Two Catalyst Formulations – One solution for NO_x after-treatment systems

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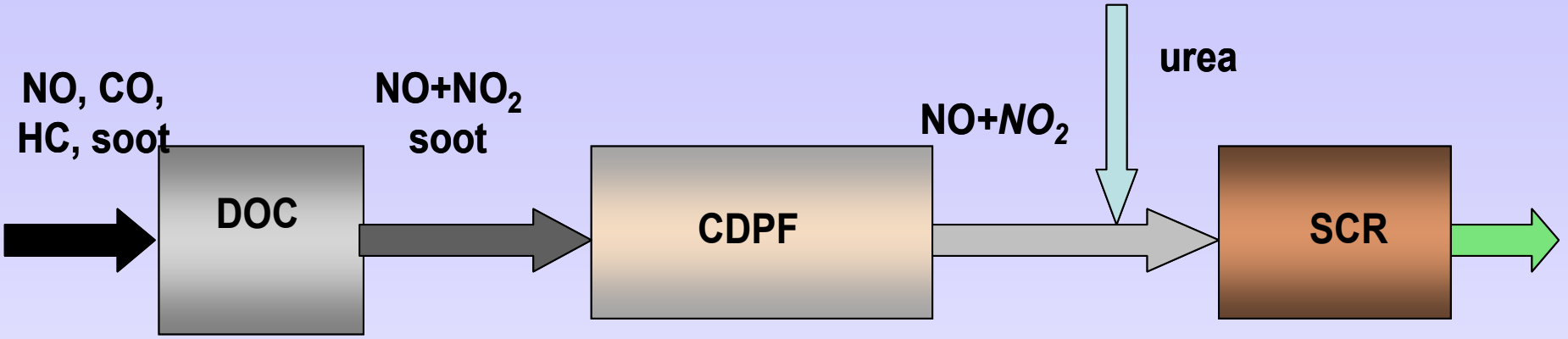
Outline

- Requirements for SCR catalysts
- SCR catalyst options for diesel exhaust aftertreatment. Lab results.

