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NOx Adsorbers for Heavy Duty Truck Engines – Testing and Simulation

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Motor Fuels: Effects on Energy Efficiency and Emissions in the Transportation Sector
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DDC

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Presentation Outline

- Experimental Plan
- Simulation
- Experimental Results
- Conclusions

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  - Single Leg
  - Dual Leg
  - Single Leg with Bypass
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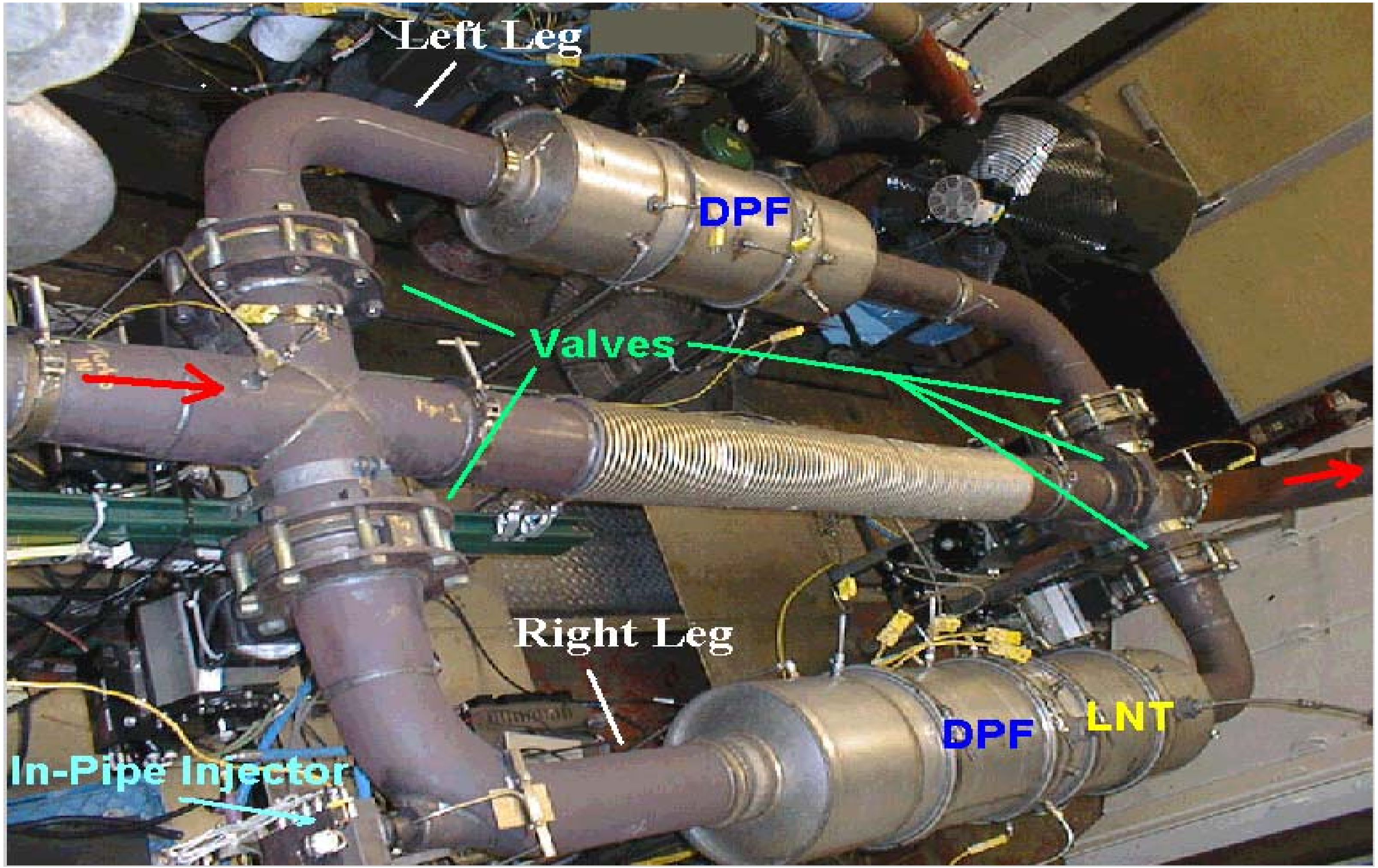
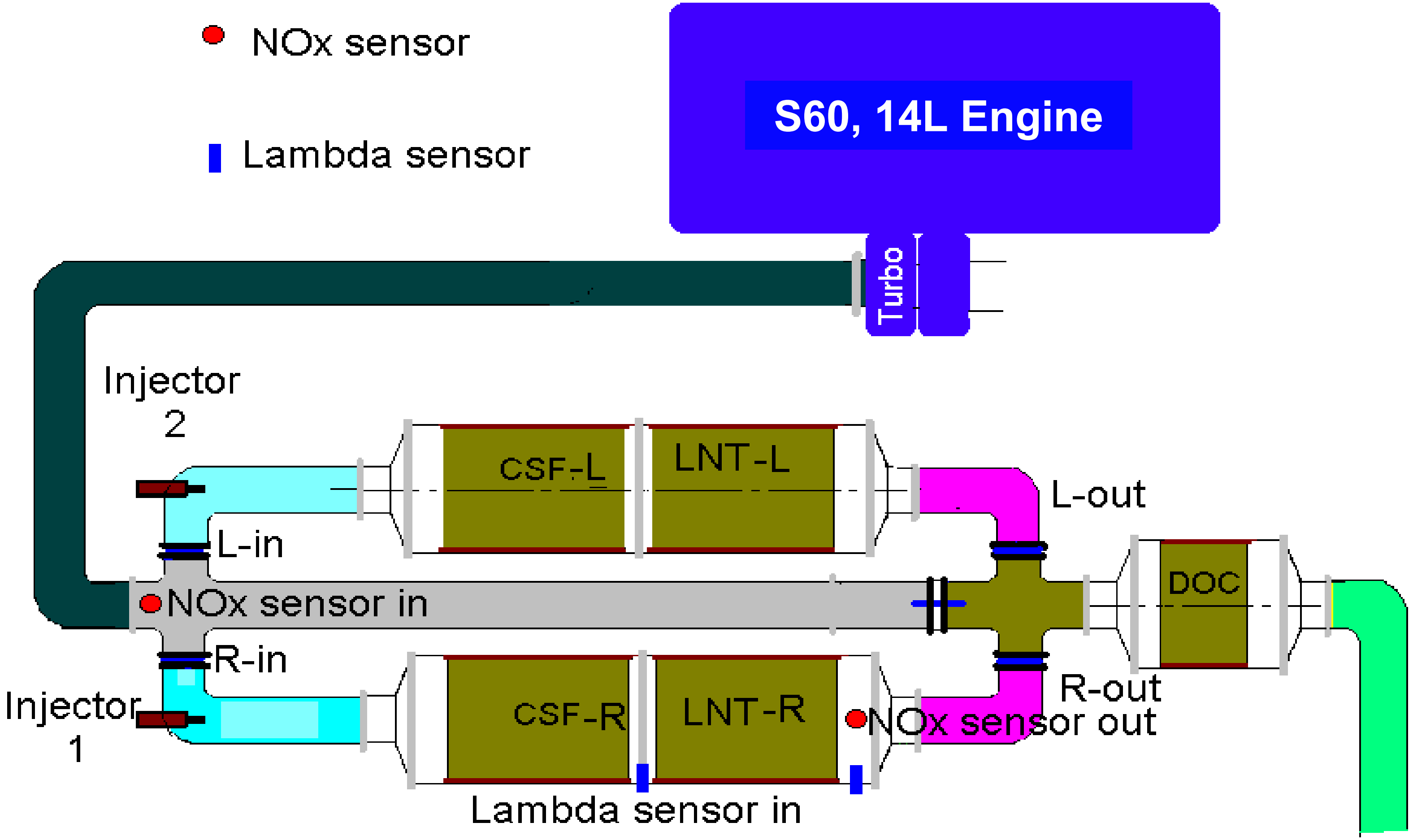
Test Setup



