Development of Truck Engine Technologies for Use with Fischer-Tropsch Fuels

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Objectives

- Identify new design features for a diesel engine and aftertreatment system that will enable more optimum use of FT diesel fuels.
- In cooperation with Navistar, develop an experimental plan and test a FT fueled engine. Evaluate the most promising design features and develop strategies for lowering NO_x emissions.
- Based on these test results, build-up an optimized engine and retest to demonstrate the lower bound of exhaust emissions while maintaining diesel-like thermal efficiency.

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Test Engine

- International supplied the test engine (an International V8 7.3L), control electronics, engine hardware, DeNOx catalysts, trap and engineering support
- Engine specification:
  - 104mm bore,106mm stroke,V8 configuration
  - turbocharged and charge cooled
  - 2 valve cylinder head design
  - re-entrant bowl design
  - HEUI injection system

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Test Fuels

- Key features of Fischer Tropsch fuel
  - Cetane number 75
  - Sulfur <1-3.5ppm
  - Specific gravity 0.77-0.78
  - Net Energy 18,890-18,884 BTU/lb
  - Aromatics <1%
- Baseline fuel (Referred to as CARB or D2(10% arom) fuel)
  - Cetane number 50
  - Sulfur <60ppm
  - Specific gravity 0.83
  - Net Energy 18611 BTU/lb
  - Aromatics <10%

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Selected Design Features

- The design features chosen to achieve the lowest NOx emissions using FT fuel were:
  - Redesigned combustion bowl for higher EGR tolerance.
  - EGR system designed for high EGR flow with large cooler.
  - Dual DeNOx catalyst system using secondary fuel injected upstream.
  - Exhaust cooler to achieve optimum temperature into DeNOx catalyst.
  - Particulate trap to clean up any excess smoke.

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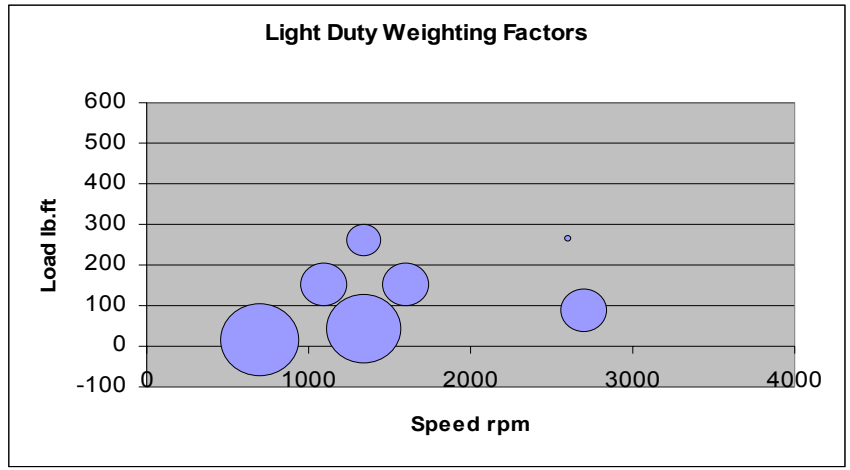
Weighting Factors

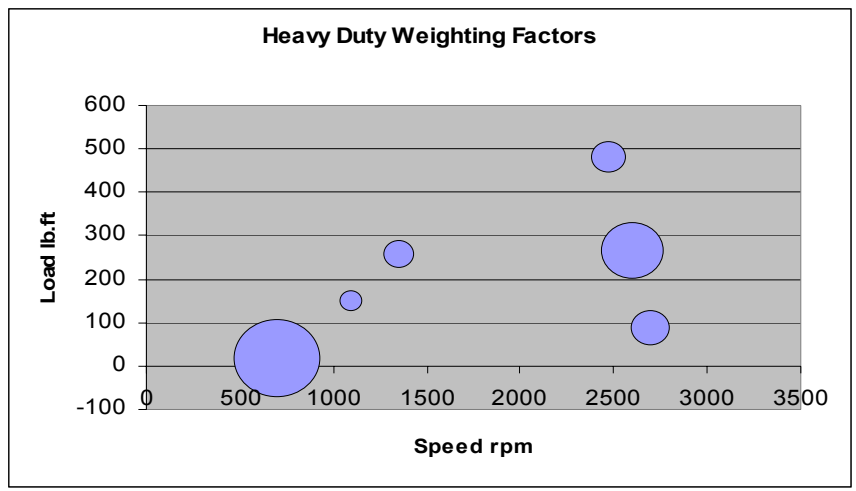
Light Duty Weighting Factors

Mode	Speed rpm	BMEP bar	Load Nm	Weighting
1	700	0.0	19.3	0.251
2	1350	1.0	57.4	0.221
3	1100	3.5	202.4	0.095
4	1600	3.5	203.3	0.096
5	1350	6.0	348.6	0.058
6	2480	11.2	651.8	0.000
7	2600	6.2	360.2	0.004
8	2700	2	116.2	0.095



Heavy Duty Weighting Factors

Mode	Speed rpm	BMEP bar	Load Nm	Weighting
1	700	0.00	19.3	0.382
3	1100	3.50	202.6	0.032
5	1350	6.00	348.5	0.063
6	2480	11.22	651.7	0.073
7	2600	6.19	359.7	0.207
8	2700	1.97	115.4	0.084



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Test Schedule

- Baseline 8 mode emissions tests on FT and CARB fuel including analysis of particulate samples
- Engine rebuilt with alternate piston bowl for increased EGR tolerance. EGR system sized for high EGR rates installed
- Nozzle protrusion optimized with new bowl and EGR swings conducted
- Evaluate DeNOx catalyst response on FT fuel including temperature response, HC:NOx ratio, space velocity
- Map response of final build engine and aftertreatment system
- Conduct final tests to compare fuels using optimized settings

