



## Inertia Dynamometer Brake Output Versus Temperature, Wet Output and Water Recovery

### 1 Introduction

**Note:** Nothing in this standard supercedes applicable laws and regulations.

**Note:** In the event of conflict between the English and domestic language, the English language shall take precedence.

**1.1 Purpose.** This standard documents an inertia dynamometer test used to measure brake output over a range of brake temperatures and during wet braking and water recovery conditions.

**1.2 Applicability.** To all passenger car and light truck brake corners.

**1.3 Remarks.** This procedure is intended to quantify brake output over the temperature range -30 °C to 400 °C (including output after a 2 h soak at ambient), as well as during and after water spray.

### 2 References

**Note:** Only the latest approved standards are applicable unless otherwise specified.

#### 2.1 External Standards/Specifications.

None

#### 2.2 GM Standards/Specifications.

GMW14933

GMW14974

GMW14985

GMW15142

#### 2.3 Additional References.

CG190 GM Evaluation Reports

### 3 Resources

**3.1 Facilities.** Milford Proving Ground Brake Component Development inertia brake dynamometer or equivalent GMW14350 Test Improvement Process (TIP) accredited test dynamometer shall be used.

**3.1.1 Calibration.** The test facilities and equipment shall be in good working order and shall have a valid calibration label.

**3.1.2 Alternatives.** Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

**Note:** Alternative test facilities and equipment must obtain an official GM TIP accreditation for GMW14985 prior to submitting test data to GM.

#### 3.2 Equipment.

**3.2.1** An inertia brake dynamometer capable of performing corrected pressure control and modulated brake applies.

**3.2.2** The following measurements shall be made and digitally recorded at 500 Hz.

**3.2.2.1** Dynamometer speed.

**3.2.2.2** Brake corner pressure.

**3.2.2.3** Brake torque.

**3.2.2.4** Brake rotor/Drum temperature.

#### 3.3 Test Vehicle/Test Piece.

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**3.3.1** Production representative brake corner hardware shall be used to produce the tailstock assembly.

**3.3.2** New brake pads and rotors shall be used.

**3.4 Test Time.**

Calendar time: 2 days

Test time: 36 h to 48 h

Coordination time: 2 h

**3.5 Test Required Information.** Not applicable.

**3.6 Personnel/Skills.** One (1) technician trained for the operation of an inertia brake dynamometer and to perform the duties described in paragraph 4 is required.

## 4 Procedure

### 4.1 Preparation.

**4.1.1** Install an embedded thermocouple, as specified in GMW14974.

**4.1.2** Install test brake assembly on dynamometer.

**4.1.2.1** For disc brakes: The assembled corner Lateral Run Out (LRO) shall not exceed 50  $\mu\text{m}$ , should be measured per GMW14933 and recorded in test documentation. The corner LRO shall be measured on the inboard face of the rotor at a radius 10 mm inside of the rotor outer diameter using a dial indicator.

**4.1.2.2** For drum brakes: the runout and roundness shall not exceed print specifications for the component and shall be recorded in the test documentation (pretest component measurement). For drum brake assemblies tested using this procedure, drum brake centerline clearances should be set to a nominal centerline clearance condition (see definition in Glossary).

If drum brake backing plate assemblies are received from a production source pre-assembled, they can be used "as received," with the centerline clearances measured and recorded. They should only be adjusted if out of the specification range. If drum brake shoes are installed at the testing facility, assembly should be set using proper service procedures to the nominal production intent centerline clearance.

### 4.2 Conditions.

**4.2.1 Environmental Conditions.** Cooling air is provided to the brake. Cooling air temperature shall be between  $-40^{\circ}\text{C}$  and  $30^{\circ}\text{C}$ . Cooling air humidity control is not required.

**4.2.2 Test Conditions.** Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

**4.2.2.1** The dynamometer inertia shall be set as described in GMW15142 using Gross Vehicle Weight parameters.

**4.2.2.2** During water spray test sections for a disc brake, water is sprayed onto the rotor outer diameter near the caliper's bracket at 6 L/minute  $\pm$  2 L/minute from a distance of 25 cm  $\pm$  5 cm. For drum brakes, water is sprayed at the drum to backing plate interface from slightly above and from the inboard side at 6 L/minute  $\pm$  2 L/minute from a distance of 25 cm  $\pm$  5 cm. The water stream shape shall allow soaking of the inboard and outboard linings and rotor cheeks. An example of water spray setup for a disc brake is displayed in Appendix B, Figure B1. See Appendix B, Figure B2 for drum brake setup picture.

**4.3 Instructions.** Run the test per instructions listed in Appendix A, Table A1.

## 5 Data

### 5.1 Calculations.

**5.1.1 Digital Signal Processing Rate.** All test data are processed at 200 Hz.

**5.1.2 Digital Signal Zeroing.** Brake pressure and torque channels are digitally zeroed based on 0.5 s of digitally recorded data prior to each brake apply.

