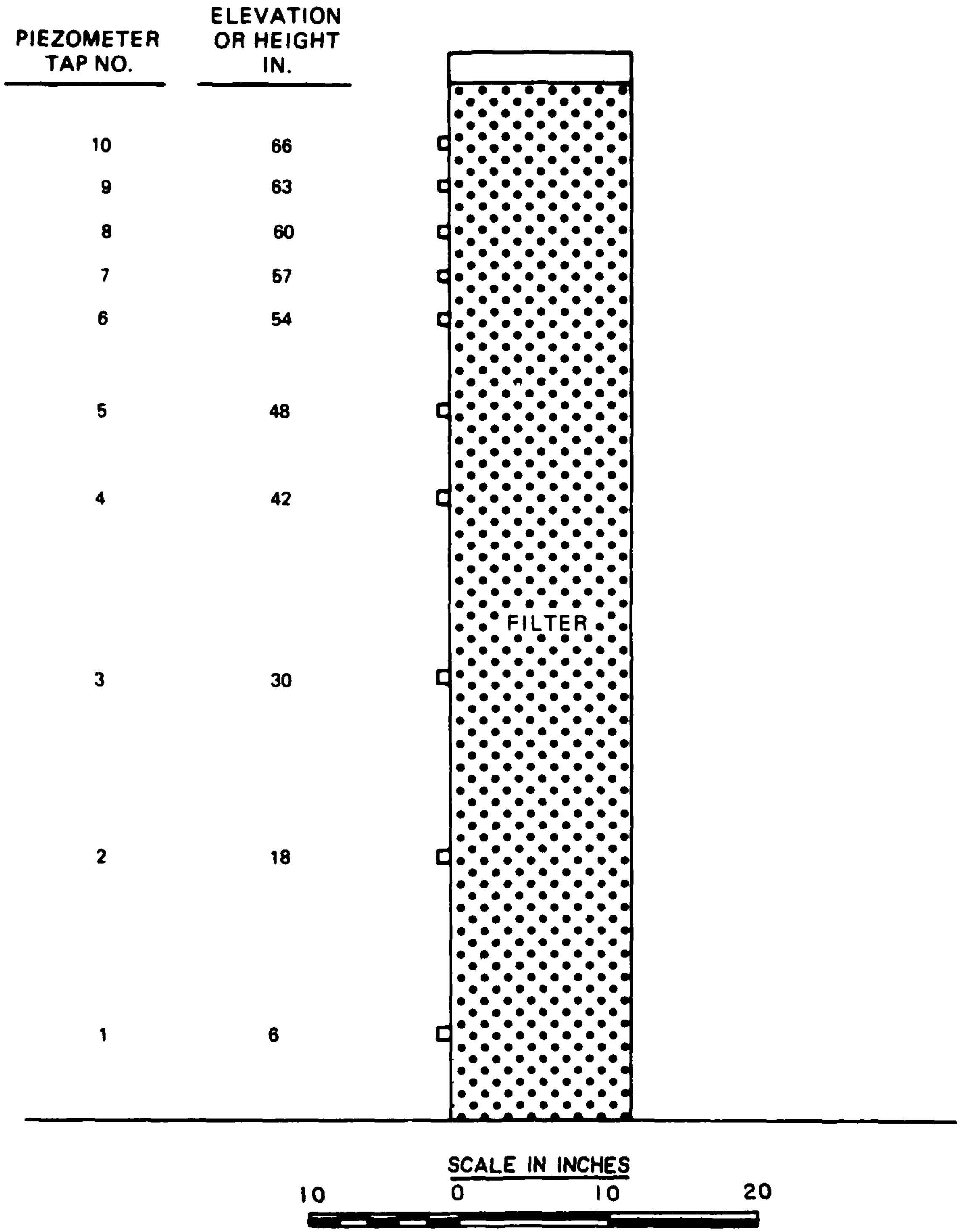


Figure 55. Schematic diagram showing location of piezometer taps for internal stability tests

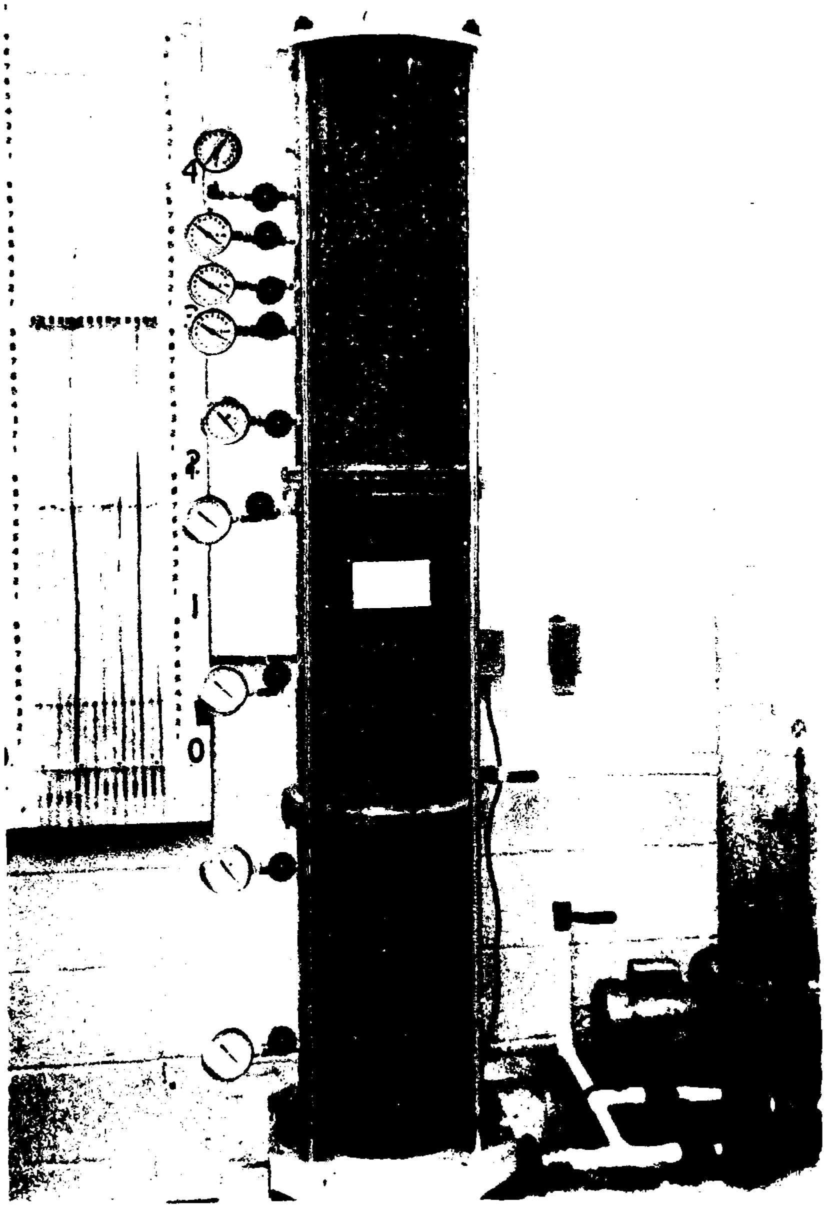
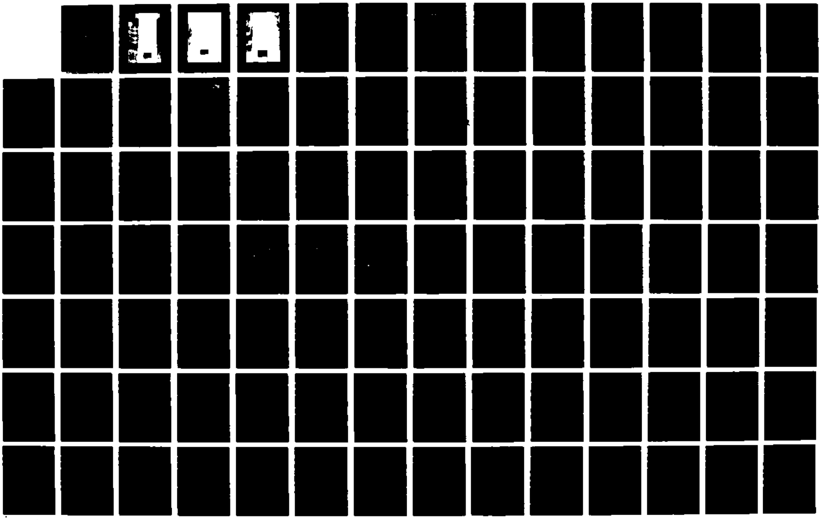
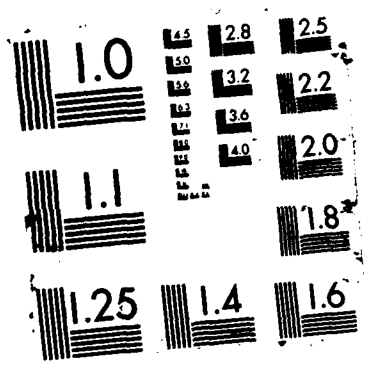


Figure 56. Overall view after test

AD-A185 623 LABORATORY TESTS ON GRANULAR FILTERS FOR EMBANKMENT DAMS(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS GEOTECHNICAL LAB E B PERRY AUG 87 2/4

UNCLASSIFIED WES/TR/GL-87-22 F/G 13/2 NL




1.0
2.8
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2.2
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4.0
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1.4
1.6

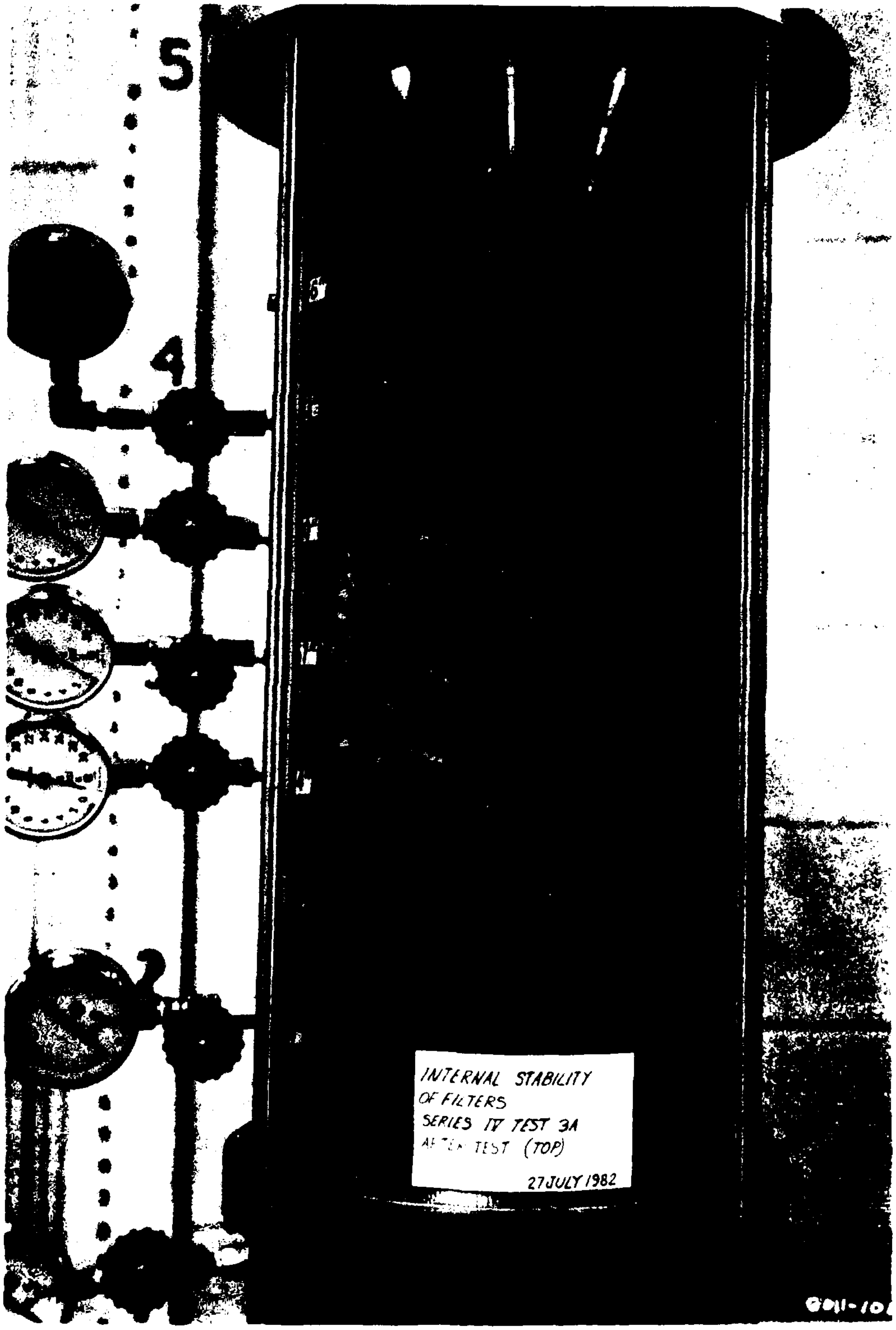

Figure 57. Top cylinder with grid after test

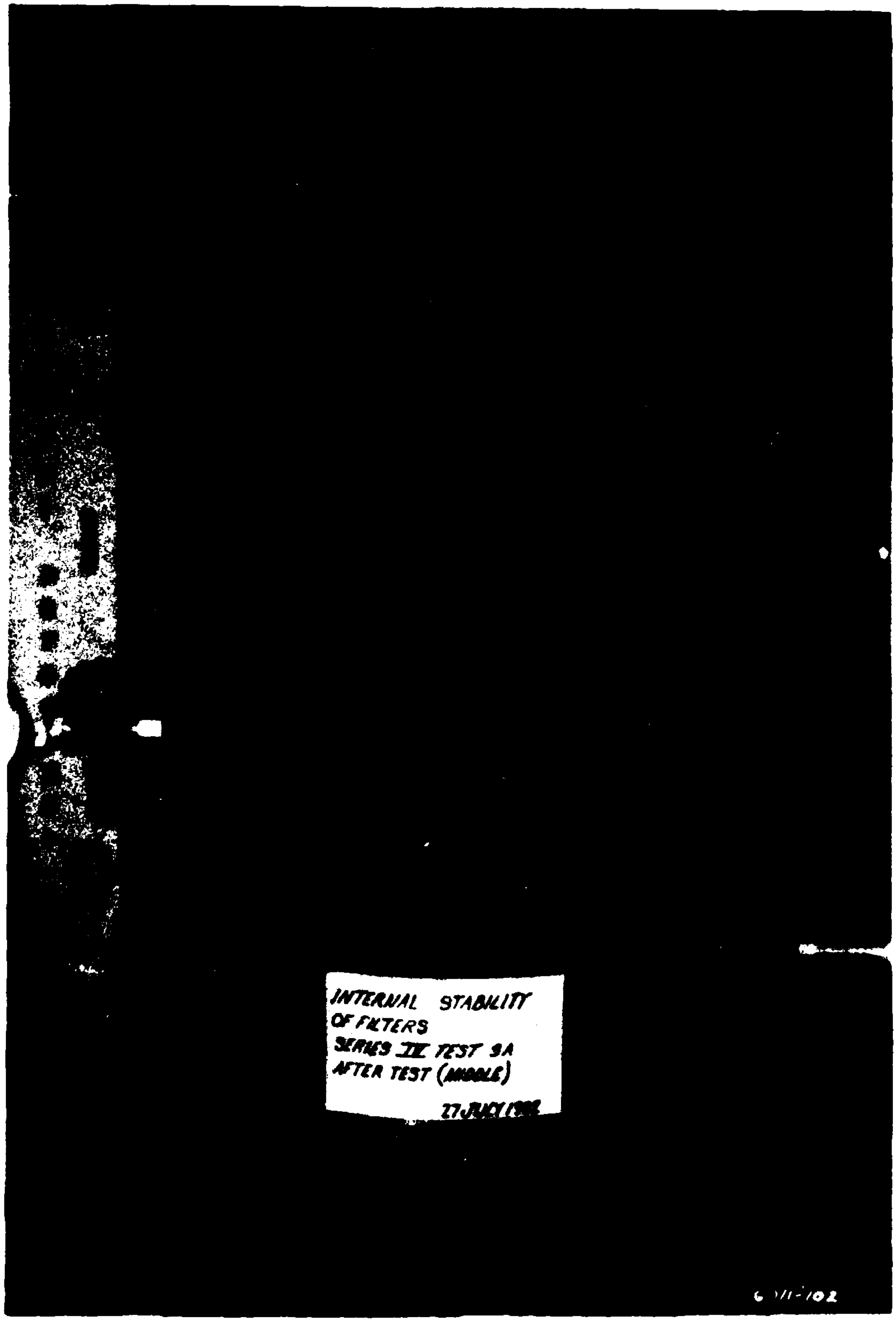

Figure 58. Middle cylinder with grid after test

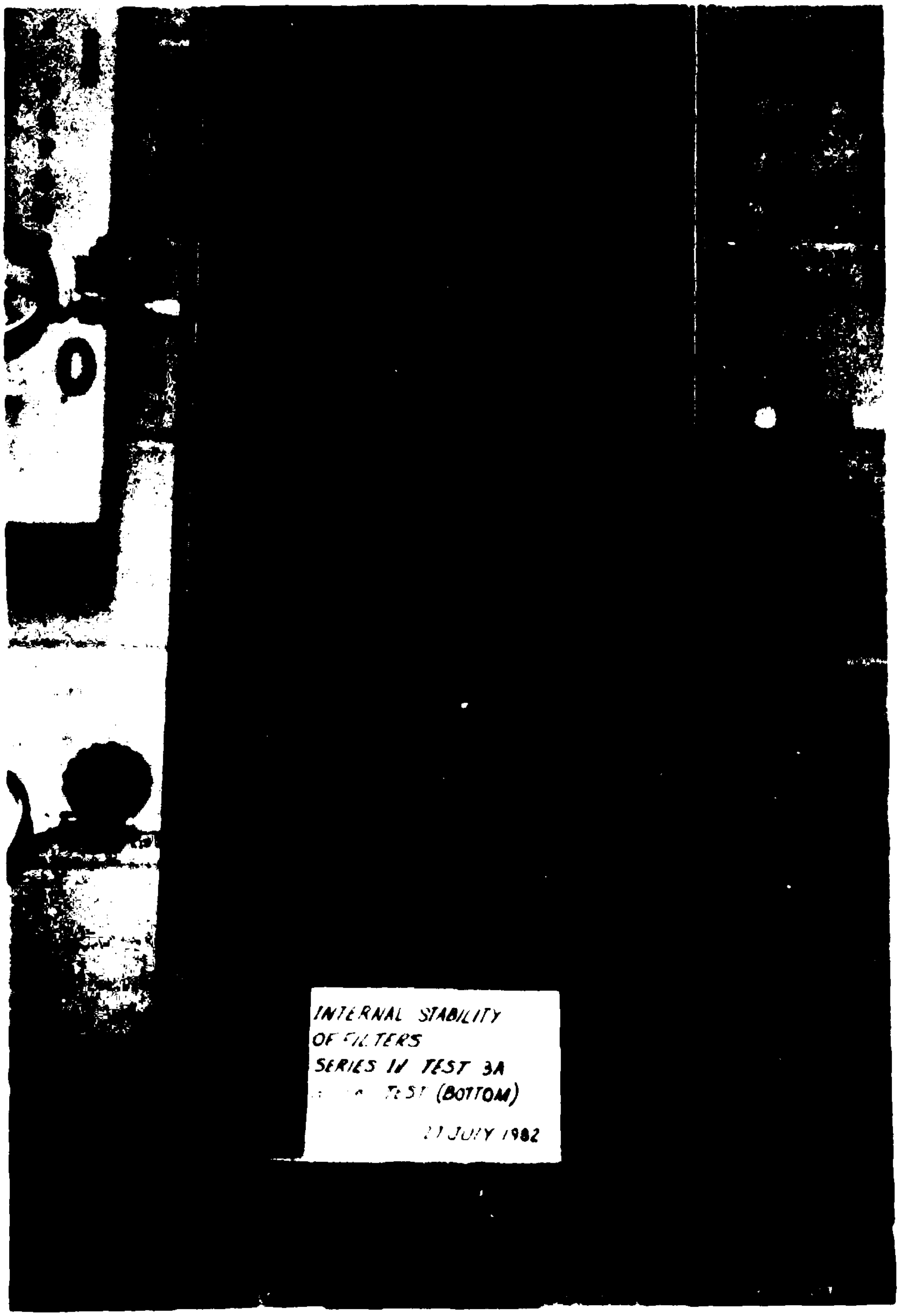

Figure 59. Bottom cylinder with grid after test

voids of the soil) occurred in the uppermost portion of the filter (60- to 63-in.) in each of the filter test analyzed (5 of 6 tests conducted). This reduction in permeability at the top of the filter due to air segregation would have to be taken into account when using permeability profiles to indicate particle migration within the specimen.

52. Dry unit weight profiles of the filter. Pretest and posttest dry unit weight profiles for Test No. 1, 1A, 2, 2A, 3, and 3A are given in Figures 60-65, respectively. Table 12 gives changes in dry unit weight of the filter based upon comparison of pretest and posttest density of the top, middle, and bottom lucite cylinders used to form the specimen. As previously mentioned, Test No. 1 was compacted by striking the permeameter with a rubber mallet, and the results from this test are considered atypical. Since Test No. 2 to 6 were constructed of dry, loose (relative density 0 to 24 percent) sand and gravel, the dry unit weight may have increased as a result of settlement due to saturation, consolidation due to seepage flow, and/or particle migration. When particle migration occurred, the No. 40 screen at the base of the filter apparatus (Figure 44) would restrict the flow of particles larger than fine sand (0.42 m) resulting in an increase in dry unit weight at the bottom of the specimen. As shown in Figures 62 and 65 and in Table 12, an increase in posttest dry unit weight with depth occurred for Test No. 2 and 3A. The magnitude of the increase in posttest dry unit increased with increase in the coefficient of uniformity.

53. Comparison between filter gradations. The posttest grain size of fine particles (5, 10, and 15 percent fines) profile of the filter for Test No. 1, 1A, 2, 2A, 3, and 3A are given in Figures 66 to 71, respectively. Internal movement would be indicated by a decrease in particle size with depth of the filter. As shown in Figure 66, internal movement occurred, either during construction and/or saturation or filter testing, within the middle portion (26- to 38-in.) of the filter for Test No. 1. As mentioned previously, Test No. 1 was compacted by striking the permeameter with a rubber mallet, and the results from this test are considered atypical. Comparison among posttest gradations of the top, middle, and bottom 6 in. of the filter are given in Appendix E and summarized in Table 12. Internal movement within the specimen would result in a grading that was finer with depth. If movement occurred throughout the specimen, the middle of the specimen might show no net change in gradation or might be coarser in gradation (Kenney and Lau 1984). Internal

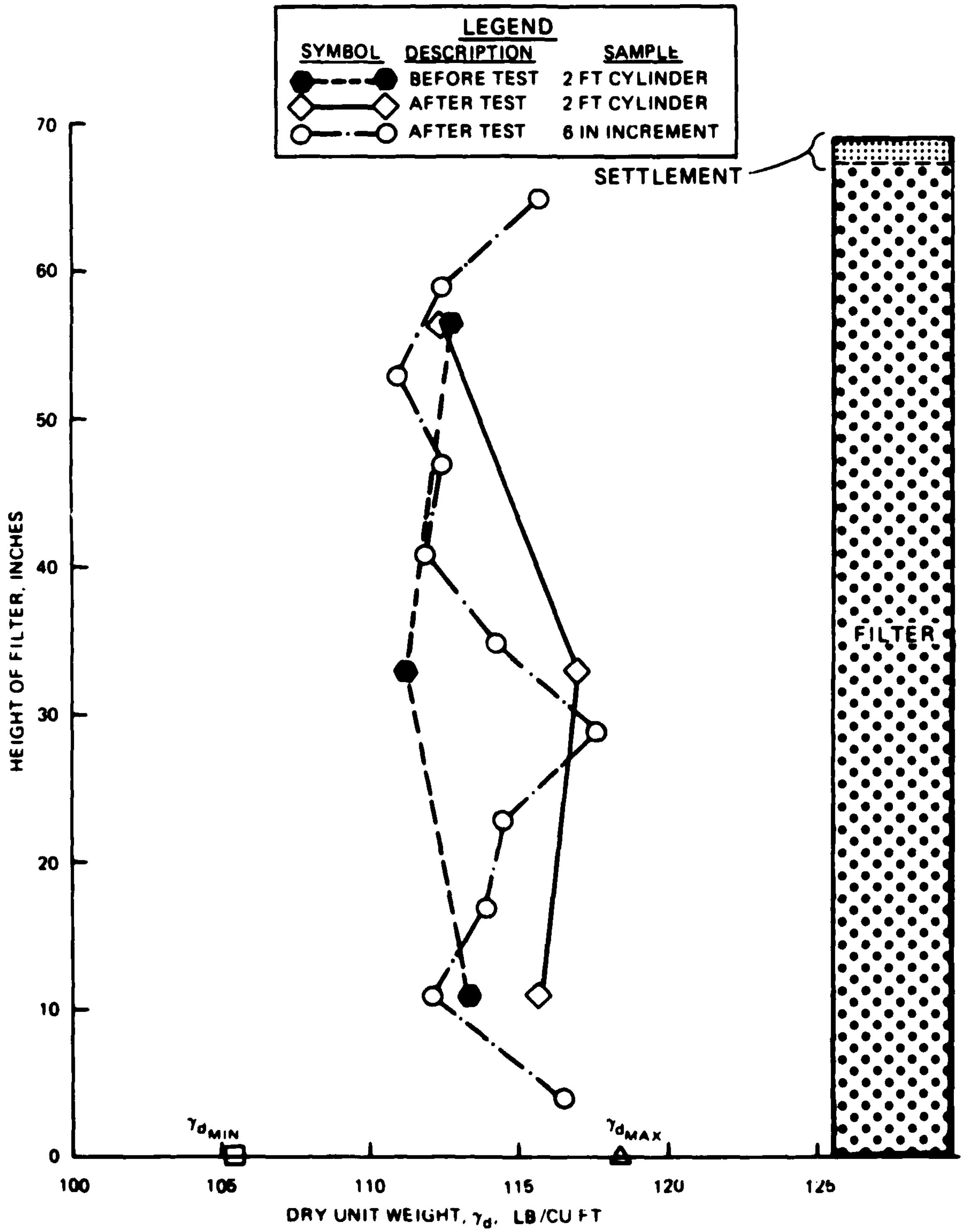

Figure 60. Pretest and posttest dry unit weight profiles of filter for Test No. 1

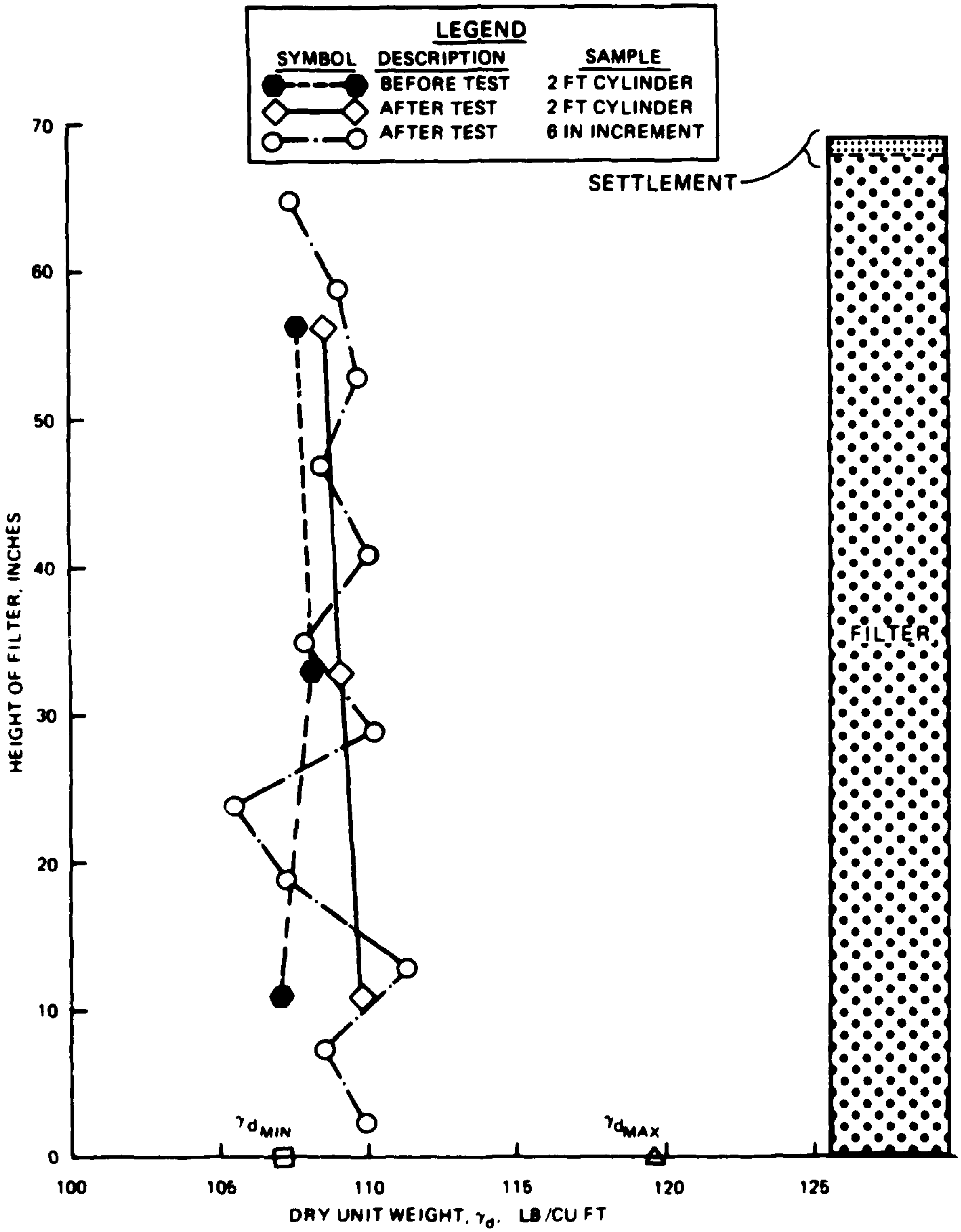

Figure 61. Pretest and posttest dry unit weight profiles of filter for Test No. 1A

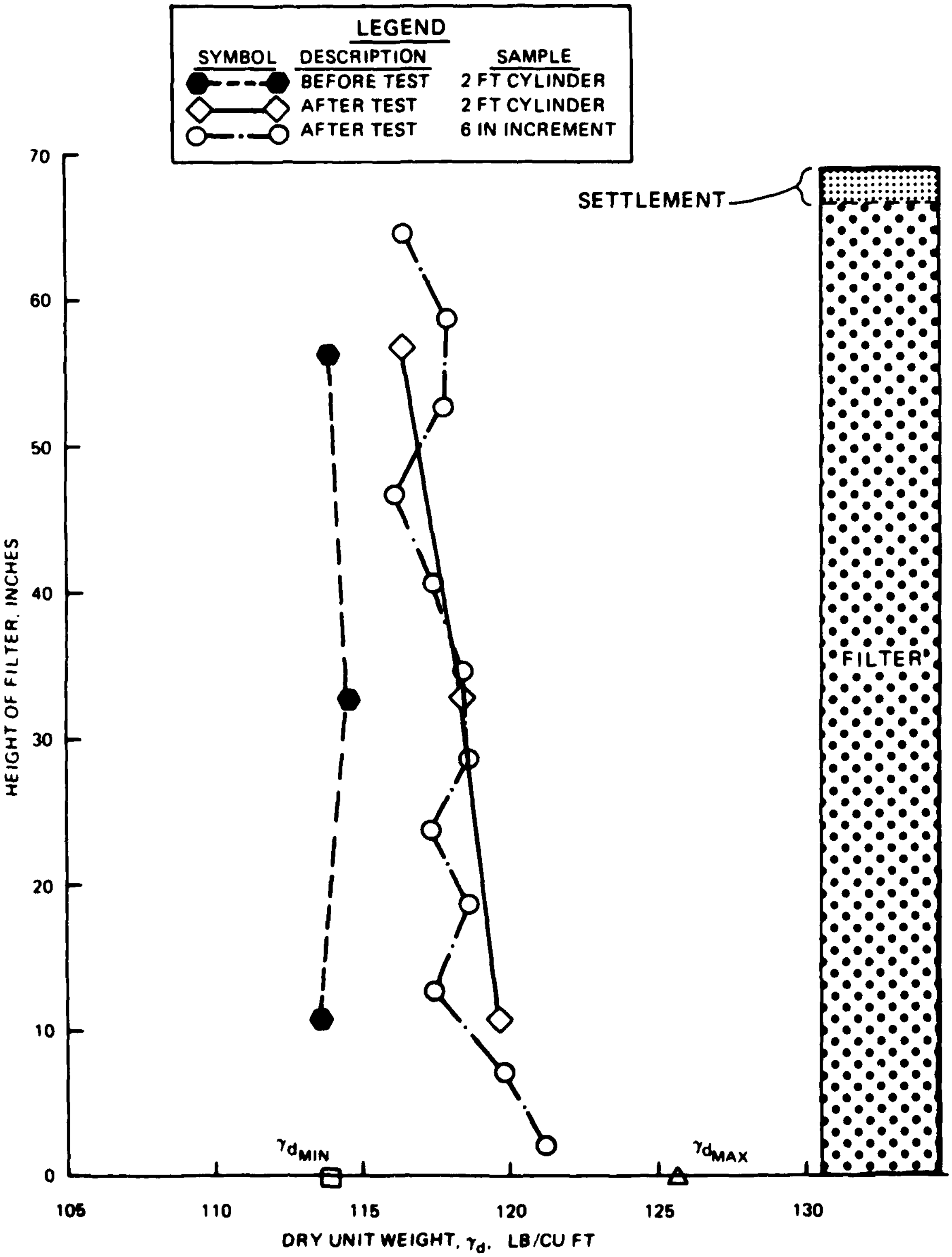

Figure 62. Pretest and posttest dry unit weight profiles of filter for Test No. 2

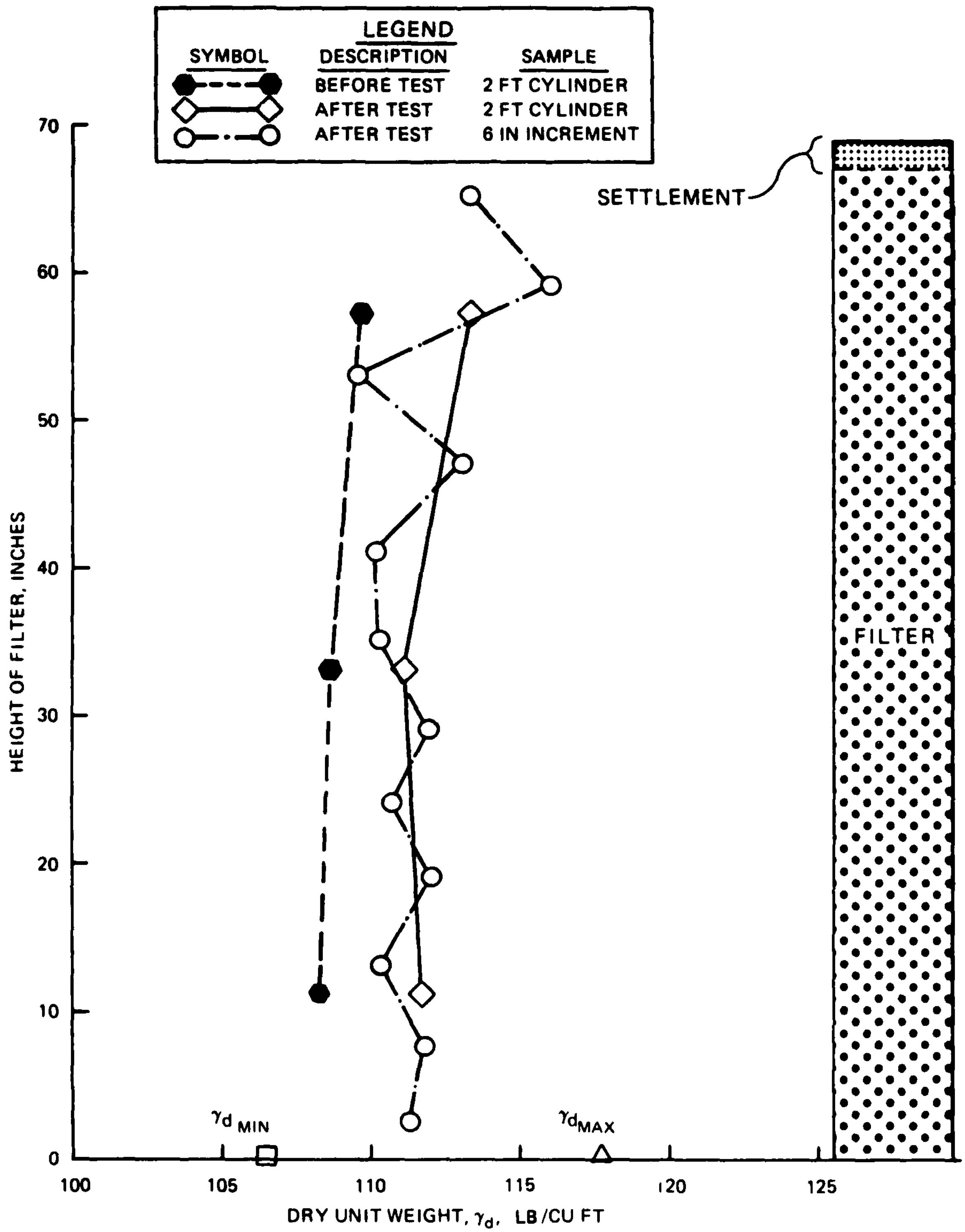

Figure 63. Pretest and posttest dry unit weight profiles of filter for Test No. 2A

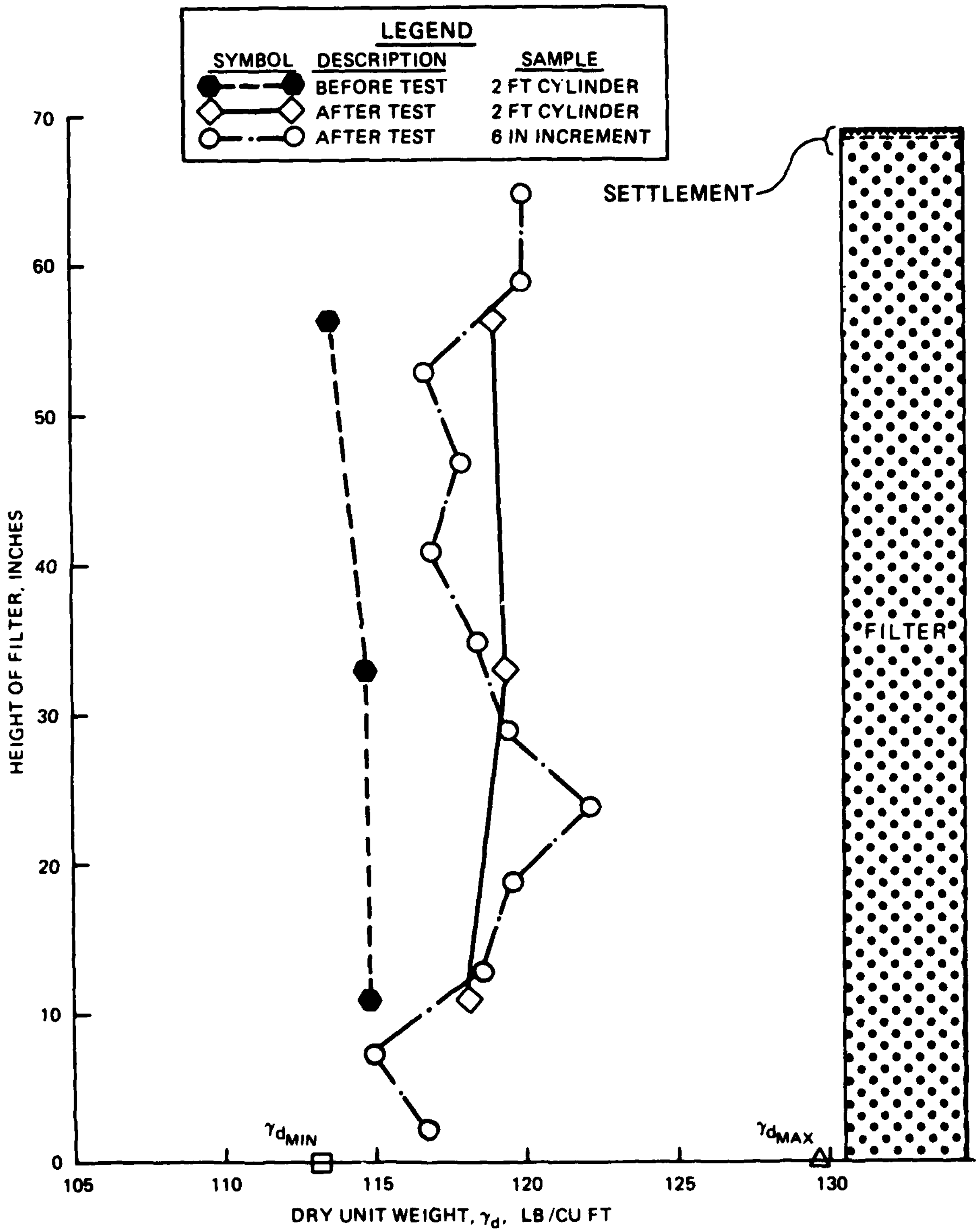

Figure 64. Pretest and posttest dry unit weight profiles of filter for Test No. 3

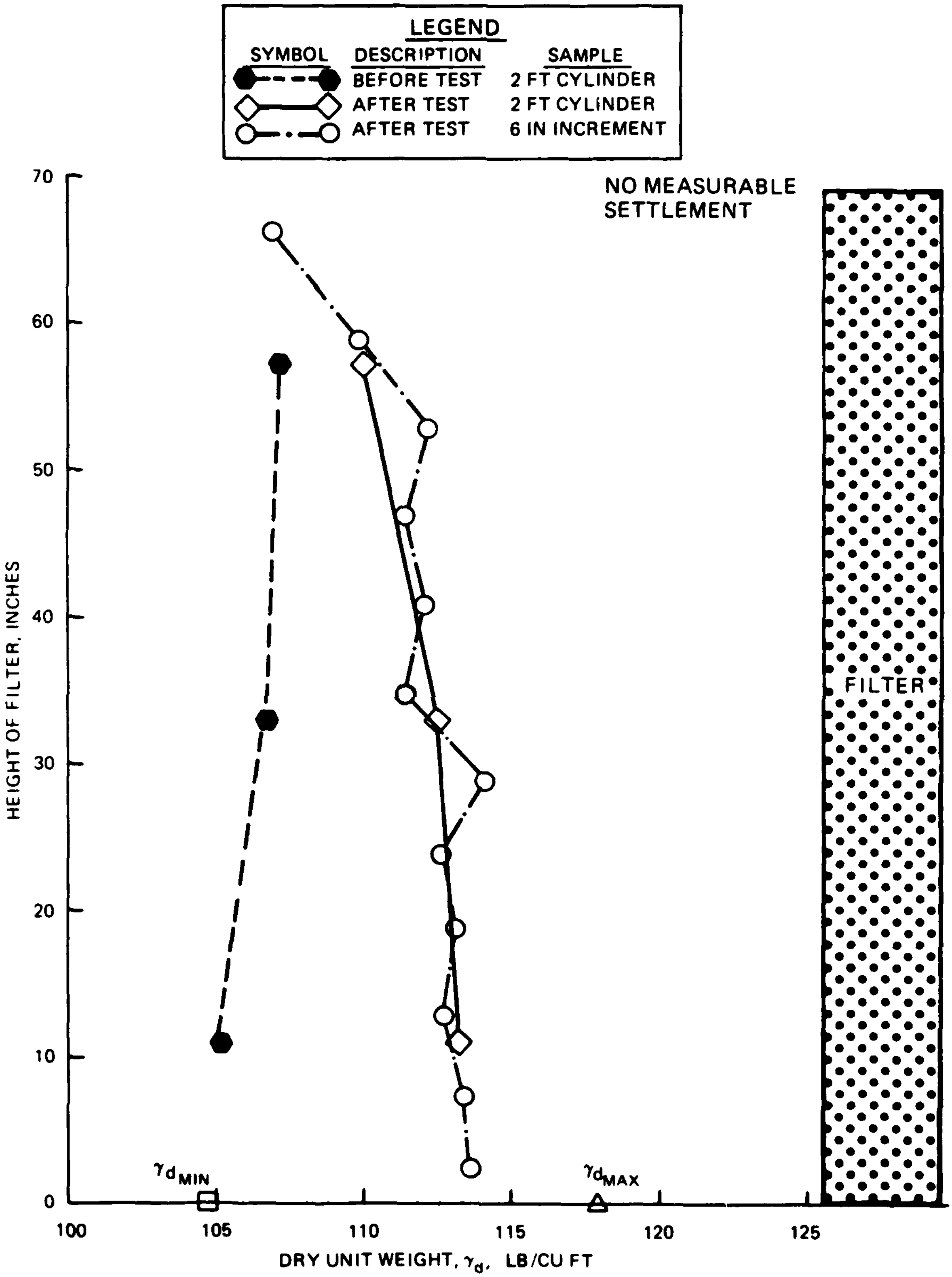

Figure 65. Pretest and posttest dry unit weight profiles of filter for Test No. 3A

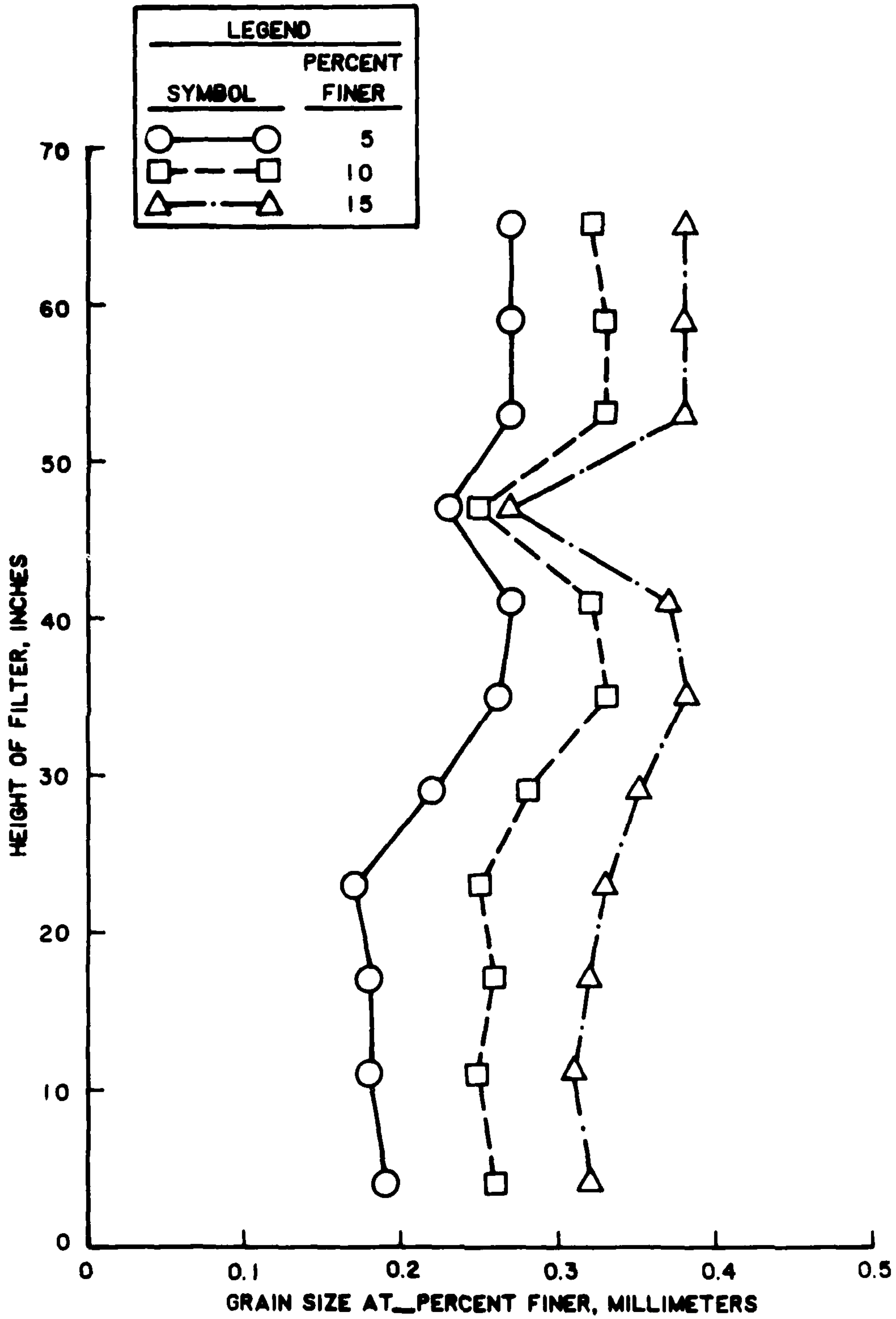

Figure 66. Posttest grain size of fine particles profile of filter for Test No. 1

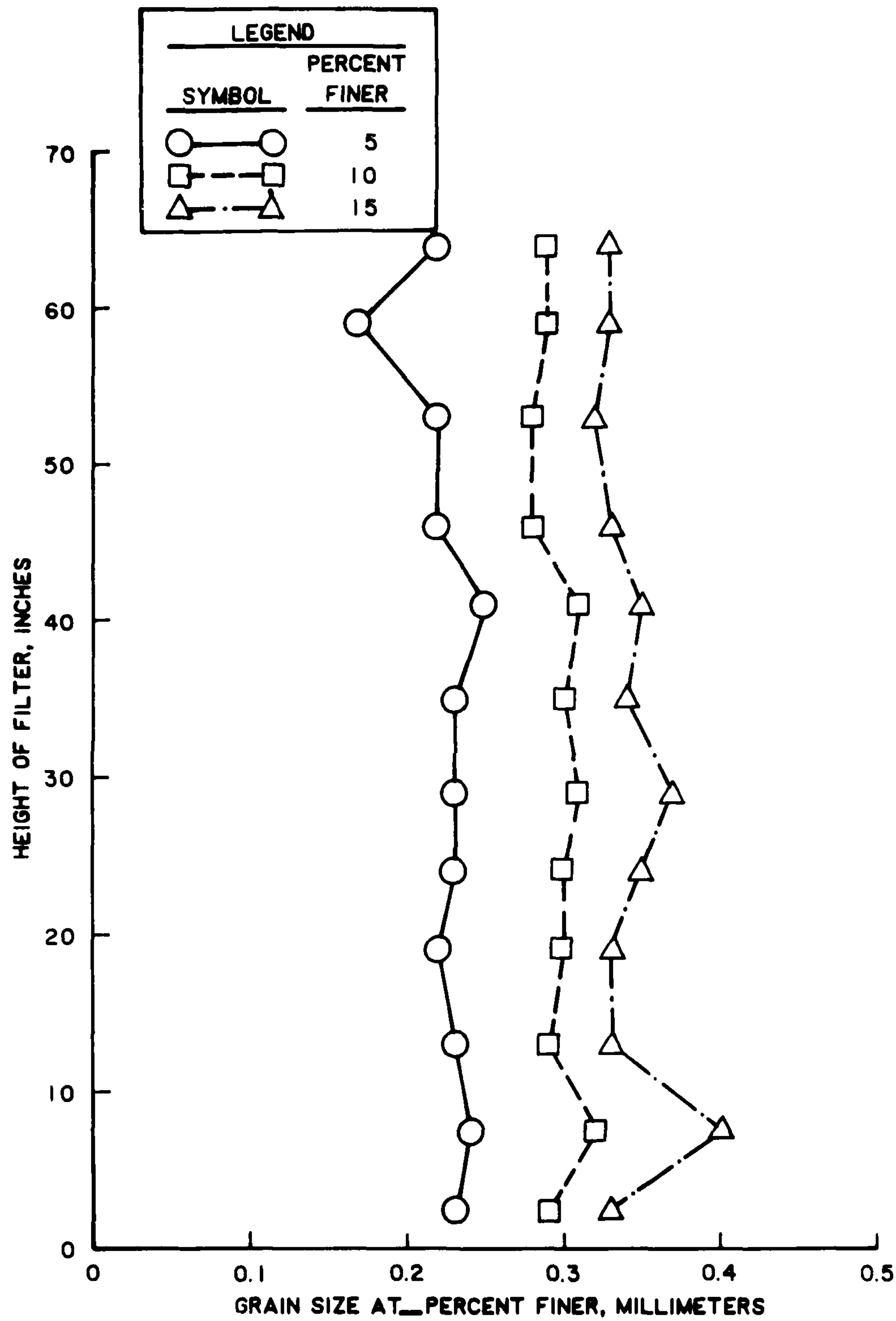

Figure 67. Posttest grain size of fine particles profile of filter for Test No. 1A

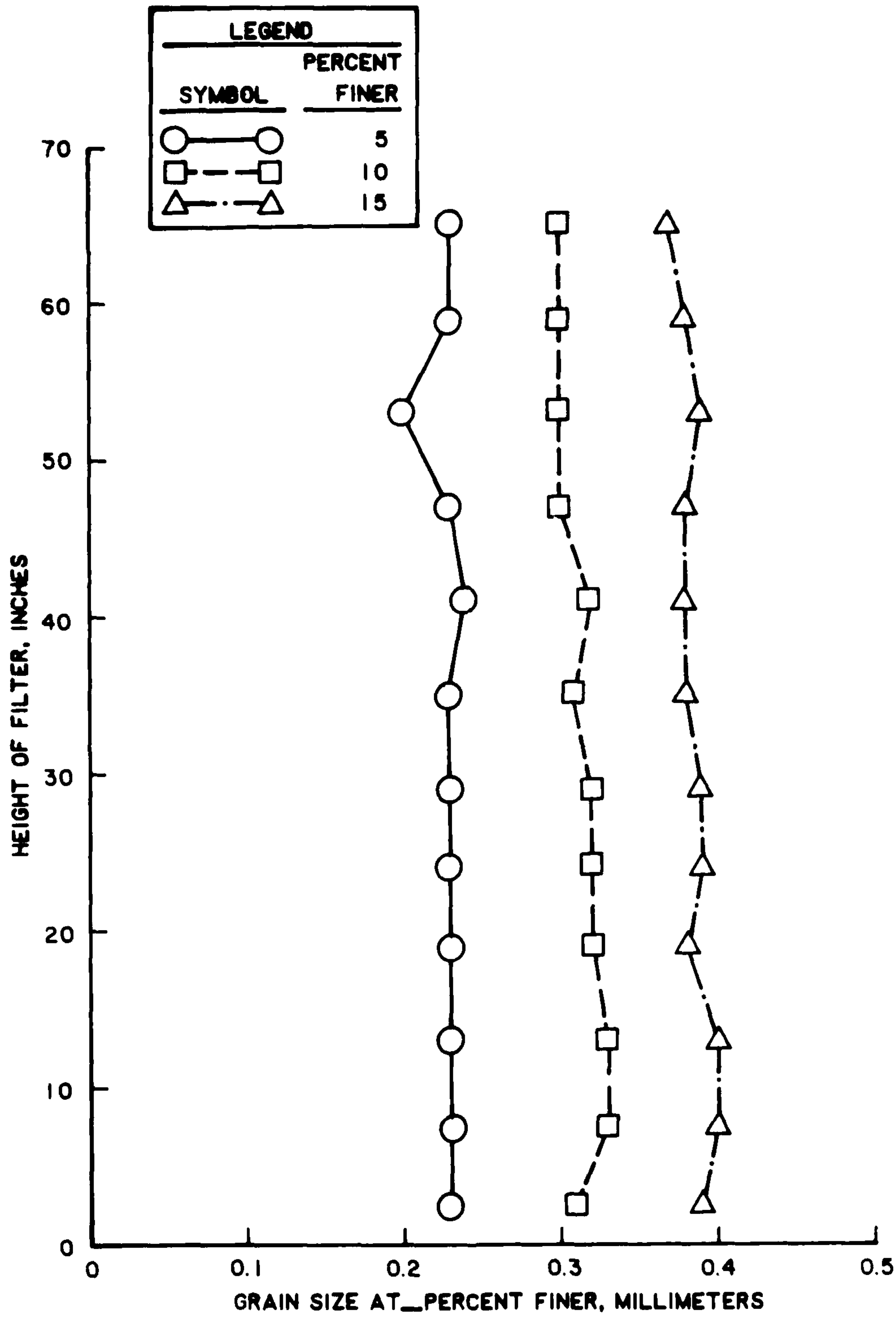

Figure 68. Posttest grain size of fine particles profile of filter for Test No. 2

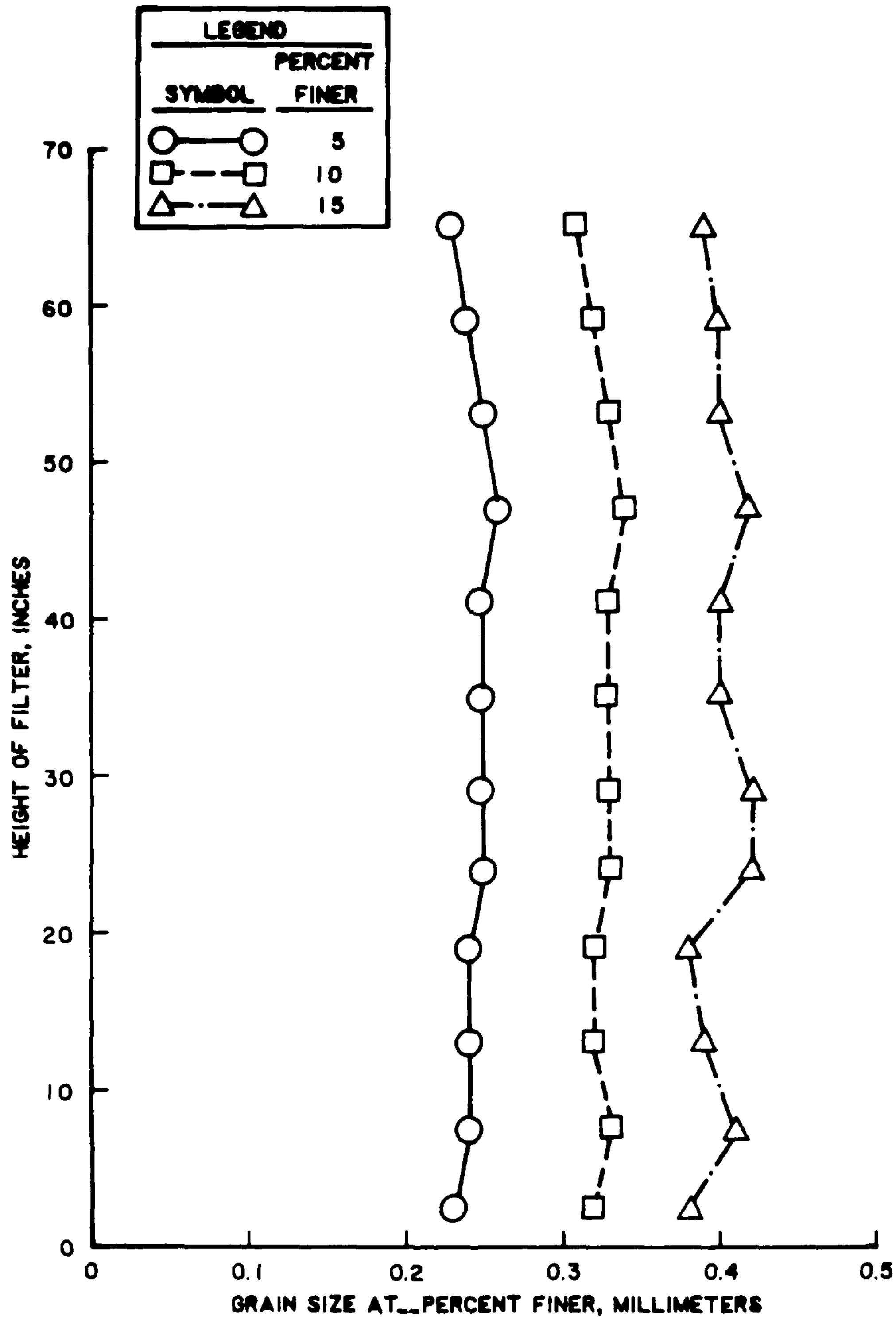

Figure 69. Posttest grain size of fine particles profile of filter for Test No. 2A

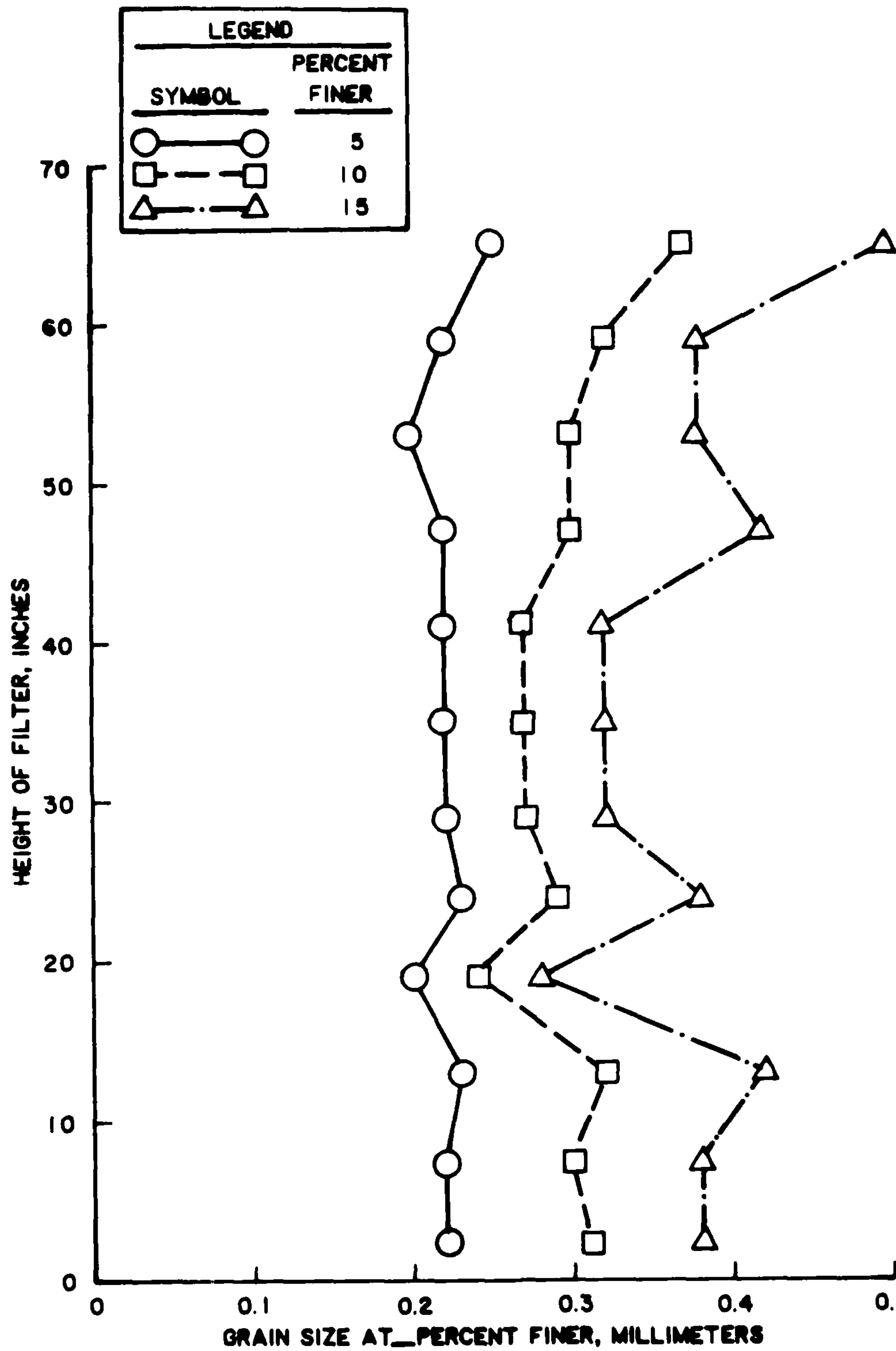

Figure 70. Posttest grain size of fine particles profile of filter for Test No. 3

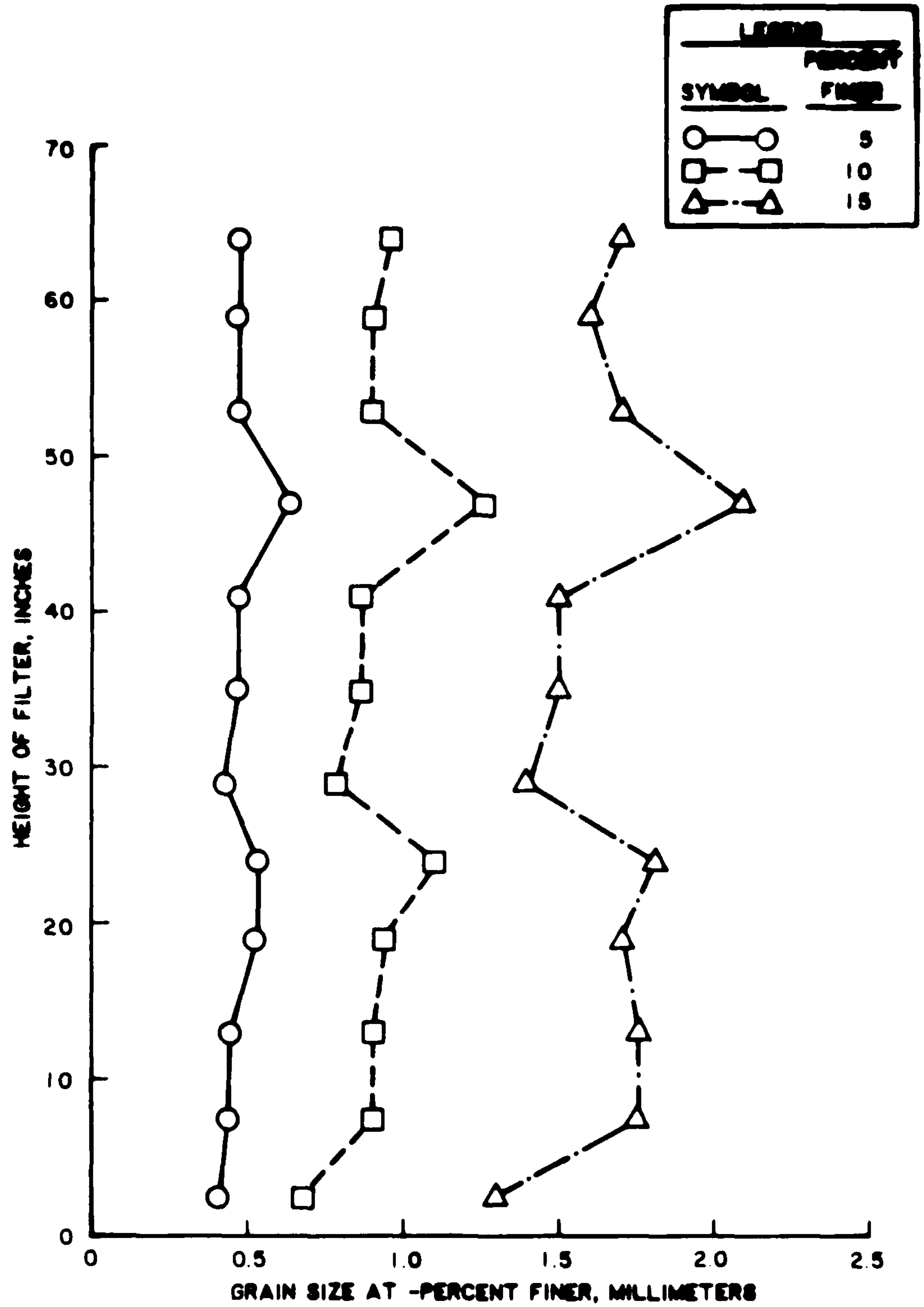

Figure 71. Posttest grain size of fine particles profile of filter for Test No. 3A

movement is indicated for Test No. 3 that was coarser at the top of the specimen and Test No. 3A that was finer at the bottom of the specimen.

54. Permeability profiles of the filter. Permeability profiles of the filter for Test No. 1, 1A, 2, 2A, 3, and 3A are given in Figures 72 to 77, respectively. Internal movement would be indicated by a decrease in permeability with depth of the filter. Air segregation would cause a reduction in permeability at the top of the filter. As shown in Figures 72 to 77 and Table 12, none of the tests showed a permeability profile that would be indicative of internal movement, i.e., a decrease in permeability with depth.

Analysis of Test Results

55. Table 13 gives a summary of soils and test results. Internal movement within the filter occurred for the poorly-graded gravelly sand and sandy gravel. The magnitude of internal movement increased with increase in the coefficient of uniformity. The internal stability tests, though limited, suggest that poorly-graded gravelly sand and sandy gravel with coefficients of uniformity (Equation 11) equal to or greater than 20 are internally unstable and should not be used as filters.

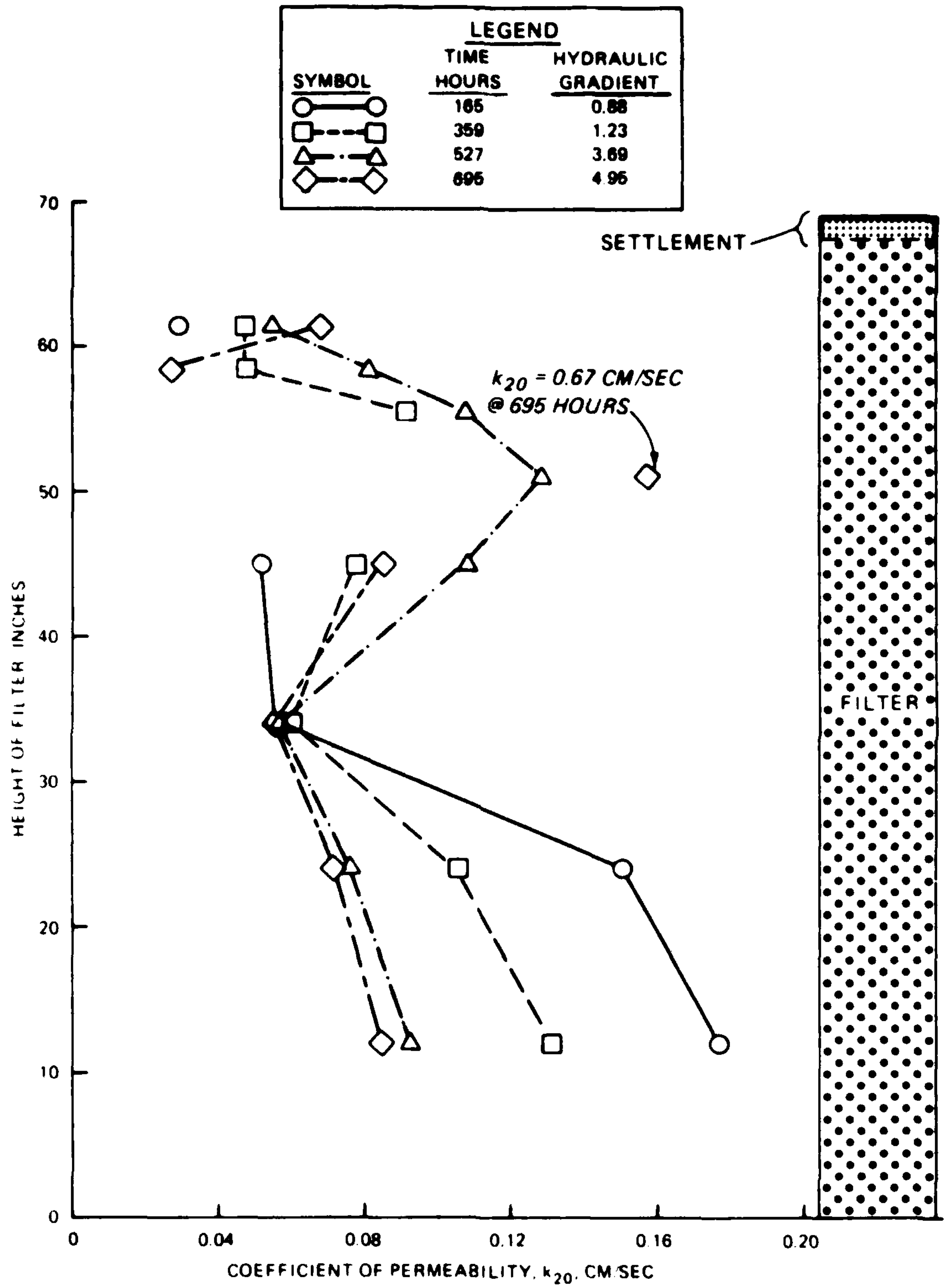

Figure 72. Permeability versus height of filter for Test No. 1

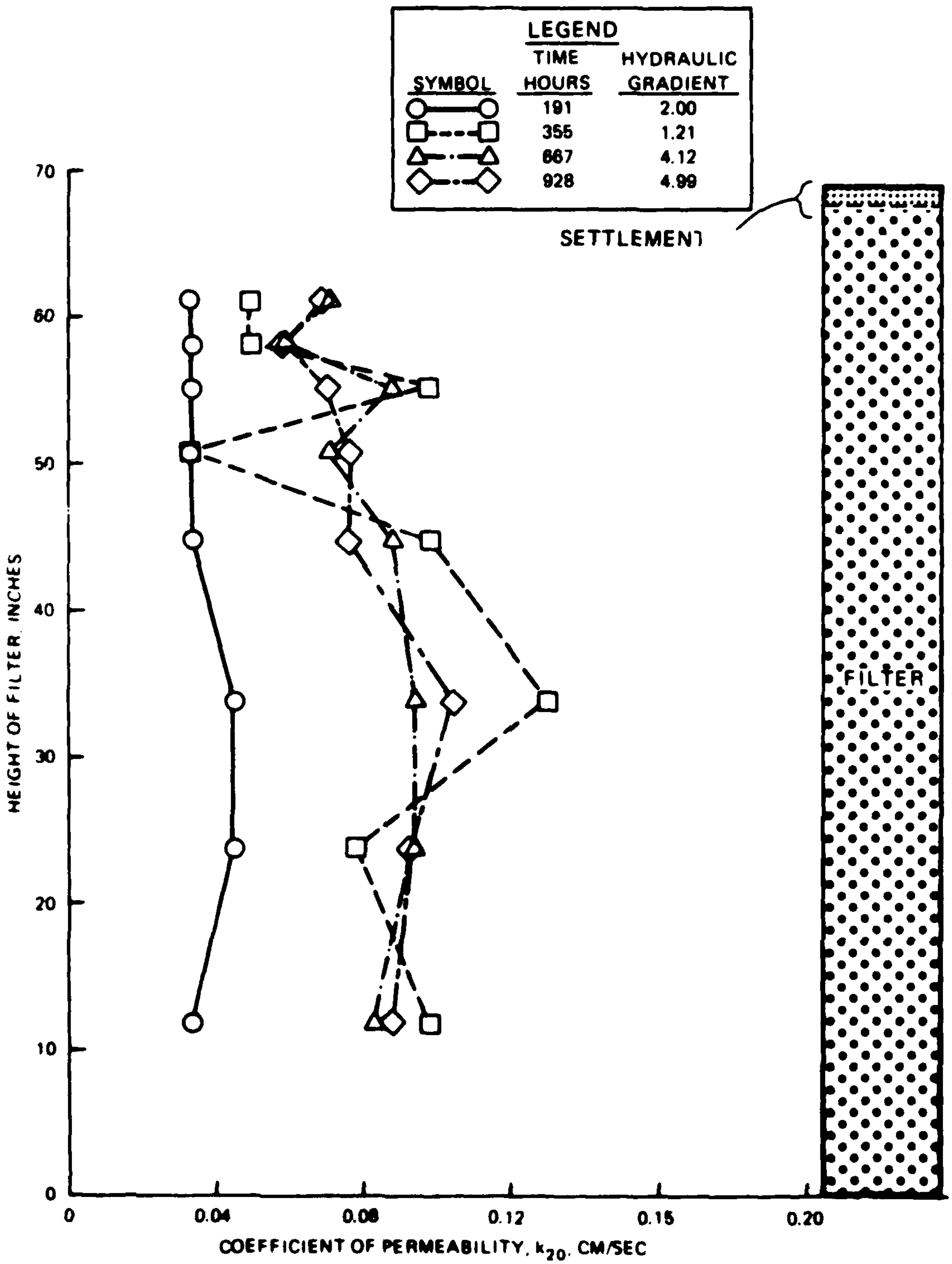

Figure 73. Permeability versus height of filter for Test No. 1A

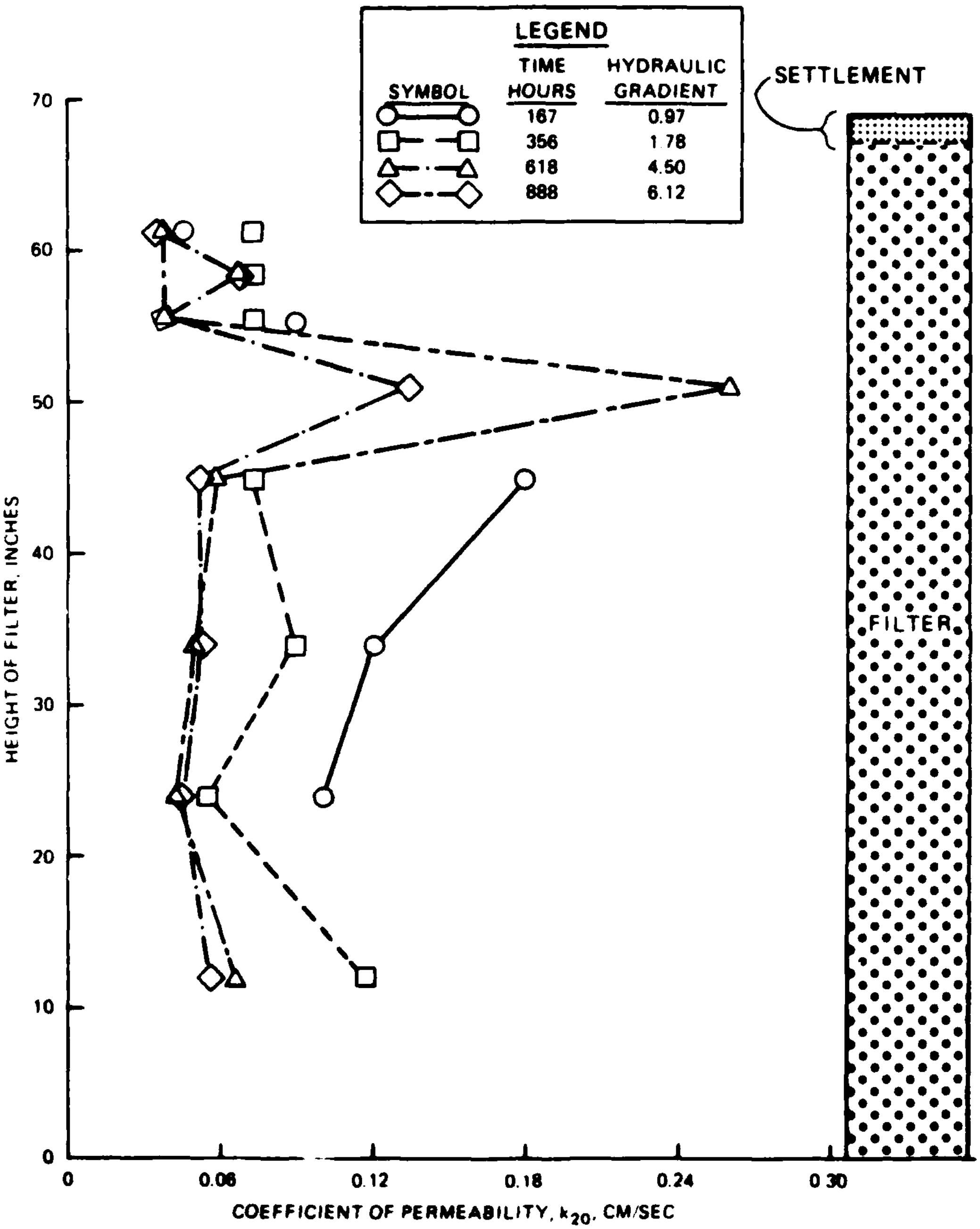

Figure 74. Permeability versus height of filter for Test No. 2

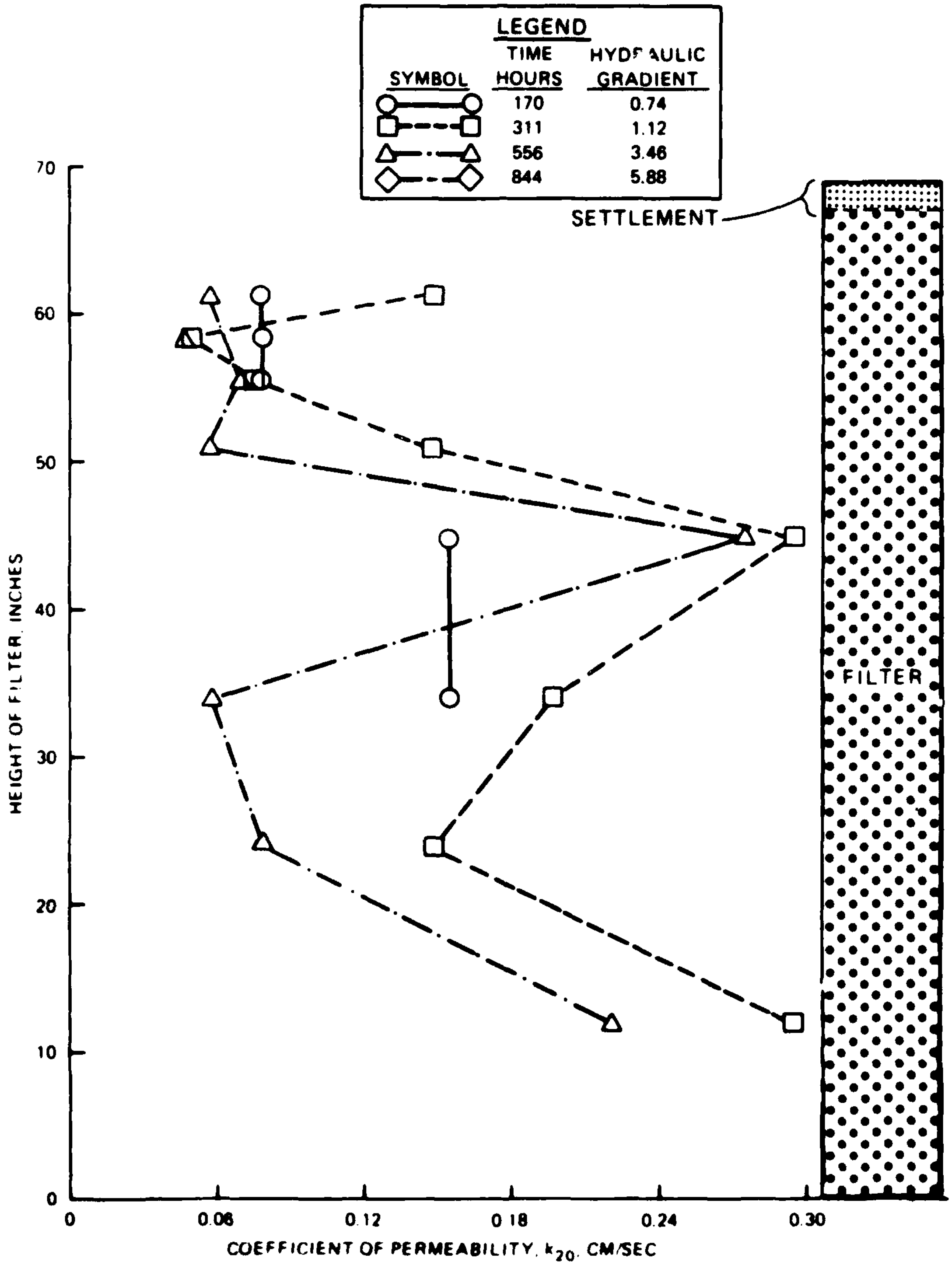

Figure 75. Permeability versus height of filter for Test No. 2A

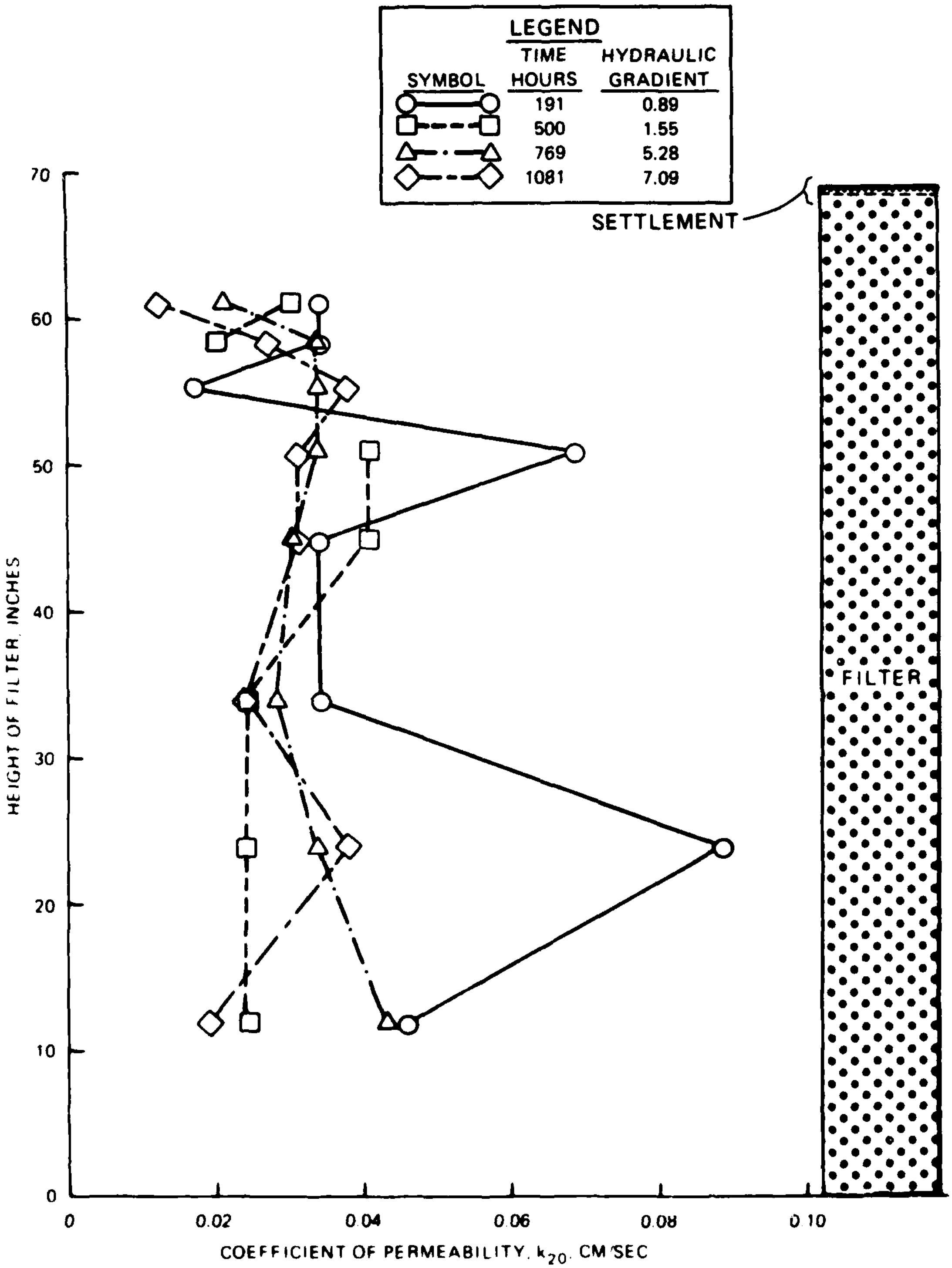

Figure 76. Permeability versus height of filter for Test No. 3

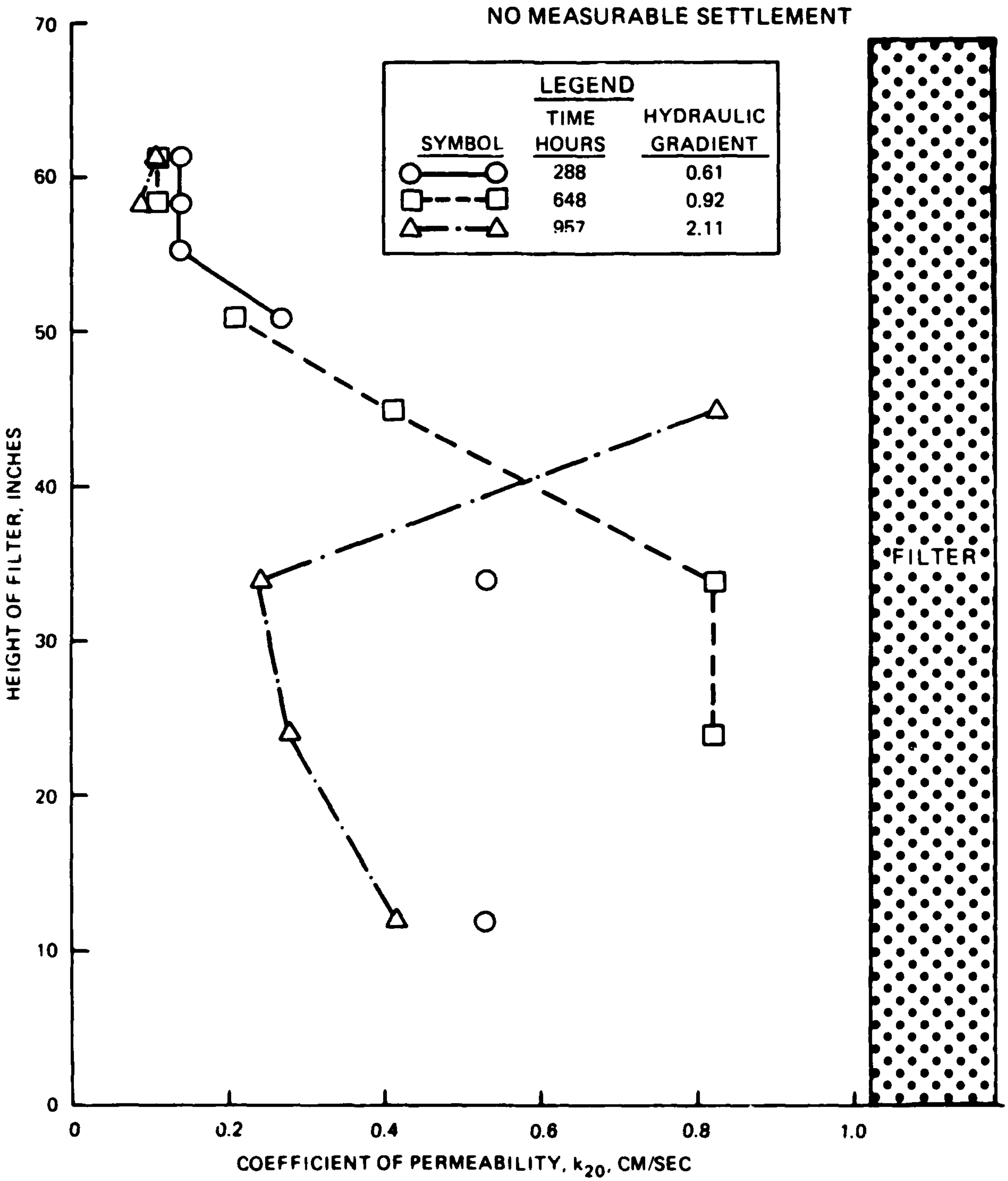

Figure 77. Permeability versus height of filter for Test No. 3A

PART V: PROPOSED CHANGES TO CE FILTER CRITERIA

Filter Tests on Cohesionless Base Material

Uniform (poorly-graded) base

56. The filter tests with a uniform (poorly-graded) base, though limited, suggest that the second stability ratio (Equation 2, Part II)

$$\frac{D_{50_F}}{D_{50_B}} \le 25$$

where

D_{50_F} = size of filter material at 50 percent passing

D_{50_B} = size of base material at 50 percent passing

should not be used and that there is no need for requiring parallelism of filter and base gradations.

Poorly-graded base

57. The limited filter tests with a poorly-graded base indicate the second stability ratio (Equation 2, Part II) should not be used, but the requirement for parallelism of filter and base gradations should be retained.

Internal Stability of Filter Materials

58. The internal stability tests, though limited, suggest that poorly-graded gravelly sand and sandy gravel are internally unstable and should not be used as filters when the coefficient of uniformity (Equation 11, Part IV)

$$C_u = \frac{D_{60_F}}{D_{10_F}} \ge 20$$

where

C_u = coefficient of uniformity

D_{60_F} = size of filter material at 60 percent passing

D_{10_F} = size of filter material at 10 percent passing

Segregation during placement can occur for $C_u \geq 10$.

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Table 1

Applications and Functions of Filters and Drains

Applications	Functions: Remove Seepage Water	Functions: Reduce Uplift Pressure	Wave Action-Rapid Drawdown	Prevent Piping
Vertical (or inclined) drain	X			X
Horizontal drain	X	X		X
Toe drain	X			X
Beneath riprap			X	X*
Under downstream pervious shell	X	X		X
Over fissured rock foundation downstream of core	X	X		X
Interface between cutoff trench and foundation	X			X
Trench drain	X	X**		X
Around relief wells	X	X†		X
Between the pervious abutment and dam downstream of core	X	X		X
Around outlet conduits downstream of the core in dams with an impervious downstream shell	X	X		X
Under spillways and stilling basins	X	X		X

* During rapid drawdown of reservoir level.

** Trench drains are an applicable underseepage control measured for relatively shallow pervious foundations where a reduction in uplift pressure would occur because of the presence of the trench drain.

† The gravel filter is one component of the relief well that reduces uplift pressure.

Table 2

CE Filter Criteria

Test No.	Permeability: $\frac{D_{15_F}}{D_{15_B}} \geq 5$	Stability: $\frac{D_{15_F}}{D_{85_B}} \leq 5$	Stability: $\frac{D_{50_F}}{D_{50_B}} \leq 25$	Stability: Grain Size Curve of Filter Approximately Parallel to Base
1A-A (Check)*	7	5	108	No
1A-B	8	4	25	No
1A-C	9	4	12	Yes
1B-A	121	4	91	Yes
1B-B	55	2	38	Yes
1B-C	104	3	22	No

* Test 1A-A was compacted by striking the sides of the permeameter with a rubber mallet and the test results were not considered representative.

Table 3

Properties of Soils Tested

Test No.	Base				Filter			
	Unified Soil Classification	C_u*	C_c**	Description	Unified Soil Classification	C_u*	C_c**	Description
1A-A (check)	SP	1.8	1.1	Uniform (poorly-graded) fine sand	GW	50.0	1.9	Well-graded sandy gravel
1A-B	SP	1.8	1.1	Uniform (poorly-graded) fine sand	GP	8.0	0.6	Poorly-graded sandy gravel
1A-C	SP	1.8	1.1	Uniform (poorly-graded) fine sand	SP	2.6	0.7	Poorly-graded gravelly sand
1B-A	SP	10.8	0.6	Poorly-graded sand	GW	6.4	1.1	Well-graded sandy gravel
1B-B	SP	10.8	0.6	Poorly-graded sand	GW	6.2	1.1	Well-graded sandy gravel
1B-C	SP	10.8	0.6	Poorly-graded sand	GP	1.2	1.0	Uniform (poorly-graded)

*$C_u = \frac{D_{60}}{D_{10}}$

**$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

Table 4

Average Posttest Density of Filters

Test No.	Minimum Dry Unit Weight lb/cu ft	Maximum Dry Unit Weight lb/cu ft	Average Posttest	
			Dry Unit Weight* lb/cu ft	Relative Density** percent
1A-A (check)	113.0	126.4	124.5	71
1A-B	107.2	124.0	121.0	84
1A-C	105.9	118.1	114.2	70
1B-A	91.3	109.0	109.9	100
1B-B	100.5	118.8	116.1	87
1B-C	87.8	101.0	100.4	96

* Taken from 0-50-in. depth of filter.

** $$D_d = \frac{\gamma_d - \gamma_{d_{min}}}{\gamma_{d_{max}} - \gamma_{d_{min}}} \times \frac{\gamma_{d_{max}}}{\gamma_d} \times 100\%$$

Table 7

Average Coefficient of Permeability for Base and Filter

Test No.	Type of Test	Cumulative Elapsed Time* hr	Hydraulic Gradient** Base	Hydraulic Gradient** Filter	Average Coefficient of Permeability† cm/sec Base	Average Coefficient of Permeability† cm/sec Filter	Flow Conditions†† Base	Flow Conditions†† Filter	Ratio of Average Coefficient of Permeability of Filter to Base	Remarks
1A-A (check)	Permeability♦	21.0		0.05	--	1.2130		Turbulent		Migration of the base into the filter to a depth of about 6 in. occurred during construction
		94.0	--	0.08	--	0.9119				
		117.5	--	0.11	--	0.8790				
		314.5	--	0.12		0.7951				
	Filter	23.0	1.16	0.03	0.0372	1.6125	Laminar	Turbulent	38	Movement of sand in filter at 38 and 49 in. elevation immediately following application of highest gradient
		47.0	1.58	0.06	0.0334	1.3877			41	
		211.0	2.88	0.08	0.0337	1.1611			34	
		236.5	6.66	0.16	0.0337	0.9670			29	
1A-B	Permeability♦	120.4	--	0.15	--	1.1098	--	Turbulent		
		137.9	--	0.07	--	1.3363	--			
		139.4	--	0.10	--	1.2228	--			
		140.9	--	0.12	--	1.2030	--			
	Filter	72.0	1.50	0.07	0.0294	0.6527	Laminar	Turbulent	[illegible]	Migration of the base into the filter to a depth of about 3 in. occurred mainly where the coarser filter particles segregated against the sides of the cylinder
		90.5	2.00	0.04	0.0300	1.6999			50	
		109.5	2.12	0.10	0.0335	0.7111			[illegible]	
		114.5	2.66	0.08	0.0335	1.0013			[illegible]	
1A-C	Permeability♦	21.5	--	0.04	--	1.1868		Laminar		
		26.0	--	0.05	--	1.1369	--			
		44.5	--	0.07	--	1.1170	--			
	Filter	23.0	1.16	0.04	0.0367	1.1513	Laminar	Laminar	31	Slight migration of base into filter occurred.
		47.0	2.24	0.07	0.0325	1.0415			32	
		93.0	3.16	0.11	0.0363	1.0679			29	
		260.5	5.42	0.16	0.0320	1.0854			34	
1B-A	Permeability♦	2.0	--	0.01	--	11.9833	--	Undefined	--	
	Filter	28.0	6.44	--	0.0006	--§	Undefined	Undefined		
		94.0	10.15	--	0.0006	--				
		117.0	12.92	--	0.0003	--				
		160.5	16.61	--	0.0002					
		308.5	20.30	--	0.0002	--				
		476.5	22.15	--	0.0001	--				
		524.5	21.22	--	0.0002	--				
1B-B	Permeability♦	5.0	--	0.06	--	3.4619	--	Laminar	--	
		22.0	--	0.03	--	3.7796	--		--	
	Filter	21.0	5.40	0.01	0.0003	0.6798	Undefined	Laminar	2266	During the last 12 hr of the test, a cavity 3 1/4 by 3/4 in. appeared in the base material near the top
		94.5	11.92	0.01	0.0004	0.5830			1457	
		190.0	19.12	--§	0.0002	--§			--	
		357.0	27.00	--	0.0019	--				
1B-C	Permeability♦	7.0	--	0.01	--	21.2519	--	Undefined	--	
	Filter	23.8	0.00	0.00	0.0865	27.6720			320	Saturation was very slow and difficult. A cavity was blown out in the top of the sand base by an air bubble during saturation. Once the filter test began, the base became dry under low gradient.
		26.8	0.00	0.01	0.1243	8.7533	Undefined	Undefined	70	
		96.8	1.20	0.09	0.1672	2.0363			14	
		195.8	17.20	0.08	0.0041	0.9218			225	
										Test was shut down for a 7-day period prior to application of highest gradient

* Measured from start of permeability test or from start of filter test.
** Measured across taps 8 and 10 (elevations 60 and 66 in., respectively) for the base and across taps 1 and 6 (elevations 6 and 36 in., respectively) for the filter.
† $k_{20} = \frac{q \times L \times R_T}{\Delta h \times A}$

where k_{20} = coefficient of permeability at 20 C.
q = flow rate.
L = length of specimen over which head loss is measured (across taps 8 and 10 for the base and taps 1 and 6 for the filter).
R_T = temperature correction factor for viscosity of water.
Δh = head loss.
A = cross-sectional area of specimen.

†† Laminar flow occurs when the permeability remains relatively constant with increase in hydraulic gradient.
♦ The permeability test was conducted on the filter prior to placing the base.
§ No measurable head loss occurred across the filter material.

Table 6

Calculation of Required Base Migration into Filter to Develop Filter Action

Test No.	D_{85_B} mm	Calculated Base Migration* mm	in.
1A-A (check)	0.275	3.7	0.1
1A-B	0.350	4.7	0.2
1A-C	0.350	4.7	0.2
1B-A	1.930	25.7	1.0
1B-B	1.930	25.7	1.0
1B-C	1.930	25.7	1.0

* Using Equation 10 in Part III.

Table 7

Filter Test Results

Test No.	Observed Migration of Base into Filter Around Periphery of Specimen* in.	Changes in Posttest Dry Unit Weight of Top 6 in. of Filter** percent	Comparison Among Posttest Gradations for 6 in. Increments of Filter†			Changes in Permeability of Top 4 in. of Filter†† percent	Ratio of Permeability of Lower Part of Base to Upper Part of Base
			Top	Middle	Bottom		
1A-A (check)	4	+24	Same	Same	Finer	-80	1.0
1A-B	3	-6	Coarser	Same	Same	-98	1.5
1A-C	Slight	+6	Same	Same	Same	-80	1.1
1B-A	0	+28	Finer	Same	Same	-	-
1B-B	0	+18	Fine	Same	Same	-	1.5§
1B-C	0	+18	Same	Same	Same	-	5.4

* Average penetration of base around periphery of filter specimen.

** Ratio of posttest dry unit weight of top 6 in. of the filter to the remaining portion of the filter.

† Based upon comparison of posttest gradation for 6-in. increment nearest the top, middle, and bottom of the specimen. (See Appendix E).

†† Comparison between the final permeability measured on the filter during the permeability test and the initial permeability measured during the filter test.

‡ Comparison between the average permeability of the lower part of the base (60 to 63 in.) to the upper part of the base (63 to 66 in.).

‡‡ Occurred during construction of the specimen.

§ The permeability of the upper part of the base is based upor one reading.

