DOE Program on Parasitic Energy Loss Reduction for Class 7/8 Trucks

Heavy Vehicle Systems Optimization

April 19, 2006
Program Objectives
Reduce Parasitic Losses for Fuel Savings
Reduce Radiator Heat Load
Provide Anti-Idling Solutions

Technical Approach
Electrify truck accessory functions and hotel type loads to improve efficiency, power management, packaging flexibility, reliability, and customer value

Fuel Savings Potential
Total fuel saving is 1550 gal/yr – 1800 gal/yr per truck
U.S. Class-8 overnight-idling population of 458,000 trucks
Fuel savings of 710 - 824 million gallons of diesel
U.S. Economy impact of $2 billion per year @ $2.75/gal)

Program Plan
Modular HVAC
Variable speed compressor more efficient and serviceable
3X more reliable compressor no belts, no valves, no hoses leak-proof refrigerant lines instant electric heat

Shore Power Converter
Supplies DC Bus Voltage from 120/240 Vac 50/60 Hz Input

Down Converter
Supplies 12 V Battery from DC Bus

Compressed Air Module
Supplies compressed air for brakes and ride control
Higher reliability variable speed faster warm-up less white smoke lower cold weather emissions

Electric Water Pump
Higher efficiency

Electric Oil Pump
Variable speed

Integrated Starter Generator
Beltless engine product differentiation improve systems design flexibility more efficient & reliable accessories

Auxiliary Power Unit
Supplies DC Bus Voltage when engine is not running - fulfills hotel loads without idling main engine overnight
Auxiliary Power Unit (APU)

- Diesel engine: 2-cylinder, 0.5 lt, 14 hp at 3,600 rpm
- Generator: 3-phase/4-pole brushless synchronous machine
- AVR control on Field Excitation powered by rotating diodes
- AC output rectified by full-bridge to produce 340 Vdc
- Electrical Efficiency 70%
- Variable Speed
- 4 kW @ 1,800 rpm
- 8 kW @ 3,600 rpm
- Electronic engine governor adjusts speed to match electrical load
Electrically Powered HVAC - CAT Development

FEATURES and BENEFITS

- Modular design
- Variable speed scroll compressor
- More efficient and serviceable
- Leak proof refrigerant lines
- 3X more reliable – 10X more durable
- Supplemental electric heat
Electrically Driven Coolant Pump - with EMP

**FEATURES and BENEFITS**

- Uses more efficient pump technology
- Variable speed drive
- Faster warm-up
- More efficient cooling system
- Potential for simplified engine front-end

Emerson Electronics EMP Pump
Dual Engine Oil Pump System - with EMP

FEATURES and BENEFITS

- Variable speed
- Pre and Post Lube Capabilities
- Maintains oil pressure below relief point
- TSD focusing on control strategies
Integrated Starter Generator - CAT/SRDL Development

- Features brushless switched reluctance technology
- Electromagnetic and Power Electronic design by SRDL
- Mechanical design by CAT

- Conforms to SAE #1,2,3 housing standards for mating with multiple engines
- Output of 30 kW at 340 Vdc
- Cranking torque up to 1200 Nm
Electrical System Architecture
SAE Type II Truck Performance Testing

Real-world truck performance data over a range of terrain and conditions

Test Track

Goal

Standard Truck

DOE Truck

Improvement

65 °F

63 °F

81 °F

Flat, smooth

Moderate grade

Steep grade

Blaine Route

Vantage Grade

65 °F

Blaine Route

Vantage Grade

63 °F

81 °F
Fuel Savings Opportunity

Over the Road Case

- decoupling accessories from engine
- operating electric accessories on-demand basis
- matching power consumption to actual need

Idle Avoidance Case

- avoiding the idling of truck’s main engine
- operating 1830 hours per year in stationary position
- powering accessories with auxiliary source, e.g. APU
Fuel Economy – Over the Road Case

Test Track Results ... ~2% Improvement

Vantage Grade Results ... ~1% Improvement

Low HVAC consumption due to 65 F conditions

1 to 2% Reduction in Fuel Consumption
## Fuel Consumption – Truck Idling Case

### Fuel Usage

<table>
<thead>
<tr>
<th></th>
<th>600 rpm</th>
<th>1000 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring &amp; Fall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild Winter</td>
<td>145 %</td>
<td>145 %</td>
</tr>
<tr>
<td>Mild Summer</td>
<td>155 %</td>
<td>235 %</td>
</tr>
<tr>
<td>Cold Winter</td>
<td>235 %</td>
<td>270 %</td>
</tr>
<tr>
<td>Hot Summer</td>
<td>270 %</td>
<td></td>
</tr>
</tbody>
</table>

