Enclosure A
L-20-071

Evaluation of the Proposed Amendment

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1.0 SUMMARY DESCRIPTION

This evaluation supports a request to amend Renewed Facility Operating License No. NPF-73 for Beaver Valley Power Station, Unit No. 2 (BVPS-2). The proposed amendment would revise Technical Specification (TS) 5.5.5.2.d, "Provisions for SG [Steam Generator] Tube Inspections," and TS 5.5.5.2.f.3, "Provisions for SG Tube Repair Methods," requirements related to methods of inspection and service life for Alloy 800 steam generator tubesheet sleeves.

A qualified inspection method has been developed using a modified probe (referred to as a Ghent Version 2 probe) to inspect the portion of the original steam generator tube wall adjacent to the nickel band (the lower half region) of the tubesheet sleeve lower joint employed with the Westinghouse Electric Company, LLC (Westinghouse) leak-limiting Alloy 800 sleeve tube repair method. Since the magnetically biased Ghent Version 2 probe has demonstrated the capability of inspecting the original tube wall adjacent to the nickel band (including the nickel band region of the sleeve), there is no reason to limit the service life of the Alloy 800 tubesheet sleeves to eight fuel cycles of operation. Therefore, the inspection method requirements specified in the note located at the beginning of TS 5.5.5.2.d, and the eight fuel cycles of operation service life requirements specified in TS 5.5.5.2.f.3, associated with the Westinghouse leak-limiting Alloy 800 sleeves, are no longer necessary and would be deleted.

2.0 DETAILED DESCRIPTION

2.1 System Design and Operation

The steam generators (SGs) in pressurized water reactor designs remove heat from the reactor coolant system and produce steam to operate the main generator and other balance-of-plant equipment. SG tubes constitute the heat transfer surface area between the primary (reactor coolant) and secondary (main steam) systems and, as such, are relied on to maintain the primary system's pressure and inventory. As an integral part of the reactor coolant pressure boundary, the SG tubes isolate the radioactive fission products in the primary coolant from the secondary system in the SGs. Maintaining tube integrity ensures that the tubes can perform their intended safety functions consistent with the plant licensing basis and applicable regulatory requirements.

The BVPS-2 SGs are Model 51M and contain mill annealed Alloy 600 tubing, which is susceptible to stress corrosion cracking. Outside diameter stress corrosion cracking (ODSCC) located at the top of the hot leg tubesheet accounts for greater than 76 percent of the tubes that require remediation in the BVPS-2 SGs. Tube sleeving is a corrective action to offset this degradation, and Westinghouse Alloy 800 sleeves have been licensed for use at BVPS-2 to address both tubesheet and tube support plate degradation. However, no tube support plate sleeves have been installed in the BVPS-2 SGs.

Westinghouse Alloy 800 tubesheet sleeves are up to 25 inches in length and have a slightly smaller diameter than the original SG tubing. The sleeves are inserted into affected SG tubes to bridge the defective area. The lower portion of the sleeve is hard

rolled against the tubesheet, and the upper portion of the sleeve is hydraulically expanded into the free-span portion of the tube above the tubesheet. The stress corrosion cracking degradation falls between the two expansion regions, so the sleeve effectively becomes the new pressure boundary and eliminates the degraded area as a concern. Figure 1 demonstrates this concept.

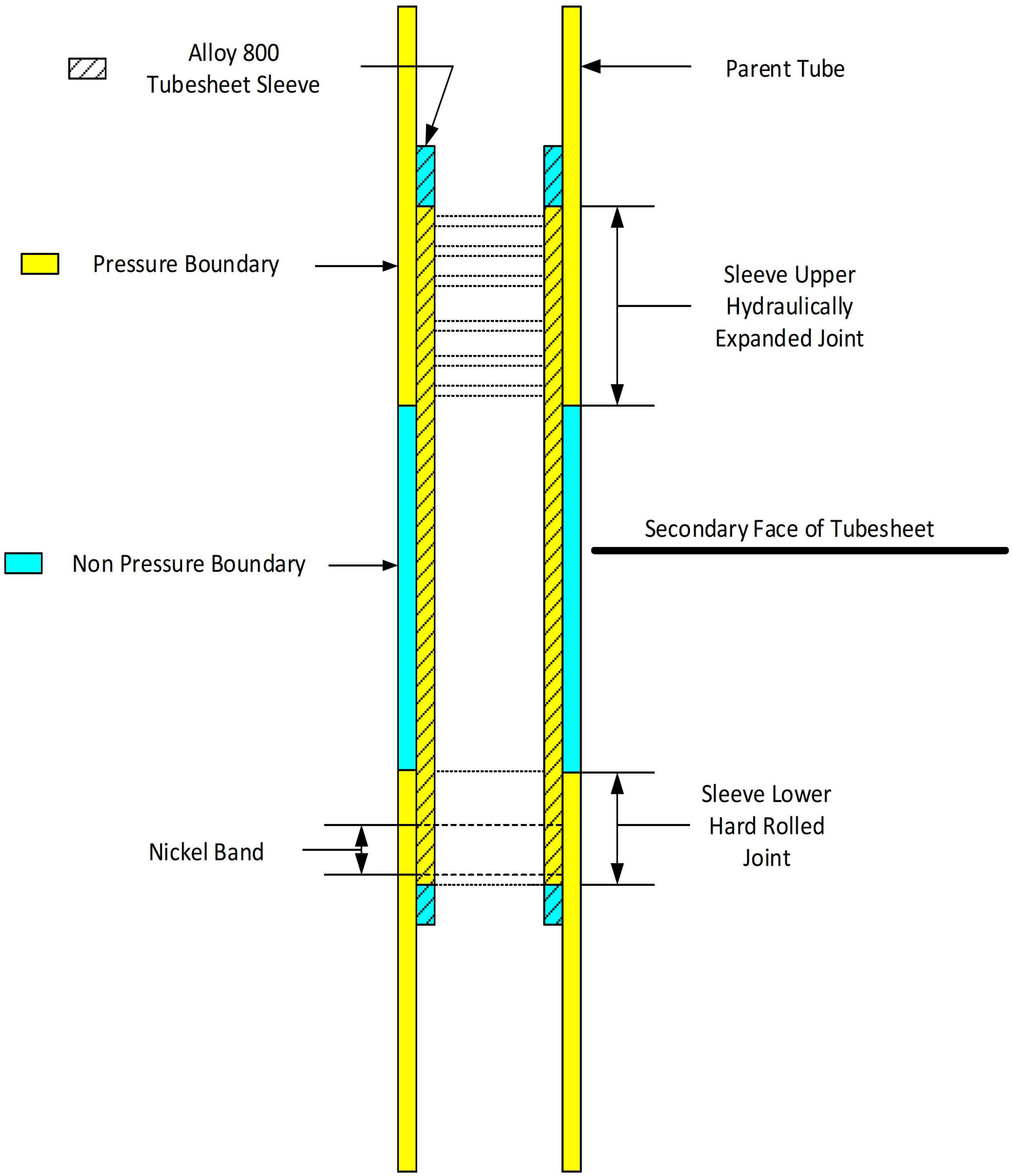

Figure 1 - Alloy 800 Tubesheet Sleeve - Location of Nickel Band

The Alloy 800 tubesheet sleeves used at BVPS-2 include a nickel band, applied 360 degrees around the outside diameter of the lower end of the sleeve where the hard roll is located. The nickel band is intended to improve the sealing characteristics of the lower joint.

2.2 Current Technical Specification Requirements

The note located at the beginning of Technical Specification 5.5.5.2.d is presented below.

- NOTE -

> The requirement for methods of inspection with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube does not apply to the portion of the original tube wall adjacent to the nickel band (the lower half) of the lower joint for the repair process that is discussed in Specification 5.5.5.2.f.3. However, the method of inspection in this area shall be a rotating plus point (or equivalent) coil. The SG tube plugging criterion of Specification 5.5.5.2.c.3 is applicable to flaws in this area.

The acceptable tube repair method listed in Technical Specification 5.5.5.2.f.3 reads as follows:

> Westinghouse leak-limiting Alloy 800 sleeves, WCAP-15919-P, Revision 2. An Alloy 800 sleeve installed in the hot-leg or cold-leg tubesheet region shall remain in service for no more than eight fuel cycles of operation starting from the outage when the sleeve was installed.

2.3 Reason for the Proposed Change

The Ghent Version 2 probe has been developed to inspect the portion of the original tube wall adjacent to the nickel band (the lower half region) of the lower joint of a tubesheet sleeve. The Ghent Version 2 probe has been site qualified in accordance with Appendix H, Supplement H2, of the Electric Power Research Institute (EPRI) Report, “Steam Generator Management Program: Pressurized Water Reactor Steam Generator Examination Guidelines,” Revision 8 (Reference 1) and has adequately demonstrated the capability of detecting axial and circumferential flaws in this region of the sleeve and tube. The plus point probe would continue to be utilized to inspect the remainder (non-nickel band region) of the tube and sleeve assembly. The plus point probe uses +POINT^{TM} eddy current coil technology (+POINT is a trademark of Zetec, Inc.).

The proposed deletion of the note located at the beginning of TS 5.5.5.2.d would remove the requirement to use the Plus point probe to inspect the portion of the original tube wall adjacent to the nickel band region of the Alloy 800 tubesheet sleeve. Deleting this note would also allow the use of an alternative inspection method (utilizing the Ghent Version 2 probe) that would ensure the SG tube integrity is maintained until the next SG inspection as required by TS 5.5.5.2.d.

The last sentence of the note located at the beginning of TS 5.5.5.2.d indicates that the SG tube plugging criterion of TS 5.5.5.2.c.3 is applicable to the flaws in the portion of the original tube wall adjacent to the nickel band region (the lower half) of the lower joint. This requirement is redundant to the requirement specified in TS 5.5.5.2.c.3, and therefore, would be deleted.

The proposed change would also delete the eight fuel cycles of operation service life restriction in TS 5.5.5.2.f.3. The Ghent Version 2 probe has been site qualified to inspect the nickel band region of the Alloy 800 tubesheet sleeve and has adequately demonstrated the capability to detect axial and circumferential flaws in this region of the sleeve and original tube wall. As such, there is no need for a service life restriction on the Alloy 800 tubesheet sleeve.

2.4 Description of the Proposed Change

The proposed amendment would delete the following note located at the beginning of TS 5.5.5.2.d.

- NOTE -

> The requirement for methods of inspection with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube does not apply to the portion of the original tube wall adjacent to the nickel band (the lower half) of the lower joint for the repair process that is discussed in Specification 5.5.5.2.f.3. However, the method of inspection in this area shall be a rotating plus point (or equivalent) coil. The SG tube plugging criterion of Specification 5.5.5.2.c.3 is applicable to flaws in this area.

The proposed amendment would change the acceptable tube repair method listed in Technical Specification TS 5.5.5.2.f.3 from:

> Westinghouse leak-limiting Alloy 800 sleeves, WCAP-15919-P, Revision 2. An Alloy 800 sleeve installed in the hot-leg or cold-leg tubesheet region shall remain in service for no more than eight fuel cycles of operation starting from the outage when the sleeve was installed.

To read as follows:

> Westinghouse leak-limiting Alloy 800 sleeves, WCAP-15919-P, Revision 2.

The proposed technical specification changes, which are submitted for Nuclear Regulatory Commission (NRC) review and approval, are provided in the Attachment. Deletions are shown by strike-through so that the reviewer may readily identify the information that would be deleted. To meet format requirements, the technical specifications would be revised and repaginated as necessary to reflect the changes being proposed by this license amendment request.

No changes are proposed for the Technical Specification Bases because the affected technical specifications do not have associated Bases.

3.0 TECHNICAL EVALUATION

3.1 Background and History

Two Westinghouse Alloy 800 sleeve designs are licensed for use at BVPS-2. One sleeve design is for tube support plates and the other design is for the tubesheet. Only the tubesheet sleeve contains the nickel band.

For tubesheet sleeves, the upper tube-sleeve joint is formed by equally spaced hydraulic expansions. The lower tube-sleeve joint is a mechanical roll expansion. The elevation of the centerline of the roll expansion is approximately located at the mid-plane elevation of the tubesheet. A “microlok” band is applied to the tube at the upper half of the roll joint. The microlok band is a thermally applied material similar to the sleeve material, which acts to increase the coefficient of friction between the tube and sleeve, thus increasing the axial load bearing capability of the sleeve joint. The nickel band was added as an additional barrier to leakage.

Westinghouse Alloy 800 sleeves were initially authorized for use at BVPS-2 by Amendment No. 170, dated September 30, 2009 (Accession No. ML092590189). Amendment No. 170 required all sleeves to be removed from service by the spring of 2017 refueling outage (2R19), regardless of the sleeve installation date, due to examination limitations of the parent tube behind the nickel band.

BVPS-2 Amendment No. 184, dated December 16, 2015 (Accession No. ML15294A439), changed the service life restriction on the Westinghouse Alloy 800 sleeves to five fuel cycles of operation beginning with the cycle the sleeve was installed.

BVPS-2 Amendment No. 193, dated February 25, 2019 (Accession No. ML18348B206), extended the service life of the Alloy 800 sleeves from five to eight fuel cycles of operation. The justification for this extension, in part, was based on the conclusion that degradation of the parent tube adjacent to the nickel band of the Alloy 800 tubesheet sleeve is not credible. The NRC staff noted in the safety evaluation that a qualified inspection technique would be needed for approval of the leak-limiting Alloy 800 transition zone [tubesheet] sleeves on a permanent basis.

3.2 Selection of Nondestructive Examination (NDE) Technique

Three volumetric NDE techniques, ultrasonic testing (UT), eddy current testing (ECT) and radiography (RT) are available to the industry to inspect SG tube sleeves. RT was determined to be too bulky and expensive to field deploy. The feasibility of using UT and ECT inspection methods were evaluated. ECT was selected based on the availability of off-the-shelf test equipment.

3.3 Eddy Current Probe Selection

Standard eddy current probes have not demonstrated the capability to penetrate the nickel band region in the lower joint of the Alloy 800 tubesheet sleeves and detect flaws

in the parent SG tube. A feasibility study was conducted to determine if flaws are detectable with off-the-shelf eddy current probes. Two probes were tested, a magnetically biased Ghent probe and a plus point probe. The plus point probe contains a single surface riding coil. The Ghent probe contains one transmitter and two receiver coils (one coil for axial indications, the other coil for circumferential indications). Both designs are rotating probes and have been utilized in multiple SG examinations.

The feasibility study determined that the magnets within the Ghent probe minimized the nickel response to allow detection of certain axial notches in the inside diameter of the parent tube. After obtaining favorable results from this study, a site-specific qualification program was conducted for the Ghent probe.

Testing performed as part of the qualification program led to the design and manufacture of a new probe, called a Ghent Version 2 probe. This new probe was designed and fabricated to permit an adequate inspection of the parent SG tube behind the nickel band of an Alloy 800 tubesheet sleeve.

