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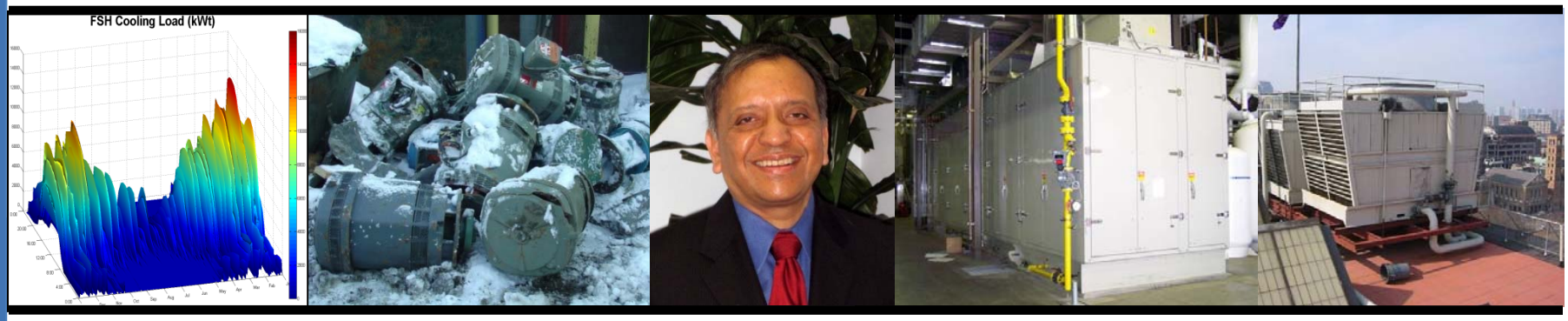

The Foundation for a High Efficiency Plant:

Operator Training and Practical Thinking

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Operators Training

An Energy Conservation Measure (ECM) you can't turn down....

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Example Existing Plant

August 2013: Day One

Example Chiller Plant:	10,000 Ton system
Average Energy Rate:	0.778 kW/ton
Average Generation Rate:	$0.12/kWh
Cost Per Hour:	$934/hr.

Equivalent Annual Rate:

$2,054,800/yr.

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First Operating Training

August 2013: Day Two

Example Chiller Plant: 10,000 Ton system

Average Energy Rate: 0.668 kW/ton

Average Generation Rate: $0.12/kWh

Cost Per Hour: $801/hr.

Equivalent Annual Rate:

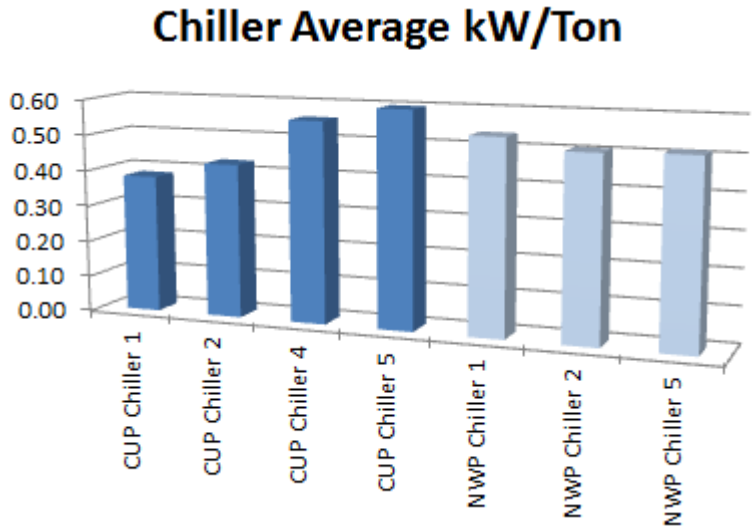
$1,763,520/yr.

Savings: $291,280/yr.

14% Reduction in one day!

No Capital Investment cost!

Payback in Months



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Questions for Yourself

- Why do Operator Training?
- How to do Operator Training?

WHY…..

Train operators now?

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WHY.....Train operators now?

- In 70s and 80s most of the operators came from Navy.
  - Too stubborn
- Unions forced and were successful in licensing codes on who can operate the energy plant.
- Todays operators have some college background and are hungry to learn.

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WHY…..Train operators now?

