Biodiesel Effects on the Operation of U.S. Light-Duty Tier 2 Engine and Aftertreatment Systems

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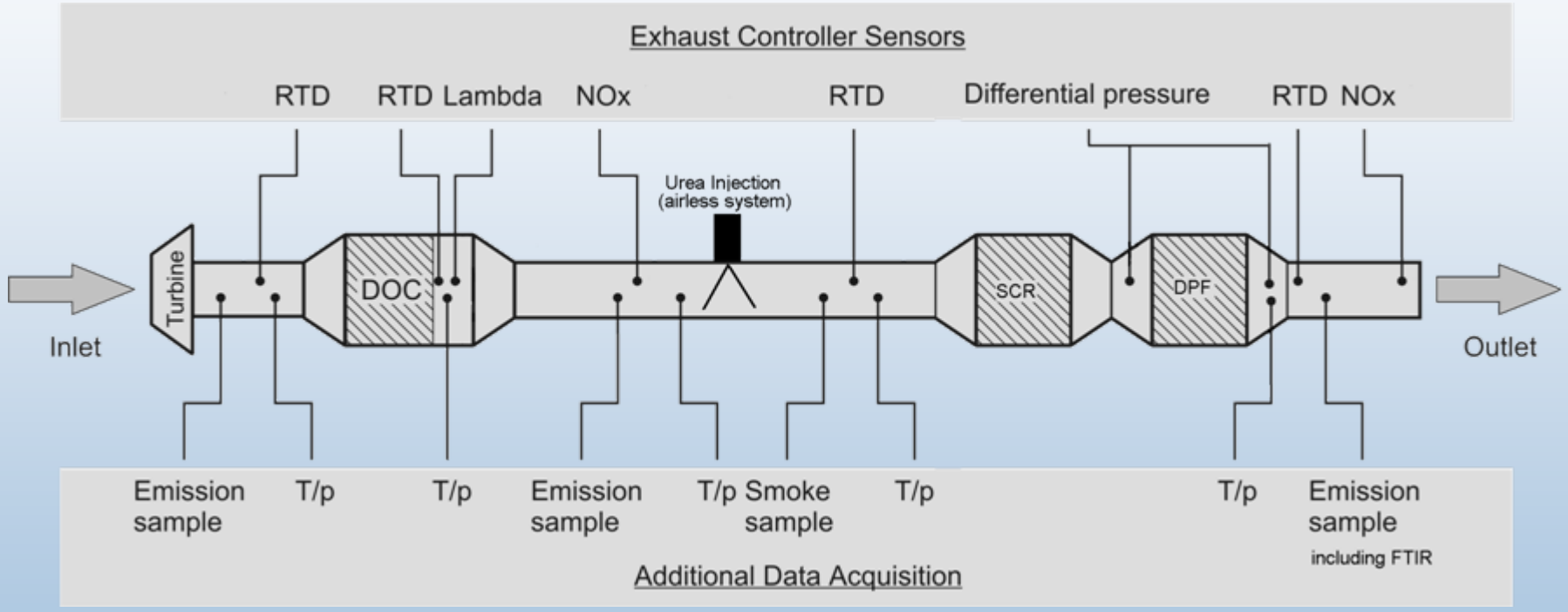
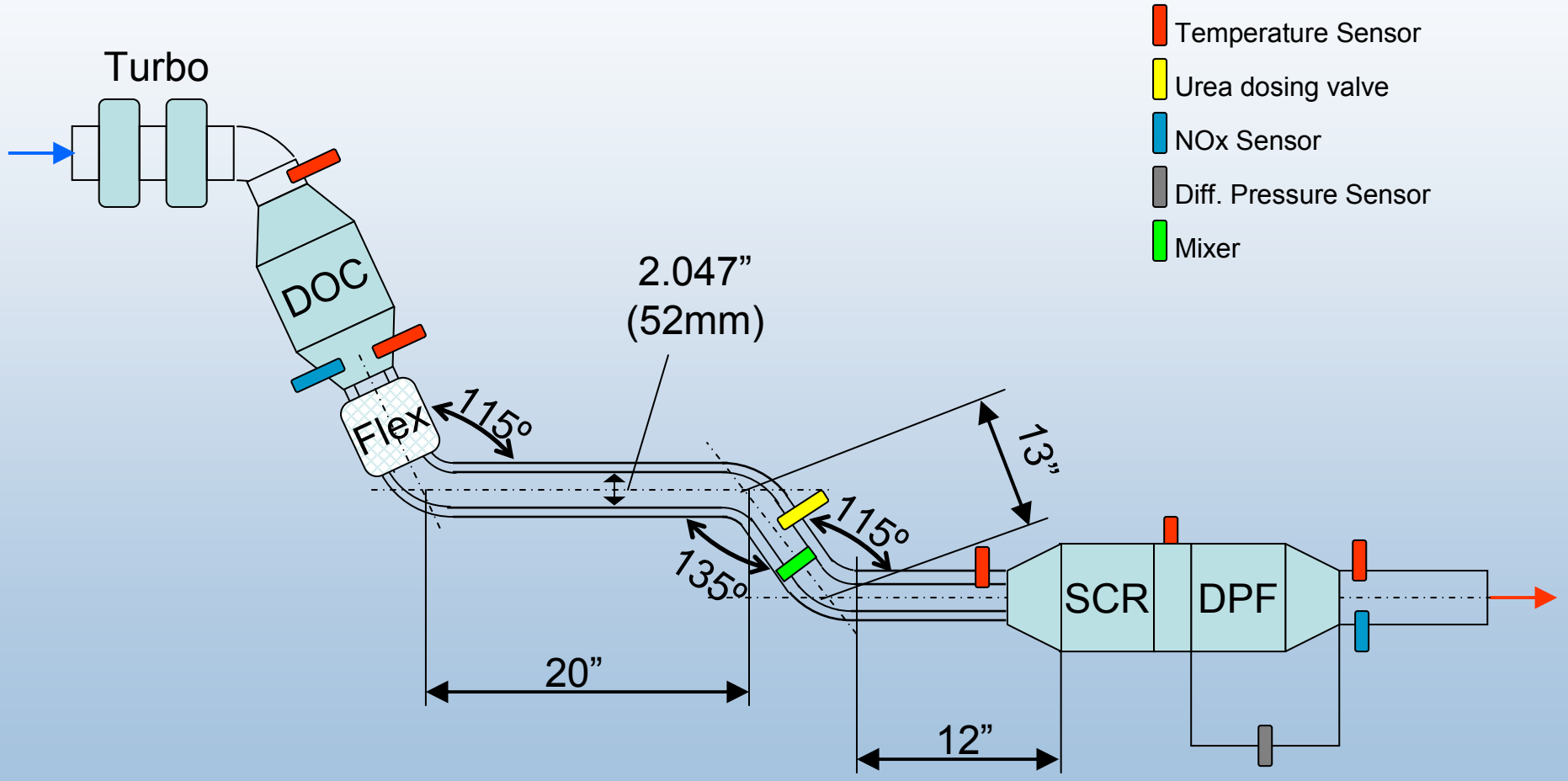
Project Goals

