Standard Method of Test for

Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)

AASHTO Designation: T 324-14

AASHTO

1. SCOPE

1.1. This test method describes a procedure for testing the rutting and moisture-susceptibility of hot mix asphalt (HMA) pavement samples in the Hamburg Wheel-Tracking Device.

1.2. The method describes the testing of submerged, compacted HMA in a reciprocating rolling-wheel device. This test provides information about the rate of permanent deformation from a moving, concentrated load. A laboratory compactor has been designed to prepare slab specimens. Also, the Superpave Gyratory Compactor (SGC) has been designed to compact specimens in the laboratory. Alternatively, field cores having a diameter of 150 mm (6 in.), 250 mm (10 in.), or 300 mm (12 in.), or saw-cut slab specimens may be tested.

1.3. The test method is used to determine the premature failure susceptibility of HMA due to weakness in the aggregate structure, inadequate binder stiffness, or moisture damage. This test method measures the rut depth and number of passes to failure.

1.4. This test method measures the potential for moisture damage effects because the specimens are submerged in temperature-controlled water during loading.

1.5. *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*:

- R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 168, Sampling Bituminous Paving Mixtures
- T 209, Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA)
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

2.2. *ASTM Standard*:

- D6027, Standard Test Method for Calibrating Linear Displacement Transducers for Geotechnical Purposes (withdrawn 2013)

3. SIGNIFICANCE AND USE

3.1. This test measures the rutting and moisture susceptibility of an HMA specimen.

4. SUMMARY OF METHOD

4.1. A laboratory-compacted specimen of HMA, a saw-cut slab specimen, or a core taken from a compacted pavement is repetitively loaded using a reciprocating steel wheel. The specimen is submerged in a temperature-controlled water bath at a temperature specified by the agency. The deformation of the specimen, caused by the wheel loading, is measured.

4.2. The impression is plotted as a function of the number of wheel passes. An abrupt increase in the rate of deformation may coincide with stripping of the asphalt binder from the aggregate in the HMA specimen.

5. APPARATUS

5.1. *Hamburg Wheel-Tracking Machine*—An electrically powered machine capable of moving a 203.2-mm (8-in.) diameter, 47-mm (1.85-in.) wide steel wheel over a test specimen. The load on the wheel is 705 ± 4.5 N (158 ± 1.0 lb). The wheel reciprocates over the specimen, with the position varying sinusoidally over time. The wheel makes 52 ± 2 passes across the specimen per minute. The maximum speed of the wheel, reached at the midpoint of the specimen, is approximately 0.305 m/s (1 ft/s).

5.2. *Temperature Control System*—A water bath capable of controlling the temperature within ±1.0°C (1.8°F) over a range of 25 to 70°C (77 to 158°F) with a mechanical circulating system stabilizing the temperature within the specimen tank.

5.3. *Impression Measurement System*—A linear variable differential transducer (LVDT) device capable of measuring the depth of the impression (rut) of the wheel at the center $\pm^1/_2$ in. along the length of the wheel's path, to within 0.15 mm (0.006 in.), over a minimum range of 0 to 20 mm (0 to 0.8 in.). The system measures the rut depth, without stopping the wheel, at least every 400 passes. Rut depth is expressed as a function of the wheel passes.

Note 1—Users may require the capability of impression measurements at different intervals across the length of the wheel's path on the test specimen.

5.4. *Wheel Pass Counter*—A non-contacting solenoid that counts each wheel pass over the specimen. The signal from this counter is coupled to the wheel impression measurement, allowing for the rut depth to be expressed as a function of the wheel passes.

5.5. *Slab Specimen Mounting System*—A stainless steel tray that is mounted rigidly to the machine. The mounting system must restrict shifting of the specimen to within 0.5 mm (0.02 in.) during testing and must suspend the specimen to provide a minimum of 20 mm (0.8 in.) of free circulating water on all sides.

5.6. *Cylindrical Specimen Mounting System*—An assembly consisting of two high-density polyethylene (HDPE) molds or plaster of paris, in accordance with Section 8 to secure the specimen (as shown in Figures 1 and 2), placed in a stainless steel tray that is mounted rigidly to the machine. This mounting system must restrict shifting of the specimen to within 0.5 mm (0.02 in.) during testing and must suspend the specimen to provide a minimum of 20 mm (0.8 in.) of free circulating water on all sides.

