Standard Method of Test for

Determining the Liquid Limit of Soils

AASHTO Designation: T 89-22

Technically Revised: 2022

Technical Subcommittee: 1a, Soil and Unbound Recycled Materials

AASHTO
American Association of State Highway and Transportation Officials
555 12th Street NW, Suite 1000
Washington, DC 20004

Standard Method of Test for

Determining the Liquid Limit of Soils

AASHTO

AASHTO Designation: T 89-22

Technically Revised: 2022

Technical Subcommittee: 1a, Soil and Unbound Recycled Materials

1. SCOPE

1.1. The liquid limit of a soil is that water content, as determined in accordance with the following procedure, at which the soil passes from a plastic to a liquid state.

1.2. The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E29.

1.3. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- M 339M/M 339, Thermometers Used in the Testing of Construction Materials
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- R 58, Dry Preparation of Disturbed Soil and Soil–Aggregate Samples for Test
- R 74, Wet Preparation of Disturbed Soil Samples for Test
- T 265, Laboratory Determination of Moisture Content of Soils

2.2. *ASTM Standards*:

- D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E230/E230M, Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
- E2877, Standard Guide for Digital Contact Thermometers

2.3. *International Electrotechnical Commission Standard*:

- IEC 60584-1: 2013 Thermocouples - Part 1: EMF Specifications and Tolerances

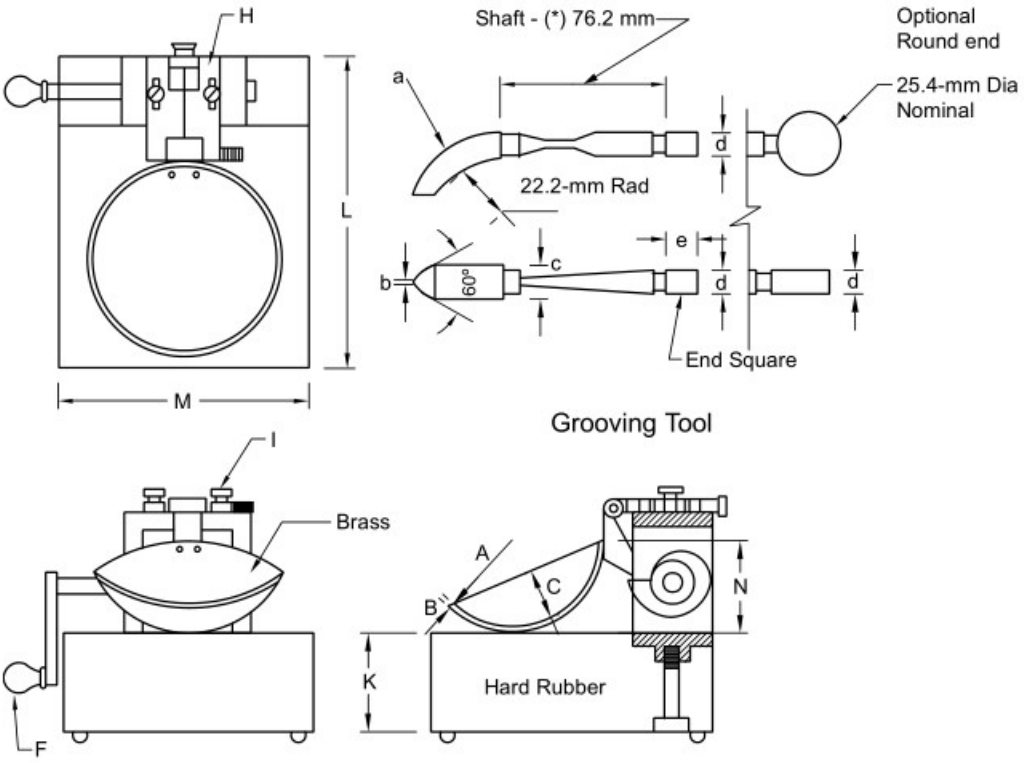
3. APPARATUS

3.1. *Dish*—A porcelain dish, preferably unglazed, or similar mixing dish, about 115 mm in diameter.

