BSVII Exhaust Aftertreatment Architecture Derived from EU7 Regulatory Learnings

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Jim Elkjær Bebe

Dinex.net

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Dinex Product Portfolio and Capabilities

Canning and catalyst technologies

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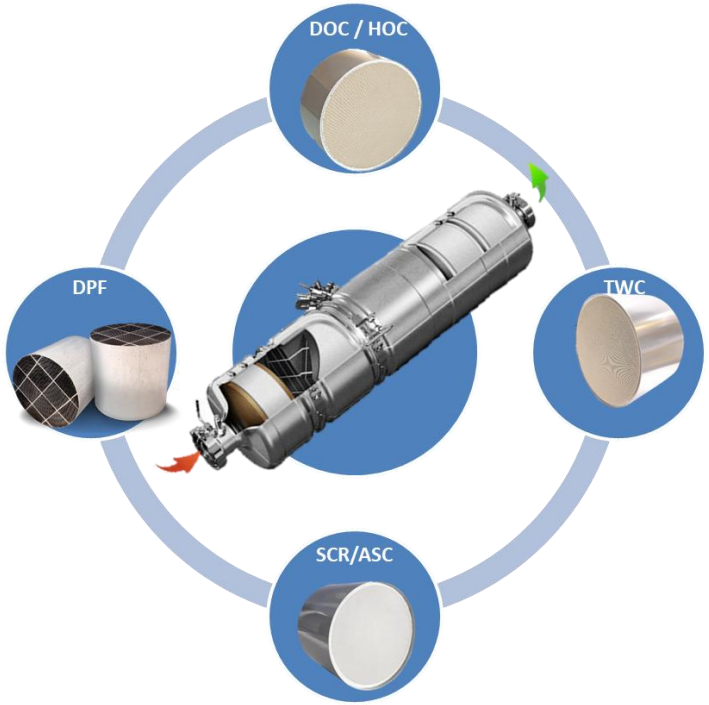
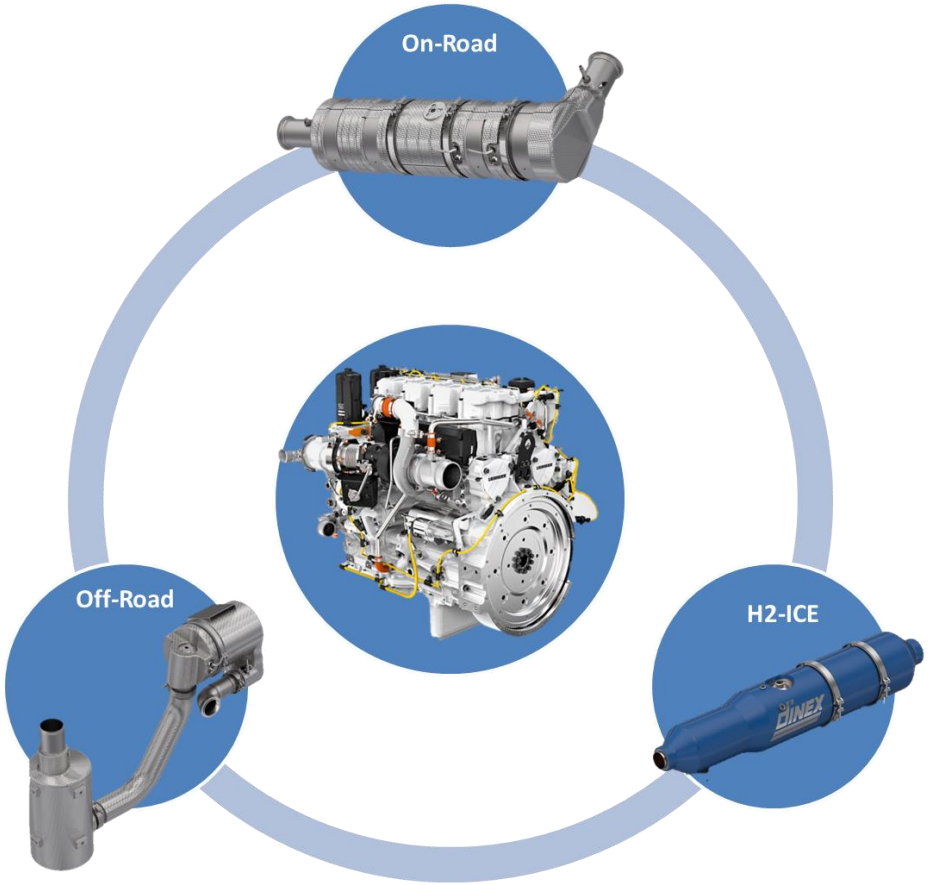
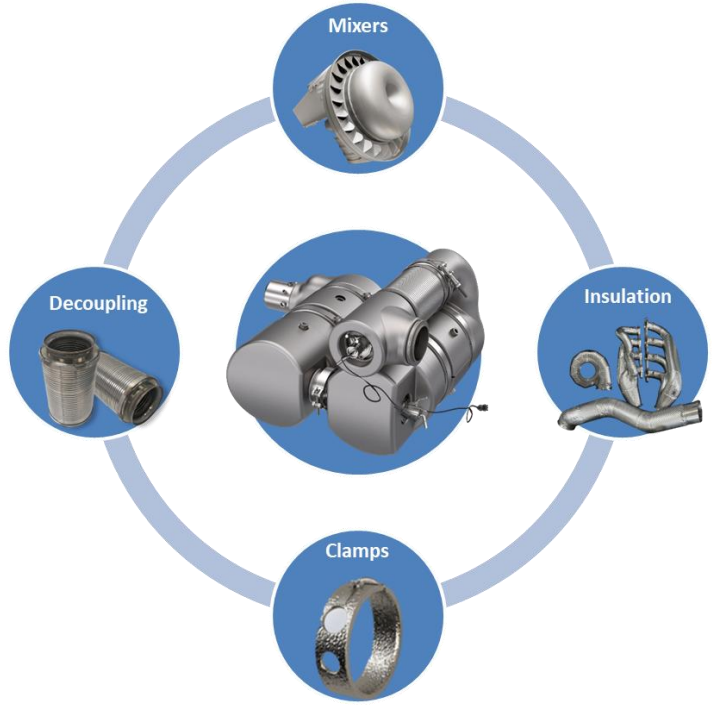
CATALYST – DIESEL, CNG & H2 ICE



