

Advanced V-SCR Technology for Euro VII and BS VII Applications

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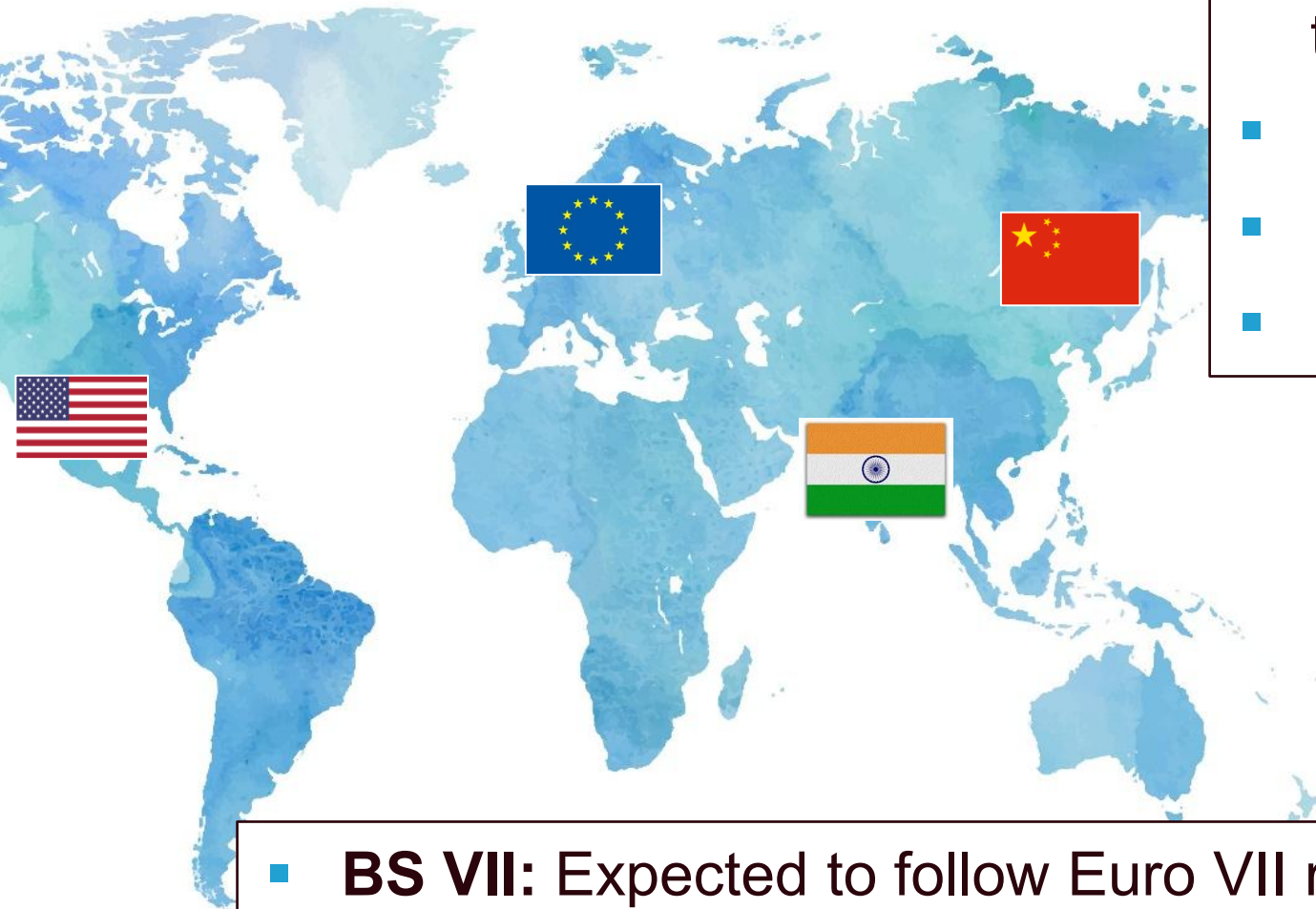
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Global Heavy Duty Emission Regulations

- **Euro VII:** Implementation second half of 2028
- Possibility of delay in implementation
- Some OEMs continue with dual dosing

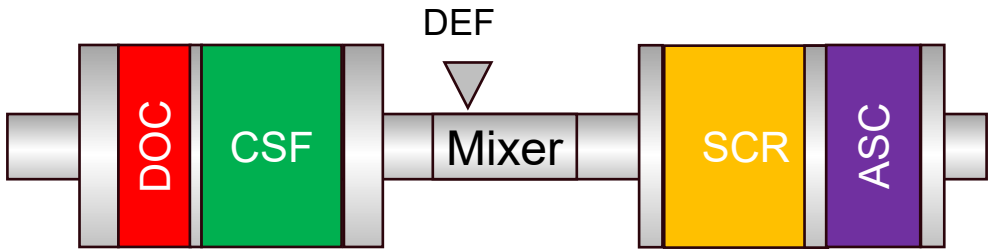
- **NS VII:** To be finalized in 2026. Expected to be more stringent than Euro VII
- Dual dosing is prime path for N3 platforms
- Cu-SCR is preferred
- CNG: filter for PN control may be needed

- **EPA27** on-road: Both dual & single dosing and Cu & V systems
- Development continues despite political uncertainties
- Off-highway ARB Tier 5 is proposed, pending at EPA



- **BS VII:** Expected to follow Euro VII requirements
- **Trem V:** Further delayed, possible dilution
- CPCB IV+: Low power engines → DOC only; high power engines → DOC+SCR+AMOX

BS-VII ~ Euro VII - Probable ATS Architecture



BS - VII Probable Architecture

BS - VI

- Single urea dosing
- For India Cu-Z has Major Stake

Dual Dosing System

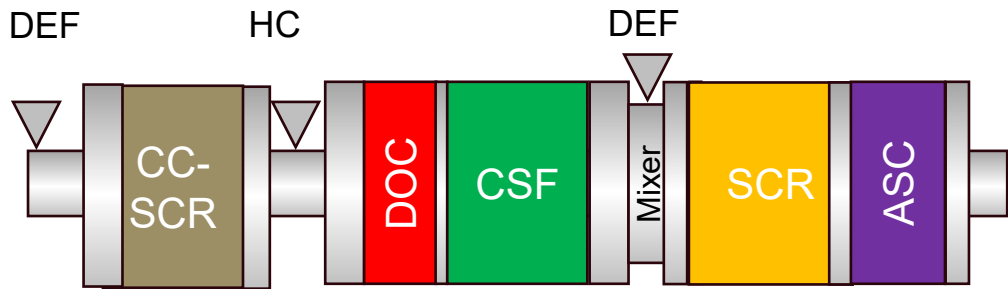
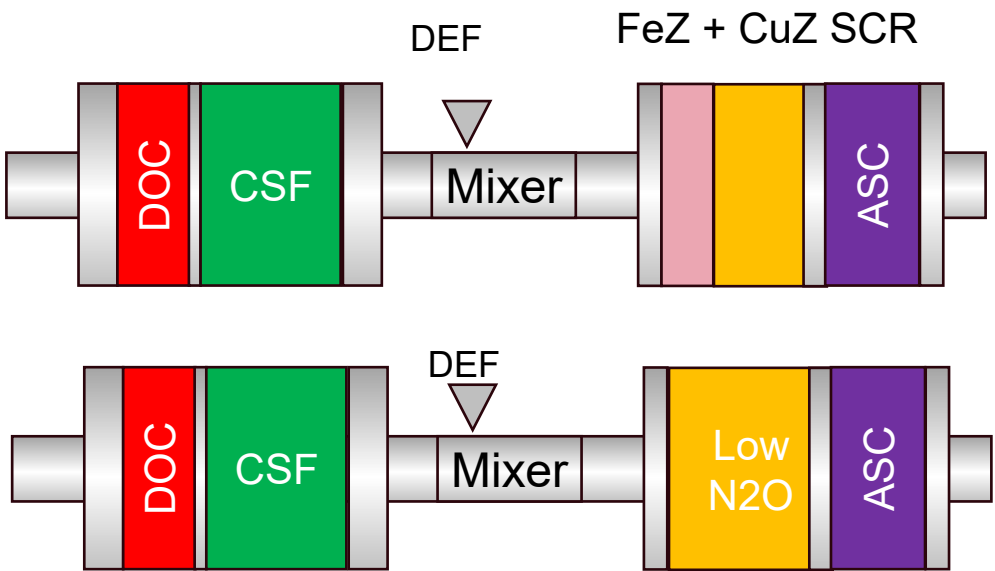
Dual dosing for better CO₂ Control and meet potential FE targets.
cc-SCR may remain prime path.
VSCR is not a must to meet relaxed N₂O targets.