Table 8

Summary of Filter Tests on Cohesionless Soils

Test No.	Base		Filter		CE Filter Criteria				Test Results		
					Permeability	Stability			Migration of Base into Filter	Internal Movement Within	
	Unified Soil Classification	C_u*	Unified Soil Classification	C_u*	$\frac{D_{15_F}}{D_{15_B}} \geq 5$	$\frac{D_{15_F}}{D_{85_B}} \leq 5$	$\frac{D_{50_F}}{D_{50_B}} \leq 25$	Grain Size Curve of Filter Approximately Parallel to Base		Base	Filter
1A-A (check)	SP	1.8	GW	50.0	7	5	108	No	No	No	No
1A-B	SP	1.8	GP	8.0	8	4	25	No	No	No	Yes
1A-C	SP	1.8	SP	2.6	9	4	12	Yes	No	No	No
1B-C	SP	10.8	GW	6.4	121	4	91	Yes	Yes	No	No
1B-b	SP	10.8	GW	6.2	55	2	38	Yes	Yes	No	No
1B-c	SP	10.8	GP	1.2	104	3	22	No	Yes	No	No

* $C_u = \frac{D_{60}}{D_{10}}$

Table 9

Properties of Soils Tested for Internal Stability

Test No.	Unified Soil Classification	C_u*	C_c**	Sand† percent	Gravel percent	Description
1	SP	10.0	0.6	79	21	Poorly-graded gravelly sand
1A	SW	10.0	1.6	100	0	Well-graded sand
2	SP	20.0	0.6	63	37	Poorly-graded gravelly sand
2A	SW	20.0	2.8	73	27	Well-graded gravelly sand
3	SP	40.0	0.5	53	47	Poorly-graded gravelly sand
3A	GP	40.0	3.3	42	58	Poorly-graded sandy gravel

* $C_u = \frac{D_{60}}{D_{10}}$

** $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

† Smaller than the No. 4 sieve (4.76mm).

Table 10

Average Density of Filters for Internal Stability

Test No.	Minimum Dry Unit Weight lb/cu ft	Maximum Dry Unit Weight lb/cu ft	Average Pretest* Dry Unit Weight lb/cu ft	Average Pretest* Relative Density** percent	Average Posttest* Dry Unit Weight lb/cu ft	Average Posttest* Relative Density** percent
1†	105.1	118.4	112.4	58	115.0	77
1A	106.8	119.4	107.4	5	109.0	19
2	113.8	125.7	113.8	0	118.1	43
2A	106.3	117.6	108.8	24	112.0	53
3	113.1	129.7	114.3	8	118.8	38
3A	104.7	117.9	106.4	14	111.9	57

* Taken from three lucite cylinders used to form specimen.

** $D_d = \frac{\gamma_d - \gamma_{d_{min}}}{\gamma_{d_{max}} - \gamma_{d_{min}}} \times \frac{\gamma_{d_{max}}}{\gamma_d} \times 100\%$

† Test 1 was compacted by striking the permeameter with a rubber mallet resulting in a higher pretest relative density compared to the other tests.

Table 11

Average Coefficient of Permeability of Filters for Internal Stability

Test No.	Cumulative Elapsed Time, T hr	Average Hydraulic Gradient*	Average Coefficient of Permeability** cm/sec	Remarks
1	165	0.88	0.0916	Mechanical pump problems occurred following application of third hydraulic gradient (T = 360 to 387 hr)
	361	1.23	0.0787	
	529	3.69	0.0868	
	703	4.95	0.1499	
1A	191	2.00	0.0360	
	359	1.21	0.0785	
	677	4.12	0.0805	
	938	4.99	0.0793	
2	167	0.97	0.1045	
	359	1.78	0.0780	
	624	4.50	0.0768	
	888	6.12	0.0588	
2A	170.5	0.74	0.1078	
	311.5	1.12	0.1684	
	575.5	3.46	0.1072	
	863.5	5.88	0.0637	
3	191	0.89	0.0424	Power off for two hours and 3/4 hour following application of first hydraulic gradient (between T = 31 hr and T = 143 hr). Two days were required to stabilize the sample (obtain relatively constant relationship between rate of flow through the specimen and time).
	499.5	1.55	0.0297	
	768.5	5.28	0.0325	
	1080.5	7.09	0.0280	
3A	288	0.61	0.2840	
	648	0.92	0.4096	
	957	2.11	0.3210	

* Average of hydraulic gradients obtained across taps 8and 9, 6 and 7, 4 and 5, 3 and 4, 2 and 3, and 1 and 2.

** $k_{20} = \frac{q \times L \times R_T}{\Delta h \times A}$

where

k_{20} = coefficient of permeability at 20 C
q = flow rate
L = length of specimen over which head loss is measured
R_T = temperature correction factor for viscosity of water
Δh = head loss
A = cross-sectional area of specimen

Table 12

Internal Stability Test Results

Test No.	Changes in Dry Unit Weight of Filter* percent				Comparison Among Posttest Gradations for 6 in. Increments of Filter**			Changes in Permeability of Filter With Depth†
	Top	Middle	Bottom	Total	Top	Middle	Bottom	
1	-0.3	+5.1	+2.1	+ 6.9	Same	Same	Same	Increase
1A	+0.9	+0.9	+2.6	+ 4.4	Same	Same	Same	Increase
2	+2.7	+3.4	+5.4	+11.5	Same	Same	Same	None
2A	+3.4	+2.3	+3.2	+ 8.9	Same	Same	Same	Increase
3	+4.9	+4.1	+2.9	+11.9	Coarser	Same	Same	None
3A	+2.6	+5.4	+7.6	+15.6	Same	Same	Finer	Increase

* Based upon comparison of pretest and posttest dry unit weight obtained from three lucite cylinders used to form the specimen.

** Based upon comparison of posttest gradations for 6-in. increment nearest the top, middle, and bottom of the specimen. (See Appendix E).

† Top (54-to-63 in.) and bottom (6- to 18-in.).

Table 13

Summary of Internal Stability Tests

Test No.	Unified Soil Classification	C_u*	Description	Increase In Posttest Dry Unit Weight With Depth	Gradation Coarser at Top and Finer at the Bottom	Permeability Increase at Top and Decrease at Bottom	Internal Movement Within Filter
1	SP	10.0	Poorly-graded gravelly sand	No	No	No	No
1A	SW	10.0	Well-graded sand	No	No	No	No
2	SP	20.0	Poorly-graded gravelly sand	Yes	No	No	Yes
2A	SW	20.0	Well-graded gravelly sand	No	No	No	No
3	SP	40.0	Poorly-graded gravelly sand	No	Yes	No	No
3A	GP	40.0	Poorly-graded sandy gravel	Yes	Yes	No	Yes

* $C_u = \frac{D_{60}}{D_{10}}$

APPENDIX A: OCCURRENCE OF AIR SEGREGATION

History of a Specimen

1. The construction-saturation-testing sequence for a typical Series 1A and/or 1B specimen is given in Figure A1.* Following completion of the permeability test, it was necessary to drain the filter specimen in order to place the base material.** Prior to running the filter test, the specimen (filter and base) was saturated. Therefore, the initial conditions existing in the specimen before commencing the filter test are a function of the history of the specimen.

2. For the permeability and internal stability tests, air segregation† may occur during the saturation of the filter material. For the filter tests, air segregation may occur in the base and/or filter materials following saturation. Also, migration of the base into the filter may occur during saturation†† and/or testing. The following section describes the procedures used to determine if air segregation occurred within the specimen during permeability and filter tests.

Method of Analysis

3. The occurrence of air segregation may be determined by plotting the height of the filter (and base if present) versus

$$\frac{i_j}{i_{avg}} = \frac{h_j - h_{j-1}}{i_{avg} \times L} \qquad \text{(A1)}$$

where i_j = hydraulic gradient at j (ratio of head loss to length over which head loss occurs)

i_{avg} = average hydraulic gradient for all increments and times at a particular flow rate

h_j = piezometer reading at j

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* No base material was used for the internal stability tests (construction-saturation-testing history was similar to that for the permeability test).

** The top plate of the test apparatus was removed to place the base material. This necessitated draining the specimen to prevent water from leaking between the bottom cylinder and the O-ring contained in the bottom of the test apparatus.

† Air segregation refers to the accumulation of air in the voids of the soil.

†† In Test No. 1A-A (check) base material migrated into the filter to about a 4-in. depth following saturation of the specimen.

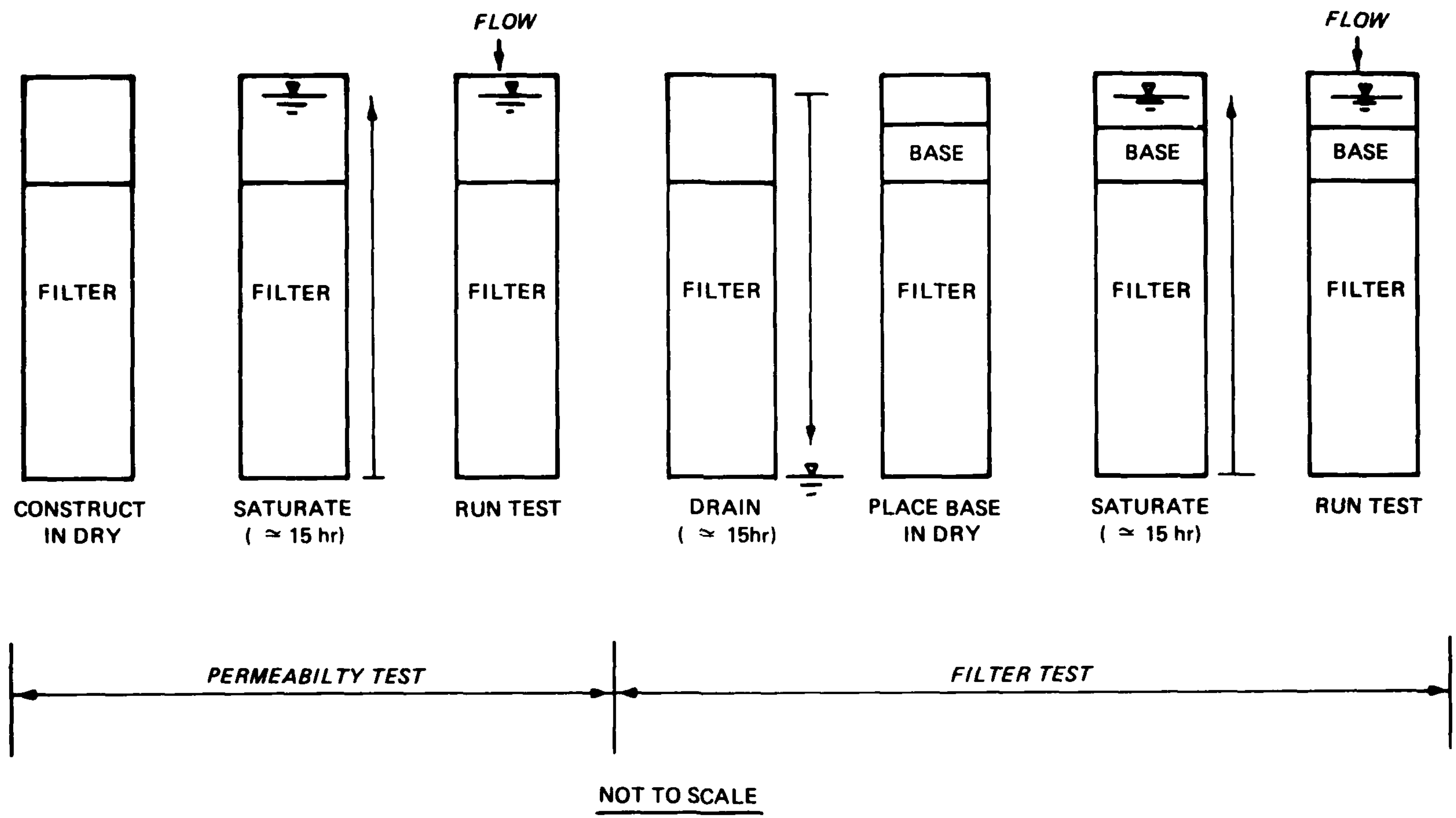

Figure A1. Construction-saturation-testing history for a typical Series 1A and/or 1B specimen.

h_{j-1} = piezometer reading at j-1

L = distance from j to j-1

Since

$$Q = k\, i\, A\, t \qquad \text{(A2)}$$

where

Q = quantity of discharge

k = Darcy's coefficient of permeability (commonly called the coefficient of permeability or the permeability)

i = hydraulic gradient

A = cross-sectional area of flow

t = time of flow

Therefore

$$k = \frac{Q}{At}\ \frac{1}{i}$$

$$k \propto \frac{1}{i} \qquad \text{(A3)}$$

Since the permeability is inversely proportional to the hydraulic gradient an increase in i_j/i_{avg} represents a decrease in permeability and vice versa.

4. For purposes of this study, air segregation is considered to have occurred in the filter for the permeability and internal stability tests and in the base for the filter test when

$$\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg} \geq 1.0 \qquad \text{(A4)}$$

where the average is taken over the uppermost portion of the filter (54- to 57-in.) and the upper portion of the base (63- to 66-in.). Air segregation and/or migration of the base into the filter is considered to have occurred in the filter for the filter test when

$$\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg} \geq 1.0 \qquad \text{(A4)}$$

Permeability and Internal Stability Tests

5. Figure A2 shows the profiles obtained by plotting the height of the filter versus i_j/i_{avg} for Test No. 1A-A (check). The results indicate air segregation occurred in the uppermost portion of the filter (54-57 in.) since

$$\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg} = 1.31 \geq 1.0 \qquad \text{(A4)}$$

No trend was observed with respect to time.

6. Although not shown herein, data from seven other tests* were analyzed in the same manner as shown in Figure A2. A summary of the results is given in Table A1. Air segregation occurred in the uppermost portion of the filter in each of the permeability and internal stability tests analyzed.

Filter Tests

7. Figure A3 shows the profile obtained by plotting the height of the filter and base versus i_j/i_{avg} for Test No. 1A-A (check). The results indicate air segregation occurred in the upper portion of the base (63- to 66-in.) since

$$\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg} = 1.09 \geq 1.0 \qquad \text{(A4)}$$

Also, the results indicate air segregation and/or migration of base occurred in the uppermost portion of the filter (54-57 in.) since

$$\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg} = 4.47 \geq 1.0 \qquad \text{(A4)}$$

No trend was observed with respect to time.

---

* Test No. 1A-C, 1B-B, 1A, 2, 2A, 3, and 3A. Test No. 1A-B was not analyzed because of variations in flow with time. Test No. 1B-A, 1B-C, and 1 were not analyzed because of insufficient data (see Appendix D).

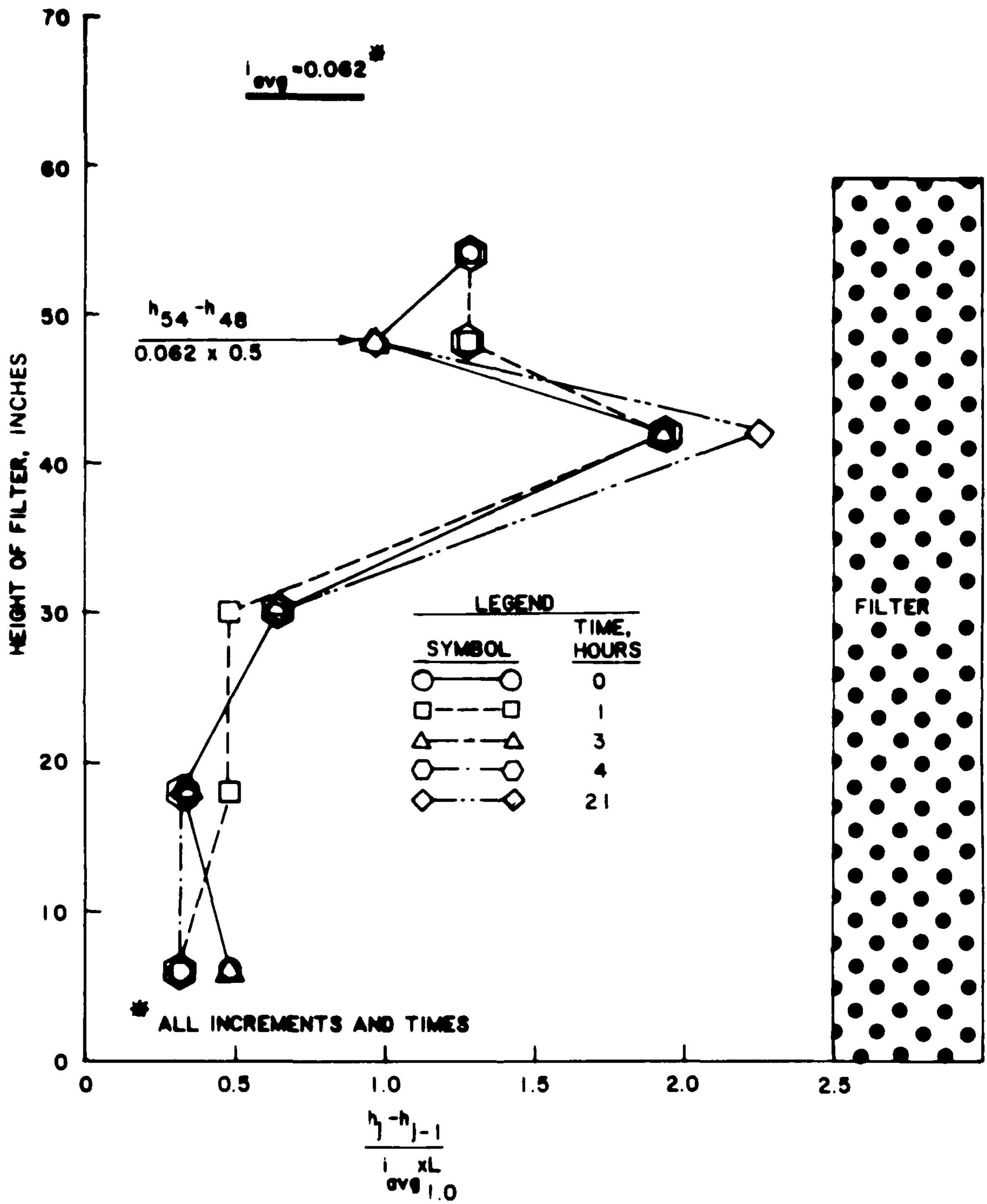

Figure A2. Nondimensional ratio of hydraulic gradients versus height of filter for Test No. 1A-A (check) during permeability tests

(Sheet 1 of 4)

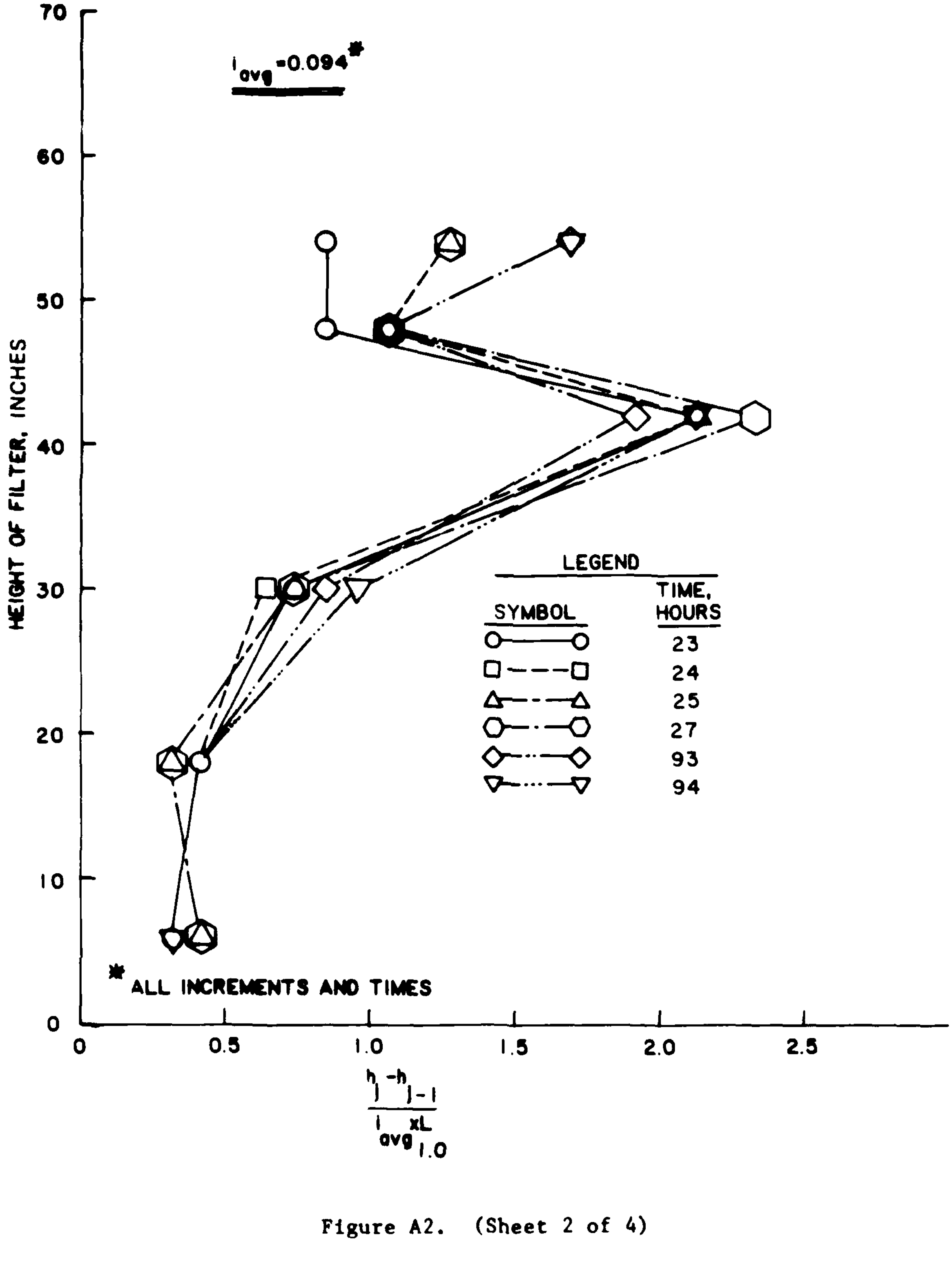

Figure A2. (Sheet 2 of 4)

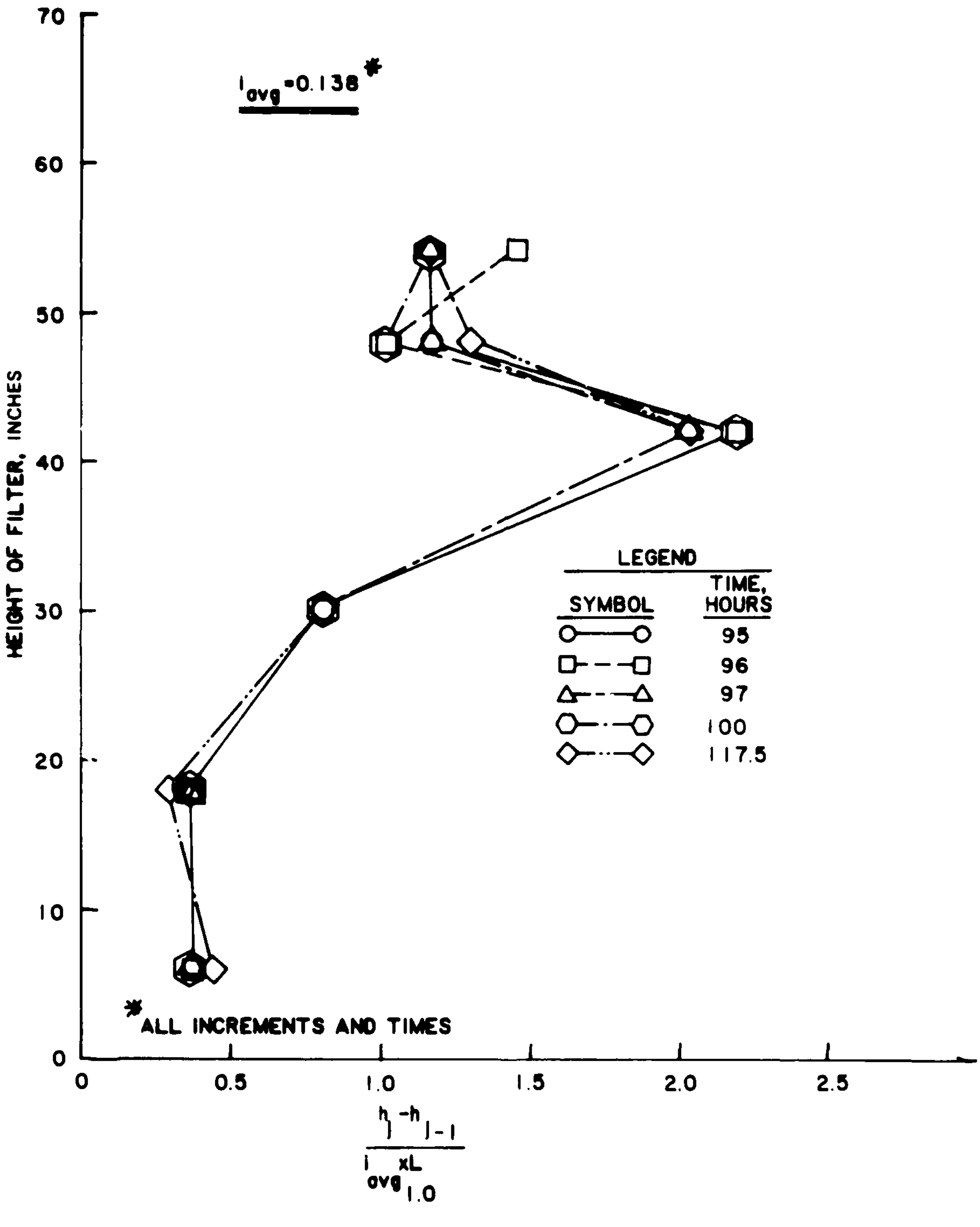

Figure A2. (Sheet 3 of 4)

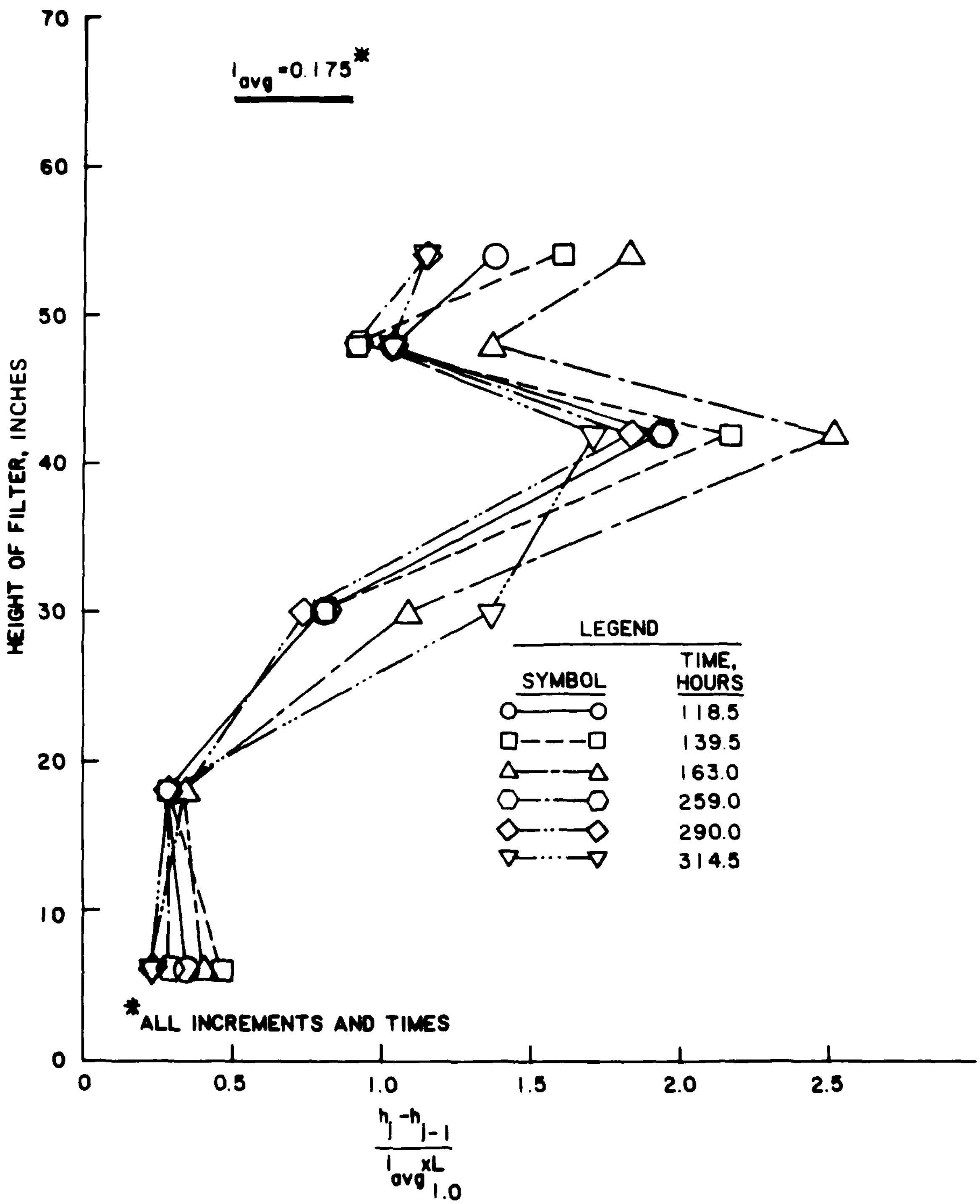

Figure A2. (Sheet 4 of 4)

Table A1

Summary of Results for Air Segregation for Permeability and Internal Stability Tests

Test No.	$\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg}$ *	Air Segregation**
1A-A (check)	1.31	yes
1A-C	1.06	yes
1B-B	1.20	yes
1A	1.15	yes
2	1.68	yes
2A	1.60	yes
3	1.38	yes
3A	1.75	yes

* Uppermost portion of specimen: 54- to 57-in. for Test No. 1A-A (check), 1A-C, and 1B-B; 60- to 63-in. for Test No. 1A, 2, 2A, 3, and 3A.

** Defined as $\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg} \geq 1.0$

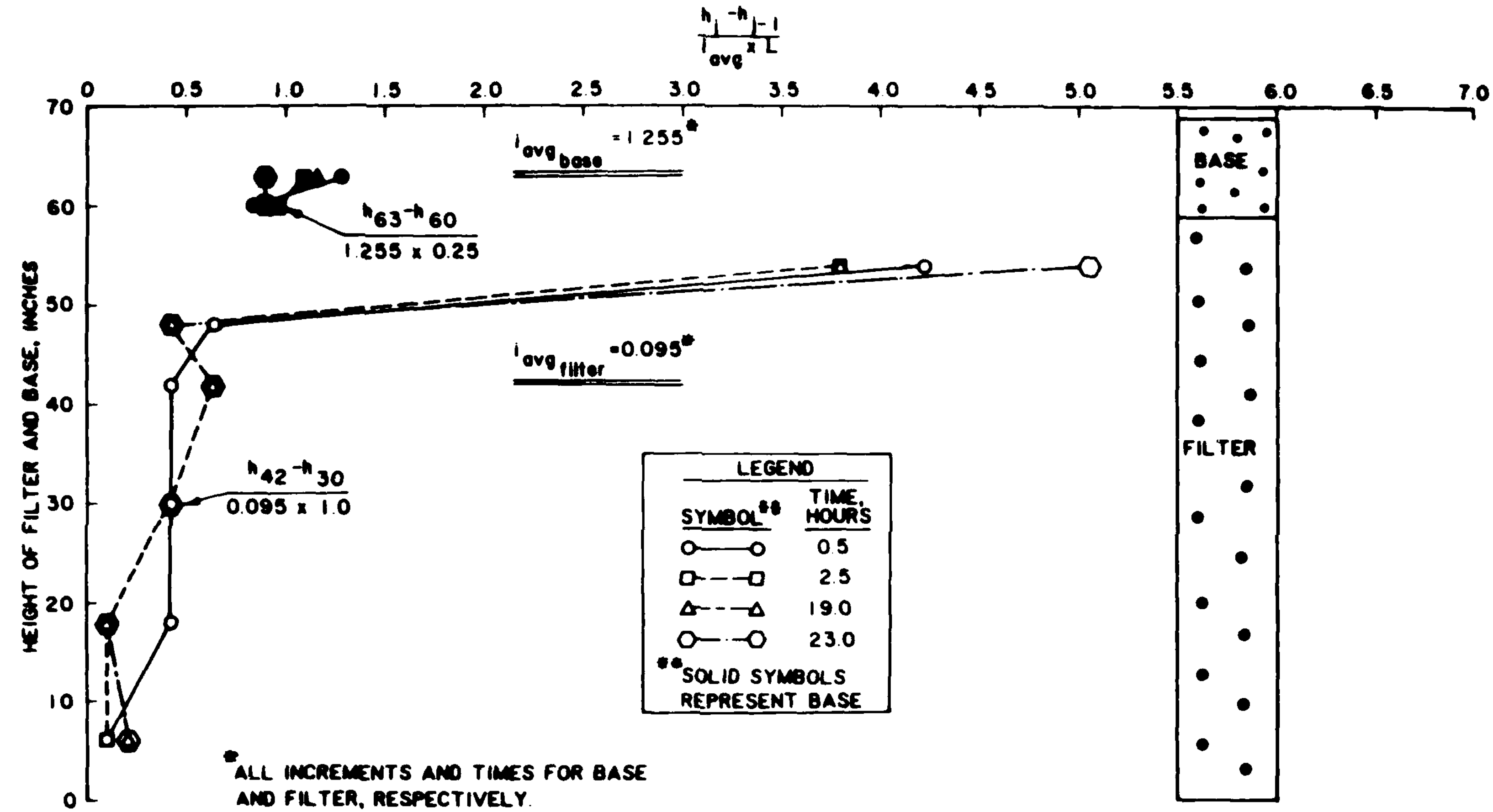

Figure A3. Nondimensional ratio of hydraulic gradient versus height of filter and base for Test 1A-A (check) during filter tests

(Sheet 1 of 4)

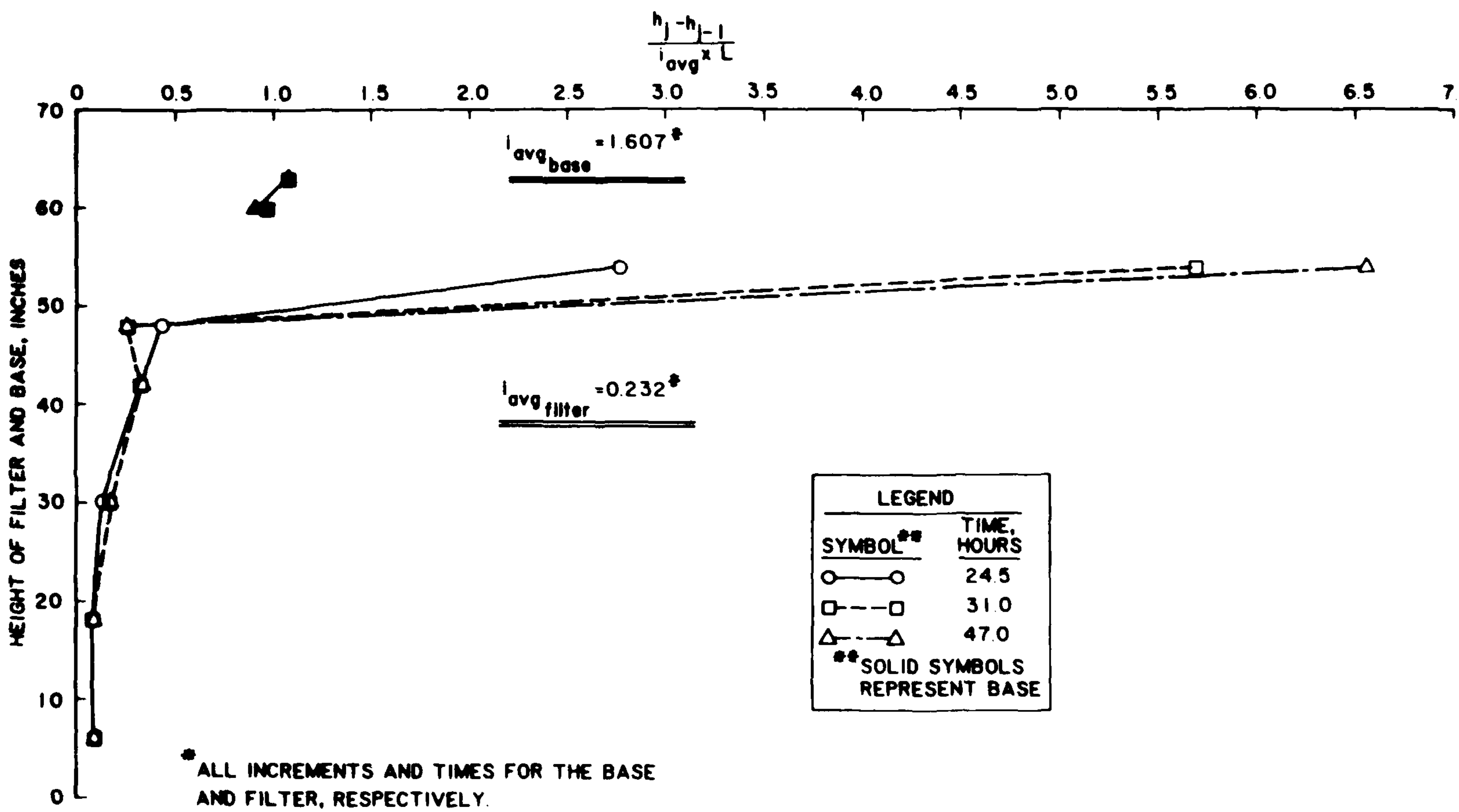

Figure A3. (Sheet 2 of 4)

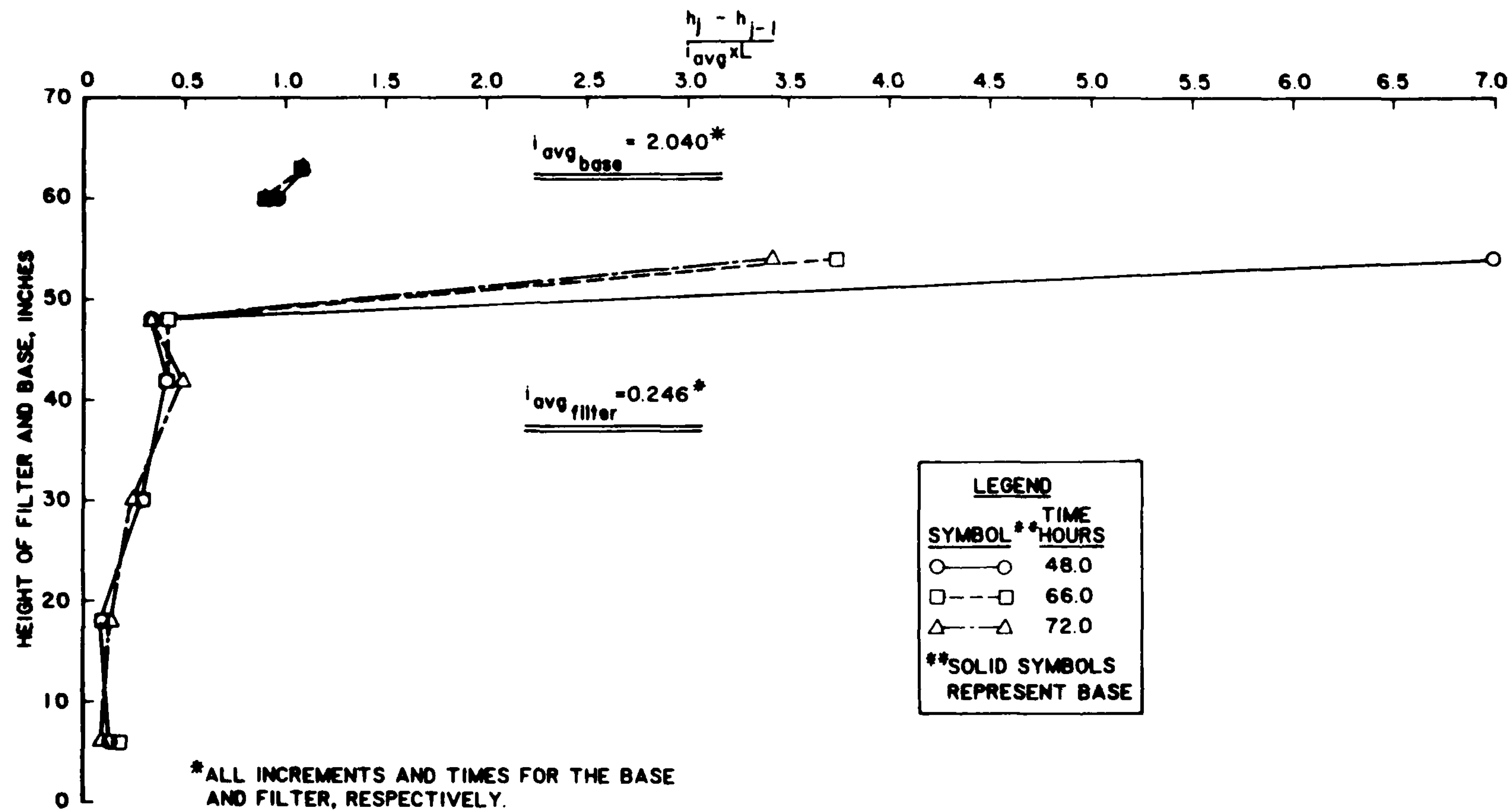

Figure A3. (Sheet 3 of 4)

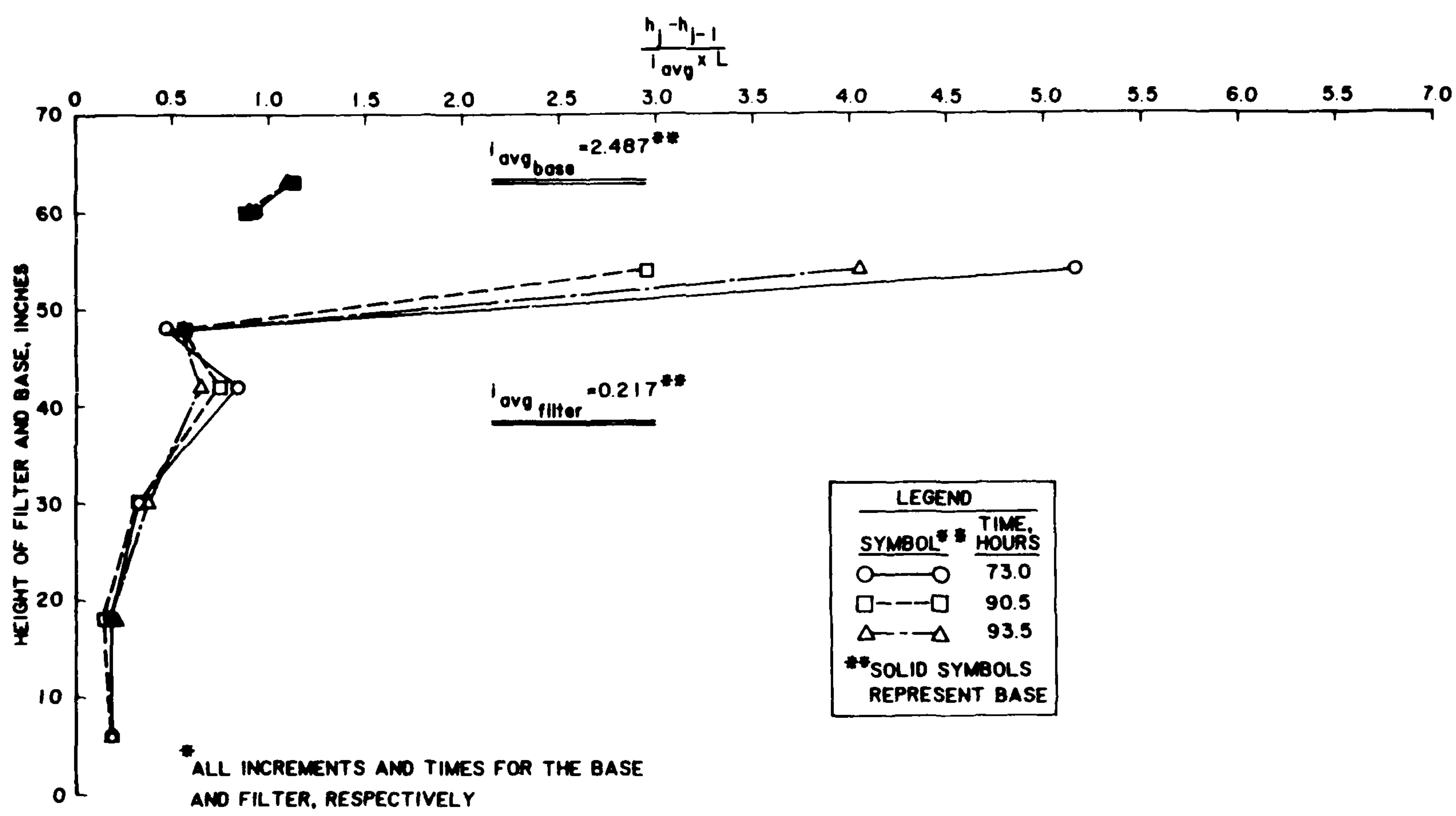

Figure A3. (Sheet 4 of 4)

8. Although not shown herein, data from four other tests* were analyzed in the same manner as shown in Figure A3. A summary of the results is given in Table A2. Air segregation occurred in the upper portion of the base in each of the filter tests analyzed. Also, air segregation and/or migration of base occurred in the uppermost portion of the filter in each of the filter tests analyzed.

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* Test No. 1A-B, 1A-C, 1B-B, and 1B-C. Test No. 1B-A was not analyzed because of insufficient data (see Appendix D).

Table A2

Summary of Results for Air Segregation for Filter Tests

Test No.	$\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg}$ *	Air Segregation**	$\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg}$ †	Air Segregation** and/or Migration of Base into Filter
1A-A (check)	1.09	yes	4.47	yes
1A-B	1.18	yes	2.74	yes
1A-C	1.02	yes	2.02	yes
1B-B	1.01	yes	4.08	yes
1B-C	1.37	yes	3.19	yes

* Upper portion of base, 63- to 66-in.

** Defined as $\left(\frac{h_j - h_{j-1}}{i_{avg} \times L}\right)_{avg} \geq 1.0$

† Uppermost portion of filter, 54- to 57-in.

APPENDIX B: PIEZOMETER, FLOW, AND WATER TEMPERATURE READINGS

TEST 1A-A (Check) - PERMEABILITY TEST*

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 0	1	3	4	21	23	24	25	27	93	94	95	96	97	100
10	66	2.51	2.50	2.49	2.50	2.50	4.58	4.59	4.56	4.57	4.69	4.69	7.20	7.19	7.19	7.18
9	63	2.52	2.51	2.50	2.51	2.51	4.58	4.59	4.57	4.58	4.70	4.69	7.20	7.18	7.19	7.18
8	60	2.52	2.51	2.50	2.51	2.51	4.57	4.59	4.56	4.58	4.70	4.69	7.20	7.19	7.19	7.18
7	57	2.52	2.51	2.50	2.51	2.51	4.57	4.59	4.56	4.58	4.70	4.69	7.20	7.19	7.19	7.18
6	54	2.50	2.49	2.48	2.49	2.49	4.55	4.56	4.53	4.55	4.66	4.65	7.16	7.14	7.15	7.14
5	48	2.47	2.45	2.45	2.45	2.46	4.51	4.51	4.48	4.50	4.61	4.60	7.08	7.07	7.07	7.07
4	42	2.41	2.39	2.39	2.39	2.39	4.41	4.41	4.38	4.39	4.50	4.50	6.93	6.92	6.93	6.92
3	30	2.37	2.36	2.35	2.35	2.35	4.34	4.35	4.31	4.32	4.42	4.41	6.82	6.81	6.82	6.81
2	18	2.35	2.33	2.33	2.33	2.33	4.30	4.31	4.28	4.29	4.38	4.37	6.77	6.76	6.77	6.76
1	6	2.32	2.31	2.30	2.31	2.31	4.27	4.28	4.24	4.25	4.35	4.34	6.72	6.71	6.72	6.71

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 0	1	3	4	21	23	24	25	27	93	94	95	96	97	100
Flow, cc/sec	36.5	38.0	37.5	37.0	37.0	51.5	53.5	51.5	50.0	52.0	49.5	65.0	65.0	63.0	65.0
	36.0	37.0	36.0	37.5	36.0	53.0	51.0	51.0	50.5	50.5	51.5	64.5	64.0	63.5	64.5
	36.5	37.0	37.0	37.5	37.5	52.5	54.0	51.0	51.0	51.0	51.0	65.5	65.5	64.5	65.0
Water Temperature C	21.0	21.0	21.0	21.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0

(Continued)

* Initial height of filter specimen was 59 in. Piezometer tap nos. 8, 9, and 10 were located above the top surface of the filter specimen.

TEST 1A-A (Check) - PERMEABILITY TEST*

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 117.5	118.5	119.5	121.5	122.5	139.5	163.0	166.0	259.0	283.0	290.0	307.5	311.0	314.5
10	66	7.16	9.55	9.59	9.60	9.61	9.60	9.60	8.79	8.81	8.74	8.74	8.70	8.82	8.87
9	63	7.16	9.55	9.59	9.60	9.61	9.60	9.60	8.79	8.81	8.74	8.74	8.69	8.82	8.86
8	60	7.16	9.55	9.59	9.60	9.61	9.60	9.60	8.78	8.81	8.74	8.74	8.69	8.82	8.86
7	57	7.16	9.55	9.59	9.60	9.62	9.61	9.60	8.78	8.81	8.74	8.74	8.70	8.82	8.86
6	54	7.12	9.49	9.55	9.55	9.57	9.54	9.52	8.73	8.76	8.69	8.69	8.65	8.77	8.81
5	48	7.03	9.40	9.44	9.47	9.48	9.46	9.40	8.64	8.68	8.61	8.60	8.57	8.68	8.72
4	42	6.89	9.23	9.27	9.28	9.29	9.27	9.18	8.49	8.51	8.45	8.44	8.42	8.52	8.57
3	30	6.78	9.09	9.13	9.14	9.15	9.13	8.99	8.35	8.37	8.32	8.31	8.29	8.40	8.45
2	18	6.74	9.04	9.07	9.09	9.10	9.08	8.93	8.30	8.32	8.26	8.25	8.24	8.35	8.40
1	6	6.68	8.98	9.01	9.02	9.04	9.00	8.86	8.26	8.27	8.21	8.21	8.19	8.30	8.36

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 117.5	118.5	119.5	121.5	122.5	139.5	163.0	166.0	259.0	283.0	290.0	307.5	311.0	314.5
Flow, cc/sec	66.5	71.0	70.5	72.0	72.8	73.5	81.0	64.0	62.0	61.0	61.5	62.0	65.0	64.0
	63.0	72.5	72.0	71.5	74.5	73.5	83.0	63.0	64.0	62.0	60.0	64.0	62.0	63.0
	61.0	72.0	70.0	72.0	72.5	71.5	83.5	62.0	67.5	64.0	63.0	63.5	62.0	65.0
Water Temperature C	21.0	21.0	22.0	22.0	22.0	22.0	19.5	19.0	23.0	23.0	23.0	23.5	24.0	24.0

(Concluded)

* Initial height of filter specimen was 59 in. Piezometer tap nos. 8, 9, and 10 were located above the top surface of the filter specimen.

TEST 1A-A (Check) - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 0.5	2.5	19.0	23.0	24.5	26.5	31.0	47.0	48.0	50.0	66.0
10	66	2.59	2.50	2.60	2.59	3.79	3.79	4.01	4.05	5.90	5.78	5.47
9	63	2.19	2.16	2.26	2.30	3.36	3.37	3.58	3.62	5.35	5.22	4.92
8	60	1.93	1.86	1.98	2.02	2.99	3.00	3.21	3.26	4.86	4.75	4.46
7	57	1.57	1.51	1.51	1.51	2.33	2.33	2.46	2.51	4.03	4.00	3.86
6	54	1.47	1.42	1.40	1.39	2.17	2.17	2.13	2.13	3.60	3.61	3.63
5	48	1.44	1.40	1.38	1.37	2.12	2.12	2.10	2.10	3.56	3.56	3.58
4	42	1.42	1.37	1.35	1.34	2.08	2.08	2.06	2.06	3.51	3.51	3.53
3	30	1.38	1.33	1.31	1.30	2.05	2.05	2.02	2.02	3.44	3.44	3.46
2	18	1.36	1.32	1.30	1.29	2.03	2.03	2.00	2.00	3.42	3.42	3.44
1	6	1.35	1.31	1.28	1.27	2.01	2.01	1.98	1.98	3.39	3.39	3.40

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 0.5	2.5	19.0	23.0	24.5	26.5	31.0	47.0	48.0	50.0	66.0
Flow, cc/sec	29.5	28.5	28.0	28.5	35.5	36.5	36.5	35.5	45.5	48.0	48.0
	30.0	28.5	29.0	28.5	35.0	35.0	35.5	35.0	46.5	46.0	50.0
	29.0	29.0	28.0	28.5	35.0	35.0	35.0	34.5	46.0	45.5	47.0
Water Temperature C	19.5	20.0	22.0	22.0	22.0	22.0	21.0	21.5	22.0	22.0	22.0

(Continued)

TEST 1A-A (Check) - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft Cumulative Elapsed Time, hours									
		68.0	72.0	73.0	90.5	93.5	95.0	98.0	211.0	214.5	234.5
10	66	5.46	5.43	7.70	7.60	7.57	9.50	9.50	9.23	8.93	8.94
9	63	4.91	4.88	7.01	6.92	6.89	8.73	9.73	9.44	7.68	7.67
8	60	4.44	4.42	6.44	6.37	6.33	8.10	8.09	7.79	6.65	6.61
7	57	3.85	3.83	5.73	5.66	5.63	7.28	7.28	6.93	5.30	5.21
6	54	3.62	3.62	5.45	5.44	5.41	7.02	7.02	6.67	4.83	4.76
5	48	3.58	3.58	5.40	5.38	5.35	6.96	6.97	6.60	4.72	4.64
4	42	3.53	3.52	5.31	5.30	5.28	6.88	6.88	6.52	4.54	4.46
3	30	3.46	3.46	5.24	5.23	5.20	6.77	6.78	6.42	4.38	4.28
2	18	3.44	3.43	5.20	5.20	5.16	6.74	6.73	6.38	4.29	4.20
1	6	3.41	3.41	5.16	5.16	5.12	6.69	6.68	6.33	4.21	4.11

Flow and Water Temperature Data

	Cumulative Elasped Time, hours									
	68.0	72.0	73.0	90.5	93.5	95.0	98.0	211.0	214.5	234.5
Flow, cc/sec	49.5	46.0	56.5	56.5	56.5	65.0	67.0	63.0	100.0	95.0
	46.0	46.5	59.0	57.0	56.5	63.0	66.5	61.5	98.5	95.0
	46.0	49.0	56.5	56.0	58.0	63.5	66.5	62.0	100.0	97.0
Water Temperature C	22.0	22.0	22.0	22.0	23.0	23.0	23.0	20.0	20.5	18.0

(Concluded)

TEST 1A-B - PERMEABILITY TEST*

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 0	1.0	3.0	96.2	99.2	100.4	102.4	119.4	120.4	120.9	121.4	137.9	138.4	139.4	139.9	140.9
10	66	2.44	2.44	2.44	2.38	2.39	8.70	8.62	8.61	8.63	2.82	2.81	2.82	4.27	4.28	6.42	6.41
9	63	2.45	2.45	2.45	2.39	2.40	8.70	8.63	8.60	8.63	2.84	2.82	2.84	4.27	4.28	6.42	6.41
8	60	2.45	2.45	2.45	2.38	2.39	8.70	8.63	8.60	8.63	2.84	2.82	2.84	4.27	4.27	6.42	6.41
7	57	2.43	2.44	2.45	2.31	2.32	8.68	8.62	8.59	8.62	2.83	2.82	2.82	4.26	4.27	6.41	6.40
6	54	2.30	2.30	2.31	2.27	2.28	8.66	8.59	8.56	8.59	2.80	2.80	2.79	4.23	4.24	6.39	6.38
5	48	2.40	2.40	2.40	2.20	2.20	8.60	8.53	8.50	8.53	2.76	2.77	2.76	4.20	4.20	6.34	6.33
4	42	2.37	2.37	2.37	2.13	2.13	8.51	8.45	8.41	8.44	2.75	2.74	2.75	4.15	4.16	6.27	6.26
3	30	2.23	2.23	2.23	2.05	2.05	8.39	8.33	8.29	8.32	2.67	2.67	2.68	4.07	4.08	6.17	6.16
2	18	2.24	2.24	2.24	1.80	1.80	8.25	8.19	8.15	8.18	2.60	2.60	2.61	3.98	3.99	6.05	6.04
1	6	1.98	1.98	1.98	1.60	1.60	8.05	8.00	7.97	7.99	2.50	2.50	2.51	3.85	3.86	5.92	5.90

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 0	1.0	3.0	96.2	99.2	100.4	102.4	119.4	120.4	120.9	121.4	137.9	138.4	139.4	139.9	140.9
Flow, cc/sec	--	--	68.7	136.2	141.5	124.7	120.6	122.6	124.7	70.0	72.6	71.0	88.0	87.3	107.8	107.2
	--	--	68.9	140.0	143.0	123.3	122.7	122.6	125.2	70.0	72.2	70.0	87.0	87.7	107.2	107.8
	--	--	69.3	139.2	136.8	124.0	121.3	126.2	122.6	70.0	70.0	70.5	86.8	87.7	107.2	107.8
Water Temperature C	26.0	26.0	27.0	26.5	26.5	26.5	26.0	26.5	26.5	27.0	27.0	27.0	26.5	27.0	26.5	26.5

* Initial height of filter specimen was 58 in. Piezometer tap nos. 8, 9, and 10 were located above the top surface of the filter specimen.

TEST 1A-B - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 2	19	47	66	70	72	73	74	90.5	91.5	93.5	109.5	110.5	112.5	114.5
10	66	2.73	2.81	3.06	3.23	3.24	3.24	4.96	4.96	4.74	6.27	6.24	6.10	9.00	9.09	9.05
9	63	2.35	2.39	2.60	2.74	2.74	2.74	4.27	4.27	4.16	5.62	5.58	5.45	8.48	8.44	8.41
8	60	2.05	2.09	2.27	2.46	2.48	2.49	3.96	3.96	3.85	5.21	5.17	5.05	7.77	7.74	7.72
7	57	1.82	1.83	1.85	2.10	2.12	2.14	3.50	3.51	3.46	4.76	4.74	4.63	7.26	7.24	7.22
6	54	1.79	1.79	1.77	1.83	1.84	1.85	3.22	3.24	3.23	4.77	4.77	4.71	7.18	7.16	7.14
5	48	1.72	1.72	1.69	1.67	1.66	1.66	3.19	3.19	3.19	4.54	4.54	4.54	7.10	7.09	7.08
4	42	1.74	1.74	1.71	1.69	1.67	1.67	3.21	3.21	3.20	4.53	4.55	4.48	7.07	7.05	7.02
3	30	1.71	1.71	1.68	1.66	1.64	1.64	3.16	3.17	3.15	4.47	4.47	4.43	7.01	6.98	6.97
2	18	1.68	1.68	1.65	1.63	1.61	1.61	3.12	3.11	3.11	4.40	4.41	4.38	6.93	6.92	6.91
1	6	1.64	1.64	1.61	1.59	1.58	1.58	3.06	3.06	3.05	4.34	4.35	4.31	6.84	6.82	6.81

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 2	19	47	66	70	72	73	74	90.5	91.5	93.5	109.5	110.5	112.5	114.5
Flow, cc/sec	33.0	33.0	32.8	32.5	32.5	32.5	42.5	44.3	44.3	54.0	53.0	53.0	67.0	66.5	66.5
	--	--	--	--	--	--	--	--	--	52.7	--	--	66.0	--	--
	--	--	--	--	--	--	--	--	--	53.0	--	--	66.0	--	--
Water Temperature C	28.0	27.5	25.5	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.5	26.5	26.5	26.5

TEST 1A-C - PERMEABILITY TEST*

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 0.5	2.5	3.5	4.5	21.5	22.0	24.0	26.0	27.0	28.0	28.5	44.5
10	66	3.22	3.21	3.20	3.21	3.20	5.06	5.07	5.08	6.82	6.82	9.18	9.20
9	63	3.23	3.22	3.21	3.21	3.20	5.06	5.08	5.08	6.82	6.81	9.17	9.20
8	60	3.23	3.21	3.21	3.21	3.20	5.06	5.07	5.07	6.82	6.82	9.17	9.19
7	57	3.22	3.21	3.20	3.20	3.20	5.05	5.06	5.07	6.81	6.80	9.16	9.18
6	54	3.22	3.19	3.19	3.19	3.19	5.04	5.05	5.05	6.79	6.78	9.14	9.16
5	48	3.18	3.16	3.16	3.17	3.16	5.01	5.02	5.02	6.75	6.74	9.09	9.11
4	42	3.16	3.14	3.14	3.15	3.14	4.98	4.99	4.99	6.72	6.71	9.05	9.09
3	30	3.11	3.10	3.10	3.11	3.10	4.93	4.94	4.94	6.65	6.65	8.98	9.01
2	18	3.08	3.07	3.06	3.07	3.06	4.88	4.89	4.90	6.60	6.60	8.92	8.95
1	6	3.09	3.04	3.03	3.03	3.03	4.83	4.84	4.84	6.54	6.53	8.84	8.87

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 0.5	2.5	3.5	4.5	21.5	22.0	24.0	26.0	27.0	28.0	28.5	44.5
Flow, cc/sec	33.5	33.8	34.0	34.0	34.6	43.4	43.7	42.9	50.3	50.3	58.8	59.0
	33.9	33.8	33.9	34.0	34.1	43.3	43.4	43.1	50.3	50.3	58.5	58.9
	33.7	36.9	33.9	34.0	34.0	43.1	43.3	43.1	50.3	50.3	58.4	59.3
Water Temperature C	23.0	24.0	24.0	24.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.5

* Initial height of filter specimen was 58 in. Piezometer tap nos. 8, 9, and 10 were located above the top surface of the filter specimen.

TEST 1A-C - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 1	17	20	23	25	44	47	67.5	89	91	93	95	97	113	116	119	122	137
10	66	1.31	1.53	1.52	1.55	3.20	3.09	3.16	5.19	5.22	5.12	5.11	6.58	6.60	6.45	6.45	6.42	6.39	6.32
9	63	1.03	1.22	1.21	1.23	2.64	2.56	2.67	4.43	4.44	4.29	4.29	5.32	5.35	5.22	5.21	5.18	5.15	5.09
8	60	0.76	0.90	0.92	0.97	1.99	1.99	2.04	3.74	3.73	3.53	3.53	4.19	4.21	4.09	4.08	4.04	4.01	3.95
7	57	0.61	0.60	0.58	0.60	1.47	1.61	1.67	3.19	3.21	3.00	3.00	3.45	3.47	3.40	3.39	3.36	3.33	3.30
6	54	0.59	0.58	0.56	0.55	1.54	1.56	1.57	3.09	3.09	2.83	2.83	Dry	Dry	Dry	Dry	Dry	Dry	3.22
5	48	0.57	0.56	0.53	0.53	1.50	1.50	1.51	3.01	3.01	2.75	2.75	3.09	3.11	3.11	3.12	3.12	3.12	3.12
4	42	0.55	0.54	0.51	0.51	1.47	1.47	1.47	2.99	2.99	2.70	2.70	3.01	3.02	3.04	3.04	3.04	3.04	3.04
3	30	0.51	0.50	0.48	0.48	1.41	1.41	1.41	2.86	2.86	2.60	2.60	2.85	2.86	2.88	2.88	2.89	2.89	2.88
2	18	0.48	0.47	0.45	0.45	1.35	1.35	1.36	2.79	2.78	2.51	2.50	2.71	2.72	2.74	2.75	2.75	2.75	2.74
1	6	0.44	0.43	0.41	0.41	1.28	1.29	1.29	2.68	2.68	2.40	2.40	2.53	2.51	2.56	2.58	2.58	2.58	2.57

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 1	17	20	23	25	44	47	67.5	89	91	93	95	97	113	116	119	122	137
Flow, cc/sec	30.7	30.7	29.8	29 7	51.8	51.9	51.7	74.4	74.0	80.2	80.2	120.3	121.7	124.4	123.7	124.0	123.4	124.0
	30.6	30.6	29.6	29.5	51.7	51.9	51.4	75.2	74.6	80.0	81.4	121.1	122.5	122.7	123.7	123.7	122.7	122.7
	30.6	30.7	29.8	30.0	51.7	51.7	51.0	75.0	74.0	80.5	81.0	121.3	123.7	124.7	123.7	123.4	123.7	123.0
Water Temperature C	24.5	25.0	26.0	26.0	26.0	24.5	24.0	24.0	23.0	23.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0

(Continued)

TEST 1A-C - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 141	144	147	161	165	169	174	185	189	190	193	198	209	213	221	235.5	244.5	257	260.5
10	66	6.32	6.29	6.26	6.28	6.26	6.24	6.22	6.19	6.15	6.14	6.10	6.10	6.10	6.10	6.59	6.58	6.58	6.60	6.54
9	63	5.08	5.06	5.03	5.04	5.03	5.01	4.99	4.96	4.93	4.92	4.88	4.88	4.88	4.88	5.02	5.03	5.03	5.04	5.00
8	60	3.94	3.93	3.91	3.90	3.89	3.88	3.87	3.84	3.82	3.81	3.78	3.78	3.77	3.77	3.85	3.85	3.85	3.86	3.83
7	57	3.29	3.29	3.27	3.26	3.25	3.25	3.24	3.22	3.21	3.20	3.17	3.17	3.16	3.16	3.22	3.22	3.22	3.23	3.20
6	54	3.22	3.22	3.21	3.19	3.20	3.19	3.18	3.16	3.15	3.14	3.11	3.11	3.11	3.11	3.17	3.17	3.17	3.17	3.15
5	48	3.12	3.11	3.10	3.09	3.09	3.09	3.08	3.06	3.06	3.05	3.03	3.02	3.01	3.01	3.08	3.07	3.07	3.06	3.05
4	42	3.04	3.03	3.02	3.01	3.01	3.00	2.99	2.98	2.98	2.97	2.94	2.95	2.98	2.98	2.99	2.99	3.00	2.99	2.98
3	30	2.88	2.88	2.87	2.86	2.86	2.85	2.85	2.83	2.83	2.82	2.80	2.79.	2.78	2.78	2.83	2.83	2.83	2.83	2.81
2	18	2.74	2.74	2.73	2.72	2.71	2.71	2.70	2.69	2.69	2.62	2.66	2.66	2.66	2.64	2.69	2.69	2.69	2.69	2.67
1	6	2.57	2.57	2.57	2.55	2.55	2.55	2.54	2.53	2.52	2.51	2.49	2.48	2.48	2.47	2.51	2.52	2.52	2.52	2.51

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 141	144	147	161	165	169	174	185	189	190	193	198	209	213	221	235.5	244.5	257	260.5
Flow, cc/sec	122.4	121.3	122.4	121.8	122.1	119.4	121.8	121.5	121.2	120.3	120.9	121.3	119.8	118.8	121.5	122.8	122.4	120.3	120.3
	122.7	123.1	122.4	121.5	121.3	122.1	122.1	121.8	122.8	120.3	121.5	121.2	119.5	120.0	123.1	121.5	121.5	122.4	121.3
	122.7	123.1	122.4	122.1	122.4	123.1	121.8	121.5	121.3	120.3	120.5	120.5	119.8	120.0	121.5	121.5	122.8	122.4	121.5
Water Temperature C	24.0	24.5	25.0	24.0	24.0	24.0	24.0	24.0	24.5	24.5	25.0	24.5	24.0	24.0	24.0	24.0	24.0	23.0	23.5

(Concluded)

TEST 1B-A - PERMEABILITY TEST*

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft Cumulative Elapsed Time, hours 1	 2
10	66	--	--
9	63	--	--
8	60	--	--
7	57	--	--
6	54	4.21	4.20
5	48	--	--
4	42	--	--
3	30	--	--
2	18	--	--
1	6	4.17	4.15

Flow and Water Temperature Data

	Cumulative Elasped Time, hours 1	 2
Flow, cc/sec	--	106.0
	--	114.0
	--	104.0
Water Temperature C	25	25.0

* Initial height of filter specimen was 58 in. Piezometer tap nos. 8, 9, and 10 were located above the top surface of the filter specimen.

TEST 1B-A - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours 0.5	3	4	21	28	94	98	117	124	140.5	148
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	(2.8)	(3.0)	(3.0)	(2.4)	(2.2)	(2.4)	(2.4)	(2.8)	(2.9)	(3.3)	(3.4)
8	60	(2.0)	(2.2)	(2.2)	(1.5)	(1.5)	(1.3)	(1.3)	(1.4)	(1.4)	(1.5)	(1.6)
7	57	Dry	--	--	--	--	--	--	--	--	--	--
6	54	(1.2)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.2)	5.54
5	48	5.45	5.33	5.31	5.36	5.27	5.29	5.31	5.38	5.39	5.51	5.54
4	42	5.45	5.33	5.31	5.36	5.27	5.29	5.31	5.38	5.39	5.51	5.54
3	30	5.45	5.33	5.31	5.36	5.27	5.29	5.31	5.38	5.39	5.51	5.54
2	18	5.45	5.33	5.31	5.36	5.27	5.29	5.31	5.38	5.39	5.51	5.54
1	6	5.45	5.33	5.31	5.36	5.27	5.29	5.31	5.38	5.39	5.51	5.54

Flow and Water Temperature Data

	Cumulative Elasped Time, hours 0.5	3	4	21	28	94	98	117	124	140.5	148
Flow, cc/sec	2.08	2.88	2.92	3.00	2.92	2.92	2.92	2.83	2.83	2.67	2.67
	--	2.92	--	--	2.92	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
Water Temperature C	23	23.5	23.5	24.0	24.5	23.0	23.5	23.0	23.5	23.5	23.5

(Continued)

TEST 1B-A - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) — Cumulative Elapsed Time, hours: 165	189	260.5	284.5	308.5	332.5	356.5	428.5	452.5	476.5	524.5
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	(3.6)	(3.8)	(4.0)	(4.1)	(4.3)	(4.4)	(4.6)	(4.8)	(4.8)	(4.7)	(4.6)
8	60	(1.7)	(1.9)	(2.0)	(2.0)	(2.1)	(2.2)	(2.2)	(2.4)	(2.4)	(2.3)	(2.3)
7	57	--	--	--	--	--	--	--	--	--	--	--
6	54	5.56	5.67	5.66	5.61	5.62	5.60	5.54	5.60	5.61	5.59	5.53
5	48	5.56	5.67	5.66	5.61	5.62	5.60	5.54	5.60	5.61	5.59	5.53
4	42	5.56	5.67	5.66	5.61	5.62	5.60	5.54	5.60	5.61	5.59	5.53
3	30	5.56	5.67	5.66	5.61	5.62	5.60	5.54	5.60	5.61	5.59	5.53
2	18	5.56	5.67	5.66	5.61	5.62	5.60	5.54	5.60	5.61	5.59	5.53
1	6	5.56	5.67	5.66	5.61	5.62	5.60	5.54	5.60	5.61	5.59	5.53

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 165	189	260.5	284.5	308.5	332.5	356.5	428.5	452.5	476.5	524.5
Flow, cc/sec	2.58	2.50	2.42	2.33	2.33	2.25	2.25	2.17	2.17	2.17	2.17
	2.67	2.50	2.42	--	--	2.25	--	--	--	--	--
	2.67	--	--	--	--	--	--	--	--	--	--
Water Temperature C	23.0	23.0	24.5	24.0	23.5	23.5	23.5	23.5	24.0	24.0	24.0

(Concluded)

TEST 1B-B - PERMEABILITY TEST*

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 3	5	22
10	66	--	--	--
9	63	--	--	--
8	60	--	--	--
7	57	4.67	4.69	3.72
6	54	4.64	4.66	3.72
5	48	4.61	4.63	3.71
4	42	4.58	4.60	3.69
3	30	4.55	4.56	3.67
2	18	4.48	4.49	3.64
1	6	4.42	4.44	3.61

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 3	5	22
Flow, cc/sec	137.0	136.0	70.0
	133.0	134.0	73.5
	127.0	132.0	71.0
Water Temperature C	24.0	24.0	23.0

* Initial height of filter specimen was 58 in. Piezometer tap nos. 8, 9, and 10 were located above the top surface of the filter specimen.

TEST 1B-B - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft Cumulative Elapsed Time, hours 1	3	21	24.5	29	45.5	51.5	69.5	76.5	94.5
10	66	6.99	7.43	8.15	--	--	--	--	--	--	--
9	63	5.71	6.02	5.59	8.59	8.42	7.79	7.60	7.66	7.95	7.57
8	60	4.39	4.50	4.22	5.60	5.65	5.53	5.36	5.02	4.98	4.59
7	57	3.15	3.15	3.14	3.15	3.15	3.15	3.15	3.15	3.16	3.15
6	54	3.15	3.14	3.14	3.14	3.13	3.14	3.13	3.10	3.12	3.15
5	48	3.15	3.14	3.14	3.14	3.13	3.14	3.13	3.14	3.15	3.15
4	42	3.15	3.14	3.14	3.14	3.14	3.14	3.13	3.13	3.15	3.15
3	30	3.15	3.15	3.14	3.14	3.14	3.14	3.14	3.14	3.15	3.15
2	18	3.13	3.12	3.13	3.07	3.12	3.12	3.11	3.10	3.11	3.12
1	6	3.13	3.13	3.13	3.08	3.12	3.12	3.11	3.11	3.11	3.12

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours 1	3	21	24.5	29	45.5	51.5	69.5	76.5	94.5
Flow, cc/sec	1.25	1.33	1.17	2.83	2.92	2.67	2.67	3.17	3.42	3.08
	1.25	1.33	1.17	2.83	2.92	2.67	2.67	3.17	3.42	3.08
	1.25	1.33	1.17	2.83	2.92	2.67	2.67	3.17	3.42	3.08
Water Temperature C	23.0	23.0	23.0	22.5	23.0	22.0	22.0	24.0	24.0	22.0

(Continued)

TEST 1B-B - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours								
		165.5	174	190	214	238	262	268	334	357
10	66	--	--	--	--	--	--	--	--	--
9	63	9.04	9.35	9.70	10.00	9.38	9.80	12.50	12.70	13.00
8	60	4.79	4.87	4.92	4.97	4.76	5.01	5.68	5.86	6.03
7	57	3.14	3.15	3.14	3.15	3.15	3.15	3.15	3.15	3.15
6	54	3.14	3.15	3.14	3.14	3.15	3.15	3.15	3.15	3.15
5	48	3.14	3.14	3.14	3.14	3.15	3.15	3.15	3.15	3.15
4	42	3.14	3.14	3.14	3.14	3.15	3.15	3.15	3.15	3.15
3	30	3.14	3.14	3.14	3.14	3.15	3.15	3.15	3.15	3.15
2	18	3.14	3.14	3.14	3.14	3.15	3.15	3.15	3.15	3.15
1	6	3.14	3.14	3.14	3.14	3.15	3.15	3.15	3.15	3.15

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours								
	165.5	174	190	214	238	262	268	334	357
Flow, cc/sec	2.33	2.50	2.33	2.33	2.00	2.08	2.83	2.50	2.58
	2.33	2.50	2.33	2.33	2.00	2.08	2.83	2.58	2.58
	2.33	2.50	2.33	[illegible]	2.00	2.08	2.83	2.58	2.50
Water Temperature C	22.0	22.0	23.0	24.0	24.0	25.0	25.0	24.0	25.0

(Concluded)

TEST 1B-C - PERMEABILITY TEST*

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 0	1	2
10	66	--	--	--
9	63	--	--	--
8	60	--	--	--
7	57	--	--	--
6	54	1.61	1.62	1.63
5	48	--	--	--
4	42	--	--	--
3	30	--	--	--
2	18	--	--	--
1	6	1.57	1.58	1.59

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 0	1	2
Flow, cc/sec	144.0	144.0	144.0
	150.0	143.0	144.0
	146.0	146.0	146.0
Water Temperature C	22.0	22.0	22.5

* Initial height of filter specimen was 58 in. Piezometer tap nos. 8, 9, and 10 were located above the top surface of the filter specimen.

TEST 1B-C - FILTER TEST

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft — Cumulative Elapsed Time, hours: 1.5	4.3	23.8	25.8	26.8	47.8	54.8	72.3	79.8	96.8	106.8	147.8	171.8	195.8
10	66	4.71	4.62	4.34	5.63	5.71	2.48	2.62	2.84	2.93	3.11	6.59	8.65	9.50	10.00
9	63	4.19	4.14	4.00	5.12	5.34	1.85	1.99	2.22	2.36	2.57	2.44	3.71	3.43	3.64
8	60	4.07	4.04	3.94	5.02	5.27	1.70	1.78	2.07	2.23	2.47	1.42	0.94	1.14	1.36
7	57	4.03	4.01	3.91	4.99	5.24	1.34	1.49	1.78	1.92	2.18	0.39	0.41	0.63	0.78
6	54	4.03	4.01	3.91	4.99	5.23	1.23	1.24	1.37	1.44	1.53	0.38	0.22	0.34	0.48
5	48	4.03	4.01	3.91	4.98	5.23	1.21	1.17	1.16	1.21	1.30	0.37	0.21	0.17	0.29
4	42	4.03	4.01	3.91	4.97	5.23	1.21	1.16	1.15	1.19	1.18	0.37	0.21	0.16	0.17
3	30	4.03	4.00	3.91	4.95	5.23	1.20	1.16	1.14	1.18	1.18	0.37	0.21	0.16	0.17
2	18	4.02	4.00	3.90	4.94	5.22	1.20	1.15	1.13	1.18	1.16	0.37	0.20	0.16	0.17
1	6	4.02	4.00	3.90	4.94	5.21	1.19	1.14	1.12	1.17	1.16	0.37	0.20	0.16	0.17

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 1.5	4.3	23.8	25.8	26.8	47.8	54.8	72.3	79.8	96.8	106.8	147.8	171.8	195.8
Flow, cc/sec	49.0	48.0	47.0	72.0	76.0	126.0	124.0	128.0	130.0	132.0	75.0	54.0	50.0	52.0
	49.0	48.0	49.0	76.0	74.0	126.0	122.0	134.0	128.0	136.0	71.0	55.0	52.0	54.0
	48.5	47.0	47.0	74.0	76.0	120.0	124.0	134.0	132.0	130.0	72.0	56.0	50.0	52.0
Water Temperature C	25.0	25.0	23.0	23.0	23.0	22.0	22.0	23.0	24.0	24.0	24.0	24.0	24.0	26.0

TEST 1 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours														
		0	2	19	22	25	41	45	49	65	69	73	93	117	137	141
10	66	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9	63	(2.9)	(3.0)	(2.4)	(2.4)	(2.2)	(1.8)	(1.4)	(1.4)	(1.4)	(1.4)	(1.4)	(1.4)	(1.4)	(1.4)	(1.4)
8	60	(2.7)	(2.8)	(2.2)	(2.1)	(2.0)	(1.7)	(1.2)	(1.1)	(1.1)	(1.1)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)
7	57	(2.7)	(2.8)	(2.2)	(2.1)	(1.9)	(1.6)	(1.2)	(1.2)	(1.1)	(1.1)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)
6	54	(2.7)	(2.8)	(2.2)	(2.2)	(2.1)	(1.6)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)	(1.2)
5	48	--	--	--	--	--	--	--	5.84	5.84	5.77	5.77	5.78	5.78	5.79	5.79
4	42	--	--	--	--	--	--	--	5.35	5.29	5.23	5.25	5.27	5.28	5.29	5.28
3	30	5.50	5.62	5.86	5.82	5.72	5.03	4.03	3.91	3.86	3.86	3.91	4.37	4.37	4.38	4.37
2	18	4.48	4.66	4.42	4.40	4.38	4.25	4.10	4.04	4.04	3.99	4.01	4.01	4.01	4.02	4.02
1	6	4.00	4.03	3.90	3.88	3.87	3.87	3.78	3.73	3.75	3.73	3.73	3.73	3.73	3.74	3.73

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours														
	0	2	19	22	25	41	45	49	65	69	73	93	117	137	141
Flow, cc/sec	33.5	35.2	39.8	40.0	40.5	42.5	35.3	36.5	37.0	36.5	37.0	37.0	37.0	37.5	37.5
	33.8	35.3	39.6	40.0	40.8	42.5	35.0	36.8	37.0	36.5	37.0	37.0	37.0	37.5	37.5
	34.3	35.3	39.6	40.0	40.5	42.5	35.0	36.5	37.0	36.5	36.8	36.8	37.0	37.5	37.5
Water Temperature C	24.2	24.5	24.5	24.5	25.0	25.0	25.0	25.2	25.0	25.0	25.2	25.0	25.0	25.0	25.3

(Continued)

TEST 1 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours 145	161	165	167	168	169	185	189	193	209	213	217	233	237	241	257
10	66	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9	63	(1.4)	(1.4)	(1.4)	(2.0)	(2.4)	(2.4)	(2.4)	(2.3)	(2.3)	(2.3)	(2.3)	(2.3)	(2.4)	(2.3)	(2.3)	(2.3)
8	60	(1.2)	(1.2)	(1.2)	(1.7)	(2.1)	(2.1)	(2.1)	(2.0)	(2.0)	(2.0)	(2.0)	(2.1)	(2.1)	(2.0)	(2.0)	(2.1)
7	57	(1.2)	(1.2)	(1.2)	(1.6)	(2.0)	(2.0)	(2.0)	(1.9)	(1.9)	(1.9)	(1.9)	(1.9)	(2.0)	(1.9)	(1.9)	(1.9)
6	54	(1.2)	(1.2)	(1.2)	(1.4)	(1.9)	(1.9)	(2.0)	(1.8)	(1.8)	(1.8)	(1.8)	(1.9)	(1.9)	(1.8)	(1.8)	(1.8)
5	48	5.79	5.79	5.79	7.27	8.14	8.02	8.15	7.96	7.95	8.11	7.93	7.93	8.07	7.91	7.90	7.89
4	42	5.28	5.29	5.29	6.74	7.50	7.40	7.50	7.36	7.37	7.52	7.35	7.35	7.47	7.34	7.35	7.31
3	30	4.37	4.37	4.36	5.17	5.73	5.75	5.89	5.72	5.87	5.95	5.85	5.85	5.91	5.84	5.85	5.82
2	18	4.02	4.02	4.02	4.55	4.96	4.87	4.92	4.78	4.91	4.94	4.94	4.94	4.95	4.94	4.95	4.90
1	6	3.73	3.73	3.73	4.00	4.25	4.14	4.15	4.15	4.31	4.34	4.30	4.30	4.33	4.30	4.31	4.30

Flow and Water Temperature Data

	Cumulative Elasped Time, hours 145	161	165	0	1	2	18	22	26	42	46	50	66	70	74	90
Flow, cc/sec	37.3	37.0	37.0	52.7	63.3	64.0	66.0	65.0	65.0	66.5	64.5	64.5	66.1	63.9	63.8	63.9
	37.3	36.8	37.0	52.7	63.7	64.3	65.5	65.0	65.0	66.0	65.0	65.0	64.0	65.0	64.0	63.1
	37.5	37.5	37.3	53.0	63.3	64.3	66.0	66.0	65.0	66.5	65.0	65.5	64.0	64.6	64.8	64.8
Water Temperature C	25.3	25.1	25.5	25.5	25.5	25.5	26.0	26.0	26.0	25.0	25.5	25.5	25.2	25.5	25.5	26.0

(Continued)

TEST 1 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours															
		281	305	309	313	329	333	337	353	357	361	366	385	388	391	409	412
10	66	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9	63	(2.3)	(2.3)	(2.2)	(2.2)	(2.4)	(2.4)	(2.4)	(2.2)	(2.2)	(2.2)	14.1	14.0	14.1	11.3	12.2	12.2
8	60	(2.1)	(2.1)	(2.0)	(2.0)	(2.1)	(2.1)	(2.1)	(2.0)	(2.0)	(2.0)	13.5	13.4	13.4	10.7	11.6	11.6
7	57	(1.9)	(1.9)	(1.8)	(1.8)	(2.0)	(2.0)	(2.0)	(1.8)	(1.8)	(1.8)	13.1	13.0	13.1	10.3	11.2	11.2
6	54	(1.8)	(1.8)	(1.7)	(1.8)	(1.9)	(1.9)	(1.9)	(1.7)	(1.7)	(1.7)	12.8	12.7	12.7	10.1	11.0	11.0
5	48	7.87	7.84	7.73	7.86	7.99	7.99	7.96	7.72	7.70	7.68	12.3	12.0	12.1	9.8	10.5	10.5
4	42	7.32	7.32	7.19	7.30	7.41	7.41	7.38	7.18	7.16	7.13	11.5	11.3	11.3	9.2	9.8	9.8
3	30	5.82	5.82	5.73	5.80	5.85	5.84	5.84	5.71	5.71	5.70	8.8	8.8	8.8	7.1	7.7	7.7
2	18	4.92	4.94	4.91	4.93	4.96	4.95	4.95	4.89	4.89	4.89	7.7	7.0	6.9	5.6	6.0	6.1
1	6	4.30	4.30	4.26	4.28	4.30	4.29	4.29	4.25	4.25	4.25	5.4	5.4	5.3	4.5	4.8	4.8

Flow and Water Temperature Data

	Cumulative Elasped Time, hours															
	114	138	142	146	162	166	170	186	190	194	366	385	388	391	409	412
Flow, cc/sec	64.6	64.6	63.7	63.7	63.0	62.4	63.4	63.0	63.0	62.0	257.1	245.7	247.3	202.5	209.1	225.0
	64.0	64.1	64.6	63.0	63.0	63.0	63.0	62.0	62.0	62.0	241.3	237.3	247.1	209.5	215.9	230.0
	64.5	63.6	64.0	62.6	61.6	63.3	63.3	62.5	62.0	62.5	254.3	244.4	247.2	197.8	219.0	206.7
Water Temperature C	26.0	26.5	26.5	26.5	24.5	24.3	25.0	25.5	26.0	26.3	27.0	27.0	27.2	27.4	27.5	27.5

(Continued)

TEST 1 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours															
		415	439	457	481	484	487	505	508	511	529	535	553	556	559	577	580
10	66	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9	63	12.3	12.4	12.6	12.7	12.5	13.0	13.3	13.5	13.4	13.8	14.0	14.1	14.1	14.1	14.1	14.1
8	60	11.7	11.9	12.1	12.2	12.0	12.5	12.8	12.9	12.9	13.2	13.5	13.6	13.6	13.6	13.6	13.6
7	57	11.3	11.4	11.6	11.7	11.5	12.0	12.3	12.5	12.4	12.8	12.4	12.4	12.4	12.4	12.3	12.3
6	54	11.0	11.1	11.3	11.5	11.4	11.8	12.1	12.2	12.2	12.5	12.2	12.2	12.2	12.2	12.2	12.2
5	48	10.6	10.8	10.9	10.9	10.9	11.4	11.7	11.7	11.8	12.0	12.0	12.1	12.1	12.1	12.1	12.1
4	42	9.8	9.9	10.1	10.3	10.4	10.8	11.1	11.1	11.2	11.4	11.3	11.4	11.4	11.4	11.4	11.4
3	30	7.7	7.7	7.8	7.9	8.2	8.6	8.8	8.8	8.9	9.1	8.8	8.8	8.8	8.8	8.8	8.8
2	18	6.2	6.2	6.3	6.3	6.7	7.1	7.2	7.2	7.3	7.4	7.0	7.0	7.0	7.0	7.0	7.0
1	6	4.8	4.8	4.9	5.0	5.6	5.8	5.9	5.9	5.9	6.0	5.3	5.3	5.3	5.3	5.3	5.3

Flow and Water Temperature Data

	Cumulative Elasped Time, hours															
	415	439	457	481	484	487	505	508	511	529	535	553	556	559	577	580
Flow, cc/sec	218.4	220.0	221.0	222.4	210.0	212.9	221.2	215.5	224.9	225.5	240.6	234.3	240.3	234.6	238.4	236.9
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Water Temperature C	27.5	27.5	27.6	27.8	27.8	28.0	28.5	28.5	28.5	27.8	28.0	27.5	27.7	28.0	27.5	27.7

(Continued)

TEST 1 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours										
		583	607	625	649	652	655	673	676	678	697	703
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	14.1	14.1	14.1	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
8	60	13.6	13.6	13.6	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
7	57	12.3	12.3	12.3	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
6	54	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
5	48	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
4	42	11.4	11.4	11.4	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3
3	30	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
2	18	7.0	7.0	7.0	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
1	6	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3

Flow and Water Temperature Data

	Cumulative Elasped Time, hours										
	583	607	625	649	652	655	673	676	678	697	703
Flow, cc/sec	237.8	238.4	239.2	239.7	240.0	240.0	238.9	238.1	238.1	237.8	237.0
	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--	--
Water Temperature C	28.0	28.0	27.5	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0

(Concluded)

TEST 1A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours										
		0	4	23	31	49	72	95	99	103	119	123
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	1.9	1.9	1.8	2.7	2.8	1.9	1.9	1.9	2.0	2.0	2.0
8	60	1.8	1.8	1.7	2.6	2.7	1.8	1.8	1.8	1.8	1.8	1.8
7	57	1.7	1.7	1.6	2.5	2.6	1.7	1.7	1.7	1.8	1.8	1.8
6	54	1.5	1.5	1.5	2.4	2.4	1.5	1.6	1.6	1.6	1.6	1.6
5	48	1.3	1.3	1.2	2.1	2.1	1.3	1.4	1.4	1.4	1.4	1.4
4	42	1.1	1.1	1.1	1.9	1.8	1.1	1.2	1.2	1.2	1.2	1.2
3	30	0.8	0.8	0.8	1.3	1.4	0.8	0.9	0.9	0.9	1.0	1.0
2	18	0.5	0.5	0.4	1.0	1.0	0.5	0.6	0.6	0.6	0.6	0.6
1	6	0.1	0.1	0.0	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2

Flow and Water Temperature Data

	Cumulative Elasped Time, hours										
	0	4	23	31	49	72	95	99	103	119	123
Flow, cc/sec	55.7	56.2	55.8	66.2	66.9	55.7	48.2	47.8	47.5	47.5	48.0
	55.6	56.4	55.3	67.1	66.4	56.8	47.5	48.2	48.2	48.5	47.5
	55.7	56.3	55.8	67.1	66.2	55.7	47.5	48.0	47.7	47.7	47.8
Water Temperature C	22.5	23.0	22.0	23.0	22.0	21.0	20.0	20.0	20.5	20.0	20.0

(Continued)

TEST 1A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours 127	143	151	167	171	175	191	195	217	242	263
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.3	2.3	2.3	2.3
8	60	1.8	1.8	1.8	1.8	1.8	1.8	1.8	2.1	2.0	2.0	2.1
7	57	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.9	1.9	1.9	1.9
6	54	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.8	1.8	1.8	1.8
5	48	1.4	1.4	1.3	1.3	1.3	1.3	1.4	1.5	1.5	1.5	1.6
4	42	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3
3	30	1.0	1.0	0.9	0.9	0.9	0.9	0.9	1.0	0.9	0.9	1.0
2	18	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5
1	6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1

Flow and Water Temperature Data

	Cumulative Elasped Time, hours 127	143	151	167	171	175	191	195	217	242	263
Flow, cc/sec	47.4	46.6	47.3	48.0	48.2	49.0	49.5	64.0	65.5	62.2	59.5
	48.5	46.8	47.0	48.2	48.3	49.2	49.5	64.7	65.5	62.7	59.8
	47.5	47.0	47.5	47.6	48.5	49.0	49.7	63.7	65.7	62.7	59.8
Water Temperature C	20.0	19.0	20.0	22.2	23.0	23.2	23.3	23.5	25.5	26.0	20.5

(Continued)

TEST 1A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours 267	287	295	311	319	335	343	359	365	383	407
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	9.0	9.3	9.3
8	60	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	8.5	8.8	8.9
7	57	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	7.9	8.2	8.3
6	54	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	7.5	7.8	7.9
5	48	1.6	1.6	1.6	1.5	1.5	1.6	1.6	1.5	6.6	6.8	6.9
4	42	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	5.8	6.0	6.0
3	30	1.0	0.9	0.9	1.0	1.0	0.9	0.9	1.0	4.5	4.6	4.6
2	18	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3.3	3.3	3.3
1	6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.6	1.7	1.7

Flow and Water Temperature Data

	Cumulative Elasped Time, hours 267	287	295	311	319	335	343	359	365	383	407
Flow, cc/sec	60.6	60.5	61.9	60.8	61.0	59.5	60.8	62.3	197.9	192.4	190.4
	59.8	59.9	61.1	60.8	61.4	59.0	60.6	62.3	190.0	192.4	--
	60.1	59.8	60.9	60.9	61.2	59.9	60.6	62.6	195.7	193.5	--
Water Temperature C	20.2	21.0	22.0	21.2	21.8	20.5	22.0	23.5	23.5	22.0	22.0

(Continued)

TEST 1A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours 429	437	463	477	501	527	552	574	600	621	629
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	9.4	9.1	8.9	8.9	9.0	8.8	8.9	8.9	8.8	10.0	10.1
8	60	8.9	8.6	8.5	8.5	8.5	8.4	8.5	8.5	8.4	9.5	9.6
7	57	8.3	8.0	7.8	7.8	7.9	7.9	8.0	8.0	7.9	8.9	9.0
6	54	7.9	7.7	7.5	7.6	7.6	7.6	7.6	7.6	7.6	8.5	8.6
5	48	6.9	6.7	6.5	6.6	6.7	6.6	6.6	6.6	6.5	7.4	7.5
4	42	6.1	6.0	5.9	5.9	5.9	5.9	5.9	5.9	5.9	6.6	6.7
3	30	4.7	4.7	4.7	4.7	4.6	4.6	4.5	4.5	4.5	5.1	5.2
2	18	3.3	3.3	3.2	3.2	3.2	3.2	3.3	3.3	3.2	3.7	3.7
1	6	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	2.0	2.0

Flow and Water Temperature Data

	Cumulative Elasped Time, hours 429	437	463	477	501	527	552	574	600	621	629
Flow, cc/sec	189.1	197.8	209.3	210.2	210.2	192.0	198.0	200.0	196.0	231.6	234.6
	185.7	193.5	213.8	208.3	209.6	184.0	198.0	200.0	198.0	231.6	230.8
	186.0	176.1	211.1	208.9	212.5	196.0	196.0	200.0	196.0	230.6	234.6
Water Temperature C	21.0	23.0	24.5	24.0	24.0	25.0	25.0	24.0	25.0	24.5	24.0

(Continued)

TEST 1A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, ft (psi) Cumulative Elapsed Time, hours 545	653	669	677	722	746	770	794	890	914	938
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	10.1	10.2	10.1	10.0	11.7	11.9	11.9	11.9	11.9	11.9	11.9
8	60	9.6	9.7	9.6	9.5	11.2	11.3	11.2	11.2	11.3	11.4	11.3
7	57	9.0	9.1	9.0	8.9	10.6	10.7	10.6	10.6	10.5	10.7	10.6
6	54	8.6	8.7	8.6	8.5	10.0	10.1	10.0	10.0	10.1	10.1	10.1
5	48	7.5	7.6	7.5	7.5	8.9	8.9	8.9	8.9	8.9	9.0	9.0
4	42	6.7	6.8	6.7	6.7	7.9	7.8	7.8	7.8	7.8	7.9	7.9
3	30	5.2	5.2	5.2	5.2	6.2	6.2	6.2	6.2	6.2	6.3	6.3
2	18	3.7	3.7	3.7	3.7	4.5	4.5	4.5	4.5	4.5	4.5	4.5
1	6	2.0	2.0	2.0	2.0	2.6	2.6	2.5	2.5	2.5	2.6	2.6

Flow and Water Temperature Data

	Cumulative Elasped Time, hours 645	653	669	677	722	746	770	794	890	914	938
Flow, cc/sec	235.0	235.4	232.6	234.3	267.1	273.3	262.9	273.5	272.7	277.3	272.7
	230.8	234.2	232.6	233.3	272.2	271.7	271.4	272.1	272.7	277.4	269.7
	235.1	230.3	233.3	232.9	275.0	274.2	266.7	275.8	267.7	277.9	271.0
Water Temperature C	24.5	23.5	24.0	25.0	25.5	25.5	25.0	25.0	24.5	24.0	24.5

(Concluded)

TEST 2 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 0	4	23	27	31	47	51	55	79	101	119
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
8	60	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5
7	57	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
6	54	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.3	3.3
5	48	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
4	42	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3 6	3.6
3	30	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3
2	18	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9
1	6	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 0	4	23	27	31	47	51	55	79	101	119
Flow, cc/sec	69.0	68.5	67.5	67.0	66.5	65.0	65.0	65.0	64.5	64.0	63.5
	69.0	69.5	67.5	66.5	67.0	66.0	65.5	65.0	64.5	64.5	63.5
	69.0	68.5	67.5	67.5	66.5	66.0	66.0	65.0	64.5	64.0	64.0
Water Temperature C	28.5	28.7	29.2	29.2	29.2	28.8	28.5	28.5	28.0	27.5	28.0

(Continued)

TEST 2 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation c' Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 123	127	143	147	151	167	170	173	175	191	195
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	3.5	3.6	3.6	3.7	3.7	3.7	5.9	6.0	6.3	6.4	6.4
8	60	3.5	3.5	3.5	3.5	3.5	3.5	5.6	5.7	6.0	6.2	6.2
7	57	3.4	3.4	3.4	3.5	3.5	3.5	5.5	5.6	5.9	6.0	6.0
6	54	3.3	3.3	3.3	3.4	3.4	3.4	5.4	5.4	5.8	5.8	5.8
5	48	3.7	3.7	3.7	3.7	3.7	3.7	5.5	5.6	5.8	5.9	5.9
4	42	3.6	3.6	3.6	3.6	3.6	3.6	5.2	5.2	5.4	5.5	5.5
3	30	3.3	3.3	3.3	3.3	3.3	3.3	4.5	4.6	4.7	4.8	4.8
2	18	2.9	2.9	2.9	2.9	2.9	2.9	3.6	3.7	3.8	3.8	3.8
1	6	2.9	2.9	2.9	2.9	2.9	2.9	3.3	3.4	3.4	3.4	3.4

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 123	127	143	147	151	167	170	173	175	191	195
Flow, cc/sec	64.0	63.5	64.0	64.0	63.5	64.0	95.0	96.0	101.1	102.2	104.4
	63.5	63.5	64.0	64.0	64.0	63.5	95.0	96.0	101.1	103.3	103.3
	63.0	63.0	64.0	64.0	63.5	63.5	95.0	96.0	101.7	102.8	102.8
Water Temperature C	28.0	28.0	28.7	28.5	28.5	28.0	28.0	28.0	28.2	29.0	28.5

(Continued)

TEST 2 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 199	215	219	223	240	266	287	291	311	315	335
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	6.4	6.5	6.5	6.5	6.5	6.5	6.6	6.5	6.9	6.7	6.9
8	60	6.2	6.2	6.2	6.2	6.2	6.2	6.3	6.2	6.6	6.4	6.6
7	57	6.0	6.1	6.1	6.1	6.1	6.1	6.2	6.1	6.5	6.3	6.5
6	54	5.8	5.8	5.8	5.8	5.8	5.8	5.9	5.8	6.2	6.0	6.2
5	48	5.9	5.9	5.9	5.9	5.9	5.9	6.0	5.9	6.3	6.1	6.3
4	42	5.5	5.5	5.5	5.5	5.5	5.5	5.6	5.6	5.8	5.7	5.9
3	30	4.8	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	4.9	5.0
2	18	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	4.0	3.9	4.0
1	6	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5	3.4	3.4

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 199	215	219	223	240	266	287	291	311	315	335
Flow, cc/sec	104.4	104.4	103.3	103.3	103.3	104.4	104.4	103.3	104.0	104.0	107.1
	103.3	103.3	103.3	103.3	103.3	103.3	103.3	103.3	105.0	104.0	110.1
	103.3	103.3	104.4	104.4	104.4	103.3	103.3	104.4	103.0	104.0	108.3
Water Temperature C	28.5	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.2	28.2	27.5

(Continued)

TEST 2 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 339	359	362	365	383	387	409	434	459	479	484
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	6.4	6.4	12.9	13.3	13.7	13.7	13.5	13.3	13.6	14.0	14.0
8	60	6.2	6.2	12.3	12.7	13.1	13.1	12.9	12.7	12.9	13.3	13.4
7	57	6.0	6.0	11.8	12.2	12.6	12.6	12.4	12.2	12.5	12.9	12.9
6	54	5.8	5.8	11.3	11.7	12.1	12.1	11.9	11.7	11.9	12.3	12.3
5	48	5.9	5.9	11.0	11.5	11.7	11.7	11.5	11.5	11.6	11.9	11.9
4	42	5.5	5.5	10.2	10.3	10.8	10.8	10.5	10.4	10.7	10.9	11.0
3	30	4.9	4.9	8.3	8.6	8.8	8.8	8.6	8.5	9.7	8.9	8.9
2	18	3.8	3.8	6.1	6.2	6.4	6.4	6.2	6.2	6.3	6.5	6.5
1	6	3.3	3.3	4.5	4.5	4.6	4.6	4.6	4.6	4.6	4.7	4.7

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 339	359	362	365	383	387	409	434	459	479	484
Flow, cc/sec	101.1	101.2	187.0	191.3	195.7	192.4	189.2	186.7	182.2	194.0	191.7
	102.4	101.2	187.2	195.2	198.8	196.9	192.0	186.7	192.0	194.0	194.4
	101.2	101.1	187.0	186.7	195.6	202.1	186.5	189.6	89.4	201.0	197.9
Water Temperature C	27.5	27.5	27.5	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0

(Continued)

TEST 2 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 503	508	527	551	578	601	624	626	630	648	655
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	14.7	14.3	14.7	13.5	13.5	13.7	13.8	17.6	17.6	17.6	17.6
8	60	14.1	13.7	14.0	12.8	12.8	13.0	13.1	16.7	16.7	16.7	16.7
7	57	13.6	13.2	13.6	12.4	12.4	12.6	12.7	16.1	16.1	16.1	16.1
6	54	12.9	12.6	12.8	11.7	11.7	11.9	12.0	15.2	15.2	15.2	15.2
5	48	12.4	12.1	12.5	11.5	11.6	11.7	11.8	14.7	14.7	14.6	14.6
4	42	11.4	11.2	11.5	10.6	10.6	10.7	10.9	13.4	13.4	13.4	13.4
3	30	9.3	9.1	9.3	8.6	8.6	8.8	8.8	10.8	10.8	10.8	10.8
2	18	6.7	6.6	6.7	6.2	6.2	6.1	6.3	7.7	7.7	7.8	7.8
1	6	4.8	4.8	4.8	4.5	4.5	4.5	4.7	5.4	5.4	5.4	5.4

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 503	508	527	551	578	601	624	626	630	648	655
Flow, cc/sec	203.6	197.7	211.4	189.1	183.3	189.1	190.2	239.7	232.9	244.1	242.9
	202.5	197.9	208.9	189.1	188.3	183.3	189.1	241.0	240.5	242.9	238.9
	206.4	204.4	206.4	188.2	188.3	186.2	177.0	238.5	237.8	230.3	237.8
Water Temperature C	27.5	28.0	28.0	28.0	28.0	28.0	28.0	28.5	29.0	29.0	29.0

(Continued)

TEST 2 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours							
		672	679	696	720	792	816	840	880
10	66	--	--	--	--	--	--	--	--
9	63	17.9	17.8	17.8	17.8	18.0	17.9	17.8	17.6
8	60	16.9	16.9	16.9	16.9	17.1	17.0	16.9	16.6
7	57	16.4	16.3	16.3	16.3	16.5	16.4	16.3	16.1
6	54	15.4	15.3	15.3	15.3	15.4	15.4	15.3	15.2
5	48	14.9	14.8	14.8	14.8	14.9	14.9	14.8	14.7
4	42	13.6	13.5	13.5	13.5	13.6	13.6	13.6	13.4
3	30	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.8
2	18	7.9	7.9	7.9	7.9	7.9	7.8	7.8	7.8
1	6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4

