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Quiet
FAST

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SAE Snowmobile Team

University of Wisconsin Madison

2010 SAE Clean Snowmobile Challenge

Design Presentation

Presented by:

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Jake Mauermann

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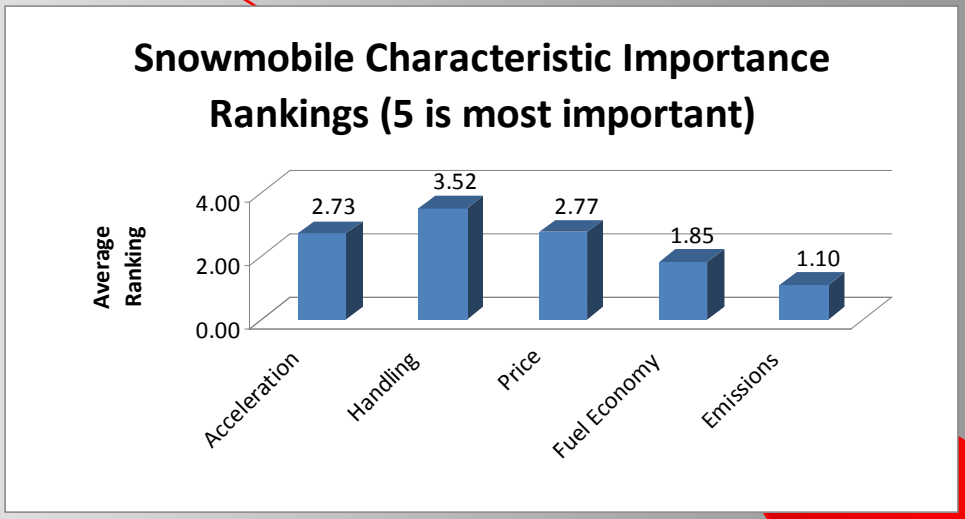
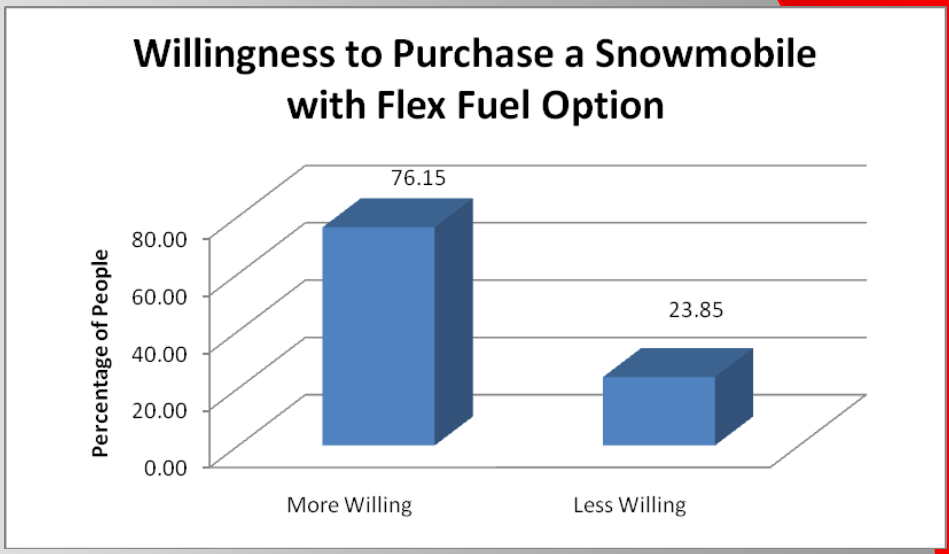
Design Considerations:

Market Survey

- Survey at Eagle River World Championship Snowmobile Derby
  - Approximately 115 surveys
- Customers Want:
  - Trail Handling
  - Acceleration
- Historical Best Sellers
  - Ski-Doo Rev XP 600 SDI
  - Polaris IQ 600





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Bucky 750 CFS

How it Appeals to Snowmobilers

Ultra Quiet

Increased Fuel Economy

20+ mpgge

Flex Fuel

Improved Acceleration

Cruise Control Capable

BAT+ Compliant

Electric Start

2007 FST LX Chassis

105 peak hp operating on E85

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Dealer & Outfitter Perspective

- Sales
  - Cleaner/Quieter Performance Model
  - Better Fuel Economy, BAT Compliant
- Maintenance
  - Integrated Catalyst/Muffler – Bolt-in Replacement
  - Plug and Play Flex-Fuel Intake/Fuel System
    - ETC, Grid Heater, Flex Fuel Sensor
- Novice Snowmobiler Operation
  - OEM Controls
- Rider Comfort
  - OEM Seat, Handlebars, Suspension, Reduced Noise

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Engine Selection

- Engine emissions from current snowmobile engines
- Ski-doo SDI system reduces two stroke emissions by 50%[1]
- Stock Polaris FS engine meets 2012 Emissions Certification

Snowmobile Engine Emissions Testing

	HC g/kW-hr	CO g/kW-hr	NO_x g/kW-hr
Two-stroke average (CSC 2009)	193.5	442.0	0.9
Arctic Cat 660 (4-stroke)	6.2	79.9	10.6
Polaris FS (4-stroke)	9.3	38.6	1.5

