DEER 2006

Progress in Thermoelectrical Energy Recovery from a Light Truck Exhaust

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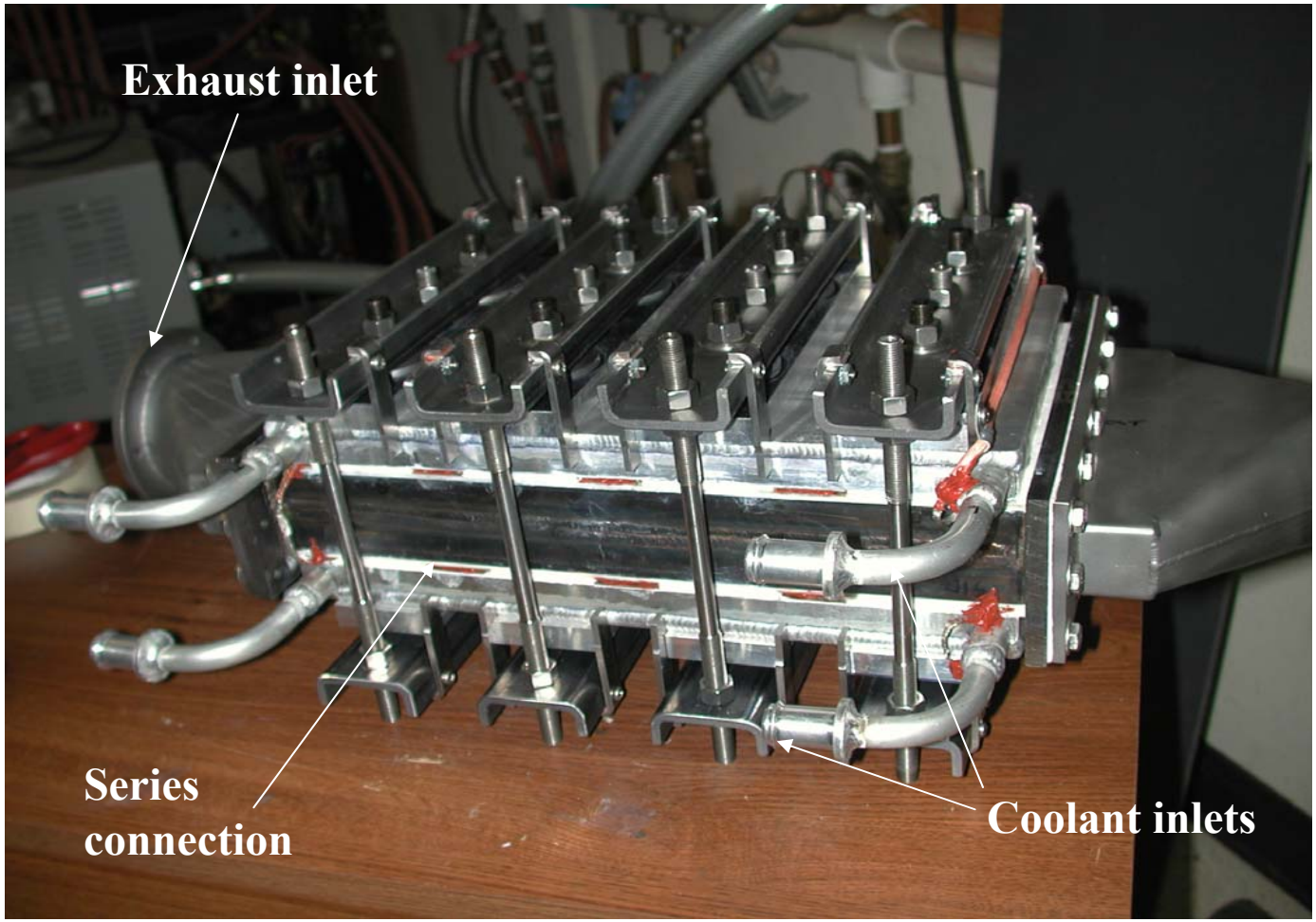
Topics

