



Engine-Level Allocable Test (ELAT)

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 the Engine Level Allocable Test (ELAT) is to measure engine generated noise and vibration source levels, for assessment to requirements, and as inputs to various vehicle system analytical models. Full powertrain source levels are quantified by the Powertrain-Level Allocable Test (PLAT) test procedure GMW14238 as described in 1.3. Unusual or impulsive noises, or transient issues such as startup clatter are not intended to be addressed by the ELAT specifically, although the setup and measured data may be useful in development testing associated with those issues (e.g., reference GMW16805).

1.2 Applicability. Gasoline and diesel engines for passenger cars and light duty trucks.

1.3 Remarks. Powertrain noise and vibration emissions are measured using specific or generalized PLAT operating conditions, as they pertain to the engine. They are measured in terms of radiated sound power, and vibration at the engine mount bracket boss locations. The PLAT procedure is a valuable reference for questions that may arise when performing an ELAT. The ELAT is to be consistent with the PLAT, including all engine-mounted acoustic treatments planned for production release, so that measured data can be compared between the two tests. An engine air inlet sound pressure measurement is also made (for naturally aspirated engines), in order to quantify the induction noise source level, treating it separately from the radiated sound of the engine. Optionally, crankshaft angular motion is measured as a torsional vibration input for manual transmission applications.

2 References

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

2.1 External Standards/Specifications.

ANSI S12.34

2.2 GM Standards/Specifications.

GMW14238

GMW16206

GMW16805

2.3 Additional References.

Bruel & Kjaer Type 3541 available from bksv.com/en/products/transducers/acoustic/calibrators/3541-A

3 Resources

3.1 Facilities. Tests are to be performed in an engine dynamometer facility with a semi-anechoic measuring environment, with ambient sound and vibration levels that do not influence the sound and vibration measurements of the engine. The ambient sound level of the room with operating dynamometer and air/fluid handling systems, should be at least 5 dB less than that of the test object in each $\frac{1}{3}$ octave band from 50 Hz to 200 Hz, and at least 10 dB less than in each band from 250 Hz to 10 000 Hz at all microphone locations. The reflectivity and size of the room must be adequate to allow far-field sound pressure measurements greater than 200 Hz, at a distance of 1 m from the engine. Necessary test room acoustic characteristics are discussed further in 4.3.6 and Appendix B.

Induction air supply and exhaust gas handling systems should be wrapped with acoustic barrier material as necessary to prevent affecting sound measurements in the 50 Hz to 10 000 Hz bands as noted in the preceding,

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for the operating engine. Similarly, transmission, drive shaft and engine mounting and fluid handling systems should be acoustically treated, only to the extent necessary to avoid influencing engine radiated noise measurement.

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 Five (5) pressure response microphones with associated signal conditioning and mounting stands to measure sound power as described in section 4.4.1. Sensitivity and frequency response must be suitable for test engine sound pressure measurements from 20 Hz to 20 kHz.

An additional 6th microphone may be necessary for (optional) measurement of sound pressure on the bottom of engine as described in 4.4.1.2.

3.2.2 One (1) pressure response microphone with associated signal conditioning and mounting stand to measure engine air inlet sound pressure for naturally aspirated engines as described in 4.4.1.3. Sensitivity and frequency response must be suitable for inlet sound pressure measurements from 20 Hz to 20 kHz.

3.2.3 Multiple triaxial accelerometers with associated signal conditioning and mounting hardware/adhesive to measure engine mount bracket boss vibration as described in 4.4.2. Sensitivity, temperature capability and frequency response of the accelerometers must be suitable for test engine acceleration measurements from 5 Hz to 1600 Hz. Any adhesive used to affix accelerometers to the test hardware must have demonstrated ability to introduce no more than ± 1 dB of measurement error over the specified frequency range.

3.2.4. Sound intensity measurement and analysis system to determine test cell reactivity index and sound power correction factors, as detailed in Appendix B. Determination of these parameters is optional only if a very similar set of hardware has been previously run in the same test cell, in which case the requester may use engineering judgement and experience to substitute previously obtained correction factors.

