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SAE Snowmobile Team

University of Wisconsin Madison

2012 SAE Clean Snowmobile Challenge

Design Presentation

Presented by:

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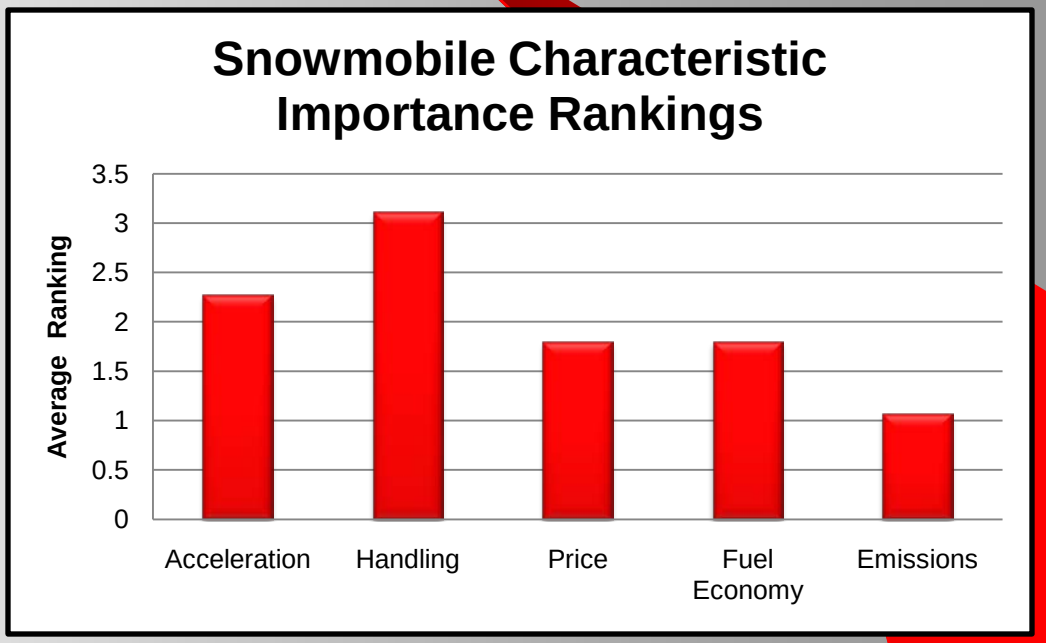
Design Considerations:

Market Survey

- Survey at Vintage Oval Races in Three Lakes, WI
  Approximately 120 surveys
- Customers Want:
  - Trail Handling
  - Acceleration
- Historical Best Sellers
  - Ski-Doo Rev XP 600 SDI
  - Polaris Rush 600



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Bucky Rush

How it Appeals to Snowmobilers

Ultra Quiet

Increased Fuel Economy

20+ mpgge

Flex Fuel

Improved Acceleration

Cruise Control Capable

Electric Start

BAT+ Compliant

2011 Rush Pro-R 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-on Replacement
  - Plug and Play Flex-Fuel Intake/Fuel System
    - ETC, Flex Fuel Sensor
- Rider Comfort
  - OEM Seat, Handlebars, Suspension, Reduced Noise
- Novice Snowmobiler Operation
  - OEM Controls

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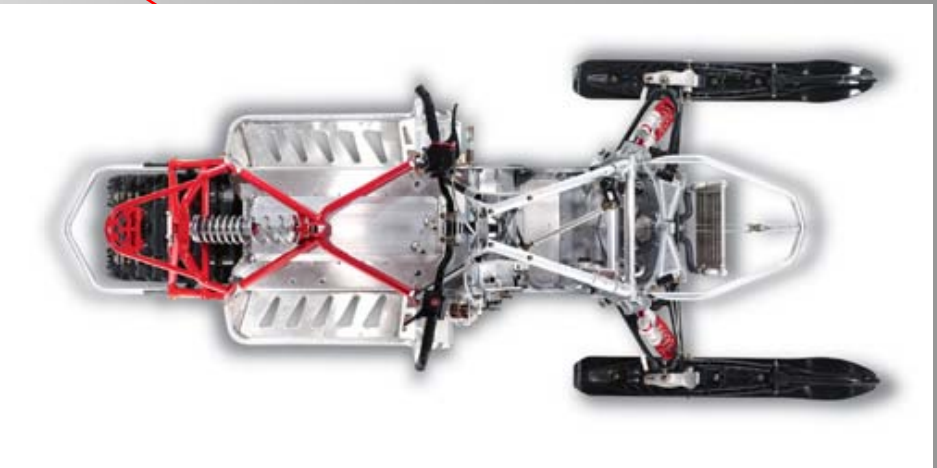
Chassis Selection

- Primary goal of improving fuel economy
- Vehicle weight is a major contributor to poor efficiency
- Rider forward ergonomics
- Progressive rate rear suspension