1: http://www.ski-doo.com/media/2004_SOTY.pdf

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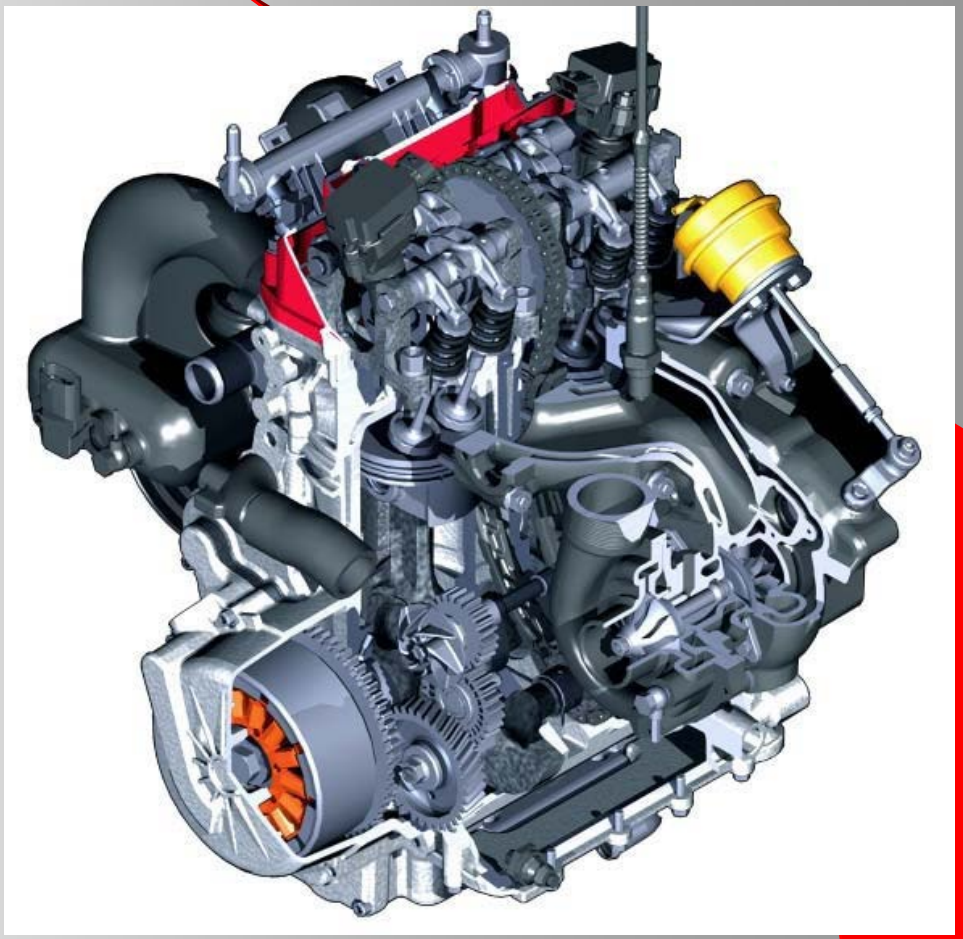
Turbo Charged Weber MPE 750 with Automotive Camshaft



Engine Type	Four Stroke
Cooling	Liquid
Cylinders	2
Displacement	750 cc
Bore x Stroke (mm)	85 x 66
Ignition	Bosch
Exhaust	Single
Fueling	EFI
Compression Ratio	9:1

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Engine Control and Emissions Reduction

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Engine Management

Woodward/Mototron PCM555

Ratings:

- Automotive/Marine Environments
- -40° – 130 °C
- 18 g Shock Load
- Up to 3 Meters Underwater

MATLAB/Simulink Engine Modeling

MotoHawk Automatic Code Generation

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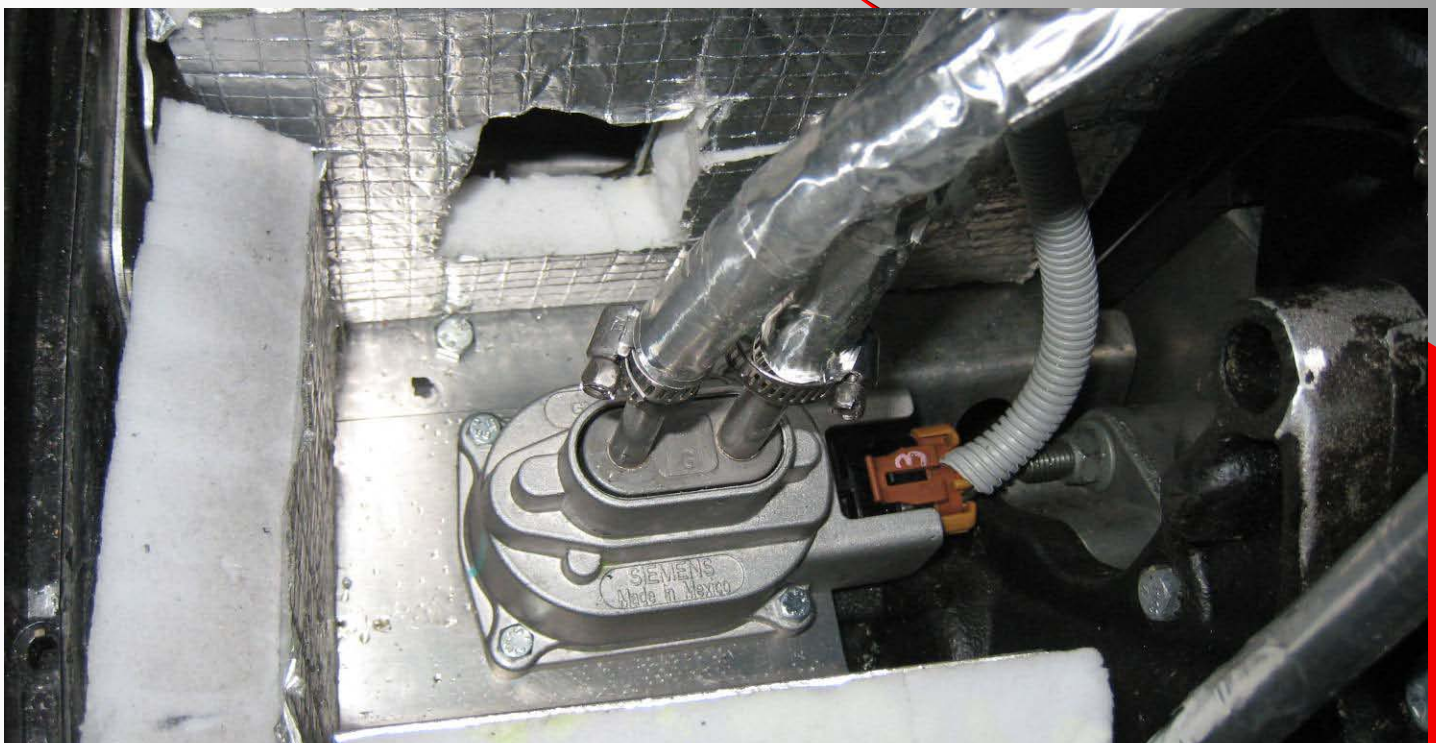
Flex Fuel Sensor



