SCR-DPF integrations for diesel exhaust

Performance and perspectives for high SCR loadings

RESEARCH | TECHNOLOGY | CATALYSTS

DEER conference, 2012-10-17

Milica Folić/Keld Johansen

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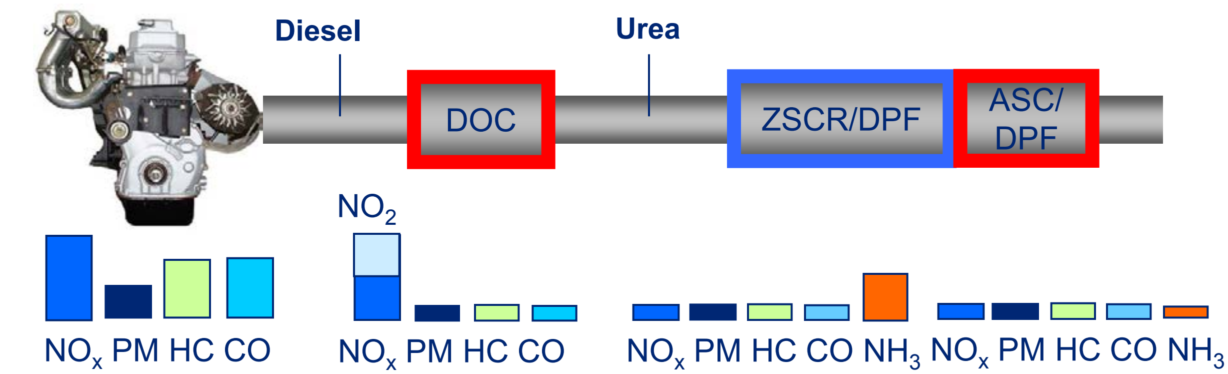
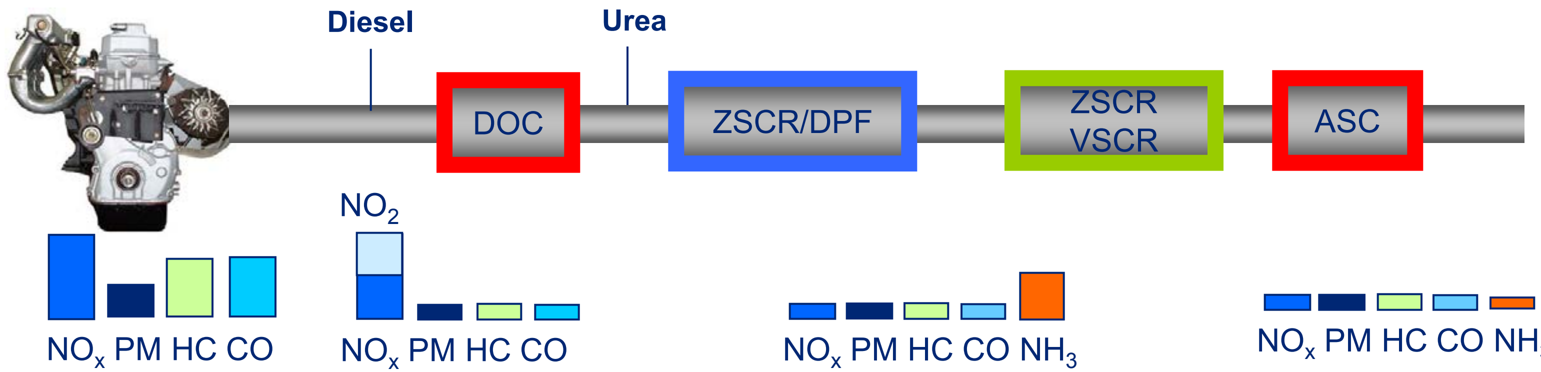
Outline

- SCR integration in DPF: Why and how?
- Challenge: High temperature stable SCR
- Filters types and porosities: Lab screening
- Results on LD engine bench
- Conclusions and future outlook

SCR integration with DPF: Why and how?





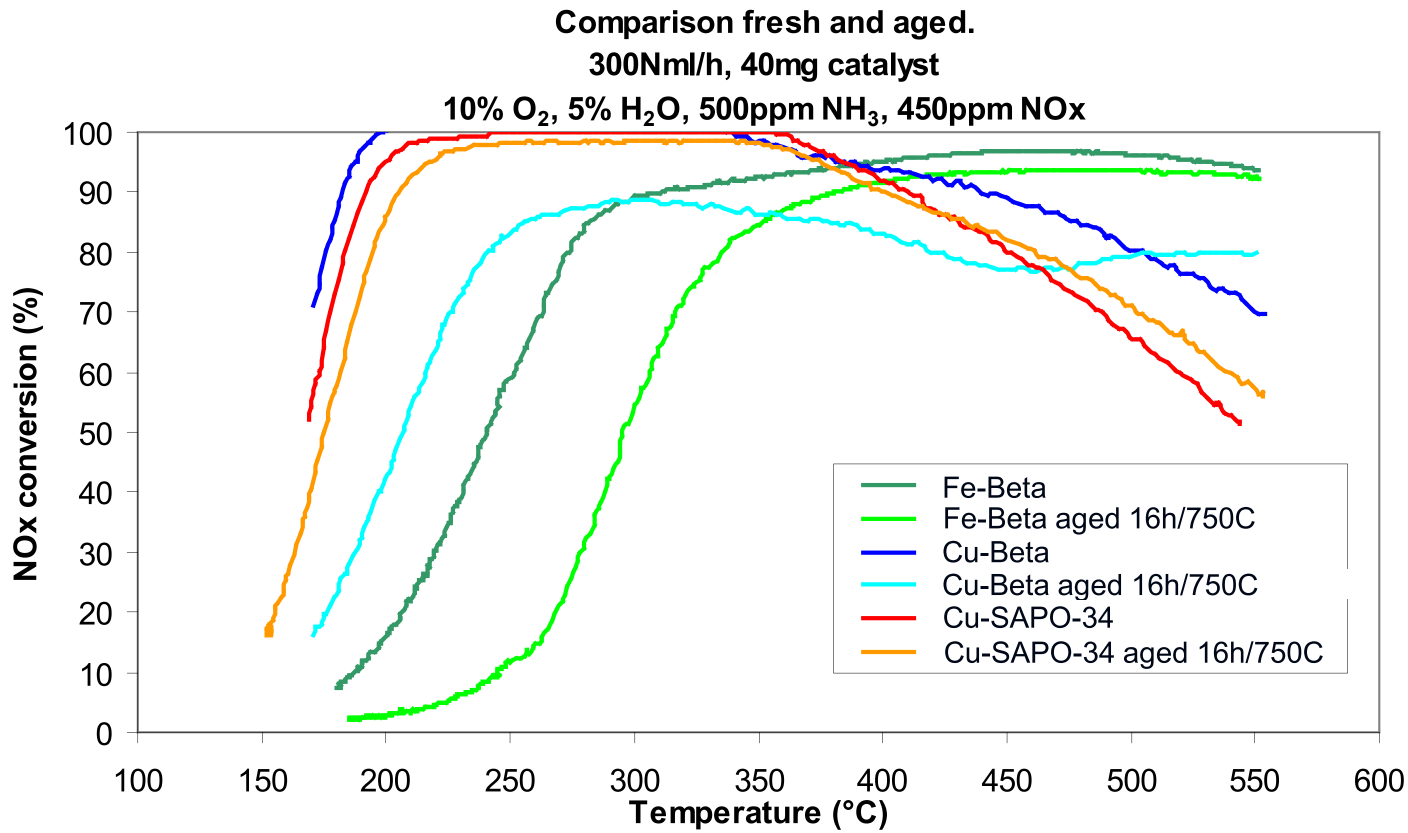
- Integration advantages:
  - Lower volume, cost
  - Improved transfer: heat, gas components
  - Earlier urea injection, improved cold start SCR
  - Low exhaust temperature

