STEAM BOILER WATER PROBLEMS AND SOLUTIONS

MAINTAINING GOOD WATER CHEMISTRY

Maintaining good water quality is critical to the long-term operation of a steam boiler system. Impurities in the water can promote corrosion, erosion, scale buildup, create leaks, block pipes, foul pumps, reduce efficiency and lead to expensive repair bills. This article reviews some of the most common problems and suggests best-practice solutions for dealing with them.

OXYGEN PITTING

Oxygen pitting is a common form of corrosion in boilers. Oxygen in the water reacts with the metal components throughout steam boiler feedwater piping, steam boiler tubes and condensate return lines, forming pits that weaken the metal and cause it to fail. There are several strategies for preventing this type of corrosion, and the best approach is to remove the excess oxygen from the water. This can be done mechanically, with a *deaerator* (DA), by adding a sparge tube to the unheated feedwater tank or chemically, by treating the water with an oxygen scavenger. Depending on the situation, it's common practice to use a combination of these approaches.

Deaerators are one example of a *pretreatment* or *external treatment* device. These are devices that remove impurities from the makeup water and render it suitable for use as boiler feedwater. Deaerators use pressure and heat to remove oxygen and other dissolved gasses from boiler feedwater. Water flows into a pressurized vessel and is heated to the point where the gasses change state and become a vapor. The vapor is then vented out into the atmosphere as steam and the purified water flows on as feedwater to the boiler.

The process requires the right combination of pressure and heat in order to work properly. The pressure should be 3-4 psi above the surrounding atmospheric pressure and the water temperature needs to be 8^{o} F above the boiling point. When the process is working correctly, it should produce a 2-3 foot plume of steam from the exterior deaerator vent and the water leaving the DA tank should have oxygen content in the range of 7-20 ppb. These four variables - pressure, water temperature, steam plume size, and water oxygen content - should all be monitored on a routine basis.

Another approach for removing oxygen from the water is to employ a chemical oxygen scavenger. These chemicals combine with oxygen to produce harmless compounds, thereby reducing the amount of oxygen in the system. They also react with the metal in the system to make it less susceptible to corrosion.

To get the maximum benefit, chemical scavengers should be applied to the feedwater upstream from the boiler. That helps to protect the feedwater lines and reduces the amount of excess oxygen that reaches the boiler. One good option is to apply the chemical to the storage section of the deaerator or feedwater tank, if there is one installed.

Sodium sulfite is the most common oxygen scavenger. When using sulfite, there are a couple of important things to consider. First, sulfite is most effective when the residual is maintained in the range of 20-40 ppm. The best way to maintain a constant residual is to apply the sulfite continuously as a function of the feedwater flow. This can be accomplished by installing a totalizing water meter, which adds the sulfite "on demand" as the DA or feedwater tank takes on fresh water. Second, it's important to avoid overexposing the sulfite to the open air. Contact with the air will consume the sulfite, rendering it useless before it mixes with the feedwater.

CARBONIC ACID ATTACK

Carbonic acid is another major cause of corrosion in boilers and condensate piping. This corrosive agent is actually a natural byproduct of the steam boiler process. The feedwater carries all of the necessary ingredients: hydrogen, oxygen, and carbonate and bicarbonate ions. As water is added to the steam boiler, the temperature releases the oxygen and carbonate/bicarbonate ions into the steam. There, they reform as carbon dioxide (CO_2). The steam then flows through the steam distribution piping, transferring its heat to the processes that require it. As the steam cools, it condenses back into water and enters into the condensate system. There the carbon dioxide mixes with the water in the condensate (H_2O) to form carbonic acid (H_2CO_3). The acid is extremely corrosive to carbon steel, as anyone who's ever seen what happens when a nail is dropped into a bottle of Coke can attest. Over time, it will carve grooves in the waterside surfaces of the condensate pipes, weakening them to the point where they will begin to leak.

An easy way to test for the presence of carbon dioxide is to measure the pH of the condensate. Carbon dioxide lowers the pH factor of the water, so a pH reading of 7.0 or lower would indicate that conditions are right for corrosion to occur. In that event, actions are required to lower the amount of carbon dioxide being produced in the steam and to neutralize any carbonic acid that might be present.

