“Save $91,000 Annually In Low Pressure Boiler Water Treatment Chemical And Fuel Costs Using a Dealkalizer”

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Summary:
This white paper shows how dealkalization of boiler feedwater improves boiler steam/condensate systems reliability, fuel savings, and chemical savings. The Return of Investment, ROI, is substantially less than one year when a dealkalizer is added to an existing boiler feedwater plant with a conventional sodium cycle water softener - deaerator pretreatment. Annual chemical savings are over $76,000 and "cycle-up" energy savings are over $15,000 savings using a dealkalizer with chloride form anion ion exchange resin. Reductions in condensate piping replacements can add further cost savings and will make the ROI even more attractive. In applications where neutralizing amine concentrations are limited by FDA regulations, the dealkalizer can be used in conjunction with reduced feed of neutralizing amines, achieving an optimized solution of reduced chemical feed with improved return condensate pH numbers. The goal of this discussion is confined to the addition of a dealkalizer post softener.

The results of adding a dealkalization are:

- Minimized waterside scale formation
- Minimized boiler-carryover
- Minimized boiler blow down through increased boiler cycles
- Increased return condensate pH values- thereby reducing the need for neutralizing amine chemical feed to control corrosion in the condensate.

Operating Expenses for Low Pressure Boilers:
The goal of any steam plant operation for low pressure boilers, those with operating pressures below 600 psig, is to reduce operating costs, without compromising the life expectancy of the equipment. Typically 60-70% of the operating expenses, fuel is the largest expense by far in a boiler operation. Other plant operating costs, make-up water to the boiler, pretreatment of the make-up water softening and dealkalization, boiler blowdown, water treatment chemicals, and application of these chemicals, collectively only amount to only 3-5 % of the total operation expense. When you take a closer look at these smaller steam plant operating costs, they control the largest expense, fuel.

The amount of fuel used to create steam or a fuel to steam efficiency is controlled by many operational factors some of which are outside of the scope of this discussion but are worth mentioning because they're dynamic. It's important to a have a general index of boiler efficiency to see if focused improvements can be made.

Operating Efficiency of Low Pressure Boilers:
A general index of boiler efficiency often overlooked is directly related to stack gas temperature of the boiler. Another way of expressing the boiler percent efficiency is expressed as:

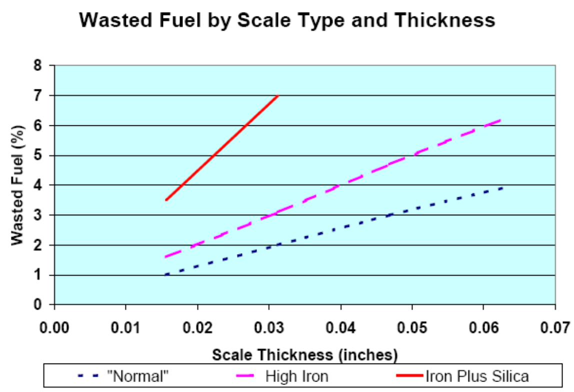
$$\mathbf{E_{Boiler} = \{BTU_{Fuel} - BTU_{Stack}\} / BTU_{Fuel}}$$

Where:
$\mathbf{E_{Boiler}}$ = Efficiency of the Boiler
$\mathbf{BTU_{Fuel}}$ = Heat value of the fuel (BTU)
$\mathbf{BTU_{Stack}}$ = Heat lost up the stack (BTU)

Typical low to medium pressure boilers range 75-85 % efficiency and there is always room for improvement. There are many operational parameters that can affect this efficiency calculation and control the overall fuel cost of a plant.

- Minimizing excess air and unburned hydrocarbons,
- Operating at or near design load, where boilers are most efficient, versus low load, through boiler loading and load balancing
- Minimizing fireside and waterside deposits
- Maximizing condensate return
- Minimizing boiler blowdown.
- Reducing stack gas temperatures by 40 ºF increases efficiency by 1%
- Increasing feedwater temperature by 10 ºF increases efficiency by 1%

In plants with blowdown heat recovery equipment, the efficiency gained by increasing feedwater temperature can easily be captured and improved by having the instrumentation in place to acquire and document the data. While many factors can



affect overall boiler efficiency as listed above, scale deposition on the boiler tube surfaces can have a large impact. Waterside boiler tube surfaces are also only looked at 1-2 times per year therefore costs can mount quickly if scale starts to develop. With properly functioning softeners, much of the deposits to waterside surfaces come from return condensate iron levels resulting in deposits of iron carbonate on high heat flux areas in the boiler.

In most low pressure boiler operations, the return condensate is the largest contributor of both iron and copper into the boiler. The return condensate pH ideally should be between 8.0-8.5 to minimize corrosion by-products of iron and copper. While copper is of concern, the majority of plants utilize black iron condensate piping making iron more of a concern. If return condensate pH is between 5.8 – 6.5, the rate of corrosion of the piping is most likely higher than the American Society of Mechanical Engineers, ASME, standard of 5 mils/year.

