



Powertrain Level Allocable Test (PLAT) Full Vehicle Chassis Dynamometer PLAT

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 test procedure is to measure powertrain noise and vibration experienced by the customer during representative operating conditions. These Powertrain Level Allocable Tests (PLAT) are intended to enable the allocation of requirements for powertrain noise and vibration sources and paths.

1.2 Applicability. This test procedure applies to multipurpose passenger vehicles and light duty trucks (Gross Vehicle Weight Rating (GVWR) of 2800 kg (6000 lb) or less).

Furthermore, this procedure applies only to step-gear automatic and manual transmission powertrains. In its unmodified form, this procedure is not applicable to hybrid and Battery Electric Vehicle (BEV) powertrains, and powertrain with Continuously Variable Transmissions (CVT). Adaptation of this procedure for such powertrains is left to the discretion of the test requester. If doing so, the operating conditions should be modified to achieve Internal Combustion (IC) engine speeds and loads, and transmission speed ratios that are comparable to step-gear powertrains.

This procedure is only applicable to vehicles in which the top forward edge of the engine compartment, with hood removed, does not extend more the 30% over the fore/aft dimension of the imaginary box described in Figure C1 (Appendix C), dimension "l" for longitudinal powertrains, and "w" for transverse powertrains.

1.3 Remarks. Procedure GMW16178 Vehicle Level Powertrain/Driveline Noise and Vibration Evaluation Procedure for Automatic Transmission is used for the assessment of GM and competitive vehicles for the purpose of establishing vehicle level powertrain noise and vibration requirements.

The PLATs defined in this document utilize similar operating conditions, but measure the noise and vibration emissions of the full powertrain treating it as a source. Furthermore, they measure the powertrain while it is installed in a vehicle, using the vehicle as a means of testing the powertrain on a chassis dynamometer and without removing it from its vehicle.

The tests are derived from the customer operating conditions of: Drive-Away Noise and Vibration, Passing Noise and Vibration, Cruise Noise and Vibration, Idle Noise and Vibration, and Accessory Noise. These tests utilize constraints in the form of constant speeds, loads, and/or analysis frequency orders.

An overview of the PLAT procedure is given in Appendix G (Figure G1, Figure G2, Table G1 and Table G2), summarizing vehicle operating conditions, powertrain measurements, and related typical Powertrain Subsystem Technical Specification (SSTS) measures.

This procedure has a companion procedure, GMW14008, PLAT for Powertrain Dyno, which is for the purpose of testing the powertrain without the vehicle, installed and operated on a powertrain dynamometer. The measurements and operating conditions in GMW14008 are similar to those found in this procedure.

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2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14007

GMW14008

GMW16178

2.3 Additional References.

ArtemiS Software, HEAD acoustics GmbH, Herzogenrath, Germany

Powertrain SSTs

3 Resources

3.1 Facilities. The test facility should be a semi-anechoic chassis dynamometer capable of fixed speed control and load control up to 140 km/h (87 mph) and 6672 N (1500 lb-f) Tractive Effort (TE) respectively. Anechoic properties should be present for frequencies above 200 Hz. Deviations to this frequency may be accepted if approved by the test requester. Rolls should be smooth, and 0.9 m (3 ft) or greater in diameter. They must be sufficiently damped so that radiated noise from the rolls does not contribute to the measured data. The test facility should have ambient temperatures between 18 °C and 30 °C (65 °F and 85 °F). Ambient noise should be no greater than a level that is 20 dB lower than the signal plus noise being measured as specified in 4.2.1.2. Excessively high or low humidity levels affect the operating characteristics of powertrains. Avoid acquiring data on such days.

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.

3.2.1 Digital Driver's Aid (DDA) (Optional). The DDA was originally designed for durability testing. It contains a set of lights that indicate the vehicle acceleration rate. This assists the tester in attaining the required moderate acceleration profile in 4.1.1.14. The DDA is available through GM Validation/Quality, Reliability and Durability (QRD) Center at the Milford Proving Ground.

3.2.2 Engine Tachometer. The tachometer provided in the vehicle gage package is acceptable if available.

3.2.3 Tire Gage.

3.2.4 Thermometer, hygrometer (relative humidity) (Optional) and anemometer (wind speed) (Optional).

3.2.5 Stopwatch.

3.2.6 Access to vehicle (weight) scales.

3.2.7 Data acquisition and processing instrumentation as specified in Sections B1 thru B4 (Appendix B).

3.2.8 Dental cement or equivalent adhesive effective in the 0 Hz to 1600 Hz frequency range to attach accelerometers.

3.2.9 Instrumentation to provide an engine speed pulse signal (tachometer) and transmission output shaft speed pulse signal (tachometer) to meet analysis equipment and recording (data acquisition) requirements, with pulse count ≥ 1 pulses per revolution (ppr). Transmission output tachometer is optional as discussed in 4.1.2.8.