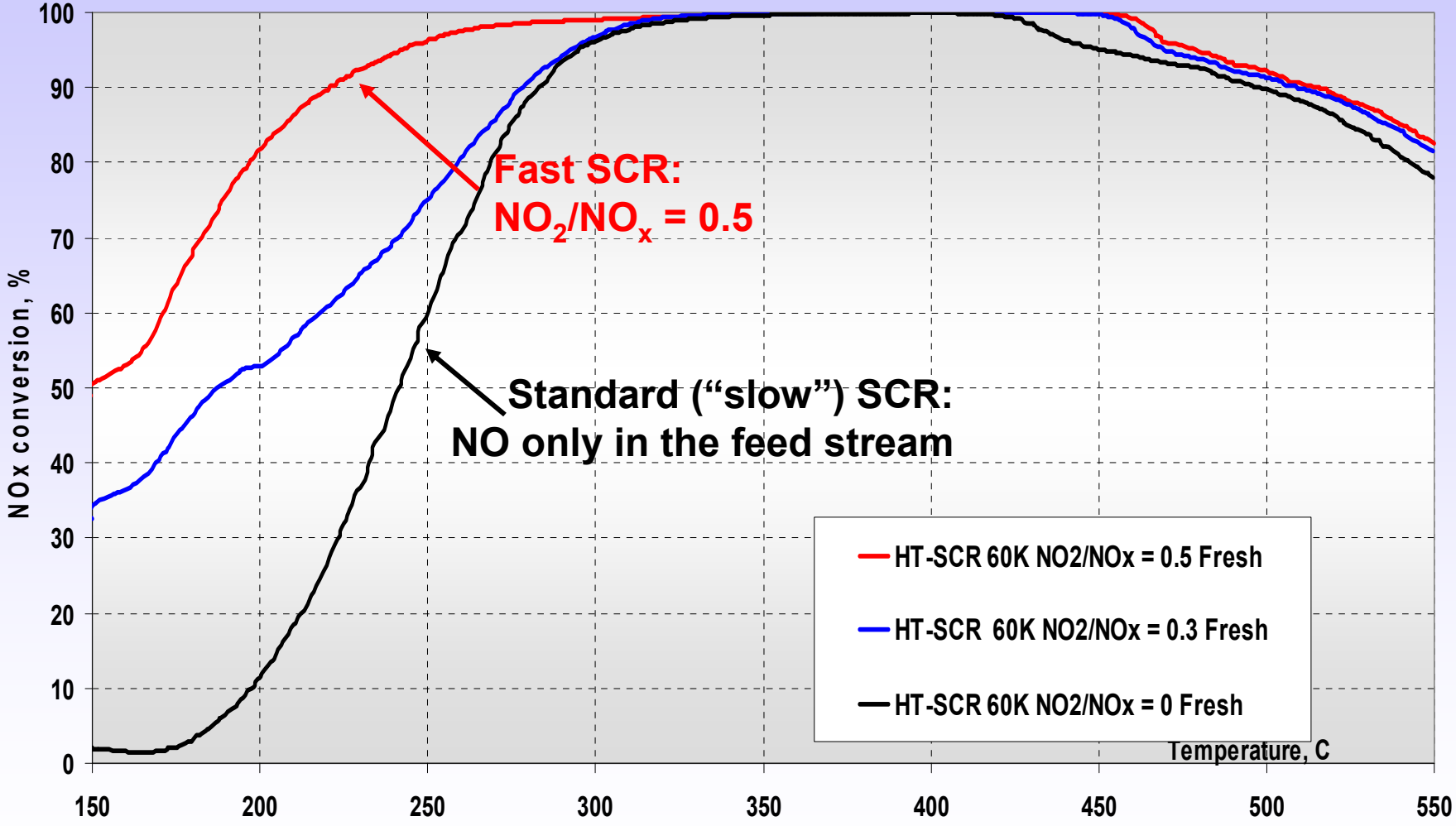
- Examples of SCR systems applications

Requirements for SCR catalyst

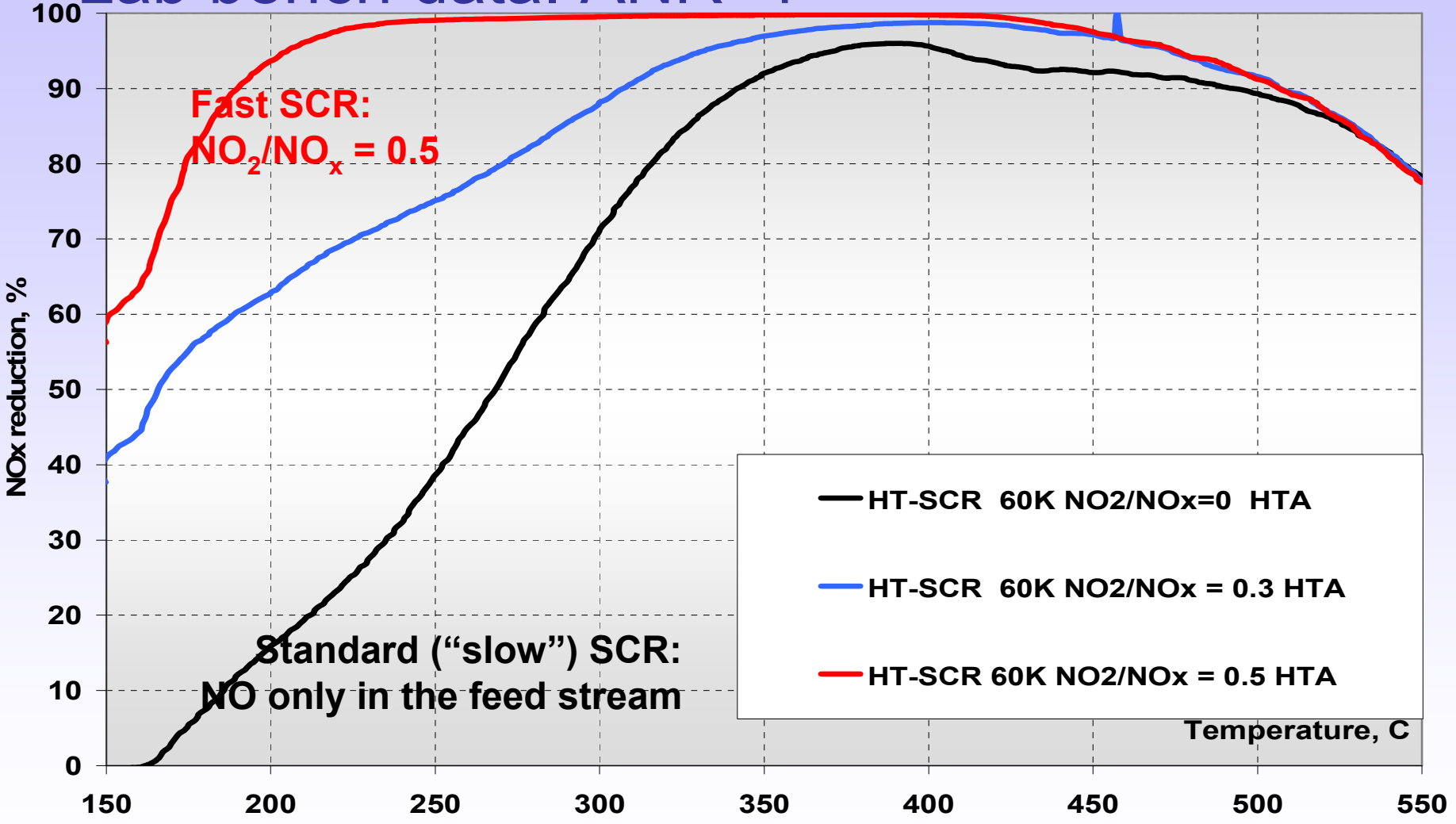


- High activity at wide temperature range
- Ability to retain catalytic activity after being exposed to high temperature during active DPF regeneration, i.e. high hydrothermal stability
- Highest possible activity for the feed-gas enriched with NO

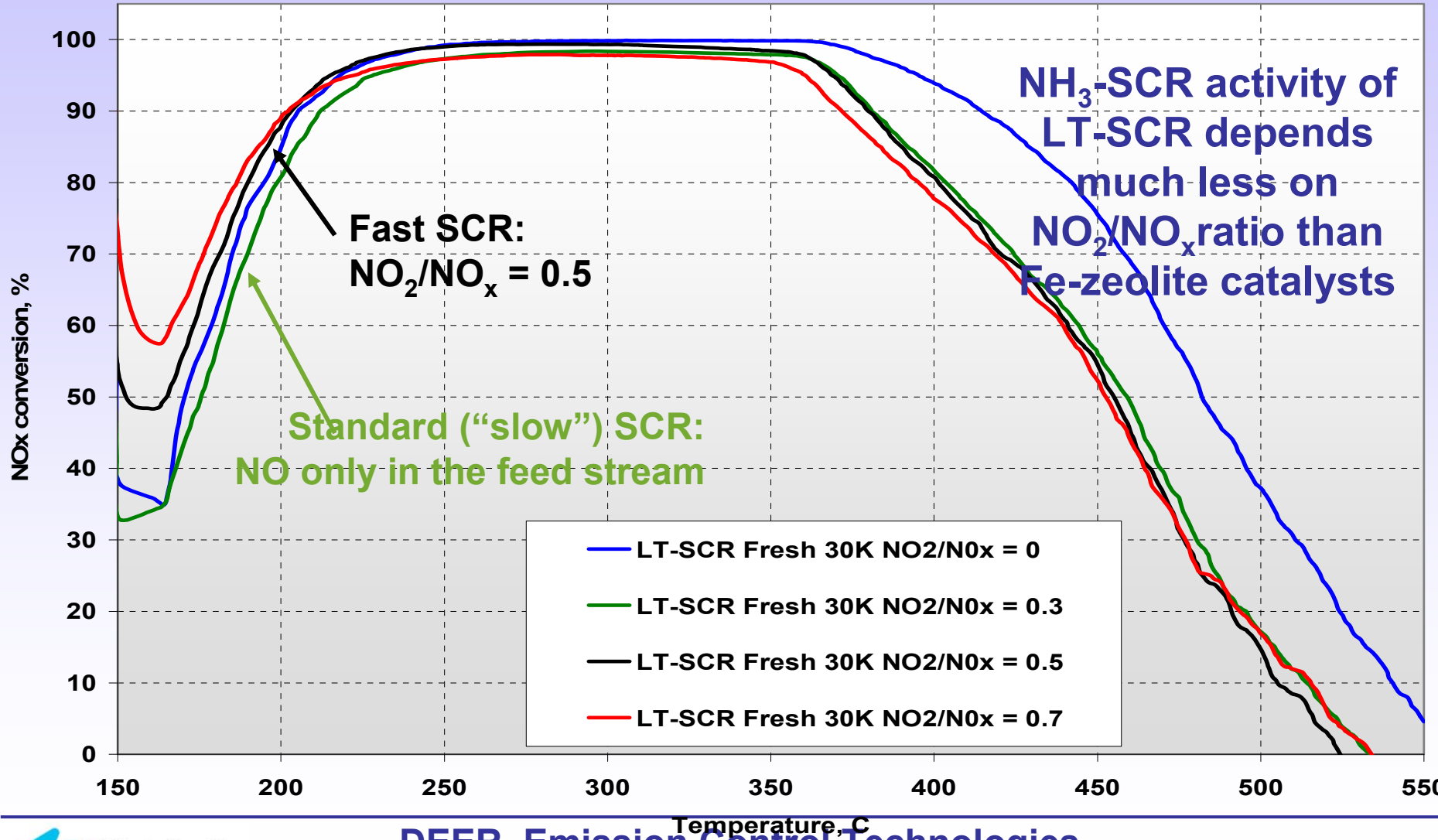
Activity of typical Fe-zeolite SCR catalyst. Lab bench data. ANR=1



