Pacific Energy Center's Retro-Commissioning Workshops:

Developing Expertise through Interactive Training

Ryan Stroupe, Pacific Energy Center
Virginia Waik, City of Palo Alto
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Blair Horst, Lawrence Livermore National Lab

NATIONAL CONFERENCE ON BUILDING COMMISSIONING

April 21, 2006
San Francisco, California

the Pacific Energy Center

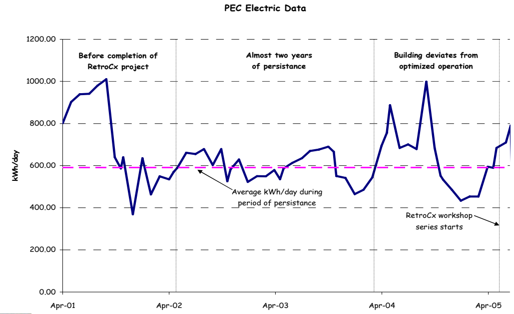
Pacific Energy Center

- 32,000 sq foot facility in San Francisco
- Offers free (publicly-funded) services
  - Classes
  - Tools
  - Consultations
- Opened and commissioned in 1991
- Retro-commissioned in 2001-2002
  - Reduced energy use by 25%
  - Many action items not addressed
    - Functionality as demonstration facility
    - Thermal comfort
    - EMS limitations

Genesis of Retro-Cx Workshop

- Many contributing reasons for workshop series
  - Regular students were asking for more hands-on
  - No training available on actual Cx activities
  - Concept complimented existing curriculum
  - Energy savings was not persisting
  - Class materials to supplement existing documentation
  - Opportunity to work with Dave Sellers and PECI
- First workshop series begins in May of 2005

PEC Electric Power Data



Class Structure

- Students required to take pre-requisite: "Identifying and Assessing Common Retro-Cx Opportunities"
- Workshop size kept small to facilitate hands-on
- Monthly meetings
- Morning lecture
  - Cx process
  - System fundamentals
  - Building owners perspective
  - Developing system tests
- Afternoon lab
  - Benchmarking utility data
  - Setting up and analyzing trends
  - Updating problem log
  - Test procedures
- Findings reported out at end of each workshop

Problem Log

Identifier	Name	Description	Location	Date of Discovery
EMS -002	Chilled Water Valve Operating	Verify chilled water valve operation	ID Location	2005/08/08
Control System -003	Supply Air Temp	Calibrate supply air temperature AHU1	AHU1	2005/08/08
Control System -004	Check Chilled Water Supply Flow Switch	• Is Chilled water valve working properly at AHU 1	ID Location	2005/08/08
Control System -005	Chilled Water Supply Temperature Sensor	calibrate chilled water supply temperature sensor	ID Location	2005/08/08
Ducts		verify whether the 1" holes in the ducts has been repaired	AHU 1	2005/08/08
Control System -006		trouble shoot flow switch for chilled water loop	ID Location	2005/08/08
Pump		pump impellor work order	Basement level at the ice tank area	2005/08/08
Control System -007		verify minimum air flow the HVAC classroom	HVAC Classroom	2005/08/08
Ducts/Terminal Units		• Balance VAV boxes 1-8 and 1-3	Varies - ID specific locations	2005/08/08
Control System -005		check the settings in the Tracer system for the VAV settings above	HVAC Classroom	2005/08/08

Project Examples

- Benchmarking and Trend Data, Virginia Waik
- Heating Hot Water Loop, Rishabh Kasliwal
- Pump Impellor Trimming, Blair Horst



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Benchmarking & Trending

Virginia Waik, City of Palo Alto Utilities

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www.cpau.org

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Why Look at Your Building Metrics?

US potential: $18 Billon in Annual *Energy Saving*
Increase Occupant *Comfort*

First Steps : Get to know your own building

-Site Assessment : Plans, Walk through, interviews, doc.
-Benchmarking: Cal Arch & Energy Star
-Trending : Excel, Energy Management Systems

Bridge gap between problem identification & solutions

Site Assessment of the PEC

Building Details

1990 building gutted and rehab
Office & Education, San Francisco
Area : **26,000 ft²** (613 max occ)
Garage: 6000 ft²

Building Operation

Mon – Fri: **7 am- 7 pm**
Sat -Sun : occasional events
Kitchen : 4 am as required
Design : T_{space} **72⁰F - 74⁰F**

Building Systems

DX Chiller & NG Boiler
Roof top **AHU**
Second Floor AHU
Primary & Secondary Loops

DDC Control & Energy Management System
Variable Air Volume
Thermal Energy Storage

Innovation in RCx Training

First hand experience of obstacles

- Really cool tools
- Safe environment to ask questions & try out ideas
- Direct exposure to operating equipment
- Full Circle: Identify problems, test, interpret findings, use common sense, work orders, specs, presentations
- Alternative approaches to resolution
- Handling data, information, records management
- ***Immediately useful***

Benchmarking
Comparing Your Site to Others

Building metrics:
- Annual Energy Use
- Location, Activity, Operating Hours
- Size & Age

