TRIGENERATION AT UNIVERSITY OF MINNESOTA
INSTALLATION OF A MODERN ABSORPTION CHILLER & DISPATCHING STRATEGIES
OVERVIEW

PRESENTATION TOPICS

• Background
• Why Absorption?
• Laying Out the Project
• Carbon Footprint Reduction
• End Results
BACKGROUND

UNIVERSITY STEAM AND CHILLED WATER UTILITIES

- U of MN tri-generation system
  - Multiple co-gen heating plants
  - Multiple chilled water districts

- 2017 Project: 24MW Gas Turbine with Heat Recovery
  - Centerpiece of Trigeneration System

- Academic Health Sciences
  - Largest and most consistent chilled water user
  - Campus is fully developed in this district
  - Projects are usually retrofits within existing building envelopes
  - Outages of infrastructure in this mission critical area of campus are high impact and very infrequent
BACKGROUND

TRI-GENERATION WITH MAIN ENERGY PLANT

- MEP began commercial operation in 2017
- CHP 101: Match thermal and electric loads
- Campus Electric Peak Demand Reduction
  - Peak demand charges ~50% of annual campus electric costs

GE LM2500 DLE Dual Fuel
220 MMBtu/hr Input (HHV)  24 MWe Generator Output
Demand-Limiting Strategies
- Steam absorbers (~9,000 tons)
- Future steam turbine chillers (6,000 tons)
- Future inlet air cooling on MEP turbine (900 ton load, +2 MW output)
- Building mass thermal energy storage
- (Future) Traditional TES options, ice and/or chilled water storage
BACKGROUND

TRIGENERATION

MAIN ENERGY PLANT (MEP)

C

T

G

22 MW

GENERATED POWER

WASTE STEAM

FIRED STEAM

HRSG

DB

absorption chiller

CAMPUS STEAM DISTRIBUTION

CAMPUS ELECTRIC DISTRIBUTION

ABSORPTION CHILLER

CHILLED WATER

1,000 Tons

Natural Gas

COAL: 30%

NATURAL GAS: 14%

NUCLEAR: 30%

WIND: 16%

SOLAR: 2%

OTHER RENEWABLES: 8%

CONVENTIONAL CHILLER

XCEL ENERGY (2018)

PURCHASED POWER

CAMPUS ELECTRIC DISTRIBUTION

CENTRIFUGAL CHILLER

CHILLED WATER

1,000 Tons

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BACKGROUND

ACADEMIC HEALTH CHILLED WATER DISTRICT

- Moos Tower / PWB
  - 4 Absorption & 3 Centrifugal
  - Capacity Range: 1,000-1,500 tons/each
  - Total Installed Capacity: 8,575 tons
  - 1 new absorption chiller added
  - Steam supplied from main energy plant (MEP)

- Molecular & Cellular Biology Building (MCB)
  - 3 Centrifugal
  - 1,300 tons/each
  - 3,900 tons

Jared, this is shown in your P&ID, is it included in the total capacity of the Academic Health district?

- 1 Absorption
  - 1,200 tons

Total Capacity: 12,475 tons (Peak: 11,178 tons) **DOES'T INCLUDE K/E – REVIEW FEASIBILITY REPORT TO SEE IF K/E WAS INCLUDED**

Jared – anything we are missing out on here?
BACKGROUND

ADDITIONAL COOLING CAPACITY - PROJECT SCOPE

- Projected 1,000 tons of additional cooling capacity by 2020
- Internal feasibility study: chiller technologies and infrastructure
  - Rigging Challenges - Moos Tower mechanical room is 50' below grade
  - Limited space available
  - Minimal outage available
  - Maintain adequate access for all existing equipment
- Projects required to support new chiller:
  - Cross-over piping upgrades (chilled water and condenser water) required to maintain N+1
  - Replacement of existing chilled water pumps
- Adequate cooling tower capacity available for new chiller
Chiller Technologies

• The following chiller technologies were considered:
  - Electric centrifugal:
    • Insufficient electric feeder capacity,
    • **Negative** impact on campus peak electric demand charges
  - Steam turbine:
    • For this part of the system, would require staffing change, MN statute requires a licensed boiler operator on-site for start-ups
  - Absorption:
    • Peak electric demand reduction
    • Locational flexibility
    • University operators already have experience with this technology.
    • Deemed the best available technology for this application.
## Lifecycle Cost Analysis

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<th>30 Yr Lifecycle Cost ($)</th>
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**LCA of existing electric chiller (peak)**

$5,175,844

**LCA of new absorber (baseload)**

$4,975,538

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*All costs in 2017 dollars*
Chiller Procurement

• Clearances: Rigging and Final Location
• Disassembly and Reassembly requirements called out to accommodate available clearances.
LAYING OUT THE PROJECT

Chiller Selection

- Chiller RFP:
  - Pre-bid site walkthrough required for all vendors
  - Submit chiller performance (zero tolerance at full design load conditions)
  - Submit condenser and chilled water DPs

- Factory Performance Test
- On-Site Performance Test
Chiller Selection

- Broad Model BS400
- Design Conditions:
  - 1,000 tons capacity
  - Evaporator: 40º/58ºF
  - Condenser: 85º/97ºF
  - Inlet Steam Pressure: 125 psig, saturated
  - Steam Consumption: 8,385 lb/hr
  - COP: 1.4
  - Steam powered condensate pump
- Tube Materials:
  - Evaporator: Copper
  - Condenser: Cupronickel
  - Absorber: Cupronickel
  - HTG: Titanium
  - LTG: Cupronickel
LAYING OUT THE PROJECT

