

Proposal to replace ECE/TRANS/WP.29/GRBP/2024/8

Document for Reference: measurement uncertainties when testing in UN Regulations under the purview of the Working Party on Noise and Tyres

Submitted by the Informal Working Group on Measurement Uncertainties*

The text below was developed by the Informal Working Group on Measurement Uncertainties (IWG MU) as a Document for Reference. According to the mandate given by the Working Party on Noise and Tyres (GRBP) at its seventy-first session (ECE/TRANS/WP.29/GRBP/69), IWG MU was given the first task to amend UN Regulations Nos. 51 and 117 with the aim to reduce measurement uncertainties. In addition, the Terms of Reference of IWG MU included developing a general approach how to handle measurement uncertainties in UN Regulations.

* In accordance with the programme of work of the Inland Transport Committee for 2024 as outlined in proposed programme budget for 2024 (A/78/6 (Sect. 20), table 20.5), 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.

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1. Scope

This document for reference might be applied to measurement procedures used in UN regulations of the Working Party on Noise and Tyres (GRBP). It supports the definition of limit values during the development of regulations by transparently presenting the measurement uncertainties embodied in the measurement procedures during type approval, conformity of production and other measurement reasons.

It is not intended to question or even soften defined limit values for type approval and production conformity in UN-Regulations.

This document for reference shall not be applied to measurement procedures for vehicles in use dealing with sound emitted by stationary vehicles, ~~as long~~ The Consolidated Resolution on the Construction of Vehicles (R.E.3) already reflects in paragraph 8.8.2.2. the measurement uncertainties of this measurement procedures for UN-Regulations Nos. 9, 41, 51, 59, 63 and 92.

1.1. Dealing with this document for reference

1.1.1. Improvement of measurement procedures used in UN-Regulations

The reference document provides a transparent and systematic view of quantitative measurement uncertainties based on experience with the application of the measurement procedure and developments in measurement technology for the further development of measurement procedures used in UN Regulations of the Working Party on Noise and Tyres (GRBP).

These can be understood as identified potentials for the future improvement of the corresponding measurement procedure and should at least be taken into account when setting future limit values.

1.1.2. Knowledge management

The reference document also serves as a knowledge management tool for measurement procedures, especially for new users who were not involved in the development of measurement procedures. Here, experience with influencing factors and the associated possible effects on the measurement result during the practical implementation of the measurement procedure are presented. This allows new users to critically scrutinize the measurement results and improve the measurement quality.

This document for reference is therefore intended as a living document for findings on measurement methods and their uncertainties. It can be understood as a kind of knowledge database.

1.2. Background

1.2.1. In all kinds of testing of objects according to standards, there is a certain measurement uncertainty. This is also the case for the measurement of sound levels of vehicles and tyres, for example, during type approval of these objects. In standards used for such measurements (ISO, ANSI, CEN, etc.), a separate chapter on measurement uncertainty is mandatory. However, this is not the case in UN Regulations within the responsibility of the Working Party on Noise and Tyres (GRBP).

1.2.2. The focus on in-use compliance checking of vehicles is increasing, as the introduction of Regulation (EU) 2018/858¹ (Market surveillance) shows. In the United States of America, such testing has been in place for decades for emissions and safety, but not for noise.

1.2.3. These kinds of tests will then be performed by institutions that were not involved in the original type approval test ("third party"). Therefore,

uncertainties connected to such market surveillance tests will be of uttermost importance, as a failure could lead to withdrawal of any previously granted type approval of the vehicle/object.

