INTERNATIONAL

Designation: F1650 − 21

Standard Practice for Evaluating Tire Traction Performance Data Under Varying Test Conditions[1]

This standard is issued under the fixed designation F1650; 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.

INTRODUCTION

Tire traction testing programs at proving grounds or other exterior test sites are often extended over a period of days or weeks. During this time period test conditions may change due to a number of varying factors, for example, temperature, rain or snow fall, surface texture, water depth, and wind velocity and direction. If tire performance comparisons are to be made over any part of the test program (or the entire program) where these test condition variations are known or suspected to affect performance, the potential influence of these variations must be considered in any final evaluation of traction performance.

1. Scope

1.1 This practice covers the required procedures for examining sequential control tire data for any variation due to changing test conditions. Such variations may influence absolute and also comparative performance of candidate tires, as they are tested over any short or extended time period. The variations addressed in this practice are systematic or bias variations and not random variations. See Appendix X1 for additional details.

1.1.1 Two types of variation may occur: time or test sequence "trend variations," either linear or curvilinear, and the less common transient or abrupt shift variations. If any observed variations are declared to be statistically significant, the calculation procedures are given to correct for the influence of these variations. This approach is addressed in Method A.

1.2 In some testing programs, a policy is adopted to correct all candidate traction test data values without the application of a statistical routine to determine if a significant trend or shift is observed. This option is part of this practice and is addressed in Method B.

1.3 The issue of rejecting outlier data points or test values that might occur among a set of otherwise acceptable data values obtained under identical test conditions in a short time period is not part of this practice. Specific test method or other outlier rejection standards that address this issue may be used on the individual data sets prior to applying this practice and its procedures.

1.4 Although this practice applies to various types of tire traction testing (for example, dry, wet, snow, ice), the procedures as given in this practice may be used for any repetitive tire testing in an environment where test conditions are subject to change.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E501 Specification for Standard Rib Tire for Pavement Skid-Resistance Tests

E524 Specification for Standard Smooth Tire for Pavement Skid-Resistance Tests

E826 Practice for Testing Homogeneity of a Metal Lot or Batch in Solid Form by Spark Atomic Emission Spectrometry

E1136 Specification for P195/75R14 Radial Standard Reference Test Tire

[1] This practice is under the jurisdiction of ASTM Committee F09 on Tires and is the direct responsibility of Subcommittee F09.20 on Vehicular Testing.

Current edition approved April 1, 2021. Published April 2021. Originally approved in 1995. Last previous edition approved in 2014 as F1650 – 98 (2014)^{ε1}. DOI: 10.1520/F1650-21.

[2] 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.

F538 Terminology Relating to the Characteristics and Performance of Tires
F2493 Specification for P225/60R16 97S Radial Standard Reference Test Tire
F2870 Specification for 315/70R22.5 154/150L Radial Truck Standard Reference Test Tire
F2871 Specification for 245/70R19.5 136/134M Radial Truck Standard Reference Test Tire
F2872 Specification for 225/75R16C 116/114S M+S Radial Light Truck Standard Reference Test Tire

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *candidate tire (set), n*—a test tire (or test tire set) that is part of an evaluation program; each candidate tire (set) usually has certain unique design or other features that distinguish it from other candidate tires (sets) in the program. **F538**

3.1.2 *control tire (set), n*—a reference tire (or reference set) repeatedly tested in a specified sequence, typically in conjunction with a candidate tire (set), throughout an evaluation program. **F538**

3.1.2.1 *Discussion*—Control tires (sets) are used for adjustment of data sets generated from an evaluation program or the statistical procedures used on data sets, or both, in order to offset or reduce variation in test results. They can also be used to improve the accuracy of candidate tire (set) data and to detect variation in test equipment.

