STEAM GENERATOR DEPOSIT MAPPING

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Abstract

Quantifying the deposit loading on the outside diameter of Steam Generator tubing provides valuable input to a long-term asset management model of the Secondary Plant. AREVA's Steam Generator Deposit Mapping uses data from the Eddy Current Testing (ECT) method to quantify this deposit loading. Analysis of the raw data enables construction of 3-dimensional and/or time-varying models that help estimate heat transfer loss and project future deposit loading. This paper presents one approach to a systematic program of Deposit Mapping using plant-specific reference standards and 3-dimensional modeling software to assess and project the deposit loading condition of steam generators.

1. Introduction

Steam Generator Secondary Side Deposit Mapping is a powerful tool for Steam Generator Asset Management. Deposit Mapping provides input into the analysis of deposit distribution, magnitude, and trending. The effective use of this knowledge of deposit conditions leads to improved operational efficiency, and reduced costs.

Deposit Mapping is particularly valuable for replacement Steam Generators in planning long-term Operation and Maintenance (O&M) expenditures for actions such as chemical cleaning and upper bundle flush, and evaluating the efficacy of the same, as well as helping diagnose thermal-hydraulic conditions such as fouling and pressure drop. The results may further be applied to predictive modeling techniques to project long-term steam generator performance and to optimize a deposit management plan for achieving plant objectives.

2. Reasons for performing Deposit Mapping

Deposits on the tube Outside Diameter (OD) of Pressurized Water Reactor (PWR) Steam Generators have been problematic to efficient operation. The ability to adequately assess the extent and location of deposits on the OD of the Steam Generator tubing is an essential tool for a long-term Steam Generator management program.

Tube OD deposits are known to cause:

- Degraded heat transfer and thermal-hydraulic performance
- Accelerated tube corrosion
- Degraded ECT examination performance

While Secondary Side visual examination and chemistry (corrosion product) transport monitoring provide valuable information, their extent and level of diagnostic detail are limited. Further, Secondary Side Inspection (SSI) requires internal access to the secondary side of the Steam Generators, which entails expenditure of dose and resources, as well as the potential for scheduling and plant configuration conflicts during an outage. The ability to characterize OD Steam Generator tube deposits through Eddy Current Testing (ECT) methods provides a unique insight into the deposit condition of the Steam Generator with little expenditure of effort during the outage, and not requiring special plant configurations (e.g. draining and opening the secondary side of the steam generators).

By using Deposit Mapping to locate and quantify the deposits, effective compensatory measures may be planned, implemented, and judged for effectiveness.

3. Deposit Mapping Data Acquisition

The Deposit Mapping data acquisition process was designed, from the outset, to make use of bobbin coil ECT data acquired in the normal course of the inspection process, and to require as little additional effort by ECT data acquisition personnel as possible. Review of existing ECT data and lab testing showed that the low frequencies (20-40 KHz) typically acquired in US plants for support structure locating are well-suited for measuring the amount of oxides on the tube OD.

While analysis of the raw ECT data alone can produce a qualitative estimate of the amount of oxide on the tube OD, the use of plant-specific reference standards greatly improves the accuracy of the measurements. In a manner very similar to using a calibration standard for the ASME bobbin coil examination, one or more Deposit Mapping reference standards are produced for each unit to be analysed.

The reference standard is comprised of tubing similar in size and composition to that in the Steam Generators of interest. The tubing is coated at specific locations with stepwise-varying thicknesses of a lab-synthesized compound similar in makeup to the deposits found in the Steam Generators. Whenever data are available, the chemical composition of the actual in situ scale found on the OD of the tubes is used as the guide for the makeup of the lab-synthesized compound. Lacking that information, a general sludge analysis is used. The thickness of the individual deposit locations on the reference standards bound the range of deposit thicknesses that are expected to be found in the plant. Further, the deposit standard design may provide locations that extend up to thicknesses expected to bound expected deposition in the future, thus making the standards fully useable for multiple operational cycles.