High temperature stable SCR formulations

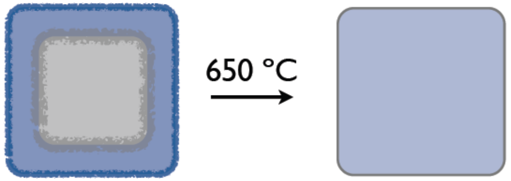
- SCR catalyst that tolerates up to 800-900°C?
  - Fe-β-zeolite – not stable and requires NO_2
  - V_2O_5/ WO_3/ TiO_2 not stable
  - Cu- β-zeolite – not stable

- Cu chabazite (and alike) materials are good candidates
  - Cu-SAPO-34 chosen for this study (ZSCR)
  - Cost-effective solution for small ring zeolites

Thermal effects and hydrothermal stability



- Big difference in hydrothermal stability: Cu-Beta vs. Cu-SAPO-34
- Cu-SAPO-34 must be activated @high T to obtain activity
  - Decrease in Cu surface concentration upon calcination



Filter materials: lab screening

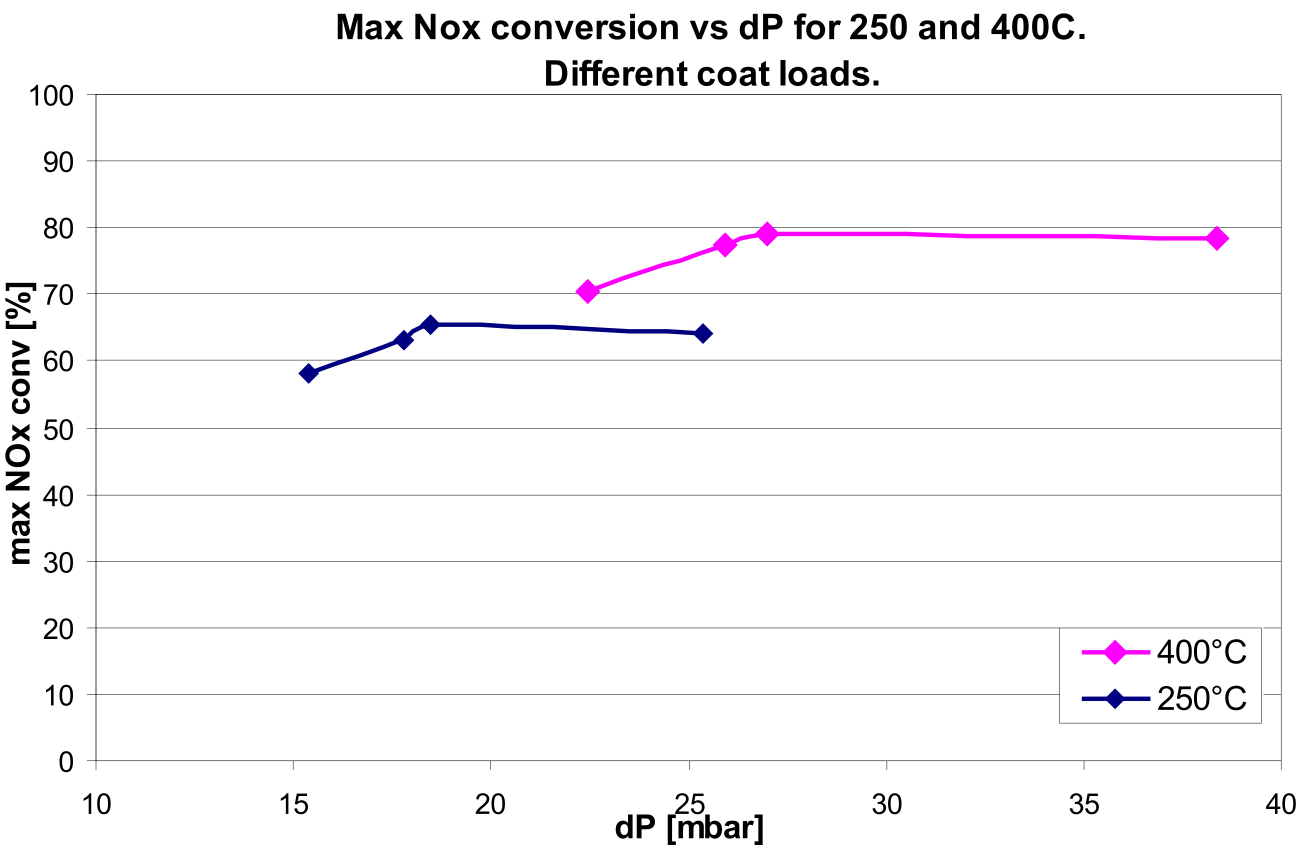
- Candidates with porosity potential (57–75%) for SCR integration:

