NOx Aftertreatment Using Ethanol as Reductant

Robert Diewald - DEER Conference, 2010

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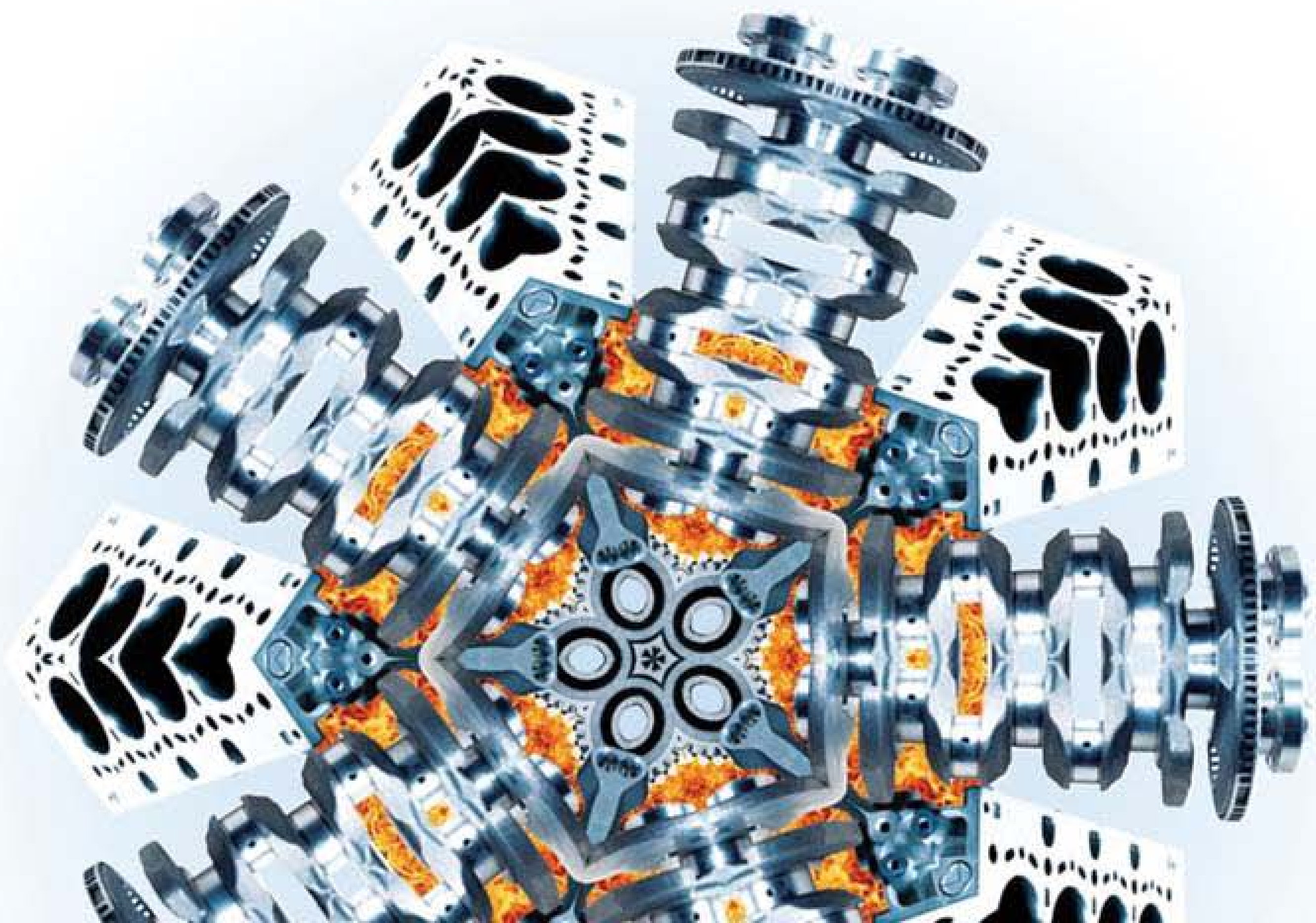
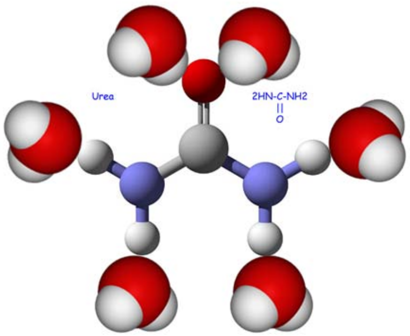


Motivation

- Urea based SCR is state-of-the art but has some issues

- Issues include DEF freezing and thus low temperature performance, mixing length needed for evaporation and hydrolysis, deposit formation and infrastructure requirements

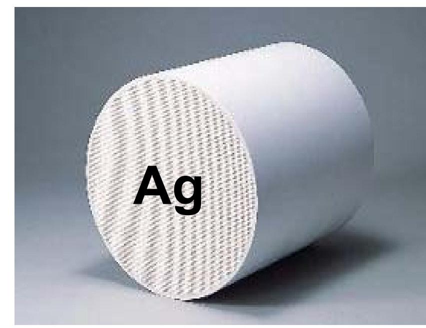
- Alternative to overcome those issues is desired. Ethanol and E85 is already available in many markets and especially in South America

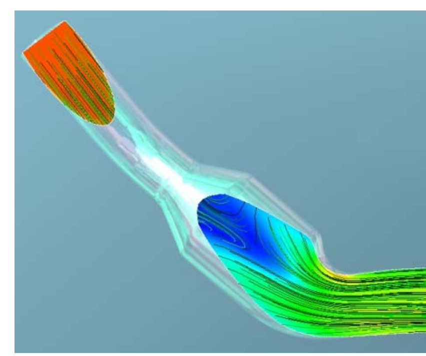


Project Overview 1/2

- AVL has conducted an internal NOx aftertreatment R&D program using E100 and E85 as reductants
- Silver/alumina based catalyst samples from a major supplier were used for testing
- An airless injection system was used and reductant evaporation and distribution were simulated using 3D-CFD

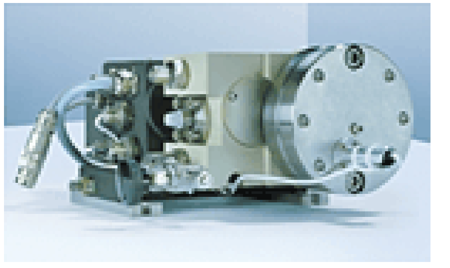
85% Ethanol



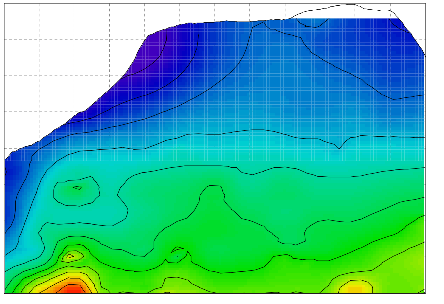


Project Overview 2/2

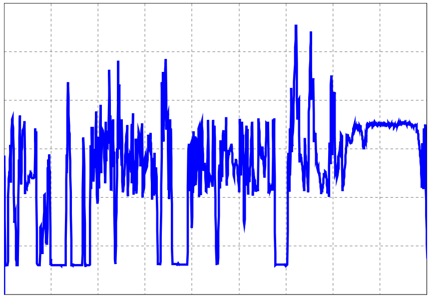
- Injection quantity was measured with adapted flow meter



