ENERGY EFFICIENCY IN THE PACIFIC NORTHWEST

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Good Audit Questions

- Is equipment appropriately sized?
- Is equipment off when not in use?
- Is equipment used for intended application?
- Are systems optimized for efficiency?

Keys to Successful Energy Projects

- Large equipment first
  - Equate to many small projects
- Low cost options
  - Controls upgrades and O&M are very cost effective
- High hours of operation
  - Contribute to short payback period
- Automatic > Manual
- Add VFDs on Variable Loads
  - Increasingly more cost effective
  - 50% speed ~ 15% power

$$P_2 = \left(\frac{RPM_1}{RPM_2}\right)^3 * P_1$$

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Energy Consumers

- Pumps
- Fans
- Boilers
- Lighting
- Air Compressors
- Chillers

Applications

- HVAC
- Refrigeration

Pump EEMs

- VFD
  - Open Balance Valves & Triple Duty Valves
  - Control to pressure setpoint

$$P_2 = \left(\frac{RPM_1}{RPM_2}\right)^2 * P_1$$

- Correct Size
  - Typically pumps operate most efficiently at full load

- Correct # of Pumps
  - Sometimes a pump in parallel can be shut down
  - One large site has 10,000,000 kWh ($500,000yr) in identified pump shutdown projects

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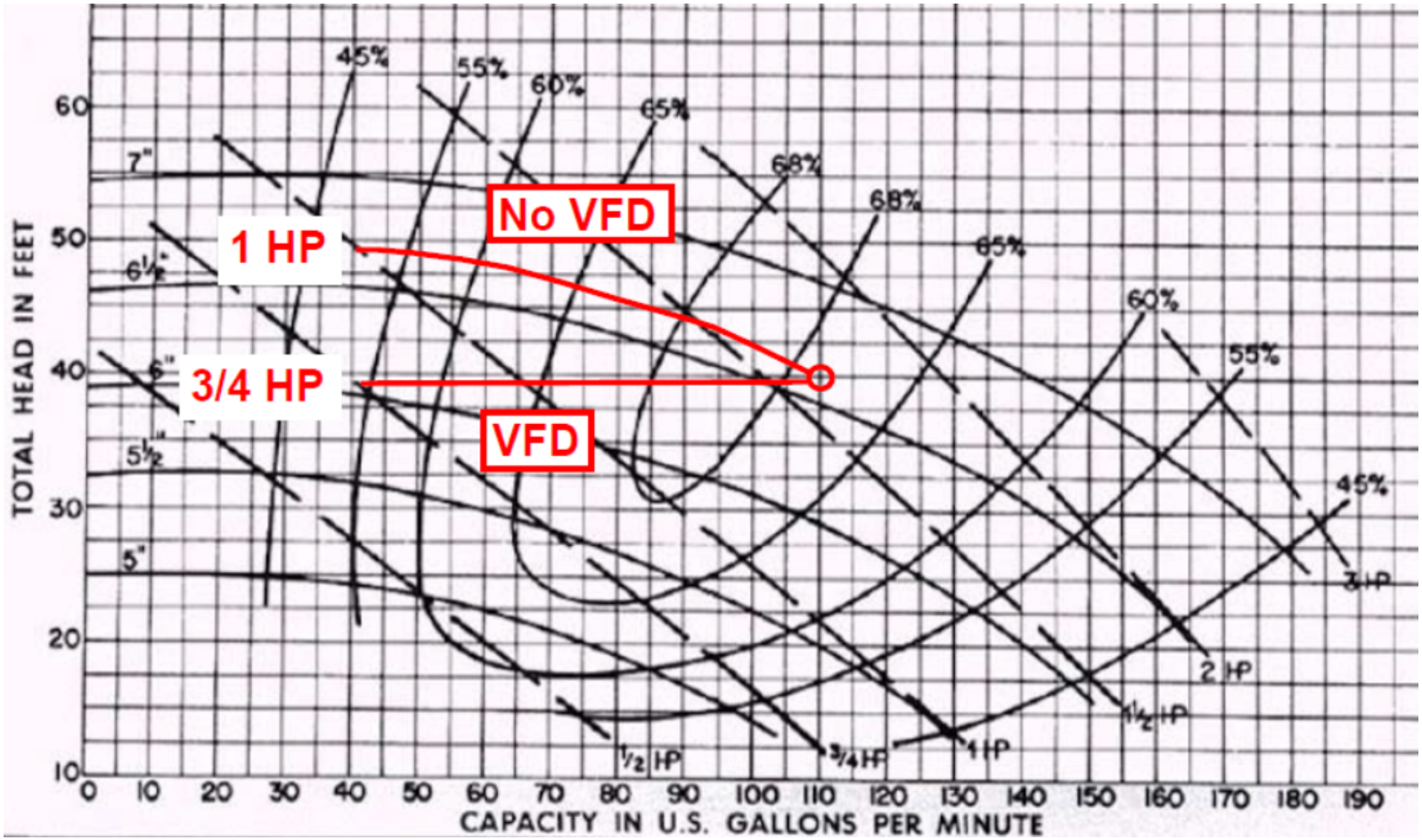
Pump VFD Analysis



