NRC / SGMP Steam Generator Task Force Meeting

August 21, 2018

Agenda

9:00 am ***Introductions & Opening Remarks (NRC and Industry)***

SGMP Steam Generator Task Force Update (Industry)

- Lessons Learned from In-Plane Fluid Elastic Instability Testing
- EPRI's Qualification Process for Automated Analysis Systems
- Welded Plug Qualification Issue Resolution
- Steam Generator Tube Plugs (Alloys and Designs in Service)
- Summary of Recently Issued SGMP Technical Reports
- Status of Industry Guidelines
- Interim Guidance
- NEI 03-08 Deviations
- Recent Operating Experience

10:35 NRC items of discussion

10:45 Public comments/questions

Lessons Learned from In Plane Fluid Elastic Instability Testing

Helen Cothron, EPRI

Two-Phase Freon Tests Completed

- In-plane fluid elastic instability was successfully achieved in a U-tube bundle with flat-bar supports in single-phase flows and over a wide range of two-phase flows with various void fractions
  - A significant achievement reached by few other experimenters
  - Most researchers have used straight-tube bundles
- Other researchers presented their test results at recent conferences

Computer Validation Data

- The test data results are well suited for computer model testing and validation
- Detailed vibration and tube-to-support interaction data recorded
- Void measurements accurately characterize two-phase flow
- Canadian Nuclear Laboratories model predicted test results well

Important Lessons Learned

- To prevent in-plane fluid elastic instability tube supports:
  - Prevent motion or
  - Provide sufficient friction damping to avoid instability

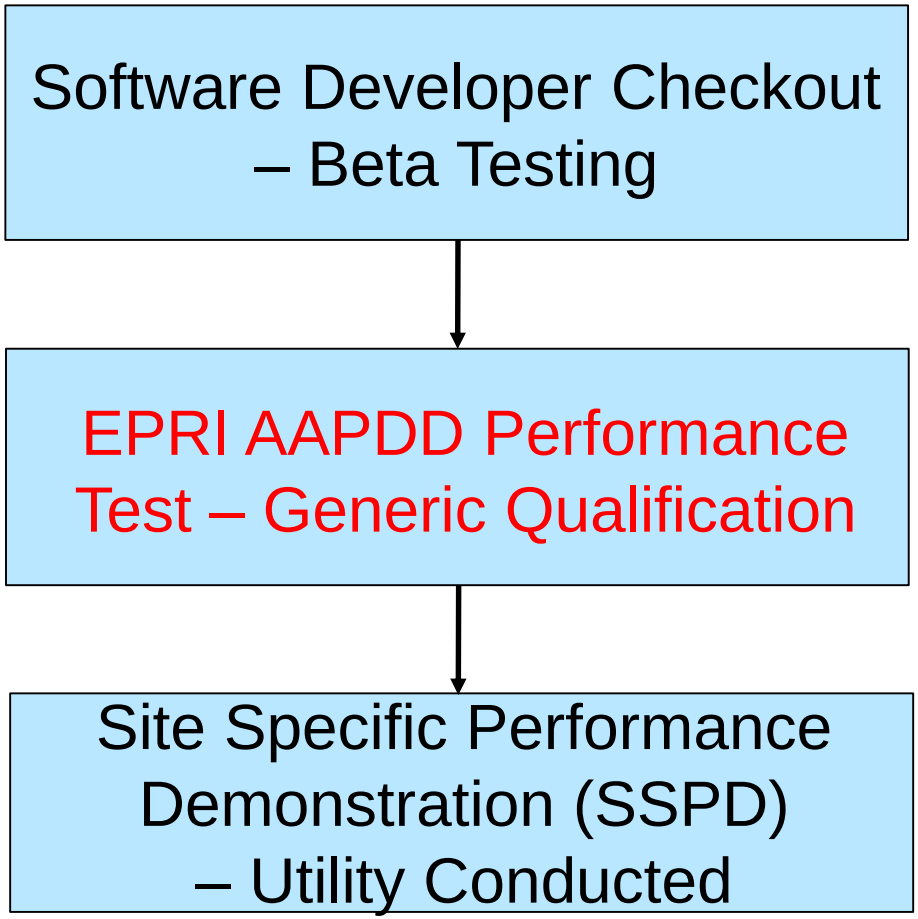
Next Steps

- Draft report will be provided to SGMP by end of August
- SGMP will continue to work with the expert panel
- Presentation of test results in 2018
  - Possible presentation to the ASME Task Group at the next Code Week (Atlanta - November 11-16)
- Maintain contact with special interest group from ASME Pressure Vessel and Piping Conference

