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

Heavy Vehicle Systems Optimization

April 19, 2006

U.S. Department of Energy
Energy Efficiency and Renewable Energy

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Program Objectives

Reduce Parasitic Losses for Fuel Savings
Reduce Radiator Heat Load
Provide Anti-Idling Solutions

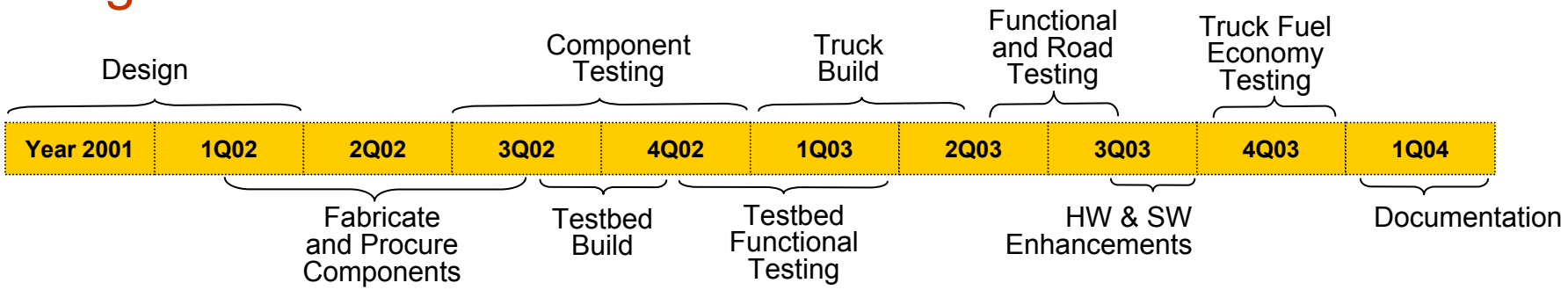
Technical Approach

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

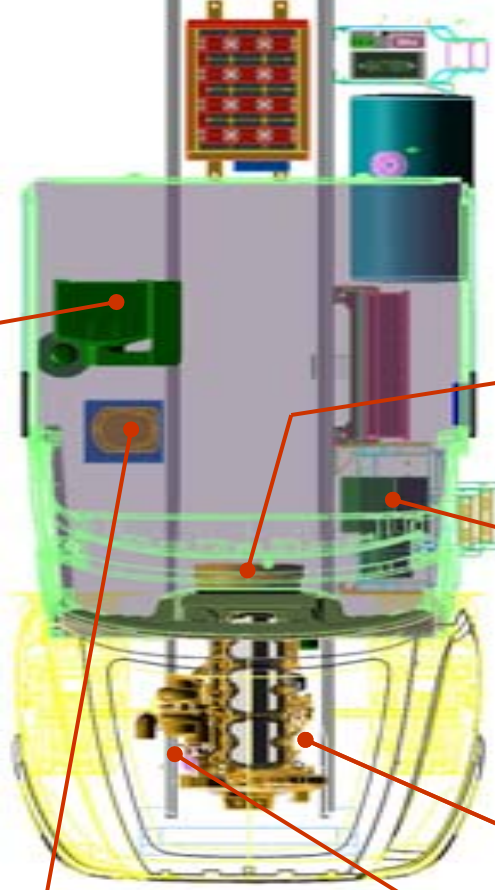
3X more reliable compressor no belts, no valves, no hoses leak-proof refrigerant lines instant electric heat

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

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

Electric Water Pump

Higher reliability variable speed faster warm-up less white smoke lower cold weather emissions

Electric Oil Pump

Variable speed Higher efficiency

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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