The Ghent Version 2 probe also contains a standard +POINT probe coil to improve field implementation efficiencies. The +POINT coil was included in this design since it is already qualified to inspect the remaining (non-nickel band) portions of the tubesheet sleeves. This new design requires that the probe only be inserted once into each sleeve for a complete inspection rather than twice (that is, the first time for the sleeve inspection and the second time for the nickel band inspection).

3.4 Electrical Discharge Machined (EDM) Notch Samples

Parent tube flaw samples were fabricated with a combination of axial and circumferential EDM notches. EDM notches meet the requirement of Supplement H2.2.1, paragraph c, of Reference 1, that states:

> Test samples fabricated using mechanical or chemical methods may be used. However, the flaws should produce signals similar to those being observed in the field in terms of signal characteristics, signal amplitude, and S/N [signal to noise] ratio.

Additional information regarding fabrication of the flaw samples, including the number, size, and location of flaws is provided in Section 4, “Description of Methodology,“ of Reference 2.The samples and notches selected meet the requirements of Appendix H, Supplement H2, paragraph H2.2.2.c, of Reference 1. In addition, the range of notch depths address the recommendations of paragraph H2.2.2.c. Eddy current data obtained using the Ghent Version 2 probe was used to support the site-specific qualification of the probe in accordance with Appendix H of Reference 1.

3.5 Probability of Detection (POD) Study

A vendor document entitled, “Probability of Flaw Detection in the Alloy 800 Mechanical Sleeve Lower Tubesheet Joint Using the Ghent Version 2 Eddy Current Probe" (Reference 3), addresses the flaw detection capabilities of the Ghent Version 2 probe. POD distributions were developed for the probe by employing a detailed testing program for detecting stress corrosion cracking in the parent tube behind the nickel band of the lower tubesheet sleeve joint.

Using the POD distributions developed from the study and industry-accepted operational assessment methodologies has resulted in satisfaction of SG performance criteria with considerable margin after one fuel cycle of operation, thus demonstrating the acceptability of the Ghent Version 2 probe to identify parent tube flaws behind the nickel band at the lower Alloy 800 tubesheet sleeve joint.

3.6 Site-Specific Qualification

Appendix H, Supplement H2.1 of Reference 1 states, in part:

> ….non EPRIQ techniques (that is, site-specific techniques) shall, as a minimum, have an independent qualified data analyst (IQDA) verify and document compliance with Appendix H.

A BVPS site-specific peer review was conducted by qualified data analysts on the data gathered from inspection of the EDM notch samples using the Ghent Version 2 probe as described in Section 7, "Peer Review of ETSS # DMW-G3/G4-NI," of Reference 2. Two IQDA's, who were not part of the peer review team, determined the ground truth from the 25 EDM notches.

The BVPS-2 site specific technical qualification program was successfully completed, meeting the requirements of Appendix H of Reference 1. The inspection frequencies used by the Ghent Version 2 probe and the detection results for each frequency are shown in Appendix B of Reference 2.

The Ghent Version 2 probe has been site qualified for detection of indications in the parent tube behind the nickel band for Alloy 800 tubesheet sleeves installed in the BVPS-2 SG's.

3.7 Field Deployment

During the fall 2018 refueling outage (2R20), the Ghent Version 1 probe was used to examine 25 randomly selected inservice hot leg tubesheet sleeves. Data collected from the probe served as "informational only."

The influence of the nickel band (background noise) was observed to be less significant in the installed tubesheet sleeves when compared to that of the lab samples that were fabricated and utilized for the probe qualification process. The in-service sleeves were installed with a higher torque value than those in the lab which creates a more intimate contact between the sleeve and the parent tube. This results in less noise as the eddy current flows more easily through the tighter contact.

The Ghent Version 2 probe was first deployed during the spring 2020 refueling outage (2R21) to examine the 567 sleeves that remained in-service. The data collected from the plus point probe section serves as the official call of record. The Ghent probe section detected scratches in the nickel band region of two sleeves that were installed in the previous refueling outage (2R20). A review of historical data showed that the scratches were present in 2R20. It could not be determined if the scratches were on the inside diameter of the tube or outside diameter of the sleeve nickel band. The two

sleeves were plugged as the scratches were in the pressure boundary. Field data quality for the Ghent probe section was characterized as very good.

3.8 Tube Sleeve Inspections

If the proposed amendment is approved, the Ghent Version 2 probe, which includes a plus point probe, will be used to inspect the Alloy 800 tubesheet sleeves each outage as directed by the degradation assessment. The plus point probe is qualified to inspect the non-nickel band region of the tube and sleeve assembly. The Ghent Version 2 probe is site qualified to inspect the nickel band region of the tubesheet sleeve and the parent tube behind the nickel band region of the sleeve.

Tubes with indications observed in the Alloy 800 sleeve or in the sleeve to tube joint shall be plugged in accordance with TS 5.5.5.2.c.2 and TS 5.5.5.2.c.3, respectively.

3.9 Conclusions

The Ghent Version 2 probe was developed to improve inspection capabilities for the nickel band region in the lower sleeve-to-tube joint within the tubesheet. The Ghent Version 2 probe has demonstrated improved inspection capabilities as compared to the plus point probe, by reducing the interfering effects of the nickel band material. POD curves were developed that resulted in satisfaction of SG performance criteria with considerable margin after one fuel cycle of operation, thus demonstrating the acceptability of the Ghent Version 2 probe to identify parent tube flaws behind the nickel band at the lower Alloy 800 tubesheet sleeve joint. Having a site qualified technique to inspect the parent tube behind the nickel band eliminates the need for an eight fuel-cycle restriction of service life, which means the sleeves may remain in service for the life of the component.

The Ghent Version 2 probe also saves time and dose for inspecting the Alloy 800 tubesheet sleeves by performing at one time, both the inspection of the length of the sleeve with the plus point probe and inspection of the parent tube behind the nickel band with the Ghent Version 2 probe.

Utilization of the newly designed Ghent Version 2 probe will improve the safety of the station by enhancing the ability to inspect the reactor coolant system pressure boundary. The use of the plus point and Ghent Version 2 probe to inspect and identify flaws in the SG tube and sleeve assembly will help to ensure the assembly is capable of performing its intended safety function, which is to maintain the integrity of the reactor coolant system pressure boundary.

4.0 REGULATORY EVALUATION

4.1 Applicable Regulatory Requirements/Criteria

<u>10 CFR 50.55a. Codes and Standards</u>

10 CFR 50.55a, paragraph (c)(1), specifies that components that are part of the reactor coolant pressure boundary must meet the requirements for Class 1 components in Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) with certain exceptions. 10 CFR 50.55a further requires,

in part, that throughout the service life of a pressurized water reactor facility, ASME Code Class 1 components must meet the requirements, except design and access provisions and pre-service examination requirements, in Section XI, "Rules for In-service Inspection of Nuclear Power Plant Components," of the ASME Code, to the extent practical. This requirement includes the inspection and repair criteria of Section XI of the ASME Code.

Qualified eddy current examination techniques will be used to perform necessary sleeve and original SG tube inspections for defect detection and to ensure structural integrity of the tube and sleeve assembly.

10 CFR 50. Appendix A. General Design Criteria for Nuclear Power Plants

General Design Criteria (GDC) 14, 15, 30, 31, and 32 of 10 CFR Part 50, Appendix A, define requirements for the reactor coolant pressure boundary with respect to structural and leakage integrity. SG tubing and tube repairs constitute a major portion of the reactor coolant pressure boundary surface area. SG tubing and associated repair techniques and components, such as plugs and sleeves, must be capable of maintaining reactor coolant inventory and pressure.

The SG Program required by the BVPS-2 Technical Specifications establishes performance criteria, repair criteria, repair methods, inspection periods and the methods necessary to meet the criteria. These requirements provide reasonable assurance that tube integrity will be met in the interval between SG inspections.

There are no proposed changes in this amendment request that impact these regulatory requirements.

4.2 No Significant Hazards Consideration Analysis

Energy Harbor Nuclear Corp. proposes to amend the Beaver Valley Power Station, Unit No. 2 Operating License NPF-73 by changing Technical Specification 5.5.5.2.d to allow for the use of an improved and qualified eddy current technique to inspect the parent tube behind the nickel band of an Alloy 800 tubesheet sleeve, and Technical Specification 5.5.5.2.f.3 to delete the eight fuel cycles of operation service life restriction on Alloy 800 tubesheet sleeves.

Energy Harbor Nuclear Corp. has evaluated whether or not a significant hazards consideration is involved with the proposed amendment by focusing on the three standards set forth in 10 CFR 50.92, “Issuance of amendment,” as discussed below.

1. Does the proposed amendment involve a significant increase in the probability or consequences of an accident previously evaluated?

Response: No

The proposed Technical Specification changes do not modify structures, systems or components of the plant, or affect plant operations, design functions or analyses that verify the capability of structures, systems or components to perform a design function.

The proposed Technical Specification changes do not increase the likelihood of a SG tube sleeve malfunction.

The leak-limiting Alloy 800 sleeves are designed using the applicable American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code and, therefore, meet the design objectives of the original SG tubing. The applied stresses and fatigue usage for the sleeves are bounded by the limits established in the ASME Code. Mechanical testing has shown that the structural strength of sleeves under normal, upset, emergency, and faulted conditions provides margin to the acceptance limits. These acceptance limits bound the most limiting (three times normal operating pressure differential) burst margin recommended by NRC Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes."

The leak-limiting Alloy 800 sleeve depth-based structural limit is determined using NRC guidance and the pressure stress equation of ASME Code, Section III with additional margin added to account for the configuration of long axial cracks. Calculations show that a depth-based limit of 45 percent through-wall degradation is acceptable. However, Technical Specifications 5.5.5.2.c.2 and 5.5.5.2.c.3 provide additional margin by requiring an Alloy 800 sleeved tube to be plugged on detection of any flaw in the sleeve or in the pressure boundary portion of the original tube wall in the sleeve to tube joint.

Degradation of the original tube adjacent to the nickel band of an Alloy 800 sleeve installed in the tubesheet, regardless of depth, would not prevent the sleeve from satisfying design requirements. Thus, flaw detection capabilities within the original tube adjacent to the sleeve nickel band are a defense in-depth measure and are not necessary in order to justify continued operation of the sleeved tube.

Evaluation of repaired steam generator tube testing and analysis indicates that there are no detrimental effects on the leak-limiting Alloy 800 sleeve or sleeved tube assembly from reactor coolant system flow, primary or secondary coolant chemistries, thermal conditions or transients, or pressure conditions that may be experienced at BVPS-2.

The consequences of a hypothetical failure of the leak-limiting Alloy 800 sleeve and tube assembly are bounded by the current steam generator tube rupture analysis described in the BVPS-2 Updated Final Safety Analysis Report because the total number of plugged steam generator tubes (including flow area reduction associated with installed sleeves) is required to be consistent with accident analysis assumptions. The sleeve and tube assembly leakage during plant operation would be minimal and well within the allowable Technical Specification leakage limits and accident analysis assumptions.

Implementation of this proposed amendment would have no significant effect on either the configuration of the plant, the manner in which it is operated, or ability of the sleeve to perform its design function.

Therefore, the proposed amendment does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the proposed amendment create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No

The proposed Technical Specification changes do not create any credible new failure mechanisms, malfunctions, or accident initiators not considered in the design or licensing bases and does not create the possibility of a new or different kind of accident from any previously evaluated.

The leak-limiting Alloy 800 sleeves are designed using the applicable ASME Code, and therefore meet the objectives of the original steam generator tubing. Therefore, the only credible failure modes for the sleeve and tube are to leak or rupture, which have already been evaluated.

The continued integrity of the installed sleeve and tube assembly is periodically verified as required by the Technical Specifications, and a sleeved tube will be plugged on detection of a flaw in the sleeve or in the pressure boundary portion of the original tube wall in the sleeve to tube joint.

Implementation of this proposed amendment would have no significant effect on either the configuration of the plant, the manner in which it is operated, or ability of the sleeve to perform its design function.

Therefore, the proposed amendment does not create the possibility of a new or different kind of accident from any previously evaluated.

3. Does the proposed amendment involve a significant reduction in a margin of safety?

Response: No

Implementation of the proposed Technical Specification changes would not affect a design basis or safety limit or reduce the margin of safety. The repair of degraded steam generator tubes with leak-limiting Alloy 800 sleeves restores the structural integrity of the degraded tube under normal operating and postulated accident conditions. The reduction in reactor coolant system flow due to the addition of Alloy 800 sleeves is not significant because the cumulative effect of repaired (sleeved) and plugged tubes will continue to allow reactor coolant flow to be greater than the flow limit established in the Technical Specification limiting condition for operation 3.4.1.

The design safety factors utilized for the sleeves are consistent with the safety factors in the American Society of Mechanical Engineers Boiler and Pressure Vessel Code used in the original steam generator design. Tubes with sleeves would also be subject to the same safety factors as the original tubes that are described in the performance criteria for steam generator tube integrity in the existing Technical Specifications. With the proposed Technical Specification changes, the sleeve and portions of the installed sleeve and tube assembly that represent the reactor coolant pressure boundary will continue to be monitored and a sleeved tube will be plugged on detection of a flaw in the sleeve or in the pressure boundary portion of the original tube wall in the leak-limiting sleeve and tube assembly. Use of the previously identified design criteria and

design verification testing ensures that the margin of safety is not significantly different from the original steam generator tubes.

Therefore, the proposed amendment does not involve a significant reduction in a margin of safety.

Based on the above, Energy Harbor Nuclear Corp. concludes that the proposed amendment involves no significant hazards consideration under the criteria set forth in 10 CFR 50.92 and, accordingly, a finding of "no significant hazards consideration" is justified.

4.3 Conclusions

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

5.0 ENVIRONMENTAL CONSIDERATION

A review has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or would change an inspection or surveillance requirement. However, the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluents that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9).

Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

6.0 REFERENCES

1. EPRI Report 3002007572, Revision 8, "Steam Generator Management Program: Pressurized Water Reactor Steam Generator Examination Guidelines," June 2016 (Accession Number ML16208A244).

2. Westinghouse Document Number SG-CDMP-19-17-P, Revision 1, "Qualification of an Examination Technique to Inspect Parent Tube Flaws Adjacent to the Nickel Band of an Alloy 800 Sleeve at Beaver Valley Unit 2," April 2020 (Proprietary)

3. Westinghouse Document Number SG-CDMP-19-19 P-Attachment, Revision 1, "Probability of Flaw Detection in the Alloy 800 Mechanical Sleeve Lower Tubesheet Joint Using the Ghent Version 2 Eddy Current Probe," April 2020 (Proprietary)

Evaluation of the Proposed Amendment
Attachment

Technical Specification Page Markups

(2 pages follow)

5.5 Programs and Manuals

5.5.5.2 Unit 2 SG Program (continued)

NDE = 95-percent cumulative probability allowance for nondestructive examination uncertainty (i.e., a value of 20-percent has been approved by NRC). The NDE is the value provided by the NRC in GL 95-05 as supplemented.

Implementation of these mid-cycle repair limits should follow the same approach as in Specifications 5.5.5.2.c.4.a through 5.5.5.2.c.4.d.