  - SiC - Cordierite - ATI - Mullite

- Coat load range 100–220 g/L depending on the filter material
- Focus on DeNOx performance and pressure drop
- DeNOx/Δp optimal SCR loadings found
- All samples benchmarked against flow-through monoliths
- Notation:
  - ’Low’ porosity: 57-60%
  - ’Medium’ porosity: 65%
  - ’High’ porosity: 75%

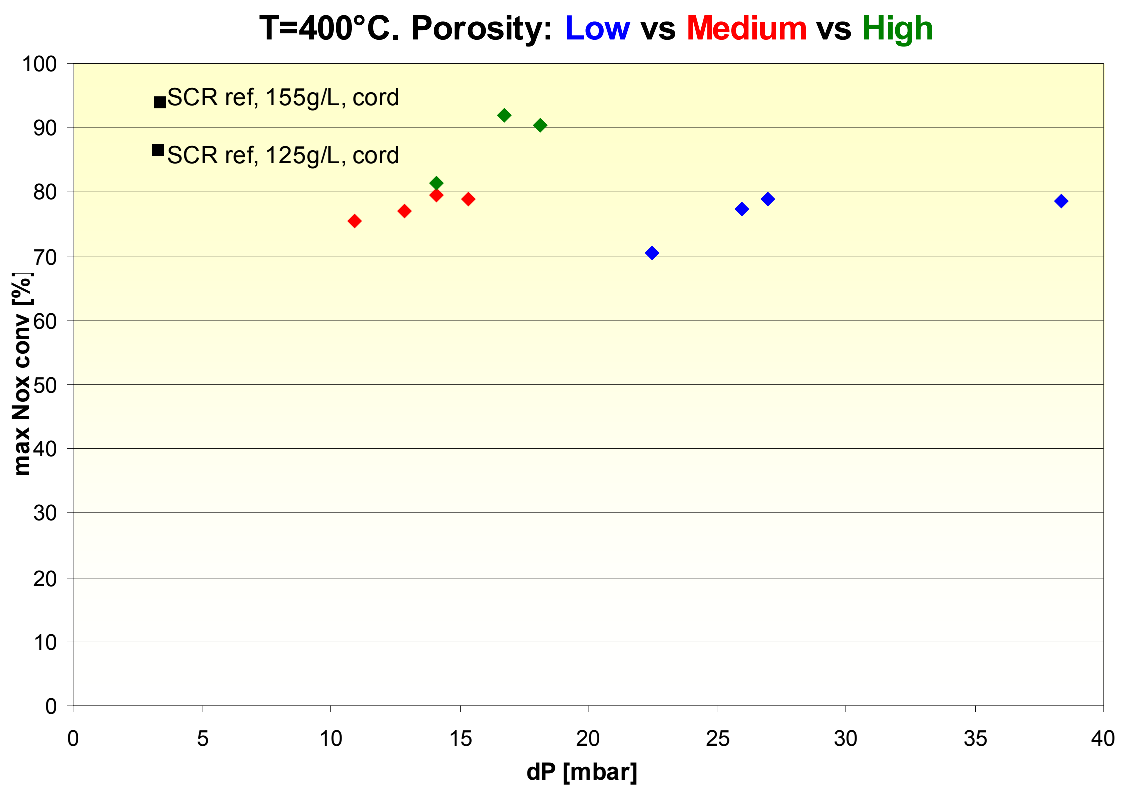
!

Optimal coat load study: Low porosity at NHSV = 100,000 h^{-1}



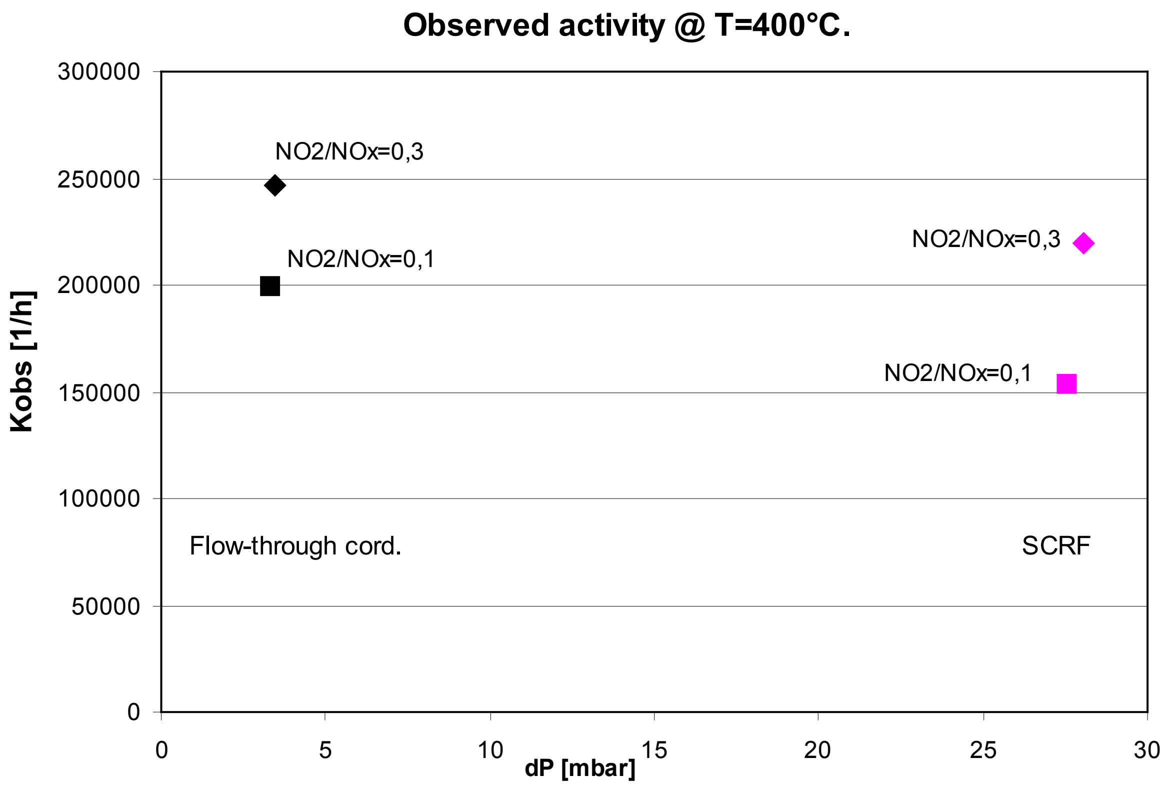
- Above certain coat load only dP continues increasing
- A small drop in NOx conversion observed at too high loads

