METHODS OF SAMPLING AND TESTING
MT 208-04
METHOD OF TEST FOR DETERMINING THE LIQUID LIMIT OF SOILS
(Modified AASHTO T 89)
and
METHOD OF TEST FOR DETERMINING THE PLASTIC LIMIT, AND THE PLASTICITY INDEX OF SOILS
(Modified AASHTO T 90)

1 Definition:

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 theses 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 AASHTO R 11.

2 Referenced Documents:

2.1 ***AASHTO:***
T 89 Determining the Liquid Limit of Soils
T 90 Determining the Plastic Limit and Plastcicty Index of Soils

MT Materials Manual:
MT-200 Dry Preparation of Disturbed Samples for Test
MT-227 Laboratory Determination of Moisture Content of Soils

3 Apparatus:

3.1 *Dish*--A porcelain dish, preferably unglazed, or similar mixing dish, about 115 mm (4½ in.) in diameter.

3.2 *Spatula*--A spatula or pill knife having a blade about 75 mm (3 in.) in length and about 20 mm (¾ in.) 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.

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 4.2 and 5.3 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.

3.4 *Grooving Tool*--A grooving tool conforming to the critical dimensions shown in Figure 1. The gage need not be part of the tool.

3.5 *Gage*--A gage, whether attached to the grooving tool or separate, conforming to the critical dimension "d' shown in Figure 1 and may be, if separate, a metal bar 10.0 ± 0.2 mm (0.394 ± 0.008 in.) thick and approximately 50 mm (2 in.) long.

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

3 Apparatus: (continued)

3.7 *Balance*--A balance sensitive to 0.01 grams.

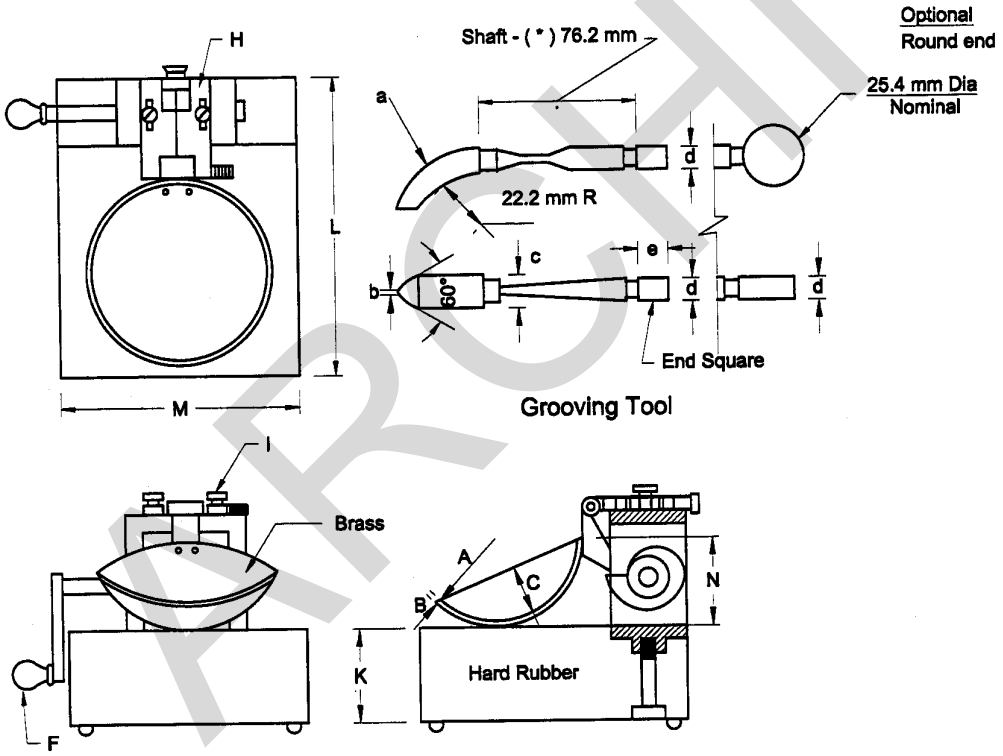
3.8 *Oven*--A thermostatically controlled drying oven capable of maintaining temperatures of 110 ± 5 C (230 ± 9 F) for drying moisture samples.

4 Sample:

4.1 A sample weighing about 100 g shall be taken from the thoroughly mixed portion of the material passing the 0.425 mm (No. 40) sieve which has been obtained in accordance with MT-200, Dry Preparation of Disturbed Soil and Soil Aggregate Sample for Test.

