Response to the ETRTO proposal for the test precision improvement of wet test for worn tyres <2024-25 test campaign>

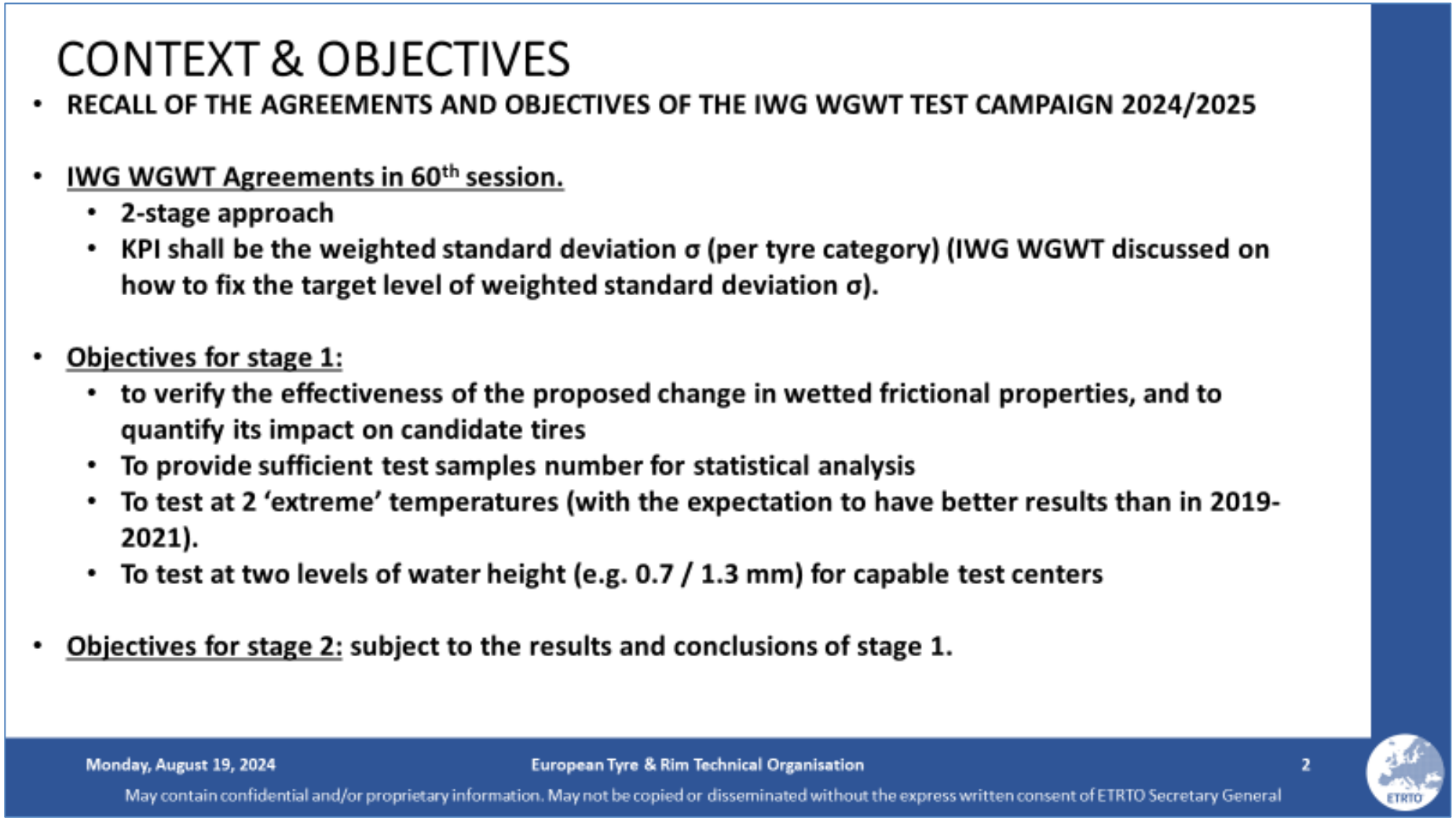
(WT-61-2 ETRTO additional inputs for workplan 2024-2025 v1)

5. September, 2024

JAPAN AUTOMOBILE STANDARDS INTERNATIONALIZATION CENTER

1. Background

ETRTO presented WT-61-2 v1 in 61st IWG WGWT.



CONTEXT & OBJECTIVES

- RECALL OF THE AGREEMENTS AND OBJECTIVES OF THE IWG WGWT TEST CAMPAIGN 2024/2025
- IWG WGWT Agreements in 60th session.
  - 2-stage approach
  - KPI shall be the weighted standard deviation σ (per tyre category) (IWG WGWT discussed on how to fix the target level of weighted standard deviation σ).
- Objectives for stage 1:
  - to verify the effectiveness of the proposed change in wetted frictional properties, and to quantify its impact on candidate tires
  - To provide sufficient test samples number for statistical analysis
  - To test at 2 'extreme' temperatures (with the expectation to have better results than in 2019-2021).
  - To test at two levels of water height (e.g. 0.7 / 1.3 mm) for capable test centers
- Objectives for stage 2: subject to the results and conclusions of stage 1.

Monday, August 19, 2024 European Tyre & Rim Technical Organisation 2

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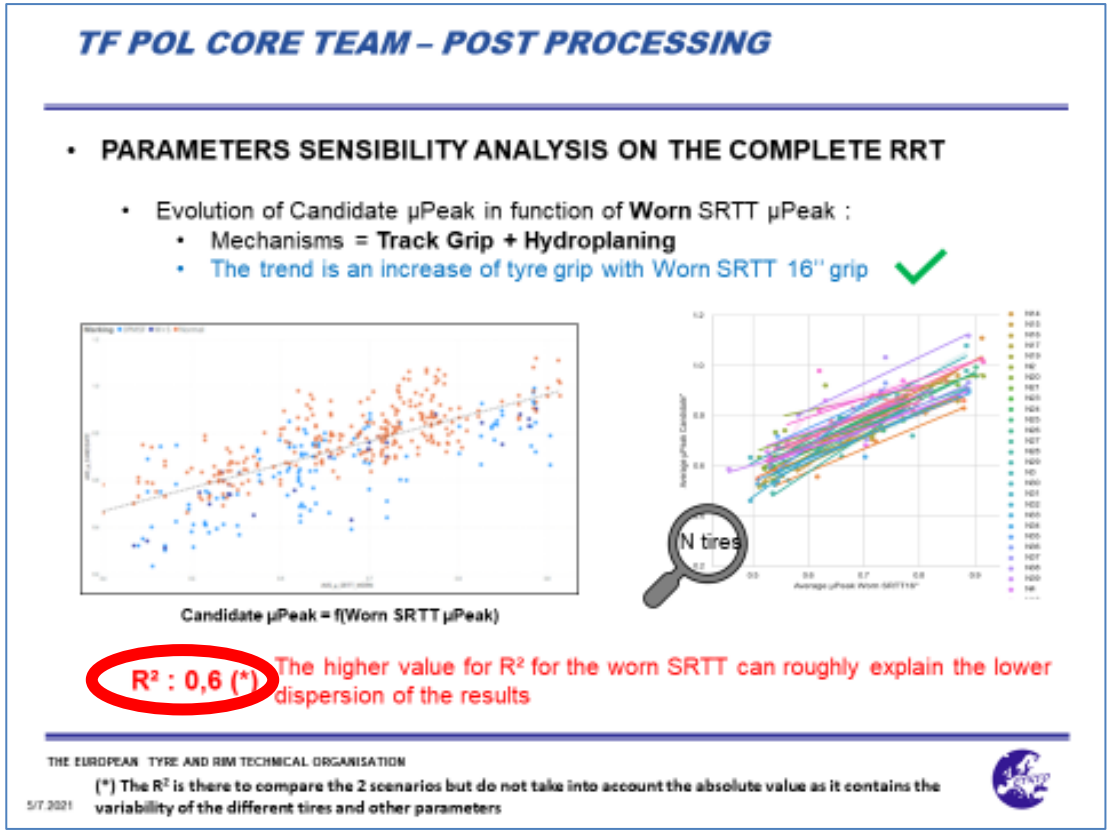
JASIC reviewed the ETRTO proposal.
Before going into the details, JASIC would like to remind the history.

