Emission Testing under load for Pollutants
e.g. NO\textsubscript{x} and PN
MAHA Maschinenbau Haldenwang GmbH & Co. KG

Antonio Multari
Haldenwang, 15\textsuperscript{th} March 2019
Transport and Air Quality

- Massive deviation – real world exhaust emission compared to limit values, even at modern diesel passenger cars

- Responsible authorities have to react effectively/fast

- About 50% of traffic based monitoring stations show exceedance of $\text{NO}_2$ concentration limit values in Germany, France, Italy, UK,…, leading to severe health damages

- Legal Basis EU Air Quality Directive 2008/50/EC (40 $\mu$g/m³ annual mean)

- Despite compliance with $\text{PM}_{10}$ AQ-limits problem with ultrafine particles and corresponding health damage not accordingly addressed yet
2018 Report: Exposure to harmful levels of air pollution

Many Europeans are exposed to harmful levels of air pollution

Up to 30% of Europeans living in cities are exposed to air pollutant levels exceeding EU air quality standards. And around 95% of Europeans living in cities are exposed to levels of air pollutants deemed damaging to health by the World Health Organization's more stringent guidelines.

EU urban population exposed to harmful levels of air pollution in 2010 - 2012, according to:

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>EU limit/target values</th>
<th>WHO guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2.5}$</td>
<td>10 - 14%</td>
<td>91 - 93%</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>21 - 30%</td>
<td>64 - 83%</td>
</tr>
<tr>
<td>O$_3$</td>
<td>14 - 17%</td>
<td>95 - 98%</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>8 - 13%</td>
<td>8 - 13%</td>
</tr>
<tr>
<td>BaP</td>
<td>24 - 28%</td>
<td>85 - 89%</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>&lt;1%</td>
<td>36 - 43%</td>
</tr>
</tbody>
</table>


Reducing Vehicle Emissions with Chemistry

Millions of Volkswagen cars have been found to emit up to 40 times more nitrogen oxides in normal operation than they did during emissions testing, miring the company in controversy. This graphic looks at the devices present in a vehicle to help reduce pollution, and how they work.

**POLLUTING COMPounds**

- NOx (Nitrogen Oxides)
- CO (Carbon Monoxide)
- HC (Unburnt Hydrocarbons)

**THE ‘DEFEAT DEVICE’**

The ‘defeat device’ found in Volkswagen cars is not a physical device, but a piece of software that detects when the car is being tested. When it detected this, it tuned the engine’s performance reducing the NOx emissions. In normal driving conditions they were much higher.

**CATALYTIC CONVERTERS**

- Rh (Rhodium)
- Pt (Platinum)
- Pd (Palladium)

Three-way catalytic converters are present in all petrol-powered cars, and help remove carbon monoxide, unburnt hydrocarbons, and nitrogen oxides. They contain precious metals such as rhodium, platinum, and palladium to accomplish this. Three-way catalytic converters can’t be used in diesel engines, as diesel’s oxygen-rich exhaust gases make their removal of NOx inefficient.

**SELECTIVE CATALYTIC REDUCTION**

- Urea
- Ammonia
- Carbon Dioxide

Selective catalytic reduction (SCR) is a method for NOx removal that is utilized in some diesel engines. It involves the injection of urea into the exhaust stream of the vehicle, where it produces ammonia, which is adsorbed onto a catalyst. The ammonia can then react with the nitrogen oxides in the exhaust stream to produce nitrogen and water. SCR is capable of achieving NOx reductions of up to 90%.

**NOx ADSORBERS**

- Lean Conditions (Oxygen Rich)
- Rich Conditions (Oxygen Starved)

NOx adsorbers can also be used in diesel engines. The majority of NOx emissions from the diesel engines are NO, and this is converted to NO2 by reaction with oxygen using a platinum catalyst. The NO2 is then absorbed in the form of nitrates by the storage material (often barium oxide). Once the trap is full, the nitrate can be desorbed, converted to nitrogen over a rhodium catalyst, and released.