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 method.



	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

Note 3 - Wear is considered excessive when the point of contact on the cup or base exceeds approximately 13 mm (0.5 in.) in diameter, or when any point on the rim of the cup is worn to approximately ½ 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 which 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.

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 ± 0.2 mm (0.394 ± 0.008 in.). See Figure 2 for proper location of the gage relative to the cup during adjustment.*

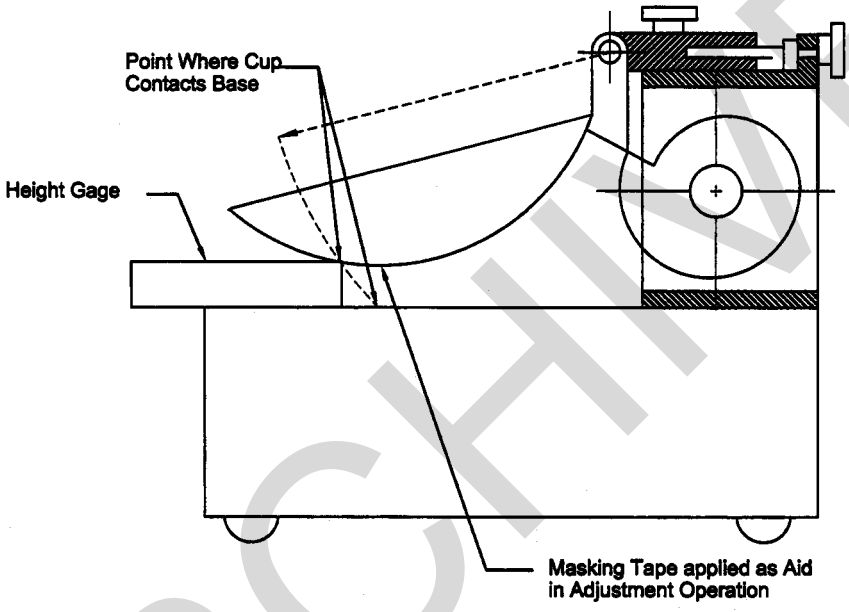


Figure 2—Calibration for Height of Drop

Note 4 - 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 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 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 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 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.

6 Procedure:

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 5 - 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.

6.2 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. With the spatula the soil shall be leveled and at the same time trimmed to a depth of 10 mm at the point of maximum thickness. The excess soil shall be returned to the mixing dish. 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.

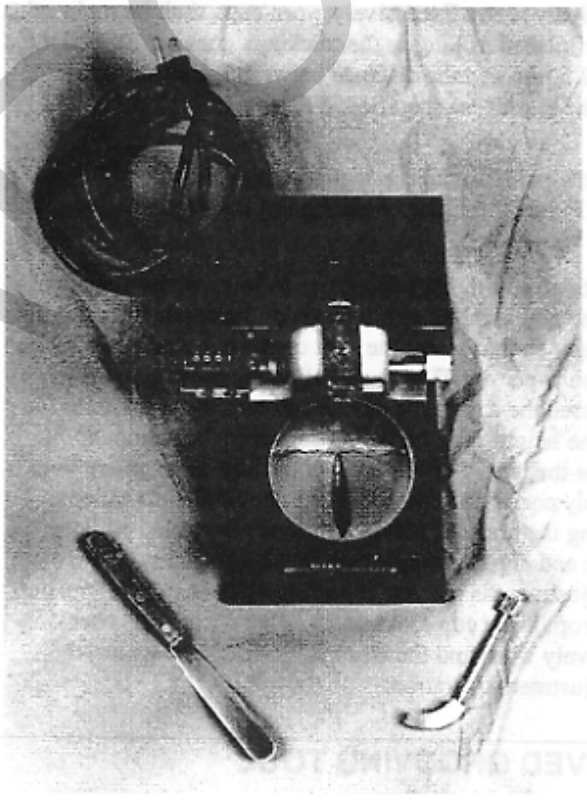


Figure 3—Liquid Limit Device With Soil Sample in Place

6 Procedure: (continued)

6.3 The cup containing the sample prepared as described in 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 (0.5 in.). 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 6 - 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 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.

6.4 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 container and soil shall then be weighed promptly and the weight recorded. The soil in the container shall be oven-dried to a constant weight at 110 ± 5 C (230 ± 9 F) and weighed. This weight shall be recorded and the loss in weight due to drying shall be recorded as the weight of water.

6.5 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.

6.6 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.

