Euro VI

- Regulation
- Emissions in real driving conditions
- Euro VI engine system technologies
- Maintenance

Meinrad Signer
Consultant, Switzerland
Swiss government contractor
Euro IV – VI requirements

Emission Limit
- NOx
- PM/PN

Test cycle

OBD

Emission-Durability
- light
- medium
- heavy

NOx Control
- Nm-reduction
- warning

Conformity in Service

PEMS Pilot Program

ESC - ETC

Emission Threshold

2005 / 2006
- Euro IV
  - NOx: 3.5
  - PM/PN: 0.02

2006 / 2007
- Euro V
  - NOx: 2.0
  - PM/PN: 0.02

2008 / 2009

2013/2014
- Euro VI
  - NOx: 0.46*
  - PM/PN: 0.01 / 6*E11

WHDC + OCE

WH-OBD

- 200’000 km
- 300’000 km
- 700’000 km

Conformity in Service

Crawl mode 20km/h

PEMS
Emission compliance

1. Type approval engine test bench
   - Emission certification
     - WHDC
     - WNTE
   - OBD family certification
   - NOx control measures certification

2. PEMS type approval test (vehicle)

3. COP Conformity of production
   - COP test bench testing
     - WHDC
   - Quality management

4. ISC in-service conformity + IUPR
   - PEMS testing (until 700 000/300 000 km)
   - IUPR ("OBD monitoring statistics")
Euro VI test procedures

Cold test

1. Test

2. Test

WHTC

10 min

Weighting factor

14%

86%

ISC-PEMS

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In service conformity ISC ▸ PEMS

**ISC/PEMS**

700 000km / 7yrs

After the granting of type approval for an engine family the manufacturer shall perform in-service testing on this engine family **within 18 months** from first registration of a vehicle fitted with an engine from that family.

The testing shall be **repeated at least every two years** for each engine family periodically on vehicles over their useful life period.
SCR tampering

- AdBlue consumption is monitored
- AdBlue quality is constantly monitored
- SCR functionality is monitored and controlled (incl. AdBlue/DEF)
  - If AdBlue is frozen and SCR not operational after certain time the vehicle speed reduces to 20km/h

Misuse/tampering of SCR-AdBlue/DEF system

- Optical and acoustical warning with increased intensity
  - First warning when AdBlue/DEF level is lower than 10%
- First degree of restriction
  - Empty tank (at 2.5% quantity left), quality out of limits
    - 20% torque reduction in complete speed range
- Second degree of restriction
  - Empty tank, water in the tank, SCR not functioning
  - Max speed of vehicle reduced to 20km/h, beginning after a new start after parking (not during driving).
Euro VI emissions in-use
Particle number count

Ambient near truck
12100

Exhaust Euro VI truck
1860
Emission factors according to handbook

**Comparison emission factors EURO III to VI: NO\(_x\)**

Example: Long haul truck 40t GVW, 50% loading

- Euro III
- Euro V - EGR
- Euro V - SCR
- Euro VI

**Graph**

- Y-axis: NO\(_x\) [g/km]
- X-axis: Average cycle speed [km/h]

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Dr. Martin Rexeis

Analysis of EURO VI vehicle emissions

Brussels, 13th of June 2015
Euro III → Euro VI Emissionen (Iveco)

- Stop and go
- Urban
- Rural
- Motorway

Source: HBEFA, FPT, TU Graz

Emission factor [g/km]
Average cycle speed (Km/h)

Refers to 40 t Euro VI Truck g/km
VTT Finland Euro VI Buses (7) in Braunschweig cycle

Euro VI Bus Emission Test results

EEV: lowest previous standard

7 Euro VI buses
Have we succeeded?

TNO In-Service Emissions Testing Programme for HDV

Long haulage diesel fuelled Euro VI vehicles show a strong reduction of the real-world NOx emissions

Average real-world NOx emissions (PEMS) during typical Dutch urban, rural and motorway conditions

Euro VI trucks aller Marken

TNO - Netherlands Organisation for Applied Scientific Research

## MAN Lion’s City Bus Euro 6
### On-Road PEMS results

### EURO VI PEMS results

- Calculation of average NOx emission from PEMS measurements [g/km]

<table>
<thead>
<tr>
<th>City Bus</th>
<th>Ø Speed [km/h]</th>
<th>Time [h]</th>
<th>Distance [km]</th>
<th>Weight [ton]</th>
<th>Passengers</th>
<th>NOx [g/km]</th>
<th>NOx [g/t-km]</th>
<th>NOx [g/Passenger-km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAN Lion’s City A78 Diesel Euro VI</td>
<td>30,0</td>
<td>4,2</td>
<td>116</td>
<td>14,9</td>
<td>46</td>
<td>0,33</td>
<td>0,022</td>
<td>0,007</td>
</tr>
<tr>
<td>MAN Lion’s City A21 CNG Euro VI</td>
<td>31,8</td>
<td>3,8</td>
<td>115</td>
<td>15,6</td>
<td>33</td>
<td>0,26</td>
<td>0,017</td>
<td>0,008</td>
</tr>
</tbody>
</table>

Same particulate number (PN) limit for CNG and diesel!