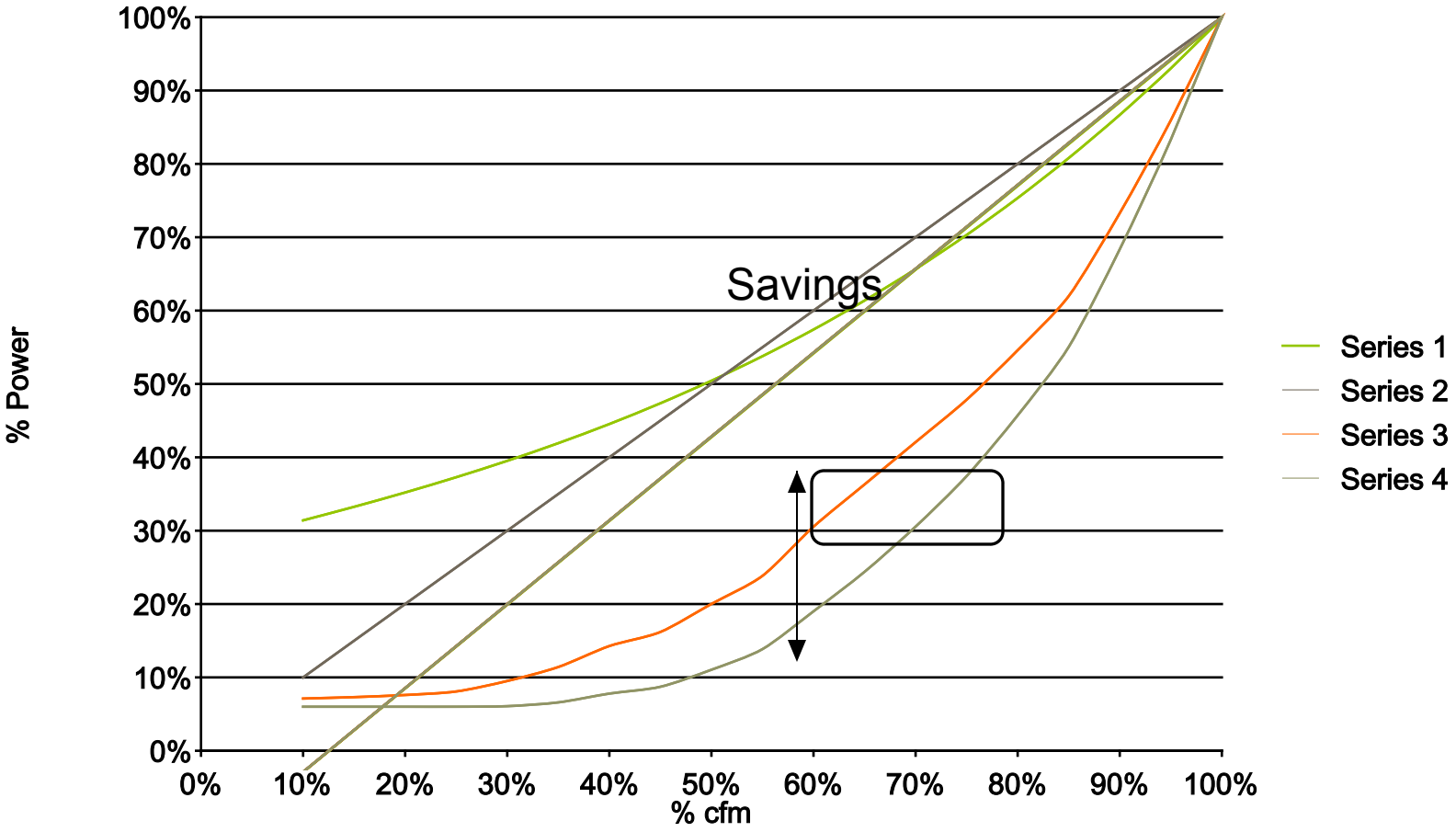
Fan EEMs

- Static Pressure Reset
  - Ducting applications (HVAC)
  - Baseline = 3” w.c.
  - EEM = 1.5” w.c.

~50% savings

- Wet bulb approach controls
  - Cooling tower fans
- VFD
  - Best VFD application

$$P_2 = \left(\frac{RPM_1}{RPM_2}\right)^{2.7} * P_1$$


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Power
Savings
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% cfm
Series 1
Series 2
Series 3
Series 4

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Case Study: Idle Motor Shutdown

Equipment for moving wood chips:

- (2) 500 HP & (1) 700 HP Blowers

Baseline: Blowers left on in “Idle” mode

- Total Idle Power = 550 kW

EEM: Turn off blowers after 1hr of idle time

- Reduced run time by 2,700 hrs/yr!

Payback = 1 second!

Cost: FREE

Savings: $75,000/yr

(1,500,000 kWh ~ 75 residences)

Boiler EEMs

- Minimally heat

  If you need 120°F water & 200°F water,
  use (2) boilers

- Minimally pressurize

  If you need 50 psi steam and 150 psi steam,
  use (2) boilers

- Automate boiler blowdown

  See case study

Case Study: Automated Boiler Blowdown Controls

Wood Drying Equipment:

- (3) 750 hp boilers

Baseline: Manual Blowdown

EEM: Automatic Blowdown

- Requires control panel, conductivity probe, throttling valve, motorized blowdown valve

→ Payback = 3 months

Cost: $8,000

Savings: $30,000/yr

(50,000 therms ~ 100 residences)

Lighting EEMs

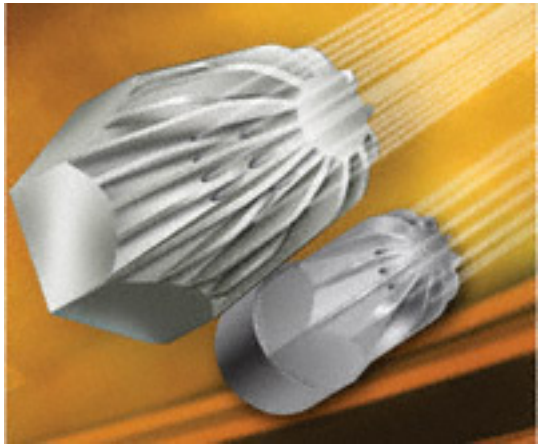
50,000 hrs
15% power
Commercial - $$
Residential – $$$$$$

10,000 hrs
25% power
Commercial - $
Residential – $$$

1,000 hrs
100% power
Commercial – DON'T USE
Residential – $

- Occupancy Controls
  - For noncritical tasks
- Daylight Controls
  - Utilize the Sun
- Design to IES light levels
  - The right amount of light