3.2. *Spatula*—A spatula or pill knife having a blade about 75 to 100 mm in length and about 20 mm in width.

3.3. *Liquid Limit Device*:

3.3.1. *Manually Operated*—A device consisting of a brass dish and carriage, constructed according to the plan and dimensions shown in Figure 1 (see Note 1).



	Liquid Limit Device							Grooving Tool				
	Cup Assembly				Base			Curved End			Gauge	
Dimension	A	B	C	N	K	L	M	a	b	c	d	e*
Description	Radius of Cup	Thickness of Cup	Depth of Cup	Cup at Cam Follower to Base	Thickness	Length	Width	Thickness	Cutting Edge	Width	Depth	Length
Metric, mm	54	2.0	27	47	50	150	125	10.0	2.0	13.5	10.0	15.9
Tolerance, mm	2	0.1	1	1.5	5	5	5	0.1	0.1	0.1	0.2	—

Note: Plate "H" may be designed for using one (1) securing screw (I).
An additional wear tolerance of 0.1 mm shall be allowed for dimension "b" for used grooving tools.
Feet for base shall be of resilient material.
(*) Nominal dimensions.
All tolerances specified are plus or minus (±) except as noted above.

Figure 1—Manual Liquid Limit Device

3.3.2. *Mechanically Operated*—A motorized device equipped to produce the rise and rate of shocks to a brass cup as described in Sections 5.2 and 6.3 of this procedure, respectively. The cup and the critical dimensions of the device shall conform to those shown in Figure 1 of this procedure. The device shall give the same liquid limit values as obtained with the manually operated device (Note 1).

Note 1—The base of the liquid limit device should have a resilience of at least 80 percent and not more than 90 percent when determined in accordance with the procedure given in the Appendix.

3.4. *Grooving Tool*:

3.4.1. *Curved Grooving Tool*—A grooving tool conforming to the critical dimensions shown in Figure 1. The gauge need not be part of the tool.

3.4.2. *Flat Grooving Tool (Alternate)*—A grooving tool made of plastic or noncorroding metal conforming to the critical dimensions shown in ASTM D4318, Figure 3. The gauge need not be part of the tool (Note 2).

Note 2—The flat grooving tool should not be used interchangeably with the curved grooving tool. There are some data that indicate that the liquid limit is slightly increased when the flat tool is used instead of the curved tool.

3.5. *Gauge*—A gauge, whether attached to the grooving tool or separate, conforming to the critical dimension "d" shown in Figure 1 of this test method or "K" in Figure 3 of ASTM D4318, and may be, if separate, a metal bar 10.0 ± 0.2 mm thick and approximately 50 mm long.

3.6. *Containers*—Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

3.7. *Balance*—The balance shall have sufficient capacity and conform to M 231, Class G 1.

3.8. *Oven*—A thermostatically controlled drying oven capable of maintaining temperatures of 110 ± 5°C for drying moisture samples. Oven(s) for heating and drying shall be capable of operation at the temperatures required, between 100 to 120°C (212 to 248°F), within ±5°C (±9°F), as corrected, if necessary, by standardization. More than one oven may be used, provided each is used within its proper operating temperature range. The thermometer used for monitoring the temperature of the oven, or for measuring the temperature of materials shall meet the requirements of M 339M/M 339 with a temperature range of at least 90 to 130°C (194 to 266°F), and an accuracy of ±1.25°C (±2.25°F) (see Note 3).

Note 3—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E2877 digital metal stem thermometer; ASTM E230/E230M thermocouple thermometer, Type J or K, Special Class, Type T any Class; IEC 60584 thermocouple thermometer, Type J or K, Class 1, Type T any Class; or dial gauge metal stem (bi-metal) thermometer.

