University of Idaho Two-Stroke Direct Injection Snowmobile

Presented By
Andrew Hooper & Dillon Savage

Overview

- Clean Snowmobile Competition Goals
- Design Goals and Target Audience
- Design Strategy
- Chassis and Engine Modifications
- Testing Results
- Summary and Conclusions
- Questions

Clean Snowmobile Competition Goals

- Provide university students with real world engineering experience
- Create clean, quiet, and fuel efficient snowmobiles while maintaining or improving performance
- Meet EPA exhaust and noise emissions standards

UICSC Design Goals

- Create a National Park certified two-stroke snowmobile
  - E-score >170, SAE J192 score<73 dBA
- Produce a reliable and accurate flex fuel system
- Generate 110-130 HP
- Deliver original equipment manufacturer level packaging

Design Strategy

- Clean and Efficient
  - E-TEC direct injection fueling
  - Flex fuel compatible for E40-E70
  - Catalytic converter
  - Eco-switch
- Quiet
  - Low speed 797cc engine
  - Add sound insulation
  - Quarter wave resonator

Chassis and Engine

- Chassis
  - 2009 Ski-Doo MXZ REV-XP
    - Performance oriented
    - Proven rider comfort
    - Improved handling
- Engine
  - Rotax 797cc H.O. Two-Stroke
    - E-TEC direct injection
    - RAVE 2 variable exhaust with tuned pipe
    - High power-to-weight ratio

Rider Viewpoint

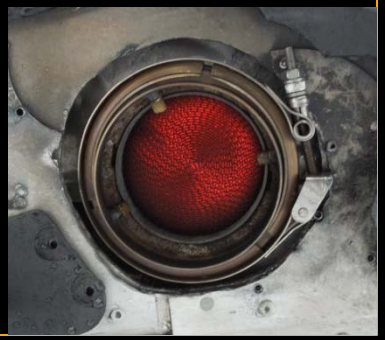
- Performance
  - 115 HP
  - 580 lb (wet)
- Fuel Efficient
  - 20 MPG (GGE)
- Comfort
  - Rider position
  - Handling

Dealer/Outfitter Viewpoint

- Low Maintenance
  - Little cost in time to maintain
- Low Cost
  - MSRP $11,411
- Meets Consumer Demand
  - Easy to sell
- Environmentally Conscious
  - Meets strict emissions and sound standards

Engine Modifications

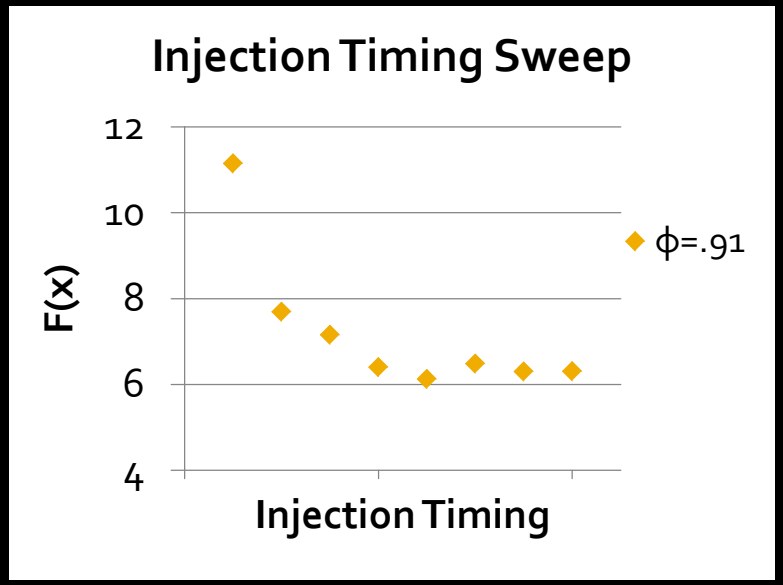
- Lowered Engine Speed
  - Reduced engine RPM lowers noise levels, increases fuel efficiency, and reduces emissions
  - Implemented eco-switch to create dual-mode snowmobile, further reducing engine speed
- Added Aristo three-way catalytic converter
  - Reduced exhaust emissions
  - Little impact on power output