Air Compressor EEMs

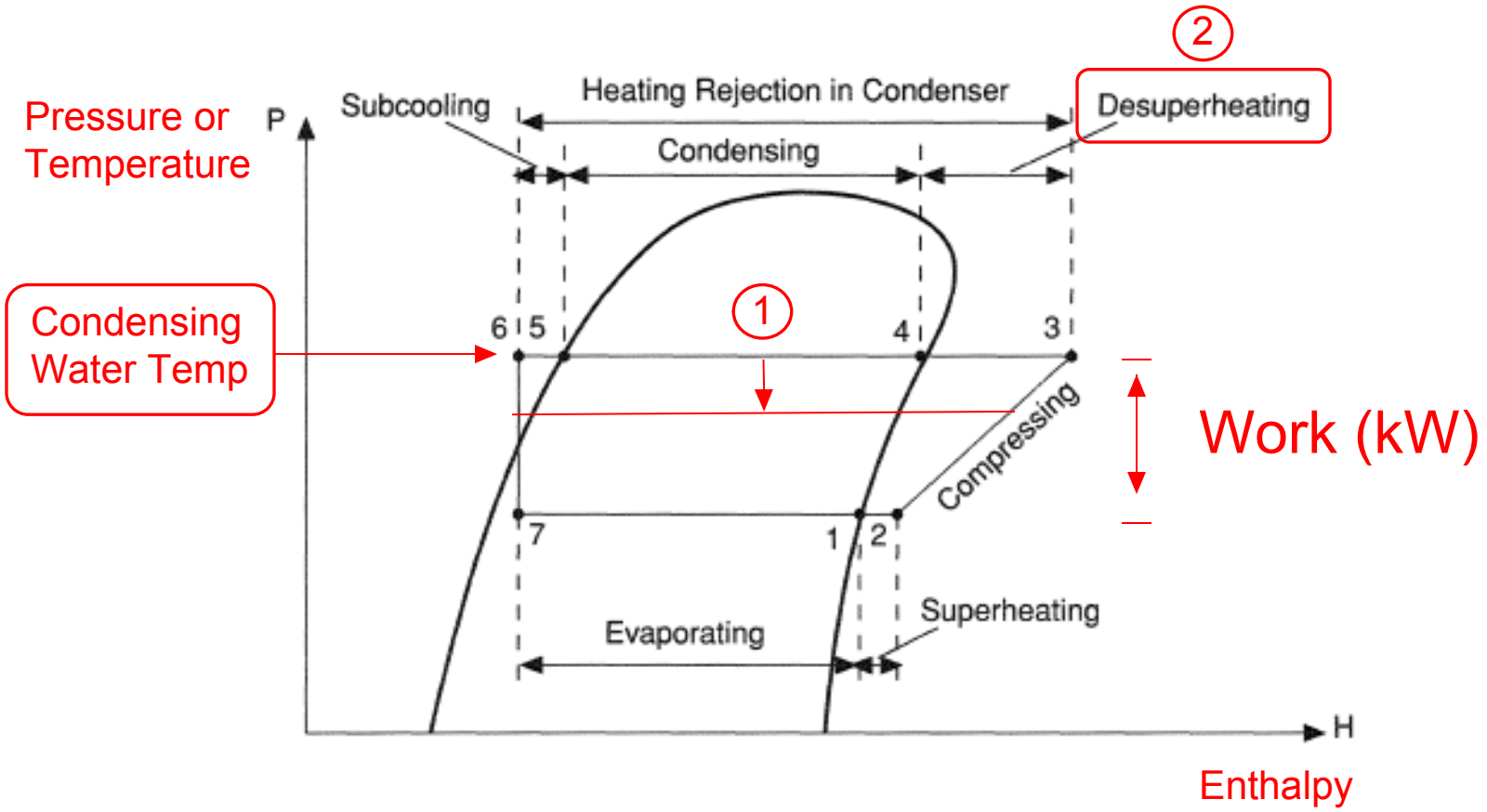


- Leak Repairs
  - Low cost, quick payback
- Engineered Nozzles
- Correct Applications
  - E.g. Don’t use for cleaning (use vacuum instead)
- VFD
  - (1) 150 hp compressor (most efficient)
- Multi-stage
  - (3) 50 hp compressors (most reliable)

Chiller EEMs

- Proper Sequencing (2+ chillers)
  - Low/No Cost, huge savings potential
- VFD
  - Over 50 % energy savings possible
- Reduce condenser water temp
  - 0.5 – 1.5 % power saved per 1°F change
- Desuperheater
  - Turns waste heat into practical heating (e.g. hot water)
- Automatic Volume Index (Vi) & Thermosyphon Oil Cooling (TSOC)
  - Efficiency new equipment options

Refrigeration Cycle (pressure-enthalpy diagram)



Case Study: Compressor Sequencing

Pasteurizer Cooling Equipment:

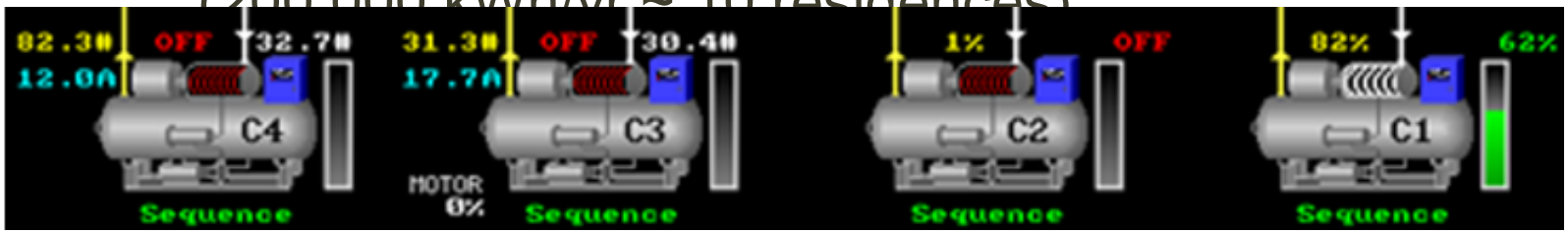
- 4 compressors (total 1,650 HP)
- C3 & C4 ⇨ new with VFDs
- C1 & C2 ⇨ old w/o VFDs

Cost: $28,000

Savings: $17,000/yr

(200,000 kWh/yr ~ 10 residences)

