SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE

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Measurement of Minimum Noise Emitted by Road Vehicles

RATIONALE

Updated to correct equations in Table 2 as well as the correct modifier in Appendix A's Item #5.

FOREWORD

This SAE Standard is derived from SAE J2805 which itself is derived from ISO 362-1. This SAE Standard retains relevant descriptions and requirements for measurement facilities, equipment, ambient conditions and other factors from SAE J2805.

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1. SCOPE

This SAE Standard is derived from SAE J2805 and specifies an engineering method for measuring the sound emitted by M and N category road vehicles at standstill and low speed operating conditions.. The specifications reproduce the level of sound which is generated by the principal vehicle sound sources consistent with stationary and low speed vehicle operating conditions relevant for pedestrian safety. The method is designed to meet the requirements of simplicity as far as they are consistent with reproducibility of results under the operating conditions of the vehicle.

The test method requires an acoustic environment which is only obtained in an extensive open space or in special designed indoor facilities replicating the conditions of an extensive open space. Such conditions usually exist during:

- Measurements of vehicles for regulatory certification.
- Measurements at the manufacturing stage.
- Measurements at official testing stations.

The results obtained by this method give an objective measure of the sound emitted under the specified conditions of test. It is necessary to consider the fact that the subjective appraisal of the annoyance, perceptibility, and/or detectability of different motor vehicles or classes of motor vehicles due to their sound emission are not simply related to the indications of a sound measurement system. As annoyance, perceptibility, and/or detectability are strongly related to personal human perception, physiological human condition, culture, and environmental conditions, there are large variations and therefore these terms are not useful as parameters to describe a specific vehicle condition.

Spot checks of vehicles chosen at random rarely occur in an ideal acoustic environment. If measurements are carried out on the road in an acoustic environment which does not fulfill the requirements stated in this SAE Standard, the results obtained may deviate appreciably from the results obtained using the specified conditions.

In addition, this standard provides an engineering method to assess the performance of external sound generation systems intended for the purpose of providing acoustic information to pedestrians on a vehicle's operating condition. This information is reported as objective criteria related to the external sound generation system's sound pressure level, frequency content, and changes in sound pressure level and frequency content as a function of vehicle speed. As such, these measures can provide pedestrians with information on the location, speed, direction of travel, acceleration, and deceleration behavior of a vehicle. Annex A contains background information relevant in the development of this SAE Standard.

2. REFERENCES

2.1 Applicable Documents

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1715 Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology

SAE J2805 Measurement of Noise Emitted by Accelerating Road Vehicles

2.1.2 ISO Publications

Available at http://webstore.ansi.org/

ISO 362-1:2007 Measurement of noise emitted by accelerating road vehicles - Engineering method - Part1: M and N Categories

ISO 10844:2014 Acoustics - Test surface for road vehicle noise measurements

ISO 26101:2012 Acoustics - Test methods for qualification of free-field environments

2.1.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60942:2003 Electroacoustics - Sound calibrators

IEC 61672-1:2002 Electroacoustics - Sound level meters - Part 1: Specifications

2.1.4 ANSI/ASA Publications

Available at http://webstore.ansi.org/

ANSI/ASA S1.11-2014 /Part1 / IEC 61260-1:2014 AMERICAN NATIONAL STANDARD Electroacoustics – Octave-band and Fractional-octave-band Filters – Part 1: Specifications

3. DEFINITIONS

For the purposes of this document, the following terms and definitions apply.

3.1 REFERENCE POINT

Point depending on the test purpose.

3.1.1 Reference point for gear selector indicating forward motion

The front end of the vehicle.

3.1.2 Reference point for gear selector indicating rearward motion

The rear end of the vehicle.

3.2 EXTERNAL SOUND GENERATION SYSTEM

System that provides an acoustic signal to the external environment of the vehicle for the purpose to provide information to pedestrians.

3.3 HIGHEST AUDIBLE FREQUENCY

Highest audible frequency of an external sound generation system as defined by the manufacturer.

3.4 COMPONENT

External sound generation system intended to emit sound information which can be tested separate from the vehicle.

3.5 CURB MASS

Complete shipping mass of a vehicle fitted with all equipment necessary for normal operation plus the mass of the following elements for M1, N1 and M2 having a maximum authorized mass not exceeding 3 500 kg:

— lubricants, coolant (if needed), washer fluid;

— fuel (tank filled to at least 90 % of the capacity specified by the manufacturer);

— other equipment if included as basic parts for the vehicle, such as spare wheel(s), wheel chocks, fire extinguisher(s), spare parts and tool kit

NOTE:The definition of curb (kerb) mass can vary from country to country, but in this SAE Standard, it refers to the definition contained in ISO 1176.

3.6 MASS IN RUNNING ORDER

Nominal mass of an N2, N3 or M2 vehicle having a maximum authorized mass greater than 3 500 kg, or an M3 vehicle as determined by the following conditions:

a. the mass is taken as the sum of the unladen vehicle mass and the driver's mass;

b. in the case of category M2 and M3 vehicles that include seating positions for additional crewmembers, their mass is incorporated in the same way and equal to that of the driver

NOTE 1 TO ENTRY: The driver's mass is calculated in accordance with ISO 2416.

3.7 FULL VEHICLE OPERATION

Operation of a vehicle with all systems and components operating as per the manufacturer's specification for normal road use.

3.8 SIMULATED VEHICLE OPERATION

Operation of a vehicle with some systems or components disabled to reduce noise interference during testing. Simulated vehicle operation may include external signals applied to the vehicle to simulate actual in-use signals.

3.9 LOWEST FREQUENCY OF INTEREST

Frequency below which there is no signal content relevant to the measurement of sound emission for the vehicle under test.

4. SYMBOLS AND ABBREVIATED TERMS

Table 1 - Lists symbols and the paragraph they are first used.

