Energy Optimization of a Large Central Plant Chilled Water System

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Agenda

- Objectives
- System Description
- Data Collection & Models
- System Optimization Opportunities
- System Optimization Results
- Conclusions

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Objectives

- **Conduct a chilled water system Energy Savings Assessment (ESA) using a Systems Approach at the Oak Hill Plant site**

- **Identify (and quantify) chilled water plant energy savings opportunities**

- **Assist plant personnel to gain familiarity with certain bestpractices and to continue to identify energy efficiency improvement opportunities at the site**

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System Description

- **<u>Chilled Water loop (42°F supply temperature)</u>**
  - Chiller #1: Trane CVHF 1280 Centrifugal – 1,250 RT
  - Chiller #2: Trane CVHF 1280 Centrifugal – 1,250 RT
  - Chiller #3: Trane CVHF Centrifugal – 1,470 RT (New)
  - Chiller #4: York YSNNNNS7 Screw – 1,180 RT
  - Chiller #5: York YSNNNNS7 Screw – 1,180 RT
  - Chiller #6: York YSNNNNS7 Screw – 1,180 RT

- **<u>Glycol loop (32°F supply temperature)</u>**
  - Glycol Chiller #1: Trane CVHF 770 Centrifugal – 600 RT
  - Glycol Chiller #2: Trane CVHF 770 Centrifugal – 600 RT
  - Glycol Chiller #3: Trane CVHF 770 Centrifugal – 600 RT

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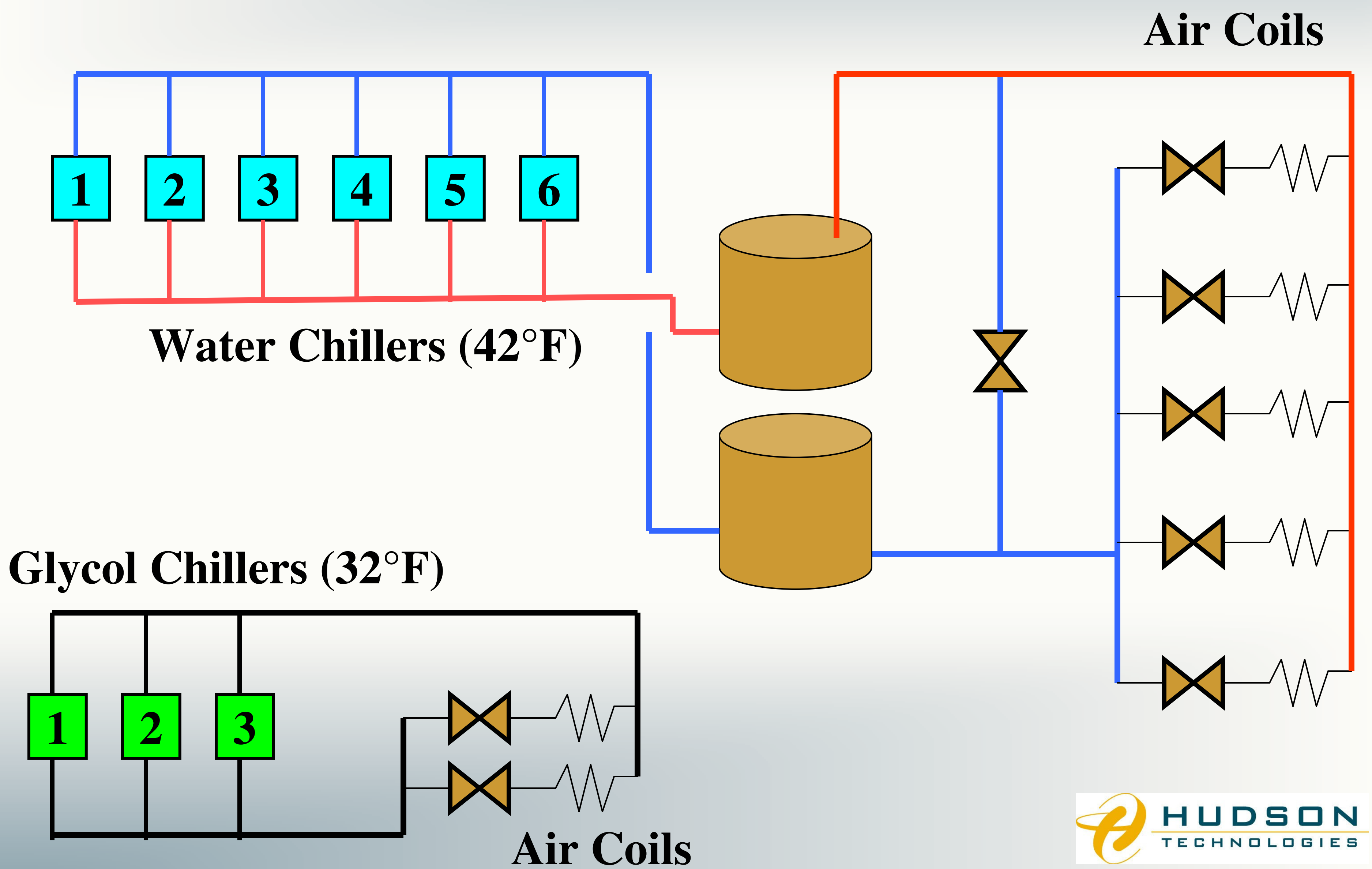
System PFD



