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

Part 2: The close-proximity method

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

Partie 2: Méthode de proximité immédiate

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Foreword

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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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

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

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

Introduction

The emission and propagation of road traffic noise greatly depends on road surface characteristics, notably on texture, flow resistivity and acoustic absorption. All these characteristics influence the generation of tyre/road noise and, in addition, the acoustic absorption 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 pressure 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 the influence of surface characteristics on tyre/road noise by a standardized method. Within the constraints of this method, this document offers an objective rating of the road characteristics to satisfy a need expressed by road planners, road administrators, contractors, manufacturers of so-called “low-noise surfaces” and other parties concerned with the control of road traffic noise.

A method satisfying the needs expressed in the foregoing, but having serious practical constraints, appears in ISO 11819-1. That method, called the statistical pass-by (SPB) method, is intended for use essentially for two main purposes. It can be used: first, to classify surfaces in typical and good condition as a type according to their influence on traffic noise (surface classification); and second, to evaluate the influence on traffic noise of different surfaces at particular sites irrespective of condition and age. However, due to severe requirements on the acoustical environment at the measurement site, the method cannot generally be used for approval of new or rebuilt surfaces at any arbitrary location. In addition, the SPB method has a number of other practical limitations, which are outlined in Annex D.

The method specified in this document, together with ISO/TS 11819-3, complements the SPB method in applications where the latter has limitations.

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

Part 2: The close-proximity method

1 Scope

This document specifies a method of evaluating different road surfaces with respect to their influence on traffic noise, under conditions when tyre/road noise dominates. The interpretation of the results applies to free-flowing traffic travelling on essentially level roads at constant speeds of 40 km/h and upwards, in which cases tyre/road noise is assumed to dominate (although in some countries it is possible that tyre/road noise does not dominate at 40 km/h when the proportion of heavy vehicles is high). For other driving conditions where traffic is not free-flowing, such as at junctions or under heavy acceleration, and where the traffic is congested, the influence of the road surface on noise emission is more complex. This is also the case for roads with high longitudinal gradients and a high proportion of heavy vehicles.

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 this document to suggest such criteria.

ISO 11819-1 defines another method: the statistical pass-by (SPB) method. The close-proximity (CPX) method specified in the present document has the same main objectives as the SPB method, but is intended to be used specifically in applications that are complementary to it, such as:

— noise characterization of road surfaces at almost any arbitrary site, with the main purpose of checking compliance with a surface specification (an example for conformity of production is suggested in Reference [1]);

— checking the acoustic effect of maintenance and condition, e.g. wear of and damage to surfaces, as well as clogging and the effect of cleaning of porous surfaces;

— checking the longitudinal and lateral homogeneity of a road section;

— the development of quieter road surfaces and research on tyre/road interaction.

NOTE This document does not describe the conditions of application for formal purposes of the measurement with the CPX method. Such conditions may be defined in other standards or legal texts. However, suggestions for the applicability of ISO 11819-1 and this document are provided in Annex D.

Measurements with the CPX method are faster and more practical than with the SPB method, but are more limited in the sense that it is relevant only in cases where tyre/road noise dominates and power unit noise can be neglected. Furthermore, it cannot take heavy vehicle tyre/road noise into account as fully as the SPB method can, since it uses a light truck tyre as a proxy for heavy vehicle tyres and does not take power unit noise into account.

The CPX method specified in this document is intended to measure the properties of road surfaces, not the properties of tyres. If the method is used for research purposes, to provide an indication of differences between tyres, the loads and inflations would normally be adjusted to other values than specified in this document.

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 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

ISO 11819-1, *Acoustics — Measurement of the influence of road surfaces on traffic noise — Part 1: Statistical Pass-By method*

ISO/TS 11819-3, *Acoustics — Measurement of the influence of road surfaces on traffic noise — Part 3: Reference tyres*

ISO/TS 13471-1, *Acoustics — Temperature influence on tyre/road noise measurement — Part 1: Correction for temperature when testing with the CPX method*

IEC 60942, *Electroacoustics — Sound calibrators*

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

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11819-1 and the following apply.