General ASME Guidelines For Low Pressure Boilers:

Speaking of ASME standards, there are numerous interrelated guidelines and limits established by the ASME for low pressure boilers, those with 0-300 psig drum pressure. Here they are at a very high level.

- Silica less than 150 ppm
- Specific conductance below 5400 or Conductivity below 1100
- Total alkalinity below 700 ppm in the boiler water
- Guidelines for corrosion rate of 5 mils/year
- Guidelines for Total Iron in boiler feed water below 0.1 ppm
- Guidelines for Total Copper in boiler feed water below 0.05 ppm
- Maximum recommended cycles of concentration limit of 50
- Guidelines recommend that the total alkalinity should supersede conductance as the blowdown control parameter.

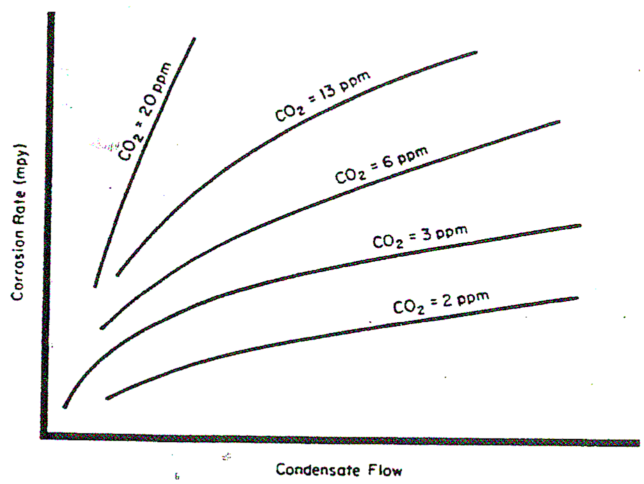
Alkalinity values above 700 ppm will result in boiler foaming and carryover of boiler water in the steam. If persistent carryover is experienced in low pressure boilers this can deposit and set-up corrosion cells in pipe threads in condensate. Large load swings whereby the boiler is operated at a load in excess of design can cause large slugs of boiler carryover and cause thermal and mechanical shock to equipment causing severe damage.

As expected, the corrosion rate will affect the life of the piping in the condensate system. The chart below shows the expected life of a Schedule 40 pipe with varying corrosion rates.

Corrosion Rate MPY	Life of Pipe (years)
0.5	250
1.0	125
2.0	62.5
3.0	41.7
4.0	31.7
5.0	25
10	12.5
25	5.0

Measuring pH Accurately:

When measuring pH in condensate, it is important to cool the sample with an in-line cooler to minimize the CO_2 flashing off from the sample. Without an in-line sample cooler, the CO_2 in the condensate sample will not form carbonic acid. This causes the pH to be measured with a false high pH. The difference between in-line cooled condensate samples and ambient cooled condensate temperatures can be 2.0 or more pH units. Keeping within ASME guidelines for total iron in boiler feedwater below 0.1 ppm and total copper below 0.05 ppm copper requires attention to the pH of return condensate, maintenance of steam traps, and knowledge of the metallurgy of the steam/condensing equipment in the steam distribution system. The chart below demonstrates the relationship between Condensate Flow and Corrosion rate.

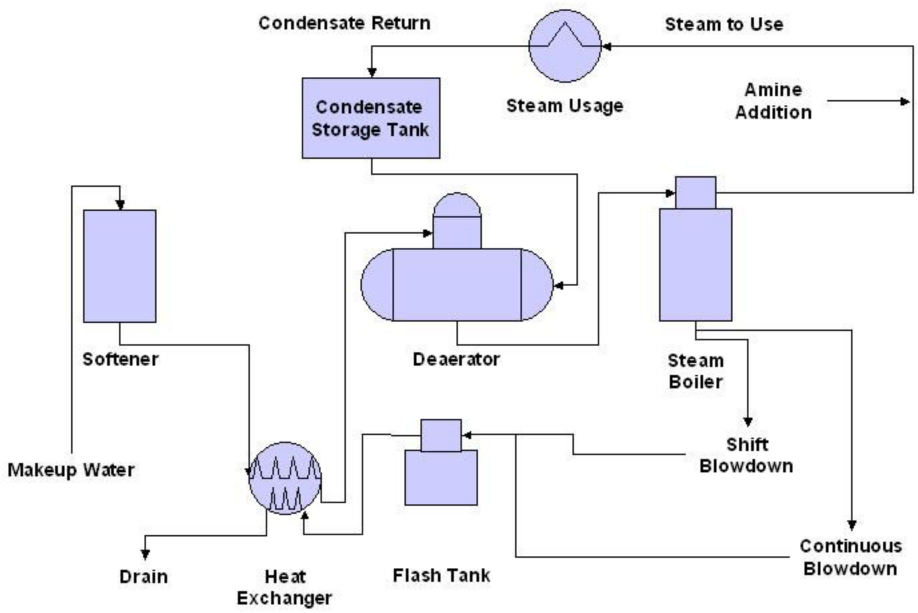


IMPACT OF CO_2 AND FLOW RATE ON CORROSION

This chart also shows equipment with large steam demands and therefore condensate flow with elevated CO_2 levels will likely have elevated corrosion rates.