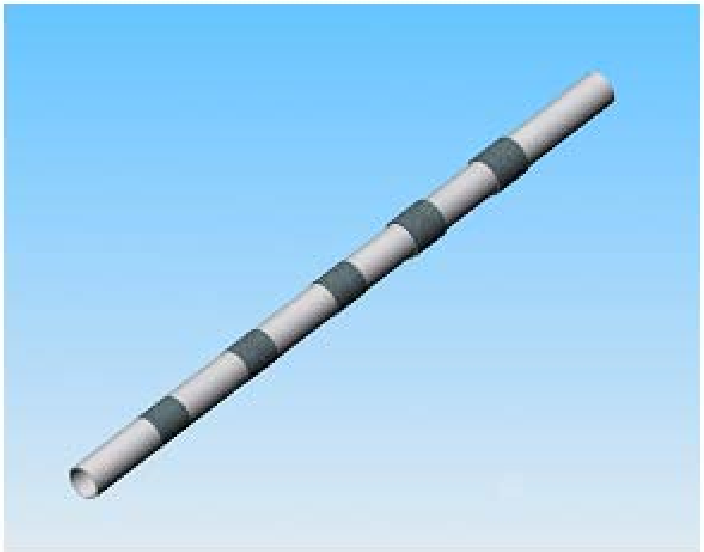

Figure 1. A 3-dimensional model of a typical Deposit Mapping reference standard

Once standards are fabricated for a plant, the actual thickness of all deposit locations is measured to 0.001 in. (0.025mm). A "baseline" ECT examination is then performed on the standard using the same frequencies and setups planned for the upcoming inspection at that plant. Combining the known thickness values with the analysis of the raw data enables the lead analyst to develop a calibration curve and benchmark the system accuracy. The analysis system can repeatably demonstrate a measurement resolution of 0.0005 in. (0.0125 mm) Standards are uniquely serialized, individually baselined, and as-built drawings are created and retained in the records system.

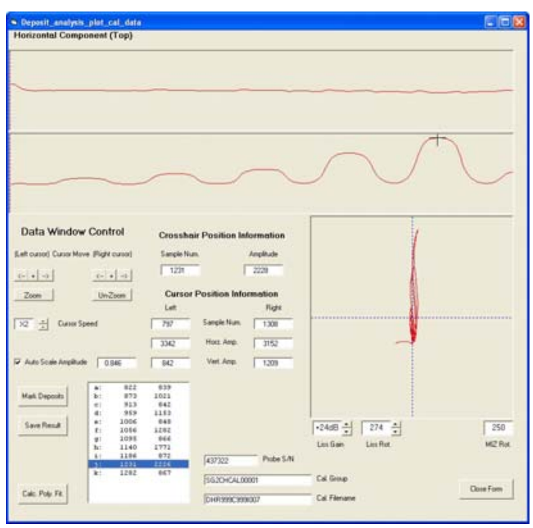

Figure 2: Data analysis of "baseline" data of a Deposit Mapping reference standard, showing the signal response of the individual deposits on the reference

When the bobbin coil examination is performed in the Steam Generators, the Deposit Mapping standards are placed in-line with the other standards. Data are acquired on the standards each time data are acquired on the ASME standards. By collecting data from the Deposit Mapping standards in the field, any system or setup variations are implicit in the data collected on the standard. Thus the signals collected in the field may be accurately corrected to the baseline signals.

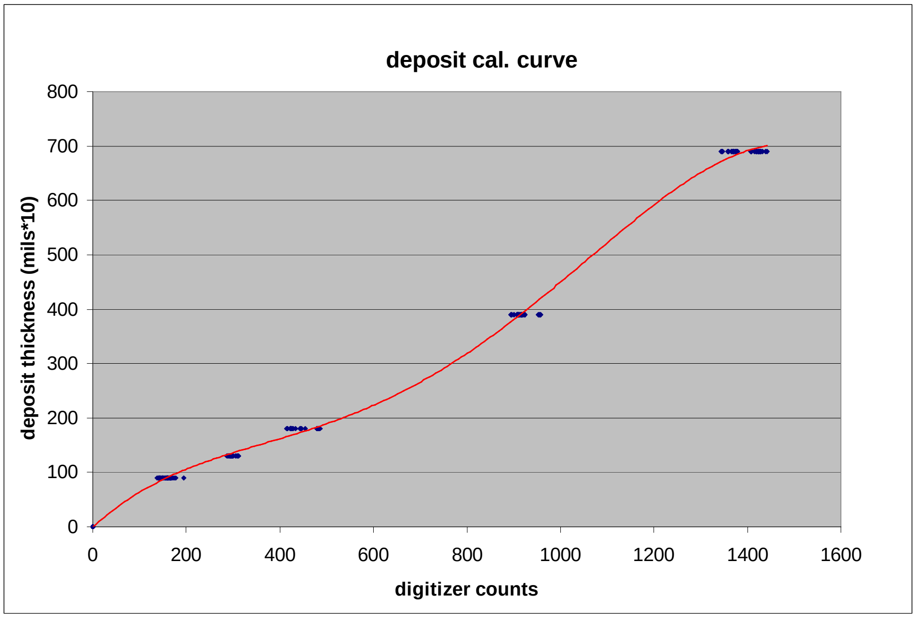

Figure 3: A typical Deposit Mapping calibration curve of deposit thickness versus digitizer counts for multiple probes and standards

