

XI.M19 STEAM GENERATORS

Program Description

The Steam Generator program is applicable to managing the aging of steam generator tubes, plugs, sleeves, and secondary side components that are contained within the steam generator (i.e., secondary side internals).

The establishment of a steam generator program for ensuring steam generator tube integrity is required by plant technical specifications. The steam generator tube integrity portion of the technical specifications at each PWR contains the same fundamental requirements as outlined in the standard technical specifications of NUREG-1430, Volume 1, Rev. 3, for Babcock & Wilcox pressurized water reactors (PWRs); NUREG-1431, Volume 1, Rev. 3, for Westinghouse PWRs; and NUREG-1432, Volume 1, Rev. 3, for Combustion Engineering PWRs. The requirements pertaining to steam generators in these three versions of the standard technical specifications are essentially identical. The technical specifications require tube integrity to be maintained and specify performance criteria, condition monitoring requirements, inspection scope and frequency, acceptance criteria for the plugging or repair of flawed tubes, acceptable tube repair methods, and leakage monitoring requirements.

The nondestructive examination techniques used to inspect tubes, plugs, sleeves, and secondary side internals are intended to identify components (e.g., tubes, plugs) with degradation that may need to be removed from service or repaired.

The Steam Generator program at PWRs is modeled after Nuclear Energy Institute (NEI) 97-06, Revision 2, "Steam Generator Program Guidelines." This program references a number of industry guidelines (e.g., the EPRI PWR Steam Generator Examination Guidelines, PWR Primary-to-Secondary Leak Guidelines, PWR Primary Water Chemistry Guidelines, PWR Secondary Water Chemistry Guidelines, Steam Generator Integrity Assessment Guidelines, Steam Generator In Situ Pressure Test Guidelines) and incorporates a balance of prevention, mitigation, inspection, evaluation, repair, and leakage monitoring measures. The NEI 97-06 document (a) includes performance criteria that are intended to provide assurance that tube integrity is being maintained consistent with the plant's licensing basis and (b) provides guidance for monitoring and maintaining the tubes to provide assurance that the performance criteria are met at all times between scheduled inspections of the tubes. Steam generator tube integrity can be affected by degradation of steam generator plugs, sleeves, and secondary side internals. Therefore, all of these components are addressed by this aging management program (AMP). The NEI 97-06 program has been effective at managing the aging effects associated with steam generator tubes, plugs, sleeves, and secondary side internals.

Evaluation and Technical Basis

1. **Scope of Program:** This program addresses degradation associated with steam generator tubes, plugs, sleeves, and secondary side components that are contained within the steam generator (i.e., secondary side internals). It does not cover degradation associated with the steam generator shell, channelhead, nozzles, or welds associated with these components.
2. **Preventive Actions:** This program includes preventive and mitigative actions for addressing degradation. Preventive and mitigative measures that are part of the Steam Generator program include foreign material exclusion programs, and other primary and secondary side maintenance activities. The program includes foreign material exclusion as a means to

inhibit wear degradation and secondary side maintenance activities, such as sludge lancing, for removing deposits that may contribute to degradation. Guidance on foreign material exclusion is provided in NEI 97-06. Guidance on maintenance of secondary side integrity is provided in the EPRI Steam Generator Integrity Assessment Guidelines. Primary side preventive maintenance activities include replacing plugs made with corrosion susceptible materials with more corrosion resistant materials and preventively plugging tubes susceptible to degradation.

Extensive deposit buildup in the steam generators could affect tube integrity. The EPRI Steam Generator Integrity Assessment Guidelines, which are referenced in NEI 97-06, provide guidance on maintenance on the secondary side of the steam generator, including secondary side cleaning. Secondary side water chemistry plays an important role in controlling the introduction of impurities into the steam generator and potentially limiting their deposition on the tubes. Maintaining high water purity reduces susceptibility to SCC or IGSCC. Water chemistry is monitored and maintained in accordance with the Water Chemistry program. The program description and evaluation and technical basis of monitoring and maintaining water chemistry are addressed in GALL AMP XI.M2, "Water Chemistry."