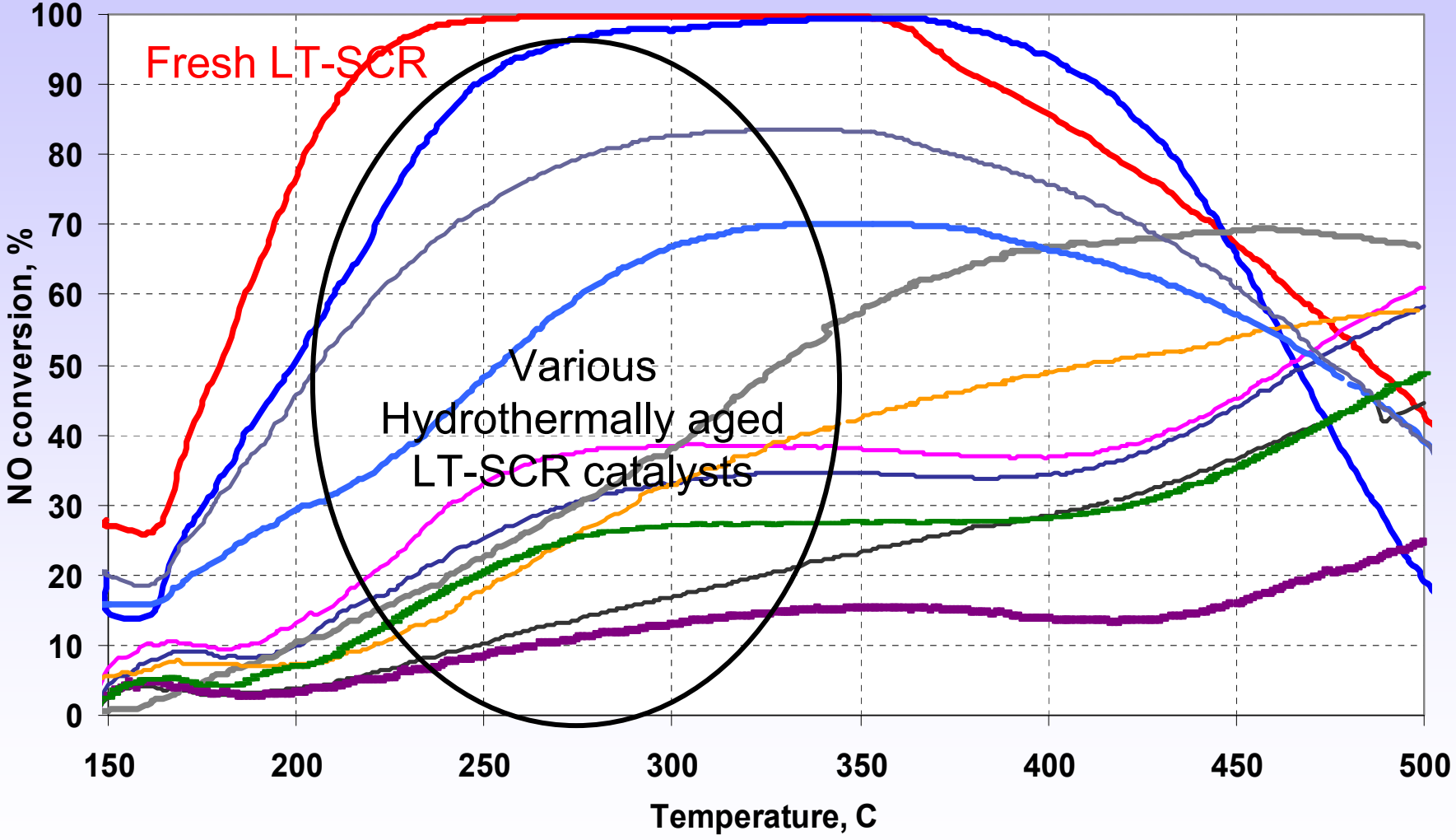
Activity of aged Fe-zeolite SCR catalyst. Lab bench data. ANR=1



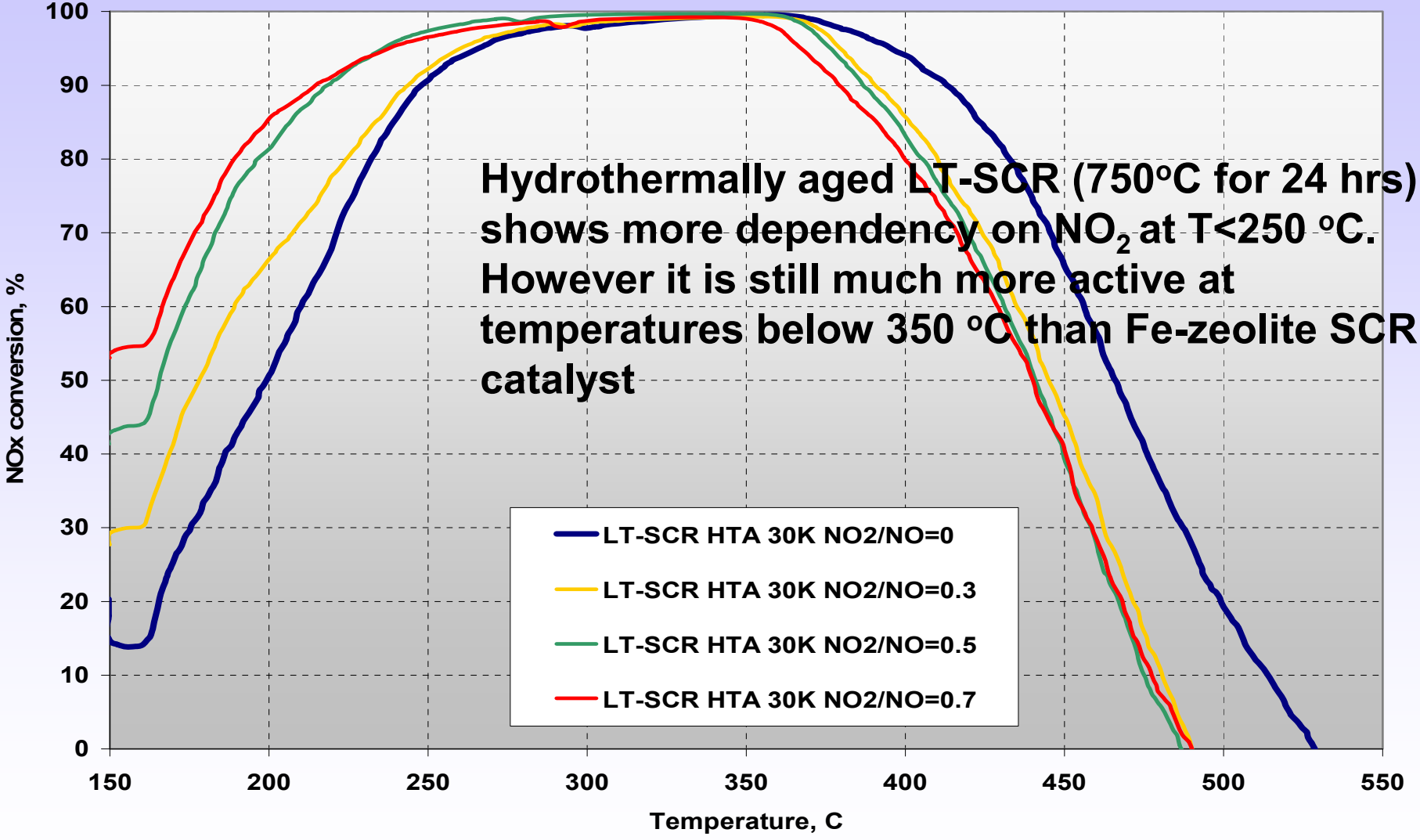
Activity of Low-temperature SCR catalyst. Lab bench data. ANR=1



LT-SCR: Hydrothermal stability challenge. Lab results with NO only in the feedgas.



Activity of Aged LT- SCR catalyst. Lab bench data. ANR=1



Hydrothermally aged LT-SCR (750°C for 24 hrs) shows more dependency on NO_2 at T<250 °C. However it is still much more active at temperatures below 350 °C than Fe-zeolite SCR catalyst

SCR catalysts systems

- Combinations of hydrothermally stable high-temperature SCR and low-temperature SCR catalysts provide NO_x after-treatment solutions for all types of applications.

- HDD: HT-SCR/LT-SCR = 1/1?
- LDD: HT-SCR/LT-SCR=1/2 or 1/3?
- Locomotive: HT-SCR/LT-SCR=2/1 or 1/1?
- Urban buses: HT-SCR/LT-SCR=0/1?

