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Regeneration, volatile nanoparticles, toxicity and other research questions for diesel emission controls

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Clean Vehicle/Engine Programs in California

- CARB has rules in place to reduce emissions from every existing diesel engine: retrofit, repower, replace
- New low carbon fuel standard: biodiesel, renewable diesel
- President Obama adopts new national policy on GHG emission reductions for new cars and trucks based on California's program (Pavley GHG limits)
- US stimulus funding under Diesel Emission Reduction Act
- Zero Emission Vehicle (ZEV) Program
- New limits under Low Vehicle Emissions Program (LEVIII)
  - Criteria emissions (gaseous and PM)
  - Contemplating particle number for diesel and GDI
- Nexus between air quality and climate change
  - Control GHG and criteria emissions (i.e., Pavley + LEVIII)
  - Black carbon and other climate forcers

*Towards HDDE 0.2 g/bhp-hr NO_X

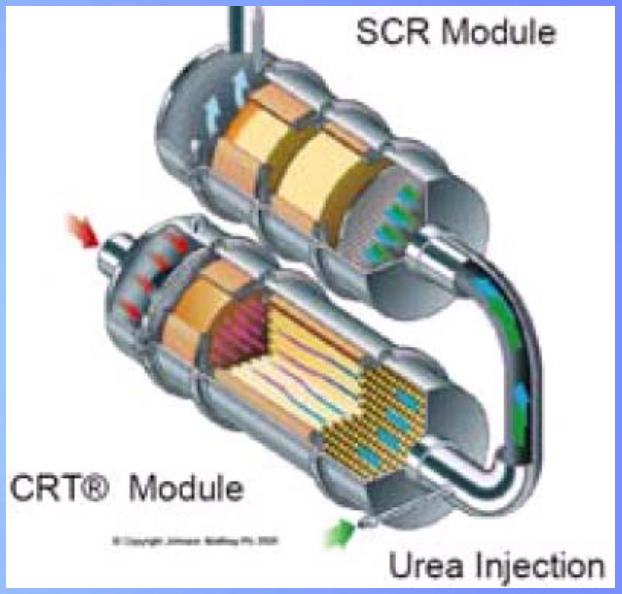
- DPF + urea-SCR technology on track for 2010
  - This approach is large departure from conventional technology
  - Potential for new compounds to form highlights need for research
- Several options for SCR catalyst on the table:
  - Vanadium, Fe & Cu zeolites
- “New” substances may require new methods

With input from Dr. J. DeVita/CARB

VEHICLE EMISSIONS LABORATORIES

DPF + urea-SCR prototype retrofit

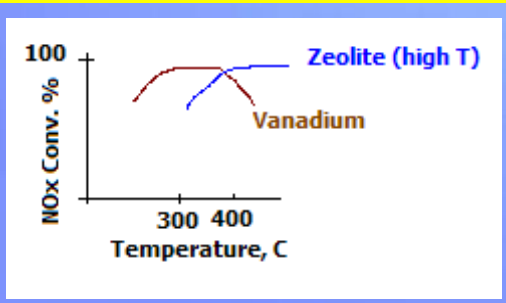
1998 Cummins, 11L, 360K miles

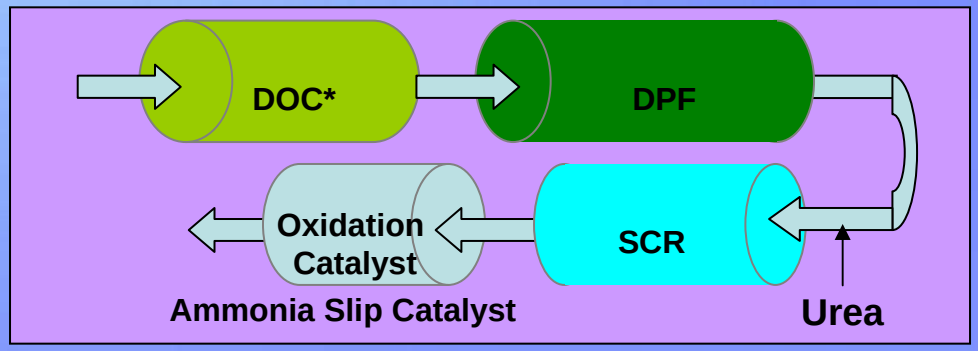


Two types of SCR retrofits:

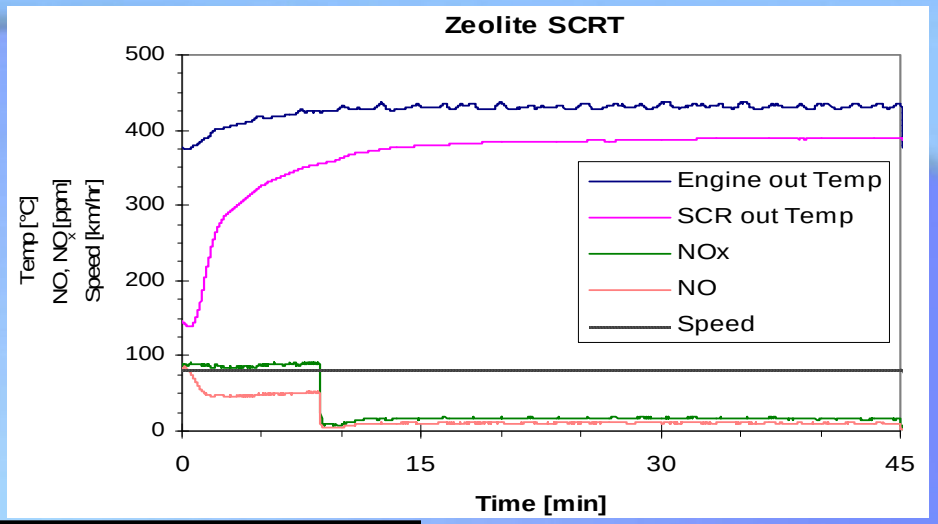
1) CRT + Fe-Zeolite-SCR

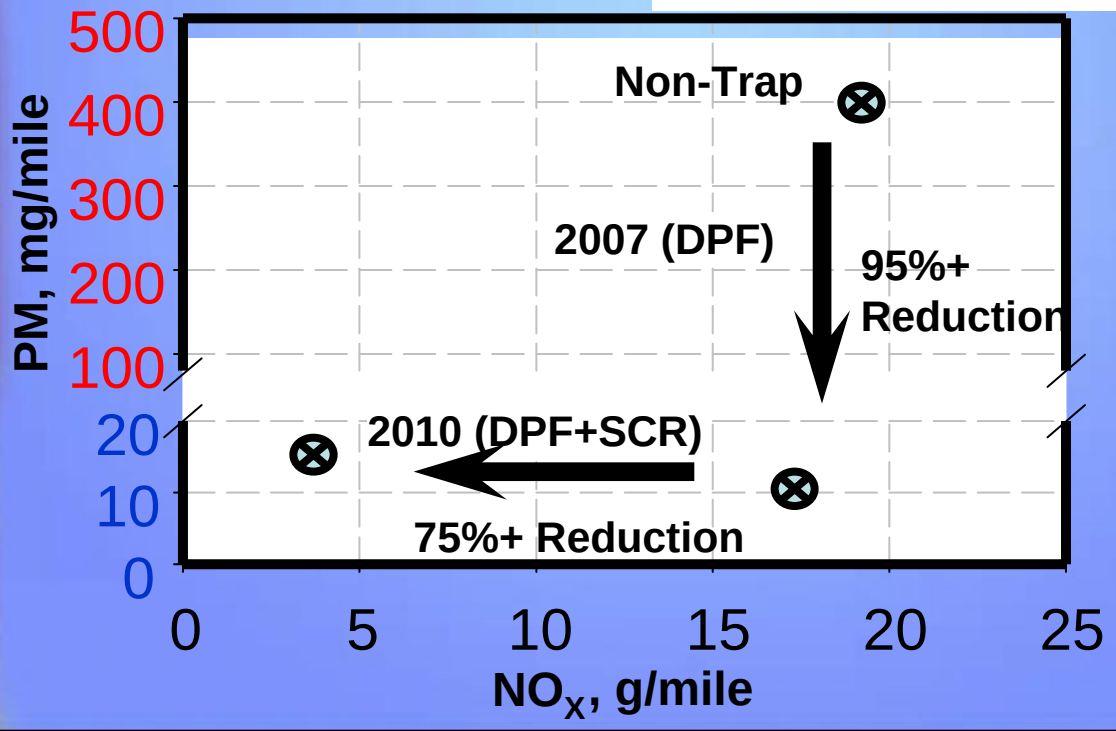
2) CRT + Vanadium-SCR





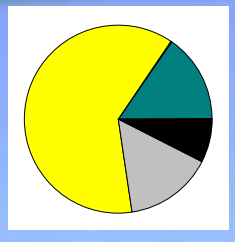
90+% PM and 75+% NOx reductions by DPF + urea-SCR Retrofits



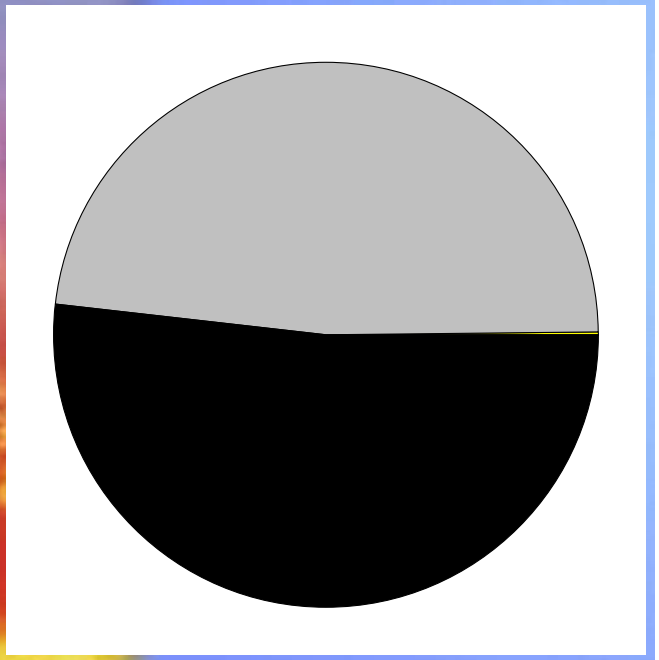


Ammonium sulfate dominates composition of particle emissions from catalyzed HD retrofits