3.2.5 (Optional, to be used for applications with manual transmissions.) Rotational laser vibrometer, or other suitable signal acquisition and conditioning equipment to measure crankshaft angular motion near the rear of the crankshaft as described in 4.4.3. A crankshaft sensor signal with sufficiently high resolution (i.e., more than 20 pulses per revolution) from a reluctor ring near the rear of the crankshaft is an example of a sufficient alternative to a torsional laser vibrometer.

3.2.6 Instrumentation to provide engine tachometer pulse train or equivalent means of recording engine crankshaft speed for data processing. One (1) tachometer pulse per revolution is recommended.

3.2.7 Instrumentation to monitor and control engine operating parameters.

3.3 Test Vehicle/Test Piece. Engine/Transmission.

3.3.1 Test engine specified by test requester, including all acoustic treatments planned for production release and engine-mounted accessory components and associated mounting brackets. No accessory drive belt shall be installed for noise measurements. Accessory component pulleys and the crankshaft damper pulley may be treated in order to assure their radiated noise performance is comparable to the case where a drive belt is present. The engine shall be filled with production intent oil type and volume.

3.3.2 Transmission to be used with the test engine. The transmission and related torque converter or fly-wheel/clutch components are ideally that of the power-train application for the test engine, provided it is wrapped and controlled to be effectively silent from a sound power standpoint, during the noise measurement portion of testing. "Effectively silent" implies that the wrapped transmission provides no more than 5% of the sound power or mean-squared sound pressure of the full system in any $\frac{1}{3}$ octave band, and also does not significantly influence vibration or tonal noise assessment. An alternative transmission may be used if necessary due to availability or unacceptable noise performance of the application-intent transmission.

3.4 Test Time.

Calendar time:	5 days
Test time:	8 hours
Coordination time:	8 hours

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3.5 Test Required Information.

3.5.1 The requester must specify and approve the test setup, based on objective measures and experience. Particular consideration should be given to test room acoustic characteristics and acoustic treatment of supporting hardware.

3.5.2 Specify engine speeds and loads associated with the operating conditions detailed in 4.3. Certain conditions may be omitted based on knowledge of the intended application, or limitations of available test hardware.

3.5.3 Specify the model/type of transmission to use for the test. If the transmission is not that of the intended powertrain application, specify the appropriate transmission operating state for test conditions in Table 1.

3.6 Personnel/Skills. One (1) test engineer or technician capable of making measurements and processing sound and vibration data, and one (1) technician capable of performing engine setup and operating an engine dynamometer as described in this procedure.

4 Procedure

4.1 Preparation.

4.1.1 Obtain engine, transmission, accessories and associated engine dress hardware described in 3.3.

4.1.2 Prepare dynamometer, engine and transmission control hardware and software necessary to achieve targeted operating conditions.

4.1.3 Procure and prepare sound and vibration transducers as listed in 3.2, and hardware and software necessary for data acquisition and processing specified in 4.4 and 5.1.

4.1.4 Determine mount bracket boss measurement locations for all intended applications, as discussed in more detail in 4.4.2 and Appendix B. Provide markup photos for documentation of accelerometer locations as-tested.

4.2 Conditions. The operating conditions of the engine are defined in order to reproduce the engine speed and torque of the PLAT operating conditions. They are summarized in Table 1. The gear states in the "Description" column refer to respective PLAT operating conditions, not the gear state of the transmission used for the ELAT.

Note: Engine Load refers to torque on the engine, not necessarily that of the dynamometer.

Engine mount bracket boss vibration data is to be measured for conditions 3, 4, 5, 7 and 9 (see Table 1), as detailed in Appendix D, Table D1, Figures D1 and D2.