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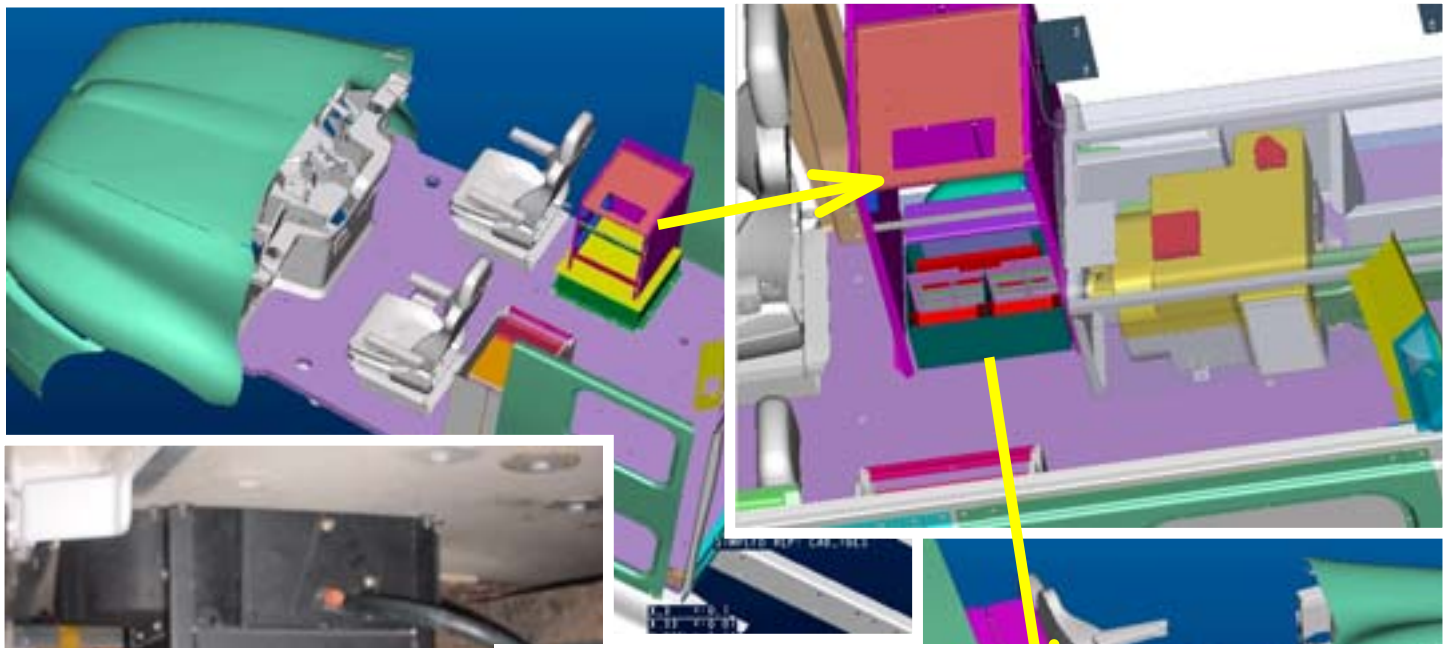
Electrically Powered HVAC - CAT Development



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

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Electrically Driven Coolant Pump - with EMP

