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Acoustics — Measurement of the influence of road surfaces on traffic noise —

Part 1:
Statistical pass-by method

Acoustique — Mesurage de l'influence des revêtements de chaussées sur le bruit émis par la circulation —

Partie 1: Méthode statistique au passage

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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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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*, in collaboration with ISO Technical Committee TC 227, *Road materials*, in accordance with the agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition of ISO 11819-1:1997 and ISO/PAS 11819-4:2013, which have been technically revised.

The main changes are as follows:

— ISO/PAS 11819-4 has now been integrated as Annex C;

— the backing board method makes possible a wider application of the method, where the old version would not meet the acoustical free field conditions;

— changes to nomenclature for vehicle categories in 3.1, including the introduction of a 'generic' vehicle category and the introduction of a minimum gross vehicle weight (8 t) for dual-axle heavy vehicles;

— changes to some key symbols and abbreviations in Clause 4;

— using a generic speed exponent for heavy vehicles instead of calculating a speed exponent from each measurement;

— using a correction to 2-axle medium vehicles for correcting them to a level typical of 3-axle heavy vehicles;

— more liberal requirement regarding the number of heavy vehicles to measure;

— an additional microphone position (at the height of 3,0 m) can be used in cases where reflecting objects could influence the results.

The objective of the changes and supplements is to make SPB measurements more practical while maintaining or reducing uncertainties.

A list of all parts in the ISO 11819 series can be found on the ISO website.

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

The emission of road traffic noise greatly depends on road surface characteristics, notably on texture and porosity; the latter due to the flow resistivity of the air voids. Both these characteristics influence the generation of tyre/road noise and, in addition, the porosity can influence the emission of sound, particularly when the emission takes place close to the surface. Power unit noise, which is usually generated at a greater height above the road surface than tyre/road noise, can also be affected during emission by the porosity characteristics of the road surface. These effects lead to differences in sound levels, associated with a given traffic flow and composition, from different road surfaces of up to 15 dB, which can have a substantial impact on the environmental acoustic quality alongside a road.

It is therefore important to be able to measure this influence by a standardized method and to arrive at a quantitative ranking of road surfaces with respect to traffic noise. This document offers such a method, the objective of which is to satisfy a need expressed by road planners, road administrators, contractors, manufacturers of so-called "low-noise surfaces" and by other parties concerned with the prediction and control of road traffic noise.

Acoustics — Measurement of the influence of road surfaces on traffic noise —

Part 1:
Statistical pass-by method

1 Scope

This document specifies a method of comparing traffic noise on different road surfaces for various compositions of road traffic for the purpose of evaluating different road surface types. Sound levels representing either light or heavy vehicles at selected speeds are assigned to a certain road surface. The method is applicable to traffic travelling at constant speed, i.e. free-flowing conditions at posted speeds of 50 km/h and upwards. For conditions where traffic is not free flowing, such as at junctions and where the traffic is congested, the method is not applicable.

A standard method for comparing the noise characteristics of road surfaces gives road and environment authorities a tool for establishing common practices or limits regarding the use of road surfaces meeting certain noise criteria. However, it is not within the scope of ISO 11819 (all parts) to suggest such criteria.

The statistical pass-by (SPB) method is suitable for use for the following main purposes:

— to classify road surfaces according to their influence on traffic noise (surface classification);

— to assist in verifying conformity of production of road surfaces;

— to evaluate acoustic performance of road surfaces throughout operation relative to new condition;

— to evaluate the influence of different road surfaces on traffic noise at sites irrespective of condition and service time;

— to evaluate acoustic performance of a road surface relative to a reference surface.

Due to practical restrictions, the method cannot be applied at all possible locations. However, the backing board method can allow some locations to be tested that were not previously acceptable.

Clause 5 gives a general description of the SPB method.

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 1996-2, *Acoustics — Description, measurement and assessment of environmental noise — Part 2: Determination of sound pressure levels*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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

IEC 60942:2017, *Electroacoustics — Sound calibrators*

IEC 61183, *Electroacoustics - Random-incidence and diffuse-field calibration of sound level meters*

IEC 61260-1, *Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications*

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

3   Terms and definitions

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

ISO and IEC maintain terminology 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   Types of noise

3.1.1
vehicle noise
total noise from an individual vehicle, including the two major components of *power unit noise* (3.1.3) and *tyre/road noise* (3.1.2)

3.1.2
tyre/road noise
noise generated by the tyre/road interaction

3.1.3
power unit noise
noise generated by the vehicle engine, exhaust system, air intake, fans, transmission, etc.

3.1.4
background noise
unwanted noise interfering with the noise that is intended to be measured

3.2   Measurement method

3.2.1
statistical pass-by method
SPB method
measurement procedure designed to evaluate vehicle and traffic noise generated on different sections of road surface under specific traffic conditions

Note 1 to entry: The measurements are taken from a great number of vehicles operating normally on the road. Results obtained using this procedure are normalized to standard speeds according to the category or type of road being considered.

3.3   Road speed categories

NOTE   Three categories of roads are defined with respect to the range of speeds at which the traffic flows and usually associated with certain areas (urban, suburban, rural, etc.).

3.3.1
"low" speed road
road category where traffic operates at an average speed of 45 km/h to 64 km/h

3.3.2
"medium" speed road
road category where traffic operates at an average speed of 65 km/h to 99 km/h

Note 1 to entry: These conditions are mostly found in suburban areas or on rural highways.

3.3.3
"high" speed road
road category where cars operate at an average speed of 100 km/h or more; but where heavy vehicles may operate at lower average speed due to speed restrictions

Note 1 to entry: These conditions are usually associated with motorway traffic in rural or suburban areas.

3.3.4
reference speed
v_{ref}
preferred speed for uniform reporting of measured data

Note 1 to entry: The reference speed is expressed in kilometres per hour. Most commonly used reference speeds are 50 km/h, 80 km/h and 110 km/h (also in ISO 11819-2) but alternative speeds may be used, if required for technical, safety and legislative reasons.

3.4   Vehicle categories

3.4.1
vehicle category
category of vehicles that have certain common features easy to identify in the traffic stream, such as the number of axles and the size, that are assumed to correspond to similarities in sound emission when driven under the same operating conditions

3.4.2
category P – passenger cars
vehicles used for passenger transportation, having two axles and having typically 4 to 5 seats

Note 1 to entry: See further Annex A.

3.4.3
category H – heavy vehicles
categories H2 (3.4.3.1) and *category H3+* (3.4.3.2) combined

3.4.3.1
category H2 – dual-axle heavy vehicles
trucks, buses and coaches with two axles and four or six wheels, and having a gross vehicle mass of at least 8 t

Note 1 to entry: See Annex A.

3.4.3.2
category H3+ – multi-axle heavy vehicles
trucks, buses and coaches with more than two axles

Note 1 to entry: See Annex A.

3.5   Measured noise quantities

3.5.1
maximum sound level
$L_{A,max}$
highest A-weighted sound pressure level recorded by the measuring instrument during a vehicle pass-by, using time weighting F

3.5.2
SPB sound level
$L_{SPB:P,vref}$ or $L_{SPB:H,vref}$
maximum A-weighted sound pressure level determined at a reference speed, v_{ref}, calculated for either vehicle *category P* (3.4.2) or *category H* (3.4.3)

3.5.3
statistical pass-by index
SPBI
noise index for comparison of road surfaces, based on the *SPB sound levels* (3.5.2), $L_{SPB:P,vref}$ and $L_{SPB:H,vref}$, and considering the mix and speeds of vehicles

3.6   Road surface terms applicable in this method

3.6.1
dense road surface
road surface featuring a wearing course with a void content of not more than 10 % (by volume)

3.6.2
porous road surface
road surface featuring a wearing course with a void content of equal to or more than 18 % (by volume)

3.6.3
negatively textured road surface
road surface featuring a relatively flat upper part and relatively narrow valleys or troughs between the main aggregate

Note 1 to entry: The skewness of its profile according to ISO 13473-2 is negative.

3.6.4
reference surface
virtual reference surface
surface which is not existing but being considered as an "average" of a dense asphalt concrete and a stone mastic asphalt surface with a maximum aggregate size of 11 mm

Note 1 to entry: The above definition is incomplete. For further details, refer to Annex F.

Note 2 to entry: This definition is valid only in ISO 11819 (all parts).

3.7   Backing board terms

3.7.1
backing board
rectangular, hard, reflective board on which a microphone is mounted

3.7.2
surface microphone
flush-mounted microphone designed to measure sound pressure on a surface without requiring the drilling of a hole through it

4   Symbols and abbreviated terms

Table 1 lists the symbols used in this document. All acoustic variables are A-weighted.

Table 1 — Symbols and abbreviated terms used in this standard and their value or unit

Symbol	Value/unit	Explanation
$L_{A,max,i,v}$	dB	The maximum sound level, A-weighted, for vehicle No. i when it passes-by at speed v
$L_{SPB:P,v_{ref}}$	dB	The SPB sound level, for vehicle category P (passenger cars), at the reference speed v_{ref}
$L_{SPB:H,v_{ref}}$	dB	The SPB sound level, for vehicle category H (heavy vehicles), at the reference speed v_{ref}

Table 1 *(continued)*

Symbol	Value/unit	Explanation
$L_{SPB:G,v_{ref}}$	dB	The SPB sound level, for vehicle category G (General; i.e. passenger cars or heavy vehicles), at the reference speed v_{ref}
$L_{A,E}$	dB	The energy-equivalent A-weighted sound exposure level
A	dimensionless	A constant used in the noise-to-speed relationship
B	dimensionless	Speed coefficient; i.e. increase in SPB level with a 10-fold increase in speed, used to correct for deviations from the reference speed, v_{ref}
v_{meas}	km/h	Measured speed of an individual vehicle during a pass-by measurement
v_{ref}	km/h	Reference speed; used to normalize SPB sound levels to a common speed

5   Measuring principle

In the statistical pass-by (SPB) method, the maximum A-weighted sound pressure levels of a statistically significant number of individual vehicle pass-bys are measured at a specified roadside location, together with the vehicle speeds. Each measured vehicle is classified into the appropriate vehicle category.

For each road and vehicle category, a reference speed is selected. Each individual pass-by level together with its vehicle speed is recorded, and a regression line of the maximum A-weighted sound pressure level versus the logarithm of speed is calculated for each vehicle category, or if the latter appears to be too uncertain, an alternate standard noise-speed relation may be used. From this relation, the average maximum A-weighted sound pressure level is determined at the reference speed. This level, for both vehicle categories P and H, is called the SPB sound level ($L_{SPB:P,v_{ref}}$ and $L_{SPB:H,v_{ref}}$) and is the mandatory result of each SPB measurement.

For the purpose of reporting a single number rating of the acoustic performance of road surfaces, the Statistical Pass-by Index (SPBI) can be calculated. This combines the appropriate SPB sound levels on a energetic basis, assuming certain proportions of these vehicle categories. The SPBI can be used for comparison of road surfaces so that their influence on sound level of a mixed traffic flow can be determined. It is not suitable for determining actual traffic noise levels.

