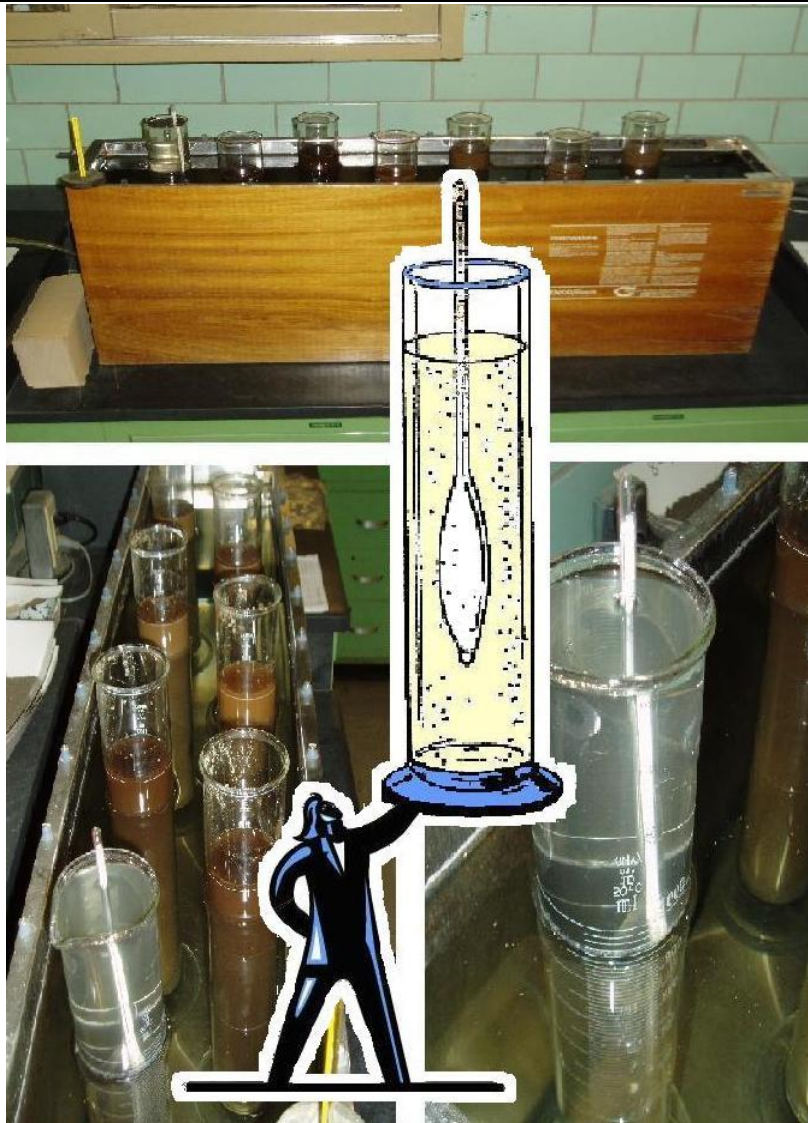


TEST METHOD AND DISCUSSION FOR THE PARTICLE SIZE ANALYSIS OF SOILS BY HYDROMETER METHOD



GEOTECHNICAL TEST METHOD

GTM-13

Revision #2

AUGUST 2015

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GTM-13
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STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING BUREAU

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PART 1
**TEST METHOD FOR THE PARTICLE SIZE ANALYSIS OF SOILS
BY HYDROMETER METHOD**

1. SCOPE

- 1.1 This manual describes the procedure used by the Geotechnical Engineering Bureau to determine the distribution of fine-grained particle sizes of soil. The procedure is a modification of AASHTO Test Method T-88-86. Values presented in this manual without a decimal point or tolerances are approximate.

2. APPARATUS AND SUPPLIES

- 2.1 Oven: A thermostatically controlled oven capable of maintaining temperatures of $230\pm 9^{\circ}$ F ($110\pm 5^{\circ}$ C) for drying the hydrometer analysis samples.
- 2.2 Balance: An AASHTO M-231, Class C balance for weighing the hydrometer analysis sample.
- 2.3 Stirring Apparatus: A mechanically operated stirring apparatus for mixing the soil slurry. The stirring apparatus consists of an electric motor capable of turning a vertical shaft at a speed of not less than 10,000 rpm without load; a replaceable paddle made of metal, plastic or hard rubber conforming to one of the designs shown in Figure 1 on Page 10 of this manual (from AASHTO T-88-86); and a dispersion cup conforming to either of the designs shown in Figure 2 on Page 10 (from AASHTO T-88-86).
- 2.4 Hydrometer: A hydrometer of the size and shape indicated in Figure 3 on Page 11 (from AASHTO T-88-86), the body of which has been blown in a mold to assure duplication of all dimensions and equipped with Scale B as designated by AASHTO T-88-86. This scale shall be graduated from 0.995 to 1.038 specific gravity and calibrated to read 1.000 in distilled water at 68° F (20° C). Hydrometers equipped with this scale shall be identified as 151H.
- 2.5 Sedimentation Cylinder: A cylinder made of glass, approximately 18 in. (450 mm) in height and 2.5 in (60 mm) in diameter, marked for a volume of 1.1 qt. (1000 mL). The inside diameter shall be such that the 1.1 qt. (1000 mL) mark is 14 ± 1.0 in. (360 ± 20 mm) from the bottom on the inside.
- 2.6 Thermometer: A thermometer conforming to ASTM 14.01.
- 2.7 Sieve: A No. 10 (2.0 mm) sieve conforming to the requirements of AASHTO Designation M-92 and a pan.
- 2.8 Pulverizing Apparatus: A mortar and rubber-covered pestle, or similar device as specified in AASHTO T-87-86, suitable for separating the aggregated soil particle without reducing the size of the individual grains.
- 2.9 Water Bath: A water bath for preventing severe fluctuations in temperature in the soil suspension during the hydrometer analysis test. A satisfactory water bath is an

insulated tank which maintains the suspension as near 68° F (20° C) as the room temperature will permit and of sufficient height so that its water level is slightly less than the level of the soil suspension in the cylinders when the cylinders are in the bath.

- 2.10 Beaker and Watch Glass: A beaker of 0.5 pt. (250 mL) capacity and a watch glass large enough to cover the top of the beaker.
- 2.11 Stirring Rod: A glass stirring rod for each beaker for mixing the hydrometer analysis sample in the dispersing agent.
- 2.12 Timing Device: A watch or clock that indicates hours, minutes, and seconds.
- 2.13 Rubber Stopper: A stopper of sufficient size for sealing the top of the sedimentation cylinder while shaking the hydrometer analysis sample.
- 2.14 Distilled Water: A supply of approximately 1.1 qt. (1 L) of distilled water per sample to be tested.
- 2.15 Water Dispenser: A dispenser for distilled water to wash the container when transferring the hydrometer analysis sample from one container to another.
- 2.16 Container: A sealable container for storing distilled water at room temperature.
- 2.17 Sodium Metaphosphate Crystals (NaPO_3)₁₃· Na_2O : A supply of purified sodium metaphosphate for preparing the dispersing agent.
- 2.18 Magnetic Stirring Apparatus: A stirring apparatus for mixing the dispersing agent.
- 2.19 Beaker: A beaker in which to mix the dispersing agent.
- 2.20 Storage Container: A large, sealable glass container for storing the dispersing agent.

3. PREPARATION OF THE DISPERSING AGENT

- 3.1 Prepare a stock solution of the dispersing agent as follows:
 - 3.1.1 Add the dispersing agent to the distilled water in the proportion of 1.4 oz. (40 g) of sodium metaphosphate to 1.1 qt. (1000 mL) room temperature distilled water.
 - 3.1.2 Mix the solution using the magnetic stirring apparatus for 1 hour or until all the sodium metaphosphate crystals have dissolved, whichever is longer.
 - 3.1.3 Allow the solution to stand for a minimum of 12 hours before using.

Note 1: Dispersion capabilities of the sodium metaphosphate solution decrease with time. Therefore, a new solution should be prepared monthly and any leftover solution discarded. The storage containers should be marked with the date the solution was prepared.

4. SAMPLE PREPARATION AND TEST PROCEDURE

- 4.1 Complete all pertinent information on the Hydrometer Analysis Data Worksheet (Appendix E: Fig. 8).
- 4.2 Dry the sample to a constant weight overnight in an oven at 230±9° F (110±5° C). Place the sample in a desiccator and allow cooling to room temperature.

- 4.3 Break up agglomerations and separate soil particles using the pulverizing apparatus.

Note 2: Care must be taken to prevent the reduction of the natural size of the soil particles and the loss of material during the pulverizing process.

- 4.4 If a gradation test has not been performed, separate the sample of predetermined weight on the No. 10 (2.0 mm) sieve and weigh the portion retained. Calculate the percent passing the No. 10 (2.0 mm) sieve. Store the portion passing in an oven at $230 \pm 9^\circ$ F ($110 \pm 5^\circ$ C). Place the sample in a desiccator and allow cooling to room temperature before using.

- 4.5 Place 50 g, weighed to the nearest 0.01 g, of soil passing the No. 10 (2.0 mm) sieve into a 0.5 pt. (250 mL) beaker. Add 0.25 pt. (125 mL) of dispersing agent and mix thoroughly with a glass rod. Leave the rod in the beaker, cover with a watchglass, and allow to stand for a minimum of 12 hours.

Note 3: Sample weights other than 50 g may be used if necessary.

- 4.6 Wash the contents of the beaker and material retained on the glass rod into the dispersion cup using the water dispenser. Add distilled water to the cup until it is approximately half full. Mix the solution in the mixing apparatus for 1 minute.

Note 4: Check the condition of the stirring paddle periodically for conformance to AASHTO Designation T-88-86 (Figure 1 on Page 10 of this manual).