Benchmarking & Trending Tools
- Cal Arch
- Energy Star
- Excel

Cal Arch - California Building Energy Reference tool

www. http://poet.lbl.gov/cal-arch

We entered 2004 data for PEC

Cal Arch - Benchmarking

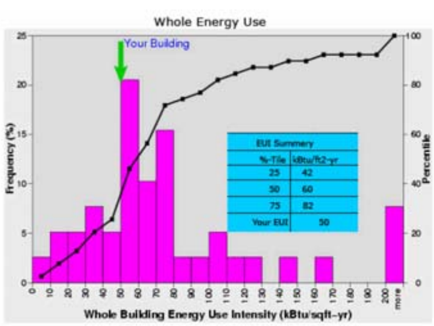
6 inputs

- Principal Activity
- Floor Area
- Annual Energy
- Zip Code

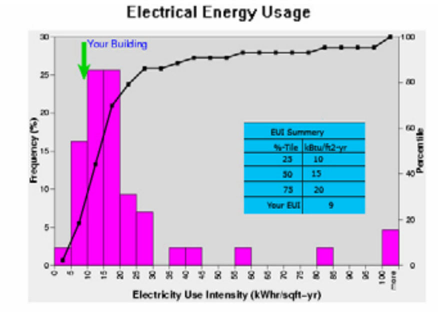
Evaluation preference

Preferred Graph type

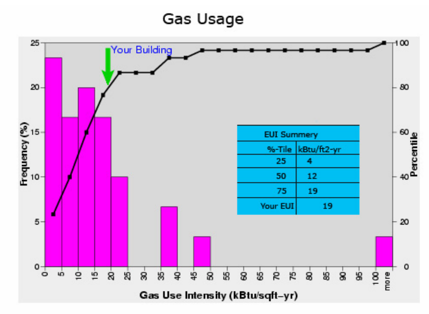
Cal Arch – PEC Whole Building

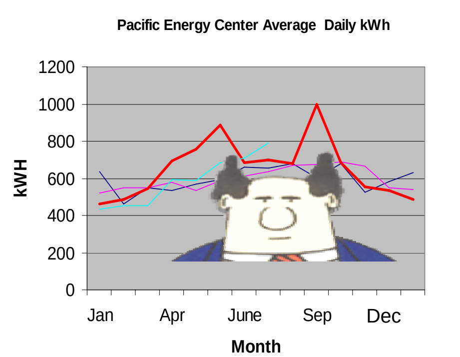


Cal Arch – PEC Electricity



Cal Arch – PEC Gas Use





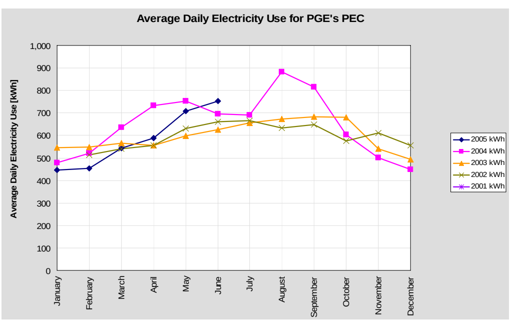
Trending with Excel

Project Name	PG&E's PEC
Utility Type	Electricity
Utility Units	kWh
Utility Company	PG&E's PEC
Account Number	
Meter Number	567*****

GAS Use					Electricity Use		
Date & Time	Billing Data	Calculated Duration in Days	Input Duration in Days	Average Daily Use in Billing Period	Off Peak	Mid Peak	On Peak
12/10/04	406	30	0	13.53	6880	7680	0
11/10/04	207	9	0	23.00	2080	2720	0
11/01/04	0	20	0	0.00	5280	2880	2880
10/12/04	217	29	0	7.48	10880	4480	4640
09/13/04	787	33	0	23.85	19520	6720	6400
08/11/04	67	29	0	2.31	11680	4160	3840
07/13/04	288	29	0	9.93	10880	4800	4800
06/14/04	445	33	0	13.48	12640	4960	4960
05/12/04	539	11	0	49.00	5760	2080	1760
05/01/04	0	18	0	0.00	6880	6880	0
04/13/04	466	32	0	14.56	13120	8960	0
03/12/04	421	30	0	14.03	8000	8320	0
02/11/04	408	30	0	13.60	7340	7520	0
01/12/04	521	32	0	16.28	8320	6720	0

Using Utility Bills and Average Daily Energy Consumption to Target Commissioning Efforts and Track Building Performance David Sellers

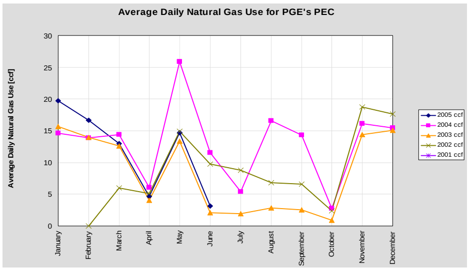
Trending: PEC Average Daily Electricity



Trending
Average Daily Use - Gas

Date & Time	Billed Usage, ccf	Calculated Duration	Input Duration in Days	Average Daily Use in Billing Period
12/10/04 12:00 PM	406	30.0	0.0	13.53
11/10/04 12:00 PM	207	9.0	0.0	23.00
11/1/04 12:00 PM	0	20.0	0.0	0.00
10/12/04 12:00 PM	217	29.0	0.0	7.48
9/13/04 12:00 PM	787	33.0	0.0	23.85
8/11/04 12:00 PM	67	29.0	0.0	2.31
7/13/04 12:00 PM	288	29.0	0.0	9.93
6/14/04 12:00 PM	445	33.0	0.0	13.48
5/12/04 12:00 PM	539	11.0	0.0	49.00
5/1/04 12:00 PM	0	18.0	0.0	0.00
4/13/04 12:00 PM	466	32.0	0.0	14.56
3/12/04 12:00 PM	421	30.0	0.0	14.03
2/11/04 12:00 PM	408	30.0	0.0	13.60
1/12/04 12:00 PM	521	32.0	0.0	16.28