Flow and Water Temperature Data

	Cumulative Elasped Time, hours							
	672	679	696	720	792	816	840	880
Flow, cc/sec	243.1	243.1	237.2	239.2	243.2	236.5	242.1	241.9
	242.1	243.2	234.5	239.2	239.5	235.1	236.4	237.9
	238.5	238.2	239.5	236.1	241.7	230.5	235.7	241.2
Water Temperature C	28.5	28.5	28.5	28.0	28.0	28.0	28.5	29.0

(Concluded)

TEST 2A – INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 0	18	41	66	89	145	170.5	173.0	175.5	197.0	222.5	240.5	264.5	287.5
10	66	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	63	0.8	0.8	0.8	0.8	0.9	0.9	0.9	1.7	1.7	2.2	2.2	2.2	2.5	2.5
8	60	0.7	0.7	0.7	0.7	0.8	0.8	0.8	1.6	1.6	2.0	2.0	2.0	2.3	2.3
7	57	0.6	0.6	0.6	0.6	0.7	0.7	0.7	1.3	1.3	1.8	1.8	1.8	2.1	2.1
6	54	0.6	0.5	0.5	0.6	0.7	0.7	0.6	1.3	1.4	1.7	1.7	1.7	2.0	2.0
5	48	0.6	0.5	0.5	0.6	0.6	0.6	0.6	1.1	1.2	1.5	1.5	1.5	1.9	1.9
4	42	0.5	0.4	0.4	0.5	0.6	0.5	0.5	1.0	1.1	1.4	1.4	1.4	1.8	1.8
3	30	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.7	0.7	1.0	1.0	1.0	1.1	1.1
2	18	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.7	0.7	0.9	0.9	0.8	0.9	0.9
1	6	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 0	18	41	66	89	145	170.5	173.0	175.5	197.0	222.5	240.5	264.5	287.5
Flow, cc/sec	46.0	48.0	48.5	49.0	49.3	51.0	49.0	82.5	85.5	94.5	91.0	99.5	115.9	104.8
	45.5	48.0	49.0	49.3	49.3	50.0	59.0	82.5	84.0	94.0	91.0	98.0	107.5	102.9
	46.5	48.0	48.8	49.0	49.3	50.0	49.5	83.0	86.0	94.0	90.0	100.0	107.2	106.3
Water Temperature C	23.0	24.0	24.0	23.5	24.0	23.0	23.5	24.0	24.0	24.5	24.0	24.5	25.0	25.0

(Continued)

TEST 2A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 311.5	335.5	383.5	407.5	431.5	455.5	479.5	575.5	599.5	623.5
10	66	—	—	—	—	—	—	—	—	—	—
9	63	2.4	9.2	9.0	9.7	9.1	9.2	9.4	9.5	14.5	14.5
8	60	2.3	8.7	8.5	9.3	8.6	8.7	8.9	9.0	13.8	13.8
7	57	2.0	8.1	7.9	8.6	8.0	8.1	8.3	8.4	13.0	13.0
6	54	1.8	7.7	7.7	8.3	7.8	7.8	7.9	8.0	12.3	12.3
5	48	1.6	6.9	6.7	7.3	6.8	6.8	7.0	7.1	11.2	11.2
4	42	1.5	6.6	6.5	7.1	6.6	6.7	6.8	6.9	10.8	10.8
3	30	1.2	5.0	4.8	5.4	5.0	5.0	5.0	5.0	7.9	7.9
2	18	0.8	3.5	3.5	3.8	3.5	3.5	3.5	3.6	5.8	5.8
1	6	0.6	2.1	2.1	2.3	2.1	2.1	2.1	2.1	3.3	3.3

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 311.5	335.5	383.5	407.5	431.5	455.5	479.5	575.5	599.5	623.5
Flow, cc/sec	96.2	202.3	193.8	197.9	190.0	186.3	193.5	182.0	232.9	241.7
	95.0	202.3	196.0	202.2	189.0	184.9	187.5	179.3	241.0	241.9
	97.8	193.9	202.2	197.9	194.0	188.0	182.0	194.0	230.8	255.9
Water Temperature C	24.5	24.5	26.0	25.0	25.0	25.0	27.0	25.5	26.0	26.5

(Continued)

TEST 2A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 648.5	671.5	698.5	719.5	743.5	767.5	791.5	815.5	863.5
10	66	—	—	—	—	—	—	—	—	—
9	63	14.9	15.1	15.3	15.3	15.3	15.3	15.4	15.4	15.3
8	60	14.3	14.5	14.4	14.4	14.4	14.5	14.6	14.6	14.5
7	57	13.4	13.6	13.7	13.7	13.7	13.7	13.8	13.8	13.7
6	54	12.7	12.8	12.9	12.9	12.9	13.0	13.0	13.0	13.0
5	48	11.5	11.6	11.7	11.7	11.7	11.8	11.9	11.9	11.9
4	42	11.1	11.2	11.3	11.3	11.3	11.4	11.5	11.5	11.5
3	30	8.1	8.2	8.3	8.3	8.3	8.4	8.5	8.5	8.5
2	18	5.9	6.0	6.0	6.0	6.0	6.1	6.1	6.1	6.1
1	6	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 648.5	671.5	698.5	719.5	743.5	767.5	791.5	815.5	863.5
Flow, cc/sec	250.0	248.6	242.9	240.8	247.2	230.6	250.0	244.7	247.4
	245.8	240.5	245.7	255.6	242.1	243.2	238.9	242.1	234.6
	244.4	237.5	237.5	237.5	242.1	235.1	238.9	239.5	234.2
Water Temperature C	26.0	26.0	26.0	26.2	26.5	27.0	26.5	27.0	28.0

(Concluded)

TEST 3 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 0	4	7	23	27	31	143	147	151	167	171	175	191	195	213.0
10	66	—	—	—	—	—	-	—	—	—	—	—	—	—	—	—
9	63	2.4	2.3	2.4	2.3	2.3	2.3	2.1	2.2	2.2	2.2	2.2	2.2	2.1	3.7	3.7
8	60	2.2	2.2	2.2	2.2	2.2	2.2	2.0	2.1	2.1	2.1	2.1	2.1	2.0	3.5	3.5
7	57	2.2	2.1	2.2	2.1	2.1	2.1	1.9	2.0	2.0	2.0	2.0	2.0	1.9	3.3	3.3
6	54	2.0	1.9	1.9	1.5	1.8	1.8	1.7	1.7	1.9	1.8	1.9	1.9	1.7	3.2	3.1
5	48	1.8	1.8	1.8	1.8	1.8	1.8	1.6	1.7	1.8	1.8	1.8	1.8	1.6	2.9	2.9
4	42	1.8	1.8	1.7	1.7	1.7	1.7	1.4	1.5	1.6	1.6	1.6	1.6	1.4	2.6	2.3
3	30	1.3	1.3	1.3	1.4	1.4	1.4	1.1	1.2	1.2	1.1	1.1	1.1	1.0	2.0	2.0
2	18	1.1	1.1	1.1	1.1	1.1	1.1	0.7	0.9	0.9	0.8	0.8	0.8	0.8	1.4	1.3
1	6	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.8	0.7

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 0	4	7	23	27	31	143	147	151	167	171	175	191	195	213.0
Flow, [illegible] sec	23.8	23.6	23.7	23.0	23.0	22.8	20.7	25.4	23.0	23.4	23.2	23.4	23.3	40.7	39.8
	24.0	23.8	23.9	22.9	23.0	22.9	20.7	25.4	23.0	23.4	23.1	23.3	23.1	40.6	40.1
	23.9	23.8	23.9	23.0	23.0	22.8	20.8	25.4	22.8	23.3	23.2	23.3	23.3	40.2	39.8
Water Temperature C	25.0	25.0	25.1	25.0	25.2	25.2	25.3	25.5	25.5	26.2	26.5	26.5	25.5	26.0	25.5

(Continued)

TEST 3 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 237.0	259.0	263.0	267.0	283.5	287.0	291.0	312.0	336.0	357.5	435.0	476.0	499.5
10	66	--	--	--	--	--	--	--	--	--	--	--	--	--
9	63	3.7	3.5	3.4	3.4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.3	3.3
8	60	3.5	3.3	3.2	3.2	3.2	3.3	3.3	3.3	3.2	3.3	3.3	3.2	3.1
7	57	3.3	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.7	2.8
6	54	3.1	2.9	2.8	2.8	2.8	2.8	3.0	3.0	3.0	3.0	3.0	2.8	2.8
5	48	2.9	2.8	2.7	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.5
4	42	2.3	2.2	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.2	2.2
3	30	2.0	1.8	1.7	1.8	1.7	1.7	1.7	1.8	1.8	1.7	1.7	1.7	1.7
2	18	1.3	1.2	1.5	1.3	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.2	1.2
1	6	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.7

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours: 237.0	259.0	263.0	267.0	283.5	287.0	291.0	312.0	336.0	357.5	435.0	476.0	499.5
Flow, cc/sec	40.0	36.8	37.0	37.3	36.8	36.5	36.5	36.3	37.0	36.0	36.3	39.8	39.3
	39.8	36.7	37.3	36.8	36.5	36.5	36.5	36.5	37.0	36.0	36.5	39.8	39.0
	39.7	36.7	37.8	37.3	36.5	36.5	36.8	36.5	37.0	36.0	36.5	40.0	39.3
Water Temperature C	25.5	24.5	25.5	25.0	24.0	24.0	24.0	24.5	25.0	24.0	25.0	24.0	23.0

(Continued)

TEST 3 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 501.5	505.5	522.5	525.5	548.5	576.5	594.5	601.5	618.0	625.5	649.5	652.5	656.5
10	66	--	--	--	--	--	--	--	--	--	--	--	--	--
9	63	13.5	13.5	13.7	14.0	13.9	14.0	14.4	14.4	15.0	15.5	15.3	14.6	14.7
8	60	12.7	12.8	13.0	13.3	13.2	13.3	13.7	13.7	14.3	14.7	14.5	13.8	13.9
7	57	12.0	12.1	12.3	12.6	12.5	12.6	13.0	13.0	13.6	14.0	13.9	13.2	13.3
6	54	11.6	11.8	11.9	12.2	12.1	12.3	12.6	12.6	13.2	13.6	13.4	12.9	13.0
5	48	10.6	10.8	10.9	11.2	11.1	11.3	11.5	11.6	12.0	12.6	12.4	11.9	12.0
4	42	9.7	9.8	10.0	10.2	10.1	10.3	10.6	10.6	11.1	11.5	11.4	10.9	11.0
3	30	7.3	7.4	7.5	7.7	7.8	7.9	8.2	8.1	8.6	9.0	9.0	8.5	8.6
2	18	5.6	5.5	5.7	5.9	5.9	6.0	6.3	6.3	6.8	7.0	6.9	6.8	6.8
1	6	3.1	3.5	3.5	3.6	3.7	3.8	3.8	4.0	4.2	4.4	4.5	4.5	4.3

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 501.5	505.5	522.5	525.5	548.5	576.5	594.5	601.5	618.0	625.5	649.5	652.5	656.5
Flow, cc/sec	107.0	108.0	111.0	113.0	111.0	111.0	111.0	113.0	111.0	115.0	113.0	109.0	108.0
	111.0	111.0	112.0	112.0	110.0	112.0	110.0	114.0	112.0	120.0	112.0	110.0	109.0
	111.0	109.0	108.0	111.0	112.0	112.0	110.0	112.0	115.0	118.0	113.0	108.0	108.0
Water Temperature C	23.5	23.5	23.5	24.0	24.0	24.0	24.0	25.0	24.0	25.0	25.0	25.0	25.0

(Continued)

TEST 3 - INTERNAL STABILITY

Piezometer Data

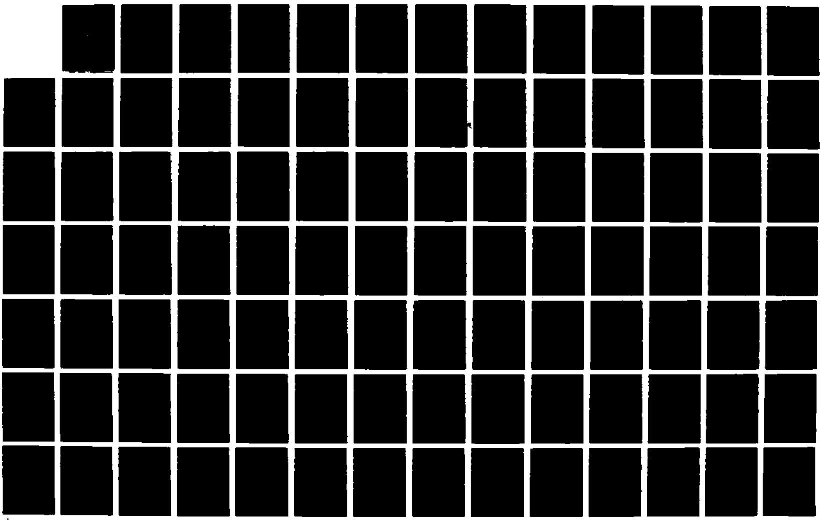
Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 672.5	680.5	696.5	704.5	722.5	746.5	768.5	776.5	792.5	817.5	821.5	841.5	843.5
10	66	--	--	--	--	--	-	--	--	--	--	--	--	--
9	63	14.8	15.1	15.5	13.6	14.8	14.9	15.6	22.6	23.7	25.4	28.6	>30.0*	28.2
8	60	14.2	14.4	14.8	12.9	14.1	14.2	14.8	21.3	22.5	24.0	27.0	>30.0*	26.6
7	57	13.6	13.7	14.1	12.4	13.6	13.7	14.3	20.4	21.5	23.0	26.0	>30.0*	25.6
6	54	13.1	13.3	13.7	12.1	13.1	13.2	13.8	19.8	20.8	22.3	25.4	>30.0*	24.4
5	48	12.2	12.4	12.7	11.1	12.0	12.3	12.8	18.3	19.5	20.8	23.9	28.9	23.4
4	42	11.2	11.4	11.7	10.2	10.6	11.2	11.7	17.0	18.0	19.3	22.0	26.7	21.9
3	30	8.8	8.9	9.1	8.0	8.7	8.8	9.3	13.8	14.6	15.6	18.0	22.0	18.0
2	18	6.9	6.9	7.2	6.3	6.9	6.9	7.3	11.1	11.7	12.6	14.0	>15.0*	14.7
1	6	4.4	4.5	4.6	4.0	4.4	4.5	4.8	7.4	7.8	8.6	9.9	12.6	10.0

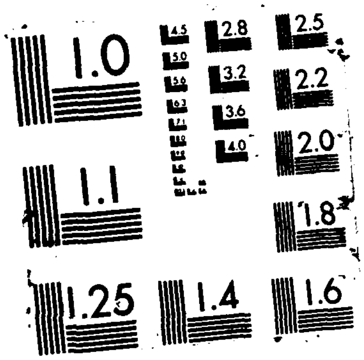
Flow and Water Temperature Data

	Cumulative Elasped Time, hours: [illegible]	680.5	696.5	704.5	722.5	746.5	768.5	776.5	792.5	817.5	821.5	841.5	843.5
[illegible]	[illegible]	[illegible]	[illegible]	101.6	105.3	108.1	111.6	145.3	147.5	149.0	165.0	189.0	158.0
[illegible]	[illegible]	[illegible]	[illegible]	102.2	106.5	106.1	112.2	146.0	149.2	153.0	166.0	190.0	159.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	106.1	108.2	146.2	147.5	151.0	169.0	188.0	159.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24.0	24.5	24.0	23.5	24.0	25.0	25.0

AD-A185 623 LABORATORY TESTS ON GRANULAR FILTERS FOR EMBANKMENT DAMS(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS GEOTECHNICAL LAB E B PERRY AUG 87 3/4

UNCLASSIFIED WES/TR/GL-87-22 F/G 13/2 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

TEST 3 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours							
		847.5	866.5	870.0	915.0	936.5	944.5	960.5	968.5
10	66	—	—	—	—	—	—	—	—
9	63	27.7	28.5	29.0	24.6	24.7	23.4	22.9	23.0
8	60	26.2	26.8	27.2	23.2	23.3	22.0	21.6	21.6
7	57	25.2	25.8	26.3	22.4	22.5	21.2	20.7	20.8
6	54	24.4	25.0	25.5	21.7	21.9	20.6	20.3	20.3
5	48	23.0	23.6	24.0	20.6	20.7	19.5	19.2	19.2
4	42	21.4	22.0	22.5	19.1	19.4	18.2	17.9	17.9
3	30	17.5	18.1	18.7	15.9	16.1	15.2	14.9	15.0
2	18	14.0	15.0	>15.0*	13.4	13.4	12.7	12.4	12.5
1	6	9.9	10.4	10.9	9.0	9.3	8.7	9.1	9.2

Flow and Water Temperature Data

	Cumulative Elasped Time, hours							
	847.5	866.5	870.0	915.0	936.5	944.5	960.5	968.5
Flow, cc/sec	154.0	157.0	152.0	140.9	136.9	131.0	125.7	125.4
	155.0	155.0	152.0	141.9	140.0	127.3	125.7	124.7
	154.0	157.0	156.0	142.9	139.0	127.6	128.8	126.0
Water Temperature C	25.0	25.0	25.0	25.5	25.0	24.5	24.2	24.5

(Continued)

* Exceeded capacity of pressure gage

TEST 3 - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 984.5	992.5	1008.5	1012.5	1016.5	1035.5	1059.5	1080.5
10	66	--	--	--	--	--	--	--	--
9	63	23.2	23.2	23.5	23.6	23.6	24.0	24.0	24.0
8	60	21.7	21.7	22.1	22.0	22.0	22.4	22.4	22.5
7	57	21.0	21.0	21.3	21.4	21.4	21.8	21.8	21.8
6	54	20.5	20.4	20.8	20.8	20.8	21.2	21.2	21.3
5	48	19.7	19.4	19.7	19.7	19.7	20.0	20.0	20.1
4	42	18.1	18.0	18.4	18.5	18.5	18.7	18.8	18.9
3	30	15.1	15.1	15.4	15.4	15.4	15.8	15.8	15.9
2	18	12.7	12.7	13.0	13.1	13.1	13.8	13.8	13.9
1	6	8.8	8.8	9.0	9.1	9.1	9.5	9.5	9.6

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 984.5	992.5	1008.5	1012.5	1016.5	1035.5	1059.5	1080.5
Flow, cc/sec	125.0	126.3	126.3	124.3	124.3	119.1	122.2	122.7
	125.0	126.3	126.7	123.3	122.5	119.8	122.5	122.8
	124.7	125.7	126.9	124.1	126.3	120.4	123.7	122.2
Water Temperature C	24.5	25.0	24.0	24.0	24.0	23.0	23.0	23.5

(Concluded)

TEST 3A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours										
		0	19	43	68	91	115	122	139	163	187	211
10	66	—	—	—	—	—	—	—	—	—	—	—
9	63	0.9	1.1	1.1	1.1	1.1	1.1	0.7	0.7	0.7	0.7	0.7
8	60	0.9	1.0	1.0	1.0	1.0	1.0	0.6	0.6	0.6	0.6	0.6
7	57	0.7	0.9	0.9	0.9	0.9	0.9	0.5	0.5	0.5	0.5	0.5
6	54	0.6	0.7	0.7	0.7	0.7	0.7	0.4	0.4	0.4	0.4	0.4
5	48	0.4	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3
4	42	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
3	30	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2
2	18	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
1	6	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1

Flow and Water Temperature Data

	Cumulative Elapsed Time, hours										
	0	19	43	68	91	115	122	139	163	187	211
Flow, cc/sec	120.5	117.8	117.3	133.1	135.7	135.3	110.0	109.1	104.5	103.7	100.0
	119.5	118.2	119.7	132.3	137.3	136.5	104.3	104.7	106.1	103.6	100.0
	124.3	118.4	119.5	130.2	135.7	136.8	107.5	105.2	105.1	106.5	100.0
Water Temperature C	25.5	26.0	26.2	26.2	26.3	26.0	25.5	26.0	26.0	26.0	26.0

(Continued)

TEST 3A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 235	260	288	292	312	316	317	319	336	340	343
10	66	--	--	--	--	--	--	--	--	--	--	--
9	63	0.7	0.7	0.7	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3
8	60	0.6	0.6	0.6	1.1	1.2	1.2	1.2	1.2	1.1	1.1	1.1
7	57	0.5	0.5	0.5	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9
6	54	0.4	0.4	0.4	0.6	0.7	0.8	0.8	0.8	0.9	0.9	0.9
5	48	0.3	0.3	0.3	0.3	0.4	0.6	0.6	0.6	0.7	0.7	0.7
4	42	0.3	0.3	0.3	0.2	0.3	0.5	0.5	0.5	0.6	0.6	0.6
3	30	0.2	0.2	0.2	0.1	0.1	0.4	0.4	0.4	0.5	0.5	0.5
2	18	0.2	0.2	0.2	0.0	0.0	0.4	0.4	0.4	0.3	0.3	0.3
1	6	0.1	0.1	0.1	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 235	260	288	292	312	316	317	319	336	340	343
Flow, cc/sec	96.8	91.4	89.1	104.9	141.5	143.7	148.4	150.8	143.1	147.5	145.2
	95.7	92.5	89.5	107.0	141.5	142.3	148.3	153.5	143.2	150.9	146.0
	95.7	92.5	89.1	107.0	141.1	150.0	147.5	151.7	142.9	146.7	158.0
Water Temperature C	26.0	26.0	26.0	26.0	25.5	25.0	25.0	25.5	25.5	25.0	25.0

(Continued)

TEST 3A – INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 360	364	385	408	432	456	460	480	487	504	528
10	66	—	—	—	—	—	—	—	—	—	—	—
9	63	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
8	60	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
7	57	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
6	54	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
5	48	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
4	42	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
3	30	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2	18	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1	6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 360	364	385	408	432	456	460	480	487	504	528
Flow, cc/sec	147.4	149.2	145.5	148.4	147.5	144.6	144.8	146.2	147.5	142.7	142.1
	149.2	148.4	146.0	147.6	150.0	148.4	148.3	147.6	145.3	142.1	142.4
	147.6	141.8	146.7	145.3	149.2	150.8	150.9	146.3	143.3	143.3	142.4
Water Temperature C	25.2	25.0	25.0	25.2	25.5	25.7	25.0	25.5	25.5	25.5	25.5

(Continued)

TEST 3A - INTERNAL STABILITY

Piezometer Data

Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 552	576	600	648	652	669	693	719
10	66	—	—	—	—	—	—	—	—
9	63	1.3	1.3	1.3	1.3	3.9	3.9	4.0	4.0
8	60	1.1	1.1	1.1	1.1	3.6	3.6	3.7	3.7
7	57	0.9	0.9	0.9	0.9	3.2	3.2	3.3	3.3
6	54	0.9	0.9	0.9	0.9	3.1	3.1	3.2	3.2
5	48	0.7	0.7	0.7	0.7	2.9	2.9	2.9	2.9
4	42	0.6	0.6	0.6	0.6	2.8	2.8	2.8	2.8
3	30	0.5	0.5	0.5	0.5	2.4	2.4	2.4	2.4
2	18	0.3	0.3	0.3	0.3	2.1	2.1	2.1	2.1
1	6	0.3	0.3	0.3	0.3	1.8	1.8	1.8	1.8

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 552	576	600	648	652	669	693	719
Flow, cc/sec	141.7	141.4	139.3	137.5	270.0	274.2	278.3	283.9
	142.2	140.9	139.6	136.0	270.3	275.8	270.6	267.2
	140.0	139.8	138.5	137.1	274.2	277.3	276.7	270.7
Water Temperature C	25.0	26.0	26.0	25.2	25.0	25.5	25.2	25.2

(Continued)

TEST 3A - INTERNAL STABILITY

Piezometer Data

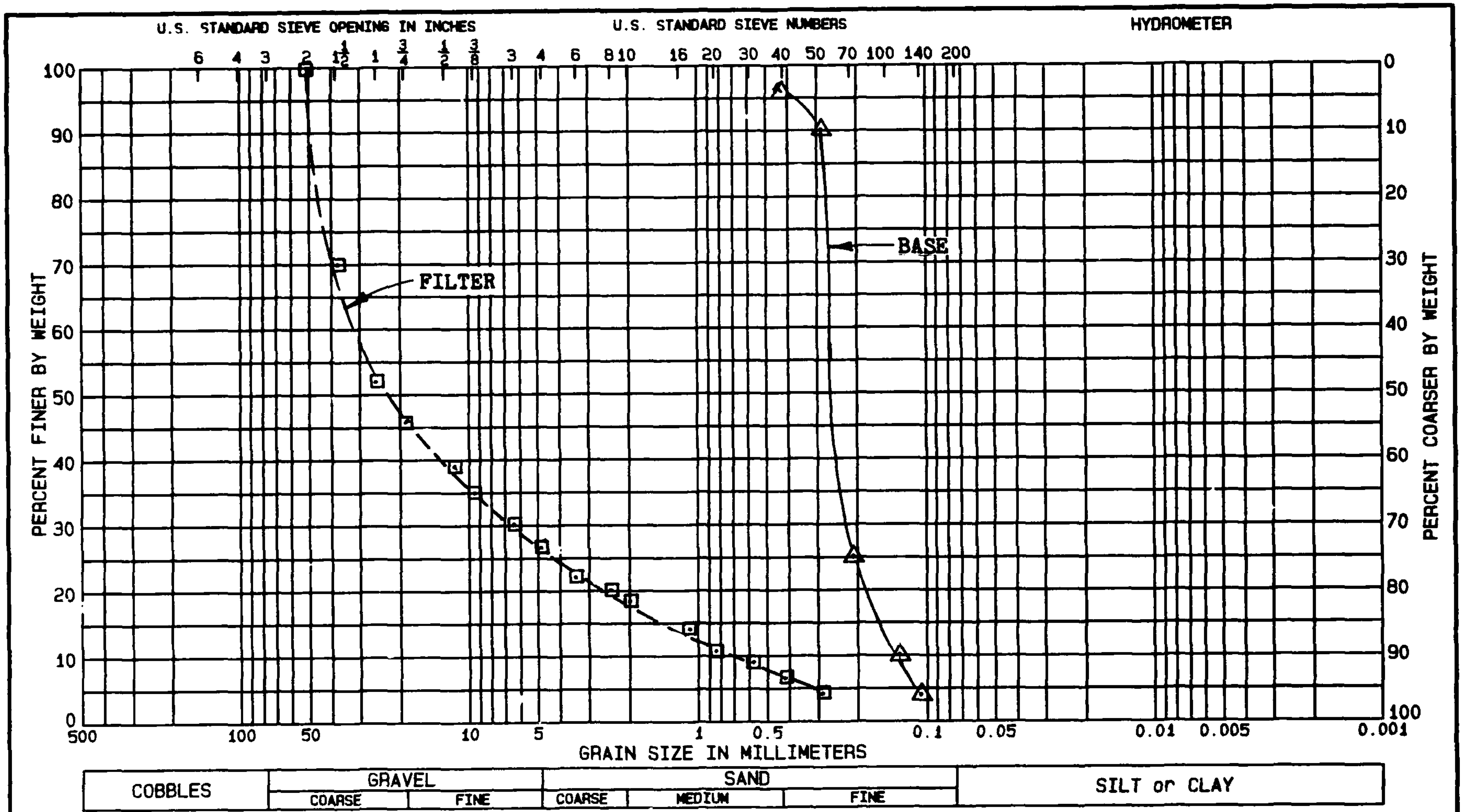
Piezometer Tap No.	Elevation or Height in.	Piezometer Reading, psi — Cumulative Elapsed Time, hours: 741	765	789	813	837	885	910	938	957
10	66	--	--	--	--	--	--	--	--	--
9	63	4.0	6.3	5.1	5.0	5.0	5.0	5.0	5.3	5.1
8	60	3.7	5.8	4.6	4.6	4.6	4.5	4.5	4.9	4.7
7	57	3.3	5.2	4.1	4.1	4.1	4.1	4.1	4.5	4.2
6	54	3.2	5.1	4.0	4.0	4.0	4.0	4.0	--	--
5	48	2.9	4.6	3.6	3.6	3.6	3.6	3.6	3.7	3.6
4	42	2.8	2.8	4.4	3.5	3.5	3.5	3.5	3.6	3.5
3	30	2.4	3.4	2.8	2.8	2.8	2.8	2.8	2.9	2.8
2	18	2.1	2.5	2.2	2.2	2.2	2.2	2.2	2.3	2.2
1	6	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8

Flow and Water Temperature Data

	Cumulative Elasped Time, hours: 741	765	789	813	837	885	910	938	957
Flow, cc/sec	272.9	272.9	264.1	293.1	277.1	284.2	276.9	287.9	281.8
	272.1	263.5	269.1	290.0	276.6	286.9	278.7	285.9	283.1
	270.3	263.2	268.2	268.8	282.0	285.3	273.9	281.4	283.6
Water Temperature C	25.0	25.0	26.0	25.5	26.0	25.5	26.2	25.2	26.5

(Concluded)

APPENDIX C: FILTER AND BASE MATERIALS BLENDED FOR THE TEST



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1A -A (CHECK)

MATERIAL BLENDED FOR TEST

BORING NO.

SAMPLE NO.

DEPTH/ELEV

DATE 00 NOV 79

PLATE C1

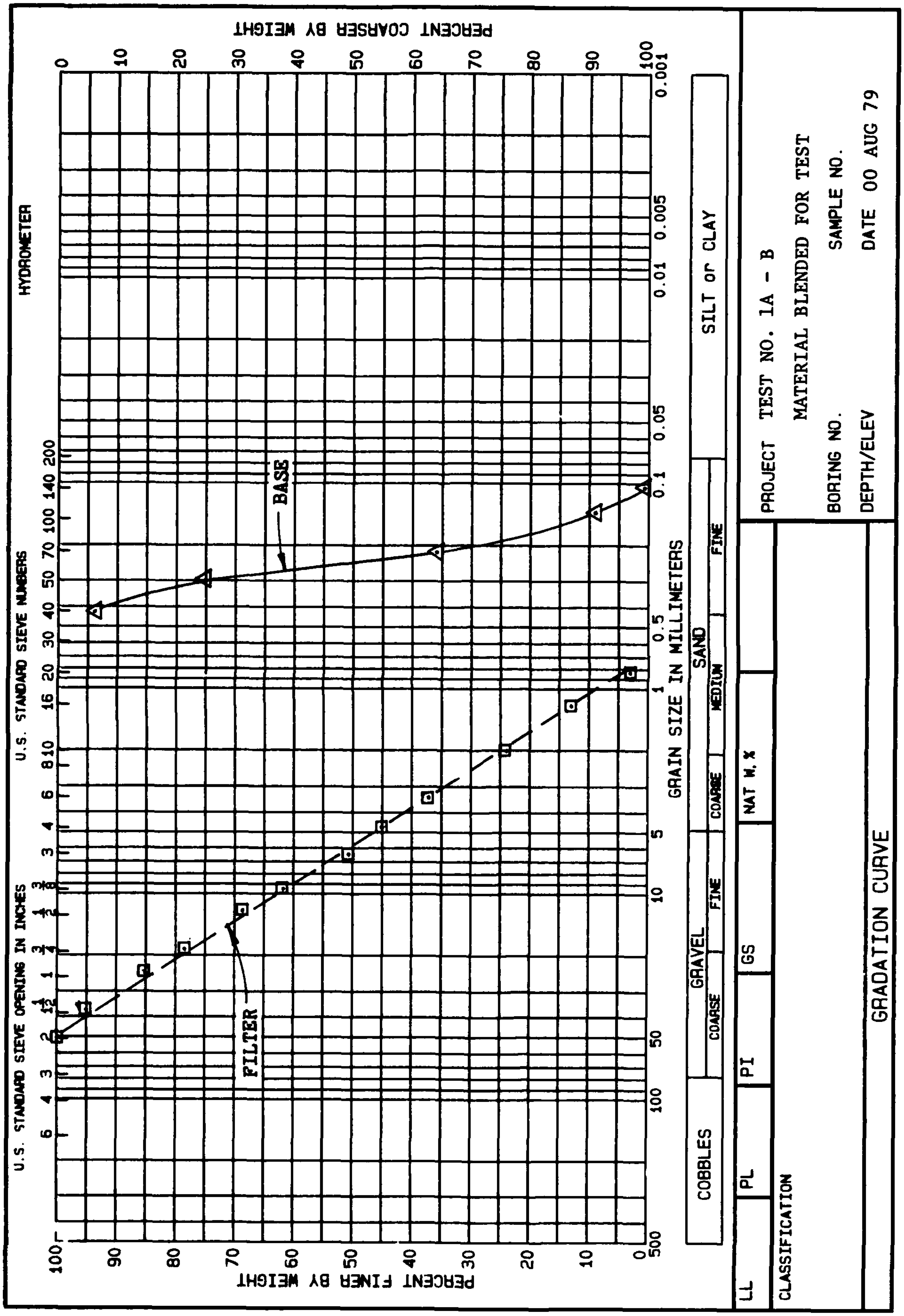
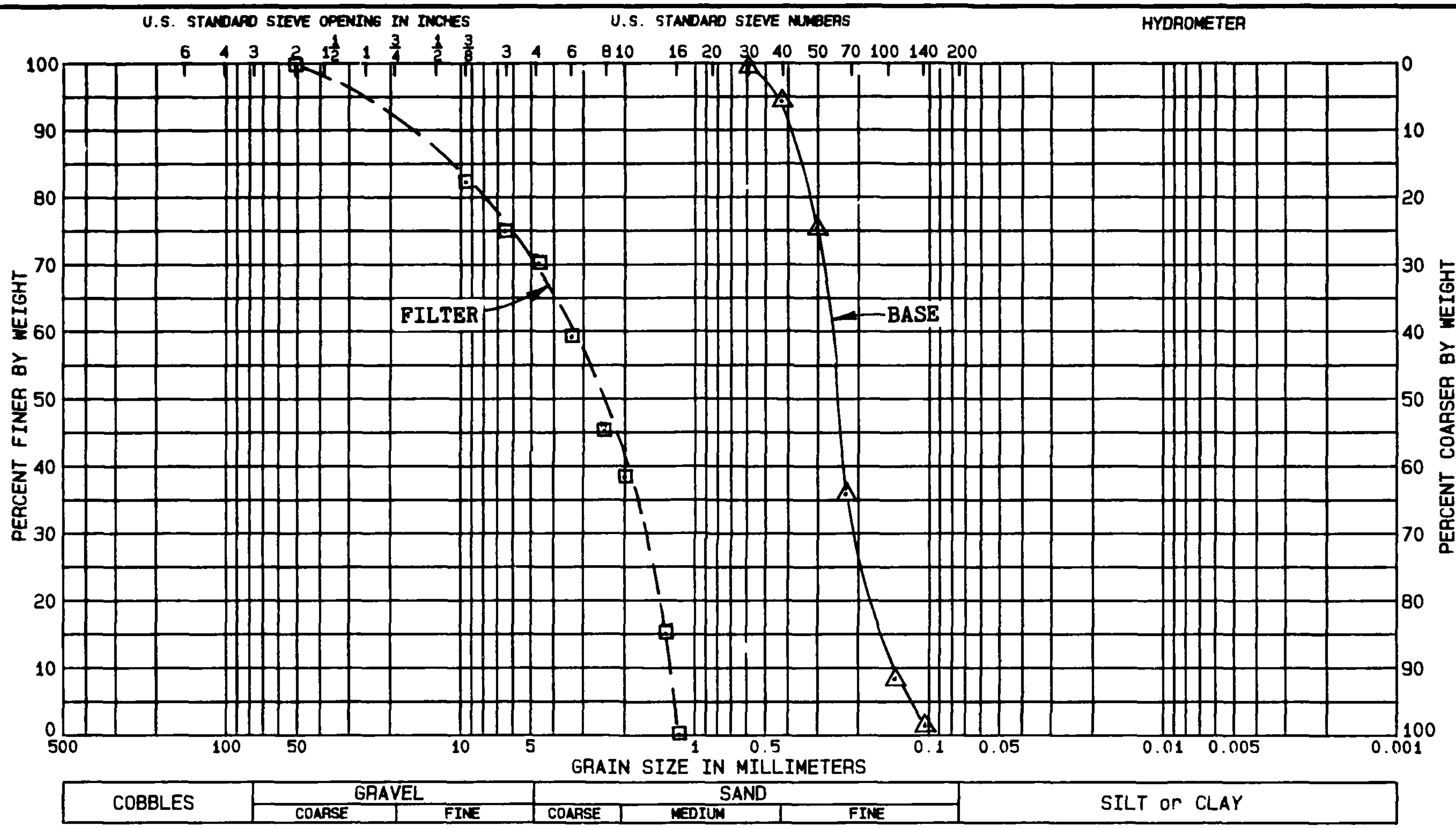

PROJECT TEST NO. 1A - B
MATERIAL BLENDED FOR TEST
BORING NO.
SAMPLE NO.
DEPTH/ELEV
DATE 00 AUG 79
GRADATION CURVE
CLASSIFICATION
LL
PL
PI
GS
NAT W, %
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
BASE
FILTER

PLATE C2



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1A - C

MATERIAL BLENDED FOR TEST

BORING NO. SAMPLE NO.

DEPTH/ELEV DATE 00 SEP 79

PLATE C3

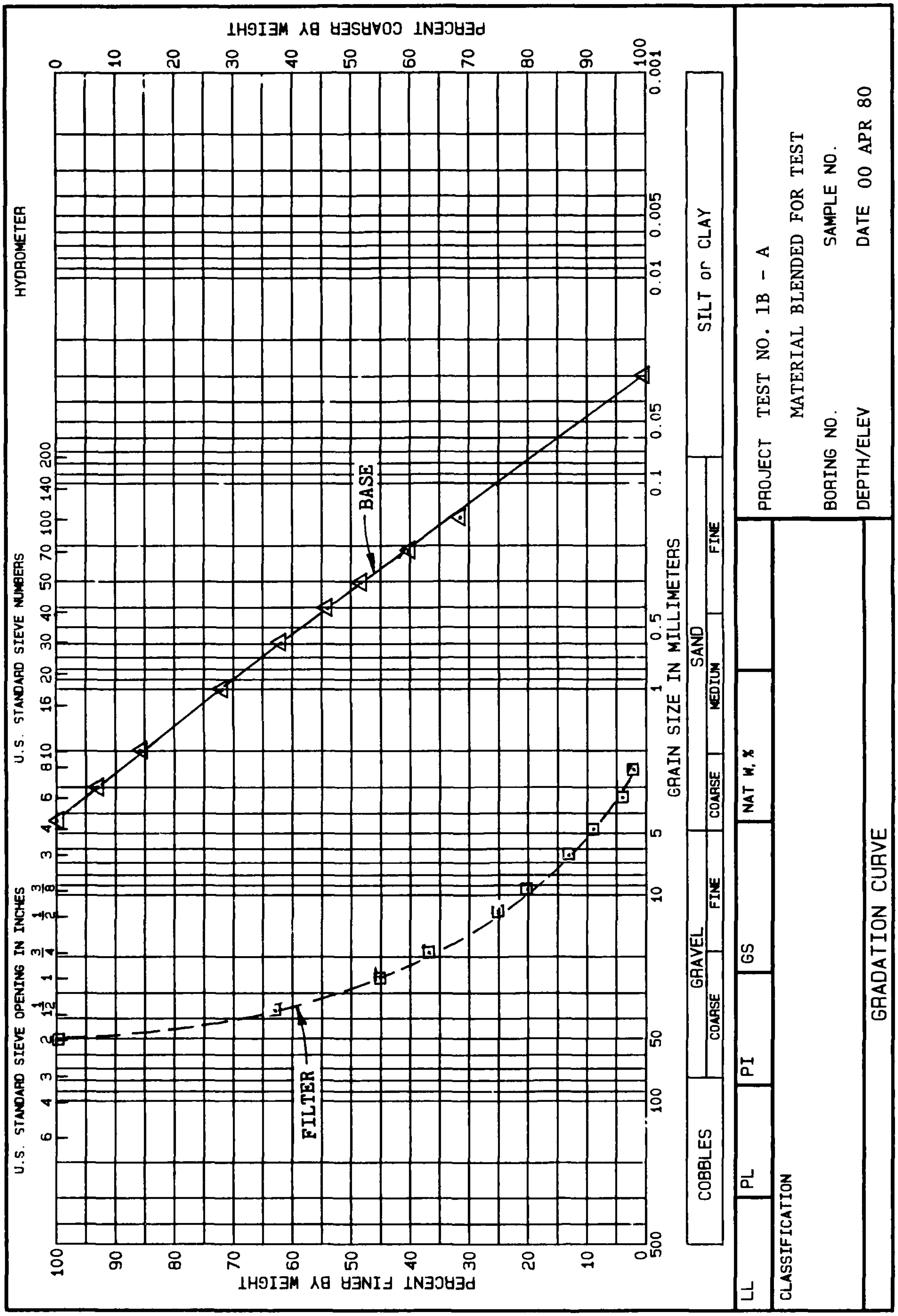
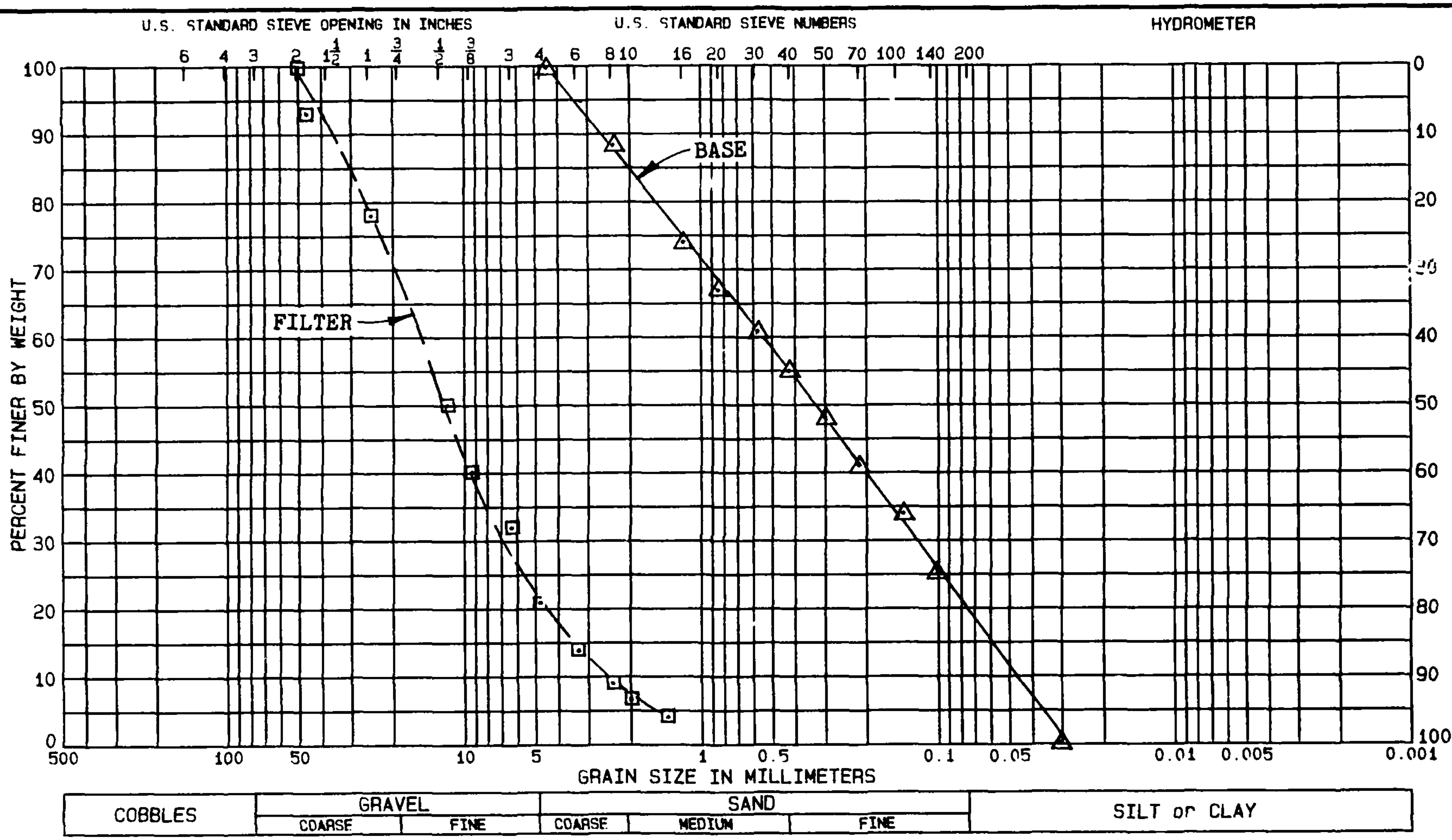

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BASE
FILTER
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1B - A
MATERIAL BLENDED FOR TEST
BORING NO.
SAMPLE NO.
DEPTH/ELEV
DATE 00 APR 80
GRADATION CURVE

PLATE C4



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

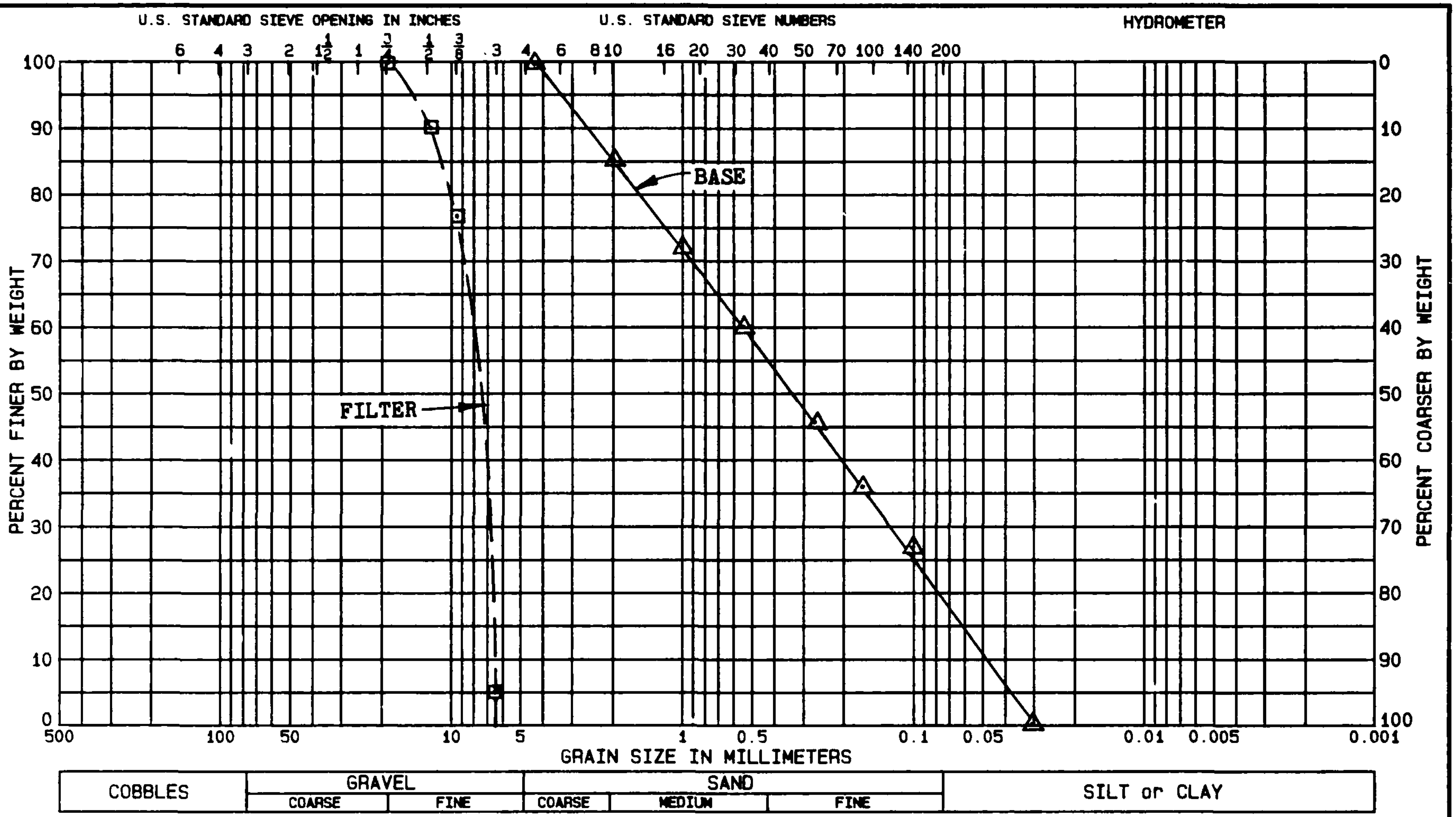
PROJECT TEST NO. 1B - B

MATERIAL BLENDED FOR TEST

BORING NO. SAMPLE NO.

DEPTH/ELEV DATE 00 MAR 80

PLATE C5



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1B - C	
MATERIAL BLENDED FOR TEST	
BORING NO.	SAMPLE NO.
DEPTH/ELEV	DATE 00 DEC 79

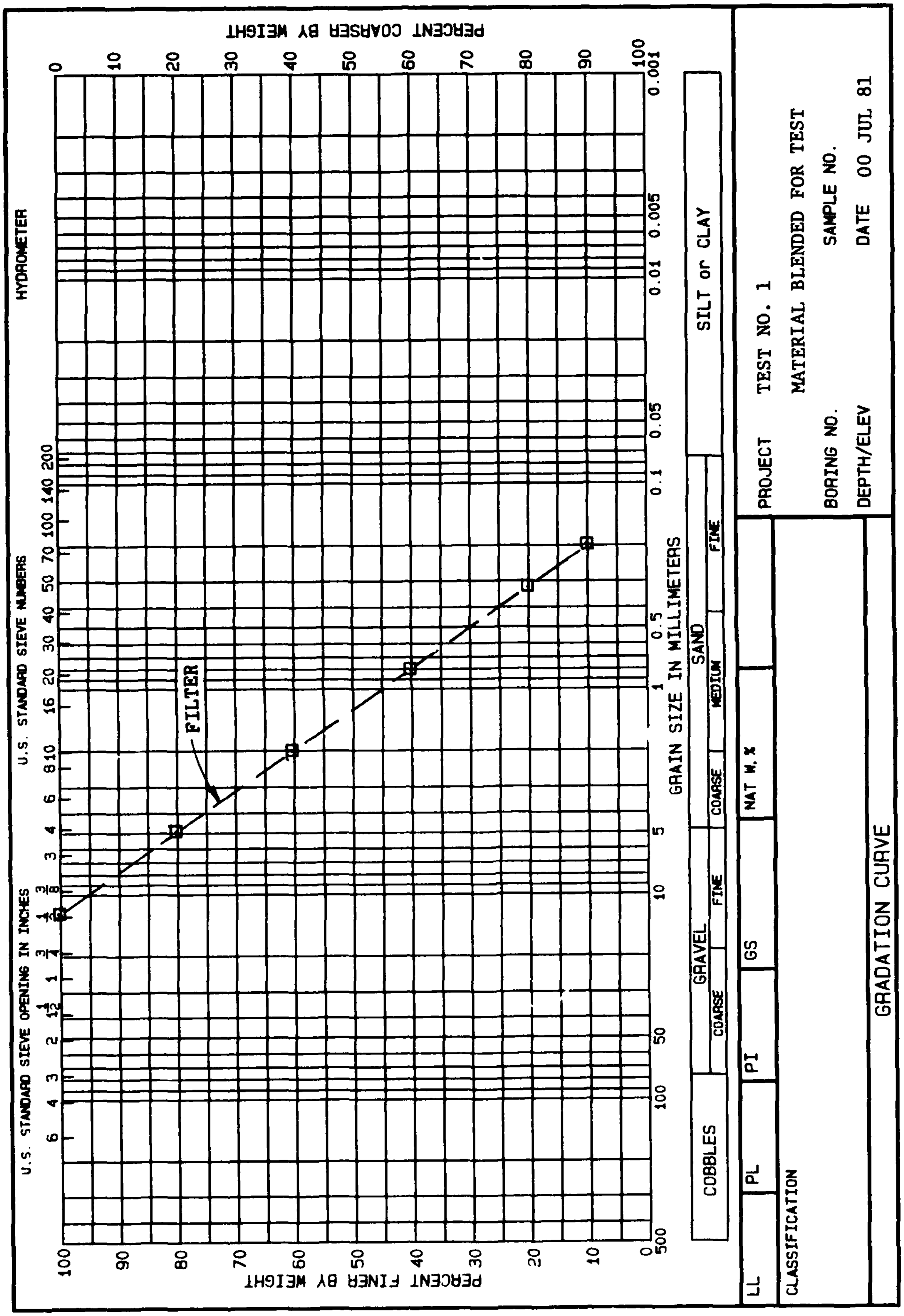

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
FILTER
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
GRADATION CURVE
PROJECT TEST NO. 1
MATERIAL BLENDED FOR TEST
BORING NO.
SAMPLE NO.
DEPTH/ELEV
DATE 00 JUL 81

PLATE C7

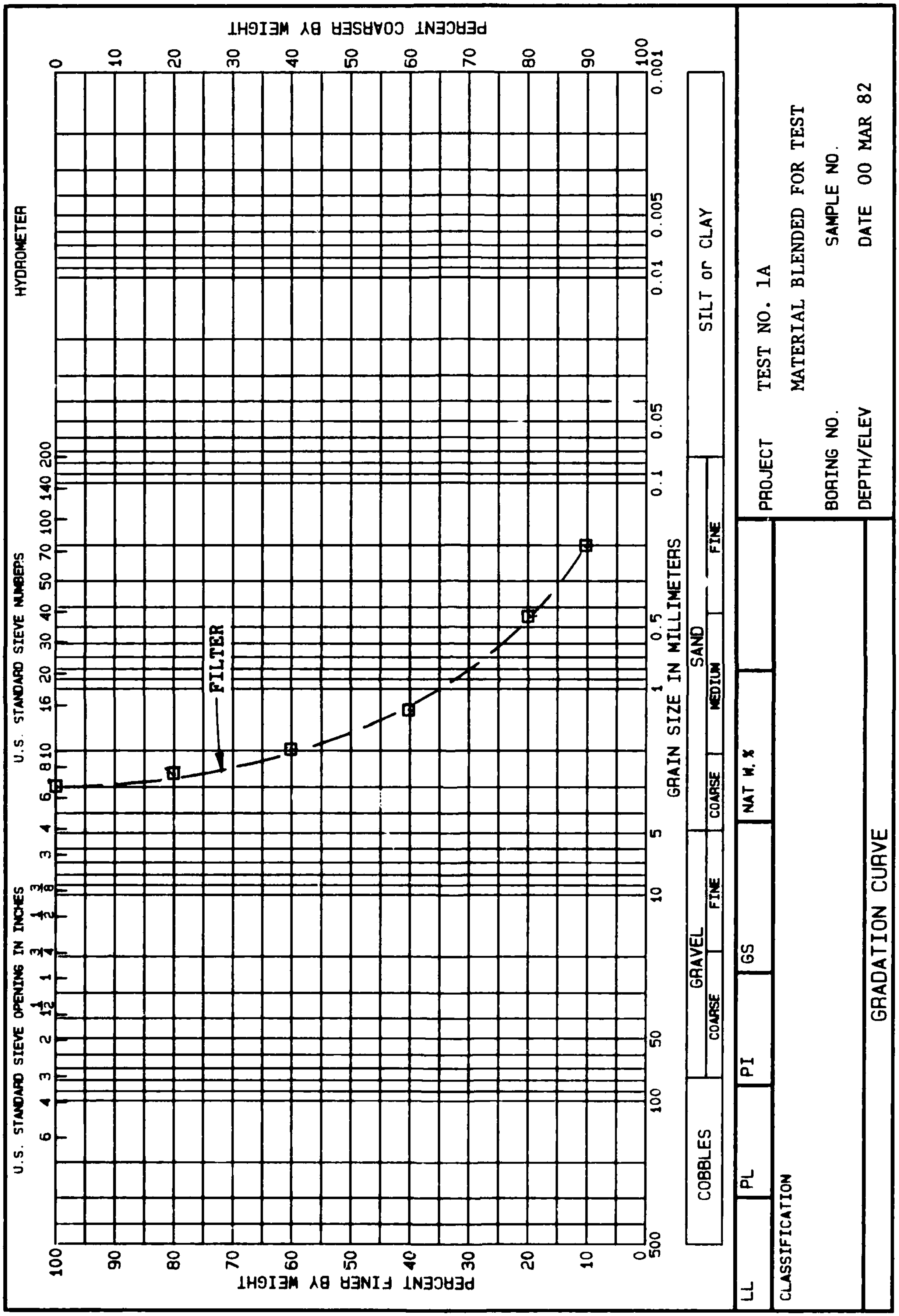
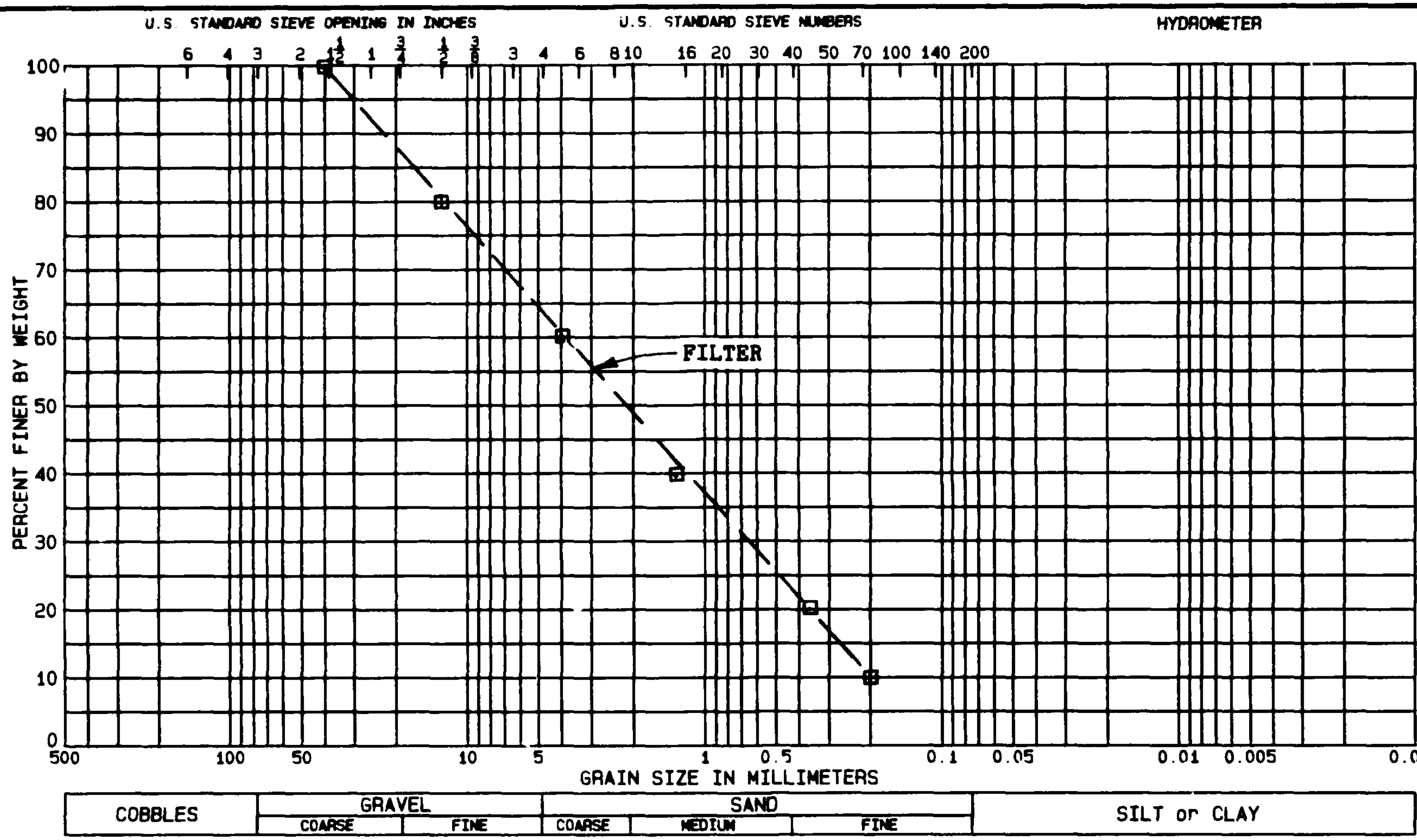

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
FILTER
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W. %
CLASSIFICATION
PROJECT TEST NO. 1A
MATERIAL BLENDED FOR TEST
BORING NO.
SAMPLE NO.
DEPTH/ELEV
DATE 00 MAR 82
GRADATION CURVE

PLATE C8



LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

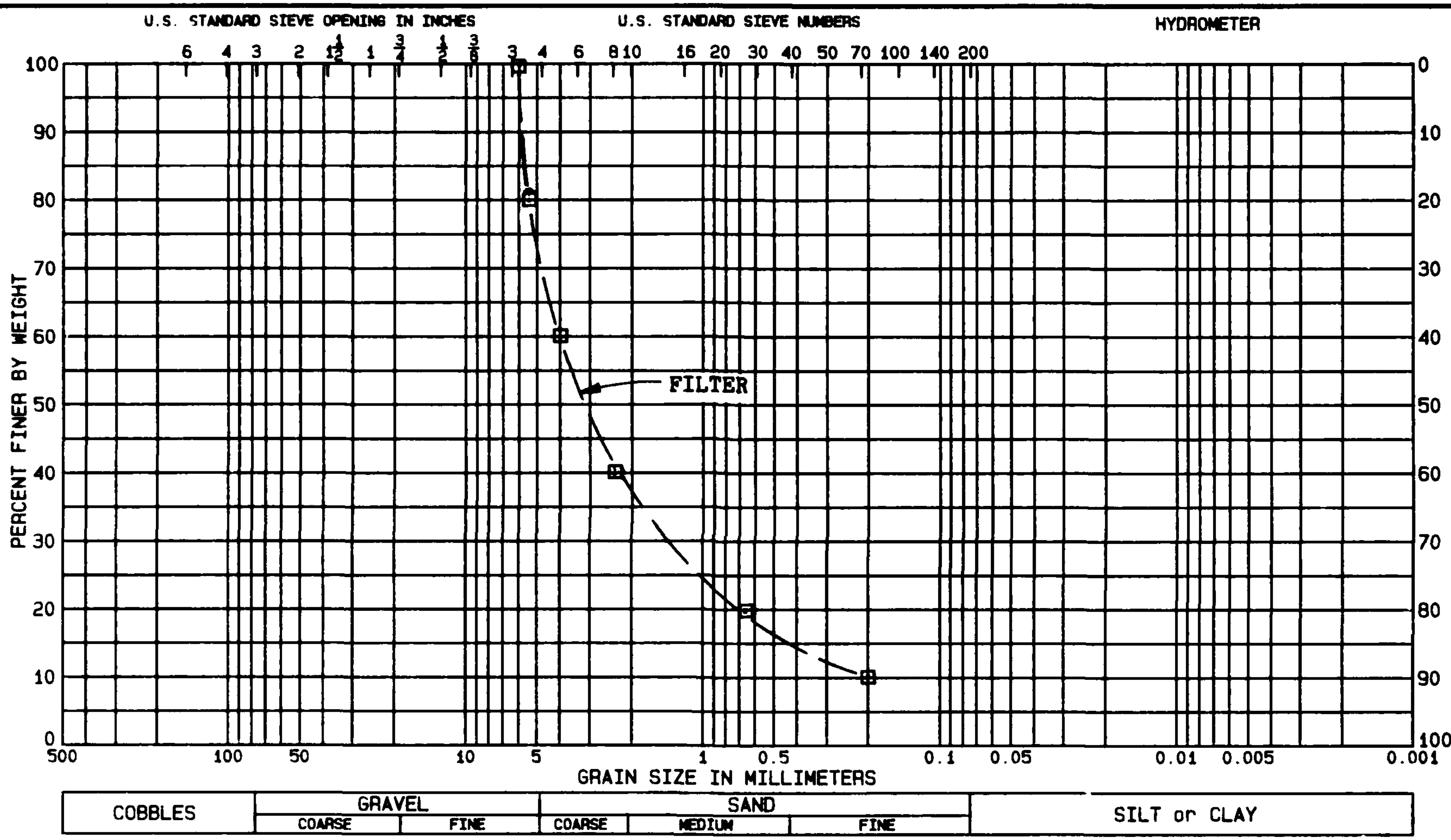
GRADATION CURVE

PROJECT TEST NO. 2

MATERIAL BLENDED FOR TEST

BORING NO. SAMPLE NO.

DEPTH/ELEV DATE 00 AUG 81



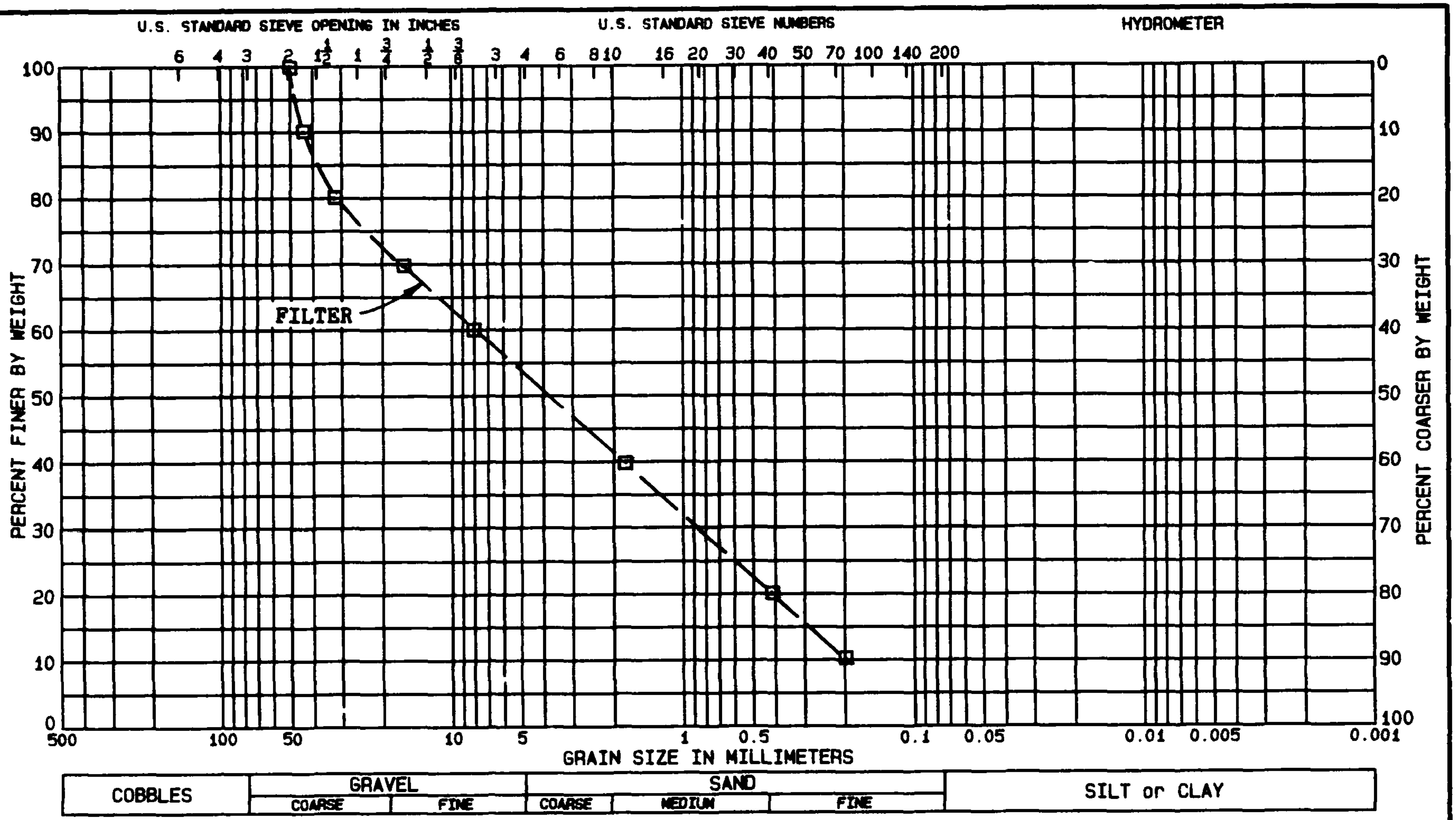
LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2A
MATERIAL BLENDED FOR TEST
BORING NO. SAMPLE NO.
DEPTH/ELEV DATE 00 MAY 82

PLATE C10

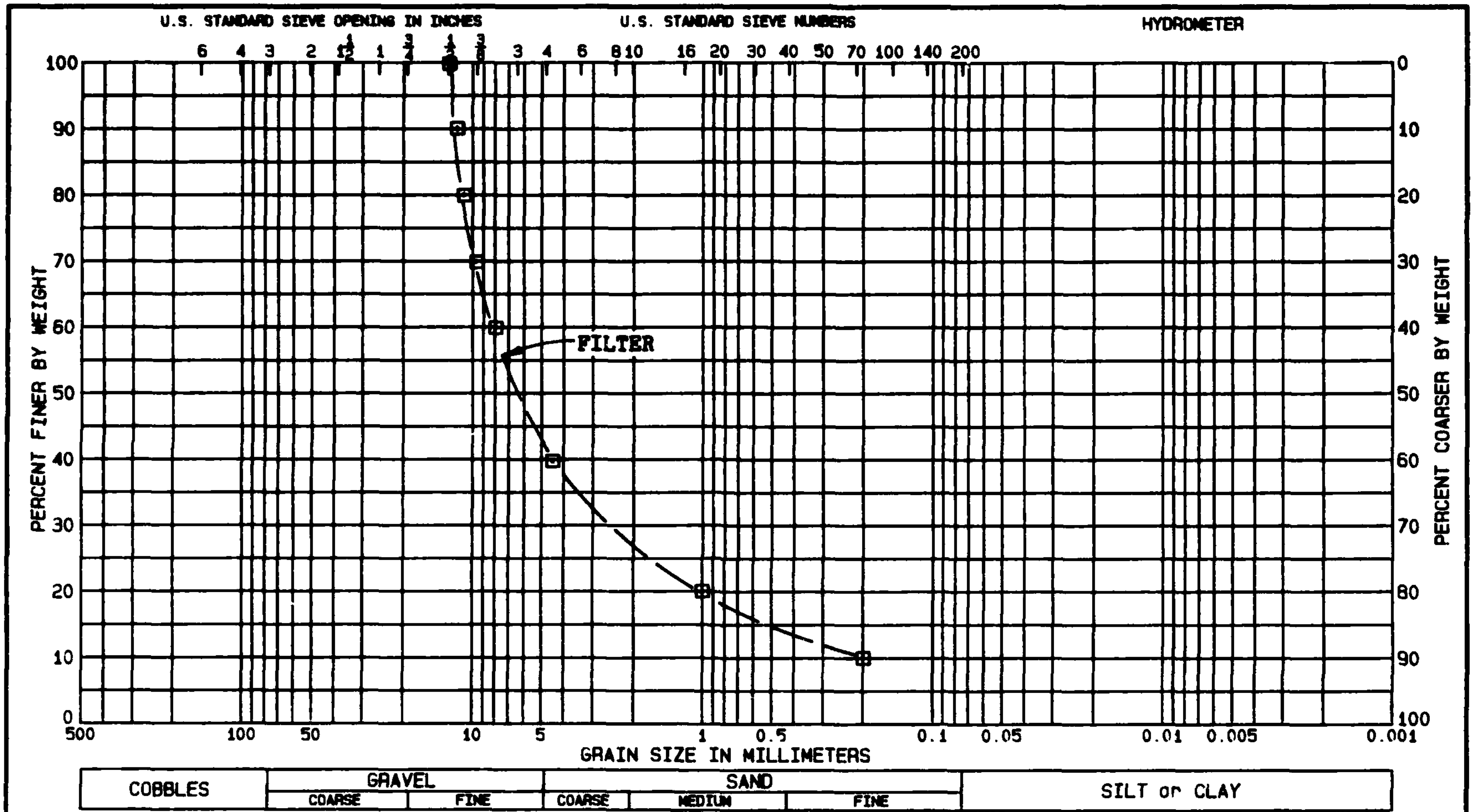


LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 3
MATERIAL BLENDED FOR TEST
BORING NO. SAMPLE NO.
DEPTH/ELEV DATE 00 DEC 81



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 3A

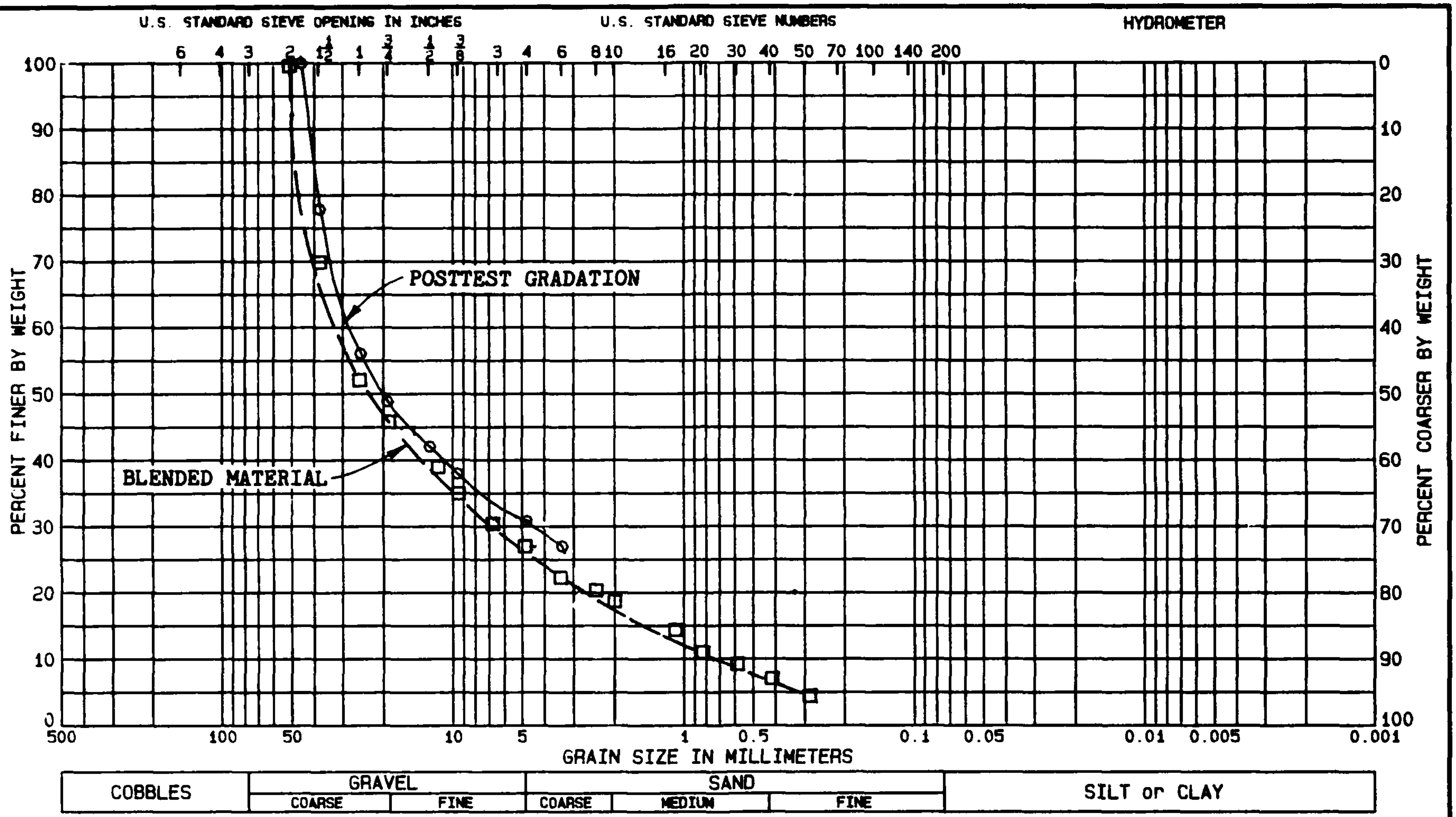
MATERIAL BELNDED FOR TEST

BORING NO. SAMPLE NO.

DEPTH/ELEV DATE 00 JUL 82

PLATE C12

APPENDIX D: COMPARISON BETWEEN POSTTEST GRADATIONS OF THE FILTER AND FILTER MATERIALS BLENDED FOR THE TEST



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

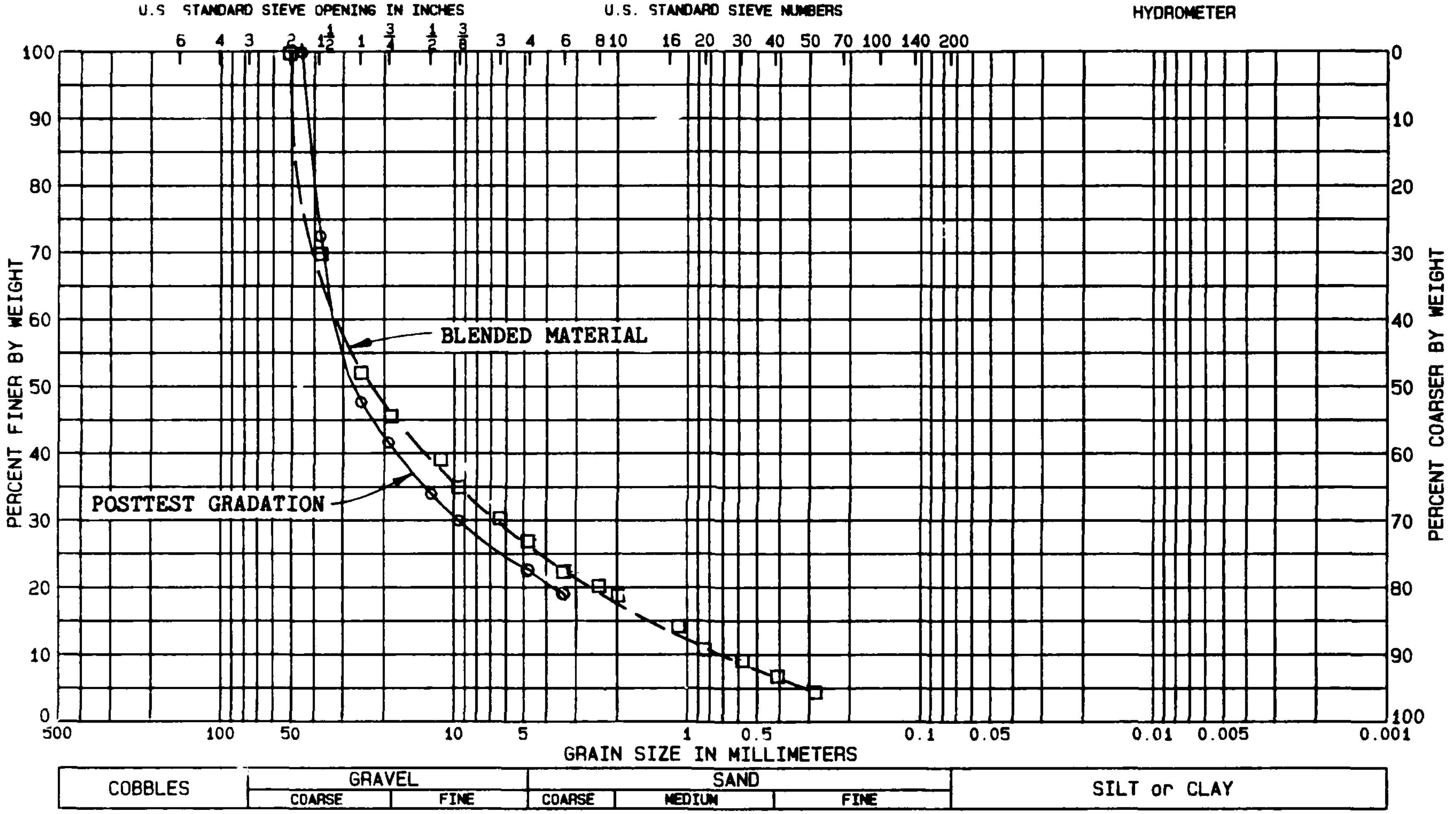
PROJECT TEST NO. 1A - A (CHECK)

53 - 59 IN.

BORING NO. SAMPLE NO. 1

DEPTH/ELEV DATE 00 NOV 79

PLATE D1



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

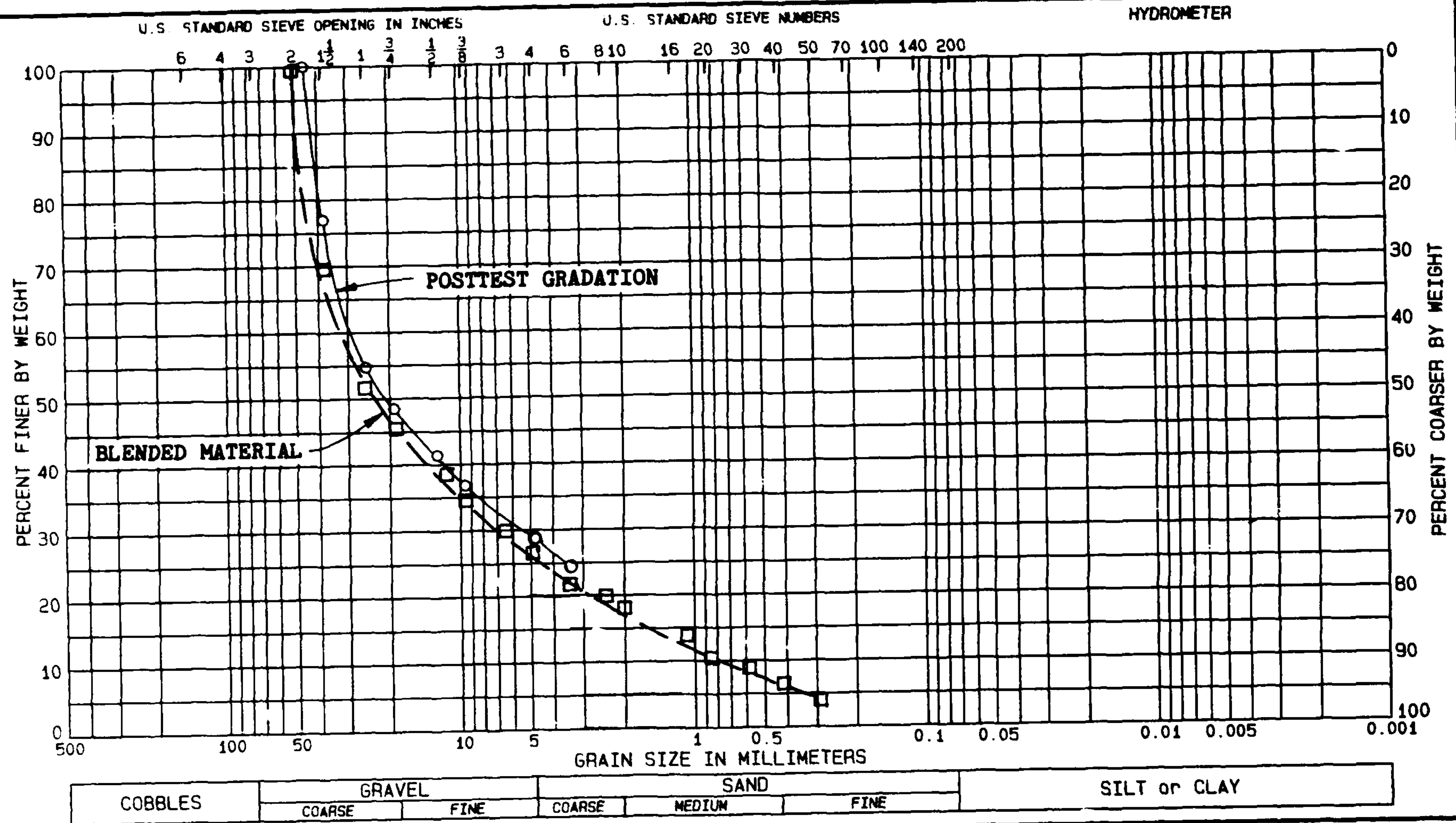
GRADATION CURVE

PROJECT TEST NO. 1A - A (CHECK)
47 - 53 IN.

BORING NO. SAMPLE NO. 2

DEPTH/ELEV DATE 00 NOV 79

PLATE D2



LL	PL	PI	GS	NAT W, %	

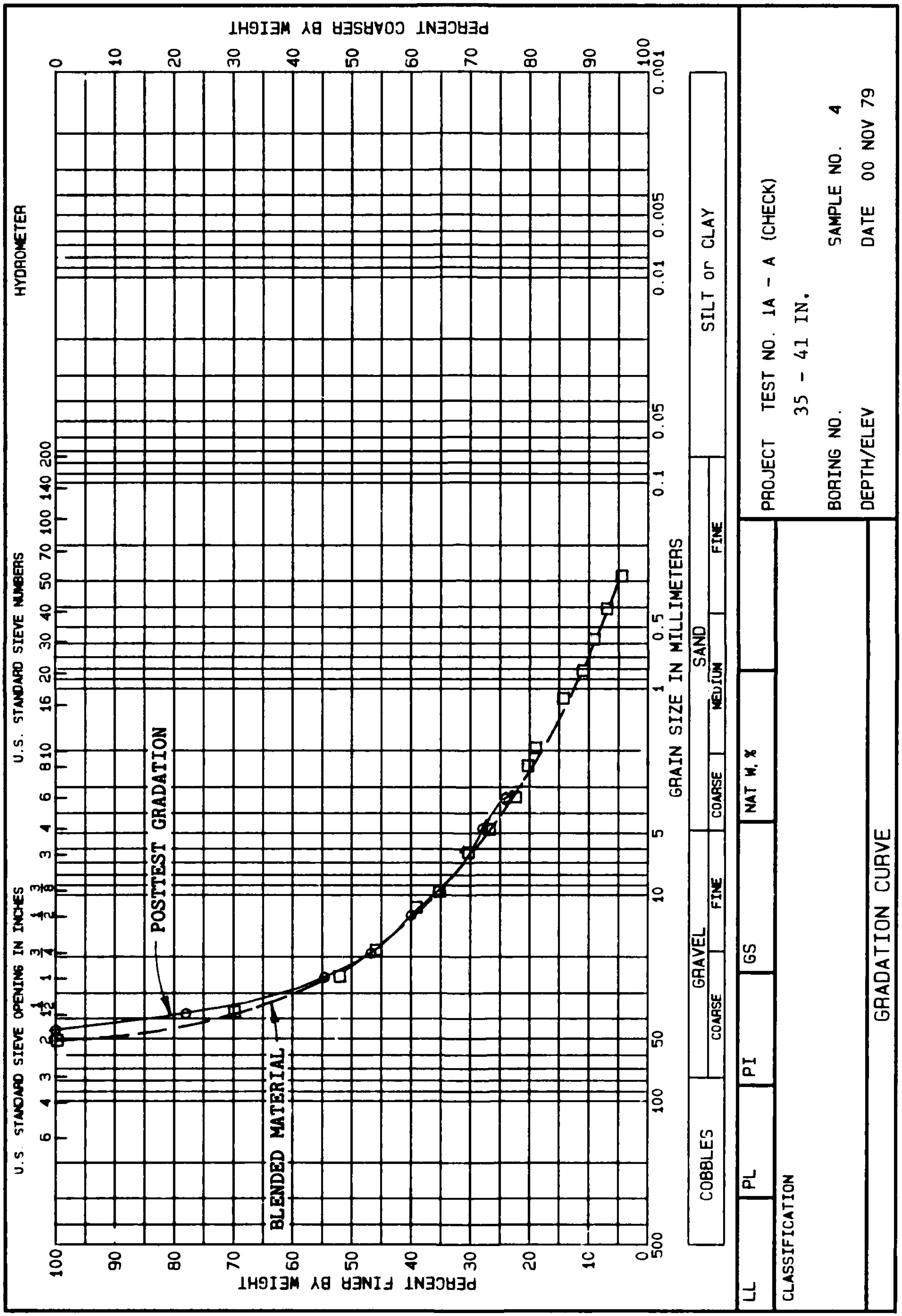
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1A - A (CHECK)
41 - 47 IN.

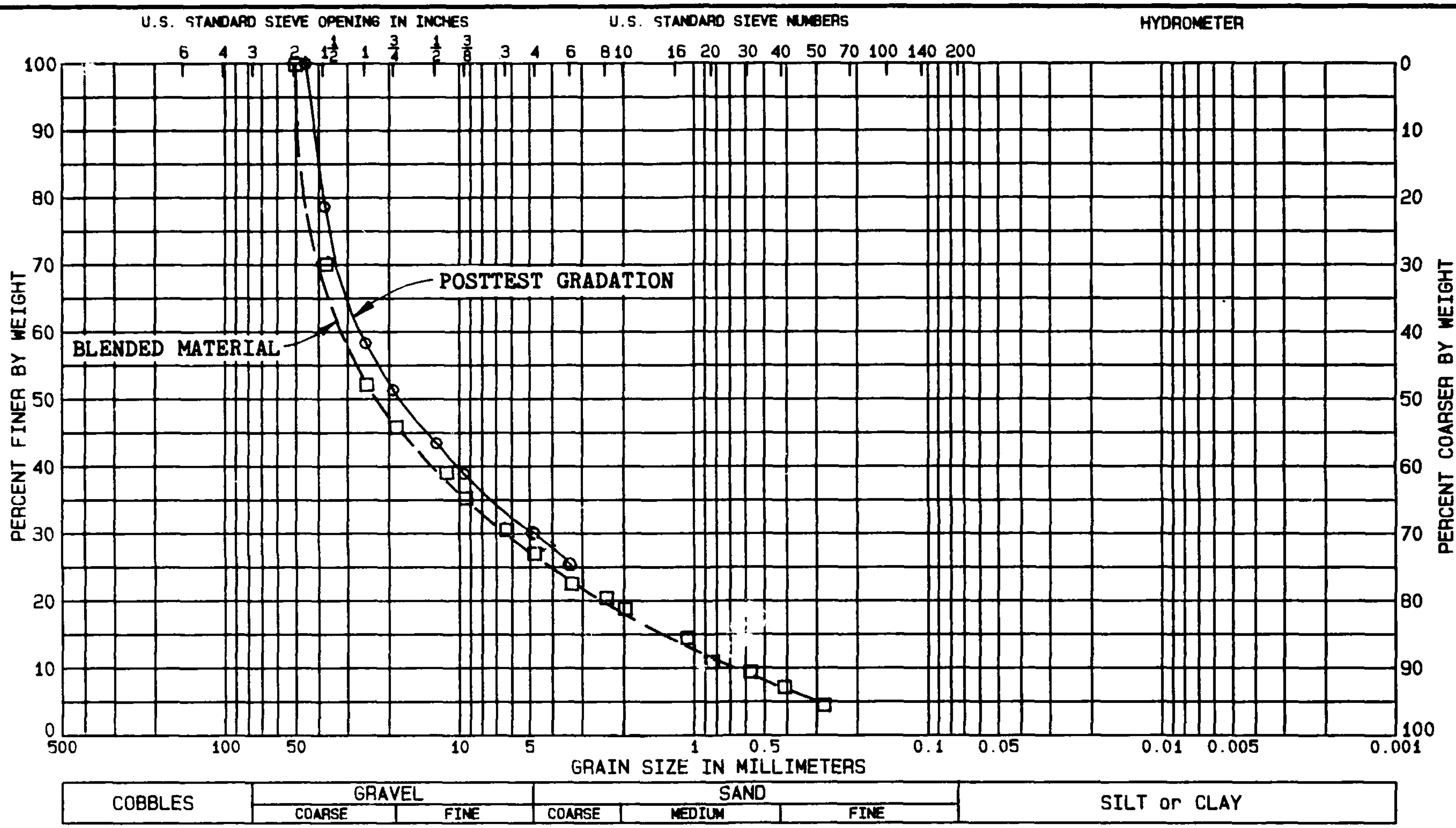
BORING NO. SAMPLE NO. 3

DEPTH/ELEV DATE 00 NOV 79



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1½ 1 ¾ ½ ⅜ 3 4 6 8 10 16 20 30 40 50 70 100 140 200
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
POSTTEST GRADATION
BLENDED MATERIAL
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1A - A (CHECK)
35 - 41 IN.
BORING NO.
SAMPLE NO. 4
DEPTH/ELEV
DATE 00 NOV 79
GRADATION CURVE

PLATE D4



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1A – A (CHECK)

29 – 35 IN.

BORING NO. SAMPLE NO. 5

DEPTH/ELEV DATE 00 NOV 79

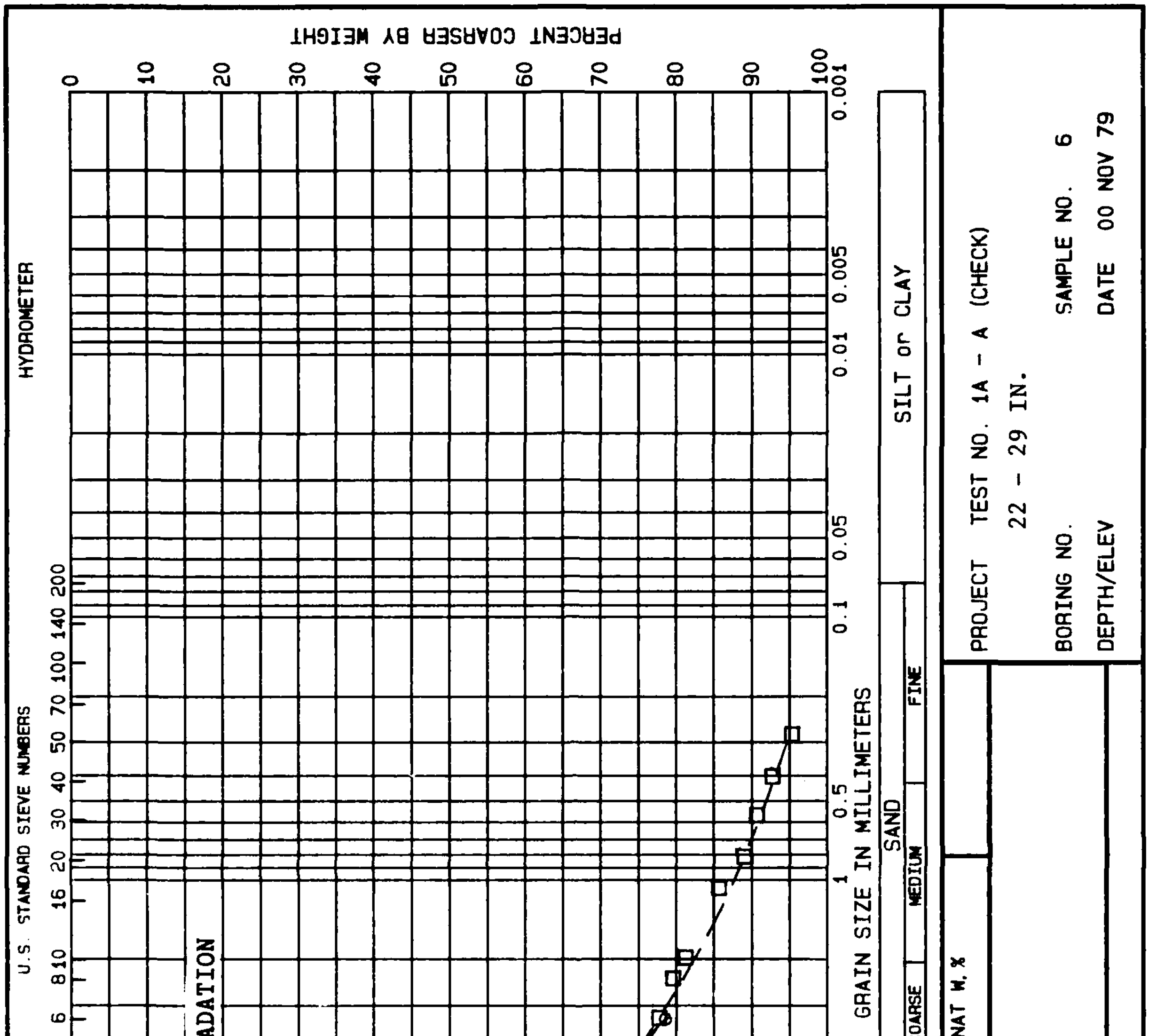
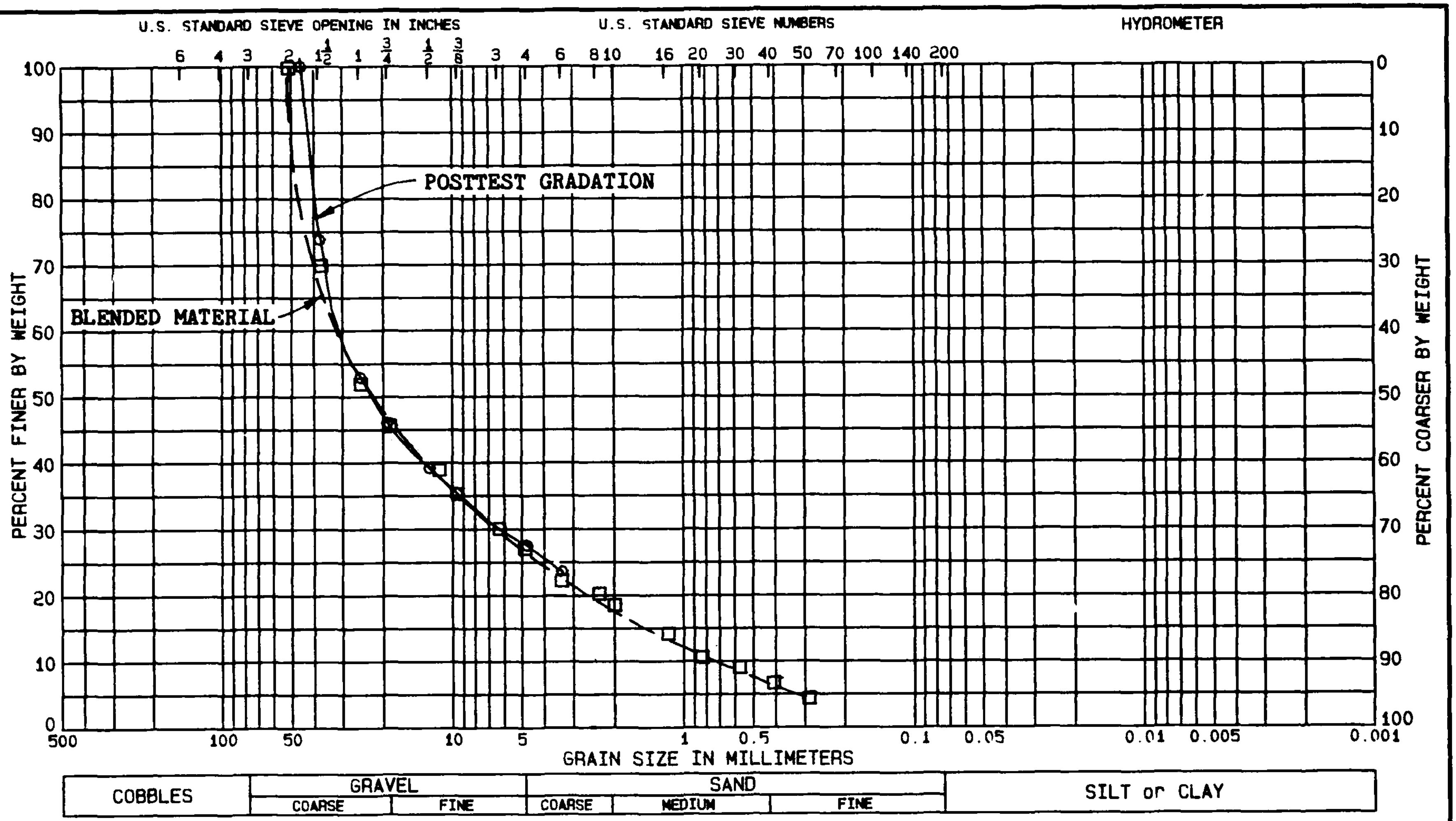

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1A - A (CHECK)
22 - 29 IN.
BORING NO.
SAMPLE NO. 6
DEPTH/ELEV
DATE 00 NOV 79
GRADATION CURVE

PLATE D6



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

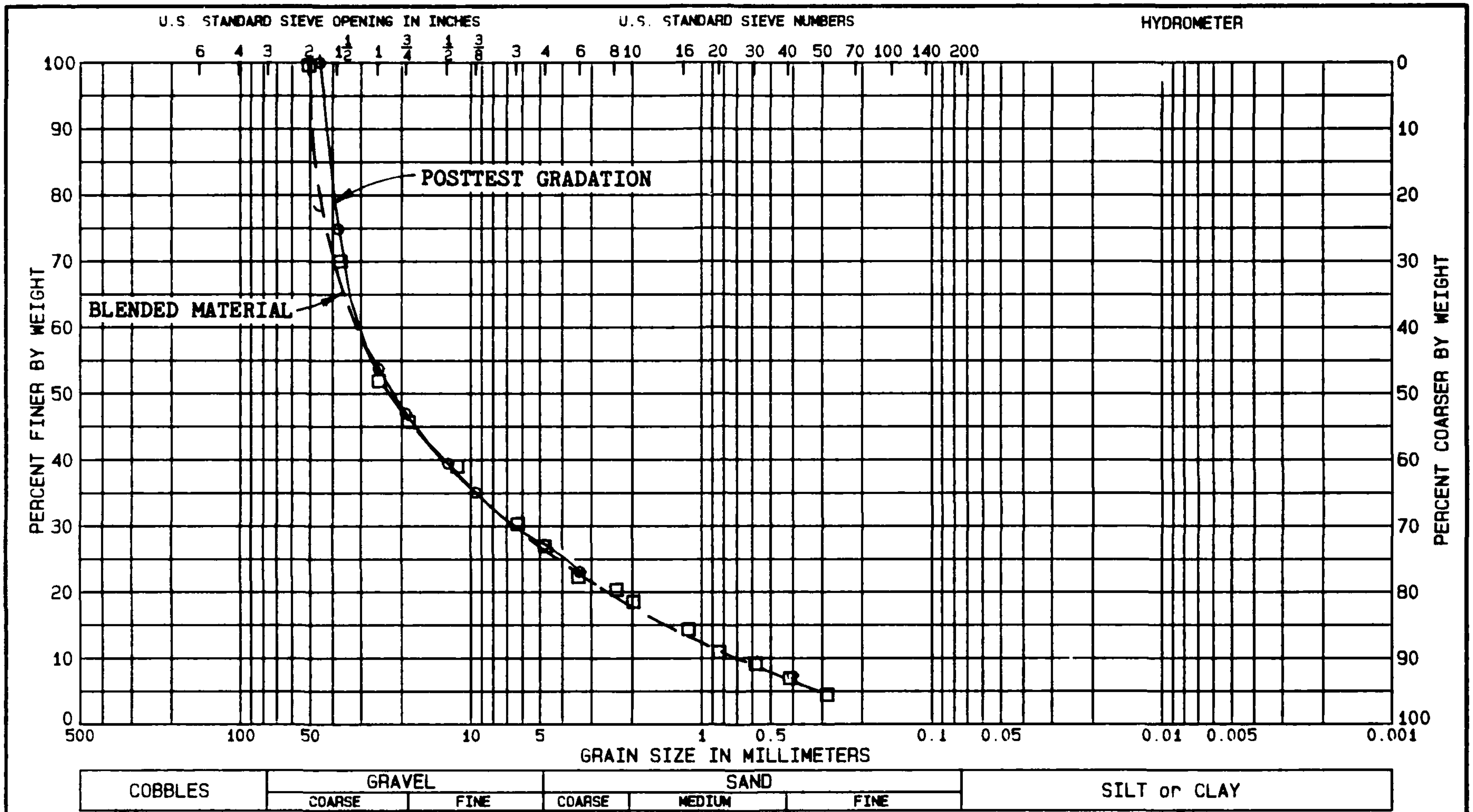
GRADATION CURVE

PROJECT TEST NO. 1A - A (CHECK)
16 - 22 IN.

