

Exhaust Energy Recovery

2008 DEER Conference



Chris Nelson

Research & Technology

August 3rd, 2008

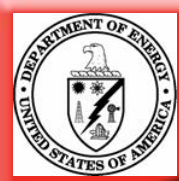


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Agenda



Program Objectives

- WHR Concept and Efficiency Goal Plan
- Program Schedule

First Generation Hardware and Evaluation

- Engine-integrated hardware set
- Performance Testing Results

2nd Generation Hardware Evolution

Summary



Goals and Objectives

Project Goals are:

- **10% Fuel Efficiency Improvement**
- **Reduce the need for increased heat rejection capacity for future heavy duty engines in Class 8 Tractors**

10% increase in fuel efficiency would:

- **Save a linehaul, Class 8 truck over 1800 gallons of fuel per year (120k miles/year at 6mpg)**
- **Reduce exhaust emissions due to less fuel use**

Reduced need for increased heat rejection:

- **Help maintain the aerodynamic advantages of today's trucks**





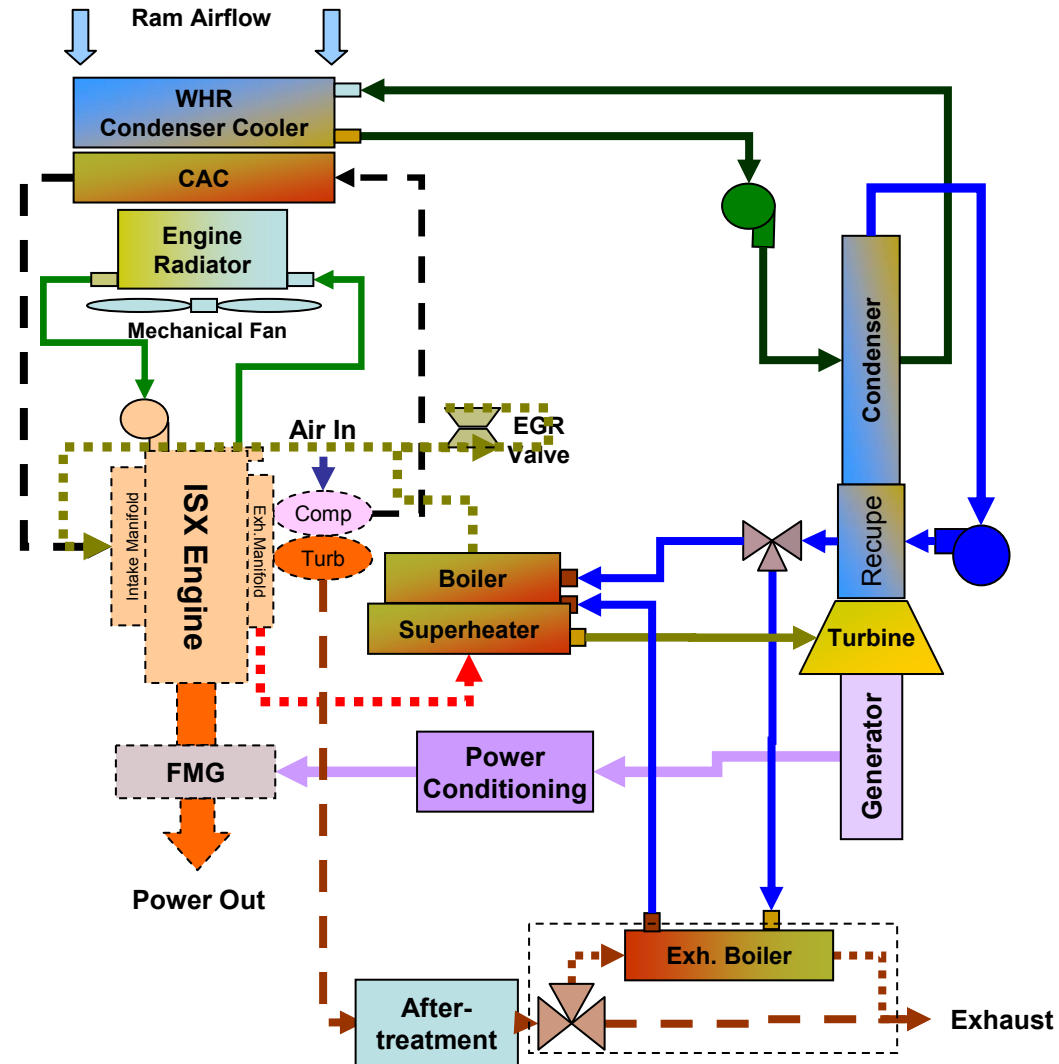
Waste Heat Recovery Concept



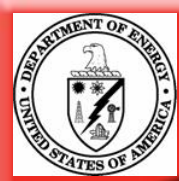
Organic Rankine Cycle

Converts otherwise wasted thermal energy from the EGR and main exhaust gas streams

Works best for high-EGR flow engine recipes for low-NOx combustion



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Recipe for 10% Efficiency Improvement



