Perspective on the Westinghouse Steam Generator Secondary Side Maintenance Approach

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ABSTRACT

Historically, Westinghouse had developed a set of steam generator (SG) secondary maintenance guidelines focused around performing recurring activities each outage without direct regards to the age, deposit loading, operational status, or corrosion status of the steam generator.

Through the evolution of steam generator design and steam generator condition data, Westinghouse now uses a proactive assessment and planning approach for utilities. Westinghouse works with utilities to develop steam generator secondary maintenance plans for long term steam generator viability. Westinghouse has developed a portfolio of products to allow utilities to optimize steam generator operability and develop programs aimed at maintaining the steam generator secondary side in a favorable condition for successful long term operation.

Judicious use of the means available for program development should allow for corrosion free operation, long term full power operation at optimum thermal efficiency, and leveling of outage expenditures over a long period of time.

This paper will review the following required elements for an effective steam generator secondary side strategy:

- **Assessment:** In order to develop an appropriate maintenance strategy, actions must be taken to obtain an accurate picture of the SG secondary side condition.
- **Forecasting:** Using available data predictions are developed for future steam generator conditions and required maintenance actions.
- **Action:** Cost effective engineering and maintenance actions must be completed at the appropriate time as designated by the plan.
- **Evaluation of Results:** Following execution of maintenance tactics, it is necessary to revise strategy and develop technology enhancements as appropriate.

1. STEAM GENERATOR SECONDARY SIDE ASSESSMENT

Many diagnostic tools are now available for SG secondary side assessment. Assessment of conditions of the secondary side is typically focused in three areas: (1) total overall deposit loading, (2) top of tubesheet (TTS) conditions, and (3) tube support plate conditions.

1.1 Total Overall Secondary Side Deposit Loading Assessment

Overall deposit inventory calculation per mass balance is typically the primary method for assessment and forecast of the SG secondary side deposit loading condition. Cycle deposit inventory is a critical data point for engineers to forecast outage maintenance techniques.

Required information for calculating mass per cycle deposit loading transport include: (1) feed water iron concentration (daily or average), (2) feed water flow rates, (3) cycle length (days), and (4) power levels corresponding to date. To represent the mass quantity of deposit inventory the resulting mass is converted to magnetite (Fe_3O_4). [4]

Another tool for estimating overall SG secondary side deposit loading is scale profiling. Scale Profiling utilizes low frequency eddy current data (bobbin data) collected during a typical inspection. This data provides comprehensive 3D view of the distribution and location of secondary side deposits within the steam generator as shown in Figure 1. The deposit or scale loading within SG can be estimated with this technology. This data provides visual representation of the areas of heaviest deposits and maintenance activities can be forecasted to a pinpointed target location. [5]

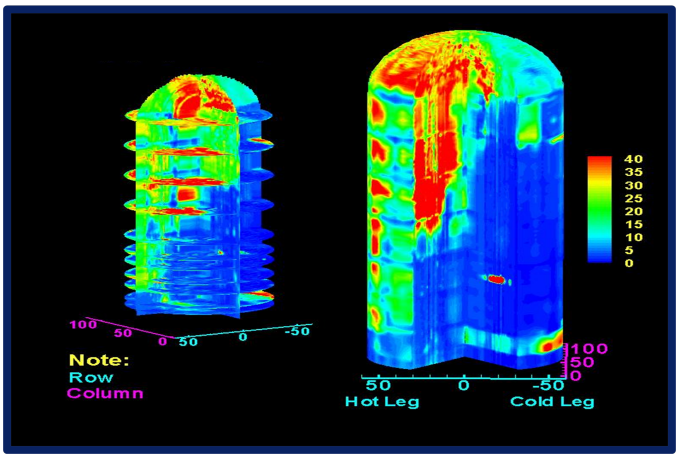

Figure 1: Example Scale Profiling Images

1.2 Top of Tubesheet Conditions Assessment

TTS conditions are typically assessed by visual inspection. Visual inspections are critical to ensure removal or dispositioning of foreign objects within the steam generator. When foreign objects remain in the SG at the TTS it creates an increased risk of potential tube wear as shown in Figure 2.