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Engine Selection

- Primary: engine-out emissions
- Secondary: high power-to-weight ratio

	Power (kW)	Weight (kg)	Fuel Economy (km/L)	Emissions (g/kW-hr)		
				HC	CO	NOx
Polaris FST	112	64	7.2	6.2	79.9	N/A
Ski-Doo 4-Tec 1200	97	62	7.6	9	116	N/A
Ski-Doo ACE 600	42	40	12.3	8	90	N/A*

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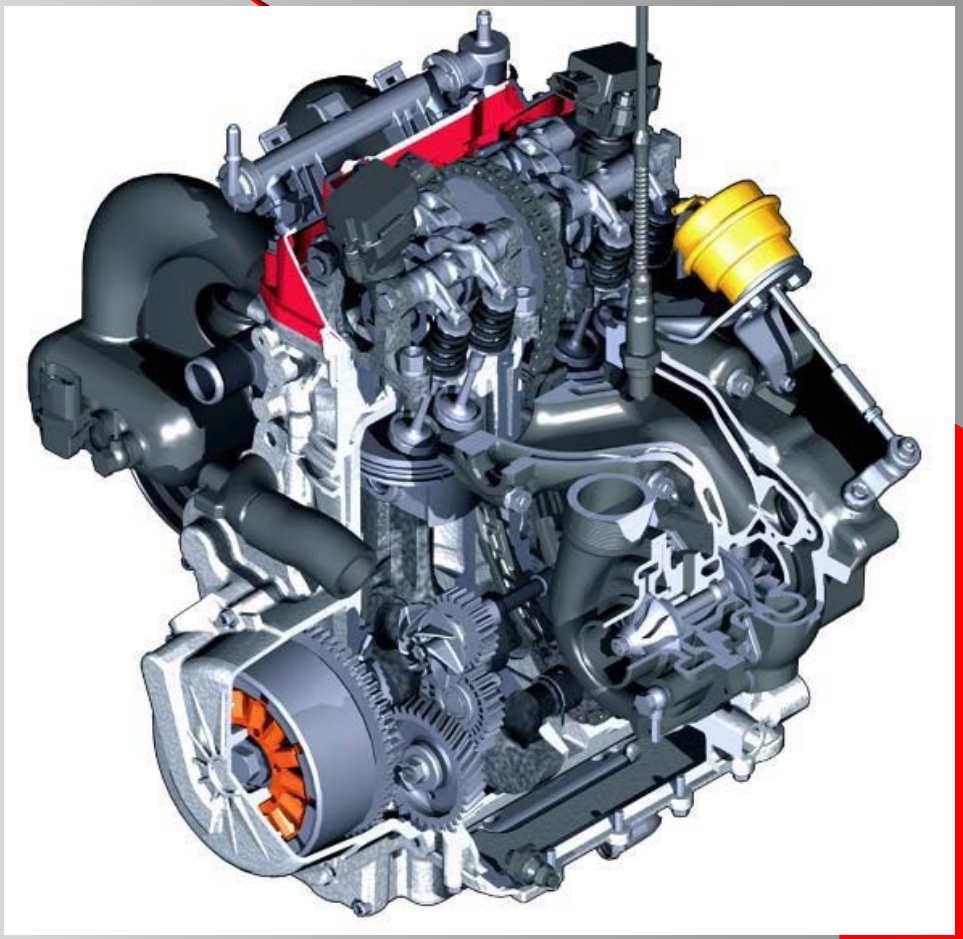
Turbo Charged Weber MPE 750 with Automotive Camshaft