METHOD A

4. SAMPLE

4.1. A sample with a mass of about 100 g shall be taken from the thoroughly mixed portion of the material passing the 0.425-mm sieve that has been obtained in accordance with R 58 or R 74; for structural analysis use R 74, Method B.

5. ADJUSTMENT OF LIQUID LIMIT DEVICE

5.1. The Liquid Limit Device shall be inspected to determine that the device is in good working order; that the pin connecting the cup is not worn sufficiently to permit side play; that the screws connecting the cup to the hanger arm are tight; that the points of contact on the cup and base are not excessively worn; that the lip of the cup is not excessively worn; and that a groove has not been worn in the cup through long usage. The grooving tool shall be inspected to determine that the critical dimensions are as shown in Figure 1 of this test method or ASTM D4318, Figure 3.

Note 4—Wear is considered excessive when the point of contact on the cup or base exceeds approximately 13 mm in diameter, or when any point on the rim of the cup is worn to approximately one half of the original thickness. Although a slight groove in the center of the cup is noticeable, it is not objectionable. If the groove becomes pronounced before other signs of wear appear, the cup should be considered excessively worn. Excessively worn cups shall be replaced. A base that is excessively worn may be refinished as long as the thickness does not exceed the tolerance shown in Figure 1 of this test method by more than –2.5 mm and the distance between the cup at the cam follower and the base is maintained within the tolerances specified in Figure 1.

5.2. Adjust the height of drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10.0 ± 0.2 mm. See Figure 2 for proper location of the gauge relative to the cup during adjustment. Check the height of drop of the cup prior to each day's testing.

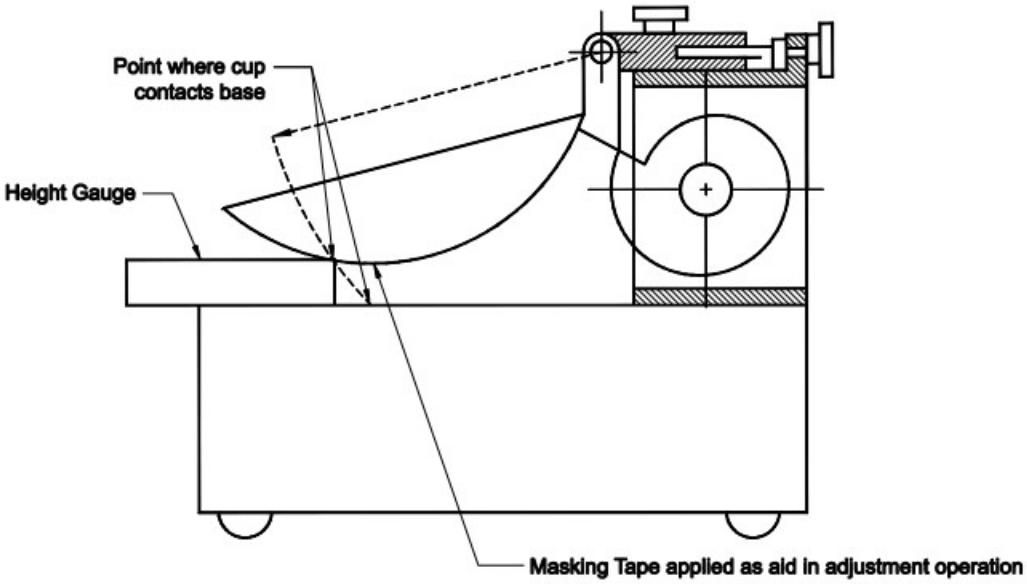


Figure 2—Calibration for Height of Drop

Note 5—A convenient procedure for adjusting the height of drop is as follows: place a piece of masking tape across the outside bottom of the cup parallel with the axis of the cup hanger pivot. The edge of the tape away from the cup hanger should bisect the spot on the cup that contacts the base. For new cups, placing a piece of carbon paper on the base and allowing the cup to drop several times will mark the contact spot. Attach the cup to the device and turn the crank until the cup is raised to its maximum height. Slide the height gauge under the cup from the front, and observe whether the gauge contacts the cup or the tape (see Figure 2). If the tape and cup are both contacted, the height of drop is approximately correct. If not, adjust the cup until simultaneous contact is made. Check adjustment by turning the crank at two revolutions per second while holding the gauge in position against the tape and cup. If a ringing or clicking sound is heard without the cup rising from the gauge, the adjustment is correct. If no ringing is heard or if the cup

