AVL List GmbH (Headquarters)

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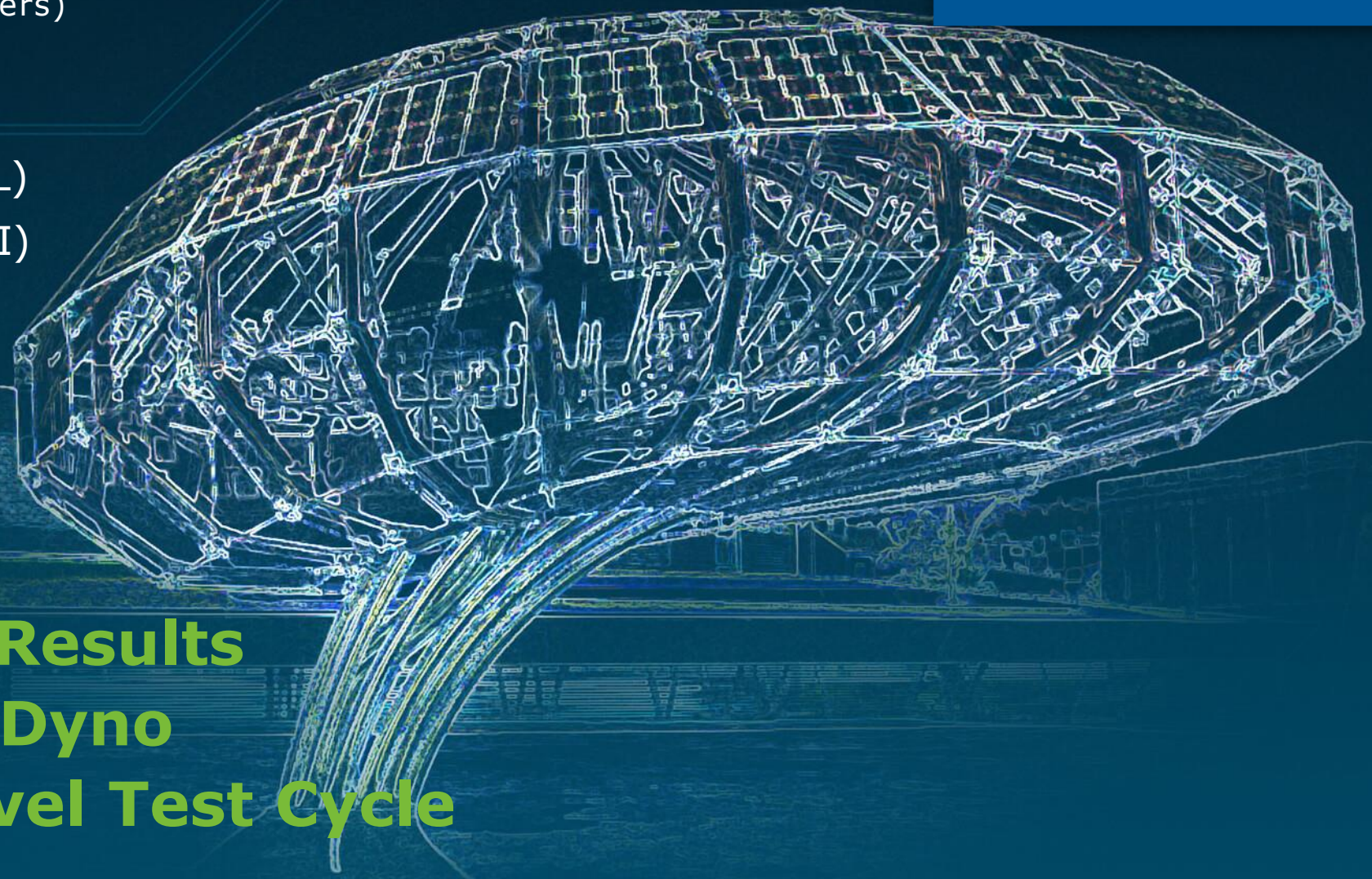