3.2.10 Thermal couples for engine cooling system and engine air inlet systems.

3.2.11 External cooling fan and spot cooling hoses in chassis dynamometer test facility.

3.2.12 Air conditioning head pressure gage set.

3.2.13 Provision for remote engine cooling with an effectively silent system. The system must enable control of engine coolant temperature within -4 °C to +6 °C (-7 °F to +11 °F) of nominal warm operating temperature, at the coolant outlet from engine location, for all test conditions. The system is required; in general, because vehicle engine cooling fans must be disabled for conditions in this test (see 4.1.2.14). The system will preferably utilize the engine coolant system in the vehicle by circulating the coolant through a remote heat exchanger system.

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Alternative means may be considered, such as a chilled air supply to the vehicle radiator. If such systems are not effectively silent, there must be a means to subtract the noise produced by the system from the radiated noise of the powertrain. The test requester must approve the use of such systems based on the ability to subtract their noise from that of the powertrain.

3.2.14 Blank-tread tires for the drive wheels of the test vehicle. These are required for front drive wheels and optional for rear drive wheels.

Note: These are required to avoid tire noise interference with the sound measurements in this procedure. Tire size must be the same as that of the vehicle application tires. If blank tread tires are not available, the test may be run with other tires if approved by the test requester. In such an event, a detailed description of the deviation, including tire model number(s) and tread condition, must be documented with the test results in Line 16 (L16) of Test Data Log Table A3 in Appendix A.

3.3 Test Vehicle/Test Piece. Not applicable.

3.4 Test Time.

Calendar time:	2 days to 3 days
Test hours:	8 hours to 16 hours
Coordination hours:	1 hour to 2 hours

3.5 Test Required Information.

3.5.1 The test vehicle must be qualified to ensure that it represents design intent. Deviations must either be corrected or noted. This is also subject to the specification of the test requester. The vehicle must also be qualified to ensure that the engine and transmission are operating properly.

3.5.2 Instructions for or specification of, Engine and Vehicle Speed, Road Load, Tractive Efforts, and Gear States as discussed in 4.1.1.

3.6 Personnel/Skills. To complete these tests, one engineer and/or technician skilled in noise and vibration data acquisition are required. To complete the preliminary investigation of operating conditions, an engineer or technician must have some experience in generating the acceleration profile described in 4.1.1.14. A chassis dynamometer operator is also required.

4 Procedure

4.1 Preparation.

4.1.1 Engine and Vehicle Speed, Road Load and Tractive Effort Determination. The following steps must be completed to determine the appropriate engine and vehicle speeds, road loads, and tractive efforts for the chassis dynamometer tests.

4.1.1.1 Obtain vehicle description, test description, and Test Data Log forms (Appendix A, Tables A1, A2, and A3, respectively). Enter appropriate information. Several items in Table A1 will be used to determine test and measurement conditions. These include engine displacement and fuel type (gasoline or diesel), Rated Engine Load (REL), powertrain orientation (longitudinal or transverse), transmission type (automatic or manual) and presence of an acoustic engine top cover (see 4.1.3.2 for definition). Be sure to document these parameters.

4.1.1.2 For manual transmissions, you must determine the Rated Engine Speed (RES) prior to performing the on-road evaluations. Enter RES and $0.55 \times \text{RES}$ in test data log in line Number 1 (L1) of Table A3 (Appendix A).

4.1.1.3 The evaluations must be completed at operator-only load (no instrumentation) and must be performed prior to the chassis dynamometer tests. Heating, Ventilation, Air Conditioning (HVAC), headlights, and electric defogger must be off. Doors and windows must be closed.

4.1.1.4 (Optional, see 3.2.1) Install and calibrate a DDA according to the instrument manual.

4.1.1.5 Install a tachometer with engine revolutions per minutes (erpm) display or use vehicle installed tachometer.

4.1.1.6 Adjust cold tire pressure to the manufacturer's specifications (allow tires to cool if the vehicle has been recently operated). Record the pressures in the Test Data Log Table A3 (Appendix A) Line Number 2 (L2).

4.1.1.7 Fill vehicle fuel tank.

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4.1.1.8 Test drive vehicle for engine warm-up and to ensure that the requirements specified in 3.5.1 are met. Make vehicle adjustments as required. A minimum of 16 km (10 mi) at 80 km/h (50 mph) is suggested. Verify that vehicle speedometer is accurate to within $\pm 5\%$. If it is not accurate, a fifth wheel or correction factor must be used to complete this procedure.

4.1.1.9 Record ambient temperature in Test Data Log Table A3 (Appendix A) Line Number 3 (L3). The temperature must be between 4 °C and 32 °C (40 °F and 90 °F).

4.1.1.10 Record relative humidity (if available) in Test Data Log Table A3 (Appendix A) Line Number 4 (L4).

4.1.1.11 Record wind speed (if available) in Test Data Log Table A3 (Appendix A) Line Number 4 (L4). Testing with a strong headwind > 8 km/h (5 mph) is discouraged as variability in shift points and drag coefficients may occur.

4.1.1.12 Proceed to level smooth and dry road surface (Milford Proving Ground (MPG) North-South Straightaway, Desert Proving Ground (DPG) East-West Straightaway or equivalent).

4.1.1.13 Manual Transmission Vehicles.

4.1.1.13.1 Shift into first gear and increase speed until the tachometer indicates vehicle is at $0.55 \times \text{RES}$ (Test Data Log Line Number 1 (L1)). Note the vehicle speed where this occurs and record vehicle speed and engine speed in Test Data Log Line Number 5 (L5) as the Drive-Away 1-2 shift point.

