State of Nevada
Department of Transportation
Materials Division

METHOD OF TEST FOR DETERMINING THE LIQUID LIMIT OF SOIL

SCOPE

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.

APPARATUS

1. Porcelain dish or similar mixing dish, approximately 115 to 150 mm (4.5 to 6 in.) in diameter.

2. Spatula or pill knife having a blade approximately 75 to 100 mm (3 to 4 in.) in length and 13 to 20 mm (1/2 to 3/4 in.) in width.

3. Liquid limit device, manually operated or mechanically operated.

   Manually operated device, a device consisting of a brass dish and carriage, constructed to the plan and dimensions shown in Figure 1. If a manually operated device is used, it shall be noted on the worksheet.

   Mechanically operated device, a motorized device equipped to produce the rise and rate of shocks to a brass cup as described below in CALIBRATION. The cup and the critical dimensions of the device shall conform to those shown in Figure 1. The device shall give the same liquid limit values as obtained with the manually operated device.

   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 below in RESILIENCE TEST.

4. Curved grooving tool, conforming to the critical dimensions shown in Figure 1. The use of a flat grooving tool shall not be permitted in this test procedure.

5. Gage, whether attached to the grooving tool or separate, conforming to the critical dimension “d” shown in Figure 1 of this method. If separate, the gage may be a metal bar 10.0 ± 0.2 mm (0.394 ± 0.008 in.) thick and approximately 50 mm (2 in.) long.

6. Containers, made of materials resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have tight 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.

7. Glass beaker, 600 mL or other suitable microwave safe container.

8. Watch glass, approximately 75 mm (3.0 in.) in diameter.

9. Balance, 500 g minimum capacity, accurate to ± .01 g.

10. Oven, thermostatically controlled, capable of maintaining temperatures of 110 ± 5ºC (230 ± 9ºF).

11. Microwave oven, preferably with vented chamber and variable power control to prevent overheating of soil.

CALIBRATION

1. The manual or mechanical 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; the screws connecting the cup to the hanger arm are tight; the points of contact on the cup and base are not excessively worn; the lip of the cup is not excessively worn; and 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.

   Wear is considered excessive when the point of contact on the cup or base exceeds 13 mm (1/2 in.) in diameter, or when any point on the rim of the cup is worn to approximately 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 by more than -2.5 mm (-0.1 in.) and the distance between the cup at the cam follower and the base is maintained within the tolerances specified in Figure 1.

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 (0.394 ± 0.008 in.). See Figure 2 for proper location of the gage relative to the cup during adjustment.

   A convenient procedure for adjusting the height of the drop is a 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, place a piece of carbon paper on the base (or use a marking pen to mark the base where it contacts the cup) and allow the cup to drop several times to 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 gage under the cup from the front, and observe whether the gage contacts the cup or the tape. See Figure 2. If the tape and cup are both contacted, the height of drop is 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 gage in position against the tape and cup. If a ringing or clicking sound is heard without the cup rising from the gage, the adjustment is correct. If no ringing is heard or if the cup rises from the gage, readjust the height of the drop. If the cup rocks on the gage 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.

METHOD A – THE THREE POINT METHOD

TEST PROCEDURE

1. The material for the liquid limit test is to be obtained by Test Method Nev. T203. Referee or dispute testing shall be performed using the mortar and rubber-covered pestle as the pulverizing apparatus.

2. A sample weighing about 100 g (minimum 85 g) shall be taken from the thoroughly mixed portion of the material passing the 425 µm (No. 40) sieve that has been obtained in accordance with Test Method Nev. T203. Note: If 85 g are not obtained, the sample is to be reported as insufficient material and no further testing is required.

   Place the sample in the mixing dish and thoroughly mix with 15 to 20 mL of water (distilled or demineralized) by alternately and repeatedly stirring, kneading and chopping with a spatula. Tap water may be used for routine testing if comparative tests indicate no differences in results between tap water and distilled or demineralized water. Referee or disputed tests shall be performed using distilled or demineralized water. Use sufficient force in the kneading action to allow the moisture to come into contact with as many of the soil particles as possible. 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 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 to an acceptable range.

   Add sufficient water to thoroughly coat and be absorbed into the soil sample uniformly.

   Some soils are slow to absorb water. It is possible to add 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.