- ❑ Evaluate the impact of Biodiesel fuel blends on the performance of advanced emission control systems for light-duty diesels e.g. conversion efficiencies, regeneration effects (NAC/DPF and SCR/DPF)
- ❑ Understand effects over time (system aging)
- ❑ Assess engine and fuel system operation impacts at end of project (i.e. combustion chamber, fuel injection system, fuel pump)

Hardware Overview – SCR System

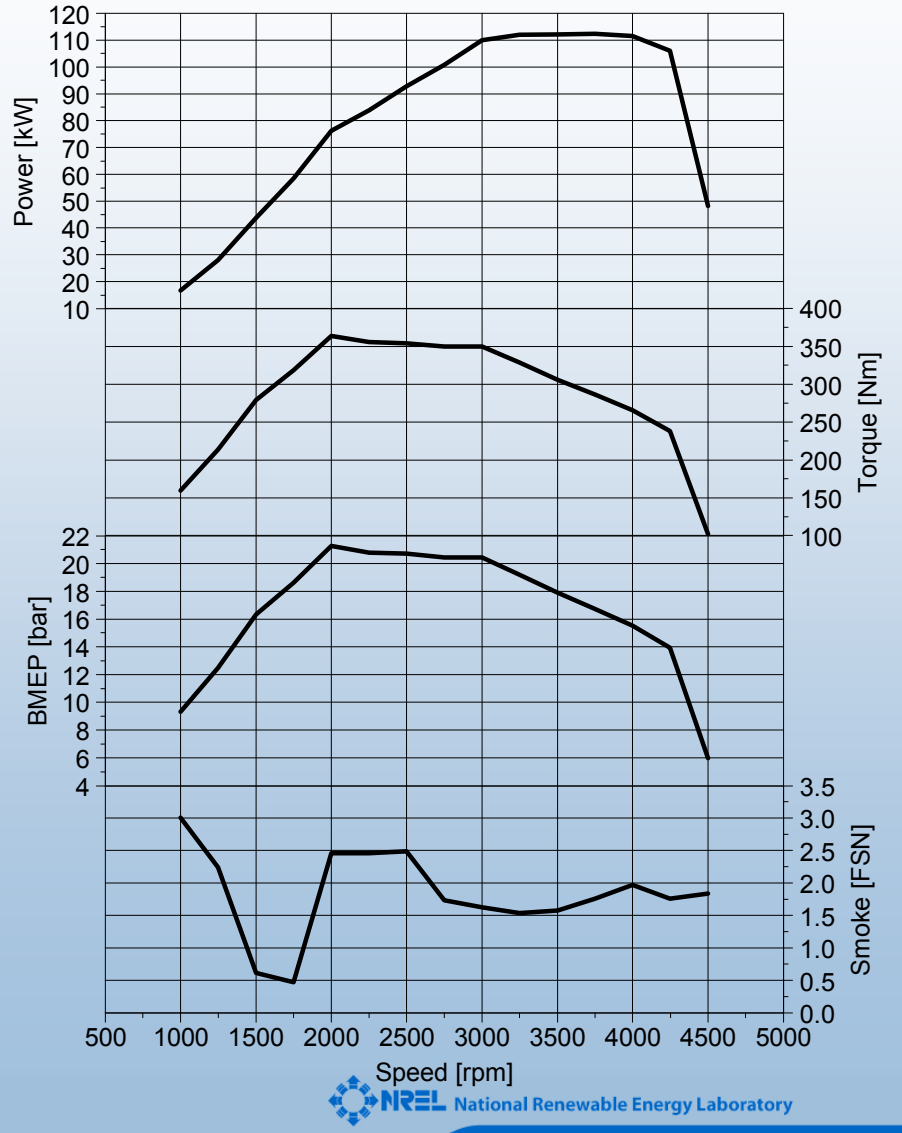


Hardware Overview – SCR System



Hardware Overview – Test Engine Hardware

Engine Power	113 kW at 4000 rpm
Peak Torque	360 Nm at 2000 rpm
Maximum Engine Speed	4700 rpm
Maximum BMEP	21 bar
Cylinder Number and Arrangement	4 Cylinder Inline
Firing Order	1 – 3 – 4 – 2
Valve Train	4 Valve DOHC
Bore to Stroke Ratio	1.0034
Displacement`	2.15 l
Compression Ratio	18
Fuel Injection System	2nd Generation Common Rail



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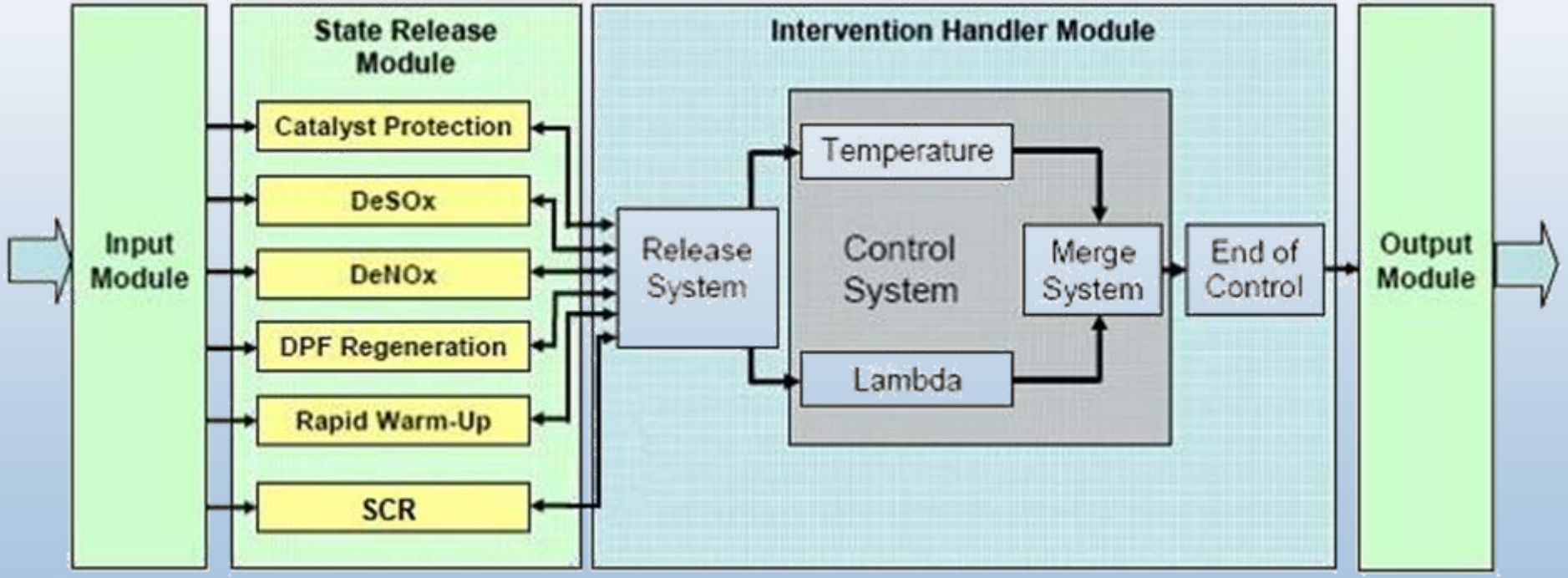
Hardware Overview – Test Vehicle Hardware