ATS



CANNING & PIPES



Agenda

- EU7 take-aways and BSVII
- BSVI to BSVII
  - Baseline
  - E-heater + single stage SCR
  - 2-stage SCR
  - Overview
- Packaging challenges and integration
  - Mixer packaging optimization
- Dinex Cold Performance Concept
- Conclusions

EU7 take-aways and BSVII

Two prevalent paths for exhaust gas aftertreatment systems are being pursued

- 1-stage SCR system in combination with electrical heater
  - Pros: Relatively lighter, lower pressure drop, comparably less SCR volume, no additional instrumentation
  - Cons: Requires separate electric circuit, durability less certain
- 2-stage SCR
  - Pros: Known elements, proven durability
  - Cons: Increased weight, pressure drop, requires 2 injectors, more sensors

Regulatory limit comparison

	BSVI limits	BSVII limits
CO	4000 mg/kWh	1500 mg/kWh
THC/NMOG	160 mg/kWh	80 mg/kWh
NOx	460 mg/kWh	200 mg/kWh
NH_3	<10 PPM	60 mg/kWh
N_2O	Unregulated	200 mg/kWh

Significant reduction in TP NOx needs to be achieved

N2O limit will have an influence on SCR selection

The BSVI Baseline

	BSVI limits	Series product
CO	4000 mg/kWh	260 mg/kWh
THC	160 mg/kWh	60 mg/kWh
NOx	460 mg/kWh	250 mg/kWh

BSVII 1-stage SCR w. e-heater

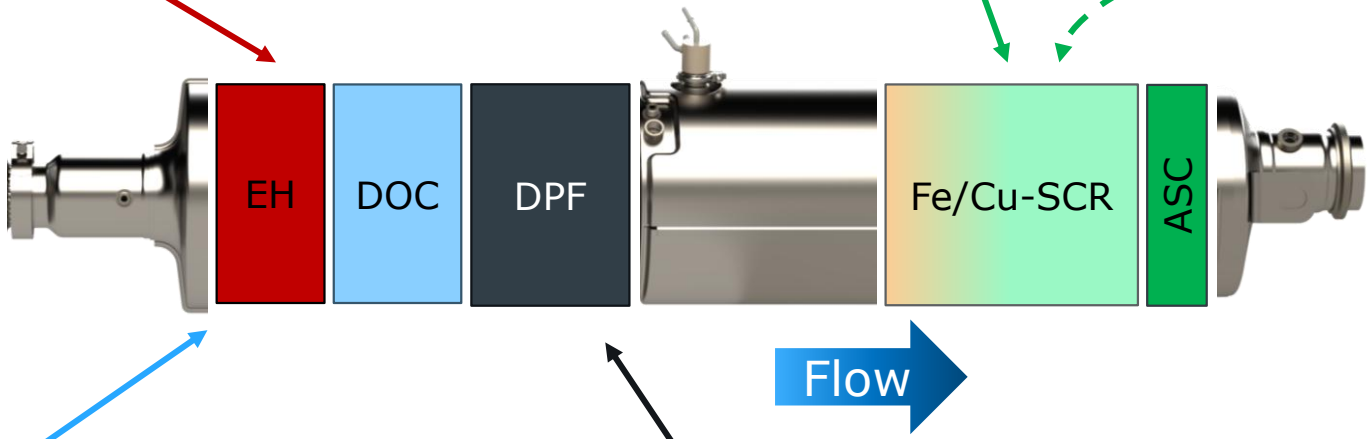
- ✓ Electric heater for speedier SCR light-off, 4kW peak power assumed for best performance cost compromise

