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# University of Wisconsin Madison

## 2008 SAE Clean Snowmobile Challenge

### *Design Presentation*

Presented by:

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**Michael Maney**



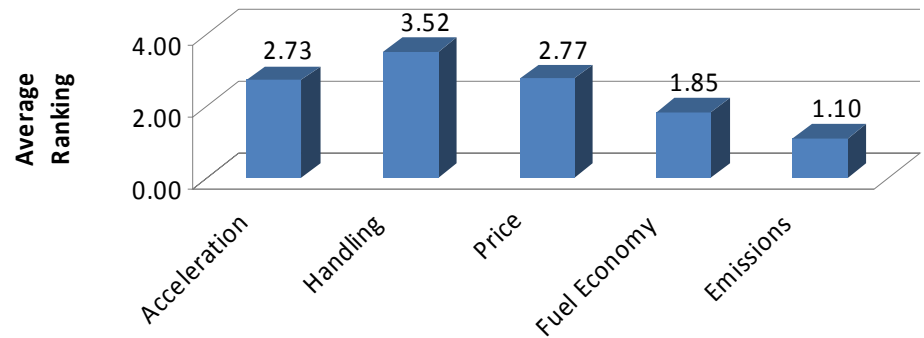


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# Design Considerations: Market Survey

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

**Snowmobile Characteristic Importance Rankings (5 is most important)**



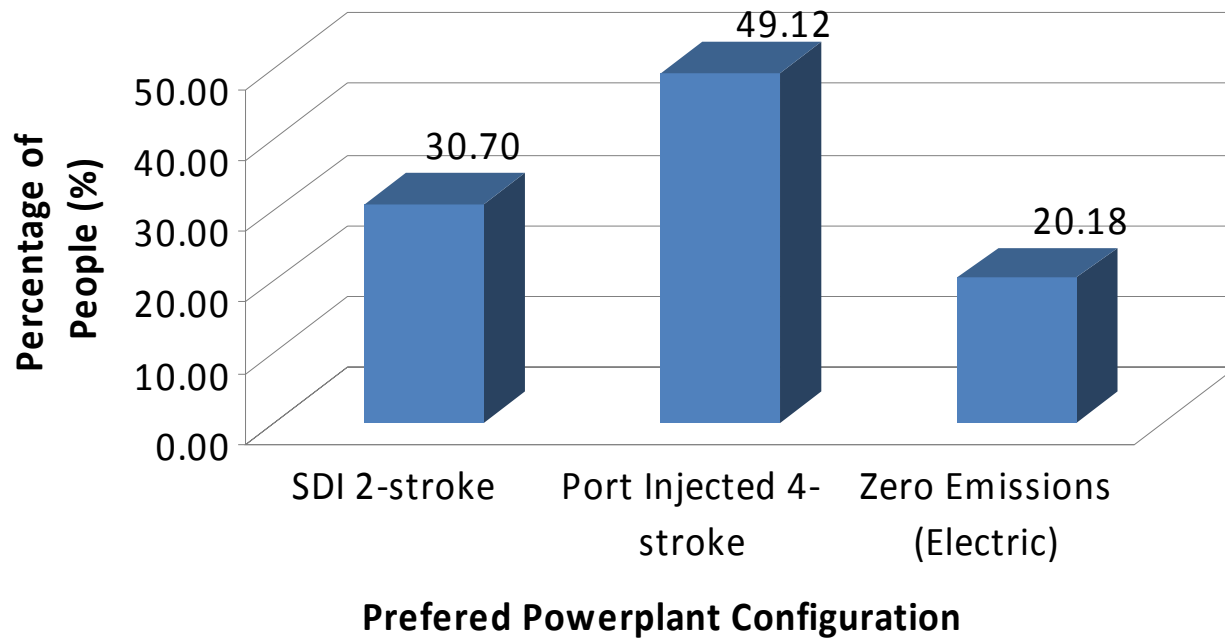


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# Customer Survey

## Snowmobile Type Preference, Given Equal Price and Performance





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# Engine Selection

## Snowmobile Engine Emissions Testing

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

	HC g/kW-hr	CO g/kW-hr	NO <sub>x</sub> g/kW-hr
Two-stroke average (SwRI 2002)	189	517	0.72
Arctic Cat 660 (4s) (SwRI 2002)	6.2	79.9	10.6
Polaris Liberty (4s) (SwRI 2002)	3.2	79.1	7.0
Polaris FS (4s)	9.3	38.6	1.5

