TECHNICAL SPECIFICATION

ISO/TS 11819-3

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

Part 3: Reference tyres

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

Partie 3: Pneumatiques de référence

Reference number
ISO/TS 11819-3:2017(E)

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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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For an explanation on 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 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 the influence of surface characteristics on tyre/road noise by a standardized method. Within the constraints of this method, ISO 11819-2 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.

ISO 11819-2, which describes the so-called close-proximity (CPX) method, relies on special tyres to be used during the testing. However, it does not specify such tyres; instead, it is the purpose of this document to specify two reference tyres for use in the CPX method.

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

Part 3: Reference tyres

1 Scope

This document specifies two tyres intended to serve as reference tyres when using the close-proximity (CPX) method specified in ISO 11819-2.

The CPX method is a method for evaluating different road surfaces with respect to their influence on traffic noise, under conditions when tyre/road noise dominates. This method ideally requires the use of standardized tyres, which have noise characteristics that are broadly representative of the effect of road surfaces on the noise emission of passenger car and heavy vehicle tyres. However, such tyres are not specified in ISO 11819-2. This document serves to specify these standardized tyres.

2 Normative references

The following documents are referred to in the text in such 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 868:2003, *Plastics and ebonite — Determination of indentation hardness by means of a durometer (Shore hardness)*

ISO 3911:2004, *Wheels and rims for pneumatic tyres — Vocabulary, designation and marking*

ISO 4000-1, *Passenger car tyres and rims — Part 1: Tyres (metric series)*

ISO 11819-2:2017, *Acoustics — Method for measuring the influence of road surfaces on traffic noise — Part 2: The close-proximity method*

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

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

ASTM F2493:2014, *Standard Specification for P225/60R16 97S Radial Standard Reference Test Tire*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11819-2, ISO/TS 13471-1 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
reference tyre
test tyre specified for the purpose of representing certain features in tyre/road sound emission, designed and constructed for use in the close-proximity (CPX) method with specified and reproducible standard characteristics

3.2
CPX level
close-proximity level
L_{CPX}
time-averaged A-weighted sound pressure level (SPL) of the tyre/road noise as determined by the close-proximity (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 ISO 11819-2 where the close-proximity method is described.

3.3
rubber hardness
H_A
quantity expressed in Shore A units of the indentation resistance of tyre rubber based on the depth of penetration of a conical indentor, using a Type A durometer defined in ISO 868:2003

3.4
rubber hardness coefficient
β_t
coefficient used for correcting the CPX level for *rubber hardness* (3.3) of the tread of tyre t

Note 1 to entry: The tyre rubber hardness coefficient is expressed in decibels per durometer Type A reading ("Shore A").

4 General principles

Different tyres rank road surface influence on noise differently. The two reference tyres in this document are denoted P1 and H1. Tyre P1 classifies the acoustic properties of road surfaces in a similar manner to the majority of passenger car tyres. Tyre H1 classifies acoustic properties in a similar manner to the majority of heavy vehicle tyres. Consequently, combining measurement results for these two tyres provides a good representation of how the noise emission of a mix of light and heavy vehicle traffic is influenced by road surfaces.

Where possible, reference tyres are selected to offer long-term consistency in manufacture and availability. This document also supplies requirements and advice with regard to the performance of the tyres over time, in order to provide time-independent CPX measurement results.

NOTE The reference tyres specified here can also meet a more general need for reference tyres. Tyre P1 in this document is already used as a reference for wet and snow grip testing according to UN ECE Regulation R117.[1] Examples of other possible alternative uses are as follows:

— as a stable reference against which the noise emission of other tyres can be compared;

— as a stable reference to check long-term performance of ISO 10844 test surfaces;

— as suitable tyres for vehicle noise testing, when it is desirable to have well-defined tyre equipment;

— as reference tyres for performing certain rolling resistance or fuel consumption tests of road surfaces.[3]

5 Reference tyres

5.1 Tyre descriptions

The following two tyres are defined as reference tyres in this document.