2. The problem of current wet test for worn tyres

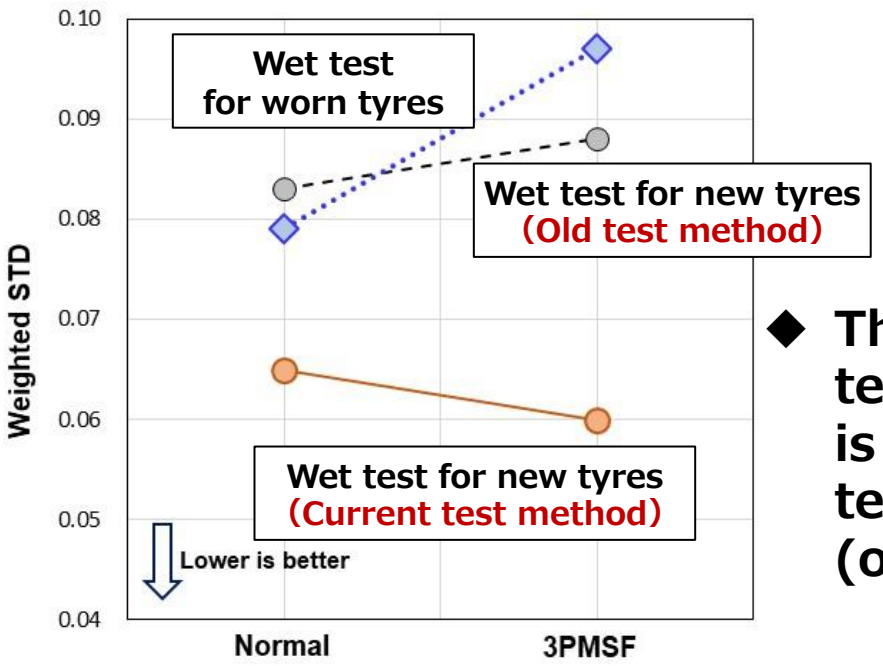


◆ **Correlation coefficient of 2019-2021 test campaign is not sufficient.**

$R^2 = 0.6$

Variation of each test (weighted standard deviation)

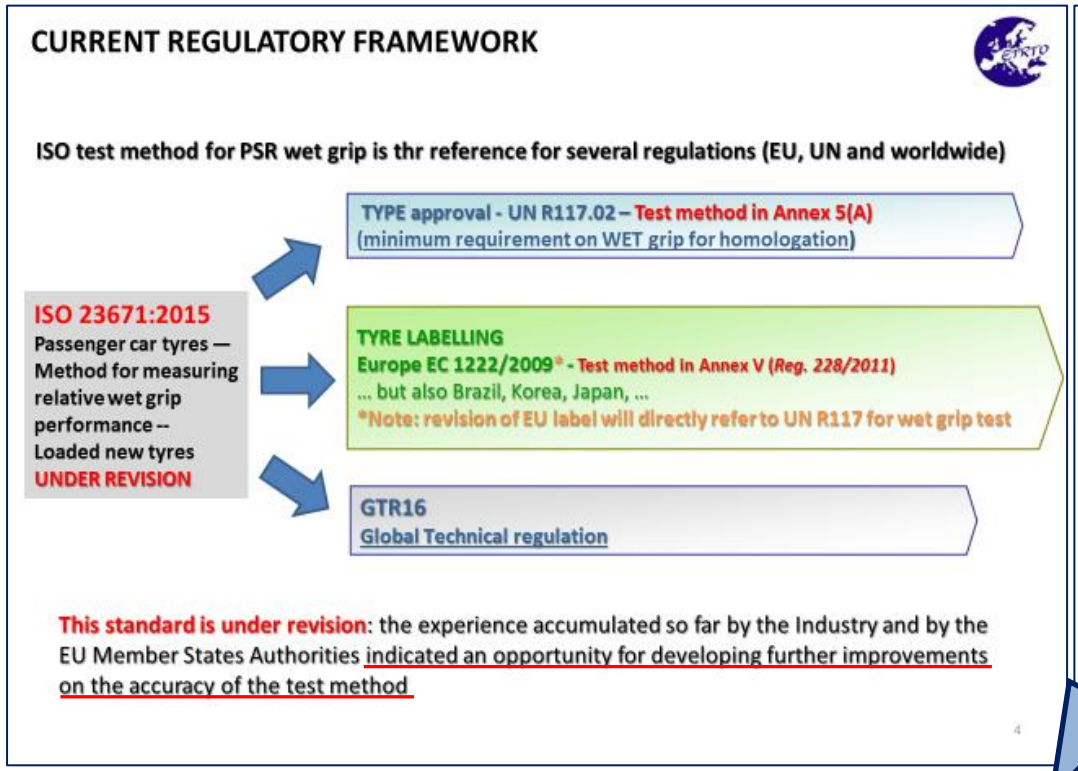
Tyre category	Wet test for new tyres		Wet test for worn tyres
	Old test method	Current test method	
Normal	0.083	0.065	0.079
3PMSF	0.088	0.060	0.097

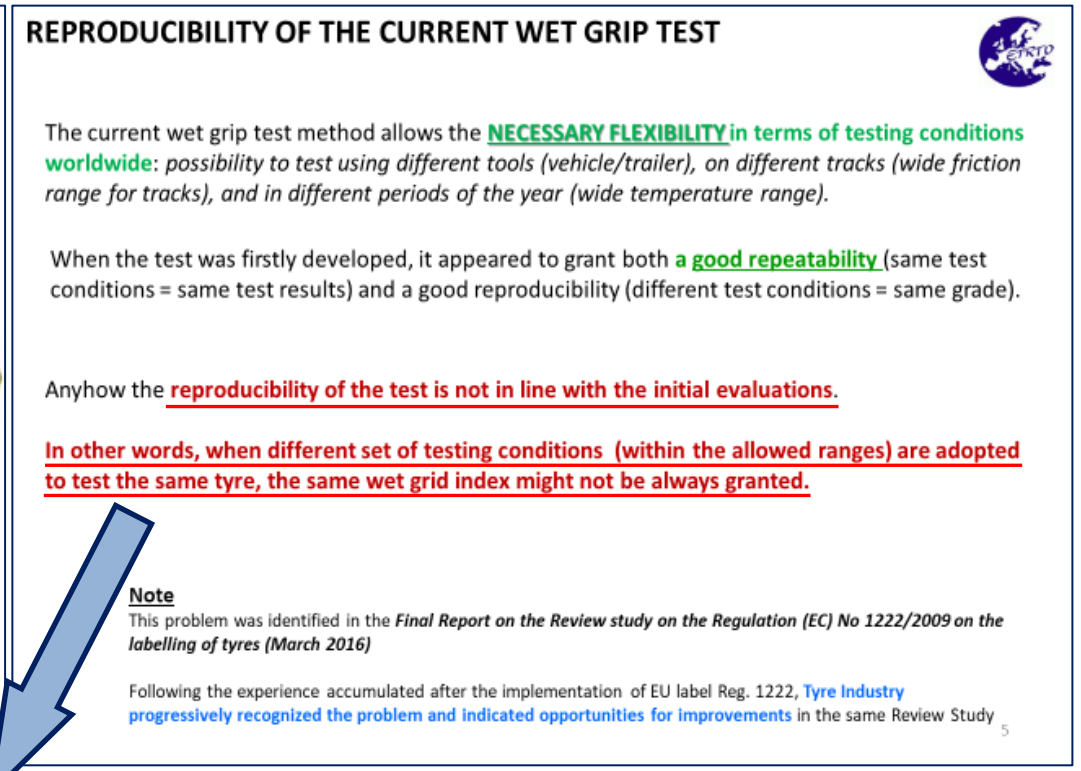


◆ **The variation of wet test for worn tyres is same level as wet test for new tyres (old test method)**

JASIC had advocated that the current wet test for worn tyres is not sufficient since 2021 and continuously requested to improve test precision including the upgrading the correction formula.

