Critical Aspects of Condensate Polishers, Its Impact on Feed Water Quality & Potential Damage Mechanisms: Review

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ABSTRACT

The condensate polishers is used in the power plants to remove the contaminants from the boiler feed water system after condensate extraction pump. Typically, silica in the form of oxides, sodium, iron oxides, crud and other scaling substances that are removed due to high feed velocity are the potential corrosion agents dissolved in the feed/steam water cycle. The Scaling & corrosion causes due to these components initiates the damage mechanism in water walls, superheaters, drum and various heat exchanging auxiliaries or increases the maintenance frequency.

The efficient operation of condensate polishers improves the quality of feed water and thus helps to maintain the healthiness of the boiler system. For ultrasuper critical and supercritical there is stringent requirements of high quality feed water. Required steam purity can be achieved by the proper operation of condensate polishers.

In present paper, the chemical parameters over which the exhaustion of condensate polishers to be decided, its potential impacts due to overrun of polishers on feed water quality, damages due to scaling and corrosion, and reduction in efficiency of polishers is reviewed and expressed.

Keywords: - Exhaustion of polishers overrun, air scoring, conductivity after cation exchange, orifice choking, tube failures.

1 INTRODUCTION

As many high pressure boilers applications rely on the condensate for the bulk of their boiler water system, condensate polishing system is an essential integral and effective components in the supply of high quality feed water. Water quality in power plant critically plays an important role for maintenance and efficient operation in lieu of limiting downtime due to boiler tube failures and preventive maintenance. High purity feed water is required to ensure proper operation of turbines and steam generator system. The lower level of impurities also helps to reduce the chances of corrosion and scale build up rates in the boiler and various heat exchanging areas. To promote the optimum performance downstream filtration or conditioning of feed water system is of great importance. To encounter all possible damage mechanisms due to deposition of crud and ionic contamination of feed water, the condensate polishing units becomes the necessities of power plant. Condensate polishing units principally works on the ion exchange mechanism. A power plant employs the condensate polishers to remove an ionic impurities and suspended crud particles from condensate return [1]. It removes micro colloidal, suspended particle which are by-products of corrosion scaling process. These particles are mostly is of all oxides of iron and silicates and other abrasive material.

As condensate polisher resin is a combination of cationic and anionic resin, it is desired to monitor the exhaustion parameters of both the resins. Proper and timely chemical analysis of polisher outlets water helps to maintain the proper steam water cycle chemistry. It is recommended to monitor pH, specific conductivity, cation conductivity, silica, iron and crud at condensate polisher outlet.

When both the resins are in the fresh condition, the pH of outlet of polishers is acidic with low specific and cation conductivity. The condenser polishers outlet water quality resembles to DM water parameters. In normal practice, the cation column conductivity and silica measurements are considered as exhaustion parameters of condensate polishers. Since the polisher resin is the combination of both cation and anion exchange resins, both the ionic resins exhaust at their different total ion exchange capacities. It is always desirable to consider the exhaustion of both these resins to avoid the ingress or any slippage of ionic and suspended impurities.

The use of mixed resin in a deep-bed condensate polisher serves to filter insoluble iron oxides and protect the downstream steam generation equipment in the event of condenser inleakage. Minimization of insoluble iron and dissolved contaminant ions in the feedwater is critical to protect the steam generator tubes from a variety of corrosion related mechanisms. These mechanisms are tied to such problems as tube denting and pitting, inter-granular attack (IGA) and inter-granular stress corrosion cracking GSCC)[2].