5. The F* methodology, as described below, may be applied to the expanded portion of the tube in the hot-leg or cold-leg tubesheet region as an alternative to the 40% depth based criteria of Specification 5.5.5.2.c.1:

   a) Tubes with no portion of a lower sleeve joint in the hot-leg or cold-leg tubesheet region shall be repaired or plugged upon detection of any flaw identified within 3.0 inches below the top of the tubesheet or within 2.22 inches below the bottom of roll transition, whichever elevation is lower. Flaws located below this elevation may remain in service regardless of size.

   b) Tubes which have any portion of a sleeve joint in the hot-leg or cold-leg tubesheet region shall be plugged upon detection of any flaw identified within 3.0 inches below the lower end of the lower sleeve joint. Flaws located greater than 3.0 inches below the lower end of the lower sleeve joint may remain in service regardless of size.

   c) The F* methodology cannot be applied to the tubesheet region where a laser or TIG welded sleeve has been installed.

d. Provisions for SG Tube Inspections

~~-NOTE-~~

~~The requirement for methods of inspection with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube does not apply to the portion of the original tube wall adjacent to the nickel band (the lower half) of the lower joint for the repair process that is discussed in Specification 5.5.5.2.f.3. However, the method of inspection in this area shall be a rotating plus point (or equivalent) coil. The SG tube plugging criterion of Specification 5.5.5.2.c.3 is applicable to flaws in this area.~~

Periodic SG tube inspections shall be performed. The number and portions of the tubes inspected and methods of inspection shall be performed with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and

5.5 Programs and Manuals

5.5.5.2 Unit 2 SG Program (continued)

3. Indications left in service as a result of application of the tube support plate voltage-based plugging or repair criteria (Specification 5.5.5.2.c.4) shall be inspected by bobbin coil probe during all future refueling outages.

   Implementation of the steam generator tube-to-tube support plate plugging or repair criteria requires a 100-percent bobbin coil inspection for hot-leg and cold-leg tube support plate intersections down to the lowest cold-leg tube support plate with known outside diameter stress corrosion cracking (ODSCC) indications. The determination of the lowest cold-leg tube support plate intersections having ODSCC indications shall be based on the performance of at least a 20-percent random sampling of tubes inspected over their full length.

4. When the F* methodology has been implemented, inspect 100% of the inservice tubes in the hot-leg tubesheet region with the objective of detecting flaws that may satisfy the applicable tube plugging or repair criteria of Specification 5.5.5.2.c.5 every 24 effective full power months or one interval between refueling outages (whichever is less).

5. For Alloy 800 sleeves: The parent tube, in the area where the sleeve-to-tube hard roll joint and the sleeve-to-tube hydraulic expansion joint will be established, shall be inspected prior to installation of the sleeve. Sleeve installation may proceed only if the inspection finds these regions free from service induced indications.

e. Provisions for monitoring operational primary to secondary LEAKAGE

f. Provisions for SG Tube Repair Methods

Steam generator tube repair methods shall provide the means to reestablish the RCS pressure boundary integrity of SG tubes without removing the tube from service. For the purposes of these Specifications, tube plugging is not a repair. All acceptable tube repair methods are listed below.

1. ABB Combustion Engineering TIG welded sleeves, CEN-629-P, Revision 02 and CEN-629-P Addendum 1.

2. Westinghouse laser welded sleeves, WCAP-13483, Revision 2.

3. Westinghouse leak-limiting Alloy 800 sleeves, WCAP-15919-P, Revision 2. ~~An Alloy 800 sleeve installed in the hot-leg or cold-leg tubesheet region shall remain in service for no more than eight fuel cycles of operation starting from the outage when the sleeve was installed.~~

Enclosure B
L-20-071

Document Number SG-CDMP-19-17-NP, Revision 1, “Qualification of an Examination Technique to Inspect Parent Tube Flaws Adjacent to the Nickel Band of an Alloy 800 Sleeve at Beaver Valley Unit 2,” dated April 2020 (Non-Proprietary)

(118 pages follow)

SG-CDMP-19-17-NP
Revision 1

April 2020

Qualification of an Examination Technique to Inspect Parent Tube Flaws Adjacent to the Nickel Band of an Alloy 800 Sleeve at Beaver Valley Unit 2

SG-CDMP-19-17-NP
Revision 1

Qualification of an Examination Technique to Inspect Parent Tube Flaws Adjacent to the Nickel Band of an Alloy 800 Sleeve at Beaver Valley Unit 2

(There are no technical changes to Revision 1 of this document. Revision 1 has been created to provide a Proprietary and Non-Proprietary (redacted) version of the document.)

April 2020

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1 PURPOSE

The purpose of this report is to document the methodology and processes that were executed to qualify a Beaver Valley Unit 2 site specific eddy current technique to detect flaws in parent tubing adjacent to the nickel band region of an alloy 800 sleeve assembly. This report also documents the successful completion of the qualification program and the final Beaver Valley Unit 2 Site-Specific Examination Technique Specification Sheet. This qualification program was conducted in accordance with the Westinghouse Electric Company Global Management System (WGMS). This system meets the requirements of the United States Nuclear Regulatory Commission related to quality control and quality assurance including the requirements set forth in 10CFR50 Appendix B, and also the standards set forth in ISO 9001.

2 REFERENCES

1. Westinghouse Report SG-SGMP-18-14, Revision 0, “Feasibility Study to Examine Capability of Magnetically Biased Ghent 3-4 Probe to Detect Parent Tube Flaws at the Same Elevation of a Nickel Band Contained on Outside Diameter of a Sleeve,” June 2018.
2. EPRI Report 3002007572, Revision 8, “Steam Generator Management Program: Pressurized Water Reactor Steam Generator Examination Guidelines,” June 2016.
3. EPRI Steam Generator Examination Guideline Appendix H Qualification for Eddy Current Plus-Point Probe Examination of ABB CE I-800 Mechanical Sleeves, ABB CENO Report No. 97-TR-FSW-019P, Rev. 00.
4. Westinghouse Letter LTR-SGS-19-016, Revision 0, “Parent Tube +Pt Flaw Detection Adjacent to Microlok of Area of Sleeve Assembly,” October 2019.
5. Westinghouse Report MRS-TRC-1425, Revision 0, “Eddy Current Examination of I-800 Sleeves Equivalency Assessment .750 Inch to .875 Inch Configuration,” September 2003.

3 BACKGROUND

Beaver Valley Unit 2 has 3 Westinghouse Model 51M steam generators that currently have (Post 2R20 Inspection) a total of 481 Alloy 800 sleeves in-service; 247 in S/G-A,169 in S/G-B and 65 in S/G-C. Each sleeve contains a [ ][a,c,e] nickel band starting [ ][a,c,e] from the sleeve end with a [ ][a,c,e] microlok band adjacent above it. These bands are located within the roll expansion region. The original demonstrations and qualifications for the Alloy 800 sleeves were performed using a **+POINT™[1]** eddy current coil that addressed various areas of the sleeve assembly, however excluded the parent tube adjacent to the nickel band region. These +Point qualifications and demonstrations are documented in References 3, 4 and 5. After reviewing +Point data from a parent tube and sleeve assembly that contained EDM notches behind the nickel band in the parent tubing, it was determined that a different inspection technique was required that improves detection through the masking effects contributed to the nickel band. It was determined after pursuing other techniques that the Ghent G3/G4 probe produced the most promising detection improvement. A feasibility study was performed to determine if pursuing a full qualification would be justifiable. This feasibility study is documented in Reference 1. After obtaining favorable results from this study, the decision was made to move forward with a full site-specific qualification program of the Ghent G3/G4 detection technique, adhering to the requirements of the EPRI Examination Guidelines (Reference 2). This report documents the phases of the program that resulted in the successful completion of this site-specific technique qualification.

[1] *+POINT™ is a trademark or registered trademark of Zetec, Inc. Other names may be trademarks of their respective owners.*

4 DESCRIPTION OF METHODOLOGY

Table H-2 of Reference 2 lists the minimum number of flawed grading units >60% through wall (TW) that must be detected to meet the technique acceptance criterion of POD ≥ 0.80 at a 90% confidence level for various data set populations. [

][a,c,e]. Table 1 summarizes the selected parent tube samples and depths, orientation and locations of the [ ][a,c,e] flawed grading units.

Table 1
Flawed Grading Unit Matrix

Sample	Flaw 1	Flaw 2	Flaw 3

a,c,e

Each of the parent tube samples [

][a,c,e]

[

]a,c,e.

[

]a,c,e.

5 PROBE DESIGN, DEVELOPMENTS AND TESTING RESULTS

The completed [

][a,c,e].

a,c,e

Figure 1
Probe Used for Initial Testing of the Parent Tube Sleeve Assemblies

After discussions with Zetec, a new design probe [

][a,c,e]. The Version 1 Combo probe is illustrated in Figure 2. This probe provided [

][a,c,e].

[ ][a,c,e]

Figure 2
Version 1 Combo Probe - Ghent G3/G4 and +Point Coils

Additional discussions were held with Zetec which led to [ ][a,c,e].

In an attempt to improve detection of the two marginal responses, [ ][a,c,e]. This Version 3 Combo probe is illustrated in Figure 4. However, [ ][a,c,e].

[ ][a,c,e]. All eddy current standards used in this qualification program are contained in Appendix E and the Certificate of Conformance for Versions 1, 2 and 3 Combo probes are contained in Appendix I.

a,c,e

Figure 3
Version 2 Combo Probe - Ghent G3/G4 and +Point Coils

a,c,e

Figure 4
Version 3 Combo Probe - Ghent G3/G4 and +Point Coils

6 SITE-SPECIFIC EXAMINATION TECHNIQUE SPECIFICATION SHEET (ETSS)

The version 2 combo probe was [ ]a,c,e. All setup parameters are included in the ETSS. The second page of the ETSS contains the data set, listing the mode (Axial / Circumferential), location, the nominal and measured depth, length and width for each of the [ ]a,c,e grading units. These measurements were performed by Curtis Industries, Inc. The Reference Standard Certification data sheets for each of the nine machined parent tube samples are contained in Appendix F. Revision 0 of the Beaver Valley Unit 2 site-specific examination technique sheet, ETSS # DMW-G3/G4-Ni is contained in Appendix A of this report.

7 PEER REVIEW OF ETSS # DMW-G3/G4-NI

A peer review of ETSS # DMW-G3/G4-Ni was conducted on July 17, 2019. Industry peer reviews for EPRI techniques must meet the rigor of supplement H4 of Reference 2. Section H2.1 of reference 2 states "In lieu of the Supplement H4 peer review, non EPRIQ (site specific) techniques shall, as a minimum, have an IQDA verify and document compliance with Appendix H." [

]a,c,e.

Table 2
Summary of Non-Reportable Flawed Grading Units

ET QDA / Level III	[ ]a,c,e kHz (1)	[ ]a,c,e kHz	[ ]a,c,e kHz (1)
#1 Mast (NDE)	[		]a,b,c
#2 Skirpan (W)			
#3 Bowser (NDE)			

(1) These frequencies also met the two-third majority acceptance criterion

8 EDDY CURRENT TESTING AND DIMENSIONAL MEASUREMENTS

Eddy current testing and dimensional measurements of the parent tubes, sleeves, EDM notches, etc., were taken throughout various stages of this technique qualification program. To document what was done and when, the data sheets and workorder descriptions for these dimensional measurements are contained in Appendix G. A listing of the various eddy current tests performed throughout the qualification program are summarized in Appendix J.

9 SUMMARY

This Beaver Valley Unit 2 site specific technique qualification program has been successfully completed, meeting the requirements of Appendix H of the EPRI steam generator examination guidelines, Reference 2. The Revision 0 of the technique ETSS # DMW-G3/G4-Ni, contained in Appendix A, documents the essential parameters necessary to be in compliance of this technique and will be used in preparing Beaver Valley Unit 2 acquisition and analysis procedures for the examination of installed Alloy 800 sleeves that contain a nickel band.

APPENDIX A
BEAVER VALLEY UNIT 2 SITE-SPECIFIC ETSS # DMW-G3/G4-NI, REVISION 0

a,c,e

[ ]

a,c,e

APPENDIX B
FINAL PEER REVIEW SIGNATURE SHEETS

a,c,e

a,c,e

a,c,e

a,c,e

APPENDIX C
PARENT TUBE SAMPLE DRAWINGS – [ ] a,c,e

[ ]a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

APPENDIX D
VERSION 2 COMBO PROBE GRAPHICS

[ ]a,c,e

Figure D-1

[ ]a,c,e

a,c,e

Figure D-2

[

]a,c,e

a,c,e

Figure D-3

[

]a,c,e

a,c,e

Figure D-4

[

]a,c,e

[ ]a,c,e

Figure D-5

[ ]a,c,e

a,c,e

Figure D-6

[

]a,c,e

a,c,e

Figure D-7

[

]a,c,e

[ ]a,c,e

Figure D-8

[ ]a,c,e

[ ]a,c,e

Figure D-9

[ ]a,c,e

[ ]a,c,e

Figure D-10

[ ]a,c,e

a,c,e

Figure D-11

[

]a,c,e

a,c,e

Figure D-12

[

]a,c,e

a,c,e

Figure D-13

[

]a,c,e

a,c,e

Figure D-14

[

]a,c,e

[ ]a,c,e

Figure D-15

[ ]a,c,e

a,c,e

Figure D-16

[

]a,c,e

[ ]a,c,e

Figure D-17

[ ]a,c,e

[ ]a,c,e

Figure D-18

[ ]a,c,e

a,c,e

Figure D-19

[

]a,c,e

[ ]a,c,e

Figure D-20

[ ]a,c,e

[ ]a,c,e

Figure D-21

[ ]a,c,e

a,c,e

Figure D-22

[

]a,c,e

a,c,e

Figure D-23

[

]a,c,e

a,c,e

Figure D-24

[

]a,c,e

[ ]a,c,e

Figure D-25

[ ]a,c,e

APPENDIX E
EDDY CURRENT CALIBRATION STANDARDS

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

APPENDIX F
CURTIS INDUSTRIES PARENT TUBE POST-EDM MACHINING DATA SHEETS

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

APPENDIX G
DIMENSIONAL MEASUREMENTS

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

[ ]a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

APPENDIX H
PERSONNEL NDE CERTIFICATIONS

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

APPENDIX I
ZETEC CERTIFICATE OF CONFORMANCE FOR VERSION 1, 2 AND 3 COMBO PROBES

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

a,c,e

APPENDIX J
PROGRAM EDDY CURRENT TESTING SUMMARY

Program Eddy Current Testing Summary

[ ] a,c,e

Document Number SG-CDMP-19-19 NP-Attachment, Revision 1, “Probability of Flaw Detection in Alloy 800 Mechanical Sleeve Lower Tubesheet Joint Using the Ghent Version 2 Eddy Current Probe,” April 2020 (Non-Proprietary)

(39 pages follow)

SG-CDMP-19-19 NP-Attachment
Revision 1

April 2020

Probability of Flaw Detection in the Alloy 800 Mechanical Sleeve Lower Tubesheet Joint Using the Ghent Version 2 Eddy Current Probe

Westinghouse

SG-CDMP-19-19 NP-Attachment
Revision 1

Probability of Flaw Detection in the Alloy 800 Mechanical Sleeve Lower Tubesheet Joint Using the Ghent Version 2 Eddy Current Probe

April 2020

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EXECUTIVE SUMMARY

In October of 2018, FirstEnergy Nuclear Operating Company (FENOC) submitted a license amendment request (LAR) to extend the service life of Westinghouse Alloy 800 steam generator (SG) tube sleeves from five fuel cycles as stated in the plant Technical Specifications to eight fuel cycles. By Nuclear Regulatory Commission (NRC) letter dated February 25, 2019, Amendment 193 to Facility Operating License No. NPF-73 was issued that extended the allowable service life of Alloy 800 sleeves as requested from five fuel cycles to eight cycles. This service life restriction was related to perceived limitations of the non-destructive examination (NDE) methods introduced by the nickel band applied to the outer diameter (OD) of the sleeve within the lower joint mechanical roll expansion region. Specifically, the NRC staff had questions regarding the capabilities of the current NDE inspection technique to detect flaws within the lower nickel banded joint of the tubesheet sleeve. The NRC staff noted in their approval for the extended sleeve service life that a qualified inspection technique would be needed to approve the tubesheet sleeve design on a permanent basis.