   Once the 25-35 shock range (preferably 30-35) is achieved, the sample is then hydrated for 30 ± 1 minute in the dish under a damp rag. After the sample has been hydrated, add 1 mL of additional water to the sample and mix for 1 minute prior to placing in the brass cup of the liquid limit device.

3. 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 (0.4 in.) at the point of maximum thickness. As few strokes of the spatula as possible shall be used, and care 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.

4. The cup containing the sample shall be lifted and dropped, mechanically or manually, at a 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 (1/2 in.). The number of shocks required to close this groove distance shall be recorded. When turning the crank of the manual device, do not hold the base of the machine with the free hand.

The soil being tested may slide on the surface of the cup instead of flowing. If this occurs, add more water to the sample, remix (including 30 ± 1 minute of hydration) and retest. If the soil continues to slide on the cup at less than 25 blows, the test is not applicable and a note should be made that the liquid limit could not be determined.

5. A slice of soil approximately the width of the spatula, extending across the soil cake perpendicular to the groove and including that portion of the groove in which the soil flowed together, shall be removed and placed in a suitable tared container. Weigh the container and soil and record the weight. Oven dry the soil in the container to a constant weight at 110 ± 5°C (230 ± 9°F) or by the following microwave oven procedure: Place a 600 mL glass beaker or other suitable container filled with approximately 300 mL of water (maintain water level during drying) into the microwave oven to prevent overheating during the drying process. Place the sample on a watch glass, then place into microwave oven. Dry the sample for 5 minutes, then at 2 minute intervals until a constant weight is achieved. Drying times may be adjusted based on type and size of microwave oven. Weigh and record the loss in weight as the weight of water.

   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.

   The foregoing operations shall be repeated for at least two additional portions of the sample to which sufficient water has been added to bring the soil to a more fluid condition. The object of this procedure is to obtain samples of such consistency that at least one determination will be made in each of the following ranges of shocks: 25-35, 20-30, 15-25, so the range in the three determinations is at least 10 shocks between the first and third shock range.

CALCULATION

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:

$$\text{Percentage Moisture} = \frac{\text{mass of water}}{\text{mass of oven dried soil}} \times 100$$

Calculate the percentage of moisture to the nearest 0.1 percent.

PREPARATION OF FLOW CURVE

A AFlow Curve≅ representing the relation between moisture content and corresponding number of shocks shall be plotted on a semi-logarithmic graph with the moisture contents as abscissa 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 plotted points. A computer method of best-fit straight-line regression

analysis may be used to determine the liquid limit. If the three points do not form a straight line, connect the points with three lines, forming a triangle. The difference between the two lines that intersect with the 25 shock ordinate shall not be more than 0.3 percent moisture. Perform the test again if this criterion is not met.

LIQUID LIMIT

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.

Calculate the liquid limit to the nearest 0.1. This liquid limit value will be utilized for calculating the plasticity index in Test Method Nev. T211.

REPORT

Report the liquid limit to the nearest whole number.

METHOD B – THE SINGLE POINT METHOD (For Headquarters Lab informational testing only)

TEST PROCEDURE

1. The material for the liquid limit test is to be obtained by Test Method Nev. T203.

2. A sample weighing about 100 g (minimum 85 g) shall be taken from the thoroughly mixed portion of the material passing the 425 µm (No. 40) sieve that has been obtained in accordance with Test Method Nev. T203. Note: If 85 g are not obtained, the sample is to be reported as insufficient material and no further testing is required.

3. Use the test procedure from Method A except that the initial amount of water to be added will be 8 to 10 mL instead of 15 to 20 mL, and the moisture sample taken shall be only for the accepted trial.

4. 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 Method A. If the second closure occurs in the acceptable range (22-28 blows) and the second closure is within two blows of the first closure, secure a water content specimen as directed in Method A.

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

CALCULATION

The water content of the soil at the time of the accepted closure shall be calculated in accordance with Method A.

LIQUID LIMIT

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

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.

$LL = W^N(N/25)^{0.121}$
or
$LL = kW^N$
where:

N = number of blows causing closure of the groove at water content,
LL = Liquid Limit corrected for closure at 25 blows,
W^4 = water content, and
k = factor given in Table 1.