- Management were not used to spending funds in training operators so “status Quo” made sense.
- Today operators do not operate equipment, they operate system.
- Changing the operation efficiency hardly requires any capital investments
- Consultants with white hair and willing to share knowledge are dying breed.
    - So make use of them and get rewarded.

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System Costs

- Energy System (Plant, Distributions and Utilization) Costs millions of dollars.
- Think about your training and development costs over the last few years vs. the total cost of operations in your plant……
- Efficiency is often confused with reliability risks?
  - Most operators aren't aware that efficient doesn't mean unreliable.
  - These thoughts and fear must first be removed by example and education.

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Our Culture and Tradition

- Stop putting fear of failure in operators mind.
- Empower them and reward them for trying
- Humans are habitual creatures.
- Long time way of doing things.
- Requires an investment in slowly changing the traditions and habits.
- Giving the operators the tools to make the transitions smooth and easy.

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Enhanced Optimization

- Much Complexity is added to the plant
  - Black Box Optimization
  - Automation
- Use of Black boxes will make plant operations even more confusing to the average operator that may not have a full understanding of the equipment.
- How much has been overridden
  - Set points hosted - back to reliability
  - Running equipment in manual.
- Black Boxes provides false security and inhabits empowering operators.

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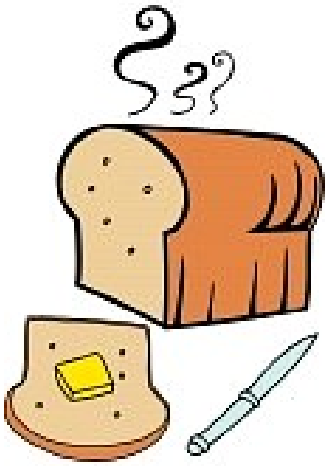
Start with the simple optimization: Operator Training and Practical Thinking



- This is our bread and butter.
- A great foundation for adding the enhanced optimization.
- Creates an environment of practical thinking.
- Empowers the operator.

- Leading to the Question…..

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HOW.....

Do it the Right Way.

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Start with the Basics…..Know Your Equipment and System

- Collecting Design and operating Data
- System Surveying by senior staff
  - Get the guys with Grey hair!!!
- Identifying and digesting system opportunities
- Work with operators and change operations with their help.
- Discuss before and after results and educate operators in layman language to build his/her confidence.

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Match Generation, Distribution, Demand

- This may be the most important part.
- Convince the operator that
  - Chilled water is not for cooling, it is for dehumidification
  - Peak load is limited to less than 300 hours a year,
- Understand the requirements of the demand.
  - Chilled Water Requirements
  - Steam Requirements
- Limits of the distribution system
  - How much capacity can be regained.
- Do not just buy the next piece of equipment for millions of dollars.

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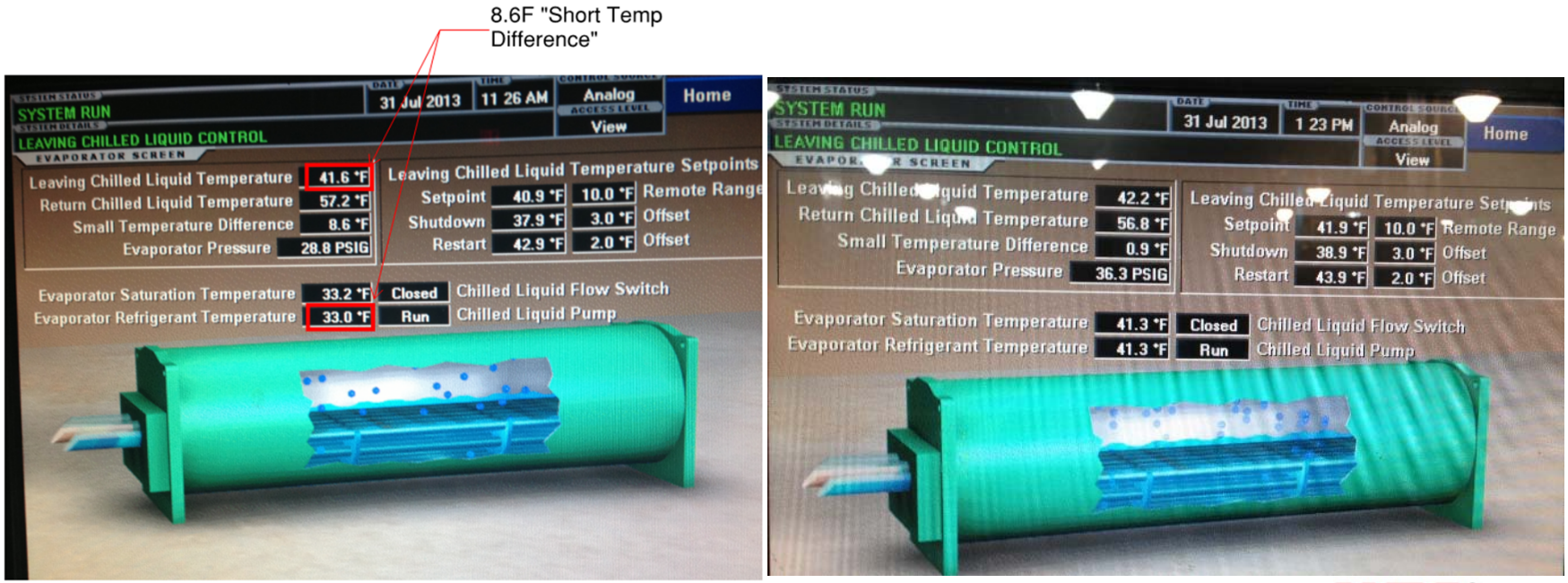
Lead by Example