- 4.7 Carefully remove the dispersion cup from the mixer and wash off the mixing apparatus shaft and paddle with the water dispenser. Transfer the contents of the dispersion cup into the sedimentation cylinder and wash all soil particles off the baffles and into the cylinder. Add room temperature distilled water until the bottom of the meniscus reaches the 1.1 qt. (1000 mL) mark. Place the cylinder into the bath for 1 hour to stabilize the temperature of the solution.

- 4.8 Remove the cylinder from the bath and place the rubber stopper snugly in the mouth of the cylinder. Thoroughly shake the contents for 1 minute using the following procedure:

4.8.1 Starting from the upright position, completely invert the cylinder for 1 second and return to the upright position for 1 second. A total of 30 inversions shall be achieved, counting the turn upside down and back as 1 inversion.

4.8.2 Any soil remaining at the bottom of the cylinder after the first few inversions should be loosened by vigorously shaking the cylinder while in the inverted position.

- 4.9 Take the hydrometer and temperature reading as follows:

4.9.1 At the conclusion of the 1 minute shake, note the time and place the cylinder into the bath. *This is the beginning of the test.* Record the time in Column 9

on the Data Worksheet (Appendix E: Fig. 8). Insert the hydrometer slowly into the solution.

Note 5: The hydrometer should be inserted approximately 30 seconds before each reading time to allow the hydrometer to come to rest. Approximately 5 seconds should be taken to slowly insert the hydrometer to keep disturbance to a minimum.

- 4.9.2 Estimate the hydrometer reading to the nearest 0.0001 specific gravity at the top of the meniscus and record it in Column 11 on the Data Worksheet. Immediately (but slowly) withdraw the hydrometer and store it in a cylinder filled with clean water. Spin the hydrometer slightly to remove any residue.
- 4.9.3 Take a temperature reading of the solution to the nearest 0.1 °C immediately following the hydrometer reading. The thermometer should extend to approximately half the depth of the solution. Record the value in Column 12 on the Data Worksheet.
- 4.9.4 The standard elapsed time reading schedule is 2, 5, 15, 30, 60, 250, 1440 and 3060 minutes.

Note 6: A 3060 minute (51 hour) reading is needed only when analyzing particle sizes to 0.001 mm. Times may be altered to suit individual testing requirements. When multiple samples are to be tested, set up times should be worked out in advance so that reading times of multiple samples do not coincide.

- 4.10 After the final hydrometer and temperature readings have been taken, remove the cylinder from the bath and check for flocculation. Flocculation is evidenced by a mixture of large and small particles in the sediment at the bottom of the cylinder and a semi-clear appearance of the solution. Normal sedimentation is layered, with the particle size increasing toward the bottom. If flocculation is suspected, the test must be rerun.
- 4.11 If a sieve analysis of the sample is required, use separate samples for hydrometer and sieve analyses. If there is an insufficient amount of material from both analyses, use the following procedure:
 - 4.11.1 Wash the contents of the hydrometer cylinder on a No. 200 (0.075 mm) sieve. Dry the fraction retained and perform a sieve analysis using desired sieve sizes. Refer to the method specified in the appropriate Departmental publication for Grain Size Analysis.

5. CALCULATIONS (*Hydrometer Analysis Data Worksheet, Appendix E, Fig. 8*)

- 5.1 Hydrometer Information
 - 5.1.1 Line 1: *Hydrometer Number*: Usually found at the end of the scale near the neck of the hydrometer.
 - 5.1.2 Line 2: *Cylinder Number*: An arbitrary designation used to identify the soil sample while the cylinder is in the bath.
 - 5.1.3 Line 3: *Composite Correction (COMCOR)*: Refer to Appendix A.
- 5.2 Sample Parameters
 - 5.2.1 Line 4: *Specific Gravity (G_s)*: The specific gravity of the hydrometer analysis sample must be determined. The specific gravity analysis is to be conducted on a representative portion of the sample from which the hydrometer analysis sample was obtained. If the amount of soil is insufficient for a specific gravity analysis and a hydrometer analysis, conduct the specific gravity analysis on the sample, dry the sample to a constant weight in an oven at $230\pm 9^\circ\text{F}$ ($110\pm 5^\circ\text{C}$) and then perform the hydrometer analysis. The specific gravity determination for either case shall be performed in accordance with current laboratory procedures.
 - 5.2.2 Line 5: *Sieve Size Used*: A No. 10 (2.0 mm) sieve is used unless otherwise required.
 - 5.2.3 Line 6: *% Passing Sieve (Pass)*: Weigh the portion retained on the No. 10 (2.0 mm) sieve and subtract from the total sample weight to obtain the weight of the portion passing. Divide the weight of the portion passing by the total sample weight and multiply by 100 to obtain the percent passing.
 - 5.2.4 Line 7: *Weight Dry Soil (W_s)*: A 50 g sample weighed to the nearest 0.01 g is normally used in the analysis.
 - 5.2.5 Line 8: $W = (100/W_s) \times (G_s/G_s - 1) = (11/\text{Line 7}) \times (\text{Line 4}/\text{Line 4-1.0})$: The value of W is used in the equation to find the Percent Passing Total Sample (Column 17).
- 5.3 Test Data and Computations
 - 5.3.1 Column 9: *Clock*: Enter the time of day to indicate the beginning of the test and reading times.
 - 5.3.2 Column 10: *Elapsed Time (T)*: Standard time values are listed. Times may be altered to suit individual requirements.
 - 5.3.3 Column 11: *Hydrometer Readings (Ra)*: Values are read directly from the hydrometer in accordance with Section 4.9.1 and 4.9.2.
 - 5.3.4 Column 12: *Temperature Readings (TEMP)*: Temperature is obtained immediately following the hydrometer reading in accordance with Section 4.9.3.
 - 5.3.5 Column 13: *Temperature Correction (Mt)*: Refer to Appendix B to obtain Mt values.
 - 5.3.6 Column 14: *Viscosity of Suspending Medium (η)*: Refer to Appendix C to obtain η values.

- 5.3.7 Column 15: *Effective Length (L)*: Refer to Appendix D to obtain L values.
- 5.3.8 Column 16: *Particle Diameter (mm)*: Value is obtained by applying Stoke's Law:

$$D = \sqrt{\frac{30 \times \eta \times L}{980 \times (G_s - 1.0) \times T}}$$

Where:

- D = Maximum grain diameter in mm.
- η = Coefficient of viscosity of the suspending medium (water) in poises (from Appendix C).
- L = Distance in cm through which particles settle in a given period of time (from Appendix D).
- G_s = Specific gravity of sample (from Line 4).
- T = Elapsed time of reading minutes (from Column 10).

- 5.3.9 Column 17: *% Passing Total Sample*: Value is obtained from the following equation:

$$\begin{aligned} \%PASSTOT &= (Mt + COMCOR + Ra) \times W \times PASS / 100 \\ &= (Column13 + Line3 + Column11) \times Line8 \times (Line6 / 100) \end{aligned}$$

- 5.3.10 Line 18: *Desired Size*: Enter the specific grain diameters that are to be analyzed (i.e. 0.01, 0.002, 0.001 mm).

5.3.11 Line 19: Percent Passing Total: To find the percent passing total for the desired sizes (from Line 18), use the following procedure:

$$\%PASSTOT = (PP \times (\%PASSING A - \%PASSING C)) + \%PASSING C$$

Where:

- A = next size larger than desired size.
- B = desired size.
- C = next size smaller than desired size.