REFEREE OR DISPUTE TESTING

METHOD

Method A shall be used in making referee or dispute tests. The results of the liquid limit are influenced by: The time required to make the test; the moisture content at which the test is begun; and the addition of dry soil to the hydrated sample (not allowed).

PROCEDURE

In making the liquid limit test for referee or dispute purposes, the following time schedule shall be used:

1. Mixing of soils with water: 5 to 10 minutes, the longer period being used for the more plastic soils.

2. Hydration: 30 ± 1 minute.

3. Remixing before placing in the brass cup: add 1 mL of water and mix for one minute.

4. Placing in the brass cup and testing: 3 minutes.

5. Adding water and remixing: 3 minutes.

6. Additional hydration: 30 ± 1 minute.

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 hydrated soil being tested.

PRECISION STATEMENT

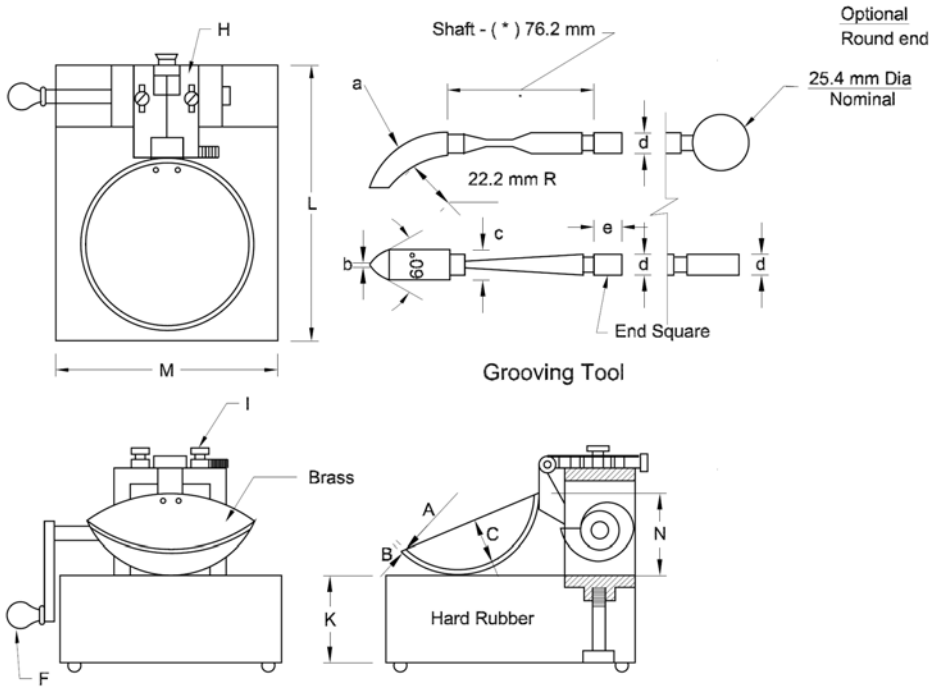
This precision statement applies to soils having a liquid limit range from 21 to 67.

1. 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.

2. 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.

RESILIENCE TEST

A device for measuring the resilience of liquid limit device bases is shown in Figure 6 and Table 2. 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. Holding the tube lightly against the liquid limit device base with one hand, 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.



	Liquid Limit Device							Grooving Tool				
	Cup Assembly				Base			Curved End			Gage	
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	0	1.5	5	5	5	0.1	0.1	0.1	0.2	—

Note: Plate "H" may be designed for using (1) one 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