- 1.2.4. Such third-party testing is not within the scope of UN Regulations. However, measurement uncertainties play also an important general role for Conformity of Production (CoP), which is part of UN Regulations for vehicles and tyres.
- 1.2.5. GRBP has therefore been asked to establish an Informal Working Group on Measurement Uncertainties (IWG MU) to work on the following topics:
 - (a) Improvements of test methods;
 - (b) Compensation, if possible (systematic errors);
 - (c) Remaining uncertainties (random errors).
- 1.2.6. As part of this work, IWG MU has developed the Document for Reference “A general approach how to handle measurement uncertainty”². That document gives the basic statistical theory, based on the outline given in the International Organization for Standardization (ISO) Guide to the expression on Uncertainty in Measurement (GUM)³.
- 1.2.7. This Document for Reference is a supplement to the above-mentioned document and outlines the status of measurement uncertainties related to testing according to UN Regulations under the purview of GRBP, e.g. Nos. 51 and 117.
- 1.2.8. The evaluation is based on the current knowledge of the impact of different measurement quantities to the overall uncertainty.
- 1.2.9. In the investigated UN Regulations, it is expected that a continuous development of the measurement procedures and limitations of boundary test conditions may influence the overall estimated uncertainties, as determined in the document. In these cases, this Document for Reference should then be updated, to comprise these changes and revise the uncertainty tables given below.

2. Measurement Uncertainties in UN Regulations

- 2.1. UN Regulation No. 9
(reserved)
- 2.2. UN Regulation No. 28
(reserved)
- 2.3. UN Regulation No. 30
(reserved)
- 2.4. UN Regulation No. 41
(reserved)
- 2.5. UN Regulation No. 51
- 2.5.1. Estimation of the calculation of the expanded measurement uncertainties for sound measurements of Annex 3 for vehicles of category M and N

The method for M_1 , N_1 and $M_2 < 3,500$ kg classes of vehicles (Annex 3) is based on two driving conditions; a constant speed test, L_{crs} , and a wide-open throttle acceleration test, L_{wot} , to determine the final type-approval level, L_{urban} . The uncertainty table in paragraph 2.4 is valid for these categories of vehicles. The uncertainty table in paragraph 2.5 is valid for vehicle categories N_2 , N_3 , $M_2 > 3,500$ kg and M_3 . Vehicles in these categories are only measured according to the wide-open throttle acceleration test.

2.5.2. ISO approach

Based on the probability distribution, variance and standard deviation, the combined standard uncertainty is calculated. For each of the quantities, their contribution to the overall uncertainty (in %) has been calculated and makes it easy to understand the influence of the quantity on the total uncertainty. The percentage is based on the total expanded uncertainty for all for test situations. Some of these quantities can be compensated for, like the influence of temperature and test track variations, while others are of random types, like instrumentation accuracy and cannot be compensated.

The uncertainty is grouped into four different categories: run-to-run, day-to-day, site-to-site and vehicle-to-vehicle. For each of these categories, the uncertainty budget is calculated separately for type approval, CoP and field testing. For type approval, the relevant uncertainty is only related to run-to-run variations, while CoP includes vehicle-to-vehicle variations as well.

2.5.3. Application

This UN Regulation is only related to type-approval and CoP testing. However, due to the introduction of market surveillance and other types of in-use testing, based on this Regulation, it is important to include the uncertainty contribution relating to vehicle-to-vehicle variations.

2.5.4. Uncertainty estimation – vehicle categories M_1 , N_1 and $M_2 \leq 3,500$ kg

Table 5.1. in the Annex is based on this UN Regulation up to Supplement 6. If UN Regulation No. 51 is amended, any implication for the measurement uncertainties shall be evaluated and if necessary, the tables in this Document for Reference shall be updated.

2.5.5. Uncertainty estimation – vehicle categories N_2 , N_3 , $M_2 > 3,500$ kg and M_3

Table 5.2. in the Annex is based on this Regulation up to Supplement 6. If the regulation is amended, any implication for the measurement uncertainties shall be evaluated and if necessary, the tables in this Document for Reference shall be updated.

2.5.6. Special case: Compliance assessment of in-use vehicles of categories M and N

This paragraph provides specifications according to the sound-level measuring method, described in UN Regulation No. 51, when in-use products are selected to verify their compliance to the exterior sound emission.

If the provided specifications in this paragraph need clarification, the requirements described in Annexes 3 and 7 of the 03 series of amendments to UN Regulation No. 51 shall be used.

