Passive Ammonia SCR

For Lean Burn SIDI Engines

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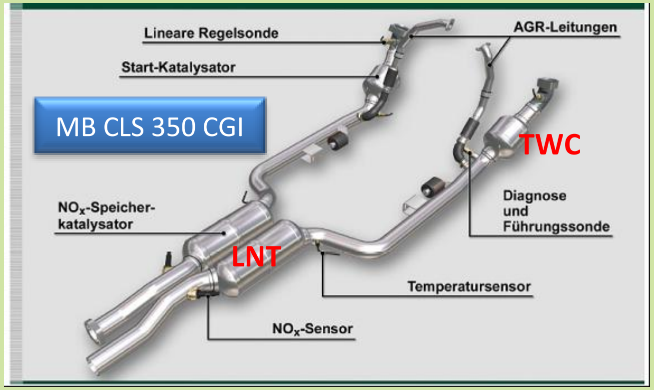
Outline

- Background and Concept
- NEDC Test Results
    - NH_3 Formation
    - NOx Conversions
- Issues and Summary

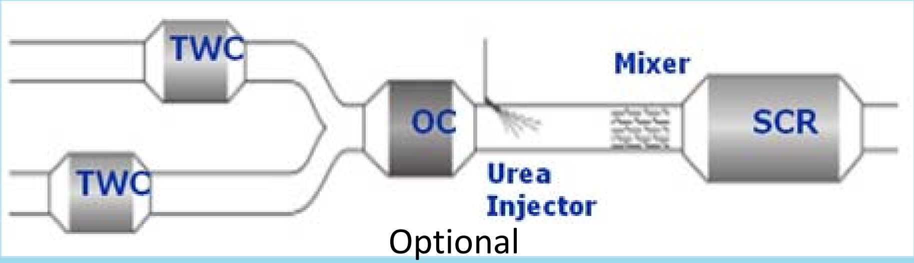
Lean NOx Aftertreatment

Lean NOx Trap (NOx Absorber Catalyst)



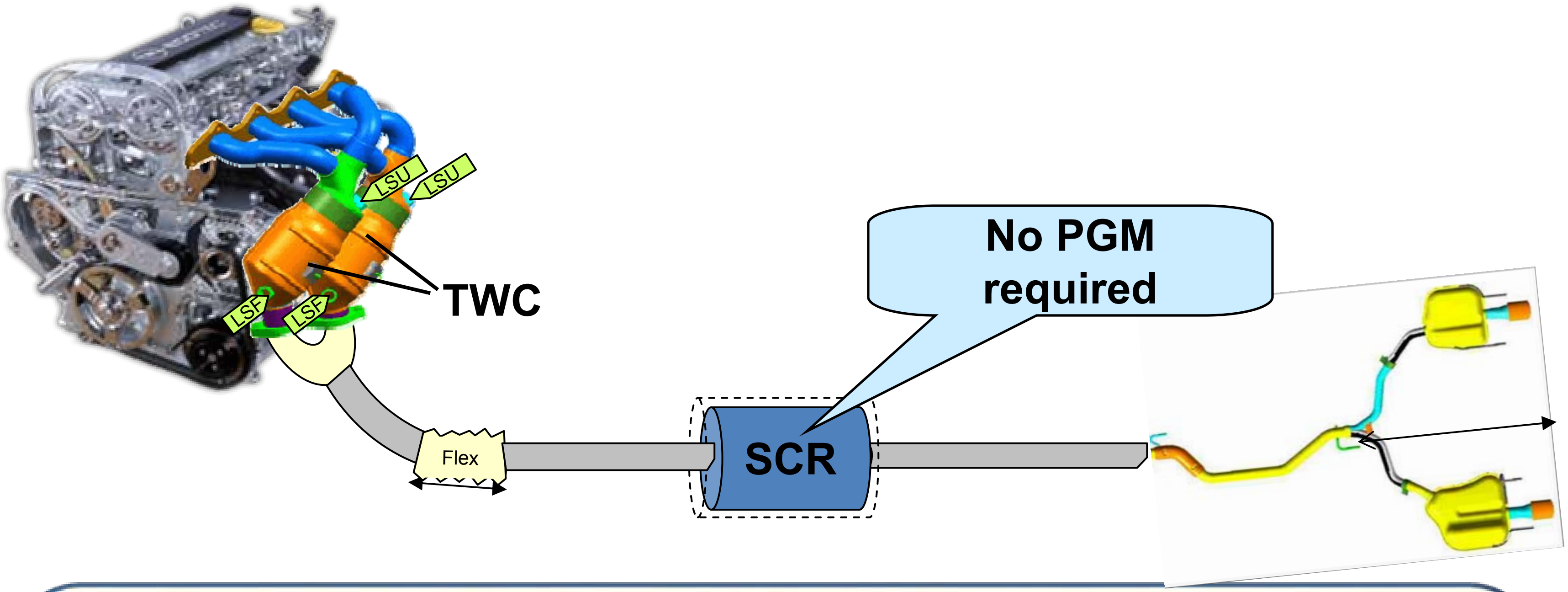
- High PGM Cost
- Narrow Operating Temperature Window
- Sulfur Poisoning and Desulfation