- ✓ Highest NO_x conversion
- ✓ Zeolite based SCR with high thermal durability, suitable for hot exhaust gas
- ✓ Control of N_2O formation via advanced Cu-zeolite or via Fe-/Cu-SCR formulation

Alternative

V-SCR & Cu-SCR

- ✓ Combination of V-SCR & Cu zeolite for simultaneous control of N_2O formation & high NOx conversion (best compromise Vs cost)



- ✓ PGM load 10 – 20g/cft depending on regen. strategy

- ✓ Cordierite DPF
- ✓ PGM load 1 – 3g/cft
- ✓ Alternative: Dinex high-porosity SiC filter

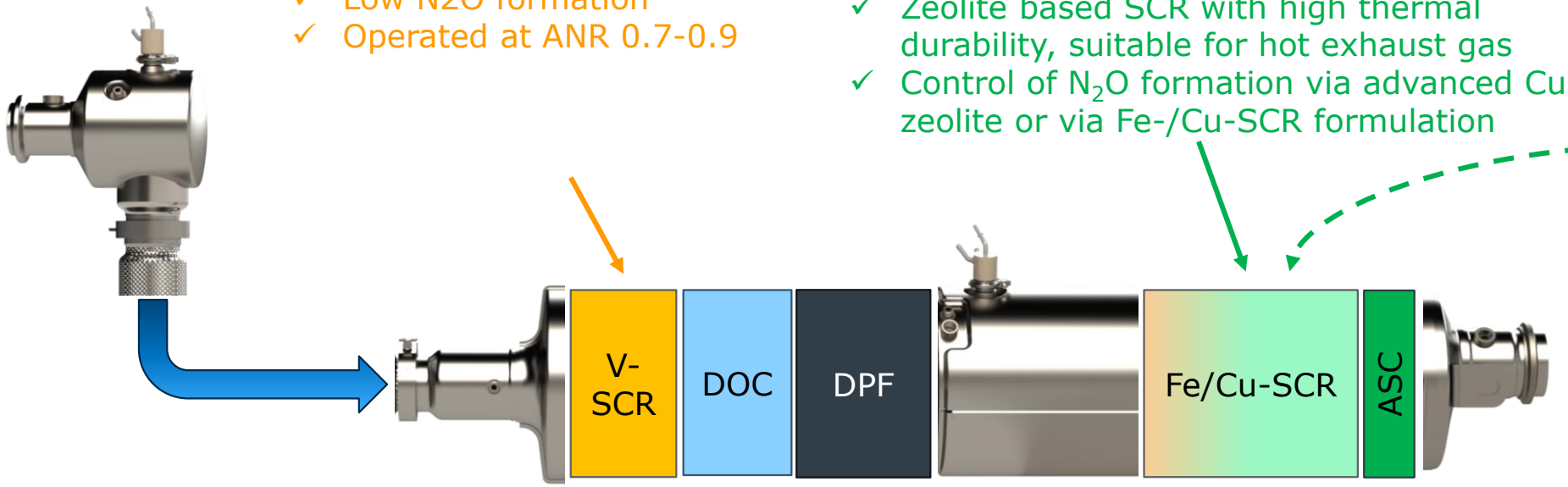
BSVII 2-stage SCR

- ✓ Low N2O formation
- ✓ Operated at ANR 0.7-0.9

- ✓ Highest NO_x conversion
- ✓ Zeolite based SCR with high thermal durability, suitable for hot exhaust gas
- ✓ Control of N_2O formation via advanced Cu-zeolite or via Fe-/Cu-SCR formulation

Alternative

V-SCR & Cu-SCR



- ✓ Combination of V-SCR & Cu zeolite for simultaneous control of N_2O formation & high NOx conversion (best compromise Vs cost)

- ✓ PGM load 10 – 20g/cft depending on regen. strategy

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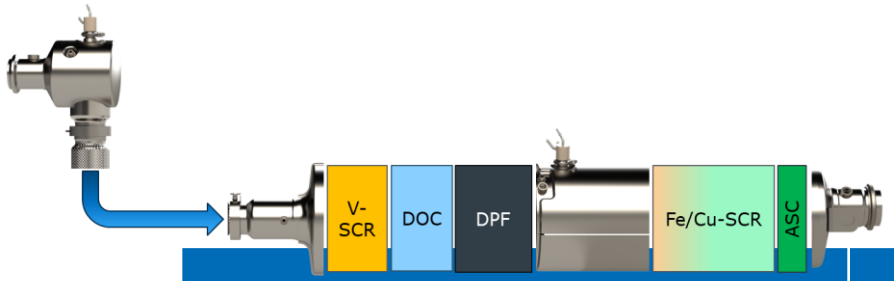
NOx conversion performance

