THE BASICS OF BOILER WATER CHEMISTRY

Presented by Cleaver Brooks' Steve Connor & Bill Hooke
October 19, 2016
TODAY’S TOPICS

• A 35,000 foot view of a sound water treatment program
• Highlights from last month’s chemical dosing webinar
• Quick overview of hot water systems
• The key water treatment problems facing steam supply systems
• Attacking the problems
• The problems with the condensate piping and its remedies
• Hot water system treatment
• Good record keeping
BOILER WATER TREATMENT
TYPICAL STEAM SYSTEM
WHAT NEEDS TO BE REMOVED

- **Dissolved Minerals**
- **Hard Scale Formers**
  - Calcium
  - Magnesium
- **TDS**
  - Calcium (Scale)
  - Magnesium (Scale)
  - Sulfate (Instability)
  - Iron (Scale)
  - Silica (Deposition)
  - Chloride (Instability)
  - Alkalinity (Foaming)
- **Dissolved Gas**
  - Free Oxygen (Corrosion)
  - Free Carbon Dioxide (Corrosion)
WATER TREATMENT PROFESSIONALS
METERING PUMPS

- Flow rate in boiler or feed water.
- Nature and concentration of the treatment liquid
- Desired concentration in liquid to be treated
CONTROLLING VOLUME
METERING PUMPS:
Two Basic Types

- Hydraulically
- Actuated
- Diaphragm

- Mechanically
- Actuated
- Diaphragm
BENEFITS OF PACKAGED DOSING SYSTEMS

- Pre-engineered for overall functionality
- Two pumps for assured performance
- Integration to BMS
- Reduce operational costs
How do you size a dosing pump?
TYPICAL CENTRIFUGAL PUMP CURVE
FLOW RANGE

.00066 gph to 9000 gph
or
1/100 of a teaspoon per minute to 150 gpm
GOOD INSTALLATION PRACTICES:

Avoid long or complex suction lines
MORE INSTALLATION TIPS:

Avoid long or complex suction lines

Avoid gas traps in suction lines
MORE INSTALLATION TIPS:

Flexible suction line

Rigid suction line

Keep foot valve 3” to 6” off bottom of tank to keep debris out.
Primary-secondary with bypass line & blend valve

Flexible designed boilers

Primary

Secondary

200°F

180°F / 160°F

140°F / 160°F

LOAD (20°F ΔT)

Constant Speed/Flow

160°F - 180°F

Constant Speed/Flow

3-Way Blend valve
HOT WATER PIPING SYSTEMS

Variable Flow Primary w/ High Mass Boilers

Secondary pumps, VFD
HOT WATER PIPING SYSTEMS

Primary-Secondary w/ Low Mass Boilers

Variable Flow Primary w/ High Mass Boilers
WATER TREATMENT

• Understanding the Basics
WATER TREATMENT MINIMIZES

- Scale
- Corrosion
- Carryover
SCALE
BOILER CORROSION

Oxygen Pit
CONDENSATE CORROSION
CONTROLLING BOILER SCALE

Mechanical means - outside the boiler

“Remove” the components that form scale

- Softeners
- Dealkalizers
- Reverse Osmosis
CONTROLLING BOILER ISSUES OUTSIDE THE BOILER

Mechanical means – outside the boiler

“Remove” the oxygen from the water
- Deaerator
- Removes Oxygen Free Carbon Dioxide
- Heat Agitate
- Vent O2 and CO2!
CONTROLLING BOILER SCALE

Prevent scale and corrosion using chemicals inside the boiler.
### Tolerances Are Based On Pressure & Temperature

Water Constituent Tolerance: 0-300 operating psig

<table>
<thead>
<tr>
<th>Feed Water</th>
<th>Boiler Water</th>
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<tbody>
<tr>
<td>Oxygen</td>
<td>Silica</td>
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<tr>
<td>Iron &amp; copper</td>
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<tr>
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<td>Free OH Alkalinity</td>
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**ASME Guidelines:**
Broken down by feed water and boiler water, and then by firetube and watertube boilers.
TOLERANCES ARE BASED ON PRESSURE & TEMPERATURE