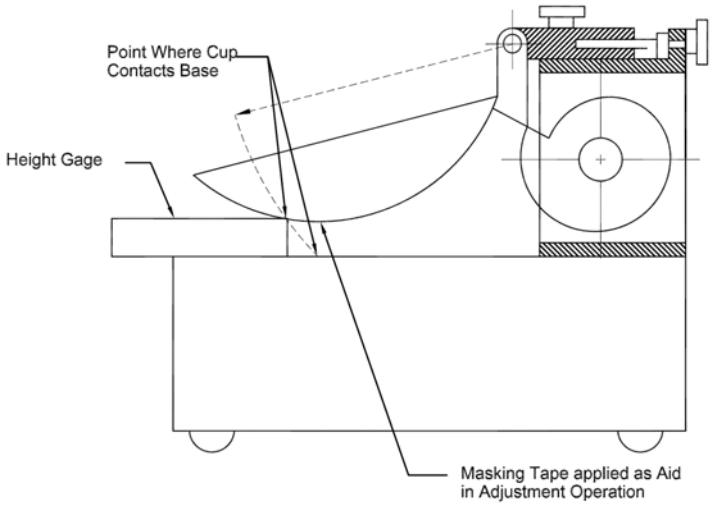


Figure 2—Calibration for Height of Drop

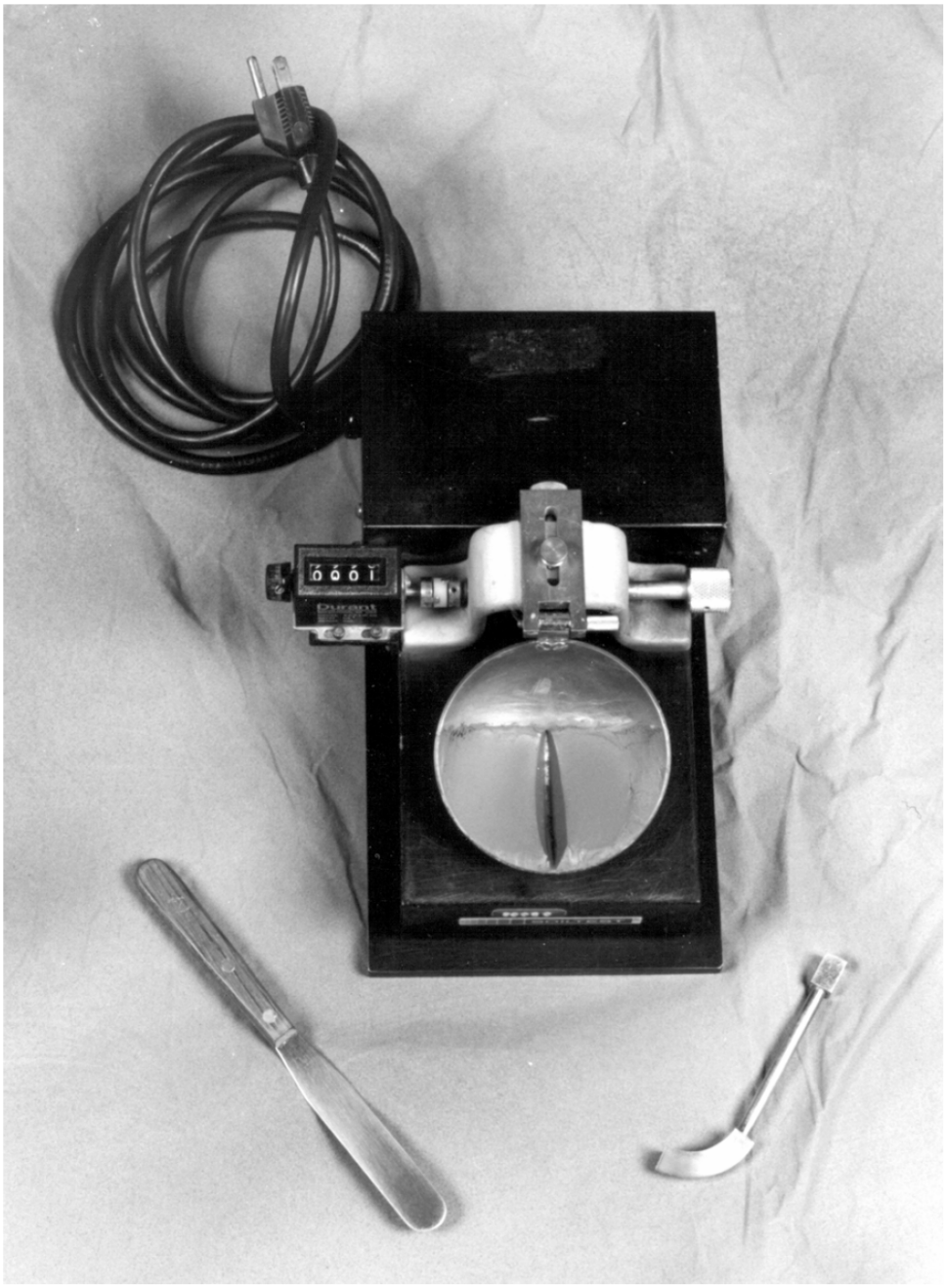


Figure 3—Liquid Limit Device with Soil Sample in Place