2. The problem of current wet test for worn tyres





In other words, when different set of testing conditions (within the allowed ranges) are adopted to test the same tyre, the same wet grip index might not be always granted.

The concern for old test method of wet test for new tyres was “the same wet grip index might not be always granted under the different test condition” therefore ETRTO proposed to improve the test precision by themselves in the past.

2. The problem of current wet test for worn tyres

Test method		Correction Formula (Trailer method)
Wet test for new tyres	**Old test method**	$G(T)=\left[\frac{\mu_{peak,ave}(T)}{\mu_{peak,ave}(R)}\times 125+a\times(t-t_0)+b\times\left(\frac{\mu_{peak,ave}(R)}{\mu_{peak,ave}(R_0)}-1.0\right)\right]\times 10^{-2}$ **Correction factor 2** **a**:temperature **b**:μ
	Current test method	$G(T_n)=K_{trailer}\cdot\{\overline{\mu_{peak}}(T_n)-[a\cdot\Delta\mu_{peak}(R)+b\cdot\Delta\vartheta+c\cdot(\Delta\vartheta)^2+d\cdot\Delta MTD]\}$ **Correction factor 4** **a**:μ **b**:temp. **c**:square of temp. **d**:MTD
Wet test for worn tyres		$G_B(T_n)=K_{trailer}\cdot\{\overline{\mu_{peak}}(T_n)-[a\cdot\Delta\mu_{peak}(R)+b\cdot\Delta\vartheta+c\cdot(\Delta\vartheta)^2+d\cdot\Delta MTD]\}$ **Correction factor 4** **a**:μ **b**:temp. **c**:square of temp. **d**:MTD

- **Even if the correction formula of wet test for worn tyres refers the current wet test for new tyres (4 correction factors), the variation of wet test for worn tyres is same as old test method of wet test for new tyres. It is obvious that current correction formula of wet test for worn tyres is not sufficient (lack of unknown factor or value of factor is not precise enough).**

JASIC believes that the improvement of correction formula including the influence of water depth is necessary.

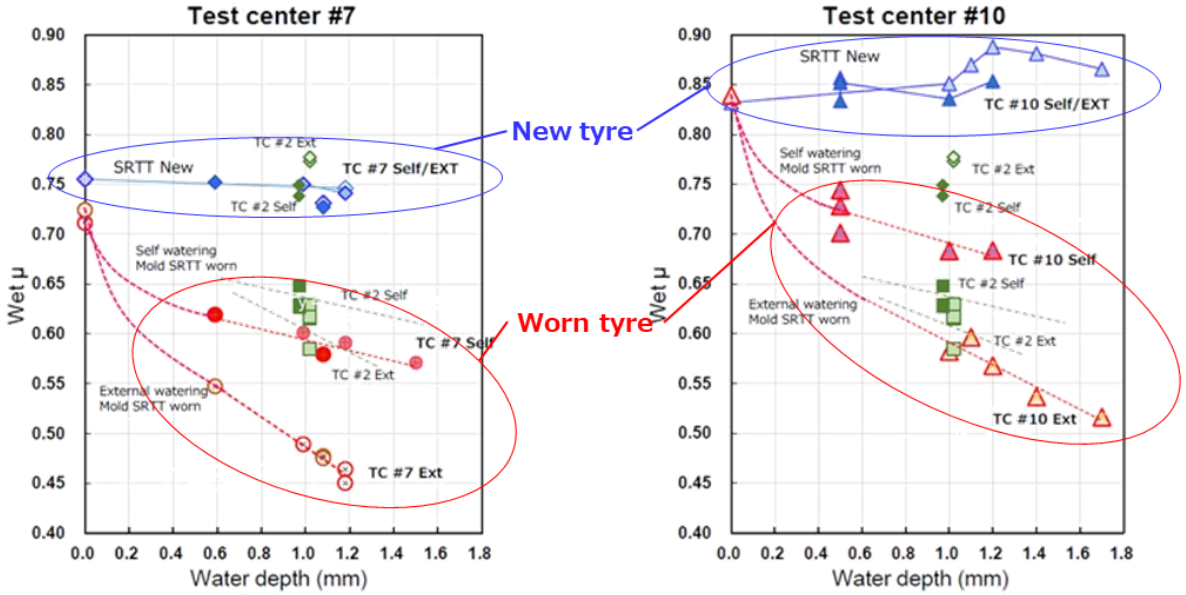
3. Previous results of test campaign for test precision improvement

Impact of water depth for worn tyre

■ **Test water height**

Test water height has significant influence on worn tyre wet performance, much more than the New tyre.

[WTPP-24-4 JASIC External – Self watering direct comparison test 240111]



< Worn tyre wet μ has higher sensitivity to the water height >

- **Wet μ of SRTT16worn is strongly influenced by the water depth compared to the new SRTT16.**
- **Therefore, JASIC believes that the water depth introduction in the correction formula is necessary.**

Wetting condition in UN R117-04 :
the water depth shall be (1.0 ± 0.5) mm

IWG WGWT confirmed that test water depth has significant influence on wet performance of worn tyre by 2022-2023 test campaign. This result also shows the importance of the water depth introduction in the correction formula.

4. The different recognition for the current test method for worn tyres

	JASIC proposal (WT-60-7)	ETRTO proposal（WT-61-2 v1)
Recognition for wet test for worn tyres	Consistently stating that the improvement of correction formula including the influence of water depth is necessary because the test precision of current wet test for worn tyres is not sufficient.	ETRTO doesn't consider the modification of the correction formula. Only to verify the effectiveness of the proposed change in wetted frictional properties, and to quantify its impact on candidate tyres.
KPI	Target (KPI) is the precision (σ) of the current wet test for new tyres. Normal : 0.065 3PMSF : 0.060	ETRTO agreed that KPI shall be the weighted standard deviation σ (per tyre category) . But ETRTO didn't show their proposal.

- JASIC advocated that the current wet test for worn tyres is not sufficient since 2021 and the improvement of the correction formula including water depth introduction in the correction formula is necessary.
- Based on the experience of the new tyre wet test improvement, target KPI (same as the precision (σ) of the current wet test for new tyres) is reasonable.

5. Comparison between latest JASIC proposal and ETRTO proposal

		JASIC proposal (WT-60-7)	ETRTO proposal (WT-61-2 v1)
Boundary condition	Correction factor	5 factors (including water depth)	4 factors (same as current)
	Margin of error	5%	5%
	Standard deviation	0.115	0.115 Information on 27/Aug
	Power level	0.8	0.8 (0.84 is acceptable)
	R^2	0.6 Refer to the 2019-2021 test campaign	0.68 Refer to WT-61-2 P11 basis for calculation is unknown
	Total number of SKU	Total 40 SKU (20 SKU/tyre category) Calculated by statistic logic Acceptable Margin of error $= 1.96 \times \frac{\sigma}{\sqrt{N}}$ $0.05 = 1.96 \times \frac{0.115}{\sqrt{N}}$ N (Sample size)= 20.3	Total 24 SKU Refer to WT-61-2 P11 basis for calculation is unknown Number of SKU/tyre category is also unknown
	Necessary test data /each candidate tyre for statistic analysis	28 test data / candidate tyre Calculated by statistic logic (5 correction factors)	12 test data / candidate tyre Refer to WT-61-2 P11 basis for calculation is unknown

ETRTO follows JASIC's logic in their own way, but there are many unknown points.

