PEMS in the European vehicle emissions legislation: Milestones and challenges

SUN Conference
24-25 September 2013
Düsseldorf, Germany

Martin Weiss, Pierre Bonnel, Adolfo Perujo, Francesco Riccobono, Pablo Mendoza Villafuerte, Theodoros Vlachos

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
Setting the stage

- EU Air Quality Directive 2008/50/EU
  - Persisting NO$_2$ 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)
EU Air Quality Directive 2008/50/EU
  - Persisting NO₂ 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% CO₂ 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
<table>
<thead>
<tr>
<th>Regulations &amp; Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy-duty vehicles</td>
</tr>
<tr>
<td>(type approval of the engine)</td>
</tr>
<tr>
<td>NRMM</td>
</tr>
<tr>
<td>(type approval of the engine)</td>
</tr>
<tr>
<td>Light-duty vehicles</td>
</tr>
<tr>
<td>(type approval of the vehicle)</td>
</tr>
</tbody>
</table>
Regulations & Activities

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)
- 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
<table>
<thead>
<tr>
<th>NO\textsubscript{X} emissions in g/km</th>
<th>Euro 3</th>
<th>Euro 4</th>
<th>Euro 5</th>
<th>Euro 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 1: rural-motorway</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route 2: rural-urban</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route 3: rural-uphill/downhill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route 4: motorway</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEDC laboratory testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicable emissions limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• 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
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
PEMS - Light-duty vehicles

<table>
<thead>
<tr>
<th>Random cycles</th>
<th>PEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✗ less sensitive to changes in driver’s behavior</td>
<td>✗ wider coverage of driving conditions</td>
</tr>
<tr>
<td>✗ less sensitive to climatic variability</td>
<td>✗ test difficult to detect</td>
</tr>
<tr>
<td>✗ long-term experience</td>
<td>✗ prevents defeat strategies</td>
</tr>
</tbody>
</table>

- **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?
Moving averaging window approach

- PEMS - Light-duty vehicles

- Average CO₂ emissions [g/km]

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

- Normal
- Severe
- Extra-severe
- Soft
- Extra-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: \( \text{NTE} > \text{Euro 6} \)
- Accounting for severity and variability in ambient conditions
Tentative time schedule

- Structured data base 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
Martin Weiss  
(light-duty vehicles)  
martin.weiss@jrc.ec.europa.eu  

Francesco Riccobono  
(particle emissions)  
Francesco.riccobono@jrc.ec.europa.eu  

Theodoros Vlachos  
(light-duty vehicles)  
theodoros.vlachos@jrc.ec.europa.eu  

Pierre Bonnel  
(light-duty vehicles)  
pierre.bonnel@jrc.ec.europa.eu  

Adolfo Perujo  
(heavy-duty vehicles and MNRM)  
adolfo.perujo@jrc.ec.europa.eu
PEMS - Light-duty vehicles

Moving averaging window approach