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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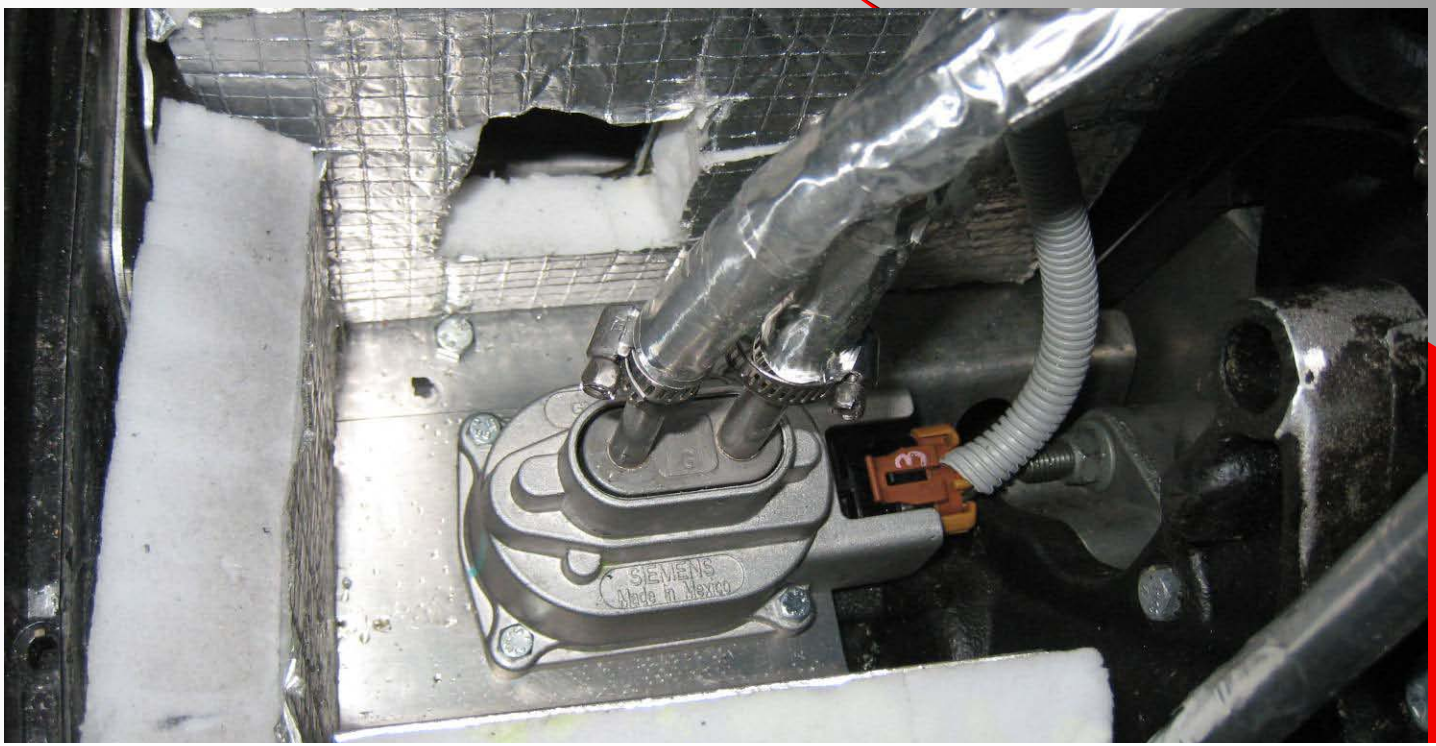
Flex Fuel Sensor



Continental Flex Fuel Sensor

- Reports ETOH Content & Fuel Temperature

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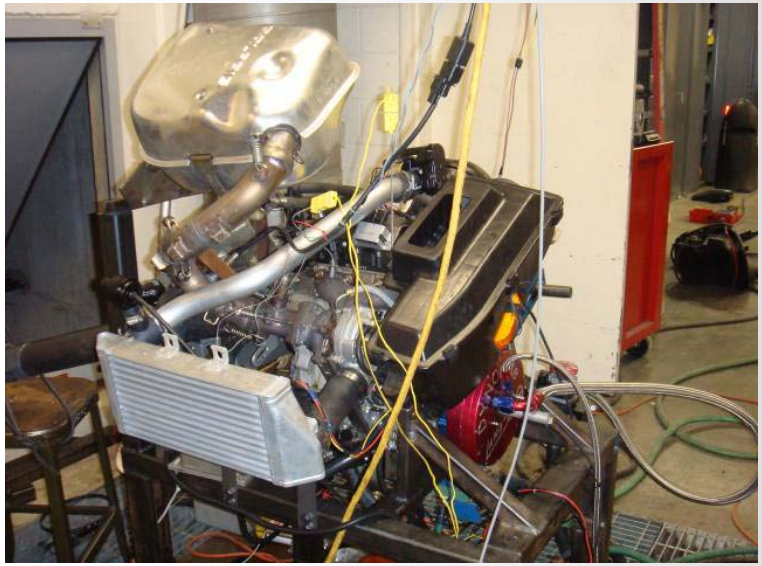
Engine Calibration



- 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 calibration points
  - Increments: 500 rpm, 0.1 PR
  - Each within ±0.01λ (open-loop)
- Feedback from O_2 Sensor

