NEXTera ENERGY POINT BEACH

August 29, 2019

NRC 2019-0026
10 CFR 50.55a

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Point Beach Nuclear Plant Unit 2
Docket 50-301
Renewed License No. DPR-27

Relief Request 2-RR-17
Extension of the Point Beach Unit 2 Steam Generator Primary Nozzle Dissimilar Metal (DM) Weld Inspection Interval

References: (1) NRC Letter to NextEra Energy Point Beach, LLC dated March 22, 2016, Point Beach Nuclear Plant, Unit 2 – Approval of Relief Request 2-RR-11; Steam Generator Nozzle to Safe-End Dissimilar Metal (DM) Weld Inspection RE: (CAC NO. MF6615) (ML 16063A058)

Pursuant to 10 CFR 50.55a(z)(1), NextEra is requesting Nuclear Regulatory Commission (NRC) approval of the proposed extension to Code Case N-770-2, Table 1, Inspection Item A-2, volumetric examination from every 5 years and Inspection Item B, volumetric examination from every second inspection period not to exceed 7 years. The extension requested is for a period not to exceed one refueling outage. The examination will be performed no later than the Fall 2021 refueling outage (U2R38), approximately 9 years from the previous examination (U2R32 in November 2012).

The enclosure to this letter provides the basis and supporting information for the proposed alternative.

Attachment 1 contains one copy of LTR-SDA-19-071-P, Revision 0, dated August 2019, "Point Beach Unit 2 Steam Generator Safe-End Dissimilar Metal Weld Alloy 52 Inspection Extension" (Proprietary). Withhold from public disclosure under 10 CFR 2.390. Upon removal of Attachment 1, this letter is uncontrolled.

Attachment 2 contains one copy of LTR-SDA-19-071-NP, Revision 0, dated August 2019, "Point Beach Unit 2 Steam Generator Safe-End Dissimilar Metal Weld Alloy 52 Inspection Extension" (Non-Proprietary).

Proprietary Information - Withhold Under 10 CFR 2.390.
Attachment 1 Contains Proprietary Information,
Upon Separation of Attachment 1 this letter is Nonproprietary.

Attachment 3 contains the Westinghouse affidavit and the proprietary information and copyright notices supporting the withholding of Attachment 1 from public disclosure pursuant to 10 CFR 2.390.

Attachment 1 contains information proprietary to Westinghouse Electric Company LLC ("Westinghouse"), it is supported by an Affidavit signed by Westinghouse, the owner of the information. The Affidavit sets forth the basis on which the information may be withheld from public disclosure by the Nuclear Regulatory Commission ("Commission") and addresses with specificity the considerations listed in paragraph (b)(4) of Section 2.390 of the Commission's regulations.

Accordingly, it is respectfully requested that the information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to the copyright or proprietary aspects of the items listed above or the supporting Westinghouse Affidavit should reference CAW-19-4934 and should be addressed to Camille T. Zozula, Manager, Infrastructure & Facilities Licensing, Westinghouse Electric Company, 1000 Westinghouse Drive, Suite 165, Cranberry Township, Pennsylvania 16066.

NextEra requests approval of this request by December 31, 2019.

This letter contains no new Regulatory Commitments or revisions to existing Regulatory Commitments.

If you have questions regarding this submittal, please contact me at 920-755-7854.

Sincerely yours,

Eric Schultz
Licensing Manager
NextEra Energy Point Beach, LLC

Enclosure

cc: Regional Administrator, Region III, USNRC
Project Manager, Point Beach Nuclear Plant, USNRC
Resident Inspector, Point Beach Nuclear Plant, USNRC

ENCLOSURE
RELIEF REQUEST 2-RR-17
NEXTERA ENERGY POINT BEACH, LLC
EXTENSION OF THE POINT BEACH UNIT 2 STEAM GENERATOR PRIMARY NOZZLE DISSIMILAR METAL (DM) WELD INSPECTION INTERVAL

Proposed Alternative
In Accordance with 10 CFR 50.55a(z)(1)

--Alternative Provides Acceptable Level of Quality and Safety--

1. ASME Code Component(s) Affected

Class 1 Dissimilar Metal welds in accordance with the requirements of Code Case N-770-2
Drawing Numbers: ISI-2120, ISI-2121

Table 1		
Examination Category	**Code Case Inspection Item**	**Description**
N-770-2	A-2	RC-34-MRCL-AI-05, Safe-End to "A" Inlet Nozzle
N-770-2	B	RC-36-MRCL-AII-01A, "A" Outlet Nozzle to Safe-End
N-770-2	A-2	RC-34-MRCL-BI-05, Safe-End to "B" Inlet Nozzle
N-770-2	B	RC-36-MRCL-BII-01A, "B" Outlet Nozzle to Safe-End

2. Applicable Code Edition and Addenda

ASME Code Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 2007 Edition though 2008 Addenda as modified by 10 CFR 50.55a and Code Case N-770-2.

3. Applicable Code Requirements

Code Case N-770-2, "Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated with UNS N06082 or UNS W86182 Weld Filler Material with or without Application of Listed Mitigation Activities Section XI, Division 1."

ASME Section XI, Division 1, "Rules for Inservice Inspection of Nuclear Power Plant Components"

10 CFR 50.55a(g)(6)(ii)(F) requires that licensees of existing, operating pressurized water reactors implement the requirements of ASME Code Case N-770-2. Inspection Item A-2 of Code Case N-770-2 requires unmitigated butt welds at Hot Leg operating temperatures of $\leq$ 625°F to be volumetrically examined every 5 years. Inspection Item B requires unmitigated butt welds at Cold Leg operating temperatures of $\geq$525°F and < 580°F to be volumetrically examined every second inspection period not to exceed 7 years.

4. Reason for the Request

Relief Request 2-RR-11 was approved on March 22, 2016 (ML 16063A058) that allowed an extension of the volumetric examinations originally required at 5 and 7 years to 7.5 years during the U2R37 Spring 2020 refueling outage. Relief is being requested at this time to extend the Hot and Cold Leg examinations one additional cycle to U2R38 scheduled for Fall 2021 to allow for a coordinated examination schedule between the Hot and Cold Leg Dissimilar Metal welds and the planned Steam Generator examinations. This coordinated examination will allow Point Beach Nuclear Plant (PBNP) Unit 2 to only drain the reactor coolant system to low levels (i.e., mid-loop) and open the Steam Generator manways once instead of twice in the third period, thus minimizing the impact to nuclear, radiological, and industrial safety.

A site-specific weld crack growth analysis for PBNP, Unit 2 (Reference 2, Attachment 1) provides the overall basis for extension of the current volumetric inspection interval for the Steam Generator Primary Nozzle Hot and Cold Leg Dissimilar Metal welds. This technical basis demonstrates that the examination interval can be extended to the requested interval length while maintaining an acceptable level of quality and safety.

5. Proposed Alternative and Basis for Use

Pursuant to 10 CFR 50.55a(z)(1), NextEra Energy proposes an extension to Code Case N-770-2, Table 1, Inspection Item A-2, volumetric examination from every 5 years and Inspection Item B, volumetric examination from every second inspection period not to exceed 7 years. The extension requested is for a period not to exceed one refueling outage. The examination will be performed no later than the Fall 2021 refueling outage (U2R38), approximately 9 years from the previous examination (U2R32 in November 2012).

PBNP Unit 2 has two (2) Model D47F steam generators (SGs) which were installed as replacements in Fall 1996 (U2R22). The SGs are primarily carbon steel with the channel head and nozzles clad with austenitic stainless steel. The SG nozzle to safe-end weld (See Figure 1) is composed of Alloy 82/182 buttering and Alloy 82 weld material. The inside surface of the weld and adjacent base material was clad with Alloy 52 at the factory during fabrication. These welds received ASME Section III examinations (liquid penetrant and radiography) prior to installation. In addition, the ASME Section XI pre-service examinations (liquid penetrant and ultrasonic examinations) were performed prior to installation at PBNP.

The subject welds received ASME Section XI, Appendix VIII-demonstrated, automated phased array ultrasonic (PA-UT) examinations as well as ASME Section XI Appendix IV-demonstrated automated eddy current (ECT) examinations in November 2012 delivered with remote tooling from the inside surface. Neither the PA-UT nor the ECT recorded indications on any of the four DM welds. The use of both ECT and PA-UT techniques ensured that neither surface-breaking flaws nor sub-surface flaws were located within the inner 1/3t of the weld which could propagate through the Alloy 52 cladding material into the Alloy 82 weld material.

NextEra had provided a copy of the U2R32 ISI examination reports, as well as manufacturing information and a copy of the archive weld sample chemistry report (ML 15225A104) as part of the previously approved Relief Request 2-RR-11 (ML 16063A058). NextEra is also providing a revised crack growth analysis (Attachment 1) which supports the examination extension to 9 years which allows inspection during the U2R38 Fall 2021 RFO.

The welds will continue to have direct bare-metal examinations performed in accordance with Code Case N-722-1 as modified by 10 CFR 50.55a(g)(6)(ii)(E) and are subject to VT-2 examinations during the RCS pressure test at the end of each refueling outage.

NextEra believes that the proposed alternative of this request provides an acceptable level of quality and safety.

Basis for Use

Technical Basis

The overall basis used to demonstrate the acceptability of extending the examination interval for Code Case N-770-2, Inspection Item A-2 components is contained in the site-specific weld crack growth analysis performed for PBNP Unit 2, (Reference 2, Attachment 1). The weld crack growth analysis demonstrates that the Point Beach Unit 2 SG primary nozzle DM welds possess adequate thickness to protect against failure due to PWSCC by performing a crack growth evaluation. In the weld crack growth analysis, a 1.5 mm inside surface flaw is postulated in the PWSCC resistant alloy 52 inlay and the amount of time is determined for the flaw to reach the maximum allowable end-of-evaluation period flaw size.

This maximum allowable end-of-evaluation period flaw size would be the largest flaw size that could exist in the DM welds and be acceptable according to the ASME Section XI Code. Crack growth was calculated based on the PWSCC growth mechanism through both the alloy 52 inlay and the Alloy 82 DM welds.