6   Instrumentation

6.1   Instruments for acoustical measurements

6.1.1   General

The instruments for measuring sound pressure levels, including microphone(s) as well as cable(s), windscreen(s), recording devices and other accessories, if used, shall meet the requirements for a class 1 instrument according to IEC 61672-1 for free field or random incidence application, as appropriate. The frequency range of 50 Hz to 10 000 Hz (centre frequencies of one-third-octave bands) shall be covered. Filters shall meet the requirements for a class 1 instrument according to IEC 61260-1.

NOTE   Frequencies below 100 Hz are not believed to have a significant effect on the result but are required in some models and national regulations[20].

An appropriate windscreen shall be used having a diameter of at least 90 mm.

6.1.2   Verification

Conformity of the sound pressure level measuring instrument including microphone, the filters and the sound calibrator with the relevant requirements of IEC 61672-1, IEC 61260-1 and IEC 60942 respectively shall be verified by the existence of a valid certificate of conformity. Conformity testing in accordance with IEC 61672-3, IEC 61260-3 and IEC 60942:2017, Annex B, respectively is required for verification.

If applicable, random incidence response of the microphone shall be verified by a procedure from IEC 61183.

All conformity testing shall be conducted by a laboratory operated in accordance with ISO/IEC 17025 and that meets the maximum-permitted uncertainty specified in IEC 61672-1, IEC 61260-1 and IEC 60942 respectively.

Unless national regulations dictate otherwise, it is recommended that the sound calibrator should be calibrated at intervals not exceeding 1 year, the conformity of the instrumentation system with the requirements of IEC 61672-1 should be verified at intervals not exceeding 2 years, and the conformity of analog filters with the requirements of IEC 61260-1 should be verified at intervals not exceeding 2 years.

NOTE   Testing in accordance with IEC 61672-3 does not fully verify conformity with the requirements of IEC 61672-1, unless it has been pattern approved in accordance with IEC 61672-2.

6.2   Instruments for vehicle speed measurements

6.2.1   General

The maximum permissible uncertainties for instruments used for vehicle speed measurements shall be ±2,5 %, at the instant when the vehicle passes the microphone.

Measuring devices which can cause significant noise by the passage of vehicle tyres should not be used.

6.2.2   Verification

Conformity of the speed measuring instrument shall be verified by the existence of a valid certificate of conformity. In case of home-made systems using photocells at a fixed distance, such verification needs to be made by accurately measuring the distance. The conformity of the speed measurement device is verified at intervals not exceeding 2 years.

6.3   Instruments for temperature measurements

6.3.1   General

The air and road temperature measuring instrument(s) shall have a maximum permissible uncertainty of ±1 °C, as specified by the manufacturer. Meters utilizing the infrared technique shall not be used for air temperature measurements.

The type of sensor used shall be reported.

6.3.2   Verification

Equipment shall be calibrated in accordance with the manufacturer's specification, in most cases requiring a calibration annually by a laboratory authorized to perform calibrations traceable to appropriate standards.

7   Test sites

7.1   Selection of measuring site

The following considerations apply for site selection.

—   The measuring location shall be alongside a part of the road where the noise characteristics of the pavement are representative for the type of pavement and the physical conditions between the lane and the microphone as well as the surroundings meet the acoustical requirements.

— Each road test section shall extend at least 30 m on both sides from the microphone location. For cases where a significant number of heavy vehicles have a length exceeding 20 m, this distance is increased to 50 m.

— The road shall be essentially level and straight. Roads with slight bends or with gradient ≤2 % may be considered valid test sites.

— Requirements on background noise at the test site in accordance with Clause 11 shall be observed. See also 8.2 regarding selection of vehicles.

— The road surface condition should be homogeneous over the entire test section. A practical way to check the homogeneity is to make a measurement with the CPX method (see ISO 11819-2) over the test section and note how typical the CPX level is on the intended SPB measurement spot. For dense road surfaces, it would be sufficient with a measurement of MPD according to ISO 13473-1.

— The road surface should be in a good condition, unless the intention of the study is to determine the effect of road condition on vehicle noise. Road surfaces which exhibit unusually high unevenness characteristics, surface cracking, bitumen bleeding, excessive stone loss or contain expansion joints, for example, would not normally be considered as suitable for surface classification purposes.

NOTE   Since some types of road surfaces change their noise characteristics rather quickly after opening for traffic, measurements on newly laid surfaces have limited validity.

7.2   Deviations from free-field conditions

For surface classification purposes, the measurement microphone should be located in the acoustical free field. Acoustic reflections from surfaces such as building façades, retaining walls, noise barriers, road cuttings and embankments shall be at least 10 dB lower than the direct sound to be measured. As a guideline, 25 m of space around the microphone free of any reflecting objects other than the ground is usually adequate to ensure that approximate free field conditions exist.

7.3   Considerations of guard rails and other barriers which can reflect or screen the sound

There shall be no large reflecting surfaces, such as solid safety barriers, large road signs or embankments, within a rectangle 30 m × 22 m in Figure 1 marked with a broken line. If safety barriers, large road signs or other major objects are present within the rectangle, they shall be removed for the measurements, if possible, or covered with effective sound absorbing material prior to the measurements. The presence of such surfaces and the type of covering shall be duly stated in the report.

Protective fences will not normally affect the results and can be ignored for the purpose of site and microphone position selection. Treatments on some noise barriers with the intention to reduce sound reflections are not sufficiently absorptive to allow such barriers within the rectangle shown in Figure 1.

NOTE 1   In ISO 11819 (all parts), a solid safety barrier is a concrete wall structure designed to prevent vehicles from leaving the road or crossing the median.

NOTE 2   In ISO 11819 (all parts), a guard rail is a structure consisting of a metal beam or plate attached to rigid posts and designed to prevent vehicles from leaving the road or crossing the median. There is also a type of guard rail consisting of stretched steel wires attached to rigid posts.

NOTE 3   In ISO 11819 (all parts), a protective fence is a structure fabricated of wire or cable (usually chain link) mounted on support posts and intended to prevent animals or human beings from entering the road.

NOTE 4   If the problem is impossible to avoid, the optional microphone position (3 m) described in 9.1 can provide a solution

7.4   Surface between the tested road surface and microphone

Ideally, the surface between the microphone position and the edge of the test lane should be covered with the same material as the road surface in the measuring lane. However, at some sites it cannot

be possible to achieve this condition. When measurements are being made for surface classification purposes, it is necessary to ensure that at least half of the area between the centre of the test lane and the microphone shall have acoustical properties similar to the road surface under test, and be essentially level with the road surface (see Figure 1). This can be accomplished by placing an appropriate covering material over non-conforming surfaces. The selection of this material is left to the judgement of the person responsible for the measurement. Figure 1 shows the angles over which the covering should be applied. If this practice is undertaken, full details shall be summarized in the report.

The 3,75 m nearest the microphone may be grass or another surface with significant absorption. However, any vegetation in this area shall be kept as short as possible.

Any roadside ditch or other significant depression shall be at least 5 m from the centre of the test lane.

When these propagation conditions cannot be met, the site is not suitable for acoustical classification measurements. Table 2 gives an informative overview of how various sound absorptive or reflective environments that do not fully comply with the propagation conditions above can influence the measurements.

NOTE 1   In Figure 3, a microphone on the other side of the road is specified in cases where it is difficult to meet the requirements with the "normal" microphone position.

NOTE 2   For overall SPB levels, the ground cover in the area 3,75 m nearest the microphone (areas 7 and 8 in Figure 1) is not important; however, spectra might be significantly distorted if the surface is acoustically soft or has a depression.

Key

1 test lane (road surface under test)
2 centre of test lane
3 lane edge marking
4 road shoulder or other roadside area
5 microphone position

6 minimum area covered with material having sound absorption similar to that of the tested road surface
7 area where there should be no ditch or significant depression, but ground cover is not important
8 no requirements regarding ditch or depressions or ground cover
9 no screening rail, large signs or safety barriers allowed within the area bounded by the dotted line between the microphone position and the test lane
10 no reflecting solid safety barrier allowed within the area bounded by the dashed line unless covered with sound absorptive material

Figure 1 — Requirements regarding freedom from reflecting or screening safety barriers, large signs or guard rails and regarding the minimum coverage with an acoustically appropriate surface between the test lane and microphone

Table 2 — Estimated effect of various sound-reflecting or sound-absorbing objects on the A-weighted sound levels at the microphone location.

Object or surface	Potential effect at the 1,2 m high microphone position	Potential effect at the 3 m high microphone position	Notes
For a highway with 2 or more lanes in each direction:			
Solid safety barrier at the median of the road	~0,5 dB increase (less for 3 lanes)	~0,7 dB increase (less for 3 lanes)	Some frequencies can be influenced by up to 1,5 dB

Table 2 *(continued)*

Object or surface	Potential effect at the 1,2 m high microphone position	Potential effect at the 3 m high microphone position	Notes
Safety barrier on median with <100 mm wide bars	No significant effect	No significant effect	
Guard rail (rail height 0,5 m) between road and microphone	Up to 4 dB decrease	Up to 1 dB increase	
Solid safety or noise barrier <1 m high between road and microphone	Up to 10 dB decrease	Up to 3 dB decrease	
Round or triangular traffic signs >5 m from microphone	No effect	No effect	
Soft ground in area 6, 7 and 8 in Figure 1	Overall levels influenced by up to 0,5 dB	Overall levels influenced by <0,5 dB	Some frequencies can be influenced by up to 1,5 dB
Soft ground in area 7 and 8 in Figure 1	No significant effect on overall levels	No significant effect on overall levels	Some frequencies can be influenced by up to 1,5 dB
Soft ground or trench or ditch in area 8 in Figure 1	No significant effect	No significant effect	Some frequencies can be influenced by up to 1 dB
Trench or ditch in area 7 in Figure 1	No significant effect on overall levels	No significant effect on overall levels	Some frequencies can be influenced by up to 1,5 dB
Shed, building or vehicle <25 m from microphone	Up to 1,5 dB increase for reflective ground	Up to 1,5 dB increase for reflective ground	
For a highway with a single lane in each direction:			
Solid safety barrier at the median of the road	Appr. 1 dB increase	Appr. 1,3 dB increase	Some frequencies can be influenced by up to 2,5 dB

7.5 Backing board

In cases where the requirements of free field conditions behind the microphone are difficult to meet, consider using the backing board method, described in Annex C.

8 Traffic conditions

8.1 Vehicle classification

Only vehicles which clearly fall within any of the categories defined in Clause 3 and in Annex A shall be measured. Where there is any doubt in classifying a vehicle, the measurement for that vehicle shall be discarded from the study.