$$PP = \frac{\log SIZE B - \log SIZE C}{\log SIZE A - \log SIZE C}$$

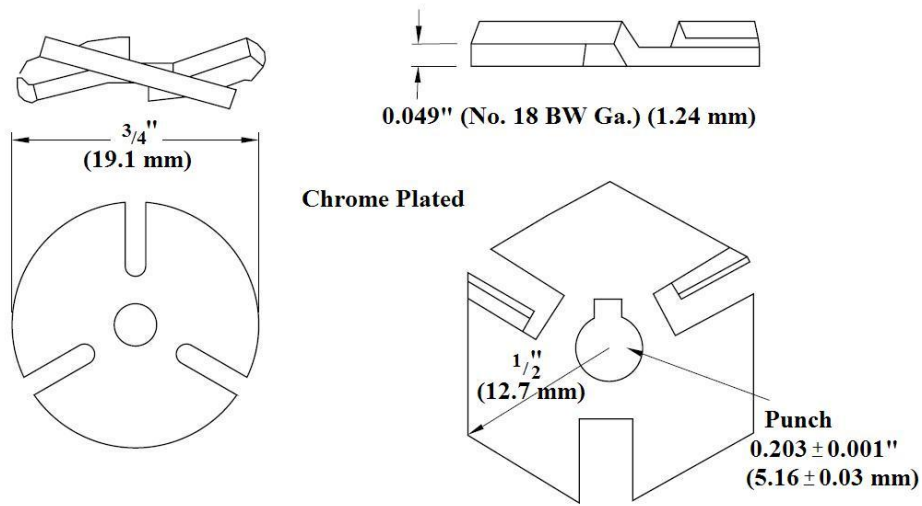


Figure 1* – Details of Stirring Paddles

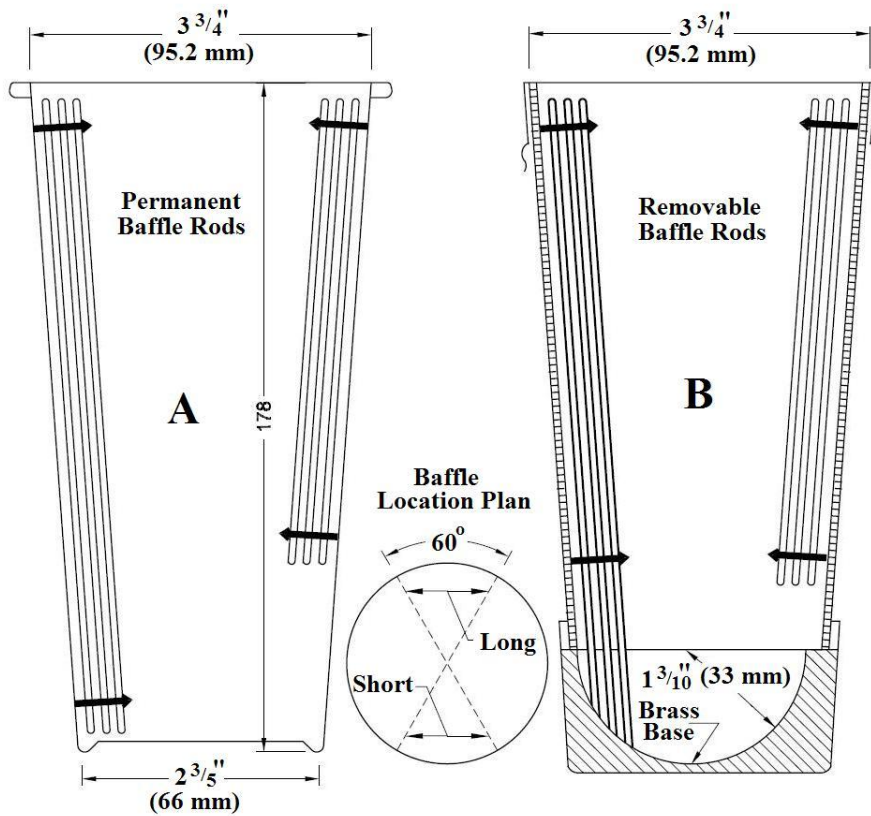
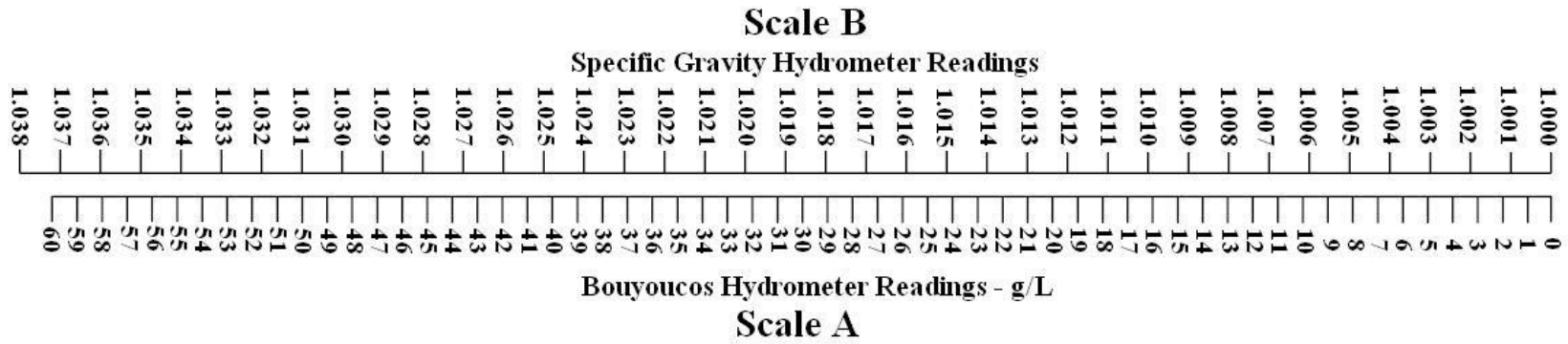


Figure 2* – Dispersion Cups

*** From AASHTO T-88-86**



The specific gravity scale (SP.G.) shall be calibrated to read 1.000 at 68°F (20°C) and it shall extend beyond the limits shown, so as to read from 0.995 to 1.038. The grams per liter scale (g/L) shall be extended 5 g/L above zero (1.000 SP.G.) and down to 60 g/L. The bulb shall be symmetrical above and below the middle diameter, and shall be blown into a mold to assure uniformity of product.

* The diameter of the stem may be varied to adjust the length of a scale specified but the stem shall be uniform in diameter from the top to bottom. The accuracy of the scale shall be ±1 scale division distributed uniformly over the scale length.

Hydrometers equipped with Scale B shall be identified as No. 151H.
Hydrometers equipped with Scale A shall be identified as No. 152H.

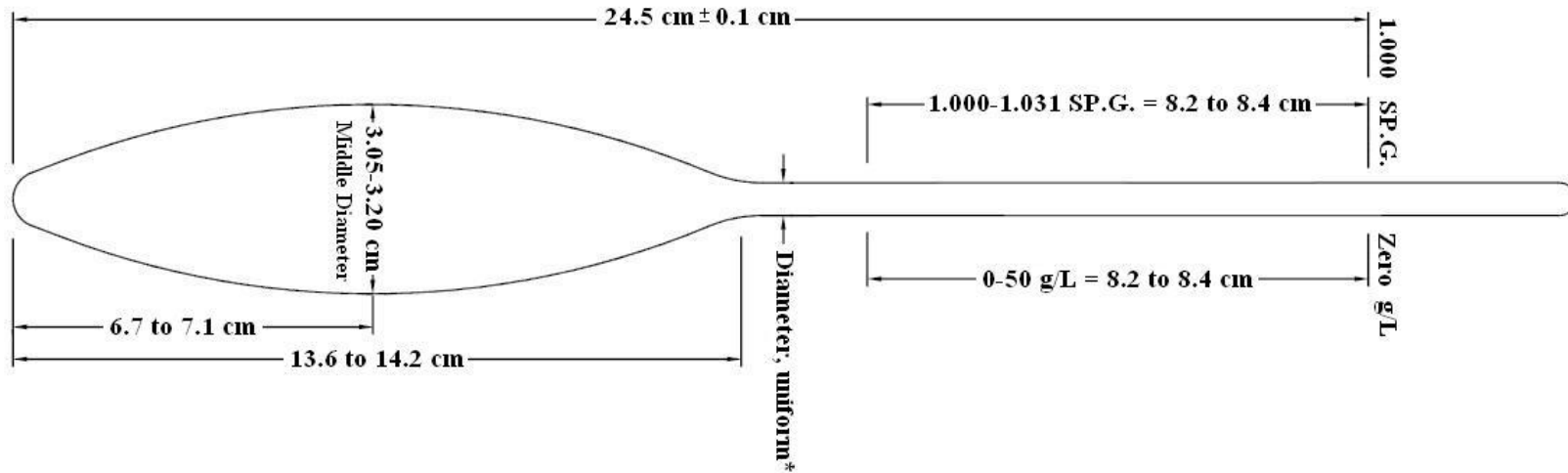


Figure 3* – Hydrometer
***From AASHTO T-88-86**

Quick Reference Guide

Note: The Quick Reference Guide is a general overview of the major actions of the test method and does not contain all the details involved for conducting the procedure. The Quick Reference Guide is intended as a reminder and should be referred to only after a good understanding of the complete test method has been obtained.

R.1 Preliminary Preparation

R.1.1 Fill in all pertinent information on the Hydrometer Analysis Data Worksheet (Appendix E: Fig. 8).

R.1.2 Check the following items:

- a. The oven maintains a temperature of $230\pm 9^{\circ}$ F ($110\pm 5^{\circ}$ C).
- b. The scale is level and calibrated.
- c. There is enough fresh Sodium Metaphosphate prepared (0.25 pt. (125 mL) per sample).
- d. Room temperature distilled water, beakers, mixing rods, cylinders, thermometers, stoppers, mixing and pulverizing apparatuses and hydrometers are available and in good condition.

R.2 Sample Preparation

R.2.1 Dry the sample in the $230\pm 9^{\circ}$ F ($110\pm 5^{\circ}$ C) oven.

R.2.2 Break up agglomerations and separate soil particles using the pulverizing apparatus.

R.2.3 If a gradation test has not been performed, weigh the sample and separate on a No. 10 (2.0 mm) sieve. Weigh the portion retained on the sieve and compute the percent passing.

R.2.4 Place 50 g weighed to the nearest 0.01 g of minus No. 10 (2.0 mm) sieve material into a beaker. Add 0.25 pt. (125 mL) dispersing agent and stir thoroughly. Let mixture stand for a minimum of 12 hours.

R.2.5 Pour contents of the beaker into the dispersion cup. Use a water dispenser to wash all particles into the cup. Add room temperature distilled water to half fill the cup. Mix for 1 minute.

R.2.6 Transfer the content into a cylinder. Use a water dispenser to wash all particles into the cylinder. Add room temperature distilled water until the bottom of the meniscus reaches the 1.1 qt. (1000 mL) mark.

R.2.7 Place cylinder in the bath and allow the temperature to stabilize for 1 hour. Remove the cylinder from the bath, place a stopper in the mouth and thoroughly shake the contents for 1 minute by the procedure described in Section 4.8.

R.3 Hydrometer and Temperature Readings

R.3.1 At the end of the shake process, note the time, place the cylinder in the bath and

record the time on the worksheet. Insert the hydrometer slowly, approximately 30 seconds before each reading. Take readings at selected time increments. Read to the nearest 0.0001 specific gravity.

R.3.2 Take a temperature reading to the nearest 0.1° C immediately following each hydrometer reading.

R.3.3 After the final readings have been taken, remove the cylinder from the bath and check for flocculation.

R.4 Calculations

R.4.1 Complete the Hydrometer Analysis Data Worksheet. Refer to Section 5 of the text.