SAPO-34 coating on different filters



- NOx conversion proportional to coat load
- High porosity gives best trade-off between dP and DeNOx

DeNOx activity with NO_2=f(Δp, T). Low porosity



- For low porosity filters, addition of NO_2 can help close the gap in activity between SCR/DPF and flow-through

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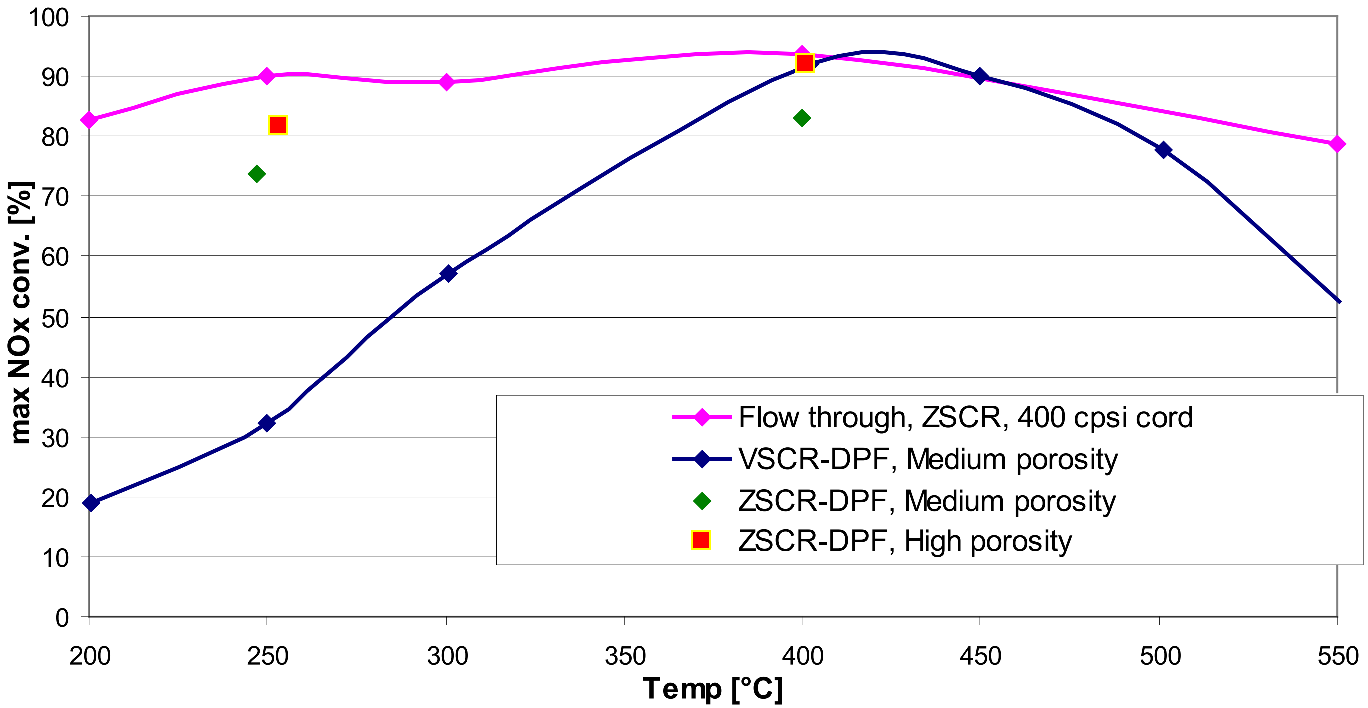
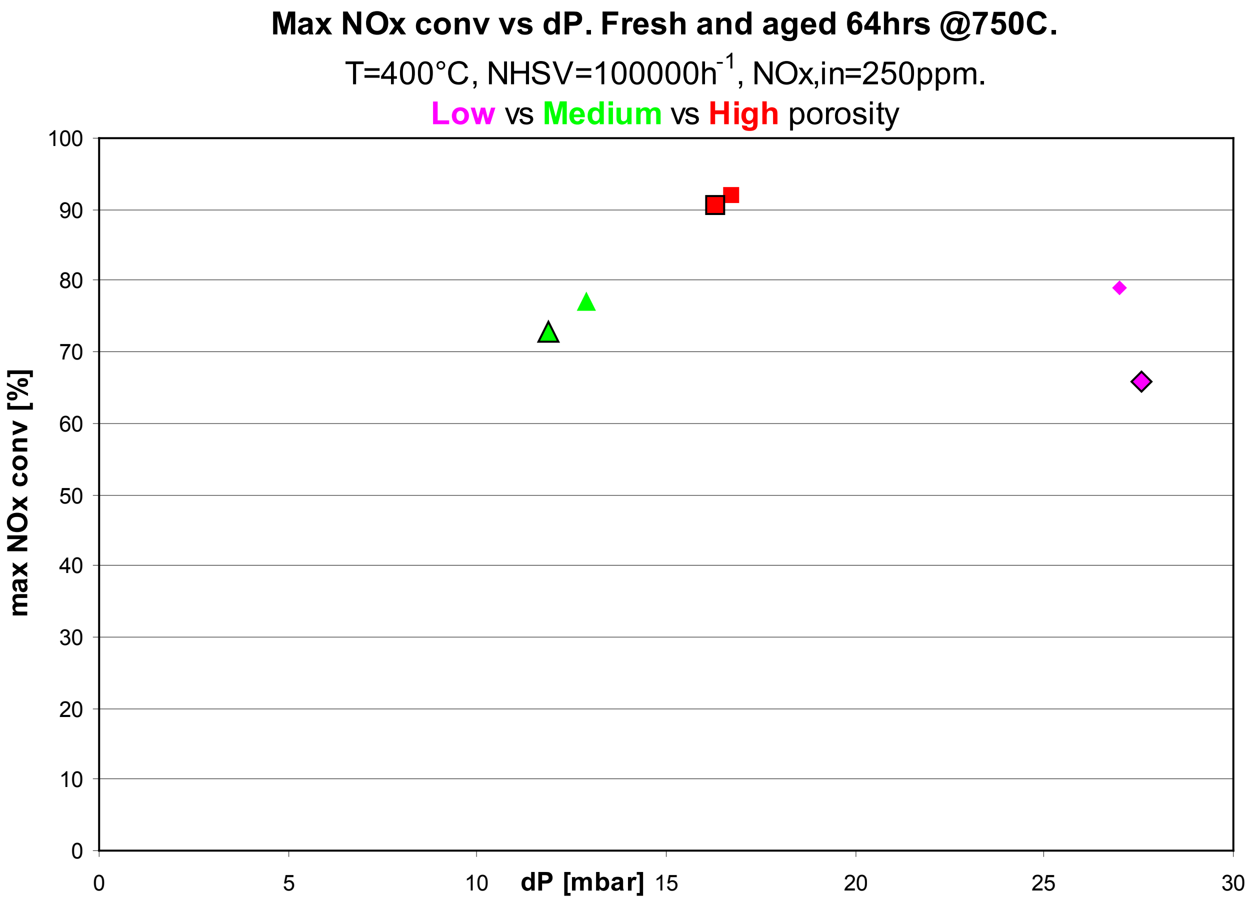
VSCR-DPF comparison with ZSCR-DPF