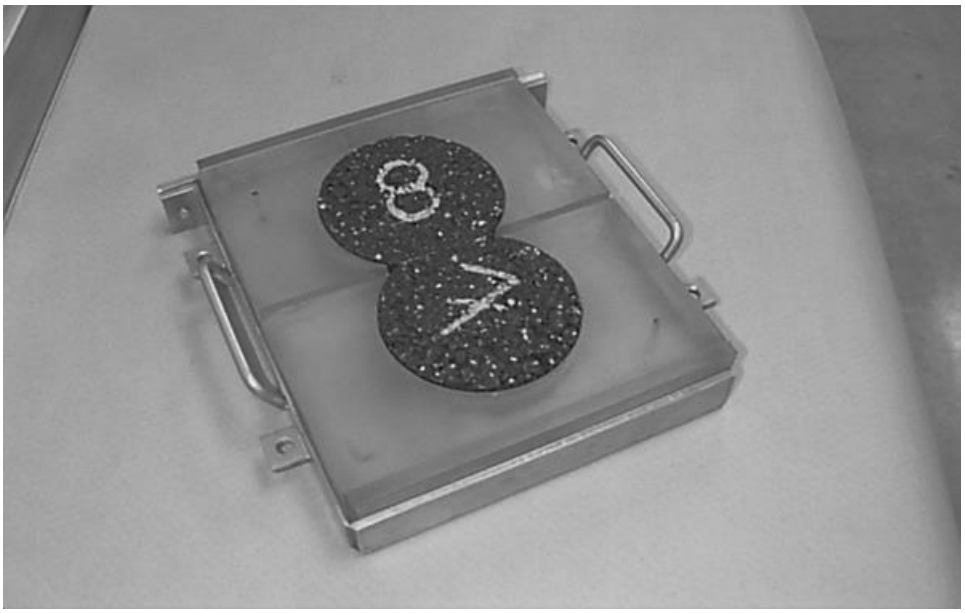
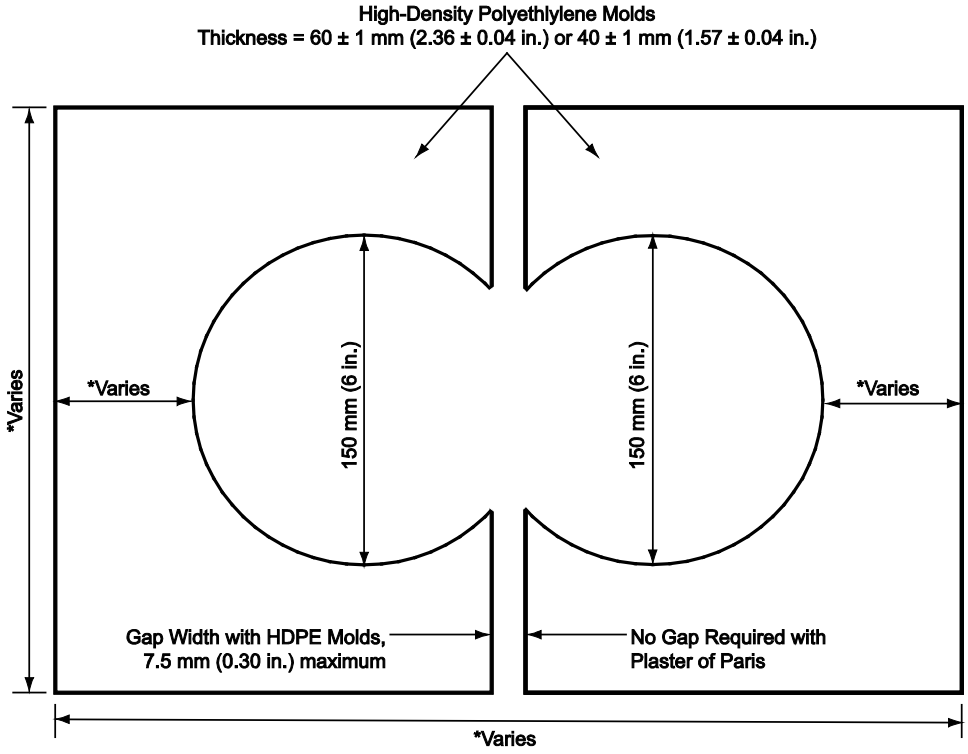


Figure 1—Cylindrical Specimen Mounting System



* Dimension may vary depending on manufacturer.