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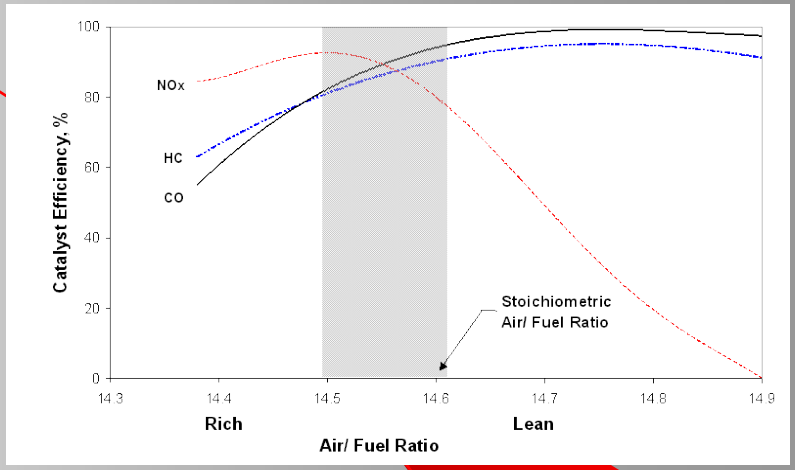
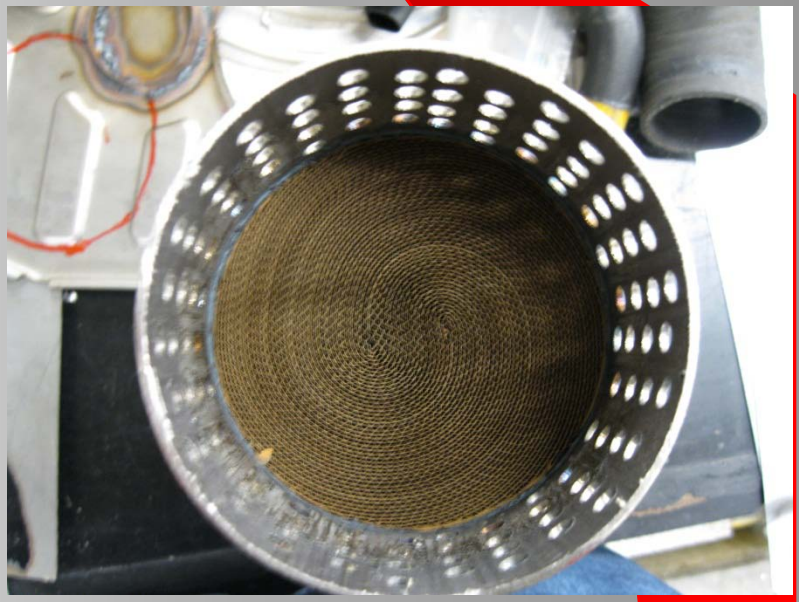
Catalytic Emissions Reduction

- 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	70mm
Length	149mm
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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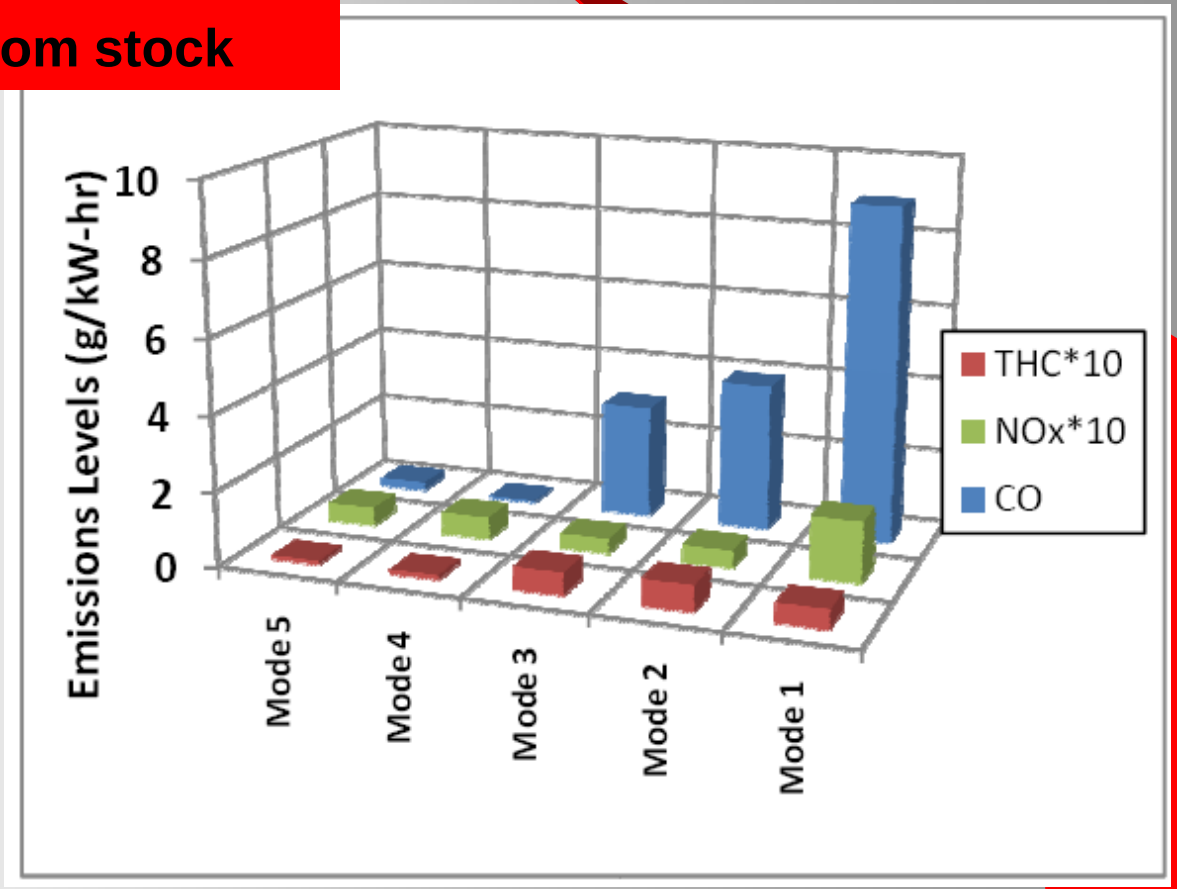
Emissions Results

