



SURFACE VEHICLE RECOMMENDED PRACTICE

J2909™

JUN2018

Issued 2010-05
Revised 2018-06

Superseding J2909 MAY2010

Light Vehicle Dry & Wet Stopping Distance Test Procedure

RATIONALE

Wet stopping distance instructions have been added to this procedure.

1. SCOPE

This document establishes best practices to measure vehicle stopping distance on dry or wet asphalt in a straight path of travel intended for the purpose of publishing stopping distance by manufacturers and media organizations for vehicles with original equipment tires. It is recommended that the test method within be adopted for all vehicles less than 4536 kg (10000 pounds) GVWR. This procedure is typically used with initial speeds of 100 km/h and 60 mph, but other speeds may be used. Since tires play a significant role in stopping distance, this procedure covers tire types typically used as original equipment on new vehicles including all-season, summer, and all-terrain tires. This document may serve as a procedural guideline for all tire types, but the surface temperature correction formulas in this procedure were developed using all-season tires and may not be applicable to other tire types.

1.1 Purpose

This vehicle stopping distance procedure outlines methodology to provide consistent results within a test facility or test site, using best known practices including standards for test equipment, vehicle and tire guideline preparation, and dry asphalt surface friction compensation.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J299 Stopping Distance Test Procedure

SAE 2011-01-0966 Light Vehicle Dry Stopping Distance, Vehicle Speed Correction, Tire Burnish, and Surface Friction Correction

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2018 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
<http://www.sae.org>

SAE WEB ADDRESS:

Full document details: [SAE J2909_201806](http://www.sae.org)

SAE values your input. To provide feedback on this Technical Report, please visit http://standards.sae.org/J2909_201806

Documents
Document Sharing Hub

2.1.2 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 21994:2007 Passenger Cars - Stopping Distance at Straight Line Braking with ABS - Open Loop Test Method

2.1.3 ATSM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

E445 Standard Test method for Stopping Distance on Paved Surfaces Using a Passenger Vehicle Equipped with Full-Scale Tires

E1136 Standard Specification for a Radial Standard Reference Test Tire

E1337 Standard Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using a Standard Reference Test Tire

F2493 Standard Specification for P225/60R16 97S Radial Standard Reference Test Tire

2.1.4 United States Government Federal Safety Standards

Available from U.S. Superintendent of Documents, Washington, DC 20402-0001, Tel: 866-512-1800, <http://bookstore.gpo.gov>.

Motor Vehicle Safety Standard No. 105 (FMVSS105); Hydraulic and Electric Brake Systems

Motor Vehicle Safety Standard No. 135 (FMVSS135); Passenger Car Brake Systems

3. DEFINITIONS

3.1 ASPHALT SURFACE

Known as asphalt concrete, it is a composite of asphalt binder and aggregate, mixed and compacted to form a road bed.

3.2 ASPHALT SURFACE, WETTED

A well-drained, sloped asphalt surface that is thoroughly wetted without any standing water. See the photograph in Appendix H.

3.3 ABS

Anti-Lock Brake System - a collection of sensing and control hardware installed on a vehicle to prevent wheel lockup during brake application (ASTM F1649).

3.4 GVWR

Gross Vehicle Weight Rating - the maximum amount allowable for the total weight of a vehicle.

3.5 TIRE BURNISHING

A break-in condition of the tire's tread surface completed under braking and/or miles driven prior to testing.

3.6 OEM - ORIGINAL EQUIPMENT MANUFACTURE

Reference to OEM applies to vehicle manufacturer's specifications.

3.7 SURFACE TEMPERATURE

The temperature of the test surface at the time of the test.

3.8 ADJUSTED STOPPING DISTANCE

The corrected stopping distance adjusted for actual initial speed, surface friction and temperature.

3.9 TANH

The mathematical hyperbolic tangent function.

3.10 TIRE TYPES

No common standard defines tire types. In general, tire types are termed by their general attributes:

3.10.1 An all-season tire is designed for use in all weather conditions, in all seasons, and generally has an M&S stamping (e.g., MS, M/S, M&S, M+S, etc.) on the sidewall indicating it meets the USTMA definition of a snow tire according to USTMA TISB Vol. 10.

3.10.2 Summer or highway tires are designed for both dry and wet weather conditions, but not for use in wintry weather. These tires often do not have an M&S stamping on the sidewall.

3.10.3 All-terrain tires generally meet the guidelines of an all-season tire and are designed for light duty off-road performance.