— **Tyre P1:** A steel-belted radial tyre for relatively large passenger cars or vans, specified in ASTM F2493:2014, having the dimensional code P225/60R16 and referred to as a standard reference test tyre (SRTT). Both the text "Standard Reference Test Tyre" and the dimensional code P225/60R16 shall be displayed on the sidewall [see Figure 1 a)].

— **Tyre H1:** A steel-belted reinforced radial tyre for light trucks and vans, manufactured by Cooper Tire & Rubber Co. in the United Kingdom under the product name "Supervan AV4",[1] having the dimensional code 195R14C. Both the text "Avon Supervan AV4" and the dimensional code 195R14C shall be displayed on the sidewall [see Figure 1 b)]. The Supervan AV4 has a reinforced carcass construction to enable the carriage of heavy loads, and has a very robust rubber compound on the sidewall.

a) Tyre P1 b) Tyre H1

NOTE Both subfigures show the sidewall where the complete DOT mark appears, including the production date WWYY. Annex D gives details about how to get access to the tyres.

Figure 1 — Sidewall markings

For both tyres, the week and year of production is marked by four digits (WWYY) on at least one of the sidewalls (where WW is week number and YY is the year). See the specifications in Clause 6.

NOTE At the time of publication, there is no known standard reference test tyre that classifies acoustic properties of road surfaces in a similar manner to the majority of heavy vehicle tyres. It is, therefore, necessary to use a market tyre for H1, even though this is unlikely to have the same high quality properties as P1 and it may have a limited availability.

Information on the storage and preservation of tyres is given in Annex B.

The availability of the reference tyres is given in Annex C.

5.2 Tyre specifications

The basic dimension designation shall be P225/60R16 for tyre P1, and 195R14C for tyre H1, in accordance with ISO 4000-1. Table 1 presents the various specifications of the tyres.

1) Supervan AV4 is the trade name of a product supplied by Cooper Tire & Rubber Co., United Kingdom. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named.

Table 1 — Specifications of the reference tyres

Tyre	Basic dimension code	Nominal cross-section width	Nominal undeflected diameter	Cross-sectional tread radius	Load index (LI)	Speed index
P1	P225/60R16	231 mm	680 mm	308 mm	97	S
H1	195R14C	198 mm	666 mm	302 mm	106/104	N

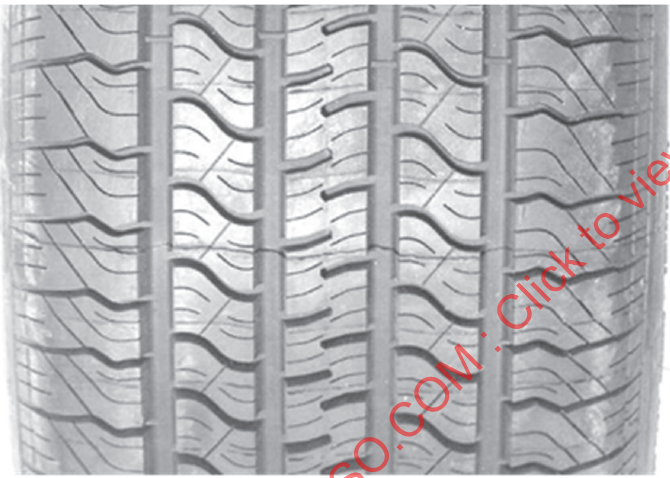
5.3 Tread pattern

The tread patterns are as follows.