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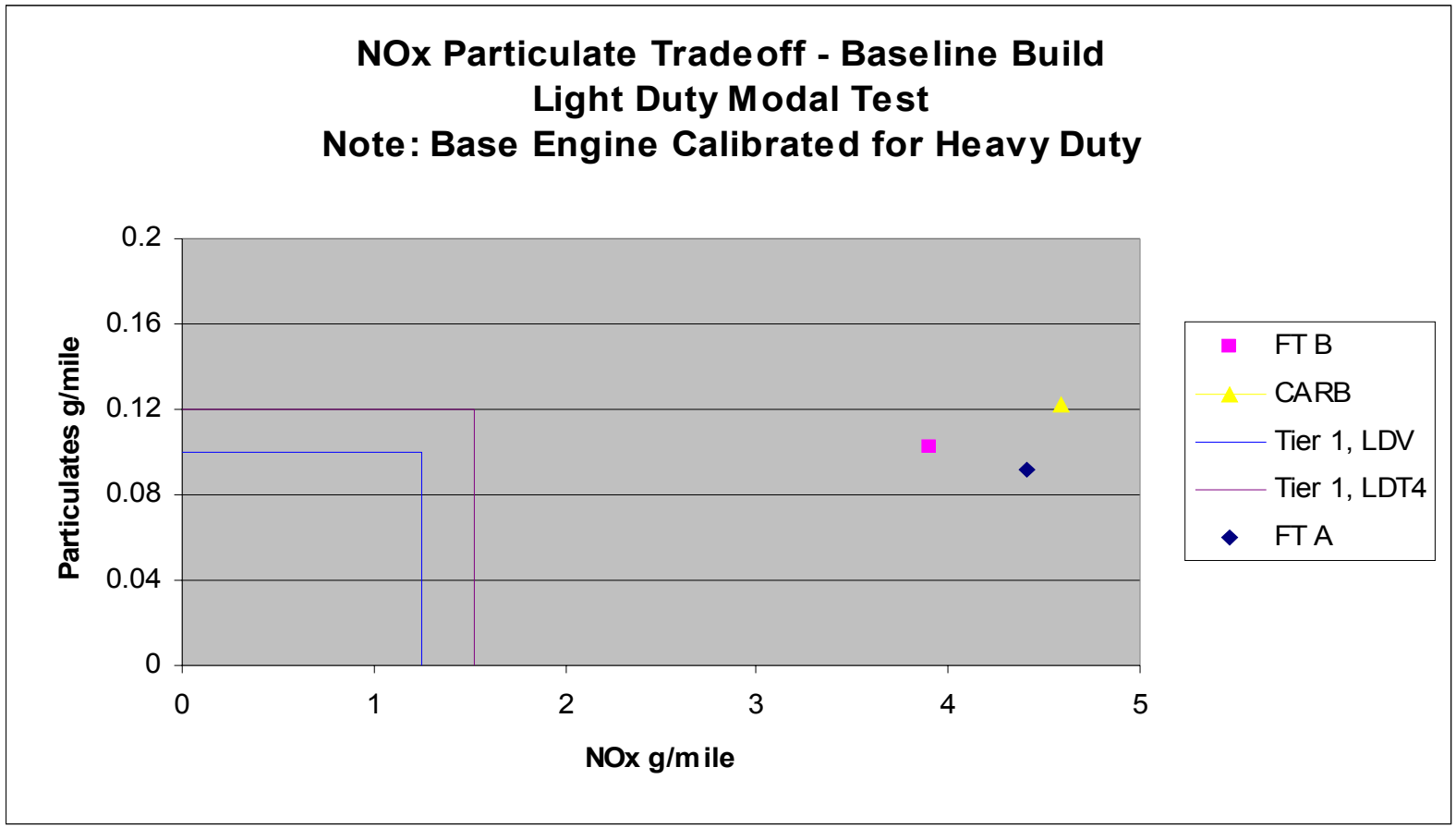
Baseline Results - Light Duty Cycle