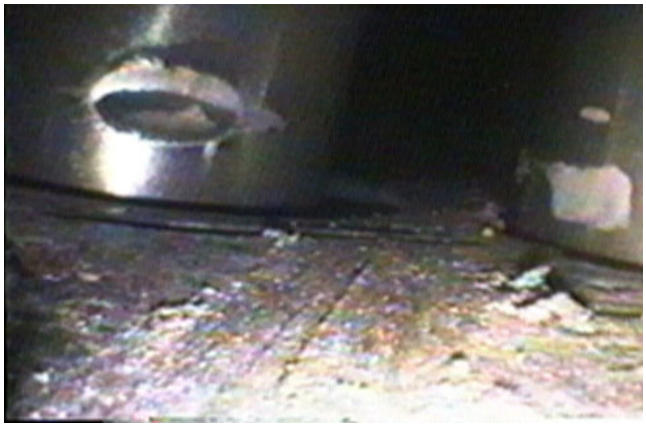

Figure 2: Industry Example of Tube Wear due to Foreign Object

Additionally, TTS visual inspections provide monitoring of TTS deposit growth. Sequential outage monitoring of areas with hard collars and bridging can be performed with visual inspection as depicted in Figure 3. Moreover, visual inspection images can provide deposit morphology clues and confirm areas of focus for cleaning [4].

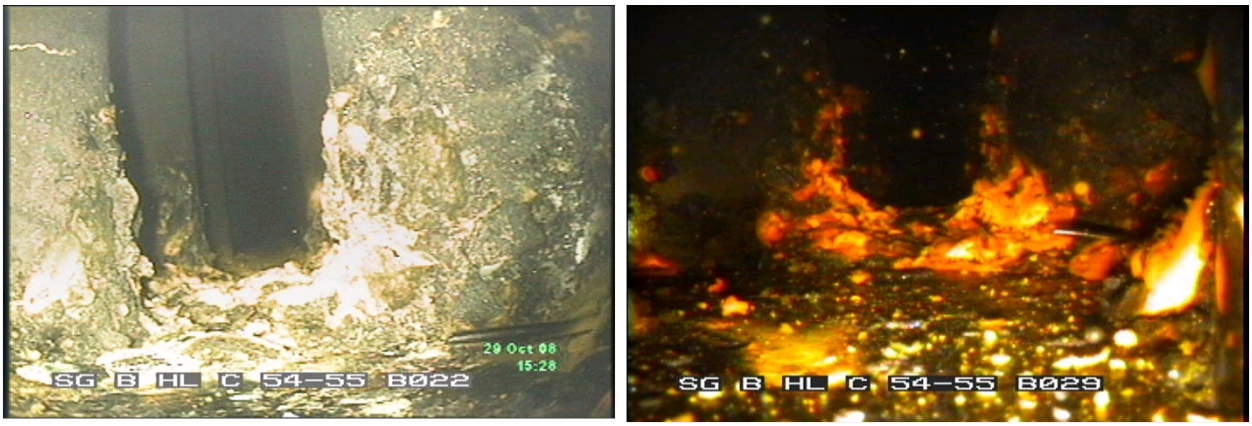

Figure 3: Example TTS Deposit Growth Monitoring

In addition to visual inspections of the TTS, sludge height mapping using eddy current data can be performed to provide another insight to the SG TTS conditions. Collection and analysis of this data over multiple outages can provide insights into sludge lancing effectiveness, deposit growth over time, and areas of focus for in-bundle visual inspections. An example sludge height map using eddy current is shown in Figure 4.