- Optimum ratio of HT and LT catalysts in a system is TBD for each particular application

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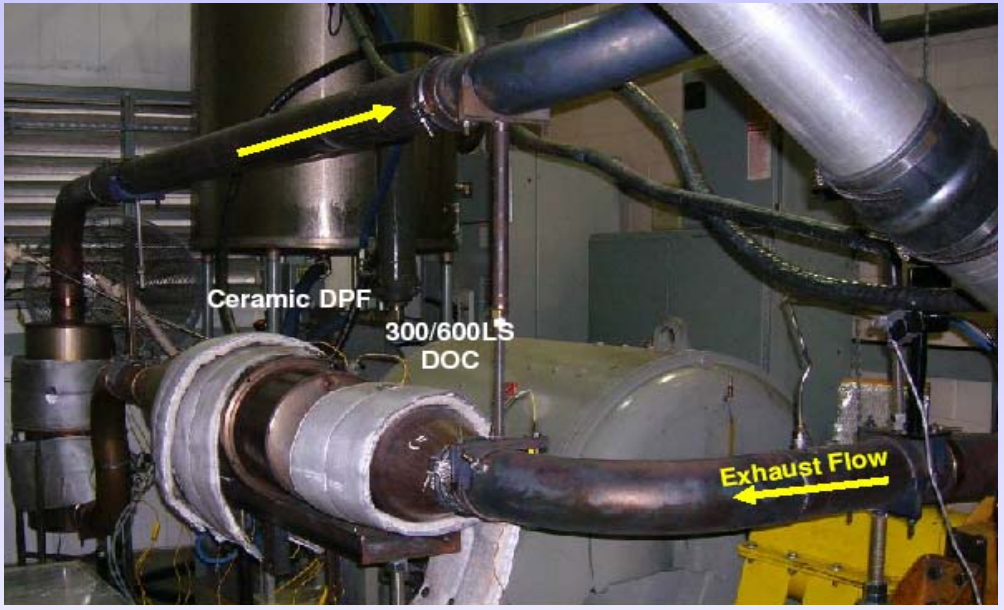
Evaluation of SCR system for HDD application at SwRI

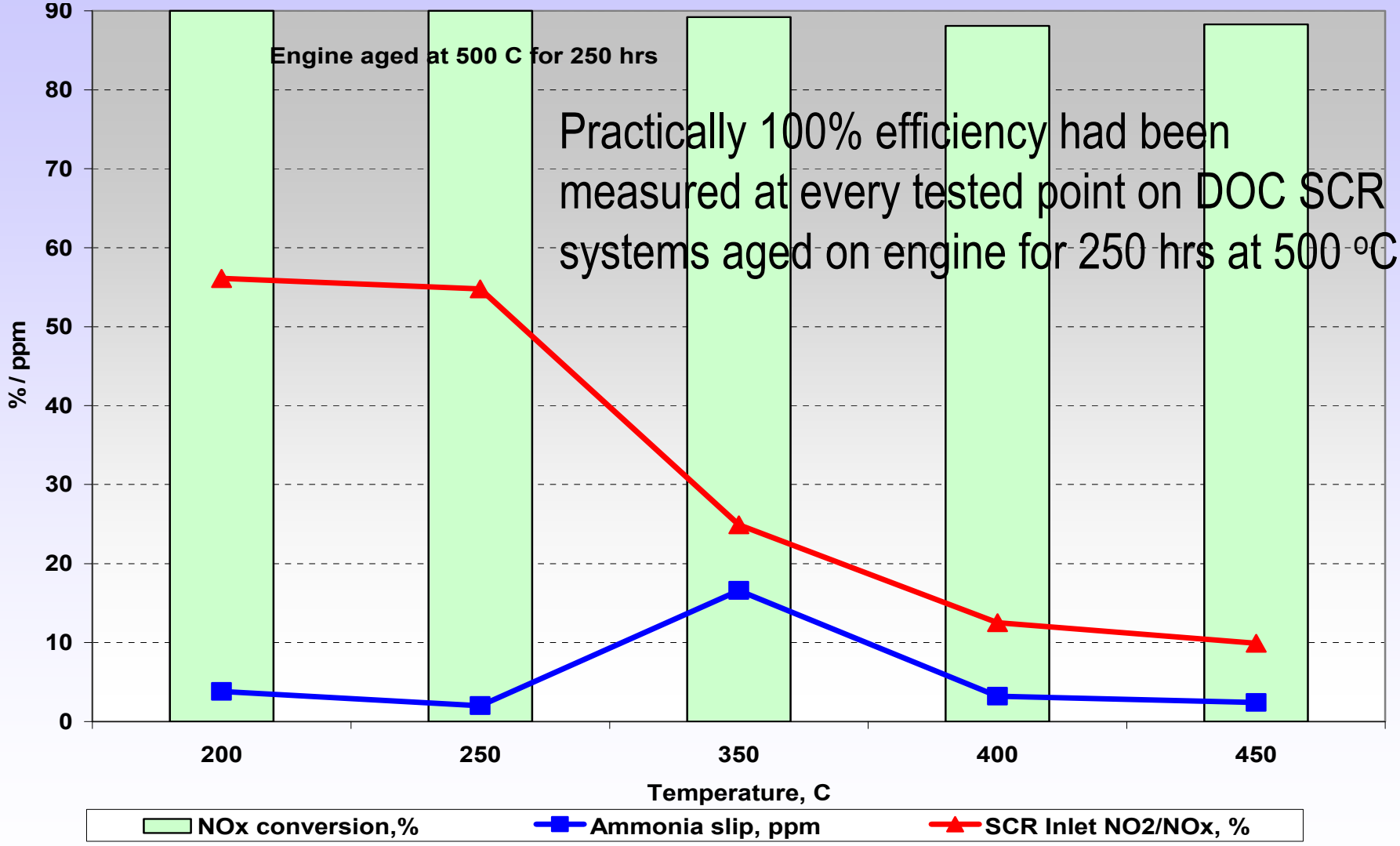
- Catalysts:
  - 9.2L DOC 40/0/0
  - 9.2L HT-SCR
  - 9.2L LT-SCR
- Aging: on 15L engine
  - 500 ^{o}C for 250 hrs
  - 650 ^{o}C for 100 hrs
- Evaluation: on 9L engine at 0, 25% 75% and 100% aging

