The Importance of IoT In the Boiler Room

Presented by Terry Conger
About Me…

■ 1999 – Began boiler journey
■ 2002 – Transitioned into Electrical Contracting
■ 2011 – Continued boiler journey
■ 2014 – Joined Cleaver-Brooks
  ■ Operations
  ■ Engineering
  ■ Product Manager, Controls Development
  ■ Product Manager, IoT
Agenda

- Challenging Times
- How Can Boiler IoT Help?
- Basic Boiler Key Performance Indicators (KPIs)
- Data Science: Beyond Monitoring
- Summary
Challenging Times

Reliability
- Maximum equipment availability
- Reduce unplanned downtime

Safety
- Provide a safe environment

Efficiency
- Maximize resource utilization
- Lower operational cost

Sustainability
- Do more with less
- Lower carbon footprint
How Can Boiler IoT Help?
What is IoT: Internet of Things

- Any-THING connect to the Internet
- Items collecting data and usage
What is Boiler IoT?

A complete IoT solution is more than just data…

Data  Information  Knowledge  Actions  Results
Much More Than Just Data

Data

Information

Knowledge

Actions

Results

1.7
Maximize Your Insights

- Provides in-depth boiler system info
- Focuses on boiler system optimization
- The right info at the right time
Boiler IoT: The Elevator Pitch

Boiler IoT is a technology that offers new solutions to help improve the reliability, efficiency, sustainability and safety of a boiler system.

A complete IoT solution is more than just data…

Data  Information  Knowledge  Actions  Results
IoT Insight Opportunity

The value of boiler IoT increases with advanced analytics

Source: the-future-of-commerce.com
Reactive to Prescriptive Transformation

- **Reactive**: Action is performed based on visuals & experience.
- **Predictive**: Action is performed before equipment issue using analytic insights.
- **Prescriptive**: Upon issue prediction, solutions are provided to correctly identify issue and improve outcome.

**Analytics**

**Human Input**

**Decision Support**

**Decision Automation**

**Operator Action**

**Feedback Loop**
Benefits of IoT in the Boiler Room

- Access: Information on demand and on the go
- Notifications: Boiler alerts and alarms
- Intelligence: Historical data at your fingertips
- Insights: Proactive response reduces downtime

= Cornerstones of an Optimized Operation

- RELIABILITY
- SAFETY
- EFFICIENCY
- SUSTAINABILITY
Reliability
A reliable system ensures the maximum availability of the equipment to prevent untimely, unplanned and uncontrolled downtime that can severely impact the cost of the operation.

Benefits of IoT in the Boiler Room

- Remote monitoring allows real-time visibility of operation 24/7/365 from anywhere
- Improved troubleshooting capabilities
- Insight into the process demand on the boiler
Benefits of IoT – Root Cause Analysis

Use historical data to troubleshoot intermittent issues

- Deep dive into failures collected data
Benefits of IoT – Trend Analysis

Boiler Diagnostic Trends
- Examine boiler system operation over time to reveal improvement opportunities.
Benefits of IoT in the Boiler Room

- Instant notifications to personnel of alarm conditions via text or email
- Greater awareness of alarm conditions allows for improved response management
- Proactively identify system anomalies through data trending

Safety
A primary objective of any facility is to provide a safe environment for all parties alike (employees, vendors, customers, associates) while protecting their well-being.
Benefits of IoT – Alarm Notifications
## Benefits of IoT – Alarm History