Emerson Electronics	EMP Pump
	

FEATURES and BENEFITS

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

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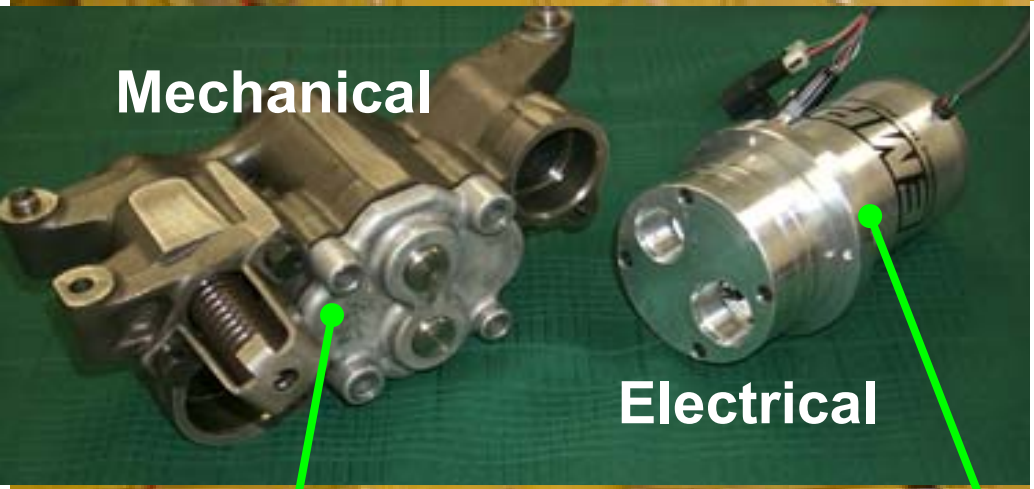
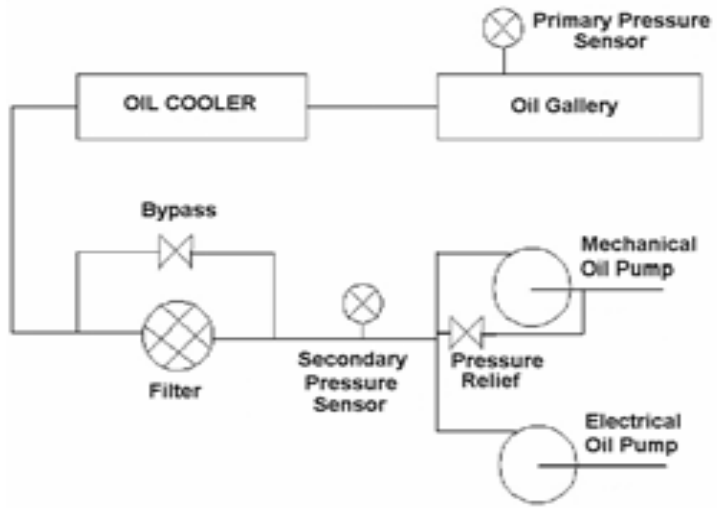
Dual Engine Oil Pump System - with EMP





FEATURES and BENEFITS

- Variable speed
- Pre and Post Lube Capabilities
- Maintains oil pressure below relief point
- TSD focusing on control strategies

