Critical Insights for Cooling Systems:
Off-Design Turndown, Thermal Balancing, and Nominal Ratings

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BEST PRACTICES
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COMPRESSED AIR / VACUUM / COOLING
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About the Speaker (Optional)

- Bachelor of Mechanical Engineering, Georgia Institute of Technology
- Master of Business Administration, Georgia State University
- Registered Professional Engineer, Georgia
- Over 30 years in industrial energy efficiency and cost control
- Principal of Integrated Services Group for 25 years

Session Topics

Three Uncommon Insights into Cooling Systems Assessment and Operation

- Leveraging Off-Design Conditions for System Efficiency
- Hydraulic Balancing vs. Thermal Balancing
- Distinction between Nominal Ratings and Actual Effective Ratings

Cooling systems are more complicated than they look

- Air systems are open loop, single (maybe double) pressure variable focus, limited range of process efficiency variations due to compression physics
- Challenges significantly a function of speed of changes
- Cooling systems are linked series of closed, interacting loops
- Substantial opportunities for efficiency changes, from 2:1 up to 8:1
- Many generalist practitioners underestimate the complexity and potential
- These are three of the most significant insights we've learned in 20+ years

Session Topics

Three Uncommon Insights into Cooling Systems Assessment and Operation

- Leveraging Off-Design Conditions for System Efficiency

Leveraging Off-Design Conditions

- Every piece of equipment has a specific design condition
  - Cooling tower – ***XYZ*** gpm @ 85°F in, 95°F out, 78°F wet bulb typical for much of U.S.A.
  - Chillers – ***XYZ*** gpm from 54°F to 44°F, ***ABC*** gpm 85°F to 95°F for water-cooled or 95°F EAT for air-cooled, ***EFG*** kW and ***H.IJK*** kW per ton
  - Pump – ***XYZ*** gpm @ ABC ft (selected from a curve of potential conditions)
  - Heat Exchanger (free cooling application) – ***XYZ*** gpm from 54°F to 44°F, ***XYZ*** gpm 42°F to 52°F

Leveraging Off-Design Conditions

- Every piece of equipment has a specific design condition
- Common knowledge recognizes certain cases where off-design conditions can be utilized
  - Reduced condenser water temperature
  - Elevated chilled water temperature
  - Similar to reducing compressed air pressure

Leveraging Off-Design Conditions

- Every piece of equipment has a specific design condition
- Common knowledge recognizes certain cases where off-design conditions can be utilized
- Too many people stop with these common uses
- Entire system is capable of yielding off-design benefits
- Requires clear understanding of system baseline condition through detailed surveys – flows, temps, pressures, etc.
- Accurate data cuts uncertainty from +/- 25-50% to +/- 10%

Sources of Off-Design Efficiency Savings

- Tower cell parallel operation (vs. staging)
- Fixed flow recirculation loops (tower or chilled)
- Fixed flow primary CHW loops
- Pressure controlled process cooling loops (tower or chilled)
- Parallel chiller operation when applicable (operating range dependent on compressor type & capacity control method)

Physical Principles at Work

- Flow friction squared to velocity, power cubed to flow on applicable systems (widely useful on cooling)

$$Friction1\ X\left(\frac{Flow2}{Flow1}\right)^2 = Friction2$$

$$Power1\ X\left(\frac{Flow2}{Flow1}\right)^3 = Power2$$

Physical Principles at Work

- Flow friction squared to velocity, power cubed to flow on applicable systems (widely useful on cooling)
- Eliminate fixed loss waste
- Reduce excess applications – flow, pressure,…
- Maximize use of heat exchanger surface area
- Maximize effective delta T across heat exchanger

Example Applications

- Fully open discharge valves
- Open balance valves to least overall closure (1+ @ 100%)
- Minimum necessary system pressures
- Reduced recirc. loop flow to towers or chillers – pumping energy saved, delta T increased
- Recirc loop flow balanced to process loop flow – pumping energy saved, tank blending reduced, delta T increased