EPRI's Qualification Process for SG Automated Eddy Current Data Analysis Systems

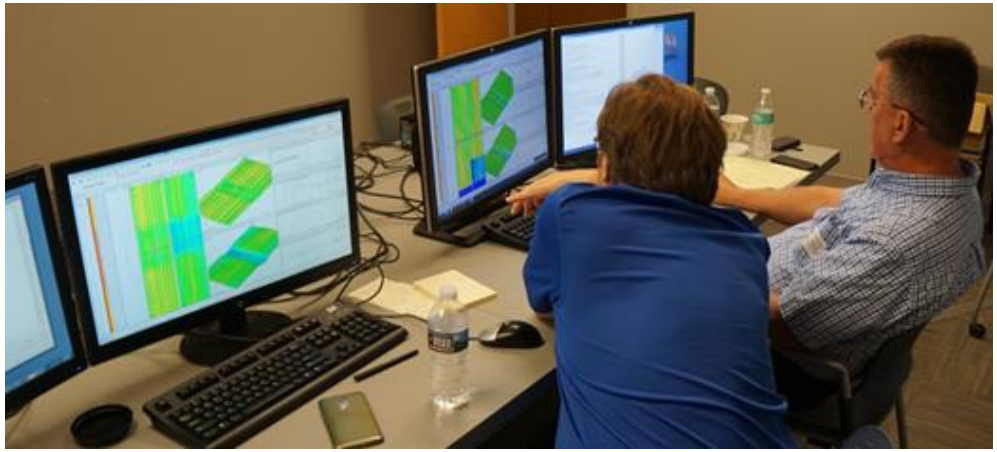
Jim Benson, EPRI

Typical Qualification Sequence for SG Automated Eddy Current Data Analysis Systems



Generic Qualification for SG Automated Eddy Current Data Analysis Systems

- EPRI has developed a generic qualification for automated eddy current data analysis systems
  - Includes the analysis of bobbin coil probe, rotating probe, and array probe eddy current data for reporting of degradation in steam generator tubing.
- EPRI Steam Generator Examination Guidelines include a requirement to qualify automated data analysis systems through performance demonstration to determine initial generic performance capability.



EPRI SG Examination Guideline Requirements for Generic Auto Data Analysis System Qualification

- The EPRI Steam Generator Examination Guidelines, Revision 8 (3002007572) identifies requirements for qualification of automated data analysis systems.
- *Generic qualification of the automated data analysis process, including the system variables, shall be demonstrated on the EPRI AAPDD … prior to field deployment.*
- *This initial qualification will validate detection and sizing/characterization algorithms for each damage mechanism found in Table G-1.*
- *Changes to generically qualified algorithms (not adjustable attributes) or the inclusion of new algorithms that replace previously qualified detection algorithm(s) shall require requalification of the automated data analysis software on the AAPDD*

Automated Analysis Performance Demonstration Database (AAPDD)

- The AAPDD is a database of eddy current data assembled by EPRI
  - Includes both field and lab acquired data
- Interpretation of the signals in the AAPDD are based on expert opinion
  - A peer review team of Qualified Data Analysts (QDAs) must agree on the interpretation of the AAPDD ECT signals that are to be used for determining system performance
- The performance of automated data analysis systems is based on how well the auto system results match the expert opinion (i.e. “eddy current truth”) results.

Automated Analysis Performance Demonstration Using AAPDD

- Grading categories for flaw detection are identified based on degradation type and location (for example, axial outside diameter stress corrosion cracking at tube support structures).
- Flaw orientation (i.e., axial or circumferential) is assigned to cracking degradation detected by rotating probes and array probes.
- Flaw sizing categories are assigned to wear and thinning detected by bobbin coil probes.
- Data are designated for use in AAPDD Training and/or Testing data sets.

