



Vehicle Level Powertrain/Driveline Noise and Vibration Evaluation Procedure for Automatic Transmission

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. The purpose of this procedure is to measure vehicle powertrain and driveline noise and vibration during idle, drive-away and cruising operating conditions. The data acquired is used to assess the performance of GM and competitive vehicles, establish noise and vibration requirements and validate to those requirements.

1.2 Applicability. This procedure is appropriate for use with passenger cars, multi-purpose passenger vehicles, minibuses and light commercial vehicles with a maximum authorized total weight of 3500 kg (7716 lb). It is applicable to hybrid and conventional transmissions that do not require manual operation to change ratio. It is not applicable to transmissions that require manual operation to change ratio. Some sections of the procedure are specific to transmission type. For the purposes of this procedure, the following transmission types are defined:

- Automatic Transmission (AT): conventional, stepped gear ration automatic transmission.
- Automated Single-Clutch Transmission (SCT): transmission with one clutch and capability to change stepped gear ratios automatically.
- Automated Dual-Clutch Transmission (DCT): transmission with two clutches and capability to change stepped gear ratios automatically.
- Continuously Variable Transmission (CVT): transmission with variable ratio achieved by mechanical power transfer.
- Electric Variable Transmission (EVT): transmission with variable ratio achieved by a combination of electrical and mechanical power transfer. This includes Extended Range Electric Vehicles (EREV) and Battery Electric Vehicles (BEV).

1.3 Remarks. This procedure is known as the Vehicle Level Allocatable Test (VLAT).

2 References

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

2.1 External Standards/Specifications.

IEC 651 ISO 2631 ISO 5349

2.2 GM Standards/Specifications.

GMW14218 GMW16206 (ID)

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

2.3 Additional References.

- Bosch Automotive Handbook, 4th Edition
- Energy Test Database on the GM intranet
- Information including technical references and standard test setup files are included in Knowledge Packet (KPac) Set NVIPDHP-S1338 Best Practice, located in the Enterprise Engineering Knowledge System (E2KS)

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- Leo L. Beranek, The Design of Speech Communication Systems, Proceedings of the Institute of Radio Engineers (IRE), September 1947
- U.S. Government Environmental Protection Agency (EPA) web site
- Vehicle Technical Specification (VTS)

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 Environment. The tests shall be performed in the designated testing environment at each GM regional site. The environment specified in the Vehicle Technical Specification (VTS) must be used for validation purposes. The test shall be performed in an anechoic environment, with a hard, flat floor surface. The ambient background noise level must be a minimum of 15 dB below the signal being measured. The ambient temperature shall be between 18 °C (65 °F) and 25 °C (77 °F). The test facility for the rolling tests shall be a semi-anechoic chassis dynamometer capable of speed control, load control and Road Load Simulation (RLS) up to 160 km/h (100 mph) and 6600 N (1485 lbf) tractive effort.

3.2 Equipment. Required equipment types and specifications are given in 3.2.1 through 3.2.4.

3.2.1 Tachometers. Driveline tachometer (prop shaft or axle shaft) and engine tachometers are required. Output must be compatible with Data Acquisition System (DAS) input requirements. Angular resolution of one or more pulses per revolution is required.

3.2.2 Microphones. Random incidence microphones are preferred for vehicle interior locations. Free-field microphones may be used for interior locations if random incidence microphones are not available. Free-field microphones are preferred for the exterior exhaust tailpipe location. Pressure microphones may be used at the tailpipe location if free-field microphones are not available. All devices shall meet Class 1 accuracy corresponding to IEC 651 or be equivalent for the application (precision ± 0.7 dB or $\pm 8\%$).

3.2.3 Accelerometers. High sensitivity accelerometers with a flat frequency response between 2.0 Hz and 2.0 kHz and a temperature range of 10 °C (50 °F) to 50 °C (122 °F) or greater shall be used.

3.2.4 Data Acquisition Equipment (DAS). The preferred digital DAS is a personal computer running Leuven Measurement Systems (LMS) Test Lab software connected to an LMS Scadas III front end, or equivalent as approved by the Global Noise and Vibration Center (GNVC) Infrastructure Team. This setup allows simultaneous digital recording of time domain data and online or post-processing of frequency and order domain data.

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:	2 days
Test time:	12 hours
Coordination time:	4 hours

3.5 Test Required Information. Vehicle information as specified in 4.1.1.1.

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. Dynamometer operation may be conducted by test engineer or technician if approved by local management.