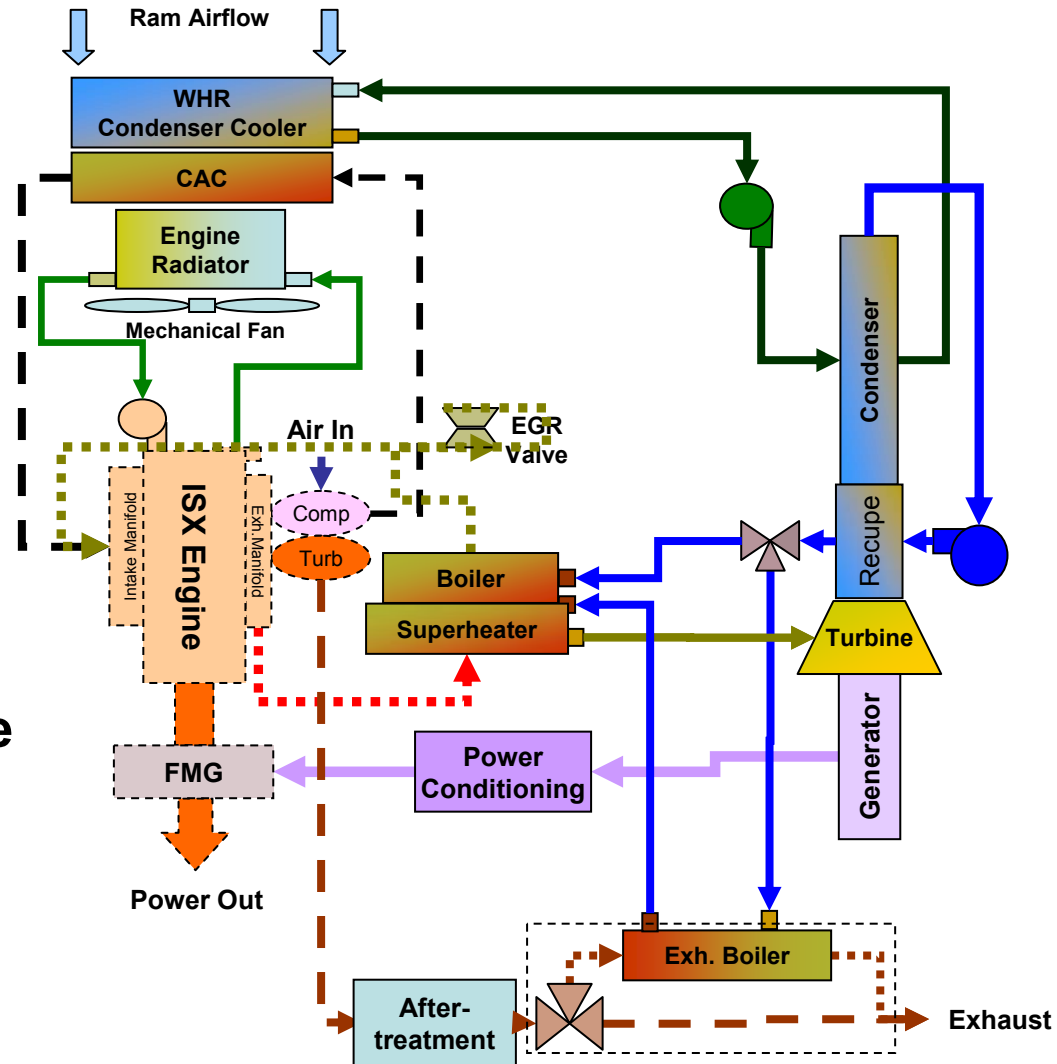
6% from EGR energy

+ 2% from Exhaust

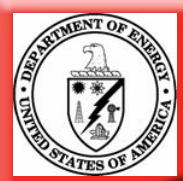
+ 2% from Electric Acc.

10% Improvement Goal

Our test results to date indicate that our model predictions are feasible and realistic



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Current Program Timeline

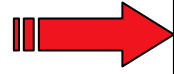
2008

2009

2010

Phase I

Research and analysis
Completed



Phase II

Component Development



1st Gen Hdwr Evaluation



Acquire 2nd Gen Hdwr

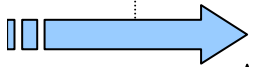
Phase III

Advanced Development
per 12/07 Review

2nd Gen Hardware Testing



WHR-Vehicle Testing



**Program End –
Common with HECC**

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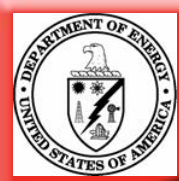
Milestones for 2007/2008