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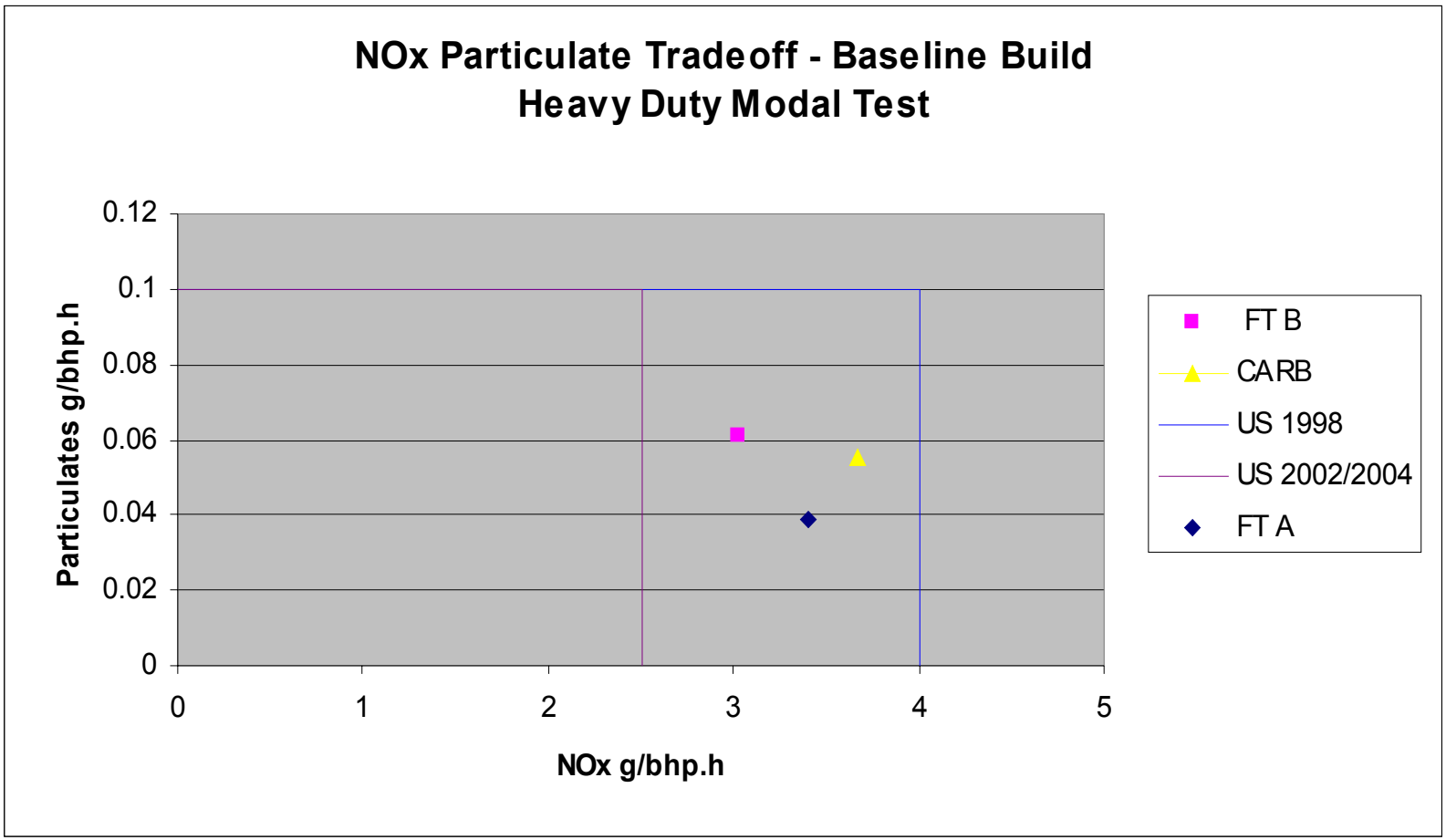
Baseline Results - Heavy Duty Cycle



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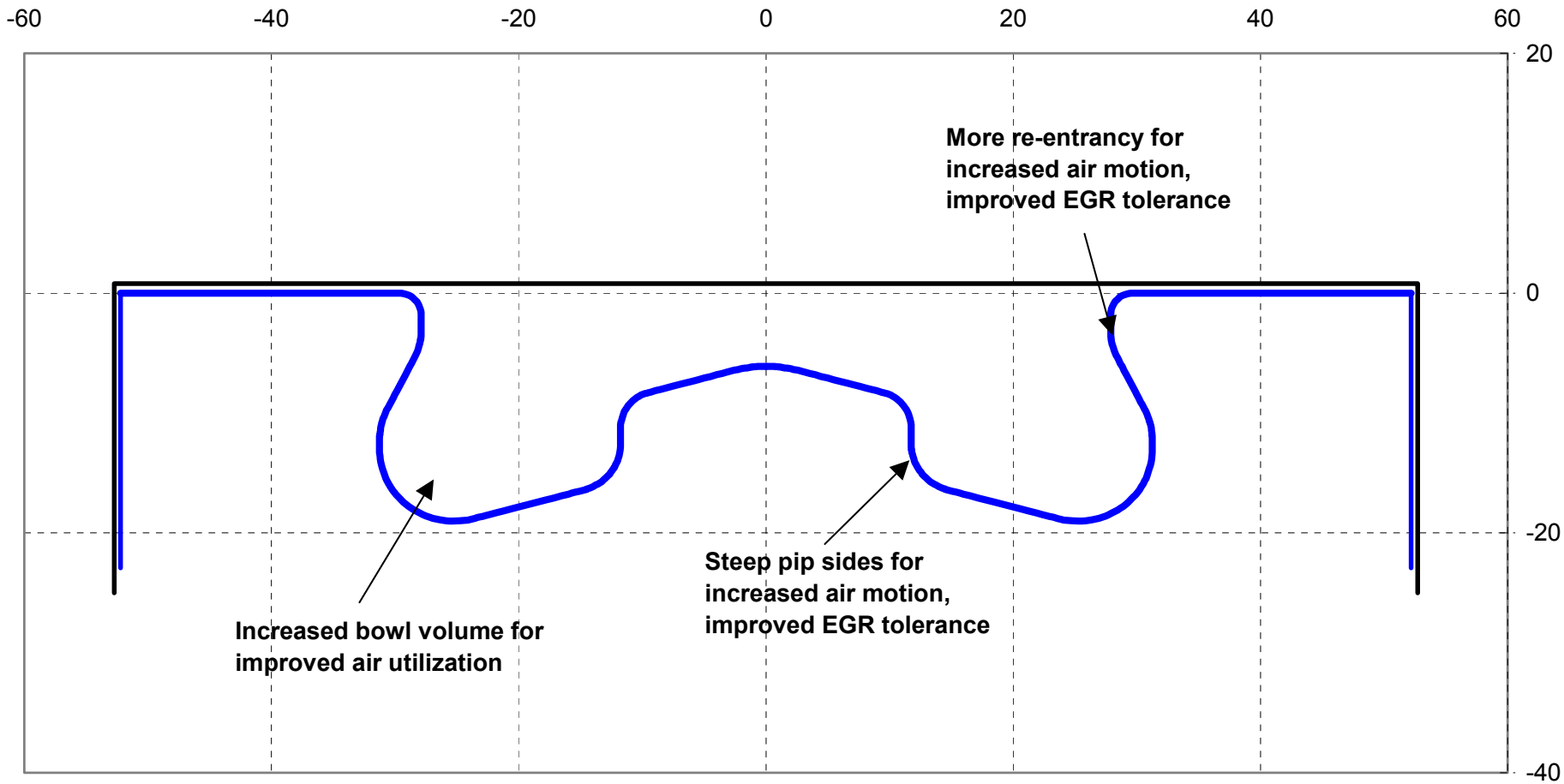
Revised Combustion Bowl