4 Procedure

4.1 Preparation.

4.1.1 Vehicle Preparation.

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4.1.1.1 Documentation. Using the vehicle preparation Data Sheet A1 provided in Appendix A, record Vehicle Identification Number (VIN), GM fleet number, and the build stage if appropriate. Record tire make and model, size and air pressure. Record engine displacement, orientation, configuration (V or in-line), and fuel type. Record the driveline configuration Front Wheel Drive (FWD), Rear Wheel Drive (RWD), All Wheel Drive (AWD), Four Wheel Drive (4WD), the number of forward gears and identify power source in the type information data entry field (i.e., hybrid, fuel cell). Record whether the interior is leather or cloth, the seating capacity, and whether the vehicle has a sliding roof or other options that could influence interior noise levels. Record the test date, time, and location. Verify and note within the documentation tab of the LMS Test Lab project the status of all hardware relative to the current release status.

4.1.1.2 Static Preparation. Verify that the vehicle meets the requirements of 3.3. Verify that the tires are inflated to the nominal (cold) pressure as specified by the vehicle manufacturer. Refill the fuel tank if it is less than three-quarters ($\frac{3}{4}$) full.

4.1.1.3 Vehicle Mass. Proceed to vehicle scale to determine vehicle test weight. Do not include driver or any additional instrumentation when measuring test weight. Record weight (in kg (lb)) and (weight + 70 kg (150 lb)) on vehicle preparation data sheet.

4.1.1.4 Road Test. A road test must be conducted to ensure proper operation of the vehicle and to determine the vehicle operating parameters that will be used to control the chassis dynamometer. Proceed to a test track with smooth level road surface, with sufficient straightaway length to safely accomplish the road tests included in 4.1.1.4.1 thru 4.1.4.2.3. The test track must have distance marking signs to enable distance/time measurements. Drive the vehicle to check for proper operation of the engine and transmission and ensure that the vehicle is free from squeaks, rattles and extraneous noises. Eliminate all extraneous noises prior to testing.

4.1.1.4.1 Speedometer Verification. Accelerate to a steady speed of 100 km/h (60 mph) and using roadside distance markers, record on the vehicle preparation data sheet the time necessary to travel 1.0 km (0.60 mi). Establish a steady speed of 50 km/h (30 mph) and using the roadside distance markers, record the time necessary to travel 0.50 km (0.30 mi). Alternatively, verify speedometer accuracy using a Global Positioning System (GPS) navigation device.

4.1.1.4.2 Off-Brake Speed Determination. Bring vehicle to a full stop with the brake pedal and then release the brake pedal. With zero (0) throttle pedal application, allow the vehicle to stabilize at a constant speed. Record the indicated speed as the off-brake vehicle speed on the vehicle preparation data sheet.

4.1.1.4.3 Coast-Down Measurements for Road Load Simulation Coefficient Determination.

Note: The following warm-up step is critical to establish consistent vehicle frictional losses during coast-down; Drive vehicle under a light load for a minimum of 20 minutes to establish normal operating temperature.

Perform the following coast-down tests to determine the road load coefficients for dynamometer simulation. Operate the vehicle on a dry straight smooth road with zero (0) grade. Establish a cruising speed of 129 km/h (80 mph). Shift into Neutral and allow the vehicle to coast-down. Measure and record to ± 0.10 s the time required to coast from 105 km/h (65 mph) to 97 km/h (60 mph). Enter the result on the vehicle preparation data sheet. Next, operate the vehicle at a cruising speed of 32 km/h (20 mph). Shift into Neutral and allow the vehicle to coast-down. Measure and record to ± 0.10 s the time required to coast from 24 km/h (15 mph) to 16 km/h (10 mph). Enter the result on the vehicle preparation data sheet (see Appendix A). Repeat process as necessary to obtain reliable data. To compensate for directional wind resistance effects and variation, conduct a minimum of two (2) coast-downs in each direction of a two-way straightaway track, then average the individual results to obtain coast-down times for calculation.

Enter coast-down times and vehicle mass into the Pre Vehicle Level Allocatable Test (PreLAT) calculator tool, which is provided in Global Document Management (GDM). Use the PreLAT calculator tool to calculate the road load coefficients based on the coast-down times. This tool uses the Bosch RLS estimation equation in Appendix C. If the PreLAT calculator tool is not available, compute the road load simulation coefficients manually, using the RLS equation provided in Appendix C.

The PreLAT calculator tool and the Bosch RLS equation produce estimates of the RLS coefficients based on coast-down data and vehicle mass. If more accurate RLS coefficients are available from other sources, then these coefficients may be used instead of the coefficients estimated from the road test coast-down in this procedure. References to other RLS coefficient sources are provided in Knowledge Packet (KPac) Set NVIPDHP-S1338, and include the Energy Test Database on the GM intranet, and the U.S. Government Environmental Protection Agency (EPA) web site on the internet.

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Note: The Knowledge Packet and the Energy Test Database are GM internal Best Practices. The supplier shall work with the GM Design Responsible Engineer to comprehend these requirements.