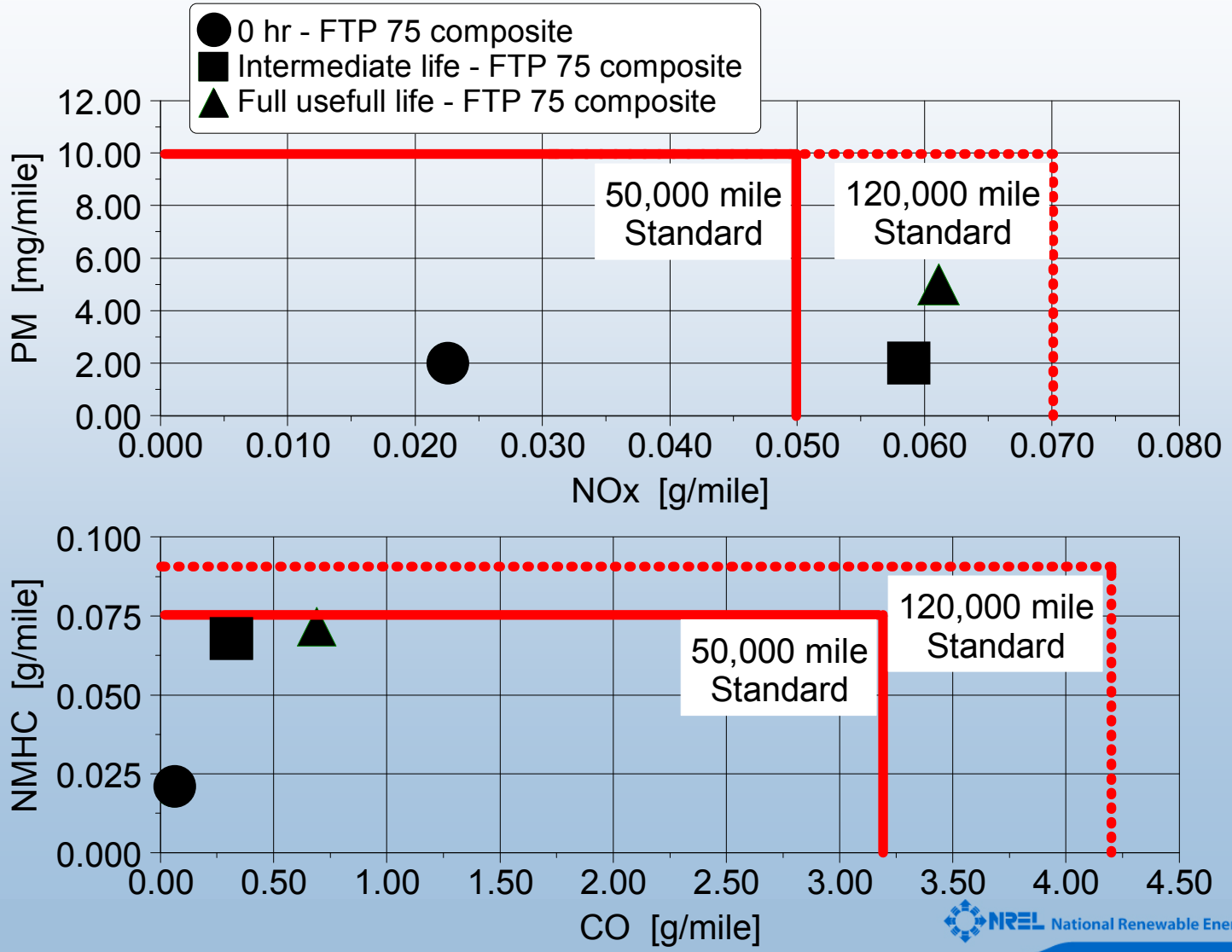
Control System Overview



Fuel Comparison

	ULSD Base Fuel	B20
Density (kg/dm^3)	*0.846*	*0.853*
Cetane Number	*42.0*	*43.2*
Carbon (wt%)	*87.08*	*85.04*
Oxygen (wt%)	*0.00*	*2.37*
Hydrogen (wt%)	*12.92*	*12.59*
Kinematic Viscosity at 40°C [mm^2/sec]	*2.28*	*2.74*

Test Results – Useful Life NOx Adsorber System



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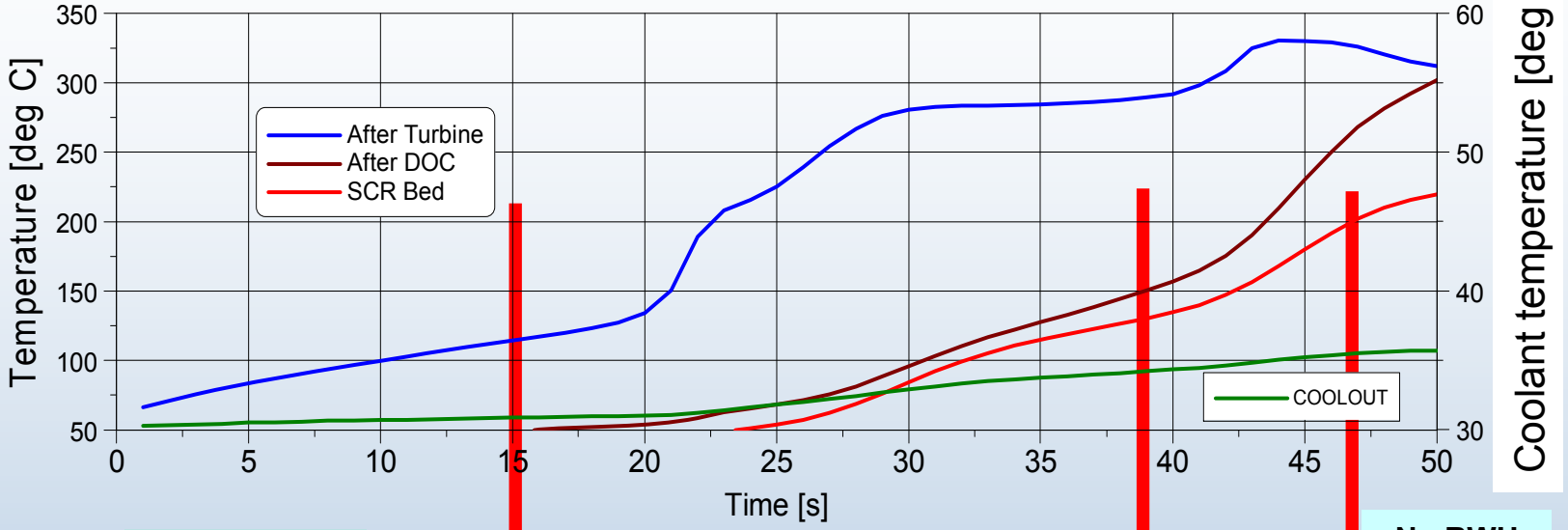
Test Results – SCR System