PEC Average Daily Gas Use



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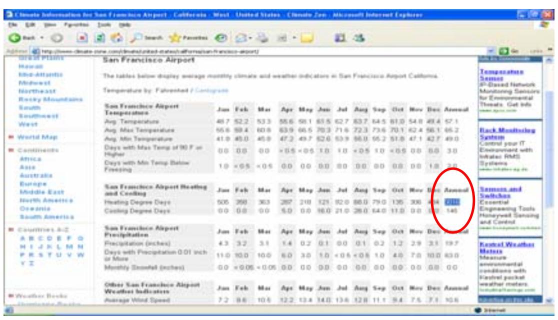
The next step - Enhancing Utilities Trending www.climate-zone.com



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Energy Star -Portfolio Manager

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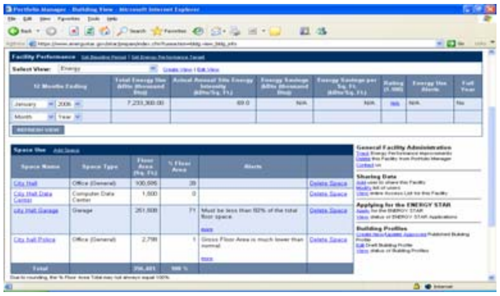
Energy Star -Portfolio Manager

https://www.energystar.gov



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Energy and Comfort Metrics

- Energy Use Intensity (kWh/ft^2/yr)
  - Heating EUI (kWh/ft^2/yr)
  - Cooling EUI (kWh/ft^2/yr)
    - Chiller (kW/ton)
    - Cooling Tower (kW/ton)
    - Cooling Load (tons/ft^2)
  - Lighting EUI (kWh/ft^2/yr)
    - Office Lighting EUI (kWh/ft^2/yr)
      - Lighting System (W/ft^2)
      - Area (ft^2)
      - Operation (hours/yr)
    - Corridor Lighting EUI (kWh/ft^2/yr)
      - Lighting System (W/ft^2)
      - Area (ft^2)
      - Operation (hours/yr)
  - Ventilation EUI (kWh/ft^2/yr)
  - Equipment EUI (kWh/ft^2/yr)
- Occupant Comfort
  - Thermal Comfort
    - Heating Min (°C)
    - Cooling Max (°C)
  - Visual Comfort
    - Illumination (lux)
    - Glare (lum-distribution)
  - Air Quality Comfort
    - Ventilation (cfm)
    - Stratification (Δ °C)

pier

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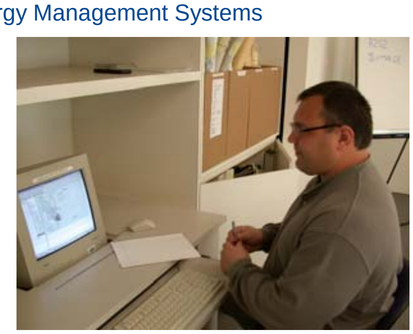
Trending – System Level

Energy Management Systems



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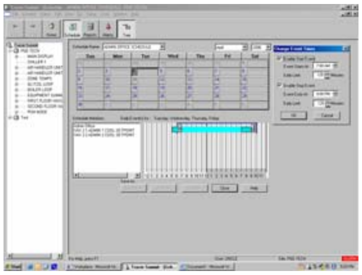
Trending – EMS

Schedules



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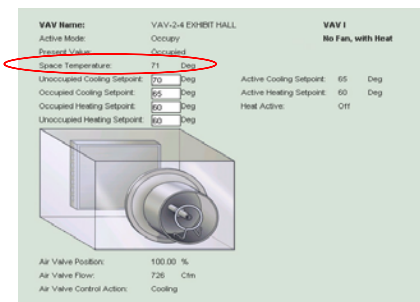
Looking at Set Points



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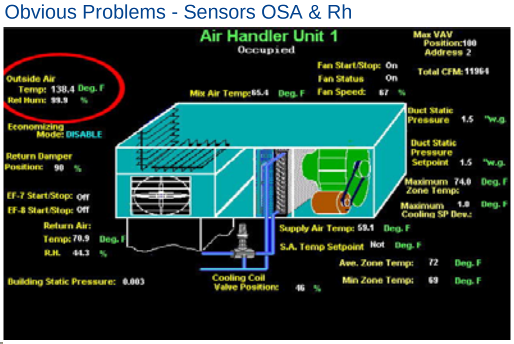
First Observations

Obvious Problems - Sensors OSA & Rh



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Creating EMS Trends

Could not discern true interaction of System components

- The process
- Tools
- Skill level
- Contractors

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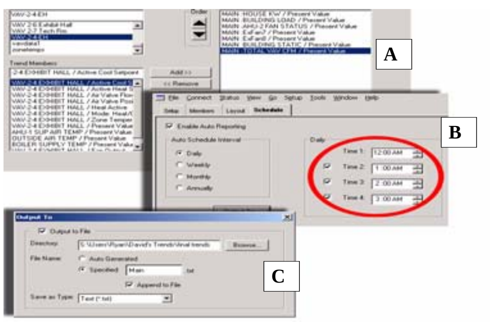
Creating EMS Trends



