Pacific Northwest
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Large Commercial Buildings: Re-tuning for Efficiency

Central Utility Plant: Pre-Re-Tuning and Re-Tuning

PNNL-SA-85063 1/11/2012 Version 1.1

Boiler Operation Issues

- Scaling deposit on water tubes
  - Formation of calcium and salts on tubes
  - From water hardness
- Scaling prevention
  - Boiler feed water chemical treatment
    - Internal or external treatment
  - Boiler blow down
    - Remove some un-boiled water from the system
    - Replace with makeup water

Boiler Efficiency

- Stack loss is amount of heat leaving the boiler without doing any work
  - Equal to 100% - stack loss
  - Stack losses are typically 15% - 30%

- Thermal (boiler) efficiency
  - Equal to 100% - Stack loss – body loss – other losses
  - Or simply defined as boiler output / fuel input
  - Conventional boiler efficiency 65% - 75%
  - High efficiency boiler efficiency 85% - 95%

Boiler Combustion Efficiency

- Amount of excess air
  - Some excess air needed for complete combustion
  - Typically ~4% excess air with O2 Trim
  - Too much excess air causes higher stack temperature
  - Can reduce efficiency by as much as 20%

- Exhaust stack temperature
  - Based on steam pressure and HW temperature
  - Higher pressure and higher temperature equals higher stack temperature

Boiler Operations

- Check the following list by analyzing the trends:
  - The boiler is on during hot summer
  - No hot water supply temperature reset
  - No differential pressure reset for hot water pump control

Boiler Operations (continued)

- Cycle hot water circulating pumps on occupancy schedules, lockouts and fan night time operation
- Hot water heating boilers require reset schedules
  - Valve leak
  - Load substantially varies
  - Pump pressure can increase when all the valves close, causing leaks when valves lift off seats
  - Why heat a building with 180^{o}F water when 80^{o}F will do it?

Boiler Operations (continued)

- Hot-water-heating boilers require reset schedules
  - Zone temps will stabilize better because valves can modulate better at lower zone loads
    - We have seen a lot of chillers unload, complaints go down and zone temps stabilize just by lowering reheat water temperatures
- Caution
  - Do not lower water temperatures on gas-fired units, if it will cause condensation within the boiler or stack
  - A bypass system is the best designed to keep the boiler warm and the loop cool

Boiler Lockout in Summer

- If boilers are only used for comfort heating, you can consider shutting off the boiler during summer
- Can avoid heating leakage and pumping cost
- For example, if boilers are used to provide reheating for terminal box, they don't need to be ON when outdoor-air temperature is high (> 70^{o}F)

Boiler Trend Data Analysis

- Purpose:
  - Determine whether the loop differential pressure (DP) set point is constant.
  - Determine the potential of resetting the DP to a lower value at partial load condition

- Approach:
  - Review the plots of loop DP, maximum heating coil valve position vs. time
  - Check whether the DP is constant
  - Check whether 20% heating coil valves are greater than 75%

Boiler Operations (cont.)

- If building loads are the only requirement for the hot water, then the hot water supply temperature can be reset according to the ambient temperature, time of day, or other appropriate scheduling variable
- Reset hot water supply temperature depending on building load
- Typical control resets hot water supply temperature with outdoor-air temperature
- Maintain 160°F – 180°F during winter season
- Maintain 120°F – 140°F during summer season
- Condensing boilers require less then 135°F return-water temperature to operate in their most efficient range

Boiler Operations (cont.)