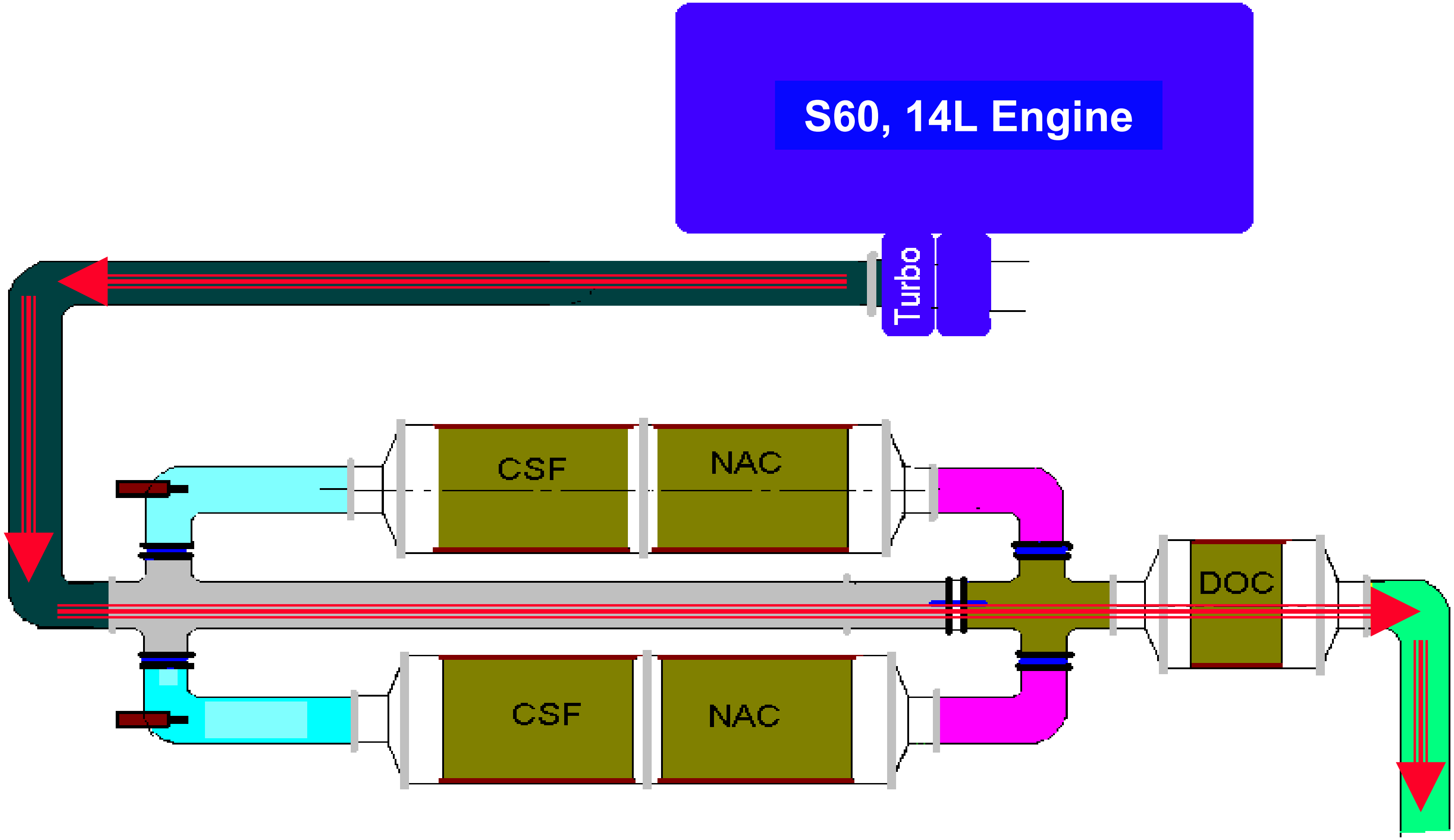
Test Setup Schematic



A.T. System Configurations and Catalysts

Configuration / Catalyst & In-Pipe injector	Dual Leg	Single Leg	Single Leg bypass
DPF	45.6 L	22.8 L	22.8 L
	100 cpsi, 11.25” * 14”		
NOx Adsorber	39 L	19.5 L	19.5 L
