
Standard Method of Test for

Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test)

AASHTO Designation: T 240-13

ASTM Designation: D2872-04

AASHTO

1. SCOPE

- 1.1. This test is used to measure the effect of heat and air on a moving film of asphalt binder and to provide residue for additional testing. The effects of this treatment are determined from measurements of the properties of the asphalt binder before and after the test.
- 1.2. The values stated in SI units are to be regarded as the standard.
- 1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
 - M 231, Weighing Devices Used in the Testing of Materials
 - M 320, Performance-Graded Asphalt Binder
 - R 16, Regulatory Information for Chemicals Used in AASHTO Tests
 - R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- 2.2. *ASTM Standards:*
 - C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
 - E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
 - E220, Standard Test Method for Calibration of Thermocouples By Comparison Techniques
 - E644, Standard Test Methods for Testing Industrial Resistance Thermometers
- 2.3. *NCHRP Document:*
 - NCHRP Web-Only Document 71 (Project 09-26), Precision Estimates for AASHTO Test Method T 308 and the Test Methods for Performance-Graded Asphalt Binder in AASHTO Specification M 320

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3. SUMMARY OF TEST METHOD

- 3.1. A moving film of asphaltic material is heated in an oven for 85 min at 163°C (325°F). The effects of heat and air are determined from changes in physical test values as measured before and after the oven treatment. The residue from this test is also used for additional testing as required in M 320. An optional procedure is provided for determining the change in sample mass.
- 3.2. Precision values for this test method have been developed for viscosity at 60°C (140°F), ductility at 15.6°C (60°F), and mass change.

4. SIGNIFICANCE AND USE

- 4.1. This method indicates the approximate change in properties of asphalt binder during conventional batch plant mixing at about 150°C (302°F) as indicated by viscosity and other rheological measurements. The residue from this test is also used to determine the conformance of an asphalt binder to M 320. It yields a residue that approximates the condition of the asphalt binder immediately after the pavement is constructed. If the mixing temperature differs appreciably from 150°C (302°F), more or less effect on the properties will occur. This method can also be used to determine mass change, which is a measure of asphalt binder volatility and mass changes resulting from oxidation.

5. APPARATUS

- 5.1. *Oven*—A double-walled electrically heated convection type with inside dimensions as follows: a height of 381 mm (15 in.), a width of 483 mm (19 in.), and a depth (with door closed) of 445 ± 13 mm (17½ ± ½ in.). The door shall contain a symmetrically located window with dimensions of 305- to 330-mm (12- to 13-in.) wide by 203- to 229-mm (8- to 9-in.) high. The window shall contain two sheets of heat-resistant glass separated by an air space. The window should permit an unobstructed view of the interior of the oven. The heating element shall be located below the oven floor and shall be adequate to maintain the required temperature. The oven shall be vented at the top and bottom. The bottom vents shall be located symmetrically to supply incoming air around the heating elements. They shall have an open area of 15.0 ± 0.7 cm² (2.31 ± 0.11 in.²). The top vents shall be symmetrically arranged in the upper part of the oven and have an open area of 9.3 ± 0.45 cm² (1.45 ± 0.07 in.²).
- 5.1.1. The oven shall have an air plenum covering the side walls and ceiling, the air space being 38 mm (1½ in.) deep from the walls and ceiling. At a midpoint in the width of the oven and 152 mm (6 in.) from the face of the circular metal carriage to its axis, a squirrel cage-type fan 133.4 mm (5¼ in.) outside diameter by 73 mm (2⅞ in.) wide shall be turned at 1725 r/min by an externally mounted motor. The squirrel cage fan shall be set so that the fan turns in an opposite direction to its vanes. The air flow characteristics of the fan-plenum system shall be suctioned from the floor of the oven through the wall plenums with the air exiting through the fan. Figures 1 and 2 show details of this fan-plenum system.
- 5.1.2. The oven shall be equipped with a proportional temperature controller capable of maintaining a temperature of 163 ± 1.0°C (325 ± 1.8°F). The sensing element of the controller may be placed at any location that enables the oven to maintain temperature control as specified in this standard. The temperature controller shall be capable of bringing the fully loaded oven back to the test temperature within a 10-min period after insertion of the samples in a preheated oven.
- 5.1.3. A thermometer shall be hung from or affixed to a mounting in the ceiling, which is 51 mm (2 in.) from the right side of the oven at a midpoint in the depth of the oven so that the bulb of the

thermometer or the tip of the sensor of the alternative thermometric device is within 25 mm (1 in.) of an imaginary line level to the shaft of the circular metal carriage.

