Existing Building Commissioning

Bringing It All Together:
EBCx Case Study

Case Study Overview

- University campus
- EBCx of 3 laboratory / classroom facilities
- Buildings varied in age: 1975, 1994, 2009
- Focus on HVAC systems
- Largely based on trend and screenshot reviews
- Used Johnson Metasys BMS

EBCx Process

- Kickoff Meeting:
  - Establish objectives, schedule, team-member roles, data requirements
  - Brainstorming and building data review to select and prioritize
  - Collect available drawings and building system information
- Data Gathering & Preliminary Review:
  - Review drawings, control sequences & schematics
  - Gain understanding of systems
  - Establish baseline conditions
  - Identify potential opportunities
  - Review screenshots of major systems

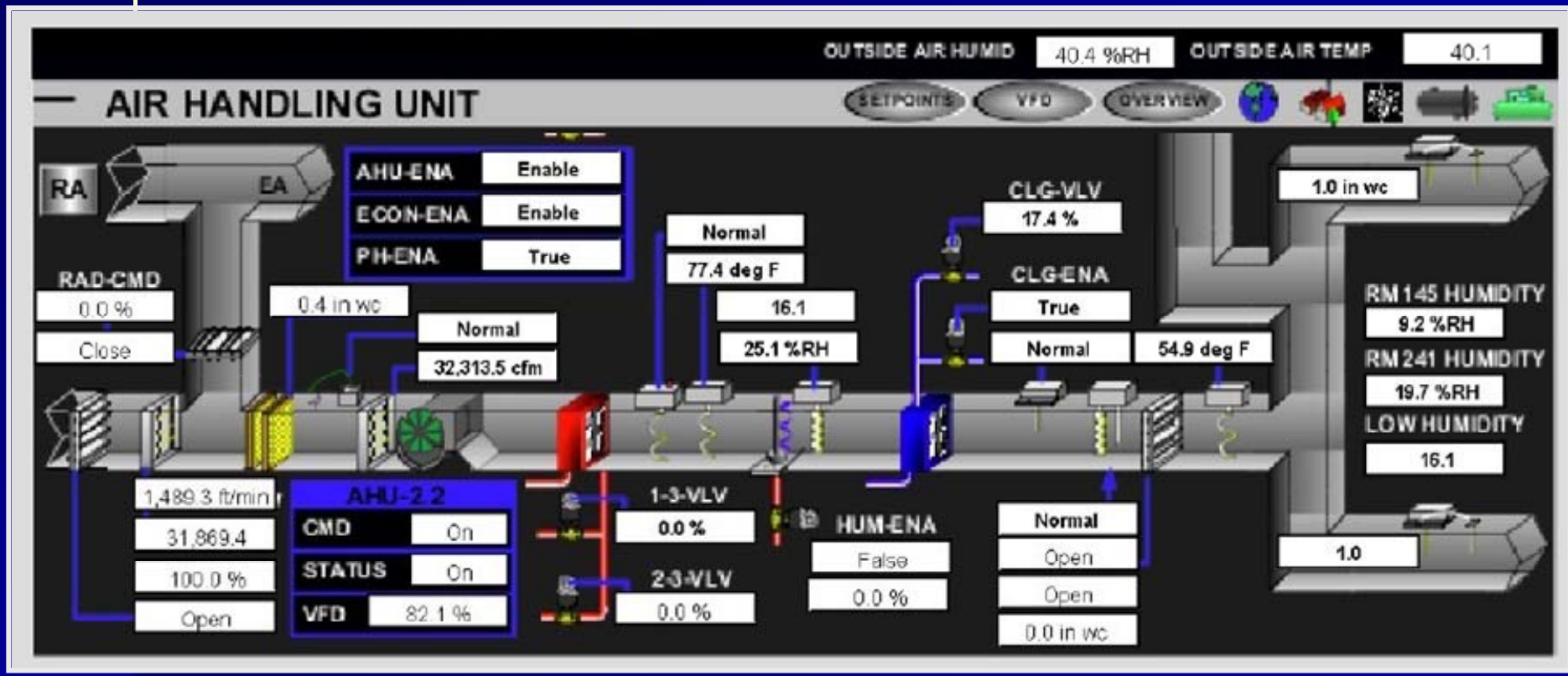
EBCx Process (cont…)

- Trend Data Review:
  - Preliminary review to ensure formatting & quality
  - Graphical analysis
  - Statistical analysis
- Measure Development:
  - Establish current conditions
  - Identify issue and duration
  - Field verification
  - Determine what needs to be fixed – how to make it better?
  - Who's going to fix it?
  - Define how measure saves energy

EBCx Process (cont…)

- Energy & Resource Savings:
  - Determine level of detail required for analysis
  - Quantify energy & resource savings – spreadsheets or models
  - Increased energy?
  - Identify key assumptions and inputs
- Cost Estimates: get quotes where possible
- Implementation: work with contractors and/or building staff
- Measurement & Verification
  - Use trend data where possible
  - Field verify and/or use work orders or contractor invoices to verify