Urea SCR



- Secondary urea tank with injection system
- High urea consumption
- Urea solution freezing
- Need customer intervention

New Concept: Passive NH_3 SCR



- Use rich pulses to generate NH_3 on the TWC and store it on the SCR

  Rich: $NO_x + CO/H_2 \longrightarrow NH_3$

- Use the stored NH_3 for subsequent lean NO_x conversion

  Lean: $NO_x + NH_3 \longrightarrow N_2$

- Rich AFR NO_x must at least balance Lean AFR NO_x

Goal of the Work

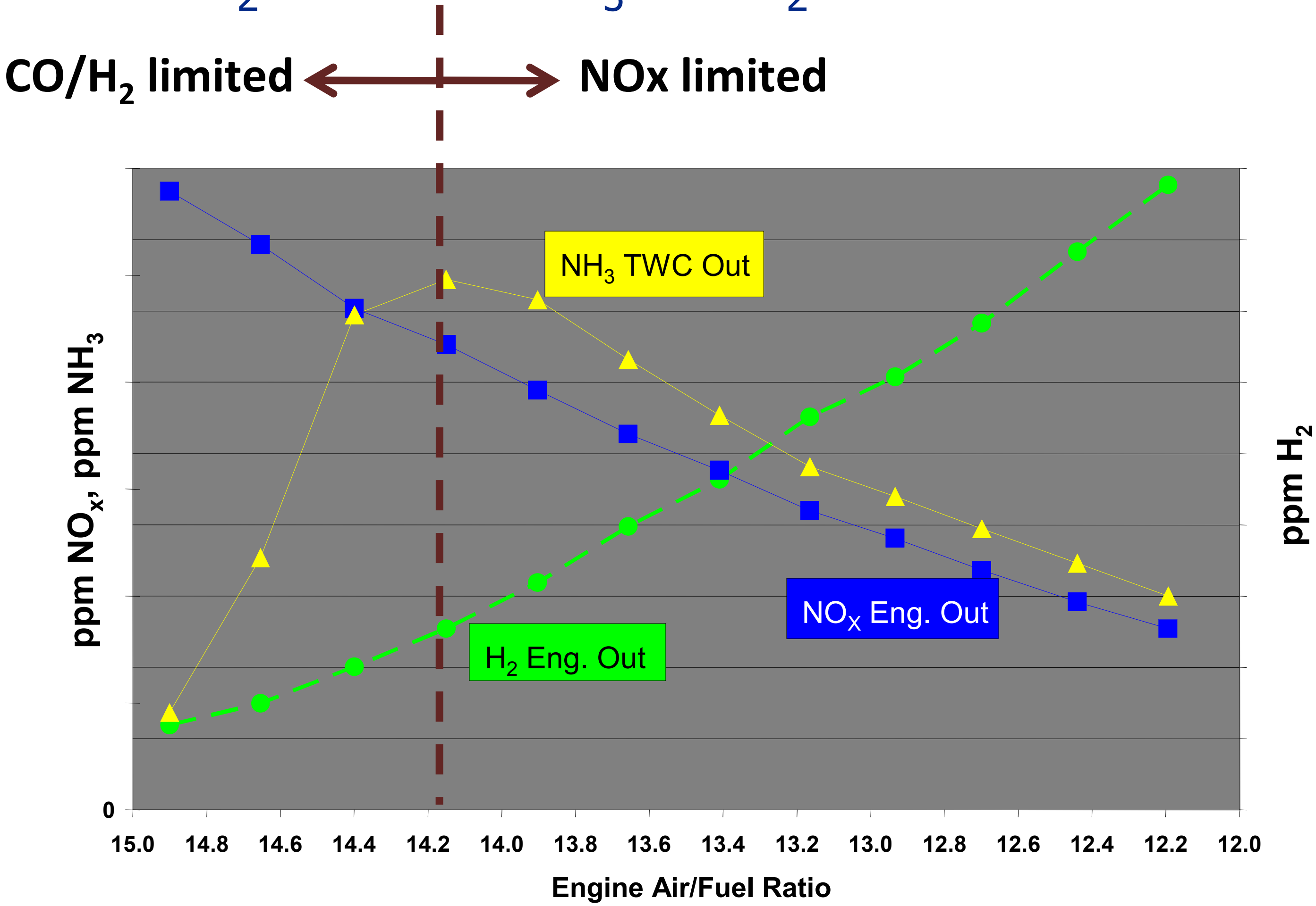
- Proof of Concept
  - Ability to make NH_3
  - Ability to store NH_3 and convert NO_x
- Catalyst Durability
  - High temperature redox aging
- Aftertreatment System Architecture
  - Thermal management