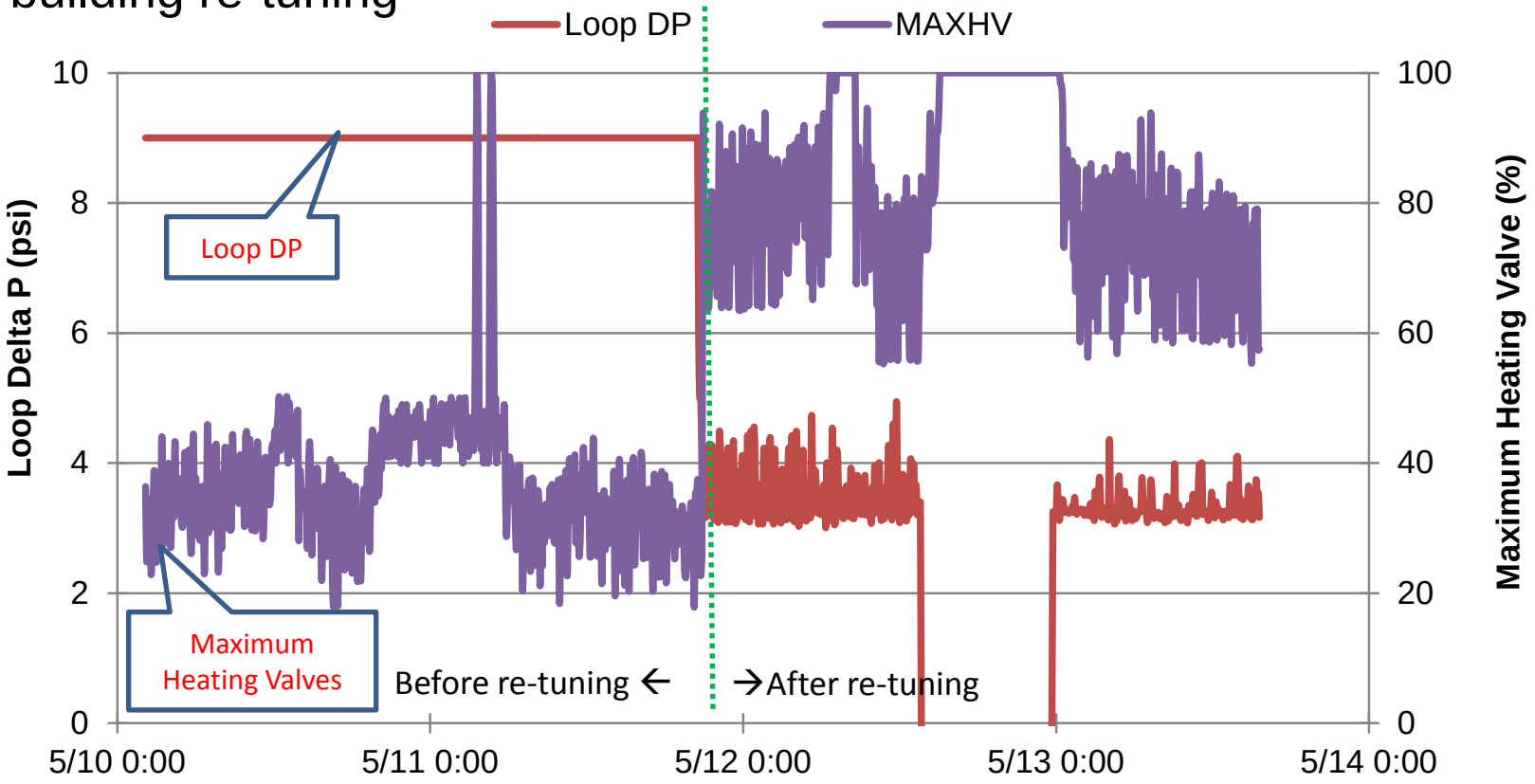
- Interview personnel who use steam or hot water in applications such as cooking, cleaning and medical uses to identify the highest steam requirement
- The plant steam pressure should be the sum of the maximum required end-use steam pressure and the steam loss of the distribution system

Boiler Operations (cont.)

- Check steam traps frequently
- Steam traps have a tendency to fail, and leakage costs can be significant
- A steam trap maintenance program is recommended
- Consult the manufacturer and manuals for proper procedures and methods for steam trap maintenance
- Condensate return :
  - Inspect the condensate return frequently
  - Collect condensate returning as much as possible

Differential Pressure (DP) Reset for Hot Water Pump

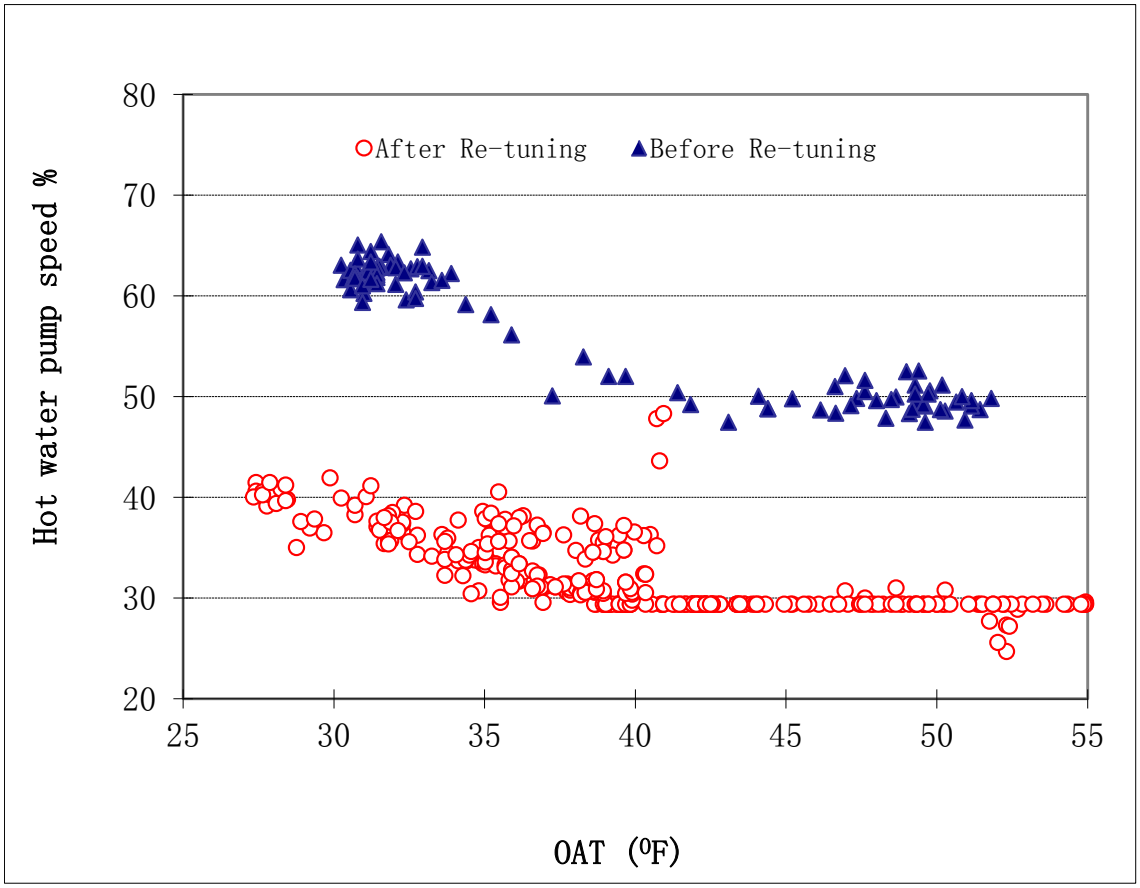
- Loop DP and maximum heating coil valves vs. time: before and after building re-tuning