The results of the analysis (Attachment 1) justify a longer examination interval for the SG inlet hot leg nozzles than the five years currently allowed for Code Case N-770-2 Inspection Item A-2 welds and 7 years for Inspection Item B. Based on the results for the SG inlet nozzle DM welds (hot leg) in Figures 7-1 and 7-2 of the analysis, (Reference 2, Attachment 1), an examination interval of up to 8.6 EFPY is acceptable for the Point Beach Unit 2 SG inlet and outlet nozzle DM welds based on the flaw growth evaluation. Therefore, the plant specific PWSCC growth results, in the attached Westinghouse Letter, justifies that Point Beach Unit 2 SG inlet and outlet nozzle DM welds can be examined after a duration of at least 8.6 EFPY (9 years) from the previous refueling outage inspections in November 2012, which will allow PBNP unit 2 to perform the inspection during the U2R38 Fall 2021 RFO.

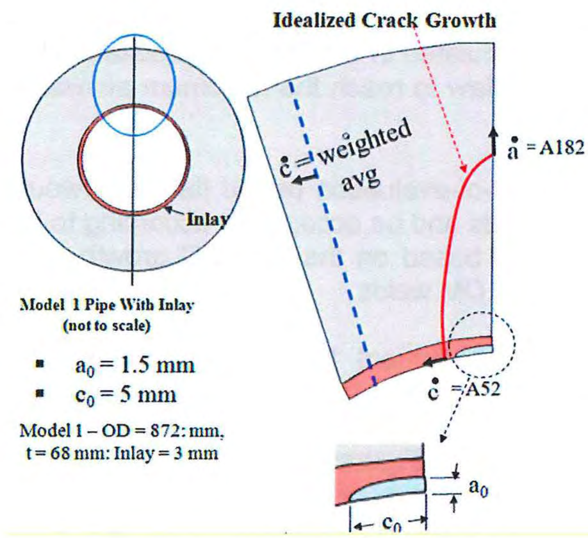
This technical basis demonstrates that the re-examination interval can be extended while maintaining an acceptable level of quality and safety.

Weld Crack Growth Analysis

An analysis has been performed for the PBNP Unit 2 Steam Generator primary nozzle to safe-end welds using several factors found in "Evaluation of the Inlay Process as a Mitigation Strategy for Primary Water Stress Corrosion Cracking in Pressurized-Water Reactors" (Reference 4), in particular:

1. Weld residual stress calculation
   a. Assume a 50% weld repair during fabrication
   b. Apply 3 weld layers and then machined to final size
   c. Use minimum thicknesses from construction records in the model

2. Flaw analysis
   a. Initial flaw depth is 1.5 mm (half the inlay weld thickness)
   b. Assume PWSCC growth of alloy 52 weld material with a factor of improvement of 18 over the Alloy 182 PWSCC rate from MRP-115.
   c. Calculate time to 75% through-wall for axial (c/a of 2) and circumferential flaws (c/a of 10).
   d. See the image below for clarification.



Based on the crack growth results from Figures 7-1 and 7-2 in Reference 2 (Attachment 1), it is demonstrated that it would take more than 8.6 EFPY (9 years) for the postulated 1.5 mm (0.06 inch) deep axial and circumferential flaw in the Point Beach Unit 2 SG inlet nozzle DM weld inlay to grow to the maximum allowable end-of-evaluation period flaw sizes with consideration of Alloy 52 with a FOI of 18 over the Alloy 182 PWSCC rate from MRP-115. It should be noted that for the SG outlet nozzle, the time duration is much longer than those provided in Figure 7-1 and 7-2 for the FOI of 18 for Alloy 52 due to the lower temperature at the outlet nozzle (T = 543°F) as compared to the inlet nozzle (T = 611.1°F) of the steam generator.

Conclusions

Extending the required PBNP Unit 2 Steam Generator Primary Nozzle Hot and Cold Leg DM weld volumetric examination for an additional operating cycle from U2R37 to U2R38 is justified given:

(1) the Alloy 82/182 weld metal has never been exposed to a PWR primary water environment;

(2) no recordable indications were identified during the ECT surface examination of the ID surface and volumetric examination of the DM welds in 2012 after more than 15 years of operation,

(3) a 50% weld repair was assumed in the weld residual stress calculation while the actual welds have no repairs

(4) an improvement factor of 18 was used in the weld crack growth analysis for Alloy 52 weld metal (no Alloy 152 weld filler metal was used for the inlay), and

(5) the PBNP Unit 2 Steam Generator Primary Nozzle to Safe-end Weld Crack Growth Analysis demonstrates that an inside surface flaw with a depth of 1.5 mm would not grow to the allowable flaw size specified by ASME XI rules over the timeframe of the requested inspection interval.

The use of this proposed alternative will provide an acceptable level of quality and safety. For these reasons, it is requested that the NRC authorize this proposed alternative in accordance with 10 CFR 50.55a(z)(1).

6. Duration of Proposed Alternative

This request is applicable to the PBNP Unit 2, 5th Interval Inservice Inspection until the U2R38 Fall 2021 RFO.

7. Precedents

NRC Letter to Eric McCartney dated March 22, 2016, “Point Beach Nuclear Plant, Unit 2-Approval of Relief Request 2-RR-11; Steam Generator Nozzle to Safe-End Dissimilar Metal (DM) Weld Inspection Re: (CAC No. MF6615), Adams Accession # ML16063A058.

8. References,

1. Code Case N-770-2, Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated with UNS N06082 or UNS W86182 Weld Filler Material with or without Application of Listed Mitigation Activities Section XI, Division 1.

2. Westinghouse LTR-SDA-19-071-P, "Point Beach Unit 2 Steam Generator Safe-End Dissimilar Metal Weld Alloy 52 Inspection Extension," August 2019 (Proprietary).

3. Westinghouse LTR-SDA-19-071-NP, "Point Beach Unit 2 Steam Generator Safe-End Dissimilar Metal Weld Alloy 52 Inspection Extension," August 2019 (Non-Proprietary).

4. Evaluation of the Inlay Process as a Mitigation Strategy for Primary Water Stress Corrosion Cracking in Pressurized-Water Reactors [ML101260554].

5. Summary of Public Meeting Between the Nuclear Regulatory Commission Staff and Industry Representative on Implementation of ASME Code Case N-770-1 dated August 12, 2011 [ML 112240818].

6. NextEra Energy Letter NRC 2015-0040 to NRC, "Point Beach Nuclear Plant Unit 2- 10CFR 50.55a Request, Relief Request 2-RR-11, Unit 2 Steam Generator Nozzle to Safe-End Dissimilar Metal (DM) Weld Inspection," August 13,2015 [ML 15225A104].

7. NextEra Energy Letter NRC 2015-0068 to NRC, "Point Beach Nuclear Plant Unit 2- Request for Additional Information for Relief Request 2-RR-11 - MF6615," November 19, 2015 [ML 15324A152].

8. Approved Relief Request 2-RR-11, "Steam Generator Nozzle to Safe-End Dissimilar Metal (DM) Weld Inspection," November 1, 2016 [ML 16063A058].

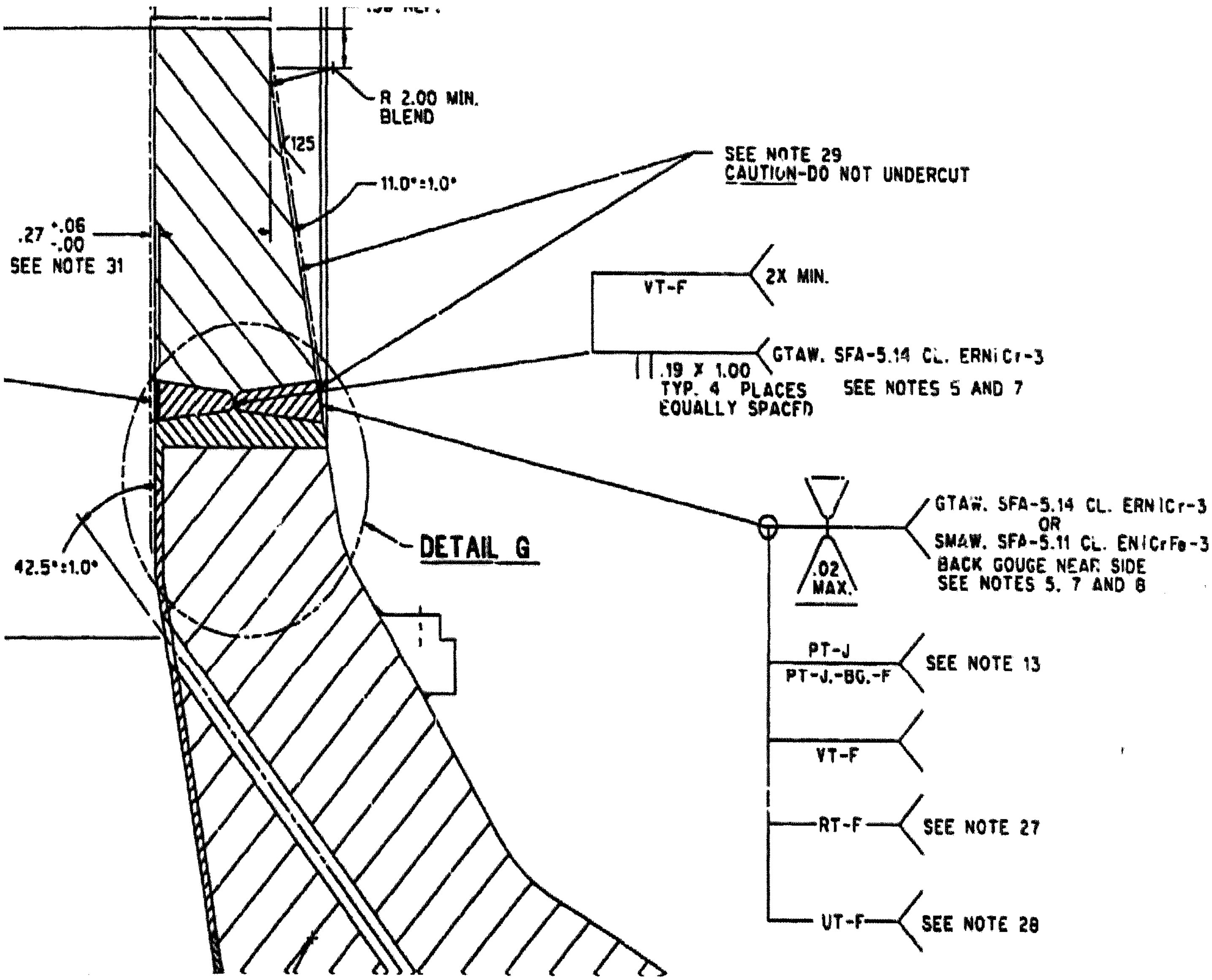
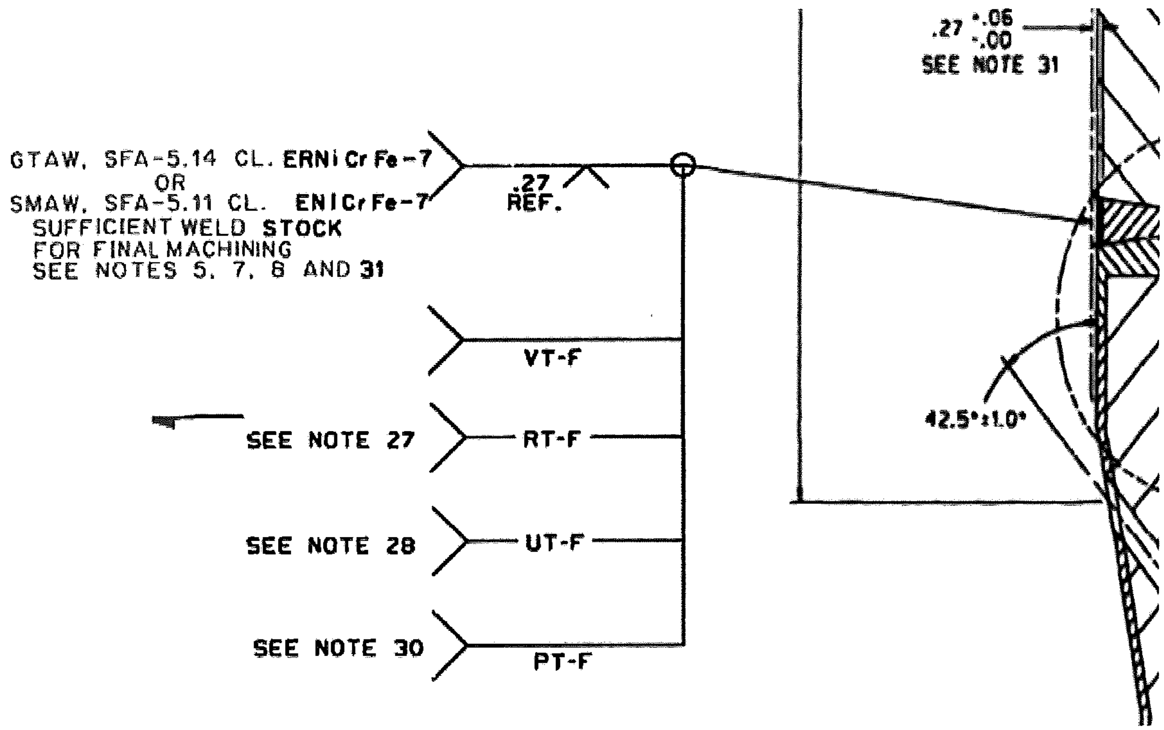


