TECHNICAL SPECIFICATION

ISO/TS 13471-2

First edition
2022-08

Acoustics — Temperature influence on tyre/road noise measurement —

Part 2: Correction for temperature when testing with the pass-by methods

Acoustique — Effet de la température sur les essais de bruit pneu/route —

Partie 2: Correction de la température lors des essais utilisant les méthodes au passage

Reference number
ISO/TS 13471-2:2022(E)

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Published in Switzerland

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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).

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

A list of all parts in the ISO/TS 13471 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

Air, tyre and road surface temperatures affect noise emission from the tyre/road interaction, as measured by means of, for example, the statistical pass-by (SPB) method specified in ISO 11819-1 or other pass-by methods. These methods allow the user to make measurements within a wide air temperature range (5 °C to 35 °C) which means that temperature influence on the results may be substantial.

Another common type of measurement where temperature effects on tyre/road noise are significant is for noise tests on tyres most commonly conducted as pass-by on test tracks with a reference surface according to ISO 10844[1]. This case is also considered in this document, with the aim to reduce the uncertainties in such measurements. These are often made for legal purposes, such as type approval or labelling of tyres or vehicles where tyres are the dominant noise source. This is further dealt with in Annex A.

Temperature effects on noise depend on both the tyre and the road surface, the temperatures of which are affected by ambient air temperature. The temperature has different effects on different noise generation mechanisms and when also considering the effect of possible power unit noise mixed with tyre/road noise, the temperature effect becomes even more complicated. Ideally, and whenever possible, temperature corrections shall be tailored to not only the tested tyre/road combination as well as to different tyre and vehicle categories, but also to the type of measurement method. For example, there is also a Technical Specification related to the CPX method (ISO/TS 13471-1[2]).

The approach to the temperature correction in this document is semi-generic, which means that under certain conditions a correction to noise for temperature is made common to a group of vehicles and tyres or a group of road surfaces as it is impossible to do it for each tyre and road surface combination. This document makes a distinction to cars and heavy vehicles and to a few major road pavement categories, and also takes into account local, regional or national conditions.

Acoustics — Temperature influence on tyre/road noise measurement —

Part 2:
Correction for temperature when testing with the pass-by methods

1 Scope

This document specifies correction procedures for the effect of temperature on vehicle noise emission, as influenced by the tyre/road noise contribution. Temperatures considered are road and ambient air temperatures.

The noise emission for which this document is applicable is measured by means of ISO 11819-1, or similar methods such as the American methods SIP and CTIM specified in References [3][4]. It is also applicable to other pass-by measurements conducted without acceleration, such as when testing tyres and vehicles on test tracks with ISO 10844[1] reference surfaces; however, given that tyre/road noise is dominant.

Measurement results obtained at a certain temperature, which may vary over a wide range, are normalized to a designated reference temperature (20 °C) using a correction procedure 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 11819-1, *Acoustics — Measurement of the influence of road surfaces on traffic noise — Part 1: The statistical pass-by method*

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 following terms and definitions apply.

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

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

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

3.1 Acoustics

3.1.1
vehicle noise
total noise from an individual vehicle, the two major components of which are *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
SPB method
statistical pass by 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 Measured noise quantities

3.2.1
maximum sound level
L_{Amax}
highest sound pressure level recorded by the measuring instrument during a vehicle pass-by, using frequency weighting A and time weighting F

3.2.2
vehicle sound level
$L_{VEH:U,vref}$
maximum A weighted sound pressure level determined at a reference speed, v_{ref}, calculated for one of the universal vehicle categories (U) defined in 3.3.2

Note 1 to entry: When testing according to ISO 11819-1, $L_{VEH,J,vref}$ is equal to $L_{SPB,J,vref}$

3.2.3
tyre/road sound level
$L_{TR:C,vref}$
maximum A weighted sound pressure level determined at a reference speed, v_{ref}, measured or calculated in conditions where there is no power unit noise (coast-by passing or similar), for one of the tyre classes (C) which can be C1, C2 or C3 defined in 3.3.1

3.3 Tyre and vehicle classes

3.3.1
tyre class
dimensional class of tyres

Note 1 to entry: Tyre classes C1, C2 and C3 are defined in ECE Regulation 117[5].

