COMMERCIAL CONDENSING BOILER OPTIMIZATION

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Senior Mechanical Engineer

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How Condensing Boilers Outperform Conventional Boilers
How Condensing Boilers Outperform Conventional Boilers

• Conventional Boilers
  • All *steam* goes out the vent
  • Safety factor to prevent condensation limits efficiency
How Condensing Boilers Outperform Conventional Boilers
How Condensing Boilers Outperform Conventional Boilers

• Conventional Boilers
  • All *steam* goes out the vent
  • Safety factor to prevent condensation limits efficiency

• Condensing Boilers
  • A portion of the *steam* is used for heating
  • No safety factor
Condensing Efficiency “Boost”

- 1 pound of captured steam heats 50 pounds of water
Condensing Boiler Efficiency Improvement

- Conventional Boiler
- Condensing--Minimum
- Condensing--Ideal
- Condensing--Your Building

If condensate drain dry

- 80%
- 85%
- 90%
- 95%
- 100%
3 Rules for “Energy Value” of Condensing Boiler System

1) Low Return Water Temperature!
2) Low Return Water Temperature!
3) Low Return Water Temperature!
Condensing Boiler Efficiency Dependence on Operating Conditions

Boiler Efficiency Curve

Return Water Temperature @ 30°F Rise

 Efficiency %

- Efficiency @ 20%
- Efficiency @ 50%
- Efficiency @ 100%

89% 90% 91% 92% 93% 94% 95% 96% 97% 98% 99% 100%
70 80 90 100 110 120 130 140 150 160 170
Boiler System Temperatures in Real Buildings & Impact on Efficiency

Condensation Threshold

Boiler Entering Water Temperature
Outdoor Temperature
Flow Impact on Boiler Efficiency Via Entering Water Temperature

Boiler Efficiency Curve

Typical Flow
Flow Impact on Boiler Efficiency Via Entering Water Temperature

Boiler Efficiency Curve

- Efficiency @ 20%
- Efficiency @ 50%
- Efficiency @ 100%

Typical Flow

Low Flow

Return Water Temperature @ 30°F Rise

Efficiency %
Traditional Burner Tuning: Excess Air Up Chimney & Reduced Condensing

![Graph showing the relationship between boiler return water temperature and boiler efficiency. The line indicates a decrease in efficiency from 98% to 86% as the temperature increases from 80°F to 140°F. The line is labeled '20% Excess Air (3.8% O2).']
Traditional Burner Tuning: Excess Air Up Chimney & Reduced Condensing

Boiler Efficiency vs. Boiler Return Water Temperature

- 20% Excess Air (3.8% O2)
- 30% Excess Air (5.3% O2)
Traditional Burner Tuning: Excess Air Up
Chimney & Reduced Condensing

Boiler Efficiency vs. Boiler Return Water Temperature

- 20% Excess Air (3.8% O2)
- 30% Excess Air (5.3% O2)
- 40% Excess Air (6.5% O2)
Project Overview: Condensing Boiler Optimization

- Preliminary Market Study & Site Selection
- Monitoring & Analysis of 12 Buildings
  - 4 Education
  - 4 Multifamily
  - 4 Government/Office
- Industry Survey
- Dissemination
Minnesota’s Condensing Boiler Market Study Findings

• **Market Dominance of Condensing Boilers**
  - Condensing boilers have become the default choice
  - Used in all building types that have space heating boilers

• **Efficiency Concerns Noted**
  - Manufacturer’s reps acknowledge often suboptimal situations
  - Part-load efficiency improvements may be significantly overstated in some cases per tuning recommendations
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Estimated Annual Efficiency Based on Monitored Conditions

Hybrid Operating Efficiency
Condensing Operating Efficiency
Condensing Rated Efficiency
Potential Efficiency with Proposed Features

- ED1
- ED2
- ED3
- ED4
- GO1
- GO2
- GO3
- MF1
- MF2
- MF3
- MF4

Plants Operating Efficiency
Potential with Measures
Condensing Rated Efficiency
## Potential Savings by Design Feature

<table>
<thead>
<tr>
<th>Measure Type</th>
<th># of Sites</th>
<th>Average of Sites with Measure</th>
<th>Average Across All Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reset Control</td>
<td>10</td>
<td>1.54%</td>
<td>1.40%</td>
</tr>
<tr>
<td>Burner Tune Up</td>
<td>10</td>
<td>0.80%</td>
<td>0.72%</td>
</tr>
<tr>
<td>Staging Control</td>
<td>8</td>
<td>1.15%</td>
<td>0.83%</td>
</tr>
<tr>
<td>Variable Speed Pumping</td>
<td>10</td>
<td>0.48%</td>
<td>0.44%</td>
</tr>
<tr>
<td>Piping Change</td>
<td>5</td>
<td>2.06%</td>
<td>0.94%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>3.97%</strong></td>
<td></td>
</tr>
</tbody>
</table>
Cost-Effective Retrofits After Installation Completed