Example of Bad and Good Operations

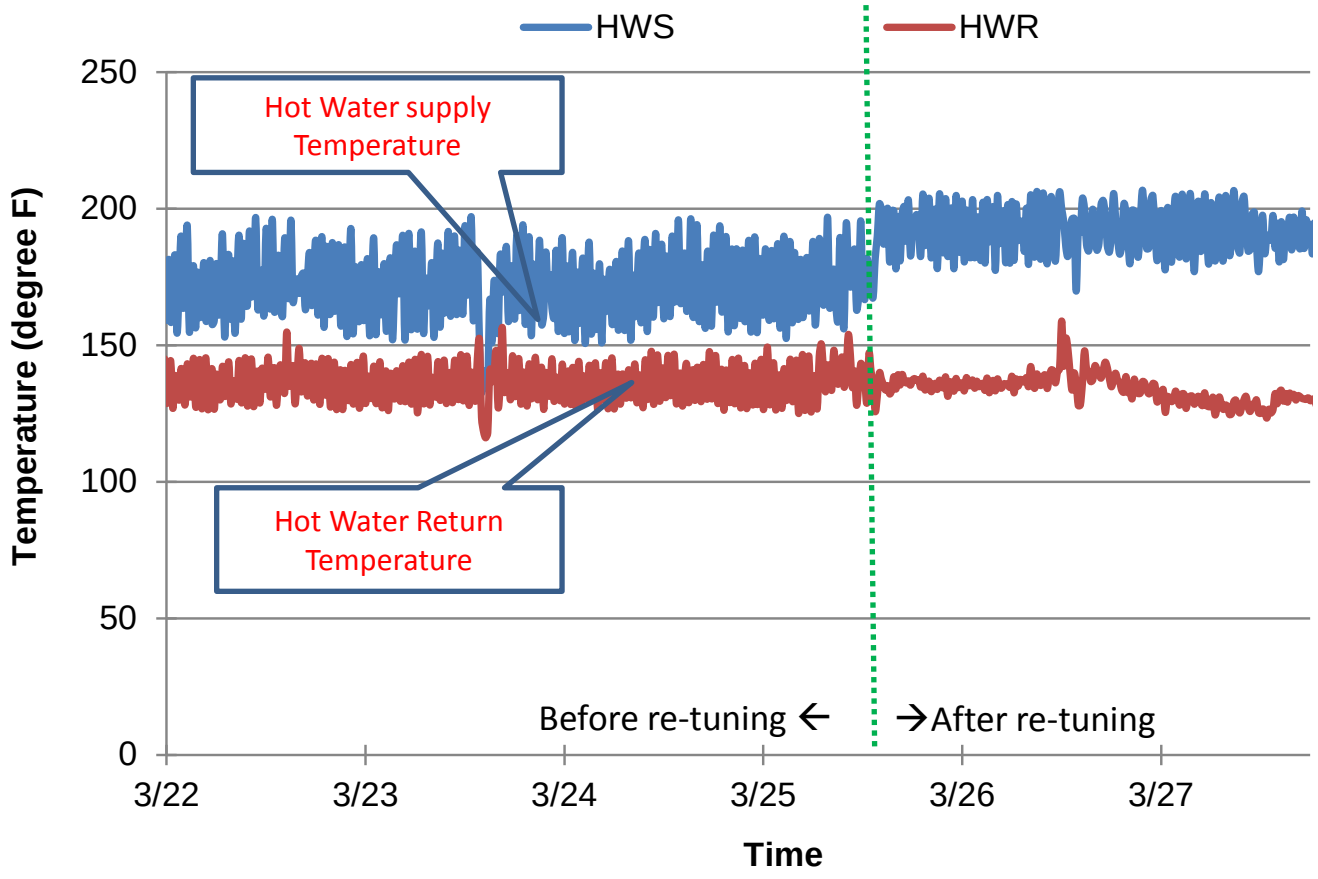
Hot Water Pump Speed

- Secondary pump speed vs. outdoor-air temperature: pump power savings by resetting loop DP set point
- Before building re-tuning -10 psi constant; after building re-tuning -3~6 psi)