Experimental

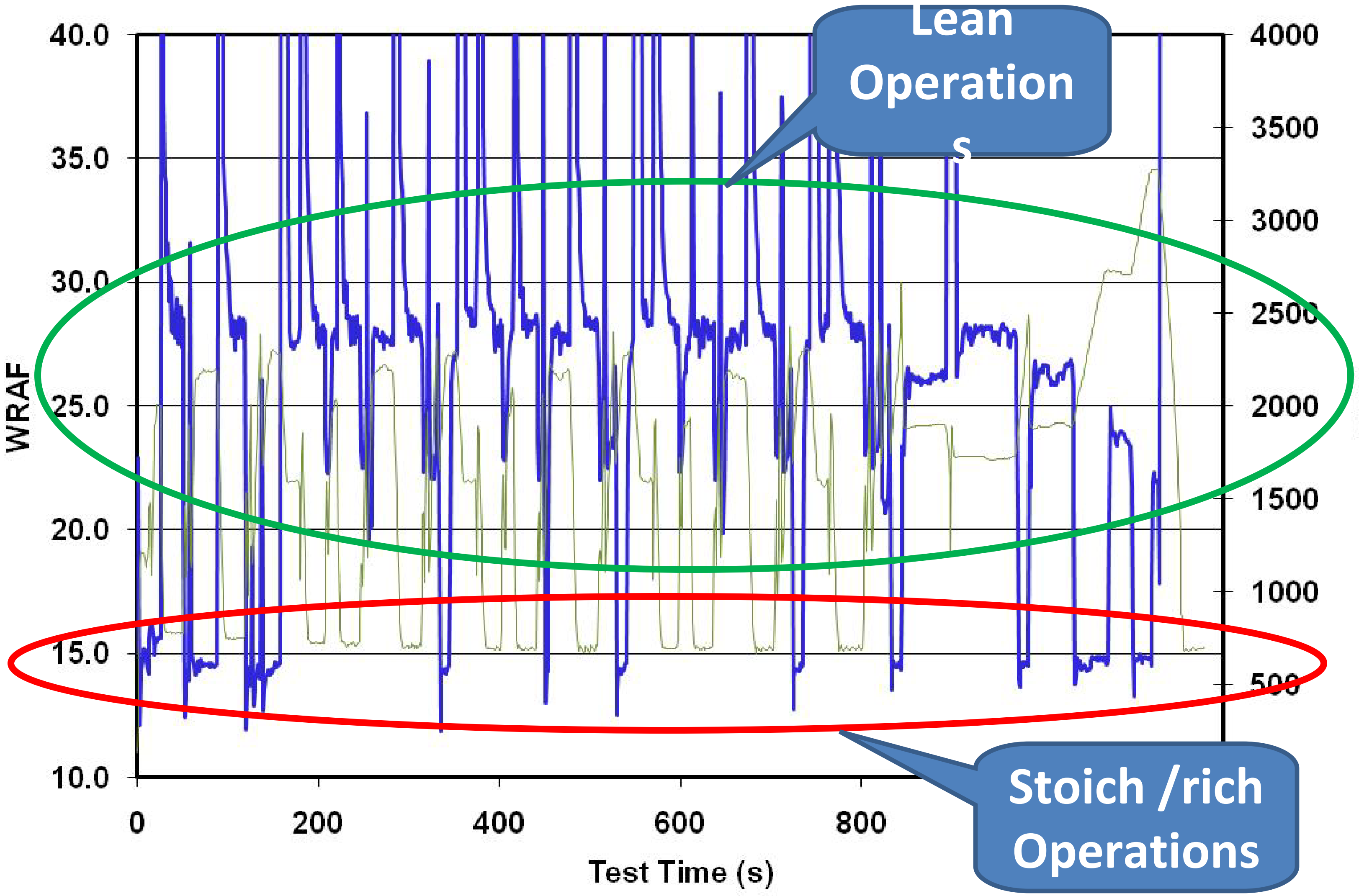
- Engine
  - 2.2L stratified-charge direct-injection engine
  - Controller: d-SPACE with micro-Autobox
- Transient Dynamometer : simulated NEDC cycle