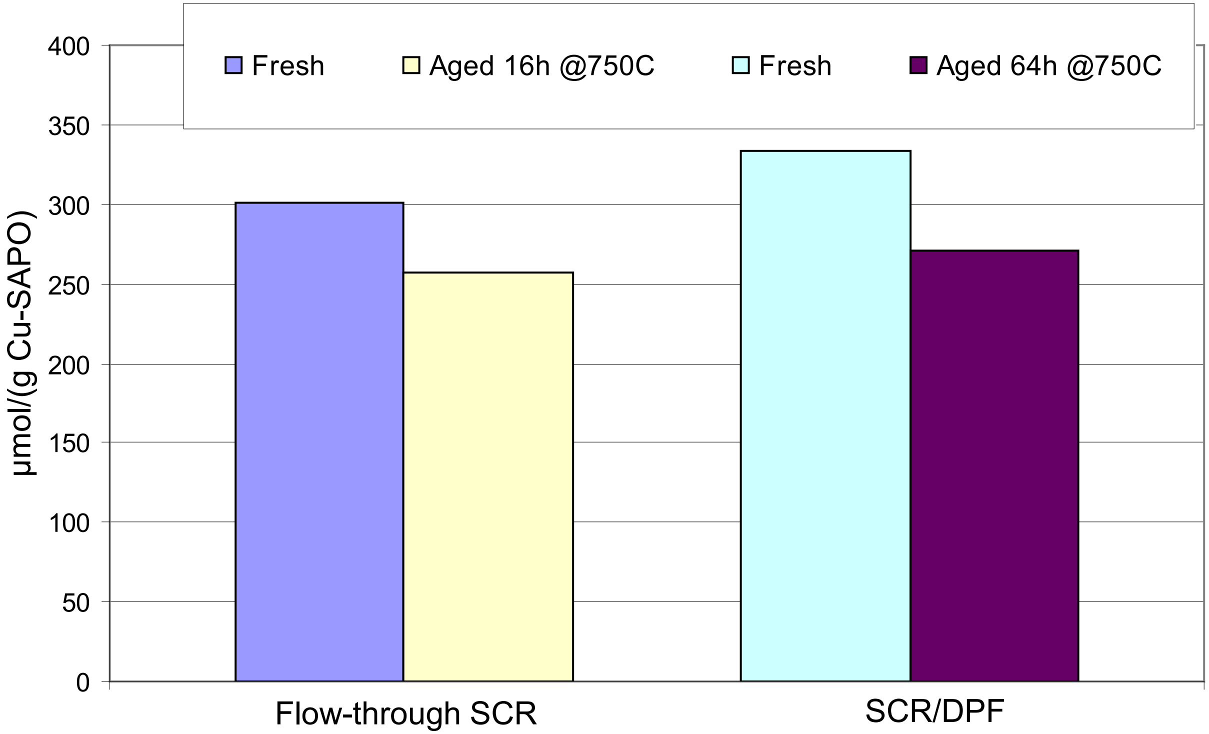
- VSCR-DPF shows good high temperature activity [400-500°C]
- BUT: Almost no low temperature activity left

Max NOx conversion after 64hrs @750°C



- Stability is proportional to the coat load/porosity
- Little change in performance of high porosity filter

Ammonia storage upon ageing



- Very stable ammonia storage capacity at 250°C
- Higher storage for filters due to better contact with coat

Laboratory findings

- Coat load optimum (120–180g/L) & coating procedure established for various materials/porosities
- High coat load gives the same DeNOx as flow-thorough
- Satisfactory performance after ageing for 64hrs @750°C
- Several porosity filters chosen for up scaling and engine bench tests with soot