2 Exhaustion Criteria for Condensate Polishers

2.1 Exhaustion of cation part of resin

While depending on the increase in the cation column conductivity, pH excursion normally starts due to exhaustion of cationic part of resin. High pH indicates the start of ammonium ion cycle after end of hydronium ion cycle. This indicates the start of exhaustion of cationic resin. Impurity removal efficiency of condensate polisher plant (CPP) in ammonium cycle is poor [3]. As Na^+ and K^+ cations has a lower activity and lower atomic size as compared to $NH4^+$ ions. Hence, there is reduction in ion exchange capacity at ammonium ion cycle. During the start of ammonium ion cycle, the cations especially Na^+ and K^+ may starts sliping through ion exchange sites of the resin particle and start ingressing in the feed water cycle. The concentration of Sodium and potassium may go beyond 500 ppb and 200 ppb respectively. This may lead to the caustic gauging of the superheaters and initiates the corrosion scaling mechanism. The damage mechanisms are more prominent in the case of boilers which are operating on once through feed cycle. Therefore, it is always desirable to check and monitor the exhaustion of cationic resin of condensate polishing unit.

2.2 Exhaustion of anionic part of resin

The excursion of cation column conductivity along with the specific conductivity indicates the exhaustion stage of anion part of resin. During this stage, it is desired to check the silica and chloride along with Conductivity after cation exchange. When conductivity after cation exchange shows even a small increasing trend, pH of the system must be monitor. By deciding the judgement criteria of pH and cation column conductivity the exhaustion of condensate polishing unit is to be decided. It is not desirable to achieve increased value of conductivity after cation exchange as pH may already crosses its safeguard limits of exchange of ions and sodium and potassium. In short, whenever conductivity after cation exchange start showing increasing trend, its pH must be monitored and polishers may be withdrawn from service on account of high pH to maintain the healthiness of feed system water system.

3 Effect of putting the exhausted CPU in service after washing

Apart from polishers having the high ion exchange capacity for soluble impurities, the condensate resin bed also acts as a fine filter for mechanical or suspended impurities under high pressure conditions. Its filtering capability is limited. Large quantities of total suspended solids can cause plugging and high pressure drop issues indeep-bed condensate polishers. Filtered particles may also cause fouling of the resin, particularly the anion resin beads, and loss of polisher efficiency. [4]

Due the force accelerated corrosions and mechanical thermal shocks, abrasive fine metal particles, or metal oxides particles which got removed from the passivated layer of water wall tubes of boiler and having a migratory nature starts ingress in the feed system. All such mechanical impurities contributed to crud. The crud may be the corrosion scaling product of the boiler system. The crud when transverse through the vessel of condensate polisher, it get trapped within the bed of resin. These micro suspended particles may adhere over the resin surface cohesively or may trapped within the cracks of resins. Due to this, the set level of differential pressure (Δp) along the resin bed is achieved. Condensate polishers minimises the accumulation of crud deposits and other ionic contaminants in boiler system [5]. The bed of crud is formed over the surface of resin layer of CPU vessel.

In some power plants, after exhaustion of polishers, in order to achieve the highest OBR of condensate polishers, the resin bed is subjected to the high pressure stroke of air through blower followed rinsing through condensate water. Normal operating pressure of these blowers may be around 8-9 kg/cm^2 which is provided for removal of tiny small resin particles from nozzles during transfer of resin for regenertion. The CPU after air score and rinse at this pressure, the crud particles which are attached to the resin surface cohesively easily got removed and washed off subsequently during the rinsing step. At this stage, the turbidity at the vessel outlet may found to be practically nil or < 1 NTU and pH around 5.5-5.7. However, the whole amount of turbidity may not be removed during this step. When polisher resin bed is again subjected to another stroke of air, the turbidity at vessel outlet in rinsing step may observed above 150 NTU.

This implies that thought the surface colloidal particles which are adhered to the surface got removed from the surface easily. But the particles which may be entrapped in the bulk or crevices of the resin or which are attached to the resin beads with strong Vander Vaal's forces are very difficult to be removed off easily. Hence when such polishers are put in service directly after the first wash, micro particles of crud may get ingressed in the feed water under CEP high pressure. i.e. [around 29 kg/cm2].

The micro turbidity may get deposited where turbulence and restrictions are maximum.e.g. the boiler tubes & heat exchange auxiliaries turn outs . This initiates the damage mechanisms and may lead to tube failures due to starvation or overheating.

