
**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



Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 11819-1 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 11819 consists of the following parts, under the general title *Acoustics — Measurement of the influence of road surfaces on traffic noise*:

- *Part 1: Statistical Pass-By method*
- *Part 2: Close-proximity method*

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Introduction

The emission and propagation of road traffic noise greatly depend on road surface characteristics, notably on texture and porosity. Both these characteristics influence the generation of tyre/road noise and, in addition, the porosity can influence the propagation of sound, particularly when the propagation 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, may also be affected during propagation 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 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 part of ISO 11819 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.

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

Part 1:

Statistical Pass-By method

1 Scope

This part of ISO 11819 describes 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 other driving conditions where traffic is not free-flowing, such as at junctions and where the traffic is congested, the road surface is of less importance.

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

The Statistical Pass-By (SPB) method is intended to be used essentially for two main purposes. First it may be used to classify surfaces in typical and good condition as a type according to their influence on traffic noise (surface classification) and, secondly, it may be used to evaluate the influence on traffic noise of different surfaces at particular sites irrespective of condition and age. This latter type of application may be useful for example where a road is to be resurfaced and "before" and "after" measurements are required in order to assess the differences in traffic noise following resurfacing. However, due to severe requirements on the acoustical environment at the site, the method cannot generally be used for approval of works at any given site.

Clause 4 gives a general description of the SPB method.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 11819. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 11819 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 10844:1994, *Acoustics — Test surface for road vehicle noise measurement*.

ISO 13473-1:1997, *Acoustics — Characterization of pavement texture using surface profiles — Part 1: Determination of mean profile depth*.

IEC 60651:1979, *Sound level meters*.

IEC 60942:1988, *Sound calibrators*.

IEC 61260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters*.

3 Definitions

For the purposes of this part of ISO 11819, the following definitions apply.

3.1 Traffic noise, vehicle noise, tyre/road noise and power unit noise

3.1.1 traffic noise

overall noise emitted by the traffic running on the road under study

3.1.2 vehicle noise

total noise from an individual vehicle, the two major components of which are power unit noise (3.1.4) and tyre/road noise (3.1.3)

3.1.3 tyre/road noise

noise generated by the tyre/road interaction

3.1.4 power unit noise

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

3.2 Statistical Pass-By (SPB) method

measurement procedure designed to evaluate vehicle and traffic noise generated on different sections of road surface under specific traffic conditions

NOTE — 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

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

3.3.1 "low" road speed category

conditions which relate to traffic operating at an average speed of 45 km/h to 64 km/h

NOTE — These conditions are usually associated with urban traffic.

3.3.2 "medium" road speed category

conditions which relate to traffic operating at an average speed of 65 km/h to 99 km/h

NOTE — These conditions are mostly found in suburban areas or on rural highways.

3.3.3 "high" road speed category

conditions which relate to cars operating at an average speed of 100 km/h or more; heavy vehicles may operate at lower average speed due to speed restrictions

NOTE — These conditions are usually associated with motorway traffic in rural or suburban areas.

3.4 Vehicle categories

A *vehicle category* consists of vehicles which have certain common features easy to identify in the traffic stream, such as the number of axles and the size. The common features are assumed to correspond to similarities in their sound emission when driven under the same operating conditions. The following vehicle categories are considered to be sufficient for description of the noise characteristics of road surfaces and are used in this part of ISO 11819 (see also annex A).

3.4.1 Category No. 1 — cars

passenger cars excluding other light vehicles

3.4.2 Category No. 2 — heavy vehicles

all trucks, buses and coaches with at least two axles and more than four wheels

NOTE — This category consists of Categories 2a and 2b together.

3.4.2.1 Category No. 2a — dual-axle heavy vehicles

trucks, buses and coaches with two axles and more than four wheels

3.4.2.2 Category No. 2b — multi-axle heavy vehicles

trucks, buses and coaches with more than two axles

3.5 maximum sound level

highest sound pressure level recorded by the measuring instrument during a vehicle pass-by, using the appropriate frequency weighting and time weighting F, for vehicles which are acoustically identifiable, i.e. are not significantly disturbed by other vehicles (see also 7.2)

3.6 Vehicle Sound Level, L_{veh}

maximum A-weighted sound pressure level determined at a reference speed from a regression line of the maximum A-weighted sound pressure level versus the logarithm of speed, calculated for each vehicle category

3.7 Statistical Pass-By Index (SPBI)

noise index for comparison of road surfaces, that is based on the Vehicle Sound Levels and takes into account the mix and speeds of vehicles

3.8 reference surface

surface selected according to the purpose of the measurement, following certain rules listed in this part of ISO 11819; levels on the reference surface are normalized to zero level (0 dB) and levels on all other surfaces are presented as differences from this reference level

NOTE — The main purpose of this method is to compare road surfaces with respect to traffic noise emission. Sound levels measured on a certain surface may, therefore, be presented in comparison to sound levels measured on another surface which is then considered as a reference surface.

3.9 absorptive surfaces

1) For road or ground surfaces: surface for which a substantial part of the incident acoustical energy is absorbed

EXAMPLES — Typical absorptive surfaces are loose gravel, sand, some porous pavements and ground covered by grass, ivy, or other low-growing vegetation.

2) For noise barriers: type of surface with which some noise barriers are equipped on the source side with the intention of reducing sound reflections.

