Energy Saving and Peak Load Reducing Engine Block Pre-heat Control

Steve Rock & Ray Puffer
Center for Automation Technologies and Systems

Engine Block Pre-heating

- Common on Diesel Engines in Cold Climates
- Typically used December – March
- Reduces Engine Wear
- Improves Gas Mileage
  Reportedly as much as 10%
- Reduces Cold-Start Emissions
  Cold engines produce 50-100x more CO, Hydrocarbons, & NOx in the first minute of operation than pre-warmed ones.
- Eliminates Labor and Cost of Using Ether to Start Cold Engines
- Far Too Often, Plug & Forget Heating is Standard Practice

1

Savings Opportunity

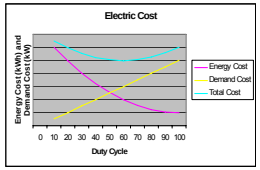
- Three Hours is Maximum Required Heating Time
- Plug & Forget is Exceedingly Wasteful
- New York State School Bus Example:

Heating Assumptions		Common Practice	Conservative Practice	**Potential Savings**
Weekdays	Return 5:00p Depart 6:00a	13 h x 5	3 h x 5	
Weekends	Idle, but heating	24 h x 2	ZERO h	
Heating Time Per Bus		113 h / wk	15 h / wk	**98 h / wk**
Heating Season Buses in NYS $ / kWh		Dec, Jan, Feb, Mar		x 17 wk x 45,000 x $0.105++
			Each Year	**$7.9M**

2

Save More: Reduce Demand

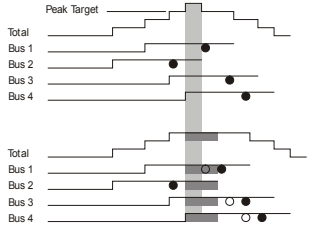
- $ = Energy Used x kWh charge +
  Billing-cycle Maximum Energy Consumed x kW Demand Charge
- In Capital District typically $8.32 / kW each month
- Brown Coach (Empire Zone) $1.32 / kW
- Optimize Cost, Not Total Energy Use
- Trade Slower, Less Efficient Heating for Reduced Demand Expense



3

Trade Energy for Demand

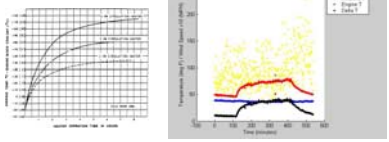
- Reduce Heating using Pulse Width Modulation (PWM) at Critical Times
- Set Peak Demand Target Per Billing Cycle
- Illustration Shows Delayed Start, but can Solve in Reverse



4

We Need Engine Heating Curves

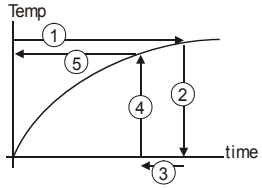
- Vehicle Class Specific
- Instrumented Test Vehicles (RTDs)
- Heater Variation Between Similar Vehicles
- Also Need Outside Air Temperature → Ultimately ΔT Sets Heating Rate



5

Walking Down A Heating Curve

- Begin at Target Departure Temperature
- Find Temperature a Fixed Time Increment Prior
- Can Interpolate Between Known Heating Curves as Heater Power Adjusts to Manage Peak Load