- Operators must be trained by showing them.
- Remove fear from operators.
- Show them the results.



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Provide the Tools.

- Simple tools that make operation decisions easier- Cheat Sheet

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Chilled Water System "Cheat Sheet"

CW Temp Setpoint

OA WB	CUP Tower Leaving CW Setpoint (DegF)		NW Plant Tower Leaving CW Setpoint (DegF)	
0 - 35		55		40
35 - 40	WB+	18 53 - 58		
40 - 45	WB+	13 53 - 58		
45 - 50	WB+	10 55 - 60		
50 - 55	WB+	8 58 - 63		
55 - 60	WB+	5 62 - 67		
60 - 65	WB+	7 67 - 72	WB+	7 67 - 72
65 - 70	WB+	7 72 - 77	WB+	7 72 - 77
70 - 75	WB+	7 77 - 82	WB+	7 77 - 82
75 - 80	WB+	7 82 - 87	WB+	7 82 - 87

Chiller Staging

Load (Tons)	CUP CHW DT	CUP Run These Chillers	NWP CHW DT	NWP Run These Chillers	Example Staging of Chillers: CUP Tons per Chiller: CUP CH-1	CUP CH-2	CUP CH-4	CUP CH-5	NWP Tons Per Chiller: NWP CH-1	NWP CH-2	NWP CH-5	Common Ad Hl	Total Tons
1,200		Free Cooling OR CUP-CH-1 OR 2 up to 1650 Tons each	6	Free Cooling HX								2,750	2,750
1,400		Free Cooling OR CUP CH-1 AND 2 up to 1650 Tons each	6		700	700							1,400
1,800		CUP CH-1 OR 2 up to 1650 Tons each	6		900	900							1,800
2,000		CUP CH-1 OR 2 up to 1650 Tons each	8		1,000	1,000							2,000
2,500		CUP CH-1 OR 2 up to 1650 Tons each	10		1,250	1,250							2,500
3,000		CUP CH-1 OR 2 up to 1650 Tons each	10		1,500	1,500							3,000
5,000		CUP CH-5 not less than 3000 Tons OR CUP CH-4 not less than 1500 Tons	12	NWP CH-1, 2 OR 5 not less than 1350 each				3,600	1,400				5,000
7,500		CUP CH-5 not less than 3000 Tons	13	NWP CH-1, 2 OR 5 not less than 1350 each				4,800	1,350	1,350			7,500
11,500		CUP CH-5 not less than 3000 Tons AND CUP CH-4 not less than 1500 Tons	14	NWP CH-1, 2 OR 5 not less than 1350 each			1,500	4,000	2,000	2,000	2,000		11,500
13,500		CUP CH-1 or 2 up to 1650 Tons each and NWP CH-5 not less than 3000 Tons	14	NW CH-1,2 OR 5 not less than 1350 Tons each			1,800	4,800	2,300	2,300	2,300		13,500
				Design:	2,500	2,500	2,000	5,000	2,500	2,500	2,500	3,000	

