GM WORLDWIDE ENGINEERING STANDARDS	Test Procedure	GMW17841

Brake Corner Stopping Distance, Consumer Reports Fade and High Speed Performance Test

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 is an inertia dynamometer test procedure to assess brake corner performance during various brake conditions.

1.2 Applicability. This procedure is applicable to all passenger cars and light trucks.

1.3 Remarks. This standard assesses brake corner performance with green (new) brakes, during a brake burnish schedule, with burnished brakes, during a 100 km/h stopping distance simulation, during Consumer Reports type Fade, with post fade brakes and for a two-stop (Vmax – 6) sequence.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14925	GMW14974	GMW15391	GMW15392
GMW14933	GMW15142		

2.3 Additional References.

- Appendix C2 of the Statement of Requirements (SOR): Rear Drum Brake Corner Assembly

3 Resources

3.1 Facilities. Milford Proving Ground Brake Component Development inertia brake dynamometer or equivalent 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 Test Improvement Process (TIP) accreditation for GMW14925 prior to submitting test data for vehicle programs

3.2 Equipment.

3.2.1 An inertia brake dynamometer capable of performing torque control, pressure control, corrected pressure control, ramp, and modulated brake applies. The inertia dynamometer should have environmental control capabilities for both temperature and humidity.

3.2.2 The following measurements shall be made and digitally recorded at 500 Hz during each brake apply and for 0.5 s prior to the start of the apply and for 0.5 s after release of brake pressure:

- Dynamometer speed, kilometers per hour (km/h).
- Brake apply pressure, kilopascal (kPa).

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- Brake torque, Newton meter (N·m).
- Brake rotor/drum temperature, Celsius (°C).
- Fluid displacement, cubic millimeter (mm3)

Note: Use compensated fluid displacement data (see glossary).

- Cooling air temperature (°C)
- Cooling air humidity, percent (%) Relative Humidity (RH)
- Optional: Rotor or Drum positional marker voltage (shaft position),(degrees)

In addition, these channels should also be recorded continuously at a 0.5 Hz rate for the full test (Global Slow recording).

3.3 Test Vehicle/Test Piece. Production representative hardware shall be used to produce the tailstock assembly. One (1) set of pads/shoes will be required per rotor/drum sample. If the test is conducted for the purpose of validation, the number of samples and requirements to be met are defined in GMW15392.

3.4 Test Time.

Calendar time:	1 day
Test time:	2 h to 4 h
Coordination time:	10 h to 24 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 4 is required.

4 Procedure

4.1 Preparation. Rotor or drum embedded thermocouple shall be installed per GMW14974.

4.2 Conditions.

4.2.1 Environmental Conditions. Cooling air shall be controlled to a nominal condition, defined as a temperature of 22 °C and at 60% Relative Humidity (RH). RH percent humidity and temperature must be recorded for all stop conditions. Cooling air should be maintained at the given conditions for the entire test sample.

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 Lightly Loaded Vehicle Weight parameters for all test sections, except the 200 stop burnish section. The burnish section should be run at Gross Vehicle Weight (GVW) parameters.

4.2.2.2 For vehicles that use regenerative braking systems, the dynamometer inertia shall be set according to 4.2.2.1 for all sections, except for the 200 stop burnish (see Appendix A, Table A1, section 4.3.5). The regenerative braking inertia level, per GMW15142**,** shall be used for the 200 stop burnish section only.

4.2.2.3 For rotors, the Assembled Lateral Run Out (ALRO) shall not exceed 50 µm ALRO and should be measured per GMW14933 and recorded in the test documentation. For the drum only measurement, the runout and roundness shall not exceed print specifications for the component and shall be recorded in the test documentation (pretest component measurement).

4.2.2.4 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, already assembled and used “as received”, centerline clearances should be measured and recorded, but not adjusted unless out of 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.

