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Development of the Sludge Visualization Program

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1. Introduction

Steam generator is the most important component in nuclear power plant because it mainly has a role of heat transfer area. Therefore, it is necessary to know as much as possible about the condition of the steam generator to maintain it well and not to lead to forced outage in power plant.

Since the first SCC of the KSNP SG on top of tube sheet in 2001, Stress Corrosion Cracking has focused on the SG tube integrity. Lots of KSNP PWR units have experienced SCC on top of tube sheet. Root cause of SCC is variously explained such as operation temperature, affection of contamination, tubing material, and deposit formation. Currently, mitigation of SCC in steam generator of KSNP is due to preventive tube repair, not the elimination of root cause. As SCC concerns have reduced, it is more focused on operation of the steam generator in the power plant. Concerned point of view to operate steam generator is deposit on the tube surface. The heat transfer surface area of the steam generator tubing is much lager than all the other surfaces in the power plant. So, it is considered that heat transfer rate is gradually interrupted by deposit formation located in tube surface, tube sheet and flow hole of support plate. For example, for Model-F steam generator that has 4600m^2 of surface area, a uniform magnetite deposit 0.1mm thick results in an inventory of approximately 2500kg on the tube surfaces.

There are numbers of methods such as visual inspection to, sludge lancing and chemical cleaning for controlling and managing the sludge in the steam generator. All of these methods provided benefits in controlling and managing sludge but all have limitations to assessing the state of sludge on the tubes. With need for the management of steam generator, we have developed the Sludge Visualization Program to know an accurate assessment of sludge formation on the tube surface over the steam generator.

2. State of Deposit Formation

Visual inspection shows deposit on the free span and flow hole (as shown in the figure 1). It may gradually cause the blockage of flow hole and the growth of the fouling factor in the steam generator. These deposits are composed of over 90% of magnetite from corrosion of the components in the secondary side of the power plant. The heat flux may actually rise somewhat as the initial deposit from a thin rough tube surface and promote heat transfer. As the deposit formation thickens and become denser, heat transfer rate of the steam generator is reduced. Deposits in the flow holes of the tube support structures, especially quarto-foiled tube support plates, can lead to instability in steam generator levels. It may cause power reduction of power plant.

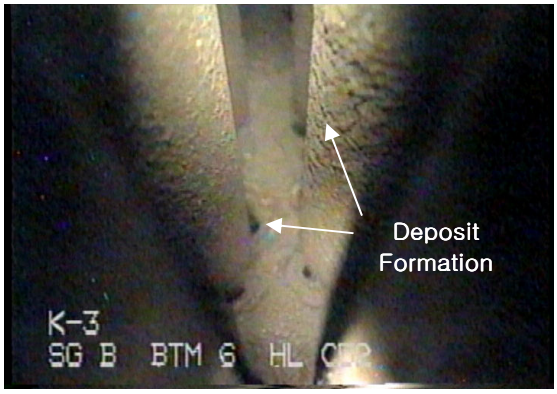

Figure 1 –Free Span & Flow Hole Deposit (KORI3)

In 2002, the UBIB (Upper Bundle In Bundle Inspection system) in the SG B in Kori unit3 was performed to recognize the deposit formation of the tube bundle in the steam generator. The inspection point were support quatrefoil blockages, deposit formations surfaces and inside bundle of tube, support structure and loose parts. The results showed that quatrefoil blockage in the hot-leg side increased from 4th support to 6th support up to 100% of flow hole and was continuing onto adjacent free span of tube surface. Even if the inspection limited and partially performed only in SG B, it was helpful to recognize the situation of deposit formation in the steam generator.

3. Sludge Visualization Program

Sludge Visualization Program has designed to know more accurate state of the sludge formation in the steam generator than the other methods that have limitations. Actually, Sludge Visualization Program cannot measure the exact amount of deposit on the steam generator, but its benefit is to understand the whole area of deposit formation. The main source of Sludge Visualization Program is low frequency absolute eddy current signal that acquires during outages. The analysis is performed after outage, so that no additional inspection time is required to acquire data.

Figure 2 shows an example of model F of Sludge Visualization Program. All models of the operating steam generator in Korea are available. Each colored U-tube displays its degree of deposit formation on the tube

surface. Blue color means default and it turns red if deposit is getting denser.

