



Chassis Dynamometer Vehicle Brake Noise 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. Objectively quantify vehicle brake noise performance.

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

1.3 Remarks. This standard is intended to quantify brake noise frequencies and amplitudes, as well as, the operating conditions under which the brake noise(s) occurs. This standard is intended to be used with any design-representative vehicle at any point in the development process, up to and including production. This standard is intended to objectively capture brake squeal in the frequency range of 1 kHz to 17 kHz and objectively measure low frequency brake noises in the range of 100 Hz to 1000 Hz, such as moan and creep/groan.

2 References

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

2.1 External Standards/Specifications.

CMVSS 135

FMVSS 135

IEC 651

SAE J2521

2.2 GM Standards/Specifications.

None

2.3 Additional References.

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

ID = This website/document 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.

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 Chassis Brake Noise Dynamometer. Milford Proving Ground (MPG), hemi-anechoic environmental chassis dynamometer or equivalent test facility shall be used. The dynamometer shall have the features listed in 3.1.3.1 through 3.1.3.8.

3.1.3.1 Velocity control, brake pressure control, and Road Load Simulation (RLS). Control modes to include pressure/velocity, pressure/RLS, and deceleration rate/RLS.

3.1.3.2 Hemi-anechoic chamber, 100 Hz cut-off frequency, Noise Criteria (NC) 15 (NC-15) rating.

3.1.3.3 Temperature control of test chamber cooling air from -20 °C to 40 °C and Relative Humidity (RH) control of 40% RH to 95% RH (-12 °C to 40 °C) and 15% RH to 95% RH (20 °C to 40 °C).

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October 2016

Page 1 of 18

3.1.3.4 Water spray capability at each brake corner sufficient to mist the corner for a minimum of 60 s.

3.1.3.5 Corner cooling capability to provide variable speed conditioned air to the brake corners to improve test efficiency.

3.1.3.6 Safety controls to sense vehicle movement and loss of tire pressure and trigger fault to stop test during an automated script driven procedure.

3.1.3.7 Brake apply system capable of controlling brake pressure at each corner between 0 bar and 100 bar during script driven testing.

3.1.3.8 Capable of both script driven and manual testing. Dynamometer control computer must be capable of integrating dynamometer controls, environmental controls, data acquisition and safety controls into a single control system.

3.2 Equipment.

3.2.1 Microphones. Random incidence microphones are preferred for all locations. Free-field microphones may be used if random incidence microphones are not available. All devices shall meet Class 1 accuracy corresponding to International Electrotechnical Commission (IEC) 651, or equivalent, for the application (precision ± 0.7 dB or $\pm 8\%$).

3.2.2 Accelerometers. Single axis accelerometer with a sensitivity of nominally $1.2 \text{ mV}/(\text{m/s}^2)$. Sensitivity should be $\pm 10\%$ from 1.5 Hz to 18 000 Hz. Temperature range should be from -73°C to 163°C .

3.2.3 Thermocouples. K-type thermocouples.

3.2.4 Data Acquisition System. The data acquisition system shall be capable of the following:

3.2.4.1 Providing frequency domain data up to 20 000 Hz.

3.2.4.2 Anti-aliasing filtering.

3.2.4.3 The simultaneous acquisition of up to ten (10) high-speed Noise, Vibration, and Harshness (NVH) channels.

3.2.4.4 The simultaneous acquisition of up to ten (10) Direct Current (DC) voltage signals corresponding to brake temperature, brake pressure, vehicle speed, and external trigger from dynamometer.

3.2.4.5 Ability to start and stop acquisition automatically from external trigger supplied by dynamometer.

3.3 Test Vehicle/Test Piece. The tests shall be performed on a production vehicle or development vehicle which represents the current release status. Any unwanted content or problems shall be eliminated prior to test.