Testing DOC and SCR at SwRI on 8.8L engine

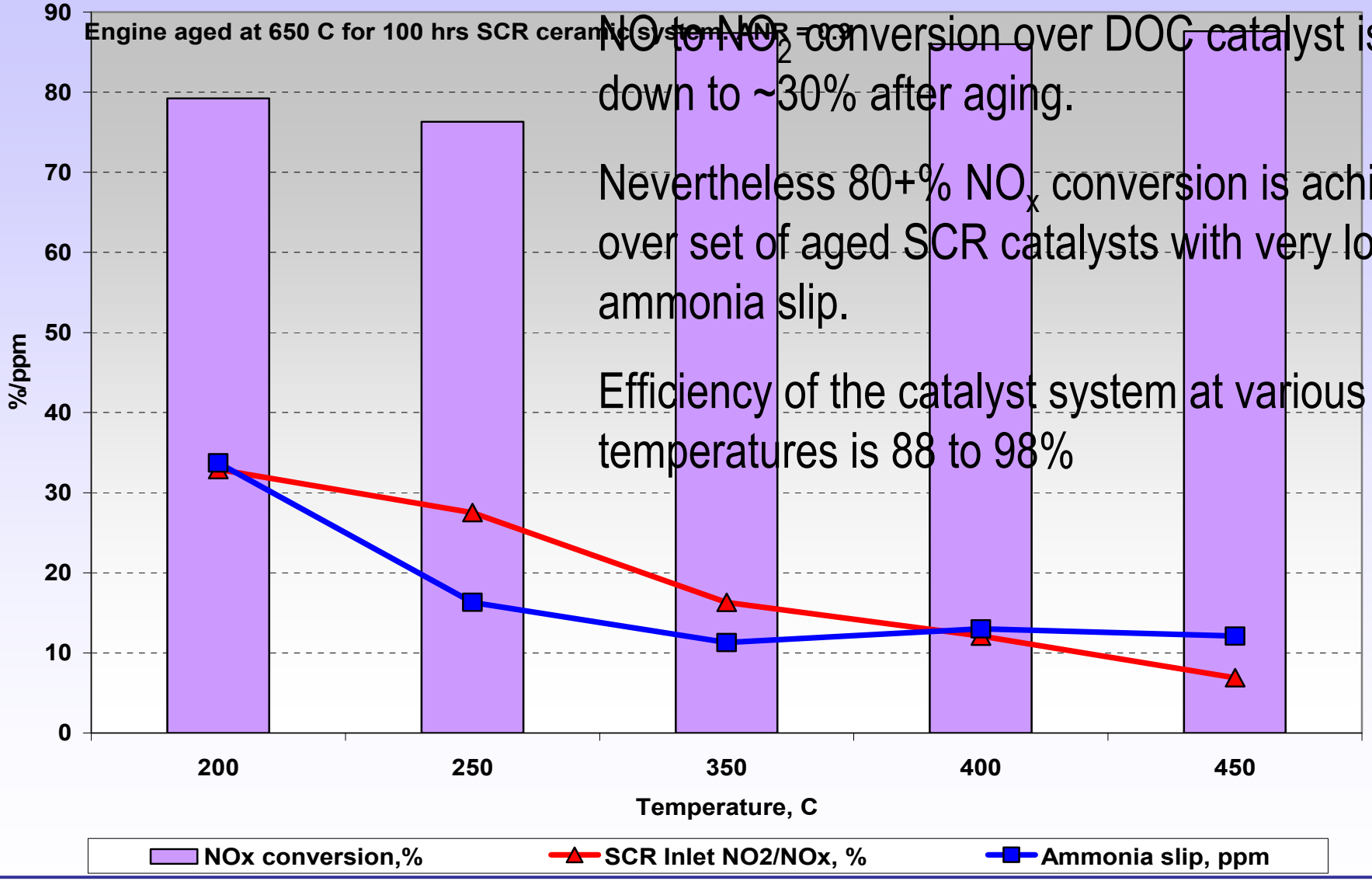


Evaluation point	Engine speed 1/min	Torque, ft-lbf	Turbo Out Temperature, °C	Exhaust Flow, kg/hr	SV DOC, 1/hr	SV SCR, 1/hr	Average Engine Out NO_x, ppm
1	1200	160	210	386	32K	18K	370
2	1800	160	250	620	52K	29K	240
3	1800	355	350	750	63K	35K	450
4	1800	515	400	860	72K	40.5K	665
5	1800	837	450	1095	91.5K	51.5K	1060

Engine test results for system aged at 500°C for 250 hrs. ANR=0.9



Engine test results for system aged at 650°C for 100 hrs. ANR=0.9

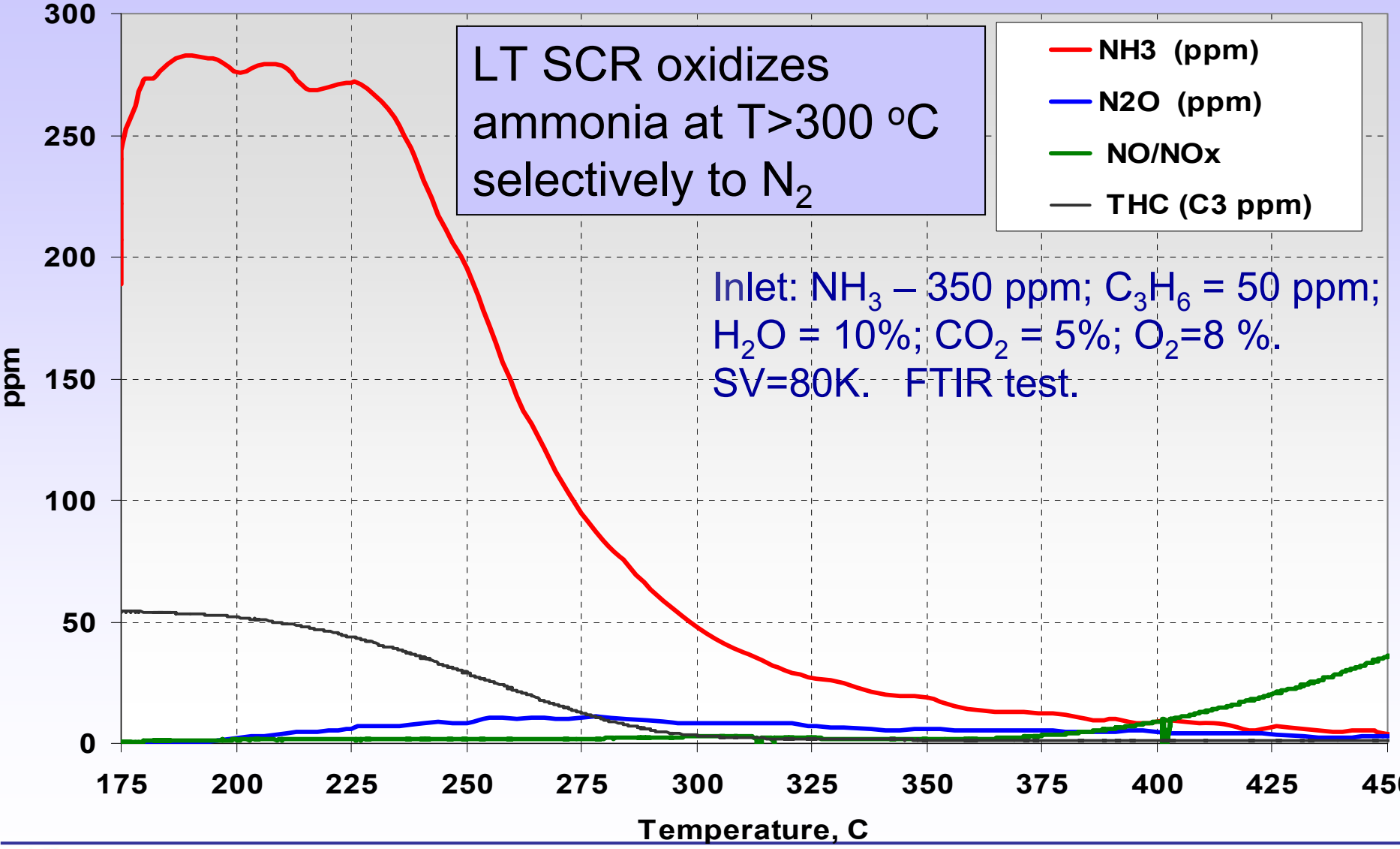


NO to NO_2 conversion over DOC catalyst is down to ~30% after aging.

Nevertheless 80+% NO_x conversion is achieved over set of aged SCR catalysts with very low ammonia slip.

Efficiency of the catalyst system at various temperatures is 88 to 98%

Ammonia oxidation by LT-SCR.