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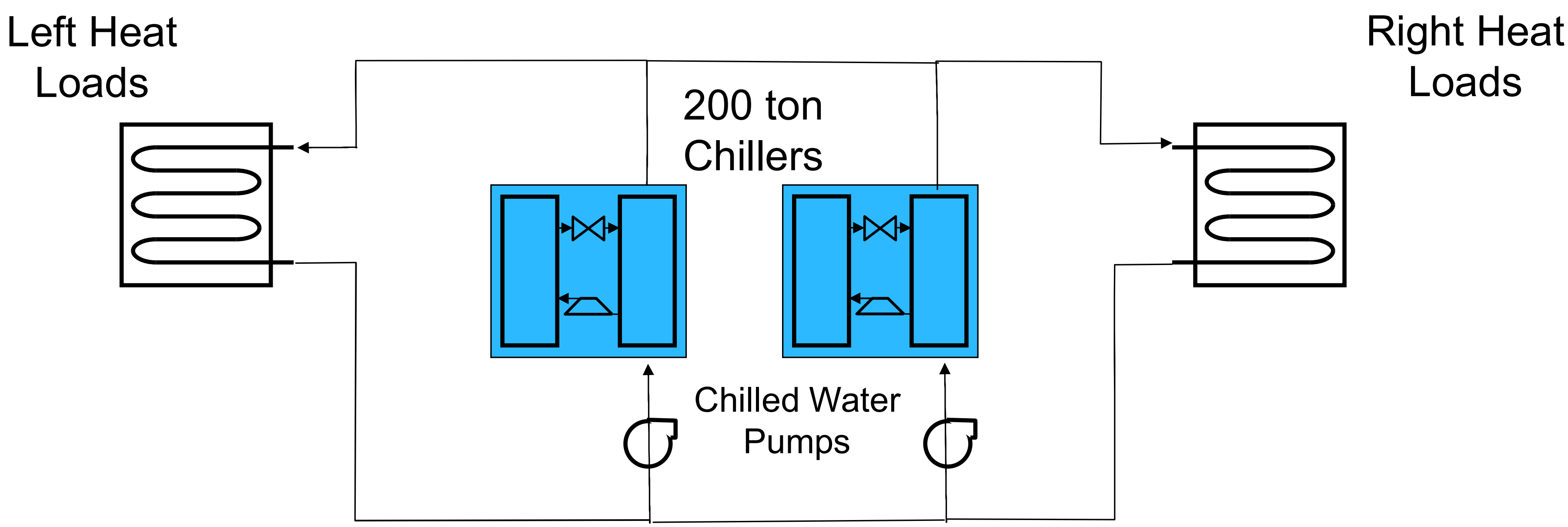
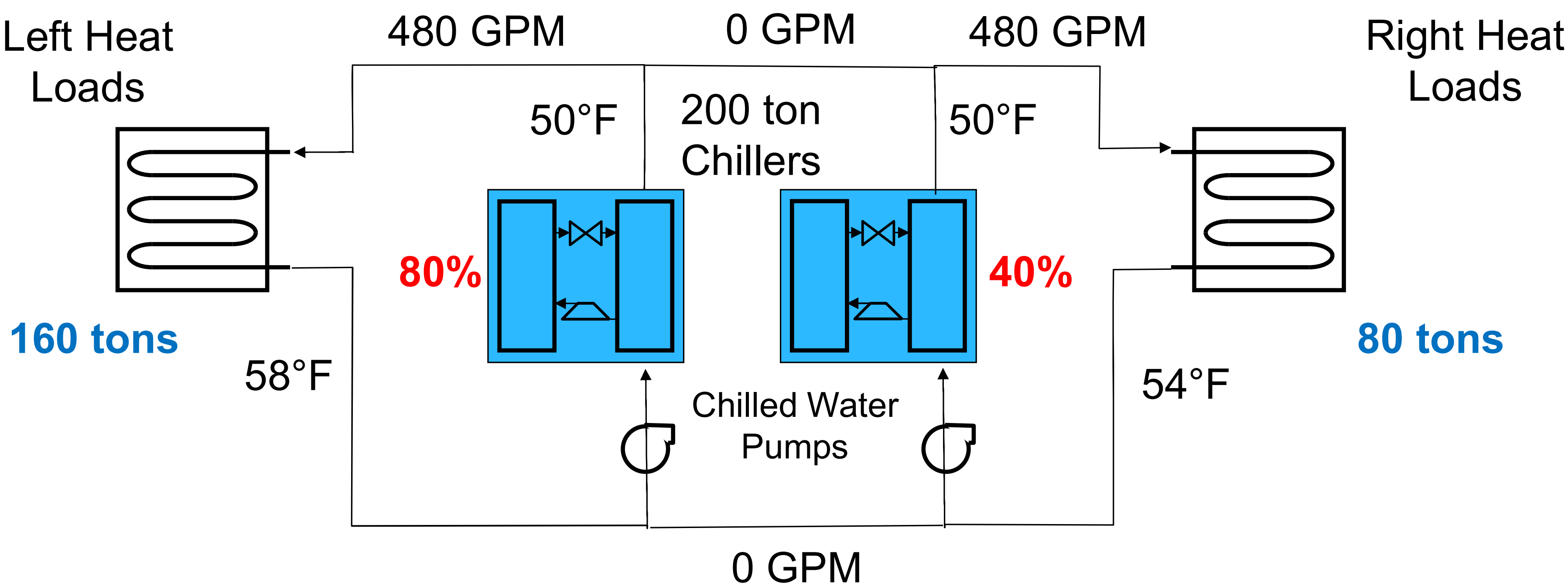
Hydraulic Balancing vs. Thermal Balancing