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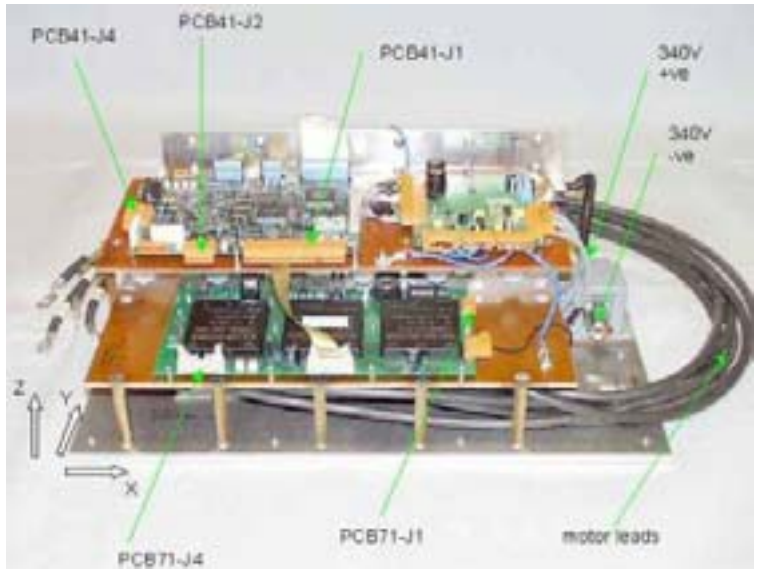
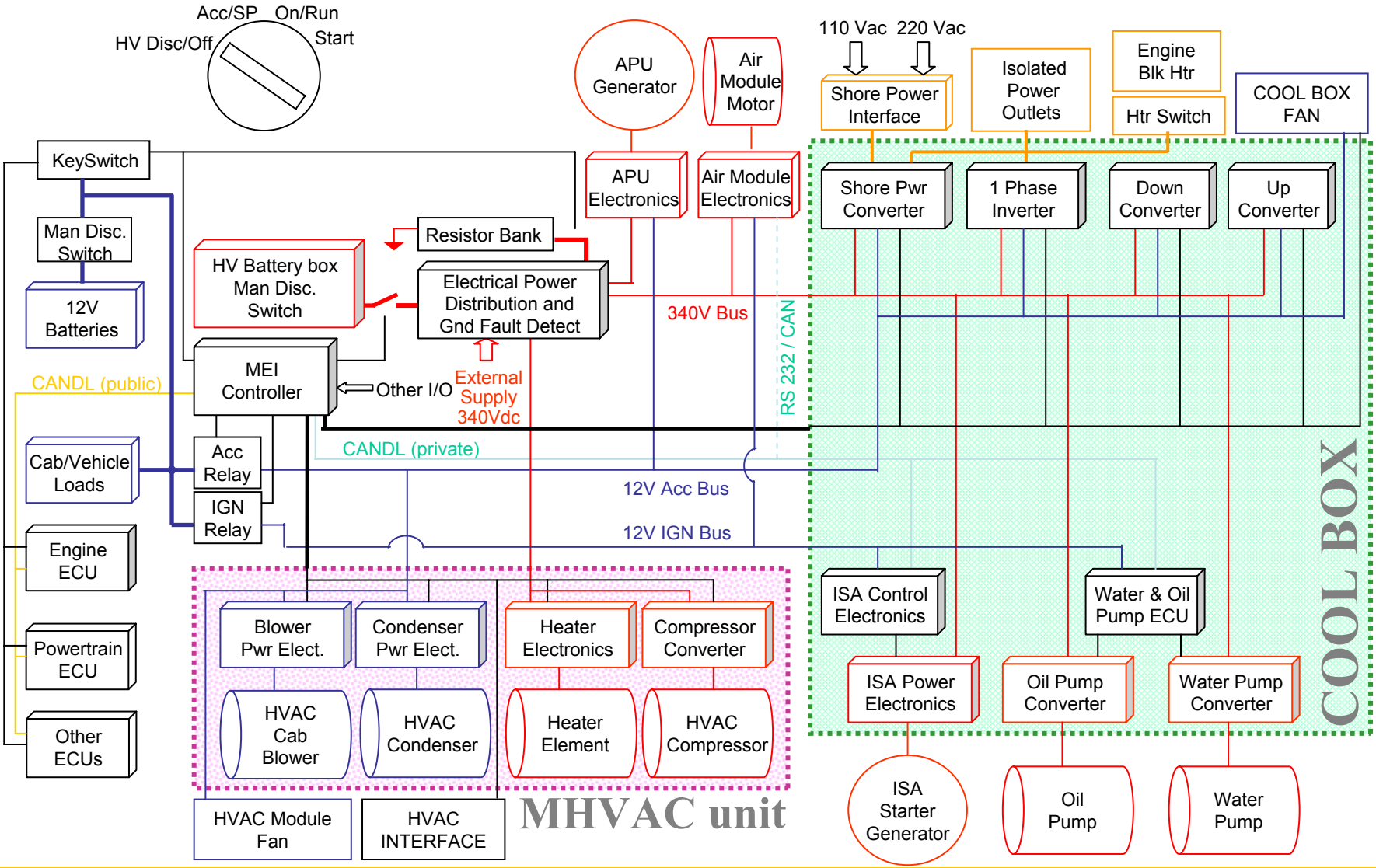
Integrated Starter Generator - CAT/SRDL Development

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



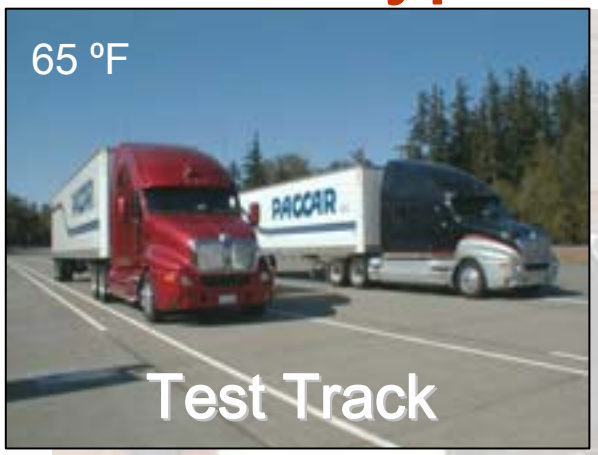
- Conforms to SAE #1,2,3 housing standards for mating with multiple engines
- Output of 30 kW at 340 Vdc
- Cranking torque up to 1200 Nm