BORING NO. SAMPLE NO. 7

DEPTH/ELEV DATE 00 NOV 79

PLATE D7



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

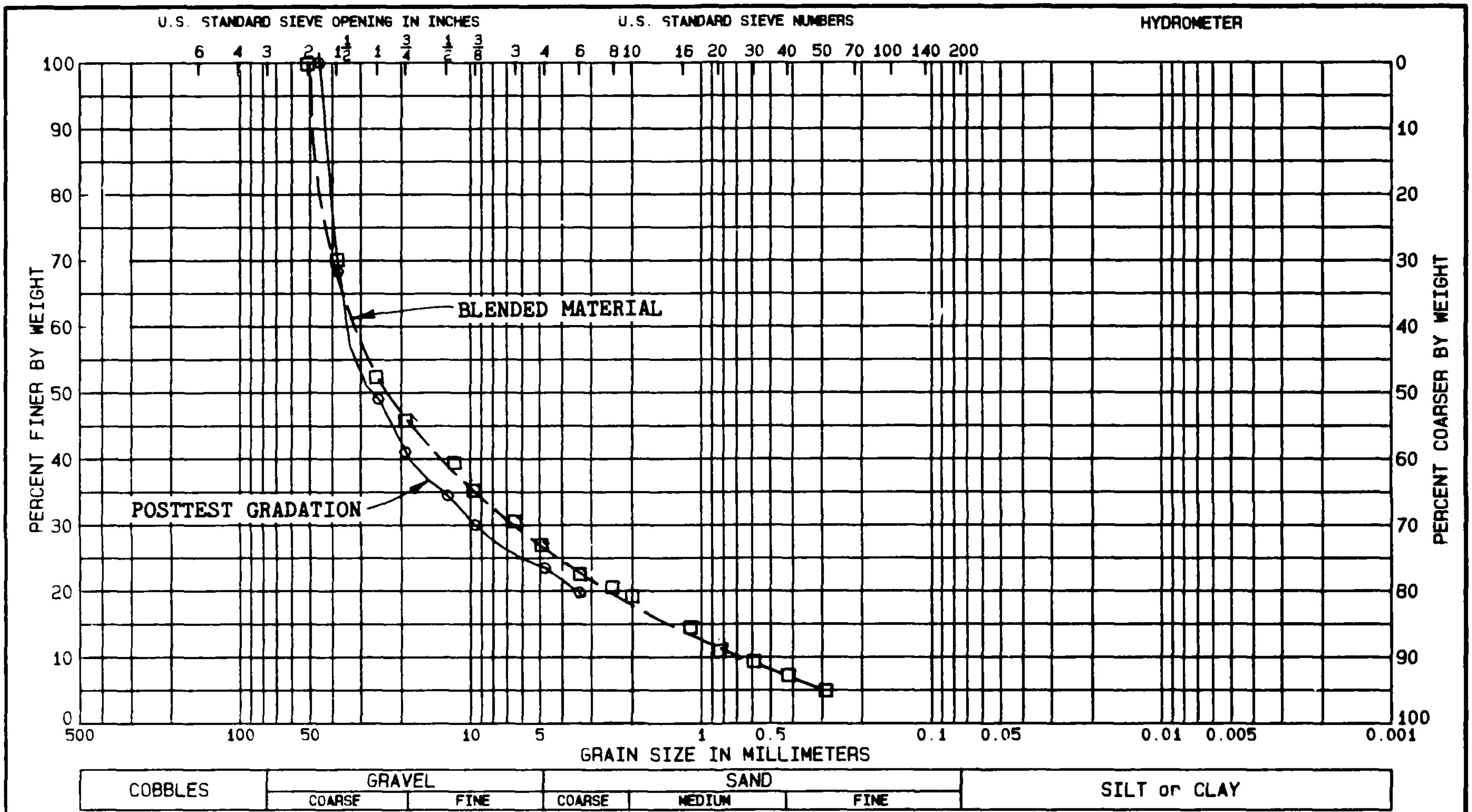
GRADATION CURVE

PROJECT TEST NO. 1A - A (CHECK)
10 - 16 IN.

BORING NO. SAMPLE NO. 8

DEPTH/ELEV DATE 00 NOV 79

PLATE D8

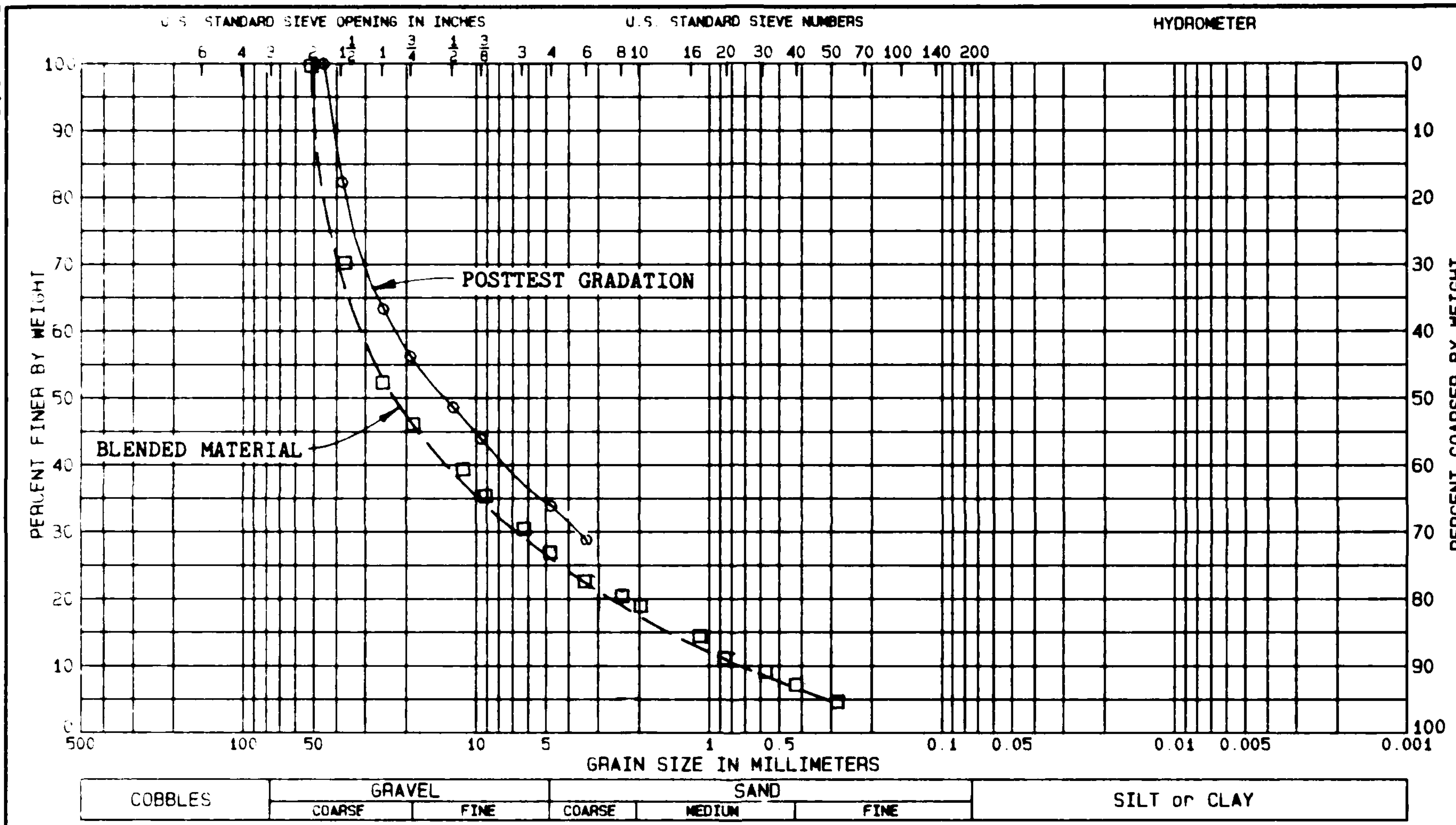


LL	PL	PI	GS	NAT W, %	
CLASSIFICATION					
GRADATION CURVE					

PROJECT TEST NO. 1A - A (CHECK)
5 - 10 IN.

BORING NO. SAMPLE NO. 9

DEPTH/ELEV DATE 00 NOV 79



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

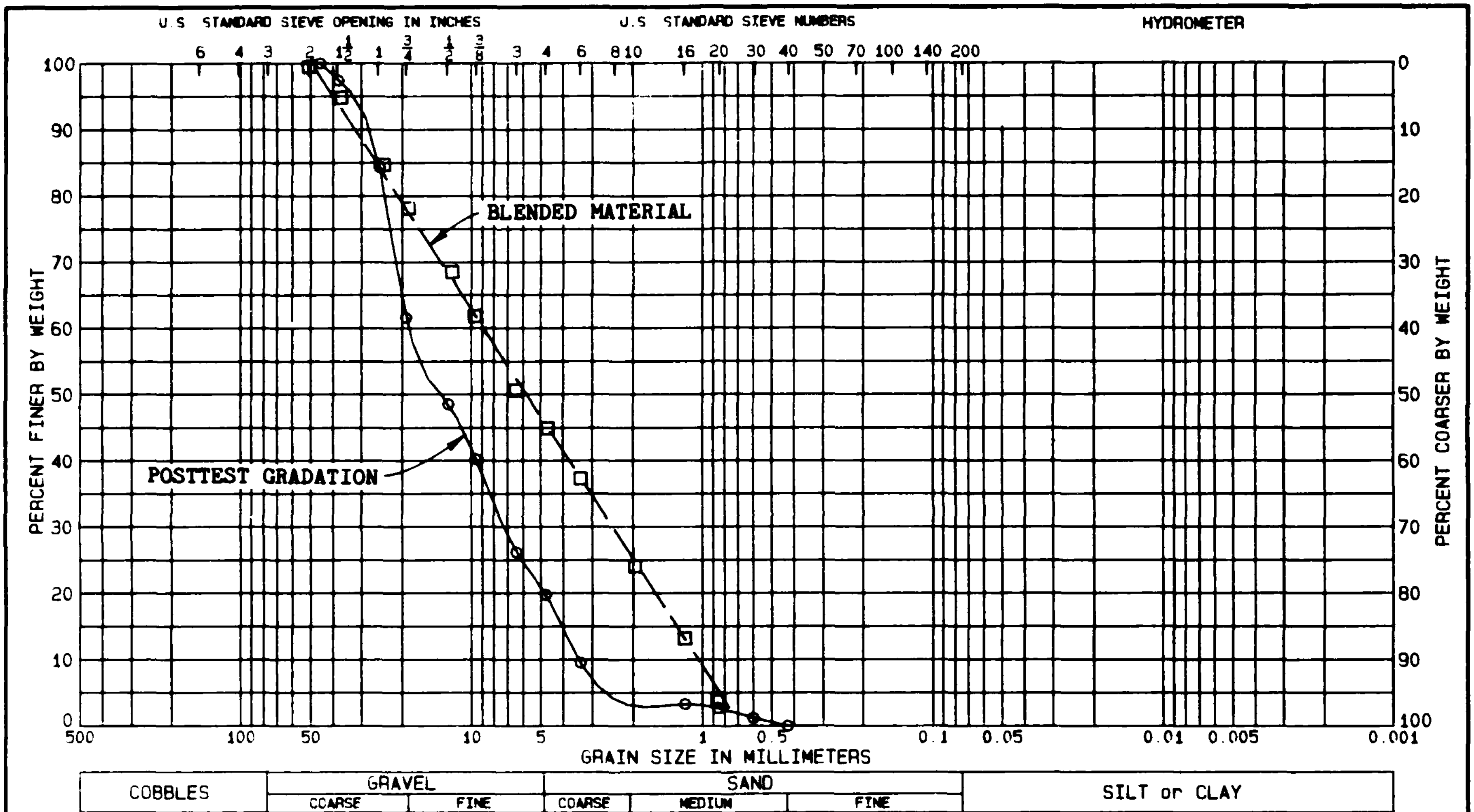
GRADATION CURVE

PROJECT TEST NO. 1A - A (CHECK)
0 - 5 IN.

BORING NO. SAMPLE NO. 10

DEPTH/ELEV DATE 00 NOV 79

PLATE D10



LL | PL | PI | GS | NAT W. %

CLASSIFICATION

GRADATION CURVE

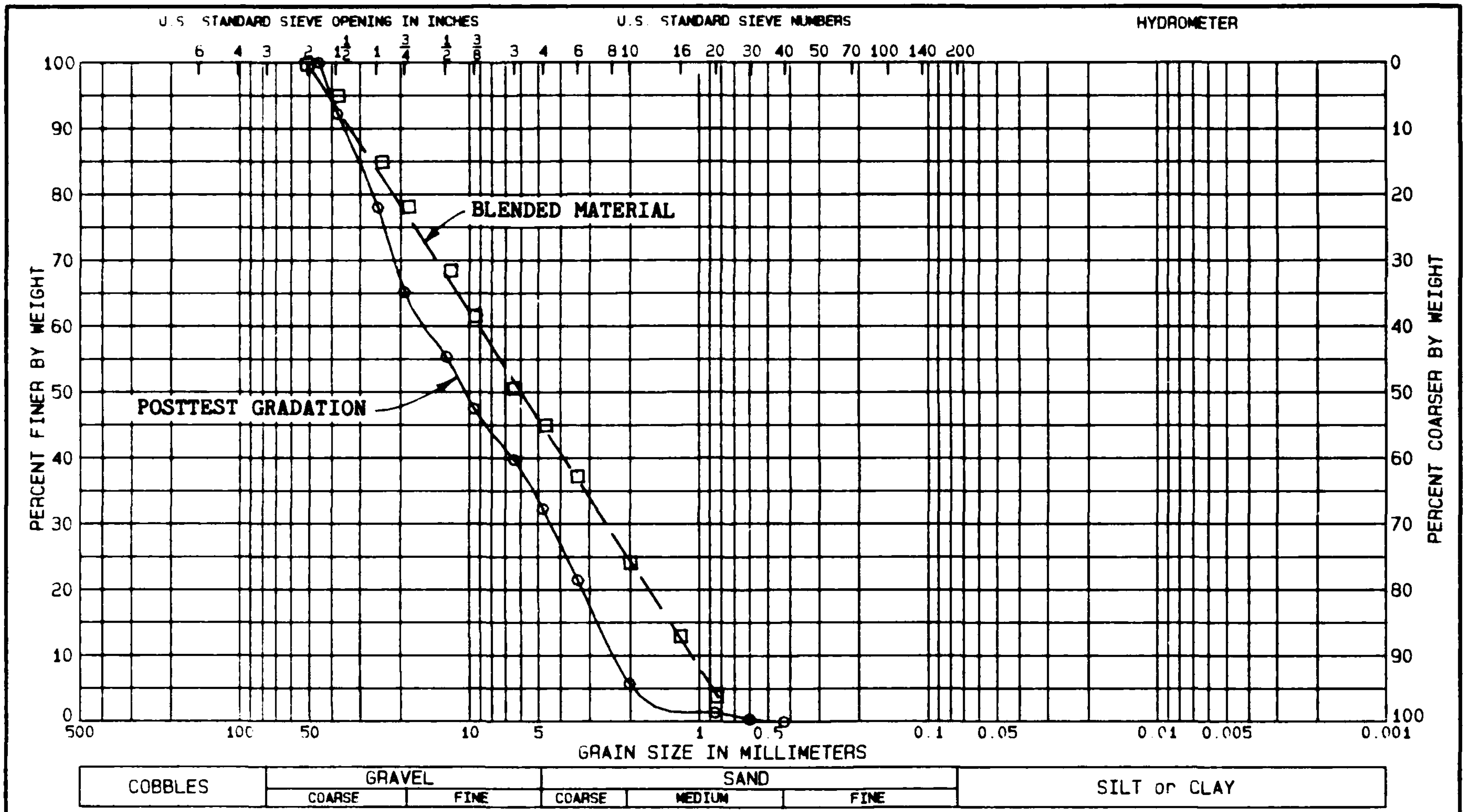
PROJECT TEST NO. 1A - B
55 - 58 IN.

BORING NO.

SAMPLE NO. 1

DEPTH/ELEV

DATE 00 AUG 79



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

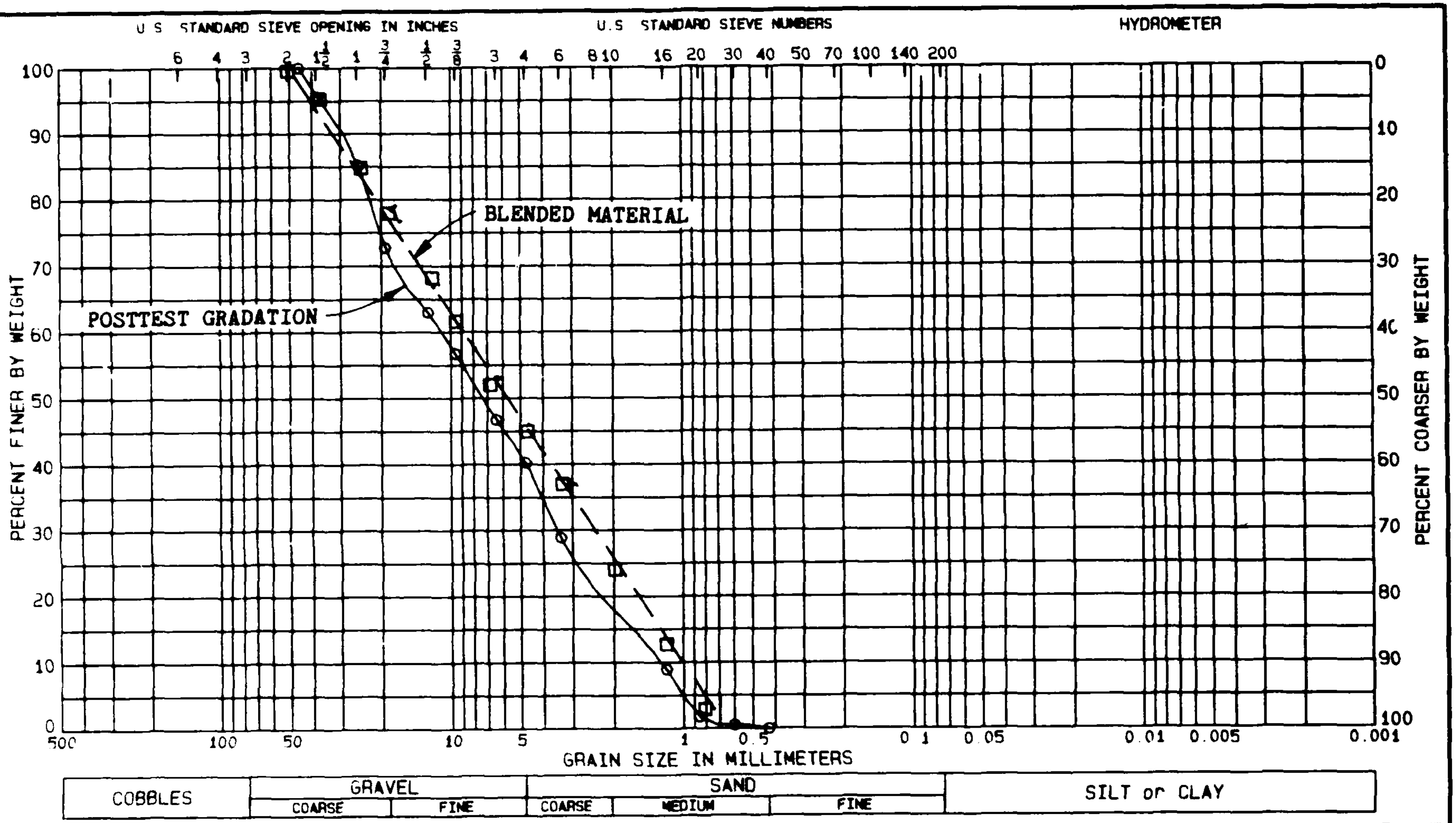
GRADATION CURVE

PROJECT TEST NO. 1A - B
49 - 55 IN.

BORING NO.
SAMPLE NO. 2

DEPTH/ELEV
DATE 00 AUG 79

PLATE D12



LL	PL	PI	GS	NAT W, %	

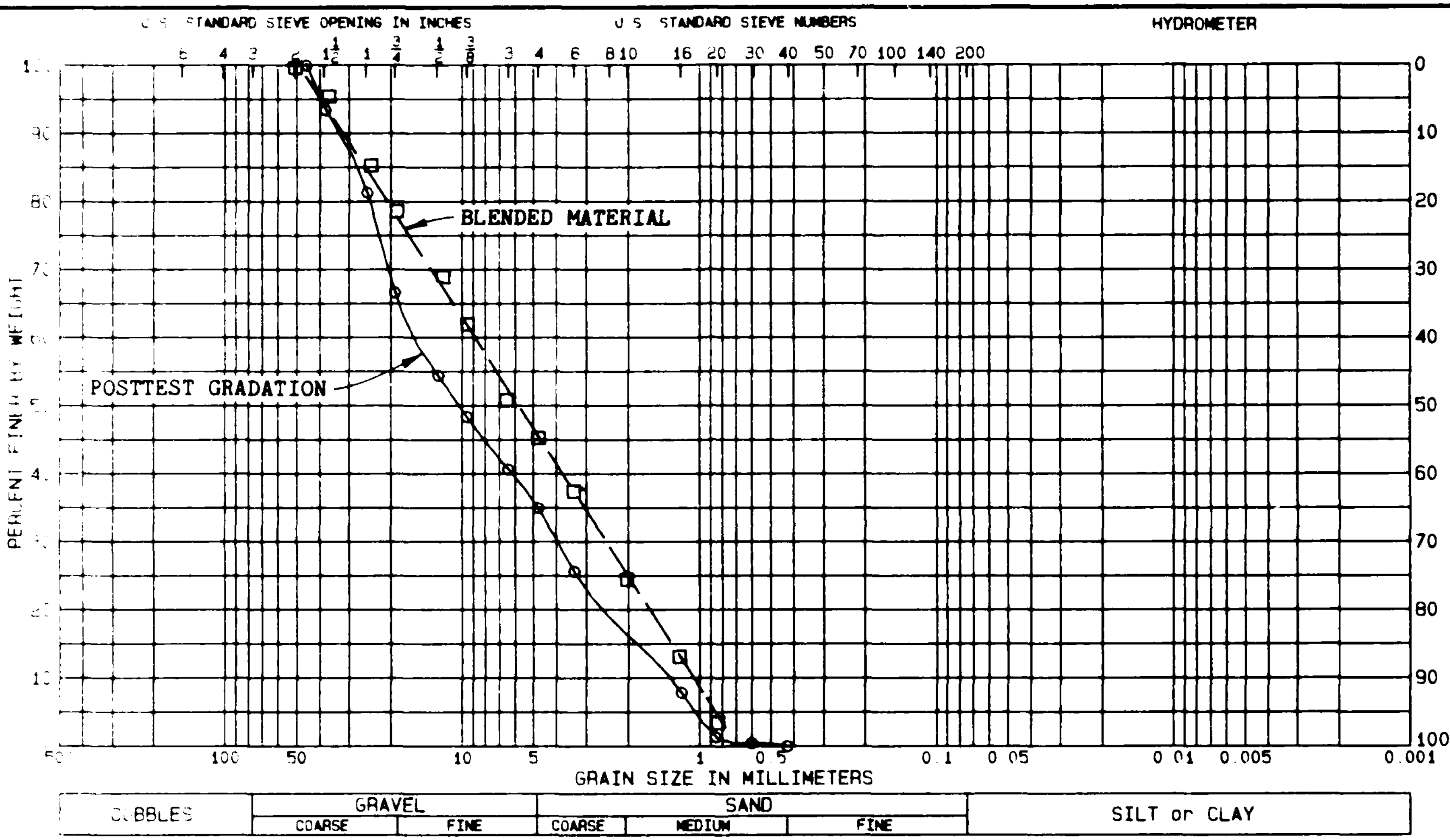
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1A - B
43 - 49 IN.

BORING NO. SAMPLE NO. 3

DEPTH/ELEV DATE 00 AUG 79

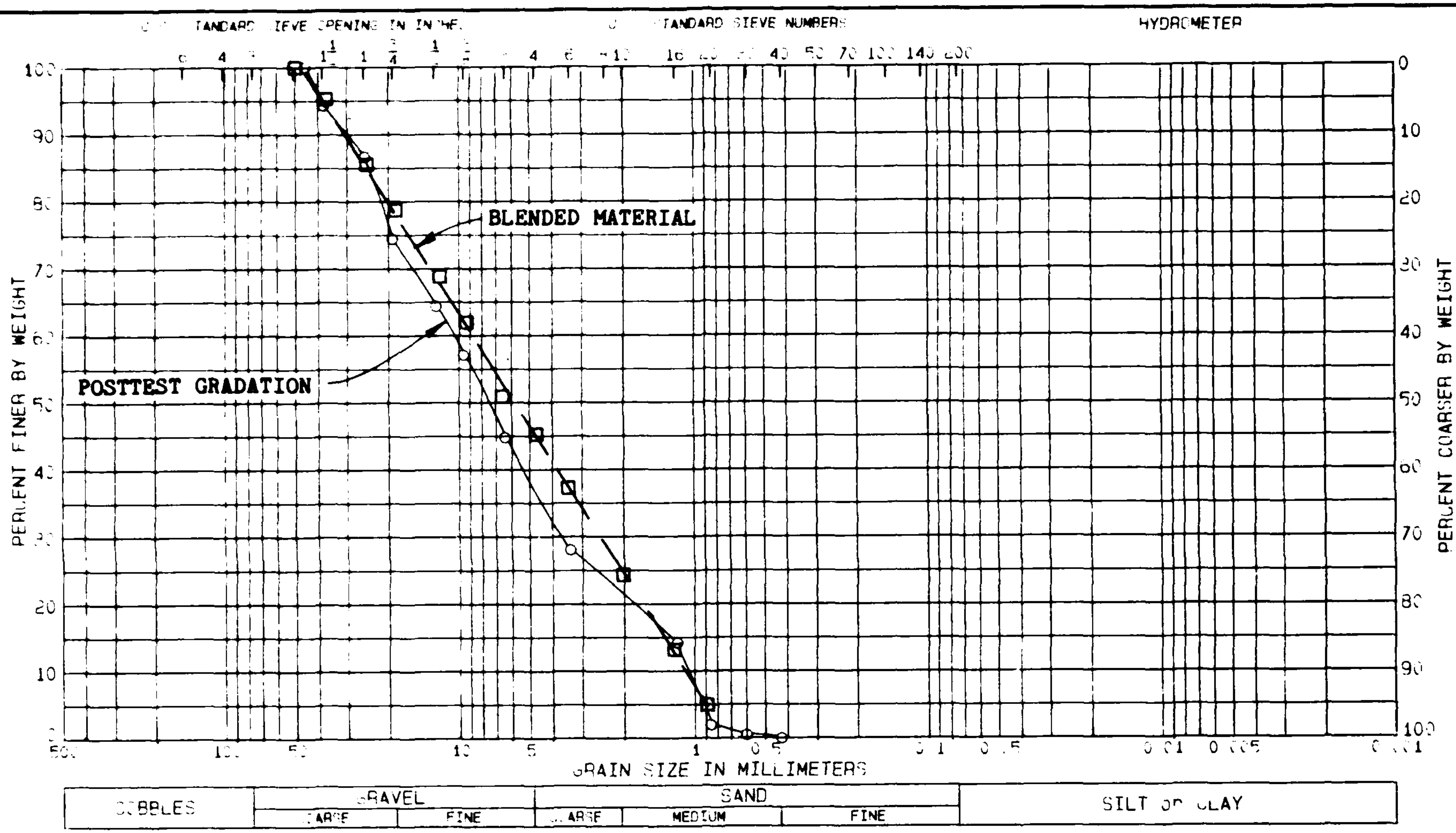


LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1A - B
37 - 43 IN.
BORING NO SAMPLE NO. 4
DEPTH/ELEV DATE 00 AUG 79



LL	PL	PI	GS	NAT W %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO 1A - B

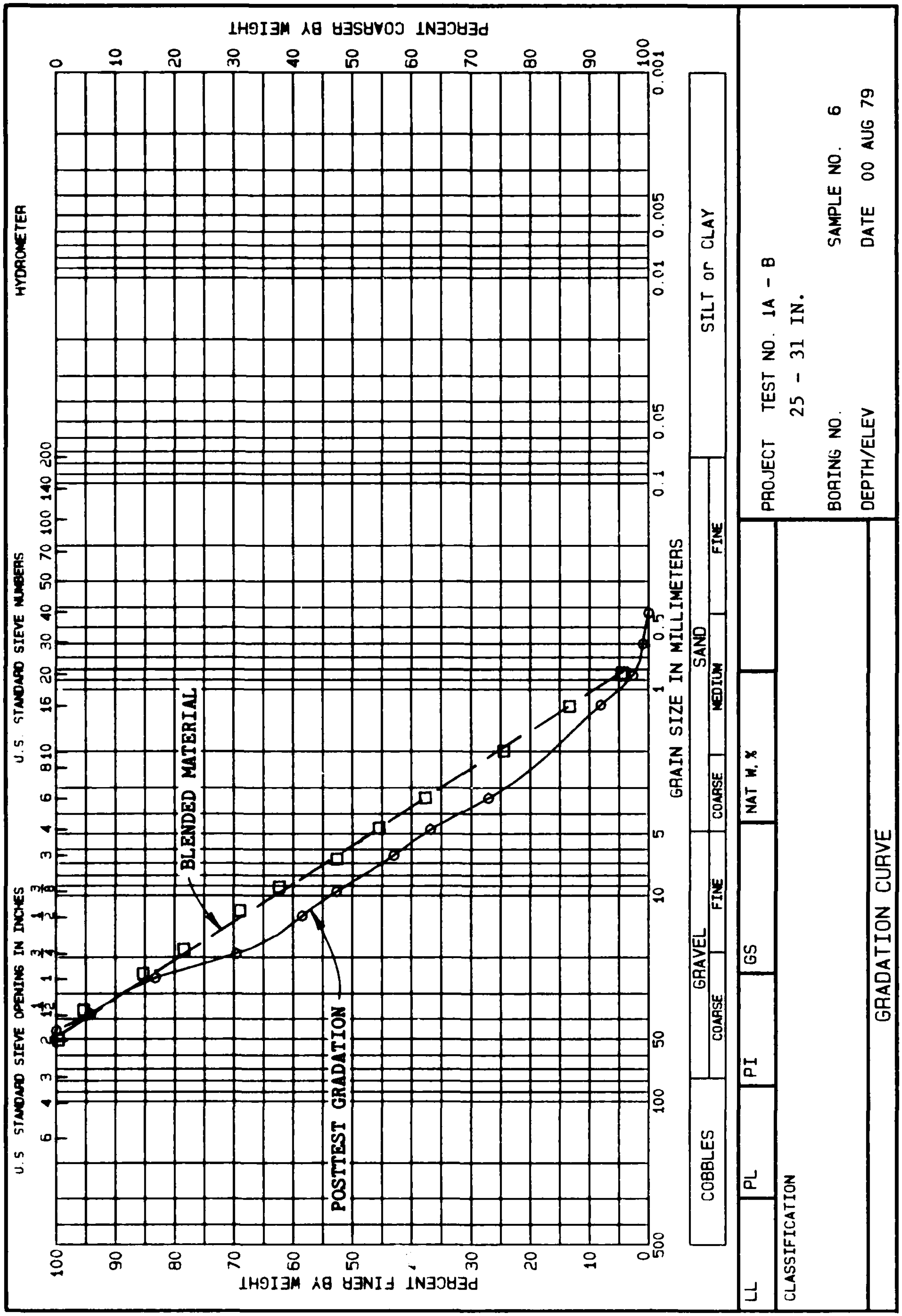
31 - 37 IN.

BORING NO

SAMPLE NO 5

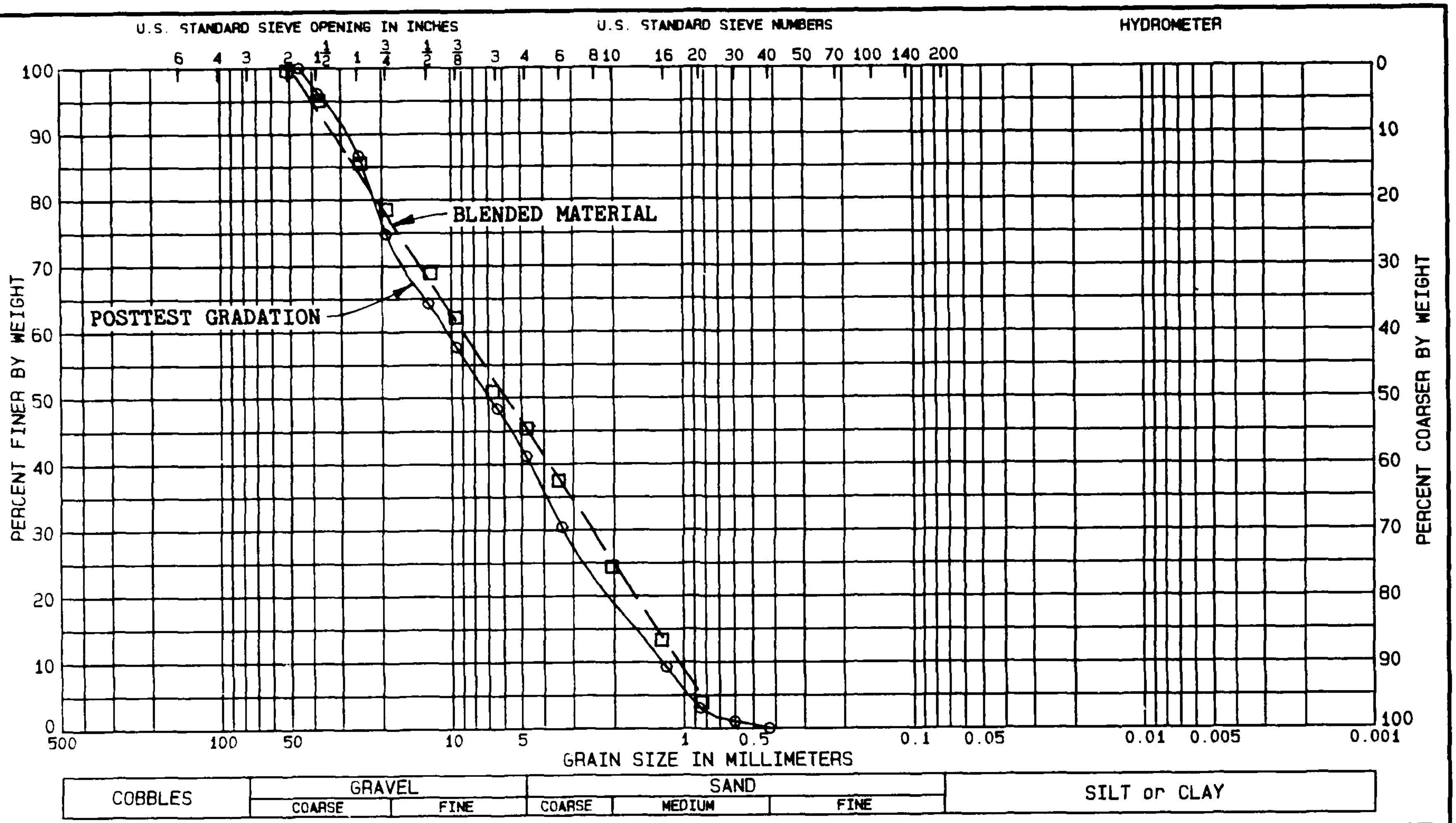
DEPTH/ELEV

DATE AUG 79



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1½ 1 ¾ ½ ⅜ 3 4 6 8 10 16 20 30 40 50 70 100 140 200
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
BLENDED MATERIAL
POSTTEST GRADATION
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1A - B
25 - 31 IN.
BORING NO.
SAMPLE NO. 6
DEPTH/ELEV
DATE 00 AUG 79
GRADATION CURVE

PLATE D16



LL	PL	PI	GS	NAT W, %	

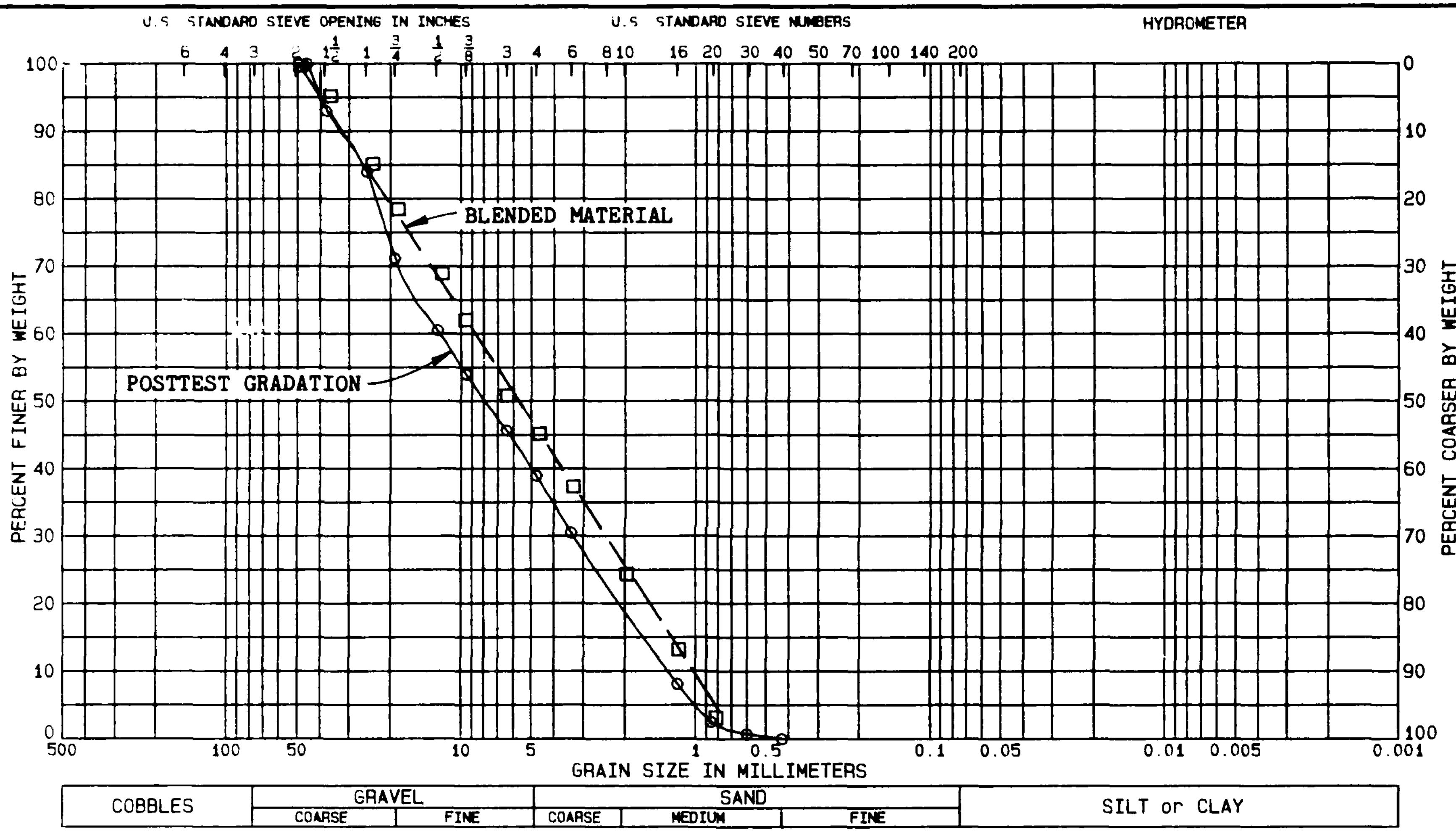
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1A - B
19 - 25 IN.

BORING NO. SAMPLE NO. 7

DEPTH/ELEV DATE 00 AUG 79



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

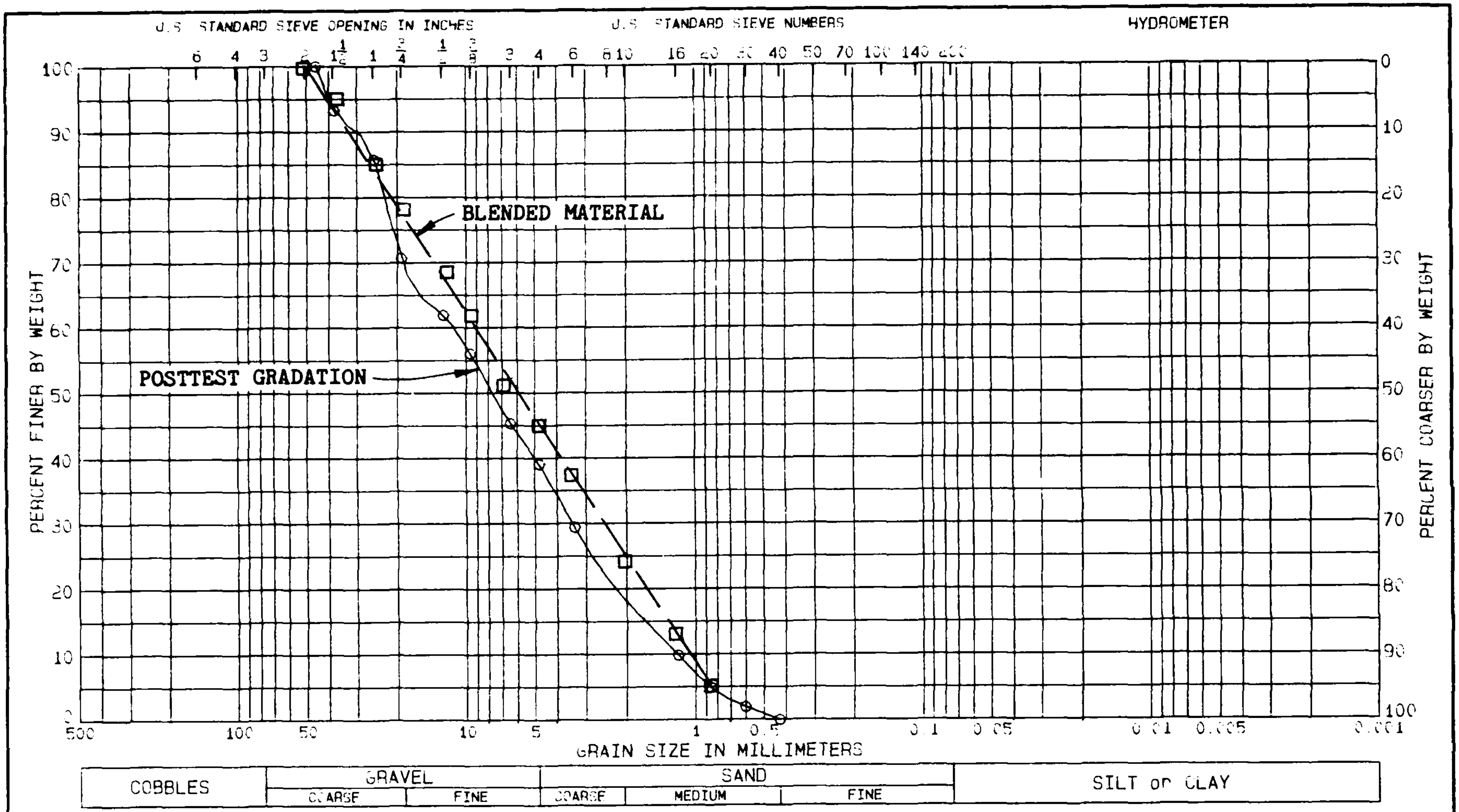
GRADATION CURVE

PROJECT TEST NO. 1A - B
13 - 19 IN.

BORING NO.
SAMPLE NO. 8

DEPTH/ELEV
DATE 00 AUG 79

PLATE D18



LL	PL	PI	GS	NAT W. %	
CLASSIFICATION					

PROJECT TEST NO. 1A - B
7 - 13 IN.

BORING NO. SAMPLE NO. 9

DEPTH/ELEV DATE 00 AUG 79

GRADATION CURVE

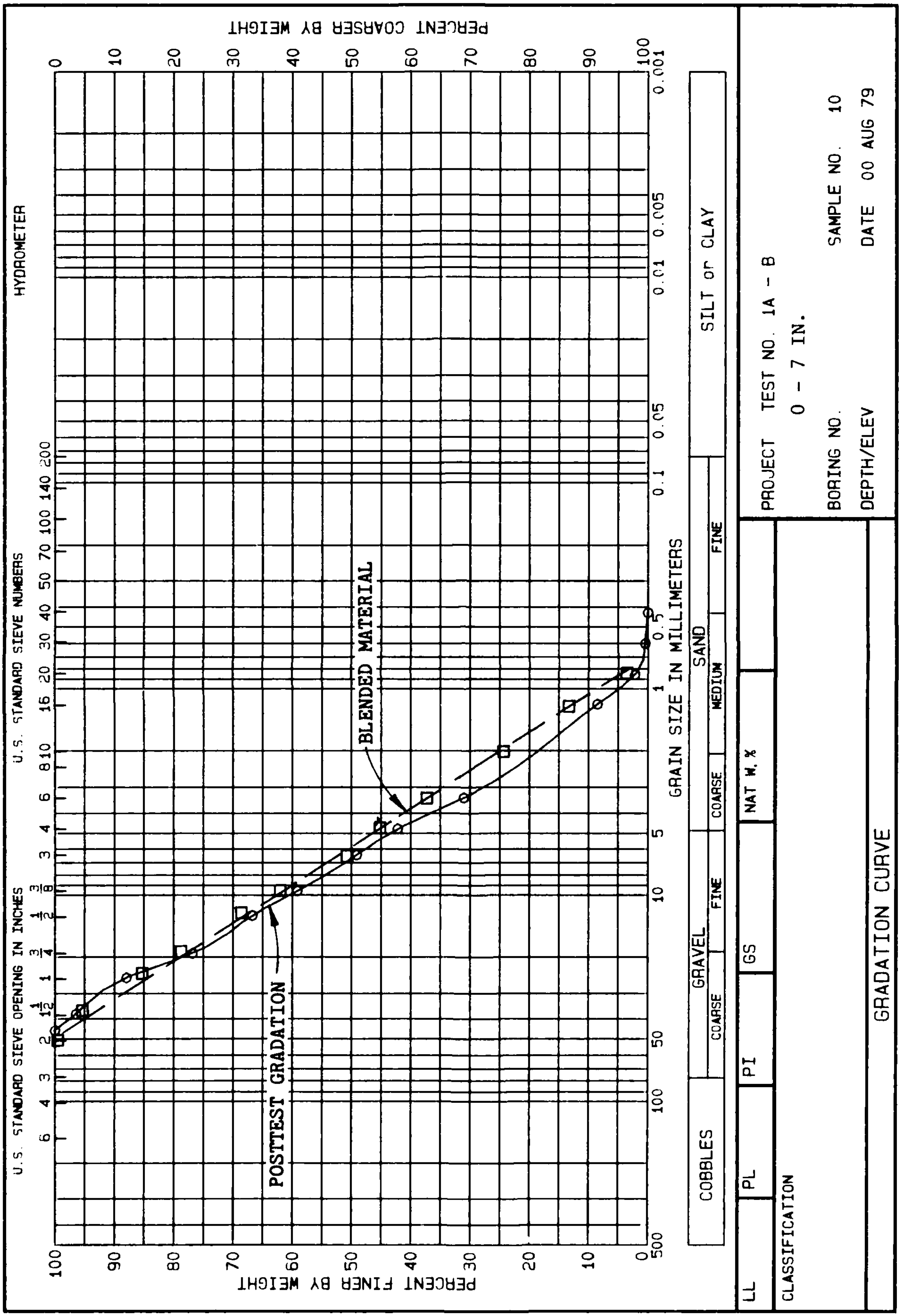
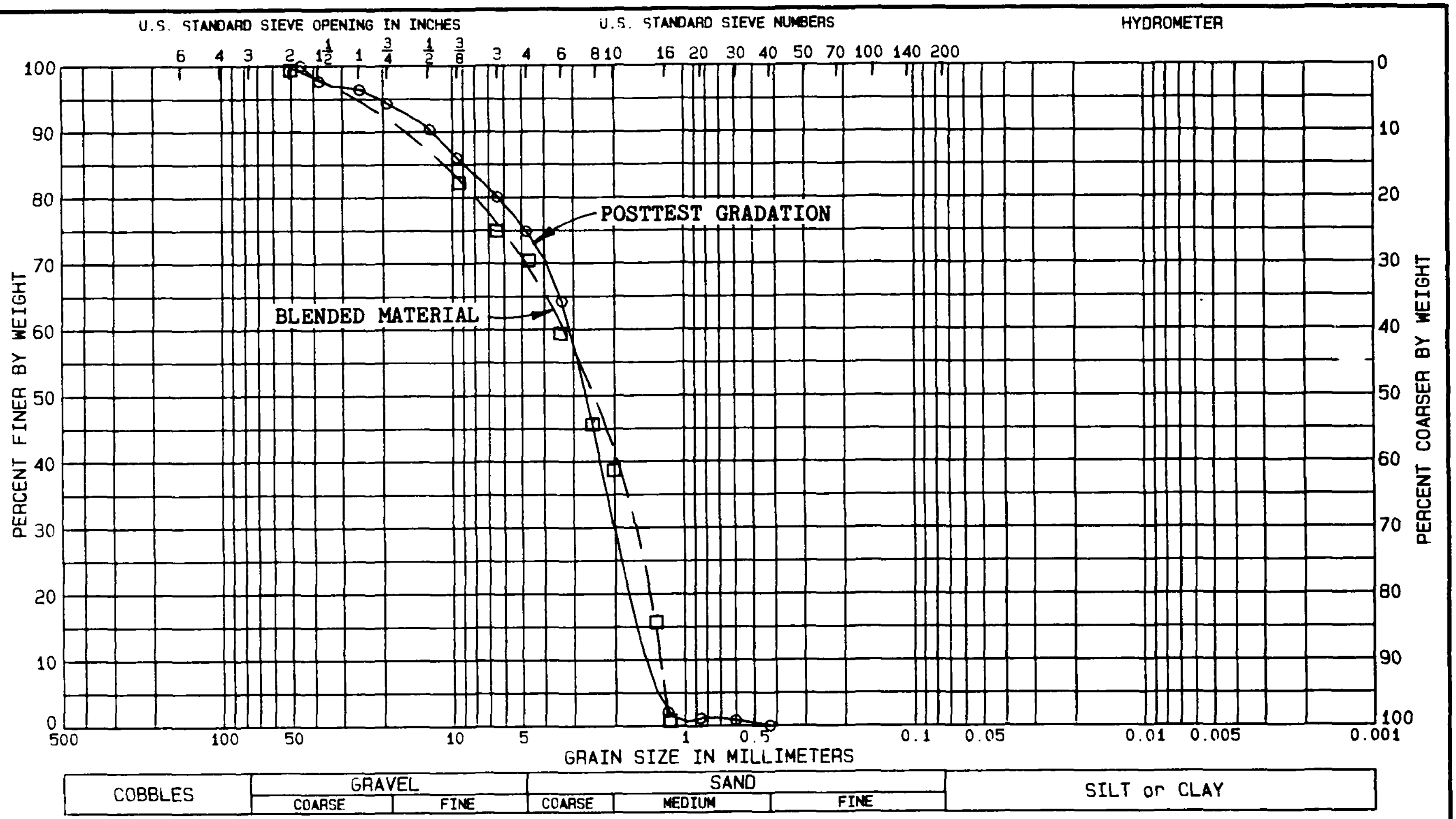
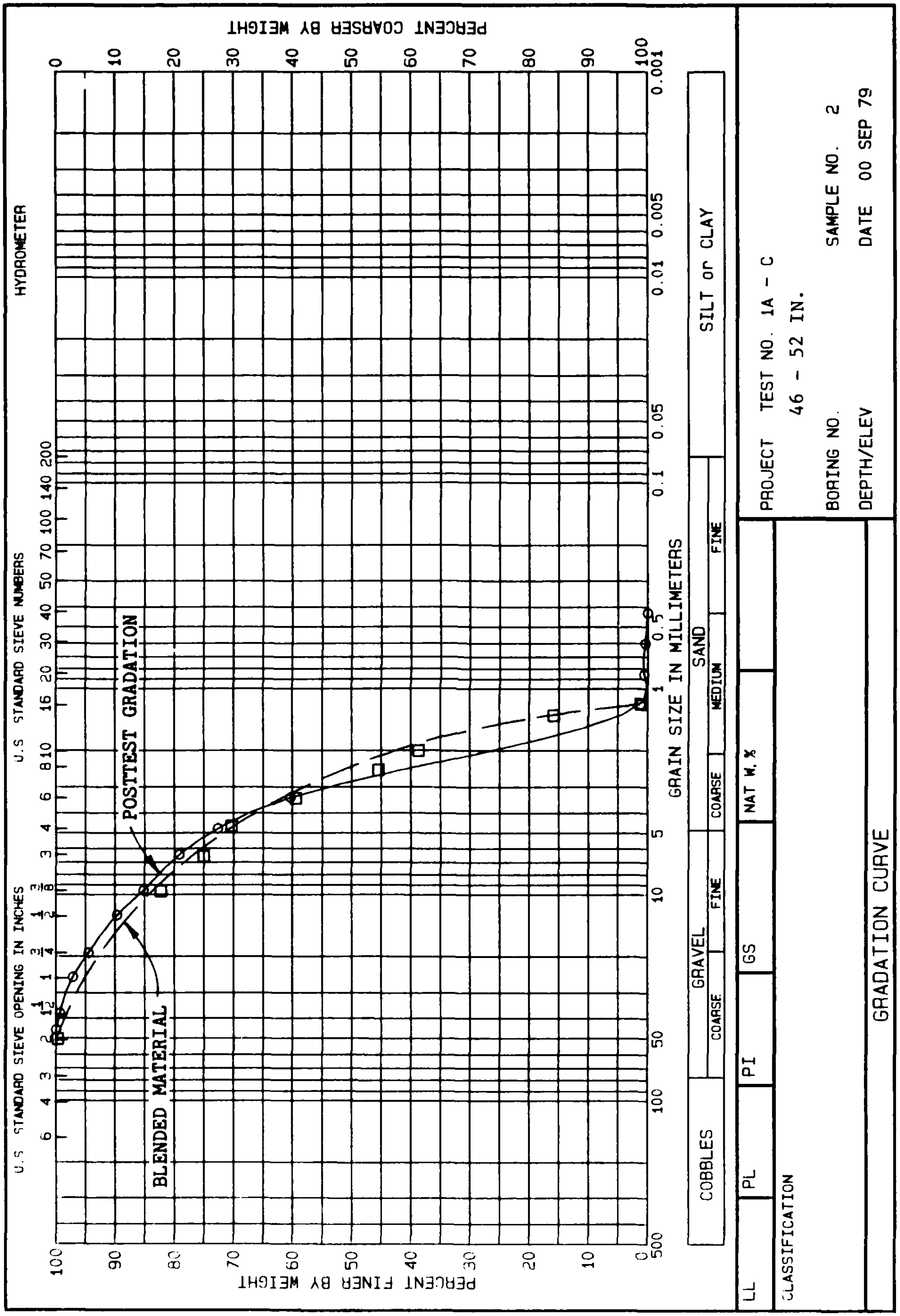

PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1A - B
0 - 7 IN.
BORING NO.
SAMPLE NO. 10
DEPTH/ELEV
DATE 00 AUG 79
GRADATION CURVE

PLATE D20

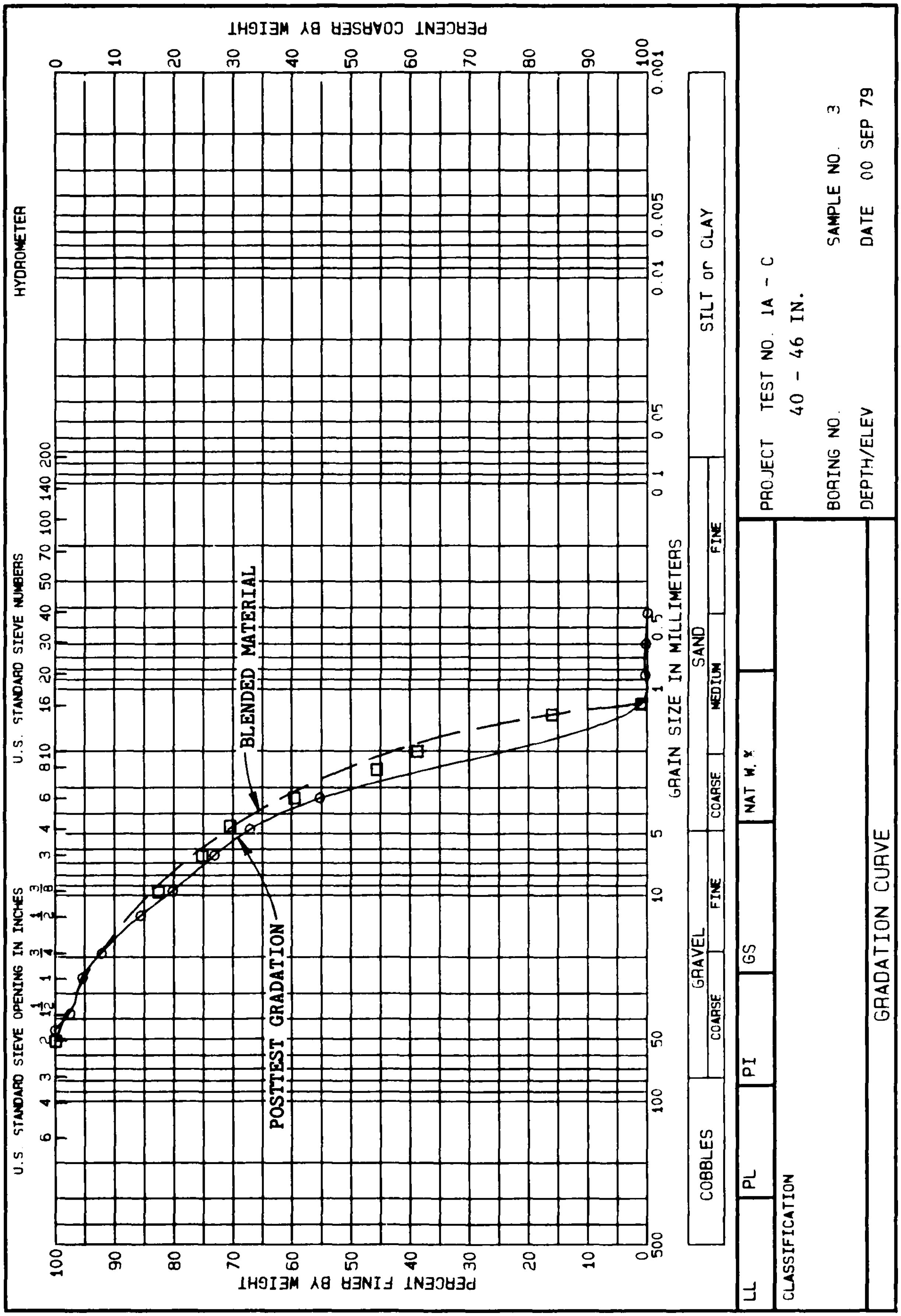


LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 1A - C 52 - 58 IN.
CLASSIFICATION						BORING NO. SAMPLE NO. 1
						DEPTH/ELEV DATE 00 SEP 79
GRADATION CURVE						



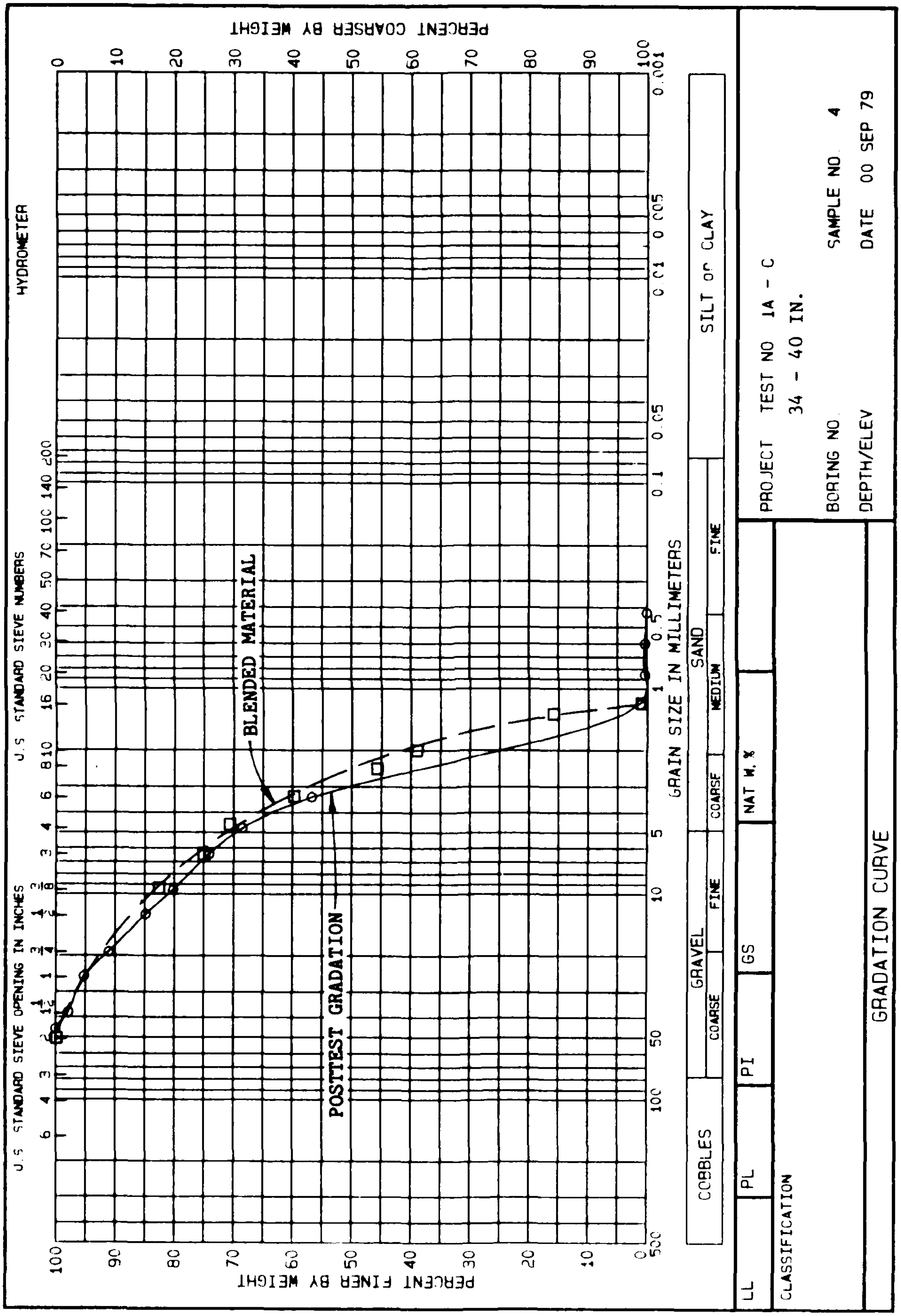
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1A - C
46 - 52 IN.
BORING NO.
SAMPLE NO. 2
DEPTH/ELEV
DATE 00 SEP 79
GRADATION CURVE

PLATE D22



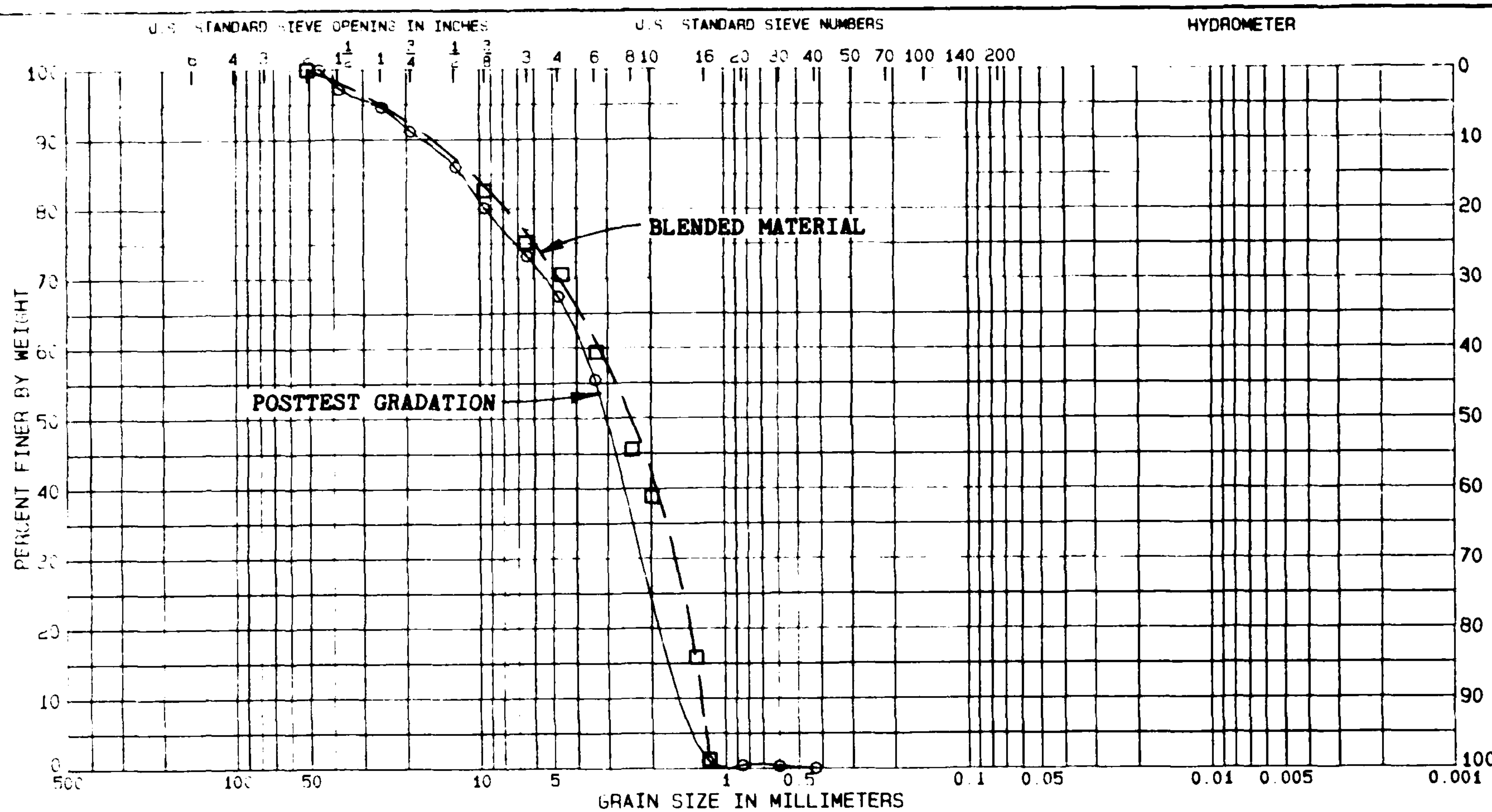
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1A - C
40 - 46 IN.
BORING NO.
SAMPLE NO. 3
DEPTH/ELEV
DATE 00 SEP 79
GRADATION CURVE

PLATE D23



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO 1A - C
34 - 40 IN.
BORING NO
SAMPLE NO 4
DEPTH/ELEV
DATE 00 SEP 79
GRADATION CURVE

PLATE D24



COBBLES	GRAVEL		SAND			SILT or CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LL	PL	PI	GS	NAT W, %	

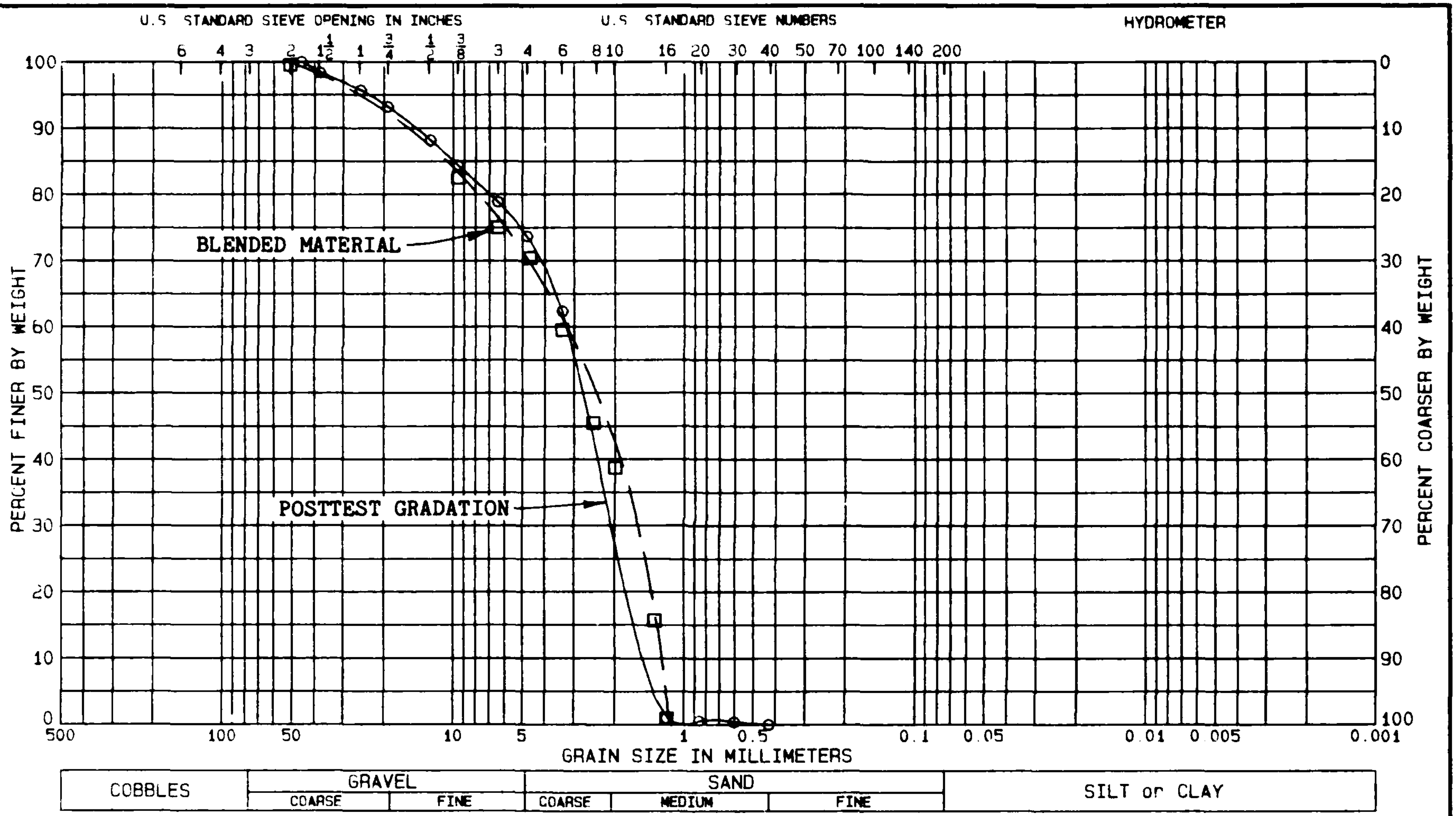
CLASSIFICATION

PROJECT TEST NO. 1A - C
28 - 34 IN.

BORING NO.　　SAMPLE NO. 5

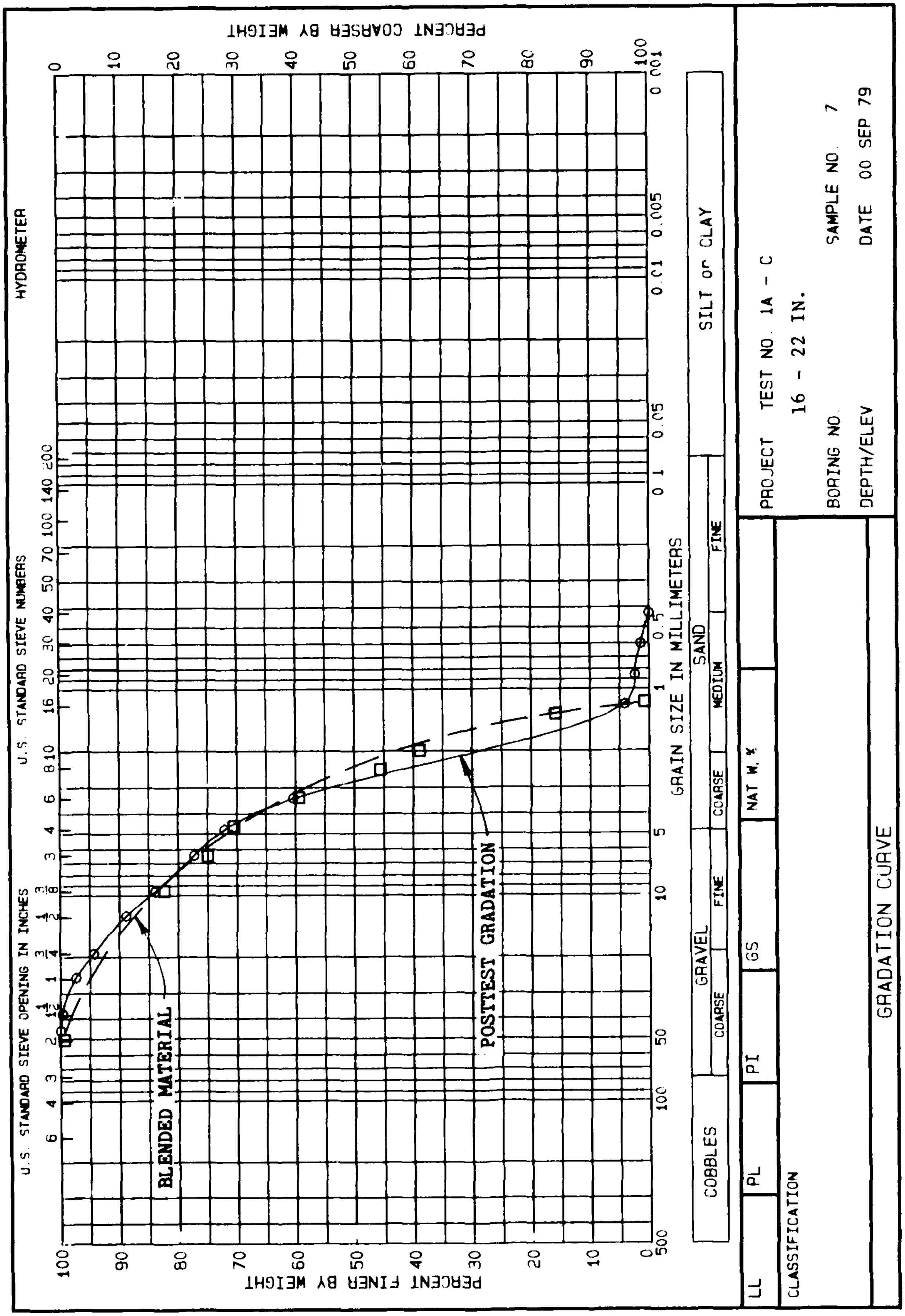
DEPTH/ELEV　　DATE 00 SEP 79

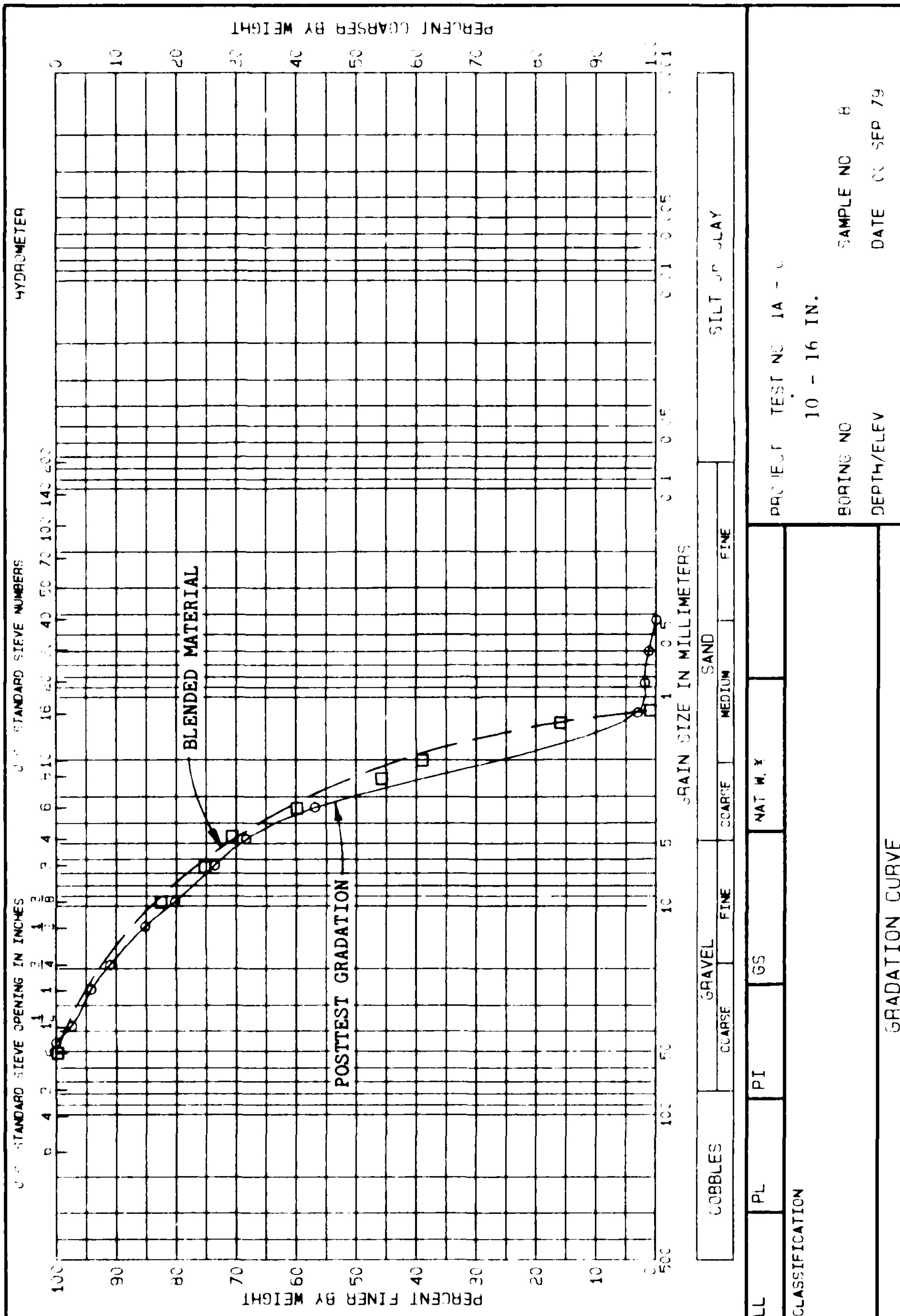
GRADATION CURVE



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 1A - C 22 - 28 IN.
CLASSIFICATION						BORING NO. SAMPLE NO. 6
						DEPTH/ELEV DATE 00 SEP 79
GRADATION CURVE						

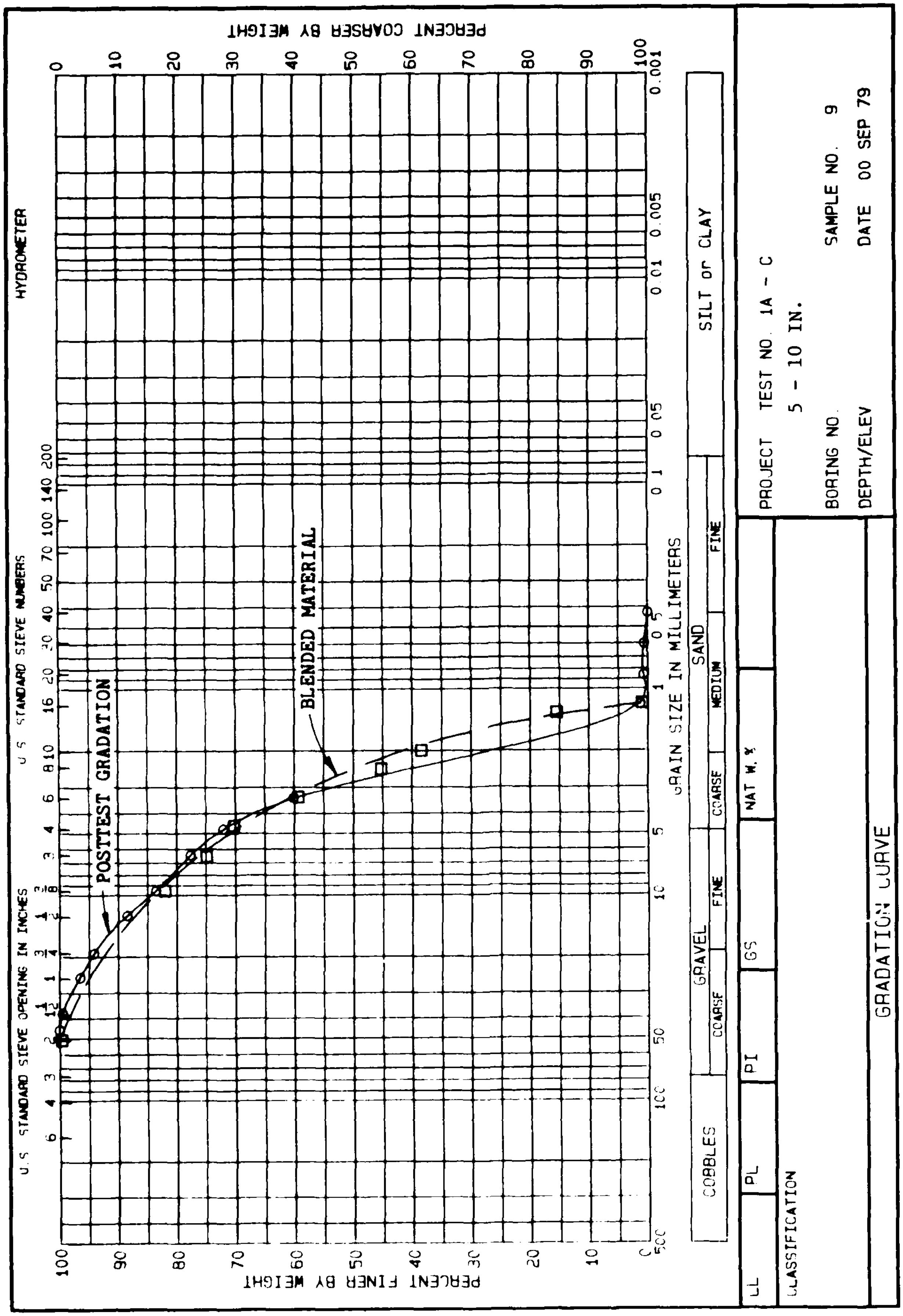
PLATE D26


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W %
CLASSIFICATION
PROJECT TEST NO. 1A - C
16 - 22 IN.
BORING NO.
SAMPLE NO. 7
DEPTH/ELEV
DATE 00 SEP 79
GRADATION CURVE



PERCENT COARSER BY WEIGHT
HYDROMETER
STANDARD SIEVE NUMBERS
STANDARD SIEVE OPENING IN INCHES
BLENDED MATERIAL
POSTTEST GRADATION
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
10 - 16 IN.
BORING NO
SAMPLE NO
DEPTH/ELEV
DATE
SEP 79
LL
PL
PI
GS
NAT W %
CLASSIFICATION
GRADATION CURVE

PLATE D28



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
POSTTEST GRADATION
BLENDED MATERIAL
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W %
CLASSIFICATION
PROJECT TEST NO. 1A - C
5 - 10 IN.
BORING NO.
SAMPLE NO. 9
DEPTH/ELEV
DATE 00 SEP 79
GRADATION CURVE

PLATE D29

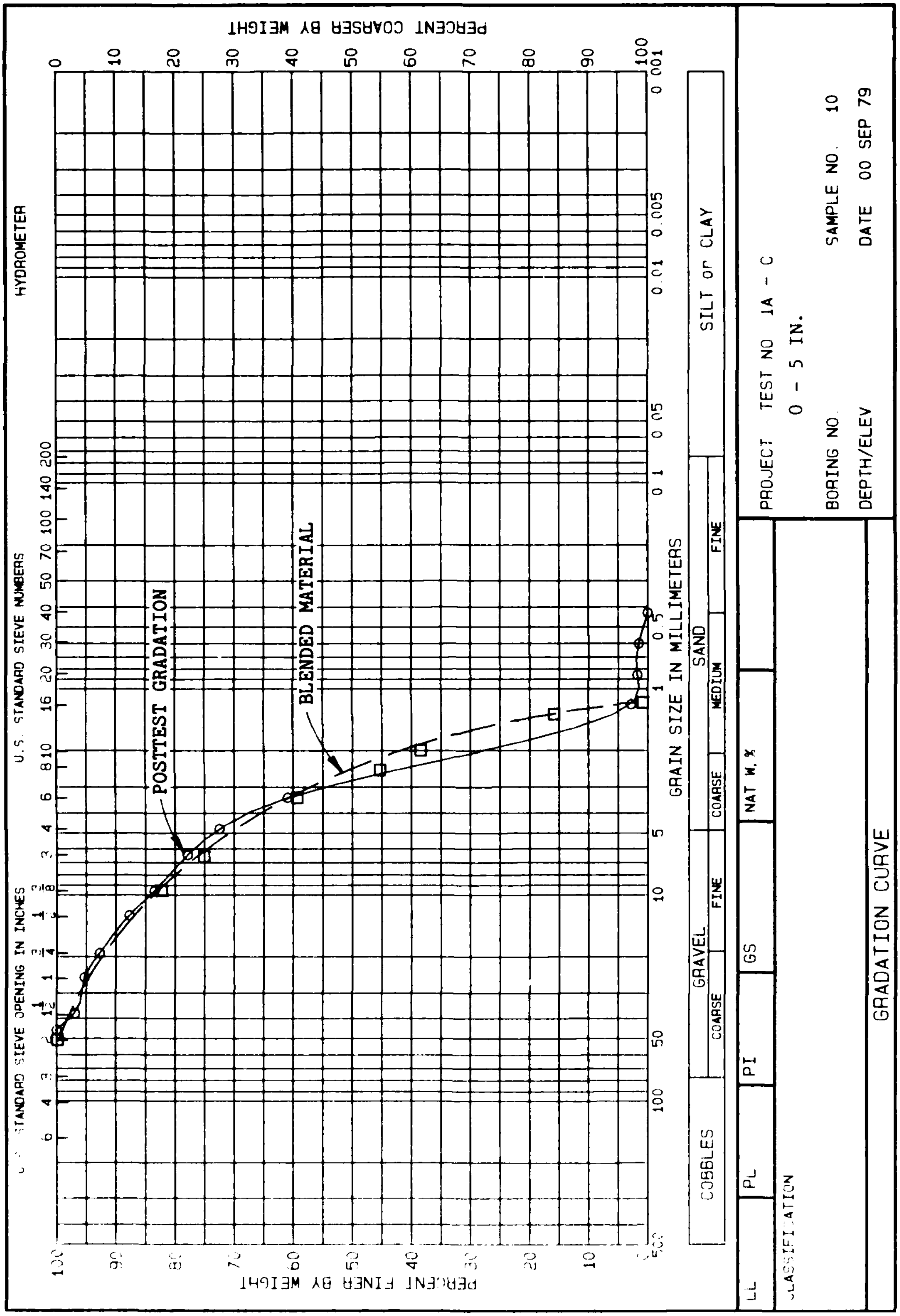
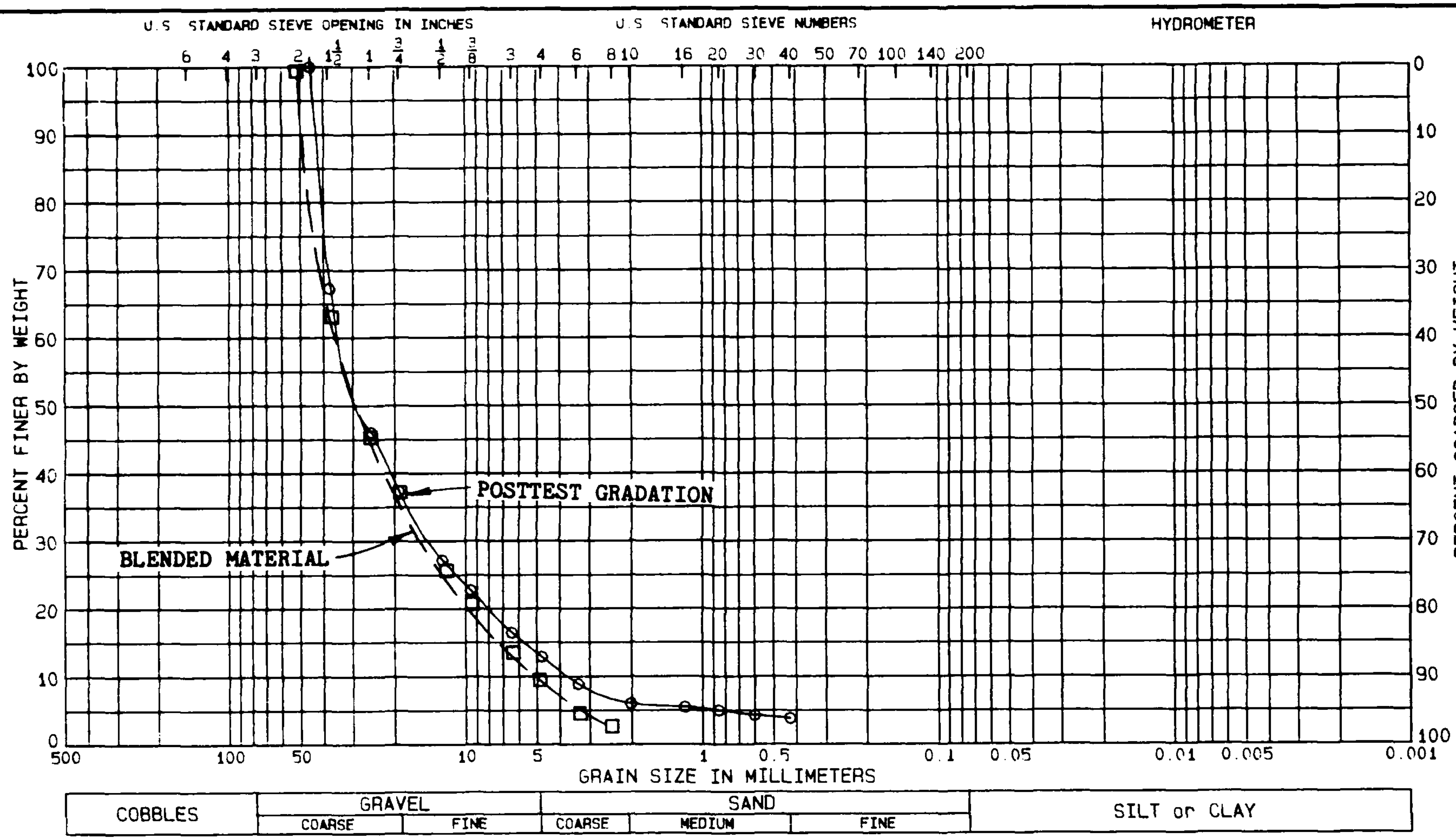

PERCENT COARSER BY WEIGHT
HYDROMETER
U.S. STANDARD SIEVE NUMBERS
U.S. STANDARD SIEVE OPENING IN INCHES
POSTTEST GRADATION
BLENDED MATERIAL
GRAIN SIZE IN MILLIMETERS
PERCENT FINER BY WEIGHT
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
CLASSIFICATION
PROJECT TEST NO 1A - C
0 - 5 IN.
BORING NO.
SAMPLE NO. 10
DEPTH/ELEV
DATE 00 SEP 79
GRADATION CURVE

PLATE D30



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

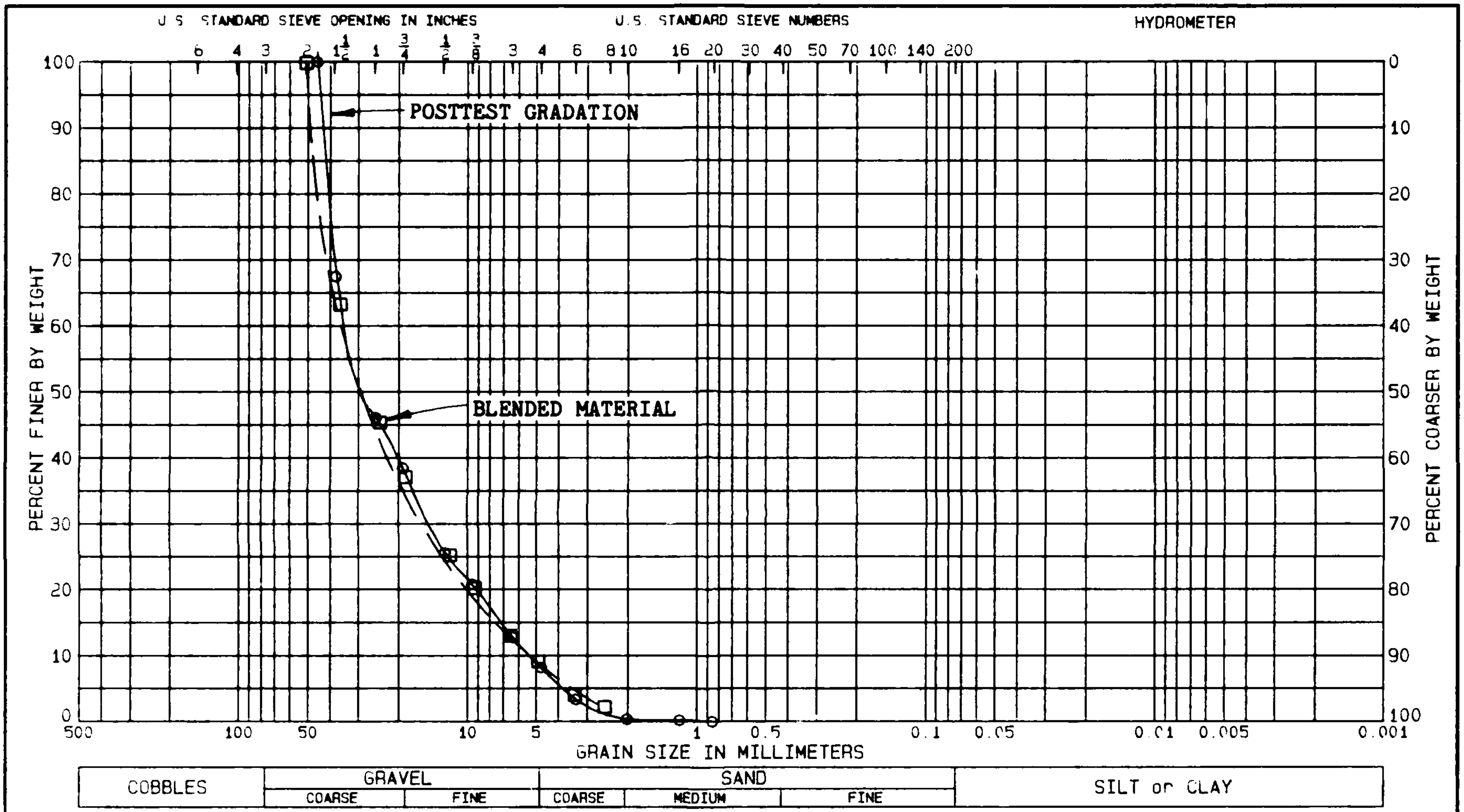
PROJECT TEST NO. 1B - A

50 - 57 IN.

BORING NO. SAMPLE NO. 1

DEPTH/ELEV DATE 00 APR 80

PLATE D31



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

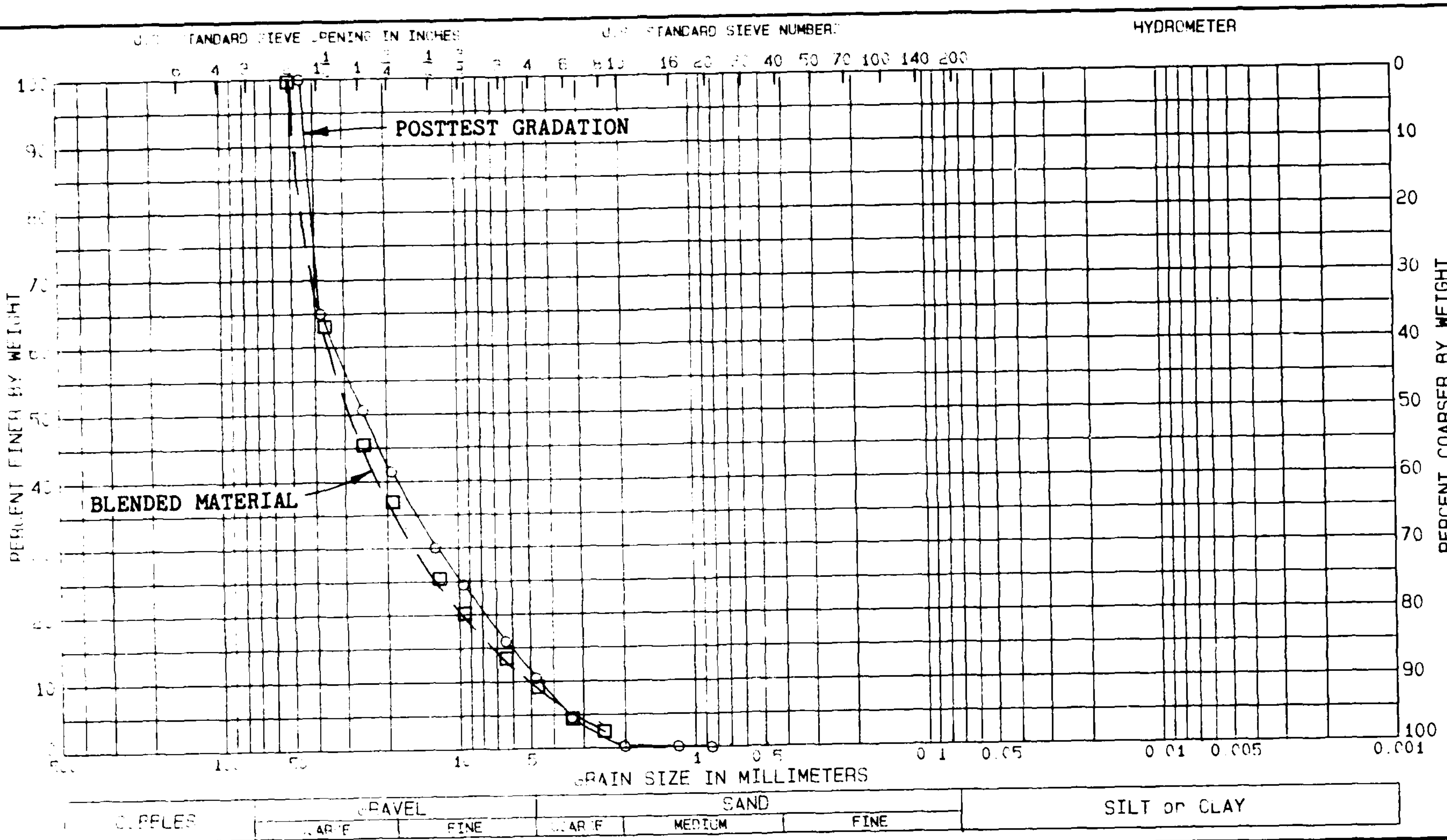
GRADATION CURVE

PROJECT TEST NO. 1B - A
44 - 50 IN.

BORING NO. SAMPLE NO. 2

DEPTH/ELEV DATE 00 APR 80

PLATE D32



LL	PL	PI		NAT W, %	

CLASSIFICATION

GRADATION CURVE

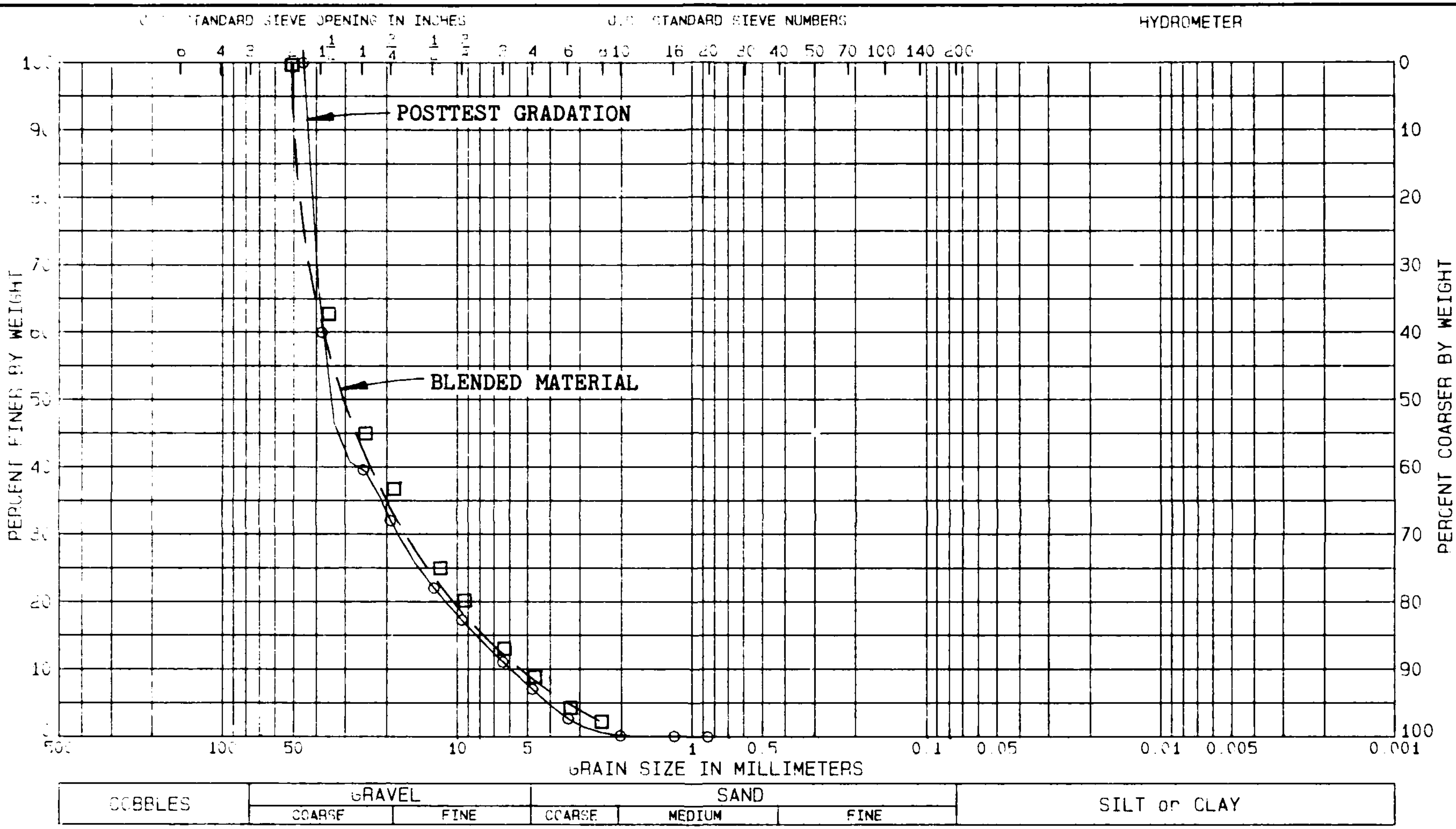
PROJECT TEST NO. 1B - A
38 - 44 IN.

BORING NO.