APPENDIX A

Determination of the Composite Correction For Hydrometer Readings

- A.1 The composite correction is the combination of the meniscus and dispersing agent corrections. The value is negative and is added to the hydrometer readings. The composite correction considers the following conditions:
- A.1.1 The hydrometer is graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is impossible to read the hydrometer through the soil suspension, it becomes necessary to read the top of the meniscus. Reading the top of the meniscus results in a lower value than actual.
 - A.1.2 Hydrometers are calibrated to read 1.000 in distilled water at 68° F (20° C). However, the addition of Sodium Metaphosphate (the dispersing agent) increases the specific gravity of the solution, thereby altering the readings. This increase must be determined in order to correct the readings.
- A.2 The composite correction is determined using the following procedure:
- A.2.1 Place 0.25 pt. (125 mL) of the dispersing agent in the dispersion cup and add room temperature distilled water to half fill the cup. Mix for 1 minute. Pour the mixture into a standard sedimentation cylinder, washing the residue from the cup into the cylinder. Add room temperature distilled water to the 1.1 qt. (1000 mL) mark. Place the cylinder in the bath and allow the temperature to stabilize for 1 hour.
 - A.2.2 Place a stopper in the mouth of the cylinder and shake in the manner cited in Section 4.8. Place the cylinder into the water bath, note and record the time. Take hydrometer and temperature readings at 5 minutes, 1, 2, and 24 hours from the end of shake in the manner described in Section 4.9. Use the most frequently occurring value for the hydrometer reading.
 - A.2.3 Apply the temperature correction to the readings using the tables or graph in Appendix B. The difference between the corrected value and the 0.00 reading (1.000 specific gravity) will be the composite meniscus and dispersing agent correction, $C_m - C_d$.
 - A.2.4 A composite correction must be determine for each individual hydrometer.

APPENDIX B

Temperature Correction Values (Mt)					
Temperature Correction (Mt) = ((Temp.-20)x0.2)					
Temp (°C)	CORR	Temp (°C)	CORR	Temp (°C)	CORR
15.0	-1.00	20.0	0.00	25.0	1.00
.1	-0.98	.1	0.02	.1	1.02
.2	-0.96	.2	0.04	.2	1.04
.3	-0.94	.3	0.06	.3	1.06
.4	-0.92	.4	0.08	.4	1.08
.5	-0.90	.5	0.10	.5	1.10
.6	-0.88	.6	0.12	.6	1.12
.7	-0.86	.7	0.14	.7	1.14
.8	-0.84	.8	0.16	.8	1.16
.9	-0.82	.9	0.18	.9	1.18
16.0	-0.80	21.0	0.20	26.0	1.20
.1	-0.78	.1	0.22	.1	1.22
.2	-0.76	.2	0.24	.2	1.24
.3	-0.74	.3	0.26	.3	1.26
.4	-0.72	.4	0.28	.4	1.28
.5	-0.70	.5	0.30	.5	1.30
.6	-0.68	.6	0.32	.6	1.32
.7	-0.66	.7	0.34	.7	1.34
.8	-0.64	.8	0.36	.8	1.36
.9	-0.62	.9	0.38	.9	1.38
17.0	-0.60	22.0	0.40	27.0	1.40
.1	-0.58	.1	0.42	.1	1.42
.2	-0.56	.2	0.44	.2	1.44
.3	-0.54	.3	0.46	.3	1.46
.4	-0.52	.4	0.48	.4	1.48
.5	-0.50	.5	0.50	.5	1.50
.6	-0.48	.6	0.52	.6	1.52
.7	-0.46	.7	0.54	.7	1.54
.8	-0.44	.8	0.56	.8	1.56
.9	-0.42	.9	0.58	.9	1.58
18.0	-0.40	23.0	0.60	28.0	1.60
.1	-0.38	.1	0.62		
.2	-0.36	.2	0.64		
.3	-0.34	.3	0.66		
.4	-0.32	.4	0.68		
.5	-0.30	.5	0.70		
.6	-0.28	.6	0.72		
.7	-0.26	.7	0.74		
.8	-0.24	.8	0.76		
.9	-0.22	.9	0.78		
19.0	-0.20	24.0	0.80		
.1	-0.18	.1	0.82		
.2	-0.16	.2	0.84		
.3	-0.14	.3	0.86		
.4	-0.12	.4	0.88		
.5	-0.10	.5	0.90		
.6	-0.08	.6	0.92		
.7	-0.06	.7	0.94		
.8	-0.04	.8	0.96		
.9	-0.02	.9	0.98		

APPENDIX B

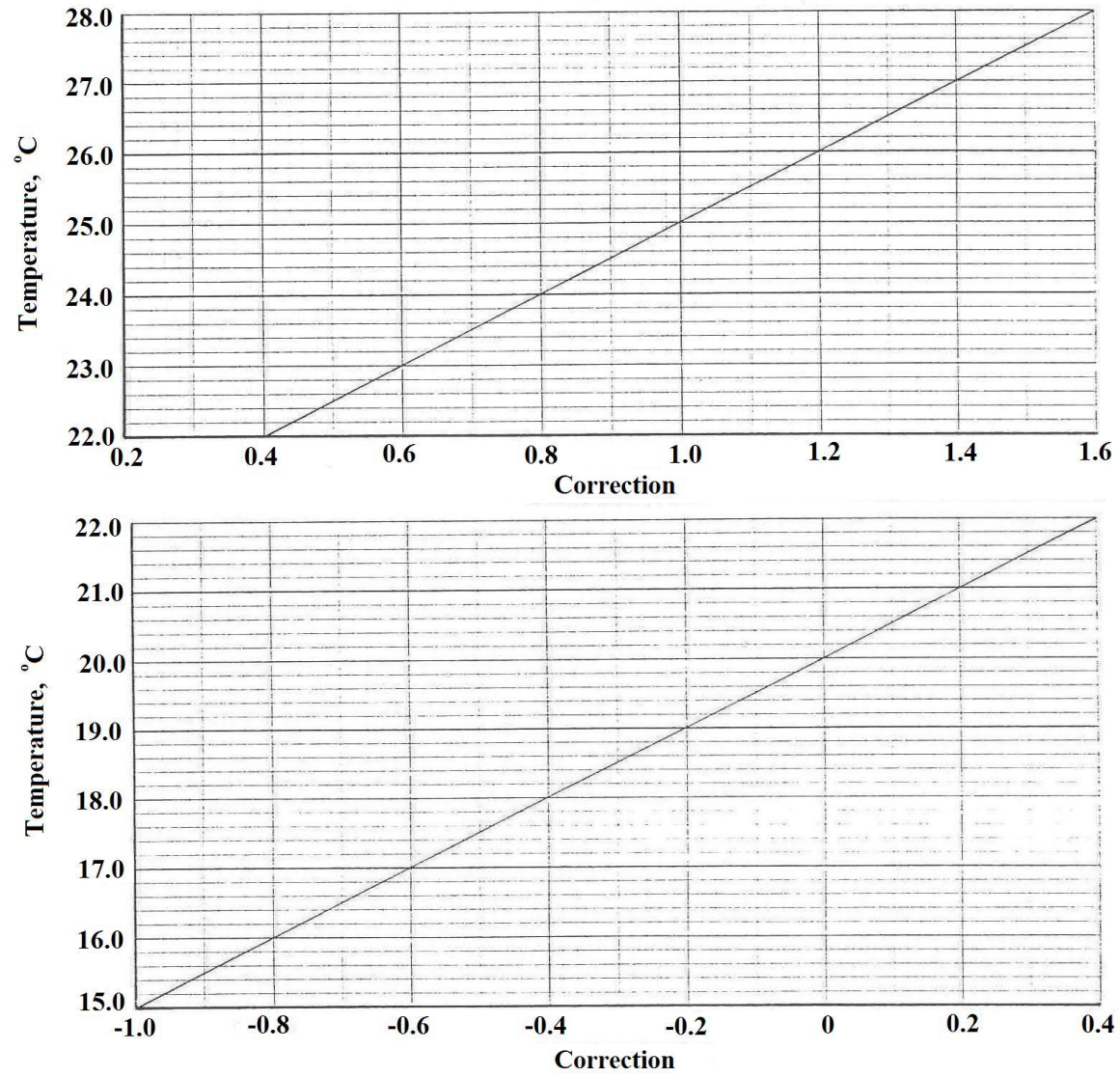


Figure 4

APPENDIX C

Value for Viscosity of Distilled Water, “η” in Poises										
Temp., °C	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
14	.01171	.01168	.01165	.01162	.01159	.01156	.01153	.01149	.01146	.01143
15	.01140	.01137	.01134	.01131	.01128	.01125	.01122	.01119	.01116	.01114
16	.01111	.01108	.01105	.01102	.01099	.01096	.01094	.01091	.01088	.01085
17	.01083	.01080	.01077	.01074	.01072	.01069	.01066	.01064	.01061	.01058
18	.01056	.01053	.01051	.01048	.01045	.01043	.01040	.01038	.01035	.01033
19	.01030	.01028	.01025	.01022	.01020	.01017	.01015	.01012	.01010	.01007
20	.01005	.01002	.01000	.00998	.00995	.00993	.00990	.00988	.00986	.00983
21	.00981	.00978	.00976	.00974	.00971	.00969	.00967	.00965	.00962	.00960
22	.00958	.00956	.00953	.00951	.00949	.00947	.00945	.00942	.00940	.00938
23	.00936	.00934	.00932	.00929	.00927	.00925	.00923	.00921	.00919	.00916
24	.00914	.00912	.00910	.00908	.00906	.00904	.00902	.00900	.00897	.00895
25	.00893	.00891	.00889	.00887	.00885	.00883	.00881	.00879	.00877	.00875
26	.00873	.00872	.00870	.00868	.00866	.00864	.00862	.00860	.00858	.00856
27	.00854	.00853	.00851	.00849	.00847	.00845	.00843	.00842	.00840	.00838
28	.00836	.00835	.00833	.00831	.00829	.00827	.00826	.00824	.00822	.00820

