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UN Regulation No. 51 (Noise of M and N categories of vehicles)

Proposal for supplement 8 to 03 series of amendments to UN Regulation No. 51

Submitted by the Informal Working Group on Measurement Uncertainties*

The text below has been prepared by the experts of the Informal Working Group on Measurement Uncertainties (IWG MU) in order to introduce measures to reduce variability. The modifications to the existing text of the UN Regulation are marked in bold for new or strikethrough for deleted characters. Some modifications include moving existing provisions to other places.

* In accordance with the programme of work of the Inland Transport Committee for 2022 as outlined in proposed programme budget for 2022 (A/76/6 (Sect.20), para 20.76), the World Forum will develop, harmonize and update UN Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

I. Proposal

Paragraph 2.24., amend to read:

"2.24. Table of symbols

Symbol	*Unit*	*Annex*	*Paragraph*	*Explanation*
…	…	…	…	…
L_{urban}	dB(A)	Annex 3	3.1.3.1.	reported vehicle sound pressure level representing urban operation; value to be reported mathematically rounded to the nearest integer
$L_{TR,\vartheta ref,(vTR,ref)}$	**dB(A)**	**Annex 3 - Appendix 2** **Annex 3 – Appendix 3**	**3.1.** **4.3**	**Reported reference test result of the tyre rolling sound measurements at left/ride side according to method described in Annex 3 Appendix 3**
slp_{ref}	**dB(A)/ log(v)**	**Annex 3 - Appendix 2**	**3.1.**	**Slope of the tyre rolling sound measurements as determined by Annex 3 Appendix 3**
$v_{TR,ref}$	**km/h**	**Annex 3 - Appendix 2** **Annex 3 – Appendix 3**	**3.1.**	**The reference vehicle speed for the reference tyre rolling sound; this speed may be different from v_{wot} or v_{crs} if tyre rolling sound data have been generated independently from the type approval test concerned. (see Annex 3 Appendix 3 paragraph 2.4.1. (b))**
$v_{crs,j}$	**km/h**	**Annex 3 - Appendix 2**	**3.2./4.3.**	**Vehicle speed when the reference point of the vehicle passes line PP' during a pass-by test according Annex paragraph 3.1.2.1.6.**
$v_{wot,PP',j}$	**km/h**	**Annex 3 - Appendix 2**	**3.3./4.4.**	**Vehicle speed when the reference point of the vehicle passes line PP' during a pass-by test according Annex paragraph 3.1.2.1.5.**
$v_{wot,BB',j}$	**km/h**	**Annex 3 - Appendix 2**	**3.3./4.4.**	**Vehicle speed when the rear of the vehicle passes line BB' during a pass-by test according Annex paragraph 3.1.2.1.5.**
ϑ_{ref}	**°C**	**Annex 3 - Appendix 2**	**3.**	**Reference air temperature: 20 °C**
$\vartheta_{crs,j}$	**°C**	**Annex 3 - Appendix 2**	**3.2.**	**Air temperature representative for one pass-by test run j under constant speed condition**
$\vartheta_{wot,j}$.	**°C**	**Annex 3 - Appendix 2**	**3.3.**	**Air temperature representative for one pass-by test run j under acceleration condition**
$L_{TR,crs,j,\vartheta crs}$	**dB(A)**	**Annex 3 - Appendix 2**	**3.2.3.**	**Tyre rolling sound adjusted to the speed condition of the constant speed test**
$L_{PT,crs,j}$	**dB(A)**	**Annex 3 - Appendix 2**	**3.2.4.**	**Extracted power train component from each valid constant speed test**
$L_{TR,crs,j,\vartheta ref}$	**dB(A)**	**Annex 3 - Appendix 2**	**3.2.2.**	**Tyre rolling sound adjusted to the speed condition of the constant speed test and the reference temperature**
$L_{crs,j,\vartheta ref}$	**dB(A)**	**Annex 3 - Appendix 2**	**3.2.5.**	**Air temperature adjusted constant speed test result**
$L_{TR,wot,j,\vartheta wot}$	**dB(A)**	**Annex 3 - Appendix 2**	**3.3.3.**	**Tyre rolling sound adjusted to the speed condition of the acceleration test**

Symbol	*Unit*	*Annex*	*Paragraph*	*Explanation*
$L_{PT,wot,j}$	**dB(A)**	**Annex 3 - Appendix 2**	**3.3.4**	**Extracted power train component from each valid acceleration test**
$L_{TR,wot,j,\vartheta ref}$	**dB(A)**	**Annex 3 - Appendix 2**	**3.3.2.**	**Tyre rolling sound adjusted to the speed condition of the acceleration test and the reference temperature**
$L_{wot,j,\vartheta ref}$	**dB(A)**	**Annex 3 - Appendix 2**	**3.3.5.**	**Air temperature adjusted acceleration test result**
$L_{TR,DB,\vartheta ref}$	**dB(A)**	**Annex 3 - Appendix 2**	**4.1.**	**Reported reference test result of the tyre rolling sound measurement left/ride side according to Annex 3 Appendix 3 taken from a database**
$L_{TR,DB,\vartheta ref}$	**dB(A)**	**Annex 3 - Appendix 2**	**4.1.**	**Reported reference test result of the tyre rolling sound measurement at v_{TEST} left/ride side according to Annex 3 Appendix 3 taken from a database**
$slp_{DB,ref}$	**kg**	**Annex 3 - Appendix 2**	**4.1.**	**Slope of the tyre rolling sound measurements as determined by Annex 3 Appendix 3 taken from a database**
$v_{DB,TR,ref}$	**km/h**	**Annex 3 - Appendix 2**	**4.1.**	**The reference vehicle speed for the reference tyre rolling sound; this speed may be different from v_{crs} or v_{wot}, if tyre rolling sound data have been generated independently from the type approval test concerned. (see Annex 3 Appendix 3 paragraph 2.4.1. (b))**
$L_{TR,DB,crs,\vartheta ref}$	**dB(A)**	**Annex 3 - Appendix 2**	**4.1.**	**Reported reference test result of the tyre rolling sound measurement at v_{crs} left/ride side according to Annex 3 Appendix 3 taken from a database**
$L_{TR,DB,wot,\vartheta ref}$	**dB(A)**	**Annex 3 - Appendix 2**	**4.1.**	**Reported reference test result of the tyre rolling sound measurement at v_{wot} left/ride side according to Annex 3 Appendix 3 taken from a database**
a_{wot_ASEP}	m/s^2	Annex 7	2.3.	maximum required acceleration at wide-open-throttle
…	…	…	…	…

“

Paragraph 3.4., amend to read and insert a new paragraph 3.4.2.:

“3.4. **Approval tests**

~~At the request of the Technical Service conducting approval tests, the vehicle manufacturer shall, in addition, submit a sample of the sound reduction system and an engine of at least the same cylinder capacity and rated maximum net power as that fitted to the vehicle in respect of which type-approval is sought.~~

3.4.1. At the request of the Technical Service conducting approval tests, the vehicle manufacturer shall, in addition, submit a sample of the sound reduction system and an engine of at least the same cylinder capacity and rated maximum net power as that fitted to the vehicle in respect of which type-approval is sought.

3.4.2. Tyre rolling sound reference measurements according to Annex 3 Appendix 3 which are carried out independent of the type approval tests

of a vehicle (see Case 2 of Annex 3 Appendix 2) are not mandatory but can be performed at the option and responsibility of the vehicle manufacturer.