Air Coils
1
2
3
4
5
6
Water Chillers (42°F)
Glycol Chillers (32°F)
1
2
3
Air Coils

Identified Chiller Plant BestPractices

- Site-level integrated chilled water and glycol loops
- High efficiency two-stage centrifugal chillers for base load and screw machines to provide for swing capacity
- Use of variable speed drives on the secondary pumping loop
- Use of variable speed drives on the condenser water pumps
- Use of two-speed fans on the cooling towers
- Significant instrumentation, data monitoring and controls
- Use of real-time data for tracking efficiency metrics (kW/ton) and a Historian for analysis
- Good periodic maintenance practices for equipment (oil analysis, cleaning of heat exchanger tubes, eddy current testing, etc.)
- Periodic calibration of all critical instrumentation

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Data Collection

- **Hourly average data for one year (10/01/07 – 09/30/08) for each chiller**
  - Ambient conditions
    - Temperature
    - Humidity
  - Chilled water flow
  - Condenser water flow
  - Power consumption
  - Chilled water supply and return temperatures
  - Condenser water supply and return temperatures
  - Bypass flow

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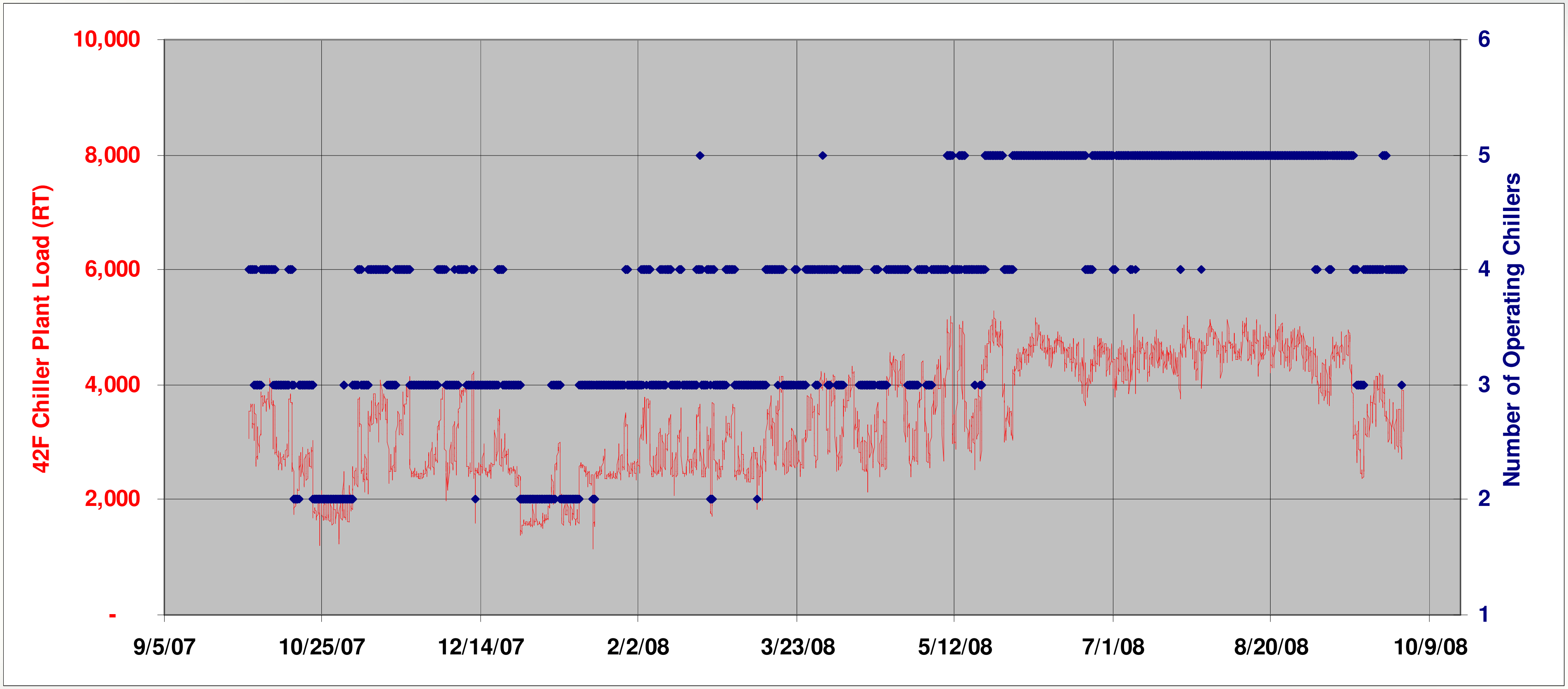
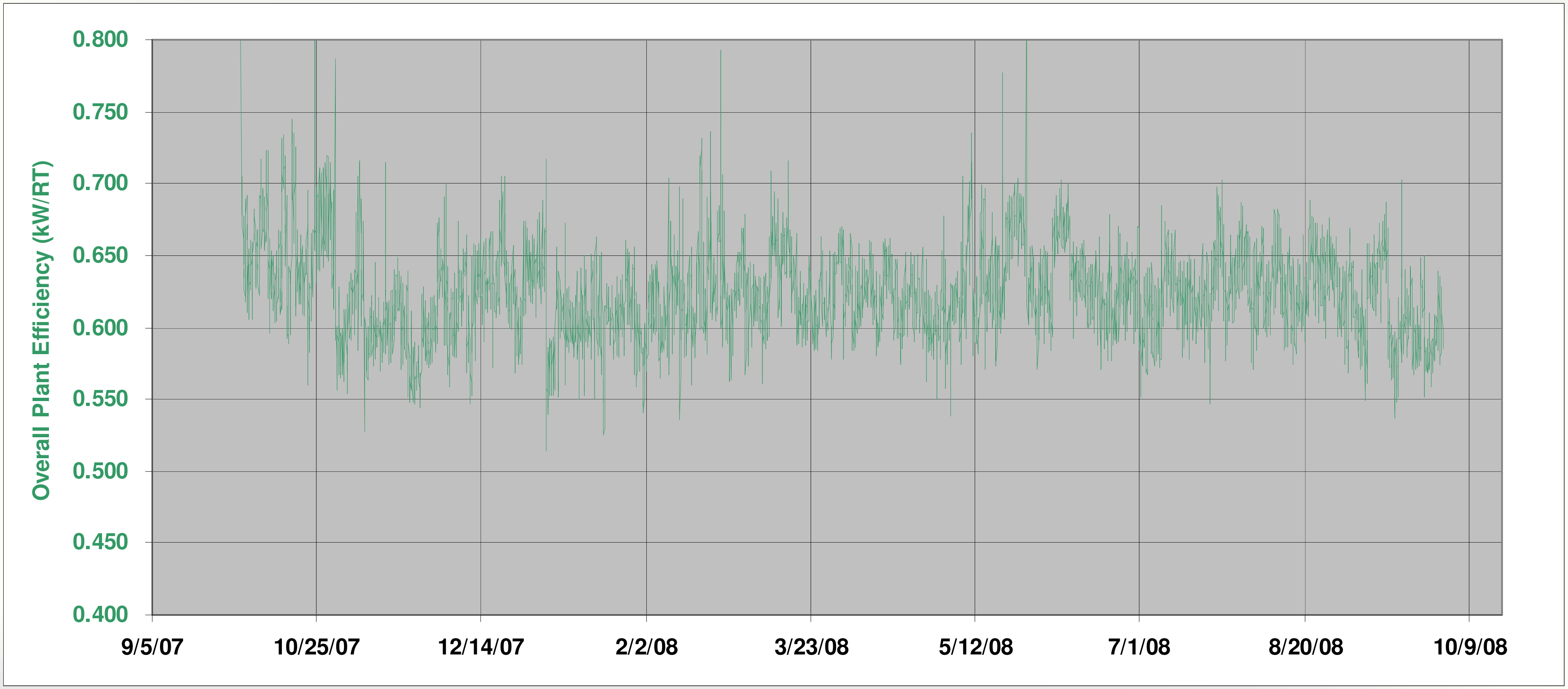
Load Profile