In response to the NRC staff questions regarding the NDE flaw detection capabilities, an improved inspection technique was developed specifically for the nickel banded area in the lower sleeve-to-tube joint within the tubesheet. The new eddy current inspection technique uses a magnetically biased transmit-receive rotating probe referred to as a Ghent Version 2 probe. Prior sleeve inspections used a motorized rotating **+POINT™**[1] probe coil. The Ghent Version 2 probe demonstrated improved inspection capabilities as compared to the +POINT probe through reducing the interfering effects of the nickel band material. As part of another effort, the Ghent Version 2 probe inspection technique was qualified to the Electric Power Research Institute (EPRI) SG Examination Guideline Appendix H requirements. This document addresses the flaw detection capabilities through establishing defined probability of detection (POD) distributions for detecting stress corrosion cracking (SCC) within the parent tubing behind the nickel banded lower tubesheet sleeve joint using the Ghent Version 2 probe.

Tubing samples containing SCC flaws were obtained from EPRI and were used to determine the POD performance for the Ghent Version 2 probe. The crack samples were installed into tubesheet simulant collars, nickel banded sleeves were installed, and inspections were performed with the Ghent Version 2 probe. The crack samples were destructively examined to determine the physical flaw sizes. Engineering analysis was performed using the crack sample NDE inspection and destructive examination results to develop POD distributions. The engineering analysis methodology followed industry accepted modeling techniques endorsed by EPRI and is referred to the model assisted probability of detection (MAPOD) method. The MAPOD method was also described within the FENOC sleeve life extension License Amendment Request (LAR) and NRC staff approval documents described above. The exclusive use of crack samples to generate the POD distributions described within this report reduces uncertainty of combining different techniques as discussed in the prior LAR submittal and NRC staff safety evaluation

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[1] *+POINT™ is a trademark or registered trademark of Zetec, Inc. Other names may be trademarks of their respective owners.*

report that supported the LAR approval. Using the developed POD distributions and industry accepted operational assessment methodologies resulted in satisfaction of all SG performance criteria with considerable margin after one fuel cycle of operation, thus demonstrating the acceptability of the Ghent Version 2 probe to identify parent tube flaws behind the nickel band at the lower Alloy 800 tubesheet sleeve joint.

Revision 1 of this document is being issued to update Reference 8 to Revision 1. There are no other technical changes to this document.

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1 BACKGROUND

In 2008, First Energy Nuclear Operating Company (FENOC) submitted a License Amendment Request (LAR) to allow repair of Beaver Valley Unit 2 steam generator (SG) tubes with Alloy 800 mechanical tube sleeves (Reference 1). The request provided two sleeve designs; one to repair tubes at tube support plate locations (TS) and one to repair tubes at the top of the tubesheet transition zone locations (TZ). The tubesheet TZ sleeve design contains a nickel band at the lower sleeve roll joint to improve the leak limiting capabilities of the joint. Figure 1-1 provides the configuration of the tubesheet sleeve design. The upper joint of the TZ sleeve and the TS sleeve hydraulic expansion joints do not contain nickel bands. The presence of the nickel band material at the lower joint provided challenges and limited data demonstrating reliable detection of flaws within the parent tubing behind the nickel band region. As such, FENOC requested a limited service life of five fuel cycles for the Alloy 800 sleeve. The NRC staff found the five-fuel cycle service life limitation to be acceptable and approved the LAR for the TZ and TS sleeves (Reference 2).

The inspection technique and program submitted to the NRC staff in support of the 2008 LAR relied upon +POINT probe technology. The qualification and demonstration of the parent tube inspection behind the nickel band consisted of electro-discharge machine (EDM) notches and a limited number of samples with cracking in the parent tube. The four crack samples penetrated through or nearly through the thickness of the tube. The qualification and demonstration concluded that the +POINT probe could detect outer diameter (OD) EDM notch flaws with depths greater than 40% through-wall (TW) in the parent tube behind the nickel band region (Reference 2). It was concluded that the outer diameter stress corrosion cracking (ODSCC) flaws that are 100% TW or approaching 100% TW could also be detected with the +POINT probe. The NRC staff found the inspection capabilities of the +POINT probe to be acceptable for the limited service life of the nickel band TZ sleeve. The limitation on the service life of the Alloy 800 sleeve limits the amount of time that degradation of the sleeve joint could occur as discussed in Reference 2.

In 2018, FENOC submitted a LAR to the NRC to extend the nickel banded TZ sleeve service life from five fuel cycles to eight fuel cycles (Reference 3). The LAR also provided a clarification that the limited service life of 5 cycles does not apply to the TS sleeve as the TS sleeve joint design does not include a nickel band. The submittal as supplemented by Reference 4 and Reference 5 provided additional and updated analyses that demonstrated that the NDE capabilities were not as restrictive as initially perceived for detection of degradation behind the nickel band region at the lower sleeve joint. The NDE technique presented within the updated analyses was still the +POINT probe technology. Probability of detection (POD) curves were developed using the industry methodology referred to as Model Assisted Probability of Detection (MAPOD) that showed reliable detection capabilities for parent tube flaws behind the nickel band using the +POINT probe technology. The NRC staff continued to have questions regarding uncertainties with the MAPOD analysis. However, the NRC staff approved the LAR as requested to extend to nickel banded sleeve service life to eight fuel cycles (Reference 6). The NRC staff noted in the license amendment approval document that "a qualified inspection technique would be needed for approval of the leak-limiting

Alloy 800 TZ sleeves on a permanent basis." The NRC staff also noted in Reference 6 that the technical basis for the MAPOD analysis (Reference 4) did not provide a direct correlation between inspection frequencies of 300 kHz for the parent tube with no sleeves and 70 kHz for the tube/sleeve configuration. These correlations were inherent to the MAPOD methodology and results. However, the MAPOD conclusions were in general agreement with the results from limited experimental assessments using nondestructive evaluation specimens with laboratory produced outer diameter stress corrosion cracks (ODSCC). The final NRC staff position as described in Reference 6 is that a time-limited service life of eight fuel cycles is justified and acceptable with the current +POINT probe inspection technology for the nickel banded region of the lower TZ sleeve joint. The NRC staff also approved the clarification that the TS sleeve does not have a time-limited service life.

In response to the NRC staff questions regarding the NDE flaw detection capabilities, an improved inspection technique was developed specifically for the nickel banded area in the lower sleeve-to-tube joint within the tubesheet through a joint FENOC, Westinghouse and Zetec effort. The improved eddy current inspection technique uses a magnetically biased transmit-receive rotating probe referred to as a Ghent Version 2 probe.

This document addresses the flaw detection capabilities through development of probability of detection distributions for detecting stress corrosion cracking (SCC) in the parent tubing behind the nickel banded lower tubesheet joint using the Ghent Version 2 probe.

a,c

Figure 1-1. Alloy 800 Leak Limiting Mechanical Tubesheet Sleeve

2 GHENT VERSION 2 PROBE DESIGN

The eddy current probe initially qualified to inspect the Alloy 800 sleeve pressure boundary is the +POINT probe. The +POINT probe is the current regulatory basis for performing baseline and inservice inspections of installed sleeves at the upper and lower joints, the sleeve between the joints and the parent tube pressure boundary behind the TS and TZ sleeve (Reference 7). With the exception of behind the nickel band for the TZ sleeve, the +POINT probe is qualified to be adequate for flaw detection capability for flaws greater than 45% through-wall (TW) for the sleeve and 50% through-wall for the parent tube in accordance with Appendix H of the EPRI SG Examination Guidelines (Reference 10). As a result, the TZ sleeve is limited to a service life of eight fuel cycles due to the NRC staff questions surrounding inspection of the parent tube behind the nickel band at the lower tubesheet joint.

FENOC, Westinghouse, and Zetec Inc., collaborated to develop an improved eddy current probe to inspect the parent tube behind the nickel band at the lower tubesheet joint. Through feasibility studies and testing programs, a modified Ghent G3/G4 probe was selected for qualification. The Ghent probe is a magnetically biased rotating transmit-receive probe. The magnets within the probe serve to suppress the undesirable effects of the nickel. The final probe design is referred to as the Ghent Version 2 probe. This probe has an increased magnet strength of [ ]^{a,c,e} from the prior prototype (Version 1) magnet strength of 50 MGO. The increased magnet strength improves the ability to saturate the nickel material and improves inspection capabilities of the parent tube behind the nickel band. A subsequent prototype Ghent probe (Version 3) was tested that contained [ ]^{a,c,e} but did not improve the inspection capability beyond that provided by the single [ ]^{a,c,e} contained in the Version 2 probe. No further improvements were judged as being obtainable with additional designs or modifications and therefore, the Version 2 probe was selected for qualification. The Ghent Version 2 probe also contains a standard +POINT probe coil to improve field implementation efficiencies by allowing simultaneous data collection with both probe coils with a single probe tube insertion. The Ghent coils target inspection of the nickel band region at the lower hard roll joint and the +POINT probe targets the remaining portions of the sleeve, including the hydraulic expansions at the upper joint.

The Appendix H qualification of the Ghent Version 2 probe was completed and documented in Reference 8. This document provides the probability of detection development for stress corrosion cracking in the parent tube behind the nickel band at the lower TZ sleeve joint.

3 GHENT VERSION 2 TEST PROGRAM

3.1 GENERAL OVERVIEW OF ANALYSIS METHOD

The approach to developing the probability of detection curves for SCC in the parent tube behind the nickel band in the lower tubesheet sleeve joint involved analysis of parent tube crack samples through a detailed testing program. The parent tube crack samples were placed in tubesheet simulated collars and nickel banded Alloy 800 sleeves were installed in the tube/collar assemblies. The tube/sleeve/collar assemblies were inspected with the Ghent Version 2 probe and analyzed to determine which flaws were detected or not detected. The eddy current voltage amplitudes were recorded for the detected flaws. All parent tube crack samples were then destructively examined to determine the size of the cracks for both the detected and undetected flaws. The NDE and destructive examination (DE) results were evaluated to develop the crack-based POD curves using industry accepted methods.

3.2 PARENT TUBE CRACK SAMPLES

Tubing samples containing SCC flaws were obtained from the Electric Power Research Institute (EPRI) to support this study. The samples were fabricated from Alloy 600 tubing that had a diameter of 0.875 inch and a nominal wall thickness of 0.050 inch. There were four tubing samples that contained a total of twelve laboratory produced axial ODSCC flaws of varying sizes. The parent tube samples were tested with the +POINT probe at a frequency of 300 kHz to obtain baseline data prior to beginning the Ghent probe sleeve testing program. Table 3-1 provides a listing of the samples and the baseline inspection results. This table also provides additional information discussed in later sections. The as-received baseline +POINT probe voltage amplitude recorded was in terms of peak-to-peak voltage (Vpp). The initial baseline +POINT probe voltages of the crack samples in the as-received condition ranged from 0.21 Vpp in Sample J-2-3 Flaw #4 to 18.07 Vpp in Sample J-3 Flaw #3. As further discussed in Section 3.3, the depths of the flaws from destructive examination ranged from [ ]^{b}.

Each crack sample had locator marks to uniquely identify each flaw in terms of circumferential location around the tube from the locator mark as noted in Table 3-1. Figures 3-1 through 3-4 provide the standard Ghent probe C-scan graphic of each parent tube sample with identification of each flaw that were taken following the NDE test program and prior to the destructive examination program.

Table 3-1. Ghent Version 2 Ni Band Sleeve Test Program Results

			As-Received Parent Tube	Sleeve/Tube/Collar Assembly	Post Test Parent Tube (No Sleeve)		
Parent Tube Sample Identification	**Flaw Number**	**Location (degrees)**	**Baseline +POINT Vpp**	**Behind Nickel Ghent Version 2 Vpp**	**Final +POINT Vpp**	**Final Standard Ghent Vpp**	**DE Exam Depth %TW**
J-2-3	1	31	0.71	NDD	0.74	1.20	
	2	71	1.49	0.35	1.49	2.62	
	3	102	0.73	NDD	0.70	1.07	
	4	285	0.21	NDD	0.21	0.27	
J-3	1	91	NI	NDD	0.44	0.28	
	2	91	NI	NDD	0.44	0.63	
	3	168	18.07	3.76	20.49	21.60	
	4	278	0.26	NDD	0.21	0.21	
	5	354	0.27	NDD	0.26	0.59	
J-8	1	46	0.86	0.09	0.86	1.38	
	2	228	0.40	NDD	0.36	0.63	
J-12A	1	312	1.02	0.39	1.41	2.55	

b

NI- Not initially recorded
NDD-No degradation detected

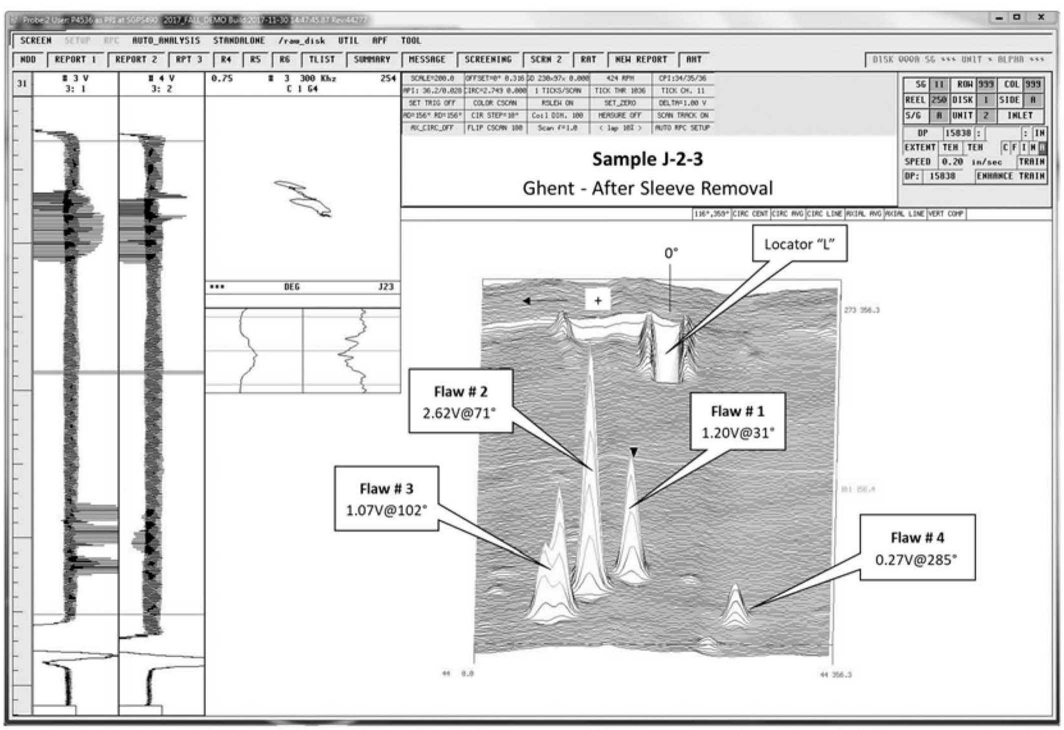

Figure 3-1. Parent Tube Crack Sample J-2-3, Post Sleeve Test Standard Ghent Probe C-Scan