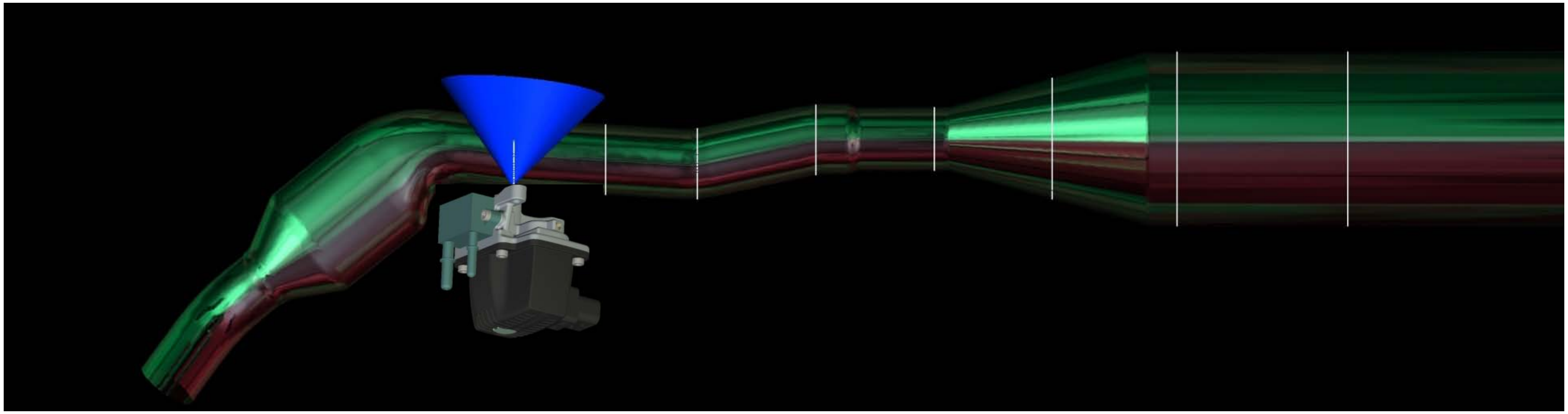
- Injection strategy was developed and calibrated



- The system performance was evaluated on an engine dyno in steady-state operation as well as in three different test cycles; WHTC, NRTC and FTP75

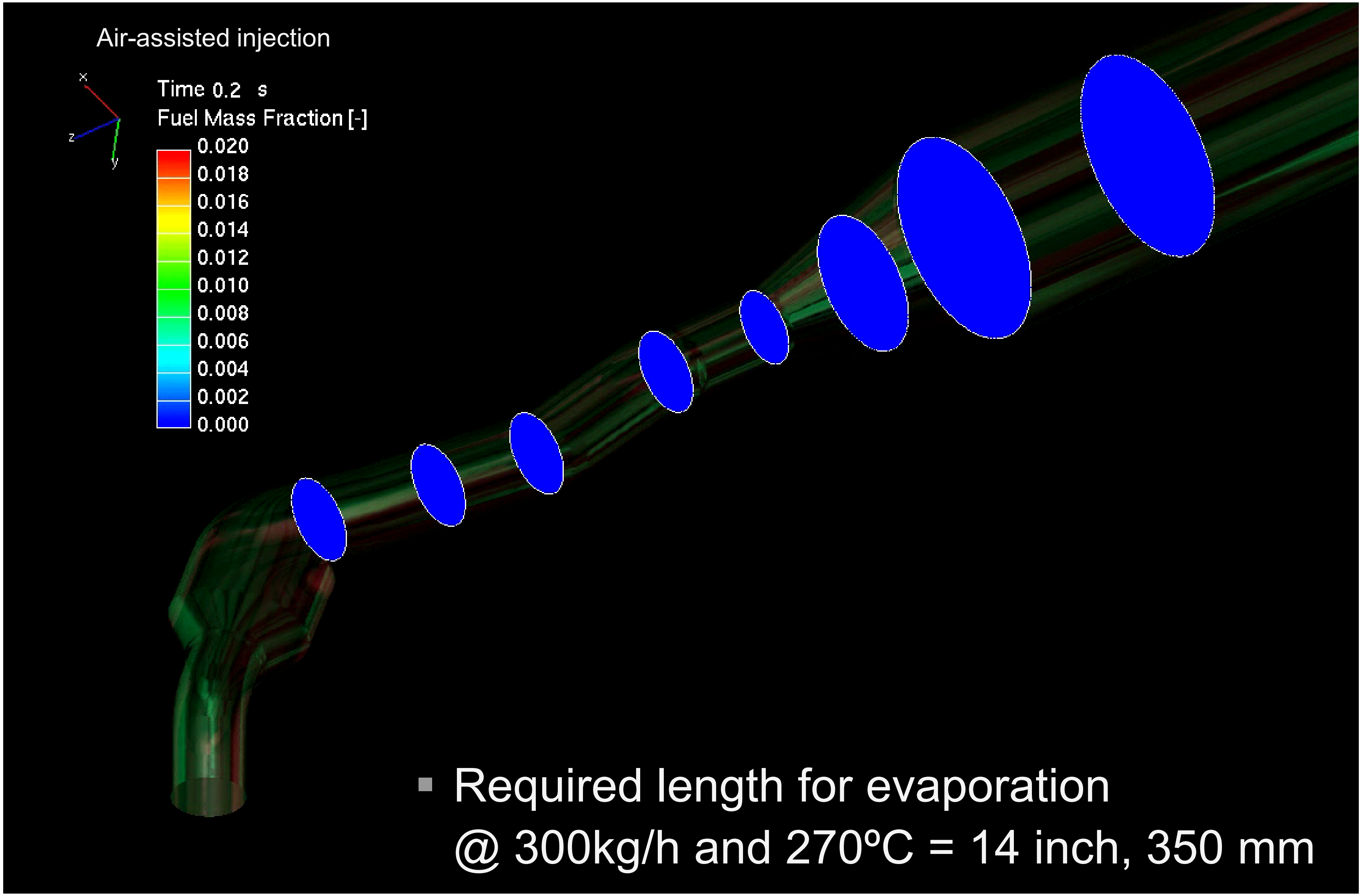


CFD Simulation of E85 Injection



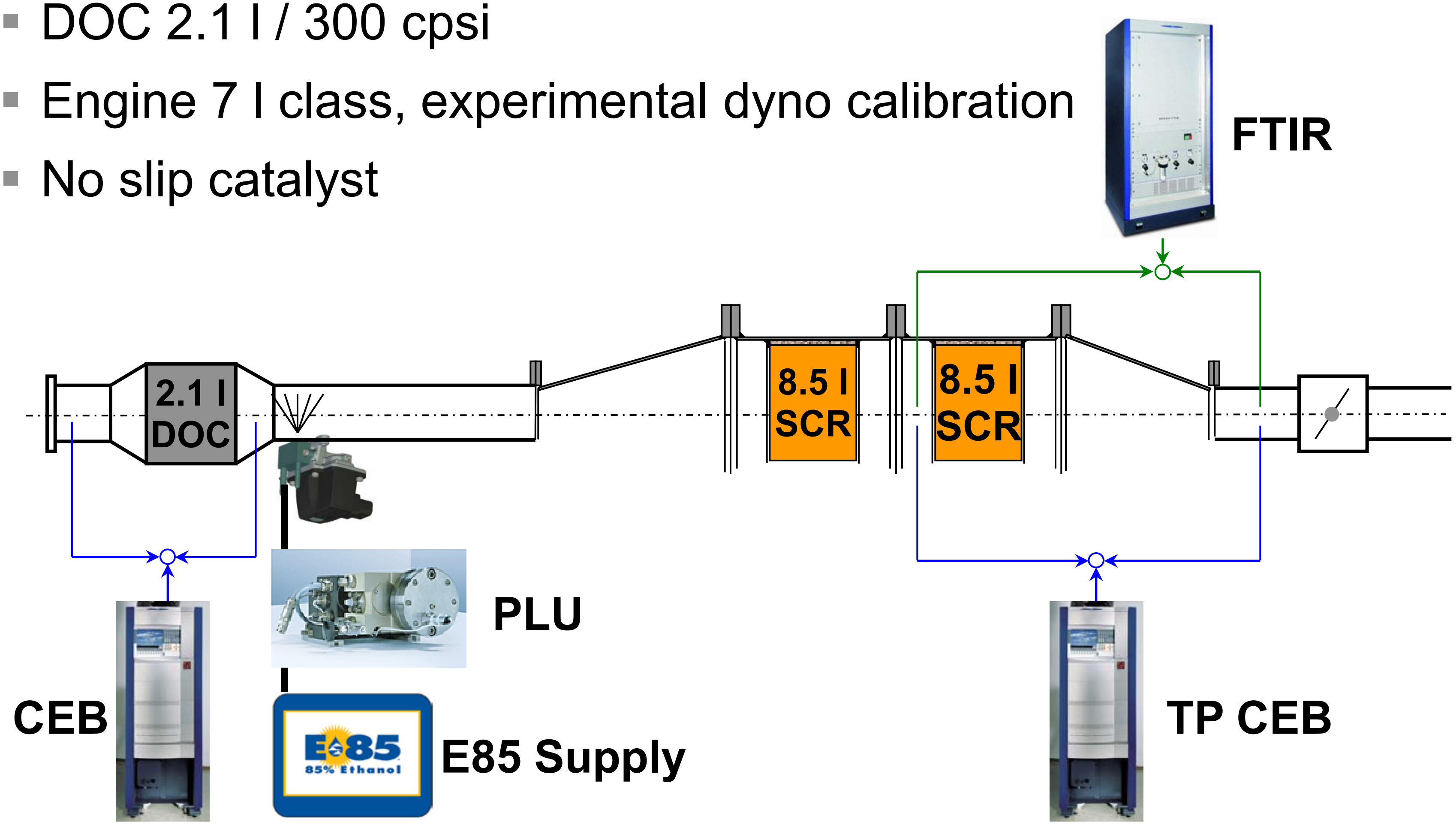
- Airless injection system (Hilite)
- Wide angle hollow cone spray nozzle
- Sauter mean diameter of 22 µm
- Exhaust flow conditions: 300 kg/h, 270 ºC