1: [http://www.ski-doo.com/media/2004\\_SOTY.pdf](http://www.ski-doo.com/media/2004_SOTY.pdf)

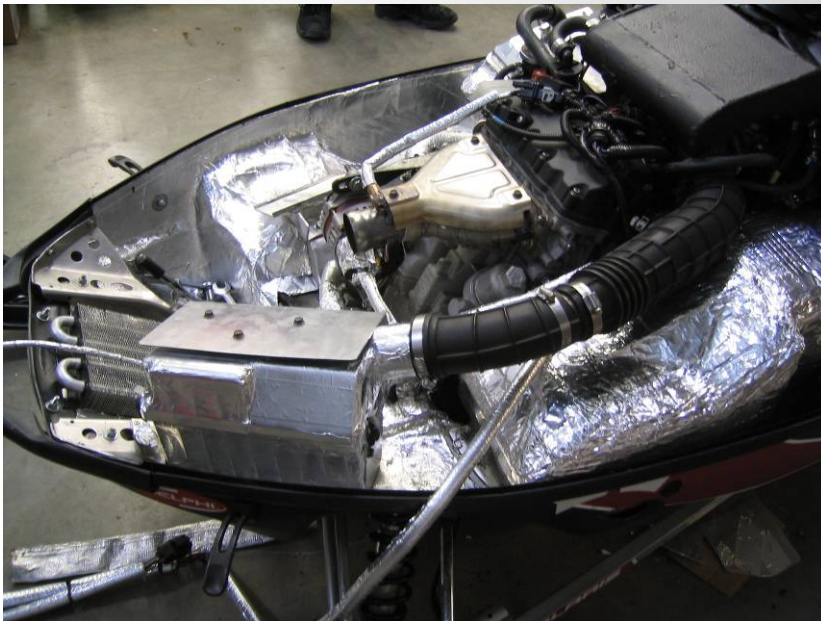




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# Powertrain Implementation

- Engine Mounts
  - Rubber vibration isolation mounts in non-parallel planes
  - Optimal center to center clutch distance



- Air Box
  - Shaped to maximize air flow and minimize size
  - Covered with sound dampening rubber
  - Intake location chosen to minimize induced air temperatures



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# Engine Management



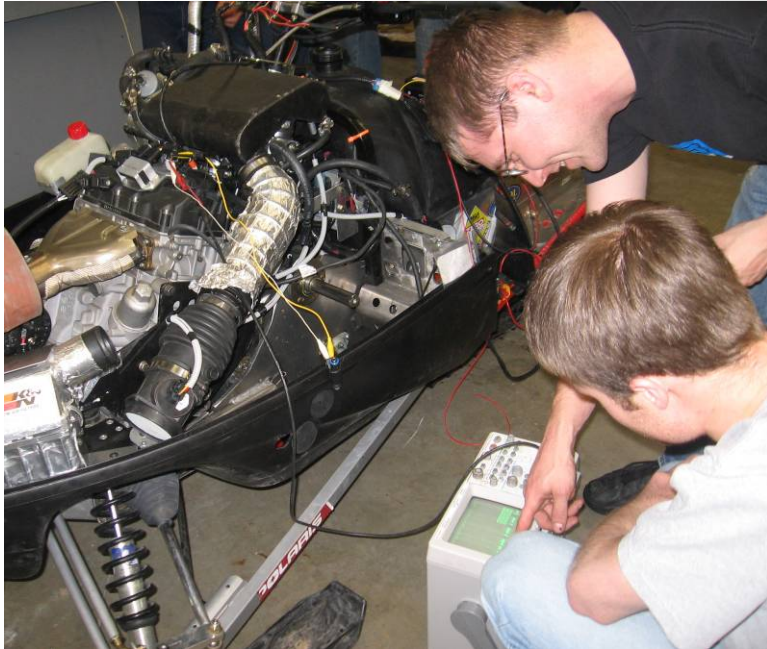
## Mototron's PCM 555

- 40° to 130 ° C
- 18 g Shock Load
- Up to 3 Meters Under Water
- Simulink Engine Model
- MotoHawk Auto-code Generation