3.11 T_{ref}

The surface temperature used to correct for all stopping distance comparisons in a given locale. It is constrained according to Table 3, and for stopping distances to be compared, those stopping distances to be normalized to the same temperature, T_{ref} .

3.12 USTMA

U.S. Tire Manufacturers Association, 1400 K Street, NW, Suite 900, Washington, D.C. 20005, www.ustires.org.

4. INSTRUMENTATION AND RECORDING

4.1 Vehicle Parameters

The minimum vehicle data channels required to conduct stopping distance testing are listed in the first column of Table 1, accompanied by suggested full scale ranges and sensor accuracy.

Table 1 - Vehicle parameters

Variable	Sensor Range	Sensor Accuracy
Longitudinal Velocity	0 to 150 km/h	±0.5 km/h
Longitudinal Distance	0 to 100 m	±0.2%
Brake Pedal Force Trigger	0 to 700 N	±5 N

It shall be ensured that transient vehicle pitch angle changes during braking do not affect the measurement of the velocity and distance variables for the chosen transducer system.

All transducers shall be calibrated according to the manufacturer's instructions. The transducer manufacturer's recommended application software and firmware version shall be used. If parts of the measuring system used can be adjusted, such calibration shall be performed immediately before the beginning of the tests.

4.1.1 Optional Vehicle Parameters

Optional vehicle parameters and their corresponding full scale range and sensor accuracy are given in Table 2. These parameters may be useful for further understanding of results and associated variation in results.

Table 2 - Optional vehicle parameters

Vehicle Data Channel	Sensor Range	Sensor Accuracy
Brake Lining Temperatures	0 to 200 °C	1.0 °C
Brake Master Cylinder Pressure	0 to 20000 kPa	100 kPa
Brake Caliper Pressures	0 to 20000 kPa	100 kPa
Road Surface Temperature	0 to 75 °C	0.5 °C
Ambient Air Temperature	0 to 50 °C	0.5 °C
Longitudinal Accelerometer	0 to 1.2 G	0.01 G
Brake Pedal Force	0 to 1000 N (1500 N max)	±5 N

4.2 Data Recording

Recommend use of digital data acquisition system with the capability to scan all data channels at a minimum sample rate of 100 Hz with the same time reference.

5. TEST CONDITIONS

5.1 Test Vehicle Preparation

5.1.1 Brake Burnish

Condition new brake hardware with a 200 stop FMVSS135 brake burnish as described in Appendix C. Mileage accumulation, typically in the range of 2500 miles, not to exceed 50% highway, is another method to burnish new brake hardware equivalent to FMVSS135 brake burnish for the purpose of stopping distance testing. Vehicles with regenerative braking technology may require more mileage accumulation. Mileage accumulation up to 5000 miles of normal city/highway driving has typically not resulted in excessive wear of the brakes provided the brakes have not been overheated.

5.1.2 Tire Burnish

Condition new tires by performing ten 100 km/h ABS stops on dry asphalt. Mileage accumulation exceeding 2500 miles ± 500 miles, not to exceed 50% highway, plus three 100 km/h ABS stops on dry asphalt is another method to burnish new tires. The tire parameters and tread widths should show a uniform wear condition with a tread depth of at least 90% of the original value across the whole width of the tread and around the whole circumference of the new tire. Tire burnish is a critical factor in determining vehicle stopping distance and when comparing stopping distance between vehicles. See Appendix A for examples of tire burnish effects on stopping distance due to mileage accumulation or consecutive ABS stops.

5.1.3 Brake Lining Temperature

Install thermocouples at each corner of the vehicles at the center of the most heavily loaded brake lining shoe or pad following instructions in FMVSS135. The purpose of measuring brake lining temperatures is to establish initial brake lining temperatures between 80 °C and 120 °C before each ABS brake stop. This can be accomplished by using brake snubs from 80 to 30 km/h at 0.2 G deceleration. For cases where measuring brake lining temperatures is not practical, special attention will be required to ensure the brake linings are not overheated and identical brake cooling procedures are used when comparing stopping distances between vehicles.

5.1.4 Tire Inflation Pressure

Tire inflation pressure shall be set to OEM specifications, or placard pressure, to within 3.5 kPa (0.5 psi). Inflation pressures shall be set to the OEM placard with the tires in their cold state at approximately the ambient air temperature for the test. The inflation pressure will change as the vehicle is driven. Do not adjust the inflation pressure of a warm tire.