2012 Emissions Testing Results

Up to 96% reduction from stock



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Fuel Economy Improvements

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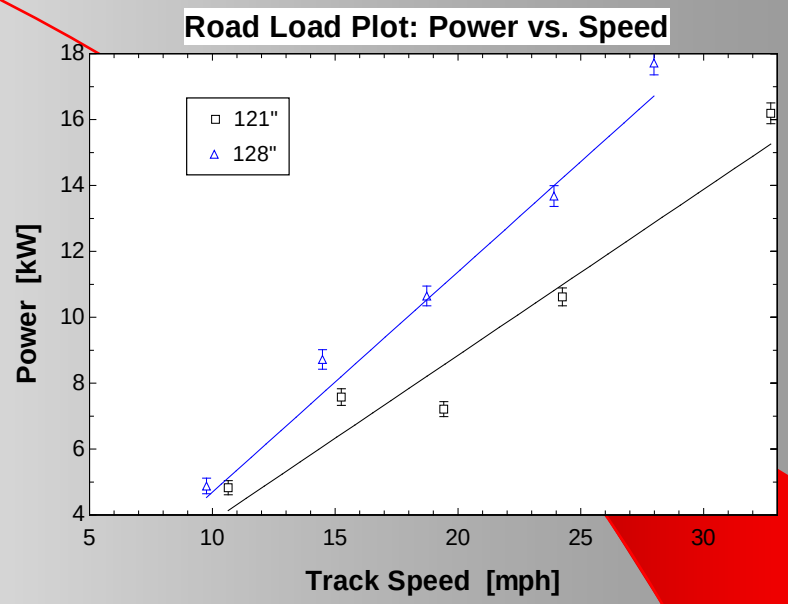
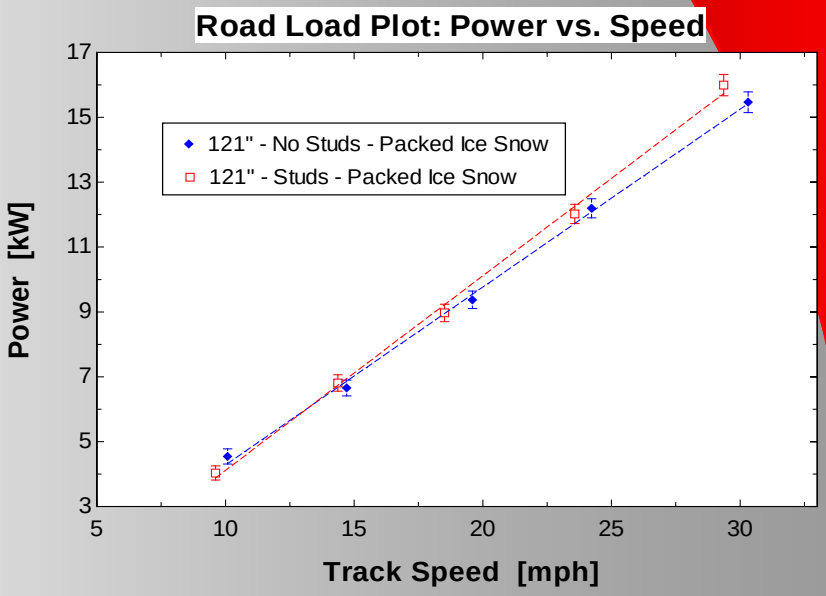
Driveline Efficiency Testing

- Tested 121” vs. 128” using electric snowmobile
- Found a 22% reduction in power required to drive at 25 mph when using 121”
- Studs reduce efficiency by 4% at 25 mph. This is weighted against their positive aspects.





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Weight Reduction

Change	Reduction (kg)
Chassis	26.88
Lithium battery	3.89
Pre-studded track	3.73
Total Savings	**34.5**
Final Weight	**290.5**

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Noise Emissions

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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 Rush – 72 dBA

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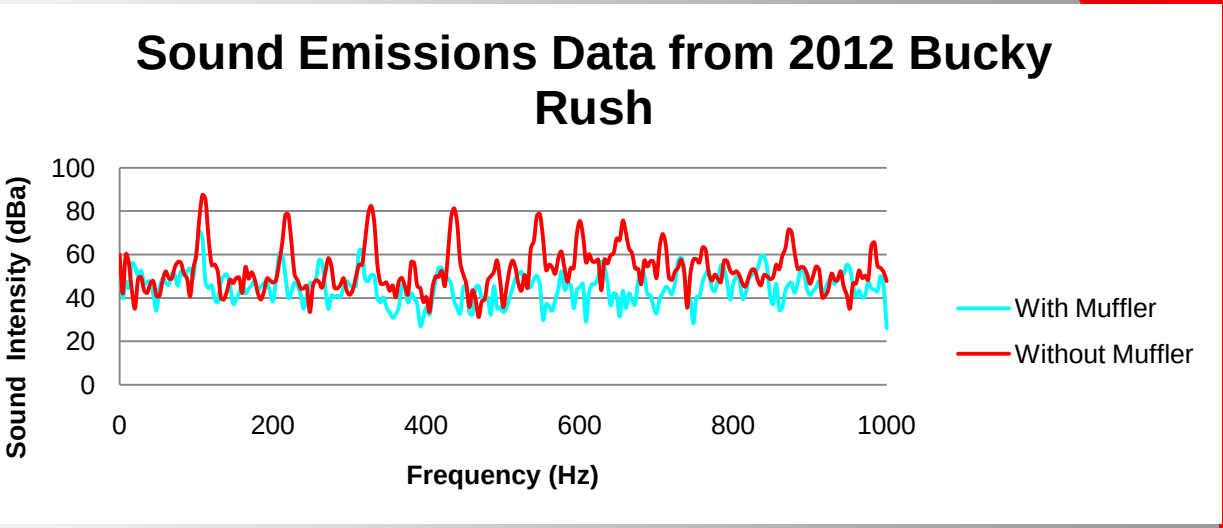
Muffler Design