Electrical System Architecture



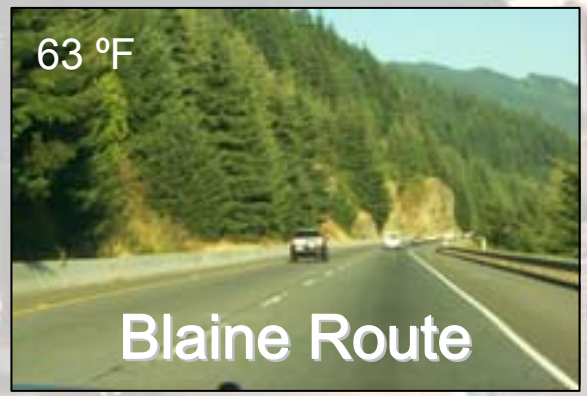
DOE MEI On-Highway Truck

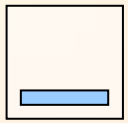
SAE Type II Truck Performance Testing



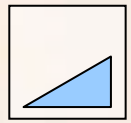
Goal

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

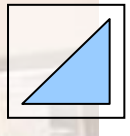




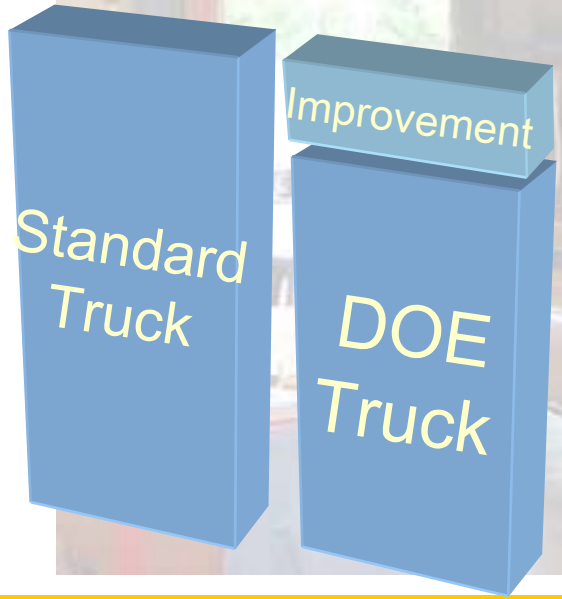
Flat, smooth



Moderate grade



steep grade



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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

