



SURFACE VEHICLE RECOMMENDED PRACTICE

J2923™

FEB2026

Issued 2016-05
Revised 2026-02

Superseding J2923 DEC2024

Inertia-Dynamometer Disc Brake Drag Measurement Test Procedure for Vehicles Less Than 4540 kg GVWR

RATIONALE

This document has been revised to correct errors found within numbering and test sequencing in the instructional tables in the test matrix.

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1. SCOPE

The SAE J2923 procedure is a recommended practice that applies to on-road vehicles with a GVWR below 4540 kg equipped with disc brakes.

1.1 Purpose

Quantify brake drag using a laboratory-based procedure under various conditions and friction couple braking history. The test sequence includes driving simulation and performance-type braking events along with optional sections for hot drag evaluation and brake drag measurement for parking brake systems.

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: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), www.sae.org.

SAE J2784 FMVSS Inertia Dynamometer Test Procedure for Vehicles Below 4540 kg GVWR

SAE J2789 Inertia Calculation for Single-Ended Inertia-Dynamometer Testing

SAE J2986 Brake Pads, Lining, Disc, and Drum Wear Measurements

SAE J3111 Brake Rotor Thickness Variation and Lateral Run-Out Measurements

2.1.2 ISO Publications

Copies of these documents are available online at www.iso.org/store.

ISO 16610-31 Geometric Product Specifications (GPS) - Filtration - Robust Profiles Filters: Gaussian Regression Filters

ISO 16610-32 Geometric Product Specifications (GPS) - Filtration - Robust Profiles Filters: Spline Filters

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Recommended Practice.

2.2.1 SAE Publications

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

SAE J2522 Inertia Dynamometer Disc and Drum Brake Effectiveness Test Procedure

2.2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9500, www.astm.org.

ASTM E4-10 Standard Practices for Force Verification of Testing Machines

ASTM E2624-09 Standard Practice for Torque Calibration of Testing Machines and Devices

2.2.3 DIN Publications

Copies of these documents are available online at www.din.de/en.

DIN 51309:2002-12 Materials Testing Machines - Calibration of Torque Measuring Devices for Static Torque

2.2.4 Other Publications

DKD-R 3-5 Calibration of Torque Measuring Devices for Static Alternating Torques

EURAMET cg-10/v.01 Guidelines on the Calibration of Static Torque Measuring Devices

ECE/TRANS/WP.29/2024/83 Proposal for a New Amendment to UN Global Technical Regulation No. 24 on Laboratory Measurement of Brake Emissions for Light-Duty Vehicles

VDA/VDE 2646 Torque Measuring Devices - Minimum Requirements in Calibrations

WLTP-Brake Mathissen, M., Grochowicz, J., Schmidt, C., Vogt, R., Farwick zum Hagen, F.H., Grabiec, T., Steven, H., and Grigoratos, T. (2018). A novel real-world braking cycle for studying brake wear particle emissions. *Wear*, 414-415, 219-226.
<https://doi.org/10.1016/j.wear.2018.07.020>.

3. DEFINITIONS

3.1 APPARENT FRICTION FOR DISC BRAKES

Ratio of brake output torque to total input torque. Also referenced as brake effectiveness.

Per Equation 1:

$$\mu = \frac{10^6 \cdot T}{2 \cdot (p - p_{Threshold}) \cdot A_P \cdot r_{eff} \cdot \eta} \quad (\text{Eq. 1})$$

where:

μ = apparent friction for disc brakes (unitless)

T = output torque (N·m)

p = brake pressure (kPa)

$p_{Threshold}$ = minimum pressure required to start developing braking torque; unless otherwise specified by the test requestor or measured as part of the project, use a zero value (kPa)

A_P = total piston area acting on one side of the caliper for disc brakes where the hydraulic pressure is exerted by the brake actuation system (mm²)

r_{eff} = radial distance from centerline of the piston to the axis of rotation for disc brakes, unless other dimensions are provided by the requestor (mm)

η = caliper brake efficiency; ratio of input hydraulic force to effective force acting on the brake pad (unitless)

3.2 BRAKE DRAG

Measurable torque generated by the brake with no active or intentional input from the brake actuation system. (N·m)

3.3 BREAKAWAY TORQUE

Torque required to initiate brake rotation after cable tension, input force, or enabling command is applied (or sent) to the parking brake mechanism. (N·m)

3.4 DECELERATION-CONTROLLED BRAKE APPLICATION

Inertia-dynamometer control algorithm that adjusts the real-time brake pressure to maintain a constant torque output calculated from the instantaneous deceleration specified in the test procedure.