4.3 Instructions. The instructions for the testing are in Appendix A, Table A1 thru Table A3.

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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.

5.1.4 Apparent Friction.

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:

A_F = Apparent Friction
A_p = Effective Piston Area (m^2)
P = Hydraulic Pressure (kPa)
P_{ho} = Holdoff Pressure (kPa)
T = Braking Torque (N·m)
r_e = Effective Radius (mm) = Radius to the center of the piston pressure

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.

Drum Brake Output:

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

Where:

A_p = Effective Wheel Cylinder Area, square meter (m^2)
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

5.2 Interpretation of Results. Reference GMW15391, GMW15392 or Appendix C2 of the Statement of Requirements (SOR) for brake corner performance requirements, as appropriate.

5.2.1 Ramp Applies. Graph Apparent Friction versus Hydraulic Apply Pressure between 0 kPa and 12 000 kPa for each ramp apply. Graph green, burnished, and post fade sections in the cold and warm conditions on separate graphs (five (5) graphs total). Also graph average apparent friction, Initial Brake Temperature (IBT),

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and maximum brake temperature versus stop number for each brake apply. (See example plots in Appendix B, Figure B1 and Figure B2.)

5.2.2 Burnish Schedule. Graph average apparent friction, IBT, and maximum brake temperature for every 10th brake apply during the burnish schedule. (See example graph in Appendix B, Figure B2.)

5.2.3 Apparent Piston Travel (APT) with Pre-conditioning. For Apparent Piston Travel (APT) calculations, use the compensated fluid displacement channel for these calculations. See glossary for definition/procedure. Graph the APT, millimeter versus hydraulic pressure, kilopascal between 0 kPa and 12 000 kPa for each APT with Pre-conditioning ramp apply. Graph burnished warm and post fade warm APT ramp applies on separate graphs. (See example graph displayed in Appendix B, Figure B3.) Two (2) graphs total.

5.2.4 Hysteresis. Graph braking torque, Newton meter (N·m) versus apply pressure, kilopascal (kPa) for the second in-stop modulation of each modulated apply. Graph green, burnished and post fade applies on separate graphs. (See example graph in Appendix B, Figure B4) Three (3) graphs total.

5.2.5 Tabular Summaries.

5.2.5.1 Apparent Friction or Drum Brake Output.

5.2.5.1.1 Ramp Applies. Create a table with the average apparent friction of the runs at 500 kPa, 1000 kPa, 5000 kPa, and 12 000 kPa for all stops, excluding the initial stop, at each brake condition (green, burnished, and post fade) for cold and warm. Include the numerical average of the pressure based average apparent friction values for each apply between 500 kPa and 12 000 kPa (or maximum attained pressure), the range and the variation between 500 kPa and 12 000 kPa at each brake condition. Also determine within condition apparent friction range and variation. (See example data in Appendix B, Table B1.) If the ramp applies utilized the 10.8 m/s^2 (1.1G) cutoff prior to attaining the 12 000 kPa data point, the apparent friction value for the highest pressure attained (rounded down to the nearest 1000 kPa value) should be reported with the corresponding pressure value.

5.2.5.1.2 Constant Deceleration/Corrected Pressure Applies. For the constant decel and corrected pressure control brake applies, determine the apparent friction at first wheel departure, the 80% distance-weighted mean apparent friction, within apply apparent friction range, within condition average apparent friction range, IBT, maximum brake rotor temperature, and percent peak-to-peak Brake Torque Variation (BTV). Create a table with the apparent friction at first wheel departure, the mean average apparent friction, average within apply apparent friction range, within condition average apparent friction range, mean IBT, mean maximum brake temperature, mean Overall peak-to-peak percent BTV, and mean Maximum peak-to-peak percent BTV. (See example data in Appendix B, Table B2.)

5.2.5.1.2.1 Burnish Schedule. Calculate the data from 5.2.2.1.2 for every 10th stop in the burnish section. See example data in Appendix B, Table B2.