Hot Water Distribution Loop DeltaT

- Average loop deltaT (supply – return) before building re-tuning = 25ºF
- Average loop deltaT after building re-tuning = 43ºF



Example Bad and Good Operation

Central Plants: Chiller Operations

- Use a chilled water reset schedule
  - For each degree rise in chilled water temperature, the chiller will gain about 2% efficiency
  - Run chillers at 80 to 90% load when possible
  - Run smaller chillers as load following
    - Let the larger chiller stay fully loaded and run the smaller chiller as the lag unit
  - Run smaller chiller at night for better part-load efficiency
  - Use a fully integrated lead/lag control scheme so chillers are not running "just because"
    - Typical operations will start a unit in the morning because this afternoon they might need it

Chiller efficiency

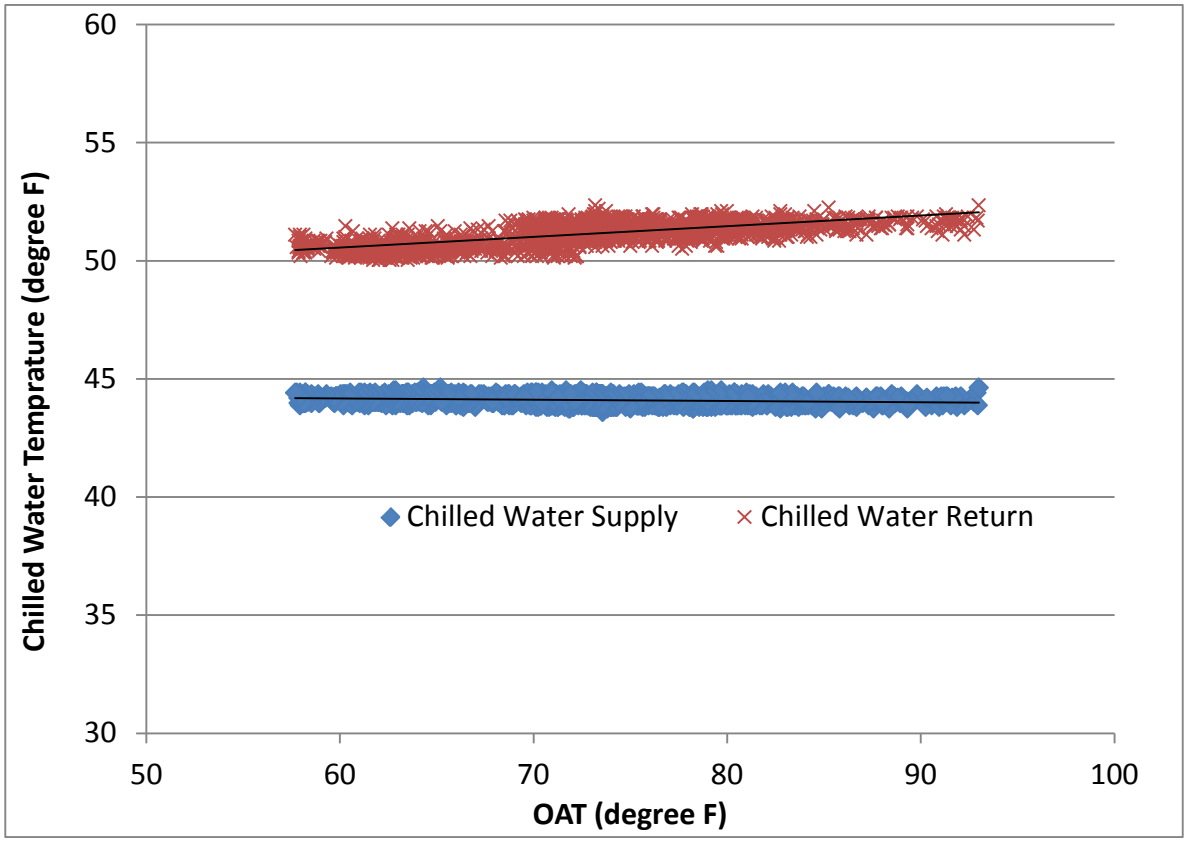
- Efficiency measures
  - kW / ton
    - kW / ton = kW input / cooling ton
  - Coefficient of Performance (COP)
    - COP = kW cooling / kW input
  - Energy Efficiency Ratio (EER)
    - EER = Cooling ton x 12 / kW input
- Conversions
  - COP = 3.516 / (kW/ton)
  - EER = 12 / (kW/ton)

Chiller Operations

- Pumps that are paired should have a true lead/lag and recovery system
  - Never run more than one pump except when load requires it, if the pumps are constant speed
  - Use variable frequency drive (VFD) pumps in optimal configuration
    - all running pumps need to be at same speed
- Never run two chillers partly loaded (unless they are variable speed) when one will carry load
  - Use auto lead/lag sequence
  - Chillers with VFDs should be used for load following
  - Chillers without VFDs should always run close to full load

