The Case for Ammonia Oxidation Catalysts in SCR Systems

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CLEERS

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Presentation Outline

- Background for ammonia oxidation catalysts
- Characterization of ammonia oxidation catalysts
- Typical laboratory evaluations
  - Aged with and without NOx
- Evaluations using heavy duty diesel engine
  - transient conditions (ETC)
  - steady state

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Why use an Ammonia Oxidation (AMOX) Catalyst ?

- While only NOx is regulated….
  - ammonia has a distinctive odor – similar to the H_2S problem in TWC
  - ammonia can contribute to particulate
- Target ammonia emissions are peaks of about 20 ppm
- Depending on engine out NOx and the desired level of NOx conversion; SCR systems are really designed to remove ammonia.
- Potential to make the after treatment system smaller
- Relaxed dosing requirements

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Sources of Ammonia Emissions

- Incomplete reaction of ammonia with NOx
- Sudden release of ammonia from the decomposition / hydrolysis of urea deposits in the exhaust line
- Ammonia release from the catalyst surface during a temperature increase. Result of changes in the equilibrium concentration of ammonia stored on the catalyst.
  - For example: Idle to A100 transition in the ESC

Possible Chemical Reactions

		Preferred Activity Level
SCR NO_x:		
$4NH_3 + 4NO + O_2 \rightarrow$	$4N_2 + 6H_2O$	High
$6NO_2 + 8NH_3 \rightarrow$	$7N_2 + 12H_2O$	High
$NO + NO_2 + 2NH_3 \rightarrow$	$4N_2 + 3H_2O$	High
Other NO_x reactions		
$4NO_2 + 4NH_3 + O_2 \rightarrow$	$4N_2O + 6H_2O$	Low
NH_3 Oxidation:		
$4NH_3 + 5O_2 \rightarrow$	$4NO + 6H_2O$	Low
$4NH_3 + 3O_2 \rightarrow$	$2N_2 + 6H_2O$	High

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Evaluation of AMOX catalysts

- Evaluation by the destruction of ammonia is insufficient
  - NOx and N_2O production must also be considered
- For NOx make:

a) Δ NOx / inlet NH_3 or b) Δ NOx / Δ NH_3

- For N_2O make;

a) 2 Δ N_2O / inlet NH_3 or b) 2 Δ N_2O / Δ NH_3

  - With NOx in the feed, NOx can contribute to the N_2O concentration via the SCR reaction
- With a pre DOC / CSF in the system some N_2O can come from the HC lean NOx reaction

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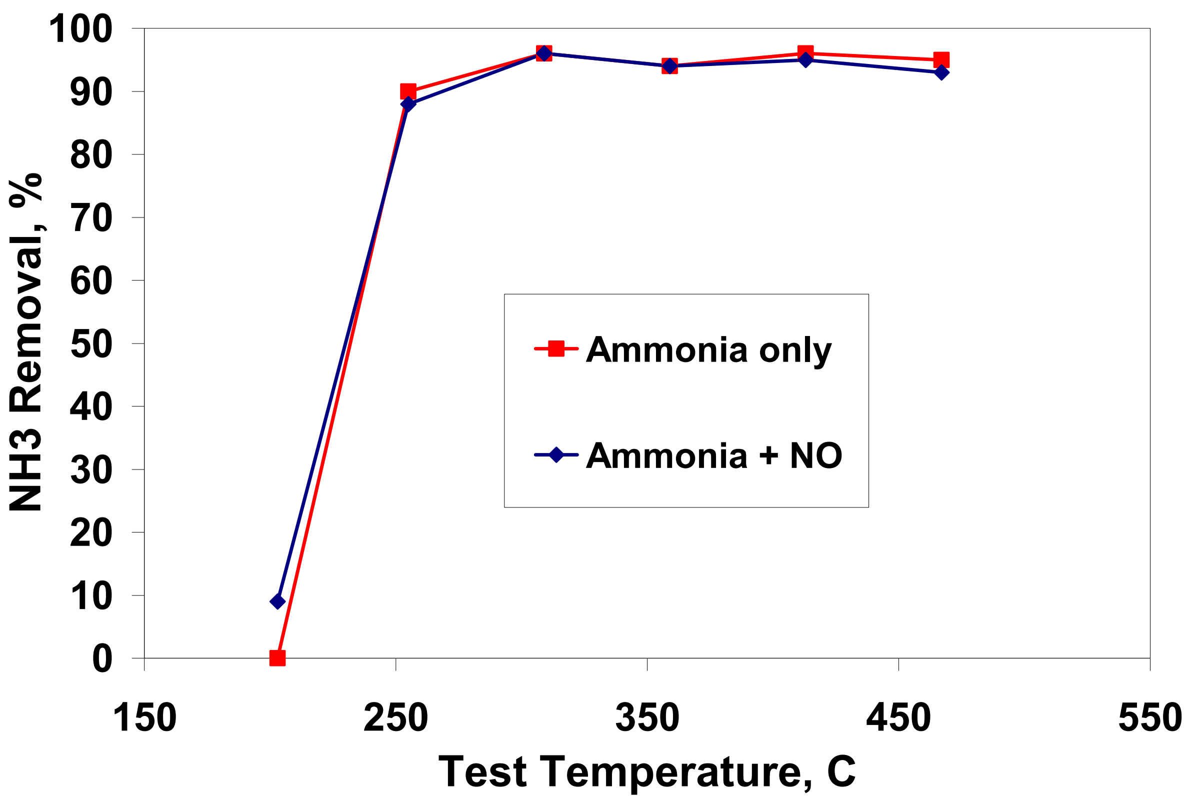
Typical ammonia removal at 5 g/ft^3 Pt, Lab reactor, 10% O_2 & H_2O



- With small catalyst lengths entrance effects are important
- Zone coated catalysts must account for the up stream honeycomb channels
- i.e.. 0.5 inch catalyst length is not the same as 0.5 catalyst coated on a 6 inch honeycomb

