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SURFACE VEHICLE RECOMMENDED PRACTICE

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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

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 rims[2] 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**

Load[3]

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

Inflation Pressure

A. <u>Passenger</u>: T&RA max as stamped on the side of the tire.
B. <u>Light Truck</u>: 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 $\left(\text{C.V.} = \frac{\text{Standard Deviation}}{\text{Mean}}\right)$.

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 <u>basic</u> 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 (SMT_1)
2. Test Tire (T_1) (SD_1)
3. Test Tire (T_2) (SD_2)

4. SMT Tire (SMT_2)
5. Test Tire (T_3) (SD_3)
6. Test Tire (T_4) (SD_4)
7. SMT Tire (SMT_3)

$$\text{Overall SMT Average } (SMT_{avg}) = \frac{SMT_1 + SMT_2 + SMT_3}{3}$$

$$\text{SMT Average } (SMT_{12}) = \frac{SMT_1 + SMT_2}{2}$$

$$\text{SMT Average } (SMT_{23}) = \frac{SMT_2 + SMT_3}{3}$$

The means and standard deviations of the Test Tires T_1 and T_2 are adjusted by:

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

Test Tires T_3 or T_4 are adjusted by:

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

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.

A.4 Preparation of Equipment

A.4.1 Test Vehicle

A.4.1.1 All transducers and instrumentation should be calibrated using recognized procedures (see Section A.5).

A.4.1.2 The test vehicle front tires should be the same size and have the same inflation pressure as used in calibration to maintain the front axle heights.

A.4.1.3 Mount test and SMT tires on appropriate rims to account for possible test vehicle transducer offset sensitivity.

A.5 Calibration

A.5.1 Calibrate the transducer for measuring driving forces as generally described in ASTM F 377.

A.5.1.1 The vehicle transmission should be placed in "Park" (P) with the emergency brake off during fore-aft calibration. This allows calibration with all the components of the drive system involved, as in the actual test mode. The test wheel brake must be deactivated during calibration.

A.5.2 Calibrate vehicle speed sensor, test wheel speed tachgenerator, and all other intermediate instrumentation according to established procedures or manufacturer's specifications.

A.5.3 The ride height required for transducer alignment (see paragraph A.3.3.2.2) is determined during calibration, using specific test loads and tire size combinations to be tested. A position transducer is used in conjunction with height adjustment device to measure the distance between the vehicle frame and rear axle.

A.5.4 All instrumentation is to be calibrated prior to each test program.

A.6 General Test Conditions

A.6.1 Conduct the tests on a level surface meeting the requirements of paragraph 5.2.

A.7 Procedure

A.7.1 Warm up electronic test equipment as required for stabilization.

A.7.2 Test tires should be stabilized at ambient temperature and shielded from direct sunlight before testing.

A.7.3 Install test tire on test vehicle. A tire with a similar loaded radius and equipped with a tire chain or other traction device should be used on the nontest side to prevent this position from spinning.

A.7.4 Adjust the vehicle static weight on the test tire to the test load.

A.7.5 Check and adjust tire inflation pressure as required immediately before testing.

A.7.6 Adjust vehicle ride height to the predetermined output reading of the position transducer (ref. paragraph A7.3) by using the leveling device. This positions the transducer to compensate for different test loads and changing test tire diameters.

A.7.7 Record tire identification and other data, including date, time, ambient temperature, and test surface information (see paragraph 5.2).

A.7.8 Conduct test at nominal 8 km/h (5 mph) test vehicle speed.

A.7.9 Activate the automatic throttle applicator to obtain a maximum 1800 N/s (400 lb/s) measured fore-aft force before spin and apply the brakes as required to maintain test vehicle speed.

NOTE—An invalid snow traction test run occurs when a tire digs through to either the base road material or to glare ice during tire acceleration or spin.

A.7.10 Record test data. Data recorded shall include tractive force, vertical force, test tire speed, ground speed and a time reference.

A.7.11 Repeat steps A.7.8 through A.7.10 (a minimum of 8 times) to complete the tire test.

NOTE— Multiple tests should not be conducted over the same surface without adequate surface reconditioning between tests.

A.7.12 Run an SMT tire at the beginning and end of each test sequence and every third test in between (SMT-T-T-SMT-T-T-SMT, etc.).

A.7.13 Each test tire should be tested at least three times, preferably on different days.