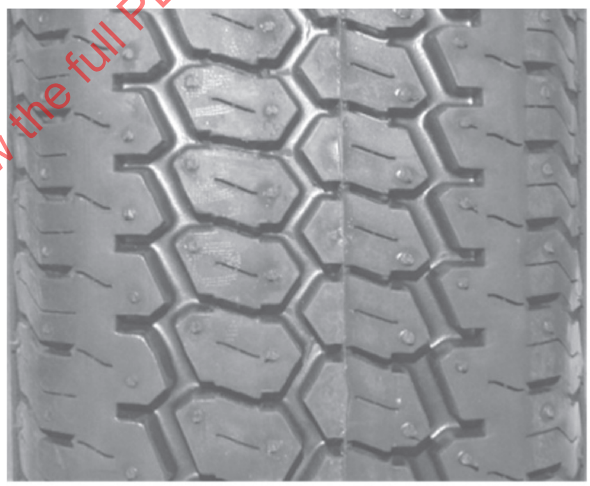
— **Tyre P1:** This tread has a geometrical pattern as illustrated in Figure 2 a) and defined in ASTM F2493:2014; see 5.1.

— **Tyre H1:** This tread has a geometrical pattern as illustrated in Figure 2 b) and defined in specifications for "Supervan AV4" by Cooper Tire & Rubber Co.; see 5.1.

For tyre H1 it has appeared that at least a few samples of this tyre have been manufactured with a misaligned tread pattern, as illustrated in Figure 3. The grooves running in the lateral direction shall not be totally blocked by the misalignment (although a thin "skin" at the joint between the two halves of the tread is normal). Therefore, the type of misaligned pattern in Figure 3 b) is not acceptable, whereas the one illustrated in Figure 3 a) is acceptable.

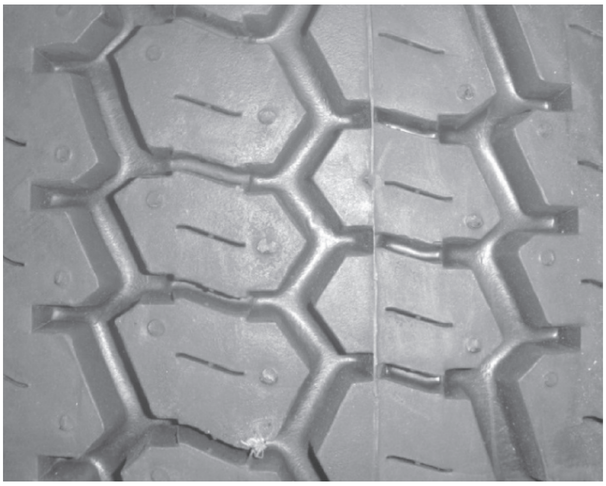


a) Tyre P1



b) Tyre H1

Figure 2 — Tread patterns



a) Zoom-in on normal tread

b) Zoom-in on a misaligned tread

Figure 3 — Tread of tyre H1

5.4 Tread pattern condition

Initial tread pattern depth as measured in the circumferential grooves shall be

— (8,0 ± 0,5) mm for tyre P1, and

— (10,0 ± 0,5) mm for tyre H1.

The tyre treads shall be as originally moulded without any tread grinding; except for that caused by normal run-in (see Clause 7), and without any repairs that change the surface of the tyre.

Tread pattern wear shall be a maximum of 1,0 mm in comparison to the initial tread depth. The tread depth change can be measured with the procedure specified in Reference [4].

The test tyres shall be examined regularly for damage to the tread and for the presence of foreign objects in the tread. Chippings or other dirt in the tread shall be removed before testing takes place and where appropriate during testing. If there is clearly noticeable wear or deformation on any part of the tyre its use shall be discontinued.

5.5 Rubber hardness

The rubber hardness shall be measured after the tyre has been run-in and at least every three months during the period when they are used for measurements. Measurements shall be performed at 20 °C ± 5 °C with a Type A durometer, using the procedure described in Annex A. The whole tyre shall have settled at an equilibrium temperature before the measurements start. The rubber hardness values H_A (expressed in "Shore A") shall be within the range

— 62 to 73 for tyre P1, and

— 60 to 73 for tyre H1.

NOTE 1 The measured value for rubber hardness is a reading which is unitless. Nevertheless, a commonly used designation is "Shore A".