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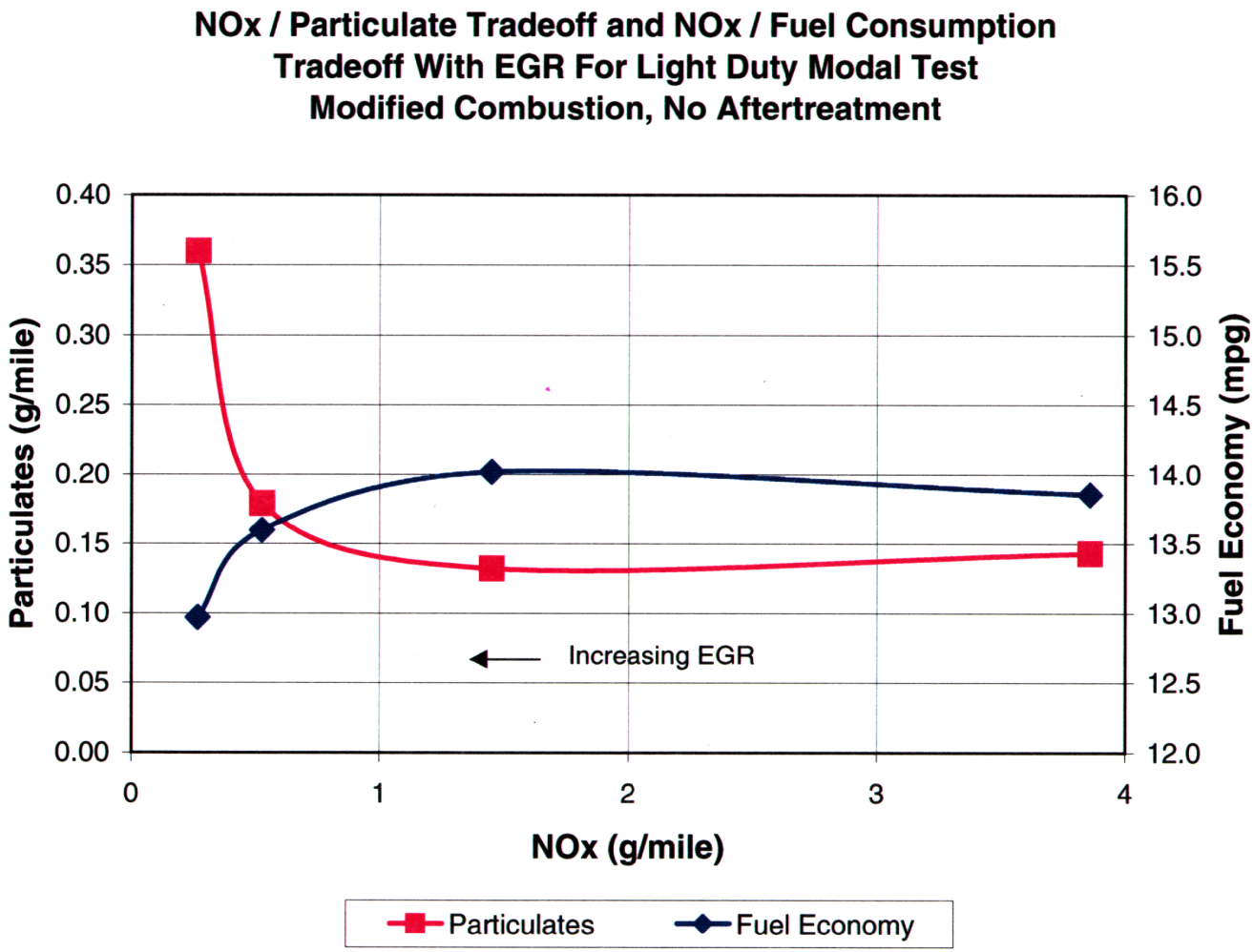
EGR Swings on Modified Engine Build



