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BOILER FEED ● CONDENSATE ● DEAERATOR ● VACUUM

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Re: Deaerators, Surge Tanks and Chemical Treatment

BACKGROUND

Deaeration Basics

In designing steam boiler systems, care must be taken to address key factors that can cause corrosion to the boiler system.

Oxygen is the main cause of corrosion. ***Dissolved oxygen is up to 10 times more corrosive than carbon dioxide, especially at higher temperatures.*** Dissolved oxygen can be introduced into the boiler system, since water exposed to air can become saturated with oxygen, and the concentration will vary with temperature – the higher the temperature, the lower the oxygen content. When dissolved oxygen is present in the feed-water, it will attack the feed-water line, heaters and economizer. However, the dissolved oxygen in the feed water does not cause corrosion by itself. Nor is the elevated temperature by itself a primary factor. The problem depends on the concentration of the dissolved oxygen and the temperature involved. The severity of the corrosion is increases when dissolved oxygen occurs with rapidly increasing water temperature. The temperature rise provides the driving force that accelerates this reaction so that even small quantities of dissolved oxygen can cause serious corrosion. For example, water is 2 1/2 times more corrosive at 195°F than it is at 140°F.

One of the most serious aspects of oxygen corrosion is it generally occurs as pitting so that the attack is concentrated in a small area of the total metal surface. Although the metal loss may not be great, deep penetration and perforation can occur in a short period. Within the boiler, for example, this attack will usually be concentrated adjacent to the normal operating water level.

If carbon dioxide is also present, then the pH will be low, the water will tend to be acidic, and the rate of corrosion will be increased. Acting simultaneously, ***carbon dioxide and oxygen can be up to 40 percent more corrosive than the same quantities of the two gases acting individually*.**

Therefore, the circulating steam, condensate, and feed water should be devoid of dissolved gases, particularly corrosive ones, and dissolved or suspended solids. The gases will give rise to corrosion of the metal. The solids will deposit on the heating surfaces giving rise to localized heating and tube ruptures due to overheating. Under some conditions it may give rise to stress corrosion cracking.

***If economizers are installed in a boiler system, good deaeration is essential because oxygen pitting is the most common cause of economizer tube failure.

The essential requirements to reduce corrosion are to maintain the feedwater at a pH of not less than 8.5 to 9, the lowest level at which carbon dioxide is absent, and to remove all traces of oxygen. The return of condensate from the plant will have a significant impact on boiler feedwater treatment - condensate is hot and already chemically treated, consequently as more condensate is returned, less feedwater treatment is required.

Elimination of the dissolved oxygen may be achieved by either physical methods or chemical treatment. However, usually a combination of both are used.

Physical methods are the first step in feedwater treatment where the feed water is heated to drive out the non condensable gases. Typically a boiler feed tank with preheat will be operating at water temperatures in the range of 180°F to 200°F. Heating the water in this temperature range leaves an oxygen content from 2 to 1 cubic centimeter per liter of feed water respectively. These values are easily derived from an Oxygen Solubility chart on the Shipco® website. Since less available NPSH is available at higher feedwater temperatures, some manufacturers shy away from raising the feedwater temperature higher due to concerns about pump caviations. However, higher temperatures can easily be accomondated by simply selecting pumps with low NPSH requirements and if needed, elevating the boiler feed tank to add additional available NPSH to prevent the boiler feed pumps from cavitating.

The small traces of oxygen that remain in the boiler feed water can be removed using an oxygen scavenging chemical (e.g., sodium sulphite, hydrazine or tannin).

This approach summarized above of using a combination of "preheat" with chemical treatment is common. However, many steam boiler plants need to reduce the amount of non condensable gases remaining to levels much less than can be achieved with preheat and ultimately, would like to reduce the amount of chemicals used in their operations. For these plants, the typical approach is to use a deaerator (i.e, mechanical deaeration) that removes nearly all non condensable gases versus the "preheat" / steam sparge tube approach.

