AUTOMATIC CONTROLS - BASIC TO COMMISSIONING

Presented to

MONTREAL ASHRAE CHAPTER

Presented by

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New System Review

- New &/or modified HVAC systems
- New &/or modified control systems
- Convert from pneumatic or electric to DDC
- Systems operate 10 hour/day to 24/7/52
- Commission all systems for known performance
- Ensure ALL systems function properly

Why Controls Are Critical

- Must have continuous and stable operation
- Need records of performance (for utility company rebates and management)
- All items need to be "talking" to each other
- Want records of operation for 24 hours a day – to ensure proper calibration and performance
- Desire repeatable operating strategies – continue with the same after confirmed

Cooling System(s) Information

- From Constant to Variable Flow Chilled Water
- All chillers operated at Full Flow all the time and very low DT most of the time: at average = 20%, ~2 deg DT
- Minimum year-around Base Load in some buildings
- Buildings conditioned by
  - HW/electric cooling units – IF they had cooling
  - HW/CHW units for some critical areas
  - HW heating only

Pumping System

a. Verify selected pump operational information.

b. Manipulate the HW system DP and confirm satisfactory pump speed and DP control.

c. Read the HW DP and the HWP VFD signal (% speed), which should be between 25-85%.

d. Watch the positioning of the Boiler 3-way diverting valve as the HWST setpoint is varied.

Pumping System - Cont'd

e. Read the position of the 3 way diverting valve, which maintains flow and min temp to boiler.

f. Note also the 2-way system cross-over minimum flow control valve. This valve modulates as needed to provide minimum flow for the system pump to continue operating when the flow reaches the minimum.

Pumping System - Cont'd

g. Perform a dead head test of each pump, to confirm that the proper impeller is installed.

h. On the operating HHWP, test the DP across the strainer and verify that the strainer is clean and the system flow meter confirms proper total flow exists.

i. Leave all control valves and fan coil unit controls in operation, calling for full heat, and proceed with the fan coil unit testing.

Confirm Operation of VAV & CAV Systems

a. Randomly choose a sample AHU on which to perform this test. If the chosen system fails the test, you may choose to test another unit in the same manner, to confirm correct approach.

b. Shut off the unit with the HOA switch and confirm that the OA and EA dampers close, the RA damper opens and the unit supply and return fan stops.

Confirm Operation of VAV & CAV Systems – Cont'd

c. Restore the unit to operating mode. With the unit in full operation, check the economizer cycle for correct operation.

d. With the coil modulating control valve fully open, read the air temperatures entering and leaving the coil to confirm the air DT.

e. Observe the Air Handler system operating to maintain comfort level, by logging periodically.

Confirm Operation of VAV & CAV Systems – Cont'd

f. If desired, have someone trip the ATFP alarm and validate proper operation of that alert system.

g. Confirm that the units shut off and the ATFP dampers close tight.

h. If desired, compare the temperature readings with the EMS readings.

Confirm Operation of VAV & CAV Systems – Cont’d

i. Ask the DDC rep to confirm the presence of a unit operational alarm and the system’s return to normal following the alarm signal reset.

j. Have the ATFP alarm signal cleared (reset) and observe the system restart. (Note that there will be a delay before the ATFP damper opens and note that the damper must open fully before the fan starts.)

Confirm Operation of VAV & CAV Systems – Cont’d

k. Confirm that the EMS properly identifies the alarm and that the AHU system shuts down when the alarm is activated; and validate the alarm reset and system re- start activities.

Confirm Operation of VAV & CAV Systems – Cont’d

l. Since these units have been equipped with a new minimum outside air control sequence of operation, it may be desired to spend some extra time validating the good control of minimum outside air through all modes of operation. This can be checked on the trend logs also.

Confirm Operation of VAV & CAV Systems – Cont’d

m. Ensure that the unit’s controls think that the outside air temperature (enthalpy) exceeds the return air temperature (enthalpy), thereby placing the damper control in the minimum OA position.

Confirm Operation of VAV & CAV Systems – Cont'd

n. Check the damper control and read the air flow to confirm proper control of the outside and return air dampers. (Note that the exhaust air damper may be converted to two-position operation to greatly improve system performance and stabilize the return air damper and return fan speed control.)

