



Brake Thermal Roughness Vehicle Evaluation

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 procedure is an evaluation of a vehicle and vehicle brake system for the phenomenon of brake thermal roughness, also known as, judder or hot judder.

1.2 Applicability. This procedure is applicable to all vehicles.

1.3 Remarks. The test schedules in this procedure are derived from thermal roughness procedures submitted for review by GM global engineering centers. This procedure includes a series of snubs intended to simulate the brake energy loading experienced during a mountain descent, a high velocity snub section applicable to European or low-metallic brake lining material markets, and a high-performance vehicle snub section.

The following statements should be considered anecdotal until such time that research data are provided to substantiate the statements.

The vehicle evaluation in this procedure results in a subjective rating by the test team of the vibration sensed due to braking-induced thermal roughness. An optional objective measurement section using an in-vehicle measurement approach similar to GMW14919 is included in order to establish a correlation between objective accelerometer measurements and subjective driver evaluations.

Brake thermal roughness is considered a brake corner issue. A brake laboratory dynamometer test, GMW14985, is available to evaluate the brake corner propensity for thermal roughness. The dynamometer test schedules were derived from this standard GMW15191, and should be used as the first tool of physical evaluation during the brake development process.

This procedure uses an abusive drive schedule to introduce heat into the brake corner hardware. Depending on the material, material structure, stiffness, geometry, etc., of the rotor/drum/lining, thermal variants in the rotor or drum may cause torque variation during braking that results in vibrations noticeable to the driver and occupants of the vehicle. The roughness or vibration will propagate through the brake pedal, the steering wheel, the seat track, the floor pan, etc., depending on the vehicle.

The abusive drive schedule in this procedure was developed specifically to produce the thermal roughness phenomenon. The extent to which GM customers will experience this thermal roughness is assumed minimal. However, instances of thermal roughness have been experienced during various global mountain descents/routes and other high-energy braking events.

The thermal cooling capability of the brake corner effects the development of thermal roughness. The Brake Equilibrium Temperature (BET) procedure GMW14924, should be used to measure the cooling capability of the brake corner. Technical specifications define the limits for the BET by program expectations.

Vehicle sensitivity to brake roughness and vibration is an issue with all brake roughness mechanisms, but the magnitude of the vibrations during the thermal roughness event may mask any vehicle sensitivity issues. However, GMW14919 is applicable to braking thermal roughness in order to understand the vehicle sensitivity contribution to thermal roughness.

Thermal roughness is also a vehicle integration issue, as there are countermeasures that can be performed on the vehicle as a whole, to minimize the possible occurrence of a drive schedule that would create thermal roughness (such as powertrain grade braking).

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2 References

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

2.1 External Standards/Specifications.

CMVSS 135 FMVSS 135

2.2 GM Standards/Specifications.

GMW14919 GMW14924 GMW14926 GMW14985

2.3 Additional References.

- Global Document Management (GDM) System
- GM Evaluation Report Template

3 Resources

3.1 Facilities.

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.

3.1.3 Asphalt or Concrete Vehicle Test Track for a Series of Timed Brake Snubs. The Circle Track at the GM Milford Proving Ground, the GM Desert Proving Ground Yuma, or equivalent track is recommended.

3.1.4 Asphalt or Concrete Vehicle Test Track for Brake Burnish Stops. The GM Milford Proving Ground North-South Straightaway, the GM Desert Proving Ground Yuma Straightaway, or equivalent track is recommended.

3.1.5 Vehicle Weighing Station.

3.2 Equipment.

3.2.1 Deceleration U-tube mounted within view of the driver.

3.2.2 Decelerometer.

3.2.3 Thermocouple the brake friction material following instructions in Federal and/or Canadian Motor Vehicle Safety Standard (FMVSS and/or CMVSS) 135 and in 4.1.3.

3.2.4 Ambient temperature thermocouple.

3.2.5 Vehicle speed measurement equipment.

3.2.6 Brake temperature monitoring equipment visible to driver and a data acquisition system capable of recording multiple temperature channels and any other requested channels (i.e., vehicle velocity, deceleration, etc.)

3.2.7 Recommended optional instrumentation. Tri-axial accelerometers at the driver's side floor, seat bottom, seat back, steering wheel, steering column, left outboard seat track, spindles (as near as possible to the wheel spin axis), caliper bracket shoulder area (one channel in rotor tangential direction) and a data acquisition system capable of measuring at least a 256 Hz scan rate. See GMW14919 for details. The driver's side floor accelerometer must be able to measure a nearly constant acceleration. Non-contact rotor thickness variation measurement equipment may also be installed, if requested.

3.3 Test Vehicle/Test Piece.

3.3.1 Test vehicle should be representative with respect to vehicle mass, vehicle mass distribution, ride height, front fascia design, wheel vent area, brake cooling enhancements (if any), brake corner hardware, and corner suspension.

3.3.2 New brake rotors, drums, pads, and linings at each vehicle corner are recommended. The measurement of rotor thickness variation and assembled rotor lateral runout (at locations outlined in GMW14926) is recommended before and after running this procedure. The initial Rotor Thickness Variation (RTV) shall not exceed 5 μm , or the RTV specified for rotor under test, and the initial Assembled Rotor Lateral Runout (ALRO) shall not exceed 50 μm or the ALRO specified for the corners under test.

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3.4 Test Time.

Calendar time: 1 day to 2 days per build/test
Test hours: 4 hours per build/test, 4 hours to 8 hours per burnish
Coordination hours: 2 hours to 4 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills.

3.6.1 Test personnel to set up vehicle for test and to drive the burnish and test schedule is required.

3.6.2 An observer to ride in the vehicle to assist in the subjective rating and the documentation of the rating is advised but not required.

