



# PARTICLE MEASUREMENT PROGRAMME

PMP-IWG

## **TASK FORCE 2 – BRAKE EMISSIONS**

**CLAUSE 1 – WLTP-BRAKE CYCLE**

# CLAUSE 1 – OVERVIEW

ILS data, the GRPE-81-12, and the TF2 protocol have been used to amend Clause 1. The proposal amending Clause 1 substitutes the initial text with 4 sub-clauses:

- ✓ 1.1 – Provides general information and high-level statistics of the WLTP-Brake cycle – Has been taken from GRPE-81-12 (\$8.1) – Minor editorial changes applied – Important addition to the overall protocol is the submission of an excel file with the 1Hz speed profile of the cycle;
- ✓ 1.2. – Discusses the specifications for controlling the initial brake temperature during to the execution of the WLTP-Brake cycle in different occasions – TF2 Protocol + GRPE-81-12 (\$8.2) + Topic from the issues log were used – Suggestions have been introduced;
- ✓ 1.3. – Discusses the provisions related to the interruption of the WLTP-Brake cycle under different scenarios – TF2 Protocol + GRPE-81-12 (\$8.2) were used;
- ✓ 1.4. – Provides the means for an effective quality control of the execution of the WLTP-Brake cycle – TF2 Protocol + GRPE-81-12 + ILS data were used – Suggestions have been introduced;

## **CLAUSE 1.2. – TRIPS INITIAL TEMPERATURE**

Specifications for the disc's brake temperature at the beginning of the trips were provided to the GRPE-81-12 and the TF2 protocol for: i) Cooling air adjustment; ii) Bedding procedure; iii) Emissions tests. These are summarized below:

- ✓ Emissions and bedding WLTP-Brake cycle repetitions differ in the application (emissions) or not (bedding) of soak times between the individual trips – Cooling adjustment is performed with Trip #10 of the WLTP-Brake cycle;
- ✓ A maximum IBT of 40°C has been set for i. The beginning of Trip #10 of the WLTP-Brake cycle during the cooling air adjustment; ii. The beginning of the overall WLTP-Brake cycle repetitions #2 to #5 during bedding, and iii. The beginning of Trips #2 to #10 during the execution of the WLTP-Brake cycle for emissions testing;
- ✓ An IBT of 20±5°C has been set for i. The beginning of the first WLTP-Brake cycle repetition during bedding and ii. The beginning of Trips #1 of the WLTP-Brake cycle for emissions testing

## CLAUSE 1.2. – TRIPS INITIAL TEMPERATURE – EMISSIONS TESTS

	Initial Trip #1	Initial Trip #2	Initial Trip #3	Initial Trip #4	Initial Trip #5	Initial Trip #6	Initial Trip #7	Initial Trip #8	Initial Trip #9	Initial Trip #10
	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
AVG	24.8 (20±5)	38.9 (<40)	38.8 (<40)	38.7 (<40)	38.8 (<40)	38.9 (<40)	34.0 (<40)	38.8 (<40)	38.9 (<40)	37.3 (<40)
MIN VALUE	17.7	27.3	27.3	27.1	27.1	27.1	25.2	27.1	26.2	26.0
5th Percentile	19.4	34.1	33.0	33.4	32.8	33.8	28.7	33.2	34.0	28.8
50th Percentile	22.9	39.7	39.7	39.7	39.7	39.7	33.9	39.7	39.7	39.1
95th Percentile	32.6	40.4	40.5	40.3	40.4	40.5	39.2	40.5	40.4	40.4
MAX VALUE	122.1	41.2	41.4	41.2	42.2	42.3	40.5	41.6	41.5	41.9

- ✓ Some non-compliances in the specification for the initial temperature of Trip #1 – These mostly relate to labs running Emission tests #2 and #3 right after the 1<sup>st</sup> test – 75% of the 221 data points within the spec – **Proposal to leave the specification as is 20±5°C;**
- ✓ Very few non-compliances in the specification for the IBT of Trips #2-10 with 95% of the 221 data points within the spec – Most probably these non-compliances relate to the controls of the dyno that start the cycle at <40.5°C **Proposal to relax the target in the text to 40+1°C;**
- ✓ A minimum specification for the IBT of Trips #2-10 is required for harmonization and to avoid extremely low temperatures (Lab R in all tests & Lab F in few tests) – **Proposal to set this to 30°C**