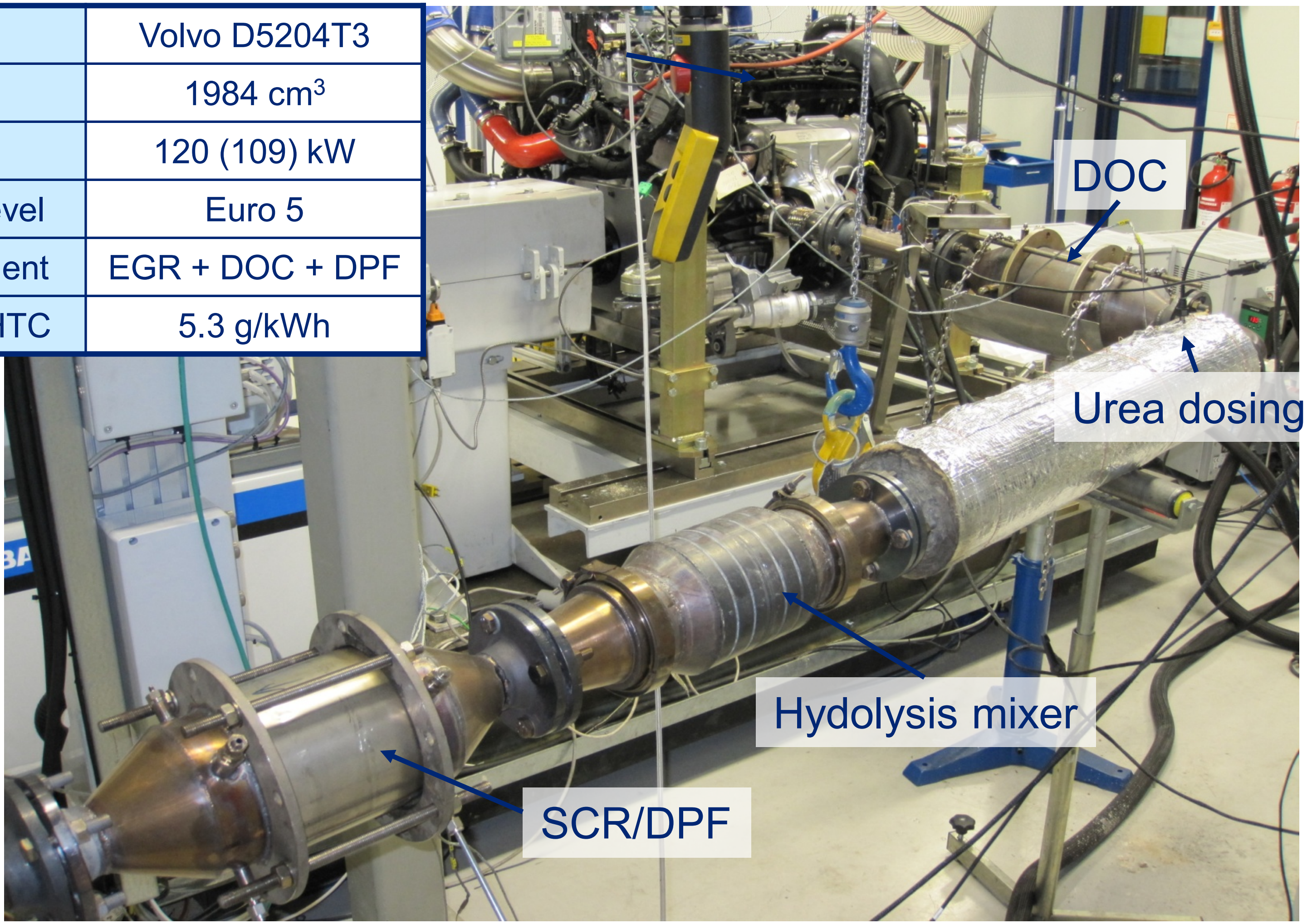
Engine validation tests

1. Soot – Δp curve
2. Active soot regeneration (T_{in}=600 ºC, 4- 5 g/l)
3. Steady state NOx activity with soot (4-5 g/l)
4. WHTC: fresh & aged filter
5. NH_3 absorption w & w/o soot
6. Passive/NO_2 soot regeneration (BPT w & w/o urea)
8. PN and PM filtration
9. Drop to idle test (4-5 g/l)
10. Ash influence

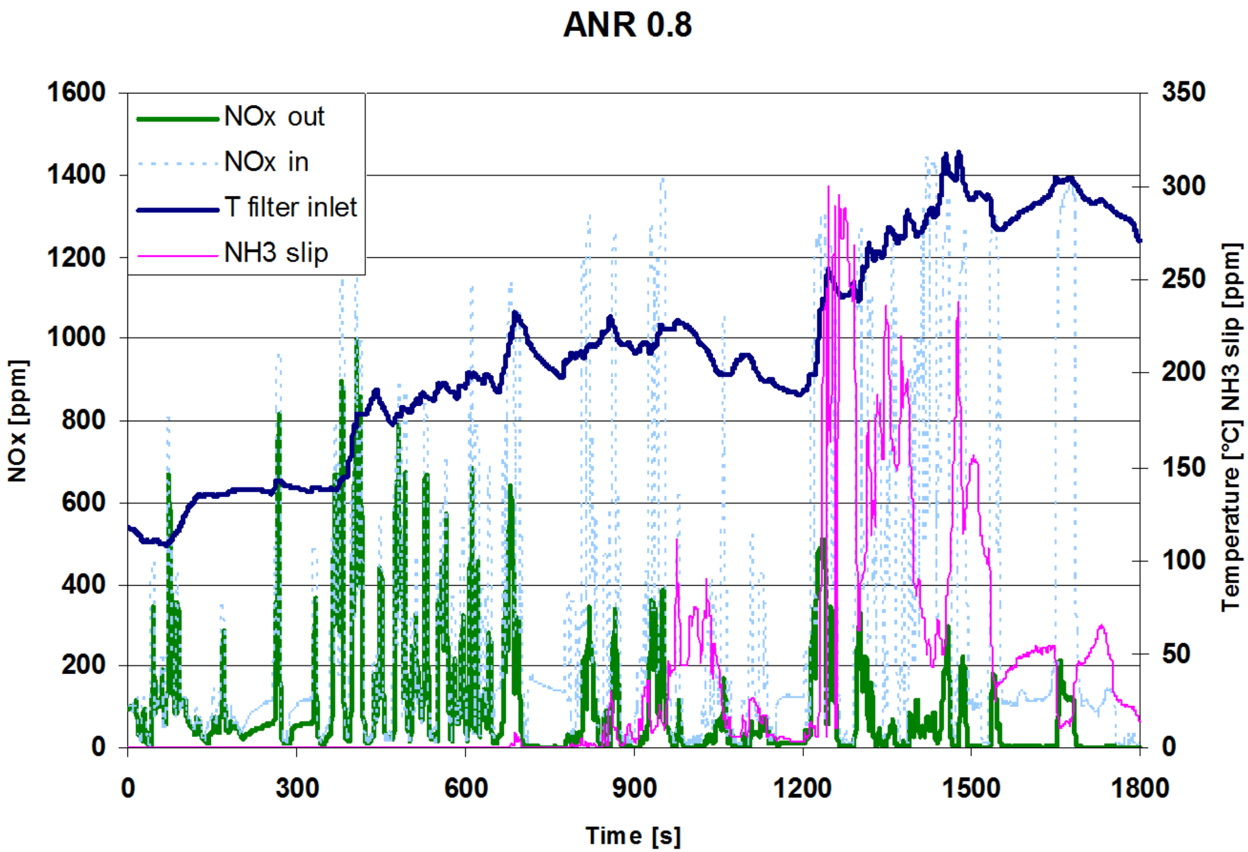
CAN TESTS WITH SOOT CHANGE THE OBTAINED LAB RATING?