Figure 2—Schematic of Cylindrical Specimen Mounting System

5.7. *Linear Kneading Compactor*—A hydraulic-powered unit that uses a series of vertically aligned steel plates to compact molded asphalt mixtures into flat, rectangular slabs of predetermined thickness and density.

5.8. *Balance*—Of 12 000-g capacity, accurate to 0.1 g.

5.9. *Ovens*—For heating aggregate and asphalt binders.

5.10. *Superpave Gyratory Compactor (SGC)*—And molds conforming to T 312.

5.11. Bowls, spoon, spatula, etc.

6. SPECIMEN PREPARATION

6.1. *Number of Test Specimens*—Prepare two test specimens for each test, either slab specimens or cylinders.

6.2. *Laboratory-Produced HMA*:

6.2.1. Batch mixture proportions in accordance with the desired job mix formula.

6.2.2. Use the mixing temperature at which the asphalt binder achieves a viscosity of 170 ± 20 cSt. For modified asphalt binders, use the mixing temperature recommended by the binder manufacturer.

6.2.3. Dry-mix the aggregates and mineral admixture (if used) first, then add the correct percentage of asphalt binder. Mix the materials to coat all aggregates thoroughly. (Wet-mix the aggregates if using a lime slurry or other wet material.)

6.2.4. Condition test samples at the appropriate compaction temperature in accordance with the short-term conditioning procedure for mechanical properties in R 30.

6.2.5. Use the compaction temperature at which the asphalt binder achieves a viscosity of 280 ± 30 cSt. For modified asphalt binders, use the compaction temperature recommended by the binder manufacturer.

6.2.6. *Laboratory Compaction of Specimens*—Compact either slab specimens or SGC cylindrical specimens.

6.2.6.1. *Compacting Slab Specimens*—Heat molds and tools to compaction temperature. Compact slab specimens 320 mm (12.5 in.) long and 260 mm (10.25 in.) wide using a Linear Kneading Compactor (or equivalent). Specimen thickness must be at least twice the nominal maximum aggregate size, generally yielding a specimen 38 to 100 mm (1.5 to 4 in.) thick. Allow compacted slab specimens to cool at normal room temperature on a clean, flat surface until cool to the touch.

6.2.6.2. *Compacting SGC Cylindrical Specimens*—Compact two 150-mm (6-in.) diameter specimens in accordance with T 312. Specimen thickness must be at least twice the nominal maximum aggregate size, generally yielding a specimen 38 to 100 mm (1.5 to 4 in.) thick. Allow compacted specimens to cool at normal room temperature on a clean, flat surface until cool to the touch.

6.3. *Field-Produced HMA—Loose Mix*:

6.3.1. Obtain a sample of HMA in accordance with T 168.

6.3.2. *Laboratory Compaction of Specimens*—Compact either slab specimens or SGC cylindrical specimens.

6.3.2.1. *Compacting Slab Specimens*—Heat molds and tools to compaction temperature. Compact slab specimens 320 mm (12.5 in.) long and 260 mm (10.25 in.) wide using a Linear Kneading Compactor (or equivalent). Specimen thickness must be at least twice the nominal maximum aggregate size, generally yielding a specimen 38 to 100 mm (1.5 to 4 in.) thick. Allow compacted slab specimens to cool at normal room temperature on a clean, flat surface until cool to the touch.

6.3.2.2. *Compacting SGC Cylindrical Specimens*—Compact two 150-mm (6-in.) diameter specimens in accordance with T 312. Specimen thickness must be at least twice the nominal maximum aggregate size, generally yielding a specimen 38 to 100 mm (1.5 to 4 in.) thick. Allow compacted specimens to cool at normal room temperature on a clean, flat surface until cool to the touch.

6.4. *Field-Produced HMA—Field Compacted (Core/Slab Specimen)*:

6.4.1. *Cutting Field Cores or Field Slab Specimens*—Field cores or field slab specimens consist of wet saw-cut compacted specimens taken from HMA pavements. Cut field cores 300 mm (12 in.), 250 mm (10 in.), or 150 mm (6 in.) in diameter. Cut field slab specimens approximately 260 mm (10.25 in.) wide by 320 mm (12.5 in.) long. Use a slab specimen thickness of 38 to 100 mm (1.5 to 4 in.). The height of a field core or field slab specimen is typically 38 mm (1.5 in.), but may be adjusted to fit the specimen mounting system by wet saw-cutting. Cut field cores in accordance with Section 6.4.2.