Where the vehicle manufacturer decides to perform such tests, they shall

(a) either be carried out by the vehicle manufacturer witnessed by the Type Approval Authority or by a Technical Service, or

(b) be carried out by the vehicle manufacturer by its laboratories and test facilities which may be designated as an approved laboratory, or

(c) by laboratories and test facilities of a Technical Service designated by the Type Approval Authority and selected by the vehicle manufacturer.

The test results shall be submitted to the Type Approval Authority as reference data to be used when tests other than type approval test[1] are carried out on a different test track.

Where no reference data have been established, no test track compensation is applicable for above mentioned tests. Therefore, only CASE 1 temperature correction is applicable.

“

Paragraph 12., amend to read and insert new paragraphs 12.2. and 12.3.:

“12. Names and addresses of Technical Services responsible for conducting approval tests and of Type Approval Authorities

~~The Contracting Parties to the 1958 Agreement applying this Regulation shall communicate to the United Nations Secretariat the names and addresses of the Technical Services responsible for conducting approval tests and of the Type Approval Authorities which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval, issued in other countries, are to be sent.”~~

12.1. The Contracting Parties to the 1958 Agreement applying this Regulation shall communicate to the United Nations Secretariat the names and addresses of the Technical Services responsible for conducting approval tests and of the Type Approval Authorities which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval, issued in other countries, are to be sent.

12.2. The Contracting Parties to the 1958 Agreement which apply this Regulation may designate laboratories of vehicle manufacturers as approved test laboratories for the purpose of tyre rolling sound measurements according to paragraph 3.4.2.

12.3. Where a Contracting Party to the 1958 Agreement applies paragraph 12.2. above, it may, if it so desires, be represented at the tests by one or more persons of its choice."

[1] **For example, but not limited to, conformity of production, or extensions of already existing approvals, or in-service conformity.**

Annex 3,

Paragraph 3.1.3. and its subparagraphs, amend to read:

"3.1.3. Interpretation of results

~~For vehicles of categories M_1 and M_2 having a maximum authorized mass not exceeding 3,500 kg, and category N_1 the maximum A-weighted sound pressure level indicated during each passage of the vehicle according to paragraphs 3.1.2.1.5. and 3.1.2.1.6. shall be rounded to the first significant digit after the decimal place (e.g. XX,X).~~

~~For vehicles of category M_2 having a maximum authorized mass exceeding 3,500 kg and categories M_3, N_2, and N_3 the maximum A-weighted sound pressure level indicated during each passage of the reference point of the vehicle between line AA' and line BB' + 5 m shall be rounded, to the first significant digit after the decimal place (e.g. XX,X).~~

~~For indoor testing, pass by sound is simulated by measurement of power train sound on the dynamometer and energetical addition of the tyre/road sound (measured separately on an outdoor test track) according to Annex 8, paragraph 2 of this Regulation.~~

~~If a sound peak obviously out of character with the general sound pressure level is observed, the measurement shall be discarded. At least four measurements for each test condition shall be made on each side of the vehicle and for each gear ratio. Left and right side may be measured simultaneously or sequentially. The first four valid consecutive measurement results, within 2 dB(A), allowing for the deletion of non valid results (see paragraph 2.1.), shall be used for the calculation of the final result for the given side of the vehicle.~~

~~The results of each side shall be averaged separately and rounded to the first decimal place. All further calculations to derive L_{urban} shall be done separately for the left and right vehicle side. The final value to be reported as the test result mathematically rounded to the nearest integer shall be the higher value of the two sides.~~

~~The speed measurements at AA', BB', and PP' shall be noted and used in calculations to the first significant digit after the decimal place.~~

~~The calculated acceleration $a_{wot\ test}$ shall be noted to the second digit after the decimal place.~~

3.1.3.1. **Measurement readings for outdoor tests** ~~Vehicles of categories M_1, N_1 and $M_2 \leq 3{,}500$ kg technically permissible maximum laden mass~~

For vehicles of categories M_1 and N_1, and for vehicles of category M_2 having a maximum authorized mass not exceeding 3,500 kg, the maximum A-weighted sound pressure level indicated during each passage of the vehicle according to paragraphs 3.1.2.1.5. and 3.1.2.1.6. shall be rounded to the first significant digit after the decimal place (e.g. XX.X).

For vehicles of category M_2 having a maximum authorized mass exceeding 3,500 kg and for vehicles of categories M_3, N_2, and N_3 the maximum A-weighted sound pressure level indicated during each passage of the reference point of the vehicle between line AA' and line BB' + 5 m shall be rounded, to the first significant digit after the decimal place (e.g. XX.X).

~~The calculated values for the acceleration test and the constant speed test are given by:~~

~~$L_{wot\ rep} = L_{wot\ (i+1)} + k * (L_{wot(i)} - L_{wot\ (i+1)})$~~

~~$L_{crs\ rep} = L_{crs(i+1)} + k * (L_{crs\ (i)} - L_{crs\ (i+1)})$~~

~~Where $k = (a_{wot\ ref} - a_{wot\ (i+1)})/(a_{wot\ (i)} - a_{wot\ (i+1)})$~~

~~In the case of a single gear ratio test the values are the test result of each test.~~

~~The final result is calculated by combining $L_{wot\ rep}$ and $L_{crs\ rep}$. The equation is:~~

~~$L_{urban} = L_{wot\ rep} - k_p * (L_{wot\ rep} - L_{crs\ rep})$~~

~~The weighting factor k_p gives the part power factor for urban driving. In cases other than a single gear test, k_p is calculated by:~~

~~$k_p = 1 - (a_{urban} / a_{wot\ ref})$~~

~~If only one gear was specified for the test, k_p is given by:~~

~~$k_p = 1 - (a_{urban} / a_{wot\ test})$~~

~~In cases where $a_{wot\ test}$ is less than a_{urban}:~~

~~$k_p = 0$~~

3.1.3.2. Measurement readings for indoor tests ~~Vehicles of categories M_2 > 3,500 kg technically permissible maximum laden mass, M_3, N_2, N_3~~

The pass-by sound of a vehicle is determined by energetical addition of the power train sound measured in an indoor facility according to paragraph xxx and the separately determined tyre/road sound measured on an outdoor test track according to Annex 8, paragraph 2. of this Regulation.

~~When the result of one test condition is used the final result L_{urban} is equal to the intermediate result.~~

~~When the results of two test conditions are used the arithmetic mean of the intermediate results of the two averages for each side of the two conditions shall be calculated. The final result L_{urban} is the higher value of the two calculated averages.~~

3.1.3.3. Validation of individual test runs

If a sound peak obviously out of character with the general sound pressure level is observed, the measurement shall be discarded. At least four measurements for each test condition shall be made on each side of the vehicle and for each gear ratio. Left and right shall be measured simultaneously. The first four valid consecutive measurement results, within 2 dB(A), allowing for the deletion of non-valid results (see paragraph 2.1.), shall be used for the further calculations below.

3.1.3.4. Calculation of results

3.1.3.4.1. Calculation for vehicles of category M_1 and N_1, and for vehicles of category M_2 having a maximum authorized mass not exceeding 3,500 kg

3.1.3.4.1.1. Each valid test run of the acceleration and – if applicable – of the constant speed tests per vehicle side and per gear ratio shall be subjected to a temperature and if applicable a test track correction according to Appendix 2 to Annex 3.

3.1.3.4.1.2. Per gear, test condition (acceleration and constant speed) and vehicle side the four valid and corrected test results shall be averaged and mathematically rounded to the first significant digit after the decimal place.

All further calculations to derive L_{urban} shall be done separately for the left and right vehicle side. The final value L_{urban} mathematically rounded to the nearest integer shall be the higher value of the two sides.

The speed measurements at AA', BB', and PP' used for reporting and further calculations shall be rounded to the first significant digit after the decimal place.