4.1.1.13.2 Shift transmission to second gear, accelerate to $0.55 \times \text{RES}$, and record vehicle speed and engine speed in Test Data Log Line Number 6 (L6) as the Drive-Away 2-3 shift point.

4.1.1.13.3 Accelerate further until the tachometer indicates the vehicle is at RES and record vehicle speed and engine speed (**Road**) in Test Data Log Line Number 7 (L7) as the Wide Open Throttle (WOT) Passing Gear 2-3 shift point.

4.1.1.13.4 Shift to third gear, accelerate to RES, and record vehicle speed and engine speed (**Road**) in Test Data Log Line Number 7 (L7) as the WOT Passing Gear 3-4 shift point.

4.1.1.13.5 Continue to upshift, accelerate to RES, and record the speeds in line Number 7 (L7) for each succeeding gear up to vehicle speeds ≤ 137 km/h (85 mph).

4.1.1.13.6 Repeat any portion of this process as necessary to obtain reliable data. Note that engine speed of the passing gear shift point may, in general, not be the same as the maximum operating speed of the engine. Maximum operating speed, referred to as "maximum engine speed", will be used separately in several of the operating conditions within this test procedure. Proceed to 4.1.1.17.

4.1.1.14 Automatic Transmissions Vehicles.

4.1.1.14.1 Determine the Drive-away 1-2 shift point vehicle speed and engine speed as follows. With vehicle at rest, place transmission in **Overdrive/Drive**. Depress the accelerator and modulate as required to achieve the vehicle speed profile shown in Table 1, which represents a moderate acceleration from a standing start.

Table 1: 1-2 Shift Point Acceleration Profile

Time (seconds)	Speed (kilometers/hour)	Speed (miles/hour)
0	0	0
2	10	6
4	26	16
6	37	23
8	47	29
12	64	40
16	77	48
20	88	55
24	98	61
28	105	65

Note: This method requires practice. Use the DDA to help maintain the correct acceleration rate. Depress the accelerator to light the middle Light Emitting Diode (LED) of the moderate acceleration range of the DDA.

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Continue to modulate the throttle to maintain the middle LED. This corresponds to the acceleration profile and achieves a peak of approximately 0.2G acceleration as determined by the algorithm of the DDA.

For either method, record the vehicle speed (v_{shift}) and engine speed (erpm) at which the 1-2 shift occurs in the Test Data Log, Table A3 (Appendix A) (L5). The vehicle speed will generally be 24 km/h to 26 km/h (15 mph to 16 mph). Repeat this process as necessary to obtain reliable data.

Note: If the vehicle cannot achieve this moderate acceleration profile, bypass this condition and the associated chassis dynamometer test. Note the change in the Test Data Log (L16).

4.1.1.15 Determine the Drive-away 2-3 shift point vehicle speed and engine speed by performing the procedure in 4.1.1.14 until the 2-3 shift occurs. The vehicle speed will generally be 48 km/h to 52 km/h (30 mph to 32 mph). Record results in Test Data Log, Table A3 (Appendix A) (L6).

Note: If the vehicle cannot achieve this moderate acceleration profile, bypass this condition and the associated chassis dynamometer test. Note the change in the Test Data Log, Table A3 (Appendix A) (L16).

4.1.1.16 Perform the following procedure to determine the WOT Passing Gear shift point vehicle speed, engine speed, and gear state. With the transmission in **Drive**, establish a constant vehicle speed of 70 km/h (43 mph). Rapidly depress accelerator to WOT and record the vehicle speed and engine speed at which the 2-3 shift occurs, up to the maximum vehicle speed of 137 km/h (85 mph).

Note: If the transmission has more than four speeds, the 3-4 shift may more accurately represent the passing condition.

Follow the same procedure and note **all** speeds at which shifts occur up to the maximum vehicle speed of 137 km/h (85 mph). If all upshift speeds exceed 137 km/h (85 mph), note speeds and gear at 137 km/h (85 mph). Record results in Test Data Log, Table A3 (Appendix A) (L7). Repeat the process as necessary to obtain reliable data. Note that engine speed of the Passing Gear shift point may, in general, not be the same as the maximum operating speed of the engine. Maximum operating speed, referred to as "maximum engine speed", will be used separately in several of the operating conditions within this test procedure.

4.1.1.17 Perform the following coast-down tests to determine a cruising road load. Operate the vehicle at a cruising speed of 129 km/h (80 mph). Shift into **Neutral** and allow the vehicle to coast down. Measure and record, to ± 0.1 s, the time required to coast from 105 km/h to 97 km/h (65 mph to 60 mph). This time is designated t_1 . 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 ± 0.1 s, the time required to coast from 24 km/h to 16 km/h (15 mph to 10 mph). This time is designated t_2 . Repeat process as necessary to obtain reliable data. Record results in Test Data Log, Table A3 (Appendix A) Lines Number 8 and Number 9, (L8) and (L9).

