Informal document GRPE-80-28
80th GRPE, 14-17 January 2020
Agenda item 7

The European Commission's science and knowledge service

Joint Research Centre

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79th UNECE GRPE session

PMP IWG Progress Report

Geneva, 13th -17th January 2020

UNITED NATIONS

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PMP meetings in 2019

- 2019-01-08: PMP 49th (GRPE Geneva summary)
- 2019-04-3/4 PMP 50th
- 2019-10-29/30 PMP 51st

- NEXT F-2-F MEETING: **2nd – 3rd April 2020** (Location: JRC Ispra - tbc)

EXHAUST PARTICLE EMISSIONS

Exhaust emissions: Sub-23nm development

- Sub-23nm development
  - Exercises
    - Light-duty
    - Raw exhaust sampling for HD testing

- Proposal for Sub-23nm additions
    - Losses in PN-systems
    - PNC parameters
    - VPR type (catalyzed or non-catalyzed evaporation tube)
    - General

Exercise conclusions

- LD exercise
  - PN-systems feasible for PN10 measurement
    - Reproducibility CoV PN23 ≈PN10
  - PN10 sensitive for losses (appropriate use of PN-systems)

- HD Exercise
  - Sub-23nm fraction similar with TP (CS) and PD(ET)
    - Deviated during regenerations
  - PD (ET) and TP (CS): PN10 and PN23 emissions within 25 %
  - Repeatability CoV similar for CS and ET (TP and PD)

Sub-23nm PN measurement proposal

- The following few slides present the proposal for Sub-23nm PN-measurement parameters
- The proposal follows closely the current PN-systems and PNCs used in the exercises and in the laboratories
- A document with the proposed changes to the test procedure is available on the PMP website.

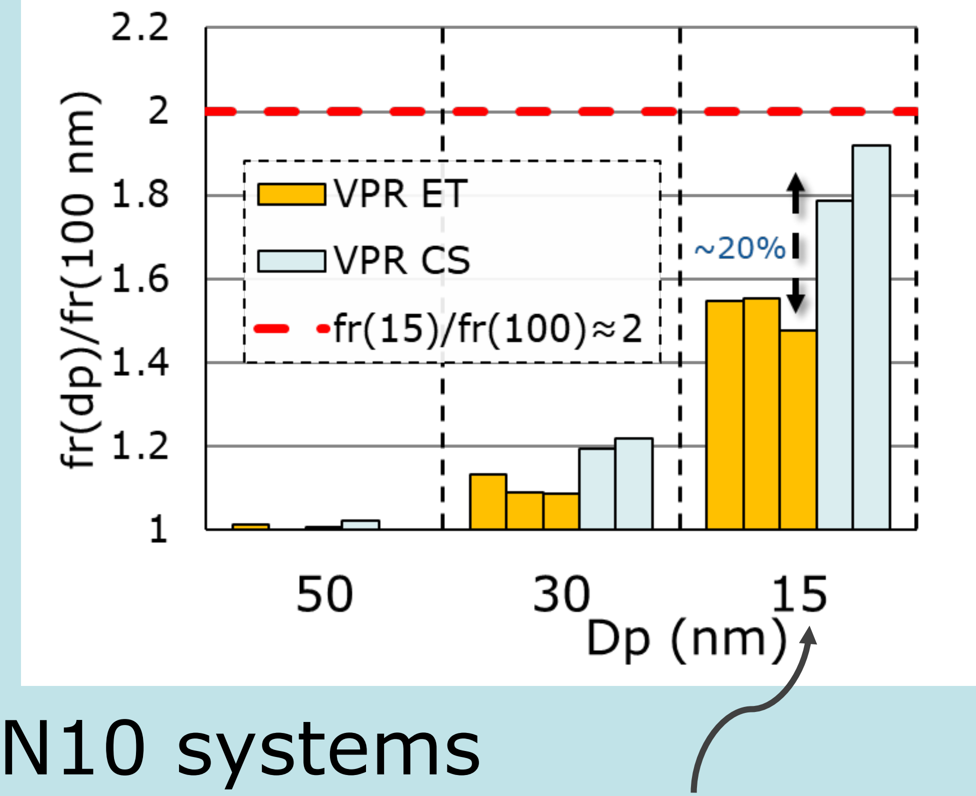
Losses in PN-systems

GTR: Penetration P for 100 nm particles
P(100 nm)≥70 %→ P(15 nm)>35%

- Requirement: losses for 15 nm particles less than 2x losses for 100 nm particles

$$\frac{fr(15\text{nm})}{fr(100\text{nm})} < 2$$

  - Limited to 15 nm as 10 nm particle generation is challenging
- Catalytic Stripper(CS) losses ~20 % higher than current systems
- Manufacturers planning to have CS in PN10 systems
- PCRF is proposed to be kept as before