2.5.6.1. Vehicle Selection

Vehicle should be selected so the following criteria are met:

- (a) Free of accidents.
- (b) The vehicle age is less than 5 years or the vehicle has a mileage of less than 120.000 km, whatever comes first.
- (c) All vehicle manufacturer defined inspection intervals are met and the vehicle is maintained accordingly;
- (d) If spare parts are mounted, they are Genuine Original Equipment Parts, especially for sound emission relevant components (according to vehicle type approval documentation).
- (e) The vehicle has a use history representative for normal use. A vehicle should not be selected, if it has been subject to abusive driving. This includes, but not limited to, any club or street racing.

- (f) Tyres are in an appropriate condition with regard to even wear, no obvious damage, not older than 2 years and a with milage of less than 10,000 km.
- (g) Vehicle has the original hard- and software for the engine, drive train and any component with influence on the sound emission of the vehicle, such as active exhausts systems, sound enhancement systems, etc.
- (h) No optional equipment mounted such as, but not limited to, roof racks or bicycle racks, which could influence the sound emission of the vehicle.

2.5.6.2. Preparation for testing

Before tests on a selected vehicle are carried out, the vehicle engine, cooling system exhaust system and tyres should be warmed up according to the specifications in UN Regulation No. 51.

If so equipped, propulsion batteries should have a state-of-charge sufficiently high to enable all key functionalities according to the specifications of the vehicle manufacturer. Propulsion batteries should be within their component temperature window to enable all key functionalities. Any other type of rechargeable energy storage system should be ready to operate during the test.

A tyre inflation pressure as specified by the manufacturer is mandatory. The wheels of the vehicles should be statically and dynamically balanced.

The fuel quality should be in line with the manufacturer's specification for the nominal power of the engine.

2.5.6.3. During Testing

Tests on vehicles are carried out in accordance with the procedures that have been used for approval of this type of vehicle. For testing, the same pre-acceleration is used as documented in the type approval test report.

The variation of results between runs may be reduced if there is a 1-minute wait, at idle in neutral, between runs.

The documentation of the compliance assessment should at least meet the documentation level of the corresponding test report of type approval measurements e.g., air temperature, air pressure and humidity.

No regeneration of any exhaust emission equipment, such as but not limited to particle filter or NOx filter shall occur during testing. In this case the measurement has to be discarded.

2.5.6.4. Considerations on measurement uncertainties of in-use vehicles testing

After the measurement, additional tyre rolling sound measurements should be carried out in accordance with Supplement 7 to the 03 series of amendments to UN Regulation No. 51 or later versions.

If reference data for tyre rolling sound are available according to CASE 2 of Supplement 7 to the 03 series of amendments to UN Regulation No. 51 or later versions, the tyre rolling sound should be normalized accordingly.

If no reference data are available, the tyre rolling sound should be corrected to the reference temperature according to CASE 1 of Supplement 7 to the 03 series of amendments to UN Regulation No. 51 or later versions.

In view of the tolerances according to different measurement conditions, it will be necessary to allow for a margin in comparison with the corresponding value recorded at the time of the type approval, that is based on the measurement uncertainties table ("Expanded Uncertainty (95%)" of "Field Test") described in Annex 5 of this Document for Reference .