APPENDIX C

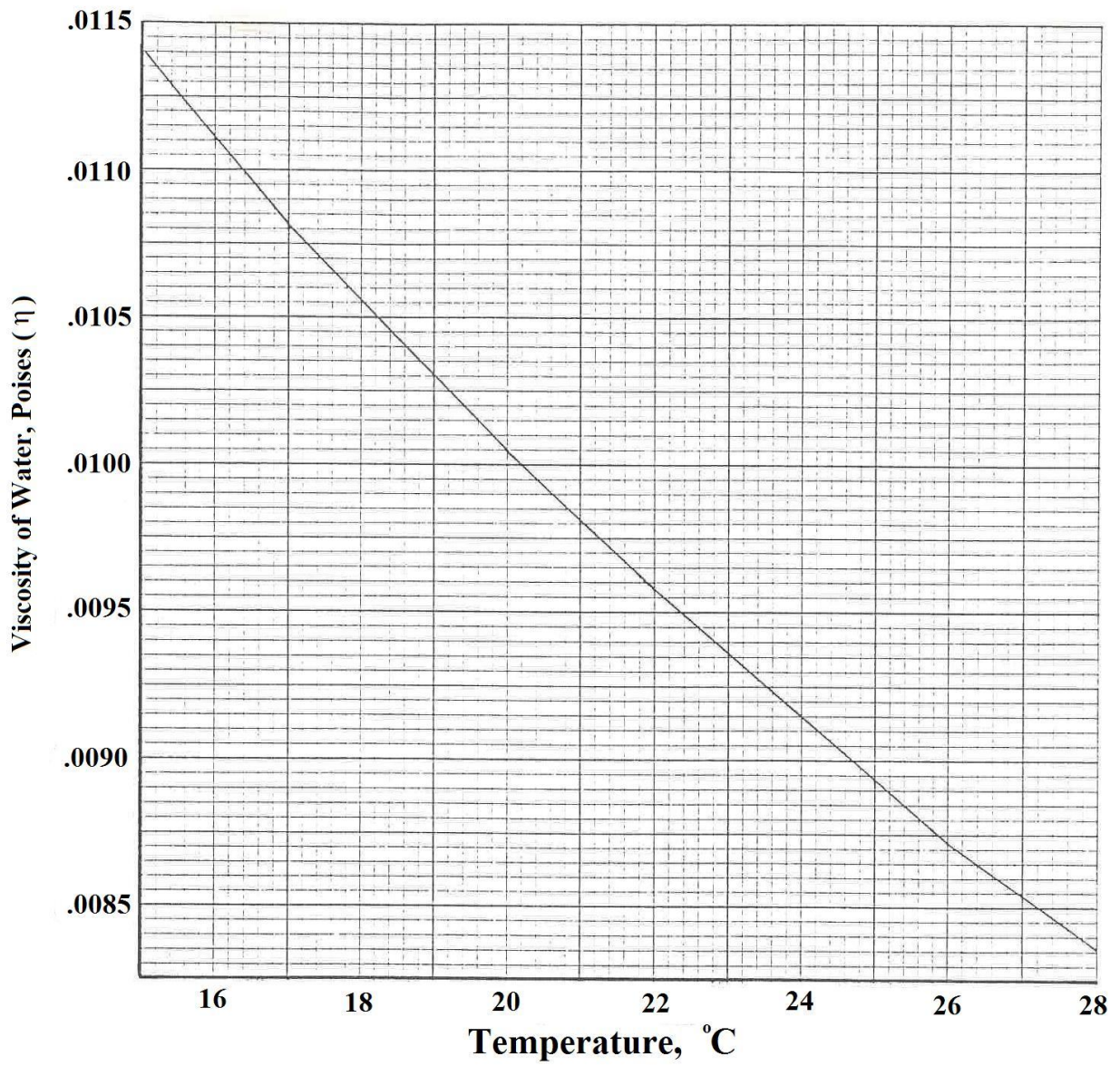


Figure 5

APPENDIX D

Determination of the Effective Length “L”

- D.1 The Effective Length “L” is the distance in cm through which soil particles fall in a given period of time. It is measured from the surface of the solution to the center of the hydrometer bulb. To determine the Effective Length, the hydrometer must be calibrated using the Hydrometer Calibration Worksheet (Appendix E: Fig. 7). The Tables for “L” in this Appendix may be used if the following conditions are met:
- D.1.1 The Effective Depth (Column 12) is 16.5 to 17.0 cm at Scale Division 1.000 (Column 9), and;
 - D.1.2 The distance on the stem from the 1.000 graduate to the 1.031 graduate is 8.2 to 8.4 cm.
- D.2 For hydrometers that do not meet the criteria of D.1, determine the Effective Length by the following procedure:
- D.2.1 Measure the distance from the 1.000 graduate to the 1.031 graduate in centimeter. Divide this value by 31 to obtain a cm/graduate value.
 - D.2.2 Multiply the meniscus correction (not including the dispersing agent correction) by the value from D.2.1.
 - D.2.3 Subtract the value from D.2.2 from the Effective Depth at Scale Division 1.000 (from the Hydrometer Calibration Worksheet).
 - D.2.4 Compute the value of “L” for each hydrometer using the equation below and enter the value in Column 15 of the Data Worksheet (Appendix E: Fig. 8).

$$L = ((\text{negative of the value from D.2.1}) \times \text{Hydrometer Reading} + (\text{value from D.2.3}))$$

APPENDIX D

Values for Effective Length “L”							
Use only for Hydrometers with a Length of 16.5 to 17.0 cm : $L = (-0.26774 \text{ cm/grad.} \times Ra + 16.67 \text{ cm})$							
Ra	L	Ra	L	Ra	L	Ra	L
0.0	16.670	5.0	15.331	10.0	13.993	15.0	12.654
0.1	16.643	5.1	15.305	10.1	13.966	15.1	12.627
0.2	16.616	5.2	15.278	10.2	13.939	15.2	12.600
0.3	16.590	5.3	15.251	10.3	13.912	15.3	12.574
0.4	16.563	5.4	15.224	10.4	13.885	15.4	12.547
0.5	16.536	5.5	15.197	10.5	13.859	15.5	12.520
0.6	16.509	5.6	15.171	10.6	13.832	15.6	12.493
0.7	16.483	5.7	15.144	10.7	13.805	15.7	12.466
0.8	16.456	5.8	15.117	10.8	13.778	15.8	12.440
0.9	16.429	5.9	15.090	10.9	13.752	15.9	12.413
1.0	16.402	6.0	15.064	11.0	13.725	16.0	12.386
1.1	16.375	6.1	15.037	11.1	13.698	16.1	12.359
1.2	16.349	6.2	15.010	11.2	13.671	16.2	12.333
1.3	16.322	6.3	14.983	11.3	13.645	16.3	12.306
1.4	16.295	6.4	14.956	11.4	13.618	16.4	12.279
1.5	16.268	6.5	14.930	11.5	13.591	16.5	12.252
1.6	16.242	6.6	14.903	11.6	13.564	16.6	12.225
1.7	16.215	6.7	14.876	11.7	13.537	16.7	12.199
1.8	16.188	6.8	14.849	11.8	13.511	16.8	12.172
1.9	16.161	6.9	14.823	11.9	13.484	16.9	12.145
2.0	16.135	7.0	14.796	12.0	13.457	17.0	12.118
2.1	16.108	7.1	14.769	12.1	13.430	17.1	12.092
2.2	16.081	7.2	14.742	12.2	13.404	17.2	12.065
2.3	16.054	7.3	14.715	12.3	13.377	17.3	12.038
2.4	16.027	7.4	14.689	12.4	13.350	17.4	12.011
2.5	16.001	7.5	14.662	12.5	13.323	17.5	11.985
2.6	15.974	7.6	14.635	12.6	13.296	17.6	11.958
2.7	15.947	7.7	14.608	12.7	13.270	17.7	11.931
2.8	15.920	7.8	14.582	12.8	13.243	17.8	11.904
2.9	15.894	7.9	14.555	12.9	13.216	17.9	11.877
3.0	15.867	8.0	14.528	13.0	13.189	18.0	11.851
3.1	15.840	8.1	14.501	13.1	13.163	18.1	11.824
3.2	15.813	8.2	14.475	13.2	13.136	18.2	11.797
3.3	15.786	8.3	14.448	13.3	13.109	18.3	11.770
3.4	15.760	8.4	14.421	13.4	13.082	18.4	11.744
3.5	15.733	8.5	14.394	13.5	13.055	18.5	11.717
3.6	15.706	8.6	14.367	13.6	13.029	18.6	11.690
3.7	15.679	8.7	14.341	13.7	13.002	18.7	11.663
3.8	15.653	8.8	14.314	13.8	12.975	18.8	11.636
3.9	15.626	8.9	14.287	13.9	12.948	18.9	11.610
4.0	15.599	9.0	14.260	14.0	12.922	19.0	11.583
4.1	15.572	9.1	14.234	14.1	12.895	19.1	11.556
4.2	15.545	9.2	14.207	14.2	12.868	19.2	11.529
4.3	15.519	9.3	14.180	14.3	12.841	19.3	11.503
4.4	15.492	9.4	14.153	14.4	12.815	19.4	11.476
4.5	15.465	9.5	14.126	14.5	12.788	19.5	11.449
4.6	15.438	9.6	14.100	14.6	12.761	19.6	11.422
4.7	15.412	9.7	14.073	14.7	12.734	19.7	11.395
4.8	15.385	9.8	14.046	14.8	12.707	19.8	11.369
4.9	15.358	9.9	14.019	14.9	12.681	19.9	11.342