Data Currently Available for AAPDD Performance Testing

- 30 Plant Sites
- 20 Steam Generator Models
- Bobbin Probe Data
  - ~ 3000 Flaws
  - ~ 3100 NDD Tubes
- Rotating Probe Data
  - ~ 1800 Flaws
  - ~ 1300 NDD Tubes
- Array Probe Data
  - ~ 2600 Flaws
  - ~ 1300 NDD Tubes

Auto Analysis System Qualification Process – EPRI Responsibilities

- Assembly of eddy current data
- Determination of expert opinion data analysis results, including conduct of peer reviews.
- Selection of AAPDD training data sets.
- Assembly and distribution of AAPDD training material
- Selection of AAPDD test data sets.
- Assembly and distribution of calibration standard data files from each calibration group to be included on the AAPDD test.
- Administration and grading of AAPDD qualification test.
- Providing the “Testing Organization” (i.e., software developer and/or NDE vendor) with AAPDD qualification test results.
- Maintaining all automatic data analysis system test results and software parameter settings.

Auto Analysis System Qualification Process – Testing Organization Responsibilities

- Contacting EPRI when ready to begin the AAPDD qualification process.
- Requesting EPRI to provide AAPDD training material
- Preparation of automatic data analysis software for taking the AAPDD qualification test.
- Contacting EPRI to set up an AAPDD qualification test date.
- Contacting EPRI to request calibration standard data files for AAPDD test data, if testing organization plans to perform calibration set-ups prior to traveling to the test location.

Auto Analysis System Qualification Process – Testing Organization Responsibilities (Con't)

- Travel to the EPRI NDE Center with a complete automated data analysis system, including hardware and software that is ready to take the AAPDD qualification test.
- Establishing calibration set-ups, as required.
- Performing AAPDD qualification test.
- Providing EPRI with the following items, upon completion of the AAPDD qualification test:
  - Unedited automatic data analysis results
  - Documentation of all software parameter settings (e.g., sorts) for each plant data set or SG type included on the AAPDD qualification test.
  - Documentation of the specific software and version used for the AAPDD qualification test
- Providing authorized organizations (i.e., utilities) with AAPDD qualification test results and data analysis parameters

Recommended Sample Size for Auto Analysis Performance Demonstration

- It is recommended that minimum numbers of flawed and unflawed grading units be used to meet the POD and statistical confidence level (CL) of Exam Guidelines Appendix G.
- It is recommended that the number of unflawed grading units selected for the practical examination be equal to at least twice the number of flawed grading units

AAPDD Performance Test – Flaw Detection and Sizing

- Minimum **Flaw Detection** Test Sample Size for Each Damage Mechanism Category: 11 flaw grading units (FGUs)
  - 11 FGUs ≥40%TW
- Minimum **Flaw Detection & Sizing** Test Sample Size for Each Damage Mechanism Category: 16 flaw grading units (FGUs)
  - 11 FGUs ≥40%TW
  - 5 FGUs <40%TW
- Flaw Detection Passing Criteria:
  - POD ≥80% at 90%CL for flaws ≥40%TW
  - % Detected ≥80% for flaws <40%TW

AAPDD Performance Test – Flaw Sizing and Orientation

Flaw Sizing

- The auto data analysis system is considered qualified for flaw sizing, on a category-by-category basis, if the following requirement is met:
  - An RMSE of ≤10% is demonstrated.

Flaw Orientation

- The auto data analysis system is considered qualified for determining orientation, on a category-by-category basis, if the following requirement is met:
  - At least 80% of the flaws included in the orientation grading are correctly reported.

Overcalls

- Results of the AAPDD test include a calculation of the average number of reported overcalls per tube
- Individual utilities may take the number of AAPDD overcalls into account when determining if an automated data analysis system is acceptable for use at a specific plant.

AAPDD Re-Tests

- If any degradation/location category fails to meet the “detection” acceptance criteria, a re-test would include all degradation/location categories that are affected by modifications to the detection algorithms.
- The re-test shall include an appropriate number of NDD tube segments to determine the overcall rate
- Previous grades for each “degradation/location” category are be provided to the Testing Organization prior to taking the re-test.