- PEMS measurements – Public test service NL(TNO) Linie 8 in Utrecht / Netherlands

<table>
<thead>
<tr>
<th>Linie 8</th>
<th>Ø Speed [km/h]</th>
<th>Time [h]</th>
<th>Distance [km]</th>
<th>Weight [ton]</th>
<th>Passengers</th>
<th>NOx [g/km]</th>
<th>NOx [g/t-km]</th>
<th>NOx [g/Passenger-km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAN Lion’s City A78 Diesel Euro VI</td>
<td>13</td>
<td>2,2</td>
<td>28,6</td>
<td>14,4</td>
<td>40</td>
<td>0,20</td>
<td>0,014</td>
<td>0,005</td>
</tr>
</tbody>
</table>

Very low vehicle speed!
Ricardo study: Euro V hybrid bus – Euro VI truck

PEMS Results
Brighton Buses & Truck Mass NOx Emissions Comparison

- The graph gives comparative (buses & truck) mass emissions over North Street.
- Truck data is of a single run of both the loaded and unloaded trailer configuration, while the bus data has been averaged from multiple runs over the same route.
Fuel consumption HD truck 40t

<table>
<thead>
<tr>
<th>Comparison &gt;15 l engines: TRUCKER MAGAZIN TEST / GER, 25.09.2014</th>
<th>Test candidate A</th>
<th>Competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel consumption [l/100 km]</td>
<td>25,7</td>
<td>26,9</td>
</tr>
</tbody>
</table>

FC test results with EURO VI vehicles show a significant improvement

Real drive data show excellent emission (PEMS) and FC(CO2) behaviour
Euro VI technologies
Euro VI technology options

- Fuel consumption
- SCR efficiency
- AdBlue consumption
- SCR efficiency
- AdBlue consumption
- EGR Rate
- EGR Rate
- Combustion
- SCR
- SCR
- EGR
- EGR
- NOx (g/kWh)
- PM (g/kWh)

**Euro VI**
- 0.02
- 6\times E11

**Euro V**
- 0.46

**Euro IV**
- 2.0
- 3.5
- 5.0

**Euro III**
- 0
- 100

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Euro VI technology options

Fuel consumption

1-st. TL

2-st. TL

PM (g/kWh)

Euro III

Euro V

Euro IV

NOx (g/kWh)

SCR efficiency

AdBlue consumption

EGR Rate

Combustion

EGR

SCR

DPF

0.02

6*E11

0.46

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Euro VI technology options

Fuel consumption

1-st. TL
2-st. TL

pm (g/kWh)

Euro III

Euro IV

Euro V

Euro VI

NOx (g/kWh)

Fuel consumption

SCR efficiency

AdBlue consumption

SCR

DPF

SCR

EGR

Combustion

6*E11

0.02

0.46

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Euro VI technologies Diesel

**Euro VI**

- SCR only for Iveco/FPT and partly Scania, all others combination of SCR/EGR
- All Euro VI have DPF
- Electronic control of engine and aftertreatment system, NOx sensor
- Fuel mandatory <10 (15)ppm
- Maintenance: typical engine maintenance as for all electronic controlled
- Diesel engines, DPF regular maintenance (at 300-400’000km)
- LowSAPS lubricants, maintenance of sensors as specified
- OBD
Euro VI technologies CNG

Euro VI

- stoichiometric combustion, spark ignition
- Some with EGR
- Multipoint port injection, direct injection
- 3-way catalyst system
- Electronic control of engine and aftertreatment system, NOx sensor
- Best fuel methane content >90%
- Maintenance: typical engine maintenance as for spark ignition engines
- OBD
## Maintenance requirements