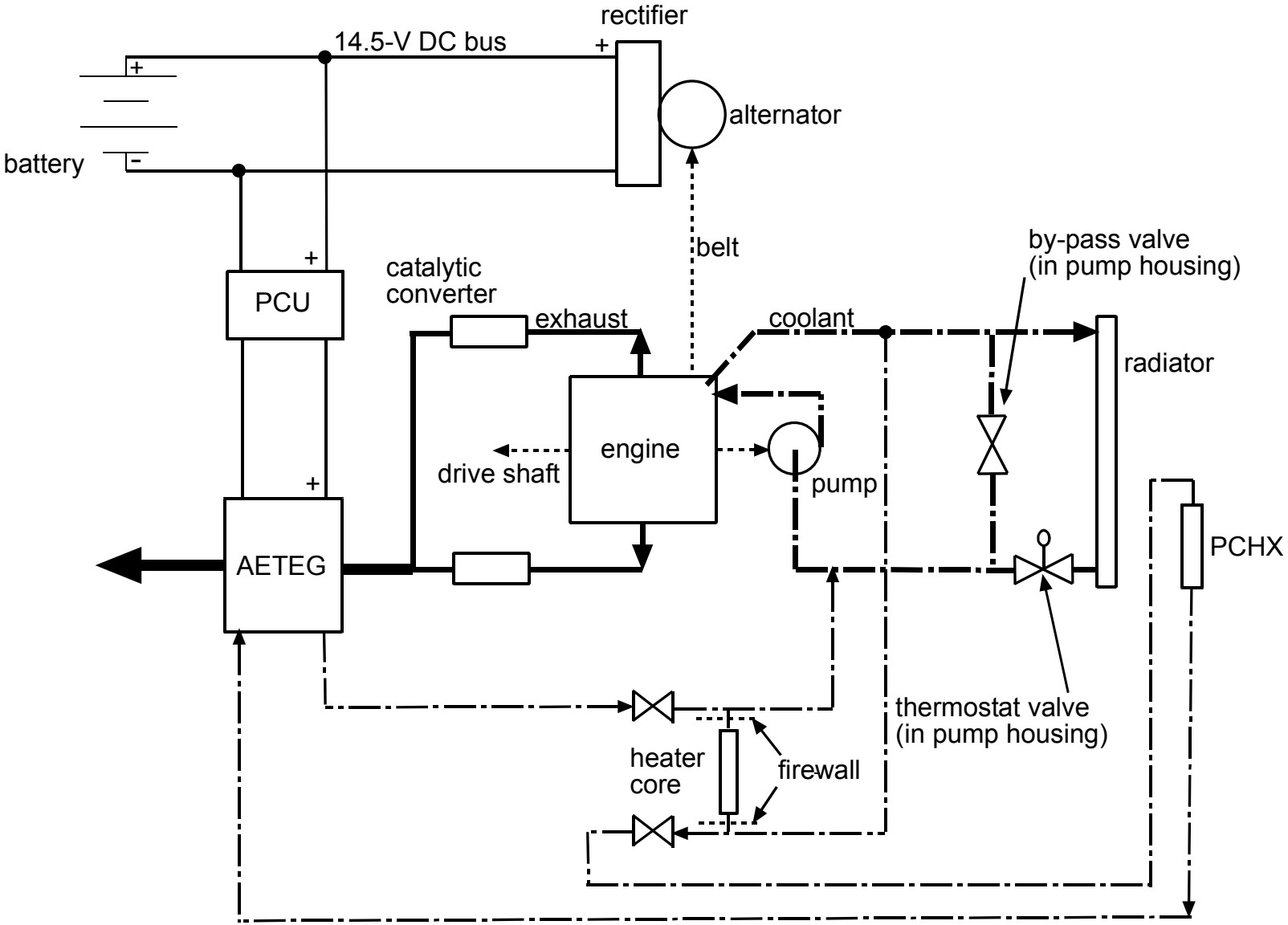
- Participants
- Project Outline
- Hardware
- Highlights of Test Results
- Performance Prediction
- Commercialization Plan

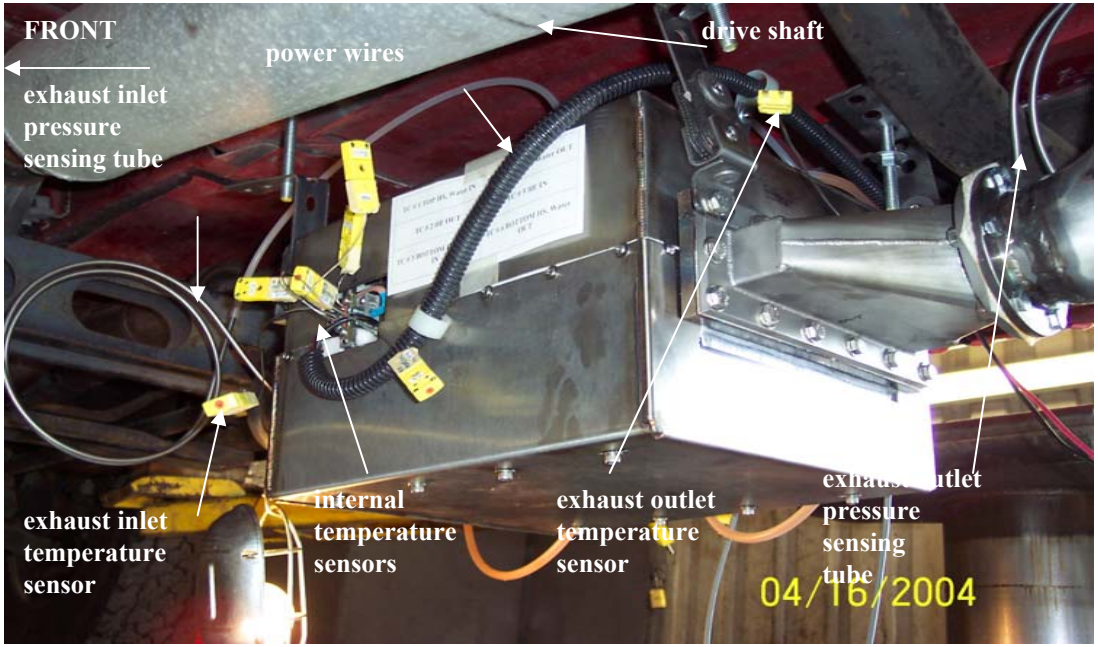
Project Team

- Technical
  - Eric Thacher (PI)
  - Brian Helenbrook (Co-PI)
  - Madhav Karri (RA)
- Commercialization
  - Elmer (Stub) Estey (Consultant)
  - Brian Piotrowski (RA)
- Delphi, Inc.: test services
- GM: test truck
- Hi-Z Technology, Inc.,: design and construction
- NYSERDA: funding