Exhaust Fans

a. Randomly select 1 thermostatically controlled exhaust fan for the final test.
b. Turn the thermostat up or down, to confirm that the fan stops and starts properly.
c. Confirm that the EMS properly indicates the operation.
d. It may be desired to have the EMS control the EF operation.

Domestic Hot Water System

a. Select the desired hot water test faucet and open it fully. Confirm that the water reaches temp within the specified time (5-10 seconds).

b. Select a faucet closest to the mechanical room, and turn on the hot water faucet and let run for approximately 5 minutes to confirm that the water temperature does not exceed desired temperature.

Domestic Hot Water System– Cont'd

c. If one is present, validate that the eye wash shower discharges desired tepid water.

d. Test the system capacity by turning on all or nearly all hot water faucets and leave open for 30 minutes to confirm that the water temperature remains at set point.

Boiler System

- Open all unit control valves, to provide full load on the boilers, to verify the desired DT.
- Turn off boiler alarm switch to confirm boiler shuts off.
- Confirm that the EMS indicates boiler alarm.
- Silence and acknowledge the boiler alarm and restore to normal operation.
- Verify selected EMS readout temperatures

Pumping Systems

- Verify selected pump operational information.
- Manipulate the HW system DP and confirm satisfactory pump speed and DP control.
- Read the HW DP and the HWP VFD signal (% speed), which should be between 25-85%.
- Watch the positioning of the 3-way diverting valve as the HWST setpoint is varied.

Pumping Systems– Cont'd

- Read the position of the 3 way diverting valve, which maintains flow and minimum temperature to the boiler.
- Note also the 2-way system cross-over minimum flow control valve. This valve modulates as needed to provide minimum flow for the system pump to continue operating when the flow reaches the minimum.

Pumping Systems– Cont'd

- Perform a dead head test of each pump, to confirm that the proper impeller is installed.
- On the operating HHWP, test the DP across the strainer and verify that the strainer is clean.
- Leave all control valves open and units in operation, calling for full heat, and proceed with the fan coil and air handling unit testing.

Validate the Performance of the Chiller and Cooling Systems

- If necessary, override the outside air cutout sensor to enable the chiller system. Confirm the proper start up sequence.
- Adjust the air handler supply air controllers to force the units to go into full cooling.
- After sufficient time for the system to stabilize, read air flow and temperatures to validate the conditions reported in the TAB report.

Confirm Operation of Split System Heat Pumps (SSHP)

- Note that the EMS only monitors space temperature and unit status on this unit.
- Ensure that the system is operating in Automatic.
- Shut off the unit with the HOA switch and confirm that the EMS initiates an alarm, indicating that the unit has failed.

Confirm Operation of Split System Heat Pumps (SSHP) – Cont'd

- Restart the unit.
- Request the DDC representative to confirm the presence of a unit operational alarm, from the above action and that the system returns to normal following the alarm signal reset.
- With the unit in full operation, read the inlet and outlet temperatures and applicable air flows.

Confirm Operation of Split System Heat Pumps (SSHP) – Cont'd

- If desired, validate temperature and/or amperage readings with the EMS readouts.
- Elevate the temperature setpoint to cause the unit to switch the reversing valve and enable the heating mode to reach the higher temperature.

Validate the System Performance When a CO2 High Level Signal is Received by the EMS

- If desired, override the CO_2 sensor to confirm that the EMS initiates a high CO_2 alarm and increases the air flow through the VAV box.
- If the alarm condition still exists after the air volume reaches maximum, confirm that the outside air damper positions to provide more outside air to purge the CO_2.

Confirm Operation of Exhaust Fans

- Randomly select 1 thermostatically controlled exhaust fan.
- Turn the thermostat up or down, to confirm that the fan stops and starts properly.
- If the EF is controlled by the EMS, confirm that it starts and stops properly to maintain the minimum and/or maximum desired temperature(s).