Notes:
1. WB likely but not necessarily corresponds to the load shown on the same row
2. Stage CW pumps and control chiller CW valves to maintain 2.75 GPM per Ton

CT Cell Staging

CUP Stage CT Cells to Get as Close to Min Flow as Possible: Cell	CUP: Min Flow (GPM)	NWP Stage CT Cells to Get as Close to Min Flow as Possible: Cell	NWP: Min Flow (GPM)
CT-1	3,950	CT-NW1B	1,500
CT-2	1,950	CT-NW2A	1,500
CT-3	2,100	CT-NW2B	1,500
CT-4a/b	2,500	CT-NW3A	1,500
		CT-NW3B	1,500
		CT-NW4A	1,500
		CT-NW4B	1,500
		CT-NW4SA	1,500

Example Staging of Cooling Towers: CUP CHW Tons	Note 2: CW GPM	CUP CT Flow Per Cell: CT-1	CT-2	CT-3	CT-4a/b	NWP CHW Tons	Note 2: CW GPM	NWP CT Flow Per Cell: CT-NW1B	CT-NW2A	CT-NW2B	CT-NW3A	CT-NW3B	CT-NW4A	CT-NW4B	CT-NW4SA
						2,750	15,000	1,875	1,875	1,875	1,875	1,875	1,875	1,875	1,875
1,400	3,850	1,925	1,925			-									
1,800	4,950	2,475	2,475			-									
2,000	5,500	2,750	2,750			-									
2,500	6,875	2,292	2,292	2,292		-									
3,000	8,250	2,063	2,063	2,063	2,063	-									
3,600	9,900	2,475	2,475	2,475	2,475	1,400	3,850	1,925	1,925						
4,800	13,200	3,300	3,300	3,300	3,300	2,700	7,425	1,856	1,856	1,856	1,856				
5,500	15,125	3,781	3,781	3,781	3,781	6,000	16,500	2,063	2,063	2,063	2,063	2,063	2,063	2,063	
6,600	18,150	4,538	4,538	4,538	4,538	6,900	18,975	2,372	2,372	2,372	2,372	2,372	2,372	2,372	2,372
		6,500	6,500	7,000	5,000			3,750	3,750	3,750	3,750	3,750	3,750	3,750	3,750

CHW Pump Staging

CUP CHW Pump Staging (Note 1) Flow Range			Active Pumps
0	-	5,000	CHWP-1 or 2. Let first pump ramp up to 90% before engaging next pump.
5,000	-	11,000	Let CHWP-1 and/or 2 ramp up to 90% before starting 3 or 4
11,000	-	15,000	CHWP-5
15,000	-	+	Let CHWP-5 ramp up to 90% before starting CHWP-1 and/or 2

Notes:
1) Pump curves not available. Recommendations based on trended performance

NWP CHW Pump Staging Flow Range			Active Pumps
0	-	13,000	1 CHW Pump
13,000	-	22,500	2 CHW Pumps
22,500	-	+	3 CHW Pumps

CW Pump Staging

CUP CHW Pump Staging Flow Range			Active Pumps
Pump curves and pump performance trends not available (no CW DP, Pump KW data not reliable). Run CHWP 1 and/or 2 and/or 3 and/or 4 when CHWP-5 would run at a speed less than 60%.			

NWP CHW Pump Staging Flow Range			Active Pumps
0	-	10,000	1 CW Pump
10,000	-	17,000	2 CHW Pumps
17,000	-	+	3 CHW Pumps