7 Calculation:

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

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

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

8 Preparation of Flow Curve:

8.1 A "Flow Curve" representing the relation between moisture content and corresponding number of shocks shall be plotted in a semi-logarithmic 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.

9 Liquid Limit:

9.1 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

10 Sample:

10.1 A sample weighing about 50 g shall be taken as described in 4.1.

11 Procedure:

11.1 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.

11.2 For accuracy equal to that obtained by the standard three-point method, the accepted number of blows for groove closure shall be restricted 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 – 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.

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

12 Calculation:

12.1 The water content of the soil at the time of the accepted closure shall be calculated in accordance with Section 7.1.

13 Liquid Limit:

13.1 The liquid limit shall be determined by one of the following methods: the nomograph, Figure 4; the multicurve; Figure 5; the slide rule with a special "blows" scale, Figure 6, 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.

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

13.3 The chart (multi-flow curve), Figure 5, is used by plotting on it a point representing the moisture content vs. number of blows for the accepted trial, and drawing a line through the plotted point parallel to the nearest chart curve. The moisture content corresponding to the intersection of this line with the 25-blow line shall be recorded as the liquid limit.

13.4 The special slide rule, Figure 6, is used by setting the hairline of the indicator slide coincident with the A-scale value of the moisture content for the accepted groove closure, and moving the special scale until the number of blows used for closure is also under the hairline. The liquid limit will then be found on the A-scale opposite the end index of the B-scale, or opposite the middle index of the B-scale, which in turn is directly in line with the 25-blow mark of the special scale.