- 5.1.4. The oven shall be provided with a 305-mm (12-in.) diameter vertical circular carriage (see Figure 2 for details). This carriage shall be provided with suitable openings and clips for firmly holding eight glass containers (see Figure 3) in a horizontal position. The vertical carriage shall be mechanically driven through a 19-mm (³/₄-in.) diameter shaft at a speed of 15 ± 0.2 r/min.
- 5.1.5. The oven shall be equipped with an air jet positioned to blow heated air into each container at its lowest point of travel. The air jet shall have an outlet orifice 1.02 mm (0.04 in.) in diameter (No. 60 drill) connected to a 7.6-m (25-ft) length of 7.9-mm (⁵/₁₆-in.) O.D. refrigeration copper tubing. This tubing shall be coiled to lie flat on the bottom of the oven and lead to a source of fresh-dried, dust-free, regulated air. The tubing in the bottom of the oven shall be exposed to the plenum of the oven and shall not be covered by aluminum foil or other material.

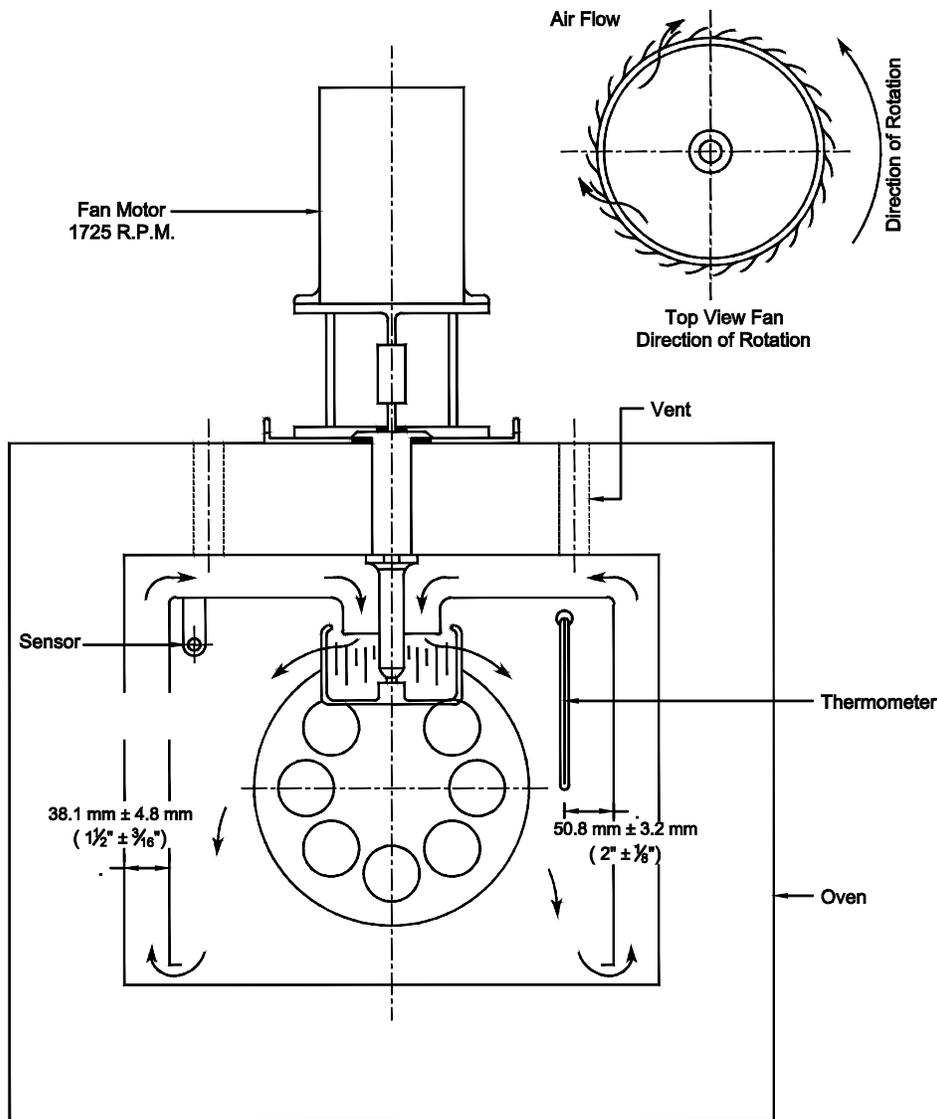


Figure 1—Schematic of Air Flow Front View

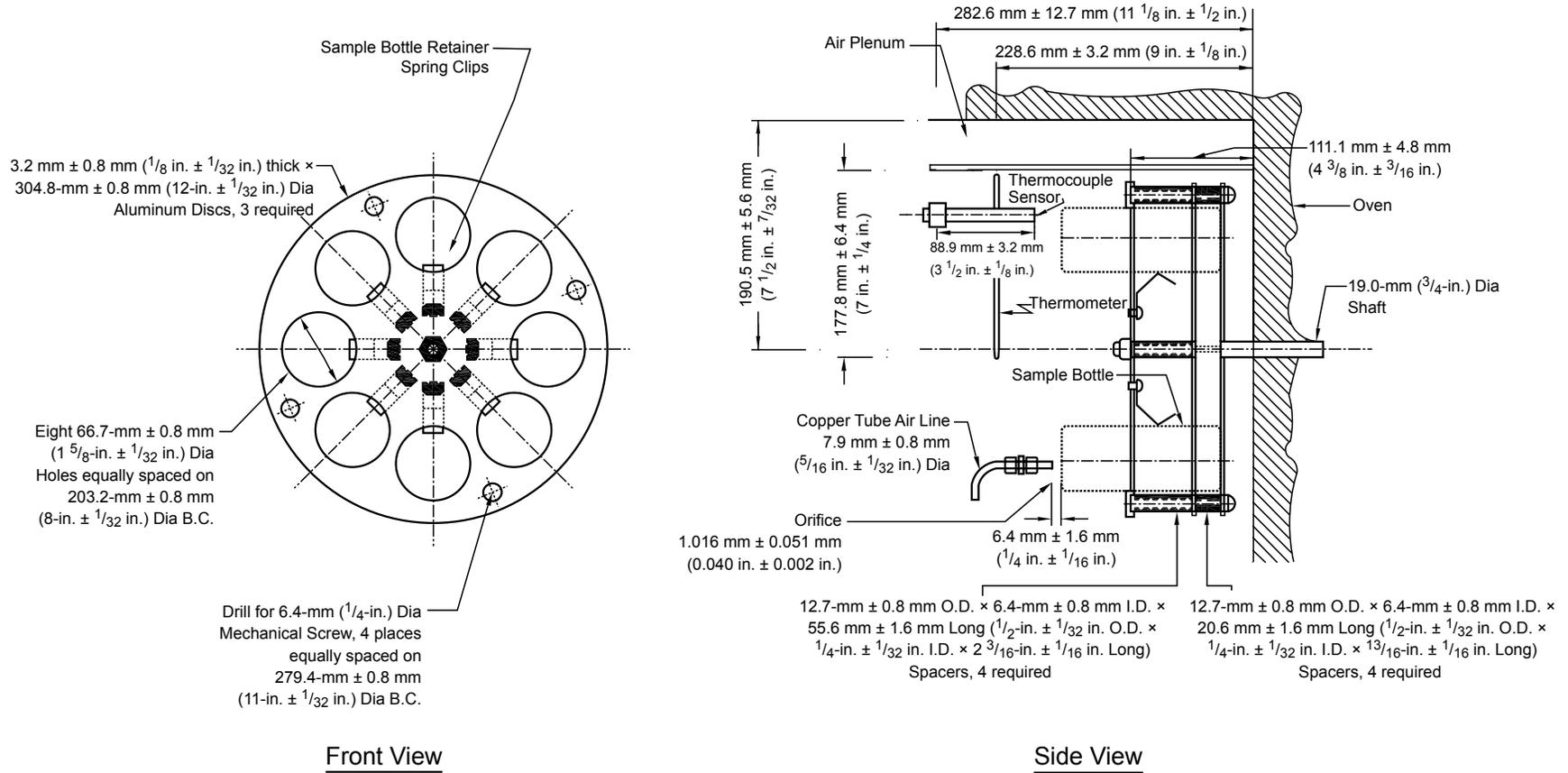


Figure 2—Circular Metal Carriage

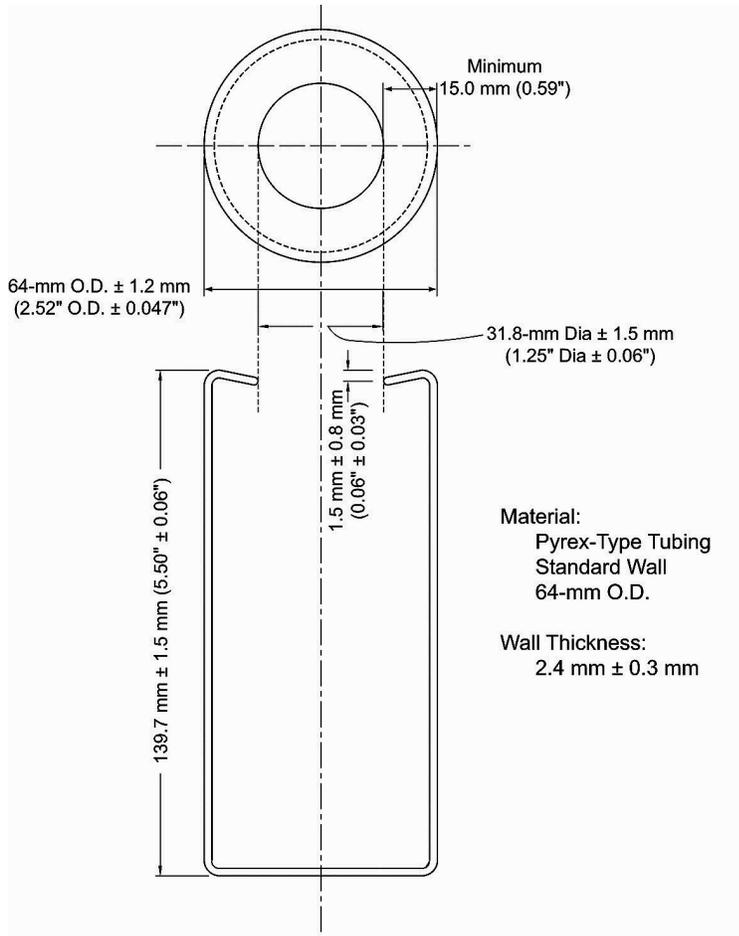


Figure 3—Sample Container

Note 1—Activated Silica Gel treated with an indicator is a satisfactory desiccant for the dried air.

- 5.2. *Flowmeter*—The flowmeter may be any suitable type capable of measuring the airflow at a rate of 4000 ± 100 mL/min. The flowmeter shall be located downstream of all regulating devices and upstream of the copper coil. The flowmeter shall be positioned so it is maintained at approximately room temperature. The flowmeter shall be standardized at least every 12 months using a wet-test meter or other method. This standardization shall be based on airflow exiting the air jet and shall be conducted with the oven off and at room temperature.
- 5.3. *Thermometer*—An ASTM 13C (13F) thermometer as prescribed in ASTM E1 with an accuracy of 0.2°C (0.5°F). The thermometer shall be calibrated according to the requirements specified in R 18. This thermometer shall be used to make all temperature measurements required by this method. In order to reduce the risks associated with thermometer breakage, the thermometer may be fully or partially encapsulated in an optically transparent polymer sheath having a maximum thickness of 0.25 mm (0.01 in.). If a sheath is used, it shall be installed such that there is substantial mechanical contact with the thermometer. The thermometer shall be standardized after installation of the sheath.
- 5.3.1. The test thermometer may be replaced with an alternative thermometric device, provided the following requirements are met:

- 5.3.1.1. The thermometric device shall be mounted in the same position as the test thermometer it replaces.
- 5.3.1.2. The thermometric device shall (1) have a maximum scale error no greater than that of the test thermometer it replaces, and (2) be capable of indicating temperature within 0.1°C (0.2°F).
- 5.3.1.3. The thermometric device shall be standardized at the interval specified in R 18. Guidance for performing the standardization is given in ASTM E220 or E644.
- 5.4. *Container*—The container in which the asphalt binder is to be tested shall be of heat-resistant glass, with a smooth interior, conforming to the dimensions shown in Figure 3. Glass may be treated (e.g., frosted) on its exterior for handling purposes.
- 5.5. *Balance*—If the loss on heating is desired, a Class B balance conforming to the requirements of M 231 is required. If only the residue is desired, a Class G 2 balance conforming to M 231 may be used. The balance shall be standardized according to the requirements specified in R 18.
- 5.6. *Cooling Rack*—A wire or sheet metal rack, constructed of stainless steel or aluminum, which allows the sample containers to cool in a horizontal position. The rack shall be constructed in a way that allows air to flow freely around each container with at least 25-mm (1-in.) clearance between containers, and at least 25-mm (1-in.) clearance between the containers and any solid surface.
- 5.7. *Electronic Level (Optional)*—A precision level for measuring the levelness of the support provided by the circular openings in the metal carriage. The length shall be at least 125 mm (5 in.), and the width shall be 30 ± 3 mm (1.2 ± 0.1 in.). The bearing surface of the level shall be ground flat. Resolution, accuracy, and repeatability shall be ± 0.1 degree. The level shall have a hold button freeze so that the level can be read after removing the level from the carriage.
- Note 2**—An SPI Tronic Digital Level PRO 360 or its equivalent has been found suitable for this purpose. The device may be purchased through local or mail order suppliers of machine tools.

6. PREPARATION OF OVEN

- 6.1. Position the air outlet orifice so that it is 6.4 mm ($1/4$ in.) from the opening of the glass container. The orifice shall also be so positioned that the jet blows horizontally into the center of the container opening when the rotating container is at its lowest position.
- 6.2. Position the thermometer specified in Section 5.3 so that the end of the bulb of the thermometer is within 25 mm (1 in.) of an imaginary line level to the center of the shaft holding the revolving carriage. If an alternative thermometric device is used, position it as specified in Section 5.3 so that the tip of the sensor is within 25 mm (1 in.) and level to the center of the shaft holding the revolving carriage.
- 6.3. Adjust the oven so that the horizontal axes of the glass containers, when in position in the carriage, are level to within ± 1.0 degree. This shall be accomplished by checking the carriage, not by checking the level of the oven. A recommended procedure for ensuring that the containers are level to 1.0 degree is given in the Appendix. Alternative procedures may be used to ensure that the carriage is level to within ± 1.0 degree. Check for wear in the bearing every 6 months and when the levelness of the carriage is checked.
- Note 3**—The bearing that supports the metal carriage is subject to wear, and excessive wear is known to allow the carriage to tilt. This affects the levelness of the containers and creates the potential for binder to creep from the bottles.

- 6.4. Start the fan. The fan shall remain on when the oven heater is on and the oven door is closed. The fan may be stopped when the oven door is opened. Stopping the fan may be accomplished manually, with an electronic door interlock, or through other means.
- 6.5. Preheat the oven for a minimum of 2 h prior to testing, with the temperature controller adjusted to the setting that will be used during the test. This setting shall be selected such that when the oven is fully loaded and the air is on, the oven will equilibrate at $163.0 \pm 1.0^\circ\text{C}$ ($325 \pm 1.8^\circ\text{F}$), as indicated by the test thermometer.
- Note 4**—Because the presence of sample containers affects the temperature distribution in the oven, containers must be present in the oven when the controller setting is determined. The use of empty containers is acceptable for this purpose.