4.1.1.4.4 Wide Open Throttle (WOT) Passing Gear Determination. (Not applicable to CVT and EVT vehicles). Determine the WOT passing gear, shift point, vehicle speed and engine speed as follows: With the transmission in Overdrive/Drive, establish a constant vehicle speed of 70 km/h (45 mph). After the transmission has stabilized, rapidly depress the accelerator to WOT (up to the maximum vehicle speed ≤ 135 km/h (≤ 84 mph)) and record on the vehicle preparation data sheet, the vehicle speed and engine speed when the first upshift occurs.

Note: If the transmission has more than four (4) speeds, the 3rd to 4th gear shift may more accurately represent the passing condition. In this case, follow the same procedure and note all speeds at which shifts occur, up to the maximum vehicle speed ≤ 135 km/h (≤ 84 mph).

Record results in vehicle preparation data sheet. The appropriate passing gear is the gear prior to the up-shift for the vehicle speed closest to, but not exceeding, 135 km/h (84 mph), (e.g., if the 2nd to 3rd shift occurs at 130 km/h (81 mph), the passing gear is 2nd gear). If all up-shift speeds exceed 135 km/h (84 mph), use engine speed for 2nd gear at 135 km/h (84 mph) and note this on the vehicle preparation data sheet.

Operate the vehicle in passing gear at approximately 70 km/h (45 mph). Press accelerator to the floor. Observe if the vehicle downshifts below passing gear. If downshift does not occur, lower vehicle speed (< 70 km/h (45 mph)), and repeat until lowest speed is found that does not cause a downshift. Record lowest WOT speed in passing gear on vehicle preparation data sheet.

4.1.1.4.5 Determination of Vehicle Speed at 2500 Engine Revolutions per Minute (ERPM) (Not applicable to CVT and EVT vehicles). Determine the 2500 ERPM vehicle speed and load as follows: Drive the vehicle at a constant speed while the transmission is in the lowest selectable gear and the indicated engine speed is as close as possible to 2500 ERPM. At this steady state operating condition, record the indicated vehicle speed on the vehicle preparation data sheet. If the indicated engine speed for the previous step was not exactly 2500 ERPM, use the measured engine speed/vehicle speed ratio to calculate the corresponding vehicle speed at 2500 ERPM.

4.1.1.4.6 Determination of Vehicle Speed at 1500 ERPM (Diesel engines only, not applicable to CVT and EVT vehicles). For diesels only, determine the 1500 ERPM vehicle speed and load as follows: Drive the vehicle at a constant speed while the transmission is in the lowest selectable gear and the indicated engine speed is as close as possible to 1500 ERPM. At the steady state operating condition, record the indicated engine speed and indicated vehicle speed on the vehicle preparation data sheet. If the indicated engine speed for the previous step was not exactly 1500 ERPM, use the measured engine speed/vehicle speed ratio to calculate the corresponding vehicle at 1500 ERPM.

4.1.2 Vehicle Preparation on Chassis Dynamometer. Allow the vehicle to adjust to test laboratory 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. Ensure that wheel chocks do not contact the body.

4.1.2.1 Set the exhaust collector and ventilation system to properly remove exhaust gases without affecting engine performance. The exhaust removal system should be placed in line with the exhaust exit at a minimum of 0.30 m (0.985 ft) away from the tailpipe(s). The exhaust removal system shall not be placed as to hinder tailpipe acoustic data.

4.1.2.2 Connect instrumentation to remotely monitor engine coolant temperatures.

4.1.2.3 Install engine tachometer (tachometer channel name T1) and note the number of pulses per revolution for entry into the DAS.

4.1.2.3.1 For vehicles equipped with an exposed rear prop shaft between the transmission and rear axle, install prop shaft tachometer (tachometer channel name T2) and enter the number of pulses per revolution into the DAS.

4.1.2.3.2 For vehicles equipped with an enclosed rear prop shaft install tachometer on rear axle (tachometer channel name T2).

4.1.2.3.3 For all other vehicles, install a wheel (or drive axle) speed tachometer (tachometer channel name T2) and enter the number of pulses per revolution into the DAS. When a wheel or drive axle tachometer is used, multiple pulses per revolution are often necessary to improve tachometer accuracy at the start of the drive-away sweeps.

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4.1.2.4 Install emergency engine shut-off lead. Check for proper orientation. Close hood.

4.1.2.5 Set up external cooling fan directed toward the engine cooling system. Raise all movable chassis dynamometer floors.

Optional: If required to maintain desired operating temperatures, install spot cooling hoses as required. Typical spot cooling locations include catalytic converter, muffler and differential.

Note: Spot cooling is to be used to maintain temperatures in between test runs and must be shut off during data acquisition.