Spark-generators produce high enough Graphite particle concentrations @ 15nm

$$\overline{\text{PCRF}} = \frac{\text{fr}(30\text{nm}) + \text{fr}(50\text{nm}) + \text{fr}(100\text{nm})}{3} \cdot \text{DR}$$

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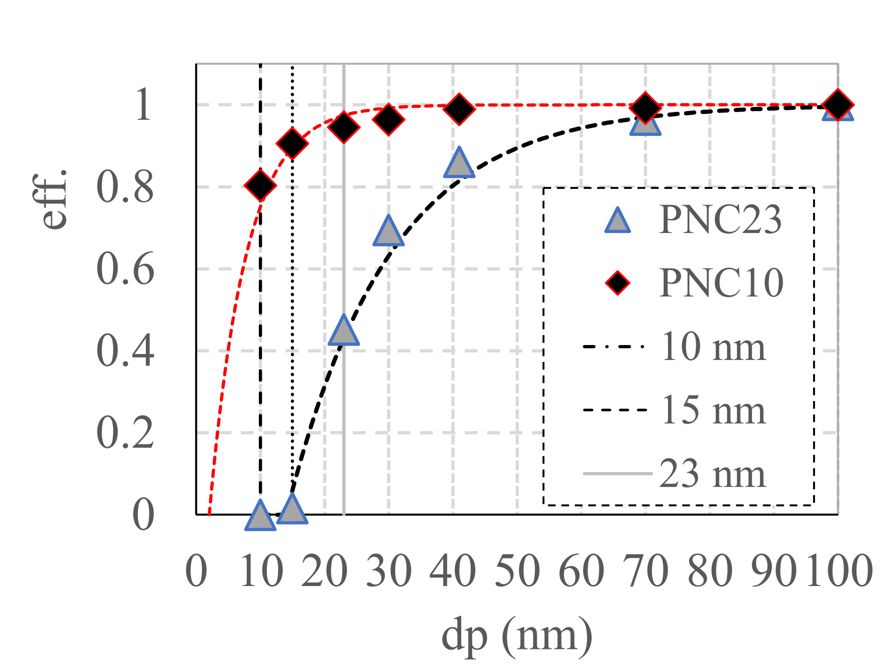
PNC parameters

- **PNC parameters from current 10 nm PNCs**
  - Real dp(50%) at around 7 nm
  - The parameters adapted from PNC10s used in the exercises and comprehensively in the field
  - PNC10 detection efficiency less sensitive to particle material (PNC exercise)
- **Calibration with Soot-like or PAO particles**
  - A PNC with 65 % efficiency at 10 nm independent on particle material
  - Soot uncertainty ~3% due to multiple charges
    - Wide distributions

dp (nm)	eff. (%)
10 ±1	65 ±15
15 ±1	> 90



VPR: catalyzed or not

- PNC-efficiency and VPR-type selection is based on minimizing artefacts
  - Artefacts are formed after VPR in PN measurement system
- Artefacts detected with ET not with CS
- Artefacts are detected mostly **below 10 nm:** PNCs of ≤4 nm D50%
  - Zheng *et al.* 2011, HD+DPF, ET, artefact below 10n
  - Johnson *et al.* 2009, HD, ET, artefact detected with 3 nm CPC
  - Giechaskiel *et al.*, 2017, moped 2-stroke,ET, artefact below 10nm
- Artefacts rarely detected with PNC10
  - Regeneration Tailpipe HD exercise and Giechaskiel *et al.*,
  - Some PMP-participants requested the usage of ET
- **Proposed that <u>both CS and ET are approved</u>**
- **Addition of stricter volatile removal efficiency requirement**