4. Deposit Mapping raw data analysis and data reduction

The Deposit Mapping data analysis is typically performed at the home office, after an outage. The automated analysis routine is written in Visual Basic code and outputs individual tube results to a text file. The analysis algorithm determines the baseline for each tube, measures the deposit response, averages the measurements within a selected sample window, converts the measurements to a thickness value based on the reference standard, then creates the text file containing all thickness information for each tube. Owing mainly to the circumferentially-integrating nature of the bobbin coil, the measured deposit value is more accurately representative of the amount of deposit on the tube rather than a local thickness at any given point.

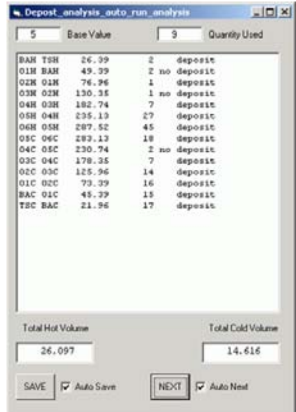

Figure 4: An auto-analysis status window

Once all raw data analysis is complete, the text files are imported into a Microsoft Access ™ database. One database is created per Steam Generator. Access is used to convert thickness measurements to a "mass per linear distance" value for each measurement window, then to sum those values over the length of the tubing to produce a total deposit loading in pounds (or kilograms) of oxide compound.

Further, Access is used to output the analysis data into a format that may be used in 3-dimensional modeling programs. In this case, CFD-VIEW™ is used to display the deposit loading data in graphic representations that are easily interpreted. Display formats include iso-surface regions of deposits at selected thicknesses, point-by-point representation of deposit thickness, and change in deposit thickness over time, among others.

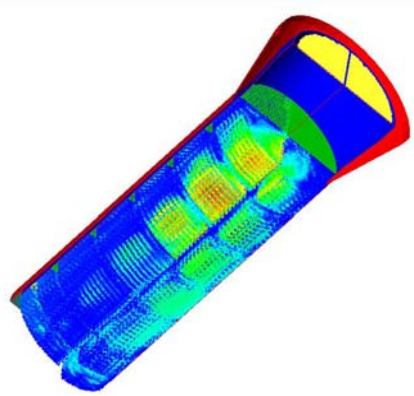

Figure 5. A CFD-VIEW[tm] rendering of individual point data for an entire Steam Generator. Blue represents minimal or no loading; cyan, yellow and red represent increasing loading.

Deposit Mapping analysis can also be performed on pre-existing data. Although the pre-existing data were not acquired with a Deposit Mapping reference standard, normalization may be performed across known structures in the Steam Generator, to greatly improve the accuracy of measurements taken from old data. This allows deposit accumulation trends to be established even when only one outage of data were collected using a reference standard.

5. Data interpretation

There is effectively no limit on the number of ways the data may be visualized in a 3-D modeling program. One of the most useful formats displays all regions where the measured deposit thickness is at least some selected value (iso-surface constant thickness). This enables Steam Generator Asset Managers to study the locations of the heaviest deposit locations, and subsequently make an effective choice of remedial treatment (e.g. upper bundle flush vs. chemical cleaning). A particularly interesting visualization can be performed by creating an animated sequence of differing values of iso-surfaces, while the wire-frame model of the Steam Generator is rotated.