SAMPLE NO. 3

DEPTH/ELEV

DATE 00 APR 80



LL	PL	PI	GS	NAT W. %	

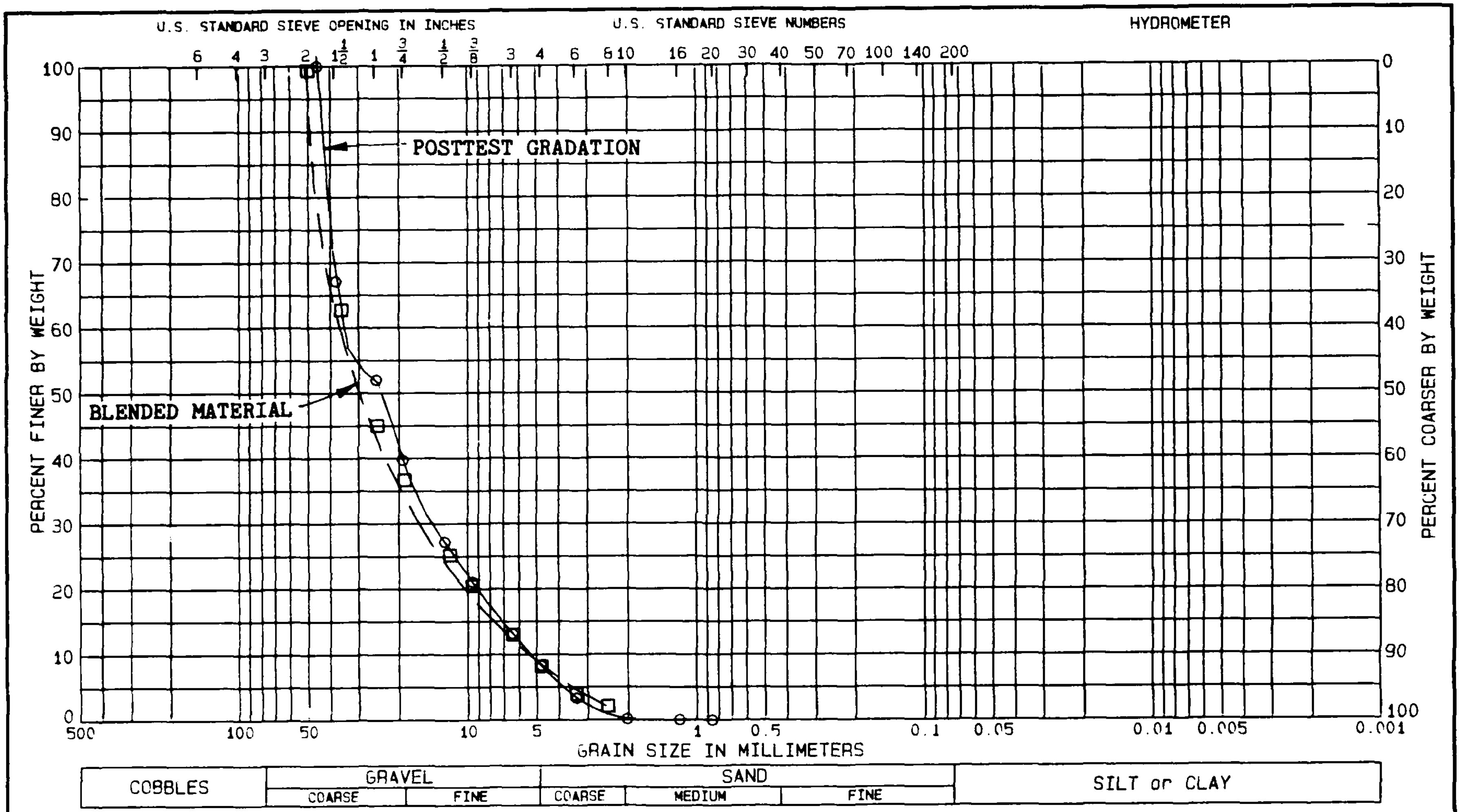
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1B - A
30 - 38 IN.

BORING NO. SAMPLE NO. 4

DEPTH/ELEV DATE 00 APR 80



LL	PL	PI	GS	NAT W, %	

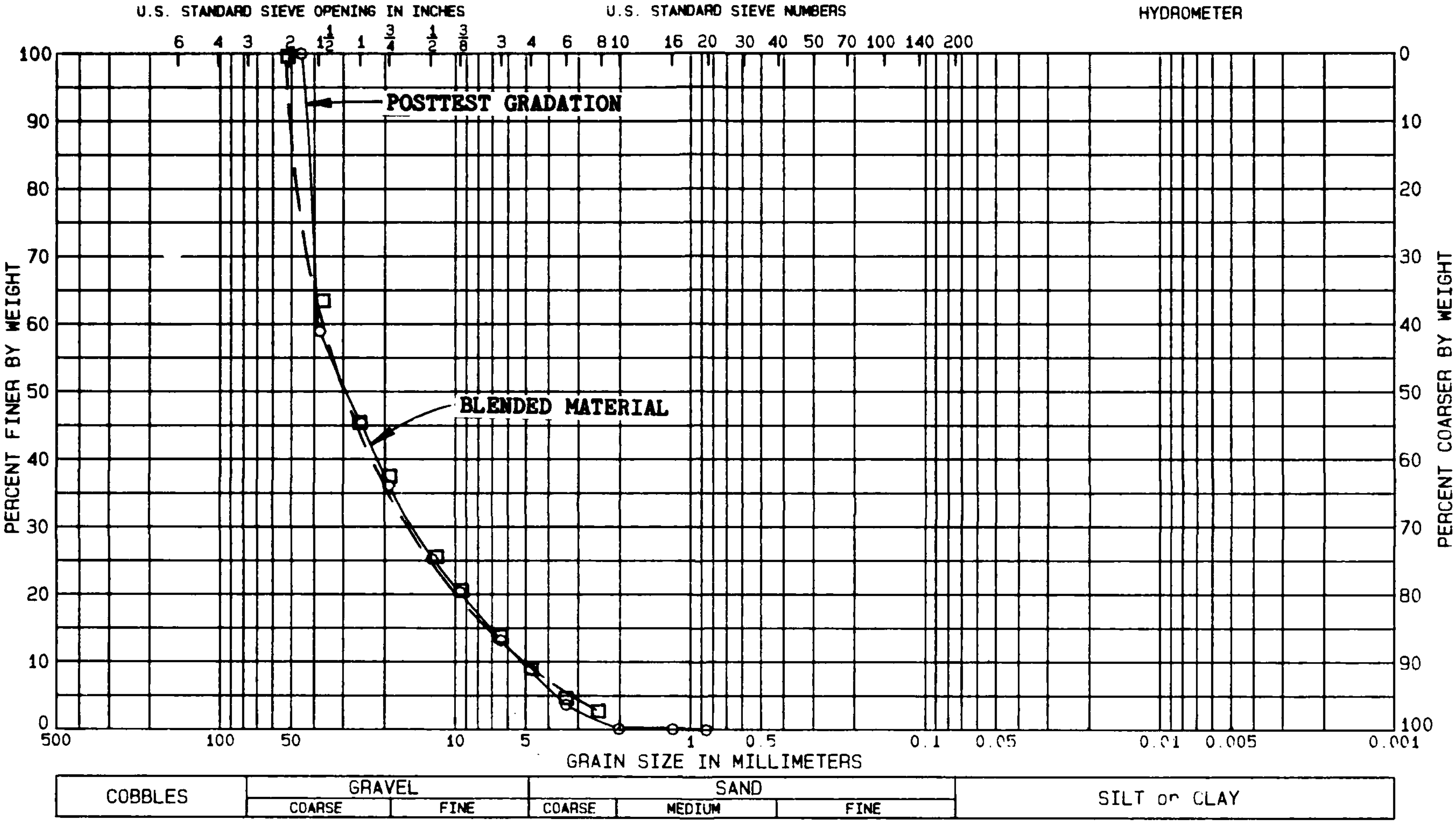
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1B - A
22 - 30 IN.

BORING NO. SAMPLE NO. 5

DEPTH/ELEV DATE 00 APR 80



LL	PL	PI	GS	NAT W, %	

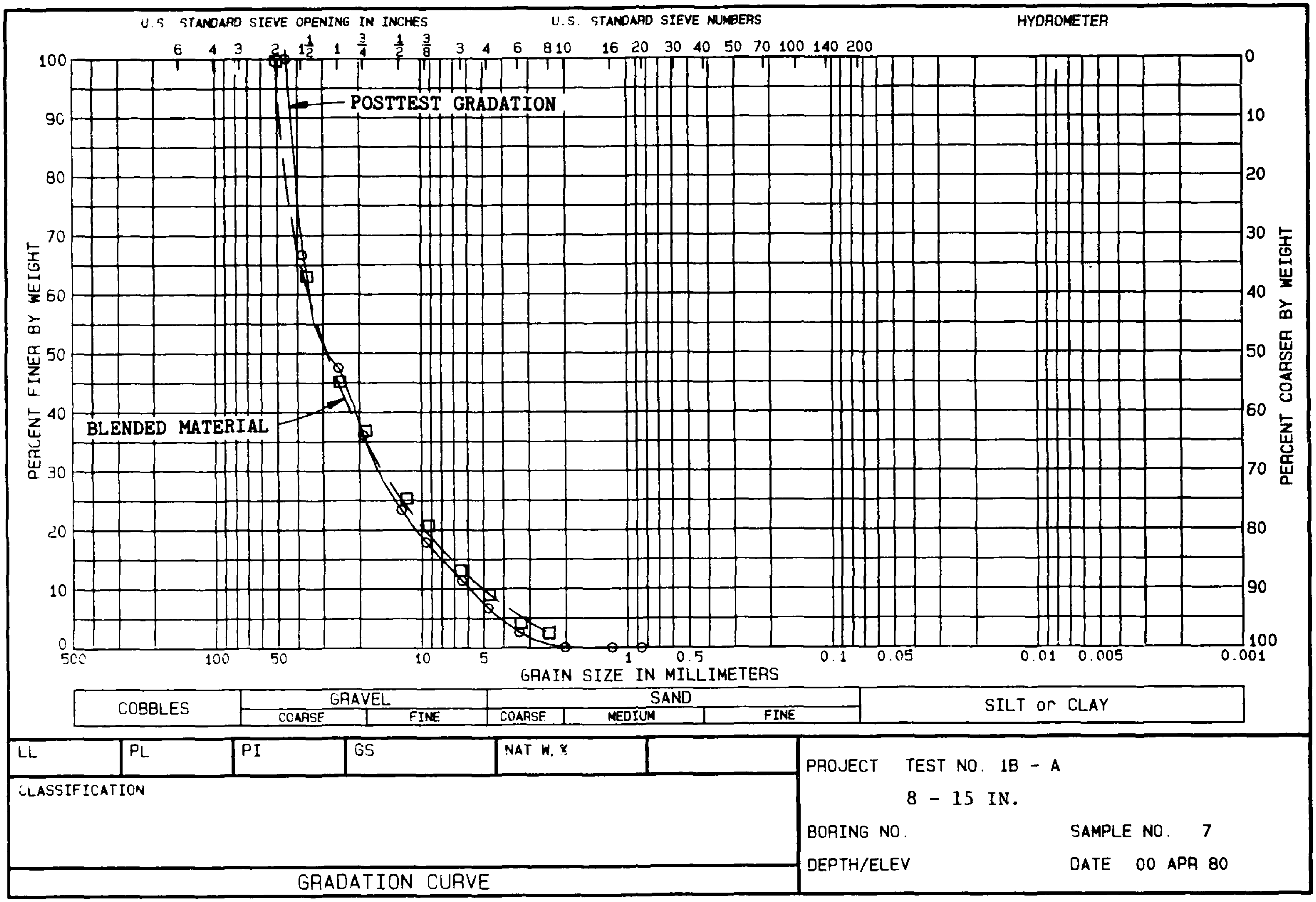
CLASSIFICATION

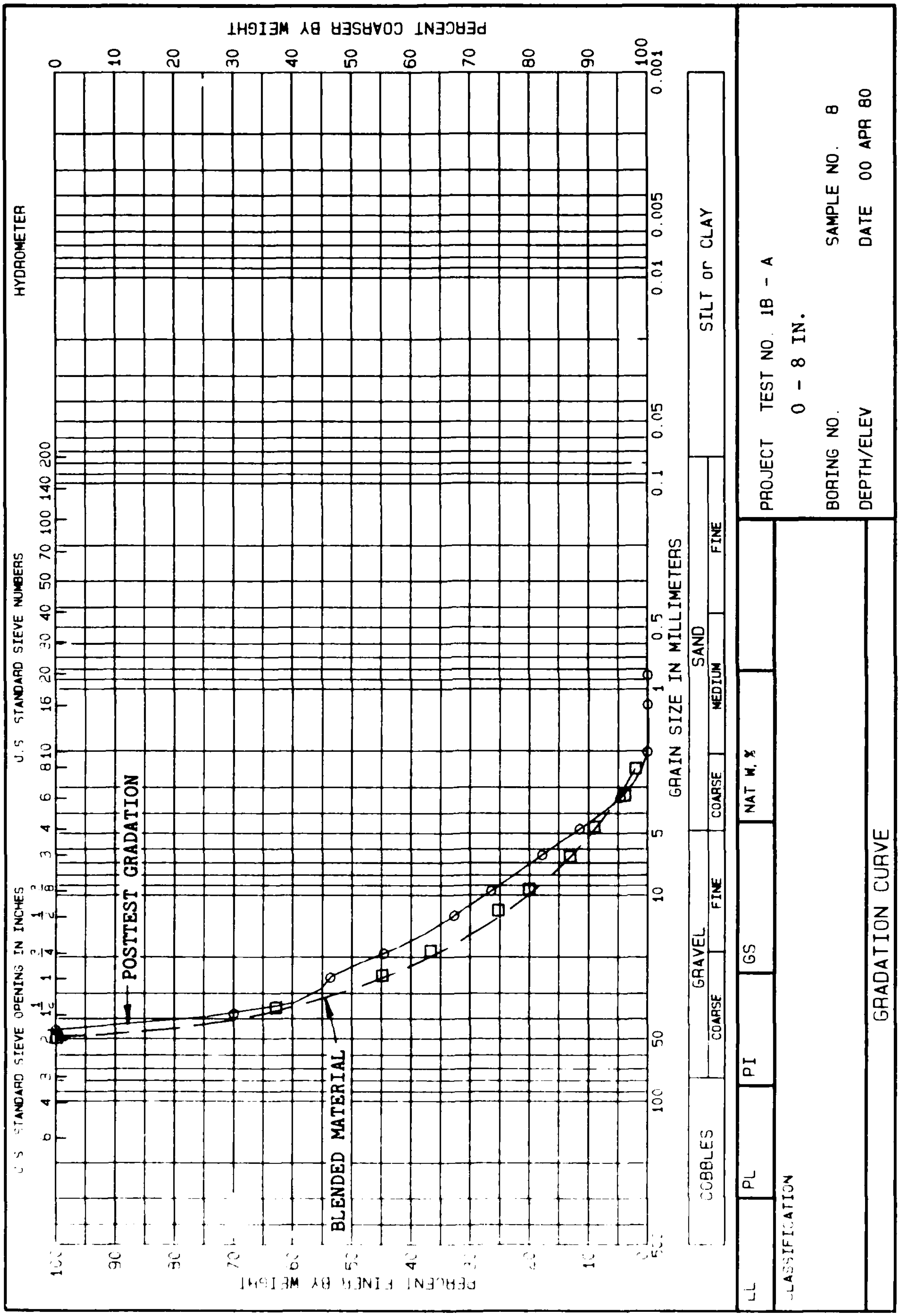
GRADATION CURVE

PROJECT TEST NO. 1B - A
15 - 22 IN.

BORING NO. SAMPLE NO. 6

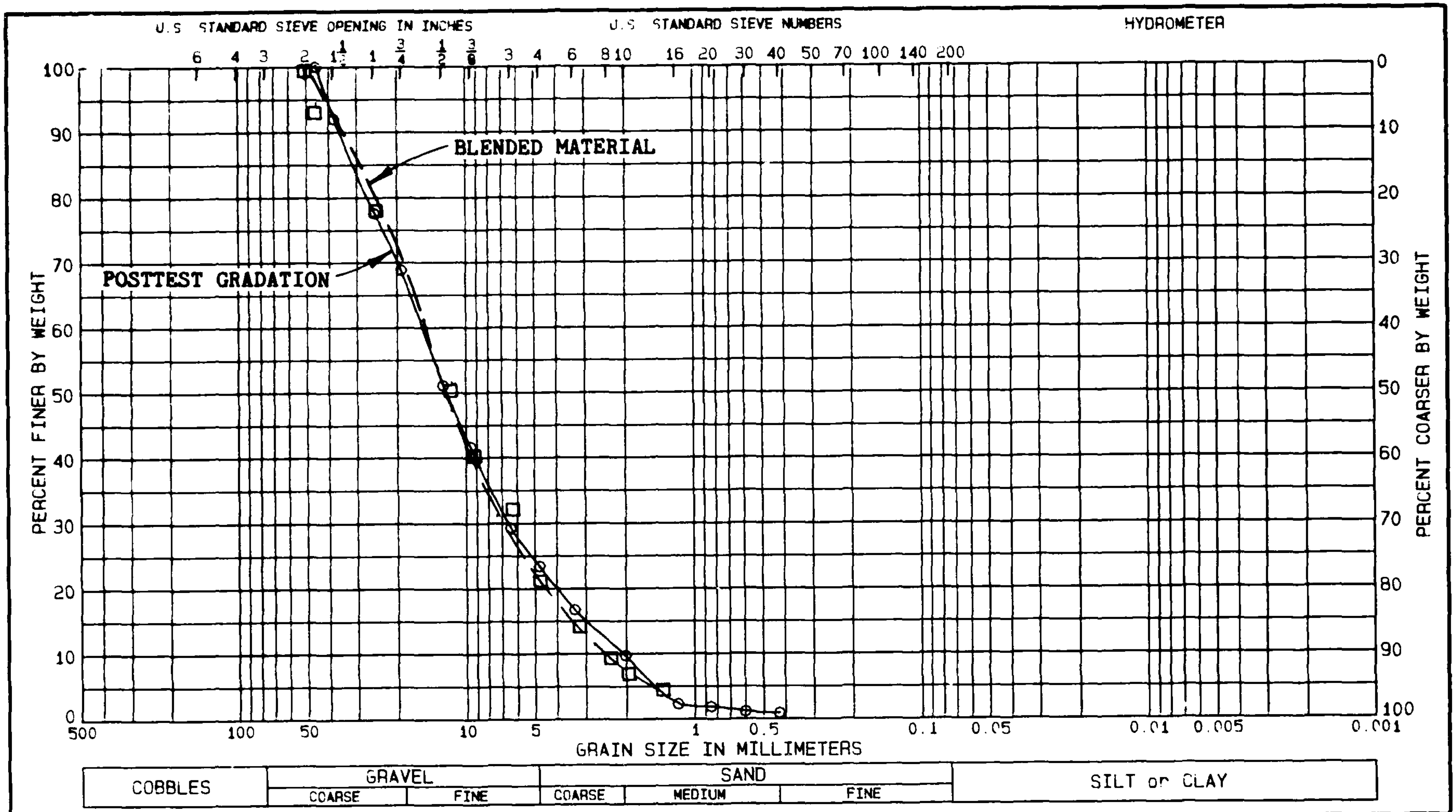
DEPTH/ELEV DATE 00 APR 80


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
POSTTEST GRADATION
BLENDED MATERIAL
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
GRADATION CURVE
PROJECT TEST NO. 1B - A
8 - 15 IN.
BORING NO.
SAMPLE NO. 7
DEPTH/ELEV
DATE 00 APR 80



PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
CLASSIFICATION
PROJECT TEST NO. 1B - A
0 - 8 IN.
BORING NO.
SAMPLE NO. 8
DEPTH/ELEV
DATE 00 APR 80
GRADATION CURVE

PLATE D38



LL	PL	PI	GS	NAT W. %	
CLASSIFICATION					

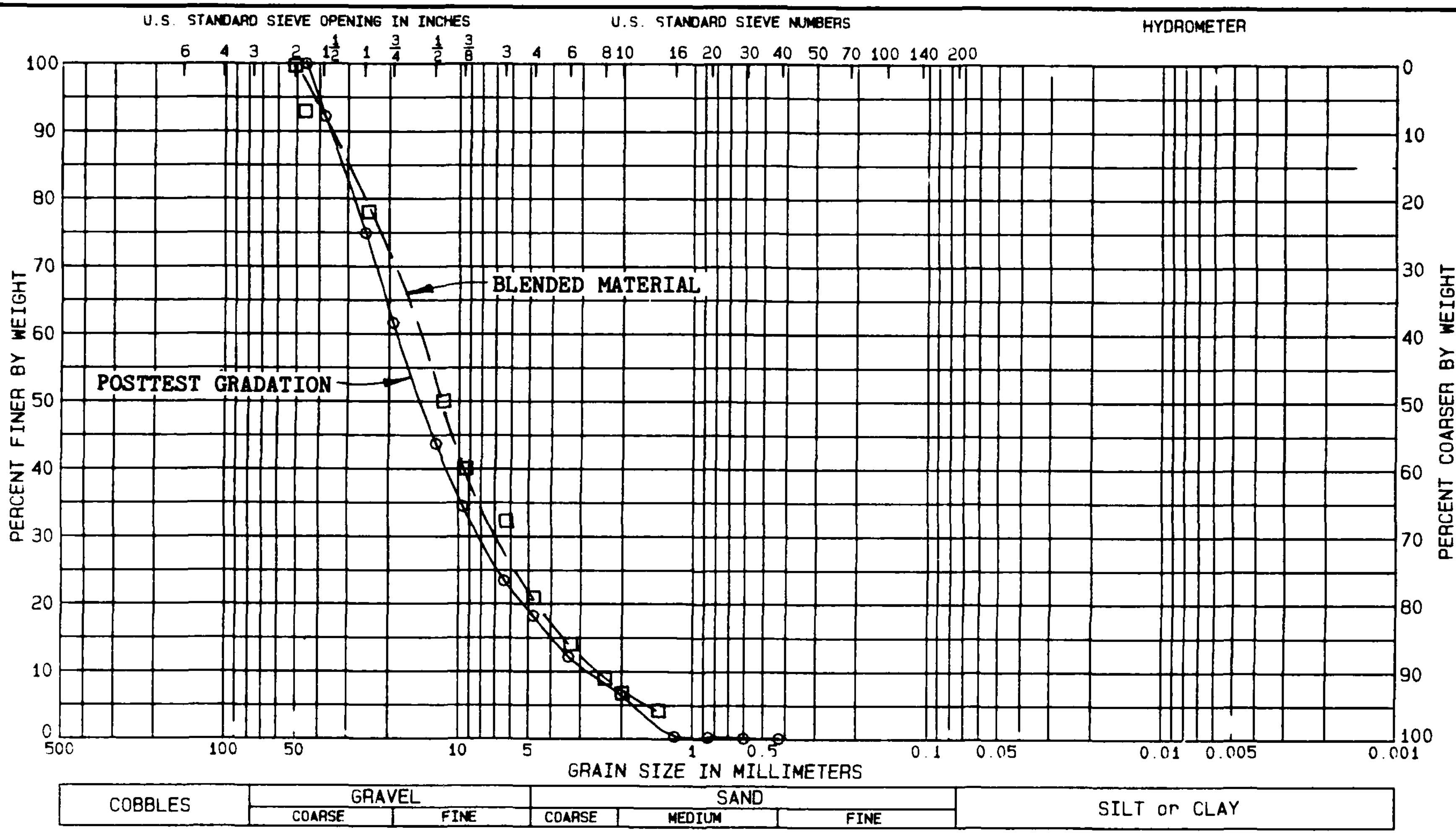
PROJECT TEST NO. 1B - B
52 - 58 IN.

BORING NO. SAMPLE NO. 1

DEPTH/ELEV DATE 00 MAR 80

GRADATION CURVE

PLATE D39



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

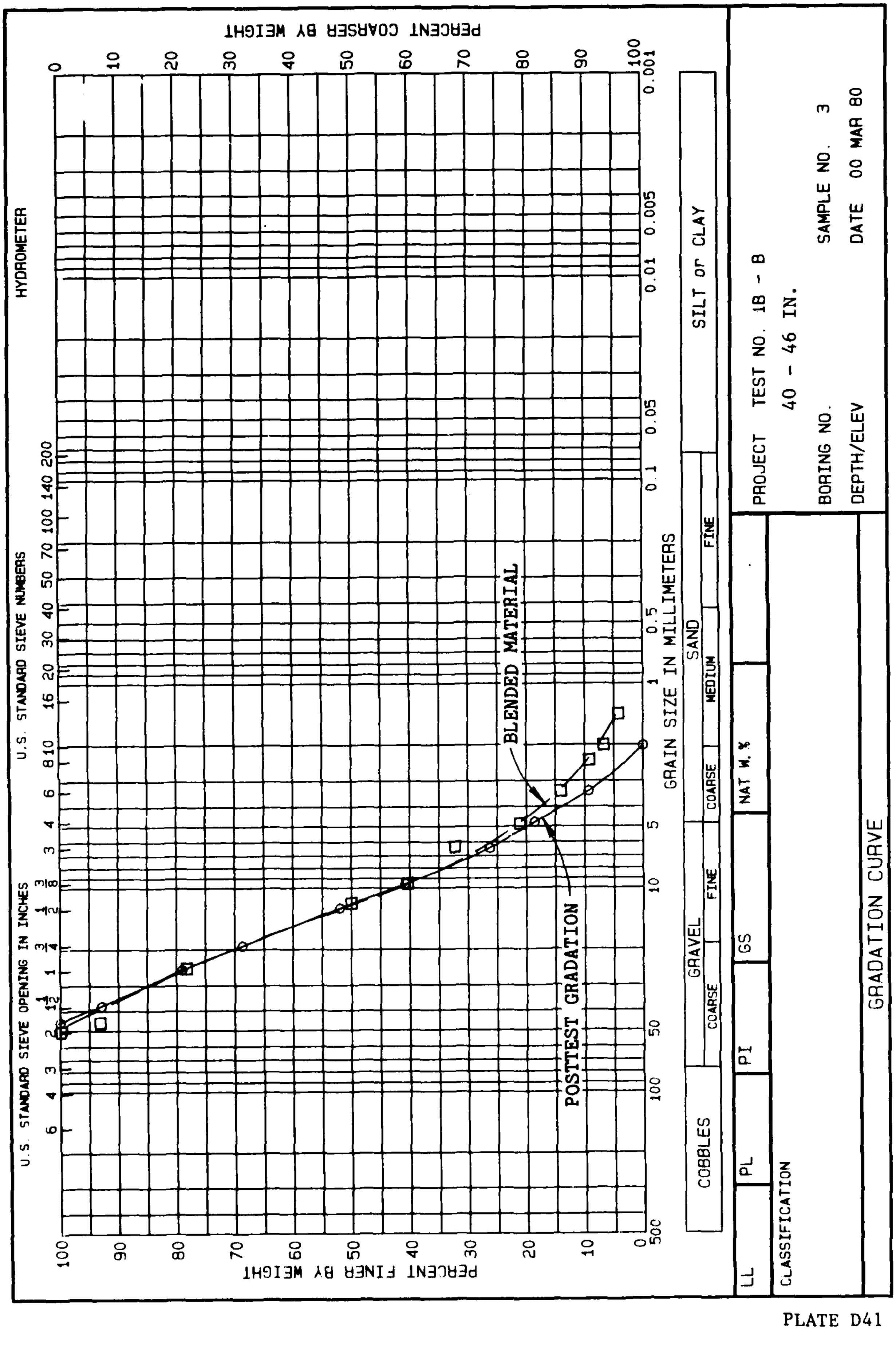
GRADATION CURVE

PROJECT TEST NO. 1B - B
46 - 52 IN.

BORING NO. SAMPLE NO. 2

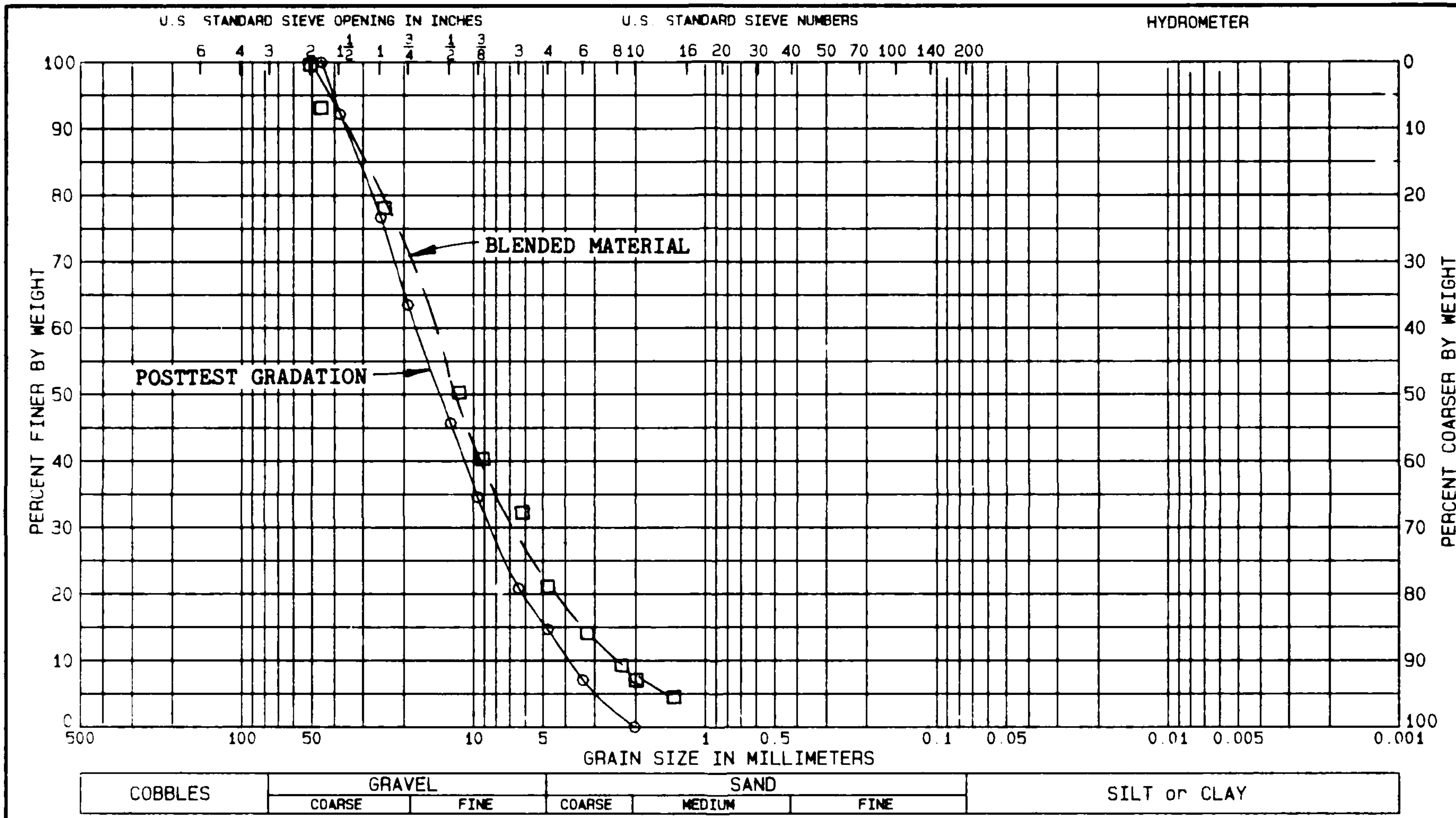
DEPTH/ELEV DATE 00 MAR 80

PLATE D40



PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W. %
CLASSIFICATION
PROJECT TEST NO. 1B - B
40 - 46 IN.
BORING NO.
SAMPLE NO. 3
DEPTH/ELEV
DATE 00 MAR 80
GRADATION CURVE

PLATE D41



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1B - B
34 - 40 IN.

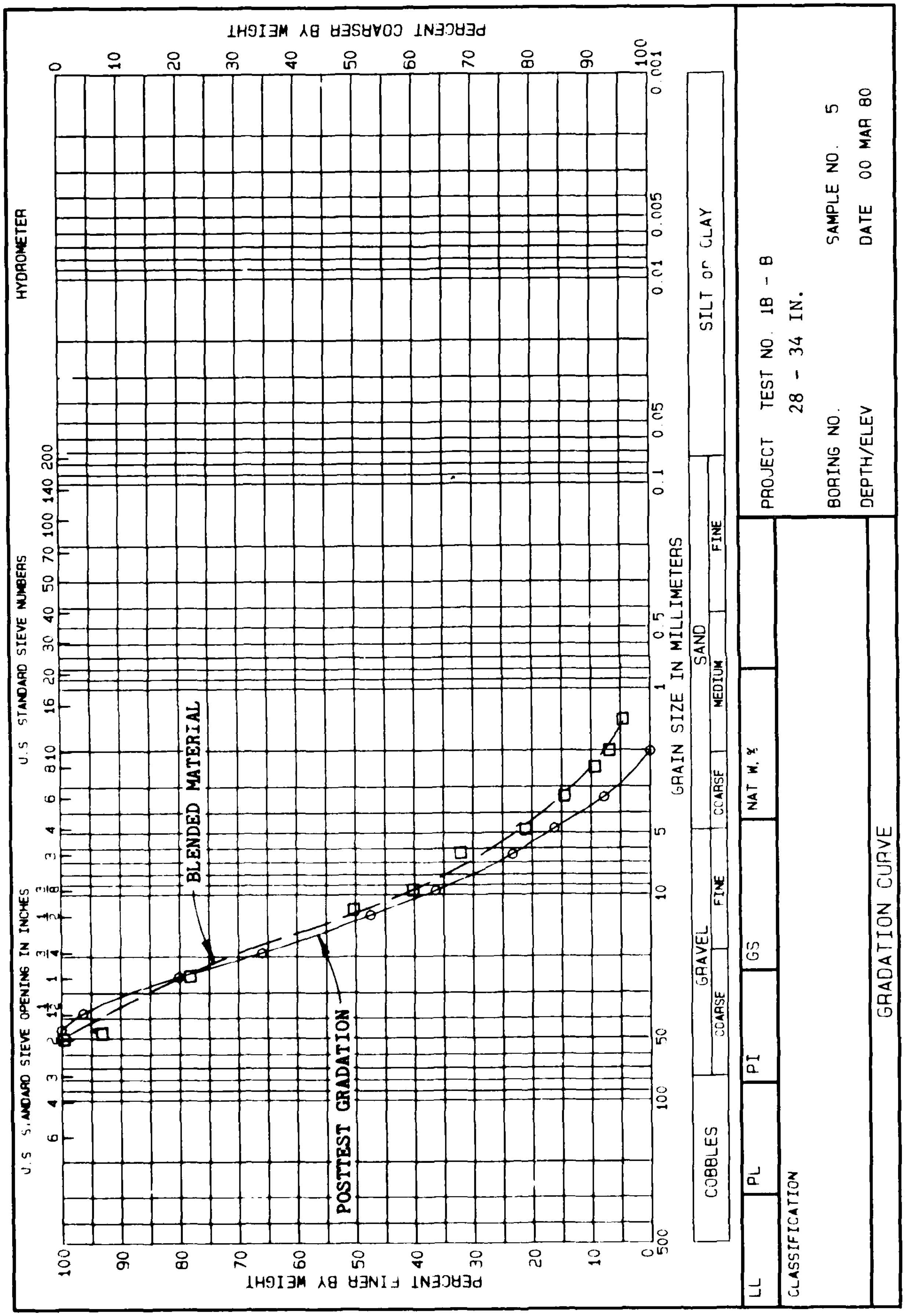
BORING NO.

SAMPLE NO. 4

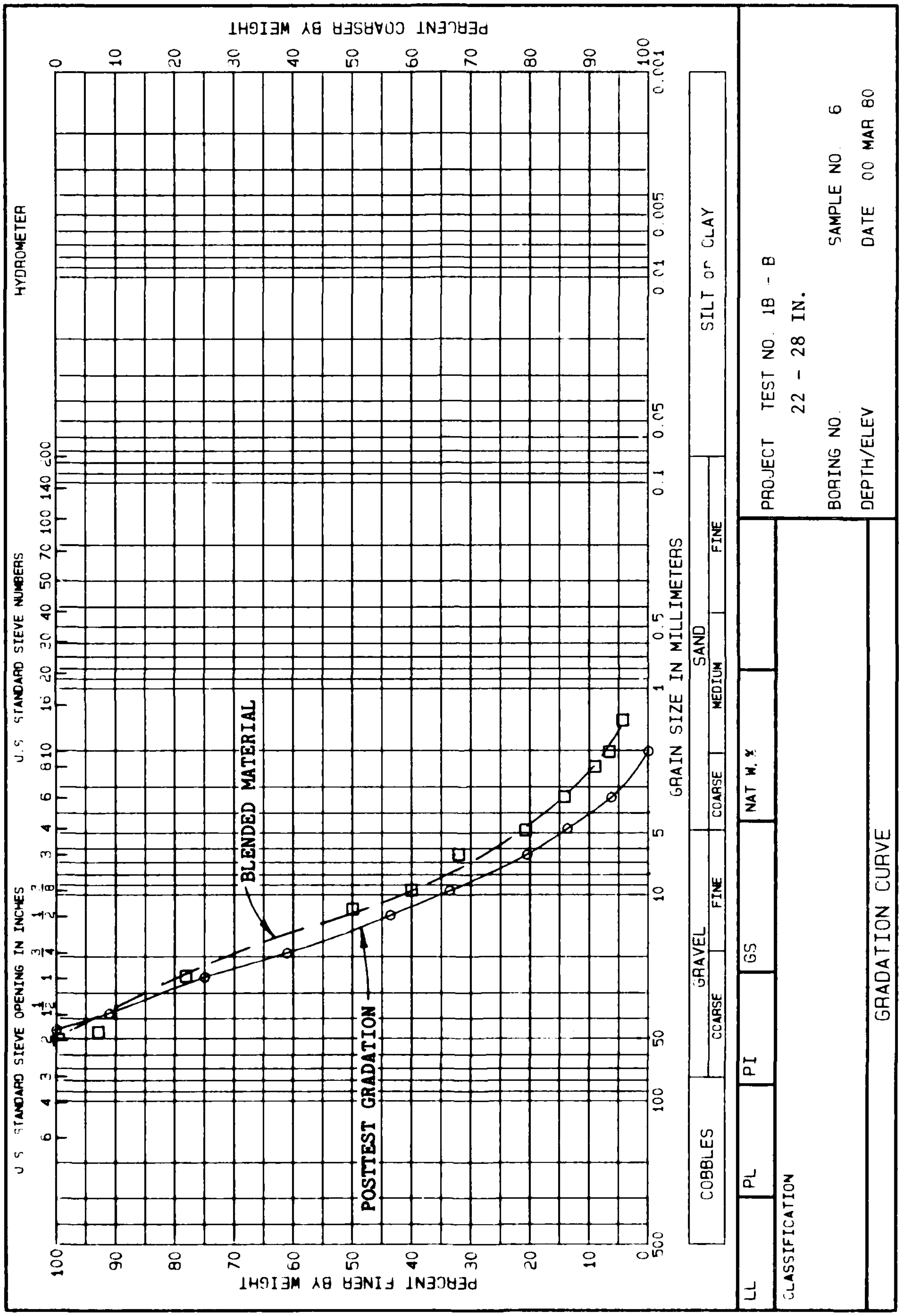
DEPTH/ELEV

DATE 00 MAR 80

PLATE D42

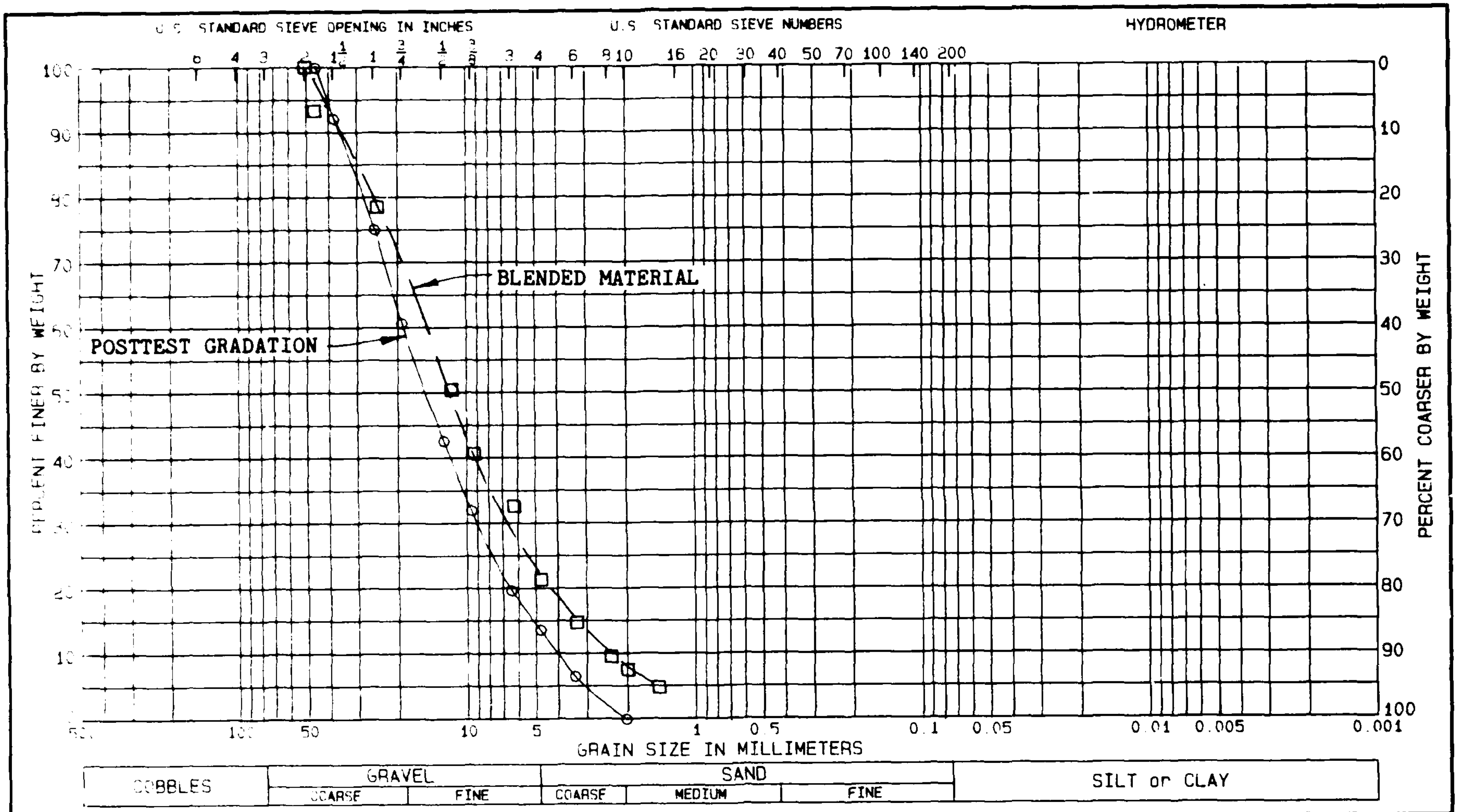


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1B - B
28 - 34 IN.
BORING NO.
SAMPLE NO. 5
DEPTH/ELEV
DATE 00 MAR 80
GRADATION CURVE



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1B - B
22 - 28 IN.
BORING NO.
SAMPLE NO. 6
DEPTH/ELEV
DATE 00 MAR 80
GRADATION CURVE

PLATE D44



LL	PL	PI	GS	NAT W, %	

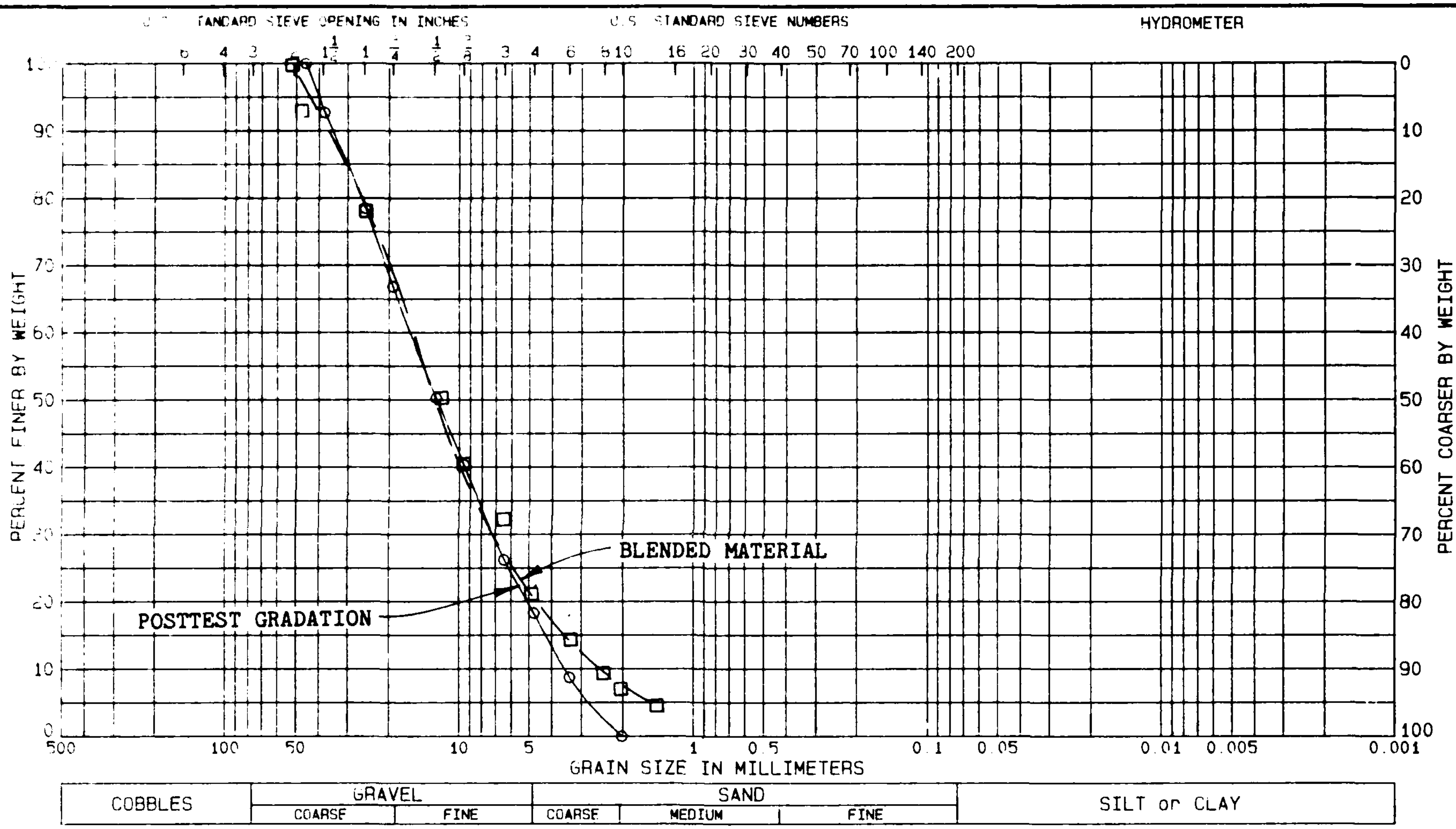
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1B - B
16 - 22 IN.

BORING NO. SAMPLE NO. 7

DEPTH/ELEV DATE 00 MAR 80



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

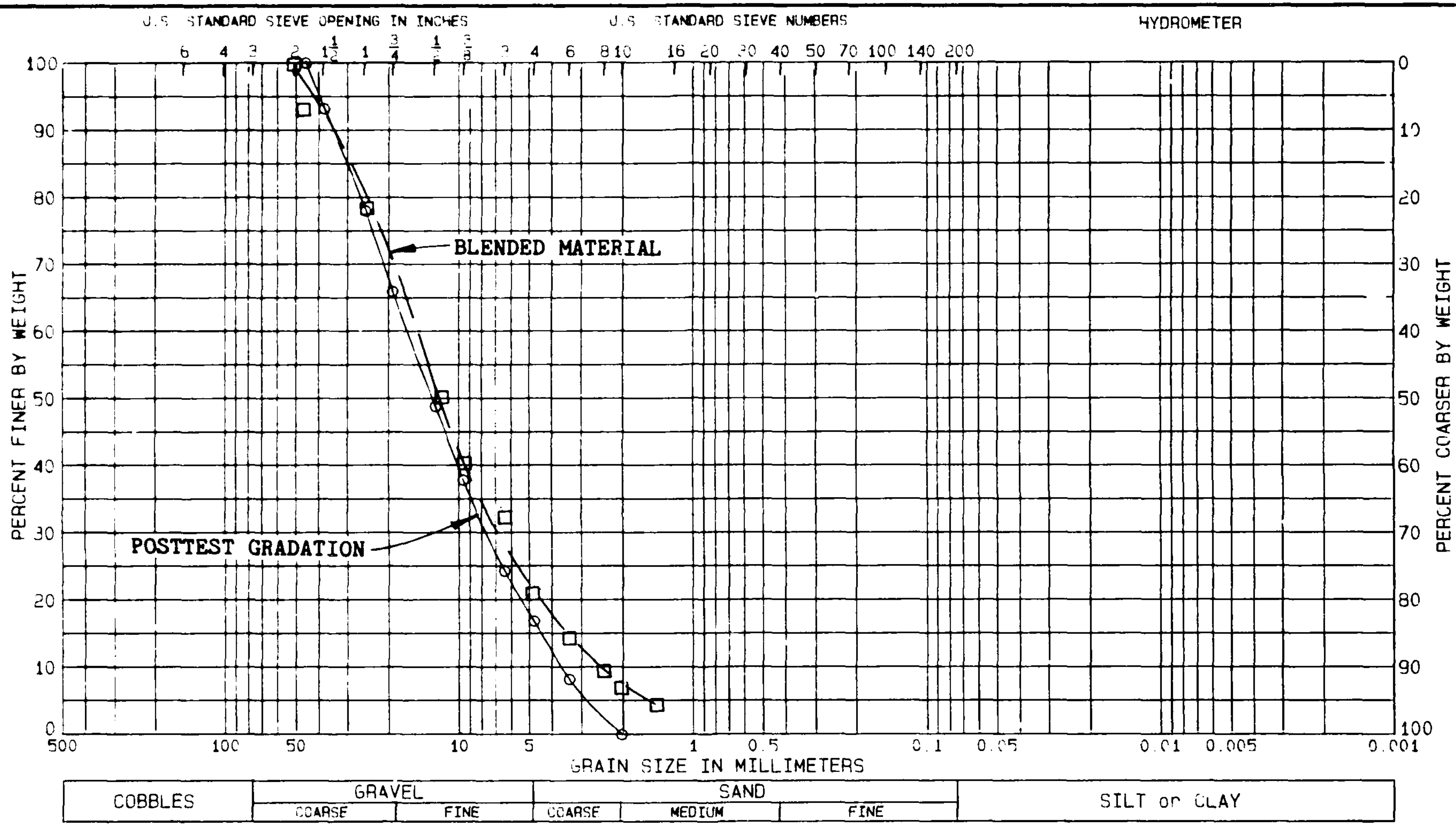
PROJECT TEST NO. 1B - B
10 - 16 IN.

BORING NO.

SAMPLE NO. 8

DEPTH/ELEV

DATE 00 MAR 80



LL | PL | PI | GS | NAT W, %

CLASSIFICATION

GRADATION CURVE

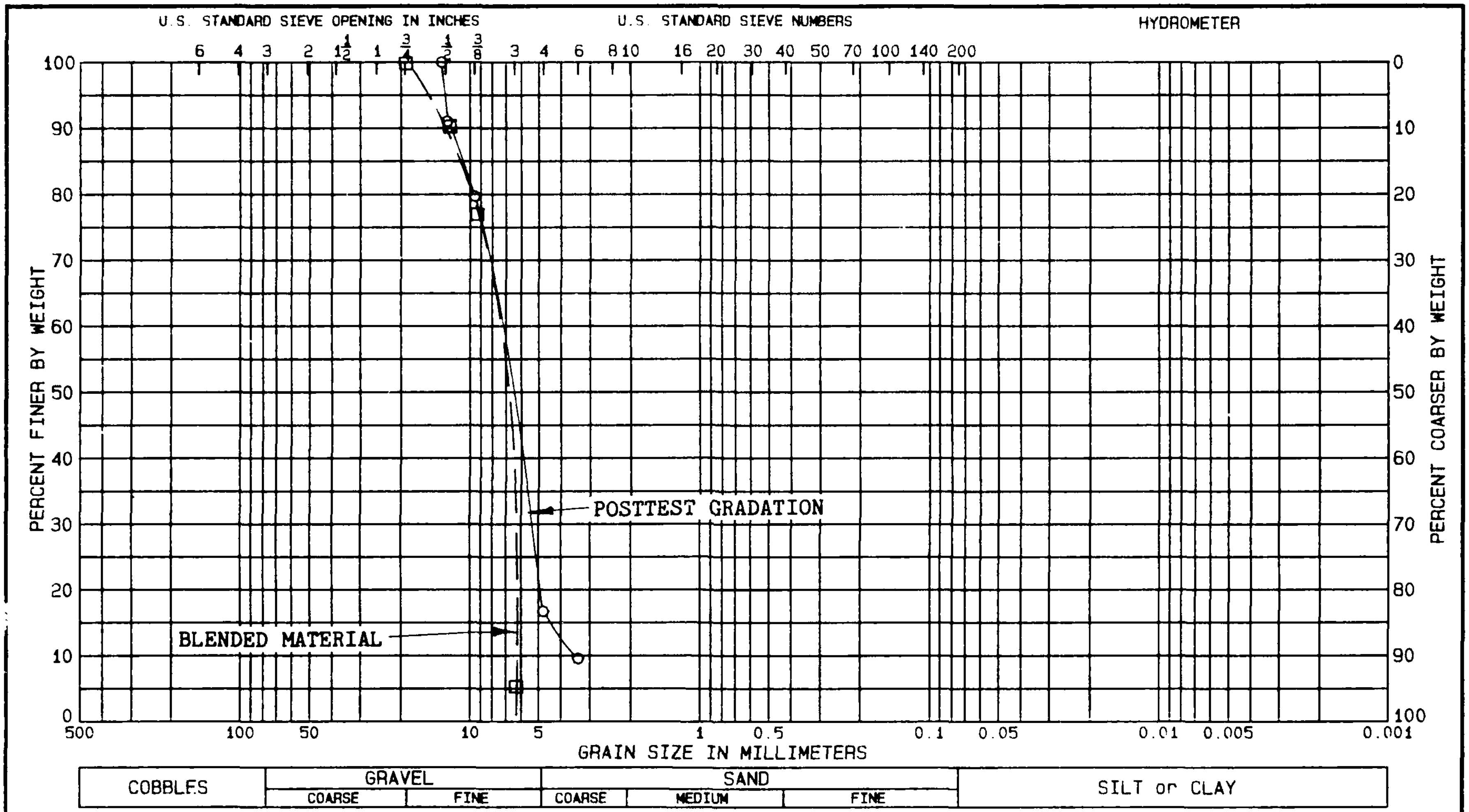
PROJECT TEST NO. 1B - B
0 - 10 IN.

BORING NO.

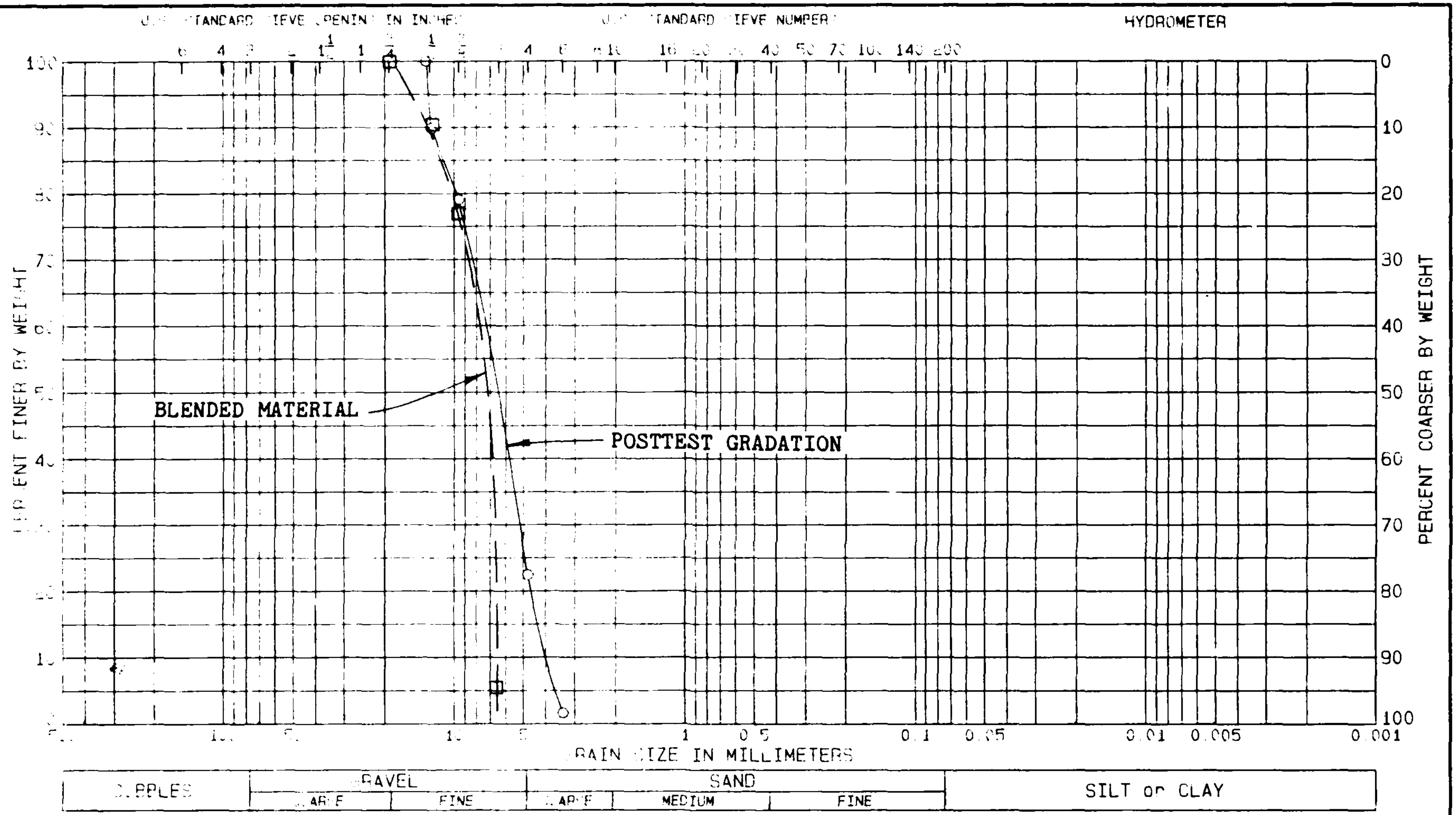
SAMPLE NO. 9

DEPTH/ELEV

DATE 00 MAR 80



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 1B - C 52 - 58 IN.
CLASSIFICATION						BORING NO. SAMPLE NO. 1
GRADATION CURVE						DEPTH/ELEV DATE 00 DEC 79



LL	PL	PI		NAT W %	

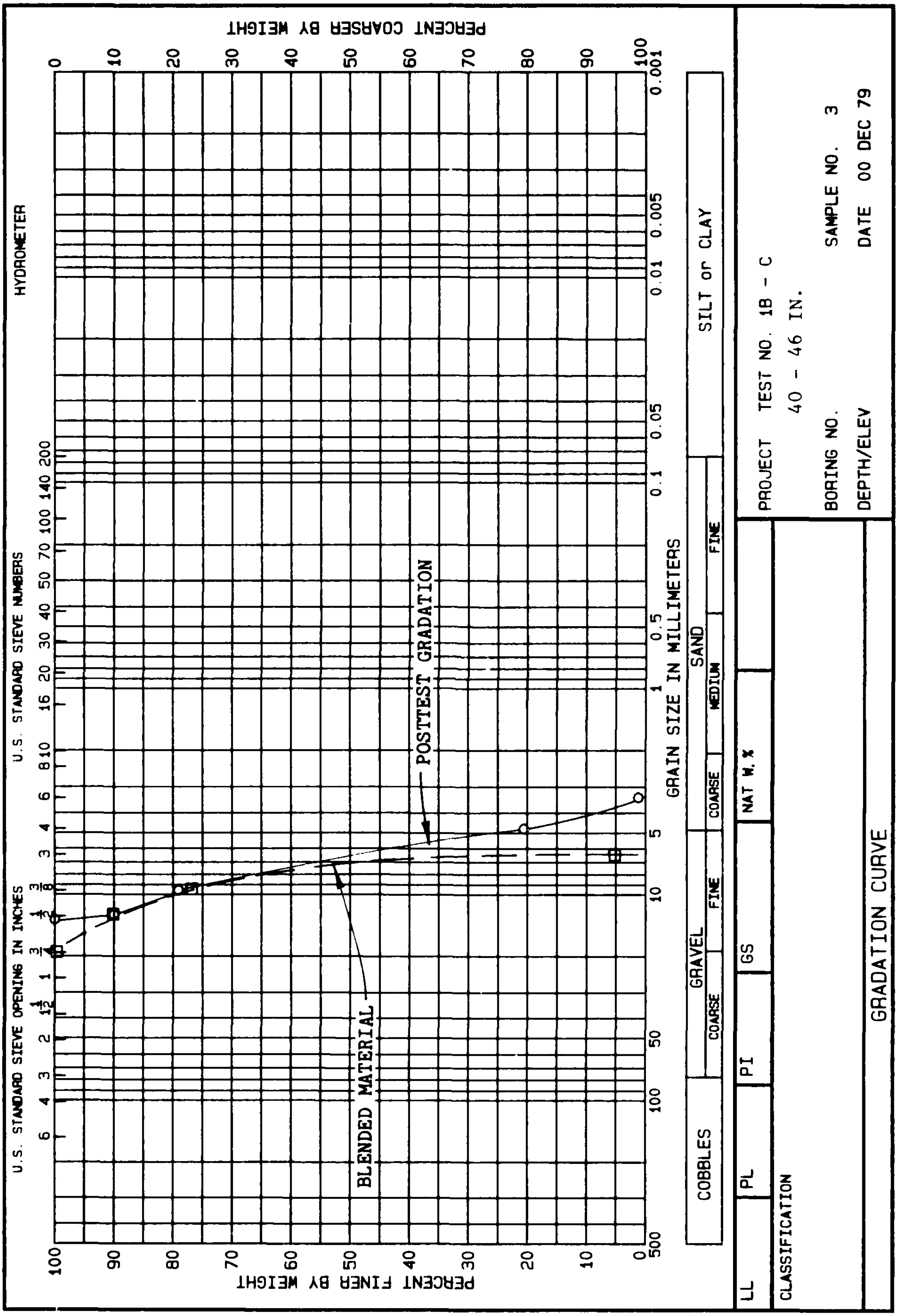
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1B - C
46 - 52 IN.

BORING NO. SAMPLE NO. 2

DEPTH/ELEV DATE 00 DEC 79



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1B - C
40 - 46 IN.
BORING NO.
SAMPLE NO. 3
DEPTH/ELEV
DATE 00 DEC 79
GRADATION CURVE

PLATE D50

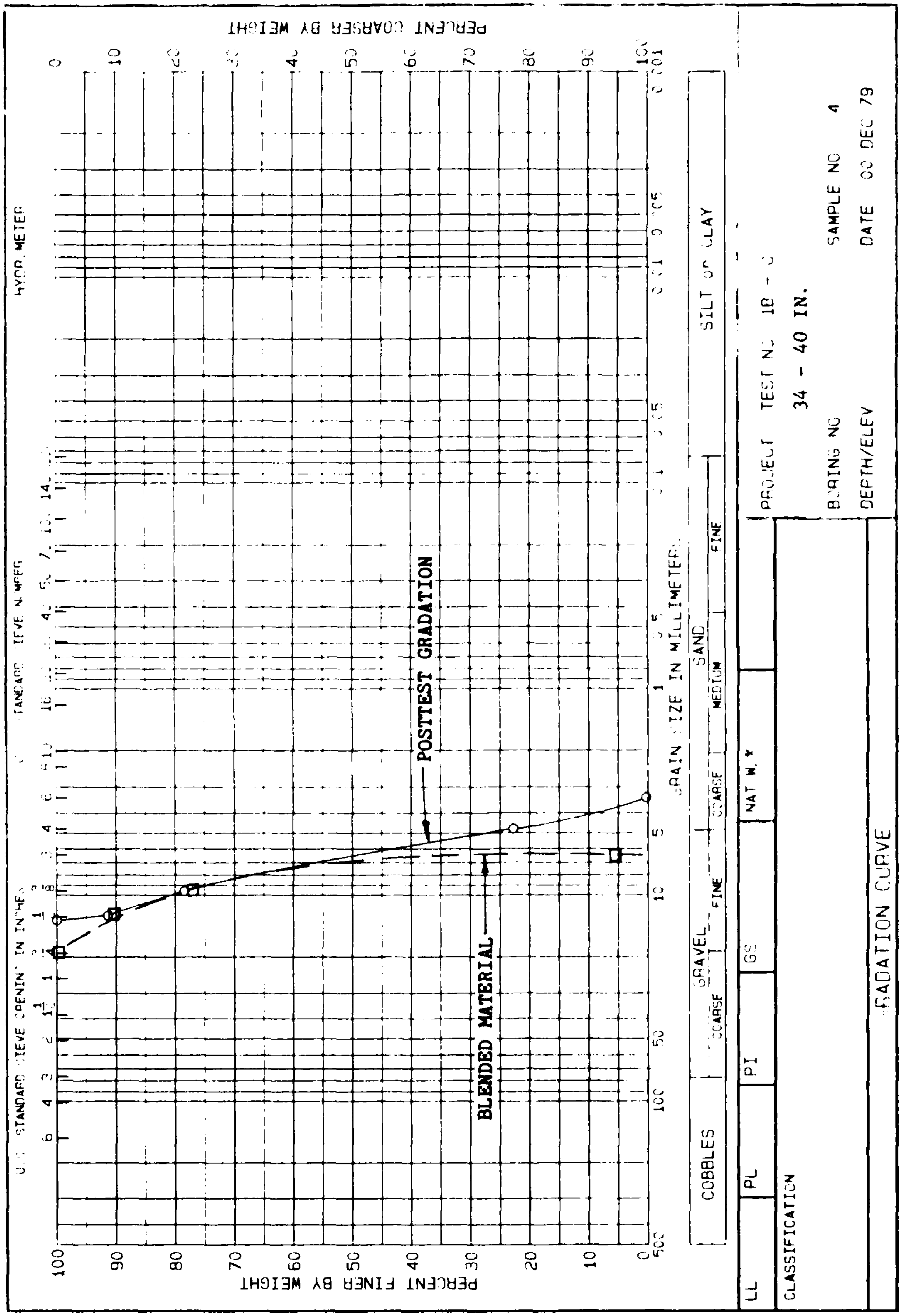

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBER
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
LL
PL
PI
GS
NAT W %
CLASSIFICATION
PROJECT TEST NO 18 - 3
34 - 40 IN.
BORING NO
SAMPLE NO 4
DEPTH/ELEV
DATE 00 DEC 79
GRADATION CURVE

PLATE D51

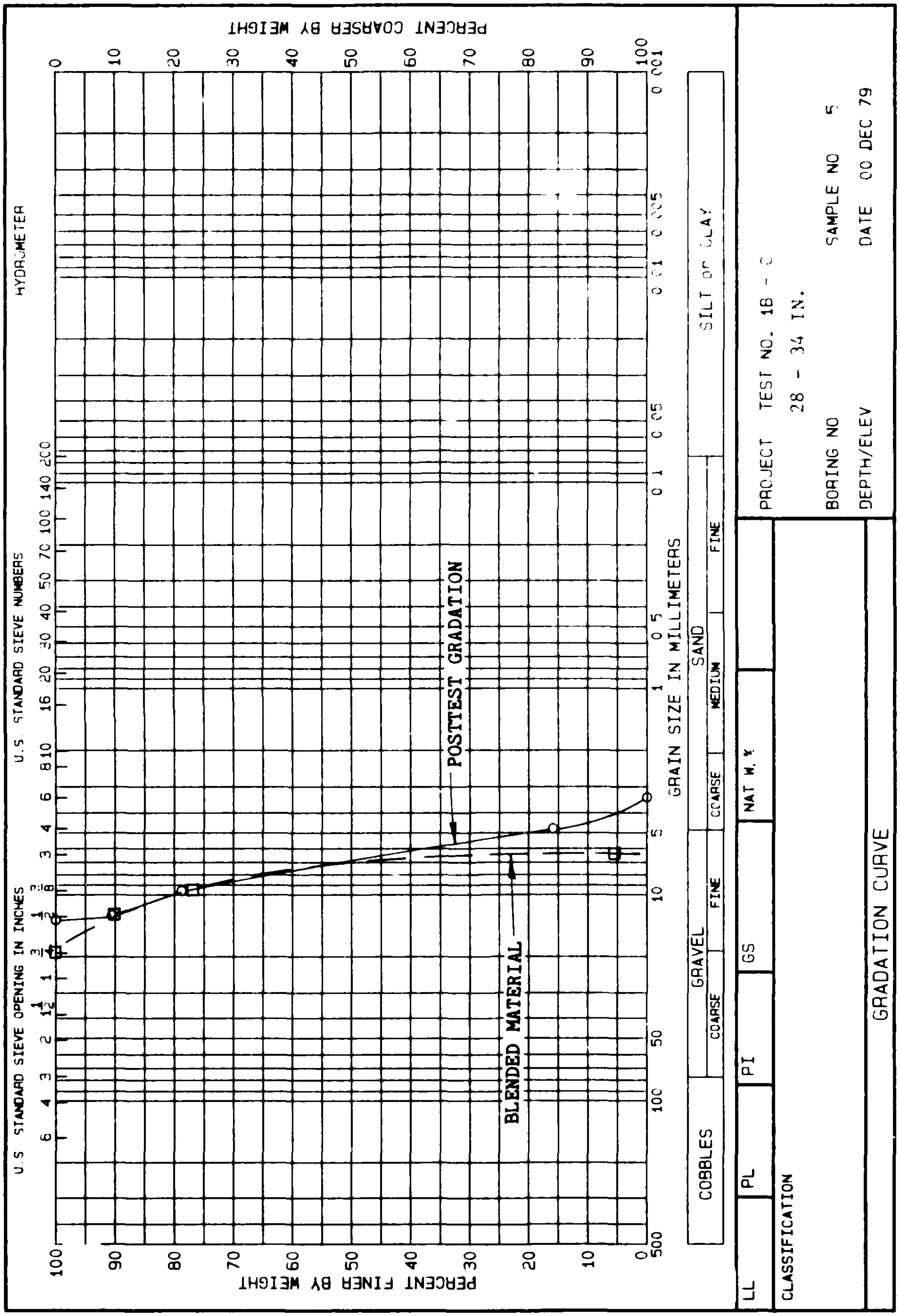
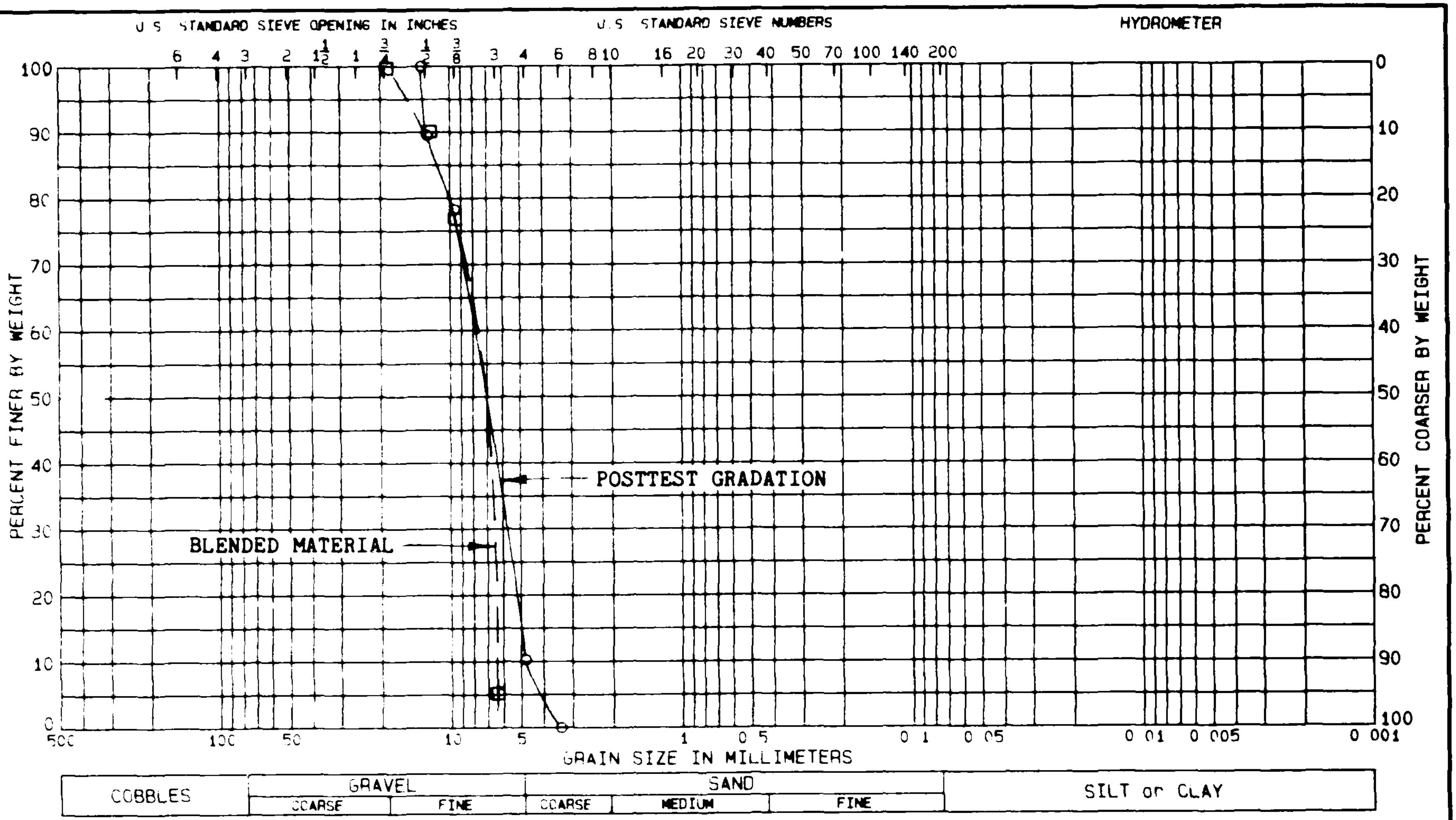

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
LL
PL
PI
GS
NAT W %
CLASSIFICATION
PROJECT TEST NO. 1B - 6
28 - 34 IN.
BORING NO
SAMPLE NO 5
DEPTH/ELEV
DATE 00 DEC 79
GRADATION CURVE

PLATE D52



LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO 1B - C

22 - 28 IN.

BORING NO — SAMPLE NO. 6

DEPTH/ELEV — DATE 00 DEC 79

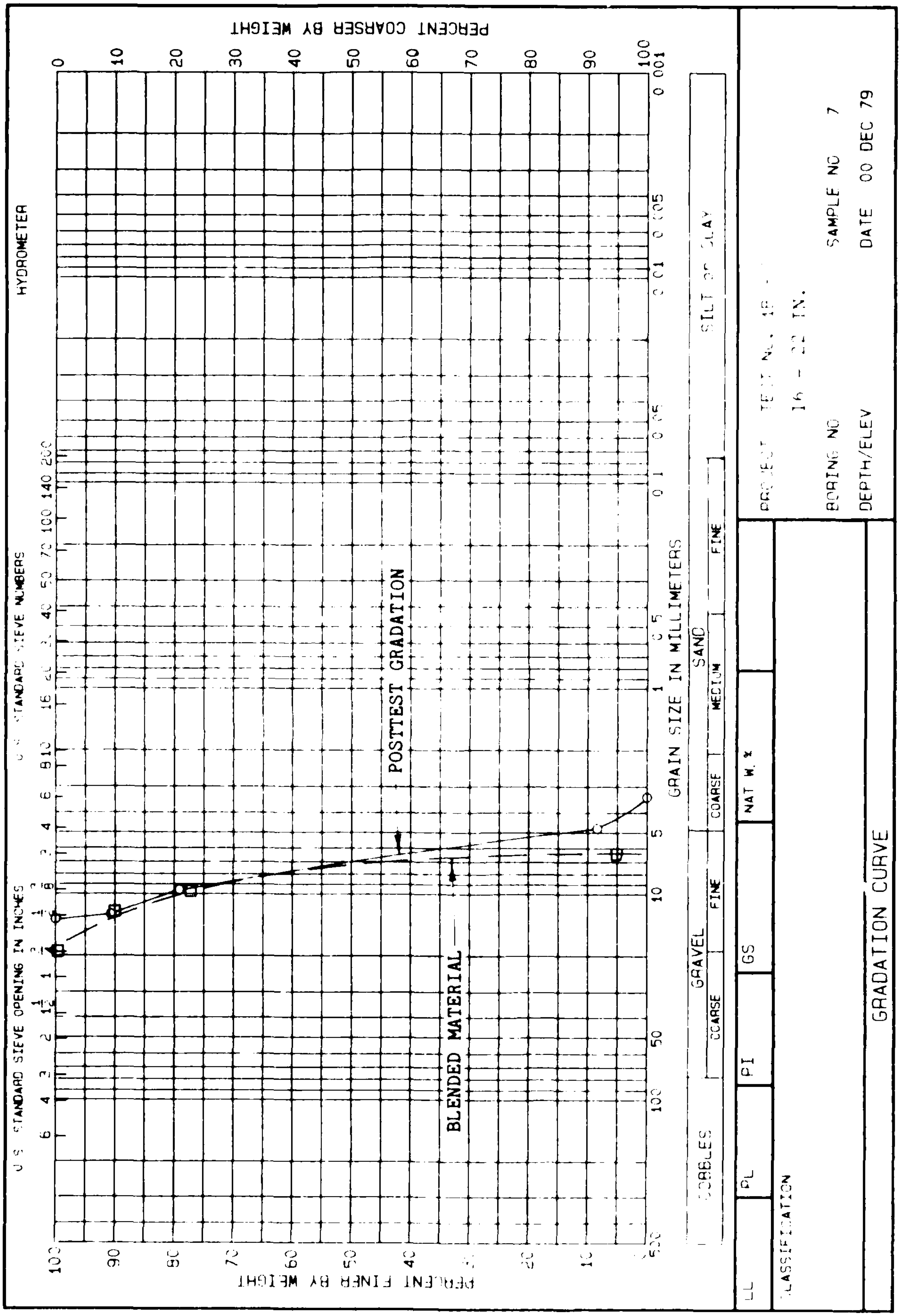
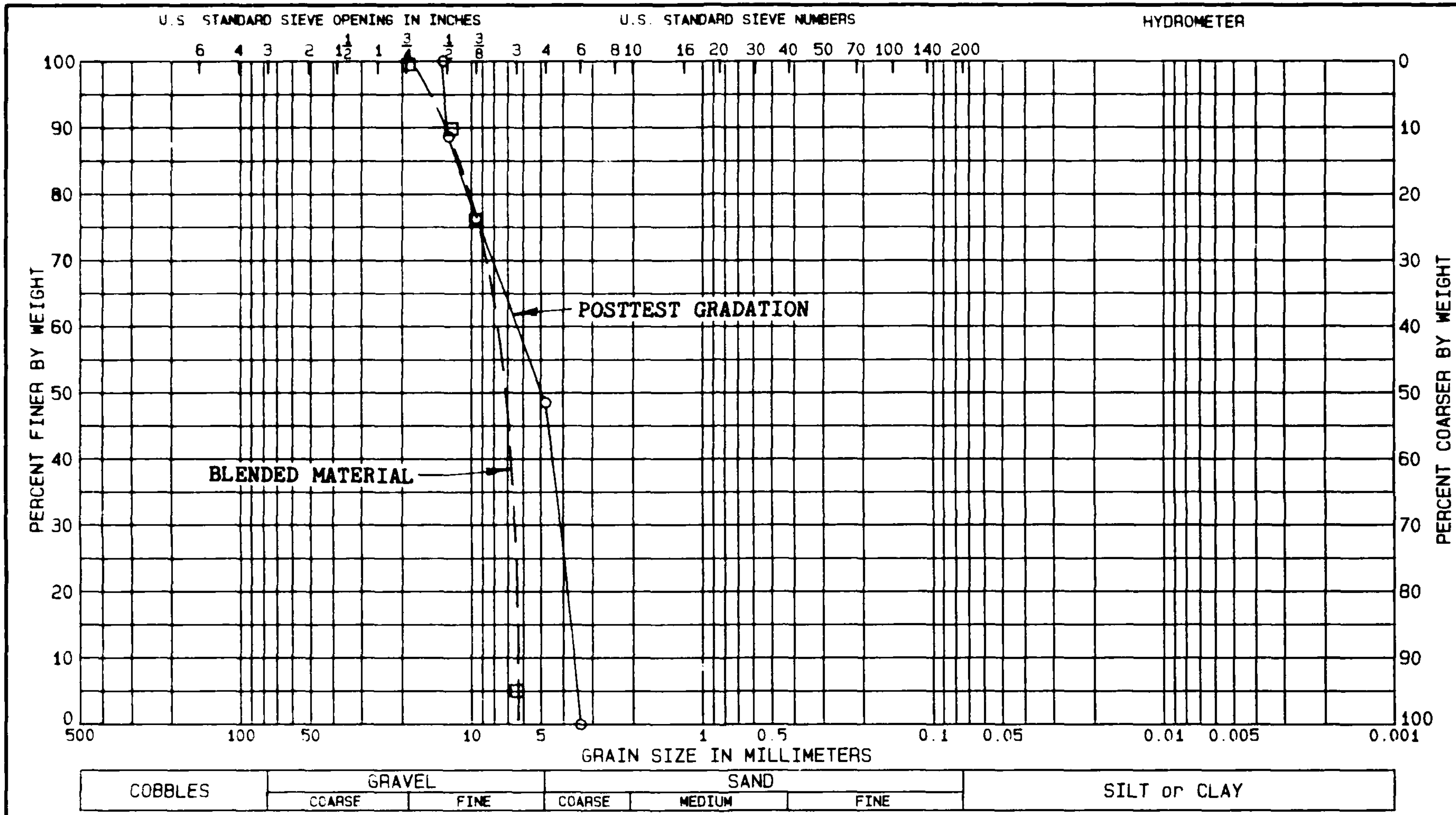

GRADATION CURVE
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
LL
PL
PI
GS
NAT W %
CLASSIFICATION
BORING NO
DEPTH/ELEV
SAMPLE NO 7
DATE 00 DEC 79
16 - 22 IN.

PLATE D54



LL	PL	PI	GS	NAT W. %	

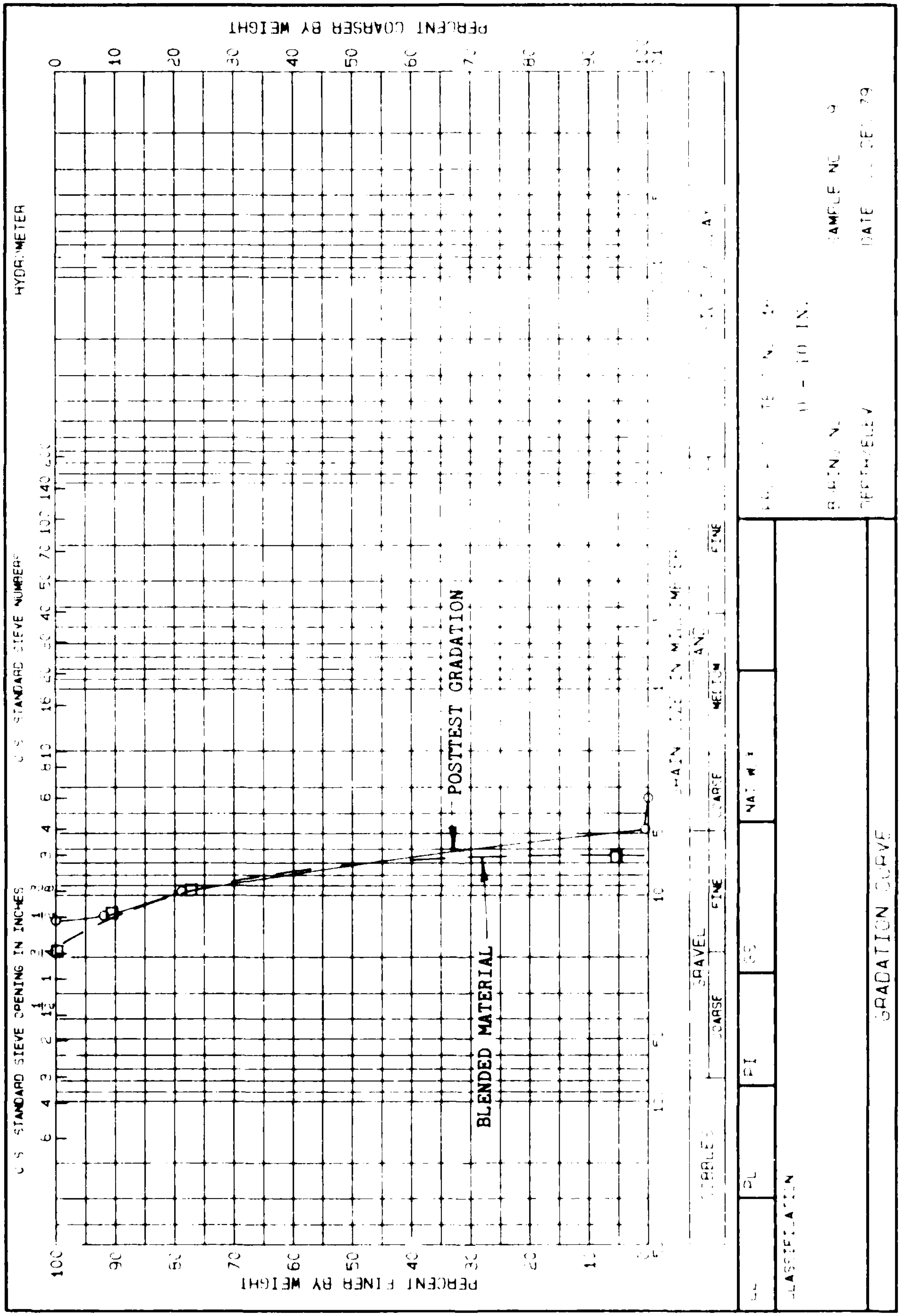
CLASSIFICATION

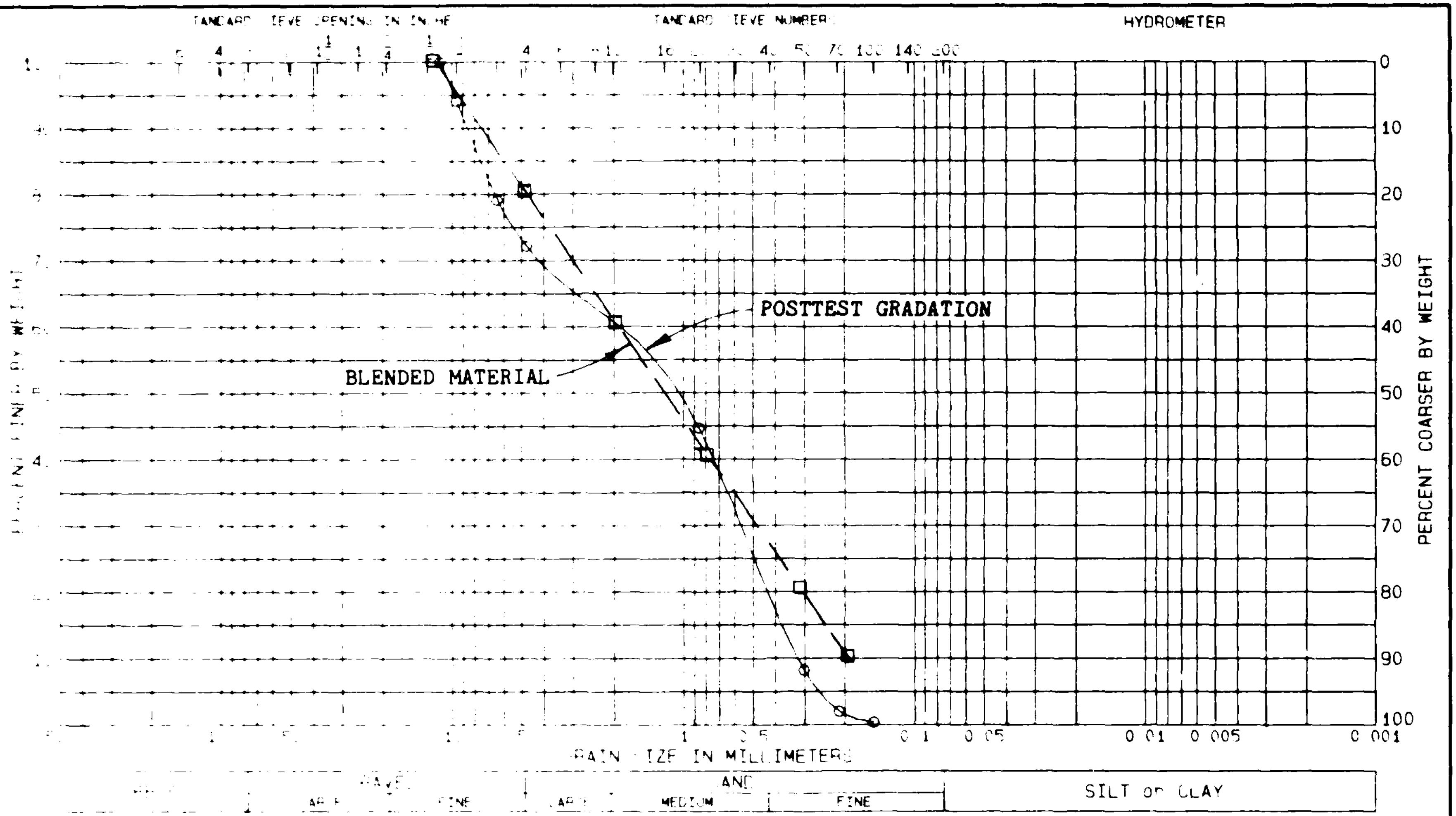
PROJECT TEST NO. 1B - C
10 - 16 IN.

BORING NO. SAMPLE NO. 8

DEPTH/ELEV DATE 00 DEC 79

GRADATION CURVE


PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
STANDARD SIEVE OPENING IN INCHES
STANDARD SIEVE NUMBERS
HYDROMETER
POSTTEST GRADATION
BLENDED MATERIAL
GRAVEL
COARSE
FINE
PI
0 - 10 IN.
DATE
GRADATION CURVE



NAT W %

PROJECT TEST NO 1

62 - 68 IN.

BORING NO

SAMPLE NO 1

DEPTH/ELEV

DATE 00 JUL 81

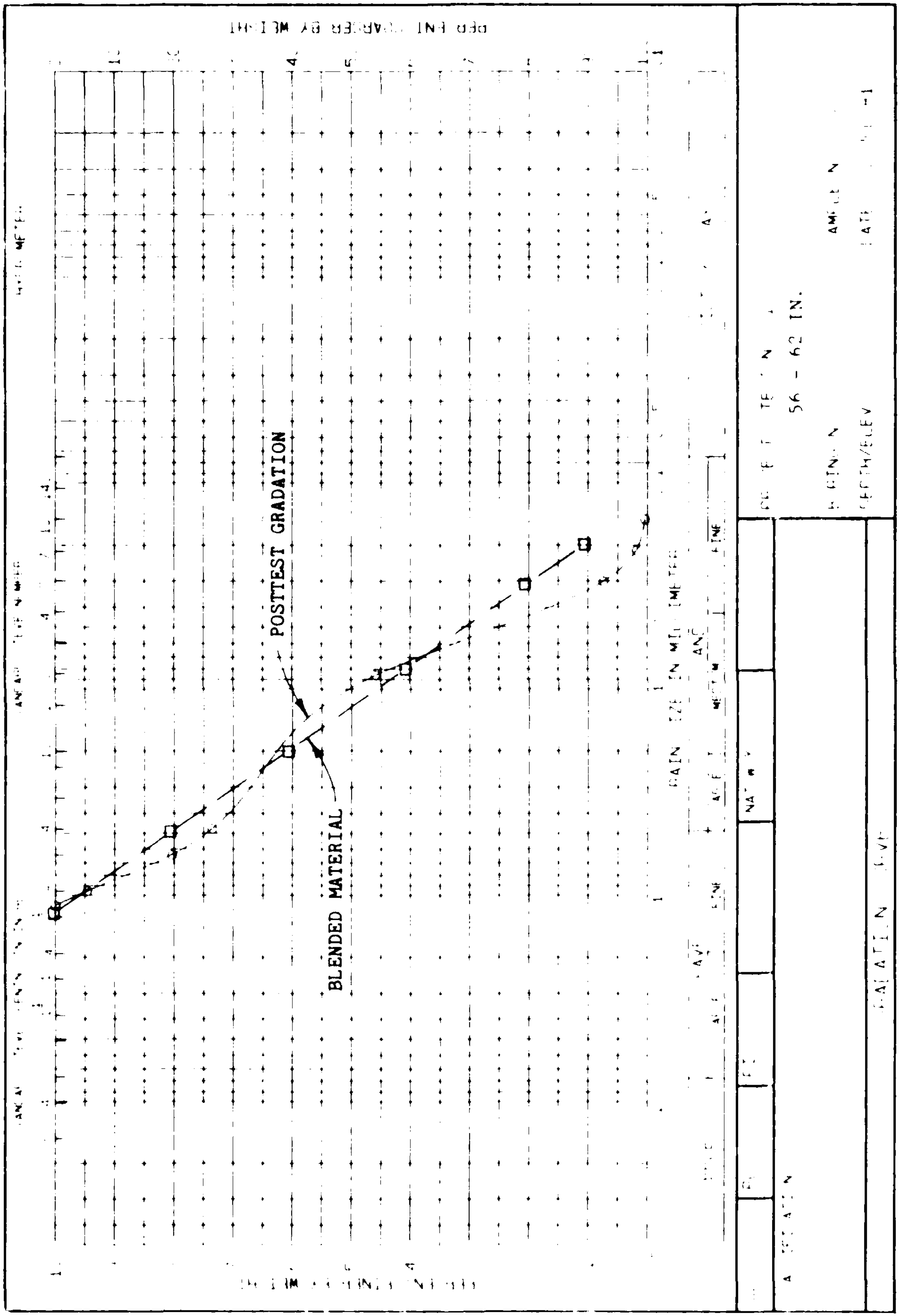
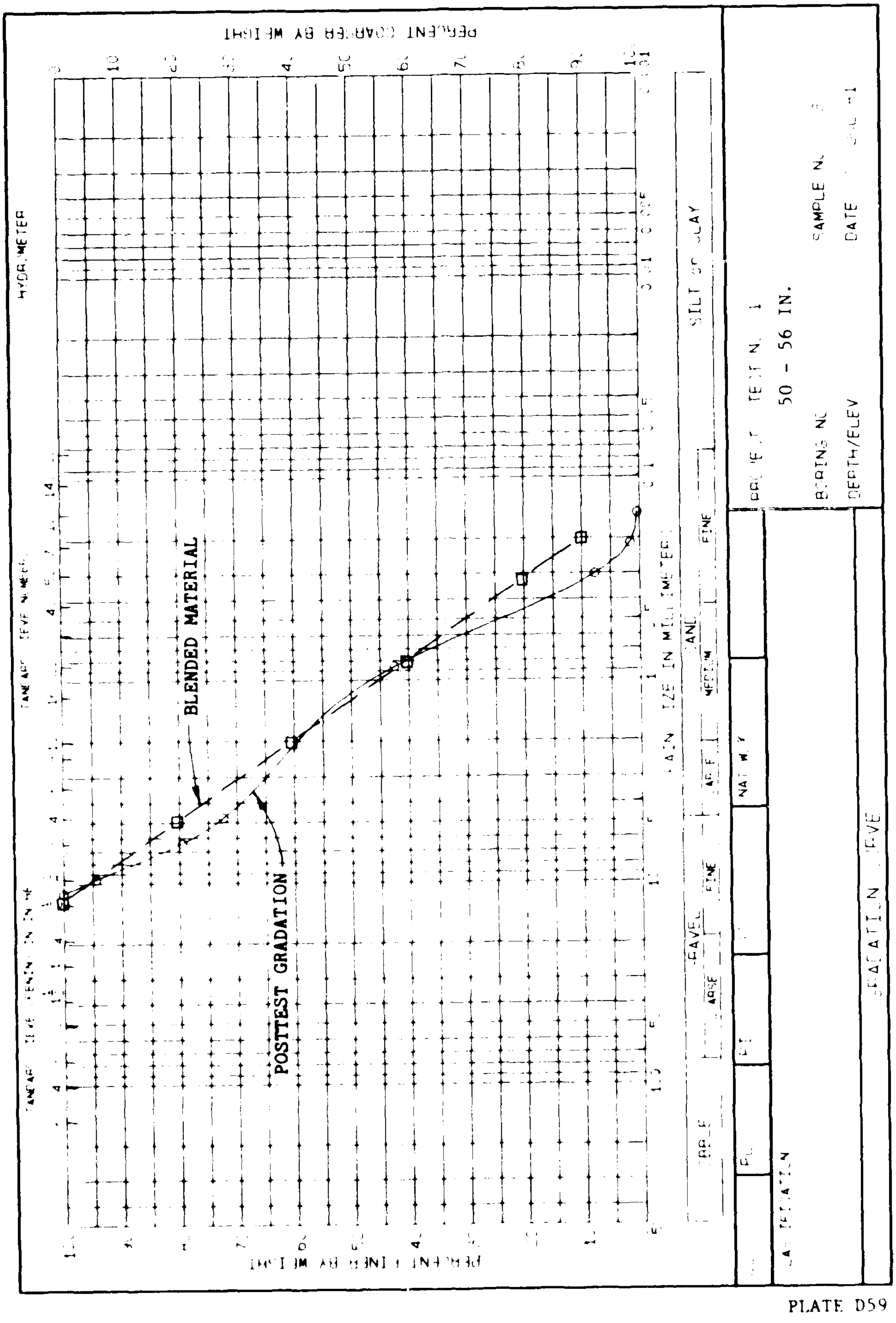


PLATE D58


PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
HYDROMETER
BLENDED MATERIAL
POSTTEST GRADATION
SILT OR CLAY
50 - 56 IN.
SAMPLE NO
DATE
BORING NO
DEPTH/ELEV

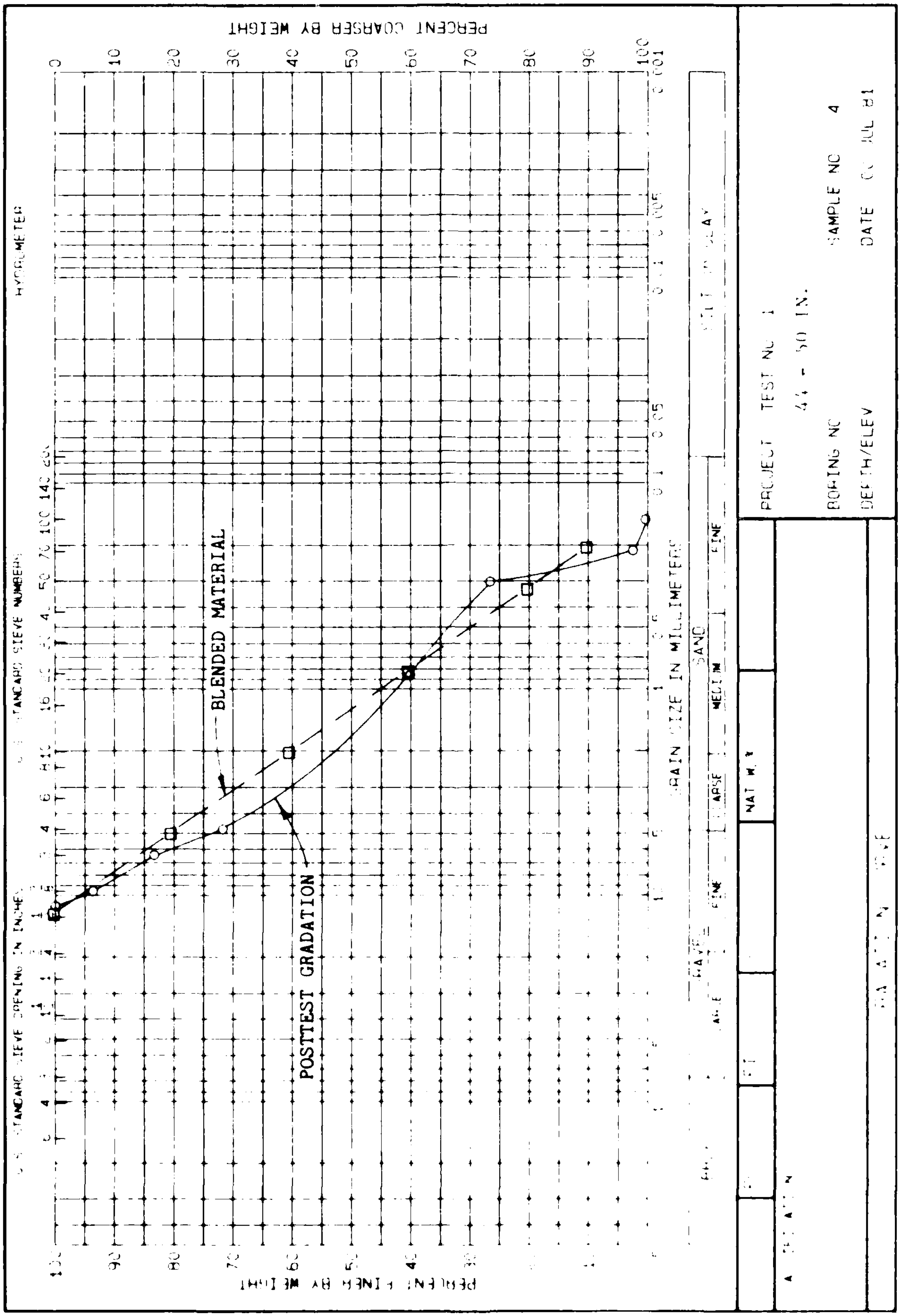
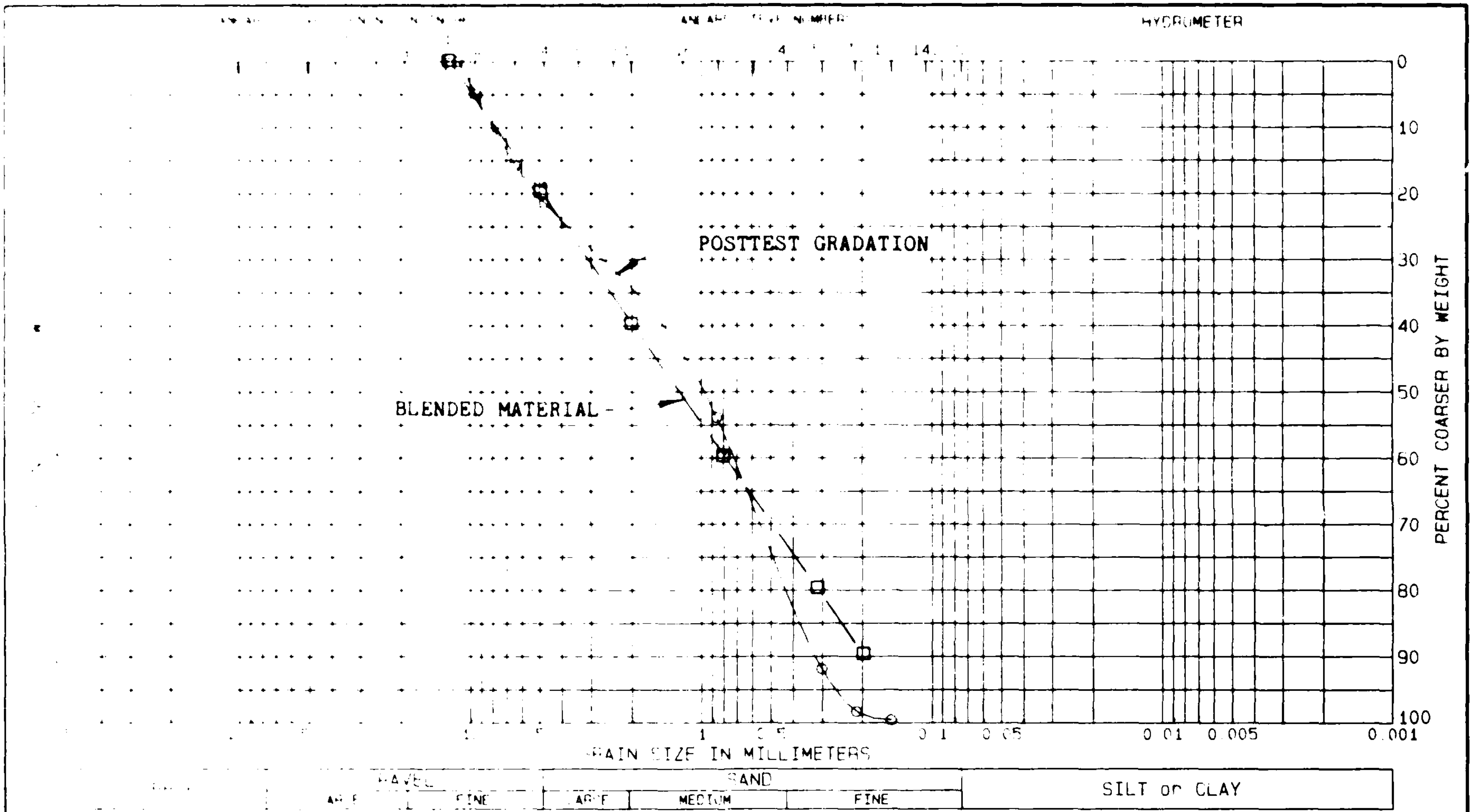

PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
HYDROMETER
GRAIN SIZE IN MILLIMETERS
SAND
FINE
BLENDED MATERIAL
POSTTEST GRADATION
NAT W %
PROJECT TEST NO 1
44 - 50 IN.
BORING NO
SAMPLE NO 4
DEPTH/ELEV
DATE

PLATE D60



NAT W.K

PROJECT TEST NO 1
38 - 44 IN.