NOTE 2 The rubber hardness of tyre P1 in new condition is specified in ASTM F2493 as (64 ± 2) Shore A at a temperature of 23 °C.

6 Test wheel and tyre mounting

The tyres shall be mounted as follows, with terminology and designation in accordance with ISO 3911:2004.

— Tyre P1 on a 165,1 mm ± 12,7 mm (6,5 inch ± 0,5 inch) wide rim. A 6,5 J x 16 wheel with an inset, outset or zero suitable to the available clearance at the axle of the CPX system is recommended.

— Tyre H1 on a 139,7 mm ± 12,7 mm (5,5 inch ± 0,5 inch) wide rim. A 5,5J x 14 wheel with an inset, outset or zero suitable to the available clearance at the axle of the CPX system is recommended.

The material shall be pressed steel or cast aluminium.

With regard to rotational direction, the test tyres shall be mounted as specified in ISO 11819-2.

Before being used for testing, the tyres shall be balanced on the appropriate wheel.

NOTE According to Reference [5], the effect of using 6 inch rim width instead of the nominal 6½ inch is approximately 0,3 dB lower CPX levels, and the effect of using 7 inch rim width instead of 6½ is approximately 0,3 dB higher CPX levels for tyre P1. This effect needs more research until a correction can be determined or the rim width be more restrictive.

7 Tyre run-in

The test tyre(s) shall be run-in on roads or a test track for a minimum of 400 km before first use. The run-in shall be made with the same tyre rotation as the tyre will be rotating when it is used for testing. If run-in is made with tyres mounted on a four-wheeled powered vehicle, the distance is reduced to a minimum of 200 km (because of the more severe operational conditions for a tyre used on a four-wheeled powered vehicle).

8 Tyre load and inflation

Tyre load and inflation are specified in ISO 11819-2.

9 Correction for the influence of rubber hardness on CPX levels

9.1 General

Available information suggests that the tyre rubber hardness influences noise emission and that a correction to a nominal reference value is feasible. Although the rubber hardness effects have been studied for tyres P1 and H1 separately, the results indicate that there are no substantial differences between them; thus the same values are applied for both tyres.[6-9] The correction is made to the overall A-weighted sound pressure level, and with the same correction applied to all frequency bands.

9.2 Correction to CPX levels

Rubber hardness correction shall be applied as follows.

Each measured A-weighted CPX level (L_{CPX}) according to ISO 11819-2 shall be corrected by the term $C_{HA,\mathrm{t}}$ (in dB), using Formula (1):

$$C_{HA,\mathrm{t}} = \beta_{\mathrm{t}}(H_{\mathrm{A}} - H_{\mathrm{ref}}) \quad (1)$$

where

β_t is the rubber hardness coefficient for tyre t, in dB/Shore A;

H_A is the measured rubber hardness, in Shore A;

H_{ref} is the reference rubber hardness = 66 Shore A;

$C_{HA,t}$ is the CPX level correction for rubber hardness (H_A) for tyre t, in dB.

NOTE 1 How this correction term is applied is described in ISO 11819-2:2017, Clause 11.

NOTE 2 Note that the rubber hardness correction $C_{HA,t}$ is negative and is subtracted from the measured level in ISO 11819-2.

9.3 Rubber hardness coefficient

To compensate for the effect of rubber hardness, the correction coefficient β_t, as specified in ISO 11819-2, based around a reference Shore hardness H_A of 66 Shore A, shall be as follows:

— Tyre P1: β_{P1} = 0,20 dB/Shore A

— Tyre H1: β_{H1} = 0,20 dB/Shore A

NOTE The correction to noise levels calculated in this way would be 0,20 (H_A − 66) dB, where H_A is the numerical value of the measured rubber hardness in Shore A, according to 5.5, and where this correction is subtracted from the measured noise level. This correction is independent of temperature, since the determination of H_A is corrected for temperature, according to A.4.