Symbol	Unit	Clause	Explanation
AA'	-	7.1.5.1	Line perpendicular to vehicle travel which indicates beginning of zone to record sound pressure level during test
BB'	-	7.1.5.1	Line perpendicular to vehicle travel which indicates end of zone to record sound pressure level during test
CC'	-	7.1.1	Centreline of vehicle travel
$f_{audible}$	Hz	7.1.6.4	Highest audible frequency of external sound generation system
$f_{i,\ speed}$	Hz	7.2.7.1	Single frequency component of external sound generation system at a given vehicle speed
$f_{i,\ ref}$	Hz	7.2.7.1	Single frequency component of external sound generation system at reference vehicle speed
del_f	%	7.2.4.3	Frequency shift expressed in percent of a reference frequency.
Δf	Hz	7.2.3	Frequency resolution of narrowband analysis used to measure frequency spectrums for the purpose of determining frequency shift information.
f_s	Hz	7.1.6.4	Sampling frequency used by digital signal processing system
j	-	6.3.2	Index for single test run within stopped or slow speed cruise test conditions
$L_{st,\ fwd}$	dB	7.1.8	Vehicle A-weighted sound pressure level in stationary forward condition.
$L_{sta,\ rev}$	dB	7.1.8	Vehicle A-weighted sound pressure level in stationary reverse condition.
L_{stop}	dB	7.1.8	Vehicle A-weighted sound pressure level
$L_{\ crs}$	dB	7.1.10	Cruise vehicle A-weighted sound pressure level
$L_{\ crs,\ 10}$	dB	7.1.10	Cruise vehicle A-weighted sound pressure level at a vehicle speed of 10 km/h.
$L_{\ crs,\ 20}$	dB	7.1.10	Cruise vehicle A-weighted sound pressure level at a vehicle speed of 20 km/h.
$L_{\ crs,\ 30}$	dB	7.1.10	Cruise vehicle A-weighted sound pressure level at a vehicle speed of 30 km/h.
L_{corr}	dB	6.3.2	Background noise correction
$L_{test,j}$	dB	6.3.2	A-weighted sound pressure level result of *j*th test run

Symbol	Unit	Clause	Explanation
$L_{testcorr,j}$	dB	6.3.2	A-weighted sound pressure level result of *j*th test run corrected for background noise
L_{bgn}	dB	6.3.1	Background A-weighted sound pressure level.
$L_{bgn,p-p}$	dB	6.3.2	Range of maximum to minimum value of the representative background noise A-weighted sound pressure level over a defined time period.
L_X	dB		A-weighted sound pressure level for any stationary or cruise condition for use in assessment of measurement uncertainty.
ΔL	dB	6.3.2	A-weighted sound pressure level of *j*th test result minus the A-weighted background noise level ($\Delta L = L_{test,j} - L_{bgn}$)
N	-	7.2.3	Block size of digital sample used for discrete Fourier transform or autopower spectrum analysis
PP’	-	7.1.5.2	Line perpendicular to vehicle travel which indicates location of microphones
$v_{AA'}$	km/h	5.2	Vehicle velocity when vehicle reference point in forward motion passes line AA’. See 3.1.1 for definition of reference point.
$v_{BB'}$	km/h	5.2	Vehicle velocity when vehicle reference point or rear of vehicle in forward motion passes line BB’. See 3.1.1 for definition of reference point.
$v_{PP'}$	km/h	5.2	Vehicle velocity when reference point in forward motion passes line PP’. See 3.1.1 for definition of reference point.
v_{ref}	km/h	7.2.4.4	Reference vehicle velocity used for calculating frequency shift percentage.
v_{test}	km/h	7.1.5.3	Target vehicle test velocity
AA’	-	7.1.5.1	Line perpendicular to vehicle travel which indicates beginning of zone to record sound pressure level during test

5. INSTRUMENTATION

5.1 Instruments for Acoustic Measurement

5.1.1 General

The apparatus used for measuring the sound pressure level shall be a sound level meter or equivalent measurement system meeting the requirements of Class 1 instruments (inclusive of the recommended windscreen, if used). These requirements are described in IEC 61672-1.

The entire measurement system shall be checked by means of a sound calibrator that fulfills the requirements of Class 1 sound calibrators according to IEC 60942.

Measurements shall be carried out using the time weighting "F" of the acoustic measurement instrument and the "A" frequency weighting also described in IEC 61672-1. When using a system that includes a periodic monitoring of the A-weighted sound pressure level, a reading should be made at a time interval not greater than 30 ms.

The instruments shall be maintained and calibrated in accordance to the instructions of the instrument manufacturer.

5.1.2 Calibration

At the beginning and at the end of every measurement session, the entire acoustic measurement system shall be checked by means of a sound calibrator as described in 5.1.1. Without any further adjustment, the difference between the readings shall be less than or equal to 0.5 dB. If this value is exceeded, the results of the measurements obtained after the previous satisfactory check shall be discarded.

5.1.3 Compliance with requirements

Compliance of the sound calibrator with the requirements of IEC 60942 shall be verified once a year. Compliance of the instrumentation system with the requirements of IEC 61672-1 shall be verified at least every 2 years. All compliance testing shall be conducted by a laboratory which is authorized to perform calibrations traceable to the appropriate standards.

5.2 Instrumentation for Speed Measurements

The road speed of the vehicle shall be measured with instruments meeting specification limits of at least ± 0.5 km/h when using continuous measuring devices.

If testing uses independent measurements of speed, this instrumentation shall meet specification limits of at least ± 0.2 km/h.

These requirements are only valid for full vehicle testing.

NOTE: Independent measurements of speed are when two or more separate devices will determine the v_{AA} v_{BB} and v_{PP} values. A continuous measuring device will determine all required speed information with one device

5.3 Meteorological Instrumentation

The meteorological instrumentation used to monitor the environmental conditions during the test shall meet the specifications of:

±1 °C or less for a temperature measuring device;

±1.0 m/s for a wind speed-measuring device;

± 5 hPa for a barometric pressure measuring device;

± 5 % for a relative humidity measuring device.

6. ACOUSTIC ENVIRONMENT, METEOROLOGICAL CONDITIONS, AND BACKGROUND NOISE

6.1 Test Site

6.1.1 General

The specifications for the test site provide the necessary acoustic environment to carry out the full vehicle or component level tests documented in this SAE standard. Outdoor and indoor test environments that meet the specifications of this SAE Standard provide equivalent acoustic environments and produce results that are equally valid.

6.1.2 Outdoor testing

The test site shall be substantially level. The test track construction and surface shall meet the requirements of ISO 10844:2011, ISO 10844:2014, or ISO 10844:1994.

Within a radius of 50 m around the center of the track, the space shall be free of large reflecting objects such as fences, rocks, bridges or buildings. The test track and the surface of the site shall be dry and free from absorbing materials such as powdery snow, or loose debris.

In the vicinity of the microphone, there shall be no obstacle that could influence the acoustic field and no person shall remain between the microphone and the noise source. The meter observer shall be positioned so as not to influence the meter reading.

NOTE 1: Buildings outside the 50 m radius might have significant influence if their reflection focuses on the test track.

