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Acoustics — Measurement of interior vehicle noise

Acoustique — Mesurage du bruit intérieur des véhicules

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 5128:1980), which has been technically revised.

The main changes are as follows:

— new technology neutral test method;

— updated test equipment;

— updated facility descriptions;

— new evaluation principle (instead L_{max} to $L_{A,eq}$)

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This measurement procedure for interior vehicle noise as presented by this document has been completely revised to better match the application needs.

The interior noise of modern vehicles has such improved, that hearing damages even under high engine speeds and loads are unlikely. Assessments on the application of the document reveal a changed focus on protection of drivers and passenger in a direction of long-term exposure in a sense of working place protection.

In most countries provisions exist, which regulate the noise burden on workers on a basis of a noise exposure over a period of 8 hours per day, a full working week over a work life of 35 years. In addition, aspects of driver distraction and fatigue have become a stronger emphasis. In order to match this application, it is no longer given to determine the maximum sound level from a set of measurements, as was provided by the previous release.

The target of this edition is to determine a time average interior sound level, which is representative for the typical driving and use of a vehicle. Therefore, in-use driving statistics were reviewed and new in-use driving data generated by the group members. A strong focus was put on the WLTP, WHVC and VECTO statistics [1][2][3] which so far provides the biggest source of statistical information.

However, it should be kept in mind that the sound inside a vehicle is strongly influenced by external factors. These factors are different for various vehicle categories. During normal driving for passenger cars at low engine speeds and loads, the sound inside the cabin comes mainly from tyre rolling sound transferred via structure- and air paths. The excitation of the tyre is dependent on the structure of the surface and the characteristics of the tyre, such as the hardness of the rubber and the tyre dimension. This standard cannot cover all eventual excitation models for smooth and rough roads or soft and hard tyres. For reproducibility a road texture has been chosen, which is commonly used in test centre.

For heavy commercial vehicles with large cabin, wind noise can become very dominant at speeds beyond 60 km/h. The wind direction, especially as lateral wind, can be very changeable.

The driving cycles differ strongly with regard to vehicle categories, the used speeds and accelerations dependent on the area, where the vehicles are used. The document provides individual cycles for urban, suburban, rural and motorway conditions, all four applicable to light duty vehicles and three of them for heavy duty vehicles. In urban and suburban areas, the interior sound of a vehicle is a mixture of powertrain and tyre rolling sound components. For rural and motorway conditions the influence of powertrain is reduced but wind noise provides a stronger contribution, especially for large trucks and buses.

The combination of the cycles is very much dependent on the typical use of a vehicle. A large variation may exist for the same product. This document focuses on a typical use for vehicle categories, but it has to be kept in mind, that a substantially different use, may lead to other results. A standardized data processing for a given vehicle category will allow benchmarking of products. The availability of the individual cycle results enables as well an estimation of the interior sound for other conditions of use.

Another important factor is the total driving time within the concept of a working day. While it appears obvious that long haulage trucks are driven many hours per day, a delivery service in a town will have a mix between driving and loading/unloading work. Where test results of this document are used with regard to occupational noise exposure standards, it is essential to consider the time contribution according to the typical use of a vehicle. Again, a large variability should be kept in mind. The test results of this document allow as well the calculation for conditions, other than selected by this document.

All definitions in this document are based on design neutral parameters – as far as practically possible – to enable an application for all kind of vehicle technologies, inclusive of hybrid vehicles and pure electric vehicles.

The test procedures and calculation schemes are engineering methods and compromise between precision, repeatability, feasibility and simplicity.

Acoustics — Measurement of interior vehicle noise

1 Scope

This document specifies an engineering method for measuring the interior sound of road vehicles of categories M and N under typical driving conditions. It does not apply to agricultural tractors and field machinery.

It specifies the conditions for obtaining reproducible and comparable measurements of sound pressure levels inside a vehicle.

These measurements are used to obtain a representative average sound level during a typical driving cycle to enable assessment of adverse effects on human health.

The results can be used for

— standardized assessment of interior sound for comparisons (e.g. benchmark, consumer information programs),

— verification tests, to decide whether or not the sound inside the vehicle is in accordance with specifications,

— regulatory purposes, for example for evaluation of sound in relation to labour or for general health standards, and

— monitoring tests, in order to check that the sound inside the vehicles has not changed since delivery, or between individual units of a consignment of vehicles.

This document does evaluate the exposure to interior sound of vehicles in a way as it is commonly used for scientific effects on human health.

It does not assess maximum interior sound of a vehicle under extreme driving situations, as today's measured maximum sound pressure levels inside vehicles are far away from the risk to create instantaneous hearing damages.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10844, *Acoustics — Specification of test tracks for measuring sound emitted by road vehicles and their tyres*

ISO 26101-1, *Acoustics — Test methods for the qualification of the acoustic environment*

ISO 13473-1, *Characterization of pavement texture by use of surface profiles — Part 1: Determination of mean profile depth*

ISO 13473-3, *Characterization of pavement texture by use of surface profiles — Part 3: Specification and classification of profilometers*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 61672-3, *Electroacoustics — Sound level meters — Part 3: Periodic tests*

IEC 60942, *Electroacoustics — Sound calibrator*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

EN 13036-7, *Road and airfield surface characteristics — Test methods — Part 7: Irregularity measurement of pavement courses: the straightedge test*

EN 13043, *Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
Mass

3.1.1
kerb mass
mass of the vehicle, with its fuel tank(s) filled to at least 90 % of its or their capacities, including the mass of the driver, of the fuel and liquids, fitted with the standard equipment in accordance with the manufacturer's specifications and, when they are fitted, the mass of the bodywork, the cabin, the coupling and the spare wheel(s) as well as the tools

[SOURCE: ISO 1176:1990, 4.6, modified — extended based on the today's applied principles used in regulations for sound emission of vehicles (see UN R51.03).]

3.1.2
test mass
m_t
mass of the vehicle subject to testing inclusive all equipment and payload

3.1.3
driver mass
m_d
nominal mass of a driver that shall be 75 kg (subdivided into 68 kg occupant mass at the seat and 7 kg luggage mass)

Note 1 to entry: According to ISO 2416.

3.2
test cycle
test conditions comprising acceleration, deceleration, steady speed and standstill to establish typical operation of a vehicle under either urban, suburban, rural or motorway condition

3.3
total power
P_n
sum of net power of all available propulsion sources

Note 1 to entry: According to ISO 1585, for vehicles with combustion engine only, P_n is the net power of the combustion engine expressed in kilowatt.

Note 2 to entry: According to UN R85, for vehicles with electric propulsion only, P_n is the net power over a time period of 5 minutes, expressed in kilowatt.

Note 3 to entry: According to UN R51, for vehicles with hybrid drive line, P_n is the sum of the net power of all available propulsion sources, expressed in kilowatt.

3.4
rated engine speed
S
engine speed at which the combustion engine develops its rated maximum net power as stated by the manufacturer

Note 1 to entry: If the rated maximum net power is reached at several engine speeds, S used in this document is the highest engine speed at which the rated maximum net power is reached.

Note 2 to entry: ISO 80000-3 defines this term as “rated engine rotational frequency”. The term “rated engine speed” was retained due to its common understanding by practitioners and its use in government regulations.

3.5
active sound system
system that is installed to a vehicle for producing exterior or interior sound, such as but not limited to sound actuators, regardless of its mounting position

3.6
modes
distinct driver-selectable condition which does affect powertrain and transmission setup, such that the emitted sound of the vehicle may vary, including distinct driver-selectable modes which can affect the sound emitted by sound enhancement systems

3.7
Irregularities

3.7.1
irregularity
maximum distance of a surface from the measurement edge of the *straightedge* between two contact points of the *straightedge* when placed perpendicular to the surface

Note 1 to entry: Measured in accordance with EN 13036-7.