3 inch length, engine aged 800 hrs @ 400 C   SV = 80,000 hr^{-1}
NH_3 = 500 ppm, NOx as NO = 500 ppm

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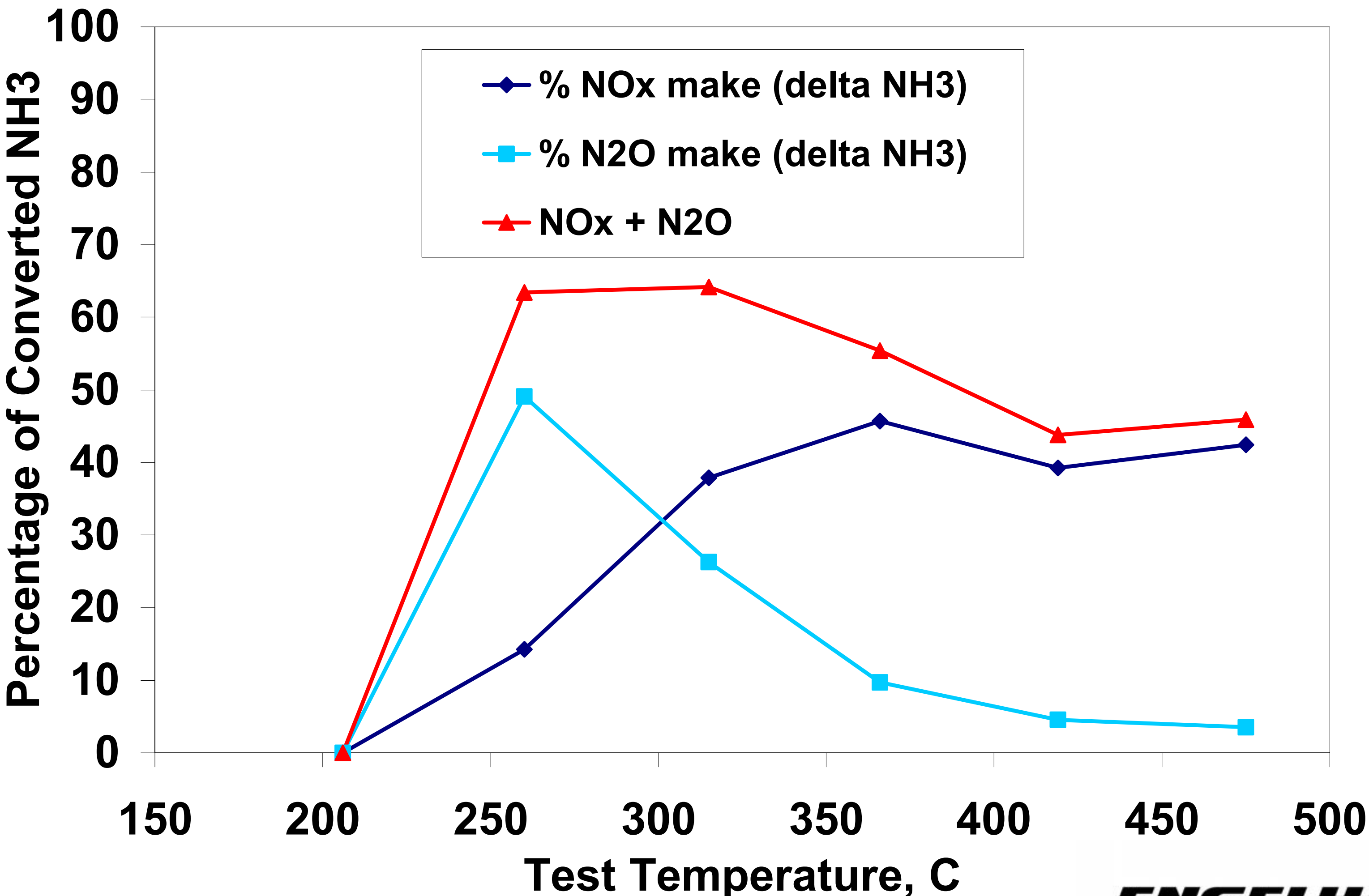
In the absence of NO the yield to N2 varies from 35 to 55 %