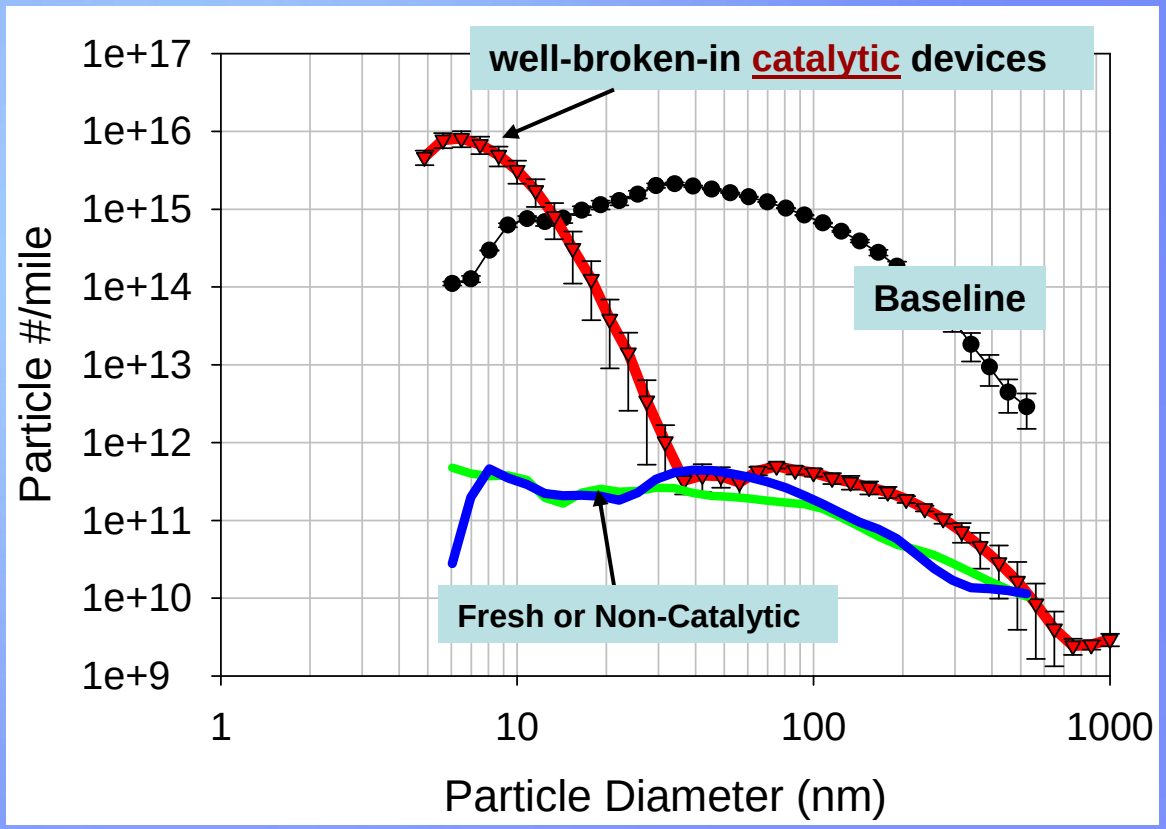
EC
OC
Sulfate
Nitrate
Ammonium



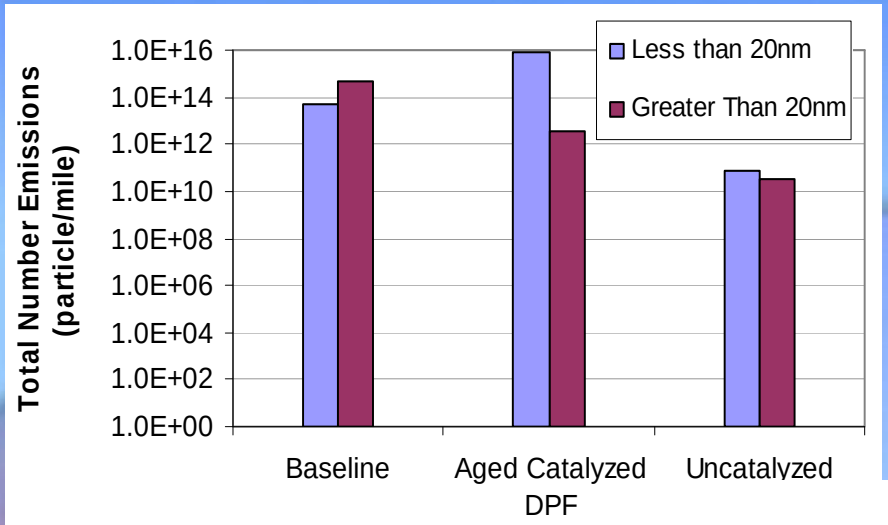
DPF +SCR
PM = 17.4 ± 6 mg/mile



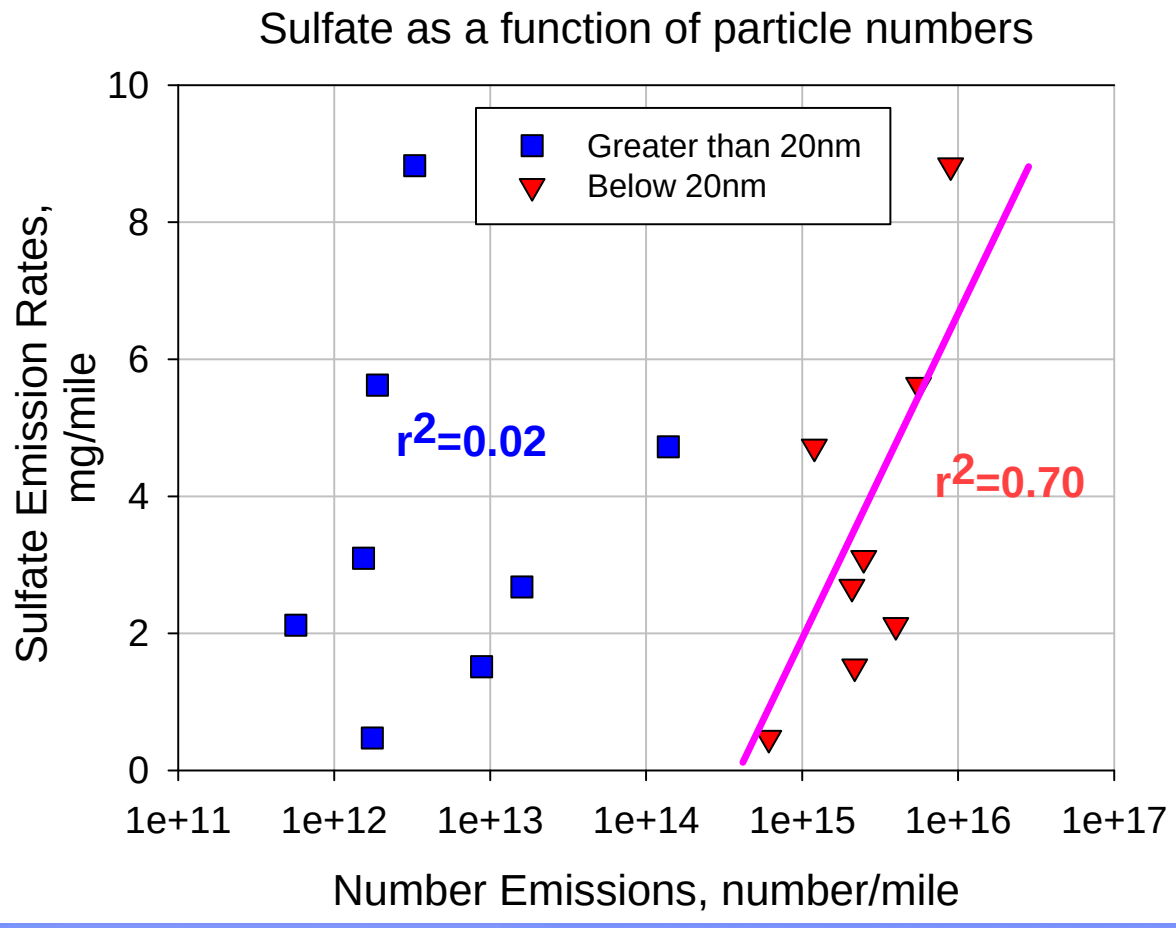
Baseline
PM = 130.3 ± 61 mg/mile