Single Dosing System

- Secondary Filter (ASCoF) might be required for mitigating NH₃ Particulates Number.
- Fe-Z + Cu-Z Zoned SCR.
- VSCR or Low N₂O Cu-SCR as a singular technology.

Pathways for Euro VII

- PN₁₀: Advanced Substrates or CSF + technologies are adequate to meet PN₁₀ regulations.
- EO NO_x > 10 g/kwh – dual dosing strategy
- EO NO_x < 10 g/kwh – single dosing strategy
- Passive systems with 10 g/cft are in the market
- Active systems with up to 15 g/cft in the market



EUVII – Emission Legislation – Heavy Duty



- ❑ EUVI emission testing procedures will be carried-over, only changing the RDE power threshold to 6%.
- ❑ PN₁₀ is being maintained from the Commission’s proposal which is raising concerns about PN emissions from urea dosing.
- ❑ Durability requirements with additional lifetime for EUV
An emission multiplier will be applied, which is only defined for M1, N1 and M2 so far. Factor is 1.2.
- ❑ Introduction timeline:
 - ❑ 48 months (new type approvals) → 29.05.2028
 - ❑ 60 months (new vehicles) → 29.05.2029

Emissions	Euro VIe WHTC	Euro VII WHSC and WHTC	Euro VII Real Driving Emissions (RDE)
NO _x in mg/kWh	460	200	260
PM in mg/kWh	10	8	-
#/kWh	PN ₂₃ 6x10 ¹¹	PN ₁₀ 6x10 ¹¹	PN ₁₀ 9x10 ¹¹
CO in mg/kWh	4000	1500	1950
NMOG in mg/kWh	160 (THC)	80	105
NH ₃ in mg/kWh	10 (ppm)	60	85
CH ₄ in mg/kWh		500	650
N ₂ O in mg/kWh	N/A	200	260

Durability	M1, N1 and M2	N2, N3≤16 t, M3≤7,5 t	N3>16 t, M3>7,5 t
Lifetime EUVI	160 kkm or 5 years	300 kkm or 6 years	700 kkm or 7 years
Main Lifetime EUVII	160 kkm or 8 years	300 kkm or 8 years	700 kkm or 12 years
Additional Lifetime EUVII	200 kkm or 10 years	375 kkm or 10 years	875 kkm or 15 years



Background

- BASF-ECMS is committed to addressing the global challenge of reducing air pollution from internal combustion engines.
- We continuously develop innovative catalyst technologies and formulations to improve performance, durability, and overall system robustness while reducing total cost of ownership.
- With the introduction of Euro VII regulations and increasingly stringent real-world emission requirements, achieving ultra-low NOx emissions while controlling N₂O formation has become a key industry focus.
- Adv V-SCR technology is being evaluated as a promising solution to deliver superior low-temperature NOx conversion while maintaining low N₂O selectivity.
- Compared with conventional Cu-zeolite SCR systems, Adv V-SCR offers significant advantages in N₂O control, making it an attractive pathway for future Euro VII and BS VII applications.
- Ensuring long-term thermal durability and sustained performance under severe operating conditions remains a critical engineering consideration



Agenda

- ❑ **Main Advantages of Adv V-SCR from Euro VII perspective**
- ❑ **Steady state performance Evaluation**
 - ❖ Impact of Space Velocity on De-NO_x Performance
- ❑ **ANR Sweep Testing under WHTC Conditions**
 - ❖ Performance Assessment Across Different ANR Levels
 - ❖ Performance Assessment Across Different Space Velocities