3. ***Parameters Monitored/Inspected:*** There are currently three types of steam generator tubing used in the United States: mill annealed Alloy 600, thermally treated Alloy 600, and thermally treated Alloy 690. Mill annealed Alloy 600 steam generator tubes have experienced degradation due to corrosion (e.g., primary water stress corrosion cracking, outside diameter stress corrosion cracking, intergranular attack, pitting, and wastage) and mechanically induced phenomena (e.g., denting, wear, impingement damage, and fatigue). Thermally treated Alloy 600 steam generator tubes have experienced degradation due to corrosion (primarily cracking) and mechanically induced phenomena (primarily wear). Thermally treated Alloy 690 tubes have only experienced tube degradation due to mechanically induced phenomena (primarily wear). Degradation of tube plugs, sleeves, and secondary side internals have also been observed, depending, in part, on the material of construction of the specific component.

The program includes an assessment of the forms of degradation to which a component is susceptible and implementation of inspection techniques capable of detecting those forms of degradation. The parameter monitored is specific to the component and the acceptance criteria for the inspection. For example, the severity of tube degradation may be evaluated in terms of the depth of degradation or measured voltage, dependent on whether a depth-based or voltage-based tube repair criteria (acceptance criteria) is being implemented for that specific degradation mechanism. Other parameters monitored include signals of excessive deposit buildup (e.g., steam generator water level oscillations), which may result in fatigue failure of tubes or corrosion of the tubes; water chemistry parameters, which may indicate unacceptable levels of impurities; primary-to-secondary leakage, which may indicate excessive tube, plug, or sleeve degradation; and the presence of loose parts or foreign objects on the primary and secondary side of the steam generator, which may result in tube damage.

Water chemistry parameters are also monitored as discussed in AMP XI.M2. The EPRI PWR Steam Generator Primary-to-Secondary Leakage Guidelines (EPRI 1008219) provides guidance on monitoring primary-to-secondary leakage. The EPRI Steam Generator Integrity Assessment Guidelines (EPRI 1012987) provide guidance on secondary side activities.

In summary, the NEI 97-06 program provides guidance on parameters to be monitored or inspected.

4. **Detection of Aging Effects:** The technical specifications require that a Steam Generator program be established and implemented to ensure that steam generator tube integrity is maintained. This requirement ensures that components that could compromise tube integrity are properly evaluated or monitored (e.g., degradation of a secondary side component that could result in a loss of tube integrity is managed by this program). The inspection requirements in the technical specifications are intended to detect degradation (i.e., aging effects), if they should occur.

The technical specifications are performance-based, and the actual scope of the inspection and the expansion of sample inspections are justified based on the results of the inspections. The goal is to perform inspections at a frequency sufficient to provide reasonable assurance of steam generator tube integrity for the period of time between inspections.

The general condition of some components (e.g., plugs and secondary side components) may be monitored visually, and, subsequently, more detailed inspections may be performed if degradation is detected.

NEI 97-06 provides additional guidance on inspection programs to detect degradation of tubes, sleeves, plugs, and secondary side internals. The frequencies of the inspections are based on technical assessments. Guidance on performing these technical assessments is contained in NEI 97-06 and the associated industry guidelines.

The inspections and monitoring are performed by qualified personnel using qualified techniques in accordance with approved licensee procedures. The EPRI PWR Steam Generator Examination Guidelines (EPRI 1013706) contains guidance on the qualification of steam generator tube inspection techniques.

The primary-to-secondary leakage monitoring program provides a potential indicator of a loss of steam generator tube integrity. NEI 97-06 and the associated EPRI guidelines provide information pertaining to an effective leakage monitoring program.

5. **Monitoring and Trending:** Condition monitoring assessments are performed to determine whether the structural- and accident-induced leakage performance criteria were satisfied during the prior operating interval. Operational assessments are performed to verify that structural and leakage integrity will be maintained for the planned operating interval before the next inspection. If tube integrity cannot be maintained for the planned operating interval before the next inspection, corrective actions are taken in accordance with the plant's corrective action program. Comparisons of the results of the condition monitoring assessment to the predictions of the previous operational assessment are performed to evaluate the adequacy of the previous operational assessment methodology. If the operational assessment was not conservative in terms of the number and/or severity of the condition, corrective actions are taken in accordance with the plant's corrective action program.