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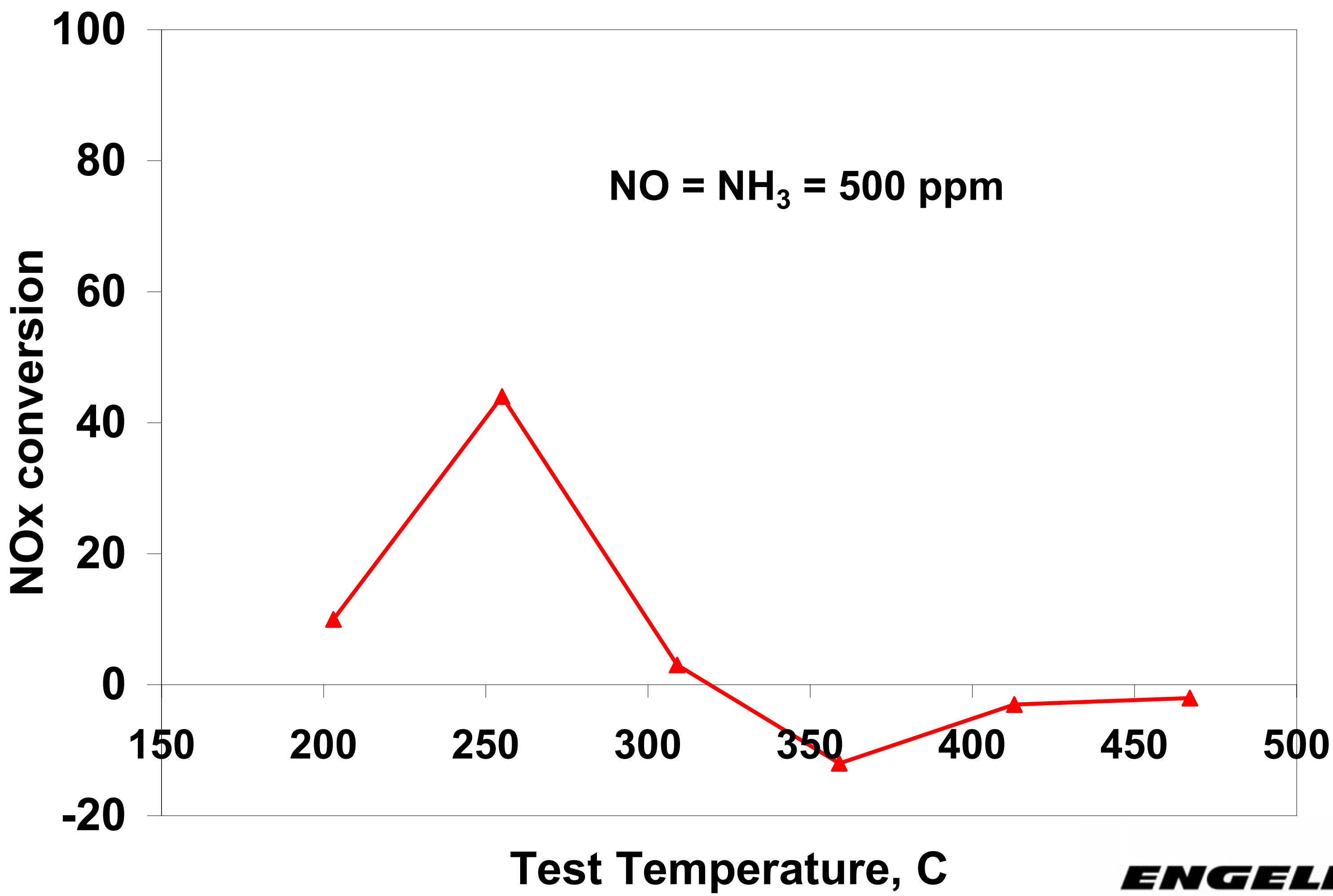
In the presence of NO(x) significant NOx removal can occur at lower temperatures



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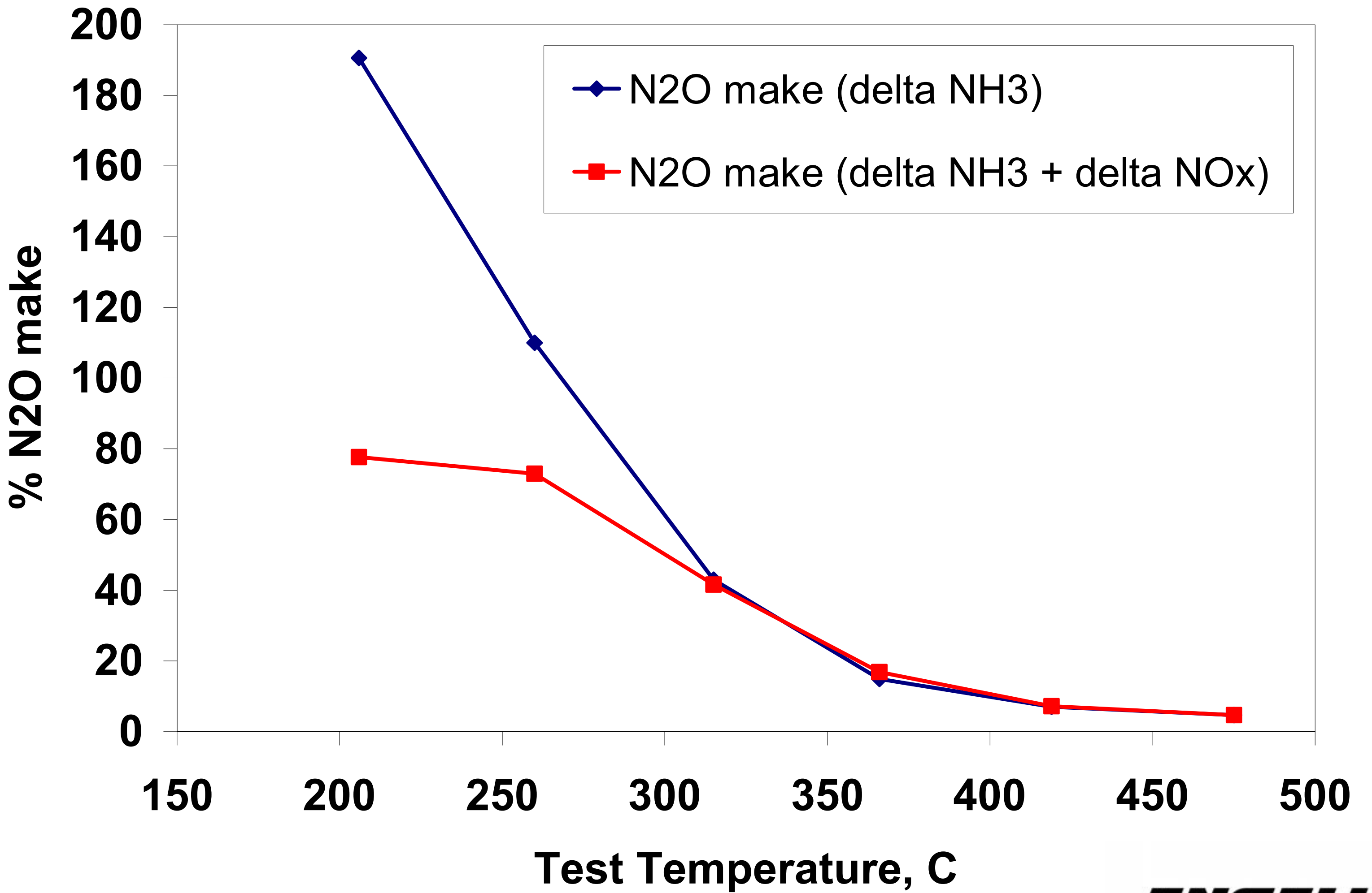
N_2O concentrations are too high to come from just NH3 oxidation