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

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

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

3.1 Road and pavement related definitions

3.1.1
road section
total stretch of the road lane subject to testing

3.1.2
road segment
part of a road section, being 20 m long and intended for normalization of sound pressure levels from the actual speed on that segment to a certain reference speed

3.2 Measurement methods and equipment

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. The method is specified in ISO 11819-1.

3.2.2
reference tyres
test tyres specified for the purpose of representing certain features in tyre/road sound emission, designed and constructed for use in this method with specified and reproducible standard properties

Note 1 to entry: The reference tyres are specified in ISO/TS 11819-3.

3.3 Acoustic quantities and symbols

3.3.1
close-proximity level
CPX level
L_{CPX}
time-averaged A-weighted sound pressure level (SPL) of the tyre/road noise as determined by the CPX method, either broadband or spectral bands, as required

Note 1 to entry: The CPX level is expressed in decibels. In order to provide more information, additional suffixes are used; see Table 1.

3.3.2
CPX level for passenger cars and other light vehicles
$L_{\mathrm{CPX:P}}$
A-weighted sound pressure level characterizing the road surface under test, which is based on the tyre/road sound pressure levels of one or more tyres representative of passenger car tyres

Note 1 to entry: The $L_{\mathrm{CPX:P}}$ is expressed in decibels. Passenger car tyres are denoted P1, P2 … .

3.3.3
CPX level for heavy vehicles
$L_{\mathrm{CPX:H}}$

A-weighted sound pressure level characterizing the road surface under test, which is based on the tyre/road sound pressure levels of one or more tyres representative of heavy vehicle tyres

Note 1 to entry: The $L_{\mathrm{CPX:H}}$ is expressed in decibels. Heavy vehicle tyres are denoted H1, H2 … .

3.3.4
CPX index
$L_{\mathrm{CPX:I}}$
index composed of the weighted average of the CPX level for passenger cars and other light vehicles ($L_{\mathrm{CPX:P}}$) and CPX level for heavy vehicles ($L_{\mathrm{CPX:H}}$)

Note 1 to entry: The $L_{\mathrm{CPX:I}}$ is expressed in decibels. The method is intended to describe performance of road surfaces for a certain traffic composition in a similar way to the SPB method in ISO 11819-1, although the numerical values for a given speed are higher. More information on the calculation of CPX indices is given in Annex M.

3.3.5
acoustic variability due to road surface inhomogeneities
s_{t}
standard deviation of the A-weighted sound pressure levels over all segments, when using reference tyre t

Note 1 to entry: The acoustic variability is expressed in decibels. This variability is normally dominated by road surface variations, although random uncertainties could add a little. Measurement speed and wheel tracks normally do not influence this value significantly. This measure is, therefore, considered to be an indication of road surface homogeneity as far as noise properties are concerned.

3.4 Symbols used for correction terms

3.4.1
measured speed
v
actual speed during a measurement

Note 1 to entry: The measured speed is expressed in kilometres per hour.

3.4.2
reference speed
v_{ref}
preferred speed for measurement

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, but alternative speeds may be used if required for technical, safety or legislative reasons.

3.4.3
speed coefficient
B
coefficient determining the speed dependence of the sound pressure levels, normally used for correction of the sound pressure level to a certain reference speed

Note 1 to entry: The correction for deviations from the reference speed is given by the expression $B \cdot \lg(v/v_{ref})$, expressed in decibels, where B is dimensionless. Values of B for specific pavements are given in 11.1 d).

3.4.4
temperature coefficient
γ_t
coefficient used for correcting CPX level for the effect of temperature for tyre t

Note 1 to entry: The temperature coefficient is expressed in decibels per degree Celcius.

3.4.5
rubber hardness coefficient
β_t
coefficient used for correcting CPX level for the effect of tread rubber hardness of tyre t

Note 1 to entry: The rubber hardness coefficient is expressed in decibels per Shore A. Refer to 11.1 f) for application.

3.4.6
device-dependent correction for sound reflections
$C_{d,f}$
correction for individual measuring devices in one-third-octave bands from 315 Hz to 5 000 Hz with the centre frequency f, to account for deviations from acoustic hemi-free-field conditions

Note 1 to entry: The device correction for sound reflections is expressed in decibels. Information on the determination of $C_{d,f}$ is given in A.2.