NH_3 Formation over TWC

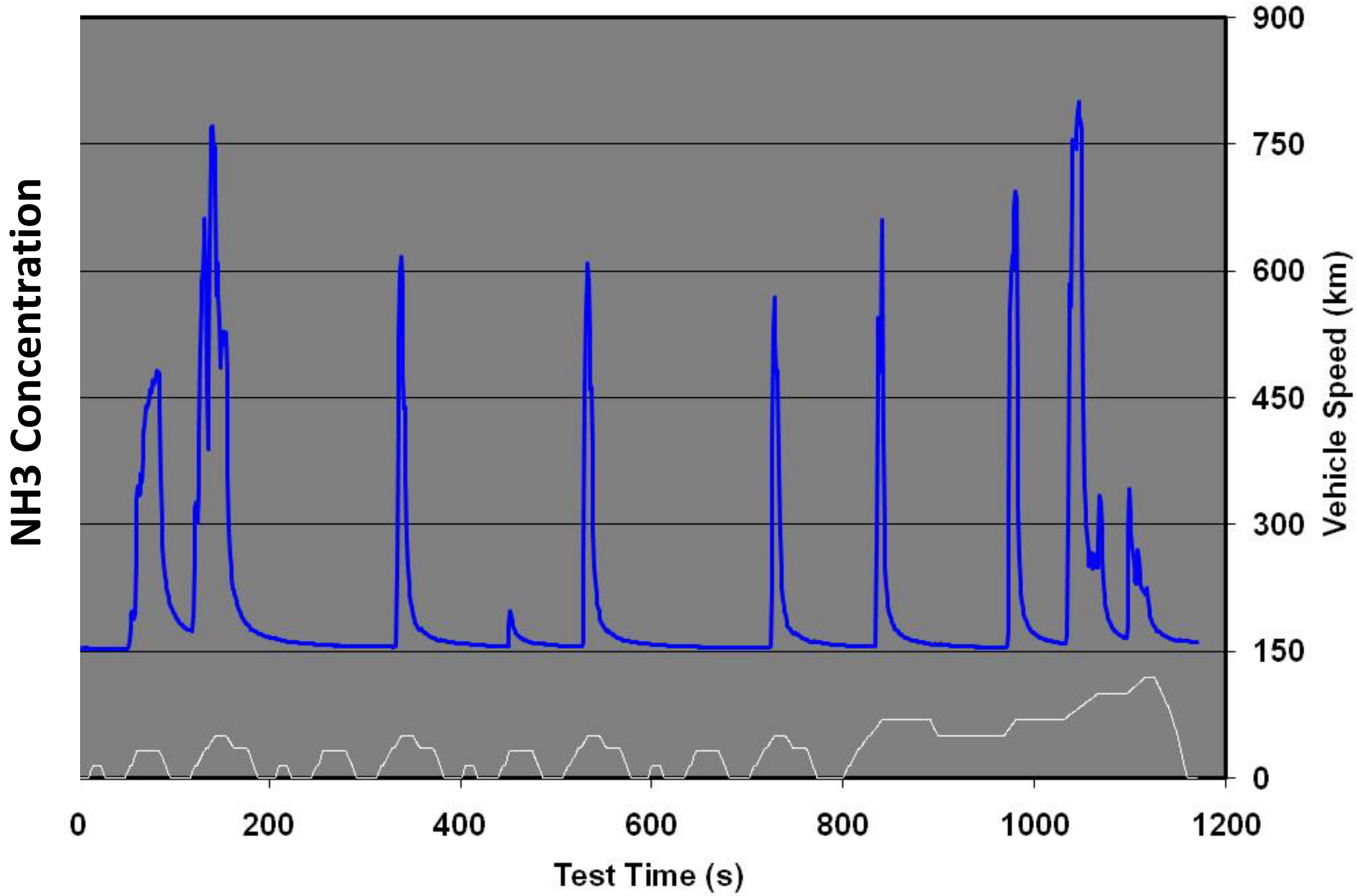
- NO + 1.5H_2 + CO ⇔ NH_3 + CO_2



Maximize Lean Operations During NEDC



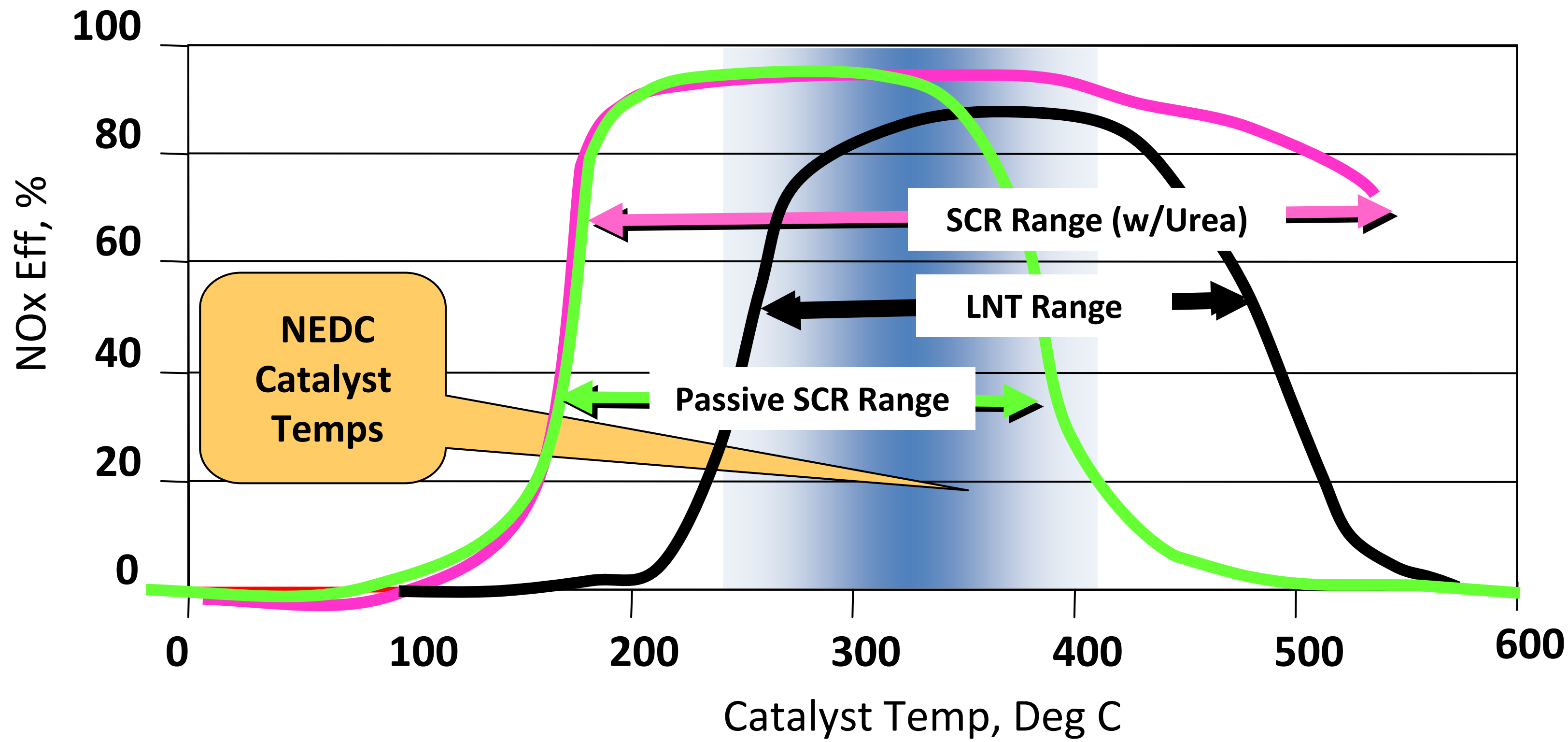
NH_3 Formation on the TWC Catalysts



Rich operations (AFR =14-14.2) during accelerations lead to NH_3 formation; minimum FE penalty (within test variability) based on test cell data