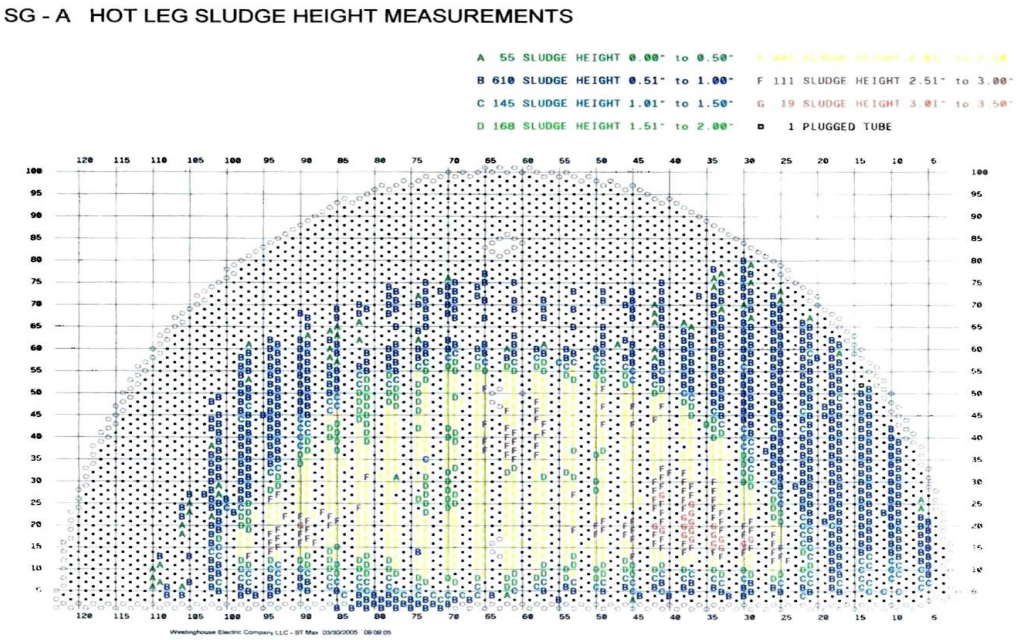

Figure 4: Sludge Height Mapping

1.3 Tube Support Plate Conditions Assessment

Visual inspections are also used to assess TSP conditions and blockage. Visual inspections can be used to monitor support plate structural integrity, TSP blockage, sludge accumulation, and tube fouling. Gathering and assessing upper bundle data is critical to planning secondary side maintenance activities that target upper bundle cleaning. Example TSP visual inspections are shown in Figure 5 and Figure 6.