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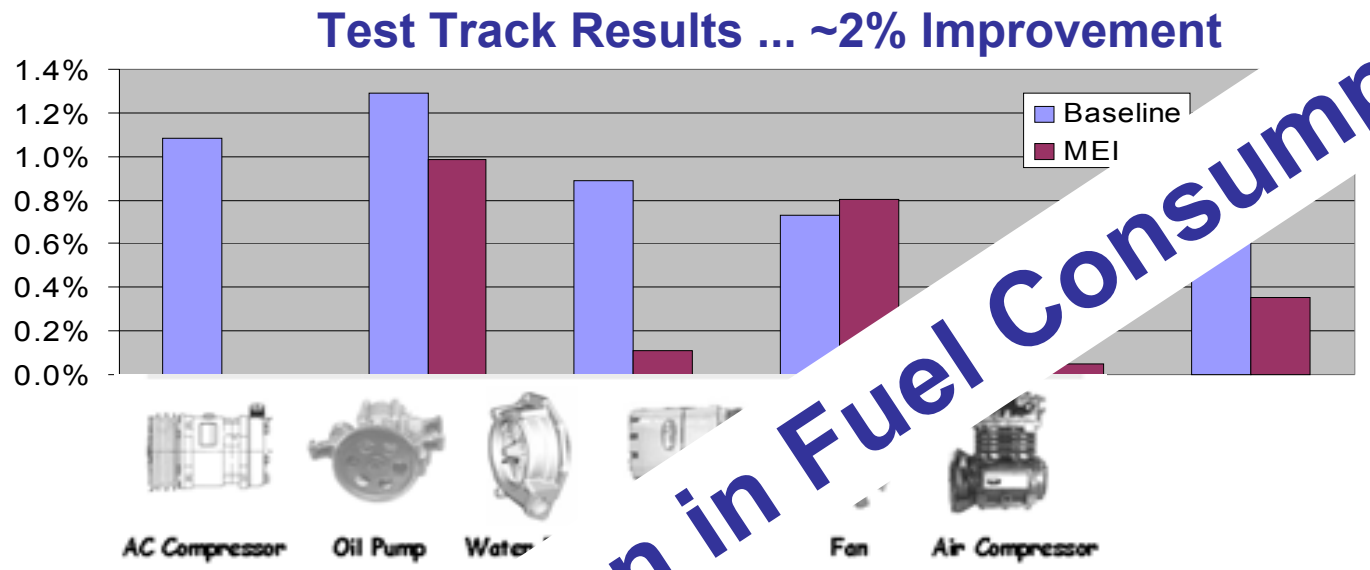
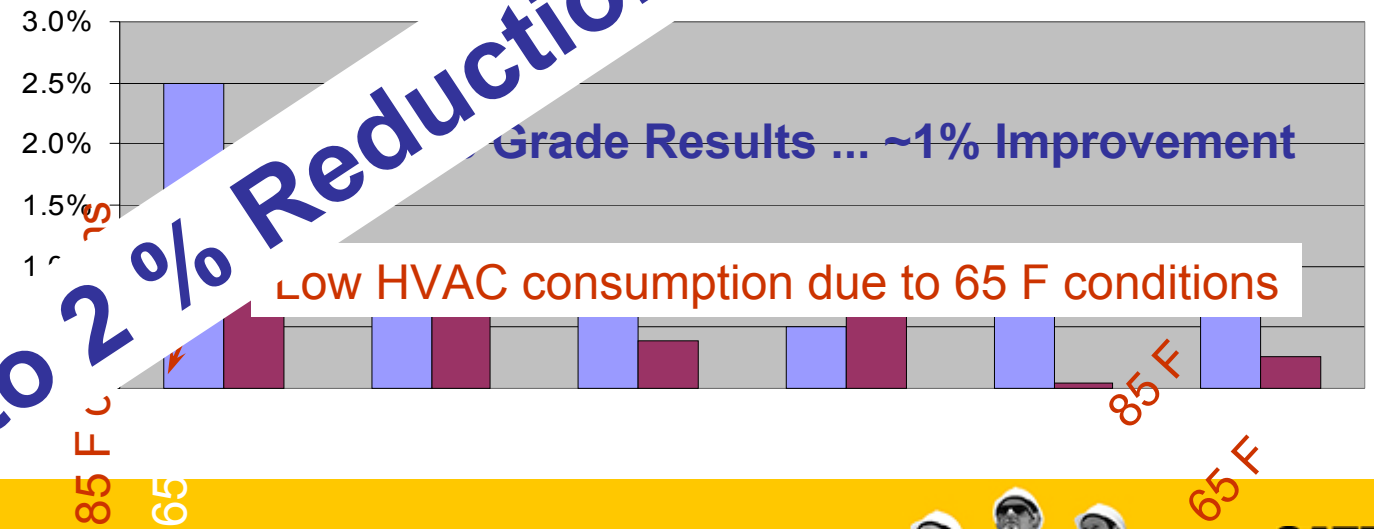
Fuel Economy – Over the Road Case