Equipment Install – Shaft Access
Moos Tower Chiller Layout and Installation

- Laser scan was essential for adequate clearance for piping, tube pull and chiller service
- Existing single stage absorption chiller was shifted 3’ to provide additional clearance
- Careful scheduling of outages, then proceeded with assembly
Chiller Performance Tests

• Witness performance test done at the Broad factory in China
  - NV5 was present

• Field performance test done upon completion of installation
  - Design capacity and peak performance were tested to zero tolerance
  - Part-load performance tested based on AHRI conditions
  - Field performance and tight metering specification included in RFP for chiller for OEM reference
Chiller Operation

- **Features of modern absorption chillers:**
  - Modern PLC’s are configured to ensure the absorption machine stays out of the crystallization zone
  - Automatically limits capacity on low entering water temperature
  - Modern machines have automatic purge systems to maintain vacuum
  - Improvements in steam control valves have allowed absorbers to react better to load changes
  - Tube metallurgy (CuNi, SS, titanium) have reduced tube issues and improved reliability

- **The absorbers are typically run at 80-90% load**
  - Maximizes equipment life (reduced HTG temp)
  - Lower entering tower water temperature reduces absorber capacity
  - Lower tower temp improves overall plant efficiency
END RESULTS

Lessons Learned

• Reassembly was more labor intensive than we had planned.

• Having a skilled contractor in place as a partner was key, especially given the tight physical constraints in all directions.

• We utilized a steam-powered condensate pump for this project. Finding adequate vertical clearance was a significant challenge.

• Laser scanning of the entire plant was a major time-saver in such a crowded plant

• Highly recommend detailing out each pipe support location when possible to avoid extra costs from field-routing

• Chiller delivery in -20F windchill is not fun. . .
ANNUAL CHILLER CO₂ EMISSIONS DEPENDS ON DISPATCH METHOD

Using Fired Steam: 0.418 kg CO₂/ T-HR

Using Centrifugal Chiller: 0.418 kg CO₂/ T-HR

XCEL ENERGY (2018)

COAL: 30%
NATURAL GAS: 14%
NUCLEAR: 30%
WIND: 16%
SOLAR: 2%
OTHER RENEWABLES: 8%

*Based on utility annual average CO₂ emissions of 0.365 MT CO₂/MWh, per Xcel CO₂ Emission Intensities 2018 and chiller efficiency of average fleet efficiency 0.515 kW/ton

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ANNUAL CHILLER CO₂ EMISSIONS DEPENDS ON DISPATCH METHOD

TRIGENERATION

MAIN ENERGY PLANT (MEP)

C T G

22 MW

GENERATED POWER

HRSG DB

Fired Steam

1,354,552 kg CO₂

VENTING WASTE STEAM

NATURAL GAS

CONVENTIONAL CHILLER

Xcel Energy (2018)

Coal: 30%

Natural Gas: 14%

Nuclear: 30%

Wind: 16%

Solar: 2%

Other Renewables: 8%

Purchased Power*

609,039 kg CO₂

CAMPUS ELECTRIC DISTRIBUTION

CENTRIFUGAL CHILLER

Chilled Water

1,000 Tons

OTHER RENEWABLES:

Wind: 16%

Solar: 2%

Other Renewables: 8%

*Based on utility annual average CO₂ emissions of 0.365 MT CO₂/MWh, per Xcel CO₂ Emission Intensities 2018 and chiller efficiency of average fleet efficiency 0.515 kW/ton

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Chilled Water

1,000 Tons

CO₂ Emissions

CENTRIFUGAL CHILLER

Chilled Water

1,000 Tons

VENTING WASTE STEAM
ANNUAL CHILLER CO₂ EMISSIONS DEPENDS ON DISPATCH METHOD

MAIN ENERGY PLANT (MEP)

22 MW

GENERATED POWER

CAMPUS ELECTRIC DISTRIBUTION

WASTE STEAM
0 kg CO₂

CAMPUS STEAM DISTRIBUTION

ABSORPTION CHILLER

CHILLED WATER
1,000 Tons

NATURAL GAS

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NUCLEAR: 30%
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XCEL ENERGY (2018)

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609,039 kg CO₂

CAMPUS ELECTRIC DISTRIBUTION

CENTRIFUGAL CHILLER

CHILLED WATER
1,000 Tons

TRIGENERATION

USING WASTE HEAT ONLY: 0.00 kg CO₂/ T-HR

*Based on utility annual average CO₂ emissions of 0.365 MT CO₂/MWh, per Xcel CO₂ Emission Intensities 2018 and chiller efficiency of average fleet efficiency 0.515 kW/ton

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END RESULTS

Moos Chiller 13 Operation vs. MEP Operation

Absorbers operating with “free” steam (lbs/hr)
Campus Cooling CO2 Footprint Reduction

- MEP reduces UMN CO2 footprint by 25%
- Conservation measures and fuel source improvements have provided another ~15% reduction
- Venting waste steam while generating at MEP is economically favorable
- Absorption cooling with this waste heat has a 40% lower CO2 footprint and ~80% lower fuel cost vs electric centrifugal plant
- ➔ Abs. cooling is a key thermal load to balance our CHP system and maximizing value
- ➔ Every pound of steam saved on campus during summer improves cooling CO2 footprint
QUESTIONS?

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