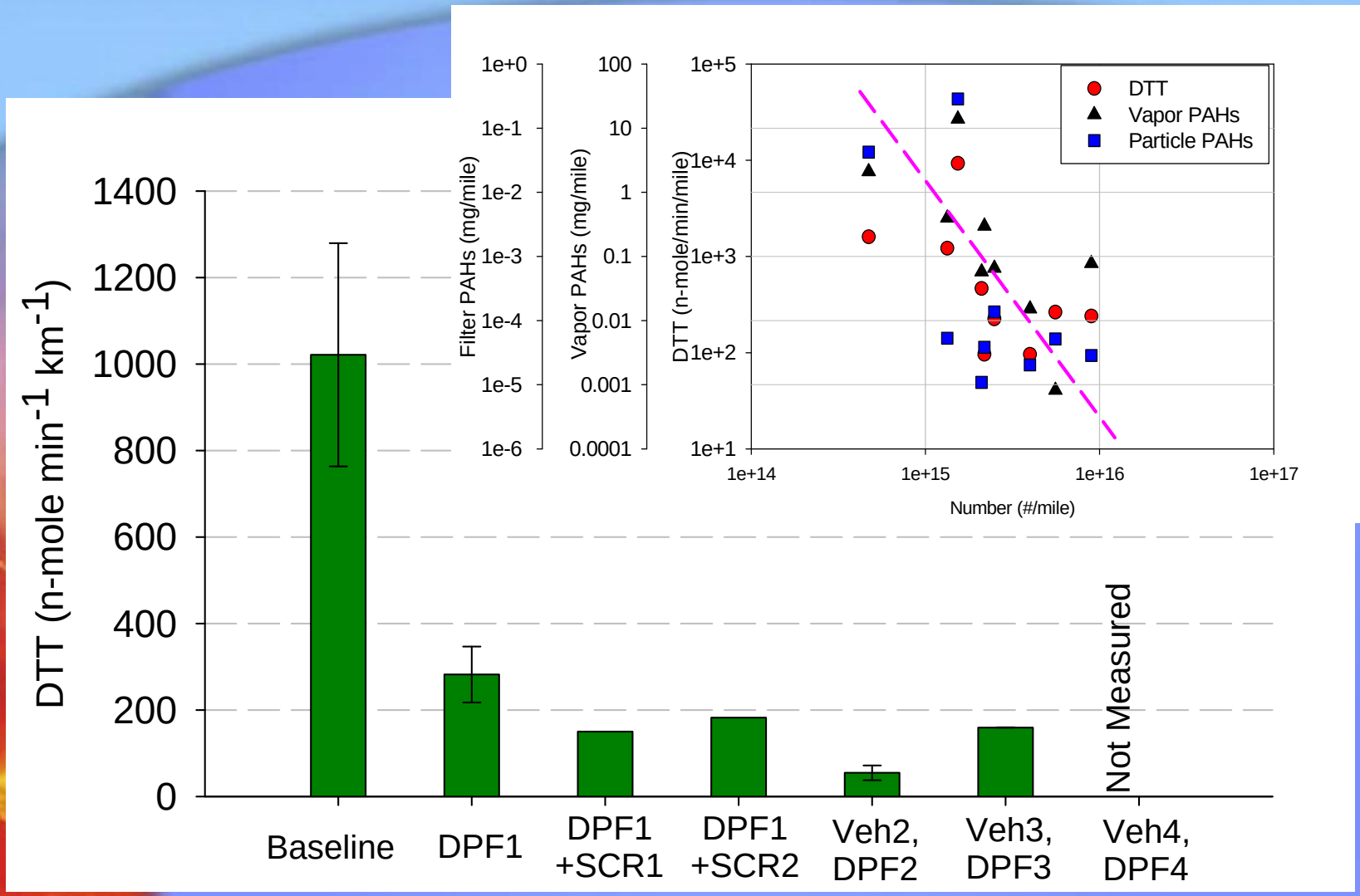
Exhaust temperature promotes substantial formation of nanoparticles for well-broken-in catalytic devices



HDDV nanoparticles are strongly correlated (r^2=0.70) with sulfate. Larger particles are not.



