Heated Automotive Partector
(aka ICAD)

An Electrical Detector for Particle Counting below 23 nm

SUREAL-23 project

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The Sureal-23 project is one of three Horizon2020 EU projects

Main goals: Understanding, Measuring and Regulating Sub-23 nm Particle Emissions from Direct Injection Engines Including Real Driving Conditions

Project partners: APTL, CRF, IFPEN, IM, NKT, FHNW, SEADM, TSI, YALE

Our role (FHNW): develop a diffusion charge based particle number sensor
Project goals (FHNW)

- Take an existing Automotive Partector (AP) from Naneos LLC and optimize its settings to achieve a lower $d_{50}$ cutoff (~10nm)
- Operate device at high temperature (150°C) to allow lower/no dilution
- Build 3 heated Automotive Partectors (HAP) ready for testing by our project partners
HAP – Principle of operation

→ Advantages
  → Small size / lower power consumption / no working fluids
  → Suitable for PEMS
HAP - Principle of operation

- Modifications to lower the cut-off size:
  - Increase charging level
  - Lower the deposition voltage
  - Optimize the flow rate
HAP - Principle of operation

- Modifications for high temperature operation:
  - Separate sensor electronics from standard housing
  - Actively cooled electrometer amplifier

Standard Automotive Partector

First HAP prototype
## HAP - Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>178x430x460mm 4HE 19&quot;</td>
</tr>
<tr>
<td>Weight</td>
<td>10 kg</td>
</tr>
<tr>
<td>Sample flow rate</td>
<td>1.72 lpm (external flow @ 20°C)</td>
</tr>
<tr>
<td>$d_{50}$ cutoff</td>
<td>11-14nm</td>
</tr>
<tr>
<td>Concentration range</td>
<td>$\sim 10^3 - 10^6$ pt/cm$^3$</td>
</tr>
<tr>
<td>Pressure range</td>
<td>$\Delta p$ at inlet should not exceed $\pm 5%$ of ambient pressure</td>
</tr>
<tr>
<td>Inlet gas temperature</td>
<td>0 - 400°C</td>
</tr>
</tbody>
</table>
Instrument characterization

- **Measurements done at our lab (FHNW):**
  - Monodisperse counting efficiency with soot and NaCl

- **Verification measurements performed by APTL:**
  - Polydisperse counting efficiency with soot
  - Linearity check

- **Vehicle measurements performed by IFPEN:**
  - WLTC cycle
Monodisperse counting efficiency:

![Graph showing counting efficiency vs particle diameter](image-url)
Monodisperse counting efficiency:
Monodisperse counting efficiency:
Monodisperse counting efficiency:

$\rightarrow d_{50}$ cut off shifted towards 10nm
calculated counting efficiency for a polydisperse aerosol with lognormal size distribution ($\sigma = 1.7$)

\[ \text{Polydisperse response for } \sigma = 1.7 \]

\[ \rightarrow \text{overshoot smoothed out} \]
Polydisperse counting efficiency verified by APTL:

Polydisperse counting efficiency measured by APTL

$d_{50}$ down to 10 nm

Polydisperse counting efficiency measured by APTL
Lab (APTL) - Linearity check

\[ HAP \ [\text{pt/ccm}] \]

\[ \text{SMPS} \ [\text{pt/ccm}] \]

\[ R^2 = 0.992 \]
WLTC data (IFPEN)

Particle number concentration on WLTC cycle (hot start)

- Particle concentration [pt/ccm]
- Free running time [s]

ICAD #/cm³ | CPC 3775 #/cm³

Graph showing particle concentration over time with data from ICAD and CPC 3775.
WLTC data (IFPEN)

HAP vs 3775 CPC

HAP = 0.72 \cdot CPC
Summary and Conclusion

- Our sensors perform as specified with only minor issues so far
  - High temperature operation: ok (150°C)
  - Lower d_{50} cutoff: ok (11-14nm)
  - CPC like counting efficiency: ok (sort of)
  - Linearity: ok (R^2 = 0.992)

- Long term stability of the HAP prototypes has to be evaluated by our project partners

- The sensor prototype can be further miniaturized if needed
Acknowledgments

- FHNW:
  - Daniel Egli
  - Peter Steigmeier

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  - Nickolas Vlachos and colleagues

- IFPEN (vehicle measurements):
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  - Mickael Leblanc
  - Loic Rouleau