6

Reverse Heating Simulation

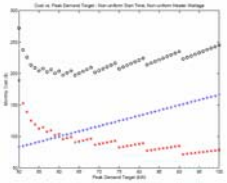
- Sum All Active Heaters Per Heating Interval
- If Load Exceeds Peak Target, Reduce Proportionally
- Update Block Temperatures One Heating Interval Prior & Repeat

```
BUS 1       BUS 2       BUS 3       BUS 4       BUS 5
H  Temp     H  Temp     H  Temp     H  Temp     H  Temp      Duty   Demand
0 -100.0000 0 -100.0000 0 -100.0000 0 -100.0000 0 -100.0000  100.0% 000000W
0 -041.1511 0 -100.0000 0 -100.0000 0 -100.0000 0 -100.0000  100.0% 000000W
1 -017.0646 0 -100.0000 0 -100.0000 0 -100.0000 0 -100.0000  100.0% 004000W
1 +003.1449 0 -100.0000 0 -100.0000 0 -100.0000 0 -100.0000  100.0% 004000W
1 +020.1014 0 -020.4606 0 -100.0000 0 -100.0000 0 -100.0000  100.0% 004000W
1 +030.1925 1 -004.5251 0 -033.1181 0 -100.0000 0 -100.0000   79.8% 006304W
1 +034.1587 1 +005.8106 1 -017.2843 0 -100.0000 0 -100.0000   53.0% 006304W
1 +037.3814 1 +014.1885 1 -004.4186 0 -100.0000 0 -100.0000   53.0% 006304W
1 +040.0000 1 +020.9796 1 +006.0355 0 -100.0000 0 -100.0000   53.0% 006304W
0 -100.0000 1 +030.5236 1 +018.3046 0 -025.0386 0 -100.0000   79.8% 006304W
0 -100.0000 1 +034.3585 1 +024.6249 1 -010.8517 0 -100.0000   53.9% 006304W
0 -100.0000 1 +037.4721 1 +029.7690 1 +000.6383 0 -100.0000   53.9% 006304W
0 -100.0000 1 +040.0000 1 +033.9557 1 +009.9441 0 -022.0773   53.9% 006304W
0 -100.0000 0 -100.0000 1 +037.2892 1 +017.4265 1 -008.2778   53.4% 006304W
0 -100.0000 0 -100.0000 1 +040.0000 1 +023.4818 1 +002.9442   53.4% 006304W
0 -100.0000 0 -100.0000 0 -100.0000 1 +032.4295 1 +015.9083   80.8% 006304W
0 -100.0000 0 -100.0000 0 -100.0000 1 +040.0000 1 +026.8609   80.8% 006304W
0 -100.0000 0 -100.0000 0 -100.0000 0 -100.0000 1 +040.0000  100.0% 004000W
0 -100.0000 0 -100.0000 0 -100.0000 0 -100.0000 0 -100.0000  100.0% 000000W
```

7

Finding The Peak Target

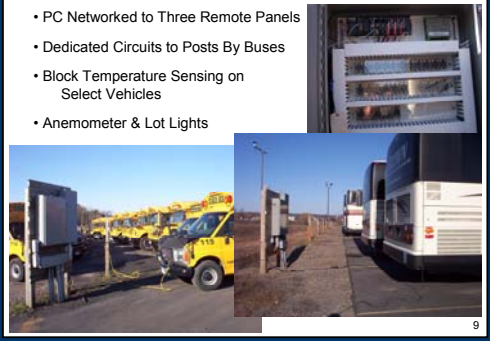
- Worst case climate assumptions for billing cycle (predict the weather)
- Worst case schedule (forecast the future)
- Iterate through progressively lower peak targets and calculate total cost for a given schedule and coldest condition scenario



8

Test-bed System @ Brown Coach, Amsterdam, NY

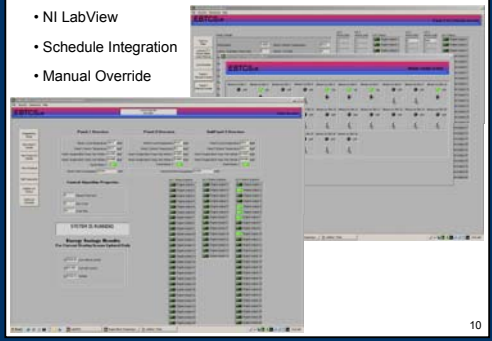
- PC Networked to Three Remote Panels
- Dedicated Circuits to Posts By Buses
- Block Temperature Sensing on Select Vehicles
- Anemometer & Lot Lights



9

User Interface

- NI LabView
- Schedule Integration
- Manual Override



10

Results & Conclusions

- Considerable Data Collection Challenges (Corrosion, Thermal Cycle, RTD Modules, & the Human Factor) Accompany the Industrial Controls-based Approach
- Variability Between Like Heater Loads
- February & March '06 Savings Analysis in Process: Preliminary ~95% Without Demand Reduction
- Demand Reduction Offers Additional Incremental Benefit But Cost-Benfit of Added Complexity Bears Examination
- A Wireless Module-on-Vehicle Approach Seems Most Sensible for Widespread Application
- Plug & Forget Model Should be Replaced

11

Acknowledgements

- Brown Coach, Amsterdam, NY, Steve Brown
- Progressive Machine & Design (PMD), Victor, NY, Eric DeMarte & Todd Snelson
- NYSERDA, Joe Tario, Project Manager

12