1-stage SCR + EH vs 2-stage SCR

Ø ANR: 1.15 | Injection release: 180 °C

	WHTC cold	WHTC hot	WHTC combined 14:86	N_2O
NOx reduction SCR	93.3%	98.9%	98.1%	--
TP emission, g/kWh	0.65	0.12	**0.19**	**0.18**
t_{inj} start SCR, s	104	0	--	--



Ø ANR_{SCR1}: 0.75 | Ø ANR_{SCR2}: 1.20 → Ø ANR_{total} 1.08 | Injection release: 180 °C

	WHTC cold	WHTC hot	WHTC combined 14:86	N_2O
NOx reduction SCR1	73.0%	72.5%	72.6%	--
NOx reduction SCR1+SCR2	92.3%	99.4%	98.4%	--
TP emission, g/kWh	0.74	0.09	**0.15**	**0.09**
t_{inj} start SCR1, s	127* (385**)	11	--	--
t_{inj} start SCR2, s	166	0	--	--

**Slight later dosing release can mean the difference between compliance and non-compliance*
***Dosing release sustained from this time*

Architecture Performance Overview

Observations and challenges

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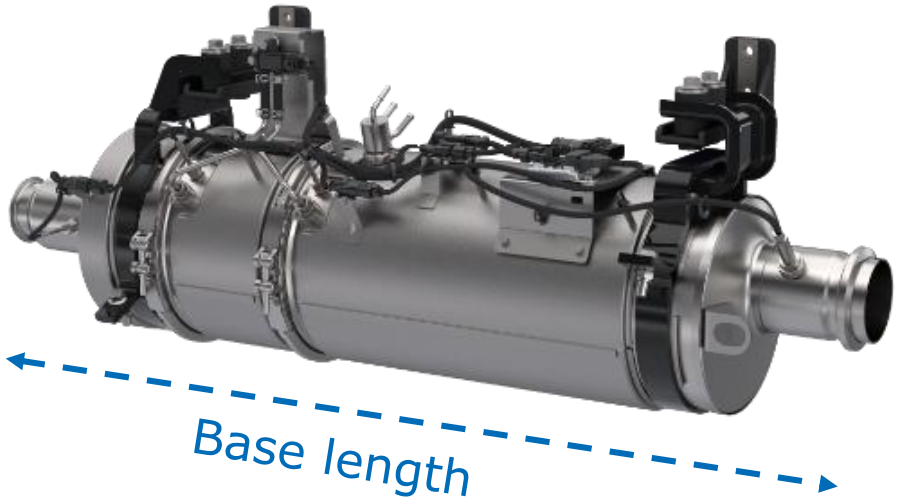
Architecture	Compliance	Advantages
1-stage SCR system w. e-heater	Yes	Fast heat-up, early dosing release
2-stage SCR system	Yes	Good cold-start performance, low N_2O formation

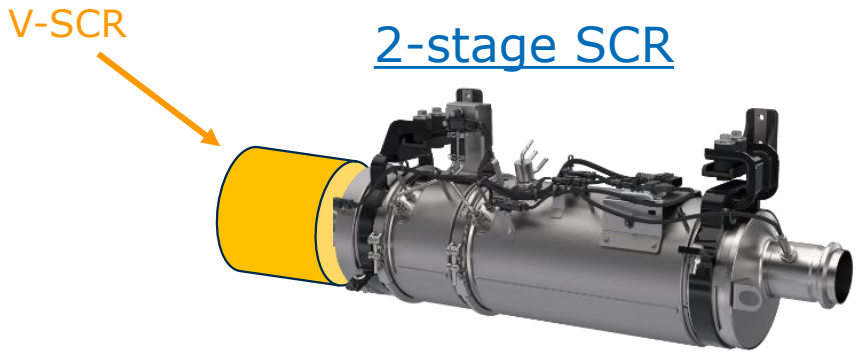
THE PACKAGING CHALLENGE

- Maintaining "base length"