Rapid Warm-up



Window 1

-Lambda Ctrl in idling
-Increased Rail pressure
-Advanced timing
-Pilot 1 and 2 ON
-Reduced Boost
-Reduced EGR

Combustion adjustment to minimize HC emissions

Window 2

-Increased Rail pressure
-Start of retarding of timing
-Pilot 1 and 2 ON
-Reduced Boost
-Optimized EGR
-Pilot 1 timing and Qnty correction

To light off DOC – Combustion Optimization to increase engine out temp

Window 3

-Reduced Rail pressure
-Retarded timing
-Pilot 2 OFF
-Post 2 ON
-Increased Boost & EGR
-Pilot 1 timing and Qnty correction

Use exotherm across DOC to heat up SCR

No RWU Window 0

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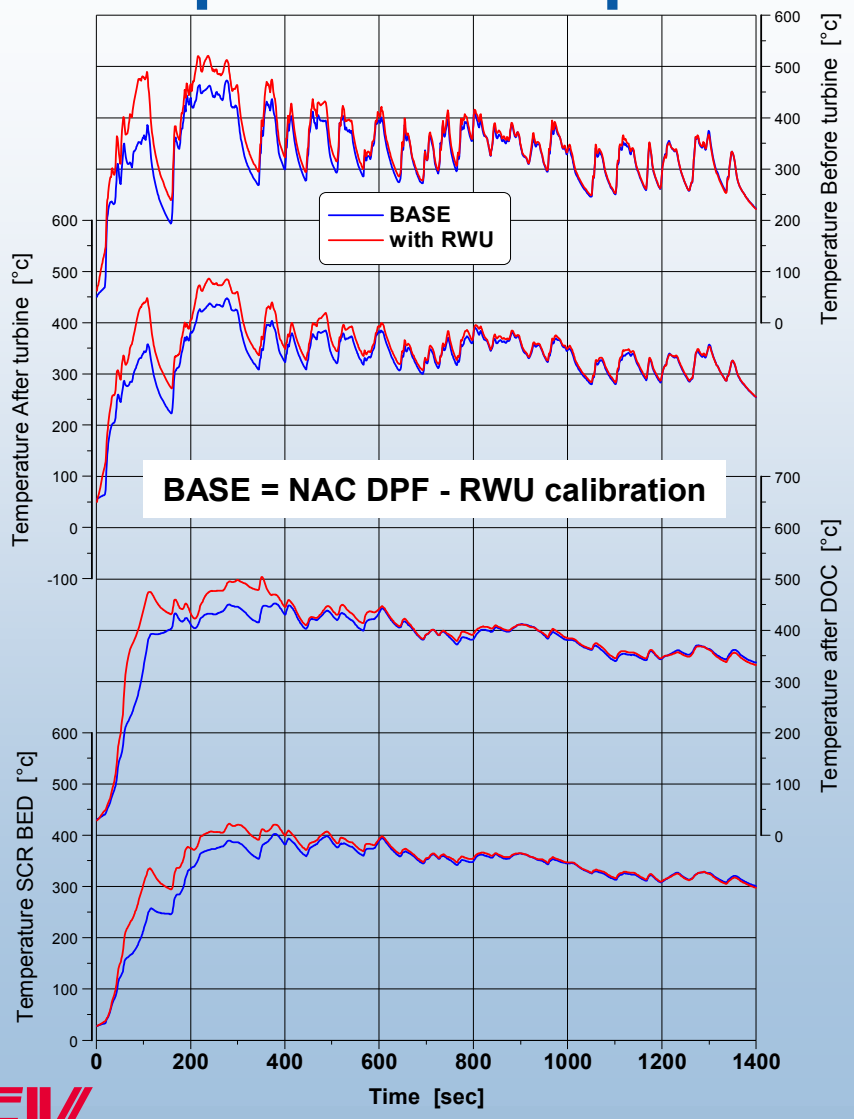
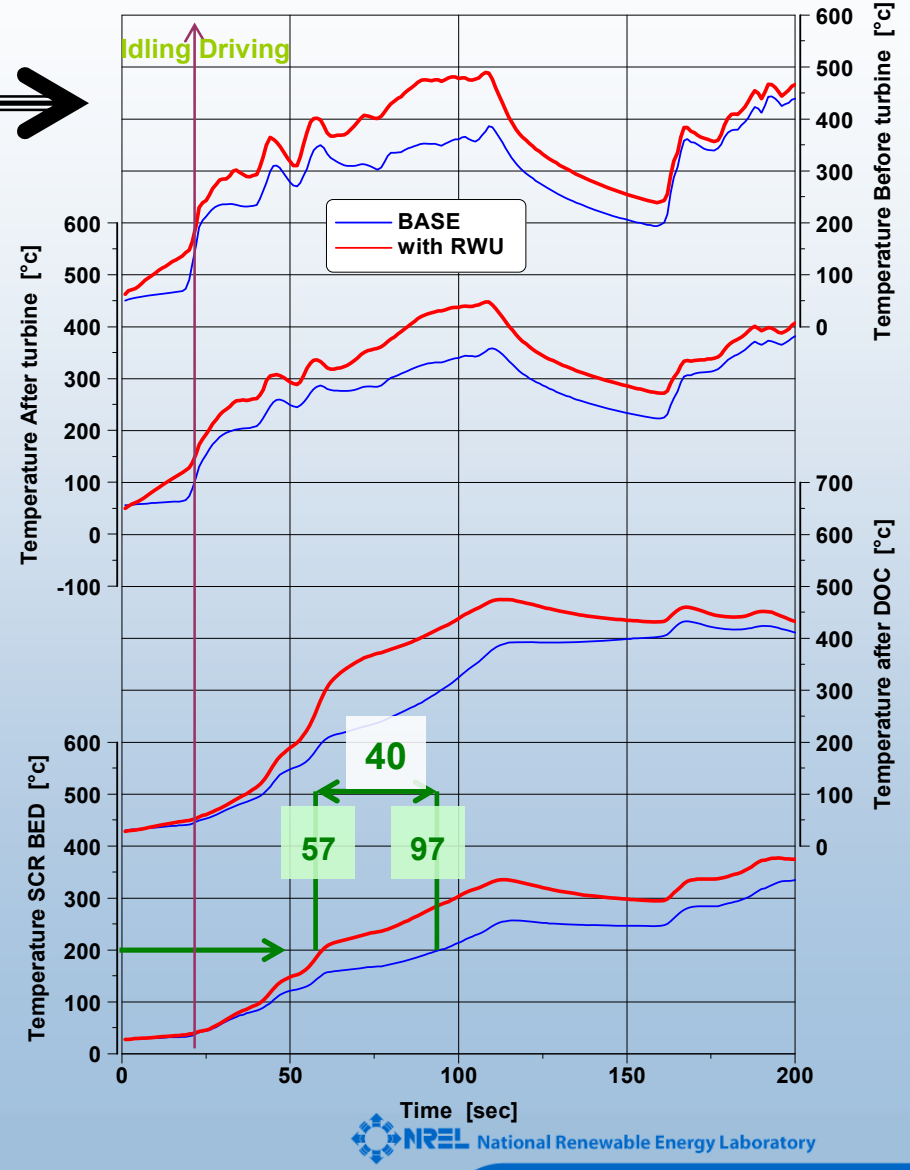
Test Results – SCR System

