How to Optimize the Performance of Your Hospital Boiler Plant: A Case Study

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Presenters:

Ryan Ollie, E.I.T., CEM, CMVP
Manager of Energy Solutions,
Advocate Health Care

Austin Rennick, P.E., CEM, CHFM, LEED AP BD+C
Manager of Facility Operations,
Advocate Condell Medical Center

Dan Doyle, P.E., LEED AP O+M
Chairman, Grumman/Butkus Associates

Tim Jendrycki, P.E.
Associate, Grumman/Butkus Associates
There Are Many Compelling Reasons for Hospitals to Conserve Energy (and Water)
Hospital Gas Usage

Year 2017 G/BA Hospital Energy and Water Benchmarking Survey
For 2016 Fossil Fuel* Energy Consumption (BTU/SF/yr)

*Fossil fuels included in the survey include natural gas, fuel oil and district steam

Facilities with Absorbers: 18, 26, 45, 46, 48, 51, 53, 57, 80, 95, 100, 104, 107, 206, 215, 219, 221 and 222
Facilities with Electricity Self-Generation: 18, 23, 24, 40, 46 and 107
Facilities with Electric Heat: 19, 22, 29, 41, 42, 57, 97, 99, 200, 202, 204, 207, 211, 218, 220 and 223
Facilities with In-House Laundry: 19, 30, 79, 84, 97, 98, 105, 200, 210, 211 and 223
Facilities with Purchased Chilled Water: 63, 64, 80, 200 and 216
Facilities with Purchased Steam: 56, 63, 64, 65, 78, 80, 111, 112, 200, 206, 213, 216 and 222
Facilities with Heat Pumps or Geothermal Systems: 15, 16, 38, 41, 106, 201, 216, 222, and 228

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Hospital Gas Cost

Year 2017 G/BA Hospital Energy and Water Benchmarking Survey
For 2016 Fossil Fuel* Energy Cost ($/SF/YR)

*Fossil fuels included in the survey include natural gas, fuel oil and district steam

Facilities with Absorbers: 18, 28, 45, 46, 48, 51, 53, 57, 80, 95, 100, 104, 107, 206, 215, 219, 221 and 222
Facilities with Electricity Self-Generation: 19, 23, 24, 40, 49 and 187
Facilities with In-House Laundry: 19, 30, 70, 84, 97, 98, 105, 200, 210, 211 and 223
Facilities with Purchased Chilled Water: 63, 64, 69, 80, 200 and 216
Facilities with Purchased Steam: 59, 63, 64, 69, 79, 80, 111, 112, 200, 206, 213, 216 and 222
Facilities with Heat Pumps or Geothermal Systems: 15, 16, 30, 41, 109, 201, 216, 222, and 223
ASHE Benchmarking Data: Cost Breakdown of Facility Budgets

- Energy represents more than half of the healthcare facility budget, according to current benchmarking data from the American Society for Healthcare Engineering.
- That’s more than staffing, materials, and service contracts combined.
What Are Some Energy-Saving Opportunities?

- Use less steam
- Watch your water treatment
- Reduce/eliminate vented steam and condensate losses
- Minimize radiant heat losses
- Minimize steam production losses
- Maximize combustion efficiency
- Recover waste heat from flue, deaerator vent for heating domestic hot water, make-up water, boiler feedwater, or combustion air
First, Some Boiler Plant Basics

- When to use steam vs. hot water
- Different boiler types
- Burners
  - Forced-draft vs. atmospheric
- Ancillary steam plant equipment
- Surge tank, condensate pumps
- Deaerator, feedwater pumps
- Flue, breeching, stack
- Steam traps
Hot Water vs. Steam

- Hot water is the best option for heating
  - Lowest maintenance cost
  - Highest efficiency
- Steam is generally used for process needs (sterilizers, humidifiers) when higher temperatures are needed or when large campus distribution is necessary.
Typical Hospital Steam Energy Balance