Static Testing

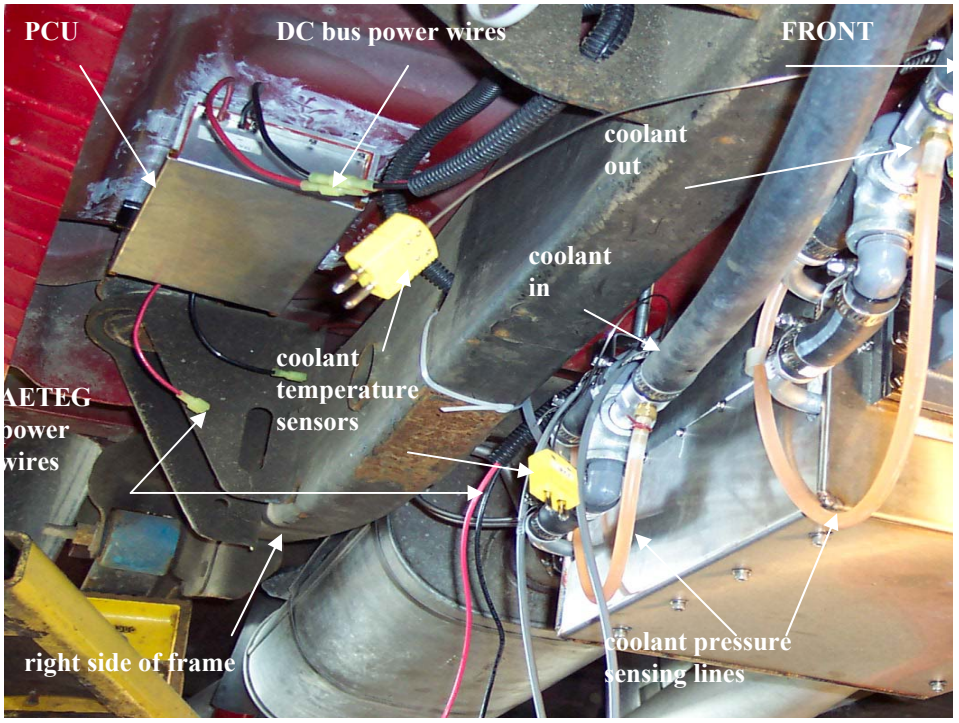

Exhaust inlet
Series connection
Coolant inlets


rectifier
14.5-V DC bus
+
+
alternator
battery
-
belt
by-pass valve
(in pump housing)
+
PCU
catalytic
converter
exhaust
coolant
radiator
engine
drive shaft
pump
+
AETEG
PCHX
thermostat valve
(in pump housing)
heater
core
firewall



Left side view

Right side view



Test Matrix

- Test configuration
  - A: Baseline, No TEG
  - B: with TEG
  - C: with TEG & Exhaust insulation
  - D: with TEG, Exhaust insulation & PCHX
- Tunnel air inlet temperature
  - 40^{o} F
  - 70^{o} F
  - 100^{o} F
- Speeds
  - Idle
  - 30 mph
  - 50 mph
  - 70 mph
- Electrical load
  - Base
  - Base+25 amps
  - Base+50 amps

Major Results from Testing -I

- Power achieved: 255.1 W (design: 330 W)
  - Climbing hill at 70 mph with city water cooling
  - Power increases with speed (show later)
  - Thermal management important: insulating exhaust & lowering coolant temperature produced dramatic increases in AETEG power

Test Results - II

- Power limited by:
  - Available space for AETEG,
  - Exhaust and coolant heat exchangers' UA,
  - Allowable continuous T_h (250°C) readily obtained

Test Results - III

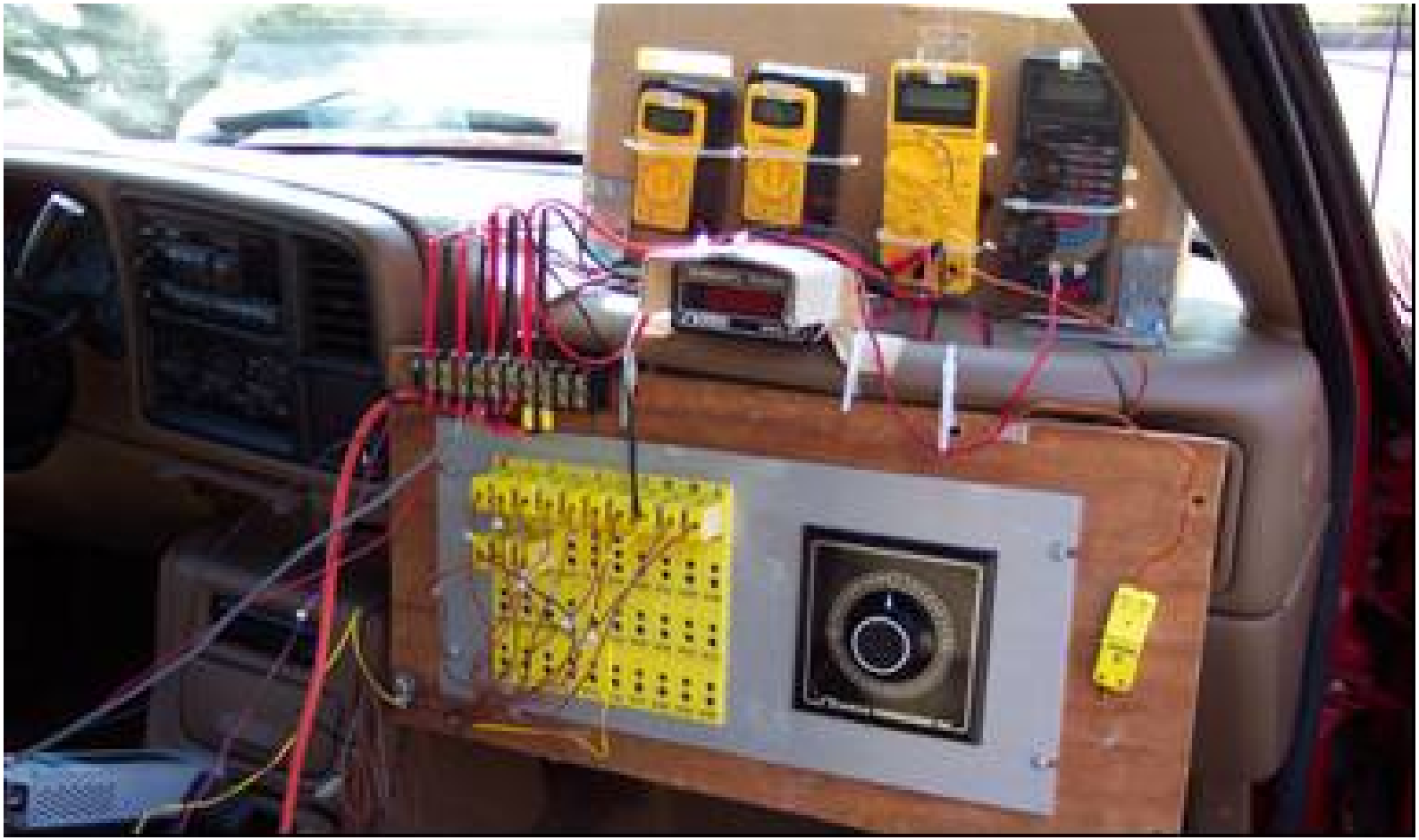
- Maximum Fuel economy increase of order 1%-2%
  - Best: Configuration D at 70 mph, horizontal road
  - Fuel savings increased with vehicle speed (but scatter large)