5. Comparison between latest JASIC proposal and ETRTO proposal

		JASIC proposal (WT-60-7)		ETRTO proposal (WT-61-2 v1)	
		Phase 1	Phase 2	Stage 1	Stage 2
Test condition	No. of test lab.	14 (only trailer method)		15 (14 trailer method/ 1 vehicle method)	
	Necessary test data /candidate tyre	27 test data / candidate tyre		15 test data / candidate tyre (for trailer method 12-15 test data) Refer to WT-61-2 P12	
	Total # of SKU	Total 40 SKU (20 SKU/tyre category) Calculated by statistic logic		Total 24 SKU # of SKU/tyre category is unknown Refer to WT-61-2 P12	
	Temp. condition	2 (H/L)	1 (M)	3 repetition include H/L	unknown
	Water depth	0.7/1.2mm	(continue)	0.7/1.3mm	unknown
	Watering system	Ext. vs Self	–	–	unknown
Test volume /lab	Lab A (only temp.)	52	26	24	unknown
	Lab B (temp / water depth)	106	52	unknown	unknown
	Lab C (temp / water depth / watering system)	130	52	–	unknown
	Working document	Feb/2026 GRBP	Sep/2026 GRBP	Not considered	unknown

ETRTO doesn't show any plan of Stage 2 even if ETRTO proposal is "step by step approach".

6. Our Question for ETRTO proposal

		JASIC proposal (WT-60-7)	ETRTO proposal (WT-61-2 v1)	JASIC concern
Boundary condition	Correction factor	5 factors (including water depth)	4 factors (same as current)	
	Margin of error	5%	5%	
	Power level	0.8	0.8 (0.84 is acceptable)	
	R^2	0.6	0.68	
	Total number of SKU	Total 40 SKU (20 SKU/tyre category)	Total 24 → 40 SKU (Number of SKU/tyre category is unknown → 20 SKU/tyre category)	If we calculate with - Margin of error:0.5% - Std variasion:0.115 Total 40 SKU (20 SKU/tyre category) is necessary. ETRTO proposal (Total 24 SKU) is too small.
	Necessary test data /each candidate tyre	28 test data / cand. tyre	12 → 23 test data / cand. tyre	If we calculate with 4 correction factors, necessary test data should be 23 test data / candidate tyre.

Test volume of ETRTO proposal is not understandable.

7. Estimated test volume of ETRTO proposal Stage 2

Test volume/ lab		JASIC	ETRTO	Estimated	Comment
Phase 1 / Stage 1	Lab A (only temp.)	52	24	24	
	Lab B (temp / water depth)	106	Unknown (same as lab A?)	24 or (48)*	If water depth assessment is included, test volume become double.
	Lab C (temp / water depth / watering system)	130	Unknown (same as lab A?)	24 or (48)*	
	Total test volume	1314	360	360 or (576)*	For trailer method 336 or (552)*
	WD submission	Feb/2026	Not considered	Not considered	
Phase 2 / Stage 2	Lab A (only temp.)	26	unknown	66	Estimated test volume for Stage 2 is more than double of Stage 1. If only same test volume as Stage 1 is expected, another 2 years (or more) will be necessary.
	Lab B (temp / water depth)	52	unknown	154 (134)*	
	Lab C (temp / water depth / watering system)	52	unknown	190 (174)*	
	Total test volume	594	unknown	1792 (1668)*	
	WD submission	Sep/2026	unknown	Feb/2028	

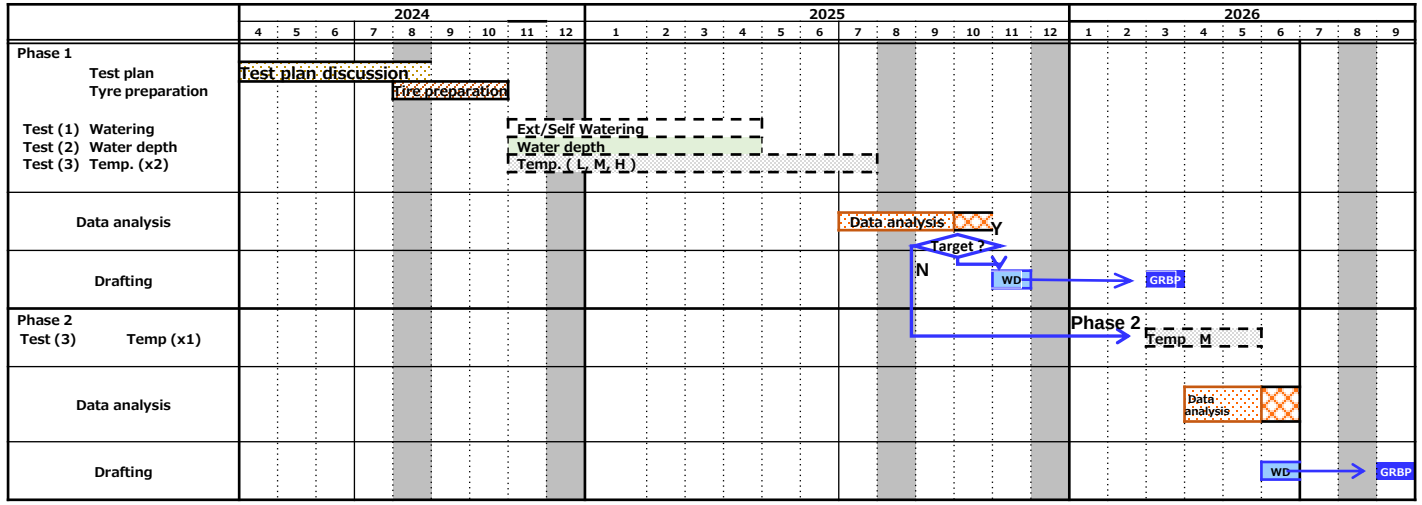
Test volume/ lab is representative one
(can be changed by optimization)

* If water depth assessment is included

JASIC estimated the test volume which is required for ETRTO test proposal Stage 2.

8. Schedule

■ JASIC test plan (WT-60-6)



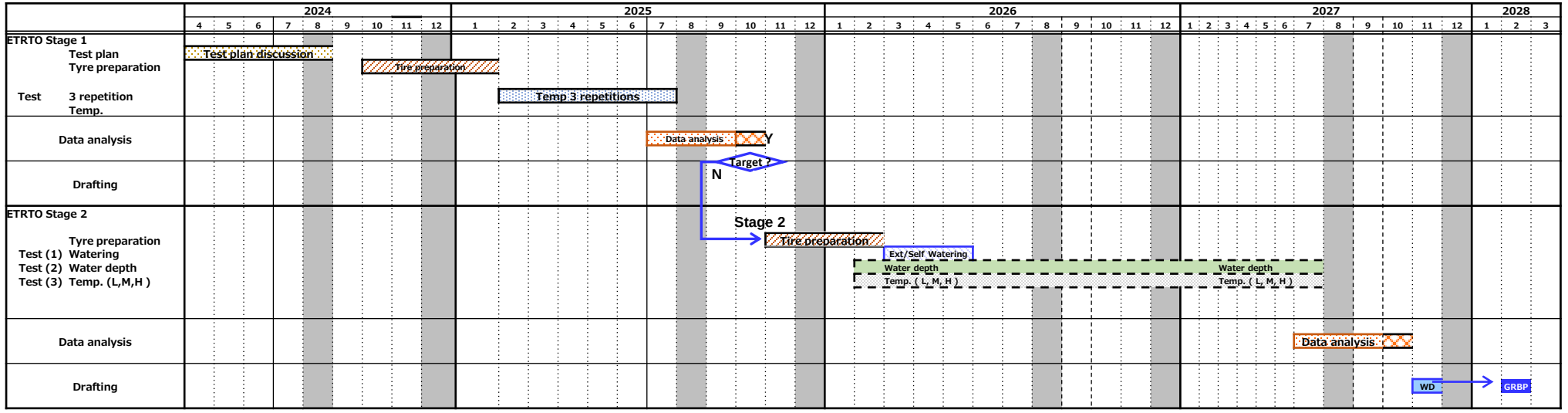
■ **JASIC test plan**

Phase 1 WD preparation in Nov. 2025
→ submit to GRBP Feb. 2026
Phase 2 WD preparation in Jun. 2025
→ submit to GRBP Sep. 2026