- Process Load, 9%
- Preheat Load, 19%
- Humid Load, 25%
- Reheat Load, 15%
- Stack Loss, 18%
- DA Demand, 8%
- Trap Load, 2%
- Flash Loss, 2%
- DA Vent Loss, 1%
- Blowdown Load, 3%
Typical Hospital Boiler Steam Demand Distribution vs. Outdoor Air Temperature
Typical Hospital Boiler Steam Demand Distribution vs. Outdoor Air Temperature with Temperature Bin Hours

Steam Flow Rate (pounds per hour) vs. Outdoor Air Temperature (degrees F)

- Stack Loss
- DA Demand (#/hr)
- Blowdown Load (#/hr)
- Humid Load (#/hr)
- Preheat Load (#/hr)
- Reheat Load (#/hr)
- Flash Loss (#/hr)
- Trap Load (#/hr)
- Process Load (#/hr)

Annual Hours
A Typical Steam Plant Configuration
What Are the “Passes” in a Firetube Boiler?

- **One-Pass**
- **Two-Pass**
- **Three-Pass**
- **Four-Pass**
Different Types of Firetube Boilers

- **Dry-Back Firetube Boiler**
- **Wet-Back Firetube Boiler**
Water-Tube Boilers

Watertube Boilers
The Deaerator

Typical Deaerator

Condensate Receiver/Deaerator Combo
What Are Some Energy-Saving Opportunities?

- Use less steam
- Watch your water treatment
- Reduce/eliminate vented steam and condensate losses
- Minimize radiant heat losses
- Minimize steam production losses
- Maximize combustion efficiency
- Recover waste heat from flue, deaerator vent for heating domestic hot water, make-up water, boiler feedwater, or combustion air
A Typical Steam Plant Configuration
Pay Attention to Your Water Treatment
Reduce/Eliminate Vented Steam, Condensate Going to Drain

Looking for leaking steam traps, PRVs, condensate being dumped
Reduce/Eliminated Vented Steam, Condensate Going to Drain

- Looking for leaking steam traps, PRVs, condensate being dumped

Leaking Steam Trap
Minimize Radiant Heat Losses

- Lower operating pressure (governed by process requirements)
- Repair damaged or missing insulation on piping and heated vessels
Minimize Steam Production Losses (Blowdown, Deaerator)

- Blowdown heat recovery
RO System for M-U Water Treatment
Maximize Combustion Efficiency

- Minimize $O_2$ / excess air without sooting
Boiler Flue Stack Economizers

Where to use recovered heat?
- Boiler feedwater
- Boiler make-up water
- Domestic hot water
Recover Heat From DA Vent

Engineering Data

Table 4: Heat Exchanger Nominal Performance

<table>
<thead>
<tr>
<th>Heat Exchanger Type</th>
<th>Nominal Capacity</th>
<th>Flow</th>
<th>Pressure drop</th>
<th>Flow</th>
<th>Pressure drop</th>
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<tbody>
<tr>
<td></td>
<td>kW</td>
<td>l/s</td>
<td>kPa</td>
<td>l/s</td>
<td>kPa</td>
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<tr>
<td>B-45</td>
<td>23</td>
<td>6.08</td>
<td>0.2</td>
<td>150</td>
<td>39.65</td>
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<tr>
<td>B-70</td>
<td>25</td>
<td>6.64</td>
<td>0.8</td>
<td>176</td>
<td>44.91</td>
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<tr>
<td>B-130</td>
<td>27</td>
<td>7.13</td>
<td>1.2</td>
<td>236</td>
<td>52.84</td>
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<tr>
<td><strong>B-180</strong></td>
<td>30</td>
<td>7.93</td>
<td>2.7</td>
<td>210</td>
<td>35.48</td>
</tr>
<tr>
<td>B-250</td>
<td>35</td>
<td>9.25</td>
<td>4.2</td>
<td>210</td>
<td>35.48</td>
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<tr>
<td>B-300</td>
<td>40</td>
<td>10.57</td>
<td>6.3</td>
<td>350</td>
<td>79.25</td>
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<td>B-400</td>
<td>46</td>
<td>12.42</td>
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<td>342</td>
<td>90.10</td>
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<tr>
<td>B-500</td>
<td>55</td>
<td>14.53</td>
<td>9.2</td>
<td>310</td>
<td>85.10</td>
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<tr>
<td>B-1000</td>
<td>95</td>
<td>25.10</td>
<td>16.7</td>
<td>275</td>
<td>185.24</td>
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</tbody>
</table>