CFD Simulation of E85 Injection



Test Cell Setup

- Two silver based SCR catalysts from a major supplier with Ø10.5”x6” / 400 cpsi
- DOC 2.1 l / 300 cpsi
- Engine 7 l class, experimental dyno calibration
- No slip catalyst

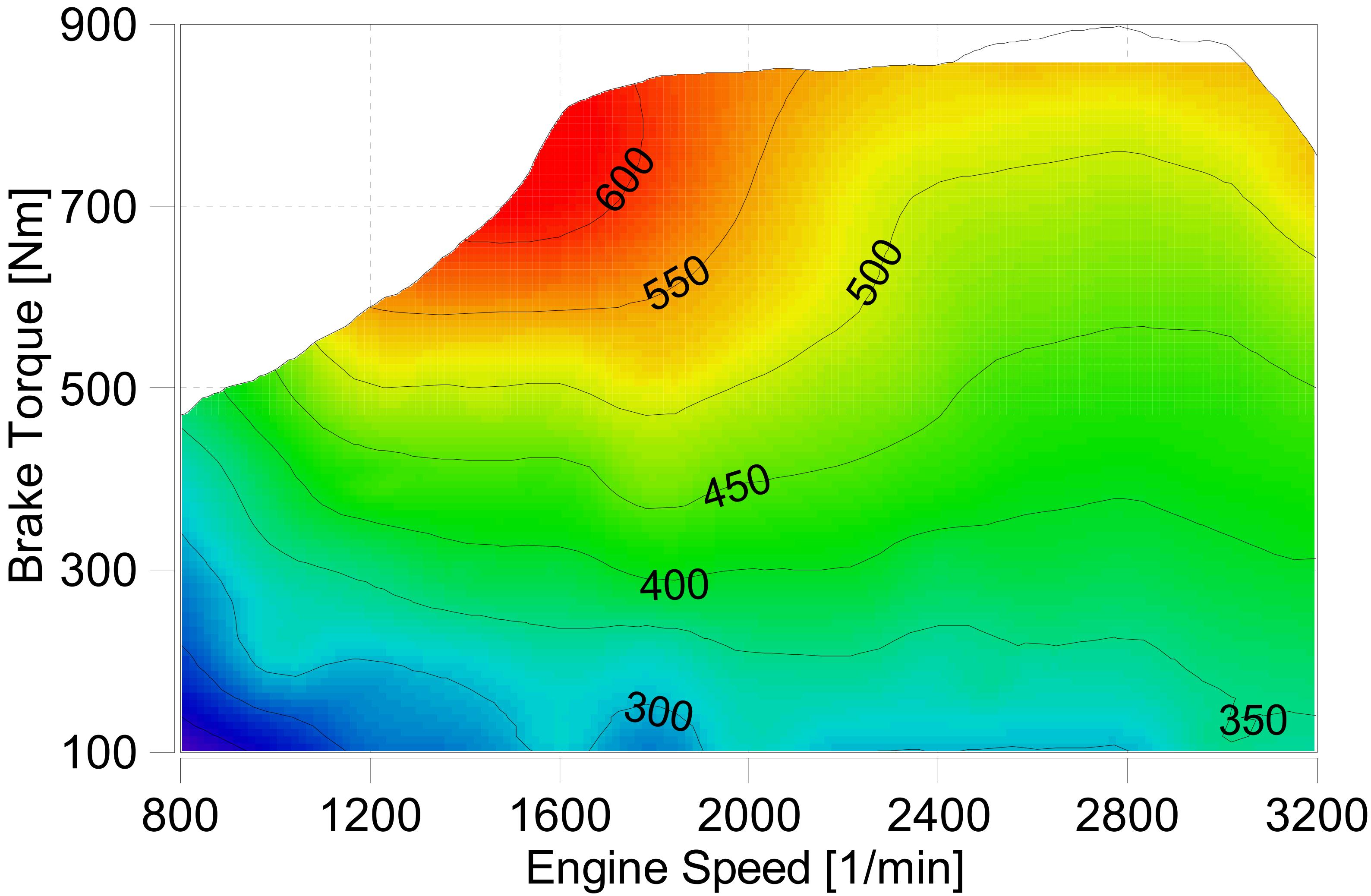


Reductant Selection

	Avg. Molecular Structure	Molar Weight	Density
Gasoline	C_8H_{18}	114 g/mole	710-770 kg/m^3
Ethanol	C_2H_5OH	46 g/mole	789 kg/m^3
E85	85% C_2H_5OH, 15% C_8H_{18}	56.2 g/mole	~ 781 kg/m^3

