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

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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
Hospital Gas Cost

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

- Facilities with Absorbers: 18, 26, 48, 52, 100, 106, 107, 205, 218, 221
- Facilities with Electricity Self-Generation: 19, 23, 24, 48, 52, 107
- Facilities with In-House Laundry: 19, 30, 79, 84, 97, 98, 105, 200, 210, 211, 223
- Facilities with Purchased Chilled Water: 83, 64, 80, 100, 216
- Facilities with Purchased Steam: 59, 63, 64, 78, 80, 111, 112, 200, 205, 213, 216, 222
- Facilities with Heat Pumps or Geothermal Systems: 15, 19, 30, 41, 106, 201, 216, 222, 228

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

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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

- Stack Loss, 18%
- Preheat Load, 19%
- Reheat Load, 15%
- Humid Load, 25%
- Blowdown Load, 3%
- DA Demand, 8%
- DA Vent Loss, 1%
- Flash Loss, 2%
- Trap Load, 2%
- Process Load, 9%

Tomorrow starts today.
Typical Hospital Boiler Steam Demand Distribution vs. Outdoor Air Temperature

- DA Vent Loss (#/hr)
- 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)
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
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>Hot Water</th>
<th>Pressure drop</th>
<th>Flow</th>
<th>Cold Water</th>
<th>Pressure drop</th>
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<tbody>
<tr>
<td></td>
<td>kW</td>
<td>Btu/h</td>
<td>gpm</td>
<td>kPa</td>
<td>gpm</td>
<td>USGPM</td>
<td>kPa</td>
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<td>B 45</td>
<td>13</td>
<td>45,000</td>
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<td>150</td>
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<td>B 70</td>
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<td>70,000</td>
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<td>0.85</td>
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<td>B 139</td>
<td>38</td>
<td>130,000</td>
<td>27</td>
<td>7.33</td>
<td>8.1</td>
<td>1.17</td>
<td>200</td>
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<td><strong>B 180</strong></td>
<td><strong>53</strong></td>
<td><strong>180,000</strong></td>
<td><strong>30</strong></td>
<td><strong>7.93</strong></td>
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<td>B 250</td>
<td>73</td>
<td>250,000</td>
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<td>9.25</td>
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<td>B 300</td>
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<td>B 400</td>
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<td>B 500</td>
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<tr>
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<td>1,000,000</td>
<td>95</td>
<td>25.10</td>
<td>16.2</td>
<td>2.35</td>
<td>705</td>
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</tbody>
</table>

Nominal values are based on 6°C (14°F) temperature difference between incoming heating and heated water.

![Heat Exchanger Diagram]

### Standard Materials:

- 316L Stainless Steel
- Titanium

**Maximum Allowable Working Pressure:**

- SS 316L: 1.03 MPA (150 psi)
- Titanium: 1.63 MPA (230 psi)

**Maximum Allowable Working Temperature:**

- SS 316L: 208°C (406°F)
- Titanium: 235°C (455°F)

### Table 5 Advanced B Series Stainless Steel - 316L

<table>
<thead>
<tr>
<th>Type</th>
<th>L (in)</th>
<th>A (in.)</th>
<th>B (in.)</th>
<th>C (in.)</th>
<th>D (in.)</th>
<th>F</th>
<th>G</th>
<th>Heat Transfer Area (sq ft)</th>
</tr>
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<tbody>
<tr>
<td>B 45</td>
<td>257</td>
<td>19.06</td>
<td>11.5</td>
<td>4.98</td>
<td>17.5</td>
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<td>B 70</td>
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<td>19.34</td>
<td>11.7</td>
<td>5.99</td>
<td>18.5</td>
<td>30</td>
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<td>19.55</td>
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<td>8.86</td>
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<td>30</td>
<td>11</td>
<td>2.13</td>
</tr>
<tr>
<td><strong>B 180</strong></td>
<td><strong>352</strong></td>
<td><strong>19.06</strong></td>
<td><strong>11.5</strong></td>
<td><strong>4.98</strong></td>
<td><strong>17.5</strong></td>
<td><strong>30</strong></td>
<td><strong>11</strong></td>
<td><strong>2.13</strong></td>
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<tr>
<td>B 250</td>
<td>632</td>
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<td>12.0</td>
<td>27.4</td>
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<td>2.13</td>
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<tr>
<td>B 400</td>
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<td>37.73</td>
<td>31.0</td>
<td>45.0</td>
<td>35.5</td>
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<td>11</td>
<td>2.13</td>
</tr>
<tr>
<td>B 1000</td>
<td>971</td>
<td>36.10</td>
<td>16.5</td>
<td>38.5</td>
<td>30.5</td>
<td>30</td>
<td>11</td>
<td>2.13</td>
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</table>
Case Study: Advocate Health Care