3.7.2
longitudinal irregularity
irregularity (3.7.1) in the direction parallel to the longitudinal axis of the track

3.7.3
transverse irregularity
irregularity (3.7.1) in the direction perpendicular to the longitudinal axis of the track

3.8
mean profile depth
MPD
average value of the height difference between the profile and a horizontal line through the highest peak (the peak level) over a 100-mm long baseline

3.9
maximum aggregate size
aggregate upper sieve size (D) based on all-in aggregate grading category of GA90

Note 1 to entry: According to EN 13043.

3.10
Vehicle category M

3.10.1
category M1
vehicles used for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat

3.10.2
category M2
vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat and having a *kerb mass* (3.1.1) plus the maximum allowable payload not exceeding 5 000 kg

3.10.3
category M3
vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat and having a *kerb mass* (3.1.1) plus the maximum allowable payload exceeding 5 000 kg

3.11
Vehicle category N

3.11.1
category N1
vehicles used for the carriage of goods and having a *kerb mass* (3.1.1) plus the maximum allowable payload not exceeding 3 500 kg

3.11.2
category N2
vehicles used for the carriage of goods and having a *kerb mass* (3.1.1) plus the maximum allowable payload exceeding 3 500 kg but not exceeding 12 000 kg

3.11.3
category N3
vehicles used for the carriage of goods and having a *kerb mass* (3.1.1) plus the maximum allowable payload exceeding 12 000 kg

3.11.4
light duty vehicle
LDV
vehicle primarily used to transport passengers and cargo (e.g., cars, vans, SUVs, pickup trucks), with category M1 and N1 and N2 with $m \leq 4536$ kg and $P_n \geq 150$ kW may be deemed as LDV. (i.e., Class 1 through Class 2 Vehicles, as designated by the U.S. Department of Transportation)

3.11.5
heavy duty vehicle
HDV
vehicle other than defined in 3.11.4 with a maximum allowable payload of more than 4 536 kg

4 Tables of symbols and abbreviated terms

Table 1 lists the symbols, terms, and abbreviated terms in the order where they are used for the first time.

Table 1 — Symbols and abbreviated terms used and corresponding clauses

Symbol	Unit	Subclause	Explanation
P_n	kW	3.3	Total power. Sum of net power of all available propulsion sources.
m_t	kg	7.5	Test mass of the vehicle
m_{kerb}	kg	7.5	Kerb mass of the vehicle
m_{xload}	kg	7.5	Extra loading for vehicles of category N2 and N3
m_{target}	kg	7.5	Target mass of the vehicle for vehicles of category N2 and N3
$m_{ra\ load\ unladen}$	kg	7.5	Unladen rear axle load for vehicles of category N2 and N3
$m_{fa\ load\ unladen}$	kg	7.5	Unladen front axle load for vehicles of category N2 and N3
m_d	kg	7.5	Driver mass
$L_{Aeq,TC}$	dB(A)	8.4.1	A-weighted equivalent continuous sound pressure level for the different test conditions. Index TC means either ACC, CST, DEC, DEC AB, CRS STAT, AC MAX and AC LOW
$L_{Aeq,ACC}$	dB(A)	8.4.2.1	A-weighted equivalent continuous sound pressure level for the acceleration test
$L_{Aeq,DEC}$	dB(A)	8.4.2.2.1	A-weighted equivalent continuous sound pressure level for the deceleration test without any braking applied
$L_{Aeq,DEC,AB}$	dB(A)	8.4.2.2.2	A-weighted equivalent continuous sound pressure level for the deceleration test with auxiliary brake device activated
$L_{Aeq,CRS}$	dB(A)	8.4.2.3	A-weighted equivalent continuous sound pressure level for the steady speed test
$L_{Aeq,STAT}$	dB(A)	8.4.3	A-weighted equivalent continuous sound pressure level for the standstill test
$L_{Aeq,AC,MAX}$	dB(A)	8.4.3	A-weighted equivalent continuous sound pressure level for the standstill test with air conditioning on and ventilation at highest operation level for maximum cooling
$L_{Aeq,AC,LOW}$	dB(A)	8.4.3	A-weighted equivalent continuous sound pressure level for the standstill test with air conditioning off and ventilation speed at lowest operation level
α_{STAT}	%	8.5	Weighting factor for the representative sound pressure level at standstill condition
α_{CRS}	%	8.5	Weighting factor for the representative sound pressure level at steady speed condition
α_{ACC}	%	8.5	Weighting factor for the representative sound pressure level at acceleration condition
α_{CST}	%	8.5	Weighting factor for the representative sound pressure level at deceleration condition
$L_{Aeq,CYCLE}$	dB(A)	8.5	Representative sound pressure level for the vehicle per cycle component
URBAN		8.5	Cycle component for urban condition
SUBURBAN		8.5	Cycle component for suburban condition
RURAL		8.5	Cycle component for rural condition
MOTORWAY		8.5	Cycle component for motorway condition
$L_{Aeq,CST}$	dB(A)	8.5.1	A-weighted equivalent continuous sound pressure level for the deceleration test, weighted combination of deceleration tests with and without auxiliary brake device applied
L'_{TEST}	dB(A)	8.5.1	Representative sound pressure level for the driving cycle without time weighting
L_{TEST}	dB(A)	8.5.1	Representative sound pressure level for the driving cycle inclusive time weighting
t_{exp}	h	8.5.2	Annual average use time of a vehicle per working day

Table 1 *(continued)*

Symbol	Unit	Subclause	Explanation
$L_{Aeq,INTERIOR}$	dB(A)	8.5.3	Representative interior sound level for a vehicle according to this standard

5 Test equipment

5.1 Instrumentation for acoustic measurement

5.1.1 General

The apparatus used for measuring the sound pressure level shall be a sound level meter or single microphones connected to a data acquisition system or equivalent measurement systems, meeting the requirements of class 1 instruments. These requirements are described in IEC 61672-1.

The entire measurement system shall be checked and adjusted by means of a sound calibrator that fulfils the requirements of class 1 sound calibrators in accordance with IEC 60942.

When no general statement or conclusion can be made about conformance of the sound level meter model to the full specifications of IEC 61672-1, 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 as described in IEC 61672-3.

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

5.1.2 Calibration

At the beginning of every measurement session, the entire acoustic measurement system shall be checked and adjusted by means of a sound calibrator as described in 5.1.1. 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 at the beginning and the end 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.

The checking and adjustment described in 5.1.2 does not invalidate the conformity of IEC 61672-1 described in 5.1.3 for the purpose of this document.

A bi-yearly IEC 61672-3 calibration permits the use of a daily sensitivity check and adjustment.

NOTE The purpose of the check at the beginning of the measurement session is twofold:

a) To insure the measurement system is in good working order, and

b) To adjust the level consistent with the environmental conditions of the day.

The purpose of the check at the end of the measurement session is also twofold:

— To insure the measurement system remains in good working order, and

— To verify the adjusted level remains within expected tolerances for a repeatable and reproduceable measurement.

5.1.3 Conformity with requirements

Conformity of the sound calibrator with the requirements of IEC 60942 shall be verified once a year. Conformity of the instrumentation system with the requirements of IEC 61672-1 shall be verified in accordance with the procedures of IEC 61672-3 at least every 2 years or after each modification of the

system (software, microphone, etc.). All conformity testing shall be conducted by a laboratory which is authorized to perform calibrations traceable to the appropriate standards.

NOTE The tests of IEC 61672-3 cover only a limited subset of the specifications in IEC 61672-1 for which the scope is large (temperature range, frequency requirements up to 20 kHz, etc.). It is not feasible to verify the whole IEC 61672-1 requirements on each item of a computerized data acquisition system. Computerized data acquisition system available comply with the necessary specifications of IEC 61672-1 and testing specifications of IEC 61672-3 as required for this document.

5.2 Instrumentation for vehicle speed and rotational engine speed measurements

5.2.1 Vehicle speed

The road speed of the vehicle shall be measured with instruments meeting specification limits of at least ±0,5 km/h.