APPENDIX B

DRAWBAR PULL TEST PROCEDURE

B.1 Scope—This method covers the measurement of driving traction of a pair of tires designed for and mounted on passenger cars or light trucks traveling straight ahead on a prepared snow surface using the two vehicle drawbar pull system.

B.2 Summary of Method—The test is conducted by towing a hold back vehicle (dynamometer) behind the test vehicle moving in a straight line. A constant speed is maintained by increasing the brake application of the dynamometer to compensate for increasing throttle setting of the test vehicle. The dynamometer braking is increased only as much as is necessary to maintain a constant test speed. The test progresses with increased throttle setting and dynamometer brake application until the test tires spin through the desired slip range.

B.2.1 Test Speed

B.2.1.1 The nominal recommended vehicle test speed is 8 km/h (5 mph).

B.2.1.2 The actual vehicle speed must be within ±1.6 km/h (1 mph) of nominal recommended.

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

B.3 Equipment

B.3.1 Test Vehicle

B.3.1.1 The test vehicle shall normally be a rear-wheel drive, four-wheel passenger car or a light truck under 44 82 N (10 000 lb) gvw (gross vehicle weight). A front-wheel drive vehicle is acceptable where test requirements dictate.

B.3.1.2 The test vehicle should be designed to carry the test load on the drive axle. The use of overload springs, air shocks or suspension blocks is acceptable.

B.3.1.3 The test vehicle should incorporate an automatic engine throttle applicator capable of providing a smooth increase of driving torque.

B.3.2 Towed Hold Back Vehicle

B.3.2.1 The towed vehicle should have capability to develop a dynamic drawbar pull force and maintain test speed dictated by test tire size and load.

B.3.3 Other Equipment

B.3.3.1 DRAWBAR ASSEMBLY—The drawbar assembly consists of a load transducer in series with a flexible (chain) or solid (tube) connection between the test vehicle and hold back vehicle. The attachment of the drawbar to the rear-wheel drive test vehicle is directly to the test vehicle's frame or rear axle assembly through a freely rotating joint. Springs can be provided to counterbalance the static weight of the force transducers and drawbar assembly.

B.3.3.2 INTERCOM—An intercom should be used between the test and dynamometer vehicles for proper coordination of the test activities.

B.3.4 Instrumentation

B.3.4.1 The test system measuring instrumentation shall have specifications sufficient to meet accuracy, filtering, and digital requirements as outlined in ASTM F 408.

B.3.4.2 Force transducer, to measure drawbar pull force. An analog or digital readout may be provided (optional) in the test vehicle for on-site calibration purposes.

B.3.4.3 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.

B.3.4.4 Tachgenerator, to measure average angular velocity of the two test wheels, installed on the test vehicle.

B.3.4.5 Multichannel Recorder or XXY or XYY Function Plotter, 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 this data is appropriate as an aid to the operator, but is not required.

B.3.4.6 Microprocessor, used for on-board data processing. This unit is not required, but simplifies data processing.

B.4 Preparation of Equipment

B.4.1 Test Vehicle

B.4.1.1 All transducers and instrumentation should be calibrated to recognized procedures.

B.4.1.2 The same tires are to remain on the nontest wheel positions throughout the test.

B.5 Calibration

B.5.1 Calibrate the force transducer, speed sensor, test wheel speed, tachgenerator, and all other intermediate instrumentation, in accordance with the manufacturer's recommended procedure.

B.5.2 All instrumentation is to be calibrated prior to each test program, and provisions should be provided for daily field calibrations.

B.6 General Test Conditions

B.6.1 Conduct the tests on a level surface meeting the requirements of paragraph 5.2.

B.7 Procedure

B.7.1 Warm up electronic test equipment as required for stabilization.

B.7.2 Test tires should be stabilized at ambient temperature and shielded from direct sunlight before testing.

B.7.3 Apply test tires to the test positions.

B.7.4 Adjust the vehicle test wheel static weight by ballasting to match the static wheel load specified for test tires.

B.7.5 Check and adjust tire inflation pressure as required immediately before testing.

B.7.6 Record tire identification and other data, including date, time, ambient temperature, and test surface information (see paragraph 5.2).

B.7.7 Approach a test site moving in a straight line at a constant nominal speed of 8 km/h (5 mph) and adjust the hold back vehicle speed to obtain near zero drawbar pull force.