Domestic Hot Water System

- Validate that the eye wash shower works properly and that it discharges tepid water.
- Select the desired hot water test faucet and open it completely. Confirm that the water reaches temperature within the specified time (5-10 seconds?).

Domestic Hot Water System- Cont'd

- Select a faucet closest to the mechanical room, and turn on the hot water faucet and let run for approximately 5 minutes to confirm that the water temperature does not exceed the desired limit.
- Test the system capacity by turning on all or nearly all hot water faucets and leave open for 30 minutes to confirm that the water temperature remains at set point.

SAMPLE PVT PLAN

- Request the BAS contractor to leave all valves open all night, with HHWST set at 160 deg F, Air Handlers' HW control valves fully closed, and OA damper fully open with RA damper under mixed air box pressure/volume control operation. Read the room temperatures at the beginning of the PVT for this responsibility, to confirm approximate uniformity of temperatures and, therefore, the uniformity of the heating water flow and heating coil performance.

Sample PVT – Cont'd

- Perform a dead head test of each pump, to confirm that the proper impeller is installed.
- Commence this test only after the rooms are approximately 80-82 deg F, since that is the approximate temperature at which the systems were TABed. Set all control valves in their full open position and leave the pump in automatic DP control.

Sample PVT – Cont'd

- Move through the building and randomly select the right number of VAV or CAV box to test.
- Measure the air flow and the return and supply air temperatures, to obtain temperature differential across the coil.
- Ask the DDC representative to restore the unit controls to automatic control to enable the cooling system operation before proceeding to the next step.

Sample Projects

- UC Santa Barbara, in operation 19 years – PM Department expanded to include some smaller buildings with old chillers, vs buying new chillers
- SDCS District Wide, in operation 18 years
- UNR, just completed conversion to VPF and Virtual Central Plant, with central EMS operating total system

New Virtual Chiller Plant

- New 12" Piping Connects 8 Key Buildings
- Converted All HVAC Systems to 2-Way Control Valves = Good Diversity Now
- VFDs on All CHW Pumps = Better Control
- Serve All or Any Building(s) From All or Any Chiller(s) = Chillers Operating by Total System Load at the Time
- Sequence Chiller Systems with EMS Based on Load: Add by Low CHW DP; Subtract by Tons Load vs Operating chillers
- Variable Flow = Diversity At All Loads
- Use Most Efficient Chillers First – Abandon those Least Efficient = Reduced Energy

Some Key Issues

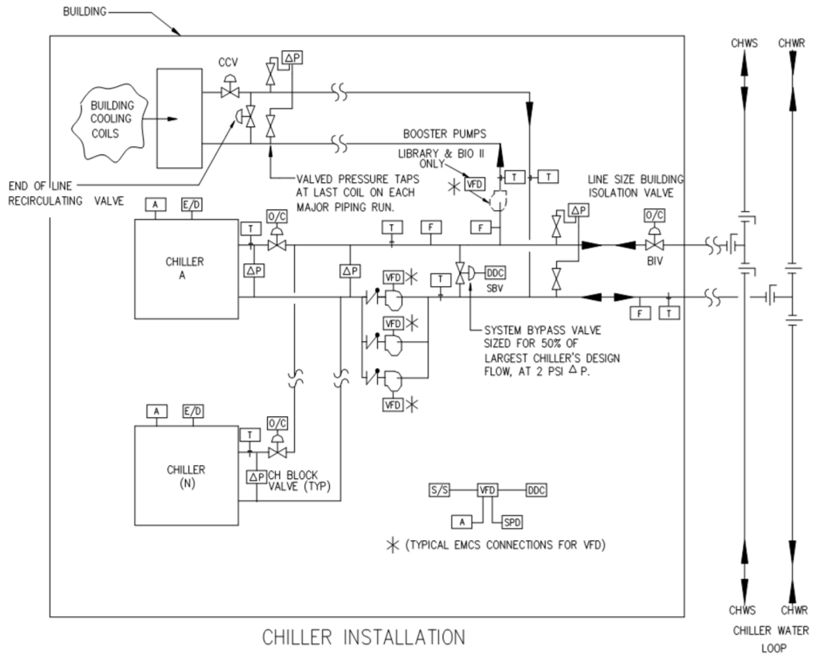
- Minimum cooling load nights, weekends and winter
- Only 1 chiller for each of most buildings; sized for maximum building cooling load
- 3-way valves on all HVAC units
- Requires full flow at all times, even to meet the load on only 1 unit