Adv V-SCR catalysts for Improved NOx performance

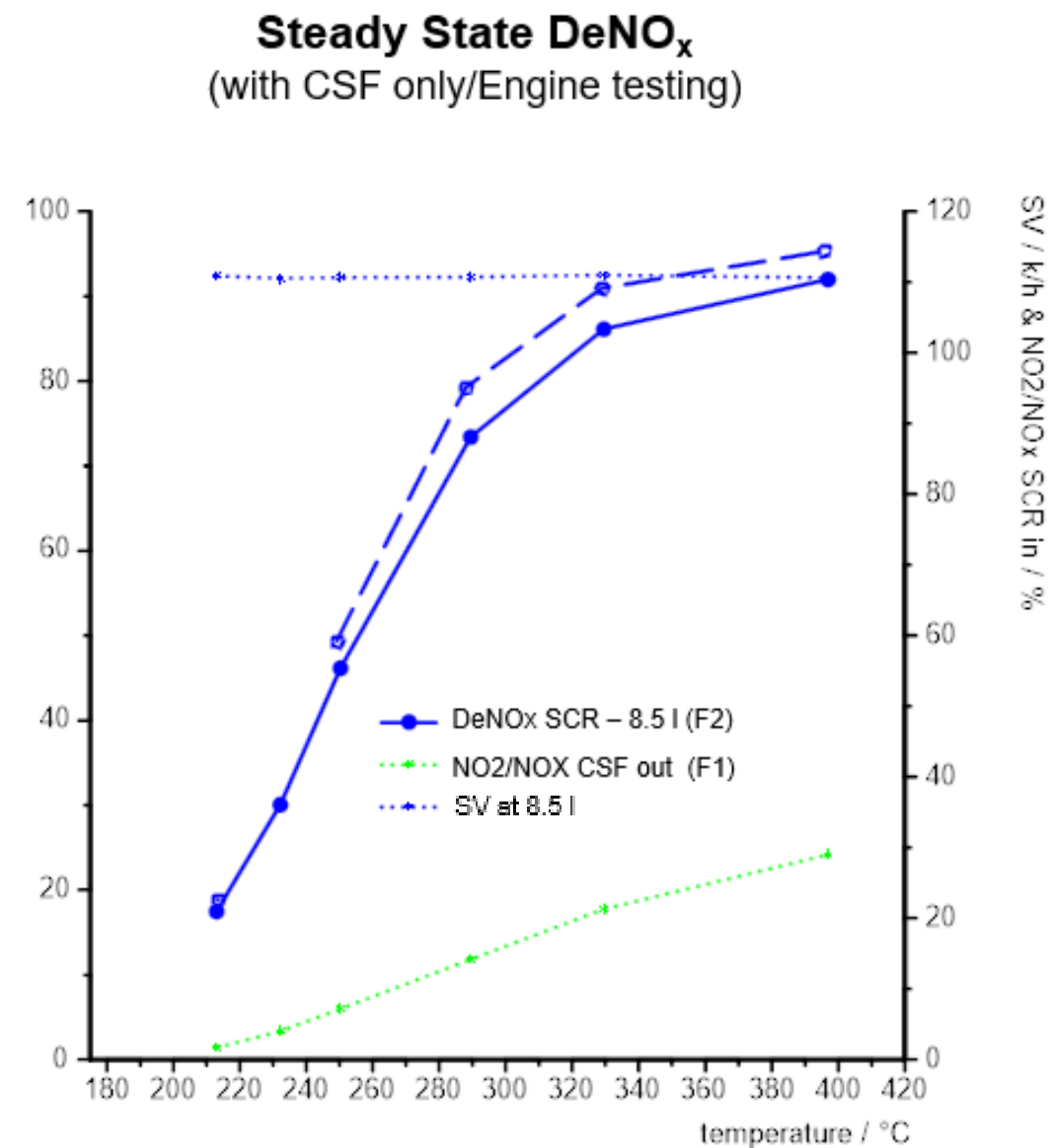
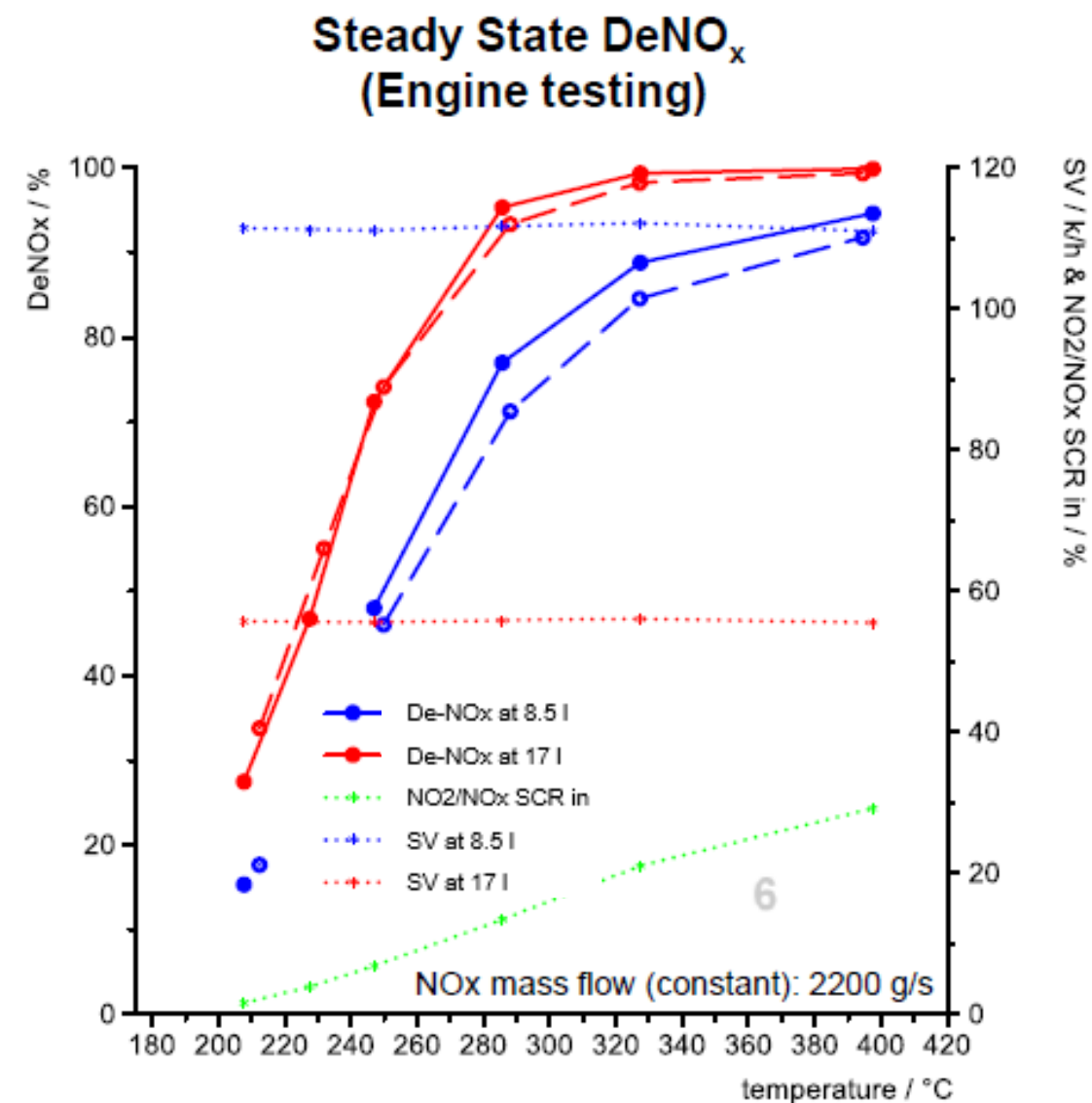
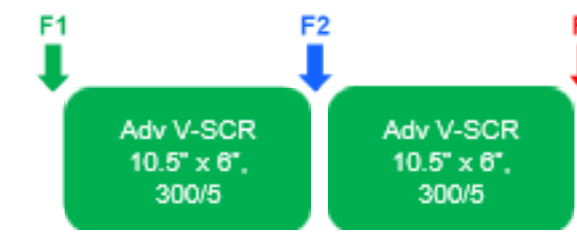


Adv V-SCR Technology for Ultra-Low NOx

- ❑ Optimized for highest de-NOx at low temp
- ❑ Technology fully industrialized and in mass production in Europe, the USA and China
- ❑ No issues observed in daily vehicle operation of trucks
- ❑ High S-tolerant and no dedicated De-SOx strategy is needed
- ❑ Adv V-SCR can act as fuel burn catalyst.



Adv V-SCR Technology for Ultra-Low NOx : *Steady State point evaluation*



solid: fresh/degreened
open: aged (100h/580°C HT)

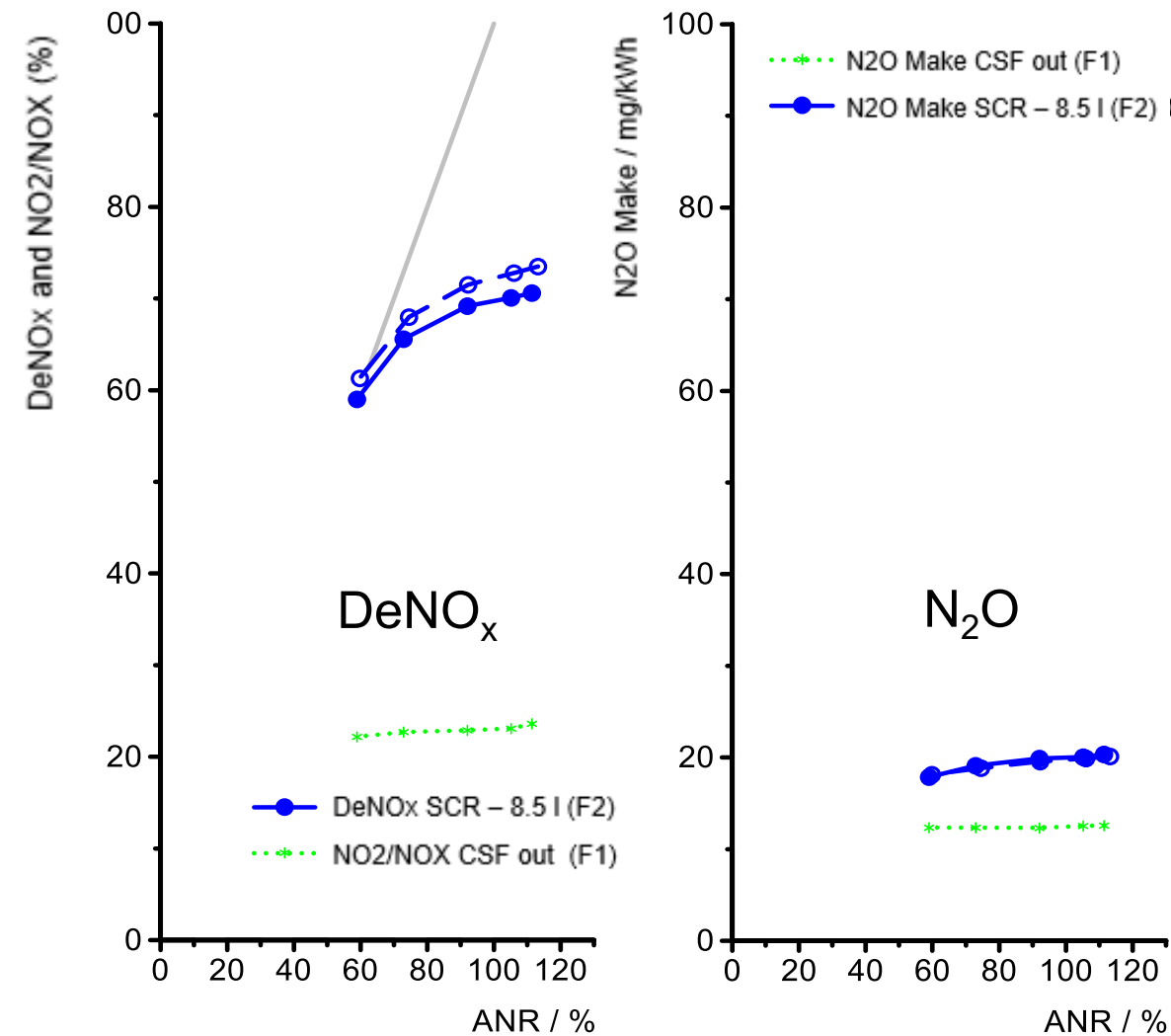
- De-NOx: **20% to >90%** at SV ~110k h⁻¹.
- ~10 to 20% De-NOx improvement at SV ~55k h⁻¹.
- Comparable fresh and aged performance at all SV
- Strong dependence of performance on space velocity.
- Excellent low-temperature activity.
- Higher catalyst volume significantly enhances NOx conversion