BORING NO

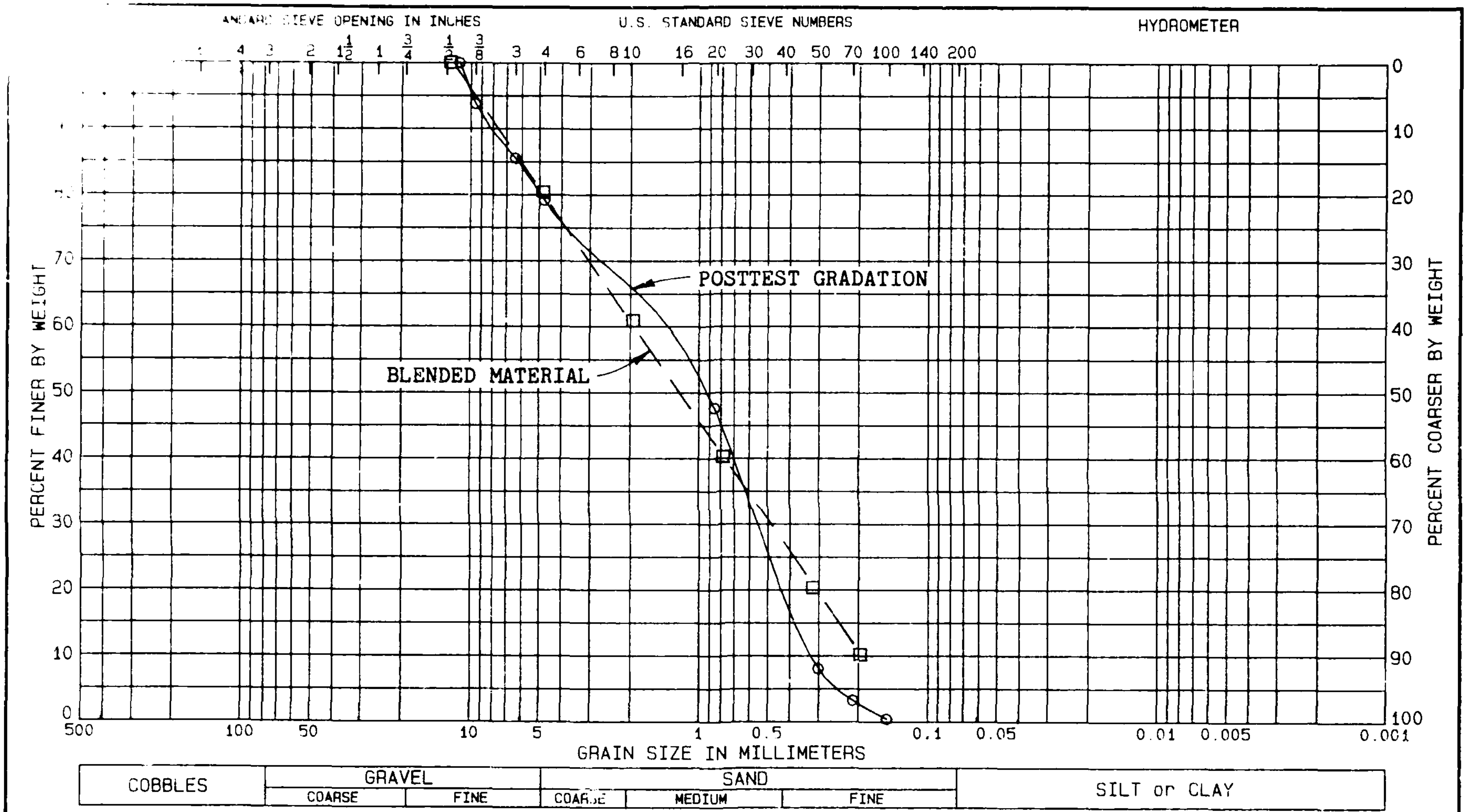
SAMPLE NO. 5

DEPTH/ELEV

DATE 00 JUL 81

GRADATION CURVE

PLATE D61



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

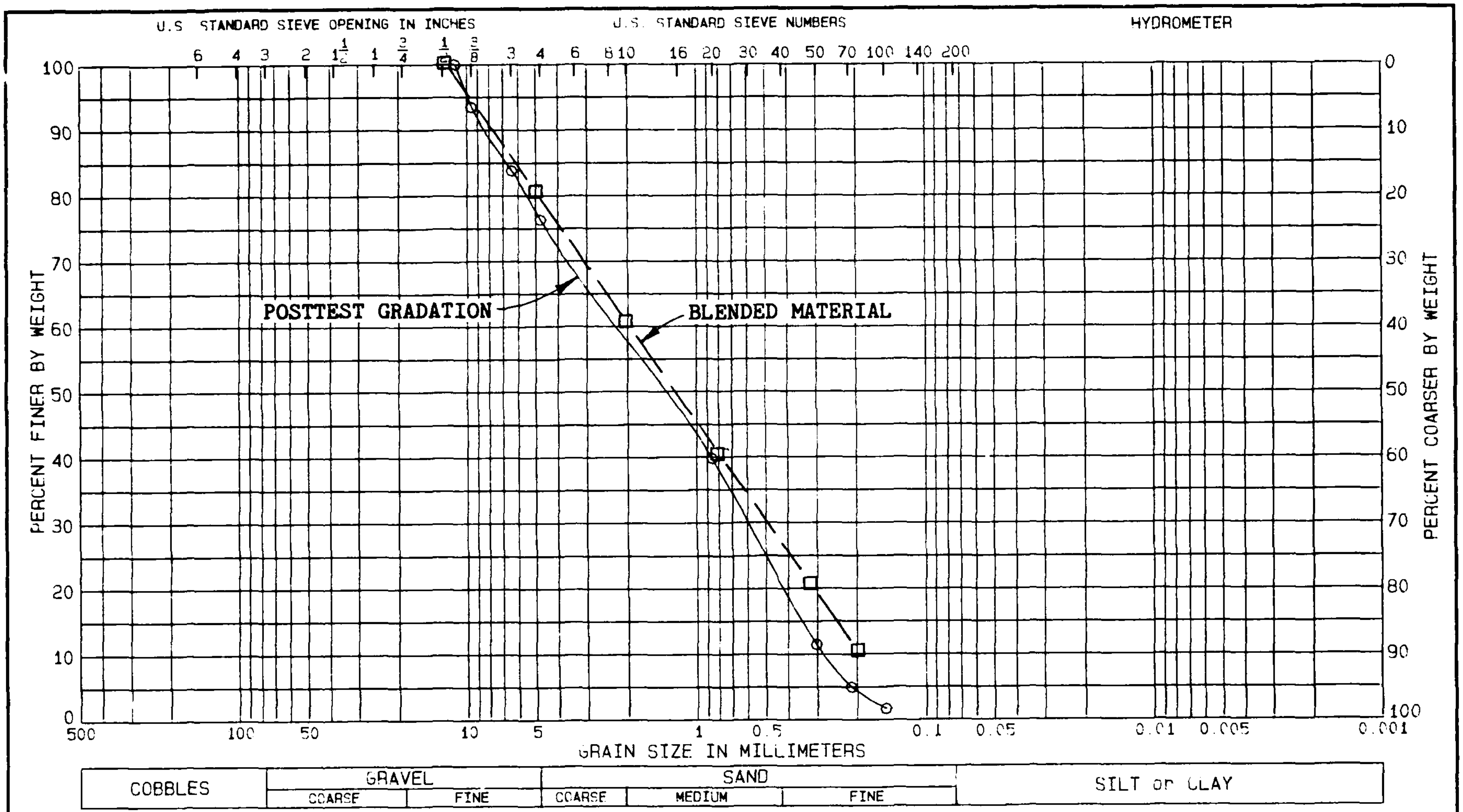
PROJECT TEST NO. 1
32 - 38 IN.

BORING NO.

SAMPLE NO. 6

DEPTH/ELEV

DATE 00 JUL 81



LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1
26 - 32 IN.
BORING NO. SAMPLE NO. 7
DEPTH/ELEV DATE 00 JUL 81

PLATE D63

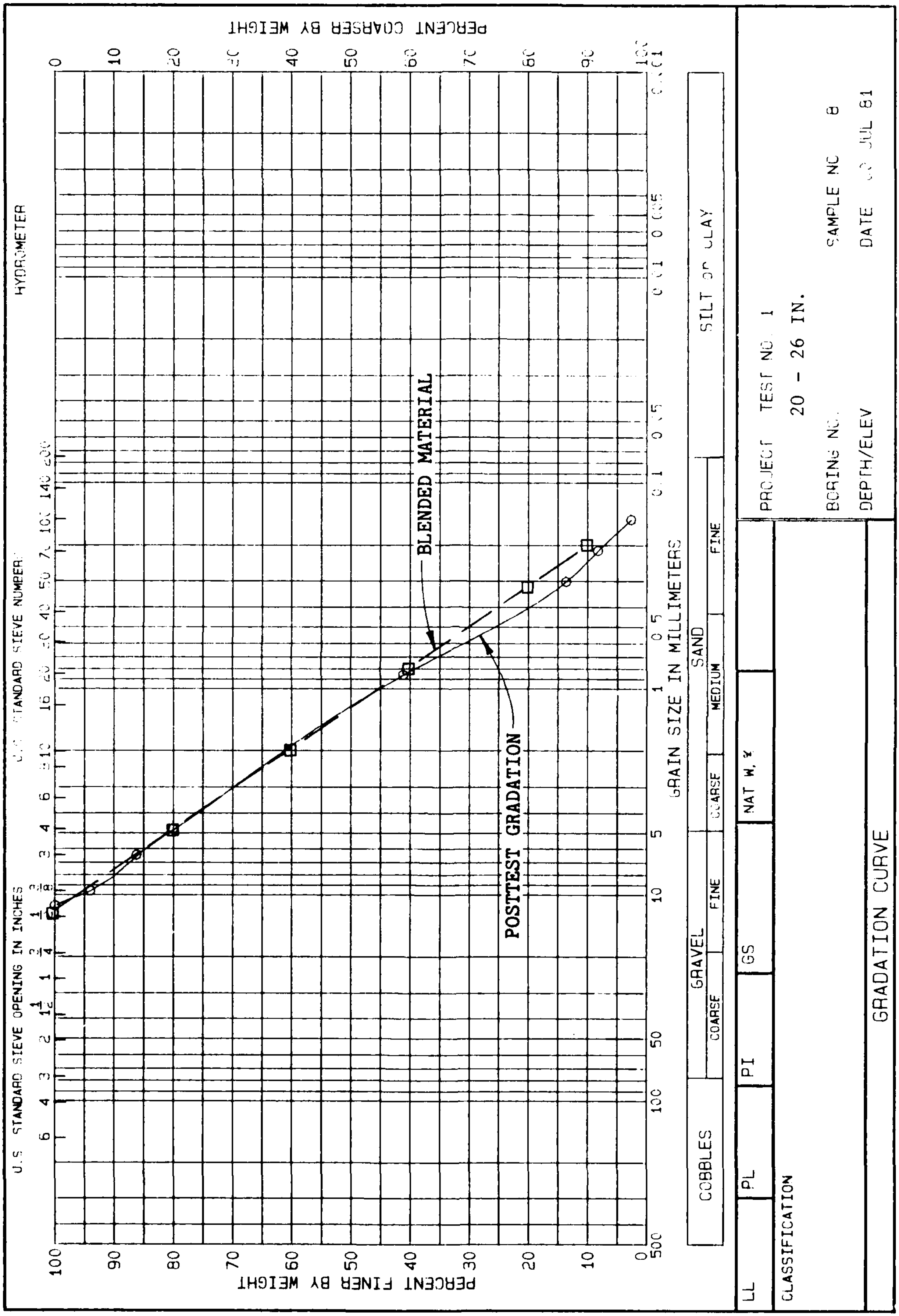
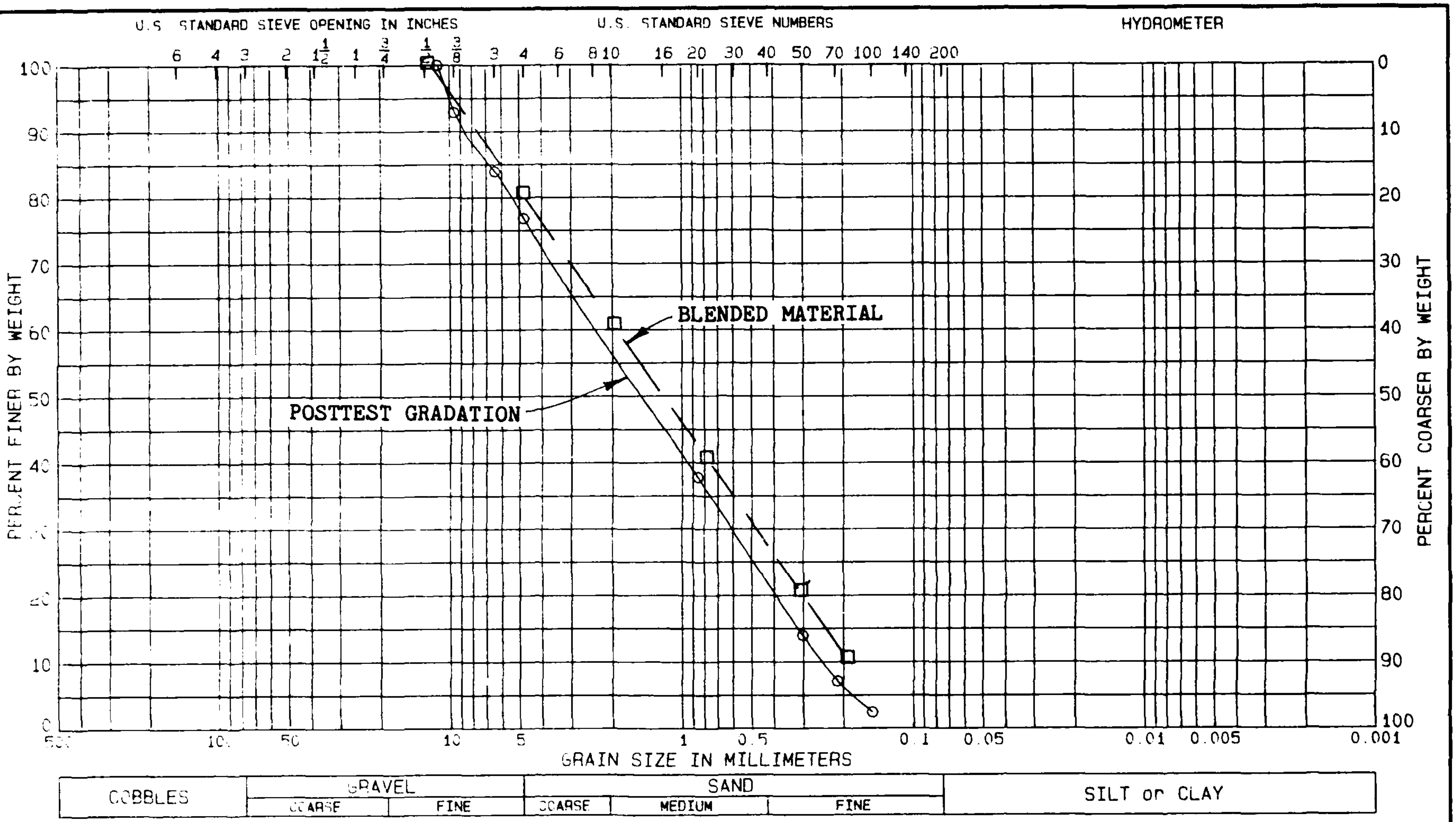

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 1
20 - 26 IN.
BORING NO.
SAMPLE NO 8
DEPTH/ELEV
DATE JUL 81
GRADATION CURVE

PLATE D64



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

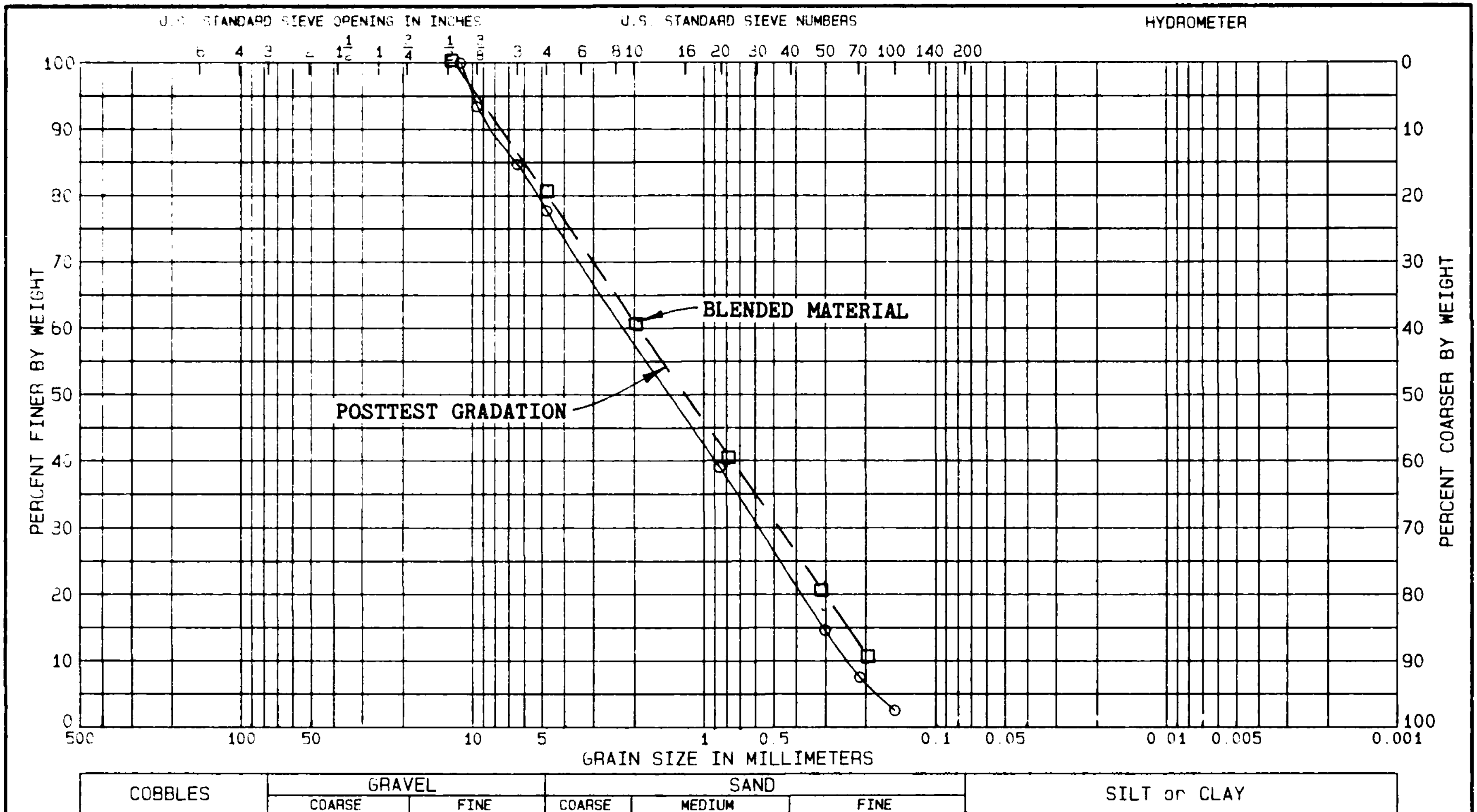
PROJECT TEST NO. 1

14 - 20 IN.

BORING NO. SAMPLE NO. 9

DEPTH/ELEV DATE 00 JUL 81

PLATE D65



LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

GRADATION CURVE

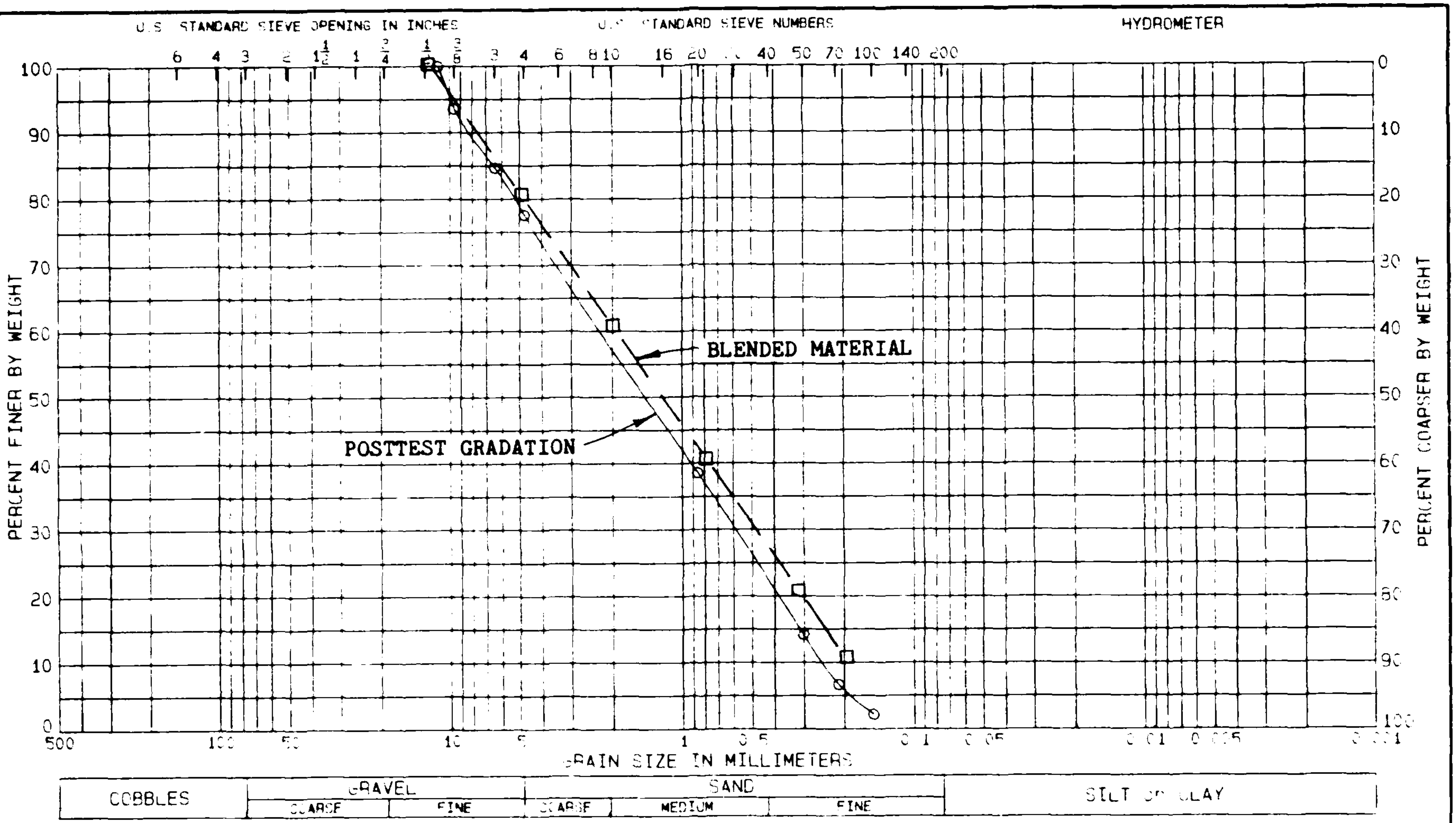
PROJECT TEST NO. 1

8 - 14 IN.

BORING NO.   SAMPLE NO. 10

DEPTH/ELEV   DATE 00 JUL 81

PLATE D66



LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO 1
0 - 8 IN.

BORING NO SAMPLE NO 11

DEPTH/ELEV DATE 00 JUL 81

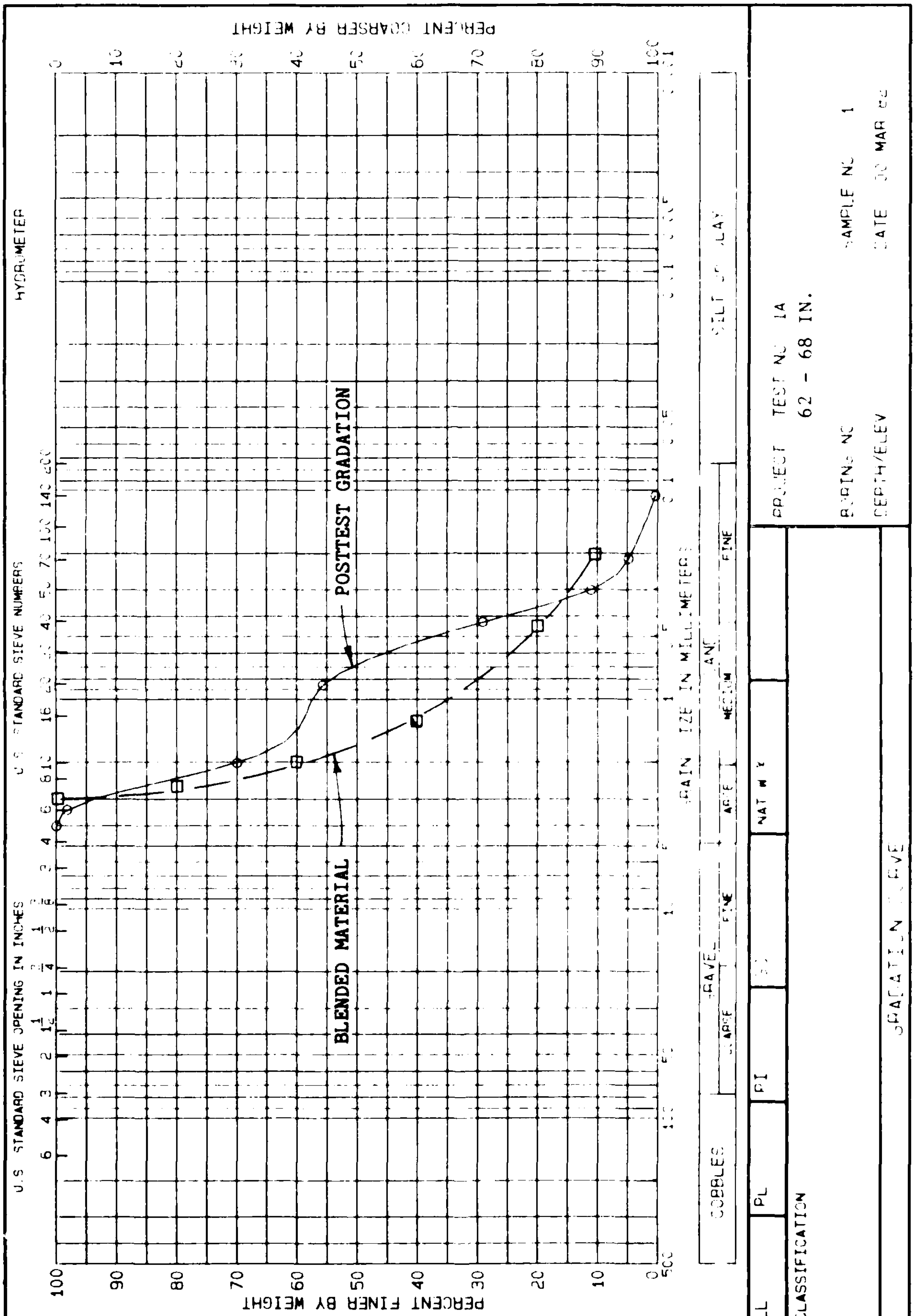
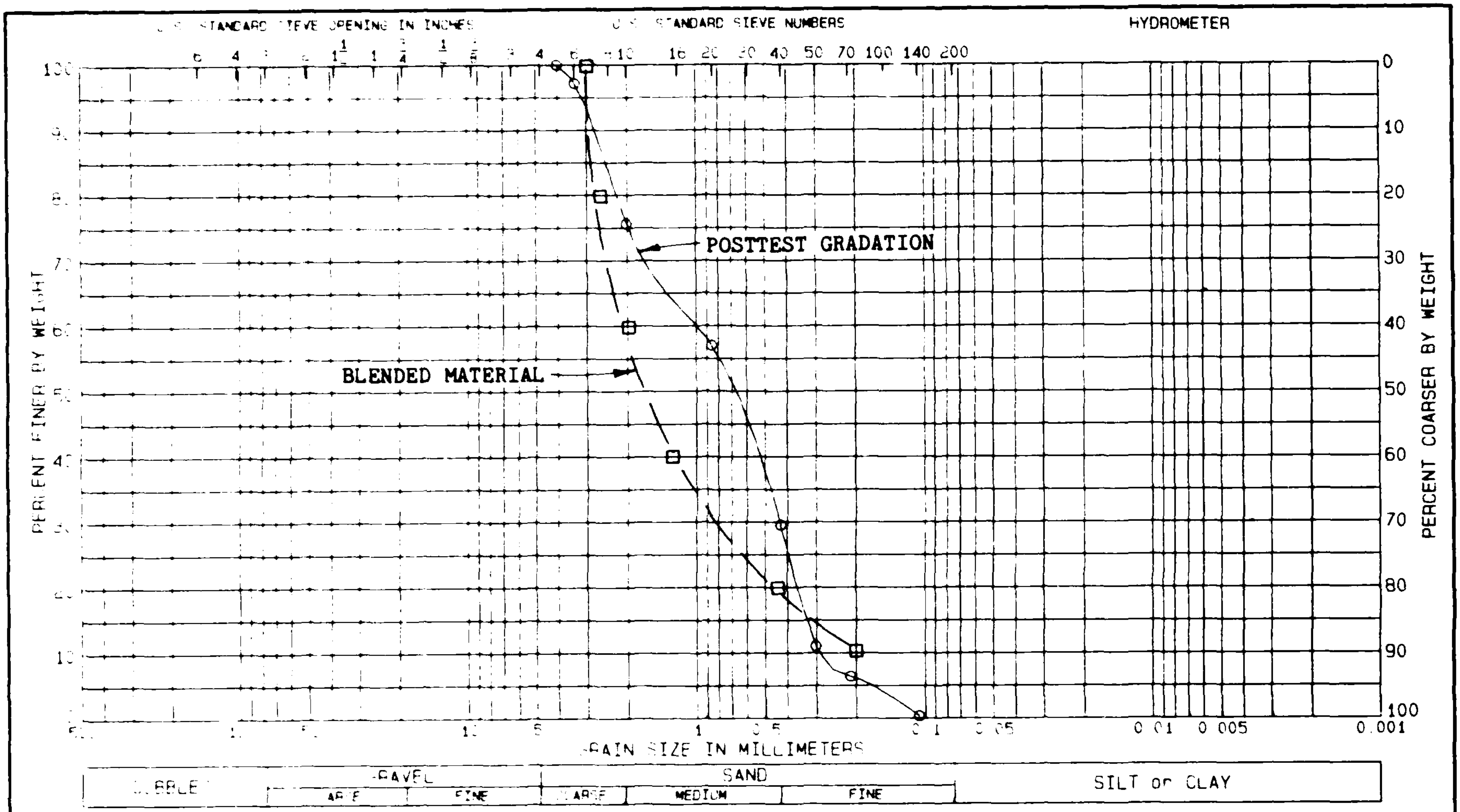

PERCENT FINER BY WEIGHT
HYDROMETER
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
62 - 68 IN.
LL
PL
PI

PLATE D68



LL	PL	PI		NAT W %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO 1A
56 - 62 IN.

BORING NO

SAMPLE NO. 2

DEPTH/ELEV

DATE 00 MAR 82

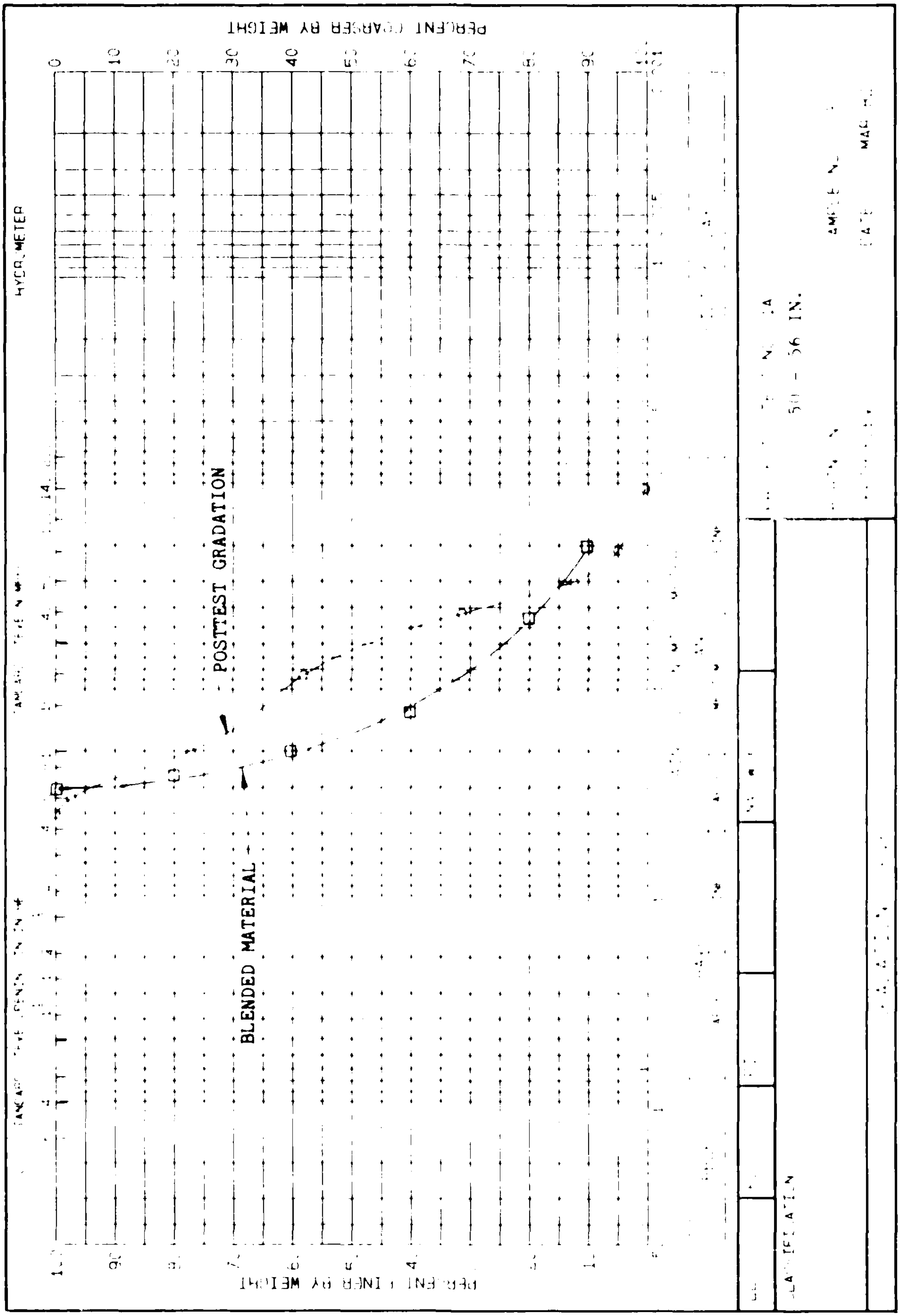

PERCENT COARSER BY WEIGHT
HYDROMETER
POSTTEST GRADATION
BLENDED MATERIAL
50 - 56 IN.

PLATE D70

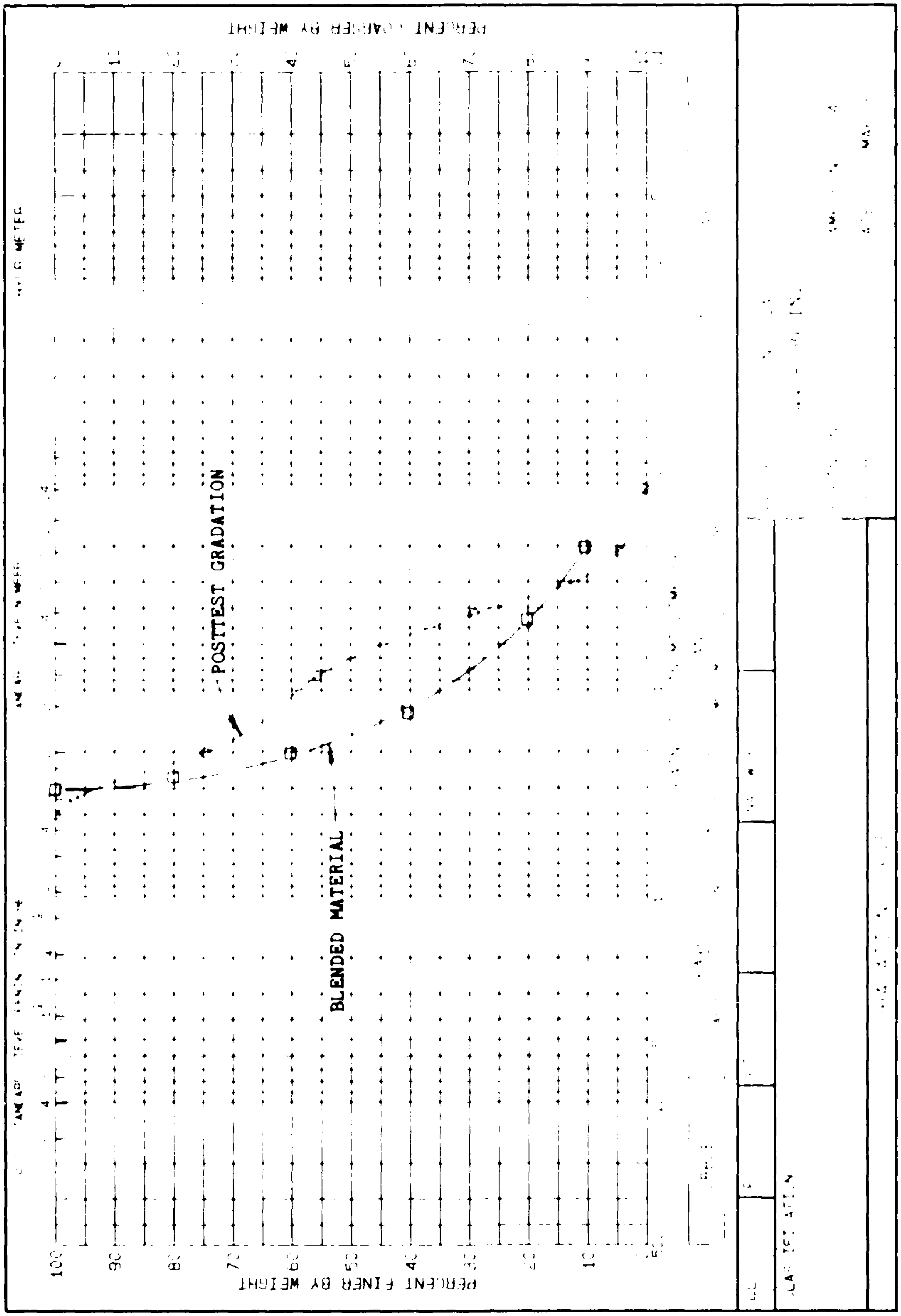

POSTTEST GRADATION
BLENDED MATERIAL
PERCENT FINER BY WEIGHT

PLATE D71

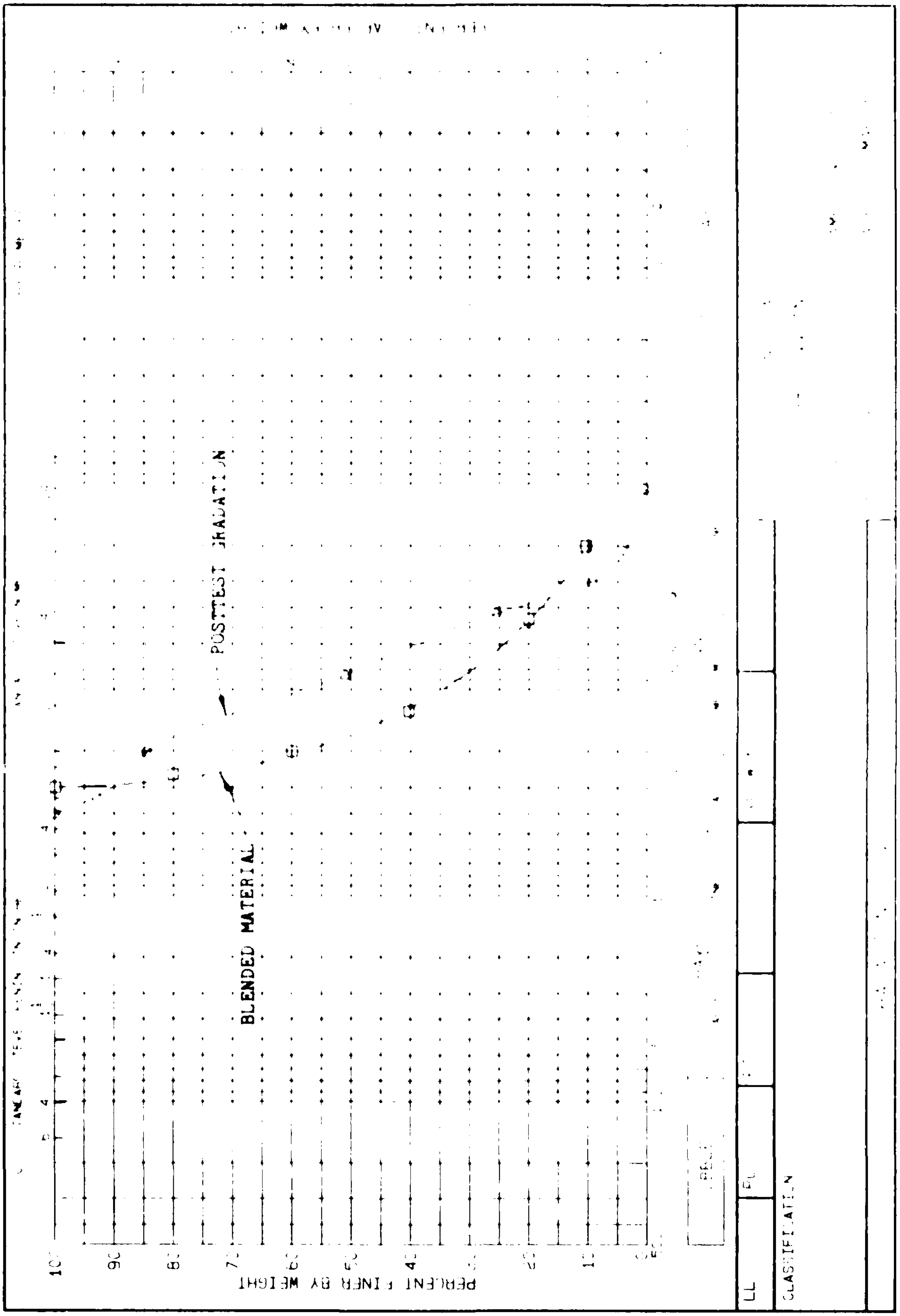

POSTTEST GRADATION
BLENDED MATERIAL
PERCENT FINER BY WEIGHT
CLASSIFICATION

PLATE D72

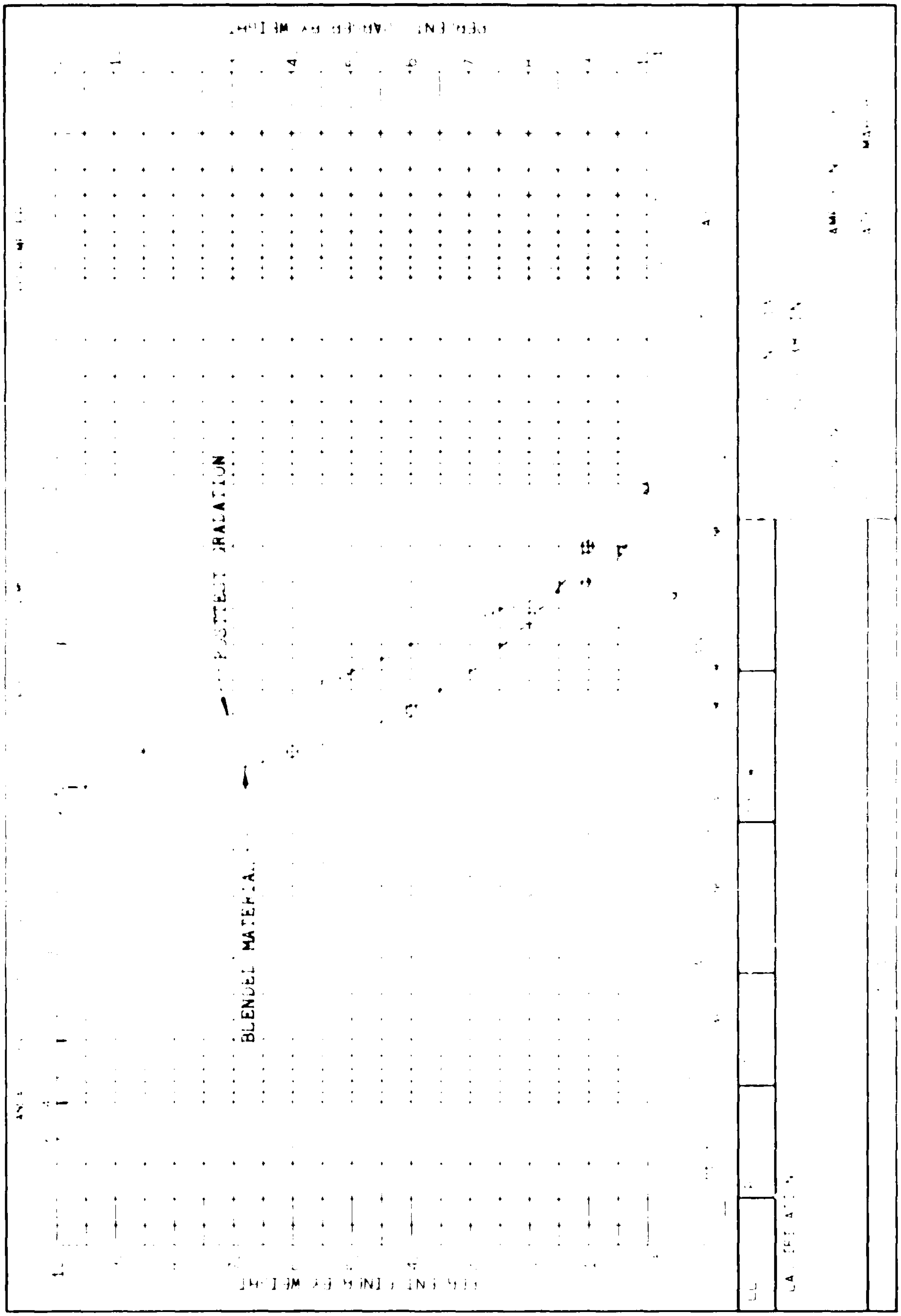


PLATE D73

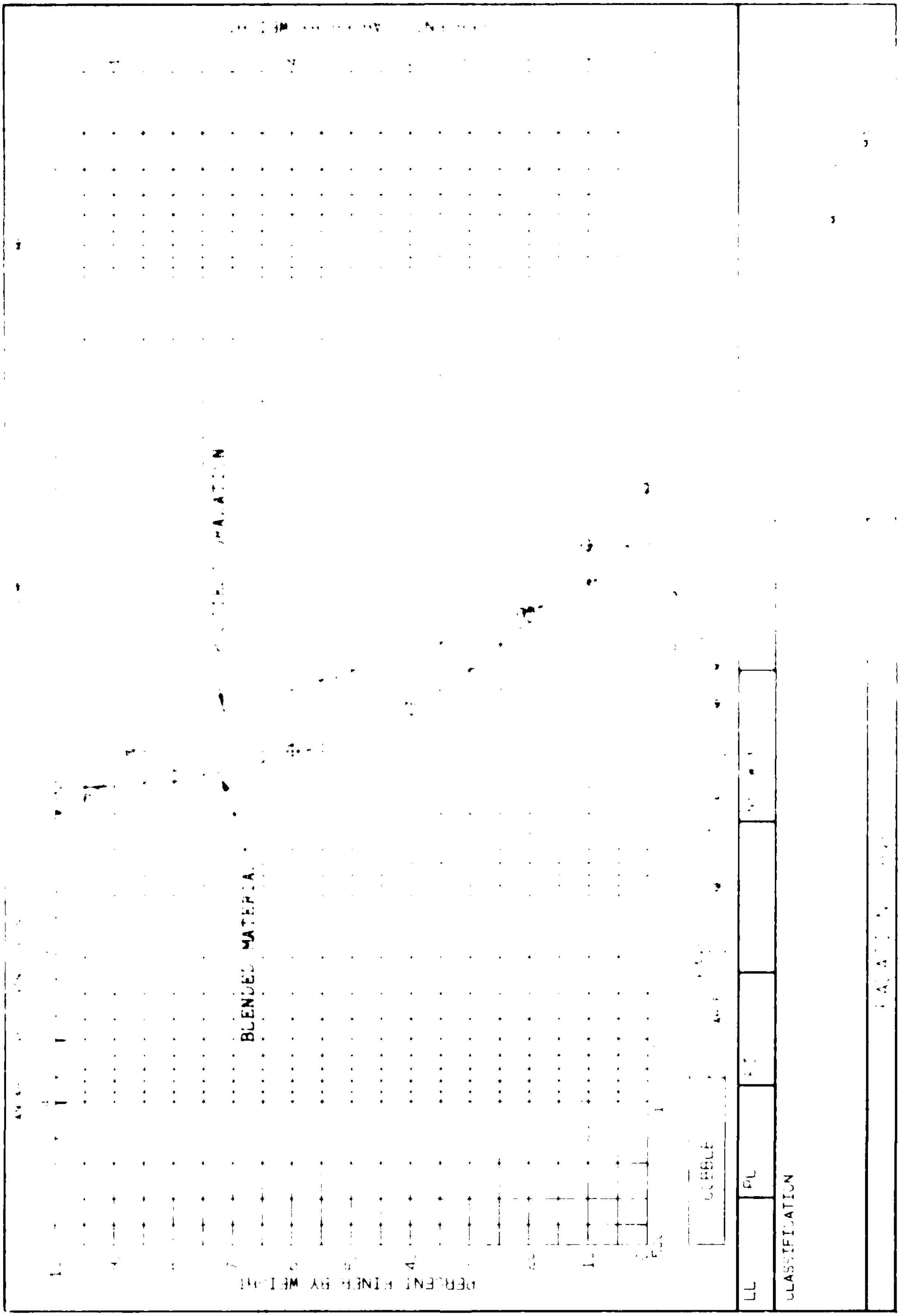
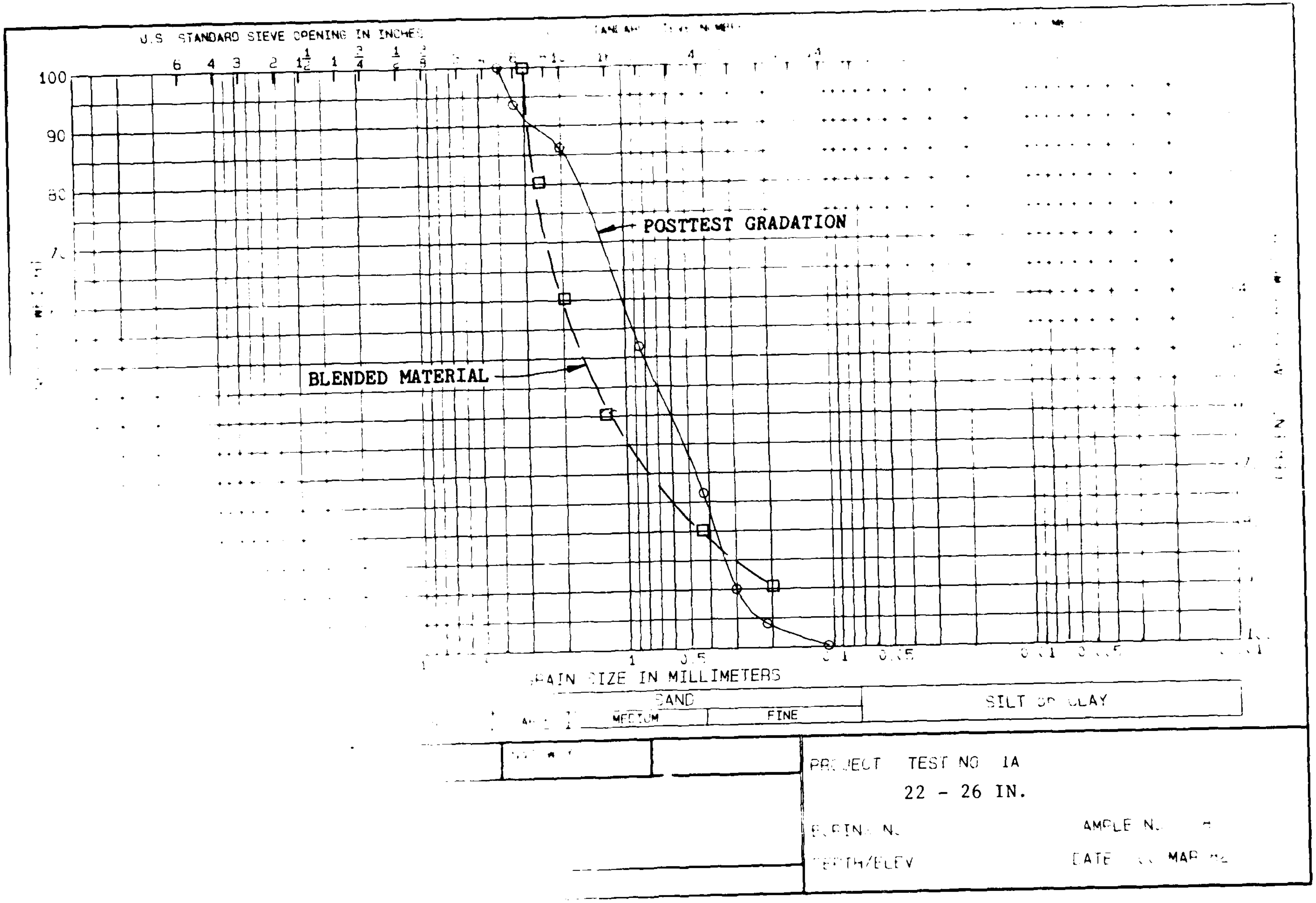
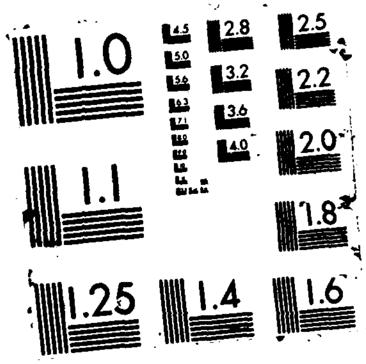

BLENDED MATERIAL
PERCENT FINER BY WEIGHT
COBBLE
LL
PL
CLASSIFICATION

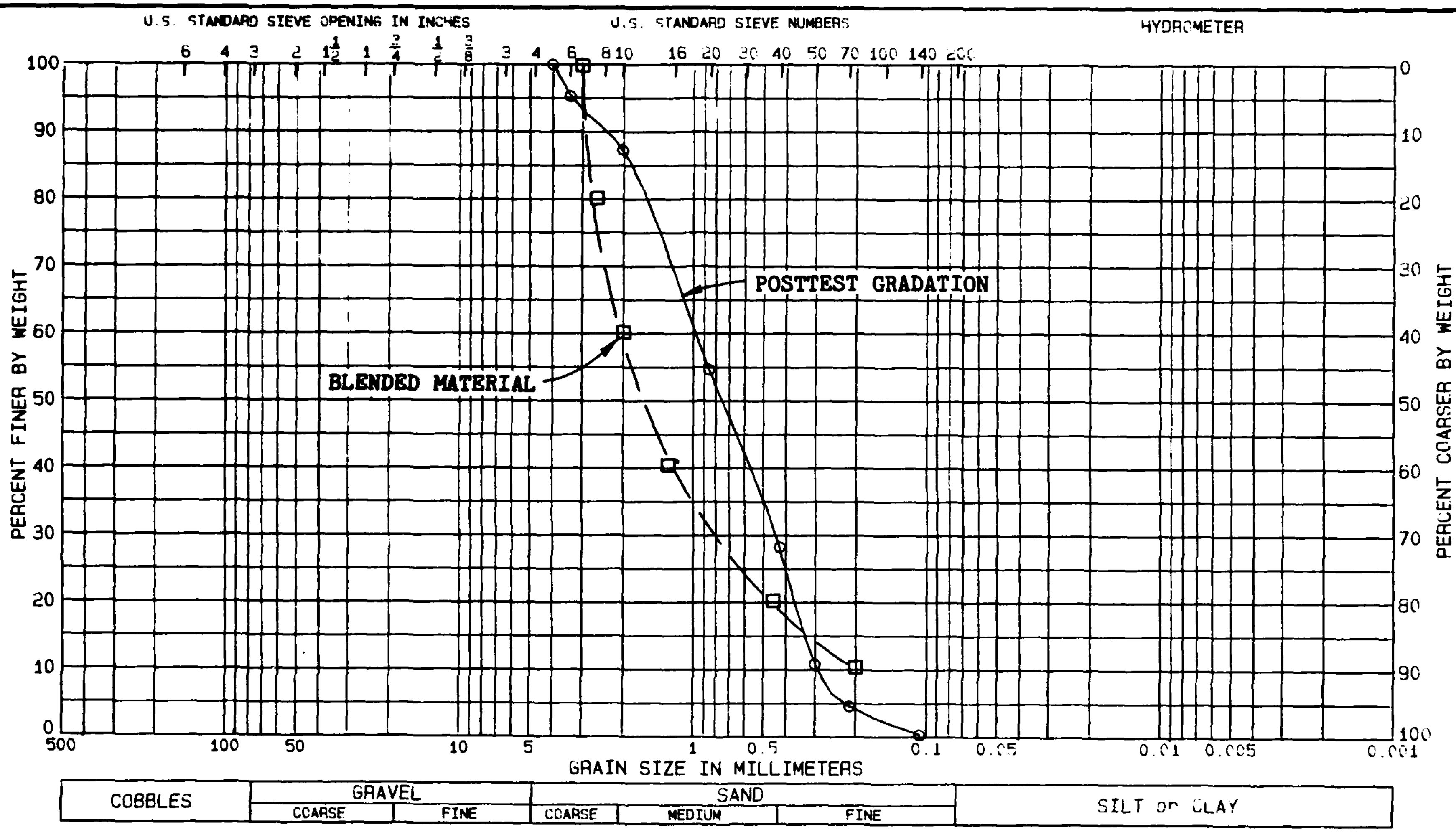
PLATE D74


U.S. STANDARD SIEVE OPENING IN INCHES
100
90
80
POSTTEST GRADATION
BLENDED MATERIAL
GRAIN SIZE IN MILLIMETERS
SAND
MEDIUM
FINE
SILT OR CLAY
PROJECT TEST NO 1A
22 - 26 IN.
BORING NO
SAMPLE NO
DEPTH/ELEV
DATE MAR

AD-A185 623 LABORATORY TESTS ON GRANULAR FILTERS FOR EMBANKMENT DAMS(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS GEOTECHNICAL LAB E B PERRY AUG 87 4/4

UNCLASSIFIED WES/TR/GL-87-22 F/G 13/2 NL


1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

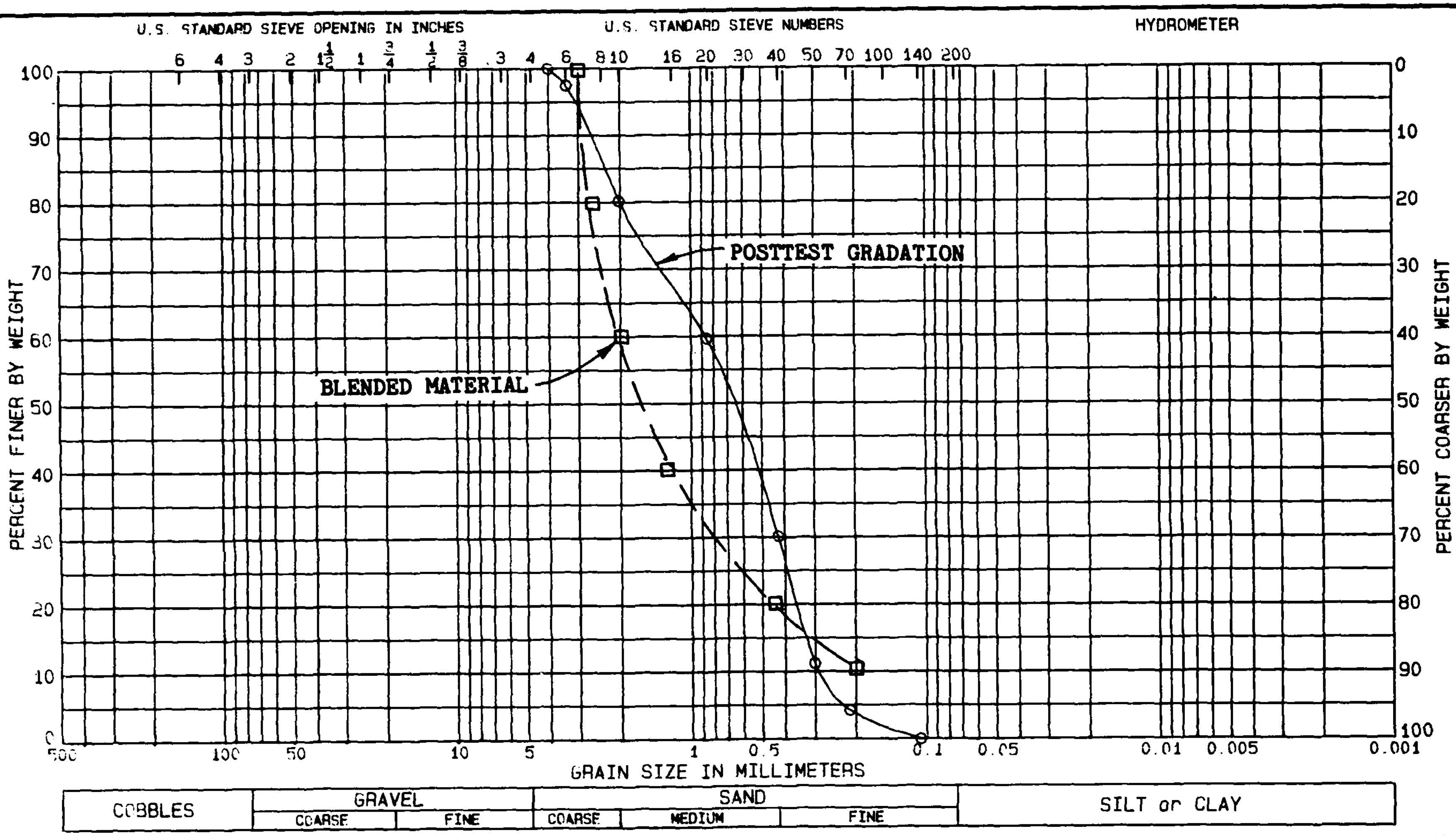
GRADATION CURVE

PROJECT TEST NO. 1A
16 - 22 IN.

BORING NO. SAMPLE NO. 9

DEPTH/ELEV DATE 00 MAR 82

PLATE D76



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

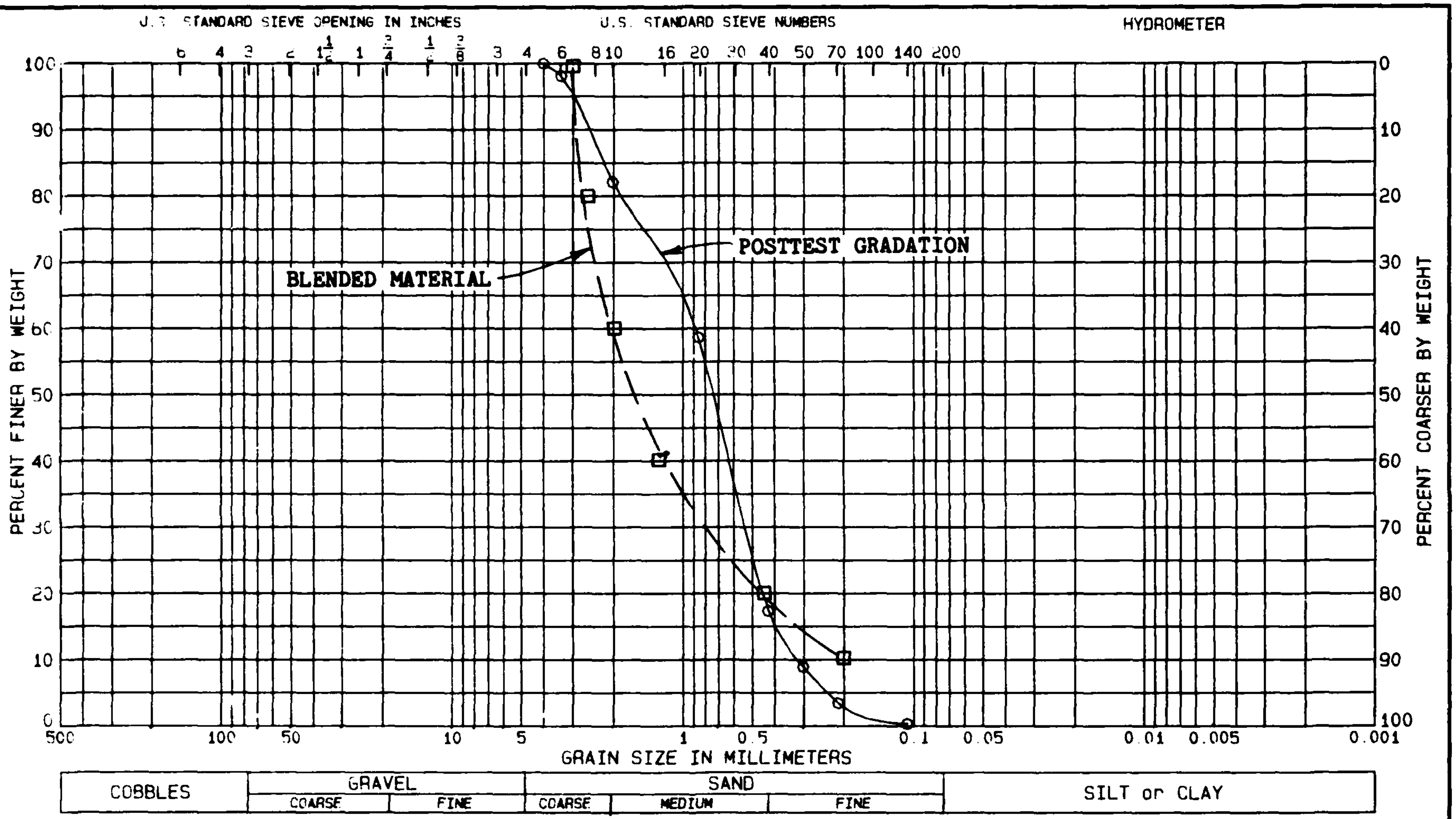
GRADATION CURVE

PROJECT TEST NO. 1A

10 - 16 IN.

BORING NO. SAMPLE NO. 10

DEPTH/ELEV DATE 00 MAR 82



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

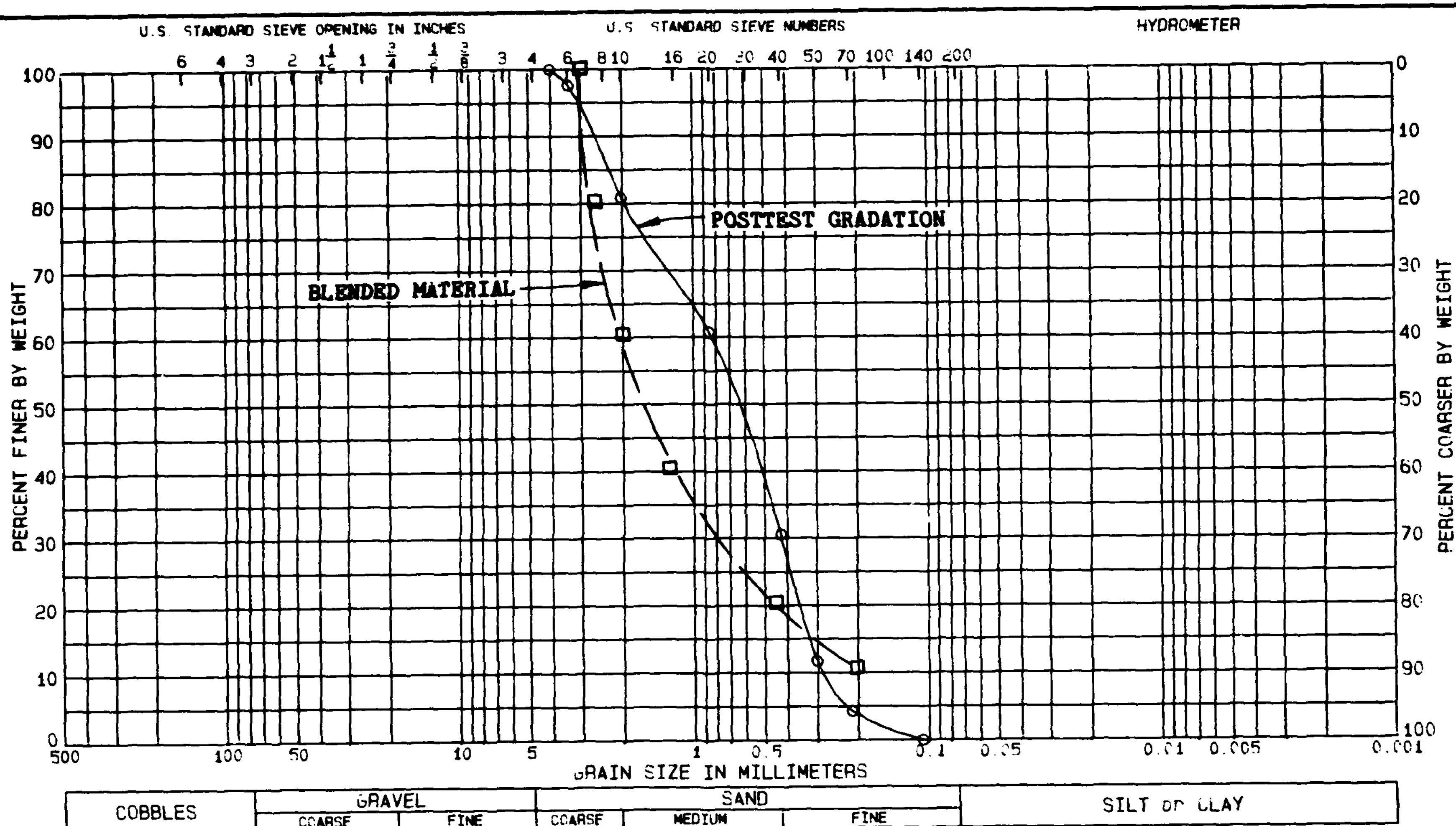
GRADATION CURVE

PROJECT TEST NO. 1A
5 - 10 IN.

BORING NO. SAMPLE NO. 11

DEPTH/ELEV DATE 00 MAR 82

PLATE D78



LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

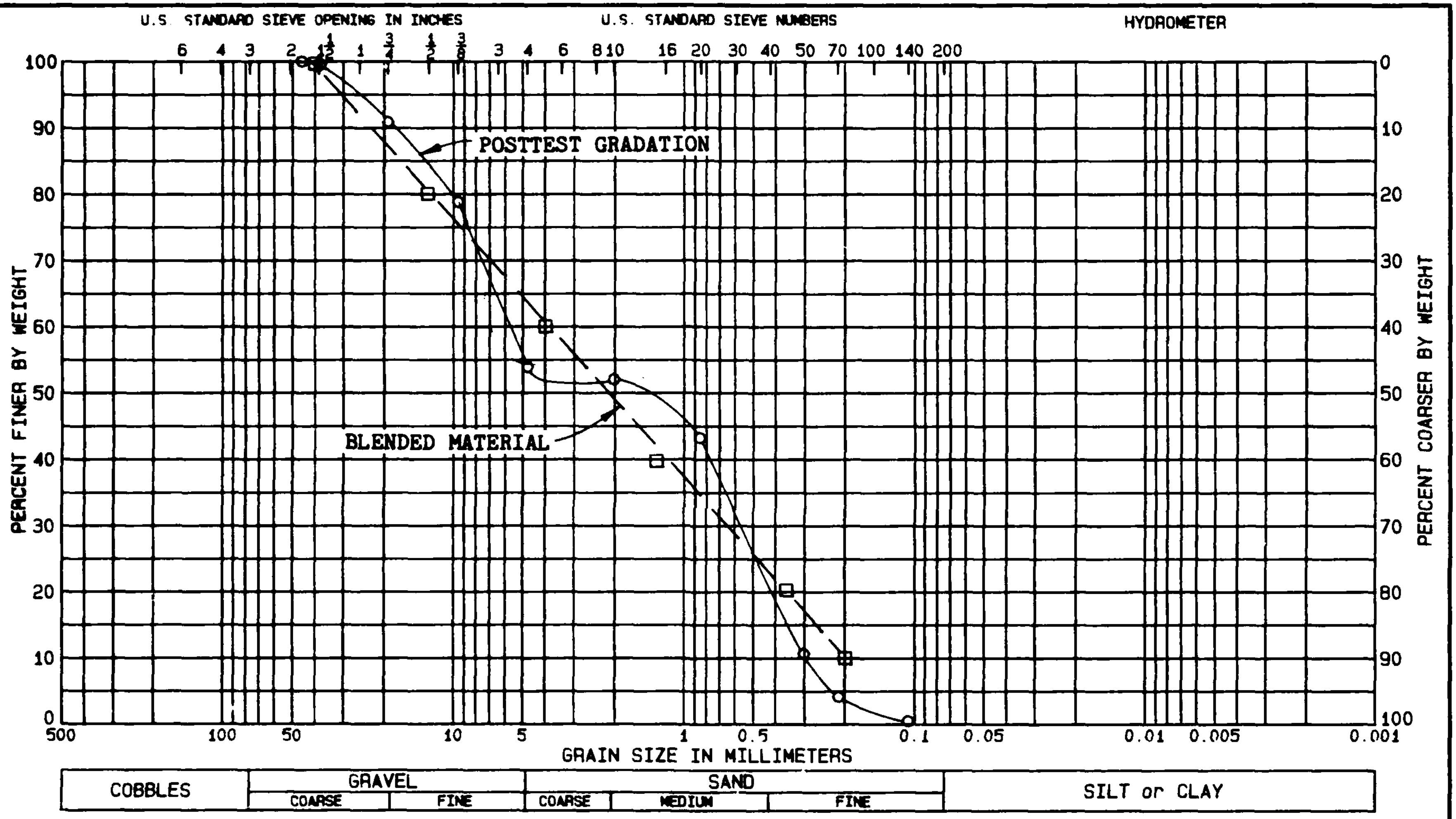
GRADATION CURVE

PROJECT TEST NO. 1A

0 - 5 IN.

BORING NO. SAMPLE NO. 12

DEPTH/ELEV DATE 00 MAR 82



LL	PL	PI	GS	NAT W.%	

CLASSIFICATION

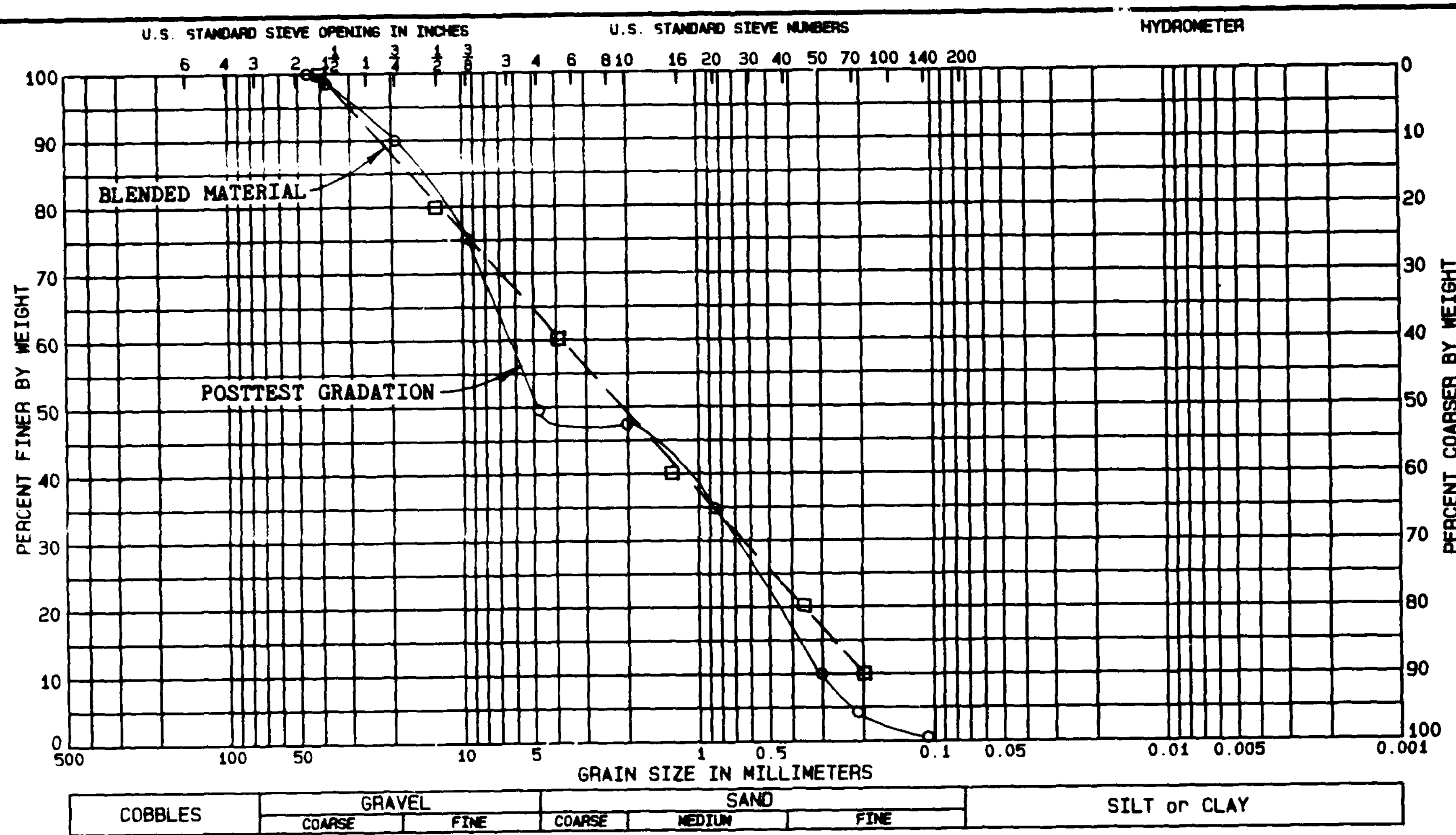
GRADATION CURVE

PROJECT TEST NO. 2
62 - 68.25 IN

BORING NO. SAMPLE NO. 1

DEPTH/ELEV DATE 00 AUG 81

PLATE D80



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

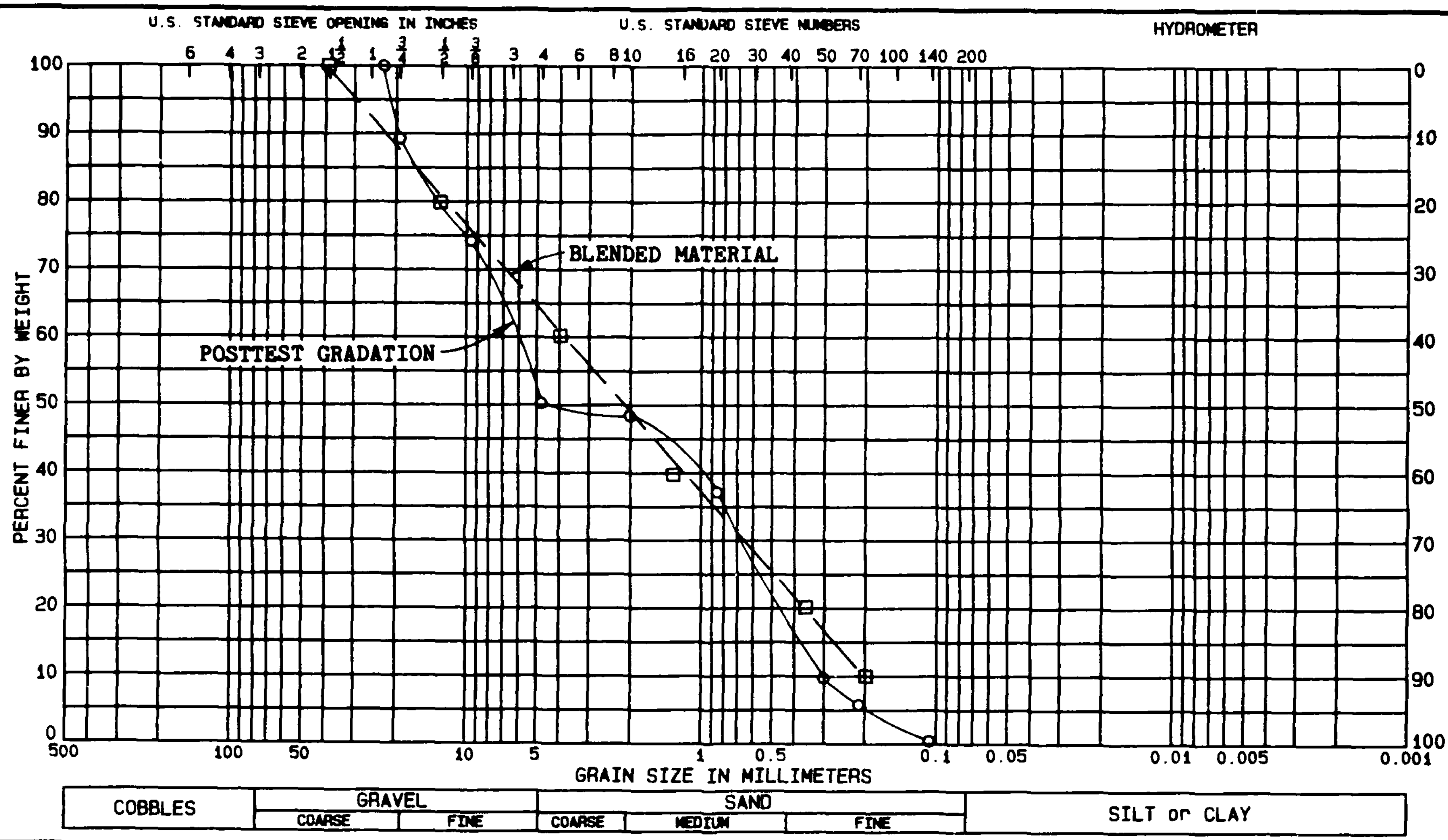
GRADATION CURVE

PROJECT TEST NO. 2
56 - 62 IN.

BORING NO. SAMPLE NO. 2

DEPTH/ELEV DATE 00 AUG 81

PLATE D81



LL	PL	PI	GS	NAT W, %	

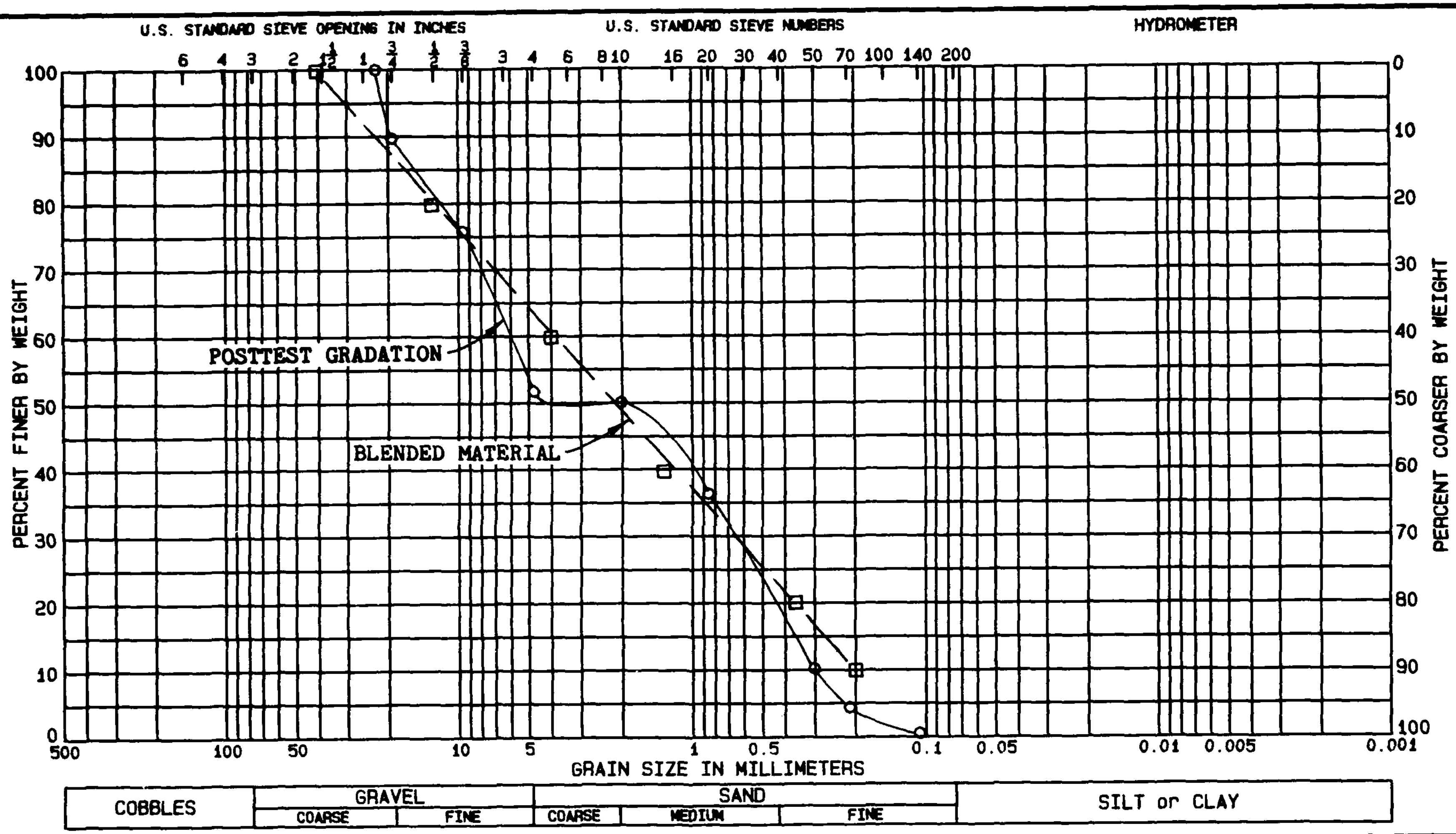
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2
50 - 56 IN.

BORING NO. SAMPLE NO. 3

DEPTH/ELEV DATE 00 AUG 81



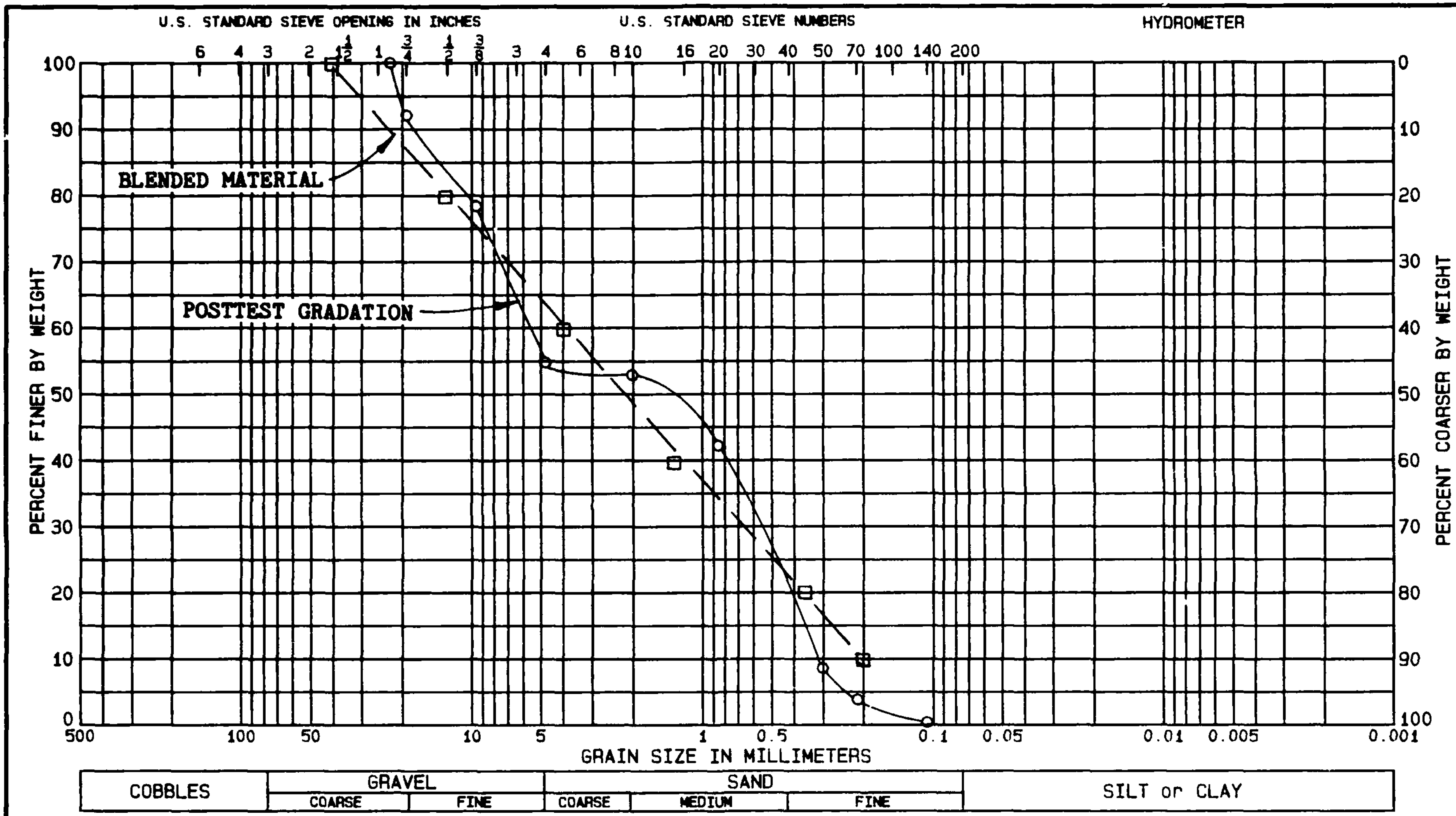
LL	PL	PI	GS	NAT W, %	
CLASSIFICATION					

PROJECT TEST NO. 2
44 - 50 IN.

BORING NO. SAMPLE NO. 4

DEPTH/ELEV DATE 00 AUG 81

GRADATION CURVE



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

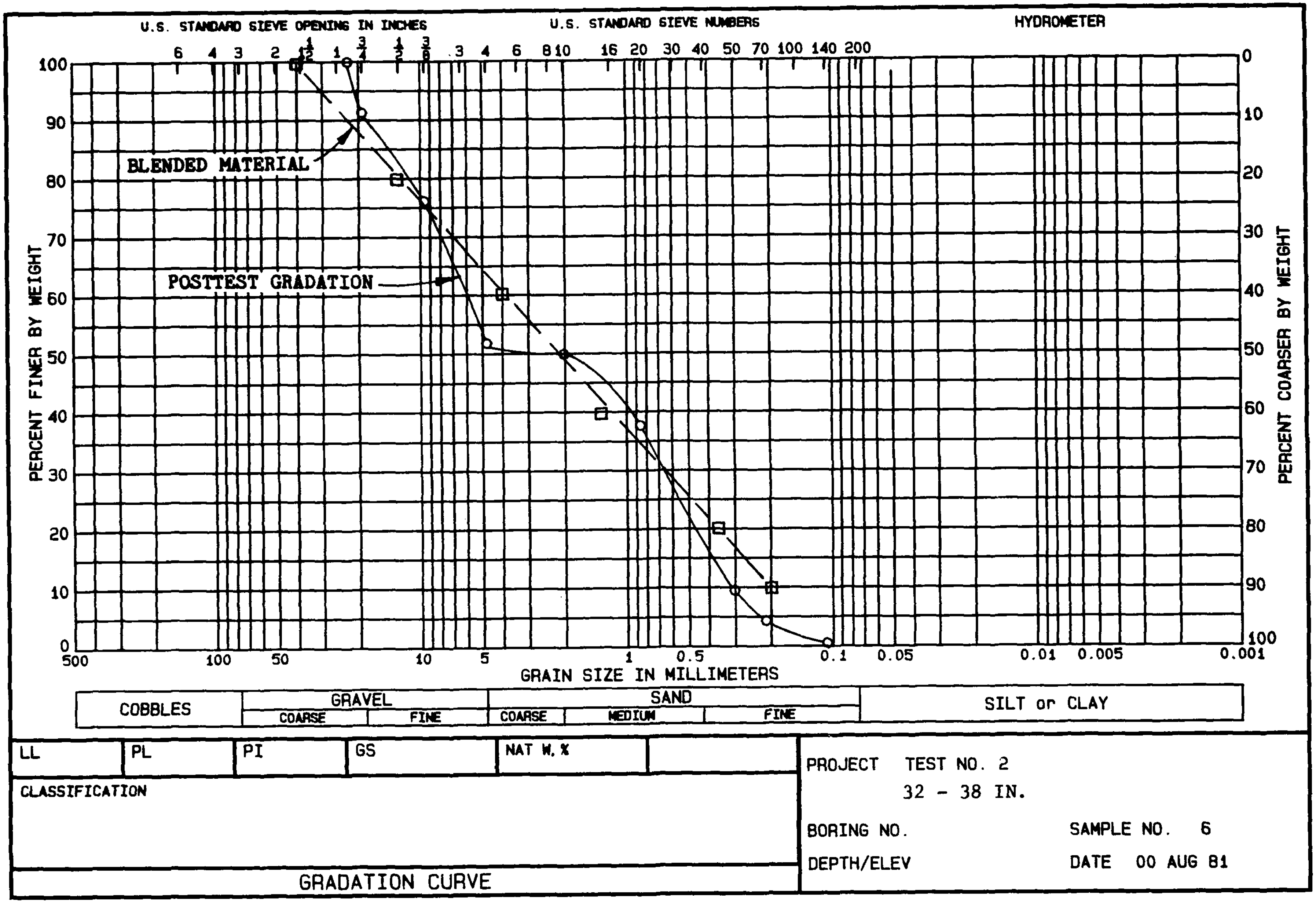
GRADATION CURVE

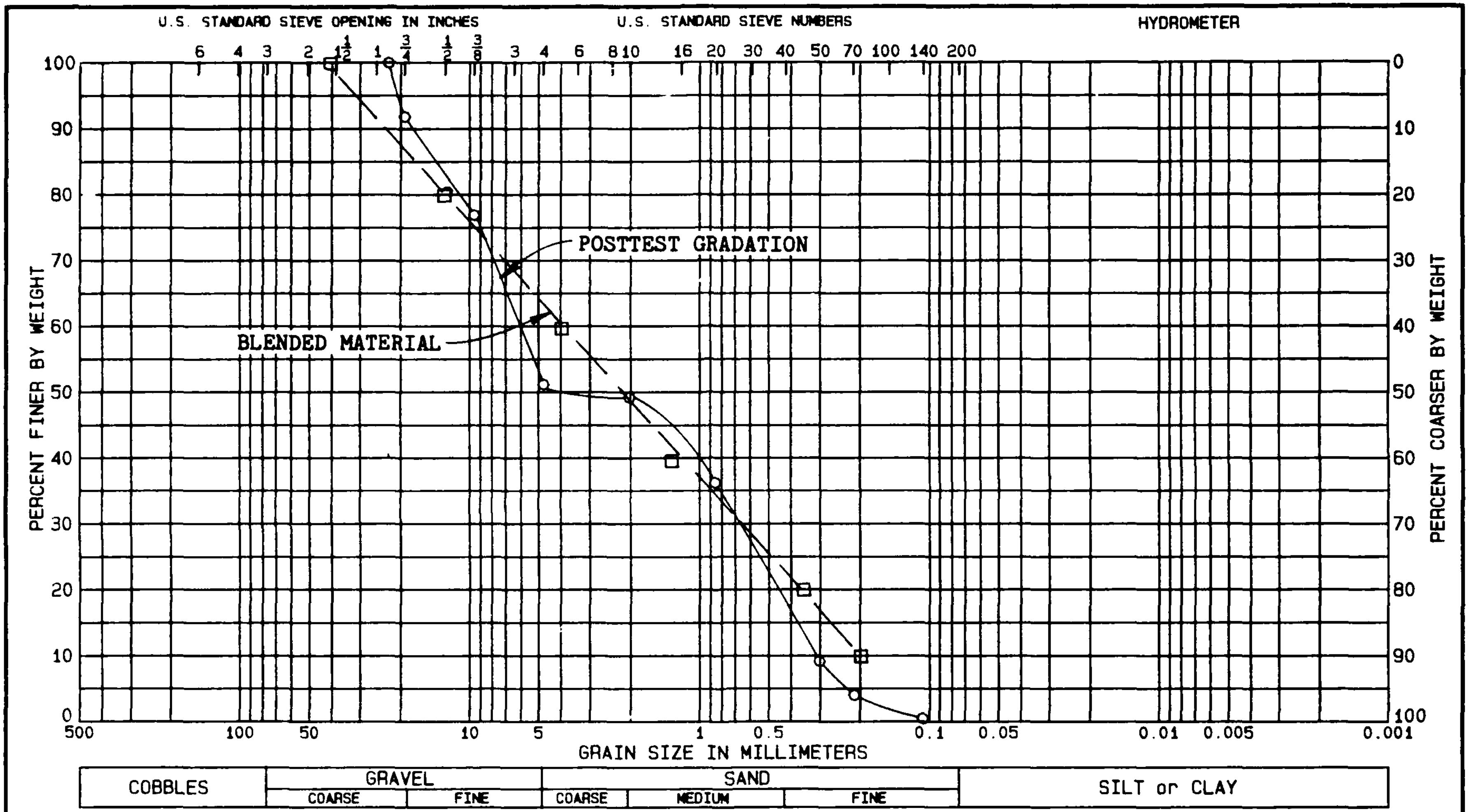
PROJECT TEST NO. 2
38 - 44 IN.

BORING NO. SAMPLE NO. 5

DEPTH/ELEV DATE 00 AUG 81

PLATE D84


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
GRADATION CURVE
PROJECT TEST NO. 2
32 - 38 IN.
BORING NO.
SAMPLE NO. 6
DEPTH/ELEV
DATE 00 AUG 81



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

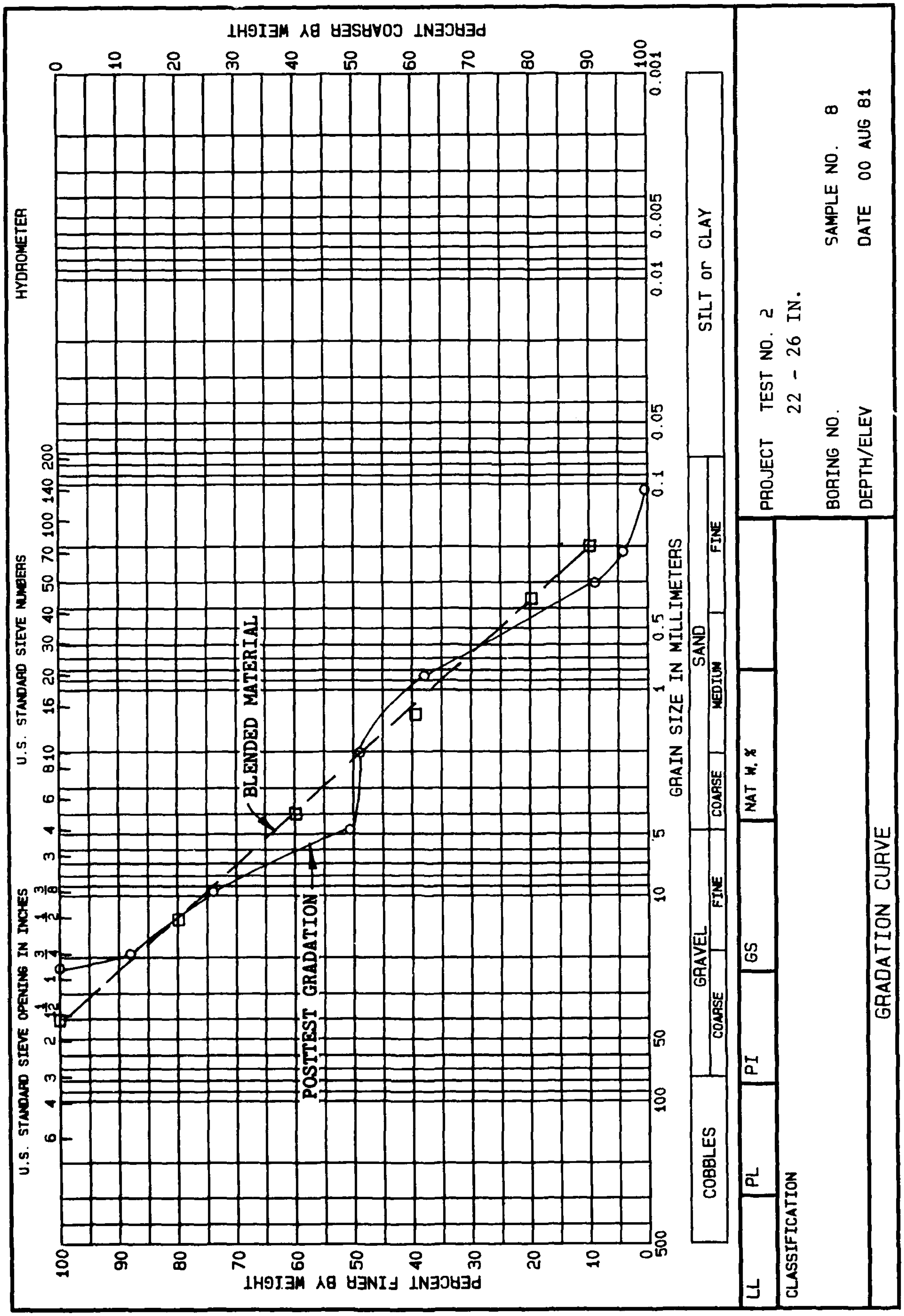
GRADATION CURVE

PROJECT TEST NO. 2
26 - 32 IN.