Rapid Warm-up





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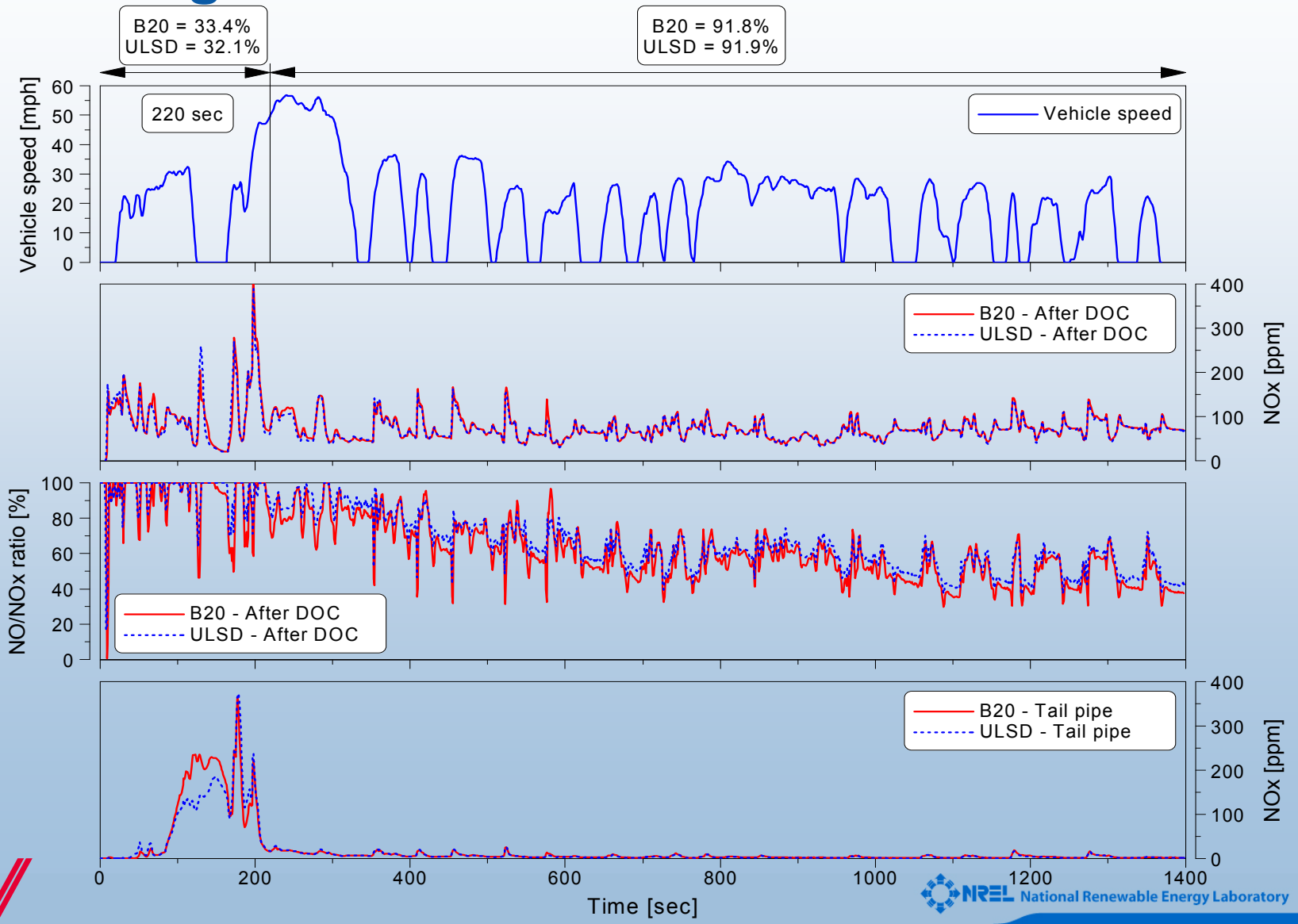
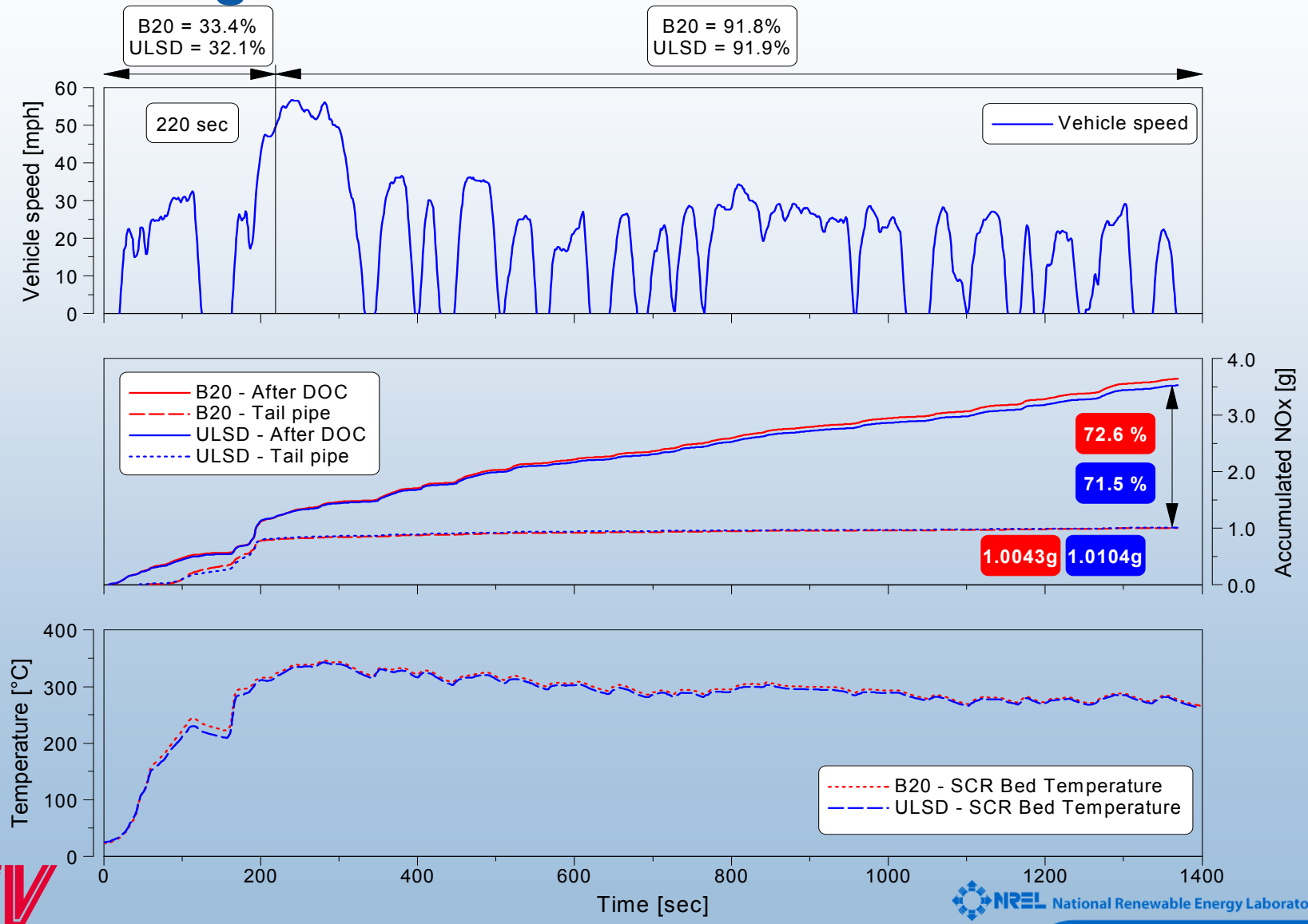
Test Results – SCR System

