boiler deposit control – informed treatment selection improves boiler system protection

Presented at the 2011 International Water Conference (IWC).

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keywords

Phosphate, Ethylenediaminetetraacetate (EDTA), Polyacrylate [PA], Polymethacrylate [PMA], Polyacrylamide [PAM], 1-Hydroxyethylidene-1, 1-diphosphonic acid [HEDP], Polyethyleneglycolallylallyl ether (PEGAE), Crystal Modification, Dispersion, Complexation.

abstract

Numerous chemicals have been used to control deposition in industrial boilers. While nearly all have performed successfully in certain situations, to achieve long-term, reliable boiler system operation it is important to select a chemical treatment program that best meets the specific operating needs of each plant.

This paper will review the benefits and limitations of individual treatment chemicals to enable informed treatment selection based on plant operating conditions.

introduction

Deposits are the root cause of most boiler waterside problems. Deposits restrict the transfer of heat from the source to the water, often leading to boiler tube overheating and failure. In addition, deposits are usually the root cause of on-load boiler corrosion, providing a site where non-corrosive boiler water concentrates into either a highly alkaline or acidic solution that corrodes the tube metal beneath the deposit.
There are many factors that affect the potential for boiler deposition. One of the major factors is boiler feedwater purity. The presence and quantity of hardness, iron, copper and silica in the feedwater greatly influences the potential for boiler deposits to form. Some other factors that affect the potential for boiler deposits to form include boiler operating pressure, heat flux, minimum water/steam circulation ratio and tube design. Since each of these factors can significantly affect the potential for boiler deposit formation, it is important to consider each of them when selecting the deposit control treatment chemicals to be used.

In addition to considering the treatment chemical’s ability to control deposition of the expected feedwater contaminants, with the growing use of high purity feedwater for low and medium-pressure boilers, it is becoming increasingly important to understand the treatment chemical’s potential for contributing to feedwater system and boiler corrosion during periods of chemical overfeed.

In some systems, soda ash was fed to boilers to precipitate calcium as calcium carbonate. This was done to avoid the formation of more difficult to remove calcium sulfate scale. However, calcium carbonate has significant solubility in low to medium pressure boiler water making it prone to form deposits on the heat transfer surfaces as boiling increases the calcium carbonate concentration in the water near the tube surface.

Consequently, in other systems, phosphate was fed to the boiler water so that less soluble calcium phosphate compounds precipitated in the bulk boiler water rather than on the heat transfer surfaces. However, the feed of phosphate sometimes led to the accumulation of large amounts of “sticky” magnesium phosphate sludge. To avoid this problem, silica was fed to form a more fluid magnesium silicate sludge that could be more effectively removed from the boiler by blowdown.

In addition to these inorganic chemicals, lignin and tannin were widely used to make the hardness sludge more fluid increasing its removal by boiler blowdown.

Although most boilers were not clean by today’s standards, since most had large diameter tubes and fairly low heat flux rates the amount of deposition formed was acceptable in most facilities. However, as water-tube package boilers became widely used in the mid to late 1960’s and as 1930 to 1950 vintage field erected boilers were replaced by new, higher heat flux boilers, the need for improved boiler deposit control technology increased.

To help attain the higher degree of boiler cleanliness required for reliable operation of these new boilers, numerous new chemical treatments have been developed. Two of the first, introduced in the late 1950’s were a chelant, the sodium salt of ethylenediaminetetraacetic acid, commonly referred to as EDTA and a polyacrylate polymer [PA]. Both of these new treatment chemicals produced cleaner boilers in many systems than achievable with the earlier treatments. Both of these treatments, as well as phosphate, mentioned earlier, are still in use today.
Figure 4: EDTA and PAA became widely available for boiler deposit control in the early 1960s.

Since those earlier years, there have been numerous additional treatment chemicals introduced to help industrial plants control boiler deposits, each with its own strengths and limitations. Several are no longer in use. Some, still used today, include polymethacrylate (PMA), an acrylate-acrylamide polymer (PAAM), 1-hydroxyethylenediamine-1,1-diphosphonic acid (HEDP), polyisopropenylphosphonate (PIPPA) and polyethylene glycol allyl ether (PEGAE).

Figure 5: In addition to Phosphate, EDTA and PAA a number of newer chemicals are now used for waterside deposit control in boilers.
These chemicals control boiler deposition by one or more of the following mechanisms:

a) Crystal growth modification of the precipitates formed in the boiler water

b) Dispersion of particulates entering the boiler with the feedwater or being formed in the boiler

c) Formation of soluble complexes with feedwater contaminants such as calcium and magnesium so they stay soluble in the boiler water

As one might suspect from the mechanisms noted, the chemicals that form the strongest soluble complexes with feedwater contamination provide the best protection against the deposition of feedwater contaminants. Why then doesn’t everyone use the chemical that forms the strongest complexes with the feedwater contaminants?