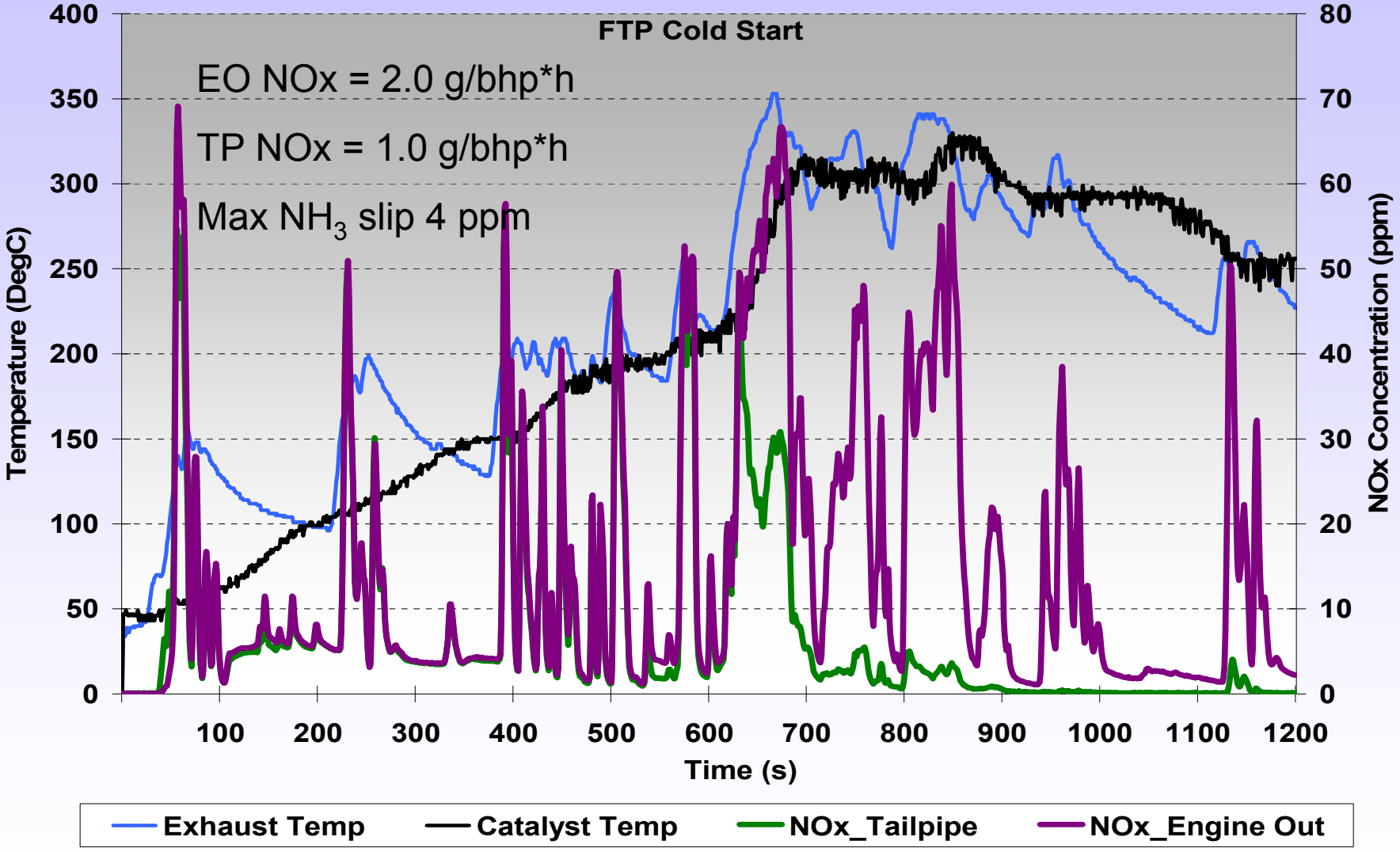


FTP tests over HT-LT SCR system on HDD engine by ECS

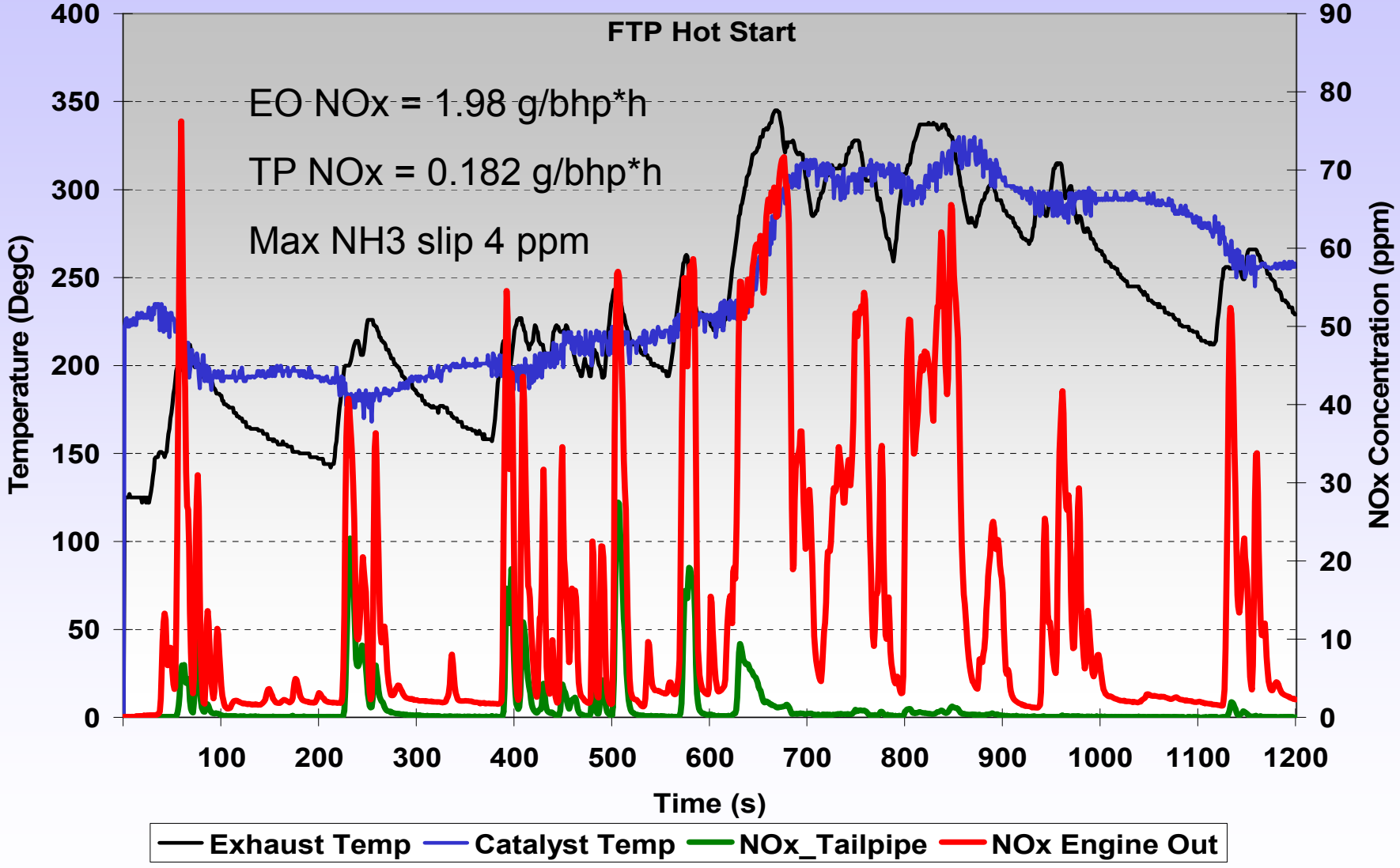
- CAT Engine
- 2004 C11
- 11.1L
- 6-cyl in line
- 305 bhp@2100 rpm
- Air-assisted urea injection

- Catalysts
- DOC (35/0/0) – 7L
- HT-SCR – 7L
- LT-SCR – 7L with 2” Pt band on outlet side

FTP Cold Start: 50% NO_x reduction



FTP Hot Start: 90.8% NO_x reduction



Low-Temp SCR system by KleenAir

- Retrofit application: UCI campus buses
- Engine: Cummins (early 1990s)
- 5.9L
- Fuel: B20 and B100
- Air-assisted urea injection