The case is more prominent for a super critical once through boiler feed water system where the feed flow is around 2150 $T.hr^{-1}$ and systems without blowdown and force accelerated corrosion is of greater concern. Moreover, the frequent and unnecessary air scoring at high pressure may damage the resin bead structure ultimately leading premature attrition of resin bead and impacts ion exchange capacities severely leading to loss of resin. To prevent the above consequences, the overrun of exhausted condensate polishers through air scoring at high pressure and rinsing must be avoided. The polishers do not make the system immune to the chemistry issues, but they do lesser impact on chemistry problems and often allow a plant to continue operating with minimum condenser tube failure that may require the immediate outage. In addition condensate polishers are suitable for operating with high performance chemistry programs such as oxygenated treatments [6]. It accelerates the start-up activities by minimising the chemistry hold. It allows a more orderly plant shut down in case of significant water contaminations.

4 Condenser polisher system outages

As discussed earlier, due to high pressure air scoring there is premature attrition of resin particle occur. This attrition may include development of cracks in resin bead and even breaking of resin particles. This may damage the cross-linking of the resin beads which also provides the micro sieves for crud entrapment. Mostly Cation exchange resins has styrene-divinylbenzene (DVB) copolymers with 6-10% cross-linking. This provides better potential for enhanced crud removal [7]. Air scoring at high pressure affect the ion exchange capacities and cross linkings of resin particle seriously. Due to attrition of resin particles following consequences may occur which may lead to forced outages of polisher system.

4.1 Reduction In Availability of Stand By Polishers

Due to breaking of resin particles, finess of resin bed increases which increases the bed compactness. The differential pressure across the polisher vessel may increase. Hence, polishers are not able to handle the total quantum of feed flow. Feed flow is diverted through auto bypass system. To cope up with such situations additional stand by polishers which are meant to be placed in service in case of exhaustion of running polishers vessels are required to be put in service. This reduces the availability of standby polishers and ultimately reduces the polisher system efficiency. This affects the requirement of feed water quality.

4.2 Polishers Forced Outages

The fine particles of resin may get trapped in the resin strainer which increases the differential pressure across the resin trap. Hence, flow cannot be passed through polisher vessel. Due to high differential pressure, the forward feed flow diverted through auto bypass system. In such cases resin traps are to be cleaned by removing the polishers from operation. Further the excess pressure on resin traps may lead to bursting of resin trap sieves or gaskets from where resin fine particles may ingress in the feed water system. Removal of resin traps for cleaning increases the system downtime and reduces the polishers system availability. Polishers system need to be operated on bypass system consequently affecting the feed water quality.

5 Potential Cause for boiler tube failures.

Ingress of turbidity due to crud may get deposited at orifice from where the water is being circulated to water wall. The orifices are designed to provide the equal flow distributions across the water wall.

Crud can deposit on orifice over a time and slowly reduces the flow to the circuit tube. Fig 1. This may lead to improper flow distribution across water walls. The heavy accumulation of crud at the orifice opening may lead to starvation of water walls and may prone to overheating. Subsequently, leading to boiler tube failures. Since the primary site for the accumulation is at economiser, the frequent failures are occur in this zone may be of short term over heating type. Further, the deposition may occur in the form of layer on the water wall surfaces which cause inefficient transfer of heat to water through metal. That may also leads to boiler tube failures. In both the cases the type of failures can be identified. In first case, the melting or flow like pattern over the tube material can be observed. In second case fish mouth vide opening is observed due to overheating as shown in the Fig 2.

Fig1. Orifice Choking due to Crud accumulation

Fig:2 Short Term Overheating of Boiler waterwall Tube due to overheating.

Condensor inleakages

Condenser in-leakage can also be a problem because the quality of the condensate recycled to the boiler or steam generator is affected by the contamination [8]. Condenser in leakage causes high chloride, sulphates in the steam generators. High TDS conditions existed in the hotwell during re-start preparations due to ingress of cooling water from the coolant side of the condenser. Although the condensate polishers provided ion exchange capacity to remove the majority of the contaminant ions, the steam generators were showing unacceptably high chloride levels.