NOTE There are various means for measuring the vehicle speed. Most common at time of publication are GPS based systems and speed signals taken from the data interfaces available on board. When using such information sources, it is strongly recommended to verify the precision of these sources with regard to signal quality and data refresh rate.

5.2.2 Rotational engine speed (if applicable)

If applicable and necessary, the rotational speed of the engine shall be measured with an instrument meeting specification limit of at least ±2 % at the engine speeds required for the measurements being performed.

NOTE Rotational engine speed signals are commonly taken from the data interfaces available on-board. When using such information sources, it is strongly recommended verifying the precision of these sources with regard to signal quality and data refresh rate.

5.3 Meteorological instrumentation

5.3.1 General

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

— within ±1,0 °C for a temperature measuring device;

— within ±1,0 m/s for a wind speed measuring device;

— within ±5,0 hPa for a barometric pressure measuring device;

— within ±5,0 % for a relative humidity measuring device.

6 Test facility

6.1 Outdoor test site

The test site shall be such that the sound radiated by the vehicle to the outside contributes to the inside noise only by reflections from the road surface and not by reflections from buildings, walls, or similar large objects outside the vehicle. During the period of measurement, the distance of the vehicle from large objects shall be greater than 20 m.

NOTE Buildings outside the 20 m distance can have a significant influence if their reflection focuses on the test track.

The test site shall be substantially level. Longitudinal and transverse slope of the operation distance shall not exceed the value provided by Annex A.

The test track and the surface of the site shall be dry and free from absorbing materials such as powdery snow or loose debris.

6.1.1 Test track surface properties

The test track surface shall comply with the specifications of Annex A.

NOTE The influence of the road surface on the overall test result can be very significant. Therefore, it is necessary to provide specifications on the road surface properties. The specifications laid down in Annex A are taken from ISO 10844 and are simplified to allow a larger variety of road surfaces.

6.2 Meteorological conditions

6.2.1 General

The meteorological instrumentation shall deliver data representative of the test site and shall be positioned adjacent to the test area.

A value representative of air temperature, wind speed and direction, barometric pressure and relative humidity during the test shall be noted in the test report.

6.2.2 Air temperature

The measurements shall be made when the ambient air temperature is within the range from -10 °C to 40 °C.

If measurements are carried out at air temperatures below 5 °C special attention shall be paid to the tyre rubber stiffening and its impact on the tyre/rolling sound. See as well the tyres selection in 7.4.

6.2.3 Wind

The tests shall not be carried out if the wind speed, including gusts, exceeds 5 m/s during the test.

NOTE Wind speed above 5 m/s and gusts can have significant influence to the measurement result, especially when the wind is lateral to the vehicle.

6.2.4 Humidity

The tests shall not be carried out if it is raining, misty, or snow on the road. Rain may cause additional noise through the roof. Wet roads may cause increased rolling noise due to spray water.

6.3 Background noise

The background noise shall be measured inside of the vehicle in standstill, powered-off, with all doors, windows and sunroofs closed.

The background noise shall be measured for duration of 10 s immediately before a series of vehicle tests. The measurements shall be made with the same microphones and microphone locations used during the test. The maximum A-weighted sound pressure level time-weighted “fast” shall be reported.

For all measurements of A-weighted sound pressure levels, the lower limit of the dynamic range set by the background noise and by the inherent noise level of the measuring equipment shall be at least 15 dB below the lowest reported A-weighted sound pressure level of the vehicle.

7 Vehicle conditions

7.1 General

The vehicle shall be equipped as specified by the vehicle manufacturer. Before the measurements are started, the vehicle shall be brought to its normal operating conditions, which means that essential components for the operation of the vehicle are at their nominal temperatures as specified by the manufacturer. This applies especially, but not limited to:

— the cooling water (if applicable);

— oil temperature (if applicable).

The temperature inside the vehicle shall be established in a way, as it is commonly the case during operation. Excessive noise from the ventilation system or air conditioning due to extreme hot or cold temperatures shall be avoided.

NOTE The term "normal" as already used above, indicates the nominal setup of the vehicle as foreseen by the manufacturer. Such "normal operation conditions" are typically explained in owner's manuals. The purpose of this document is, to assess the sound inside the vehicle as foreseen by the manufacturer. The driver can turn on the radio, adjust the ventilation according to his mood or open windows. Such alternative conditions are not in the scope of this document.

7.2 Battery state of charge

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

7.2.1 Active sound systems

Any active sound devices, either for noise control, or sound enhancement, shall operate as foreseen by the vehicle manufacturer for normal (default) operating condition and not be interfered with during the measurements.

For development purposes, these devices can be deactivated or set to other driver selectable modes. In this case, the setup condition of such devices shall be noted in the test report.

7.3 Multi-mode operation

If the vehicle is equipped with multiple driver selectable operating modes, the mode for normal operation shall be selected, respectively the default operation condition as stated by the manufacturer in the owner's manual.

For development purposes, other driver selectable modes may be tested. In this case, the setup condition shall be noted in the test report.

7.4 Tyre conditions

The tyres and rims shall be appropriate for the vehicle. The tyres shall be inflated to the pressure recommended by the vehicle manufacturer for normal operation. Tyres shall be suitable for the ambient conditions when the measurements are carried out.

Tyres with special fitment requirements, such as asymmetric or directional design, shall also be mounted in accordance with these requirements.

Before testing, tyres shall be conditioned (broken-in). Tyre break-in shall be equivalent to about 100 km of normal on-road operation. Tyres with special fitment requirements shall be broken-in in accordance

with these requirements. The tyres fitted to the test vehicle shall rotate in the same direction as when they were broken-in.

Apart from the tread wear caused by the break-in procedure, the tyres shall have preferably full tread depth. The minimum tread depth shall be at least 80 % of the full tread depth.

In case of outdoor measurements, test tyres shall be warmed-up immediately prior to testing for at least 10 min in the range of the test speed, with moderate lateral and longitudinal acceleration. The lateral acceleration shall be selected in a way to avoid excessive tread wear effects.

In case of indoor measurements, test tyres shall be warmed-up prior to testing for at least 10 min in the range of the test speed, with moderate longitudinal acceleration.

7.5 Loading of the vehicle

The vehicle shall be loaded, according to the Table 2.

Table 2 — Vehicle loading

Vehicle category	Vehicle test mass
M_1	The test mass m_t of the vehicle shall be between 0,90 $m_{kerb} \leq m_t \leq$ 1,20 m_{kerb}
N_1	The test mass m_t of the vehicle shall be between 0,90 $m_{kerb} \leq m_t \leq$ 1,20 m_{kerb}
N_2, N_3	m_{target} = 50 kg/kW x P_n with P_n given in kW Extra loading, m_{xload}, to reach the target mass, m_{target}, of the vehicle shall be placed above the rear axle(s). If the test mass m_t is equal to the target mass m_{target}, the test mass m_t shall be 0,95 $m_{target} \leq m_t \leq$ 1,05 m_{target} The sum of the extra loading and the rear axle load in an unladen condition, $m_{ra\ load\ unladen}$, is limited to 75 per cent of the technically permissible maximum laden mass allowed for the rear axle, $m_{ra\ ra\ max}$. If the test mass m_t is lower than the target mass m_{target}, the test mass m_t shall be achieved with a tolerance of ±5 %. If the centre of gravity of the extra loading cannot be aligned with the centre of the rear axle, the test mass, m_t, of the vehicle shall not exceed the sum of the front axle in an unladen condition, $m_{fa\ load\ unladen}$, and the rear axle load in an unladen condition, $m_{ra\ load\ unladen}$ plus the extra loading, $m_{xload,}$ and the driver mass, m_d. The test mass for vehicles with more than two axles shall be the same as for a two-axle vehicle. If the vehicle mass of a vehicle with more than two axles in an unladen condition, $m_{unladen}$, is greater than the test mass for the two-axle vehicle, then this vehicle shall be tested without extra loading. If the vehicle mass of a vehicle with two axles, $m_{unladen}$, is greater than the target mass, then this vehicle shall be tested without extra loading.
M_2 ($m \leq$ 3,500 kg)	The test mass m_t of the vehicle shall be between 0,90 $m_{kerb} \leq m_t \leq$ 1,20 m_{kerb}
M_2 ($m >$ 3,500 kg), M_3	m_{target} = 50 kg/kW × P_n with P_n given in kW is calculated either in conformity with conditions above (see N_2, N_3 category) or the test mass m_t of the vehicle shall be 0,90 $m_{kerb} \leq m_t \leq$ 1,10 m_{kerb}.

