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Standard Practice for Radial Light Truck Tires to Establish Equivalent Test Severity Between a 1.707-m (67.23-in.) Diameter Rotating Roadwheel and a Flat Surface¹

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1. Scope

1.1 This practice describes the procedure to identify equivalent test severity conditions between a 1.707-m diameter laboratory roadwheel surface and a flat or highway surface for radial pneumatic light truck (LT) tires.

1.1.1 Tire operational severity, as defined as the running or operational temperature for certain specified internal tire locations, is not the same for these two test conditions. It is typically higher for the laboratory roadwheel at equal load, speed and inflation pressure conditions due to the curvature effect.

1.1.2 The practice applies to specific operating conditions of light truck tires up through load range E for such tires used on vehicles having a gross vehicle weight rating (GVWR) ≤ 4536 kg (10000 lb).

1.1.3 The specific operating conditions under which the procedures of the practice are valid and useful are completely outlined in Section 6, (Limitations) of this standard.

1.1.4 It is important to note that this standard is composed of two distinct formats:

1.1.4.1 The usual text format as published in this volume of the Book of Standards (Vol. 09.02).

1.1.4.2 A special interactive electronic format that uses a special software tool, designated as prediction profilers or profilers. This special profiler may be used to determine laboratory test conditions that provide equivalent tire internal temperatures for the belt edge region for the two operational conditions, that is, the curved laboratory roadwheel and flat highway test surfaces.

1.2 The prediction profilers are based on empirically developed linear regression models obtained from the analysis of a large database that was obtained from a comprehensive experimental test program for roadwheel and flat surface testing of

typical radial light truck (LT) tires. See Section 7 and the research report² for more details.

1.2.1 For users viewing the standard on CD-ROM or PDF, with an active and working internet connection, the profilers can be accessed on the ASTM website by clicking on the links in 7.5 and 7.6.

1.2.2 For users viewing the standard in a printed format, the profilers can be accessed by entering the links to the ASTM website in 7.5 and 7.6 into their internet browsers.

1.3 For this standard, SI units shall be used, except where indicated.

1.4 *This standard does not purport to address all of the safety concerns, if any, 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 *ASTM Standards:*³

F414 Test Method for Energy Absorbed by a Tire When Deformed by Slow-Moving Plunger

F538 Terminology Relating to the Characteristics and Performance of Tires

F551 Practice for Using a 67.23-in. (1.707-m) Diameter Laboratory Test Roadwheel in Testing Tires

F1922 Test Method for Tires, Pneumatic, Vehicular, Highway

F2779 Practice for Commercial Radial Truck-Bus Tires to Establish Equivalent Test Severity Between a 1.707-m (67.23-in.) Diameter Roadwheel and a Flat Surface

IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

¹ This practice is under the jurisdiction of ASTM Committee F09 on Tires and is the direct responsibility of Subcommittee F09.30 on Laboratory (Non-Vehicular) Testing.

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² Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: F09-1002.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3. Terminology

3.1 Definitions:

3.1.1 *belt edge (BE) temperature, n*—in the cross section of a radial tire, the temperature at the edge of the stabilizer plies or belts, for example, in the rubber region of the two belt edges.

3.1.2 *contained air temperature, n*—the temperature of the air contained within the tire cavity when the tire is mounted and inflated on the proper rim.

3.1.3 *curved equivalent test severity, n*—in tire testing, the test conditions (load, rotational speed, tire inflation pressure) on the flat or highway surface that will provide equivalent internal tire temperatures, for example, at the belt edge, to a known set of curved 1.707-m roadwheel surface test conditions.

3.1.4 *endurance, n*—of a tire, the ability of a tire to perform as designed in its intended usage conditions such as load, inflation pressure, speed, time, and environmental conditions.

3.1.5 *high speed performance, n*—of a tire, the rotational speed capability of a tire to perform as designed in its intended usage conditions such as load, inflation pressure, speed, time, and environmental conditions.

3.1.6 *highway equivalent test severity, n*—in tire testing, the test conditions (load, rotational speed, tire inflation pressure) on the 1.707-m roadwheel that will provide equivalent internal tire temperatures, for example, at the belt edge, to a known set of highway or flat surface conditions.