3.1.3 *reference tire (set), n*—a special test tire (test tire set) that is used as a base value or benchmark in an evaluation program; these tires usually have carefully controlled design features to minimize variation. **F538**

3.1.4 *standard reference test tire, SRTT, n*—a tire that is commonly used as a control tire or surface monitoring tire and meets the requirements for one of the Specifications E1136, F2493, F2870, F2871, or F2872. **F538**

3.1.5 *surface monitoring tire (set), n*—a reference tire (or reference set) used to evaluate changes in the test surface over a selected time period. **F538**

3.1.6 *test (or testing), n*—a technical procedure, method, or guide performed on an object (or set of objects) that produces data; the data are used to evaluate or model properties or characteristics of the object (or set of objects). **F538**

3.1.7 *test run, n—in tire testing*, a single pass over a given test surface, or the acquisition of a sequence of data, or both, in the act of testing a tire or tire set under selected test conditions. **F538**

3.1.8 *test tire (set), n*—one or more tires, as required by the test equipment or procedure to perform a test, producing a single test result; the tires within a test tire set are usually nominally identical. **F538**

3.1.9 *traction test, n— in tire testing*, a series of *n* test runs at a selected operational condition; a traction test is characterized by an average value for the measured performance parameter. **F538**

4. Significance and Use

4.1 Tire testing is conducted to make technical decisions on various performance characteristics of tires, and good technical decisions require high quality test data. High quality test data are obtained with carefully designed and executed tests. However, even with the highest quality testing programs, unavoidable time or test sequence trends or other perturbations may occur. The procedures as described in this practice are therefore needed to correct for these unavoidable testing complications.

5. Summary of Practice

5.1 This practice specifies certain test plans for testing control tires. Testing begins with an initial test of the control tire or control tire set. A number of candidate tire traction tests are then conducted, followed by a repeat test of the control tire traction test. Additional candidate tire traction tests are conducted prior to the next control tire traction test. This sequential procedure is repeated for the entire evaluation program.

5.2 Using control tire average measured performance parameters, the performance parameters of the candidate tires (sets) are corrected for any changes in test conditions. Two correction procedures are described (Method A and Method B) that use different reference points for data correction and as such give different values for the corrected actual or absolute traction parameters. However, both test methods give the same relative ratings or traction performance indexes. See Section 10 for more details. The two test methods are summarized in more detail in Section 6 and Section 9. Both Methods A and B have advantages and disadvantages.

5.2.1 Method A uses the initial operational conditions defined by the first control tire traction test as a reference point. The calculations correct all traction test performance parameters (for example, traction coefficients) to the initial level or condition of the pavement or other testing conditions, or both. With this test method, corrections may be made after only a few candidate tire and control tire sets have been evaluated.

5.2.2 Method B uses essentially the midpoint of any evaluation program, with the grand average traction test value as a reference point. This grand average value is obtained with higher precision than the initial control tire traction test average of Method A, since it contains more values. However, Method B corrections cannot be made until the grand average value is established, which is normally at the end of any program.

5.3 Annex A1 provides illustrations of several types of typical variation patterns for control tire data. It additionally provides an example of the Method A correction calculations required to evaluate a set of candidate test tires. Method B corrections follow the same general approach as illustrated in Annex A1, with C_{avg} used in place of C1.

5.4 Annex A2 provides a recommended technique for weighting the correction of the two or three candidate tire values (for example, T1, T2, T3) between each pair of control tire values. This gives a slightly improved correction that may be important in certain testing operations.

5.5 Appendix X1 provides a statistical model for the traction measurement process. This may help the user of this practice to sort out the differences between fixed or bias components of variation and random components of variation. Appendix X1 gives a rationale for the procedures as outlined in this practice.

5.6 Annex A2 contains some background and details on the propagation of error or test variation that occurs when corrections are applied to the measured traction performance parameters and when traction performance indexes are calculated.

METHOD A—DATA CORRECTIONS BASED ON INITIAL CONTROL TIRE TRACTION TEST

6. Summary of Method A

6.1 This method corrects the data obtained throughout the evaluation program to the initial conditions (test surface or other, or both)" reference point" at the beginning of the program. The correction procedure (and calculation algorithm) for time trend variations is mathematically equivalent to that described in Practice E826. The procedure used for abrupt or step changes is provisional and is subject to change as experience is gained. In this method the initial traction test value for the control tire is a key data point. This method also allows for decisions on the need for any correction, based on a statistical analysis of the control tire data.