10 Correction for the influence of temperature on CPX levels

Available information suggests that the noise-temperature relation depends on the particular tyre and road surface and that a correction to a nominal reference value is feasible. Although the temperature effects have been studied for tyres P1 and H1 separately, the results indicate that there are no substantial differences between them; thus the same values are applied for both tyres.[10-13] The correction is made to the overall A-weighted sound pressure level, and with the same correction applied to all frequency bands.

Temperature coefficients for tyres P1 and H1 as well as the correction procedure are specified in ISO/TS 13471-1.

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

The potential uncertainties related to this document are as follows.

a) Variation in noise level between different tyre samples of nominally the same type.

b) Variation due to change in tyre properties due to wear and rubber ageing.

c) Uncertainty in the correction for tyre hardness.

d) Uncertainty in the correction for air temperature.

The general expression for the calculation of the uncertainties is given by Formula (2):

$$\delta_t = \delta_1 + \delta_2 + \delta_3 + \delta_4 \tag{2}$$

where

δ_t is the overall uncertainty related to the reference tyres and their corrections, which is defined in ISO 11819-2 as δ_6;

δ_1 is an input quantity to allow for any uncertainty due to variation in noise level between different tyre samples of nominally the same type;

δ_2 is an input quantity to allow for any uncertainty due to variation caused by change in tyre properties due to wear and rubber ageing (not picked-up by the hardness correction);

δ_3 is an input quantity to allow for any uncertainty in the correction for tyre hardness consisting of the uncertainty in the hardness H_A, and the uncertainty related to the β_t coefficient;

δ_4 is an input quantity to allow for any uncertainty in the correction for air temperature, consisting of uncertainty in the determination (measurement) of air temperature, uncertainty due to road surface properties and the uncertainty related to the temperature coefficient. In ISO/TS 13471-1 these contributions are included in the symbols T, δ and γ_t.

The values of these input quantities shall be evaluated by the test operators by the procedure given in ISO/IEC Guide 98-3. It can be based on existing statistical data, analysis of tolerances stated in this document and engineering judgement. The information needed from which to derive the overall uncertainty is given in Table 2. The table includes sensitivity coefficients, c_i, the values of which are based on the procedures and formulae used to obtain the final result, as specified in ISO/IEC Guide 98-3.

These uncertainty contributions, δ_1..... δ_4, are related only to reference tyre uncertainty contributions. The combined standard uncertainty of these corresponds to δ_6 in ISO 11819-2, while ISO 11819-2 also includes other uncertainty contributions to the determination of the CPX levels.

The combined standard uncertainty of the measured CPX level, in the part which is due to the reference tyres, is calculated with Formula (3):

$$u(y) = \sqrt{\sum_{i=1}^{4} \left(c_i u_i\right)^2} \tag{3}$$

where

c_i is the sensitivity coefficient for input x_i; $c_i = \dfrac{\partial f}{\partial x_i}$ with : $y = f\left(x_1, x_2, x_3, x_4\right)$;

u_i is the standard uncertainty in input x_i.

The expanded uncertainty U is determined by multiplying the combined standard uncertainty, $u(y)$, by the appropriate coverage factor, k, for the chosen coverage probability as described in ISO/IEC Guide 98-3.

Table 2 — Uncertainty budget for the determination of the CPX level, due to the reference tyre

Quantity	Estimate	Probability distribution	Standard uncertainty, u_i	Sensitivity coefficient, c_i	Uncertainty contribution
δ_1	0	normal		1	
δ_2	0	normal		1	
δ_3	0	normal		1	
δ_4	0	normal		1	
Combined standard uncertainty, $u(y)$					

Table 3 provides an estimate of the uncertainties.