Note 2 to entry: Essentially, C1 tyres are used on cars and other light vehicles, C2 tyres are used on large SUV:s, vans and small trucks, while C3 tyres are used on heavy vehicles. However, refer to the reference [5] for more precise definitions based on tyre load indices.

3.3.2
vehicle category
universal category of vehicles (U), using a certain class of tyres, that can be either P (passenger cars using C1 tyres), H (heavy vehicles using C3 tyres) or M (a medium category of vehicles using C2 tyres, mostly consisting of large SUV:s, vans and small trucks)

Note 1 to entry: Vehicle categories P and H are defined in ISO 11819-1:-[1)], and tyre classes are defined in 3.3.1. Vehicle category M is not used in ISO 11819-1.

3.4 Road surface

3.4.1
surface course
upper course of the pavement, which is in contact with the tyres

Note 1 to entry: Various main types of road surfaces are described in Annex A.

3.5 Temperatures

3.5.1
air temperature
ambient air temperature
temperature of the air surrounding the traffic flow

Note 1 to entry: The air temperature is expressed in degree Celsius.

Note 2 to entry: Instructions on where and how to measure air temperature are given in 6.2.

3.5.2
road temperature
road surface temperature
temperature representative of the temperature in the wheel tracks of the road surface

Note 1 to entry: The road temperature is expressed in degree Celsius.

Note 2 to entry: Instructions on where and how to measure road surface temperature are given in 6.3.

3.5.3
tyre temperature
general term for the temperature of the test tyres

Note 1 to entry: The tyre temperature is expressed in degree Celsius.

Note 2 to entry: Tyre temperature varies substantially between different parts of the tyre, as well as with the tyre operating conditions. In this document, distinction is not made between these different parts, but the tyre is seen as a unit with a temperature that influences noise emission in a particular way.

3.5.4
reference temperature
T_{ref}
air temperature (3.5.1) of 20,0 °C representing a hypothetical, ideal measurement case, to which actual measurements are normalized

3.5.5
temperature correction term for tyre class t
$C_{\mathrm{T,t}}$
term used for correcting the *tyre/road sound level* (3.2.3) for temperature T for tyre class t

Note 1 to entry: The temperature correction term is expressed in decibels.

1) A revision of ISO 11819-1 where the vehicle categories are defined is currently under preparation.

3.5.6
temperature correction term for vehicle category
$C_{T,U}$
term used for correcting the *vehicle sound level* (3.2.2) for temperature *T* for vehicle category U

Note 1 to entry: The temperature correction term is expressed in decibels.

Note 2 to entry: This term represents how $C_{T,t}$ is “diluted” by power unit noise of the particular vehicle category (see Clause 9).

3.5.7
temperature coefficient
γ_t
coefficient used for correcting the *tyre/road sound level* (3.2.3), for the effect of temperature for tyre class t

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

Note 2 to entry: Tyre t can be classes C1, C2 or C3 (3.3.1).

3.5.9
temperature coefficient
γ_U
coefficient used for correcting the *vehicle sound level* (3.2.2) for the effect of temperature for vehicle category U

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

Note 2 to entry: Vehicle category U can be P, M or H (3.3.2).

Note 3 to entry: This coefficient is the version of γ_t taking into account how it is “diluted” by power unit noise of the particular vehicle category (see Clause 9)

4 Principles of the correction procedures

The general effect of temperature is an increase in sound levels with colder temperatures and a decrease in sound levels with warmer temperatures. Based on the empirically determined relationship between tyre/road noise and ambient air temperature, the aim is to normalize all coast-by and pass-by noise measurements (including, for example, SPB measurements) to a reference temperature. This is done from the actual air temperature during the measurement, within a temperature range where the relationship is reasonably linear.