7. Procedure

7.1 The test procedure is given in terms of testing tire sets of four tires, that is, one tire on each of four vehicle positions. If only one tire is to be tested (trailer or other dynamometer vehicle testing), follow the procedure as outlined with the understanding that the one tire replaces the tire set.

7.2 Assemble all the tire sets to be tested in any evaluation program or for daily testing. Select the test speeds to be used and other operational test conditions as well as the order in which the candidate tire sets are to be tested.

7.2.1 For any selected order, a test plan is established with reference tire (set) designated as a control tire set tested at regular intervals among the selected candidate tire sets. Select the number of test runs or replicates for both control and candidate tire sets. A complete test for a tire set is defined as the total of *p* traction tests, one at each selected operational test condition, with *n* replicate test runs for each operational condition (for example, speed and surface type).

7.2.2 Tests with a surface monitoring tire may also be conducted on a regular basis in addition to the control tire.

7.3 *Test Sequence*—The control tires may be standard tires as specified in Specifications E501, E524, E1136, and F2493, or a tire set similar in design and performance level to the candidate tire sets. Conduct a complete test for the control tire sets in relation to the candidate tire sets as given in Table 1. Two test plans are given: Plan A, in which (excluding the initial control tire set) candidate tire sets constitute 67 % of the tires tested, and Plan B, in which candidate tire sets constitute 75 % of the tires tested.

TABLE 1 Test Plans for Tire Performance Evaluation[A]

Plan A:
Test in the order: C1, T1, T2, C2, T3, T4, C3, T5, T6, C4, etc.
Plan B:
Test in the order: C1, T1, T2, T3, C2, T4, T5, T6, C3, T7, T8,T9, C4, etc.

[A] *Ci* = average measured parameter (for *n* test runs) for a selected operational condition for the *i*th control set test (that is, *i* = 1, 2, 3, etc.)
Ti = average measured parameter (for *n* test runs) of a selected operational condition for the *i*th candidate set test (that is, *i* = 1, 2, 3, etc.).

7.4 *Number of Test Runs at Each Speed or Operational Condition*—The number of test runs or replicates, *n*, for each speed or other selected operational condition for each candidate tire set and each control tire set, except the first set, shall be selected. The number of test runs depends on the test method. Good testing procedure calls for as many test runs as possible. If direction of test is important on any test surface, one half of the test runs shall be in each direction.

7.4.1 *Number of Test Runs: Initial Control Tire Set*—The initial test for the control tire set, indicated by C1, is a key value used for correction of candidate tire set performance parameter values as testing proceeds. Therefore, the average performance parameters for C1 must be evaluated with a high degree of confidence and the recommended number of test runs for C1 should be at least two times the number of test runs selected in 7.4.

7.4.2 *More than One Control Tire*—In some types of testing, the control tire is damaged or changed by the testing to the extent that it ceases to function as a stable control. In such situations it is necessary to use more than one control tire throughout any evaluation program. In such cases a control tire indication scheme such as C1-1, C1-2, C1-3, C2-4, C2-5, C2-6, C3-1, etc., is suggested. In this scheme, C1-1 = control tire 1, sequence use 1; C1-2 = control tire 1, sequence use 2; … ., C2-4 = control tire 2, sequence use 4, etc.

7.5 *Table of Results*—Prepare a table of test results and record all data with columns for:

7.5.1 Test sequence number, a sequential indication from 1 to *m*, of all the tests for any program of evaluation,

7.5.2 Tire set identification,

7.5.3 Speed or other selected operational test condition(s), and

7.5.4 Average value (for *n* test runs) for the measured parameter for that operational condition.

7.6 Both control and candidate tire set data shall be included in the table in the order as tested. If deemed important, a separate table of ambient temperature, wind direction, wind velocity, or other weather information also shall be prepared on a selected time (hourly) basis.

8. Calculations for Corrected Traction Performance Data

8.1 *Preliminary Control Tire Set Data Review*—The decision to correct data, for any part of the test program where candidate tire set comparisons are to be made, is based on the time or test sequence response of the control tire parameters for each speed or other selected operational test condition. Corrections may also be made for the entire test program. If a significant trend is found or if significant transient perturbations are found, corrections are made for candidate tire set traction performance parameters.