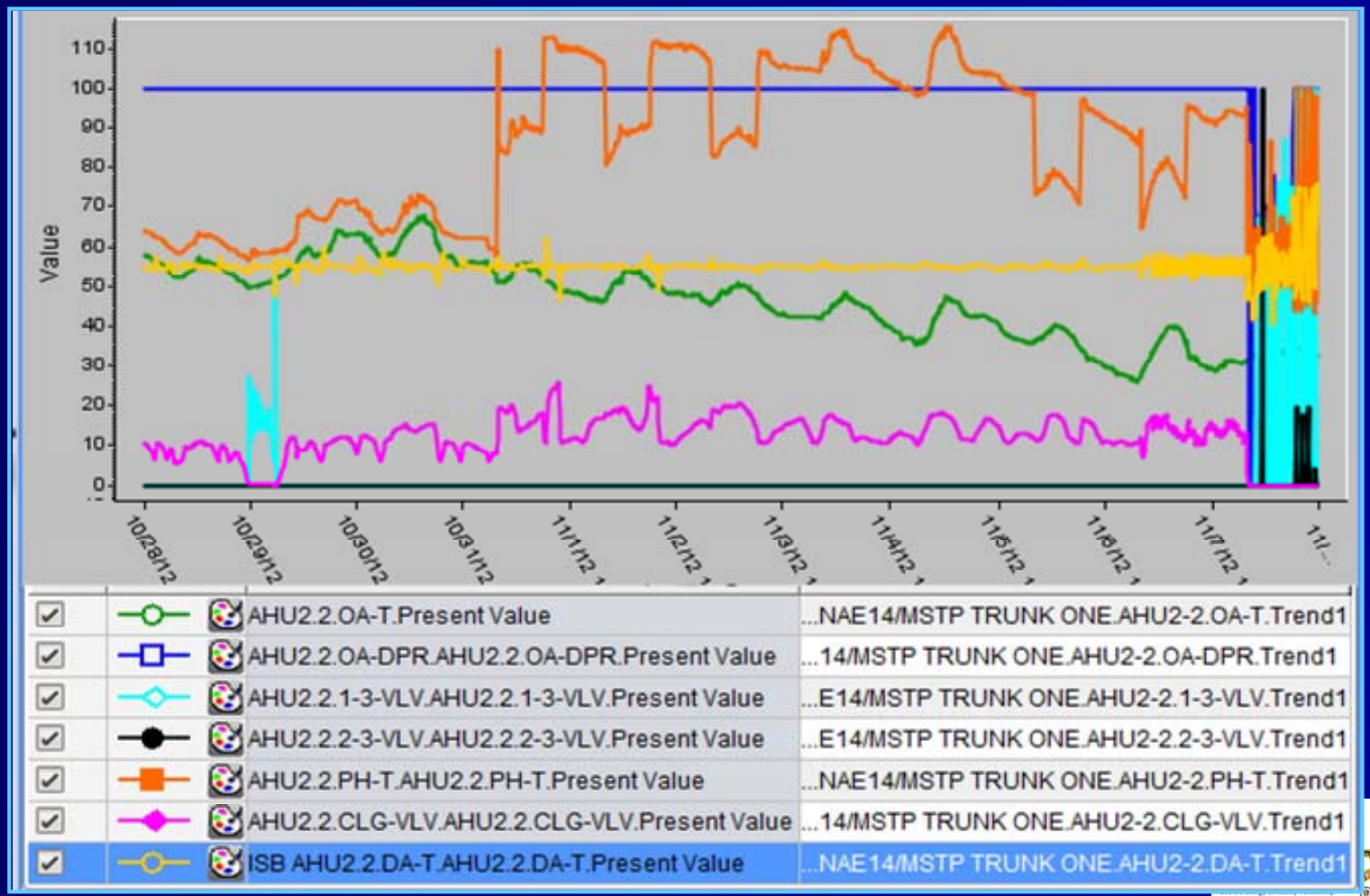
Leaking Steam Valve: Screenshot



- Field verification found valve sticking open

Leaking Steam Valve: Trend Data

- Trend data from BMS confirms issue – began on October 31.



Leaking Steam Valve: Energy Savings Calculations

- Where do savings come from?
  - Wasted steam energy
  - Unnecessary cooling energy
- How to calculate savings?
  - ...with trends of airflow and temperature it's easy!
  - $Q_{Btu/hr} = 1.08 \times FLOW_{CFM} \times [T_{in} - T_{out}]$
  - Count steam savings when steam should not be needed
  - Count CHW savings when CHW valve open and steam valve closed
  - What is duration of issue and savings?

Leaking Steam Valve:
Key Assumptions, Inputs, & Parameters

- Important to state key assumptions!