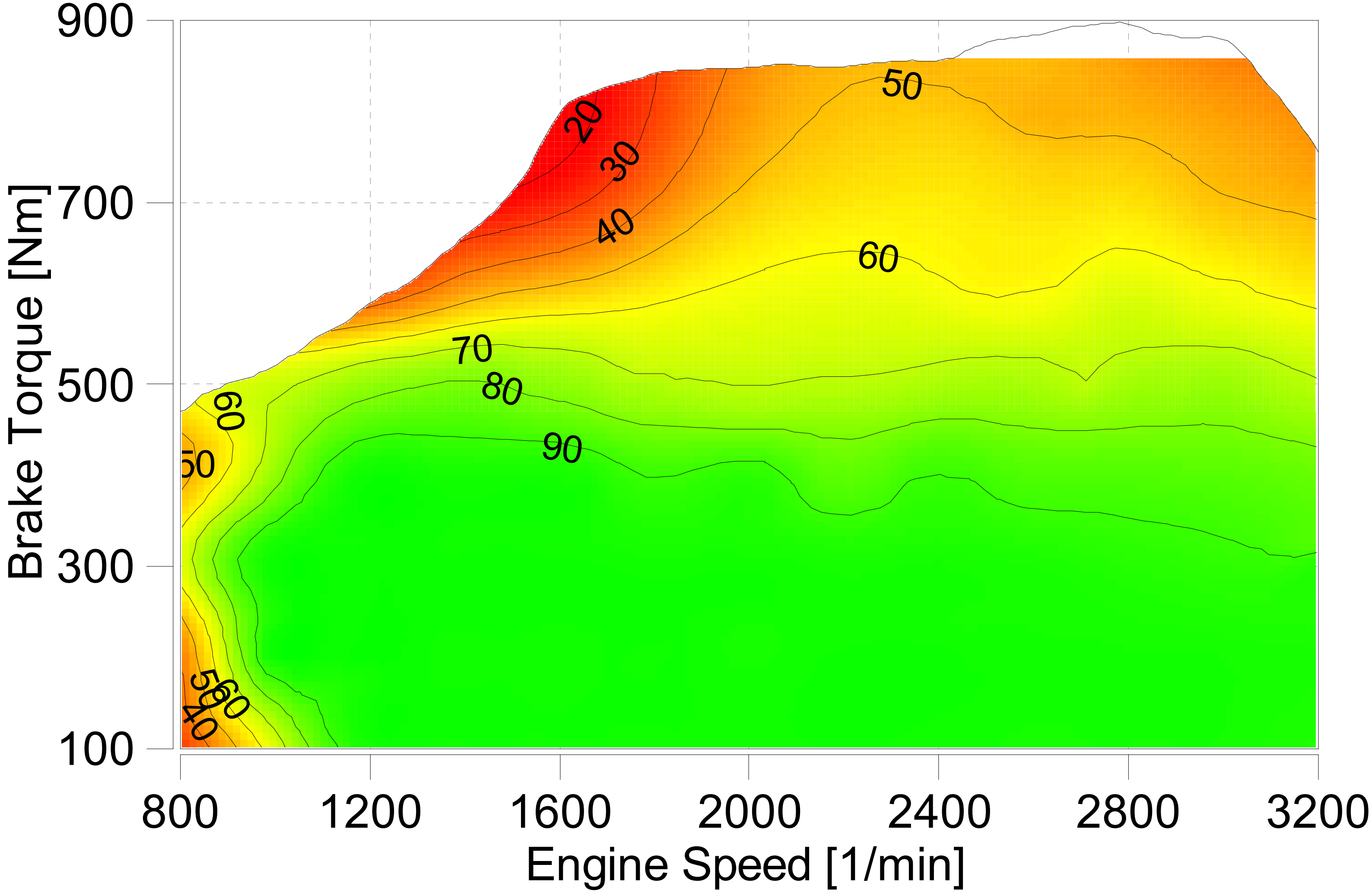
- E85 performed better than E100
- Results shown are for E85

SCR Inlet Temperature [ºC]



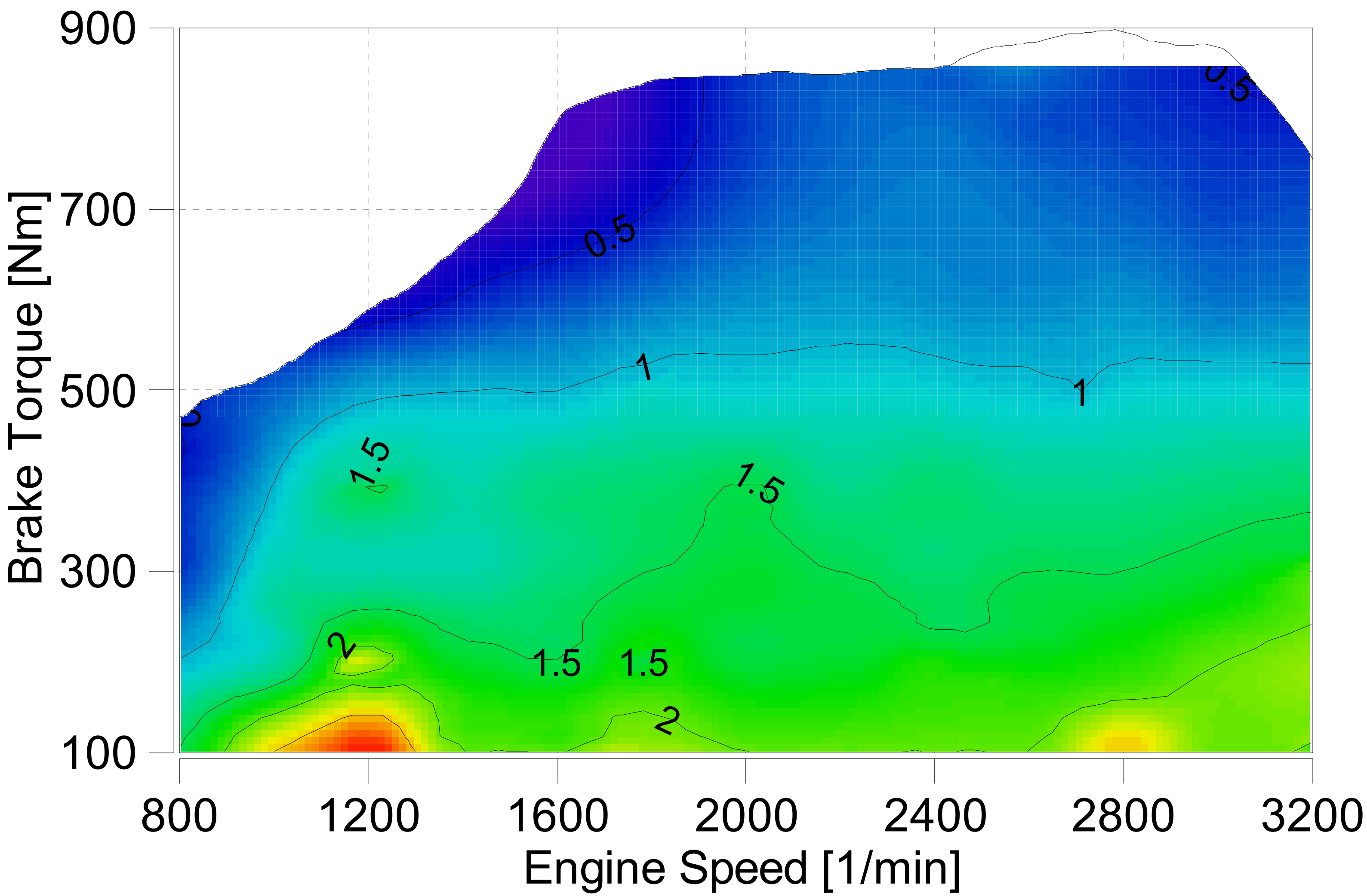
- Chassis dyno calibration

Steady-State NOx Conversion Efficiency with E85 as Reductant [%]