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<td>Silica 150 ppm</td>
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<td>Iron &amp; copper 0.1 &amp; 0.05 ppm</td>
<td>Total Alkalinity 700 ppm</td>
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<td>Total Hardness 0.3 ppm</td>
<td>Free OH Alkalinity 200-400 ppm</td>
</tr>
<tr>
<td>pH 8.3 – 10.0</td>
<td>Specific Conductance 7000 umhos</td>
</tr>
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<td>Non-Volatile TOC (Total Organic Carbon) 1 ppm</td>
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ASME Guidelines:
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INTERNAL BOILER
WATER TREATMENT
CHEMICAL PROGRAM
EFFECTIVE INTERNAL BOILER WATER TREATMENT CHEMICAL PROGRAM

1. Prevents corruption in the pre-boiler (feedwater) system, the boiler, and in the steam and condensate systems
2. Prevents scale in the boiler
3. Provides a boiler water chemistry that allows for the efficient production of clean, dry steam
FIRST - CORROSION
WATER TUBE BOILER
OXYGEN PITTING
OXYGEN PITTING ON
FIRE TUBE BOILER
Some oxygen enters a boiler system, even with effective mechanical pretreatment.

Oxygen scavengers are used to tie up oxygen to prevent oxygen attack.

The #1 cause of boiler tube failure is Oxygen Corrosion.

Preventing Oxygen Corrosion.

Chemical control: Oxygen scavengers

- Sulfite – reacts with oxygen to form harmless salt
- Others
OXYGEN CORROSION CONTROL INSIDE BOILER

Sulfite – reacts with oxygen to form harmless salt

\[
\text{SO}_3 + \text{O}_2 = \text{SO}_4
\]

It takes 10 ppm of sulfite to tie up 1 ppm of Oxygen. Oxygen Corrosion is #1 cause on boiler tube failure.
OXYGEN CORROSION CONTROL IN BOILER

Where is sulfite fed?

Sulfite is fed, as a liquid:
1) Storage section of Deaerator
2) Feedwater line
CONTROLLING BOILER
ISSUES OUTSIDE BOILER

Deaeration
Plus Sulfite Feed

Sulfite Feed
CONTROLLING BOILER
ISSUES OUTSIDE BOILER

No Deaeration
Plus Sulfite Feed

Sulfite Feed

Feedwater Tank
CONTROLLING BOILER
ISSUES OUTSIDE BOILER

No Deaeration
Plus Sulfite Feed

Sulfite Feed

Feedwater Tank
How much sulfite do you need to provide a cushion to protect against oxygen intrusion?

- 20-60 ppm of sulfite residual are normal limits.
CORROSION CONTROL – BOILER

• Sulfite Demand
• If there is a large demand for sulfite, adding large amounts will add TDS to the boiler; this can result in demand for extra blowdown.
• More sulfite, increased blowdown. More blowdown, more make up. More make up more sulfite. “Sulfite Chase”
• Review the operation, the limits and control to minimize/ eliminate the “Sulfite Chase”.
DISSOLVED OXYGEN IN BOILER DEMANDS SULFITE

O₂ demands 10 ppm of sulfite for each 1 ppm of O₂
EFFECT OF SCALE ON BOILER FUEL USAGE

Boiler Fuel Efficiency Losses
Excess Fuel Used Due to Scaling

A $\frac{1}{16}''$ scale deposit in a boiler can add as much as 14% to the boiler system’s fuel bill

Invest in a good water treatment program
PREVENTING SCALE

• Scale control – What is scale?
• **Scale deposition** occurs when the solution equilibrium of the water is disturbed by pressure and temperature changes, dissolved gases or incompatibility between the mixing of a water source and chemicals.
• Minerals in solution no longer remain in solution and drop out as a deposit, SCALE.
SCALE CONTROL

Pretreatment equipment

- Softener, Reverse Osmosis, etc.
What does it look like?
LIGHT SCALE IN MUD DRUM OF WATER TUBE BOILER
MODERATE TO HEAVY SCALE IN FIRETUBE BOILER
CLEANED TUBES MARKED
ALLOW COMPARISON
Watertube Boiler
Scale Accumulation
100% Restricted
TUBE FAILURE
(FROM SCALE)
TOLERANCES ARE BASED ON PRESSURE & TEMPERATURE

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ASME Guidelines:
Broken down by feed water and boiler water, and then by firetube and watertube boilers.
THE CHEMISTRY INVOLVED IN SCALE CONTROL