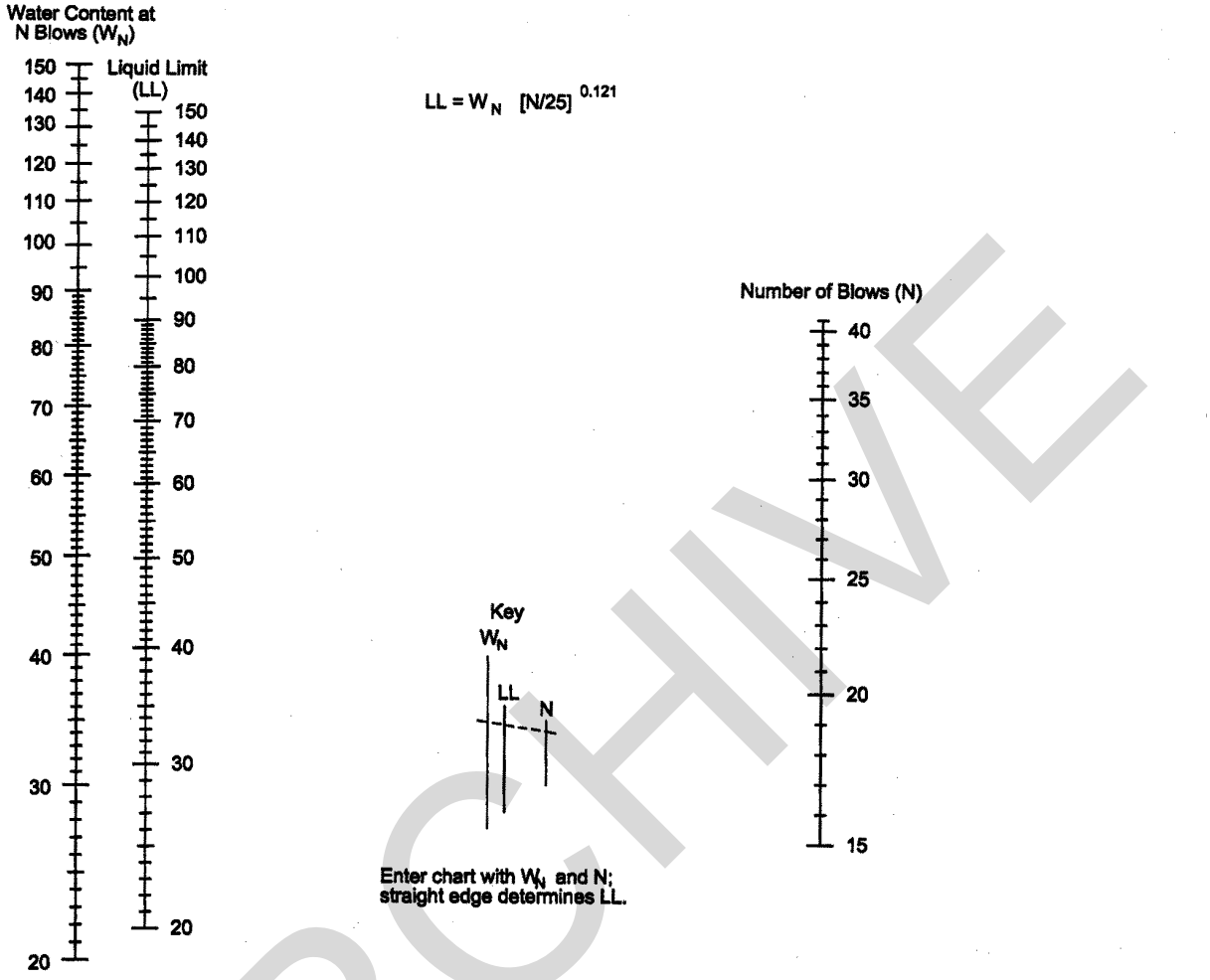


Figure 4—Nomographic chart Developed by the Waterways Experiment Station, Corps of Engineers, U.S. Army, to Determine Liquid Limit Using Mean Slope Method

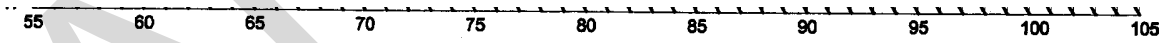


Figure 5—Chart Developed by Washington State Highway Department for the Calculation of the Liquid Limit

FIGURE 5 Chart Developed by Washington State Highway Department for the Calculation of

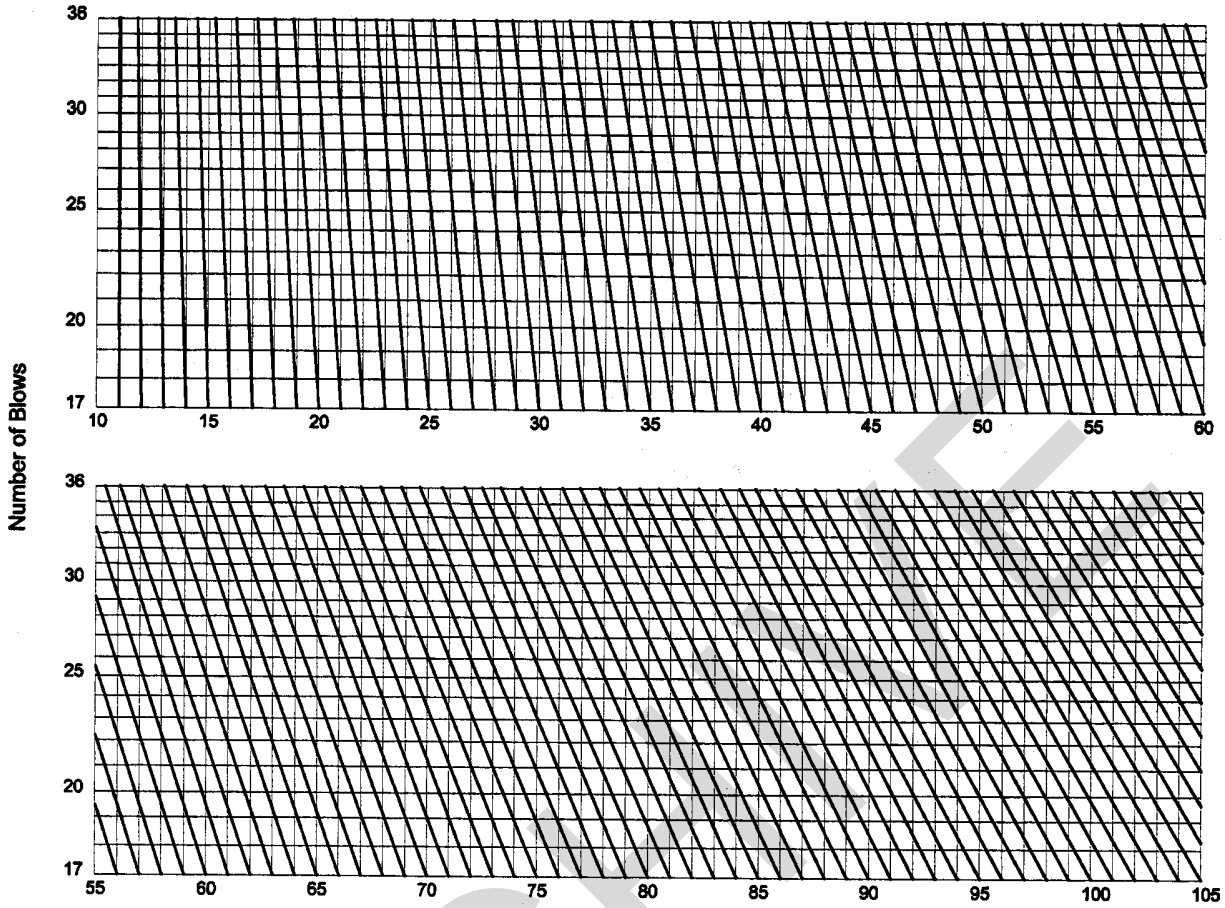
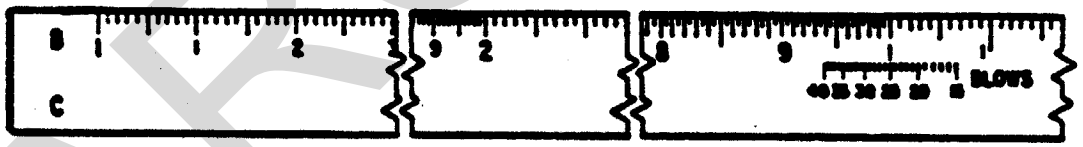
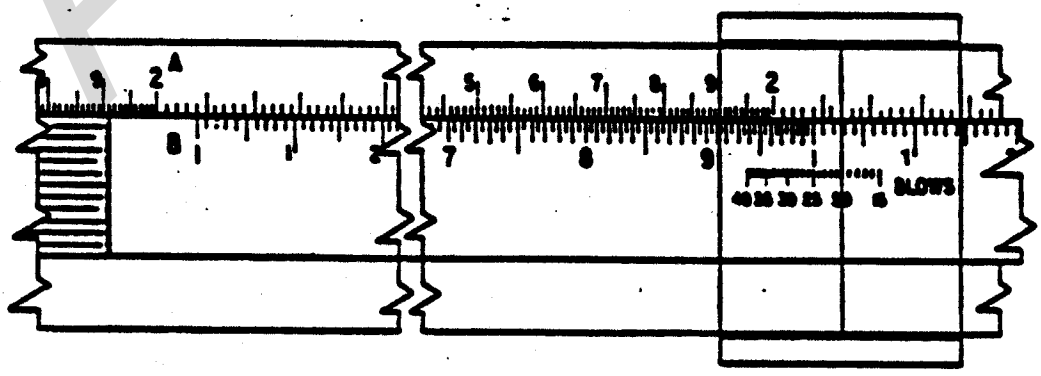