Unfortunately, when overfed, those chemicals that form the strongest complexes with feedwater contaminants, also present the greatest risk of feedwater system and boiler corrosion when they are overfed. As revealed by Godfrey, et.al, when overfed, EDTA and polyphosphonic acid both increased the potential for system corrosion more than a polyacrylate/acrylamide polymer which increased the potential for corrosion more than a polymethacrylate polymer. Boyette, etal, confirmed the PAAM – PMA relationship and showed that an alternative polymer, polyoxyethyleneglycolallylether (PEGAE), reduces the potential for corrosion from overfeed even lower than PMA. In addition, Boyette, etal, showed that polyisopropenyl phosphonic acid (PIPPA), a very highly effective iron dispersant was less potentially corrosive to mild steel than either PAA or PAAM and essentially equivalent to PMA (Figure 10).
Effect of Polymer Selection on Iron Pick Up Across Model Economizer During Treatment Overfeed

Figure 10: EDTA and HEDP are both potentially more corrosive than these polymers when overfed. PMA and PIPPA are less potentially corrosive than PAA and PEGAE is the least potentially corrosive of all.

strengths and limitations of commonly used boiler deposit control treatments

**Phosphate** – Phosphate precipitates feedwater calcium as the feedwater enters the boiler. This avoids the natural tendency for the soluble calcium to be concentrated by boiling, precipitating and depositing on the tube surfaces in the highest heat flux areas of the boiler.

Phosphate is well suited for deposit control in low heat flux boilers with feedwater hardness approaching or exceeding 1 ppm. Phosphate treatments should normally be fed directly to the boiler water and supplemented by an organic dispersant to aid removal of precipitated hardness sludge by boiler blowdown.

In addition to the above stated use for deposit control, phosphates are used widely to limit boiler water pH excursions from low-level contamination of otherwise high purity boiler feedwater such as that provided by demineralizers.

**Ethylenediaminetetraacetate (EDTA)** – EDTA forms strong complexes with feedwater calcium, magnesium, ferrous iron and copper. Consequently, it is unequaled for the control of most boiler deposition problems. However, overfeed, especially to systems with low feedwater pH, can lead to corrosion of feedwater lines, economizers and low to medium-pressure boilers.

Consequently, EDTA is best suited for application to those systems that have lime and zeolite softened water since feedwater hardness variations up to 1 ppm, or more are common, and feedwater pH typically approaches 10.

Feed to the feedwater line is required and feedrate control in proportion to feedwater hardness is strongly recommended.

**Polyacrylate (PAA) – polyacrylamide (PAM) – polyacrylate – acrylamide (PAAM)** – PAA, PAM and PAAM perform as effective hardness and iron dispersants when fed with phosphate treatment and as fairly strong complexing agents when used as an “all polymer” treatment. As with EDTA, properly applied, PAA, PMA and PAAM are good deposit control agents. However, being strong complexing agents, they also present a significant risk of feedwater line, economizer and low and medium-pressure boiler corrosion if overfed. Again, the lower the feedwater and boiler water pH, the greater the risk of corrosion.

Another concern with PAA, PAM and PAAM treatment is a high risk of forming difficult to remove calcium-polymer deposits during feedwater hardness excursions.
PAA and PAM are best suited for co-application with phosphate. When used with high purity feedwater, feeding directly to the boiler is recommended. This will reduce the pickup of iron from the feedwater circuits of systems with low levels of feedwater contamination.

1-Hydroxyethylidene-1, 1-Diphosphonic Acid (HEDP)
– HEDP functions as an effective hardness dispersant when fed with phosphate treatment at low boiler water alkalinity and silica levels. HEDP also functions fairly effectively as a complexing agent in low pressure boilers but rapidly loses effectiveness as pressure approaches 600 psig. When under fed due to feedwater hardness excursions, insoluble calcium phosphonate deposits may form. However, being a fairly strong complexing agent, HEDP also presents a significant risk of feedwater line, economizer and low and medium-pressure boiler corrosion if overfed. The lower the feedwater and boiler water pH, the greater the risk of corrosion.

HEDP has been effective for application to boilers that operate at pressures below 600 psig and have significant feedwater iron. At pressures approaching 600 psig, there is a some decomposition to orthophosphate which creates a tendency for HEDP complexed hardness to deposit as calcium phosphate in the highest heat transfer areas of the boiler.