4.1.1.18 Refill fuel tank if more than one-fourth ($\frac{1}{4}$) tank has been used.

4.1.1.19 Proceed to weigh station to determine vehicle test mass. Test mass does not include the driver or any additional instrumentation. Record mass and (mass + 68 kg (150 lb)) in Test Data Log Table A3 (Appendix A) Line Number 10 (L10).

4.1.1.20 To compute the cruising road load, $F_{\text{RdLoad, Cruise}}$, use the vehicle mass and the coast-down time intervals in the following equation:

$$F_{\text{RdLoad, Cruise}} \text{ (N)} = 2.235 \times m \times (1/t_2 + 1.087 \times (1/t_1 - 1/t_2))$$

Where:

m = Mass of vehicle + 68 kg (L10)

t_1 = 105 km/h to 97 km/h (65 mph to 60 mph) coast down time (seconds) (L8)

t_2 = 24 km/h to 16 km/h (15 mph to 10 mph) coast down time (seconds) (L9)

The result is the force at the road necessary to maintain a 105 km/h (65 mph) cruise condition on a flat smooth road with no grade or significant head/tail winds. Record $F_{\text{RdLoad, Cruise}}$ in Test Data Log, Table A3 (Appendix A) Line Number 11 (L11).

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4.1.1.21 Calculate drive-away shift point loads. (**Note:** This instruction is required for gasoline engines and optional for diesel engines.) To compute the drive-away road loads, $F_{RdLoad, DA}$, use the vehicle mass and the vehicle speed at shift points in the following equation:

$$F_{RdLoad, DA} (N) = (2.06 - 0.0137 \times v_{shift} - (1.91 - 0.374 \times v_{shift}) \times e^{(-0.129 \times v_{shift})}) \times m + 0.0386 \times v_{shift}^2$$

Where:

m = Mass of vehicle + 68 kg (L10)

v_{shift} = Vehicle speed at shift point (km/h) (L5, L6)

Record $F_{RdLoad, DA}$ for the 1-2 and 2-3 shift conditions in test data log, Table A3 (Appendix A) (L12).

4.1.1.22 Determine the Drive-Away Shift Point/1500 erpm Drive-Away and 2500 erpm Drive-Away vehicle speed, engine speed, vehicle load, and gear state, and record the result in the Test Data Log, Table A3 (Appendix A) (L14). The shift point speeds and gear states are those corresponding to either the Drive-Away 1-2 Shift Point (Table A3 (L5)) or the Drive-Away 2-3 Shift Point (Table A3 (L6)), depending on the engine speed of the Drive-Away 1-2 Shift Point, and approval of the test requester.

4.1.1.22.1 Unless otherwise specified, the Drive-Away Shift Point is 2-3 if the engine speed of the Drive-Away 1-2 Shift Point (L5) is less than 1800 erpm. And, unless otherwise specified, the Drive-Away Shift Point is 1-2 if the engine speed of the Drive-Away 1-2 Shift Point (L5) is greater than or equal to 1800 erpm. The choice of 1-2 or 2-3 is subject to approval of the test requester. The proper shift point should be that which is most noticeable, with respect to powertrain noise and vibration, during the Drive-Away acceleration maneuver. The choice may be other than that instructed above (based on 1800 erpm) if necessary to select the most noticeable condition, as determined and approved by the test requester.

4.1.1.22.2 Once the choice is made, indicate the appropriate shift point, 1-2 or 2-3, in Field 1 of Line 14 (L14) (Table A3, Appendix A). Indicate the appropriate Drive-Away Gear in Field 1 of Line 14 (L14) as:

- One (1) if Drive-Away Shift Point is 1-2
- Two (2) if Drive-Away Shift Point is 2-3

Indicate the appropriate Drive-Away Shift Point Vehicle Speed and Drive-Away Shift Point **Road** Engine Speed in Field 1 of Line 14 (L14) from that in Line 5 (L5) if Drive-Away Shift Point is 1-2, or from Line 6 (L6) if Drive-Away Shift Point is 2-3. Indicate the appropriate Drive-Away Shift Point Load in Field 1 of Line 14 (L14) from the appropriate value in Line 12 (L12). Reference Table A1, Appendix A.

Note: The Drive-Away Shift Point Load is required for gasoline engines and optional for diesel engines.

4.1.1.22.3 For both gasoline and diesel engines, copy the Drive-Away Shift Point Vehicle Speed to Field 2 of Line 14 (L14), as Drive-Away Shift Point **V**. Copy the Drive-Away Shift Point **Road** Engine Speed to Field 2 of Line 14 (L14) as Drive-Away Shift-Point **n**. Obtain engine displacement **D** from Table A1 (Appendix A), and calculate the 2500 erpm Drive-Away Load F_{2500_DA} with the formula provided at the end of Table A3 (Appendix A). Enter the value in Table A3 (L14) Field 2. For diesel engines, obtain REL from Vehicle Description, and calculate the 1500 erpm Drive-Away Load F_{1500_DA} with the formula provided at the end of Table A3 (Appendix A).

