Proposal for Amendment 5 of the Mutual Resolution No. 1 (M.R.1) of the 1958 and the 1998 Agreements

Submitted by the Chair (Republic of Korea) of the Informal Working Group on the Deployable Pedestrian Protection Systems of UN Global Technical Regulation No. 9.

The text reproduced below was prepared by the expert from the Informal Working Group on the Deployable Pedestrian Protection Systems of UN Global Technical Regulation No. 9.
It is to amend the Proposal for a new Amendment 5 of the Mutual Resolution No. 1 (M.R.1) of the 1958 and the 1998 Agreements and proposes provisions on a new Addendum 6 concerning the development of HBM qualification corridors for Annex 2 to GTR No. 9.
The modifications to the current text of the Working Document ECE/TRANS/WP.29/GRSP/2023/7e and GRSP-73-XX are marked in bold for new or strikethrough for deleted characters.

Contents, amend to read:

"Contents

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Section II,

Paragraphs 3. and 3.1., Specific provisions, amend to read:

3. Specific provisions

3.1. The table below details the individual addenda to this Mutual Resolution in which details of the design, construction, maintenance and preparation of the test devices or equipment can be found.

ECE/TRANS/WP.29/1101	*Generic name of the Test Tool*	*Regulation(s) requiring the test Tool Device*	*Global technical regulation(s) requiring the Test Tool or Device*	*Date of adoption of the Addendum*
… - Addendum 1 to M.R.1	(Reserved) BioRID Dummy	…	…	…
Amend.1 - Addendum 2 to M.R.1	WorldSID 50th male Dummy	No. 135	No. 14	12 Nov. 2014
Amend.2 - Addendum 3 to M.R.1	FlexPLI	No. 127	No. 9	
Amend.3 - Addendum 4 to M.R.1	(Reserved) Q Dummy	…	…	**…**

ECE/TRANS/WP.29/1101	*Generic name of the Test Tool*	*Regulation(s) requiring the test Tool Device*	*Global technical regulation(s) requiring the Test Tool or Device*	*Date of adoption of the Addendum*
Amend.4 - Addendum 5 to M.R.1	GV models	No. 127	No. 9	**[ ]**
Amend.5 - Addendum 6 to M.R.1	**HBM corridors**	**No. 127**	**No. 9**	**[ ]**

"

Appendix, amend to read:

"Addendum 1 – [Reserved for Bio Rear Impact Dummy (BioRID) specifications]

Addendum 2 – Specifications for the Construction, Preparation and Certification of the World Side Impact 50th percentile adult male anthropomorphic test device (WorldSID 50th male)

Addendum 3 – Specifications for the Construction, Preparation and Certification of the flexible Pedestrian Legform Impactor (FlexPLI)

Addendum 4 – [Reserved for Q Dummies]

Addendum 5 – Generic Vehicle (GV) models for qualification of HBMs for HIT determination simulations

Addendum 6 – Reference Results of Human Body Models for HIT determination simulations (HBM corridors)

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1. General provisions

1.1. **This Addendum provides the specifications for the reference corridors for the qualification of pedestrian models according to GTR No.9 amendment 3 Annex 2, hereafter called Annex 2 for HIT determination simulation. This document specifies the corridors and describes their development.**

1.2. **The reference Human Body Models have been validated in a harmonised way. This information is background and explains the validation. The validations do not have to be repeated by the users for the qualification of the Human Body Models.**

2. Background - validation of reference Human Body Models

2.1. This section contains a description of the validation of the reference AM50 human body models that were used for the definition of the qualification corridors, as depicted in Chapter 2.5 of Annex 2. The validation procedure, in contrast to the qualification simulations1, describes the process towards determination of the degree to which the reference models represent the pedestrian kinematics during real world crashes.

