



Inertia Dynamometer Brake Thermal Roughness

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 procedure to assess thermal roughness.

1.2 Applicability. This procedure is applicable to all passenger car and light truck brake corners.

1.3 Remarks. This standard assesses brake torque variation as a function of brake operating temperature. This standard creates the environment when the brake pulsation phenomenon sometimes referred to as "hot judder" may occur. This type of brake pulsation occurs only at elevated brake operating temperatures. The dynamometer test schedules outlined in this procedure were derived from GMW15191 and should be used as the first tool of physical evaluation during the brake development process.

Three (3) evaluation methods are used to assess thermal roughness. The first method is applicable to all passenger car and light truck brake corners. The second method is applicable only to high performance vehicles. The third method is applicable to vehicles in the European or similar markets.

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

GMW15142

GMW15191

2.3 Additional References.

- CG190 Evaluation Report Template (ID)
- Global Document Management (GDM) (<https://documents.gm.com/gdm3/component/main>) (ID)

(ID) = This information is limited to internal access within General Motors and shall not be accessed outside this company. Contact the GM Lead Engineer for further instructions.

3 Resources

3.1 Facilities. Milford Proving Ground Brake Component Development inertia brake dynamometer or equivalent Test Improvement Process 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.

3.2 Equipment.

3.2.1 An inertia brake dynamometer capable of constant pressure control applies.

3.2.2 A dial indicator and a micrometer with a minimum resolution of 1 μ m.

3.2.3 Optional: Non-contact proximity sensors with a minimum resolution of 1 μ m and a frequency response of at least 1000 Hz.

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

- a. Dynamometer speed in kilometers per hour (km/h).

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- b. Braking time in seconds (s).
- c. Brake apply pressure in kilopascals (kPa).
- d. Brake torque in Newton meters (N·m).
- e. Brake rotor/drum temperature in degrees Celsius (°C).
- f. Cooling air temperature in degrees Celsius (°C).
- g. Cooling air humidity in percent (%) relative humidity (RH).

3.2.5 Optional: During a brake apply cycle, the following measurements shall be made and digitally recorded at 1000 Hz.

- a. Rotor Lateral Runout (LRO) micrometers (µm) at one (1) to three (3) points along the brake swept area on both the inboard and outboard rotor faces. See Figure A1, Appendix A. Note: The minimum point is at the specified outer diameter location.
- b. Rotor Thickness Variation micrometers (µm), calculated from LRO measurement.
- c. Rotor positional marker voltage (shaft position), shaft position signal allows for more accurate Brake Torque Variation (BTV) analysis.

3.3 Test Vehicle/Test Piece. Production representative brake corner hardware shall be used for testing and to produce the tailstock assembly.

3.4 Test Time.

Calendar time: 1 day
Test hours: 8 hours
Coordination hours: 2 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. One technician trained in the operation of an inertia brake dynamometer and to perform the duties described in Section 4 is required.

4 Procedure

4.1 Preparation.

4.1.1 Thermocouple. The embedded thermocouple shall be installed in the rotor or drum per GMW14974.

4.1.2 Rotor Assembled Lateral Runout (ALRO).

- a. For rotors: The pretest and posttest assembled corner LRO shall not exceed 50 µm. 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 or non-contact proximity sensors (or equivalent). The assembled LRO shall be measured and recorded both pretest and posttest.
- b. For drums: Not applicable.

4.1.3 Rotor Thickness Variation and Drum Roundness and Runout.

- a. For rotors: The initial rotor thickness variation (RTV) shall not exceed 5 µm. The RTV shall be measured at a radius 10 mm inside of the rotor outer diameter. If a micrometer is used, make the thickness measurements every 10 degrees around the rotor for a total of 36 measurements. Optional: Non-contact proximity sensors may be placed on the assembly to measure rotor thickness variation. The transducers shall be placed as shown in Figure A1, Appendix A.
- b. For drums: The initial drum roundness and runout shall meet component drawing specifications.

4.2 Conditions.

4.2.1 Environmental Conditions. Cooling air temperature shall be between 10 °C and 30 °C. Cooling air humidity control is not required, but RH percent (%) and temperature must be recorded.

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 See GMW15142 for loading conditions. The inertia equivalent to the gross vehicle loading condition weight is recommended.

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4.3 Instructions.

4.3.1 This test is written for one (1) brake hardware build, either “new” condition or “with-use” condition. Thermal roughness is dependent on previous thermal conditioning history of the hardware, initial rotor thickness variation, and lining wear conditions.

4.3.2 Perform GMW14925 procedure up to and including the Burnished Warm Modulated Applies (GMW14925, Appendix table titled, Instruction for Test – Start of Test thru 4.3.10).

4.3.3 Perform brake warm-up stops until rotor temperature is greater than 100 °C, and then perform a sequence of the Base Thermal Roughness Schedule for a total of 15 snubs (see definition in 7.1). Perform cooldown; allow the rotor to cool to 50 °C with 50 km/h cooling air speed and 10 km/h dynamometer speed after each 15 snub sequence.

4.3.4 Repeat 4.3.3 four (4) times for a total of five (5) times. This completes the Base Thermal Roughness Schedule.

4.3.5 For European, Middle East or similar market vehicles and brake systems using low-metallic friction materials, perform the Base Thermal Roughness Schedule (4.3.2 to 4.3.4) starting with a green friction set. Perform brake warm-up stops until rotor temperature is greater than 100 °C, and then perform the 90% Vehicle Maximum Speed (Vmax) Thermal Roughness Schedule (described in 7.1). Perform the cooldown per 4.3.3 after each sequence of five (5) stops.