■ **ETRTO test plan**

Stage 1 WD submission is not considered
Stage 2 (JASIC estimation)
WD preparation in Nov. 2027
→ submit to GRBP Feb. 2028

■ ETRTO test plan (WT-61-2 v1) Test volume/Schedule of Stage 2 is estimated by JASIC



In case of ETRTO proposal, the complete timing of test precision improvement will be delayed at least 1.5 years because of step by step approach.

9. Summary

■ Our conclusion

- **JASIC advocated that the current wet test precision for worn tyres is not sufficient since 2021 and the improvement of the correction formula including water depth factor introduction in the correction formula is necessary.**

- **ETRTO proposal is ;**

  - **Modification of correction formula including water depth factor introduction is considered in Stage 2**
  - **The basis for the calculation made by ETRTO is unknown and no explanation about Stage 2.**
  - **If we estimate ETRTO Stage 2 test volume /schedule based on JASIC proposal, the schedule will be delayed drastically (additional 1.5 years).**

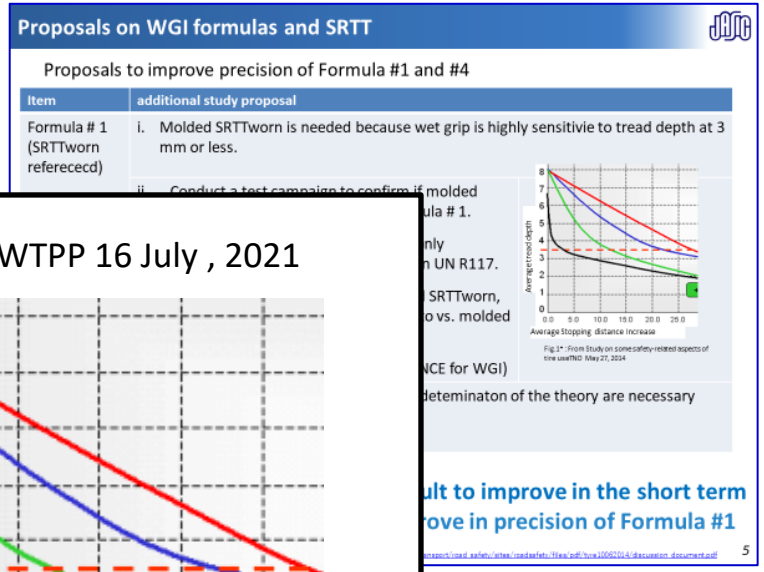
Based on above, JASIC cannot accept ETRTO proposal (WT-61-2 v1) .
We propose you to adopt JASIC proposal which is more technically reasonable.

Appendix　History of “Step by step approach”

Timeline of Terms of Reference for test precision improvement

ToR	2022	2023	2024	2025	2026	2027	2028
Timeline for “Improve the precision of test procedure” was split 2 steps. 1st step　Introduction of Molded SRTTw 2nd step　Improvement of test precision							
GRBP-75-28 (Feb/2022)	★Sep/22 Molded SRTTw		★Feb/24 Improvement of test precision				
Timeline was split 2 steps again. 1st step　Define Water depth measurement methods 2nd step　Improvement of test precision							
GRBP-77-03 (Feb/2023)			★Feb/24 Define Water depth measurement methods		★Feb/26 Improvement of test precision		
IWG WGWT is discussing another split as below.							
JASIC proposal					★Feb/26 (Phase 1) Upgrade the correction formula if succeed	★Sep/26 (Phase 2) Upgrade the correction formula	
ETRTO proposal					★Feb/26 (Stage 1) No submission is expected		★?(Stage 2) Improvement of test precision

Appendix　Known fact of water depth influence on the tyre wet performance



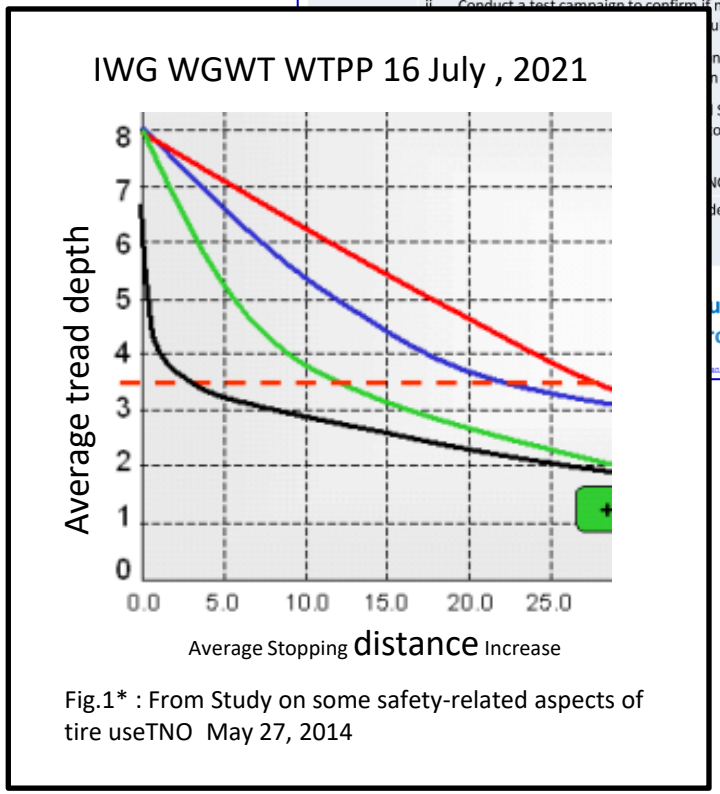
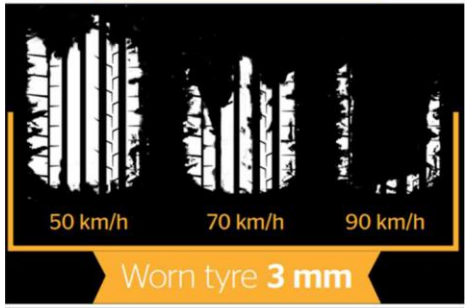
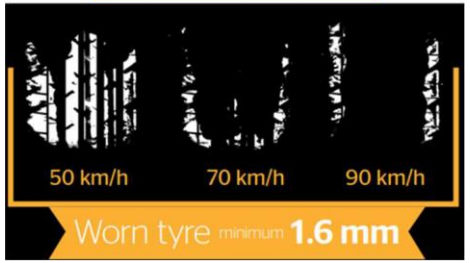


Fig.1* : From Study on some safety-related aspects of tire useTNO May 27, 2014





WT-35-02 Tender - Wet Grip Worn Tyre_Interim report - D1_v0.7.pdf
TENDER FOR: Study on wet grip of worn tyres [IDIADA]

Table 2 Friction quotient values at different speeds [46].