3.5 DISC THICKNESS VARIATION (DTV)

Measurable variability of the disc variable of thickness over one full revolution.

3.6 DRUM BRAKE EFFECTIVENESS (C^*)

Per Equation 2:

$$C^* = \frac{10^5 \cdot T}{2 \cdot (p - p_{Threshold}) \cdot A_p \cdot r_{eff} \cdot \eta} \quad (\text{Eq. 2})$$

where:

C^* = effectiveness for drum brakes (unitless)

T = output torque (N·m)

p = brake pressure (kPa)

$p_{Threshold}$ = minimum pressure required to start developing braking torque; unless otherwise specified by the test requestor or measured as part of the project, use a zero value (kPa)

A_p = total piston area acting on one side of the caliper for disc brakes; total wheel cylinder area for drum brakes (mm²)

r_{eff} = radial distance from the centerline of the piston to the axis of rotation for disc brakes; internal drum diameter divided by two for drum brakes, unless the requestor provides other dimensions (mm)

η = brake efficiency; unless otherwise indicated by the test requestor or measured as part of the project, use 100% (unitless)

3.7 GROSS VEHICLE WEIGHT (GVWR)

Maximum vehicle weight indicated by the manufacturer. (kg)

3.8 INITIAL BRAKE TEMPERATURE (IBT)

Rotor temperature at the start of the brake application. (°C)

3.9 LATERAL RUN OUT (LRO)

Maximum allowed brake lateral run out shall be less than 50 µm.

3.10 LIGHTLY LOADED VEHICLE WEIGHT (LLVW)

Unloaded vehicle curb weight plus 180 kg for driver and test instrumentation. (kg)

3.11 MAXIMUM PARK BRAKE INPUT FORCE

Measured or calculated force applied at the brake equivalent to 400 N input force at the cabin for hand-operated (or 500 N for foot-operated) parking brake systems. For calculated values, use the pedal (or hand lever) ratio, the cable efficiency, and the multiplying factor of the parking brake mechanism to determine the effective force acting on the brake pads. For electric park brake systems, unless otherwise specified by the test requestor, the maximum force is the nominal value at full nominal current and nominal voltage of the system. For all park brake systems, unless otherwise specified by the test requestor, use a maximum park brake input force of 1500 N. Refer to FMVSS 135 S7.12.2(d) or equivalent for details.

3.12 MAXIMUM VEHICLE SPEED (V_{max})

Highest speed attainable by accelerating at a maximum rate from a standstill to a distance of 3.2 km on a level surface, with the vehicle at LLVW for vehicles per FMVSS 135 or at GVWR for vehicles per FMVSS 105. For electric vehicles, the speed attainable is determined with the propulsion batteries at a state of charge of not less than 95% at the beginning of the run. (km/h)

3.13 PRESSURE-CONTROLLED BRAKE APPLICATION

Inertia-dynamometer control algorithm that maintains a constant input pressure to the brake irrespective of the torque output.

3.14 TIRE DYNAMIC ROLLING RADIUS (RR)

Tire radius that equates to the revolutions per mile (RevsPerMile) published by the tire manufacturer for the specific tire size. If unknown, the rolling radius can be calculated from the RevsPerMile value using Equation 3. Use the tire dynamic rolling radius to calculate test inertia and the dynamometer rotational speed in revolutions per minute (rpm) for a given linear vehicle speed.

$$RR = \frac{1609344}{2 \cdot \pi \cdot rpm} \quad (\text{Eq. 3})$$

where:

RR = tire dynamic rolling radius (mm)

rpm = tire manufacturer specification for revolutions per mile indicated by the tire manufacturer

4. TEST CYCLES

4.1 Dynamic Brake Application

To achieve the target pressure or deceleration level during dynamic braking, use a pressure ramp rate of 5000 kPa/s.

Figure 1 illustrates the main time stamps used to characterize the brake application.