Case History:

The system this paper is describing is for a beverage distilling company.



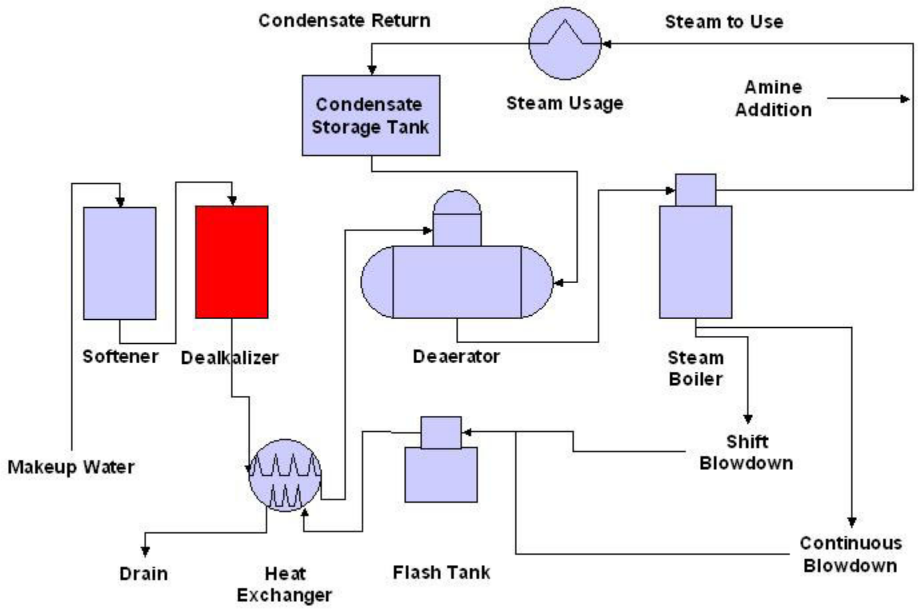
They currently have a boiler feed water system incorporating a makeup water softener and deaerator. One of the largest uses of steam is in a large steam dryer that demands high steam rates and produces high flows of condensate with high CO_2 levels. When measured using a sample cooler, the pH values are reported to be around 5.8. While specific corrosion rates are not known the relationships below would indicate they would be elevated in this specific area due to high condensate flow and increased H+ ion contact with internal pipe surfaces.

Neutralizing amines such as morpholine, cyclohexylamine, and diethylaminoethanol, and mixtures thereof, are typically used to boost condensate pH by neutralizing the carbonic acid H_2CO_3 formed in condensate. The amount of amine fed is directly proportional to the amount of CO_2 that condenses in the steam condensate. Generally, the higher the alkalinity in the boiler feedwater the more CO_2 that is produced in the steam and later absorbed into the steam condensate forming carbonic acid. Carbonic acid being a weak acid suppresses the pH of the condensate. The ratio of CO_2 formation in steam condensate is approximately 1 ppm of carbonate alkalinity to approximately 0.44 ppm of CO_2. Other factors that determine how much CO_2 end up in the condensate are temperature of the condensate and if properly sized atmospheric vents are installed on heat exchangers and or flash tanks. Because CO_2 is non-condensable, it prefers to be in the vapor phase and therefore is easily flashed off reducing the amount of carbonic acid formed.

The following are the pertinent operating parameters:

Flow Rate:	200	gpm
Total Alkalinity in Raw Water:	88	ppm
Makeup CO2 (Calculated):	38.7	ppm
Amine Cost:	$3.00	/lb
Amine Dosage:	1.0	Amine lb/ CO_2 lb
Steam Generation:	2,640,000	lbs/day
Boiler Pressure:	185	psig
Boiler Temperature:	375	F
Makeup Water Temperature	50	F
Fuel Heat Value:	3800	Btu/lb
Fuel Costs	$2.02	/MM Btu
Boiler Efficiency	70%	

As shown below, we are adding a dealkalizer after the makeup water softener.