Table 1: Operating Conditions

ID #	Diesel	Gasoline	Description	Engine rpm (erpm)	Engine Load (Torque)/Transmission State Details. Also see Notes 1 thru 6 following this table.
0	✓		Cold Idle	Nominal idle	No load, neutral idle, nominal erpm, measured 5 s after starting at 20 °C ambient engine and coolant temperature.
1	✓	✓	Idle, Accessories Off	Nominal warm idle erpm	Torque converter stall torque in Drive for automatic transmission applications. Neutral, no load, for manual transmission applications, or if driveline rattle prevents using converter stall torque for automatic transmission application.
2	✓	✓	High Idle	<u>Gas:</u> 750 <u>Diesel:</u> 850	No load, neutral. Customized control of fuel, ignition and air flow may be used as necessary to achieve optimal steady engine speed.
3.1		✓	Driveaway Shift Point	From PLAT, if defined	Speed and associated engine load from PLAT, or calculated from actual or surrogate PLAT parameters using equation in Note 4 .
3.2	✓		1500 erpm, 20% Load	1500	20% rated engine load.

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ID #	Diesel	Gasoline	Description	Engine rpm (erpm)	Engine Load (Torque)/Transmission State Details. Also see ^{Notes 1 thru 6} following this table.
4.1	✓	✓	2500 erpm Part Load Driveaway	2500	Engine load from PLAT, or calculated using equation in ^{Note 5} .
4.2		✓	2500 erpm Heavy Load Driveaway	2500	75% rated engine load.
4.3	✓		Diesel Heavy Load Driveaway	30% of maximum engine speed	75% rated engine load (or maximum engine load, if 75% rated engine load cannot be achieved at specified speed).
5	✓	✓	Full Load, High Speed	<u>Gasoline:</u> 4000. <u>Diesel:</u> 3000	Full Load.
6	✓	✓	Full Load Passing Gear Shift Point	Shift Point from PLAT, or Rated Engine Speed if PLAT unknown	Full Load, maximum engine shift speed.
6.1	✓	✓	Full Load Fixed Speed Shift Point	<u>Gasoline:</u> 6000. <u>Diesel:</u> 4000	Maximum engine torque at 6000 erpm for gas engines and 4000 erpm for diesel engines. Not applicable if maximum shift speed is less than specified fixed speed.
7	✓	✓	Full Load Passing Gear Speed Sweep	1000 to maximum engine speed	Full Load. Uniform sweep rate to achieve a total elapsed time of 30 s to 60 s for the entire speed range. Sweep may be broken into segments if necessary due to thermal limits.
8.1	✓	✓	Low Load Driveaway Speed Sweep	1000 to maximum engine speed	PLAT load if available (calculate from chassis dynamometer tractive effort). Typically, 20 Nm to 50 Nm. Use sweep rate of 5000 erpm/minute for proper measurement of tonal noise performance.
8.2	✓	✓	Coast Down Speed Sweep	Maximum engine speed to 1000	Motored Engine Torque (ignition and fuel on, zero (0) commanded pedal). Uniform sweep rate to achieve a total elapsed time of 30 s to 60 s for the entire speed range.
9	✓	✓	Cruise Load Speed Sweep	1000 to maximum engine speed	20% Rated Load, or PLAT load if specified by requester (calculate from chassis dynamometer tractive effort). Uniform sweep rate to achieve a total elapsed time of 30 s to 60 s for the entire speed range.

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ID #	Diesel	Gasoline	Description	Engine rpm (erpm)	Engine Load (Torque)/Transmission State Details. Also see Notes 1 thru 6 following this table.
10		✓	Engine Air Inlet Sound Pressure Level (SPL)	1000 to maximum engine speed	Full Load. Throttle opening angle representative of production intent calibration, or wide open throttle (WOT) as a worst-case measure (results should be labelled accordingly). Uniform sweep rate to achieve a total elapsed time of 30 s to 60 s for the entire speed range.

Note: ID = Identification (operating condition), # = number, rpm = revolutions per minute.

Note: Condition numbering approach in Table 1 is where the digit following the dot represents a variant of the more general integer number operation. Subsequent in-document references to operating condition numbers, follow this approach.

Note 1: For operating conditions (ID #'s) 3-10, transmission operation in Direct Drive is preferred in order to minimize transmission contribution to radiated noise and vibration. For tests using an automatic transmission, the torque converter clutch should be locked whenever possible for part load conditions 3, 4, 8, and 9 in order to maximize load accuracy. Torque converter clutches may be operated unlocked for Full Load conditions 5, 6, 7 and 10.