Table 3 — Typical values of standard uncertainties due to variations due to the reference tyre

Sources of uncertainty	Estimate	Probability distribution	Sensitivity coefficient	Uncertainty contribution for P1 and H1
Variation in noise level between different tyre samples of nominally the same type	0	normal	1	0,15 dB / 0,3 dB
Variation due to change in tyre properties due to wear and rubber ageing	0	normal	1	0,1 dB / 0,2 dB
Uncertainty in the correction for tyre hardness	0	normal	1	0,15 dB / 0,2 dB
Uncertainty in the correction for air temperature	0	normal	1	0,25 dB / 0,3 dB
Combined standard uncertainty				0,3 dB / 0,5 dB

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

Table 4 — Typical values for the expanded uncertainty due to the reference tyres

Coverage probability	Expanded uncertainty, tyre P1	Expanded uncertainty, tyre H1
80 %	0,4 dB	0,6 dB
95 %	0,6 dB	1,0 dB

12 Documentation

Each reference tyre shall be documented in a report, which shall include the following information (mandatory if not indicated as optional).

Tyre type and acquisition:
1. P1 or H1:
2. Commercial tyre designation:
3. Week and year of manufacturing:
4. Purchased from:
5. Tyre owned/used by (organization):
Tyre preparations:
6. Tyre run-in, date and distance:
7. Tyre run-in, rotation:

Rubber hardness:

Date of measurement	Measured and temperature corrected hardness ($H_{A,measured}$ and H_A)	Rubber temperature at the measurement occasion	Notes

Accumulated tyre use (optional, estimation):

Time period considered	Estimated distance of operation (km)	Estimated number of days of operation	Main type of storage (incl. approx. storage temperature)

Annex A
(normative)

Measurement of rubber hardness

A.1 General

It is important to consider the Shore hardness of the tread of the reference tyres as it is known that values change with time and can affect the CPX measurement results.[6-9] A standard test method is described below which will meet the requirements of this document.

Tyre hardness shall be measured at intervals of three months or shorter, if the tyres are in use. It is not necessary to measure hardness in connection with each noise measurement.

A.2 Equipment

For all measurements, a Type A durometer shall be used, meeting the requirements of ISO 868:2003. The indenter consists of a truncated cone with a diameter of 0,79 mm and angle of 35°. Penetration depth is a measure for the Shore hardness. A low penetration depth represents a high Shore A value (up to 100), a high penetration depth (up to 2,5 mm maximum) represents a low Shore A value.

A.3 Measurement procedure

The reference tyre shall be conditioned to a test temperature of 20 °C ± 5 °C. Measurements shall not start until the whole tyre is at equilibrium temperature. The durometer shall also be conditioned to a temperature of 20 °C ± 5 °C. The durometer shall be checked prior to use with appropriate rubber reference block(s) that are commercially available for this purpose. However, note that these have limited time stability. These blocks should be stored at a relatively cold temperature in order to avoid changes in hardness. Every two years, or according to the manufacturer's recommendations, the durometer shall be calibrated according to the procedure described in ISO 868.

As the durometer needle deflects to an initial maximum when put on the tread the scale shall be read within 2 s after the presser foot has made contact with the tread. The presser foot shall be applied to the centre of the tyre tread rib, as rapidly as possible without shock, keeping the foot parallel to the tread surface. Enough pressure shall be applied to obtain firm contact between the presser foot and the tread surface.

Measurements shall be made at a number of points on the tread as detailed below. At each mandatory position, independent measurements shall be taken until four consecutive readings differ by no more than two units.