Continental Flex Fuel Sensor

- Reports ETOH Content & Fuel Temperature

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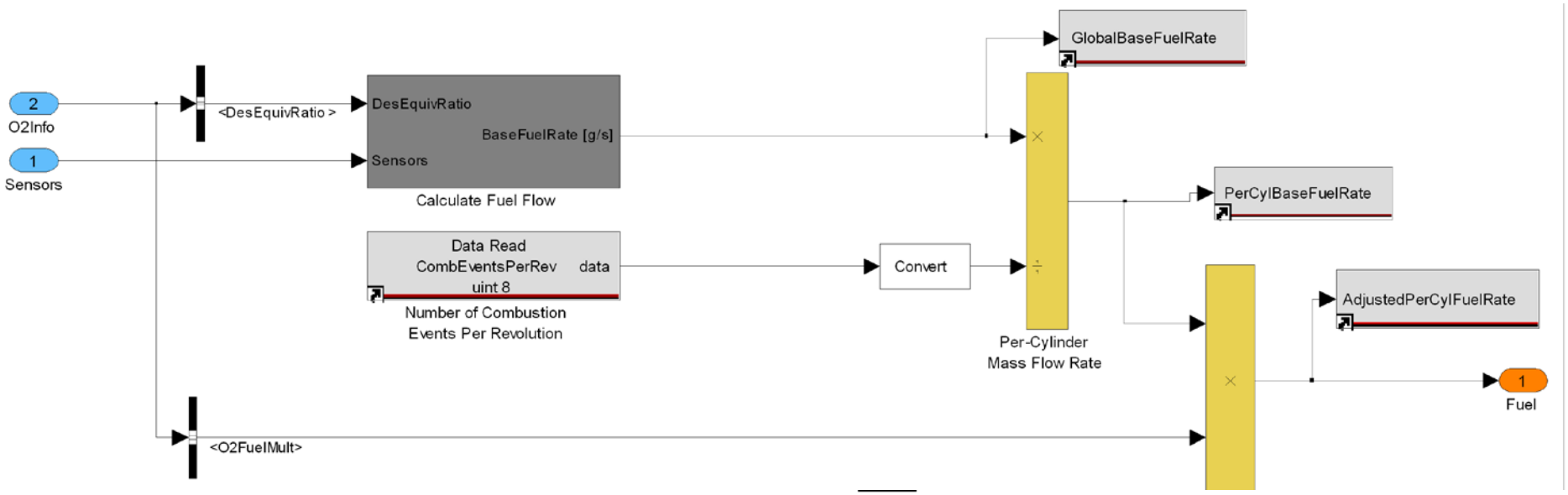
Flex Fuel Control Algorithm



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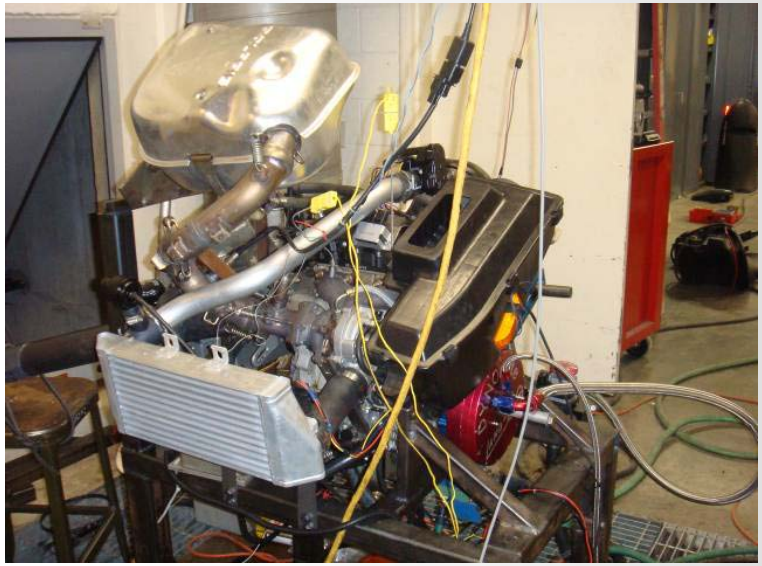
Engine Calibration



- DYNOmite Water-Brake Dyno
- Horiba CO & CO_2 NDIR Analyzer
- Heated wide-band O_2 sensor
- Chemiluminescent NOx Analyzer
- Exhaust Thermocouples

- Calibrated Spark Advancement
- Calibrated Volumetric Efficiency within 1% of Stoichometric
  - 160 cal points
  - Increments: 500 rpm, 0.1 PR
  - Each within ±0.01λ (open-loop)
- Feedback from O_2 Sensor
  - Lean/rich target switching

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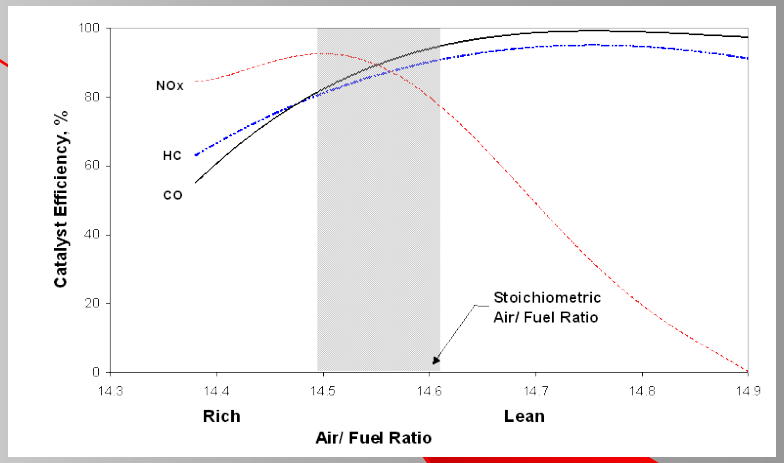
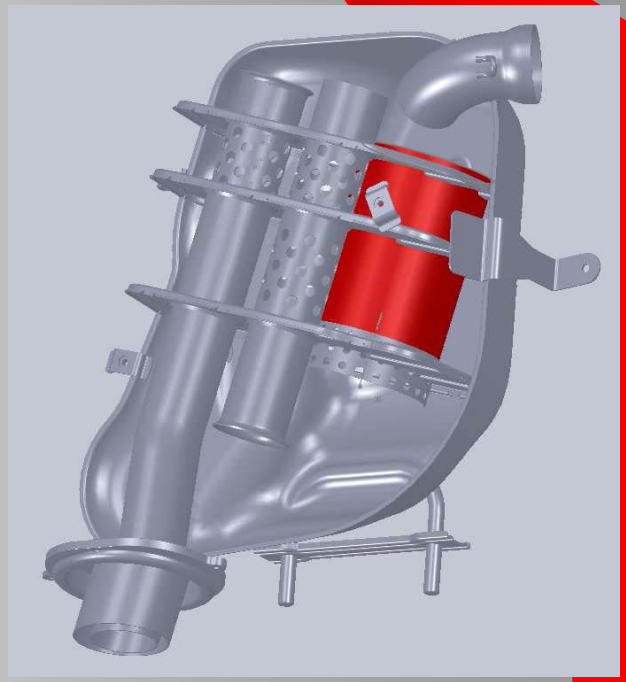
Catalytic Emissions Reduction