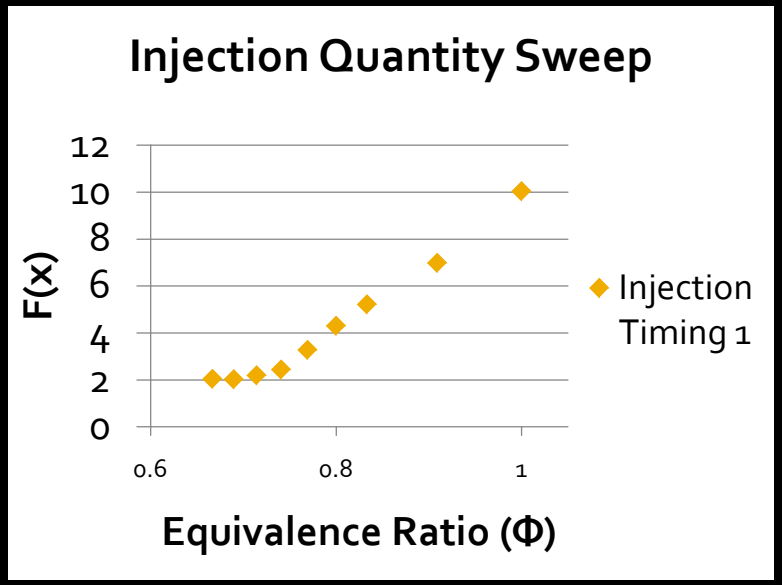


Calibration Equipment

- Borghi & Saveri eddy current dynamometer
- Innovate LM2 wide band O_2
- Horiba 5 gas analyzer
- Max Machinery fuel measurement system

Calibration Strategy





$$\Phi = \frac{AFR_{stoich}}{AFR_{meas}}$$

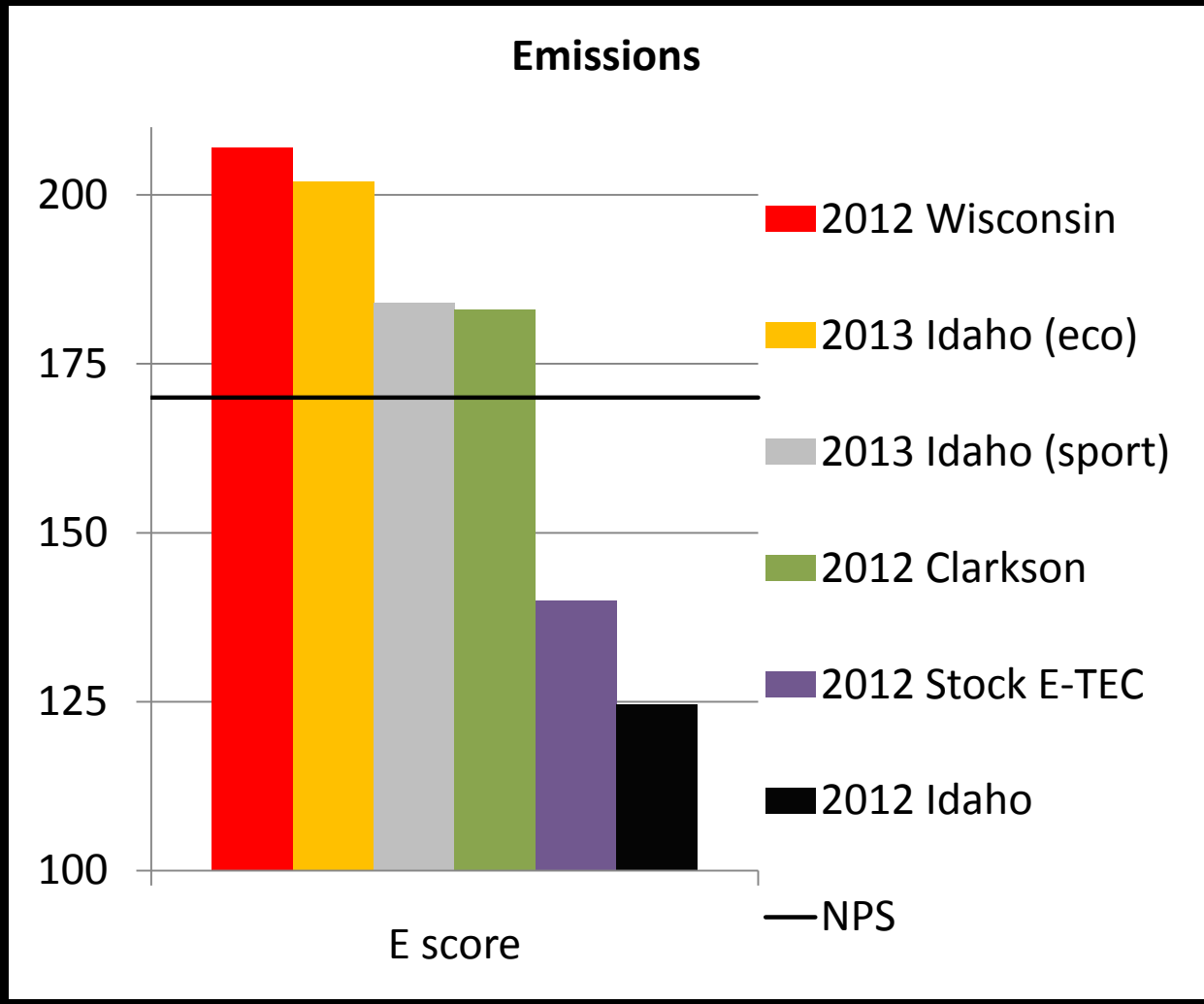
- $$F(x) = W_m * \frac{\left(\frac{6*UHC+NO_x}{150} + \frac{CO}{400}\right)}{P}$$
- Calibrated at 10% ethanol