1-stage SCR w. e-heater

2-stage SCR



Compact Evaporation and Mixing Device

Functionality and performance

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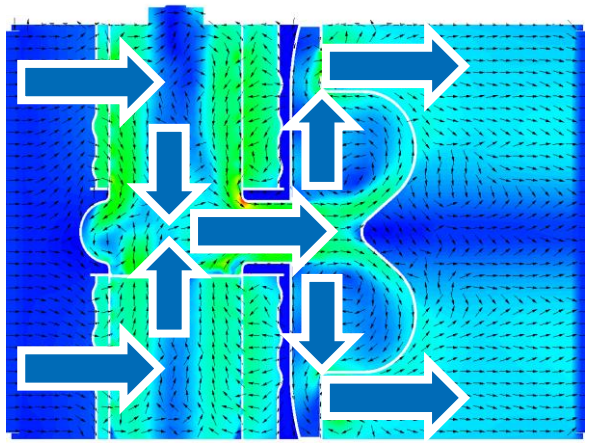
Functionality

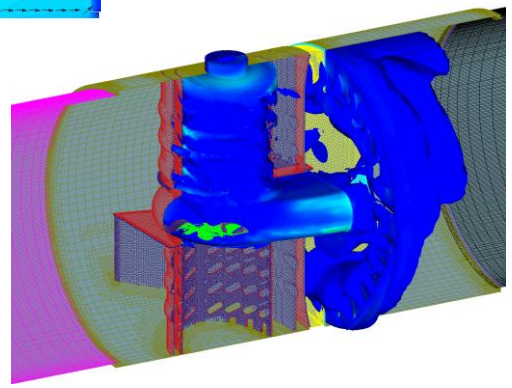


General flowpath:

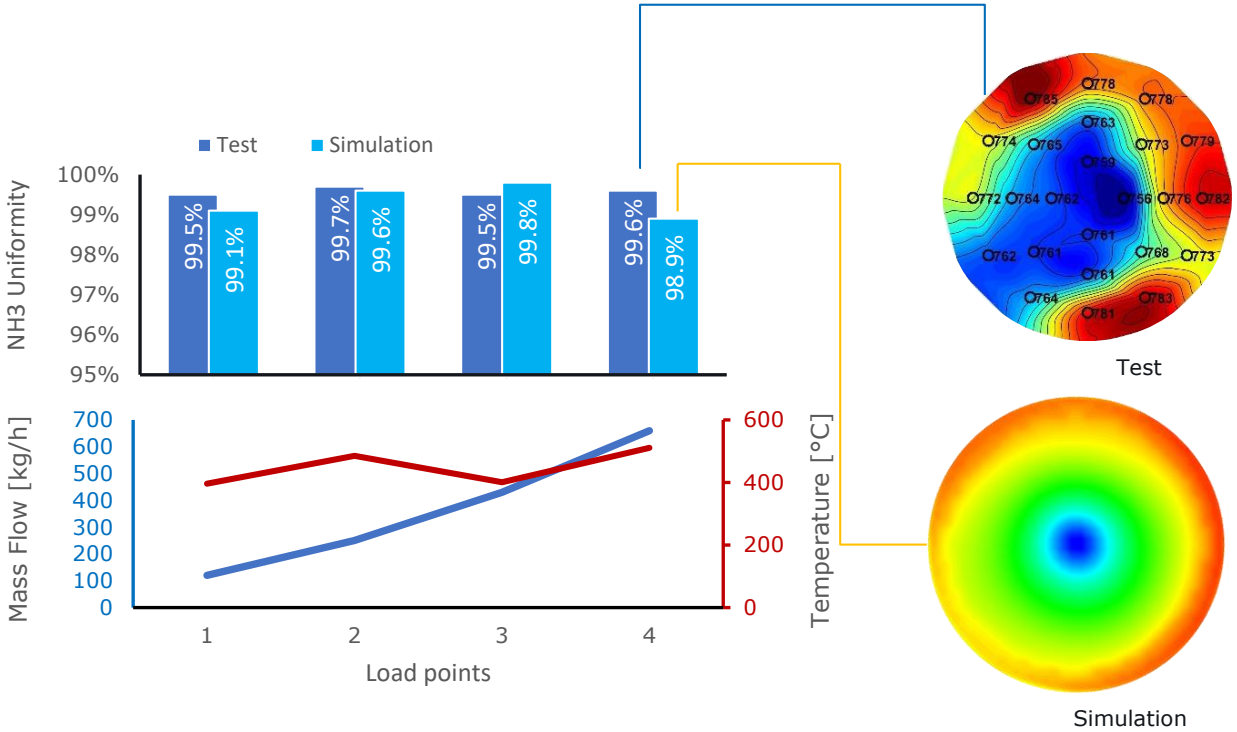
Flow consists of two opposing swirls coming from two inlet sections, top to center and bottom to center, forming a single center outlet to a distribution device.