8.2 *Evaluating the Control Tire Data*—Using the data table(s) generated in accordance with the procedures outlined in 7.5, plot the average control tire traction test parameter (that is, for C1 to Ci) at each speed or other operational condition, as a function of the test sequence number for the control set or the "test time" period (hours) that has elapsed for each control tire test. For a good evaluation of potential drift, at least five control set values (that is, C1 to C5 as defined in Table 1) should be available; six or more is better.

8.2.1 The plot of average control traction test parameter versus test sequence number or time period is examined for two types of response: (*1*) any upward or downward drift or trend and (*2*) the less common occurrence of any transient or step change of either a temporary or permanent value shift. Annex A1 gives some typical control tire versus test sequence number plots. Since the time drift may be nonlinear, a transformation may be applied to the data to permit a linear regression analysis to be conducted. A curvilinear time trend can be converted into a relationship that very closely approximates linearity on the basis of the logarithmic transformation of both the test sequence number and the average parameter test value.

8.2.2 The calculated correlation coefficient, $R_{(calc)}$, from the transformed data linear regression analysis is used to determine if the trend or drift is significant. If the calculated coefficient is significant, a correction of the candidate tire set traction parameter values is made. Correction for any significant drift is made on a basis that allows for any overall curvilinear trend (see 8.5).

8.3 *Evaluating the Significance of Drift*—For the linear or log transformed traction parameter versus linear or log transformed test sequence number plot, evaluate the correlation coefficient, $R_{(calc)}$, using any typical software or spreadsheet statistical calculation algorithm.

8.3.1 Determine if $R_{(calc)}$ is significant for the control tire traction parameter by referring to Table 2, a table of 95 % confidence level "critical" correlation coefficient values, $R_{(crit)}$, for varying degrees of freedom (DF). If the calculated correlation coefficient is greater than the tabulated critical value, the calculated coefficient is significant and corrections are applied to the candidate tire data in accordance with 8.5.

8.3.2 If the correlation coefficient is not significant, no corrections are required and the original candidate tire set performance data may be used for evaluation.

TABLE 2 Critical Values of Correlation Coefficient[A]

DF	R(crit)
1	0.997
2	0.950
3	0.878
4	0.811
5	0.754
6	0.706
7	0.666
8	0.631
9	0.602
10	0.576
12	0.532
14	0.497
16	0.468
18	0.443
20	0.422
25	0.380
30	0.349

[A]Critical values for the correlation coefficient, R(crit) at the 95 % confidence level or at $p = 0.05$ are given as a function of the degrees of freedom, DF. The value for DF is equal to ($N - 2$), where N is the number of pairs of data, number of log (average parameter) values, plotted for the control set, that is, Ci.

8.4 *Evaluating the Significance of Transient Variations*—The procedure outlined for a decision on the existence of a transient or shift variation is given as a recommended approach. Transient variations are one of two types: (*1*) After several control tire values with an established trend, an abrupt change in one or more control tire traction parameter values occurs (this is followed by a return to the established trend); or (*2*) after an established trend is observed, an abrupt shift occurs and a new trend is established with no return to the original level.

8.4.1 The significance of the shift is established by comparing the magnitude of the step with the standard error of the estimate (or the standard deviation) of the control tire traction values about the regression line. Calculate the standard error of the estimate (SE) for the actual or log transformed data (see 8.2 and 8.3) according to the type of transient shift. All of the calculations as outlined below must be performed on the same basis, that is, all with actual values or all with transformed values.

8.4.2 *For a Type 1 Shift*—With any typical statistical software, calculate the SE for the regression line fitted to all the data points, omitting the shifted or transient offset points. Designate this as SE(MR), the main regression standard error of estimate. If there are several (four or more) offset points, calculate the SE for the regression line fitted to these points. Designate this as SE(O), the offset point standard error of estimate. If there are three or fewer offset points, calculate their average; designate this as OP_{avg}.

8.4.3 *For a Type 2 Shift*—With any statistical software, calculate the SE of each of the two regression trend lines (actual values or transformed). Designate these as SE(1) for the first trend line and SE(2) for the second line.