Nominal values are based on 60°C (140°F) temperature difference between incoming heating and heated water.

Table 5: Advanced B Series Stainless Steel - 316L

<table>
<thead>
<tr>
<th>Type</th>
<th>L</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
<th>Heat Transfer Area</th>
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<tbody>
<tr>
<td></td>
<td>mm</td>
<td>cm</td>
<td>mm</td>
<td>cm</td>
<td>mm</td>
<td>cm</td>
<td>m² (ft²)</td>
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<tr>
<td>B-45</td>
<td>267</td>
<td>10.5</td>
<td>106</td>
<td>4.2</td>
<td>11.9</td>
<td>0.45</td>
<td>0.183 (1.97)</td>
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<tr>
<td>B-70</td>
<td>345</td>
<td>13.6</td>
<td>176</td>
<td>6.9</td>
<td>17.8</td>
<td>0.68</td>
<td>0.258 (2.79)</td>
</tr>
<tr>
<td>B-130</td>
<td>385</td>
<td>15.3</td>
<td>275</td>
<td>11.0</td>
<td>27.5</td>
<td>1.00</td>
<td>0.307 (3.30)</td>
</tr>
<tr>
<td>B-180</td>
<td>383</td>
<td>15.2</td>
<td>193</td>
<td>7.6</td>
<td>19.3</td>
<td>0.70</td>
<td>0.265 (2.90)</td>
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<tr>
<td>B-250</td>
<td>517</td>
<td>20.3</td>
<td>228</td>
<td>11.7</td>
<td>22.8</td>
<td>1.00</td>
<td>0.347 (3.80)</td>
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<td>632</td>
<td>24.8</td>
<td>142</td>
<td>5.6</td>
<td>14.2</td>
<td>0.50</td>
<td>0.181 (1.95)</td>
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<td>B-400</td>
<td>747</td>
<td>29.4</td>
<td>157</td>
<td>6.2</td>
<td>15.7</td>
<td>0.60</td>
<td>0.213 (2.33)</td>
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<tr>
<td>B-500</td>
<td>856</td>
<td>33.9</td>
<td>164</td>
<td>6.5</td>
<td>16.4</td>
<td>0.68</td>
<td>0.261 (2.82)</td>
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<tr>
<td>B-1000</td>
<td>917</td>
<td>36.1</td>
<td>175</td>
<td>6.9</td>
<td>17.5</td>
<td>0.74</td>
<td>0.299 (3.25)</td>
</tr>
</tbody>
</table>

Standard Materials:
- 316L Stainless Steel, Titanium
- Maximum Allowable Working Pressure:
  - SS: 316L: 1.0 MPa (150 psi)
  - Titanium: 1.03 MPa (150 psi)
- Maximum Allowable Working Temperature:
  - SS: 316L: 208°C (400°F)
  - Titanium: 350°C (662°F)
Case Study: Advocate Health Care

Phase 1

- New burners on 10 boilers at 6 hospitals
Case Study: Advocate Health Care
Phase 2