Input Parameters & Key Assumptions		
Steam System Delivery Efficiency	85%	
Chiller System Delivery Efficiency	90%	
CHW Plant Electric Efficiency	0.60	kW/ton
Estimated Avg RA Temp	72	F
Fan Full-load Power	52.7	BHP
Fan Full-load Power	42.7	kW
Affinity Exponent for Supply Fan	2.5	
Electric Avg Unit Cost	$0.075	$/kWh
Steam Avg Unit Cost	$13.00	$/MMBtu
*Steam savings only when stm valve closed & PHT>MAT+FanT		
*CHW savings only when steam leaking & CHW valve open		

Leaking Steam Valve: Energy Savings Calculations

Min	13	0	-4	16.2	0	0	0.0	0.0	0	35	0	36	0	0	0.0
Max	93	100	36,111	86.8	41,373	100	42.7	11.0	100	148	100	105	1,619,005	2,674,970	74.5
Average	42	97	16,349	48.1	20,501	51	11.0	1.8	2	104	35	58	1,194,578	1,036,778	55.9
Date / Time	**OA-T (F)**	**OA-DPR (% open)**	**OA-FLW (cfm)**	**Calc'd MAT (F)**	**SF-FLW (cfm)**	**SF-SPD (%)**	**Calc'd Fan Pwr (kW)**	**Calc'd Fan dT (F)**	**1-3-VLV (% open)**	**PH-T (F)**	**CLG-VLV (% open)**	**DA-T (F)**	**Chris Steam Q (Btu/hr)**	**Chris CHW Q (Btu/hr)**	**Calc'd Lkg dT (F)**
1/3/12 11:30:00 AM EST	24.8	100	28,175	31.9	33,168	86	29.3	3.5	0	77.5	14.03	64.8	1,508,790	457,170	42.1
1/3/12 11:45:00 AM EST	25.0	100	28,003	32.3	33,201	87	29.9	3.6	0	76.3	13.67	64.2	1,445,198	433,221	40.3
1/3/12 12:00:00 PM EST	24.3	100	28,021	31.8	33,207	86	29.1	3.5	0	74.9	12.23	63.0	1,421,949	429,147	39.6
1/3/12 12:15:00 PM EST	24.1	100	28,059	31.4	33,047	85	28.4	3.4	0	75.1	10.31	63.2	1,439,892	426,614	40.3
1/3/12 12:30:00 PM EST	24.1	100	27,729	31.6	32,875	86	29.2	3.5	0	76.0	9.70	64.6	1,451,068	404,786	40.9
1/3/12 12:45:00 PM EST	24.1	100	27,940	31.4	32,961	84	27.3	3.3	0	76.4	9.37	65.1	1,484,979	405,435	41.7
1/3/12 1:00:00 PM EST	24.6	100	27,580	32.1	32,781	86	29.4	3.6	0	76.9	9.71	65.5	1,457,885	402,885	41.2
1/3/12 1:15:00 PM EST	24.4	100	27,590	31.3	32,290	85	28.5	3.5	0	76.8	9.92	65.3	1,463,650	402,372	42.0
1/3/12 1:30:00 PM EST	24.6	100	27,178	32.4	32,583	84	28.0	3.4	0	77.0	10.63	65.7	1,446,854	397,778	41.1
1/3/12 1:45:00 PM EST	24.4	100	27,223	32.0	32,418	84	27.6	3.4	0	76.3	10.74	65.1	1,432,904	394,047	40.9
1/3/12 2:00:00 PM EST	24.6	100	27,068	32.5	32,471	84	27.4	3.4	0	76.5	10.95	65.3	1,426,997	395,628	40.7
1/3/12 2:15:00 PM EST	24.6	100	27,199	32.2	32,421	84	28.0	3.4	0	76.1	10.95	65.1	1,415,267	386,343	40.4
1/3/12 2:30:00 PM EST	24.8	100	27,283	32.1	32,245	84	27.6	3.4	0	76.5	10.95	65.3	1,429,204	391,319	41.0
1/3/12 2:45:00 PM EST	24.8	100	26,864	31.9	31,657	83	27.2	3.4	0	76.7	11.05	65.1	1,414,047	398,436	41.4
1/3/12 3:00:00 PM EST	24.8	100	27,214	31.8	31,981	83	27.2	3.4	0	75.9	10.94	64.7	1,404,717	387,842	40.7
1/3/12 3:15:00 PM EST	24.6	100	27,040	32.0	32,059	85	28.4	3.5	0	75.3	10.13	64.1	1,375,091	387,666	39.7
1/3/12 3:30:00 PM EST	24.4	100	27,284	31.7	32,242	84	27.3	3.4	0	74.6	8.86	63.7	1,376,195	381,331	39.5
1/3/12 3:45:00 PM EST	24.4	100	27,262	31.4	31,970	83	26.5	3.3	0	74.2	7.90	63.9	1,363,294	356,793	39.5
1/3/12 4:00:00 PM EST	24.2	100	27,244	31.6	32,254	84	27.5	3.4	0	73.8	6.94	64.1	1,351,079	338,466	38.8