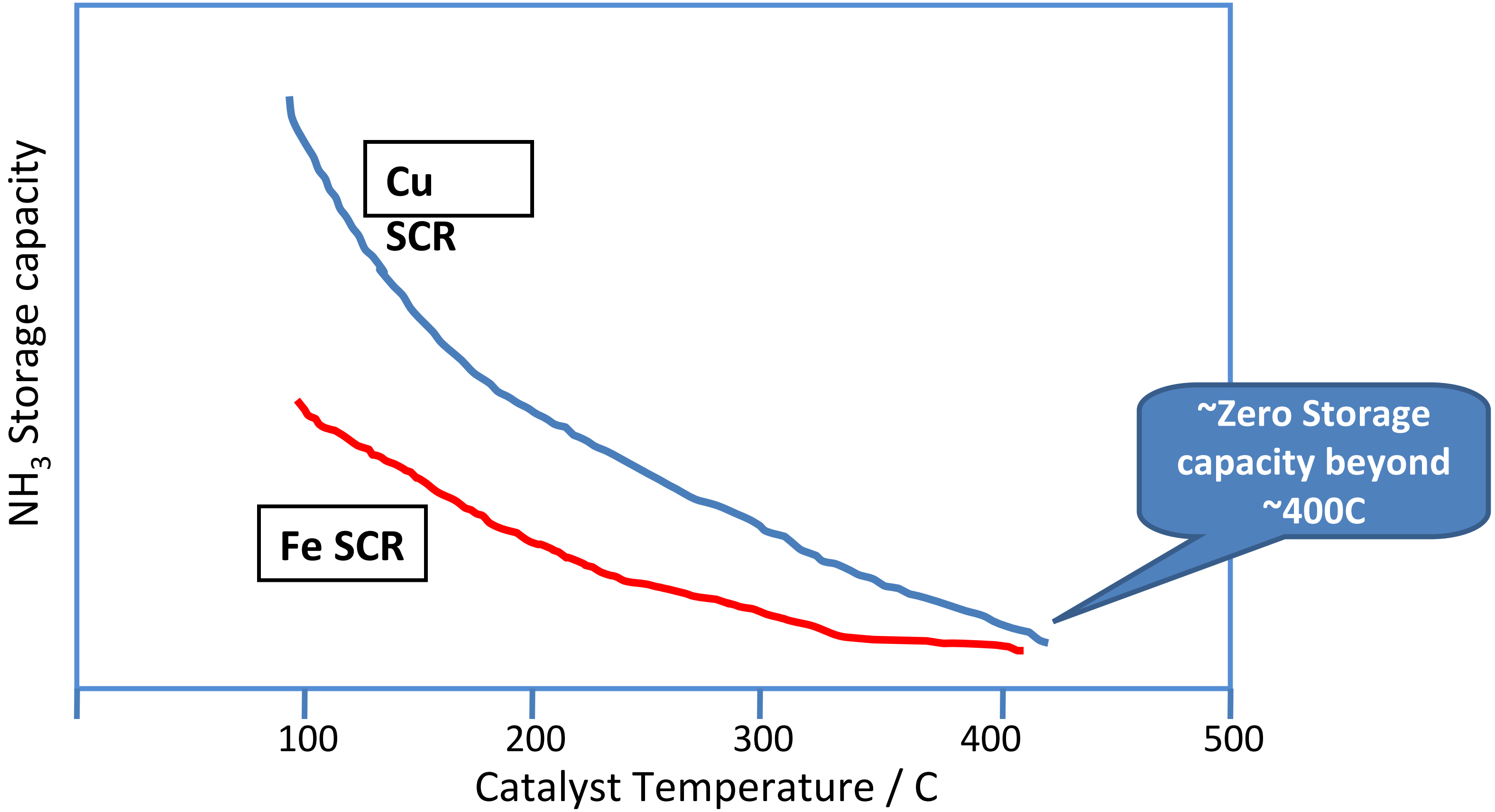
LNT & SCR NO_x Conversion Capability

Typical Thermal Operating "Windows" with Aged Catalysts



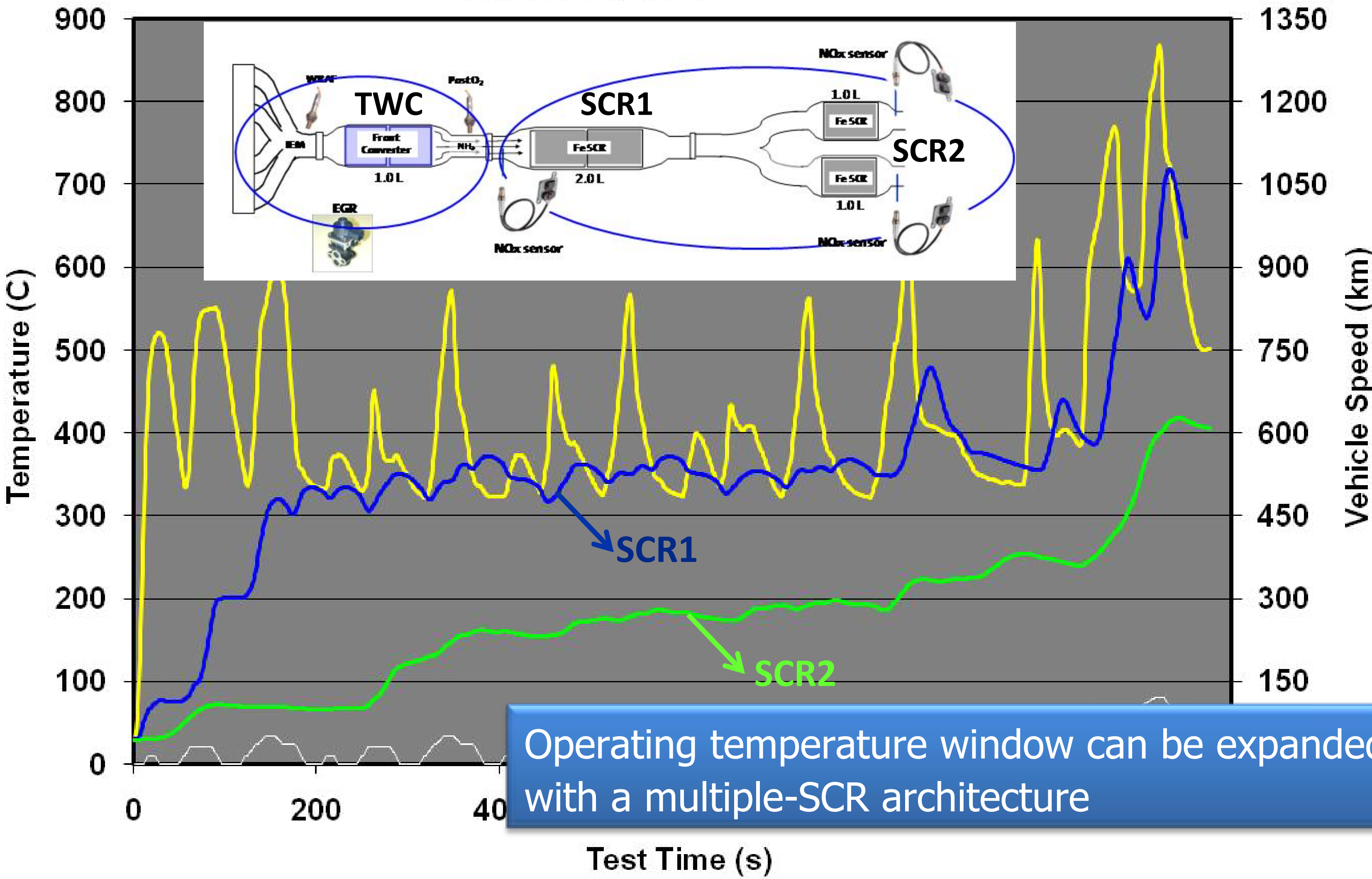
- Passive SCR conversion window about as broad as LNT, but at lower temperatures
- Lacking steady NH_3 supply, passive SCR NO_x conversion limited at high temperature
- Effective NO_X conversion only possible in reduced window of operation

NH_3 Storage Capacity Limitations
– Why passive SCR has smaller conversion window