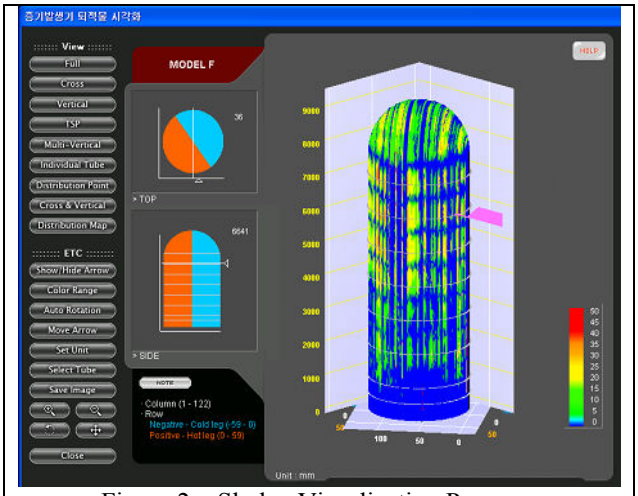

Figure 2 – Sludge Visualization Program

Accumulated single tube information takes to the entire images. There are choices to view images that one tube to whole tube, depending on support elevation, and hot-leg side to cold-leg side. Rotating the tube bundle is also available. Figure 3 shows deposit formation on each support and single selected tube only. Figure 4 shows a zoomed area of support plate.

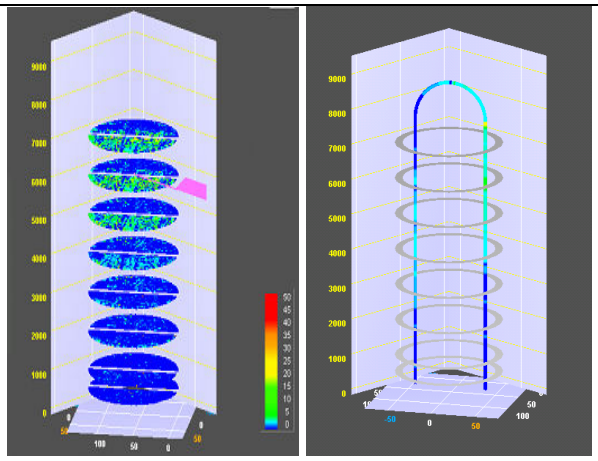
Figure 3 – Support Elevation & Single Tube View

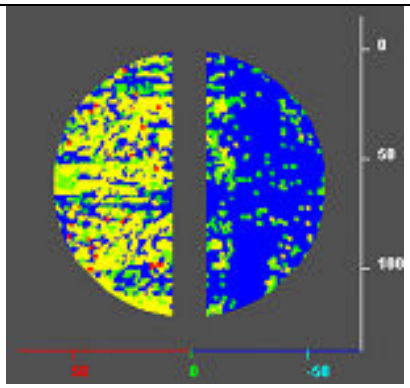
Figure 4 – Single Support View (H/L & C/L)

Important benefits result form performing Sludge Visualization Program prior to a maintenance outage. Visual Inspection of particular area like U-tube in steam generator has limitation. Inspection tool may not be available or may be difficult to access. Even if access port are visible, access to some area may not be possible because of physical configuration of the components of the tube bundle in the steam generator. It also does not allowed to expand time of visual inspection. However, visual inspection is very helpful for interpretation Sludge Visualization Program data. So, this program can be very useful to select regions that are interest for visual inspection in the following outage and to prioritize those regions. To make a decision to perform maintenance that remove deposit in the tube bundle may be difficult. As Sludge Visualization Program shows a relatively small amount of deposits have accumulated on the tubes and a large amount of deposits have accumulated on the top tube sheet, then sludge lancing is in order, it brings clear decision for maintaining the steam generator.

In addition, Sludge Visualization Program may use comparisons made before and after chemical cleaning. After through several outages, the trend of the deposit formation can be determined.

4. Conclusion

Sludge Visualization Program has been developed for the accumulated deposit on the steam generator and is also useful tool used for managing deposits. This Sludge Visualization Program allows a single image to show the deposit in entire steam generator and images of specific location show more detailed pictures of the deposit. As the implementation of SGMP is a requirement for all operating steam generator in Korea, Sludge Visualization Program provides the utility additional information to make decisions relative to management of steam generator deposits.

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