THE CONDENSATE STORY

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Overview

- The value of condensate
- Condensate corrosion
- System survey
- Condensate treatment
  mechanical
  chemical
- Monitoring and control

The Value of Condensate

Heat:
  Reduced fuel usage - typically $6-13 per 1000 gal

Water:
  Decreased makeup water demand
  Decreased pretreatment costs
  Reduced water discharge

Boiler Reliability
  Improved feedwater quality
Calculate the Value of Condensate

\[ \text{Potential Savings} = \frac{H_f \times C}{FV \times B} \times FC \]

Where:
- \( H_f \) = difference in \( hf \) between condensate stream and make-up (Btu/hr)
- \( C \) = condensate stream flow (lbs/hr)
- \( FV \) = heat value of fuel (Btu/fuel unit)
- \( B \) = boiler efficiency (%)
- \( FC \) = cost of fuel ($/fuel unit)

Use of Steam System Assessment Tool
Results of Condensate Corrosion

- Frequent kiln coil replacement
- Steam/condensate line replacement
- Excess iron entering boiler
  - efficiency loss
  - deposits result in potential tube ruptures
  - boiler cleaning due to iron deposits
- Unscheduled outages

Primary Causes of Condensate Corrosion

Condensate treatment is the battle against three dissolved gases:
- carbon dioxide \((\text{CO}_2)\)
- oxygen \((\text{O}_2)\)
- ammonia \((\text{NH}_3)\)
Carbon Dioxide Comes from Alkalinity in Make-Up Water

Breakdown of feedwater alkalinity

\[ 2 \text{HCO}_3^- \xrightarrow{\text{heat}} \text{CO}_3^{2-} + \text{H}_2\text{O} + \text{CO}_2 \]

Bicarbonate \hspace{1cm} Carbonate \hspace{1cm} Water \hspace{1cm} Carbon Dioxide

\[ \text{CO}_3^{2-} + \text{H}_2\text{O} \xrightarrow{\text{heat}} 2\text{OH}^- + \text{CO}_2 \]

Carbonate \hspace{1cm} Water \hspace{1cm} Hydroxide \hspace{1cm} Carbon Dioxide

Air in leakage
Pumps, receivers, etc.

Carbon Dioxide

Dissolves in the condensate forming carbonic acid

\[ \text{CO}_2(g) + \text{H}_2\text{O}(g) \rightarrow \text{No Reaction} \]

\[ \text{CO}_2(g) + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{CO}_3(l) \text{ (carbonic acid)} \]

Then, \[ \text{H}_2\text{CO}_3(l) \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]

pH Value of CO2 in Pure Water at Various Concentrations

Western Dry Kiln Association 12 May, 2005
Carbonic Acid Corrosion

Results in a thinning and grooving of the metal surface. Usually on the pipe where the condensate lays.

Oxygen Sources

- Air in-leakage: pumps, traps, vacuum systems, vented receivers, week-end shutdowns
- Inefficient deaeration operation
- Raw water intrusion: pump seals, heat exchanger leaks

Oxygen Corrosion

- \( O_2 \) attack results in pitting type corrosion.
- Rapid localized metal loss.
- Combined corrosion rate of carbon dioxide and oxygen is 10-40% faster than the sum of either alone.
System Survey

- A complete system survey is the key to any effective corrosion prevention strategy.
- The survey defines system needs and limitations allow for proper MOC solution
  Mechanical
  Operational
  Chemical

Key Considerations

- Make-up water quality
  CO₂ generation
- Percent condensate return
  amine recycled, determines makeup quantity
- Potential for system contamination
- System configuration and complexity (steam uses)
  amine selection

Mechanical Reduction of Corrosion Potential

- Prevent stagnation/coil water logging
- Reduce air in leakage
- Assure proper deaeration
- Reduce feedwater alkalinity

Mechanical: Steam Trap Maintenance

- Annual maintenance checks
- Four-six years, 50 percent of traps will likely be failing open or closed
- Efficiency/corrosion
- Problems do not surface until too late w/o a formal trap program

Mechanical: Condensate Delivery Potential Issues

- Above ground condensate recovery tanks
  rely on steam pressure through coils to elevate to the height of tank
- Condensate pumps not utilized
  rely solely on steam pressure to push condensate to boiler house
- Both can result in stagnant condensate
  elevated corrosion rates
decreased coil efficiency

Operational/Mechanical Common Air In-Leakage Sites

- Vacuum systems
- Vented receivers
- Condensate pumps, traps, and valves
- Intermittently operating systems

Operational: Feedwater Alkalinity Reduction

- Lime softening
- Reverse osmosis
• Dealkalization
• Demineralization
• Increased condensate return

Chemical: Condensate Treatment

• Neutralizing amines
• Filming amines

Condensate Treatment Requirements

• Effective corrosion protection
• Distribution throughout system
• Which chemistry do we primarily use to combat carbonic acid?

Why Amines are so Popular

• Direct neutralization of CO₂
• Direct elevation of pH
• Easy to feed/control
• Compatible with other system treatments
• Treatment recycles
• Blends available: able to distribute through entire systems

Neutralizing Amines Limitations/Considerations

• Not effective against oxygen
• Perhaps not best choice in high alkalinity waters
• Not all locations will have same pH: a blend of amines is typically required
  good distribution volatility ratio

Filming Amines

• Long chain amines that absorb onto the metal surface
• Function at the lower pH range of 6.5 to 9.0
• Protect against acids, $O_2$, and ammonia
• Dosage dependent on surface area and not contaminant concentration
• Cost effective in high $CO_2$ systems

Filming Amines Limitations/Considerations

• Film formation takes time
• pH control still necessary
• Should be fed after turbines and condensate polishers
• Will clean up old deposits
• Overfeed may cause sticky deposits and "gunk" ball formation
• Nalco ACT

Quality Control: Condensate Monitoring

• pH
• Conductivity
• Corrosion rates
• Corrosion byproducts

Secondary Testing and Troubleshooting

• Dissolved oxygen
• Hardness
• Silica
• Ammonia
• Alkalinity
• Product residual

Corrosion and Corrosion Byproducts

• Grab samples
  filtration millipore testing
  wet chemistry
  colorimeter testing
  * total iron
  * insoluble iron (particulate)
  * soluble iron (indicative of recently corrosion activity
• Corrosion coupons
• Corrosion sensor

Nalco Corrosion Sensor

• Monitors corrosivity of condensate
  real time indication
• Provides direct MPY readings up to 300°F
• Collects and displays all data
Sampling Requirements

- Cooled to less than 90 °F* (pH)
- Sample flow throttled at outlet only*
- Stainless steel sample lines
- Continuous flow
- Adequate velocity

Sampling

- Sample tap locations
- 45 degrees off bottom of horizontal pipe
- Representative of system
- Prior to condensate receivers*

Sampling Horizontal Lines

Key Take-Aways

- Condensate is a precious commodity
  Never underscore its value
  Take every opportunity to return as much condensate as possible, look for lost condensate, it is out there.
- Every system is unique
  Complete proper survey
- Always mechanical before chemical
  Alkalinity removal prior to boiler
  Check each trap once per year
  Proper flow for condensate return
- Proper condensate monitoring in place