Mechanical Deaeration:

Deaerators can reduce the amount of dissolved oxygen down to .005 c.c. of oxygen per liter of feedwater which is a concentration roughly 400 times less than the boiler feed with preheat set to raise water temperature to 180^{O}F. Free carbon dioxide is also removed.

Whether the design of the deaerator is a *tray type*, *spray type,* or a combination *spray-tray* design, the goal

- *Tray-Type Design:* Deaerators using a tray-type design release dissolved gases in the incoming water by reducing it to a fine spray as it cascades over several rows of trays. The steam heats the water to steam saturation temperature, thereby boiling the water droplets and releasing all but the very last traces of dissolved oxygen. Deaerated water then falls to the storage space in the receiver below, where a steam blanket protects it from recontamination.

- *Spray-Type Design:* Spray-type deaerators work on the same general principle as the tray-type, but differ in their operation. Spring-loaded nozzles located in the top of the unit spray the water into a steam atmosphere that heats it. The steam heats the water, and at the elevated temperature, the solubility of oxygen is extremely low and most of the dissolved gases are removed from the system by venting. The spray will reduce the dissolved oxygen content to 20-50 ppb, while the trays further reduce the oxygen content to approximately 7 ppb or less.

- Spray-Tray Design: Spray-Tray deaerators have both spray nozzles and trays.

  Nozzles and trays should be inspected regularly to ensure that they are free of deposits and are in their proper position.

  During normal operation, the vent valve on top of the deaerator must be open to maintain a continuous plume of vented vapors and steam at least 18 inches long. If this valve is throttled too much, air and non condensable gases will accumulate in the deaerator. This is known as “air blanketing” and can be remedied by increasing the vent rate.

  For optimum oxygen removal, the water in the storage section must be heated to steam saturation conditions. From inlet to outlet, the water is deaerated in less than 10 seconds.

  The storage section is typically designed to hold enough water for 10 minutes of boiler operation at full load.

Chemical Deaeration:

Complete oxygen removal cannot be attained by mechanical deaeration alone. Manufacturers of deaerators state that a properly operated deaerator can mechanically reduce the dissolved oxygen concentrations in the feed water to .005 cc per liter (7 ppb) and 0 free carbon dioxide. Typically, plant oxygen levels vary from 3 to 50 ppb. Therefore, the traces of dissolved oxygen remaining in the feed water must then be chemically removed with an oxygen scavenger.

Oxygen scavengers are added to the boiler water, preferably in the storage tank of the deaerator (Note***: If a surge tank is present, oxygen scavengers should NOT be added***. See discussion below on surge tanks) so the scavenger will have the maximum time to react with the residual oxygen.

The most commonly used oxygen scavenger is sodium sulfite. It is inexpensive, very effective and rapidly reacts with the trace amounts of oxygen.

It is also easily measured in boiler water. In most cases, it is the oxygen scavenger of choice. However, there are instances in some high-pressure boiler applications (i.e., generally above 900 psig), that some of the sulfite may decompose and enter the steam, causing problems in the condensate systems and condensing steam turbines. In these cases, substitute (usually organic-based) oxygen scavengers can be used.

On system operating below 900 psig, the excess sulfite (up to 200 ppm) in the boiler will not be harmful. To maintain blow down rates, the conductivity can then be raised to compensate for the extra solids due to the presence of the higher level of sulfite in the boiler water. This added consideration (in protecting the economizer) is aimed at preventing a pitting failure. Make the application of an oxygen scavenger, such as catalyzed sulfite, a standard recommendation in all of your boiler treatment programs.

SURGE TANKS

What is a surge tank?

A surge tank functions like a boiler feed tank except that *it feeds a deaerator instead of a boiler*. On a surge tank, the make-up water is added into this tank and blended with the return water to avoid shocking the deaerator with extreme temperature and capacity variations. In addition, the pumps on the surge tank must run continuously, pumping the water directly into the modulating transfer or the make-up valve on the deaerator. The second transfer pump on a Shipco® surge tank is a standby pump that is energized by a low-level switch on our two-tank or two-compartment deaerator design. The standby pump runs automatically in case the lead pump fails or can't keep up.

