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Standard Test Methods for Tire Performance Testing on Snow and Ice Surfaces[1]

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1. Scope

1.1 These test methods cover the evaluation of tire performance on snow and ice surfaces utilizing passenger car or light truck vehicles. Since the tires are evaluated as part of a tire/vehicle system, the conclusions reached may not be applicable to the same tires tested on a different vehicle.

1.2 These test methods do not purport to identify every maneuver useful for determining tire performance in a winter environment.

1.3 These test methods are not meant to evaluate vehicle performance. Allowing for the variability of test results with different vehicles, these procedures have been developed and selected to evaluate relative tire-snow performance.

1.4 These test methods are suitable for research and development purposes, where tires are compared during a single series of tests. They may not be suitable for regulatory statutes or specification acceptance because the values obtained may not necessarily agree or correlate either in rank order or absolute traction performance level with those obtained under other environmental conditions on other surfaces or the same surface after additional use.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *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:*

E 178 Practice for Dealing with Outlying Observations[2]

E 1136 Specification for a Radial Standard Reference Test Tire[3]

F 457 Test Method for Speed and Distance Calibration of a Fifth Wheel Equipped with Either Analog or Digital Instrumentation[4]

F 538 Terminology Relating to the Characteristics and Performance of Tires[4]

F 811 Practice for Accelerometer Use in Vehicles for Tire Testing[4]

F 1046 Guide for Preparing Artificially Worn Passenger and Light Truck Tires for Testing[4]

F 1650 Practice for Evaluating Tire Traction Performance Data Under Varying Test Conditions[4]

F 1805 Test Method for Single Wheel Driving Traction in a Straight Line on Snow and Ice Covered Surfaces

3. Terminology

3.1 *Definitions:*

3.1.1 *test (or testing)*, *n*—a procedure performed on an object (or set of nominally identical objects) using specified equipment that produces data unique to the object (or set).

3.1.1.1 *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. **F 538**

3.1.2 *test tire*, *n*—a tire used in a test. **F 538**

3.1.3 *test tire set*, *n*—one or more test tires as required by the test equipment or procedure, to perform a test, thereby producing a single test result.

3.1.3.1 *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 the test tire set may be submitted for test tire, if a test tire set is required for the testing. **F 538**

3.1.4 *candidate tire*, *n*—a test tire that is part of a test program.

3.1.4.1 *Discussion*—The term "candidate object" may be used in the same sense as *candidate tire*. **F 538**

3.1.5 *candidate tire set*, *n*—a set of candidate tires. **F 538**

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 04.03.

[4] *Annual Book of ASTM Standards*, Vol 09.02.

3.1.6 *reference tire*, *n*—a special tire included in a test program; the test results for this tire have significance as a base value or internal benchmark. **F 538**

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

3.1.8 *grooming*, *v—in tire testing*, mechanically reworking a snow test surface in order to obtain a surface with more consistent properties. **F 538**

3.1.9 *ice, dry*, *n*—smooth ice without loose surface materials. **F 538**

3.1.10 *snow, hard pack*, *n—in tire testing*, packed base without loose snow. **F 538**

3.1.11 *snow, medium pack*, *n—in tire testing*, groomed packed base with 2.5 to 5.0 cm (1 to 2 in.) loose snow. **F 538**

3.1.12 *snow, soft pack*, *n—in tire testing*, freshly fallen or deeply groomed base snow with 5.0 to 7.5 cm (2 to 3 in.) loose snow. **F 538**

3.1.13 *vertical load*, *n*—the normal reaction of the tire on the road which is equal to the negative of normal force. **F 538**

3.1.14 *spin velocity*, *n*—the angular velocity of the wheel about its spin axis. **F 538**

3.1.15 *longitudinal slip velocity (L/T)*, *n*—the effective rolling radius multiplied by the difference between the spin velocity (in rad/unit time) of a driven or braked tire and that of a free rolling tire when each is traveling in a straight line. **F 538**

3.1.16 *longitudinal force (F)*, *n—of a tire*, the component of the tire force vector in the X′ direction. **F 538**

3.1.17 *driving force (F)*, *n—of a tire*, the positive longitudinal force resulting from the application of driving torque. **F 538**

3.1.18 *driving coefficient (nd)*, *n*—the ratio of the driving force to a normal force. **F 538**

3.1.19 *control tire*, *n*—a reference tire used in a specified manner throughout a test program.

