Emission testing of Euro 6 b/c LPG passenger cars and perspectives

Simone Casadei

Head of Mobile Sources Sector – Emission Laboratory

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We are a national centre for applied research, innovation and technology transfer offering testing services, technical consultancy and innovation support.

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Partner of Enterprise Europe Network, to support innovation, technology transfer and internationalization of companies and research centers

10/05/2020
**Italian Ministry of Health**: suitability to perform physico-chemical tests in accordance with **Good Laboratory Practices**.

**Environmental Monitoring** → gas emissions control; evaluation of fuel characteristics

**Product and Process Safety** → tests on gas, vapour, mist and dust; runaway reactions and thermal stability
Main goals (problems) for Manufacturers to produce PCs and LCVs conform to the Euro 6 (2014) pollutants’ emission standards and contemporarily to EC Reg. 631/2019 regarding CO$_2$ emission levels

- Emission reduction of NOx by diesel engines and PN by GDI engines
- Reduction of fuel consumption / CO$_2$ emissions, according to Reg. 631/2019
- The application of new generation aftertreatments for exhaust emissions
- The continuous improvement of the quality of fossil fuels
- The application of new generation aftertreatments for exhaust emissions
- The use of alternative fuels more environmentally friendly → LPG?
- The use of biofuels (better if 2$^{nd}$ – 3$^{rd}$ generation) blended with fossil fuels
- The use of new power modes as progressive electrification (hybridization and electric vehicles)

Values calculated as an average for the fleet of each manufacturer:

**PCs**
- 95 g CO$_2$/km (by 2021)
- -15% by 2025 (~ 80 g CO$_2$/km?)
- -37.5% by 2030 (~ 60 g CO$_2$/km?)

**LCVs**
- 147 g CO$_2$/km (by 2020)
- -15% by 2025 (~ 125 g CO$_2$/km?)
- -31% by 2030 (~ 100 g CO$_2$/km?)

Both of these goals can be achieved only if new engine technologies are combined with:
Assogasliquid Federchimica and AEGPL commissioned Innovhub-SSI to conduct tests to detect regulated and unregulated exhaust emissions and fuel consumption on a fleet of 5 Euro 6b/c bifuel LPG passenger cars (PCs).

The aim of the testing program was to compare the gasoline vs the LPG fueling emission and fuel consumption performances.

The emission factors of a multitude of pollutants and greenhouse gases by bifuel LPG modern cars - whose data were lacking in scientific and technical literature - have been determined.

The PCs have been tested according to a protocol defined with Assogasliquid Federchimica, shared and discussed with the ERMES Group and ISPRA (Italian Institute for the Environmental Protection and Research): both recognized it as appropriate to determine emission factors suitable to feed European and Italian transport emission inventories.
Gaseous on-line analysis (CO, THC, NMHC, NO$_x$, CO$_2$), total PM.

PN - PMP compliant system for EURO 5/6 vehicles

Microsoot Sensor (MSS): particulate carbonaceous fraction emission (soot)

ELPI – EEPS: emission modal profile and dimensional distribution of fine, ultrafine, nanoparticles

FT-IR spectrophotometer: regulated, ammonia, nitrous oxide, VOCs, aldehydes, ...

PEMS on road testing (RDE)

NO$_x$, CO, THC + CH$_4$, CO$_2$

PN – Solid Particles Number

Regulated and unregulated exhaust emissions detected in lab. (up) and on road (down)
**Euro 6b/c LPG tested fleet: 5 passenger cars, 4 Euro 6b and 1 Euro 6c**

<table>
<thead>
<tr>
<th>Motor vehicle id.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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</thead>
<tbody>
<tr>
<td>Homologation Emission Standard</td>
<td><strong>Euro 6b</strong></td>
<td><strong>Euro 6b</strong></td>
<td><strong>Euro 6b</strong></td>
<td><strong>Euro 6b</strong></td>
<td><strong>Euro 6c</strong></td>
</tr>
<tr>
<td>Mileage at test start (km)</td>
<td>6780</td>
<td>1966</td>
<td>6650</td>
<td>2000</td>
<td>1984</td>
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<tr>
<td>Engine displacement (cc)</td>
<td>1248</td>
<td>1598</td>
<td>1197</td>
<td>1590</td>
<td>1598</td>
</tr>
<tr>
<td>N. cylinder / N. valve/cyl</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Max power (kW)</td>
<td>63 @ 6000 rpm</td>
<td>115 @ 6000 rpm</td>
<td>66 @ 4800 rpm</td>
<td>86 @ 6000 rpm</td>
<td>75 @ 5500</td>
</tr>
<tr>
<td>Max torque (Nm)</td>
<td>120 @ 4000 rpm</td>
<td>155 @ 3900 rpm</td>
<td>160 @ 1400 rpm</td>
<td>154 @ 4000</td>
<td>156 @ 4000</td>
</tr>
<tr>
<td>Power system</td>
<td>Positive Ignition</td>
<td>Positive Ignition</td>
<td>Positive Ignition - GDI</td>
<td>Positive Ignition</td>
<td>Positive Ignition</td>
</tr>
<tr>
<td>Emission treatment technology</td>
<td>TWC</td>
<td>TWC</td>
<td>TWC</td>
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<td>TWC</td>
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</table>
Driving cycles sequence and their characteristics