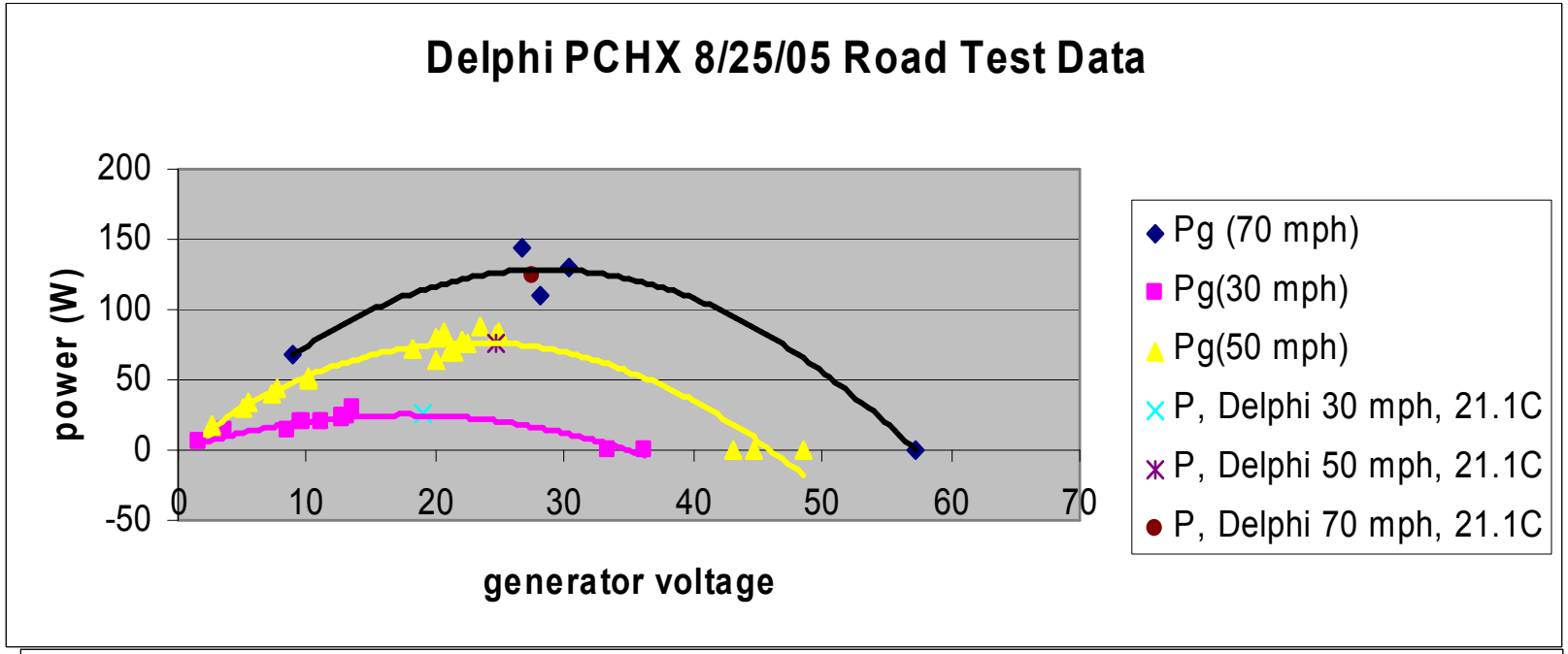
Testing Results - IV

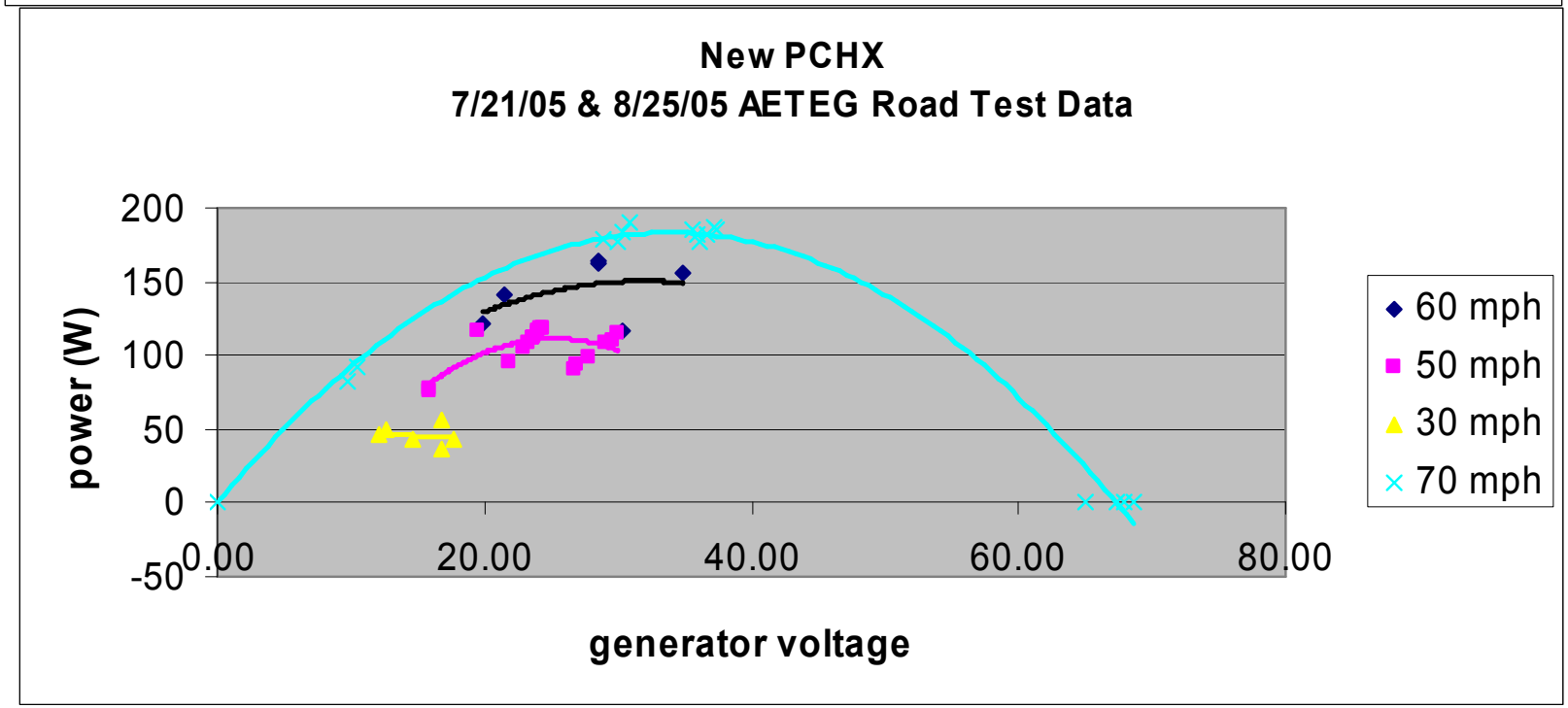
- Effects on truck
  - Parasitic losses: blow down power, pumping power, increased weight
  - In some low speed tests, latter two losses gave a reduction in the fuel economy
  - Extra cooling load on vehicle cooling system not significant
- Submitted to J. Auto. Engineering