Phase 1

- New burners on 10 boilers at six hospitals
Case Study: Advocate Health Care
Phase 2
➢ Recover heat from flue gas and DA vents at 10 hospitals
<table>
<thead>
<tr>
<th>Hospital</th>
<th>Vent Condenser</th>
<th>Stack Economizer</th>
<th>Steam Boiler</th>
<th>Domestic Water Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>BroMenn Medical Center</td>
<td></td>
<td>(1)</td>
<td>(1)</td>
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<tr>
<td>Christ Medical Center</td>
<td></td>
<td>(3)</td>
<td>(3)</td>
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</tr>
<tr>
<td>Condell Medical Center</td>
<td></td>
<td>(1) on common vent with (2)</td>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>Good Samaritan Hospital</td>
<td></td>
<td>(2)</td>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>Good Shepherd Hospital</td>
<td></td>
<td>(2)</td>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>Illinois Masonic</td>
<td></td>
<td>(1)</td>
<td>(1)</td>
<td>Feedwater Heating</td>
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<tr>
<td>Lutheran General Hospital</td>
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<td></td>
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<tr>
<td>South Suburban Hospital</td>
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<td>(2)</td>
<td>(2)</td>
<td>Feedwater Heating</td>
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<tr>
<td>Sherman Hospital</td>
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<td>(2)</td>
<td>(2)</td>
<td>Feedwater Heating</td>
</tr>
<tr>
<td>Trinity Hospital</td>
<td></td>
<td>(1)</td>
<td>(1)</td>
<td>Domestic Water Heating</td>
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</table>
## Scope of Project as Actually Implemented

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

DA STEAM VENT ORIFICE:
1/8" = 10 LBS/HR
1/4" = 40 LBS/HR
3/8" = 80 LBS/HR
1/2" = 145 LBS/HR
Effect of Entering Water Temperature on Vent Condenser Effectiveness

Vent Condenser Output vs. Entering Water Temperature

Vent Condenser Recovery (%) vs. Vent Condenser Entering Water Temperature (deg F)
Boiler Flue Stack Economizers

400°F (Flue Gas)

280°F

COLD WATER IN

HOT WATER OUT

Flue Stack Economizer
Typical HP Steam Plant Operating Parameters

- **Vent to Atmosphere**: 60 F
- **Make-up Water**: CW (180 F), LPC
- **Condensate Surge Tank**: 160 F
- **Overflow Drain**: Condensate Transfer Pump (160 F)
- **Spray Deaerator**: 227 F @ 5 psig
- **Overflow Trap**: Boiler Feed Pump (227 F)
- **Boiler Feed Water**: 338 F @ 100 psig
- **Boiler Flue Vents**: 438 F @ 100% load, 365 F @ 25% load
- **Level Controller**
Domestic Water Heating

- DHW
- DCW

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

- CW
- LPC

- CONDENSATE SURGE TANK
- SPRAY DEAERATOR
- BOILER FEED PUMP
- BOILER FEED WATER

- LEVEL CONTROLLER

- NEW NON-CONDENSING BOILER STACK ECONOMIZER WITH INTERNAL BYPASS DAMPER

- BOILER FLUE VENT

- ADVANCE HEALTH CARE
  Tomorrow starts today
Some Lessons Learned…

- Do one measure at multiple sites in lieu of multiple measures at one site
  - Pros:
    - Get better pricing
    - Dealing with single vendor/contractor
    - Consistency of approach/implemention across all sites
  - 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>
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<th>Utility Incentives</th>
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<tbody>
<tr>
<td>Nicor</td>
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<tr>
<td>Peoples Gas</td>
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<tr>
<td>North Shore Gas</td>
</tr>
<tr>
<td>ComEd</td>
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<tr>
<td>Total</td>
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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?

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