Requirements for AAPDD Performance Tests

- A passing grade must be achieved for all damage mechanisms in order to pass the AAPDD test for a specific probe type
- The software counts any reported flaw indication, that doesn't correspond to a “flaw grading unit”, as an overcall

Re-Test Requirements Following Failure of AAPDD Test

- Re-tests can be taken at any time
- Additional training material is provided to the testing organization, as appropriate
- A sample of missed flaws or overcalls may be reviewed with the testing organization, as appropriate

AAPDD Requalification Requirements

- Requalification of an auto data analysis system is required when:
  - A new damage mechanism is added to the AAPDD
  - A new probe design is added to the AAPDD
  - NDE vendor makes changes to the version of the auto analysis code which previously passed the AAPDD test
- Example of auto analysis software changes requiring requalification:
  - New algorithm logic that is different than those previously qualified
- Example of auto analysis software changes NOT requiring requalification:
  - Changes to user adjustable settings (e.g., threshold values)

Data Analysis Modes Tested by AAPDD

- For the AAPDD, only non-edited analysis test results are graded
- Single Pass Analysis - Multiple algorithm single integrated automated analysis process
  - AAPDD tests results can be provided for each auto analysis algorithm within a single integrated automated data analysis system.
    - In order to provide results for each algorithm, the auto systems must generate separate analysis results for each algorithm to be graded
  - Vendor provides EPRI with 1) software name, 2) version # and 3) algorithm designation for each auto data analysis algorithm that is graded.

Utility Review of AAPDD Test Results

- SGMP member utilities can request AAPDD test results directly from the organizations that participated in the performance demonstration
- Results of the AAPDD testing will provide utility engineers with automated data analysis system performance information on a variety of steam generator tube degradation mechanisms and locations.
- This information will assist SG program owners in selecting an automated data analysis system for use at their plants.

Welded Plug Qualification Issue Resolution

Lee Friant, Exelon

Framatome Welded Plug Qualification Issue

- Background
  - Contingency plans were being developed for a utility which included potential removal and replacement of Alloy 600 taper-welded plugs (manually installed)
  - While performing qualification for new plugs, it was discovered that the current analysis methodology that would be utilized to determine tubesheet bore dilations is more conservative and appropriate than the method previously used (c. 1996)
  - Dilation of the tubesheet hole (as a result of transients) impacts the fatigue life of the weld, originally defined as 40 years

Framatome Welded Plug Qualification Issue

- Re-analysis of previously installed taper-welded plugs performed with actual/projected heat up and cool down cycle counts shows an acceptable fatigue life up through the next few operating cycles
  - Requires entering the plugs in the fatigue monitoring program
  - Additional analysis to be performed to maximize life of the installed plugs remaining in the industry (2 units)
- Framatome has determined there is no Part 21 issue (no substantial safety hazard)

Investigation of Generic Implications

- Framatome provided a letter to SGMP summarizing the issue with some details for the other vendors to evaluate the generic implications
- SGMP forwarded the letter to BWXT Canada and Westinghouse
  - The only other suppliers of welded plugs for the US fleet
- SGMP received letters from BWXT Canada and Westinghouse confirming that the analyses for their welded plugs do not have the shortcomings of the previous Framatome analysis
  - Existing plug stress and fatigue analyses are conservative and the limits in the ASME Code continue to be met
- SGMP sent a letter to members forwarding these letters
- The issue is only applicable to two US units
  - Not considered a generic issue

International Operating Experience with Steam Generator Tube Plugs

Lee Friant, Exelon

Recent International Operating Experience

- OE No. 1
  - During 3rd 10-year outage, leakage was identified from a plug in the cold leg
    - Plug was made of Alloy 600
      - Initially reported as Alloy 690
    - All Alloy 600 plugs removed from the cold leg and replaced (hot leg plugs previously replaced)
    - Mechanism not reported
- OE No. 2
  - Discovery of cracking in a manual tubesheet welded plug which was installed inservice
    - I-82 weld and plug material
    - Leaking during service
    - Tubesheet overlay cracked
  - Mechanism not confirmed

Steam Generator Tube Plugs (Alloys and Designs in Service)

Lee Friant, Exelon

US Plug Alloys and Designs in Service

- Of the more than 8,000 tubes plugged in service and reported in the SGMP Degradation Database the vast majority are Alloy 690 mechanical plugs
  - Approximately 80 tubes have welded Alloy 600 plugs
    - 15 units
    - Majority shop-welded
  - Approximately 15 tubes have mechanical Alloy 600 plugs
    - Two units
    - All have mechanical Alloy 690 plug-in-a-plug
- Inspections
  - Visual prior to each eddy current inspection for signs of leakage
  - Visual and process validation during installation
- No recent operating experience in the US

Summary of Recently Issued SGMP Technical Reports

Helen Cothron, ERI

Steam Generator Flaw Handbook Calculator for Excel, v2.0 – 3002012947 – April 2018