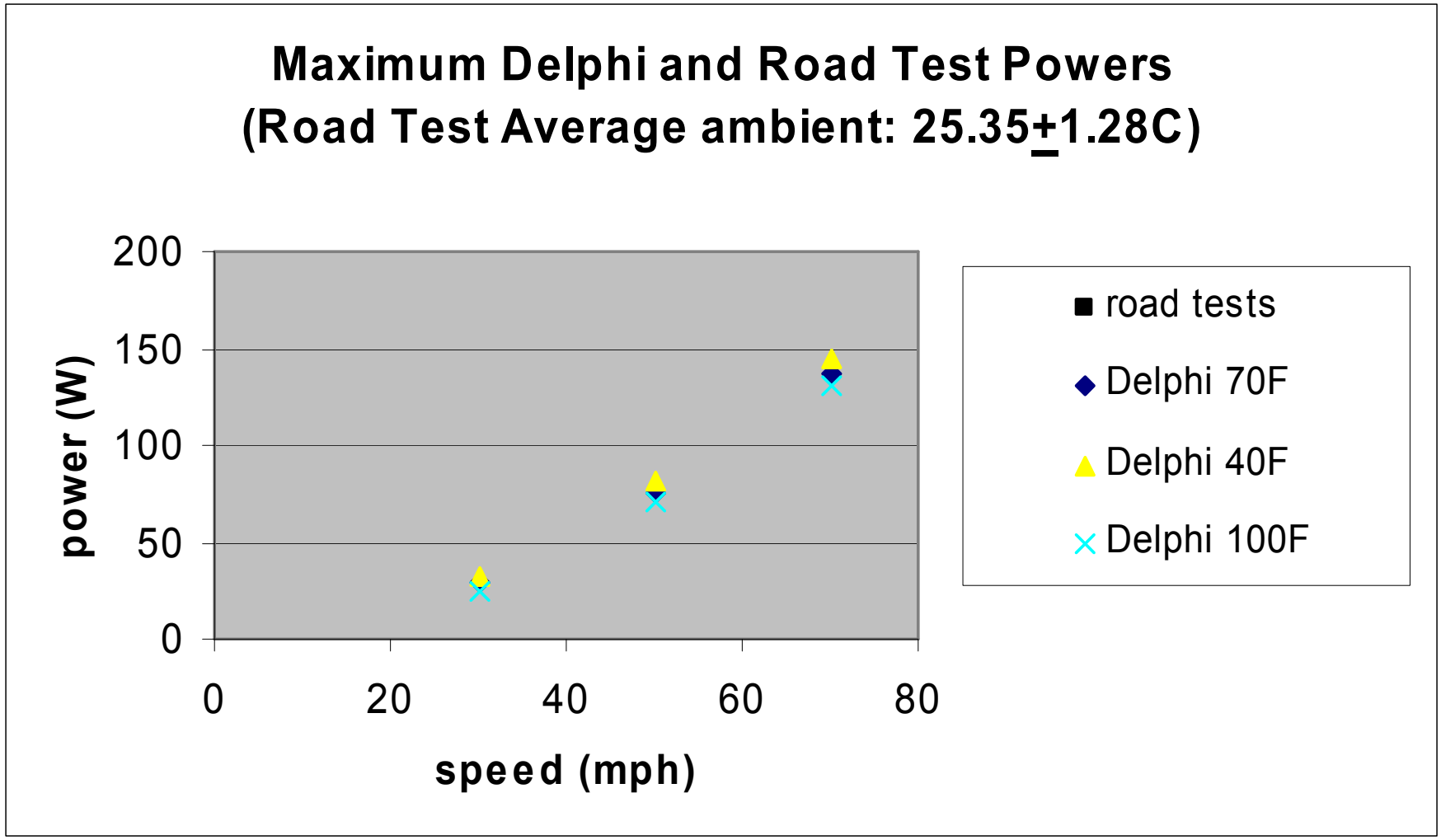
Road Test


08/26/2005




Delphi PCHX 8/25/05 Road Test Data
power (W)
200
150
100
50
0
-50
0
10
20
30
40
50
60
70
generator voltage
Pg (70 mph)
Pg(30 mph)
Pg(50 mph)
P, Delphi 30 mph, 21.1C
P, Delphi 50 mph, 21.1C
P, Delphi 70 mph, 21.1C