### Alert Notifications

<table>
<thead>
<tr>
<th>Notification</th>
<th>Serial Number</th>
<th>System Type</th>
<th>Tag Name</th>
<th>Customer</th>
<th>Alert Time</th>
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</thead>
<tbody>
<tr>
<td>Low Water (LWCO trip)</td>
<td></td>
<td>Hawk ICS</td>
<td>LWCO Shutdown</td>
<td></td>
<td>Wednesday, June 17, 2020, 2:16:59 AM - 7 hours ago</td>
</tr>
<tr>
<td>Aux. Low Water Cutoff</td>
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<td>Hawk ICS</td>
<td>ALWCO</td>
<td></td>
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<td>LWCO Shutdown</td>
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<td></td>
<td>Wednesday, June 17, 2020, 2:09:30 AM - 7 hours ago</td>
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<tr>
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<td>Low Combustion Air (Low CAP switch)</td>
<td></td>
<td>Hawk 4000 V2</td>
<td>Combustion Air Pressure Low</td>
<td></td>
<td>Tuesday, June 16, 2020, 9:28:28 PM - 11 hours ago</td>
</tr>
<tr>
<td>Low Water (LWCO trip)</td>
<td></td>
<td>Hawk 4000 V2</td>
<td>LWCO Shutdown</td>
<td></td>
<td>Tuesday, June 16, 2020, 9:27:34 PM - 11 hours ago</td>
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<td>Low Water (LWCO trip)</td>
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<td>Hawk 4000 V2</td>
<td>LWCO Shutdown</td>
<td></td>
<td>Tuesday, June 16, 2020, 9:23:58 PM - 11 hours ago</td>
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<tr>
<td>FSG General Alarm</td>
<td></td>
<td>Hawk 4000 V2</td>
<td>Burner Control Alarm</td>
<td></td>
<td>Tuesday, June 16, 2020, 2:06:30 PM - 19 hours ago</td>
</tr>
<tr>
<td>Low Combustion Air (Low CAP switch)</td>
<td></td>
<td>Hawk 4000 V2</td>
<td>Combustion Air Pressure Low</td>
<td></td>
<td>Tuesday, June 16, 2020, 2:06:23 PM - 19 hours ago</td>
</tr>
<tr>
<td>Aux. Low Water Cutoff</td>
<td></td>
<td>Hawk 4000 V2</td>
<td>ALWCO</td>
<td></td>
<td>Tuesday, June 16, 2020, 2:04:17 PM - 19 hours ago</td>
</tr>
<tr>
<td>FSG General Alarm</td>
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<td>Hawk 4000</td>
<td>Burner Control Alarm</td>
<td></td>
<td>Tuesday, June 16, 2020, 12:10:37 PM - 21 hours ago</td>
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</tbody>
</table>
Benefits of IoT – Alarm Replay

Review 5 minutes of ALL data prior to alarm/shutdown
**Efficiency**
Maximum efficiency ensures a limited amount of resource utilization (water, fuel, air, power) to complete the required application needs.

**Benefits of IoT in the Boiler Room**

- Monitor boiler performance over time
- Compare key KPIs of multi-boiler or multi-site applications
- Using trends, optimize load-managed system configurations
Benefits of IoT – Trend Analysis

Multi-Boiler Diagnostic Trends

- Compare the operation of multiple boilers over time to uncover suboptimal load management configurations
Benefits of IoT in the Boiler Room

- Boiler OEM insights help to streamline, standardize and simplify your boiler operation
- Maximize boiler plant uptime by optimizing system configuration
- Gain insights into seasonal changes and how they impact your boiler operation

Sustainability
Sustainability simply means doing more with less and continuously striving to lower the carbon footprint.
Benefits of IoT – OEM Intelligence

Quickly compare your system operation to OEM specifications anytime, from anywhere.
Boiler Intelligence
Basic Boiler KPIs: Insights & Improvement Opportunities

- Efficiency
- Flame Signal Strength
- Oxygen Level
- Stack Temperature
- On-Off Cycles
Basic Boiler KPIs: Insights & Improvement Opportunities

**Efficiency**
- Boiler control system has required data to calculate efficiency
- Fuel-to-steam/water efficiency
- Effectiveness of radiant and convective heat transfer in the pressure vessel
- Typically 78%-83% for high pressure steam
- Direct tie to fuel usage
- Compare against design efficiency
- Monitor trends and address if declining
Basic Boiler KPIs: Insights & Improvement Opportunities

- **Flame Signal Strength**
  - Flame safeguard displays signal strength
  - Strong signal required for reliability
  - Weak or bouncing signal can lead to shut down
  - Declining signal likely to lead to shut down and unscheduled downtime
  - Weak signal may indicate combustion issue
  - Data trending can be used to trigger combustion retune
Basic Boiler KPIs: Insights & Improvement Opportunities

■ Oxygen Level
- Oxygen level in stack flue gas indicates excess air in combustion
- Percentage excess air above stoichiometric required to complete combustion
- Burners are designed for different optimum O₂ levels depending on firing rate and NOx levels
- Too-low O₂ can lead to unburned fuel, and too-high O₂ reduces boiler efficiency
- O₂ outside nominal range can lead to combustion issues or shut down
- Trending helps trigger combustion retune and avoid unplanned downtime
Basic Boiler KPIs – $O_2$ Level

