Standard 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[1]

This standard is issued under the fixed designation F2779; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 commercial radial truck-bus 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 load range F through L for such commercial radial truck-bus tires.

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 tread centerline, belt edge, or ply ending 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 commercial truck and bus tires. See Section 7 and References (**1, 2**)[2,3] 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:*[4]

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

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

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 (working, widest) plies or belts, for example, in the rubber region of the belt edges.

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[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] The boldface numbers in parentheses refer to the list of references at the end of this standard.

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

[4] 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.

3.1.2 *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 flat or highway surface test conditions.

3.1.7 *load range, n—of a truck-bus tire*, a letter designation (F, G, H, J, L, M) used to identify a given size tire with its load and inflation limits when used in a specific type of service.

3.1.8 *maximum rated load, n*—the load corresponding to the 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.

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

3.1.10 *ply ending (PE) temperature, n— in the cross section of a radial tire*, the temperature at the higher turn-up end of the body ply, for example, in the apex component region of the ending.

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

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

3.1.17 *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**

3.1.18 *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.

3.1.19 *tread centerline (CL) temperature, n—in the cross section of a radial tire*, the temperature under the center of the tread region, for example, at the bottom region of the tread rubber component.

3.1.20 *truck-bus tire, n*—a tire that is intended for service on commercial truck-bus vehicles.

4. Summary of Practice

4.1 This practice provides a procedure to determine 1.707-m diameter roadwheel tire test conditions (speed, load, and inflation pressure) for equivalent test severity with flat surface test conditions. 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 for the determination of the flat surface tire test conditions for equivalent test severity with a specific 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 7.1.

4.3 Equivalent test severity is defined as the set of test conditions (load, speed, and tire inflation pressure) that provides equivalent steady state tire belt edge (BE), tread centerline (CL), or ply ending (PE) temperatures for: *(1)* a conversion from flat surface conditions to 1.707-m diameter roadwheel conditions, or *(2)* a conversion from 1.707-m diameter roadwheel conditions to flat surface conditions.[3]

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.[3]

5.2.1 The fit of the models to the data is shown as the coefficient of determination, R^2, for the two critical crown area temperatures, i.e. tread centerline and belt edge, as well as the ply ending area:

$$R^2 = 0.89, 0.90, \text{ and } 0.89 \text{ respectively}$$

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

6. Limitations

6.1 The procedures within this standard are valid for commercial radial pneumatic truck-bus tires of load range F through load range L and for the following ranges of test speed, tire inflation pressure and tire load, for flat test surfaces and 1.707-m diameter roadwheels:

6.1.1 Tire test speed in the range of 77 to 132 km/h (flat surface) and 40 to 132 km/h (curved surface).

6.1.2 Tire test inflation pressure in the range of 58 to 107 % of sidewall-stamped inflation pressure.

6.1.3 Tire test load in the range of 49 to 128 % of sidewall-stamped maximum load.

6.1.4 Ambient temperature = 38°C.

6.2 The procedures described in Section 7 identify equivalent operating conditions for a flat surface and a 1.707-m diameter roadwheel by using empirical models to match tire internal component temperatures. These empirical models were 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, tread centerline, or ply ending region temperatures. Before using the profilers, the user will have targeted a roadwheel "delta temperature" amount in degrees C (or % degrees C) for one (or more) of these regions with respect to the temperatures in these regions 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, load, and/or inflation from the known highway operating conditions within the limitations specified in 6.1.

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' or the 'FTC (or CTF) Delta % DegC' prediction profilers, four variables are available for interactive modification:

"$RW_{1.7m}$Delta km/h"	The change in tire rotational speed for the roadwheel relative to the highway speed.
"$RW_{1.7m}$% of Flat Inf"	The percent change in roadwheel tire inflation relative to the highway tire inflation.
"$RW_{1.7m}$% of Flat Load"	The percent change in roadwheel tire load relative to the highway tire load.
"Speed $Rating_{km/h}$"	The manufacturer's recommended highway speed rating for a specific tire.