OXIDATIVE STRESS POTENTIAL OF TOTAL PM PER DISTANCE DRIVEN IS REDUCED BY ALL HD RETROFITS



uncatalyzed

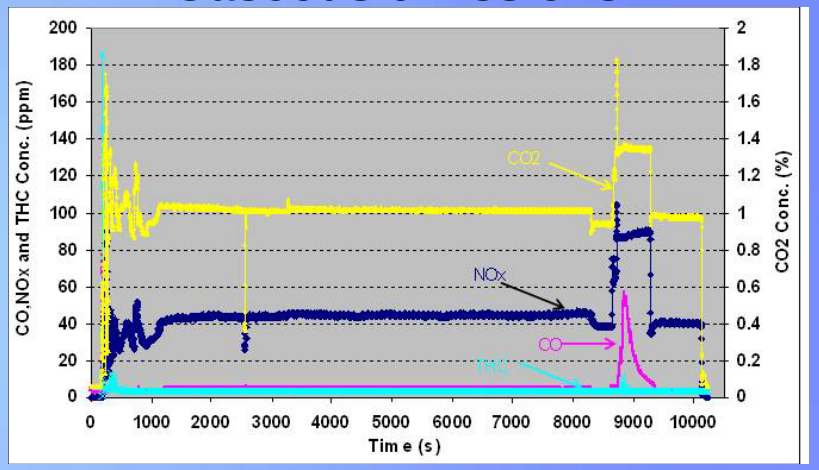
catalyzed

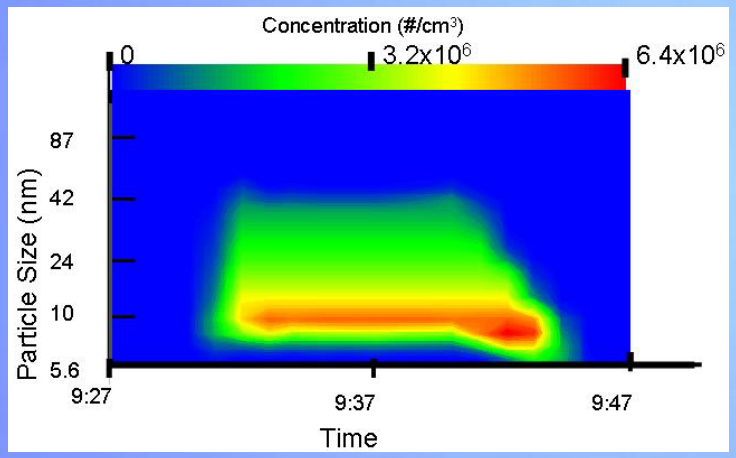
uncatalyzed

Heavily catalyzed

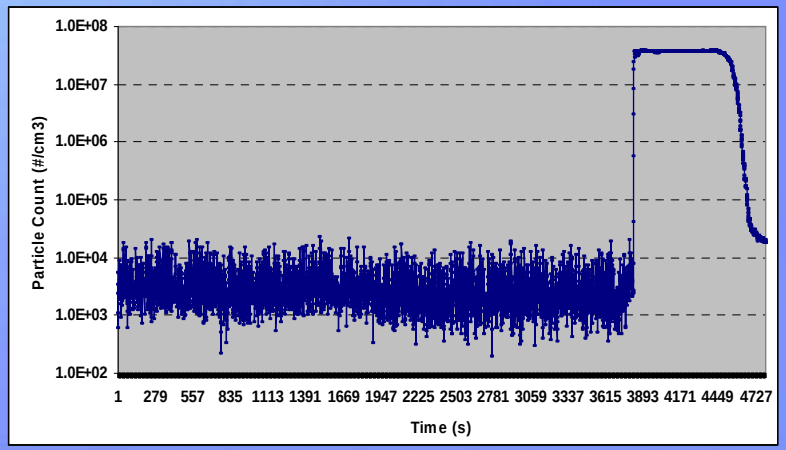
Golden Vehicle* DPF Regeneration: During Constant Speed Test

Gaseous emissions





Particle number emissions



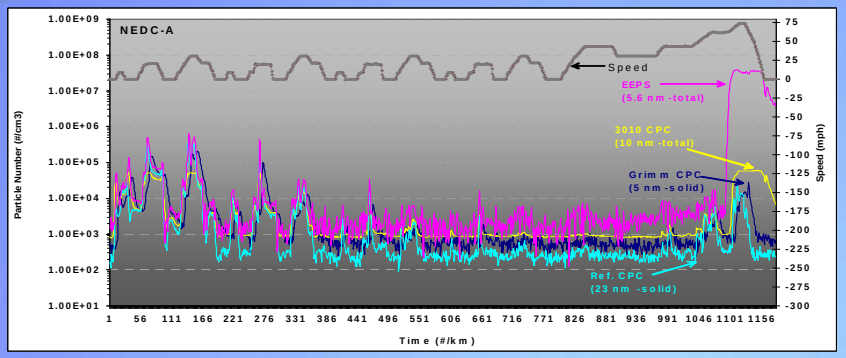
Particle size and concentration distributions during DPF regeneration

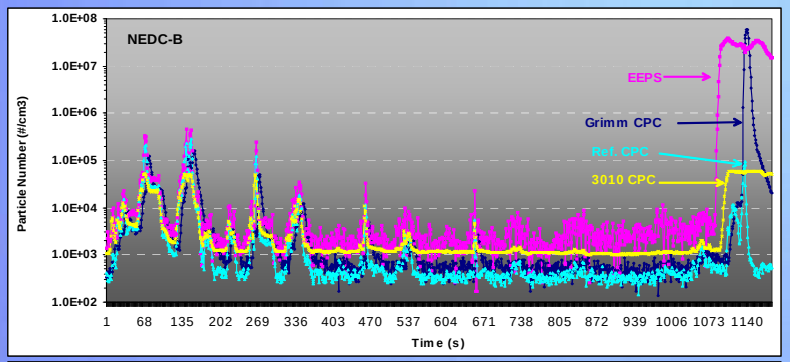
Note: Nanoparticle formation!!!