rises from the gauge, readjust the height of drop. If the cup rocks on the gauge during this checking operation, the cam follower pivot is excessively worn and the worn parts should be replaced. Always remove tape after completion of adjustment operation.

6. PROCEDURE USING THE CURVED GROOVING TOOL

6.1. The soil sample shall be placed in the mixing dish and thoroughly mixed with 15 to 20 mL of distilled or demineralized water by alternately and repeatedly stirring, kneading, and chopping with a spatula. Further additions of water shall be made in increments of 1 to 3 mL. Each increment of water shall be thoroughly mixed with the soil as previously described before another increment of water is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit Device shall not be used for mixing soil and water. If too much moisture has been added to the sample, the sample shall either be discarded, or mixed and kneaded until natural evaporation lowers the closure point into an acceptable range.

Note 6—Some soils are slow to absorb water; therefore, it is possible to add the increments of water so fast that a false liquid limit value is obtained. This can be avoided if more mixing and/or time is allowed. Tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water. However, referee or disputed tests shall be performed using distilled or demineralized water.

When sufficient water has been thoroughly mixed with the soil to form a uniform mass of stiff consistency, a sufficient quantity of this mixture shall be placed in the cup above the spot where the cup rests on the base and shall be squeezed and spread with the spatula to level and at the same time trimmed to a depth of 10 mm at the point of maximum thickness. As few strokes of the spatula as possible shall be used, care being taken to prevent the entrapment of air bubbles within the mass. The excess soil shall be returned to the mixing dish and covered to retain the moisture in the sample. The soil in the cup of the device shall be divided by a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean sharp groove of the proper dimensions will be formed as shown in Figure 3. To avoid tearing of the sides of the groove or slipping of the soil cake on the cup, up to six strokes from front to back or from back to front counting as one stroke, shall be permitted. The depth of the groove should be increased with each stroke and only the last stroke should scrape the bottom of the cup.

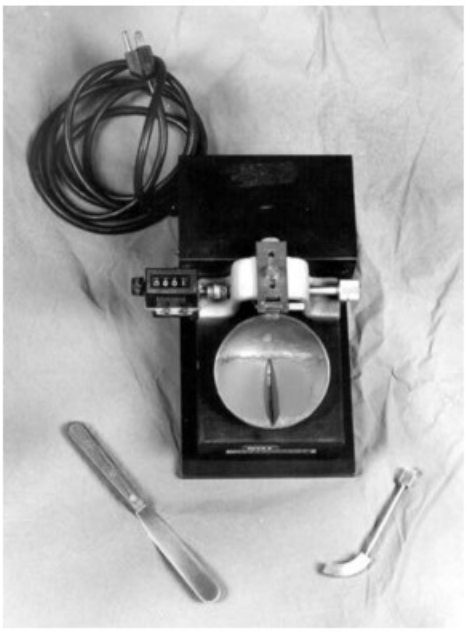


Figure 3—Liquid Limit Device with Soil Sample in Place

6.2. The cup containing the sample prepared as described in Section 6.2 shall be lifted and dropped by turning the crank F at the rate of approximately two revolutions per second until the two sides of the sample come in contact at the bottom of the groove along a distance of about 13 mm. The number of shocks required to close the groove this distance shall be recorded. The base of the machine shall not be held with the free hand while the crank F is turned.

Note 7—Some soils tend to slide on the surface of the cup instead of flowing. If this occurs, more water should be added to the sample and remixed, then the soil–water mixture placed in the cup, a groove cut with the grooving tool and Section 6.2 repeated. If the soil continues to slide on the cup at a lesser number of blows than 25, the test is not applicable and a note should be made that the liquid limit could not be determined.