Note 2—Take care to load the sample so it is level to the surface of the mold. Trim the sample if it is too tall, or use shims if it is too short (supporting with plaster if needed). Calibrate the down pressure from the wheel to be 705 N (158 lb) at the center, level to the top of the mold position. Even a small change in elevation will change the down pressure significantly.

6.4.2. *Cutting SGC Cylindrical Specimens and Field Cores*—Cut specimens after they have cooled to room temperature using a wet or dry saw. Saw the specimens along a secant line (or chord) such that when joined together in the molds, there is no space between the cut edges. The amount of material sawed from the SGC cylindrical specimens may vary to achieve a gap width no greater than 7.5 mm (0.3 in.) between the molds.

7. DETERMINING AIR VOID CONTENT

7.1. Determine the bulk specific gravity of the specimens in accordance with T 166.

7.2. Determine the maximum specific gravity of the mixture in accordance with T 209.

7.3. Determine the air void content of the specimens in accordance with T 269. The recommended target air void content is 7.0 ± 1.0 percent for laboratory-compacted specimens. Field specimens may be tested at the air void content at which they are obtained.

8. PROCEDURE

8.1. *Slab and Large Field Core Specimen Mounting*—Use plaster of paris to rigidly mount the 300 mm (12 in.), 250 mm (10 in.), or slab specimens in the mounting trays. Mix the plaster at approximately a 1:1 ratio of plaster to water. Pour the plaster to a height equal to that of the specimen to fill the air space between the specimen and the sides of the mounting tray. The slab specimen will be in direct contact with the mounting tray; however, plaster may flow underneath the specimen. The plaster underneath the specimen must not exceed 2 mm (0.08 in.). Allow the

plaster at least 1 h to set. If using other mounting material, it should be able to withstand 890 N (200 lb) of load without cracking.

8.2. *SGC Cylindrical and Field Core Specimen Mounting*—Place the HDPE molds in the mounting tray or use plaster of paris to rigidly mount the 150-mm (6-in.) diameter samples in the mounting tray meeting the dimensions outlined in Figure 2. If plaster of paris is used, pour the plaster to a height equal to that of the specimen to fill the air space between the specimen and the sides of the mounting tray. The specimen will be in direct contact with the mounting tray; however, plaster may flow underneath the specimen. The plaster underneath the specimen must not exceed 2 mm (0.08 in.) in thickness. Allow the plaster at least 1 h to set. For HDPE molds, insert the cut specimens in the molds. Shim the molds in the mounting tray as necessary. Secure the molds into the mounting tray by hand-tightening the bolts of the edge plate.

8.3. Place the mounting tray(s) with the test specimens into the device. Adjust the height of the specimen tray as recommended by the manufacturer, and secure by hand-tightening the bolts.

8.4. Turn the testing device and computer on.

8.5. Start the software used to communicate with the testing device.

8.6. Enter the pertinent project information and testing configuration requirements.

8.6.1. Select the test temperature based upon the applicable specifications.

8.6.2. Select the maximum allowable rut depth based upon the applicable specifications.

8.6.3. Select the maximum number of passes based on the applicable specifications.

8.6.4. Enter a start delay of 30 min to precondition the test specimens. The temperature of the specimens in the mounting tray will be the test temperature selected in Section 8.6.1 upon completion of this preconditioning period.

8.7. Proceed to Section 8.8 to operate the testing device in "Auto" mode. Proceed to Section 8.9 to operate the testing device in "Manual" mode.

Note 3—Perform the test in "Auto" mode for testing devices manufactured in the United States later than 1998, where software will automatically open and close the valves to fill and drain the water bath. Perform the test in "Manual" mode for devices made available to the United States prior to 1998.

8.8. *Performing the Test in Auto Mode*:

8.8.1. Adjust the height of the LVDT in accordance with the manufacturer's recommendations.

Note 4—The LVDT for each steel wheel is automatically zeroed at the start of the test. The software will display a zero at the start of the test.