The calculated acceleration $a_{acc\ test}$ used for reporting and further calculations shall be rounded to the second significant digit after the decimal place.

The calculated interim values for the acceleration test and the constant speed test are given by:

$$L_{wot\ rep} = L_{wot\ (i+n)} + k * (L_{wot(i)} - L_{wot\ (i+n)})$$

$$L_{crs\ rep} = L_{crs(i+n)} + k * (L_{crs\ (i)} - L_{crs\ (i+n)})$$

where $k = (a_{wot\ ref} - a_{wot\ (i+n)})/(a_{wot\ (i)} - a_{wot\ (i+n)})$
with n as determined by paragraph 3.1.2.1.4.1.

In the case of a single gear ratio test inclusive the non-locked condition according to paragraphs 3.1.2.1.4.2. and 3.1.2.1.4.3. the interim values $L_{acc\ rep}$ and $L_{crs\ rep}$ are the averaged test results of each test condition (acceleration and constant speed).

The final result is calculated by combining $L_{acc\ rep}$ and $L_{crs\ rep}$. The equation is:

$$L_{urban} = L_{wot\ rep} - k_P * (L_{wot\ rep} - L_{crs\ rep})$$

The weighting factor k_P gives the part power factor for urban driving. In cases other than a single gear test, k_P is calculated by:

$$k_P = 1 - (a_{urban} / a_{wot\ ref})$$

If only one gear was specified for the test, k_P is given by:

$$k_P = 1 - (a_{urban} / a_{wot\ test})$$

In cases where $a_{wot\ test}$ is less than a_{urban}:

$$k_P = 0$$

In cases where the PMR of the vehicle is lower than 25 the final result L_{urban} is the result of the acceleration test:

$$L_{urban} = L_{wot\ rep}$$

3.1.3.4.2. **Calculation for vehicles of category M_2 having a maximum authorized mass exceeding 3,500 kg and for vehicles of categories M_3, N_2, and N_3**

For each gear and vehicle side, the valid test runs shall be averaged separately, rounded to the first decimal place, and be reported as interim results.

All further calculations to derive L_{urban} shall be done separately for the left and right vehicle side. The final value L_{urban} to be reported as the test result mathematically rounded to the nearest integer shall be the higher value of the two sides.

The speed measurements at line BB' shall be noted and used in calculations to the first significant digit after the decimal place.

The engine speed measurements (if applicable) at line BB' shall be noted and used in calculations to the full integer.

In the case of a single gear test, inclusive the non-locked condition, the final result L_{urban} is equal to the intermediate result.

In the case of a two-gear test, the final result is the arithmetic mean of the intermediate results. The final result L_{urban} is the higher value of the two calculated averages."

Annex 3, add a new Appendix 2 to read:

"Annex 3 – Appendix 2

Correction for the tyre rolling sound component of pass-by sound measurements

1. Scope of the correction

This Appendix contains provisions on the correction for the tyre rolling sound component of pass-by sound measurements of Annex 3 and applies to vehicles of categories M_1 and N_1, and for vehicles of category M_2 having a maximum authorized mass not exceeding 3,500 kg.

2. General (see the flowchart in Appendix 3, Figure 7a to Figure 7d)

This Appendix provides correction for temperature and test track dependent on the tyre category and purpose.

For the correction, tyre rolling sound reference values are needed. Tyre rolling sound measurements shall be carried out according to the test procedure of Appendix 3 to Annex 3 of this regulation.

2.1. These measurements might be carried out during the type approval of a vehicle type (CASE 1 as described in paragraph 2. of this appendix) or be performed as an independent test to be used for type approval tests of different vehicle types (CASE 2 as described in paragraph 3. of this appendix).

For the further processing of data, the following tyre rolling sound reference information shall be available from the test according to Appendix 3 to Annex 3:

(a) The tyre rolling sound $L_{TR,\vartheta ref}$ separately for the left and the right side of the vehicle

(b) The slope of the tyre rolling sound slp_{ref} separately for the left and for the right side of the vehicle

(c) The reference speed $v_{TR,ref}$ to which these sound levels are assigned. If tyre rolling sound measurements are directly carried out in junction with the pass-by measurements, the reference speed $v_{TR,ref}$ shall be determined in a way to be equal to the vehicle test speed v_{crs} and v_{wot}.

2.2. The test results for each gear as determined according to Annex 3 paragraphs 3.1.2.1.4., test condition (acceleration or constant speed) and per vehicle side, are subject to the temperature correction.

2.3. For simplicity, the formula below uses the index x as place holder for the applicable gear ratio(s) i or i+n. No index is introduced for left and right side, but all calculations shall be done separately for left and right side of the vehicle.

2.4. If tests are carried out at air temperatures below 5 °C according to paragraph 2.1.3. of Annex 3, the temperature correction is applicable down to an air temperature of 0 °C. For any tests carried out at air temperatures below 0°C, the temperature correction shall be calculated with 0 °C, regardless of the measured air temperature.

3. CASE 1

The temperature correction is based on tyre rolling sound measurements carried in junction with pass-by tests according to Annex 3.

3.1. Tyre Rolling Sound Reference

The rolling sound of the tyre $L_{TR,\vartheta_{ref},v_{TR,ref}}$ and the tyre sound level slope slp_{ref} for left and right side of the vehicle shall be determined for a reference vehicle speed $v_{TR,ref}$ at the reference temperature ϑ_{ref} according to Appendix 3 to Annex 3.

3.2. Temperature correction for constant speed test results

3.2.1. The reference speed shall be identical to the reference test speed of the constant speed test v_{crs} determined in Annex 3. In most cases this will be 50 km/h. If the tyre reference speed $v_{TR,ref}$, differs from v_{crs}, adjust the tyre rolling sound per vehicle side to the test speed v_{crs} by:

$$L_{TR,crs,j,\vartheta_{ref}} = L_{TR,\vartheta_{ref},v_{TR,ref}} + slp_{ref} \times \lg \frac{v_{crs}}{v_{TR,ref}}$$

3.2.2. For each valid pass-by test run j under constant speed the following values per gear are available from the measurements according to Annex 3 paragraph 3.1.2.1.:

(a) the reported sound levels $L_{crs,j}$,

(b) the vehicle speed $v_{crs,PP',j}$, and

(c) the air temperature $\vartheta_{crs,j}$.

3.2.3. For each individual test run (gear, condition and vehicle side), a tyre rolling sound reference shall be calculated for the applicable air temperature $\vartheta_{crs,j}$.

$$L_{TR,crs,j,\vartheta crs} = L_{TR,crs,j,\vartheta_{ref}} + K_1 \times \lg\left(\frac{\vartheta_{ref} + K_2}{\vartheta_{crs,j} + K_2}\right)$$

where ϑ_{ref} **= 20 °C and**
K_1 **= 3.4 for C_1 and C_2 tyres and**
K_2 **= 3.0 for C_1 tyres and**
K_2 **= 15.0 for C_2 tyres**

3.2.4. For each gear, run and vehicle side under constant speed extract the power train component $L_{PT,crs,j}$ from the test result $L_{crs,j}$, by calculation.

$$L_{PT,crs,j} = 10 \times \lg\left(10^{0,1 \times L_{crs,j}} - 10^{0,1 \times L_{TR,crs,j,\vartheta_{crs}}}\right)$$

In case that $L_{TR,crs,\vartheta_{crs}}$ is greater than $L_{crs,j}$ the power train component $L_{PT,crs,j}$ is determined by

$$L_{PT,crs,j} = 10 \times \lg\left(0,01 \times 10^{0,1 \times L_{crs,j}}\right)$$

