# PMP IWG – BRAKE PARTICLE EMISSIONS

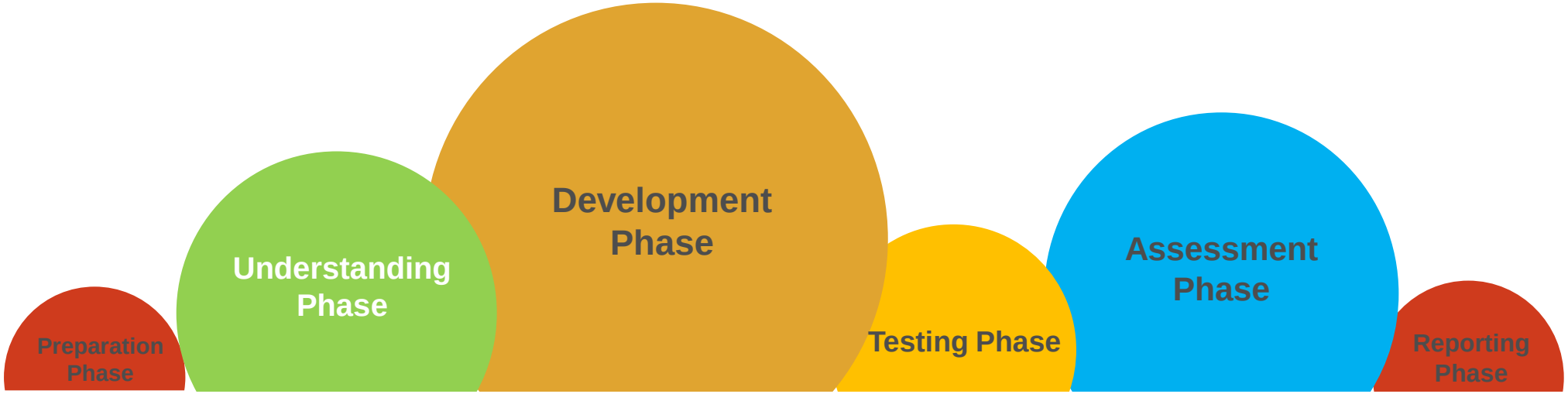
## DEVELOPMENT OF A COMMONLY ACCEPTED METHOD FOR MEASURING BRAKE PARTICLE EMISSIONS

## 27th TF2 MEETING
## BRIEF OVERVIEW

*Theo Grigoratos*

*08 April 2021*

# The PMP Procedure at a glance




### Understanding Phase

Study of existing brake dyno configurations for brake PM & PN sampling and measurement

**COMPLETED**

### Testing Phase

Application of the reuirements in an Interlaboratory study. Decisions on technical specifications

**DEADLINE – DEC 2021**

### Reporting Phase

Publication of the PMP-Brake Protocol

**DEADLINE – JUN 2022**

### Preparation Phase

Literature review & decision on test method approach

**COMPLETED**

### Development Phase

Definition of minimum requirements for sampling and measurement of brake PM and PN emisssions

**ON-GOING DEADLINE – JUN 2021**

### Assessment Phase

Assessment of the RR results. Refinements and finalization of the method specifications

**DEADLINE – FEB 2022**

European Commission

# Task Force 2 – Development phase

The aim of this phase is to define a set of minimum requirements for brake particle emissions measurement. The following parameters have been identified:

| Parameter 1 | Parameter 2 | Parameter 3 | Parameter 4 | Parameter 5 | Parameter 6 | Parameter 7 | Parameter 8 | Parameter 9 |
|---|---|---|---|---|---|---|---|---|
| Cycle Definition | Background Concentration | Dynamometer Climatics | Temperature Measurement | Bedding-in Procedure | Enclosure Design | PM Measurement | PN Measurement | Other Topics |
| ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |

# Task Force 2 – Defined Cycle (WLTP-Brake Cycle)

Decision is to run the time based WLTP-Brake Cycle profile. The aim is to adjust the cooling air flowrate for the different dynos following the specifications of the PMP cooling methodology in GRPE 81-12

