

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1652

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Dynamometer Effectiveness Characterization Test for Passenger Car and Light Truck Caliper Disc Brake Friction Materials

1. Scope—This SAE Recommended Practice establishes an inertia dynamometer test procedure, using an exemplar caliper disc brake, to characterize the effectiveness of disc brake friction materials for passenger cars and light-duty trucks, up to and including 2700 kg (5954 lb) GVW. SAE J1652 provides a method of characterizing friction material effectiveness on a full disc brake, using test conditions that approximate those for U.S. mandated new vehicle brake tests.

1.1 Test Features—Brake effectiveness is the retarding force per unit brake application force. Effectiveness can be reported as regressed specific torque or as a brake effectiveness factor (BEF).

1.2 Test Application—Brake effectiveness values calculated from SAE J1652 may be used to aid in the selection of replacement friction materials for automotive disc brakes that are similar in design and usage to that of the exemplar brake.

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.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J661—Brake Lining Quality Control Test Procedure

SAE J866—Friction Coefficient Identification System for Brake Linings

SAE J2115—Brake Performance and Wear Test Code Commercial Vehicle Inertia Dynamometer

2.1.2 FMVSS PUBLICATIONS—Available from The Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

FMVSS 116

FMVSS 135

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3. Test Preparation

3.1 Dynamometer Configuration—SAE J1652 is to be run on an inertia dynamometer with the following minimum capabilities:

- 3.1.1 Variable speed drive system with speed resolution to ± 1 rpm and calibrated to $\pm 0.5\%$ accuracy at 100 km/h (62 mph). The drive should have the capability to accelerate the specified inertia from 0 to 1000 rpm in 20 s.
- 3.1.2 Incremental inertia discs to simulate vehicle mass up to $75 \text{ kg}\cdot\text{m}^2$ (55 slug ft^2) within $\pm 1.4 \text{ kg}\cdot\text{m}^2$ (± 1 slug ft^2).
- 3.1.3 Test brake station, fully enclosed in an air duct of sufficient size that the brake hardware takes up not more than 50% of the duct cross-sectional area. The test brake fixture is constructed from a vehicle knuckle, caliper and rotor that meet original equipment specifications with an adapter to attach the knuckle to the dynamometer.
- 3.1.4 A pressure transducer, accurate to within $\pm 0.5\%$ at full scale and calibrated with a reference standard from 690 to 14 000 kPa (100 to 2030 psi).
 - 3.1.4.1 The pressure transducer is mounted just outside the air duct to minimize transducer thermal drift. A pressure connection is made at the piston centerline on the back of the caliper. A short (about 152 mm) (6in) brake line with 6 mm (0.25 in) inside diameter, connects the transducer to the caliper. Excessive distance between the caliper and the pressure transducer results in a high indicated pressure level before torque response. Examine instantaneous torque/pressure/time data to verify that reported pressure does not exceed 345 kPa (50 psi) when torque reaches 30 N·m (22 ft-lb).
- 3.1.5 A tailstock section and load cell connected to the test brake knuckle. Load cell is to be calibrated over the range from 7 to 2700 N·m (5 to 1991 ft-lb) and measure brake torque with an accuracy of $\pm 0.5\%$ at 2700 N·m. (1991 ft-lb).
- 3.1.6 A closed-loop servo control system to control brake applications under specified pressure or torque control conditions. Servo control system capabilities include:
 - a. Linear pressure rise rates free of inflection points, so that all 100 Hz data points are within the specified ramp rate band, over the range from 345 kPa (50 psi) through 95% of maximum during the ramp portion of a brake application.
 - b. Torque ramp, free of inflection points other than those due to friction material characteristics, over the range from 54 N·m (40 ft-lb) through 95% of maximum during the ramp portion of a brake application.
 - c. Not more than 5% torque or pressure over-shoot beyond preset level.
 - d. For torque control applications, transition from pressure ramp control to torque control is achieved within $\pm 3\%$ of the preselected sustained torque level.
 - e. Ability to maintain an average sustained torque level within $\pm 1\%$ of a specified level. The torque range during the sustained portion of a torque control application should not exceed 34 N·m (26 ft-lb).
- 3.1.7 A negative pressure, closed-loop brake cooling system to maintain required cooling air flow rate and temperature during the entire test procedure. A metal screen with nominal 6 to 12 mm (0.24 to 0.47 in) openings in the air duct about 30 cm (12 in) upstream of the brake is recommended to improve air flow uniformity.
- 3.1.8 An automated and integrated control and data acquisition system to control brake applications and record data as specified.