3.2.5. Calculate per gear, run and vehicle side the air temperature adjusted constant speed test result $L_{crs,j,\vartheta_{ref}}$ using the temperature normalized tyre rolling sound $L_{TR,\vartheta_{ref}}$ calculated by

$$L_{crs,j,\vartheta_{ref}} = 10 \times \lg\left(10^{0,1 \times L_{PT,crs,j}} + 10^{0,1 \times L_{TR,crs,j,\vartheta_{ref}}}\right)$$

3.3. Temperature correction for acceleration test results

3.3.1. For each gear, run and vehicle side, adjust the tyre rolling sound to the speed condition of the acceleration test

$$L_{TR,wot,j,\vartheta_{ref}} = L_{TR,\vartheta_{ref},v_{TR\,ref}} + slp_{ref} \times \lg\left(0.5 \times \left(v_{BB',wot} + v_{PP',wot}\right)/v_{TR,ref}\right)$$

3.3.2. For each valid pass-by test run under acceleration the following values per gear are available from the measurements according to Annex 3 paragraph 3.1.2.1.:

(a) the reported sound levels $L_{wot,j}$,

(b) the vehicle speeds $v_{wot,PP',j}$ and $v_{wot,BB',j}$, and

(c) the air temperature $\vartheta_{wot,j}$.

3.3.3. For each individual test run (gear, condition and vehicle side), a tyre rolling sound reference shall be calculated for the applicable air temperature or $\vartheta_{wot,j}$.

$$L_{TR,wot,j,\vartheta_{wot}} = L_{TR,wot,j,\vartheta_{ref}} + K_1 \times \lg\left(\frac{\vartheta_{ref} + K_2}{\vartheta_{wot,j} + K_2}\right)$$

where ϑ_{ref} = 20 °C and
K_1 = 3.4 for C_1 and C_2 tyres and
K_2 = 3.0 for C_1 tyres and
K_2 = 15.0 for C_2 tyres

3.3.4. For each gear, run and vehicle side extract the power train component $L_{PT,wot,j}$ from the reported acceleration test $L_{wot,j}$, by calculation.

$$L_{PT,wot,j} = 10 \times \lg\left(10^{0,1 \times L_{wot,j}} - 10^{0,1 \times L_{TR,wot,j,\vartheta_{wot}}}\right)$$

In case that $L_{TR,wot,j,\vartheta_{wot}}$ is greater than $L_{wot,j}$ the power train component $L_{PT,wot,j}$ is determined by

$$L_{PT,wot,j} = 10 \times \lg\left(0,01 \times 10^{0,1 \times L_{wot,j}}\right)$$

3.3.5. Calculate per gear the acceleration test result $L_{wot,j,\vartheta_{ref}}$

$$L_{wot,j,\vartheta_{ref}} = 10 \times \lg\left(10^{0,1 \times L_{PT,wot,j}} + 10^{0,1 \times L_{TR,wot,j,\vartheta_{ref}}}\right)$$

3.4. Proceed to calculate L_{urban} using the temperature normalized sound pressure levels $L_{crs,j,\vartheta_{ref}}$ and $L_{wot,j,\vartheta_{ref}}$ according to the procedure of Annex 3 paragraph 3.1.3.4.1.2.

4. CASE 2

The temperature correction based on tyre rolling sound measurements that have been performed independent from the pass-by tests subject to the temperature correction.

CASE 2 is applicable, when pass-by tests carried out according to Annex 3 shall be compared with already existing results – e.g., from type approval, that have been performed under a different temperature condition and on a different test track.

4.1. The necessary information on tyre rolling sound representative for the tyre used on the vehicle is available from former type approval tests or have been carried out separately according to Appendix 3 to Annex 3 of this UN Regulation. The essential information is provided by the test report of that Appendix and is:

(a) the tyre rolling sound $L_{TR,DB,\vartheta_{ref}}$ at the reference temperature ϑ_{ref},

(b) the reference vehicle speed $v_{TR,DB,ref}$, and

(c) the tyre rolling sound slope $slp_{DB,ref}$.

4.2. Determine the tyre rolling sound for the vehicle according to CASE 1 above and extract the power train relevant components $L_{PT,crs,j}$ and $L_{PT,wot,j}$ for each gear and run accordingly.

4.3. Temperature correction for constant speed test results

4.3.1. The reference speed shall be identical to the reference test speed of the constant speed test v_{test} determined in Annex 3. In most cases this will be 50 km/h. If the tyre reference speed $v_{TR,DB,ref}$ differs from v_{crs}, adjust the tyre rolling sound per vehicle side to the test speed v_{crs} by:

$$L_{TR,DB,crs,j,\vartheta_{ref}} = L_{TR,DB,\vartheta_{ref}} + slp_{DB,ref} \times lg\left(v_{crs,j}/v_{TR,DB,ref}\right)$$

4.3.2. For each gear, test run and vehicle side, calculate the air temperature and test track adjusted constant speed test results $L_{crs,j,\vartheta_{ref}}$ by

$$L_{crs,j,\vartheta_{ref}} = 10 \times lg\left(10^{0,1\times L_{PT,crs,j}} + 10^{0,1\times L_{TR,DB,crs,j,\vartheta_{ref}}}\right)$$

4.4. Temperature correction for acceleration test results

4.4.1. For each gear, test run and vehicle side, adjust the tyre rolling sound $L_{TR,DB,\vartheta_{ref}}$ to the speed condition of the acceleration test

$$L_{TR,DB,wot,j,\vartheta_{ref}} = L_{TR,DB,\vartheta_{ref}} + slp_{DB,ref} \times lg\left(0.5 \times \left(v_{BB',wot,j} + v_{PP',wot,j}\right)/v_{TR,DB,ref}\right)$$

4.4.2. For each gear, test run and vehicle side, calculate the acceleration test result $L_{wot,j,\vartheta_{ref}}$ by

$$L_{wot,j,\vartheta_{ref}} = 10 \times lg\left(10^{0,1\times L_{PT,wot,j}} + 10^{0,1\times L_{TR,DB,wot,j,\vartheta_{ref}}}\right)$$

4.5. Proceed to calculate L_{urban} with the temperature normalized sound pressure levels $L_{crs,j,\vartheta_{ref}}$ and $L_{wot,j,\vartheta_{ref}}$ according to the procedure of Annex 3 paragraph 3.1.3.4.1.2.

Figure 7a **Flowchart for vehicles tested according to paragraph 3.1.2.1. of Annex 3 to this Regulation – Correction of pass-by measurements for temperature and if applicable for test track differences**