NOTE 2: The term, “Substantially level” is intended to convey that the test site should not have slopes or discontinuities that would render invalid the assumption the site provided free-field acoustic propagation. This is not to limit slopes on the test site necessary for water management, drainage, etc. Engineering judgment is expected to be applied to determine the effect on the site of any obstacle. The test track itself is subject to the requirements specified.

NOTE 3: The ISO 10844:1994 and ISO 10844:2011 standards will be considered for removal at the next review period. It is recommended that all test surfaces be constructed to and meet the requirements of ISO 10844:2014.

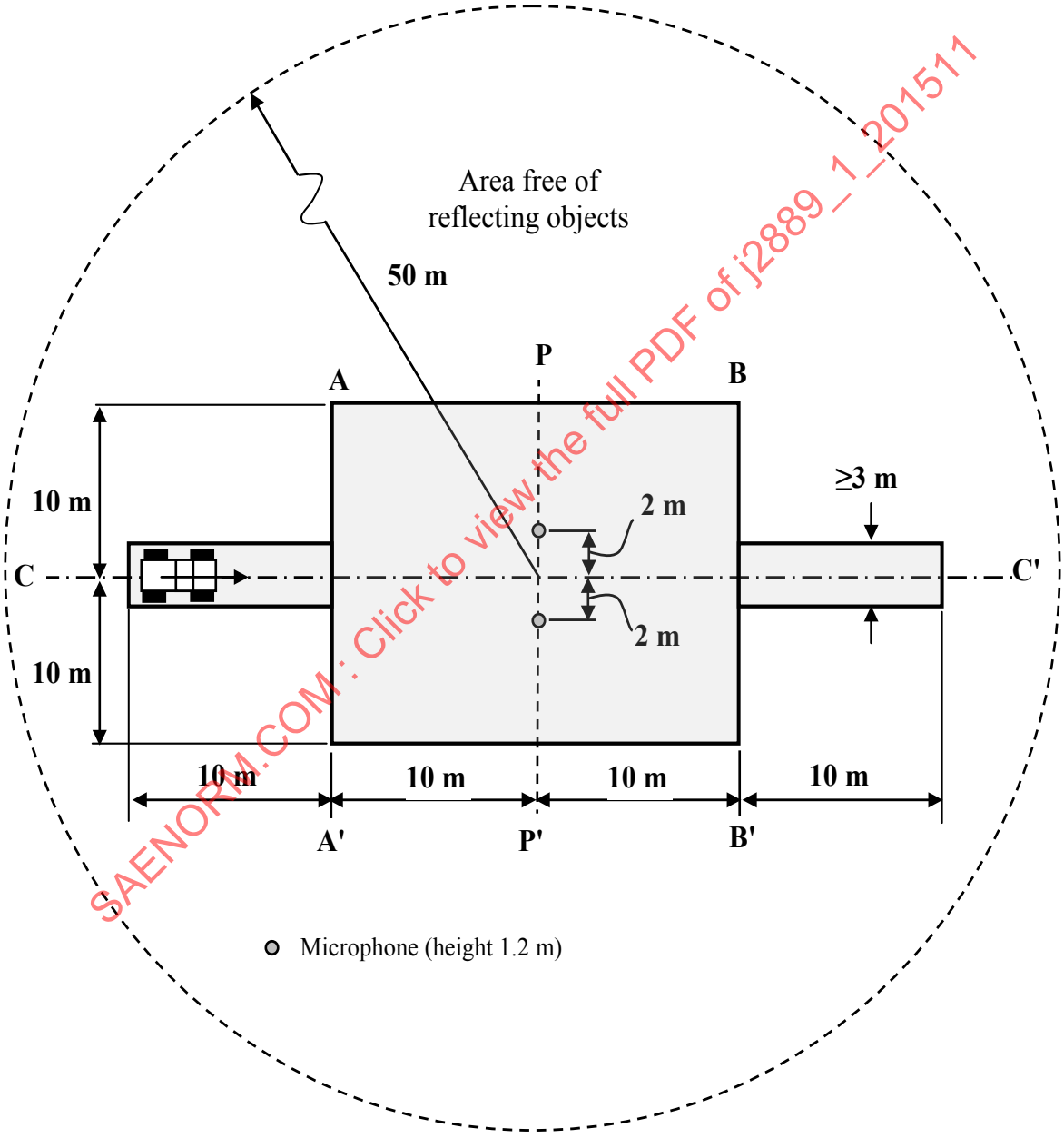

Figure 1 - Test site dimensions - shaded area is the minimum area to be covered with a surface complying with ISO 10844

6.1.3 This sub clause specifies conditions applicable when testing a full vehicle, either operating as it would on the road with all systems operational, or operating in a mode where only the external sound generation system is operational.

The test facility shall have a cutoff frequency, as defined in ISO 26101, lower than the lowest frequency of interest.

In the vicinity of the microphone, there shall be no obstacle that could influence the acoustic field and no person shall remain between the microphone and the noise source. The meter observer shall be positioned so as not to influence the meter reading. Microphones shall be located as specified in Figure 1.

NOTE:It is expected that users of this standard will understand that valid measurements can only be made when the cut-off frequency is lower than the lowest frequency of interest. A specific numerical requirement for cut-off frequency is not given due to the range of variation of appropriate cut-off frequencies depending upon the measured vehicle.

6.1.4 Indoor external sound generation system testing

This sub clause specifies conditions applicable when testing only the external sound generation system separate from the vehicle.

The test facility shall meet the requirements of ISO 26101.

The test facility shall have a cutoff frequency lower than the lowest frequency of interest.

In the vicinity of the microphone, there shall be no obstacle that could influence the acoustic field and no person shall remain between the microphone and the noise source. The meter observer shall be positioned so as not to influence the meter reading. Microphones shall be located as specified in 7.2.4.1.1

6.2 Meteorological Conditions

6.2.1 General

Metrological conditions are specified to provide a range of normal operating temperatures and to prevent abnormal readings due to extreme environmental conditions.

A value representative of temperature, relative humidity, and barometric pressure shall be recorded during the measurement interval.

6.2.2 Outdoor measurements

The meteorological instrumentation shall deliver data representative for the test site and shall be positioned adjacent to the test area at a height representative of the height of the measuring microphone.

The measurements shall be made when the ambient air temperature is within the range from 5 to 40 °C.

The ambient temperature may of necessity be restricted to a narrower temperature range such that all key vehicle functionalities that can reduce vehicle noise emissions (e.g., start/stop, hybrid propulsion, battery propulsion, fuel-cell stack operation) are enabled per manufacturer's specifications.