<table>
<thead>
<tr>
<th></th>
<th>Euro IV</th>
<th>Euro V</th>
<th>Euro VI</th>
<th>Euro V / VI CNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lubricating oil</td>
<td>EGR or SCR</td>
<td>EGR / SCR</td>
<td>EGR / SCR / DPF</td>
<td>(EGR) / 3way Cat</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td></td>
<td></td>
<td>E9, APT CJ-4 (low SAPS)</td>
<td>Gas engine oil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AdBlue DEF</td>
<td>Standard 2-4%</td>
<td>Standard 3-5%</td>
<td>Standard 4-7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPF</td>
<td></td>
<td></td>
<td>Maintenance after 300’000-500’000 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SCR dosing unit</td>
<td>Filter replacement</td>
<td>Filter replacement</td>
<td>Filter replacement</td>
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<tr>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Breather filter</td>
<td>Replacement</td>
<td>Replacement</td>
<td>Replacement</td>
<td>Replacement</td>
</tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Engine general</td>
<td>standard</td>
<td>standard</td>
<td>standard</td>
<td>Standard</td>
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<tr>
<td>Sensors</td>
<td>NOx sensor</td>
<td>NOx sensor</td>
<td>NOx/NH3 sensor</td>
<td>Oxigen sensor</td>
</tr>
</tbody>
</table>

mSCO GmbH CH-9320 Arbon
Summary

• Euro VI regulation provides low emissions under all conditions of use, from sea level to altitude and from low to high temperatures
• Euro VI regulation is strongly based on in-use emission control and checked with PEMS for each engine family over the useful life
• In-use emission emission measurement has confirmed the excellent emission performance of Euro VI

• Euro VI is the way forward
Back-up
SCR – DPF Systems

- Designed and manufactured by Cummins Emission Solutions
- Domed end cones
- Fully insulated
- Airless Urea Injection
- No acoustic section needed
- Copper Zeolite SCR design for improved conversion efficiency at lower temperature
- Switch Back Design to allow for compact installations
Selective Catalytic Reduction

Injection of AdBlue ...
(Urea – Water solution / 32.5 wt.-% Urea)
with / w.o. compressed air (dosing system)

AdBlue
Urea + Water

Control system
connected to
engine ECU

NO

NO₂

SCR Catalyst

SCR Catalyst

NH₃ = Ammonia

N₂

H₂O

NO₂

NO

NH₃

NH₃

NH₃

NO

H₂O

N₂

Injection of AdBlue ...

(Urea – Water solution / 32.5 wt.-% Urea)

with / w.o. compressed air (dosing system)
Euro IV – V technologies Diesel

Euro IV

• either SCR (using AdBlue) or EGR
• Electronic controls of engine and aftertreatment system, NOx sensor
• DPF sometimes used for buses, then in combination with Oxidation cat
• Fuel sulfur best is <10ppm, 50 ppm is still ok, 500ppm detrimental for oxi-cat and EGR
• Maintenance: typical engine maintenance as for all electronic controlled
• Diesel engines, in case of DPF regular filter maintenance (at 300-400’000km)
• LowSAPS lubricants, maintenance of sensors as specified

Euro V

• either SCR (using AdBlue) or EGR with DPF or the combination of both
• Electronic controls of engine and aftertreatment system, NOx sensor
• DPF used for the version with EGR only, of for bus application
• Fuel sulfur best is <10ppm, when DPF is installed also <10ppm, otherwise 50ppm could work
• Maintenance: typical engine maintenance as for all electronic controlled
• Diesel engines, in case of DPF regular filter maintenance (at 300-400’000km)
• LowSAPS lubricants, maintenance of sensors as specified
Euro VI Maintenance requirements Diesel

Lubricating Oil
ACEA classification E9, APT CJ-4 (low SAPS)

Fuel
Ultra low sulphur diesel fuel (<10 ppm sulphur)

AdBlue / DEF
Refill with standard fluid meeting specifications

DPF
Clean following the maintenance guidelines (usually between 300-500’000km)

Dosing unit filter
Replacement in-line with maintenance guidelines
Preventing blockage of AdBlue / DEF flow in injector

Breather filter
As it is a closed system, filters must be replaced according to guidelines
CNG engines layout

- Stoichiometric NG applications offer 5 – 8% lower CO2 emissions than On Road Diesel which corresponds to a operating cost saving of 25 – 30%.
- A lean burn combustion concept or the application of EGR may allow for a further reduction. Exhaust emissions, however, would not be as low as with the stoichiometric version.
No additional fluid on board the vehicle

Fuel quality sensitive (in particular sulfur)

Increased fuel consumption → 2-stage turbocharging

Deposit formation possible, negative influence on lubricant performance

Increased cooling power → installation constrains → increased consumption

High EGR rates even under full load conditions

Second fluid on board, AdBlue-consumption depending on conversion rate

Engine optimised for low fuel consumption

Fuel quality sensitive at high conversion rate conditions

No negative effects on lubricant

Big volume to be installed

Limits with respect to conversion rate (temperature)

Fuel quality sensitive (passive regeneration)

LowSAP lubricants are required
Figure 1. Major vehicle markets and national standards for all new HDVs.

Source: ICCT