Flex Fuel

- Continental flex fuel sensor
- Custom analog circuit
- Fuel correction based on stoichiometric AFR of ethanol blends
- Correction refined at E40, E55, E70

Emissions Results

- Eco mode
  - 202
- Sport mode
  - 183
- Both pass EPA and NPS

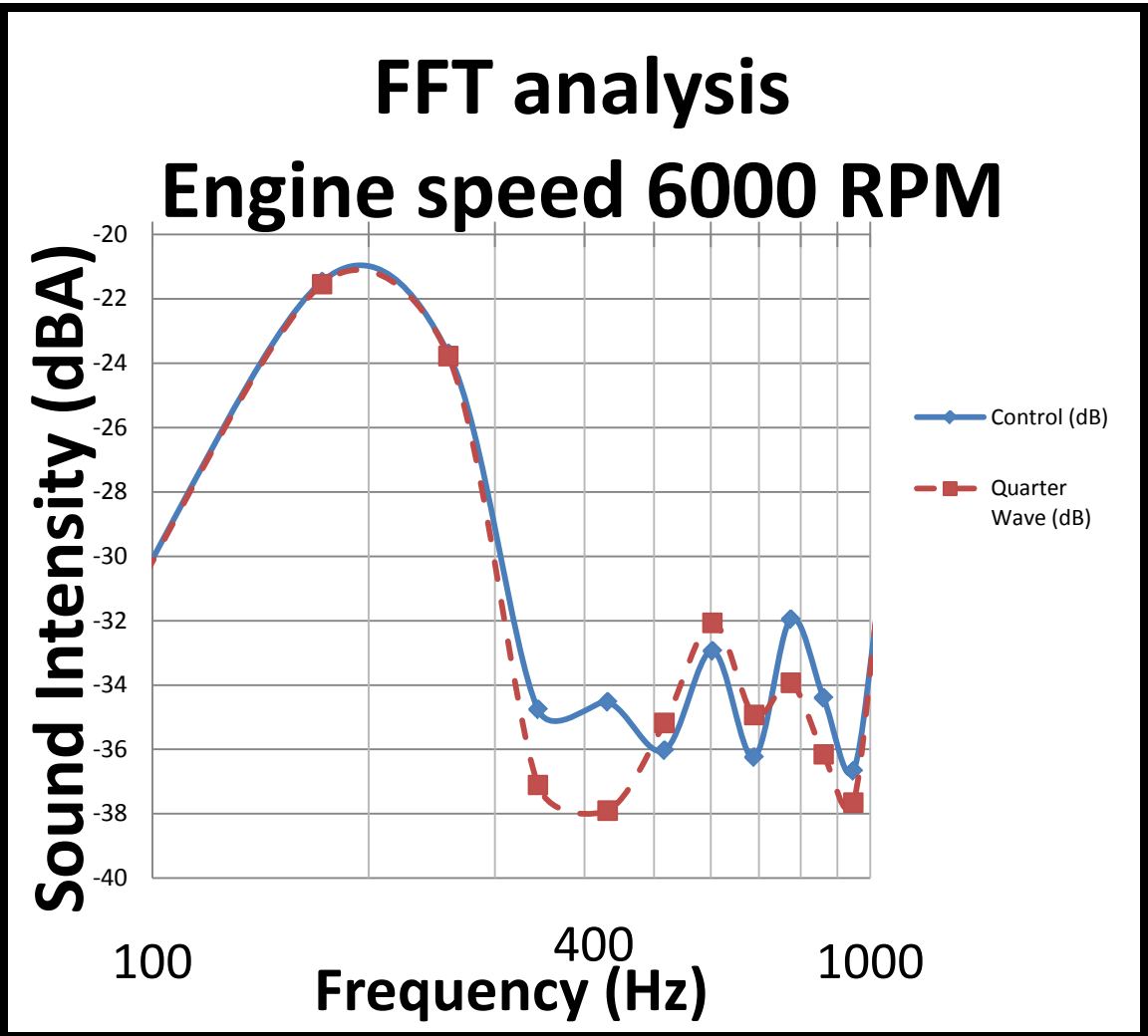


Noise Reduction Strategies

- Exhaust
  - Quarter wave resonator
  - Exhaust valves lowered
- Intake
  - Lined air boxes with sound material
- Mechanical
  - Lower engine speeds
  - Sound material in panels