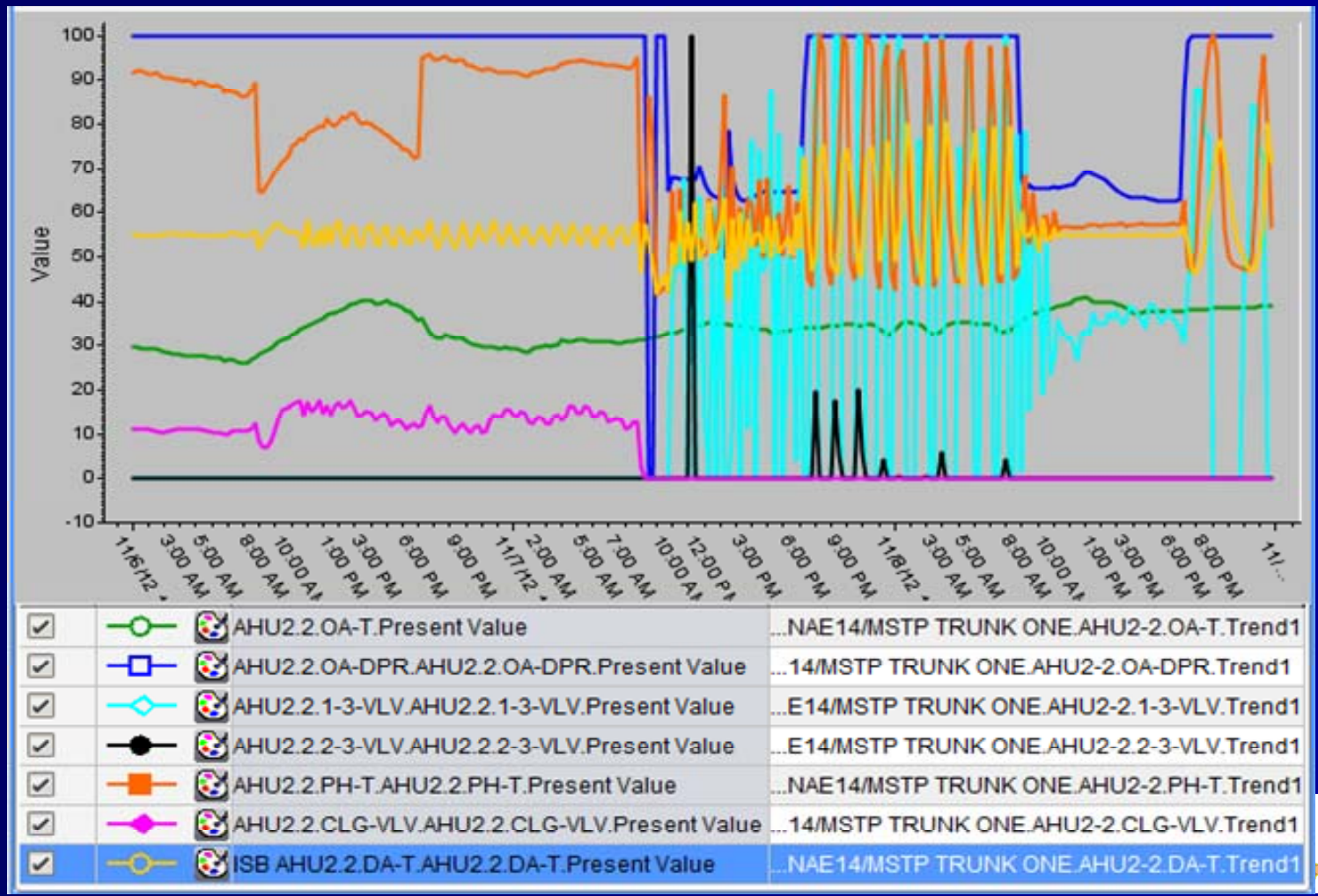
Leaking Steam Valve:
Energy Savings & Project Economics

- Present energy savings in energy units and costs
- Annualize savings when possible
- Perform cost estimate for implementation/repair