Steady Progress -

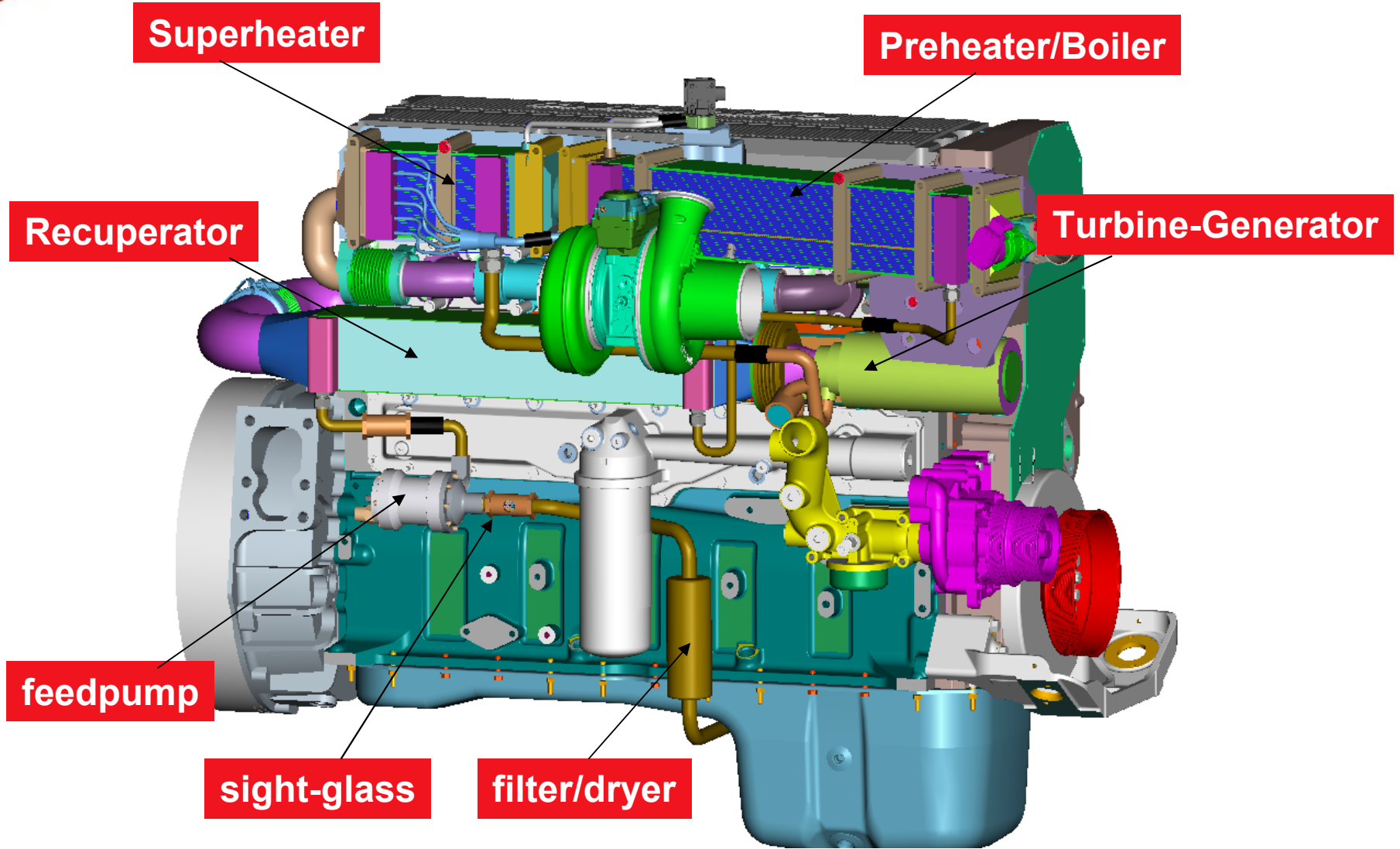
Design 1st Gen Hardware	June '07	
Acquire 1st Gen Hardware	Dec. '07	
1st Gen Engine Build	Feb. '07	
First WHR Engine Start –	April '08	
WHR Steady State Power Generation –	June '08	
Exhaust Recovery and Transients –	August '08	
Second-Generation Hardware Design -	Q3/Q4 '08	

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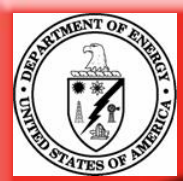