3.1.7 *light truck tire, n*—a tire that has a LT prefix or suffix in the tire size description: this indicates that the tire was primarily intended for service on light trucks with gross vehicle weights (GVWR) ≤ 4536 kg.

3.1.8 *load range, n*—of a light truck tire, a letter designation (B, C, D, E) used to identify a given size tire with its load and inflation limits when used in a specific type of service. **F414, F1922**

3.1.9 *maximum rated load, n*—the load corresponding to a maximum tire load capacity at the rated inflation pressure in accordance with the publications of tire and rim standards current at the time of manufacture.

3.1.10 *measured inflation pressure, n*—gauge pressure of a tire measured at a given time under ambient temperature and barometric pressure. **F538**

3.1.11 *rated inflation pressure, n*—the minimum cold inflation pressure specified at the maximum rated load of a tire in accordance with the publications of tire and rim standards current at the time of manufacture.

3.1.12 *rim, n*—specially shaped circular periphery to which a tire may be mounted with appropriate bead fitment. **F538**

3.1.13 *test inflation pressure, n*—specified gauge pressure of a tire mounted on a rim, measured at a given time under ambient temperature and barometric pressure for evaluation purposes.

3.1.14 *test load, n*—the force applied to a tire through the rim; it is normal to the metal loading plate onto which the tire is loaded. **F538**

3.1.15 *tire, pneumatic, n*—a hollow tire that becomes load-bearing upon inflation with air, or other gas, to a pressure above atmospheric. **F538**

3.1.16 *tire, radial, n*—a pneumatic tire in which the ply cords that extend to the beads are laid substantially at 90° to the center line of the tread, the tire being stabilized by a belt. **F538**

3.1.17 *tire speed rating, n*—the maximum speed for which the use of the tire is rated under certain conditions as designated by the speed symbol marked on the tire sidewall or maximum speed rating as determined by the manufacturer.

3.1.18 *tire test speed, n*—the tangential speed at the point of contact with the road curved surface of a rotating tire for evaluation purposes.

4. Summary of Practice

4.1 This practice provides a procedure to determine the 1.707-m diameter roadwheel tire test conditions (speed, load, and inflation pressure) for flat surface equivalent test severity. It also enables the user to determine the 1.707-m diameter roadwheel test conditions for a specific increase or decrease in severity with respect to flat surface test severity. The converse is also true, determining the flat surface test conditions that provide equal test severity to a selected set of 1.707-m diameter roadwheel test conditions.

4.2 This practice provides a prediction profiler procedure (see Section 7 and Annex A1) to establish equivalent test severity between a 1.707-m diameter rotating wheel (Practice F551) and a flat surface, by adjusting test speed, load and inflation pressure. The prediction profiler provides the ability to identify numerous test conditions and resultant belt edge temperature differentials within the confines of this practice as described in Section 6.

4.3 Equivalent test severity is defined as the set of test conditions (load, speed, and tire inflation pressure) that provide equivalent steady state tire internal operating temperatures at the belt edge (BE) for: (1) a conversion from flat surface conditions to a 1.707-m diameter roadwheel conditions or (2) a conversion from a 1.707-m diameter roadwheel conditions to a flat surface conditions.²

5. Significance and Use

5.1 Historically, tires have been tested for endurance by a variety of test methods. Some typical testing protocols have been: (1) proving grounds or highway testing over a range of speeds, loads, and inflations, (2) testing on fleets of vehicles for extended periods of time, and (3) indoor (laboratory) testing of tires loaded on a rotating 1.707-m diameter roadwheel; however, the curved surface of a 1.707-m diameter roadwheel results in a significantly different tire behavior from that observed on a flat or highway surface.

5.1.1 This practice addresses the need for providing equivalent test severity over a range of typical tire operating conditions between a 1.707-m diameter roadwheel surface (Practice F551) and a flat surface. There are different deformations of the tire footprint on curved versus flat surfaces resulting in different footprint mechanics, stress/strain cycles, and significantly different internal operating temperatures for the two

types of contact surface. Since tire internal temperatures are key parameters influencing tire endurance or operating characteristics under typical use conditions, it is important to be able to calculate internal temperature differentials between curved and flat surfaces for a range of loads, inflation pressures and rotational velocities (speeds).