6.3. A slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, shall be removed and placed in a suitable container. The soil in the container shall be dried in accordance with T 265 to determine the moisture content, and the results recorded.

6.4. The soil remaining in the cup shall be transferred to the mixing dish. The cup and grooving tool shall then be washed and dried in preparation for the next trial.

6.5. Repeat the foregoing operations, adding sufficient water to bring the soil to a more fluid condition. Obtain the first sample in the range of 25 to 35 shocks, the second sample in the range of 20 to 30 shocks, and the third sample in the range of 15 to 25 shocks. The range of the three determinations shall be at least 10 shocks.

7. ALTERNATE PROCEDURE USING THE FLAT GROOVING TOOL

7.1. The procedure shall be the same as prescribed in Sections 6.1 through 6.6, except for the procedure in Section 6.2 for forming the groove. Form a groove in the soil pat in accordance with Section 11.2 of ASTM D4318.

8. CALCULATION

8.1. The water content of the soil shall be expressed as the moisture content in percentage of the mass of the oven-dried soil and shall be calculated as follows:

$$\text{percentage moisture} = \frac{\text{mass of water}}{\text{mass of oven-dried soil}} \times 100 \qquad (1)$$

8.1.1. Calculate the percentage of moisture to the nearest whole percent.

9. PREPARATION OF FLOW CURVE

9.1. A “flow curve” representing the relation between moisture content and corresponding number of shocks shall be plotted on a semilogarithmic graph with the moisture contents as abscissae on the arithmetical scale, and the number of shocks as ordinates on the logarithmic scale. The flow curve shall be a straight line drawn as nearly as possible through the three or more plotted points.

10. LIQUID LIMIT

10.1. The moisture content corresponding to the intersection of the flow curve with the 25-shock ordinate shall be taken as the liquid limit of the soil. Report this value to the nearest whole number.

METHOD B

11. SAMPLE

11.1. A sample with a mass of about 50 g shall be taken as described in Section 4.1.

12. PROCEDURE

12.1. Using the curved grooving tool (Section 6) or the flat grooving tool (Section 7) the procedure shall be the same as prescribed in Sections 6.1 through 6.5 except that the initial amount of water to be added in accordance with Section 6.1 shall be approximately 8 to 10 mL and the moisture sample taken in accordance with Section 6.4 shall be taken only for the accepted trial.

12.2. For accuracy equal to that obtained by the standard three-point method, the accepted number of blows for groove closure shall be restricted to between 22 and 28 blows. After obtaining a preliminary closure in the acceptable blow range, immediately return the soil remaining in the cup to the mixing dish and, without adding any additional water, repeat as directed in Sections 6.2 and 6.3. If the second closure occurs in the acceptable range (22 to 28, inclusive) and the second closure is within two (2) blows of the first closure, secure a water content specimen as directed in Section 6.4.

12.3. Groove closures between 15 and 40 blows may be accepted if variations of ±5 percent of the true liquid limit are tolerable.

13. CALCULATION

13.1. The water content of the soil at the time of the accepted closure shall be calculated in accordance with Section 8.1.

14. LIQUID LIMIT

14.1. The liquid limit shall be determined by one of the following methods: the nomograph, Figure 4; the correction factor method, Table 1; or by any other method of calculation that produces equally accurate liquid limit values. The standard three-point method shall be used as a referee test to settle all controversies.