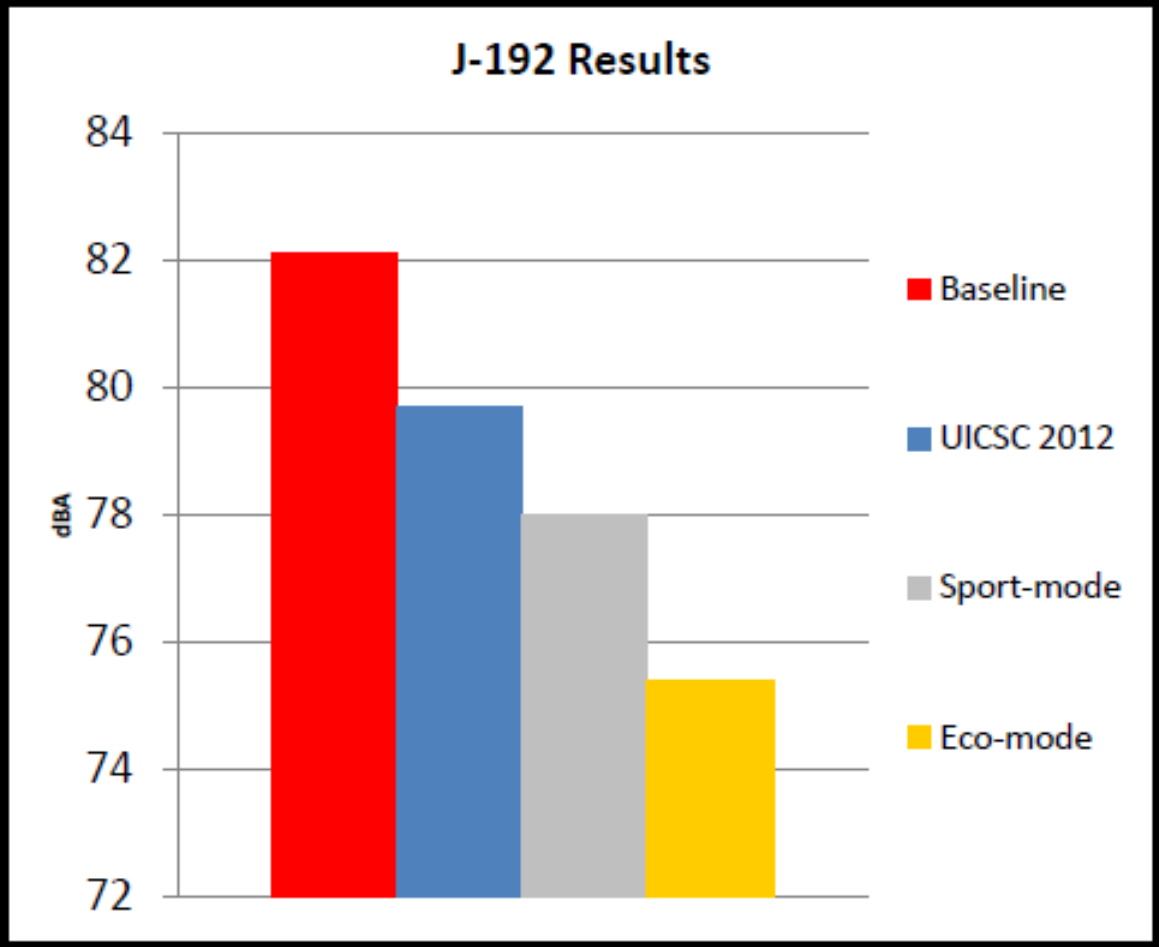
Exhaust Quarter Wave Resonator

- Achieves 4 dB reduction at designed frequency
- 2 dBA reduction SAE J192 exhaust side measurement



Noise Results

- From 2012 design to 2013 design
  - 1.7 dBA reduction in sport-mode
  - 4.3 dBA reduction in eco-mode



MSRP Breakdown

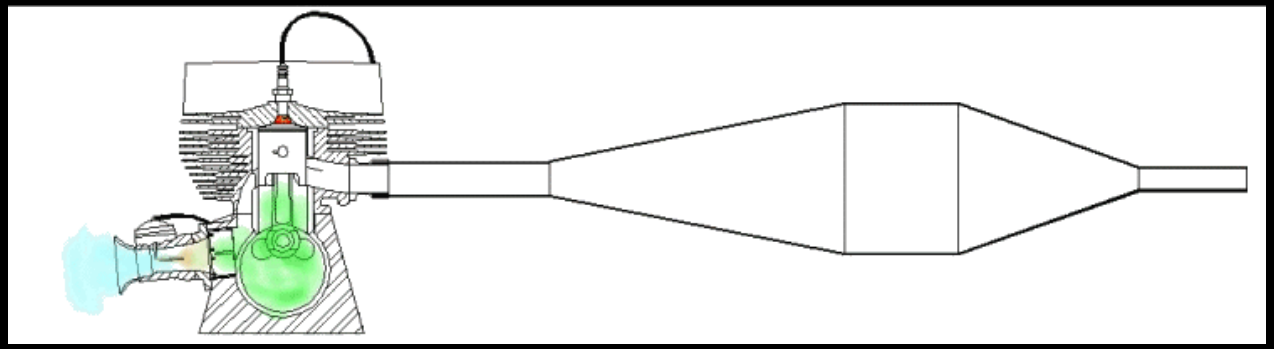
