PEMS in the European vehicle emissions legislation: Milestones and challenges

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European Commission DG - Joint Research Centre (JRC)
IET - Institute for Energy and Transport
The Joint Research Centre

JRC - the European Commission’s in-house science service to support EU policy making
Role of the JRC

- Independent research and policy assessment
- Establishing empirical data and rationale for policy making
- Coordinating and guiding technical activities
- Cooperating with industry, member states, and research institutions
EU Air Quality Directive 2008/50/EU

- Persisting NO₂ exceedance in urban areas
PEMS - Light-duty vehicles

- Environmental background

Annual mean, nitrogen dioxide, 2009, based on daily averages with percentage of valid measurements 75% in µg/m³

- ≤ 20
- 20–40
- 40–42
- ≥ 42

Source: Copyright EEA (2011)
Setting the stage

- EU Air Quality Directive 2008/50/EU
  - Persisting NO\textsubscript{2} exceedance in urban areas
  - Main contributor is road transport

- GHG emissions reductions of 20% – Europe 2020 Strategy

- Long-term vision for transport in Europe - 2011 Transport White Paper:
  - 60% CO\textsubscript{2} reduction by 2050
  - Halving the use of conventionally-fuelled cars in cities by 2030; phase them out in cities by 2050
Balancing environmental objectives with societal (mobility) and economic (competitiveness, jobs) objectives

Emissions legislation and vehicle tests should be:
- practical: technically feasible, simple, transparent, and cheap for manufacturers
- effective: to ensure clean vehicles during use (not only in the test cell)
- flexible: to accommodate future developments (vehicle technologies, state of knowledge, societal demands)

PEMS offers multiple advantages over conventional vehicle testing in the laboratory
Practicality and costs

• In-use conformity testing of heavy-duty engines and NRMM: PEMS avoids extracting engines from vehicles

Effectiveness

• Vehicle testing (mainly light-duty vehicles):
  - PEMS allows quantify real-world on-road emissions
  - PEMS forces an optimized design of increasingly complex emissions control technologies
  - PEMS can limit the use of defeat strategies
  - PEMS can ensure clean vehicles on the road
Regulations & Activities

- **Heavy-duty vehicles** (type approval of the engine)
- **NRMM** (type approval of the engine)
- **Light-duty vehicles** (type approval of the vehicle)
Heavy-duty vehicles
- Regulations 582/2011 & 64/2012: Type approval and in-service conformity testing based on on-road testing with PEMS
- Verifying the conformity of engines on vehicles during normal use
- ‘Real-world’ emissions not explicitly addressed; aim is a functional and performance check of emissions control technologies
- Review of current procedures until the end of 2014
- PEMS-PM instrumentation evaluation completed; industry-run Pilot Program
- Until 2014, assessment of requirements for EURO VI+ engines under urban and low-load operation
NRMM
- Industry-run Pilot Program for in-service conformity testing completed in 2012
- PEMS implementation for Stage IV or V under discussion
- Likely adaptation of heavy-duty procedures to NRMM
Light-duty vehicles
- Regulation 715/2007 on Euro 5/6 limits aims “to ensure that real world emissions correspond to those measured at type approval. The use of portable emission measurement systems and the introduction of the ‘not-to-exceed’ regulatory concept should also be considered.”
- Establishment on-road emissions in 2010
- Real-driving emissions (RDE) working group since 2011; development of a complementary test procedure since 2012
- Introduction of the complementary test procedure 2014/2017
- Feasibility of PEMS-PN under investigation (alternative: random cycles)
PEMS - Light-duty vehicles

- Establishing on-road emission values
- JRC has tested 26 light-duty vehicles with PEMS until September 2013
- 4 standard test routes – covering a wide range of driving conditions
PEMS - Light-duty vehicles