4.1.1.23 Determine the WOT Passing Gear Shift Point vehicle speed, engine speed, and gear state based on the results of procedures 4.1.1.13 (manual transmissions) or 4.1.1.16 (automatic transmissions), Table A3 (Appendix A) (L7). The appropriate Passing Gear Shift Point corresponds to the gear state before the shift closest to but not exceeding 137 km/h (85 mph). If all upshift speeds exceed 137 km/h (85 mph), use engine speed and gear at 137 km/h (85 mph). Circle the appropriate passing gear erpm, mph, and gear entries in the Table A3 (Appendix A) (L7).

4.1.1.24 Determine the Low Load Drive-Away Sweep load and gear state. The gear state is based on the type of transmission, and is as follows:

- MT4, AT4: First (1st) gear
- MT5, AT5, AT6: Second (2nd) gear
- MT6: Third (3rd) gear

Where:

MTn = Manual Transmission with **n** gear states

ATn = Automatic Transmission with **n** gear states

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Enter the gear state in Table A3 (Appendix A) Line 15 (L15), Field 1. The Drive-Away Sweep load is that corresponding to a constant vehicle acceleration of 1 m/s². The load is calculated with the following equation:

$$F_{RdLoad, 1m/s^2} = m(N)$$

Where:

$$m = \text{Mass of vehicle} + 68 \text{ kg in (units N)} \quad (L10)$$

Enter the load in Table A3 (Appendix A) Line 15 (L15), Field 2.

4.1.2 Vehicle Preparation.

4.1.2.1 Verify that vehicle preparation conditions used for 4.1.1 are still valid (tire pressure, fuel level and engine operation).

4.1.2.2 Allow the vehicle to adjust to test lab ambient temperature. Install blank-tread tires, as specified in 3.2.14, to the drive wheels of vehicle. Document tire description and any related deviations in Line 16 (L16) of Table A3, Appendix A.

4.1.2.3 Attach vehicle to chassis dynamometer rolls. Ensure that wheel chucks do not contact the body.

4.1.2.4 Set exhaust collectors and ventilation system to properly remove exhaust gases and muffle tailpipe sound of all exhaust tailpipes with minimal effect on engine performance. If possible, completely seal the connection of the exhaust collector(s) to the tailpipe(s) without producing collector-to-tailpipe rattle noise. If the connection cannot be completely sealed, set exhaust collector(s) so that end of collector(s) extend over end of tailpipe(s) as much as possible, and gap around tailpipe(s) is minimized.

4.1.2.5 Remove engine compartment hood. Remove any splash shields that are present underneath the engine and transmission. Also remove any underhood shields that cover the top of the engine compartment. This does not apply to acoustic engine top covers which are addressed separately. See 4.1.3.2 for detail. As much as possible, also remove batteries, fluid reservoir bottles, and other similar objects that are located within a line of sight between any of the microphones and the powertrain.

4.1.2.6 Install thermocouple in engine cooling system at engine block coolant outlet location.

4.1.2.7 Obtain or create a log form for documenting vehicle/powertrain operating conditions. Operating conditions include at least those listed in 4.2.2.

4.1.2.8 Install erpm tachometer pulse signal and transmission output speed tachometer pulse signal instrumentation, and connect signal(s) to appropriate channels on data acquisition system, with consideration of microphone and accelerometer channel assignments as specified in 4.1.6.1 and 4.1.6.2.

Note: The transmission output tachometer signal is to be recorded for potential future investigation of noise and vibration orders synchronized with output speed. Such analysis is unspecified in this procedure. Recording of this signal is optional, based on the anticipated need for said analysis.

4.1.2.9 Set up external cooling fan directed toward the engine cooling system.

4.1.2.10 Install spot cooling hoses as required for safe and proper vehicle operation (e.g., at exhaust converter, muffler, and differential locations).

4.1.2.11 Install throttle controller.

4.1.2.12 Turn off vehicle radio and HVAC system. Ensure parking brake is not set.

4.1.2.13 Battery should be at a minimum of 80% state of charge. This can be estimated by measuring the open circuit voltage after allowing the battery to stand unused for at least three (3) h (to dissipate the surface charge). This open circuit voltage should not be below 11.75 V. If the voltage is low, fast charge the battery at 50 A for 30 minutes minimum. (At idle, some vehicles do not generate enough electricity to run all of the vehicle's accessories and charge the battery. Under this condition, repeat the charge if vehicle is operated longer than 15 minutes and the battery voltage drops too low. Do **not** acquire data while the battery is being charged.)

4.1.2.14 Disable all (vehicle) electric engine cooling fans and remove all (vehicle) engine-driven or pump-driven cooling fans. Fan shrouds are to be removed whenever possible, especially large shrouds as commonly used for engine-driven or pump driven fans. Test condition of the fans and fan shrouds are to be documented with the test results, including photographs of the fan environment in the test vehicle.

4.1.2.15 Install a remote engine cooling system such that engine coolant temperature can be controlled in an effectively silent manner. See 3.2.13 for system specifications.