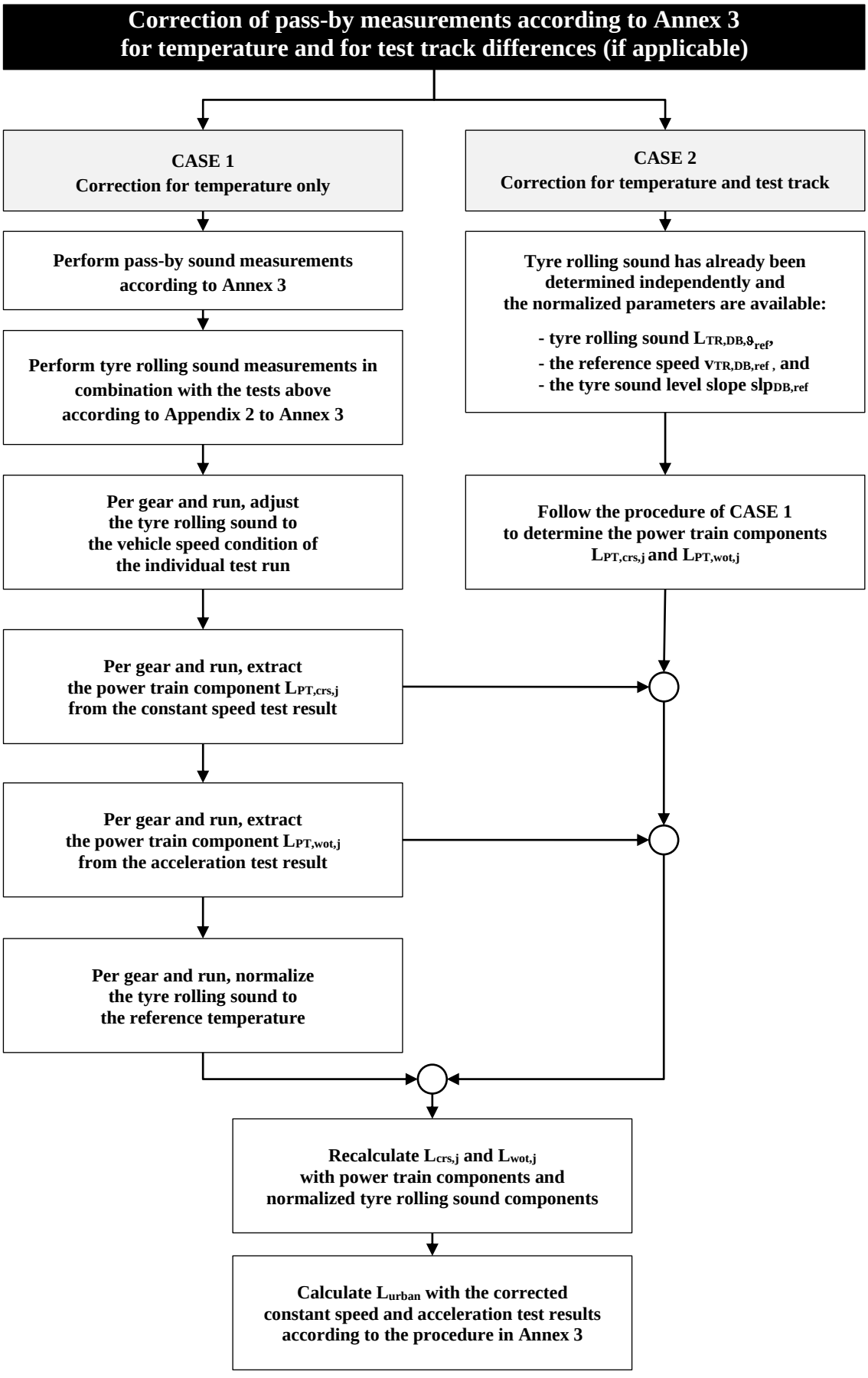


Figure 7b **Flowchart for vehicles tested according to paragraph 3.1.2.1. of Annex 3 to this Regulation – Temperature Correction for Tyre Rolling Sound Components CASE 1**

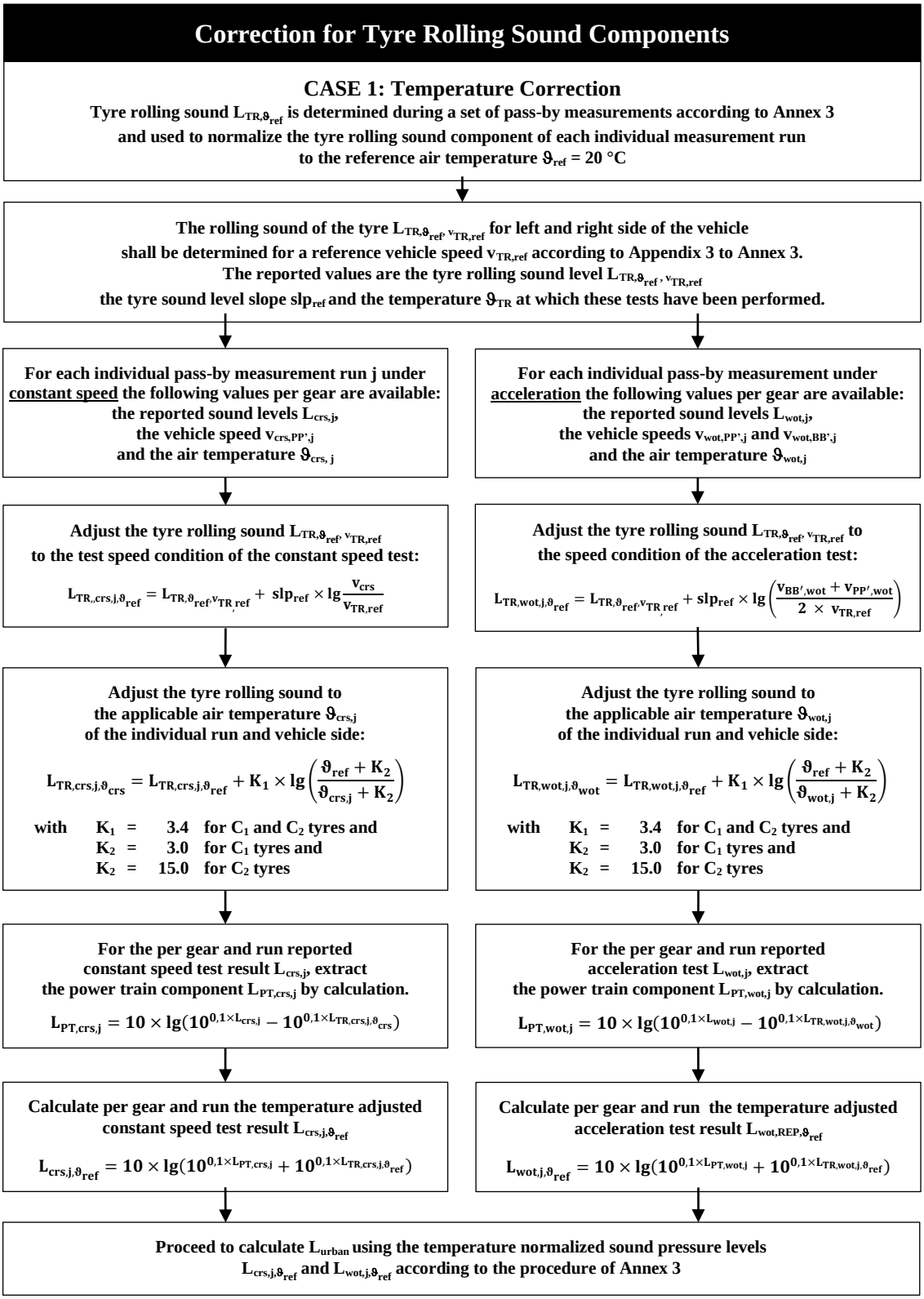
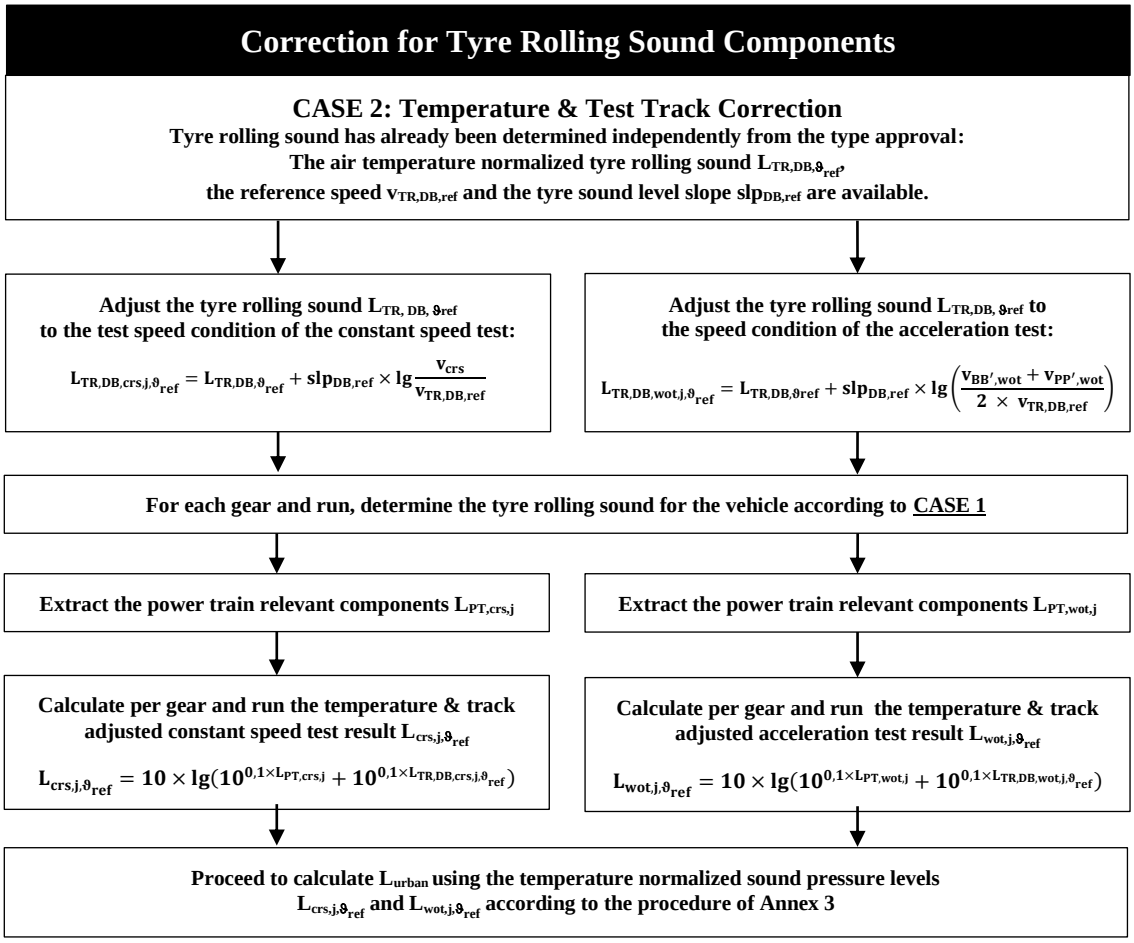