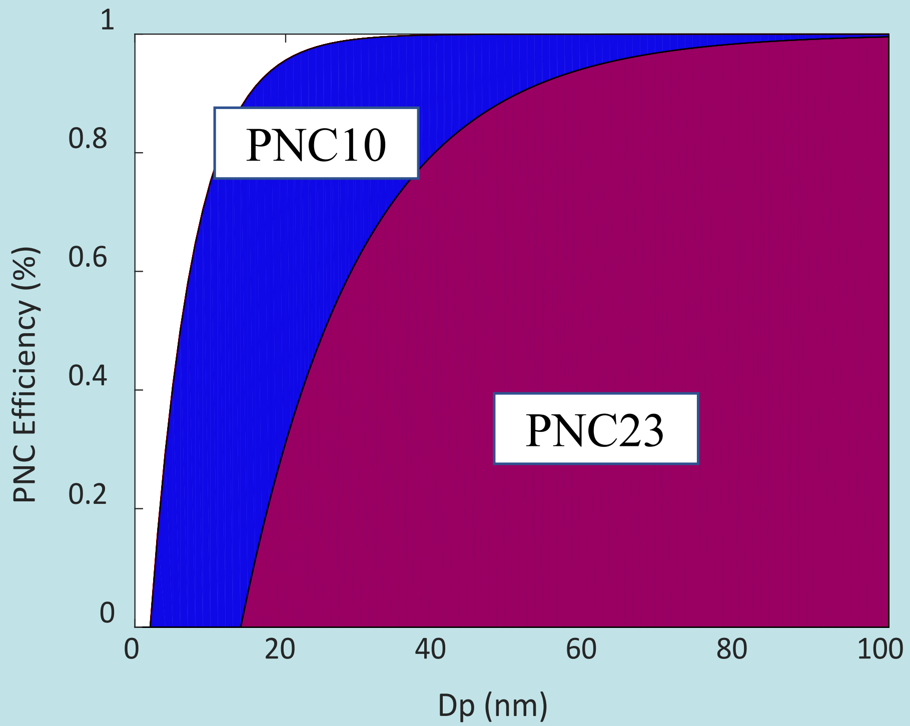
Wrap-up

dp (nm)	eff. (%)
10 ±1	65 ±15
15 ±1	> 90

- Proposal for Sub-23nm
  - PNC 65 % counting efficiency at 10 nm
    - Current systems in the market
  - Losses at 15 nm < 2x losses at 100 nm
    - Current systems comply with the requirement
  - Both catalyzed and non-catalyzed evaporation tube approved
    - Request in PMP IWG
    - Artefacts rarely detected in above 10 nm

Question from PMP IWG

- Could the PN10 emission measurement cover also PN23 emission measurement in regulatory measurements?
  - If the vehicle passes the possible future PN10 limits could it be considered to pass also PN23-limit, although PN10 limits may not be valid in the region?
- The aim is to avoid double measurements



HORIZON 2020 projects

- The group is monitoring the progress of the three projects funded by EU under the H2020 scheme
  - DownToTen
  - PEMS4nano
  - SUREAL-23
- Projects are in finalizing stage
  - Reporting in progress
  - Input used later for Sub-23nm development

Sub-23 nm exhaust particles

- Objective: Address the still open points in the next weeks and freeze the proposal in the next PMP meeting (April/2020)
- Subsequent administrative steps:
    - Amendment to GTR 15 or to Reg. 83/49?
    - Two different procedures in GTR 15: >23 and <23 nm
- Following months to collect and process data on emission levels of latest vehicle models
    - To support the assessment of the PN-limits

NON-EXHAUST PARTICLE EMISSIONS

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BRAKE PARTICLE EMISSIONS
METHOD FOR MEASURING BRAKE WEAR PARTICLES

OVERVIEW OF THE LATEST ACTIVITIES

- The development of the novel cycle has been concluded and the cycle has been evaluated through an extensive Round Robin campaign – The most important results and conclusions have been reported to the *50th PMP Meeting* and the *79th GRPE Meeting*
- The measurement results of the Round Robin were further analyzed with the aim of providing recommendations regarding the correct application of brake dyno parameters for emissions measurement – Detailed analysis has been provided to the *51st PMP Meeting*
- The most important parameters are *the adjustment of the cooling air flowrate*, *the application of soak times* between the 10 trips of the WLTP-based cycle, *the proposed methodology for the temperature measurement* and the *definition of the climatic controls* – *51st PMP Meeting*