Only measurement equipment and necessary personnel shall occupy the interior of the vehicle. In passenger cars, and in the cabs of trucks, no more than two persons (driver and observer) shall be present. In buses with more than eight seats, no more than three persons shall be present.

NOTE The limitation of test personnel is specified for the reason of simplicity, but it is not necessarily representative of the conditions during normal use, especially for trucks, buses and other commercial vehicles, and may cause an over estimation of the noise inside the vehicle, as more passengers will increase the absorption inside the vehicle.

7.6 Openings, windows and auxiliaries

Openings such as sunroofs, convertible roof, all windows and ventilating inlets and outlets shall be shut, if possible, unless their influence upon the sound level inside the vehicle is to be investigated.

Unless specified for particular tests in this document, any auxiliary equipment such as windscreen wipers, entertainment/communication systems, ventilating fans and air-conditioners shall not operate during the tests in motion. If any auxiliary equipment can only be operated automatically, its operating shall be stated in the test report. If the vehicle is fitted with intermitting running devices, such as brake compressor, cooling fan, regeneration of particle traps, these systems shall not be interfered with during the measurements.

7.7 Seat adjustment

Adjustable seats shall be set as close as possible to the mid-position of the horizontal and vertical range of adjustment. If the back-rest of the seat is adjustable, it shall be set as near to the vertical position as possible. Adjustable headrests shall be set at the mid-position.

7.8 Squeak and Rattle (test equipment)

Test equipment shall be installed in the vehicle such that noise due to squeak and rattle is avoided.

8 Test procedure

8.1 Microphone positions

8.1.1 General

The sound inside a vehicle can vary considerably with the microphone position. Therefore, measuring points should be selected in sufficient number and in such a manner that the distribution of the sound in the vehicle is adequately represented with respect to driver and passenger ear locations.

For all vehicle categories, one measuring point shall be at the driver's position.

For passenger vehicles, with one back seat row, an additional measurement position shall be the back-seating position at the opposite side of the driver. For passenger vehicles with three seating rows, the microphone position shall be in the second row in the middle and in the back row at the opposite side of the driver.

For buses, additional measuring positions are needed at the middle and in the back of the vehicle adjacent to the longitudinal axis of the vehicle.

For buses for public transportation seating and standing positions shall be included where appropriate.

For coaches seating positions shall be included where appropriate.

For trucks, the driver and co-driver seat shall be measured. In cases where a truck provides an additional seating row for a crew, the back-right seat shall be measured in addition.

If coaches or trucks have a sleeping berth or the vehicle has a stretcher like in an ambulance, a measurement position may be included as well.

NOTE Sleeping in the sleeping berth is not allowed in most countries, while a truck is driven. However, the provisions were kept especially with regard to stretchers in ambulances.

8.1.2 Single microphone

The microphone shall be oriented horizontally, with the direction of maximum sensitivity coincident with the direction in which a person occupying the seat or standing position would be facing, if such direction is not defined, in the direction of travel.

The microphone shall be no closer than 0,15 m to walls or upholstery.

The microphone used during the tests shall be mounted in such a way that it is not affected by vibrations of the vehicle. The mounting shall prevent excessive (more than 20 mm) amplitudes relative to the vehicle.

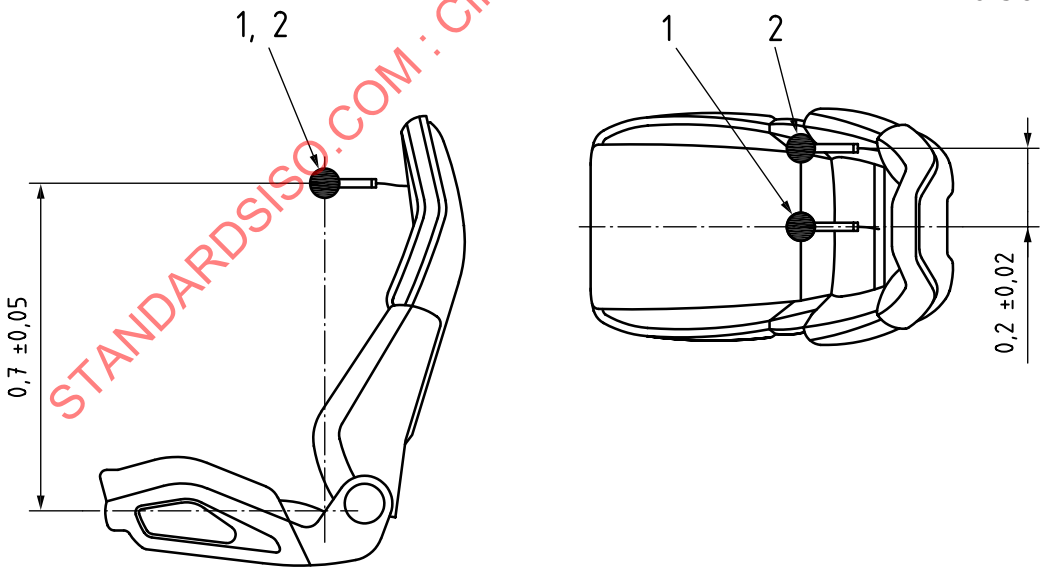
8.1.3 Related to seats

The vertical coordinate of the microphone shall be 0,70 m ± 0,05 m above the intersection of the unoccupied seat surface and the surface of the back of the seat (see Figure 1).

The horizontal coordinate shall be the middle plane (or plane of symmetry) of the unoccupied seat. At the driver's seat, with the driver present, the horizontal coordinate shall 0,20 m ± 0,02 m to the right (to the left for right-hand drive vehicles) from the middle plane of the seat.

If two microphones per seating position are used, (e.g. artificial head or binaural head microphone) the microphones shall be positioned symmetrically to the longitudinal centreline of the seat. If the microphones are horizontally adjustable, they shall be positioned in a distance of 0,10 m ± 0,02 m from the middle plane of the seat.

Dimensions in metres



Key

1, 2 microphone positions

Figure 1 — Microphone position (left hand drive vehicle)

8.1.4 Related to standing locations

The vertical coordinate shall be 1,60 m ± 0,05 m above the floor. The horizontal coordinates shall correspond to a person standing at the selected points.

8.1.5 Related to sleeping-berths

In sleeping-berths, such as in sleeper trucks or stretchers in ambulances, the microphone shall be placed 0,15 m ± 0,02 m above the middle of the unoccupied pillow

8.2 Test cycles

This document defines operation conditions for driving in urban, sub-urban, rural, and motorway situations. Each of these situations is defined by the operating conditions below at driving speeds and accelerations taken from statistical analysis.

8.3 Vehicle operating conditions

8.3.1 General

The vehicle operating conditions as described in 8.3.2 to 8.3.4 represent real world driving conditions for different vehicle categories. They include

a) acceleration,

b) steady speed,

c) deceleration, and

d) standstill.

Based on tests under these operation conditions, the measurement results will be integrated to a final average exposure sound pressure level for a typical use of the vehicle in real driving, taking into account urban, rural and motorways situations:

For different vehicle categories different time weightings of these operating conditions will be used.

In any test condition, the engine speed of an internal combustion engine propelling a vehicle shall be limited to 80 % of its rated engine speed. If during a test this maximum engine speed is exceeded, the next higher gear shall be used. If both the start and end speed cannot be achieved in the higher gear, the start speed can be increased in steps of 2 km/h until the end speed is reached

8.3.2 Acceleration and deceleration tests

8.3.2.1 Acceleration targets

Acceleration tests shall be carried out in a speed range defined by the start and end speed for each cycle according to Tables 3 and 4. The acceleration shall be established latest at the specified start speed. It is recommended to start the acceleration from a lower speed, e.g. 1 km/h below the target start speed.