<table>
<thead>
<tr>
<th>Site</th>
<th>Outdoor Reset</th>
<th>Burner Tune-Up</th>
<th>Staging Control</th>
<th>Variable Speed</th>
<th>Piping</th>
<th>Package Cost</th>
<th>Package Savings (Therms)</th>
<th>Payback (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>$8,800</td>
<td>4,437</td>
<td>2.8</td>
</tr>
<tr>
<td>ED2</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td></td>
<td></td>
<td>$1,600</td>
<td>789</td>
<td>2.9</td>
</tr>
<tr>
<td>ED3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td></td>
<td>$3,100</td>
<td>2,822</td>
<td>1.6</td>
</tr>
<tr>
<td>ED4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>$2,600</td>
<td>768</td>
<td>4.8</td>
</tr>
<tr>
<td>GO1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>$13,500</td>
<td>4,379</td>
<td>4.4</td>
</tr>
<tr>
<td>GO2</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td></td>
<td></td>
<td>$2,750</td>
<td>5,248</td>
<td>0.7</td>
</tr>
<tr>
<td>GO3</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>$250</td>
<td>229</td>
<td>1.6</td>
</tr>
<tr>
<td>MF1</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>$3,400</td>
<td>1,217</td>
<td>4.0</td>
</tr>
<tr>
<td>MF2</td>
<td></td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>MF3</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>$620</td>
<td>376</td>
<td>2.4</td>
</tr>
<tr>
<td>MF4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td></td>
<td>$800</td>
<td>420</td>
<td>2.7</td>
</tr>
</tbody>
</table>

**Sum**  
10 | 8 | 5 | 2 | 1 | $37,420 | 20,686 | 2.6

X = Included; O = Excluded; Blank = No Opportunity
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Survey Findings: Primary Boiler Control System
# Survey: Most Commonly Witnessed Issues Impacting Efficiency

<table>
<thead>
<tr>
<th>Issue</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning off and on frequently (short cycling)</td>
<td>67%</td>
</tr>
<tr>
<td>Difficulties coordinating control between a BAS and the boiler(s)</td>
<td>61%</td>
</tr>
<tr>
<td>Piping arrangements circulate water through an idle, non-condensing boiler</td>
<td>44%</td>
</tr>
<tr>
<td>Boiler minimum temperature limited by the need to heat service hot water</td>
<td>44%</td>
</tr>
<tr>
<td>Outdoor reset control does not lower temperature as much as it could in mild weather</td>
<td>39%</td>
</tr>
</tbody>
</table>
Survey: What Would be Most Worthwhile to the Owner for Future Installations

<table>
<thead>
<tr>
<th>Potential Program Element</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Piping Design Review</td>
<td>11%</td>
</tr>
<tr>
<td>b. Control Sequence Review</td>
<td>11%</td>
</tr>
<tr>
<td>c. Site-Specific Savings Estimate</td>
<td>6%</td>
</tr>
<tr>
<td>d. Bonus Rebate for Quality Design</td>
<td>11%</td>
</tr>
<tr>
<td>e. Bonus Rebates for Individual Design Features</td>
<td>6%</td>
</tr>
<tr>
<td><strong>f. Commissioning of Installation and Controls</strong></td>
<td><strong>44%</strong></td>
</tr>
<tr>
<td>g. New Training Options for Designers &amp; Installers</td>
<td>11%</td>
</tr>
</tbody>
</table>
Survey: What Would be Most Worthwhile to the Owner for Previous Installations

<table>
<thead>
<tr>
<th>Potential Program Element</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Specialized Engineering Review</td>
<td>11%</td>
</tr>
<tr>
<td>b. Gas Rebate for Variable Speed Drive</td>
<td>6%</td>
</tr>
<tr>
<td>c. Rebates for Control Upgrades</td>
<td>6%</td>
</tr>
<tr>
<td>d. Rebates for Optimizing Control Settings</td>
<td>17%</td>
</tr>
<tr>
<td>e. Resources on Optimal Control &amp; Operation</td>
<td>11%</td>
</tr>
<tr>
<td>f. Site-Specific Guide for Controls</td>
<td>6%</td>
</tr>
<tr>
<td>g. New Training Options for Operators</td>
<td>44%</td>
</tr>
</tbody>
</table>
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Dissemination of Project Findings

• Presentations:
  • 2014 CenterPoint Energy Technology Conference
  • 2015 AEE/ASHRAE Twin Cities Energy Expo
  • 2016 Minnesota Blue Flame Gas Association’s Natural Gas Conservation Conference [will be downloadable on Minnesota Blue Flame Gas Association website]

• Detailed final report--available soon (pending review)

• Future webinar--utility program issues focus
In Conclusion…

• While less than simple rating values suggest, condensing boiler savings is still large in nearly all buildings

• Maximizing savings depends on:
  • Minimizing temperature settings (outdoor reset adjustment)
  • Optimal boiler staging control programming
  • Burner tuning of air-fuel ratio to lower limit of recommended oxygen range
  • Avoiding sub-optimal piping

• Possible utility program developments
  • Support for specialized commissioning
  • Support for new operator training options
  • Rebates for optimization of control settings
Thank You

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