The reference condition has been determined to be a hypothetical measurement of noise at an ambient air temperature of 20,0 °C. The relationship between noise and temperature has been determined from a compilation of several published investigations. It has been found that the relationship depends on the class of tyres and types of road surfaces, and somewhat different relationships are, therefore, necessary to apply based on the road surface type, and to some extent the condition of the surface (porosity)[6].

In this way, measured overall A-weighted levels as well as spectral levels, corrected for the difference between actually measured temperature and the reference temperature using formulae given in this document, are normalized to a common reference condition where air temperature would be 20 °C.

In general, it is advised that measurements be made as close as possible to the reference temperature, in order to avoid large corrections. In cases when one wants to compare, for example, a before–after measurement of some type, the lowest uncertainties will result if such before–after measurements are made at similar temperatures; in particular, if temperatures during measurements are relatively far from the reference temperature.

When using a semi-generic correction procedure, it is accepted that the use of an average temperature coefficient for either tyre/road noise or vehicle noise considered in this document, with a distinction between a few major road pavement categories, will lead to some over- and under-estimations of temperature corrections for individual tyres, vehicles or pavements. However, the errors of such imperfect corrections are more than balanced by the correction itself as it normalizes the results to a common and comparable scale.

This procedure will reduce the uncertainty in coast-by, SPB and other pass-by measurements due to varying temperature substantially. An analysis of uncertainty is included in this document.

Refer to Annex B for a discussion about the choice of temperature to use for normalization.

5 Temperature measurement equipment

The air, road and tyre 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.

NOTE Obviously, the tyre temperature measurement option is impossible in SPB measurements.

The 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.

The type of sensor used shall be reported.

6 Measurement methods

CAUTION — This document may involve hazardous operations when measurements are made on trafficked roads or streets. The personnel and the vehicles present on the measuring site shall be equipped with safety or warning devices in accordance with the regulations in force for work in the traffic flow (if any) on that particular site at that particular time. Otherwise, this document does not purport to address the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

6.1 General

The measurements shall comprise at least the first of the following operations.

— Measurement of air temperature representative of the ambient air at the test site (mandatory).

— Measurement of road temperature representative of the road surface of the test site (optional).

— Measurement of tyre temperature (optional).

The thermometer manufacturer's instructions shall be observed. The result is the reading rounded to the first decimal, in °C.

NOTE Regarding the various temperatures considered, a discussion follows in 6.2 to 6.4. See also the discussion in Annex B.

6.2 Measurement of air temperature

Locate the temperature sensor so that it is unobstructed and safe, and in such a way that it is protected from direct solar radiation and heat radiation from road or other surfaces. The protection from solar radiation may be achieved by a shading screen. Heights of 1,2 m to 1,5 m above road surface level are suitable. The position of the sensor shall be reported.

The temperature measurement shall have a duration of at least 15 s of stable temperature.

6.3 Measurement of road surface temperature (optional)

Position the temperature sensor in order to measure where the temperature is representative of the temperature in the wheel tracks. Collect the measurements approximately simultaneously with the noise measurement. Where portions of the roadway are in full sun and other portions are shaded it is advised to collect and average the temperature values approximately over the same test section as noise is collected.

The temperature measurement shall cover a few spots or a spot large enough to average out possible differences between surface objects having different albedos.

NOTE 1 Surface temperatures can be different on bright exposed stones than on the much darker bitumen/sand mortar between such stones.

NOTE 2 Regarding the problems with road surface temperatures, see the discussion in Annex B.

6.4 Measurement of tyre temperature (optional)

If one can control the test vehicle, tyre temperature measurements can be made either continuously on-board the vehicle or immediately before or after the measurement. Position the temperature sensor in order that it measures the tyre tread surface temperature. Where appropriate, in order to avoid dirt thrown from the tyre by centrifugal forces, the sensor should not be positioned in the tyre plane but a little outside the tyre plane. If tyre temperature is measured, the measuring position on the tyre shall be reported.