3.1.8.1 The frequency content of the information gathered in SAE J1652 is less than 15 Hz. Appropriate analog and digital filtering to insure good analog amplitude quantification is necessary. Therefore, a minimum analog filtering with a 200 Hz, low pass, two-pole filter is required along with a minimum digital sampling rate of 100 Hz. The digital filter shall not insert a relative phase shift between channels of measured data. All data, including instantaneous data points, are reported as 100 Hz filtered values.

3.2 Data Processing System—An automated data processing system is recommended to carry out specified calculations, including least squares regression analysis.

3.3 Brake Hardware Specifications

3.3.1 BRAKE CALIPER—DELCO, original equipment, right-hand, front axle disc brake caliper for 1992 GM B-CAR. GM part number 18015428.

3.3.1.1 Inspect and assemble caliper per manufacturer's recommendations. Replace caliper or knuckle if abutment surfaces show signs of peening or indentations.

3.3.1.2 Inspect seals and boots before each test and replace with original equipment parts when there is any indication of wear or thermal abuse.

3.3.1.3 Inspect caliper slide pins before each test and replace with original equipment parts when there is any indication of bending or Brinell marks. After assembly, verify a low caliper slide force.

3.3.2 KNUCKLE—DELCO, original equipment, right hand brake knuckle. GM part number 18016024.

3.3.2.1 Check caliper to knuckle clearance before each test. Inspect for dirt or corrosion build-up on the caliper/knuckle interface and for out-of-square mounting of the caliper on the knuckle. The manufacturer's specified clearance (total both sides) between the caliper housing and stops on the knuckle assembly is 0.4 to 0.9 mm (0.016 to 0.035 in).

3.3.3 FRICTION MATERIAL ASSEMBLIES—GM B-CAR front axle disc brake assemblies. Friction material attachment to the backing plate should correspond to how parts are marketed. FMSI 7214-D52 for integrally molded or FMSI 7214A-D52 for riveted parts.

3.3.3.1 For riveted assemblies, minimum rivet break away torque is 544 mN.m (77 oz in) with semi-tubular rivets or 339 mN.m (48 oz in) with eyelets.

3.3.3.2 Except where parts are manufactured with an insulator attached to the backing plate, tests should be run without external noise or thermal insulators. Where specified in the original equipment disc brake assembly, an insulator may be used between the friction material and backing plate.

3.3.3.3 Critical pad and assembly dimensions for riveted parts are detailed in Appendix A. Integrally molded parts should have functionally equivalent dimensions.

3.3.4 ROTOR—DELCO, 305 mm (12 in) outside diameter, GM part number 18016226. Rotors are nondirectionally ground with a 0.5 to 1.5 μ m (20 to 59 μ in) Ra SCALE surface finish.

3.3.4.1 Each test is run with a new original equipment rotor. Rotors should not be lathe cut or ground before use.

3.3.4.2 Just prior to starting a test, clean rotor with isopropyl alcohol and paper towels.

3.3.5 Rotor and friction material storage and handling should be such as to avoid rust, contamination, nicks or other physical damage to test parts.

3.3.6 THERMOCOUPLE INSTALLATION—See Appendices A and B for details of pad and rotor thermocouple installations.

3.3.6.1 Use #24 AWG “J” type thermocouple wire (solid, glass on glass), at least 60 cm (24 in) long for rotor and pad thermocouple wires.

3.3.6.2 For rotor and pad thermocouples, use a 3.18 mm (0.125 in) OD X 3.18 mm (0.125 in) long, silver soldered, copper thermocouple plug per SAE J2115. It is recommended that plugs be formed slightly out of round to insure a secure fit into the drilled hole.

3.3.6.3 For inner pad, drill a 3.0 mm (0.120 in) hole through steel backing plate and friction material. Hole location is to be on the line of the pad long axis, 13 mm (0.51 in) forward of the center point. Use a setting tool to locate thermocouple plug 1.50 mm (0.060 in) below wear surface.