Gaseous NH3 pathway

Gaseous species are mixed inside the pipe



Performance in current application



Compact Evaporation and Mixing Device

What changes and why it works

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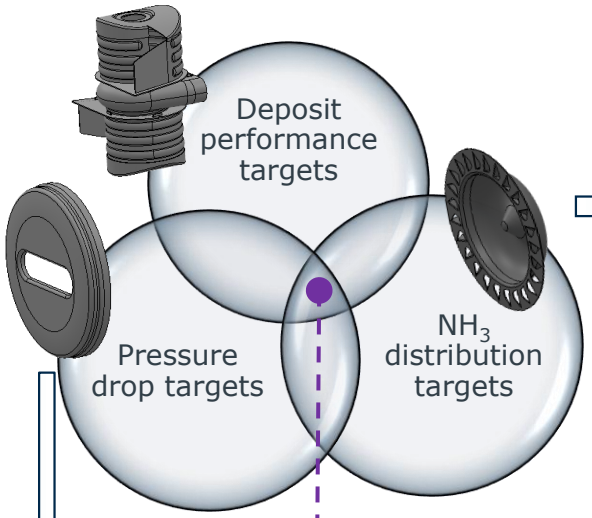
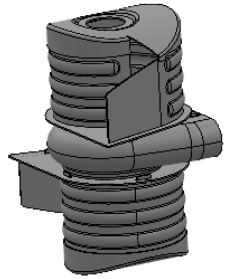
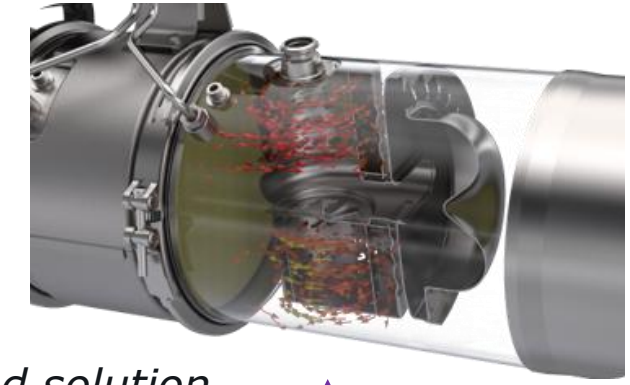
Possibility to customize individual components of the mixer in order to achieve the optimal balance between all performance targets.



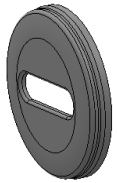


- Enhanced near-injector flow conditions for more efficient evaporation and mixing

- Shallower donut to reduce overall length and improve flow conditions out of swirl baffle



Optimized solution



- *Mixer target is pressure neutrality*

Compact Evaporation and Mixing Device

New package and performance

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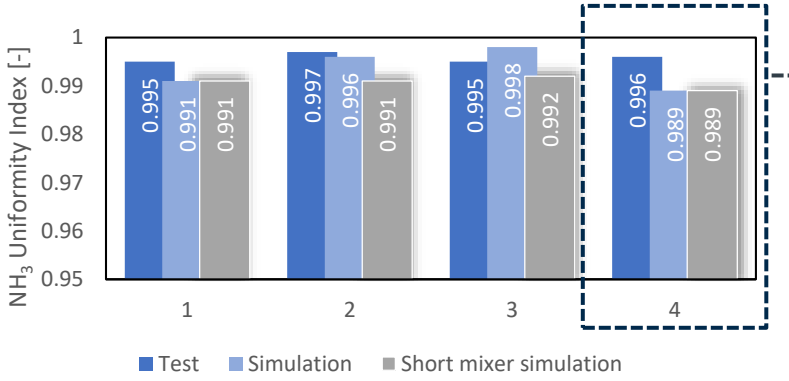
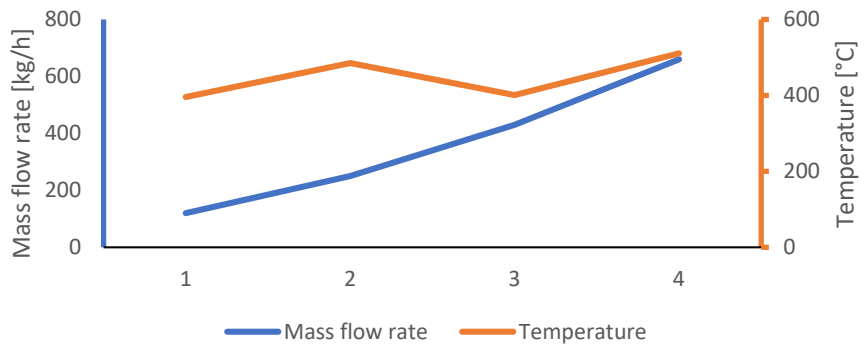
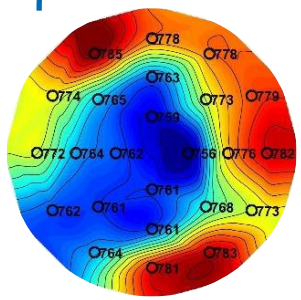
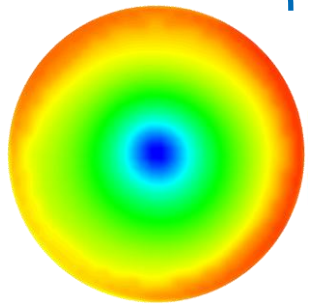
Performance in ”BSVII” application