- Base price ~ $10,424
- UICSC price ~ $11,411
- Major contributors
  - Ice ripper track $314
  - Skis $248
  - Sound deadening material $182

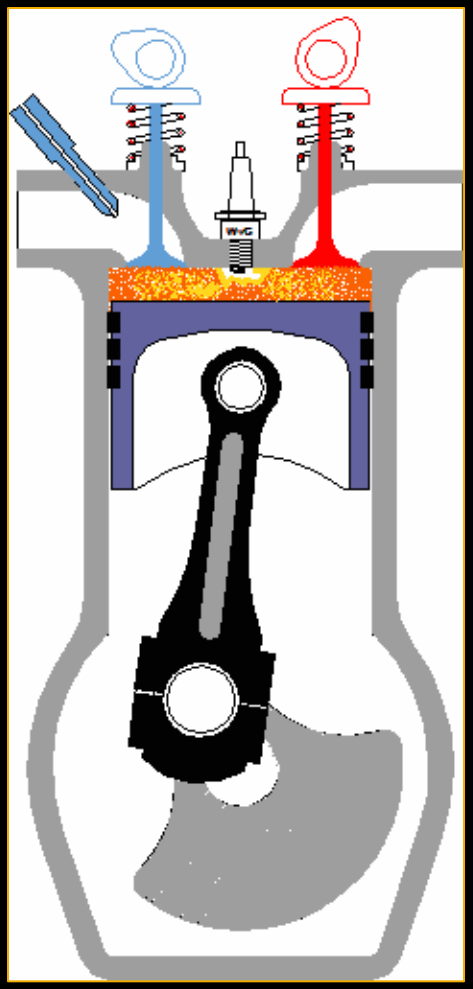
Conclusion

- Clean
  - Passes NPS emissions standards
- Quiet
  - Near NPS sound standard
- Efficient
  - 20 MPG (GGE)
- Affordable
  - $11,411
- Two-stroke riding experience

Questions?