Brake Dust PM Results measured on a Dyno running the Novel Test Cycle

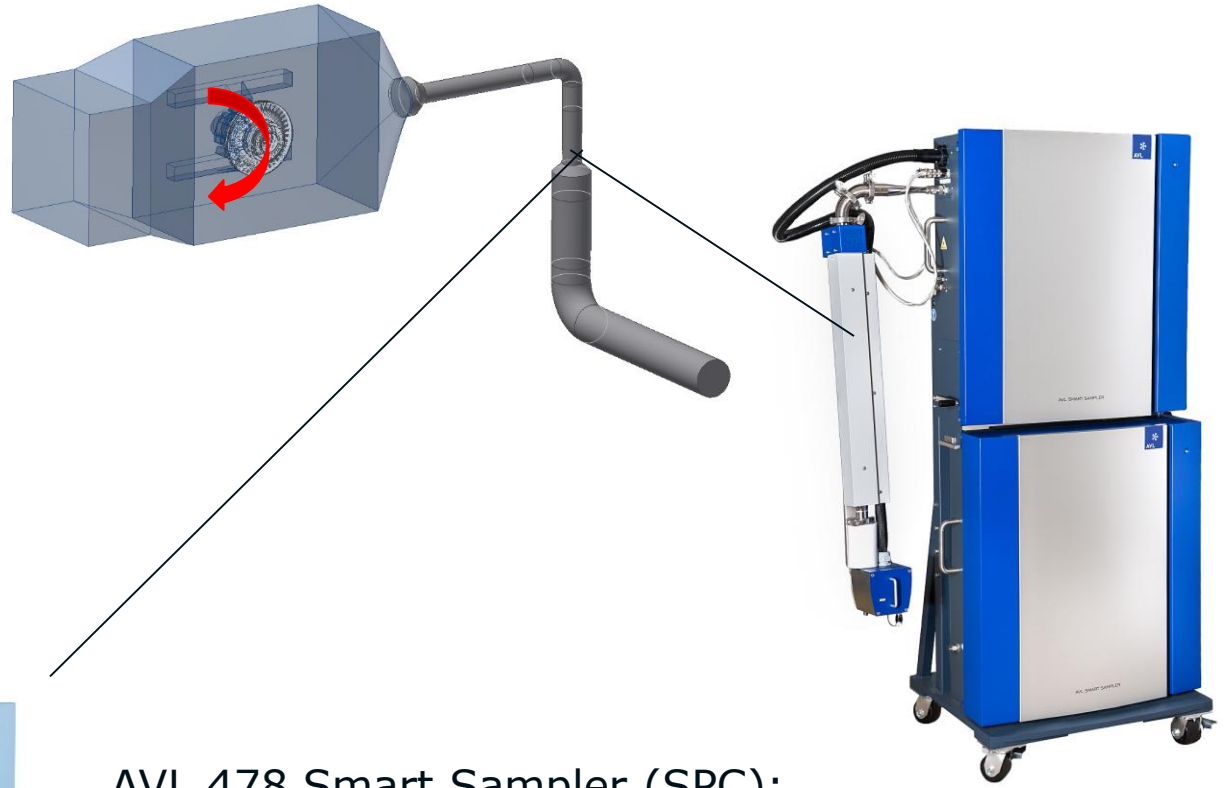
Objectives

Second phase of the campaign focused on PM measurements in the novel PM10 tunnel from TUI.

Main targets:

- Identify optimal sampling settings/conditions (i.e. filter loadings, pressure drop, etc.) for brake-wear PM.
- Study the repeatability of measurements performed using the novel cycle.

Existing PM exhaust instrumentation was used.



AVL 494 PM-PEMS containing filter sampler & photoacoustic Soot Sensor (MSS):
Allows collection of filter samples plus recording of real-time signal

AVL 478 Smart Sampler (SPC):
Standard partial flow sampler for exhaust PM certification. Can be operated with/without dilution tunnel attached. Contains internal cyclone (2.5µm), which can be bypassed. Wide flow range possible.

Experimental Setup

Tunnel operated at 170 m^3/h.

Two probes mounted in the vertical section of the tunnel. One probe for each instrument.

Conductive Teflon tubes were used to connect the sampling probe to the instruments.

The SPC dilution tunnel was used in selected tests focusing on the effect of filter temperature.