More Key Issues

- Difficult to get State funding for central plants
- Very limited space for campus expansion – no room for Central Plant
- Every chiller repair was "major issue" – no time to shut it down for normal repair

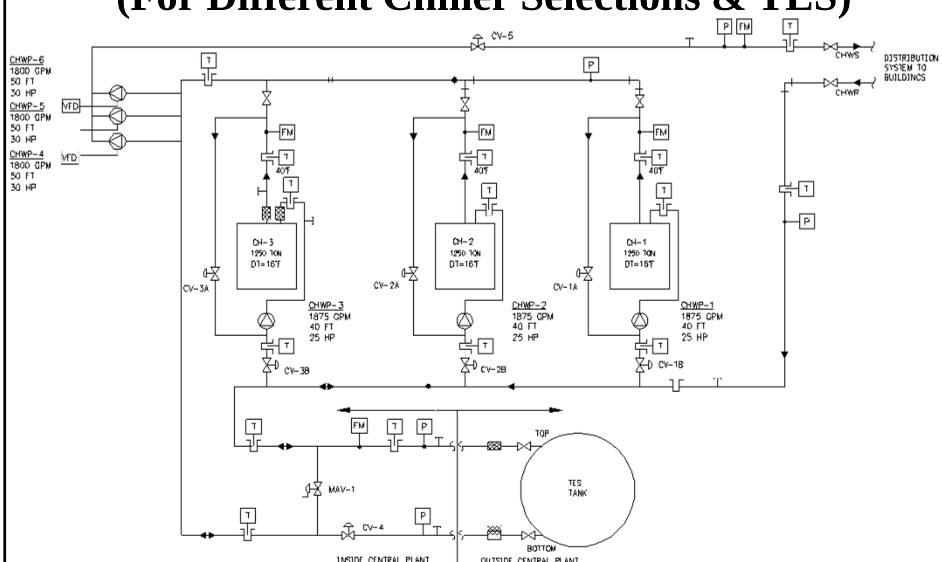
Still More Key Issues

- Very low CHWR - CHWS DT
- Not good for chiller to operate at low DT, for both longevity and energy consumption
- Possibly up to 5 kW / Ton at low DT



Alternate Chiller Piping Diagram

(For Different Chiller Selections & TES)



Piping System

- A variable primary pumping system for maximum efficiency – providing the controls are properly designed, installed, commissioned, and operated properly and effectively
- Saves space – only one set of pumps
- Reduced electrical service – less total load connected
- Properly sized piping and DT permits system to operate at 5-15 psi DP most of the time

Condenser Water

- Optimize total energy consumption
- Select CTF for minimum possible CWIT for chillers – about 1% improvement per 1F reduced CWIT
- With VFDs on CWPs, reduce flow through operating chiller when possible

Cooling Towers

- VFDs on all fans and, if big plant, all CWPs – operating most hours with less than design chiller flow
- Control VFDs to maintain minimum CWIT at CTF design approach plus OAWBT = the best one can do
- Operate multiple CTFs, if possible, with min fan speed, if fan is operating – may need variable flow nozzles on CTFs

Key Points For Control

- System Bypass Valve (SBV)
- End of line DP
- Pumping system DP and speed control
- Check valve required on each pump
- End of line ¾" 2-position recirculating ACV
- Booster pump, when needed for higher DP
- Building Isolation Valve (BIV)
  - Modulating, to permit flow control for building

System Bypass Valve Control

- Primary: Maintain minimum flow through operating chiller; DP across evaporator tubes works good
- Secondary: Maintain CHWRT at 54F for constant 38F CHWST, regardless of CHWRT from system (16F chiller DT)
- Sizing: To flow up to 75% of operating chiller design flow at 2 psi DP.