Chilled Water Plant Efficiency



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Chilled Water Plant Efficiency

Chiller #	1	2	3	4	5	6	Overall Plant
Operating hours	7,469	7,458	2,633	6,877	6,336	2,591	**8,750**
Load (RT)	924	944	868	887	863	846	**3,428**
Power (kW)	553	511	610	599	561	591	**2,144**
Efficiency (kW/RT)	0.597	0.541	0.705	0.677	0.650	0.704	**0.623**

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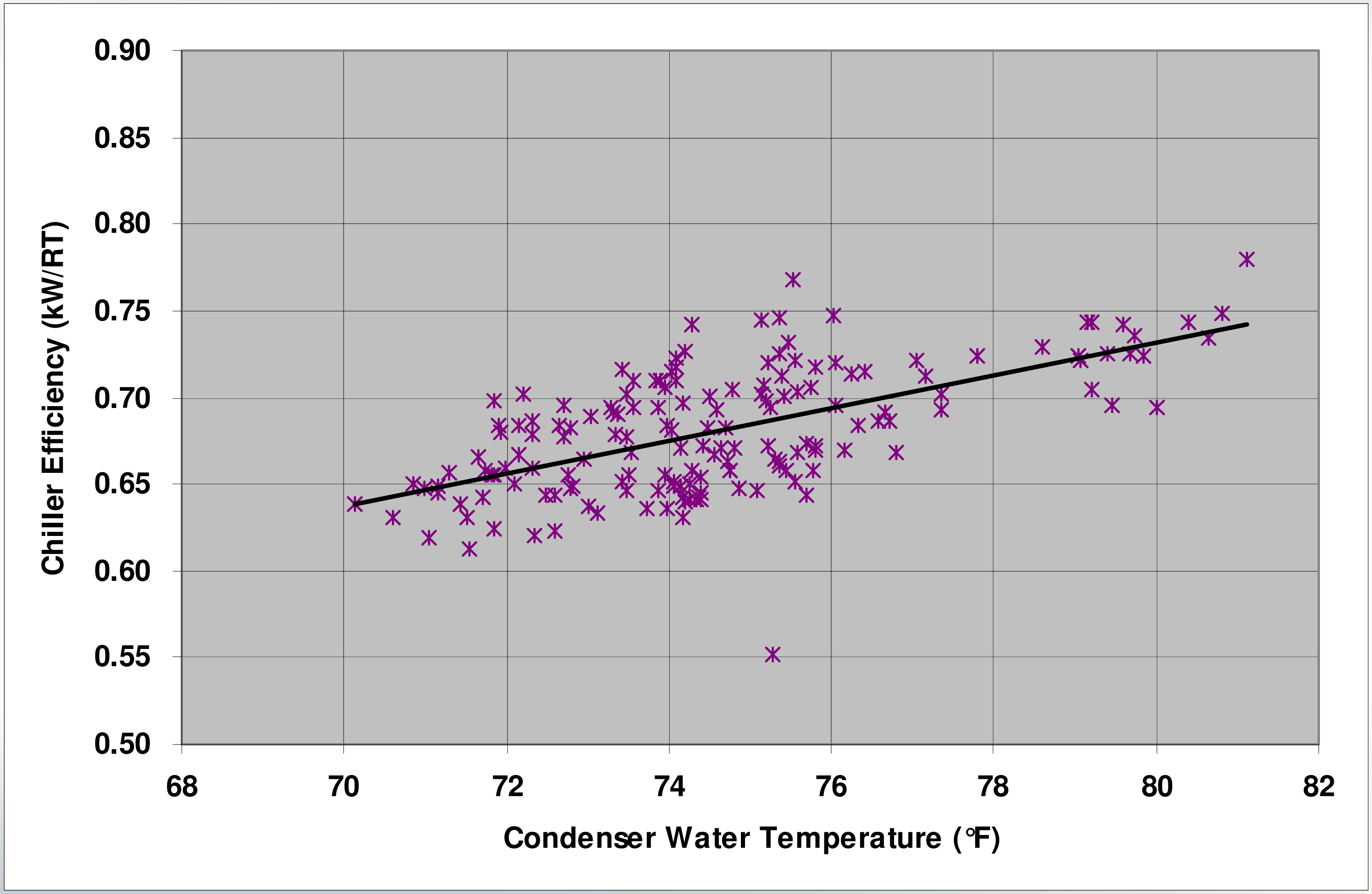
Chiller Efficiency