- Recover heat from flue gas and DA vents at 10 hospitals
<table>
<thead>
<tr>
<th>Location</th>
<th>Condenser Type</th>
<th>Equipment Details</th>
<th>Heating System</th>
</tr>
</thead>
<tbody>
<tr>
<td>BroMenn Medical Center</td>
<td>Vent Condenser</td>
<td>(1) Stack Economizer (1) Steam Boiler</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Christ Medical Center</td>
<td>Vent Condenser</td>
<td>(3) Stack Economizers (3) Steam Boilers</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Condell Medical Center</td>
<td>Vent Condenser</td>
<td>(1) Stack Economizer on common vent with (2) Boilers</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Good Samaritan Hospital</td>
<td>Vent Condenser</td>
<td>(2) Stack Economizers (2) Steam Boilers</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Good Shepherd Hospital</td>
<td>Vent Condenser</td>
<td>(2) Stack Economizers (2) Steam Boilers</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Illinois Masonic</td>
<td></td>
<td>(1) Stack Economizer (1) Steam Boiler</td>
<td>Feedwater Heating</td>
</tr>
<tr>
<td>Lutheran General Hospital</td>
<td>Vent Condenser</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Suburban Hospital</td>
<td>Vent Condenser</td>
<td>(2) Stack Economizers (2) Steam Boilers</td>
<td>Feedwater Heating</td>
</tr>
<tr>
<td>Sherman Hospital</td>
<td>Vent Condenser</td>
<td>(2) Stack Economizers (2) Steam Boilers</td>
<td>Feedwater Heating</td>
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<tr>
<td>Trinity Hospital</td>
<td>Vent Condenser</td>
<td>(1) Stack Economizer (1) Steam Boiler</td>
<td>Domestic Water Heating</td>
</tr>
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</table>
## Scope of Project as Actually Implemented

<table>
<thead>
<tr>
<th>Location</th>
<th>Equipment Description</th>
<th>Heating Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>BroMenn Medical Center</td>
<td>Vent Condenser (1) Stack Economizer (1) Steam Boiler</td>
<td>Domestic Water Heating</td>
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<tr>
<td>Christ Medical Center</td>
<td>Vent Condenser (1) Stack Economizers (1) Steam Boilers</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Condell Medical Center</td>
<td>Vent Condenser (1) Stack Economizer on common vent with (2) Boilers</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Good Samaritan Hospital</td>
<td>Vent Condenser (2) Stack Economizers (2) Steam Boilers</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Good Shepherd Hospital</td>
<td>Vent Condenser (2) Stack Economizers (2) Steam Boilers</td>
<td>Domestic Water Heating</td>
</tr>
<tr>
<td>Illinois Masonic</td>
<td>Vent Condenser (1) Stack Economizer (1) Steam Boiler</td>
<td>Feedwater Heating</td>
</tr>
</tbody>
</table>
DA Tank Vent Condenser

- DA vent releases dissolved gasses to atmosphere
- Normally based on 0.5% of total mass flow rate of DA tank
- Established and set at maximum design condition but operates at same flow rate at all reduced conditions
- Recovery fluid is heated from condensing vent steam
- Recovery fluid can overheat and "steam" if flow is stopped or too low
- Heating untreated make-up water above 180°F can scale the heat exchanger
DA Tank Vent Condenser

**New Steam Vent Condenser**

- **DA Steam Vent Orifice:**
  - 1/8" = 10 LBS/HR
  - 1/4" = 40 LBS/HR
  - 3/8" = 80 LBS/HR
  - 1/2" = 145 LBS/HR

**Diagram Components:**
- **Make-Up Water (CW)**
- **LPC**
- **Overflow Drain**
- **Condensate Surge Tank**
- **Spray Deaerator**
- **Overflow Trap**
- **Boiler Feed Pump**
- **To Steam Boiler**
Effect of Entering Water Temperature on Vent Condenser Effectiveness

Vent Condenser Output vs. Entering Water Temperature

Vent Condenser Entering Water Temperature (deg F)

Vent Condenser Recovery (%)
Boiler Flue Stack Economizers

400°F (FLUE GAS)