Figure 1
Excerpt from Westinghouse Drawing 6147E62
Weld Detail

Figure 1
Excerpt from Westinghouse Drawing 6147E62
Alloy 52 Cladding Detail



Attachment 1
Westinghouse LTR-SDA-19-071-P, Revision 0, dated August 2019, "Point Beach Unit 2 Steam Generator Safe-End Dissimilar Metal Weld Alloy 52 Inspection Extension"
(Proprietary)

(38 pages follow)

Attachment 2

Westinghouse LTR-SDA-19-071-NP, Revision 0, dated August 2019, "Point Beach Unit 2 Steam Generator Safe-End Dissimilar Metal Weld Alloy 52 Inspection Extension" (Non-Proprietary)

(38 pages follow)

LTR-SDA-19-071-NP
Revision 0

Point Beach Unit 2 Steam Generator Safe-End Dissimilar Metal Weld Alloy 52 Inspection Extension

August 2019

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Approved: Lynn A. Patterson*, Manager, RV/CV Design & Analysis

***Electronically approved records are authenticated in the electronic document management system.**

Westinghouse

FOREWORD

This document contains Westinghouse Electric Company LLC proprietary information and data which has been identified by brackets. Coding (a,c,e) associated with the brackets sets forth the basis on which the information is considered proprietary.

The proprietary information and data contained in this report were obtained at considerable Westinghouse expense and its release could seriously affect our competitive position. This information is to be withheld from public disclosure in accordance with the Rules of Practice 10CFR2.390 and the information presented herein is to be safeguarded in accordance with 10CFR2.390. Withholding of this information does not adversely affect the public interest.

This information has been provided for your internal use only and should not be released to persons or organizations outside the Directorate of Regulation and the ACRS without the express written approval of Westinghouse Electric Company LLC. Should it become necessary to release this information to such persons as part of the review procedure, please contact Westinghouse Electric Company LLC, which will make the necessary arrangements required to protect the Company's proprietary interests.

The proprietary information in the brackets has been deleted in this report. The deleted information is provided in the proprietary version of this report (LTR-SDA-19-071-P Revision 0).

1.0 Introduction

The Point Beach Unit 2 Steam Generators (SG) were fabricated with factory welded stainless steel safe ends attached to the SG primary nozzles with Alloy 82 DM (Dissimilar Metal) welds. The inside surface of the welds and adjacent base materials were cladded with Primary Water Stress Corrosion Cracking (PWSCC) resistant Alloy 52 material during fabrication. In November 2012, these welds were examined using ultrasonic volumetric and eddy current surface examination methods with no indication on any of the four DM welds.

Per Code Case N-770-2 Inspection Item A-2 [1], unmitigated butt welds at hot leg operation temperature, such as the SG primary inlet nozzle DM weld, are inspected every 5 years; and also per Inspection Item B [1], unmitigated butt weld at cold leg temperatures such as the SG outlet nozzle DM weld are inspected every second inspection period not exceeding 7 years. Point Beach Unit 2 received relief [2, 3, 4] from N-770-1 requirements to perform the volumetric examinations after 7.5 EFPY (Effective Full Power Years) from the previous inspection in November 2012 for the SG primary nozzle DM welds examination. Therefore, the next volumetric examination of Point Beach Unit 2 Steam Generator primary nozzle dissimilar metal welds is planned for the March 2020 refueling outage.

In this letter report, Point Beach Unit 2 is providing justification to seek relaxation beyond 7.5 EFPY in order to perform the volumetric examination of the SG DM welds in Fall 2021 refueling outage, which is 9 years (8.6 EFPY) from the previous November 2012 inspection. The technical justification to inspect after 9 years (8.6 EFPY) is based upon two separate analyses:

1. In Section 2 of this report, a Factor of Improvement (FOI) comparison evaluation will be performed similar to that used to defer inspections of Alloy 690 reactor vessel head penetration examinations, such as in [6, 7]. The methodology consists of determining the plant specific minimum Alloys 52 FOI for comparison with the laboratory crack growth rate data presented in MRP-375 [5], and other industry data in order to support the requested extension period of 9 years. The analysis will calculate the minimum FOI for Point Beach Unit 2 SG nozzle DM welds based on the actual operating temperature and the RIY (Reinspection Years) parameter, per ASME Code Case N-729-4 [9], for the requested examination interval. The calculated RIY for Point Beach Unit 2 is then compared with the Code Case N-729-4 interval for Alloy 600 nozzles of RIY = 2.25 in order to determine the ratio for the factor of improvement for the Point Beach Unit 2 SG DM Alloy 52 weld inlay.

   Therefore, the FOI methodology consists of comparing the plant specific calculation of the minimum FOI for Alloy 52 with laboratory data for Alloy 600 or Alloy 182. MRP-375 [5] stated "*Much of the available laboratory data indicate a factor of improvement of 100 for Alloys 690/52/152 versus Alloys 600/182 (for equivalent temperature and stress conditions) in terms of crack growth rate. Moreover, existing laboratory and plant data demonstrate a factor of improvement in excess of 20 in terms of the time to PWSCC initiation.*" The Point Beach Unit 2 plant specific FOI calculation would use the actual temperature in the crack growth rate calculations, and compare it to the FOI of 20 (lesser of PWSCC crack growth rate or the PWSCC initiation) which is provided for Alloy 690/52/152 data in MRP-375 [5]. If the plant specific FOI is bounded by MRP-375, then the analysis would demonstrate margin to ensure the potential of PWSCC is remote in the Alloy 52 weld. This methodology was also used in St. Lucie relief request for Alloy 690/52/152 reactor vessel head penetration [6, 7].

As part of the NRC safety evaluation report in Reference [7], crack growth rate data for Alloy 690/52/152 from Pacific Northwest National Laboratory (PNNL) and Argonne National Laboratory (ANL) [8] was also considered. As a result, the summary data report from PNNL and ANL from [8] will also be considered when evaluating the FOI that is calculated for Point Beach Unit 2 SG DM welds.

2. A separate analysis will also be performed based on a detailed Primary Water Stress Corrosion Crack (PWSCC) growth analysis through the Alloy 52 inlay and the Alloy 82 DM weld materials of the Steam Generator nozzle for duration of 9 years (8.6 EFPY) from November 2012. The analysis considers latest plant specific loadings, geometry, welding residual stresses, and calculates the stress intensity factor and PWSCC growth for postulated axial and circumferential flaws in the nozzle DM weld region. The analysis will determine the minimum calculated FOI needed for the PWSCC growth in Alloy 52 material as compared to the Alloy 182 PWSCC rate based on MRP-115 [14] to demonstrate an inspection period of at least 8.6 EFPY (9 calendar years). The PWSCC growth evaluation is documented in Appendix A as a stand-alone section in this letter report.

   As part of the PWSCC growth analysis, it should be noted that the PWSCC growth rate is highly dependent on the temperature at the location of the flaw, furthermore, the crack growth rate increases as the temperature increases. Therefore, during periods when the plant is not in operation, such as refueling outages or shutdowns, the temperature at the SG nozzles is low such that crack growth due to PWSCC is insignificant. Therefore, PWSCC growth calculation should be determined for the time interval when the plant is operating at full power. The amount of time when the plant is operating at full power is determined based on previous plant operation data and the anticipated outages scheduled until the next inspections. This operation duration at full power is referred to as Effective Full Power Years (EFPY). For Point Beach Unit 2, based on operational data, the time interval between the previous inspection in November 2012 and the proposed future inspection in Fall 2021, is conservatively determined to be 8.6 EFPY (9 calendar years). For Point Beach Unit 2, this translates to a power availability factor of 95.5% to account for the time the plant is operating at full normal operating temperature.