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# E85 Calibration



- DYNOMite Water-Brake Dyno
- Horiba CO & CO<sub>2</sub> Analyzer
- HEGO sensor
- Chemiluminescent NO<sub>x</sub> Analyzer
- Exhaust Thermocouples
  
- Calibrated Spark Advancement and Volumetric Efficiency within 1% of Stoichiometric
- O<sub>2</sub> Sensor PID Control 'Finds' Stoichiometric

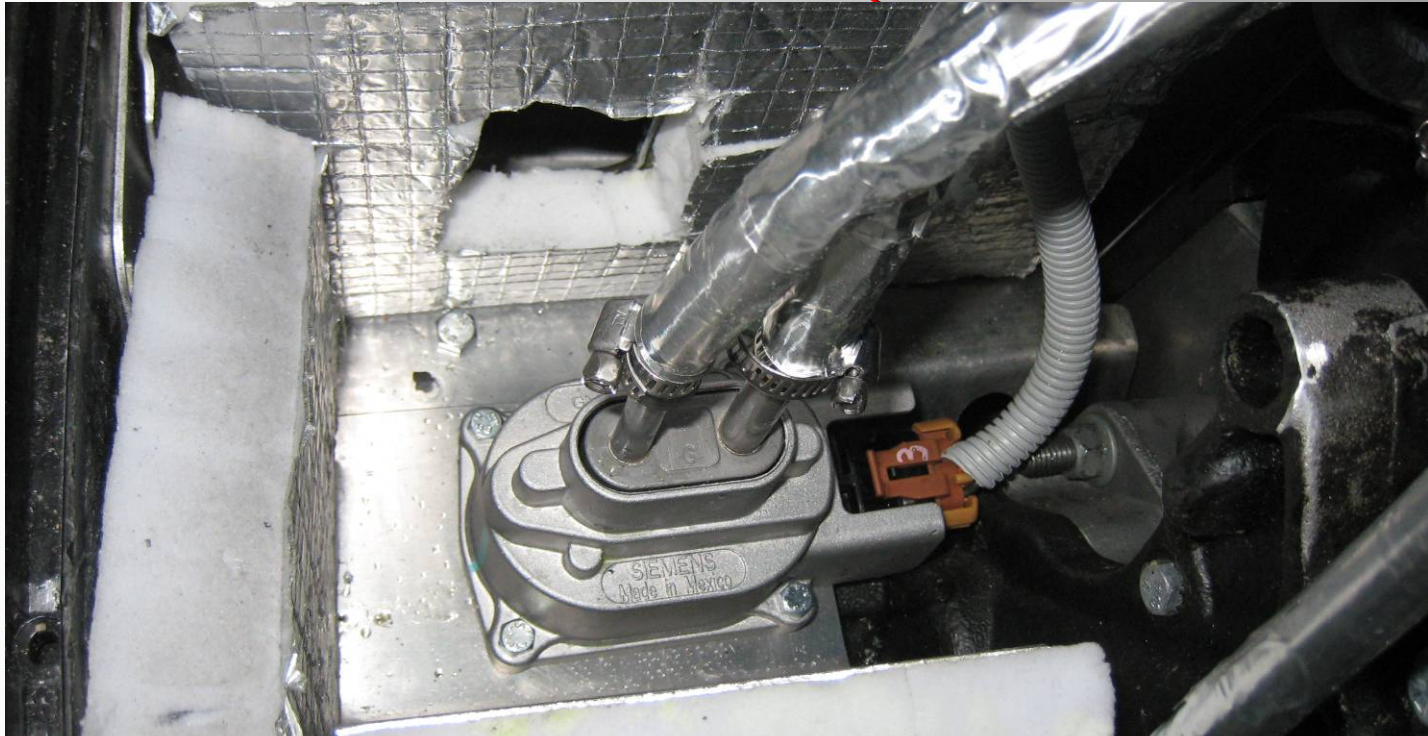
**31.25% Gain in Peak Power!**





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# Flex Fuel Sensor