WHR

First Generation Hardware Design

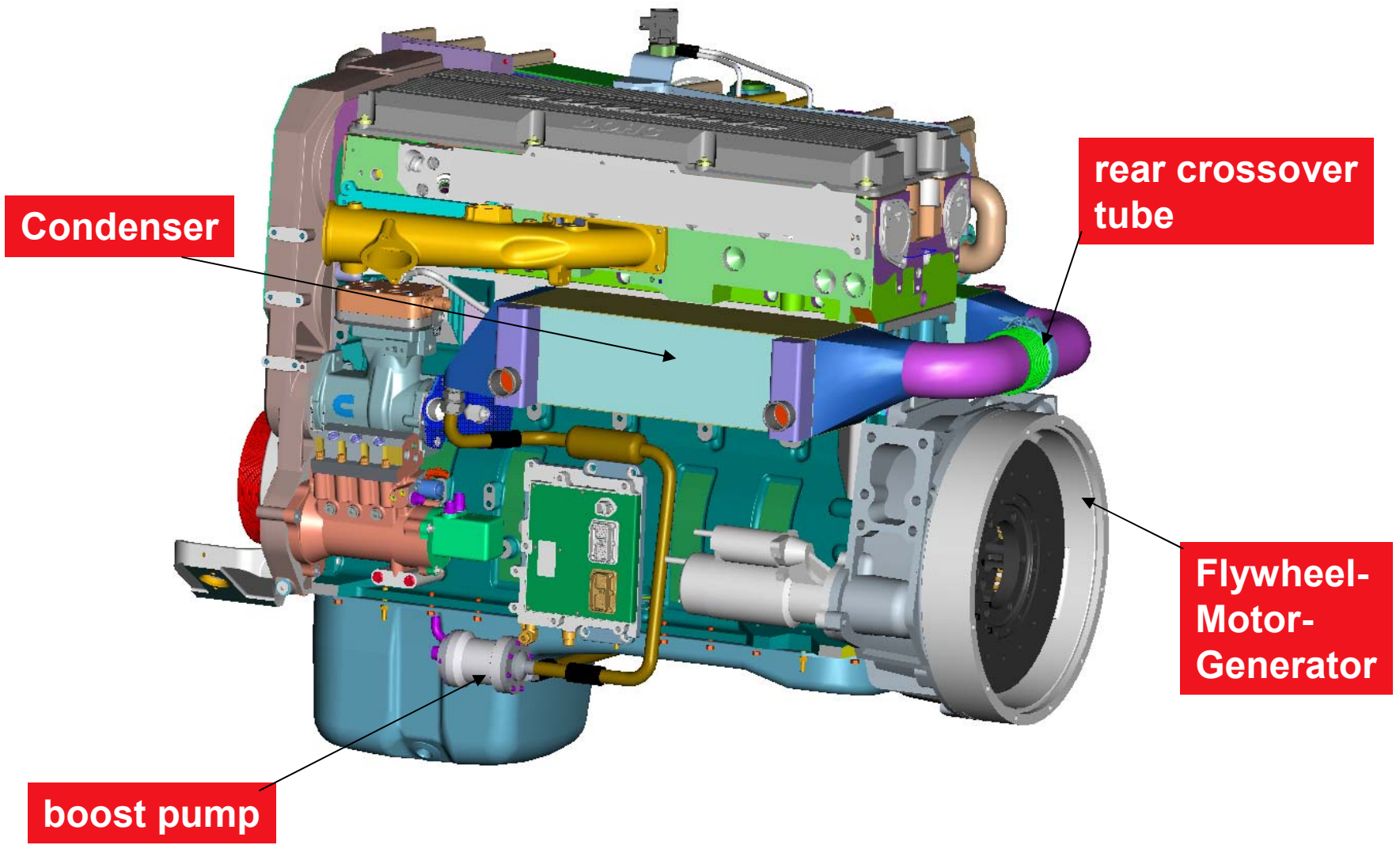


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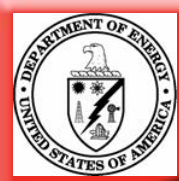


WHR

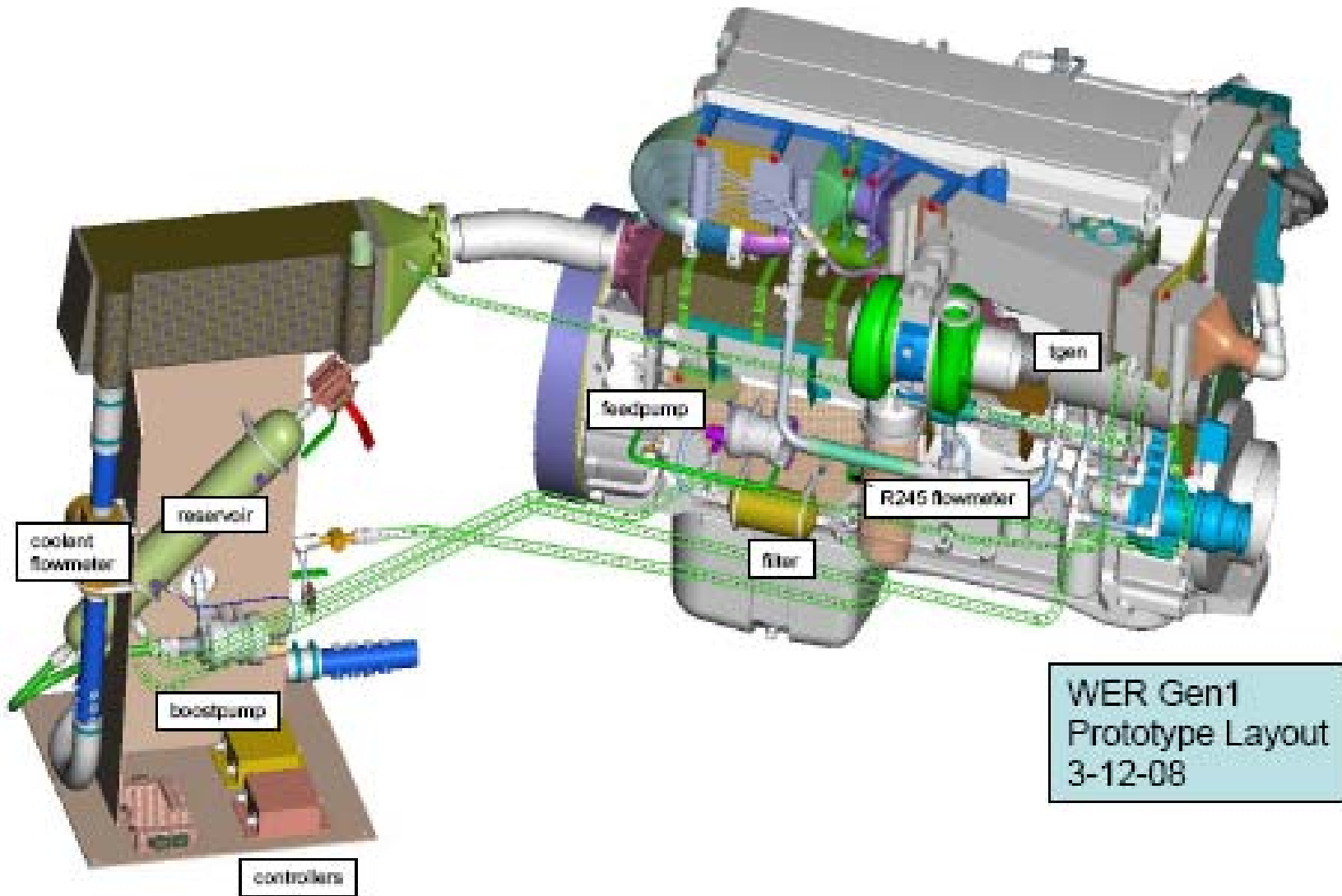
First Generation Hardware Design



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First Generation Test Cell Installation

