RDE MEASUREMENTS OF A GDI WITHOUT AND WITH A GPF

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J. Andersson; Ricardo Consulting Engineers Ltd.
EU RDE legislation to close the gap between lab and real-world emissions

Source: the ICCT
• Not To Exceed limit (NTE) = Euro 6 limit x Conformity Factor (CF)
  – CF defined for NOx and PN
  – CF applies to urban part and total trip

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• RDE boundary conditions define normal driving
  – Route specifications
  – Ambient conditions
  – Driving dynamics

• RDE legislation being finalised

NTE: Not To Exceed
CF: Conformity Factor
NT: New Type Approval
All: All new vehicles
CO₂ legislation promotes fuel-efficient Gasoline Direct Injection (GDI) in the EU

Particles emitted by DI gasoline vehicles reported higher than Euro 6c limit of $6 \times 10^{11}$ #/km, especially under real driving conditions

Gasoline Particulate Filters (GPF) are an effective route to reduce the number of ultrafine particles under all driving conditions.
Content

• Test programme set-up

• Particulate emissions on regulatory test cycles (NEDC and WLTC)

• Real-Driving Particulate Emissions (RDE)
  – On the road
  – On the chassis dyno: impact of boundary conditions

• Conclusion
Test programme set-up

• Vehicle
  – C-segment, 1.4l engine
  – Market representative GDI technology; Euro 6b certified
  – Original configuration w/o GPF
  – Add coated GPF demonstrator underfloor

• HORIBA PEMS equipment
  – Gaseous PEMS (CO₂, CO, NOx)
  – PEMS-PN demo unit

• Parameters to evaluate
  – fuel type & quality
  – driving dynamics (RDE on dyno)
  – cold ambient temperature (RDE on dyno)
  – sub-23nm PN

• Test matrix

<table>
<thead>
<tr>
<th>Exhaust</th>
<th>Fuel</th>
<th>NEDC + WLTC</th>
<th>RDE on road</th>
<th>RDE on dyno</th>
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</thead>
<tbody>
<tr>
<td>Original (without GPF)</td>
<td>Ref E5</td>
<td>1x</td>
<td>-</td>
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<tr>
<td></td>
<td>Ref E10</td>
<td>1x</td>
<td>3x</td>
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<td></td>
<td>Market E5</td>
<td>1x</td>
<td>3x</td>
<td>6x</td>
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<tr>
<td>With coated GPF</td>
<td>Ref E10</td>
<td>1x</td>
<td>3x</td>
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<td></td>
<td>Market E5</td>
<td>1x</td>
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• Test programme set-up

• Particulate emissions on regulatory test cycles (NEDC and WLTC)
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• Conclusion
PN results w/o GPF are below Euro 6c limit on NEDC and WLTC with E5 ref fuel, but go above limit with other fuels.
PN results with GPF stay below Euro 6c limit on NEDC and WLTC

<table>
<thead>
<tr>
<th>PN (#/km)</th>
<th>NEDC w/o GPF</th>
<th>NEDC with GPF</th>
<th>WLTC w/o GPF</th>
<th>WLTC with GPF</th>
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- Euro 6c limit
- Measurement range if repeated
PM emissions are well below Euro 6c limit on NEDC and WLTC, no measurable difference between two vehicle configurations.

<table>
<thead>
<tr>
<th>PM (mg/km)</th>
<th>NEDC w/o GPF</th>
<th>NEDC w GPF</th>
<th>WLTC w/o GPF</th>
<th>WLTC w GPF</th>
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**Measurement range if repeated**
Content

- Test programme set-up

- Particulate emissions on regulatory test cycles (NEDC and WLTC)

- Real-Driving Particulate Emissions (RDE)
  - On the road
  - On the chassis dyno: impact of boundary conditions

- Conclusion
Measured data are within the RDE boundary conditions

Ambient conditions

Altitude accumulation

Excess of driving dynamics

1200m/100km
PN results w/o GPF increase towards Euro 6d NTE limit on the road

SAE2017-01-0985
PN results with GPF are well below Euro 6d NTE limit on the road.

- **SAE 2017-01-0985**
No CO₂ penalty was measured for the GPF on the road
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RDE on dyno to investigate impact of going towards RDE boundary conditions

1. Change accelerations

2. Change dyno load

3. Change ambient temperature
PN results w/o GPF increase above Euro 6d NTE limit towards RDE boundary conditions

![Graph showing PN results](image)

- Euro 6d NTE limit
- Measurement range if repeated
PN results with GPF remain below Euro 6d NTE limit towards RDE boundary conditions

- Measurement range if repeated
- Euro 6d NTE limit
All PM results remain significantly below 4.5 mg/km towards RDE boundary conditions.

1. Change accelerations

2. Change dyno load

3. Change ambient temperature

<table>
<thead>
<tr>
<th>PM (mg/km)</th>
<th>total RDE w/o GPF</th>
<th>total RDE with GPF</th>
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Measurement range if repeated
Test programme set-up

Particulate emissions on regulatory test cycles (NEDC and WLTC)

Real-Driving Particulate Emissions (RDE)
  - On the road
  - On the chassis dyno: impact of boundary conditions

Conclusion
RDE PN emissions from a Euro 6b GDI vehicle were measured with and without a GPF

NEDC + WLTC

RDE on road

towards RDE boundary conditions on the chassis dyno

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Conclusion

SAE2017-01-0985
Thank you for your attention!

• Acknowledgements
  – AECC members for funding and supporting
  – Concawe for working in partnership
  – Ricardo for testing and data analysis

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