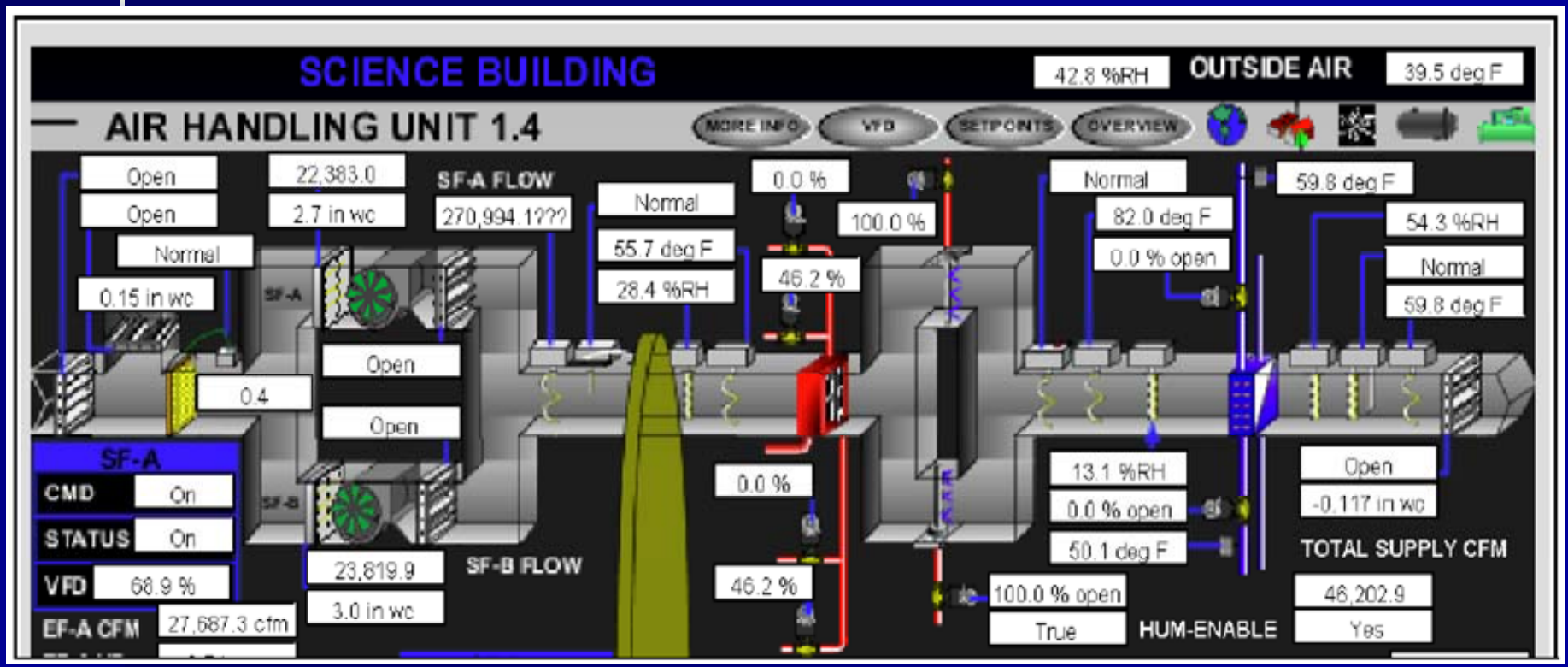
Leaking Steam Valve Wasted Energy		
Avg dT between PHT & DAT	55.9	F
Annual Steam Energy Savings	**4,193**	**MMBtu/yr**
Annual Steam Cost Savings	$54,513	
Annual Chiller Energy Savings	3,395	MMBtu/yr
Annual Chiller Energy Savings	282,930	ton-hrs/yr
Annual Chiller Energy Savings	**169,758**	**kWh/yr**
Annual Chiller Cost Savings	$12,732	
Total Cost Savings	**$67,245**	

ISB-2: AHU 2.2 - Leaking Steam Valve		
Annual Steam Energy Savings	4,193	MMBtu/yr
Annual Steam Cost Savings	$54,513	$/year
Annual Electric Energy Savings	**169,758**	**kWh/year**
Average Demand Reduction	19.4	kW/month
Annual Electric Cost Savings	$12,732	$/year
Total Cost Savings ($/year)	$67,245	$/year
Estimated Implementation Cost	$2,100	
Project Simple Payback (years)	0.03	years
Project ROI	3202%	