NOTE Obviously, this option is impossible in SPB measurements.

7 Temperature range

7.1 General

In order to reduce the uncertainty, it is recommended that noise measurements be made at air temperatures as close as practical to the reference air temperature (20,0 °C).

7.2 Temperature range within which the correction procedure is valid

The correction procedures in this document shall be applied only if air temperatures are within 5 °C and 35 °C.

NOTE 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 bituminous mixture. This is known to cause extra stick-snap sound from the rolling tyre (see Reference [7], in particular chapter 12.1).

8 Temperature correction procedure

8.1 Correction to noise levels

Temperature correction shall be applied as follows. Each measured noise level, L_{Amax}, where appropriately determined according to ISO 11819-1 shall be corrected by adding the term $C_{\mathrm{T,t}}$, using Formula (1):

$$C_{T,t} = -\gamma_t \left(T - T_{\mathrm{ref}}\right) \quad (1)$$

where

$C_{T,t}$ is the noise level, L_{Amax}, correction for temperature (T) for tyre class (t), in dB, to be added to the measured noise level; t can also be represented by the vehicle category (U) in which the particular tyre class is used, see Note 1;

γ_t is the temperature coefficient for tyre class t (either C1, C2, or C3), in dB/°C;

T is the air temperature (T) during the noise measurement, in °C;

T_{ref} is the reference air temperature = 20,0 °C.

The γ_t values are indicated in 8.2 below. However, to consider the potential effect of power unit noise, if appropriate, one shall consider the weighting factors presented in Clause 9.

For ISO 13325[8] or relevant parts of ISO 362[9], temperature influence can be corrected in the same way as described above.

NOTE 1 For SPB measurements (ISO 11819-1), t refers to C1 tyres for the P vehicle category and C3 tyres for the H vehicle category. For other vehicle pass-by measurements, where tyre/road noise dominates, C1 tyres refer to vehicle category P, C2 tyres refer to vehicle category M, and C3 tyres refer to vehicle category H.

NOTE 2 The requirement on where to apply this correction coefficient is described in ISO 11819-1, or in other applicable standards.

8.2 Temperature coefficient

Based on, among others, the following References [6][10][11][12][28][29] and [30] the γ_t values are as follows.

For dense asphaltic surfaces (such as DAC, SMA, TAL with air voids typically below 18 %, and surface dressings, the latter also known as chip seals; see Annex A), the coefficients are:

$$\gamma_{C1} = -0,10 \quad (2)$$

$$\gamma_{C2} = -0,07 \quad (3)$$

$$\gamma_{C3} = -0,06 \quad (4)$$

where

γ_{C1} is the numerical value of the temperature coefficient for tyre class C1, expressed in dB/°C;

γ_{C2} is the numerical value of the temperature coefficient for tyre class C2, expressed in dB/°C;

γ_{C3} is the numerical value of the temperature coefficient for tyre class C3, expressed in dB/°C;

For convenience, the coefficients are compiled in Table 1.

For cement concrete surfaces of all types (see Annex A), the coefficients are:

$$\gamma_{C1} = -0,07 \quad (5)$$

$$\gamma_{C2} = -0,06 \quad (6)$$

$$\gamma_{C3} = -0,06 \tag{7}$$

For porous asphalt surfaces and high-porosity TAL (not seriously clogged; see Annex A), the coefficients are:

$$\gamma_{C1} = -0,05 \tag{8}$$

$$\gamma_{C2} = -0,04 \tag{9}$$

$$\gamma_{C3} = -0,04 \tag{10}$$

Table 1 — Compilation of temperature coefficients

Tyre class (t) → Road surface category ↓	C1	C2	C3
Dense asphaltic surfaces	−0,10	−0,07	−0,06
Cement concrete surfaces	−0,07	−0,06	−0,06
Porous asphalt surfaces	−0,05	−0,04	−0,04
Other surfaces	See Note 2 and/or Annex A		

NOTE 1 Note that the formulae in no way represent a physical relationship; they are just a mathematical expression that rather closely fit relationships found for coast-by or pass-by measurements at high speeds, assumed to represent tyre/road noise. It is practical to use the formulae here as they are easy to implement in software.