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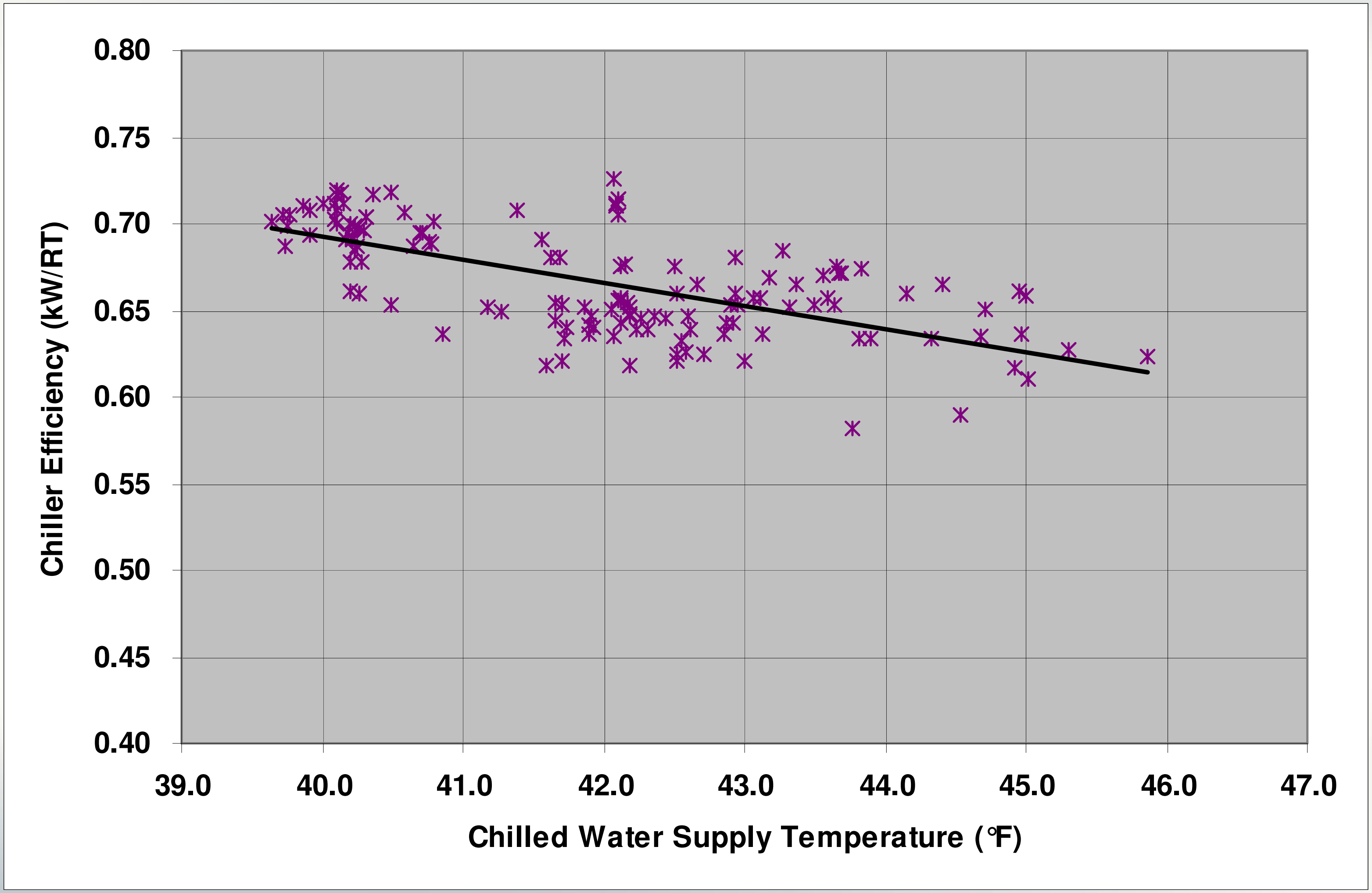
Chiller Efficiency