EXCESS AIR EFFECTS ON EFFICIENCY FOR NATURAL GAS

<table>
<thead>
<tr>
<th>% of Excess Air</th>
<th>% Oxygen ($O_2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>4.5</td>
</tr>
<tr>
<td>35</td>
<td>5.8</td>
</tr>
<tr>
<td>45</td>
<td>7</td>
</tr>
<tr>
<td>55</td>
<td>7.9</td>
</tr>
</tbody>
</table>
Basic Boiler KPIs: Insights & Improvement Opportunities

- **Stack Temperature**
  - Direct tie to boiler efficiency
  - Varies with firing rate, steam operating pressure, $O_2$ level
  - Higher stack temperature with other variables unchanged indicates reduced efficiency
  - Monitoring stack temperature helps to maintain optimum efficiency
Basic Boiler KPIs – Stack Temp

- **Stack Temperature Efficiency Impact**
  - Every 40°F rise = 1% loss in fuel-to-steam efficiency
Basic Boiler KPIs – Stack Temp

Impact of:

■ **Dirty Waterside**
  - 1/32” scale results in a 2% increase in fuel consumption
  - Scale buildup results in higher furnace-tube metal temperature, increased thermal stress and can lead to failure with unplanned downtime

■ **Dirty Fireside**
  - 1/8” soot results in a 1% increase in fuel consumption
Basic Boiler KPIs
Insights & Improvement Opportunities

■ On-Off Cycles
  ■ Each cycle heats cool ambient air through the boiler and to the stack
  ■ Frequent cycling amounts to significant BTU purge losses
  ■ Increases wear and tear on boiler components and reduces lifecycle
  ■ Example – 100 HP high pressure steam boiler will experience a loss of approximately 2500 BTU/cycle
Data Science: Beyond Monitoring
Data Science: Beyond Monitoring

■ What is Data Science?
  ■ Finding actionable insights from large sets of data
  ■ Machine learning
  ■ Forecasting the future based on past patterns
  ■ Predicting failures
  ■ Establishing solutions to prevent failure
Data Science: Beyond Monitoring

What Does This Have To Do With My Boiler?

- Early detection of failures
- Eliminate unscheduled downtime
- Better planning for repairs and diagnostics-based maintenance
- Reduced spending
- Identify areas for upgrades
What if your technicians knew exactly when the boiler experienced an unplanned shutdown?
What if…. 

- the operator knew exactly where to start troubleshooting?

**PROMETHA ALERT**

- Alert: Burner Control Alarm
- Description: Burner Control is in Alarm State
- Unit: Boiler #1
- Customer: Acme Rockets
- Boiler Down: YES
- Alarm Priority: HIGH

Troubleshooting Tip: Boiler #1 burner control alarm condition occurred during transition from pilot ignition to main flame ignition and Boiler #2 was at 67% firing rate. Check lightoff settings and confirm adequate main inlet fuel pressure

- Click Here for Root Cause Trend Link
What if….

- you had the technology to know that an offline boiler may not start when called on?
What if….

- you had a boiler summary that gave you insights to your boiler operation this week versus last week?

### Sample Customer
Salt Lake City, UT

#### Boiler 1
T1234-1-1

<table>
<thead>
<tr>
<th>Metric</th>
<th>This Week</th>
<th>Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. High Outdoor Temp</td>
<td>96 ºF</td>
<td>97 ºF</td>
</tr>
<tr>
<td>Avg. Low Outdoor Temp</td>
<td>69 ºF</td>
<td>68 ºF</td>
</tr>
<tr>
<td>Total Boiler Runtime</td>
<td>102.1 Hrs</td>
<td>112.1 Hrs</td>
</tr>
<tr>
<td>Total Boiler Cycles</td>
<td>210</td>
<td>264</td>
</tr>
<tr>
<td>Avg. Operating Press/Temp</td>
<td>78 psi</td>
<td>73 psi</td>
</tr>
<tr>
<td>Avg. Efficiency</td>
<td>82.9%</td>
<td>83.9%</td>
</tr>
<tr>
<td>Max Cycles/Hr</td>
<td>5.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Avg. Cycles/Hr</td>
<td>2.75</td>
<td>1.75</td>
</tr>
<tr>
<td>Avg. Firing Rate</td>
<td>26.6%</td>
<td>46.6%</td>
</tr>
<tr>
<td>Avg. Stack Temp. @ 25% Firing Rate</td>
<td>355.2 ºF</td>
<td>353.2 ºF</td>
</tr>
<tr>
<td>Avg. Stack Temp. @ 50% Firing Rate</td>
<td>365.2 ºF</td>
<td>363.2 ºF</td>
</tr>
<tr>
<td>Avg. Stack Temp. @ 75% Firing Rate</td>
<td>375.2 ºF</td>
<td>373.2 ºF</td>
</tr>
<tr>
<td>Avg. Stack Temp. @ 100% Firing Rate</td>
<td>385.2 ºF</td>
<td>383.2 ºF</td>
</tr>
<tr>
<td>Quantity of Shutdown Alarms</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Hours in Shutdown Condition</td>
<td>1.2 Hrs.</td>
<td>2.2 Hrs.</td>
</tr>
</tbody>
</table>
What if…

- you had a report that gave you a weekly average of each boiler for comparison of operation?