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 ply ending, tread centerline, and belt edge regions identified on the *y*-axis, depending whether the "Delta Deg C" or the "Delta % Deg C" prediction profiler is used:

"FTC Pred PE Delta DegC" (or "FTC Pred PE Delta % DegC")

"FTC Pred CL Delta DegC" (or "FTC Pred CL Delta % DegC")

"FTC Pred BE Delta DegC" (or "FTC Pred BE Delta % DegC")

7.3 The curved-to-flat (CTF) prediction profilers maintain the same labels for the *y*-axis 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 Buttons (available on the ASTM F09 site):

http://www.astm.org/flat_percent.html
http://www.astm.org/flat_delta.html

7.6 Curved-to-Flat (CTF) Prediction Profiler – Macro Buttons (available on the ASTM F09 site):

http://www.astm.org/curved_percent.html
http://www.astm.org/curved_delta.html

8. Keywords

8.1 commercial tire; curved to flat; endurance; equivalency; flat to curved; high speed; highway equivalent; roadwheel; roadwheel testing; temperature; test severity; tire; tire temperature; truck-bus; 67.23-in.; 1.707-m

ANNEX

(Mandatory Information)

A1. 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" (or "% Deg C delta") increase or decrease as well, and this is illustrated in the second example. 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 6.1.

A1.2 For the example of a 120 km/h (75 mph) rated tire with a known set of flat surface operating conditions:

A1.2.1 The prediction of the required 1.707-m diameter road wheel tire rotational speed for equivalent belt edge temperature while keeping tire load and tire inflation pressure equal to the flat surface tire load and tire inflation pressure is based on the "FTC Pred BE Delta_DegC" prediction profiler, which yields the following results. See Fig. A1.1.

A1.2.2 A reduction in tire rotational speed of approximately 41 km/h ("$RW_{1.7m}$ Delta KPH") from the flat surface tire rotational speed is required to maintain approximately equal belt edge temperature from flat to curved (that is, "FTC Pred BE Delta_DegC").

A1.2.3 Also, the tread centerline temperature ("FTC Pred CL Delta_DegC") is predicted to be approximately 15°C higher than the flat surface centerline temperature with this roadwheel tire rotational speed reduction.

A1.2.4 Finally, the ply ending temperature ("FTC Pred PE Delta_ DegC") is predicted to be approximately 4°C lower than the flat surface ply ending temperature.

A1.3 For the example of the same tire with a known set of flat surface operating conditions:

A1.3.1 The prediction of the required 1.707-m diameter roadwheel tire rotational speed for a belt edge temperature increase of 10 % versus the flat surface belt edge temperature while keeping tire load and tire inflation pressure equal to the flat surface tire load and tire inflation pressure is based on the "FTC Delta %_DegC" prediction profiler, which yields the following results. See Fig. A1.2.

A1.3.2 A reduction in tire rotational speed of approximately 22 km/h ("RW1.7m Delta KPH") from the flat surface tire rotational speed creates an approximately 10 % higher belt edge temperature from flat to curved (that is, "FTC Pred BE Delta %_DegC").

A1.3.3 Also, the tread centerline temperature ("FTC Pred CL Delta %_DegC") is predicted to be approximately 28 % higher than the flat surface centerline temperature with this roadwheel tire rotational speed reduction.

A1.3.4 Finally, the ply ending temperature ("PE Delta %_DegC") is predicted to be approximately 3 % higher than the flat surface ply ending temperature.