Note 2: The effects of engine control system timers must be considered for steady state operating conditions 3, 4, 5 and 6. Engine fuel and ignition parameters are to be those associated with the initial 10 s of sustained operation at these speeds and loads. If control system programming (calibration) causes fuel or ignition parameters to be modified during sustained operation at speed and load, only the operating state during the first 10 s of sustained operation is to be used for noise and vibration data collection. Control system modification or repeat test runs are to be used, if necessary, to achieve the desired operating range. Diesel engine data should be acquired mainly during normal engine operation. It is at the discretion of the requester to consider different calibration modes (normal vs. warm up) or Diesel Particulate Filter regeneration modes.

Note 3: For all test conditions except condition 0, engine coolant and oil temperature should be maintained between nominal warm operating temperature (approximately 90 °C) and an additional +10 °C for coolant, and +25 °C for oil. For all test conditions engine air supply temperature should be maintained at 25 °C ± 2 °C. Engine air supply should be maintained at: 990 mbar to 1010 mbar absolute pressure, and 21% to 41% relative humidity, although air supply pressure may be allowed to vary within 960 mbar to 1040 mbar, and humidity may be allowed to vary beyond 21% to 41%, if approved by the test requester.

Note 4: Engine torque load for Driveaway Shift Point may be calculated from GMW14238 PLAT operating condition using the following equation and definitions (unit conversion factor is included in the constant term):

$$\frac{2.652 \times F_{RdLoad,DA}}{\varepsilon \times (n/V)} \quad (\text{Nm})$$

Where:

$F_{RdLoad,DA}$ = Total tractive effort, in Newtons (N), for vehicle application.

ε = Total driveline, transmission and torque converter mechanical efficiency of vehicle application, for condition of interest. 0.85 is a reasonable estimation if not otherwise known.

(n/V) = erpm divided by road speed in kilometers per hour (kph).

Note 5: Engine torque load for 2500 erpm Part Load Driveaway, if not directly available from PLAT, may be calculated using the following equation and definitions:

$$\frac{(21.87 \times D) + 20.49}{\varepsilon} \quad (\text{Nm})$$

Where:

D = Engine displacement in liters.

ε = Total driveline, transmission and torque converter mechanical efficiency of vehicle application, for condition of interest. 0.85 is a reasonable estimation if not otherwise known.

Typical torque values are approximately 25% rated load for boosted engines, and approximately 35% rated load for naturally aspirated engines.

Note 6: The rated torque (also known as advertised torque), which is to be used when calculating load for a percent of rated torque measurement, is the maximum torque produced over the full operating range of the engine. Calculated percent load should not be based on the maximum torque measured only at the desired measurement speed. Rated engine torque may be a program target, rather than an observed value, during early engine development.

4.2.1 Environmental Conditions. No unique environmental conditions are required for ELAT measurements. An ambient temperature test cell, with external coolant supply able to maintain warmed-up operating oil and coolant temperature between approximately 90 °C and 100 °C (with excursions to higher temperatures for heavy load conditions) is typical. Environmental conditions may be specified if necessary to obtain specific operating modes for related development testing.

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.

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4.3 Instructions.

4.3.1 Engine Installation. The engine should be mounted on vehicle application mounts and mount brackets if available. If not available, custom brackets and generic isolation mounts may be used. Stiffness of custom brackets should not be dramatically different than the application brackets, in order to minimize influence on mount bracket boss vibration data. Mounting pedestals, coolant hoses and fuel lines must be wrapped with acoustic barrier material if necessary to prevent interference with the sound measurements.

As installed for test, the distance from the bottom of the engine to the floor should be 0.5 m to 1.1 m. The distance from the rear of the engine radiating surfaces to the acoustic treatment of the rear wall must be at least 1.3 m unless approved otherwise by the test requester. This is discussed and illustrated further in Appendix A, Figure A1 and 4.3.5.1. The rear distance is further constrained by location requirements for a rear microphone, which effectively limits the distance to be greater than or equal to 81 cm under any circumstances.