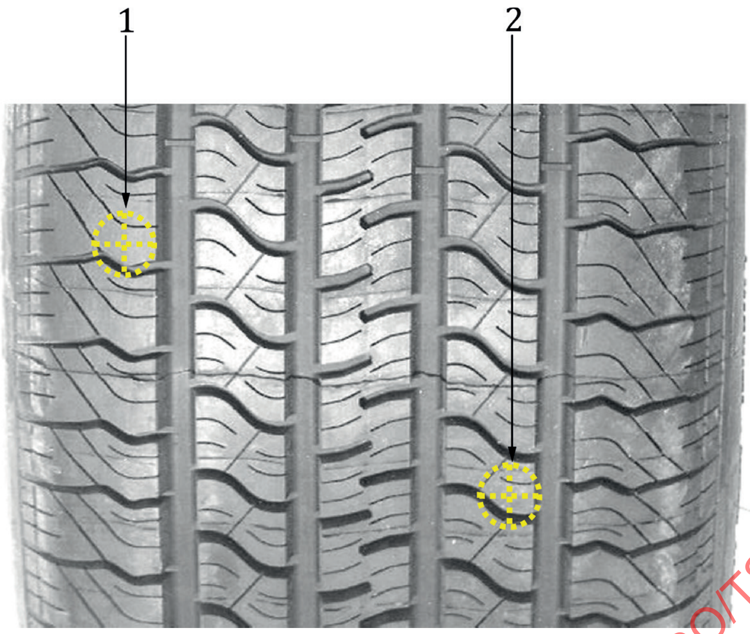
Mandatory positions:

— outer rib of tyre tread: four equi-spaced points around the tread;

— inner centre rib of tyre tread: four equi-spaced points around the tread.

Here, “outer rib” refers to the side of the tyre where the complete DOT number is applied (see Figure 1).

Figures A.1 and A.2 illustrate the positions on sections of the P1 and H1 reference tyres respectively. Note that one shall aim at finding the areas where the durometer needle can be applied as far as possible from any sipe or edge of the block.

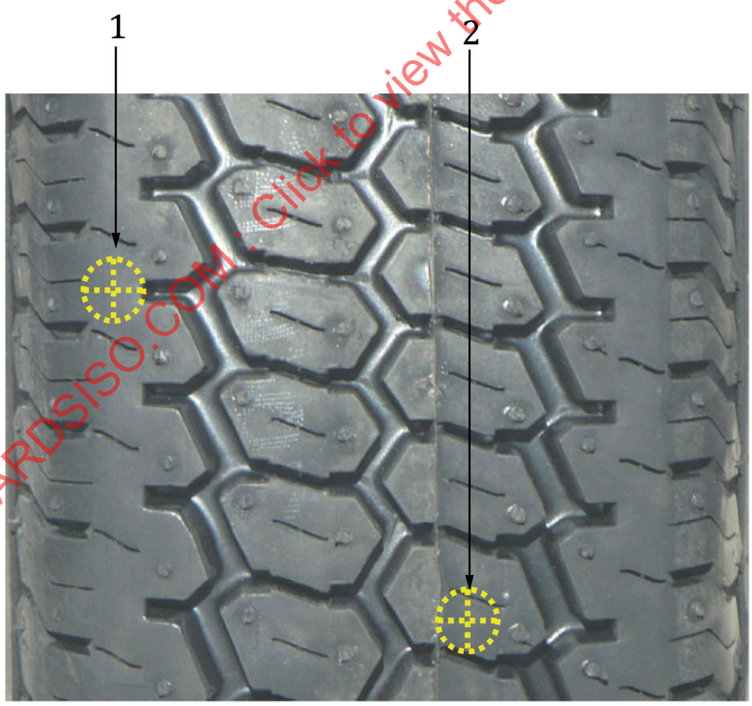


Key

1 outer rib

2 inner centre rib

Figure A.1 — Measuring positions on section of the tyre P1 tread



Key

1 outer rib

2 inner centre rib

Figure A.2 — Measuring positions on a section of the tyre H1 tread

Note that the pressure foot of the durometer has a diameter of 18 mm and there are no tread blocks (continuous areas of rubber) big enough to take the whole foot. The pressure foot should be positioned such that the largest available area of continuous rubber is covered.

A.4 Temperature correction applied to rubber hardness measurement

Tyre temperature, *T*, shall be measured immediately before rubber hardness is measured and be within the range 15 °C to 25 °C. If tyre temperature deviates from the reference temperature 20 °C, correction of the measured rubber hardness $H_{A,measured}$ value shall be made according to Formula (A.1):

$$H_A = H_{A,measured} + 0{,}25(T_{measured} - 20) \quad \text{(A.1)}$$

where

H_A is the numerical value of the rubber hardness, expressed in Shore A;

$H_{A,measured}$ is the numerical value of the measured rubber hardness, expressed in Shore A;

$T_{measured}$ is the numerical value of the measured tyre temperature, expressed in °C.