- ***IBT of 40°C shall be applied for every trip of the cycle when performing emission measurements. Trip #1 shall commence at ambient temperature.*** This will allow for a significant reduction of the soak time during testing. IBT of exactly 40°C shall be applied when performing the cooling air flowrate adjustment by means of trip #10 of the WLTP-Brake Cycle.
- More details regarding the application of the WLTP-Brake Cycle (including the adjustment of the cooling air flowrate) are included to the GRPE 81-12 protocol "***Part 1: Inertia Dynamometer Protocol to Measure and Characterise Brake Emissions Using the WLTP-Brake Cycle***".

**The topic is considered closed with only pending topic being the finalization of the PMP cooling methodology**

# Task Force 2 – Background Concentration

Each laboratory shall follow the recommendations described below regarding the background concentration check:

- The cooling air entering the brake enclosure during a brake particle emission test shall pass through a medium capable of reducing particles of the most penetrating particle size in the filter material by ***at least 99.95%***, or through ***a filter of at least class H13*** as specified in EN 1822;
- It is encouraged that the cooling air entering the brake enclosure during an emission test passes through a ***charcoal (or activated carbon) filter*** with the aim of removing volatile organic species.
- ***The background concentration shall be defined on a PN basis.*** Each laboratory shall report their background concentration which shall not exceed the maximum allowed value of ***X particles/cm$^3$***;
- It is recommended to perform the BG check at two levels. ***The first level foresees the system installation*** (or when there are indications of malfunction), while ***the second level foresees regular background checks*** before and after the execution of a brake emissions test.

**The topic is considered closed – the values will be defined after the end of the interlaboratory study**

# Task Force 2 – Dyno Climatics

Volume flow should be constant during the test. Brake/caliper orientation relative to incoming cooling air plays a major role (see Brake Enclosure Design).

- ***Volume flow*** as well as ***its measurement point(s)*** need to be reported in order to avoid wrong comparisons.
- ***Cooling air temperature and Relative Humidity shall be adjusted to 20±2°C and 50±5%, respectively.*** Labs need to make sure they stay as close to the target values as possible (20°C and 50% RH). The same values apply for the adjustment of the cooling air flowrate during trip #10. ***20±5°C and 50±10% RH are allowed for no longer than the 10% duration of the cycle.***

**The topic is considered closed**

# Task Force 2 –Temperature Measurement

A common protocol describing the temperature measurement is required to ensure repeatable and comparable measurements.

- ***Only embedded thermocouples shall be used for recording brake temperature regimes.*** Sliding thermocouples might also be used in addition but shall not be considered for lab-to-lab comparison purposes.
- ***The disc thermocouple should be located in the outboard plate rubbing surface, radially positioned 10 mm outwards of the center of the friction path, and recessed ½ mm deep into the face of the disc.*** On vented discs the thermocouple should be centered between two fins of the disc plate.
- More details regarding the measurement method have been included to the protocol ***"Part 1: Inertia Dynamometer Protocol to Measure and Characterise Brake Emissions Using the WLTP-Brake Cycle"***

**The topic is considered closed**

# Task Force 2 – Bedding-in procedure

Bedding shall be long enough to ensure the ***stabilization of the friction couple behavior***. However, there needs to be a compromise in terms of the stabilization in order to reach a ***reasonable testing time***.

- It is recommended to apply ***5 WLTP-Brake Cycles for bedding disc/pad couples and drum brakes***. The number of cycles required might be revised after the RR exercise.
- It is recommended that the 5 WLTP-based novel cycles run consecutively without any interruption. ***Soak times shall not apply between the individual trips during the bedding procedure***. However, each repetition shall commence with IBT of 40°C (1st repetition at ambient temperature).