Conductivity Control in the Boiler

ASME limits

- Conductivity 7000 umhos
  - Neutralized
- Alkalinity 700 ppm
  - Applications vary
  - Load / demand
CONDUCTIVITY CONTROL
IN THE BOILER

• Blowdown – two types with two distinct functions
  • Surface blowdown
    • Small amount of boiler water drawn off near surface continuously or intermittently
    • Function is to control concentration of dissolved solids; provide correct boiler water chemistry
  • Bottom blowdown
    • Water emptied from mud drum or bottom of firetube boiler; function is removal of “sludge”
    • Done on regular schedule
CONDUCTIVITY CONTROL IN THE BOILER

FEEDWATER

STEAM
Top Blowdown to Remove Dissolved Solids

BOILER
Bottom Blowdown to Remove Suspended Solids
CONDUCTIVITY CONTROL IN THE BOILER

- Surface Blowdown
  - Manual control: needle valve orifice plate
  - Automatic sensors and control
- Bottom Blowdown
  - Frequent short blowdowns better than one long one
SCALE CONTROL

- Control Conductivity in the Boiler
- Automating Surface Blowdown
  
  Automatic sensors and electronic valve control

  Neutralized conductivity vs neutralized
SCALE CONTROL

Automated Conductivity Control in Boiler

[Diagram of automated conductivity control system in a boiler, showing components such as a sensing probe, orifice union, and a blow-down to heat exchanger.]
EFFECT OF SCALE ON BOILER EFFICIENCY

Pound for pound, soot decreases heat transfer more than scale

Have your boilers tuned up!
CONTROLLING SCALE WITH CHEMICAL FEED

Olden days
SCALE CONTROL USING CHEMICAL

- Scale control chemicals
  - Sludge conditioners/dispersants
    - Phosphonates
    - Polymers, copolymers, acrylates

Blended together to alter the physical structure of solids that want to form scale and drop out; keep them dispersed and in suspension.
SCALE CONTROL USING CHEMICALS

Small amounts of hardness and iron can get into the boiler

Crystals form, Crystals from scale
CONTROL FEED OF CHEMICALS THAT PREVENT SCALE

- Polymer
  - Test Control
    - Colormetric
    - Photometric
- OH alkalinity 200 +
  - Drives reactions
  - Maintain limits
CONTROL FEED OF CHEMICALS THAT PREVENT SCALE

- Polymer Control Limits?

- Upsets
  - Overwhelm Polymer
    - OH alkalinity drops
    - Milky look to Boiler
Feed of chemicals that prevent Scale, sludge conditioner

- Where to feed sludge conditioner:
  - The feedwater line
  - The DE aerator
  - The boiler
What should be done to prevent scale

1. Maintain feedwater quality
   a. Iron is a binder, minimize iron
2. Keep conductivity within limits
3. Keep OH alkalinity within limits
4. Maintain Sludge conditioner
   a. Be on lookout for upsets
CONDENSATE CORROSION
CORROSION CONTROL – CONDENSATE SYSTEM

Alkalinity enters the boiler in the make up water / feedwater.

(pH 8.3-10.0)

CO$_3$
HCO$_3$

Add Heat - the alkalinity (CO$_3$, HCO$_3$) breaks down to H$_2$O and CO$_2$. 
CORROSION CONTROL – CONDENSATE SYSTEM

H$_2$O + CO$_2$ released in the breakdown of alkalinity. CO$_2$ goes out of boiler with steam.

When steam condenses, CO$_2$ combines with condensate H$_2$O. It reacts to form H$_2$CO$_3$. Carbonic acid

Untreated, this results in acidic condensate corrosion
CORROSION CONTROL –
CONDENSATE SYSTEM

• Neutralizing amine
  • Alkaline chemical that volatilizes leaves with steam
  • Condenses with steam and neutralizes H₂CO₃ in condensate

<table>
<thead>
<tr>
<th>Amine</th>
<th>Distribution Ratio</th>
</tr>
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<tbody>
<tr>
<td>Morpholine</td>
<td>0.4</td>
</tr>
<tr>
<td>Diethylaminoethanol</td>
<td>1.7</td>
</tr>
<tr>
<td>Dimethylisopropanolamine</td>
<td>1.7</td>
</tr>
<tr>
<td>Cyclohexylamine</td>
<td>4.0</td>
</tr>
<tr>
<td>Ammonia</td>
<td>10.0</td>
</tr>
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Condensate treatment feed

- Neutralizing amine:
  - Feed to the steam header
  - Feed to feedwater line
Condensate treatment limits.