8.2 Selection of vehicles for measurement

Measurements shall only be taken on individual vehicle pass-bys which can be clearly distinguished acoustically from other traffic on the road. The following criteria shall be used to judge if a vehicle pass-by is distinguishable.

a) Just prior to and just after the passage of a vehicle intended for measurement, the A-weighted sound pressure level shall be at least 6 dB below the measured maximum A-weighted sound pressure level during the pass-by. See Figure 2.
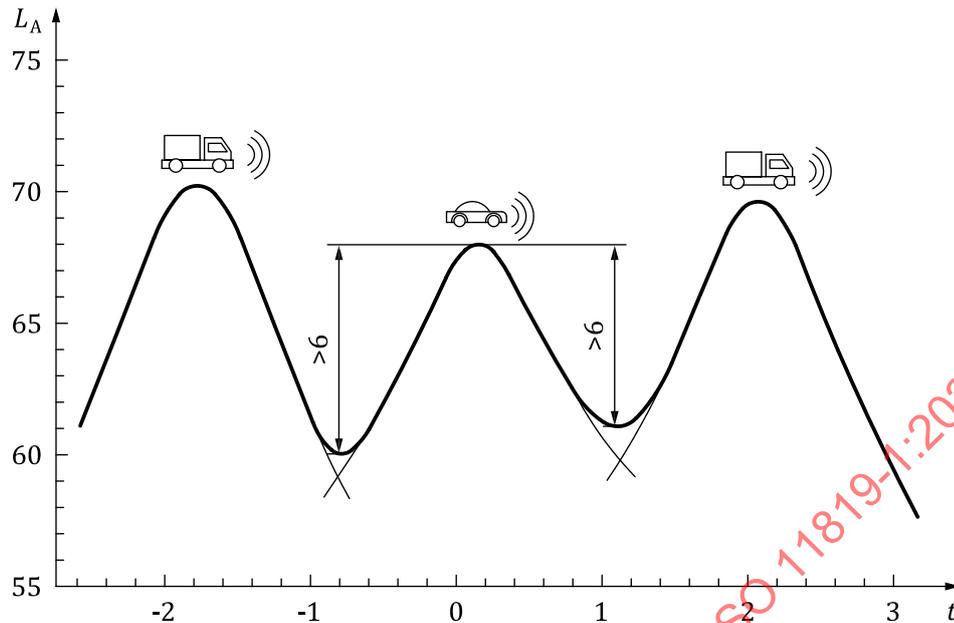
Key

t time, in seconds

L_A A-weighted sound level, in dB

NOTE   The solid thick line shows the (idealistic) total sound level from the tested vehicle passing between two disturbing vehicles.

Figure 2 — Illustration of required signal-to-noise ratio for individual vehicle pass-bys

b) When selecting vehicles for measurement, care should also be taken to ensure that sound from other vehicles overtaking the target vehicle or passing on the other carriageway do not influence the measured result. In these cases, it is possible that the maximum sound level from the target vehicle and other traffic will occur approximately simultaneously so that the peaks obtained are then indistinguishable. Such measurements shall be discarded.

c) Only vehicles that are considered as representative of the current vehicle fleet shall be considered.

d) Vehicles which clearly exhibit unusual or atypical noise characteristics such as might occur due to a faulty or modified exhaust system; vehicle body rattles or audible warning devices shall be discarded from the measurement. Vehicles with auxiliary equipment which emits audible sound should also be discarded.

e) Sound levels should be measured only from vehicles judged to be moving at constant speed. Individual vehicles judged to deviate significantly in their lateral position from the median axis of the test lane shall be discarded from the analysis.

See also the conditions mentioned in Clause 11.

8.3 Minimum number of vehicles

For purposes of road surface classification, a minimum number of vehicles shall be measured.

To reduce random uncertainties, the following minimum numbers of vehicles shall be measured, within each vehicle category:

— Category P (cars): minimum 100;

— Category H (heavy vehicles, i.e. H2 and H3+ together): minimum 40.

See also Clause 13 regarding expected uncertainties.

NOTE   The minimum numbers are determined from a balance between uncertainty and precision and the time needed to measure the desired number of vehicles in the actual traffic. For example, for Category H, the uncertainty of the LSPB:H increases by ~0,2 dB when decreasing the number from 50 to 40. If, on the other hand, the number is increased from 50 to 80, uncertainty will decrease by ~0,1 dB[10].

8.4   Road speed categories

For the classification of road surfaces, it is necessary to distinguish between the three road speed categories, defined in 3.2. Each of the three categories is associated with a reference speed to be used for normalization of sound levels; see also 12.6. The acoustical behaviour of road surfaces can be different for these road speed categories.

The sound levels $L_{SPB:P,v_{ref}}$ and $L_{SPB:H,v_{ref}}$ shall always be reported for at least one of the road speed categories.

9   Measuring procedure

9.1   Microphone position

The horizontal distance from the microphone position to the centre of the lane in which the vehicles to be measured travel shall be 7,5 m ± 0,1 m. The microphone location is shown in Figure 1 and in Figures 3 a) and 3b).

An exception is if there is a two-lane road (one lane per direction, see Figure 3b) and the shoulder closest to the test lane is too narrow to provide a surface having the appropriate acoustical reflectivity (see 7.4), in which case, a microphone position on the other side of the road can be used (microphone distance is still 7,5 m).

In the case of a 2 × 2 lane road (Figure 3 a)), if the shoulder is too narrow to provide the appropriate acoustical reflectivity according to 7.4, one shall first consider if it is practical and safe to divert the traffic into the "fast" lane. If this is not the case, one may select microphone position 2 instead.

Examples provided assume right-hand traffic. In cases of left-hand traffic, the positions shall be reversed.

The microphone shall be located 1,2 m ± 0,1 m above the plane of the road lane. Unless otherwise indicated by the manufacturer of the sound level meter, the microphone shall be horizontal and directed perpendicularly towards the path of the vehicles.

There should be a distance of no less than 0,1 m between the microphone membrane and any microphone mounting rod or stand to avoid influence from sound diffraction or reflections.

An additional (optional) microphone position, 3,0 m ± 0,1 m above the plane of the road lane, can be used in cases where reflecting objects, such as solid safety barriers could influence the results in the normal microphone position. With respect to the direction of the microphone, the same requirements as above apply. Refer to 12.1 for processing of those measurement results.

The additional microphone position is recommended for use as a supplementary position in cases where sound diffractions and reflections on objects near the ground level can constitute a problem or when the ground conditions in Figure 1 are not achieved. It can also be a useful supplement when vertical directivity of the noise emission is an important issue.

Dimensions in metres

a) 2 × 2 lane motorway (or corresponding)

b) 1 × 2 lane highway or street
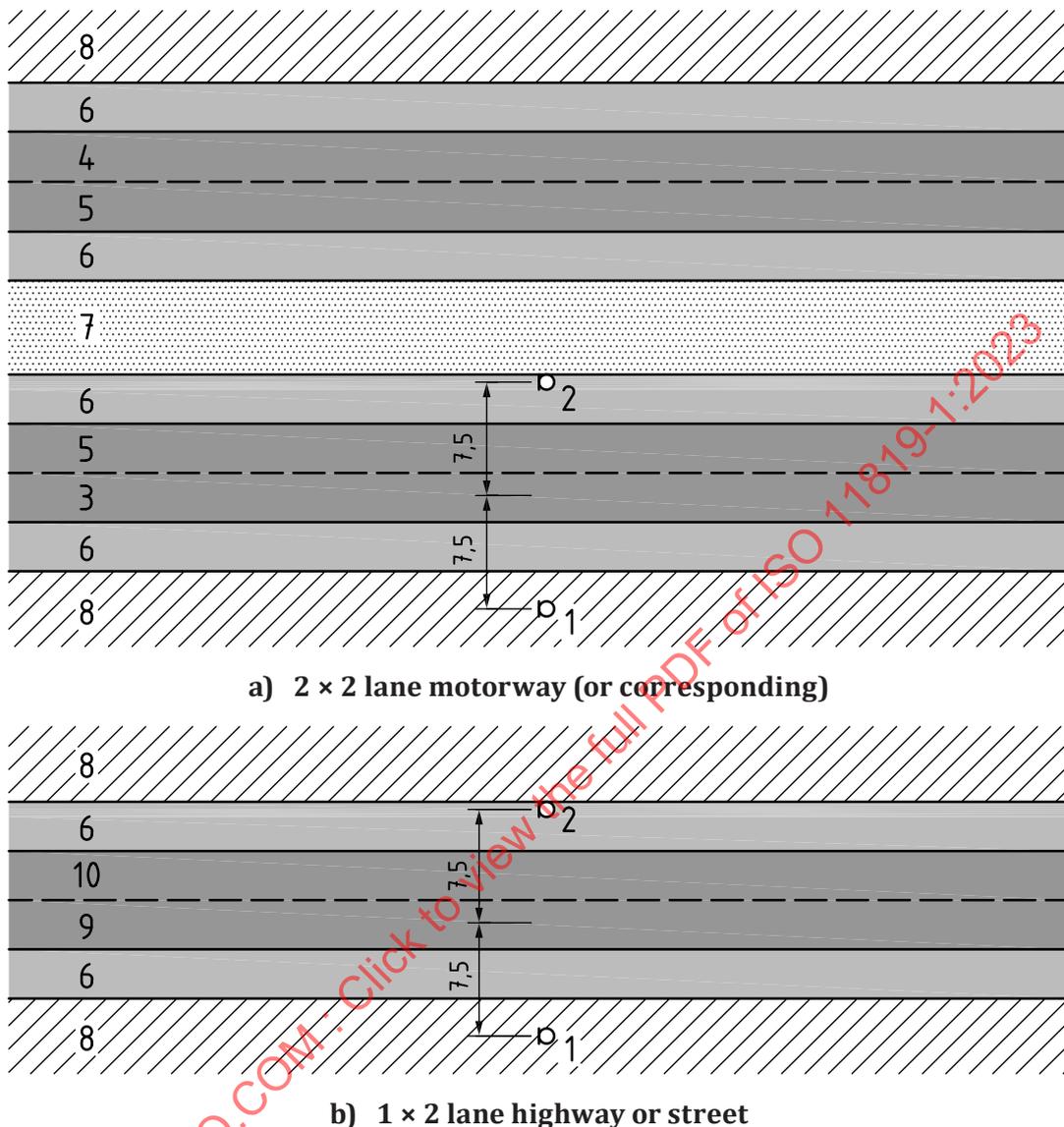
Key

1	microphone position 1 (7,5 m from median)	6	shoulder
2	microphone position 2 (7,5 m from median)	7	median area
3	slow lane (measuring lane)	8	roadside area, e.g. grass or gravel
4	slow lane	9	driving lane (measuring lane)
5	fast lane	10	opposing lane

Figure 3 — Typical road configurations and microphone positions

9.2 Calibrations

At the beginning and at the end of every measurement session, the entire sound pressure level measuring system shall be checked at one or more frequencies by means of a sound calibrator meeting the requirements for a class 1 instrument according to IEC 60942. Without adjustment, the difference between the readings of two consecutive checks shall be less or equal to 0,5 dB. If this value is exceeded, the results of measurements obtained after the previous satisfactory check shall be discarded.

9.3 Sound level measurement

During each vehicle pass-by, the maximum A-weighted sound pressure level, $L_{A,max}$, shall be measured using time weighting F.

9.4 Frequency spectrum measurement

Frequency spectra shall be measured in one-third-octave bands using time weighting F. The spectrum shall be captured when the A-weighted sound pressure level during a vehicle pass-by is at its maximum.

It is recommended that the frequency spectrum is presented with A-weighting applied to each frequency band.

9.5 Speed measurement

The vehicle speed shall be measured at approximately the moment when the vehicle midpoint passes closest to the microphone.

If the measurement is made with a radar device directed towards the vehicle from a road-side location, the measured speed will be lower than the actual speed due to the measurement angle. It is important to correct for this effect. If the instrument itself does not provide such a correction, the reading shall be corrected manually.