Improvements for 2010

- Lean/Rich Switching maximizes three-way catalytic efficiency
- Exhaust system re-designed to minimize weight, engine back-pressure and risk of pre-catalyst leaks



Manufacturer	W.C Heraeus GmbH
Diameter	105mm
Length	140mm
Substrate	SuperFoil® Metal Honeycomb
Density	600 cpsi (cells per square inch)
Loading	Platinum 11.1 g/ft^3 Palladium 55.6 g/ft^3 Rhodium 8.3 g/ft^3



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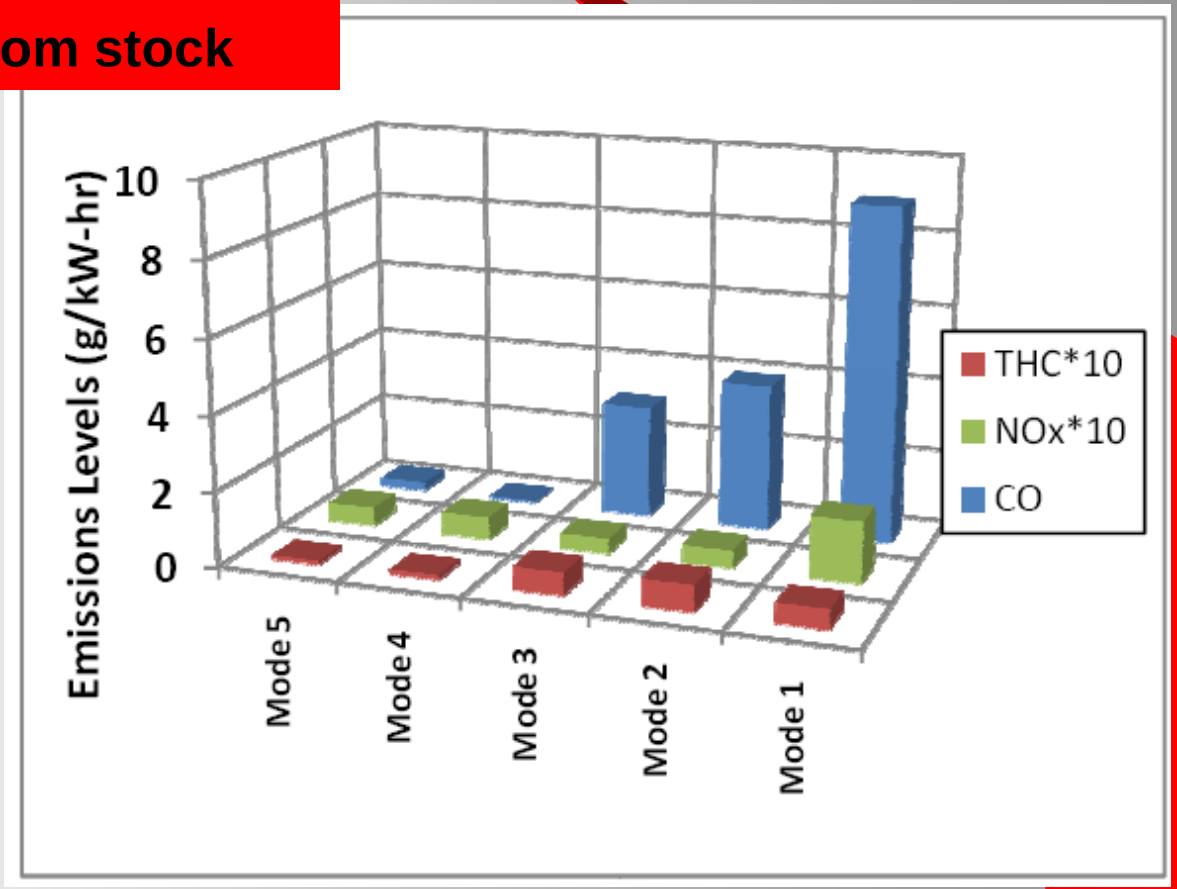
Emissions Results

2010 Emissions Testing Results

Up to 98% reduction from stock



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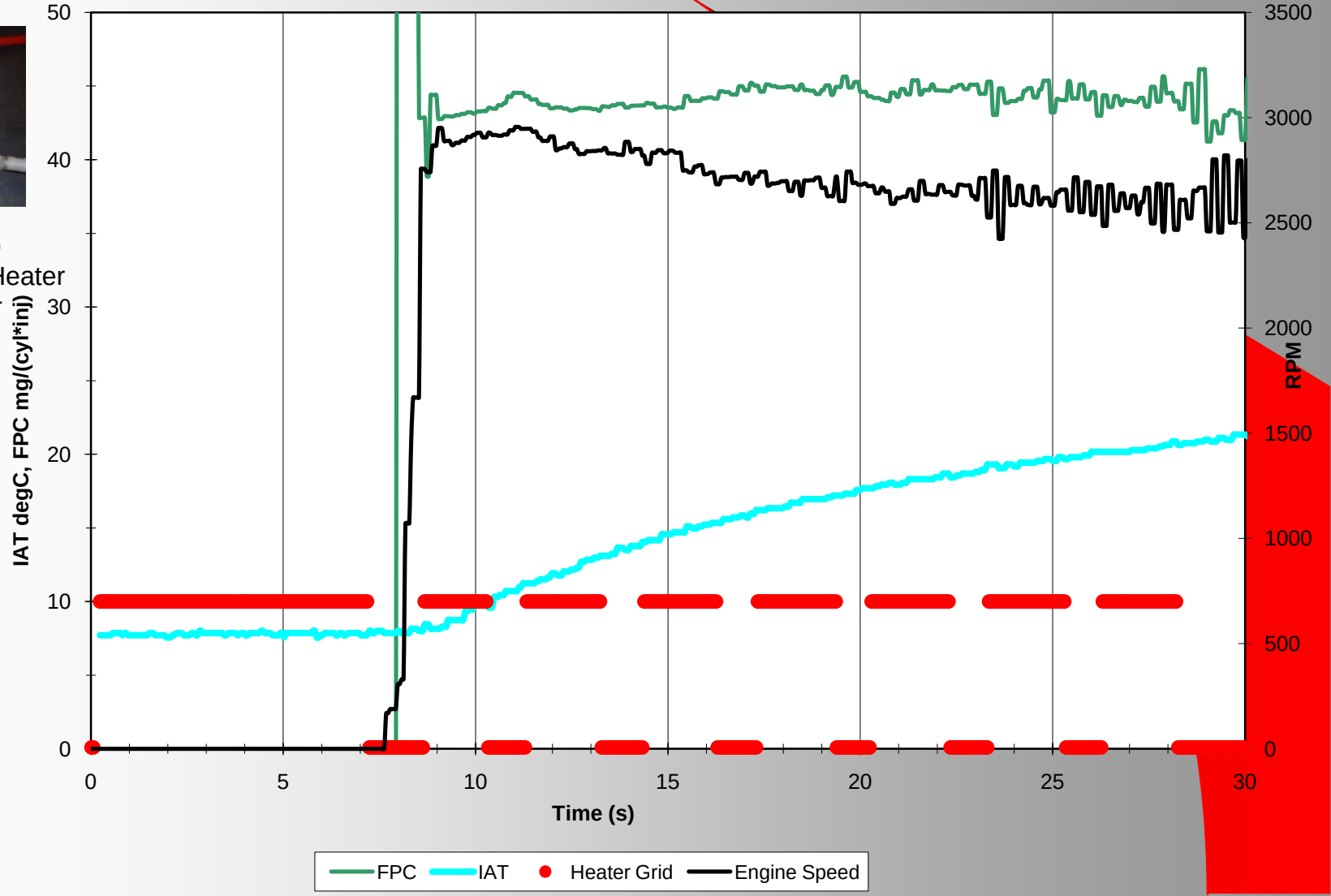
Air Intake Heater aids Cold Start