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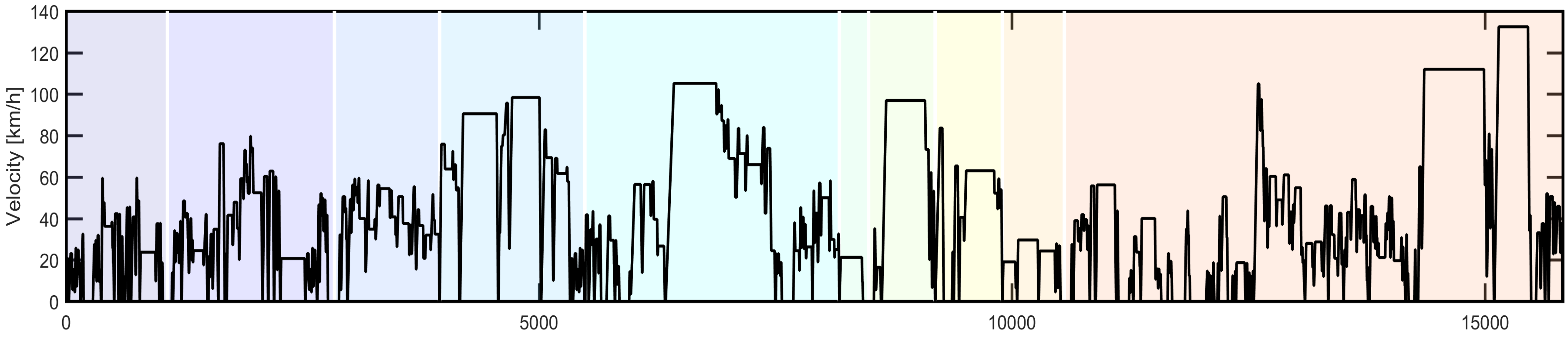
ACHIEVED MILESTONES
BRAKE CYCLE

Novel cycle release: Ford took over the development of the cycle based on PMP initial work in close collaboration with PMP TF1. Development phase lasted almost 2 years including vehicle and lab validation



The number of publications on brake emission studies adopting the novel cycle is continuously increasing. The cycle is freely available at: **https://data.mendeley.com/datasets/dkp376g3m8/1**

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METHOD FOR MEASURING BRAKE WEAR PARTICLES
ACHIEVED MILESTONES

1. Cooling air adjustment: Definition of the problem – The application of non-comparable cooling air flowrates to different dynos/labs results in discrepancies of the recorded brake temperature regimes. This has a negative effect on the quality of PN measurements as well as on the reproducibility of results among the labs

The proposed methodology for the adjustment of the cooling air flowrate is relatively simple, not much time and resource consuming and accessible to all labs with a certain level of technical capacity. **The method applies for all brakes featured in passenger cars -** Detailed description has been provided to the *51st PMP Meeting*

2. Definition of climatic controls: Definition of the problem – Cooling air temperature and RH of the incoming air have been demonstrated to be important factors affecting the brake temperature. Therefore they should be controlled. Not proper control has a negative effect on the quality of PN and PM measurements

Cooling air is proposed to be adjusted to **20°C±2°C and 50%±5% RH**. These values refer to the averages during the whole cycle duration. Labs need to make sure they stay as close to the target value as possible

METHOD FOR MEASURING BRAKE WEAR PARTICLES
ACHIEVED MILESTONES

3. Temperature measurement: Definition of the problem – Brake temperature on the dyno can be measured by means of embedded or sliding thermocouples. The two methods do not provide the same level of accuracy. It has been demonstrated that incorrect/inaccurate temperature measurement has a negative effect on the quality of PN measurements

Disc temperature measurement and subsequent analysis shall be performed by means of **embedded thermocouples**. Recommendations on the correct installation and use of the TCs will be provided by TF1