5.2.5.1.2.2 100 km/h Stopping Distance. Calculate the data listed in 5.2.2.1.2 for all stops in the 100 km/h Stopping Distance schedule. See example data in Appendix B, Table B2.

5.2.5.1.2.3 Consumer Reports Fade Schedules. Calculate the data listed in 5.2.2.1.2 for all stops in both Consumer Reports Fade schedules. See example data in Appendix B, Table B2.

5.2.5.1.2.4 Vmax Two-stop Sequence. Calculate the data listed in 5.2.2.1.2 for the two stop Vmax fade sequence. See example data in Appendix B, Table B2.

5.2.5.2 Apparent Piston Travel with Pre-conditioning. For APT calculations, use the compensated fluid displacement channel for these calculations. See glossary for definition/procedure. Report average apparent piston travel at 500 kPa, 1000 kPa, 5000 kPa, and 12 000 kPa using each of the first and second ramp applies of Apparent Piston Travel with Pre-conditioning test in the burnished and post fade conditions. (See example data in Appendix B, Table B3.) If the ramp applies utilized the 10.8 m/s^2 (1.1G) cutoff prior to attaining the 12 000 kPa data point, APT values for 12 000 kPa should be extrapolated from a regression analysis of the existing data. A notation should be made in the table that the value was extrapolated.

5.2.5.3 Holdoff Pressure. Report average holdoff pressure for all ramp applies, excluding the initial stop, at each ramp apply condition (green, burnished, and post fade conditions, warm and cold, if applicable). (See example data in Appendix B, Table B4.)

5.2.5.4 Hysteresis. Report average maximum torque difference and average percent torque hysteresis (average maximum torque difference divided by maximum torque) for the green, burnished, and post fade brake conditions. Also include in the table, the within condition torque hysteresis range and the pressure at the

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maximum torque hysteresis. Then calculate the average torque difference and average percent (%) torque hysteresis (average torque difference divided by maximum torque) within a lower pressure bound of 25% of maximum pressure and an upper pressure bound of 75% of maximum pressure. Report the pressure values used for the analysis (lower and upper). In all cases, the table should be an average of the data for the three (3) runs. (See example data in Appendix B, Table B5)

5.2.5.5 Channel Summary. A table with channel summary information should be included in the test report. The following data should be included for each stop in the test (labeled by test section and stop number):

- Initial speed (km/h).
- Release speed (km/h).
- Initial brake rotor temperature (°C).
- Maximum brake rotor temperature (°C).
- Cycle time (second – start of brake apply to start of brake apply).
- Stop time (seconds).
- Time-based average brake pressure (kPa).
- Maximum brake pressure (kPa).
- Time-based average torque (Nm).
- Maximum torque (Nm).
- Torque-based average deceleration (g).
- Maximum fluid displacement (mm^3).
- Average Apparent Friction (unitless – 80% distance weighted value for step apply, 500 kPa to12 000 kPa average if ramp apply).
- Cooling air temperature (°C).
- Cooling air humidity (%RH).
- Cooling air speed at the brake enclosure outlet (km/h).
- See example data in Appendix B, Table B6.

5.3 Test Documentation. Publish test information and results according to General Motors company protocol using the Evaluation Report template and Global Document Management (GDM) 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 at First Wheel Departure: This value is intended to provide an assessment of the Apparent Friction just prior to reaching the peak pressure target for a given brake apply (assumed to be at or near the point where the tire first becomes adhesion limited on a high coefficient surface during a vehicle assessment). It is calculated by taking the average apparent friction between 85% and 95% of the peak pressure during the ramp portion of the apply. Use the calculation for ramp applies (see 5.1.4) to calculate this average.

Apparent Piston Travel: Apparent piston travel is the measured fluid displacement divided by the piston or drum cylinder area. Use the compensated fluid displacement measurement for this calculation.

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

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