The technical specifications require condition monitoring and operational assessments to be performed (although the technical specifications do not explicitly require operational assessments, these assessments are necessary to ensure that the tube integrity will be

maintained until the next inspection). Condition monitoring and operational assessments are done in accordance with the technical specification requirements and guidance in NEI 97-06 and the EPRI Steam Generator Integrity Assessment Guidelines.

The goal of the inspection program for all components covered by this AMP is to ensure that the components continue to function consistent with the design and licensing basis of the facility (including regulatory safety margins).

Assessments of the degradation of steam generator secondary side internals are performed in accordance with the guidance in the EPRI Steam Generator Integrity Assessment Guidelines to ensure the component continues to function consistent with the design and licensing basis and to ensure technical specification requirements are satisfied.

6. **Acceptance Criteria:** Assessment of tube and sleeve integrity and plugging or repair criteria of flawed and sleeved tubes is in accordance with plant technical specifications. The criteria for plugging or repairing steam generator tubes and sleeves are based on U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.121 and are incorporated into plant technical specifications. Guidance on assessing the acceptability of flaws is also provided in NEI 97-06 and the associated EPRI guidelines, including the EPRI Steam Generator In-Situ Pressure Test Guidelines and EPRI Steam Generator Integrity Assessment Guidelines.

Degraded plugs, degraded secondary side internals, and leaving a loose part or a foreign object in the steam generator are evaluated for continued acceptability on a case-by-case basis. NEI 97-06 and the associated EPRI guidelines provide guidance on the performance of these evaluations. The intent of these evaluations is to ensure that the components affected by parts or objects have adequate integrity consistent with the design and licensing basis of the facility.

Guidance on the acceptability of primary-to-secondary leakage and water chemistry parameters also are discussed in NEI 97-06 and the associated EPRI guidelines.

7. **Corrective Actions:** For degradation of steam generator tubes and sleeves (if applicable), the technical specifications provide requirements on the actions to be taken when the acceptance criteria are not met. For degradation of other components, the appropriate corrective action is evaluated per NEI 97-06 and the associated EPRI guidelines, the American Society of Mechanical Engineers (ASME) Code Section XI (2004 Edition),¹³ 10 CFR 50.65, and 10 CFR Part 50, Appendix B, as appropriate. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable for ensuring effective corrective actions.
8. **Confirmation Process:** Site quality assurance (QA) procedures, review and approval processes, and site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process and administrative controls.

¹³ Refer to the GALL Report, Chapter 1, for applicability of other editions of the ASME Code.

In addition, the adequacy of the preventive measures in the Steam Generator program is confirmed through periodic inspections.

9. **Administrative Controls:** As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the administrative controls.
10. **Operating Experience:** Several generic communications have been issued by the NRC related to the steam generator programs implemented at plants. The reference section lists many of these generic communications. In addition, NEI 97-06 provides guidance to the industry for routinely sharing pertinent steam generator operating experience and for incorporating lessons learned from plant operation into guidelines referenced in NEI 97-06. The latter includes providing interim guidance to the industry, when needed.

The NEI 97-06 program has been effective at managing the aging effects associated with steam generator tubes, plugs, sleeves, and secondary side components that are contained within the steam generator (i.e., secondary side internals), such that the steam generators can perform their intended safety function.

References

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- 10 CFR 50.65, *Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants*, Office of the Federal Register, National Archives and Records Administration, 2009.
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- EPRI 1013706, *PWR Steam Generator Examination Guidelines: Revision 7*, Electric Power Research Institute, Palo Alto, CA, October 2007.
- EPRI 1014983, *Steam Generator In-Situ Pressure Test Guidelines: Revision 3*, Electric Power Research Institute, Palo Alto, CA, August 2007.
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- EPRI 1016555, *Pressurized Water Reactor Secondary Water Chemistry Guidelines: Revision 7*, Electric Power Research Institute, Palo Alto, CA, February 2009. NEI 97-06, Rev. 2, *Steam Generator Program Guidelines*, Nuclear Energy Institute, September 2005.
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NRC Information Notice 88-99, *Detection and Monitoring of Sudden and/or Rapidly Increasing Primary-to-Secondary Leakage*, U.S. Nuclear Regulatory Commission, December 20, 1988.

NRC Information Notice 89-65, *Potential for Stress Corrosion Cracking in Steam Generator Tube Plugs Supplied by Babcock and Wilcox*, U.S. Nuclear Regulatory Commission, September 8, 1989.

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