4 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 road-side location together with the vehicle speeds. Each measured vehicle is classified into one of three vehicle categories: "cars", "dual-axle heavy vehicles" and "multi-axle heavy vehicles". Other vehicle categories are not used for this evaluation, since they do not provide any additional information regarding road surface influence.

For each of three speed ranges defined in 3.3, as well as for each of the three vehicle categories, a nominated reference speed is given. 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. From this line, the average maximum A-weighted sound pressure level is determined at the reference speed. This level is called the Vehicle Sound Level, L_{veh} .

For the purpose of reporting the acoustic performance of road surfaces the Vehicle Sound Levels for cars, dual-axle heavy vehicles and multi-axle heavy vehicles are added on a power basis, assuming certain proportions of these vehicle categories, to give a single "index" which constitutes the final result. This index is called the Statistical Pass-By Index (SPBI) and 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.

5 Measuring instruments

5.1 Sound level instrumentation

The sound level meter (or the equivalent measuring system) shall meet the requirements of a Type 1 instrument according to IEC 60651.

A windscreen shall be used and should be of a type specified by the microphone manufacturer as suitable for the particular microphone. It should be ascertained from the manufacturer that the windscreen does not detectably influence the performance of the sound level meter under the ambient conditions of the test.

5.2 Frequency analysis instrumentation

Frequency analysis of the measured sound using one-third-octave band resolution is recommended, but not mandatory. The frequency range of 50 Hz to 10 000 Hz (centre frequencies of one-third-octave bands) shall be covered. The one-third-octave-band filters shall conform to IEC 61260.

5.3 Calibration

At the beginning of the measurements, and following any warm-up time specified by the manufacturer, the overall sensitivity of the sound level meter or the equivalent measuring system (including the microphone) shall be checked. If necessary, it shall be adjusted according to the manufacturer's instructions. This may require use of a sound calibrator. These checks shall be repeated at the end of the measurements and the values obtained recorded. Any deviations shall be recorded in the test report. If the calibration readings on the sound level meter differ by more than 0,5 dB during a series of measurements, the test shall be considered invalid. The same procedure shall be followed if a frequency analyser is used.

The sound calibrator device shall meet the requirements of IEC 60942, Class 0 or Class 1.

The compliance of the sound calibrator with the requirements of the appropriate class of IEC 60942 shall be verified annually. The compliance of the sound level meter, or equivalent measuring system, with the requirements of IEC 60651 shall be verified at least every two years. This shall be performed by a laboratory accredited or otherwise authorized to perform calibrations traceable to the national standards.

5.4 Vehicle speed measurement instrumentation

The vehicle speed at the instant when the vehicle passes the microphone shall be measured with a standard uncertainty of less than $\pm 3\%$. Measuring devices which rest on the road surface and are activated by the passage of vehicle tyres should not be used.

5.5 Temperature measurement instrumentation

The temperature measuring instrument(s) shall have a maximum permissible error of 1 °C. Meters using an infrared technique shall not be used for air temperature measurements.

6 Test sites

6.1 Selection of measuring site

The following considerations apply for site selection.

- a) Each road test section shall extend at least 30 m on both sides from the microphone location. For the "high" road speed category this distance is increased to 50 m.
- b) The road shall be essentially level and straight. Roads with slight bends or with gradient $\leq 1\%$ may be considered as valid test sites for the purposes of this part of ISO 11819.
- c) The number of vehicles judged to be moving at constant speed shall be sufficient in order to allow a reasonable total measuring time.
- d) The requirements on background noise at the test site according to clause 12 shall be observed. See also 7.2 regarding selection of vehicles.
- e) The road surface should be in a good condition, unless the intention is to study the effect of condition, and be homogeneous over the entire test section. 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.
- f) The traffic flowing on the road section of interest should contain sufficient numbers of each category of vehicle to enable a full analysis of each vehicle category to be carried out.

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.

6.2 Paired and single site measurements

Measurements described in this part of ISO 11819 will commonly be taken at a single test surface and then compared with similar measurements taken at other surfaces where traffic may be different. However, in some cases, the noise characteristics of different surfaces can be compared by taking

simultaneous measurements on two or more road sections where the surfaces to be compared have been laid in adjacent road sections. These are referred to as 'paired' measurements since the measurement technique employs the selection of the same vehicles from the traffic stream as they pass each measurement site.

The use of this technique will improve the accuracy of the comparison due to the elimination of differences in traffic composition and climate.

From 6.1 it follows that the measurement locations will need to be separated along the road by at least 60 m (100 m for the "high" road speed category).

Vehicles excluded from one of the paired sites, for example due to selection specified in 7.2, shall also be excluded from the other paired site.

6.3 Deviations from free-field conditions

For surface classification purposes, the measurement microphone should be located in the acoustical free field. In practice, this means that acoustic reflections from surfaces such as building façades, 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.

6.4 Considerations of guard rails and other barriers which may reflect or screen the sound

There shall be no large **reflecting** surfaces, such as solid safety barriers or embankments, within 10 m of a line drawn from the measuring microphone position, crossing the roadway perpendicular to the line of travel. This is precisely shown as a rectangle in figure 1a). If safety barriers are present within the rectangle, they shall be 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.