8.4.4 *Significance of Transient Shift*—The significance is determined by comparing the magnitude of the shift or offset with the magnitude of the standard errors in question.

8.4.4.1 *Significance For a Type 1 Shift*—If there are four or more offset points, the shift is significant if the difference between the offset regression line and the main regression line (at the shift point) is greater than the sum [2 SE(MR) + 2 SE(O)], that is, greater than the sum of the two standard deviation limits (2 σ limits) about each regression line. If there are three or fewer offset points, the shift is significant if the difference between OP_{avg} and the value of the regression line at the initial point of offset is greater than [4 SE(MR)].

8.4.4.2 *Significance For a Type 2 Shift*—The shift is significant if the difference between the two regression lines at the point of initial offset is greater than the sum [2 SE(1) + 2 SE(2)].

8.4.5 If significant transient shifts are found, corrections are made in accordance with 8.5.

8.5 *Making the Corrections*—For each speed or other operational condition, arrange the control tire set average (measured) traction test values in chronological or test sequence order, that is, C1, C2, C3, ... Ci. Normal correction procedure is defined on the basis of equivalent corrections to each candidate tire in the interval between two successive control tire traction tests (see 8.5.1). An alternative correction procedure using a weighting technique for the first and second candidate tires between successive control tires (Plan A) or the first, second, and third (Plan B), is given as an option in Annex A2. This optional correction procedure may be more important for Plan B testing with three candidate tires between each successive set of control tires. For the normal procedure, compute the "correction" factors, Fj, as follows:

$$
\begin{aligned}
F1 &= (C1+C2)/2C1 \\
F2 &= (C2+C3)/2C1 \\
F3 &= (C3+C4)/2C1 \\
F4 &= (C4+C5)/2C1 \\
F5 &= (C5+C6)/2C1 \\
&\ldots \\
Fj &= (Ci+Ci+1)/2C1
\end{aligned}
\tag{1}
$$

8.5.1 Divide the measured candidate tire set performance parameter values by the appropriate "correction" factor to obtain the "corrected value" for the candidate tire set performance parameter. The appropriate correction factor is that factor calculated from the control tire (C values) that brackets the measured candidate tire parameter values within the test sequence (time) span for the two C values. Thus, apply the Factor F1 to the candidate tire test values between C1 and C2; apply F2 to the candidate tire test values between C2 and C3, etc. The following equations give the general expression for the" corrected parameter" values for Plan A, in terms of the measured parameter values and the value of Fj. Expressions for the other "corrected parameter" values have the same calculation procedure, for example:

$$
\begin{aligned}
&(\text{Corr})\ \text{Parameter Candidate Set } 1 = \\
&\text{"as measured" Parameter Candidate Set1}/F1 \\
&(\text{Corr})\ \text{Parameter Candidate Set } 2 = \\
&\text{"as measured" Parameter Candidate Set2}/F1 \\
&(\text{Corr})\ \text{Parameter Candidate Set } 3 = \\
&\text{"as measured" Parameter Candidate Set3}/F2 \\
&(\text{Corr})\ \text{Parameter Candidate Set } 4 = \\
&\text{"as measured" Parameter Candidate Set4}/F2 \\
&\ldots \\
&(\text{Corr})\ \text{Parameter Candidate SetM} = \\
&\text{"as measured" Parameter Candidate SetM/Fj}
\end{aligned}
\tag{2}
$$

8.5.2 Tabulate the corrected candidate parameter values as an additional column in the table format as outlined in 7.5. Indicate on the table that Method A correction was used.

METHOD B—CORRECTIONS BASED ON AVERAGE OF CONTROL TIRE TRACTION TESTS

9. Summary of Method B

9.1 This method corrects the data obtained throughout the evaluation program using the same basic calculation algorithm as for Method A, with one important difference. The candidate tire traction values are corrected to a "reference point" characterized by the grand average traction test value (averaged over *all* control tire traction test values). This method also applies the corrections to all candidate tire traction test data values. No statistical tests of significance for trends or transient shifts are required. See Appendix X2 for some background on how making corrections influences the $\pm 2\ \sigma$ limits on candidate tire relative performance as outlined in Section 10.