A surge tank is not a condensate pump since a condensate pump turns on and off based on the water level in its receiver. When a condensate style unit is used as a surge tank, it defeats the entire purpose of a surge tank by allowing large variations in capacity and temperature into the system. *The main purpose of the surge tank is to level out the transients or control the fluctuations in capacity and* **temperature** *so the deaerator runs as smoothly and effectively as possible.*
If controlling these variations in temperature were not important, no need would exist to use expensive controls that modulate on the deaerator.

Before discussing issues of surge tank operation, it would helpful to understand some basics on deaeration.

When is Surge Tank Used?

The general rules of thumb for determining the need for a surge tank are as follows:

- On systems with 80% or more make-up, a surge tank is not required.
- On systems with more than 20% returns, a surge tank is required to achieve good deaeration. The surge tank becomes the collection vessel for system returns and make-up.

Surge Tank Designs?

The surge tank can be an integral part of the deaerator, commonly referred to as a Two-Compartment design or be a separate, freestanding tank typically referred to as a Two-Tank design.

Two-Compartment designs typically are not used on applications that required 24/7 operations year round since the system would need to be shut down for maintenance. A Two-Tank design of piped properly allows for maintenance of either the deaerator or surge tank without shutting down the system.

When surge tanks are freestanding, the surge tank can be either elevated or floor-mounted. The surge tank may be placed on the floor because with condensate temperatures of 150^oF, 180^oF or even 200^oF, the water temperature is low enough that NPSH is not a major concern. For example, with 194^oF water there is 10.46 feet of available NPSH at sea level.

Common Misconceptions Regarding Surge Tank Operation

- **Surge Tank is Not Needed Because Temperature of Returns is Hot**: A common misconception is since the boiler system returns are typically in the temperature range of 150^oF to 180^oF, a surge tank is not needed. The returns can simply be dumped directly into the deaerator without affecting the performance of deaerator. Generally, people with this view are focused only on the water temperature of the returns and *don't understand the effect of a large amounts of water, even hot water, flowing into the deaerator causing fluctuations in water level.*

  One of the key performance factors for deaeration operation is controlling the transients – preventing major swings in the water level of the deaerator. A deaerator will reach its rating (i.e., .03 or .005) <u>only</u> if it maintains the water temperature at the saturation point (i.e., boiling point).

  The need to control the transients and prevent major swings in the deaerator is the primary reason why a surge tank is required in a boiler system.

  If large amounts of water, even relatively hot returning condensate, are "dumped" into a deaerator, the effect will be similar to pouring a glass of warm water into a boiling pan of water on your stove at home. The boiling is momentarily squelched which stops the oxygen from being released thereby preventing the deaerator from achieving its rated performance level.

- **Oxgyen Scavengers Must be Added Into Surge Tank to Protect It From Corrosion:** Sometimes end users and chemical vendors want to put oxygen scavengers into the surge tanks to protect the surge tank from corrosion. The surge tank is a vented vessel! Therefore, adding oxygen scavengers accomplishes little except to increase chemical usage.

As mentioned previously (under Deaeration Basics), temperature accelerates the corrosive effect of small amounts of oxygen. Water is 2 ½ times more corrosive at 195°F than at 140°F. Therefore, by adding the colder makeup water to the surge tank, the blended water temperature (i.e., returning condensate mixed with makeup water) is lowered thereby minimizing the corrosive effects of oxygen.

Design Options To Extend Life of Surge Tanks

Several design options are available to engineers and end users who want to extend the life of a surge tank:

- A black steel receiver can be made thicker.
- A black steel receiver can be lined with 7156 Plasite.
- Receiver can be made of 304L or 316L stainless steel.
- Receiver can be made of cast iron.