The tests shall not be carried out if the wind speed, including gusts, at microphone height exceeds 5 m/s, during the sound measurement interval.

6.2.3 Indoor measurements

The measurements shall be made when the ambient air temperature is within the range from 5 to 40 °C.

The ambient temperature may of necessity be restricted to a narrower temperature range such that all key vehicle functionalities that can reduce vehicle noise emissions (e.g., start/stop, hybrid propulsion, battery propulsion, fuel-cell stack operation) are enabled per manufacturer's specifications.

6.3 Background Noise

6.3.1 Measurement criteria for A-weighted sound pressure level

The background, or ambient noise, shall be measured for duration of at least 10-seconds before and after a series of vehicle tests. A 10 second sample taken from this measurement shall be used to calculate the reported background noise, taking account to insure the 10 second sample selected is representative of the background noise in absence of any transient disturbance. The measurements shall be made with the same microphones and microphone locations used during the test.

When testing in an indoor facility, the noise emitted by the roller-bench, chassis dynamometer, or other test facility equipment, without the vehicle installed or present, inclusive of the noise caused by air handling, facility vehicle cooling, shall be reported as the background noise.

The maximum A-weighted sound pressure level in the selected 10 second sample shall be reported as the background noise, L_{bgn}, along with the maximum to minimum range of the background noise from both microphones,, $L_{bgn, p\text{-}p}$, and the 1/3 octave frequency corresponding to the reported maximum level of background noise, shall be reported per ANSI S1.11, Class 1. Figure 2 provides graphical information on the determination of the range of background noise.

When analysis in 1/3 octaves is required, the background noise shall meet the requirements of 6.3.3

NOTE 1:Background noise measurements account for the variations both in time and in both microphones. The intent of the above statement is to capture the entire range of variation experienced at the test facility to provide an assessment of the suitability of the test facility to carry out the specified measurement..

NOTE 2:The range of background noise, $L_{bgn, p\text{-}p}$, is specified to ensure the background noise is sufficiently stationary, in an acoustic sense, to be able to apply the background correction of Table 2 to A-weighted sound pressure levels. One-third octave measurements do not have the necessary background noise time stability to allow for compensation.

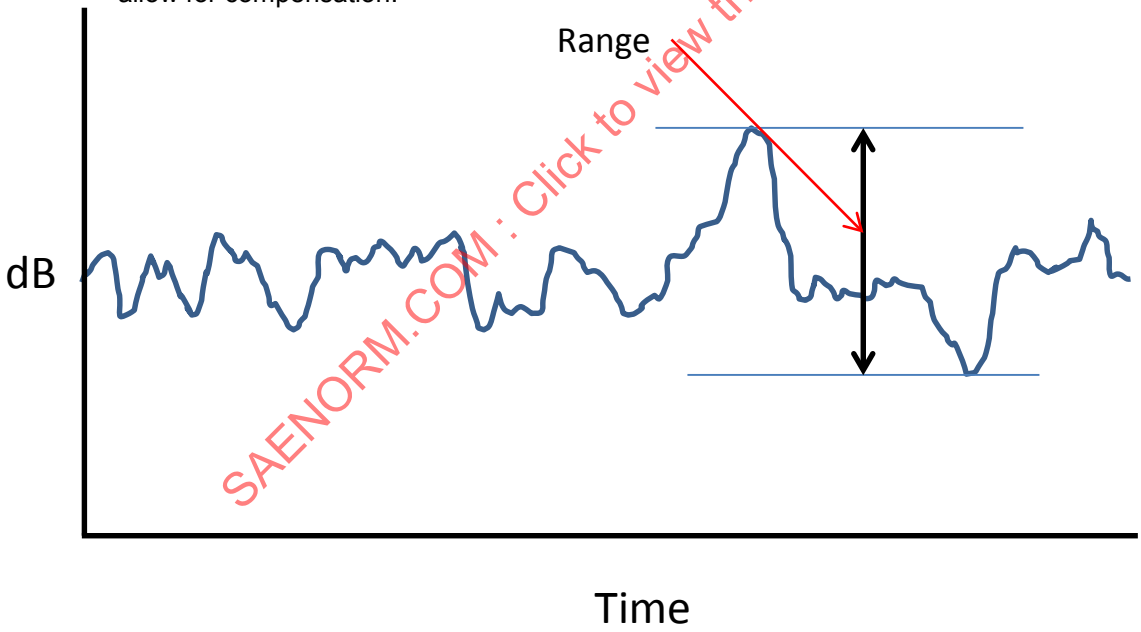

Figure 2 - Determination of the range of background noise.

6.3.2 Vehicle A-weighted sound pressure level measurement correction criteria

Depending on the level and peak to peak fluctuation of the background noise, the measured *j*th test result within a test condition, $L_{test,j}$, shall be corrected according to the table below to obtain the noise-corrected level $L_{testcorr,j}$. Except where noted, $L_{testcorr,j} = L_{test,j} - L_{corr}$.

Table 2 - Correction for background noise when measuring full vehicle overall sound pressure level.

Correction for Background Noise			
Background Noise Level L_{bgn}	Range of maximum to minimum value of the representative background noise A-weighted sound pressure level over a defined time period in dB $L_{bgn,\ p\text{-}p}$	Sound Pressure Level of *j*th test result minus Background Noise Level in dB $\Delta L = L_{test,j} - L_{bgn}$	Correction in dB L_{corr}
> 25 A-weighted sound pressure level (dBA)		$\Delta L > 10$	0 dB
	< 2	$8 \le \Delta L < 10$	0.5 dB
		$6 \le \Delta L < 8$	1.0 dB
		$4.5 \le \Delta L < 6$	1.5 dB
		$3 \le \Delta L < 4.5$	2.5 dB
		$\Delta L < 3$ dB	Do not correct, report out: $L_{testcorr,\ j} \le L_{bgn}$
< 25 A-weighted sound pressure level (dBA)	See 6.3.2, paragraph 4	$L_{bgn} < 10$ dB	Do not correct, report out: $L_{testcorr,\ j} < L_{test,j}$
		$L_{bgn} > 10$ dB	0 dB

The trained technician should ensure that measurements are only performed when there is no transient disturbance that could potentially result in an inappropriate noise correction.

Background noise corrections to measurements are only valid when the range of the maximum to minimum background noise A-weighted sound pressure level are 2 dB or less. In all cases where the range of the maximum to minimum background noise is greater than 2dB, the maximum level of the background noise shall be 10 dB or greater below the level of the measurement. When the maximum to minimum range of background noise is greater than 2 dB and the level of the background noise is less than 10 dB below the measurement, no valid measurement is possible.