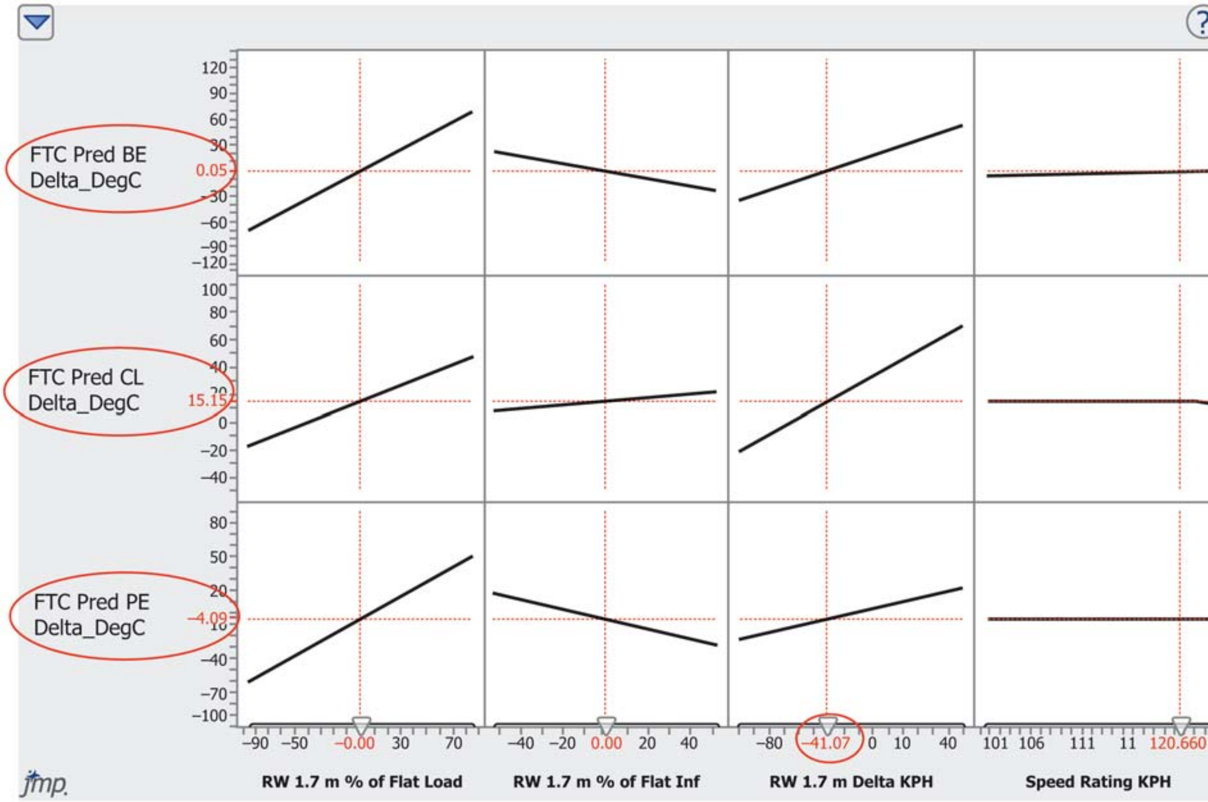

FIG. A1.1 Prediction Profiler – Flat-to-Curved Delta for Equivalent Belt Edge Temperature

