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Standard Practice for Tire Testing Operations–Basic Concepts and Terminology for Reference Tire Use[1]

This standard is issued under the fixed designation F1806; 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~~ Scope*

1.1 This practice presents some basic concepts for tire testing and a standard set of terms relating to the use of reference tires frequently used for comprehensive tire testing programs. The tests may be conducted in a laboratory on various dynamometer wheels or other apparatus as well as at outdoor proving ground facilities. The overall objective of this practice is to develop some elementary principles for such testing and standardize the terms used in these operations. This will improve communication among those conducting these tests as well as those using the results of such testing.

1.2 In addition to the basic concepts and terminology, a statistical model for tire testing operations is also presented in Annex A1. This serves as a mathematical and conceptual foundation for the terms and other testing concepts; it will improve understanding. The annex can also serve for future consultation as this practice is expanded to address additional aspects of the testing process.

1.3 This overall topic requires a comprehensive treatment with a sequential or hierarchical development of terms with substantial background discussion. This cannot be accommodated in Terminology F538.

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

1.5 *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]

D4483 Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries
E1136 Specification for P195/75R14 Radial Standard Reference Test Tire
F538 Terminology Relating to Characteristics and Performance of Tires
F1650 Practice for Evaluating Tire Traction Performance Data Under Varying Test Conditions
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

[1] This practice is under the jurisdiction of Committee F09 on Tires and is the direct responsibility of Subcommittee F09.94 on Terminology.

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[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.

***A Summary of Changes section appears at the end of this standard**

3. Significance and Use

3.1 Tire testing operations usually consist of a sequence of tests that involve special "reference" tires in addition to the candidate tires being evaluated for their performance characteristics. Reference tires serve as an "internal benchmark" which may be used to adjust for variation in test results to give improved comparisons among the candidate tires. Numerous approaches have been adopted using different terminology for such testing. This causes confusion and the purpose of this practice is to standardize some of the elementary concepts and terminology on this topic.

4. Summary of the Practice

4.1 Elementary testing concepts, terms, and definitions are developed in hierarchical or sequential order beginning with basic testing operations. Each definition may be accompanied by a specific discussion or expanded text section appropriate to general definitions. Many of the terms could be defined as adjectives; however, as recommended by ASTM policy, the word "tire" is included in each definition avoiding the complication of defining adjectives. The definitions apply equally to items or objects other than tires.

5. Basic Testing Concepts and Terms

5.1 *Background on Testing:*

5.1.1 Despite the adoption of standardized testing procedures, test result variation influences data generated in any type of testing. As outlined in Annex A1, there are two main categories: [1] variation inherent in the production process for a group of nominally identical objects or tires and [2] variation due to the measurement operation. Each of these two sources may be further divided into two types of variation; [1] systematic or bias variation (the variation causing one laboratory to be consistently different from another laboratory) and [2] random error variation. Both types can exist simultaneously for either of the main categories.

5.1.2 Random variation can be reduced to a low level by appropriate replication and sampling procedures, but bias variation cannot be so reduced. Bias variation can be reduced or eliminated by the appropriate use of reference objects or tires. This is the major rationale for their use in testing operations (see Annex A1).

5.1.3 Bias variation can also be reduced or eliminated by comprehensive programs to sort out causes of such perturbations and eliminate these causes.

5.2 *Elementary Testing Terms:*

5.2.1 *test (or testing), n*—a ~~procedure~~ technical procedure, method, or guide performed on an object (or set of ~~nominally identical objects) using specified equipment that produces data unique to~~ objects) that produces data; the data are used to evaluate or model properties or characteristics of the object (or ~~set).~~set of objects). **F538**

5.2.1.1 *Discussion*—~~Test data are used to evaluate or model selected properties or characteristics of the object (or set of objects).~~ The scope of testing depends on the decisions to be made for any program, and sampling and replication plans (see definitions below) need to be specified for a complete program description.~~F538~~

~~5.2.2 *test tire, n*—a tire used in a test. F538~~

~~5.2.3 *test program, n*—an ordered series of tests grouped together using a predefined plan.~~

~~5.2.3.1 *Discussion*—A test program may include multiple test repetitions over an extended time period. F538~~

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

5.2.2.1 *Discussion*—The four nominally identical tires required for vehicle stopping distance testing constitute a test tire set. In the discussion below where the test tire is mentioned, it is assumed that test tire set may be substituted for test tire, if a test tire set is required for the testing.

5.2.3 *test program, n*—an ordered series of tests grouped together using a predefined plan. **F538**

5.2.3.1 *Discussion*—A test program may include multiple test repetitions over an extended time period.