## Continental Flex Fuel Sensor

- Reports ETOH Content & Fuel Temperature





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# Emissions Reduction

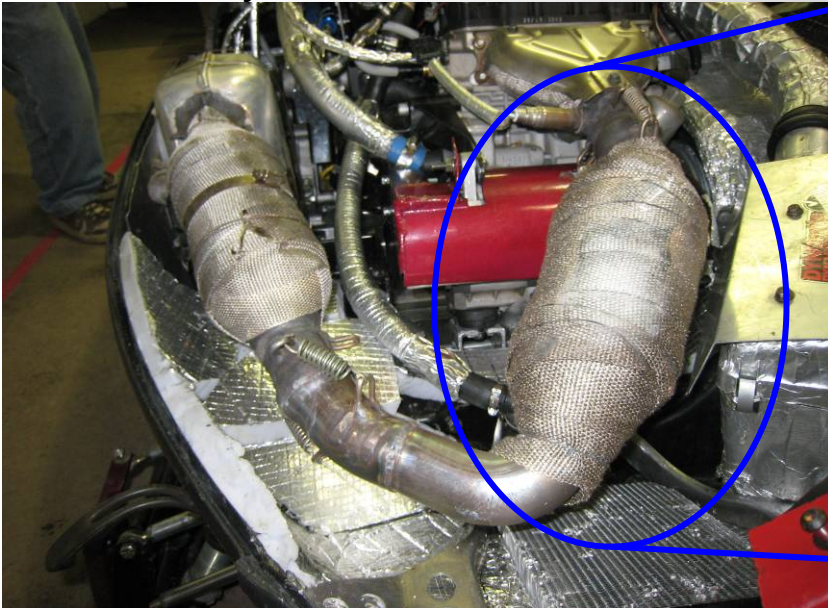
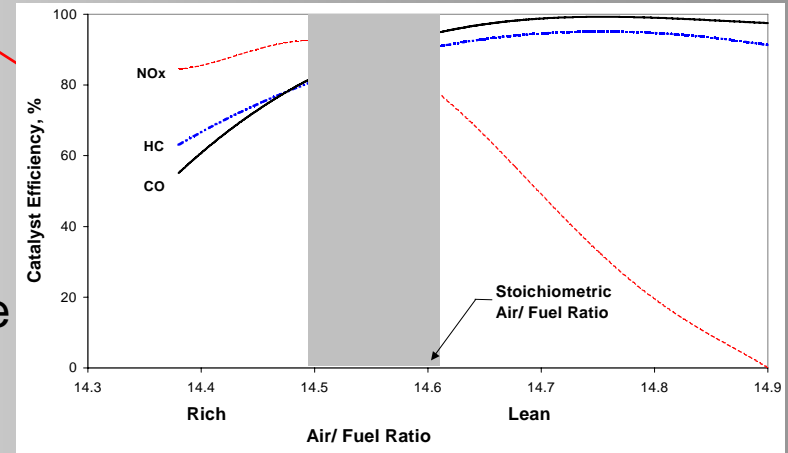


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# Emissions Reduction

## Improvements for 2008

- Engine calibrated to run stoich at all engine speeds and loads
- Exhaust system re-designed to minimize weight, engine back-pressure and risk of pre-catalyst leaks
- One 600 cpsi W.C Heraeus GmbH Catalyst