	300 cpsi, 11.25” * 12” (2*6”)		
DOC	9.8 L	9.8 L	9.8 L
Post-Engine Injector	Yes	No	Yes

Engine Baseline Test Configuration



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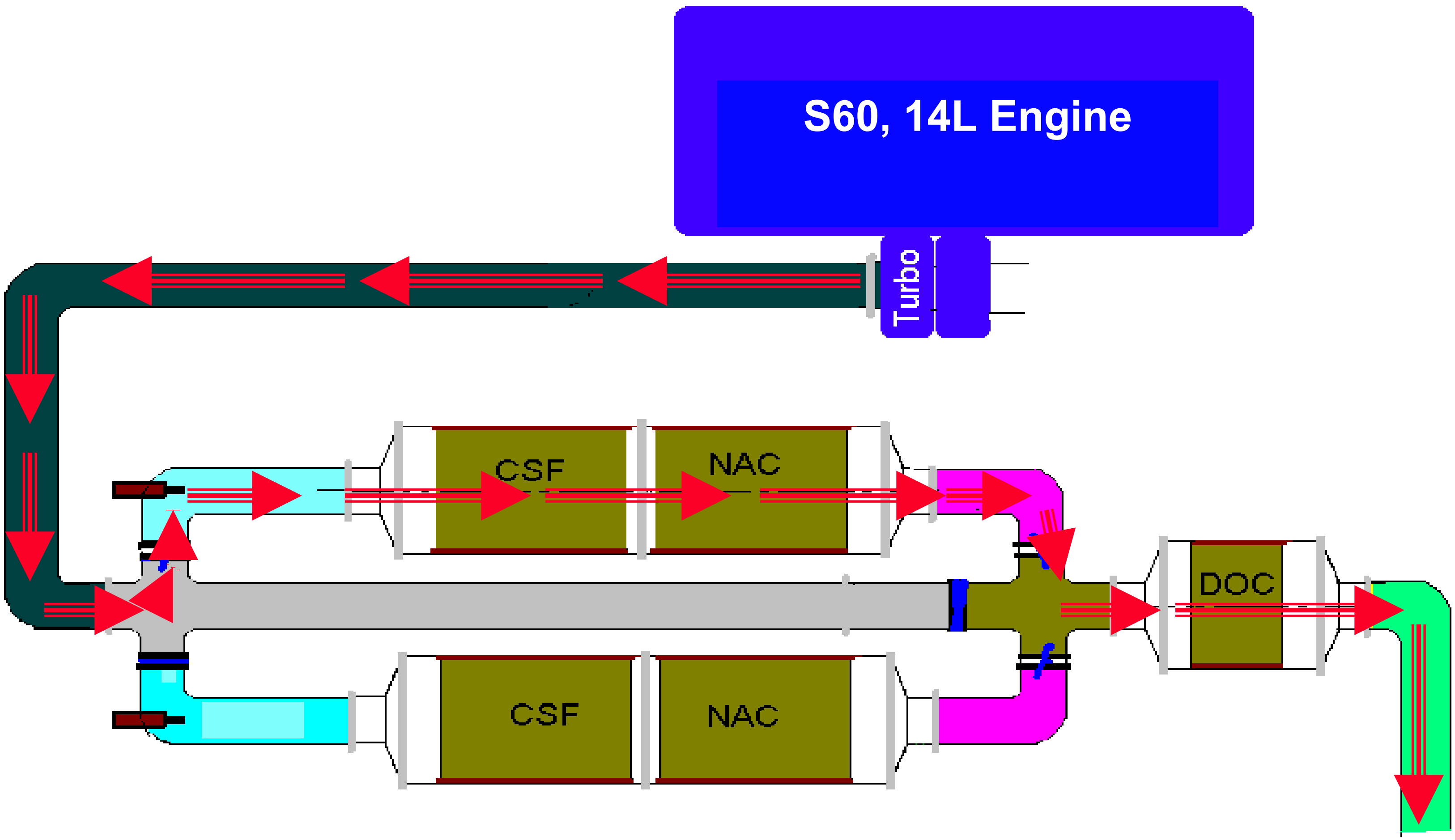
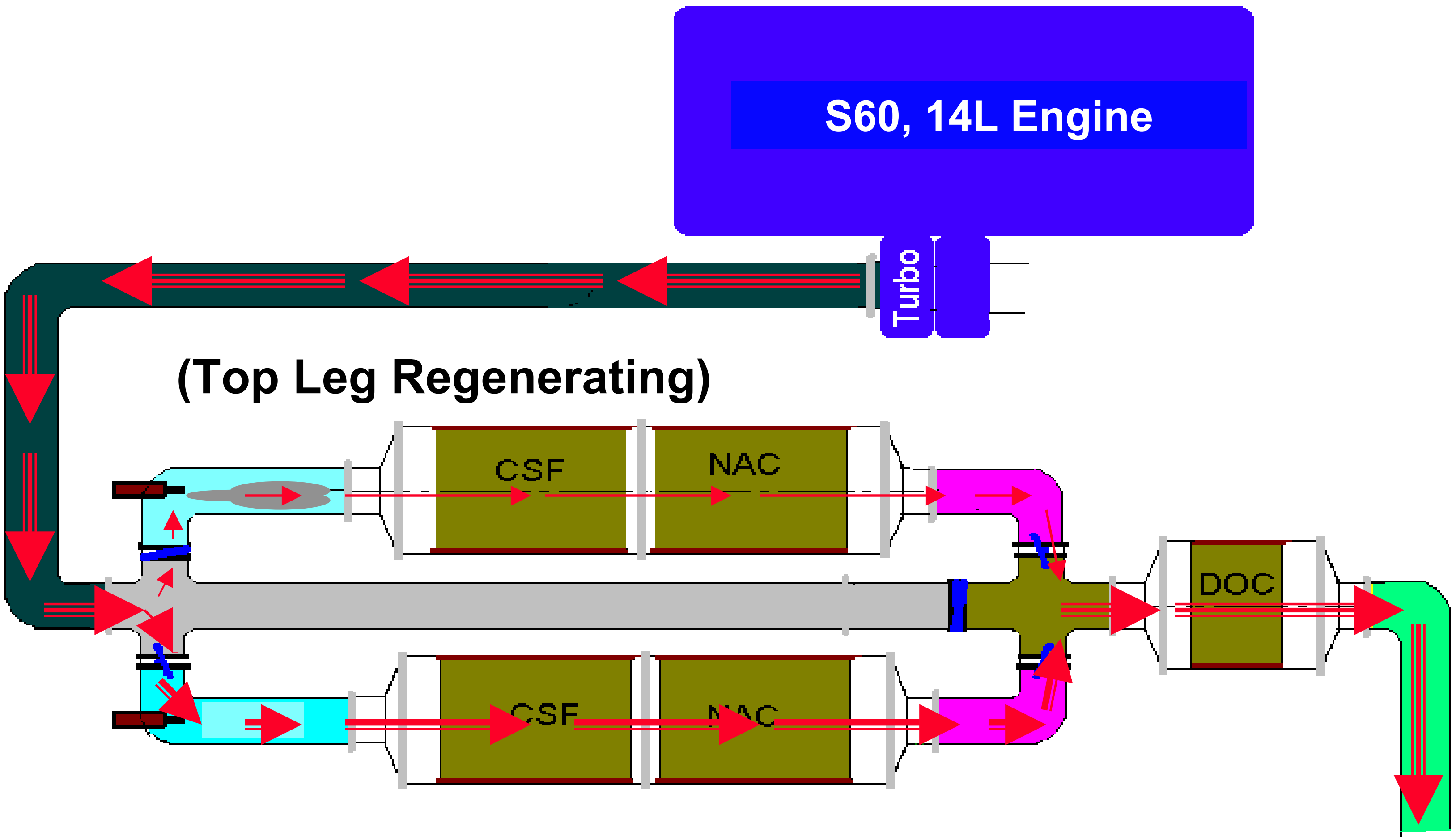
Single Leg Configuration