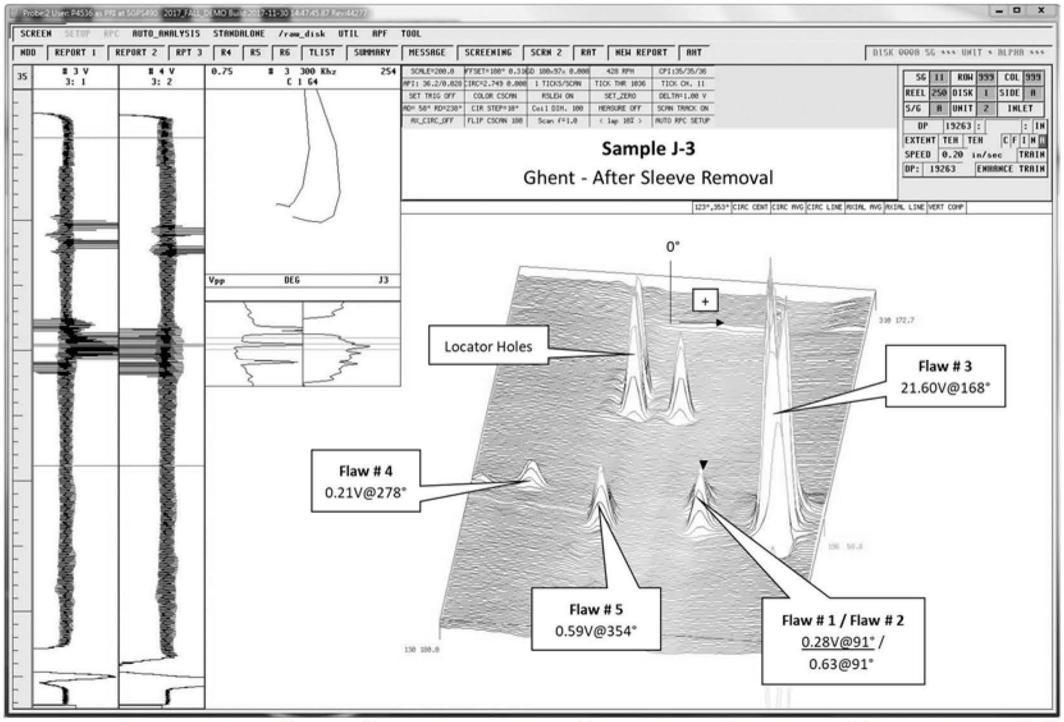

Figure 3-2. Parent Tube Crack Sample J-3, Post Sleeve Test Standard Ghent Probe C-Scan

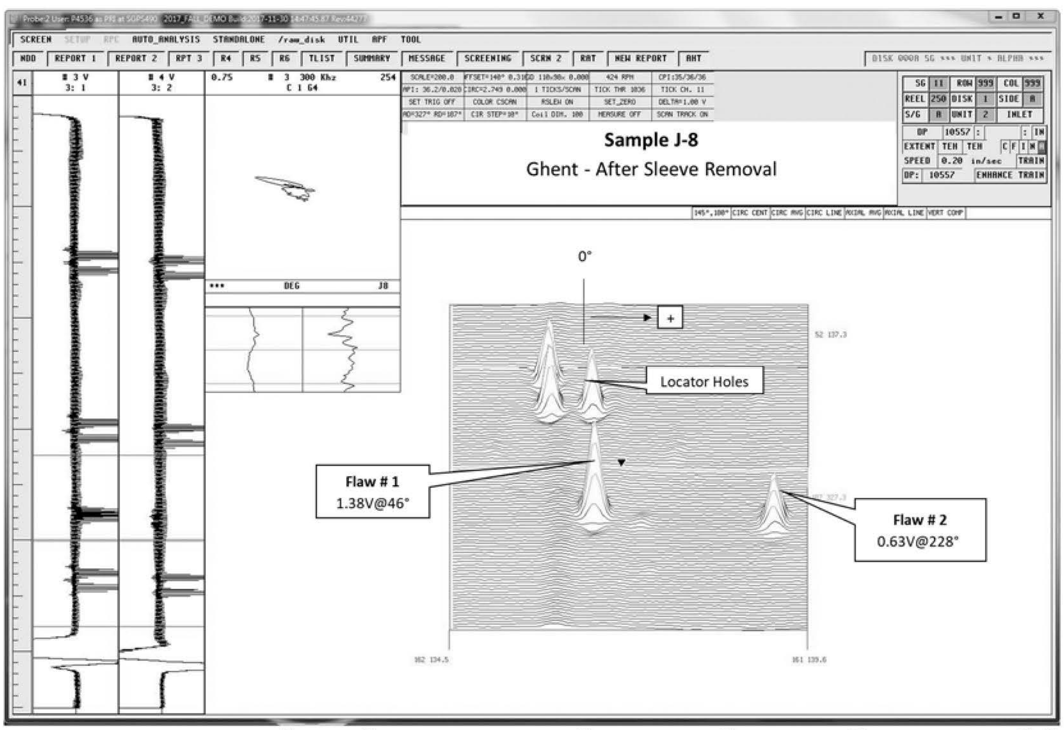

Figure 3-3. Parent Tube Crack Sample J-8, Post Sleeve Test Standard Ghent Probe C-Scan

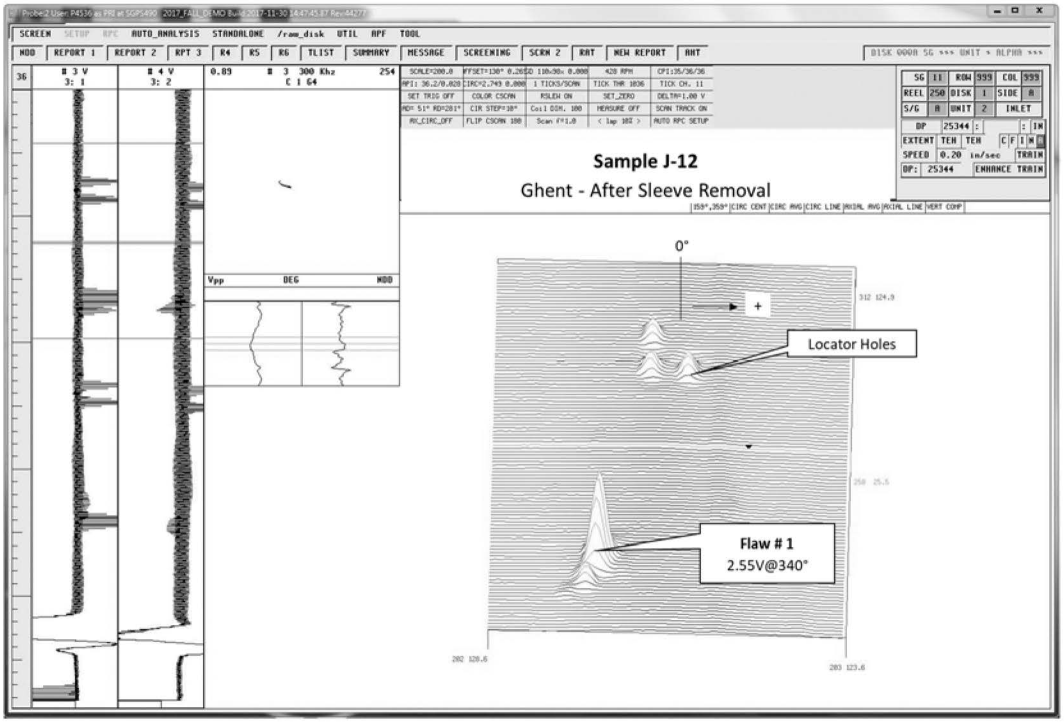

Figure 3-4. Parent Tube Crack Sample J-12, Post Sleeve Test Standard Ghent Probe C-Scan

3.3 GHENT VERSION 2 PROBE INSPECTION OF NICKEL BAND TZ SLEEVES

The test program for the Ghent Version 2 probe utilized test assemblies consisting of the parent tube crack sample, a nickel band TZ sleeve and a tubesheet simulant collar. Eddy current data was collected on each test assembly using the Ghent Version 2 probe.

The tubesheet simulant collar was a split collar fabricated from low alloy carbon steel. The split collar design provided the ability to be used assembled and then disassembled for each of the parent tube crack samples. The tubesheet bore was machined to closely match the parent tube outer diameter. This was done to prevent the cracks from deforming or "opening up" due to ligament tearing when the parent tube was hard rolled into the tubesheet simulant collar. This was demonstrated through a previous test program which was discussed in the Question 5 response of Reference 5. Each parent tube crack sample was manually hard-rolled into the collar until firm contact was achieved to further prevent deformation of the cracks. As the Ghent probe is surface riding, not achieving full expansion to the full diameter of a prototypic in-generator tubesheet bore would have negligible effects on the eddy current results due to the small amount of tube wall thinning.

Eddy current data was collected for each parent tube/sleeve/collar test assembly using the Ghent Version 2 probe using the techniques and essential variables described in the Appendix H qualification documented in Reference 8. The data was collected at frequencies of 240/130/70/40 kHz. The 70kHz frequency channels are used to report degradation within the parent tube behind the nickel band at the lower sleeve

joint. All further references to the Ghent Version 2 eddy current results (i.e., voltage amplitude) herein are based upon the 70kHz reporting channel results.

Following analysis of the collected eddy current data, it was determined that four of the twelve parent tube flaws were detected through the nickel band region of the TZ sleeve using the Ghent Version 2 probe. From Section 3.4, the flaw depths from destructive examination depths of the detected flaws were [ ]^{b}. The depths of the flaws not detected ranged from [ ]^{b}. The eddy current graphics of the parent tube/sleeve/collar assemblies are shown in Figures 3-5 through 3-10. Because the sleeve nickel band could not completely encompass all of the multiple flaws contained in Sample J-2-3, it was necessary to re-position the sleeve and re-test the assembly two additional times. Figures 3-5, 3-6, and 3-7 show the results after each sleeve repositioning. Each figure clearly delineates the flaws that were within and not within the nickel band region.

Upon completion of the eddy current analysis of the test assemblies, the parent tube samples were removed from the tubesheet simulation split collar and the sleeves removed from the parent tubes. Additional eddy current was performed on each sample to obtain the final as-left condition prior to destructive examination. Each parent tube sample (no sleeve) was tested with the +POINT probe and a non-modified standard Ghent G3/G4 probe. These results are shown in Table 3-1. Comparison of the pre-test and post-test +POINT probe results show little to no change in the voltage amplitudes. Therefore, the measures taken to avoid flaw ligament tearing during the test program were successful.

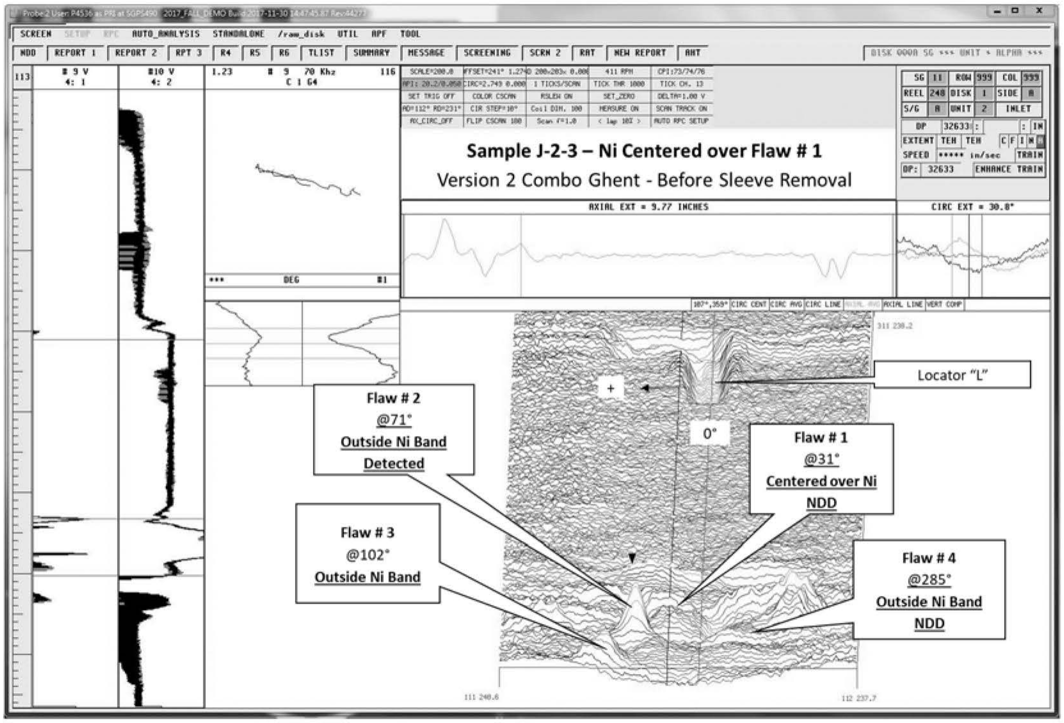

Figure 3-5. Sample J-2-3 Sleeve/Tube Assembly Ghent V2, Nickel Over Flaw #1 C-Scan