*Additional Elements*

JRC invites the labs to run a campaign with the aim of comparing the bedding of a brake couple with the application of 5 WLTP-Brake Cycles as described above against the application of ten repetitions of trip #10 of the WLTP-Brake Cycle

**The topic is considered closed; however, based on the outcome of the interlaboratory study the bedding procedure might be revised**

# Task Force 2 – Brake Enclosure Design (1/2)

Design requirements for the enclosure are defined with the aim of achieving maximum transport efficiency, maximum particle distribution/uniformity and minimum residence time.

- The brake enclosure shall incorporate good aerosol sampling practice that includes the ***avoidance of sharp bends and abrupt changes in cross-section*** and the use of smooth internal surfaces (i.e. curved edges) to reduce flow recirculation zones. ***Gradual changes in the cross-section are permitted***; however, it is recommended to apply smooth transition angles to overcome these cross-section changes and ***avoid application of 90 degrees – and larger – bends***;
- The brake enclosure shall come in dimensions which allow for measurements of ***all common sizes of LDV brake assemblies***. However, it is strongly recommended to ***avoid oversized enclosures due to higher residence times and increased particle losses***. Maximum dimensions might be specified in the future when more data become available

# Task Force 2 – Brake Enclosure Design (2/2)

- The use of ***electropolished surfaces*** (i.e. stainless steel), or other electrically conductive material ***to avoid particle losses by electrostatic deposition***, is recommended;
- The enclosure shall be designed in such a way that a ***maximum particle residence time of X sec is ensured*** (value to be agreed after the experimental RR phase). Every lab shall report the maximum residence time for their setup based on their specific design for a given cooling air flow rate.
- The caliper shall be positioned in a way to minimize a potential interference with the incoming cooling air. Depending on the orientation of the duct works (horizontal or vertical), it is recommended to ***install the caliper at the upper part of the disc in a position between 1 and 2 o´clock or 10 and 11 o´clock*** considering the direction of evacuation;
- The brake disc shall rotate in the ***direction of the evacuation*** (CCW) independently of the orientation of the duct works (horizontal or vertical).

**The topic is considered closed – the values will be defined after the end of the interlaboratory study**

# Task Force 2 – PM Measurement

PM ($PM_{2.5}$ and $PM_{10}$) should be measured gravimetrically. Great care needs to be taken to ensure isokinetic sampling. TF2 members have been requested to carefully study the corresponding chapter drafted by Brembo-Dekati-JRC and come back with suggestions.

*Topics for consideration*

- ✓ Sampling system layout with possible differences in $PM_{2.5}$ and $PM_{10}$ measurement, sampling points and devices (i.e. impactors or cyclones)
- ✓ Detailed specifications for the impactors/cyclones, the filter media + efficiency, the weighting method (including filter conditioning and related standards or regulations) and others are required
- ✓ Recommendations for minimizing coarse particles losses and ensuring accurate and reproducible $PM_{2.5}$ and $PM_{10}$ measurement
- ✓ Other topics (?)

# Task Force 2 – PN Measurement

PN down to 10 nm should be measured directly preferably by means of a full-flow CPC or OPC technique. Indirect measurements, conversions, and corrections shall be avoided. Specifications for measurement of both total PN and solid only PN shall be prepared and provided.

*Topics for consideration*

- ✓ How should one deal with volatile background? How does it affect PN measurement in both cases (Solid vs. Total)
- ✓ The calibration procedure has not been discussed yet. Are there any preliminary proposals for both cases (Solid vs. Total)?
- ✓ Other topics (?)

# Task Force 2 – Other Topics

- Minumum parameters to be registered and commonly acceptable format. A first proposal for some of the parameters have been included to the protocol "***Part 1: Inertia Dynamometer Protocol to Measure and Characterise Brake Emissions Using the WLTP-Brake Cycle***"
- Cleaning procedure of the test bench after testing. How should this be done? How often? Any other considerations?
- System size and spacing considerations. Some partners have expressed concerns regarding the overall required space for the brake dyno and the necessary equipment
- Discussion on what happens if a test is interrupted between the different cycle repetitions or within the same cycle between the different trips
- Other topics (?)

# Thank you



European Commission