4.1.2.6 Install throttle controller. Throttle controller must be self-supporting on the floor of the vehicle and must not contact the seat, dashboard or steering wheel.

4.1.2.7 Turn off the vehicle radio.

4.1.2.8 Turn off the Air Conditioning (A/C). Set Heating, Ventilation and Air Conditioning (HVAC) fan speed to "off". If "off" is not available, set to minimum speed available. Set HVAC position selector to floor only. Do not use combination or defrost switch settings which engage air conditioning compressor for dehumidification.

4.1.2.9 Verify that the parking brake is released.

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

4.1.2.11 Position the seats and headrests according to Appendix B, B1 thru B4. If equipped with tilt/telescoping steering, position the steering column in the center position of travel for both tilt and telescope. Make sure electronic key remote is not inside the vehicle or manually prevent the driver door from locking. Check that all windows, sliding roof and sun screen are fully closed.

4.1.3 Data Acquisition Software Preparation. Open data acquisition software capable of acquiring synchronously tracked orders of a tachometer (LMS Signature Testing Advanced, or equivalent).

4.1.3.1 Channel Assignments. Use the following recommended channel assignments and naming conventions:

1. LFRE_SPL (Left Front Right Ear Sound Pressure Level). For Right Hand Drive (RHD) vehicles, use RFLE_SPL (Right Front Left Ear Sound Pressure Level).
2. RR_SPL (Right Rear Sound Pressure Level). For RHD vehicles, use LR_SPL (Left Rear Sound Pressure Level).
3. ROW_3_SPL (3rd Row Center Seat Sound Pressure Level), applicable vehicles only.
4. 50_CM_EXH_SPL (50 cm Exhaust Sound Pressure Level).
5. FA_ST_WH_ACCEL (Steering Wheel Fore/Aft Acceleration at 12:00).
6. LAT_ST_WH_ACCEL (Steering Wheel Lateral Acceleration at 9:00).
7. VERT_ST_WH_ACCEL (Steering Wheel Vertical Acceleration at 12:00).
8. FA_DFOST_ACCEL (Front Outboard Driver's Seat Track Fore/Aft Acceleration).
9. LAT_DFOST_ACCEL (Front Outboard Driver's Seat Track Lateral Acceleration).
10. VERT_DFOST_ACCEL (Front Outboard Driver's Seat Track Vertical Acceleration).
11. FA_DRIST_ACCEL (Rear Inboard Driver's Seat Track Fore/Aft Acceleration).
12. LAT_DRIST_ACCEL (Rear Inboard Driver's Seat Track Lateral Acceleration).
13. VERT_DRIST_ACCEL (Rear Inboard Driver's Seat Track Vertical Acceleration).
14. FA_TRANS_ACCEL (Reference only for Transmission Noise Test).
15. LAT_TRANS_ACCEL (Reference only for Transmission Noise Test).
16. VERT_TRANS_ACCEL (Reference only for Transmission Noise Test).
17. ENG_REF_ACCEL (Active Fuel Management (AFM) Vehicles Only, Engine Reference Acceleration, top of engine, centerline, cross-crank direction).
18. MAP (Manifold Absolute Pressure), AFM Vehicles Only.
19. DYNO_SURF_FORCE (Dynamometer Total Surface Force).
20. DYNO_SPEED (Dynamometer Vehicle Speed).
21. Exhaust Temp (optional).

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22. VERT_DIFF_ACCEL (AWD/RWD only for identifying the first (or primary) and second harmonics of axle gear mesh order).
23. FAN_1 (Engine cooling Fan One reference tachometer for idle tests).
24. FAN_2 (Engine cooling Fan Two reference tachometer for idle tests).

Verify that each channel has the appropriate settings for the data acquisition equipment installed.

4.1.3.2 Calibration Validation. Check equipment for valid calibration date. Replace out-of-date equipment. Turn on all instrumentation 5 minutes prior to calibration verification. Verify calibration of the transducers as follows:

4.1.3.2.1 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 the next channel, accept the calculated sensitivity and store the sensitivity in the test setup. Repeat for each microphone.

4.1.3.2.2 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 the next channel, accept the calculated sensitivity and store the sensitivity in the test setup. Repeat for each accelerometer.

4.1.3.3 Tracking Setup. Verify that the tachometers are functional and that the trigger levels are set to the appropriate level.

Set dynamometer to control vehicle speed. Operate vehicle in 1st gear at constant speed and note engine and driveline rotations per minute.

Determine the Vehicle Speed to Driveline Speed (V/D) ratio by using the observed driveline speed indicated by the driveline tachometer and the vehicle speed indicated by the dynamometer control panel. This ratio will be needed to set up a derived tachometer for online processing. The V/D ratio is calculated as follows:

$$V/D = \frac{\text{Vehicle Speed (km/h)}}{\text{Driveline Speed (RPM)}}$$

Set up a derived tachometer with name Vehicle Speed, using the relationship Vehicle Speed = Driveline Tachometer (T2) x (V/D). Set tachometer settings to trigger and capture immediate Revolutions per Minute (rpm).