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 document and their value or unit

Symbol	Value/unit	Explanation
$L_{CPX:t,v_{ref}}$	dB	Measure of the acoustic properties of the tested road section, for tyre t, at the reference speed v_{ref}
$L'_{CPX:t,w,r,i,f}$	dB	Energy-based average spectrum at the microphone positions m = 1 and m = 2 (for the subscript symbols, see below)
$L_{CPX:t,w,r,i,f,m,v_{ref}}$	dB	Time-averaged tyre/road SPL ("CPX level") over the time it takes to run a road segment (20 m)
$L_{CPX:P,v_{ref}}$	dB	Measure of the acoustic properties of the tested road section, for tyre(s) "P" representing passenger cars and other light vehicles, at the reference speed, v_{ref}
$L_{CPX:H,v_{ref}}$	dB	Measure of the acoustic properties of the tested road section, for tyre(s) "H" representing heavy vehicles, at the reference speed, v_{ref}
$L_{CPX:I,v_{ref}} =$ $0{,}5 \cdot L_{CPX:P,v_{ref}} + 0{,}5 \cdot L_{CPX:H,v_{ref}}$	dB	"CPX index" representing the overall acoustic properties of the tested road section, for tyre(s) representing light and heavy vehicles combined (with equal weighting), at the reference speed, v_{ref}
B	Dimensionless	Speed coefficient; i.e. increase in CPX level with tenfold increase in speed, to be able to correct for deviations from the reference speed, v_{ref}
$C_{d,f}$	dB	Device correction term (frequency dependent) to account for deviations from free field conditions
γ_t	dB/°C	Temperature coefficient for correction for tyre t to account for deviations from reference temperature of 20 °C. The value is negative for tyres P1 and H1
β_t	dB/Shore A	Rubber hardness coefficient for correction for tyre t to account for deviations from a reference hardness
f	315 Hz, ... 5 000 Hz	One-third-octave-band centre frequency
i	1, 2, 3 ...	Road segment number
m	1, 2 3, 4, 5, 6	Front and rear mandatory microphone positions Optional microphone positions
n	1, 2, 3 ...	Total number of runs, n_r, wheel tracks, n_w, or road segments, n_i
r	1, 2, 3 ...	Run number
H_A		Rubber hardness in durometer type A of test tyre tread
H_{ref}		Reference rubber hardness in durometer type A
s_t	dB	Acoustic variability; a measure of road surface homogeneity
t	P H	Tyre type defined for testing Passenger car tyres Heavy vehicle tyres or approximate proxy
T_i	°C	Air temperature at road segment i (index not needed if continuous temperature measurements are not made)

Table 1 *(continued)*

Symbol	Value/unit	Explanation
v	km/h	Actual measured speed
v_{ref}	km/h	Preferred nominal speed for measurement; thus a reference speed used when reporting results
w	1, 2, 3, ...	The wheel tracks in a lane where test tyres are rolling. Track number 1 is closest to the road shoulder, 2 is the opposite wheel track within that same lane; 3, 4, and so on are additional tracks

5 Measurement principle

In the CPX method, the average A-weighted SPLs emitted by specified tyres are measured over an arbitrary or a specified road distance, together with the vehicle testing speed, by at least two microphones located close to the tyres. For this purpose, a special test vehicle, which is either self-powered or towed behind another vehicle, is used. Reference tyres are mounted on the test vehicle, either one by one or both at the same time. Two uniquely different reference tyres have been selected in order to represent the tyre/road characteristics which are to be studied.

Although the microphones are positioned in close proximity to the source of tyre/road noise, a substantial part of the propagation effect associated with acoustically absorptive surfaces is actually included in the microphone signal. This is demonstrated by model calculations and the results of the CPX validation experiment (References [2], [3]). See Annex D for further information.

The tests are performed with the intention of determining a tyre/road sound pressure level, here referred to as the CPX level, L_{CPX}, at one or more of the nominated reference speeds. This can be achieved by testing at a reference speed or by normalizing for speed deviations.