Background compensation is not permitted for one-third octave band measurements.

These criteria are established to ensure accurate vehicle measurements while recognizing the practical issue that A-weighted sound pressure levels lower than 25 dB are not necessary to measure accurately for the purposes of this SAE Standard. The use of indoor test facilities may be necessary to achieve the specifications in this SAE Standard.

NOTE: The requirements for margin between background noise and test results are given to maintain an uncertainty of 1 dB or less solely due to background noise. Total measurement uncertainty will include uncertainty due to additional factors.

6.3.3 Background noise requirements when analyzing in one-third-octave bands

When analysing one-third octaves according to this International Standard, the level of background noise in each one-third octave of interest, analysed according to 6.3.1, shall be at least 6 dB below the measurement of the vehicle or external sound generation system under test in each one-third-octave band of interest. The overall A-weighted sound pressure level of the background noise shall be at least 10 dB below the measurement of the vehicle or external sound generation system under test.

Background compensation is not permitted for one-third octave band measurements.

6.3.4 Measurement background noise when testing a component

When measuring an external sound generation system separate from the vehicle as provided in this International Standard, the background noise level shall be at least 10 dB lower than the measured level of the component under test.

The background, or ambient noise, shall be measured for a duration of at least 10 s before and after a series of vehicle tests. A 10-s sample taken from this measurement shall be used to calculate the reported background noise, taking account to ensure the 10-s sample selected is representative of the background noise in absence of any transient disturbance. The measurements shall be made with the same microphones and microphone locations used during the test.

The maximum A-weighted sound pressure level in the combined 10-s samples shall be reported as the background noise, L_{bgn} along with the one-third-octave frequency spectrum per ANSI S1.11, Class 1, corresponding to the maximum level of background noise, shall be reported. For measurements where narrowband results are reported, the narrowband background noise shall be reported at the same frequency resolution as the measurement results.

7. TEST PROCEDURES

7.1 Full Vehicle Testing

7.1.1 Microphone positions

The distance from the microphone positions on the microphone line PP' to the perpendicular reference line CC' (see ISO 10844) as specified in Figure 1 on the test track or in an indoor test facility shall be 2.0 m ± 0.05 m.

The microphone shall be located 1.2 m ± 0.02 m above the ground level. The reference direction for free field conditions as specified in IEC 61672-1 shall be horizontal and directed perpendicularly towards the path of the vehicle line CC'.

7.1.2 Conditions of the vehicle

7.1.2.1 General conditions

The vehicle shall be supplied as specified by the vehicle manufacturer.

Before the measurements are started, the vehicle shall be brought to its normal operating conditions.

7.1.2.2 Battery state of charge

If so equipped, propulsion batteries shall have a state-of-charge sufficiently high to enable all key functionalities per the manufacturer's specifications. Propulsion batteries shall be within their component-temperature window to enable all key functionalities that could reduce vehicle noise emissions. Any other type of rechargeable energy storage system shall be ready to operate during the test.

7.1.2.3 Accessory loads

If the vehicle is equipped with an internal combustion engine and a second source of propulsive power, all vehicle loads that may automatically force an engine re-start or prevent engine shut down shall be switched off.

All audio, entertainment, communication, and navigation systems shall be switched off.

NOTE: Example loads could include air conditioning, defroster operation, window de-icing, seat heaters or coolers, etc.

7.1.2.4 Multi-mode operation

If the vehicle is equipped with multiple driver selectable operating modes, the mode which provides the lowest sound emission during the test conditions of 7.1.5 shall be selected.

When the vehicle provides multiple operating modes that are automatically selected by the vehicle, it is the responsibility of the manufacturer to determine the correct manner of testing to achieve the minimum sound emission.

In cases where it is not possible to determine the vehicle operating mode providing the lowest sound emission, all modes shall be tested and the mode giving the lowest test result shall be used to report the vehicle sound emission per this SAE Standard.

NOTE: Modes include, but are not limited to: Engine operation state (on or off), driver selectable operating modes (sport, eco, winter, etc.), vehicle selectable operating modes (sport, eco, winter, etc.,), and transmission selection mode (sport, eco, winter, etc.). This does not include transmission gear selection such as Park, Drive, Reverse, or Neutral.

7.1.2.5 Vehicle non-pedestrian safety warning signals

No sound or noise source not related to pedestrian safety shall operate during the tests..

NOTE: The purpose of this requirement is to ensure no sound or noise source not related to pedestrian safety shall operate during the test.

7.1.3 Test mass of the vehicle

Measurements shall be made on vehicles at curb mass or mass in running order, as defined by the manufacturer with an allowable tolerance of ±15 percent.

7.1.4 Tire selection and condition

The tires for test are selected by the vehicle manufacturer, and shall correspond to one of the tire sizes and types designated for the vehicle by the vehicle manufacturer.

NOTE: Tire noise will contribute to the sound emission of the vehicle at any speed over 0 km/h. At vehicle speeds in excess of 20 km/h, tire noise will have a significant contribution to measured sound pressure levels.

7.1.5 Operating conditions

7.1.5.1 General Conditions

The path of the centerline of the vehicle shall follow line CC' as closely as possible throughout the entire test, from the approach to line AA' until the rear of the vehicle passes line BB'. Any trailer, which is not readily separable from the towing vehicle, shall be ignored when considering the crossing of the line BB'.

For the purpose of measuring the performance of an external sound generation system, the sound pressure level of the vehicle may be measured with the vehicle at 0 km/h and the external sound generation system controlled as to simulate operation at any vehicle speed of interest. In such cases, the true test level at the vehicle speed of interest will be equal or higher to the simulated test level.

7.1.5.2 Test speeds

The vehicle shall reach the test speed, v_{test}, when the reference point according to 3.1 is at line PP'. During the constant speed test the acceleration control unit shall be positioned to maintain a constant speed between AA' and BB'. The vehicle shall be operated as defined by the manufacturer for normal operation.

NOTE: Normal operation may include shutoff of one or more propulsion sources.

7.1.5.3 Standstill Conditions

7.1.5.3.1 General

The test speed v_{test} shall be 0 km/h with the reference point on the PP' line.

If the vehicle is equipped with an internal combustion engine and a second source of propulsive power, the stopped condition test measurement shall be made after a time delay from the vehicle stopped condition to allow engine shutdown, and before vehicle loads can force an engine re-start.