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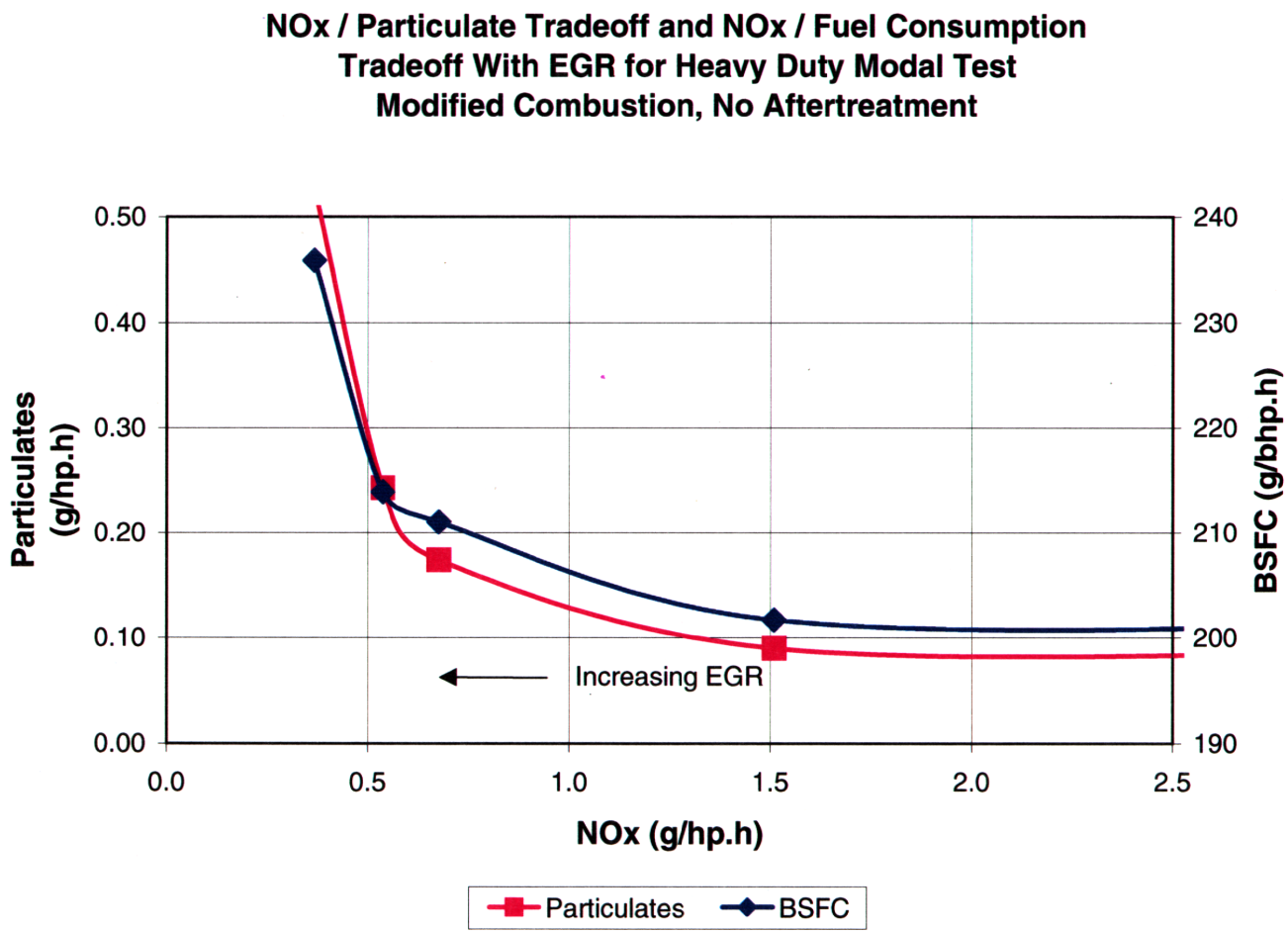
EGR Swings on Modified Engine Build



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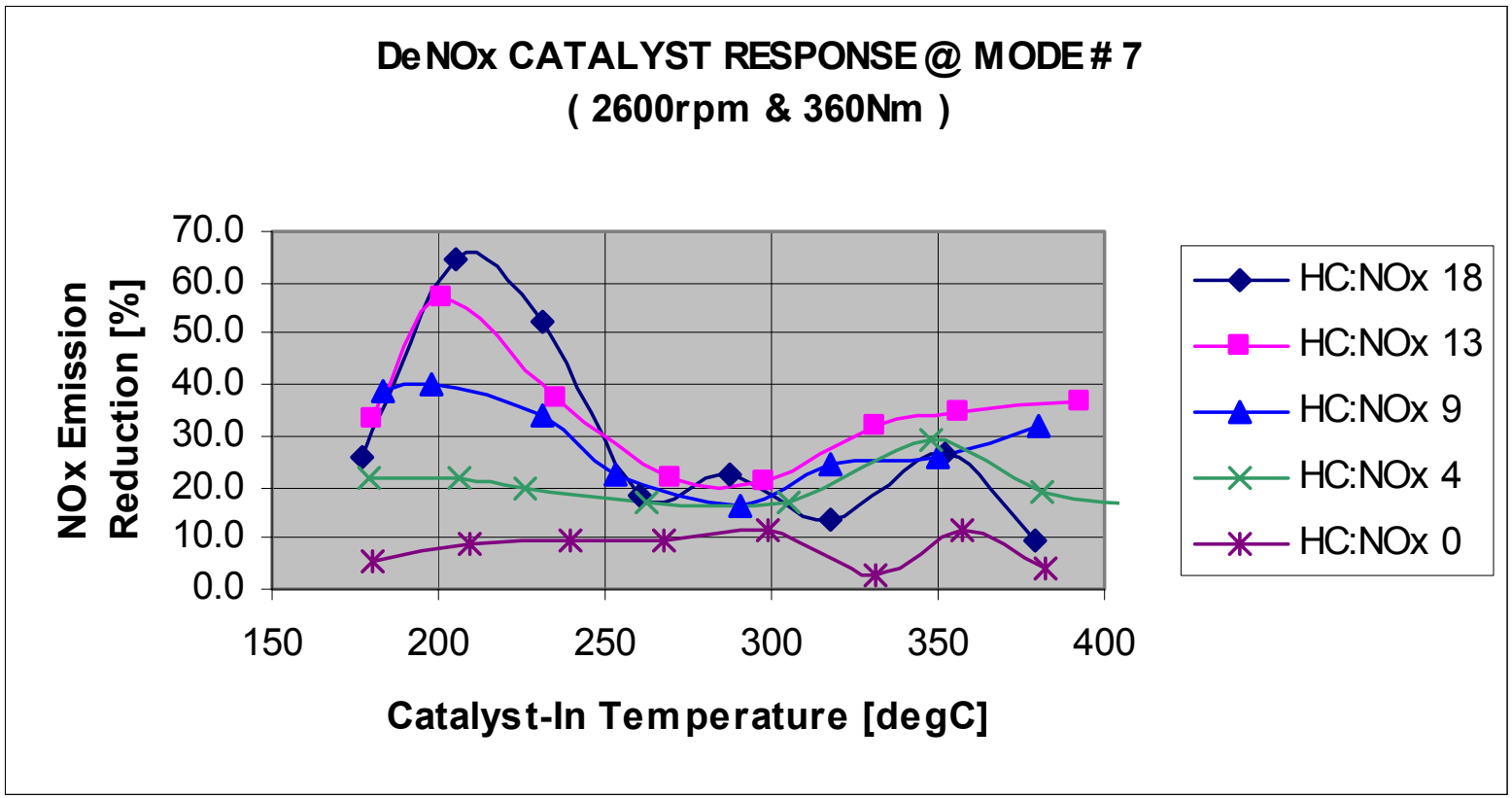
DeNOx Catalyst Response