NO\textsubscript{X} emissions in g/km

<table>
<thead>
<tr>
<th>Euro 3</th>
<th>Euro 4</th>
<th>Euro 5</th>
<th>Euro 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (diesel)*</td>
<td>B (gasoline)</td>
<td>Route 1: rural-motorway</td>
<td>Route 2: rural-urban</td>
</tr>
<tr>
<td>C (diesel)*</td>
<td>D (diesel)</td>
<td>Route 3: rural-uphill/downhill</td>
<td>Route 4: motorway</td>
</tr>
<tr>
<td>E (diesel)</td>
<td>F (gasoline)</td>
<td>NEDC laboratory testing</td>
<td>Applicable emissions limit</td>
</tr>
<tr>
<td>G (gasoline)</td>
<td>H (diesel)</td>
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<td>I (diesel)</td>
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PEMS - Light-duty vehicles

NOx emissions in g/km

Euro 3
- Route 1: rural-motorway
- Route 2: rural-urban
- Route 3: rural-uphill/downhill
- Route 4: motorway
- NEDC laboratory testing
- Applicable emissions limit

Euro 4

Euro 5

Euro 6

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<th>Vehicle</th>
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<tr>
<td>A (diesel)*</td>
<td>2.00</td>
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<tr>
<td>B (gasoline)</td>
<td>1.75</td>
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<tr>
<td>C (diesel)*</td>
<td>1.50</td>
</tr>
<tr>
<td>D (diesel)</td>
<td>1.25</td>
</tr>
<tr>
<td>E (diesel)</td>
<td>1.00</td>
</tr>
<tr>
<td>F (gasoline)</td>
<td>0.75</td>
</tr>
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<td>G (gasoline)</td>
<td>0.50</td>
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• Real-driving emissions (RDE) working group to establish a complementary test procedure
• JRC coordinates the technical work
• Candidate procedures: Fixed test cycles
  Random test cycles
  PEMS on-road testing
  Vehicle modeling
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• Candidate procedures: Fixed test cycles
  Random test cycles
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<th>PEMS</th>
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<td>+ less sensitive to changes in driver’s behavior</td>
<td>+ wider coverage of driving conditions</td>
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<tr>
<td>+ less sensitive to climatic variability</td>
<td>+ test difficult to detect</td>
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<tr>
<td>+ long-term experience</td>
<td>+ prevents defeat strategies</td>
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- RDE working group develops on-road testing with PEMS as complementary test procedure until mid 2014
Key issues – Test route

• coverage of normal driving conditions
• special attention to urban driving
• 30/30/30 split on low/medium/high (extra-high speed) defined *a priori*
• Definition of maximum speed and idling shares

Key issues – Ambient conditions

• larger temperature range than current type approval
• Applying PEMS regulation on heavy-duty vehicles (?)
Key issues - Driving style, (micro) coverage of driving conditions, averaging of tests

- three data evaluation tools (TU Graz, TNO, JRC)
- weighing of driving data (TU Graz)
- binning/zoning of driving data (TNO, JRC)
Moving averaging window approach

- Implemented for heavy-duty vehicles

NEDC: Average over entire test

Averaging windows

How to determine the severity of on-road driving?
PEMS - Light-duty vehicles

Moving averaging window approach

Average CO₂ emissions [g/km]

- Low-speed
- Medium-speed
- High-speed
- Extra high-speed

- Normal
- Severe
- Extra-severe
- Extra-soft
- Soft

- 25% (?)
- 50% (?)
- 25% (?)
Key issues - Not-to-exceed (NTE) principle

- Aim is not to reproduce average driving but to cover the range of driving conditions
- Under permissible conditions, vehicles should be clean
- Accounting for statistical uncertainty: NTE > Euro 6
- Accounting for severity and variability in ambient conditions
Tentative time schedule

- Structured database of PEMS tests from 10/2013
- One tool for data analysis chosen by end 2013/early 2014
- Fine tuning and vehicle testing until mid 2014
- Procedure drafting until mid 2014
- Implementation end 2014
- Binding NTE limits Euro 6c 2017
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PEMS - Light-duty vehicles

Moving averaging window approach