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Transmitted by the experts from IWG MU

Proposal for a Document for Reference: Measurement Uncertainties when Testing in WP.29 GRBP Vehicle Regulations

The text below was developed by the Informal Working Group on Measurement Uncertainties (IWG MU) as a document for reference. According to the mandate of 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 No.117 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.

Document for Reference:

Measurement Uncertainties when Testing in WP.29 GRBP Vehicle Regulations

Contents

1 Background

In all kinds of testing of objects according to standards, there is a certain measurement uncertainty. This is also the case of 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 ECE regulations within the responsibility of Working Party on Noise and Tyres, GRBP.

The focus on In-use compliance checking of vehicles is increasing, as the introduction of the Regulation (EU) 2018/858[1] (Market surveillance) is showing. In the US., such testing has been in place for decades for emissions and safety (not noise).

These kinds of tests will then be performed by institutions 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 they could withdraw any previous given type-approval to the vehicle/object.

Such third-party testing is not within the scope of UN ECE, however measurement uncertainties have also an important role in general for Conformity of Production (COP), which is part of UN ECE regulations for vehicles and tyres.

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)

As part of this work, IWG MU has developed a Document for Reference: “A general approach how to handle measurement uncertainty”[2]. This document gives the basic statistical theory, based on the outline given in the ISO Guide to the expression on Uncertainty in Measurement (GUM)[3].

This Document for Reference is a supplement to the above-mentioned document and outlines the status of measurement uncertainties related to testing according to regulations which are subject of GRBP e.g., UN Regulation No. 51/03 and UN Regulation No.117.

The evaluation is based on the current knowledge of the impact of different measurement quantities to the overall uncertainty.

In investigated 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 this document. In these cases, this Document for Reference should then be updated, to comprise these changes and revise the uncertainty tables given in this document.

2 Measurement Uncertainties in 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 M1, N1 and M2 < 3500 kg classes of vehicles (Annex 3) is based on two driving conditions; a constant speed test, Lcrs, and a wide-open throttle acceleration test, Lwot, to determine the final type-approval level, Lurban. 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 classes N2, N3, M2 >3500 kg and M3. Vehicles in these classes are only measured according to the wide-open throttle acceleration test.

2.5.2 ISO approach

Based on the probability distribution, the variance and the 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 4 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 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 – M1, N1 and M2 < 3500 kg

Table 5.1. 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.

2.5.5 Uncertainty estimation – N2, N3, M2 > 3500 kg and M3

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.

2.6 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 category C1, C2 and C3.

Table 15.1. in the Annex is based on this regulation in its 04 series of amendments up to Supplement 1.

Is it also valid to 02 and 03 series of amendments of UN R 117?

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: 70-90 km/h, reference speed: 80 km/h
- C3: 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 this regulation up to supplement 1 of the 04 series of amendments of 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 M1, N1 and M2 < 3500 kg

Situation	*Input Quantity*	*Estimated deviations of the meas. result (meak-*		*Impact on Lurb*	*Probability Distribution*	*Variance*	*Standard uncertainty*	*Share*	*Comb. stand. uncertainty*	*Uncertainty Budgets*			*expanded uncertainty 95%*
		Lwot	*Lcrs*							*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	0,02%					
	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 > 3500 kg and M3

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	*Lcrs*							*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. 117

Table 15.1.: Uncertainty calculation for tyres

Estimation of uncertainty per situation	*Input quantity*	*Estimated deviations from meas.results (peak-to-peak)*	*Probability distribution*	*Variance*	*Standard uncertainty*	*Share, %*
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