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Catalysts used for engine evaluation

- SCR
  - TiO_2 – WO_3 – V_2O_5
  - Aged and reduced in volume to guarantee unreacted ammonia
- AMOX
  - oxidation catalyst with 5 g/ft^3 Pt
  - two catalyst volumes to study SV effects
- Urea dosing
  - in house system, NOx following based NOx sensor post turbo
  - unless indicated NH_3 / NOx = 0.8, constant
- Engine is 12.6 liter, Euro 3, turbo charged, after cooled, no EGR

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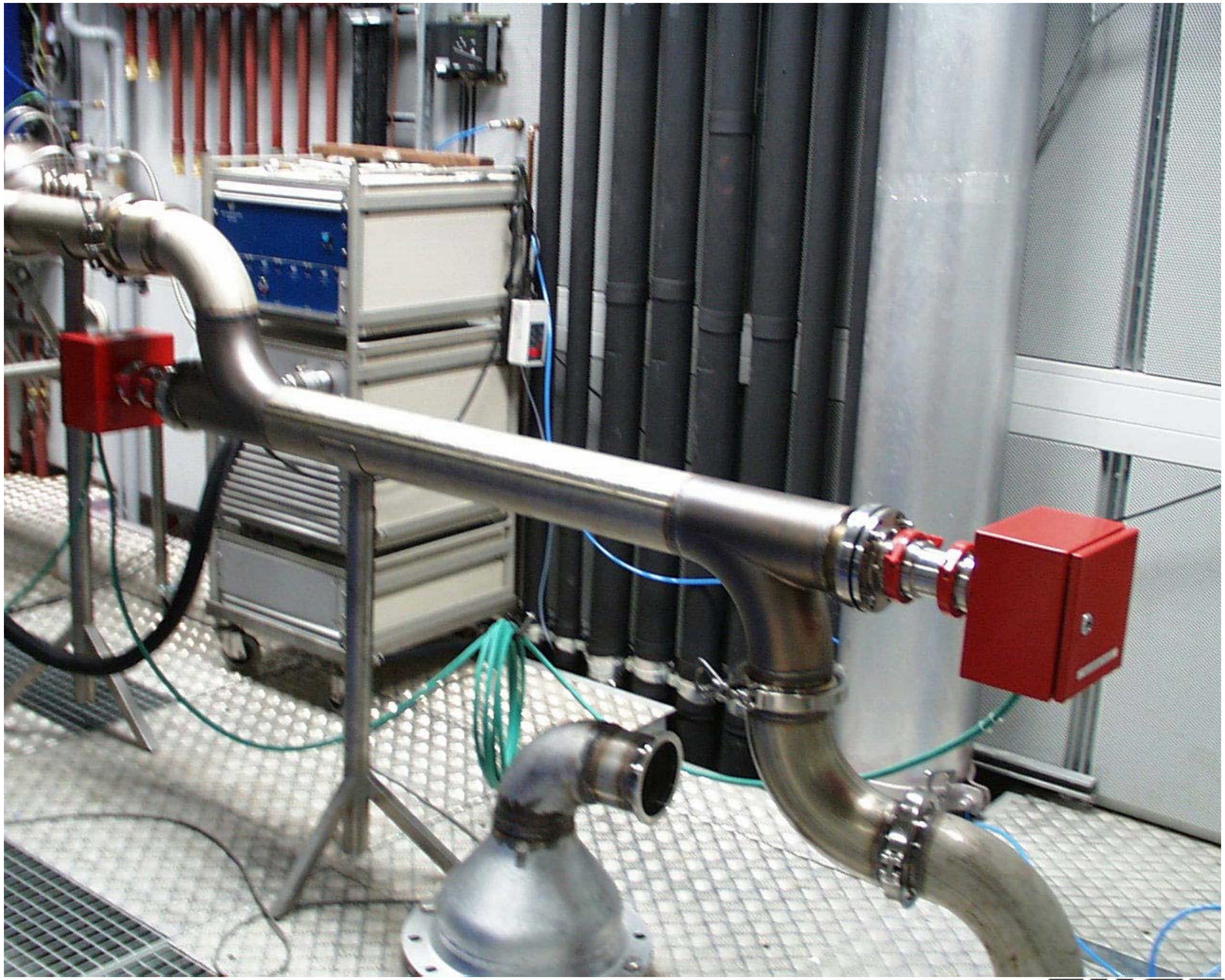
Ammonia measurement in the test cell used LDS 3000 behind SCR/AMOX catalysts