4.3.6 Assess the condition of the hardware and repeat 4.3.5 four (4) additional times for a total of five (5) times. This completes the 90% Vmax Thermal Roughness Schedule.

4.3.7 Perform the cooldown per 4.3.3.

4.3.8 For High Performance Vehicles, perform brake warm-up stops until rotor temperature is greater than 100 °C, and then perform the High Performance Thermal Roughness Schedule for a total of 15 snubs (described in 7.1). Perform the cooldown per 4.3.3. (**Note:** High Performance Schedule is not applicable for drum brakes).

4.3.9 Assess the condition of the hardware and repeat 4.3.8 three (3) additional times for a total of four (4) times. This completes the High Performance Thermal Roughness Schedule.

5 Data

5.1 Calculations. Any needed calculations are described in 5.1.1.

5.1.1 Data Presentation.

5.1.1.1 The test report should include a general description of the parts tested, including important dynamometer setup parameters (e.g., inertia setting (kilograms-meters squared) and rolling radius (millimeters)).

5.1.1.2 Perform order tracking on torque-time data for each stop to determine the peak-to-peak BTV resulting from the first four (4) orders. Using the peak-to-peak torque variation and phase angle of each of the first four (4) orders, reconstruct each stop. Record the overall peak-to-peak BTV (Newton meters (N·m) and percent (%)), average torque (N·m), average apparent friction, initial brake speed (kilometers/hour), cycle time (seconds), initial brake temperature (degrees Celsius) and maximum brake temperature (degrees Celsius) for each thermal roughness snub/stop (see Table B1, Appendix B).

5.1.1.3 Plot the average apparent friction, initial brake temperature and maximum brake temperature versus stop condition (see Figure B1, Appendix B).

5.1.1.4 Plot the overall peak-to-peak BTV percent (%) versus snub number for each thermal roughness stop (see Figure B2, Appendix B).

5.1.1.5 Plot the overall peak-to-peak BTV Newton meters (N·m) versus snub number for each thermal roughness stop (see Figure B3, Appendix B).

5.1.1.6 Plot the overall peak-to-peak BTV percent (%) versus initial brake rotor temperature for each thermal roughness stop (see Figure B4, Appendix B).

5.1.1.7 Plot the overall peak-to-peak BTV Newton meters (N·m) versus initial brake rotor temperature for each thermal roughness stop (see Figure B5, Appendix B).

5.1.1.8 Optional: Calculate the maximum in-stop RTV. Perform order tracking on RTV-time data for each stop to determine the maximum order component of the in-stop RTV. Record the maximum in-stop RTV and dominant order component for each thermal roughness stop.

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5.1.1.9 Optional: Plot the maximum in-stop RTV versus Initial Brake Temperature (IBT) and snub number for each thermal roughness stop.

5.2 Interpretation of Results. Results may be compared to applicable technical specifications or to the results for other brake corners.

5.3 Test Documentation. Publish the test information and results according to GM corporate protocol using the Evaluation Report Template (CG190) 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.

90% Vmax Thermal Roughness Schedule: Snubs are made from 90% Vmax initial speed to 80 km/h with a first stop IBT of 100 °C, constant pressure control, 2 km/h cooling air speed, 20 000 kPa/s pressure apply rate, and with 45 s between the start of each brake application. The target pressures for a single sequence are as in Table 1:

Table 1: Target Pressures

Stop	Pressure Level (kPa)
1	3000
2	1500
3	5000
4	5000
5	3000

If vehicle acceleration data is known, those data should be used to determine the brake cycle time, and, if it less than 45 s, the cycle time should be lowered accordingly.

Assembled Lateral Runout (ALRO): Lateral runout as measured in the assembled condition (in the full corner module).

Base Thermal Roughness Schedule: Snubs are made from 115 km/h initial speed to 30 km/h with a first stop IBT of 100 °C, 2 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 2000 kPa constant pressure control, with 45 s between the start of each brake application. If vehicle acceleration data is known, those data should be used to determine the brake cycle time, and, if it is less than 45 s, the cycle time should be lowered accordingly.

Brake Torque Variation: The peak-to-peak BTV refers to the difference between the maximum and minimum braking torque during one rotor/drum revolution. Order tracking on torque data during the steady state portion of the braking event should be performed (Fast Fourier Transform of Torque vs. Revolution Data).

Overall peak-to-peak BTV is determined by transforming the first four (4) integer orders of the order tracking results back to the revolution domain and calculating the peak-to-peak BTV for a single revolution of the resultant signal. Overall BTV is reported as the sum of the first four (4) of the locatable integer order BTV components within the steady state portion of the braking event. Percentile overall BTV is reported as a percentage of the average steady state torque: (Overall BTV divided by Average torque) × 100.

Note: See Figure B6, Appendix B, for an example of determining the analysis range. First, determine the steady state portion of the brake apply using the pressure and torque signals (should not include the ramp up of pressure or the release of torque or hydraulic pressure). The first 10% and the last 10% of this steady state portion should then be eliminated. Analysis should then be performed on the remaining 80% of the brake apply.

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