THE CONDENSATE STORY

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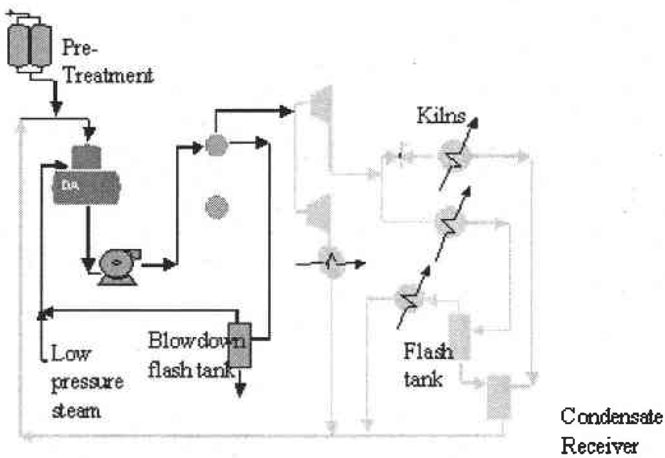
Overview

- 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

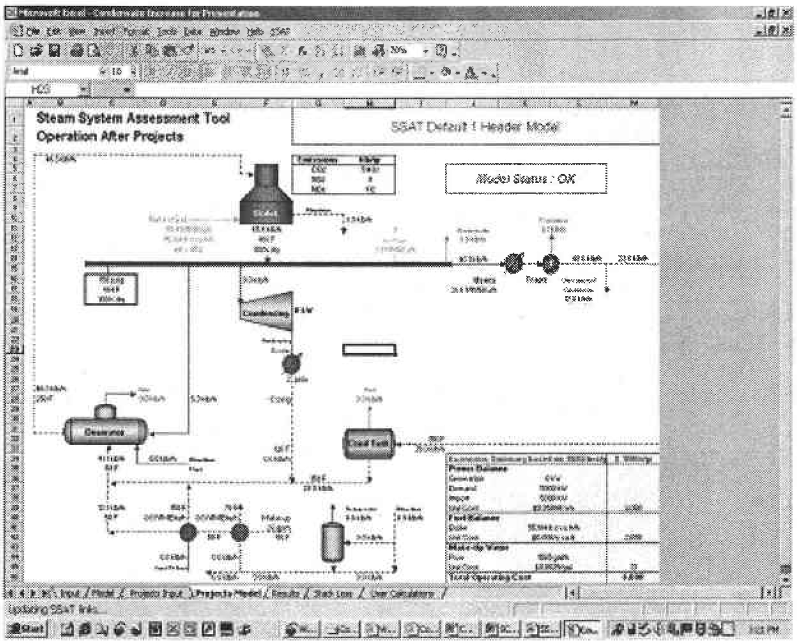
Calculate the Value of Condensate

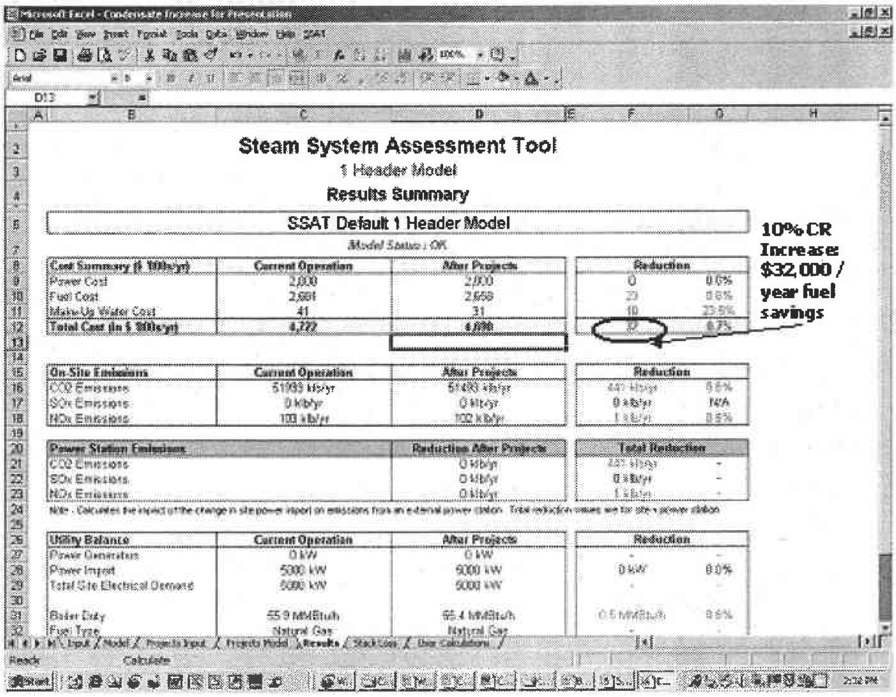
$$\text{Potential Savings} = \frac{H_f \times C}{FV \times B} \times FC$$

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	(CO_2)
oxygen	(0_2)
ammonia	(NH_3)

Carbon Dioxide Comes from Alkalinity in Make-Up Water

Breakdown of feedwater alkalinity

$$2\,HCO_3^- \xrightarrow{heat} CO_3^{-2} + H_2O + CO_2$$

Bicarbonate → Carbonate, Water, Carbon Dioxide

$$CO_3^{-2} + H_2O \xrightarrow{heat} 2OH^- + CO_2$$

Carbonate, Water → Hydroxide, Carbon Dioxide

Air in leakage

Pumps, receivers, etc.