The results from the above two methodologies, along with a discussion on PWSCC initiation of Alloy 52 weld (see Section 3) and a qualitative review of service history for Alloy 52 welds (Section 4), will be used to demonstrate technical justification for Point Beach Unit 2 welds, in order to support the examination extension of 9 years (8.6 EFPY) from the previous refueling outage inspections in November 2012 for the SG dissimilar metal welds. References provided in the main body of the letter are located in Section 6, while references for Appendix A are located at the end of the appendix.

2.0 Alloy 52 Factor of Improvement Calculation Based on RIY from Code Case N-729-4

Provided herein is the calculation of the minimum factor of improvement (FOI) on crack growth for the Alloy 52 weld inlay at the Point Beach Unit 2 SG primary nozzle DM welds, in order to determine the acceptability of extending the volumetric inspection interval to 9 years (8.6 EFPY). The FOI is calculated by comparing the potential for PWSCC crack propagation between the Alloy 52 and Alloy 600/82/182 materials. The Alloy 52 material potential for PWSCC is calculated based on the Arrhenius equation with the major inputs consisting of the operating temperature at the SG location, and the operating period for inspection deferral (i.e. 9 years or 8.6 EFPY).

The methodology for using FOI to demonstrate extension of inspection interval has been implemented numerous times for reactor vessel heads with Alloy 690 nozzles, for example at St. Lucie Unit 1 [6, 7]. The basis for the inspection extension is to address the effect of differences in operation temperature and its impact on the Reinspection Years (RIY) parameter, which is defined in ASME Code Case N-729-4 [9]. The RIY parameter adjusts the time between inspections for the effect of operating temperature using the thermal activation energy appropriate to the PWSCC growth for the material of interest.

The RIY parameter used for Alloy 600 material is adjusted to the reference temperature using an activation energy (Q) of 130 kJ/mole (31 kcal/mole) [9]. Based on available laboratory data for Alloy 690 [see Attachment 2 of Reference 6], the same activation energy of 130 kJ/mole (31 kcal/mole) is applicable to model the temperature sensitivity of the hypothetical PWSCC flaw growth. Other industry data suggest a higher value of activation energy may be considered for the evaluation of FOI for Alloy 690/52/152. During the latest May 2019 *Industry/U.S. Nuclear Regulatory Commission Materials Programs Technical Information Exchange Public Meeting*, a presentation provided jointly by EPRI and NRC [10] discussed the status of the ongoing cooperative research on PWSCC initiation testing at PNNL. Based on the presentation [10], an activation energy of 185 kJ/mole (44 kcal/mole) was considered for PWSCC initiation times for Alloy 690/52/152 materials. On the other hand, based on MRP-237 Rev. 2 [pg. K-7 of Reference 11], for an Alloy 152 weld test, the activation energy could be conservatively taken as high as 224 kJ/mole (53 kcal/mole). The particular high value of activation energy of 224 kJ/mole is similar to the activation energy assumed for PWSCC initiation in N-729-4, where the value of Q_i = 209 kJ/mole (50 kcal/mole). Thus, the activation energy considered in the FOI calculation herein conservatively ranges from 130 kJ/mole (31 kcal/mole) to as high as 224 kJ/mole (53 kcal/mole) for the Alloy 52 material, in order to provide a bounding analysis. Note that based on the discussion in Section 3.1 of MRP-375, laboratory data indicates there is no significant difference in PWSCC susceptibility between Alloys 52 and 152, as was the case for Alloy 82 and 182. Hence the activation energy of Alloy 152 is considered representative of Alloy 52.

To begin the analysis, the RIY parameter is calculated first. RIY quantifies the potential for crack propagation between successive volumetric/surface examinations for the Alloy 52 weld based on operating temperature and the activation energy discussed above. The RIY parameter is defined by ASME Code Case N-729-4 [9] as follows:

$$RIY = \sum_{j=n1}^{n2} \left\{ \Delta EFPY_j exp\left[-\frac{Q_g}{R}\left(\frac{1}{T_{op,j}} - \frac{1}{T_{ref}}\right)\right]\right\}$$

where:

RIY	=	reinspection years, normalized to a reference temperature of 1059.67°R (588.71°K or 600°F)
$\Delta EFPY_j$	=	effective full power years accumulated during time period j
Q_g	=	activation energy for crack growth, for Alloy 52 weld as low as 130 kJ/mole (31 kcal/mole) and as high as 224 kJ/mole (53 kcal/mole)
R	=	universal gas constant (1.103×10^{-3} kcal/mol-°R)
$T_{op,j}$	=	absolute 100% power temperature during time period j (°R =°F+459.67)
T_{ref}	=	absolute reference temperature (1059.67°R)
n	=	number of the time periods with distinct 100% power temperature since initial operation
$n1$	=	number of the first time period with distinct 100% power temperature since time of most recent volumetric/surface inspection (or replacement)
$n2$	=	number of the most recent time period with distinct 100% power temperature

For conservatism, one interval using the highest temperature was used. The RIY expression simplifies to the following assuming a single representative operating temperature over the period between successive examinations:

$$RIY = \Delta EFPY_j exp\left[-\frac{Q_g}{R}\left(\frac{1}{T_{op}} - \frac{1}{T_{ref}}\right)\right]$$

Conservatively assuming that the EFPYs of operation accumulated at Point Beach Unit 2 since the previous volumetric inspection (November 2012) is equal to the calendar years since inspection, the RIY for the requested extended period of 9 EFPY is considered for calculation.

Based on EPU (Extended Power Uprate) program design parameters in WCAP-16983-P [12], the normal operating temperatures for the SG inlet and outlet nozzle are 611.1°F and 543°F respectively. The calculation herein conservatively considers a bounding temperature of 611.1°F for the RIY, as follows:

With activation energy, Q_g = 130 kJ/mole (31 kcal/mole)

$$RIY = (9\text{ EFPY})\exp\left[-\frac{31}{1.103\times10^{-3}}\left(\frac{1}{611.1+459.67} - \frac{1}{600+459.67}\right)\right] = (9)(1.32) = 11.848$$

With activation energy, Q_g = 224 kJ/mole (53 kcal/mole)

$$RIY = (9\text{ EFPY})\exp\left[-\frac{53}{1.103\times10^{-3}}\left(\frac{1}{611.1+459.67} - \frac{1}{600+459.67}\right)\right] = (9)(1.60) = 14.401$$

The FOI implied by these RIY values for Point Beach SG DM Alloy 52 weld (relative to the limiting RIY for Alloy 600) is calculated as the following ratio:

With activation energy, Q_g = 130 kJ/mole (31 kcal/mole)

$$FOI = \left[\frac{RIY_{Alloys\ 52}}{RIY_{Alloys\ 600}}\right] = \frac{(9)(1.32)}{2.25} = \frac{11.848}{2.25} = 5.26$$

With activation energy, Q_g = 224 kJ/mole (53 kcal/mole)

$$FOI = \left[\frac{RIY_{Alloys\ 52}}{RIY_{Alloys\ 600}}\right] = \frac{(9)(1.60)}{2.25} = \frac{14.401}{2.25} = 6.40$$

Thus, based on the range of activation energies for Alloy 52 PWSCC propagation, the calculated FOI ranges between 5.26 to 6.40 as compared to the potential for PWSCC for Alloy 600 material. Next, these calculated FOI values can be compared to actual laboratory PWSCC crack growth rate data for Alloys 690/52/152 versus the crack growth rate for Alloy 600 [13] and Alloy 182 [14]. If the calculated FOI of 6.40 as determined previously are below the FOI determined based on actual laboratory measured data then a technical justification can be demonstrated to defer the Point beach SG Alloy 52 weld after 9 years or 8.6 EFPY from the previous volumetric inspection. Alloy 182 material is the appropriate reference for defining the FOI for Alloy 52 weld material. As discussed in Section 3.1 of MRP-375, Alloy 182 weld metal is chosen as the reference for defining the FOI for Alloys 52 and 152 weld metals because Alloy 182 is more susceptible on average to PWSCC initiation and growth than Alloy 82 (due to the higher Chromium content of Alloy 82). However, the above calculated FOI is compared to both Alloy 600 and Alloy 182 laboratory data as discussed in MRP-375.

MRP-375 investigated laboratory PWSCC growth rate data for the purpose of assessing FOI values for growth. Data analyzed to develop a conservative factor of improvement include laboratory specimens with substantial levels of cold work for the Alloy 690 base material. It is important to note that much of the data used to support Alloy 690 CGR (crack growth rates) was produced using materials with significant amounts of cold work, which tends to increase the CGR. Similar processing, fabrication, and welding practices apply to the original (Alloy 600) and replacement (Alloy 690) components.

Figure 3-2 of MRP-375, compares data from Alloy 690 specimens with less than 10% cold work and the statistical distribution from MRP-55 [13] describing the material variability in CGR for Alloy 600. Most of the laboratory comparisons were bounded by a factor of improvement of 20, and all were bounded by a factor of improvement of 10. Most data support a FOI of much larger than 20. This is similar for testing of the Alloy 690 Heat Affected Zone (HAZ) as shown in Figure 3-4 of MRP-375 (relative to the distribution from MRP-55) and for the Alloy 52/152 weld metal (relative to the distribution from MRP-115 [14]) as shown in Figure 3-6 of MRP-375. Based on the data, it is conservative to assume a FOI of 20 for PWSCC growth rates for Alloy 52/152 materials.

As discussed previously, based on the plant-specific FOI calculated above for Point Beach SG DM Alloy 52 weld, a minimum FOI of 6.40 over Alloy 600 or Alloy 182 materials is necessary to achieve an inspection interval of 9 years or 8.6 EFPY. Based on MRP-375 [5], per the available laboratory data a factor of improvement of 100 for Alloys 690/52/152 versus Alloys 600/182 (for equivalent temperature and stress conditions) is permissible for PWSCC crack growth. Moreover, existing laboratory and plant data [5] demonstrate a factor of improvement in excess of 20 in terms of the time to PWSCC initiation.