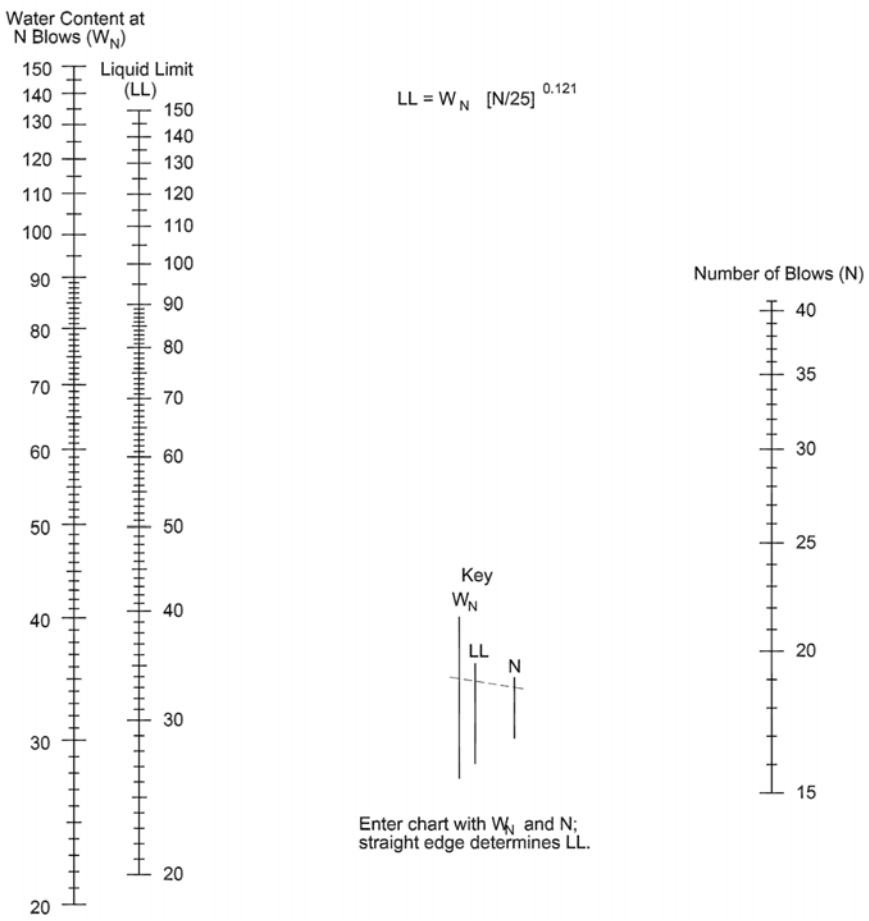


Figure 4—Nomographic Chart Developed by the Waterways Experiment Station, Corps of Engineers, U.S. Army, to Determine Liquid Limit Using Mean Slope Method