NOTE 2 For road surfaces not fitting any of the categories of Formulae (2) to (7), determine a surface-specific coefficient by experiments, or use the coefficient for the category which is judged to be the most similar, for example as described in Annex A.

NOTE 3 The generic road surface type designated DAC includes dense asphalt concrete, stone mastic asphalt (SMA) and thin asphalt layer (TAL).

NOTE 4 The temperature effects have been studied mainly for the tyre classes C1 and C3[10]. For C2, there are very few results, but the C2 tyre designated H1 in ISO/TS 11819-3[13] was found to have coefficients similar to C1 tyres. In Reference [30], a temperature coefficient of 0,053 was found. Considering the “dilution” effect of power unit noise in Reference [30] being 0,8 according to Table 2, temporarily, C2 tyres have been assigned a coefficient of 0,07 for dense asphalt.

NOTE 5 As it can seem confusing with the minus signs in Formula (1), as well as minus signs for the coefficients (Formulae (2) to (10)) too, here is an example that can clarify the calculations.

First, note that the minus sign for the coefficients, originate from the negative correlation found between noise and temperature. Assume that a measurement made at T = 30 ºC, with a tyre of C1 category on a dense asphalt pavement, gave a noise level of 78, dB.

Formula (2) then requires the use of the correction coefficient γ_{C1} = −0,10

Applying Formula (1) ($C_{T,t} = -\gamma_t (T - T_{ref})$) then means that the correction $C_{T,t}$ becomes $C_{24,C1}$ = −(−0,10)(24-20) = 0,1·4 = 0,4 [dB], which means that the measured level of 78,1 dB shall become 78,5 dB (at 20 ºC) after temperature correction.

8.3 Spectral correction

It is known that the correction should ideally be made based on spectra. Available data suggest that the temperature influence is the highest at low and high frequencies, while the peak frequency, which often appears around 800 Hz to 1 250 Hz, is affected to a lesser degree[14]. However, collected data are not sufficiently consistent to allow a frequency-dependent temperature correction. In order to avoid a discrepancy between separately measured overall levels and the same calculated from spectra, the same correction shall be applied for all frequencies.

9 Compensation for the effect of power unit noise

The corrections according to the previous Clause refer to tyre/road noise alone. In pass-by measurements, power unit noise of vehicles adds to the tyre/road noise and thus "dilutes" the temperature influence. Currently, there are no means of determining temperature influences on power unit noise so it must be treated as an unknown parameter. The following indicates a way to deal with this issue.

When there may be some power unit noise present, such as during SPB and other pass-by noise measurements, the temperature coefficient shall be reduced according to Formula (11):

$$\gamma_U = W_U \cdot \gamma_t \qquad (11)$$

where

γ_t is the temperature coefficient for tyre class t;

W_U is the correction factor describing how much of the overall noise level that is estimated to come from the tyre/road contribution for the relevant vehicle category (P, M or H). This coefficient may vary between 0 (no tyre/road noise present) and 1,0 (all noise is tyre/road noise). It is influenced by the speed of the vehicles passing-by;

γ_U is the temperature coefficient reduced to represent the "diluted" effect of temperature on tyre/road noise when power unit noise is present.

The W_U is determined as an example in Table 2, based on Reference [15], among other vehicle/traffic noise models. Knowing or estimating the vehicle composition in a particular case, the user is recommended to apply the most relevant model to determine the proportionality constant W_U.