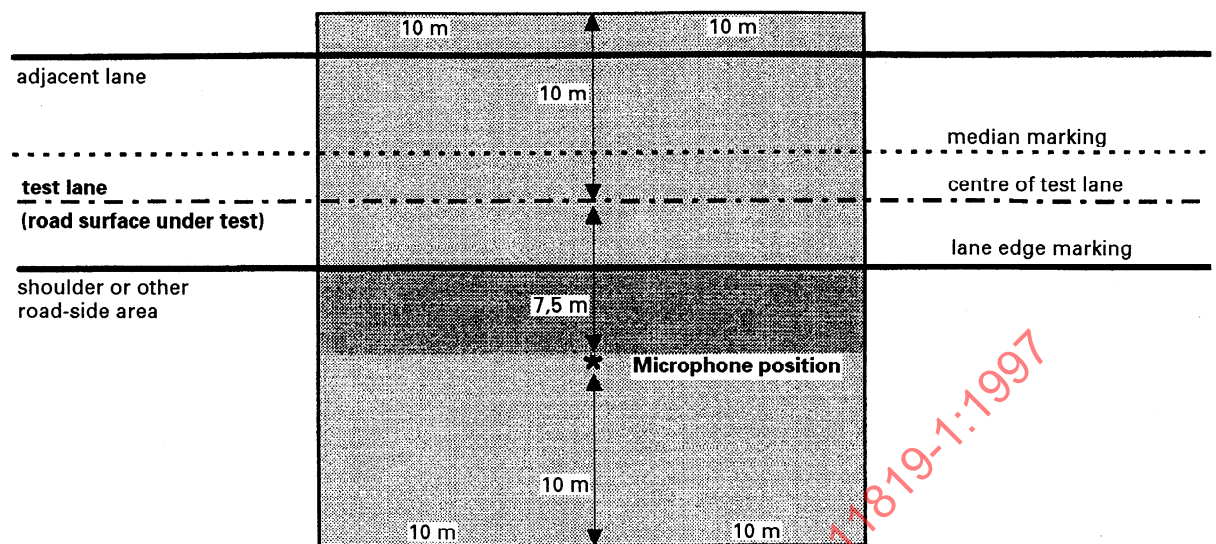
It is necessary to temporarily remove a short section of any safety barrier or guard rail located in front of the measurement microphone to ensure that minimal **screening** from the obstacles occurs at the measurement location. Within the part of the rectangle shown in figure 1a) which is between the road and a line parallel to the road and which goes through the microphone position, there shall be no potentially screening roadside barrier or guard rail.

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 1a).

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

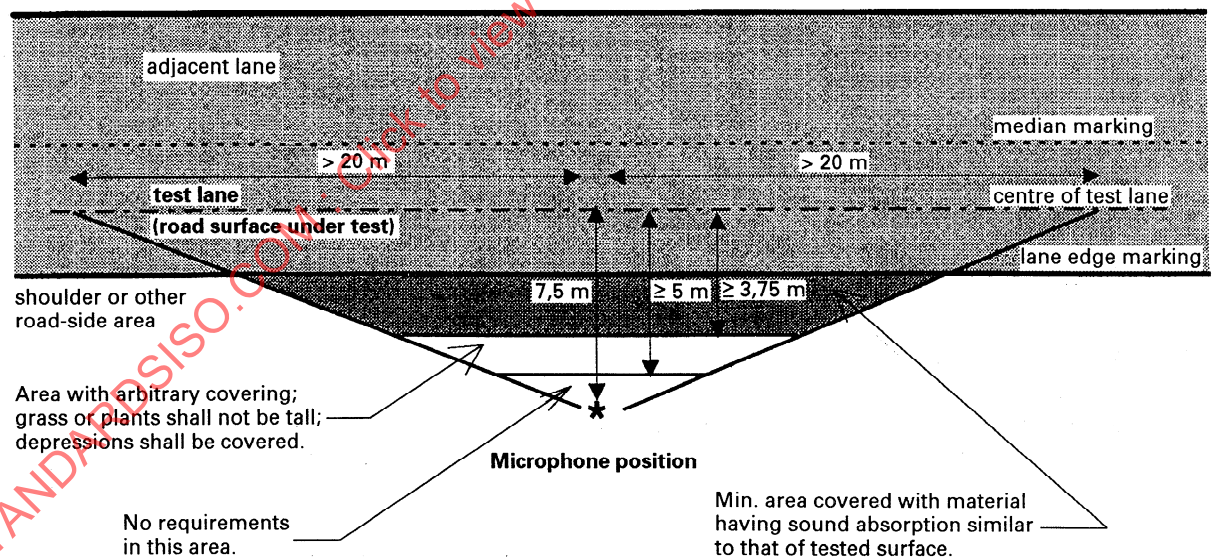
NOTE 2 In ISO 11819, a guard rail is a structure consisting of a metal beam or plate attached to rigid posts and designed to prevent vehicles from leaving the road or crossing the median. There is also a type of guard rail consisting of stretched steel wires attached to rigid posts.

NOTE 3 In ISO 11819, 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 of entering the road.