Vehicle Speed(*km/h*)	Tire condition	Road conditions				
		Dry	Wet	Rain (water<1*cm*)	Havy rain (water<2*cm*)	Ice
Coefficient of static friction						
50 *km/h*	New	0.85	0.65	0.55	0.52	<0.1
	Used	1.1	0.53	0.41	0.25	
90 *km/h*	New	0.82	0.62	0.32	0.06	
	Used	0.95	0.21	0.11	0.06	
130 *km/h*	New	0.75	0.43	0.23	0	
	Used	0.9	0.22	0.11	0	

The contact area of worn tyres decreases rapidly.
As the result, wet μ reduces drastically.

Existing literature and IDIADA report clearly explained that influence of water depth to worn tyre (sharrow tread depth tyre) is significant.

Appendix　Results of previous test campaign

① Molded SRTT worn

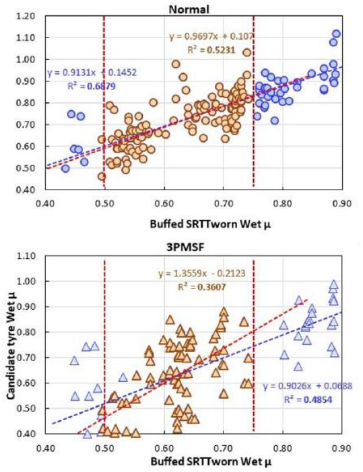
	Buff SRTTw	Molded SRTTw
CV μpeak	13.9%	13.1%
CV BFC	10.7%	12.9%

No significant improvement

② Test track surface friction range

② Test track surface friction range

[2019-'21 test campaign, Norma / 3PMSF screening test data]

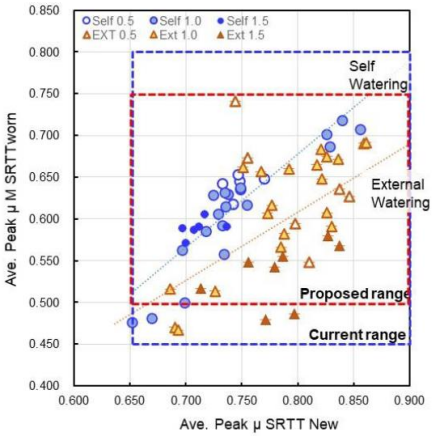


μ Range	Normal	3PMSF
0.45-0.80	R^2=0.68	0.48
0.50-0.75	**0.52**	**0.36**

[2019-21 Test campaign results]

If the friction range is narrowed, however SRTT-Candidate tyre correlations is the same or worse.

[2022 Mold SRTTworn test campaign data]



From the 2023 test campaign result, only 2 test centers were out of the friction range (0.50 - 0.75)

No significant improvement

The results of past test campaign were reviewed, however the precision improvement was not confirmed.

Appendix　Information of Test center capability

Test Center (Lab # refer to attendance list which made by ETRTO)		#8	#13	#5	#1 #9 #11	#6 #14 #15	#3 #7 #12	#2 #10	#4
Test method	Trailer method	YES	YES	YES	YES	YES	YES	YES	
	Vehicle method			YES					YES
Watering system	External watering	Option	YES	YES	YES		YES		YES
	Self watering	YES	YES	YES		YES		YES	
Standard test (temp. condition)		OK	OK	OK	OK	OK	OK	OK	OK
Water depth (0.7/1.3mm)		OK	OK	OK (only self watering)	OK	OK			
Watering system (External/Self)		OK	OK	OK					

For test precision improvement

- G(Tn) formula re-evaluation.
  Required SKU size for Variation smoothing between test tyres (Margin of error for GB(Tn));

  - General conditions;
    - Probability level (α) : 0.05 (Confidence level is 95%)
    - Desired statistical power level (1-β) : 0.8
  - Conditions from test campaign;
    - Anticipated effect size R^2 : 0.6 (From 2021 test campaign result)
    - Standard deviation : 0.115
    - Z-value : 1.96 (Corresponds to the confidence level 95%)

Standard deviation

$$\text{Acceptable Margin of error} = 1.96 \times \frac{\sigma}{\sqrt{N}}$$

$$0.05 = 1.96 \times \frac{0.115}{\sqrt{N}}$$

Required SKU size : **N = 20** for each tyre category

Appendix Test sample size --- [Overall, statistical theory]

For test precision improvement

- G(Tn) formula re-evaluation.
  Required sample size for multiple regression analysis;
  - General conditions;
    - Probability level (α) : 0.05
    - Desired statistical power level (1-β) : 0.8
  - Conditions from test campaign;
    - Anticipated effect size R2 : 0.6 (From 2021 test campaign result)
    - Number of predictors (a,b,c,d + water depth) : 5

$$G_B(\mathrm{T}_n) = K_{\mathrm{trailer}} \times \{\overline{\mu_{peak}}(\mathrm{T}_n) - [\ a \cdot \Delta\mu_{peak}(\mathrm{R}) + b \cdot \Delta\vartheta + c \cdot (\Delta\vartheta)^2 + d \cdot \Delta MTD\ ]\}$$

- plus Water depth

Minimum required sample size : **n = 28** for each candidate tyres.

Proposal :

- Sufficient sample size test campaign for multiple regression analysis n=28 for each candidate tyres.
- Add test water depth factor which has influence on wet μ.

Appendix　Test sample size (= Necessary test data /candidate tyre)

https://www.danielsoper.com/statcalc/formulas.aspx?id=1

x^2 A-priori Sample Size for Multiple Regression Formulas

Below you will find descriptions and details for the 9 formulas that are used to compute a-priori sample size values for multiple regression models.

Beta function:

$$\mathrm{B}(x,y) = \int_0^1 t^{x-1}(1-t)^{y-1}\,dt$$

Cohen's f^2 effect size for an F-test:

$$f^2 = \frac{R^2}{1-R^2}$$

where R^2 is the squared multiple correlation.

Error function:

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2}\,dt.$$

F-distribution cumulative distribution function (CDF):

$$F(x; d_1, d_2) = I_{\frac{d_1 x}{d_1 x + d_2}}(d_1/2, d_2/2),$$

where d_1 and d_2 are the degrees of freedom, and I is the regularized lower incomplete beta function.

Lower incomplete beta function:

$$\mathrm{B}(x;\, a, b) = \int_0^x t^{a-1}\,(1-t)^{b-1}\,dt.$$

Noncentral F-distribution cumulative distribution function (CDF):

$$F(x|d_1, d_2, \lambda) = \sum_{j=0}^{\infty} \left(\frac{\left(\frac{1}{2}\lambda\right)^j}{j!} e^{-\frac{\lambda}{2}} \right) I\left(\frac{d_1 F}{d_2 + d_1 F} \middle| \frac{d_1}{2} + j, \frac{d_2}{2} \right)$$

where d_1 and d_2 are the numerator and denominator degrees of freedom, $?$ is the noncentrality parameter, F is the Fisher F-value, and I is the regularized lower incomplete beta function.

Noncentral F-distribution noncentrality parameter:

$$\lambda = f^2 n$$

where f^2 is the effect size and n is the sample size.

Normal distribution cumulative distribution function (CDF):

$$F(x;\, \mu, \sigma^2) = \frac{1}{2}\left[1 + \operatorname{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right],$$

where μ is the mean, σ is the standard deviation, and *erf* is the error function.

Regularized lower incomplete beta function:

$$I_x(a,b) = \frac{\mathrm{B}(x;\, a, b)}{\mathrm{B}(a,b)}.$$

where the numerator is the lower incomplete beta function, and the denominator is the beta function.