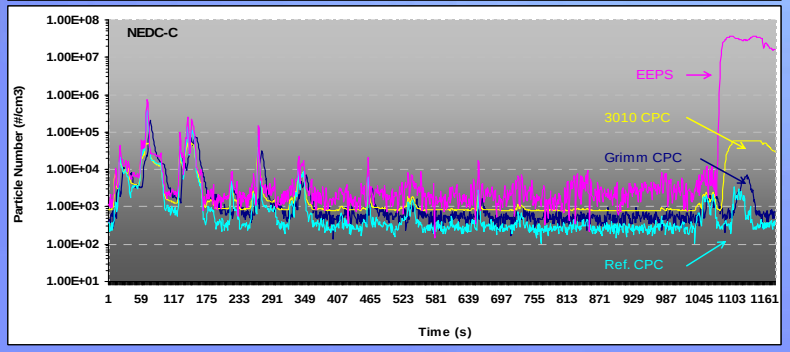
Also see 11th ETH pres in 2007

Golden Vehicle DPF Regeneration (cont')

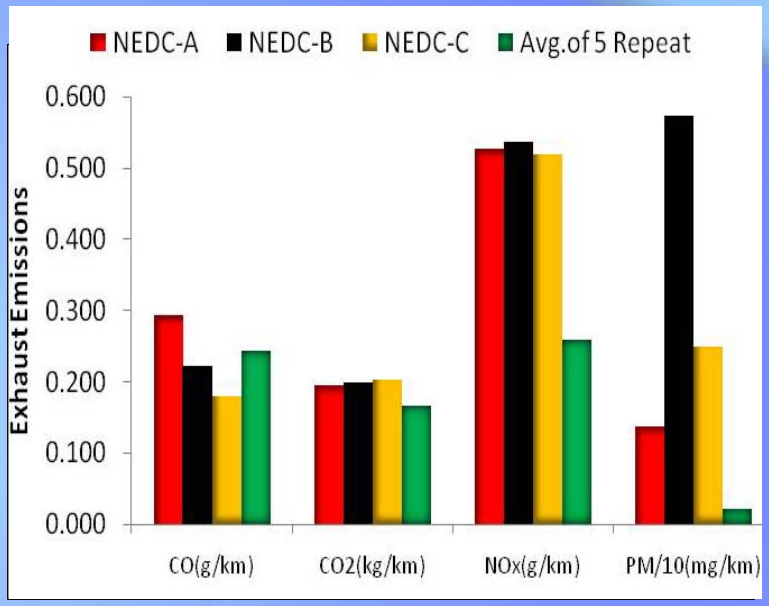
Particle emissions in three consecutive partial DPF regenerations during three NEDC cycles