Storage and Release



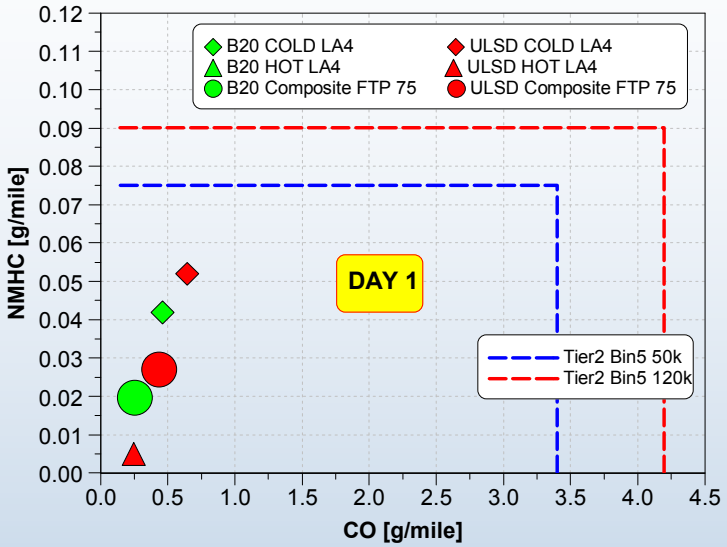
Test Results – SCR System

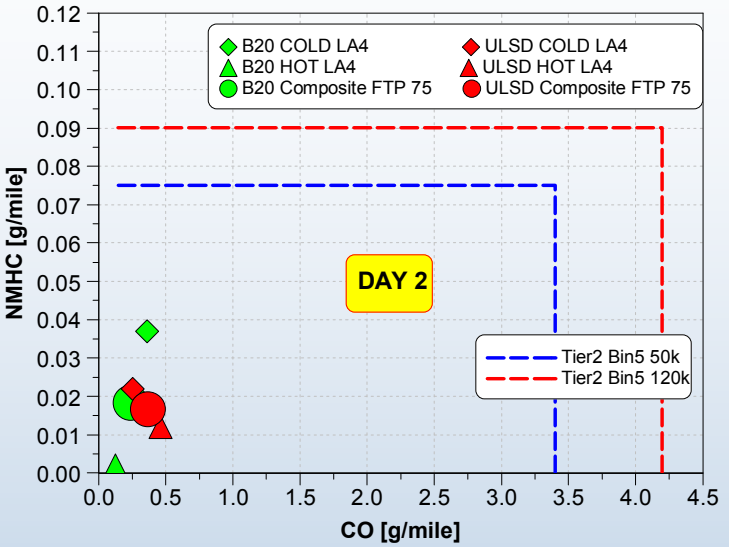
Storage and Release

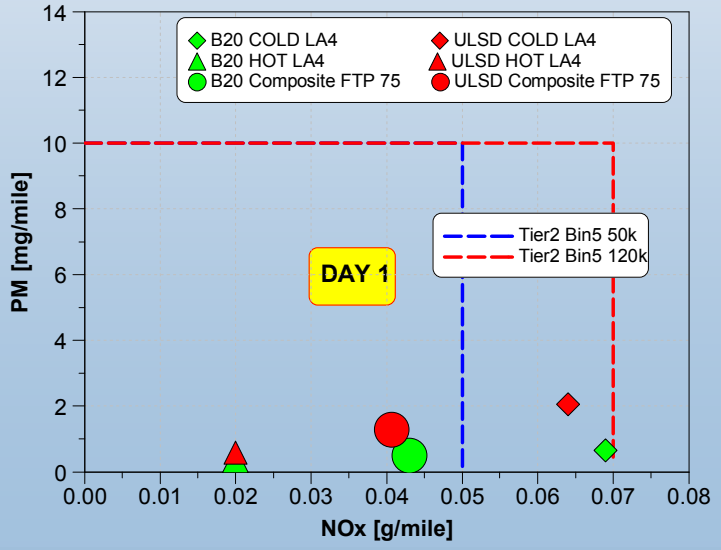


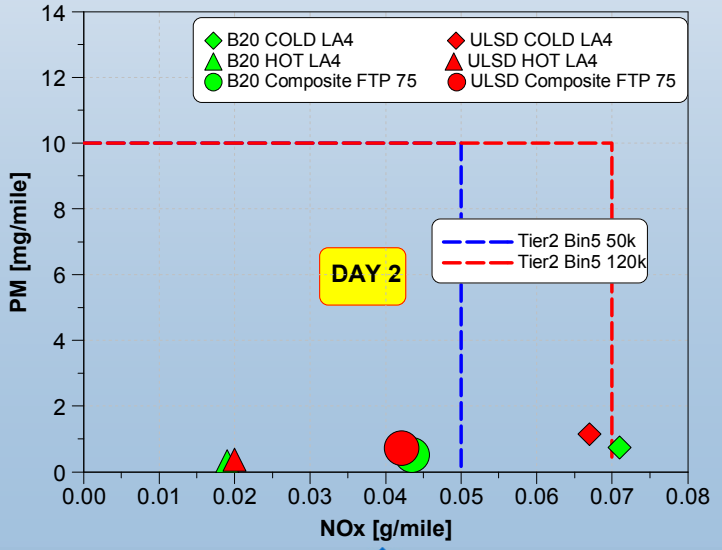
Test Results – SCR System

Vehicle Test Results









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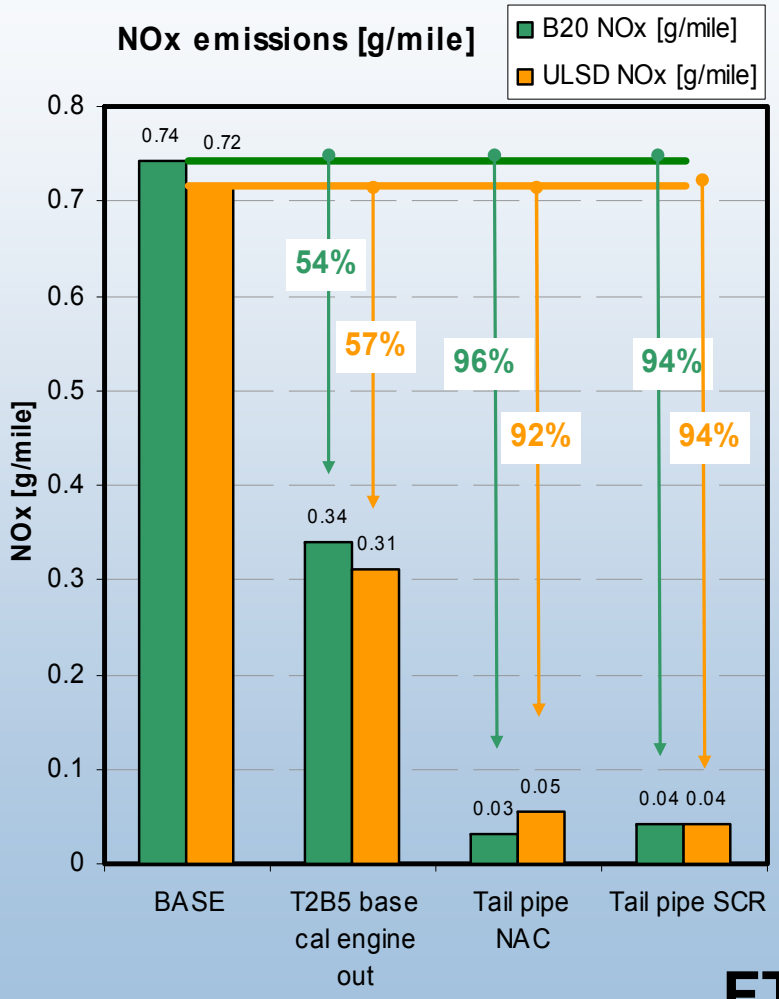
Test Results – SCR System

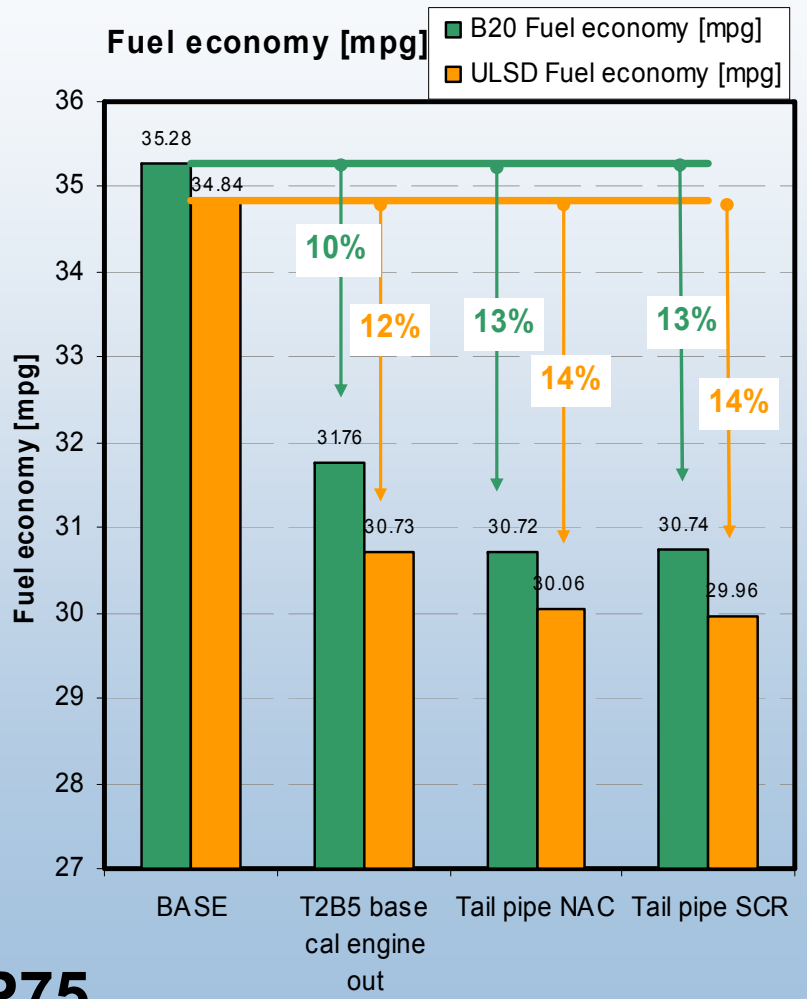
Vehicle Test Results

NREL SCR DPF aftertreatment system evaluation using B20 and ULSD fuel												
	Date	Test #	Fuel	Test Type	Result	HC g/mile	NMHC g/mile	CO g/mile	NOx g/mile	CO2 g/mile	PM mg/mile	Fuel Econ miles/gal
DAY 1	2/15/08	2006-0227-071	B20	FTP2BAG	C-LA4	0.103	0.042	0.464	0.070	366.6	0.65	27.7
	2/15/08	2006-0227-071		FTP2BAG	H-LA4	0.042	0.000	0.077	0.021	316.0	0.36	32.2
	2/15/08	2006-0227-071		**FTP75 composite**	**Weighted**	**0.071**	**0.020**	**0.259**	**0.044**	**339.782**	**0.495**	**30.065**
	2/15/08	2006-0227-072		**HFET/US06**	**HFET**	**0.029**	**0.000**	**0.119**	**0.026**	**198.6**	**0.32**	**51.2**
	2/15/08	2006-0227-072		**HFET/US06**	**US06**	**0.040**	**0.000**	**0.389**	**0.113**	**285.4**	**1.14**	**35.6**
DAY 2	2/20/08	2006-0227-073		FTP2BAG	C-LA4	0.101	0.037	0.356	0.071	362.9	0.75	28.0
	2/20/08	2006-0227-073		FTP2BAG	H-LA4	0.050	0.002	0.129	0.019	310.4	0.32	32.8