9.2 The test procedure for Method B is exactly as given in Section 7 of this practice. Follow all instructions as given in this section.

9.3 *Making the Corrections*—For each speed or other operational condition, arrange the control tire set average (measured) traction test values in chronological or test sequence order, C1, C2, C3, ... Ci. Compute the "correction" factors, Fj, as follows:

$$
\begin{aligned}
F1 &= (C1+C2)/2C_{avg}, \\
F2 &= (C2+C3)/2C_{avg}, \\
F3 &= (C3+C4)/2C_{avg}, \\
F4 &= (C4+C5)/2C_{avg}, \\
F5 &= (C5+C6)/2C_{avg}, \\
&\ldots \\
Fj &= (Ci+Ci+1)/2C_{avg}
\end{aligned}
\tag{3}
$$

where:

C_{avg} = average of all Ci values in any program.

9.3.1 Divide the measured candidate tire set performance parameter values by the appropriate "correction" factor to obtain the "corrected value" for the candidate tire set performance parameter. The appropriate correction factor is that factor calculated from the control tire (C values) that brackets the measured candidate tire parameter values within the test sequence (time) span for the two C values. Thus, apply the Factor F1 to the candidate tire test values between C1 and C2; apply F2 to the candidate tire test values between C2 and C3; etc. The following equations give the general expression for the" corrected parameter" values for Plan A in terms of the measured parameter values and the value of Fj. Expressions for the other "corrected parameter" values have the same calculation procedure:

$$
\begin{aligned}
&(\text{Corr})\ \text{Parameter Candidate Set } 1 = \\
&\text{"as measured" Parameter Candidate Set1}/F1, \\
&(\text{Corr})\ \text{Parameter Candidate Set } 2 = \\
&\text{"as measured" Parameter Candidate Set2}/F1,
\end{aligned}
$$

$$\text{(Corr) Parameter Candidate Set 3} = \tag{4}$$

$$\text{“as measured” Parameter Candidate Set3/F2, and}$$

$$\text{(Corr) Parameter Candidate Set 4} = \text{“as measured” Parameter Candidate Set4/F2,}$$

$$\ldots$$

$$\text{(Corr) Parameter Candidate SetM} = \text{“as measured” Parameter Candidate SetM/Fj}$$

9.3.2 Tabulate the corrected candidate tire parameter values as an additional column in the table format as outlined in 7.5. Indicate in the table that Method B correction was used.

10. Calculations for Relative or Comparative Performance Evaluation

10.1 Once the calculations for correcting the absolute traction performance data are completed, relative or comparative performance among any selected group of candidate tire sets may be evaluated.

10.1.1 Select one set of tires to act as a reference standard tire. This may be a control tire set or a special candidate tire set. Calculate the traction performance index, TPI, for each of the candidate tire sets according to Eq 5 using either corrected traction performance data if corrections were made, or original data if no corrections were made. The traction performance index, TPI, is an index where higher values indicate improved or superior performance compared to lower TPI values. Therefore, TP parameter values used in Eq 5 should reflect this performance characteristic. If certain measured performance parameters are used, such as stopping distance, where lower values indicate superior traction performance, then an inverse relationship is required for Eq 5, that is, invert the ratio in the brackets.

$$\text{TPI} = [\text{TP parameter (i)/TP parameter (ref std)}]100 \tag{5}$$

where:

TP parameter (i) = corrected or original average traction performance parameter for the test for candidate tire set (i), and

TP parameter (ref std) = corrected or original average traction performance parameter for the test for the selected reference standard tire.

10.1.2 Tabulate the TPI values as an additional column in the table format as described in 7.5.

11. Citing This Practice

11.1 When this practice is cited in any particular traction or other similar tire test standard, the following information shall be given to adequately describe the correction procedure that was utilized.

11.1.1 The citation shall be in either of the following formats:

$$\text{Format 1:F1650} - \text{A or F1650} - \text{B} \tag{6}$$

where:

A = Method A used; B = Method B used,

or

$$\text{Format 2:F1650} - \text{AW or F1650} - \text{BW} \tag{7}$$

where:

W indicates that the optional weighting technique was used.