- Balance between volume and backpressure
- Target Peaks in Frequencies to reduce sound



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Questions?

Key Design Points

- Lightweight Chassis
- Custom exhaust
- Woodward/Mototron control system
- Electric Throttle Control
- Ethanol compatible fuel system
- Flex-fuel sensor
- Studded track

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Emissions and Standards

Standards	HC	CO	E-number
EPA Phase 1 (‘06-’09)	<100	<275	75
EPA Phase 2 (‘10-’11)	<75	<275	91
EPA Phase 3 (‘12)	<75	<200	110
EPA BAT	<15	<120	170
SAE CSC 2011	<90	<275	100

Vehicle	HC	CO	E-number
UW CSC 2009	0	5	208
BRP 600ACE (4-stroke)	8	90	182
BRP 800 ETEC (DI 2-stroke)	?	?	?

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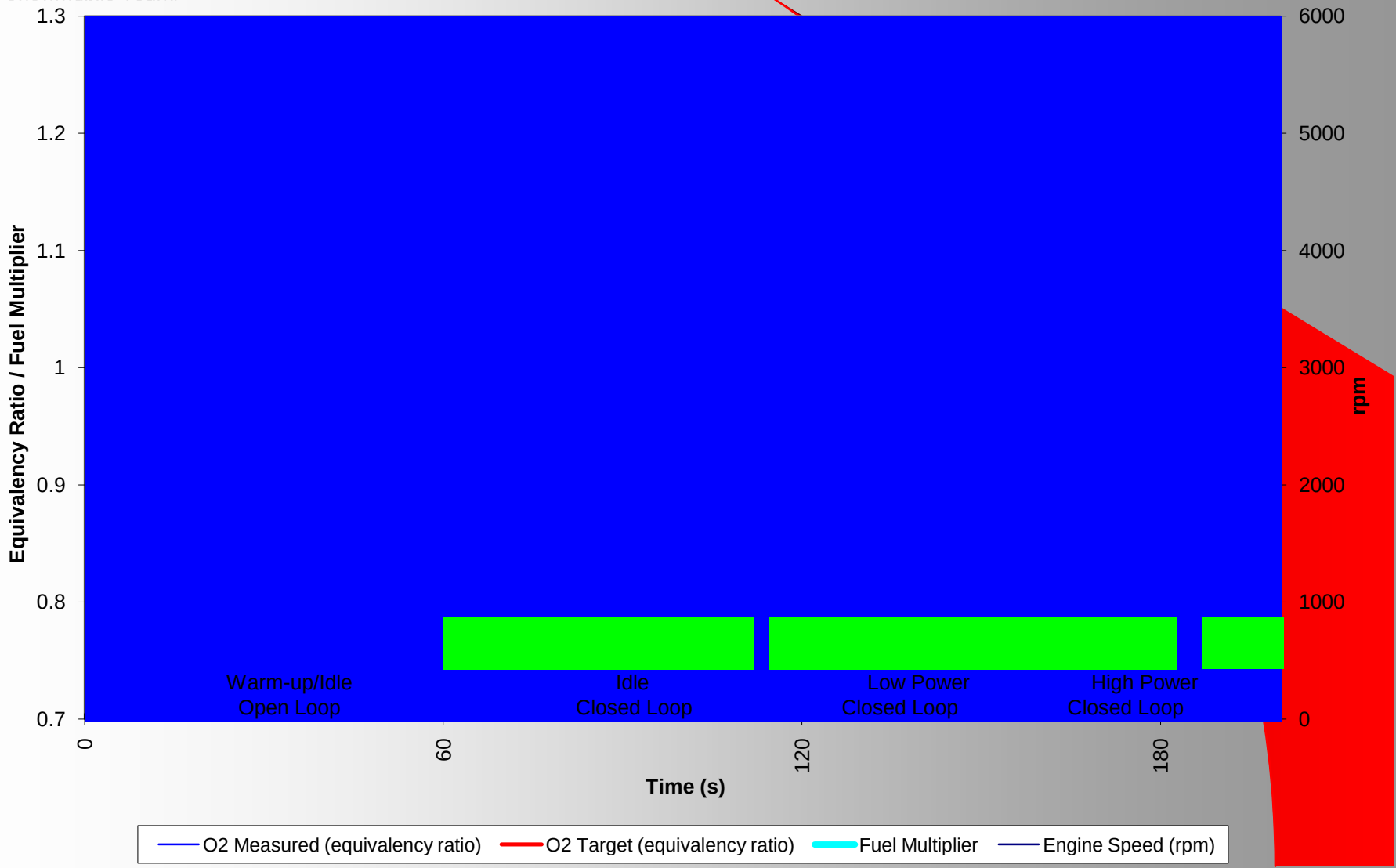
Closed-loop operation after cold start