Leaking Steam Valve: Implementation & Verification



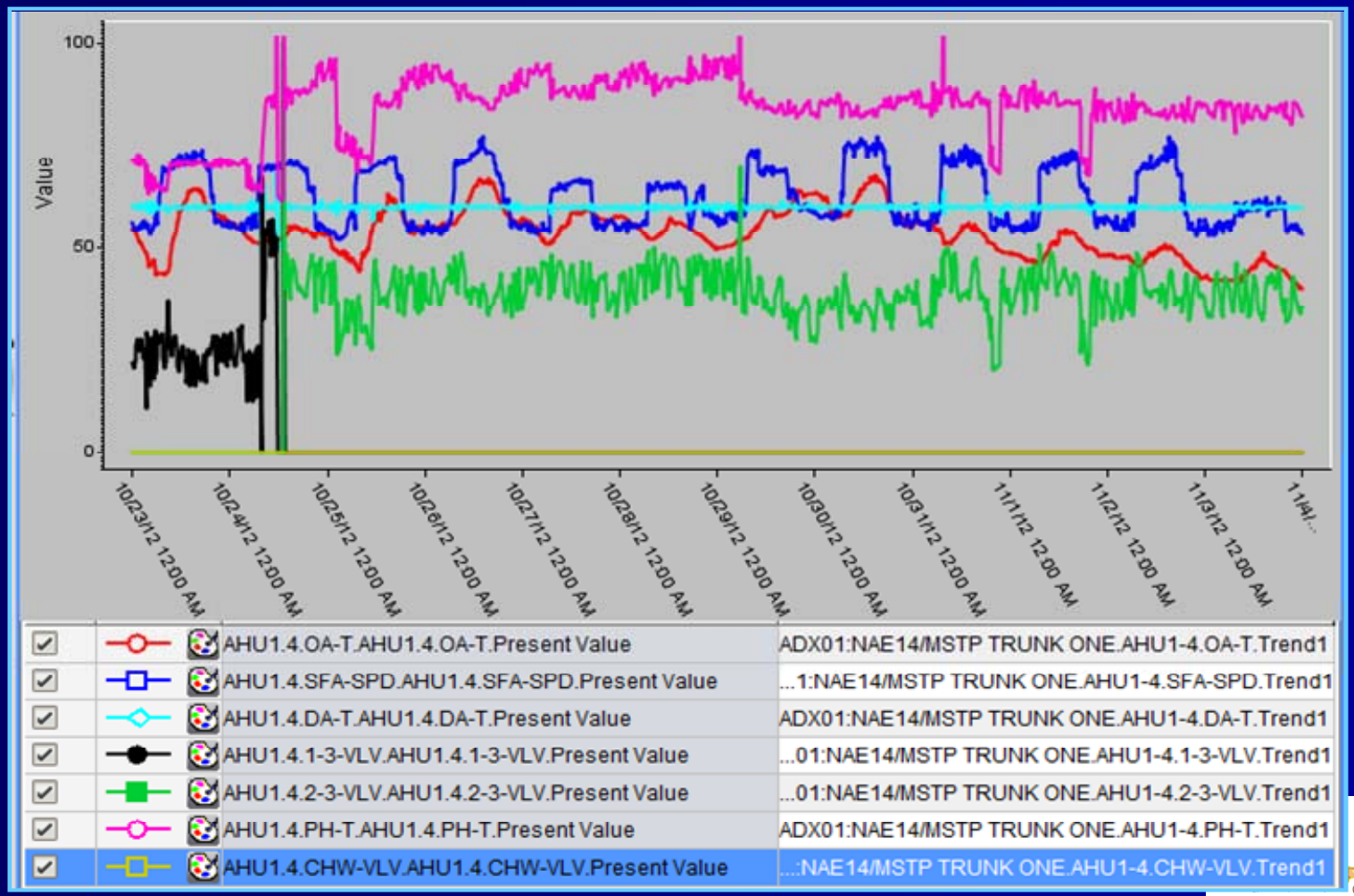
Leaking CHW Valve: Screenshot



- Field verification found actuator incorrectly operating one valve

Leaking CHW Valve: Trend Data

- Trend data from BMS confirms issue.



Leaking CHW Valve: Energy Savings Calculations

- Where do savings come from?
  - Wasted CHW energy
  - Unnecessary steam energy
- How to calculate savings?
  - ...with trends of airflow and temperature it's easy!
  - $Q_{Btu/hr} = 1.08 \times FLOW_{CFM} \times [T_{in} - T_{out}]$
  - Count steam savings when steam valve open and CHW valve closed
  - Count CHW savings when CHW valve closed & cooling occuring
  - What is duration of issue and savings?

Leaking CHW Valve:
Key Assumptions, Inputs, & Parameters

- Important to state key assumptions!

Input Parameters & Key Assumptions		
Steam System Delivery Efficiency	85%	
Chiller System Delivery Efficiency	90%	
CHW Plant Electric Efficiency	0.60	kW/ton
Estimated Avg RA Temp	72	F
Fan Full-load Power	124.8	bhp
Fan Full-load Power	101.2	kW
Affinity Exponent for Supply Fan	2.5	
Electric Avg Unit Cost	$0.075	$/kWh
Steam Avg Unit Cost	$13.00	$/MMBtu
*CHW savings only when PHT>DAT & CHW valve closed		
*Steam savings only when steam valve open & CHW closed		