Another set of laboratory data compiled by PNNL [18] and presented by Bruemmer, Olszta, and Toloczko were also considered in addition to the laboratory FOI results from MRP-375. The testing in [18] was for Alloy 52M and 152 weldments, which included a mockup inlay repair weld, a mockup overlay weld, a V-groove weld, and two narrow gap welds. One of the specimens was for Ringhals mock-up of Alloy 52M inlay applied onto the Alloy 82 material, which can be considered similar to the Point Beach SG DM weld configuration. Most of the laboratory comparisons from [18] were bounded by a factor of improvement of 20, and all were bounded by a factor of improvement of 10. Per Figures 28 and 29 of [18], the data support a FOI of much larger than 20 for Alloy 52M inlay material as compared to the Alloy 600 MRP-55 and Alloy 182 MRP-115 crack growth rates.

The NRC in its review of St. Lucie Alloy 690 head extension [6, 7] also considered Alloy 690/152/52 crack growth date from PNNL and ANL reports [8], some of these data were previously published in [18]. Based on a review of the PNNL/ANL data presented in [8], the application of a FOI of 6.40 for the Point Beach SG DM Alloy 52 weld to the 75th percentile curves in MRP-55 and MRP-115 bounded essentially all of the data included in the PNNL and ANL data summary report. This provides another basis to support justification of extending the inspection of the Alloy 52 DM welds at Point Beach Unit 2 SG to 9 years or 8.6 EFPY.

The plant specific minimum FOI of 6.4 for the Point Beach Unit 2 SG Alloy 52 DM weld, as calculated in this section, is bounded by various laboratory data that demonstrates a much larger FOI of approximately 20 to 100 over the Alloy 600/182 rates. Therefore, given the lack of PWSCC initiation or cracking detected (discussed later in this report) to date in any Pressurized Water Reactor (PWR) plant applications of Alloys 690/52/152, the simple FOI assessment can be used as a supporting basis to extend the inspection interval to 9 years or 8.6 EFPY for Point Beach Unit 2 SG DM weld.

A plant specific PWSCC evaluation is also performed in Appendix A to demonstrate that crack growth for postulated axial and circumferential flaws in the Alloy 52 weld (with a FOI of 18 over the Alloy 182 PWSCC rate from MRP-115 [14]) will take longer than 8.6 EFPY (9 years) to reach the maximum allowable end-of-evaluation flaw size calculation per ASME Section XI. The calculated FOI of 18 for Alloy 52 is also bounded by various laboratory data that demonstrates a FOI in excess of 20 to 100 over the Alloy 600/182 rates. Therefore, the detailed fracture mechanics basis provided in Appendix A supplements the FOI calculations performed in this section of the report.

3.0 PWSCC Crack Initiation of Alloy 52 Materials

Due to the excellent service history for Alloy 690 base material and Alloy 152/52 weld material this section provides a comparison of PWSCC initiation of the Alloy 690 base and weld materials as compared to the Alloy 600 base and weld metals based on actual laboratory measured data.

Based on the discussions provided in Section 3.2.1.3 of MRP-375 [5], laboratory tests by EDF (Electric de France) showed that Alloy 182 cracked after 95 hours, and Alloy 82 cracked after 570 hours. In comparison, Alloy 52/152 still had not cracked after >21,000 hours. This resulted in a FOI for Alloy 52/152 of 37 compared to Alloy 82 and over 150 compared to Alloy 182. Also per MRP-375, KAPL (Knolls Atomic Power Laboratory) tested Alloy 52/152 welds for 2300 hours at 640°F (338°C) and 5300 hours at 680°F (360°C). The former tests showed no indications of PWSCC, while the latter only had a few, isolated "pockets." KAPL estimated the FOI of Alloy 52/152 over Alloy 82 to be approximately 100. Tests by MHI (Mitsubishi Heavy Industries) have demonstrated specimens of both Alloys 52 and 152 that have not cracked after 107,000 hours [Section 3.2.1.3 of [5]]. Furthermore, based on more recent data by MHI for the Alloy 52 and 152 welds specimen, there was no evidence of cracking after >122,535 hours at temperature of 360°C; this translates to 71 years of operation at 325°C (617°F) [Table 6 of Reference [15]].

During the latest May 2019 *Industry/U.S. Nuclear Regulatory Commission Materials Programs Technical Information Exchange Public Meeting*, the presentation provided jointly by EPRI and NRC [10] discussed the status of the ongoing cooperative research on PWSCC initiation testing at PNNL. Based on the presentation [Slide 9 of Reference 10], temperature-adjusted PWSCC initiation times provided based on the latest test data show that Alloy 690/52/152 have not experience any PWSCC initiation at >181,752 hours (20.7 years) for an adjusted temperature of 325°C (617°F). When compared to the slowest PWSCC initiation time for Alloy 182 weld at 17,514 hours for an adjusted temperature of 325°C [Slide 9 of Reference 10], this represents a FOI of >10x for PWSCC initiation of Alloy 52 welds.

Therefore, the discussion provided here for PWSCC initiation supports that the Alloy 52 DM weld at Point Beach will take a significantly long time (more than 20 years up to even 71 years) before any evidence of crack initiation is detected at the SG DM locations.

Provided in the next section is a qualitative review of the operation experience for cracked Alloy 600/82/182 materials as a comparison to the operation time for Point Beach Alloy 690/52/152 materials to demonstrate the highly PWSCC resistance characteristics of the later materials as compared to the former when operating in the same environment and temperature.

4.0 Operation Experience of Alloy 82/182/600 versus Alloy 52/152/690 Welds

This section provides a comparison of the operating experience of components installed with highly PWSCC resistance materials of Alloy 52/152/690 in relationship to the operating experience of Alloy 82/182/600 in PWR reactor coolant system service. To date, there have been no occurrences of PWSCC cracking in Alloy 52/152/690 components in PWR environment. Information related to Alloys 690, 52, and 152 in PWRs is located in MRP-110 [16] and in MRP-111 [17].

Steam Generators

Replaced steam generators with Alloy 690 tubing have been in operation since 1989 at D. C. Cook 2, Indian Point 3, and Ringhals 2. No corrosion induced flaws have been detected at these plants or any subsequent plants that have started up since that time with Alloy 690 tubes in either replacement or original steam generators. In contrast, PWSCC was detected after one cycle of operation at several units with Alloy 600MA tubes, e.g., Doel 3, Tihange 2 and V. C. Summer, and after the second cycle at a number of other plants with Alloy 600MA tubes. This experience indicates that there is a service demonstrated factor of improvement of about 20 or more, with the value increasing as the PWSCC-free service life of Alloy 690 tubes continues to accumulate.

Steam generator tubes are joined to the tube sheet using autogenous welds between the tube and Alloy 52/152 cladding on the primary face of the tubesheet. Thus, each steam generator has thousands of welds and heat affected zones. There have been no reports of PWSCC initiation or cracking detected at these weld joints between Alloy 690 tubes and the cladding on the tubesheet (the cladding on early Alloy 690 steam generators was Alloy 82/182, while for later units has been Alloy 52/152). The earliest U. S. steam generator with Alloy 52 welds installed was in 1994 for V. C. Summer, which has over 25 years of experience with no cracking. While the Alloy 690 tube to tubesheet weld joints are not routinely inspected with sensitive methods, significant cracking would likely have been detected as result of leakage or visible cracks, as has occurred occasionally with Alloy 600 tube to tubesheet welds.

Many steam generator tubes have also been plugged using Alloy 690TT tube plugs since the late 1980s. There have been no reports of PWSCC being detected in these plugs. The plugs have been of two main kinds: mechanical plugs with an internal expanding mandrel that expands and seals the plug envelope and tube to the tube sheet, and rolled in thimble tubes. In both cases, the plugs are made from thick wall rod material rather than from thin tubes. In contrast to the over 30 years of trouble free service with Alloy 690TT plugs, plugs made of Alloy 600MA and even Alloy 600TT experienced PWSCC within one to two years of service. Therefore, over thirty (30) years of experience for steam generators indicates that there is a service demonstrated factor of improvement of about 30 or more for Alloy 52/152/690, with the value increasing as the PWSCC-free service life of Alloy 690 tube plugs continues to accumulate.

Pressurizers

Alloy 690 and its weld metals were also used to repair pressurizer components in more than 17 plants since 1994. The high service temperature in the pressurizer, (typically 653°F) is particularly aggressive regarding PWSCC initiation and growth. Many of these pressurizer components that have been repaired with Alloy 690 and its weld metals, have the equivalent of more than 100 EDY (Effective Degradation Years) of time-temperature exposure since installation without cracking. Inspections performed have shown no evidence of PWSCC indications.

Reactor Vessels Heads with Alloy 690 Nozzles

New and repaired reactor pressure vessel heads with Alloy 690 nozzles started to be used in the industry from 1991. From 1992 onwards, a significant number of reactor pressure vessel heads have been replaced with wrought Alloy 690 tubes and Alloy 52/152 weld metal (early replacements in France). In the USA, over 45 heads have been replaced with Alloy 52/152/690 materials and the service performance has been excellent. Most of these heads have over 40 to 100 penetration nozzles made of Alloy 690 and welded with Alloy 52/152 welds. These replacement heads have operated over 25 years with no inspection findings, and most all have been inspected at least once, with no findings. In both France and the USA, detailed inspections are required at 10 year intervals for the reactor vessel heads. More recently, based on the high resistant to PWSCC of Alloy 690/52/152 in replaced reactor vessel head, the NRC will allow plants to volumetrically inspect every 20 years as part of 10 CFR Part 50 proposed rulemarking on Code Case N-729-6 [22].

Repairs with Alloy 52/152 Material

Alloy 52 and 152 weld metals started to be used in repairs and in replacement components starting in the mid-1990s. There have been no reports of service induced PWSCC in these welds. Furthermore, Alloy 52/152 welds perform well in primary water mostly because of its Chromium chemistry.

Weld inlays were installed at Ringhals 3 and 4 in Sweden. For the hot leg nozzle at Ringhals 4, the inlay was applied in 2002, and then inspected with UT (Ultrasonic testing) and ECT (Eddy Current Testing) in 2005 with no indications. Furthermore, inspection based on UT and ECT in 2010 also demonstrated no indication after 11.7 EDY. This particular location is currently on a 10 year re-inspection frequency. Similarly, Ringhals 3 hot leg DM weld had inlay applied in 2003, and inspected with UT and ECT in 2006 with no indications. Subsequently, this location was re-inspected with UT and ECT in 2010 with no indication after 10.4 EDY, now this location is also on a 10 year re-inspection frequency. The experience of Ringhal inlays on hot leg nozzle DM welds demonstrates a good precedence for the beneficial use of Alloy 52 inlay material applied to the Alloy 82 weld.