Dual Leg Configuration



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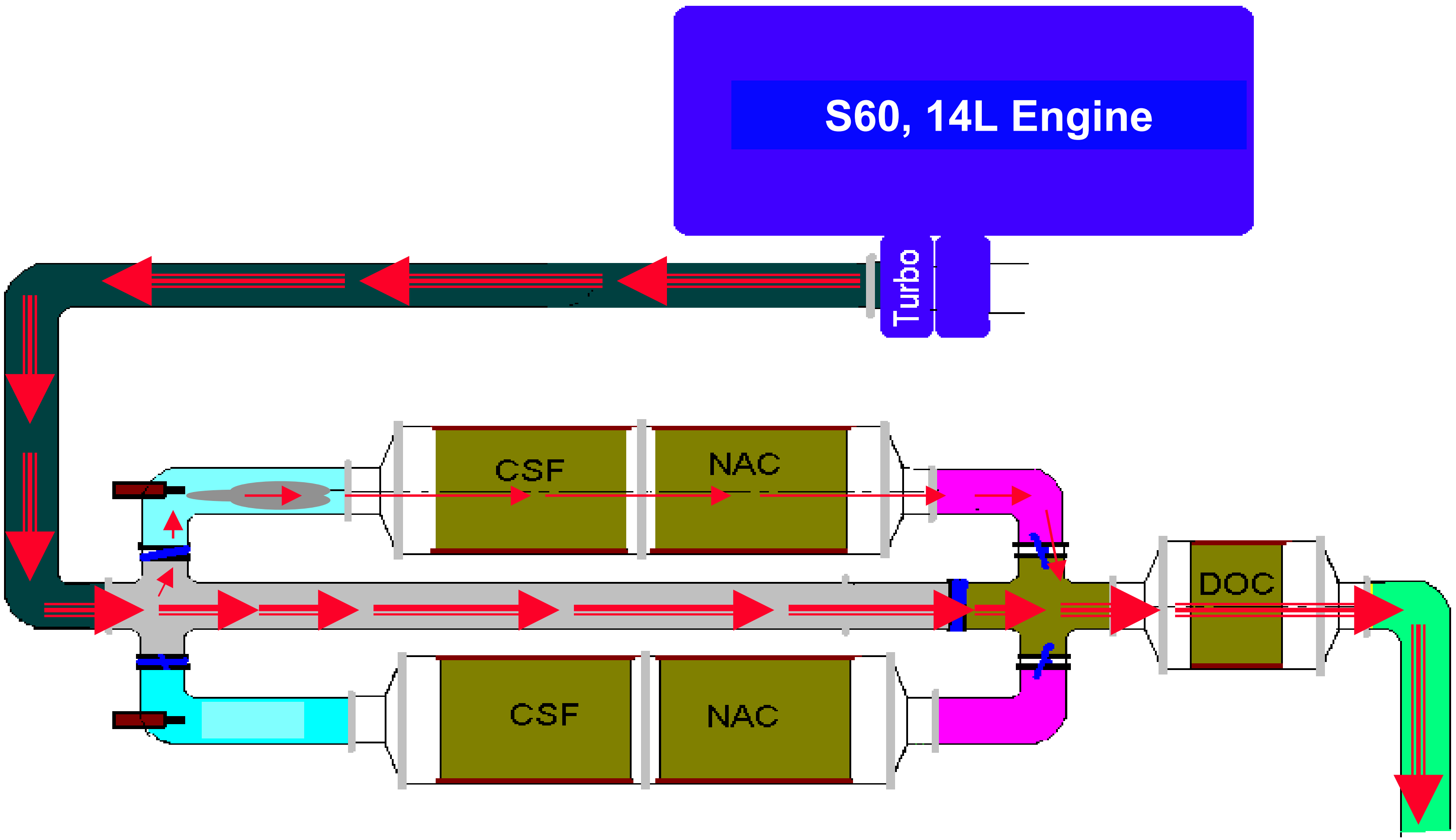
Single Leg with Bypass Configuration (Regeneration)