1 to 2 % Reduction in Fuel Consumption

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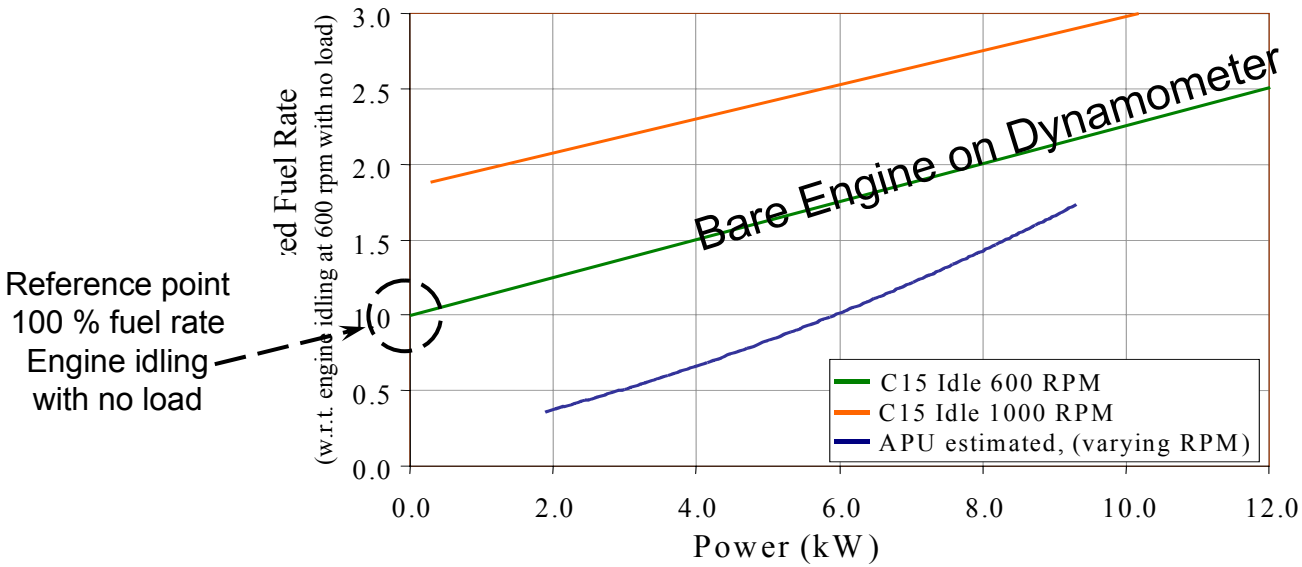
Fuel Consumption – Truck Idling Case

	Fuel Usage				
	600 rpm			1000 rpm	
	Spring & Fall	Mild Winter	Mild Summer	Cold Winter	Hot Summer
Truck Idling	145 % 3.7 kWm	145 % 3.7 kWm	155 % 4.4 kWm	235 % 4.7 kWm	270 % 7.4 kWm



Fuel Savings Opportunity – Truck Idling Case

	Fuel Usage				
	600 rpm			1000 rpm	
	Spring & Fall	Mild Winter	Mild Summer	Cold Winter	Hot Summer
Idling Std Truck	145 % 3.7 kWm	145 % 3.7 kWm	155 % 4.4 kWm	235 % 4.7 kWm	270 % 6 kWm
APU 1.2 kWe	20 %	---	---	---	---
APU 2.0 kWe	---	30%	30%	---	---
APU 2.8 kWe	---	---	---	40 %	40%

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

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Fuel Consumption – Truck Idling Case

Idling Scenario	Main Engine Fuel Consumed % baseline	APU Fuel Consumed % baseline	Power Load (hotel load for all conditions)	Main Eng Brake Power	APU Electric Power
6 mo Spring/Fall	145 (600 rpm)	20	HVAC Off	3.7 Kw	1.2 Kw
2 mo Mild Summer	155 (600 rpm)	30	A/C On	3.7 Kw	2.0 Kw
2 mo Mild Winter	145 (600 rpm)	30	Heater On	4.4 Kw	2.0 Kw
1 mo Cold Winter	235 (1000 rpm)	40	Heater On	4.7 Kw	2.8 Kw
1 mo Hot Summer	270 (1000 rpm)	60	A/C On	7.4 Kw	2.8 Kw