Next, a comparative discussion will be provided for cracking of hot leg nozzles Alloy 82/182 welds based on operation conditions and duration as compared to the time Point Beach Unit 2 SG DM welds have been in operation composed of Alloy 52 material. Based on current operation data, the Alloy 52 inlay weld at Point Beach Unit 2 SG DM weld have been operating for 19 EFPY [19], with no cracking at hot leg temperatures of 605-611°F since the time the replaced steam generators were put in service in 1997. In contrast, V. C. Summer discovered through-wall axial cracking at hot leg DM weld in October 2000 after being in-service since 1984 when the plant was commercially started. One of the leading factor of cracking at V. C. Summer was extensive weld repairs on the inside surface and cold work of the weld due grinding [20]. Compared to V. C. Summer, Point Beach Unit 2 SG DM welds does not have repairs and have been in operation with the Alloy 52 PWSCC resistant weld for a longer time period.

Another example of cracking in Alloy 182/82 welds at hot leg temperature is that of Seabrook. In October 2009, the 10-year in-service inspection at Seabrook identified an axial indication in the Alloy 182/82 DM at one of the reactor outlet nozzles. The plant has been in operation since 1990 and was at 16.53 EFPY with hot leg operating temperatures of 621°F when the flaw was discovered in 2009. In contrast, Point Beach Unit 2 SG Alloy 52 welds have been operating at hot leg temperature for over 19 EFPY with no evidence of PWSCC initiation or cracking.

In 2012, North Anna Unit 1 discovered two through-wall axial flaws at the SG inlet nozzle Alloy 182 welds when preparing to apply full structural weld overlays at the location during a planned outage. Note that no leakage was observed during operation prior to the outage. Fabrication records indicated extensive ID (Inside Diameter) weld repairs were performed for the SG in question which had the through-wall flaws [21]. Unlike North Anna Unit 1, Point Beach Unit 2 SG DM Alloy 52 does not have any ID repairs that could result in PWSCC initiation due to high tensile residual stresses from repair processes; thus operating experience demonstrates a low likelihood of PWSCC initiation or growth.

The discussion in this section demonstrates the excellent service history of Alloy 52/152/690 materials, whether installed or used as repair, as compared to Alloy 82/182/600 materials. Based on service history, many of the Alloy 52/152 welds have been in operation longer than Alloy 82/182 welds at hot leg conditions, with no evidence of PWSCC initiation or cracking. Furthermore, in contrast with other plants that have PWSCC cracking at hot leg nozzles with history of ID weld repairs, the inside surface of Point Beach Unit 2 SG DM does not have any evidence of repair processes due to welding, which demonstrates a very favorable condition to negate PWSCC initiation or cracking in the Alloy 52 weld layer.

5.0 Conclusion

This letter report provides technical basis to justify that the examination interval of the Point Beach Unit 2 SG DM welds can be longer than 8.6 EFPY (9 years) from the previous refueling outage inspections in November 2012. The technical justification is based on the factor of improvement calculation for plant specific operating temperatures at hot leg conditions for the Point Beach Unit 2 SG Alloy 52 weld. The calculated FOI for Point Beach Alloy 52 weld is 6.4 (per Section 2) over Alloy 600 or Alloy 182 materials. Based on a review of the PNNL/ANL laboratory data presented in [8] which has been considered in previous NRC reviews [6, 7], the calculated FOI value of 6.4 for the Point Beach SG DM Alloy 52 weld is bounded by the FOI needed for PWSCC growth for Alloy 52 welds based on a comparison of the of Alloy 600 (MRP-55) and Alloy 182 (MRP-115) curves against measured laboratory data [8] for Alloy 52/152 material. This simplistic FOI approach provides technical support for extending the inspection of the Alloy 52 DM welds at Point Beach Unit 2 SG to 8.6 EFPY (9 years).

A plant specific PWSCC growth analysis is also performed in Appendix A of this letter report for Point Beach Unit 2 SG nozzle DM weld. The crack growth analysis started with an initial flaw depth of 1.5 mm (half of the Alloy 52 weld inlay thickness), for a postulated axial flaw with aspect ratio (flaw length/flaw depth) of 2 and a postulated circumferential flaw with aspect ratio of 10. The evaluation includes PWSCC growth of the postulated initial flaws through the Alloy 52 inlay with a factor of improvement of 18 above the MRP-115 [14] crack growth rate for Alloy 182 material. The PWSCC growth then continues for the postulated flaw through the Alloy 82 material of the Point Beach SG DM weld, till it reaches the maximum allowable end-of-evaluation flaw size. Based on the crack growth results from Figures 7-1 and 7-2 (in Appendix A of this letter report), it is demonstrated that it would take more than 8.6 EFPY (9 years) for the postulated 1.5 mm (0.06 inch) deep axial and circumferential flaw in the Point Beach SG inlet nozzle DM weld inlay to grow to the maximum allowable end-of-evaluation period flaw sizes. It should be noted that for the SG outlet nozzle, the time duration is much longer than those provided in Figure 7-1 and 7-2 (Appendix A) for a FOI of 18 for Alloy 52.

Operating experience and current data indicate that Alloy 690 and associated weld metal Alloy 52/152, are highly PWSCC resistant materials. These materials are extremely PWSCC initiation resistant, with very slow PWSCC growth from starter indications. PWSCC initiation data from laboratory results supports that the Alloy 52 DM weld at Point Beach will take a significantly long time (more than 20 years up to even 71 years) before any evidence of crack propagation is detected at the SG DM locations.

Lastly, it should be noted that Point Beach Unit 2 SG DM welds have been in operation with the Alloy 52 weld for more than 19 EFPY, with no cracking at hot leg temperatures of 605-611°F since the time the replaced steam generators were put in service in 1997. On the other hand, several instances of cracking were already discovered for Alloy 600/82/182 materials at the beginning of life for components operating at hot leg temperatures. Hence, there is strong basis from service history that components fabricated and repaired with Alloy 690/52/152 materials have not experienced any PWSCC initiation or cracking to date.

Therefore, based on the quantitative FOI calculations in Section 2, along with the plant specific PWSCC growth analysis in Appendix A, and the qualitative review of service history for Alloy 52 welds, there is technical justification for Point Beach Unit 2 SG DM welds to operate safely for 8.6 EFPY (9 years) from the previous refueling outage inspections in November 2012.

6.0 References

1. ASME Section XI Division 1 Code Case N-770-2, "Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities Section XI, Division 1," Approval Date June 9, 2011.

2. NextEra Energy Point Beach Unit 2 Letter to NRC, "10 CFR 50.55a Request, Relief Request 2-RR-11, Unit 2 Steam Generator Nozzle to Safe-End Dissimilar Metal (DM) Weld Inspection," August 13, 2015, NRC ADAMS Accession No. ML15225A104.

3. NextEra Energy Point Beach Unit 2 Letter to NRC, "Point Beach Nuclear Plant Unit 2 – Request for Additional Information for Relief Request 2-RR-11 – MF6615," November 19, 2015, NRC ADAMS Accession No. ML15324A152.

4. NRC letter to NextEra Energy Point Beach Unit 2, "Point Beach Nuclear Plant, Unit 2 – Approval of Relief Request 2-RR-11; Steam Generator Nozzle to Safe-End Dissimilar Metal (DM) Weld Inspection RE: (CAC No. MF6615)," March 22, 2016, NRC ADAMS Accession No. ML16063A058.

5. Materials Reliability Program: Technical Basis for Reexamination Interval Extension for Alloy 690 PWR Reactor Vessel Top Head Penetration Nozzles (MRP-375). EPRI, Palo Alto, CA: 2014. 3002002441.

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10. Focht, E., Crooker, P., Toloczko, M., Zhai, Z., Jenks, A., "EPRI-NRC Cooperative Research Project: PWSCC Crack Initiation Characterization of Alloys 600/182 and Alloys 690/52/152 - Status Update," Presented at the *Industry / U.S. Nuclear Regulatory Commission Materials Programs Technical Information Exchange Public Meeting*, May 21-22, 2019, Rockville, MD, NRC ADAMS No. ML19134A252.

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12. Westinghouse Document, WCAP-16983-P, Revision 1, "Point Beach Units 1 and 2 Extended Power Uprate (EPU) Engineering Report," October 2014

13. Materials Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick-Wall Alloy 600 Materials (MRP-55) Revision 1, EPRI, Palo Alto, CA: 2002. 1006695.

14. Materials Reliability Program Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Alloy 82, 182, and 132 Welds (MRP-115), EPRI, Palo Alto, CA: 2004. 1006696.

15. Sakima, K., Maeguchi, T., et. al., "An Update on Alloys 690/52/152 PWSCC Initiation Testing," 17th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, August 9-13, 2015, Ontario, Canada.

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19. Nextera Report, Docket 50-301, "Point Beach Nuclear Plant, Unit 2, Fall 2012 Unit 2 (U2R32) Steam Generator Tube Inspection Report." May 16, 2013, NRC ADAMS Accession No. ML13140A015.

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21. License Event Report No. 50-338/2012-001-00, "North Anna Power Station, Unit 1, Degraded Reactor Coolant System Piping Due To Primary Water Stress Corrosion Cracking," NRC ADAMS Accession No. ML12151A441.

22. NRC Proposed rulemaking for ASME 2015-2017 Code Editions, 10 CFR Part 50, Federal Register, Vol. 83, No. 218, November 9, 2018.

Appendix A

Point Beach Unit 2 Steam Generator Primary Nozzle to Safe-End Weld PWSCC Growth Analysis

Point Beach Unit 2 Steam Generator Primary Nozzle to Safe-End Weld PWSCC Growth Analysis

1.0 Introduction

The potential for Primary Water Stress Corrosion Cracking (PWSCC) of the Point Beach Unit 2 Steam Generator (SG) inlet and outlet nozzle Dissimilar Metal (DM) weld requires an appropriate assessment of the examination frequency as well as the overall examination strategy for nickel-base alloy components and weldments. The Point Beach Unit 2 SGs were fabricated with factory welded stainless steel safe ends attached to the SG primary nozzles with Alloy 82 DM welds. The inside surface of the welds and adjacent base materials were cladded with PWSCC resistant Alloy 52 material during fabrication.