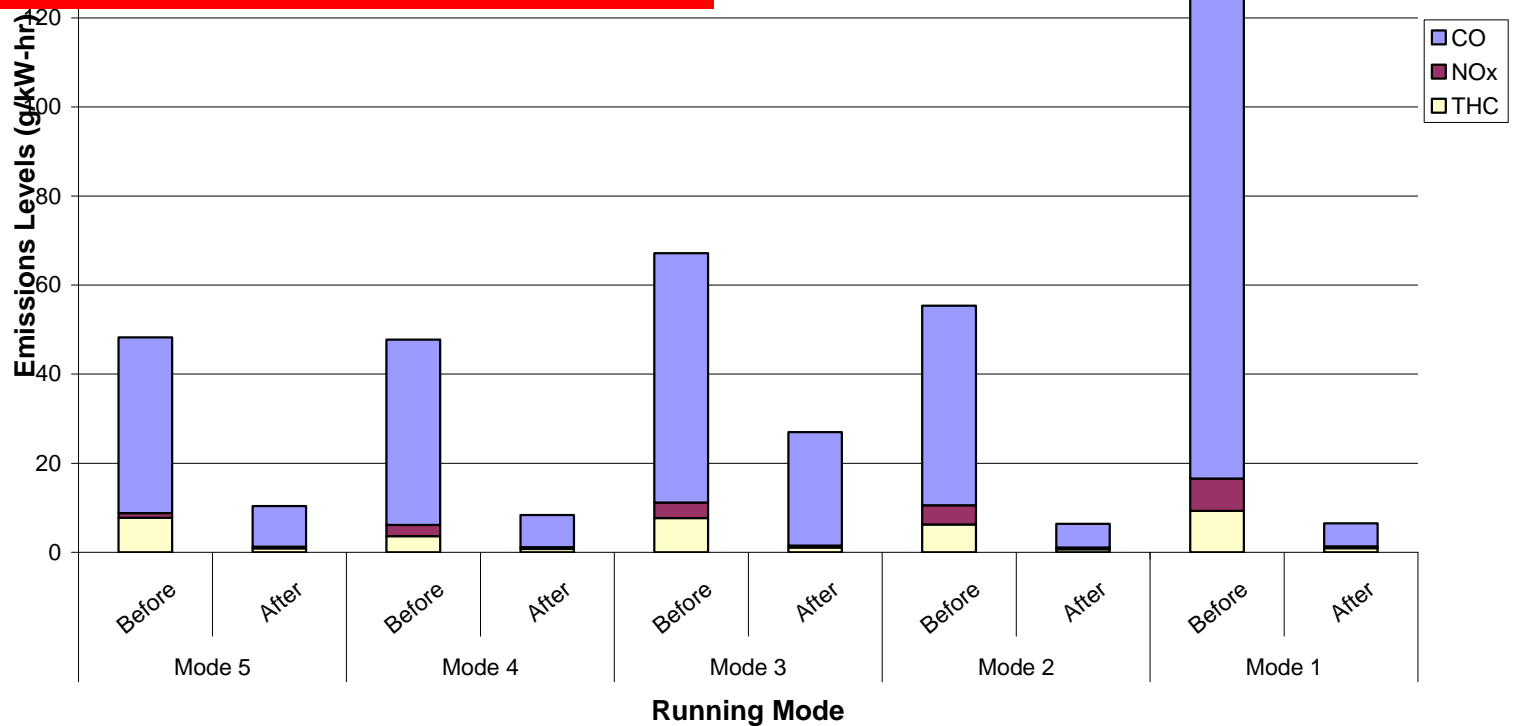
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# Emissions Results