Polymethacrylate – (PMA)
– PMA functions as an effective hardness dispersant when fed with phosphate. When used with carbonate or as an “all polymer” treatment the complexes formed with feedwater hardness and iron contamination are not as strong as those formed by EDTA, HEDP, PAA and PAAM. However, when properly applied, PMA is effective for controlling deposits and there is a substantially lower risk of feedwater, economizer and boiler corrosion from product overfeed as shown in figure 10. Also, the risk of forming calcium polymer deposits in the event of feedwater hardness excursions is much lower than when using PAA, as shown in Figure 11.

It is recommended that product be fed directly to the steam drum in plants with high purity feedwater. When polymer feed to the feedwater is preferred to simplify chemical application and control, it is recommended that the PMA be fed in proportion to feedwater contamination levels to reduce the potential for treatment under or over feed due to feedwater purity variations.

PMA is well suited for application in plants where low treatment costs are of high priority and feedwater hardness and iron are well controlled. While some deposit control effectiveness is noted at pressures up to 1500 psig, most reliable performance is obtained at pressures below 1000 psig.

Polyethyleneglycolallylether (PEGAE)
– PEGAE provides effective control of feedwater hardness and iron deposition in boilers operating at pressures up to 900 psig.

PEGAE is especially well suited for application to low-pressure boilers with high purity feedwater, such as plants with reverse osmosis – sodium zeolite softened or demineralized make up water. This is because PEGAE provides effective control of deposition from low level feedwater contamination and the potential for feedwater line and boiler corrosion due to polymer overfeed is very low compared to other treatments as shown in Figure 10.
Polyisoprenylphosphonate (PIPPA) – PIPPA provides highly effective iron deposit control at boiler pressures up to 1800 psig. Although PIPPA forms weak complexes with iron at boiler feedwater and boiler water temperature and pH, it is a highly effective dispersant under these conditions.

PIPPA is well suited for application in plants where iron deposit control is of prime importance. It has been frequently used to not only maintain clean boilers deposit free but to safely and effectively remove existing iron deposition from boilers on line. Unlike most other boiler deposit control chemicals the effectiveness of PIPPA applications can be observed on line by monitoring blowdown iron levels to determine how effectively feedwater iron is being removed from the boiler.

**Figure 12:** Heavy iron deposition on plant 101-C waste heat boiler tubes.

**Figure 13:** Boiler blowdown iron levels increase when PIPPA is applied to plant 3 waste heat boiler beginning April, 2009.

**Figure 14:** October, 2009 plants 1 and 2 converted their waste heat boilers from PMA to PIPPA dispersant and blowdown iron increased as deposits were removed.

As with other polymers when treating systems with high purity feedwater, it is preferable to feed PIPPA directly to the steam drum. This will reduce the pickup of iron from the feedwater circuit. As shown in Figure 10, when polymer feed to the feedwater is preferred to simplify chemical application and control, the potential for iron pick up across the feedwater circuit is comparable to that of PMA and less than that of other treatments commonly used for iron deposit control, such as PAA and PAAM.

**summary**

To select the deposit control chemistry that will best enable the boiler plant operator to achieve long term, reliable operation, the characteristics of each individual chemical should be considered in view of the plant operating conditions.

For example, when a plant has lime-zeolite softened make up water, the feedwater will normally have low level hardness during normal operation but may be exposed to periodic spikes in hardness due to carryover of particulate from the lime softener. In this instance a treatment that forms strong complexes with the incoming hardness but also provides some good dispersant ability such as a blend of EDTA and PMA will often be a good choice. While there is always some potential for feedwater line and low pressure boiler corrosion due to over feed of EDTA, this potential is lower with lime...
softened make up water because the feedwater pH of around 10 forms a more protective oxide layer than formed by feedwater of lower pH. Protection from overfeed can also be improved by feeding the product in proportion to both feedwater flow and hardness.

By contrast, EDTA will normally be a poor choice for plants with higher purity feedwater, such as that provided by demineralizer or reverse osmosis (RO) make up water treatment. These plants will usually have low levels of feedwater hardness and iron contamination in the feedwater. If not treated this low level contamination will lead to long term deposition problems, but it does not require the strong complexing power of EDTA to maintain effective deposit control. In this instance, PEGAE will often be the best choice for boilers operating at pressures up to 900 psig, especially if the treatment is to be fed to the feedwater. This is because PEGAE will remove less iron from the feedwater system during periods of overfeed than the other commonly used chemicals, preserving the integrity of the feedwater system and adding less corrosion product to the boiler.

On the other hand, if the feedwater has a high level of iron due to condensate corrosion, or if the boiler operates at pressures above 900 psig and has a high heat flux and marginal circulation as found in many plants in the hydrochemical processing industry it may be necessary to keep the tube surfaces almost spotless to avoid acidic phosphate or caustic corrosion. In these instances, PIPPA will often be the best treatment choice.

references