## **CLAUSE 1.2. – TRIPS INITIAL TEMPERATURE – BEDDING+COOLING**

- ✓ The proposal for not including cooling sections within the 5 WLTP-Brake bedding cycles did not reveal any significant problem of overheating the brakes – A few labs did not apply this specification on-going investigation;
- ✓ Therefore, it is proposed to leave the specification for initial temperatures during bedding as is: The 1<sup>st</sup> repetition of the WLTP-Brake cycle\* shall commence at  $20\pm 5^{\circ}\text{C}$ , whereas the following cycles shall commence at  $40\pm 1^{\circ}\text{C}$ ;
- ✓ The specification for the initial temperature during the cooling air adjustment procedure is proposed to stay as is only relax the target to  $40\pm 1^{\circ}\text{C}$  – Additionally, it is proposed to perform the necessary warm-up through the application of Stops #1 to #7 of Trip #10 OR through an alternative sequence that does not involve high energy brake events

\* The same principle shall apply if an alternative bedding method is agreed

## **CLAUSE 1.3. – CYCLE INTERRUPTIONS**

Specifications for possible tests interruptions were provided to the GRPE-81-12 and the TF2 protocol for: i) Bedding procedure; ii) Emissions tests – No provisions were provided for the Cooling air adjustment method;

- ✓ A few incidents of interruptions of the bedding procedure were reported. Labs continued as suggested in the protocol – Only one case of interruptions during the emissions testing procedure. The Lab stopped the test and launched a new one;
- ✓ Provisions for tests interruptions during bedding and emission tests have not changed – However, it has been proposed to add a specification that brake parts shall not be “disassembled” in the cases that the test will continue – Need to agree on reasonable time;
- ✓ Provisions for tests interruptions during cooling air adjustment have been introduced – Since cooling adjustment is carried out during Trip #10 it is proposed that the lab discontinues the test in case of interruption