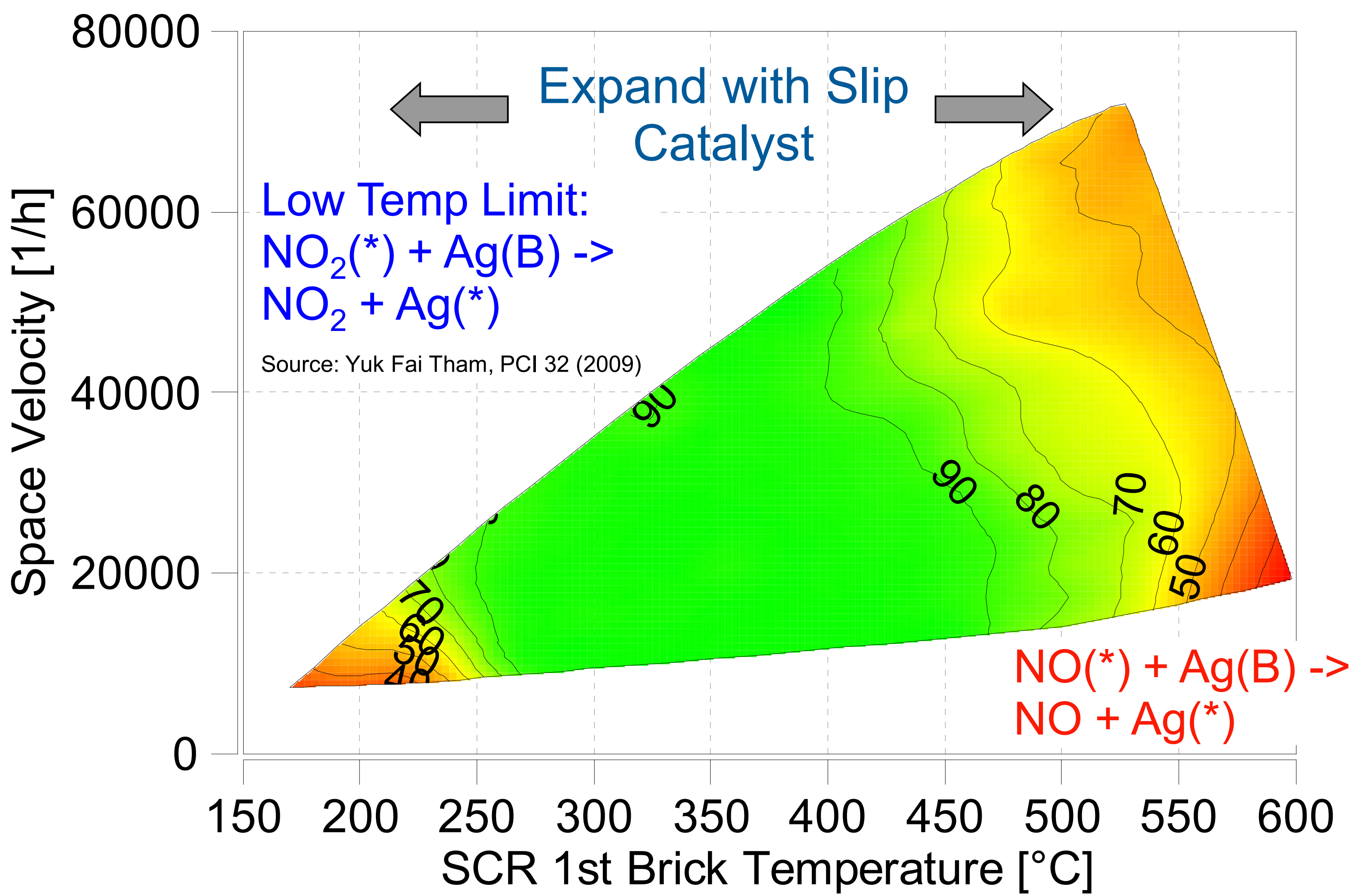
- Boundaries: max. 25 ppm ammonia and 300 ppm HC slip

Steady-State E85 to NOx Ratio [mole/mole]



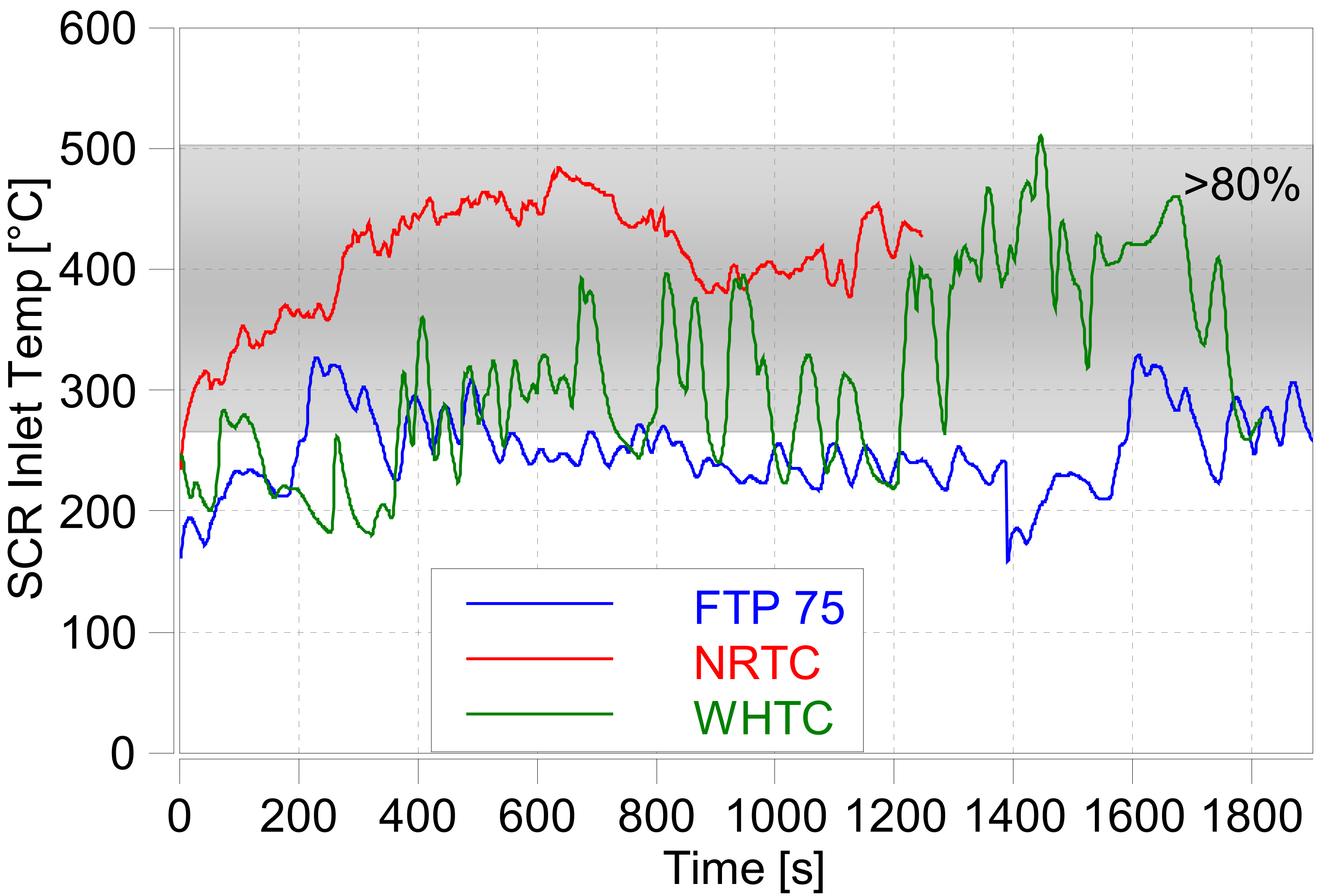
- Boundaries: max. 25 ppm ammonia and 300 ppm HC slip