No reflecting solid safety barrier allowed within this rectangle unless covered with sound absorptive material. No screening rail or safety barrier allowed within the part of this rectangle which is between the microphone position and the test lane (darker shaded part)

a)



b)

Figure 1 — Requirements regarding freedom from reflecting or screening safety barriers or guard rails (upper part, Fig. 1a) and regarding the minimum coverage with acoustically appropriate surface between the test lane and the microphone (lower part, Fig. 1b)
(Figure not to scale)

6.5 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 may not 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 surface under test, and be essentially level with the road surface. See figure 1b). This may 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 1b) 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. 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 (note, however, the possibility specified in 8.1 and figure 3 of using a microphone on the other side of the road in cases where it is difficult to meet the requirements with the "normal" microphone position).

6.6 Special site conditions

In cases where the intention is to investigate the effect of a modification or other change in the road surface, it may be desirable to make a "before/after" study. In such studies it is not necessary to meet all the site requirements, as long as it can be ascertained that there are no changes of importance for sound emission, propagation or reflections from the "before" until the "after" situations. One shall then observe that significant changes in vegetation from season to season might have an influence.

Such special studies shall be duly identified as being "special" in the measuring protocol and any site conditions at variance with the specifications given in 6.1 to 6.5 shall be reported.

7 Traffic conditions

7.1 Vehicle classification

Only vehicles which clearly fall within any of the categories described in 3.4 shall be measured. Where there is any doubt in classifying a vehicle, the measurement for that vehicle shall be discarded from the study.

A more detailed vehicle classification is optional. See annex A for the categories that should be used in such cases.

7.2 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.

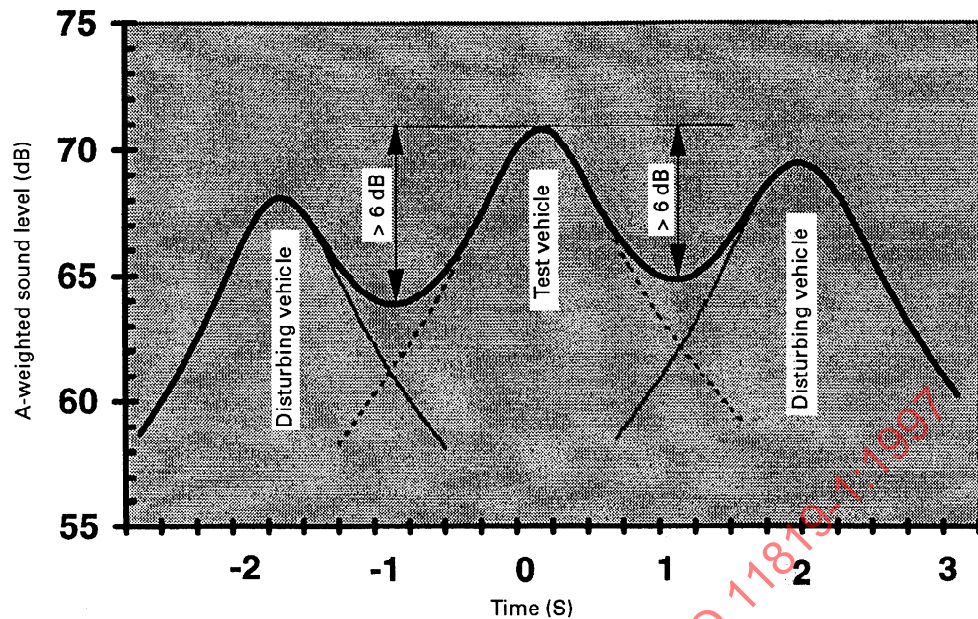


Figure 2 — Illustration of required signal-to-noise ratio for individual vehicle pass-bys
(The solid thick line shows the total sound level from two disturbing vehicles and the tested vehicle.)

NOTE — This will ensure that at the time when the maximum sound level is generated, the collective sound from other traffic will be at least 10 dB below the registered maximum level and will therefore have negligible effect on the measured level.

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) Additionally, vehicles which clearly exhibit unusual or atypical noise characteristics such as might occur due to a faulty 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.

d) The 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 12.

7.3 Minimum number of vehicles

Provided the purpose of the measurement is surface classification, the minimum number of vehicles specified below applies.

To ensure that random errors do not become unacceptably large, the following minimum numbers of vehicles shall be measured, within each vehicle category:

* Category 1 (Cars):	min. 100
* Category 2a (Dual-axle heavy vehicles):	min. 30
* Category 2b (Multi-axle heavy vehicles):	min. 30
* Categories 2a and 2b together (Heavy vehicles) :	min. 80

See also 9.6 regarding expected uncertainties.

NOTE — This means that, for example, if there are 30 vehicles in Category 2a, 50 vehicles are needed in Category 2b in order that Categories 2a and 2b together contain at least 80 vehicles. The minimum numbers are due to requirements on precision balanced against the time needed to measure the desired number of vehicles in the actual traffic.

7.4 Road speed categories

For the classification of road surfaces, it is necessary to distinguish between three road speed categories, as defined in 3.3. Each of the three categories is associated with a defined reference speed to be used for normalization of sound levels; see also 9.2. The acoustical behaviour of road surfaces may be different for these road speed categories.

The sound levels L_{veh} and the SPBI calculated from them (see 9.5) shall always be reported for at least one of the road speed categories.

8 Measuring procedure

8.1 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 $7,5 \text{ m} \pm 0,1 \text{ m}$. The microphone location is shown as "Position 1" in figure 3.

An exception is if there is a two-lane road (one lane per direction) and the right-side shoulder is too narrow to provide a surface having the appropriate acoustical reflectivity (see 6.5), in which case, "Position 2" shall be used (microphone distance is still 7,5 m).