Phillips and Temro
JD300 Air Intake Heater
1.1 kW grid heater



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Driveline Efficiency Testing

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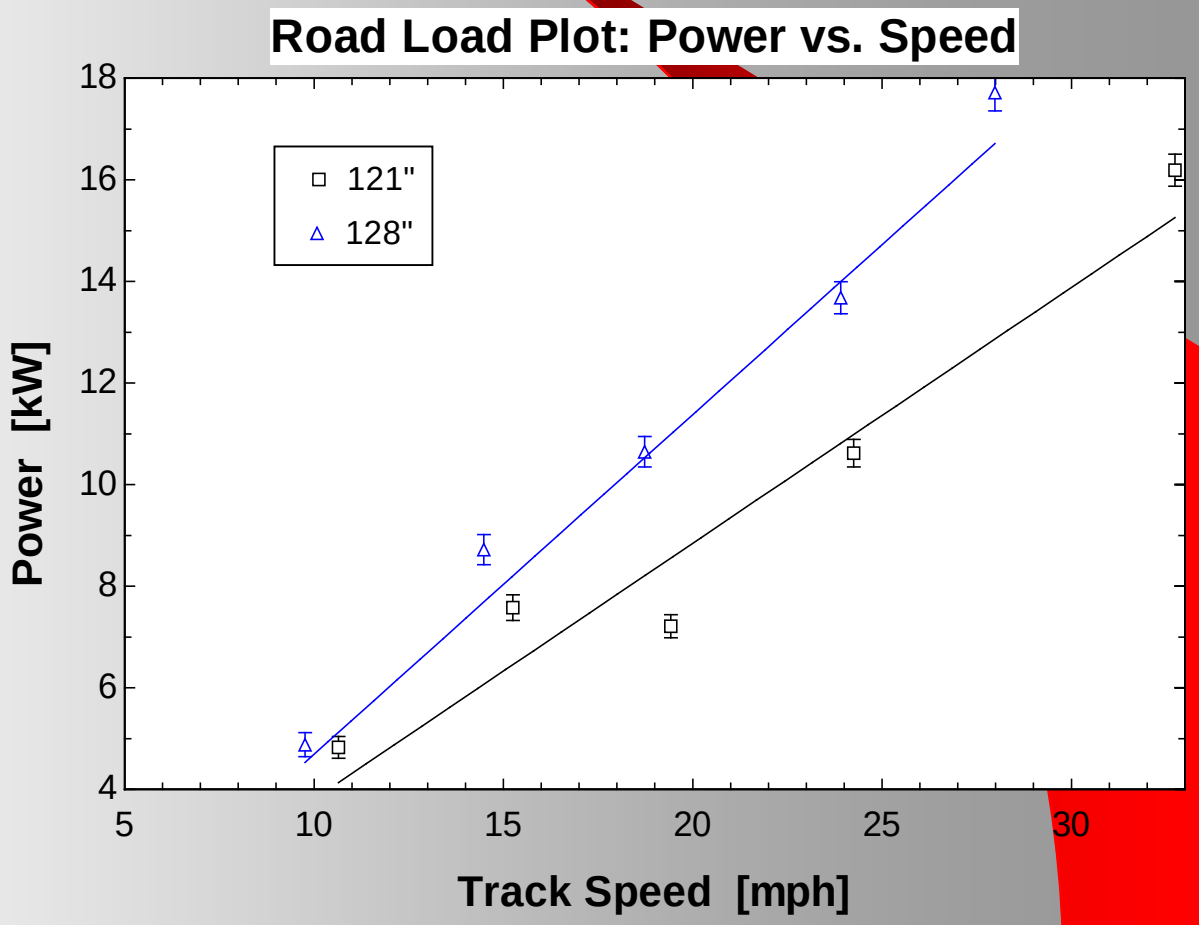
Track Length Comparison

- 128” track length standard on 2007 Polaris FST LX
- Tested 121” vs. 128” using electric snowmobile
- Found a 22% reduction in power required to drive at 25 mph when using 121”
- Overall weight reduction of 28.6 lbs.



