Performance Based S/G Inspection Methodology - An Example -

Presented by:

Bob Cullen, Entergy

Presentation Outline

- Introduction
- Summary of Plant Status at Implementation of PBI Program
- Summary of PBI Interval Determination
- Degradation Mechanism Assessment, Performance Measures, and Condition Monitoring Limit (CML)
- Maximum PBI Interval and Minimum Inspection Scope
- Utility Considerations for Determining PBI Intervals and Inspection Scope

Introduction - Implementation

- Implementation of this approach follows the guidelines in EPRI TR-114736-V1, "Risk Informed Inspection for Steam Generators - Volume 1, Deterministic Performance Based Criteria".

- Consistent with section 4 of draft revision 6 of the EPRI SG Exam Guidelines

Introduction - Objective

- Provide the technical basis for implementing a performance based inspection (PBI) program for the 2nd generation S/Gs
  - Allow inspection intervals to be based on the time that acceptable structural and leakage performance criteria are maintained
  - Ensure adequate safety margins are maintained and, at the same time, reduce inspection costs and personnel radiation exposure.

Introduction - Approach

- Determine the maximum operating interval where the degradation in any one tube does not exceed the degradation level allowed by application of deterministic structural and leakage performance criteria.

- Both service experience and analytical predictions are used to determine an inspection interval that ensures the performance criteria are satisfied.

Introduction - Implementation

- Determine the degradation-specific PBI intervals that satisfy the performance criteria.
- Define the inspection scope and sample size for the inspection at the end of the PBI interval.
- Follow other program requirements such as: in situ testing, primary and secondary chemistry controls, leakage monitoring, and foreign materials exclusion

Introduction - Implementation

- Maintain a program to detect, remove and evaluate loose parts to reduce the likelihood of unanticipated tube degradation and provide added assurance that structural and leakage criteria will be met during the PBI interval.
  - FME Program
  - Metal Impact Monitoring System
  - Foreign Object Search & Retrieval (FOSAR)

Initial Conditions

- Second generation S/Gs (44F)
  - Advanced materials (690 TT)
  - Advanced design (SS TSP)
- Completed four in-service eddy current inspections
- Five FOSAR completed (each RFO)

FOSAR Results

- Loose parts have been detected.
- Some, but not all, loose parts were removed at each RFO.
- Typical loose parts removed from the S/Gs are small with mass ranging from 0.2 to 2.5 grams.
- Evaluations considering stationary and migratory loose parts were performed at each RFO, and indicated no significant degradation would occur due to the presence of loose parts for periods ranging from 5 to 7.2 years after the RFO.

Degradation Condition for S/Gs at Initiation of the PBI Program

- Based on the inspection results it may be concluded that no corrosion or AVB wear degradation has occurred in the four S/Gs.
- Based on the inspection results it may be concluded that wear degradation attributed to loose parts is minimal.

Summary of PBI Interval Determination

- Defined deterministic, plant-specific structural and leakage performance criteria.
  - NEI 97-06, Revision 1, January 2001
- Defined the degradation mechanisms that may generate structurally significant defects during operation.

Summary of PBI Interval Determination

- For each potential degradation mechanism, determined a nondestructive examination (NDE) measurement parameter, and a value of this parameter that satisfies the performance criteria.
  - EPRI S/G Integrity Assessment Guidelines: Revision 1
  - EPRI S/G Degradation Specific Management Flaw Handbook

Summary of PBI Interval Determination

- For each potential degradation mechanism, predicted the operating time at which the degradation in any one tube will be equal to the value of the NDE measurement parameter corresponding to the performance criteria.

Summary of PBI Interval Determination

- Structural performance criteria for the wear and corrosion mechanisms correspond to allowable flaw depths significantly less (approximately 50%) than the tube wall thickness.
  - Consequently, the potential for leakage is negligible, and the structural performance criteria and NDE measurement parameters bound the leakage values.

Potential Degradation Mechanisms

- A comprehensive degradation mechanism evaluation was performed for the following tube degradation mechanisms:
  - AVB wear
  - Wear from loose parts
  - Circumferential ODSCC in the TTS region of the hot leg
  - Axial and volumetric OD IGA/SCC in the TTS region of the hot leg
  - OD IGA/SCC in the TSP region of the hot leg
  - PWSCC at TTS and low row U-bends are not relevant mechanisms