CHW DP Control

- DP as low as possible = Min pumping HP
- Design piping systems & coils for low DP
- No 3-way valves – use small 2 position ACV at end of piping run
- Feedback from valve controls helpful
- Keep at least 1 CHW ACV near full open just meeting cooling plenum temperature setting
- All pumping systems maintaining same DP to distribution piping system

End of Line 2 Position ACV

- Sometimes want to maintain cold water flow throughout piping system for “instant” response to call for cooling
- Open ¾” ACV when end of line HVAC unit ACV is closed – just enough flow to keep cold water. No big penalty, like a 3” 3-way ACV on the end ACU would be

CHW Booster Pumps

- Booster pump may be needed to serve any load or building DP that exceeds others
- Include VFD for finite control
- Operate BP only when needed
- When operating BP, remove that DP from main CHWP control logic

Building Isolation Valve

- Isolates building systems when cooling not needed in building
- Modulating BIV permits limiting flow into the building – or major piping runs – during full flow requirements
- Use valve with zero DP at full flow

BAS Extension / Expansion

- Newly converted system
- Expanded to monitor & control new Virtual Chiller Plant
- Added many sequences of operation
- Dial-up capability for monitoring from off-site
- Extensive trending capability for new energy conservation confirmation and reporting

BAS Extension / Expansion (cont’d)

- New and expanded system to replace or integrate multiple older systems
- New expansion and modification of recently installed up-to-date BAS, including monitoring and controlling new Virtual Chiller Plant
- Many revised or added sequences of operation included in the new system

BAS Extension / Expansion (cont’d)

- New system required to monitor results of new energy conservation projects, including the virtual chilled water plant.
- Utility company demanded accurate measurement and verification data to confirm value of this major rebate.

BAS Extension / Expansion (cont’d)

- New system required to have off-site dial-up service in place for engineer to monitor performance of controls and the newly integrated virtual chiller plant from office
- Dialed up daily for many weeks to assure proper performance and report to owner

BAS Extension / Expansion (cont’d)

- Calculated and charted energy savings, based on comparative data
- Plotted assigned data points to confirm proper control
- With 38F CHWST, no room for “undershooting” or “overshooting” – lose too many benefits from low temperature CHWS

BAS Extension / Expansion (cont'd)

- REMEMBER:
  - 25% reduction in CHW DP = 44% reduction in pumping power
  - 25% reduction in CHW Flow = 58% reduction in pumping power
  - Dropping from 42F to 38F CHWST on a 12F DT coil provides 20F DT coil (LMTD central point remains constant)
  - 20 vs 12F DT = 60% flow = 78% reduction in pumping power!

BAS Extension / Expansion (cont'd)

- Integrates all system information to control at optimum energy
- DP reading requiring the most DP controls the CHWP speed
- AHU with CHW ACV >95% open and discharge air temperature above requirements to meet space needs controls that building's DP, which controls operating CHWP speed

Controls are Critical to the Success!

- “Secret” to successful operation = the System Bypass Valve control
- Accurate instrumentation – mandatory
- Well instrumented – essential
- Thorough and accurate “calibration” – for reliable performance
- Detailed/thorough Operator Training – for sustainability

Why Controls Are Critical

- “System Bypass Valve” to Control -
  - Minimum CHW flow through chiller
  - Maximum CHWRT into chiller for proper CHWST out of chiller
- Chilled Water Pump Control -
  - Operate at Minimum speed = minimum energy consumed
  - Maintain minimum DP “at end” of <u>each</u> primary (critical) piping loop – <u>each</u> building

Why Controls Are Critical (Cont’d)

- AHU Automatic Control Valves
  - ALL to be 2-way
  - At least one per building nearly full open
  - Feedback from ACV control to DP control
  - Feedback from Building DP control to Pump DP and speed control
- Booster Pump Control, IF Needed
  - Start only when needed for excessive building DP
  - Use VFDs for sustainable integration

Chiller Controls

- Ensure capacity controls calibrated to +/- 0.1F CHWST, using PID.
- Capacity controlled easily and smoothly
- Minimum CHW flow as low as possible = optimized pumping
- Operate only enough and the right chillers to do the job needed
- Maintain lowest possible CWIT