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4.1.2.16 Install an auxiliary muffler to the engine air inlet in such a manner as to effectively eliminate any noise radiated from the inlet and the tubing connecting the inlet to the muffler. The muffler must be placed at least 2 m from any measurement microphones, and must be effectively silent. For this purpose, the engine air inlet is defined as the location, farthest upstream in the engine airflow, of the intake manifold inlet, throttle body, and mass airflow sensor. Vehicle induction system components upstream of these are to be removed to accommodate the muffler, but only if engine operation is not adversely affected. If removing the induction components causes engine performance to be adversely effected, or if removal is impractical for other reasons, the components may remain in place, with the muffler attached to the inlet of the vehicle air induction system. In this case, the vehicle induction components must be made effectively silent by acoustic barriers/wrapping, etc., or they must be confirmed to be effectively silent. They must also be removed from the engine compartment as much as possible to minimize obstruction of sound radiated from the powertrain to the measurement microphones. Likewise, the tubing connecting the muffler to air inlet must be located to minimize obstruction of sound radiated from the powertrain to the measurement microphones. Test condition of the muffler and induction components are to be documented with the test results, including photographs. Photographs should include views of the vehicle engine compartment (engine bay) in enough detail to show the entire powertrain, compartment surfaces, and induction components.

4.1.2.17 Install a thermocouple in the engine airflow, at the location of the engine air inlet.

4.1.3 Component Preparation.

4.1.3.1 Measure powertrain dimensions as described in Sections F1 and F2 (Appendix F), PLAT Sound Power Estimation Procedures. Record dimensions in Table A3 (Appendix A) (L13).

4.1.3.2 Document powertrain orientation (longitudinal or transverse) for sound power calculation in Table A1 and Table A3 (Appendix A) (L13). Document the presence of an acoustic engine top cover(s) (None, Small, or Large) in Table A1 and Table A3 (Appendix A) (L13). For purposes of this procedure, an acoustic engine top cover is defined as a cover attached to the powertrain that **significantly** attenuates sound radiated from the top surface and edges of the imaginary box defining the major radiating surfaces of the powertrain. The imaginary box is that illustrated in Figure C1 (Appendix C). Specify None, Small, or Large cover. Specify None if no cover is present. If a cover(s) is present, specify the size of the cover(s) based on the cover's total surface area compared to the area of the top surface and edges of the imaginary box, as follows:

- None: $\leq 20\%$
- Small: 20% to 60%
- Large: 60% to 100%

Specification of cover size requires subjective judgment. Selection must be approved by the test requester. Note that specification of the top cover is separate from the decision to include it in the test. Specification of the top cover will provide a means to account for its effect on sound radiation pattern and the three (3) microphone sound power measurement herein. As a separate matter, the test may be conducted without the top cover installed if the test requester wishes to measure sound power of the powertrain without a cover.

4.1.4 Instrumentation Preparation.

4.1.4.1 Channel Assignments. Connect all transducers to appropriate instrumentation for data recording. Channel assignments are specified in 4.1.6.1 (for microphones) and 4.1.6.2 (for accelerometers). The channel assignments are optional but strongly recommended.

4.1.5 Instrumentation Calibration.

4.1.5.1 Data Recorder Calibration. Periodic calibration of the data recorder/acquisition system should be performed by the appropriate Instrumentation Group.

4.1.5.2 Microphone Calibration. Calibrate the microphone(s) using appropriate reference tone. View reference signal on an oscilloscope or equivalent display device to check signal integrity (harmonic distortion, etc.) for each microphone.

4.1.5.3 Accelerometer Calibration. Calibrate the accelerometers using appropriate reference signal. View reference signal on an oscilloscope or equivalent display device to check signal integrity (harmonic distortion etc.) for each accelerometer.

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4.1.6 Transducer Placement/Installation.

4.1.6.1 Microphone Placement. Place microphone(s) as indicated in Figure C1 (Appendix C). Orient pressure response microphones for a 90 degree sound incidence angle. Orient free-field response microphones for a 0 degree incidence angle. Assign data acquisition channels so that microphone numbers (1 through 3 as shown) are the same as channel numbers. Place windscreens on microphones. Document microphone locations with photograph(s) showing microphones in relation to vehicle and powertrain.

4.1.6.2 Accelerometer Placement. Attach triaxial accelerometers to powertrain, at points where the powertrain, including mount brackets, attaches to elastomeric mounts and torque reaction struts. Note that adhesive must provide for undistorted vibration measurements from 0 Hz to 1600 Hz (reference 3.2.8). Place accelerometers as close as possible to the rubber of the mounts, on the mount bracket. Align the accelerometer axis with those of the vehicle coordinate system. The vehicle coordinate system is defined as:

- x = Vehicle fore/aft, positive forward
- y = Vehicle lateral, positive driver's left to right
- z = Vehicle vertical, positive upward

Note those accelerometer axes are to be aligned with vehicle coordinates regardless of a mount's orientation and coordinate system. Assign data acquisition channels as follows. Assign a number to each powertrain mount as illustrated in Figure C2 (Appendix C). Assign channel numbers starting with engine mount number one (1), and use Channel 1 for x, 2 for y, and 3 for z. Increment channel numbers (following Channel 3) from x to z, for powertrain mounts two (2) and higher, progressing with increasing mount number. Document accelerometer locations and orientations with sketches or other graphic(s) depicting the locations on the powertrain. Also document the same with photographs of each accelerometer.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 Test facility should have ambient temperatures between 18 °C and 29 °C (65 °F and 85 °F). Record the ambient temperature in Table A1 (Appendix A) (L3).