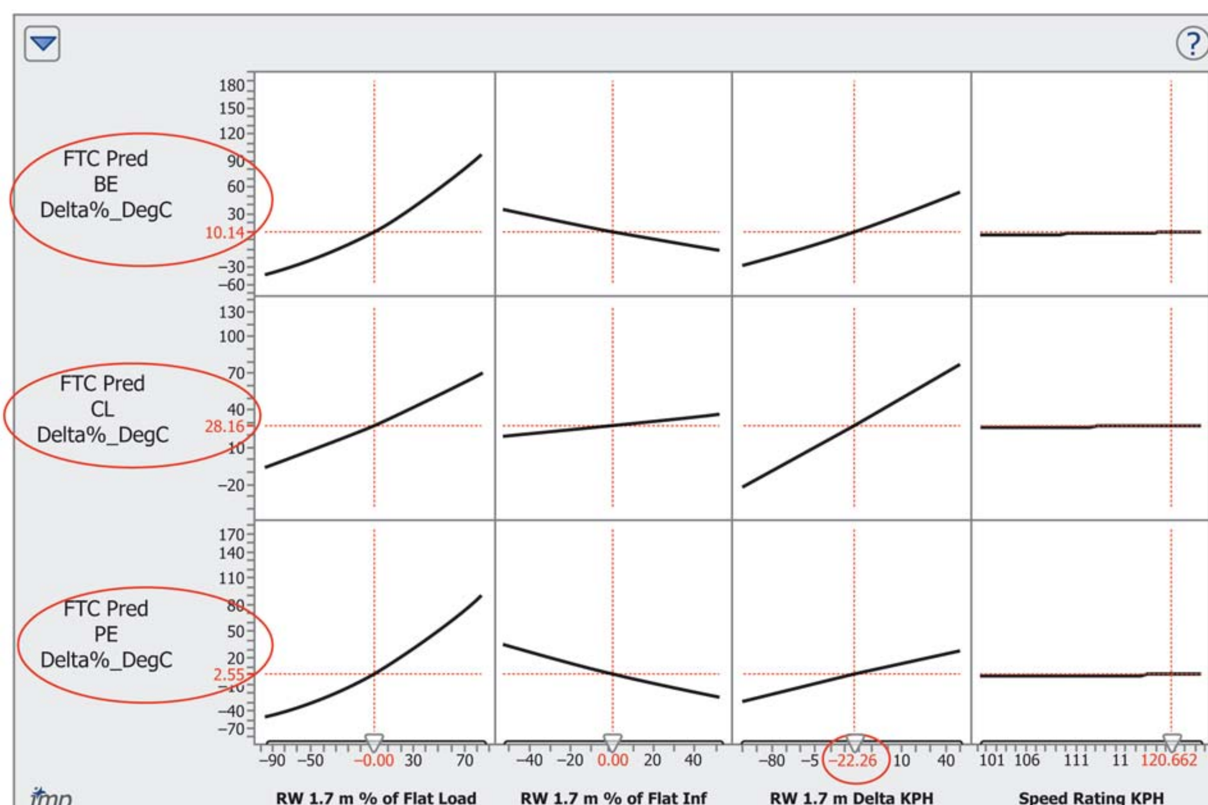

FIG. A1.2 Prediction Profiler – Flat-to-Curved % Delta for 10 % Increase in Belt Edge Temperature

APPENDIXES

(Nonmandatory Information)

X1. BASIS OF THE PROFILING TO PREDICT EQUIVALENT TEST CONDITIONS

X1.1 *Measured Tire Temperature Locations*—As defined in Section 3 (Terminology), belt edge (BE), tread centerline (CL), and ply ending (PE) temperatures were measured and predicted at the locations as shown within the tire in Fig. X1.1.

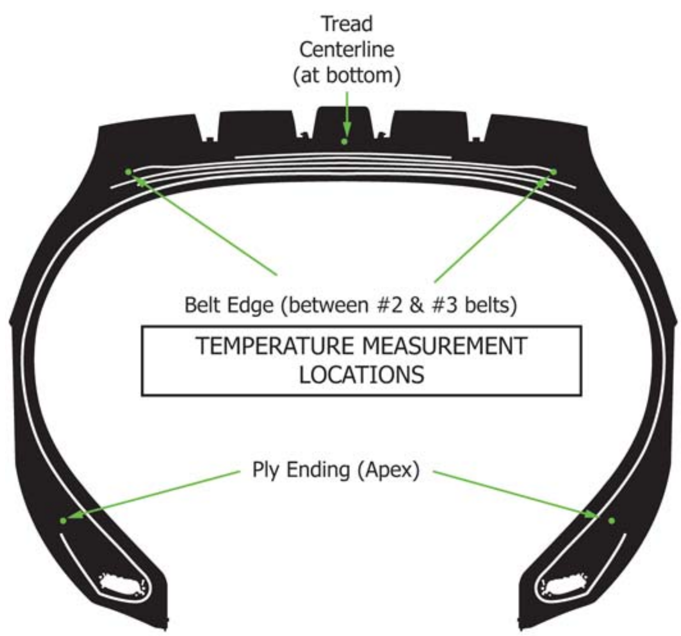

FIG. X1.1 Belt Edge (BE), Centerline (CL), and Ply Ending (Apex) (PE) Temperature Measurement Locations

X2. RATIONALE

X2.1 A standard practice is needed to provide an industry standard for commercial radial truck-bus tire laboratory temperature algorithms that equilibrate with flat surface (highway) operating temperatures and to determine equivalency for road versus laboratory operating conditions. Users of the new standard are expected to be government agencies, independent tire testing labs, and tire manufacturers.

X2.2 Therefore, the ASTM standard practice was developed so that commercial radial truck-bus tire performance can be evaluated through a standard industry method based upon internal tire temperatures that have been predicted using the algorithms developed by the Truck-Bus Test Development Task Group of the F09 Tire Committee.