New PCHX
7/21/05 & 8/25/05 AETEG Road Test Data
power (W)
200
150
100
50
0
-50
0.00
20.00
40.00
60.00
80.00
generator voltage
60 mph
50 mph
30 mph
70 mph


Maximum Delphi and Road Test Powers
(Road Test Average ambient: 25.35±1.28C)
power (W)
200
150
100
50
0
0
20
40
60
80
speed (mph)
road tests
Delphi 70F
Delphi 40F
Delphi 100F

System Optimization

Things to Improve -I

- **Increase T_H and decrease T_C**
  - Higher $(UA)_h$ and $(UA)_c$
  - Better pre-cooling of engine coolant
  - Air cooling (lowest coolant inlet temp, <u>but</u> must fix low h_C)?
  - Better insulation

Things to Improve - II

- **Reduce or eliminate parasitic losses**
  - Air cooling does (but maybe creates new ones)
  - Reduce coolant pressure loss in coolant heat exchanger (CHX)
  - Reduce exhaust gas heat exchanger (EGHX) pressure drop
  - Reduce AETEG weight (mainly EGHX)
- **Increase PCU efficiency**
- **Use quantum well TE material**
  - Yes, but all the foregoing must also be done

New EGHX and CHX

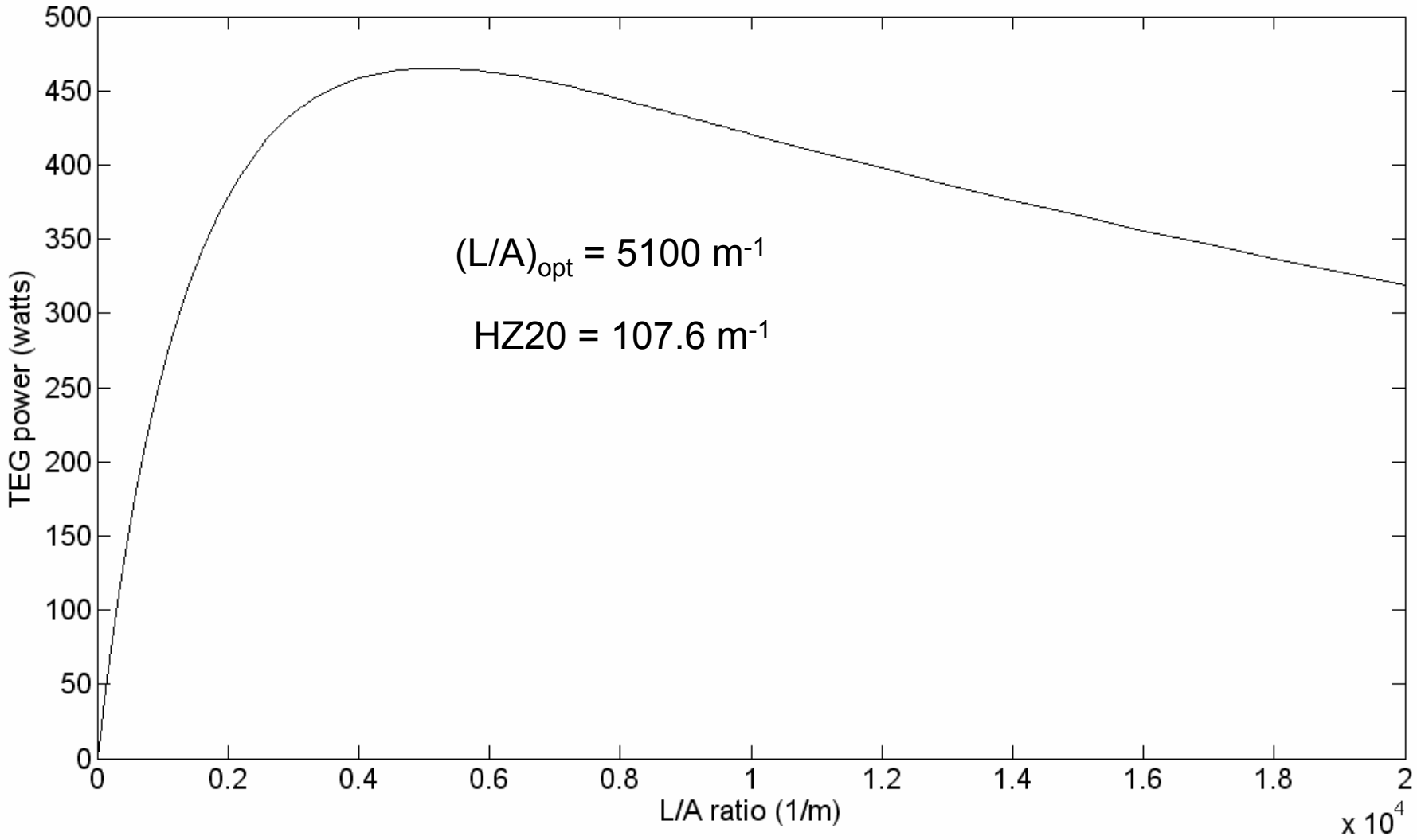
- CHX
  - Increased number of fins
  - Flow-averaged UA increased about 50%
  - Pressure loss decreased
- EGHX
  - Impingement features
  - Flow-averaged UA increased about 55%
  - Pressure loss increased