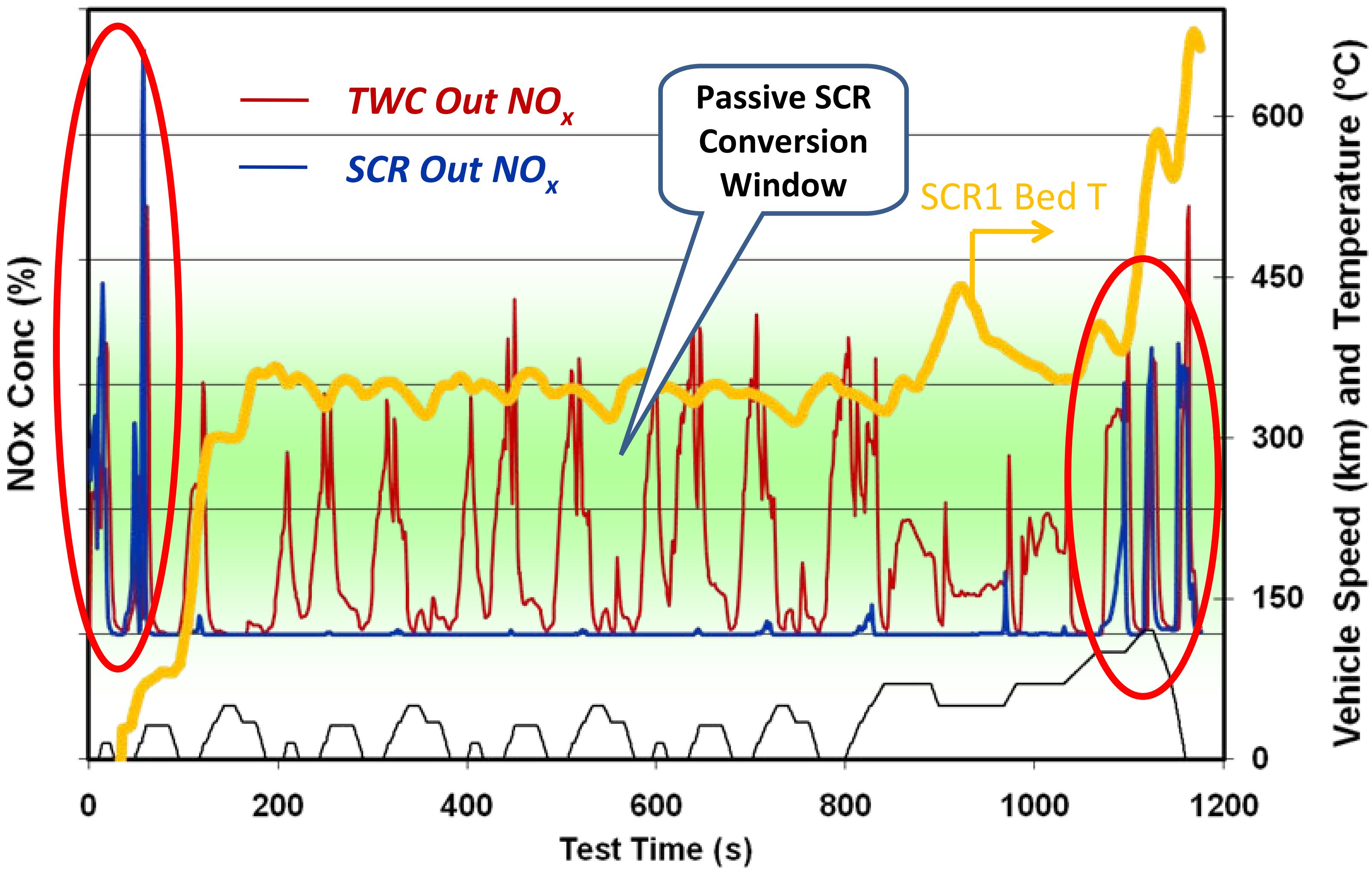
- Passive SCR is a discontinuous approach – must store NH_3 for use in lean periods
- Storage capacity of known catalysts is negligible beyond 400 C
- Effective NO_X conversion limited by intrinsic storage capacity