3.4 Test Time.

Calendar time: 4 days

Test hours: 50 hours

Coordination hours: 4 hours

3.5 Test Required Information. Vehicle information, as required.

3.6 Personnel/Skills. One (1) qualified engineer or technician trained in the use of data acquisition equipment and having basic knowledge of acoustic and vibration signal processing. One (1) qualified chassis dynamometer operator. At MPG, Dynamometer operation may be conducted by test engineer or technician if approved by local management of dynamometer equipment.

4 Procedure

4.1 Preparation.

4.1.1 Vehicle Preparation. Reference Data Sheet B1, Appendix B.

4.1.1.1 Vehicle Mass. Load the vehicle to curb mass plus driver and full fuel load. Other loading conditions may be specified by the requesting engineer. All ballast must be properly secured. Record vehicle test weight in kilograms (kg).

4.1.1.2 Vehicle Pre-Dynamometer Preparation.

4.1.1.2.1 If the brake hardware is production intent, the hardware on the vehicle can be tested in its current condition. New brake hardware (linings and rotors/drums) may be installed, if requested by the test engineer.

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October 2016

Page 2 of 18



Documents

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4.1.1.2.2 Thermocouple brake linings per Canada Motor Vehicle Safety Standard/Federal Motor Vehicle Safety Standard (CMVSS/FMVSS) 135.

4.1.1.2.3 Remove axle shafts or drive shaft if testing a driven axle.

4.1.1.2.4 Install flexible brake lines to each corner and bleed each corner using a bleeder ball. A quick connect fitting is used to connect the bleeder ball to the individual brake line. Confirm brake fluid type prior to bleeding brakes.

4.1.1.2.5 Install the accelerometers on the caliper bracket, lining backing plate, or the caliper housing for a disc brake, and on the backing plate for a drum brake, using dental cement or similar adhesive or a magnetic base.

4.1.1.3 Data Acquisition Preparation.

4.1.1.3.1 Calibration Verification. Check equipment for valid calibration date. Replace equipment without valid calibration date. Turn on all instrumentation 5 minutes prior to calibration verification. Verify calibration of the transducers as in 4.1.1.3.1.1 through 4.1.1.3.1.2.

4.1.1.3.1.1 Microphone Calibration Verification. Mount the first measurement microphone on a certified calibrator and switch the calibrator on. Using the calibration function of the software, enter the calibrator frequency and sound level, then measure the signal and observe the calculated sensitivity of the channel. If the calculated sensitivity of the channel is not within 15% of the latest calibration certificate for the microphone, replace the microphone and repeat. Before conducting verification of next channel, accept the calculated sensitivity to store the sensitivity in the test setup. Repeat for each microphone. Adapt these instructions to the calibration verification method for the microphones and data acquisition system being used.

4.1.1.3.1.2 Accelerometer Calibration Verification. Mount the first measurement accelerometer on a certified calibrator and switch the calibrator on. Using the calibration function of the software, enter the calibrator frequency and vibration level, then measure the signal and observe the calculated sensitivity of the channel. If the calculated sensitivity of the channel is not within 15% of the latest calibration certificate for the accelerometer, replace the accelerometer and repeat. Before conducting verification of next channel, accept the calculated sensitivity to store the sensitivity in the test setup. Repeat for each accelerometer. Adapt these instructions to the calibration verification method for the accelerometers and data acquisition system being used.

4.1.1.3.2 Acquisition Setup. Verify/accomplish the following acquisition settings:

NVH Channels:

- **Bandwidth** = 20.0 kHz
- **Resolution** = 25.0 Hz
- **Overlap** = 50%
- **Format:** Spectra Peak Hold
- **Window:** Hanning
- **Final Weighting:** A for acoustic channels, and linear for all other channels
- **Format:** Root Mean Square (RMS)
- **Amplitude Correction**

Non-NVH Channels:

- **Sampling Frequency** = 100 Hz

4.1.1.4 Preparation on Chassis Dynamometer.

4.1.1.4.1 Allow the vehicle to adjust to test lab ambient temperature. Attach vehicle to chassis dynamometer rolls. If lateral body tie downs are used, flexible rubber isolators must be used to isolate the body.

