Issue of PN in GDIs

Slides presented during preparation of RDE3
GDI passenger cars in the EU

- In 2014 the market share of GDI represented 35 % of new car registration or **4,379,784 vehicles sold in the EU**
- Rising by 178% since 2008
- These vehicles conform to a temporary EURO6 emission limit of $6 \times 10^{12}$
PN emissions with in lab (PMP) and on the road (PEMS)

GDI1,2, DPF : Giechaskiel et al. 2015, Frontiers in Env. Sci. Air Pollution
GDI3: Demuynck (AECC) 2016, Bonn, ICPC 4
GDI4: Bosteels (AECC) 2016, ICPC 3rd
Real world influence on particle generation

- The previous was just a snapshot
- Many other influences:
  - Fuel
  - Ambient temperature
  - Payload
  - Aggressive Driving

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**Graph**

- **Heavy fuel**
  - Fuel 1 → 2
  - 23°C → -7°C
  - 5% → 32%
  - Norm. → Aggr.

- **Lab results (WLTP)**
  - +350%
  - +73%
  - +18%
  - +56%

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- Giechaskiel et al. 2015, Frontiers in Env. Sci. Air Pollution
- Riccobono et al. 2016
- ACEA/JAMA presentation
How low can PN from GDIs go in real life?

- Even with a Gasoline Particle Filter (GPF) these influences can amount to a significant contribution.
- Care needs to be taken to have efficient GPFs.
- Current practice suggests 60% efficiency, but can go up to 80% or even higher.
Summary of results from LDV PN-PEMS investigations

- Equipment improved a lot and are improving continuously.
- Issues: Condensation at electrometers, dilution ratio uncertainty, failure of heated line, noise at low temperatures

<table>
<thead>
<tr>
<th>PN-PEMS</th>
<th>Phase I (LDV)</th>
<th>Phase II (LDV)</th>
<th>ILCE (LDV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVL (DC)</td>
<td>-40% to +80%</td>
<td>-49% to +48%</td>
<td>-</td>
</tr>
<tr>
<td>Horiba (DC) ^</td>
<td>-100% to +100%</td>
<td>+11% to +150%</td>
<td>-</td>
</tr>
<tr>
<td>Horiba (CPC)</td>
<td>-</td>
<td>-21% to +49%</td>
<td>-41% to 54%</td>
</tr>
<tr>
<td>Testo (DC)</td>
<td>-6% to +114%</td>
<td>-48% to +55%</td>
<td>-39% to 42%</td>
</tr>
<tr>
<td>Pegasor (DC) ^</td>
<td>-50% to +120%</td>
<td>-58% to +199%</td>
<td>-</td>
</tr>
<tr>
<td>Sensors (DC) $</td>
<td>-50% to +200%</td>
<td>-85% to +309%</td>
<td>-</td>
</tr>
<tr>
<td>Sensors (CPC)</td>
<td>-</td>
<td>Technical issues</td>
<td>-</td>
</tr>
<tr>
<td>Maha (CPC)</td>
<td>-</td>
<td>-45% to +49%</td>
<td>-</td>
</tr>
<tr>
<td>Shimadzu (DC) ^</td>
<td>-</td>
<td>-35% to +97%</td>
<td>-</td>
</tr>
</tbody>
</table>

^ Not compliant with latest technical specs
$ Concept prototype. Discontinued
PN-PEMS Measurement uncertainty

Need to translate the EURO-6 limit (measured by PMP at CVS) into the equivalent measured with PN-PEMS

<table>
<thead>
<tr>
<th>PN-PEMS vs</th>
<th>Theory</th>
<th>1 lab – many cars</th>
<th>1 car – many labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMP_TP</td>
<td>&lt;25%</td>
<td>&lt;35%</td>
<td>&lt;40%</td>
</tr>
<tr>
<td>PMP_CVS</td>
<td>&lt;50%*</td>
<td>&lt;55%</td>
<td>&lt;54%</td>
</tr>
<tr>
<td>TP vs CVS (PMP)</td>
<td>&lt;30%</td>
<td>&lt;40%</td>
<td>&lt;35%</td>
</tr>
</tbody>
</table>

* Assuming 25% effect of sampling location (losses + exhaust flow uncertainties)
Proposal for PEMS-PN

- Inclusion of PN for RDE is technically feasible
- Equipment fulfill the technical specifications and have shown good behaviour during extensive testing
- Since technology exists (GPF) that allows even GDIs to be significantly lower than the EURO 6 limits, only the measurement uncertainty may be recognised
- Theory and the most extensive set of data available (JRC interlab and own tests) show that the uncertainty of measuring at the EURO 6 limit is at maximum 50%
- \( NTE_{PN} \): 1+ Margin PN (with Margin PN=0.5)
- With annual review clause
- In 2017 for new types, in 2018 for new vehicles