Table 3 — Acceleration test parameter (LDV)

Cycle	Start speed km/h	End speed km/h	Stabilization time s	Target acceleration m/s^2	Estimated nominal travel distance m	Estimated nominal test time s
URBAN	20 (-1)	40 (+1)	5,0	1,2 ± 0,2	39	4,6
SUBURBAN	40 (– 1)	60 (+1)	5,0	1,1 ± 0,2	70	5,1
RURAL	70 (– 1),	90 (+1)	4,0	1,1 ± 0,2	112	5,1
MOTORWAY	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
NOTE The acceleration in motorway conditions, with the purpose to follow traffic flow, is typically low and could be regarded as steady speed.						

Table 4 — Acceleration test parameter (HDV)

Cycle	Start speed km/h	End speed km/h	Stabilization time s	Target acceleration m/s^2	Estimated nominal travel distance m	Estimated nominal test time s
URBAN	20 (-1)	35 (+1)	5,0	1,0 ± 0,2	32	4,2
RURAL	35 (-1)	50 (+1)	4,0	0,7 ± 0,2	70	6,0
MOTORWAY	70 (-1)	80 (+1)	4,0	0,4 ± 0,2	164	6,9

8.3.2.2 Deceleration targets

The deceleration tests may be carried out as a separate tests, or be done directly after an acceleration phase, when the acceleration pedal is released. The starting speed for a deceleration test is the end speed of the acceleration test, as provided by Table 3 and 4. Deceleration is achieved by releasing the acceleration pedal without any applied active braking.

8.3.2.3 Deceleration test with auxiliary braking devices actively applied

If the vehicle is equipped with an auxiliary braking device (for example, but not limited to, engine brake) additional tests shall be carried out with the engine brake applied. The gear shall be selected such, that the engine speed is at S and the vehicle speed closest to 40 km/h. The engine brake shall be set to automatic mode, if available. If no automatic mode is available, the mode that provides a deceleration closest to, but not exceeding [0,7 m/s^2] shall be used.

8.3.2.4 Transmission Setup

8.3.2.4.1 General

Given by the large variety of transmission design over all vehicle categories, this document divides the technologies in two classes, transmissions that can be locked to a discrete gear ratio and transmissions that operate fully automatically without any capability for locking a specific gear ratio. Vehicles with only one gear ratio or without any transmission are counted to the second category.

8.3.2.4.2 Non-locked transmissions

The gear selector shall be set to the normal range as specified by the vehicle manufacturer in the owner's manual. This is typically "D-Range" (drive range).

When the start speed is achieved, but before the measurements are started, a minimum stabilization time as specified in the Table 3 and 4 shall be maintained to allow the transmission for a proper gear setup.

The accelerator shall be positioned such, that in average the specified acceleration is achieved between the start speed and the end speed. Therefore, it is permitted to use a mechanical or electronic device to position the accelerator for a partial load acceleration.

8.3.2.4.3 Locked transmissions

The highest gear ratio shall be selected, which enables an acceleration as specified by Table 3. The accelerator shall be positioned such, that in average the specified acceleration is achieved between the start speed and the end speed. Therefore it is permitted to use a mechanical or electronic device to position the accelerator for a partial load acceleration.

For the test, a stable acceleration shall be ensured, such that the vehicle neither is started from too low engine speeds, nor has any delayed acceleration response, or provides a significant acceleration change within the test area.

8.3.3 Steady speed test

8.3.3.1 Target speeds

The target speeds and minimum measuring time for the steady speed test are given by Tables 5 and 6. The target speed shall be achieved with an accuracy of ±1 km/h throughout the whole measurement period. If applicable, a cruise control may be used to stabilize the speed of the vehicle.

In cases where the target speed exceeds the maximum vehicle design speed, that test shall be carried out at the maximum vehicle design speed.

Table 5 — Steady speed test parameter (LDV)

Cycle	Target speed km/h	Stabilization time s	Test time s	Estimated travel distance m
URBAN	40 ± 1,0	5,0	5,0	111
SUBURBAN	60 ± 1,0	5,0	5,0	167
RURAL	90 ± 1,0	4,0	5,0	225
MOTORWAY	120 ± 1,0	3,0	5,0	267

Table 6 — Steady speed test parameter (HDV)

Cycle	Target speed km/h	Stabilization time s	Test time s	Estimated travel distance m
URBAN&SUBURBAN	30 ± 1,0	5,0	5,0	83
RURAL	50 ± 1,0	4,0	5,0	125
MOTORWAY	85 ± 1,0	3,0	5,0	189

8.3.3.2 Transmission setup

8.3.3.2.1 Non-locked transmissions

The gear selector shall be set to the normal range as specified by the vehicle manufacturer in the owner's manual. This is typically "D-Range".

When the target speed is achieved, but before the measurements are started, a minimum stabilization time as specified in Table 3 or Table 4 shall be maintained to allow the transmission for a proper gear setup.

8.3.3.2.2 Locked transmissions

In case of locked transmission, the steady speed test shall be carried out in a gear shall be at the highest gear, for which the operation of the vehicle under the given test condition is stable.

8.3.4 Standstill condition

The vehicle shall be started and be brought to normal operation condition according to 6.1 to 6.4. If the vehicle is equipped with a "Stop-Start" function for the engine, it shall be deactivated, if possible.

In cases where the engine cannot be started, this shall be noted in the test report. The interior sound shall be measured then without an engine operating.

Any vehicle, lockable or non-lockable, which is equipped with an automatic driving mode as specified by the vehicle manufacturer in the owner's manual for normal operation, shall be set to this mode (typically D-Range), and the service brake engaged.

Vehicles with manual transmission shall be set to neutral, with the clutch released, and the service brake engaged.

Tests at standstill consists of two operation conditions with the following setup:

— Condition AC,LOW:

  Air conditioning off and ventilation speed at lowest operation level, but not turned off. The airflow distribution shall be selected as recommended by the manufacturer for default distribution.

— Condition AC,MAX:

  Air conditioning on and ventilation at highest operation level for maximum cooling, or heating, if no air conditioning is equipped. The airflow distribution shall be selected as recommended by the manufacturer for default distribution.

8.4 Measurement readings and data processing

8.4.1 General

The measurement readings and followed calculations shall be done separately for each single measurement position.

The main measurement quantities are the A-weighted equivalent continuous sound pressure level, L_{Aeq}. The acquisition time for the test condition is 5 s unless otherwise specified.

Per test condition and microphone position, three valid measurements according to 8.4.2 and 8.4.3. shall be carried out.

Measurements are valid, if they do not differ by more than 2 dB. Any measurement disturbed by either background disturbance inside the vehicle, wind gusts or other reasons shall be discarded and repeated. This applies as well to vehicle conditions such as but not limited to recuperation cycles of particulates traps or NO_x filters.

The result per microphone position to be used for further calculations in 8.5 and 8.6 is the energetic average of the $L_{Aeq,TC}$ of the three valid runs per test condition, rounded to the first digit.

8.4.2 Measurement readings for measurements in motion

8.4.2.1 Acceleration phase

The measurement reading starts when the accelerator is depressed as necessary for the appropriate acceleration and the specified vehicle start speed is reached. It is suggested to establish the acceleration from a slightly lower vehicles speed, allowing for stable acceleration and to start the measurement reading. The measurement ends when the vehicle end speed is reached and before the acceleration pedal is released. The reported test result is $L_{\mathrm{Aeq,ACC}}$.

