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Joint Research Centre
Effect of low temperature on pollutant emissions of hybrid vehicles: Preliminary studies for Low Temp. TF

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Sustainable Transport Unit, Energy Transport & Climate
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Current Regulation for cold temperature test

Regulation No. 83

Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements
<table>
<thead>
<tr>
<th>T °C</th>
<th>Cycle</th>
<th>Road-Load</th>
<th>Vehicles</th>
<th>Pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>-7.0 ±3</td>
<td>UDC</td>
<td>Determined at -7 °C or 10% reduction of coast-down time</td>
<td>P.I. including hybrids + information regarding NOx after-treatment for C.I.</td>
<td>HC, CO</td>
</tr>
<tr>
<td>-7.0 ±3</td>
<td>UDC</td>
<td>&quot;</td>
<td>&quot;</td>
<td>THC, CO, CO₂</td>
</tr>
<tr>
<td>-7.0 ±1.7</td>
<td>FTP</td>
<td>Performing coast-down tests and calculating road-load coefficients at -7 °C</td>
<td>Otto-cycle and diesel including multi-fueled, alternative fueled, hybrid electric, and zero emission vehicles</td>
<td>NMHC, CO, CO₂ *</td>
</tr>
<tr>
<td>-6.7</td>
<td>CVS-75</td>
<td>&quot;</td>
<td>Gasoline + information regarding NOx after-treatment for C.I.</td>
<td>CO</td>
</tr>
<tr>
<td>-7.0 ±3</td>
<td>Low+ Medium of WLTC</td>
<td>&quot;</td>
<td>P.I.; C.I.; hybrids</td>
<td>THC, CO, NOx</td>
</tr>
</tbody>
</table>

* CO₂ is analysed and results used for the determination of the vehicle fuel economy. Cold temperature standards apply for CO and NMHC emissions.
Issues under revision by Low Temp. TF

- **Cycle**
  - Introduction of WLTC → NEDC obsolete

- **Criteria pollutants**
  - Are NOx, PN, PM, NMHC and CO₂ emissions affected by cold temperature?

- **Applicability**
  - Are emissions from diesel and **electrified vehicles** affected by cold T?
Experimental approach

- Two OVC-HEVs
- Tested following Type 1 procedure at 23 °C and -7 °C
- Road load at -7 °C as described in Type 6 Reg. 83 (i.e. 10% reduction of coast-down time)
- A/C set at 21 °C (U.S. 1066.710 for cold temperature testing)
## Tested vehicles

<table>
<thead>
<tr>
<th></th>
<th>OVC-HEV1</th>
<th>OVC-HEV2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ICE</strong></td>
<td>GDI</td>
<td>PFI</td>
</tr>
<tr>
<td><strong>ICE Displacement (l.)</strong></td>
<td>1.4</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Drivetrain layout</strong></td>
<td>Parallel</td>
<td>Parallel/Series</td>
</tr>
<tr>
<td><strong>Battery Type</strong></td>
<td>Li-Ion</td>
<td>Li-Ion</td>
</tr>
<tr>
<td><strong>Nominal voltage (V)</strong></td>
<td>345</td>
<td>300</td>
</tr>
<tr>
<td><strong>Nominal capacity (kWh)</strong></td>
<td>8.7</td>
<td>12</td>
</tr>
<tr>
<td><strong>Emission category</strong></td>
<td>Euro 6b</td>
<td>Euro 6b</td>
</tr>
</tbody>
</table>
Test option selected from GTR-15
Higher emissions at lower T

- \( \text{CO}_2 \): 30% higher
- NOx: 7 times higher
- THC: 4 times higher
- CO: 3 times higher
- NH\(_3\): 50% higher
- PN: 4 times higher
OVC-HEV1 gaseous & particulate emissions

Emissions even higher when heating-ON

- \( \text{CO}_2 \): 72% higher
- \( \text{NO}_x \): 9 times higher
- \( \text{THC} \): 6 times higher
- \( \text{CO} \): 4 times higher
- \( \text{NH}_3 \): 2.5 times higher
- \( \text{PN} \): 5.3 times higher
OVC-HEV2 gaseous & particulate emissions

Higher emissions at lower T

- \( \text{CO}_2 \): 60% higher
- THC: 7 times higher
- CO: 5 times higher
- \( \text{NH}_3 \): 2 times higher
- PN: 4 times higher
- NOx: 2 times lower
OVC-HEV2 gaseous & particulate emissions

Emissions when heating-ON?

- CO$_2$: 160% higher
- THC: 13% lower
- CO: 85% higher
- NH$_3$: 70% higher
- NO$_x$: 20% lower
- PN: 6.5 times lower
OVC-HEV2 gaseous & particulate emissions

OVC-HEV2 is a PFI → EU PN emission standards are not applicable.
Total emissions during CD can be **MUCH** higher than during CS test.
• Engine ignites from start during phase-1 allowing “controlled” heating of the after-treatment.

• This strategy results in an AER = 0 km
All electric range

- OVC-HEV1 AER decreased 18% and OVC-HEV2 40% at -7°C compared to 23°C

- OVC-HEV2 AER was 0km at -7°C with heating-ON
  - OVC-HEV1 decreased 23% at -7°C with heating-ON
Compared to “pure ICE” vehicles at -7°C

- OVC-HEV1 emissions are comparable to pure ICE Euro 6b gasoline LDV
  - NOx higher than the worst gasoline LDV studied

- OVC-HEV2 (PFI):
  - THC and CO higher than pure ICE Euro 6b gasoline
  - CO₂ slightly lower
  - PN 1 order of magnitude higher than pure ICE Euro 6b gasoline vehicles

Data from diesel and gasoline vehicles can be found at Suarez-Bertoa and Astorga,
Impact of cold temperature on Euro 6 passenger car emissions,
Environmental Pollution. 234, 318-329. 2018
Summary

- Emissions from tested vehicles were strongly and negatively affected by cold ambient temperatures
  - Higher emissions at -7 °C than at 23 °C

- High emissions were observed during both CD and CS tests.

- Use of heating system further increased emissions in most cases.

- Emissions from OVC-HEV can be as high as those of “pure ICE”.

Issues to be addressed for OVC-HEVs

• Are emissions affected at cold temperature? **Yes**

• Is CS test enough to fully address OVC-HEV emissions at cold T? **No, CD test also needed**

• Is there a negative impact on emissions if heating system is used? **Yes**

• Is it possible to follow Type 1-like procedure for OVC-HEVs at -7°C? **Yes**
Thank you

Any questions?
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