

SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

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Passenger Car and Light Truck Tire Dynamic Driving Traction in Snow

1. **Scope**—This SAE Recommended Practice defines the best known techniques for evaluating dynamic passenger car and light truck tire driving traction in snow. There are many snow conditions which a typical driver will encounter that are not specifically addressed in this Recommended Practice. Dynamic driving traction in this Recommended Practice is under a narrow, controlled range of conditions of temperature, snow compaction and depth (commonly called the "Test Window") to minimize test variability. Tire rankings may differ on other types of snow and ice conditions.

1.1 **Object**—The object of this SAE Recommended Practice is to provide a uniform test procedure for measuring the dynamic driving traction of passenger car and light truck tires in snow.

2. References

2.1 **Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

ASTM F 377
ASTM F 408
ASTM F 457

2.2 **Related Publications**—The following publications are provided for information purposes only and are not a required part of this document.

A. H. Bowker and G. J. Lieberman, Engineering Statistics, Prentice-Hall.
A. J. Duncan, Quality Control and Industrial Statistics, Richard D. Irwin.
SP-250, Statistics for the Engineer, Society of Automotive Engineers, Inc.
Tire Performance Criteria Procedures and Specifications, General Motors Corporation

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- 3. Preparation of Tire(s) for Test**—All tires to be tested shall be trimmed to remove protuberances in the tread and upper sidewall area caused by mold air vents or flashes at mold junctions. All tread labels shall also be removed at this time. Tires must not have evidence of force or runout tread grinding.¹ Test tires shall be mounted on rims² of a width approved by the Tire and Rim Association (T&RA) for the tire size being tested, inflated to the T&RA design inflation pressure, applied to an appropriate vehicle, loaded to 50–100% tire maximum load at recommended inflation, and run on a paved road for a minimum of 80 km (50 mile) at 80–88 km/h (50–55 mph). This break-in is run to remove mold lubricant and mold sheen from the tread surface. Excessive acceleration, braking and cornering, that might result in abnormal tread surface wear are to be avoided.

NOTE— Tires that have been buffed to simulate wear must be run on a paved road until all evidence of buffing has been removed.

4. Equipment

- 4.1 Test Vehicles**—Either a self-contained traction vehicle or a two-vehicle drawbar pull system designed to measure dynamic driving traction forces and meeting the requirements outlined in Appendix A or B is required.
- 4.2 Course Preparation Equipment**—Snow handling equipment and a device designed for compacting the snow surface in a uniform manner is normally needed (see Appendix C).
- 4.3 Course Measuring Equipment**
- 4.3.1 SNOW COMPACTION MEASURING DEVICE—CTI SNOW PENETROMETER—See Appendix D.
- 4.3.2 SNOW MONITORING TIRE (SMT)—INDUSTRY STANDARD TIRES FOR CHARACTERIZING TEST SURFACE—See Appendix E.
- 4.3.3 CALIBRATED THERMOMETERS OR OTHER TEMPERATURE MEASURING DEVICES—Used to measure ambient and snow temperatures.

5. Test Procedure

5.1 Test Conditions

Load³

- A. Passenger: 75% of maximum load as branded on tire.
 B. Light Trucks: 5500 N (1200 lb).

Inflation Pressure

- A. Passenger: T&RA max as stamped on the side of the tire.
 B. Light Truck: Bias ply tires - 300 kPa (45 psi), radial tires - 350 kPa (50 psi), but not to exceed maximum shown on tire sidewall.

Vehicle Test Speed - 8 ± 1.6 km/h (5 ± 1 mph).

NOTE— Change in speed for any test run should not exceed 0.8 km/h (0.5 mph).

1. Force or runout grinding may produce incorrect results due to surface texture changes in the tread rubber.
 2. For meaningful comparisons, tires of similar size should be run on comparable width rims.
 3. These loads were selected to represent typical usage.

5.2 Test Surface—The test surface shall be of a reasonable depth, 50–100 mm (2–4 in), of prepared natural snow over a moderately packed snow base. This surface shall have a mean CTI Penetrometer reading between 70 and 80 (see Appendix D) and snow monitoring tire mean friction coefficient of 0.18–0.26 (See Appendix E). A sufficient number of measurements shall be taken in establishing the average to ensure course uniformity. The range of the measurements shall not exceed 8 points for the Penetrometer nor 0.05 coefficient for the Snow Monitoring Tire. The temperature of the prepared test course as measured one inch below the surface shall be in the range of –12 °C (+10 °F) to –4 °C (+25 °F). Snow course preparation is extremely critical for obtaining valid results. See Appendix C for additional details.

5.3 Testing Procedure—Tests should be conducted as outlined in procedures shown in Appendix A or B.

6. Data Reduction and Analysis

6.1 Data Reduction

6.1.1 The quantitative measure of tire performance shall be the average tractive force a tire produces during a test. This average may be determined by one or both of the following methods:

1. Digital or analog average determined between 2–24 km/h (1–15 mph) DIV of a tractive force vs DIV curve.

NOTE— DIV (Differential Interface Velocity) is the difference between the test tire speed and the test vehicle speed.

