Development of an ATS with enhanced AdBlue mixer performance for future global emission standards

A simulation-led and field-informed AdBlue Mixer development methodology for RDE-compatible aftertreatment systems

JAY KACHHADIYA, SUHAS MESTRY
Tenneco Clean Air India Ltd
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- AdBlue Mixer design drivers
- Mixer Development Strategy
- Tenneco Mixer Portfolio
- Case Study :- Next Gen Double Swirl for BSVII & EU VII
- Summary

General Business - Tenneco Confidential

TENNECO GLOBAL NETWORK

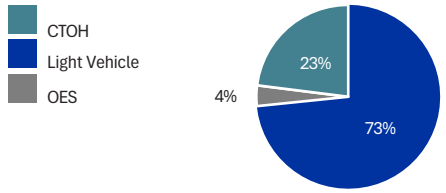
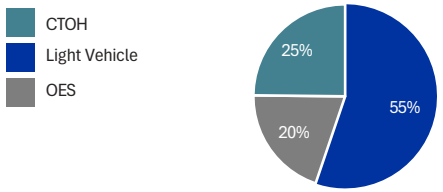
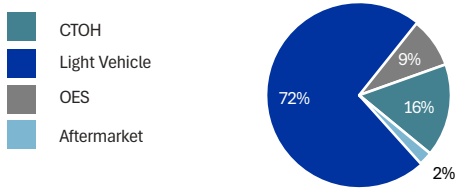
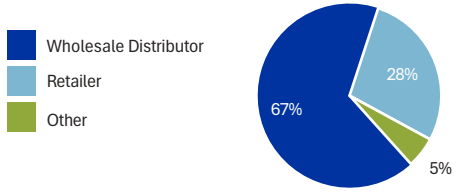
71,000
Global team members

39
Globally networked engineering & technical centers

196
Manufacturing sites worldwide

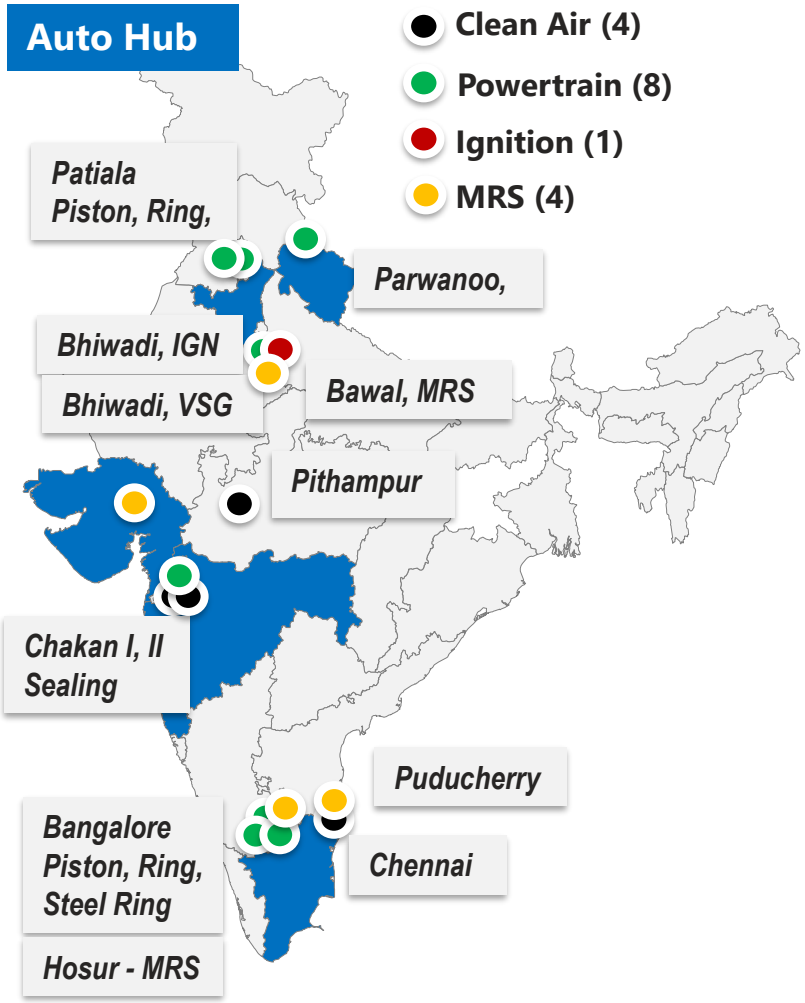
29
Aftermarket distribution centres

TENNECO – DIVERSE PORTFOLIO

	Clean Air	Powertrain	Performance Solutions	DRiV
Description	Engine emission control and acoustic performance	Engine components for improved efficiency and durability	Products and systems designed to optimize ride experience	Aftermarket business with a broad "House of Brands"
Brands	TENNECO	CHAMPION, GOETZE, DEVA, GLYCODUR®, DARO	MONROE, ÖHLINS, BentleyHarris, CLEVITE ELASTOMERS, TENNECO	CHAMPION, FELPRO, GOETZE, MONROE, MOOG, WAGNER, WALKER
Key Products	Turbo Bypass Catalyst Truck Exhaust System Light Vehicle Systems	Pistons Bearings Piston Rings Ignition Sealing & Gaskets Valves Valve Seats & Guides	NVH Systems Protection Braking Öhlins MRS	Shocks &Struts Steering & Suspension Braking Sealing
Revenue by Segment				