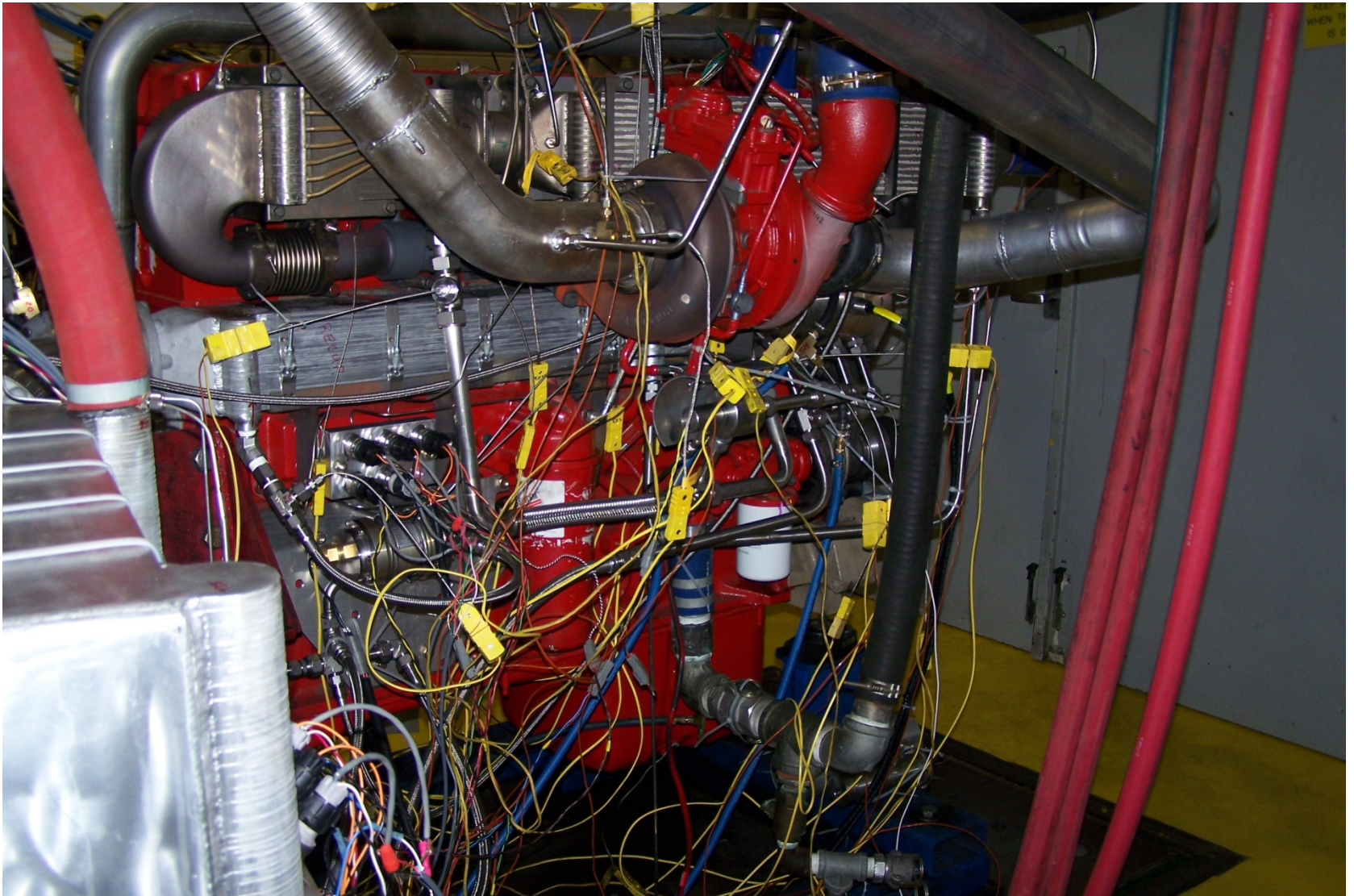


WER Gen1
Prototype Layout
3-12-08

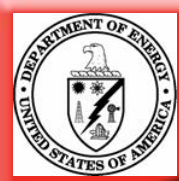
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ISX with WHR System in Test Cell