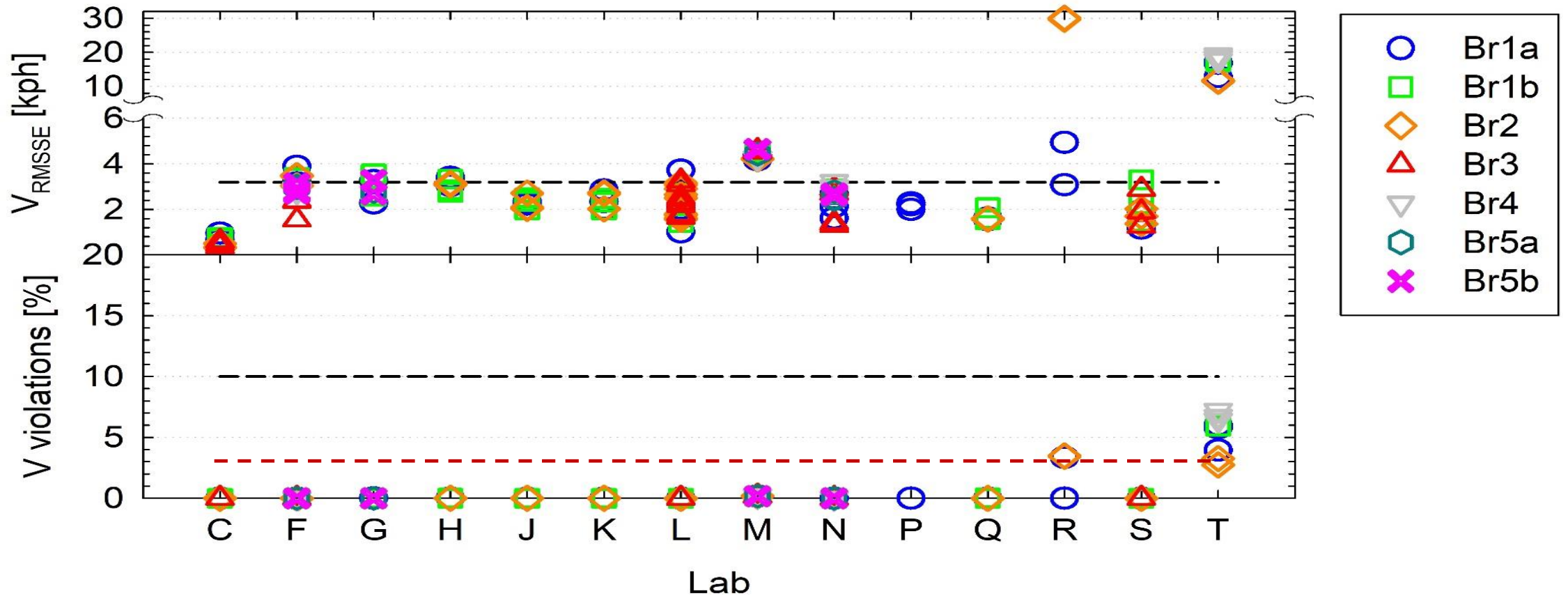
## CLAUSE 1.4. – QUALITY CRITERIA

Specifications for checking the correct execution of the WLTP-Brake cycle have been provided in the GRPE-81-12 and the TF2 protocol for: i) Cooling air adjustment; ii) Bedding procedure; iii) Emissions tests. Two different checks were specified:

- ✓ ***A maximum 10% of speed violations are allowed during the execution of the WLTP-Brake Cycle.*** A speed violation occurs whenever the actual speed of the dynamometer exceeds the upper or lower speed trace tolerance compared to the nominal speed.
- ✓ ***Speed error as RMSSE (Root Mean Sum Square Error) during the execution of the WLTP-Brake Cycle (SAE J2951:2014)*** – Recommendation for not exceeding an RMSSE of 1.6 km/h. Specification defining that RMSSE >3.2 km/h results in a defective test.

The ILS data revealed serious problems for certain labs to follow the correct WLTP-Brake cycle script. The aforementioned criteria alone were not enough to identify these issues – Additional parameters shall be considered for the quality check of the correct execution of the WLTP-Brake cycle.

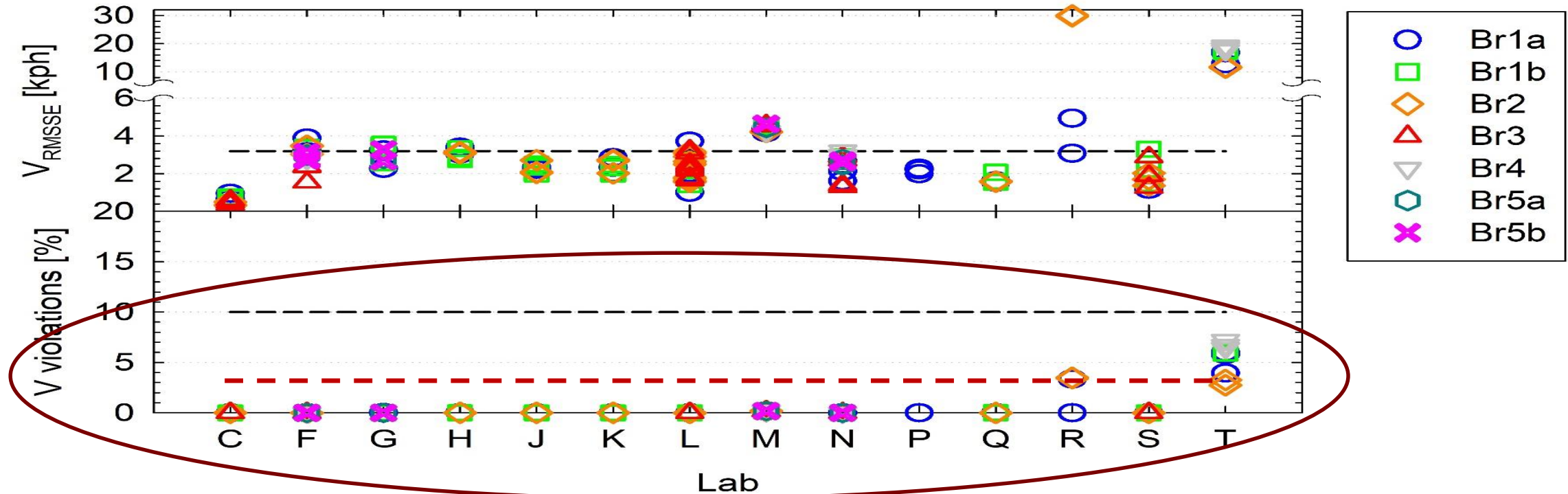
# QUALITY CRITERIA – SPEED VIOLATIONS



Accumulated emissions data from all Labs and brakes for standard emission tests – Data from Labs B and D have not been included due to severe problems with the time-base files – Analysis performed by A. Mamakos using the time-based files