See also Note 2 for precautions regarding measurements for the "low" road speed category.

9.6 Temperature measurement

Air and road surface temperature during the measurement shall be measured in accordance with ISO/TS 13471-2.

10 Meteorological conditions

10.1 Wind

Wind speed at the microphone height shall not exceed 5 m/s during the measurement.

10.2 Temperature

Unless the measurement specifically aims at determining the influence of weather or other environmental conditions on sound emission, measurements shall be carried out only when road surfaces are dry and ambient air temperature is within the range 5 °C to 35 °C.

It is recommended that measurements be made at air temperatures as close as practical to the reference air temperature (20 °C).

10.3 Recommendations on road surface moisture

Road surfaces can be assumed to be sufficiently dry for measurements if the minimum time for drying after rainfall in Table 3 are observed[9]. However, as actual drying time will depend on wind and sunshine conditions, the values given may be adjusted accordingly.

Unless more than 2 days have passed since the latest precipitation, a check of whether a surface assumed to have a significant porosity still contains residual moisture is recommended.

Compressed air is blown into the road surface, e.g. using a standard pistol-grip air jet or a spray can with compressed air, directed vertically towards the surface. Any remaining moisture is revealed in a clearly visible spray cloud. The surface can be regarded as dry if five tests at representative points along

the length of the road surface fail to show a spray cloud. Blotting paper can also be used to indicate presence of water.

NOTE 1   Experience with sound measurements on porous road surfaces has shown that A-weighted levels can be influenced by up to 2 dB due to residual moisture in an apparently dry surface.

NOTE 2   This test can be carried out using a portable compressor. A short pulse of compressed air at 0,5 kPa to 0,8 kPa is sufficient for the test.

Table 3 — Recommended minimum time periods between rainfall and measurement

Surface type	Recommended time before measurements	Comments
Dense, non-permeable surfaces, e.g. hot rolled asphalt, dense asphalt concrete, cement concrete	No special time	Make visual judgement of whether the pavement is dry or humid/wet
Negatively textured road surfaces, potentially containing deep troughs, e.g. stone mastic asphalt and thin asphalt layers	3 h	After 3 h, make visual judgement of whether the pavement is dry or humid/wet
Porous (permeable) surfaces	24 h to 48 h	The lower value is acceptable only if there is sunshine during the day, and significant air movement over the surface either by wind or by traffic. Furthermore, the daytime should not be short as in wintertime

11 Background noise

A-weighted sound pressure levels from activities other than traffic on the road site shall be at least 10 dB below the maximum sound level from the quietest vehicle pass-bys recorded. Regarding sound pressure levels from other vehicles, see 8.2.

Measurements which obviously are disturbed by wind gusts, background noise or by other sources shall be discarded.

12 Normalization of data

12.1 Compensating for the effect of the additional (higher) microphone position

If the higher microphone position has been used, the measured maximum sound levels (including spectral levels) at the 3,0 m position shall be increased by 1,0 dB for dense pavements and 0,7 dB for porous pavements (air voids ≥18 %) in order to represent the results at a microphone height of 1,2 m.

NOTE 1   The correction constants have been determined based on measurements compiled by WG 33, for example but not only by Reference [9]. The tolerance of the constants for varying pavement properties is around ±0,5 dB (maximum for both dense and porous pavements). This is considered in the uncertainty analysis. Frequency band levels might need somewhat different correction constants.

NOTE 2   The data for the two microphone positions can turn out to be different. Both have its advantages and disadvantages. It is up to the user to decide which one is the most accurate for the measured case.

12.2 Combining vehicle categories H2 and H3+ into a common heavy vehicle category H

The SPB sound level and associated frequency spectra in third-octave band levels for each vehicle in category H2 (if measured) shall be normalized to the generic level of category H3+, by adding 2,7 dB. In

this way, all heavy vehicles of category H2 and H3+ will be collected into a single heavy vehicle category H.

NOTE 1   Except for urban locations, the number of measured vehicles of category H3+ usually dominates over category H2. To reach the minimum number of measured heavy vehicles it is preferred to use data for both vehicle categories, which the normalization above makes possible. However, measurement of H2 vehicles are not needed if such vehicles are uncommon in the traffic flow.

NOTE 2   The difference of 2,7 dB is a result of a comprehensive compilation of available data by the working group that developed this standard. It relies on the definitions of vehicle categories in Annex A.

12.3 Noise versus speed - regression analysis (for passenger cars)

The following applies only to passenger cars.

In general, it is assumed that sound pressure levels increase with speed according to the following Formula (1):

$$L_{A,\max,i,v} = A + B \cdot \lg v_i \tag{1}$$

Where

$L_{A,\max,i,v}$ is the measured maximum sound level, in dB, for passenger car No. i;

A is a constant;

B is a constant, termed speed coefficient (rounded to the nearest decimal);

v_i is the speed of vehicle No. i, in km/h.

The data for the measured maximum sound levels and speed for each individual car shall be analysed with a regression analysis of sound level versus the logarithm of speed, from which the constants A and B will be determined. The formula thus obtained shall be reported as Formula (2):

$$L_{SPB:P,v} = A + B \cdot \lg v \tag{2}$$

where

$L_{SPB:P,v}$ is the SPB level, in dB, for passenger cars (P), versus the speed v;

A, B constants determined from the regression;

v is the vehicle speed, in km/h.

It is useful to produce a regression diagram, as illustrated in Annex D. In this diagram, the 95 % confidence limits for the regression line shall be calculated and added. Annex D provides information about how to calculate the limits.

12.4 Noise versus speed – normalization to reference speed (for heavy vehicles)

The following applies only to heavy vehicles.

It is assumed that sound pressure levels increase with speed according to the following Formula (3):

$$L_{A,\max:j,v} = A + B \cdot \lg v \tag{3}$$

where

$L_{\mathrm{A,max:}j,v}$ is measured maximum sound level, in dB, for heavy vehicle No. j, passing-by at speed v, in km/h;

A is a constant;

B is a constant, termed speed coefficient (rounded to the nearest decimal);

v Is the vehicle speed, in km/h.

For heavy vehicles, when plotting the data points in a regression diagram of sound level versus logarithm of speed (same as for passenger cars), it usually appears that the spread in sound levels is very high at the same time as the speed range is relatively narrow. This can introduce uncertainty in the determination of constant B. Uncertainty can be reduced if B is predetermined by measurements including a large number of vehicles travelling at a wide range of speeds.

Therefore, select a generic speed coefficient B, which is presented in Table 4.

Table 4 — Generic speed coefficient B, for three categories of road surfaces, to be used for heavy vehicles

Vehicle category	Cement concrete	Porous asphalt concrete (≥18 % voids)	All other road surfaces (<18 % voids)
H (H3+ and H2)	30	25	25

NOTE   The generic speed coefficients are a result of a comprehensive compilation of available data by the working group that developed this standard. A potential uncertainty in B of ±5 will result in an uncertainty of only ±0,25 dB for a speed difference of ±10 km/h.

First, the arithmetic average, $L_{\mathrm{A,ave,H}}$, of all maximum sound levels for all accepted passes of H vehicles, together with the 95 % confidence interval, are calculated. Further, the corresponding arithmetic average of their vehicle speeds, $v_{\mathrm{ave,H}}$ and the standard deviation of speeds, $sv_{\mathrm{ave,H}}$ are calculated. The latter is used in the determination of the useful speed range according to 12.7.

Then a normalization of the measured noise level to the noise level at the reference speed (Table B.1) is made for all H vehicles together, based on the measured average noise levels and average speeds, according to this Formula (4):

$$L_{\mathrm{SPB:H}} = L_{\mathrm{A,ave,H}} - B \cdot \lg\left(\frac{v_{\mathrm{ave,H}}}{v_{\mathrm{ref}}}\right) \tag{4}$$

where

$L_{\mathrm{SPB:H}}$ the SPB level, in dB, for heavy vehicles (H), at the nominated reference speed v_{ref};

$L_{\mathrm{A,ave,H}}$ the arithmetic average of all heavy vehicle sound levels;

B is the constant presented in Table 4;

$v_{\mathrm{ave,H}}$ is the average vehicle speed for the heavy vehicles, in km/h.

It is useful to produce a plot of noise levels versus speed, as illustrated in Annex D. Formula (4) shall be reported, together with the 95 % confidence interval, which is the same as the 95 % confidence interval of A.

12.5 Noise versus speed – normalization of frequency spectra for vehicles in categories P and H

In cases where there is a large data set (containing significantly more than the minimum number of vehicles), one can calculate the sound level in each frequency band separately, over the appropriate frequency range, by using the same kind of regression as for the overall A-weighted levels ($L_{A,max}$).

NOTE 1   This procedure will show if and how the speed constant varies over different frequency bands.

However, for more typical (smaller) data sets, the following is recommended.

— Calculate the arithmetic average of all spectra for vehicles in category P or H over the appropriate frequency range, to obtain the "averaged frequency spectrum".

— Based on the result, calculate the A-weighted overall level.

— Check the difference between the SPB sound level (12.3 or 12.4) and the A-weighted overall level.

— Use the difference so obtained to normalize the averaged frequency spectrum, by the same constant for all frequencies, so that the A-weighted overall level of this spectrum fits the SPB sound level. The frequency spectrum obtained will be the final "normalized average frequency spectrum".

NOTE 2   The latter procedure assumes that the noise versus speed relation is constant over the entire frequency band which is, of course, a simplification.

12.6 Determination of SPB sound level at reference speeds

The reference speeds for the vehicle categories in the road speed categories are specified in Table B.1.

The sound levels for each category of vehicle at the corresponding reference speed will be the SPB sound level, i.e. $L_{SPB:P,vref}$ or $L_{SPB:H,vref}$ according to Formulae 2 and 4 with v equal to v_{ref}. In this way, for a given road site, separate SPB sound level values are obtained for cars and heavy vehicles.

All levels shall be calculated to two decimal places and rounded and reported to one decimal place.

12.7 Useful speed range for the speed normalization

For the regression calculation and subsequent normalization to a reference speed the following condition shall be met.

The range of speeds covered by the measured vehicles shall be such that the reference speed shall deviate from the measured average speed by less than ± one-and-a-half standard deviation, for both cars and heavy vehicles.

12.8 Correction of sound levels according to temperature

The SPB sound levels, $L_{SPB:P,vref}$ and $L_{SPB:H,vref}$, should be corrected to a reference air temperature of 20 °C. This can be made according to one of three methods:

Method 1: if temperature measurements are made at each individual vehicle pass-by, along with sound measurements, correct each measured sound level individually ($L_{A,max}$) for measured vehicles.

Method 2: for each set of measured vehicles in which temperature varies only within 5 °C, correcting all SPB sound levels for temperature using the average temperature of this set is acceptable. If measurements continue with further variation of temperature, the same procedure can be used per each set of measurements that are within 5 °C.

Method 3: correction may also be made within certain time periods when temperature does not vary more than (say) 5 °C.

The correction shall be made in accordance with ISO/TS 13471-2. Method 1 is preferred, but not required. Irrespective of method, one shall note both minimum and maximum as well as the time- or vehicle averaged temperature during the measurement session. Also, the temperature correction coefficient used shall be reported.