4. Soak times: Definition of the problem – Long soak times required for the brake to reach the starting temperature of each trip result in a substantial prolongation of the cycle. Additionally, long soak times might introduce artefacts in the PM measurement as air flow is applied in order to cool down the brakes faster

It has been shown that the application of 35-40°C as initial test temperature does not affect PN emissions. It is recommended to adjust the soak time of the cycle to the temperature of 40°C when conducting emissions tests

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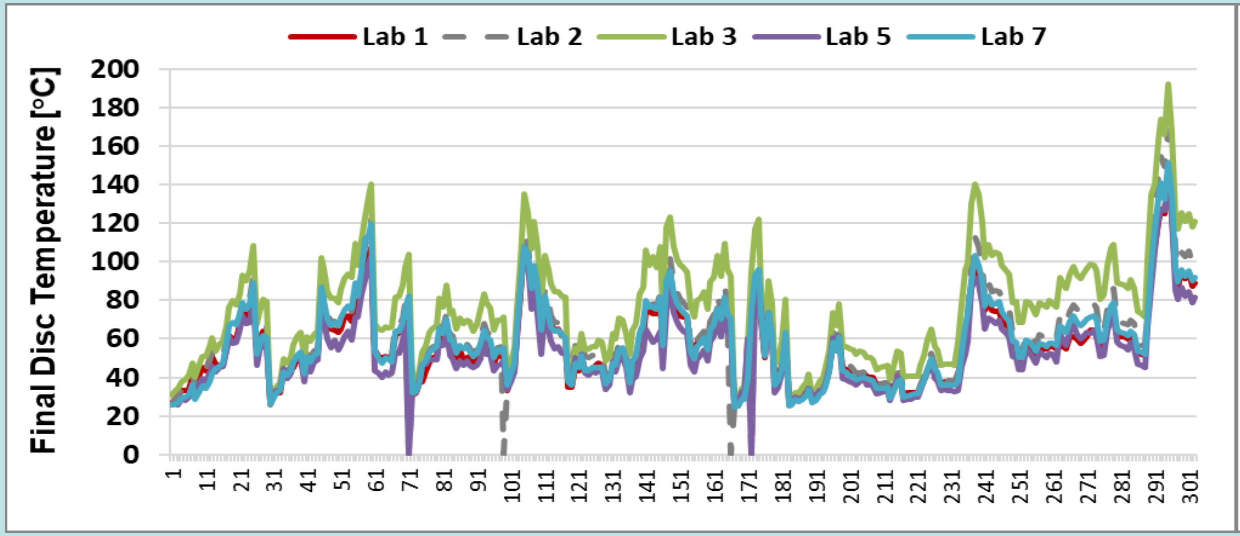
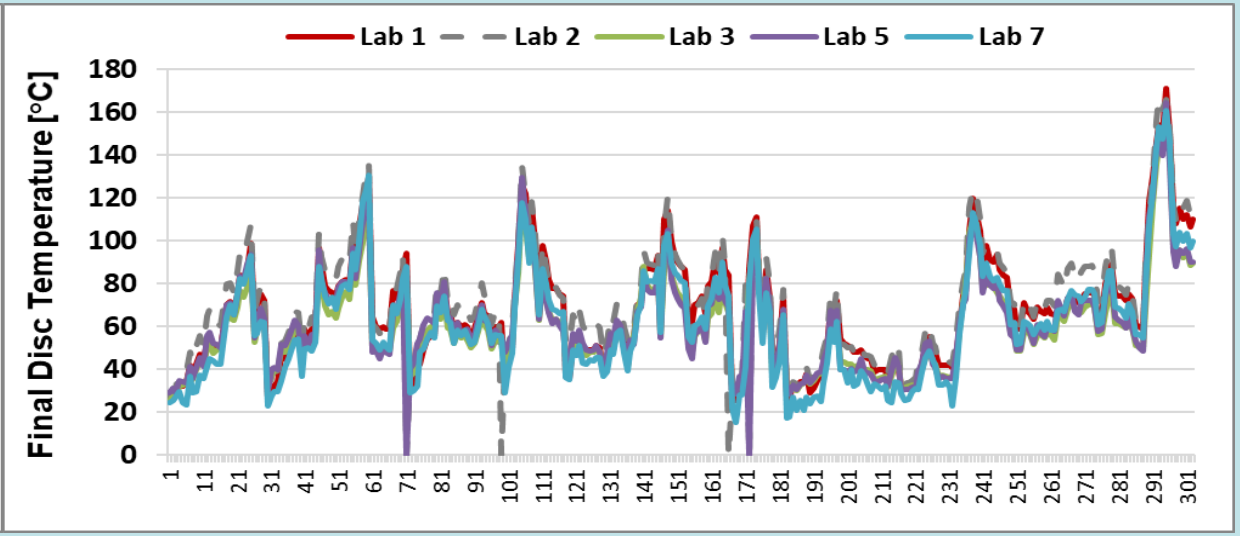
ACHIEVED MILESTONES
TEMPERATURE MEASUREMENT