4.3.2 Transmission. The powertrain application-specific transmission should be assembled to the engine if it is available, and can be effectively silenced for the sound measurements. If either of those conditions cannot be met, an alternative transmission may be used. All access holes in the transmission, and any openings between the engine and transmission, must be closed and sealed for noise measurements. The transmission and torque converter or flywheel/clutch selected for test must be documented with the test results.

4.3.3 Air Induction System. A combustion air supply is to be connected to the engine air inlet in a manner that does not adversely affect radiated noise or engine torque. The air induction system, from the engine air inlet to the induction system air inlet or any portion thereof, for a vehicle-specific application may be used if it is acoustically wrapped to the extent specified by the test requester, such that it does not interfere with measurements of sound radiated from the engine. If used, the induction system air inlet must be connected to an external air supply so that radiation from the inlet does not interfere with the sound measurements. Engine torque must be documented and confirmed to be within 2% of values obtained with a typical vehicle air induction system. Reference Appendix C, Figure C1.

For boosted engines, charge air cooling is required in order to meet engine air inlet temperatures comparable to vehicle application or development dynamometer operation, as specified by the test requester. Adequate charge air cooling generally involves a unique water-to-air setup in place of an application-intent air-to-air cooler, unless the air-to-air cooler can be modified to provide both effective cooling and quiet operation so as to not influence radiated noise measurements as previously called out. Charge air ductwork, whether application-intent or unique to the dynamometer setup, should also be acoustically treated if specified by the requester.

A separate setup is required for Engine Air Inlet SPL condition 10, described in 4.4.1.3. For the engine inlet measurement, the air supply pipe, or induction system, upstream of the engine air inlet is to be removed in order to measure sound pressure at the engine air inlet. Note that the mass airflow sensor, if present, may remain on the engine with a limited portion of the induction system, or the test requester may specify that the airflow sensor be retro-fitted directly to the intake manifold/throttle body using a minimal length of adaptive tubing. The airflow sensor may be removed, with sound pressure measurements taken at the intake manifold/throttle body if the engine can be operated correctly without the sensor. The setup must be documented with photographs and/or drawings which include tubing length and component diameters. A sound barrier blanket is to be placed over the engine, if necessary, so that radiated sound from the engine does not produce more than 5% of the mean-squared sound pressure from the engine air inlet for a bandwidth greater than or equal to $\frac{1}{3}$ octave. If necessary, the test requester may approve the sound levels without measurement, based on engineering judgment and experience.

4.3.4 Exhaust System. For the purpose of this procedure, the "engine exhaust components" include exhaust manifolds, close-coupled exhaust catalysts which attach directly to the manifolds, "cross-over" pipes which connect manifolds on multi-bank engines and any pipe that is located within 4 cm of the engine surface. All engine exhaust components should be present for test. The vehicle exhaust system components, downstream of the engine exhaust components, may be replaced with an appropriately set back-pressure restriction valve. The exhaust system, from the outlet of the engine components to the exit of the test room, must be wrapped with acoustic barrier material to the extent necessary to prevent interference with the sound measurements. The downstream components, with any acoustic barrier material, must not interfere with the sound measurements by producing more than 3% of the sound power or mean-squared pressure for any of the sound measurement results of bandwidth greater than or equal to $\frac{1}{3}$ octave. If necessary, the test requester may approve the sound levels without measurement, based on engineering judgment and experience.

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4.3.5 Instrumentation.

4.3.5.1 Microphone Placement. Five (5) microphones are to be placed on a conformal measurement surface that is 1 m from the sides and top of an imaginary box which encloses the engine major radiating surfaces, as detailed in Appendix A, Figure A1 and described in the following.