2.2. For their individual validations, the different HBMs had to undergo a harmonized procedure. This procedure consisted of simulations of the HBM against a model representing a generic vehicle frontend (SAE buck2) used in post-mortem-human-subject (PMHS) experiments3. The SAE buck simulation model is part of the THUMS User Community validation repository4. It has been validated by comparing its responses to previously published impactor tests with a hardware version of the SAE buck2, shown in Figure 1.

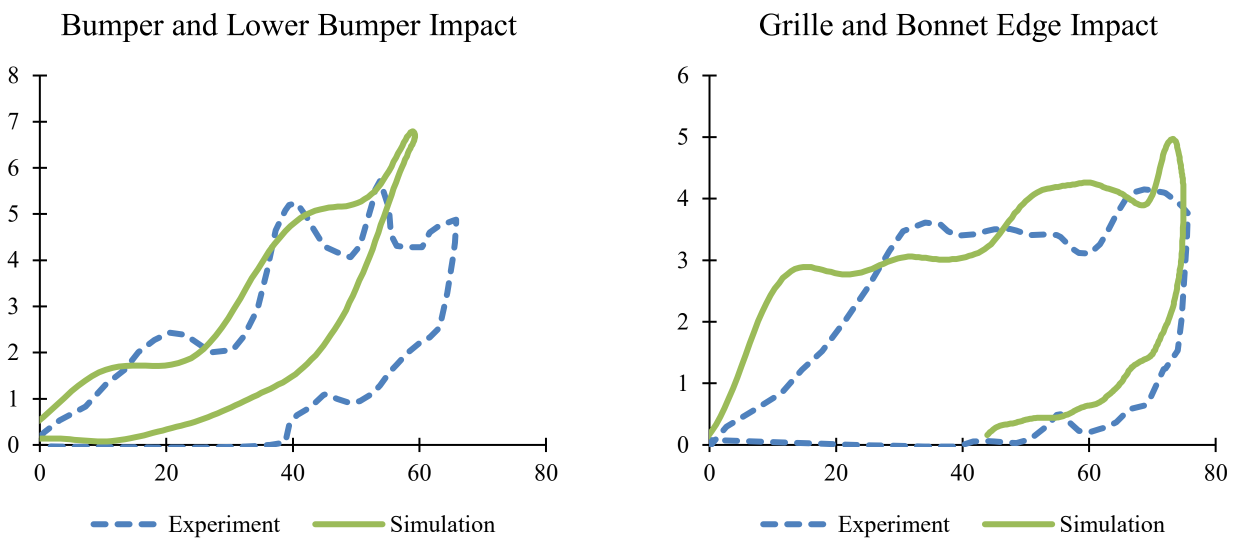

Figure 1: Impactor responses of SAE bucks used for Human Body Model validation

2.3. **The HBM responses were compared to scaled corridors3 derived from three tests with PMHS. The procedure used for the validation of those models that were used for the qualification corridors is limited to the purpose of pedestrian Head Impact Time (HIT) and Wrap Around Distance (WAD) calculation. It is not suited to qualify for injury assessment in UN-GTR No. 9 or any other crashworthiness regulation. If HBMs are intended for extended usage, more enhanced validations are needed.**

2.4. **To validate the very same model, which is used for the qualification simulations, the HBM posture was not aligned with the PMHS tests, but corresponded to Table 2-1 of Annex 2 instead. The main difference between the two postures from the PMHS tests and Annex 2 Table 2-1 is the arm posture (the PMHS leg position and the proposed HBM position both target the SAE J27825 measures and are therefore comparable). Previous studies have shown that the arm posture effects HIT by roughly ±3 ms1 which is smaller than the range of results observed in the PMHS study.**

2.5. **The HBMs were positioned vertically relative to the SAE buck such that the centre of gravity of the acetabulum (AC) (as defined in Fig. A.3 in Annex 2) is positioned at a height of 932 mm. (Based on the offset between H-Point and pelvis reference point used for tracking defined in SAE J27825, the provided location of the pelvis reference point3 was offset by 73 mm to convert it to the AC location. The minimum value of the pelvis reference point from the corridor was taken to ensure that the centre of gravity of the head (HC) requirements from Table 2-1 of Annex 2 are not contradictory.) For the lateral position, AC was aligned with the vehicle centreline.**