India Snapshot

17 Manufacturing Plants



5 Segment Served

Commercial Truck

Light Vehicles

Industrial Engines

Off Highway

2-Wheeler

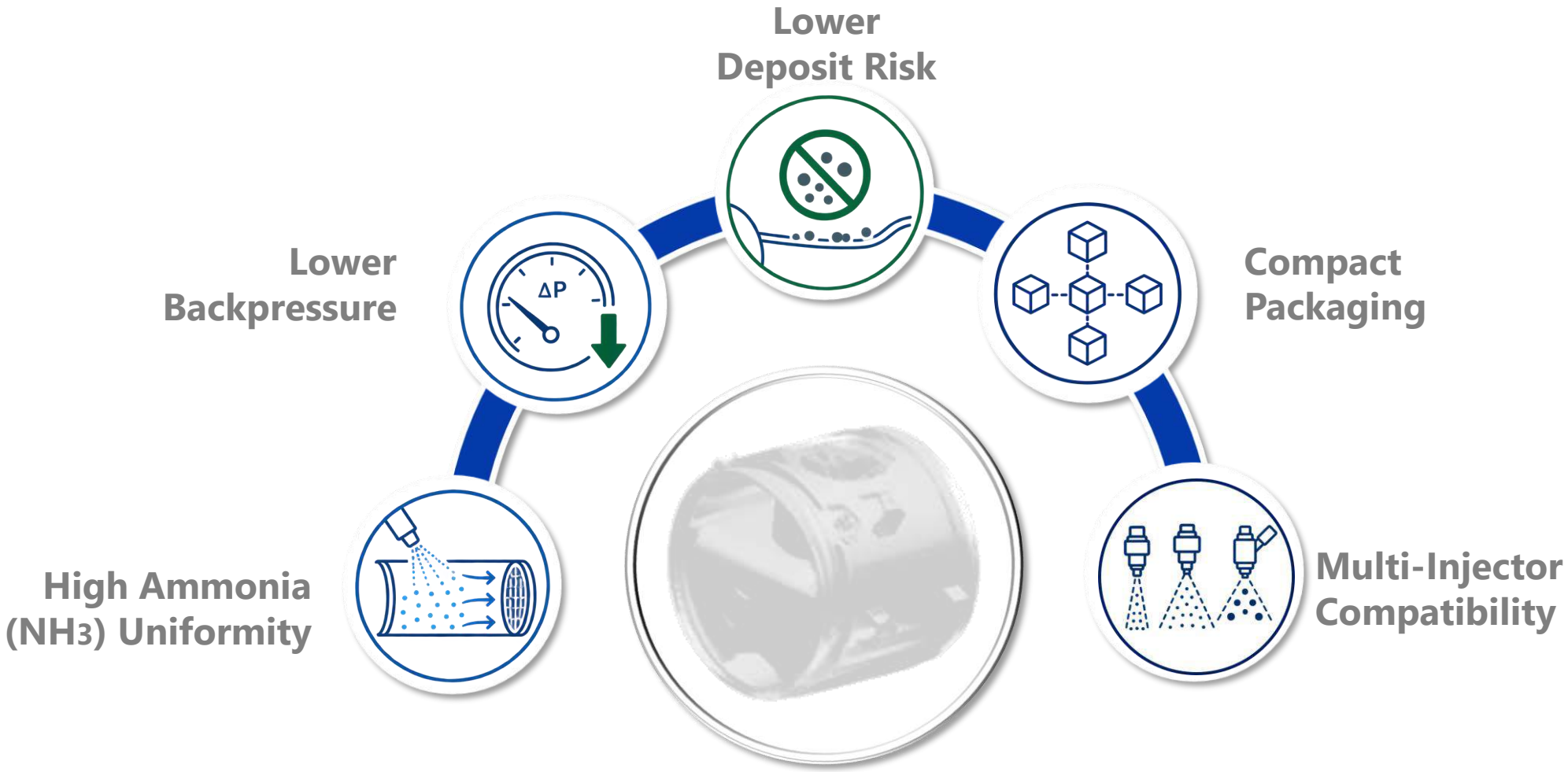
+45 Customer Served

MARUTI SUZUKI
TOYOTA
VINFAST
VE COMMERCIAL VEHICLES
ASHOK LEYLAND
JCB
HYUNDAI
TATA MOTORS
FORCE MOTORS
ISUZU
mahindra
Hero
BMW
JOHN DEERE
KIA
ROYAL ENFIELD
RENAULT NISSAN
PIAGGIO
kirloskar Oil Engines
SKODA | VOLKSWAGEN
Škoda Auto Volkswagen India Private Limited
Cummins
Cummins India Limited
HONDA
BHARATBENZ
TVS

Do we need just a Mixer???

We need a Multi-Specialist Mixer

Engineered to balance multiple performance requirements.



WHY?

Regulatory and OEM drivers

Regulations

- Lower NO_x
- CAFE
- RDE & ISC

Performance

- NH_3 uniformity target
- Nox conversion target
- Low-temperature operation

Integration

- OEM packaging envelope
- Injector position and spray cone
- Serviceability
- Multiple injector compatibility

Field Learnings

- Wider engine operating window
- Real driving conditions

Robustness

- Maximum dosing rate
- Deposit sensitivity
- Thermal durability

System Efficiency

- Pressure-drop target
- Catalyst-volume reduction
- Fuel-consumption and CO_2 impact
- Cost optimization

Mixer Development Strategy

From Certification Points to Real-World Performance

BSVI DEVELOPMENT APPROACH

Component focused | Limited operating window

Operating points
Limited operating points

Operating Conditions
Steady-state evaluation

Injector Strategy
Fixed injector strategy

Dosing Range
Moderate dosing range

Development Focus
Component Optimization

Catalyst Volume
Conservative catalyst volume

Field data integration
Limited field data integration

RDE/FUTURE-NORM STRATEGY

Component focused | Limited operating window

Extended engine-map coverage
Wider operating window (RDE)

Transient and real-world evaluation
Dynamic engine operating conditions

Multi-injector compatibility
Supports various injector types, spray angles and droplet sizes

Wider and higher dosing range
Covers full RDE operating window

Complete ATS optimization
Mixer, catalysts, thermal and control integration

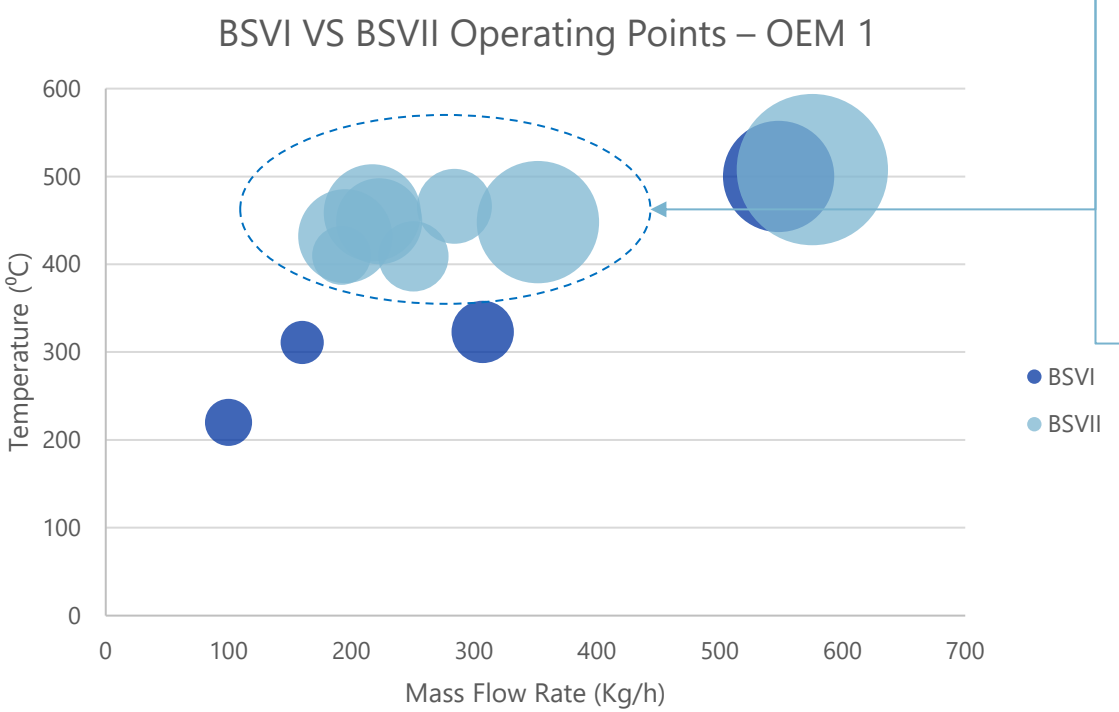
Higher catalyst utilization target
Enable optimized substrate volume