→ Payback = 1.6yrs

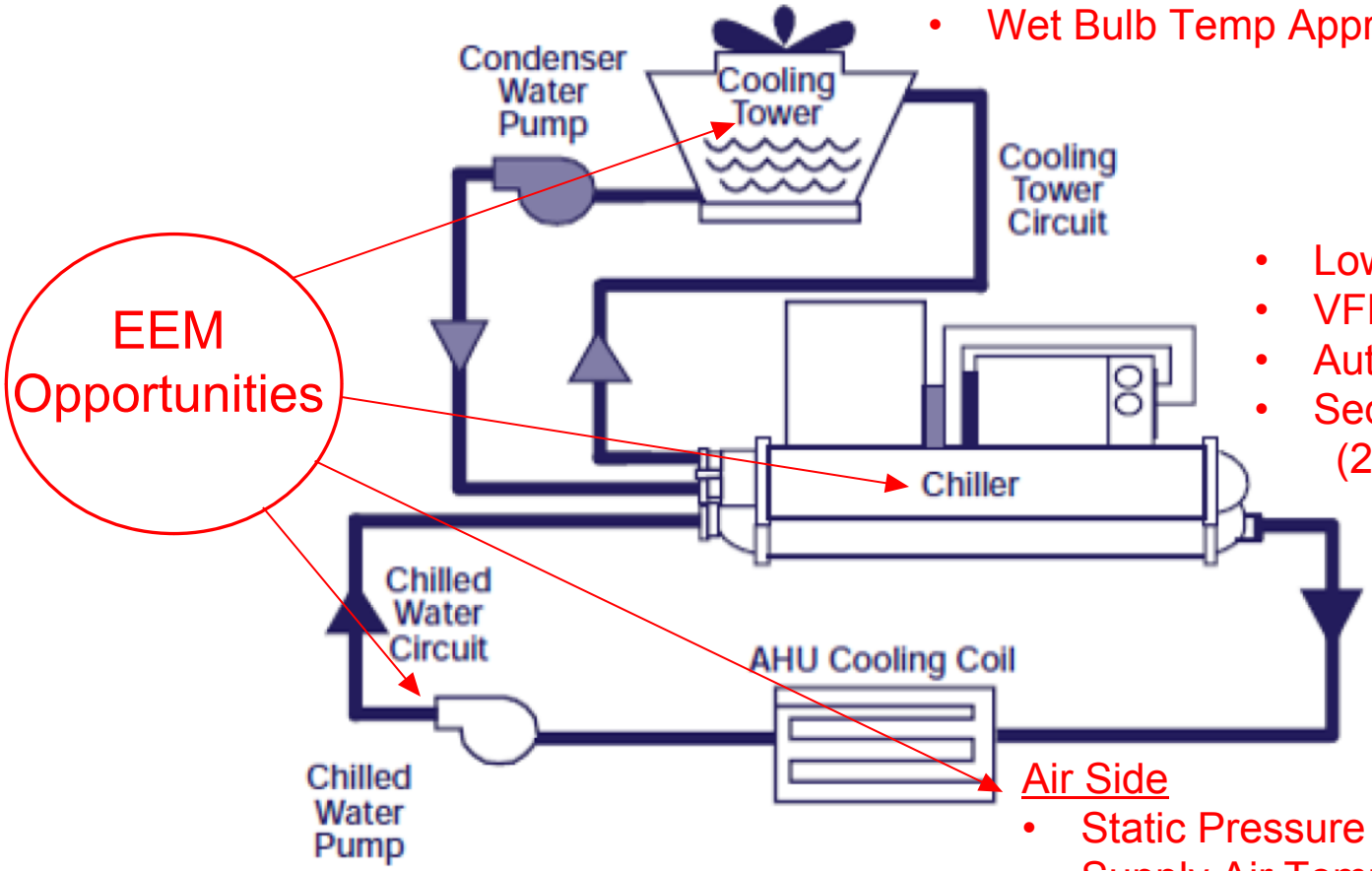


Typical HVAC EEMs

- Avoid simultaneously heating and cooling
- Minimally cool & heat
- Minimally ventilate
  - Fan, heating & cooling savings
  - “Sick Building Syndrome” led to many over-ventilated spaces in the 1980s
- Use VAV system when serving multiple zones
- Supply air temperature reset
  - Heating and cooling savings
- Static pressure reset
  - Fan savings
- Schedule temperature setbacks when unoccupied
- Economize (“free cooling”)
  - Cooling savings
  - Economizers are often broken

HVAC Cooling System

- Fan VFDs
- Oversized Cooling Tower
- Wet Bulb Temp Approach



- Lower CW Temp
- VFD Chiller
- Auto Vi & TSOC
- Sequencing (2+ chillers)

- VFD CHW Pump

Air Side

- Static Pressure Reset
- Supply Air Temperature Reset
- Scheduling (temp setbacks)

Typical Refrigeration EEMs

- Compressor VFD
- Evaporator VFDs
- Condenser Fan VFDs
- Control System
- Defrost Float Drainers
- TSOC in lieu of LIOC
- Variable Vi
- Oversized Condenser (reduces CWT)
- Hot Gas Defrost
- Desuperheater for Under Floor Heating

Screw Compressor VFD

- Motor speed will vary to maintain suction pressure
- Once motor speed reaches minimum speed (~40%), the screw compressor will begin to unload on the slide valve
- On highly variable loads such as cold storage applications, this is a cost effective measure

Evaporator & Condenser Fan VFDs

- Evaporator Fans
  - Fan speed modulates to maintain zone temperature
  - Be cautious of minimum fan speed recommendations b/c air flow must be delivered long distances in cold storages
  - Baseline operation is continuous fan operation or fan cycling (with cycle time to accommodate defrost)
- Condenser Fans
  - Fan speed modulates to maintain condensing pressure
  - Baseline operation is fan cycling, typically with pressure switches

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Control Systems

- Dynamic compressor staging
- Floating suction pressure
- Floating condensing pressure with ambient wet bulb
- VFD Control
- Defrost control
  - Liquid runtime
  - On demand

Evaporator Defrost

- Electric
  - Electric resistance coils are located between the rows of an evaporator coil as well as in the drain pan.
  - This type of defrost is typical in commercial and packaged refrigeration applications.
- Water
  - Water from 50°F – 100°F is washed over the exterior surface of the coil.
  - This is typical in nurseries, blast freezers, IQFs or anywhere the air quality is not ideal as this cleans the coil surface in the process.
- Hot gas
  - Superheated discharge refrigerant gas is directed through the drain pan and coil.
  - This is a great method for defrosting since this is free heat
  - This is typical for industrial applications with built up systems.