Performance Studies

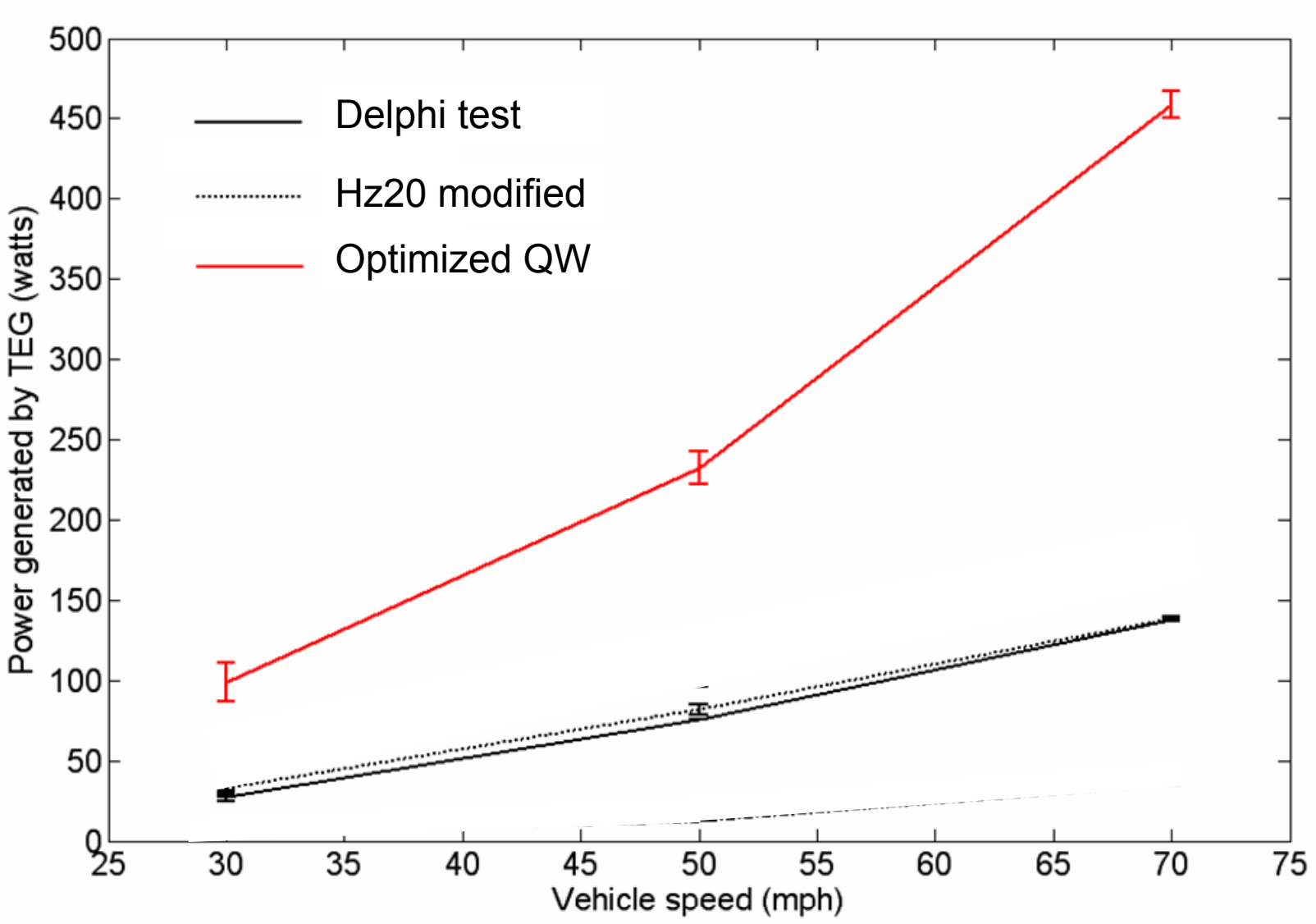
Studies

- Test truck
  - ADVISOR 2002
  - Scaled library SUV engine map
  - Simulated test at 30, 50, and 70 mph
  - QW & Baseline
    - Properties: Hi-Z Technology B_4C/B_9C (p) & Si/SiGe (n)
- Orion bus (a series hybrid)
- Natural gas-fueled fixed generator