280°F

FLUE STACK ECONOMIZER

COLD WATER IN

HOT WATER OUT

BOILER

BOILER
Typical HP Steam Plant Operating Parameters

- **Condensate Surge Tank**: 160°F
- **Spray Deaerator**: 227°F @ 5 psig
- **Boiler Feed Pump**: 227°F
- **Steam Boiler**: 338°F @ 100 psig
- **Boiler Feed Water**: 438°F @ 100% load
  - 365°F @ 25% load
- **Make-up Water**: CW, LPC
  - CW: 60°F
  - LPC: 180°F
- **Overflow Drain**: 160°F
- ** Overflow Trap**: 160°F
Domestic Water Heating

**DOMESTIC HEATING:**
- 135°F @ 10 GPM
- 97°F @ 20 GPM
- 85°F @ 30 GPM

**Diagram Details:**
- DHW
- DCW
- CW
- LPC
- BOILER FLUE VENT
- NEW NON-CONDENSING BOILER STACK ECONOMIZER WITH INTERNAL BYPASS DAMPER
- LEVEL CONTROLLER
- STEAM BOILER
- BOILER FEED WATER
- CONDENSATE SURGE TANK
- SPRAY DEAERATOR
- BOILER FEED PUMP
- CONDENSATE TRANSFER PUMP
Some Lessons Learned...

➢ Do one measure at multiple sites in lieu of multiple measures at one site

   o Pros:
     ▪ Get better pricing
     ▪ Dealing with single vendor/contractor
     ▪ Consistency of approach/implementation across all sites

   o Cons:
     ▪ Managing/coordinating with multiple boiler room operators, each with different ideas and preferences
     ▪ Coordinating project at multiple construction sites simultaneously
Some Lessons Learned...

- Pre-purchase major equipment
  - Get a single manufacturer
  - Owner picks “best value” product instead of contractor selecting lowest price
    - Life Cycle vs. First Cost
  - Cuts delivery time
Some Lessons Learned...

- Limit Change Orders
  - Budget for control points!
    - Sensors (inlet/outlet of every heat recovery device)
    - BAS trend setup
    - You need to be able to verify/prove savings to justify investment to senior leadership
  - Maintenance
    - Discovered potential accessibility issues for routine maintenance
    - Added steel platforms/catwalks at half of the sites
Some Lessons Learned…

- Miscellaneous
  - Spend more time and money up front to better detail scope/budget
  - Carry some contingency funds
    - Operators at each site have different needs and ideas
    - Carrying some extra money to accommodate reasonable requests creates good will, helps get buy-in
Some Lessons Learned...

- Maximize utility incentives
  - Burners
    - Total project cost: $1.6 million
    - Utility incentives: $830,700
  - Heat Recovery
    - Total project cost: ~ $1.9 million
    - Utility incentives: $281,266

<table>
<thead>
<tr>
<th>Utility Incentives</th>
<th>Amount</th>
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<tr>
<td>Nicor</td>
<td>$555,300</td>
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<tr>
<td>Peoples Gas</td>
<td>$202,000</td>
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<tr>
<td>North Shore Gas</td>
<td>$53,400</td>
</tr>
<tr>
<td>ComEd (for new VFDs on fan meters)</td>
<td>$20,000</td>
</tr>
<tr>
<td>Total</td>
<td>$830,700</td>
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</table>
Some Lessons Learned...

- **Metering**
  - Install extensive boiler plant metering to be able to closely track gas/steam usage, blowdown, make-up water. This is essential to allow the team to run trends and track boiler plant efficiency

- Use blowdown and M-U meters to get a reduced sewer bill
Thank You......Questions?

Ryan Ollie
ryan.ollie@advocatehealth.com

Austin Rennick
austin.rennick@advocatehealth.com

Dan Doyle
ddoyle@grummanbutkus.com

Tim Jendrycki
tjendrycki@grummanbutkus.com