One way to decrease carbon dioxide production is to reduce the amount of makeup water coming into the boiler. Remember that raw makeup water carries the building blocks for both carbon dioxide and carbonic acid, so limiting the amount of new makeup water also limits the production of those compounds. A good first step is to optimize the cycles of concentration. Blowdowns add makeup water to the system, so it's best not to exceed the number needed to effectively control scaling and carryover. The second step is to ensure the system is returning as much condensate as possible to the boiler feedwater. There are a lot of good reasons to reuse condensate: it saves on water cost, requires less energy to heat, already contains residual levels of the neutralizing amines and oxygen scavengers, and will have fewer impurities than raw makeup water. To maximize the amount of condensate being returned, the system should be checked to eliminate wasted steam and repair any leaks in the condensate piping steam traps and auxiliary equipment.

Another way to reduce carbon dioxide is to install a pretreatment device called a *dealkalizer*. Dealkalizers remove alkalinity through a process known as *ion exchange*, which converts the carbonate and bicarbonate ions in the makeup water to chloride. They are generally installed on the feed water line upstream of the deaerator or feedwater tank, if one is installed.

The next priority is to eliminate the carbonic acid from the condensate. The most common method of treating carbonic acid attack is to use *neutralizing amines*, which counteract the acid by lowering the alkalinity in the water. The choice of amine depends on the length of the condensate piping. For example, *Morpholine* is more effective for short runs of 800 feet or less. *Diethylaminoethanol* (DEAE) is more effective for runs of up to one mile. For distances beyond that, *Cyclohexylamine* is a better choice.

Like sulfite, neutralizing amines need to be applied continuously as a function of the feedwater flow. Unlike sulfite, they shouldn't be fed into the deaerator because of the risk that they might escape through the vent. Instead, they should be fed directly into either the boiler or the feedwater piping. In cases where the condensate piping is overly long or complex, it's also possible to install "satellite" feed stations that feed the amine directly into the steam piping distribution.

A successful treatment program would result in pH levels in the range of 7.5 to 8.5.

SCALE AND SLUDGE

Now that we've dealt with the problem of dissolved gasses, let's talk about how to control the other impurities that can be found in makeup water. Raw makeup water can also contain *suspended solids*, such as small bits of debris, and *dissolved solids*, like small particles of dust or soil. These solids can eventually wind up at the bottom of the boiler, where they accumulate as sludge. The water can also contain *minerals* such as calcium and magnesium, which can cause scale to form on the waterside surfaces of the boiler. Both sludge and scale can collect to the point where they insulate steam boiler tubes, which causes them to overheat and potentially explode, so it's very important to have processes in place to control that risk.

One approach for dealing with these impurities is to install pretreatment devices to remove them from the makeup water. Filtration devices will reduce the level of solids in the water, while devices like sodium zeolite softeners can remove minerals such as calcium and magnesium.

When using a softener, it's important to select one that matches the capacity and throughput requirements for the site. Once it's installed, it must be monitored closely to ensure that it's operating within its capacity. If the demands at the site exceed the design capacity of the device, it will lose efficiency and allow impurities to enter the boiler system. Scale and sludge damage are often the result of poor monitoring and control of softeners.

The best way to track the efficiency of a softener is to maintain a log of its *realized capacity*. The realized capacity is the level of hardness that is actually being removed from the water during each regeneration cycle. If this number is lower than the design capacity provided by the manufacturer, then the system isn't removing minerals efficiently and will need to be regenerated more frequently. If the realized capacity remains unsatisfactory, an elution study may be required to identify the cause.

BLOWDOWN

Chemical treatment products are designed to control scale and sludge. Blowdowns play a critical part in this process. Regardless of how well you follow your chemical treatment plan, scale and sludge can still accumulate in the steam boiler. It's best to look at blowdowns as a part of the overall strategy for removing sludge and total dissolved solids (TDS) to prevent scale from forming.