Figure 7c **Flowchart for vehicles tested according to paragraph 3.1.2.1. of Annex 3 to this Regulation – Temperature/Test Track Correction for Tyre Rolling Sound Components CASE 2**



Annex 3, add a new Appendix 3 to read:

"Annex 3 – Appendix 3

Coast-by test method for measuring tyre-rolling sound emission

1. Measuring instruments

Unless otherwise specified, the measuring instruments shall comply with the provisions of Annex 3 of this UN Regulation.

1.1. Meteorological equipment

Unless otherwise specified, the meteorological equipment shall comply with the provisions of Annex 3 of this UN Regulation.

2. Conditions of measurement

2.1. Test site

The test site shall comply with the provisions of Annex 3 of this UN Regulation.

2.2. Meteorological conditions

Tests carried out on request of the manufacturer at temperatures below 5° C shall be accepted as well, however temperature correction to be applied is limited to a minimum air temperature of 0 °C. See paragraph 2 of Appendix 2 to Annex 3 of this Regulation as well.

2.3. Ambient noise

The background noise provisions shall be in line with Annex 3 of this UN Regulation.

2.4. Test vehicle requirements

2.4.1. General

The test vehicle shall be either

(a) the vehicle directly used for tests according Annex 3 of this UN Regulation. In this case, the requirements of paragraphs 2.4.2. to 2.4.4. inclusive the subparagraphs do not apply. The vehicle shall comply with the specifications of Annex 3 of this UN Regulation, or

(b) a motor vehicle compliant with the provisions of paragraphs 2.4.2. to 2.4.4.

2.4.2. Vehicle load

The vehicle shall be loaded such as to comply with the test tyre loads as specified in paragraph 2.5.2. below.

2.4.3. Wheelbase

The wheelbase between the first and the second axles fitted with the test tyres shall for Class C_1 be less than 3.50 m and for Class C_2 tyres be less than 5 m.

2.4.4. Measures to minimize vehicle influence on sound level measurements

The test vehicle shall be suitable for vehicles to which this tyre will be fitted, this is fulfilled, if the vehicle has been cross-checked to the vehicle type to which the tyres are dedicated with regard to the design criteria below:

2.4.4.1. Requirements:

(a) Spray suppression flaps or another extra device to suppress spray.

(b) Retention of elements in the immediate vicinity of the rims and tyres, which may screen the emitted sound.

(c) Wheel alignment (toe in, camber and caster) shall be in full accordance with the vehicle manufacturer's recommendations.

(d) Sound absorbing material in the wheel housings or under the underbody.

(e) Ground clearance: if available, the body level shall be adjusted to a comparable ground clearance as applicable for the vehicle type.

2.4.4.2. Recommendations to avoid parasitic noise:

(a) During testing it should be ascertained that brakes are not poorly released, causing brake noise.

(b) It should be ascertained that electric cooling fans are not operating.

(c) Windows and sliding roof of the vehicle shall be closed during testing.

2.5. Tyres

2.5.1. General

Four tyres shall be fitted on the test vehicle to be representative for the tyre configuration as it will be used for the type approval of a vehicle. Tyres with special fitting requirements shall be tested in accordance with these requirements (e.g., rotation direction). The tyres shall have a minimum tread depth of 80%.

New tyres shall be "run-in" prior to testing to remove compound nodules or other tyre pattern characteristics resulting from the moulding process. This will normally require the equivalent of about 100 km of normal use on the road.

Tyres are to be tested on rims specified by the vehicle manufacturer.

2.5.2. Tyre loads

2.5.2.1. If the test vehicle is a vehicle subject to tests according to Annex 3 according to this UN Regulation, the provisions on the tyre loads below do not apply.

2.5.2.2. In other cases, the loads on the tyres shall be representative for the vehicle to which these tyres are dedicated with a tolerance +/- 20% not exceeding 90% of the maximum tyre load.

2.5.3. Tyre inflation pressure

2.5.3.1. If the test vehicle is a vehicle subject to type approval according to this Regulation, the tyre inflation pressure shall be according to paragraph 2.2.2. of Annex 3.

2.5.3.2. In other cases, the tyre pressure shall be adjusted according to the manufacturer's specification for the tyre load as selected according to paragraph 2.5.2.2. above.

2.5.4. Preparations prior to testing

Prior to testing tyres shall be warmed up by running under test conditions for at least 10 min to allow the rubber compound to warm-up.

3. Method of testing

3.1. General conditions

For all measurements the vehicle shall be driven in a straight line over the measuring section (AA' to BB') in such a way that the median longitudinal plane of the vehicle is as close as possible to the line CC'.

When the front end of the test vehicle has reached the line AA' the vehicle shall be brought to coast-down by full release of the acceleration pedal. If applicable, the influence of the power train noise shall be minimized, e.g. the driver shall have put the gear selector to neutral position and switched off the engine. If abnormal noise (e.g. ventilator, self-ignition) is emitted by the test vehicle during the measurement, the test shall be disregarded.