In December 2013, NextEra Energy submitted Relief Request 2-RR-7 to the Nuclear Regulatory Commission (NRC) per ML13365A310 [1], as supplemented with Request for Additional Information (RAI) responses per ML14206A929 [2], to request re-categorization of the primary steam generator (SG) nozzle to safe-end welds to Inspection Item G, "Uncracked Butt Weld Mitigated With an Inlay" per Code Case N-770-1 [3]. Re-categorization of the welds to Inspection Item G would allow inspection of the welds once every 10-year inspection interval in lieu of once every 5 years for Inspection Item A-2 (SG inlet nozzle) and every second inspection period not exceeding 7 years for Inspection Item B (SG outlet nozzle). Note that ASME Section XI Code Case N-770-2 [4] is the latest NRC approved version per 10CFR50.55a. The inspection frequency guidelines in Code Case N-770-2 for Inspection Item A-2, B, and G are the same as those provided in N-770-1.

In response to the NextEra Energy Relief Request [1], the NRC requested a flaw evaluation be performed to demonstrate that the SG DM welds possess adequate thickness to protect against failure due to PWSCC. This request was completed in Westinghouse letter report LTR-PAFM-15-11-P Revision 0 [5] in June 2015. The crack growth evaluation in the letter report provided a technical basis for extending the examination interval for the steam generator dissimilar metal welds from 5 and 7 years for the steam generator inlet and outlet nozzle, respectively, to a duration of 7.5 EFPY.

In August 2015, NextEra Energy submitted Relief Request 2-RR-11 in ML15225A104 [6] and ML15324A152 [7] to the NRC which included the LTR-PAFM-15-11-P Revision 0 [5] PWSCC growth analysis of the SG inlet and outlet nozzle dissimilar metal welds. The Relief Request 2-RR-11 was approved by the NRC per ML16063A058 [8] in March 2016, which allowed the SG DM welds to be inspected 7.5 EFPY from the last examination for these welds.

The volumetric and eddy current surface examinations were previously performed for the Point Beach Unit 2 SG primary nozzle DM welds during the November 2012 refueling outage with no indication on any of the four DM welds. The next scheduled volumetric examination for the SG primary nozzle DM welds is planned for the March 2020 refueling outage which is 7.5 EFPYs past November 2012 refueling outage. Point Beach Unit 2 is seeking relaxation beyond 7.5 EFPY previously determined in LTR-PAFM-15-11-P [5] to perform the volumetric inspection in Fall 2021, which is at least 9 years (8.6 EFPY) past November 2012, by performing an updated crack growth evaluation in this Appendix A of the letter report. The crack growth evaluation will be used to determine the maximum time allowed between inspections for the SG DM welds.

The crack growth analysis herein will start with an initial flaw depth of 1.5mm (half of the Alloy 52 weld inlay thickness), for a postulated axial flaw with aspect ratio (flaw length/flaw depth) of 2 and a postulated circumferential flaw with aspect ratio of 10. The evaluation includes PWSCC growth of the postulated initial flaws through the Alloy 52 inlay with a factor of improvement of 18 above the MRP-115 [11] crack growth for Alloy 182 material. The justification for the use of the factor of improvement of 18 for the Alloy 52 weld is provided in the main body of this letter report, as supported by numerous expert panel reviews and laboratory data. Also note that once the postulated flaw is through the Alloy 52 inlay, additional PWSCC growth will be performed through the Alloy 82 DM weld thickness based on the crack growth rate in MRP-115. The flaw evaluation will be consistent with the methodology in ML101260554 [9] and the previously accepted flaw evaluation in LTR-PAFM-15-11-P [5].

2.0 Methodology

In order to support the technical justification for a proposed extension to the examination intervals for the Point Beach Unit 2 SG primary nozzle DM welds, it is necessary to demonstrate the structural integrity of the SG primary nozzle DM welds subjected to the PWSCC growth mechanism. To demonstrate the structural integrity of the DM welds, it is essential to determine the operation duration for which it would take the postulated initial axial and circumferential flaws to grow to the maximum allowable end-of-evaluation period flaw size.

A postulated initial flaw depth of 1.5 mm (0.06 inch) (half the inlay weld thickness) is used for the flaw evaluation, consistent with ML101260554 [9] and LTR-PAFM-15-11-P [5]. Per Relief Request 2-RR-11 in ML15225A104 [6], the SG primary nozzle welds had performed an ASME Section XI, Appendix VIII qualified automated phased array ultrasonic (PA-UT) examination as well as ASME Section XI Appendix IV automated eddy current (ECT) examination in November 2012 with remote tooling from the inside surface. Neither the PA-UT nor the ECT recorded indications on any of the four DM welds. The use of both ECT and PA-UT ensured that neither surface breaking nor subsurface flaws were located within the lower 1/3 thickness of the weld which could propagate through the Alloy 52 cladding material into the Alloy 82 weld material. Therefore, based on the nondestructive examination (NDE) results, the initial postulated flaw depth of 1.5 mm (0.06 inch), which is half the inlay weld thickness, is appropriate for the SG DM welds.

The maximum allowable end-of-evaluation period flaw size is determined in accordance with the 2007 Edition with 2008 Addenda of the ASME Section XI Code [10]. To determine the maximum allowable end-of-evaluation period flaw sizes and the crack tip stress intensity factors used for the PWSCC analysis, it is necessary to establish the stresses, crack geometry, and the material properties at the locations of interest. The applicable loadings which must be considered consist of piping loads acting at the DM weld regions and the welding residual stresses which exist in the region of interest.

The loadings considered in the analysis included the latest piping loads, taking into consideration the replacement steam generator and the Extended Power Uprate (EPU) programs. In addition to the piping loads, the effects of welding residual stresses are also considered. The nozzle geometry and piping loads used in the fracture mechanics analysis are shown in Section 3.0. A discussion of the plant specific welding residual stress distributions used for the DM welds is provided in Section 4.0. The determination of the maximum allowable end-of-evaluation period flaw sizes is discussed in Section 5.0.

The flaw growth is determined due to the PWSCC growth mechanism in the SG primary nozzle Alloy 82 DM weld and Alloy 52 inlay material. The PWSCC growth model for the Alloy 82 DM weld material is per MRP-115 [11]. For the Alloy 52 inlay, the PWSCC growth considers a factor of improvement of 18 over the MRP-115 [11] crack growth rate for the Alloy 182 material. This factor of improvement is used to justify performing the volumetric examination of the SG DM welds in Fall 2021 refueling outage, which is 9 years (8.6 EFPY) from the previous November 2012 inspection. The PWSCC growth is calculated based on the normal operating temperature and the crack tip stress intensity factors resulting from the normal operating steady state piping loads and welding residual stresses as discussed in Section 6.0. Section 7.0 provides the flaw growth curves used in determining the allowable inspection interval for the Point Beach Unit 2 SG primary nozzle DM welds.

3.0 Nozzle Geometry and Loads

Geometry, Material Properties, and Normal Operating Parameters

The Point Beach Unit 2 SG inlet and outlet nozzle dissimilar metal weld geometries were based on SG drawing [12]. The dimensions are shown in Table 3-1. The limiting material properties used were based on those for the weaker stainless steel safe end material in lieu of the DM weld material. The nozzle normal operating temperatures were based on EPU program design parameters in WCAP-16983-P [13]. A normal operating pressure of 2250 psia was used in the analysis.

Table 3-1
Point Beach Unit 2 Steam Generator Primary Nozzle Geometry, Normal Operating Temperatures, and Material Properties

a,c,e

Piping Loads

The piping loads due to pressure, deadweight, 100% power normal operating thermal expansion, seismic events, and Loss of Coolant Accident (LOCA) events were considered for the analysis of the SG inlet and outlet nozzles. The Operation Basis Earthquake (OBE) loads are assumed to be the same as the Safe Shutdown Earthquake (SSE) loads for conservatism. The axial force and moment components for various loadings are summarized in Table 3-2. The loadings considered in this analysis included the effects of the replacement steam generator program and the EPU program in WCAP-16983-P [13]. The loads in Table 3-2 bound both loops of the Point Beach Unit 2 reactor coolant system.

Table 3-2
Point Beach Unit 2 Piping Loads

a,c,e

4.0 Dissimilar Metal Weld Residual Stress Distribution

The residual stresses used in the generation of the crack growth evaluation charts are obtained from the finite element residual stress analysis for the Point Beach Unit 2 Steam Generator dissimilar metal weld geometry in C-8850-00-01 [15].

The finite element analyses in C-8850-00-01 [15] were performed to simulate the weld fabrication process for the nozzle safe end weld region assuming an initial 50% inside surface weld repair in accordance with the guidelines in MRP-287 [16]. A two-dimensional axisymmetric finite element model of the nozzle was used in the finite element analysis. The finite element model geometry includes a portion of the low alloy steel nozzle, the stainless steel safe end, a portion of the stainless steel piping, the DM weld attaching the nozzle to the safe end (along with an inlay on the inside surface), and the stainless steel weld attaching the safe end to the piping. Figure 4-1 shows a sketch of the final nozzle DM weld configuration. The following fabrication sequence was simulated in the finite element residual stress analysis:

- The SG nozzle is buttered with weld-deposited Alloy 82 material. The inside surface of the buttering and the nozzle is cladded with weld deposited Alloy 52 material.
- The nozzle and buttering are post weld heat treated at 1100°F.
- The nozzle is welded to the safe end ring forging with an Alloy 82 weld, with a layer of Alloy 52 on the inside surface.
- A repair cavity of 50% of the wall thickness is machined out of the weld region as per the guidance in MRP-287 [16]. The repair cavity is filled with Alloy 82 weld metal, with a layer of Alloy 52 on the inside surface.
- The outside and inside diameters of the weld region are machined to final size.
- A shop hydrotest is performed at a pressure of 3110 psig and temperature of 300°F.
- The safe end is machined with the piping side weld prep.
- The machined safe end is welded to a long segment of stainless steel piping using a stainless steel weld.
- A plant hydrotest is performed at a pressure of 2485 psig and a temperature of 300°F.
- After the plant hydrotest, normal operating temperature and pressure was uniformly applied three times to consider any shakedown effects, after which the model was set to normal operating conditions.

The resulting hoop and axial welding residual stresses under normal operating conditions in the DM weld region are shown in Figures 4-2 and 4-3 respectively. The normal operating hoop welding residual stresses have been modified slightly from C-8850-00-01 [15] as shown in Figure 4-2 and used in the crack growth analysis. This is done so that the 3rd order polynomial fit of the modified hoop stress will adequately represent the original hoop stresses at the inside surface of the inlay from C-8850-00-01 [15], as shown in Figure 4-2. The 3rd order polynomial stress fit provides a better fit for the hoop stresses than a 4th order polynomial.