5.1.5 Vehicle Test Weight

Vehicle weight shall be set at curb weight with the fuel level set between $\frac{3}{4}$ and full capacity. Stopping distance testing shall occur with driver and test instrumentation only. The total load of the driver plus instrumentation should not exceed 150 kg. If the vehicle is to be tested in any other load condition, for example at GVWR, then the additional payload shall be evenly distributed such that cross-axle variations do not exceed 50 kg.

5.1.6 Vehicle Operational Test Conditions

Vehicles with an automatic transmission should have the gear selector in highest forward gear during stopping distance testing. Vehicles with manual transmissions should have the clutch disengaged or be shifted into neutral before applying brake pedal during the stop. All vehicle openings (windows, hood, trunk, etc.) should be closed. All vehicle accessories should be turned off, except for headlights if required for test track operation.

On vehicles equipped with a vacuum booster, the brake force depends on the vacuum level of the vacuum brake booster. Therefore, a sufficient vacuum shall be ensured at the beginning of braking. To achieve a sufficient vacuum level, it is recommended to move the vehicle in a drag operation for a short time during the cooling phases between individual braking events. When doing so, the accelerator pedal can be released for at least 10 seconds at high engine speed (e.g., by engaging a suitable gear). Afterwards, the brake shall not be operated before the next measurement because this will reduce the established vacuum level.

5.2 Test Track Conditions

5.2.1 Test Track Ambient Air and Surface Temperature

See Table 3 for the test track surface temperature and ambient air temperature ranges. The variation of the surface temperature and ambient air temperature during a sequence of measurements shall not exceed 10 °C. Surface friction is normalized by the test surface temperature as outlined in 5.2.2. Record the test track surface and ambient air temperatures at time of test. For all-season tires, T_{ref} is the test track surface temperature at the time of the vehicle test. For summer tires, T_{ref} is the reference temperature chosen by the user within the limits specified in Table 3. In all cases, stopping distances should only be compared when corrected to the same T_{ref} .

The summer tire track surface temperature tolerances are narrower than those for other tires because there is no temperature correction for summer tires. The tolerance was chosen to give a maximum of 2% error in stopping distance due to temperature.

Table 3 - Minimum and maximum temperatures in °C

Tire Type	Dry Test Track Surface			Wet Test Track Surface			Ambient Air	
	Minimum [°C]	Maximum [°C]	T_{ref} Range [°C]	Minimum [°C]	Maximum [°C]	T_{ref} Range [°C]	Minimum [°C]	Maximum [°C]
Summer	$T_{ref} - 8$	$T_{ref} + 8$	20-45	$T_{ref} - 7$	$T_{ref} + 7$	20-25	10	55
All-Season & All-Terrain	5	55	5-55	10	33	10-33	5	40

5.2.2 Test Track Road Surface Friction

The purpose of measuring road surface friction is to be able to provide a common reference point for comparing stopping distances between vehicles tested at different times. The road surface friction can be a function of temperature, cleanliness, recent usage history, rain etching, humidity and other unknown factors.

The road surface friction coefficient should be quantified with one of these three procedures. The road surface friction coefficients and the temperature sensitivities are likely to be different for each procedure.

1. An ASTM E1136 standard reference test tire in accordance with ASTM E1337 method, at a speed of 64 km/h (40 mph).
2. An ASTM F2493 standard reference test tire in accordance with ASTM E1337 method, at a speed of 64 km/h (40 mph).
3. A reference vehicle with reference tires tested in accordance with SAE J2909 method with the stopping distance corrected for initial vehicle speed only.

The friction coefficient between the tire and the test track surface typically varies with surface temperature and other factors. The following strategies can be used to estimate the test track surface friction at the desired surface temperature, T_{ref} .

1. Use a temperature correction formula to calculate the test track surface friction at a temperature of T_{ref} degrees from a test track surface friction measurement at a different temperature. The temperature correction formulas in this procedure are not recommended for summer tires since these formulas are based on typical all-season tires.
2. Measure the test track surface friction at two different times and interpolate to estimate the test track surface friction at T_{ref} degrees. For this approach, the test track surface temperature should be following a consistent trend, either consistently rising or falling.

5.2.2.1 Dry Surface Temperature Correction

Examples of dry asphalt surface friction variation are shown in Appendix B for both old, greater than 10 years of age, and new, less than 1 year of age, asphalt surfaces. As an example, test track surface friction as a function of test track surface temperature is shown in Figure 1 determined from a linear regression model of actual measurements. Test track surface friction can be predicted as a function of surface temperature using the polynomial equation shown in Figure 1. Note that a test track surface friction and a surface reference temperature will have to be selected as a reference point, T_{ref} . The test track surface friction corrections will then be made relative to this reference point, T_{ref} . See Appendix E for an example.