SPC via 1.5 m conductive Teflon line without tunnel, 1m line without tunnel (dashed line)

PM-PEMS via
1m conductive Teflon line

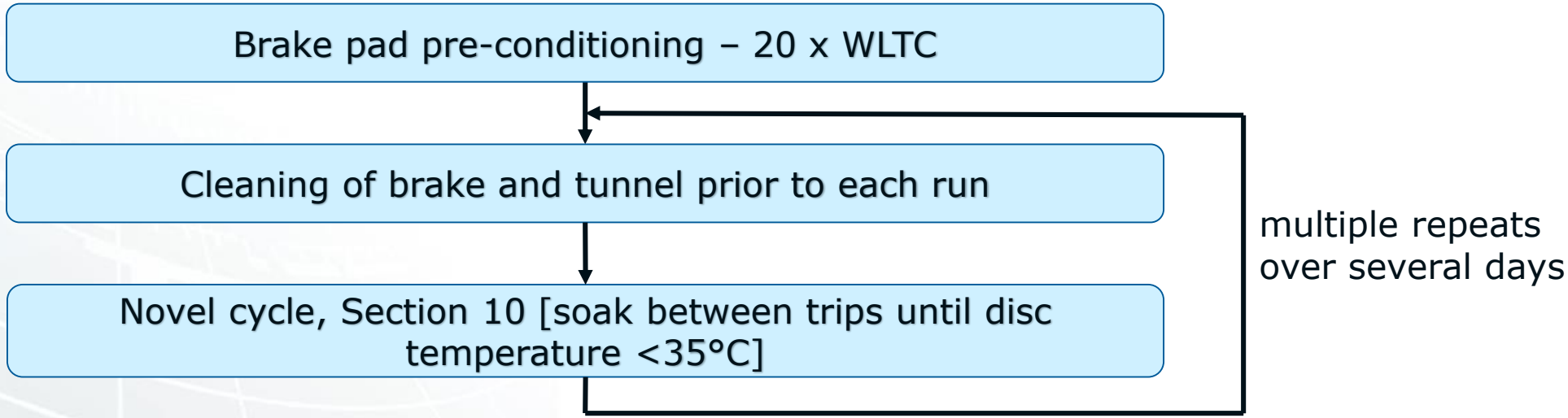
Experimental – Test procedure

Two different types of commercial brake pads were tested. One set was of series-production pads from European market (ECE) and one was of non-asbestos organic (NAO) type.

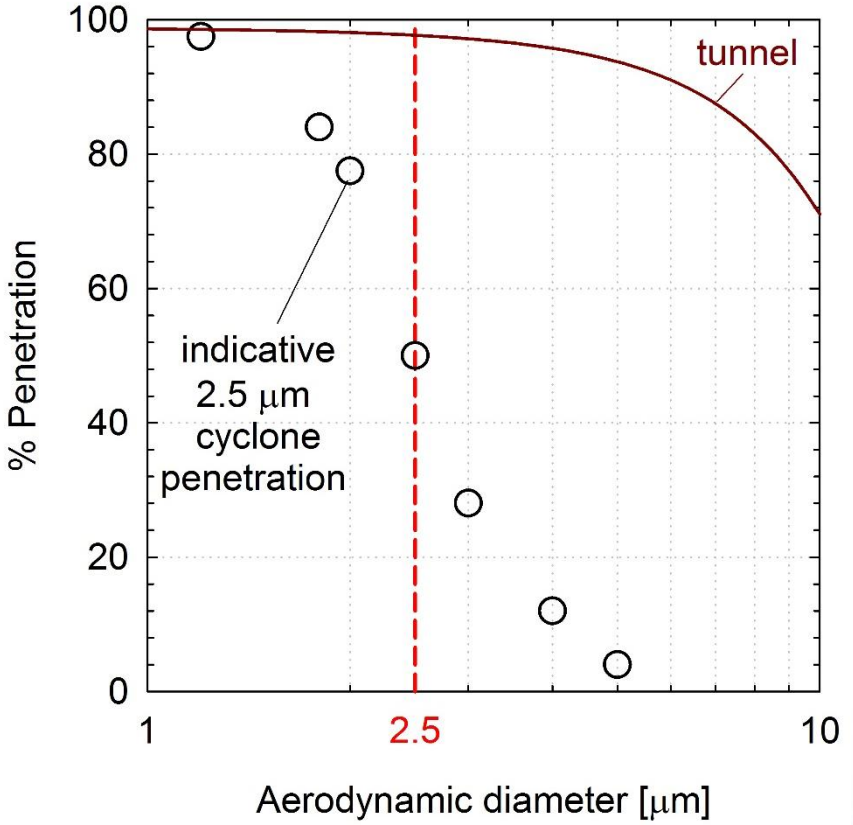
Instruments operated with and without 2.5 um cyclone. Samples collected on 47mm TX40 filters (stain diameter 38mm). Filter conditioning and weighing according to R49. Filter temperature 35°C and 47°C.