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EMS Trends Enhancement

Universal Translator: utonline.org

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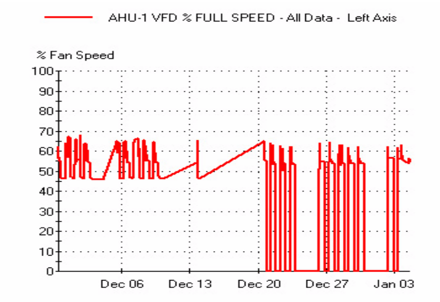
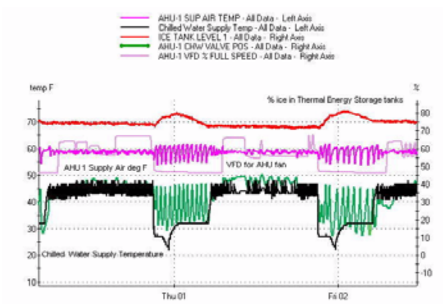
Looking at Scheduling



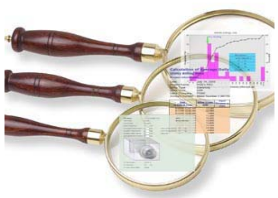
Looking at Multiple Trends



Web Resources

- PEC Center: http://www.pge.com/pec/
- Cal Arch: http://poet.lbl.gov
- Energy Star Portfolio Manager: https://www.energystar.gov
- Weather Info to refine bill analysis: www.climate-zone.com
- Public Interest Energy Research: http://www.energy.ca.gov/pier
- Universal Translator utonline.org
- LBL – Evan Mills Research: http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html
- PECI Utilities Billing Analysis: *Using Utility Bills and Average Daily Energy Consumption to Target Commissioning Efforts and Track Building Performance* (PDF 310kB) David Sellers -- Find this and more at www.peci.org

Summary - Conclusion



- Site Assessment
- Benchmarking
- Trending
  - Excel
  - EMS
    - Setpoints
    - Schedules
    - Interactions

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Start looking at your own building metrics
to find savings & comfort opportunities

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NATIONAL CONFERENCE ON BUILDING COMMISSIONING

Hot Water System Retro-Commissioning

Rishabh Kasliwal, Cogent Energy

April 21, 2006
San Francisco, California

the Pacific Energy Center

Hot Water Loop test

2006 Team Members (L to R)
Virginia Waik, Kristin Heinemeier ,
Sergey Makarenko, Rishabh Kasliwal

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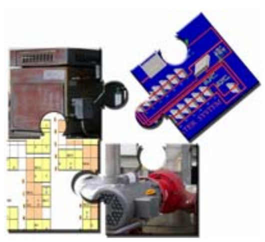
Executive Summary & Pieces of the Puzzle

- System Functional but has deficiencies
- More testing required to fully identify system performance
- Components
  - Boiler
    - Not able to operate per design conditions
  - HW Loop (Piping)
    - (15) 2-way valves and (3) 3-way valves
    - Little flow variation
  - HW System Pump
    - Pump Selection could have been better
    - Adequate performance
  - Zone conditions
    - Verified low temperatures in trouble zones



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Retro-Commissioning Plan

- Three step approach
  - Step 1: Understand the System
  - Step 2: Trend Based Functional Testing
  - Step 3: Manual Functional Testing

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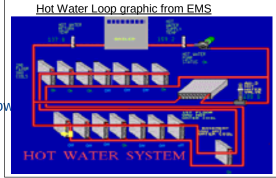
RCx Step 1: Understand the System

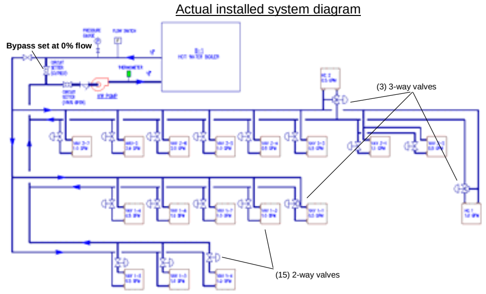
- Review available documentation
  - Mechanical Plans
  - Systems Manual
  - EMS graphics
- System walk through
  - Obtain name plate data
- Occupant interview to document know issues
- Create system diagram
- Identify obvious RCx issues

Hot Water Loop graphic from EMS



HW Loop – System Diagram

Actual installed system diagram

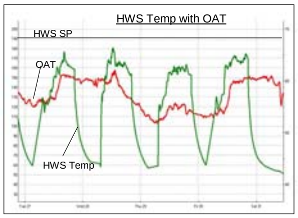


RCx Step 2: Trend Based Functional Testing

- Identify points to trend
  - HW Supply Temp
  - HW Return Temp
  - Pump status
  - Outside Air Temp
  - VAV 1-1 to 1-8 and VAV 2-1 to 2-7
    - Current mode (heating or cooling)
    - Zone temp
- Trend period
  - 5 weeks (December 4, 2005 to Jan 9, 2006)
- Trend interval
  - 1 min

RCx Step 2: Trend Based Functional Testing – Results (1)

- HW Loop is on a fixed schedule 7:00 AM to 9:00 PM, Mon - Fri
- Loop design conditions are HWST 190°F / HWRT 160°F
- Boiler is able to obtain a max. HWST of 180°F. Typical HWST is 160°F
- HWST is not reset based on OAT



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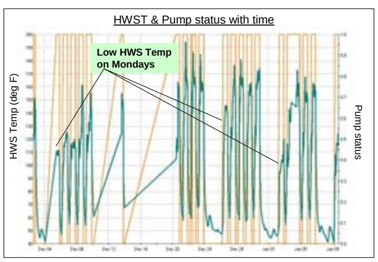
RCx Step 2: Trend Based Functional Testing – Results (2)



- HW Loop suffers from extended warm-up
  - It takes all of Monday to heat up the HW Loop !