Defrost Control

- Fixed Time of Day
  - Each evaporator defrosts via a mechanical time clock.
  - This type of defrost is independent of coil load or ice accumulation.
  - This is typical in commercial and packaged industrial refrigeration applications (most likely with electric defrost).
- Liquid Runtime
  - Cumulative runtime of liquid line solenoid valves are monitored. Once the runtime equals a predetermined value, the evaporator will initiate a defrost cycle.
  - This is typical of hot gas defrost evaporators in built up industrial systems
- On Demand
  - This is a newer technology
  - Intelli-Frost by Logix is gaining popularity and proving to be an efficient alternative to liquid runtime defrost strategy
- Defrosts are necessary to maintain adequate heat transfer across the coil, but introduce additional load into the refrigerated space which must then be removed.

Defrost Float Drainers

- Float drainers fully condense defrost vapor which then gravity drains to the LPR. This prevents defrost vapor from entering compressor inlet and creating a false load due to increased mass flow.

Oversized Condenser

- Use the surface area of the condenser to your advantage.
- Oversizing a condenser will lower the approach temperature between the ambient wet bulb temperature and the saturated condensing temperature.
- This will allow for lower condensing pressures whenever possible.
- Typical Baseline: 90°F SCT / 68°F WBT
- Typical EEM: 85°F SCT / 70°F WBT

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Energy Engineering Fact Sheet

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Common Unit Conversions

1 kW = 3,412 Btu/h

1 ton = 12,000 Btu/h

1 MMBtu = 1,000,000 Btu = 10 Therms
1 Therm = 100,000 Btu
1 MBH = 1 kBtu/h = 1,000 Btu/h
1 Boiler hp = 33,475 Btu/h

1 psi = 2.31 ft of head

1 hp = .746 kW = 2,545 Btu/h

°C = 5/9 * (°F-32) °F = 9/5 * °C + 32 °R = °F + 460
°K = (°F + 460) * 5/9 = °C +273

Common Formulas

kW = Volts * Amps * PF * 1.73 / 1,000 (for 3 phase power)

kW of Motor Load = .746 * hp * Load Factor / Motor Efficiency

Airside Sensible Cooling Load (tons) = 1.08 * cfm * ΔT / 12,000

Waterside Cooling Load (tons) = 500 * gpm * ΔT / 12,000

Airside Heating Load (Btu/h) = 1.08 * cfm * ΔT

Waterside Heating Load (Btu/h) = 500 * gpm * ΔT

kW/ton = 12 / EER

EER = Cooling COP * 3.412

COP = Work Done / Energy In

Pump hp = Ft Head * gpm / 3960 / Pump Eff

Fan hp = Static Press * cfm / 6354 / Fan Eff

Motor kW (when shaft power is known) = Shaft hp * .746 / Motor Eff

Affinity Laws (P=Power, H=Head/Pressure, Q = flow)

$Q_1/Q_2 = RPM_1/RPM_2$
$H_1/H_2 = (RPM_1/RPM_2)^2$
$P_1/P_2 = (RPM_1/RPM_2)^3$
*Actual exponents are lower than formulas

Common Rules of Thumb

Water Cooled Chiller Efficiency = .5 - .8 kW/ton

Chilled Water Flow = 2.4 gpm/ton

Condenser Water Flow = 3.0 gpm/ton

DX/Air cooled chiller efficiency = 1-1.3 kW/ton

AHU Airflow = 400 cfm/ton

Lighting Power Density = .75 to 1.5 watts/sf (office and similar)

Equivalent Full Load Hours (EFLH) = 350 – 600 hrs for non-process cooling loads in PNW.

CW Reset = A decrease in condenser water temp will save between .5% and 1.5% per deg at the chiller. Constant speed chillers are closer to .5%, VFD closer to 1.5%. The same applies to refrigerant temperature in a refrigeration system.

CHW Reset (Const Speed Chiller) = An increase in chilled water temperature will save approximately .75% per deg at the chiller.

CHW Reset (VFD Chiller) = An increase in chilled water temperature will save approximately 2% per deg at the chiller. Note that if the coils have two way valves, this could increase pump power.

Suction Temperature Reset = An increase in refrigerant suction temperature will save approximately 2% in compressor power per degree.

EUI = A typical existing commercial building in the PNW may be in the range of 75-125 kBtu/sqft. New construction will be closer to 50-60 kBtu/sqft.

Please remember that analytical techniques can be complex and this provides only references, equations and rules of thumb, not complete analytical techniques.

Revised 2/08/14

THE END

If you want a copy of this presentation, please let me know

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