- Catalysts:
- LT-SCR – 10L
- Clean Up DOC (10/0/0) – 5L

SCR systems on UCI campus buses

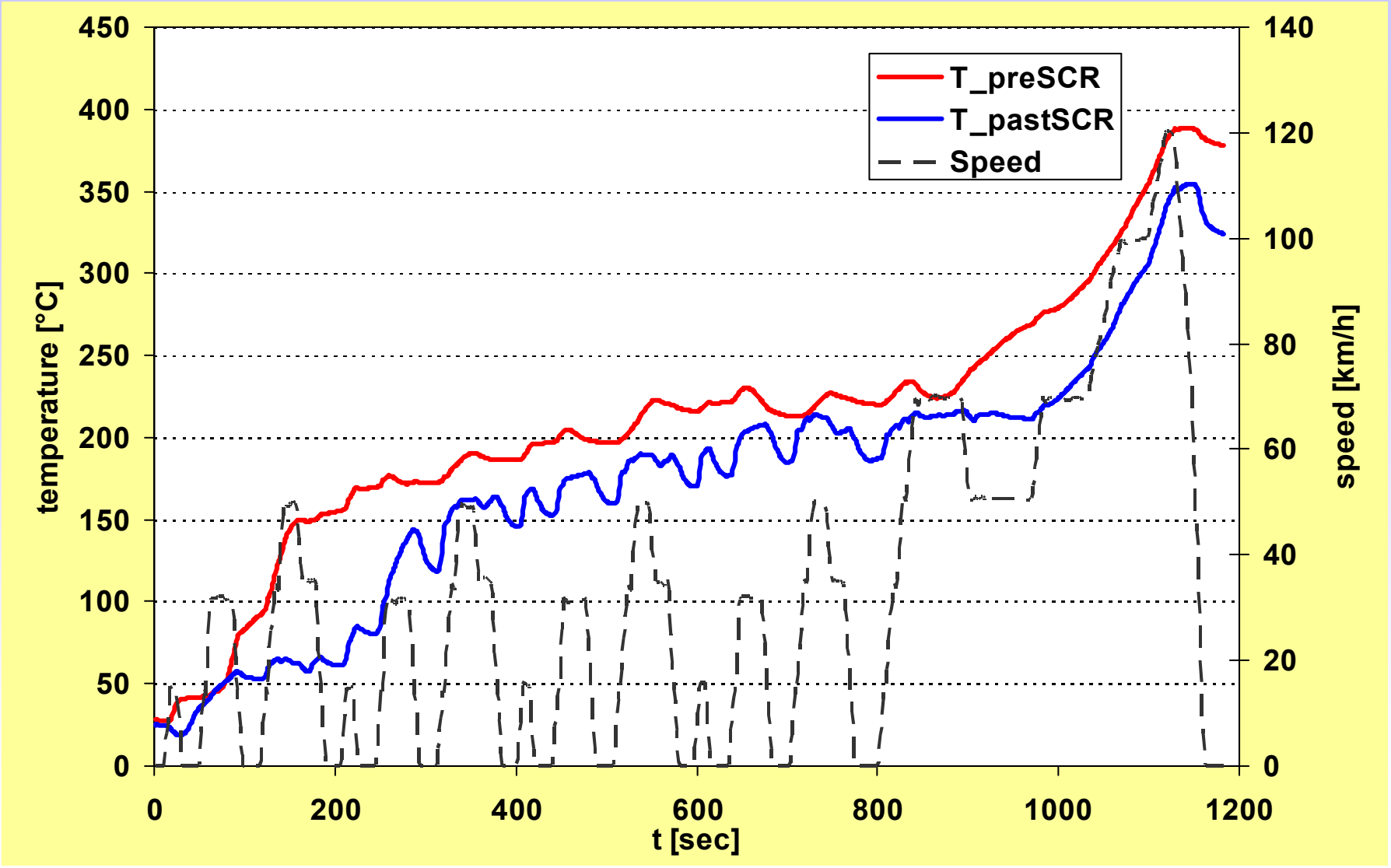
- System performance:
- NOx reduction: 80-92%
- HC,CO removal: >90%
- PM ~ 50%
- Program started in 2005.
  No system failures.

Evaluation of HT/LT SCR systems on LDD vehicle by Emitec

- Vehicle: MB Sprinter 2004 MY/ Euro III
- Engine:
  - 2.15 L/4cyl
  - Turbocharged
  - 95 KW@3800 rpm
- Urea injection: not air-assisted

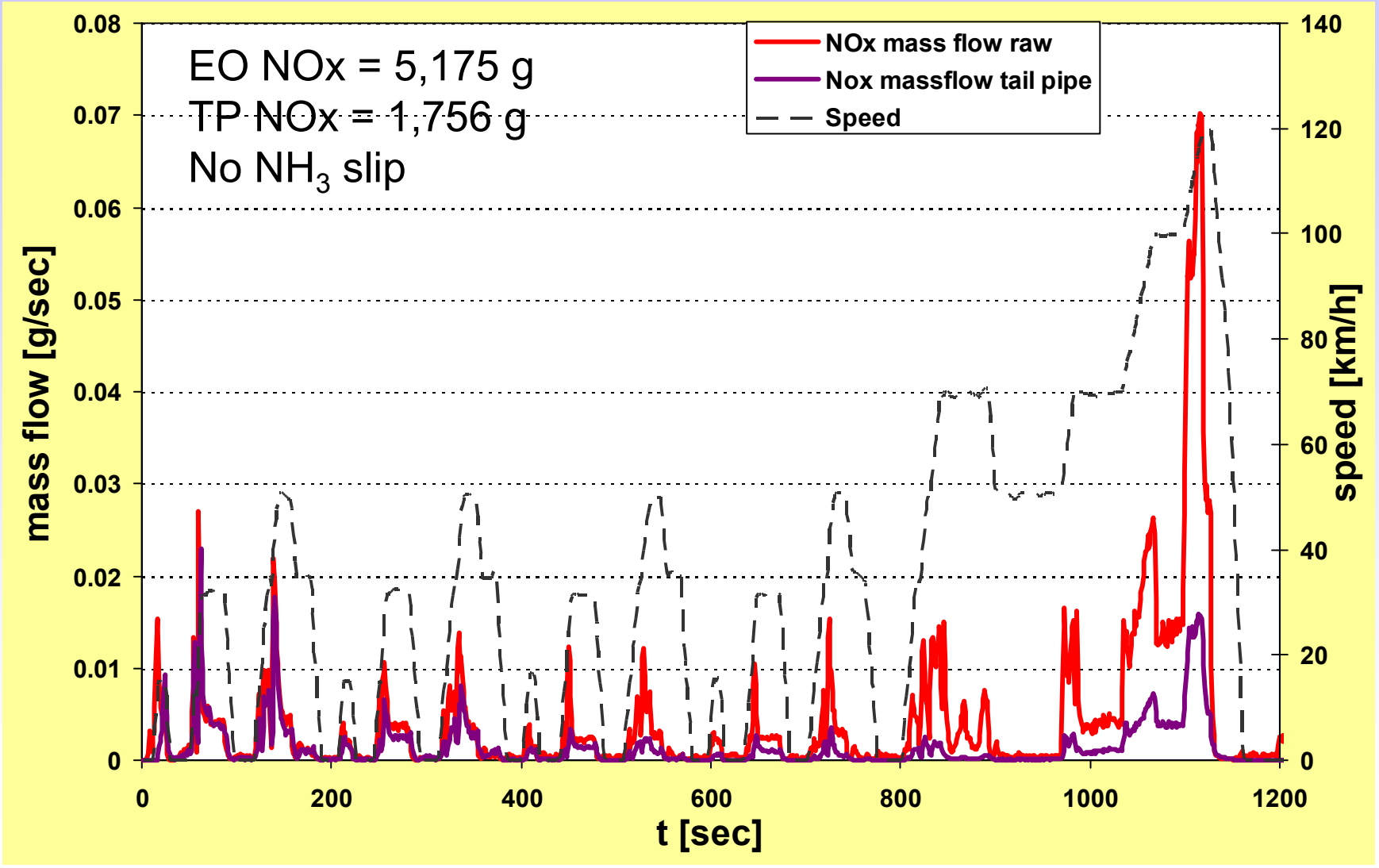
- Catalysts:
- DOC: two coated PM-substrates
- SCR on metallic substrates:
  - 4.4 L HT-SCR
  - 1.8L HT-SCR+2.6LT-SCR
  - 4.4 L LT-SCR