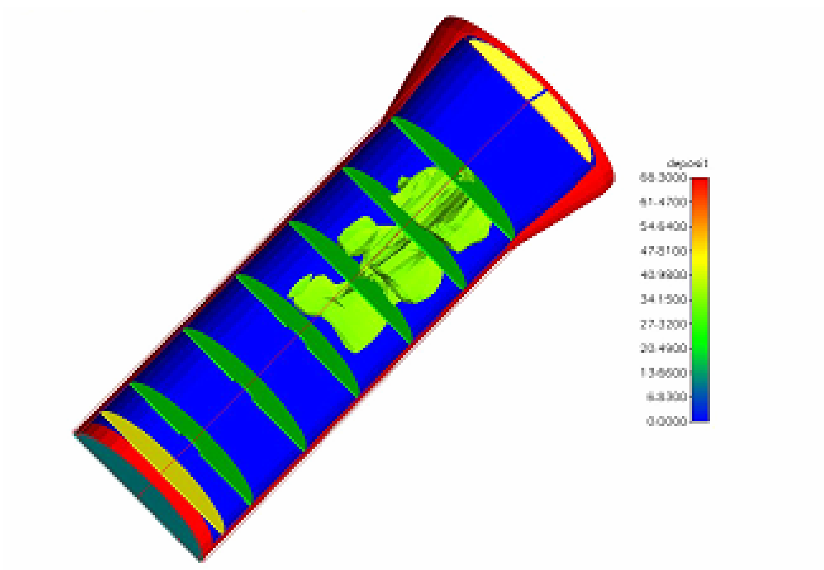

Figure 6. An iso-surface/constant thickness view of deposits in a Steam Generator.

Figure 7: A profile of deposits on one tube prior to chemical cleaning

Figure 8. Profile of deposits on the same tube following chemical cleaning

6. Application of method and knowledge

As a Steam Generator Asset Manager, Deposit Mapping contributes answers to several common questions:

- Where is the deposit accumulating?
- How will it impact operation?
- If SSI is to be performed, where should it look to survey deposits?
- What is best technique for deposit removal?
- How effective was the cleaning action?
- What actions have caused a shift in deposit distribution?

Deposit Mapping has been used at several plants to aid in the disposition of all these issues.

AREVA's Deposit Mapping process has been in field use for approximately three years. In that time, additional uses have been continuously discovered. Analysis techniques are being developed to quantify deposit loading in Tube Support Plate (TSP) openings. When the analysis was applied to real plant data, and the TSP data were subsequently visualised in CFD-VEW^{tm}, evidence of flow patterns and deposit distribution on the TSPs was readily evident (figure 9).

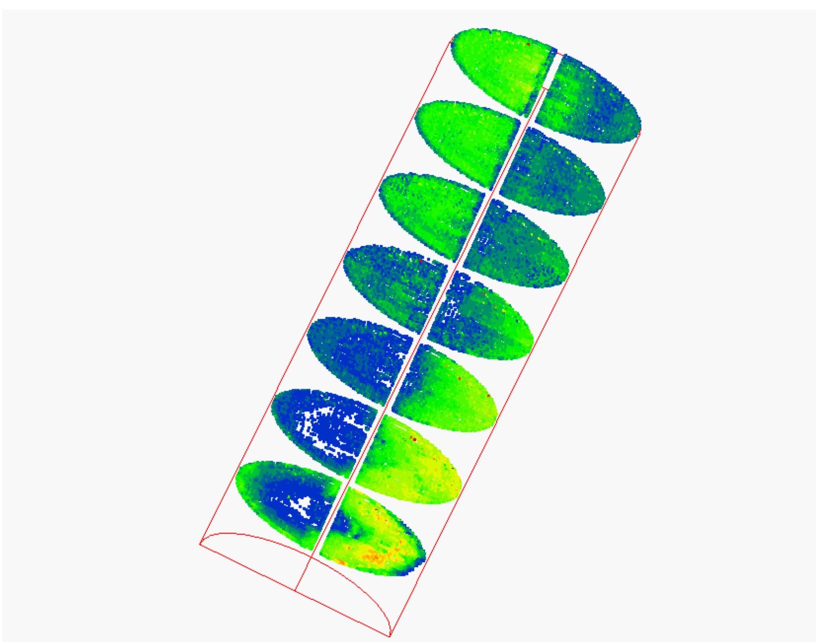

Figure 9. Tube support plate deposit loading, showing patterns of deposits

In a fashion not unlike the development of the X-ray and Magnetic Resonance Imaging (MRI) in medicine, Deposit Mapping is a new diagnostic method. Before the existence of these new techniques, diagnostics were performed by other methods that provided less information. Newer methods facilitate the sharpening of treatment protocols. With better imaging of the deposit distributions, new conclusions may be drawn regarding the flow conditions inside the Steam Generator, and how this effects the operation of the unit.

7. Conclusion

Deposit Mapping is a powerful tool for Steam Generator asset management. Deposit Mapping provides additional insight into deposit loading locations, severity, and trending. The additional knowledge of deposit status can lead to reduced cost, greater efficiency, and extended component lifespan. Deposit Mapping is especially valuable for use with replacement Steam Generators experiencing thermal-hydraulic issues such as fouling or pressure drop by defining areas to focus inspections, and for planning long-term O&M expenditures for measures such as chemical cleaning and upper bundle flush. New uses for the information derived from Deposit Mapping are being discovered on a continuous basis.