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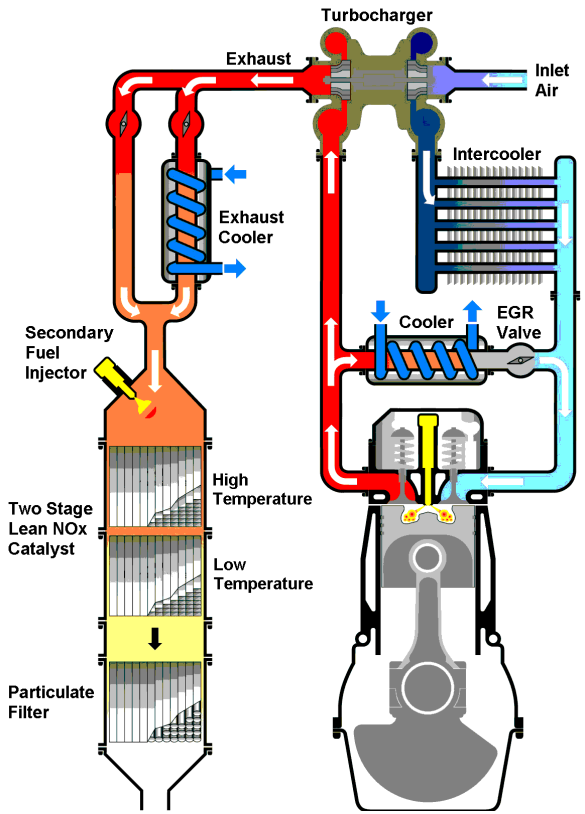
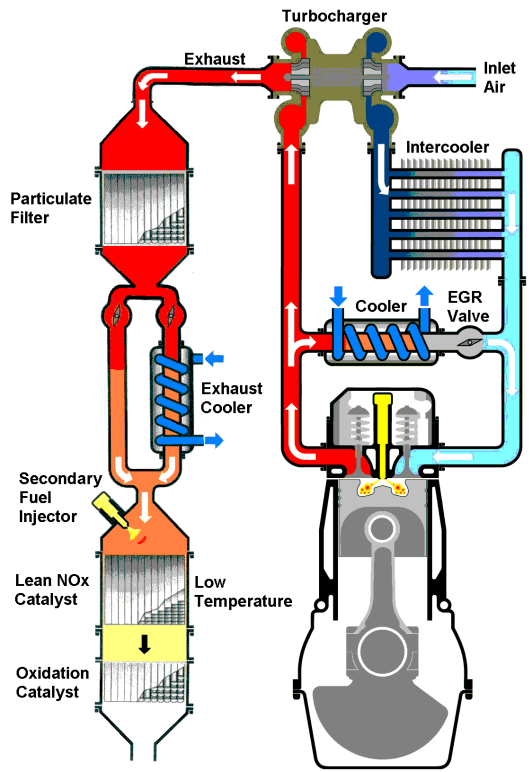
Schematic of Engine and Aftertreatment System



As Tested



Suggested Layout

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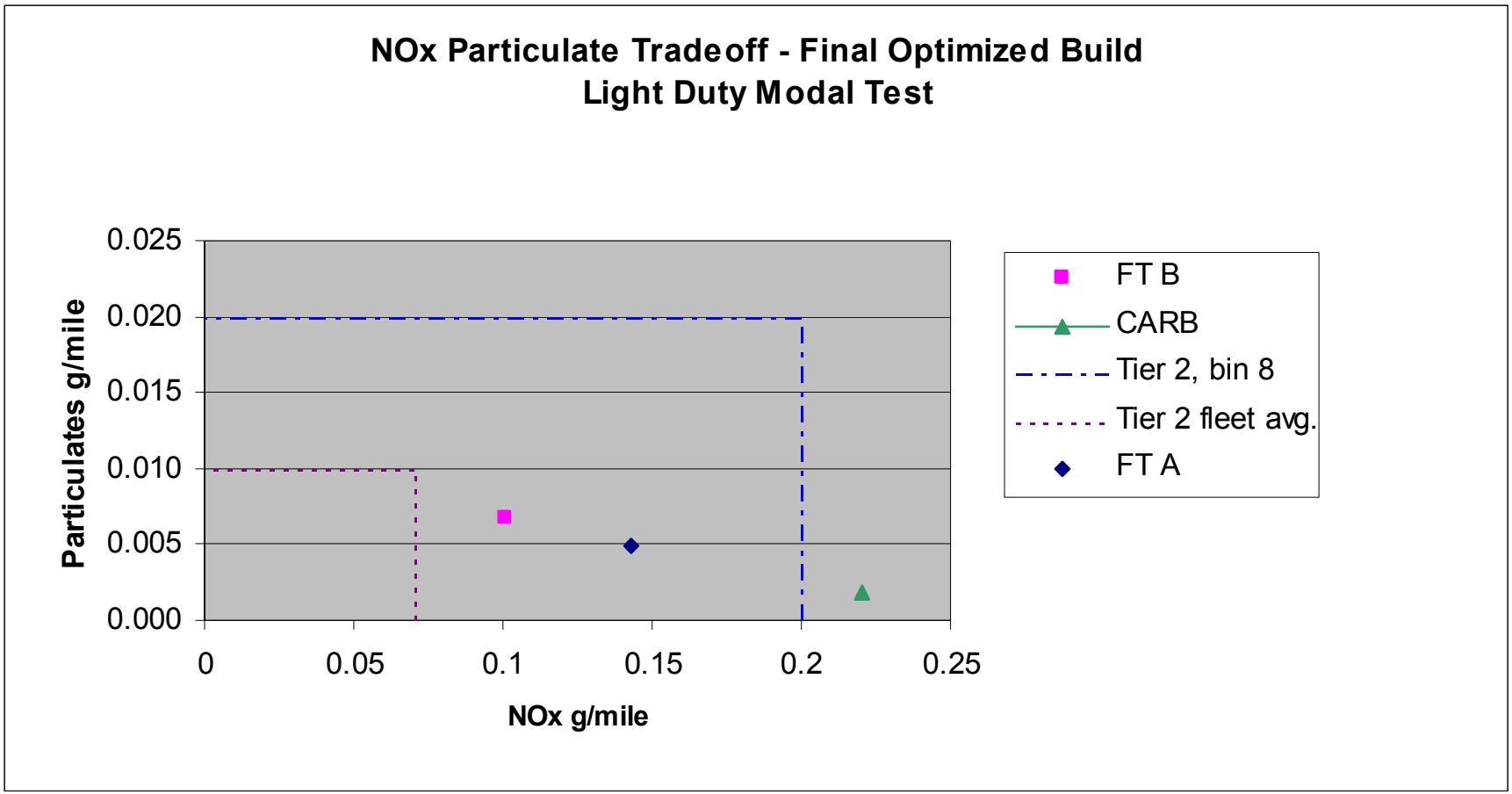
Results for Final Optimized Build