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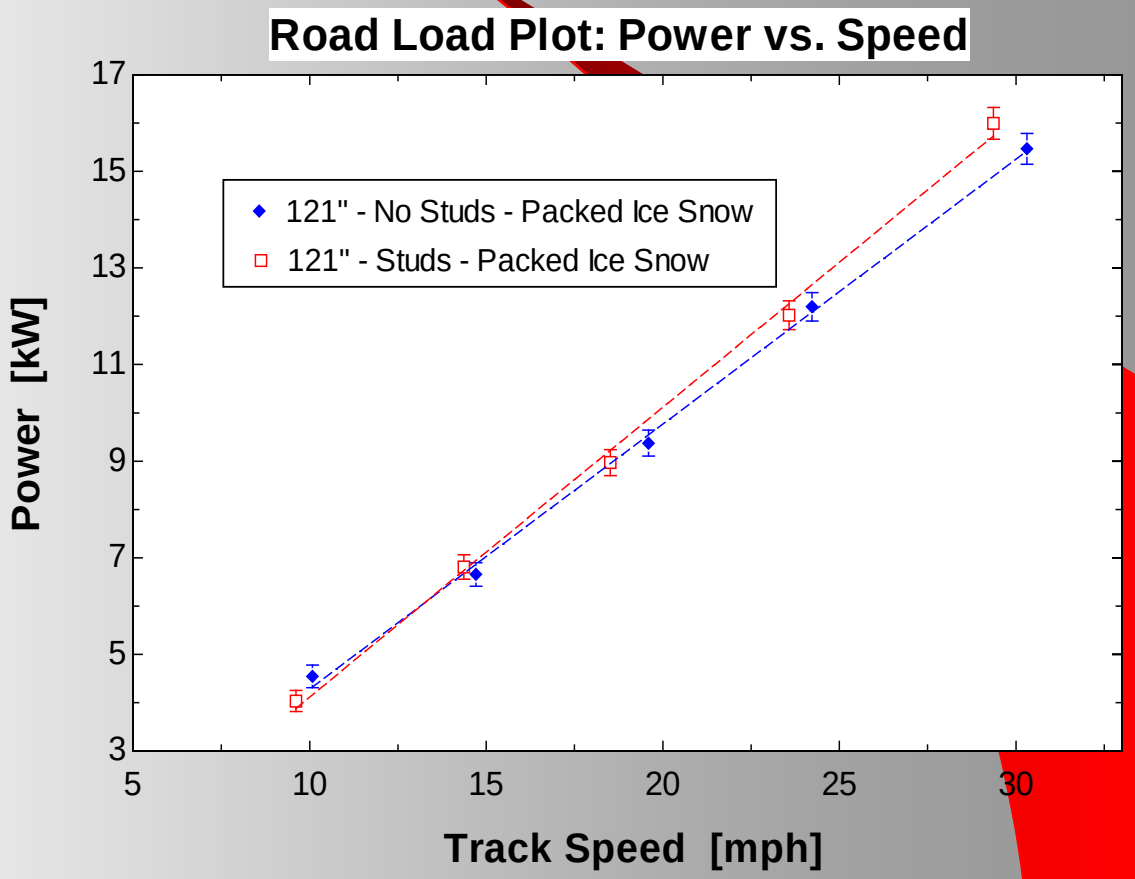
Effect of Studs

- Tested same track studded vs. non-studded
- Found a 4% difference in power required to drive at 25 mph
- This impact was weighed against the positive aspects of studs



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Sound Testing

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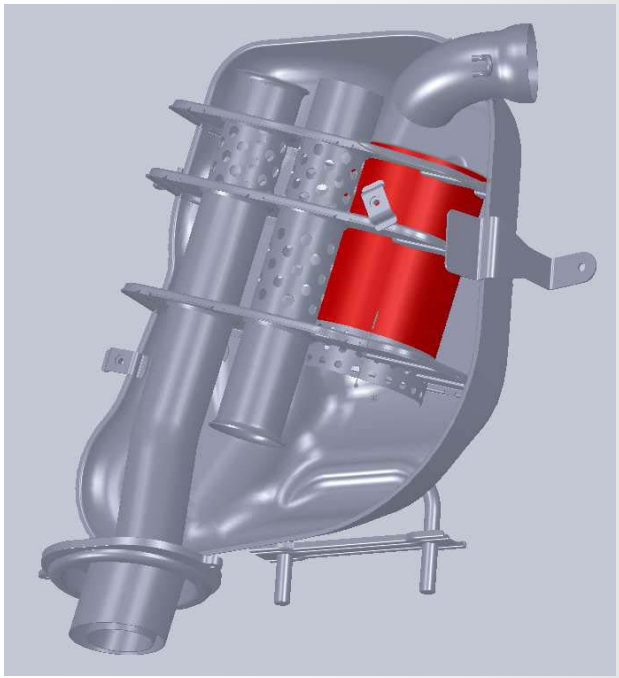
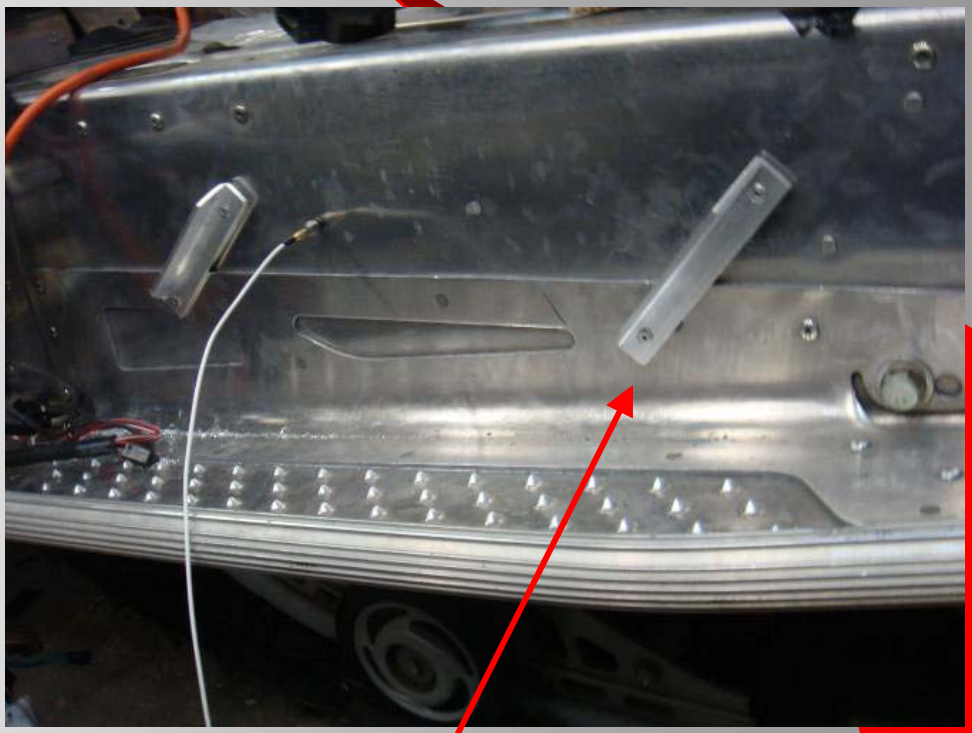
Sound Reduction

Engine

- Three Stage Exhaust System
  - Turbocharger turbine
  - Catalyst
  - Custom-Modified Muffler