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

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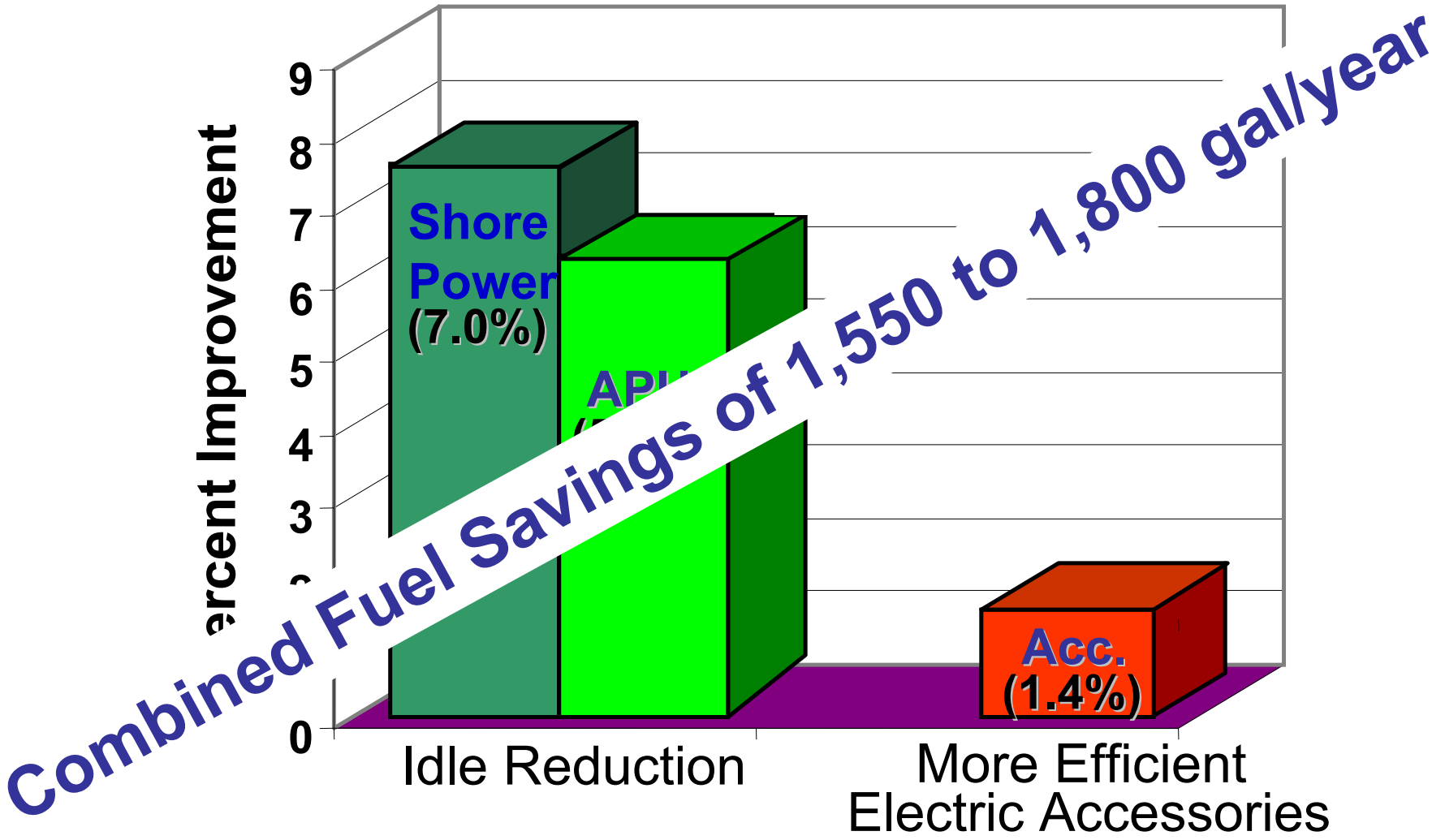
Fuel Economy Improvements for Case Study with Test Truck consuming 20,000 gal. over-the-road and 1,500 gallons during overnight idling



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
- Fuel savings of 710 - 824 million gallons of diesel
- U.S. Economy impact of $2 billion per year @ $2.75/gal)

Questions ???

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Electric Oil Pump
Variable speed
Higher efficiency

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