## Comparison of Emissions Before and After Catalyst

**2008 Emissions Testing Results**

**96% reduction from stock**





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# Sound Testing



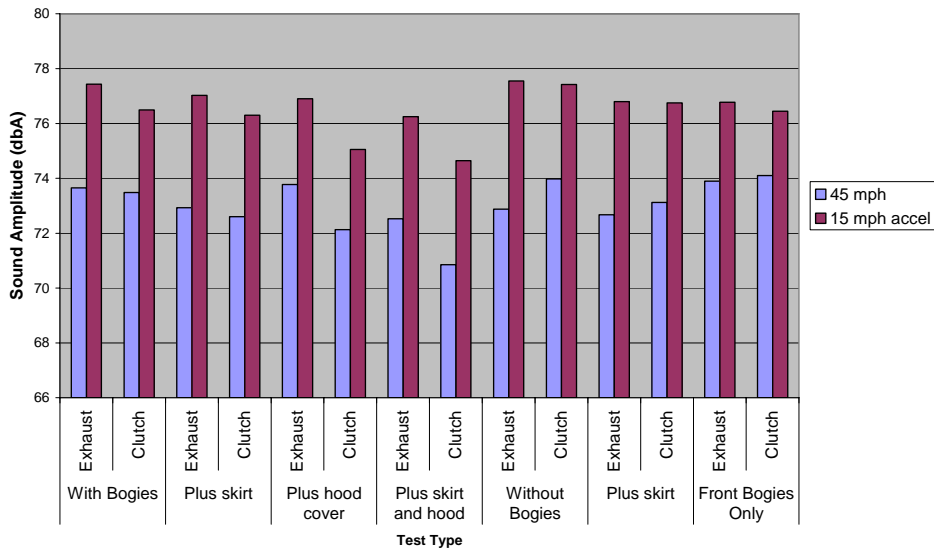


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# Sound Pass-By Testing

Sound Testing Results



Hood Barrier

Track Skirt



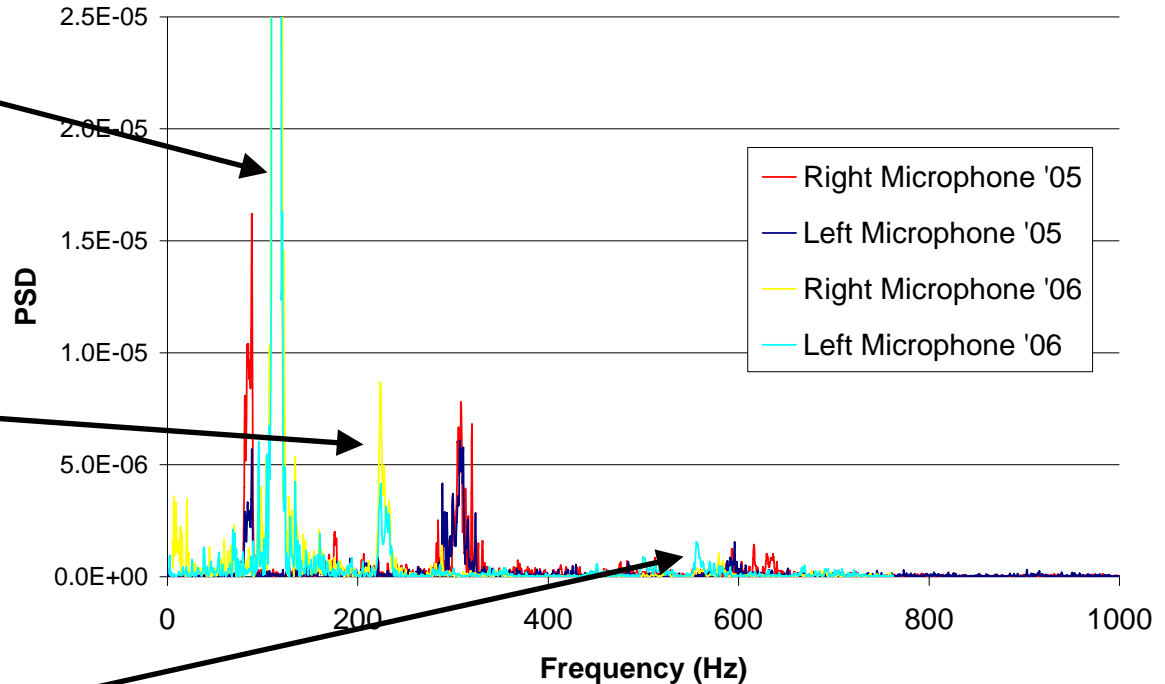
Contributions of Components  
to Overall Noise



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# Frequency Analysis of Sound

Power Spectral Density (Un-Weighted) Plot of 2005 and 2006 Configuration of Bucky Classic 750 During 7.1 m Pass By Testing