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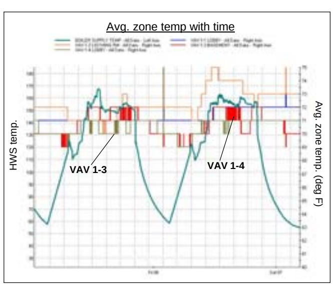
RCx Step 2: Trend Based Functional Testing – Results (3)



- Trends verify low space temperature in basement (trouble) zones i.e., VAV 1-3 & 1-4

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RCx Step 3: Manual Functional Testing

- Test Goals
  - Determine Boiler heating capacity and performance
  - Examine HW Pump size and flow capacity
  - Investigate pump performance at variable flow (load) conditions
  - Examine DAT at the most hydraulically remote coils from the boiler and the known trouble zones

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Designing the Procedure & Test

- Start off with the CHW Loop Functional Test template
- Utilized Functional Test Guide as a resource to writing tests

http://www.peci.org/ftguide/

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Test Procedure

- Will perform Six Tests with each test simulating a different load condition
- Gather following data for each test
  - **Boiler:** Combustion efficiency
  - **HW Pump:** Pump power, amps, motor speed, differential pressure (DP) to correlate to flow
  - **HW Loop:** HWST, HWRT
  - **Zones:** Set points, DAT at zones (diffusers)

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The Six Tests

1. As Found
2. Shut Off Test
   - Shut off the discharge valve
   - Verified pump curve and amps
3. Full Open Test
   - All 18 valves set to full open
   - Verified boiler capacity
   - Observed some flow variation
4. Full Closed Test
   - All 18 valves set to full close
   - Flow variation less than expected
5. 1/3rd Open Test
   - Little flow variation
   - Verified low DAT in trouble zones
6. 2/3rd Open Test
   - Verified low DAT in trouble zones

Test Findings (1) – HW Pump performance

- Shut off test to determine pump curve & impeller
- Note pump selection could have been better
- Note curve is flat and thus DP to Flow correlation is somewhat inconclusive

Test D	Design
Test 1	As-found
Test 2	Shut-off
Test 3	All open
Test 4	All closed
Test 5	1/3 open
Test 6	2/3 open

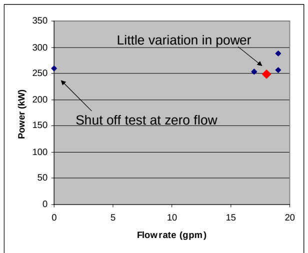
Test Findings (1) – HW Pump performance continued

- Verified pump impeller at 4.875"
- Maximum flow is close to total coil capacity
- Flow rate does not vary significantly (but remember curve is flat and DP readings are very close)
- It is possible that bypass exists or 2-way valves leak resulting in little flow variation

		DP	GPM	Watts	dT	btu/hr	
Test 2	Shutoff	23.99	0		30		
Test 4	all closed	23.33	17	254	38	323,000	
Test 1	As-Found	23.33	17	254	36	306,000	
Test 5	1/3 open	22.99	19	257	30	285,000	Most reliable capacity
Test 6	2/3 open	23.99	0	260			Unreliable
Test 3	all open	22.90	19	288	46	437,000	
	Rated	23.00	18	249		195,000	
	Design	22	13				

Test Findings (1) – HW Pump performance continued

- Pump power measurements – amps, watts



Measuring power at the panel

More measurements – Pump RPM and Amps

Strobe meter to measure motor RPM

Amp meter to measure motor amps

Test Findings (1) – HW Pump power performance summary

- Power does not vary significantly
- It is possible that the motor is inefficient at low loads, and that little kW variation is expected even with flow variation
  - Measured amps at shut off: 6.06 amps
  - Measured amps as found: 6.12 amps
    - Little variation: power is not a reliable indicator of varying flow

Test Findings (2) – Boiler Capacity and Performance

- Boiler Capacity – seems higher than nominal rating, but may be within uncertainty of readings
- HW Supply and Return temps are lower than design
- EMS readings are within 10% of field measurements
- HWRT is about **130°F** which means the coils "see" at least **130°F** water

		DP	GPM	Watts	dT	btu/hr	
Test 2	Shutoff	23.99	0		30		
Test 4	all closed	23.33	17	254	38	323,000	
Test 1	As-Found	23.33	17	254	36	306,000	
Test 5	1/3 open	22.99	19	257	30	285,000	Most reliable capacity
Test 6	2/3 open	23.99	0	260			Unreliable
Test 3	all open	22.90	19	288	46	437,000	
	Rated	23.00	18	249		195,000	
	Design	22	13				

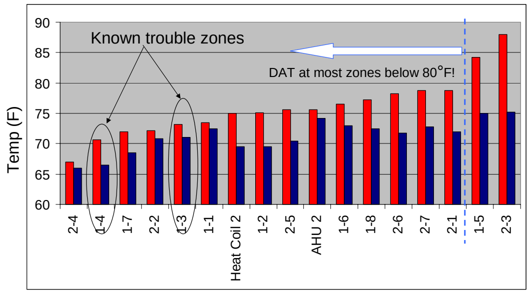
Installed boiler system

Test Findings (3) – Floor Plan & Zone Temperatures

Measuring DAT at the zone

Verified that hydraulically remote zones have depressed DAT

Test Findings (3) – Zone Temperatures continued



Max. (red) and Min (blue) zone temp observed

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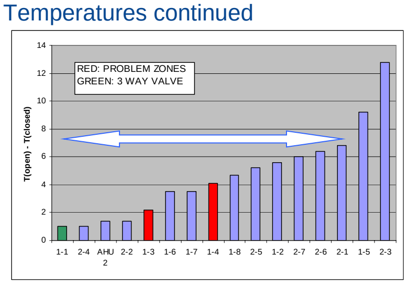
Test Findings (3) – Zone Temperatures continued



Less than 8°F differential in DAT with heating coil valve open and closed. Much less than typical variation of 25°-30°F.