Engine bench: LD test cell

Engine	Volvo D5204T3
Displacement	1984 cm^3
Rated power	120 (109) kW
Original emission level	Euro 5
Original after treatment	EGR + DOC + DPF
Engine out NOx WHTC	5.3 g/kWh



WHTC. ANR=0,8 for Low porosity filter



NO_2/NOx 70% DOC out

Average NHSV=38000h^{-1}

Average $T_{before\ filter}$ = 220°C

ANR	NOx conv [%]	Average NH_3 slip [ppm]
0.8	71.3	37.4
1	81.4	100

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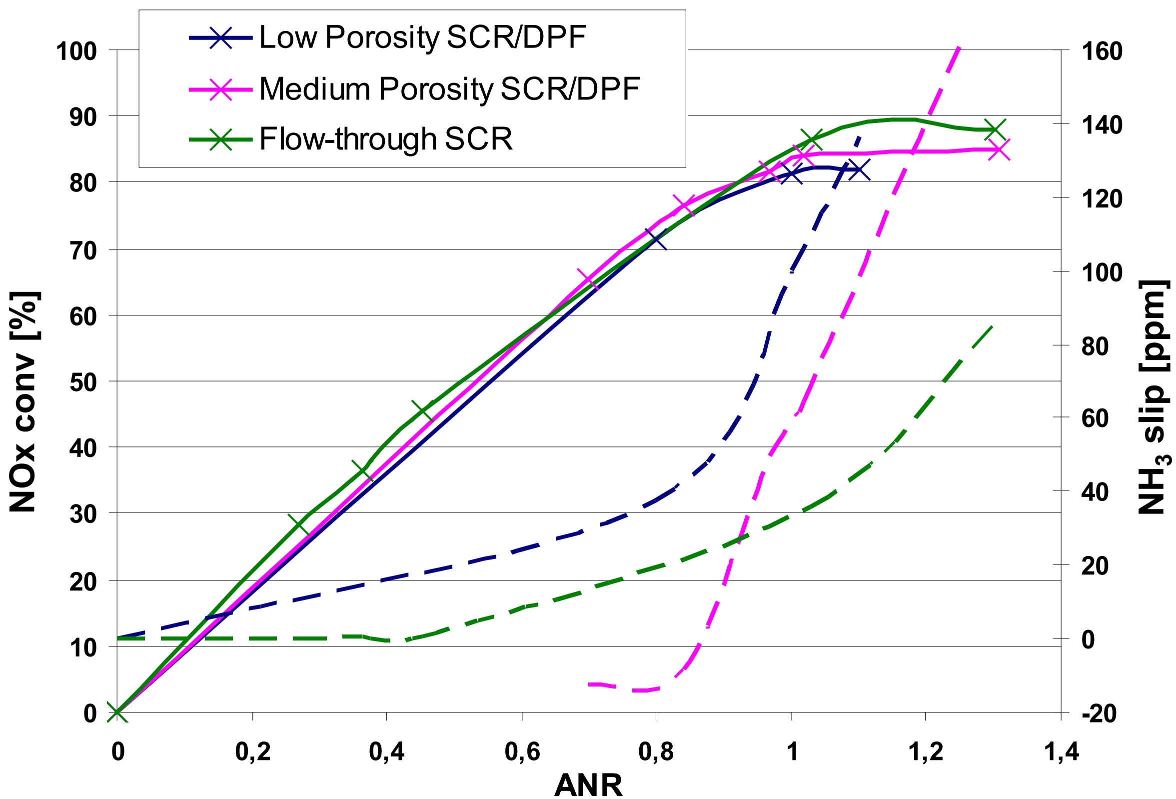
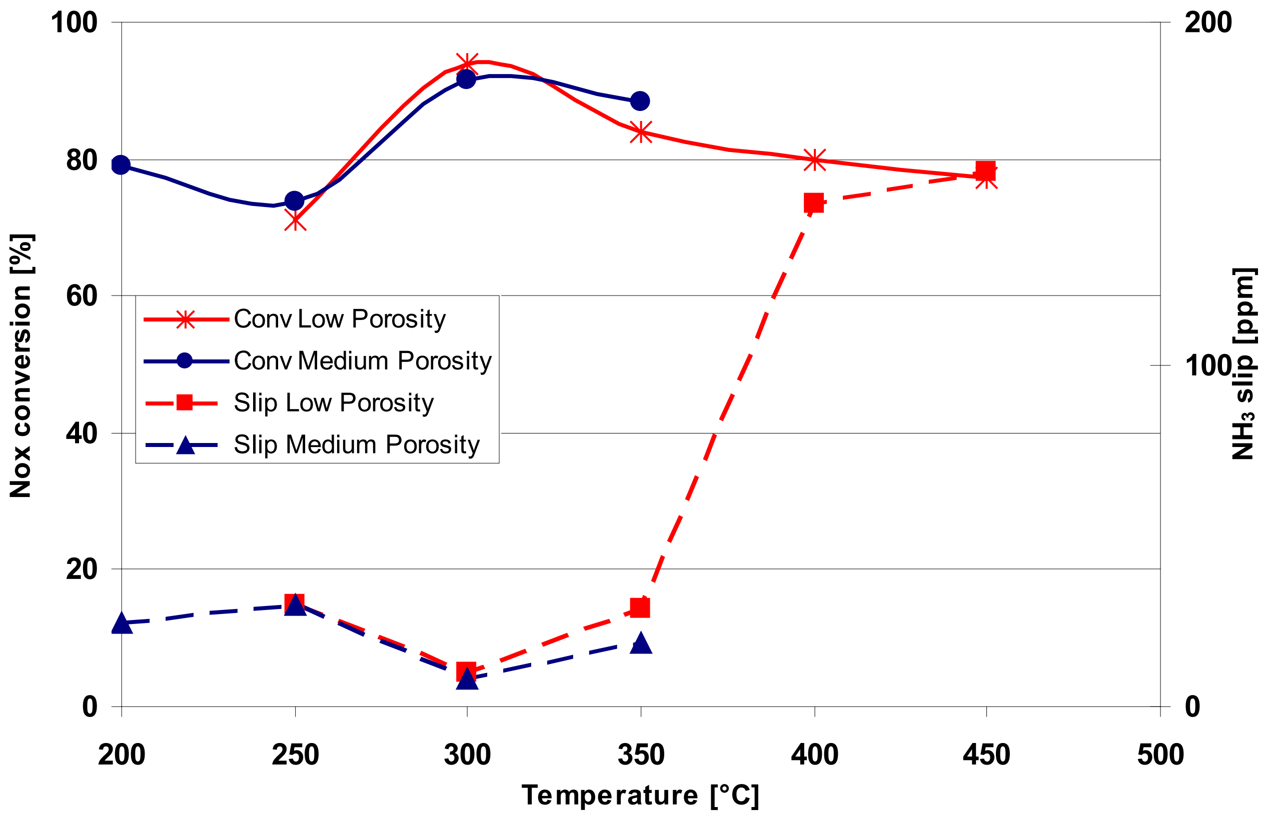
Comparison with flow-through SCR