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

- Maximum Order: 64
- Order resolution: 0.1
- Acoustic Channels and transmission vibration channels:
 - Bandwidth = 12.8 kHz
 - Resolution = 1.0 Hz
- Vibration channels excluding transmission channels:
 - Bandwidth = 800 Hz
 - Resolution = 1.0 Hz

4.1.3.5 Online Processing Setup.

4.1.3.5.1 Verify/accomplish the following online processing settings for the acoustic channels and transmission vibration channel, if included:

- Format: Autopowers Linear
- Window: Hanning (for fixed sampling)
- Window: Uniform (for synchronous sampling)

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- Final Weighting/Window:
 - A-weighting for Acoustic
 - Linear for Vibration (must be corrected as a derived channel)
- Format: Root Mean Square (RMS)
- Function: Order
- Energy Corrections
- Stationary Averaging Type: Energy

4.1.3.5.2 Set up the vibration channels to process online data with the following parameters:

- Window: Hanning (for fixed sampling)
- Window: Uniform (for synchronous sampling)
- Format: RMS
- Function: Order
- Energy Correction
- Stationary Averaging Type: Energy

4.1.3.5.3 In addition, set software to acquire the following:

- Fixed Sampled Orders 0.5 to 40 in 0.5 increments of engine speed with an Order bandwidth of 0.1
- Overall Level
- Articulation Index

4.1.3.6 Measure Setup. Set the software to save time data files.

4.1.3.7 Build Test Variant Sections. If using the automated test setup software provided in GDM, run the PreLat calculator. Fill out information forms and follow prompts. Select Build Sections to generate test variant sections. A new section will be created for each variant. The measurement tracking will need to be set up prior to recording each variant. If automated test setup software is not used, manually create individual test sections with corresponding naming for each test variant in 4.1.4.

4.1.4 Data Acquisition Equipment Preparation. (See Appendix B, B1 thru B4).

4.1.4.1 Install interior microphones as specified in Appendix B. Standard positions are the driver's seat and the rear seat opposite side. For the driver's position only, install a dummy head/torso unit if a human driver is not used. Driver's microphone position shall be established prior to test with seat positioned as specified in Appendix B. When test must be conducted with human driver, seat position may be readjusted the minimum amount necessary to allow safe operation of controls. Install exterior exhaust tailpipe microphone as specified in GMW14218. Connect remote speaker to one (1) interior measurement microphone or to a dedicated interior monitor microphone so that interior noise may be monitored aurally in real time during data collection.

4.1.4.2 Install accelerometers as specified in Appendix B. Install accelerometers so that the X direction aligns with Fore/Aft of vehicle, Y direction aligns with Cross-Car (lateral) direction of vehicle and Z direction aligns with vertical direction. Position adjustable steering columns to mid-travel positions for tilt and telescope, as specified in Appendix B. Install a triaxial accelerometer at the 12:00 position (for X,Z) and 9:00 position (for Y) of the steering wheel, using a machined accelerometer mounting pad with two (2) tape bands to secure the pad to the wheel rim. Install triaxial accelerometers at the rear inboard and front outboard locations of the driver's seat track. If seat position must be adjusted to provide access to seat track during accelerometer installation, readjust seat position to mid-travel position specified in Appendix B prior to test. On AWD and RWD vehicles, install a uniaxial accelerometer on the pinion nose of the rear differential in the vertical direction as specified in Appendix B.

4.1.4.2.1 For AFM equipped vehicles (or competitive equivalent), install a reference accelerometer on the engine to indicate when AFM is active. Locate this accelerometer on the upper portion of engine, on the intake manifold or other major structural engine component. Orient such that sensitive axis is tangential to crank rotation.

4.1.4.2.2 For AFM equipped vehicles (or competitive equivalent), install auxiliary Manifold Absolute Pressure (MAP) sensor or use vehicle data bus to obtain vehicle MAP signal. Connect analog MAP signal output to DAS.

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4.1.4.2.3 Install transmission reference accelerometer on the case of the transmission, at the mount location closest to the transmission output shaft.

4.2 Conditions.

4.2.1 Environmental Conditions. Check that the environmental conditions meet the requirements outlined in 3.1. If conditions are outside of the specified range, make a note in the deviation section of the test log.

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.

Reference Test Condition Summary Table in Appendix F.

4.3 Instructions.

4.3.1 Vehicle Warm-Up.

Note: For Diesel engines only, proceed to Cold Idle Test Variant L (see 4.3.4.2.8) and conduct that test prior to vehicle warm-up.