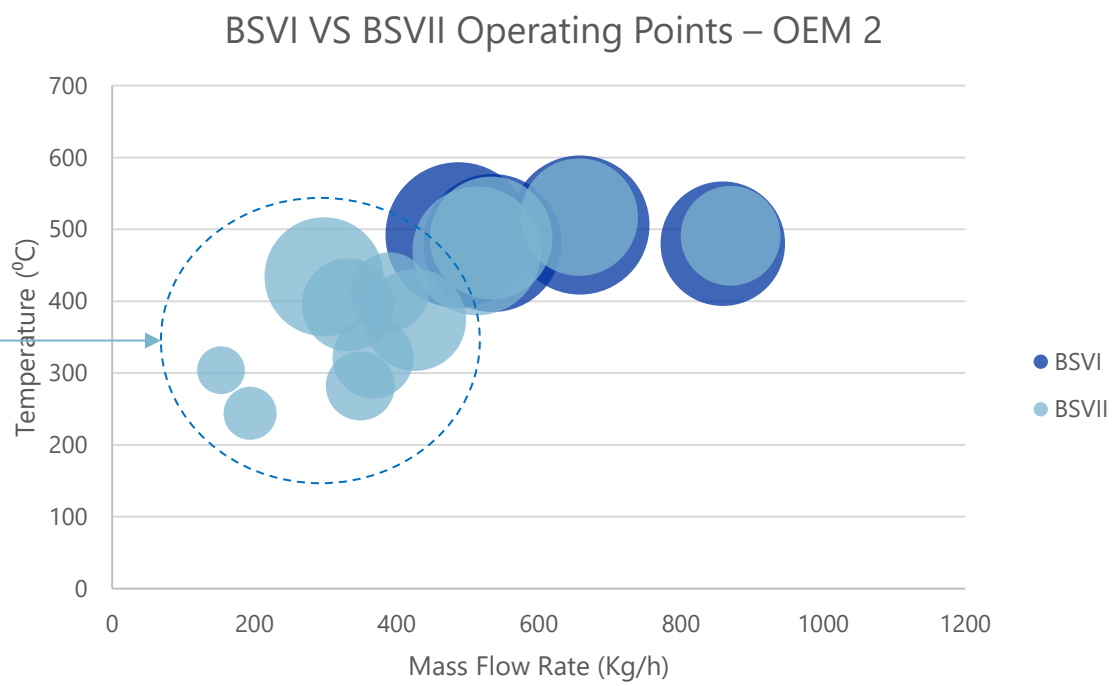
Field-informed development loop
Real-world data drives continuous improvement

1. Expanded Engine Map Coverage

Additional operating points added for mixer design

- Real driving conditions
- System robustness
- Optimized DEF Dozing



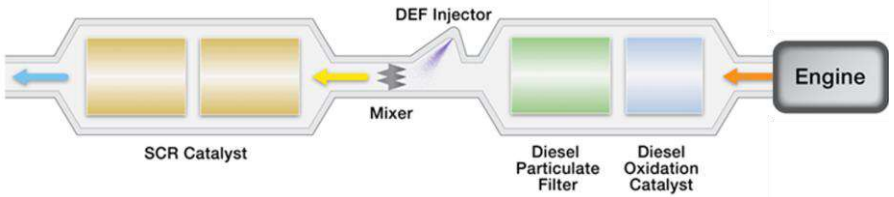


Complicated Mixer Development

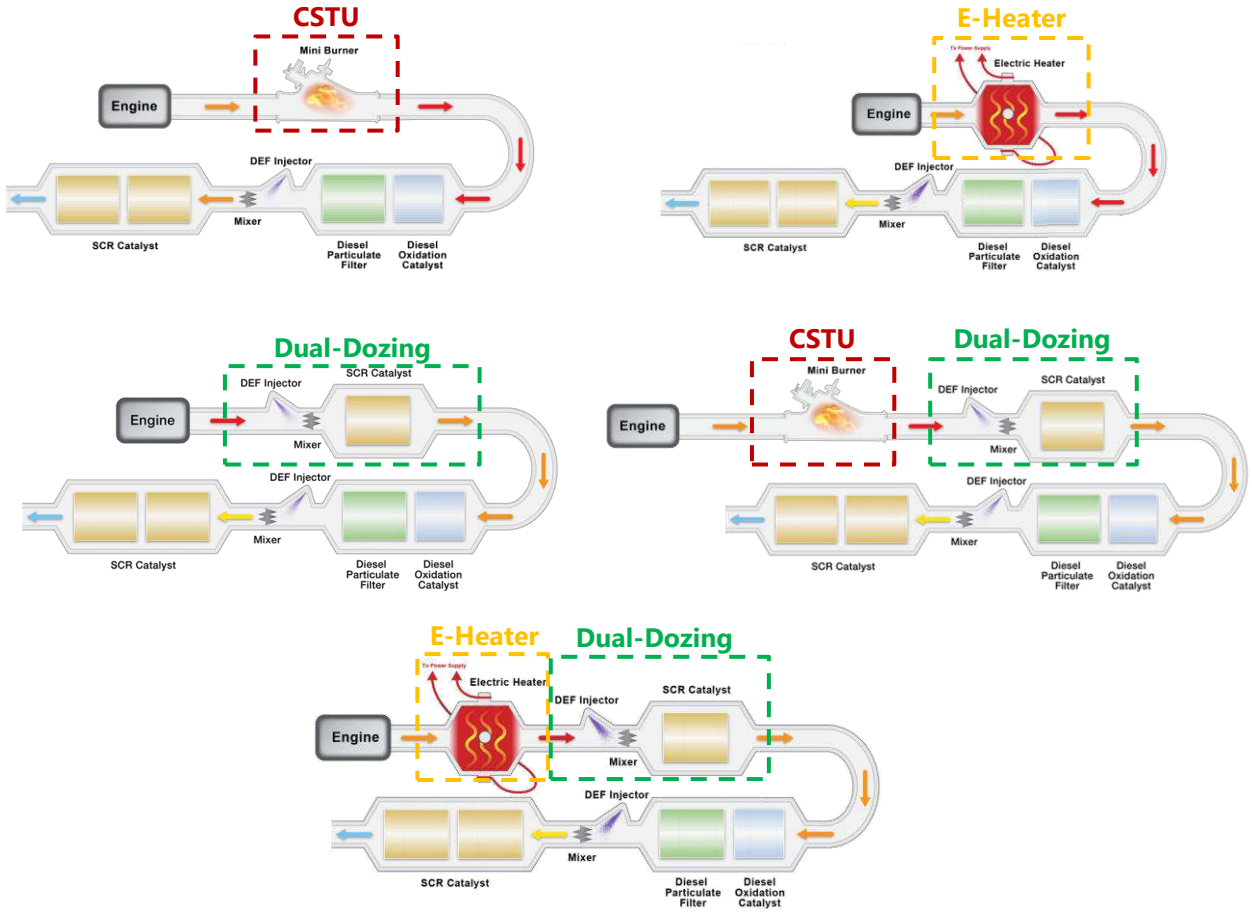
Performance required across wide range of operating conditions

