# BRAKE PARTICLE EMISSIONS

## BRAKE EMISSION TASK FORCE 2
## FUTURE OUTLOOK

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

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European Commission

# DISCUSSION ON TESTING PARAMETERS


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**PN and PM measurements for brake wear particle emission**

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JASIC

PMP – Particle Measurement Program Informal Working Group
Task Force 2– Brake Dust Sampling and Measurement

**COMMON PARAMETERS FOR TESTING**

1. **Defined Cycle (WLTP-novel)**

   **First option is to run the time based WLTP profile.** The aim is to adjust the cooling air volume for the different dynos. When adjusting the air volume is not possible changing the brake intervals to match the vehicle temperatures is suggested.

   **Proposal to apply another set of brake stops to initially setup the emission setup.** It could look like: Heat the brake to i.e. 200°C with brake applies from 60-0 kph (0.2g deceleration). Afterwards, spin brake at 50 kph recording the time to cool rotor temperature from 200-30°C. Repeat these steps as many times as needed while adjusting cooling air to match the profile provided. Verify the cooling rate is also appropriate at 80 and 110 kph rotational speeds. The proposed set will be performed additionally to WLTP.

2. **Background/blank concentration check**

   **Valid measurements only when quantity of emissions collected/measured during testing is at least five times the corresponding overall blank value.** Each Lab shall report the applied method for the blank evaluation. To ensure a reproducible background concentration it is necessary to filter the inflowing air. Blank value should be evaluated by one of the following methods:

   - Measured at test duct flow, cooling air at temperature and humidity conditions, with ventilation applied for 1h after the end of testing without any system modification (preffered)
   - By pushing the pads back away from disc to avoid contact and dust creation
   - Measured at test duct flow, cooling air at temperature and humidity conditions, and with no brake pad or rotor installed

3. **Defined range of cooling air temperature and RH**

   Volume flow should be constant and even if not all participants are able to adjust the cooling airflow it is important that we try to match the vehicle temperature profile. **Brake/caliper orientation relative to incoming cooling air plays a major role.** Needs to be reported in order to avoid wrong comparisons.

   - Incoming cooling air temperature at (20±5)°C
   - Incoming cooling air humidity at (50±10)% RH
   - Measuring principle and position for the flowrate
   - Brake/caliper orientation relative to incoming cooling air

4. **Common brake system for the first round of experiments**

   All dynos should execute the tests with the same "car" parameters. Spreader springs will not be used. Each lab will use their own knuckle fixture (TU Ilmenau proposes to use knuckle-fixed attachment to ensure real conditions – the use of post fixtures is

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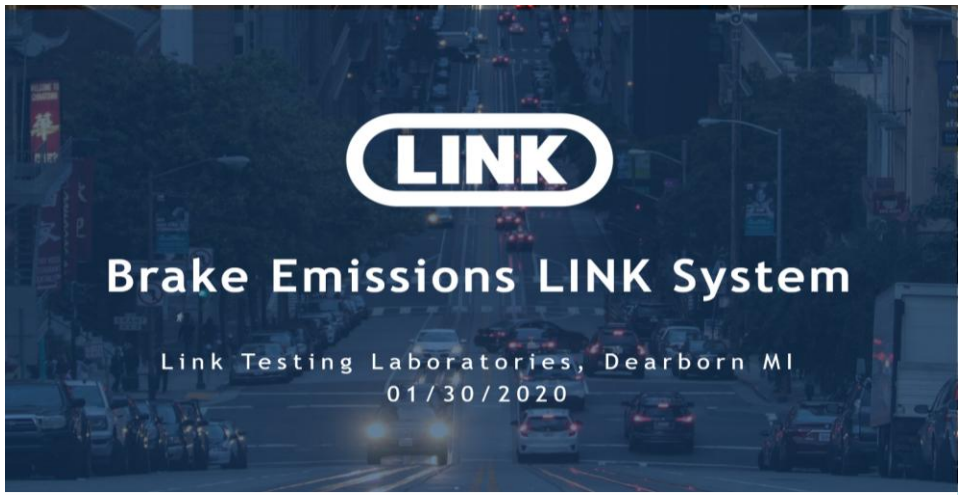


**CHALLENGES IN THE DEVELOPMENT OF A COMMONLY ACCEPTED METHOD FOR MEASURING BRAKE DUST:**
A HORIBA PERSPECTIVE…

30.10.2019; Joel Danzer, Dmytro Lugovyy, Yoshinori Otsuki

HORIBA

European Commission

# DISCUSSION ON TESTING PARAMETERS
# DEFINED CYCLE – SOLVED

## 1. Defined Cycle (WLTP-novel)

**First option is to run the time based WLTP profile. The aim is to adjust the cooling air volume for the different dynos.** ~~When adjusting the air volume is not possible changing the brake intervals to match the vehicle temperatures is suggested.~~