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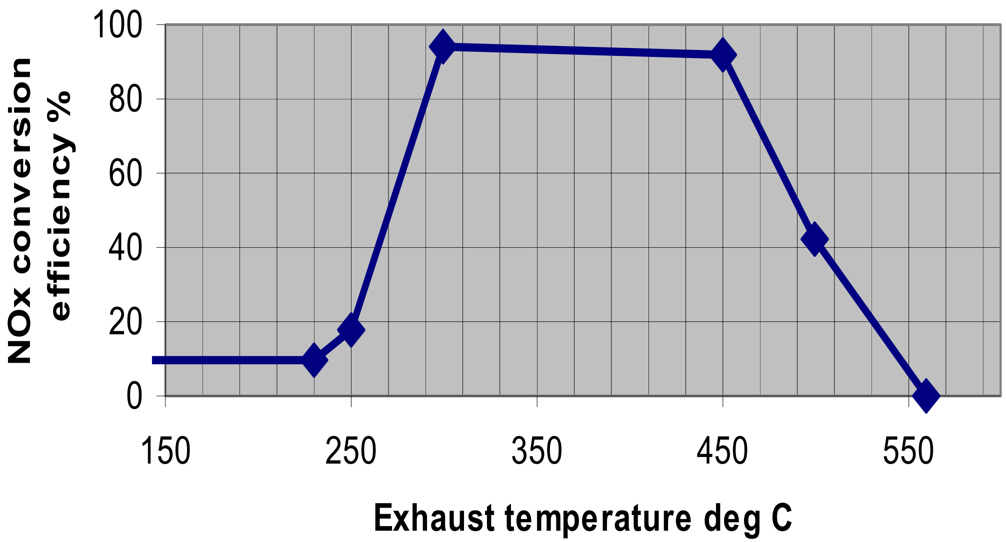
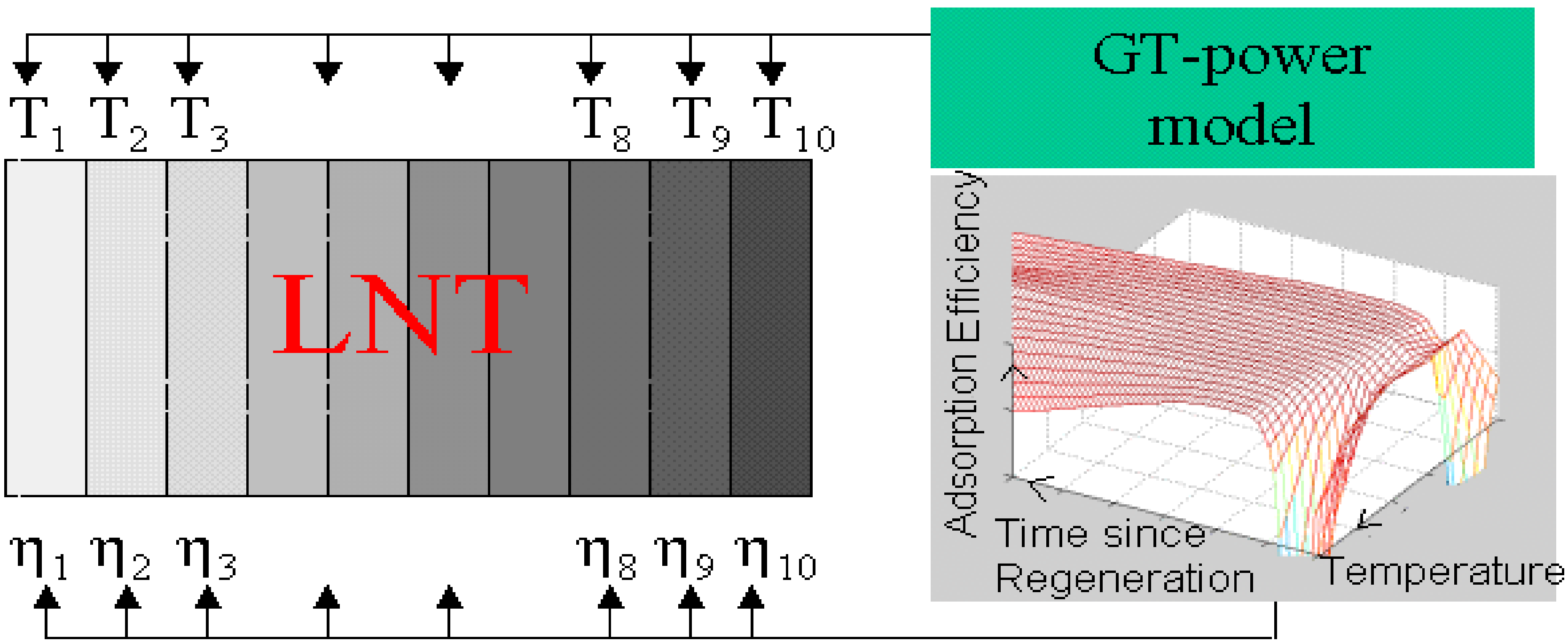
NOx Adsorber Efficiency