In the case of a 2x2 lane road (refer to the upper half of figure 3), if the shoulder is too narrow to provide the appropriate acoustical reflectivity according to 6.5, 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 the microphone position 2 instead.

The above assumes right-hand traffic. In cases of left-hand traffic, the positions shall be reversed.

The microphone shall be located $1,2 \text{ m} \pm 0,1 \text{ m}$ above the plane of the road lane. Unless otherwise indicated by the manufacturer of the sound level meter, its reference axis for free field conditions (see IEC 651) shall be horizontal and directed perpendicularly towards the path of the vehicles.

8.2 Sound level measurement

During each vehicle pass-by the maximum A-weighted sound pressure level shall be measured using time weighting F.

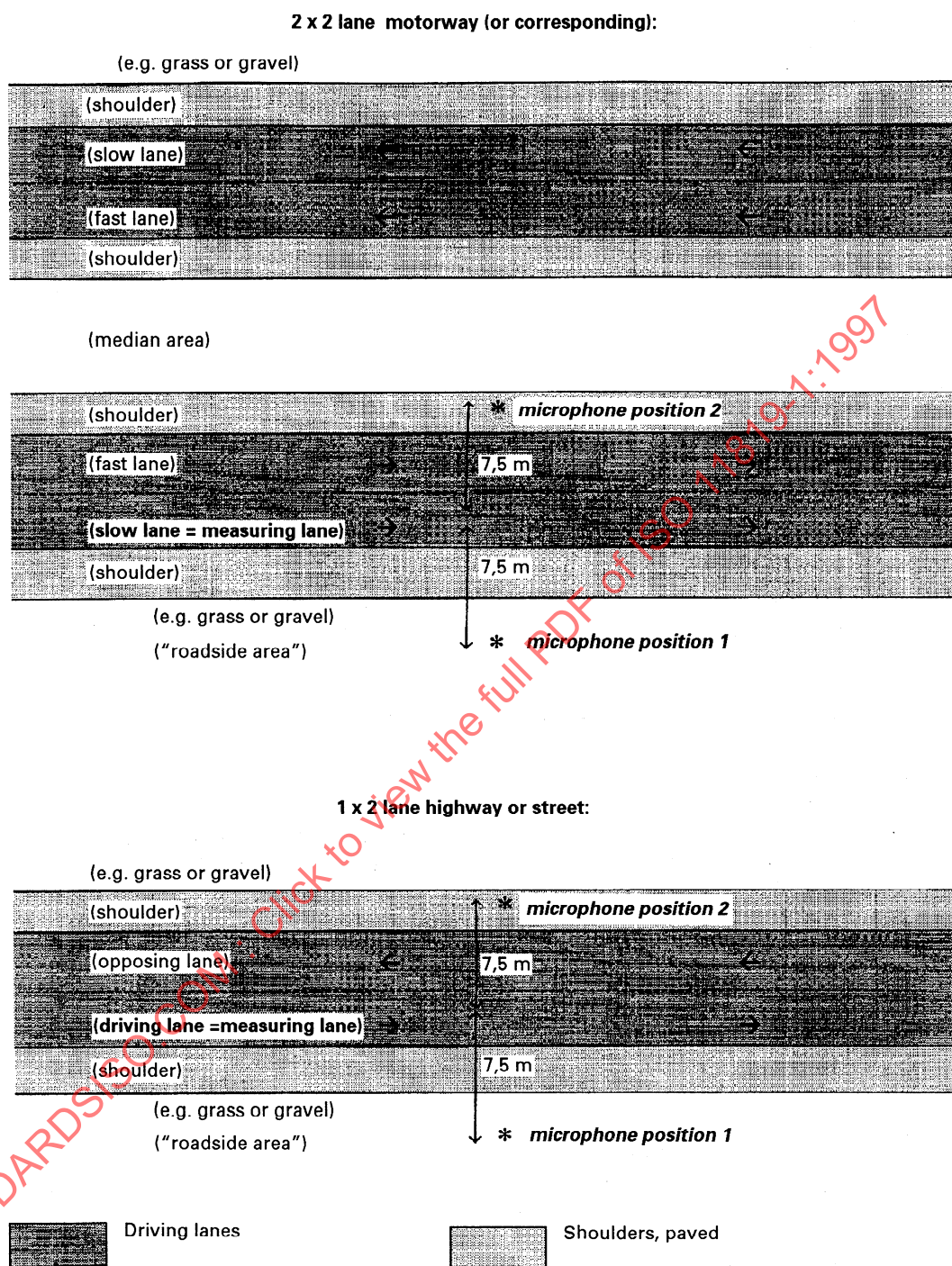


Figure 3 —Typical road configurations and microphone positions

8.3 Frequency spectrum measurement (recommended)

It is recommended to measure one-third-octave band frequency spectra. The averaging time should correspond to "F". The spectrum should be captured when the A-weighted sound pressure level during a vehicle pass-by is at its maximum.

8.4 Speed measurement

The vehicle speed at the moment when the vehicle midpoint passes the microphone shall be measured. Paired measurements according to 6.2 require measurements at each microphone location.

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 due to the angle error. It is important to correct for the error due to this effect. If the instrument itself does not provide such a correction, the reading shall be corrected manually.