2.6. UN Regulation No. 54

- (reserved)
- 2.7. UN Regulation No. 59
(reserved)
- 2.8. UN Regulation No. 63
(reserved)
- 2.9. UN Regulation No.64
(reserved)
- 2.10. UN Regulation No. 75
(reserved)
- 2.11. UN Regulation No. 92
(reserved)
- 2.12. UN Regulation No. 106
(reserved)
- 2.13. UN Regulation No. 108
(reserved)
- 2.14. UN Regulation No. 109
(reserved)
- 2.15. UN Regulation No. 117
- 2.15.1. Estimation of the calculation of the expanded uncertainty for measurements of the sound of tyres of Annex 3 for tyres of categories C1, C2 and C3.
- Table 15.1. in the Annex is based on UN Regulation No. 117 in its 04 series of amendments up to Supplement 1, but is also valid for the 02 and 03 series of amendments.
- The test condition described in Annex 3 requires four tyres to be fitted on a test vehicle. The pass-by noise is measured during coast-by measurements at the following speed intervals:
- C1/C2 tyres: 70-90 km/h, reference speed: 80 km/h
 - C3 tyres: 60-80 km/h, reference speed: 70 km/h
- The evaluation of uncertainty is based on the ISO approach.
- 2.15.2. Application
- The uncertainty calculation below is only related to type-approval of a single tyre. Thus, the influence of tyre variations (for example for noise labelling purposes) are not relevant for estimation of the overall 95% expanded uncertainty
- 2.15.3. Uncertainty estimation for tyres
- Table 15.1. in the Annex is based on UN Regulation No. 117 up to Supplement 1 of the 04 series of amendments. If the Regulation is amended, any implication for the measurement uncertainties shall be evaluated and if necessary, the table in this Document for Reference shall be updated.
- 2.16. UN Regulation No. 124
(reserved)
- 2.17. UN Regulation No. 138
(reserved)

- 2.18. UN Regulation No. 141
(reserved)
- 2.19. UN Regulation No. 142
(reserved)
- 2.20. UN Regulation No. 164
(reserved)
- 2.21. UN Regulation No. 165
(reserved)

3. References

- [1] Regulation (EU) 2018/858 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.
- [2] ECE/TRANS/WP.29/GRBP/2022/9/Rev.1. A general approach how to handle measurement uncertainty
- [3] ISO/IEC Guide 98-3:2008. Uncertainty of measurements. Part 3 – Guide to the expression of uncertainty in measurements (GUM:1995).

Annex

Measurement Uncertainty Tables

- 1. UN Regulation No. 9**
reserved
- 2. UN Regulation No. 28**
reserved
- 3. UN Regulation No. 30**
reserved
- 4. UN Regulation No. 41**
reserved

5. UN Regulation No. 51

Table 5.1.

Estimation of uncertainty per situation for M_1, N_1 and $M_2 \leq 3,500$ kg, based on this Regulation up to Supplement 6