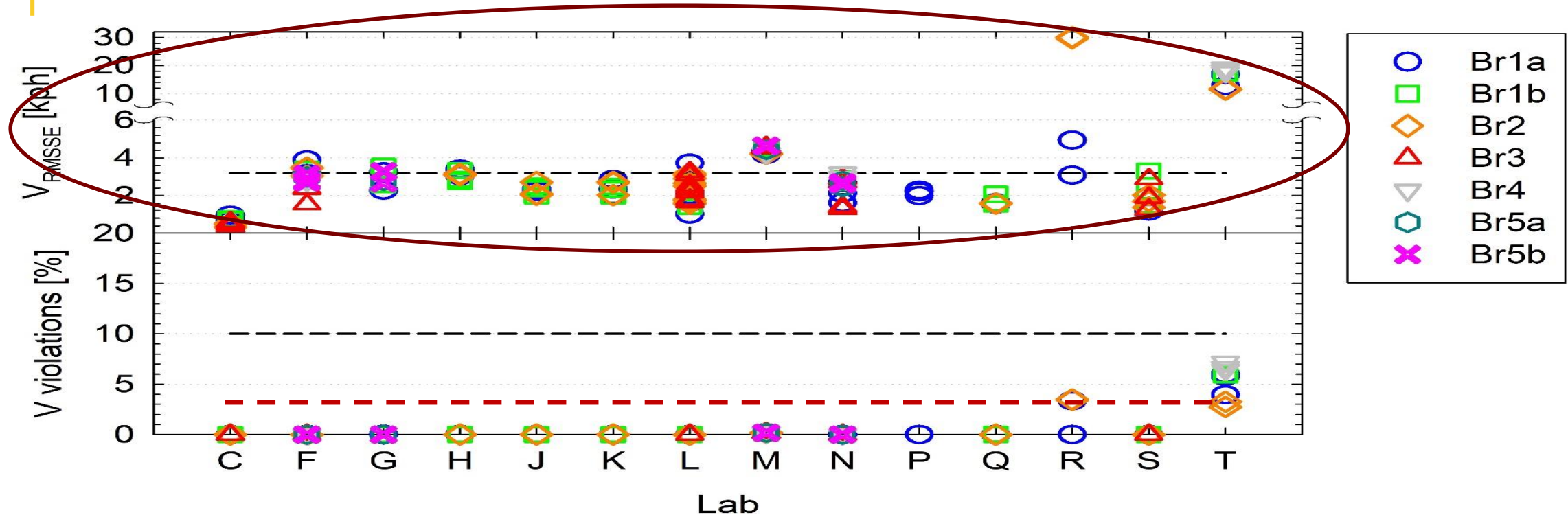
# QUALITY CRITERIA – SPEED VIOLATIONS



- Speed violations >10%: None – Labs B and D not included in the analysis due to serious alignment issues
- Speed deviations 0-5%: All Labs except for Labs B, D – Also a few tests from Lab T – Vast majority close to 1%
- Speed deviations 5-10%: Only Lab T in specific tests (Br1b & Br4)

**Suggestion to further reduce the maximum allowed violations as defined in the GTR to 3% (from 10%) – Speed control is much easier on a brake dyno level compared to full vehicle chassis dyno**

# QUALITY CRITERIA – SPEED VIOLATIONS



- RMSSE >3.2 km/h: 62 out of 203 emission tests (30%) – Labs M & T (All tests) – Labs F, G, H, L, R (Some tests) – (B excluded)
- RMSSE 1.6-3.2 km/h: 95 out of 203 emission tests (47%) – All Labs except Labs M, R, T (All had higher RMSSE violations)
- RMSSE <1.6 km/h: Only Lab C (All tests) – Labs L, Q, S (Some tests)

***ILS data do not provide indications regarding the influence of the RMSSE violations to PM emissions – Suggestion to remove (?) the RMSSE violations spec or apply only the 3.2 kph spec***