~~Proposal to apply another set of brake stops to initially setup the emission setup. It could look like: Heat the brake to i.e. 200°C with brake applies from 60-0 kph (0.2g deceleration). Afterwards, spin brake at 50 kph recording the time to cool rotor temperature from 200-30°C. Repeat these steps as many times as needed while adjusting cooling air to match the profile provided. Verify the cooling rate is also appropriate at 80 and 110 kph rotational speeds.~~

## Additional Elements

- ✓ It was agreed to reduce soak time by applying IBT of 40°C for every trip except for the 1st one (start of cycle)
- ✓ More details regarding the application of the WLTP protocol will be included to the protocol "Part 1: Inertia Dynamometer Protocol to Measure and Characterise Brake Emissions Using the WLTP-Brake Cycle" to be circulated in February

# DISCUSSION ON TESTING PARAMETERS
# BACKGROUND CONCENTRATION – NOT SOLVED

## 2. Background/blank concentration check

**Valid measurements only when quantity of emissions collected/measured during testing is at least five times the corresponding overall blank value.** Each Lab shall report the applied method for the blank evaluation.

## Open topics - to be discussed/agreed

- ✓ Do we need to correct the measured particle emissions over the test cycle by the particle background concentration? How reliable is background subtraction and up to what level?
- ✓ AVL-TUI reported background concentrations in the order of ~150#/cm$^3$ for 23 nm with emissions at the 60% of the cycle being close to background. Will we propose a maximum allowed background concentration (i.e. ~100#/cm$^3$ for 10 nm)?
- ✓ The particle background concentration measurement needs to be described in detail. The following methods are proposed:
  - *Measured at test duct flow with ventilation applied for 1h after the end of testing without any system modification (preffered)*
  - *By pushing the pads back away from disc to avoid contact and dust creation*
  - *Measured at test duct flow, cooling air at temperature and humidity conditions, and with no brake pad or rotor installed*

# DISCUSSION ON TESTING PARAMETERS
# DYNO CLIMATICS – SOLVED

### 3. Defined range of cooling Air Temperature and Relative Humidity

**Volume flow should be constant** ~~and even if not all participants are able to adjust the cooling airflow it is important that we try to match the vehicle temperature profile.~~ Brake/caliper orientation relative to incoming cooling air plays a major role. Needs to be reported in order to avoid wrong comparisons.

### Additional Elements

- ✓ 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). ***20±5°C and 50±10% RH are allowed for no longer than the 10% duration of the cycle***
- ✓ More details regarding the settings of the dyno will be included to the protocol "Part 1: Inertia Dynamometer Protocol to Measure and Characterise Brake Emissions Using the WLTP-Brake Cycle" to be circulated in February

# DISCUSSION ON TESTING PARAMETERS
# MEASUREMENT OF BRAKE TEMPERATURE – SOLVED

## 4. Common method for measuring the Brake Temperature

There should be a common protocol regarding the temperature measurement. **The disc thermocouple should be located in the outboard plate rubbing surface, radially positioned 10 mm outwards of the centre of the friction path, and recessed ½ mm deep into the face of the disc. On vented discs the thermocouple should be centred between two fins of the disc plate.**

## Additional Elements

- ✓ Only embedded thermocouples shall be used for recording brake temperature regimes. Sliding thermocouples might also be used as complementary
- ✓ More details regarding the measurement method will be included to the protocol "Part 1: Inertia Dynamometer Protocol to Measure and Characterise Brake Emissions Using the WLTP-Brake Cycle" to be circulated in February

# DISCUSSION ON TESTING PARAMETERS
# BEDDING-IN PROCEDURE – NOT SOLVED

## 5. Definition of a common bedding-in procedure

**Appropriate bedding-in is very important when emission tests are performed. Therefore it is recommended:**

- ✓ *Application of one WLTP novel cycle before adjusting cooling air flowrate and*
- ✓ *Application of at least four WLTP novel cycles before running emission tests*

## Open topics - to be discussed/agreed

- ✓ Possibility to shorten the bedding procedure? What recommendations are given for the purging between the cycles during the bedding procedure?
- ✓ Do we need different bedding procedures or criteria for different brake materials (ECE/NAO)?
- ✓ Criteria when the bedding is finished? What metric should be used (PN, PM, μ)? HORIBA suggests using integrated PN values for the bedding. However, subsequent cycles needs to be taken into account when defining proper criteria
- ✓ What needs to be reported regarding the bedding procedure (if any)?

