Concept for an automotive 10nm calibration standard
CONTENTS

- 10nm exhaust PN counter instrument definition
- Calibration concept
- Calibration aerosol
- Calibration setup
- Discussion of advantages/disadvantages
Performance of exhaust PN counter is dominated by **Catalytic Stripper penetration**

- Steep drop of system performance at 10/15nm **independent of CPC counting efficiency**
- Main target of calibration must be **CS penetration**
  - Thermally stable standard aerosol
- Data/knowledge of CS penetration in this application is **insufficient**

Data source: Pems4nano Report D2-4

Penetration at 10nm: 50% vs. 100nm at 15nm: 67% vs. 100nm
EXHAUST PN COUNTER INSTRUMENT DEFINITION

Define the full instrument performance curve, similar to PN-PEMS

<table>
<thead>
<tr>
<th>Size [nm]</th>
<th>(10)</th>
<th>15</th>
<th>23</th>
<th>41</th>
<th>60-80</th>
<th>(100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System efficiency (23nm)</td>
<td>0</td>
<td>&lt;5%</td>
<td>47±12%</td>
<td>&gt;90</td>
<td>102%</td>
<td>102%</td>
</tr>
<tr>
<td>Imaginable efficiency (10nm)</td>
<td>&lt;50%</td>
<td>40-80%</td>
<td>60-90%</td>
<td>80-100%</td>
<td>90-110%</td>
<td>90-110%</td>
</tr>
</tbody>
</table>

- Numbers **highly dependent** on the available VPR (CS/ET) technology → **benchmarking** required!
- Direct visual representation of the actual device performance (unlike separated KF+CPC+PCRF curve)
- 10nm point could be omitted, since performance directly related to 15nm (mostly diffusion losses) and calibration error is largest at 10nm!
- A point at 60-80nm could be used instead of 100nm for easier calibration: very similar performance to 100nm, but higher concentration and use of shorter DMA possible
- **No pointless discussion, what an arbitrary “new PCRF” would look like**
CALIBRATION CONCEPT

Permitted calibration range

Ideal Performance

Particle Size

Efficiency

100%

0%

10 nm

>60 nm
Calibration is closely linked to instrument definition.
You cannot decide on one without the other.

Proposal: 2-part calibration

- CPC linearity: calibration of CPC linearity from 1.000-25.000 #/cm³ (tbd)
  - Measured at >20nm (plateau)
  - Error definition: residual errors <5%

- Whole System counting efficiency at 15nm, 23nm, 41nm, 60-80nm
  - incorporates both VPR penetration and CPC counting efficiency
  - single normalization factor at 60-80nm to adjust curve to “100%”
  - a certain minimal penetration through the VPR should be required
  - CPC counting efficiency does not need to be calibrated, since lower cutoff is determined by VPR penetration while CPC plateau efficiency is stable
  - High dilution factors (up to 1:3000) not needed anymore with current engines
Priorities

– Define a single standard aerosol to end current confusion and enable traceability and accreditation
– Aerosol suitable for CPC and VPR
– Compatibility with (future) PN-PEMS calibration
– Thermally stable aerosol (clear definition of “what is thermally stable”)
– Ease of use and cost efficient operation
CALIBRATION AEROSOL

Instruments that work and are comparable:

– Propane diffusion-flame “CAST” at stoichiometric/lean combustion mixture
  – Ess, Vasilatou 2019: Characterization of a new miniCAST with diffusion flame and premixed flame options: Generation of articles with high EC content in the size range 30nm to 200nm
  – Andres (2013): EMRP ENV02 PartEmission, D1.1.2, Temperature resistant aerosol standards at 30 nm, 50 nm and 100 nm for number concentration calibration

– Spark discharge graphite “Palas DNP” (at least down to 15nm)
  – Meuller (2012) Review of Spark Discharge Generators for Production of Nanoparticle Aerosols

Devices that could be used through a transfer function from the standard:

– Silver nucleation oven ➔ not validated for whole exhaust counter, input necessary
– NaCl nebulizer/drier ➔ strong influence on CPC cutoff, input necessary
- Sampling volume open to ambient
- **Pressure-free** sampling for the particle counters
- Possibility of parallel calibration
- Slight overpressure at generator (~50 mbar)
DISCUSSION

Pro

– Applicable to PMP-compliant and PN-PEMS counters
– A single, straightforward standard enables traceability and accreditation
– A single calibration sheet and curve directly tells the device performance to the user
– Aerosol similar to engine exhaust
– Direct comparison to PN-PEMS
– Less calibration testing required
– Higher accuracy: one instead of two combined calibration curves for counting efficiency
– High error associated with $D_{50}$ calibration avoided

Contra

– Different calibration procedure from PN-23nm ➔ but compatible with PEMS calibration lines
– CPC cannot be swapped out without recalibration ➔ questionable even today, because it would mean having 2 different calibration dates
– Possible requirement of transfer function or transfer value to current procedure
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**10nm Exhaust PN Counter System Performance**

- **CS 10nm: penetration ~50% vs. 100nm**

**Data sources**
- CS Penetration: Pems4nano Report D2-4
- 10nm CPC: Calibration Round Robin Report