8.4.2.2 Coast-down phase

8.4.2.2.1 Deceleration phase

The measurement reading starts, immediately after the accelerator was released. The measurement reading ends, when the vehicle has slowed down to the speed provided by Table 3 and 4 as the starting speed for the acceleration test. The reported test result is $L_{\mathrm{Aeq,DEC}}$

8.4.2.2.2 Vehicles equipped with auxiliary braking devices

The measurement starts right before the engine brake is activated and be held for at least 5 seconds. The reported test result is $L_{\mathrm{Aeq,DEC,AB}}$.

8.4.2.3 Steady speed phase

The measurement reading starts when target speed according to 8.3.3 is reached and a steady speed is established. The accelerator shall be positioned to maintain a steady speed throughout the measurement period. The measurement ends before the accelerator is released. The reported test result is $L_{\mathrm{Aeq,CRS}}$.

8.4.3 Measurement readings and data processing for the standstill condition

For each of the two operating conditions the interior sound pressure level shall be measured for the duration indicated in 8.4.1. The reported test results are $L_{\mathrm{Aeq,AC,MAX}}$ and $L_{\mathrm{Aeq,AC,LOW}}$.

The results of the two tests are combined to a representative sound pressure level for the standstill test by Formula (1):

$$L_{\mathrm{Aeq,STAT}} = 10 \cdot \lg\left(0{,}1 \cdot 10^{0{,}1 \cdot L_{\mathrm{Aeq,AC,MAX}}} + 0{,}9 \cdot 10^{0{,}1 \cdot L_{\mathrm{Aeq,AC,LOW}}}\right) \mathrm{dB(A)} \quad (1)$$

The test result for the standstill condition is uniform for each cycle.

8.5 Cycle related calculations

8.5.1 Cycle specific representative sound pressure levels

The test results for each individual cycle are a combination of the test conditions as measured according to 8.3.2. to 8.3.4. With the assumption that all tests have approximately a measurement duration of 5 s, the cycle representative results are determined using the shares provided by Tables 7 and 8. All subsequent calculations shall be carried out per microphone position individually, as given by Formula (2):

Table 7 — Weighting factors α of test condition (LDV)

Cycle	Standstill α_{STAT}	Steady speed α_{CRS}	Acceleration α_{ACC}	Coast-down α_{CST}
URBAN	0,25	0,35	0,20	0,20
SUBURBAN	0,10	0,50	0,20	0,20
RURAL	0,10	0,50	0,20	0,20
MOTORWAY	0,05	0,85	0,05	0,05

Table 8 — Weighting factors α of test condition (HDV)

Cycle	Standstill α_{STAT}	Steady speed α_{CRS}	Acceleration α_{ACC}	Coast-down α_{CST}
URBAN	0,20	0,40	0,20	0,20
RURAL	0,10	0,60	0,20	0,10
MOTORWAY	0,05	0,80	0,05	0,10

$$L_{Aeq,CYCLE} = 10 \cdot \lg \left(\begin{array}{l} \alpha_{STAT} \cdot 10^{0,1 \cdot L_{Aeq,STAT}} + \alpha_{CRS} \cdot 10^{0,1 \cdot L_{Aeq,CRS}} + \alpha_{ACC} \cdot 10^{0,1 \cdot L_{Aeq,ACC}} \\ + \alpha_{CST} \cdot 10^{0,1 \cdot L_{Aeq,CST}} \end{array} \right) \text{dB(A)} \quad (2)$$

where the index CYCLE means either URBAN, SUBURBAN, RURAL or MOTORWAY.

Since there is no measurement procedure for acceleration on motorway for LDV, the L_{Aeq} test result from the steady speed test at motorway shall be used.

In cases where measurements with auxiliary braking devices according clauses 7.3.2. and 6.5.3. have been carried out the representative sound pressure level for the deceleration test is the energy weighted combination of the deceleration test result with and without auxiliary braking device applied, according to Formula (3):

$$L_{Aeq,CST} = 10 \cdot \lg \left(0,4 \cdot 10^{0,1 \cdot L_{Aeq,DEC}} + 0,6 \cdot 10^{0,1 \cdot L_{Aeq,DEC,AB}} \right) \text{dB(A)} \quad (3)$$

8.5.2 Cycle combines representative sound pressure levels

The sound pressure levels $L_{Aeq,CYCLE}$ are interim results and representative for permanent driving in these areas. These values shall be merged together to a sound pressure level L'_{TEST}, which is representative for a typical use of the vehicle in real world driving, as given by Formula (4):

$$L'_{TEST} = 10 \cdot \lg \left(\beta_{URB} \cdot 10^{0,1 \cdot L_{URB}} + \beta_{SUB} \cdot 10^{0,1 \cdot L_{SUB}} + \beta_{RUR} \cdot 10^{0,1 \cdot L_{RUR}} + \beta_{MOT} \cdot 10^{0,1 \cdot L_{MOT}} \right) \quad (4)$$

The result L'_{TEST} shall be rounded to one significant digit after the decimal place (xx,x).

The weighting factor is dependent on the various vehicle categories. Representative values are provided by Table 9.

Table 9 — Weighting factor β of cycles

Vehicle Category	URBAN β_{URB}	SUBURBAN β_{SUB}	RURAL β_{RUR}	MOTORWAY β_{MOT}	Comments
M1	0,50	0,25	0,20	0,05	Private use
M2	0,35	0,25	0,20	0,20	Limousine service
M3	0,20	n. a.	0,30	0,50	Coaches
M3	0,80	n. a.	0,20	0,0	City bus
N1	0,40	0,20	0,20	0,20	Delivery
N2	0,30	n. a.	0,55	0,15	Distributer
N3	0,30	n. a.	0,55	0,15	Distributer
N3	0,15	n. a.	0,30	0,55	Long Haulage

8.5.3 Exposure normalization

The typical usage of vehicles varies strongly by category and purpose. Table 10 provides annual average usages of vehicles per day.

Table 10 — Annual average use of the vehicle per working day

Purpose of use	Exposure t_{exp} h	Vehicle category	Comments
Private	1	M1	Private Use
Taxi, Limousine Service	4	M1, M2	Professional Use
Public Transportation, Long Distance Travel	8	M3	Coaches, City Bus
Public Transportation, (Passenger)	1	M3	Coaches, City Bus
Short Distance Delivery	3	N1	Delivery Services
Inter-Urban Mid Distance Delivery	4	N2, N3	Distributer
Long Distance Delivery	8	N3	Long Haulage

In order to allow a reliable estimate off the long term exposure on vehicle users, the test result of 8.4.4. needs to be time corrected relative to a reference of an 8-hour period.

The final, time normalized result, which is representative for the typical use of a vehicle, is given by Formula (5):

$$L_{TEST} = L'_{TYPE} + 10 \cdot lg\left(\frac{t_{exp}}{8}\right) \text{ dB} \quad (5)$$

The time normalized result L_{TEST} per microphone position shall be reported to one significant digit after the decimal place (xx,x).

8.6 Final result

The final result $L_{Aeq,INTERIOR}$ is the energetic average of all test results L_{TEST} from all microphone positions, with same exposure time, rounded to the nearest integer (e.g. 62,4 dB(A) is 62 dB(A), and 62,5 dB(A) is 63 dB(A)).

$$L_{Aeq,INTERIOR} = 10 \cdot \lg\left(\left(\sum 10^{0,1 \cdot L_{TEST}}\right) / n_{TEST}\right) \quad (6)$$

$L_{Aeq,INTERIOR}$ represents the interior sound level of a vehicle evaluated according to this standard.

For busses, the microphones in the driver's position, the middle, and the rear shall be reported individually.

Note For instance, the exposure time at sleeping berths in ambulances is less than for the driver.