As discussed earlier, overrun of polishers, rise in differential pressure across the polisher vessel, choking of resin traps and subsequent unavailability of standby polishers are the potential threats during the condenser ingress. In all the cases polishers are either unavailable or running on auto bypass systems. The boilers operating on once through cycle systems are at the risk in chemistry point of view in all the above mentioned cases. Even ingress of 10 % of high TDS content due to condenser in leakages may affect the boiler metallurgy seriously. The effect may be catastrophic and may lead to frequent tube failures.

The boiler operating on oxygenated treatments are at more potential risk as the conductivity after the cation exchanges may increase gradually if polishers are failed to exchange the high TDS ingress in the feed cycle. The chemistry may not have a fair control on oxygen dosing regimen. In such cases, it necessitates shifting of cycle chemistry from oxygenated treatment to AVT (O).

CONCLUSION

The chemical analysis of condensate polisher has been carried out considering an output between regeneration as a length of study. It is clear that as the pH of the condensate polishers start increasing, indicates that the cationic part of resin is exhausting and operation of polishers on ammonium ion cycle started. During this the corrosion scaling prone cations such as Na/k/ca^{2+}/Mg^{2+} and Fe^{2+} starts ingressing in the feed water cycle thereby perturbing the required quality of feed water system and affecting healthiness of the system. pH of polisher may be the criteria of exhaustion of polishers. Considering pH, cation column conductivity may be considered in congruence with one another and polishers should be removed from service after exhaustion. Overrun of the polisher through air scoring at high pressure must be avoided especially for the boilers operating at critical pressures.

The variation of effluent parameters of polishers after air score and rinse at high pressure may be the problem of concern and initiate the damage mechanisms. Crud particles which are adhered to the surface of the resin particles are prominently get removed along with some ionic load. When condensate polishers are subjected to another stroke of air scoring and rinsing till clearance of turbidity, the some part of ionic impurities which are not exchanged efficiently again washed off from resin surface along with high turbidity may be around 150 NTU. Under such operating conditions, if polisher were put in the service, high volume turbidity which is coming out as a effluent in second stroke of washing & starts ingressing and affecting the feed water quality. This leads to deterioration of resin quality and loss of resin due to attrition. The cross linkings of polymers across the resin bead may damage. This crosslinking of polymers is acts as a micro sieves for micro crud. Further, reduction in availability of polishers and may lead to system outages. The deposition of crud on water wall, water wall economiser turned outs and orifices may lead to boiler tube failures either due to overheating or starvation.

Rise in differential pressure across the polisher vessel, choking of resin traps and subsequent unavailability of standby polishers are the potential threats during the condenser ingress. In all the cases polishers are either unavailable or running on opening of auto bypass systems. The boilers operating on once through cycle systems are at the risk in chemistry point of view in all the above mentioned cases. Even ingress of 10 % of high TDS content due to condenser in leakages may affect the boiler metallurgy seriously. The effect may be catastrophic and may lead to frequent tube failures. Tolerance period during condenser inleakages of feed cycle reduces leading to immediate forced outage of boilers.

The boiler operating on oxygenated treatments are at more potential risk due to high cation column conductivity if polishers are failed to exchange the high TDS ingress in the feed cycle. The chemistry may not have a fair control on oxygen dosing regimen. In such cases, it necessitates shifting of cycle chemistry from oxygenated treatment to AVT (O).

Boiler system becomes vulnerable towards chlorides and sulphate contaminants handling may withdrawn from running conditions if feed cycle operating with unavailability of condensate polishers or polishers operating with auto bypass systems in service.

Thus, the practise of overrun of condensate polishers over pH and air score rinse after first exhaustion must be avoided to maintain the healthiness of the system with minimum chemistry hold and to reduce the failure, maintenance frequency.

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