- Insight: Just because the pipes are filled does not mean desired and / or intended cooling is taking place
- Key principle: Equal water flows do not mean equal thermal loads
- Imbalanced thermal loads result in several performance issues:
  - Loss of temperature control to plant
  - Inefficient use of cooling equipment – unequal loading
  - Inefficient use of cooling equipment – low delta T

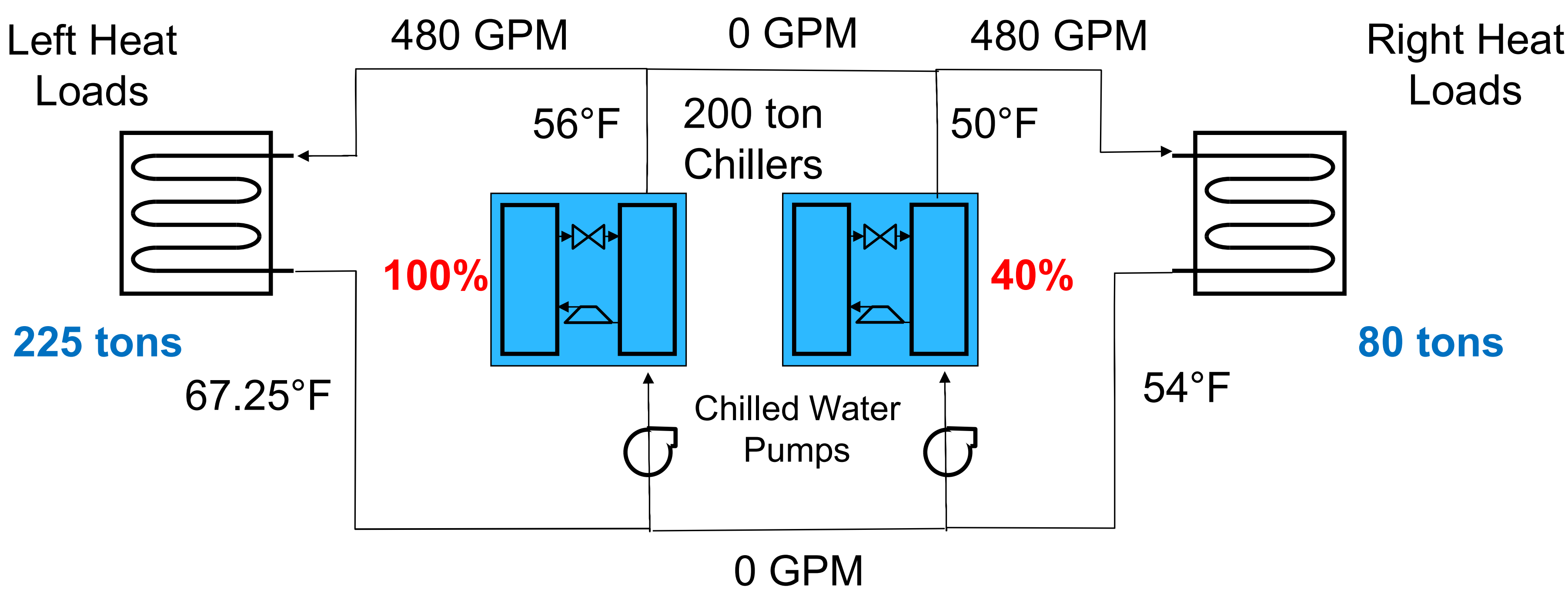
Example Imbalanced System



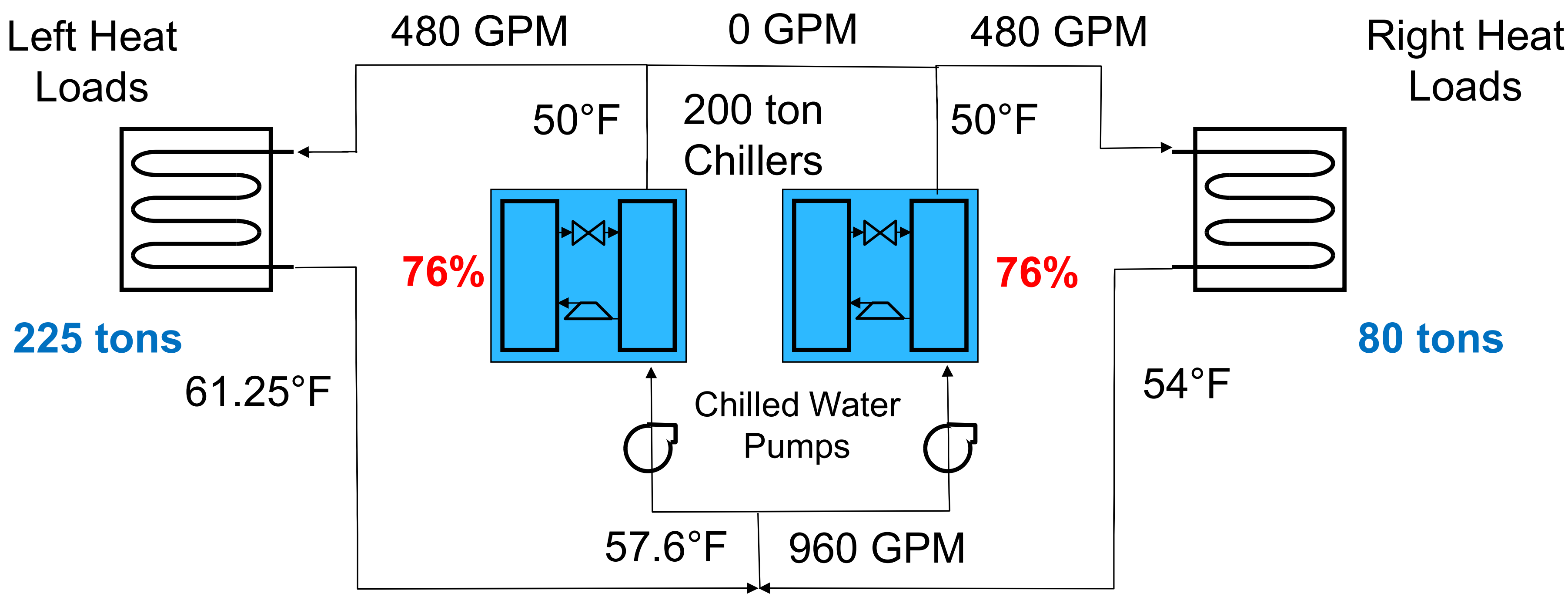
Example Imbalanced System –Individual Chillers Meeting Loads



Example Imbalanced System – Individual Chillers **Not** Meeting Loads



Simple Correction for Imbalanced System



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Nominal Ratings vs. Actual Effective Ratings

- Insight: Nominal rating often does not equal usable or realized capability

“A ton is not a ton is not a ton”

- Key principle: Actual effective capability depends on the specific application circumstances
- Very commonly experienced with cooling components:
  - Pump flow
  - Cooling tower heat rejection
  - Chiller heat rejection
  - Heat exchanger performance

Nominal Ratings vs. Actual Effective Ratings

- Insight: Nominal rating often does not equal usable or realized capability
- Key principle: Actual effective capability depends on the specific application circumstances
- Very commonly experienced with cooling components
- Compressed air example – Receiver storage capacity: stated in gallons (which don't change) but effective CF of air depend on charging pressure vs. system pressure, specific pressures, etc.

Physical Principles at Work

- Flow friction squared to velocity, power cubed to flow
- Maximize use of heat exchanger surface area
- Maximize effective delta T across heat exchanger

Nominal Ratings vs. Actual Effective Ratings Example

- Common case: Chiller not meeting expectations (either low total cooling provided or poor efficiency)

- Common causes:
  - Insufficient condenser flow (water or air, high condenser pressure)
  - Incorrect CHW flows (evaporator design conditions)
  - Poor temperature conditions (high or low delta T, off-design setpoint)
  - Heat exchanger performance (fouled tubes, suboptimal flow and / or temps)

Summary

- Leverage off-design conditions for higher system efficiency
- Design systems for effective loading and operation, not just full pipes
- Correctly assess cooling equipment capability based on actual conditions

Contact Information for Follow Up / Questions

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