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

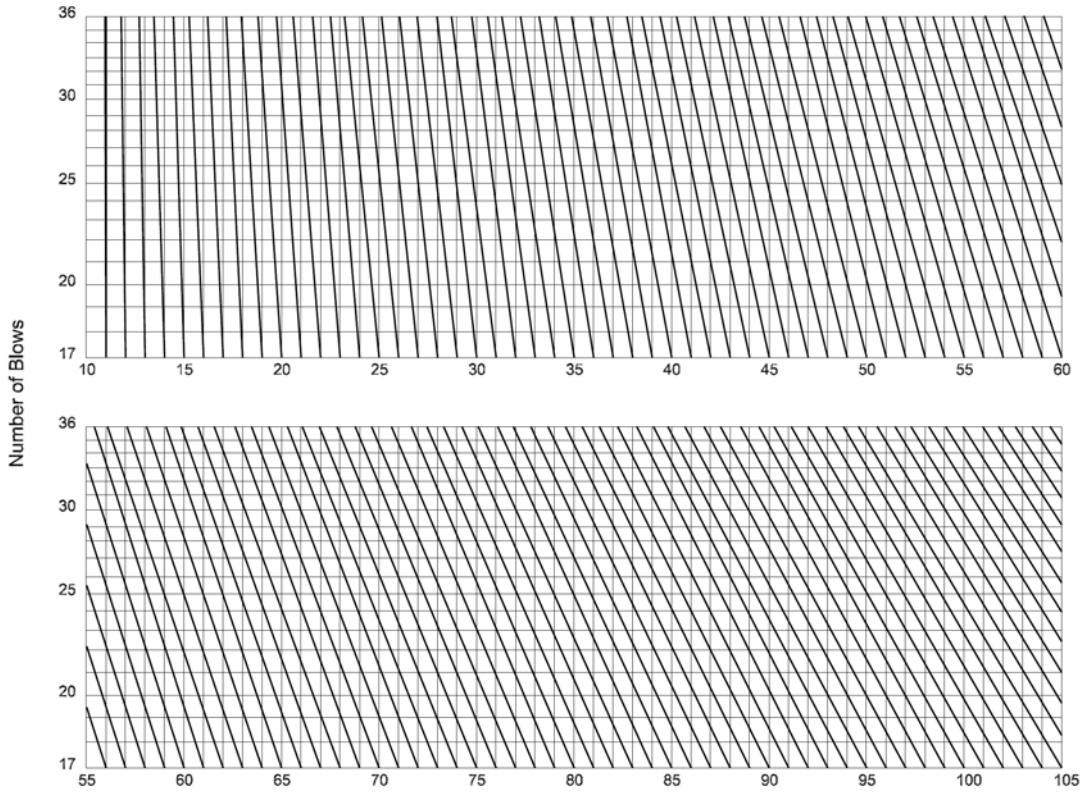


Figure 5—Chart Developed by Washington State Highway Department for the Calculation of the Liquid Limit

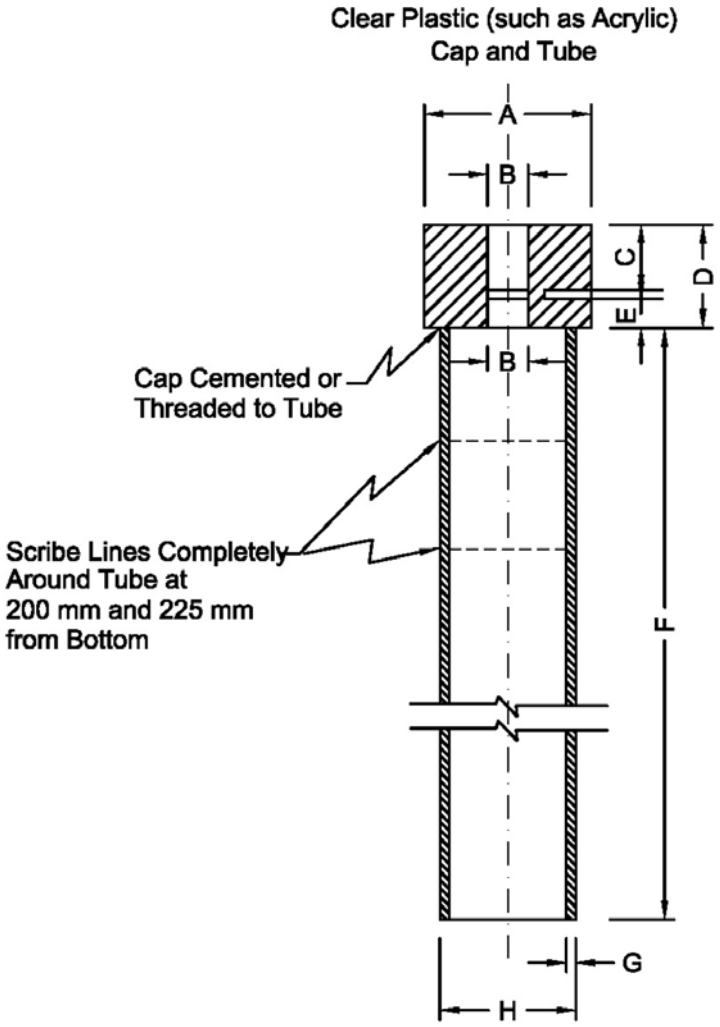


Figure 6—Resilience Tester

Table 2— Table of Measurements for Resilience Tester

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

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

[b] Tube stands plumb.