	2/20/08	2006-0227-073		**FTP75 composite**	**Weighted**	**0.074**	**0.018**	**0.236**	**0.043**	**335.075**	**0.518**	**30.503**
	2/20/08	2006-0227-074		**HFET/US06**	**HFET**	**0.029**	**0.000**	**0.129**	**0.014**	**201.1**	**0.58**	**50.5**
	2/20/08	2006-0227-074		**HFET/US06**	**US06**	**0.025**	**0.000**	**0.146**	**0.118**	**285.8**	**2.19**	**35.6**
DAY 1	2/22/08	2006-0227-077	ULSD	FTP2BAG	C-LA4	0.124	0.052	0.645	0.064	356.6	2.05	28.4
	2/22/08	2006-0227-077		FTP2BAG	H-LA4	0.061	0.005	0.264	0.020	311.1	0.59	32.6
	2/22/08	2006-0227-077		**FTP75 composite**	**Weighted**	**0.091**	**0.027**	**0.443**	**0.040**	**332.515**	**1.278**	**30.659**
	2/22/08	2006-0227-078		**HFET/US06**	**HFET**	**0.040**	**0.000**	**0.236**	**0.028**	**198.8**	**0.40**	**51.1**
	2/22/08	2006-0227-078		**HFET/US06**	**US06**	**0.042**	**0.000**	**0.462**	**0.121**	**287.3**	**7.14**	**35.3**
DAY 2	2/27/07	2006-0227-080		FTP2BAG	C-LA4	0.082	0.022	0.258	0.067	371.3	1.14	27.4
	2/27/07	2006-0227-080		FTP2BAG	H-LA4	0.081	0.012	0.465	0.020	318.9	0.37	31.8
	2/27/07	2006-0227-080		**FTP75 composite**	**Weighted**	**0.081**	**0.017**	**0.368**	**0.042**	**343.528**	**0.734**	**29.713**
	2/27/07	2006-0227-081		**HFET/US06**	**HFET**	**0.040**	**0.000**	**0.270**	**0.022**	**201.4**	**0.53**	**50.6**
	2/27/07	2006-0227-081		**HFET/US06**	**US06**	**0.044**	**0.000**	**0.453**	**0.131**	**289.2**	**4.77**	**35.1**