Figure 5—Chart Developed by Washington State Highway Department for the Calculation of the Liquid Limit



A - LOCATION OF SPECIAL SCALE (BLOWS) WITH RESPECT TO B SCALE OF SLIDE RULE



B - SLIDE RULE SET FOR 21.4 PERCENT MOISTURE AT 20 BLOWS, INDICATING CALCULATED LIQUID LIMIT OF 20.8

14 Method to be Used:

14.1 In making check or referee tests, Method A shall be used. The results of liquid limit tests are influenced by:

14.1.1 The time required to make the test.

14.1.2 The moisture content at which the test is begun.

14.1.3 The addition of dry soil to the seasoned sample.

15 Procedure:

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

15.1.1 Mixing of soil with water -- 5 to 10 minutes, the longer period being used for the more plastic soils.

15.1.2 Seasoning under a damp cloth -- 30 minutes.

15.1.3 Remixing before placing in the brass cup -- add 1 ml of water and mix for 1 minute.

15.1.4 Placing in the brass cup and testing -- 3 minutes.

15.1.5 Adding water and remixing -- 3 minutes.

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

METHODS OF SAMPLING AND TESTING
MT-208
METHOD OF TEST FOR DETERMINING THE PLASTIC LIMIT, AND THE PLASTICITY INDEX OF SOILS
(Modified AASHTO T 90)

1 Scope:

1.1 The plastic limit of a soil is the lowest water content determined in accordance with the following procedure at which the soil remains plastic. The plasticity index of a soil is the range in water content, expressed as a percentage of the mass of the oven-dried soil, within which the material is in a plastic state. It is the numerical difference between the liquid limit and plastic limit of the soil.

1.2 The following applies to all specified limits in this standard: For the purposes of determining conformance with theses 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 AASHTO R 11.