4.1.1.4.2 Install the hydraulic pressure controller to the brake corners and bleed the brakes.

4.1.1.4.3 Connect brake lining thermocouples to chassis control system.

4.1.1.4.4 Install transducers and data acquisition equipment. The interior microphone should be placed near the driver's right ear as shown in Appendix C, Figure C1. Connect microphones and accelerometers to the dynamometer data acquisition panel.

4.1.1.4.5 Install vehicle proximity sensors and tire pressure sensors.

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October 2016

Page 3 of 18

4.1.1.4.6 Install water spray stand next to spot cooling ducts and aim water spray into the wheel opening at the brake rotor.

4.1.1.4.7 Direct spot coolers at the brake rotor/drum.

Note: Spot cooling is to be used to maintain temperatures in between test runs and may need to be shut off during data acquisition if it increases chamber background noise.

4.1.1.4.8 Verify that parking brake is released.

4.1.1.4.9 Remove all camouflage for validation testing. Eliminate any unwanted content or problems, (e.g., ground-outs). Check that the spare wheel is securely seated.

4.2 Conditions.

4.2.1 Environmental Conditions. The specific conditions are specified in each test section.

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 Powertrain shall be off during testing. The dynamometer will power the wheels.

4.2.2.2 All windows shall be fully opened during all sections of the procedure.

4.2.3 Operating Conditions. See SAE J2521 for explanation of the brake pressure profiles.

4.3 Instructions. Brake Test Matrix. This standard consists of a sequence of 24 test sections. Table 1 defines the test sequence and associated environmental conditions for each test section. The referenced tables that detail the tests and conditions are in Appendix A, Tables A1 through A13.

5 Data

5.1 Calculations.

5.1.1 Graphical Summaries.

5.1.1.1 Squeal Summary. For the squeal summary charts, plot the squeal events for each brake corner with a unique color marker. Plot the Forward and Reverse stops with different markers. See Figures A1 thru A3, Appendix A for example.

5.1.1.1.1 Sound Pressure Level (SPL). Plot SPL vs. Frequency between 100 Hz and 17 000 Hz for each noise event during the schedule for each brake corner. Plot the squeal events for each brake corner with a unique color marker. Plot only noises that are greater than 30 dBA.

5.1.1.1.2 Temperature. Plot Lining Temperature vs. Frequency between 100 Hz and 17 000 Hz for each noise event greater than 30 dBA for each brake corner.

5.1.1.1.3 Pressure. Plot Caliper Pressure vs. Frequency between 100 Hz and 17 000 Hz for each noise event greater than 30 dBA for each brake corner.

5.1.1.1.4 Speed. Plot Vehicle Speed vs. Frequency between 100 Hz and 17 000 Hz for each noise event greater than 30 dBA for each brake corner.

5.1.1.1.5 Decel vs Frequency. Plot Vehicle Decel vs. Frequency between 100 Hz and 17 000 Hz for each noise event greater than 30 dBA for each brake corner.

5.1.1.1.6 Decel vs Speed. Plot Vehicle Decel vs. Speed between 0 km/h and 120 km/h for each noise event greater than 30 dBA for each brake corner.

5.1.1.1.7 Relative Humidity. Plot Chamber Relative Humidity vs. Frequency between 100 Hz and 17 000 Hz for each noise event greater than 30 dBA for each brake corner.

5.1.2 Summaries.

5.1.2.1 Noisy Stop Summary. Plot the percent noisy stops for each section of the test. See Figure A4, Appendix A for example.

5.1.2.2 Low Frequency Noise Summary. Plot SPL vs. Frequency between 100 Hz and 1000 Hz for each noise event during the schedule for each brake corner for the following sections: Dynamic Groan/Grind; Creep/Groan; and Moan. Plot only noises that are greater than 30 dBA.