Situation	Input Quantity	Estimated deviations of the meas. result (weak-)		Impact on Lurb	Probability Distribution	Variance	Standard uncertainty	Share	Comb. stand. uncertainty	Uncertainty Budgets			expanded uncertainty 95%
		Lwot	Lers							Type Approval	CoP	Field Tests	
Run to Run	Microclimate wind effect	1,60	1,50	1,57	gaussian	0,15	0,392	5,6%	0,53	0,53	0,53	0,53	1,1
	Driver #1: Deviation from centred driving	0,50	0,50	0,50	rectangular	0,02	0,144	0,8%					
	Driver #2: Start of acceleration	0,60	0,00	0,40	rectangular	0,01	0,144	0,5%					
	Driver #3: Speed variations of +/- 1km/h	0,30	0,50	0,50	rectangular	0,02	0,144	0,8%					
	Driver #4: Load variations during cruising	0,00	1,00	0,34	gaussian	0,01	0,085	0,3%					
	Varying background noise	0,40	0,40	0,40	rectangular	0,01	0,115	0,5%					
	Variation on operating temperature of engine (WOT) and tyres (WOT&CRS) => See ISO 362-1 note	0,80	0,80	0,80	rectangular	0,05	0,231	2,0%					
Day to Day	Barometric pressure (Weather +/- 30 hPa)	0,40	0,40	0,40	gaussian	0,01	0,100	0,4%	0,92	0,92	0,92	0,92	1,8
	Air temperature effect on tyre noise (5-10°C)	0,00	0,00	0,00	rectangular	0,00	0,000	0,0%					
	Air temperature effect on tyre noise (10-40°C)	2,20	3,60	2,67	rectangular	0,60	0,772	21,9%					
	Varying background noise during measurement	0,00	0,00	0,00	rectangular	0,00	0,000	0,0%					
	Air intake temperature variation	1,60	0,00	1,06	rectangular	0,09	0,305	3,4%					
	Residual humidity on test track surface	0,90	2,10	1,31	rectangular	0,14	0,377	5,2%					
Site to Site	Altitude (Location of Track) -100 hPa/1000m (fr.1015 to 915 hPa)	0,70	0,70	0,70	rectangular	0,04	0,202	1,5%	1,24		0,62	1,24	2,5
	Test Track Surface	3,40	5,50	4,11	rectangular	1,41	1,187	51,8%					
	Microphone Class 1 IEC 61672	1,00	1,00	1,00	gaussian	0,06	0,250	2,3%					
	Sound calibrator IEC 60942	0,50	0,50	0,50	gaussian	0,02	0,125	0,6%					
	Speed measuring equipment continuous at PP	0,10	0,10	0,10	rectangular	0,00	0,029	0,0%					
	Acceleration calculation from vehicle speed measurement	0,50	0,50	0,50	rectangular	0,02	0,144	0,8%					
Vehicle to Vehicle	Production Variation on Tyres; Aging of Tyres until delivery to customer (1dB after one year)	0,80	1,50	1,04	gaussian	0,07	0,259	2,5%	0,57		0,57	0,57	1,1
	Tyres at minimum tread depth	0,40	0,40	0,40	gaussian	0,04	0,209	1,8%					
	Variation on Tyre Size and Brand (non-OEM)	0,00	0,00	0,00	gaussian	0,00	0,000	0,0%					
	Production Variation in Power, incl. proper break-in of a brand-new engine	0,40	0,40	0,40	rectangular	0,01	0,115	0,5%					
	Battery state of charge for HEVs (3 dB(A))	0,00	0,00	0,00	rectangular	0,00	0,000	0,0%					
	Production Variability of Sound Reduction Components	1,10	0,00	0,73	gaussian	0,03	0,182	1,2%					
	Impact of variation of vehicle mass	1,60	1,60	1,60	rectangular	0,21	0,462	7,8%					

100 %

Overall Combined Uncertainty +/-	Expanded uncertainty (95%) +/-
1,73	3,46

Expanded uncertainty (95%) +/-		
Type Approval	CoP	Field Test
2,12	2,71	3,46

Table 5.2.
 Estimation of uncertainty per situation for N₂, N₃ and M₂ > 3,500 kg and M₃, based on this Regulation up to Supplement 6