High NOx reduction efficiency within the catalyst temperature range

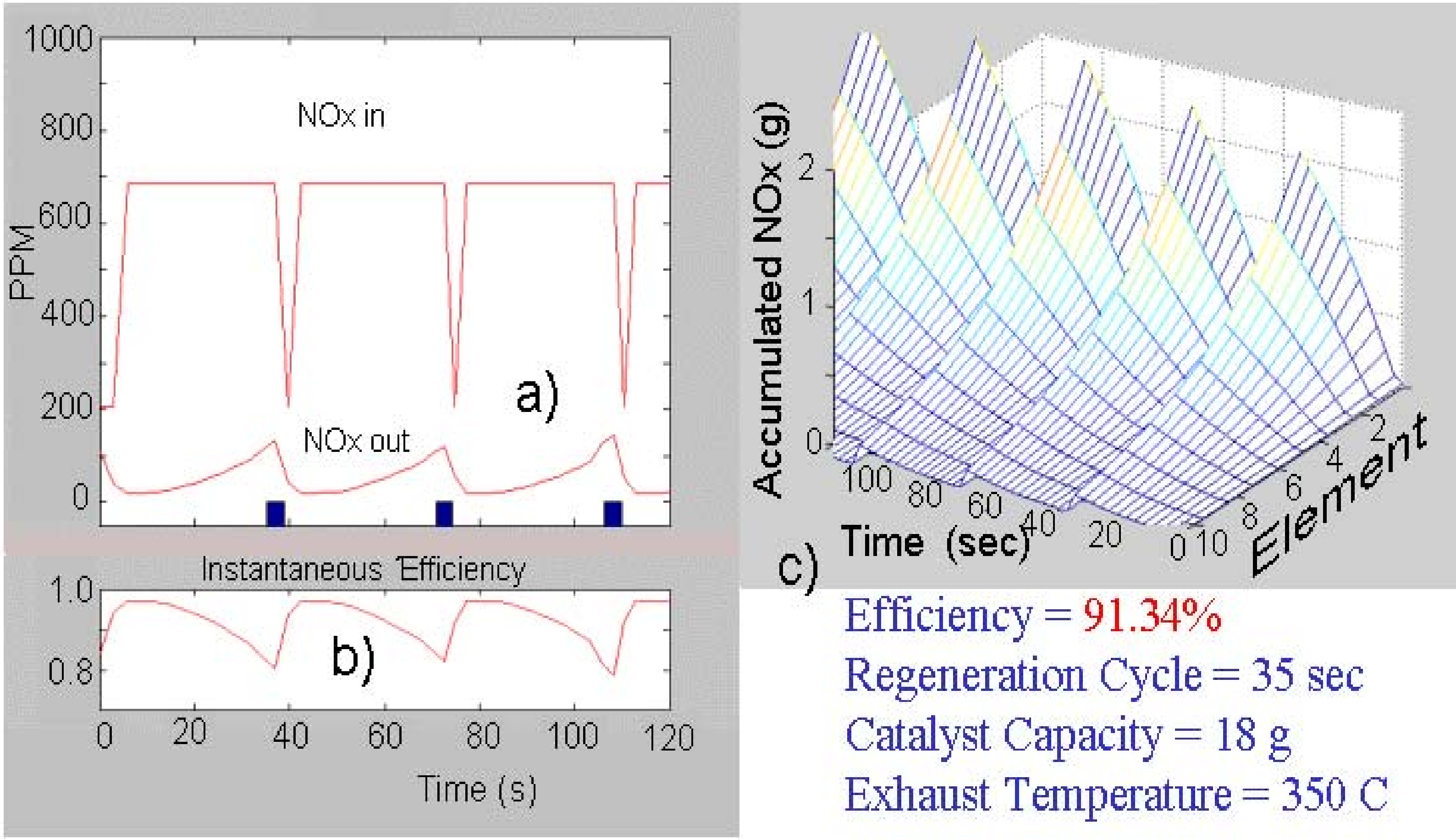
One-D Empirical Model



$$\eta_{overall} = 1 - \prod_{i=1}^{10} (1 - \eta_i)$$

at a time step

NOx In, Out Level and Adsorption inside LNT (Steady State)