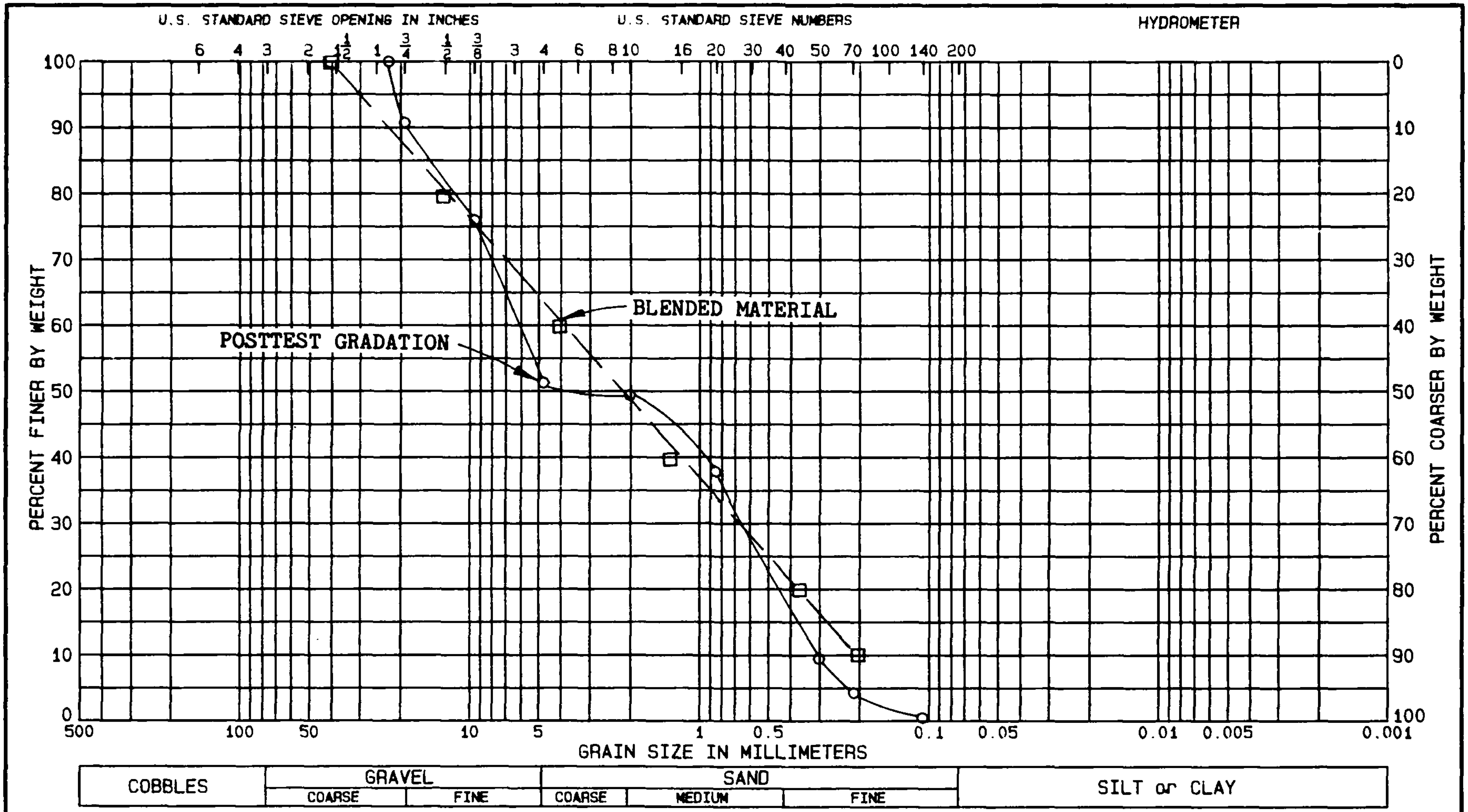
BORING NO. SAMPLE NO. 7

DEPTH/ELEV DATE 00 AUG 81

PLATE D86



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1½ 1 ¾ ½ ⅜ 3
4 6 8 10 16 20 30 40 50 70 100 140 200
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 2
22 - 26 IN.
BORING NO.
SAMPLE NO. 8
DEPTH/ELEV
DATE 00 AUG 81
GRADATION CURVE



LL	PL	PI	GS	NAT W, %	

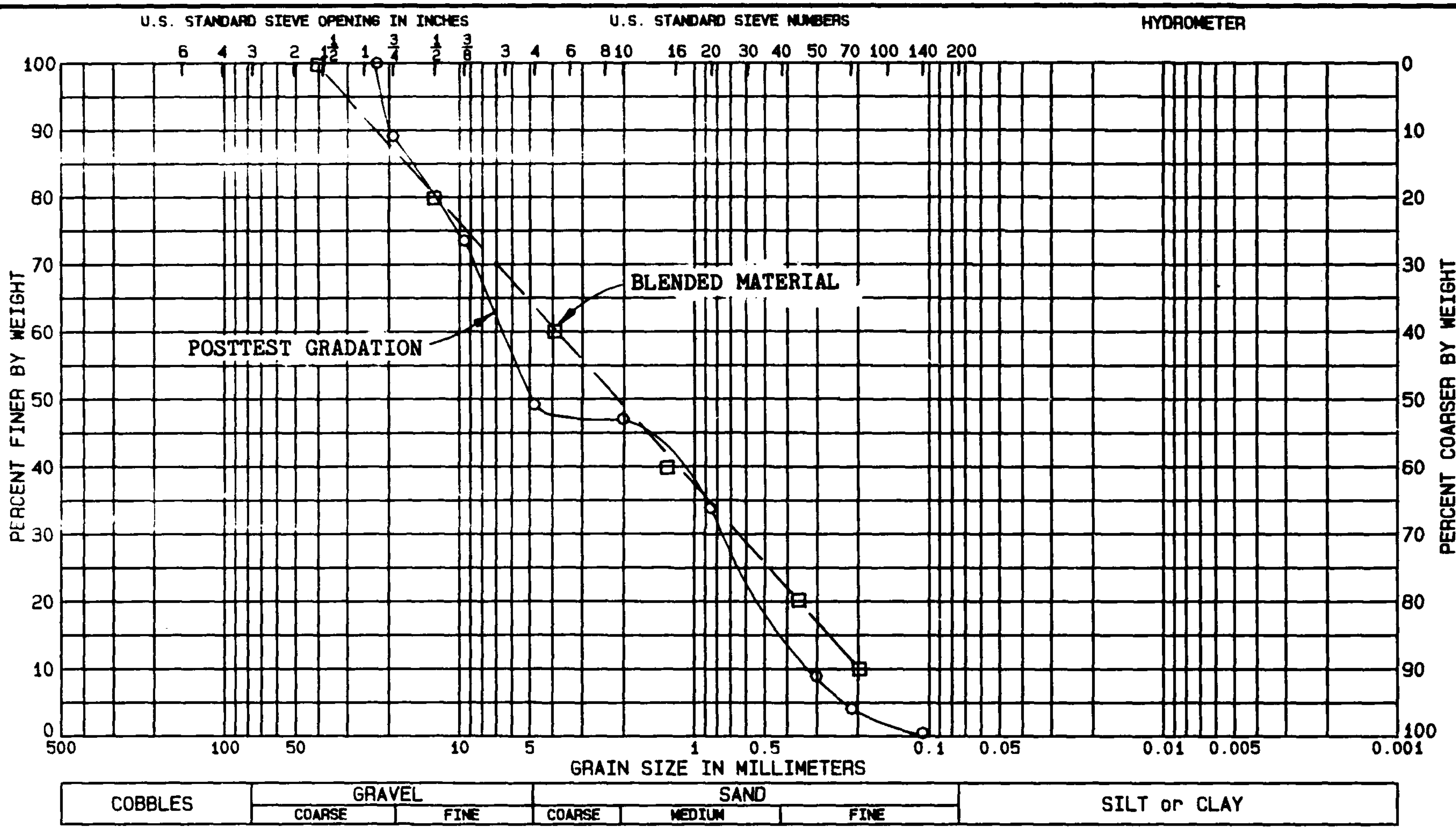
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2
16 - 22 IN.

BORING NO. SAMPLE NO. 9

DEPTH/ELEV DATE 00 AUG 81



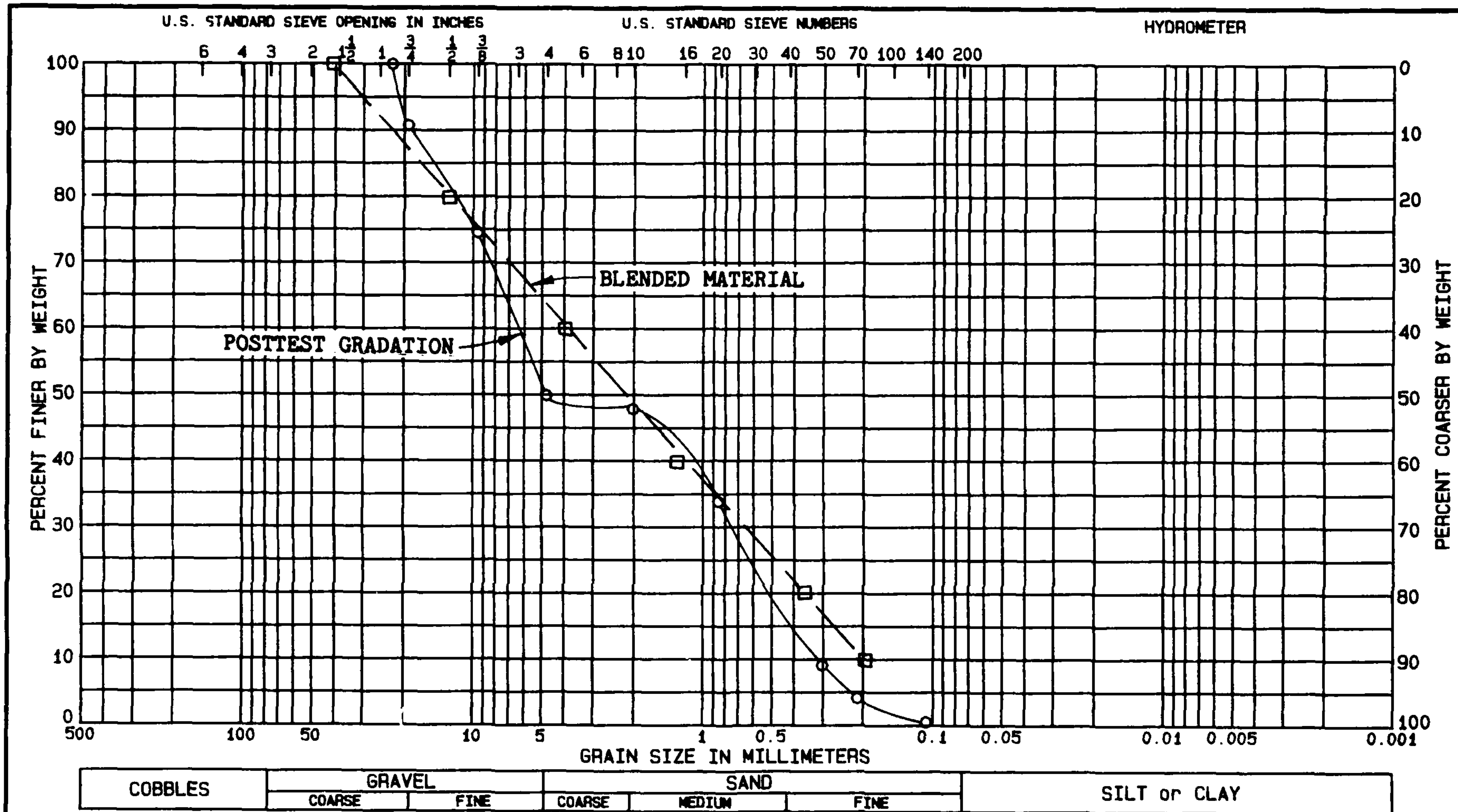
LL	PL	PI	GS	NAT W, %	
CLASSIFICATION					

PROJECT TEST NO. 2
10 - 16 IN.

BORING NO. SAMPLE NO. 10

DEPTH/ELEV DATE 00 AUG 81

GRADATION CURVE



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2
5 - 10 IN.

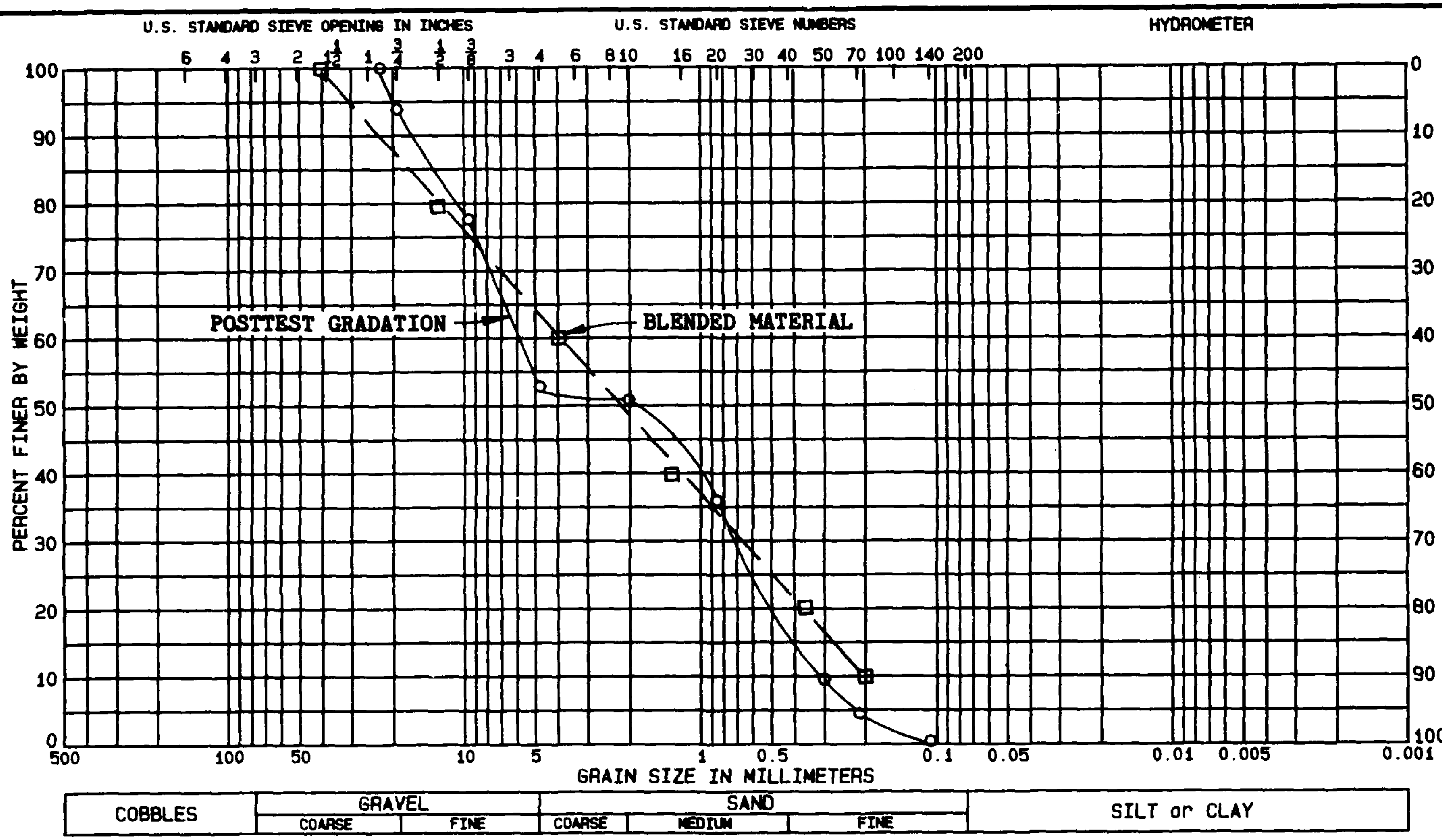
BORING NO.

SAMPLE NO. 11

DEPTH/ELEV

DATE 00 AUG 81

PLATE D90



LL	PL	PI	GS	NAT W, %	

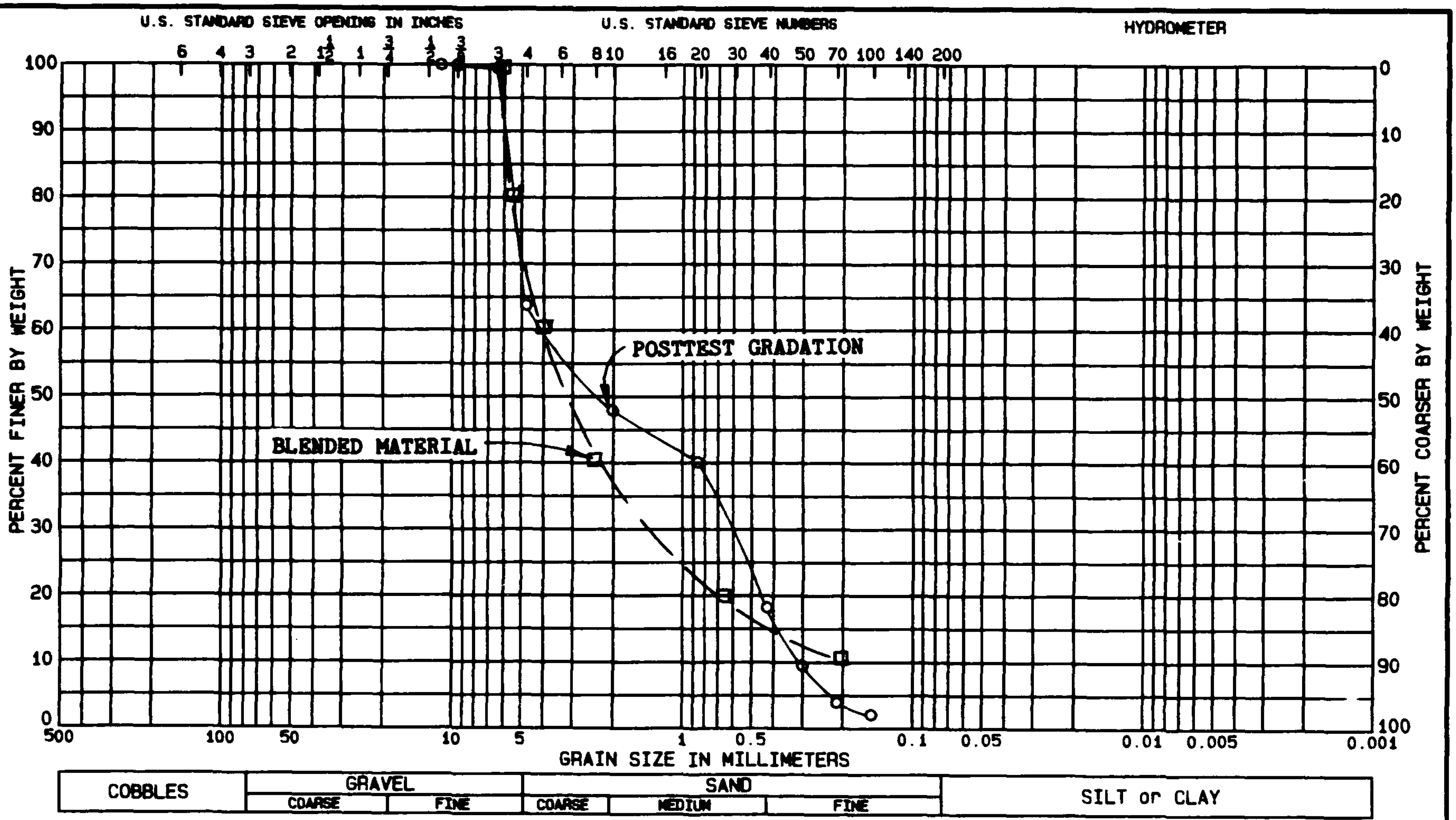
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2
0 - 5 IN.

BORING NO. SAMPLE NO. 12

DEPTH/ELEV DATE 00 AUG 81



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2A
62 - 68.25 IN.

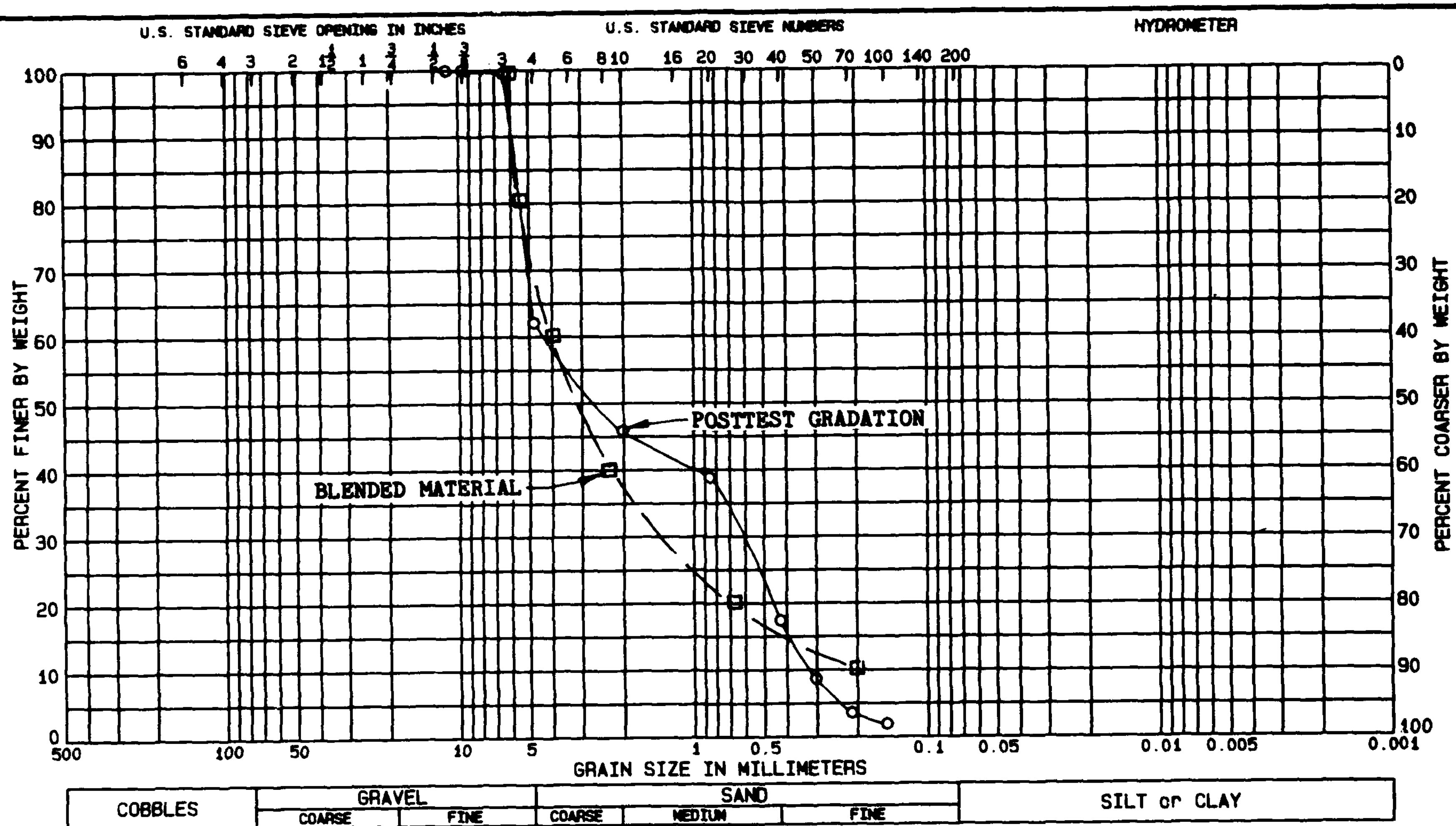
BORING NO.

SAMPLE NO. 1

DEPTH/ELEV

DATE 00 MAY 82

PLATE D92



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2A
56 - 62 IN.

BORING NO. SAMPLE NO. 2

DEPTH/ELEV DATE 0C MAY 82

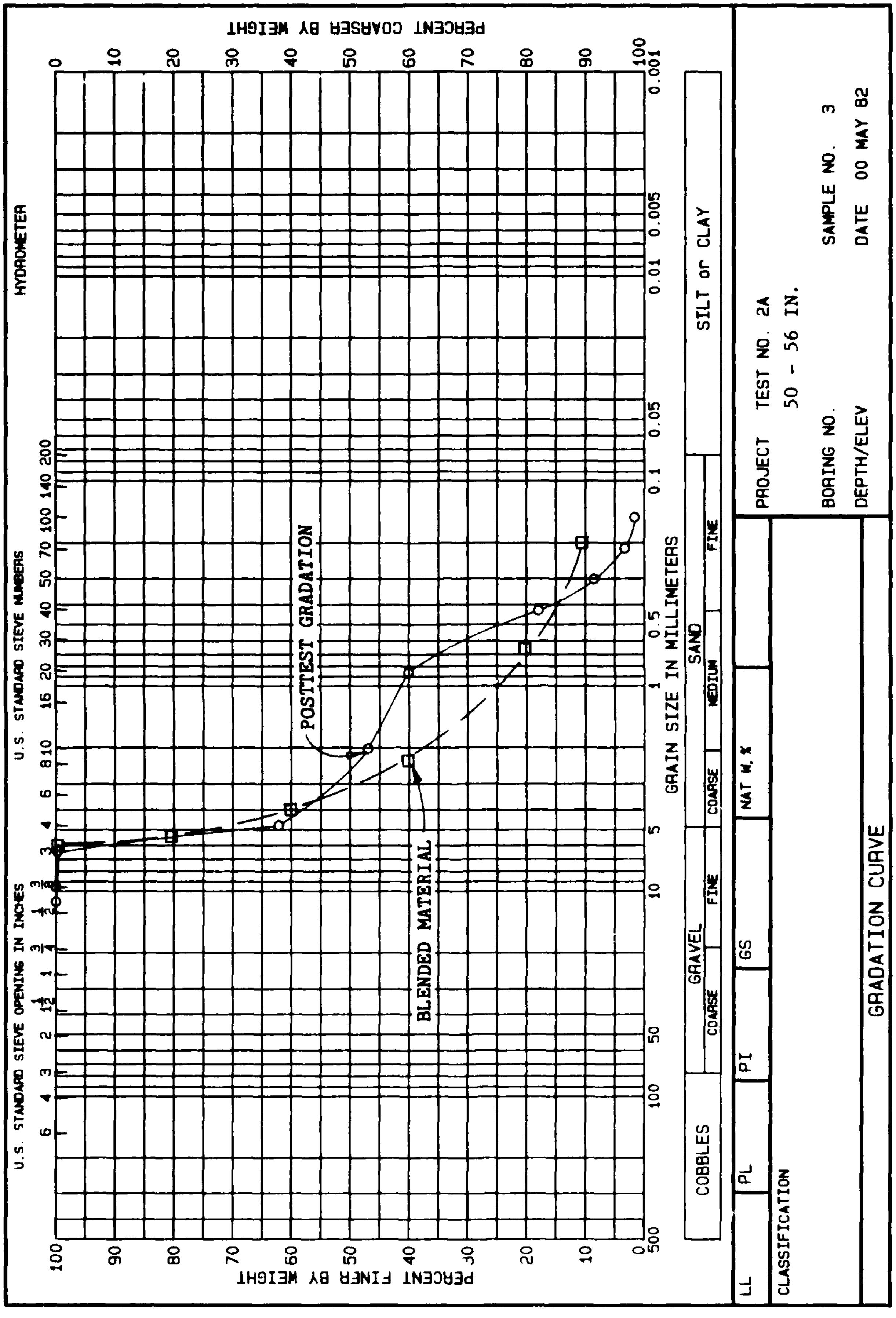
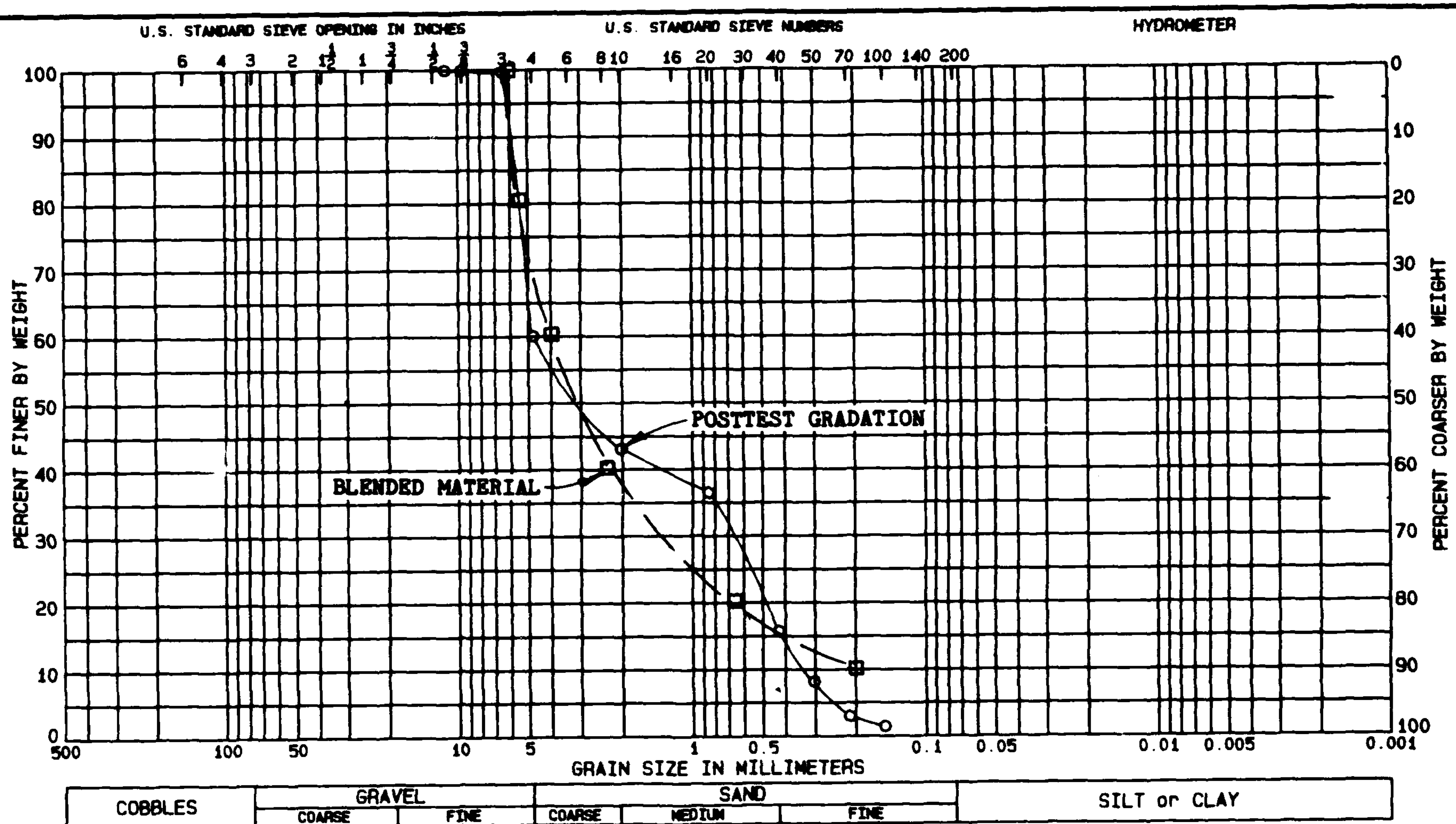

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 2A
50 - 56 IN.
BORING NO.
SAMPLE NO. 3
DEPTH/ELEV
DATE 00 MAY 82
GRADATION CURVE

PLATE D94



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 2A 44 - 50 IN.
CLASSIFICATION						BORING NO. SAMPLE NO. 4
GRADATION CURVE						DEPTH/ELEV DATE 00 MAY 82

PLATE D95

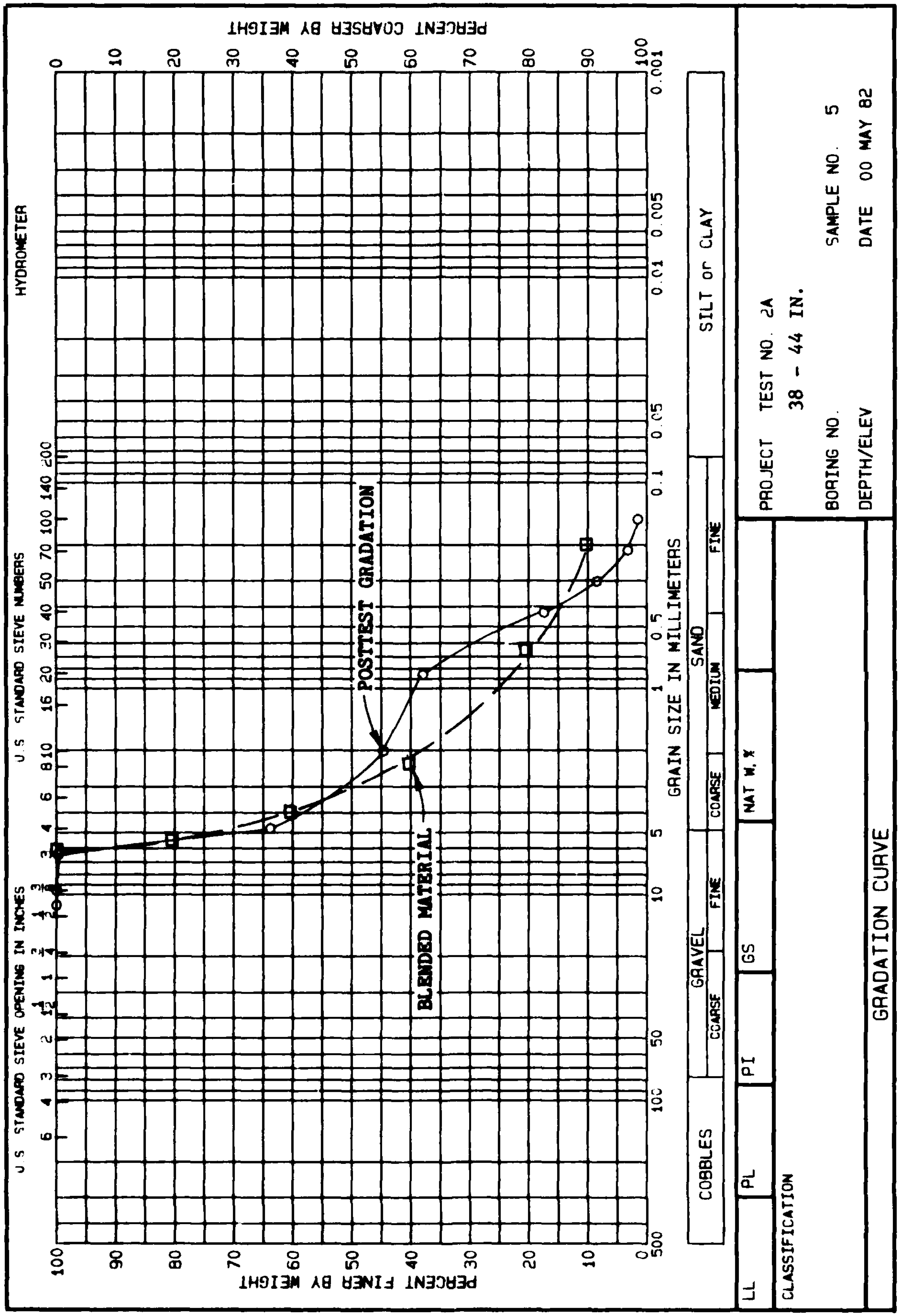
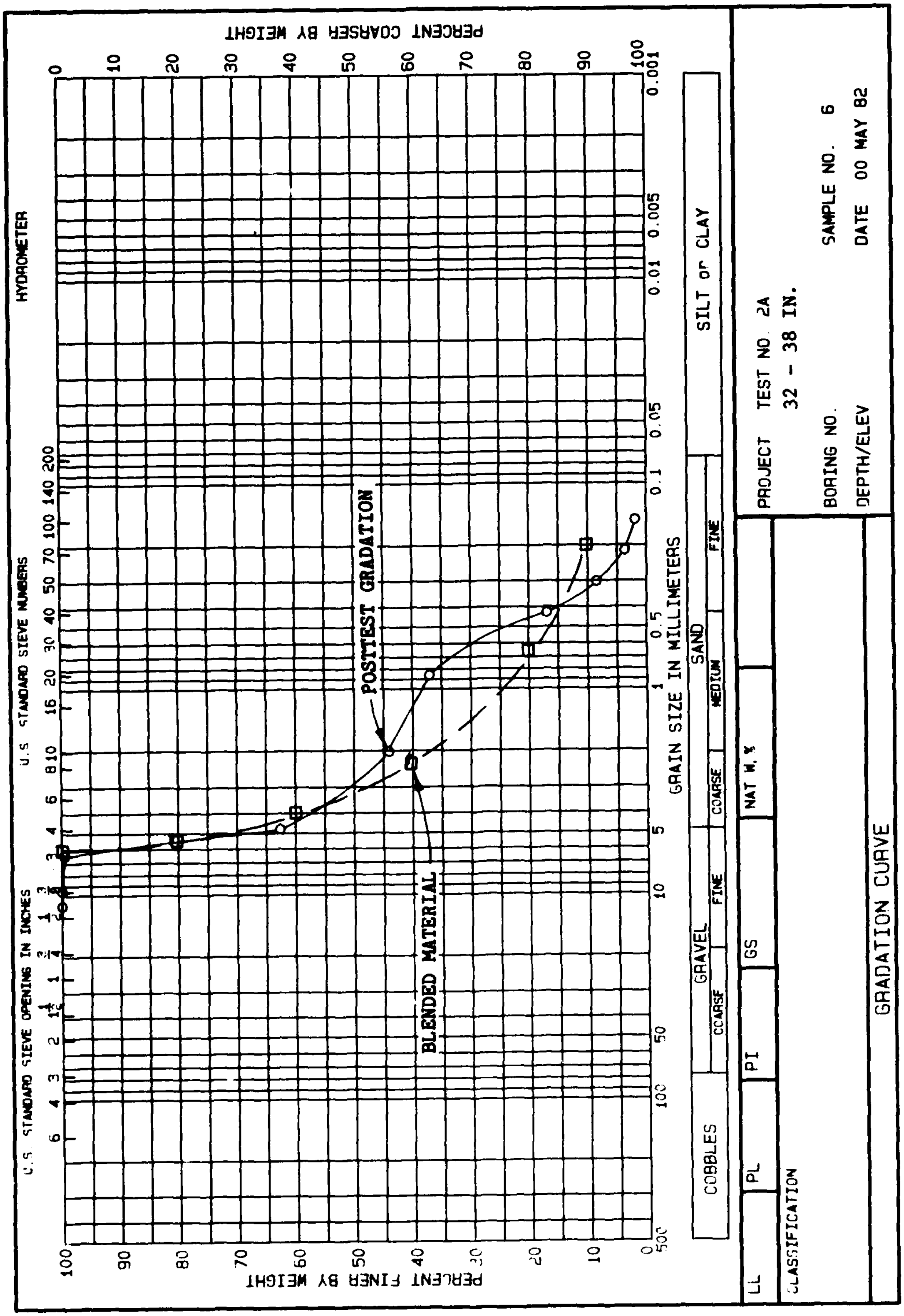

GRADATION CURVE
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
CLASSIFICATION
PROJECT TEST NO. 2A
38 - 44 IN.
BORING NO.
SAMPLE NO. 5
DEPTH/ELEV
DATE 00 MAY 82

PLATE D96



PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W. %
CLASSIFICATION
PROJECT TEST NO. 2A
32 - 38 IN.
BORING NO.
SAMPLE NO. 6
DEPTH/ELEV
DATE 00 MAY 82
GRADATION CURVE

PLATE D97

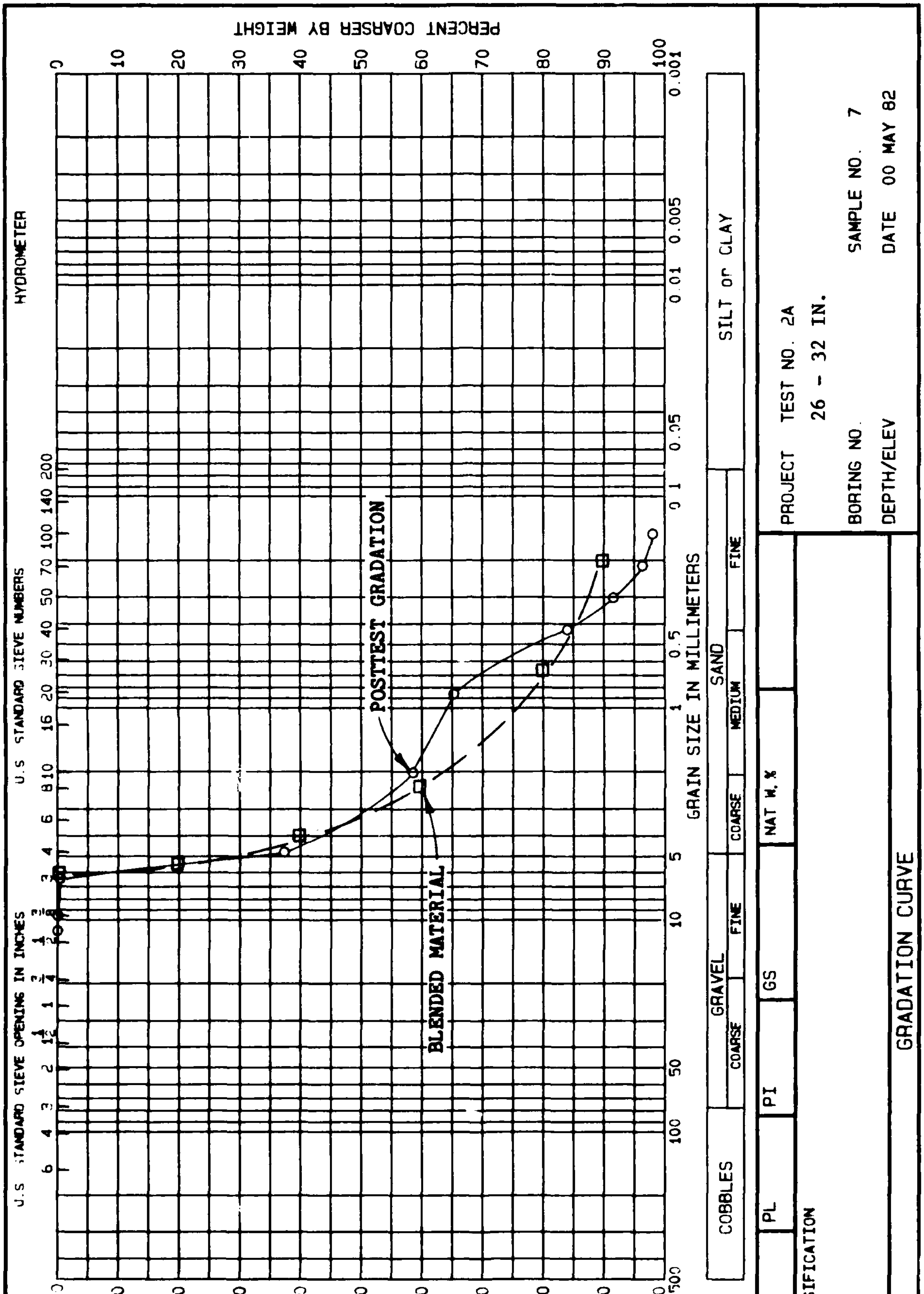
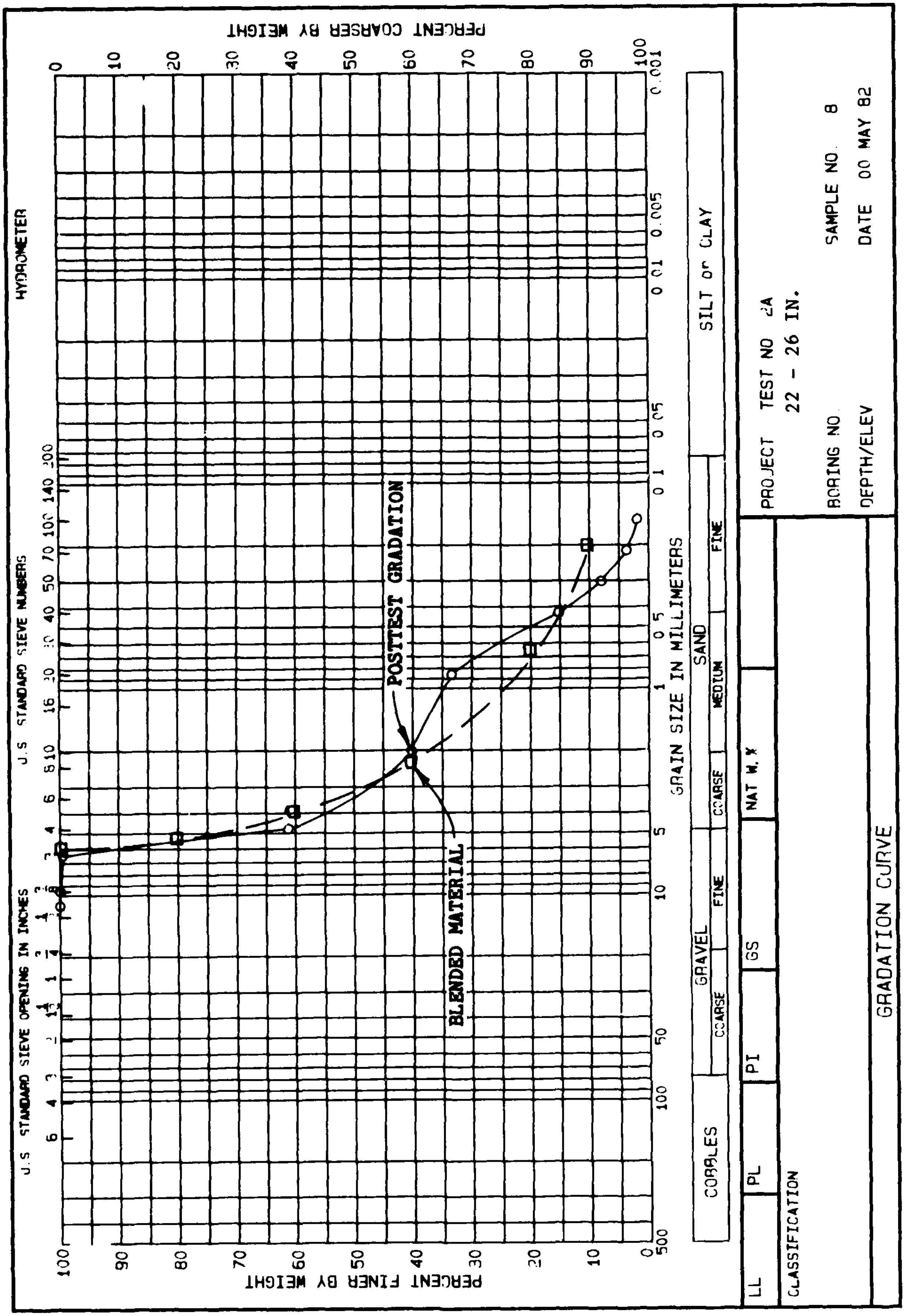

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W. %
CLASSIFICATION
PROJECT TEST NO. 2A
26 - 32 IN.
BORING NO.
SAMPLE NO. 7
DEPTH/ELEV
DATE 00 MAY 82
GRADATION CURVE

PLATE D98



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W %
CLASSIFICATION
PROJECT TEST NO 2A
22 - 26 IN.
BORING NO
SAMPLE NO 8
DEPTH/ELEV
DATE 00 MAY 82
GRADATION CURVE

PLATE D99

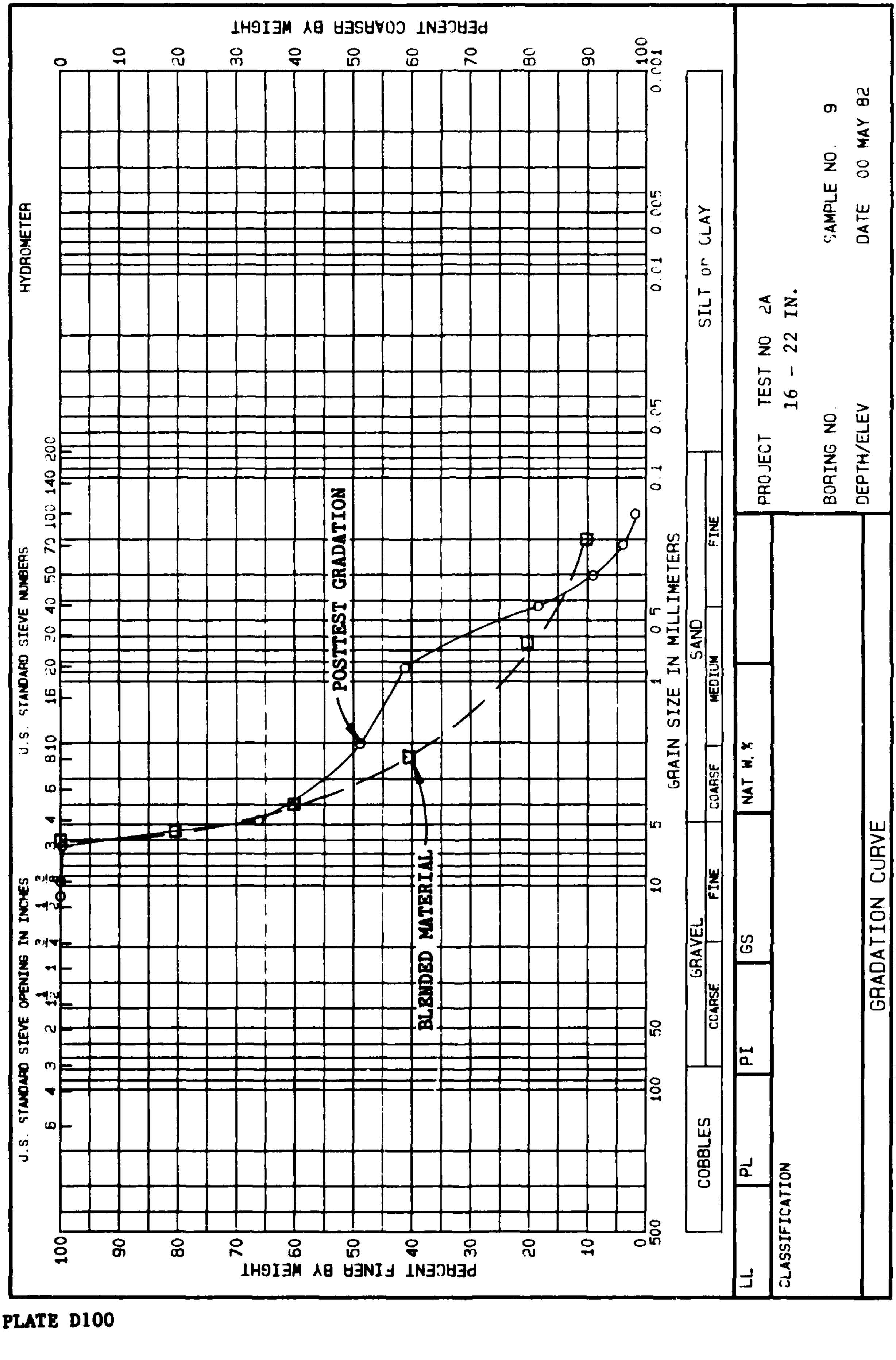
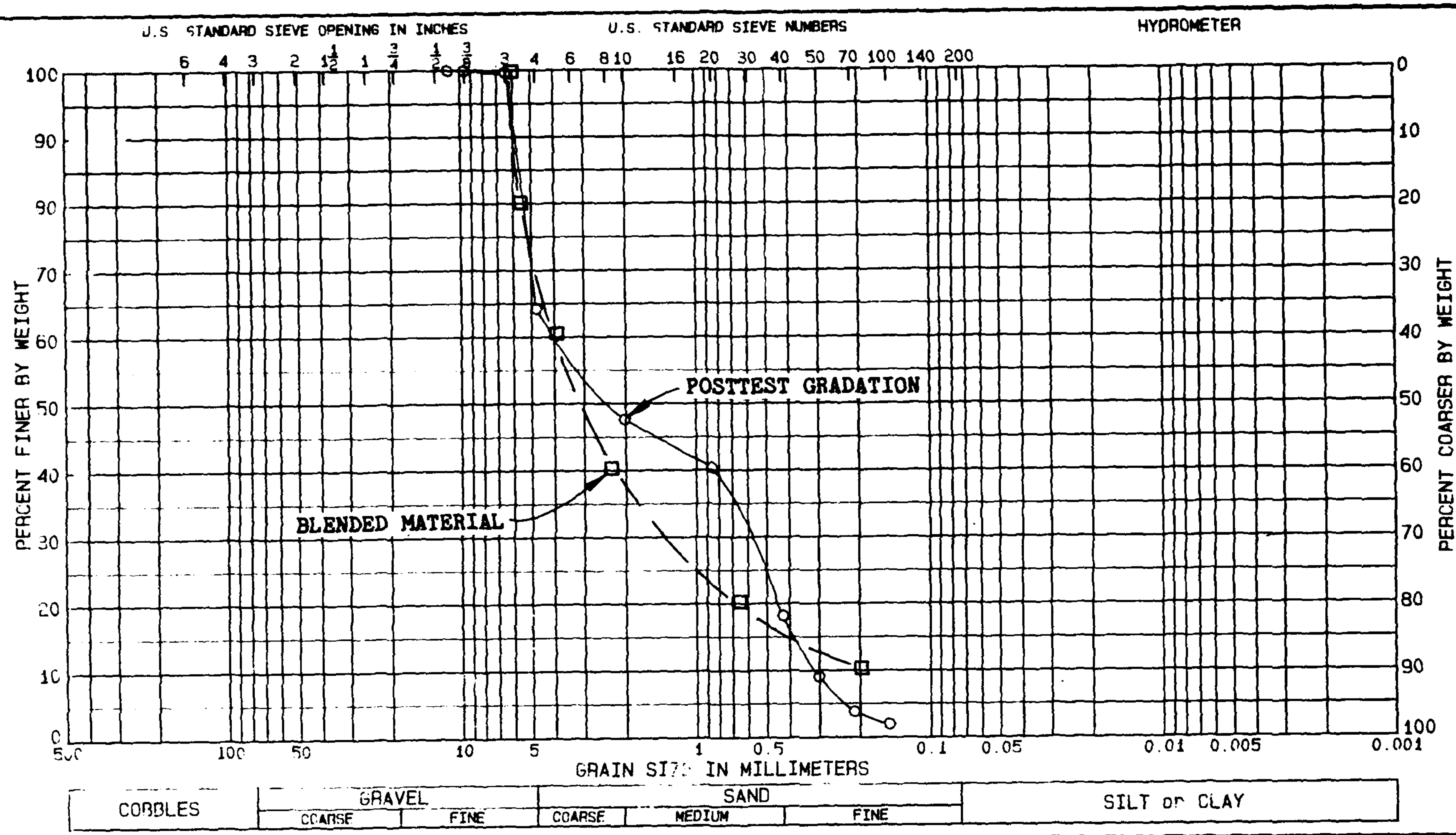

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO 2A
16 - 22 IN.
BORING NO.
SAMPLE NO. 9
DEPTH/ELEV
DATE 00 MAY 82
GRADATION CURVE

PLATE D100



LL	PL	PI	GS	NAT W, %	

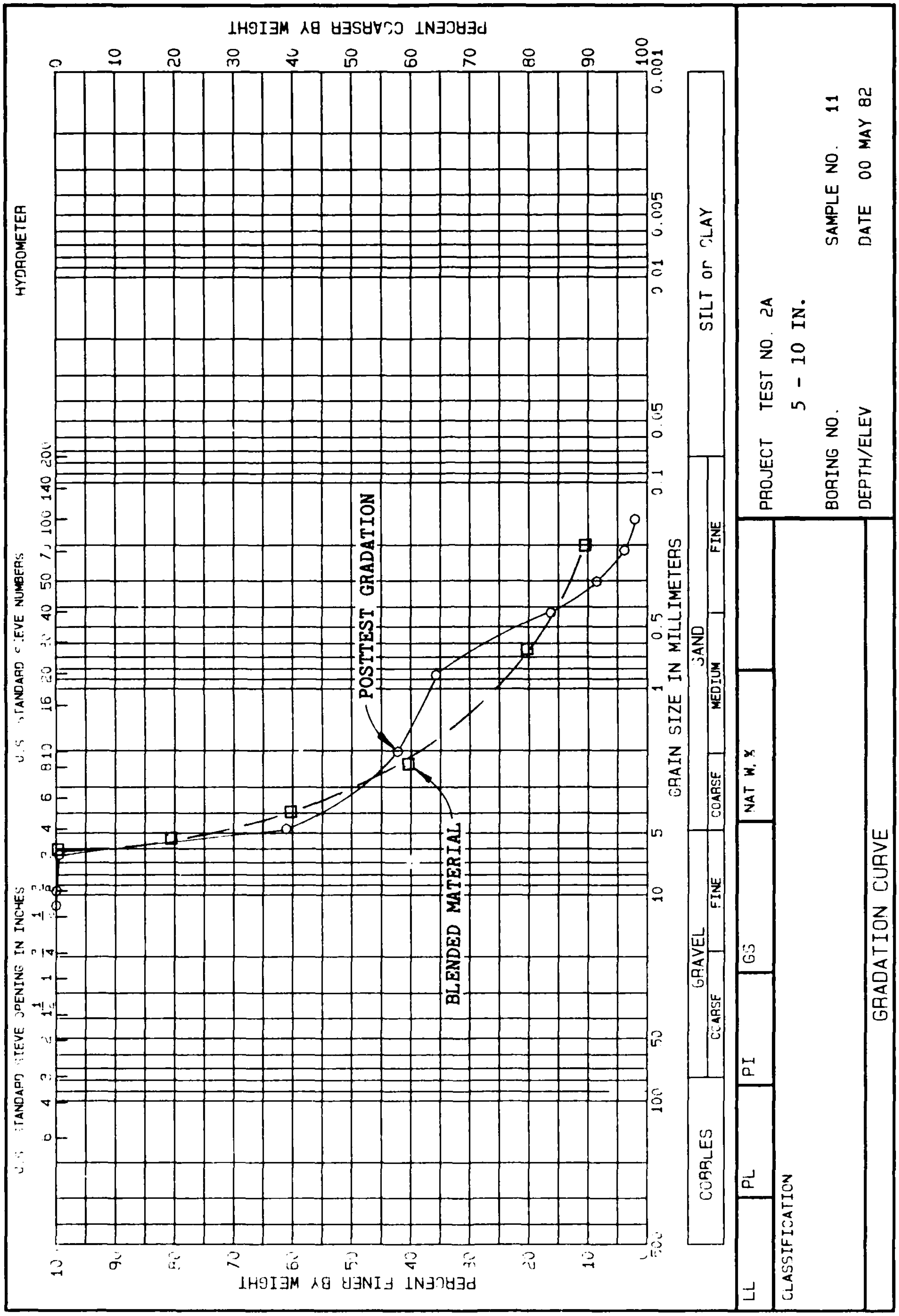
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2A
10 - 16 IN.

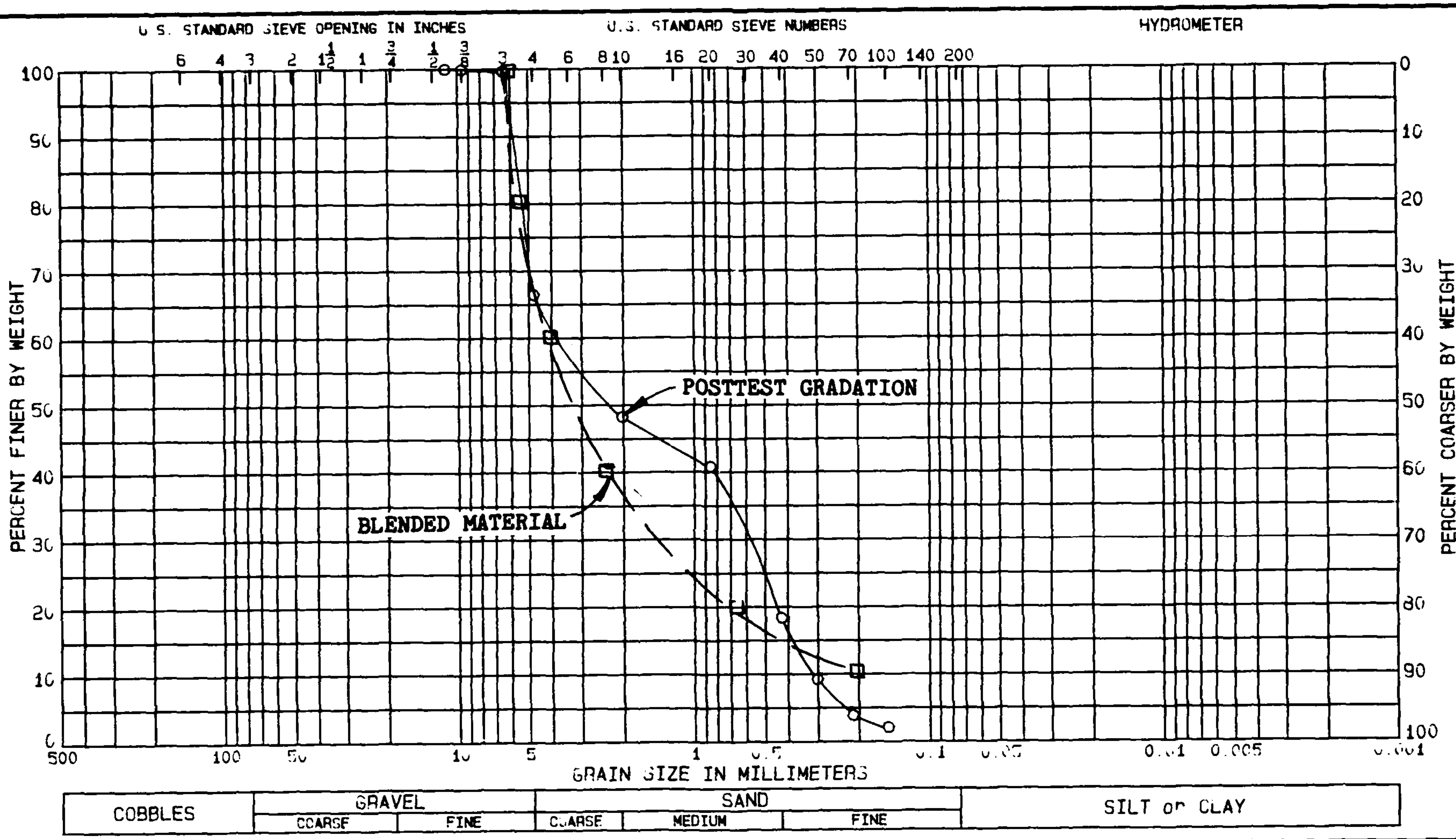
BORING NO. SAMPLE NO. 10

DEPTH/ELEV DATE 00 MAY 82



PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W. %
CLASSIFICATION
PROJECT TEST NO. 2A
5 - 10 IN.
BORING NO.
SAMPLE NO. 11
DEPTH/ELEV
DATE 00 MAY 82
GRADATION CURVE

PLATE D102



LL	PL	PI	GS	NAT W. %	

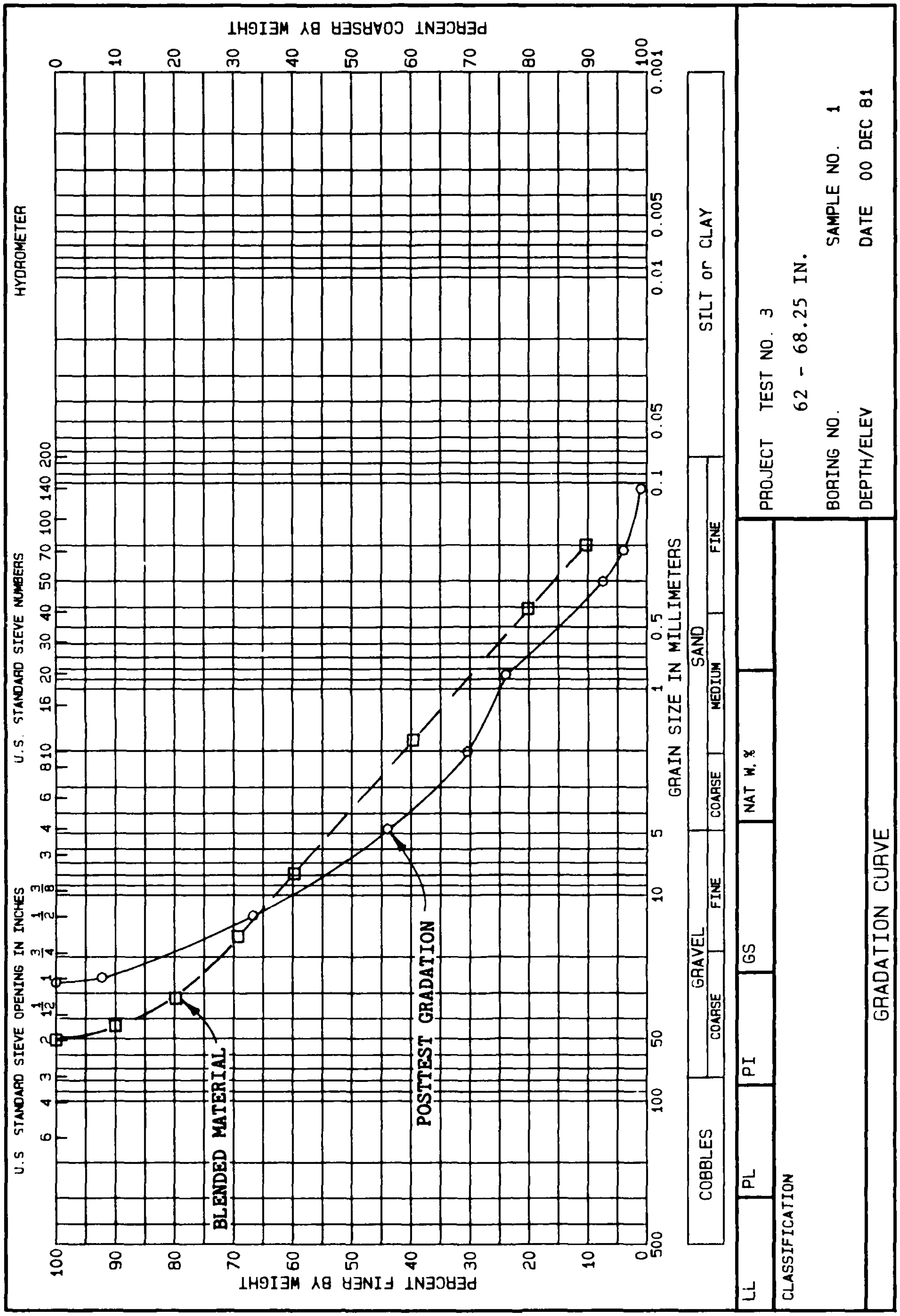
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2A
0 - 5 IN.

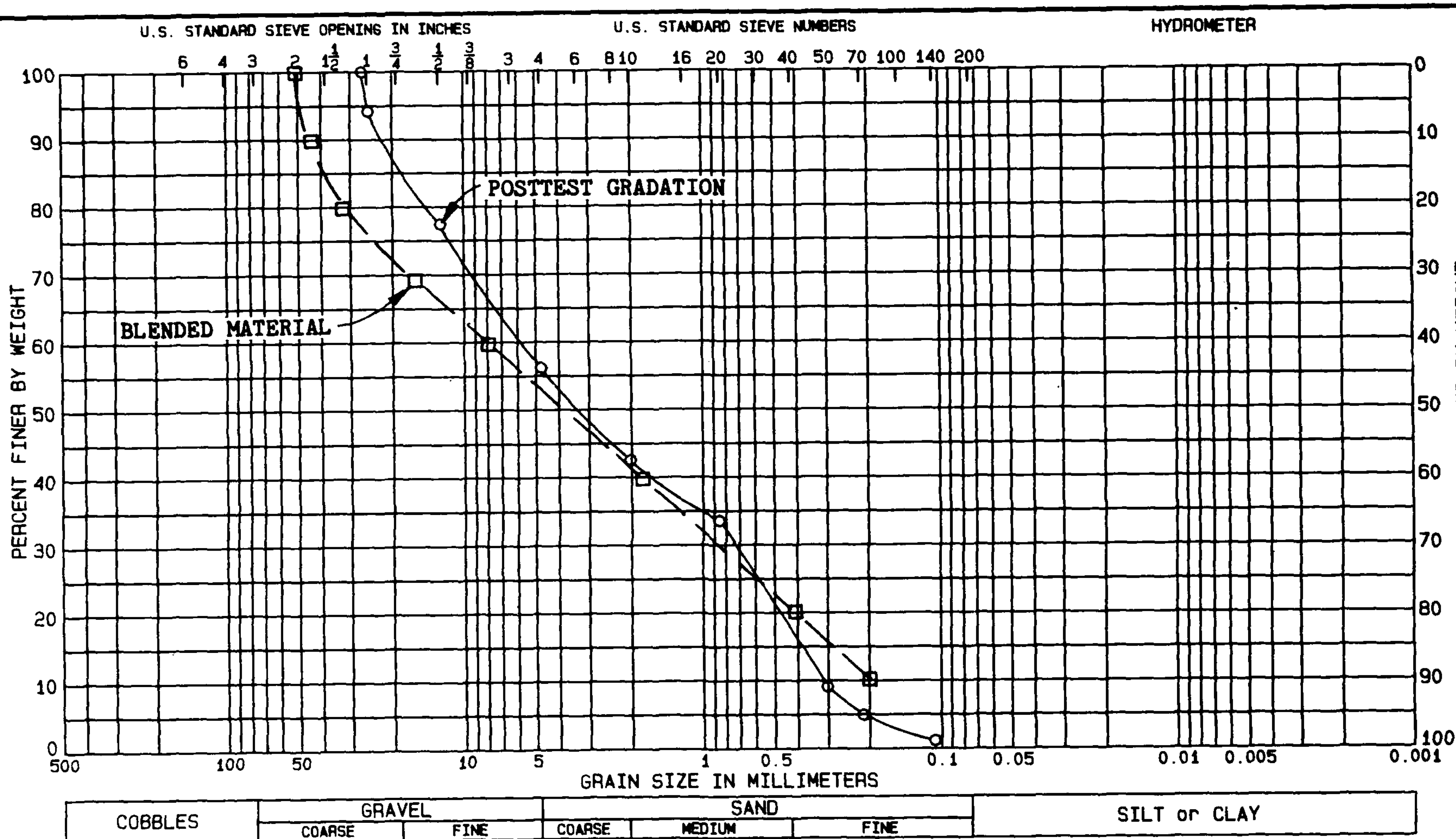
BORING NO. SAMPLE NO. 12

DEPTH/ELEV DATE 00 MAY 82

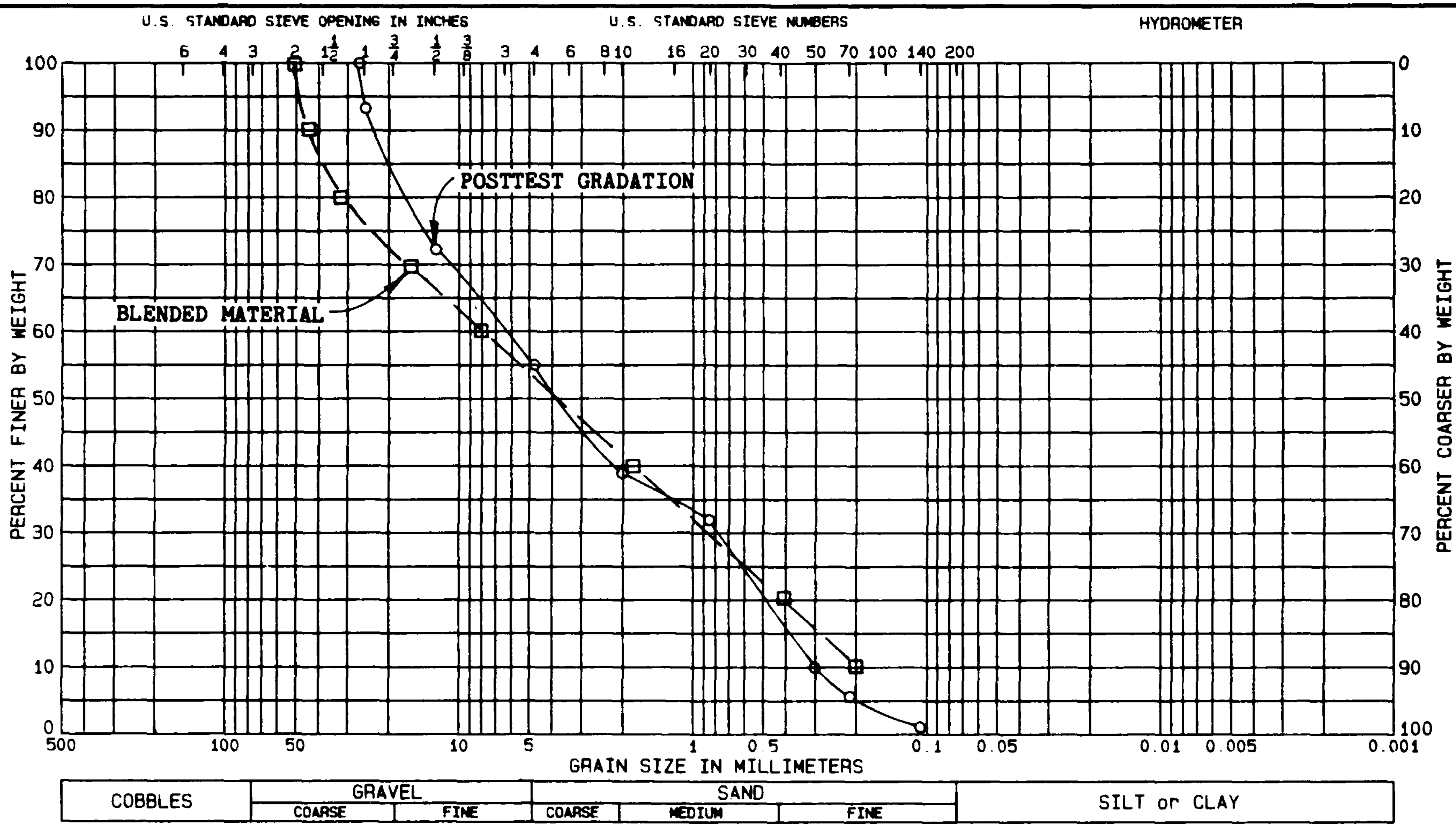


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1½ 1 ¾ ½ 3/8 3 4 6 8 10 16 20 30 40 50 70 100 140 200
PERCENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
PERCENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
CLASSIFICATION
PROJECT TEST NO. 3
62 - 68.25 IN.
BORING NO.
SAMPLE NO. 1
DEPTH/ELEV
DATE 00 DEC 81
GRADATION CURVE

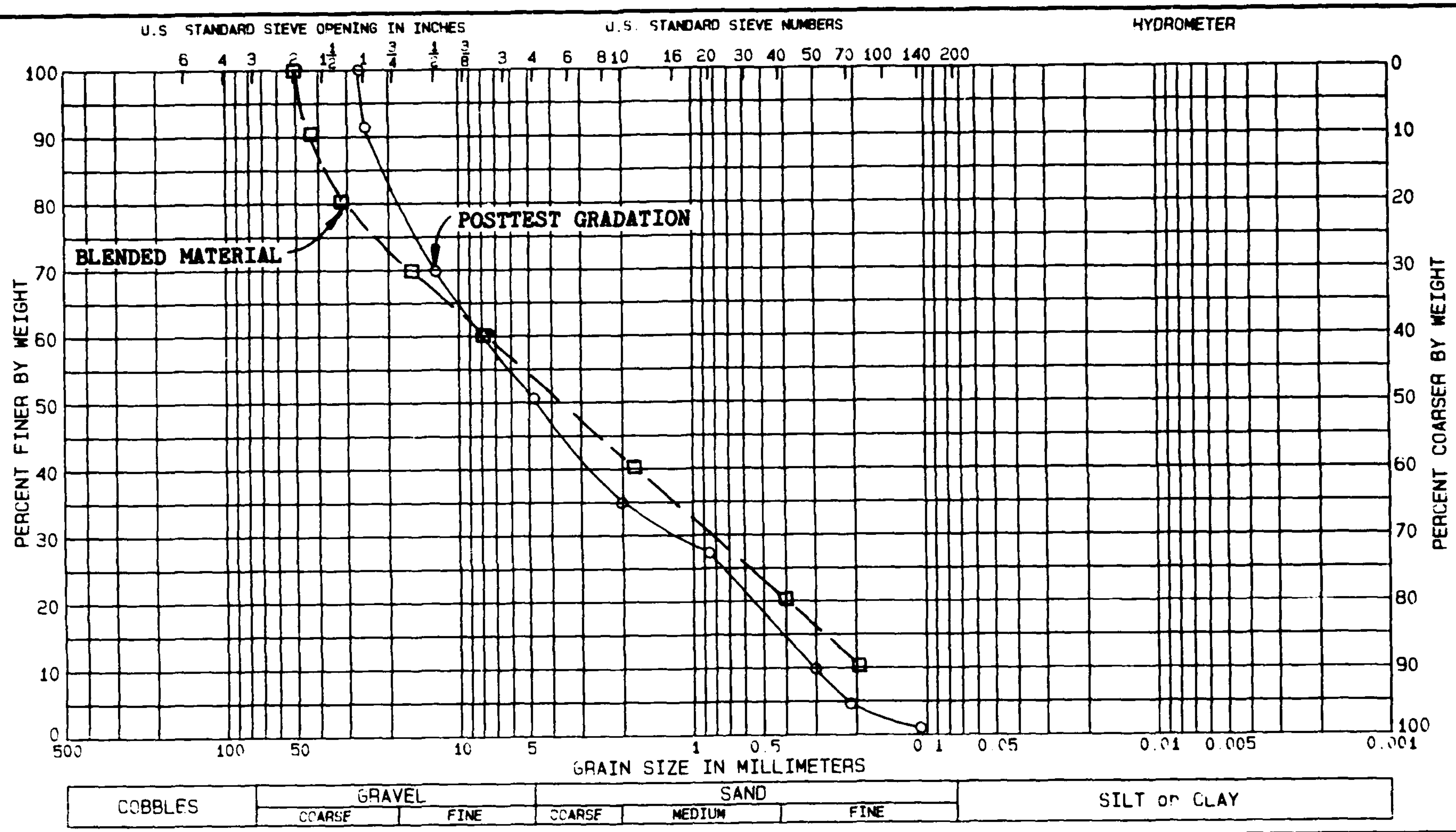
PLATE D104



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 3 56 - 62 IN.
CLASSIFICATION						BORING NO. SAMPLE NO. 2
GRADATION CURVE						DEPTH/ELEV DATE 00 DEC 81



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 3 50 - 56 IN.
CLASSIFICATION						BORING NO. SAMPLE NO. 3
						DEPTH/ELEV DATE 00 DEC 81
GRADATION CURVE						



LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

GRADATION CURVE

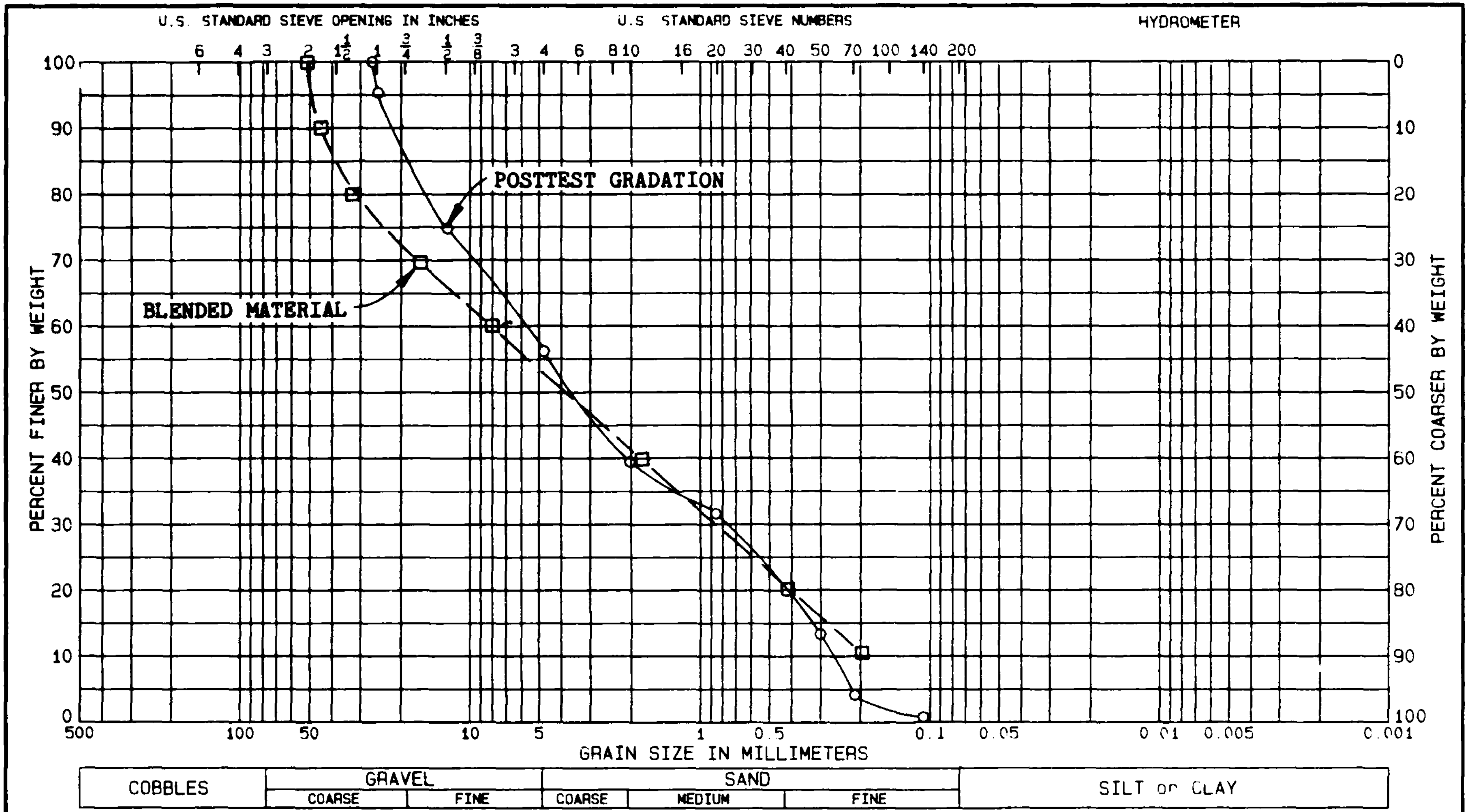
PROJECT TEST NO 3

44 - 50 IN.

BORING NO SAMPLE NO. 4

DEPTH/ELEV DATE 00 DEC 81

PLATE D107



LL	PL	PI	GS	NAT W, %	

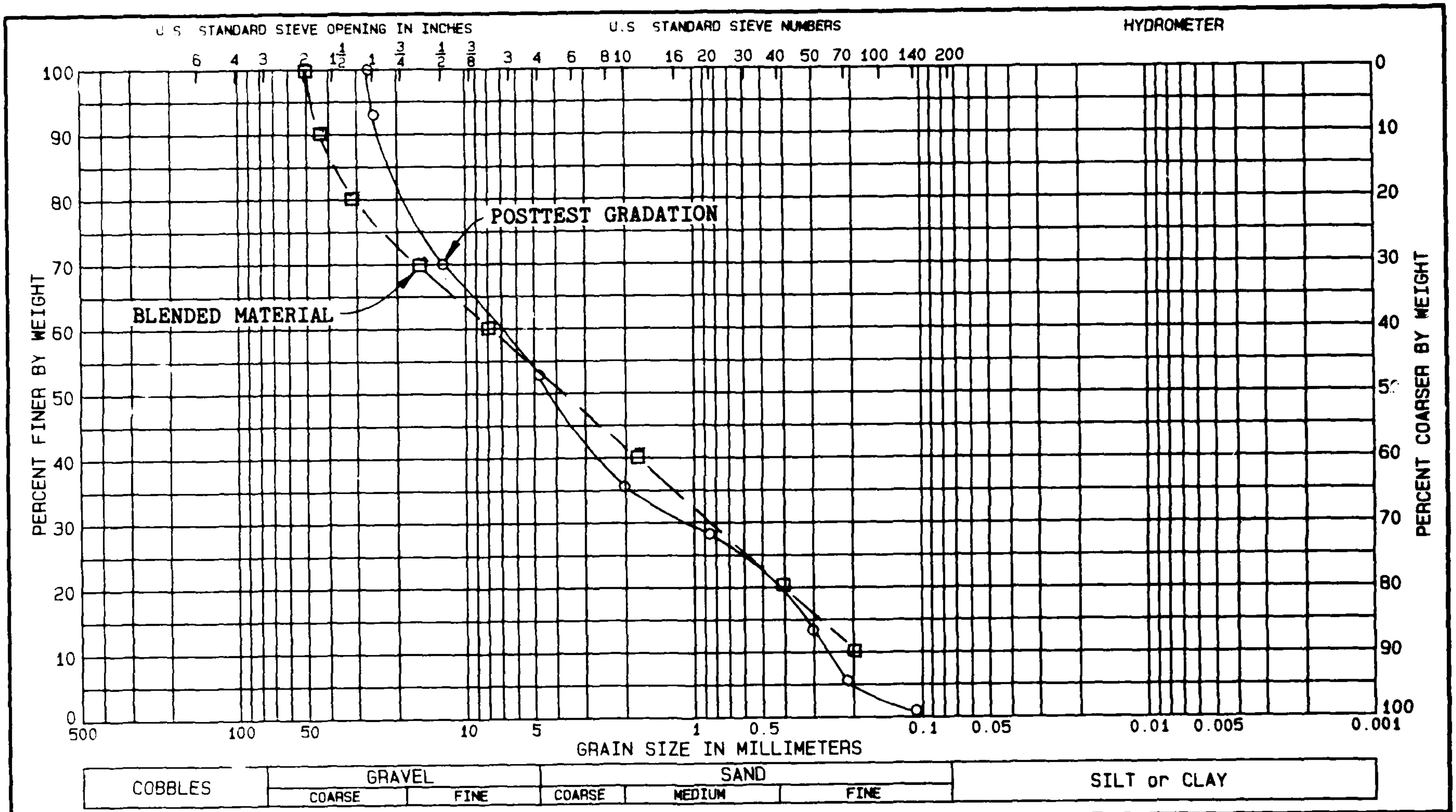
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 3
38 - 44 IN.

BORING NO. SAMPLE NO. 5

DEPTH/ELEV DATE 00 DEC 81



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 3
32 - 38 IN.

BORING NO. SAMPLE NO. 6

DEPTH/ELEV DATE 00 DEC 81

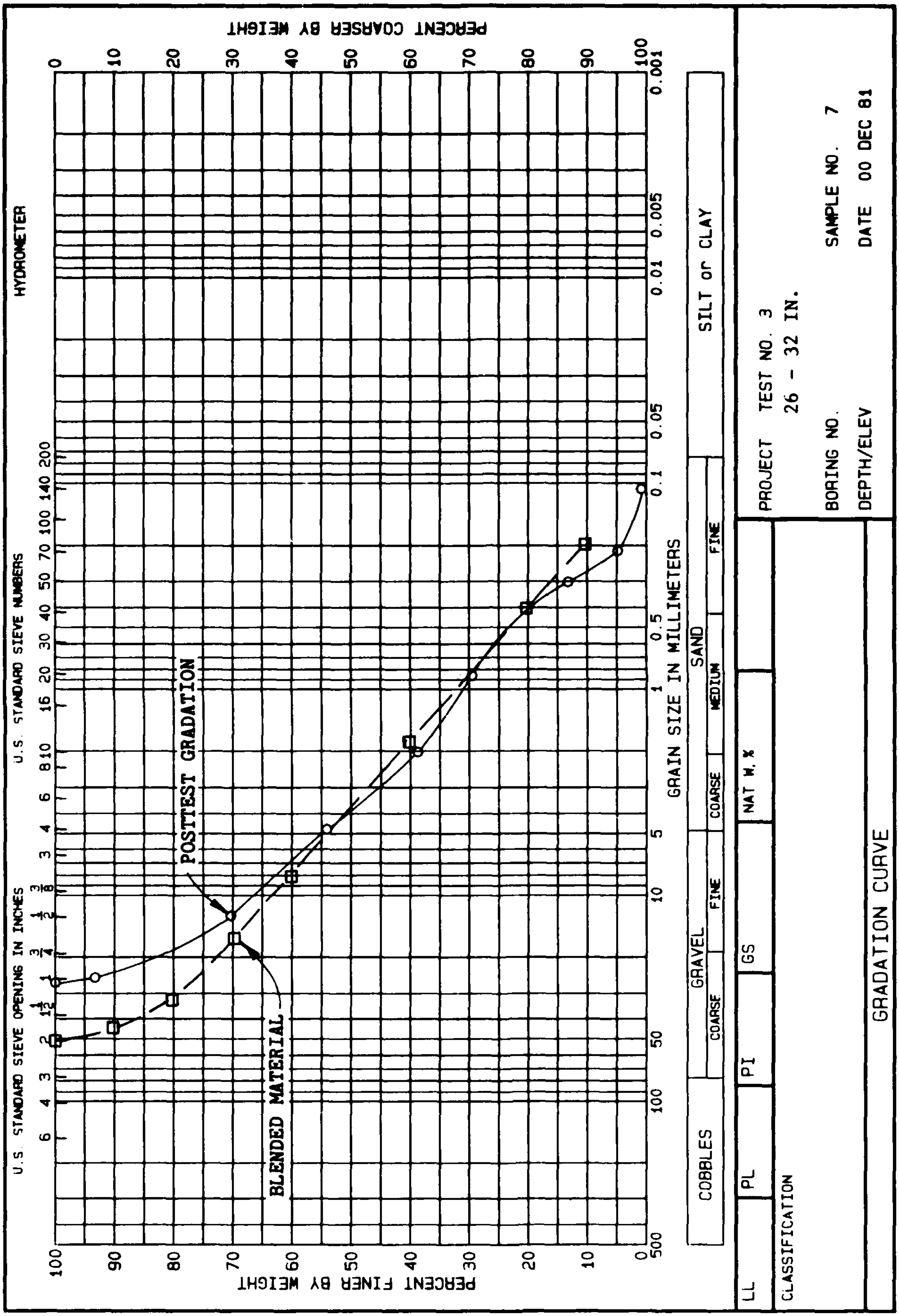
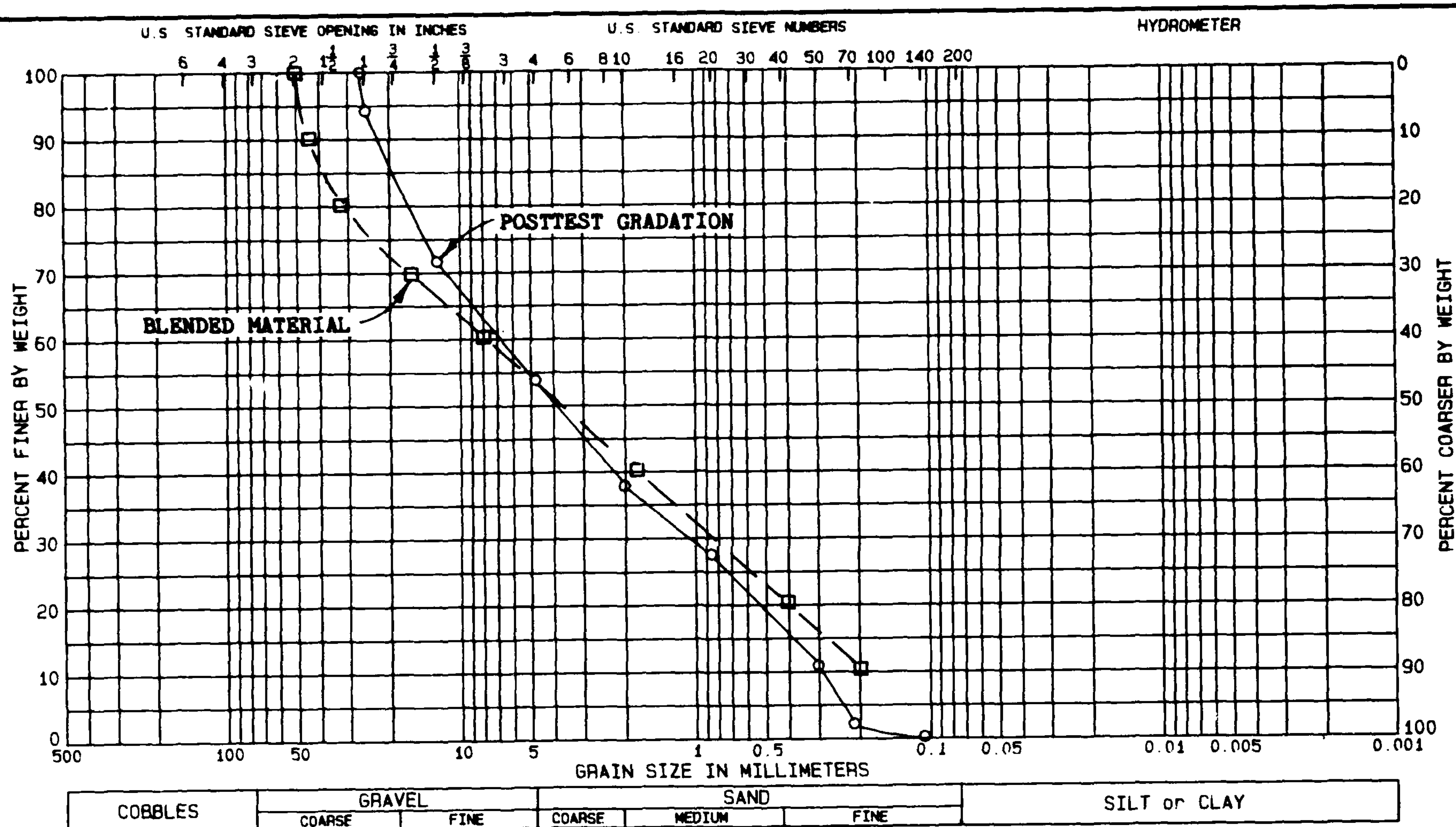

PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 3
26 - 32 IN.
BORING NO.
SAMPLE NO. 7
DEPTH/ELEV
DATE 00 DEC 81
GRADATION CURVE

PLATE D110



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 3
22 - 26 IN.

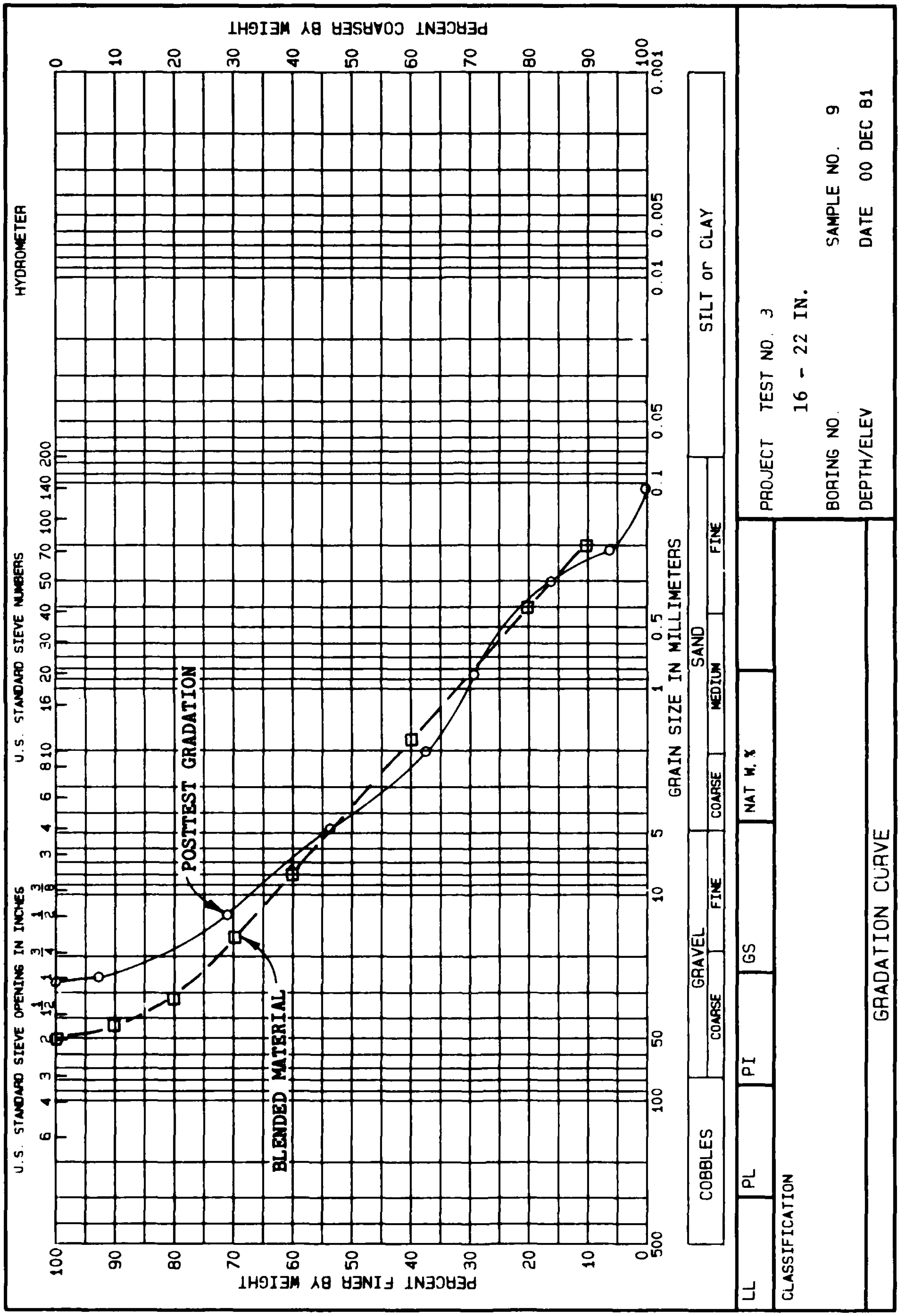
BORING NO.