The imaginary box encloses the engine from rear (flywheel side) to the plane of the accessory pulleys, from side to side, and from top to bottom. Some judgment is required to select the surfaces of the box. They should coincide with the outer dimension of the outer-most components that radiate significant noise; such as manifolds and covers. The components and physical features that define the surfaces of the imaginary box are to be approved by the test requester and clearly documented with the test results. The dimensions and location of the imaginary box are used in the sound power calculation as described in 5.1.1.1 and Appendix A.

The microphones are in line with the center of the box on the sides, front and top of the engine. The rear microphone is located as low as possible while still at least 40 cm away from any prop-shaft/guard, transmission or air handling ductwork surfaces, and at least 10 cm away from the acoustic treatment of the room wall. The rear microphone must remain on the conformal measurement surface, 1 m from the imaginary box, and it must not be more than 71 cm above the imaginary box. The test requester must approve the location of the rear microphone if it is located 10 cm from the acoustic treatment of the wall.

The bottom of the imaginary box is to coincide with the bottom surface of the oil pan. It may be used to locate a microphone for a separate measurement of sound pressure on the bottom of the engine, as described in 4.4.1.2. The location of all microphones and the dimensions and location of the imaginary box must be clearly documented with the test results.

Microphone type and placement for Engine Air Inlet SPL (measured only in the case of naturally aspirated engines) requires a unique setup, as shown in Appendix C, Figures C1 and C2. A single microphone is to be located 0.1 m from the center of the engine air inlet, on a line which forms a 45 degree angle with the center-line axis of the inlet. A pressure microphone should be used, not a free-field microphone. The microphone cartridge should be oriented perpendicular to the line extending from the cartridge to the center of the air inlet. Further detail on the microphone location is provided in Appendix C, Figure C2.

Associated acoustic treatment to shield the measurement from engine radiated noise is described in 4.3.3.

4.3.5.2 Accelerometer Placement. Accelerometer placement for mount bracket boss vibration measurements is specified in Appendix D. It is not required to measure vibration signatures simultaneously with radiated noise data. Furthermore, due to the potentially high number of boss measurement locations and directions, it may be necessary to measure the boss locations for different mount bracket footprints as separate runs.

4.3.6 Test Room Evaluation. The suitability of the test facility for far-field sound pressure measurements greater than 200 Hz at a distance 1 m from each side of the engine must be verified. The reactivity index, L_k , provides a useful measure of the reflectivity of the test environment, and must be greater than or equal to -1.5 dB(A) at each microphone location used to measure sound power. Measurement and calculation of the reactivity index is specified as part of the determination of microphone correction factors described in Appendix B.

4.4 Instructions - Measurements.

4.4.1 Sound Measurements.

4.4.1.1 Sound Power Sound power is to be measured using the technique described in the following content (a modified version of ANSI S12.34), for $\frac{1}{3}$ octave bands from 250 Hz to 10 kHz using sound pressure microphones and the "far-field" assumption. All sound pressure measurements must be made at a sample rate of 40 kHz or greater, for compatibility with impulsive noise processing described in 4.4.1.4.

The reactivity index, L_{ki} , is to be measured at each microphone location for operating conditions 4 and 5 (see Table 1), and must be used to correct each sound pressure measurement for error in the far-field assumption. Refer to Appendix A, Figure A1 for illustration and more detail regarding the measurement surface, imaginary box and microphone locations, and Appendix B for reactivity measurements and calculation of microphone correction factors.

4.4.1.2 Sound Pressure Level on Bottom of Engine. SPL may be measured under the engine for at least conditions 5 and 7 in Table 1. It is made within the frequency range of 22.4 Hz to 12.8 kHz. For this measurement, a pressure response microphone is located 0.5 m below the bottom surface, aligned with the center of the imaginary box described in 4.3.5.1 and illustrated in Appendix A, Figure A1. Note that the microphone must not be located less than 20 cm from the floor. The 0.5 m distance from the bottom of the imaginary box must be

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reduced, as little as possible, if necessary in order to maintain the minimum 20 cm distance from the floor. The location of the microphone must be documented with the test results, noting the distance from both the bottom of the imaginary box and the floor. Note that the floor must not be covered with sound absorbing material. It is to remain reflective for this measurement.