See also the last paragraph of 9.6 for precautions regarding measurements for the "low" road speed category.

8.5 Temperature measurement

8.5.1 General

Measurements of air temperature are mandatory, whereas measurement of road surface temperature are recommended.

The measurements shall have a duration of at least 15 s. The thermometer manufacturer's instructions are to be observed. The result is the reading rounded to the nearest whole degree Celsius.

If continuous monitoring is not available, temperature shall be measured at 15 min intervals.

8.5.2 Air temperature

The temperature sensor shall be positioned in an unobstructed location as close to the centre of the test surface as is practical and safe, in such a way that it is exposed to the airflow and protected from direct solar radiation. The latter may be achieved by a shading screen. The sensor should be positioned 1,0 m to 1,5 m above the road surface level, to minimize the influence of road surface thermal radiation at low airflows.

8.5.3 Road surface temperature

The temperature sensor shall be positioned at a location where the temperature is representative of the temperature in the wheel tracks, and without interfering with the sound measurement.

If an instrument with a contact temperature sensor is used on rough road surfaces, heat-conductive paste shall be applied between the surface and the sensor to ensure adequate thermal contact.

9 Normalization of data

9.1 Regression analysis

A linear regression analysis of sound pressure levels on speed shall be made using data pairs consisting of the maximum A-weighted sound level versus the logarithm (base 10) of speed for each vehicle pass-by. A regression line shall be fit to the data points for each separate vehicle category, using the least squares method.

NOTE — Since speed is not the only factor determining vehicle sound emission, the correlation sound level-speed may not always be high, particularly for heavy vehicles and for small speed ranges. This does not preclude the calculated regression from being used for compensating as much as possible for speed influence.

9.2 Determination of Vehicle Sound Level at reference speeds

The reference speeds for the vehicle categories in the road speed categories are specified in table 1 below. Note that the reference speeds are the same for the two heavy vehicle groups.

The ordinate sound level of the regression line for each category of vehicle at the corresponding reference speed is taken to be the Vehicle Sound Level, L_{veh} . In this way, for a certain road site, three L_{veh} values are obtained: for cars, dual-axle heavy vehicles and multi-axle heavy vehicles.

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

Table 1 — Reference speeds and weighting factors (W_x) in the different road speed categories
(the weighting factors refer to 9.5)

Vehicle category		Road speed category					
		Low		Medium		High	
Name	No.	Ref speed [km/h]	W_x	Ref speed [km/h]	W_x	Ref speed [km/h]	W_x
Cars	1	50	0,900	80	0,800	110	0,700
Dual-axle heavy vehicles	2a	50	0,075	70	0,100	85	0,075
Multi-axle heavy vehicles	2b	50	0,025	70	0,100	85	0,225

9.3 Useful speed range for the regression line

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 be within the range of plus-or-minus one standard deviation from the actually measured average speed for heavy vehicles and plus-or-minus one-and-a-half standard deviation for cars.

9.4 Correction of sound levels according to temperature

The Vehicle Sound Levels should be corrected to a reference air temperature of 20 °C. A suitable method is at present under consideration. Both the uncorrected and the corrected levels shall be reported. However, until a suitable correction method has been prepared, only uncorrected L_{veh} values are mandatory to report.

Alternatively, if temperature measurements are made at each individual vehicle pass-by, along with sound measurements, it is preferred to correct each measured sound level individually for temperature instead of just the Vehicle Sound Level.

9.5 Determination of the Statistical Pass-By Index (SPBI)

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 shall be calculated as follows:

$$\text{SPBI} = 10 \lg [W_1 \times 10^{L_1/10} + W_{2a} (v_1/v_{2a}) \times 10^{L_{2a}/10} + W_{2b} (v_1/v_{2b}) \times 10^{L_{2b}/10}] \quad \text{dB}$$

where

SPBI is the Statistical Pass-by Index, for a standard mix of light and heavy vehicles;
 L_1 , L_{2a} and L_{2b} are the Vehicle Sound Levels for vehicle categories 1, 2a and 2b according to 9.2;
 W_1 , W_{2a} and W_{2b} are the weighting factors, which are equivalent to the assumed proportions of vehicle categories in the traffic, according to table 1;
 v_1 , v_{2a} and v_{2b} are the reference speeds of individual vehicle categories, according to table 1.

Typical values for the weighting factors W_x (W_1 , W_{2a} and W_{2b}) may vary considerably from place to place, country to country and with time of day and night. The values selected in table 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_{veh} values allows such SPBI calculations to be made, but when reporting these optional calculations the non-standard weighting factors used shall always be duly specified.

In many cases the main use of the SPBI would be to compare a certain surface with a reference surface according to Case 2 of clause 10, and present the result as a difference value. This difference is the same as the difference measured in equivalent levels for the assumed reference speeds and proportions of heavy vehicles according to table 1.

NOTE — SPBI is not an equivalent level (L_{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 "energetically" adding the L_{veh} values together, with each L_{veh} 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 L_{veh} levels. It is valid for cases where speeds of cars and heavy vehicles are as given in table 1. The index cannot be used for estimation of effects of speed.

9.6 Measurement uncertainty

The expected random errors for single-site measurements (see 6.2), expressed as standard deviations and confidence intervals, according to pre-normative research have been found to be as presented in table 2. These are due mainly to variations in sound level between different vehicles within the category in question. The standard deviation is the deviation with the speed effect removed, i.e. based on the residuals around the regression line of sound level versus the (logarithm of) speed.