Table 2 — Example of proportion of tyre/road noise in the overall vehicle sound levels, W_U

Vehicle/tyre category	Speed range (45 to 64) km/h	Speed range (65 to 99) km/h	Speed range >99 km/h
P (C1)	0,9	1,0	1,0
M (C2 tyres)	0,8	1,0	1,0
H (C3 tyres)	0,6	1,0	1,0

NOTE This assumes that the power unit noise is unaffected by temperature, which is generally not true. However, such temperature effects are extremely complicated and not subject of this document.

10 Measurement uncertainty assessment according to ISO/IEC Guide 98-3

10.1 General

The result of the application of the temperature correction procedure when testing with pass-by methods described in this document is subject to several uncertainties. The cause and nature of these uncertainties are either known, but randomly distributed in an uncontrollable way, or are of a systematic nature, but affect the result in an unpredictable way.

In accordance with ISO/IEC Guide 98-3, the effects shall be evaluated based on their contribution to the combined standard uncertainty and then a coverage probability is defined, resulting in a coverage factor k by which the combined standard uncertainty is multiplied, yielding the expanded uncertainty.

10.2 Potential uncertainties

The potential uncertainties include:

- the road surface does not fit adequately into the selected road surface category or the actual properties of the road surface are not entirely representative;
- the tyre/road and power unit noise contributions of the measured vehicles deviate from the ones of the vehicle/tyre classes described in this standard;
- the selected temperature coefficient for the tyre class (C1, C2 or C3) is not representative of the actual tyre or tyres of the vehicle fleet;
- uncertainty in temperature measurement equipment and in the measurement itself.

10.3 Uncertainty estimation of temperature correction

The general expression for the true temperature correction $C_{T,t}$, for a certain tyre or group of tyres (t), road surface type (rs), and speed range (v), is given by Formula (12):

$$C_{T,\mathrm{t}} = -\gamma_\mathrm{t} \left(T - T_\mathrm{ref} \right) + \delta \qquad (12)$$

where

$C_{T,t}$	is the temperature correction, in dB; see Formula (1);
γ_t	is the temperature coefficient for tyre t, for road surface type rs and speed range v, including any uncertainty due to incorrect temperature coefficient or its relation to the parameters;
T	is the measured air temperature, including any measurement uncertainty;
T_ref	is the reference temperature (20 °C);
δ	is an input quantity to allow for any uncertainty due to equipment, procedure and deviating road surface properties. The uncertainty sources are listed below.

10.4 Sources of uncertainty

10.4.1 Temperature coefficients (γ_t), δ_1

The temperature correction procedure assumes that the underlying data which were used to derive the presented correction factors were correctly obtained using a sufficient amount of empirical data for each road surface category and each tyre class. Temperature effects are difficult to measure and isolate; additional precautions regarding measurement set-up and procedure are therefore required to minimize the occurrence of parasitic phenomena and reduce the standard uncertainties when investigating temperature effects. Although quality criteria were applied when selecting the underlying data[10][14], the selected coefficients and their variation with speed are still subject to uncertainty.

10.4.2 Temperature measurements (T), δ_2

The temperature correction procedure assumes that the temperature measurement equipment is accurate and that the temperature sensor for ambient air temperature is installed in a way that it is exposed to the relevant airflow and protected from direct solar radiation. Errors can occur whenever the sensor may be heated up due to solar radiation or due to its exposure to the heat from any external source.

10.4.3 Road surface category (rs), δ_3

In some cases, for example in the case of semi-dense or partially clogged porous road surfaces, the user's selection of the appropriate road surface category may not be ideal, since the real temperature effects may be somewhere between those of dense and porous road surfaces. Also, within a specific road surface category, there are variations between the surface types that are neglected in this procedure (for example road surfaces with rough surface texture versus smooth surface texture). Furthermore, the procedure in this document is not absolutely clear on how to select the right category, but relies on a certain amount of subjective assessment and decision-making by the user.