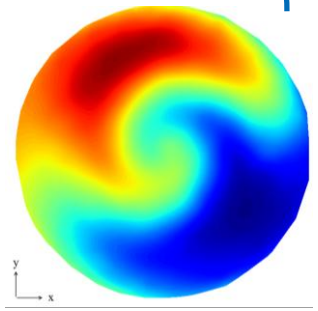




30% length reduction







Test

Simulation

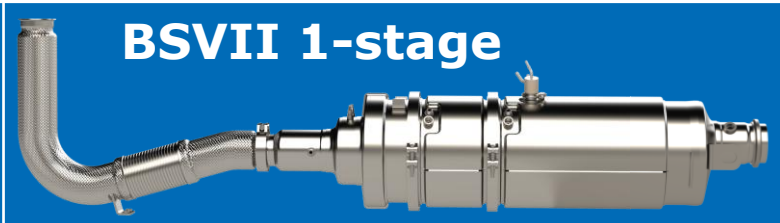
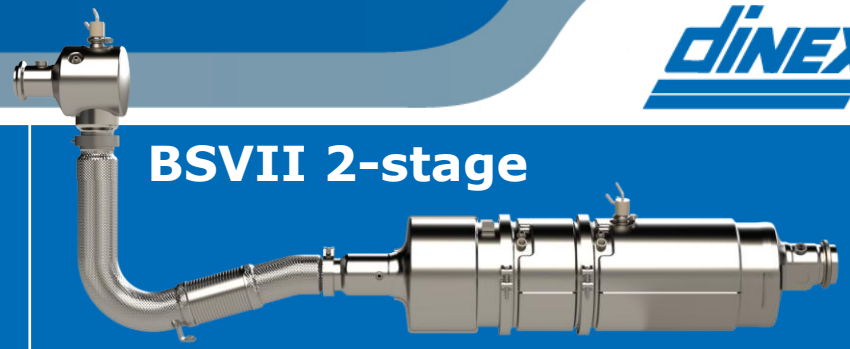
Short mixer simulation

dP: 10,5kPa

dP: 9,7kPa

Integration Effort

Comparing the two architectures

	BSVI	BSVII 1-stage 	BSVII 2-stage 
Inlet pipe	*BASE*	Carryover	Requires integration of +1 dosing unit and mixer
Inlet to DOC-out	*BASE*	Requires e-heater integration w. new cone	Inlet cone is carryover. Longer Sleeve for SCR1 + DOC needed
DPF	*BASE*	Carryover	Carryover
Main mixer	*BASE*	Incremental upgrade +80% of parts remain the same	Incremental upgrade +80% of parts remain the same
SCR-in to outlet	*BASE*	50% longer main SCR to be accomodated	Same SCR length, coating must be changed
Add-on components	*BASE*	E-heater, power electronics wiring	+1 dosing system, +1 NOx & T-sensor