Results – Steady-State NOx Conversion Efficiency [%] Using E85 as Reductant



- >80% NOx conv. efficiency in temp. window of 270 – 500 ºC

Temperature Profiles over Hot Cycles in Front of SCR Catalysts

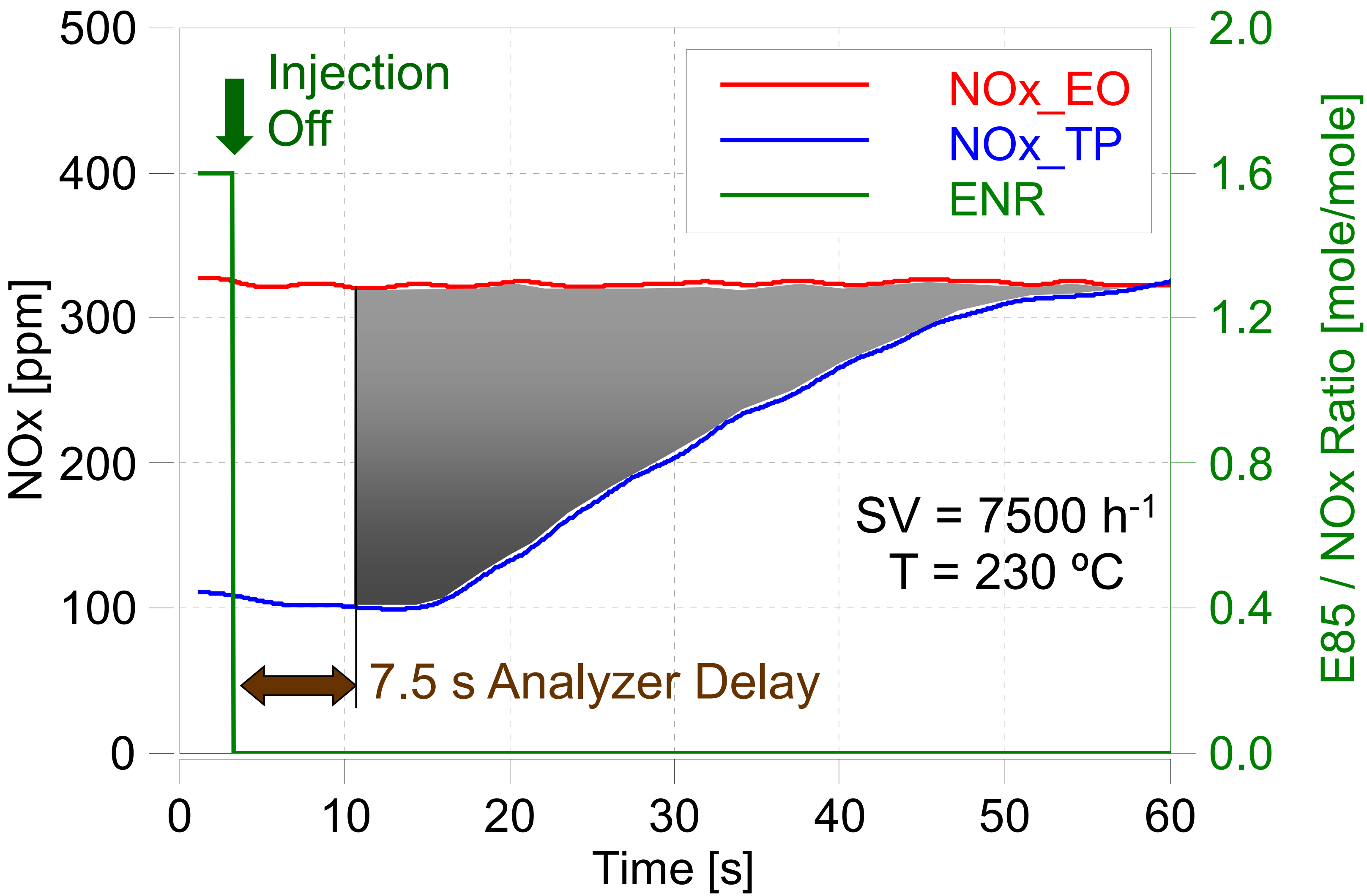


- NRTC has most favorable temperature profile

Controls Development

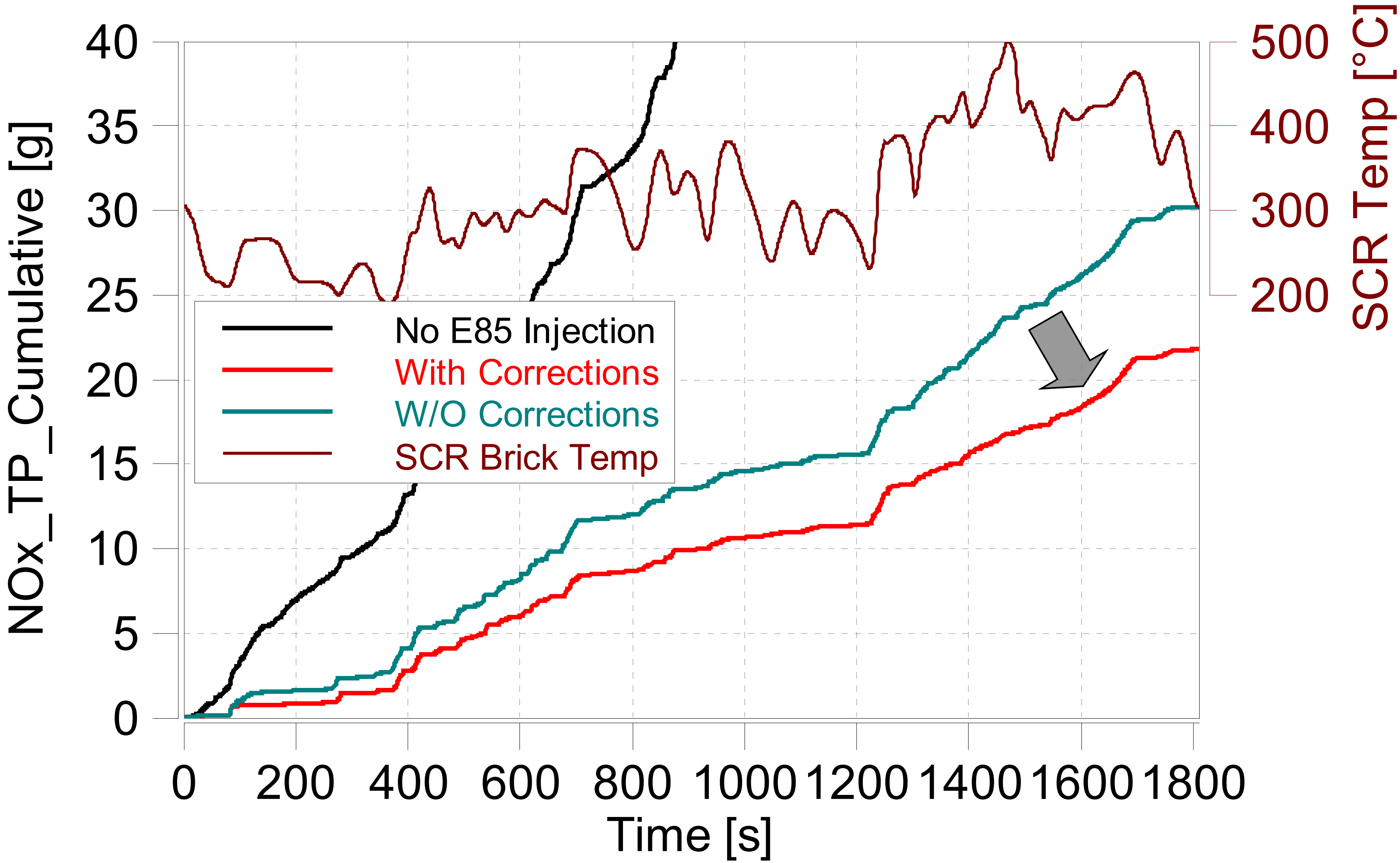
- Map based pre-control of ethanol injection quantity
- Consideration of storage effects
- Introduction of transient corrections
- Algorithm to eliminate cross sensitivity of NOx sensors