7. PROCEDURE

- 7.1. The sample as received shall be free of water. Heat the sample in its container with a loosely fitted cover in an oven not to exceed 163°C (325°F) for the minimum time necessary to ensure that the sample is completely fluid. Manually stir the sample but avoid incorporating air bubbles.
- 7.2. When mass change is determined, record the mass of two empty containers using an analytical balance having a readability of 0.001 g or better. Pour 35 ± 0.5 g of the sample into each of the number of glass containers required to provide sufficient material for the tests that are to be performed on the residue.
- 7.3. Immediately after pouring the sample into a glass container, turn the container to a horizontal position. Rotate the container slowly for at least one full rotation, and attempt to precoat its cylindrical surface. It is not necessary to precoat the open end of the container, and care should be taken to prevent the sample from flowing out of the container during this step. Ensure that the asphalt binder does not coat the central part of the open end of the container. Place the container horizontally in a clean cooling rack that is maintained in a draft-free, room-temperature location away from ovens or other sources of heat.
- Note 5**—Complete precoating of the cylindrical surface may not be possible for highly modified binders.
- Note 6**—For maximum precision in determining mass change, the cooling rack should be in a location that is the same temperature and humidity as the balance used for measuring the mass of the containers.
- Note 7**—Static electricity may cause unstable mass measurements, due in part to the characteristics of the glass sample containers. This problem can be minimized by mounting a passive ion source inside the balance draft shield.
- 7.4. Allow the glass containers to cool in the cooling rack for at least 60 min but no more than 180 min before placing the containers in the oven.
- 7.5. When mass change is being determined, use two separate containers for this determination. After cooling, determine the mass of these containers using an analytical balance having a resolution of 0.001 g or better. Separately place each container vertically on the balance and record the mass to the full resolution of the balance.
- 7.6. With the oven at operating temperature and the airflow set at 4000 ± 300 mL/min, arrange the containers holding the asphalt binder in the carriage so that the carriage is balanced. Fill any unused spaces in the carriage with empty containers. Close the door, and rotate the carriage assembly at a rate of 15 ± 0.2 r/min. Maintain the glass containers in the oven with the air flowing and the carriage rotating for 85 min. The test temperature of $163 \pm 1.0^\circ\text{C}$ ($325 \pm 1.8^\circ\text{F}$) shall be reached within the first 10 min—otherwise discontinue the test.

- 7.7. At the conclusion of the testing period, remove any containers for mass change determination, and place them horizontally in the cooling rack. Then remove each remaining container, one at a time, and transfer its contents to a collection container having a capacity at least 30 percent greater than the total expected volume of residue. This transfer shall be accomplished by first pouring out any residue that will flow freely from the container, and then scraping out as much of the remaining residue as practical. While the residue is being removed from each container, the oven door shall remain closed, with the heater power on, the air on, and the remaining samples rotating in the carriage. The final container shall be removed from the oven within 5 min of removal of the initial container.

Note 8—Any scraping tool may be used, as long as an average of 90 percent or more of the residue is removed from the sample containers. It has been determined that circumferential scraping tends to be more effective than lengthwise scraping.

- 7.8. After removing the residue from each of the containers, gently stir the residue in the collection container to homogenize the residue without introducing air into it.

- 7.9. If the mass change is being determined, allow the designated containers to cool on the cooling rack for at least 60 min but not more than 180 min. After cooling, determine the mass of these containers using an analytical balance having a resolution of 0.001 g or better. Separately place each container vertically on the balance, and record the mass to the full resolution of the balance.

- 7.9.1. Make a note on the report if any sample appears to have flowed out of the container. If mass has flowed from the container, do not use the container for mass change determination. The results from one container may be used to determine mass change if mass has flowed from the container. If only one container is used to determine mass change, note it on the report. Use two containers for referee purposes.

Note 9—Some labs have reported problems with the asphalt binder flowing from the container during the test. If this occurs, check the levelness of the circular openings in the carriage and the dimensions of the container. Containers with a small annular ring appear to be particularly susceptible to this problem. Containers that do not comply with the dimensional requirements should be removed from service.

Note 10—To improve mass change precision, the containers used for determining mass change should be handled only with clean gloves or tongs. Transfer to the balance should be done with tongs to prevent contamination and temperature changes, which could distort the mass measurement.

8. REPORT

- 8.1. Report the results from the rolling thin-film oven (RTFO) test in terms of the physical changes in the asphalt binder brought about by this method. These values are obtained by performing appropriate tests on the asphalt binder before and after the RTFO test.

Note 11—Physical test results required for M 320 are reported as part of the test methods specified in M 320, not as part of this test method.

- 8.2. When determined, report the average mass change of the material in the two containers as a mass percent of the original material. Report this calculated result to the nearest 0.001 percent. A mass loss shall be reported as a negative number, and a mass gain shall be reported as a positive number.

Note 12—This test can result in either a mass loss or a mass gain. During the test, volatile components and reaction products (primarily water) evaporate (causing a decrease in mass) while oxygen reacts with the sample (causing an increase in mass). The combined effect determines whether the sample has an overall mass gain or an overall mass loss. Samples with a very low

percentage of volatile components will usually exhibit a mass gain, whereas samples with a high percentage of volatile components will usually exhibit a mass loss.