APPENDIX D

Values for Effective Length “L”							
Use only for Hydrometers with a Length of 16.5 to 17.0 cm : $L = (-0.26774 \text{ cm/grad.} \times Ra + 16.67 \text{ cm})$							
Ra	L	Ra	L	Ra	L	Ra	L
20.0	11.315	25.0	9.976	30.0	8.638	35.0	7.299
20.1	11.288	25.1	9.950	30.1	8.611	35.1	7.272
20.2	11.262	25.2	9.923	30.2	8.584	35.2	7.245
20.3	11.235	25.3	9.896	30.3	8.557	35.3	7.219
20.4	11.208	25.4	9.869	30.4	8.531	35.4	7.192
20.5	11.181	25.5	9.843	30.5	8.504	35.5	7.165
20.6	11.155	25.6	9.816	30.6	8.477	35.6	7.138
20.7	11.128	25.7	9.789	30.7	8.450	35.7	7.112
20.8	11.101	25.8	9.762	30.8	8.424	35.8	7.085
20.9	11.074	25.9	9.735	30.9	8.397	35.9	7.058
21.0	11.047	26.0	9.709	31.0	8.370	36.0	7.031
21.1	11.021	26.1	9.682	31.1	8.343	36.1	7.005
21.2	10.994	26.2	9.655	31.2	8.316	36.2	6.978
21.3	10.967	26.3	9.628	31.3	8.290	36.3	6.951
21.4	10.940	26.4	9.602	31.4	8.263	36.4	6.924
21.5	10.914	26.5	9.575	31.5	8.236	36.5	6.897
21.6	10.887	26.6	9.548	31.6	8.209	36.6	6.871
21.7	10.860	26.7	9.521	31.7	8.183	36.7	6.844
21.8	10.833	26.8	9.495	31.8	8.156	36.3	6.817
21.9	10.806	26.9	9.468	31.9	8.129	36.9	6.790
22.0	10.780	27.0	9.441	32.0	8.102	37.0	6.764
22.1	10.753	27.1	9.414	32.1	8.075	37.1	6.737
22.2	10.726	27.2	9.387	32.2	8.049	37.2	6.710
22.3	10.699	27.3	9.361	32.3	8.022	37.3	6.683
22.4	10.673	27.4	9.334	32.4	7.995	37.4	6.656
22.5	10.646	27.5	9.307	32.5	7.968	37.5	6.630
22.6	10.619	27.6	9.280	32.6	7.942	37.6	6.603
22.7	10.592	27.7	9.254	32.7	7.915	37.7	6.576
22.8	10.565	27.8	9.227	32.8	7.888	37.8	6.549
22.9	10.539	27.9	9.200	32.9	7.861	37.9	6.523
23.0	10.512	28.0	9.173	33.0	7.835	38.0	6.496
23.1	10.485	28.1	9.146	33.1	7.808		
23.2	10.458	28.2	9.120	33.2	7.781		
23.3	10.432	28.3	9.093	33.3	7.754		
23.4	10.405	28.4	9.066	33.4	7.727		
23.5	10.378	28.5	9.039	33.5	7.701		
23.6	10.351	28.6	9.013	33.6	7.674		
23.7	10.325	28.7	8.986	33.7	7.647		
23.8	10.298	28.8	8.959	33.8	7.620		
23.9	10.271	28.9	8.932	33.9	7.594		
24.0	10.244	29.0	8.905	34.0	7.567		
24.1	10.217	29.1	8.879	34.1	7.540		
24.2	10.191	29.2	8.852	34.2	7.513		
24.3	10.164	29.3	8.825	34.3	7.486		
24.4	10.137	29.4	8.798	34.4	7.460		
24.5	10.110	29.5	8.772	34.5	7.433		
24.6	10.084	29.6	8.745	34.6	7.406		
24.7	10.057	29.7	8.718	34.7	7.379		
24.8	10.030	29.8	8.691	34.8	7.353		
24.9	10.003	29.9	8.665	34.9	7.326		

APPENDIX D

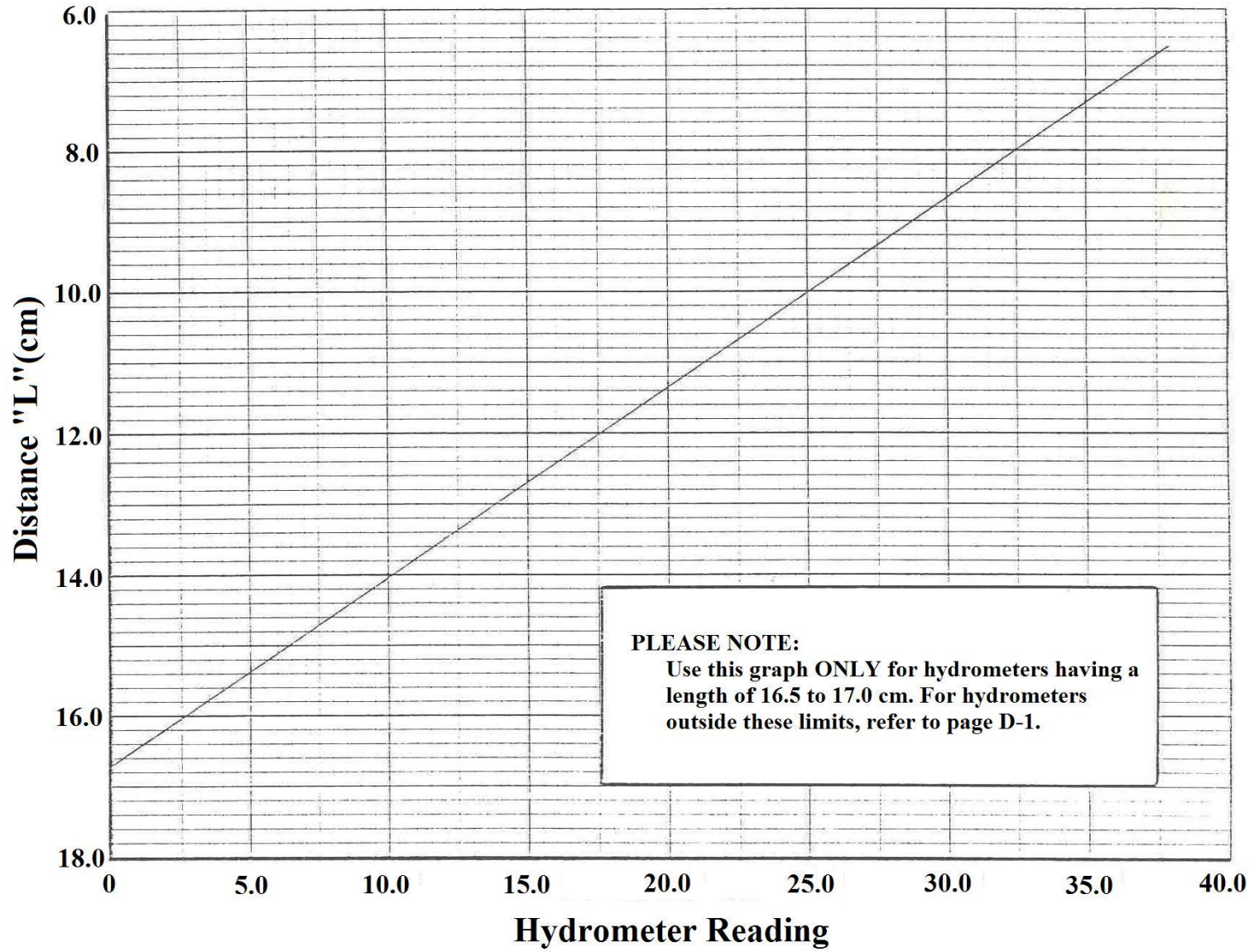


Figure 6

APPENDIX E

NEW YORK STATE
DEPARTMENT OF TRANSPORTATION
SOIL MECHANICS BUREAU

Date: _____
Calibrated By: _____
Checked By: _____

HYDROMETER CALIBRATION WORKSHEET

Hydrometer No. _____

- (1) Vol of Hydrometer (= wt in gm) $V_H =$ _____ cc.
- (2) Length of Graduate from 500 to 900 cc..... = _____ cm.
- (3) Area of Graduate = $400 \div (2)$ $A =$ _____ cm^2
- (4) $\frac{V_H}{A} = (1) \div (3) =$ _____ cm.
- (5) Length of Hydrometer Bulb
(Dist. from Neck to Tip of Bulb) $h =$ _____ cm.
- (6) $\left(h - \frac{V_H}{A}\right) = (5) - (4) =$ _____ cm.
- (7) $1/2 \left(h - \frac{V_H}{A}\right) = (6) \div 2 =$ _____ cm.
- (8) Dist. from Neck to 1.040 $L =$ _____ cm.

(9)	(10)	(11)	(12)
Scale Divisions	R_H , cm.	H_I	Effective Depth, H_R , cm.
R_r	From 1.040 to R_r	$H_I = R_H + L$	$H_R = H_I + 1/2 \left(h - \frac{V_H}{A}\right)$
1.040			
1.035			
1.030			
1.025			
1.020			
1.015			
1.010			
1.005			
1.000			
0.995			

13. Plot a curve expressing the relation between H_R (12) and R_r (9).
14. On nomographic chart, construct the R_r scale to right of H_R scale, using curve obtained in (13) above.
15. Meniscus Correction _____ cm.