Take away: Adv V-SCR delivers robust NOx conversion across a wide temperature window with clear benefits at lower SV

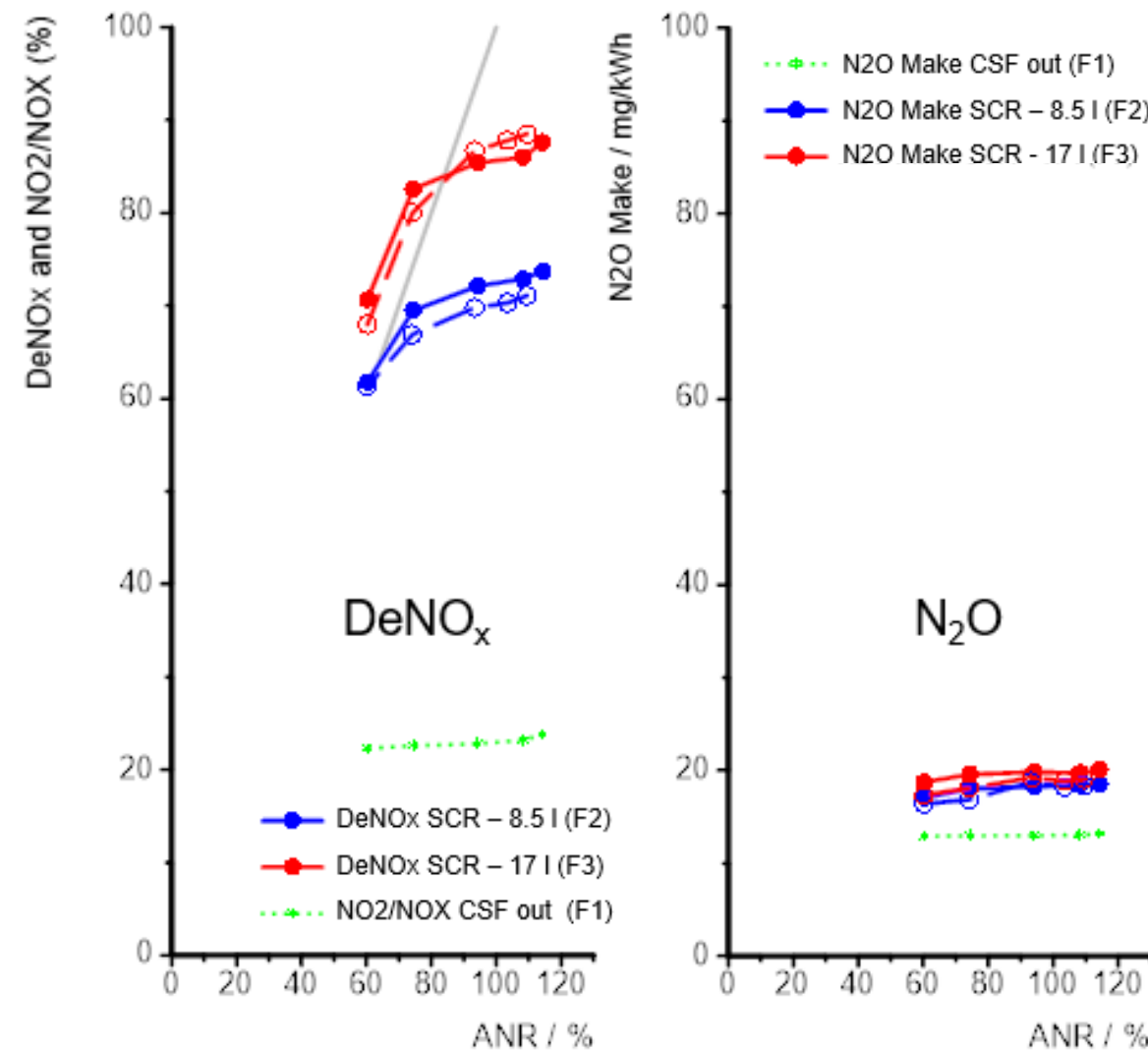
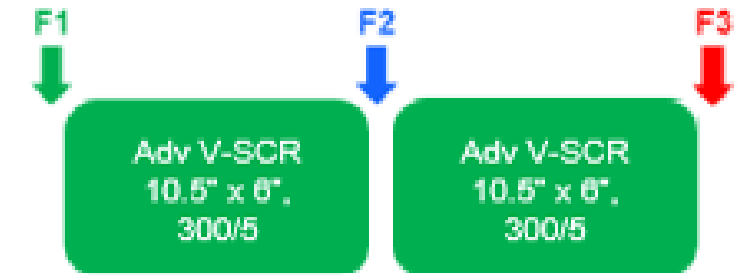


Adv V-SCR Technology under Transient conditions: WHTC ANR Sweep test & SCR Volume impact on the performance

WHTC ANR Sweep
(with DOC/CSF)



WHTC ANR Sweep
(with DOC/CSF)



solid: fresh/degreased
open: aged (100h/580°C HT)