Chiller DeltaT: Low DeltaT Operation

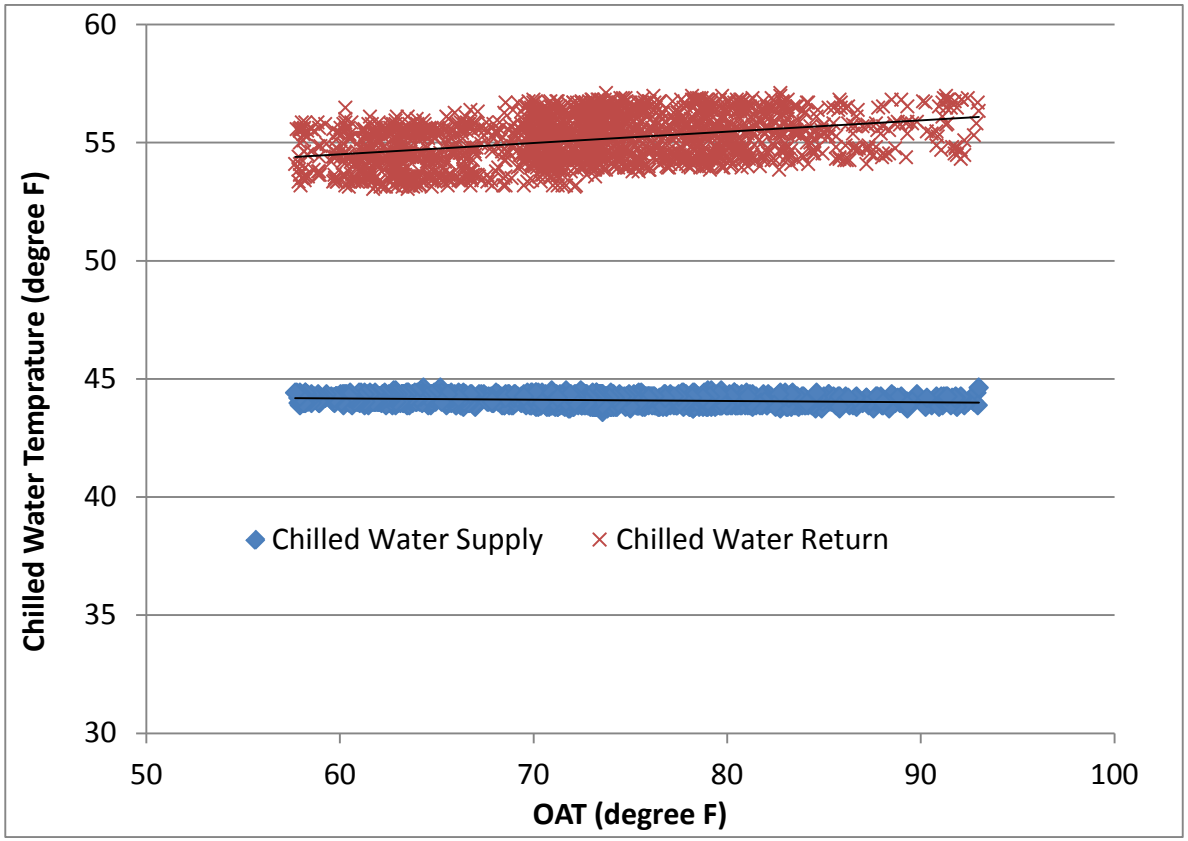
- Design DeltaT=11.5ºF (DeltaT = Return – Supply)