Set dynamometer to control vehicle throttle and RLS force. Operate vehicle at 80 km/h (50 mph) for a minimum of 20 minutes. Conduct Vehicle Rotational Loss calculation steps as follows, immediately following this warm up procedure.

4.3.2 Vehicle Rotational Losses. Use the dynamometer to calculate the vehicle losses in Neutral as specified by local dynamometer procedure. Losses must be calculated for operating speeds between 5.0 km/h (3.0 mph) and 140 km/h (90 mph) or greater. Set the dynamometer controller to apply the calculated vehicles losses when in RLS control mode.

4.3.3 Road Load Coefficient Verification.

4.3.3.1 Operate the vehicle under load, at 80 km/h (50 mph) in Throttle/RLS mode, for at least 20 minutes prior to the start of this procedure.

4.3.3.2 Shift vehicle transmission to Neutral.

4.3.3.3 Use the dynamometer controller to accelerate the rolls to a speed of 129 km/h (80 mph). Set dynamometer to control vehicle throttle and RLS force. Allow the vehicle to coast-down at minimum accelerator pedal position. Measure and note to ± 0.1 s the time required to coast from 105 km/h (65 mph) to 97 km/h (60 mph) and from 24 km/h (15 mph) to 16 km/h (10 mph). Store results in the "Coast-Down Verification" section of the LMS project for reference.

4.3.3.4 Compare these coast-down times to coast-down times measured on the road in Neutral (refer to vehicle preparation data sheet). The time difference must not exceed 10%. If the difference is greater than 10%, re-check RLS coefficient entry, units, proper engine operating temperature, etc. Correct any discrepancies and re-measure the coast-down times on the dynamometer until the difference is 10% or less.

4.3.3.5 Shift vehicle transmission to Drive.

4.3.3.6 Set dynamometer to control vehicle throttle pedal position and apply RLS force. With zero (0) throttle pedal applied, bring vehicle to a stop with the brake pedal and then release. Allow the vehicle wheels to move from a stop and stabilize at a constant speed. Note this off-brake vehicle speed. Compare this vehicle speed to vehicle speed found on the road test. The difference must be less than 10%. If the difference is greater than 10%, re-check RLS coefficient entry, units, proper operating temperature, etc. Correct any discrepancies and re-measure the off-brake speed on the dynamometer until the difference is 10% or less.

4.3.4 Measurement Test Variants. Prior to the start of the data acquisition phase of the test, re-verify all instrument and vehicle settings. Confirm radio/entertainment system is off and HVAC settings are as specified in 4.1.2. Verify external cooling fan is off prior to starting data acquisition. For online data processing, set adjustments to process data according to Section 5 prior to the start of test.

Verify parameters are set up correctly for each test variant section (see 4.1.3 and 4.1.4).

Set the digital acquisition input voltage range such that it maximizes the signal resolution without causing an overload during the course of the test. Make a pre-test run for range adjustment if necessary.

During all tests, listen to the monitor speaker for any warning tones or other abnormal noises that do not represent intended operating conditions. Reject data from any non-representative run, correct the condition and repeat the run.

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4.3.4.1 Sweep Variants. For each variant, assess the run-to-run repeatability of the data acquired before proceeding to the next test variant. Check accelerometer data for evidence of transducers loosening or falling off (such as would be shown by extreme changes in levels from run-to-run). The repeatability acceptance guideline for sound pressure data is that overall level should be within 2 dB (A-weighted) run-to-run. Engine firing order, harmonic orders of firing, primary imbalance orders and secondary imbalance orders should be within 3 dB (A-weighted) run-to-run at local maxima. If run-to-run repeatability does not converge to meet these guidelines after multiple runs, document the level of variation achieved by storing data from a minimum of three (3) runs representing the range of variation.

4.3.4.1.1 Variant A (Required): Drive-away Acceleration Sweeps – Fixed Pedal.

Set dynamometer to control vehicle speed through the throttle pedal and apply RLS. Put the transmission selector in Drive or equivalent position that enables the transmission to shift automatically.

Set the data acquisition method to tracked, and tracking mode to time, with an increment of 0.1 s. Set the acquisition duration to 30 s. Assure that the vehicle speed is less than 8 km/h (5 mph) before starting the run. Begin recording data when the vehicle speed reaches 8 km/h (5 mph).

For each of the drive-away sweep variants, the single point vehicle speed vs. time target time and velocity (see Table 1) is specified in the following. Depress the vehicle accelerator to a fixed point and plot the vehicle speed vs. time for 30 s. If the vehicle speed plot does not pass through the target point within $\pm 2\%$ while increasing, adjust the pedal position and repeat the run. A vehicle speed plot within $\pm 2\%$ of the target point is considered an acceptable run, reference Appendix K. Record at least two (2) runs to verify consistency.