8.7 Test report

For the documentation of the measurements, it is necessary to report at least the following information

a) a reference to this document, i.e. ISO 5128:2023;

b) the details of the test site, site orientation, and weather conditions including wind speed and air temperature, wind direction, barometric pressure and humidity;

c) the type of measuring equipment, including the windscreen;

d) the maximum A-weighted sound pressure level typical of the background noise;

e) the identification of the vehicle:

- vehicle category,
- body variant (e.g. sedan, convertible, hatchback, ...),
- kerb mass and test mass of the vehicle
- engine, power, rated engine speed
- transmission system, including available transmission ratios,
- rim size
- size, load index, speed category and type of tyres, tyre pressure, tyre production type,
- driver selectable modes

f) the vehicle setup for the test (information to be provided per cycle):

- transmission gears or gear ratios used during the test per cycle,
- mode selected for the test;
- microphone positions

g) test specific information:

- vehicle speed at the beginning of measurement,
- vehicle speed at the end of the measurement,
- vehicle speed after the deceleration phase,
- all valid A-weighted sound levels as indicated for each test, listed per measurement position,

— achieved acceleration, if applicable for the test;

h) the auxiliary equipment of the vehicle running during the test, where applicable;

i) the parameters used for the calculation of L_{CYCLE}, $L'_{TEST,POS}$, $L_{TEST,POS}$ and $L_{INTERIOR}$;

j) general comments, observation, special remarks.

9 Measurement uncertainty

The measurement procedure described in Clause 8 is affected by several parameters (surface texture variation, microphone positions affected by cavity resonances, environmental conditions, measurement system uncertainty, etc.) that lead to variation in the resulting level observed for the same subject. The source and nature of these perturbations are not completely known and sometimes affect the result in a non-predictable way.

The uncertainty of results obtained from measurements according to this document can be evaluated by the procedure given in ISO/IEC Guide 98-3 or by inter-laboratory comparisons in accordance with ISO 5725 (all parts).[2] Since extensive inter- and intra-laboratory data were not available, the procedure given in ISO/IEC Guide 98-3 was followed to estimate the uncertainty associated with this document.

The uncertainties given below are based on existing statistical data, analysis of tolerances stated in this document, and engineering judgement. The uncertainties determined are grouped as follows:

a) variations expected within the same test laboratory and slight variations in ambient conditions found within a single test series (run-to-run);

b) variations expected within the same test laboratory but with variation in ambient conditions and equipment properties that can normally be expected during the year (day-to-day);

c) variations between test laboratories where, apart from ambient conditions, equipment, staff, and road surface conditions are also different (site-to-site).

If reported, the expanded uncertainty together with the corresponding coverage factor for the stated coverage probability of 95 % as defined in ISO/IEC Guide 98-3 shall be given.

These uncertainties are given by Table 11. The values express the peak-to-peak variability of results for a given measurement object and do not cover product variation.

Table 11 — Variability of measurement results for a coverage probability of 95 %

Vehicle category	Run-to-run dB	Day-to-day dB	Site-to-site dB
Light duty vehicle	0,8	3,6	5,0
Heavy duty vehicle	1,4	3,5	3,8

The expressed uncertainty values are peak-to-peak and are given for a discrete cycle mix. They might vary to a certain extent when different cycle mixes are considered. Annex B provides further background information for the determination of the uncertainty factors.

Annex A
(normative)

Specification on test track properties and performances

A.1 Requirements of the test track

A.1.1 Drive lane properties

The drive lane shall have

a) a longitudinal irregularity less than 10 mm;

b) a transverse irregularity less than 10 mm;

c) an average maximum aggregate size (D) between 6,3 mm and 12,5 mm;

d) an average aggregate grading conforming to the aggregate grading envelope described in Table A.1;

e) an average in-place air voids in place of no more than 9,0 %, and

f) a mean profile depth (MPD), measured according to ISO 13473 1, between 0,3 mm and 1,0 mm.

The MPD may be increased to 1,2 mm for vehicles of category N2, N3 and M3

g) Longitudinal and transverse slope of the operation distance shall not exceed 1 %.

Table A.1 — Aggregate grading envelope

Sieve mm	Passing Sieve % by mass
1,4 *D* [a]	100
D	90 to 100
2	15 to 72
0,063	2,0 to 15,0

[a] Where the sieve calculated as 1,4 D is not an exact number in the standard sieve sizes, then the next nearest sieve in the set shall be used.

A.1.2 Conformity tests

a) Measurements for irregularity and mean profile depth shall be located along the total length of the drive lane in each wheel track at 50 m intervals to cover the whole track.

b) Measurements for maximum aggregate size, aggregate grading, and in-place air voids shall be determined from asphalt mixture test results from construction, or alternatively from extracting a minimum of 4 cores from the drive lane.

A.1.3 Homogeneity of surface properties

In order to ensure that the properties of the drive lane are homogeneous, both the average of all measurement locations and 80 % of the measurement locations shall meet the requirements with respect to texture and irregularity.

A.2 Measurement methods and data processing

A.2.1 Irregularity measurement methods

The irregularity of the drive lane shall be determined in accordance with EN 13036-7.

A.2.2 Texture measurements methods

The profile shall be measured in accordance with ISO 13473-1 for MPD. The measurement instrumentation shall meet the requirements of class DE defined in ISO 13473-3.

Additional details according to ISO 13473-1, MPD shall be measured in the wheel tracks of the drive lane and the following two options can be used:

— Continuous measurement: MPD is measured continuously over the entire drive lane. The measured profile shall be divided into sections each 50 m long, for which MPD shall be evaluated separately as average over each section. Measurement runs shall be made in each wheel track.

— Segmented measurement: MPD is measured every 50 m in each wheel track. Measurement locations shall be evenly distributed over the drive lane length every 50 m. At each such measurement location, a minimum length of 2,0 m of profile shall be measured, each one at least 0,8 m long and positioned in a way which give statistically independent MPD values.

Annex B
(informative)