13 Measurement uncertainty

The procedure to calculate uncertainties is explained in ISO/IEC Guide 98-3. First, one shall identify each significant uncertainty source, indicated as $\delta1 + \delta2 + \delta3 + \delta4 + \delta5 + \delta6$, as an example. The following major sources of uncertainty in this procedure have been identified and require processing according to the procedure specified in ISO/IEC Guide 98-3:

— instrumentation uncertainty;

— uncertainty due to local propagation conditions;

— uncertainty due to insufficient correction of environmental influences;

— uncertainty due to operational variations regarding vehicle selection;

— uncertainty due to local and time variations in the vehicle fleet.

A more elaborated list of potential uncertainties appears in Annex H.

The value of these input quantities shall be evaluated by the test operators. It can be based on existing statistical data, analysis of tolerances stated in this document and engineering judgement. The information needed to derive the overall uncertainty is given in Table H.1. The table includes sensitivity coefficients c_j, the values of which are based on the procedures and formulae used to obtain the final result, as specified in ISO/IEC Guide 98-3.

The estimate of the measured SPB level, $L_{SPB:G,v_{ref}}$, here denoted by y, is determined from a series of quantities x_j through a functional relationship $L_{SPB:G,v_{ref}} = f(x_1, x_2, \ldots, x_6)$. Thus, the various x_j represent the parameters that determine the estimate of the SPB level.

The combined standard uncertainty of the measured SPB level is calculated with Formula (5):

$$u(y) = \sqrt{\sum_{j=1}^{6} (c_j u_j)^2} \tag{5}$$

where

c_j Sensitivity coefficient for input x_j; $c_j = \dfrac{\partial f}{\partial x_j}$ with $y = f(x_1, x_2, \ldots, x_6)$;

u_j The standard uncertainty in input x_j.

The expanded uncertainty, U, is determined by multiplying the combined standard uncertainty, $u(y)$, by the appropriate coverage factor, k, for the chosen coverage probability as described in ISO/IEC Guide 98-3. See Table 5 for an example of how the uncertainty budget is developed (note that the actual number of contributions is more than the 6 indicated in Formula (6); refer to Table H.1 in Annex H).

Table 5 — Uncertainty budget for the determination of the SPB level (separate for light vehicles and heavy vehicles)

Uncertainty source	Estimate	Probability distribution	Standard uncertainty, u_j	Sensitivity coefficient, c_j	Uncertainty contribution
$\delta1$	0	normal			

Table 5 *(continued)*

Uncertainty source	Estimate	Probability distribution	Standard uncertainty, u_j	Sensitivity coefficient, c_j	Uncertainty contribution
δ2	0	normal			
δ3	0	normal			
δ4	0	asymmetric			
δ5	0	asymmetric			
Combined standard uncertainty, $u(y)$, according to Formula (5)					

H.4 gives a detailed listing of the standard uncertainties and sensitivity coefficients of each source and gives typical values. Using these values, the uncertainty budget analysis results in a combined standard uncertainty in the SPB level as indicated in Table 6 as the expanded uncertainty and coverage probability for the case where the method is applied, and individual source uncertainties are consistent with Table H.1.

NOTE   The confidence intervals, around the SPB sound levels, assume that the number of vehicles is 100 cars and 40 heavy vehicles. The corresponding random uncertainty of the SPBI will be a combination of these uncertainties according to the chosen weighting factors (see Annex B).

The uncertainties quantified in Table 6 represent road speed categories "medium" road speed and "high" road speed. Results of measurements made for the road speed category "low" road speed can be influenced more by driving behaviour than others (some vehicles can be in an acceleration or deceleration mode which is not always easy to notice) and should be treated with caution. It might, for example, be wise to monitor their speed also slightly before and after they pass the microphone.

Table 6 — Estimated expanded uncertainty for a coverage probability (based on Table H.1)

Vehicle category	Coverage factor	Coverage probability	Expanded uncertainty
	k	%	dB
Light vehicles (P)	1,3	80	1,4
	2,0	95	2,2
Heavy vehicles (H)	1,3	80	2,1
	2,0	95	3,2

14 Reported data

14.1 General information

The test report shall include the following data (mandatory if not indicated as optional).

— date and time of day for start and end of measurements;

— organization and operators responsible for the measurement;

— purpose of the measurement;

— type of measurement equipment (including calibrator, sound level meter or equivalent system, measuring equipment for speed and meteorological data and, if used, equipment for measurement of surface macrotexture);

— whether the optional microphone position was used;

— whether the backing board method was used (and if so, the extra requirements given in C.12).

14.2 Information relating to the location and appearance of the test site

— location of the test site;

— site plan (horizontal), including microphone location (position 1 or 2) and identifying tested road lane, the type of road surface(s) between the tested lane and the microphone, as well as acoustically reflecting objects within 25 m from the microphone;

— cross profile (vertical) of the site from the other side of the road to the microphone position (optionally, photos might be used to illustrate the site and the cross profile);

— details of special provisions taken to assure conformity with Clause 7.

14.3 Information relating to the type and construction of the tested road surface

— type of road surface (asphalt concrete, stone mastic asphalt, surface dressing, etc.), including any standardized or otherwise commonly used designation of the road surface;

— maximum aggregate size of the road surface material;

— thickness of road surface layer (only for porous surfaces);

— other details in the production and construction of the road surface layer; in particular, those which may have an influence on noise properties (optional);

— macrotexture profile depth, according to ISO 13473-1 (optional);

— representative photo of the surface, covering an area ~100 mm by 150 mm, including a scale (optional)

14.4 Information relating to the condition of the tested surface and environmental factors

— age of the surface and state of maintenance;

— any special surface treatment;

— any notes regarding the homogeneity of the surface (such as ruts, separations);

— date of latest precipitation, in the case of porous surfaces;

— brief description of where and how often the temperature measurements were taken (optional);

— average, maximum and minimum air temperatures over the measurement period;

— average, maximum and minimum road temperatures over the measurement period.

14.5 Road speed category and vehicle information

— the road speed category in question and reference speed(s);

— the number of vehicles in each category on which the measurements are based.

14.6 Measured and calculated sound level and speed data

— $L_{\text{SPB:P},v_{\text{ref}}}$ for vehicle categories P, and $L_{\text{SPB:H},v_{\text{ref}}}$ for vehicle categories H, uncorrected for temperature (optional);

— $L_{\text{SPB:P},v_{\text{ref}}}$ for vehicle categories P, and $L_{\text{SPB:H},v_{\text{ref}}}$ for vehicle categories H, corrected for temperature;

— SPBI, uncorrected for temperature (optional); If not in accordance with Annex B, vehicle category weighting factors, W_x, shall be reported;

— SPBI, corrected for temperature (optional); If not in accordance with Annex B, vehicle category weighting factors, W_x, shall be reported;

— slope and intercept of regression line (to one decimal) of sound pressure level versus (log) speed, average and standard deviation of the speeds and the 95 % confidence intervals of the SPB sound level versus speed. In the case of using the generic speed exponent, this exponent shall be reported. It is optional but illustrative to produce a regression diagram, as illustrated in Annex D (should then be one for P vehicles and another one for H vehicles);

— Frequency spectra in third-octave bands, A-weighted and normalized for speeds, according to Clauses 9 and 12.

— In case the optional microphone position was used, also those data shall be reported.

14.7 Others

— whenever used, the reference surface shall be reported, i.e. which of the options in Annex G has been used, in addition to items above describing its construction and condition (wherever applicable);

— details of special provisions taken to assure conformity with this document; for example, if not meeting the minimum number of heavy vehicles;

— see also Annex I which includes an example of a report form.

Annex A
(normative)

Vehicle categories

A.1 Vehicle categories worldwide

There is no standard system of classification of vehicles in various categories that is applied worldwide. In certain regions, such as in the European Union, the classification is rather uniform, but apart from this, most countries have their own classification. A reason for this is the sometimes very different sizes of heavy-duty vehicles that are common and/or allowed to travel in the countries. Also, the variations in terminology are sometimes a problem. An exception is 4-wheel passenger cars, for which the definition is sufficiently uniform worldwide for use in this standard.

It follows that the definitions of heavy vehicle categories below may not fit very well with the practice used in some countries. This needs to be accepted in an international standard. The user of this document should attempt to comply with the definitions below as well as possible, or when it is not possible, describe an own classification.

A.2 Principles

The basic idea is to determine the acoustic properties of road surfaces for two cases: light vehicles (represented by passenger cars) and heavy vehicles (represented by a mix of medium-size trucks and busses and heavy-size trucks and busses). It is not necessary to include the vehicle categories in sizes between these two or including two-wheelers, since the chosen two categories will fully represent the vehicle mix when it comes to the acoustical properties of the road surfaces.

Since there is substantial variation between noise emission of individual vehicles even within a "narrow" category, to reduce uncertainties, the measurements should include a great number of vehicles in each category. This is generally no problem for passenger cars but is usually a practical problem for the heavy vehicles, since they commonly constitute only 5 % to 25 % of the vehicles in the traffic while at the same time the variation in noise levels is large. Therefore, as a compromise between practicality and uncertainty, the vehicles to include in a certain category are restricted in order to exclude outliers. This will reduce variations in noise levels while not reducing the number of acceptable vehicles too much.

A.3 Two main categories

A.3.1 General

The two main categories in this method are:

— light vehicles, represented by passenger cars, and denoted P;

— heavy vehicles, denoted H, represented by a mix of the two sub-categories; medium-size trucks and busses (denoted H2) and heavy-size trucks and busses (denoted H3+).

Since the vehicle categorization during measurements generally is made visually, the distinction between the categories is based upon the number of axles. H2 stands for heavy vehicles having two axles (i.e. dual-axle) while H3+ stands for heavy vehicles having multiple axles (i.e. three or more axles).

These categories are described more in detail below.

A.3.2   Light vehicles (P for passenger cars)

The category P includes passenger cars and "crossover SUV:s" typically having four or five seats, but not included in the list below.

Light vehicles that should not be included in the measured data set are then:

— vehicles with less than 4 and more than 5 seats;

— pick-up trucks;

— utility vehicles;

— small vehicles such as the Japanese K category;

— SUV:s with off-road tyres (if is perceived by the measuring crew that the tyres sound as off-road tyres);

— sports cars if they emit power unit noise that is perceived by the measuring crew as "distinctly louder than normal cars";

— other cars or SUV:s that emit power unit noise that is perceived by the measuring crew as result of a "faulty or tampered with muffler or exhaust system";

— vehicles that sound as if they are equipped with studded tyres (unless this is a tyre category of interest to include by the ordering organization).

Electric or electric-hybrid vehicles shall be considered valid to include in this method, unless they fall in any of the categories above.

If in doubt, choose to neglect the vehicle which is difficult to categorize.

A.3.3   Dual-axle heavy vehicles (H2), also considered as "medium heavy vehicles"

This category is basically represented by medium-sized trucks (for urban deliveries) and busses having two axles only but using 2 or 4 tyres on the driving axle. The intention is that such vehicles will be rather easy to identify visually in the traffic flow. They will have a gross vehicle mass (GVM) exceeding 8 t and up to 16 t (metric) (12 t or 16 t may vary from country to country), and they are equipped with C2 and in some cases C3 tyres.

Vans or heavy utility vehicles shall not be included as they normally would not be heavy enough.