8.8.2. If using cylindrical specimens, lower the wheels onto the edge of the test specimens such that a majority of the wheel is in contact with the HDPE molds in the mounting tray. If using slabs, lower the wheels onto the specimen no more than 5 min prior to the beginning of the test. In either case, the sample must not be submerged longer than 60 ± 5 min prior to starting the test. This includes the conditioning time.

8.8.3. Start the test by selecting the "Start" button of the testing device software.

Note 5—The start delay time or preconditioning time will start after the water heats to the test temperature selected in Section 8.6.1.

8.8.4. The wheel-tracking device will stop when 20,000 passes have occurred, when some other predetermined number of passes has occurred, or when the test has achieved the maximum impression depth established in Section 8.6.2. The testing device software automatically saves the test data file.

8.8.5. Raise the wheel(s) and remove the specimen mounting tray(s) and rutted specimens.

8.8.6. Proceed to Section 8.10.

8.9. *Performing the Test in Manual Mode*:

8.9.1. Close the drain valve(s) and fill the water bath of the wheel-tracking device with water until the float device(s) raises to a horizontal position.

Note 6—Adjust the amount of hot and cold water if necessary, as the water temperature may vary.

8.9.2. Precondition the test specimens in the water bath for 30 min after the water has reached the selected test temperature. Do not place the sample in the conditioning bath more than 60 ± 5 min prior to beginning the test. This includes the preconditioning time.

8.9.3. Lower the wheels onto the specimens after the test specimens have preconditioned at the selected test temperature for 30 min. For machines that start automatically after the selected preconditioning time, it is allowable to lower the wheels before the preconditioning cycle. The wheel must not be in contact with the specimen for more than 5 min prior to starting the wheel.

8.9.4. Ensure the micro-control unit's LVDT reads between 10 and 18 mm (0.4 and 0.7 in.). Adjust the LVDT height to obtain this reading. Loosen the two screws on the LVDT mount and slide the LVDT up or down to the desired height. Tighten the screws.

8.9.5. Start the test.

8.9.6. The wheel-tracking device will stop when 20,000 passes have occurred, when some other predetermined number of passes has occurred, or when the test has achieved the maximum impression depth established in Section 8.6.2. The device will also disengage if the average LVDT displacement (read from the micro-control unit, not the screen) is 40.90 mm (1.6 in.) or greater for an individual specimen. Note that the screen readout subtracts the initial LVDT reading from the total displacement.

8.9.7. Open the valve(s) beneath the tanks and drain the water bath. Raise the wheel(s) and remove the specimen mounting tray(s) and rutted specimens.

8.10. Clean the water bath, heating coils, wheels, and temperature probe with water and scouring pads or per the manufacturer's recommendations. Use a wet-dry vacuum to remove particles that have settled to the bottom of the baths. Clean the filter element and spacers after every test or per the manufacturer's recommendations. Do not use solvents to clean the water bath.

8.11. Turn the wheels after each test, so the same section of the wheel surface is not in contact with the test specimen from test to test. This rotation will provide for even wear over the entire wheel. The test should operate with a smooth movement across the test specimen.

9. CALCULATIONS

9.1. For the purposes of this method, a "test" is defined as:

a) Two 320-mm (12.5-in.) long by 260-mm (10.25-in.) wide slab specimens, two 250-mm (10-in.) core specimens, or two 300-mm (12-in.) core specimens representing similar material run in the Hamburg Wheel-Tracking Device simultaneously; or

b) Four 150-mm (6-in.) gyratory specimens or four 100-mm (4-in.) core specimens grouped in pairs (1 and 1a) representing similar material run in the Hamburg Wheel-Tracking Device simultaneously.

The test results will be reported as the average value of both specimens (a) or both pairs of specimens (b).

9.2. Plot the rut depth versus number of passes for each test. Figure 3 shows a typical plot of the output produced by the Hamburg Wheel-Tracking Device. From this plot, obtain the following values:

- slope and intercept of the first steady-state portion of the curve, and
- slope and intercept of the second steady-state portion of the curve.