As an alternative test method, the acceleration pedal may be positioned such to maintain a constant speed between line AA' with an accuracy of +/- 1 km/h. The procedure is recommended especially for electric vehicles when a release of the acceleration pedal would result is a forced deceleration (recuperation) with higher negative torque on the tyre.

3.2. Nature and number of measurements

The maximum sound level expressed in A-weighted decibels (dB(A)) shall be measured simultaneously for the left and ride side of the vehicle and be reported to the first decimal place as the vehicle is coasting between lines AA' and BB' (front end of the vehicle on line AA', rear end of the vehicle on line BB').

For each pass-by measurement n the vehicle speeds $v_{PP',n}$ shall be reported, when the reference point of the vehicle (see definition 2.11) passes the lines PP'. In case of a test vehicle according 2.4.1. (b) test might be needed at various reference points, if the tyre configuration shall be used on vehicles with different reference points. The vehicles speeds shall be mathematically rounded to the first decimal place.

At least six measurements shall be made on each side of the test vehicle approximately equally spaced over the speed range specified in paragraph 3.3. below.

3.3. Test speed range

The test vehicle speeds shall be within the range from 40 km/h to 60 km/h.

4. Interpretation of results

The measurement shall be invalid if an abnormal discrepancy between the values is recorded (see background noise and measurement reading provisions of annex 3).

4.1. Determination of test result

Reference speed $v_{TR,ref}$ used to determine the final result will be 50 km/h, unless the reference speed is reduced during the type approval test according to the provisions of paragraph 3.1.2.1.4.1. (d) of Annex 3 of this UN Regulation.

4.2. Temperature correction

Each test result $L_{TR,i}$ shall be normalized to the air temperature ϑ_{ref} by applying a temperature correction, according to the following:

$$L_{TR,i,\vartheta_{ref}} = L_{TR,i,\vartheta_{TR}} + K_1 \times \lg\left(\frac{\vartheta_{TR,i} + K_2}{\vartheta_{ref} + K_2}\right)$$

where
- ϑ_{ref} = 20 °C and
- $\vartheta_{TR,i}$ = the measured air temperature per run i and
- K_1 = 3.4 for C_1 and C_2 tyres and
- K_2 = 3.0 for C_1 tyres and
- K_2 = 15.0 for C_2 tyres.

4.3. **Regression analysis of rolling sound measurements**

The tyre-road rolling sound level $L_{TR,\vartheta_{ref},v_{TR,ref}}$ is determined by a regression analysis for each vehicle side separately according to:

$$L_{TR,\vartheta_{ref},v_{TR,ref}} = \overline{L} - slp_{ref} \times \overline{v}$$

where $\overline{L}$ **is the mean value of the rolling sound levels L_i, measured in dB(A):**

$$\overline{L} = \frac{1}{n}\sum_{i=1}^{n} L_{TR,i,\vartheta_{ref}}$$

n is the measurement number ($n \geq 6$),

$\overline{v}$ **is the mean value of logarithms of speeds v_i:**

$$\overline{v} = \sum_{i=1}^{n} v_i$$

with $v_i = lg\frac{v_i}{v_{TR,ref}}$

slp_{ref} **is the slope of the regression line in dB(A):**

$$slp_{ref} = \frac{\sum_{i=1}^{n}(v_i - \overline{v})\left(L_{TR,i,\vartheta_{ref}} - \overline{L}\right)}{\sum_{i=1}^{n}(v_i - \overline{v})^2}$$

4.4. **The final result $L_{TR,\vartheta_{ref},v_{TR,ref}}$ for the reference speed $v_{TR,ref}$ and the slope slp_{ref} of the regression line shall be reported per vehicle side to the first decimal place.**

5. **Test report**

5.1. **Authority present during the tests: .....**

5.1.1. **Name and address of applicant: .....**

5.1.2. **Test report No.: .....**

5.1.3. **Date of test: .....**

5.1.4. **Location of test track: .....**

5.1.4.1. **Date of track certification to ISO 10844:2014: .....**

5.1.4.2. **Issued by: .....**

5.1.4.3. **Method of certification: .....**

5.1.5. **Test vehicle**

5.1.5.1. **Vehicle used for tyre testing (strike trough what is not applicable):**

type approval vehicle / tyre test vehicle

5.1.5.2. **In case of a type approval vehicle**

5.1.5.2.1. **Type description: .....**

5.1.5.3. **In case of a tyre test vehicle**

5.1.5.3.1. **Make, model, year, modifications, etc.: .....**

5.1.5.3.2. **Test vehicle wheelbase: ..... mm**

5.1.6. **Tyre Information**

5.1.6.1. **Manufacturer and Brand Name or Trade description: .....**

5.1.6.2. **Tyre Class: .....**

5.1.6.3. **Category of use: (M_1, N_1 or N_2 < 3.5 t).....**

5.1.6.4. **Tyre test details (front/rear axle): .....**

5.1.6.5. Tyre size designation: .....

5.1.6.6. Tyre service description: .....

5.1.6.7. Reference inflation pressure: ..... kPa

5.1.7. Reported values

5.1.7.1. Tyre Rolling Sound Level $L_{TR,\vartheta_{ref},v_{TR,ref}}$ (left/right side of the vehicle):dB(A)

5.1.7.2. Reference speed v_{ref} according to paragraph 4.1: .....km/h

5.1.7.3. Regression slopes slp_{ref} (left/right side of the vehicle): .....dB(A)/log(v)

5.1.8. Comments (if any): .....

5.1.9. Date:.....

5.1.9.1. Signature: ....."

Annex 6,

Paragraph 2.1., amend to read:

"2.1. The vehicle(s) under test shall be subjected to the test for measurement of sound of vehicle in motion as described in paragraph 3.1. of Annex 3.

For vehicles of category M_1 and N_1**, and for vehicles of category** M_2 **having a maximum authorized mass not exceeding** ~~≤~~ 3,500 kg ~~technically permissible maximum laden mass~~,

(a) the same mode, gear(s)/gear ratio(s), gear weighting factor k and partial power factor k_P as determined during the type approval process may be used, provided ~~these~~ **this** information ~~are~~ **is** available from the type approval test report for the applicable vehicle variant of the family. If not, ~~these~~ **this** information shall be determined anew. The test report shall document which way of data processing was selected.

(b) the test mass mt of the vehicle shall be between $0.90\ m_{ro} \leq mt \leq 1.20\ m_{ro.}$

Notwithstanding the provisions of paragraph 2.2.3.4.2. on tyre conditioning for testing, manufacturer may use a simplified conditioning according to the vehicle manufacturers specification to avoid excessive use of the tyres during the conditioning."

Annex 7,

Paragraph 1., amend to read

"1. General (see the flowchart in Appendix 2, Figure 1)
This annex describes a measurement method to evaluate compliance of the vehicle with the additional sound emission provisions (ASEP) conforming to paragraph 6.2.3. of this Regulation.

It is not mandatory to perform actual tests when applying for type-approval. The manufacturer shall sign the declaration of compliance set out in Appendix 1. The approval authority may ask for additional information about the declaration of compliance and carry out the tests described below.

The procedure set out in this annex requires the performance of a test in accordance with Annex 3.

If the tests according to Annex 7 are carried out in the course of type approval, all tests either for Annex 3 and for Annex 7 shall be carried out on same test track and under similar environmental conditions.[2]

If Annex 7 tests are carried out when type approval has already been granted, e.g. during tests for conformity of production or for in-use compliance, the tests in motion specified in Annex 3 shall be carried out with the same mode, gear(s)/gear ratio(s), gear weighting factor k and partial power factor k_P as determined during the type approval process.

The test results of Annex 3 shall be used within Annex 7 without any temperature correction."