2. Compactness required to accommodate additional elements

BSVI/EUVI
ATS ARCHITECTURE



BSVII/EUVII
ATS ARCHITECTURE

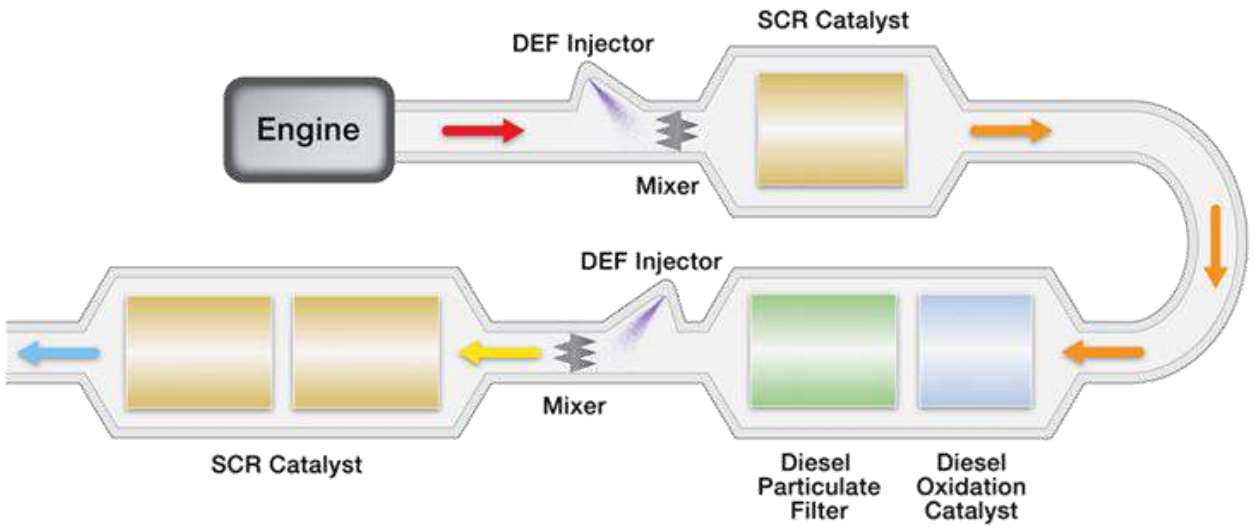


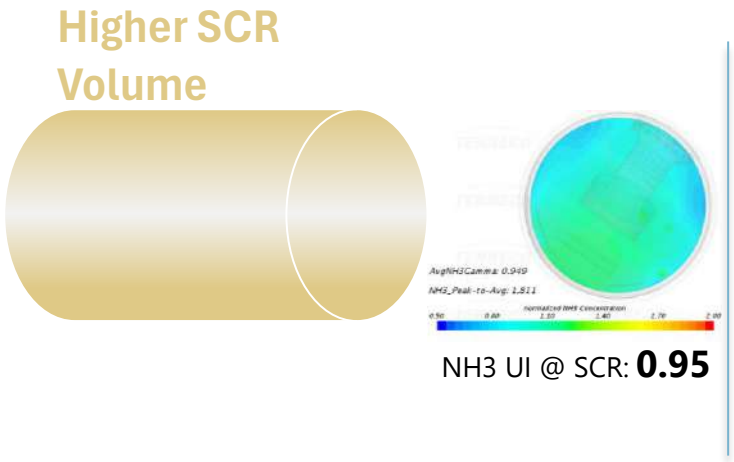
1. Additional pre-dozing/ CSTU/ E-Heater added to meet the stringent NOx requirement

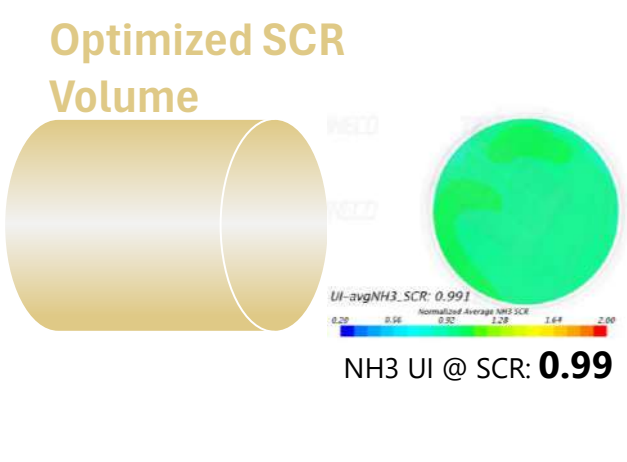
2. Overall ATS length should be optimized to fit in the vehicle packaging

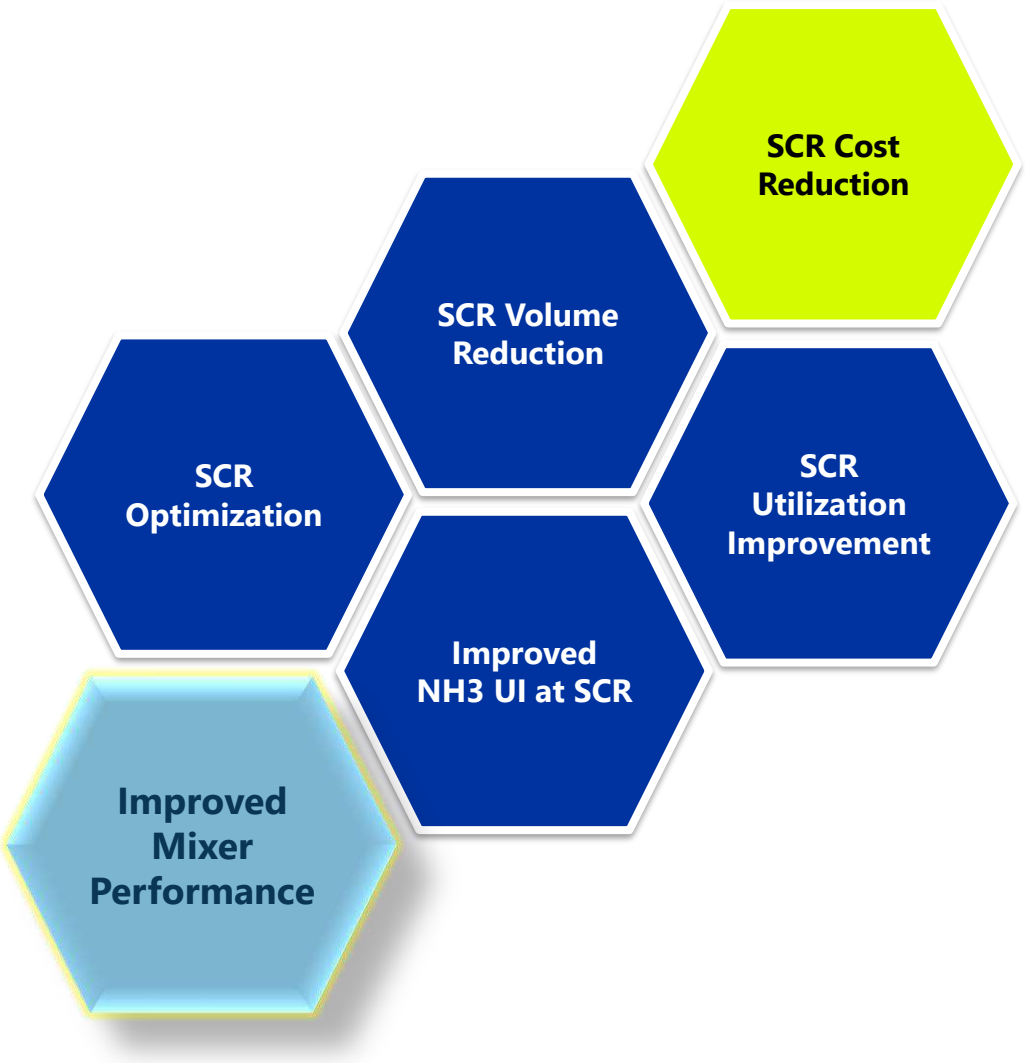
3. Backpressure of additional substrate/Mixer/Heater must be accommodated in the system