2.6. **No ground floor was modelled. Gravity was applied and the HBM was positioned as close as possible to the vehicle model. The SAE buck model driving towards the HBM with an initial velocity of 40 km/h. The same contact settings as defined in 2.2 of Annex 2 were used (i.e. the static and dynamic coefficient of friction between the car and the HBM is set to 0.3.).**

2.7. **All outputs as described in 2.3. of Annex 2 were generated and analysed. From the simulations, the HIT was calculated according to 3.3 of Annex 2. All reference HBMs fulfilled the criteria defined in Table 2-11 of Annex 2 based on the scaled corridors from the PMHS tests[3] (transformed to the coordinate system defined in Figure A.1 of Annex 2) while also fulfilling all quality checks defined in 2.4. of Annex 2. For the calculation of ΔHCx, HCx was offsetted with its value at the time of first contact with the vehicle to be in line with the PMHS tests[3]. For the HIT, the mean value from the PMHS tests was taken and a tolerance of +5 / -10 percent was added (consistent to the trajectories as specified in SAEJ2868[6]).**

Table 1: Validation of AM50 HBMs

	HIT (ms)		ΔHCx (mm)		HCz (mm)	
	Min	Max	Min	Max	Min	Max
Reference from PMHS Tests	117	159	-1653	-1402	1020	1271
GHBMC M50-PS v5.3.4 LS-DYNA MPP R10.2	136.6		-1492		1160	
GHBMC M50-PS v1.5 Radioss 2019.2.5	139.4		-1614		1181	
GHBMC M50-PS v5.33 R1.09 VPS 2019.0.4	130.3		-1500		1186	
GHBMC M50-P v5.3.4 LS-DYNA MPP R10.2	140.7		-1503		1182	
JAMA pedestrian_AM50 ver6.2.1. LS-Dyna MPP R10.0	141.9		-1586		1191	
THUMS v4.02 TB024 (05/22) LS-Dyna MPP R9.3	141.6		-1622		1223	
THUMS v4.02 (licensed) LS-Dyna MPP R12	140.5		-1609		1224	
THUMS v4.02 VWG006.2 Aud165VH VPS 2020.54	135.6		-1574		1219	

2.8. **For the other statures, no reference PMHS tests were available. The following reference HBMs have been used for developing the corridors of Annex 2.**

Table 2: Reference models used for 6yo and AF05

05F	6yo
GHBMC F05-PS v5.3.4 LS-DYNA MPP R10.2	GHBMC 6YO-PS v2.8.1 LS-DYNA MPP R10.2
GHBMC F05-PS v1.6 Radioss 2019.2.5	GHBMC 6YO-PS v2.4-scale Radioss 2019.2.5
GHBMC F05-PS V1.6 R1.09 VPS 2019.0.4	GHBMC C6YO-PS v2.43 R1.11 VPS 2019.0.4
GHBMC F05-P v5.3.4 LS-DYNA MPP R10.2	JAMA pedestrian_6YO ver6.2.1. LS-Dyna MPP R10.0
JAMA pedestrian_AF05 ver6.2.1. LS-Dyna MPP R10.0	THUMS v4.02 TB024 (05/22) LS-Dyna MPP R9.3
THUMS v4.02 TB024 (05/22) LS-Dyna MPP R9.3	THUMS v4 (licensed with mass adjustment) LS-Dyna R12
THUMS v4.00 VWG003 Aud080VF VPS 2020.54	PIPER v00.08 PIPEpA100V6 VPS 2020.54
THUMS v4 (licensed) LS-Dyna MPP R12	PIPER v1.0.2 LS-Dyna MPP R12

3. Reference Results for Qualification Simulations

3.1. **From the qualification simulations with the generic vehicle models, HIT values and the location of HC at the time of head impact shall be compared with the references in Tables 3-5.**