Very Light profile sweep is applicable only for EVT vehicles with electric drive capability (engine off).

For EVTs: Run light and moderate sweeps with Engine-ON State of Charge (SOC), confirm that Internal Combustion Engine (ICE) is ON for entire test.

For EREV/BEVs: Run very light, light and moderate sweeps with maximum SOC, confirm that ICE is OFF for entire test.

See Appendix J for SOC guidelines.

Table 1: Vehicle Speed vs. Time

Time	Very Light	Light	Moderate
seconds	km/h (mph)	km/h (mph)	km/h (mph)
0	8.0 (5.0)	8.0 (5.0)	8.0 (5.0)
12.5	22 (13.7)	-	-
18.5	-	60 (37.3)	-
23.5	-	-	100 (62.1)

4.3.4.1.2 Variant A (Optional): Drive-away Acceleration Sweeps - Profiles.

Set dynamometer to control vehicle speed through the throttle pedal and apply RLS. Put the transmission selector in Drive or equivalent position that enables the transmission to shift automatically.

Set the data acquisition method to tracked, and tracking mode to time, with an increment of 0.1 s. Set the acquisition duration as required to capture the corresponding sweep time for each profile listed in Table 2.

For each of the drive-away sweep velocity-time profiles specified in the following, program the dynamometer controller such that it controls the throttle pedal to ramp the vehicle speed from off-brake vehicle speed to maximum speed specified, according to the velocity-time profiles specified (see Table 2).

Very Light profile sweep is applicable only for EVT vehicles with electric drive capability (engine off).

For EVTs: Run light and moderate sweeps with Engine-ON State of Charge (SOC), confirm that Internal Combustion Engine (ICE) is ON for entire test.

For EREV/BEVs: Run very light, light and moderate sweeps with maximum SOC, confirm that ICE is OFF for entire test.

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See Appendix J for SOC guidelines.

Table 2: Velocity-Time Profiles

Time seconds	Very Light km/h (mph)	Light km/h (mph)	Moderate km/h (mph)
0	8.0 (5.0)	8.0 (5.0)	8.0 (5.0)
5	14.4 (9.0)	27.7 (17.2)	40.6
10	19.7 (12.2)	42.2 (26.2)	62.5
15	24.4 (15.2)	53.6 (33.3)	79.0
20	28.5 (17.7)	62.7 (39.0)	92.3
25	32.2 (20.0)	70.6 (43.9)	103.4
30	35.5 (22.1)	77.3 (48.0)	113.0
35	38.6 (24.0)	83.3 (51.8)	121.3
40	41.4 (25.7)	88.6 (55.1)	128.8
45	43.9 (27.3)	93.5 (58.1)	135.5
50	46.4 (28.8)	97.9 (60.8)	141.7
55	48.6 (30.2)	102.0 (63.4)	-
60	50.7 (31.5)	105.8 (65.7)	-
65	-	109.3 (67.9)	-
70	-	112.6 (70.0)	-
75	-	115.6 (71.8)	-
80	-	118.5 (73.6)	-
85	-	121.3 (75.4)	-
90	-	123.9 (77.0)	-

Acquire data for each run. Repeat each of the acceleration sweeps for a minimum of two (2) runs or until data is repeatable. Compare speed profiles from "Target" section. Adjust throttle control to maintain target profile and verify surface force is realistic (i.e., minimum surface force oscillation due to pedal corrections).

4.3.4.1.3 Variant B: Cruise Sweep.

For RWD and AWD vehicles, set the DAS to acquire fixed-sampled online noise and vibration data for first, second, integer orders from six (6) thru 17 and even orders from 18 thru 32 of prop shaft speed (tachometer channel T2), with order resolution of 0.1 order. For FWD vehicles, set the DAS to acquire the integer orders one (1) through 10 of the drive axle (tachometer channel T2), with order resolution of 0.1 order. Set the acquisition duration as required to capture the entire high gear sweep, using a practice run if necessary after establishing sweep start and end points as specified in the following steps. Set dynamometer to control vehicle speed through the throttle pedal, and to use RLS as the applied load.

Connect instrumentation to enable monitoring of Torque Converter Clutch (TCC) slip speed. Put the transmission shift lever in Drive or equivalent position that enables the transmission to shift automatically. Use an ERPM vs. time data display on the data acquisition system to monitor automatic gear shift events and TCC apply events, as indicated by engine speed step changes.

Accelerate the vehicle slowly until transmission shifts into highest gear, and TCC is applied (as noted by decrease in engine speed). After highest transmission gear is established and TCC is applied, slowly reduce speed until TCC clutch releases (as noted by step increase in ERPM) or transmission downshifts, whichever occurs first. Note the speed at which this occurs for reference in the next step. This is the minimum high gear cruise speed.