- The Flaw Handbook Calculator software is an automated Microsoft Excel® spreadsheet which calculates steam generator tube structural limits using the Flaw Handbook degradation models and the Integrity Assessment Guidelines probabilistic methodology.
- This revision upgraded the software to be compatible with the latest Microsoft Excel Versions

Steam Generator Progress Report, Revision 19 – 3002013120 – July 2018

- Information on steam generator degradation experience is recognized as a valuable utility resource.
- Experiences at other plants provide utility personnel with an early warning of potential problems at their plants, allowing them to take appropriate actions to eliminate or minimize the impact of steam generator degradation mechanisms.
- This report can be used to analyze trends, such as degradation occurrence by tubing material or SG location and can be considered when performing a SG operational assessment.
- This report, along with the additional on-line reporting capabilities in the EPRI SG Degradation Database (SGDD), is expected to be a great asset to utilities to address the requirements of NEI 97-06 and NEI 03-08.

MULTEQ Equilibrium of an Electrolytic Solution with Vapor-Liquid Partitioning and Precipitation: The Database Version 9.0 – 3002013656 – August 2018

- MULTEQ database is used by plant personnel and researchers to predict chemistry parameters for both the primary and secondary side in PWRs (and BWRs)
- Version 9 of the MULTEQ database was released in August and represents additions or updates for many species (35) including:
  - LiOH, KOH, NaOH – Important species on Primary and Secondary Sides, especially to support KOH development
  - New Antimony entries – Some plants experiencing significant radio-antimony in primary systems and this will help understand deposition
  - Amine species (ETA) – Improved data sources for common secondary side pH control agent
  - Change to use of Standardized Species Names
- Many improvements and additions, but work on boric acid to be incorporated in next version
- Development of the MULTEQ database ongoing and will continue to incorporate the latest available information

Status of Industry Guidelines, Interim Guidance, NEI 03-08 Deviations

Helen Cothron, EPRI

SGMP Industry Document Status and Revision Schedule

Guideline Title	Current Rev #	Report #	Last Pub Date	Imple-mentation Date(s)	Interim Guidance	Review Date	Comment
SG Integrity Assessment Guidelines	4	3002007571	June 2016	8/31/17	None	2020	
EPRI SG In Situ Pressure Test Guidelines	5	3002007856	Nov 2016	8/31/17	None	2020	
PWR SG Examination Guidelines	8	3002007572	June 2016	8/31/17	None	2020	
PWR SG Primary-to-Secondary Leakage Guidelines	4	1022832	Sept 2011	4/11/2012 7/11/2012	None	2015	Rev 5 in progress – Target 2019 for publication

SGMP Industry Document Status and Revision Schedule

Guideline Title	Current Rev #	Report #	Last Pub Date	Imple-mentation Date(s)	Interim Guidance	Review Date	Comments
PWR Primary Water Chemistry Guidelines	7	3002000505	April 2014	1/28/2015	None	2019	
PWR Secondary Water Chemistry Guidelines	8	3002010645	Sept 2017	6/27/2018	None	2021	

Interim Guidance and NEI 03-08 Deviations

- No interim guidance has been issued since the last meeting
- No active NEI 03-08 deviations
- No significant operating experience

NRC and Public Comments

Acronyms

Acronyms

- AAPDD — Automated Analysis Performance Demonstration Database
- ASME — American Society of Mechanical Engineers
- BWR — Boiling Water Reactor
- CL — Confidence Level
- ECT — Eddy Current Testing
- EPRI — Electric Power Research Institute
- FGU — Flaw Grading Units
- KOH — Potassium Hydroxide
- LiOH — Lithium Hydroxide
- NaOH — Sodium Hydroxide
- NDD — No Detectable Degradation
- NDE — Nondestructive Examination
- NEI — Nuclear Energy Institute
- NRC — Nuclear Regulatory Commission

Acronyms

- ODIGA Outside Diameter Intergranular Attack
- ODSCC Outside Diameter Stress Corrosion Cracking
- OE Operating Experience
- POD Probability of Detection
- PWR Pressurized Water Reactor
- PWSCC Primary Water Stress Corrosion Cracking
- QDA Qualified Data Analyst
- RMSE Root Mean Square Error
- SG Steam Generator
- SGDD Steam Generator Degradation Database
- SGMP Steam Generator Management Program
- SSPD Site Specific Performance Demonstration
- TT Thermally Treated
- US United States

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