Sensing Devices

- CHWST & CHWRT sensors should be "matched pair," or "matched trio" = better
  - =/< +/- 0.25F, for net =/< +/- 0.1F DT
  - Without "matched set," reading could be off by up to 5% of full load for 10F DT Chiller
- All water system sensors =/< +/- .25F
- All air system sensors =/< +/- 0.5F
- DP sensors =/< +/- 0.25 PSI

Critical Items

- Proper Design
- Building CHW System - Flow, Pipes and Pump Head
- Accurate Instrumentation - Everywhere – Don't go "cheap"!
- Feedback From AHU Controls to BAS to control the loop systems
- Flexibility of Chiller Selection
- Proper Operation – Per Design, don't turn the chiller control to 42^0F!

Critical Items (Cont'd)

- Selection of the Right BAS Operator
- Proper & Repeated BAS Operator Training
  - HVAC System Performance
  - Chiller Performance
  - CHW Pumping
  - CHW Pressure Control
  - Interactive Relationships
  - Proactive Role of Operator & O&M folks

Results

Yes, It Works!

Yes, It Has Saved $$$!

Yes, The Maintenance Personnel DO Love It! They even expanded it!

Utility Co. Rebate

- Thanks to the EMS and the monitoring data, Utility Co got enough info from 2 years of data to pay the full rebate claimed for 3 years, which was GREAT!
- The accuracy of data, as they perceived it, gave high level of creditability, which was also GREAT!

THANK YOU!

Related Chiller Operation

- 10 Ton average load on 50 Ton system = an average of 20% of design load = energy intensive
- With 3-way valves, even 20% load requires full flow; therefore, pumping full flow continuously

New Building Connections

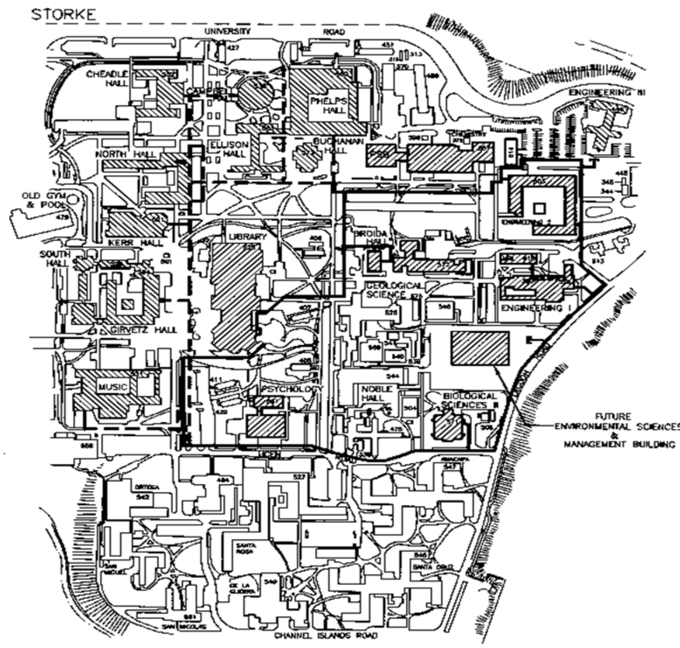
- ORIGINAL LOOP – BY DESIGN TEAMS (3660 TONS)
  - 240 TON – BREN
  - 800 TON – LIFE SCIENCES
  - 70 TON – PSYCHOLOGY ADD'N (NO NEW CHILLER)
  - 150 TON – MUSIC BLDG CONNECTION (NO NEW CHILLER)
  - 350 TON – SAASTB (STUDENT AFFAIRS & ADMIN SVCS)
  - 200 TON – MSRB (NO NEW CHILLER)
  - 850 TON – CNSI (CAL NANO SCIENCE INSTITUTE)
  - 1000 TON–ESB (ENGINEERING SERVICES BUILDING)
- WEST LOOP – BY O & M STAFF (NEW LOOP-800 TONS)
  - 2-200 TON – HSSB (PRIMARY)
  - 150 TON – SNIDECOR
  - 250 TON – SRB (STUDENT RESOURCE BUILDING)