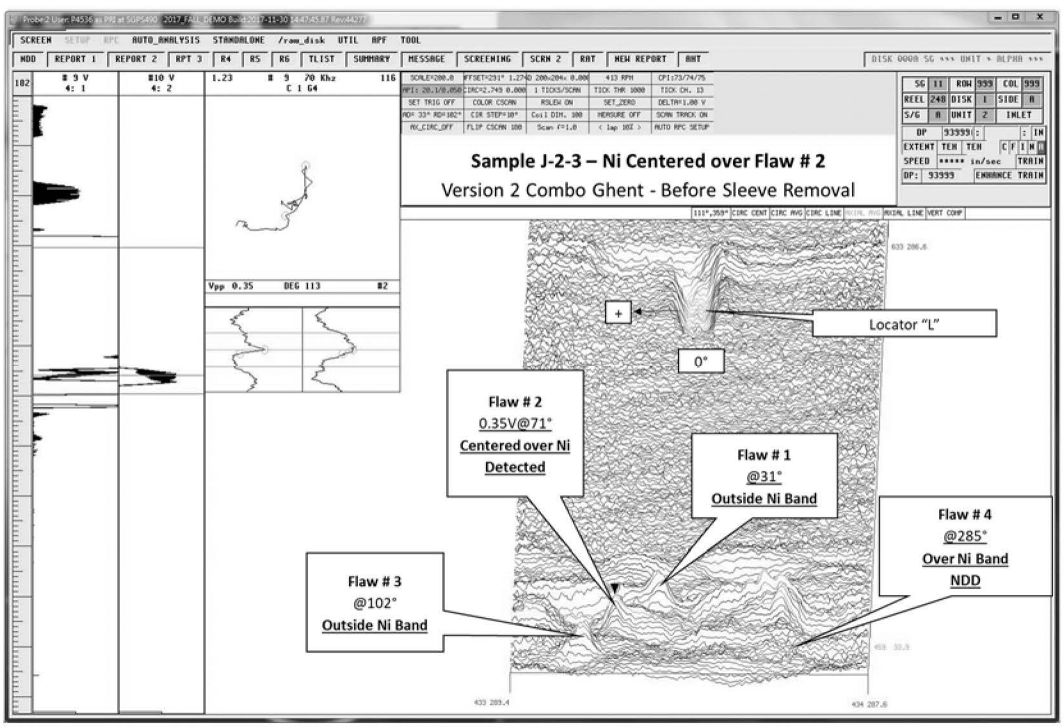

Figure 3-6. Sample J-2-3 Sleeve/Tube Assembly Ghent V2, Nickel Over Flaw #2/Flaw #4 C-Scan

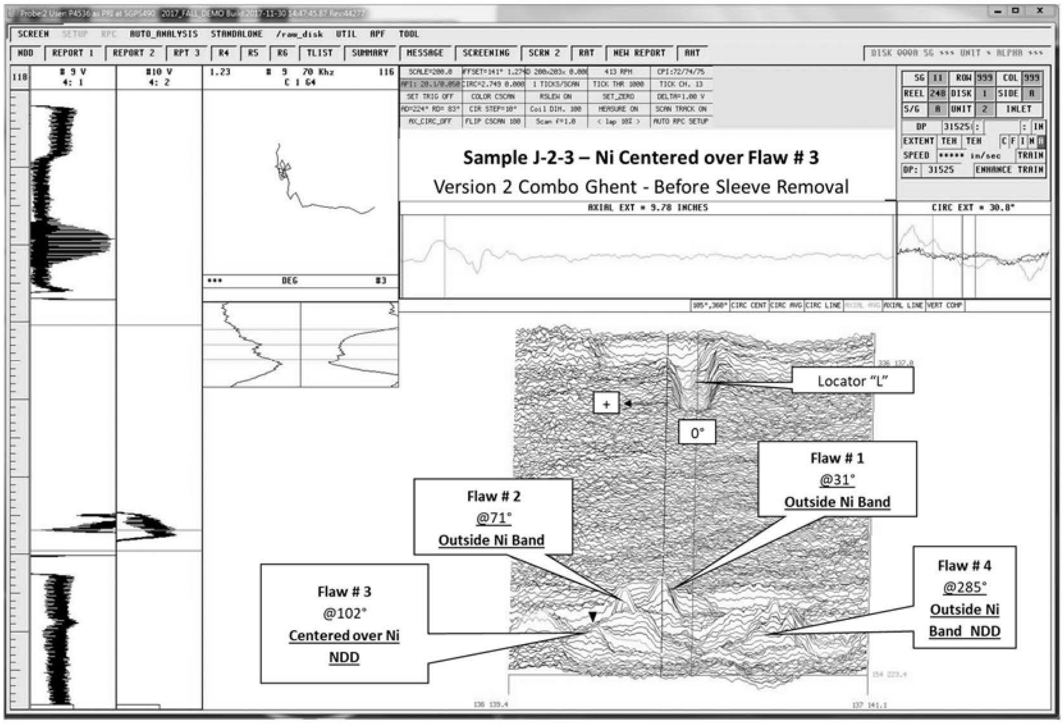

Figure 3-7. Sample J-2-3 Sleeve/Tube Assembly Ghent V2, Nickel Over Flaw #3 C-Scan

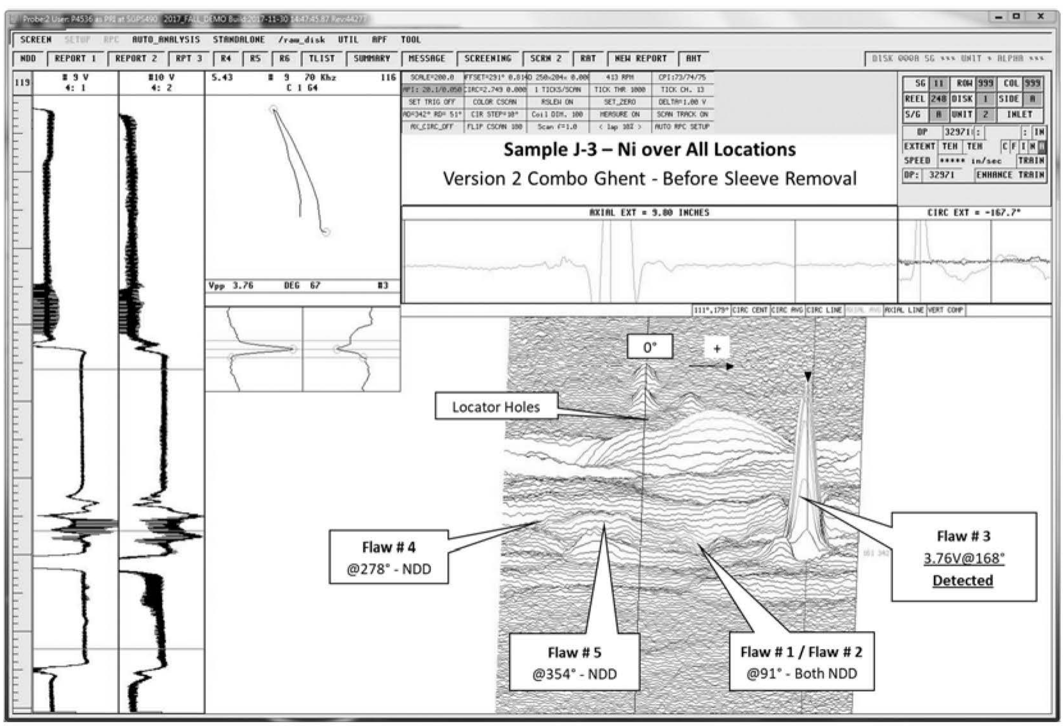

Figure 3-8. Sample J-3 Sleeve/Tube Assembly Ghent V2, Nickel Over All Flaws C-Scan

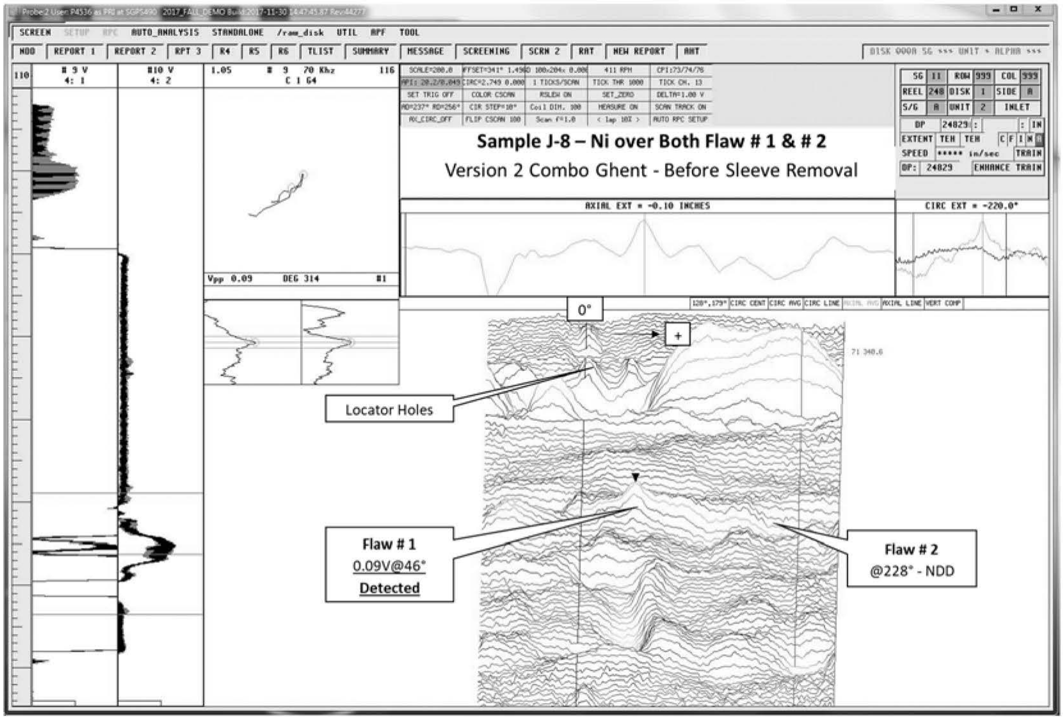

Figure 3-9. Sample J-8 Sleeve/Tube Assembly Ghent V2, Nickel Over All Flaws C-Scan

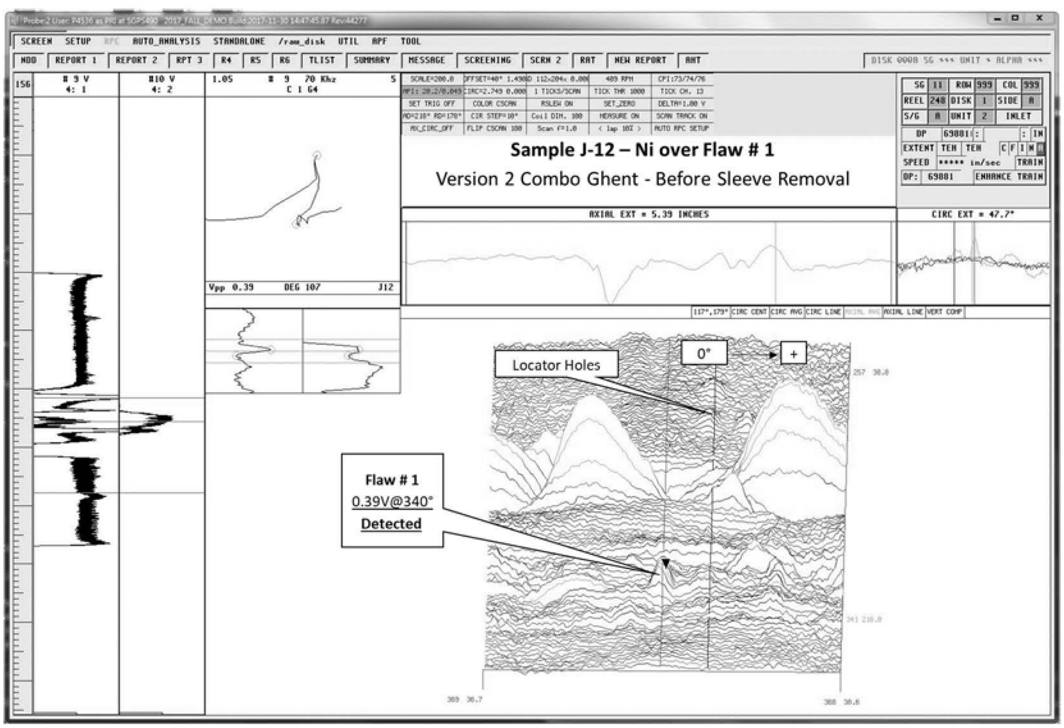

Figure 3-10. Sample J-12 Sleeve/Tube Assembly Ghent V2, Nickel Over Flaw C-Scan

3.4 DESTRUCTIVE EXAMINATION

The destructive examination of the parent tube crack samples was performed by Westinghouse at the Churchill laboratory facilities. Reference 9 provides the complete results of the destructive examination. A summary of the key findings is provided below.

Each tube sample was internally pressure tested to facilitate opening of the tight cracks in preparation for the destructive examinations. The pressure tests resulted in fish-mouth openings of several of the deeper flaws and widened the crack openings of the shorter and shallow cracks. The pressure testing used internal bladders with copper foil covering the flaw to protect the bladder from the sharp edge of the crack should the tube burst. Figure 3-11 shows the four parent tube samples following the burst testing. Prior to the pressure test, each sample was examined using low magnification light optical microscopy (LOM) to assess the general surface condition and to further identify the presence of the cracking. This examination showed that the character of the flaws is typical of environmentally assisted axial stress corrosion originated on the tube outer diameter surface. Figure 3-12 shows a typical flaw morphology from the outer diameter surface as shown for Sample J-2-3.

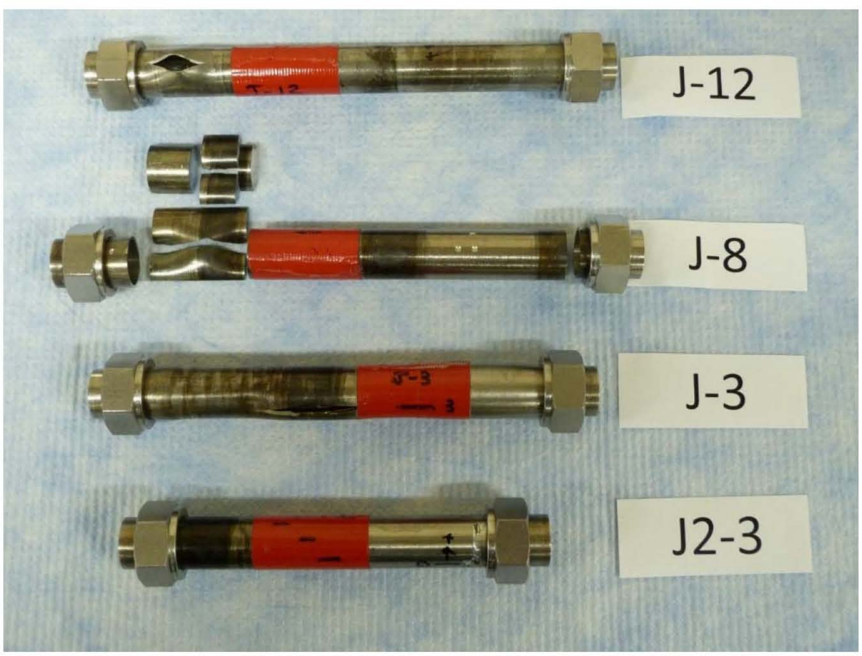

Figure 3-11. Parent Tube Crack Samples Following Burst Testing

Figure 3-12. Typical Crack Morphology from LOM Surface Examination of Sample J-2-3

The destruction examination of the flaws consisted of scanning electron microscope (SEM) fractography to ascertain the radial flaw depths across the tube wall thickness. From the SEM fractography, the maximum flaw depths were recorded. Figure 3-13 provides a typical fractograph as shown for Sample J-2-3 Flaw #2. The recorded flaw depths from the destructive examination are provided in Table 3-2. The maximum depth of the twelve flaws range from [ ][b].