Example of Bad Operation

Chiller DeltaT: Example of Good Operation

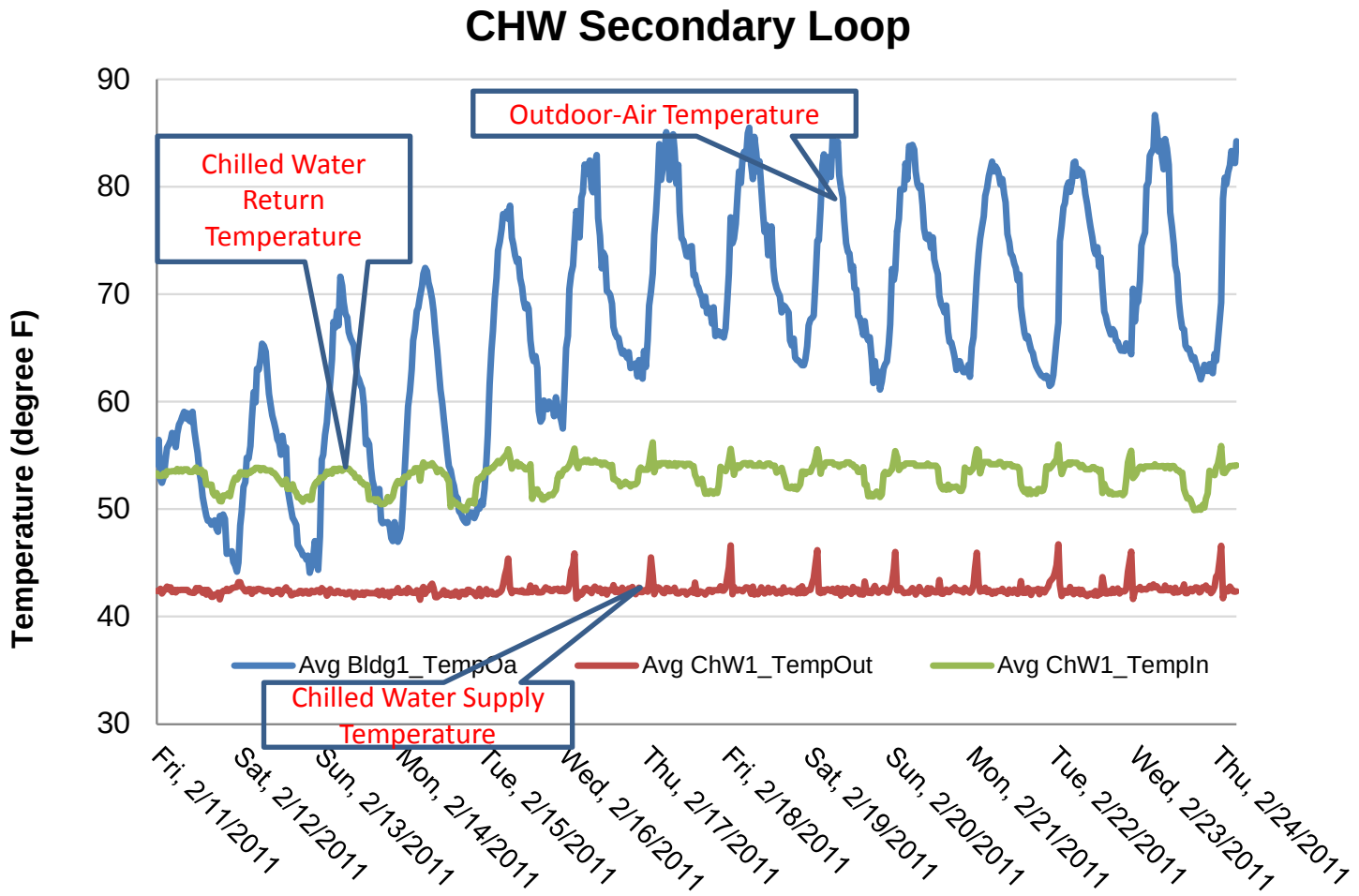
- Design DeltaT=11.5ºF



Example of Good Operation

Chiller DeltaT: Example of Good Operation

- Secondary chilled water loop



Example of Good Operation

Chiller Operations: CHWST is Low at Partial Load

- Chilled water supply temperature (CHWST) is generally set at a constant value
  - Constant CHWST can lead to loss in chiller efficiency,

    especially when all cooling coil valves are partially open and the chilled water pump is at low speed
- Example of bad operation
  - Maximum cooling coil valve is less than 50% open
  - Chilled water pump VFD is at low speed (<50%) and
  - Loop deltaT is less than 8^{o}F

Chiller Operation Data Analysis: CHWST Reset

- Purpose:
  - Determine whether the CHWST is too low
  - Determine potential of resetting CHWST to a higher value at partial load condition

- Approach:
  - Review plots of CHWST, CHWRT and maximum cooling coil valve position vs. time
  - Review the plots of CHWST and CHWRT vs. outdoor-air temperature
  - Check whether the CHWST is constant and the loop deltaT is low (<8^{o}F)
  - Check whether 20% cooling coil valves are greater than 75%

Chiller Operations Re-Tuning: Reset CHWST (continued)

- Increase CHWST set point 0.5°F at a time
  - Don't do it too fast to prevent chiller trip off
- Increase CHWST set point up to 5°F higher than the design value
- If maximum open valve in the primary chilled water loop is less than 90-95% open, increase the chilled water supply temperature
- If more than one valve is 100% open, decrease the chilled water supply temperature gradually

Chiller Operations Re-Tuning: Reset CHWST (continued)

- Ensure system energy efficiency is not affected
- Increasing chilled water temperature may increase distribution pump (secondary pump) power consumption
- Use differential pressure reset control to optimize secondary chilled water pump control
- If chilled water pump speed increases to more than 80%, CHWST set point should be lowered gradually to design set point

Chiller Operations: DP Set Point for Chilled Water Pump Control is too High

- It is common practice to install differential pressure (DP) sensor
  - DP set point is generally set to meet the design condition
- At part load, cooling coil valves are forced to close to maintain design DP set point and chilled water pumps are operated at high speed
- Example of bad operation
  - Maximum cooling coil valve is less than 50% open
  - Chilled water pump VFD is operated at high speed (>75%)

Chiller Data Analysis: DP Reset

- Purpose:
  - Determine whether the loop DP set point is constant
  - Determine the potential of resetting the DP to a lower value at part load condition