# QUALITY CRITERIA – NUMBER OF BRAKE EVENTS

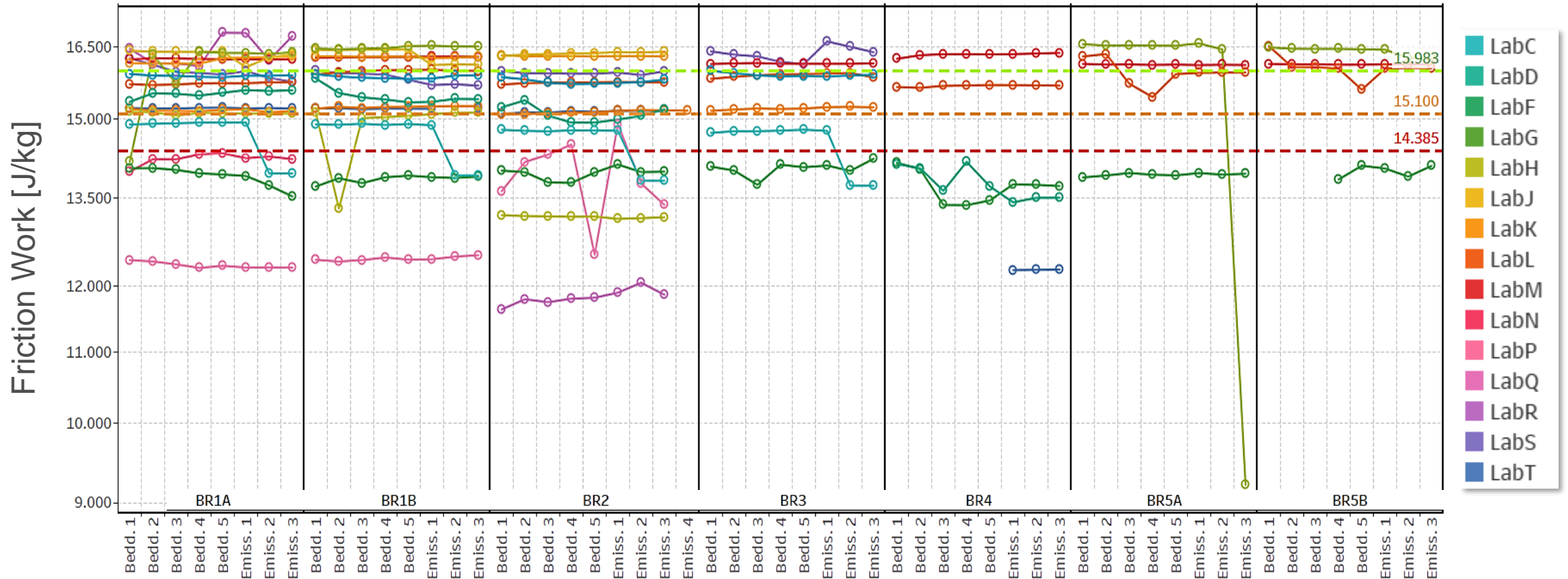
No specifications for cross-checking and verifying the application of all brake events of the WLTP-Brake cycle has been provided in the GRPE-81-12 or the TF2 protocol.

Lab	Test	Emissions 1	Emissions 2	Emissions 3
Lab-J	Br1a	301	301	301
Lab-J	Br1b	301	301	301
Lab-K	Br1b	302	302	
Lab-M	Br1a	301	301	301
Lab-M	Br1b	301	301	301
Lab-M	Br2	301	301	301
Lab-M	Br3	301	301	301
Lab-M	Br4	301	301	301
Lab-M	Br5a	301	301	301
Lab-M	Br5b	301	301	301

- ✓ ILS data reveal a problem in certain tests to apply the correct number of brake events during the execution of the WLTP-Brake cycle script
- ✓ This could be a problem if there is a systematic error in the script or if certain brake applications are omitted (i.e. high energy applications)