Efficiency = 91.34%

Regeneration Cycle = 35 sec

Catalyst Capacity = 18 g

Exhaust Temperature = 350 C

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Single Leg Control Strategy

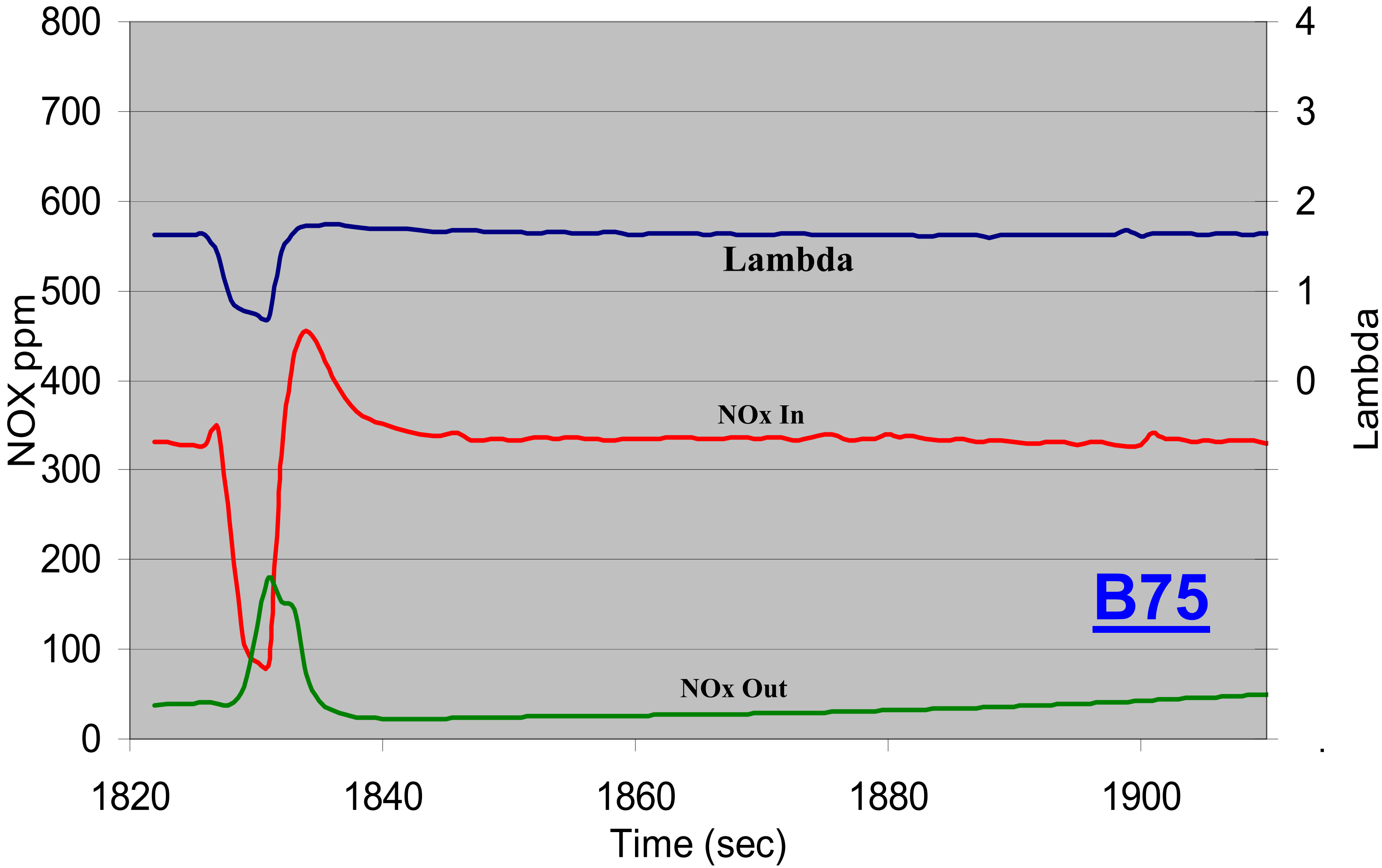
- Target: Lambda < 1 and Torque smoothness.
- Approach
  - Turbo vane position used to force maximum EGR mass into intake, reducing inlet air mass. This will reduce BTRQ.
  - Advanced BOI to compensate for the BTRQ drop.
  - More FPC to increase richness of exhaust.

Single Leg Results*

ESC Mode	A50	B25	B75	B100
Rich/Lean, (sec)	3/69	5/145	5/80	7/53
NOx conv. %	72 (Rich time fixed)	77 (Rich time fixed)	88 (Target: lowest NOx out level)	78 (Target: Lowest NOx out level)
FEP %	1.0	1.2	2.05	1.2

* Fresh Catalyst

Single Leg Data



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Dual Leg Results*

Conditions	EURO III ESC Mode							
	A25		A50		A75		B50	
Valve Setting(sec)	Close	Open	Close	Open	Clos e	Open	Close	Open
	58	58	52	52	58	58	54	54
SSV(1/hr)	4280	38520	6196	55760	9360	84241	9258	83318
Inj duration	3 sec		3 sec		3 sec		3 sec	
Temp in, C	319		353		427		382	
NOx, ppm (g/hphr)	210(2.36)		440(2.67)		480(2.62)		330(2.28)	
Conv Eff, %	92.4		96		94		90	
FEP, %	5.9		3.2		1.9		2.3	