<table>
<thead>
<tr>
<th></th>
<th>Boiler 1</th>
<th>Boiler 2</th>
<th>Boiler 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimization Rating</td>
<td>92%</td>
<td>94%</td>
<td>0%</td>
</tr>
<tr>
<td>Total Boiler Runtime</td>
<td>102.1 Hrs</td>
<td>112.1 Hrs</td>
<td>0 Hrs.</td>
</tr>
<tr>
<td>Total Boiler Cycles</td>
<td>210</td>
<td>264</td>
<td>0</td>
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<tr>
<td>Max Cycles/Hr</td>
<td>5.0</td>
<td>3.0</td>
<td>0</td>
</tr>
<tr>
<td>Avg. Cycles/Hr</td>
<td>2.75</td>
<td>1.75</td>
<td>0</td>
</tr>
<tr>
<td>Avg. Efficiency</td>
<td>82.9%</td>
<td>83.9%</td>
<td>0%</td>
</tr>
<tr>
<td>Avg. Operating Press.Temp</td>
<td>78 psi</td>
<td>73 psi</td>
<td>0 psi</td>
</tr>
<tr>
<td>Avg. Operating Press.Temp Setpoint Dev.</td>
<td>-0.57</td>
<td>-2.4</td>
<td>0</td>
</tr>
<tr>
<td>Max Operating Press.Temp – Setpoint Dev.</td>
<td>9.95</td>
<td>14.65</td>
<td>0</td>
</tr>
<tr>
<td>Min Operating Press.Temp – Setpoint Dev.</td>
<td>-68.02</td>
<td>-54.54</td>
<td>0</td>
</tr>
<tr>
<td>Avg. Flame Strength</td>
<td>4.92</td>
<td>3.14</td>
<td>0</td>
</tr>
<tr>
<td>Avg. Feed Water Temperature</td>
<td>201.5 ºF</td>
<td>181.3 ºF</td>
<td>0</td>
</tr>
<tr>
<td>Avg. Firing Rate</td>
<td>26.6%</td>
<td>46.6%</td>
<td>0%</td>
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<td>0 Hrs.</td>
</tr>
</tbody>
</table>

Click to View O2 vs. Firing Rate Insights
What if….

you had a boiler summary that gave you a complete overview of your boiler system operation?

Sample Customer
Salt Lake City, UT
System Summary
Weekly Report
7/26/20 thru 8/1/20

<table>
<thead>
<tr>
<th>Metric</th>
<th>This Week</th>
<th>Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Optimization Rating</td>
<td>93%</td>
<td>94%</td>
</tr>
<tr>
<td>Avg. High Outdoor Temp</td>
<td>96 °F</td>
<td>97 °F</td>
</tr>
<tr>
<td>Avg. Low Outdoor Temp</td>
<td>69 °F</td>
<td>68 °F</td>
</tr>
<tr>
<td>Average Header Pressure</td>
<td>78 psi</td>
<td>75 psi</td>
</tr>
<tr>
<td>Boiler Capacity Utilization</td>
<td>32%</td>
<td>30%</td>
</tr>
<tr>
<td>Quantity of Boiler Shutdown Alarms</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Boiler Shutdown Alarms – Total Hours</td>
<td>3.2 Hrs.</td>
<td>4.2 Hrs.</td>
</tr>
</tbody>
</table>
What if….

- you could predict, or even prevent, a boiler failure?

60 Seconds
+ Excessive Steam Press. Fluctuation
+ Firing Rate Increase
Thermal Shock Risk
In Summary

Optimized Boiler Operation

- Personnel is notified immediately of critical boiler alarms, enabling rapid response
- Operational issues are detected early
- Unscheduled downtime is reduced
- Maintenance is proactive and more effective with root cause insights
- Improved boiler efficiency

Enjoy the peace of mind of an optimized boiler operation using IoT!
Thank you!