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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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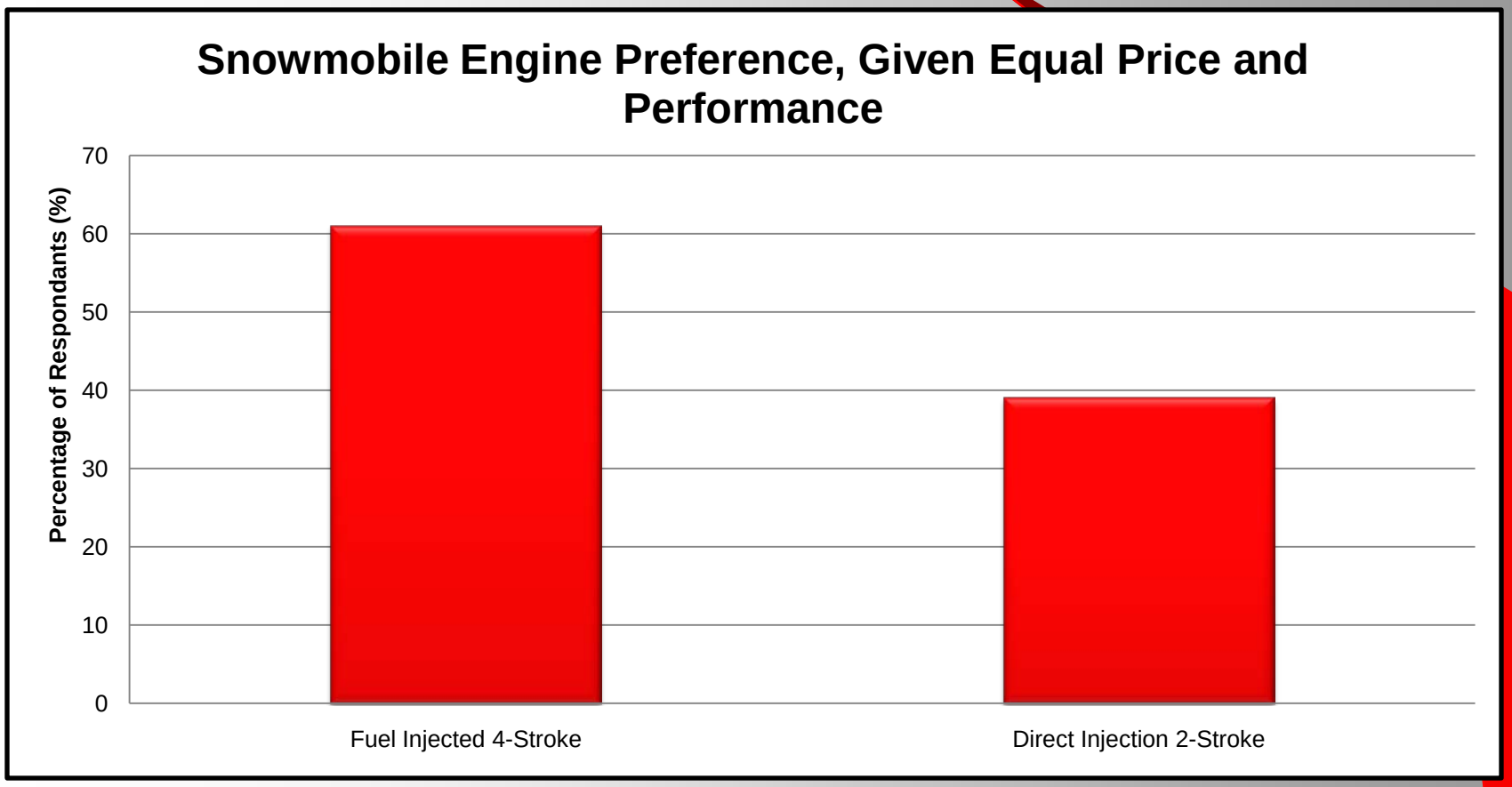
Customer Survey