7.1.5.3.2 Forward testing

For forward testing, the front plane of the vehicle shall be on the PP' line.

7.1.5.3.3 Backing testing

For backing testing, the rear plane of the vehicle shall be on the PP' line.

7.1.5.3.4 Manual transmission vehicle

The vehicle shall be tested in the appropriate stopped mode as defined in 7.1.2.4. The gear selector shall be in a gear and the vehicle shall remain at 0 km/h for the duration of the test. The manufacturer shall determine the appropriate condition for testing.

NOTE: The common situation for stopped vehicle testing would be for a manual transmission vehicle to have the gear selector in neutral. However, for the purpose of this test, the intention is to place the vehicle in a state where it is ready to move.

7.1.5.3.5 Automatic transmission vehicle

The vehicle shall be tested in the appropriate stopped mode as defined in 7.1.2.4. The gear selector shall be in in the normal driving position for testing when the front plane of the vehicle is on the PP' line. The gear selector shall be in the reverse driving position for testing when the rear plane of the vehicle is on the PP' line. The vehicle shall remain at 0 km/h for the duration of the test, the manufacturer shall determine the appropriate condition for testing.

7.1.5.3.6 Vehicle commencing motion

The test speed v_{test} shall be 0 km/h with the reference point on the PP' line.

The vehicle sound pressure level shall be measured for a duration of 15 s.

If the vehicle is equipped with an internal combustion engine and a second source of propulsive power, the stopped condition test measurement shall be made after a time delay from the vehicle stopped condition to allow engine shutdown, and before vehicle loads can force an engine re-start

7.1.5.4 Slow speed cruise

7.1.5.4.1 General

If a vehicle is tested in an indoor facility, the vehicle shall be located with the front or rear reference point on the PP' line, as appropriate. The vehicle A-weighted sound pressure level shall be measured for a duration of 5 s and reported. The one-third-octave frequency spectrum corresponding to the reported maximum A-weighted sound pressure level shall be reported,

7.1.5.4.2 Automatic transmission vehicle

The gear selector shall be placed as specified by the manufacturer for normal driving.

7.1.5.4.3 Manual transmission vehicle

The gear selector shall be placed in the highest gear which can achieve the target vehicle speed with constant engine speed.

7.1.5.4.4 Forward testing at 10 km/h

The test speed v_{test} shall be 10 km/h ± 1.0 km/h between AA' and PP'.

7.1.6 Measurement Readings and Reported Values

7.1.6.1 General

It is recommended that persons technically trained and experienced in current sound measurement techniques select the test instrumentation and conduct the tests.

At least four measurements for all test conditions shall be made on each side of the vehicle and for each mode tested.

The first four *j*th valid consecutive measurement results for any test condition, within 2.0 dB of overall SPL, allowing for the deletion of non-valid results, shall be used for the calculation of the appropriate intermediate or final result.

NOTE: Satisfying the criteria listed above requires evaluation of measured sound pressure data vs. time to select the appropriate time segments for proper analysis and reporting of measured values according to this SAE Standard.

7.1.6.2 Measurement of a vehicle in standstill conditions

This paragraph specifies the requirements to measure the vehicle sound emission in standstill conditions.

The vehicle sound pressure level shall be measured for duration of 5 s.

The maximum A-weighted sound pressure level indicated during each standstill run for each microphone position, $L_{test,j}$, shall be noted, to the first significant digit after the decimal place (for example – XX,X). If a sound peak obviously out of character with the general sound pressure level is observed, that measurement shall be discarded. The selected sound sample shall be representative of the vehicle minimum sound emission in the condition of test in absence of any transient disturbance. $L_{test,j}$ shall be corrected according to 6.3.2 to obtain $L_{testcorr,j}$.

For each maximum A-weighted sound pressure level for each microphone position, the corresponding one-third-octave results for each microphone position , shall be reported.

7.1.6.3 Measurement of a vehicle in motion

This paragraph specifies the requirements to measure the vehicle sound emission in motion.

7.1.6.3.1 Outdoor testing

The maximum A-weighted sound pressure level indicated during each passage of the vehicle between AA' and PP' ($L_{test,j}$) shall be noted for each microphone position, to the first significant digit after the decimal place (for example – XX,X).

If a sound peak obviously out of character with the general sound pressure level is observed, that measurement shall be discarded. The selected sound sample shall be representative of the vehicle minimum sound emission in the condition of test in absence of any transient disturbance. $L_{test,j}$ shall be corrected according to 6.3.2 to obtain $L_{testcorr,j}$.

For each maximum A-weighted sound pressure level, the corresponding one-third-octave spectrum shall be reported for each microphone position.

7.1.6.3.2 Indoor testing

The vehicle sound pressure level shall be measured for duration of 5 s.

If a sound peak obviously out of character with the general sound pressure level is observed, that measurement shall be discarded. The selected sound sample shall be representative of the vehicle minimum sound emission in the condition of test in absence of any transient disturbance. $L_{test,j}$ for each microphone position shall be corrected according to 6.3.2 to obtain $L_{testcorr,j}$.

For each maximum A-weighted sound pressure level, the corresponding one-third-octave spectrum shall be reported for each microphone position.

7.1.6.3.3 Analysis in one-third-octave bands

This paragraph specifies the requirements to analyze in one-third-octave bands in any vehicle or component configuration.

Background noise shall meet the requirements of 6.3.3. Any one-third octave spectrum measured when the conditions of 6.3.3 are not satisfied may only be reported for information.

No background correction shall be applied to any measured one-third octave result.

NOTE: The test conditions are standstill, and cruise.

7.1.6.4 Measurement of a vehicle commencing motion

This paragraph specifies the requirements to measure the peak vehicle noise emission characteristic for a commencing motion sound.

The A-weighted sound pressure level measured during each specified test period shall be recorded to the first significant digit after the decimal place (for example – XX.X).

Measurement starts with the vehicle stopped and the propulsion system active for sufficient period to achieve stable operation, the transmission in any drive gear, and the service brakes activated to hold the vehicle stationary; for manual transmission vehicles, the clutch pedal shall also be depressed.

After 5 s ±2 s the service brakes are released and vehicle motion is initiated to accelerate the vehicle from full stop triggering the commencing motion sound. The commencing motion sound should be recorded for a period of 3 s - 5 s.

The sustained peak A – weighted sound pressure level measured during each test shall be noted to the first decimal (see Figure 2). If a sound peak obviously out of character with the general sound pressure level is observed, that measurement shall be discarded.

The sample frequency, F_s ,shall be 2 times higher than the highest audible frequency, $F_{audible}$,in order to avoid leakage effects.