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Test Findings (3) – Zone Temperatures summary

- All heating valves responded to call for heating
- Temperature differentials are not as high as expected (avg. 5 degrees against typ. 25°-30°F)
- Temperature Differentials in problem zones are relatively low
- DAT in problem zones are low

- Low DAT not due to excessive reheat air flow
- Low DAT could be a result of dirty coils

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Test Conclusions

- Boiler not performing per design criteria
  - Design: 190°F HWST, 160°F HWRT
  - Actual: 160°F HWST, 130°F HWRT (typical)
- Little variation in loop flow & pump power
  - Flat pump curve causes uncertainty in correlating DP to flow
  - Only 3 known 3-way valves in system
    - Possibility of unknown bypass
    - Possibility of leaky 2-way valves
- Depressed max. DAT and low space temperature variation
  - Possibility of dirty coils resulting in max. DAT of 80°F
  - Possibility of unknown bypass resulting in hydraulic short circuit
  - Depressed DAT not due to excessive reheat air flow

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Recommendation

- HW Loop performance could be determined with more testing
  - Investigate possible hydraulic crossover
    - Trace system loop to look for unknown mixing between supply and return piping
    - Investigate leaks at 2-way valves
  - Investigate possibility of scaling in coils
- Other O&M issues
  - HW Loop sensors need conductive paste
  - Consider sensor replacement or calibration

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Pacific Energy Center's
Retro-Commissioning Workshops:

Developing Expertise through Interactive Training

NATIONAL CONFERENCE ON BUILDING COMMISSIONING

Chilled Water Pump Testing and Remedial Action Saves the PEC $1,500 per year!

Blair Horst, PE, CEM, GBE
Lawrence Livermore National Lab

April 21, 2006
San Francisco, California

the Pacific Energy Center

Chilled Water Pump Testing and Remedial Action

History of the PEC & HVAC Systems

Initial Retro-Commissioning in 2002
(Ross Sherrill Engineering)

- **CHW pumps throttled to 53-gpm each, 106-gpm total**
- **Changed: operate 1 pump in lead-lag, no throttling; cooling load satisfied adequately**

Retro-Commissioning Workshop (2005-2006)

- **Investigated design & operating history**
- **Conducted Pump Test**
- **Evaluated alternatives**
- **Modified Pump**
  - » **Improved operations**
  - » **Saved Energy**

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Chilled Water Pump Testing and Remedial Action

Discovering the Opportunity

Design:

- **CHW flow of 106-gpm at 110-Ft. W.C. TDH**
- **2-pumps operating**

Investigate design parameters:

- **Review design documentation**
- **Tour; review existing systems operations**
- **Discuss operations with facility personnel**
- **Prepare problem log for findings to be investigated**

Evaluate pump selection:

- **Verify flow and head**
  - » **Rough check of pump head needed**
  - » **Rough check of flow required**

TDH = Total Discharge Head, Feet – Water Column (Ft W.C.)

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Chilled Water Pump Testing and Remedial Action

Discovering the Opportunity

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  - » **Rough check of flow required**

CHW = Chilled Water TDH = Total Discharge Head, Feet – Water Column (Ft W.C.)

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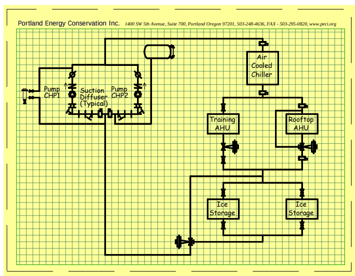
Chilled Water Pump Testing and Remedial Action

PEC Chilled Water System Diagram



Chilled Water Pump Testing and Remedial Action

PEC Chilled Water System Diagram

Design Head Loss = 106-Ft W.C.

Calculated head loss = 55.3-Ft W.C. about 50% of the design value ➔ ***we have an opportunity!***

Conduct pump test to:

- Develop system curve
- Quantify operating characteristics

Check Pump Head Needed

Pipe		**Length Ft**
2 floors; allow 12-ft each		24.0
Top of AHU-1		10.0
Basement; allow		8.0
Subtotal Elevation Diff		42.0
Supply & Return Pipe		84.0
Elbows	13-Ea	65.0
X-Y plane offsets		24.0
Pipe, Equivalent Length		173.0
Head Loss		**Ft. W.C.**
Piping Allowance		5.7
Contingency	20%	1.1
Cooling Coil	5 psi	11.5
Chiller	10 psi	23.1
Ice Depth	3 psi	6.9
Tri Svc Vlv	3 psi	6.9
Total System Pressure Drop		**55.3**