X2.3 The standard refers to prediction profilers to determine laboratory test conditions that provide equivalent tire temperatures for either the tread centerline, belt edge, or ply ending regions between curved (laboratory roadwheel) and flat (highway) test surfaces. The profilers are empirically-based, linear regression modeling tools that are included within this standard.[3]

X2.4 *Commercial Radial Truck-Bus Tire Endurance Performance*:

X2.4.1 Tire endurance performance is not only dependent on tire design but also on operating conditions such as load, inflation pressure, and speed as well as the environment in which the tire operates.

X2.4.2 In service, tires are subjected to a variety of conditions:

X2.4.2.1 Ambient temperatures can range from –20ºC to over 40ºC.

X2.4.2.2 Highway speeds can range from 90 to 120 km/h.

X2.4.2.3 Vehicle tire loads can vary with respect to its gross vehicle weight rating (GVWR).

X2.4.2.4 Inflation pressure can range from the vehicle manufacturer's recommended inflation pressure, to the sidewall-stamped inflation pressure, to a fleet service pressure, or to something less due to service related conditions.

X2.4.3 For commercial truck-bus tires, the tire is considered to be severely underinflated by the Rubber Manufacturers Association (RMA) (**3**) and the Occupational Health and Safety Administration (OSHA) (**4**) when it is at or below 80 % of the recommended inflation pressure.

X2.4.4 Certain combinations of these operating conditions can result in tires experiencing elevated temperatures when operated under high loads, high speed or low inflation pressure and have a bearing on tire performance and service life (**5**).

X2.4.5 At highly elevated tire operating temperatures, thermally-driven changes in tire material properties can occur and tire performance and service life may be negatively impacted. A properly maintained and operated tire will have temperatures that do not result in significant thermal changes in the tire material properties.

X2.4.6 Therefore, endurance testing is done as part of the evaluation of tire performance.

X2.4.7 Testing for endurance, like many other tire tests, is usually performed in the laboratory on a 1.707-m diameter roadwheel. The tire is rotated under load and speed on a surface that has a relatively small curvature compared to the highway, where the surface is nearly flat. Due to this difference in curvature between a flat surface and the roadwheel, several tire effects are created and must be considered:

X2.4.7.1 A foreshortening of the tire contact patch (or "footprint") resulting in higher overall footprint contact pressures and tire stresses.

X2.4.7.2 A change in shape of the footprint itself; i.e. different from its optimal, flat surface shape that results in increases to the centerline contact pressure and tire stresses.

X2.4.7.3 An overdeflection of the tire sidewall due to the reverse curvature of the footprint.

X2.4.7.4 An increase in the flex cycle severity.

X2.4.8 As a result, local heat generation rates increase and tire temperatures will often be significantly higher when the tire is tested on the roadwheel compared to a tire used on the road at the same load, inflation pressure and rotational speed.

X2.4.9 Consequently, laboratory test conditions that are equal to road conditions can result in end-of-test (EOT) events that are not representative of typical highway tire removal conditions. For example, thermal reversion manifested as tread chunking, can be a laboratory EOT condition which is a consequence of the testing method. In such cases, the test termination does not correspond to what would have taken place during normal on-vehicle use. Occurrences of such non-representative EOT events effectively nullifies the validity of the test and prevents an evaluation of the endurance issues that may exist for the tire. Furthermore, if the test is required for compliance qualifications, tires that may have excellent endurance performance on the road can be removed prior to the required test completion as a result of the non-representative EOT event.

X2.4.10 Therefore, due to the significance of the tire operating conditions, for example, speed, inflation pressure, and load on tire performance, and the increased severity of testing on a curved surface, it is necessary to conduct roadwheel tire tests using test conditions that reflect temperature equivalency to specific road (flat surface) operating conditions if a meaningful measure of tire endurance is to be achieved.

X2.5 This standard practice describes the procedures of using the flat-to-curved (FTC) prediction profiler to identify the equivalent test severity conditions on a 1.707-m diameter laboratory roadwheel from specific flat or highway operating conditions for load range F–L tires used on vehicles having a gross vehicle weight rating (GVWR) of > 4536 kg.

X2.6 The practice is applicable to the converse, as well, i.e. highway test conditions can be identified from specific road-wheel test conditions by the curved-to-flat (CTF) prediction profiler.

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