NEDC + ERMES

<table>
<thead>
<tr>
<th></th>
<th>UDC</th>
<th>EUDC</th>
<th>ERMES</th>
</tr>
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<tbody>
<tr>
<td>duration</td>
<td>s</td>
<td>780</td>
<td>400</td>
</tr>
<tr>
<td>maximum speed</td>
<td>km/h</td>
<td>50.0</td>
<td>120.0</td>
</tr>
<tr>
<td>average speed</td>
<td>km/h</td>
<td>19.5</td>
<td>62.7</td>
</tr>
<tr>
<td>length</td>
<td>km</td>
<td>4.1</td>
<td>7.0</td>
</tr>
<tr>
<td>time at idle</td>
<td>%</td>
<td>30.8</td>
<td>10.0</td>
</tr>
</tbody>
</table>

WLTC

<table>
<thead>
<tr>
<th></th>
<th>LOW</th>
<th>MIDDLE</th>
<th>HIGH</th>
<th>EXTRA-HIGH</th>
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<tbody>
<tr>
<td>Duration</td>
<td>s</td>
<td>593</td>
<td>431</td>
<td>455</td>
</tr>
<tr>
<td>Average speed</td>
<td>Km/h</td>
<td>18.8</td>
<td>39.7</td>
<td>56.5</td>
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<tr>
<td>Maximum speed</td>
<td>Km/h</td>
<td>56.5</td>
<td>76.6</td>
<td>97.4</td>
</tr>
<tr>
<td>Length</td>
<td>km</td>
<td>3.09</td>
<td>4.75</td>
<td>7.14</td>
</tr>
<tr>
<td>Time at idle</td>
<td>%</td>
<td>25.3</td>
<td>10.7</td>
<td>6.6</td>
</tr>
</tbody>
</table>

10/05/2020
Main results: regulated emissions Vs limits, \( \text{CO}_2 \) and fuel consumption

- All Euro 6 b/c emission limits Respected for both LPG (blue) and gasoline (orange) feedings
- Statistically significant increases in CO emissions for NEDC (4/5 PCs) and significant reductions for ERMES with LPG feeding
- Statistically significant increases in HC and NMHC emissions with LPG feeding in cold start phase, well reduced by the catalyst once thermal regime reached
- Statistically significant decreases in NOx emissions with LPG feeding (3/5 PCs)
- Statistically significant decreases in \( \text{CO}_2 \) emissions with LPG feeding for all cycles (~8/9%)
- Statistically significant increases in fuel consumption with LPG feeding for all cycles (+30%)
Unregulated emissions main results: particles and gaseous pollutants

- **Extremely limited emissions of PM and soot** for both LPG (blue) and gasoline (orange) feedings.

- Low emissions of PN-PMP compliant ($< 6 \times 10^{11}$ [#/km] except GDI PC fed with gasoline). Reduction with LPG.

- Reduction of total particle number between 5,6 nm and 10 µm aerodynamic diameter with LPG.

- Statistically significant increase in NH$_3$ emissions with LPG feeding (3/5 PCs).

- Very low formaldehyde emissions, significant just in cold start.

- Statistically significant increases in N$_2$O with LPG feeding in ERMES cycle (2/5 PCs).

- To be investigated: NH$_3$, N$_2$O, NO$_2$, 1,3-butadiene, benzene.

10/05/2020
On road real driving emissions: main results Vs AEGPL research (on Euro 5/6 PCs)

- All Euro 6 d-Temp & D RDE limits Respected except PN limit for the GDI PC fed with gasoline
- Significant decrease of PN emission with LPG, according to the AEGPL research
- Very low NO\textsubscript{X} emissions for both fuels, according to AEGPL research → Absence of NO\textsubscript{X} diesel issue
- Significant decrease in CO\textsubscript{2} emission with LPG feeding for all cycles (around - 10%), according to the AEGPL research
- Very low differences on CO, HC emissions comparing gasoline vs LPG feeding → low importance of cold start phase in RDE tests
- Also on road significant increase in fuel consumption with LPG feeding (+30%)
With LPG all emission limits on regulated pollutants were respected both in laboratory (NEDC/WLTC) and on-road (RDE by PEMS) → Absence of NO\textsubscript{x} diesel issue

Significant reductions in particles emissions with LPG feeding, better than gasoline in respecting GDI 6*10\textsuperscript{11} #/km particles limit

Significant reductions in CO\textsubscript{2} emissions, both in lab. and on road: LPG Vs gasoline reduction ~10%

More research and attention to the unregulated gaseous emissions are needed (NH\textsubscript{3}, N\textsubscript{2}O, …)

LPG, if well installed and managed, can be a good solution to reach pollution and CO\textsubscript{2} targets
Further developments: Euro 6 d LPG and Natural Gas vehicles

- Results shared with ISPRA for National Inventory Report 2020 submission: country specific hot emission factors for Euro 6 Small and Medium LPG passenger cars have been applied for CO, NOX, VOC, PM Exhaust, FC, CH4, NH3, N2O. Italian Greenhouse Gas Inventory 1990-2018 (2020)

- All data have been shared within the ERMES group to be implemented in the data structure of HBEFA 4.2 and COPERT

- Tank To Wheel public data availability for Life Cycle Analisys

Next steps regarding alternative fuels vehicles testing

- Testing LPG/petrol and Natural Gas/petrol bifuel Euro 6 d passengers cars (standard in force from 1/1/2020 for new models, from 1/1/2021 for all models)

- Target: contribute to the continuous update of emission factors at national and European level
Simone Casadei

✉ simone.casadei@mi.camcom.it

📞 +39 02 8515.3509
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