DEFINITION OF THE PROBLEM – Brake temperature can be measured with embedded or/and sliding TC. The two methods do not provide the same level of accuracy. Round Robin data were used to evaluate the differences



Final disc temperature profile measured by sliding TCs over the 1st repetition of T1 for 5 different labs



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ACHIEVED MILESTONES
SOAK TIMES

DEFINITION OF THE PROBLEM – Long soak times required for the brake to reach the starting temperature of each trip result in a substantial prolongation of the cycle. Additionally, long soak times might introduce artefacts in the PM measurement as air flow is applied in order to cool down the brakes faster

TU Ilmenau Data – TF2	Cooling air speed: 50kph - mean temperature per section [°C]										mean (total) [°C]	time (total)
	1	2	3	4	5	6	7	8	9	10		
w/o soak time	57.8	74.1	67.2	66.7	61.8	59.0	39.5	75.9	44.1	61.5	62.5	4h24min
Init 35Grad	55.6	67.4	56.2	63.3	58.6	30.4	34.7	53.5	30.3	61.8	57.7	5h09min
w soak time	55.0	64.8	53.2	60.3	57.3	21.3	30.9	49.4	24.3	60.7	55.7	41h24min

It has been shown that the application of 35-40°C as initial test temperature does not affect the brake temperature significantly. It is recommended to adjust the soak time of the cycle to the temperature of 40°C when conducting emissions tests. This will significantly reduce testing time

METHOD FOR MEASURING BRAKE WEAR PARTICLES
OPEN ITEMS – ON-GOING/FUTURE ACTIVITIES

1. Particle background concentration: Definition of the problem – Background concentrations higher than ~100 #/cm^3 can lead to overestimation of PN emissions at some parts of the cycle. Background contribution increases with increasing tunnel flow. Minimum requirements for the background concentration should be set

2. Brake enclosure: Definition of the problem – The geometry of the brake enclosure highly affects the transport efficiency of the sampling system. It is recommended to define at least some basic design guidelines and technical requirements for the brake enclosure in order to minimize particle losses

3. PM & PN measurement: Definition of the problem(s) – Lack of detailed specifications for PM measurement (i.e. cyclone, filter media and required efficiency, detailed weighting protocol, etc.) and PN measurement (i.e. solid vs total PN concentration, calibration procedure, volatile background, etc.). Round robin validation exercise and possible adjustments will be required once the methods are accurately defined

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TYRE WEAR PARTICLE EMISSIONS

CURRENT STATUS AND FUTURE OUTLOOK

- No experimental results were presented to the 50th and the 51st PMP Meeting. Results from two on-going campaigns had been presented to the 48th PMP Meeting
- Research interest as well as updated results on tyre wear emissions will come up with the initiation of the funded H2020 LC-MG-1-14-2020 call
- The EC has mandated the development of a methodology for measuring tyres abrasion rate. ETRMA has presented its proposal to the COM. The proposal will become available from ETRMA after some adjustments that will take place in the next months. It is expected to be presented to the next PMP Meeting
- After the development of the methodology the PMP is willing to investigate the relationship between tyre wear PM emissions and their abrasion rate

Changes to PMP mandate?

Requests from contracting Parties

- Request from RDE IWG: Extension of the scope of the PMP IWG to PEMS-PN (10 nm)

- EC & UK:
    - Non-exhaust emissions (brake wear): Extension of the mandate of the PMP IWG to include the development of a methodology that can be used for regulatory purpose

Any questions?

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