Engine

1<sup>st</sup> order Track

2<sup>nd</sup> order Track



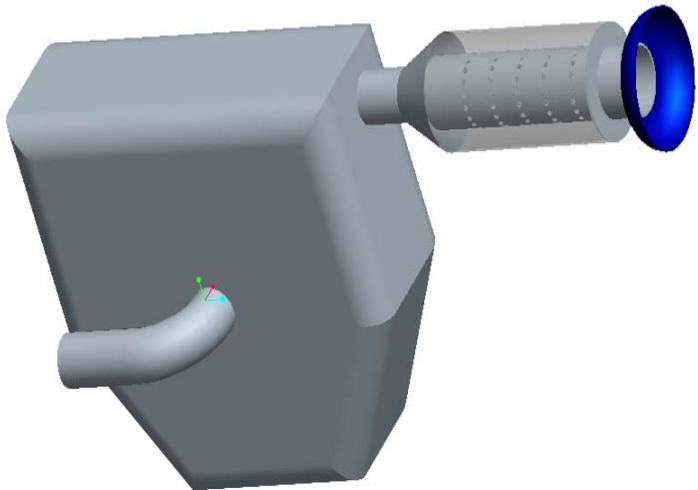
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# Sound Reduction

## Engine

- Three Stage Exhaust System
  - Catalysts
  - High Frequency Diffuser
  - Arctic Cat T660 Muffler