In the case of paired measurements (see 6.2) the errors are reduced. If instead the individual levels for each vehicle on each site are studied (in pairs), the errors due to vehicle fleet variation will be considerably reduced. This is because the studied vehicle fleet on each site will be identical.

In addition to the random errors, there are always systematic errors due to instrumentation and calibration imperfections and due to deviations from ideal acoustical propagation conditions. The systematic error due to measuring instruments is ± 1 dB for the precision instrument system required here. Another important uncertainty in this procedure is that of variations in vehicle fleet composition, which may vary from place to place and time to time. The latter error may amount to 0,3 dB to 0,8 dB within a "typical" European country (see reference [3] in annex F).

Repeatability according to ISO 5725-1^[1] is better than 1,0 dB according to reference [4] in annex F.

Table 2 — Expected random errors in A-weighted sound pressure level
(rounded to one decimal).

Vehicle class	Standard deviation for individual vehicles around L_{veh}	95 % confidence interval around L_{veh}
Cars	1,5 dB	0,3 dB
Heavy vehicles, dual-axle	2,0 dB	0,7 dB
Heavy vehicles, multi-axle	2,0 dB	0,7 dB
NOTE — The confidence intervals, around the Vehicle Sound Levels, assume that the number of vehicles is 100 cars and 40 heavy vehicles of each type. The corresponding random error of the SPBI will be a combination of these errors according to the chosen weighting factors.		

The errors quantified in table 2 represent road categories "medium" and "high". Results of measurements made for the road speed category "low" may be influenced more by driving behaviour than others (some vehicles may be in an acceleration or deceleration mode which is not always easy to notice) and should be treated with caution. It may, for example, be wise to monitor their speed also slightly before and after they pass the microphone.

10 Reference road surface

The following options regarding reference surfaces apply.

10.1 General case

The reference surface is a dense, smooth-textured, asphaltic concrete surface with a maximum chipping size of 11 mm to 16 mm. From the acoustical point of view, this is approximately equivalent to a stone-mastic asphalt surface with the same maximum chipping sizes. The surface shall have been trafficked for at least one year when used as a reference here. Macrotexture depth as measured according to ISO 10844 or ISO 13473-1 shall be within 0,50 mm and 1,00 mm. To ascertain that the surface is acoustically non-absorbing, air voids content or the sound absorption coefficient shall meet the requirements specified in ISO 10844.

Not only the measuring procedure but also the location of the samples, as specified in ISO 10844, shall be observed.

10.2 Normalized reference case

The reference surface is a fictitious surface of which the levels L_{veh} for each vehicle category are defined by convention. This can, for instance, be based on the average results of a great number of SPB measurements on asphaltic concrete surfaces as specified under 10.1. An example is given in annex D.

The normalized reference case shall be the normally used case when testing potential low noise surfaces.

10.3 Equivalent age case

This reference surface type is the same as the general case, but the age of the reference surface is always the same as that of the surface under consideration. This means that when a new surface is measured, the reference surface shall also be new. This case may be used when the purpose is to compare two or more surfaces as a function of their age.

10.4 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 particular, selected surfaces.

11 Meteorological conditions

11.1 Wind

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

11.2 Temperature

Unless the measurement specifically aims at determining the influence of weather or other environmental conditions on sound emission, ambient air temperature shall be within 5 °C to 30 °C. The road surface temperature shall be within 5 °C to 50 °C.

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

11.3 Condition of the surface

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. If the surface can be expected to have a voids content exceeding 8 %, then measurement shall not be made until it has been verified that the pores are dry. Refer also to 6.1 regarding selection of the test site.

11.4 Check of moisture in porous surfaces

Unless more than 4 days have passed since the latest precipitation, the method described below should be used to check whether a surface assumed to have a significant porosity still contains residual moisture.

Compressed air is blown into the road surface (e.g. using a standard pistol-grip air jet, directed vertically towards the surface). Any remaining moisture will be revealed in a clearly visible spray cloud. The surface may be regarded as dry if five tests at different points on 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 may 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.

12 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 during pass-bys recorded from the vehicles included in the data base, particularly for the quietest vehicles recorded. Regarding sound pressure levels from other vehicles, see 7.2.

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

If the measured levels are expressed in one-third-octave bands, this condition shall also be met for each one-third octave.

13 Reported data

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

General information:

1. Time of day and date of measurement
2. Organization and operators responsible for the measurement
3. Purpose of the measurement
4. Type of measurement equipment (incl. calibrator, sound level meter or equivalent system, measuring equipment for speed and meteorological data and, if used, equipment for measurement of surface macrotexture)

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

5. Location of the test site
6. Site plan (horizontal), including microphone location (position 1 or 2) and identifying tested road lane, the type of surfacing(s) between the tested lane and the microphone, as well as acoustically reflecting objects within 25 m from the microphone
7. Cross profile (vertical) of the site from the other side of the road to the microphone position (*optionally, photos might be used to illustrate points 6 and 7*)

Information relating to the type and construction of the tested surfacing:

8. Type of surfacing (asphalt concrete, stone mastic asphalt, etc.), including any standardized or otherwise commonly used designation of the surfacing
9. Maximum chipping size
10. Thickness of surface layer (optional for non-porous surfaces). May be estimated from mass, density and area if not directly measured
11. Residual air voids content of surface layer, according to ISO 10844, in case of porous surfaces (optional)
12. Sound absorption coefficient, according to ISO 10844, in case of porous surfaces (optional)
13. Macrotexture depth, according to ISO 10844 or ISO 13473-1 (optional)
14. Representative photo of the surface, covering an area approximately 100 by 150 mm, including a scale (optional)
15. Attachment with surface specification (work recipe or equivalent) supplied to the contractor who has laid the surface (optional). May then include most of the items 8-13 above

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

16. Age of the surface and state of maintenance
17. Any special surface treatment
18. Any notes regarding the homogeneity of the surface
19. Date of latest precipitation, in the case of porous surfaces
20. Average, maximum and minimum air temperatures over the measurement period
21. Average, maximum and minimum road temperatures over the measurement period (optional)

Road speed category and vehicle information:

22. The road speed category in question
23. The number of vehicles in each category on which the measurements are based
24. Vehicle category weighting factors W_x , if not in accordance with this part of ISO 11819

Measured and calculated sound level and speed data:

25. L_{veh} for vehicle categories 1, 2a and 2b, uncorrected for temperature
26. L_{veh} for vehicle categories 1, 2a and 2b, corrected for temperature (optional, see 9.4)
27. SPBI, uncorrected for temperature
28. SPBI, corrected for temperature (optional, see 9.4)
29. Slope and intercept of regression line of sound pressure level versus (log) speed, average and standard deviation of the speeds and the standard deviation of the sound pressure level residuals (standard deviation around the regression line). See 9.1

Others:

30. Whenever used, the reference surface shall be reported, i.e. which of the four options in clause 10 has been used, in addition to items 5 to 21 above describing its construction and condition (wherever applicable)
31. Details of special provisions taken to assure conformance with this part of ISO 11819

See also annex E which includes an example of a report form.

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Annex A

(informative)

Vehicle categories

The following vehicle categories may be used optionally if a more detailed vehicle classification is desired than that of the standard:

1. Cars:

- Passenger cars

1b. Other light vehicles:

- Cars with trailers
- Cars with caravans
- Light utility vehicles, i.e. vehicles which are intended to carry some goods but with maximum 4 wheels
- Minibuses or small vans (maximum 4 wheels)
- Motor homes
- Recreational and utility vehicles (maximum 4 wheels; motorcycles not included)

2a. Dual-axle heavy vehicles:

- Commercial trucks with 2 axles and more than 4 wheels
- Buses and coaches with 2 axles and more than 4 wheels

2b. Multi-axle heavy vehicles:

- Trucks, buses and coaches with more than 2 axles

These sub-categories can further be grouped into the following main categories:

Categories 1+1b:

Light vehicles

Categories 2a+2b = Category 2:

Heavy vehicles

This rough classification does not prevent the observer defining sub-groups within these identified above for personal use, but for comparisons these categories should be used.

Motorcycles may be an (optional) extra category. For classifying roads, this should normally be left out.

If the observer is uncertain about the classification of some passing vehicles, that vehicle should be disregarded or put it in a "special class".

Annex B

(informative)

Validity and stability of the method

The validity of the method described in this part of ISO 11819 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 may also influence the results at low speeds. Vehicles are relatively uniform in their sound emission characteristics at least seen over the European countries (except in some east European countries), North America, Australia, New Zealand and industrialized countries of Asia. Minor but not negligible differences may, 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, according to reference [5] in annex F. Exceptions include some East European countries where an old vehicle fleet is rapidly exchanged. The possible introduction of sound emission limits for tyres may also influence this stability.

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.

Annex C

(informative)

Monitoring the stability of vehicle noise emission

This annex addresses the problems with stability described in annex B. The following (optional) procedure can be used to check the stability of vehicle sound levels, 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 3 years. It will then be possible to check changes and/or differences in vehicle sound emission over time and from country to country (possibly also between very different climatic regions).

The following procedure should be used:

- a) A reference surface designed in accordance with the general case of clause 10 should be used. However, maximum chipping size should be 11 mm to 14 mm. Furthermore, the surface should have been trafficked for at least 2 years and at most 8 years.
- b) Macrottexture depth should be measured according to annex A of ISO 10844:1994 or ISO 13473-1. The macrottexture depth should be within 0,60 mm and 1,00 mm.
- c) Measurements should be made in accordance with clauses 5 to 12, but include at least twice as many vehicles in each category as the minimum according to 7.3.
- d) Air temperature should be within the range 10 °C to 30 °C and road temperature within the range 10 °C to 40 °C.
- e) Calibration differences (before/after measurements) according to 5.3 shall not exceed 0,3 dB.
- f) Reporting of data should be in accordance with clause 13. In addition, the grading curve of the road surface should be reported (preferably in accordance with the example given in annex B of ISO 10844:1994).

NOTE 1 Differences over time or location in the range of 1,0 dB to 1,5 dB are normal and do not mean that vehicle sound emission has necessarily changed.

NOTE 2 Test results according to this part of ISO 11819 are not expected to remain valid for more than approximately 5 years due to changes of vehicles and tyres with time.

NOTE 3 It may also, or alternatively, be useful to apply the method specified in ISO 11819-2, utilizing reference tyres which are supposed to be stable over time, for comparison with the SPB method.