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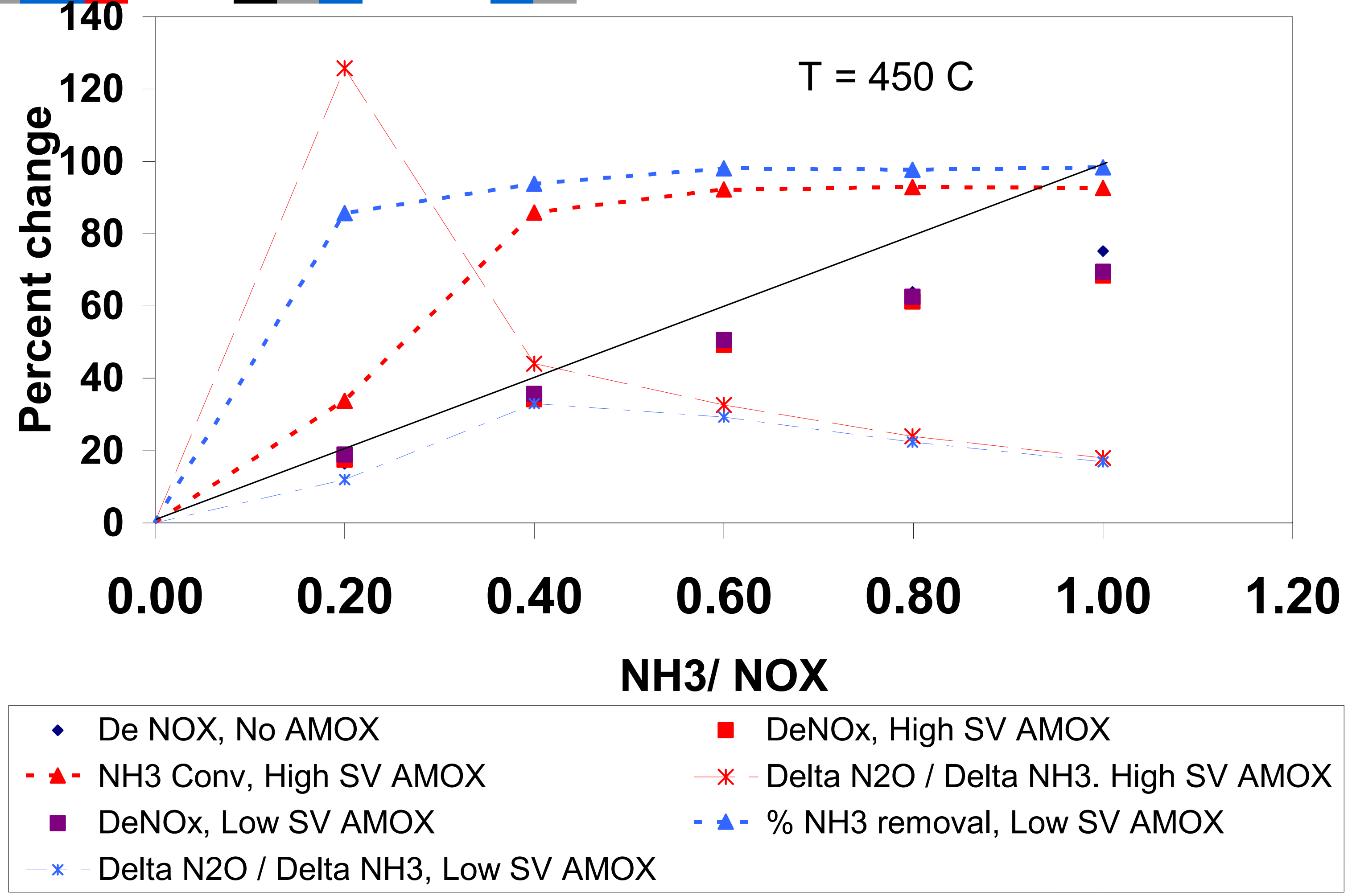
At constant temperature, the N_2O make decreases as the NH_3 concentration increases, SV AMOX = 90,000 and 270,000 hr^{-1}



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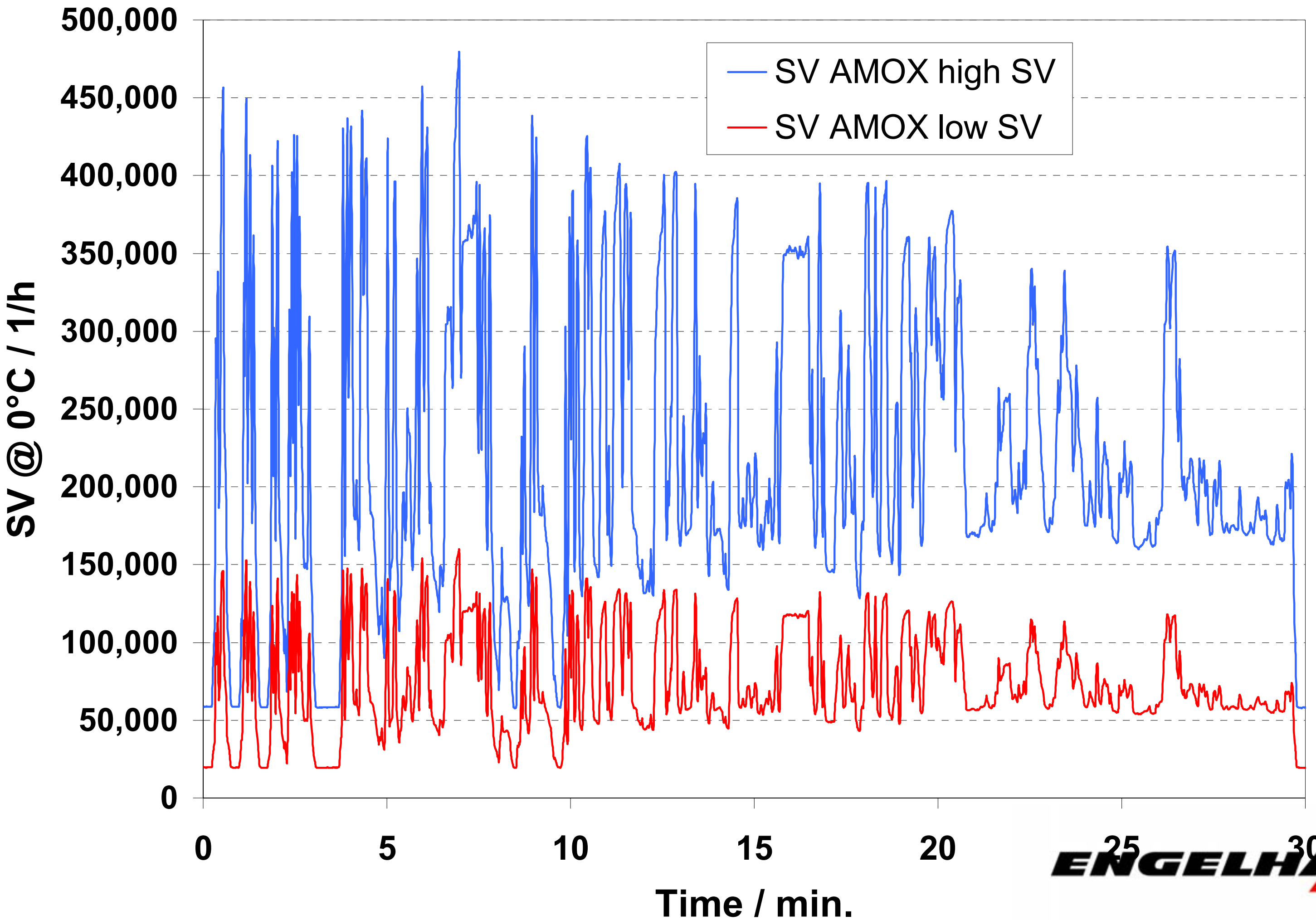
For the two AMOX volumes studied – SV ranges from 50,000 – 150,000 and 150,000 - 450,000 hr^{-1}, Data from ETC