Carbon Dioxide

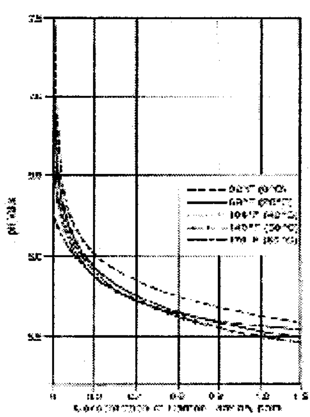
Dissolves in the condensate forming carbonic acid

$$CO_{2(g)} + H_2O_{(g)} \text{ --> No Reaction}$$

$$CO_{2(g)} + H_2O_{(l)} \text{ --> } H_2CO_{3(l)} \text{ (carbonic acid)}$$

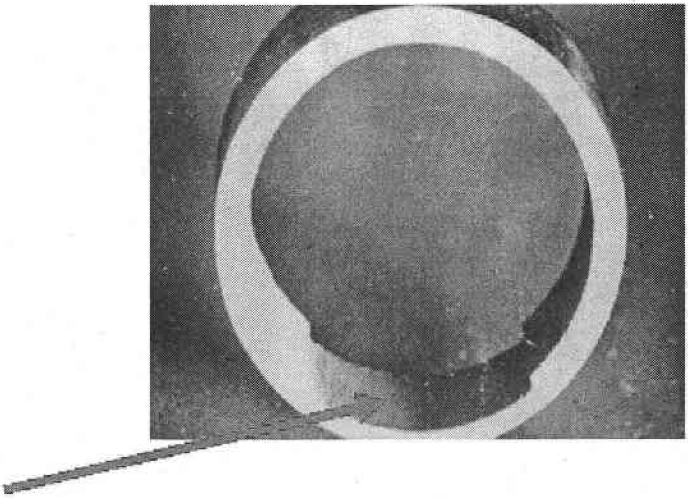
$$\text{Then, } H_2CO_{3(l)} \text{ <--> } H^+ + HCO_3^-$$

pH Value of CO2 in Pure Water at Various Concentrations



Carbonic Acid Corrosion

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

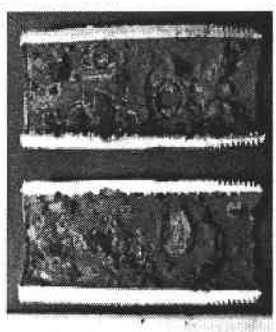


Oxygen Sources

- 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
  - CO_2 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

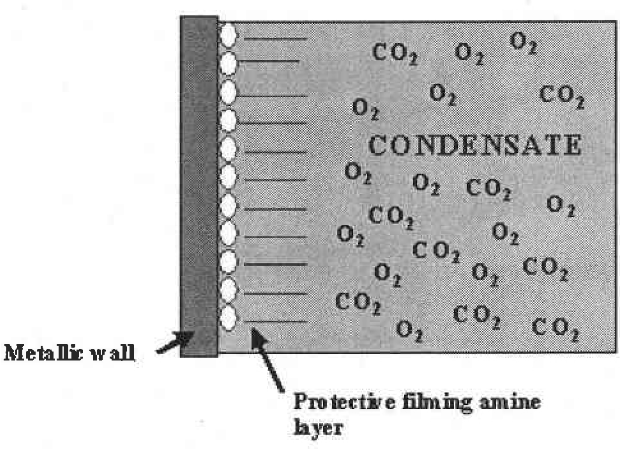
- Direct neutralization of CO_2
- Direct elevation of pH
- Easy to feed/control
- Compatible with other system treatments
- Treatment recycles
- Blends available: able to distribute through entire systems

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

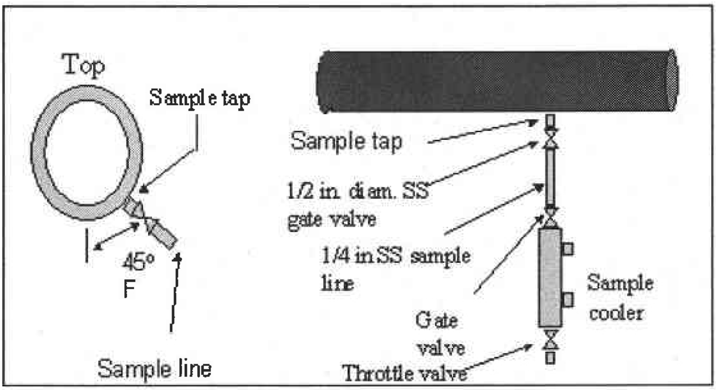
Sampling Requirements

- 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