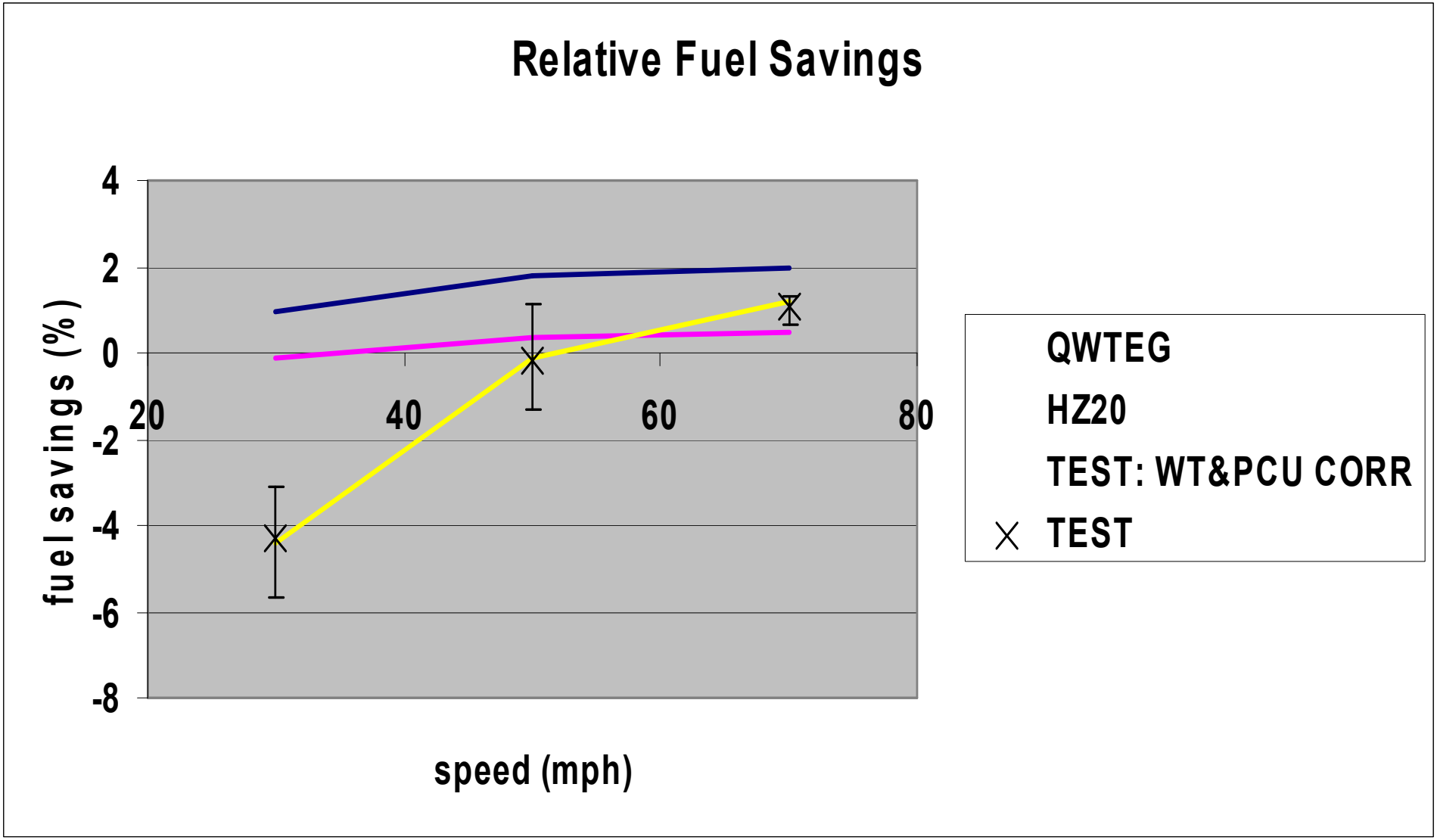
Optimization at 70 mph



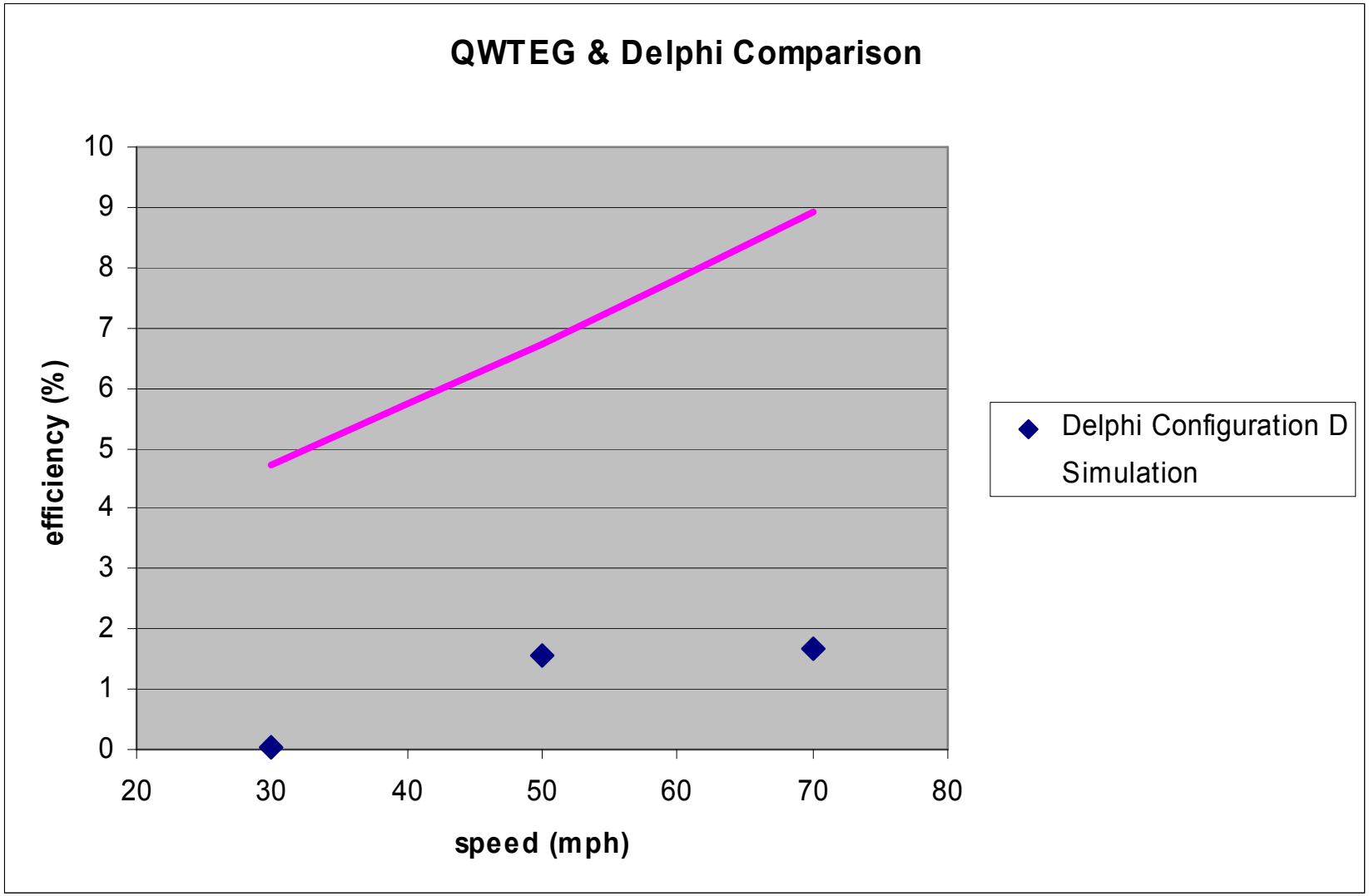
Test Truck Simulation



Fuel Economy Changes



Efficiency Comparison



Commercialization Conclusion

- Current thermoelectric generator technology is better suited to waste heat recovery from fixed engines where weight and size are not so constrained and operating conditions are more stable.

Future Work

- Develop new ideas for using radiator not PCHX
- Finite element analysis of AETEG
- Bench test new EGHX in AETEG
- Bench test new CHX
- Redesign for lower weight
- Run simulations using new EGHX
- Project with Lockheed Martin Co.