Chassis



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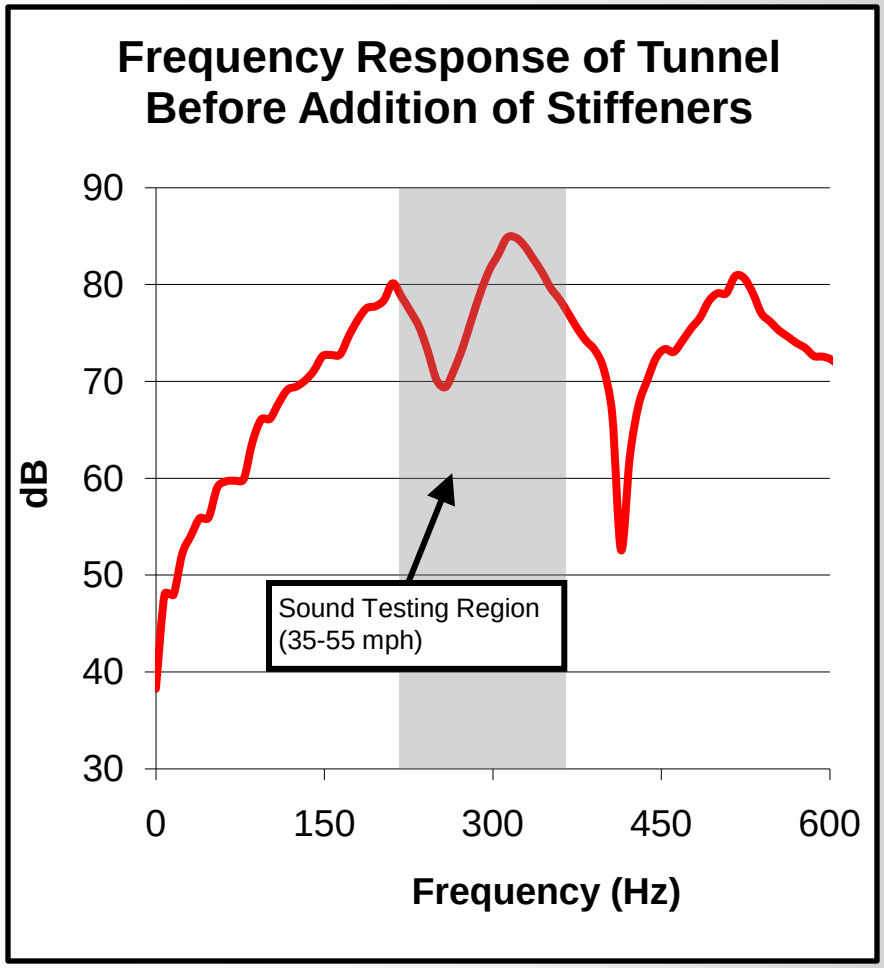
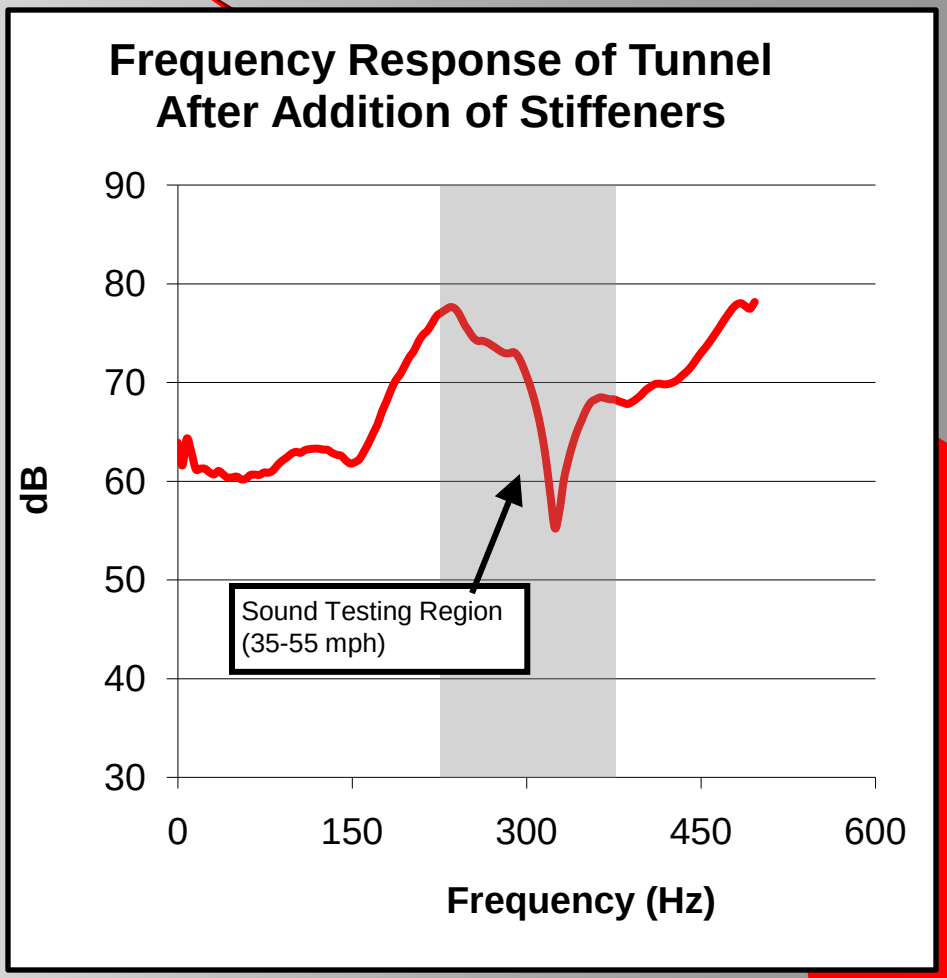
Resonance of Tunnel





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Total Sound Reduction

- Measured sound level of based on pass-by testing - SAE Standard J192

- J192 Limit – 78 dBA maximum
- Stock Muffler – 76 dBA
- Bucky CFS – 72 dBA

- 60% Noise Reduction

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Questions?

Modifications

- Custom exhaust
- Mototron control system
- Electric Throttle Control
- Air intake heater
- Ethanol compatible fuel system
- Fuel oxygenation sensor
- Studded track
- Shorter, lighter suspension
- Chassis noise reduction
- Lightweight Drive Shaft
- Improved Idle Cooling