Surface blowdowns help to control total dissolved solids (TDS). They can be performed manually, with a manual throttling valve, or automatically, with a microprocessor blowdown controller. It's better to control surface blowdowns continuously, or in small frequent increments, rather than infrequent long increments. Proper surface blowdowns avoid wide swings in both the level of TDS and the chemical treatment residual.

Bottom blowdown is used primarily for removing sludge. It's generally not used to control TDS unless it's the only blowdown option available. The trick is to determine the right frequency for performing a bottom blowdown. If it's not done often enough, sludge and deposits will build up to the point they impact the efficiency and safety of the boiler. But if it's done too often, the cost to add heat and treat the additional makeup water can be substantial. The frequency ultimately depends on the quality of the feedwater, the type of treatment program being followed and the load on the boiler. Proper blowdown frequency is achieved when adjustments are made to match boiler load changes, while maintaining the specific control ranges.

INADEQUATE SAMPLING AND TESTING PROCEDURES

The success of any water management plan depends on the quality and accuracy of its testing procedures. The test results determine the actions the maintenance team needs to take to keep the system running smoothly. If those results aren't correct, it could cause the team to make bad decisions that reduce the efficiency and shorten the useful life of the system they're trying to maintain.

The first step is to ensure the quality of the samples to be tested. Samples need to be truly representative of the system conditions. A poor sample will yield results that call for unwarranted or insufficient adjustments to the program.

Samples of boiler water should be collected at the surface blowdown line. If there is no blowdown line, then a sample can be collected from the water column beneath the sight glass. The person taking the sample should use a sample cooler to protect against being burned during the sampling process. The cooler will also keep the sample from flashing (vaporizing).

Steps should be taken to avoid contaminants that could affect the outcome of the test. Sample lines should be flushed thoroughly to remove stagnant water. Sample containers should be cleaned prior to use. Containers should be dedicated for a specific type of sample, i.e. boiler, feedwater, condensate etc. Wide-mouth containers made of heavy duty, temperature-resistant polypropylene are recommended over glass.

It's also important to know the degree of stability of the substance being tested. For example, sulfite continues to react with oxygen after the sample is drawn. So the test for sulfite levels needs to take place as soon as the sample is drawn; otherwise, the results from the sample won't be representative of the sulfite concentration in the boiler. Tests for causticity and pH levels are similar and should be performed following the sulfite test. All other tests are not as time critical and can follow after those.

RECORD KEEPING

Accurate record keeping is essential for maintaining the health of a steam boiler system. Every test taken, every change you make, every blowdown, every layup and every restart should be fully documented. Testing records should include the date of the test, the type of test performed, the result, and the action (if any) that was taken as a result. Repair records should include dates, the type of repair that was made, and the reason for the repair. Other actions require similar documentation. It's also good to track certain statistics over time, so that you can understand trends and spot anomalies early. Good metrics to include are:

1. Makeup Water: water meter readings, hardness, conductivity
2. Feed Water: water meter readings, hardness, alkalinity, iron, silica, pH, conductivity
3. Boiler Water: sulfite, phosphate, causticity or pH, alkalinity/causticity, chloride, silica, polymer, conductivity
4. Condensate pH, conductivity, iron, hardness
5. Chemical Treatment dosages, chemical pump setting
6. Microprocessor settings, trend reports, operation and calibration

Good documentation will indicate the current status, the trends of chemical treatment, and describe general boiler operations. Accurate records are particularly valuable for preventing boiler failures and for determining the cause when failures do occur. Well-maintained records can predict the condition of the boiler before inspections are performed.

Maintain log records that are organized and easy to read. Many operations use computer-generated spreadsheets, databases, and graphs for analysis of conditions. Your water management service company should provide reports which include analysis and recommendations for maintaining a good water treatment program.

FOR MORE INFORMATION

If you would like more information on how to properly maintain your boiler, please feel free to contact us here at Solid Blend. Our qualified professionals would be happy to help with any questions you might have.

REFERENCES

1. Association of Water Technologies, "Technical Reference and Training Manual, 2nd Edition," 2009, Association of Water Technologies, Inc.