3.3.6.4 For outer pad, drill a 3.0 mm (0.120 in) hole through the steel backing plate and friction material. Hole location is to be at the midpoint of the pad long axis, 20 mm (0.78 in) from pad outside diameter. Use a setting tool to locate thermocouple plug, 1.50 mm (0.060 in) below the wear surface.

3.3.6.5 For the rotor, drill a 2.95 mm (0.116 in) hole through the inner pad rotor face. Locate hole between ribs at the center point between pad ID and OD. Deburr hole and mount thermocouple 1.0 mm (0.040 in) below rotor wear surface.

3.3.7 BRAKE FLUID—Glycol-based, original equipment quality brake fluid such as DOW HD50-4 or equivalent, that meets minimum requirements of FMVSS 116, is recommended.

3.3.7.1 If an alternate fluid has been used, flush system thoroughly and replace seals prior to running SAE J1652.

3.4 Brake Installation

3.4.1 FIXTURE ALIGNMENT

3.4.1.1 Check knuckle to drive axle run-out at two bearing lands with tailstock locked. Adjust to not more than 0.10mm (0.004 in) run-out before proceeding to 3.4.1.2.

3.4.1.2 Install rotor and measure run-out with rotor free turning. Replace rotor if run-out exceeds 0.10 mm (0.004in). Rotor run-out is measured on the inner pad face, 13 mm (0.5 in) from rotor outside diameter.

3.4.1.3 Engage rotor to the drive and recheck run-out at low speed with tailstock locked. Run-out should not exceed 0.10 mm (0.004 in).

3.4.2 CALIPER LOCATION

3.4.2.1 Long axis of caliper should be parallel within ± 15 degrees of air flow direction. Dynamometer rotation must be consistent with vehicle orientation for a right-hand brake.

3.4.2.2 Dynamometer cooling air is either horizontal from left or vertical from top. Caliper location should be as shown in Appendix C.

3.4.3 Mount friction material assemblies in caliper and assemble brake.

3.4.4 Bleed caliper thoroughly after mounting on knuckle.

3.4.5 Connect rotor thermocouple to a slip ring and pad thermocouples to tailstock connectors. Use thermocouple extension wire between slip ring and circuit card.

4. Test Parameters and Control Specifications—(See 7.4)**4.1 Wheel Load—**783 kg (1726 lb).**4.2 Tire Rolling Radius—**304.8 mm (12.0 in).**4.3 Test Inertia—** $72.5 \text{ kg}\cdot\text{m}^2 \pm 1.4 \text{ kg}\cdot\text{m}^2$ ($53.5 \text{ slug ft}^2 \pm 1 \text{ slug ft}^2$). (See 7.5)**4.4 Brake Apply Speed (ISPD km/h)—**Hold to $\pm 1\%$ of specified.**4.5 Final Speed (FSPD km/h)—**Speed at brake release.**4.6 Stopping Distance (STPD m)—**For GM B-Car front disc, stopping distance is 1.915 (# revolutions from brake apply to brake release).**4.7 Sustained Torque (SUTD N·m)—**Applicable to torque and pressure controlled applications only. Use the distance averaged torque over the range from level reached through 522 rpm for fade snubs or 70 rpm for full stops.4.7.1 Sustained torque is $725 \text{ N}\cdot\text{m} \pm 7 \text{ N}\cdot\text{m}$ ($535 \text{ ft}\cdot\text{lb} \pm 5 \text{ ft}\cdot\text{lb}$) for all torque control applications in the test.**4.8 Average Torque (AVTD, N·m)—**Applicable to torque and pressure controlled applications only. Use the distance averaged torque within the window from 54 N·m (40 ft·lb) at brake apply to 70 rpm for full stops or 522rpm fade snubs.**4.9 Maximum Torque (MXT, N·m)—**For ramp applications, maximum torque is the maximum 100 Hz torque value between threshold and brake release. For torque and pressure controlled applications, maximum torque is the maximum 100 Hz torque value within the window from 54 N·m (40 ft·lb) through 70 rpm for full stops or through 522 rpm for fade snubs.**4.10 Regressed Specific Torque (RGST N·m/kPa)—**Regressed specific torque is the calculated slope of the linear least squares regression for pressure and torque within the window specified for each type of application.**4.11 Coefficient of Determination (R^2)—**The coefficient of determination is the square of the correlation coefficient between observed and fitted torque values and is generated as part of the least square regression analysis. Analysis of instantaneous data is recommended for R^2 values less than 0.990.**4.12 Sustained Pressure (SPRD, kPa)—**Applicable to torque and pressure control applications only. Use the distance averaged pressure over the range from level reached through 70 rpm for full stops or 522 rpm for fade snubs. For pressure control applications, sustained pressure should be within $\pm 1\%$ of specified.**4.13 Average Pressure (APRD, kPa)—**Applicable to torque and pressure control applications only. Use the distance averaged pressure over the range from 54 N·m (40 ft·lb) initial torque through 70 rpm for full stops or 522 rpm for fade snubs.**4.14 Maximum Pressure (MXPR, kPa)—**For ramp applications, maximum pressure is the maximum 100 Hz pressure value over the range from 54 N·m (40 ft·lb) through brake release. For torque and pressure controlled applications, maximum pressure is the maximum 100 Hz pressure value within the window from 54 N·m (40ft·lb) through 70 rpm for full stops or through 522 rpm for fade snubs.**4.15 Hold Off Pressure (PHO, kPa)—**The calculated pressure value obtained from the least square regression line at zero torque.