B.7.8 Turn on the recorder drive just prior to reaching the test site.

B.7.9 Activate the automatic throttle applicator to obtain a maximum 1800 N/s (400 lb/s) measured drawbar force before spin.

NOTE—An invalid snow traction test run occurs when a tire digs through to either the base road material or to glare ice during tire acceleration or spin.

B.7.10 Record test data. Data plotted or recorded shall include drawbar force or traction coefficient vs DIV, ground speed, and a time reference.

B.7.11 Repeat paragraphs B.7.8 to B.7.10 to obtain a minimum of eight acceptable curves according to the criteria in paragraph 6.2.1.

NOTE— Tests should not be conducted over the same surface without adequate surface reconditioning between tests.

B.7.12 Run an SMT tire at the beginning and end of each test sequence and every third test in between (SMT-T-T-SMT-T-T-SMT, etc.).

B.7.13 Each test tire should be tested at least three times, preferably on different days.

B.7.14 Every effort should be made to have the same test drivers perform the same test functions through a sequence of tests.

APPENDIX C

SNOW TEST COURSE SITE SELECTION, PREPARATION, AND MAINTENANCE—

There are three basic requirements for the selection of a test course site. First, the test area must be flat. A maximum of 1% grade, including crown is preferable. This ensures testing of the tire and not the grade requirements of the vehicle. Second, the test area should be limited access. Having only test vehicles on the test surface reduces maintenance requirements for the surface. Third, no vegetation should be exposed. If a field is used, all vegetation should be cut and/or covered such that it is never exposed during testing. This may also apply to private road areas when vegetation occurs in pavement cracks. Appropriate test sites include airport runways, private road systems, large unused parking lots, and open level fields.

Once a site has been selected, a course must be prepared. Developing a base is the most critical step in this preparation. A good base must adhere to the firm subsurface and be completely smooth and uniform in consistency. Without a good base, it is impossible to develop good test data.

Deep loose snow cannot generally be compacted into a satisfactory hard pack base. Therefore, it should be packed in layers. Excessive snow should be removed to a depth of 2–4 in, depending on the compressibility of the snow before packing. After the first layer is packed, the snow which was previously removed can be brought in from the banks to a depth of 2 in (provided the banked snow has not hardened into large chunks) and compacted again. This process is repeated until sufficient base depth is developed. Allowing a base to sit undisturbed overnight or longer will usually firm it up. Defining sufficient base depth is difficult.

The base must be of sufficient depth so that a spinning test tire does not dig down to anything but more base snow. Required depth changes depending on test tread designs but usually a minimum of 2 in is necessary. Throughout a test season, it will be necessary to groom the surface to keep it smooth and free from holes and undulations. Use of a road grader is the most ideal method; however, a standard snow plow, preferably with a long wheel base, can be used if a speed is selected to minimize suspension rocking which can result in increased undulations.

Once a base is established, the preferred method is to wait for natural snow to accumulate to a sufficient depth to allow appropriate testing conditions. When a large test area is available, various sections can be designated as virgin, soft, medium, and extra hard test areas. This allows testing on medium and extra hard surfaces while other sections are accumulating sufficient depth for soft and virgin snow conditions. The preferred snow condition for best discrimination among tire types is medium packed snow over a hard packed base. Medium packed snow corresponds to CTI penetrometer readings between 70 and 80 and Snow Monitoring Tire friction coefficients of 0.18–0.26 (see Appendices D and E). Test surfaces can be groomed to these levels. Test surfaces should always be quantified by averaging several locations along the test course. The range of these measurements shall not exceed 8 points for the penetrometer nor 0.05 coefficient for the Snow Monitoring Tire.

Each time a surface is used for testing, it gets packed down and consequently becomes harder. Therefore, the same test area cannot be used over and over for the same compaction range without reconditioning. Mechanical snow reconditioners to loosen hard packed snow can be used when fresh snow is not available. However, whenever a surface is reconditioned or regroomed, it should be rechecked to ensure that the penetrometer and the Snow Monitoring Tire measurements are correct.

It is also necessary to check a test surface periodically during a test day to ensure that it has not changed significantly. This may be accomplished by monitoring the SMT test results and rechecking with the penetrometer.