Source: www.compoundchem.com | Rh = Rhodium | Pt = Platinum | Pd = Palladium
PEMS- Road Measurements
Euro 6 Diesel Cars Exceeding the NO\textsubscript{x} Limits

Average NO\textsubscript{x} Emissions from Euro 6 Diesel Cars in mg/km

*1: Vehicles from OEM delivered
*2: Nox Limit Euro VI at Truck 125 mg/km

Source: PEMS Measurements, DUH (NGO), Germany
New Concept: Brake Tester combined with Emission Testing under load for Pollutants e.g. NO\textsubscript{x} and PN

- using motors with different coils and better balancing
- frequency converters control motors
- using different frequencies and voltages, bench is able to accelerate the car to 20 km/h, and keep the car at this speed
- at 20 km/h we can still have a torque of 5 Nm, which corresponds to 1150 N per side = load is given to measure NO\textsubscript{x} correctly
  - important to see EGR and Ad blue activities
New Concept: Brake Tester combined with Emission Testing under load for Pollutants e.g. NO\textsubscript{x} and PN

- Quick, Efficient and Reproducible Test Cycle < 2 Minutes

```
<table>
<thead>
<tr>
<th>Speed</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 km/h</td>
<td>Variable; depending on vehicle</td>
</tr>
<tr>
<td>5 sec</td>
<td>0 km/h</td>
</tr>
<tr>
<td>6 – 7 sec</td>
<td>20 km/h</td>
</tr>
<tr>
<td>10 – 15 sec</td>
<td>Variable; depending on vehicle</td>
</tr>
</tbody>
</table>
```
New Concept: Brake Tester combined with Emission Testing under load for Pollutants e.g. NO\textsubscript{x} and PN

with electrochemical cells for NO\textsubscript{x} measurement - NO plus NO\textsubscript{2} separately
NO$_x$ Concentration and Particle Number, Mercedes E220d

Source: DUH (NGO), Germany
NO\textsubscript{x} - Concentration and Particle Number, Opel Insignia

Source: DUH (NGO), Germany
Particle Number Concentrations in Idle or under Load, Opel Zafira

Source: DUH (NGO), Germany
Passed // Failed with Limits of 200 ppm NO\textsubscript{x} and 20,000 PN per (ccm) cm\textsuperscript{3}

<table>
<thead>
<tr>
<th>BMW 318d</th>
<th>Opel Insignia Sports Tourer</th>
</tr>
</thead>
<tbody>
<tr>
<td>PN [p/ccm]</td>
<td>9.847</td>
</tr>
<tr>
<td>NO\textsubscript{x} [ppm]</td>
<td>77</td>
</tr>
<tr>
<td>Result</td>
<td>Passed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ford Focus 1.0 EcoBoost</th>
<th>Opel Zafira</th>
</tr>
</thead>
<tbody>
<tr>
<td>PN [p/ccm]</td>
<td>19.150</td>
</tr>
<tr>
<td>NO\textsubscript{x} [ppm]</td>
<td>136</td>
</tr>
<tr>
<td>Result</td>
<td>Passed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mercedes E 220d</th>
<th>VW Passat 1.6 Cheap replacement catalyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>PN [p/ccm]</td>
<td>10.167</td>
</tr>
<tr>
<td>NO\textsubscript{x} [ppm]</td>
<td>46</td>
</tr>
<tr>
<td>Result</td>
<td>Passed</td>
</tr>
</tbody>
</table>

Source: DUH (NGO), Germany
Test Limits for the Future PTI Test

- For Euro 6 vehicles a **PN limit value of 20,000 per cubic centimeter** is proposed for checking the functionality of particulate filters. If the particle filter is working, the test values are well below this test value.

- For the nitrogen oxide concentration, an average **NO\textsubscript{x} concentration of 200 ppm** (parts per million) for **Euro 6 vehicles** is proposed on the basis of a large number of RDE measurements with PEMS measuring instruments.

- Based on these suggestions, some vehicles were assessed.
Thank you for your attention!

MAHA Maschinenbau Haldenwang GmbH & Co. KG
Hoyen 20 | 87490 Haldenwang | Germany

Antonio Multari
MAHA Sales Director International | CITA Technical Expert Emissions

Phone +49 8374 585 123
Fax +49 8374 585 497
Mobile +49 176 11585 049
Mail antonio.multari@maha.de
www.maha.de

Any use and disposal such as copying and distribution rights of this presentation is subject to MAHA Maschinenbau Haldenwang GmbH & Co. KG