solid: 300/5

open: 400/4

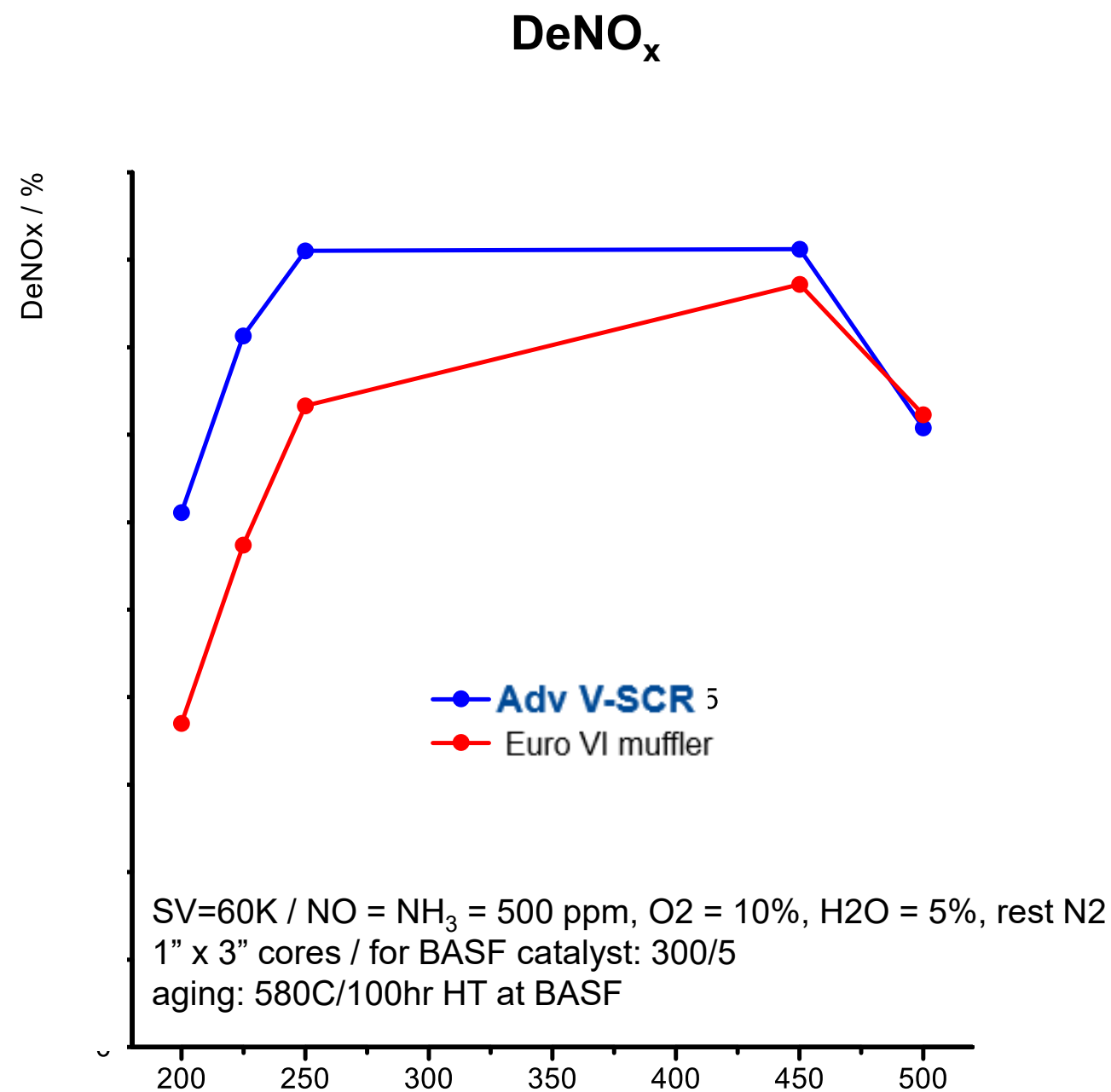
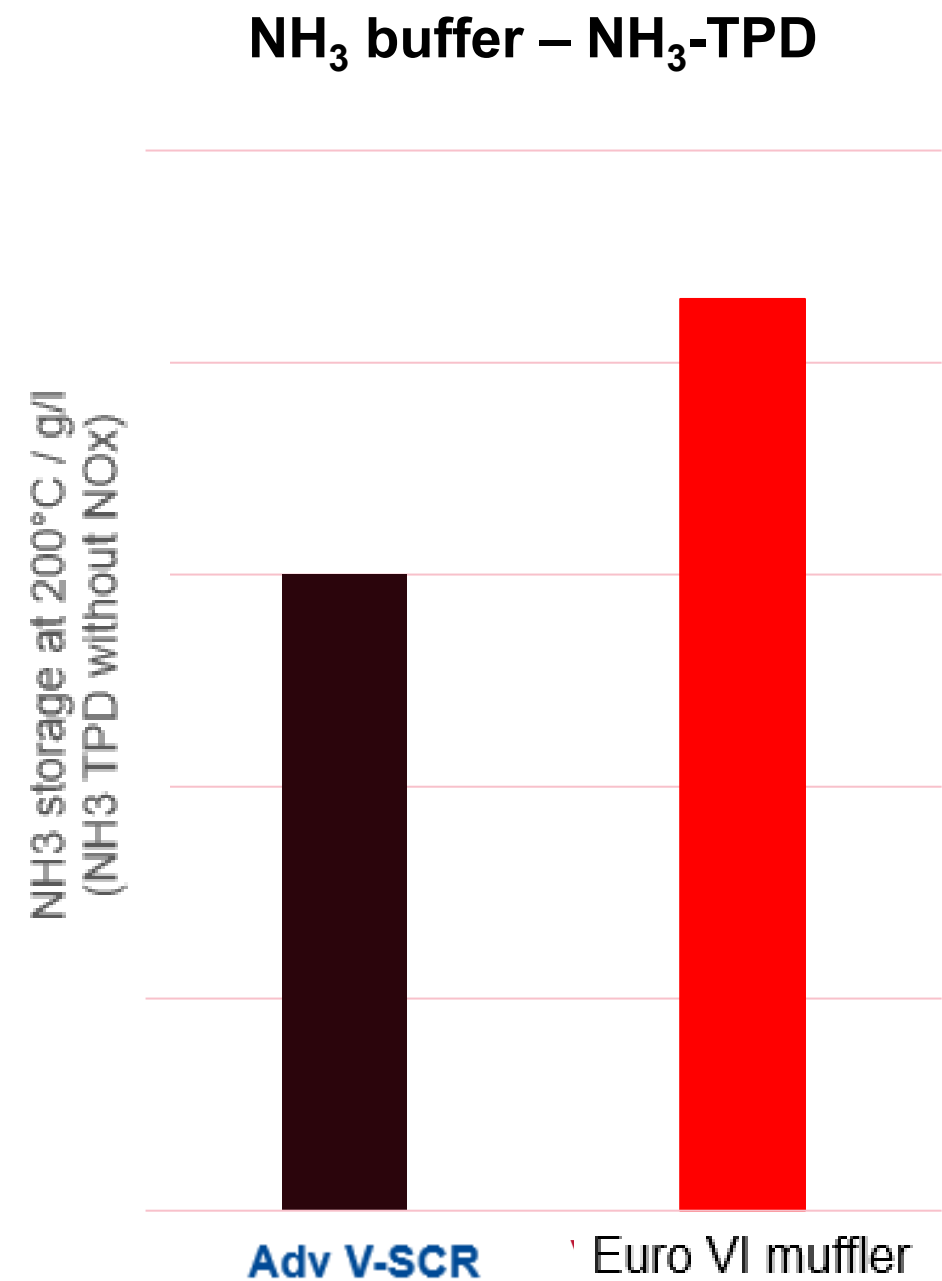
- Around 20% delta p benefit was seen with 300/5 in comparison to our in-house technology
- ANR range: **0.6 to 1.2**
- NO₂/NO_x ≈ **20%**
- Evaluated at **110k and 55k h⁻¹ SV**.
- De-NO_x improvement:
 - ❖ ~10% at low ANR
 - ❖ Up to ~20% at high ANR
- N₂O emissions consistently **<20 mg/kWh**.

Take away:

- ❖ Adv V-SCR delivers robust NO_x conversion across a wide temperature window with clear benefits at lower SV.
- ❖ Excellent NO_x-N₂O trade-off across the complete ANR range.