4.16 Initial Temperatures (IN1 rotor, IN2 inner pad, IN3 outer pad, DEGREES C)—Initial temperatures are measured at brake apply.

4.16.1 Use initial rotor temperature (IN 1) for all temperature controlled brake applications. Initial rotor temperatures should be within $\pm 3\text{ }^{\circ}\text{C}$ ($\pm 5\text{ }^{\circ}\text{F}$) of specified.

4.17 Final Temperature (FN1 Rotor, FN2 inner pad, FN3 outer pad, DEGREES C)—Final temperatures are measured 5 s after brake release.

4.18 Cycle Time (CYCT, SEC.)—Actual time (brake apply to brake apply) between each brake application.

4.18.1 Once the instrument check has started, the test is to be completed without intermediate shutdown or delays between sections. A delay of up to 10 min may be required between the instrument check and start of the burnish to generate data from the instrument check section. One additional brief shutdown is allowed prior to stop number 150 during the burnish. Record time and reason in test report.

4.19 Drag Torque (N·m)—Drag torque is the sustained torque level when brake is released and drive is rotating. If drag torque exceeds 14 N·m (10 ft-lb) during instrument check cooling curve, abort test and inspect friction assemblies, caliper, rotor, knuckle and alignment. Repair or replace parts and start a new test with the same rotor and pads. If drag torque exceeds the specified limit a second time, replace rotor and pads. If drag torque exceeds 14 N·m (10 ft-lb) for 15 s consecutively during any portion of the test, include the level in test report.

4.20 Pressure Ramp Rate (kPa/s)—Pressure ramp rate is 5170 kPa/s $\pm$ 275 kPa/s (750 psi/s $\pm$ 40 psi/s) for all applications in the test. For torque and pressure control applications, hold 5170 kPa/s $\pm$ 275 kPa/s (750 psi/s $\pm$ 40 psi/s) ramp rate through at least 97% of specified sustained torque or pressure.

4.20.1 Pressure ramp rate is calculated from the slope of the pressure/time curve over the range from 690 kPa (100psi) to 90% of target sustained torque, sustained pressure or maximum torque achieved in ramp applications. Use 100 Hz instantaneous torque/pressure/time data as the basis for calculating pressure ramp rates.

4.21 Brake Release—For ramp applications, brake release is at 2710 N·m (2000 ft-lb) or 13 800 kPa (2000 psi) or 26 rpm, whichever occurs first. For torque and pressure control stops, brake release is at 26 rpm. For torque control fade snubs, brake release is at 487 rpm.

4.22 Ranges for Data Collection and Regressed Specific Torque—Calculations are summarized in Table 1.

4.22.1 DATA COLLECTION RANGES—For all brake applications, data collection starts at the first 100 Hz data point after reaching 54 N·m (40 ft-lb) torque. This data point should be within 10 ms after reaching 54 N·m (40ft-lb). For ramp applications, data is collected through 2710 N·m (2000 ft-lb) or 13 800 kPa (2000 psi) or 26 rpm, whichever occurs first. For torque and pressure control stops, data is collected through 70 rpm. For torque control fade snubs, data is collected through 522 rpm.