2-Stroke Versus 4-Stroke





Eco-mode Emissions

Colored boxes require input of measured data. Fuel H/C should be found from a fuel sample, 1.92 is from the 2005 CSC compeition and is a good approximation for E-10 Gasoline.

5-Mode speed and Torque		
Max rpm	5500	rpm
Max Torque	68.3	ft-lbs

	Target rpm	Target Torque (ft-lbs)	Measured rpm	Measured Torque (ft-lbs)
Mode 1	5500	68.30	**5500**	**67**
Mode 2	4675	34.83	**4650**	**34.1**
Mode 3	4125	22.54	**5250**	**27.5**
Mode 4	3575	12.98	**3500**	**16**
Mode 5	idle	0	**1200**	**0.1**

Measured Data — HC_{wet} calibrated to Methane

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5			
G_{fuel}	**20.91**	**6.85**	**4.11**	**2.74**	**0.68**	kg/hr		
HC_{wet}	**516**	**996**	**1260**	**1242**	**810**	ppm Methane	Hexane	* multiply by 6 wh
CO_{dry}	**0**	**0.07**	**0.02**	**0.01**	**0**	%		
CO_{2dry}	**15.4**	**10.4**	**12.6**	**11.8**	**5.3**	%		
NO_{xdry}	**797**	**176**	**27**	**8.3**	**0**	ppm NO_2+NO		
$O2_{dry}$	**1.05**	**7.1**	**4.5**	**5.6**	**14**	%		

5-Mode Specific Emissions

	HC	NOx	CO	HC+NOx	
Average Specific Mass	2.61	2.03	1.10	4.64	gm/kW-hr
EPA 2012 Score	**206.63**	**Must be greater than 100 for EPA and greater than 170 for NPS**			

Sport-mode Emissions

Colored boxes require input of measured data. Fuel H/C should be found from a fuel sample, 1.92 is from the 2005 CSC compeition and is a good approximation for E-10 Gasoline.

5-Mode speed and Torque		
Max rpm	7000	rpm
Max Torque	83	ft-lbs

	Target rpm	Target Torque (ft-lbs)	Measured rpm	Measured Torque (ft-lbs)
Mode 1	7000	83.00	**7000**	**84**
Mode 2	5950	42.33	**5950**	**43**
Mode 3	5250	27.39	**5250**	**29**
Mode 4	4550	15.77	**4550**	**16**
Mode 5	idle	0	**1200**	**0.1**

Measured Data	HC_{wet} calibrated to Methane							
	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5			
G_{fuel}	**37.6**	**12.14**	**6.198**	**3.289**	**0.759**	kg/hr		
HC_{wet}	**2616**	**1476**	**1662**	**2091**	**1269**	ppm Methane	Hexane	* multiply by 6 wh
CO_{dry}	**6.46**	**0.026**	**0.01**	**0.01**	**0**	%		
CO_{2dry}	**11.63**	**13.28**	**12.22**	**10.84**	**5.1**	%		
NO_{xdry}	**77.22**	**372**	**89.5**	**15.2**	**0.36**	ppm NO_2+NO		
$O2_{dry}$	**0.25**	**3.6**	**5.1**	**6.74**	**14.19**	%		

5-Mode Specific Emissions					
	HC	**NOx**	**CO**	**HC+NOx**	
Average Specific Mass	5.80	1.07	84.65	6.87	gm/kW-hr
EPA 2012 Score	**184.26**	**Must be greater than 100 for EPA and greater than 170 for NPS**			

5 Mode Emissions Test

- $E = (1 - \frac{(HC + NO_x - 15)}{150}) * 100 + (1 - \frac{CO}{400}) * 100$
- Constituents are in weighted g/kw-hr

Mode	1	2	3	4	5
Speed	100%	85%	75%	65%	Idle
Load	100%	51%	33%	19%	0
Weight	12%	27%	25%	31%	5%

J-192 sound

Quarter Wave Resonator

- $f = \left(\frac{RPM}{60}\right) * Pistons$

$$f = \frac{c}{4L} \ (Hz)$$

$$c = \frac{\sqrt{\gamma RT}}{M} \ \left(\frac{m}{s}\right)$$