3.2. **These tables have been created using simulations with validated HBMs (see 2.). The corridors were created based on the results of the above shown reference models. The mean values were calculated for HIT, HCx and HCz together with the standard deviation. The tolerance was defined for each measure as mean value ± 2.5 x standard deviation.**

3.3. **The trajectories are measured relative to the generic vehicle model, which means that the x-displacement of the generic vehicle has to be subtracted from the measured x coordinate HCx in the global coordinate system. For HCz the global z-coordinate are used.**

3.4. **The AM95 does not need to be specifically qualified. AM95 models which can be used are all derived from AM50 models and therefore the AM95 only has to meet the positioning requirements and no specific qualification simulations need to be performed.**

Table 3: AM50

GV Type	Velocity (km/h)	HIT (ms)		HCx (mm)		HCz (mm)	
		Min	Max	Min	Max	Min	Max
FCR	30	152	197	-1438	-1005	1019	1117
	40	127	150	-1489	-1105	1006	1158
	50	107	121	-1504	-1179	1024	1169
RDS	30	163	199	-1574	-1104	931	1125
	40	133	156	-1659	-1191	931	1178
	50	112	127	-1665	-1283	981	1183
SUV	30	127	144	-1000	-624	1092	1193
	40	101	116	-1032	-737	1103	1187
	50	86	99	-1110	-799	1109	1191

Table 4: 6YO

GV Type	Velocity (km/h)	HIT (ms)		HCx (mm)		HCz (mm)	
		Min	Max	Min	Max	Min	Max
FCR	30	60	79	-388	-325	909	942
	40	49	61	-427	-358	905	954
	50	43	50	-457	-387	889	972
RDS	30	65	81	-478	-362	857	914
	40	52	63	-495	-409	852	923
	50	44	54	-524	-449	848	929
SUV	30	35	50	-154	-97	1010	1033
	40	28	39	-183	-134	1024	1050
	50	18	36	-218	-160	1023	1089

Table 5: AF05

GV Type	Velocity (km/h)	HIT (ms)		HCx (mm)		HCz (mm)	
		Min	Max	Min	Max	Min	Max
SUV	30	90	102	-622	-447	1042	1133
	40	69	82	-679	-496	1046	1126
	50	59	70	-736	-527	1048	1127

References

[1] Klug, Corina; Feist, Florian; Raffler, Marco; Sinz, Wolfgang; Petit, Philippe; Ellway, James; van Ratingen, Michiel (2017): Development of a Procedure to Compare Kinematics of Human Body Models for Pedestrian Simulations. In: 2017 IRCOBI Conference Proceedings. http://www.ircobi.org/wordpress/downloads/irc17/pdf-files/64.pdf.

[2] Pipkorn, Bengt; Forsberg, Christian; Takahashi, Yukou; Ikeda, Miwako; Fredriksson, Rikard; Svensson, Christian; Thesleff, Alexander (2014): Development and component validation of a generic vehicle front buck for pedestrian impact evaluation. In: 2014 IRCOBI Conference Proceedings. http://www.ircobi.org/wordpress/downloads/irc14/pdf_files/82.pdf

[3] Forman, J. L.; Hamed Joodaki; Ali Forghani; Patrick Riley; Varun Bollapragada; David Lessley et al. (Hg.) (2015): Biofidelity Corridors for Whole-Body Pedestrian Impact with a Generic Buck. International Research Council on the Biomechanics of Injury. Lyon, France. http://www.ircobi.org/wordpress/downloads/irc15/pdf_files/49.pdf

[4] SAE Buck Models: DOI: 10.5281/zenodo.7870181

[5] Performance Specifications for a Midsize Male Pedestrian Research Dummy SAE J2782_201911 https://doi.org/10.4271/J2782_201911

[6] Pedestrian Dummy Full Scale Test Results and Resource Materials SAE J2868_201010