Other pollution sources:

NP from GDI & $\text{NO}_x/\text{NO}_2$ from Diesel

Jan Czerwinski, AFHB
BFH-TI, Biel, CH

4th NPC, TECHNION, Haifa, June 21st, 2016
NP from GDI
DRIVING CYCLES

WLTC driving cycle

NEDC driving cycle

phase 1 (ECE)

phase 2 (EUDC)
PARTICLE SIZE DISTRIBUTIONS OF DIFFERENT VEHICLES AT TAILPIPE & 40 KM/H
COMPARISON OF NP-EMISSIONS IN NEDC COLD AND HOT.

VEHICLE 3; CVS TUNNEL

[AFHB, SAE 2015-01-1079]
SMPS PARTICLE SIZE DISTRIBUTIONS AT CONSTANT SPEEDS WITH DIFFERENT GDI VEHICLES (w/o GPF).

[AFHB, VERT Forum March 2016]
NSMPS PARTICLE SIZE DISTRIBUTIONS AT CONSTANT SPEEDS WITH DIFFERENT GDI VEHICLES (W/O GPF).

[AFHB, VERT Forum, March 2016]
GPF
EXAMPLE OF PSD'S WITH SMPS & nSMPS AND PARTICLE COUNTS FILTRATION EFFICIENCY (PCFE) WITH V1, GPF 1 AT 95 KM/H

![Graph showing PN and PCFE with SMPS and nSMPS at 95 km/h with and without GPF.](image-url)
### Comparison of PN-emissions in WLTC cold and hot for different vehicles

<table>
<thead>
<tr>
<th>PN #/km</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
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<tbody>
<tr>
<td>Low part cold</td>
<td></td>
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<tr>
<td>#/km</td>
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<tr>
<td>V1, GPF1</td>
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<td>V1, GPF2</td>
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<tr>
<td>V1, GPF4</td>
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<td>V2, GPF1</td>
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<td>Whole WLTC cold</td>
<td>limit 6.0x10^{12}</td>
<td>limit 6.0x10^{11}</td>
<td>limit 6.0x10^{12}</td>
<td>limit 6.0x10^{11}</td>
<td>limit 6.0x10^{12}</td>
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<td>#/km</td>
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<th>V4</th>
<th>V5</th>
<th>V6</th>
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<tbody>
<tr>
<td>Low part hot</td>
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<td>#/km</td>
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<tr>
<td>V1, GPF1</td>
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<tr>
<td>V2, GPF1</td>
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</table>

### Diagrams

- **Low part cold:** PN emissions for different vehicles with limits 6.0x10^{12} and 6.0x10^{11}.
- **Whole WLTC cold:** PN emissions for different vehicles with limits 6.0x10^{12} and 6.0x10^{11}.
- **Low part hot:** PN emissions for different vehicles with limits 6.0x10^{12} and 6.0x10^{11}.
- **Whole WLTC hot:** PN emissions for different vehicles with limits 6.0x10^{12} and 6.0x10^{11}.
PCFE's of the investigated GPF's in WLTC hot

V1, GPF1
V1, GPF2
V1, GPF3
V1, GPF4
V2, GPF1

CPC

[AFHB, VERT Forum, March 2016]
Conclusions (1)

- PN cold 4 ÷ 5 times higher, than hot
- for the vehicles with gasoline DI, there is no increase of PC’s in nuclei mode (below 10 nm) at the measured constant speeds, the particle counts below 10 nm are negligible
- not always typical PSD
- due to the electronic regulation of the engine the NP-emission of some vehicles (here vehicle 3) are periodically fluctuating
Conclusions (2)

- the PN-emission level of the investigated GDI cars in WLTC without GPF is in the same range of magnitude very near to the actual limit value of $6.0 \times 10^{12}$ #/km

- with the GPF’s with better filtration quality it is possible to lower the emissions below the future limit value of $6.0 \times 10^{11}$#/km

- the filtration efficiency of GPF can attain 99% but it can also be optimized to lower values – in this respect the requirement of “best available technology for health protection” should be considered
GPF & Lube Oil Consumption
EFFECT OF INCREASED LUBE OIL CONSUMPTION

SEAT LEON 1.4 TSI; THREE-WAY CATALYST; FUEL: GASOLINE (REF) & GAS. + 2% OIL
H... «HIGH», L... «LOW» METALS & ASHES IN LUBE OIL
SMPS
Effect of GPF with increased lube oil consumption

Seat Leon 1.4 TSI; three-way catalyst; fuel: gasoline + 2% oil H; with & w/o GPF SMPS
Other non-legislated components from GDI
GASOLINE VEHICLES FOR RESEARCH OF NH₃
SAMPLING POSITIONS (SP) FOR GASOLINE VEHICLES – TESTING NH$_3$
COMPARISON OF AVERAGE NH₃-RESULTS
3 CARS IN WLTC
DIFFERENT SAMPLING POSITIONS, DILUTION CALCULATED WITH CO₂

SP....Sampling positions
Sp1, Sp2....non diluted
Sp3, Sp4, Sp5, bag....diluted
NO$_2$ & NO$_x$
From Diesel
\[ \eta_{th} = 1 - \frac{T_L}{T_H} \]

\[ \rightarrow T_H \sim T_{max} \text{ Combustion} \]

\[ \rightarrow \text{NO}_x \text{ engine out} \uparrow \]

exhaust aftertreatment
The NO$_2$/NO$_x$ ratio with different DPF's & coatings in the VERT verification tests.

[AFHB, SAE 2007-01-0321]
Other Engines
PEUGEOT 406 WITH FAP

- DI
- TC
- DPF
- 1.997 dm³
- 4000 rpm
- 110 kW
NO$_2$/NO$_X$ AFTER CATALYST AND PARTICLE TRAP ON PEUGEOT 406 WITH FAP
ENGINE AT 1715 RPM, 80KM/H, ON ROLLER TEST BENCH
EFFECT OF SULPHUR CONTENTS (IN ppm S) IN FUEL ON NO CONVERSION OVER CRT-CATALYST

Johnson Matthey
SAE 2002-01-1271
Conclusions (4)

- higher $\eta_e$, higher NO$_x$
- NO$_2$/NO$_X$ – maximum at 300°C - 350°C

**FBC**

- at short term no effect on NO$_2$/NO$_X$
- at long term with Pt strong effect

**Absolute NO$_2$-values depend on:**

- engine out emissions & temp.
- position & temp. of DOC (Ox.Cat)
- coating, fuel S & SV

[AFHB, SAE 2007-01-0321]
[AFHB, SAE 2013-01-0526]
NO$_2$ Diesel Cars
DPF + SCR FOR PASSENGER CARS
PERSPECTIVES FOR LOWERING NO$_x$

- low temperature deNO$_x$ (adsorber, LNT, multi SCR)
- EGR HP, EGR LP, cooling
- special combustion procedures at part load, HCCI
Can the problems of energy, environment and health be solved with technics alone?
Thank you for your attention