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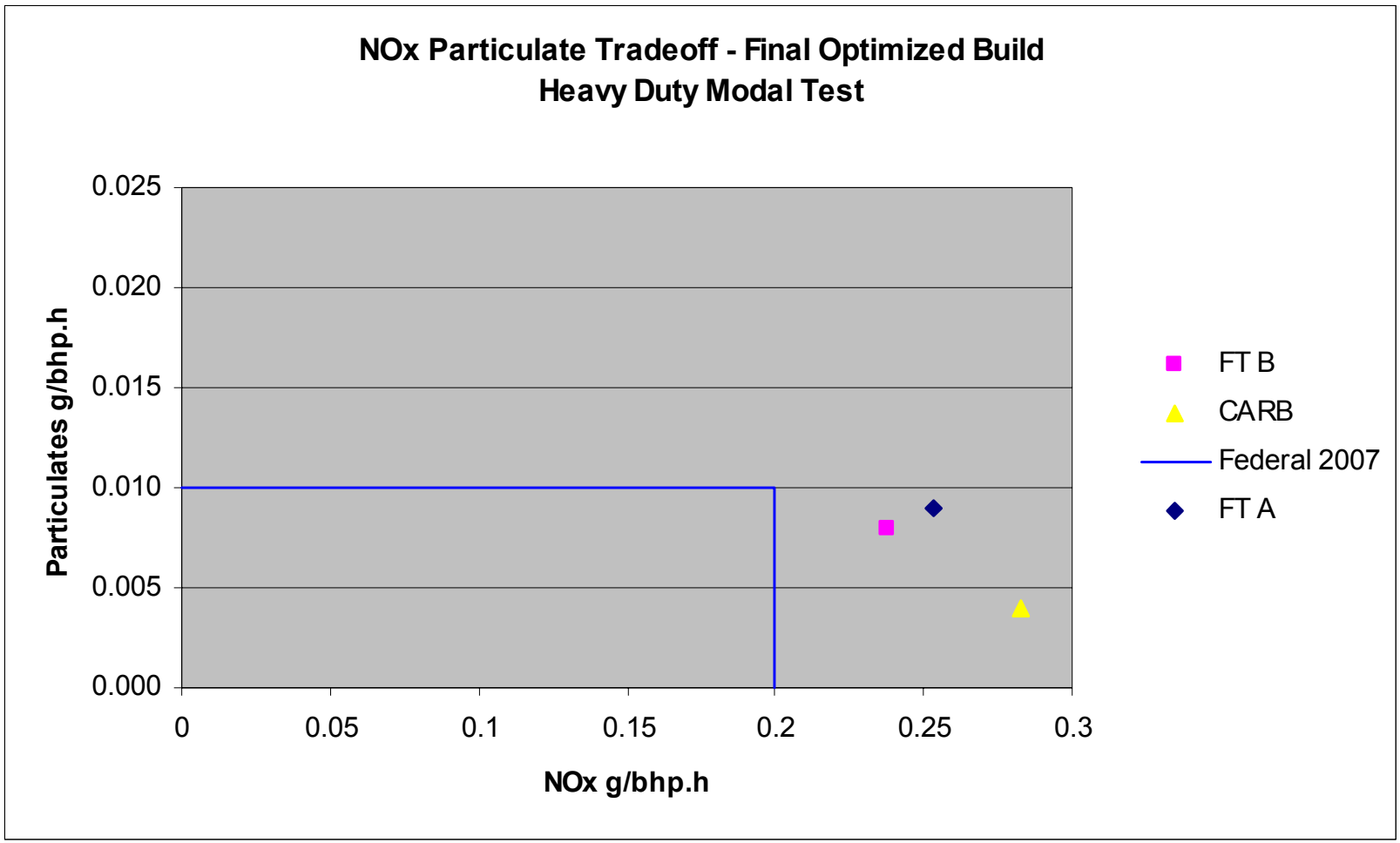
Results for Final Optimized Build