B.1 Flowchart for vehicles without auxiliary brake

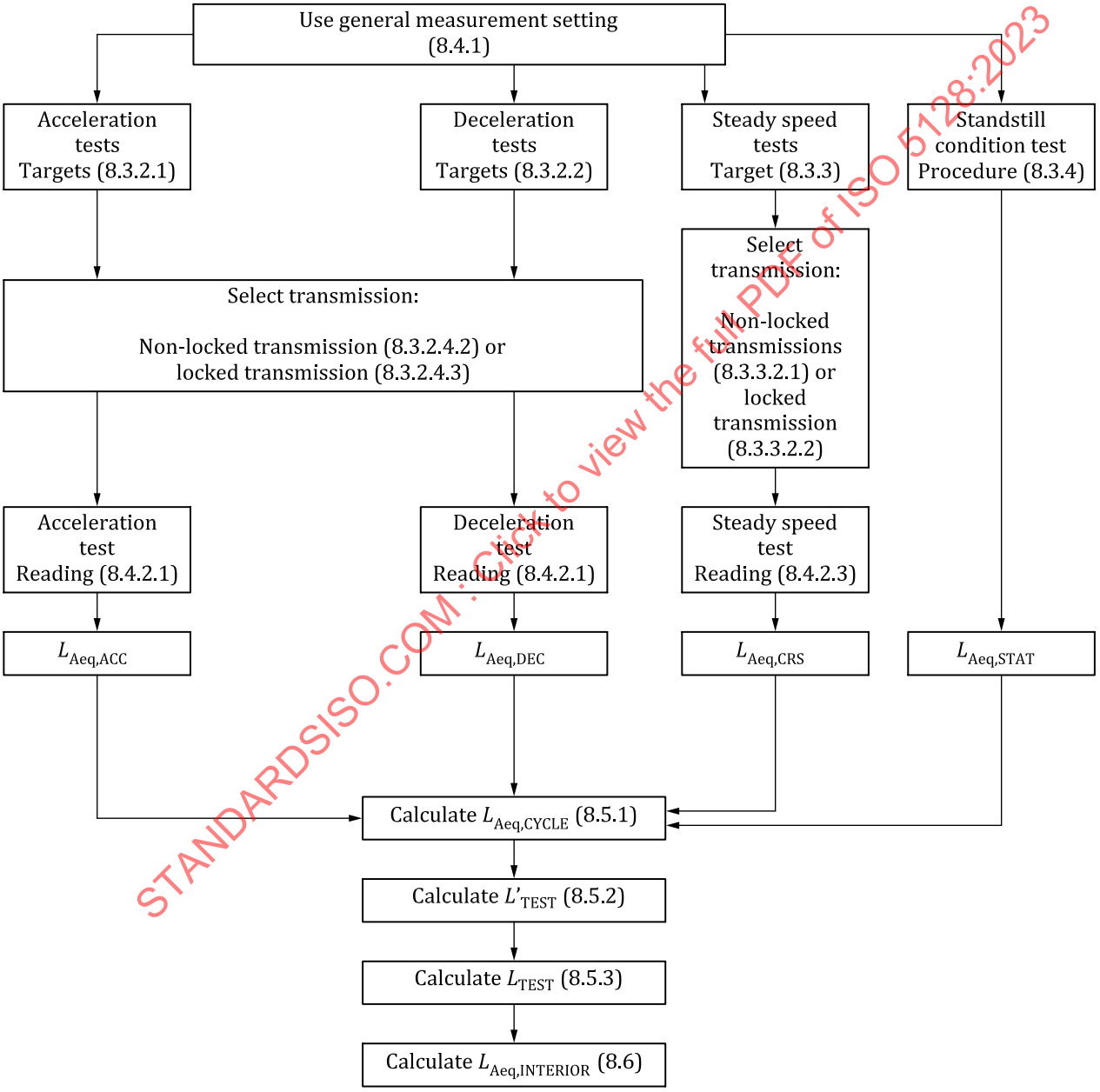


Figure B.1 — vehicles without auxiliary brake

B.2 Flowchart for vehicles with auxiliary brake

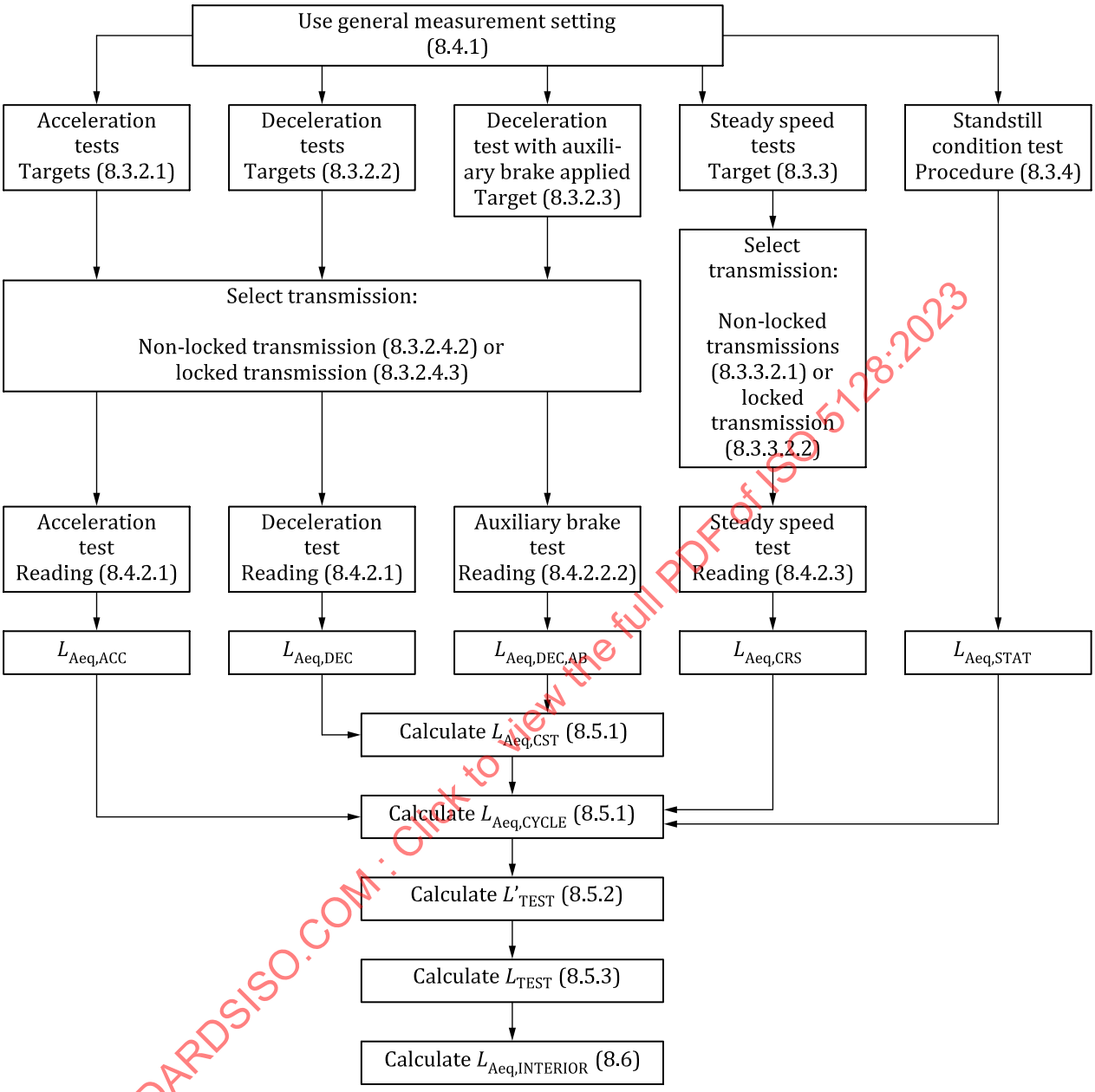


Figure B.2 — Flowchart for vehicles with auxiliary brake

Annex C
(informative)

Considerations on the precision of this standard

C.1 General

C.1.1 Variation in driving cycles and cycle mixes

This standard provides driving cycles based on analysis of the working group on the typical use of a vehicle category. The variation in use can be substantial different, leading to very different test results. An example for a passenger car may explain the variation. The selected cycle is representative for typical private use. More than 1 million driving kilometres confirm, that vehicles are used less than 45 minutes per day, primarily under urban conditions at low speeds and for private use. The same car may as well be used as a taxi. The operation time is then substantial higher. However, in that case the principles of a working place apply. In case of professional use as a salesman long distance driving is more representative, but again the vehicle may then be seen as a working place.

Different driving cycles will lead to different test results. This standard has not assessed the variation in the interior sound level given by different driving cycles. The working group suggests to use the provided cycles to enable benchmarking and exchangeability of test results.

C.1.2 Impact of various roads and tyres

Interior sound can be very much dependent on the road where the test is carried out. The tyre rolling sound is transferred via air born and structure born noise. While air born tyre rolling noise inside the vehicle is dependent on the body insulation, primarily the door and window sealing, the structure born noise is dependent on the chassis design, the coupling with the vehicle body and the vibration flow paths. Sensitivities of the body and the cavity resonances can lead to singular frequency sensitivities leading to booming noises at discrete vehicle speeds. Such booming noise are not representative for the overall sound inside the vehicle, as typically the drivers adjust the operation condition of the vehicle to avoid such booming noises.

This document has provided a minimum quality definition based on ISO 10844 to balance between measurement variation and practicability. For better reproducibility it would be advisable to narrow the road surface specifications, but a full ISO road over a length of several 100 m to enable all tests of this standard is actually almost nowhere available.

The simplification is representative for modern typical urban roads in good condition. Substantial use of the vehicle on worse roads will lead to higher interior sound. However, on poor roads the typical speed of use of the vehicle will as well be lower and compensate to a certain extent the impact of the road.

C.1.3 Microphone positions

Interior sound can be substantially affected by the structure of the cabin. The sound level is typically higher for the ear which is closer to the window. When cavity resonances are measured, the sound level can easily increase by several decibel. However, such cavity resonances are local and only given for discrete operation conditions. They are not representative over the whole operation range. Within the given tolerance for the microphone positioning, the sound level may differ due to such effects. If abnormal sound levels are measured, especially under cruise condition, the location of the microphone should be adjusted within the given tolerance and the measurement repeated to analyse the impact.