4.2.1.2 The ambient sound pressure level prevailing in the dynamometer chamber with relevant HVAC, cooling, and the chassis dynamometer systems operating must not be greater than values corresponding to 20 dB below the measured one-third ($\frac{1}{3}$) octave levels of the operating vehicle with ambient sound present. This applies to bands 250 Hz through 10 000 Hz, for the steady state operating conditions in this test. Conformance to this condition is to be checked by measuring the ambient sound levels Background Noise Number 1, Background Noise Number 2, and Background Noise Number 3, in 4.3.12.1, 4.3.12.2, and 4.3.12.3 respectively. Background sound pressure measurements (from 4.3.12) are to be processed as sound power (5.1.1.1) and compared to operating vehicle sound power levels (with ambient sound present) on a one-third ($\frac{1}{3}$) octave basis. The 20 dB criteria must be achieved for all bands and operating conditions where Background Noise Number 1 or Number 2 (4.3.12.1 or 4.3.12.2) is compared to operating conditions 4.3.7 through 4.3.11, and Background Noise Number 3 (4.3.12.3) is compared to operating conditions 4.3.13 through 4.3.16. For conditions 4.3.7 through 4.3.11, Background Noise Number 1 or Number 2 is chosen to match the systems functioning during those operating tests. See section 4.3.12 for a description of the systems. Deviations from the 20 dB criteria may be allowed in some cases if they are small and approved so by the test requester.

4.2.1.3 Lighting in the dynamometer chamber must be representative of daytime, sunny, outdoor conditions such that automatic vehicle headlamps and daytime running lamps operate in that respective mode of activation during all operating tests.

4.2.1.4 The floor under the powertrain must be reflective and at grade elevation. Moveable floor platforms must be raised to grade level during data recording.

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 Vehicle setup conditions are as described in 4.1.2.

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4.2.2.2 The operating conditions of the powertrain are summarized in Table 2. Tractive Effort refers to the total tractive effort of all load carrying wheels. Conditions apply to both gasoline and diesel engines except where specified separately. AT refers to automatic transmission powertrains, and MT refers to manual transmission powertrains. Section 4.3 provides detailed instructions for applying these conditions and carrying out the test. The respective instruction in 4.3 is shown in Table 2 for reference. Refer to 4.3 for additional details regarding each condition. Note that **maximum engine speed** is not engine speed of the Passing Gear Shift Point. These speeds may, in general, be different. Maximum engine speed refers to the maximum achievable operating speed of the engine. Engine speed of the Passing Gear Shift Point is described in 4.1.1.13 and 4.1.1.16.

Engine Temperatures: Engine coolant temperature, measured at engine outlet, is to be within -4 °C (-7 °F) and +6 °C (+11 °F) of nominal warm operating temperature during sound and vibration data recording (data acquisition) for all test conditions except 4.3. See 4.3 for conditions therein. Nominal warm operating temperature is that which results from normal operation of the engine thermostat and vehicle engine cooling system.

Air temperature: Air temperature, measured at the engine air inlet (reference 4.1.2.16), is to be within the range of 19 °C to 26 °C (66 °F to 79 °F) for all test conditions during sound and vibration data recording/acquisition.

Table 2: Operating Conditions

Identification Number	Description	Engine Speed (rpm)	Tractive Effort	Transmission Gear State	Instruction Section
0	Cold Idle for Diesel Engines	Nominal idle rpm at 19 °C to 26 °C coolant temperature, 5 s after starting	0	PARK	4.3.1
1	Idle Accessories Off	Nominal idle rpm for warm temperature	0 (AT: Vehicle brakes and torque converter provide stall torque to engine)	AT: Drive MT: Neutral	4.3.14
2	750/850 erpm Idle	Gasoline: 750 Diesel: 850	0	PARK	4.3.15
3.1	Drive-Away Shift Point	Drive-Away shift point, Table A3 (L14)	Drive-Away Shift Point Load, $F_{RdLoad, DA}$, Table A3, (L14)	Drive-Away Gear, Table A3, (L14)	4.3.9
3.2	1500 erpm Drive-Away Condition for Diesel Engines	1500	1500 erpm Drive-Away Load, F_{1500_DA} , Table A3, (L14)	Drive-Away Gear, Table A3, (L14)	4.3.11
4	2500 erpm Drive-Away	2500	2500 erpm Drive-Away Load, F_{2500_DA} , Table A3, (L14)	Drive-Away Gear, Table A3 (L14)	4.3.10
5	3000/4000 erpm Wide Open Throttle Passing Gear	Gasoline: 4000 Diesel: 3000	Tractive effort resulting from full engine Load or Wide Open Throttle (WOT)	Passing Gear, Table A3, (L7)	4.3.8
6	Wide Open Throttle Passing Gear Shift Point	Passing gear shift point, Table A3 (L7)	Tractive effort resulting from full engine Load or WOT	Passing Gear, Table A3, (L7)	4.3.7