Performance Comparison: Adv V-SCR showed Performance Advantage vs. Reference SCR From European Market



Adv V-SCR
1" x 3", 300/5
aged

blue: Adv V-SCR on 300/5
red: EUVI muffler

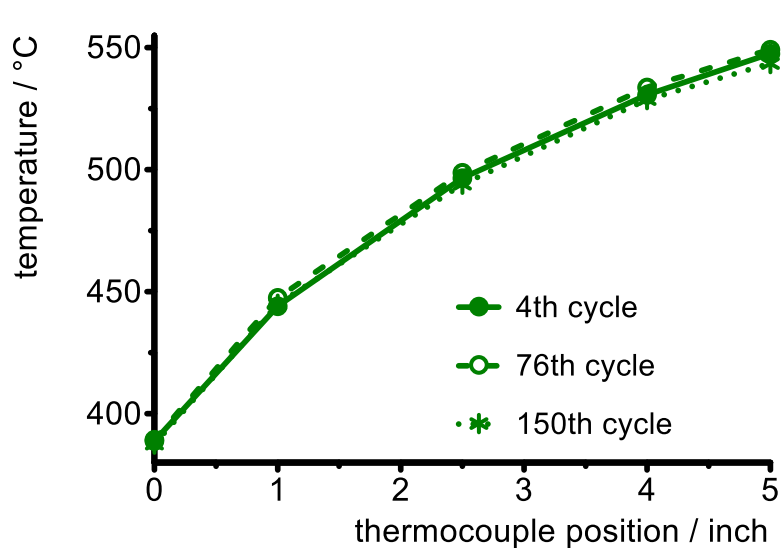
Take away:
❖ Improved low temp performance even with lower NH₃ storage



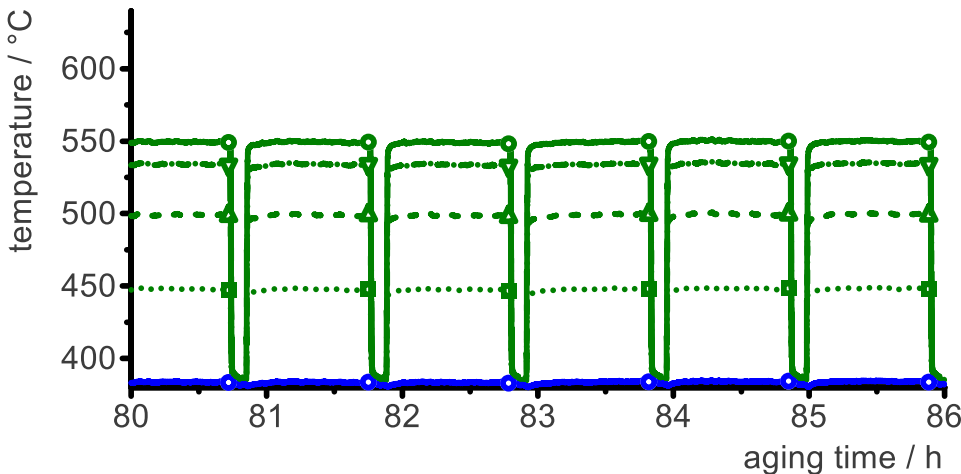
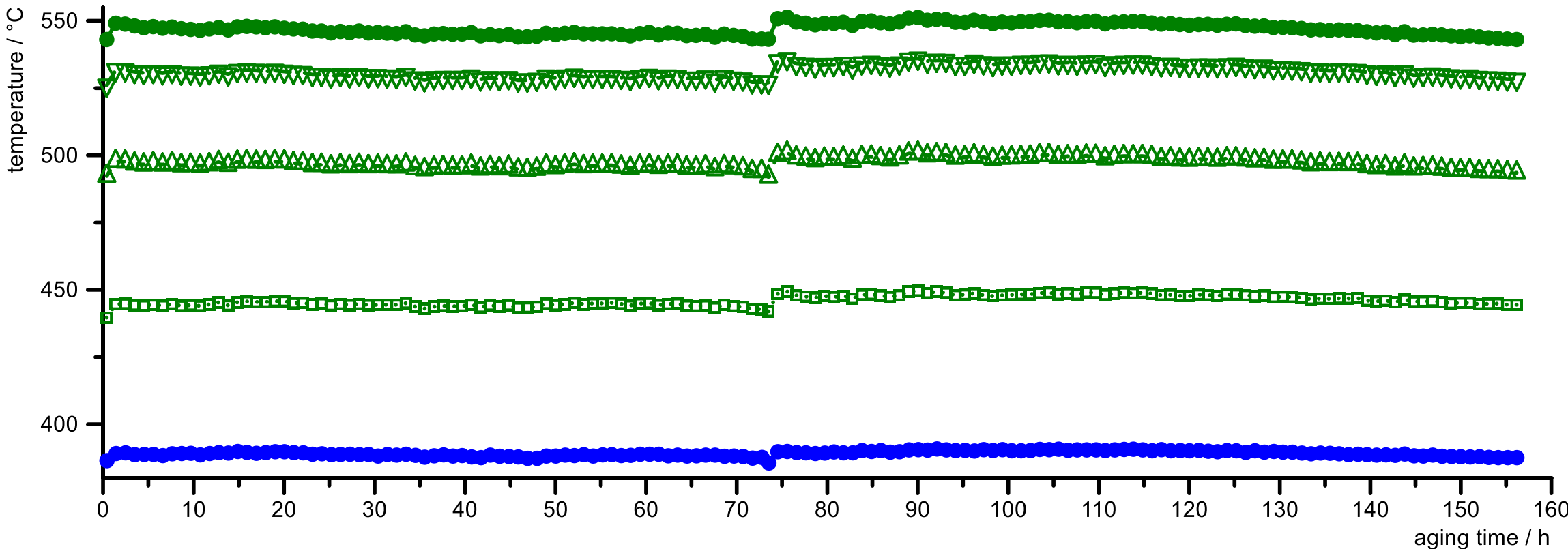
Adv V-SCR catalysts for Fuel Burning



Fuel Burning Aging : *Stable Fuel Burning Conversion Inside the V-SCR Catalyst*



position / inch	T(4th cycle) / °C	T(76th cycle) / °C	T(150th cycle) / °C
0	389	389	388
1	444	448	445
2,5	497	499	494
4	531	534	529
5	548	549	544