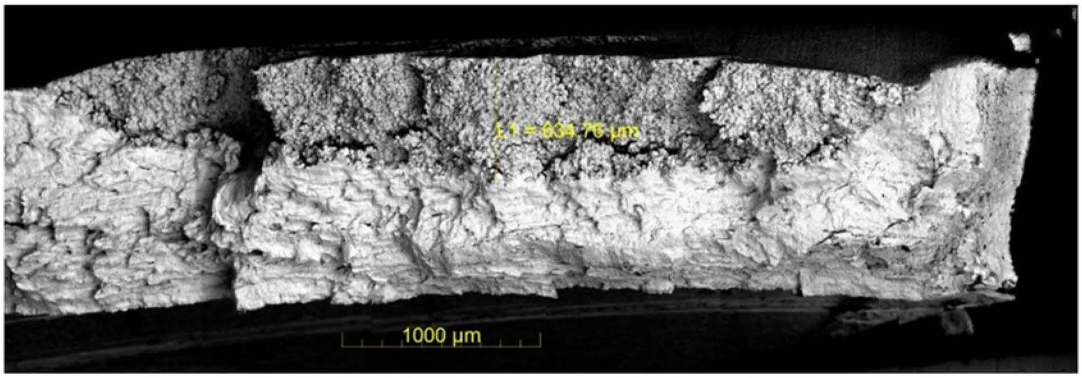

Figure 3-13. Typical SEM Fractograph for Sample J-2-3 Flaw #2

Table 3-2. Destructive Examination Results

Tube Sample	Flaw No.	Flaw Location	Post Sleeve Standard Ghent Voltage (Vpp)	Max. Radial Flaw Depth (µm)	Max. Radial Depth of Flaw (mils)	DE Flaw Depth (%TW)[1]
J-2-3	1	31 deg	1.2			
	2	71 deg	2.62			
	3	102 deg	1.07			
	4	285 deg	0.27			
J-3	1	91 deg	0.28			
	2	91 deg	0.63			
	3	168 deg	21.6			
	4	278 deg	0.21			
	5	354 deg	0.59			
J-8	1	26 deg	1.38			
	2	228 deg	0.63			
J-12	1	340 deg	2.55			

b

(1) The percent through-wall flaw penetration is based on the nominal undegraded 50.0-mil wall thickness.

4 PROBABILITY OF DETECTION MODELING AND RESULTS

The results from the tube crack sample eddy current and destructive examinations performed and described in the previous sections provide the necessary information to develop the probability of detection parameters for SCC in the parent tube behind the nickel band at the lower sleeve joint. The methodology used to develop the POD distributions follow industry accepted methods, specifically binary (hit-miss) Generalized Linear Modeling (GLM). The use of binary hit-miss GLM models for SG NDE applications is discussed in the EPRI SG Integrity Assessment Guidelines (Reference 11). For these applications NDE flaw detections, coded as “1” (hits), and flaw non-detections, coded as “0” (misses), are plotted using a structural parameter, typically flaw depth, and non-linearly regressed using a mathematical function to define the POD model. The mathematical functions used for SG NDE applications are typically the log-logistic and logistic functions, whereas the log-logistic function being more widely used. Binary hit-miss POD modeling can be performed for discrete data points directly from actual NDE results; herein referred to as the “simple POD” method. Binary POD modeling through probabilistic simulations by combining noise and structural parameter distributions to develop a large database of hits and misses for plotting is also used for SG applications. This method is known as the noise-based Model Assisted Probability of Detection (MAPOD) method. EPRI has developed a software package (Reference 13) to develop noise-based POD curves using the log-logistic function.

The simple hit-miss POD model and the noise-based MAPOD model are used to describe the capabilities of the Ghent Version 2 probe to detect SCC in the parent tube behind the nickel band at the lower TZ sleeve joint. These models and their results are discussed in the following sections.

4.1 SIMPLE HIT-MISS POD MODEL

The simple hit-miss POD model uses the Ghent Version 2 probe eddy current data collected for each of the twelve flaws in the parent tube crack samples and their corresponding depths from destructive examination. Table 3-1 provides the sleeve/tube/collar eddy current results for flaw detection or non-detection (NDD) using the Ghent Version 2 probe and the destructive examination depth. The Ghent Version 2 probe detected four of the twelve available flaws. The maximum depths of the detected flaws were [ ]^{a,c,e}. These detected flaws (hits) were coded as “1” for the binary modeling input. The remaining eight flaws were not detected. The non-detected flaw depths ranged from [ ]^{a,c,e}. These non-detected flaws (misses) were coded as “0” for the binary modeling input.

Figure 4-1 provides the resultant POD curves for the log-logistic and logistic functions for the binary GLM modeling. The POD performance for the log-logistic and logistic functions are essentially identical. The 95th percentile log-logistic POD, or POD(0.95), is 74.5% TW. The 50th percentile POD for both function types is 67.8% TW.

a,c,e

Figure 4-1. Ghent Version 2 Probe Simple POD for Parent Tube SCC Behind Sleeve Nickel Band

4.2 NOISE-BASED MAPOD MODEL

The noise-based MAPOD model performs hit-miss simulations through probabilistic sampling of three distributions; a tube noise distribution, a flaw depth to flaw voltage amplitude distribution (Ahat), and a flaw signal-to-noise (S/N) threshold distribution for determining hits/misses. The POD model first samples a random depth and determines the corresponding flaw voltage amplitude from the Ahat distribution. A random noise voltage amplitude is sampled from the noise distribution. A S/N value is determined from this sampled data and compared to a sampled S/N threshold value. If the simulated flaw S/N value is greater than the sampled S/N threshold value, the sampled flaw depth is considered to be detected (a hit). Likewise, if the simulated flaw S/N is less than the sampled S/N threshold, then the sampled flaw depth is considered to be non-detected (a miss). This process is repeated 100,000 times to develop a robust hit-miss data set for input to the binary GLM model to produce the POD curve.

4.2.1 Development of the Ahat Distribution

The flaw depth to flaw voltage amplitude correlation (Ahat) is derived from the Ghent Version 2 eddy current data described in Section 3.3 and the maximum depths determined through destructive examination of the same flaws as described in Section 3.4. Figure 4-2 shows the correlation of the Ghent Version 2

probe raw voltage amplitude (Vpp) to the maximum depth from destructive examination for the flaws behind the nickel band that were detected by the Ghent Version 2 probe. The Ahat correlation used in the MAPOD model is in the form of the natural logarithm (Ln) of voltage amplitude on either depth (linear Ahat function) or the natural logarithm of depth (logarithm Ahat function). Figures 4-3 and 4-4 provide the Ahat correlations for the linear Ahat and logarithm Ahat functions, respectively. As shown on these figures, the linear Ahat (Ln(Vpp) on depth) provides a slightly better correlation and slighter lower standard error. Therefore, the linear Ahat correlation will be used for the MAPOD simulations.

a,c,e

[ ]

Figure 4-2. Maximum Depth to Voltage Amplitude for Detected Flaws

a,c,e

Figure 4-3. Ghent Version 2 Probe Linear Ahat Function Correlation

a,c,e

Figure 4-4. Ghent Version 2 Probe Logarithm Ahat Function Correlation

4.2.2 Development of the Noise Distribution

The Ghent Version 2 probe was developed and fabricated following the most recent SG inspection outage at Beaver Valley Unit 2. As such, no field data has been collected with the Ghent Version 2 probe in which to build an in-generator noise distribution. A noise distribution was developed using the available data from the Ghent Version 2 probe EPRI Appendix H qualification program as described in Reference 8. This qualification program contained nine tube/sleeve collar test assemblies. The collected eddy current data was re-analyzed to measure the axial noise voltage amplitude at two locations per test assembly. The noise data was taken at the reporting frequency of 70kHz with a window width of 60 degrees that is appropriate for axially oriented degradation. Figure 4-5 provides the resultant noise distribution. This noise distribution from the Appendix H qualification test assemblies is a reasonable representation of in-generator noise as the effects of the nickel band provides the largest contributor to noise in the parent tube/sleeve configuration within the tubesheet.

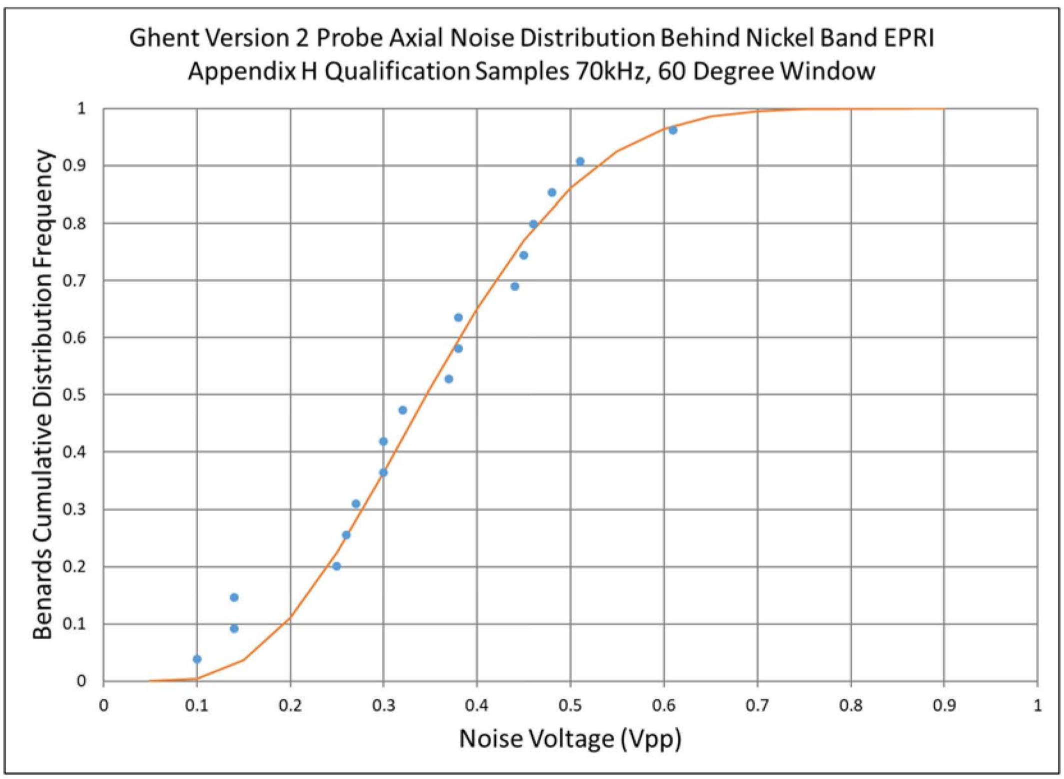

Figure 4-5. Ghent Version 2 Probe Axial Noise Distribution, 70kHz 60 Degree Window

4.2.3 S/N Threshold Value Development

The noise based MAPOD model uses an upper and lower S/N threshold to determine if a simulated flaw S/N ratio results in flaw detection or non-detection. For each of the 100,000 simulations, a uniform distribution between the lower and upper S/N threshold values is randomly sampled to serve as the criteria for simulated flaw detection. Simulated flaw S/N values greater than the sampled S/N threshold are treated as flaw detections and likewise, flaw S/N values less than the threshold values are flaw non-detections. The upper and lower threshold values are determined by examining the results of the parent tube/sleeve/collar assembly eddy current data collected and described in Section 3.3. The lower S/N threshold value is determined by evaluating the detected flaw data, while the upper S/N threshold value is determined by evaluating the non-detected flaw data.

[

]a,c,e.

The Ghent Version 2 probe voltage-to-depth correlation shown in Figure 4-2 is used to estimate the voltage amplitude of undetected flaws. [

]a,c,e

[

]a,c,e This is illustrated in Figure 4-6.

Table 4-3 provides the estimated S/N ratios of undetected flaws [

]a,c,e

The S/N threshold values used in the MAPOD model were [ ]a,c,e for the upper threshold.

Table 4-1. Ghent Version 2 Probe Test Sample Noise

Sample	Noise Data Point	Noise Vpp	Sample Average Noise Vpp	Sample Minimum Noise Vpp	Sample Maximum Noise Vpp
J-2-3	1				
	2				
	3				
	4				
J-3	1				
	2				
J-8	1				
	2				
J-12	1				
	2				

b

a,c,e

Table 4-2. Test Sample Signal-to-Noise Adjacent to Detected Flaws

EPRI Sample	Flaw No.	Ghent V2 Flaw Voltage Vpp	Noise Beside Flaw Vpp	S/N Using Average Noise	S/N Using Minimum Noise	S/N Using Maximum Noise
J-2-3	2	0.35				
J-8	1	0.09				
J-12A	1	0.39				
J-3	3	3.76				
		Average Excluding Sample J-3				

b

a,c,e

a,c,e

Figure 4-6. Voltage-to-Depth Correlation Uncertainty

Table 4-3. Estimated Signal-to-Noise Ratio of Non-Detected Flaws

EPRI Sample	Flaw	Depth %TW	Est. Ghent V2 Vpp	S/N using Minimum Noise Vpp	95/50 Using Standard Error of 0.14 Vpp	95/50 S/N
J-2-3	1					
	3					
	4					
J-3	1					
	2					
	4					
	5					
J-8	1					

b

a,c,e

4.2.4 MAPOD Simulations

POD simulations were performed using the noise-based MAPOD methodology using the noise distribution, linear Ahat correlation, and the S/N threshold values described above in Sections 4.2.1, 4.2.2, and 4.2.3. The resultant POD curve is shown in Figure 4-7. The 95th percentile POD for the log-logistic function is 93.7% TW and the 50th percentile is 77.1% TW. The logistic function produces similar results with a POD(0.95) of 92.3% TW and a POD(0.50) of 77.6% TW.

Comparison of the simple POD (Figure 4-1) to the noise based MAPOD results (Figure 4-7), initially shows an apparent disparity between the detection capabilities of each method. The simple POD results in a POD(0.95) of 74.5% TW whereas the noise-based MAPOD results in a POD(0.95) of 93.7% TW. Further investigations discussed below have shown that the noise-based MAPOD method introduces unique conditions to the effect of the nickel band on the Ahat and noise distributions that are not present for applications with no nickel material. These effects account for noise both within the Ahat correlation and the noise distributions, thereby compounding the masking effects of the nickel material. The MAPOD methodology is based on the presumption that the full effects of noise and flaw masking are accounted for within the noise distribution. The nickel band material in the sleeve/tube configuration reduces the flaw voltage amplitude in addition to introducing a noise component. This effect was demonstrated through the NDE program described in Section 3.3, with supplemental data analysis. The simple POD distribution (Figure 4-1) was generated with the flaw depths and the detection hit or miss result as the only inputs. The full effect of the nickel band material on detection is inherent in the detection result with no direct dependence on the developed noise and Ahat distributions. Therefore, the simple POD distribution provides the better representation of actual flaw detection performance. To reduce the compounding masking effects of the nickel, an adjustment was applied to the noise-based MAPOD method that reduced the compounding masking effects of the nickel material to produce a POD distribution more comparable with the simple POD result as discussed below.