	Filter	Flow-through
$NHSV_{av}$ [h^{-1}]	38000	47000

Steady state DeNOx, low and medium porosity filters

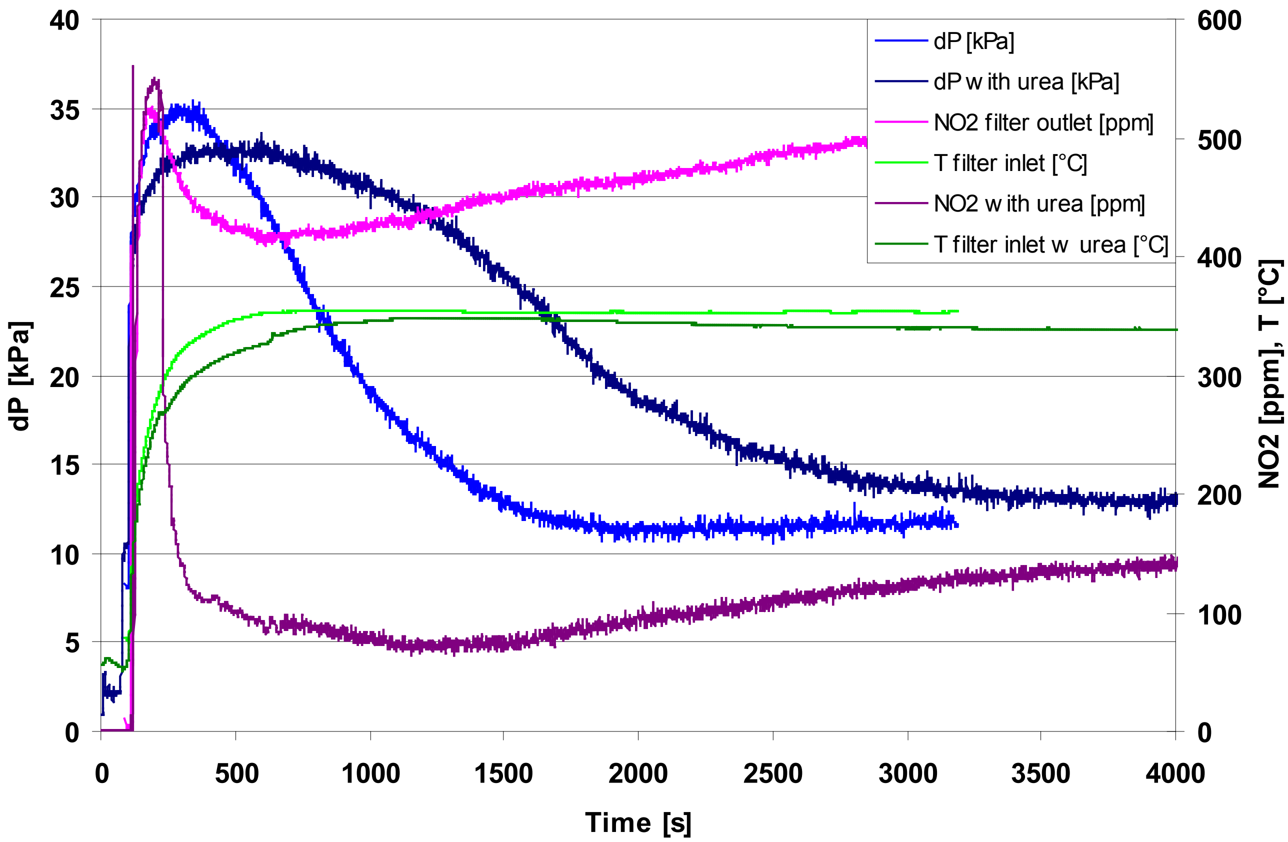


- NHSV=55000h^{-1}. ANR=0,9. Conversion over DOC + ZSCR/DPF

Passive regeneration @ T~350°C
Low porosity filter

Soot [g/l]	No urea	With urea
Start	6.15	5.4
End	1.8	2.45
Regen. efficiency	71%	55%

BPT=295°C



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Conclusions and future outlook

- SCR+DPF replacement with ’ZSCR/DPF only’ is possible
- Good NOx conversions in test cycles for different porosities
- High coat load gives equivalent activity to flow-through
- dP for ZSCR/DPF is near traditional cDPF + SCR systems
- Passive regeneration: SCR and soot compete for NO_2. DOC must be optimized for high NO_2
- Active regeneration: max soot load and T ramping management need good control (thermal peaks risk)
- Selection of high loading ZSCR/DPF requires full validation!

Henrik Bentzer

Bjarne Møller

Anni Stahl

Jakob Høj

Tais Jeppesen

Shannie Nielsen

Kenneth Larsen

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