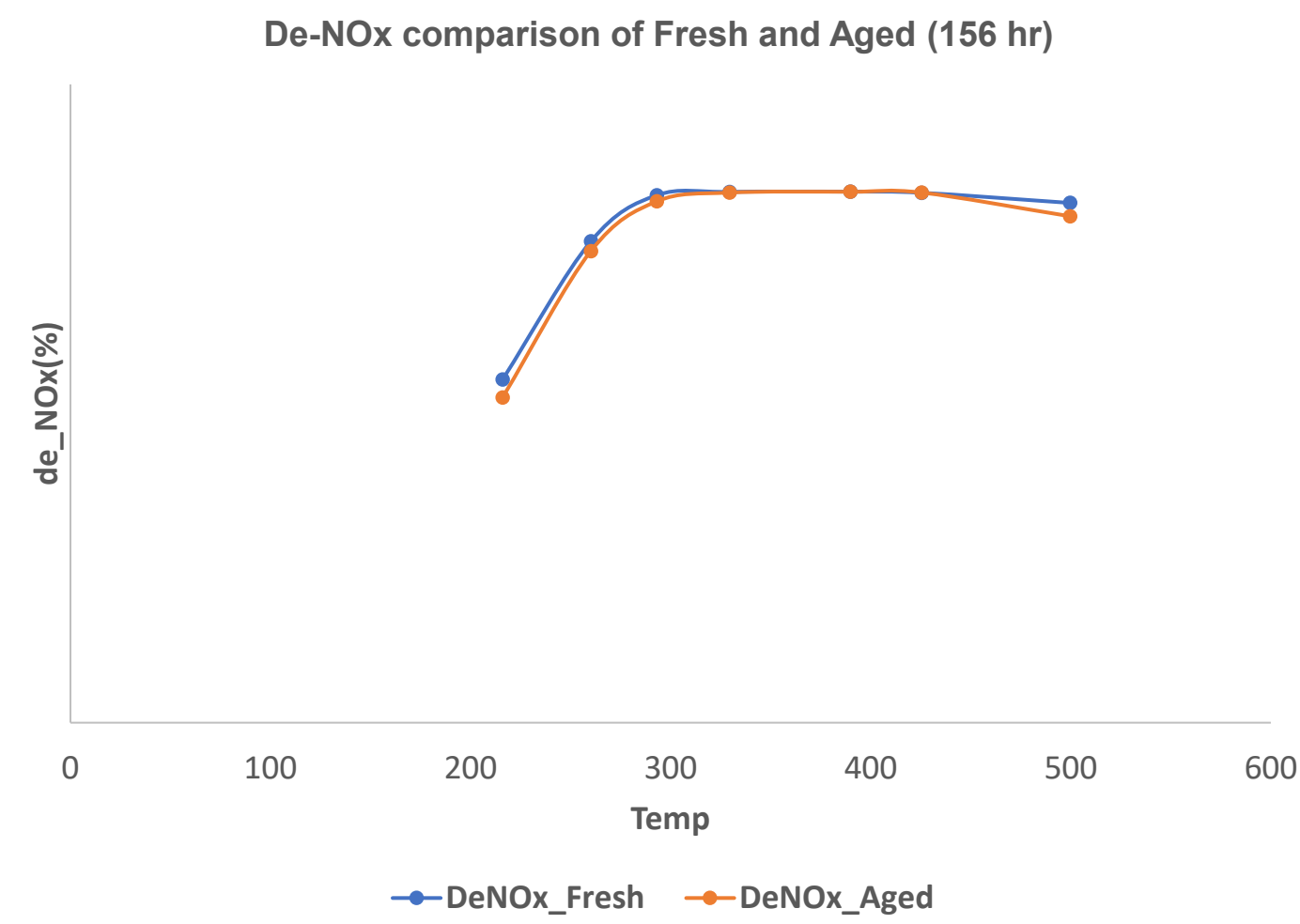


$T_{pre\ SCR} = 389^{\circ}C$
exhaust mass flow = 621kg/h
conc. H_2O SCR out = 10.7%

- Tests with de-greened V-SCR
- Aging cycle:
 - 55min fuel dosing on
 - 5min fuel dosing off
 - $T_{SCR\ in} = \sim 390^{\circ}C$ (avg.)
 - target: $T_{SCR\ out} = 550^{\circ}C$
- No indication for any aging
- Stable heat generation during fuel burning
- No indication for loss of active sites



Steady State DeNOx Performance of Adv V-SCR after 156 hr fuel burning



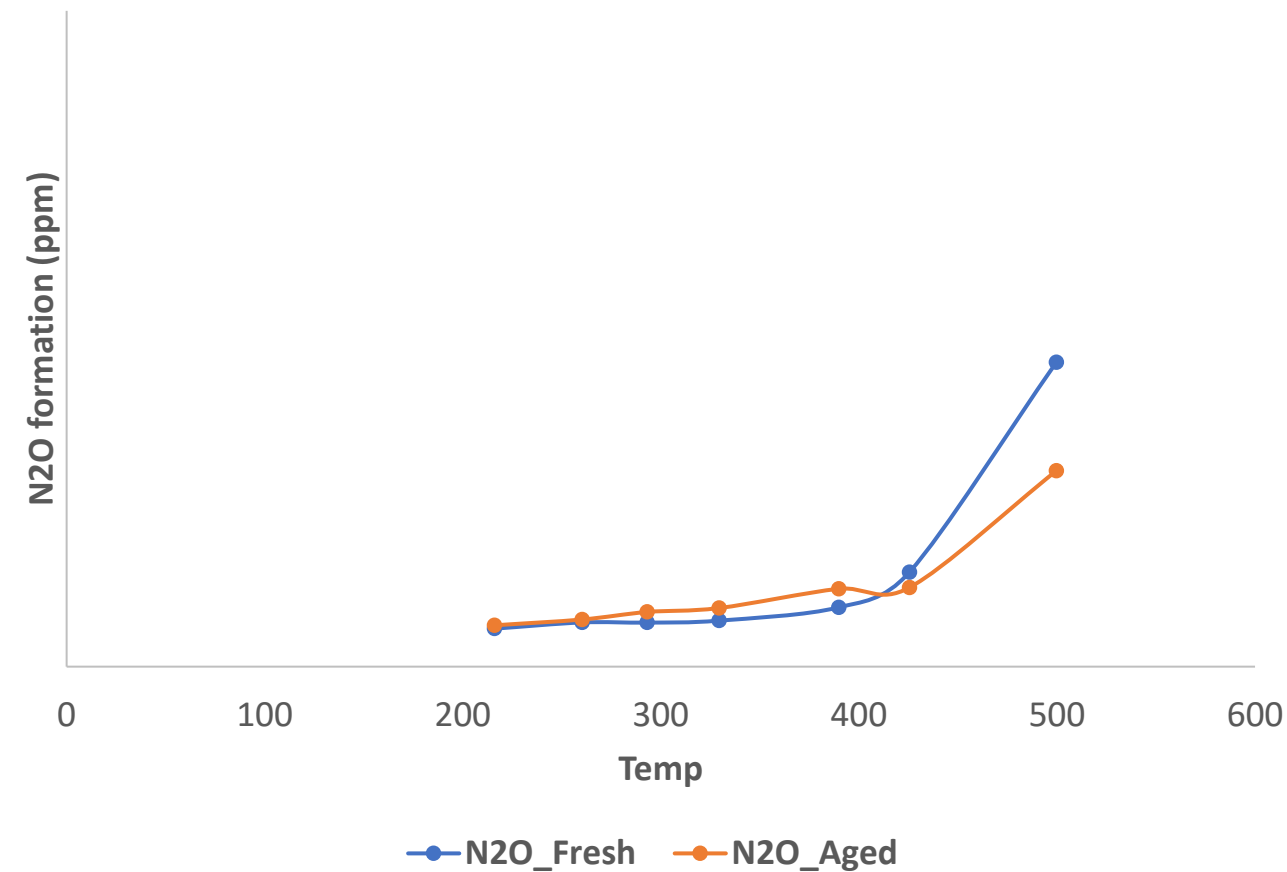
- ❑ 156-hour fuel-burn aging at **550°C target temperature**.
- ❑ NOx conversion largely retained after aging.
- ❑ Demonstrates strong thermal durability.

*Similar ANR, mass flow and temperatures for both tests.

Take away: Adv V-SCR maintains robust De-NOx performance following severe fuel-burn aging

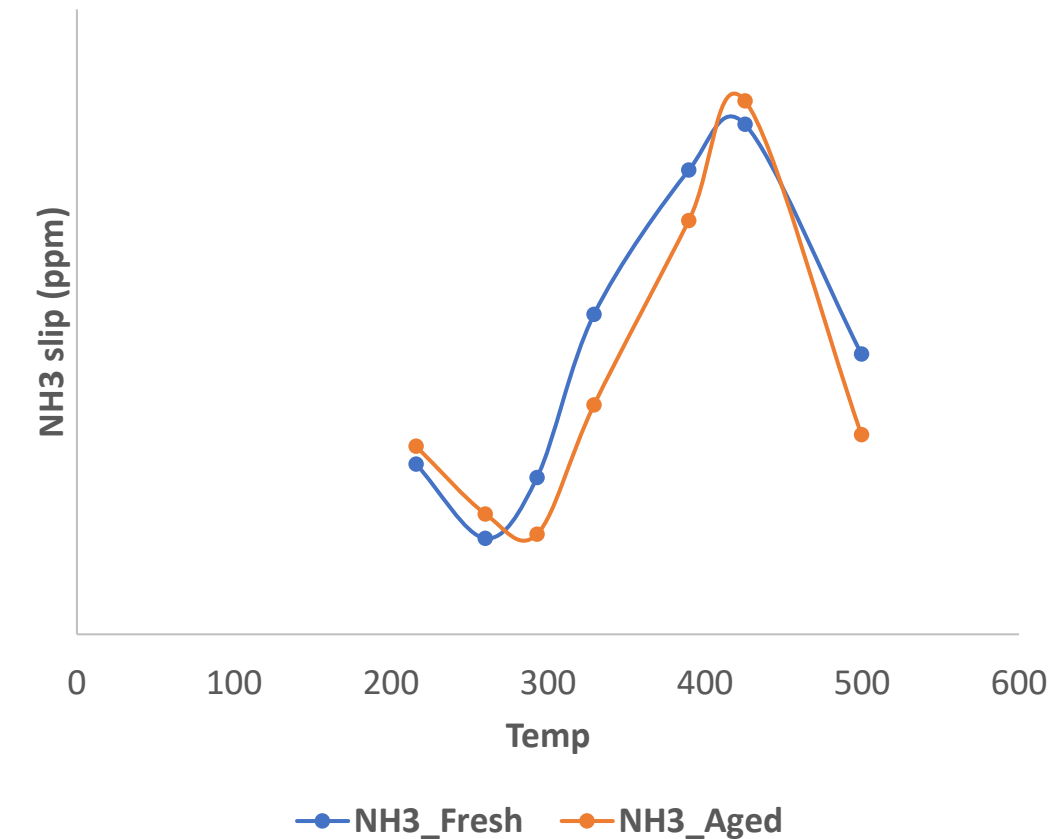
Steady State NH_3 Slip & N_2O formation over Adv V-SCR after fuel burning

