NPTI APPROACHES FOR \textit{deNO}_{x}-\textit{SYSTEMS}

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HD vehicles with DPF + SCR TeVeNO\textsubscript{x}

2012-2013
Theveno\textsubscript{x} ...

Testing of Vehicles with NO\textsubscript{x}-Reduction Systems

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3 Types of vehicle tests

Test type 1
- HD Chassis Dynamometer

Test type 2
- Real World Operation on the Road

Test type 3
- Simple Function Test
  (short operation on the road)
Investigated vehicles
## Investigated vehicles:

<table>
<thead>
<tr>
<th>Vehicles</th>
<th>Exhaust system</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Mercedes Actros Blutec 6 330 kW 12000km</td>
</tr>
<tr>
<td>B</td>
<td>DAF Truck 340 kW</td>
</tr>
<tr>
<td>C</td>
<td>MAN TGS 400 kW</td>
</tr>
<tr>
<td>D</td>
<td>MAN TGS 397 kW 220 km</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicles</th>
<th>Exhaust system</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>OEM CRT+SCR</td>
</tr>
<tr>
<td>G</td>
<td>OEM SCR</td>
</tr>
<tr>
<td>H</td>
<td>OEM SCR</td>
</tr>
<tr>
<td>I</td>
<td>OEM SCR</td>
</tr>
<tr>
<td>J</td>
<td>NOxOFF DPF+SCR retrofit</td>
</tr>
</tbody>
</table>
Vehicle E on the MAN HD chassis
dynamometer with OEM SCR & retrofitted DPF
Sampling positions on vehicle F

engine-out

- CPK-NOx-sensor engine out
- CPK-Temp.-sensor engine out
- Anapol

NP (MD-19)

CPK-NOx-sensor tailpipe

Impinger

2CLD with heated filter

tailpipe

Horiba (MEXA120NO)
Measuring set-up with vehicle G

engine-out

tailpipe
Some results
Switch-on dosing
retrofit system cDPF & SCR; $\alpha = 0.75$
vehicle A; ULSD; Chassis Dyno
$K_{\text{NO}_x}$ with different analyzers at stationary operation

OEM SCR; dosing & dosing not activated
vehicle C, ULSD; Chassis Dyno LARAG

**OP1 / 50 km/h**

<table>
<thead>
<tr>
<th></th>
<th>2CLD</th>
<th>CPK out</th>
<th>Anapol</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCR disabled</td>
<td>600</td>
<td>300</td>
<td>900</td>
</tr>
<tr>
<td>SCR enabled</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**t. b. SCR ≈ 275 °C**

**OP2 / 67 km/h**

<table>
<thead>
<tr>
<th></th>
<th>2CLD</th>
<th>CPK out</th>
<th>Anapol</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCR disabled</td>
<td>600</td>
<td>300</td>
<td>900</td>
</tr>
<tr>
<td>SCR enabled</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**t. b. SCR ≈ 360 °C**
Comparison of KNOx-values from different periods of the trip: 2CLD whole trip → CPK & SCR active time

Vehicle F; ULSD; AdBlue; Dosing activated

<table>
<thead>
<tr>
<th>Period</th>
<th>KNOx [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>whole trip</td>
<td></td>
</tr>
<tr>
<td>non-urban 1 (cold)</td>
<td></td>
</tr>
<tr>
<td>motorway</td>
<td></td>
</tr>
<tr>
<td>non-urban 2</td>
<td></td>
</tr>
</tbody>
</table>

1. 2CLD whole trip, average trips 4,5,6
2. CPK only active periods, average trips 4,5,6
SWOFF - intervention of ECU after long idling

OEM SCR; dosing activated
Vehicle D; ULSD; Chassis Dyno LARAG

1) The system interrupts the injection of AdBlue as soon as the wheels stop to rotating
2) After long idling the engine control takes automatically intervention

Dosing activated
Dosing off

NOx-in reference
NOx-out

NOx downstream

Reference
## Experiences in TeVeNO\textsubscript{x} (1)