# DISCUSSION ON TESTING PARAMETERS
# BRAKE ENCLOSURE DESIGN – NOT SOLVED

## 6. Brake enclosure design – Fast and effective evacuation of the enclosure (residence time)

The cooling air flow should be constant during the entire test. **A brake enclosure design – as well as appropriate materials – to minimize particle losses should be employed. Also it is recommended to use a brake enclosure design to minimize flow disturbances**

## Open topics - to be discussed/agreed (non exhaustive)

- ✓ Horiba recommends to describe the terms "minimize particle losses" and "minimize flow disturbances" a little bit more in detail
- ✓ HORIBA highly recommends to define at least some basic design guidelines (dimensions?) and technical requirements for the brake enclosure
- ✓ Each lab shall report the residence time based on calculations performed in house
  - *Estimation of the losses by means of the LINK PALS Macro (Optional)*
  - *CFD studies (Optional)*
  - *Brake dyno real measurements using industrial particle emitters (Optional)*
- ✓ Other topics (?)

# DISCUSSION ON TESTING PARAMETERS

# RESIDENCE TIME AND LOSSES IN THE DUCT – NOT SOLVED

## 7. Estimation of the losses and calculation of residence time in the duct

Emitted particles are transported from the point of emission through the entire system setup (brake dyno + measurement instrument) before they are actually detected. **Each lab shall report the estimation of the losses based on calculations performed in house.**

## Open topics - to be discussed/agreed (non exhaustive)

- ✓ No criteria are defined yet for the residence time. Shall we define certain criteria?
- ✓ It needs to be considered that different flow rates/flow velocities in different laboratories lead to significant differences in the residence time within the exhaust duct
- ✓ Each lab shall report the residence time based on calculations performed in house
  - *Estimation of the residence time by using the duct diameters and air flow (Optional)*
  - *Estimation of the losses by means of the LINK PALS Macro (Optional)*
  - *CFD studies (Optional)*
  - *Particle size distribution (Optional)*

# DISCUSSION ON TESTING PARAMETERS

## PM MEASUREMENT – NOT SOLVED

### 8. PM Measurement method

**PM should be measured gravimetrically ($PM_{2.5}$ and $PM_{10}$ are within the scope of this project).** Great care needs to be taken to ensure isokinetic sampling. TF2 members have been requested to carefully study Chapter 5 and come back with any questions on the methodology described.

### Open topics - to be discussed/agreed (non exhaustive)

- ✓ Low filter loadings needs to be considered in a quite moderate cycle like the WLTP cycle when introducing multi-cascade impactors
- ✓ Detailed specifications for the cyclone, the filter media + efficiency, the weighting method etc. are required. Cyclones with well defined specifications are necessary for both $PM_{2.5}$ and $PM_{10}$
- ✓ Isokinetic sampling with velocity ratios confined within the DIN 13284 recommendations
- ✓ AVL suggests that simple models for particle losses in tubing/bends are not reflecting the true penetrations. Shall weighing of pads to quantify PM recovery be applied?
- ✓ Recommendations for minimizing coarse particles losses
- ✓ Other topics (?)

# DISCUSSION ON TESTING PARAMETERS

## PN MEASUREMENT – NOT SOLVED

### 9. PN Measurement method

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

### Open topics - to be discussed/agreed (non exhaustive)

- ✓ How should one deal with volatile background? Is it important? 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)?
- ✓ Is parallel measurement with 10 and 23 nm CPC possible? What are the benefits of such an approach?
- ✓ Other topics (?)

# DISCUSSION ON TESTING PARAMETERS

## OTHER TOPICS – NOT SOLVED

### 10. Other topics

**Other topics to be discussed/agreed within TF2.**

### Open topics - to be discussed/agreed (non exhaustive)

- ✓ Minimum parameters to be registered – A common format shall be agreed. More details regarding the reported parameters will be included to the protocol "Part 1: Inertia Dynamometer Protocol to Measure and Characterise Brake Emissions Using the WLTP-Brake Cycle" to be circulated in February
- ✓ Cleaning of the test bench after testing. How should this be done? How often? Any other recommendations?
- ✓ Possible future Round Robin. What are the needs for the RR? What is the correct timing for the RR? Any other recommendation for the campaign?
- ✓ Other topics (?)