### Fuel Consumption – Truck Idling Case

- **C15 Idle 600 RPM**
- **C15 Idle 1000 RPM**
- **APU estimated, (varying RPM)**
- **Bare Engine on Dynamometer**

Reference point:
- Engine idling with no load at 60 % fuel rate
- Engine idling at 600 rpm with no load
### Fuel Savings Opportunity – Truck Idling Case

<table>
<thead>
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<th>Fuel Usage</th>
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<tr>
<td><strong>Idling Std Truck</strong></td>
<td></td>
<td>145 % 3.7 kWm</td>
<td>145 % 3.7 kWm</td>
<td>155 % 4.4 kWm</td>
<td>235 % 4.7 kWm</td>
</tr>
<tr>
<td><strong>APU 1.2 kWe</strong></td>
<td>20 %</td>
<td>---</td>
<td>---</td>
<td>---</td>
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</tr>
<tr>
<td><strong>APU 2.0 kWe</strong></td>
<td></td>
<td>30%</td>
<td>30%</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>APU 2.8 kWe</strong></td>
<td></td>
<td></td>
<td></td>
<td>40 %</td>
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#### Seasonal Breakdown
- 6 months Spring/Fall
- 2 months mild Summer
- 2 months mild Winter
- 1 month cold Winter
- 1 month hot Summer

**APU fuel rate with HVAC off**
- 35 Amp 12 V load

**APU fuel rate with HVAC on**
- at 95 F ambient and 45% humidity
# Fuel Consumption – Truck Idling Case

<table>
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<tr>
<th>Idling Scenario</th>
<th>Main Engine Fuel Consumed % baseline</th>
<th>APU Fuel Consumed % baseline</th>
<th>Power Load (hotel load for all conditions)</th>
<th>Main Eng Brake Power</th>
<th>APU Electric Power</th>
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<tr>
<td>6 mo Spring/Fall</td>
<td>145 (600 rpm)</td>
<td>20</td>
<td>HVAC Off</td>
<td>3.7 Kw</td>
<td>1.2 Kw</td>
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<tr>
<td>2 mo Mild Summer</td>
<td>155 (600 rpm)</td>
<td>30</td>
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<td>235 (1000 rpm)</td>
<td>40</td>
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<tr>
<td>1 mo Hot Summer</td>
<td>270 (1000 rpm)</td>
<td>60</td>
<td>A/C On</td>
<td>7.4 Kw</td>
<td>2.8 Kw</td>
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### Idle Reduction Fuel Savings Opportunity

- Assume truck idling for 1830 hr/yr and nominal fuel rate of 0.5 gal/hr (100% rate)
- Conventional Truck consumes 1500 gal/year
- More Electric Truck with APU consumes 250 gal/yr
- APU yields fuel savings opportunity of 1250 gal/yr
- Shore Power fuel savings opportunity is 1500 gal/yr
Fuel Economy Improvements for Case Study with Test Truck consuming 20,000 gal. over-the-road and 1,500 gallons during overnight idling.

Combined Fuel Savings of 1,550 to 1,800 gal/year
Summary and Conclusions

- Several high power electric accessories were demonstrated
  - Starter/Generator and Battery Charger
  - Coolant and Engine Oil Pumps
  - Heating and Air Conditioning System
  - Auxiliary Power Unit
  - Developed architecture & control system
- Over the road fuel economy gains of 1 - 2% est.
- Difficulty accurately measuring over the road fuel savings with 1 truck
- Better methodology would be to measure a group of trucks over a period of time
Summary and Conclusions

- Shore power or APU’s yield savings in fuel consumption
  - Dependent on actual usage
  - Truck idling reductions yields significant fuel savings
  - 5.8 – 7.0 % of total yearly fuel usage

- Total fuel saving is 1550 gal/yr – 1800 gal/yr per truck
- U.S. Class-8 overnight-idling population of 458,000 trucks
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Questions ???