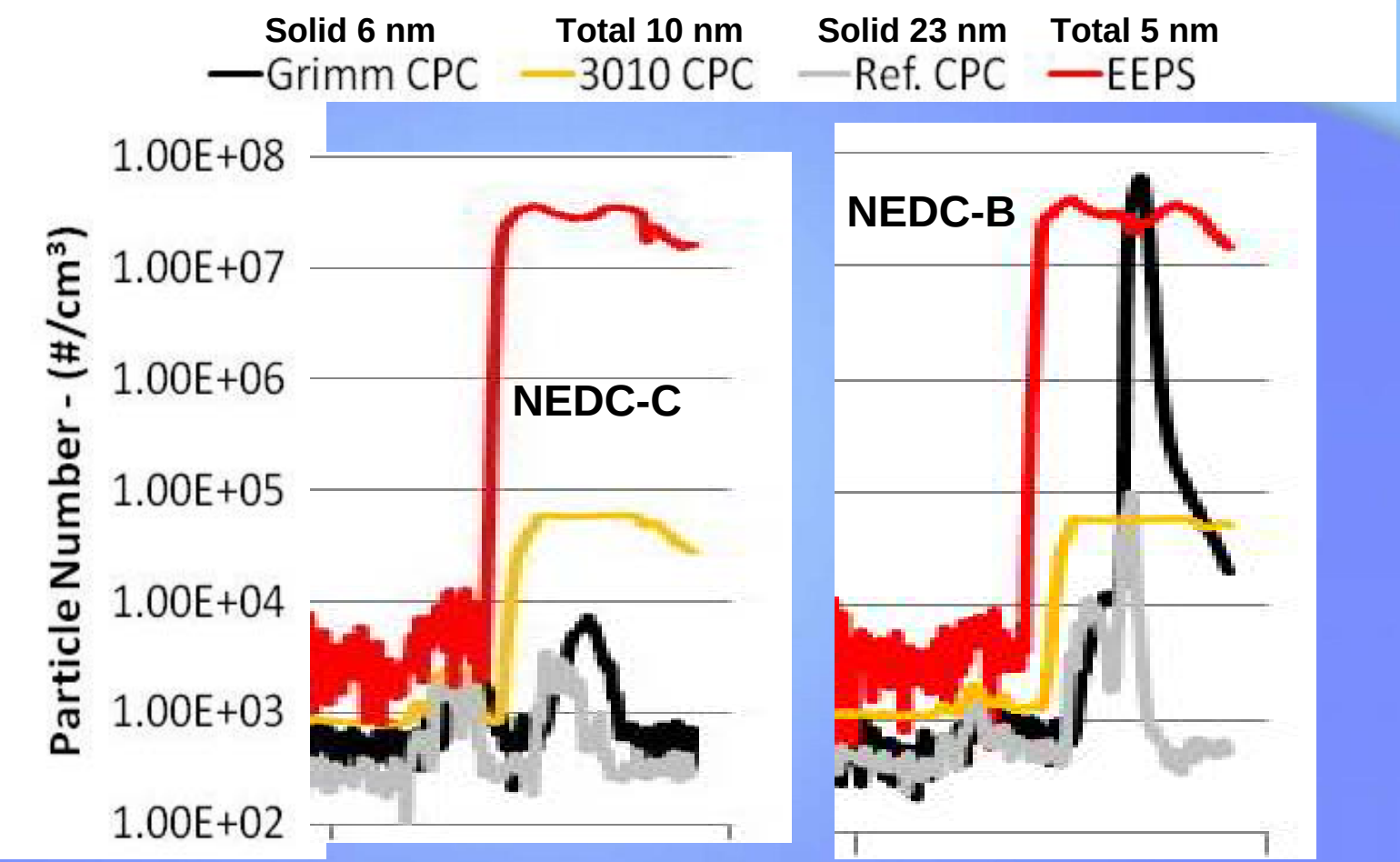


Gaseous and PM Emissions:



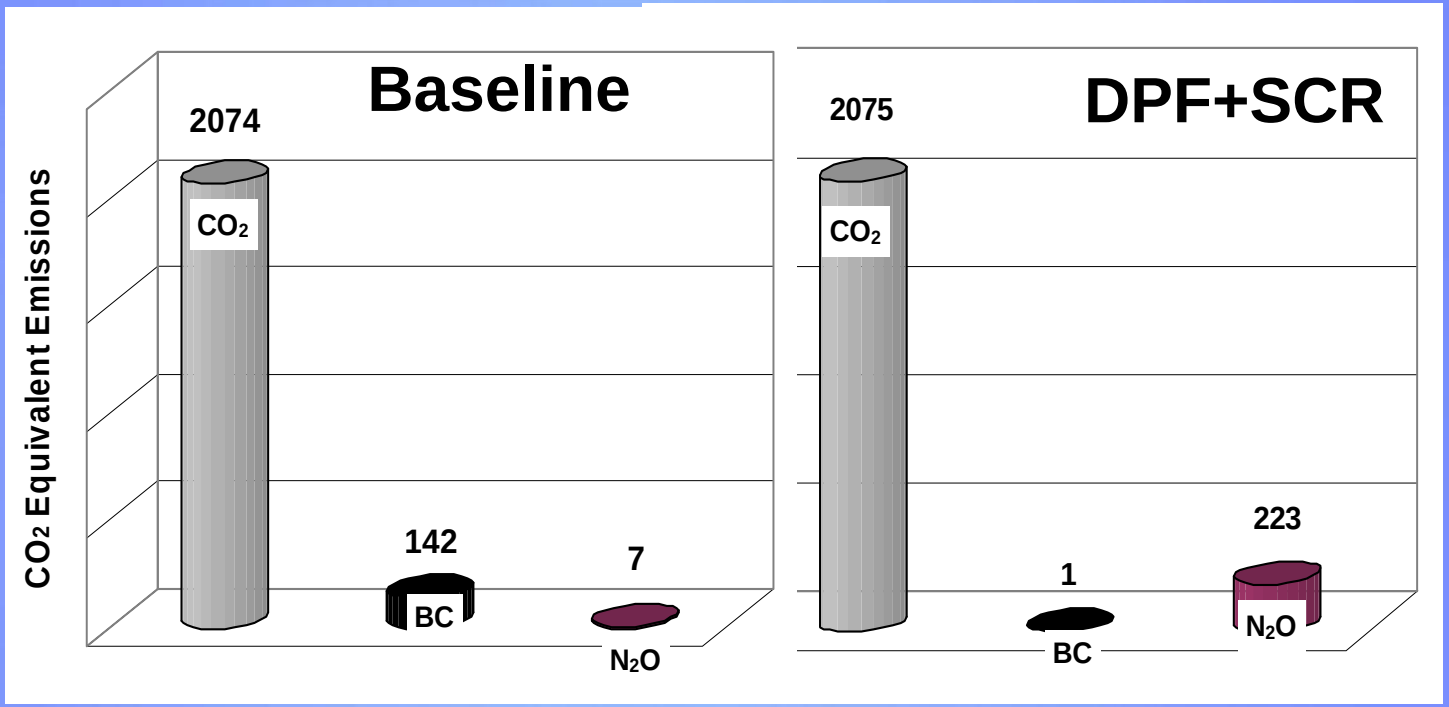
- Particle emissions increase sharply during DPF regeneration
- The PMP systems detected a moderate increase in particle numbers
- Grimm CPC measured higher particle numbers than PMP CPCs
- Those particles could be either volatiles that survived the VPR, or
- Sub-20 nm solid particles emitted during DPF regeneration

Comparison of particle number emissions during regeneration (NEDC B & C)



- Ref. CPC only shows a small increase in particles relative to cold start
- Particle number does not reflect the PM increase measured by filters

Emissions of Greenhouse Gases and Black Carbon



- Black carbon reduced by DPF
- N_2O increase by prototype SCR retrofit
- Net greenhouse gas emission impact is minor by DPF+SCR retrofits

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