*Fresh Catalyst - Half System Operation

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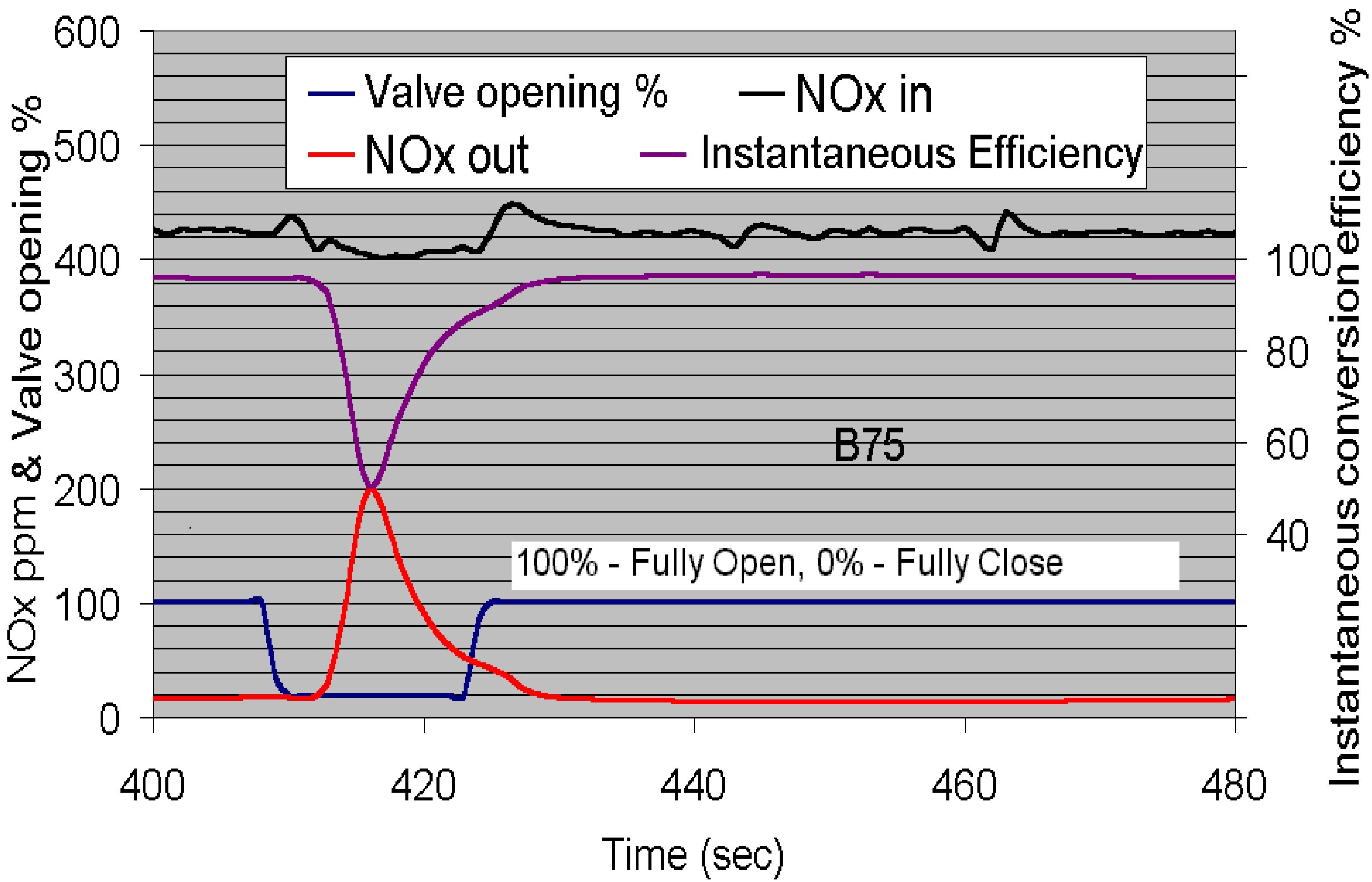
Single Leg with Bypass Results *

Conditions	EURO III ESC Mode							
	A25		A75		B25		B75	
Valve Setting(sec)	Close	Open	Close	Open	Close	Open	Close	Open
	15	140	15	100	15	140	15	100
Inj duration	3 sec		3 sec		3 sec		3 sec	
Temp in, C	319		427		343		392	
Conv. Eff, %, Across LNT	92.0		92.5		91.0		92.5	
Conv. Eff, %, Overall	83.0		80.4		82.0		80.4	
FEP, %	4.0		1.5		3.0		1.3	

* Fresh Catalyst

Test Results - Single Leg with Bypass*



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Conclusions-Single Leg

- The simplest A.T. configuration, but engine management and performance is challenging.
- Issues:
  - The “Ideal” Lambda curve shape when rich.
  - Driveability (Torque Variation)
  - Durability(Liner Temperature, cylinder pressure, turbocharger, …)
  - Transient control (Closed loop control on Torque and Lambda)
  - Desulfation

Conclusions- Dual Leg

- The most complex A.T. configuration, but least core engine management modification involved.

- Issues:
  - Valve mechanism and mechanical durability.
  - Space claim.
  - Secondary fuel injection system.
  - Multiple catalyst reliability.
  - Transient Control.
  - Desulfation.

Conclusions- Single Leg with Bypass

- A compromise between the single-leg and dual-leg systems.
- Has some common features and challenges of each.

Concluding Remarks

- A steady state NOx adsorber regeneration cycle can be designed using a NOx sensor and a Lambda sensor.
- Development of transient regeneration control logic is an order of magnitude more difficult, especially for the single leg system.
- Based on simulation, FTP NOx conversion will be only ~ 50% for the single leg system.
- Thermal stress on the cylinder kit and turbocharger during regeneration cycling must be addressed.
- Fuel sulfur at any level is a challenge.