Thus, the higher limit is uniquely determined by the number of axles being two and that they are equipped with 4 or 6 tyres. Visually, it is usually possible to see if the rear axle has two or 4 tyres.

The lower limit is 8 t. In Japan for example, this is easy to see by checking the size of the licence plate. In other countries, see Figure A.1 for examples.

Electric vehicles or electric-hybrid vehicles driven in electric mode shall be considered valid to include in this method, on the condition that when reference speed is lower than 70 km/h their proportion in the H2 database is reasonably typical to the fleet on the tested road, and provided they are flagged (indicated as electric), and if it is possible to distinguish such vehicles from the rest. The flagged vehicles shall still be considered in the calculations, but the expected effect on the result (if potentially significant) can be commented in the report at the discretion of the responsible author.

NOTE   Vehicles driven in electric mode would normally be significantly quieter than combustion-engine-driven vehicles at speeds lower than 50 km/h and potentially quieter also in the range (50 to70) km/h. For such vehicles, power unit noise will be insignificant, which means that tyre/road noise will be dominant. Under such conditions, low-noise road surfaces would normally provide higher noise reduction compared to the references, than for vehicles with combustion engines, as the power unit noise will not put a lower limit to the lowest possible noise level. See further illustrations in Figure A.1.

A.3.4 Multi-axle heavy vehicles (H3+)

This category is represented by full-sized trucks having three or more axles. Nevertheless, the following categories should be avoided:

— Vehicles operating off-road a significant time (having off-road drive tyres), for example concrete mixer trucks as well as tipper and dump(er) trucks;

— Road trains (more than eight axles).

Electric vehicles or electric-hybrid vehicles driven in electric mode shall be considered valid to include in this method, on the condition that when reference speed is lower than 70 km/h their proportion in the H3+ database is reasonably typical to the fleet on the tested road, and provided they are flagged (indicated as electric), and if it is possible to distinguish such vehicles from the rest. The flagged vehicles shall still be considered in the calculations, but the expected effect on the result (if potentially significant) can be commented in the report at the discretion of the responsible author.

NOTE   See NOTE in A.3.3.

A.3.5 Special conditions in certain countries

In Japan there is a distinction between vehicles below and above 8 t of GVM (gross vehicle mass): the trucks and busses up to 8 t have a smaller licence plate than those above 8 t (width 33 versus 44 cm)[11]. This makes it easy to determine which vehicles near the lower weight limit will qualify as H2 vehicles.
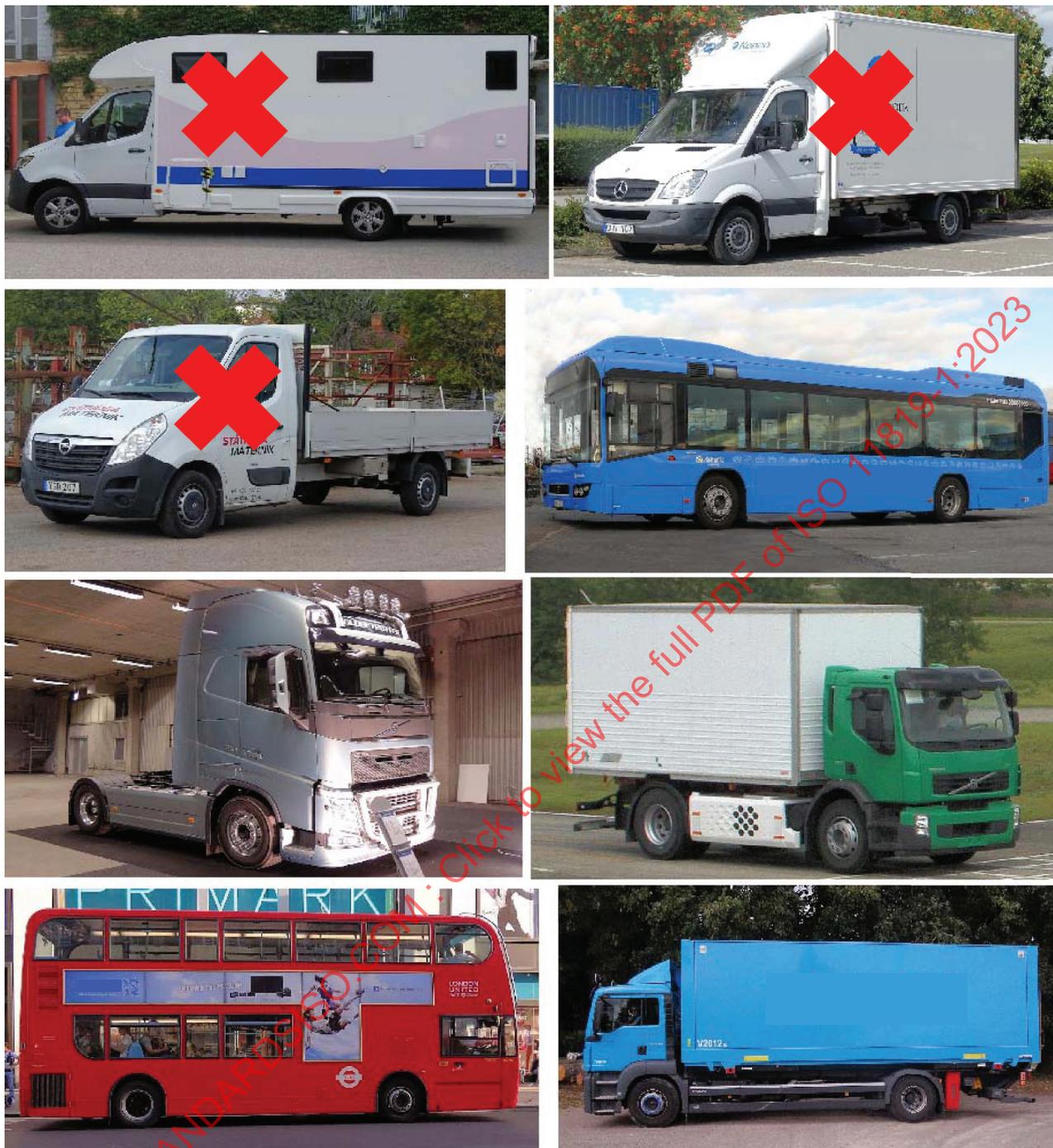
NOTE   The vehicles with a red cross are too small to be accepted, i.e. not likely to be able to have a total mass (GVM) of 8 t (as they seem to have too small C2 tyres). The other vehicles have C3 tyres and will have a total mass (GVM) between 8 t and 16 t.

Figure A.1 — Examples of dual-axle heavy vehicles (H2) accepted and some not accepted in the data set (pictures not to same scale)

Annex B
(informative)

Determination of the statistical pass-by index (SPBI)

The statistical pass-by index (SPBI) is useful for comparing results of measurements, but to be standardized it shall use a standard set of weighting factors for the proportions of heavy vehicles in the traffic mix. Reporting the SPBI is optional but when it is reported it shall be calculated according to this Annex.

In order to obtain an aggregate (overall) level of road surface influence on traffic noise for a mix of vehicles, a statistical pass-by index can be calculated as given by Formula (B.1):

$$\text{SPBI} = 10\lg\left[W_P \times 10^{\frac{L_{\text{SPB:P},v_{\text{ref},P}}}{10}} + W_H\left(\frac{v_{\text{ref},P}}{v_{\text{ref},H}}\right) \times 10^{\frac{L_{\text{SPB:H},v_{\text{ref},H}}}{10}}\right] \text{dB} \tag{B.1}$$

Where

SPBI	is the statistical pass-by index, for a standard mix of light and heavy vehicles;
$L_{\text{SPB:P},v_{\text{ref},P}}$, $L_{\text{SPB:H},v_{\text{ref},H}}$	are the SPB sound levels for vehicle categories P and H according to 12.2 and 12.3;
W_P , W_H	weighting factors, which are equivalent to the assumed proportions of vehicle categories in the traffic, according to Table B.1;
$v_{\text{ref},P}$, $v_{\text{ref},H}$	reference speeds of individual vehicle categories, according to Table B.1.

Table B.1 — Reference speeds, v_{ref}, and weighting factors (where W is either W_P or W_H) in the different road speed categories

Vehicle category		Road speed category					
Name	ID	Low		Medium		High	
		Reference speed (km/h)	W	Reference speed (km/h)	W	Reference speed (km/h)	W
Cars	P	50	0,90	80	0,80	110	0,70
Heavy vehicles	H	50	0,10	80	0,20	80	0,30

Typical values for the weighting factors (W_P and W_H) may vary considerably from place to place, country to country and with time of day and night. The values selected in Table B.1 should represent globally most typical cases which allow simple comparisons of road surfaces. However, it is recognised that in many cases one would prefer to use other, perhaps nationally adapted factors as a supplement. The mandatory reporting of all $L_{\text{SPB:P},v_{\text{ref},P}}$ and $L_{\text{SPB:H},v_{\text{ref},H}}$ values allows such SPBI calculations to be made, but when reporting optional calculations, the non-standard weighting factors used shall always be duly specified.

In many cases the main use of the SPBI (which is based on $L_{\text{A,max}}$ measurements) would be to compare a certain surface with a reference surface according to Case G.2 of Annex G and present the result as a difference value. This difference is a good approximation of the difference measured or calculated in

equivalent levels ($L_{A,eq}$) for the assumed reference speeds and proportions of heavy vehicles according to Table B.1.

NOTE   SPBI is not an equivalent level ($L_{A,eq}$) of traffic noise but can be used to describe the relative influence of the road surface on such levels. The SPBI is an index obtained by energy-based summation of the $L_{SPB:P,v_{ref},P}$ and $L_{SPB:H,v_{ref},H}$ values together, with each one weighted in accordance with the expected typical proportion of the vehicle category in question. The index will numerically have a value close to the mean LSPB levels. It is valid for cases where speeds of cars and heavy vehicles are as given in Table B.1. The index cannot be used for estimation of effects of speed.

Annex C
(informative)

The backing board variant

C.1 General

This annex specifies a modified version of the SPB method that uses a microphone mounted on a backing board instead of a microphone in normal, free-field conditions. It is applicable to measurements where the basic requirements on the acoustic environment are not achievable. This can be the case in an urban, built-up, environment or in the presence of safety barriers, noise barriers, embankments or road cuttings.

NOTE   The presence of safety barriers are not always a justification for using the backing board method. It depends on the location, height and construction of the barriers. It is up to the user to decide whether the safety barrier has a significant influence on the measurements in the normal microphone position. It can be better to use the higher microphone position than the backing board in such cases. See further C.4.3.

C.2 Measurement principle of the backing board

The principle is the same as for the main part of the SPB method, except that the microphone is mounted on a backing board rather than being used in normal free-field conditions.

By mounting the microphone membrane very close to the backing board during measurements, noise from behind (for example, reflections from façades or noise barriers) is suppressed. The noise coming from the front is reflected by the backing board in a controlled way so that it can be considered by applying a correction to the measured value. In principle, the A-weighted sound pressure level increases by 6 dB due to a doubling of the sound pressure caused by the backing board.

C.3 Apparatus

C.3.1 General

The same measuring instruments as for the SPB method shall be used.