3.1.19.1 *Discussion*—A control tire may be of either type and typical tire use is the reference (control) tire in Practice F 1650 that provides algorithms for correcting (adjusting) test data for bias trend variations (See Practice F 1650 and Annex A1). **F 538**

3.1.20 *surface monitoring tire*, *n*—a reference tire used to evaluate changes in a test surface over a selected time period. **F 538**

3.1.21 *standard reference test tire (SRTT)*, *n*—a tire that meets the requirements of Specification E 1136, commonly used as control tire or a surface monitoring tire.

3.1.21.1 *Discussion*—This is a Type 1 reference tire. **F 538**

3.1.21.2 *Discussion*—A surface monitoring tire may also be used as a control tire.

3.1.22 *snow, medium hard pack*, *n—in tire testing*, packed base with some loose snow.

3.1.23 *ice, dry*, *n*—smooth ice without loose surface materials. **F 538**

4. Summary of Test Method

4.1 These test methods describe a series of vehicle maneuvers which can be utilized by the tire and vehicle industry to consistently measure the properties of a tire's performance on snow and ice surfaces in the braking, driving and cornering traction modes.

4.2 These test methods outline the procedures for conducting the following tests:

4.2.1 Road circuit handling,

4.2.2 Winter hill climb,

4.2.3 Winter slalom,

4.2.4 Acceleration—straight ahead,

4.2.5 Braking—straight ahead, and

4.2.6 Step steer.

5. Significance and Use

5.1 These test methods describe techniques for assessing the performance characteristics of tires in a winter environment on snow and ice surfaces in a standardized manner. When only snow is referred to hereafter, it should be understood that ice is implied as appropriate.

5.2 A series of maneuvers are conducted to characterize several aspects of the tire performance in snow, since a single maneuver is not sufficient to characterize all aspects of a tire's performance.

6. Interferences

6.1 Factors which may affect tire snow performance and must be considered in the final analysis of data include:

6.1.1 Snow/ambient temperature,

6.1.2 Mechanical breakdown of snowflake into granular crystals,

6.1.3 Solar heat load and tire temperature,

6.1.4 Tire wear condition or preparation,

6.1.5 Tire pressure and vertical load,

6.1.6 Test vehicle characteristics,

6.1.7 Snow surface characteristics,

6.1.8 Test driver, and

6.1.9 Rim selection.

7. Apparatus

7.1 Due to the nature of these test methods, specific requirements for apparatus will be limited. A general discussion of types of apparatus and their uses follows.

7.1.1 *Time Measurement*—This provides one of the simplest and lowest cost methods of quantifying tire performance. However, since time measurement inherently involves averaging over a time period, the measurements obtained provide only a general overview of performance.

7.1.1.1 Time measurement apparatus may be onboard the vehicle or stationary and may vary from handheld stopwatches to optical start/stop gates or combined apparatus for measurement of time and other properties (for example, fifth wheel apparatus).

7.1.1.2 Many tests measure time to complete a slalom or hill-and-curve course. Other tests involve measuring the time necessary to reach some condition, such as the time necessary to stop from a given speed or the time to achieve a certain speed from rest.

7.1.2 *Speed and Distance Measurement*—Vehicle speed and distance measurement may be used for evaluating tire snow performance. There are a number of technologies for measuring speed and distance.

7.1.2.1 *Fifth Wheel Based*—This test method requires that a lightly loaded free-rolling wheel be attached to the vehicle. A revolution counting device on this wheel is used to provide typical distance resolutions of 1 cm (0.4 in.). Fifth wheel type devices are highly reliable but may slip on low friction surfaces or bounce on a rough surface, providing inaccurate readings. A fifth wheel may not be appropriate on a road circuit handling course. Fifth wheel type devices are not suitable for use in radical maneuvers or situations where the vehicle may slide or spinout, as these maneuvers may cause damage to the devices. See Test Method F 457 for additional information on fifth wheels.

7.1.2.2 *Non-Contact Optical*—Optical sensors are available which can measure both longitudinal and lateral speed. Since these sensors do not contact the road surface they may be used without damage in tests which may involve spinouts or significant lateral motion. However, optical sensors depend on surface microtexture and they may not work on all surface conditions.

7.1.2.3 *Wheel Speed*—A wheel speed sensing device (optical encoder or tachometer) mounted on the wheels of the test vehicle permits the measurement of rotational speed of the wheels and the calculation of distance traveled. These test methods may be prone to error due to wheel slip or changing rolling radius. Wheel speed sensors are usually used in conjunction with 7.1.2.1 or 7.1.2.2 to determine the extent of wheel spin.