Dyno setting: Left front wheel of an entry-level luxury car (same as previous campaigns)

- Inertia: 60.4 kgm^2
- Effective radius: 126 mm
- Rotor size: 278 mm



Estimated penetrations

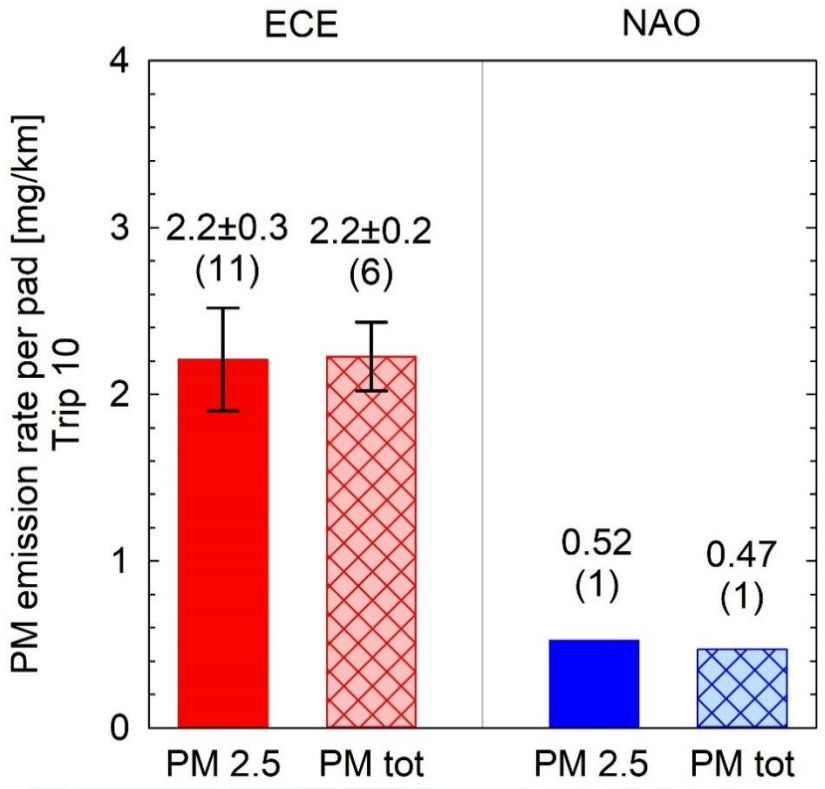


1D particle penetration calculations were performed for the tunnel to establish a frame of reference.

Good engineering practice was followed to minimize losses in the connections to the instrumentation.

We do anticipate though losses inside the instruments, especially inside the SPC, owing to the complex flow path and relatively high operating flows (~50 Nlpm).