Energy Savings Opportunity

- **Reduce condenser water temperature**
  - Condenser water maintained currently at 75°F
  - Controlled by two-speed fans
  - Typically, 10% energy used by fans, 20% by pumps and 70% by compressor
  - Compressor kW/RT increases with higher condenser water temperature
  - Float condenser pressure for maximum savings
  - Implementation to lower condenser water to 70°F
  - Potential savings ~7%

Energy Savings Opportunity

- **Constraints / Precautions - Reduce condenser water temperature**
  - Check manufacturers' recommendations – 65°F minimum condenser water temperature
  - Refrigerant Stacking issues
  - Concerns about leaks in low pressure (R123) chillers

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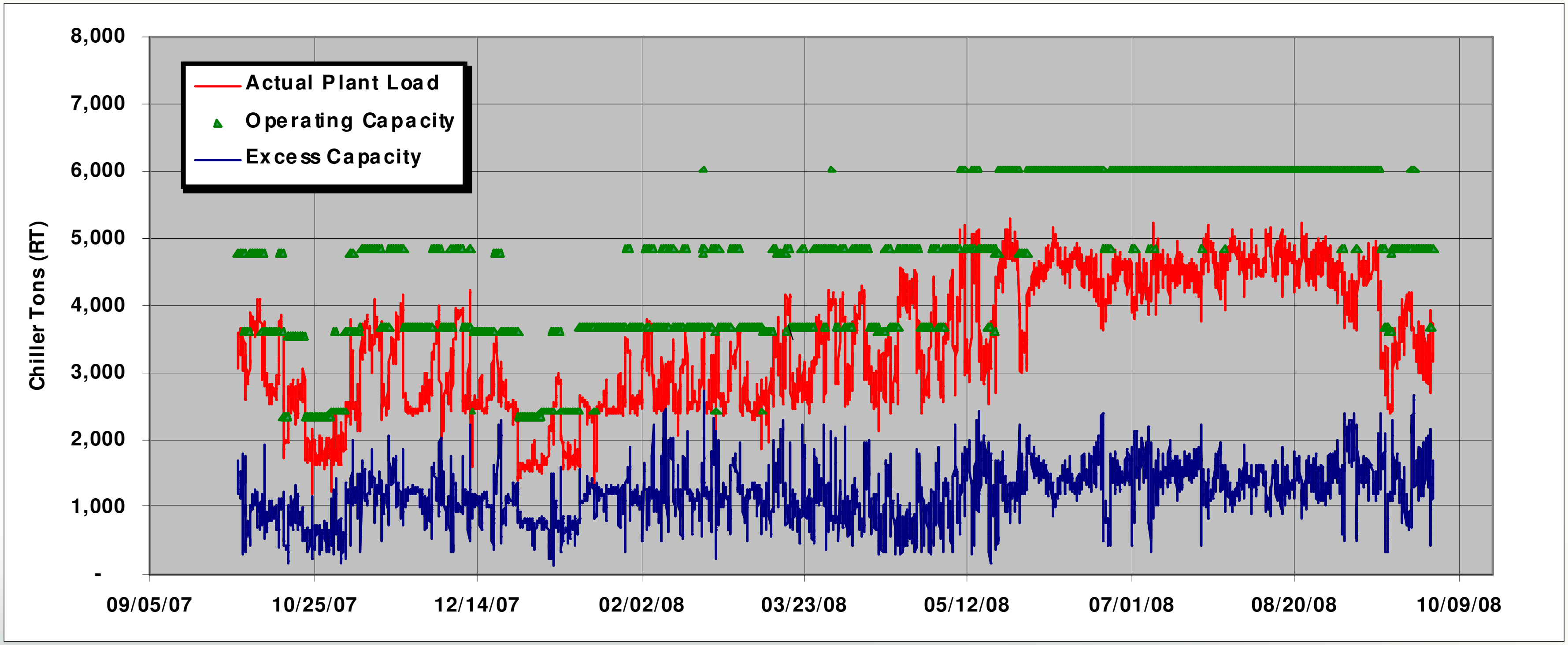
Energy Savings Opportunity