3. SCR optimization to meet cost target

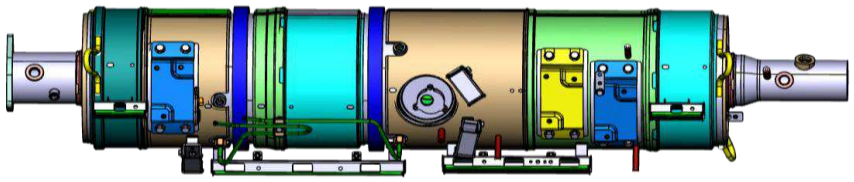




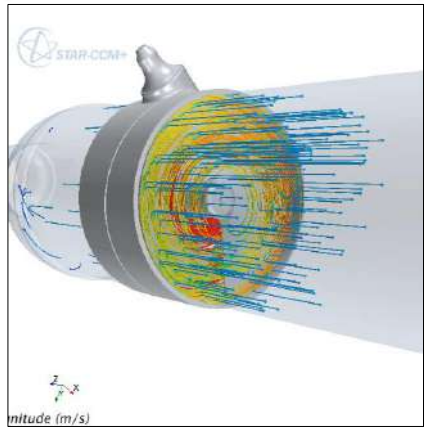


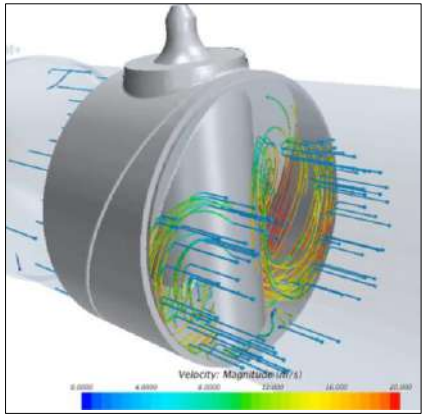


What is AdBlue Mixer?

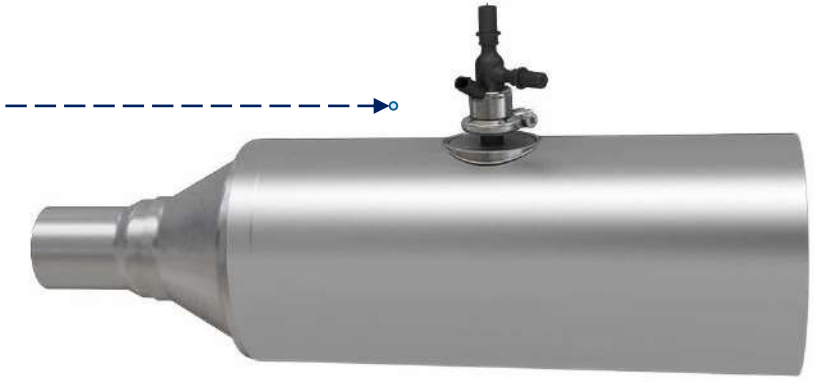


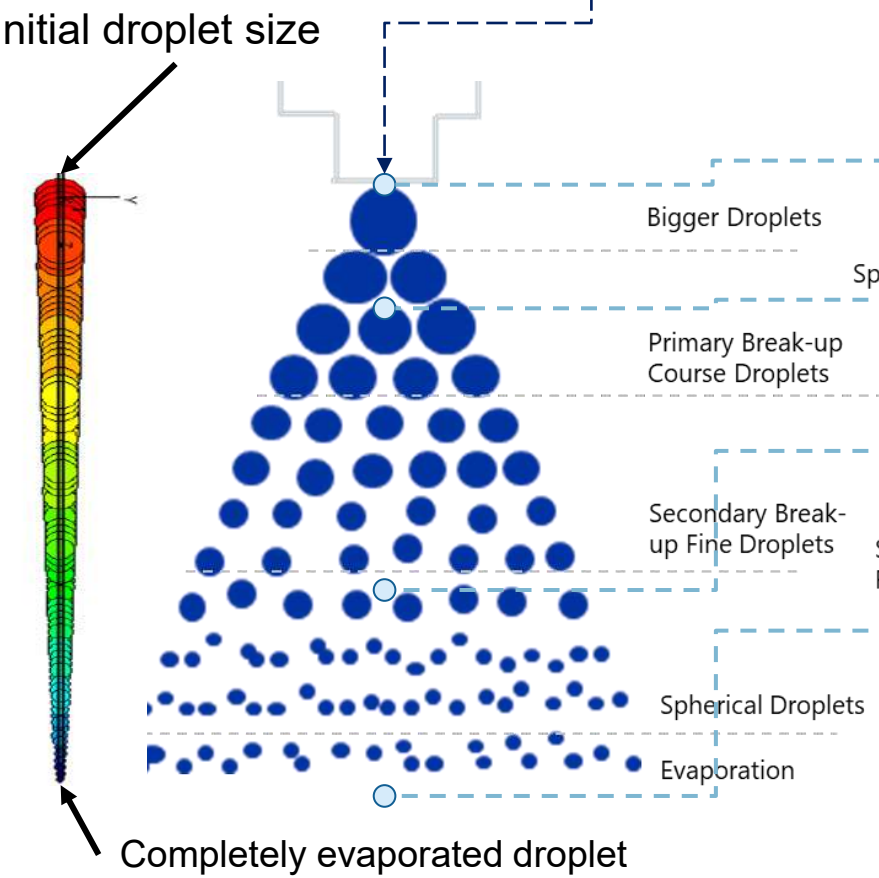
Mixer Asy





AdBlue Injector





Injection
- Injection of liquid urea into the exhaust system

Spray/Gas Mixing
- Atomize droplets and mix them with exhaust gas while minimizing wall wetting in critical areas

Droplet Evaporation
- Within the flow (preferred) OR
- On hot surfaces (less deposit risk)

Urea Processing
- Thermolysis: Urea converts into gaseous NH3 and HNCO
- Hydrolysis: HNCO reacts with water to gaseous NH3
- Mixing: NH3 to be homogeneously mixed with exhaust gas

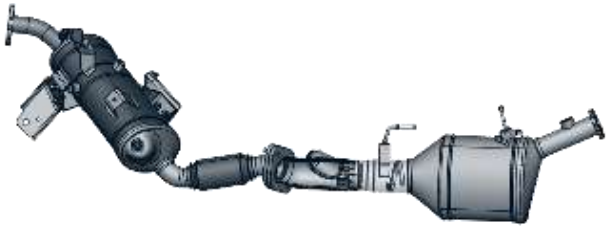
Flow & NH3 Uniformity
- NH3 distribution must match NOx distribution over SCR surface