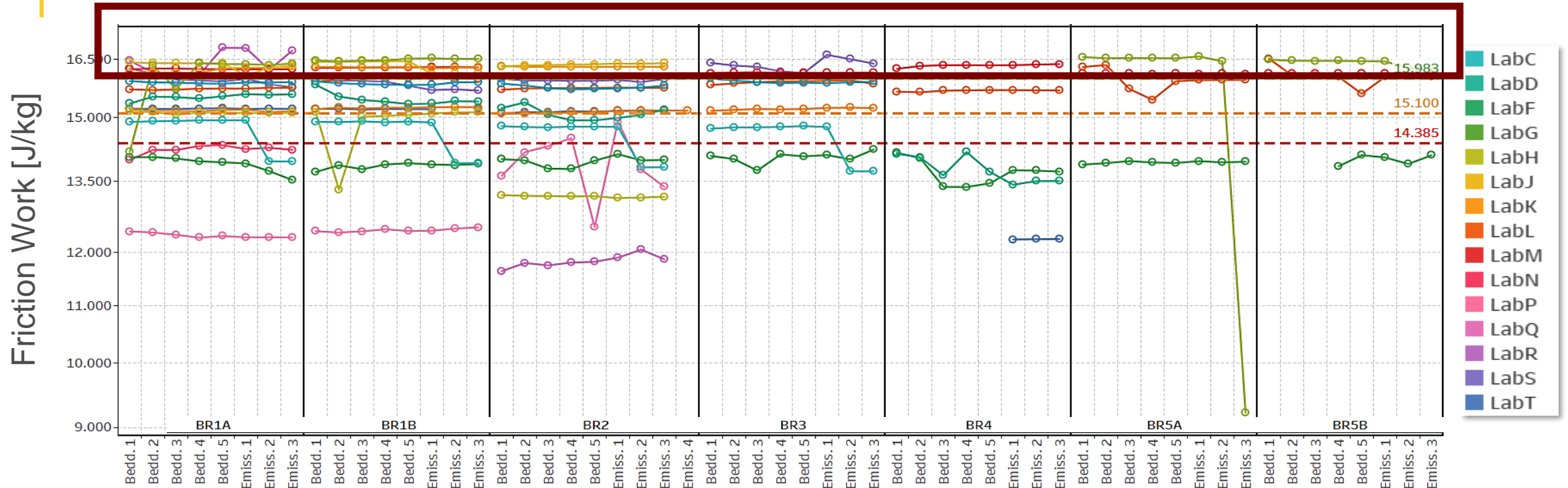
***Suggestion to introduce a verification of the number of brake events at least during emissions testing – The number of brake events shall be verified using the submitted event-based files***

# QUALITY CRITERIA – FRICTION WORK



Accumulated bedding and emissions data from all Labs and brakes for standard emission tests – Nominal WLTP-Brake cycle friction work is 15983 J/kg – Analysis performed by J.V. Wild using the event-based files