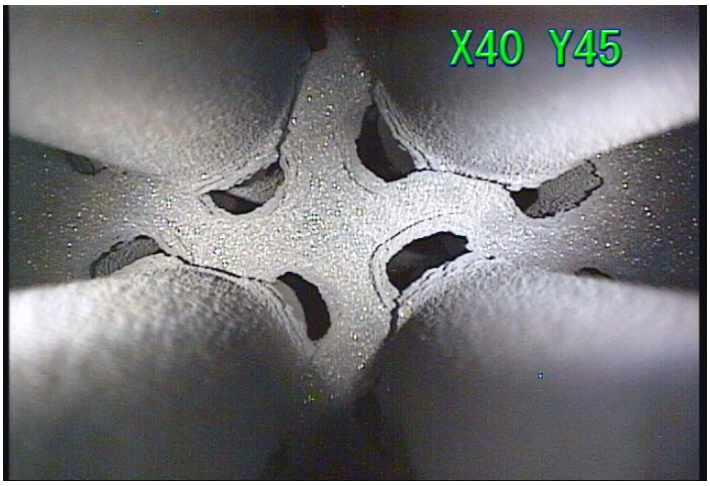

Figure 5: Example Quatrefoil Design TSP Visual Inspection

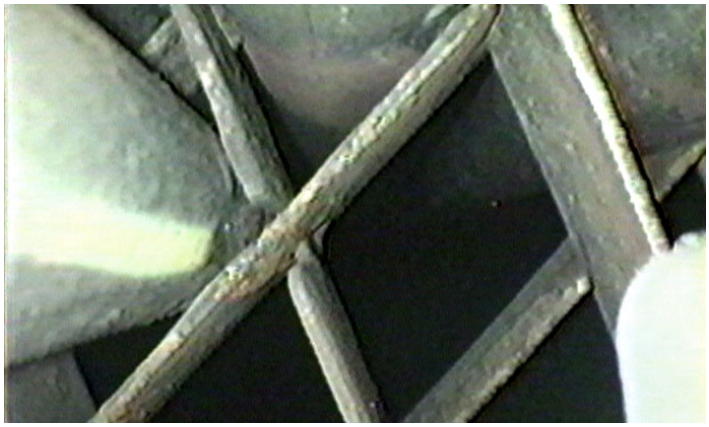

Figure 6: Example Eggcrate Design TSP Visual Inspection

In addition to visual inspections, assessment of wide range water level can provide an indication of TSP blockage for quatrefoil and trefoil style support plate designs. Plant wide range water level is the most reliable method for TSP blockage assessment. Without change in indicated wide range level, no conclusion regarding impact on TSP blockage of quatrefoil and trefoil designs can be made. Observed TSP blockage (assessed through detailed visual inspection) has been correlated to changes in wide range level on a plant-specific basis.

2. STEAM GENERATOR SECONDARY SIDE FORECASTING

Once SG assessment data is available, SG secondary side forecasting is completed. Predictions are developed for future steam generator conditions and required maintenance actions. The goal of steam generator services planning is preservation of the steam generator asset while maintaining optimum performance. SG secondary services planning must take into account all available data and all forces which affect service planning. Effective SG condition forecasting and planning is often accomplished through a joint Utility/Westinghouse Steam Generator Asset Management Team (SGAMT).

2.1 Steam Generator Asset Management Teams

The goal of any SGAMT is the development of a long term SG maintenance plan that is both cost effective and maximizes safe steam generator performance. Development of a SG maintenance plan is accomplished through efficient communication of industry lessons learned and operational experiences between all SGAMT members.

A joint Utility/Westinghouse SGAMT is developed as a technically focused team. All secondary maintenance planning decisions are driven by the data gathered during SG operation and outage services. The SGAMT consists of members with various engineering roles. Typically the following facets of engineering discipline are represented on the SGAMT.

- Steam Generator Integrity
- Secondary Side Chemistry
- Steam Generator Maintenance
- Field Service
- Visual Inspection
- Thermal & Hydraulic
- Regulatory & Licensing

A multifaceted SGAMT is critical when making SG secondary maintenance planning decisions. The risk of planning secondary services based on SG data from one perspective is avoided with this approach. Execution of joint Utility/Westinghouse SGAMT balances all elements of SG Secondary Side Maintenance Planning [1].

2.2 The Elements of Steam Generator Secondary Side Maintenance Planning

Three elements are associated with SG secondary long term maintenance planning; (1) the technical element, (2) the financial element and (3) the human element.

The technical element of SG secondary services planning takes into account the assessment of current SG conditions, the projection for future SG conditions, and the potential long term service scenarios. All technical assessments are dependent on the quantity and quality of the data available to make predictions.

The financial element of SG secondary services planning takes into account long term service scenario cost evaluation assessments. The lowest cost service scenarios are typically identified

and their implementation is compared to a risk assessment. The selection of desired strategic scenario based on technical and financial inputs is ultimately influenced by the human element.

The human element factors can supersede both technical and financial element planning. The human element considers that strategic planning models cannot be relied on implicitly. This element can be satisfied though the multifaceted SGAMT discussed in Section 1.1.

The human element takes into account non-financial and non-technical considerations. The SG secondary maintenance plan versus other plant needs is also evaluated. Since individual SG secondary side services are not typically "urgent", consequences of postponing SG secondary services on SG fitness must be acknowledged and addressed. This assessment of all factors which weigh into SG secondary services long term maintenance planning can only fully be accomplished through the application of human element filters. The human element in SG secondary services planning can result in different choices for similar inputs at different utilities.

Long term optimization of SG performance can only be achieved through SG condition assessment, forecasting and the development/routine review of strategic maintenance plans. [3]

3. STEAM GENERATOR SECONDARY SIDE ACTION

Through assessment and forecasting, the appropriate actions for optimum SG secondary side management can be determined and executed. The goal is to be both cost effective and optimize steam generator performance with maintenance actions. Secondary side maintenance recommendations from the SGAMT should be implemented to ensure these goals are met. Actions for SG secondary side maintenance are typically performed in three service areas (1) visual inspection and retrieval services, (2) mechanical cleaning services, and (3) chemical cleaning services.