Storage Investigations



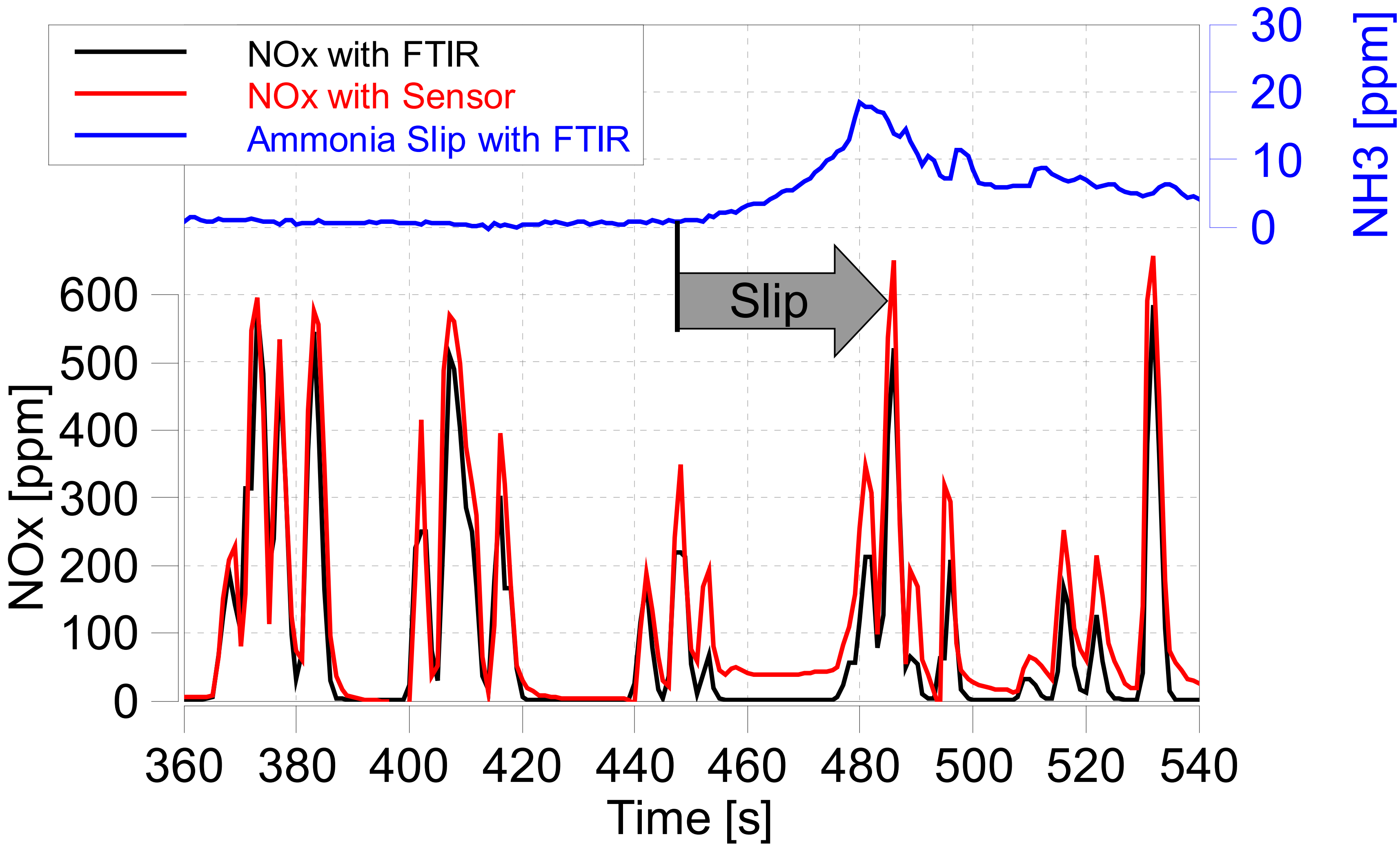
- Much less storage compared to urea based SCR

Transient Corrections



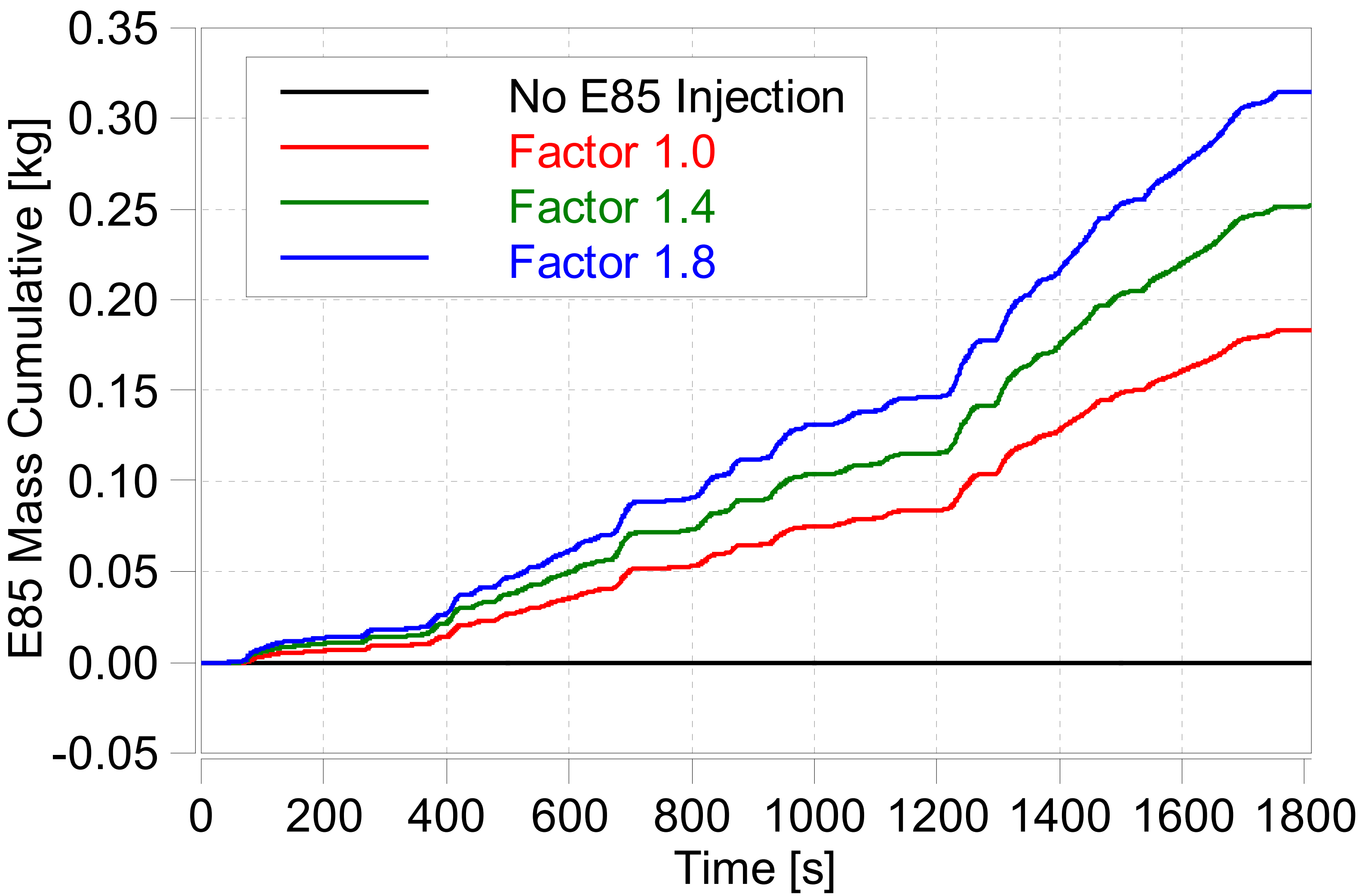
- Further improvement while controlling by-product formation