14.2. The key in Figure 4 illustrates the use of the nomograph (mean slope).

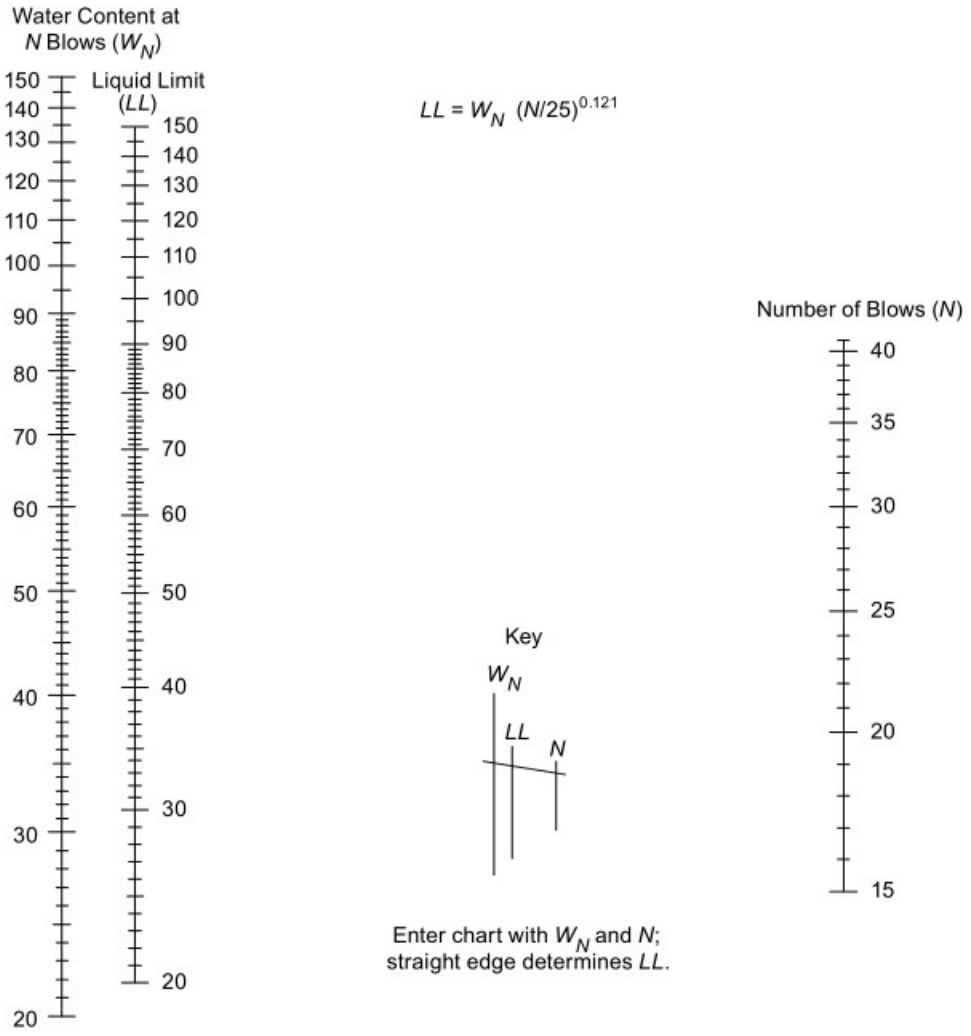


Figure 4—Nomographic Chart Developed by the Waterways Experiment Station, Corps of Engineers, U.S. Army, to Determine Liquid Limit Using Mean Slope Method

14.3. The correction factor method, Table 1, uses the moisture content of the liquid limit sample multiplied by a factor (k) of the second closure blow count. Figure 5 was developed for the Calculation of the Liquid Limit.

$$LL = W_N(N/25)^{0.121} \quad (2)$$

or

$$LL = kW_N \quad (3)$$

where:

N = number of blows causing closure of the groove at water content,
LL = liquid limit corrected for closure at 25 blows,
W_N = water content, and
k = factor given in Table 1.