NEDC Temperatures

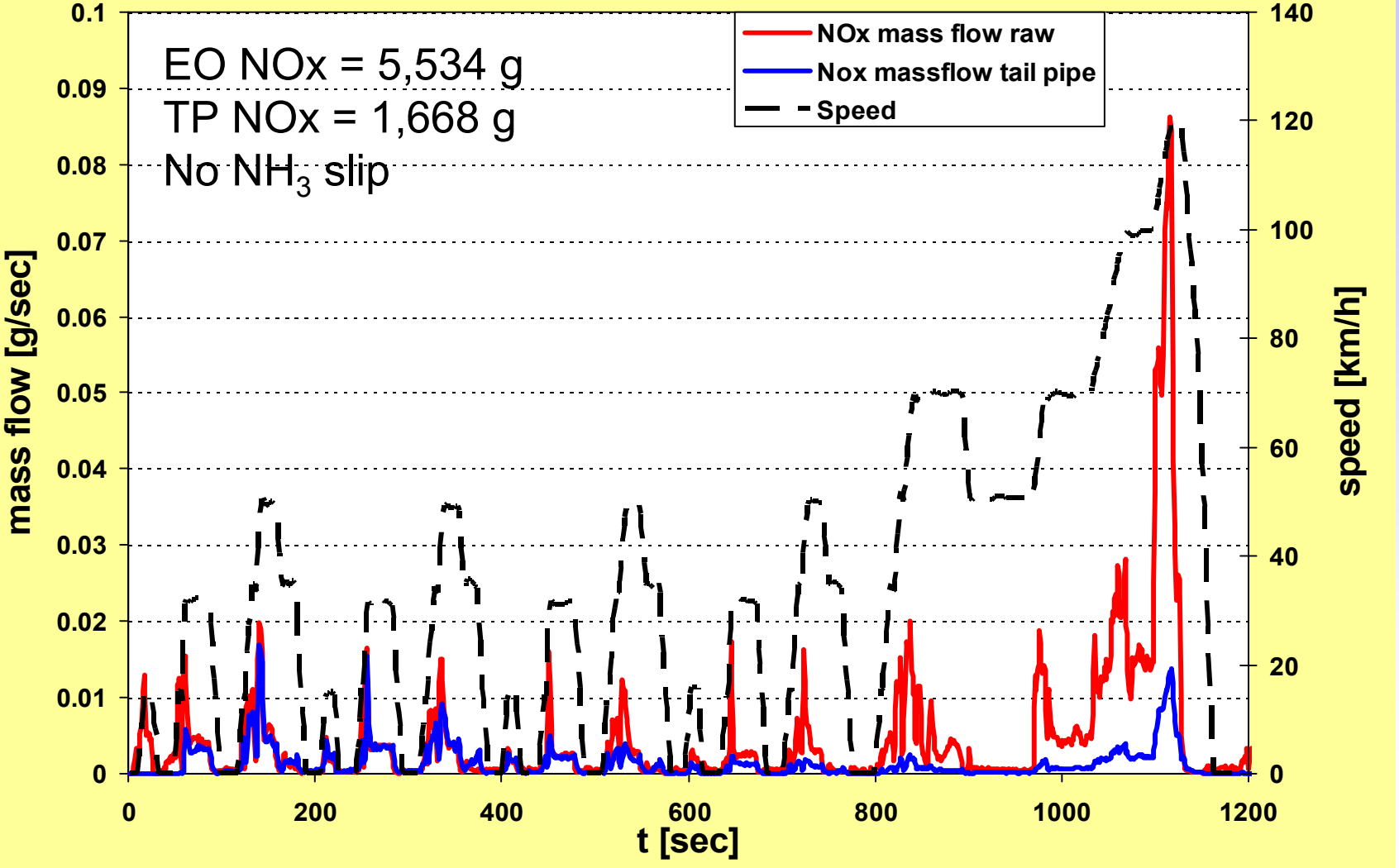


NEDC. 4.4L HT-SCR

66.1% NOx reduction

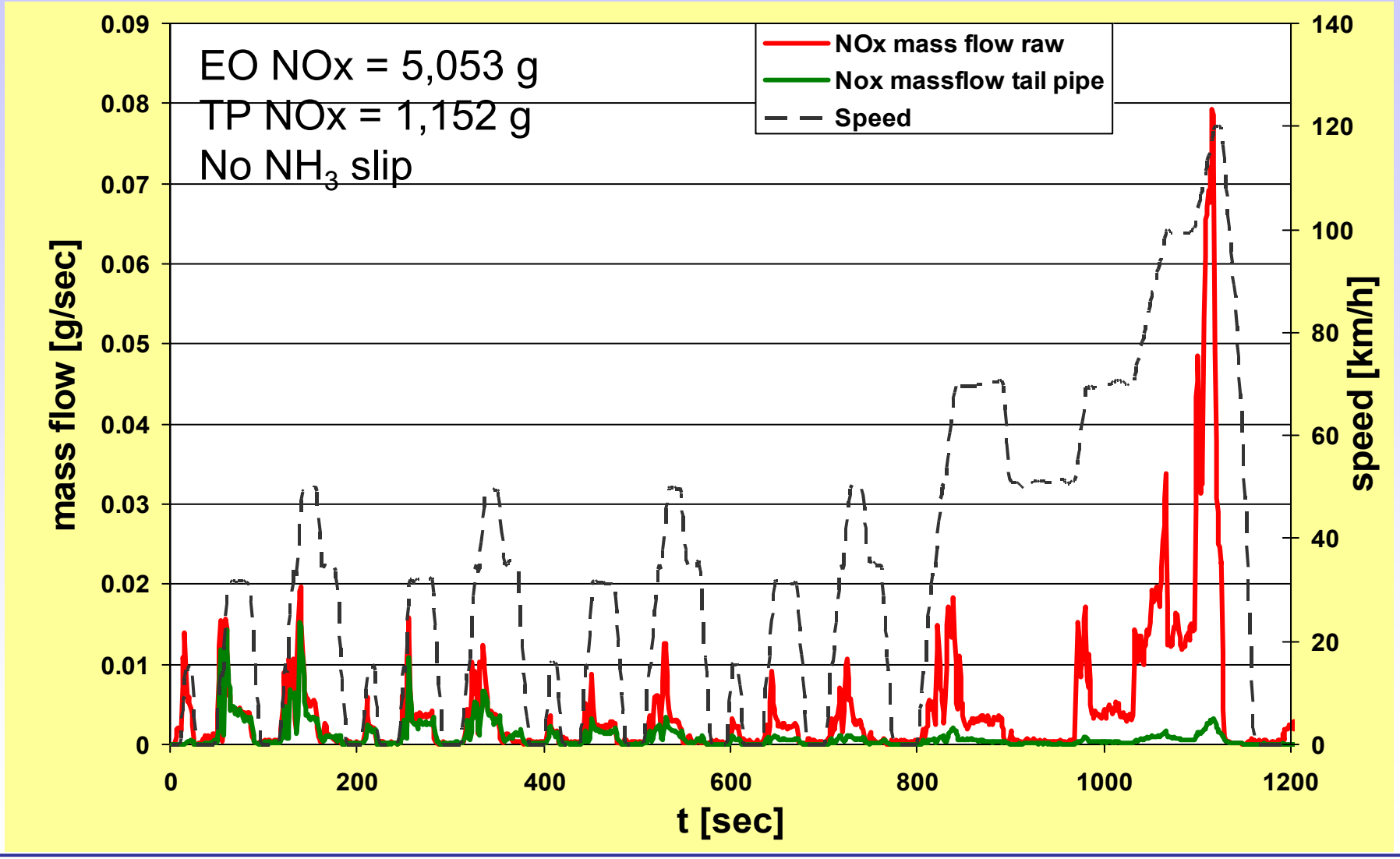


NEDC: 1.8L HT-SCR+2.6L LT-SCR: 69.9% NOx reduction



NEDC. 4.4L LT-SCR

77.2% NOx reduction



SCR for LDD

- LT-SCR alone looks like the best choice for LDD SCR system if we base our decision on NEDC tests results.
- At real driving conditions SCR system would be exposed to high-temperature exhaust for extended period of times during highway driving. So HT-SCR catalyst has to be present in the system as well.
- Optimum ratio of HT and LT SCR is to be determined.

Summary

- It is critical for SCR applications to have an effective Low-T SCR that can work with low-NO_2
- Efficient SCR systems can be built with suitable combinations of hydrothermally stable Low-T and High-T SCR catalysts
- Ratio of LT-SCR and HT-SCR in a system can be tailored for each main application category.

- You have choice of SCR catalysts

Thank you Diesel Warriors!