The benefits of dealkalization in steam boiler applications

Learn how to calculate return on investment for a dealkalizer.

By Mario C. Uy

So much has been written about the importance of protecting steam boilers from deposition and corrosion. However, the ultimate fate of a boiler system also lies in how well its condensate is maintained and controlled.

A typical condensate system includes heat exchangers, heating coils, heating jackets, steam traps, condensate receivers, condensate pumps and all the piping connecting these components.

Some steam will also condense in the steam lines. This is more prominent in intermittent steam flow applications where steam can cool down substantially (during the off cycle) to form a large amount of condensate, resulting in water hammer, low BTU value and other mechanical problems.

To prevent these problems, steam traps are installed in steam lines to remove the prematurely formed condensate.

System risks

The biggest problem in condensate systems is corrosion. Condensate corrosion is primarily caused by the acidity of carbon dioxide (CO_2). In certain few applications, dissolved oxygen can contribute to corrosion in the condensate.

If not properly protected against the acidity of CO_2, any of the condensate components — including some st-amlines — will fail, leading to system outage, production loss and the potential loss of business.

In addition, the by-products of corrosion (i.e., iron oxide) are returned to the steam boilers, where they are deposited on the boiler internals. Deposition reduces efficiency. Severe deposition increases the potential for boiler outage, production loss and possible loss of lives.

	Given	Calculated
Make-up, gallons/day	3000	
Operation (24/7), days/year	365	
Total carbonate alkalinity, ppm typical Lake Michigan water	110	
Total carbonate alkalinity, grains		6.4
ppm CO_2/ppm of total carbonate alkalinity	0.44	
lbs CO_2/year		441
% CO_2 reduction w/ dealkalization, typical	75%	
lbs CO_2 reduction/year with dealkalization		331
lbs amine needed/lb CO_2, typical	1	
Lb amine reduction/year		331
Cost/lb amine, typical	$3.00	
Savings/yr, amine reduction		$993
Grains per cu ft dealkalization resin (w NaOH)	12,000	
Grains per day		19,200
Cu ft resin required for 1 regen/day		1.6
Cu ft resin, equipment, typical std capacity	2	
No. of regen/day, based on std size unit		0.8
No. of regen per yr, based on std size unit		292
Lb salt/cu ft for regen	6	
Lb salt/regen		12
Lb salt/year		3,504
Cost salt/lb, typical	$0.12	
Cost salt/yr		$420
Lb NaoH/cu ft for regen	1	
Lb NaOH/regen		2
Lb NaOH/yr		584
Cost NaOH/lb, typical	$0.18	
Cost NaOH/yr		$105
Gal. water/regen	104	
Water/sewer cost/1000gallons, typical	$2.25	
Cost water/sewer per yr		$ 68
Electricity to run regen, negligible		0
Total operating cost		$593
Net savings with dealkalizer (amine reduction savings - operating cost)		$400
Capital cost, installed dealkalizer, typical	$1,950	
Return on investment (ROI)		21%

Sources of carbon dioxide (CO_2)

Although raw water contains dissolved CO_2, the larger source is from the carbonate and bicarbonate alkalinity in the make-up water.

The carbonate and bicarbonate break down in the steam boilers to release CO_2 in the following respective ways:

$Na_2CO_3 + H_2O + \text{heat} \rightarrow 2NaOH + CO_2$ or

$2NaHCO_3 + \text{heat} \rightarrow Na_2CO_3 + CO_2 + H_2O$

Based on the above equations, 1 ppm of total carbonate alkalinity will break down to produce 0.44 ppm of CO_2. Depending on temperature and several other chemical factors, it may be possible that not all carbonate alkalinity will be converted.

Effects of CO_2

Since CO_2 is a gas, it will travel with the steam. As the steam begins to condense, the CO_2 will begin to dissolve in the condensate, forming carbonic acid:

$CO_2 + H_2O \rightarrow H_2CO_3$

The rate at which CO_2 dissolves in condensate depends on the condensate temperature and the partial pressure of CO_2. As the temperature of water decreases, it will absorb more gases.

By Henry's law, the higher the partial pressure of a specific gas, the more of it will dissolve in water, at a given temperature.

As the steam condenses and as the condensate travels further away from the steam boiler, the condensate temperature becomes cooler. Since cooler water temperature absorbs more gases, it will absorb more CO_2, increasing the carbonic acidity of the condensate.

Using make-up water with alkalinity, a steam boiler will produce a mixture of steam and CO_2. As the steam condenses, the ratio of CO_2 to the remaining steam increases, thus increasing its partial pressure.

By applying Henry's law, the condensate will begin to absorb more CO_2, increasing the carbonic acidity of the condensate.

The above phenomena explain why isolated units and long condensate runs tend to suffer more corrosion. Such corrosion is more apparent in applications where the steam production and/or flow is intermittent or interrupted periodically.

A typical characteristic of carbonic acid corrosion is smooth channeling and erosion on the pipe internal. Much like a river eroding its banks, the carbonic acid thins out the pipe, eventually wearing it out. Usually, any leak manifests itself around pipe threads since they are the thinnest parts of the piping.

Solutions

The most typical solution is the addition of certain amines to neutralize the acidity of the carbonic acid or to provide a film on the condensate surfaces as a protective coating against corrosion.

Popular neutralizing amines are morpholine, diethylaminoethanol (DEAE), cyclohexamine. A popular filming amine is octadecylamine.

Certain amines are not acceptable in certain applications. For example, amines are absolutely not acceptable in any applications with dairy products and the use of amines is a concern if the steam is used for humidification. Typical amine dosage is about 1 ppm of amine per 1 ppm of CO_2.

Another solution that is becoming popular is to remove the source of the CO_2 via pretreatment, such as dealkalization, deionization and reverse osmosis (RO). Pretreatment is even more essential in applications where the use of amines is restrictive, prohibited or cost prohibitive. The amines are by far the most expensive chemicals used in steam boilers.

Among the pretreatment methods, dealkalization is the most cost effective. It has the lowest capitalization and operating costs. Since it uses regular salt to regenerate, it is safer than deionization where acid and caustic regenerants are required.

Some dealkalizers include caustic feed to reduce the CO_2 in the influent water, but it can be eliminated without any major consequence if the handling of caustic is a concern.

The chart on page 42 demonstrates a sample return on investment (ROI) calculation you can use to justify the investment of a dealkalizer. Certain assumptions are made and may differ from your applications.

Summary

As a general rule, the higher the make-up carbonate alkalinity and/or the higher the make-up rate, the better the ROI will be.

Dealkalization becomes even more attractive in applications where the amines are regulated or restricted. In situations where amines are totally unacceptable, you may have to consider other more expensive options such as deionization and/or RO. □

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