Situation	Input Quantity	Estimated deviations of the meas. result (peak-peak)		Impact on Lurb	Probability Distribution	Variance	Standard uncertainty	Share	Comb. stand. uncertainty	Uncertainty Budgets			expanded uncertainty 95%
		Lwot	Lers							Type Approval	CoP	Field Tests	
Run to Run	Microclimate wind effect – head or tail	0	NA	0	gaussian	0,000	0,00	0,0%	0,30	0,30	0,30	0,30	0,59
	Deviation from centred driving	0,50	NA	0,50	rectangular	0,021	0,14	2,0%					
	Speed at BB’ – Target vehicle speed (+/- 5 km/h), (target engine speed (+/-2%)	0,40	NA	0,40	rectangular	0,013	0,12	1,3%					
	Varying background noise	0,10	NA	0,1	gaussian	0,001	0,03	0,1%					
	Variation on operating temperature of engine and tyres => See ISO 362-1 note	0,80	NA	0,80	rectangular	0,053	0,23	5,1%					
Day to Day	Ambient temperature influence on sound transmission in air	0,6	NA	0,6	rectangular	0,030	0,17	2,9%	0,46	0,46	0,46	0,46	0,91
	Ambient barometric pressure influence on sound transmission in air	0,9	NA	0,9	rectangular	0,068	0,26	6,5%					
	Ambient humidity influence on sound transmission in air	0,1	NA	0,1	rectangular	0,001	0,03	0,1%					
	Ambient air temperature influence on engine power (based on R85)	1,0	NA	1,0	rectangular	0,083	0,29	8,0%					
	Ambient air temperature effect on ICE vehicles due to tyre noise (5-40°C)	0,4	NA	0,4	rectangular	0,013	0,12	1,3%					
	Barometric pressure effect on engine power (based on R85)	0,4	NA	0,4	rectangular	0,013	0,12	1,3%					
Site to Site	Altitude effect on combustion and sound propagation (Range: 1000 m) (95-105 kPa)	0,9	NA	0,9	rectangular	0,068	0,26	6,5%	0,50		0,50	0,50	1,0
	Test Track Surface	1,3	NA	1,3	gaussian	0,106	0,33	10,2%					
	Microphone Class 1 IEC 61672	1	NA	1	gaussian	0,063	0,25	6,0%					
	Sound calibrator IEC 60942	0,5	NA	0,5	gaussian	0,016	0,13	1,5%					
	Speed measuring equipment continuous at BB	0,1	NA	0,1	gaussian	0,001	0,03	0,1%					
Vehicle to Vehicle	Production Variation on Tyres; Aging of Tyres until delivery to customer (1dB after one year)		NA						0,70		0,35	0,70	1,4
	Tyre – generic dispersion (Normal, tread depth, inflation pressure, model etc)	2,8	NA	2,8	gaussian	0,49	0,70	47,2%					
	Production Variation in Power, incl. proper break-in of a brand-new engine		NA										
	Battery state of charge for HEVs (3 dB(A))		NA										
	Production Variability of Sound Reduction Components		NA										
Test mass – variation as a consequence of the definition		NA											

100 %

Overall Combined Uncertainty +/-	Expanded uncertainty (95%) +/-
1,02	2,04

Expanded uncertainty (95%) +/-		
Type Approval	CoP	Field Test
1,09	1,64	2,04

6. UN Regulation No. 54

reserved

- 7. UN Regulation No. 59**
reserved
- 8. UN Regulation No. 63**
reserved
- 9. UN Regulation No.64**
reserved
- 10. UN Regulation No. 75**
reserved
- 11. UN Regulation No. 92**
reserved
- 12. UN Regulation No. 106**
reserved
- 13. UN Regulation No. 108**
reserved
- 14. UN Regulation No. 109**
Reserved

15. UN Regulation No. 117Table 15.1.
Uncertainty calculation for tyres

<i>Estimation of uncertainty per situation</i>	<i>Input quantity</i>	<i>Estimated deviations from meas.results (peak-to-peak)</i>	<i>Probability distribution</i>	<i>Variance</i>	<i>Standard uncertainty</i>	<i>Share, %</i>
Single run-to single run	Microclimate wind effect	0,8	gaussian	0,04	0,20	1,4
	Deviation from centered driving	0,5	rectangular	0,02	0,14	0,7
	Varying background noise	0,4	rectangular	0,01	0,12	0,5
Day-to-day	Residual temperature influence (After correction for C1/C2)	0,9	rectangular	0,07	0,26	2,3
	Vehicle contribution	2,0	gaussian	0,25	0,50	8,5
	Residual humidity on test track surface	1,1	rectangular	0,10	0,32	3,4
Site-to-site	Test track surface	5,4	rectangular	2,43	1,56	82,3
	Microphone class 1	0,5	gaussian	0,02	0,13	0,5
	Sound Calibrator class 1	0,5	gaussian	0,02	0,13	0,5
	Speed measuring equipment	0,1	gaussian	0,00	0,03	0,0
Sum				2,95		100,0

Coverage Factor	Overall expanded uncertainty +/-	Expanded uncertainty, 95% +/-
k=2 (95%)	1,72	3,44

16. UN Regulation No. 124

reserved

17. UN Regulation No. 138

reserved

18. UN Regulation No. 141

reserved

19. UN Regulation No. 142

reserved

20. UN Regulation No. 164

reserved

21. UN Regulation No. 165

reserved