Table 1—Factors for Obtaining Liquid Limit from Water Content and Number of Blows Causing Closure of the Groove

Number of Blows, *N*	Factor for Liquid Limit, *k*
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014

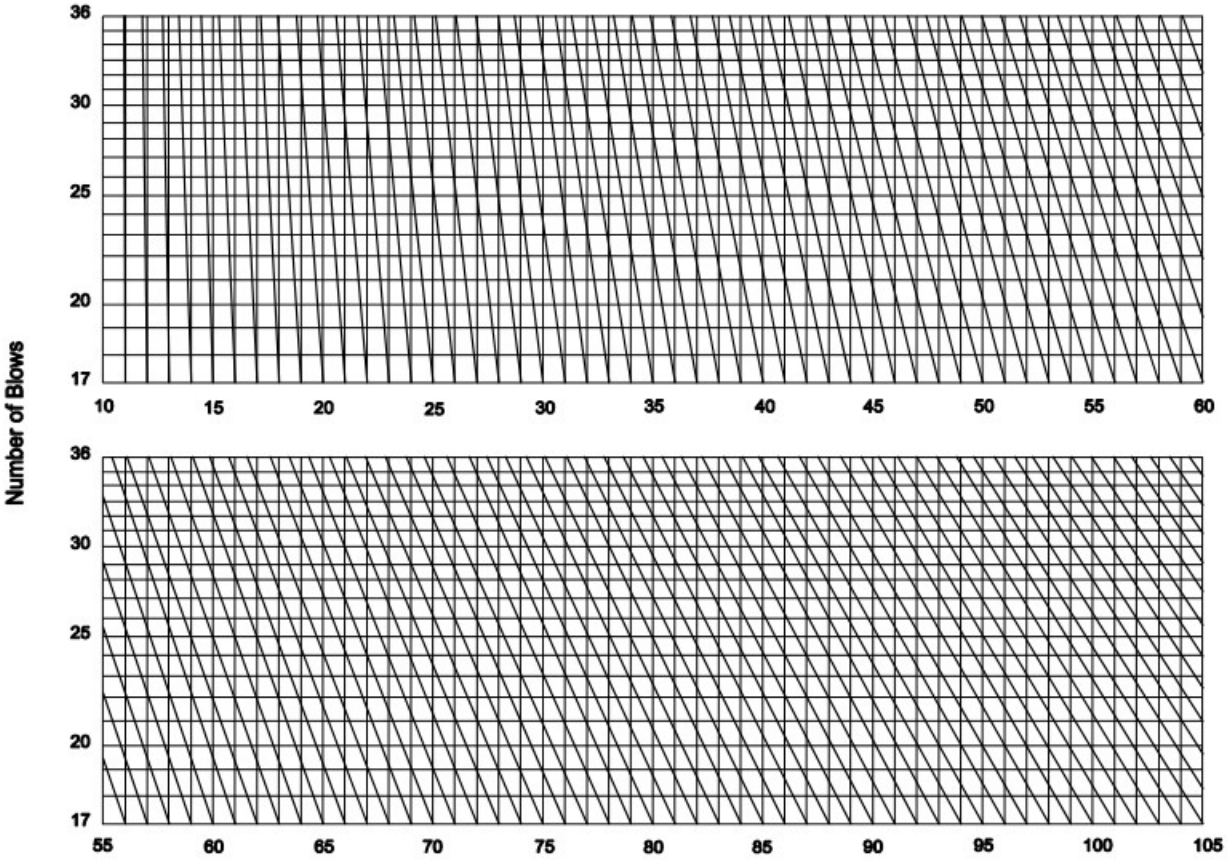


Figure 5—Chart Developed by Washington State Highway Department for the Calculation of the Liquid Limit

CHECK OR REFEREE TESTS

15. METHOD TO BE USED

15.1. Method A, using the curved grooving tool procedure (Section 6), shall be used in making check or referee tests. The results of liquid limit tests are influenced by:

15.1.1. The time required to make the test;

15.1.2. The moisture content at which the test is begun; and

15.1.3. The addition of dry soil to the seasoned sample.

16. PROCEDURE

16.1. Therefore, in making the liquid limit test for check or referee purposes, the following time schedule shall be used:

16.1.1. *Mixing of soil with water*—5 to 10 min, the longer period being used for the more plastic soils;

16.1.2. *Seasoning in the humidifier*—30 min;

16.1.3. *Remixing before placing in the brass cup*—add 1 mL of water and mix for 1 min;

16.1.4. *Placing in the brass cup and testing*—3 min; and

16.1.5. *Adding water and remixing*—3 min.