Leaking CHW Valve: Energy Savings Calculations

Min	26	32,534	0	0	62	0	50	0	0	0.0
Max	68	50,133	100	100	131	100	64	3,038,072	3,038,072	73.8
Average	46	39,623	100	41	87	100	60	1,159,778	1,159,538	27.3
Date / Time	**OA-T (F)**	**SF-FLW (cfm)**	**1-3-VLV (% open)**	**2-3-VLV (% open)**	**PH-T (F)**	**CLG-VLV (% open)**	**DA-T (F)**	**Steam Q (Btu/hr)**	**CHW Q (Btu/hr)**	**Calc'd Lkg dT (F)**
10/24/12 10:00:00 AM EDT	51.3	46,117	48	0	86.7	0	60.5	1,305,175	1,305,175	26.2
10/24/12 10:15:00 AM EDT	51.1	46,362	52	0	84.4	0	59.7	1,237,455	1,237,455	24.7
10/24/12 10:30:00 AM EDT	51.3	46,441	57	0	86.6	0	60.1	1,330,468	1,330,468	26.5
10/24/12 10:45:00 AM EDT	51.3	46,454	53	0	87.0	0	60.3	1,342,459	1,342,459	26.8
10/24/12 11:00:00 AM EDT	52.0	46,180	48	0	86.8	0	60.3	1,323,816	1,323,816	26.5
10/24/12 11:15:00 AM EDT	51.5	46,418	49	0	84.2	0	59.9	1,220,987	1,220,987	24.4
10/24/12 11:30:00 AM EDT	51.8	46,667	53	0	125.5	0	68.8	2,857,928	2,857,928	56.7
10/24/12 11:45:00 AM EDT	52.2	46,416	0	0	68.2	0	53.7	0	724,841	14.5
10/24/12 12:00:00 PM EDT	51.7	46,815	0	0	62.7	0	51.0	0	591,280	11.7
10/24/12 12:15:00 PM EDT	51.9	47,003	0	0	61.9	0	50.6	0	573,066	11.3
10/24/12 12:30:00 PM EDT	52.1	46,692	0	0	61.7	0	50.4	0	569,220	11.3
10/24/12 12:45:00 PM EDT	52.6	46,565	0	0	61.9	0	50.4	0	577,774	11.5
10/24/12 1:00:00 PM EDT	52.8	46,672	0	0	61.9	0	50.4	0	579,104	11.5
10/24/12 1:15:00 PM EDT	53.1	46,767	100	100	119.7	0	61.6	2,936,158	2,936,158	58.1
10/24/12 1:30:00 PM EDT	53.1	46,728	0	41	83.9	0	59.9	1,212,941	1,212,941	24.0
10/24/12 1:45:00 PM EDT	53.7	46,709	0	47	87.8	0	59.7	1,418,251	1,418,251	28.1
10/24/12 2:00:00 PM EDT	53.4	47,062	0	49	87.8	0	59.9	1,420,097	1,420,097	27.9
10/24/12 2:15:00 PM EDT	53.9	46,887	0	44	88.9	0	60.7	1,428,850	1,428,850	28.2

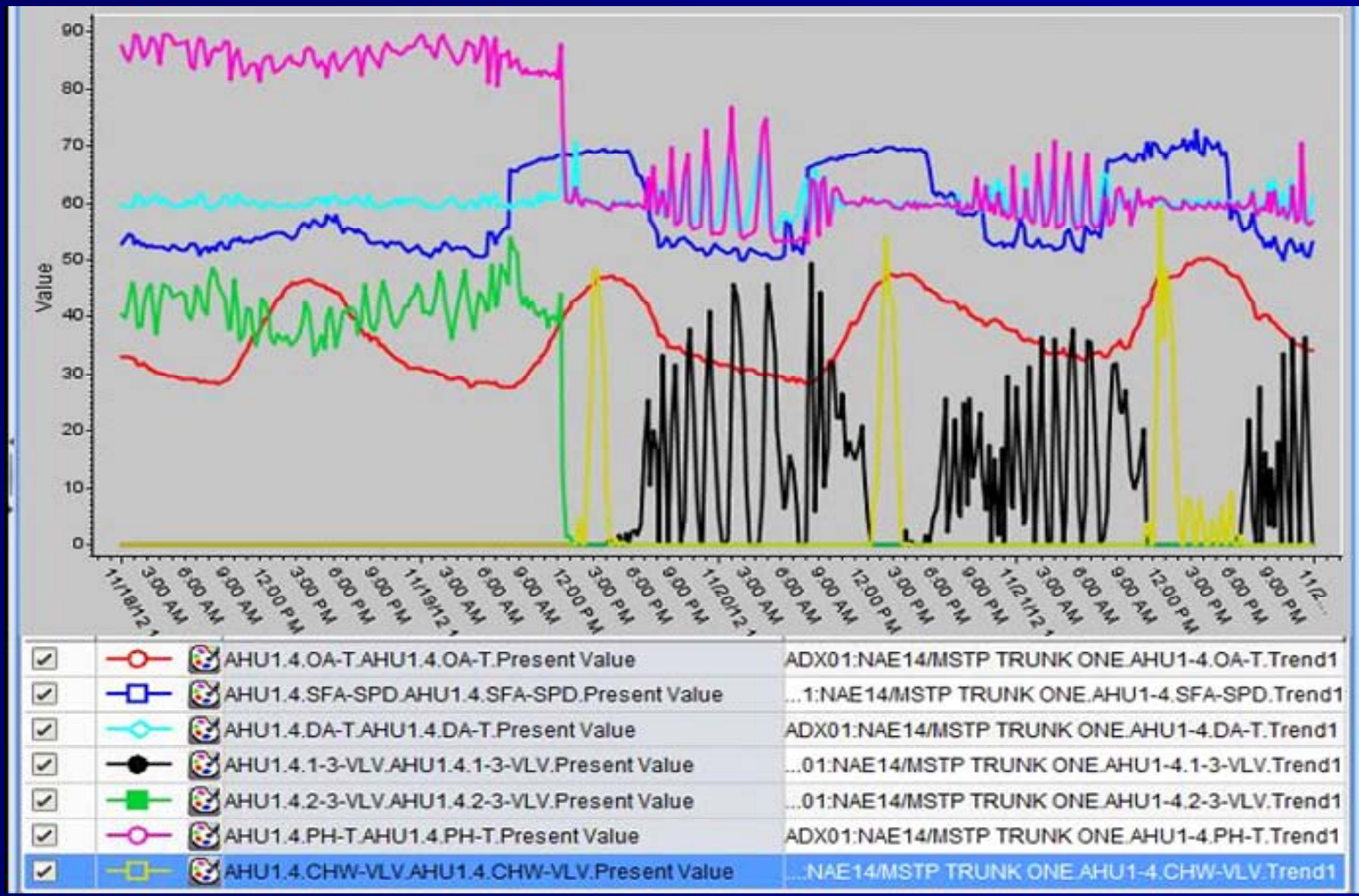
Leaking CHW Valve:
Energy Savings & Project Economics