5.2 Interpretation of Results. Results may be compared to technical specifications or to tests on other vehicles.

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October 2016

Page 4 of 18

5.3 Test Documentation. Publish test results according to GM corporate protocol using the Evaluation Report Template (CG190) and Global Document Management (GDM) system.

Table 1: Test Sequences

Sequence Number		Section Name	Appendix A Reference	Environmental Conditions
1	Warm - First Sequence	Break-in	Table A1	15 deg C and 50% RH
2		Bedding	Table A2	
3		Warm Stops	Table A3	
4		Warm Drag Module	Table A4	
5		Intermediate Conditioning and Warm-Up Module	Table A5	
6		Backward/Forward	Table A6	
7		Deceleration Module	Table A7	
	0.5 hour Transition 2°C & 50% RH			
	Cold/Damp First Sequence	Water spray + soak vehicle for 4 hours at 2°C & 95% RH		
8		Cold Damp Backward/Forward	Table A8	2 deg C & 95% RH
		Water spray + soak vehicle for 4 hours at 2°C & 95% RH		
9		Creep/Groan	Table A9	5 deg C & 95% RH
10		Moan	Table A10	
	1 hour Transition 20°C & 0% RH			
	Cold - First Sequence	soak vehicle 1 hour at -10°C & 0% RH, followed by 1 hour at -10°C & 50% RH		
11		Cold Backward/Forward	Table A11	-10°C & 50% RH
12		Cold Matrix 1	Table A12	
13		Cold Matrix 2	Table A13	
	0.5 hour Transition 2°C & 50% RH			
14	Warm - Second Sequence	Warm Stops	Table A3	15 deg C and 50% RH
15		Warm Drag Module	Table A4	
16		Intermediate Conditioning and Warm-Up Module	Table A5	
17		Backward/Forward	Table A6	
18		Deceleration Module	Table A7	
	0.5 hour Transition 2°C & 50% RH			
	Cold/Damp First Sequence	Water spray + soak vehicle for 4 hours at 2°C & 95% RH		
19		Cold Damp Backward/Forward	Table A8	2 deg C & 95% RH
		Water spray + soak vehicle for 4 hours at 2°C & 95% RH		
20		Creep/Groan	Table A9	5 deg C & 95% RH
21		Moan	Table A10	
	1 hour Transition 20°C & 0% RH			
	Cold - First Sequence	soak vehicle 1 hour at -10°C & 0% RH, followed by 1 hour at -10°C & 50% RH		
22		Cold Backward/Forward	Table A11	-10°C & 50% RH
23		Cold Matrix 1	Table A12	
24		Cold Matrix 2	Table A13	
	Defrost chamber/vehicle 2.5 hours at 30°C & 15% RH			

Note: & = and, deg = degree.

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October 2016

Page 5 of 18



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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.

Brake Burnish Schedule: Two hundred (200) stops per the CMVSS/FMVSS 135 burnish schedule.

Initial Brake Pad Temperature: The average of the left and right brake lining temperature prior to a brake apply.

7.2 Acronyms, Abbreviations, and Symbols.

&	and
CMVSS	Canada Motor Vehicle Safety Standard
DC	Direct Current
deg	degree
FMVSS	Federal Motor Vehicle Safety Standard
FWD	Front Wheel Drive
GDM	Global Document Management
GSSLT	Global Subsystem Leadership Team
IEC	International Electrotechnical Commission
kg	kilograms
LFRE	Left Front Right Ear
LHD	Left Hand Drive
MPG	Milford Proving Ground
NC	Noise Criteria
NVH	Noise, Vibration, and Harshness
RH	Relative Humidity
RLS	Road Load Simulation
RMS	Root Mean Square
RRE	Rider Right Ear
RWD	Rear Wheel Drive
SPL	Sound Pressure Level
VIN	Vehicle Identification Number

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMW16417

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October 2016

Page 6 of 18



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