Results – PM-PEMS

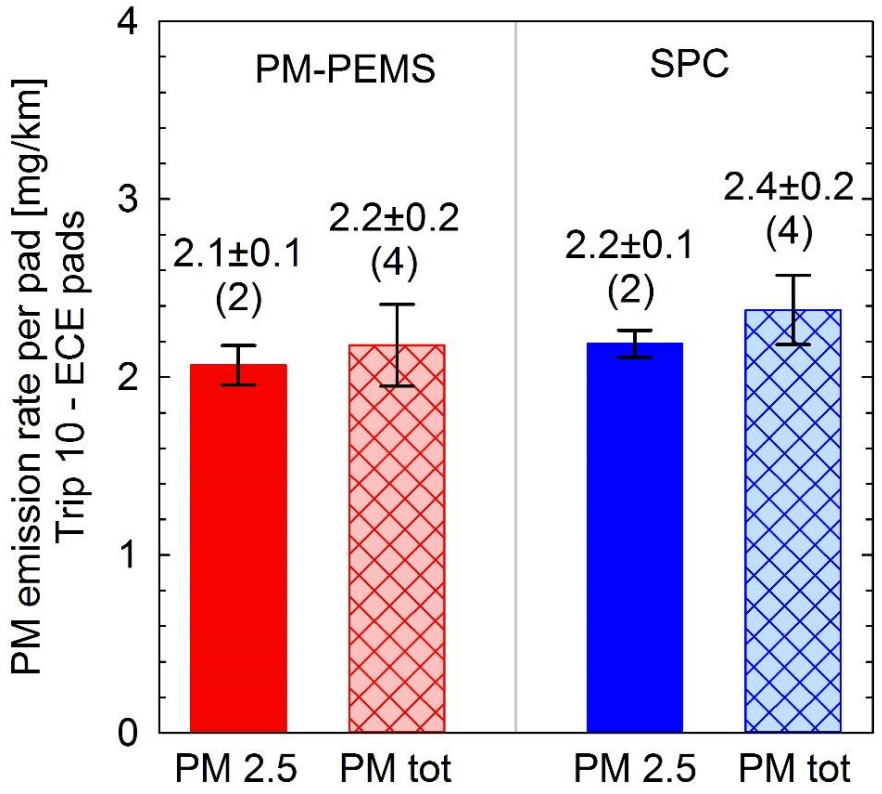


The PM results for ECE pads showed repeatability in the order of 10%.

Emission rates ~4.5 times lower for NAO pads.

2.5 µm cyclone had no effect on PM emissions.

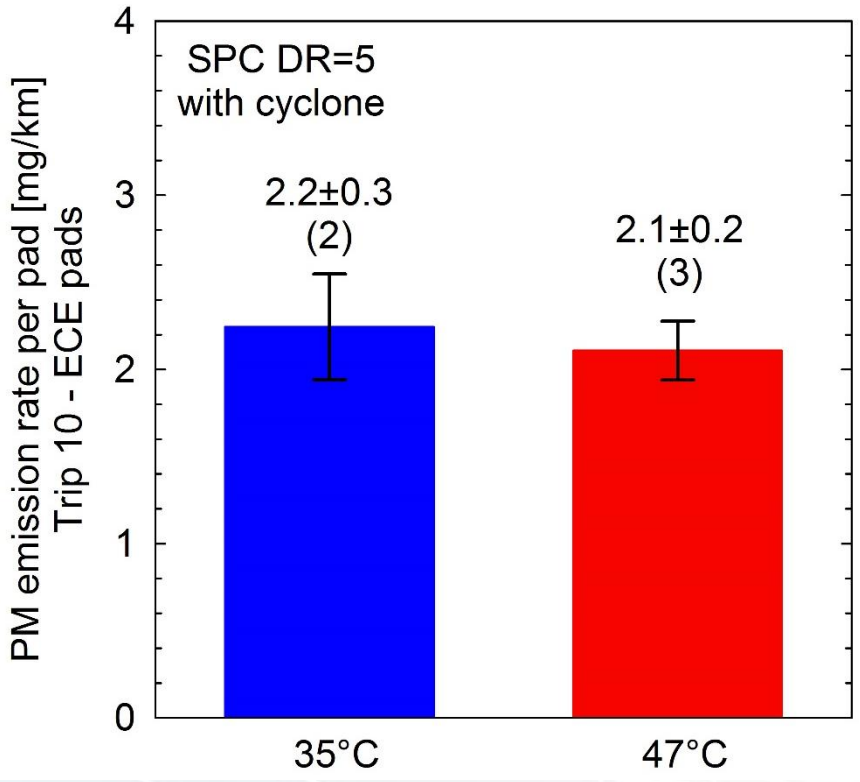
SPC vs PM PEMS PM data



No statistically significant differences could be observed between the SPC and PM-PEMS mass emission rates in the subset of data in which the SPC operated without the dilution tunnel (49 Nlpm sample flowrate).

2.5 µm cyclone had no effect on either PM-PEMS or SPC.

Temperature effect



Effect of filter temperature was investigated for ECE pads in limited tests with the SPC operating with its dilution tunnel.

No statistically significant differences could be observed.

Mass collected - backpressure

Filter loadings on SPC comparably high, between 2.4 mg and 3 mg, but pressure drop was minor <15 mbar.