7.1.2.4 *Accelerometers*—Several commercial performance computers exist which calculate speed and distance traveled based on internally mounted accelerometers.[5] These devices perform numerical integration to compute speed and distance from the acceleration signal. Accelerometer-based devices are non-contact and self-contained; they are easy to transfer between vehicles. These devices are best suited to tests which involve primarily straight ahead motion and which involve events of short duration.

7.1.2.5 *Radar*—Self-contained radio and microwave speed sensing devices are not widely used for tire performance testing. Development of these devices is continuing.

7.1.2.6 *Telemetry*—Vehicle position sensing equipment is available which utilizes both stationary and vehicle mounted tranceivers. Using multiple stationary antennae, this equipment may provide dynamic vehicle position, speed and orientation data with great accuracy. The disadvantages to this approach are the cost of the systems and the difficulty in moving the system to a different test site. Telemetry is not widely used at present but may be of value in the future.

7.1.3 *Acceleration Measurement*—Acceleration measurement is a primary technology used for evaluating tire snow performance. Due to their low cost and ease of mounting, three-axis accelerometers provide a simple way to evaluate some aspects of tire performance.

7.1.3.1 Accelerometers function by measuring the acceleration of a vehicle. This acceleration depends on the forces existing at the tire/surface interface.

7.1.3.2 Accelerometers typically have bandwidths in excess of 100 Hz, allowing dynamic measurement of forces in a handling test.

7.1.3.3 Drawbacks to the use of accelerometers include: sensitivity to wind and vehicle orientation changes, such as body pitch and roll, which occur in handling maneuvers (gyro-stabilized platforms can be used to eliminate this problem); the need to mount the accelerometer at or near the center of gravity of the test vehicle to obtain accurate data; the fact that accelerations on snow and ice surfaces are typically small in magnitude; and the fact that accelerometer signals are typically noisy, leading to the need for filtration of the signal. See Practice F 811 for additional accelerometer usage information.

7.1.4 *Vehicle Orientation*—Devices to measure vehicle orientation include gyroscopes, wheel steer angle transducers and some telemetry systems.

7.1.4.1 Measurement of the test vehicle's orientation about its pitch and roll axis is typically used for correction of accelerometer based test systems.

7.1.4.2 Measurement of the test vehicle's orientation about its yaw axis as well as wheel steer angle measurement are used in cornering performance testing.

7.1.4.3 Due to high cost, vehicle orientation measurement devices are typically used only on tests requiring a high degree of accuracy.

7.1.5 *Force*—Direct measurement of tire/surface forces is normally accomplished using load cells.

7.1.5.1 Load cells provide the most accurate measure of tire forces under dynamic conditions.

7.1.5.2 Using specially designed suspensions, load cell based systems may be built which are not significantly affected by body roll of the test vehicle.

7.1.5.3 Due to mounting requirements, load cell-based systems typically are not easily transferred between multiple vehicles.

8. Selection and Preparation of Test Tires

8.1 Ensure that all test tires are approximately the same age and stored essentially at the same conditions prior to testing unless otherwise specified.

8.2 Test tires shall be mounted on Tire and Rim Association (T&RA)[6] or applicable document,[7,8] recommended rims by using conventional mounting methods. Proper bead seating shall be assured by use of suitable lubricant. Excessive use of lubricant should be avoided to prevent slipping of the tire on the wheel rim.

[5] The Vericom VC-200 has been found satisfactory for this purpose. It is available from Vericom Corp., 6000 Culligan Way, Minnetonka, MN 55345.

[6] Current yearbook of the Tire and Rim Association, 175 Montrose Ave., West, Suite 150, Copley, OH 44321.

[7] Current yearbook of the European Tyre and Rim Technical Organization. Available from the ETRTD, 32 Avenue Brugmann, 1060 Brussels, Belgium.

[8] Current yearbook of the Japan Automotive Tire Manufacturers' Association, Inc. Available from JATMA, 9th Floor, Toranomon Bldg., 1-12 Toranomon 1-Chrome, Minato-ku, Tokyo, Japan.

8.3 Test tire balance is optional.

8.4 Test tire break-in is optional; however, the design of the test may necessitate on-the-road conditioning of up to 322 km (200 miles). Tire break-in may improve repeatability of result on ice surfaces.