Experience and Case Studies

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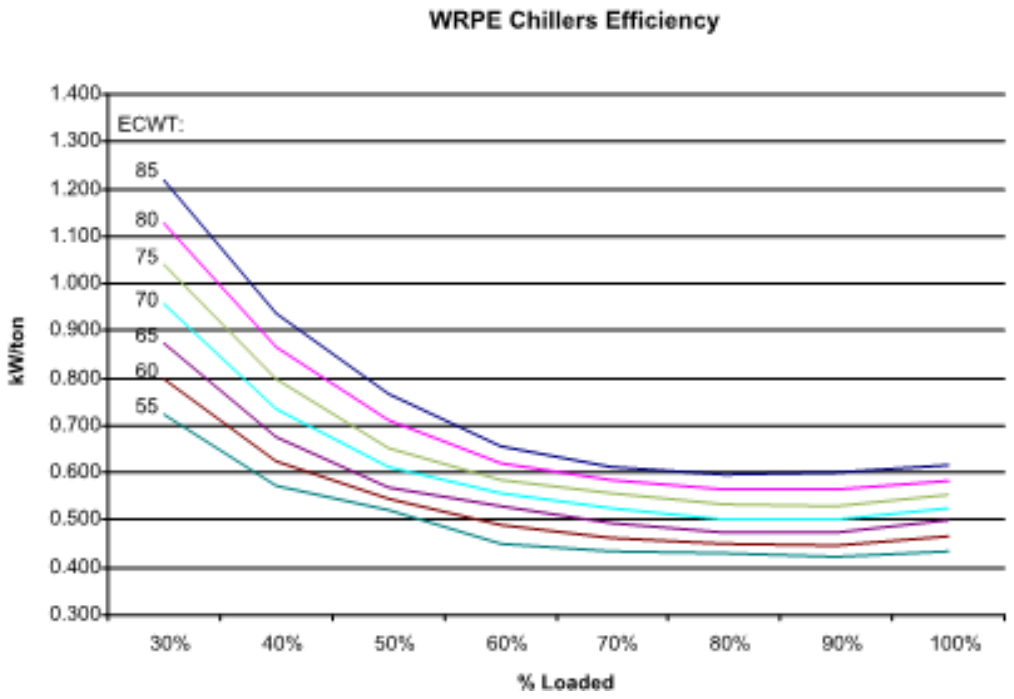
Architect of the Capitol (AOC)

- 30,000 ton chilled water system.
- Savings of $450,000/yr.



Actual Operator Comments: Most Useful Parts

- *Information compiled*
- *Rethink old and new ways to operate*
- *Strategies for operations*
- *Guide to successfully operate*
- *Getting everyone on the same page*
- *Relating Data to Operations*

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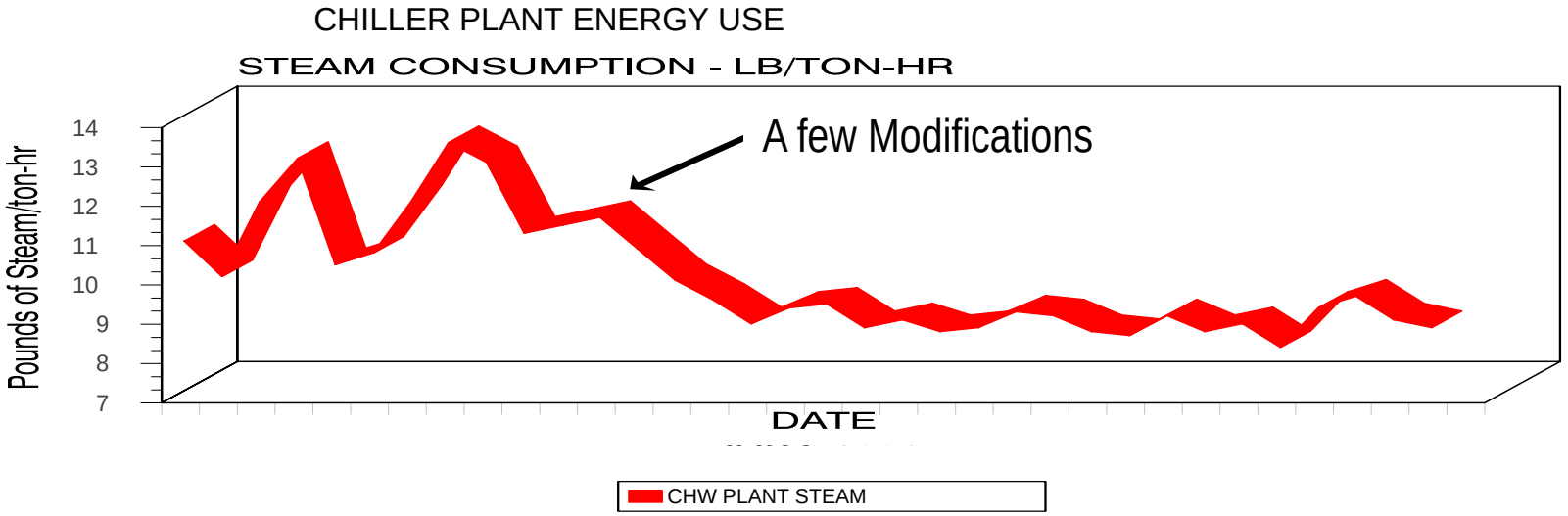
Northeastern University #1