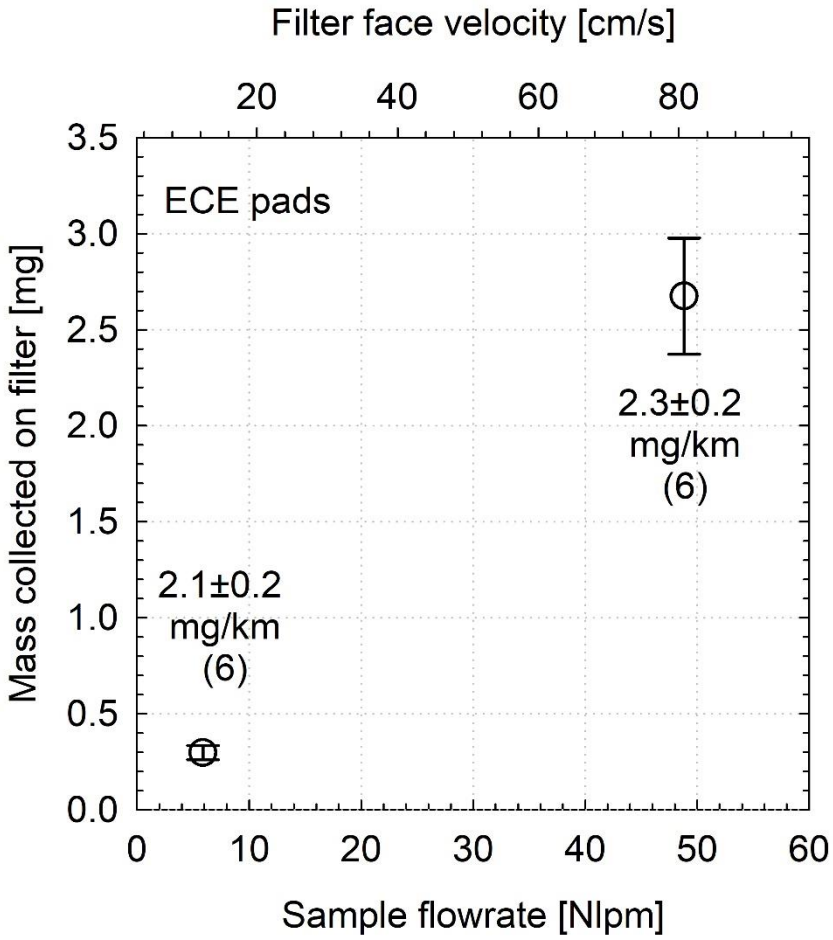
Typical filter loadings on PM-PEMS between 0.25 mg and 0.3 mg. No significant pressure drop.

→ Overloading of filters less critical than in exhaust applications. It is possible to sample a full cycle on one 47 mm filter. Sample flow of 10-20 Nlpm would lead to loadings of around 1 mg.

Results similar despite the rather large difference in filter face velocities.

→ Adsorption does not seem to be important (as long as you have properly conditioned dilution air).

Two repetitions of the full cycle suggested that trip 10 contributes to more than 40% of the total emitted PM.



Conclusions

- The use of a 2.5 µm cyclone did not have an effect on PM measured over trip 10 of the novel cycle for either ECE or NAO pads.
- The results suggest that there is not much mass above 2.5 µm. After multiple days of testing both cyclones (PM-PEMS and SPC) were empty.
- PM repeatability for trip 10 was in the order of 10%.
- Despite the considerably high amount of collected mass (up to 3 mg), the backpressure was very low (<15 mbar) even at the higher filter face velocity examined (80 cm/s).
- NAO brake-pads led to 4-5 fold lower PM emissions.

Outlook

- A follow-up campaign is planned for CW16 with a focus on the repeatability on the full cycle using the brake-pads from TF1.

- Based on the findings of the previous campaigns, the following measurement instrumentation will be employed, which corresponds to the recommendation of AVL and TUI:
  - PM:
    - Single filter holder with no cyclone
    - Isokinetic sampling ($0.8 < U_0/U < 1.2$)
    - Sample flow rate in the order of 10 lpm to facilitate sampling (minimize losses)
  - PN:
    - 10 nm full flow CPC calibrated according to ISO 27891.
    - R49 compliant Volatile Particle Remover with Catalytic Stripper and PCRF calibrated at 15, 30, 50 and 100 nm.

Thank You

AVL

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