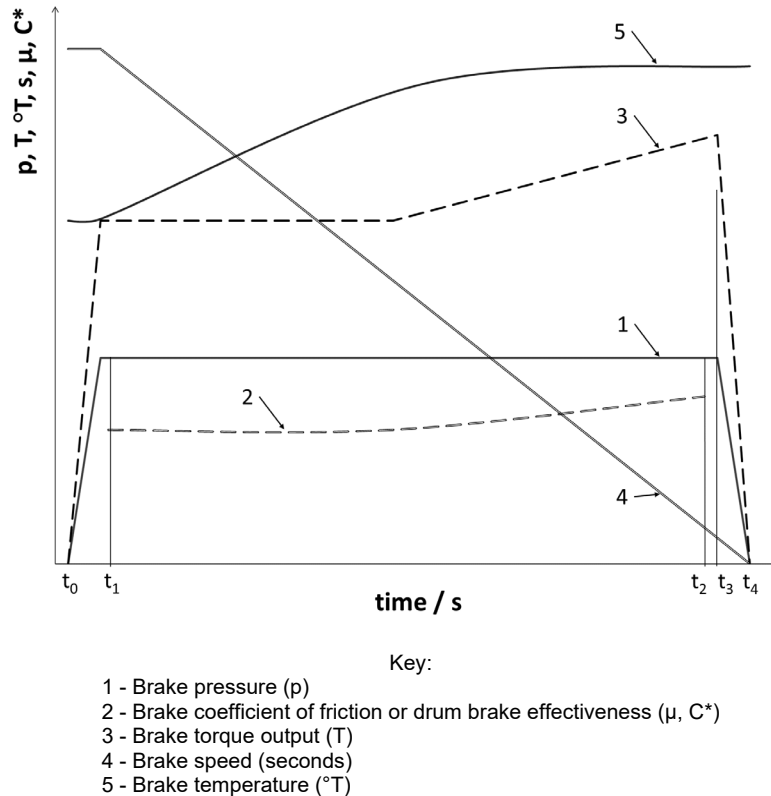


Figure 1 - Typical brake deceleration (constant pressure) time stamps

4.1.1 Time t_0

Brake application initiation. At this time, the pressure starts to rise.

4.1.2 Time t_1

Time at which pressure or torque reached the target level. At this time, the brake reaches its target level for torque or pressure control. At time t_1 , the calculation of average by time and the average by distance begins.

4.1.3 Time t_2

Time at the end of averages. At time t_2 , the inertia-dynamometer data acquisition system terminates the average calculation by time and average by distance. Time t_2 is the end of the stable portion of the brake application. Time t_2 is when the speed is 0.5 km/h above the release speed (t_3).

4.1.4 Time t_3

Time at release speed. At time t_3 , the inertia-dynamometer servo controller releases the brake (specified in 8.1.3).

4.1.5 Time t_4

Time at brake pressure and torque lost. At time t_4 , pressure and torque are below the minimum thresholds. The inertia-dynamometer considers the braking event complete.

4.2 IBT Control

4.2.1 Brake Warm-Up Operation for Dynamic or Brake Drag Applications

If the temperature decreases below the IBT for the next braking condition, warm up the brake by conducting brake drag operation at 50 km/h until the brake temperature is 5 °C above the IBT for the next nominal brake application. Control brake pressure at 2000 kPa for disc brakes and 3000 kPa for drum brakes. Do not conduct brake warm-up for sections with an IBT at or below 35 °C.

NOTE 1: In cases when a brake warm-up is required for sections with an IBT at or below 35 °C (e.g., when restarting the test after a test interruption), conduct brake warm-ups at 25 km/h and control brake pressure at 1000 kPa for disc brakes and 1500 kPa for drum brakes.

NOTE 2: In cases when the dynamometer faults while performing a Worldwide harmonized light-duty vehicles test procedure braking cycle (WLTP-Brake), do not perform warm-ups. Instead, restart the specific trip where the failure happened from the start of said trip.

4.2.2 Brake Warm-Up during the Fade Schedules

If the brake does not achieve the IBT (see 4.3), perform a brake drag application at 80 km/h with a torque equivalent to 1.96 m/s² deceleration to warm up the brake. Do not apply the warm-up procedure for more than 20 seconds.

4.2.3 Brake Cool Down

If the brake temperature is 5 °C or above the IBT of the next brake application, rotate the brake at 20 km/h until the brake cools down to within 5 °C of the IBT.