4.4.1.3 Engine Air Inlet Sound Pressure Level (SPL). Engine Air Inlet SPL is measured for condition 10 in Table 1 in the case of a naturally aspirated engine. SPL is measured near the engine air inlet, within the frequency range of 22.4 Hz to 12.8 kHz. It is measured using a separate engine set-up, as described in 4.3.3.

4.4.1.4 Sound Pressure Signal Diesel Knocking Index (DKI) and Gasoline Ticking Index (GTI). Procedures are being developed and improved for assessment of impulsive noise character at a propulsion system level. The diesel propulsion system DKI and gasoline propulsion system GTI (limited to idle operation) are described in GMW16206. For processing via GMW16206, individual microphone time data recordings for applicable test conditions (0 thru 3 and 4.1 in Table 1) should be available for resampling to 48 kHz (acquisition sample rate 40 kHz or greater) and export as a 24 bit Waveform Audio File Format (WAV) file at 94 dB scaling for processing specific to GMW16206. Details regarding which microphones to use and which operating conditions to consider should be provided by the test requester. For diesels, follow the GMW16206 procedure. It is recommended to report the lowest DKI/GTI measured with the five (5) ELAT microphones, but also to report the 5-microphone average for each respective test condition.

4.4.2 Vibration Measurements. Unless otherwise noted and according to Appendix D, vibration measurements are to be made using an orthogonal coordinate system local to each mount bracket boss footprint, where: x is outward along the boss axis, y is "horizontal", perpendicular to the boss axis, and z is perpendicular to x and y (generally "vertical"), except in the case of a vertical boss axis. As detailed in Appendix D, accelerometers should be located as close as possible to the boss tip where engine mount brackets will be attached in the production intent application. Accelerometers are to be rigidly attached (with a ± 1 dB allowable margin for adhesive compliance up to at least 1600 Hz at operating temperature). Vibration data should be measured for useable frequencies in the range up to 1600 Hz (suggested sampling rate 4096 Hz). For bracket or boss naming, "Left" and "Right" sides of the engine are as viewed from the engine flywheel, facing the front of the engine.

At the time of this update, vibration measurements are not to be used for assessment to requirements. Until appropriate experience-based requirements are established, vibration data is only to be used for product development purposes as input for structure-borne noise simulation.

4.4.3 Crankshaft Angular Motion. Crankshaft angular motion is to be measured for all manual transmission applications. Motion is to be measured at rear of the crankshaft, using a rotational laser vibrometer, a magnetic pick-up, or a high resolution (58X) crankshaft sensor signal. The rear location is defined as the end of the crankshaft where the flywheel attaches. Motion is to be measured relative to the engine case. If the vibrometer or pick-up transducer is mounted to something other than the engine, then the effects of engine case motion relative to the transducer must modify the signal by less than 5%. The measurement location and transducer mounting setup must be documented with the test results. Data will be measured for the engine firing frequency up to maximum engine speed, and for time domain peak levels for idle conditions, see 5.1.2.3.

4.5 Instructions.

4.5.1 Set up the engine and document the setup as described in 4.3.

4.5.2 Calibrate microphones, accelerometers and associated data acquisition and processing equipment.

4.5.3 Mount accelerometers to engine (and possibly transmission) and document locations as specified in 4.3.5. Accelerometers may need to be moved between bracket attachment locations to over the course of testing, if channel count or transducer availability is limited.

4.5.4 If crankshaft angular vibration is to be measured, set up the equipment for its measurement and document the set-up as specified in 4.4.3.

4.5.5 Determine and document the dimensions and location of the imaginary box to be used for measurement of sound power as specified in Appendix A, Figure A1. Locate the five (5) microphones used for measurement of sound power and document their location as specified in 4.3.5.1.

4.5.6 Locate the (optional) microphone under the engine for measurement of sound pressure on bottom of engine as described in 4.4.1.2. Document the location of the microphone.

4.5.7 Prepare and calibrate the sound intensity measurement system to be used to measure reactivity index using operating conditions 4 and 5 (as described in Table 1 and 4.4.1.1) and measure reactivity index as

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