- Present energy savings in energy units and costs
- Annualize savings when possible
- Perform cost estimate for implementation/repair

Improper Cooling Valve Wasted Energy		
Avg dT between PHT & DAT for past month	27.3	F
Wasted CHW energy for month to date	778	MMBtu/yr
Wasted steam energy for month to date	823	MMBtu/yr
Months savings applied to for year	5.0	months/yr
Annualized Chiller Energy Savings	3,888	MMBtu/yr
Annualized Chiller Energy Savings	324,040	ton-hrs/yr
Annualized Chiller Energy Savings	**194,424**	**kWh/yr**
Annualized Chiller Cost Savings	$14,582	
Annualized Steam Energy Savings	**4,117**	**MMBtu/yr**
Annualized Steam Cost Savings	$53,524	
Total Cost Savings	**$68,106**	

ISB-4: AHU 1.4 - Faulty Cooling Valve Actuation		
Annual Steam Energy Savings	4,117	MMBtu/yr
Annual Steam Cost Savings	$53,524	$/year
Annual Electric Energy Savings	**194,424**	**kWh/year**
Average Demand Reduction	22.2	kW/month
Annual Electric Cost Savings	$14,582	$/year
Total Cost Savings ($/year)	$68,106	$/year
Estimated Implementation Cost	$1,200	
Project Simple Payback (years)	0.02	years
Project ROI	5675%	

Leaking CHW Valve: Implementation & Verification



EBCx Case Study Summary

EEM	EEM Name	Electric Demand Savings (kW)	Electric Energy Savings (kWh/yr)	Electric Cost Savings ($/year)	Steam Savings (MMBtu /yr)	Steam Cost Savings ($/yr)	Total Cost Savings ($/yr)	Project Cost Estimate ($)	Simple Payback (years)
Science Building									
SB-1	Fan Speed Reduction on AHU 2.1 & 2.2	9.1	79,996	$6,000	0	$0	$6,000	*$3,000*	0.5
SB-2	Repair Steam Valve on AHU 2.2	19.4	169,783	$12,734	4,193	$54,509	$67,243	*$2,100*	0.0
SB-3	Repair Cooling Valve on AHU 2.1	3.8	33,329	$2,500	426	$5,538	$8,038	*$900*	0.1
SB-4	Repair Cooling Valve on AHU 1.4	22.2	194,424	$14,582	4,117	$53,521	$68,103	*$1,200*	0.0
SB-5	Optimize Heat Wheels on AHUs 1.1-1.4	11.9	103,809	$7,786	0	$0	$7,786	*$8,800*	1.1
Subtotals		*66.4*	*581,341*	*$43,601*	*8,736*	*$113,568*	*$157,169*	*$16,000*	*0.1*
Research Center									
RC-1	Install VFDs on EFs & Reduce Airflow	42.0	365,400	$27,405	0	$0	$27,405	*$75,977*	2.8
RC-2	Install VFDs on HW Reheat Pumps	11.0	96,557	$7,242	0	$0	$7,242	*$19,173*	2.6
RC-3	Install VFDs on HW Radiation Pumps	4.4	25,898	$1,942	0	$0	$1,942	*$16,049*	8.3
Subtotals		*57.4*	*487,855*	*$36,589*	*0*	*$0*	*$36,589*	*$111,199*	*3.0*
Grad Research									
GR-1	AHUs 8 & 16: Repair Steam Valves & Return Units to Normal Schedule	0.0	59,643	$4,473	1,015	$13,195	$17,668	*$3,800*	0.2
Subtotals		*0.0*	*59,643*	*$4,473*	*1,015*	*$13,195*	*$17,668*	*$3,800*	*0.2*
OVERALL TOTALS		**124**	**1,128,839**	**$84,663**	**9,751**	**$126,763**	**$211,426**	***$130,999***	**0.6**