5.2 Data from lab and road tire temperature measurement trials were combined, statistically analyzed, and tire temperature prediction models derived.²

5.2.1 The fit of the models to the data is shown as the coefficient of determination, R^2 , for the critical belt edge:

$$R^2 = 0.90$$

Two Standard Deviations (2-sigma) = 3.2°C
(that is, 95 % of the variation from the means
is within $\pm 3.2^\circ\text{C}$)

5.2.2 These prediction models were used to develop the prediction profilers outlined in Section 7 and Annex A1.

6. Limitations

6.1 The procedures as given are valid for radial pneumatic LT tires up through load range E for the following ranges of test speed, tire inflation pressure and test load, for flat test surfaces and a 1.707-m diameter roadwheels:

6.1.1 Tire test speed in the range of 80 to 137 km/h (flat and curved surface).

6.1.2 Tire test inflation pressure in the range of 50 to 110 % of the inflation pressure associated with the maximum load capacity of the tire, for example, sidewall stamped.

6.1.3 Tire test load in the range of 41 to 143 % of the maximum load capacity of the tire, for example, sidewall-stamped maximum rated load.

6.2 The procedures described in Section 7 determine equivalent operating conditions between a flat surface and a 1.707-m diameter roadwheel by using empirical models to match tire internal belt edge temperatures. These empirical models are derived from a wide variety of tires tested within the above ranges and can be used to interpolate at any conditions within the constraints listed above. It is not recommended that the procedures be used for extrapolation beyond the constraints listed above.

7. Procedure

7.1 Equivalent Test Severity Prediction Profilers:

7.1.1 The flat-to-curved (FTC) prediction profilers are SAS JMP interactive displays based on algorithms developed from laboratory and highway tire temperature measurements. They provide 1.707-m diameter roadwheel tire test (rotational) speed, tire test load, and tire test inflation pressure conditions for equivalent test severity (as well as for lesser or more severe test severity) based upon the belt edge region temperatures. Before using the profilers, the user will have targeted a roadwheel “delta temperature” amount in degrees C for the tire

running on a flat surface, that is, the targeted operating difference in temperature between the roadwheel and highway condition. By first identifying the desired “delta temperature(s),” the user will be able to identify (via the profilers) roadwheel test conditions to achieve the temperature “delta(s).” The equivalency determination is based upon a “delta” in rotational speed (km/h), % load, and/or % inflation from the known highway operating conditions within the limitations specified in Section 6.

7.1.2 The converse also applies for equivalent highway test conditions that can be identified from specified roadwheel test conditions by use of the curved-to-flat (CTF) prediction profilers.

7.2 When using either the ‘FTC (or CTF) Delta DegC’ prediction profilers, three variables are available for interactive modification:

Delta 1.7 m Dia RW KPH	The change in tire rotational speed for the roadwheel relative to the highway speed in km/h.
1.7 m Dia RW % Flat Surface Inflation	The percent change in roadwheel tire inflation relative to the highway tire inflation.
1.7 m Dia RW % Flat Surface Load	The percent change in roadwheel tire load relative to the highway tire load.

7.2.1 These variables appear along the x -axis of the prediction profiler and can be changed by clicking and dragging. Effects of changing these variables can be viewed as temperature changes in the belt edge region identified on the y -axis as:

“LT BE Flat Surface to 1.7 m Dia RW Delta DegC”

7.3 The curved-to-flat (CTF) prediction y -axis is labeled “LT BE 1.7 m Dia RW to Flat Surface Delta DegC” while the x -axis are labeled from the perspective of identifying the required changes from roadwheel conditions to flat conditions in order to achieve the targeted severity levels on the flat surface.