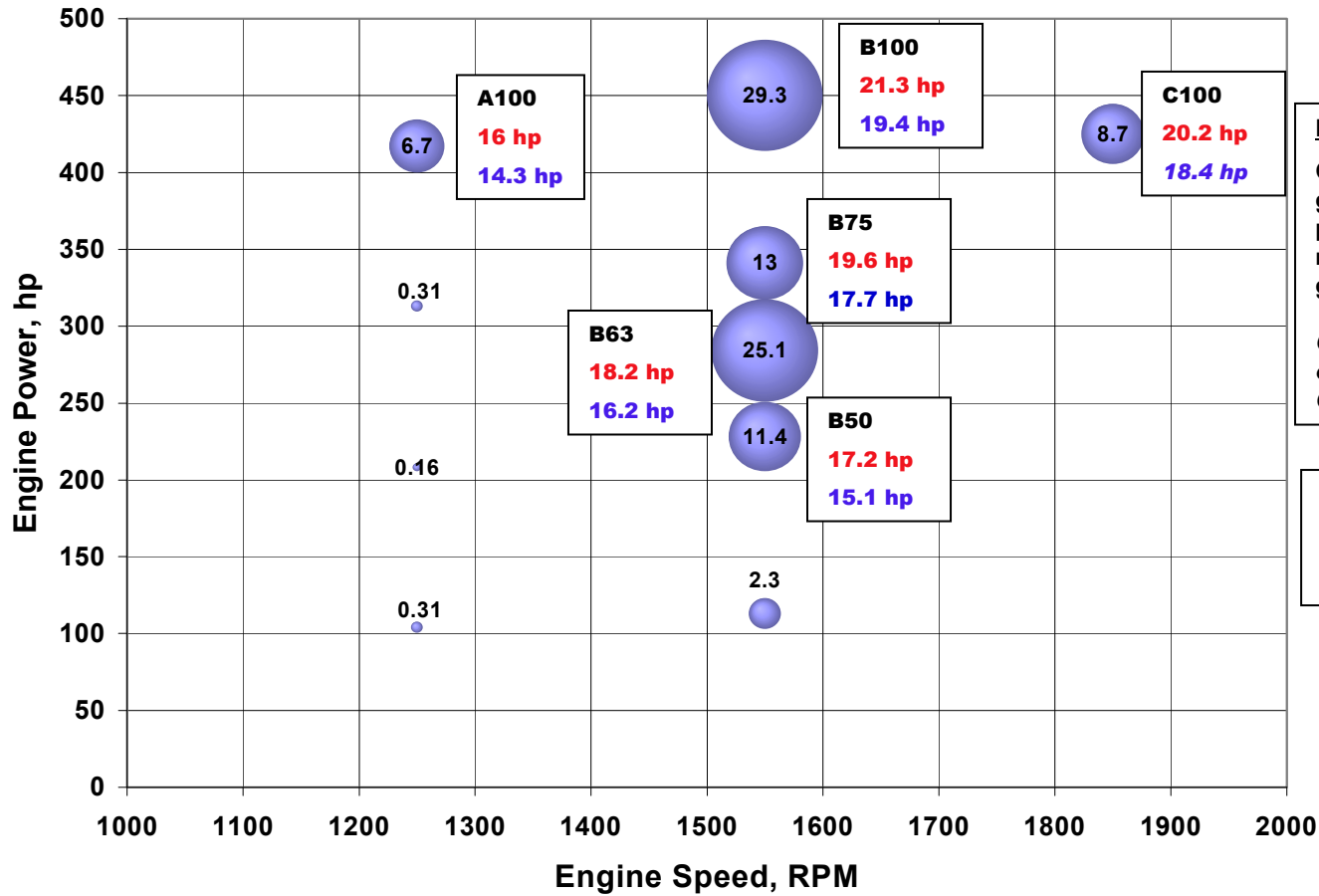


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Duty Cycle Fuel Efficiency Improvement

International Prostar on HDCC Cycle in VMS (13-Mode)



EGR Only Heat Recovery
 Gen1 Test results reflect greater than expected parasitics which may be reduced in future hardware generations
 C100 Gen1 Test Result is extrapolated from other Gen1 data

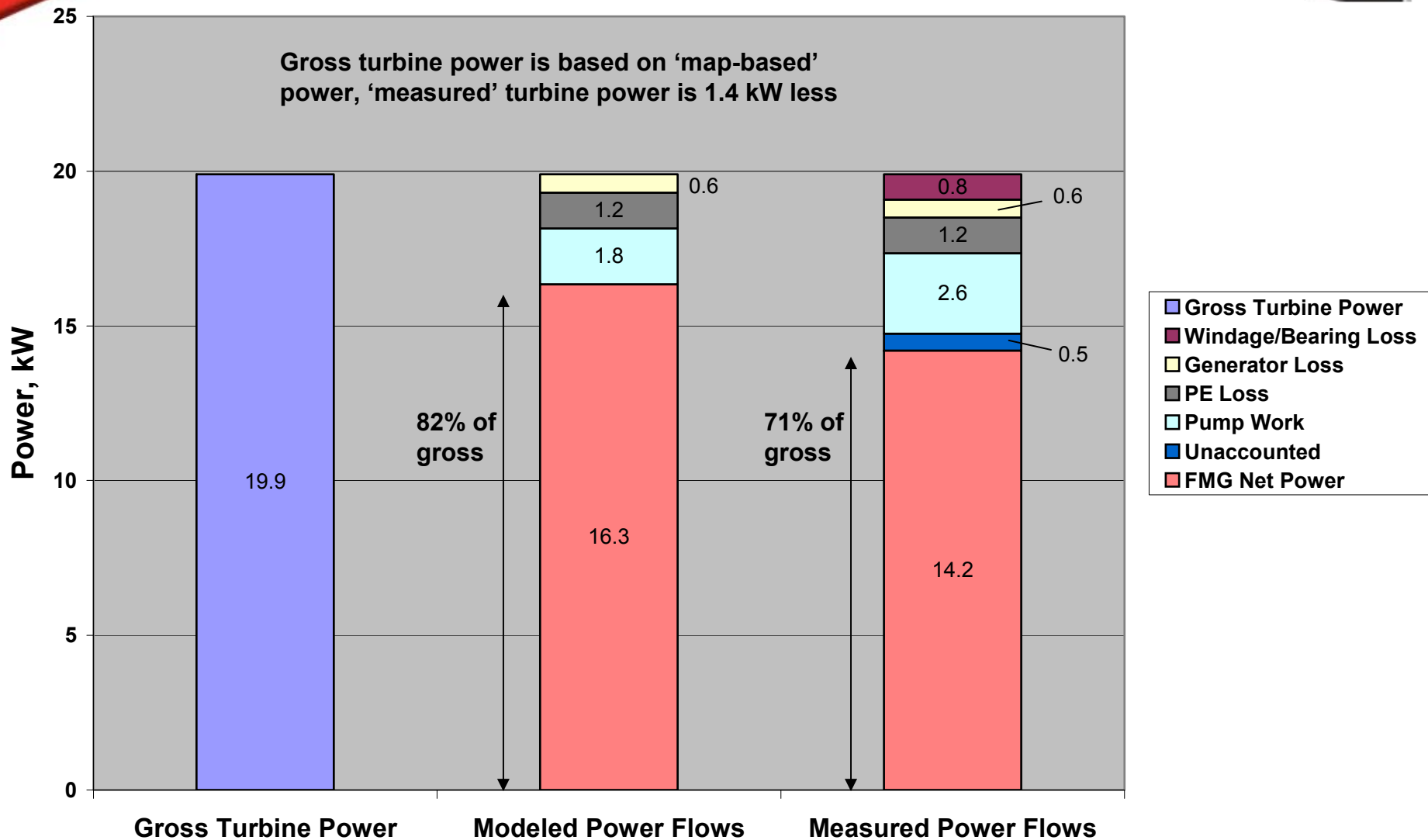
Engine Operating Point
 Predicted WHR Power
 Observed Gen1 Power