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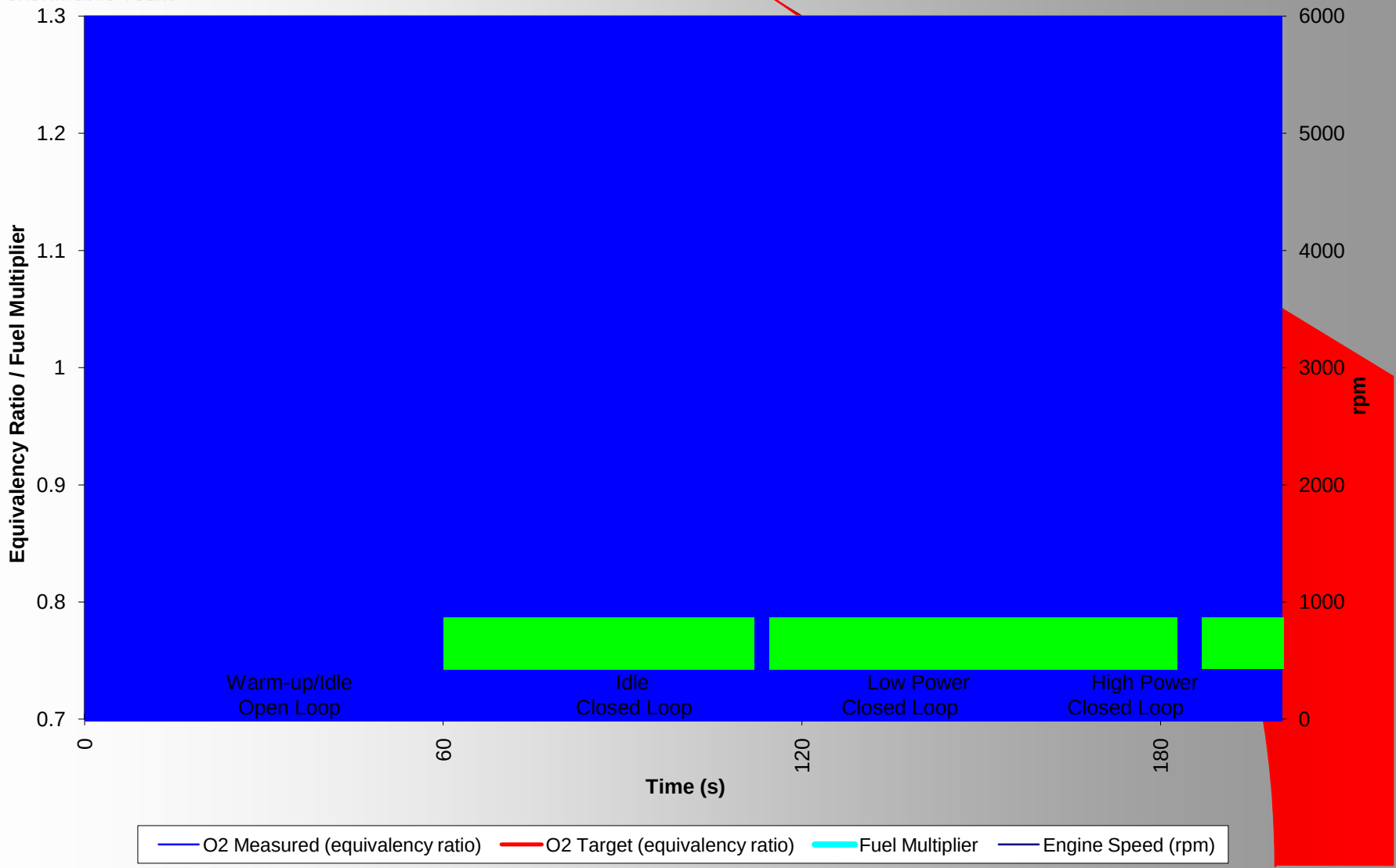
Closed-loop operation after cold start



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Why Not DI2S?

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Emissions Testing Modes

	Engine Speed (rpm)	Torque (N-m)	Power (kW)
Mode 1 (WOT)	5500	105.9	61.0
Mode 2 (85%)	4675	54.0	26.4
Mode 3 (75%)	4125	34.9	15.1
Mode 4 (65%)	3575	20.1	7.5
Mode 5 (idle)	1500	0.0	0.0

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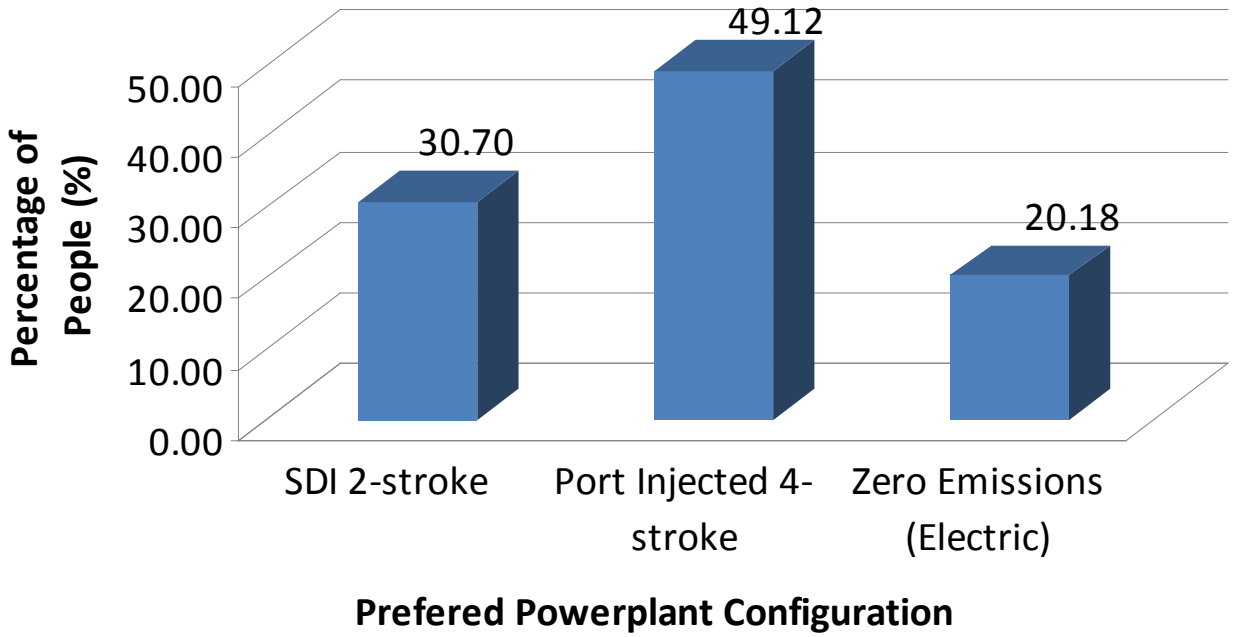
Customer Survey



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Catalyst Specs

Manufacturer	W.C Heraeus GmbH
Diameter	105mm
Length	140mm
Substrate	SuperFoil® Metal Honeycomb
Density	600 cpsi (cells per square inch)
Loading	Platinum 11.1 g/ft^3 Palladium 55.6 g/ft^3 Rhodium 8.3 g/ft^3

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Drive Shaft