Figure 7

APPENDIX E

Form SM-33b (3/87)

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
SOIL MECHANICS BUREAU

HYDROMETER ANALYSIS DATA WORKSHEET

PROJECT: _____ P.I.N. : _____ REGION : _____ HOLE : _____ SAMPLE : _____ DEPTH : _____ SAMPLE FROM: [] TRIAX; [] SOIL SURVEY; [] OTHER _____	NAME _____ DATE _____ TEST BY : _____ COMP. BY : _____ CHECKED BY: _____
HYDROMETER INFORMATION 1. HYDROMETER NO.: _____ 2. CYLINDER NO. : _____ 3. COMPOSITE COR.: _____ Remarks: _____	SAMPLE PARAMETERS 4. SPEC. GRAV. (Gs) : _____ 5. SIEVE SIZE USED : _____ 6. % PASSING SIEVE : _____ 7. WT. DRY SOIL. (Ws): _____ 8. $W = (100/W_s) \times (G_s/G_s - 1.0)$ = : _____

TEST DATA AND COMPUTATIONS

9	10	11	12	13	14	15	16	17
CLOCK	TIME ELAPSED	HYDRO READING Ra	TEMPERATURE		n	L	PART. DIA. (mm)	%PASS TOTAL SAMPLE
	ST'D		CTE	READING				
	0							
	2							
	5							
	15							
	30							
	60							
	250							
	1440							
	3060							
18. DESIRED SIZE								
19. % PASS TOTAL								

COLUMN 16:

$$\text{STOKES LAW } D = \sqrt{\frac{30 \times n \times L}{980 \times (G_s - 1.0) \times T}} = \sqrt{\frac{30 \times \text{Column 14} \times \text{Column 15}}{980 \times (\text{Line 4} - 1.0) \times \text{Column 10}}}$$

COLUMN 17:

$$\% \text{PASS TOTAL} = (M_t + \text{COMCOR} + R_a) \times W \times \text{PASS} / 100$$

$$(\text{Column 13} + \text{Line 3} + \text{Column 11}) \times \text{Line 8} \times (\text{Line 6} / 100)$$

LINE 19:

$$\% \text{PASS TOTAL} = [PP \times (\% \text{ PASS SIZE A} - \% \text{ PASS SIZE C})] + \% \text{ PASS SIZE C}$$

$$PP = \frac{\log \text{SIZE B} - \log \text{SIZE C}}{\log \text{SIZE A} - \log \text{SIZE C}}$$

SIZE A = NEXT SIZE LARGER THAN DESIRED SIZE
 SIZE B = DESIRED SIZE
 SIZE C = NEXT SIZE SMALLER THAN DESIRED SIZE

Figure 8

PART 2
**DISCUSSION OF THE TEST METHOD FOR THE PARTICLE SIZE
ANALYSIS OF SOILS BY HYDROMETER METHOD**

ABSTRACT

The New York State Department of Transportation Geotechnical Engineering Bureau has developed a test method for the particle size analysis of soils by the Hydrometer Method based on AASHTO Designation T-88-86, Particle Size Analysis of Soils. New York State has modified the AASHTO procedure to meet the requirements of the New York State testing program. Extensive testing and investigation has been conducted by New York State and others to develop, modify and confirm various aspects of the procedure and equipment.

The discussion of the New York State procedure comments on the modifications to the former procedure and the significant variations from AASHTO Designation T-88-86 with respect to sample preparation, dispersing agents, dispersing solutions, dispersion methods, readings and corrections.

1. SAMPLE PREPARATION

- A. Sample Drying Temperature
The effects of drying the soil samples in a 230° F (110° C) oven instead of a 140° F (60° C) oven were investigated in at least two studies by the New York State Department of Transportation Geotechnical Engineering Bureau. AASHTO Materials Reference Laboratory (AMRL) Sample Nos. 63 and 67 through 72 were used for a study in 1983, and AMRL Sample Nos. 83 and 84 were used for a study in 1986. Both studies indicate trends of slightly finer grain size distributions for samples dried in a 230° F (110° C) oven. The variations can be attributed to the soil breaking down under the higher temperature. However, variations in the results between the two temperatures are less than 1% and for all practical purposes are insignificant. Therefore, the small advantage of using the lower 140° F (60° C) temperature are far outweighed by the time savings obtained when drying at 230° F (110° C). Also, since 230° F (110° C) ovens are used in other test procedures conducted by New York State, a substantial cost savings is realized by eliminating the need for duplicate ovens to accommodate the two temperatures.
- B. Hygroscopic Moisture Content
Since soil samples used by New York State are dried in a 230° F (110° C) oven, it is assumed that there is no hygroscopic moisture in the soil. It is not necessary to conduct a hygroscopic moisture content determination and corresponding correction, and the time saved can be considered a cost savings, especially when large numbers of samples are involved.

- C. **Pestle Type**
A rubber covered pestle should be used to break the soil agglomerations. Breaking the soil agglomerations with a ceramic pestle may be faster, but the ceramic pestle may crush the soil grains and thereby alter the particle size distribution.
- D. **Sample Separation Sieve Size**
AASHTO Designation T-88-86 specifies that the hydrometer sample be separated on a No. 10 (2.0 mm) sieve. New York State has in the past commonly separated the sample on a No. 40 (0.425 mm) sieve. Testing conducted before the current hydrometer research program began, and also more recently, determined that the results from samples separated on a No. 10 (2.0 mm) sieve were the same as those separated on a No. 40 (0.425 mm) sieve. Since there is no difference in the results, and it is easier to separate a sample on the larger No. 10 (2.0 mm) sieve with less of a chance of crushing the soil grains, separating the hydrometer sample on a No. 10 (2.0 mm) sieve has been incorporated into the New York State procedure.
- E. **Sample Size**
A study conducted by New York State in 1985 on a manufactured soil of 75% silt and 25% clay reports that 100 g samples tend to produce slightly higher percents passing a given particle size than 50 g samples. The difference, however, is generally less than 1.5% and decreases with decreasing grain size. The study concluded that there is no appreciable difference between the values obtained from a 50 g sample than from a 100 g sample. It is recommended, however, that 50 g samples be used for clayey soils and 100 g samples be used for sandy soils because this has been the common practice of New York State.

2. DISPERSING AGENTS AND SOLUTIONS

- A. **Types and Amounts of Dispersing Agents**
There are many chemicals available for use as dispersing agents in the hydrometer analysis. Each chemical has varying degrees of effectiveness depending on the type of soil being dispersed. Dispersing agents have been studied by Chu and Davidson (1954), Wintermyer and Kinter (1954), the Bureau of Reclamation (1961), and others. Each researcher has determined that no one chemical is suitable as a dispersing agent for all soils.

Sodium metaphosphate (also called sodium hexametaphosphate) has been identified by various studies as the most suitable dispersing agent for general use. It is only slightly less effective than the most widely effective dispersing agents, but sodium metaphosphate is infinitely soluble and considerably more stable. Further study of sodium metaphosphate has shown that the dispersing action begins to decrease after about 6 weeks. Preparing a new solution monthly will avoid any problems related to the instability of the dispersing agent.

Several varieties of sodium metaphosphate are readily available. The study by Chu and Davidson (1954) reports that all varieties of sodium metaphosphate produce roughly the

same results for the types of soil used in the study. However, Chu and Davidson recommend using only one kind of sodium metaphosphate in a standard procedure. New York State conducted a study to determine the difference between a sodium metaphosphate solution labeled $(\text{NaPO}_3)_6$ and one labeled $(\text{NaPO}_3)_{13} \cdot \text{Na}_2\text{O}$. The study indicated that there was no difference between the two solutions and it was determined that the difference in labeling was due to the fact that chemists are now able to analyze the chemicals more precisely and better define their composition.

Chu and Davidson (1954) report that the degree of dispersion when using sodium metaphosphate is independent of the amount of dispersing agent when the amount of solution is within the range of 20-120 mL. The 0.25 pt. (125 mL) used by New York State and specified by both AASHTO and ASTM is sufficiently close to the recommended range.

Since the New York State procedure is in agreement in regard to the type and amount of dispersing agent with AASHTO and ASTM, and a justification for each item has been presented, no change to the procedure is necessary.

B. Buffered Solutions

New York State undertook a study to determine the effects of buffering the dispersing agent used in the hydrometer analysis. It has been reported by others that the dispersing effects of sodium metaphosphate are improved when the solution is raised to a pH of 8 or 9. However, studies by New York State in 1984 on AMRL Sample No. 63, in 1985 on AMRL Sample No. 75, and in 1986 on AMRL Sample Nos. 83 and 84 indicate buffered sample gradation curves to be less than 1.5% higher than non-buffered sample gradation curves. Also noted in the study was the fact that the pH of the buffered solution was unstable and would increase significantly over a period of 1 week.

Considering the minimal improvement of the test results and the instability of the buffered solution, buffering the dispersing agent is not recommended.

C. Temperature Stabilized Solutions

Extensive testing by New York State on AMRL samples and manufactured samples has verified that stabilizing the temperature of the hydrometer sample and solution before beginning the test has a significant effect on the results. Studies in 1983 and 1985 showed a 2 to 2½ % difference in the results, with the stabilized samples resulting in a finer gradation. It is theorized that by allowing the temperature of the hydrometer sample and solution to stabilize for 1 hour in the water bath, the effects of thermal currents and trapped, minute air bubbles are minimized. The studies concluded that a temperature stabilization period should be incorporated into the test procedure.

A follow-up study conducted in 1986 comparing 1 hour and 2 hour stabilization periods determined that the difference in the results of the two times was less than 0.5% and the small improvement in results does not justify the time and expense of the longer period. It is therefore recommended that a 1 hour temperature stabilization period be included in the hydrometer analysis test procedure.

3. DISPERSION METHODS

The effects of various soil dispersion methods on the Particle Size Analysis of Soils by the Hydrometer Method has been under investigation since the 1940's. Some of the various dispersing methods include: end-over-end, electric magnetic mixer, mechanical mixer, air jet dispersion apparatus and ultrasonic. At this time, only the mechanical mixer (ASTM Mixing Apparatus) and the air jet dispersion apparatus (Wintermyer Dispersion Cup or Soil Dispersion Tube (SDT)) will be discussed. Other methods, while producing comparable results, offer no advantages over the mechanical mixer or the air jet methods.

Much attention was given to dispersion methods in the early 1960's when ASTM adopted the air jet dispersion method as a recommended alternate to the mechanical mixer. Studies of dispersion methods were conducted by Davidson and Chu (1953), Hall (1960), the Bureau of Reclamation (Holtz, et al., 1961), and others, as well as the New York State Geotechnical Engineering Bureau (1960 through 1963). Each of the test results showed significant differences in the particle size distribution between the mechanical mixer and air jet dispersion methods. The largest differences, 20 to 30%, were reported in the study by Hall, and the smallest differences, 3 to 5%, were reported in the study by New York State.