2. Digital or analog average of 1.5 sec of data from a tractive force vs time plot. Data acquisition begins when DIV is 3 km/h (2 mph). Minimum ending DIV must be 16 km/h (10 mph).

6.1.2 To convert the average tractive force to a coefficient of friction, divide by the average test load (see 5.1). The average test load can be determined in the same manner as the average tractive force. If the average test load is not available, the nominal test load is an acceptable alternative value.

6.2 Data Analysis

6.2.1 Determine mean and standard deviation of test sequence. Eliminate outlier test data, which is defined as any individual test value more than 1.5 standard deviations from the calculated mean. After eliminating outlier test values, recalculate the mean and standard deviation of the test sequence.

6.2.2 Examine the data for variation by some means such as coefficient of variation $\left(C.V. = \frac{\text{Standard Deviation}}{\text{Mean}} \right)$.

If the data has extreme variations (C.V. greater than 0.20), the individual tire data should not be used and the test sequence repeated.

6.2.3 The SMT tire should be used to monitor changes in the test site conditions so that test tire coefficients can be adjusted appropriately. A basic method to adjust test tire coefficients for SMT tire variations is as follows:

6.2.3.1 The SMT tire coefficients are averaged for a sequence of tests (usually one test day).

6.2.3.2 Each test tire coefficient is then adjusted by multiplying by the ratio of the overall SMT tire coefficient (paragraph 6.2.3.1) to the average coefficient of the individual SMT tires tested before and after that test tire. The standard deviation of each test tire is also adjusted by multiplying by the same ratio. The following example test sequence computations illustrate the method, using four test tires:

1. SMT Tire (SMT₁)
2. Test Tire (T₁) (SD₁)
3. Test Tire (T₂) (SD₂)

4. SMT Tire (SMT₂)
5. Test Tire (T₃) (SD₃)
6. Test Tire (T₄) (SD₄)
7. SMT Tire (SMT₃)

$$\text{Overall SMT Average (SMT}_{\text{avg}}) = \frac{\text{SMT}_1 + \text{SMT}_2 + \text{SMT}_3}{3}$$

$$\text{SMT Average (SMT}_{12}) = \frac{\text{SMT}_1 + \text{SMT}_2}{2}$$

$$\text{SMT Average (SMT}_{23}) = \frac{\text{SMT}_2 + \text{SMT}_3}{3}$$

The means and standard deviations of the Test Tires T₁ and T₂ are adjusted by:

$$\left(\frac{\text{SMT}_{\text{avg}}}{\text{SMT}_{12}} \right) (T_1 \text{ or } T_2), \left(\frac{\text{SMT}_{\text{avg}}}{\text{SMT}_{12}} \right) (SD_1 \text{ or } SD_2)$$

Test Tires T₃ or T₄ are adjusted by:

$$\left(\frac{\text{SMT}_{\text{avg}}}{\text{SMT}_{23}} \right) (T_3 \text{ or } T_4), \left(\frac{\text{SMT}_{\text{avg}}}{\text{SMT}_{23}} \right) (SD_3 \text{ or } SD_4)$$

- 6.2.3.3 Comparative test tire data is then determined by normalizing the test tire coefficients to a 0.22 coefficient of SMT values on a proportionate basis.
- 6.2.3.4 The above procedure should be considered only as a fundamental outline for test tire adjustment to minimize error caused by changes in uncontrolled variables. Other, more complex, methods for test tire adjustment can be used. These methods generally incorporate test variability and sample size. If variations in SMT tire values were observed that cannot be accounted for, or if test tire data is corrected more than 5%, the entire test should be repeated.
- 6.2.4 Testing error must be determined using appropriate techniques. An overall mean using a minimum of three different tests (data obtained on different days) should be calculated from the means calculated in accordance with paragraph 6.2.1. Means obtained from more than one day of testing combined with testing error, best represent a given tire's performance. Differences between specific tires or among tire groups must be determined in a statistical manner. The Student's T test or Analysis of Variance techniques are appropriate for determining these differences. Individual tire performance values do not necessarily imply significant differences. See Appendix F for the Recommended Statistical Procedure.

7. Precision and Accuracy

- 7.1 **Precision**—This precision statement is based on data obtained from five test laboratories and reflects the combined variability of both self-contained and drawbar pull driving traction tests. Two candidate tires and the recommended Snow Monitoring Tire (SMT) were tested:

Candidate 1—P195/75R14 Large Lug Type M&S
 Candidate 2—P195/75R14 All Season Type M&S
 SMT—P195/75R14 Uniroyal "Steeler" #32164-U

Performance for each tire was determined by averaging three test replications. All tests were conducted within the recommended SAE test conditions. The precision of results for tires of this type could be expected to fall within ±0.04 spin coefficient.