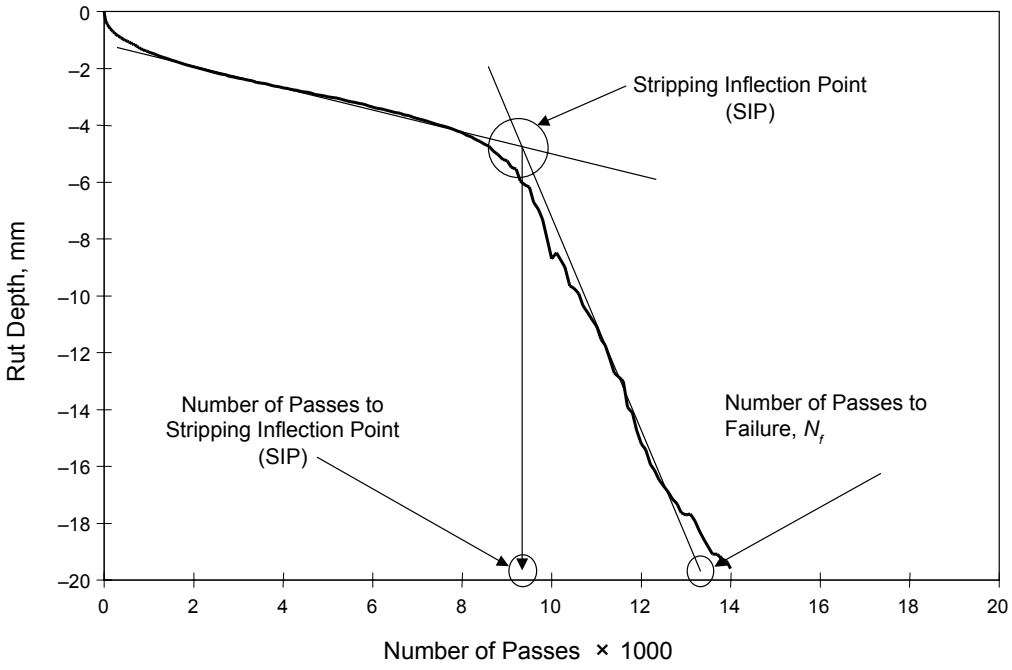


Figure 3—Hamburg Curve with Test Parameters

9.3. Calculate the following test parameters, all expressed in "Passes."

$$\text{stripping inflection point (SIP)} = \frac{\text{intercept (second portion)} - \text{intercept (first portion)}}{\text{slope (first portion)} - \text{slope (second portion)}} \qquad (1)$$

where:

Failure rut depth is the specified maximum allowable rut depth for the test.

Note 7—The specifying agency may choose to define a "test" as an individual slab or core specimen or as a pair of specimens as defined in Section 9.1.

10. REPORT

10.1. *The report must include the following parameters*:

10.1.1. HMA production (field or lab);

10.1.2. Compaction method (slab or SGC cylindrical specimen);

10.1.3. Number of passes at maximum impression;

10.1.4. Maximum impression;

10.1.5. Test temperature;

10.1.6. Specimen(s) air voids;

10.1.7. Type and amount of anti-stripping additive used;

10.1.8. Creep slope;

10.1.9. Strip slope; and

10.1.10. Stripping inflection point.

11. PRECISION AND BIAS

11.1. Work is underway to develop precision and bias statements for this standard.

Note 8—Field-compacted samples have proven to be insufficiently controlled for inclusion in a precision and bias statement.

12. KEYWORDS

12.1. Compacted hot mix asphalt; moisture-susceptibility; rutting; wheel-track testing.

APPENDIXES

(Nonmandatory Information)

X1. MAINTENANCE

X1.1. Grease all of the grease fittings with fresh grease every 20 tests (not to exceed 2 months) per the manufacturer's recommendations.

X2. CALIBRATION/EQUIPMENT VERIFICATION

X2.1. Verify the water bath temperature is within ±1.0°C (1.8°F) of the temperature readout from the testing device or software every 6 months. Measure the water bath temperature at four locations per the manufacturer's recommendations. Average the four measurements and report this as the water bath verification temperature.

X2.2. Verify the LVDT calibration in accordance with ASTM D6027 or per the manufacturer's recommendations.

X2.3. Verify the load from the wheel loading assembly at the level position per the manufacturer's recommendations to be 705 ± 4.5 N (158 ± 1.0 lb). A calibrated load cell, accurate to 0.4 N (0.1 lb) is sufficient for this check.

X2.4. Verify that the wheel is reciprocating on the test sample at 52 ± 2 passes per minute.