SAMPLE AIR HANDLER COOLING LOAD PROFILE

(A 50 TON DUAL DUCT W/O ECONOMIZER)

OA TEMP.	% YEARLY	COOLING	FAN ENERGY	COOLING			
DEG F	HOURS	BIN HR/YR	KWH/YR	KBTU/YR	TON HRS/YR	TONS/HR (1)	% TOTAL
92	0.06	5	110	2810.00	234.17	46.83	0.27
87	0.18	16	413	9571.00	797.58	49.85	0.93
82	0.65	57	1,403	29253.00	2437.75	42.77	2.83
77	2.15	188	4,483	89294.00	7441.17	39.58	8.64
72	5.67	497	10,478	165747.00	13812.25	27.79	16.04
67	11.86	1,039	17,353	207403.00	17283.58	16.63	20.08
62	19.91	1,744	26,648	224824.00	18735.33	10.74	21.76
57	25.45	2,229	27,500	129707.00	10808.92	4.85	12.56
52	21.31	1,867	17,655	71259.00	5938.25	3.18	6.90
47	8.97	786	6,820	76816.00	6401.33	8.14	7.44
42	2.98	261	2,283	21568.00	1797.33	6.89	2.09
37	0.72	63	550	4277.00	356.42	5.66	0.41
32	0.09	8	83	515.00	42.92	5.36	0.05
TOTAL	**100**	**8,760**	**115,779**	**1,033,044**	**86,087**	**10**	**100**

(1) This value is the average hourly load of the system under each bin temperature, with the annual average hourly load listed as "% Total." The average load is only 20% of the design capacity!



Utility Meters

Confirm that there are smart meters installed on the water, gas and electric service to the site, which is monitored by the EMS.

Confirm that the readings are correct, for proper billing or splitting of the total utility bills.

Utility Meters

- Confirm that there are smart meters installed on the water, gas and electric service to the site, which is monitored by FMD, with no involvement from this facility's EMS.

Confirm Operation of Air Handling Units (VAV units with economizers)

- The following is a proposed plan for conducting the PVT of a central plant heating and cooling equipment, Air Handlers, Exhaust Fans, VAV/CAV boxes, and domestic water systems at a sample building on a Pacific Coast Military Base – primarily heating only

Confirm Operation of HVAC Units (VAV Units with Economizers) Cont'd

- Request the DDC representative to confirm the presence of a unit operational alarm and the system's return to normal following the alarm signal reset.
- Restore the unit to operating mode. With the unit in full operation, check the economizer cycle for correct operation.
- If desired, compare the temperature readings with the EMS readings.

Confirm Operation of HVAC Units (VAV Units with Economizers) Cont'd

- With the coil modulating control valve fully open, read the air temperatures entering and leaving the coil to confirm the air DT.
- Observe the Air Handler system operating to maintain comfort level.
- If desired, have someone trip the ATFP alarm and validate proper operation of that alert system.

Confirm Operation of HVAC Units (VAV Units with Economizers) Cont’d

- Confirm that the unit shuts off and the ATFP dampers close tight.
- Have the ATFP alarm signal cleared (reset) and observe the system restart. (Note that there will be a delay before the ATFP damper opens and note that the damper must open fully before the fan starts.)

Confirm Operation of HVAC Units (VAV Units with Economizers) Cont’d

- Confirm that the EMS properly identifies the alarm, that the AHU system shuts down when the alarm is activated and validate the alarm reset and system’s re- start activities.
- Since these units have been equipped with a new min outside air control sequence, it may be desired to spend some extra time validating the good control of minimum outside air through all modes of operation. This can be validated on the trend logs also.

Confirm Operation of HVAC Units (VAV Units with Economizers) Cont'd

- Ensure that the unit's controls think the outside air temp (enthalpy) exceeds the return air temp (enthalpy), thereby placing the damper control in the minimum OA position.
- Check the damper control and read the air flow to confirm proper control of the outside and return air dampers. (Note that the EAD has been converted to two-position operation to greatly improve system performance and stabilize the RAD and RF speed control.)