**EGR-Only WHR Net benefit for Prostar on HDCC cycle = 6% Predicted
 5.0% Observed as modeled with observed data**

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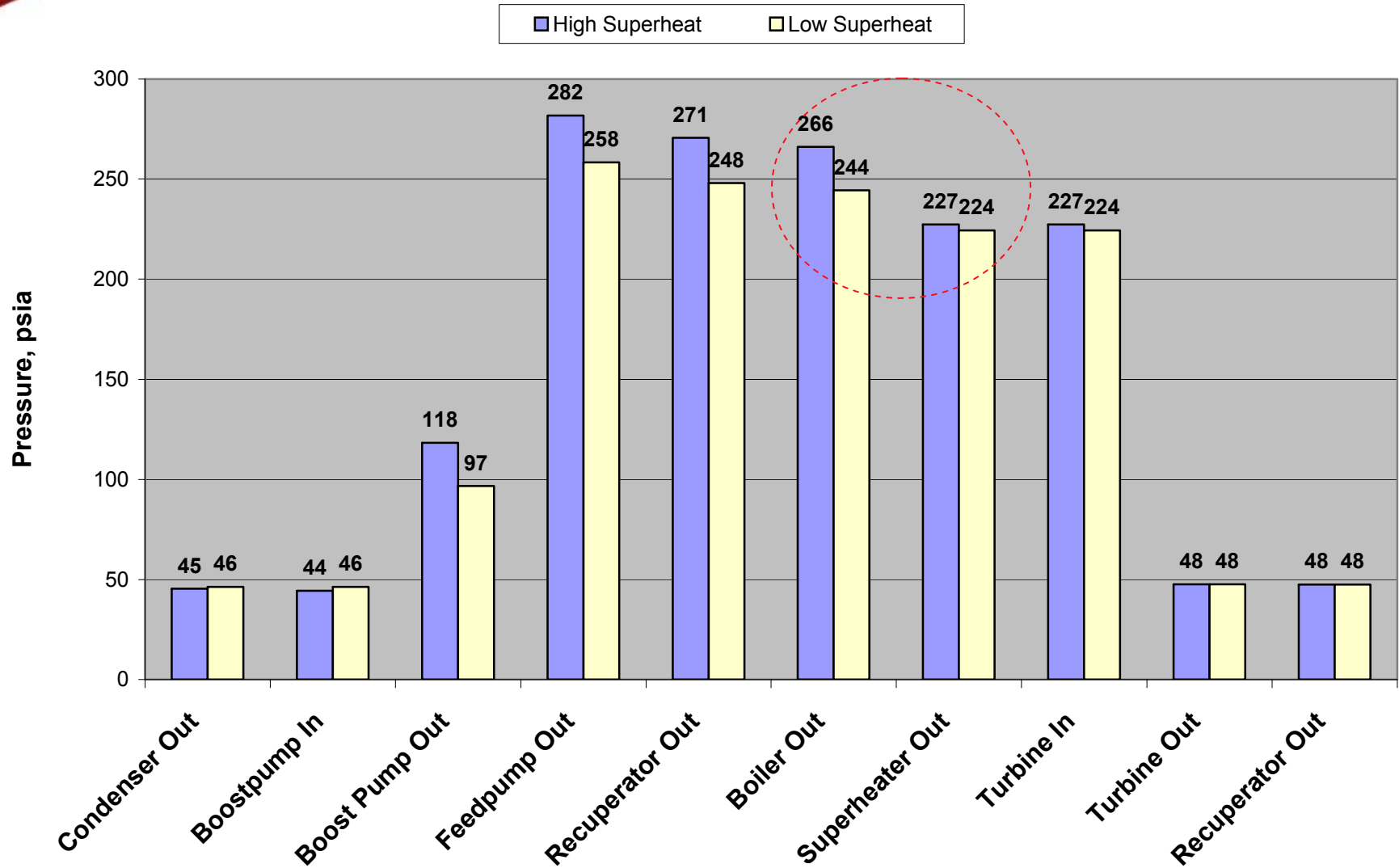
Electrical Power Flows – B100 Operation



