



Inertia Dynamometer Brake Torque Variation Sensitivity

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 the relationship between brake torque variation sensitivity and rotor thickness variation, or drum roundness and/or total indicated runout.

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

1.3 Remarks. This standard quantifies the relationship or transfer function between brake corner-level torque variation and rotor thickness variation or drum roundness/runout under a number of brake corner operating conditions. These operating conditions include elevated temperatures, but are generally under the temperature threshold that would induce thermal roughness in the green or newly burnished friction condition. The dynamometer test schedules outlined in this procedure were derived from and complement GMW14919 and should be used as the first tool of physical evaluation during the brake development process. The data provided by this procedure can be used in conjunction with the test results from GMW14919 to determine the corner-level and vehicle-level contribution to brake roughness, compared to corner specifications, and aid in the resolution of brake roughness during the vehicle and brake development process.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14919	GMW14974	GMW15142	GMW15392
GMW14925	GMW14985	GMW15391	

2.3 Additional References.

- Appendix C2 of the Statement of Requirements (SOR): Rear Drum Brake corner Assembly
- Evaluation Report Template (ID)
- Global Document Management (GDM) System (<https://documents.gm.com/gdm3/component/main>) (ID)

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

3 Resources

3.1 Facilities. The Milford Proving Ground Brake Systems Laboratory inertia brake dynamometer or equivalent test facility shall be used. The dynamometer should already be approved for the GMW14985 procedure through the Test Improvement Process (TIP). No specific TIP Certification is required for this procedure.

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

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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 constant pressure control, corrected pressure control, ramp, and modulated brake applies.

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

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

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

- Dynamometer speed in kilometers per hour (km/h).
- Braking time in seconds (s).
- Brake apply pressure in kilopascals (kPa).
- Brake torque in Newton meters (N·m).
- Brake rotor/drum temperature in degrees Celsius ($^{\circ}\text{C}$).
- Cooling air temperature in degrees Celsius ($^{\circ}\text{C}$).
- 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.

- 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 Appendix A, Figure A1.

Note: The minimum point is at the specified outer diameter location.

- 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: 1.5 days

Test time: 28 hours

Coordination time: 2 hours

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 Section 4 is required.

4 Procedure

4.1 Preparation.

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

4.1.2 Rotor Assembled Lateral Runout (ALRO). 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.

4.1.3 Rotor Thickness Variation (RTV). Five (5) vehicle sets (or axle sets if only front or rear brake corners are of interest) of rotors with machined Rotor Thickness Variation (RTV) are recommended for passenger cars and light trucks as outlined in Table 1 or as specified in the applicable Vehicle Technical Specification (VTS). When rotor thickness variation is machined into rotors, care should be taken to maintain the same level of LRO and

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surface finish that is specified for the production rotor. If the rotor originally has an FNC layer for production, this Ferritic Nitrocarburized (FNC) layer will be partially removed during the machining process to achieve the required Rotor Thickness Variation, as noted in Tables 1 and 2.

Table 1: Recommended RTV Levels for Passenger Cars and Light Trucks

Passenger Car RTV Level (microns)	Light Truck RTV Level (microns)
≤ 6 (1 st Order) (Production – meets rotor print specification)	≤ 6 (1 st Order) (Production – meets rotor print specification)
10 (1 st Order)	10 (1 st Order)
10 (2 nd Order)	10 (2 nd Order)
20 (1 st Order)	30 (1 st Order)
20 (2 nd Order)	30 (2 nd Order)

Note: When machining RTV, maintain print specifications for Lateral Runout and Surface Finish.

Table 2: Recommended Drum Roundness Variation Levels for Passenger Cars and Light Trucks

Drum Roundness Level (microns)
≤ 20 (Production - meets drum print specification)
30 Note 1
40 Note 1

Note 1: Contact GM Engineering to confirm required levels for drum roundness and runout.

4.1.4 Optional: Non-contact proximity sensors may be placed on the assembly to measure RTV. The transducers shall be placed as shown in Appendix A, Figure A1.

4.2 Conditions.

4.2.1 Environmental Conditions. Cooling air is provided to the brake. 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 Loading Conditions. The dynamometer inertia shall be set as described in GMW15142 using Gross Vehicle Weight parameters.

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4.3 Instructions. The test should be performed as described in Table 3. Perform warmup stops as described in 7.1 to obtain initial brake rotor temperature, if necessary.

Table 3: Test Sequence and Instructions

Test Procedure Section Number	Test Script Section Number	Test Section Name	Braking Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
N/A	N/A	Pretest Part Measurement	N/A	N/A	Measure rotors or drum pretest to confirm RTV or runout specification levels are at appropriate levels	N/A
N/A	N/A	Start-of-Test (SOT) Rotor Assembled Lateral Run out Measurements	N/A	N/A	N/A	Record the rotor lateral run out on the inboard brake plate at a position 10 mm inward of the rotor outer edge
Pretest Equipment Check						
4.3.1	0100	Ramp applies	100	5	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 10.8 m/s ² (1.1 g) deceleration limit (whichever occurs first).	Initial brake rotor temperature ≤ 90 °C
4.3.2	0100	Modulated applies	100	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If ≤ two (2) modulations achieved, reduce the maximum pressure to generate two (2) to three (3) modulations.	Initial brake rotor temperature ≤ 90 °C
Green						
4.3.3	0200	Cold ramp applies	100	3	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 10.8 m/s ² (1.1 g) deceleration limit (whichever occurs first).	Initial brake rotor temperature ≤ 40 °C
4.3.4	0300	Warm ramp applies	100	5	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 10.8 m/s ² (1.1 g) deceleration limit (whichever occurs first).	Initial brake rotor temperature ≤ 90 °C
4.3.5	0400	Modulated applies	100	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If ≤ two (2) modulations achieved, reduce the maximum pressure to generate two (2) to three (3) modulations.	Initial brake rotor temperature ≤ 90 °C