<table>
<thead>
<tr>
<th>De-NO\textsubscript{x} Rates</th>
<th>PCFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus A 80-85%</td>
<td>99.9%</td>
</tr>
<tr>
<td>Bus B 30-70%</td>
<td>DPF not tested</td>
</tr>
<tr>
<td>Truck C 88-95%</td>
<td>no DPF</td>
</tr>
<tr>
<td>Truck D 42-88%</td>
<td>no DPF</td>
</tr>
<tr>
<td>Truck E 84% (OP1)</td>
<td>99.5%</td>
</tr>
<tr>
<td>Truck F 63-94%</td>
<td>99.9%</td>
</tr>
<tr>
<td>Truck G 28-70% Diesel</td>
<td>no DPF</td>
</tr>
<tr>
<td>19-55% D/CNG</td>
<td></td>
</tr>
<tr>
<td>Truck H 20-84%</td>
<td>no DPF</td>
</tr>
<tr>
<td>Truck I 20-92%</td>
<td>no DPF</td>
</tr>
</tbody>
</table>
The foundations for the quality verification procedures of SCR-systems are established,

The SCR-systems are not active at lower temperatures < 200°C,

SCR-testing on vehicle is a better approach than on engine dyno,

simple & low-cost quality check is possible.
LD vehicles with DPF + SCR

IUCD...In Use Control Diesel
IUCD: exhaust emissions during const. speed, with cold start

Vehicle 1; EGR, DOC, DPF, SCR; fuel: Diesel; tailpipe.
IUCD: exhaust emissions during const. speed and idling.

**Vehicle 2;** EGR, DOC, DPF, SCR; fuel: Diesel; tailpipe.
IUCD: exhaust emissions during const. speed and idling.

**Vehicle 3**: EGR, DOC, DPF, SCR; fuel: Diesel; tailpipe.
IUCD: catalyst temperature during const. speed and idling.

**Vehicle 3**; EGR, DOC, DPF, SCR; fuel: Diesel; tailpipe.
Complementary information
(to be required)

- OBD data, NO\textsubscript{x}-sensors
- AdBlue indication
- AdBlue purchasing and consumption
- Visual control of AdBlue system
Open questions

- Fixing of the minimum limit value of NO\textsubscript{x} reduction rate (RR)
- Solution of the question “wheel-stop $\rightarrow$ RAI-stop”,
- Fixing of the time to drive after load jump for LD and for HD
- More testing for statistical robustness
- Testing of LNT
- Testing with failures
VERTdeNO$_x$ certification protocol

For HD/LD SCR-retrofit
**VERTdeNOₓ Testing Procedures for HD/LD SCR-retrofit**

Vehicle equipped with a VERT-conform DPF-system

<table>
<thead>
<tr>
<th>Step-tests</th>
<th>VdeNOₓ1</th>
<th>VdeNOₓ2</th>
<th>VdeNOₓ3</th>
<th>VdeNOₓ4</th>
</tr>
</thead>
<tbody>
<tr>
<td>on chassis dynamometer</td>
<td>light-off</td>
<td>max. gas flow</td>
<td>max. temp.</td>
<td>K_NOₓ</td>
</tr>
<tr>
<td>RDE</td>
<td>3 repetitions</td>
<td>Gas PEMS</td>
<td>PN PEMS</td>
<td>Durability</td>
</tr>
<tr>
<td>End check</td>
<td>results from VdeNOₓ₃</td>
<td>short RDE</td>
<td>simple function test</td>
<td>on road circuit</td>
</tr>
</tbody>
</table>

**Abbreviations**

HD ... heavy duty
LD ... light duty
K_NOₓ ... NOₓ conversion efficiency
PN ... particle number
RDE ... real driving emissions
PEMS ... portable emission measuring system
Conclusions

• With DPF, SCR and GPF, it is possible to:
  - Eliminate PN and
  - Reduce NO\textsubscript{x} below the legal limits

• Quality control in-use is possible
  (for deNO\textsubscript{x}, PTI more efforts are necessary)

• Quality procedures for deNO\textsubscript{x} systems are elaborated
Thank you for your attention!