## Track



Tunnel Stiffeners

Direct Sound Barrier

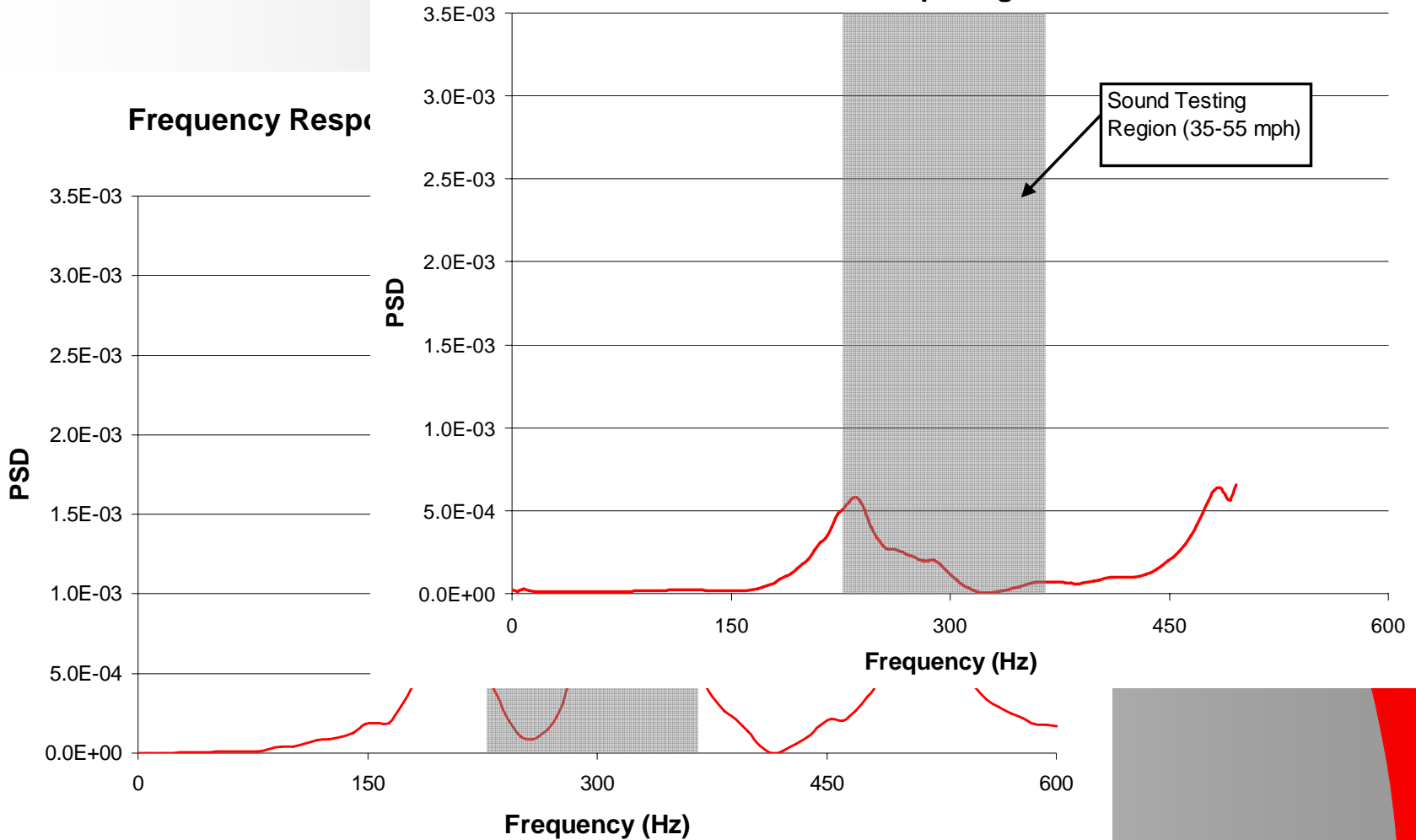
Silent Track



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# Resonance of Tunnel

### Frequency Response of Tunnel After Addition of Stiffeners and Dampening







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# Total Sound Reduction

- Track noise greatly decreased by installation of Arctic Cat Silent Track
- Engine noise appears to be the only audible snowmobile sound, showing reduction of track noise
- Measured sound level of 73.2 dBA - sound level based on pass by testing, which meets SAE Standard J192
  - 2 dBA reduction from 2007 CSC



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# Weight Reduction



- Muffler
  - T660 muffler is approximately 7 lbs lighter than stock FS muffler
- Front Suspension
  - Chromoly trailing arms
  - 6061 Al. radius rods
  - 12 lbs lighter
  - Shorter turning radius
- Polycarbonate Hood
- Hydroformed Hollow Drive Shaft



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# Questions?

## Sled modifications

- Trailing arms
- Arctic Cat exhaust
- Rapid prototype battery-box
- Larger fuel injectors
- Moto-tron ECU system
- E-85 compatible fuel components
- Ethanol Sensor
- Arctic Cat Silent Track
- LED headlights and taillights
- Sound dampening materials
- Lightweight Drive Shaft





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# Emissions Testing Modes

	<b>Engine Speed (rpm)</b>	<b>Torque (N-m)</b>	<b>Power (kW)</b>
<b>Mode 1 (WOT)</b>	8000	54.9	46.0
<b>Mode 2 (85%)</b>	6800	28.0	19.9
<b>Mode 3 (75%)</b>	6000	18.1	11.4
<b>Mode 4 (65%)</b>	5200	10.7	5.8
<b>Mode 5 (idle)</b>	1700	1.4	0.2





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# Catalyst Specs

<b>Manufacturer</b>	W.C Heraeus GmbH
<b>Diameter</b>	105mm
<b>Length</b>	140mm
<b>Substrate</b>	Metal Honeycomb
<b>Density</b>	600 cpsi (cells per square inch)
<b>Loading</b>	Platinum 7.4 g/ft <sup>3</sup> Palladium 37.0 g/ft <sup>3</sup> Rhodium 5.6 g/ft <sup>3</sup>



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# Injector Specs

	<b>Gasoline Injector</b>	<b>Ethanol Injector</b>
<b>Bosch Part #</b>	0 280 156 236	0 280 156 290
<b>Body Color</b>	Yellow	Black
<b>60 Sec Flow</b>	213 g	400 g
<b>Impulse Flow</b>	6.3 mg	11.2 mg
<b>Impulse Time</b>	2.5 ms	2.5 ms
<b>Rail Pressure</b>	300 kPa	300 kPa
<b>Driver Stage</b>	SEFI	SEFI



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# Exhaust





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# Drive Shaft







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# LED Headlights

