



Rough Road Vibration Evaluation Procedure

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 test procedure supports the Vehicle Technical Specification (VTS) requirement for Rough Road Vibration.

1.2 Applicability. This test procedure applies to passenger vehicles and light duty trucks operated on a continuous rough paved road.

1.3 Remarks. The vehicle vibration levels at critical tactile interfaces at constant speed on rough roads are used to evaluate vehicle performance. The Rough Road VTS 3.2.1.3.8.2.2 specifies vibration levels at steering wheel and seat track locations.

2 References

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

2.1 External Standards/Specifications.

ISO 2631

ISO 5349

2.2 GM Standards/Specifications.

GMW14264

2.3 Additional References.

- PCB Piezotronics, Inc., 3425 Walden Avenue, Depew, NY 14043-2495 USA
- Siemens PLM Software; Global Headquarters, 5800 Granite Parkway, Suite 600, Plano, TX 75024 USA
- Vehicle Technical Specification (VTS)

3 Resources

3.1 Facilities. A rough road with continuous irregularities of broadband frequency (5 Hz to 50 Hz) is required. Vehicle speed and road surface must follow the conditions specified in the program VTS. Typical vehicle speed is 72 km/h (45 mph).

Typical Road Surfaces:

- GMB (Cruz Alta Proving Ground): Engineered Spalled Concrete surface on D1 track.
- GME (Test Center Dudenhofen): Engineered Spalled Concrete surface.
- GMM: Vehicles shipped to GMNA if validation is required.
- GMNA (Milford and Yuma Proving Grounds): Engineered Spalled Concrete surface on Ride and Handling Loop.
- GMK (Cheong-na Proving Ground): Engineered Spalled Concrete surface on Ride and Handling Loop.
- SGM (Guangde Proving Ground): Engineered Spalled Concrete surface.

Note: Data could be acquired for a vehicle excited by a road simulator for comparison or development purposes. Not recommended for validation.

Note: Data for different operating conditions, road surfaces or simulators will not be comparable.

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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.

3.2 Equipment. Required equipment types and specifications are detailed in 3.2.1 thru 3.6.

3.2.1 Test Equipment. Appendix A, Tables A1 thru A3, contain more detailed information regarding acquisition system, accelerometers and examples.

3.2.1.1 Data Acquisition Equipment. Use the preferred digital data acquisition hardware system and software identified by the Global Noise and Vibration Infrastructure Team to be capable of performing this procedure (e.g., LMS SCADAS Mobile and LMS Test Lab software, available from Siemens PLM Software, Siemens Industry, Inc.) See Appendix A, Table A1 for minimum acquisition system specifications.

3.2.1.2 Accelerometers. High sensitivity and low mass triaxial accelerometers with a flat frequency response between 1 Hz and 1000 Hz and a temperature range of 18 °C to 30 °C or greater shall be used. Accelerometer specifications and examples in Appendix A, Tables A2 and A3.

3.3 Test Vehicle/Test Piece. Any passenger vehicle or light truck.

3.4 Test Time.

Calendar time:	1 to 2 days
Test time:	6 to 10 hours
Coordination time:	4 to 12 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. To complete these tests, one (1) technician or engineer skilled in noise and vibration data acquisition is required. The technician or engineer must be approved to drive on the Proving Grounds road system. For data analysis, one (1) engineer skilled in vibration data acquisition and analysis is required.

4 Procedure

4.1 Preparation.

4.1.1 Tire Pressure. Adjust cold tire pressure to the manufacturer's specifications for the test load condition at the ambient temperature at which the tests are to be conducted. Tires should be balanced to production specifications.

4.1.2 Ballast Condition. If test conditions require loading other than standard, i.e., driver and equipment weight only, install appropriate ballast and secure.

4.1.3 Steering Column and Wheel.

4.1.3.1 Steering Column Angle. Adjust tilt steering columns to eliminate any relative angle between the lower and upper steering column. If the vehicle has a rake type column adjustment, locate it in the midpoint of its travel.

4.1.3.2 Steering Wheel Alignment. Ensure that the steering wheel is aligned while the vehicle is straight down the road. If the steering wheel is not aligned, note the wheel position when the vehicle is going straight. This will be the wheel position used when the steering wheel accelerometers are installed.

4.1.4 Instrumentation Calibration. The calibration should be checked periodically.

Note: If accelerometers are replaced, the calibration file must be updated. All transducers are precision, high cost instrumentation. They must be handled with extreme care. **Do not drop them.**

4.1.5 Accelerometer Placement.

4.1.5.1 Steering Wheel Accelerometers. Install one (1) triaxial accelerometer at the top of the wheel in the 12 o'clock position and one (1) at the side of the wheel in the 3 o'clock position. Align the accelerometers to the vehicle global coordinate system, not to the steering wheel local coordinate system (see Appendix A, Figure A1).

Note: As a precaution, for leather trimmed steering wheels, protect the steering wheel with special tape before mounting the transducer.

4.1.5.2 Seat Track Accelerometer. Install a triaxial accelerometer at the driver seat rear inboard seat track (DRIST) attachment location (see Appendix A, Figure A2).