TENNECO

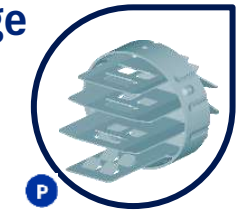
Mixer Architectures

All Mixers shown below are patented by Tenneco

Close Coupled + Underbody ATS



Two Stage Mixer

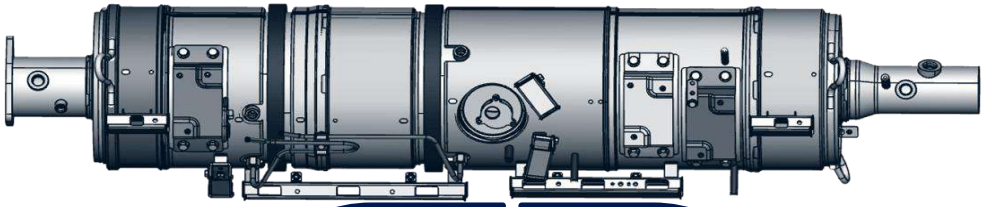


Auger Mixer

Close Coupled ATS

Stairway Mixer

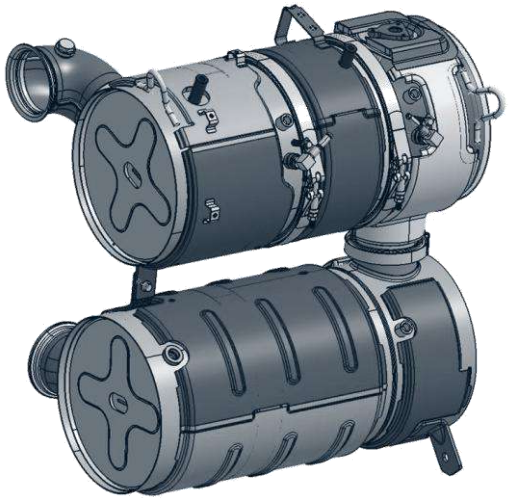
Inline ATS



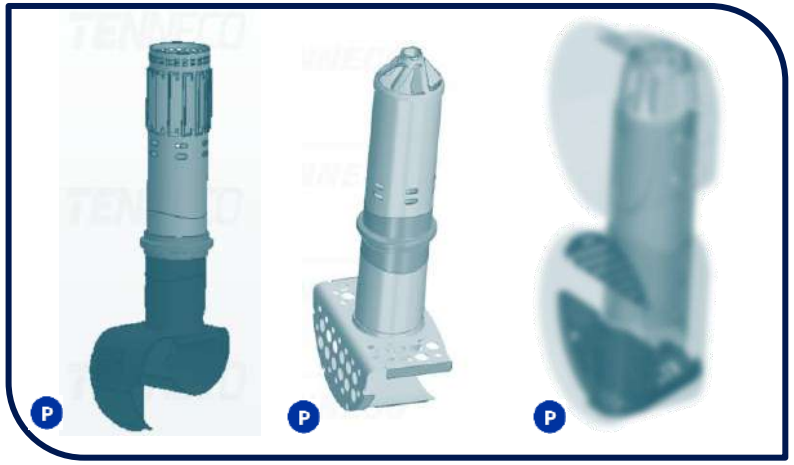
Double Swirl Mixer

Rasp & Bowl Mixer

U or C Shape ATS

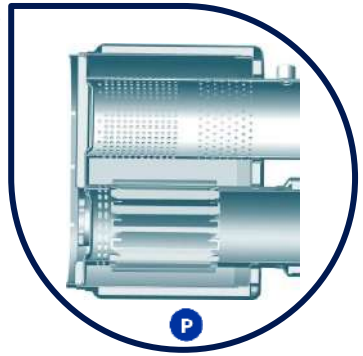


End Can Mixers



Compact ATS

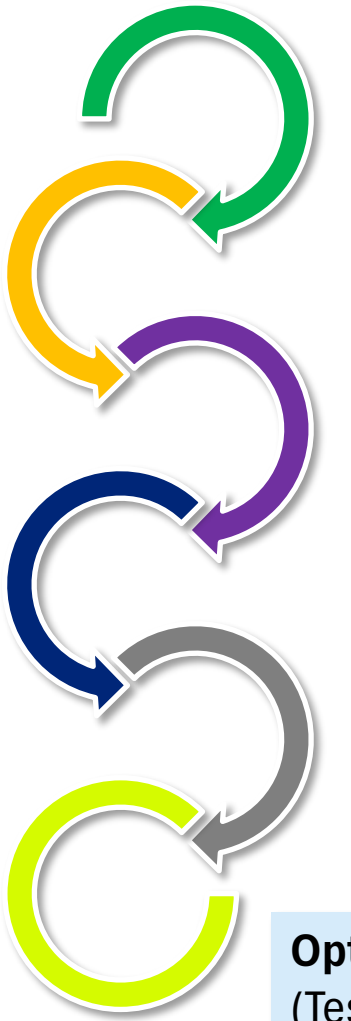
Mix Box Mixer



TENNECO

Case Study: NextGen Double Swirl Mixer

Mixer Development Methodology



Customer Voice & Data Collection

Mixer Concept Preparation

CFD Simulation & Parameter Optimization

Promising Mixer Concept Selection

Flow Bench Testing (Inhouse)

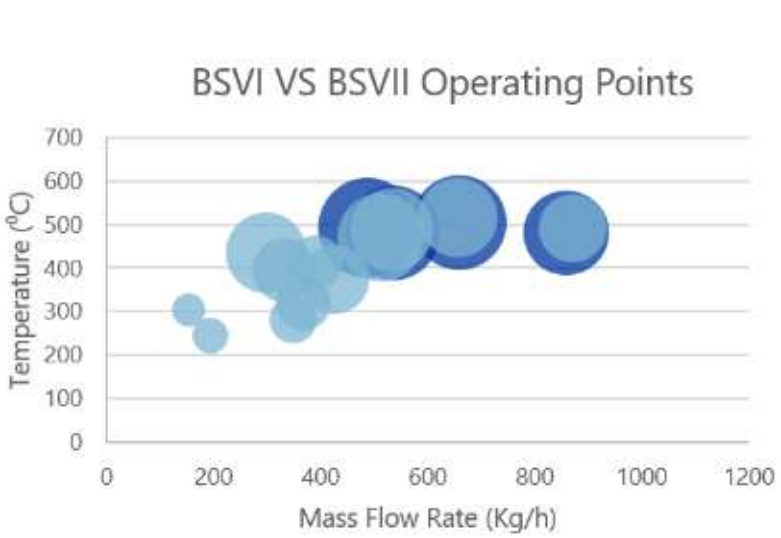
Best Concept Selection & Validation with OEM

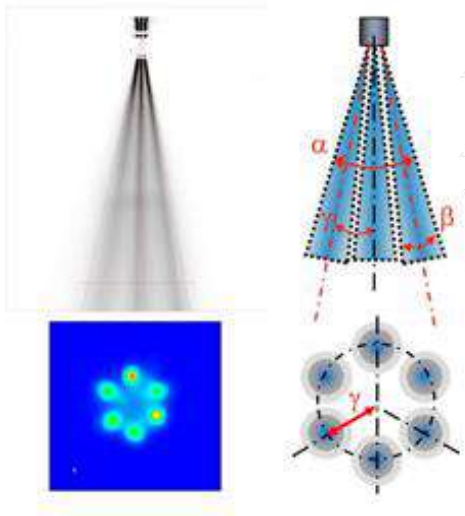
Optimized Mixer Design
(Tested and Validated)

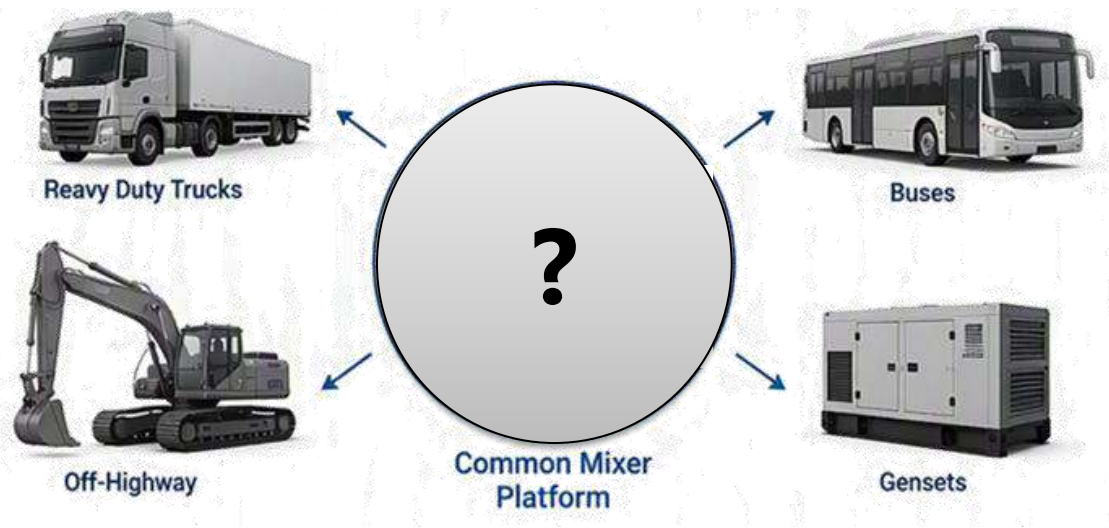
Simcenter
Simcenter STAR-CCM+
Siemens Digital Industries Software