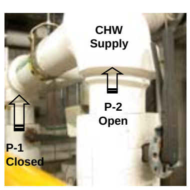
Check Flow Needed 10-gpm ➔ ok

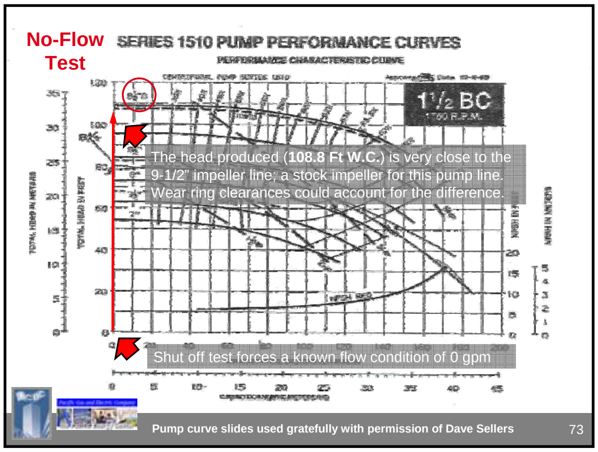
AHU = Air Handling Unit psi = pounds per square inch gpm = gallons per minute

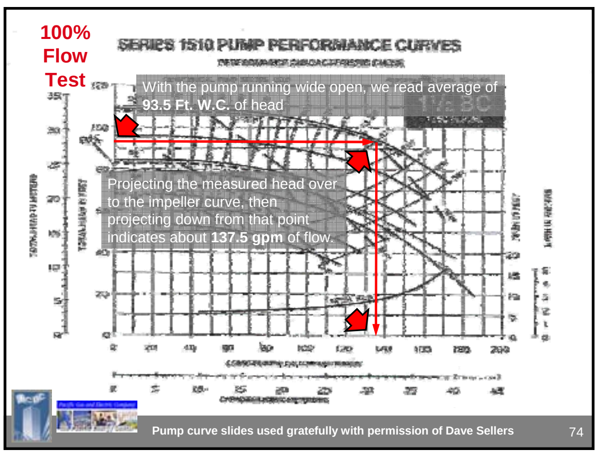
Chilled Water Pump Testing and Remedial Action

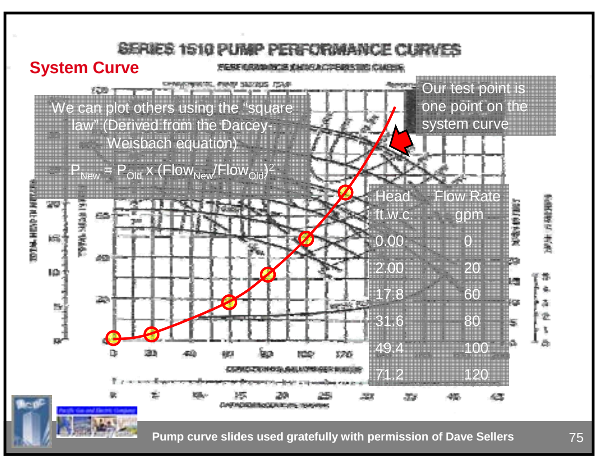
Conduct Pump Test

- Control: Pump P-2 in lead
- Assure Pump P-2 is operating
- Assure Pump P-1 is isolated
- Lock & Tag-Out Breaker









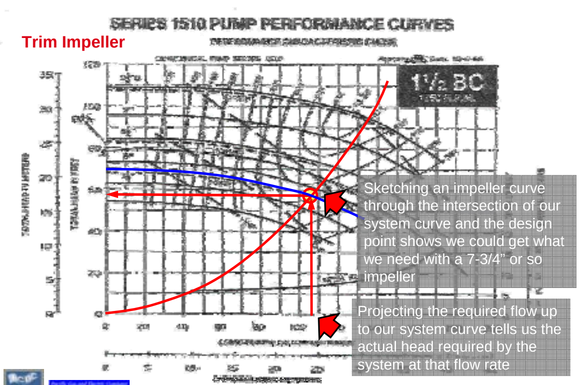
Head ft.w.c.	Flow Rate gpm
0.00	0
2.00	20
17.8	60
31.6	80
49.4	100
71.2	120

Chilled Water Pump Testing and Remedial Action

Develop & Evaluate Alternative Solutions

- ❑ Trim the existing impeller to smaller size
- ❑ Change to a lower speed motor
- ❑ Reduce rotational speed using a Variable Frequency Drive
- ❑ Throttle flow of the existing pump to the design flow rate

Trim Impeller



Chilled Water Pump Testing and Remedial Action

❑ Trim the existing impeller to smaller size

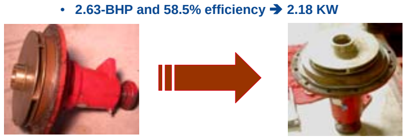
Reviewing pump curve:

Intersection of Design Flow with System Curve

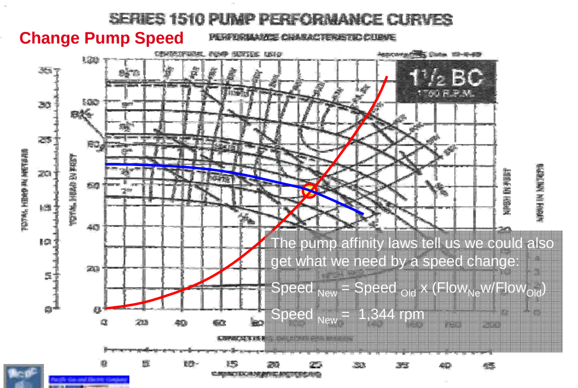
→ Impeller trimmed to 7-3/4-inches diameter

Operating Parameters:

- Flow = 106-gpm
- Pumping head = 57-Ft. W.C.
- 2.63-BHP and 58.5% efficiency → 2.18 KW



Change Pump Speed



Pump curve slides used gratefully with permission of Dave Sellers

Chilled Water Pump Testing and Remedial Action

❑ Change to a lower speed motor

Reviewing pump curve & affinity laws:

Speed New = Speed Old x ($Flow_{New}/Flow_{Old}$) = 1,344 rpm

Performance is predicted based on pump affinity laws:

$GPM_{NEW} = GPM_{OLD} \times (RPM_{NEW} \div RPM_{OLD})$, Solving for RPM_{NEW}:

$RPM_{NEW} = RPM_{OLD} \times (GPM_{NEW} \div GPM_{OLD})$ ➔ 1750 x (137.5 ÷ 106) = 1,349 RPM

$BHP_{NEW} = BHP_{OLD} \times (RPM_{NEW} \div RPM_{OLD})3$ ➔ 4.65 x (1,349 ÷ 1,750)3 x 0.746 = **1.76 KW**

While this alternative shows the <u>most energy savings</u> it is <u>not feasible due prohibitive cost</u> ;

- » **Pump & Motor are a unit & costly**
- » **Replacement requires piping reconfiguration**
- ➔ **would be prohibitively expensive**

Chilled Water Pump Testing and Remedial Action

❑ Reduce rotational speed using a Variable Frequency Drive

An alternative method of changing rotational speed

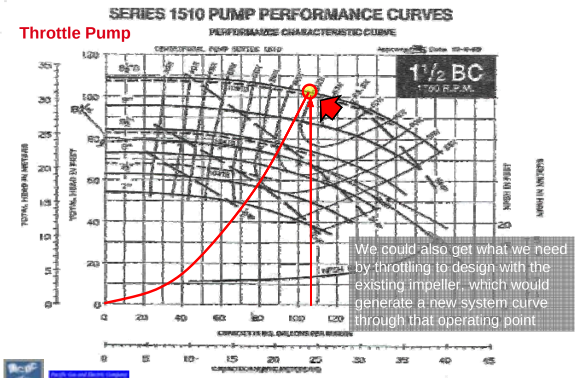
Savings similar to changing to a lower speed pump/motor

Additional efficiency losses from VFD ➔ 1.86 KW

While this alternative shows high energy savings it is also <u>not feasible due prohibitive cost</u> ;

- » **Pump & Motor are a unit & costly**
- » **Replacement requires piping reconfiguration**
- » **Actual flow doesn't vary much during the day, and**
- ➔ **would be prohibitively expensive**

Throttle Pump



Chilled Water Pump Testing and Remedial Action

- ❑ **Throttle flow of the existing pump to the design flow rate**

  Reviewing pump curve:

  ➔ Flow throttled to design flow rate

  Operating Parameters:
  - **Flow = 106-gpm**
  - **Pumping head = 100.9-Ft. W.C.**
  - **4.65-BHP and 61.8% efficiency ➔ 3.85 KW**

Chilled Water Pump Testing and Remedial Action

Table 1 – Summary Pump Modification Alternatives

Parameter	Base Case	Trim Impeller	Lower Speed w/ VFD[5]	Throttle Flow
Impeller Size (Inches – Diameter)	9½"	7-3/4"	9½"	9½"
Rotational Speed (RPM)	1,750-RPM	1,750-RPM	1,349-RPM	1,750-RPM
Flow Rate (gpm)	137.5-gpm	106.0-gpm	106.0-gpm	106.0-gpm
Pumping Head (Ft. W.C.)	93.5-Ft. W.C.	55.0-Ft. W.C.	Not Calculated	100.9-Ft. W.C.
Pump Break Horsepower (BHP)[1]	5.00-BHP	2.63-BHP	2.13-BHP	4.65-BHP
Pump Power Demand (kW)[2]	4.14-kW	2.18-kW	1.86-kW	3.85-kW
Annual Power Use (kWH/Yr)[3]	18,115-kWH/Yr	9,529-kWH/Yr	8,161-kWH/Yr	16,847-kWH/Yr
Annual Power **Cost** ($ / Year)[4]	$2898 / Year	**$1,525 / Year**	**$1,306 / Year**	$2,696 / Year

Notes
1. Values interpolated from pump curve, Figure 4.
2. Electric demand (kW) is calculated assuming motor efficiency of 91.2%.
3. Annual power use is determined from 4,380-hours per year operations based on PEC trend data.
4. Annual electric power costs are based on the PEC's average rate during 2005 0f $0.16 / kWH.
5. Calculations include an added efficiency reduction of 5% due to internal losses of the VFD.

Chilled Water Pump Testing and Remedial Action

- Disassemble Pump
- Remove impeller

- Take impeller to machine shop with dedicated, digitally controlled, grinding machine
- Grind impeller to a 7-3/4" diameter and dynamically rebalance

Chilled Water Pump Testing and Remedial Action

- **Replace the pump seal and gasket**
  - Existing pump seal has about a 10-year life; half consumed
  - Makes sense to replace it as pump is already opened
  - Pump life is extended

Chilled Water Pump Testing and Remedial Action

- **Reprogram lead-lag controls**
  - Place pump P-1 in **lead**-always position
  - Place pump P-2 in always-**lag** position

  Since only pump P-1 impeller was trimmed, this step assures the most efficient pump is always in lead position.
- **Restart the chilled water distribution system**

  follow normal procedure

Chilled Water Pump Testing and Remedial Action

Bottom Line

Pump Impeller Trimmed – Implementation Cost		$2,479
Electric Demand Savings	1.96 KW	
Electric Energy Savings	9,529 kWH / year	
Annual Power Cost Saved	**$1,525** @ $0.16/kWH blended 2005	

Simple Payback Period — 1.8 years

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