5.2.4 *candidate ~~tire,~~ tire (set), n*—a test tire (or test tire set) that is part of ~~a test~~ 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**

5.2.4.1 *Discussion*—The term "candidate object" may be used in the same sense as *candidate tire*.~~F538~~

~~5.2.6 *candidate tire set*—a set of candidate tires. F538~~

5.3 Tire testing may be divided into two major categories:

5.3.1 *local testing, n*—testing conducted at one laboratory or test site for the purpose of comparing a number of candidate tires for selected characteristic properties. **F538**

5.3.1.1 *Discussion*—A tire manufacturer's internal development programs and proving ground testing conducted by a contract testing organization to compare commercial market tires are two examples of local testing.~~F538~~

5.3.2 *global testing, n*—testing conducted at two or more laboratories or test sites for the purpose of comparing candidate tire performance at each location for selected characteristic properties. **F538**

5.3.2.1 *Discussion*—Producer-user testing or interlaboratory comparisons for such properties as rolling resistance, endurance, or high speed dynamometer wheel performance are examples of global testing.~~F538~~

5.4 *sample, n*—a selected number of *n* test objects that accurately represent the lot or population of interest. **F538**

5.4.1 *Discussion*—A lot is a finite number of objects such as a limited period of tire production at a given facility or a selected number of tires of a particular commercial market type. A population is the collection (or potential collection) of all objects produced by a given process or operation.~~F538~~

5.5 *sampling, v*—the act of selecting samples. **F538**

5.5.1 *Discussion*—The primary purpose of sampling is the reduction of random production process variation. See Annex A1 for details.~~F538~~

5.6 *replicate, n*—either *(1)* an individual test object from a sample of *n* objects or *(2)* one of *m* individual test values for a test object. **F538**

5.6.1 *Discussion*—Each test object of a set of replicates is nominally identical to all other objects from that particular source. Nominally identical implies that in long run testing all objects would give essentially identical average test values.~~F538~~

5.7 *replication, v*—the act of selecting and testing a number of replicates. **F538**

5.7.1 *Discussion*—The primary purpose of replication is the reduction of random measurement variation. See Annex A1 (A1.3.6) for additional discussion on types of replication.~~F538~~

6. Reference Tire Concepts and Terms

6.1 In this section a basic term, reference tire, is defined. A number of terms, each describing a special type of reference tire, are derived from the basic term. Reference tires usually have special characteristics unique to a particular test program. However, for some testing programs the same reference tire may be used for more than one purpose.

6.1.1 *reference ~~tire,~~ tire (set), n*—a special ~~tire included in a test program; the test results for this tire have significance~~ test tire (test tire set) that is used as a base value or ~~internal benchmark.~~ benchmark included in an evaluation program; these tires usually have carefully controlled design features to minimize variation. **F538**

6.1.2 There are two types of reference tires or objects that may be used in any test program.

6.1.2.1 *Type 1 (reference tire), n*—tires subject to production, composition, and often, performance specifications; they are designed to have minimal variation and to be stable in their characteristic properties for an extended period of time.

6.1.2.2 *Type 2 (reference tire), n*—tires appropriately selected from a lot by a process that ensures minimal variation characteristic properties for the duration of any test program.

(1) Discussion—Type 2 reference tires may be selected on an ad hoc basis and when the test program is complete they are no longer considered as reference objects.

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

6.1.3.1 *Discussion*—A control tire (set) may be of either type, and typical tire use is the reference (control) tire (set) in Practice F1650 that provides algorithms for correcting (adjusting) test data for bias trend variations (See Practice F1650 and Annex A1). ~~F538~~

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

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

6.1.5.1 *Discussion*—This is a Type 1 reference tire.~~F538~~

6.1.6 *witness tire, n*—a reference tire with an extended period of stability for specified characteristic properties. **F538**

6.1.6.1 *Discussion*—A Type 1 reference tire is typical for this application.

6.1.7 *master set, n*—a selected group of witness tires, each with different test response characteristics to provide a range of values for the measured property or properties. **F538**

6.1.7.1 *Discussion*—A master set is frequently tested to determine if a test device is functioning in a normal or intended manner. If certain known or expected relationships are not found among the witness tires constituting the set, remedial action is required for the testing equipment. Master sets are frequently used for global testing.~~F538~~

6.1.8 *test matrix, n*—a group of candidate tires usually with specified reference tires; all tests are normally conducted in one test program. **F538**

6.1.8.1 *Discussion*—A test matrix may be used in either a local or global test program. See also *candidate tire ~~set.~~(set).*~~F538~~

6.1.9 *calibration tire, n*—a witness tire designed to provide a fixed or known test value for selected properties. **F538**

6.1.9.1 *Discussion*—Calibration tire test results can be used as standard values to determine acceptability of laboratory or test site performance. If a specified performance level is not found, certain instrument adjustments may be made to compensate for unavoidable biases in interlaboratory or between-site programs.~~F538~~

7. Evaluating Testing Precision

7.1 As indicated in Annex A1, there are two categories of variation: production process and measurement. Each of these may in turn have two subclassifications: bias deviations and random deviations. The potential effect of all these sources can exert a profound influence on the variability of test data. The presence of these sources is the rationale for using reference tires and for designing comprehensive testing programs with appropriate replication to reduce the effect of such variations.