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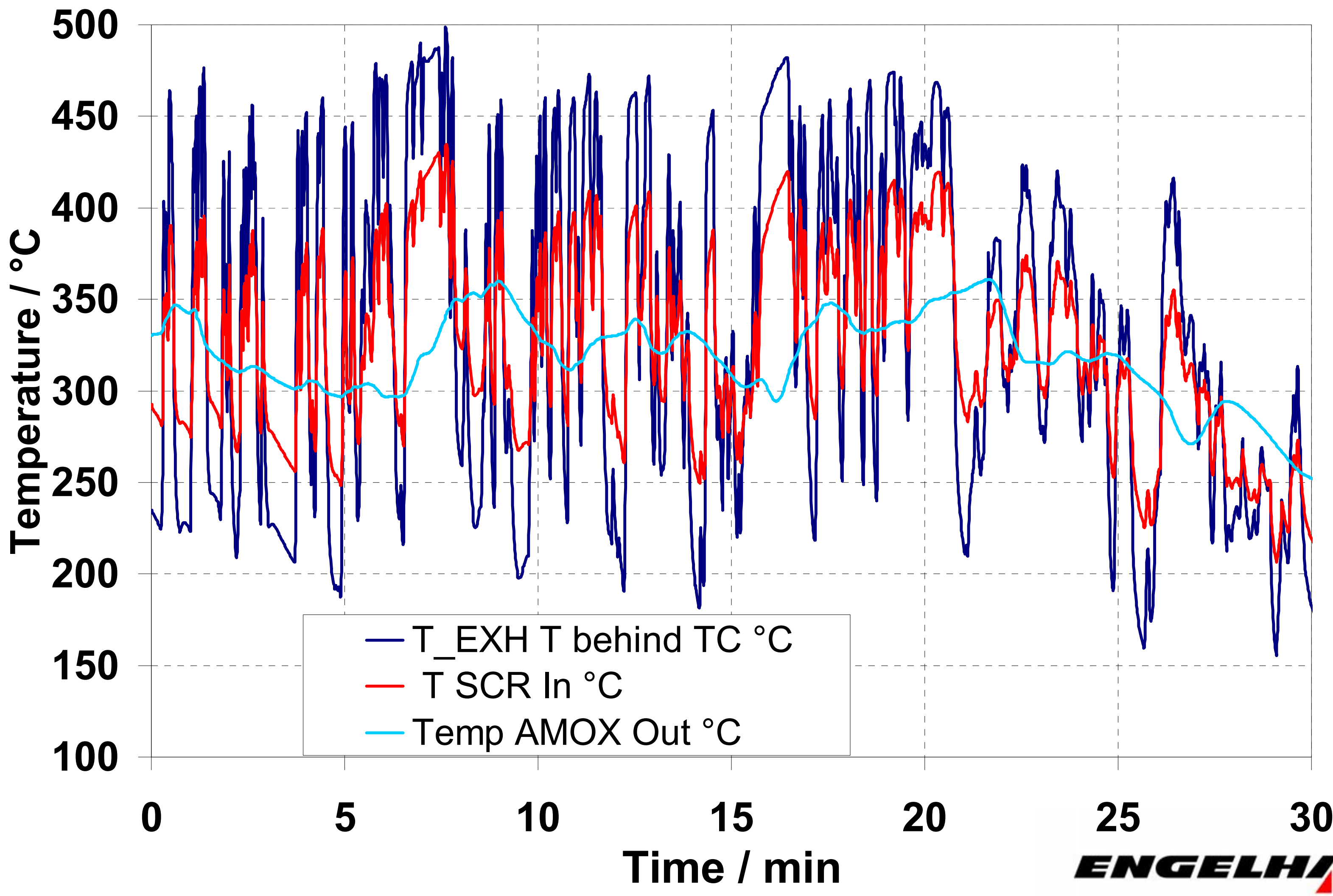
The catalyst volume ahead of the AMOX dampens temperature changes and range, ETC