# QUALITY CRITERIA – FRICTION WORK

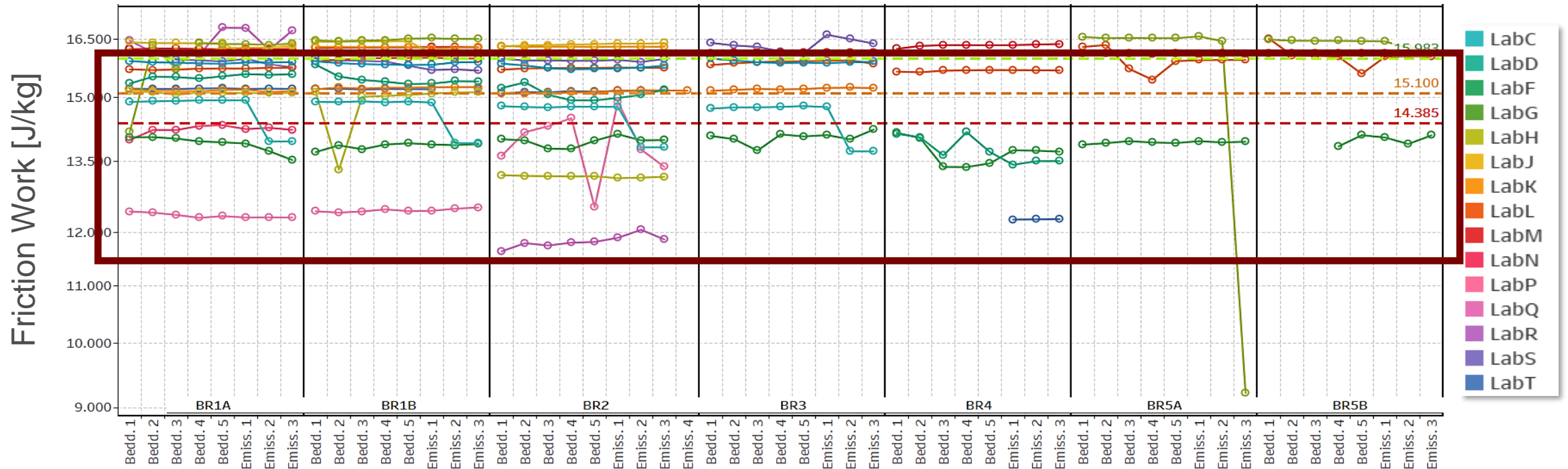


- Friction work >15.983 J/kg (emissions tests): 86 out of 221 emission tests (39%) – Labs G, J, K, (M), N, (R), (S)
- Friction work deviations 0-5%: 85 out of 221 emission tests (38%) – Labs G, J, K, (M), N, R, S
- Friction work deviations 5-10%: Lab R (Br1a)
- Friction work deviations >10%: None

***A single data point (Lab-R for Br1a) does not allow for safe conclusions regarding the influence of high friction work to brake PM and PN emissions***



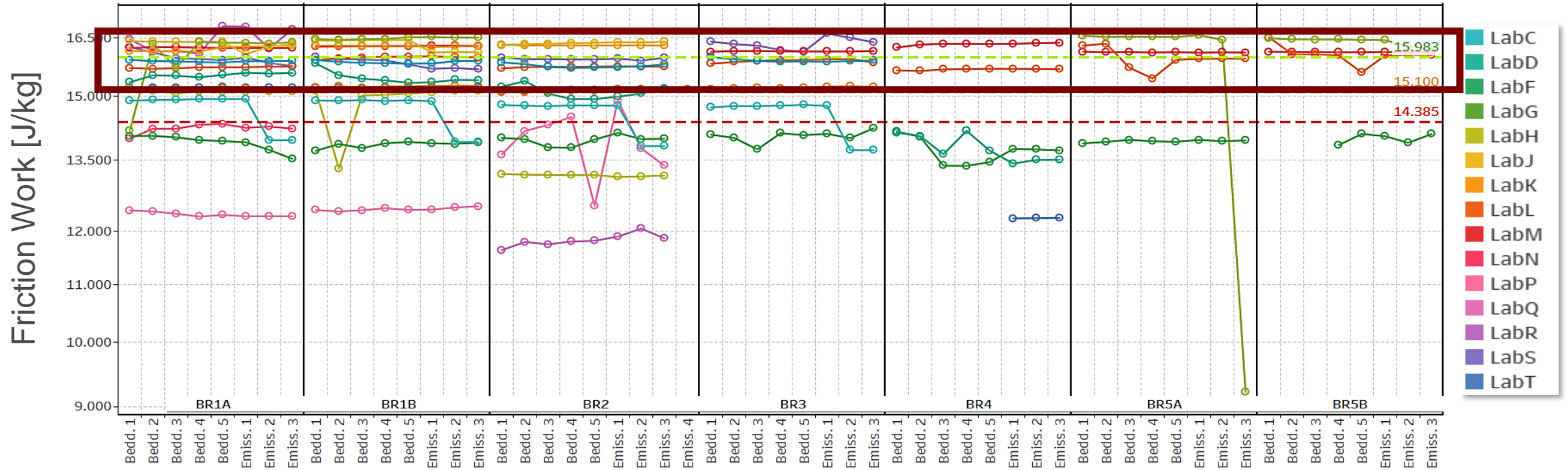
# QUALITY CRITERIA – FRICTION WORK



- Friction work <15.983 J/kg (Std tests): 135 out of 221 emission tests (61%) – Labs B, C, D, H, L, (M), P, Q, (R), (S), T
- Friction work deviations -0-5%: 78 out of 221 emission tests (35%) – Labs D, L, M, S, T
- Friction work deviations -5-10%: 22 out of 221 emission tests (10%) – D (Br2), H, L (Br2), T (Br2)
- Friction work deviations >-10%: 35 out of 221 emission tests (16%) C (All avg.), P, Q, D (Br4), H (Br2), R (Br2), T (Br4)

**Labs with >10% deviation from the nominal friction work (C, P, Q & H, R) all reported significantly reduced PM emissions compared to the unfiltered (and filtered) average of all labs**

# QUALITY CRITERIA – FRICTION WORK



**Friction work deviations 5-10%**  
 22+1=23 out of 221 emission tests (10%)

**Suggestion to introduce a provision for total friction work within  $\pm 5\%$  of the nominal value during emissions tests – Failure to comply will result in rejection of the emissions test**

# Thank you



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