Tyre temperature shall be measured on the same spots as the spots for rubber hardness measurement, and the average of all values shall be taken as tyre temperature *T*. The whole tyre shall then be at equilibrium temperature. The temperature measuring instrument shall have a maximum permissible error of ± 1 °C, as specified by the manufacturer. Meters utilizing the infrared technique may be particularly useful for tyre temperature measurements.

NOTE This correction is based essentially on the work presented in Reference [14].

A.5 Calculation and reporting of results

At each mandatory position, independent measurements shall be taken until four consecutive readings differ by no more than two units. These four consecutive measurements shall be averaged as Shore A values for one mandatory position (rounded to the nearest integer). There are eight mandatory measurement points (four on each rib) and an average as well as maximum and minimum values shall be calculated and reported as the overall Shore hardness value (H_A).

Annex B
(informative)

Storage and preservation of tyres

When the tyres are not in use it is recommended to store them indoors under dry atmospheric conditions at an average temperature of 0 °C to 5 °C. Electrical motors or other ozone generating equipment should not be present in the same room.

The following text, part of it originally produced by Avon Tyres, supplemented with advice from other sources, gives further advice concerning the storage and preservation of the reference tyres.

General: In view of the influence of temperature, humidity and light, indoor storage is essential.

Humidity: The storeroom should be cool, dry and moderately ventilated. Moist conditions should be avoided. Care shall be taken to ensure that no condensation occurs.

Light: There should be protection from sunlight and strong artificial light with high ultraviolet content. The room should normally be dark.

Temperature: The storage temperature should ideally be 0 °C to 5 °C. At temperatures exceeding 10 °C, certain forms of deterioration may be accelerated sufficiently to affect the ultimate service life. Direct contact with pipes and radiators shall be avoided. The effects of sub-zero temperatures are not permanently deleterious, but can cause the products to stiffen. Care should be taken therefore to avoid distorting them during handling at low temperatures. When tyres are taken from low temperature storage for immediate use, their temperature should be raised to approximately 20 °C throughout, before they are put into service.

Oxygen, ozone and chemical agents: As ozone is particularly harmful, storage rooms should not contain any equipment generating ozone such as fluorescent lighting, mercury vapour lamps, electric motors or other equipment that may produce sparks or other electrical discharges. Combustion gases and vapour that may produce ozone via photochemical processes should also be excluded. Solvents, fuels, lubricants, chemicals, acids, disinfectants and the like should not be kept in the storerooms. Rubber solutions should be stored in a separate room and the administrative regulations on the storage and handling of inflammable liquids shall be observed. The use of a polyethylene bag around the tyre may help isolate the tyre from degeneration, provided the contained air is dry and condensation does not occur.

Fire risk: While not easily ignitable, once on fire, tyres can emit large quantities of heat, flame and toxic smoke including CO, CO_2 nitrogen oxides and sulfur oxides.

Short-term storage (months): Tyres mounted on a wheel can be stacked horizontally, or vertically as shown in Figure B.1. Inflation should then be approximately 100 kPa. If tyres are stacked horizontally in direct contact with each other, the stacks should not be higher than two tyres on top of each other, even if tyres are not mounted on wheels.

Long term storage (years): For long-term storage, tyres should preferably not be mounted on a wheel but be stored in a relaxed condition free from tension, compression or other deformation since these may cause cracking or permanent distortion. Tyres should be stored upright on tyre shelves having two or four horizontal tubes that may be purchased on the market (see Figure B.2). To avoid deformation it is recommended to rotate them slightly once a month. Another option is to stack maximum two tyres horizontally on a shelf.