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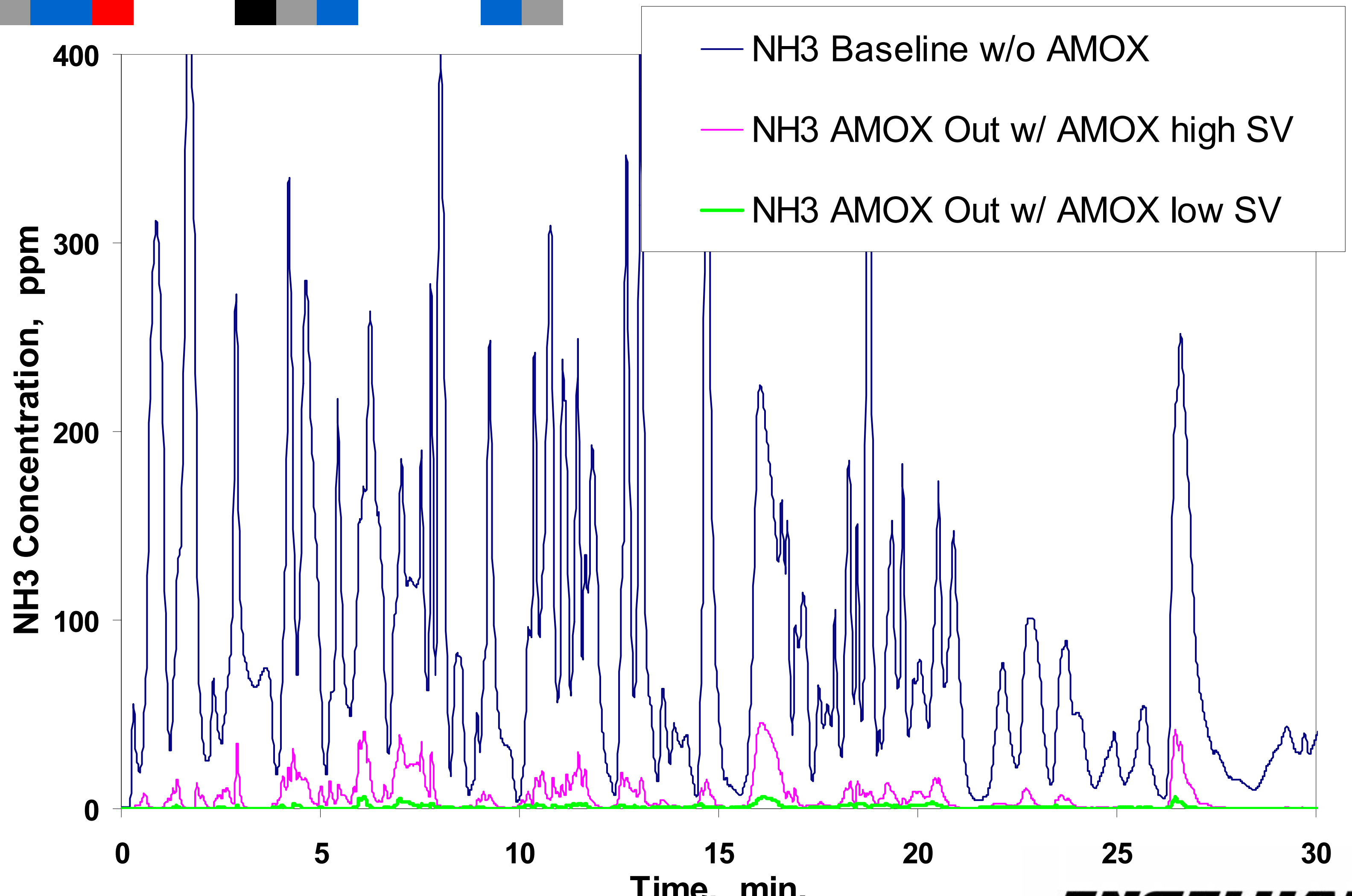
Even with a small catalyst volume (high SV) effective ammonia control is obtained (ETC modal data)



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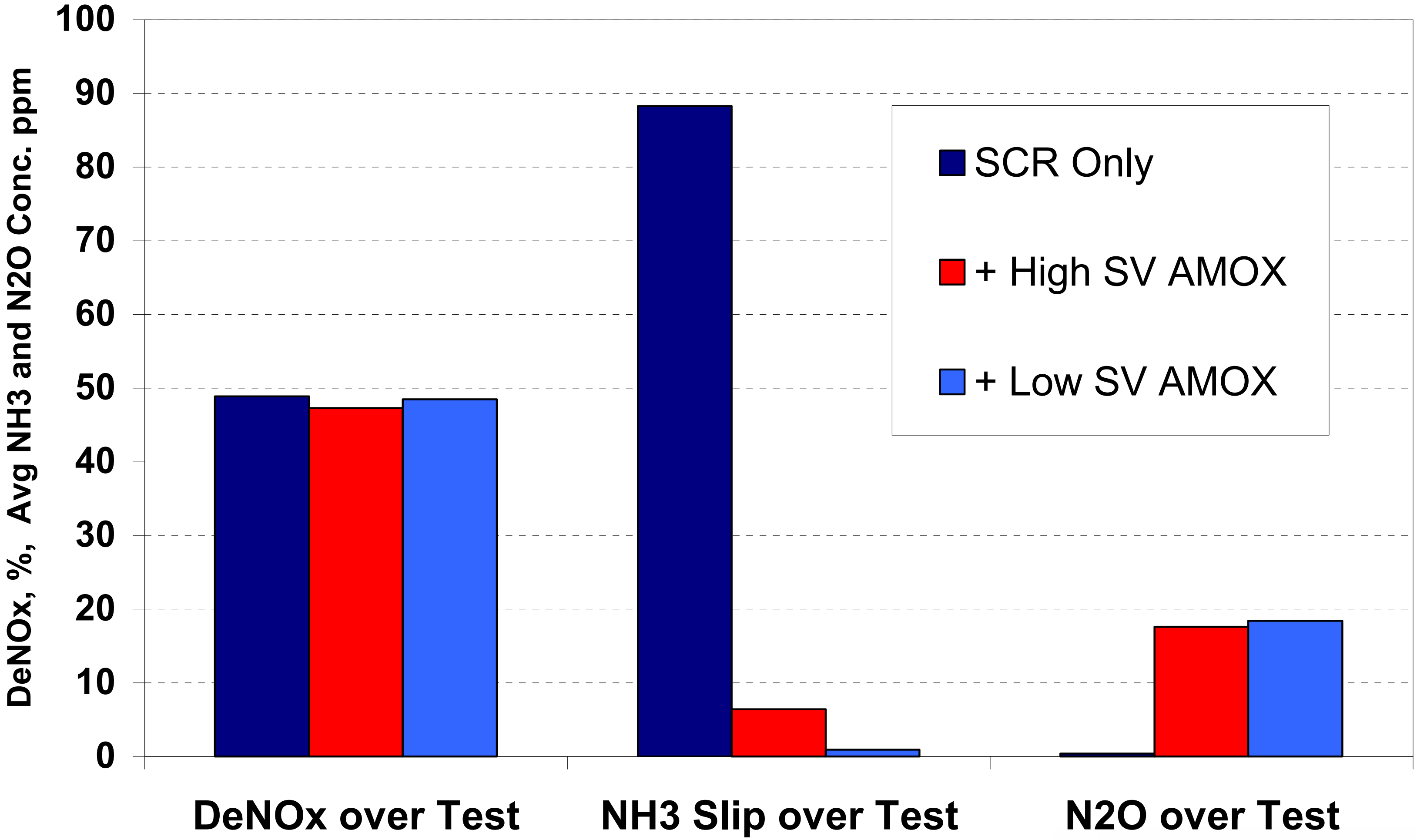
The oxidation of ammonia is not accompanied by an increase in NOx, Cycle data for the ETC