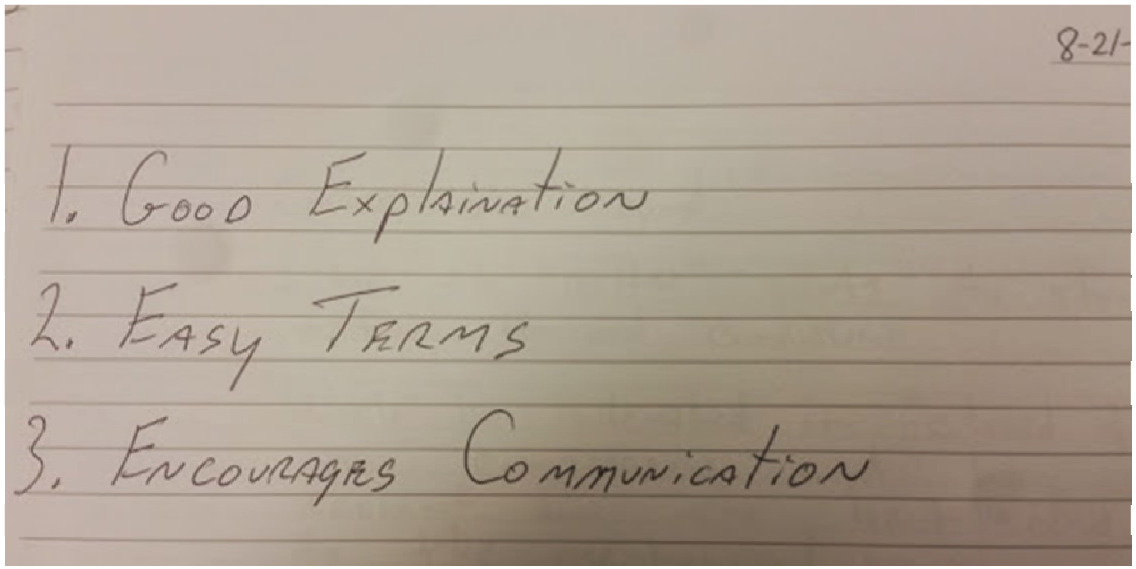
- Plant outsourced plant operation
- 25,000 ton chilled water system.
- New operator team was not familiar with the existing equipment.
- Engaged in all day training sessions to educate, and operate with great efficiency.



Northeastern University #2

- 10,000 ton chilled water system.
- Very Low Delta T in winter. 6 degrees
- Hydraulic Imbalance
  - Pump Staging required
- Cooling Tower Staging
- Chiller Staging
- Savings of $150,000/yr.
- Identified $370,000/yr.

Q: What was useful?
All of it. The towers, the pumps, and chiller performance.



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Lockheed Martin

- 4000 ton chilled water system.
- Regained Capacity of Chilled Water Plant

Chilled Water Operator Training Feedback.

I. Overall Comment
   - Learned a lot about our system.

II. What Part you found most useful.
   - That we have enough supply to be able to put the rest of the plant on chilled water.

LOCKHEED MARTIN

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Bristol Myers Squibb (BMS)

- Unique Project
- BMS wanted to ensure that operators were well trained, and knowledge was sustained for long term
- BMS engaged in a year long Operational Oversight
  - Daily Review of System Operation-interact with operators
  - Cheat Sheet for System Operations based on Big Data Analytics
  - On site monthly for additional training and review
- Immediate Project Payback

Bristol-Myers Squibb

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Summary

- Operators training is not a luxury. Make it a requirement
- Operators training Empowers operators.
- Empowerment initiates changes by operators
- Improved plant operation initiated by operators gives him a reason to wake up in the morning and report to work
- Generally no capital funds are required.
- Payback is in months not years.

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An ECM you can't turn down….Operator Training.

Thank You

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