3.1 Visual Inspection and Retrieval Services

As discussed in sections 1.2 and 1.3, visual inspection data is critical to SG secondary side condition assessment and monitoring. Visual inspection and retrieval services focus on the TTS, upper bundle, steam drum, and specialty areas. The main purpose of these services is to:

- Perform component cleanliness inspection
- Locate and document anomalous conditions
- Locate foreign objects
- Remove foreign objects as directed by customer

SG secondary side visual inspection technology has greatly evolved since its inception. Example visual inspections performed with current technology are shown in Figure 7 and Figure 8.

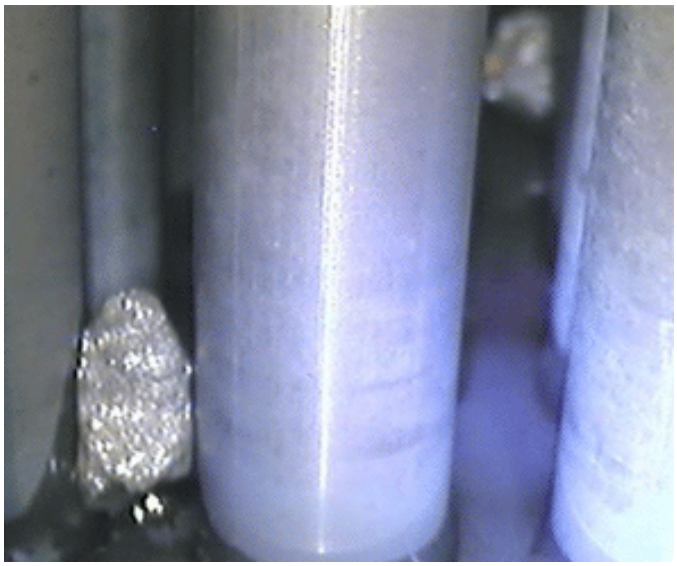

Figure 7: Foreign Objects Seen In-bundle from the Annulus Region

Figure 8: In-bundle View of a Foreign Object

Actions should be taken to perform SG secondary side visual inspections every steam generator outage if possible to optimize SG assessment and available data for SGAMT conditions and action forecasting. Visual inspection areas and the extent of each inspection are recommended through SGAMT forecasting and planning.

3.2 Mechanical Cleaning Services

Mechanical cleaning services are typically the main element of SG secondary maintenance actions. TTS mechanical cleaning is typically performed with sludge lancing (water lancing) services. Sludge lancing services are critical to maintain TTS health and avoid tube degradation. As shown in Figure 3, if loose sludge is not removed from the SG it will consolidate and

contribute to collar growth. Westinghouse has developed custom sludge lance tooling for multiple SG designs and conditions. An example of Westinghouse custom designed sludge lance tooling is shown in Figure 9. The tooling shown is capable of performing lancing in SG rows and is inserted in inspection port openings. It was custom designed to introduce a crisscross pattern when lancing, eliminating shadow zone sludge. Regular sludge lancing is a key component to maintaining SG secondary health and application frequency should be assessed as part of SG assessment and forecasting by a SGAMT.