N_2O formation_Fresh Vs Aged (156 hr)



- ☐ N_2O formation increases at elevated temperatures due to NH_3 oxidation.
- ☐ No significant increase in N_2O observed after aging.
- ☐ NH_3 slip remained well controlled across the temperature window

NH_3 slip_Fresh Vs Aged (156 hr)



- ☐ N_2O formation on both fresh and aged is similar
- ☐ Only a marginal increase in N_2O formation with increasing ANR
- ☐ Excellent balance between NO_x conversion and N_2O control

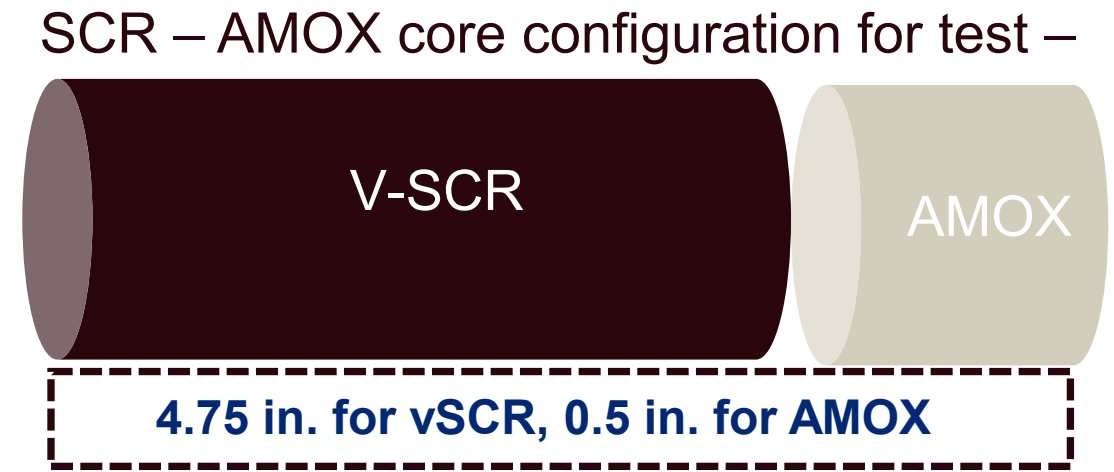
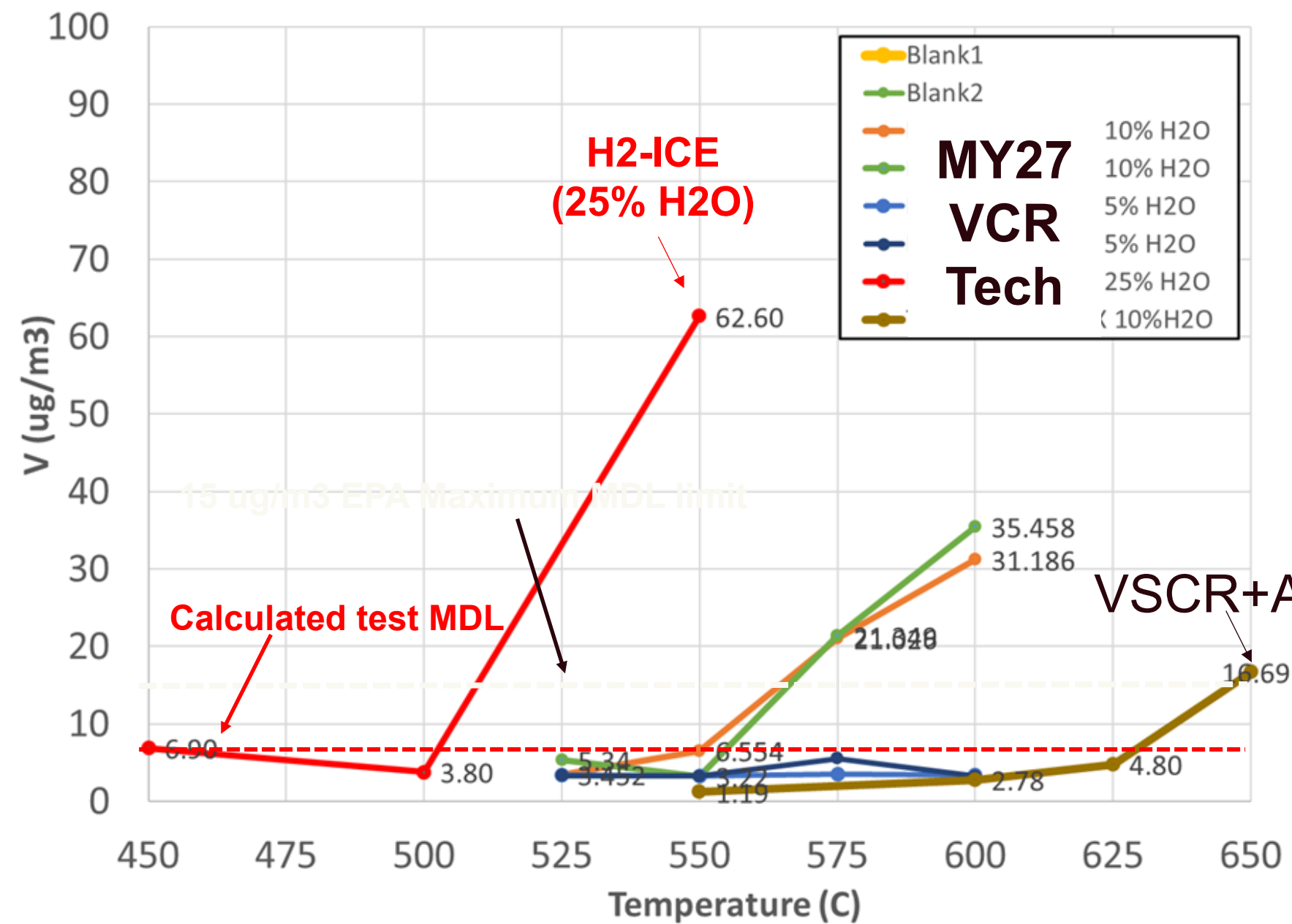
Take away: Fuel-burn aging has minimal impact on NH_3 slip and N_2O selectivity

High temp Sublimation temp of Adv V-SCR



Third Party V Sublimation Testing Result

Gas-flow →



- Vanadium sublimation below MDL up to 550°C
- Sublimation increases above 550°C
- SCR + AMOX sizing representative of current US MY2027 architecture
- Downstream AMOX increases the system sublimation threshold
- Results align closely with BASF internal validation data

Take away: Adv V-SCR demonstrates excellent thermal stability with negligible vanadium sublimation up to 550°C. Integration of AMOX further enhances high-temperature robustness.

Conclusion on Main SCR Selection:

Adv V-SCR Being the Recommended Catalysts

- ❑ Best-in-class De-NOx performance at low backpressure.
- ❑ Strong low-temperature activity.
- ❑ Minimal performance loss after aging.
- ❑ Stable performance under steady-state and transient conditions.
- ❑ Excellent NOx/N₂O balance.
- ❑ Mature technology with proven commercial deployment in Europe, North America, and China.



Thank you