4 Procedure

4.1 Preparation.

4.1.1 Obtain sign off that the vehicle is representative. Check and adjust tire pressures as needed. Weigh vehicle. Document the information on the Run Sheets located in Appendix A, Figures A1 thru A4.

4.1.2 Remove tire and wheel assemblies. Balance using a spin balancer.

4.1.3 Install thermocouples in brake linings. Use plug-type thermocouples installed in the approximate center of the facing length and width of the most heavily loaded shoe or disc pad, one per brake. For brake drum shoe, recess the thermocouple 1 mm under the surface. For disc brake pad, recess the thermocouple 2 mm under the surface. A second thermocouple may be installed at the beginning of the test sequence if the lining wear is expected to reach a point causing the first thermocouple to contact the metal rubbing surface of a drum or rotor. For center-grooved shoes or pads, thermocouples are installed within 3 mm to 6 mm of the groove and as close to the center as possible.

4.1.4 Place the ambient temperature thermocouple inside a containing tube. The tube shall be mounted on the outside of the vehicle exposed to the free air stream. Recommended mounting position is on the right front quarter panel.

4.1.5 Install the brake hardware. Tighten fasteners to manufacturer's recommended torque requirements. Measure the rotor thickness variation of rotors before installation, if requested.

4.1.6 Complete installation of instrumentation and data acquisition system. Make certain that driver can monitor vehicle speed, deceleration and brake temperatures as needed.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 The test may be conducted in any ambient temperature and wind conditions. Note, however, that the brake cooling will be affected by the ambient conditions. Document the conditions on the Run Sheets located in Appendix A, Figures A1 thru A4.

4.2.1.2 Road surface should be dry. Test may be run on a damp track if surface is dry enough to show no visible tire marks. Use engineering judgment.

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 If comparing several vehicles, always use the same burnish, vehicle loading, and transmission position and run the tests in similar ambient conditions.

4.2.2.2 Having an observer in the vehicle is highly recommended. For safety and accuracy of execution of the drive schedule, the driver should be freed from having to write down the subjective rating for each stop while driving the schedule.

4.2.2.3 Lightly loaded vehicle weight is recommended for both the burnish and the drive schedule. However, gross vehicle loading may be added to the test sequence in addition to the lightly loaded condition, if requested. Lightly loaded vehicle weight for this test is defined as the weight of the vehicle as received for test plus the driver, plus 60 kg including any instrumentation, plus full to 75% capacity fuel load. If a passenger is to ride in

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the vehicle during test, the 60 kg additional load should be eliminated. Document the vehicle weight on the Run Sheets located in Appendix A, Figures A1 thru A4.

4.2.2.4 A Drive or In-Gear transmission position is recommended for the drive schedule. However, a Neutral transmission position may be added to the test sequence, if requested.

4.2.2.5 With Use: The test is written for one brake hardware build. Thermal roughness is dependent on previous thermal conditioning history of the hardware, initial rotor thickness variation, and lining wear conditions. As such, it is recommended that the test be repeated for the worn condition with 10 μm of first order rotor thickness variation and a half-worn lining condition. The half-worn linings should be conditioned as defined in GMW14985.

4.3 Instructions.

4.3.1 Burnish. Perform a brake burnish. A 200 stop FMVSS 135 and/or CMVSS 135 brake burnish is recommended. A 50 stop FMVSS 135 and/or CMVSS 135 burnish may be used to shorten test time. Using lightly loaded vehicle weight is acceptable, but should be noted in the Evaluation Report as an exception to the FMVSS 135 and/or CMVSS 135 burnish which specifies gross vehicle loading.

4.3.2 Data Sampling Parameters. The data are sampled at a minimum of 10 Hz for brake temperatures, 100 Hz for vehicle velocity and deceleration and at least 256 Hz for all accelerometer channels.

4.3.3 General Instructions for Brake Snubs. Follow the instructions in Table 1 when performing the brake snub sequences.

Table 1: General Instructions for Brake Snub Sequences

Brake Pedal Apply:	Use fast ramp apply of 130 N/s to 150 N/s.
Initial Brake Temperature:	Temperature of warmest brake 0.32 m before start of stop.
Brake Cooling Laps:	Distance as needed. Speed up to 100 km/h.
Brake Warming:	As needed. Brake applications from a speed of 70 km/h, at a deceleration rate not greater than 3 m/s ² .
Constant Deceleration:	Modulate brake pedal to maintain specified deceleration after initial ramp apply.
Coastdown Snubs:	Snubs performed without brake applies to calibrate drive/observer to the vehicle vibrations in the off-brake condition due to test surface, wheel balance, suspension tuning, etc.
Rating:	Use subjective rating scale described in Table 4. Select a rating for each snub so that a rating profile is created.

4.3.4 Baseline Thermal Roughness Schedule. Perform five cycles of a 15 snub brake sequence as outlined in Table 2 and Figures A1 thru A3 (Appendix A). Prior to the beginning of at least the first snub sequence, a coastdown snub should be performed, recorded, and evaluated for non-brake vibration. An Initial Brake Temperature (IBT) of 100 °C $\pm$ 10 °C should be attained before the beginning of each snub sequence by performing warming snubs or brake cooling laps as necessary. The snubs should be initiated with a fast ramp apply at 115 km/h in order to achieve a deceleration level of 0.25G $\pm$ 0.05G. The brake should be released at 30 km/h. Accelerate at Wide Open Throttle (WOT) between each snub in a sequence. Evaluate each stop subjectively for roughness and record optional accelerometer channels during snubs. Use the rating scale in Table 4 to rate the overall vehicle vibration during each snub. Also rate the disturbance at the pedal, the steering wheel, through the body and note any brake noise. Attempt to distinguish the transfer path of the disturbance and the brake corner causing the disturbance.

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