The minimum sample frequency shall be 24,000 Hz.

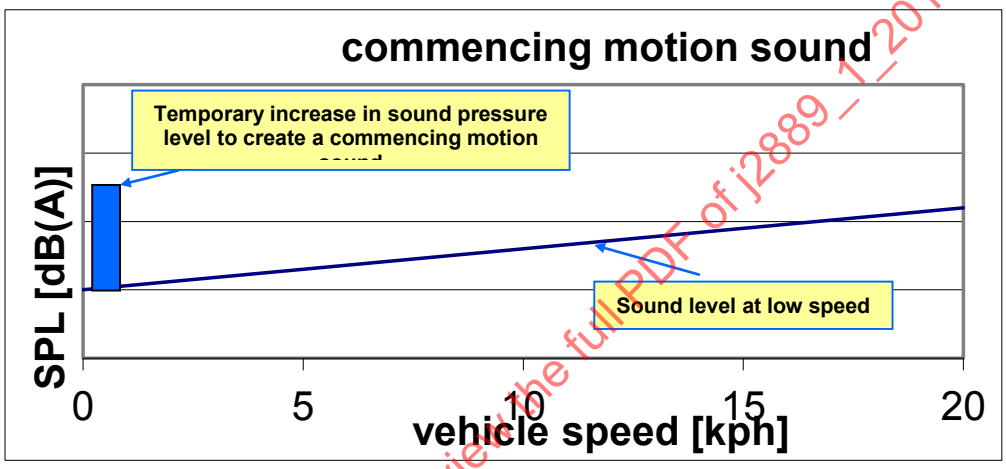

Figure 3 - Illustrative example of commencing motion sound

7.1.7 Data compilation

For a given test condition and mode (7.1.2.4) the background-corrected results, $L_{testcorr,j}$, and the corresponding one-third-octave spectrums of each side of the vehicle for each individual test shall be averaged separately. The average for each side shall be rounded to the first decimal place. The A-weighted sound pressure level intermediate result is the lower value of the two averages as follows:

For ΔL < 3 dB, and L_{bgn} p-p <= 2 dB, L_{crs} and L_{stop} shall be expressed as the lower or equal to the intermediate result;

For all other cases, L_{crs} and L_{stop} shall be expressed as equal to the intermediate result.

The one-third octave reported spectrum shall be the arithmetic average of the four individual run one-third-octave spectra corresponding to the maximum A-weighted sound pressure level for each individual measurement run.

If individual run results are reported as an inequality, this value shall be used in subsequent averaging and the intermediate result shall be reported as an inequality.

7.1.8 Stationary results

The L_{stop} value for each mode according to 7.1.2.4 shall be the result from 7.1.5.3 using the definitions of 7.1.6

If 1/3 octave bands are analyzed, they shall use the result of 7.1.6.3.3

7.1.9 Commencing motion result

The L_{cm} value for each mode according to 7.1.2.4 shall be the result from 7.1.5.4 using the definitions of 7.1.6

If 1/3 octave bands are analyzed, they shall use the result of 7.1.6.3.3

7.1.10 Slow speed cruise result

The L_{crs} value for each mode according to 7.1.2.4 shall be the result from 7.1.5.5 using the definitions of 7.1.6

If 1/3 octave bands are analyzed, they shall use the result of 7.1.6.3.3

7.1.11 Reported value

The reported value L_{stop} and L_{crs} shall be the minimum of the L_{stop} and L_{crs} values determined according to 7.1.5.3 and 7.1.5.5 for each mode according to 7.1.2.4.

7.2 Measurement of Sound to Determine Frequency Shift

7.2.1 General

The specifications contained in these sections are intended to measure the emitted acoustic information from an external sound generation system installed for purposes of providing acoustic information to pedestrians in the near vicinity of a vehicle. The information so measured characterizes the frequencies emitted by the system, as well as the change in frequency as a function of vehicle operating parameters.

No background correction shall be applied to any measured result.

See Annex B for further information on frequency shift

7.2.2 Instrumentation

The entire acoustic measurement system including microphone(s) and any subsequent measurement apparatus shall fulfill the requirements of IEC 61672-1 class 1 sound level meter.

The digital sound recording system shall have at least a 16 bit quantization. The sampling rate, F_s, and the dynamic range shall be appropriate to the signal of interest.

NOTE: No specific requirements have been given for sampling rate due to the wide range of signal frequency content that may be analysed. It is expected that knowledgeable and trained personnel will select appropriate sampling rates.

7.2.3 Signal processing requirements

The frequency resolution, Δf, of the measurement shall be 1 Hz or less. The sound analysis system shall be capable of performing Discrete Fourier Transform and Auto Power Spectrum analysis at a frequency resolution and over the frequency range containing all frequencies of interest. The block size, N, used for subsequent signal processing shall enable the required Δf, where $\Delta f = F_s/N$.

Analyzer settings shall be determined by the user to provide data according to these requirements.

7.2.4 Test facilities

The test facility shall meet the requirements of 6.1

7.2.4.1 Vehicle test facilities

The test facility shall meet the requirements of 6.1

7.2.4.2 Component test facilities

The test facility shall meet the requirements of 6.1

The sound emitting component of the external sound generation system is recommended be mounted 0,5 m above a reflecting plane (floor) of the test space. The primary propagation axis of the sound emitting component shall be oriented horizontal to the reflecting plane.

The microphone is recommended be located 1.0 m from the centre of the component at a height of 0.5 m.

NOTE: Specific recommendations have been given for placement of the external sound generation system and the microphone within the test facility to provide guidance for successful testing. There are other arrangements of the external sound generation system and microphone that can be effective to measure frequency content.

7.2.5 Frequency shift measurement test procedure

7.2.5.1 General

The frequency shift shall be measured by a vehicle, a simulated vehicle operation, or a component based test procedure.

7.2.5.1.1 Full vehicle operation

The vehicle shall be installed in an indoor test facility where the vehicle can operate in the same manner as outdoors. The test facility shall have the capability to simulate actual road load input to the vehicle. All microphone locations shall be as for the full vehicle test conditions as specified in Figure 1. The front plane of the vehicle shall be on the PP' line.

Outdoor variant : The vehicle shall be operated in the same outdoor test facility and according to the same general operating condition as for the full vehicle testing (§ 7.1). The microphone shall be installed on board of the vehicle in the direct vicinity of the emitting surface of the external sound generating system. The acquisition system shall be installed on board of the vehicle.