7.2 *Evaluating Precision*—Special programs to evaluate the magnitude of variability for any routine or special test operations are part of the effort to reduce variability and improve test precision. Committee F09 has agreed (in 2006) to use the precision standard of Committee D11 (rubber testing), Practice D4483, for any precision evaluation programs. Precision is defined in Practice D4483 as "a measurement (testing) concept that expresses the ability to generate test results that agree with each other in absolute

magnitude." The parenthetical word "testing" is added to this definition for this purposes of this practice to indicate that it is the overall testing process, which includes sampling and replication, that should be considered when discussing precision.

7.2.1 For local testing, this action usually consists of appropriate sampling and replication plans and the evaluation of "test-to-test" variation for candidate tires. With a "test-to-test" standard deviation (or variance) obtained under the appropriate conditions, decisions on statistical (and technical) differences between candidate tires can be made for a program at any specific location. For global testing, programs can be organized to evaluate another "test-to-test" standard deviation, where this now applies to between-lab as well as to between-test comparisons. The word "laboratory" is used in this standard in a generic sense – the word may refer to an actual laboratory or to a proving ground or other location for tire testing.

7.3 *Repeatability and Reproducibility:*

7.3.1 The terms repeatability and reproducibility are frequently used when discussing testing and the results of testing programs. Some interpretations of these terms are different than the standard definitions given in Practice D4483.

7.3.1.1 *repeatability, n*—an established value, below which the absolute difference between two "within-laboratory" or "within test site" test results may be expected to lie, with a specified probability.

(1) Discussion—The two test results are obtained with the same method on nominally identical test materials under the same conditions (same operator, apparatus, laboratory, location, and specified time period), and in the absence of other indications, the specified probability is 0.95 (that is, 95 %). The established value also may be called a "critical difference."

7.3.1.2 *reproducibility, n*—an established value, below which the absolute difference between two "between-laboratory" or "between test site" test results may be expected to lie, with a specified probability.

(1) Discussion—The two test results are obtained with the same method on nominally identical test materials under different conditions (different laboratories, locations, operators, apparatus, and in a specified time period), and in the absence of other indications, the specified probability is 0.95 (that is, 95 %). The essential characteristic of reproducibility is the variability of test results among typical laboratories or test sites.

7.3.2 Both repeatability and reproducibility are to some degree generic in their definition. Additional information must be supplied before the terms can be used without ambiguity. The most important issue is the between–test result time period or frequency; it must be specified. What constitutes a test result must be defined. Both of these are addressed in Practice D4483. Other details on testing are also needed. It is important to emphasize two details about repeatability and reproducibility; (*1*) both are statistical parameters; defined as 2.83× *S*, where *S* is the standard deviation for either parameter measured in a specified way as outlined in Practice D4483 and (*2*) both parameters indicate precision in an inverse manner; high precision equals small values for either parameter.

NOTE 1—One source of confusion is the use of the words repeatability and reproducibility alone to indicate a desired or high level of precision. "A test has repeatability" is an inappropriate use of the word repeatability if consistency with Practice D4483 is desired. "A test has good (or low) repeatability" is appropriate usage.

7.4 *Process and Measurement Variation:*

7.4.1 Annex A1 contains a brief section (A1.4) on evaluating process and test measurement variance. This can be done rather easily for a non destructive test such as tire wet traction testing or rolling resistance testing. A more detailed analysis on this topic is beyond the scope of this practice in its present format.

8. Keywords

8.1 control tire; monitoring tire; reference tire; repeatability; reproducibility; test matrix; witness tire

ANNEX

(Mandatory Information)

A1. STATISTICAL MODEL FOR TEST MEASUREMENT

A1.1 Background

A1.1.1 The purpose of this annex is to present some of the concepts and definitions used and implied when test measurement variation is discussed. Using a mathematical model format improves understanding and more clearly demonstrates how the variation concepts relate to each other. In the annex, some of the words or terms are given a specific definition; some are informally defined by the context of their use.

A1.1.2 All measurement values are perturbed to some degree by a "system-of-causes" that produces error or variation in the measured parameter. There are two general variation categories for any system:

A1.1.2.1 *Measurement Variation*—deviations in the operation of devices or machines that evaluate certain properties for any class of objects or material; these deviations perturb the observed values for these properties.

A1.1.2.2 *Production variation*—deviations in certain properties that are (*1*) inherent in the production process that produces the different classes of objects or materials being tested or (*2*) acquired deviations (storage or conditioning effects) after such processes are complete.