II. Justification

General

1. The Informal Working Group on Measurement Uncertainties (IWG MU) identified the temperature behaviour of tyre rolling sound component as a contributor to the measurement uncertainty of pass-by noise tests.

2. Since in UN Regulation No. 117 a temperature correction of tyre rolling sound is already established, IWG MU investigated an adaptation of the existing calculation procedure. Due to the different testing conditions in UN Regulation No. 117, new scientific investigations and industry data in pass-by testing the group worked out a temperature correction, which is adapted to the requirements of UN Regulation No. 51.

3. All text in this proposal is produced by IWG MU by amending the 03 series of amendments to UN Regulation No. 51.

Paragraph 2.24.

4. In the 'table of symbols' the symbols used in the new Appendices 2 and 3 of Annex 3 have been filled in.

Paragraph 3.4.

5. New paragraph 3.4.2. was introduced to make clear that the rolling sound test is only an option which is in responsibility of the vehicle manufacturer. Due to the practical work three possibilities to carry out the measurements are described.

Paragraph 12.

6. New paragraphs 12.2. ad 12.3. have been inserted to legalize the laboratories of the vehicle manufacturers to perform only the rolling sound measurements for this Regulation. In UN Regulation No. 117, the same approach for rolling sound measurements is used for the tyre manufacturers.

Annex 3, paragraph 3.1.3.

7. Paragraph 3.1.3. for 'interpretation of results' has been completely restructured for more clarity. Additional subchapters have been introduced to describe measurement readings for outdoor tests, measurement readings for indoor tests, the validation of individual test runs and the calculation of results.

8. The old subparagraphs 3.1.3.1. and 3.1.3.2. have been integrated in the new subparagraph 3.1.3.4. "Calculation of Results".

[2] Measurements for Annex 7 for a particular vehicle type may be carried out on ~~a~~ different test tracks or under different environmental conditions, each according to the provisions of this Regulation, if the test results ~~L_{woti} and L_{crsi} for the gear,~~ **of the lower gear used for the calculation of L_{urban} in Annex 3. and** representing the anchor point, do not differ by more the +/- 1.0 dB from the test results at the time when the tests according to Annex 3 have been carried out.

9. In the subparagraph “Calculation of Results” the wording of the definition vehicle categories was optimized for more clarity. The accuracy of engine speed measurements has also been added.

Annex 3, new Appendix 2

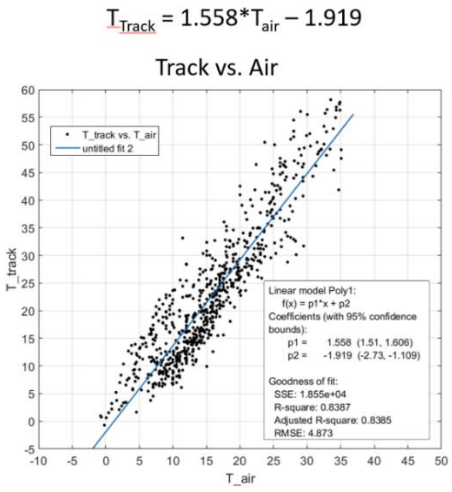
10. A new appendix has been added to describe the correction for temperature and test track (if applicable), dependent on the tyre category and purpose. Therefore, two different cases are described:

CASE 1 Tyre rolling sound measurements carried in junction with pass-by tests according to Annex 3.

CASE 2 Tyre rolling sound measurements that have been performed independent from the pass-by tests subject to the temperature correction.

11. Since air temperature is more stable than track temperature due to weather conditions the correction is based on air temperature.

Figure A
Measurements of air and track surface temperature (about 700 measurement points under various ambient conditions (summer, winter, cloudy, sunny, etc.))



Source: BMW Group; 2021

12. The tyre rolling sound component will be corrected to a reference air temperature. Thus, the temperature range is less critical as today.

Background information according to paragraph 2.4.

13. Tests at temperatures below 5°C should normally be avoided, but sometimes it is unavoidable due to practical considerations. Therefore, manufacturer could on request carry out tests at lower temperatures.

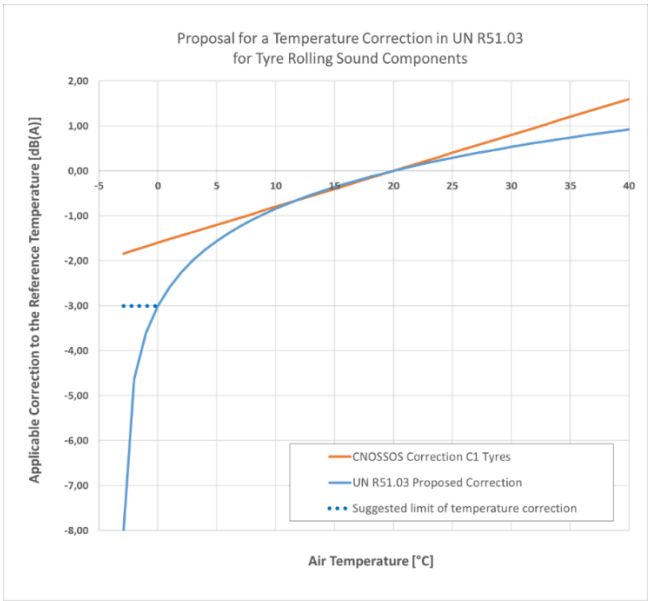
14. The 03 series of amendments to UN Regulation No. 51 temperature correction is a logarithmic function to address the extreme temperature situations at very low and very high temperatures *within the specified temperature range* more adequate relative to linear functions (in the diagram below, the common NOise aSSessment MethOdS (CNOSSOS) applied correction is shown).

15. However, at air temperatures below 5°C, the correction is very much based on the chosen logarithmic function. Especially normal (summer) tyres change their rolling sound performance very fast (becoming louder) due to the change of the physical behaviour of the rubber compound. This effect starts typically below 7°C. Therefore, in many countries it is suggested not to use summer tyres at cold temperatures. After a tyre has changed its compound properties, the characteristics become stable again, so that the tyre does not become significant louder at further reduced temperatures.

16. It is suggested to limit the correction function to the air temperature of 0 °C. This means, when tests are carried out at air temperatures below 0°C, the correction is based on 0°C.

17. The maximum applicable correction is limited to 3 dB(A). This is in line with typical observation on tyre rolling sound for tyres at very cold temperatures.

Figure B
Temperature Correction for C_1 Tyre Rolling Sound Component



Source: OICA, 2021

Background information according to paragraphs 3.2.3. and 3.3.3.

18. In the situation that you carry out a tyre rolling sound reference measurement at the beginning of your testing of the vehicle. Due to the weather situation, the afterwards carried out cruise and acceleration tests might have a drift in temperature (e.g., sun is shining very much). In this case the temperature of tyre reference is too much different from the measurement subject for correction. Before you can extract the power train sound, the tyre reference measurement needs to be adjusted to the temperature condition of the test.

Annex 3, new Appendix 3

19. Addition of new appendix to describe the related coast-by test method for measuring tyre rolling sound emission that matches to the requirements of the 03 series of amendments to UN Regulation No. 51, Annex 3. The measurement results of this method are the base for the calculation of the temperature correction described in Appendix 2 of Annex 3.

Annex 6, paragraph 2.1.

20. The possibility of a simplified conditioning of the tyres in conformity of production (COP) tests has been added to avoid excessive use of tyres before delivery to customer.

Annex 7, paragraph 1.

21. Since Annex 7 needs no temperature compensation (relative judgement) the anchor point must be based on the test results of Annex 3 without any temperature correction. Usually the Annex 7 tests are performed in conjunction with the Annex 3 tests.