Test Results

Comparison NOx Adsorber SCR System





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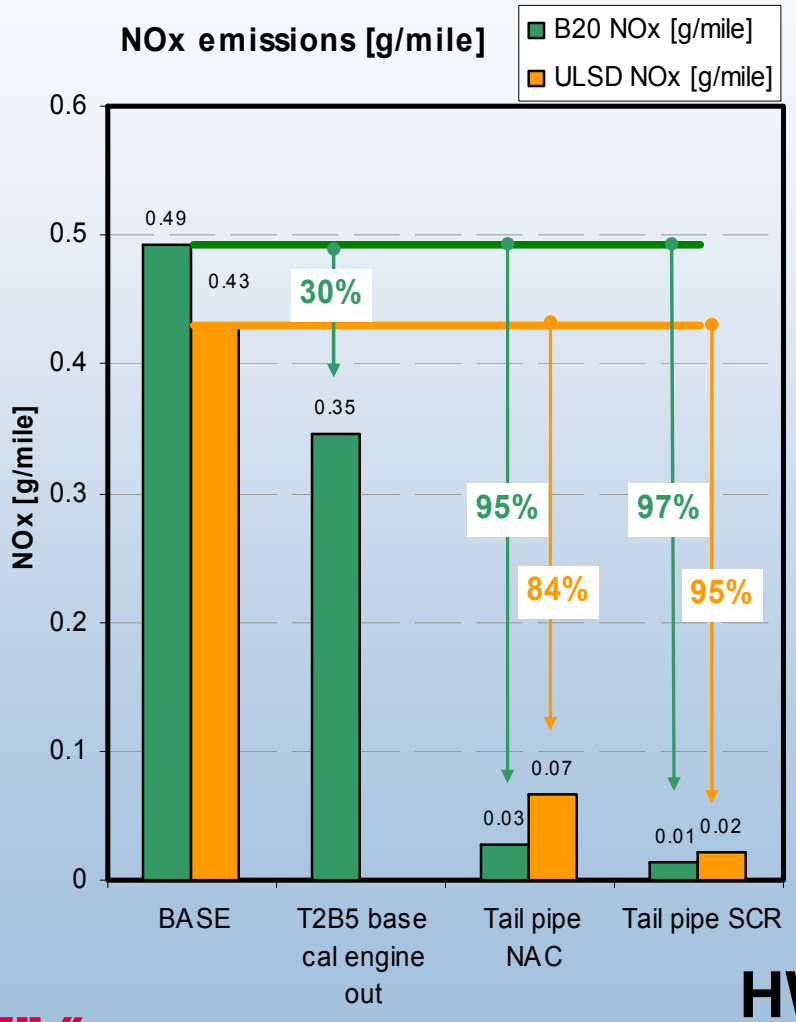
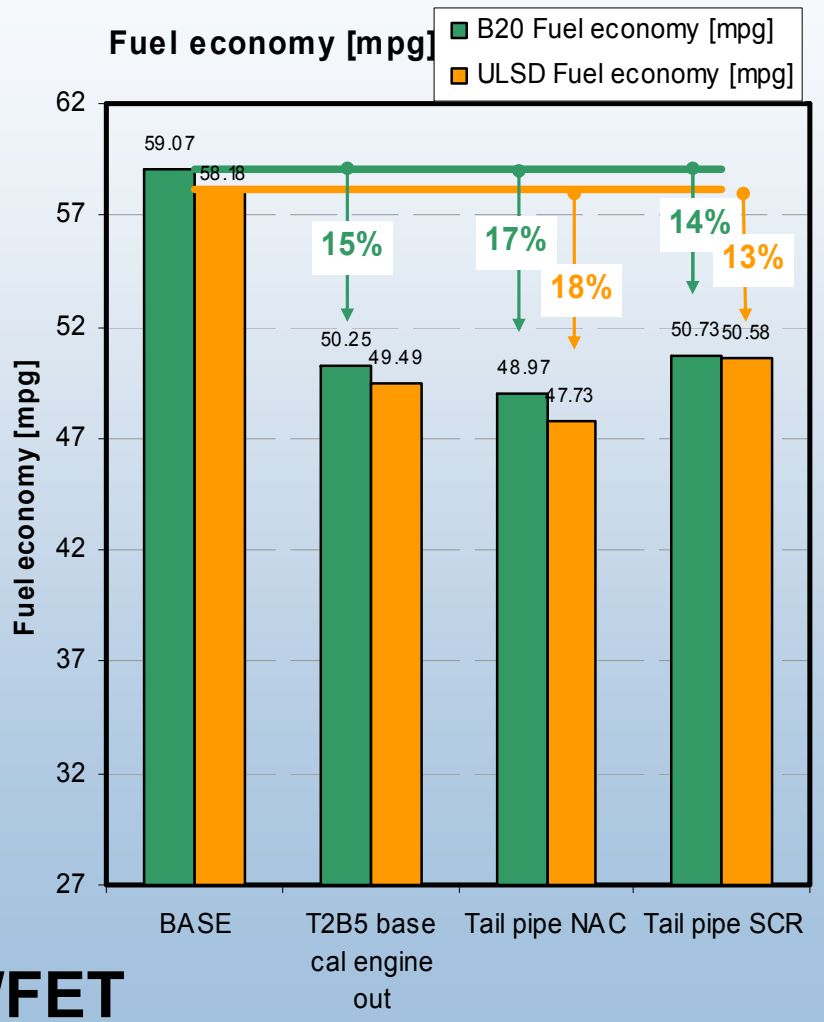
Test Results

Comparison NOx Adsorber SCR System





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Summary and Conclusions

- ❑ Successful completion of the NOx adsorber durability task resulted in compliance with emission standards for 120,000 miles with useful life aged catalysts
- ❑ SCR system development completed in test cell and vehicle with the successful demonstration of compliance with Tier 2 Bin 5 emission standards
- ❑ Detailed investigations on rapid warm-up, storage and release as well as total system performance were conducted and shared with the development team
- ❑ SCR system durability task completed and final emissions evaluation is currently underway
- ❑ Detailed engine and fuel injection system evaluation currently underway

Acknowledgments

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