CATIA

Customer Voice & Data Collection







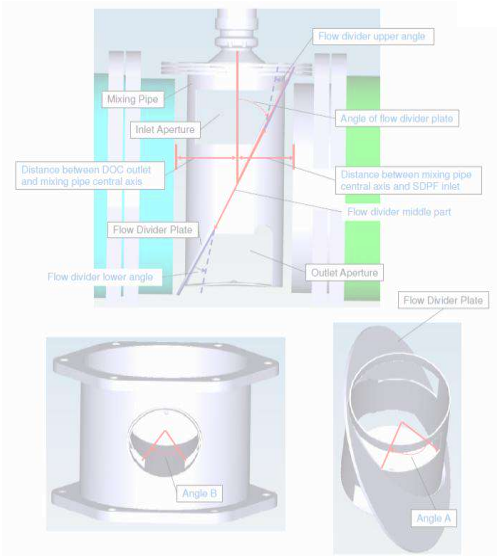
Operating Points Consolidation

Injector characteristics and spray data collection

Mixer serviceability, modularity, Scalability and packaging requirement gathering

Mixer Concept Preparation

1. Mixer Architecture Selection
2. Performance Critical Parameter Selection
3. Critical Operating Point Selection
4. Mixer concept preparation with variation of critical parameters



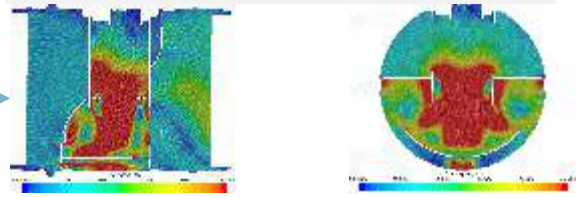
Inf_Exh_cb_wet	TG_Turbine_o	AdBlue Dosing (est)	Exhaust Energy	HeatFlux	EER
(kg/h)	(°C)	(kg/h)		KW	EER
870	491	1.4184	4,27,176	82.7	78.6
657	517	1.9892	3,30,689	67.5	45.5
533	488	2.1456	2,80,104	56.2	31.3
513	470	2.3652	2,41,116	45.6	26.0
426	365	1.4868	1,55,490	24.9	23.5
390	423	0.89064	1,84,970	29.3	45.1
367	321	0.936	1,17,807	16.7	26.1
349	282	0.6777	98,418	11.9	27.0
332	395	1.2312	1,31,140	22.3	25.0
298	434	2.0189	1,29,332	23.4	15.8
194	244	0.4017	47,336	4.5	18.8
153	304	0.3252	46,512	6.2	28.4

CFD Simulation & Parameter Optimization

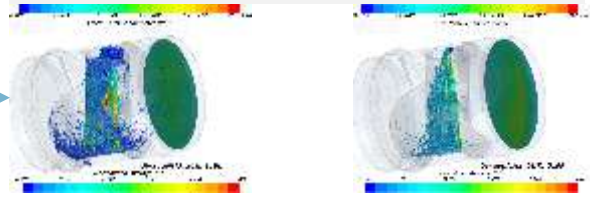
Base Concept Simulation & Result Analysis → **Study the effect of various features** → **Identifying the features with high correlation & fine tuning**

Base Mixer

Flow Profile

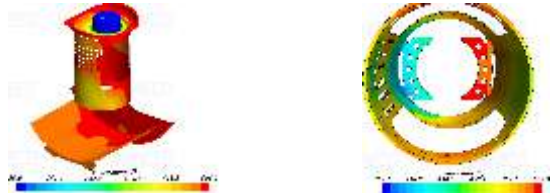


Droplet Behavior

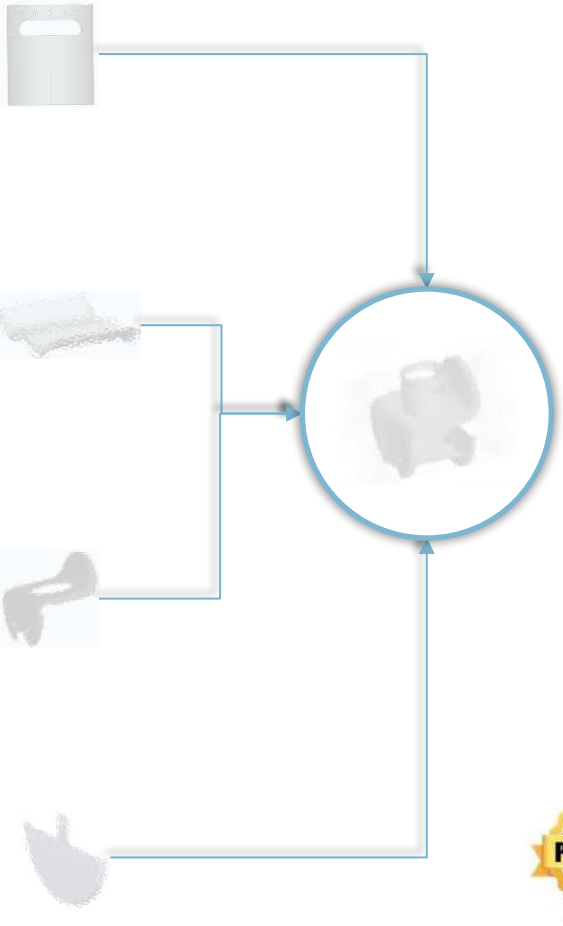


Urea Impingement & Wall Wetting

Temperature Profile



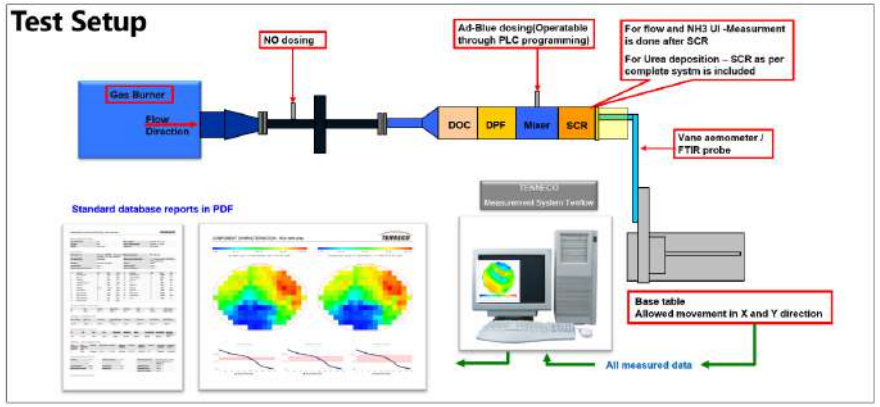
- **Mixing Pipe**
- **Mixing Tub**
- **S Plate**
- **Support Plate**