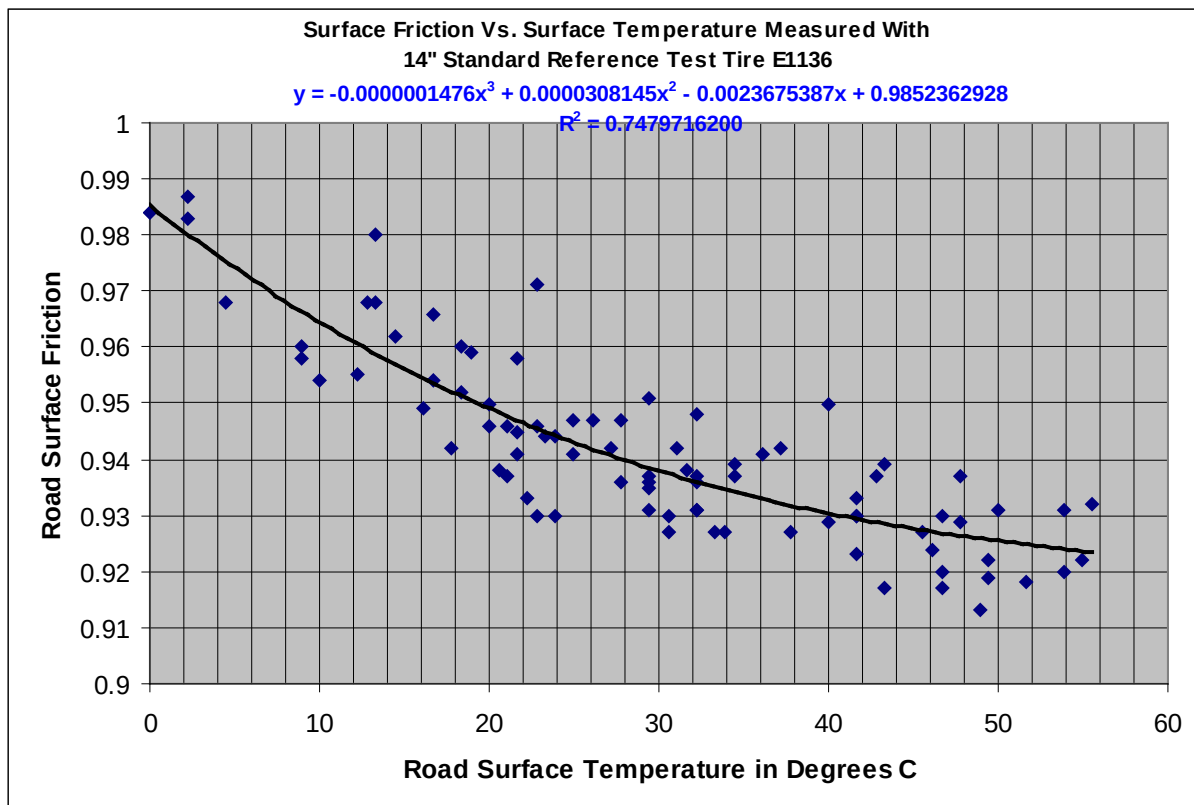


Figure 1 - Surface friction versus surface temperature example

5.2.2.2 Wet Temperature Correction

For all-season tires, stopping distances tend to increase as the road surface temperature increases. If the test track surface friction is measured at a different temperature than a vehicle test, the following formula can be used to calculate the test track surface friction at the temperature of a vehicle test. This assumes other factors influencing test track friction such as the change in grip level is only due to temperature and environmental factors such as acid rain and track evolution, are constant:

$$PFC_{vt} = \frac{1.105 - 0.0042 * T_{vt}}{1.105 - 0.0042 * T_{ft}} * PFC_{ft}$$

where:

PFC_{vt} = peak friction coefficient at the temperature of the vehicle test (N/N)

T_{vt} = surface temperature (°C) of the vehicle test

T_{ft} = surface temperature (°C) of the friction test

PFC_{ft} = peak friction coefficient measured during the friction test (N/N)

This wet temperature correction formula is based on the change in average deceleration versus surface temperature for 11 production vehicles on all-season tires plus the ASTM E1136 tire tested according to ASTM E1337. The minimum temperatures in these studies ranged from 7 to 25 °C; the maximum temperatures ranged from 24 to 42 °C. The slope of -0.0042 1/°C is the average of all twelve data points. Figure 2 is a summary of the temperature sensitivities used for the wet temperature correction.