Neutralizing amine:
• Maintain condensate pH at 7.8-8.5
• Based on make up water use
• Feed slowly
CORROSION CONTROL – CONDENSATE SYSTEM

Condensate treatment feed

- Filming amine
  - Must be fed into steam
  - Forms film on all metal surfaces in condensate system
ACIDIC CORROSION
A REPAIR ON CONDENSATE PIPING
CONDENSING BOILERS

• Typically >90% efficient
• By product of combustion is acidic condensation,
• Leaves the boiler through the drain.
• Condensate leaving the boiler normally has a very low pH- 4-6.
  • This can be sent to the drain
  • It will need neutralization.
    • For discharge limits
    • Preservation of drain piping
The neutralization system comprises the plastic neutralization tank with condensate inlet, makeup valve, drain trap, granulate chamber and condensate outlet.
HOT WATER BOILERS

Treatment for Hot water boilers not overlooked.

Closed Loops
“Don’t have any make up water”
• Make up automatic

Water Meter?
HOT WATER BOILERS

Treatment types

- Nitrite
- Molybdenum
- Organics

Nitrites can feed bacteria, not recommended for chilled loops.
HOT WATER BOILERS

Treatment for Hot water boilers not overlooked.

- Chemical feed
- Bypass feeder
- Filter
- Chemical Pump
SUMMARY WATER TREATMENT IS IMPORTANT

Cleaner heat transfer surfaces better efficiency

<table>
<thead>
<tr>
<th>Thickness of Scale in Inches</th>
<th>Loss of Efficiency</th>
<th>Coal Wasted /Ton</th>
<th>Oil Wasted/1000 Gal.</th>
<th>Gas Wasted/1000 ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/64 or .01562</td>
<td>4%</td>
<td>80 lbs</td>
<td>40 gallons</td>
<td>40 cubic feet</td>
</tr>
<tr>
<td>1/32 or .03124</td>
<td>7%</td>
<td>140 lbs</td>
<td>70 gallons</td>
<td>70 cubic feet</td>
</tr>
<tr>
<td>1/16 or .06248</td>
<td>11%</td>
<td>220 lbs</td>
<td>110 gallons</td>
<td>110 cubic feet</td>
</tr>
<tr>
<td>1/8 or .125</td>
<td>18%</td>
<td>360 lbs</td>
<td>180 gallons</td>
<td>180 cubic feet</td>
</tr>
<tr>
<td>3/16 or .1875</td>
<td>27%</td>
<td>540 lbs</td>
<td>270 gallons</td>
<td>270 cubic feet</td>
</tr>
<tr>
<td>1/4 or .250</td>
<td>37%</td>
<td>760 lbs</td>
<td>380 gallons</td>
<td>380 cubic feet</td>
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SUMMARY WATER TREATMENT IS IMPORTANT

• Water treatment is important.
• Not treating a boiler guarantees it will fail.
SUMMARY WATER TREATMENT IS IMPORTANT

Tracking the boiler chemistry will allow for:

- Better control
- Fewer big swings
- Insight into operating changes/problems

![Graph showing boiler chemistry data over time](image-url)
Logs help:
1. Permit trends to be tracked
2. Show chemical use, prevent inventory mistakes-
3. Document program administration/protection
SUMMARY WATER TREATMENT IS IMPORTANT

• Oxygen Corrosion is #1 cause of Boiler tube failure
• Scale may possibly be removed with acid cleaning
• Corrosion means replacing equipment and piping.
TODAY’S TAKE-A-WAYS

• A sound water treatment programs involves both mechanical and chemical remediation.
• The impurities which need to be attacked include hard scale formers, TDS, and corrosive gasses.
• Proper dosing pump selection and installation is critical.
• Dosing pump selection is based on flow and pressure within a fairly broad range.
• Hot water systems need chemical treating too, and they are changing to improve overall system cost, operation and efficiency.
• The more sulfite added to control oxygen, the more sulfate is formed which adds to the TDS, increasing blowdown.
• Ratio is 10 PPM sulfite to tie up 1 PPM of O2.
• 1/16” scale = 14% increase in fuel burned.
• Condensate line corrosion often leads to iron in the feed water.
• The logging and tracking of the boiler and system chemistry is extremely important!
QUESTIONS?

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