Appendix Test volume - JASIC proposal

JASIC Phase 1 Test volume

		Normal																				3PMSF																TTL
		Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	
Temp + Water depth + Watering system	Test center 1	6	6	6	6	6	6	3	2	3	3	2	3	3	3	2	2	2	3	2	2	6	6	6	6	6	6	3	2	3	3	2	3	3	3	2	2	2	3	2	2	142
	Test center 2	6	6	5	6	6	5	2	2	3	2	3	3	3	3	3	2	2	3	3	3	6	6	5	6	6	5	2	2	3	2	3	3	3	3	3	2	2	3	3	3	142
	Test center 3	6	6	6	6	6	6	2	3	2	3	2	2	3	3	2	3	3	2	2	3	6	6	6	6	6	6	2	3	2	3	2	2	3	3	2	3	3	2	2	3	142
Temp + Water depth	Test center 4	3	3	3	3	3	2	3	3	2	3	2	3	2	2	3	2	3	3	2	3	3	3	3	3	3	2	3	3	2	3	2	3	2	2	3	2	3	3	2	3	106
	Test center 5	2	3	2	3	2	3	3	2	3	2	3	3	3	2	3	3	3	2	3	3	2	3	2	3	2	3	3	2	3	2	3	3	3	2	3	3	3	2	3	3	106
	Test center 6	2	2	2	2	3	3	3	3	2	3	3	3	2	3	3	3	3	3	3	2	2	2	2	2	3	3	3	3	2	3	3	3	2	3	3	3	3	3	3	2	106
	Test center 7	2	2	3	3	2	3	3	3	2	3	3	2	3	3	3	3	3	2	2	3	2	2	3	3	2	3	3	3	2	3	3	2	3	3	3	3	3	2	2	3	106
	Test center 8	3	2	3	2	3	3	2	2	3	3	3	2	2	2	3	3	3	3	3	3	3	2	3	2	3	3	2	2	3	3	3	2	2	2	3	3	3	3	3	3	106
	Test center 9	3	3	3	3	3	3	2	3	3	2	3	3	3	3	2	2	3	2	2	2	3	3	3	3	3	3	2	3	3	2	3	3	3	3	2	2	3	2	2	2	106
Temperature	Test center 10	2	0	2	2	0	2	2	2	2	2	0	2	2	2	0	2	0	0	2	0	2	0	2	2	0	2	2	2	2	2	0	2	2	2	0	2	0	0	2	0	52
	Test center 11	2	2	2	0	2	2	2	2	0	0	2	2	0	0	0	2	0	2	2	2	2	2	2	0	2	2	2	2	0	0	2	2	0	0	0	2	0	2	2	2	52
	Test center 12	0	2	0	0	2	0	2	2	2	0	2	0	2	2	2	0	2	2	2	0	0	2	0	0	2	0	2	2	2	0	2	0	2	2	2	0	2	2	2	0	48
	Test center 13	0	0	2	2	0	0	0	2	2	2	2	2	0	2	2	2	0	2	2	2	0	0	2	2	0	0	0	2	2	2	2	2	0	2	2	2	0	2	2	2	52
	Test center 14	2	2	0	0	0	0	2	0	2	2	0	0	2	0	2	2	2	2	2	2	2	2	0	0	0	0	2	0	2	2	0	0	2	0	2	2	2	2	2	2	48
		39	39	39	38	38	38	31	31	31	30	30	30	30	30	30	31	29	31	32	30	39	39	39	38	38	38	31	31	31	30	30	30	30	30	30	31	29	31	32	30	1314

JASIC Phase 2 Test volume

	Normal																				3PMSF																		TTL
	Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	
Test center 1	2	2	2	2	2	2	2	0	2	2	0	2	2	2	0	0	0	2	0	0	2	2	2	2	2	2	2	0	2	2	0	2	2	2	0	0	0	2	0	0	52
Test center 2	2	2	0	2	2	0	0	0	2	0	2	2	2	2	2	0	0	2	2	2	2	2	0	2	2	0	0	0	2	0	2	2	2	2	2	0	0	2	2	2	52
Test center 3	2	2	2	2	2	2	0	2	0	2	0	0	2	2	0	2	2	0	0	2	2	2	2	2	2	2	0	2	0	2	0	0	2	2	0	2	2	0	0	2	52
Test center 4	2	2	2	2	2	0	2	2	0	2	0	2	0	0	2	0	2	2	0	2	2	2	2	2	2	0	2	2	0	2	0	2	0	0	2	0	2	2	0	2	52
Test center 5	0	2	0	2	0	2	2	0	2	0	2	2	2	0	2	2	2	0	2	2	0	2	0	2	0	2	2	0	2	0	2	2	2	0	2	2	2	0	2	2	52
Test center 6	0	0	0	0	2	2	2	2	0	2	2	2	0	2	2	2	2	2	2	0	0	0	0	0	2	2	2	2	0	2	2	2	0	2	2	2	2	2	2	0	52
Test center 7	0	0	2	2	0	2	2	2	0	2	2	0	2	2	2	2	2	0	0	2	0	0	2	2	0	2	2	2	0	2	2	0	2	2	2	2	2	0	0	2	52
Test center 8	2	0	2	0	2	2	0	0	2	2	2	0	0	0	2	2	2	2	2	2	2	0	2	0	2	2	0	0	2	2	2	0	0	0	2	2	2	2	2	2	52
Test center 9	2	2	2	2	2	2	0	2	2	0	2	2	2	2	0	0	2	0	0	0	2	2	2	2	2	2	0	2	2	0	2	2	2	2	0	0	2	0	0	0	52
Test center 10	1	0	1	1	0	1	1	1	1	1	0	1	1	1	0	1	0	0	1	0	1	0	1	1	0	1	1	1	1	1	0	1	1	1	0	1	0	0	1	0	26
Test center 11	1	1	1	0	1	1	1	1	0	0	1	1	0	0	0	1	0	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	0	0	0	1	0	1	1	1	26
Test center 12	0	1	0	0	1	0	1	1	1	0	1	0	1	1	1	0	1	1	1	0	0	1	0	0	1	0	1	1	1	0	1	0	1	1	1	0	1	1	1	0	24
Test center 13	0	0	1	1	0	0	0	1	1	1	1	1	0	1	1	1	0	1	1	1	0	0	1	1	0	0	1	1	1	1	1	0	0	1	1	1	0	1	1	1	26
Test center 14	1	1	0	0	0	0	1	0	1	1	0	0	1	0	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	0	1	0	1	1	1	1	1	1	24
	15	15	15	16	16	16	14	14	14	15	15	15	15	15	15	14	16	14	13	15	15	15	15	16	16	16	14	14	14	15	15	15	15	15	15	14	16	14	13	15	594

Appendix Test volume - ETRTO proposal

ETRTO Stage 1 Test volume (without water depth assessment)

	Normal												3PMSF												
	Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	Tyre 21	Tyre 22	Tyre 23	Tyre 24	
Test center 1				3		3				3		3				3		3				3		3	24
Test center 2		3		3				3		3				3		3				3		3			24
Test center 3			3	3		3				3					3	3		3				3			24
Test center 4		3		3		3				3				3		3		3				3			24
Test center 5							3	3			3	3							3	3			3	3	24
Test center 6	3		3				3	3					3		3				3	3					24
Test center 7							3	3		3	3								3	3		3	3		24
Test center 8	3		3						3		3		3		3						3		3		24
Test center 9	3				3	3			3				3				3	3			3				24
Test center 10	3	3					3					3	3	3					3					3	24
Test center 11					3			3			3	3					3			3			3	3	24
Test center 12			3		3	3	3								3		3	3	3						24
Test center 13				3	3				3			3				3	3				3			3	24
Test center 14		3	3		3				3					3	3		3				3				24
Test center 15 V	3	3							3		3		3	3							3		3		
Sum TC 1-14	12	12	15	15	15	15	15	15	12	15	12	15	12	12	15	15	15	15	15	15	12	15	12	15	336
Sum TC 1-15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	360

ETRTO Stage 1 Test volume (with water depth assessment)