A frequency, f_i, shall be identified that is intended to change as a function of vehicle speed, which can be measured and can be tracked for operating conditions specified in this SAE Standard.

NOTE 1: Typical signal analysis tools provide frequency and time coordinates of the tonal component can be obtained by using a cursor on the autopower spectrogram to pick frequency and time coordinates that correspond with vehicle speed.

NOTE 2: No specific frequency identification process has been specified as there is no known identification specification that can clearly identify frequencies which shift with vehicle operating conditions, primarily vehicle speed, when the frequency content of the desired signal and any background noise is unknown. See Appendix B for further information.

NOTE 3: It is not recommended to carry out the frequency shifting measurements in outdoor facilities with the vehicle in motion. At the present time, accurate frequency measurements from a moving object over a speed range relative to the stationary PP' microphones will not provide reliable results. It is not recommended to carry out the frequency shifting measurements in outdoor facilities with the vehicle in motion using signal from PP' microphones. On board microphones do not have relative motion from the sound generation system and deliver a reliable signal for frequency shifting measurement.

NOTE 4: It is understood when using an indoor test facility that the vehicle will remain in position relative to the microphones. This is for the purpose to provide an acoustically stationary signal for subsequent analysis and reporting of results.

NOTE 5: For on-board microphone installed in the direct vicinity of the emitting surface of the external sound generating system, it is recommended :

- to position the microphones on the axis (if it exists) of the acoustic emission of the system,
- at a distance of 8 cm from the emitting surface : not too far to be polluted by other noises, not too closed to have no any distorted signal
- to use a decoupling attachment device between microphone and vehicle body

It is not recommended to perform the pitch shifting measurements in indoor facilities with the tires rotating. This is due to the contaminating signal from the tire/roll interface.

7.2.5.1.2 Simulated vehicle operation (for indoor or outdoor)

The vehicle shall be operated in a test facility where the vehicle can accept an external vehicle speed signal simulating vehicle operation. All microphone locations shall be as for the full vehicle test conditions as specified in Figure 1. The front plane of the vehicle shall be on the PP' line.

A frequency, f_i, shall be identified that is intended to change as a function of vehicle speed, which can be measured and can be tracked for operating conditions specified in this International Standard.

NOTE 1: Typical signal analysis tools provide frequency and time coordinates of the tonal component can be obtained by using a cursor on the autopower spectrogram to pick frequency and time coordinates that correspond with vehicle speed.

NOTE 2: No specific frequency identification process has been specified as there is no known identification specification that can clearly identify frequencies which shift with vehicle operating conditions, primarily vehicle speed, when the frequency content of the desired signal and any background noise is unknown. See Appendix B for further information.

NOTE 3: It is understood when using an indoor test facility that the vehicle will remain in position relative to the microphones. This is for the purpose to provide an acoustically stationary signal for subsequent analysis and reporting of results. The use of the simulated operation further removes potentially interfering noise due to the tyre/road noise.

7.2.5.1.3 Component test procedure

A frequency, f_i, shall be identified that is intended to change as a function of vehicle speed, which can be measured and can be tracked for operating conditions specified in this International Standard.

NOTE: Typical signal analysis tools provide frequency and time coordinates of the tonal component can be obtained by using a cursor on the auto spectrum to pick frequency and time coordinates that correspond with vehicle speed or other vehicle operating parameters of interest.

7.2.5.2 Measurement procedure

The frequency characteristics of the sound shall be measured together with an input signal to the external sound generation system corresponding to the reference vehicle

The sound output of the system shall be measured as follows:

- Record at least 5 seconds of the sound.
- Using a Hanning window, calculate the autopower of the signal with a frequency resolution of at least 1 Hz using at least 66.6% overlapping averages from the 5 second time signal.

1. The main frequencies, $f_{i,speed}$, of the external sound generation system shall be measured and recorded. The corresponding vehicle speeds, $f_{i,speed}$ and $f_{i,ref}$ shall be measured and recorded

2. Calculate *del_f*, the frequency shift of the external sound generation system signal according to equation (1):

$$del\_f = \{[(f_{i,speed} - f_{i,ref})/(v_{test} - v_{ref})]/f_{i,ref}\} \cdot 100 \quad \text{(Eq. 1)}$$

where

$f_{i,speed}$ is the frequency at a given speed value;

$f_{i,ref}$ is the frequency at the reference speed value;

v_{test} is the vehicle velocity, actual or simulated, corresponding to the frequency $f_{i,speed}$;

v_{ref} is the vehicle velocity, actual or simulated, corresponding to the frequency $f_{i,ref}$;

This equation is only valid when the actual vehicle speed, v_{test}, is higher than the reference vehicle speed, v_{ref}

3. Results shall be reported using Table 3.

Table 3 - Vehicle speeds for measurement

Target Speed	**Actual Speed Km/h**	**Frequency,** $f_{i,\ speed}$ (Hz)	**Frequency Shift**
Reference vehicle speed			Not Applicable
10 km/hr			
15 km/hr			
20 km/hr			

NOTE: The reference speed should be 5 km/h unless other speeds are desired.

8. TEST REPORT

The test report includes the following information:

a. Reference to this SAE Standard;

b. Details of the test site, site orientation and weather conditions including wind speed, air temperature, wind direction, barometric pressure, and humidity; or if an indoor facility is used, description of the facility including dimensions and cut-off frequency of facility;

c. The type of measuring equipment, including the windscreen;

d. The A-weighted sound pressure level typical of the background noise;

e. The one-third-octave-band spectrum typical of the background noise;

f. The identification of the vehicle, its engine, its transmission system, including available transmission ratios, size and type of tires, tire pressure, tire production type, power, test mass, vehicle length and location of the reference point;

g. The auxiliary equipment of the vehicle, where appropriate, and its operating conditions;

h. All valid A-weighted sound pressure level values measured for each test, listed according to the side of the vehicle and the direction of the vehicle movement on the test site;

i. All valid individual narrowband frequencies measured and all one-third octave frequency spectra measurements for each test;

j. The technology content of the vehicle's propulsion system (e.g., internal combustion engine, stop/start, battery electric, hybrid, plug-in hybrid, extended-range electric, fuel cell);

k. Any special test or vehicle conditions, including operating modes of the vehicle, or settings reflective of the technology content listed in j);

l.)If a vehicle is being tested to measure the sound emission performance of an external sound generation system, this system shall be noted in the report;

m. The final results $L_{crs,10}$, $L_{st,rev}$ and $L_{st,fwd}$

9. NOTES

9.1 Marginal Indicia

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