**5.1.3 Hysteresis.** For the second modulation during each modulated apply, determine the maximum difference in braking torque between the hydraulic release and apply conditions at a given pressure. Divide this difference by the peak torque and multiply by 100 to determine the percent torque hysteresis.

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**5.1.4 Apparent Friction.****5.1.4.1 Apparent Friction (disc brake):**

Constant Deceleration Apply:

$$AF = \frac{\left( \frac{T}{2 * r_e} \right)}{P * A_p}$$

Ramp Apply:

$$AF = \frac{\left( \frac{T}{2 * r_e} \right)}{(P - P_{ho}) * A_p}$$

**Where:**

$AF$  = Apparent Friction

$A_p$  = Effective Piston Area, square meter (m<sup>2</sup>)

$P$  = Hydraulic Pressure, kilopascal (kPa)

$P_{ho}$  = Holdoff Pressure, kilopascal (kPa)

$T$  = Braking Torque, Newton meter (N·m)

$r_e$  = Effective Radius, millimeter (mm) = Radius to the center of the piston pressure

**5.1.5 Apparent Friction Variation (disc brake).** The apparent friction variation is the variation of friction level from the average friction level. It is calculated as follows: Percent Variation equals [(apparent friction range) divided by (average friction)] multiplied by 100.

**5.1.5.1 Drum Brake Output:**

$$Output = \frac{T}{(r_e) * (P - P_{ho}) * (A_p)}$$

**Where:**

$A_p$  = Effective Wheel Cylinder Area, square meter (m<sup>2</sup>)

$P$  = Hydraulic Pressure, kilopascal (kPa)

$P_{ho}$  = Holdoff Pressure, kilopascal (kPa)

$T$  = Braking Torque, Newton meter (N·m)

$r_e$  = Effective Radius, millimeter (mm) = Drum Diameter divided by 2

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**5.2 Interpretation of Results.** Compare results to requirements in applicable technical specifications.

### 5.2.1 Graphical Summaries.

**5.2.1.1** Plot average apparent friction (output), Initial Brake Temperature (IBT), and maximum brake temperature for every 10<sup>th</sup> brake apply during the burnish section, every 5<sup>th</sup> apply during the re-burnish sections, and for every brake apply during the Output versus Temperature and Wet Output and Water Recovery Sections. An example plot is displayed in Appendix B, Figure B3.

**5.2.1.2** Plot the Overall Mean Apparent Friction (output) versus Braking Condition. There will be one (1) Apparent Friction value for each test condition. An example plot is displayed in Appendix B, Figure B4.

### 5.2.2 Tabular Summaries.

**5.2.2.1 Output versus Temperature Section.** Determine the average apparent friction (output), in-stop apparent friction (output) range, and percent peak-to-peak Brake Torque Variation (BTV) for all stops, excluding the initial stop, at each brake condition. Also, determine the two-sequence mean within-apply apparent friction (output) range, two-sequence mean within-condition apparent friction (output) range, two-sequence maximum overall percent peak-to-peak BTV, and two-sequence mean maximum single revolution maximum percent peak-to-peak BTV for each brake condition. Example data is displayed in Appendix B, Table B1.

**5.2.2.2 Wet Output and Water Recovery Section.** Determine the average apparent friction (output) for the following:

- Burnish applies 180, 190, and 200 and average apparent friction (output) of re-burnish applies 40, 45, and 50.
- Each of the 15 recovery applies.
- Each apply, excluding the initial apply, during the remaining Wet Output and Water Recovery Sections.

Also, determine the number of recovery applies necessary to exceed the average apparent friction of applies 40, 45, and 50 of the 50-stop re-burnish section. Report the preceding values for each of the three Wet Output and Water Recovery Sequences. Also, report the three-sequence mean for each of the preceding values. Example data is displayed in Appendix B, Table B2.

**5.3 Test Documentation.** Publish test information and results using the CG190 GM Evaluation Reports template or equivalent and the Global Document Management system or its successor.

## 6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

## 7 Notes

### 7.1 Glossary.

**Apparent Friction Variation (Disc Brake):** The apparent friction variation is the variation of friction level from the average friction level. Variation is calculated as follows:

Percent Variation =  $100 * [\text{Apparent Friction Range} / \text{Average Friction}]$ .

**Average Apparent Friction or Drum Brake Output:** The distance-weighted average of the instantaneous friction or output. For constant deceleration brake applies, this is determined during the steady state portion of the braking event. This excludes the initial 10% of the stop after hydraulic pressure/torque has reached steady state level and the final 10% of the stop before pressure release as the dynamometer speed approaches zero. For ramp applies, average apparent friction or output is determined according to details specified in paragraph 5.1.4.

**Brake Burnish Schedule:** 200 corrected pressure control stops at an IBT of  $\leq 100^\circ\text{C}$ , 80 km/h initial speed, 40 km/h to 60 km/h cooling air speed, 3500 kPa/s apply rate to a  $3.04 \text{ m/s}^2$  (.31G) deceleration rate.

**Brake Temperature:** Brake temperature in this standard refers to rotor or drum temperature.

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