		Normal												3PMSF												
		Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	Tyre 21	Tyre 22	Tyre 23	Tyre 24	
Temp + Water depth	Test center 1				6		6				6		6				6		6				6		6	48
	Test center 2		6		6				6		6				6		6				6		6			48
	Test center 3			6	6		6				6					6	6		6				6			48
	Test center 4		6		6		6				6				6		6		6				6			48
	Test center 5							6	6			6	6							6	6			6	6	48
	Test center 6	6		6				6	6					6		6				6	6					48
	Test center 7							6	6		6	6								6	6		6	6		48
	Test center 8	6		6						6		6		6		6						6		6		48
	Test center 9	6				6	6			6				6				6	6			6				48
Temperature	Test center 10	3	3					3					3	3	3					3					3	24
	Test center 11					3			3			3	3					3			3			3	3	24
	Test center 12			3		3	3	3								3		3	3	3						24
	Test center 13				3	3				3			3				3	3				3			3	24
	Test center 14		3	3		3				3					3	3		3				3				24
	Test center 15	3	3							3		3		3	3							3		3		
	Sum TC 1-14	21	18	24	27	18	27	24	27	18	30	21	21	21	18	24	27	18	27	24	27	18	30	21	21	552
	Sum TC 1-15	24	21	24	27	18	27	24	27	21	30	24	21	24	21	24	27	18	27	24	27	21	30	24	21	576

※ Test matrix of ETRTO Stage 1 is slightly modified for estimation of Stage 2 test volume.

Appendix Test volume - Estimated ETRTO Stage 2

Only for Trailer method

ETRTO Stage 2 Test volume Estimated (without water depth assessment in Stage 1)

	Normal																				3PMSF																				TTL
	Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	
Test center 1	8	8	8	7	8	7	5	2	5	4	2	4	5	5	2	2	2	5	2	2	8	8	8	7	8	7	5	2	5	4	2	4	5	5	2	2	2	5	2	2	186
Test center 2	8	7	5	7	8	5	2	2	5	2	5	5	5	5	5	2	2	5	5	5	8	7	5	7	8	5	2	2	5	2	5	5	5	5	5	2	2	5	5	5	190
Test center 3	8	8	7	7	8	7	2	5	2	4	2	2	5	5	2	5	5	2	2	5	8	8	7	7	8	7	2	5	2	4	2	2	5	5	2	5	5	2	2	5	186
Test center 4	5	4	5	4	5	2	5	5	2	4	2	5	2	2	5	2	5	5	2	5	5	4	5	4	5	2	5	5	2	4	2	5	2	2	5	2	5	5	2	5	152
Test center 5	2	5	2	5	2	5	4	2	5	2	4	4	5	2	5	5	5	2	5	5	2	5	2	5	2	5	4	2	5	2	4	4	5	2	5	5	5	2	5	5	152
Test center 6	2	2	2	2	5	5	4	4	2	5	5	5	2	5	5	5	5	5	5	2	2	2	2	2	5	5	4	4	2	5	5	5	2	5	5	5	5	5	5	2	154
Test center 7	2	2	5	5	2	5	4	4	2	4	4	2	5	5	5	5	5	2	2	5	2	2	5	5	2	5	4	4	2	4	4	2	5	5	5	5	5	2	2	5	150
Test center 8	4	2	4	2	5	5	2	2	4	5	4	2	2	2	5	5	5	5	5	5	4	2	4	2	5	5	2	2	4	5	4	2	2	2	5	5	5	5	5	5	150
Test center 9	4	5	5	5	4	4	2	5	4	2	5	5	5	5	2	2	5	2	2	2	4	5	5	5	4	4	2	5	4	2	5	5	5	5	2	2	5	2	2	2	150
Test center 10	1		3	3		3	1	3	3	3		1	3	3		3			3		1		3	3		3	1	3	3	3		1	3	3			3			66
Test center 11	3	3	3		1	3	3	1			1	1				3		3	3	3	3	3	3		1	3	3	1			1	1				3		3	3	3	62
Test center 12		3			1		1	3	3		3		3	3	3		3	3	3			3			1		1	3	3		3		3	3	3			3	3	3		64
Test center 13			3	1				3	1	3	3	1		3	3	3		3	3	3			3	1				3	1	3	3	1		3	3	3		3	3	3	66
Test center 14	3	1					3		1	3			3		3	3	3	3	3	3	3	1					3		1	3			3		3	3	3	3	3	3	64
	50	50	52	48	49	51	38	41	39	41	40	37	45	45	45	45	45	45	45	45	50	50	52	48	49	51	38	41	39	41	40	37	45	45	45	45	45	45	45	45	1792

ETRTO Stage 2 Test volume Estimated (with water depth assessment in Stage 1)

	Normal																				3PMSF																				TTL
	Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	Tyre 1	Tyre 2	Tyre 3	Tyre 4	Tyre 5	Tyre 6	Tyre 7	Tyre 8	Tyre 9	Tyre 10	Tyre 11	Tyre 12	Tyre 13	Tyre 14	Tyre 15	Tyre 16	Tyre 17	Tyre 18	Tyre 19	Tyre 20	
Test center 1	8	8	8	7	8	7	5	1	5	2	1	2	5	5	2	2	2	5	2	2	8	8	8	7	8	7	5	1	5	2	1	2	5	5	2	2	2	5	2	2	174
Test center 2	8	7	5	7	6	5	2	1	3	2	3	5	5	5	5	2	2	5	5	5	8	7	5	7	6	5	2	1	3	2	3	5	5	5	5	2	2	5	5	5	176
Test center 3	8	8	7	7	6	7	2	5	1	2	2	1	5	5	2	5	5	2	2	5	8	8	7	7	6	7	2	5	1	2	2	1	5	5	2	5	5	2	2	5	174
Test center 4	3	2	5	4	3	2	5	3	2	4	2	5	2	2	5	2	5	5	2	5	3	2	5	4	3	2	5	3	2	4	2	5	2	2	5	2	5	5	2	5	136
Test center 5	2	3	2	5	2	5	2	2	5	1	2	4	5	2	5	5	5	2	5	5	2	3	2	5	2	5	2	2	5	1	2	4	5	2	5	5	5	2	5	5	138
Test center 6	1	2	1	1	5	3	4	4	2	5	5	5	2	5	5	5	5	5	5	2	1	2	1	1	5	3	4	4	2	5	5	5	2	5	5	5	5	5	5	2	144
Test center 7	2	2	3	3	2	3	2	4	2	4	4	2	5	5	5	5	5	2	2	5	2	2	3	3	2	3	2	4	2	4	4	2	5	5	5	5	5	2	2	5	134
Test center 8	4	2	2	2	5	3	1	2	2	5	4	2	2	2	5	5	5	5	5	5	4	2	2	2	5	3	1	2	2	5	4	2	2	2	5	5	5	5	5	5	136
Test center 9	2	3	5	3	4	4	2	5	4	2	5	3	5	5	2	2	5	2	2	2	2	3	5	3	4	4	2	5	4	2	5	3	5	5	2	2	5	2	2	2	134
Test center 10	1		3	3		3	1	3	3	3		1	3	3		3			3		1		3	3		3	1	3	3	3		1	3	3			3			66
Test center 11	3	3	3		1	3	3	1			1	1				3		3	3	3	3	3	3		1	3	3	1			1	1				3		3	3	3	62
Test center 12		3			1		1	3	3		3		3	3	3		3	3	3			3			1		1	3	3		3		3	3	3			3	3	3		64
Test center 13			3	1				3	1	3	3	1		3	3	3		3	3	3			3	1				3	1	3	3	1		3	3	3		3	3	3	66
Test center 14	3	1					3		1	3			3		3	3	3	3	3	3	3	1					3		1	3			3		3	3	3	3	3	3	64
	45	44	47	43	43	45	33	37	34	36	35	32	45	45	45	45	45	45	45	45	45	44	47	43	43	45	33	37	34	36	35	32	45	45	45	45	45	45	45	45	1668