Cross Sensitivity of NOx Sensors to Ammonia



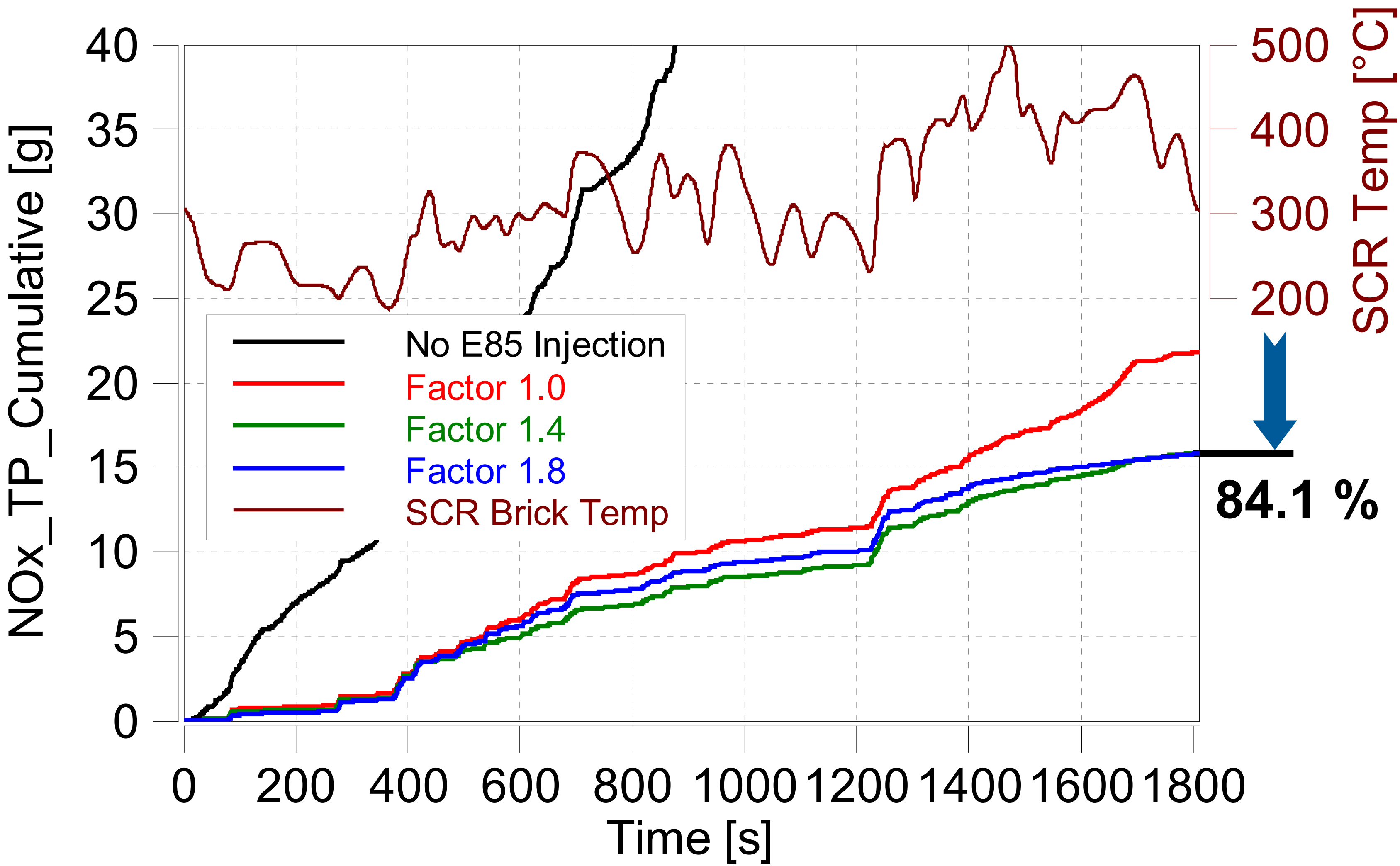
- Algorithm to distinguish between NOx and NH_3 applied

WHTC - E85 to NOx Ratio Variation
Cumulative Injected E85 Mass



- Evaluation of NOx Reduction Potential and Byproduct Formation

WHTC - E85 to NOx Ratio Variation
NOx Conversion Efficiency

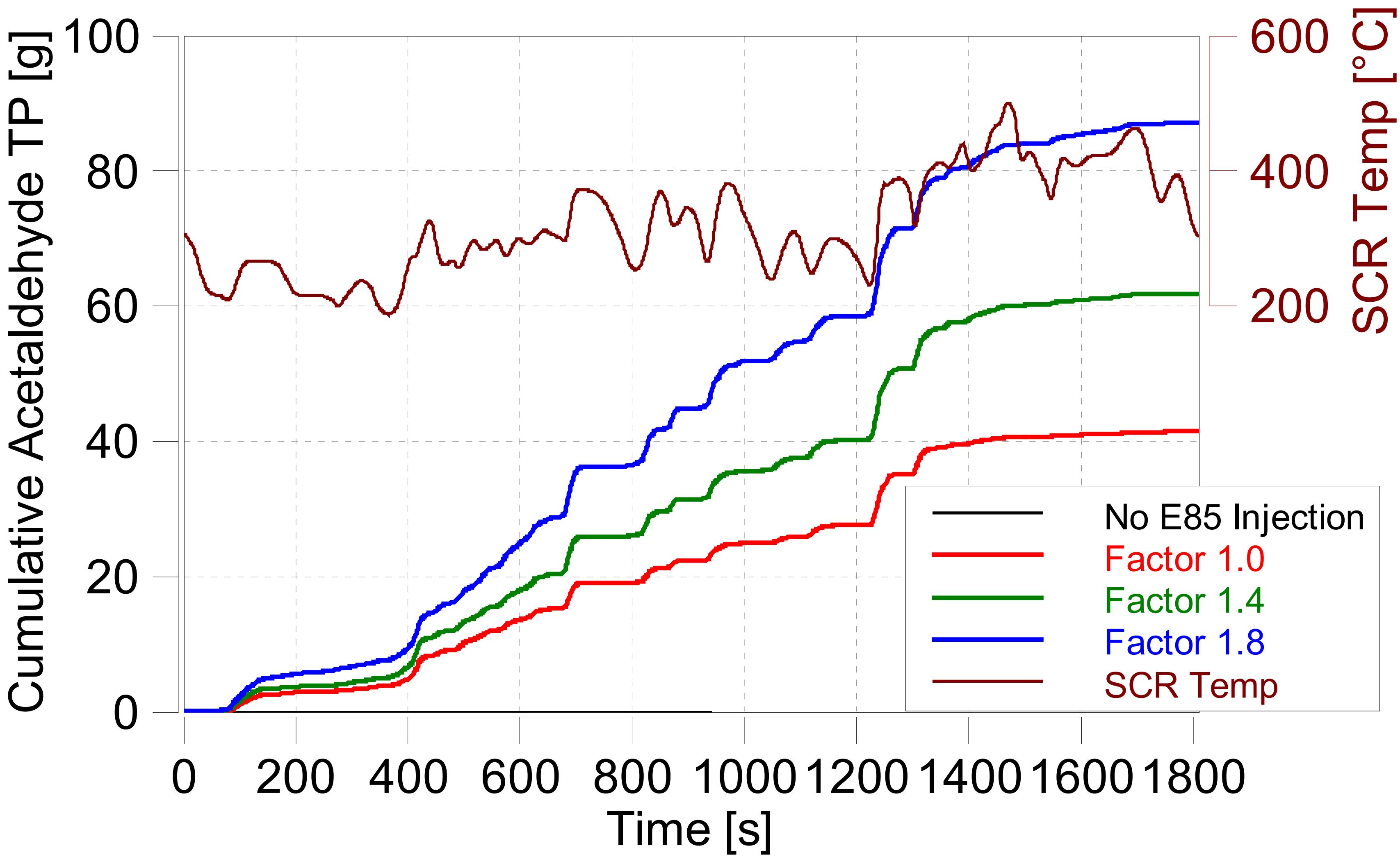


- 84.1% NOx conversion efficiency with Factor 1.4

Summary of Cycle Results

	WHTC	NRTC
NO_x Conversion Efficiency	84.1%	91.4%
E85 Consumption with Test Engine	5.3%	4.5%
Predicted DEF Cons. With Test Engine	4.1%	4.6%
Predicted US2010 / Tier 4 E85 Cons.	1.5%	1.5%

WHTC - E85 to NOx Ratio Variation
Cumulative Tailpipe Acetaldehyde



- Substantial amount of acetaldehyde slip throughout the test

Qualitative Comparison of Two SCR Technologies

	E85 / E100	*Urea*
NO_x Conversion Efficiency	-	o
Evaporation	++	o
Freezing	++	o
Deposit Formation	+	o
Byproduct Formation	--	o

Summary and Conclusions

- Very quick evaporation was demonstrated using CFD
- A controls strategy for ethanol injection was developed and calibrated
- High NOx conversion efficiencies >90% are possible if operated in the temperature range between about 270 and 500 ºC
- Further catalyst development is required to minimize by-product formation
- A slip catalyst is mandatory for this technology

Acknowledgements

- Nick Zayan, AVL,
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- Hilite - dosing system