10.4.4 Vehicle effect, δ_4

With statistical pass-by measurements, it may be that the sample of measured vehicles is influenced by local, regional and national predominance of certain vehicle types. Examples of significant effects include the proportion of electric-driven cars, busses or trucks in the traffic, and the presence and composition of short-haul, medium-haul and long-haul trucks, all of which vary across urban, fringe urban and rural areas. Furthermore, in some cases, there may be a significant number of special high-capacity heavy vehicles, and/or trucks with double-trailers. The contributions of tyre/road and power unit noise of such vehicles can deviate from the ones of the vehicle/tyre classes described in Table 2.

10.4.5 Solar radiation and warming of tyres, δ_5

It is recognised that the most relevant temperature accounting for temperature effects is the tyre temperature. Even when road or air temperatures are constant, tyre temperature may vary according to the warm-up or cooling of tyres due to changing driving patters. Since tyre temperature is very difficult to measure during pass-by, the temperature selected for correction is air temperature. Tyre temperature is influenced not only by energy losses inside the tyre, but also by the cooling of the air surrounding the tyre as well as by the cooling or warming by the road surface in the tyre/road contact. The latter is influenced by energy input from solar radiation. It may be that in some cases solar radiation is so high, or the surface has a very low albedo (such as a new asphalt surface), that it leads to disproportionally high road surface temperatures. This in turn leads to additional warming of tyres. In such cases, the real temperature effects can surpass the temperature correction provided in this study.

10.4.6 Tyre effect, δ_6

The selected temperature coefficient for the tyre class (C1, C2 or C3) is generic and not necessarily representative of the actual tyre, group of tyres, or tyres of the vehicle fleet in statistical pass-by measurements. It may be that some tyres are of unusual construction, such as off-road or studded tyres.

10.5 Estimation of uncertainties

In the procedure in this document, the sources of uncertainty and the resulting contribution of each source is listed in Table 3 per vehicle/tyre class. For information about the interpretation of the probability distributions, refer to ISO/IEC Guide 98-3.

NOTE 1 Estimated uncertainty contributions are products of standard uncertainties and corresponding sensitivity coefficients rounded to the nearest multiple of 0,05.

The total spread in measurement results expected in this procedure leads to the expanded uncertainties listed in Table 4.

NOTE 2 It is estimated that the semi-generic temperature correction in this document will be effective in reducing temperature-related uncertainties in pass-by measurements to less than half of those of non-corrected measurements.

Table 3 — Typical values of standard uncertainties after applying the temperature correction procedure

Sources of uncertainty	Estimate of the measurand	Probability distribution	Sensitivity coefficient	Uncertainty contribution	
				P (C1 tyres) dB	H (C2 and C3 tyres) dB
Temperature coefficients γ_t (δ_1)	$\gamma_{t\ estimated}$	normal	1	0,15	0,25
Temperature measurement (δ_2)	$T_{estimated}$	normal	1	0,1	0,1
Road surface category (δ_3)	0	normal	1	0,15	0,1
Vehicle effect (δ_4)	0	normal	1	0,05	0,15
Solar radiation and tyre warming (δ_5)	0	asymmetric	1	0,1	0,05
Tyre effect (δ_6)	0	asymmetric	1	0,15	0,15
Combined standard uncertainty				0,30	0,36

Table 4 — Typical values for the expanded uncertainty

Coverage probability %	Coverage factor (k)	Expanded uncertainty	
		P (C1 tyres) dB	H (C2 and C3 tyres) dB
80	1,28	0,4	0,5
95	1,96	0,6	0,7

11 Test report

The temperature corrections will normally be reported in the document presenting the measured noise levels, and there one shall observe what this requires (see e.g. ISO 11819-1 or ISO 13325). In addition, one shall not forget to report the following issues.

— Weather conditions (for example, sunshine, cloudiness or sunshine with shadows).

— Road surface main type; refer to the categories described in Annex A (include a special note in case of doubt about which category the measured test section belongs to).