8.5 The removal of tread area protuberances is recommended.

8.6 Test tires shall have no evidence of force or run-out grinding.

8.7 Any objects (for example, shipping labels) in the tread area shall be removed prior to testing.

8.8 Tires that have been buffed to simulate wear must be prepared and run until all evidence of buffing is removed in accordance with Guide F 1046.

8.9 Mounted test tires shall be placed near the test site in such a location that they all have the same temperature prior to testing. Test tires should be shielded from the sun to avoid excessive heating by solar radiation.

8.10 Test tires shall be checked and adjusted for specified pressure just prior to testing.

9. Preparation of Apparatus

9.1 The test vehicle shall normally be representative of the type on which the test tires are used. The test vehicle shall be operated with approximately the same static weight throughout the test maintaining the same number of on-board personnel and the fuel load between one-half and three-fourths full. Any ballasting shall be a function of the individual program test requirements.

9.2 Safety equipment shall be selected based upon the severity of the tests. Seat belts shall be utilized during all testing. The use of roll bars or roll cages, warning lights, etc. is recommended.

9.3 Instrumentation shall be installed in accordance with manufacturers recommendations.

10. Calibration

10.1 *Fifth Wheel*—Calibrate in accordance with Test Method F 457.

10.2 Calibrate other instrumentation in accordance with manufacturers recommendations.

11. Procedure

11.1 *Course Surface*—See Annex A1-Annex A4 for climate and snow properties, surface characterization, course preparation and course maintenance.

11.2 *Organizing the Tire Test Program*—If two or more candidate (or experimental) tire sets are to be evaluated for any of the six tire performance procedures of 4.2.1-4.2.6, F 1650 should be consulted to layout or organize the test program with respect to the number and sequence of control tires to be tested. F 1650 also provides calculation procedures to determine if any time trend or other environmental changes have occurred in the testing conditions and if such changes have occurred F 1650 provides algorithms for applying corrections to produce performance data that are free from the perturbations induced by such changes.

11.3 *Performance Tests—Winter Handling*:

11.3.1 *Road Circuit Handling Test*—This test is designed to provide actual road performance confirmation of the differences measured in the winter traction tests. As with all performance tests, vehicle dynamics enter into the observations and can influence tire performance. Prior to any performance data presentation, analyze the raw or as obtained performance data according to the protocols as given by F 1650 and if data corrections are required use corrected data for the final presentation.

11.3.1.1 *Test Course*—Select a winter road handling course to provide a range of varying winter environment driving conditions. The course is comprised of packed snow, frozen ice, and other conditions representing a cross section of winter driving environments. Incorporate hills and curves in the course to subjectively evaluate the tractive potential of a vehicle equipped with test tires. The course may feature a variety of corner and radius combinations with uphill acceleration, downhill braking, and high speed level areas. See X1.1 for sample course. Pre-runs of the course for driver orientation and placement of pylons or markers for control of driving line are recommended. Position pylons or markers at the start and at the end of the course. The test criteria consists of best effort time over measured course along with identification of each mode of control loss.

11.3.1.2 *Road Circuit Handling Test Procedure*—Initiate the test from a stop at the starting pylon or marker, starting the vehicle and a timing device simultaneously and accelerating to a speed considered by the driver to be the maximum limit for the conditions. A stop of maximum deceleration is accomplished at the end of the course and the elapsed time recorded. Make subjective notes after each lap. Repeat the test a minimum of two times on each set of test tires with control tires being run at the start and end of the test sequence. When instruments are used, log the lateral and longitudinal acceleration data for each test run.

11.3.1.3 *Data Analysis*—Summarize the outcome of individual tests performed on each tire. The information provided as a result of the subjective handling tests shall include lap times, a multi-point subjective evaluation and control loss description. Calculate a rating comparing total elapsed time to negotiate the test course for the test tires compared to the control tires. Calculate a rating comparing the average subjective performance of each tire set. Analyze the subjective hill and curve data to relate the mechanism of traction loss and the controllability of each of the tire sets. The times recorded for each of the test runs is related to the controllability of the system. Analyze the data from the on-board computer (if used) to establish the test tire sets longitudinal and lateral *g*-capabilities as it relates to the test surface and specific vehicle maneuver in a dynamic operating mode.

11.3.1.4 *Data Reporting*—Present the data to compare the performance of the test tires by their relative performance to the control tire set and show a general overview of the tests by groups, method and conditions. The report shall include observations and comments. Present the data from the instrumented testing in a graphical format with peak longitudinal and lateral *g*-values identified. Include a map of the test course in the report.