Re-establish high gear TCC applied condition by accelerating the vehicle, and then slowly reduce speed until slightly (0.50 km/h (0.30 mph) to 1.0 km/h (0.60 mph)) above the minimum high gear cruise speed noted in previous step. Set the dynamometer controller to sweep from the minimum high gear cruise speed to 140 km/h (90 mph), using an acceleration rate of 0.70 km/h/s (0.40 mph/s)

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Note: This acceleration is approximately equivalent to 2% grade load, with zero (0) acceleration. If TCC releases, or if transmission downshifts (as noted by step increase in ERPM), incrementally decrease the ending speed as required to avoid downshift or TCC release, and adjust sweep time to maintain the prescribed acceleration rate of 0.70 km/h/s (0.40 mph/s).

Using the high gear sweep starting and ending points established in the preceding steps, acquire data as the vehicle is swept from the minimum high gear cruise speed to the ending speed.

Note: Increase gradient on dynamometer to 1% and repeat this sweep. Continue increasing the gradient by 1% increments until the vehicle downshifts during the sweep. Save data from all gradient sweep conditions including the run on which the downshift occurred (denote gradient in the run name).

Note: For SCT/DCT, TCC instructions do not apply. For SCT/DCT, conduct the high gear sweep in automatically shifted mode, starting from the lowest vehicle speed at which the transmission remains in high gear and ending at a vehicle speed of 140 km/h (90 mph), with an acceleration rate of 0.70 km/h/s (0.50 mph/s).

For CVTs or EVTs: Run test in Drive or equivalent from 10 km/h (6 mph) to 140 km/h (90 mph) in 185.7 s, an acceleration rate of 0.70 km/h/s (0.50 mph/s).

For EVTs: Run with Engine-ON SOC, confirm that ICE is ON for entire test.

For EREV/BEVs: Run with maximum SOC, confirm that ICE is OFF for entire test.

See Appendix J for SOC guidelines.

4.3.4.1.4 Variant C: Maximum Pedal Acceleration Sweep.

Set dynamometer to control the accelerator pedal position and apply RLS. Set the data acquisition duration as required to capture the entire maximum pedal acceleration sweep, using a practice run if necessary after establishing sweep start and end points as specified in the following steps.

Put the transmission selector in Drive or equivalent. Set dynamometer to control throttle position and apply RLS. Program the dynamometer controller to establish 100% pedal position in 1 s or less. Record data as vehicle accelerates from off-brake speed to 140 km/h (90 mph).

Repeat for a minimum of two (2) runs or until data is repeatable.

Note: If tire slip occurs with 100% pedal application in 1 s or less, incrementally increase pedal apply ramp time and make trial runs until tire slip is eliminated.

For EVTs: Run with Engine-ON SOC, confirm that ICE is ON for entire test.

For EREV/BEVs: Run with maximum SOC, confirm that ICE is OFF for entire test.

See Appendix J for SOC guidelines.

For stepped-ratio automatic transmissions with manual gear selection capability, conduct the following additional test: **Commanded-Gear Maximum Pedal Acceleration Sweep.** Refer to vehicle preparation data sheet for appropriate passing gear identification. Put the transmission selector in passing gear. Set dynamometer to control the accelerator pedal position and apply RLS. Establish dynamometer speed equal to lowest vehicle speed achievable without an automatic downshift (with selector in manual passing gear position). Program the dynamometer controller to establish 100% pedal position in 1 s or less. Record data as vehicle accelerates from lowest vehicle speed in passing gear to maximum usable ERPM, where maximum usable ERPM is defined as fuel shutoff minus 200 ERPM. If transmission upshifts prior to fuel shutoff minus 200 ERPM, then terminate data acquisition when upshift occurs. Repeat for a minimum of two (2) runs or until data is repeatable.

4.3.4.1.5 Variant D: Coast-Down Sweep.

Put the transmission selector in Drive or equivalent position that enables automatic shifts. If the transmission is equipped with a Normal mode for which automatic shifts are enabled, select the Normal mode for this test. Set dynamometer to control throttle position and apply RLS.

Set the data acquisition duration as required to capture the entire coast-down sweep, using a practice run if necessary after establishing sweep start and end points as specified in the following steps.

Use the dynamometer to increase the roll speed to 140 km/h (90 mph) by depressing the throttle. Release the vehicle throttle pedal and record data as vehicle coasts down at zero (0) throttle pedal position, until off-brake speed is reached.

For EVTs: Run with Engine-ON SOC, confirm that ICE is ON for entire test.

For EREV/BEVs: Run with maximum SOC, confirm that ICE is OFF for entire test.

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