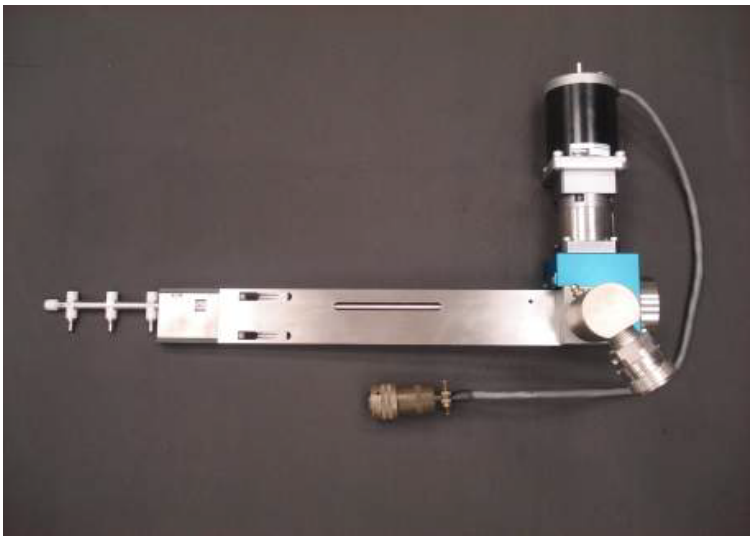

Figure 9: Example Westinghouse Custom SG Sludge Lancing Tool Design

In addition to sludge lancing, Ultrasonic Energy Cleaning (UEC) technology is another option for TTS mechanical cleaning services. This technology uses high frequency sound waves inside the secondary side of recirculating SGs to break up hard sludge deposits on the top of the tubesheet. This technology is typically used in combination with Advanced Scale Conditioning Agent (ASCA) technology discussed in section 3.3. A UEC transducer assembly which is inserted into the SG secondary side is shown in Figure 10.

Figure 10: UEC Transducer Assembly

3.3 Chemical Cleaning Services

SG secondary side chemical cleaning services have traditionally been regarded as a restorative treatment for SGs experiencing active degradation or heavy deposit loading. However, with the development of a mild chemical cleaning maintenance alternative, this service can now be incorporated into multiple outages over SG life. As a result of this technology development, chemical cleaning services are now grouped into "hard" or full-scale chemical cleaning services and "soft" or low-concentration chemical cleaning services. For hard chemical services, Westinghouse uses the EPRI/SGOG chemical cleaning process. For soft chemical cleaning services, a utility-specific, customized ASCA process is used.

The EPRI/SGOG chemical cleaning process removes large amounts of deposits from the SG often returning the SGs to a "like-new" condition. Application of this process helps extend SG operation, helps prevent plant capacity loss, and helps prevent costly SG replacement. However, the EPRI/SGOG hard chemical cleaning process requires a large equipment setup, impacts the outage schedule, and is high cost.

ASCAs are dilute cleaning solutions which promote the dissolution of a portion of the overall secondary side deposit inventory along with entrained mineral species from the deposit matrix. The ASCA process was developed to provide customers with a chemical cleaning option while avoiding the potential drawback of a traditional hard chemical cleaning campaign. ASCA technology has continually grown in popularity since its development as a result of the many process benefits while maintaining minimal outage impacts. Utilities have applied ASCAs for a variety of reasons including:

- Partial removal of secondary side deposit inventory
- Improvement in sludge removal quantity over traditional mechanical cleaning processes
- Reduction of tube support plate (TSP) blockage
- Improvement in steam generator thermal performance
- Partial dissolution and softening of consolidated top of tubesheet (TTS) collars

Whereas hard chemical cleaning is applied typically one to two times over SG life, ASCAs can be applied multiple times due to the minimal corrosion experienced during the process, low cost, minimal equipment, and minimal outage impact.

4. STEAM GENERATOR SECONDARY SIDE EVALUATION OF RESULTS

The key to a long-term, proactive SG secondary side management is not only the assessment of SG conditions; but also the evaluation of the results achieved by maintenance actions. Although standard secondary services such as visual inspections and sludge lancing are important to SG secondary side health, it is import to assess the result of these actions on a regular basis and determine if and when larger scale maintenance is required.

Optimization of SG secondary side performance requires a holistic approach to ensure all data is properly evaluated and action plans are not considered as "standard." Data from both condition evaluations and maintenance results should be used to plan and optimize future SG secondary maintenance actions.

5. CONCLUSION

Westinghouse has developed a proactive approach to SG secondary side maintenance through cooperation with our customers. This approach has led to utility individualized SG secondary side maintenance plans for long term SG viability. By working though the proactive SG secondary maintenance planning steps of assessment, forecasting, action and evaluation of results, utilities should recognize optimum SG performance.

Westinghouse has developed products and services to meet all four areas of SG secondary side maintenance planning. Westinghouse proactively works with customers to provide a well developed SG secondary side maintenance program. Implementation of this SG secondary maintenance model should ensure long term full power operation at optimum SG thermal efficiency, and leveling of outage expenditures over a period of time.

6. REFERENCES

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