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Drive Shaft

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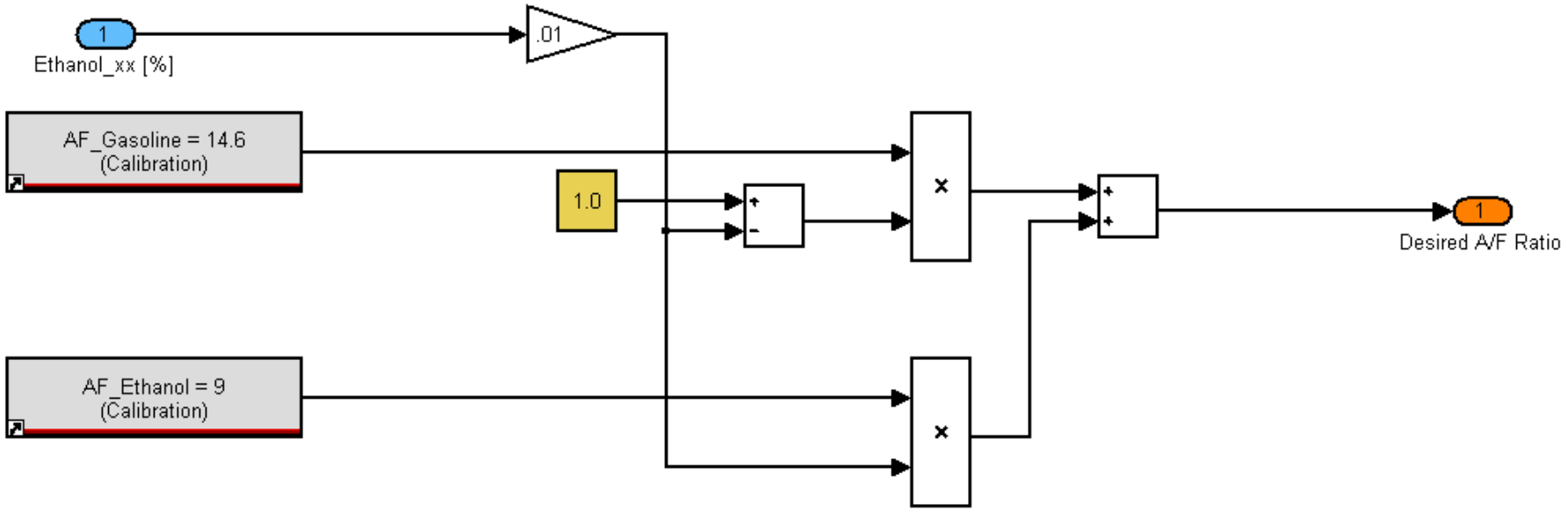
Flex Fuel Control Algorithm



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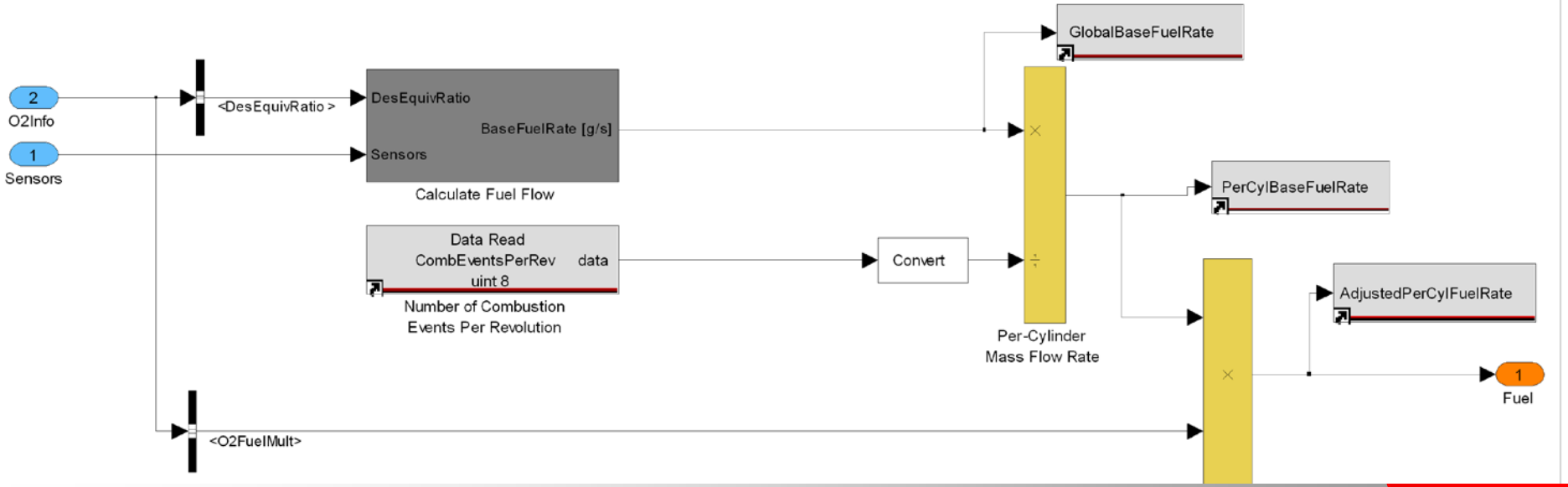

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Lean/Rich Oscillation Strategy