APPENDIX D

SMITHERS/CTI[4] SNOW COMPACTION GAUGE—

The compaction and shear strength of snow have a major effect on the snow traction performance of tires. These parameters cannot be isolated, but a rating can be placed on the results of both variables by making a combined vertical and horizontal compression test.

After considerable research on past methods of measuring snow compaction, it was found that these methods were too far removed from the actual action of a tire tread in snow to be meaningful. Smithers/CTI designed and built a "compaction tester" to measure the combined effect of the vertical compaction and the horizontal compressibility of snow.

The CTI Snow Compaction Gauge is shaped like a plumb bob (see Figure D1), except that the point is rounded with a 1.6 mm (1/16 in) radius. A measuring rod is fitted in the other end. Each gauge is adjusted in the laboratory to have a weight of 220 ± 1 g, including the knurled nut on top of the drop rod. The drop height has been adjusted to 218.9 ± 0.25 mm (8.62 ± 0.01 in).

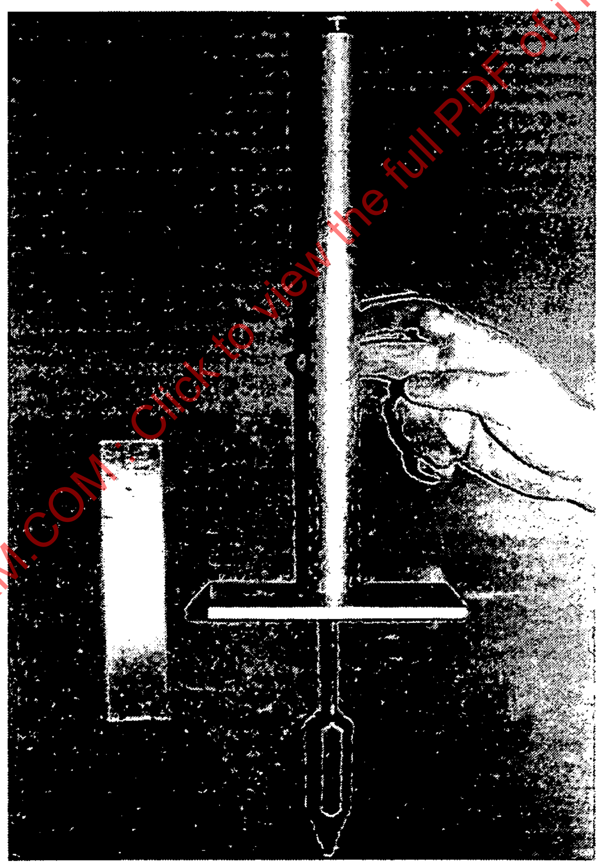

FIGURE D1—SMITHERS/CTI SNOW COMPACTION GAUGE

4. Smithers Scientific Services, Inc., Akron, Ohio.

In use, the mass of the projectile and the measuring rod is dropped a preset distance through a guide tube with a flanged end which rests on the test surface. The kinetic energy is expended in both vertical penetration and side compression. The penetration distance is converted by a hand-held scale to read the compaction numbers (50–100) directly.

To better understand the meaning of the readings, the following table is offered. It should be noted that numbers below (60) are difficult to obtain in snow.

TABLE D1—

Surface Description	CTI Compaction Range
Steel	100
Ice	93 – 98
Extra Hard Hard Pack Snow	84 – 93
Standard Medium Hard Pack Snow	70 – 84
Soft Pack or Loose Pack Snow	50 – 70
Virgin Snow - No Rating: (Use depth and moisture content)	
Water	1

The recommended snow test conditions of 70–80 (see Appendix C) represent a range in which good discrimination among tire types can be obtained. The range obtained when measuring different locations on a test course should be no greater than 8 to ensure course consistency.

<u>Instructions for Use</u>

When using the CTI Snow Compaction Gauge in the field, it should be kept on top of the snow to maintain the metal at approximately the same temperature as the snow. It is also necessary that the gauge does not accumulate an excessive amount of snow on the inside. This will not happen if the plunger is wiped after each drop. Should it occur through unforeseen circumstances, it is preferable to melt the snow from the inside, rather than disassemble the unit. If for some reason the unit must be disassembled, be sure to note the location of any washers used in the assembly. Also note the position of the lead shot weights in the plunger opening for the drop rod.