Alternatively, a surface microphone may be used.

C.3.2 Backing board

C.3.2.1 Dimensions

The backing board shall have a rectangular shape.

The width shall be 900 mm ± 10 mm and the height 750 mm ± 10 mm (see Figure C.1).

C.3.2.2 Position

The backing board shall be oriented parallel to the road and 7,5 m ± 0,1 m from the centre of the road lane that is the subject of the measurement.

C.3.2.3   Position when used in narrow roads or streets

When the road or street does not allow the backing board to be placed as far as 7,5 m from the middle of the tested lane, a closer position may be used. This could be necessary when there are buildings, solid barriers or other walls very close to the road or street on one side.

In such cases, one may consider placing the backing board 5,0 m ± 0,1 m from the middle of the lane being tested. The microphone shall then be placed at a height of 0,8 m ± 0,1 m above the road level (see Figure C.1).

NOTE   The lower height is intended to give an angle of incidence of sound waves from sources near the road surface similar to that given by the normal backing board and microphone positions.

Dimensions in millimetres
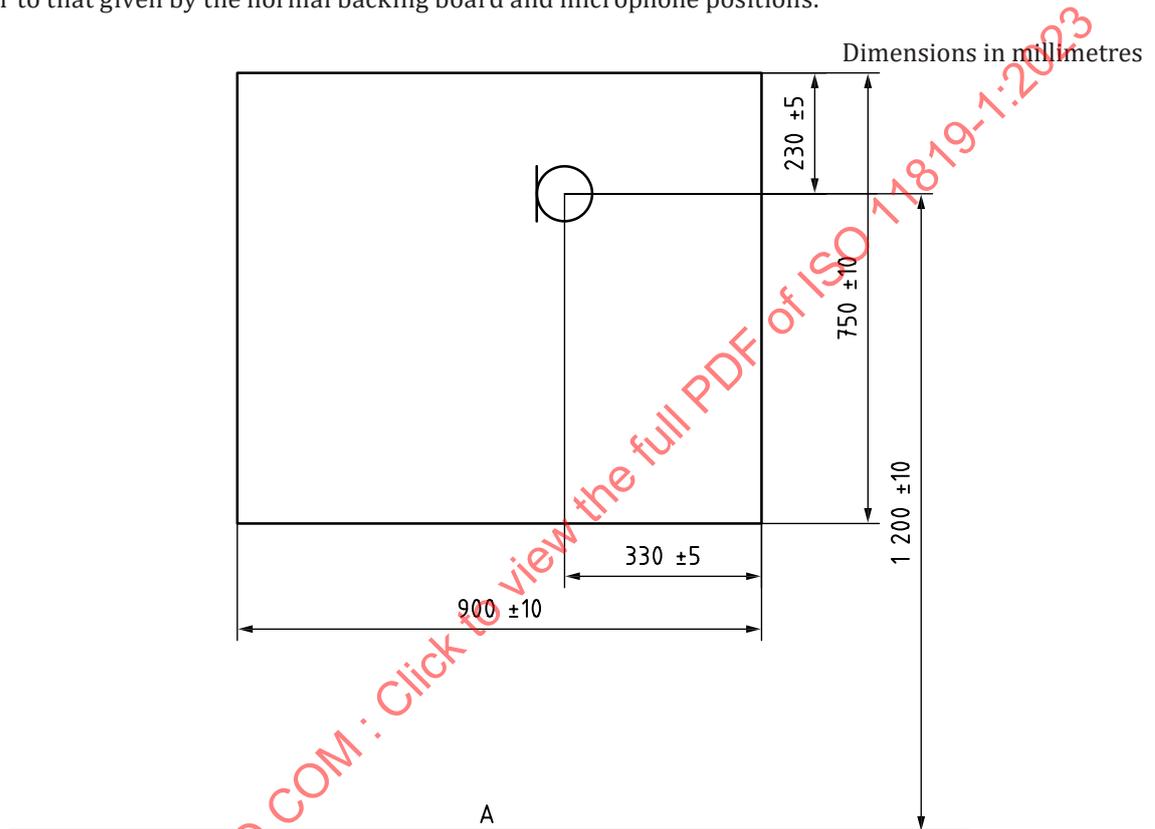
Key

A   the plane of the road lane extended to the microphone position

Figure C.1 — Backing-board dimensions and microphone position as seen from sound source (independent of traffic direction)

C.3.2.4   Material

The board shall be acoustically hard and at least 15 mm thick to avoid vibration[12].

If metal is used, the properties shall satisfy ISO 1996-2.

The mass of the board shall be at least 14 kg/m^2[13].

NOTE 1   For example, medium-density fibre board has been found to work well.

NOTE 2   More information about material properties is available in ISO 1996-2:2017, Annex B.

C.3.2.5 Microphone position

The microphone shall be located in the same position relative to the road as for the SPB method according to 9.1. To achieve this, the position of the backing board is set with respect to the microphone.

In order to minimize the effect of diffraction with constructive interference at the edges, position the microphone away from the centre of the board and from the board's diagonals and centrelines. Mount the microphone in the upper right-hand corner of the board, 330 mm ± 5 mm from the right-hand edge and 230 mm ± 5 mm from the upper edge, see Figure C.1[14].

Microphones having a diameter greater than 12,7 mm (1/2 inch) shall not be used.

C.3.2.6 Mountings

The following microphone mountings are permitted:

— the microphone mounted as close as practicable to the board, with the casing touching the board if feasible (microphone casing parallel to the board);

— a surface microphone mounted flush with the surface of the board.

Figure C.2 shows a close-up view of the mounting.

| a) Free-field microphone | b) Surface microphone |

Figure C.2 — Examples of microphone mountings[13][14][15]

A third option is to mount the microphone through a hole in the board, with the membrane flush with the board surface[4]. This might be a little less practical than the other options but gives an equivalent result.

C.3.2.7 Effect of microphone type

For the frequency range considered, it is acceptable to use either a free-field or pressure microphone.

The choice of either a free-field or surface microphone can have a marginal effect on the measured levels. In general, the surface microphone has the lower effect, but the differences are just a few tenths of a decibel, so no correction for microphone type is required.

C.3.2.8 Microphone protection

The free-field microphone, if chosen, shall be protected from the influence of wind, etc., by a suitably shaped windscreen mounted around it.

A windscreen is not required for a surface microphone.

C.4   Test sites

C.4.1   Selection of measuring site

The measuring-site selection criteria shall be those of the SPB method according to Clause 7, except for criteria related to reflections from behind (see below).

C.4.2   Deviations from free-field conditions

The provisions relating to acoustic reflections from objects in front of the microphone given in 7.2 apply; for reflections from behind the microphone and the backing board, there are no restrictions.

C.4.3   Guard rails and other barriers that can reflect or screen sound

The criteria for taking into consideration guard rails or other barriers that can reflect or screen sound shall be the same as those of the SPB method (7.3), except in respect of objects and reflections from behind, for which there are no restrictions.

Any large object located behind the backing board (within 25 m) shall be noted in the test report, together with an estimation of its distance from the board.

NOTE   If there is a large object such as a building façade or bus located close behind the backing board, there could be a small increase in noise levels. Increases of up to 0,5 dB have been measured for such objects located 0,6 m behind the backing board[12]. The amount of influence due to reflected sound depends on the frequency content of the vehicle noise source and the dimensions and proximity of the reflecting object.

C.4.4   Surface between tested road surface and microphone

This surface shall be in accordance with 7.4.

C.5   Traffic conditions

The traffic conditions shall be in accordance with Clause 8.

C.6   Measuring procedure

The measuring procedure shall be in accordance with Clause 9.

C.7   Normalization and correction of data

C.7.1   Correction for the influence of the backing board

C.7.1.1   Speed and vehicle category

For the reported levels of noise to be equivalent to those measured in free-field conditions, a correction of 6,0 dB shall be subtracted from the calculated vehicle sound levels for the different vehicle categories[15][16].

C.7.1.2   Additional corrections when using backing board in narrow roads or streets

In addition to the correction specified above, a correction of 3,5 dB shall be used to correct for the difference in distance (5,0 m versus 7,5 m). As in the case of the corrections above, this additional correction shall be subtracted from the calculated vehicle sound levels.

NOTE   The value of 3,5 dB is derived from the "acoustical distance law" and has been verified in practice to be approximately valid for cars as well. For multi-axle heavy vehicles, the validity is lower.

C.7.2   Other normalizations and corrections

Any other normalizations or corrections are made in compliance with Clause 12.

C.8   Determination of statistical pass-by index (SPBI)

The SPBI shall be determined in accordance with Annex B, but with the SPB sound levels corrected as instructed in C.7.1 for the backing board influence.

C.9   Frequency spectra

Frequency spectra determined using the backing board version of the SPB method should be considered with great care. Especially, the backing board will not be large enough for properly reflecting the lowest frequencies. Nevertheless, it is recommended that frequency spectra corrected with the values in C.7.1.1 be reported for possible future reference.

NOTE   Studies have indicated that one-third-octave-band levels in bands below 500 Hz and above 2 000 Hz can in some situations not be properly corrected using the values given in C.7.1.1[12].

C.10 Measurement uncertainty

The measurement uncertainty is according to Clause 13, plus an additional uncertainty related to the correction factors in C.7.1.1 of ~0,5 dB, expressed as a standard uncertainty. This additional uncertainty should be added linearly[15].

For one-third-octave-band levels, the uncertainty is unknown, see Note in C.9.

When the short distance for backing board location (5 m) is used, the estimated additional uncertainty of the SPB sound levels (0,5 dB) shall be replaced by values of 0,7 dB for cars and 1,0 dB for heavy vehicles.

For frequency spectra, the uncertainty is even higher. Consequently, frequency spectra measured this close to the road are too uncertain to be recommended.

C.11 Meteorological conditions

The meteorological conditions shall be in accordance with Clause 10.

C.12 Background noise

The background noise shall be in accordance with Clause 11.

C.13 Reported data

The same data as in Clause 14 shall be reported, supplemented by the following:

— dimensions, weight, material of the backing board;

— type of microphone, mounting method, windscreen and microphone position on the board;

— details of objects behind the backing board in accordance with 7.4;

— vehicle sound levels and SPBI corrected for the backing board.

In addition to the above reported data, it shall be clearly noted if the backing board was placed at 5,0 m from the middle of the tested lane instead of the normal 7,5 m.

Annex D
(informative)

Adding 95 % confidence intervals

This annex provides instructions on how one can add confidence intervals around the regression line in the plot of noise levels versus speed for cars, according to 12.3.

Consider relation (1) in 12.3 and a set of n data points $(\lg v, L_{A,max,i,v}) = (x_i\, y_i)$ for which one calculates the regression line with the following Formula (D.1):

$$y = A + Bx \tag{D.2}$$

The 95 % confidence limits around the estimated y-value $y_0 (= A + Bx_0)$ for given abscissa value x_0 can be calculated with the following Formula (D.2):

$$x_0 = A + B\, x_0 \pm t_{n-2;0,025}\, s\, \sqrt{\frac{1}{n} + \frac{(x_0 - \bar{x})^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}} \tag{D.2}$$

where

$t_{n-2;0,025}$ t-value for n degrees of freedom and $\alpha = 0,05/2 = 0,025$, a parameter which can be found in basic statistical tables. For example, for $n = 100$: $t_{98;0,025} \approx 1,984$. For $n = 80$: $t_{78;0,025} \approx 1,992$;

s standard deviation of the y_i-values;

$\bar{x}$ average value of the values x_i.