Multiple SCR Architecture

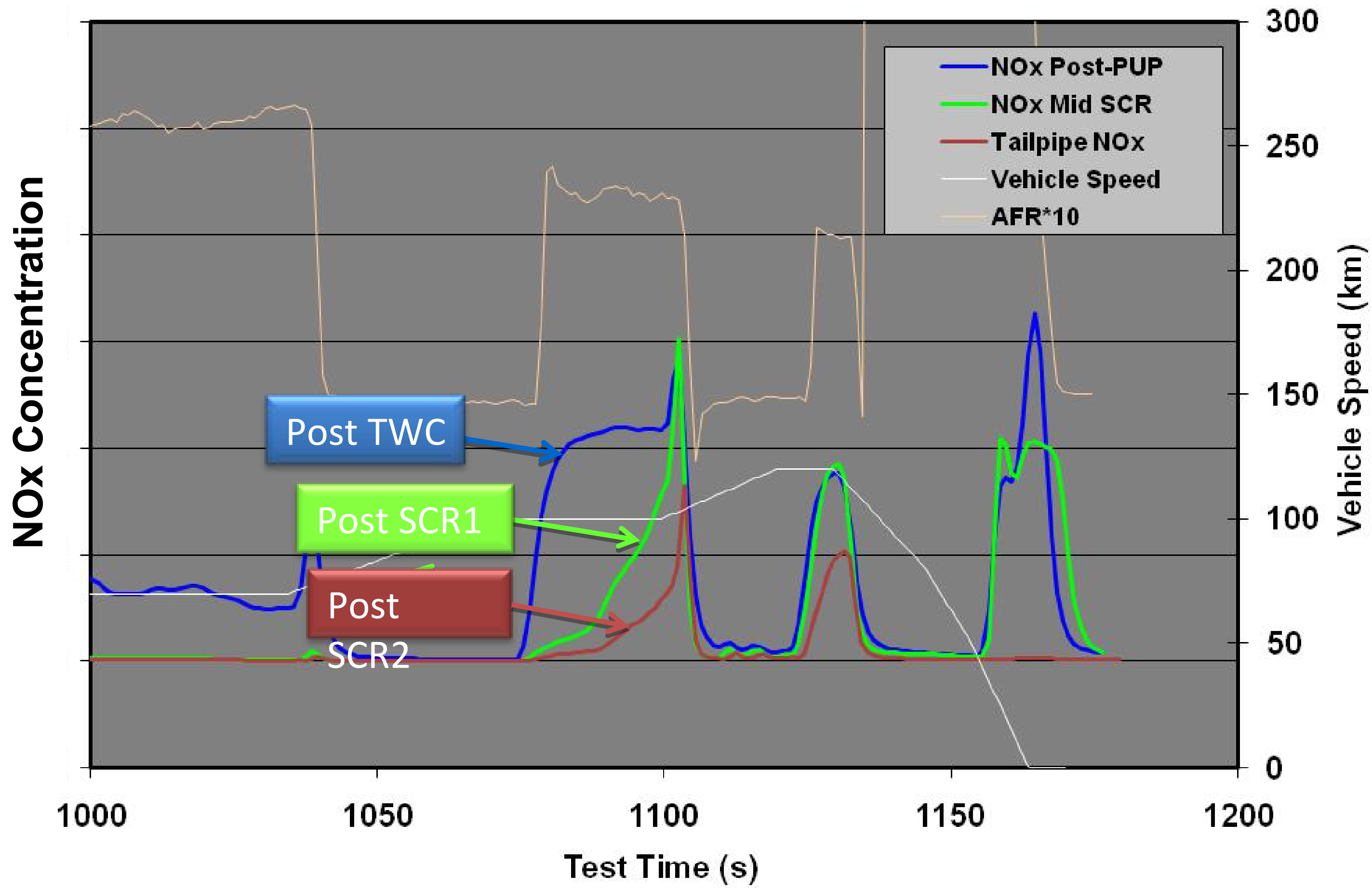


Operating temperature window can be expanded with a multiple-SCR architecture

NO_x Conversion Efficiencies over SCR



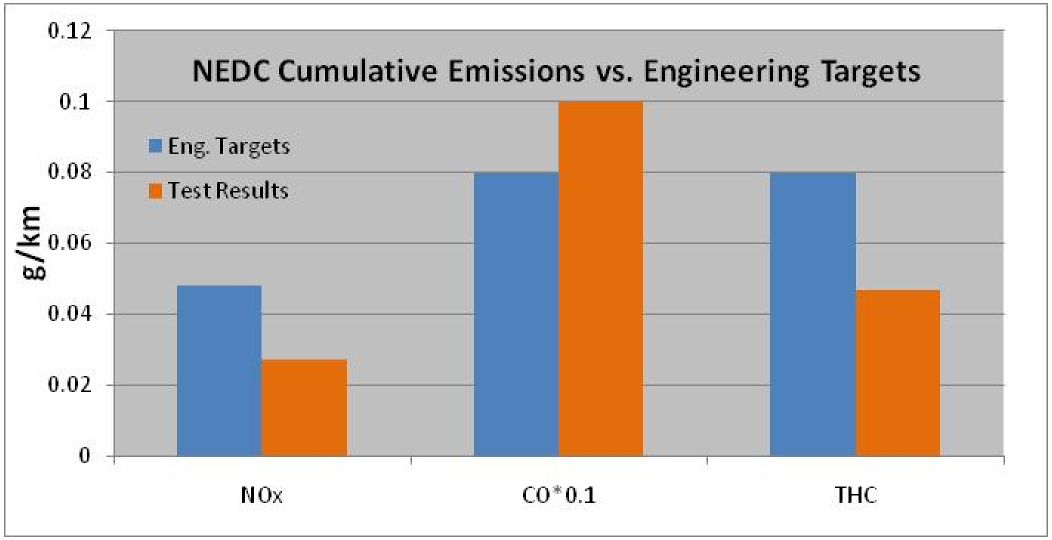
NOx Conversion During EUDC



Multiple-SCR architecture required to reduce NOx emissions during high speed (>100km/h) lean cruise during EUDC

NEDC Test Results with NH_3 SCR

- Passive NH_3 SCR has potential to meet Euro6 emission targets with aged converters
- Minimum fuel economy penalty for NH_3 formation during NEDC (within test variability)
- No significant slip of secondary emissions (NH_3, N_2O)



4-1 exhaust manifold
PUP Converter (aged RAT H 50h)
4L SCR (aged RAT 750 50 h)

Remaining Issues

- NH_3 formation and OBD control method
- Sulfur impact: sulfur is known to greatly inhibit NH_3 formation on TWC
- HC emission reduction is challenging due to the low exhaust temperatures
- Further improvements in SCR catalyst technologies are required for high speed (≥100 km/h) lean operations.

Summary

- Passive NH_3 SCR has been demonstrated as a high efficiency and low cost alternative lean NO_x aftertreatment technology for stratified gasoline engines.
- Very high NO_x conversion efficiencies were achieved during NEDC transient cycles.
- Multiple SCR architecture expands the operating temperature window of passive SCR
- Plan to further develop the system for US applications (SULEV)

Passive NH_3 SCR: key enabler for lean gasoline engines