A1.1.2.2.1 *Discussion*—

Certain types of variation may be inherent in any particular realization of a test device, that is, independent of the test device operation.

A1.1.3 The system-of-causes is defined by the scope and organization of any testing program and by the replication and sampling operations that are part of the program. These systems can vary from simple to very complex. The production process can be (*1*) the ordinary operation of a manufacturing facility or (*2*) some smaller processing or other operation that produces a material or class of objects for testing.

A1.2 General Model

A1.2.1 For any established "system-of-causes," each measurement, $y(i)$, can be represented as a linear additive combination of fixed or variable (mathematical) terms as indicated by Eq A1.1. Each of these terms is an individual component of variation and the sum of all components is equal to the total variation observed in the measurement operation. The equation applies to any brief time period of testing for a standardized test procedure. All participants test a number of classes of objects (each class having a number of individual nominally identical objects) or different materials, drawn from a lot of some specified uniformity, employ the same type of apparatus, use skilled operators, and are conducting testing in a typical environment.

$$y(i) = \mu(o) + \mu(j) + \sum(b) + \sum(e) + \sum(\beta) + \sum(\varepsilon) \tag{A1.1}$$

where:

$y(i)$ = a measurement value, at time (i), using specified equipment and operators, at laboratory (q),
$\mu(o)$ = a general or constant term or mean value, unique to the type of test being used,

$\mu(j)$ = a constant term (mean value), unique to material or object class (j),
$\sum(b)$ = the (algebraic) sum of some number of individual bias deviations in the process that produced material or object class (j),
$\sum(e)$ = the (algebraic) sum of some number of individual random deviations in the process that produced material or object class (j),
$\sum(\beta)$ = the (algebraic) sum of some number of individual bias deviations, for measurement (i), generated by the measurement system, and
$\sum(\varepsilon)$ = the (algebraic) sum of the number if individual random deviations, for measurement (i), generated by the measurement system.

A1.2.2 Eq A1.1 identifies three main sources of generic variation components: (*1*) constant terms (population mean values); (*2*) bias deviation terms, and (*3*) random deviation terms. These three are discussed in detail in succeeding sections.

A1.3 Specific Model Format

A1.3.1 A more useful format is obtained when Eq A1.1 is expressed using Eq A1.2, where the summations are replaced by a series of typical individual terms appropriate to interlaboratory testing on a number of different objects or materials, for a particular time period sufficient to complete the testing. This permits greater insight into the model and how it relates to real testing situations.

$$y(i) = \mu(o) + \mu(j) + \sum b + \sum e + \beta(L) + \beta(E) + \beta(OP) + \varepsilon(E) + \varepsilon(OP) \quad \text{(A1.2)}$$

where:

$\beta(L)$ = a bias deviation term unique to laboratory (q),
$\beta(E)$ = a bias deviation term unique to the specific equipment or machine,
$\beta(OP)$ = a bias deviation term unique to the operator (s) conducting the test,
$\varepsilon(E)$ = a random deviation inherent in the use of the specific equipment, and
$\varepsilon(OP)$ = a random deviation inherent in operator's technique.

Other types of testing perturbations not included in Eq A1.2 may exist, such as bias and random components due to temperature and other factors such as the time of the year that testing is conducted.

A1.3.2 *The $\mu(o)$ + $\mu(j)$ Terms*—In the absence of bias or random deviations of any kind, a set of objects would have individual measured test values given by the sum of the two terms, $\mu(o) + \mu(j)$. The term $\mu(o)$ would be unique to the test employed and each candidate would be characterized by the value of $\mu(j)$, which would produce a varying value for the sum $[\mu(o) + \mu(j)]$ for comparisons among any number of candidates. The sum $[\mu(o) + \mu(j)]$ would be the "true" test value for any candidate, that is, without error or variation of any sort.

A1.3.3 *The Production Terms $\sum(b) + \sum(e)$*—There will always be some bias and random variation in the candidate test objects produced by the process that generates them. These usually unknown number of bias and random variations are designated by $\sum(b) + \sum(e)$. Special production operations and other precautions can frequently be employed to reduce this variation to a level where it is substantially less than the test variation. In some testing programs this production variation is assumed to be zero. However, if such special precautions are not taken or for highly accurate evaluation programs, the production process variation must be taken into account. This is accomplished by appropriate program organization and the use of plans that allow for replicate sampling of the lots of objects for each candidate set.

A1.3.4 *The Measurement Bias (β) Terms*—The classic statistical definition of a bias is "the difference between the average measured test results and the accepted reference value (true value); it measures in an inverse manner the accuracy of a test", see Practice D4483. Bias deviations are non-random components and for a series of extended measurements (a long run) the value of bias terms may be either fixed or variable as well as + or - , depending on the system-of-causes. The variable bias terms are