12. Keywords

12.1 data correction; test variation; testing trends; traction testing

ANNEXES

(Mandatory Information)

A1. TYPICAL VARIATIONS OF CONTROL TIRE DATA AND AN EXAMPLE OF CORRECTION CALCULATIONS FOR CANDIDATE SET WET TRACTION EVALUATION

A1.1 *Typical Control Tire Data Response*—Figs. A1.1-A1.5 illustrate typical test sequence number responses for control tire data. Wet traction coefficient data are shown in the illustrations for one typical test speed.

A1.1.1 Fig. A1.1 is a plot for a zero slope response, that is, no trend, that has a low standard error of the estimate (standard deviation of the points about the fitted line), SE, and indicates relatively good test precision across the indicated test period. The SE expressed as a coefficient of variation, CV, (relative to average traction level) is 1.5 %. Fig. A1.2 is a similar plot also with no trend but poorer test precision, that is, much greater scatter of the points about the fitted zero slope line with an SE (on CV basis) of 3.8 %.

A1.1.2 Fig. A1.3 illustrates a typical transient or step shift in control tire data in the middle of the test period. Such a shift might result from a substantial inadvertent reduction in water depth for higher speed wet traction testing, with a return to initial water depth near the end of the test period. The comparatively good fit of the other four points at the 0.50 traction coefficient level constitutes a base level for point fit and regression analysis; this is designated as the main regression or MR level. The SE calculated from the regression analysis, when multiplied by four (see 8.4 and especially 8.4.4.1) gives a value for [4 SE(MR)] as indicated by the error bar in Fig. A1.3. No transformation was applied to the data for Fig. A1.3.

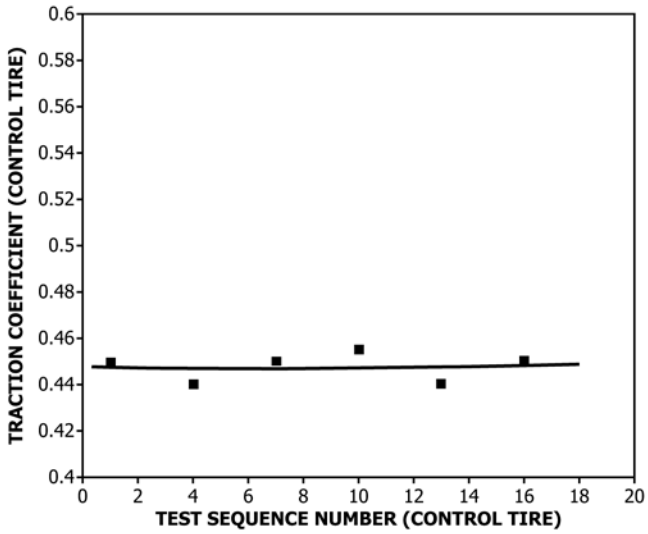

FIG. A1.1 Typical Control Tire Data With No Significant Trend, With Good Test Precision, That is, Small Standard Error of Estimate, *SCV* = 1.5 %, *R(calc)* = 0.04

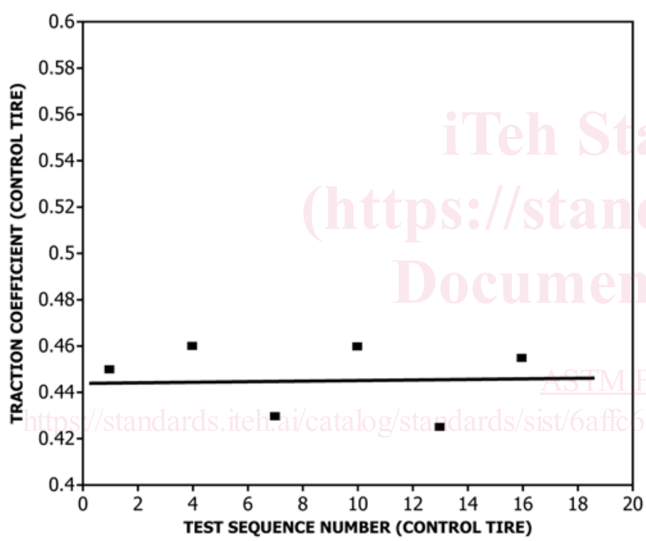

FIG. A1.2 Typical Control Tire Data With No Significant Trend, With Poorer Test Precision, *SCV* = 3.8 %, *R(calc)* = 0.17