2 Referenced Documents:

MT Materials Manual
MT-200 Dry Preparation of Disturbed Samples for Test
MT-208 Determining the Liquid Limit of Soils
MT 227 Laboratory Determination of Moisture Content of Soils

3 Apparatus:

3.1 *Dish* – A porcelain evaporating dish, or similar mixing dish about 115 mm in diameter.

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

3.3 *Surface for Rolling* – A ground glass plate or piece of smooth, unglazed paper on which to roll the sample.

3.4 *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 weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

3.5 *Balance* – The balance shall sufficient capacity and conform to AASHTO M 231, Class G1.

3.6 *Oven* – A thermostatically controlled drying oven capable of maintaining temperatures of 110 ± 5ºC (230 ± 9ºF) for drying samples.

4 Sample:

4.1 If the plastic limit only is required, take a quantity of soil weighing about 20 g from the thoroughly mixed portion of the material passing the 0.425 mm (No. 40) sieve, obtained in accordance with paragraph 3.1. Place the air-dried soil in a mixing dish and thoroughly mix with distilled or demineralized water until the mass becomes plastic enough to be easily shaped into a ball. Take a portion of this ball weighing about 8 g for the test sample.

Note 1 - 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.

4.2 If both the liquid and plastic limits are required, take a test sample weighing about 8 g from the thoroughly wet and mixed portion of the soil prepared in accordance with the Standard Method of

Test for Liquid Limit for Soils (MT-208). Take the sample at any stage of the mixing process at which the mass becomes plastic enough to be easily shaped into a ball without sticking to the

4 **Sample:** (continued)

fingers excessively when squeezed. If the sample is taken before completion of the liquid limit test, set it aside and allow to season in air until the liquid limit test has been completed. If the sample taken during the liquid limit test is to dry to permit rolling to a 3 mm (1/8 in.) thread, add more water and remix.

5 **Procedure:**

5.1 Select a 1.5 to 2.0 g portion from the mass taken in accordance with Section 4. Form the selected portion into an ellipsoidal mass.

5.2 Use one of the following methods to roll the soil mass into a 3 mm diameter thread at a rate of 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position again.

5.2.1 *Hand Rolling Method* - Roll the mass between the fingers and the ground-glass plate (or a piece of paper laying on a smooth horizontal surface) with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The thread shall be further deformed on each stroke so that its diameter reaches 3 mm, taking no more than 2 min. The amount of hand or finger pressure required will vary greatly, according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

5.2 When the diameter of the thread becomes 3 mm (1/8 in.), break the thread into six or eight pieces. Squeeze the pieces together between the thumbs and fingers of both hands into a uniform mass roughly ellipsoidal in shape and reroll. Continue this alternate rolling to a thread 3 mm (1/8 in.) in diameter, gathering together, kneading and rerolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The crumbling may occur when the thread has a diameter greater than 3 mm (1/8 in.). This shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3 mm (1/8 in.) in diameter. The crumbling will manifest itself differently with the various types of soil. Some soils fall apart in numerous small aggregations of particles; others may form an outside tubular layer that starts splitting at both ends. The splitting progresses toward the middle, and finally, the thread falls apart in many small platy particles. Heavy clay soils require much pressure to deform the thread, particularly as they approach the plastic limit, and finally, the thread breaks into a series of barrel-shaped segments each about 6.4 to 9.5 mm (¼ to _ in.) in length. At no time shall the operator attempt to produce failure at exactly 3 mm (1/8 in.) diameter by allowing the thread to reach 3 mm (1/8 in.) diameter by allowing the thread to reach 3 mm (1/8 in.) then reducing the rate of rolling or the hand pressure, or both, and continuing rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal-shaped mass bearer to the required 3 mm (1/8 in.) final diameter.

5.3 Gather the portions of the crumbled soil together and place in a weighed container. Immediately cover the container.

5.4 Repeat the operations described in sections 5.1 through 5.3 until the 8 g specimen is completely tested. Determine the moisture content of the soil in the containers in accordance with MT-227, and record the results.

6 Calculations:

6.1 Calculate the plastic limit, expressed as the water content in percentage of the mass of the oven-dry soil, as follows:

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

Report the plastic limit to the nearest whole number.

6.2 Calculate the plasticity index of a soil as the difference between its liquid limit and its plastic limit, as follows:

Plastic index = liquid limit - plastic limit

6.3 Report the difference calculated as indicated in 6.2 as the plasticity index, except under the following conditions:

6.3.1 When the liquid limit or plastic limit cannot be determined, report the plasticity index as NP (non plastic).

6.3.2 When the plastic limit is equal to, or greater than, the liquid limit, report the plasticity index as NP.