16.2. No trial requiring more than 35 blows or fewer than 15 blows shall be recorded. In no case shall dried soil be added to the seasoned soil being tested.

17. PRECISION STATEMENT

17.1. This precision statement applies to soils having a liquid limit range from 21 to 67.

17.2. *Repeatability (Single Operator)*—Two results obtained by the same operator on the same sample in the same laboratory using the same apparatus, and on different days, should be considered suspect if they differ by more than 7 percent of their mean.

17.3. *Reproducibility (Multilaboratory)*—Two results obtained by different operators in different laboratories should be considered suspect if they differ from each other by more than 13 percent of their mean.

18. KEYWORDS

18.1. Atterberg; clay soil; liquid limit; plasticity index.

APPENDIX

(Nonmandatory Information)

X1. MEASURING THE RESILIENCE OF LIQUID LIMIT DEVICE BASES

X1.1. A device for measuring the resilience of liquid limit device bases is shown in Figure X1.1 and Table X1.1. The device consists of a clear acrylic plastic tube and cap, an 8-mm diameter polished steel ball, and a small bar magnet. The cylinder may be cemented to the cap or threaded as shown.

The small bar magnet is held in the recess of the cap, and the steel ball is fixed into the recess in the underside of the cap with the bar magnet. The cylinder is then turned upright and placed on the top surface of the base to be tested. Hold the tube lightly against the liquid limit device base with one hand, and release the ball by pulling the magnet out of the cap. Use the scale markings on the outside of the cylinder to determine the highest point reached by the bottom of the ball. Repeat the drop at least three times, placing the tester in a different location for each drop. The average rebound of the steel ball, expressed as a percent of the total drop, equals the resilience of the liquid limit device base. Tests should be conducted at room temperature.

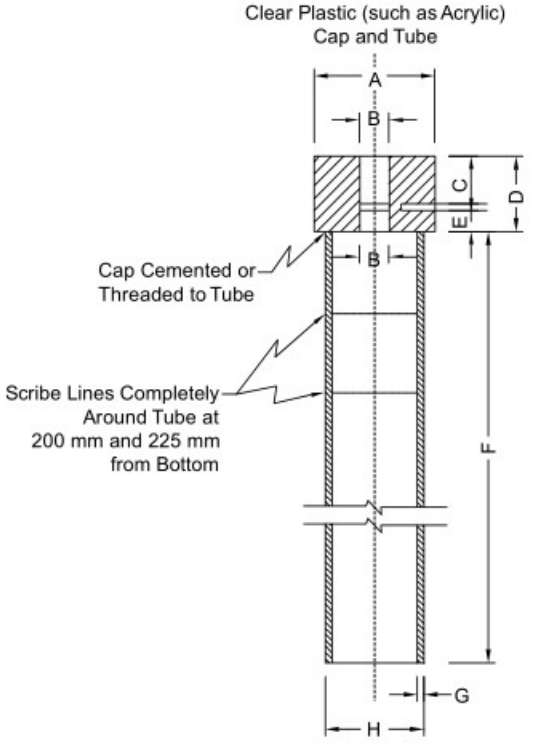


Figure X1.1—Resilience Tester

Table X1.1—Table of Measurements for Resilience Tester[a]

Dimension	Description	Metric, mm
A	Diam. of cap	38.0[b]
B	Diam. of hole	9.0[b]
C	Depth of hole	18.0[b]
D	Height of cap	25.5[b]
E	Depth of hole	8.0
F	Length of tube	250.0
G	Wall thickness	3.2[b]
H	O.D. of tube	31.8[b]
Scribed lines from bottom	Upper 90%	225.0
	Lower 80%	200.0

[a] Tube stands plumb.

[b] These dimensions are not critical in the performance of the test.