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Identification Number	Description	Engine Speed (rpm)	Tractive Effort	Transmission Gear State	Instruction Section
7	Wide Open Throttle Passing Gear Sweep	AT: Lowest possible speed to Passing gear shift point MT: 1000 to maximum engine speed	Tractive effort resulting from full engine Load or WOT	Passing Gear, Table A3, (L7)	4.3.3
8.1	Low Load Drive-Away Sweep	Minimum to maximum engine speed	Drive-Away Sweep Load, $F_{RdLoad, 1m/s^2}$, Table A3, (L15)	Low Load Drive-Away Sweep Gear state Table A3, (L15)	4.3.4
8.2	Coast Down Sweep	AT: Passing gear shift point to lowest possible speed MT: Maximum to minimum engine speed	Tractive effort required to drive engine for minimum throttle/load setting	Passing Gear, Table A3, (L7)	4.3.5
9	High Gear Cruise Sweep	AT: Speeds from 56 km/h to 137 km/h or maximum engine speed MT: 1000 to speed at 137 km/h or maximum engine speed	Cruising Road Load, $F_{RdLoad, Cruise}$, Table A3, (L11)	High Gear	4.3.6
10	Not used in this procedure. See GMW14007.	Not applicable	Not applicable	Not applicable	Not applicable
11	Idle Accessories On	Nominal idle rpm for warm temperature	0 (AT: Vehicle brakes and torque converter provide stall torque to engine)	AT: Drive MT: Neutral	4.3.13
12	Engine Cranking	Cranking speed	0	PARK	4.3.16

4.3 Instructions. This section, 4.3, describes vehicle/dynamometer operation and data acquisition/recording instructions for conducting the test. The instructions are ordered in a manner that helps achieve the specified powertrain conditions while recording measurements in an efficient manner. The order may be modified, but only if the measurement and operating conditions associated with these instructions are maintained. The operating condition identification number from Table 2 is shown in brackets “()” next to each respective instruction.

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It is assumed that instrument acquisition/recording procedures necessary to achieve adequate signal-to-noise ratio of measured signals will be followed, while assuring that all specified vehicle operating conditions are achieved. It is also assumed that adequate care will be taken to assure signal presence and integrity in general. For this purpose, it is recommended that microphone, accelerometer, and tachometer signals be surveyed and monitored during recording by viewing signals with oscilloscope (or equivalent) and listening to microphone and accelerometer signals.

It is also assumed that adequate care will be taken to ensure that engine coolant temperature and engine air inlet temperature remain as specified (4.2.2.2) during data recording for each condition.

It is also assumed that adequate care will be taken to ensure that vehicle engine cooling fan(s) remain off or disabled during data recording for each condition. Recall that the vehicle cooling fans are to be disabled and not operating (reference 4.1.2.14) for any operating conditions in this procedure.

The following vehicle/powertrain operating conditions are to be documented with each test condition during sound and vibration data recording (data acquisition):

- Engine speed (erpm)
- Vehicle speed (mph)
- Tractive effort (TE)
- Engine coolant temperature (at engine outlet)
- Air temperature at the engine air inlet
- Transmission gear selection
- Air Conditioning (A/C) compressor (high-side) head pressure for Idle Accessories On condition

These conditions are to be documented in a test log. The conditions are to be documented at the beginning and end of each data acquisition, for every test condition (steady state and speed sweep).

Prepare data acquisition/recording systems for recording and raise all moveable floor platforms under the powertrain (4.2.1.4).

4.3.1 Cold Idle Condition for Diesel Engines (Condition 0).

Note: This test condition is used for diesel engines only.

4.3.1.1 Ensure that engine coolant and air temperatures are within the range of 19 °C to 26 °C (66 °F to 79 °F), as close as possible to 22 °C (72 °F). Ensure transmission is in **PARK** selection, and that the vehicle is not loaded against the parking pawl if present. Ensure that engine accessories will remain off when engine is started. Turn vehicle HVAC system off.

4.3.1.2 Prepare signal/recording/acquisition instrumentation gain settings for loud idle conditions. There will be only 5 s of engine operation available for gain/range setting (prior to acquisition) during this test condition. If appropriate values are unknown, then idle the engine to determine appropriate values, turn the engine off, and allow temperatures to return to the values in 4.3.1.1. Prepare acquisition instrumentation to begin recording 5 s after the engine starts. Ensure that external and spot cooling is turned off.

4.3.1.3 Start engine, noting the time at which ignition begins. Record 20 s of linear (unweighted) sound data, beginning 5 s after ignition. Record operating conditions, and document accessory and cooling fan state in test log.

4.3.1.4 Turn engine off.

4.3.2 Warm Up for Warm Test Conditions.

4.3.2.1 Turn on external and spot cooling systems.

4.3.2.2 Warm up powertrain until tires are warm, and engine coolant temperature stabilizes. Operate vehicle in first gear at 2000 erpm and 440 N (100 lb-f) TE for this purpose, then reduce TE and return to closed throttle. Engine coolant temperature (measured at engine outlet) should stabilize to within -4 °C (-7 °F) and +6 °C (+11 °F) of nominal warm operating temperature as would result from normal operation of the engine thermostat and vehicle engine cooling system. Adjust the remote cooling system accordingly to achieve this coolant temperature. Note the nominal warm operating temperature and respective -4 °C to +6 °C range so it can be checked throughout the remaining test conditions.

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