- Reduce number of operating chillers



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Energy Savings Opportunity

- **Reduce number of operating chillers**
  - Typically, one more chiller than needed – capacity in excess of 1,200 RT on average and sometimes as high as 2,000 RT
  - Bypass flowmeter readings (average ~2,500 gpm)
  - Benefits of shutting down one chiller
    - Reduction of overall chillers kW/RT
    - Reduction in pumping power
    - Improved heat transfer in the evaporators
    - Reduction in maintenance costs
  - Preliminary estimates ~10% energy savings

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Energy Savings Opportunity

- **Increase primary chilled water flow through chillers**
  - Design rating is based on 42°F chilled water, 85°F condenser water and 100% load (Tons)
  - But this happens for 1-3% of the operating hours
  - Chiller has a lot more capacity at off-design conditions
  - Implement – Variable Primary Flow and increase chilled water flow
  - Chiller moves to full-load conditions and kW/RT reduces
  - Preliminary estimates ~5-10% energy savings
  - Constraints / Precautions
    - Pumping power capability
    - Compressor horsepower limitation

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Energy Savings Opportunity

- **Transfer load from 32°F glycol loop to 42°F chilled water loop**
  - Full load operating efficiency
    - 32°F glycol chiller – 0.727 kW/RT
    - 42°F water chiller – 0.60 kW/RT
  - It is possible to transfer 50% of the glycol loop load
  - Potential energy savings – 3-5%
  - Constraints / Precautions
    - Load balancing issues
    - Availability of additional heat transfer area on the chilled water loop
    - Change of control setpoints

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Energy Savings Opportunity

- **Implement SMART algorithm to reset chilled water supply temperature**
  - 1°F increase in chilled water supply temperature leads to a reduction of 0.015 kW/RT
  - DAS has information on chilled water flow control valve positions of almost all the air-handling units
  - Automatically increase chilled water supply temperature till a control valve reaches 80% open
  - Currently, done on a manual basis
  - Constraints / Precautions
    - Dynamic flow issues
    - Will have to ensure "no hunting"

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BestPractices

- **Implement real-time calculation of chiller efficiencies and trending**
  - Will provide information for further optimization
  - All the data is already available

- **Implement a Chiller Chemistry™ program**
  - Fluids – Refrigerant, Oil and Water should be tested every six months
  - An engineering analysis combining all these results
  - Root-cause analysis
  - Best Predictive Maintenance – can be done online

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Energy Savings Opportunities

Opportunity	**Energy Savings**		**Cost Savings ($)**	**Project Cost ($)**	**PB**
	kWh	Therms			
Reduce condenser water temperature	815,000	0	53,000	40,000	N
Reduce number of operating chillers	1,400,000	0	91,000	25,000	N
Increase primary chilled water flow through the chillers	930,000	0	60,000	10,000	N
Transfer load from the 32°F glycol loop to the 42°F chilled water loop	315,000	0	20,000	25,000	M
Implement SMART algorithm to reset chilled water supply temperature	NC	0	NC	NC	M
Implement real time monitoring and add trending of efficiency	NA	NA	NA	25,000	N
Implement a Chiller Chemistry™ PM program	NC	0	NC	5,000	N

*NA – Not Applicable
**NC – Not Calculated (See write up for details)

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Conclusions

- **Instrumentation & monitoring of “critical” parameters was key for optimization of the chilled water plant**

- **A Systems Approach is needed for optimizing any energy system**

- **Typically, chilled water and refrigeration systems are neglected in plants but they offer significant energy savings potential**

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Discussion & Questions

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