Standard practice in the field is to drive the front wheels of the test vehicle equipped with highway tires over the test bed, then turn the vehicle to the right or left to expose a tire track. Place the gauge in the center of the tire track. With the plunger rod raised, rotate the gauge 45 degrees and back to gently smooth the tread pattern left by the tire. Be sure the plunger is bottomed internally on the upper part of the drop tube. Keep a very light pressure on the aluminum foot to prevent it from changing position or lifting off the snow.

Release the drop rod assembly and immediately set the brass engraved measurement scale on top of the drop tube, close to the knurled nut. Read the CTI Compaction Number from the scale at the top outer edge of the knurled nut.

Calibration may be checked by placing the unit on a smooth hard surface with the plunger in the down position. The gauge should now read 100 to the top of the knurled nut. If the unit should be disassembled for any reason, then the drop length should be checked for 218.9 + 0.25 mm (8.62 ± 0.01 in) and the plunger assembly weight adjusted for 220 ± 1 g.

APPENDIX E

SNOW MONITORING TIRE—

Test course surface quantification can be obtained by using an industry designated Snow Monitoring Tire or SMT. The current [5] industry SMT is the Uniroyal "Steeler" steel belted radial P195/75R14 TPC, spec number 1024 (Uniroyal development reference number 32164-H). This tire must not be subjected to tread grinding procedures.

On an appropriately prepared surface (medium packed snow, see Appendix C), the average friction coefficient of this tire is 0.18–0.26. This performance represents a range in which good discrimination among tire types can be obtained.

Use of the SMT concept allows for direct surface measurement comparisons of all test agencies' test sites. It also allows common base comparison of performance obtained by various agencies using the procedure outlined in this Recommended Practice.

5. If the tread design, tire construction, or rubber compounds in this SMT tire are changed, Uniroyal will notify the SAE Test Committee, who will review the changes and make recommendations if a new SMT tire should be considered.

APPENDIX F

COMPARATIVE RATINGS AND SIGNIFICANT DIFFERENCES

F.1 ***Background***—As is the case for many tire tests, there is no absolute reference for comparison of various test tires. The commonly accepted method of comparing tires is the calculation of a percentage rating. The general rule is to arbitrarily set the control or SMT performance level equal to 100%, then candidate performance is calculated by comparing the candidate performance to the control performance.

When the data is such that a larger value indicates performance superior to the control or SMT use equation (F1).

$$\text{Rating} = \frac{\text{Test}}{\text{Control (or SMT)}} \times 100\% \qquad \text{(Eq. F1)}$$

When the data is such that a smaller value indicates performance superior to the control or SMT use equation (F2).

$$\text{Rating} = \frac{\text{Control (or SMT)}}{\text{Test}} \times 100\% \qquad \text{(Eq. F2)}$$

Driving traction testing uses equation (F1).

F.2 ***Calculation of Rating***—All empirical data contains a certain amount of scatter due to variations in test conditions. This scatter must be taken into account by statistical means to establish a level of significance or range of confidence for the percentage rating.

Paragraph 6.2.3.2 outlines a basic method to adjust test tire coefficients for SMT tire variations during testing. It is assumed at this point that the data meets other criteria for suitability, i.e. paragraph 6.2.2 coefficient of variation limits.

Once the procedures in paragraph 6.2.3.2 have been completed, the percentage rating can be easily calculated by substituting adjusted test coefficients and average SMT coefficients into equation (F1).

F.3 ***"Weighting the Data"***—A more complete method of accounting for variation in the SMT tire performance is to apply "weighting" techniques to the data. The "weighted" data is based on the variability and number of test runs for each individual SMT tire data entry. In other words, the more variable SMT tire data will receive less weight in the weighted averages.

For example, assuming a test sequence of: SMT tire (SMT_1), Test Tire (T_1), Test Tire (T_2), SMT Tire (SMT_2), Test Tire (T_3), Test Tire (T_4), SMT Tire (SMT_3), the weighted SMT tire average (SMT avg) would be:

$$\frac{SMT_1\frac{\sqrt{N_1}}{\sigma_1} + SMT_2\frac{\sqrt{N_2}}{\sigma_2} + SMT_3\frac{\sqrt{N_3}}{\sigma_3}}{\frac{\sqrt{N_1}}{\sigma_1} + \frac{\sqrt{N_2}}{\sigma_2} + \frac{\sqrt{N_3}}{\sigma_3}} \qquad \text{(Eq. F3)}$$