- 7.2 Accuracy**—No statement of accuracy can be prepared for this method since there is no absolute value for use as a comparison.

PREPARED BY THE SAE TIRE TEST SUBCOMMITTEE

APPENDIX A

SELF-CONTAINED DRIVING TRACTION TEST PROCEDURE

A.1 Scope—This method covers the measurement of driving traction for passenger and light truck tires traveling straight ahead on prepared or selected test surfaces of uniform consistencies as measured using a single instrumented vehicle. This procedure and equipment described herein are intended for snow-covered surfaces.

A.2 Summary of Test Method—This test utilizes a rear-wheel drive, four-wheel test vehicle with one specially-instrumented drive wheel to measure the fore-aft and vertical forces on its tire and with the capability of deactivating the brake on this wheel. The test is conducted by gradually increasing the driving torque to the test wheel and maintaining test speed by modulating the brakes of the other nontest wheel positions. The test progresses with increasing throttle setting and brake application until the desired maximum test tire spin is achieved.

A.2.1 Test Speed

A.2.1.1 The nominal recommended vehicle test speed is 8.0 km/h (5 mph).

A.2.1.2 The actual vehicle speed must be within ± 2 km/h (1 mph) of nominal recommended.

A.2.1.3 Speed variation during any individual test run must not exceed 1 km/h (0.5 mph).

A.3 Equipment**A.3.1 Test Vehicle**

A.3.1.1 The test vehicle shall be a rear-wheel drive, four-wheel vehicle specially fabricated and instrumented to measure the fore-aft and vertical forces at one wheel position at the tire/surface interface while driving torque is applied. Vehicle size and selection depends on the tire size and loading condition to be tested. Automatic transmission is recommended.

A.3.1.2 The test vehicle shall have the capability of maintaining a specified test vehicle speed to within 1 km/h (0.5 mph) even at maximum levels of application of driving torque.

A.3.1.3 The test vehicle shall be equipped with an automatic throttle applier to provide for a smooth increase of driving torque.

A.3.1.4 The brake system will be modified to deactivate the test wheel brake upon initiation of a tire test.

A.3.1.5 Predetermined test vehicle ride heights are adjusted in conjunction with a position transducer to obtain proper transducer orientation.

A.3.2 Calibration Instrumentation

A.3.2.1 Appropriate loading platform or load cells, air bearings, and other auxiliary equipment required for calibrating the vertical and fore-aft force transducer (ref. ASTM F377).

A.3.2.2 Required instrumentation for calibrating speed transducers, and adequate support equipment to calibrate and maintain all intermediate instrumentation (ref. ASTM F457).

A.3.3 Instrumentation

A.3.3.1 The test system measuring instrumentation and transducer shall have specifications sufficient to meet accuracy, filtering, and digital requirements as outlined in ASTM F408.

A.3.3.2 A force transducer, to measure tractive force produced by the test tire and the vertical force on the test tire is required. This transducer is generally mounted at the axle tire-brake backing plate interface of the test wheel position.

A.3.3.2.1 It is important that the orthogonal measuring axes of the force transducer be properly oriented to the plane of the road surface. Improper orientation of the transducer can cause errors in the input force signal. Misalignment can result from initial setting of transducer angle, dynamic change due to suspension rotation or "wind-up", or dynamic change due to ride motion.

A.3.3.2.2 Prior to testing at different loads or changing test tire diameter, the force measuring transducer must be repositioned to null the vertical load component induced into the fore-aft channel. This is particularly important in dual-axis measuring devices because:

$$\text{fore-aft force indicated} = T_A \cos \alpha \pm V_A \sin \alpha \quad (\text{Eq. A1})$$

$$\text{vertical- force indicated} = V_A \cos \alpha \pm T_A \sin \alpha \quad (\text{Eq. A2})$$

where:

T_A = actual fore-aft force

V_A = actual vertical force

α = angle of transducer positioning error

If the fore-aft channel is zeroed with the static load applied to the transducer, the $\pm V_A \sin \alpha$ term of Equation 1 will be essentially nulled (neglecting the effect of dynamic vertical load change, which should be made very small). Because there is no practical way to zero the vertical channel with fore-aft force applied, the $\pm T_A \sin \alpha$ error of Equation 2 cannot be compensated for and increases in magnitude with increasing fore-aft force development.

A.3.3.3 Vehicle speed sensor, to determine vehicle speed accurately. This may be accomplished with a speed pickup from a front wheel of the test vehicle, a fifth wheel, or some other appropriate device.

A.3.3.4 Tachgenerator, to measure angular velocity of test wheel.

A.3.3.5 Data recorder, to provide a permanent record of transducer output signals prior to any data processing. This recorded data can be used for hand processing of data or to provide an information source for confirming outputs of any digital or analog data processors. A visual display of these data is appropriate as an aid to the operator, but is not required.

A.3.3.6 Microprocessor, used for on-board data processing. This unit is not required, but simplifies data processing.