— Average or range of air temperature during the measurement.

— Average or range of road surface temperature during the measurement, if measured (optional).

— Average or range of tyre temperature during the measurement, if measured (optional).

— Where tyre temperature was measured (mandatory if tyre temperature was measured).

— Location on or in the road surface where temperature was measured (optional).

Annex A
(informative)

Information about road surface types

A.1 General

In Clause 8, the temperature coefficient is specified as formulae for three categories of road surfaces. These three categories are as follows.

— Dense asphaltic surfaces (such as DAC, SMA, TAL with air voids typically below 18 %, and surface dressings, the latter also known as chip seals).

— Cement concrete surfaces of all types.

— Porous asphalt surfaces and high-porosity TAL (not seriously clogged).

More information about these categories is presented in A.2. It can also be useful to consult a road surface terminology dictionary, such as Reference [16].

A.2 Description of road surface categories

A.2.1 Dense asphalt surfaces

This category includes the following types.

— (Dense) asphalt concrete (DAC) as defined in EN 13108-1[17].

— Porous asphalt concrete (PAC) as defined in EN 13108-7[18], but in clogged condition; i.e. approximately 50 % or more of the pores are clogged by dirt and bitumen.

— Porous asphalt concrete (PAC) as defined in EN 13108-7, but with design air void content below 18 %, corresponding to void categories H to Z in EN 13108-7. These are often referred to as open-graded friction courses (OGFC) or open-graded asphalt concrete (OGAC).

— Stone mastic asphalt (SMA) as defined in EN 13108-5[19].

— Thin asphalt layers (TAL), which are asphaltic surface courses with a thickness of less than 30 mm, in which the aggregate particles are essentially gap-graded to form a stone-to-stone contact and to provide an open surface texture, in this case with air void content less than 18 %.

— DAC, SMA or TAL types to which a significant amount of rubber particles have been added (rubber up to 3 % by weight of the total mix); these are often referred to as “asphalt rubber” or “rubber asphalt”.

— All kinds of reclaimed asphalt with air void content below 18 % (see EN 13108-8[20]).

— Surface dressings (also known as chip seals) as defined in EN 12271[21].

— High friction surface courses (HFSC or HFS); surface treatments which utilize alternative materials such small-sized polish- and wear-resistant aggregates (often bauxite), bonded to the pavement surface using proprietary resin binders.

— Surface specified in ISO 10844[1].

A.2.2 Cement concrete surfaces

This category includes all kinds of road surfaces where the binder is cement, as defined in EN 13877-1[22]; both with low and high porosity.

A.2.3 Porous asphalt surfaces

This category includes the following types.

— Porous asphalt concrete (PAC) as defined in EN 13108-7, but with design air void content of 18 % or higher, corresponding to void categories A to G in EN 13108-7, and not deteriorated into clogged condition.

— The same as above, but in partly clogged condition; in this case less than approximately 50 % of the pores are clogged by dirt and bitumen.

— Thin asphalt layers (TAL), as mentioned above, but with design air void content 18 % or more; TAL with small maximum aggregate sizes (4 mm to 6 mm) should be classified in the dense asphalt category for tyre H1 also for air void contents above 18 % (see EN 13108-2[23]).

— PAC or TAL types to which a significant amount of rubber particles has been added (rubber up to 3 % by weight of the total mix); but having design air void content 18 % or more – these are often referred to as “open graded” types of “asphalt rubber” or “rubber asphalt” (although it is not often that design air void content is 18 % or higher).

NOTE 1 “Void content” in this document refers to geometric determination according to EN 12697-6[24].

NOTE 2 In case it is impossible to judge whether the surface has an air void content above or below 18 % (for example, after consulting the road contractor or the road authority), consider the surface as belonging to the dense asphalt surface category.

NOTE 3 In case it is impossible to judge whether the pores in the surface are clogged to more or less than 50 %, consider the surface as belonging to the porous asphalt surface category.