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Refrigerant Side Pressures

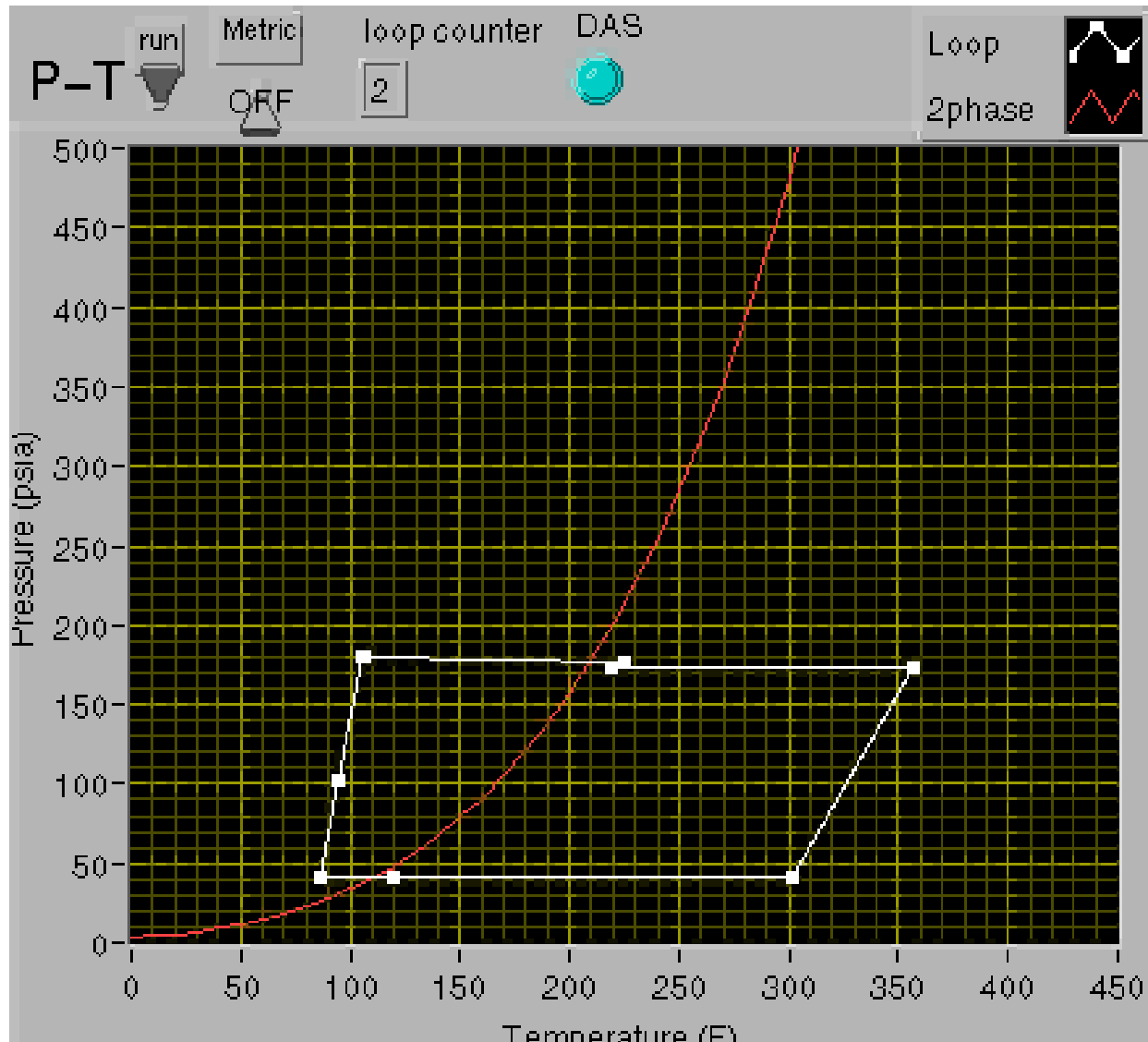


Need to reduce high-side system pressure drop, costs additional pump work

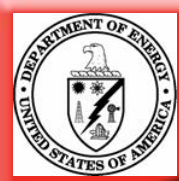
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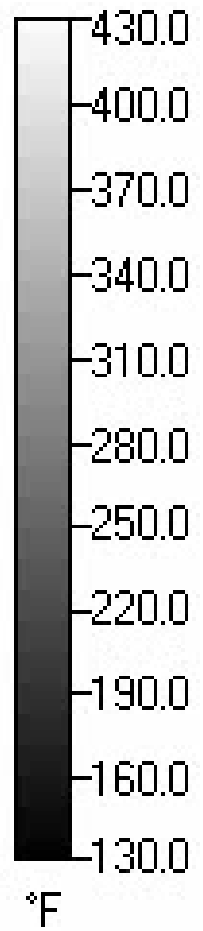
System Cycle Demo



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System Thermal Image Movie



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Review and Summary

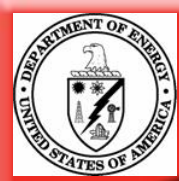


Significant Progress -

- **First Generation evaluation is well underway**
- **Initial results are promising - we are building our knowledge base**
- **Now moving to exhaust heat capture in addition to EGR heat**
- **Development of transient controls for driveability. Initial results look good.**

Go Forward Plans

- **2nd Generation system design and analysis is underway**
- **Continue System refinement and evolution**



Cummins Waste Heat Recovery



Cummins Inc. appreciates the partnership support of the U.S. Department of Energy in this highly innovative and unique program –

Thank You!