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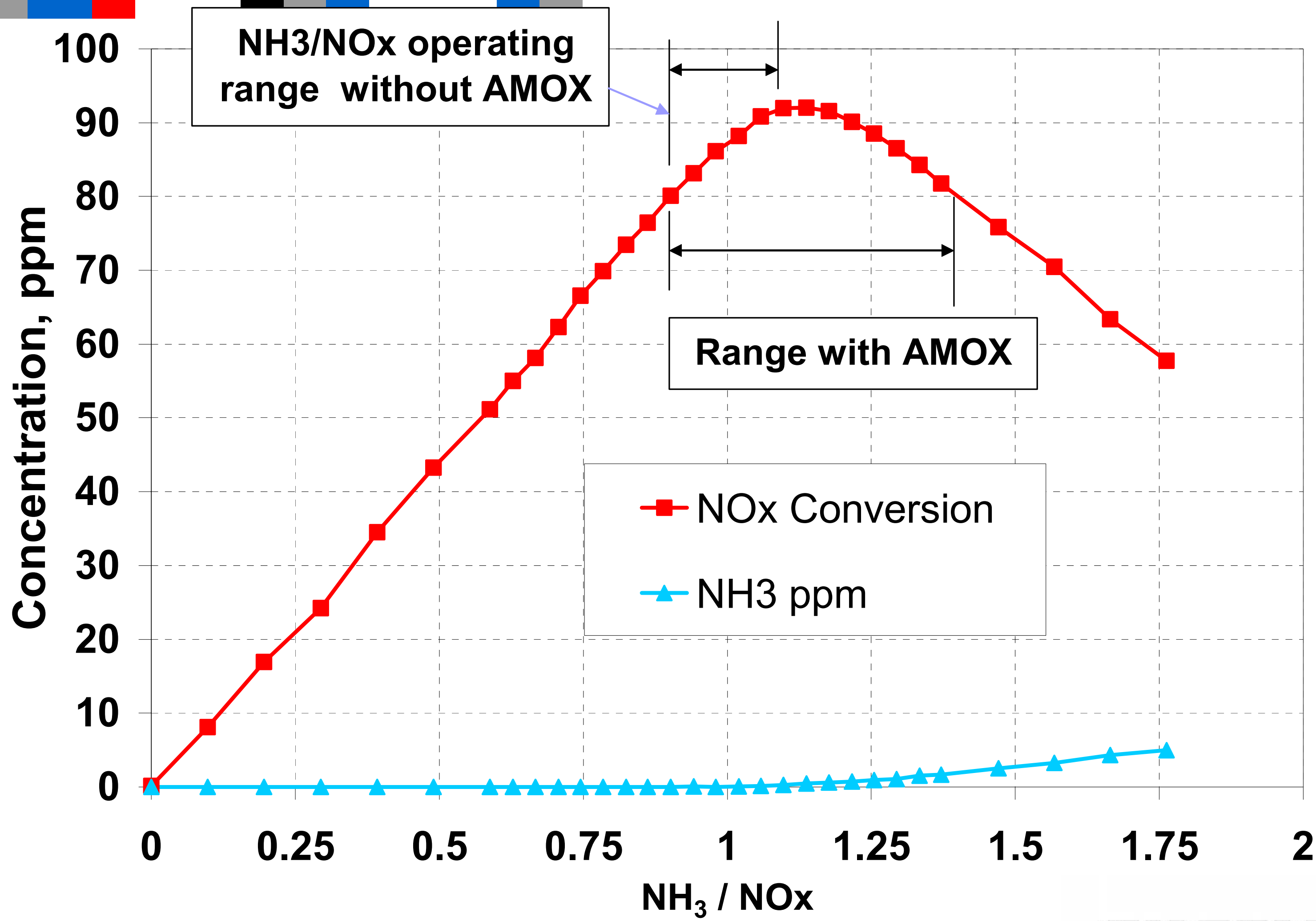
Extending the NH_3/NOx to higher ratios shows the dosing flexibility created by the AMOX (different catalyst system, 450 C)



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Conclusions

- Catalysts have been developed that are effective in removing ammonia without excessive NOx or N_2O make
- The selectivity and activity of these catalysts is strongly dependent on the operating conditions
  - transient operation is more benefical than steady state
  - NH_3 / NOx ratio
- The greatest contribution of the AMOX catalyst will be in its ability to expand the range of NH_3/NOx ratios over which high NOx conversion can be achieved.

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