Degradation Specific Performance Criteria Measures and CML

Mechanism	SL	90% Total Uncertainty (a)	CML
AVB wear	68% TW	8.05% TW	60% TW
Wear from loose parts	62% TW (2" flaw)	20% TW	42% TW (2" flaw)
OD Circ. SCC; HL, TTS	77.8 PDA	17.54 PDA	60.3 PDA
OD Axial IGA/SCC; HL, TTS	73% TW (1" flaw)	20.18% TW	53% TW (1" flaw)
OD IGA/SCC; HL, TSP	73% TW (1" flaw)	20.18% TW	53% TW (1" flaw)

(a) Determined from the material, relational, and NDE analyst and technique uncertainties using the simplified statistical method in the EPRI S/G Integrity Assessment Guidelines

PBI Intervals

Times to Reach the CML and the PBI Intervals

Degradation Mechanism	Tube PBI Interval (EFPM after last inspection)
AVB wear	>> 480
Circumferential ODSCC: HL at TTS	665
Axial and volumetric OD IGA/SCC: HL at TTS	341
OD IGA/SCC: HL at TSP	281
First corrosion at CML	233 (a)
First corrosion detected	125 (b)
Loose parts wear	**79.2**

(a) Time for 95% probability that no defect reaches the CML

(b) Time for 95% probability that no defect is detected

Inspection Scope for Loose Parts

- The shortest time to reach CML is 79.2 EFPM and is associated with wear from loose parts.
- The first PBI would occur at the scheduled refueling outage nearest to the end of the PBI interval.
- Any loose parts found during each refueling outage must be evaluated to determine if the inspection interval should be modified to satisfy the structural and leakage performance criteria.

Inspection Scope for Loose Parts

- Because volumetric wear-like indications attributed to loose parts have been detected previously, and small loose parts remain in the some S/Gs, loose parts wear is classified as a detected degradation mechanism.
  - Based on this classification a 100% sample of the region susceptible to loose parts wear should be examined at 79.2 EFPM.
  - The region considered susceptible to loose parts wear is determined from service experience. This experience should be updated at each refueling outage prior to the PBI interval based on the results of the FOSAR program.
  - The next inspection interval for wear from loose parts would be determined based on the results from the FOSAR program and the results from the primary side tube examinations at 79.2 EFPM.

Inspection Scope for Loose Parts

- At 79.2 EFPM, neither AVB wear nor corrosion would be "anticipated" degradation mechanisms because the predicted times to CML are greater than the operating time at 79.2 EFPM.
- Consequently, no inspections for AVB wear or the corrosion mechanisms are required for the PBI program at 79.2 EFPM.

Inspection Scope for Corrosion

- The first PBI interval for corrosion degradation is 125 EFPM.
- Because corrosion degradation has not been detected, it is an "anticipated" mechanism.
  - A 20% sample of the susceptible regions is inspected at the end of the PBI interval.
  - Susceptible regions have been identified by the results from the degradation assessment.
  - If degradation is detected by the 20% sampling, then additional evaluations and inspections should be performed to assess the extent and severity of the detected degradation.

Inspection Scope for Corrosion

- The inspection scope should provide a high degree of assurance that the susceptible region has been bounded and that tubes that may be susceptible to the degradation mechanism do not have degradation levels exceeding the structural and leakage performance criteria.

- The next inspection interval for corrosion would be determined based on available industry experience and the results from the tube examinations at 125 EFPM

Inspection Scope for Corrosion

- At 125 EFPM, AVB wear is not an "anticipated" degradation mechanism because the predicted time to CML is greater than the operating time at 125 EFPM.
- Consequently, no inspections for AVB wear are required for the PBI program at 125 EFPM.

Inspection Scope for AVB Wear

- The first PBI interval for AVB wear degradation is greater than 480 EFPM.
- Because AVB wear has not been detected, it is an "anticipated" mechanism.
  - A 20% sample of the susceptible regions is inspected at the end of the PBI interval.
  - Susceptible regions have been identified by the results from the degradation assessment.

Inspection Scope for AVB Wear

- If degradation is detected by the 20% sampling, then additional evaluations and inspections should be performed to assess the extent and severity of the detected degradation.

- The inspection scope should provide a high degree of assurance that the susceptible region has been bounded and that tubes that may be susceptible to the degradation mechanism do not have degradation levels exceeding the structural and leakage performance criteria.

Inspection Scope for AVB Wear

- The next inspection interval for AVB wear would be based on the tube inspection results obtained at the end of the first PBI interval for AVB wear.

Utility Considerations for Setting Inspection Intervals and Scope

- Regulatory Factor: Current Tech Spec limit of 40 months (plus 25%) needs to be eliminated with NEI generic SG license amendment.
- Optical Factor: How we are viewed by the public, NRC and the industry
- Comfort Factor: How confident we are in our degradation predictions and industry data.