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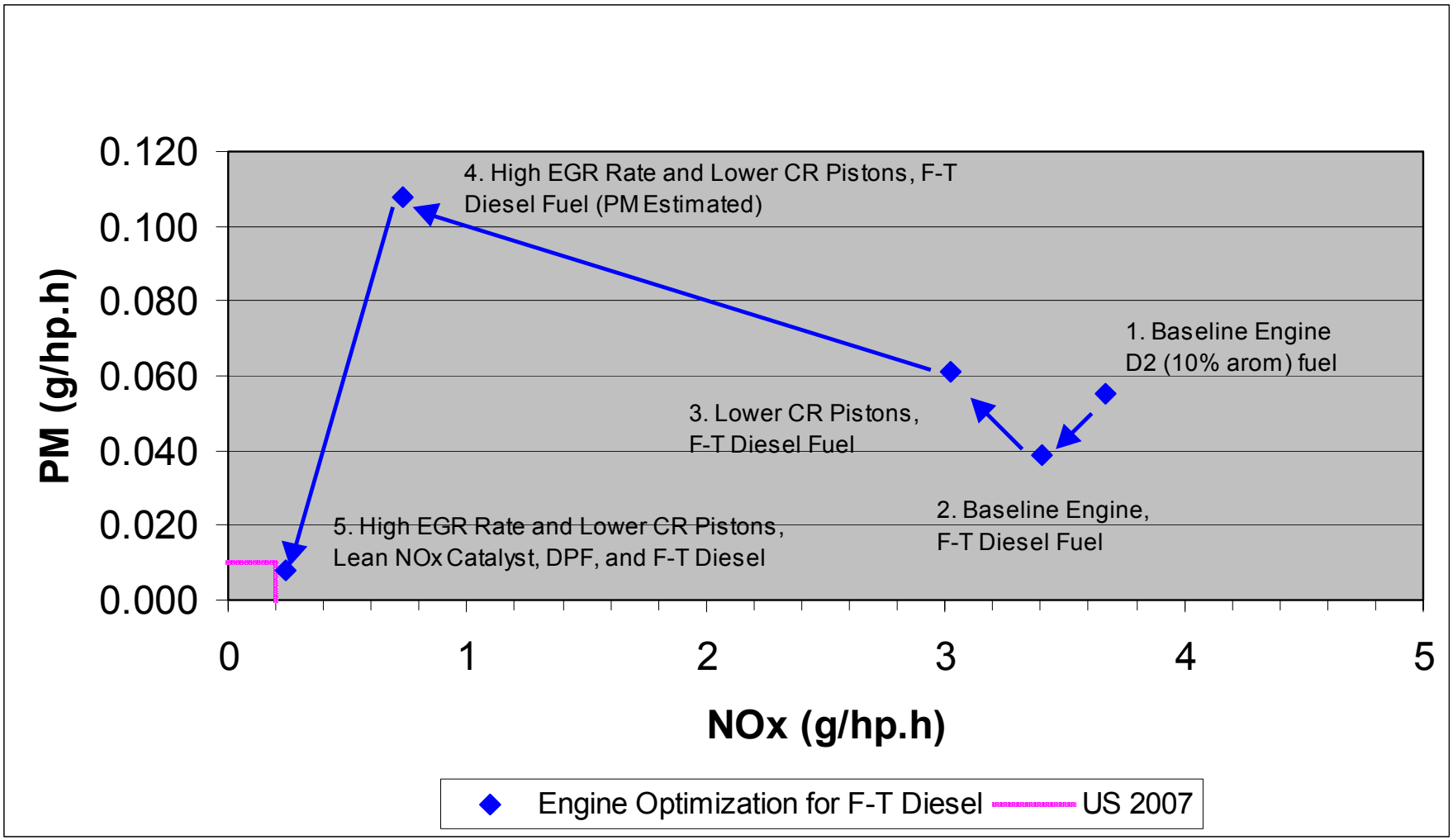
Emission Reduction Pathway for Heavy Duty Truck



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Discussion of Results - Challenges

- To obtain the maximum NOx reduction from a DeNOx catalyst management of the exhaust temperature is required. This program employed an exhaust cooler - no such devices are in production for vehicles and the durability and economics of such systems would need to be investigated.
- Further development of the secondary fuel system and catalyst is required to reduce hydrocarbon breakthrough.
- The regeneration of the trap needs to be examined at high EGR rates where to NOx:soot may not be favorable and alternative regeneration strategies may be required.
- Transient control of the engine was not addressed in this program. Transient control of the engine at high EGR rates and at the lower limits of acceptable AFR is a significant technical challenge.
- Nitrous Oxide emissions was not measured during this program but can be significant for a low temperature platinum based catalyst. Catalyst development needs to address this.

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Discussion of Results

- Steady state keypoints were selected based on a cycle simulation of a relatively heavy medium duty F250 vehicle with a Navistar 7.3L engine. A lighter vehicle with a smaller engine would give lower emissions in g/mile over the light duty FTP cycle.
- Particularly for the heavy duty test a 4 valve engine design with central injector would show smoke benefits at high loads with high EGR rates and low air fuel ratio which may allow increased EGR.

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Conclusions

- High EGR rates produce a large reduction in NOx emissions on the Navistar engine but to meet Tier 2 and US 2007 HD emissions aftertreatment is required even with Fischer Tropsch fuel.
- Steady state modal test results close to Tier 2 fleet average and 2007 heavy duty emissions proposals were achieved with EGR, rematched combustion, DeNOx catalyst, exhaust cooler and a particulate trap. This represents over a 90% reduction of NOx compared to the baseline build.
- Compared to the baseline test the fuel consumption was increased 1.7% over the light duty test and 5.6% over the heavy duty test using FT fuel.
- Tests on FT fuel showed lower NOx, mainly a result of higher DeNOx conversion efficiency. EGR and timing swing tests at a selected keypoint showed 1% lower fuel consumption using FT fuel (when corrected for higher fuel energy) compared to CARB and better DeNOx efficiency.

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