Chemical Savings:
In our case approximately 88 ppm total alkalinity is in the raw water. Therefore, the expected amount of CO_2 in the water would be 38.7 ppm. To counteract the carbonic acid feed rates for neutralizing amines are generally 1 ppm of amine per 1 ppm of CO_2. Feed rates of neutralizing amines in large boiler operations of 110,000 lbs/hr can demand large amounts of amine feed to achieve ideal return condensate pH values of 8.0 – 8.5.The use of dealkalizer post softener can prevent up to 75-80% of the CO_2 formation in the condensate. The dealkalizer does this by removing the total alkalinity in the boiler make-up water before reaching the boiler.

Total CO_2 Removal:	93.1 lbs/day
Chemical Savings:	$209.48 /day
Chemical Savings:	**$76,460 /year**

Without amine feed and without dealkalization condensate with high iron and copper typically travels back to the condensate holding tank and then to the boiler deaerator, and directly into the boiler. As stated above, increased iron and copper traveling back in the return condensate, from low pH condensate, can be minimized efficiencies are affected by a multitude of operational factors.

Cited earlier were ASME guidelines for boiler feedwater, because condensate return in our case was 20-30% it has direct impact on the overall boiler feedwater quality. Installation of a dealkalizer post softener will also affect the boiler water cycles of concentration that can be run in the boiler.

$$\textbf{Cycles} = C_{BoilerWater}/C_{BoilerFeed}$$

Where:
Cycles=Boiler Water Cycles of Concentration
$C_{BoilerWater}$ = Conductivity of the Boiler Water
$C_{BoilerFeed}$ = Conductivity of the Boiler Feedwater

In our case it was reported that boiler water carry over has been occurring. While there are operating, mechanical, and chemical causes for boiler carryover, eliminating the alkalinity from the boiler feedwater will allow the boiler to be run at higher cycles of concentration. As explained above, caution must be exercised when running the total alkalinity very close to or exceeding the ASME limit of 700 ppm in the boiler water. This will result in boiler foaming and carryover of boiler water in the steam. If persistent carryover is experienced in low pressure boilers this can deposit and set-up corrosion cells in pipe threads in condensate.

In our case there is approximately 20 % condensate return and 80 % make-up, therefore the chemical make-up of the feedwater will control the maximum number of cycles namely the total raw alkalinity. Knowing the alkalinity of the raw water is 88 ppm, without dealkalization the estimated maximum number of number of cycles that could be achieved staying within the limits of ASME guidelines of 700 ppm total alkalinity, would be approximately = 9 –10 cycles of concentration.

If the water is consistently dealkalized to less than 10 ppm, then based strictly on the total alkalinity parameter the maximum cycles that could be achieved would be the ASME maximum recommended limit of 50 cycles. ASME guidelines also recommend that the total alkalinity should supersede conductance as the blowdown control parameter. The main list of parameters would have to be reviewed are listed above for 0-300 psig drum pressure for silica, total alkalinity or conductivity.

Using the charts below, we can develop an understanding of the energy savings by "cycling up" the boiler. Assuming 10% blowdown currently and we very conservatively reduce the blowdown rate to 9%, this will save over $12,000/year in wasted heat. If we only reduce the blowdown rate to 7%, this will save over $35,000 in wasted heat.

"Cycle-Up" Savings: $12,121 - $35,581/year

New Blowdown Rate	10%	9%	8%	7%
Present Blowdown Rate	Steam Savings (lbs/day)			
15%	172,549	204,783	236,317	267,173
14%	136,434	168,669	200,202	231,058
13%	101,149	133,384	164,918	195,773
12%	66,667	98,901	130,435	161,290
11%	32,959	65,193	96,727	127,582
10%	0	32,234	63,768	94,624

New Blowdown Rate	10%	9%	8%	7%
Present Blowdown Rate	Heat Savings (Btu/day)			
15%	61,600,000	73,107,700	84,365,200	95,380,600
14%	48,707,000	60,214,700	71,472,200	82,487,600
13%	36,110,300	47,618,000	58,875,600	69,891,000
12%	23,800,000	35,307,700	46,565,200	57,580,600
11%	11,766,300	23,274,000	34,531,500	45,546,900
10%	0	11,507,700	22,765,200	33,780,600

New Blowdown Rate	10%	9%	8%	7%
Present Blowdown Rate	Fuel Savings ($/year)			
15%	$64,882	$77,003	$88,861	$100,463
14%	$51,302	$63,423	$75,281	$86,883
13%	$38,034	$50,155	$62,013	$73,615
12%	$25,068	$37,189	$49,046	$60,649
11%	$12,393	$24,514	$36,372	$47,974
10%	$0	$12,121	$23,978	$35,581

Conclusion:

Adding a dealkalizer to this boiler water treatment system will easily save over $91,000 annually and probably significantly more. Depending upon the complexity of installing the equipment, the ROI will be approximately 8 – 11 months. Clearly, this analysis is highly dependent upon the specific equipment at this plant. If you would like Res-Kem to help you with your specific boiler water problem, please contact us at sales@reskem.com