As discussed in Section 3.3, parent tube crack Sample J-2-3 contained multiple flaws that extended beyond the test sleeve nickel band. Therefore, the sleeve was re-positioned twice to ensure that each of parent tube flaws were eddy current tested within the center of the nickel band. The voltage amplitude of Flaw #2 was 0.36 Vpp when centered within the nickel band. When the sleeve was re-positioned, Flaw #2 was located on the edge of the nickel band. The effect of the nickel material on flaw signals at the edge of the band is [

]^{a,c,e} These results are shown on Table 4-4.

A MAPOD simulation was performed using an "optimized" Ahat correlation to address the combined effect of nickel on the Ahat and noise distributions. To account for the compounding effects of the nickel material,

[

]a,c,e The optimized linear Ahat correlation and the full noise distribution from the Appendix H qualification samples (Figure 4-5) were used in the MAPOD simulations. Figure 4-8 provides the resultant POD curve. The optimized MAPOD simulation produced a POD(0.95) of 86.0% TW and a POD(0.50) of 69.6% TW. The logistic POD function yields similar results. The optimized MAPOD simulation result is more comparable to the simple POD result thus demonstrating a reasonable method to reduce compounding nickel material effects.

Table 4-4. Test Sample J-2-3 Flaw Voltage Inside and Outside of Ni Band

Test Sample	Center of Nickel Vpp	Edge of Nickel Locn 1 Vpp	Edge of Nickel Locn 2 Vpp	Outside of Nickel Vpp
J-2-3 Flaw # 1	NDD	[		]
J-2-3 Flaw # 2	0.36			
J-2-3 Flaw # 3	NDD			

b

a,c,e

[ ]

Figure 4-7. Ghent Version 2 Probe Noise Based MAPOD for Parent Tube SCC Behind Sleeve Nickel Band

a,c,e

Figure 4-8. Ghent Version 2 Probe Noise Based MAPOD Using Optimized Ahat Correlation

4.3 APPLICABILITY OF OD FLAW DETECTION TO ID FLAW

The principal degradation concern with a lower sleeve joint is the potential for primary water stress corrosion cracking (PWSCC) as a result of the stresses imparted to the tube due to the sleeve installation (Reference 7). Reference 4 describes the three elements necessary for SCC initiation; a corrosive environment, a susceptible material, and tensile residual stress. If any one of these elements are absent or reduced below some threshold, SCC cannot occur. The lower sleeve joint is located approximately in the middle of the full depth rolled tubesheet (neutral axis) thereby isolating the lower sleeve joint from the secondary side chemical environment. Therefore, ODSCC in the parent tube at the lower sleeve joint is not a credible or potential degradation mechanism and is substantiated by the lack of ODSCC within the tubesheet being reported by the industry. PWSCC has occurred within the industry in the expanded portion of the tubesheet in non-sleeved tubes. These occurrences were predominately located at bulges, overexpansions or other geometric discontinuities caused by tubesheet drilling anomalies during tubesheet fabrication. Even though Reference 4 concluded that the occurrence of PWSCC within the parent tube behind the nickel band at the lower sleeve joint is sufficiently low, the focus of NDE inspection techniques is detection of PWSCC.

The NDE test program and POD curves developed within this document were based on ODSCC flaw samples. This was due to the unavailability of PWSCC flaw samples. The detection of OD flaws provides a conservative estimate of ID flaws due to the nature of eddy current magnetic theory. Multiple test frequencies are used to concentrate the eddy current field at various depths of penetration through the material being tested. For the inspection of the parent tube/sleeve joint within the tubesheet, the test frequency of 70 kHz concentrates the eddy current field on the inner portion of the parent tube for optimum detection of ID originating flaws such as PWSCC. As the magnetic fields at 70 kHz frequency penetrate deeper into the parent tube material, the signal strength and the signal density decreases, thus decreasing the flaw detection capability. Consequently, detection of flaws originating at the outer parent tube surface is diminished as compared to flaws originating at the inside parent tube surface. This effect is more profound for shallower OD originating flaws which require greater depth of magnetic field penetration for flaw detection. Shallower flaws that may not be detected on the tube OD may be detected if they originated on the tube ID where the magnetic field signal strength and density is greater. Therefore, POD curves based on OD originating flaws conservatively bound the POD for ID originating flaws. The detection capability for ID originating flaws is improved over OD flaw detection at the same frequency.

4.4 EXAMPLE OPERATIONAL ASSESSMENT USING DEVELOPED POD CURVES

An example operational assessment (OA) was performed to demonstrate the acceptability of the Ghent Version 2 probe POD curves developed in Sections 4.1 and 4.2. A fully probabilistic OA was performed in accordance with the guidance of Reference 11 for each of the three POD curves provide in Figures 4-1, 4-6, and 4-7. The OA assessed the SG performance criteria for probability of burst (POB) and probability of leakage (POL) over an inspection interval of one fuel cycle. The SG performance criteria that must be satisfied for Beaver Valley Unit 2 are as follows:

- POB, ≤ 5%
- POL, ≤ 5%
- Upper 95th percentile steam line break leakage (SLB), ≤ 0.10 gpm (allotment for leakage not associated with an alternate repair criterion)
- Lower 5th percentile burst pressure, ≥ 4525 psi (i.e., 3 times normal operating differential pressure)

The OA evaluations assumed that the parent tube flaws were located in the straight leg freespan region of the tube with no sleeve or tubesheet present. The burst and leakage equations of Reference 14 provided the calculation methodologies. These are very conservative assumptions as the presence of the tubesheet behind the parent tube and the presence of the sleeve eliminates the burst potential and greatly reduce the postulated leakage compared to a freespan flaw.

The fully probabilistic OA begins with determining the undetected flaw size distribution in terms of depth and length. The undetected flaw depth distribution is generated using the developed POD curves. The flaw length distribution is assumed to be a uniform distribution from [ ]^{a,c} inch in axial length.

The upper bound length extends to the full length of the nickel band and the lower bound length provides a conservative estimate for an undetected flaw. The number of undetected flaws is assumed to be three. This is a conservative value as there have been no reports in the industry of flaws in the roll flat region of the parent tube at the lower sleeve joint. The industry maximum depth growth distribution provided in Reference 11 was applied to the beginning of cycle (BOC) flaw distribution. No length growth was applied as the BOC length distribution is a reasonable estimate of the flaw lengths at the end of the cycle. Each probabilistic OA run contained 100,000 simulations. The population of affected tubes is 481, which is the total number of TZ sleeves currently in service at Beaver Valley Unit 2 and all were assumed to be contained in one SG.

Three fully probabilistic runs were performed. The only difference between in the runs was the applied depth POD curve. All other inputs were the same. Case A used the simple hit/miss POD defined in Figure 4-1. Case B used the optimized Ahat POD curved defined in Figure 4-8 and Case C used the unadjusted Ahat POD curve defined in Figure 4-7. Case C is a conservative estimate of POD due to the compounding effects of the nickel material on both the noise distribution and Ahat correlation. This run was performed for comparison purposes.

Table 4-5 provides the results of the three fully probabilistic OA runs. For all cases, the SG performance criteria were satisfied following one fuel cycle of operation. Case A resulted on a POB of 1.15%, a POL of 0.034%, a burst pressure of 5355 psi and no SLB leakage with application of the simple hit/miss curve of Figure 4-1. Case B resulted in slightly higher values, but well within the SG performance criteria. SG performance criteria was also satisfied for the conservative Case C using the POD curve based on an unadjusted Ahat correlation (Figure 4-7). The resultant POB and POL for Case C was 3.53% and 0.148%, respectively, with no predicted SLB leakage. These results assumed parent tube flaws located in the freespan without the constraining effects of the tubesheet or presence of a tube sleeve. For the actual tube/sleeve/tubesheet configuration, parent tube burst is not possible, and leakage would be greatly diminished.

The results of this OA demonstrate the acceptability of the Ghent Version 2 probe and the associated POD curves to detect parent tube flaws with SCC behind the nickel band region in the lower tubesheet sleeve joint.

Table 4-5. Fully Probabilistic Operational Assessment Results

Case	Applied POD Curve	Probability of Burst (%)	Probability of Leak (%)	Upper 95^{th} Percentile SLB Leakage (gpm)	Lower 5^{th} Percentile Burst Pressure (psi)
Case A	Simple Hit/Miss Figure 4-1	1.15	0.034	0	5355
Case B	Optimized Ahat Figure 4-8	2.25	0.106	0	5025
Case C	Unadjusted Ahat Figure 4-7	3.53	0.148	0	4746
SG Performance Criteria	--	≤ 5	≤ 5	≤ 0.10	≥ 4525

5 CONCLUSIONS

In response to the NRC staff questions regarding the NDE flaw detection capabilities, the Ghent Version 2 was developed specifically to improve inspection capabilities for the nickel banded area in the lower sleeve-to-tube joint within the tubesheet. The Ghent Version 2 probe demonstrated improved inspection capabilities as compared to the +POINT probe through reducing the interfering effects of the nickel band material. Through a testing program of axial ODSCC flaws, the Ghent Version 2 probe was able to detect cracks from [ ]^{b} TW in simulated parent tube/sleeve/tubesheet collar assemblies. A POD curve was generated based upon the detection and non-detection of the test assembly flaws that resulted in a 74.5% TW at the 95^{th} percentile and 67.8% at the 50^{th} percentile. A noise based MAPOD was developed that addressed the effect of nickel material on eddy current noise and flaw voltage amplitudes. MAPOD simulations demonstrated a 95^{th} percentile POD of 86.0% TW and 69.6% TW at the 50^{th} percentile. The OA process using these developed POD curves resulted in satisfaction of all SG performance criteria with considerable margin after one fuel cycle of operation, thus demonstrating the acceptability of the Ghent Version 2 probe to identify parent tube flaws behind the nickel band at the lower Alloy 800 TZ sleeve joint. Through implementation of a 100% Ghent Version 2 probe inspection of all in-service Alloy 800 sleeves each outage, the eight-cycle service life restriction can be eliminated.

6 REFERENCES

1. First Energy Letter No. L-08-307, "Beaver Valley Power Station Unit No. 2 Docket No. 50-412, License No. NPF-73, License Amendment Request No. 07-007 Alloy 800 Steam Generator Tube Sleeving," October 2008. (NRC ADAMS Accession No. ML082890823)
2. USNRC Letter, "Beaver Valley Power Station, Unit 2 – Issuance of Amendment RE: The use of Westinghouse Leak-limiting Alloy 800 Sleeves for Steam Generator Tubes Repair (TAC No. MD9969)," September 2009. (NRC ADAMS Accession No. ML092590189)
3. First Energy Letter No. L-18-081, "Beaver Valley Power Station Unit No. 2 Docket No. 50-412, License No. NPF-73, Steam Generator Technical Specification Amendment Request," March 28, 2018. (NRC ADAMS Accession No. ML18087A293)
4. Westinghouse Letter LTR-SGMP-18-3 P-Attachment, Revision 0, "Steam Generator Alloy 800 Nickel Band Tubesheet Sleeve Operating Cycle Length Extension License Amendment Request: Technical Basis," March 2018.
5. Westinghouse Letter LTR-SGMP-18-40 P-Attachment, Revision 0, "Responses to Request for Additional Information Regarding Beaver Valley Power Station Unit No. 2 Amendment Request for Use of Westinghouse Leak-Limiting Alloy 800 Sleeves in Steam Generators," October 2018.
6. USNRC Letter, "Beaver Valley Power Station, Unit 2 – Issuance of Amendment 193 RE: Revise Steam Generator Technical Specifications (EPID L-2018-LLA-0075)," February 2019. (NRC ADAMS Accession No. ML18348B206)
7. WCAP-15919-P, Revision 2, "Steam Generator Tube Repair for Westinghouse Designed Plants with 7/8 Inch Inconel 600 Tubes Using Leak Limiting Alloy 800 Sleeves," January 2006.
8. Westinghouse Report SG-CDMP-19-17, Revision 1, "Qualification of an Examination Technique to Inspect Parent Tube Flaws Adjacent to the Nickel Band of an Alloy 800 Sleeve at Beaver Valley Unit 2," April 2020.
9. Westinghouse Report RT-TR-19-43, Revision 0, "Steam Generator Tube OD Flaw Sizing in Support of Ghent Probe POD for Beaver Valley Unit 2 Nickel Band Sleeving," November 2019.
10. EPRI Technical Report 3002007572, "Steam Generator Management Program: Pressurized Water Reactor Steam Generator Examination Guidelines: Revision 8," June 2016.
11. EPRI Technical Report 3002007571, "Steam Generator Management Program: Steam Generator Integrity Assessment Guidelines: Revision 4," June 2016.
12. EPRI Technical Report 3002007856, "Steam Generator Management Program: Steam Generator In Situ Pressure Test Guidelines: Revision 5," June 2016.
13. EPRI Product 30020010334, "Steam Generator Management Program: Model Assisted Probability of Detection Using R (MAPOD-R) Version 2.1," 2017.

14. EPRI Technical Report 3002005426, "Steam Generator Management Program: Steam Generator Degradation Specific Management Flaw Handbook, Revision 2," October 2015.

Enclosure F
L-20-071

Affidavit

(3 pages follow)

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:
COUNTY OF BUTLER:

(1) I, Zachary S. Harper, have been specifically delegated and authorized to apply for withholding and execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse).

(2) I am requesting the proprietary portions of SG-CDMP-19-17-P, Revision 1, "Qualification of an Examination Technique to Inspect Parent Tube Flaws Adjacent to the Nickel Band of an Alloy 800 Sleeve at Beaver Valley Unit 2" and SG-CDMP-19-19 P-Attachment, Revision 1,"Probability of Flaw Detection in the Alloy 800 Mechanical Sleeve Lower Tubesheet Joint Using the Ghent Version 2 Eddy Current Probe," be withheld from public disclosure under 10 CFR 2.390.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged, or as confidential commercial or financial information.

(4) Pursuant to 10 CFR 2.390, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse and is not customarily disclosed to the public.

(ii) Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information

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to meet NRC requirements for licensing documentation without purchasing the right to use the information.

(5) Westinghouse has policies in place to identify proprietary information. Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage (e.g., by optimization or improved marketability).

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

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(6) The attached documents are bracketed and marked to indicate the bases for withholding. The justification for withholding is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (5)(a) through (f) of this Affidavit.

I declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: 4/16/2020

Zachary S. Harper, Manager
Licensing Engineering