An example of a graph with $(\lg v, L_{A,max,i,v})$ data for cars, the regression line, and the 95 % confidence limits is shown in Figure D.1.
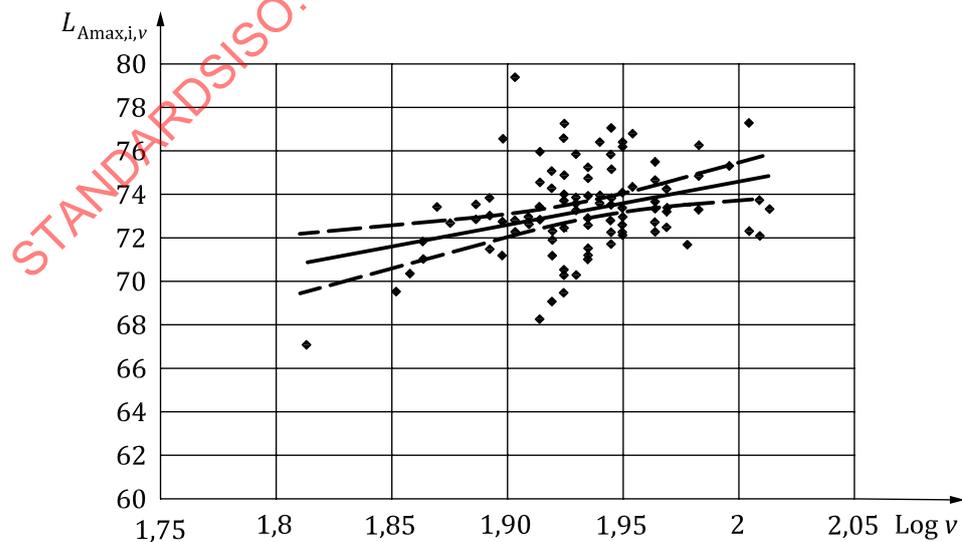
NOTE   The abscissa shows speed v expressed as the logarithm of v (2,0 corresponds to 100 km/h).

Figure D.1 — Example (for cars) of regression of noise versus speed with 95 % confidence limits shown as broken lines

Annex E
(informative)

Validity and stability of the method

The validity of the method described in this document depends on the stability over time and over location of the sound emission characteristics of the mix of vehicles used for testing. To a smaller extent, driving behaviour can also influence the results at low speeds. Vehicles are relatively uniform in their sound emission characteristics at least seen over the European countries, North America, Australia, New Zealand and industrialized countries of Asia. Minor but not negligible differences can, however, occur between some of these due to differences in legislation policies, infrastructure, climate and vehicle usage.

The stability over time has been found to be relatively good for the medium and high speeds considered in this standard[17]. The changes in sound emission limits for tyres have not yet made a significant impact on this stability, maybe since the tightened limits have been balanced by wider tyres and heavier loads.

This method is valid in cases only when vehicles travel at constant speed from 45 km/h and upwards. It has been found that in such cases tyre/road noise dominates vehicle noise emission and driving conditions are of limited importance.

The SPB method is applied only in acoustic environments free of reflections against buildings, walls, embankments or other solid objects and at relatively low heights over ground. However, SPB measurement results to determine the acoustic properties of road surfaces are often used to estimate the noise exposure also in cases with reflecting objects (see above) and/or at much higher elevations. Extreme cases can be when there are high rise buildings on both sides of an expressway. It is then important to note that a certain noise reducing effect of a low noise pavement does not necessarily result in a similar noise reduction in partly reverberant sound fields as in the free field. For example, when a sound absorbing pavement is located in a kind of "canyon" between walls or buildings, or in a tunnel-like structure, the noise reducing effect of a porous pavement is generally somewhat greater than when the pavement is located in a free field.

On the other hand, at higher elevations compared to the reference case the noise reduction may be lower. The 3 m microphone height could then be more representative than the 1,2 m microphone height.

Annex F
(informative)

Reference road surface

F.1 General

When reporting the measured result for a certain road surface, it is common to compare it to some reference case, i.e. the corresponding results measured on a surface type, which is considered as being a reference surface. This annex contains recommendations regarding the choice of such surfaces, in order to avoid the use of very different references.

A virtual reference surface concept was defined in the EU HARMONOISE project[18] which developed a model for predicting noise emission and immission from road and railway traffic. In this one, a reference case was defined, including a reference surface. The surface was chosen to be an average of a dense asphalt concrete (DAC) and a stone mastic asphalt (SMA) surface, each one having a maximum aggregate size of 11 mm and with an age of at least one year. The reason for this choice was that either an SMA or a DAC surface with ~11 mm maximum aggregate size is very common, and rather easy to find, in each of the European countries. Certain corrections were introduced in cases where the 11 mm aggregate size is difficult to find, enabling maximum aggregates from 10 mm up to 16 mm to be used, plus correction for age. This allowed the use in a particular case of an actual reference surface, which deviated slightly from the reference, provided corrections were applied to account for the deviations from the ideal and virtual referenced. The procedure, including the corrections to bring an actual case to the virtual reference case, is described in some detail in Reference [19].

Later, the same concept was taken over by the IMAGINE project and is also the concept used in the European method according to the CNOSSOS project (see Reference [20]).

F.2 Virtual reference surface

The reference surface is a surface not existing as such in reality, but being considered as an "average" of a DAC and an SMA surface with a maximum aggregate size of 11 mm. Ages shorter than two years should be avoided; also the surface should not be old enough to be subject to ravelling, cracking or other mechanical defects. The virtual reference case depends strongly on the representativity of the actual reference surface used in relation to its nominal values. When this concept is used the procedure is as specified in a) to d).

a) In the series of measurements considered, make sure that at least one surface which is as close in construction and condition to the virtual reference surface as possible is measured (either DAC or SMA; maximum aggregate size shall be between 10 mm and 16 mm, ideally 11 mm; its condition shall be good but not new).

b) Use the correction procedure in Reference [19] to determine what the nominal noise level difference (correction ΔL_{SPBref}) is between the actual reference used [as identified in F.2 a)] and the virtual reference surface.

c) Apply this correction to the measured level(s) of the actual reference surface used and use these corrected level(s) as the level(s) representing the virtual reference surface (be careful to use the correct plus or minus sign).

d) Using the virtual reference surface as a zero-reference level in decibels, all other similarly measured surfaces can be compared to this one, presented as a difference in noise level compared to the virtual reference surface (i.e. a noise reduction).

The virtual reference surface will be more stable the more road surfaces (within the restrictions) that are included in establishing this reference case. A minimum of two DAC 11 and two SMA 11 would be a reasonable selection. Observe that this reference case can be updated at certain intervals; either annually or when more and more data have been collected. However, in order to be able to trace all comparisons utilising this reference case, it is essential to keep for a long time identifiable records of which surfaces that are/were included in each version of the reference case.

F.3 Normalized reference case

The reference surface is a fictitious surface on which the levels LSPB for each vehicle category are specified by convention. This can, for instance, be based on the average results of a great number of SPB measurements on asphalt concrete surfaces, after which a certain level is decided upon which would represent this case; corrected to the reference temperature 20 °C. The reference surface is then an average of all surfaces included in the test. The normalized reference case depends strongly on the stability of the vehicle mix and accuracy in correction for temperature.

F.4 Arbitrary reference case

The reference surface is any arbitrary surface, other than above, that the testing organization selects. In this case, measurements are useful only for comparisons between the selected surfaces.

F.5 Conclusion

The virtual reference case (F.2) has the advantage of being aligned with the HARMONOISE, IMAGINE and CNOSSOS methods for noise prediction, used European-wide. As is pointed out in Reference [19], this reference case is also close to references used in the Nord2000 (Reference [21]), as well as in Japanese and US prediction models, which makes it suitable for worldwide use in cases wherever the use of a reference is of interest. If this case is used, whenever a noise reduction is calculated, the results are reasonably comparable worldwide.

Annex G
(informative)

Monitoring the stability of sound levels of vehicle fleets

This annex addresses the problems with stability described in Annex E. The following (optional) procedure can be used to check the stability of sound levels of a vehicle fleet, irrespective of country or climatic region and year. If this procedure is followed, it means that the user may monitor the stability over time and place of the vehicle sound emission and possibly take actions if the stability is found to be insufficient (bearing in mind the limited precision of this calibration procedure).

It is recommended that the agency responsible for road traffic noise in each country or state conducts or initiates such a calibration at time intervals of no more than 5 years. It will then be possible to check changes and/or differences in vehicle fleet sound emission over time and from country to country (possibly also between very different climatic regions).

For the purposes of this Annex, the uncertainty of the SPB method, also considering variability and inhomogeneity of conventional pavements, is not sufficient to determine changes in noise emission of the vehicle categories considered in this standard. Since it is believed that the most stable tyre/road noise emission source over a considerable time, that is available, is the reference tyre P1 specified in ISO/TS 11819-3, the following procedure is suggested.

Select a virtual reference surface according to F.2; i.e. a combination of a dense asphalt concrete (DAC) and a stone mastic asphalt (SMA), both having a maximum aggregate size of 11 mm. This is the same as the reference case in the traffic noise prediction method CNOSSOS-EU[20].

Make sure that each one of the selected surfaces cover road sections ("reference road sections") of at least 200 m which are suitable for CPX measurements according to ISO 11819-2.

Make sure that each of these road sections near the middle of each section also have a few locations, which are ideal for SPB measurements; here called "candidate locations". These shall especially be located on straight road sections with no longitudinal slope (within ±0,5 %).

Determine the CPX levels for the tyre P1 at the reference speed 80 km/h on the road surfaces selected above. This shall be done by observing all requirements and corrections specified in ISO 11819-2, ISO/TS 11819-3 and ISO/TS 13471-2.

Select location for SPB measurements by checking the CPX levels (per each 20 m) near each candidate location, such that the CPX level over ±20 m from the candidate location is near the average of the CPX level for the entire reference road section. Select the most suitable location ("SPB location") on each reference surface for SPB measurement, which has a CPX level near the average for the reference road section while also meeting high standards for the acoustic environment according to Clause 7.

Note the CPX level at the "SPB location" for each reference surface and calculate the arithmetic average of those, called "CPX reference level" and denoted $L_{\mathrm{CPX,ref}}$.

Make measurements of SPB levels for both the P and H categories at the SPB locations on each of the reference surfaces. On each surface, require double as many acceptable vehicles as listed in 8.4. This can require measurements consuming more than one day on each surface and it is then extra important to monitor air and road surface temperatures and make corrections according to 12.7.

The result is the SPB level for P and H vehicle categories separately, normalized to the reference speed (80 km/h, possibly supplemented by either 50 km/h or 110 km/h) and corrected by a term representing the CPX level of the virtual reference surface:

$$L_{\mathrm{SPB:P_{ref}}v_{\mathrm{ref}}} = L_{\mathrm{SPB:P}v_{\mathrm{ref}}} - L_{\mathrm{CPX,ref}} + 101 \tag{F.1}$$