It was determined by ASTM Committee D-18 through extensive investigation that air jet dispersion methods provide a better dispersion of soil particles than mechanical mixing without the appreciable degradation of the soil particles caused by mechanical mixing. However, the use of the air jet dispersion method has several disadvantages that outweigh the advantages for use by New York State.

A major advantage of the air jet dispersion method is the great reduction in the amount of degradation of the soil particles. Degradation is most severe when sandy soils are dispersed in the mechanical mixing apparatus.

Degradation decreases as the particle size decreases, and at the clay size there is no significant difference between the amount of degradation caused by the mechanical mixer and that caused by air jet dispersion. In New York State, most hydrometer testes are run on silts and clays so degradation of the soil particles is minimal. Therefore, the apparent advantage of air jet dispersion of reducing the degradation of the soil particles is diminished.

The air jet dispersion method provides results significantly different from the mechanical mixing method. If the air jet dispersion method was to be adopted for use by New York State, the previously established experience base formed by years of testing using mechanical mixing would be invalidated and a new set of standardization values would have to be developed. A large “inertia” force is involved in such a process, as most individuals are reluctant to change. Also, it is difficult to justify a change to a successful system, even though the system uses values that are not necessarily absolutely correct, but are consistent relative to each other.

There have been problems reported in the past by New York State with the use of air jet dispersion apparatuses. It was found that removing the sample for the Wintermyer Cup was difficult. There were problems with maintaining the 25 psi (172 kPa) air pressure and the 2 cfm (1.7 m³/h) air flow from the house air system while using the Wintermyer Cup and the Soil Dispersion Tube. Also, the air jet dispersion apparatus are more complex and the operating procedure is more involved than the mechanical mixer. Any increase in complexity increases the possibility of operator error and inherent test deviations.

From testing, it has been found that the optimum time for dispersion of most soils using the air jet apparatus is about 10 minutes and using the mechanical mixer is about 1 minute. Since there is a substantial dispersion time difference between the two methods, then from the production point of view there is a significant time savings, and therefore cost savings, when using the mechanical mixer over the air jet dispersion method.

Considering the fact that New York State generally tests only silts and clays and degradation of soil particles during dispersion is not an appreciable factor; an experience base has already been established using results by the mechanical mixing apparatus; the existing system is successful; and the mechanical mixing apparatus is simpler and quicker to use than the air jet dispersion apparatus; it is recommended that New York State continue to use the mechanical mixer as the dispersion apparatus in the Particle Size Analysis of Soils by Hydrometer Method.

4. READINGS AND CORRECTIONS

A. Accuracy of Readings

There have been some questions as to the significance of the accuracy to which the thermometer and hydrometer scales can and need to be read. The New York State Geotechnical Engineering Bureau procedure calls for temperature readings to the nearest 0.1° C and hydrometer readings to the nearest 0.1 graduate (0.0001 specific gravity), whereas AASHTO T-88-86 requires readings to the nearest 0.5 for each, respectively. An analysis was conducted by New York State in 1987 to determine the sensitivity of the value of the percent passing to rounding from the nearest 0.1 to the nearest 0.5. It was found that all the rounded temperature values fell within plus or minus 0.2% of a line representing no deviation. Approximately 80% of the rounded hydrometer readings fell within plus or

minus 0.5% and the remaining 20% fell within plus or minus 0.7%.

It was decided to continue reading the thermometer to the nearest 0.1° C and the hydrometer to the nearest 0.1 graduate (0.0001 specific gravity) even though there is no significant increase in the accuracy of the results because reading the thermometer and hydrometer to the nearest 0.1° C and 0.1 graduate, respectively, has been the common practice of New York State.

B. Composite Correction

The composite correction from the hydrometer readings under AASHTO procedure is composed of the dispersing agent, meniscus and temperature corrections. The composite correction is basically determined by reading the hydrometer in the dispersing solution at two different temperatures and interpolating between the results for values at temperatures other than at those tested. It is then necessary to develop a graph or table for each individual hydrometer to determine the composite correction for various temperatures.

The New York State method is somewhat more convenient than the AASHTO procedure in that the temperature correction is applied separately from the dispersing agent and meniscus corrections. By applying the temperature correction separately, it is not necessary to develop a graph or table for each hydrometer used, but rather only one graph or table for the range of temperatures normally encountered that can be used to correct all hydrometers.

Studies conducted in 1955, 1958, and 1963 comparing the results of hydrometer tests using the composite corrections calculated by the two methods show that there is no difference. The studies also report that the error introduced from using a straight line to represent the actual curve is minimal and has no appreciable effect on the results when the temperatures are relatively close to 68° F (20° C). Testing by New York State is ordinarily performed within 68±9° F (20±5° C) and the errors from using a straight line to estimate the curve are negligible.

The temperature correction has been found experimentally to be 0.17 to 0.23 specific gravity per °C. A value of 0.2 specific gravity per °C has proven to be satisfactory and errors introduced are insignificant.

Since it is slightly more convenient, it is recommended to apply the temperature correction separately from the dispersing agent and meniscus corrections.

C. Effective Length Correction

The refinement of the Hydrometer Analysis as a result of the ongoing Hydrometer Research program can be seen by the improvement in the Laboratory Performance charts in the AMRL Reports. However, prior to 1983, the plots for the results of the hydrometer analyses continued to be erratic and regularly below the AMRL average.

It was realized in 1983 that the test procedure was not correcting for the change in length of the hydrometer reading due to the meniscus. The length correction due to the meniscus (not the same as the meniscus portion of the composite correction) was added to AMRL Sample Nos. 73 and 74 (February, 1984) and a noticeable improvement in the results was observed. It was then found that the effective length, assumed in previous testing to be 17.5 cm, was actually about 16.5 cm. A value of 16.5 was used for the effective length in the next set of AMRL samples, Nos. 75 and 76 (August, 1984), and the results were in good agreement with the AMRL average. Testing since August, 1984 has continued to produce results consistent with the AMRL averages.

5. SUMMARY AND CONCLUSIONS

The Particle Size Analysis of Soils by the Hydrometer Method as included in AASHTO Designation T-88-86 has been modified by the New York State Department of Transportation Geotechnical Engineering Bureau to meet the specific needs of the New York State testing program. Some portions of the former New York State method have been changed in order to comply with AASHTO Designation T-88-86. Each item discussed is enumerated below and has been verified by extensive testing either by New York State or by others.

1. New York State dries the soil samples in a 230° F (110° C) oven instead of a 140° F (60° C) oven because of the savings in time.
2. Since New York State dries the soil samples in a 230° F (110° C) oven, it can be assumed that there is no hygroscopic moisture in the soil and the hygroscopic moisture content adjustment is not necessary.
3. The former New York State method allowed the use of a ceramic pestle to break up soil agglomerations. However, because of the possibility of crushing the soil grains, the 1987 New York State method requires the use of a rubber covered pestle.
4. New York State has in the past used a No. 40 (0.425 mm) sieve to separate the soil samples. Since the original selection of a No. 40 (0.425 mm) sieve was somewhat arbitrary, the New York State method now uses a No. 10 (2.0 mm) sieve to comply with AASHTO Designation T-88-86.
5. Although there is generally no significant difference between results using 50 g and 100 g samples, it is recommended that 50 g samples be used for clayey soils and 100 g samples be used for sandy soils because this has been the common practice of New York State.
6. It is confirmed that sodium metaphosphate (or sodium hexametaphosphate) is the most suitable dispersing agent for general use. A quantity of 125 mL per sample is sufficient for production testing.
7. A sodium metaphosphate solution labeled $(\text{NaPO}_3)_6$ and one labeled $(\text{NaPO}_3)_{13} \cdot \text{Na}_2\text{O}$ are the same chemical. The two designations are a result of chemist now being able to analyze the chemicals more precisely and better define their composition.
8. New York State does not buffer the dispersing agent solution as recommended by

AASHTO Designation T-88-86 because the buffered solution is unstable and the advantages of buffering are minor.

9. As reported by various studies, a temperature stabilization period has a significant effect on the particle size distribution of the tested soil. The minimal improvement of a two hour stabilization period over a one hour period does not justify the additional time and expense. Therefore, a one hour temperature stabilization period has been added to the test procedure.
10. New York State uses a mechanical mixer to disperse the soil sample in the dispersing solution and does not recommend the use of the air jet dispersion cup. New York State generally tests only silts and clays and the degradation of the soil particles at that size is not a factor, an experience base has already been established using results by mechanical mixing apparatus, the system is successful, and the mechanical mixing apparatus is simpler and quicker to use than air jet dispersion apparatus.
11. New York State specifies reading the thermometer to the nearest 0.1° C and the hydrometer to the nearest 0.1 graduate (0.0001 specific gravity) even though there is no significant increase in the accuracy of the results because reading the thermometer and hydrometer to the nearest 0.1° C and 0.1 graduate, respectively, has been the common practice of New York State.
12. The composite correction determined by AASHTO Designation T-88-86 is composed of the dispersing agent, meniscus and temperature correction, whereas the New York State Method defines the composite correction as including the dispersing agent and meniscus corrections and then applies the temperature correction separately. Although the two methods determine and define the composite correction differently, the final results are not affected.
13. A straight line is used to represent the actual curve for the composite correction in both methods. The error introduced is insignificant when temperatures are relatively close to 68° F (20° C) and increases only slightly as temperatures move away from 68° F (20° C).
14. The New York State Method includes a meniscus length correction (not the same as the meniscus portion of the composite correction) not included in the former method. Also, the New York State Method uses a more correct value of 16.5 cm for the effective length instead of 17.5 cm as used previously.