- 8.3. Report asphalt binder loss from any of the mass change containers. Report if mass change is based on one container.

9. PRECISION AND BIAS

- 9.1. Criteria for judging the acceptability of the viscosity at 60°C (140°F) and the ductility at 15.6°C (60°F) test results on the residue after heating are given in Table 1. The values given in Column 2 are the standard deviations that have been found to be appropriate for the materials and conditions of test described in Column 1. The values given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. The values given in Column 4 are the coefficients of variation that have been found to be appropriate for the materials and conditions of test described in Column 1. The values given in Column 5 are the limits that should not be exceeded by the difference between the results of two properly conducted tests expressed as a percent of their mean.

Table 1—Precision of Test on Residue

Test Methods	Standard Deviation (1s)	Acceptable Range of Two Results (d2s)	Coefficient of Variation (Percent of Mean) (1s%)	Acceptable Range of Two Results (Percent of Mean) (d2s%)
<i>Single-operator precision:</i>				
Viscosity at 60°C (140°F)	—	—	2.3	6.5
Ductility at 15.6°C (60°F) ^a	3 cm	9 cm	—	—
<i>Multilaboratory precision:</i>				
Viscosity at 60°C (140°F)	—	—	4.2	11.9
Ductility at 15.6°C (60°F)	6 cm	16 cm	—	—

^a This is based on the analysis of data resulting from tests by 16 laboratories on two asphalt binders ranging from 13 to 30 cm.

- 9.2. *Precision for Change in Mass*—Criteria for judging the acceptability of change in mass results obtained by this method are given in Tables 2 and 3. Table 2 should be consulted as the final qualifier for precision purposes. Table 3 has been added for the convenience of the user.
- 9.3. *Single-Operator Precision (Repeatability)*—The equation in Column 2 of Table 2 indicates that the standard deviation of the test results (1s) can be expressed as a function of the mass change (X) for the conditions of test described in Column 1. Two results obtained in the same laboratory, by the same operator using the same equipment, in the shortest practical period of time, should not be considered suspect unless the difference in the two results exceeds the value determined by multiplying the 1s estimate determined in Column 2 for the average value of the two results by a factor of 2.83. This is shown in Table 2, Column 3.
- 9.4. *Multilaboratory Precision (Reproducibility)*—The equation in Column 2 of Table 2 indicates that the standard deviation of the test results (1s) can be expressed as a function of the mass change (X) for the conditions of test described in Column 1. Two results submitted by two different operators testing the same material in different laboratories shall not be considered suspect unless the difference in the two results exceeds the value determined by multiplying the 1s estimate determined in Column 2 for the average value of the two results by a factor of 2.83. This is shown in Table 2, Column 3.

Table 2—Precision Estimates

Condition	Standard Deviation (1s) ^{a,b}	Acceptable Range of Two Test Results (d2s) ^{a,b,c}
<i>Single-operator precision:</i>		
Mass loss (%)	$1s = 0.0061 + 0.0363(X)$	$d2s = (0.0061 + 0.0363(X_{avg})) \times (2.83)$
<i>Multilaboratory precision:</i>		
Mass loss (%)	$1s = 0.00153 + 0.1365(X)$	$d2s = (0.00153 + 0.1365(X_{avg})) \times (2.83)$

^a These values represent the 1s and d2s limits described in ASTM C670.

^b X and X_{avg} should be entered into equations as positive numbers.

^c The value X_{avg} represents the average value of two test results.

Note 13—The precision estimates given in Table 2 are based on the analysis of test results from eight pairs of AMRL proficiency samples. The data analyzed consisted of results from 166 to 191 laboratories for each of the eight pairs of samples. The analysis included five binder grades: PG 52-34, PG 64-16, PG 64-22, PG 70-22, and PG 76-22 (SBS modified). The samples used in the analysis had an average mass loss ranging from -0.05 to -0.51 percent. The equations for precision estimates are reliable only in situations when the change in mass is negative. The details of this analysis are in the final report for NCHRP Project No. 9-26, Phase 3.