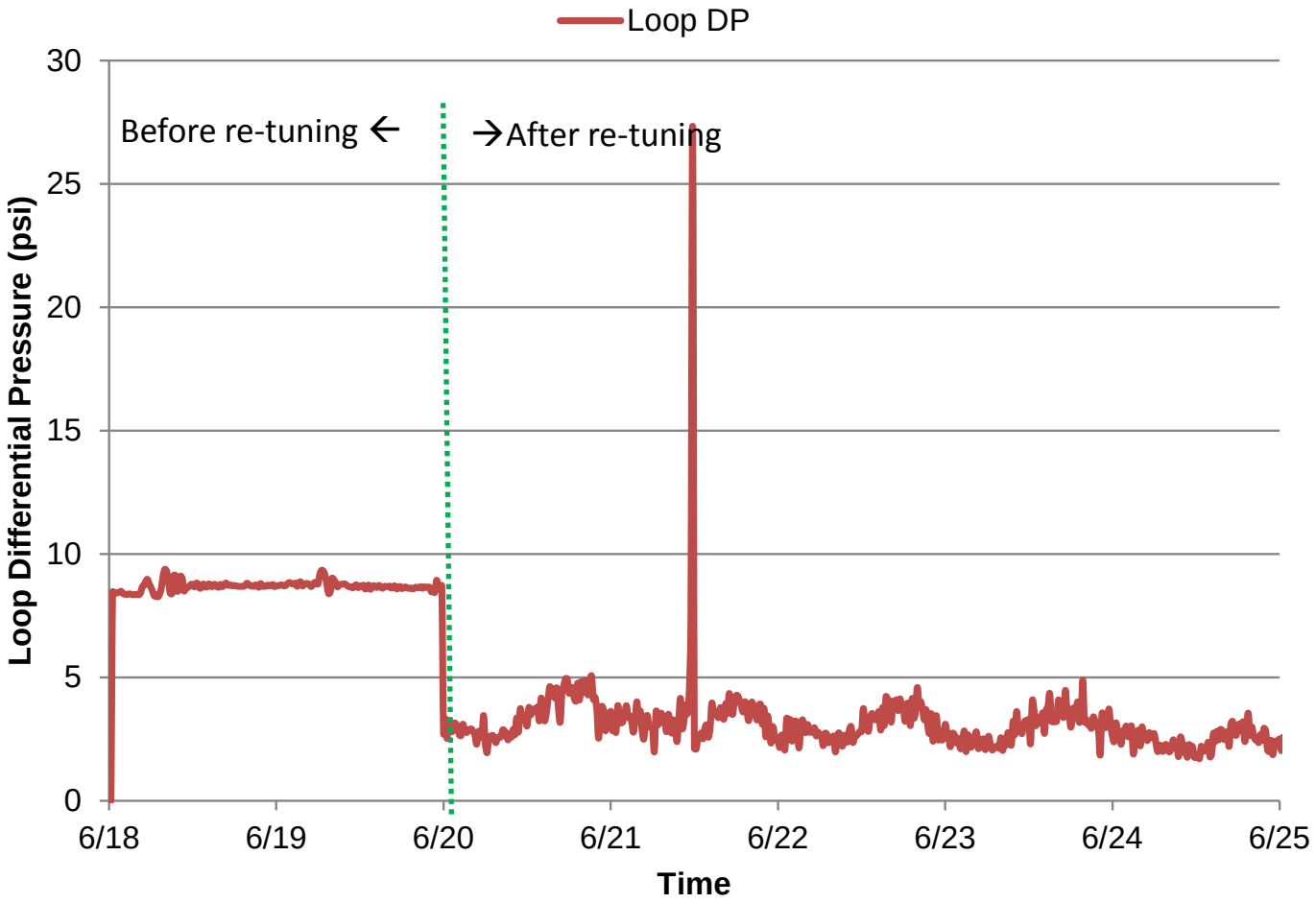
- Approach:
  - Review plots of loop DP and maximum cooling coil valve position vs. time
  - Review plots of CHWST and CHWRT vs. outdoor-air temperature
  - Check whether DP is constant
  - Check whether 20% cooling coil valves are greater than 75%

Chiller Re-Tuning: Resetting Differential Pressure

- Reduce loop DP set point gradually at partial-load condition
- If the maximum open valve in the chilled water loop is less than 95% open, decrease the DP set point 0.5 psi at 15-minute intervals
- Determine the minimum loop DP based on system configuration and coil condition
  - For example, lower loop DP to 5 psi, if DP sensor is installed across the remote cooling coil in the loop
- Increase the loop DP set point to design value if the maximum cooling coil valve opens to 100%
- It can be implemented in building automation system
  - A dead band is recommended in the control