For each reference tyre and each individual test run with that tyre, the average sound pressure levels over short measuring distances (segments of 20 m each), together with the corresponding vehicle speeds, are recorded. The sound pressure level of each segment is normalized to a reference speed by a simple correction procedure. Averaging is then carried out according to the purpose of the measurement, i.e. measuring a particular segment or a number of consecutive segments (a section).

The CPX level, $L_{CPX:t,v_{ref}}$, is the resulting average sound pressure level for the two mandatory microphones at the reference speed, v_{ref} for reference tyre t, where t is P or H.

Where both close-proximity sound levels have been determined, the close-proximity sound index $L_{CPX:I}$ is the average of $L_{CPX:P}$ and $L_{CPX:H}$ with equal weight given to the two indices. $L_{CPX:I}$ is intended for single value comparison.

There are some issues in the method which deserve special caution when applying this method, especially under circumstances that are not the most common. Annex J provides a discussion of such issues.

6 Measuring instruments

6.1 Sound level instrumentation

Within the minimum frequency range of 315 Hz to 5 000 Hz, the sound level meter or the equivalent measuring system shall meet the requirements of IEC 61672-1, class 1. The microphones shall be of the “free-field” type.

An appropriate windscreen shall be used having a diameter of at least 90 mm. The sound properties of windscreens will deteriorate as the material is progressively exposed to dirt. It is therefore good practice to check the performance of the windscreens frequently and to replace them with new, fresh material when they show patterns of dirt coverage.

6.2 Frequency analysis instrumentation

Frequency analysis of the measured sound using one-third-octave-band resolution is mandatory. The range 315 Hz to 5 000 Hz (centre frequencies of one-third-octave bands) is the minimum range to be covered. The one-third-octave-band filters shall conform to IEC 61260-1.

6.3 Sound calibration instrumentation

At the beginning of the measurements, and following any warm-up time specified by the manufacturer, the overall sensitivity of the sound level meters or the equivalent measuring system (including the microphone) shall be checked. If necessary, adjust it according to the manufacturer's instructions. This may require use of a standard sound source, such as a calibrator or pistonphone. This check shall be repeated at the end of the measurements, and at least after every 4 h of operation. Any deviations shall be recorded in the test report. If the calibration readings differ by more than 0,5 dB between the checks, all intermediate measurements shall be considered invalid.

The sound calibration device shall meet the requirements of IEC 60942, class 1.

6.4 Vehicle speed measuring instrumentation

The average speed of the vehicle over the measured segment shall be measured, with a maximum permissible error of ±1 % of the indicated value.

For speed measurement, if a tyre is used it shall not be mounted on a drive axle.

6.5 Position monitoring instrumentation

GPS or other means of identifying the start positions of measurements are very useful in order to avoid problems in identifying a test section and to be able to return to the same place at a later occasion or for other types of measurements. It is recommended that the GPS system is of a type specified with a maximum permissible error of ±5 m.

6.6 Temperature measuring instrumentation

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

6.7 Tyre load measuring equipment

The weighing equipment used to determine the load of the test tyres shall have a maximum permissible error of ±5 %, as specified by the manufacturer.

6.8 Inflation pressure measuring equipment

The equipment used to determine the inflation pressure of the test tyres shall have a maximum permissible error of ±4 %.

6.9 Verification of measuring system and measuring instrumentation

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 61672-1 shall be verified at least every two years. This shall be performed by a laboratory authorized to perform calibrations traceable to the appropriate standards. It is recommended that all other instrumentation should be calibrated at least every two years.

7 Test sites

In performing a CPX measurement, there are a number of practical constraints which define the minimum requirements for the road section to be suitable for assessment. These can be summarized as follows.

— The approach to the road section shall be of sufficient length to allow the reference speed to be reached before reaching the road section. There shall be a run-in of at least 10 m of the same surface type before the road section begins.

— The road section (excluding the run-in) shall be at least 20 m long, and preferably longer than 100 m.

— The road section shall not include bends with a radius of curvature less than 250 m at 50 km/h and 500 m at 80 km/h.

— The surface of the road section up to a distance of 0,5 m perpendicularly from the sidewall of the test tyre facing the microphone shall be the same surface type as in the wheel track or have similar acoustical impedance characteristics.