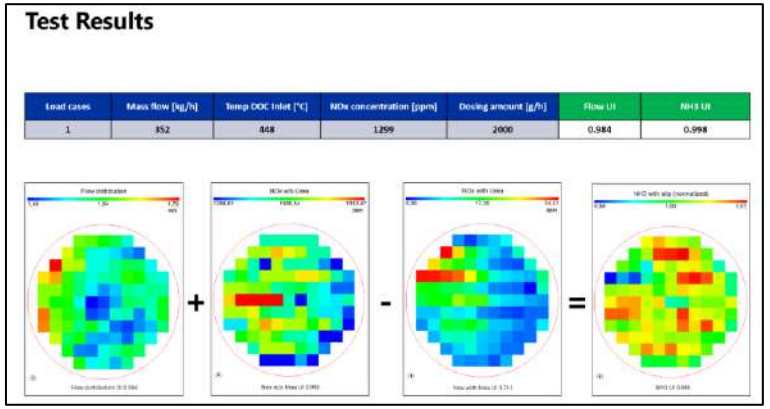


Promising Mixer Concept Selection

	NH3 Uniformity	Deposition Risk	Mixer Backpressure	Compatibility with multiple Injectors	Manufacturing Complexity	Cost
Mixer Concept 1	🟢	🟢	🟢	🟢	🟢	🟢
Mixer Concept 2	🟢	🟢	🟢	🟢	🟡	🟡
Mixer Concept 3	🟢	🟢	🟡	🟡	🟢	🟢

Flow Bench Testing (Inhouse)





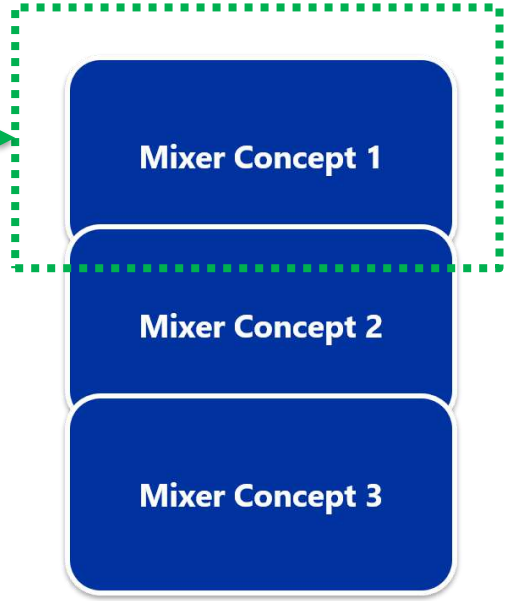
Back Pressure Testing

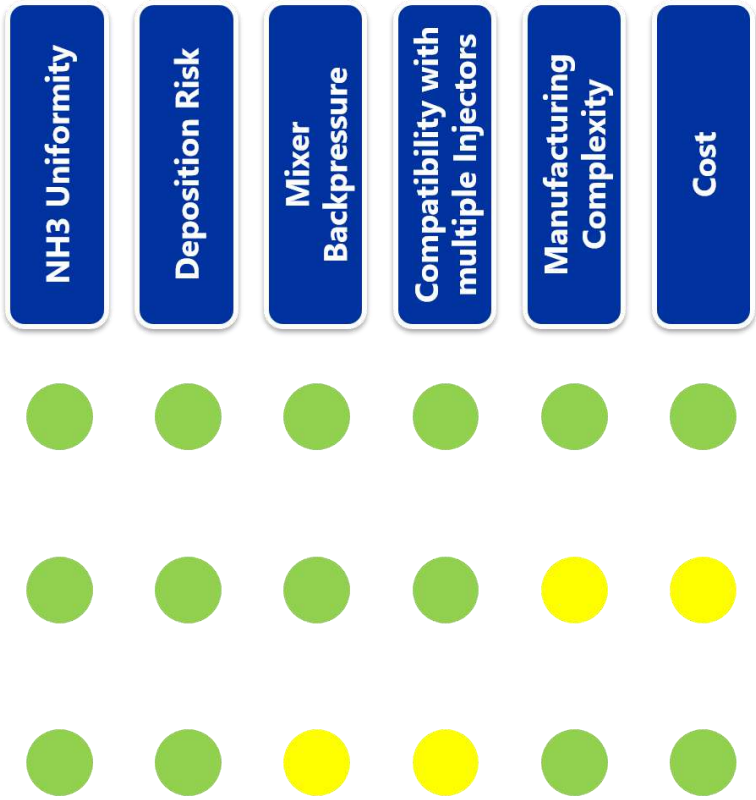
Flow Uniformity Testing

NH3 Uniformity & Deposition Testing

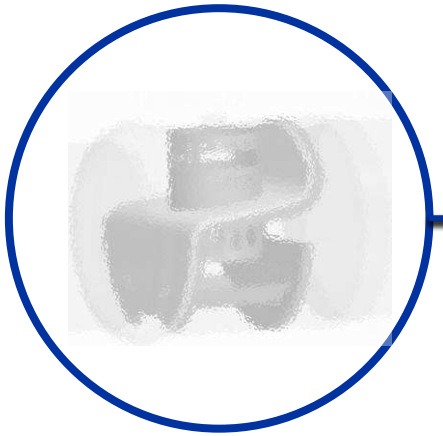
Best Concept Selection & Mixer Validation with OEM

Concept 1 got selected based on the test results and other merits on customer specific requirements





Gen2 DS Mixer - Summary



High NH3 Uniformity
>0.99 NH3 UI on all OPs

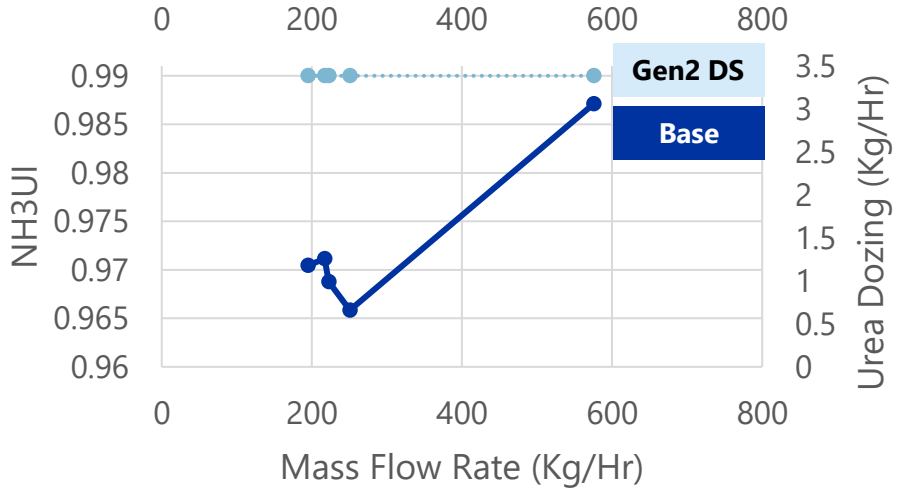
Lower deposit Risk
Wall Impingement is very low,
No Deposit observed in testing

Lower Backpressure
35% Reduction

Compact Packaging
Serviceable design of Mixer with same ATS length

Multiple Injector Compatibility
Bosch (9 bar, 7.5bar, 5bar), Cummins UL 2.2

NH3UI comparison w.r.t MFR & Dozing



Serviceable > Mixer & SCR Assembly

Tangible Outcome

Improved Fuel Efficiency

Reduction in DEF Consumption

Serviceable Mixer Design

Same Mixer for Multiple Vehicle Platforms

TENNECO
Q & A