Chiller Data Analysis: Before and After Chiller Re-tuning

- Before: Constant loop DP set point at 9psi



Example of Bad and Good Operation

Chiller Plant Re-Tuning: Chiller Staging Control

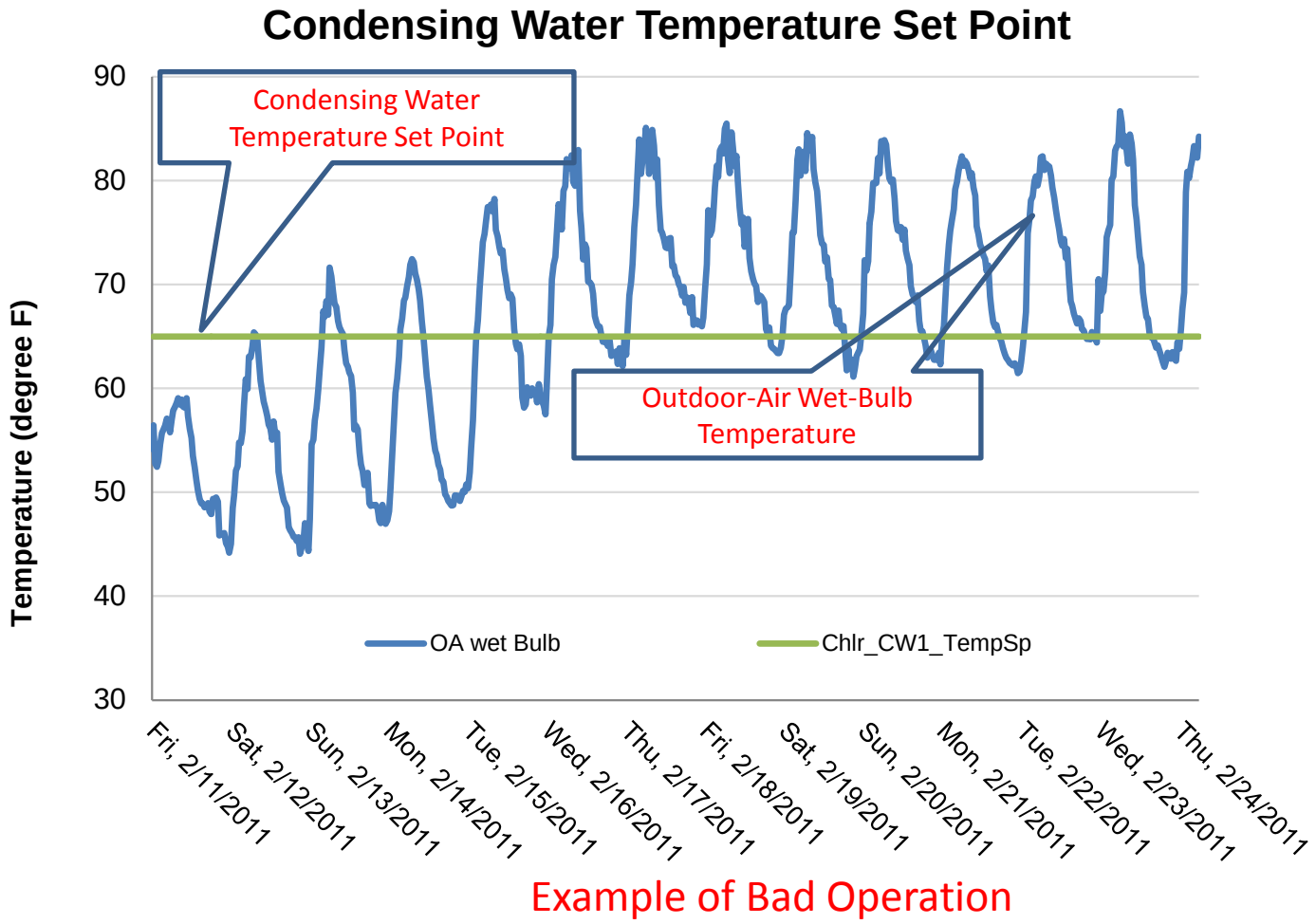
- Running chillers in high efficiency range can result in significant electrical energy savings and can improve the reliability of plant operation
- Determine and understand the optimal load range for each chiller
  - This information should be available from the chiller manufacturer
  - For example, the kW/ton has the minimum value for some old chillers when the chiller load varies from 50% to 80% of the design value
- Turn on the most efficient chiller first
  - Optimize the pump and fan operation accordingly
- Turn on additional chillers to maintain load ratio (chiller load over the design load) within the optimal efficiency range for each chiller

Chiller Plant Re-Tuning Condensing Water Temperature Control

- Reset condensing water return temperature based on wet-bulb temperature
- General guidelines:
  - Cooling tower water return temperature set point should be at least 5ºF higher than ambient wet bulb temperature
  - This prevents excessive cooling tower fan power consumption
  - Cooling tower water return temperature should not be lower than 65ºF for chillers made before 1999 and should not be lower than 55ºF for newer chillers
  - Consult chiller manufacturer's manual for more information
- Cooling tower water return temperature reset can be implemented using building automation system

Chiller Plant Re-Tuning Condensing Water Temperature Control (No reset)

- Constant condensing water temperature set point (65ºF)



Example of Bad Operation

Chiller Plant Re-tuning Cooling Tower Fan Operations

- Using more than one cell
  - Provides natural cooling
  - Especially during mild or cool days

- For example, use all towers when one of the three chillers is used
  - This may eliminate fan power consumption entirely at low ambient condition
  - Pump power may actually stay the same

Chiller Plant: Variable Condensing Water Flow

- Modulate condenser pump speed to maintain deltaT across chiller condenser
- Chiller flow requirements
  - Chiller has minimum and maximum flow requirements across condenser
  - Too low/high flow can cause compressor surge and affect efficiency
- Other considerations
  - Pump head is high enough for the open loop system
  - Too low flow or too high deltaT also can cause scale build-up

QUESTIONS?
www.pnnl.gov/buildingretuning