— The limitations on background noise at the test site according to A.5 shall be observed.

— Where measurements are taken using a test vehicle without an enclosure (see 9.1), those parts of the road section where there are reflecting surfaces within a distance of 2 m from the microphone shall be excluded from the assessment. This includes guard rails, Jersey barriers or any other barriers or embankments, rocks, parked vehicles, bridges and buildings. In cases where the test vehicle includes an enclosure complying with the requirements of Annex A, no restrictions apply to objects at the roadside.

With regard to the last requirement, 2 m is selected as a precaution against the possible effect of multiple reflections between two hard surfaces: the vehicle side panel (if any) and the roadside object. If the user can show that such reflections for the vehicle configuration opposite a solid parallel wall never have any influence on the measured levels at a distance less than 2 m, the distance can be reduced to that lower distance – however, never less than 1 m. If applicable for the tested road, such reflection tests shall be referred to in the test report.

8 Meteorological conditions

8.1 Wind

It is recommended that ambient wind speed does not exceed 5 m/s at the microphone height during the measurement for test vehicles without an enclosure around the microphone and test tyre. If the test tyre(s) is/are enclosed, wind speeds up to 10 m/s are acceptable.

If the test vehicle manufacturer or user can prove that the vehicle can travel in higher wind speeds, in any direction, without a significant influence on the measurement result, the recommendation above can be ignored. The same conditions as in A.3.2 shall then be met.

8.2 Temperature and other weather-related issues

Measurements shall be carried out only when road surfaces are dry and ambient air temperature is within the range representative for that climatic zone:

— moderate and continental: 5 °C to 30 °C;

— tropical and subtropical: 10 °C to 35 °C.

The surfaces can be assumed to be sufficiently dry if the minimum time periods for drying-up after rainfall given in Table F.1 are observed.

NOTE 1 The allowed temperature range is related to local road materials. In the warmer zones, high temperatures are common and bitumen viscosity is adjusted to it, while the same temperature in a cooler climate can cause bleeding of the bitumen. This is known to cause extra stick-snap sound from the rolling tyre.

NOTE 2 Annex F also gives guidelines for estimating the level of moisture within the voids of porous surfaces by a simple test method.

9 Test vehicle

9.1 General design

The test vehicle may be one of the following types.

— A self-powered vehicle on which one or two reference (test) tyre(s) is/are fitted to the axle closest to the microphones. It could also be a vehicle with an extra tyre fitted for testing purposes.

— A trailer towed by a separate vehicle. There shall be one or more test tyres, which are mounted on the trailer. Additionally, the trailer may have tyres for support.

The test tyre(s) may or may not be surrounded by an enclosure covering the tyres except for a certain clearance to the road, the purpose of which is to protect the microphones from external noise and wind influences.

The requirements on the test vehicle have the objective to come as close as possible to the reference case in which a tyre is rolling on a road surface with microphones in an acoustical hemi-free-field, i.e. where there are no sound reflections except from the road surface and no background noise.

The requirements and design recommendations in the following are intended to approach this ideal situation within practical constraints.

For the purposes of this document there are three sources of unwanted contribution to the free field sound transmission from tyre to microphone:

a) background noise related to the system, consisting of sources such as wind noise and sound from the towing vehicle;

b) background noise from unrelated sources such as passing vehicles and reflections against roadside objects;

c) contributions from unwanted reflections against parts of the system, such as insufficiently absorbing enclosures and parts of suspensions systems.

The vehicle shall comply with the requirements described in Annex A. See also 10.7 regarding possibilities of discarding segments where this requirement is exceeded.

9.2 Microphone positions and mounting

At least two microphones shall be used. The two mandatory microphones shall be in operation simultaneously. The positions of the mandatory microphones under static condition relative to the test tyre shall be as follows (see Figure 1 and Table 2):

— distance horizontally from the plane of an undeflected part of the tyre sidewall shall be 0,20 m ±0,01 m;

— the height above pavement level shall be 0,10 m ± 0,01 m.

All measurements refer to the centre of the microphone diaphragm. It is recommended that the “front“ microphone (1) be turned at an angle of 45° to the rolling direction, and the “rear“ microphone (2) be