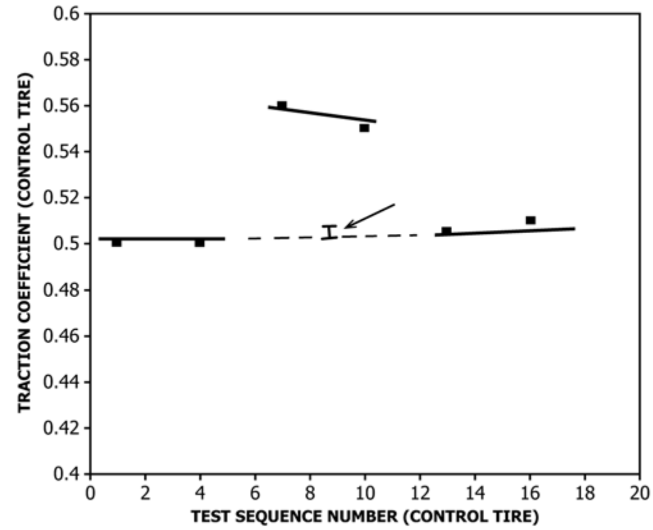

FIG. A1.3 Typical Control Tire Data With a Significant Transient or Step Response, With [4 SE(MR)] "Error Bar" Indicated by Arrow

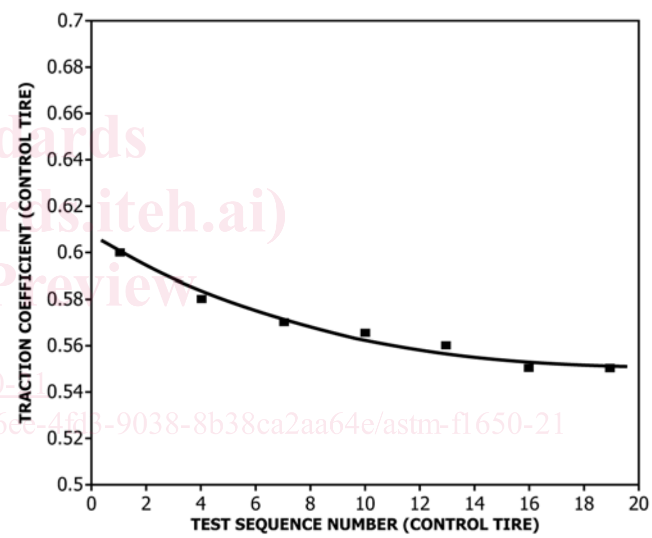

FIG. A1.4 Typical Control Tire Data With a Significant Non-Linear Trend

A1.1.3 Fig. A1.4 illustrates a very typical curvilinear downward trend in control tire set data. Such a trend is normally due to test pavement polishing (reduction in microtexture) due to the traction testing. Fig. A1.5 is a plot of the transformed data of Fig. A1.4, that is, log (test sequence number) versus log (traction coefficient). It illustrates a good linear relationship and permits a linear regression analysis to be conducted on the log transformed data. The very significant $R_{(calc)}$ value is 0.987 and SE (on CV basis) is 1.1 %.

A1.2 *Correction Calculation Example: Method A*—Table A1.1 lists control tire set and candidate tire set wet traction coefficient data for a test program with nineteen data sets. Test Plan A was used with two candidate tire sets between successive control tire set tests. Table A1.2 lists the control tire set wet traction coefficients for C1 through C7. These data are the same as the data shown in Fig. A1.4 and Fig. A1.5 and represent a significant curvilinear trend.

A1.2.1 Table A1.3 lists the data as given in Table A1.1 along with columns that are needed for the correction based on non-weighted calculations. The corrected traction coefficients for T1 through T12 are given in the fourth column along with the correction factors as used and the values for F1 through F6. The last two columns give the as-measured TPI and the corrected TPI. The reference standard tire is T1.