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Test Procedure Section Number	Test Script Section Number	Test Section Name	Braking Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
4.3.6	2100	Green/Cold BTV assessment – 1000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an Initial Braking Temperature (IBT) of 40 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 1000 kPa constant pressure control.	Initial brake rotor temperature $\leq 40\text{ }^{\circ}\text{C}$
4.3.7	2200	Green/Cold BTV assessment – 2000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 40 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 2000 kPa constant pressure control	Initial brake rotor temperature $\leq 40\text{ }^{\circ}\text{C}$
4.3.8	2300	Green/Cold BTV assessment – 3000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 40 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 3000 kPa constant pressure control	Initial brake rotor temperature $\leq 40\text{ }^{\circ}\text{C}$
4.3.9	2400	Green/Warm BTV assessment – 1000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 90 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 1000 kPa constant pressure control	Initial brake rotor temperature $\leq 90\text{ }^{\circ}\text{C}$
4.3.10	2500	Green/Warm BTV assessment – 2000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 90 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 2000 kPa constant pressure control	Initial brake rotor temperature $\leq 90\text{ }^{\circ}\text{C}$
4.3.11	2600	Green/Warm BTV assessment – 3000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 90 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 3000 kPa constant pressure control	Initial brake rotor temperature $\leq 90\text{ }^{\circ}\text{C}$
4.3.12	0500	GMW14925 Burnish	80	200	Corrected Pressure control stops from 80 km/h, 3500 kPa/s apply rate to a 0.31 g target deceleration rate, and a cooling air speed of 50 km/h.	Initial brake rotor temperature = $100\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$

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Test Procedure Section Number	Test Script Section Number	Test Section Name	Braking Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
4.3.13	9999	Cool down	10	NA	Allow brake rotor to cool to 50 °C with 50 km/h cooling air speed and 10 km/h dynamometer speed	End rotor temperature $\leq 50\text{ °C}$
Burnished Section						
4.3.14	0800	Cold ramp applies	100	3	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 10.8 m/s ² (1.1 g) deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 40\text{ °C}$
4.3.15	0900	Warm ramp applies	100	5	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 10.8 m/s ² (1.1 g) deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 90\text{ °C}$
4.3.16	1000	Modulated applies	100	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two modulations achieved, reduce the maximum pressure to generate two to three modulations.	Initial brake rotor temperature $\leq 90\text{ °C}$
4.3.17	3100	Burnished/Cold BTV assessment – 1000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 40 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 1000 kPa constant pressure control	Initial brake rotor temperature $\leq 40\text{ °C}$
4.3.18	3200	Burnished/Cold BTV assessment – 2000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 40 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 2000 kPa constant pressure control	Initial brake rotor temperature $\leq 40\text{ °C}$
4.3.19	3300	Burnished/Cold BTV assessment – 3000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 40 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 3000 kPa constant pressure control	Initial brake rotor temperature $\leq 40\text{ °C}$
4.3.20	3400	Burnished/Warm BTV assessment – 1000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 90 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 1000 kPa constant pressure control	Initial brake rotor temperature $\leq 90\text{ °C}$

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Test Procedure Section Number	Test Script Section Number	Test Section Name	Braking Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
4.3.21	3500	Burnished/Warm BTV assessment – 2000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 90 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 2000 kPa constant pressure control	Initial brake rotor temperature $\leq 90\text{ }^{\circ}\text{C}$
4.3.22	3600	Burnished/Warm BTV assessment – 3000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 90 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 3000 kPa constant pressure control	Initial brake rotor temperature $\leq 90\text{ }^{\circ}\text{C}$
4.3.23	3700	Burnished/Hot BTV Assessment – 1000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 200 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 1000 kPa constant pressure control	Initial brake rotor temperature $\leq 200\text{ }^{\circ}\text{C}$
4.3.24	3800	Burnished/Hot BTV Assessment – 2000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 200 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 2000 kPa constant pressure control	Initial brake rotor temperature $\leq 200\text{ }^{\circ}\text{C}$
4.3.25	3900	Burnished/Hot BTV Assessment – 3000 kPa Target	115	10	Snubs are made from 115 km/h initial speed to 5 km/h with an IBT of 200 °C, 30 km/h cooling air speed, 20 000 kPa/s pressure apply rate, 3000 kPa constant pressure control	Initial brake rotor temperature $\leq 200\text{ }^{\circ}\text{C}$
4.3.26	9999	Brake Cooldown	10	N/A	Allow brake rotor to cool to 50 °C with 50 km/h cooling air speed and 10 km/h dynamometer speed	End rotor temperature $\leq 50\text{ }^{\circ}\text{C}$
4.3.27	N/A	Posttest Part Measurement	N/A	N/A	Measure rotors or drum posttest to confirm RTV or runout specification levels remain unchanged	N/A

Note: For all Ramp apply sections, a pressure level equivalent to a 1.1 g deceleration shall be used as a cutoff. In other words, when the pressure level is reached, the brake pressure shall be released instantly and the test shall proceed to the next stop.

Note: Cooling Air Speed – Cooling air speed shall be 30 km/h for each section, unless otherwise stated in the table.

5 Data

5.1 Calculations.

5.1.1 Digital Signal Processing Rate. Apparent friction test data is processed at 200 Hz. BTV data should be processed at 500 Hz.

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