SAMPLE NO. 8

DEPTH/ELEV

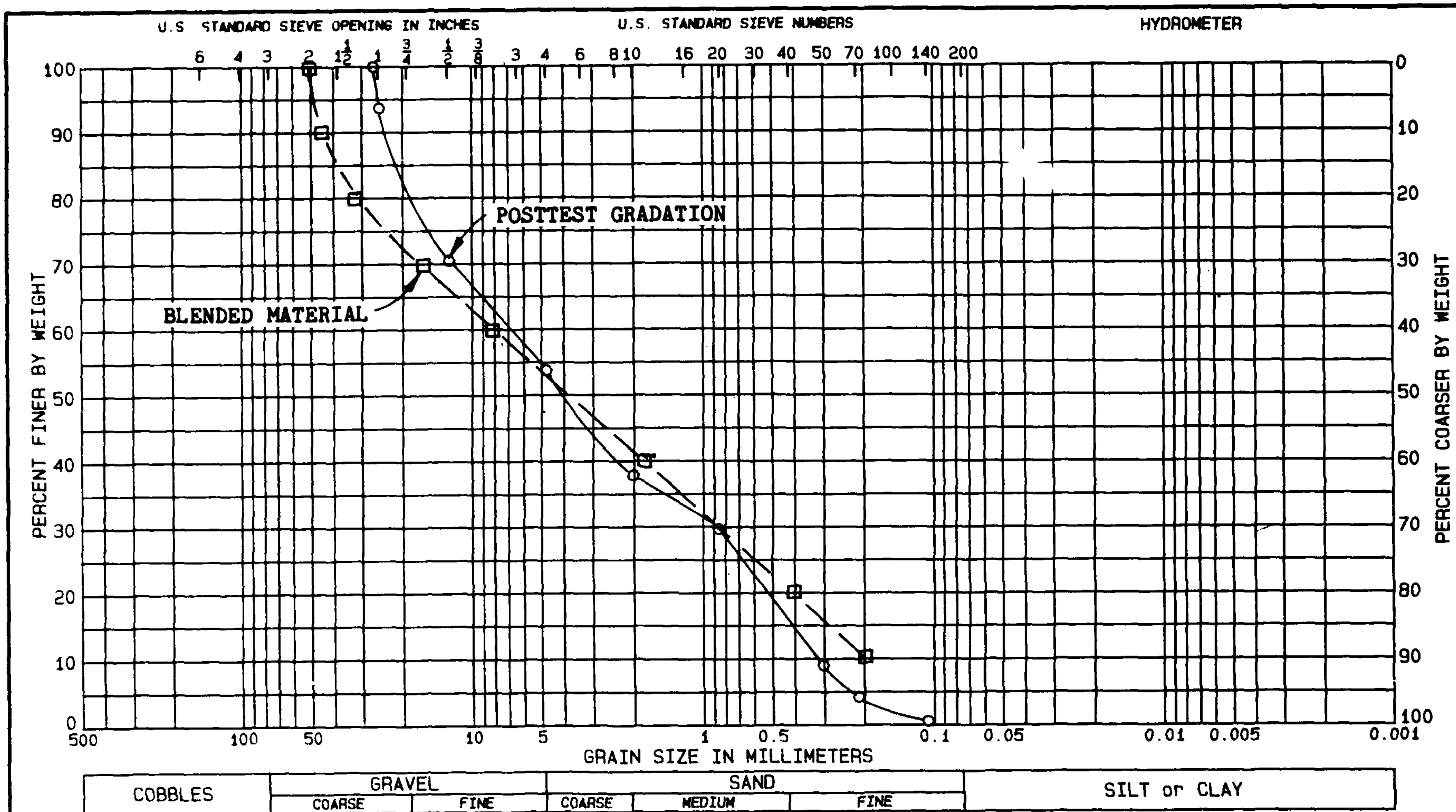
DATE 00 DEC 81

PLATE D111

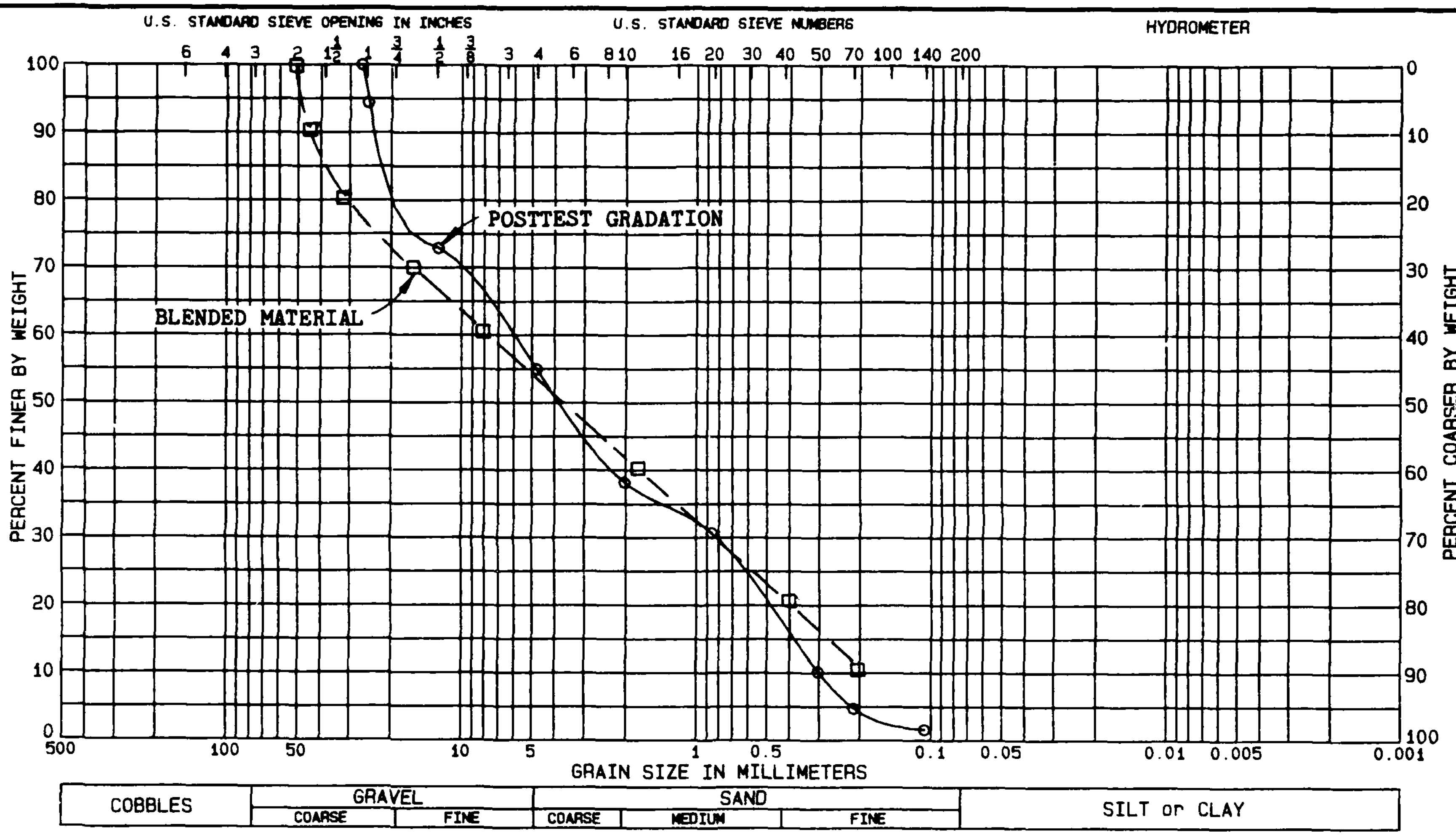


U.S. STANDARD SIEVE OPENINGS IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W. %
CLASSIFICATION
PROJECT TEST NO. 3
16 - 22 IN.
BORING NO.
SAMPLE NO. 9
DEPTH/ELEV
DATE 00 DEC 81
GRADATION CURVE

PLATE D112



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 3
CLASSIFICATION						10 - 16 IN.
						BORING NO. SAMPLE NO. 10
GRADATION CURVE						DEPTH/ELEV DATE 00 DEC 81



LL	PL	PI	GS	NAT W, %	

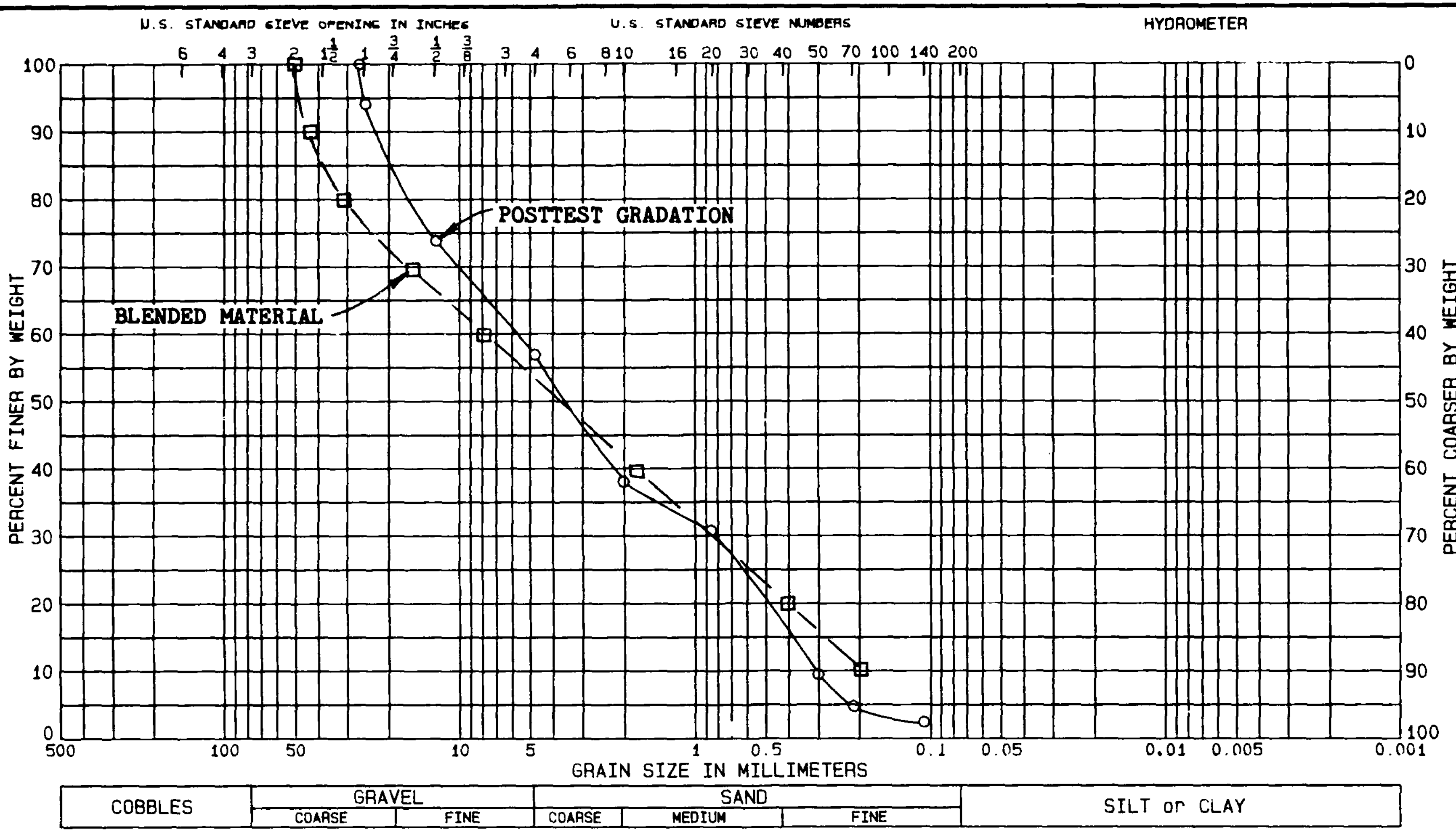
CLASSIFICATION

PROJECT TEST NO. 3
5 - 10 IN.

BORING NO. SAMPLE NO. 11

DEPTH/ELEV DATE 00 DEC 81

GRADATION CURVE



LL	PL	PI	GS	NAT W, %	

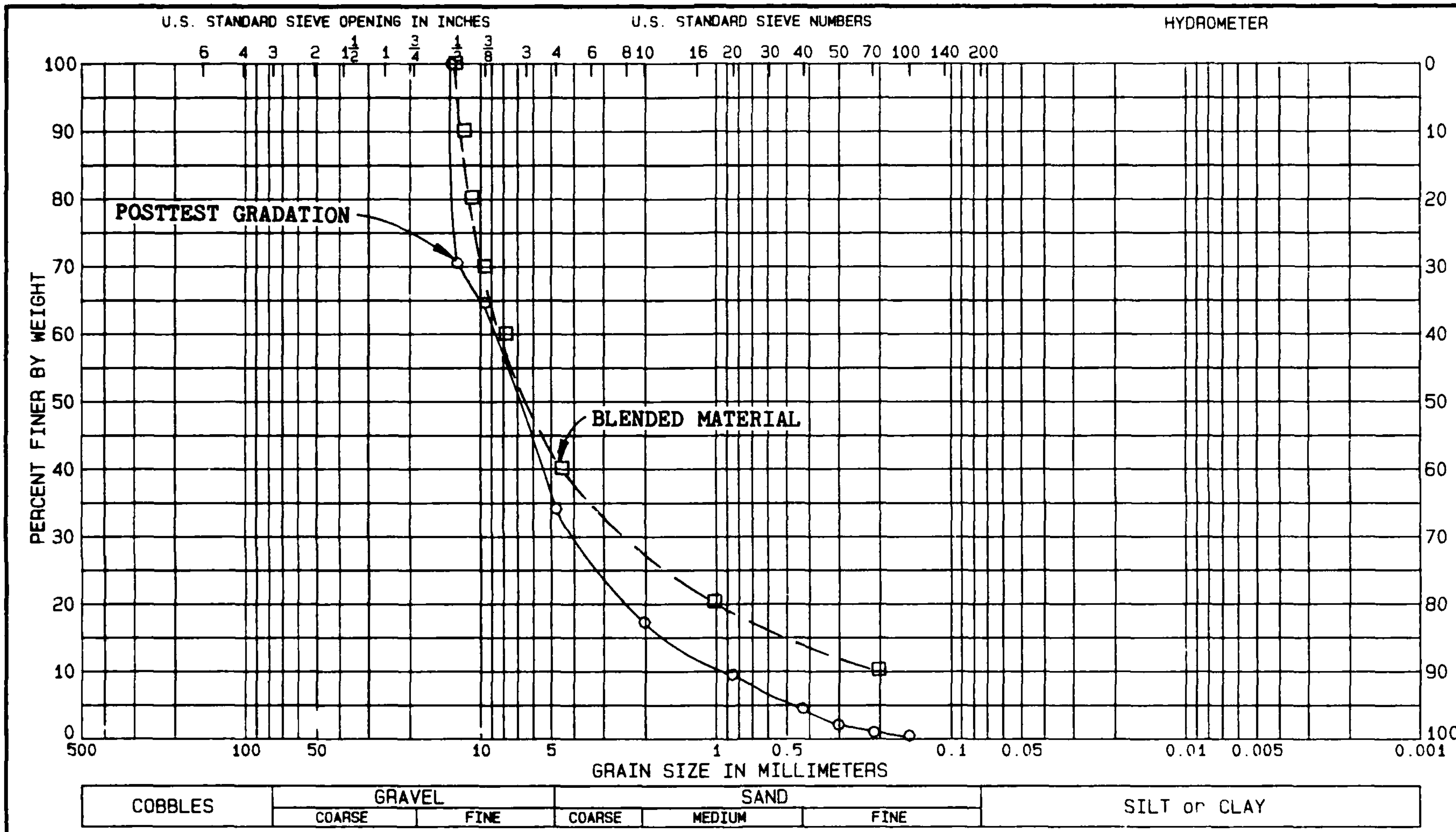
CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 3
0 - 5 IN.

BORING NO. SAMPLE NO. 12

DEPTH/ELEV DATE 00 DEC 81



LL	PL	PI	GS	NAT W, %	

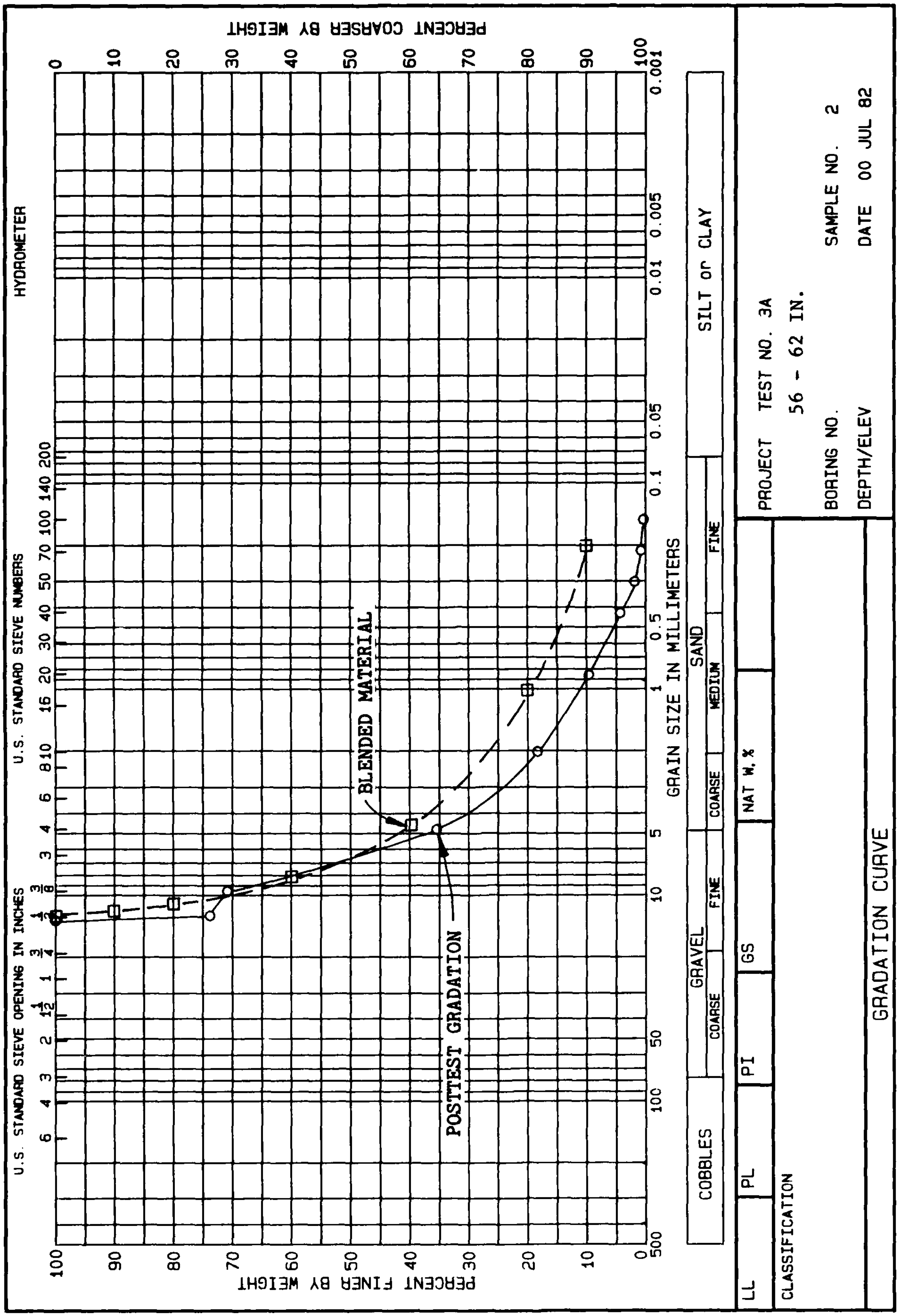
CLASSIFICATION

PROJECT TEST NO. 3A
62 - 70.5 IN.

BORING NO. SAMPLE NO. 1

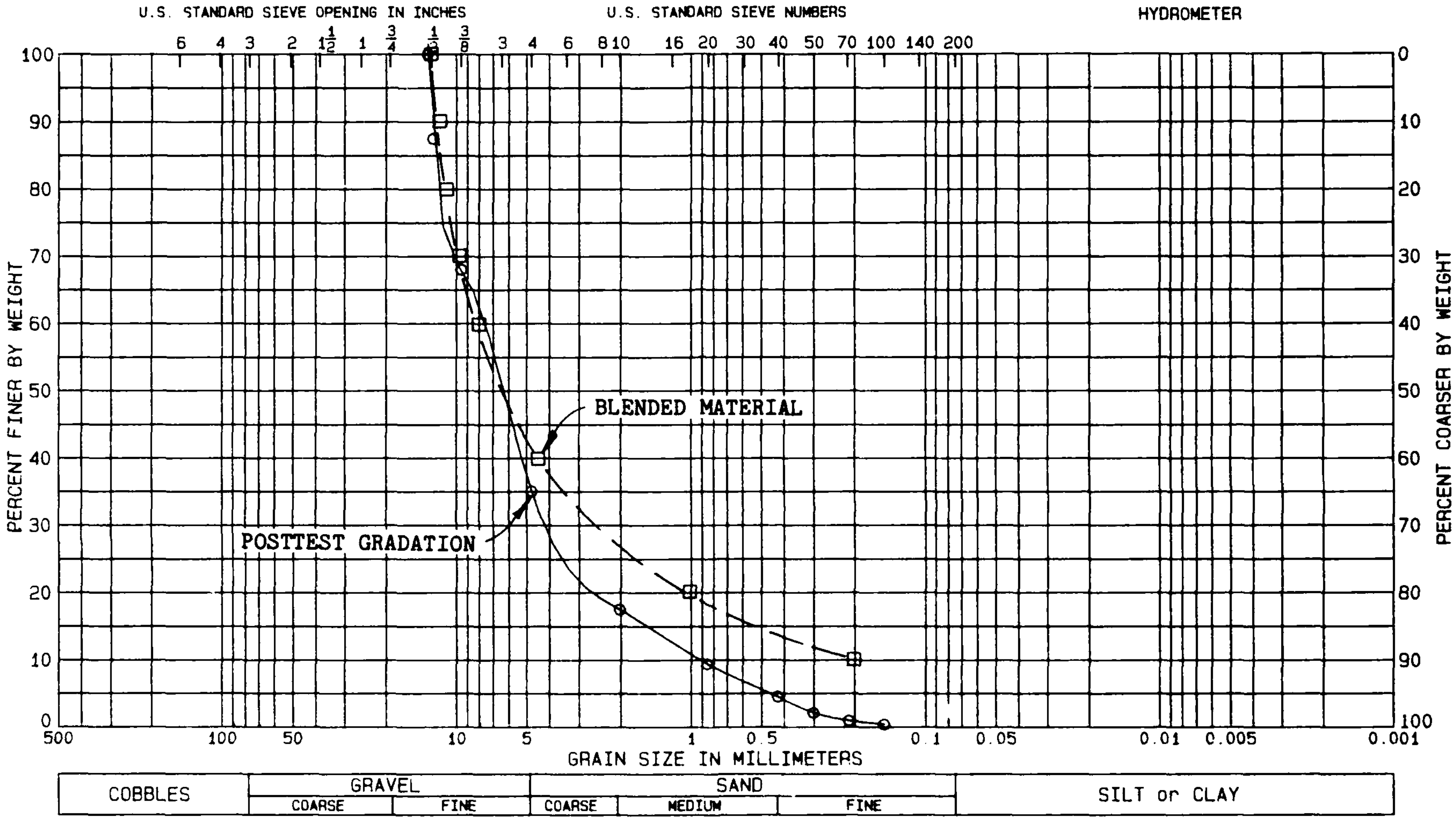
DEPTH/ELEV DATE 00 JUL 82

GRADATION CURVE



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W,%
CLASSIFICATION
PROJECT TEST NO. 3A
56 - 62 IN.
BORING NO.
SAMPLE NO. 2
DEPTH/ELEV
DATE 00 JUL 82
GRADATION CURVE

PLATE D117



LL	PL	PI	GS	NAT W. %	

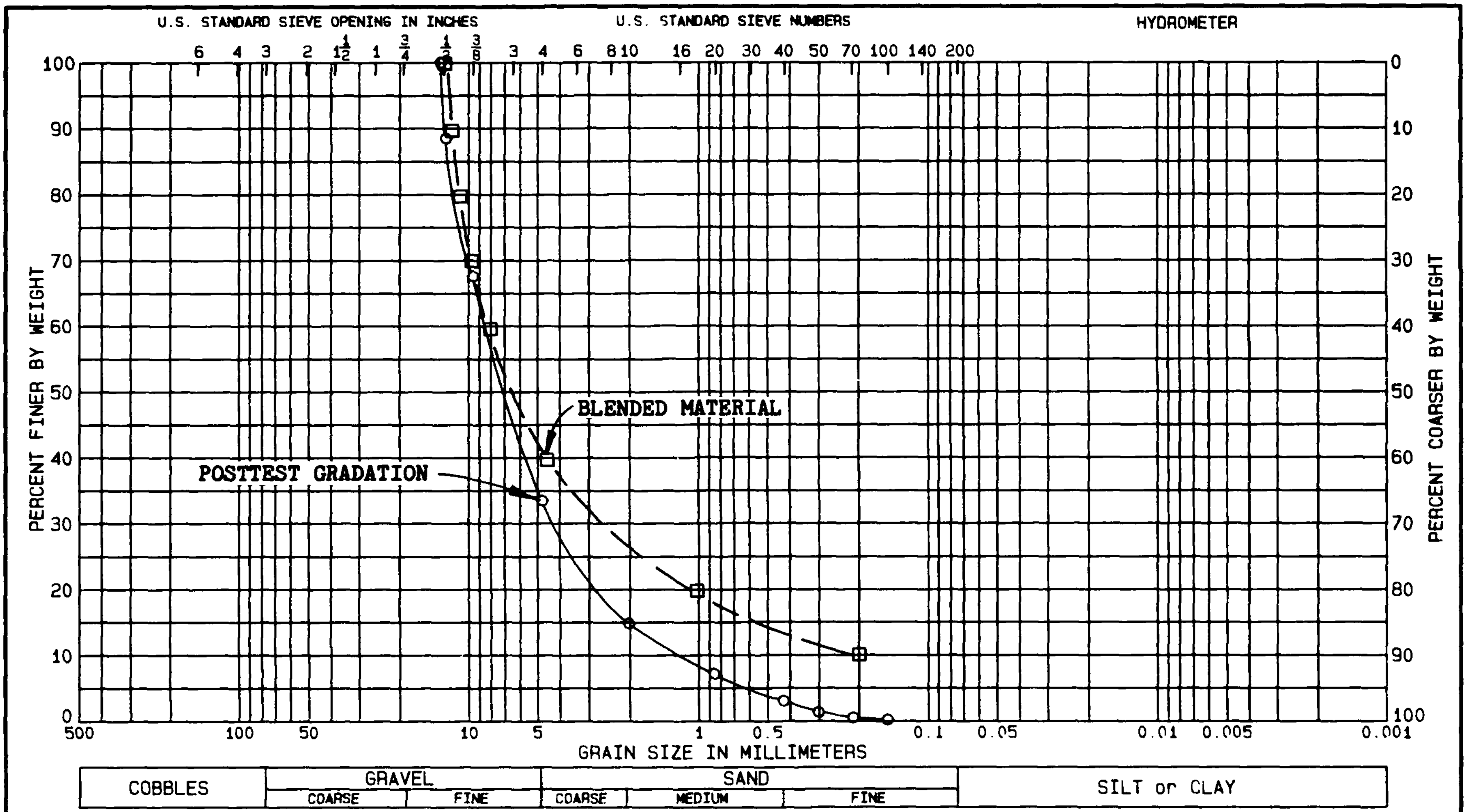
CLASSIFICATION

GRADATION CURVE

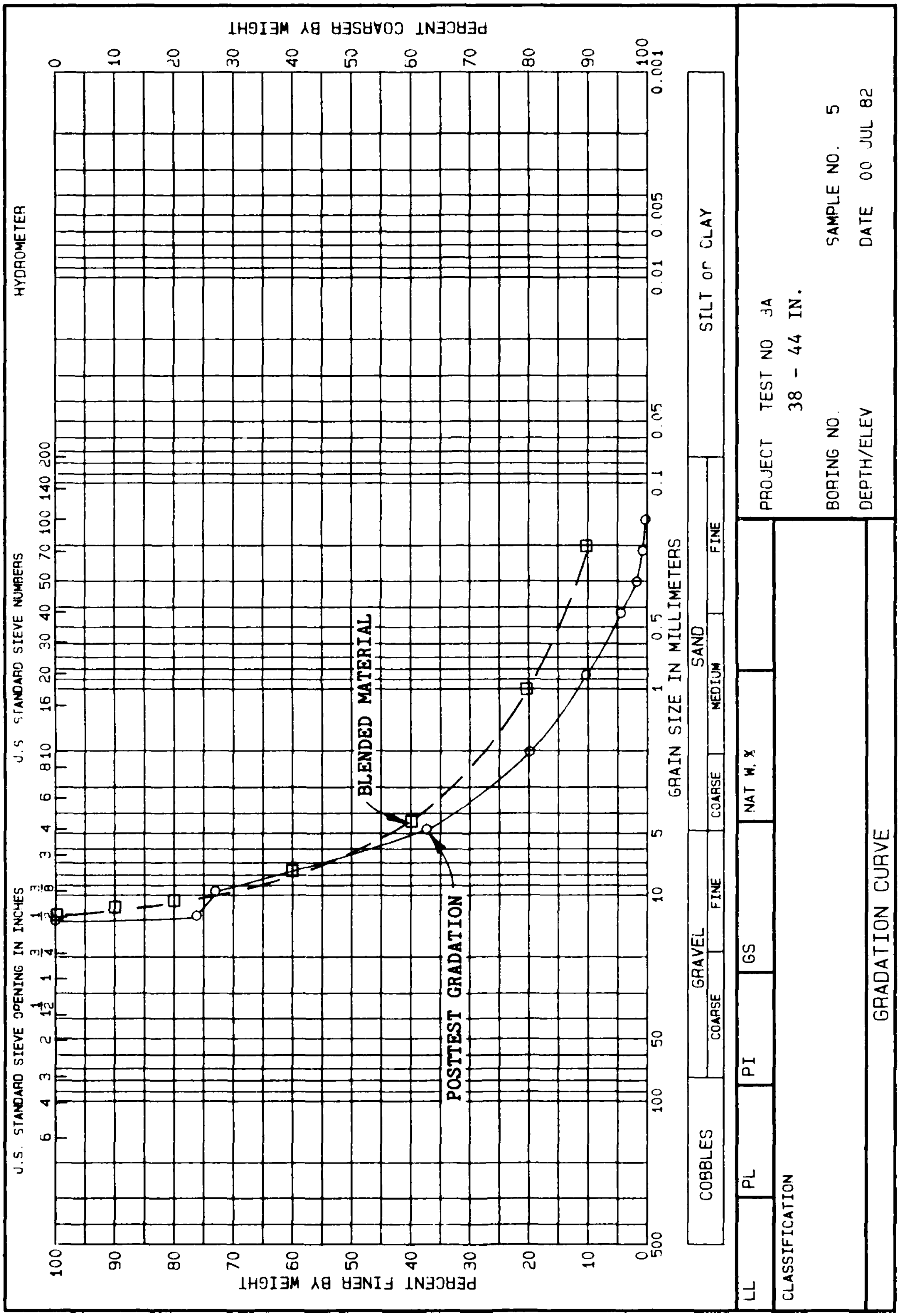
PROJECT TEST NO. 3A
50 - 56 IN.

BORING NO. SAMPLE NO. 3

DEPTH/ELEV DATE 00 JUL 82

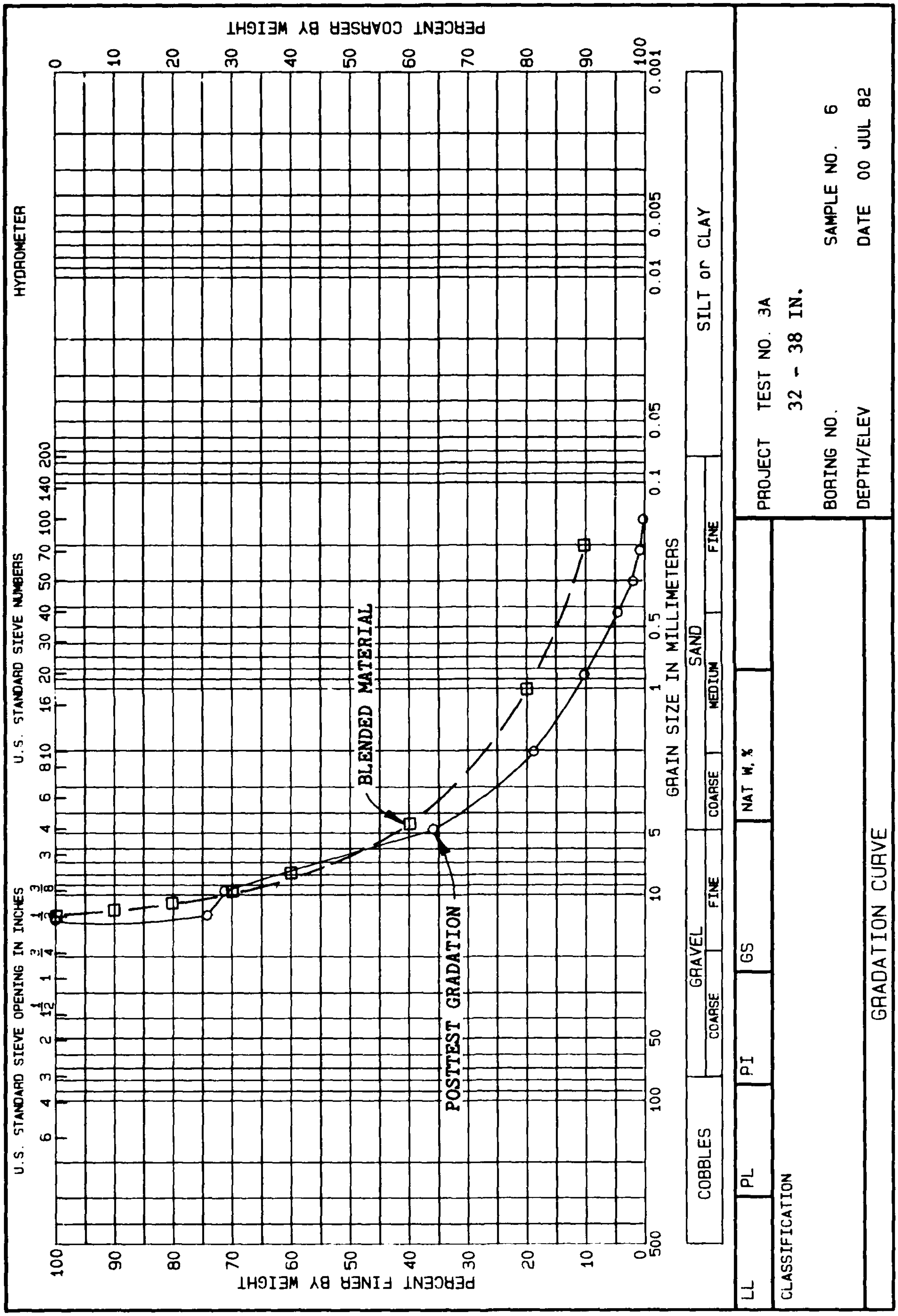


LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 3A 44 - 50 IN.	
CLASSIFICATION						BORING NO.	SAMPLE NO. 4
GRADATION CURVE						DEPTH/ELEV	DATE 00 JUL 82

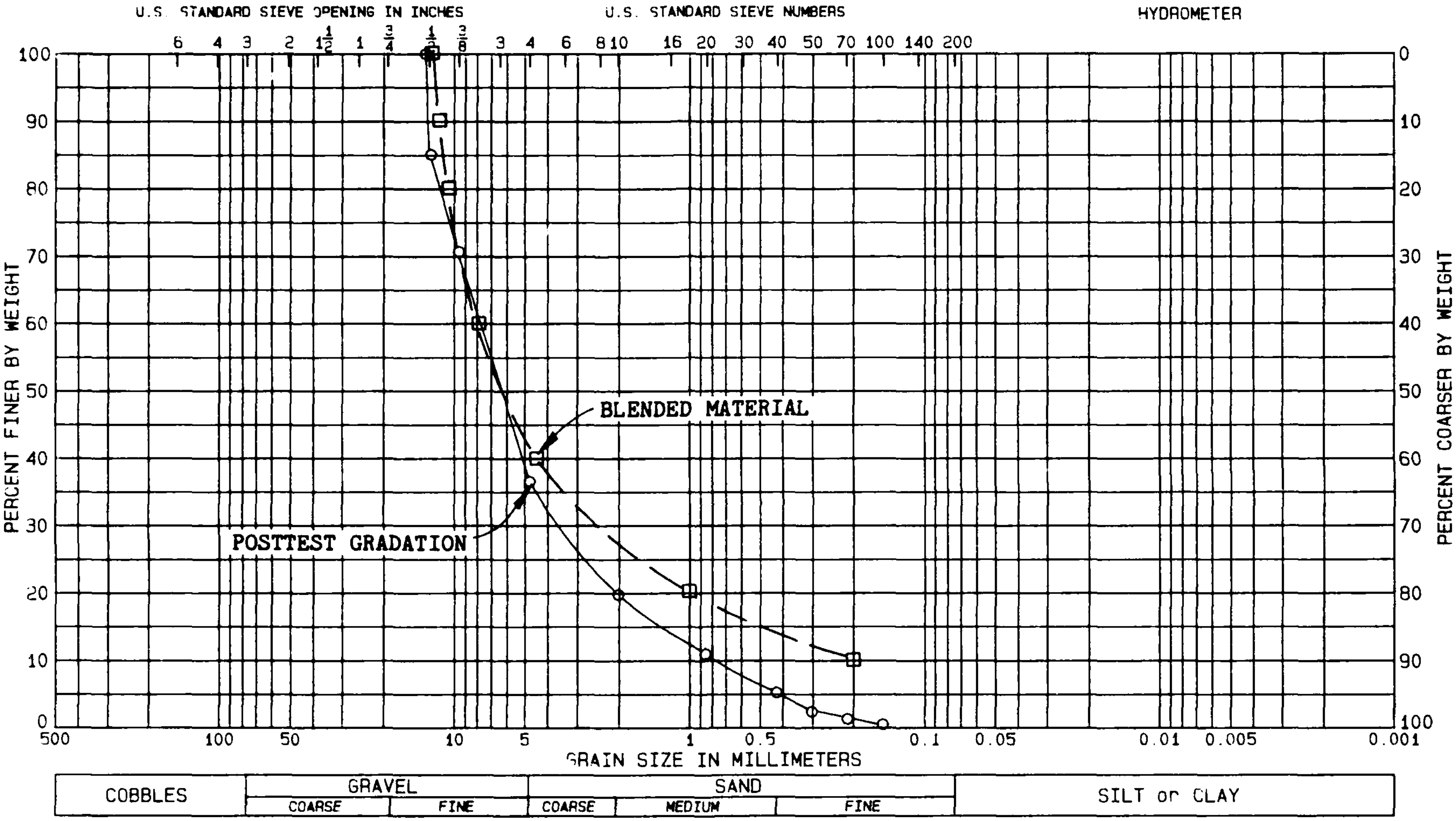


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO 3A
38 - 44 IN.
BORING NO.
SAMPLE NO. 5
DEPTH/ELEV
DATE 00 JUL 82
GRADATION CURVE

PLATE D120

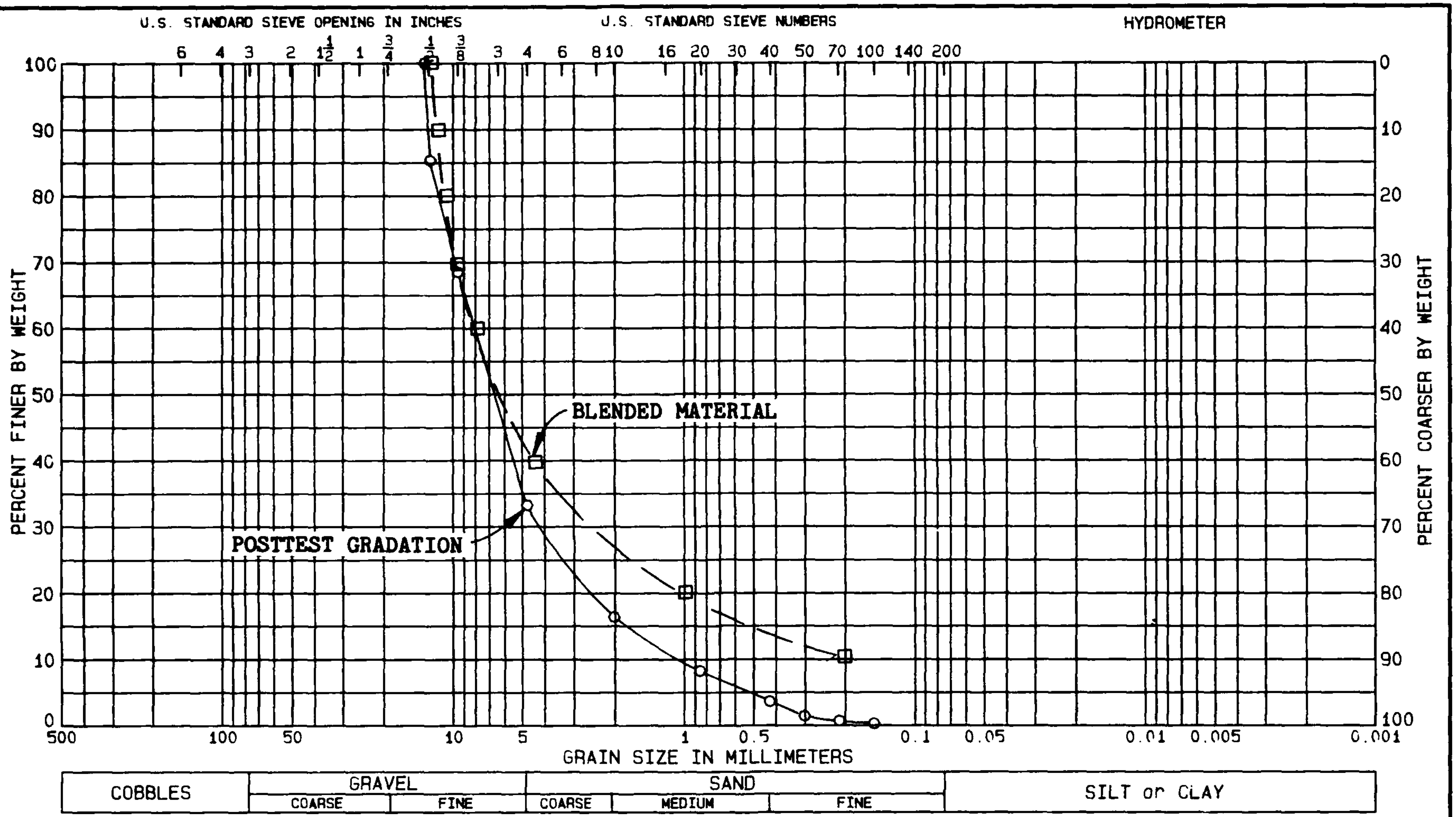


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
6 4 3 2 1½ 1 ¾ ½ ⅜ 3 4 6 8 10 16 20 30 40 50 70 100 140 200
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
BLENDED MATERIAL
POSTTEST GRADATION
GRAIN SIZE IN MILLIMETERS
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO. 3A
32 - 38 IN.
BORING NO.
SAMPLE NO. 6
DEPTH/ELEV
DATE 00 JUL 82
GRADATION CURVE



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 3A 26 - 32 IN.
CLASSIFICATION						BORING NO. SAMPLE NO. 7
GRADATION CURVE						DEPTH/ELEV DATE 00 JUL 82

PLATE D122



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

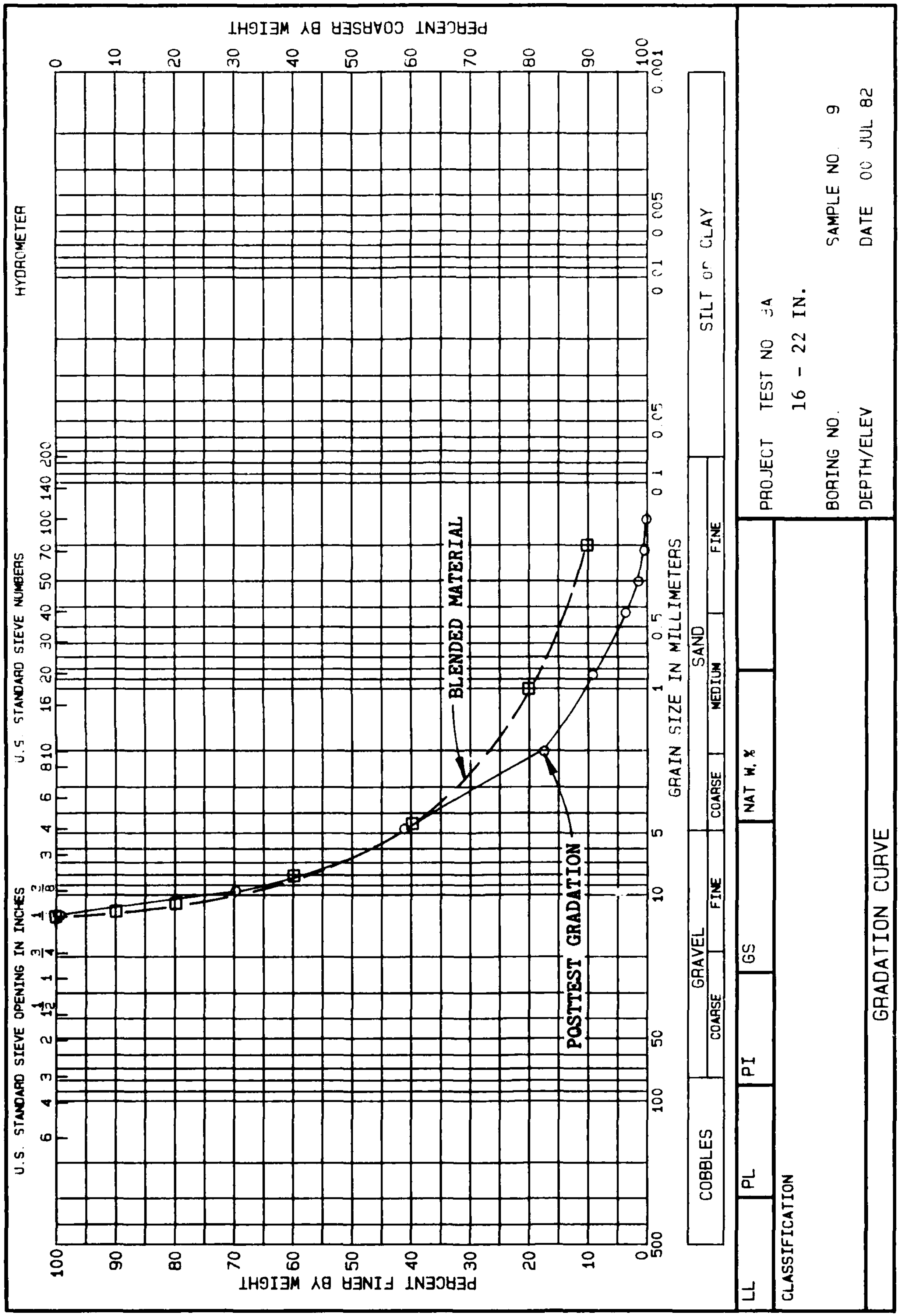
PROJECT TEST NO. 3A
22 - 26 IN.

BORING NO.

SAMPLE NO. 8

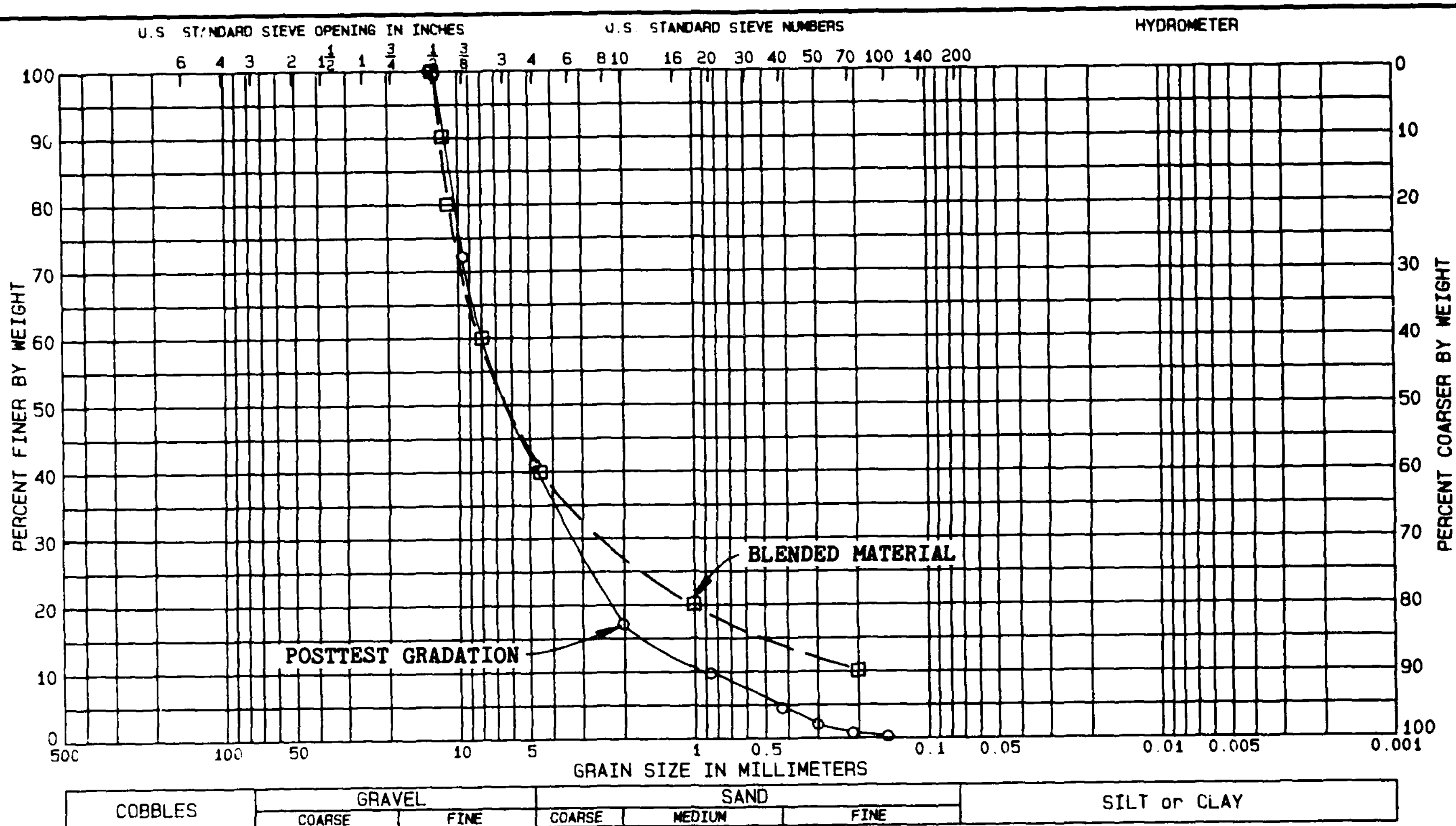
DEPTH/ELEV

DATE 00 JUL 82



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO 3A
16 - 22 IN.
BORING NO.
SAMPLE NO. 9
DEPTH/ELEV
DATE 00 JUL 82
GRADATION CURVE

PLATE D124



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 3A
10 - 16 IN.

BORING NO.

SAMPLE NO. 10

DEPTH/ELEV

DATE 00 JUL 82

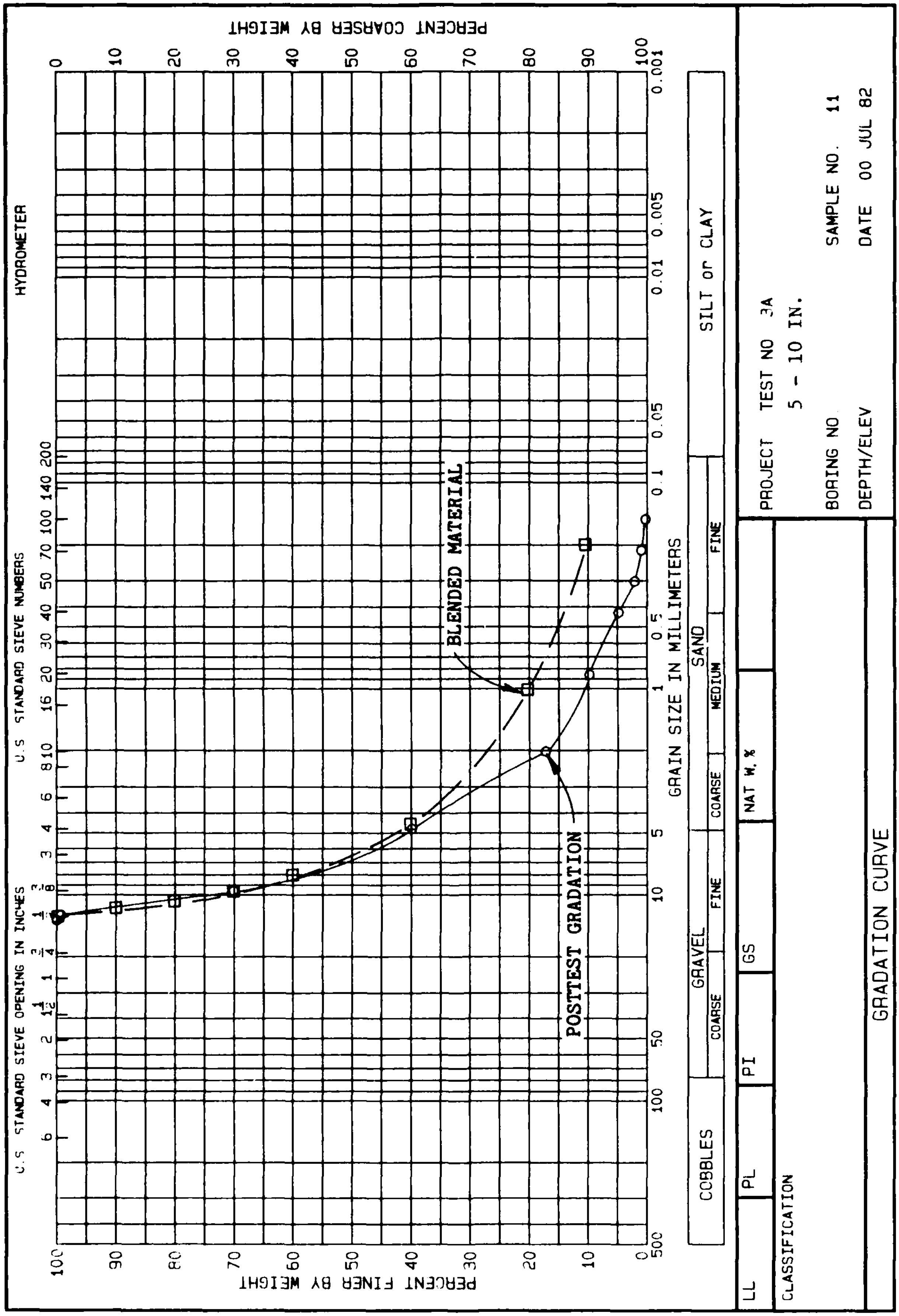

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
BLENDED MATERIAL
POSTTEST GRADATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
CLASSIFICATION
PROJECT TEST NO 3A
5 - 10 IN.
BORING NO.
SAMPLE NO. 11
DEPTH/ELEV
DATE 00 JUL 82
GRADATION CURVE

PLATE D126

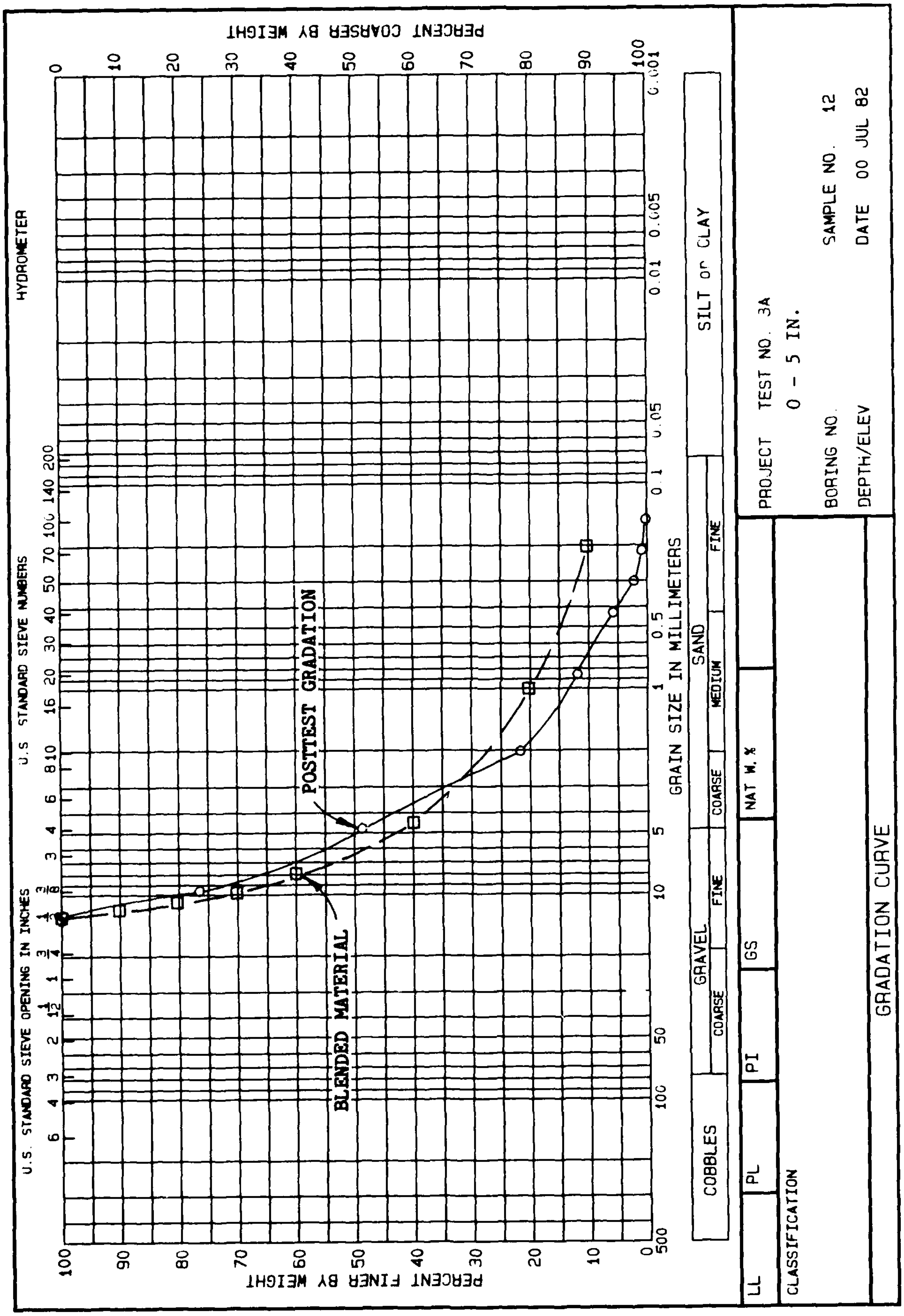
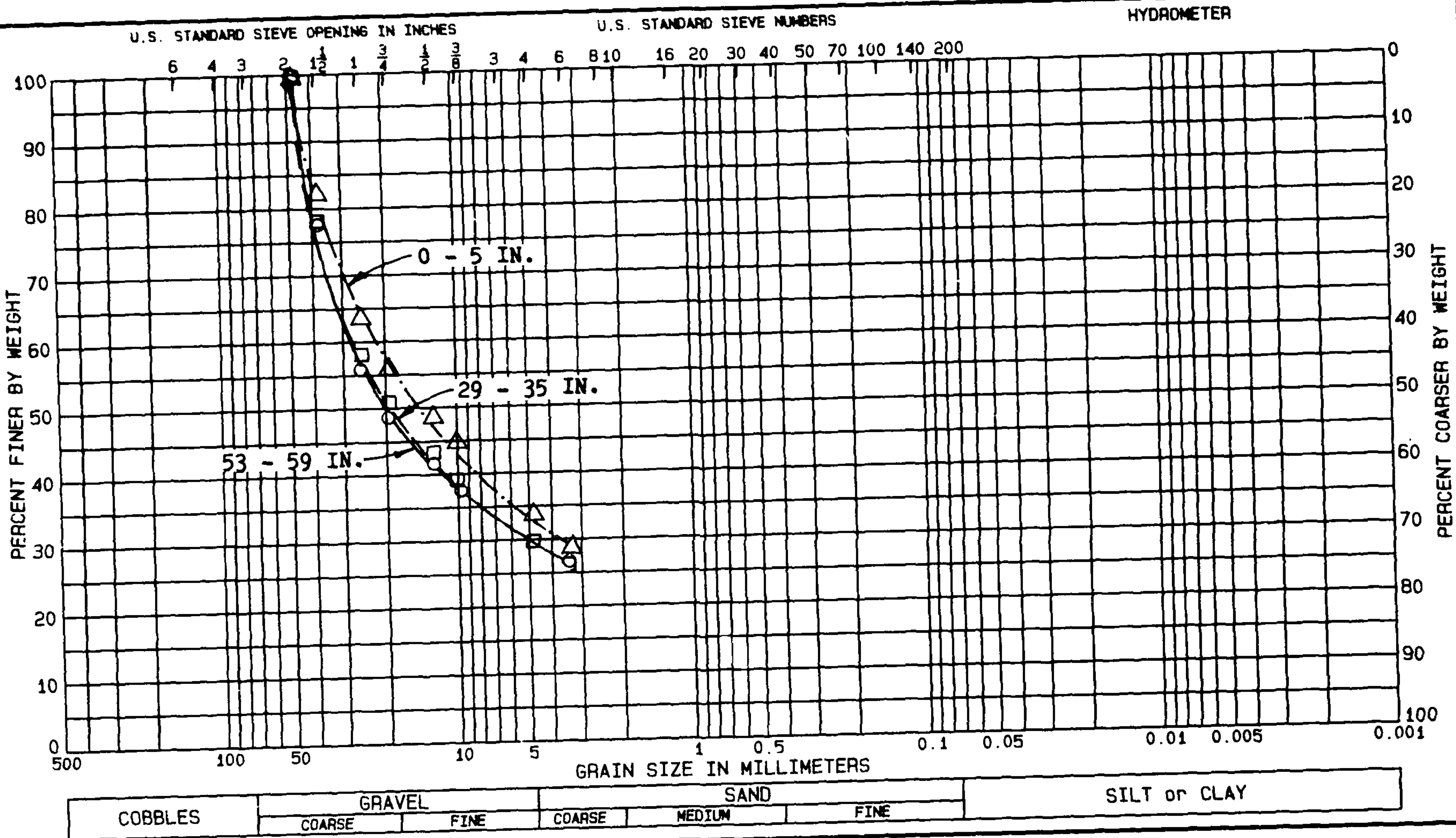

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
POSTTEST GRADATION
BLENDED MATERIAL
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W.%
CLASSIFICATION
PROJECT TEST NO. 3A
0 - 5 IN.
BORING NO.
SAMPLE NO. 12
DEPTH/ELEV
DATE 00 JUL 82
GRADATION CURVE

PLATE D127

APPENDIX E: COMPARISON AMONG POSTTEST GRADATIONS OF THE TOP, MIDDLE, AND BOTTOM 6 IN. OF THE FILTER



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TESZ NO. 1A - A (CHECK)

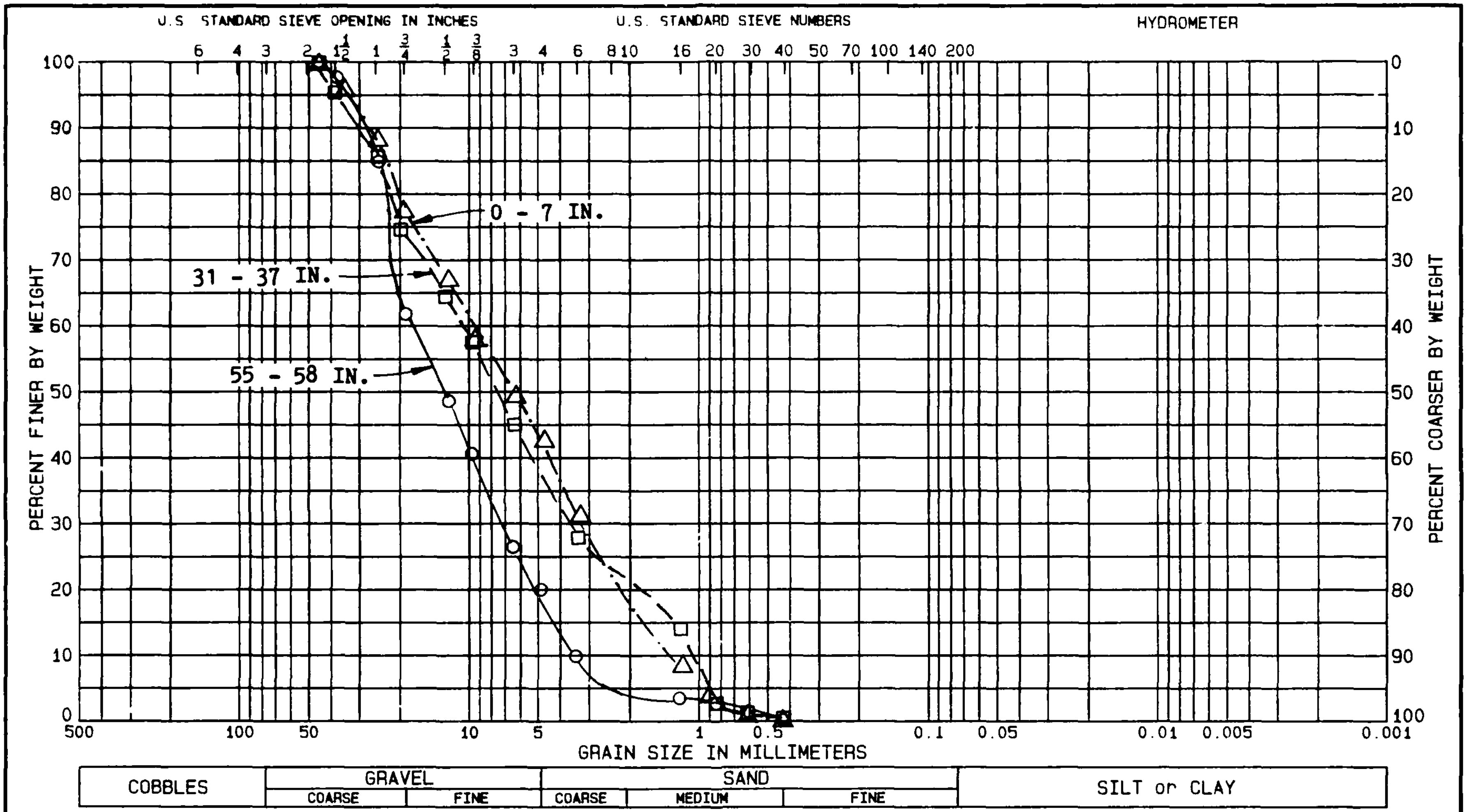
BORING NO.

SAMPLE NO.

DEPTH/ELEV

DATE 00 NOV 79

PLATE E1



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

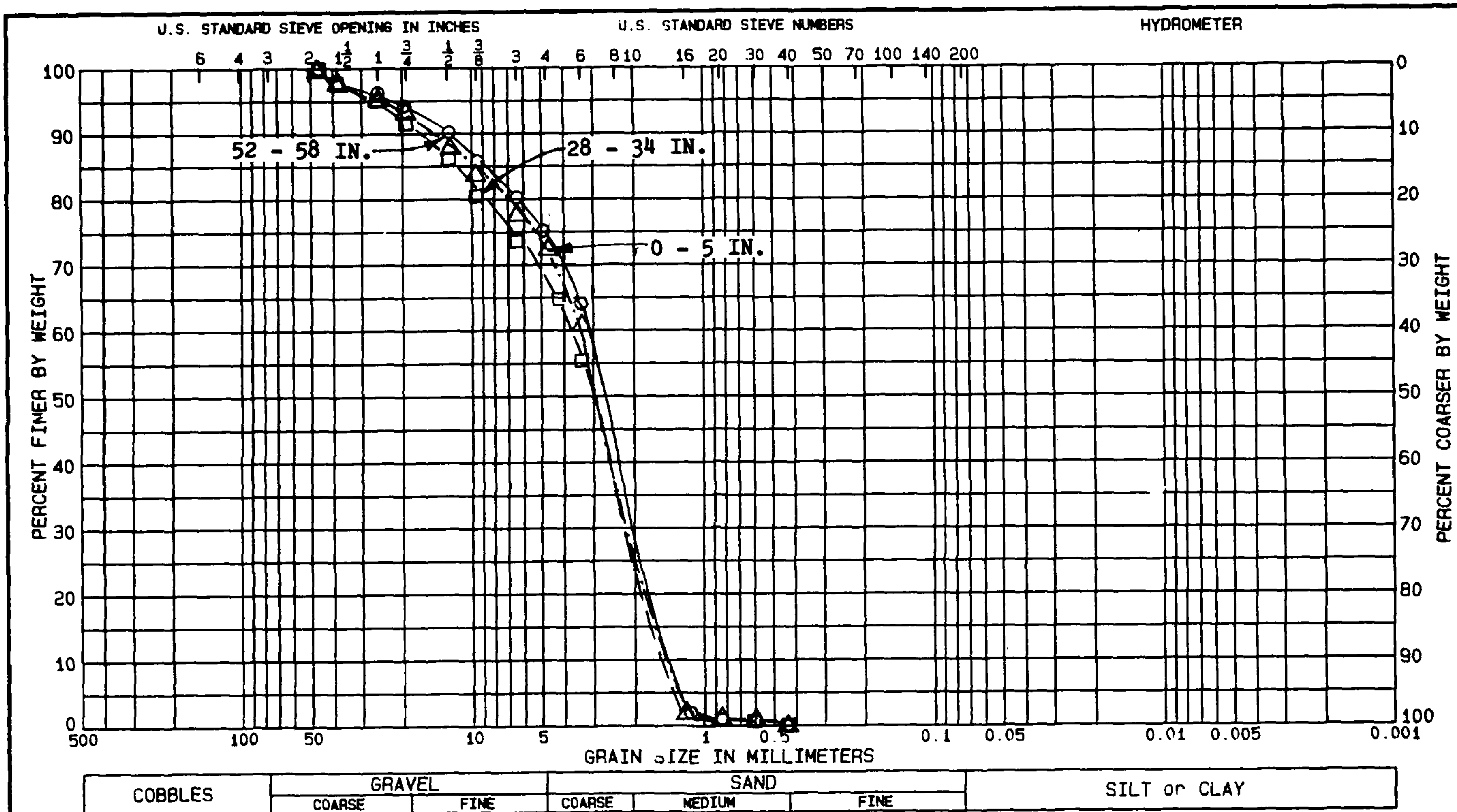
GRADATION CURVE

PROJECT TEST NO. 1A - B

BORING NO. SAMPLE NO.

DEPTH/ELEV DATE 00 AUG 79

PLATE E2



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

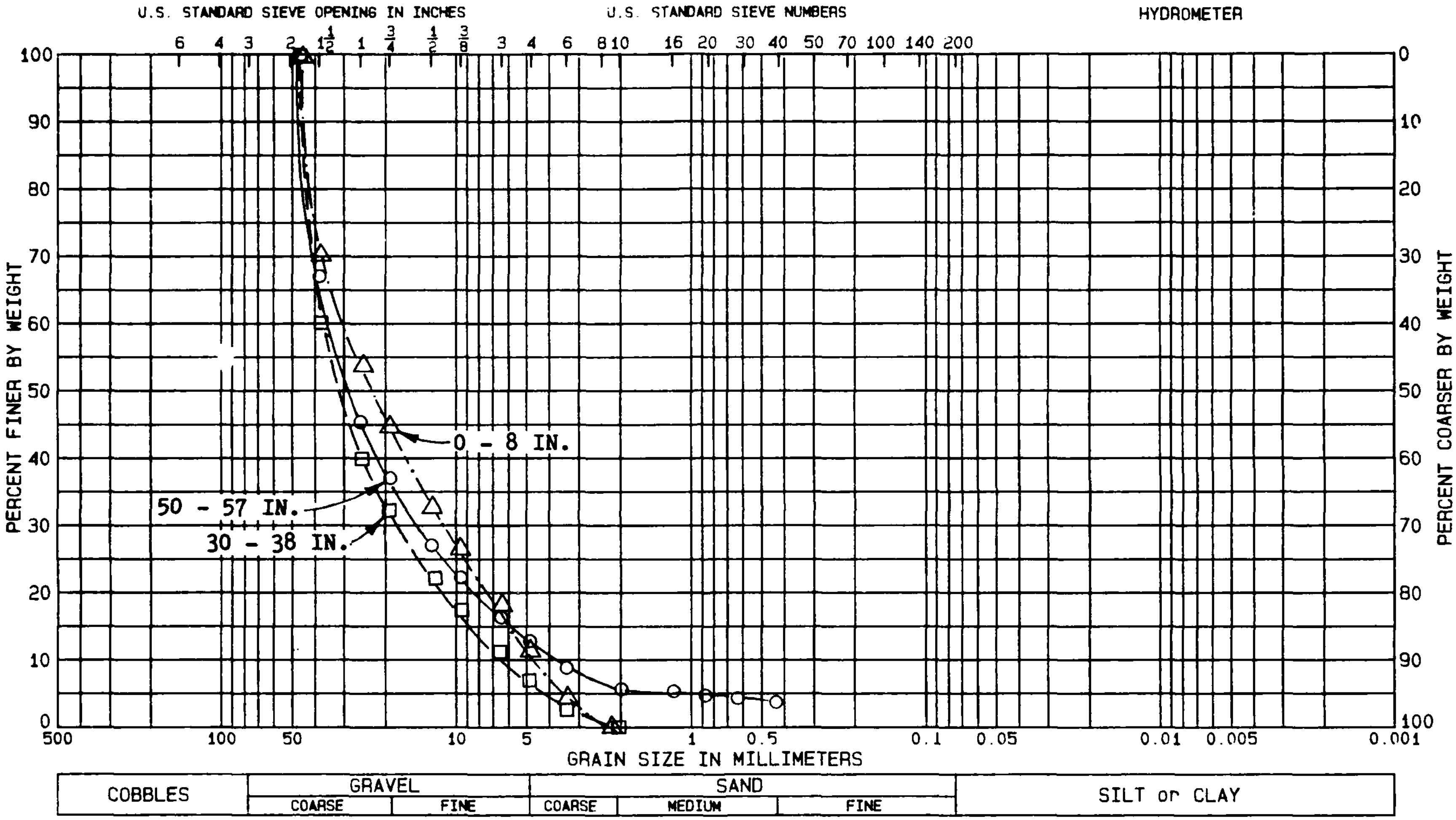
GRADATION CURVE

PROJECT TEST NO. 1A - C

BORING NO. SAMPLE NO.

DEPTH/ELEV DATE 00 SEP 79

PLATE E3



LL	PL	PI	GS	NAT W. %	

CLASSIFICATION

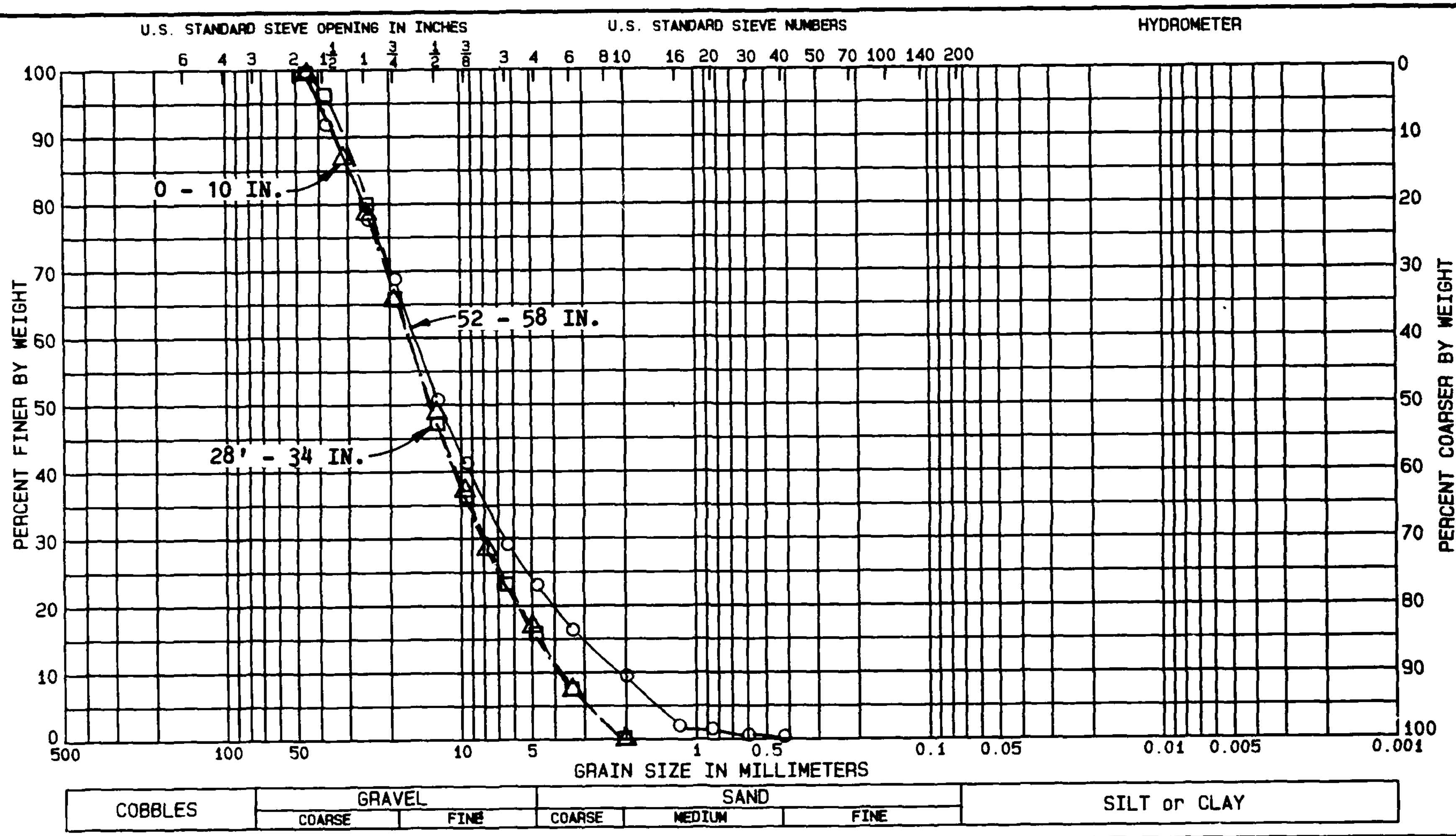
GRADATION CURVE

PROJECT TEST NO. 1 B - A

BORING NO. SAMPLE NO.

DEPTH/ELEV DATE 00 APR 80

PLATE E4



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

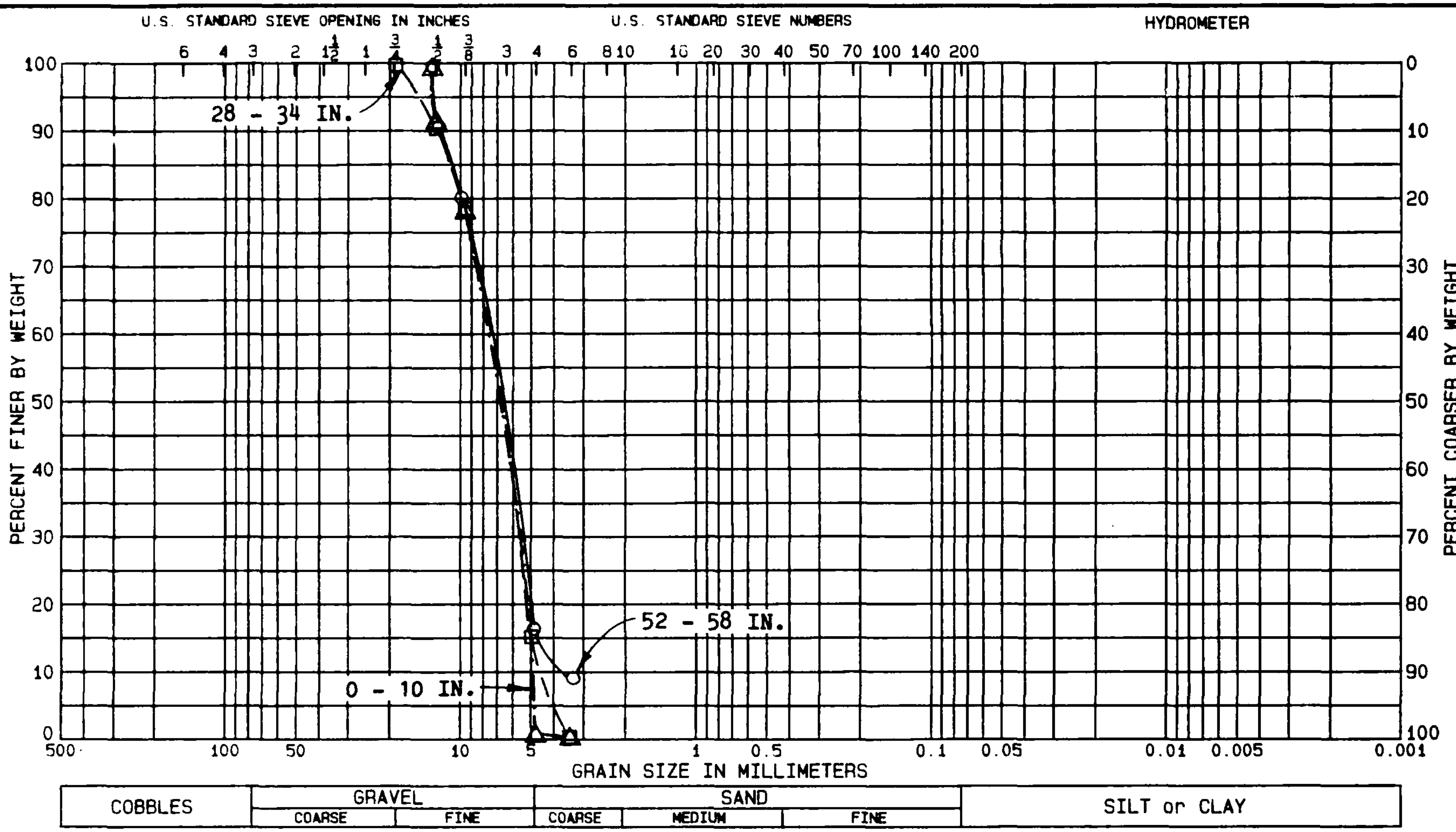
PROJECT TEST NO. 1B - B

BORING NO.

SAMPLE NO.

DEPTH/ELEV

DATE 00 MAR 80



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

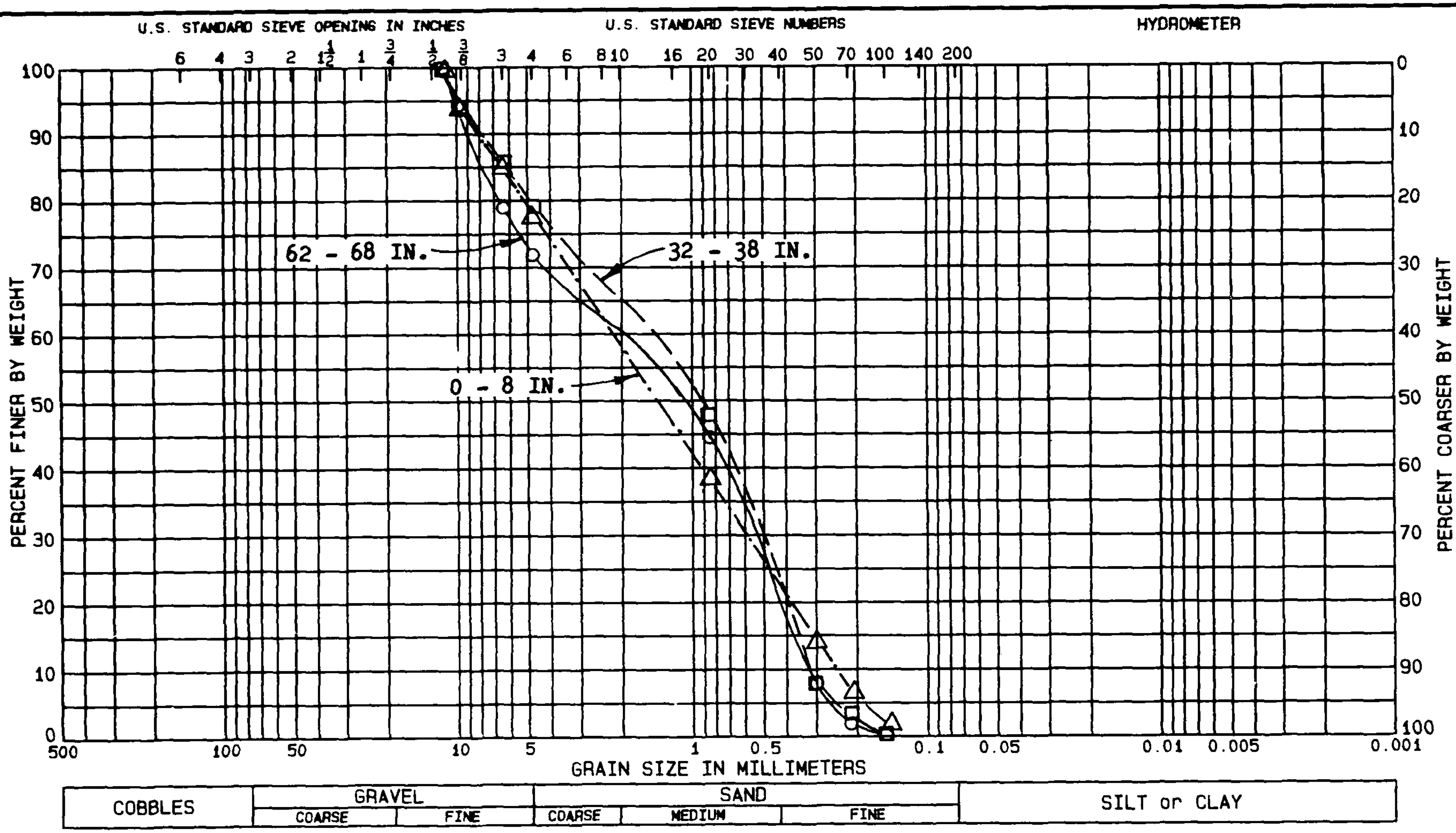
PROJECT TEST NO. 1B - C

BORING NO. SAMPLE NO.

DEPTH/ELEV DATE 00 DEC 79

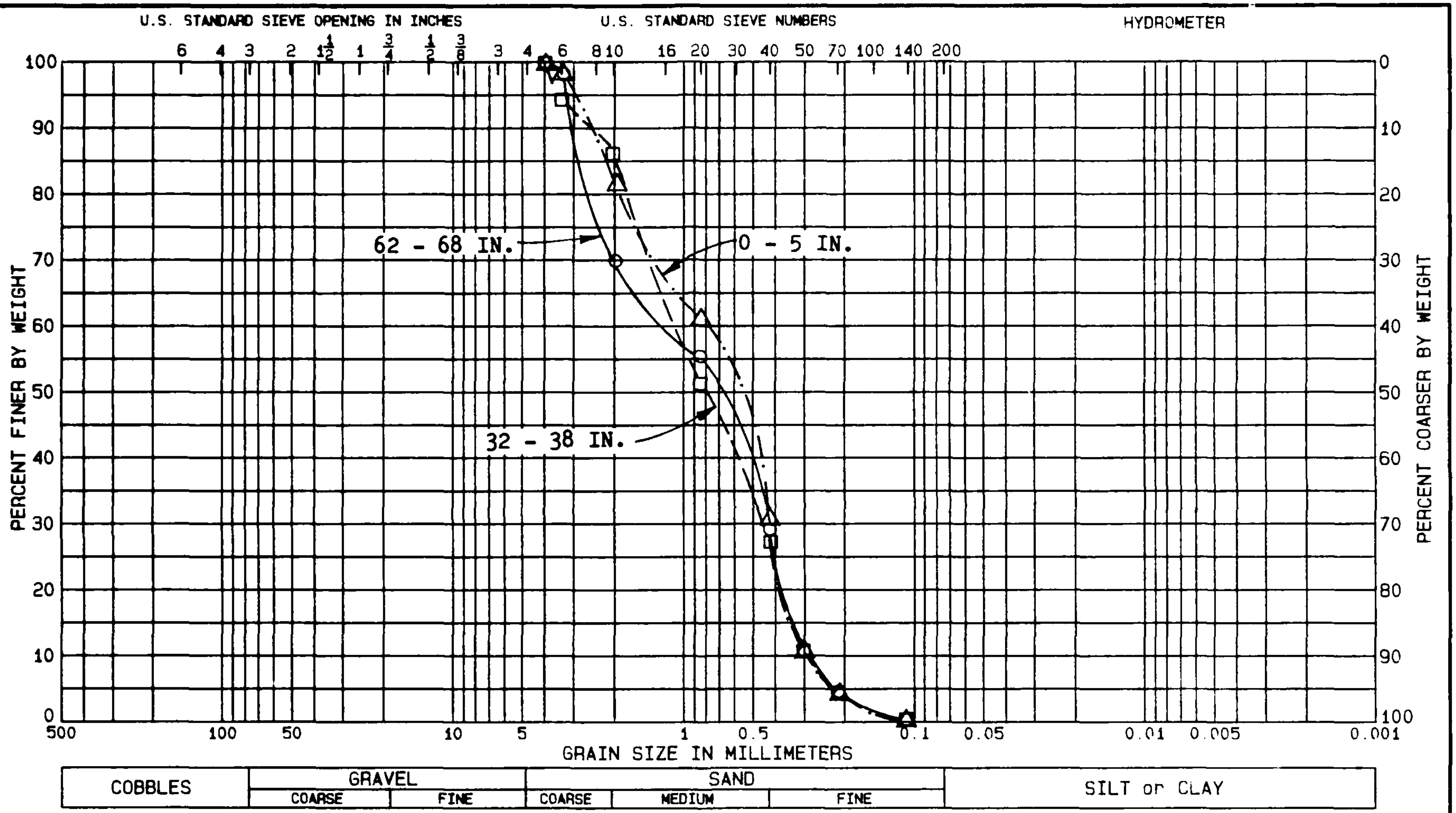
GRADATION CURVE

PLATE E6



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 1	
CLASSIFICATION						BORING NO.	SAMPLE NO.
						DEPTH/ELEV	DATE 00 JUL 81
GRADATION CURVE							

PLATE E7



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 1A

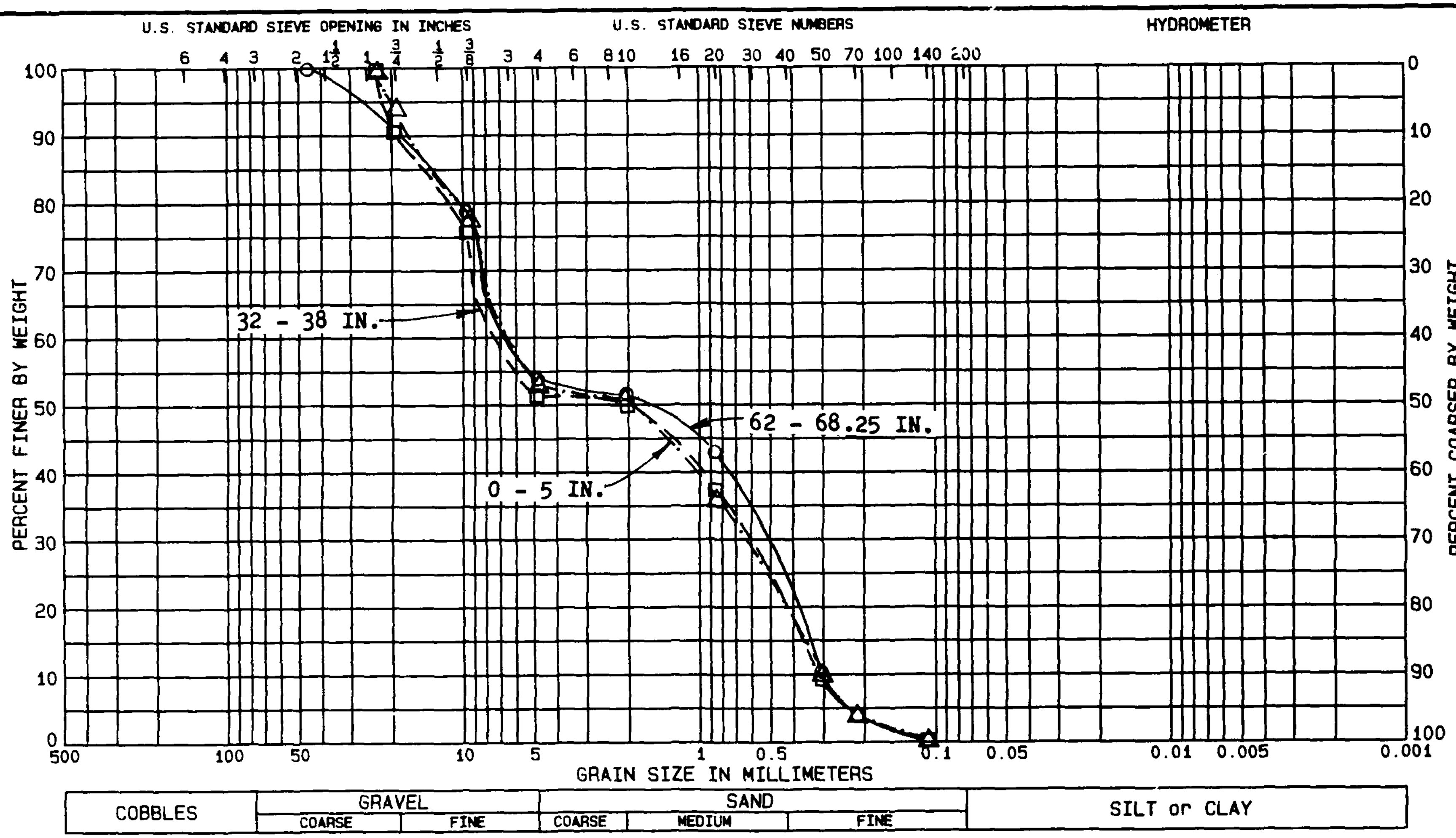
BORING NO.

SAMPLE NO.

DEPTH/ELEV

DATE 00 MAR 82

PLATE E8



LL	PL	PI	GS	NAT W, %	

CLASSIFICATION

GRADATION CURVE

PROJECT TEST NO. 2

BORING NO.

SAMPLE NO.

DEPTH/ELEV

DATE 00 AUG 81

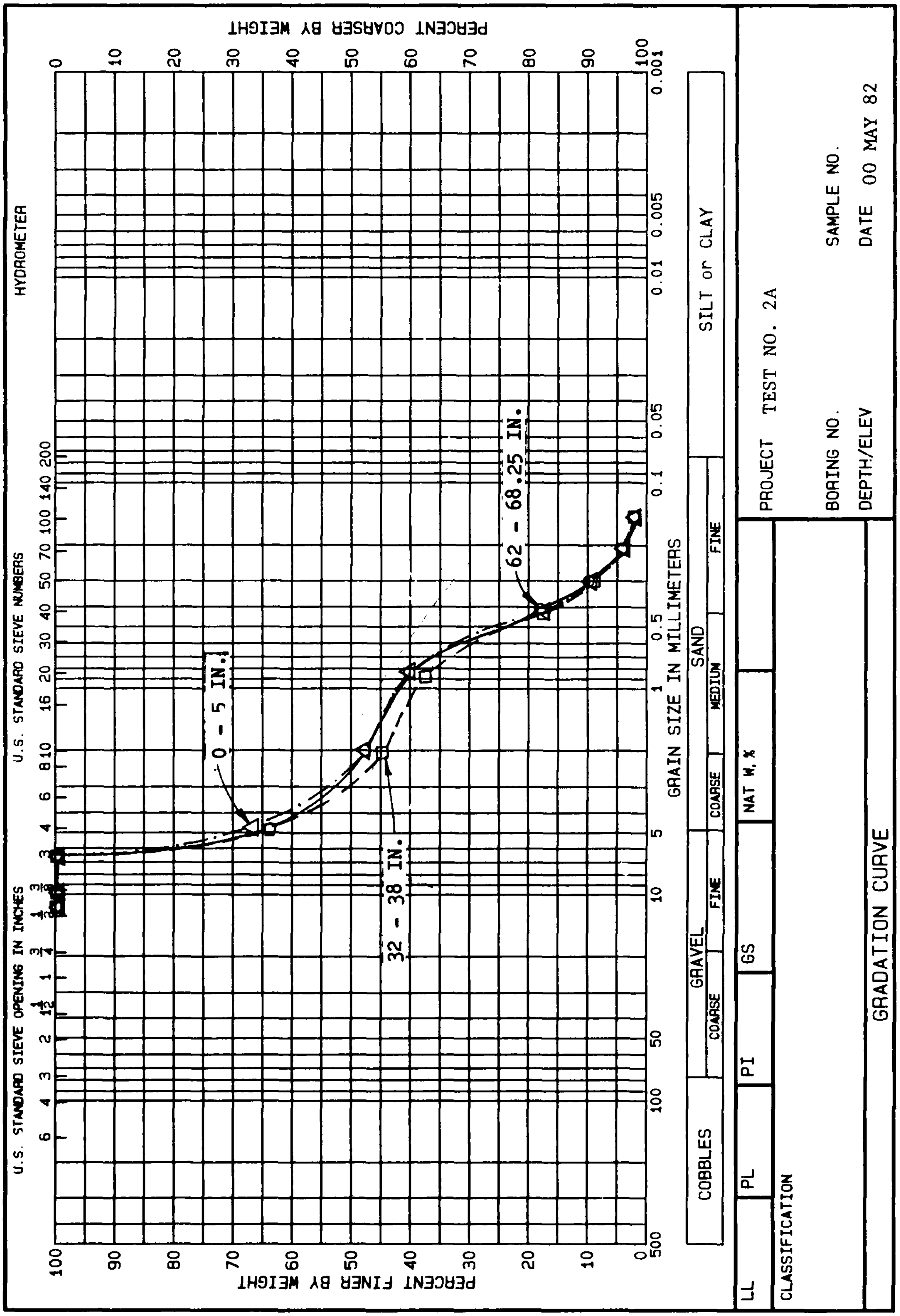
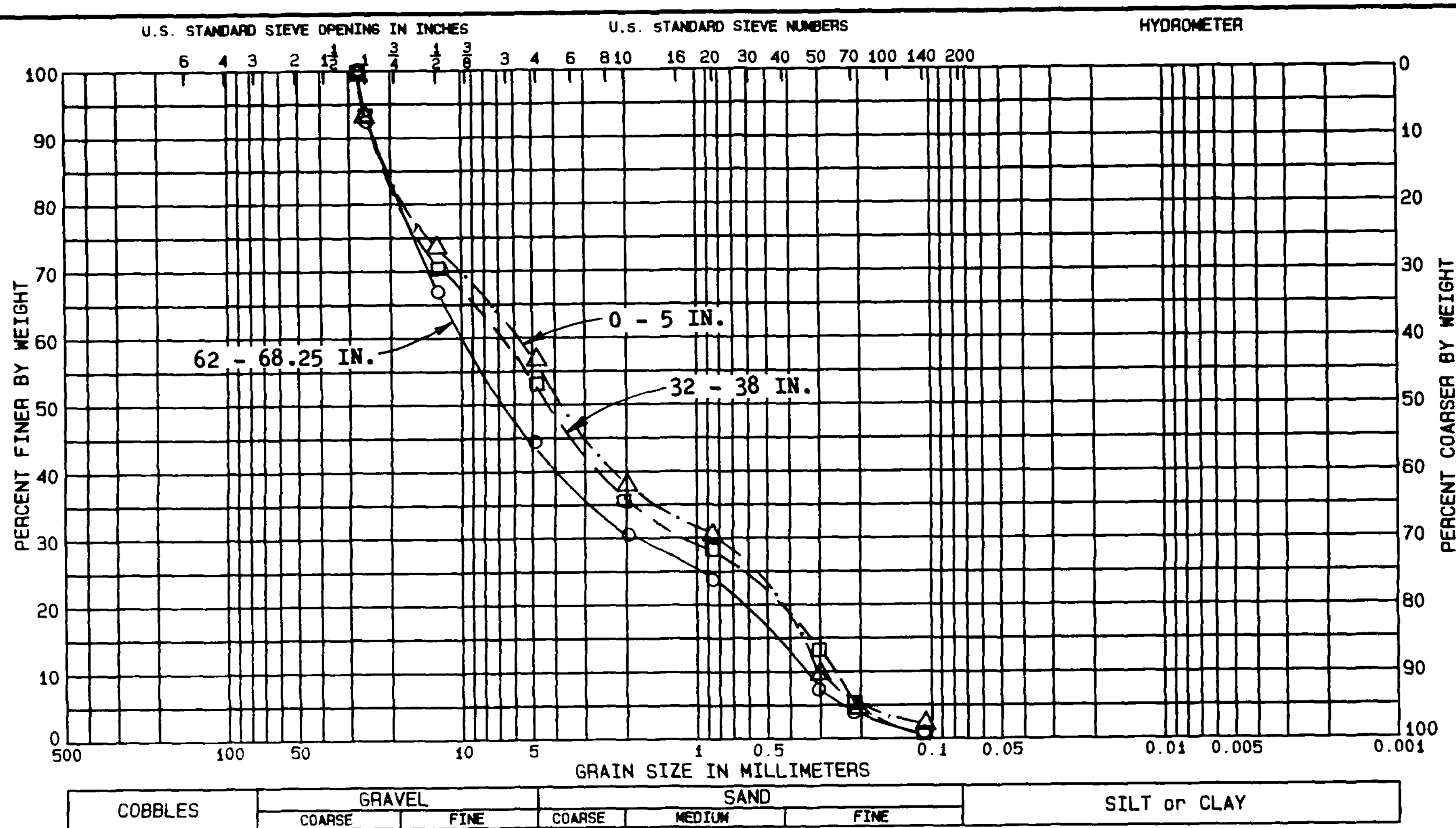

U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
0 - 5 IN.
32 - 38 IN.
62 - 68.25 IN.
LL
PL
PI
GS
NAT W,%
CLASSIFICATION
PROJECT TEST NO. 2A
BORING NO.
SAMPLE NO.
DEPTH/ELEV
DATE 00 MAY 82
GRADATION CURVE

PLATE E10



LL	PL	PI	GS	NAT W, %		PROJECT TEST NO. 3
CLASSIFICATION						BORING NO. SAMPLE NO.
						DEPTH/ELEV DATE 00 DEC 81
GRADATION CURVE						

PLATE E11

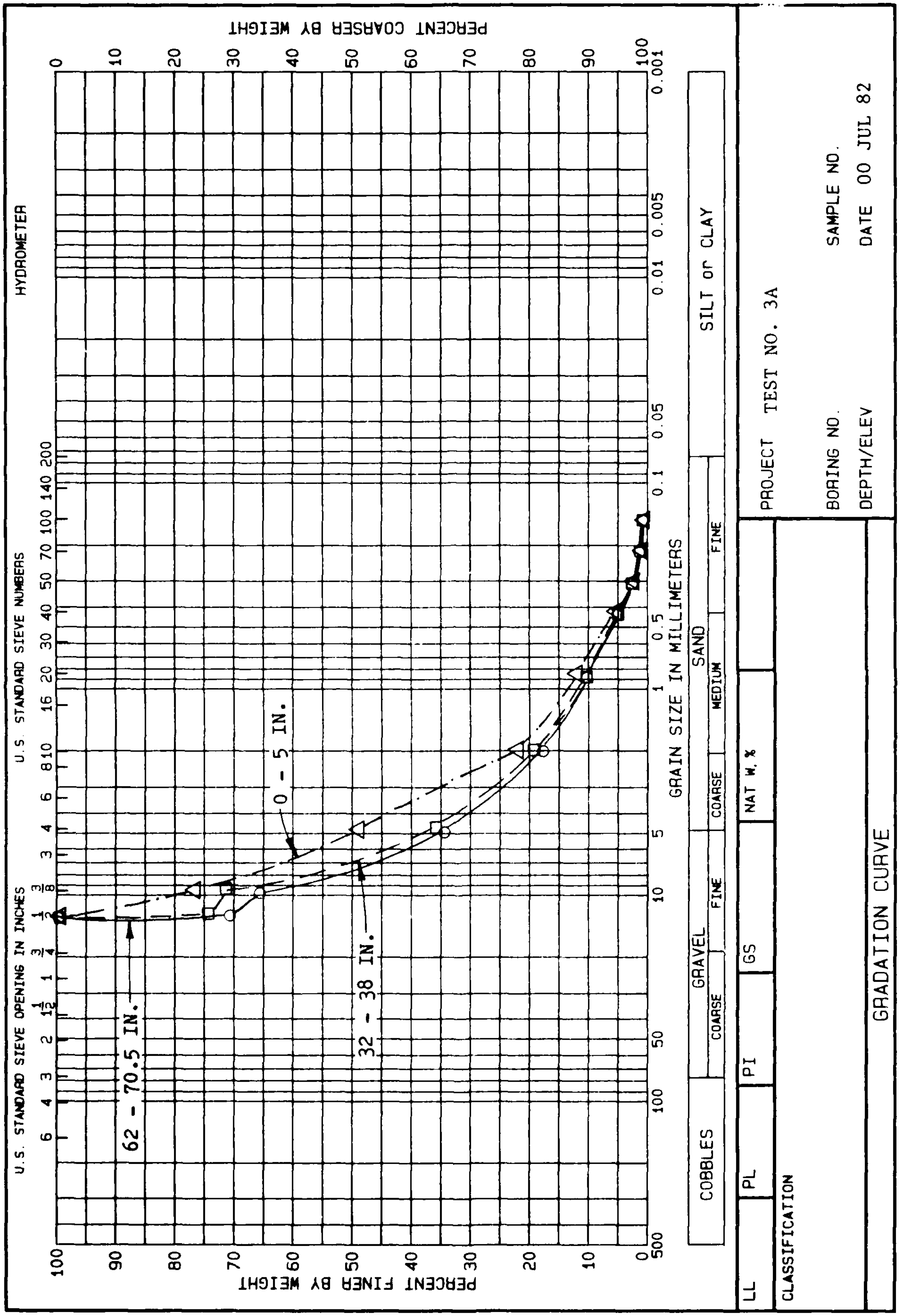

PERCENT COARSER BY WEIGHT
HYDROMETER
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
6 4 3 2 1½ 1 ¾ ½ ⅜ 3 4 6 8 10 16 20 30 40 50 70 100 140 200
62 - 70.5 IN.
32 - 38 IN.
0 - 5 IN.
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
LL
PL
PI
GS
NAT W, %
PROJECT TEST NO. 3A
BORING NO.
SAMPLE NO.
DEPTH/ELEV
DATE 00 JUL 82
CLASSIFICATION
GRADATION CURVE

PLATE E12

END
12-87
DTIC