Table 3—Stratified Estimates of Precision

Condition	Standard Deviation (1s) ^a	Acceptable Range of Two Test Results (d2s) ^a
<i>Single-operator precision:</i>		
Mass Loss (%)		
0.0 to 0.1%	0.0079	0.0224
0.1 to 0.2%	0.0115	0.0327
0.2 to 0.3%	0.0152	0.0429
0.3 to 0.4%	0.0188	0.0532
0.4 to 0.5%	0.0224	0.0635
<i>Multilaboratory precision:</i>		
Mass Loss (%)		
0.0 to 0.1%	0.0084	0.0236
0.1 to 0.2%	0.0220	0.0623
0.2 to 0.3%	0.0357	0.1009
0.3 to 0.4%	0.0493	0.1395
0.4 to 0.5%	0.0630	0.1781

^a The values represented in this table are the 1s and d2s limits described as stratified values. Table 2 of this standard should be consulted as the final qualifier for precision purposes.

9.5. *Bias*—No information can be presented on the bias of the procedure because no material having an accepted reference value is available.

APPENDIX

(Nonmandatory Information)

X1. RECOMMENDED PROCEDURE FOR DETERMINING THE LEVELNESS OF THE CARRIAGE'S OPENINGS

X1.1. *Verify the accuracy and sensitivity of the electronic level as follows:*

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- X1.1.1. *Accuracy*—Place a square glass plate on a rigid bench top and place the level in the center of the glass plate in a direction parallel to one of the sides. If necessary, shim the glass plate so that it does not rock when pressed at its corners. Observe the position of the bubble and shim one edge of the glass plate until the bubble is centered between the markings on the vial. Take a reading. Rotate the level end-for-end and again observe the position of the bubble and take a reading. The readings should not differ by more than 0.2 degree.
- X1.1.2. *Sensitivity*—With the level in the center of the glass plate and parallel to one of the edges, shim one end of the level and observe the change in position of the bubble. The shim shall be of sufficient thickness to raise the level by 0.20 degree (0.5 mm in 140 mm [0.020 in. in 5.25 in.]). The addition of the shim shall cause a distinct and observable change in the position of the bubble. If the shift in the position of the bubble is not observable, the level lacks adequate sensitivity and shall be replaced.
- X1.2. Check the bearing that supports the carriage for wear. If there is any noticeable movement of the carriage when it is manually rotated in an upward motion, replace the bearing before proceeding.
- X1.3. Rotate the carriage so that one of the openings is at 90 degrees clockwise from the vertical direction (3 o'clock position). Insert the level into the opening, capture the reading, remove the level, and record the angle to the nearest 0.1 degree. Rotate the carriage by 180 degrees in a clockwise direction and repeat the measurement.
- X1.4. The readings for each position should be 0.0 ± 1.0 degree. Shim the underside of the oven until the requirements are met.
- X1.5. Repeat the process for the other openings. All readings should be 0.0 ± 1.0 degree. If this requirement cannot be met, consult the manufacturer.

¹ Similar, but not technically identical to ASTM D2872-04. The differences between standards are as follows:

- In Section 5.1.2, the required tolerance for the temperature of the oven is $\pm 1.0^\circ\text{C}$ ($\pm 1.8^\circ\text{F}$) in T 240 and $\pm 0.5^\circ\text{C}$ ($\pm 1.0^\circ\text{F}$) in the ASTM method.
- The position of the orifice is $\frac{1}{4} \pm \frac{1}{16}$ in. in Figure 2 of T 240 and is $\frac{1}{4} \pm \frac{1}{8}$ in. in Section 6.1 of the ASTM method.
- In Section 5.2, T 240 has requirements for the tolerance and standardization of the flowmeter.
- In Section 5.3.1, the T 240 requirements for the alternative thermometric device differ from the ASTM method.
- In Section 5.4, T 240 allows exterior frosting of the glass container.
- In Section 5.7, T 240 includes an optional electronic level.
- In Section 6.3, T 240 requirements for leveling and checking the bearing differ from the ASTM method.
- In Section 6.5, the RTFO is required to be preheated for at least 2 h in T 240 and for at least 16 h in the ASTM method.
- In Section 7.1, the maximum temperature of the oven for preparation of the sample is 163°C (325°F) in T 240 and 150°C (302°F) in the ASTM method.
- In Section 7.9.1, T 240 includes a detailed procedure in the event that mass flows out of the container.
- The Appendix is in T 240 but not in the ASTM method.