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4.1.5.3 Additional Accelerometer Locations. The steering wheel 12 o'clock position, steering wheel 3 o'clock position and DRIST locations are required to match the locations specified in VTS 3.2.1.3.8.2.2 for validation. Additional locations may be added as necessary for development iterations. The following (listed but not limited to) locations may be of interest and are suggested by the Structural Vibration Team:

- Windshield header (for convertible vehicles).
- Driver front outboard seat track (DFOST), see Appendix A, Figure A3.
- Spindle points (input vibration).
- Center floor console top rear corners (driver and passenger sides), see Appendix A, Figure A4.

Note: Additional points are not limited to the preceding.

4.1.6 Data Acquisition System (DAS) Installation.

4.1.6.1 Install the DAS and laptop computer (on the GM built systems) on the passenger seat and fasten as required. The monitor should be easily seen from the driver seat, and the keyboard should be within easy reach of the driver.

4.1.6.2 Ensure that all cable connections are made for power, sensors and computer.

4.1.6.3 Data acquisition parameters can be set up as described in Section 5 if online processing is desired when acquiring data, or time domain data may be captured and processed at a later time.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 The test roads must be free of debris, standing water or snow. Wind which makes steering inputs necessary should be avoided. Recommendation: < 32km/h (< 20 mph).

4.2.1.2 Limited objective data exists describing the effect of ambient temperature on measure shake performance. Additionally, temperature effects may be dependent on specific vehicle design characteristics. To improve the accuracy of measured data, it is recommended that the ambient temperature for testing be between 4 °C and 32 °C (40 °F and 90 °F). If small changes are being evaluated, comparison tests should be limited to a range of 7 °C (20 °F).

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.

4.3 Instructions.

4.3.1 Fill vehicle fuel tank.

4.3.2 Test weight includes driver and instrumentation.

4.3.3 Turn on the instrumentation to begin warm up.

4.3.4 Travel a total of approximately 15 km (9 mi) on a freeway type condition (e.g., two (2) laps around the Milford Proving Ground (MPG) Circular Track) for vehicle and tire warm up. A slightly more severe condition (e.g., MPG Ride and Handling Loop) can be substituted if the first road does not provide sufficient input amplitude.

4.3.5 Time domain accelerations shall be measured with the data acquired for the 16 s on typical road surfaces (see 3.1). Shorter time duration due to facility constraints is acceptable if repeatable data is obtained. A minimum of three (3) test runs are to be recorded and compared to assure repeatability.

4.3.6 Repeatability from run-to-run, setup-to-setup and driver-to-driver are influenced by the following:

- Tire Pressure.
- Fuel Tank Level.
- Steering Wheel and Seat Position.
- Transducer Location and Orientation.
- Road Condition.
- Ambient Temperature.
- Vehicle Temperature.
- Speedometer Calibration.

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- Test Speed.
- Lane Position.
- Steering Wheel Grip.

5 Data

5.1 Calculations. Power Spectral Density (PSD) shall be calculated from time domain data, resulting in frequency domain acceleration amplitude, decibel(s) (dB) (i.e., $(\text{m/s}^2)^2/\text{Hz}$), versus frequency (Hz). PSD units allow the quantification of acceleration amplitude regardless of the Fast Fourier Transform (FFT) resolution used. See data plot example in Appendix A, Figure A5.

The following digital signal processing parameters shall be used:

- Function: Autopower Spectrum.
- Format: Power Spectral Density (PSD).
- Scale: Root Mean Squared (RMS).
- Time Length: 16 s.
- Frequency Resolution: Recommend 0.5 Hz.
- Frequency Range: 0 Hz to 100 Hz.
- Window Type: Hanning.
- Amplitude Correction Factor: Energy.
- Averaging Type: Linear.
- Overlap: 75%.
- Average all available runs.

5.2 Interpretation of Results. At a driver interface location a 3 dB to 5 dB difference between two (2) conditions generally corresponds to a difference of one (1) subjective rating point if the difference is at one of the largest amplitude peaks in the spectrum. For details on the Subjective Rating Scale, refer to GMW14264.

Unlike sound pressure level measurements in decibel(s) (dB) (referenced to the threshold of human hearing), the $1 (\text{m/s}^2)^2/\text{Hz}$ acceleration reference value is a large number. Most measurements are much less than $1 (\text{m/s}^2)^2/\text{Hz}$, which results in the decibel (dB) value being negative.

A difference of 3 dB corresponds to a ratio of 2:1 on a power scale $((\text{m/s}^2)^2)$.

Human sensitivity varies across the frequency range and from location to location on the body (i.e., hands versus feet). A peak response in a driver interface measurement at a particular frequency may not be as objectionable as an equal amplitude response at another frequency. Additional calculation using human vibration sensitivity weighting functions can be done as an option, see Appendix B.

Some very general guidelines regarding what vehicle modes affect the vibration levels:

- Vehicle rigid body mode: 0 Hz to 5 Hz.
- Powertrain rigid body mode: 5 Hz to 15 Hz.
- Suspension modes: 8 Hz to 15 Hz.
- Seat/floor modes: 10 Hz to 20 Hz.
- Global body structural modes: 15 Hz to 25 Hz.
- Component modes: 25 Hz to 50 Hz.

The data should be compared to previously measure vehicles and to the VTS requirement.

5.3 Test Documentation. The data should be plotted, see example at Appendix A, Figure A5. All data should be stored in the database.

Note: GMNA MPG uses LMS Tech Manager as the data repository.

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