7.4 See Annex A1 for examples of prediction profilers outputs.

7.5 Flat-to-Curved (FTC) Prediction Profiler – Macro Button (available on electronic copy or ASTM F09 site):

http://www.astm.org/F2869_flat_to_curved.html

7.6 Curved-to-Flat Surface (CTF) Prediction Profiler – Macro Button (available on electronic copy or ASTM F09 site):

http://www.astm.org/F2869_curved_to_flat.html

8. Keywords

8.1 curved to flat surface; endurance; equivalency; flat to curved surface; high speed temperature; LT metric; highway equivalent; radial light truck tire; roadwheel; roadwheel testing; test severity; tire; tire temperature; 67.23-in.; 1.707-m

ANNEX
(Mandatory Information)
A1. PROCESS TO PREDICT EQUIVALENT TEST CONDITIONS AND PREDICTION PROFILER EXAMPLES

A1.1 To obtain highway equivalent test severity on a 1.707-m diameter roadwheel based upon the operational factors of tire rotational speed, tire load, and tire inflation pressure:

A1.1.1 A targeted severity level is first identified for the tire on the curved surface, that is, tire internal temperature delta(s) with respect to the same tire operated on a flat surface. For the first example that follows, the targeted test severity level is for the belt edge temperature as “equal to” (that is, Delta Deg C = 0). The prediction profilers have the capability to target a specific “Deg C delta” increase or decrease as well. The targeted severity level is based upon a known set of flat surface operating conditions (tire load, tire rotational speed, tire inflation pressure)

A1.1.2 For the targeted severity level (for example, “equal to”) based upon the known highway (flat) conditions, the prediction profiler can determine the 1.707-m diameter road wheel test conditions of tire test load, tire test rotational speed, and tire test inflation pressure.

A1.1.3 This can be an iterative procedure to identify the required 1.707-m diameter road wheel test conditions of tire test load, tire test rotational speed, and tire test inflation pressure by specifying two of the three variables and using the profilers to identify the third, subject to the limitations specified in Section 6.

A1.2 *Example #1*—For any LT tire up through load range E with a specified set of flat surface operating conditions, predict the required 1.707-m diameter roadwheel load for equivalent belt edge temperature while keeping speed and inflation pressure equal to the flat surface speed and inflation pressure. The FTC prediction profiler yields the following results. See Fig. A1.1.

A1.2.1 *Step 1*—You will not move the speed bar because you want to maintain the same speed on the 1.707-m diameter roadwheel that you have on the flat surface, therefore, the differential should be zero.

A1.2.2 *Step 2*—You will not move the inflation pressure bar because you want to maintain the same inflation pressure on the 1.707-m diameter roadwheel that you have on the flat surface, therefore, the differential should be zero.

A1.2.3 *Step 3*—Move the load bar to the left to decrease the belt edge temperature (y-axis) differential to approximately zero.

A1.2.4 *Step 4*—For Equivalent Test Severity, it is desired to have the belt edge temperature difference to be approximately zero between the flat surface and the 1.707-m diameter roadwheel. While keeping speed and inflation pressure equal to the flat surface speed and inflation pressure, a reduction in load of approximately 12.3 % from the flat surface load is required to maintain equal belt edge temperatures in the transition from a flat surface to the 1.707-m diameter roadwheel.

A1.3 *Example #2*—For any LT tire up through load range E with a specified set of 1.707-m diameter roadwheel operating conditions, predict the required flat surface inflation pressure adjustment required for equivalent belt edge temperature while keeping speed and load equal to the 1.707-m diameter roadwheel speed and load. The CTF prediction profiler yields the following results. See Fig. A1.2.

A1.3.1 *Step 1*—You will not move the speed bar because you want to maintain the same speed on the flat surface that you have on the 1.707-m diameter roadwheel, therefore, the differential should be zero.

A1.3.2 *Step 2*—You will not move the load bar because you want to maintain the same load on the flat surface that you have on the 1.707-m diameter roadwheel, therefore, the differential should be zero.

A1.3.3 *Step 3*—Move the inflation pressure bar to the left to decrease the belt edge temperature (y-axis) differential to approximately zero.

A1.3.4 *Step 4*—For Equivalent Test Severity, it is desired to have the belt edge temperature difference to be approximately zero between the 1.707-m diameter roadwheel and the flat surface. While keeping speed and load equal to the 1.707-m surface speed and load, a reduction in inflation pressure of approximately 23.8 % from the 1.707-m surface inflation pressure is required to maintain equal belt edge temperatures in the transition from curved to flat