Easier ← Integration → Harder

Dinex Cold Performance Concept

Active & passive technologies for better performance at low temperature

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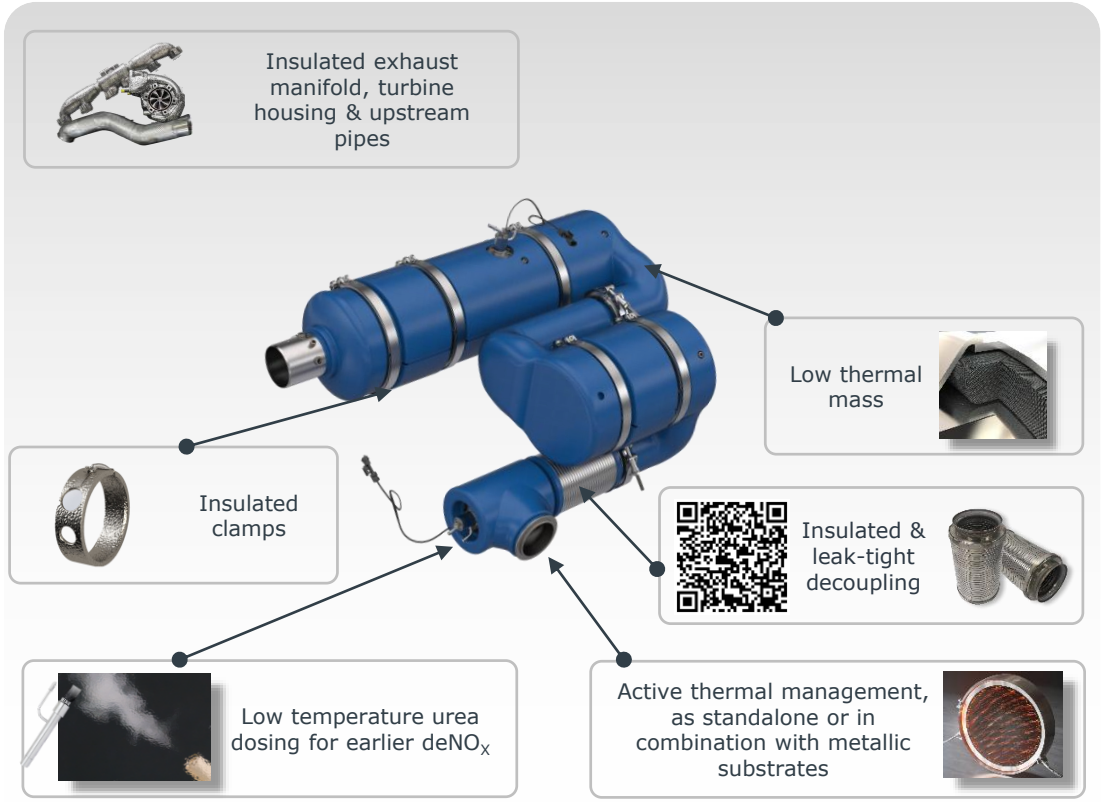

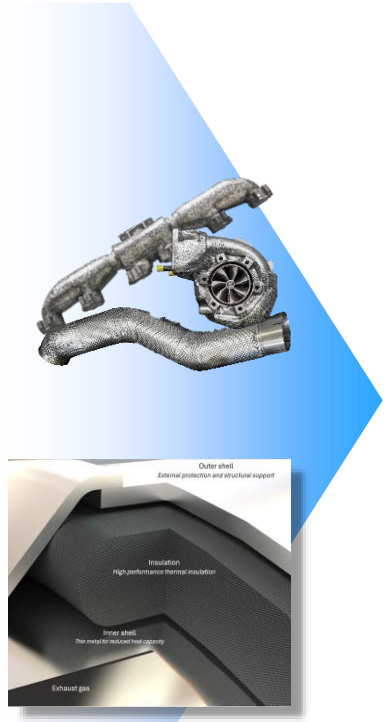

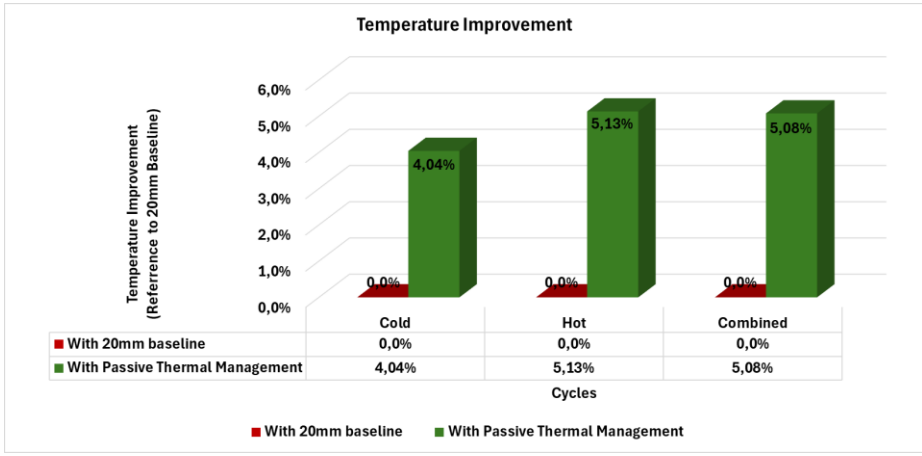

Relative temperature improvement considers engine work and the 5:95 NRTC cycle weighing for combined results

Conclusions

- For this application to meet the expectations for BSVII two primary paths have been identified and proven viable by simulation
  - 1-stage SCR w. e-heater
  - 2-stage SCR

- Both solutions present a packaging challenge which can at least partially be met by improving upon the in-production technology

- The exhaust temperature at the ATS inlet and subsequent dosing release can be decisive for the preferred path
  - Additional robustness can be achieved by incorporating Cold Performance Concept measures

- For the 1-stage SCR w. e-heater the AdBlue consumption is higher on the WHTC and energy needs to be put towards the e-heater. However system backpressure remains relatively lower. Suggesting that the optimum cost scenario will be application specific


THANK YOU
for your attention!