The axial residual stresses from C-8850-00-01 [15] have also been modified as shown in Figure 4-3, and the modified stresses are fitted to a 4th order curve fit in order to adequately represent the original axial stresses from C-8850-00-01 [15]. The modified axial stresses shown in Figure 4-3 are used in the crack growth analysis.

The axial stresses used in the PWSCC growth analysis are based on the combination of the axial welding residual stresses and the stresses due to pressure, normal operating thermal expansion loads, and the deadweight loads.

As stated in ML101260554 [9], the weld residual stress calculation should model the inlay in three weld layers before the weld is machined to final size; however, in the C-8850-00-01 [15] residual stress evaluation, the inlay is made of two weld layers and is then machined to the final size. It is important to note that the Point Beach Unit 2 SG inlay was applied during fabrication, and not as an inservice repair. Since the inlay was applied during fabrication, the inlay is built out even with the inside surface of the cladding and safe-end and the final machining is applied to the entire inside surface of the component, including the inlay, nozzle cladding, and safe-end. For a traditional inservice repair, the inlay is built out past the inside surface of the surrounding material and only the inlay is machined, which would result in higher stresses in the inlay. Since, for the Point Beach Unit 2 SG, the inlay is machined to final size along with the surrounding material, the differences that would result in the residual stress distribution due to applying two weld layers as opposed to three will be insignificant based on engineering judgment. The consideration of the 50% inside surface weld repair which was conservatively modeled in the finite element analysis even though the Point Beach Unit 2 SG primary nozzle DM welds are free of repairs, provides additional basis that the residual stress evaluation is conservative.

The welding residual stress used herein is consistent with that originally considered in LTR-PAFM-15-11-P [5] and approved by the NRC in ML16063A058 [8].

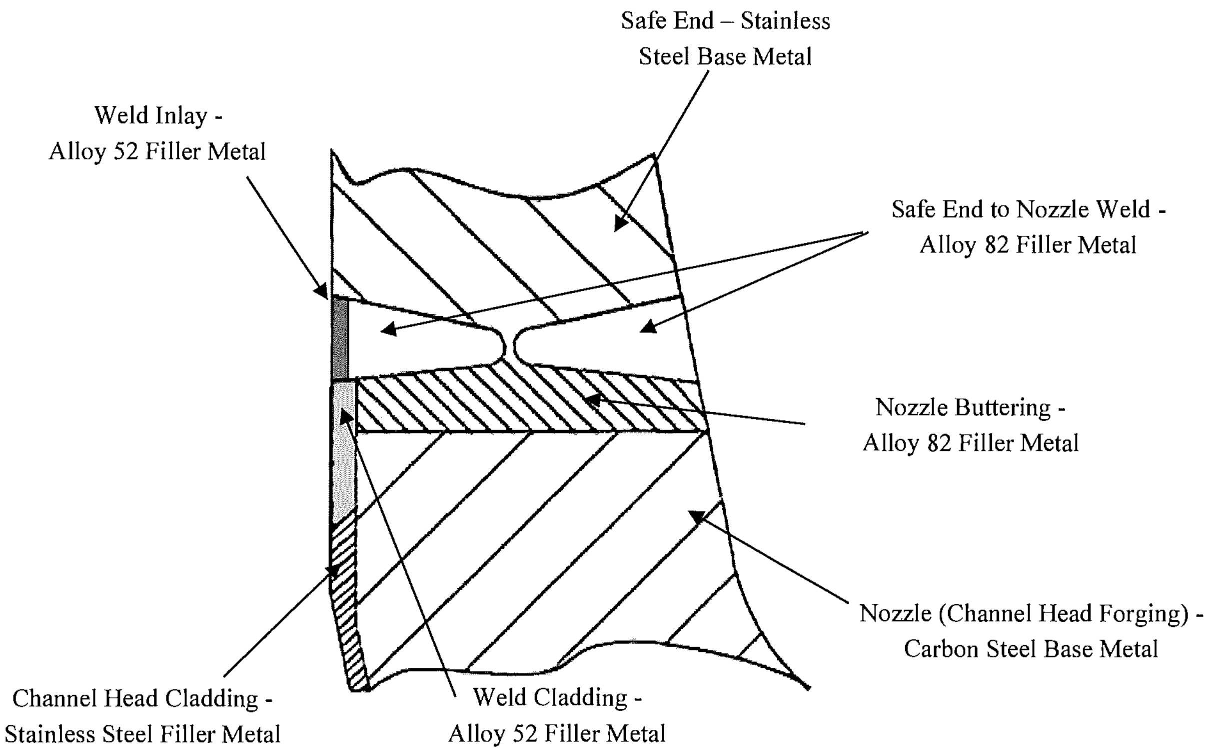

Figure 4-1: Point Beach Unit 2 Steam Generator Dissimilar Metal Weld Configuration

a,c,e

Figure 4-2: Through-Wall Hoop Residual Stress at the SG Inlet and Outlet Nozzle DM Welds Under Normal Operating Conditions

a,c,e

Figure 4-3: Through-Wall Axial Residual Stress at the SG Inlet and Outlet Nozzle DM Welds Under Normal Operating Conditions

5.0 Maximum Allowable End-of-Evaluation Period Flaw Size Determination

In order to develop the technical justification for a longer interval between examination of the SG primary nozzle DM welds, the first step is the determination of the maximum allowable end-of-evaluation period flaw sizes. The maximum allowable end-of-evaluation period flaw size is the size to which an indication can grow to until the next inspection or evaluation period. This particular flaw size is determined based on the piping loads, geometry, and the material properties of the component. The evaluation guidelines and procedures for calculating the maximum allowable end-of-evaluation period flaw sizes are described in paragraph IWB-3640 and Appendix C of the ASME Section XI Code [10].

Rapid, nonductile failure is possible for ferritic materials at low temperatures, but is not applicable to the nickel-base alloy material. In nickel-base alloy material, the higher ductility leads to two possible modes of failure, plastic collapse or unstable ductile tearing. The second mechanism can occur when the applied J integral exceeds the J_{Ic} fracture toughness, and some stable tearing occurs prior to failure. If this mode of failure is dominant, then the load-carrying capacity is less than that predicted by the plastic collapse mechanism. The maximum allowable end-of-evaluation period flaw sizes of paragraph IWB-3640 for the high toughness materials are determined based on the assumption that plastic collapse would be achieved and would be the dominant mode of failure. However, due to the reduced toughness of the DM welds, it is possible that crack extension and unstable ductile tearing could occur and be the dominant mode of failure. To account for this effect, penalty factors called "Z factors" were developed in ASME Code Section XI, which are to be multiplied by the loadings at these welds. In the current analysis for Point Beach Unit 2, Z factors based on MRP-216 [17] are used in the analysis to provide a more representative approximation of the effects of the DM welds. The Z-factors for Alloy 82/182 from MRP-216 [17] have been incorporated into the latest NRC approved ASME Section XI 2013 Edition per 10CFR50.55a. The use of Z factors in effect reduces the maximum allowable end-of-evaluation period flaw sizes for flux welds and thus has been incorporated directly into the evaluation performed in accordance with the procedure and acceptance criteria given in IWB-3640 and Appendix C of ASME Code Section XI. It should be noted that the maximum allowable end-of-evaluation period flaw sizes is 75% of the wall thickness in accordance with the requirements of ASME Section XI paragraph IWB-3640 [10].

The maximum allowable end-of-evaluation period flaw sizes determined for both axial and circumferential flaws have incorporated the relevant material properties, pipe loadings, and geometry. Loadings under normal, upset, emergency, and faulted conditions are considered in conjunction with the applicable safety factors for the corresponding service conditions required in the ASME Section XI Code. For circumferential flaws, axial stress due to the pressure, deadweight, thermal expansion, seismic, and pipe break loads are considered in the evaluation. As for the axial flaws, hoop stress resulting from pressure loading is used.

The maximum allowable end-of-evaluation period flaw sizes for the axial and circumferential flaws at the SG primary nozzle DM welds are provided in Table 5-1. The maximum allowable end-of-evaluation period axial flaw size was calculated with an aspect ratio (flaw length/flaw depth) of 2. The aspect ratio of 2 is reasonable because the axial flaw growth due to PWSCC is limited to the width of the DM weld configuration. For the circumferential flaw, an aspect ratio of 10 is used.

It should be noted that the resulting maximum allowable end-of-evaluation period flaw sizes were limited by the ASME Code limit of 75% of the weld thickness for both flaw configurations.

Table 5-1
Maximum End-of-Evaluation Period Allowable Flaw Sizes
(Flaw Depth/Wall Thickness Ratio - a/t)

Axial Flaw (Aspect Ratio = 2)	Circumferential Flaw (Aspect Ratio = 10)
0.75	0.75

6.0 PWSCC Growth Analysis

The PWSCC growth analysis involves postulating an inside flaw in the dissimilar metal weld inlay for the nozzles of interest. The objective of this analysis is to determine the service life required for a postulated inside surface flaw to propagate to a size that exceeds the maximum allowable end-of-evaluation period flaw depth as described in Section 5.0. An initial flaw depth of 1.5 mm (0.06 inch) into the inlay will be used in the crack growth evaluation. Note that for all postulated inside surface flaws, the governing crack growth mechanism for the SG primary nozzle DM welds is PWSCC.

Crack growth due to PWSCC was calculated for both axial and circumferential flaws based on the normal operating condition steady-state stresses combined with the welding residual stresses. For axial flaws, the hoop stresses are due to pressure and residual stresses. For circumferential flaws, the axial stresses considered are due to pressure, thermal expansion, deadweight, and residual stresses. The input required for the crack growth analysis is basically the information necessary to calculate the crack tip stress intensity factor (K_I), which depends on the geometry of the crack, its surrounding structure, and the applied stresses. The geometry and loadings for the nozzles of interest are discussed in Section 3.0 and the applicable residual stresses used are discussed in Section 4.0. Once K_I is calculated, PWSCC growth due to the applied stresses can be calculated using the crack growth rate for the Alloy 82 nickel-base alloy from MRP-115 [11]. For PWSCC through the Alloy 52 inlay thickness, a factor of improvement of 18 over the MRP-115 [11] crack growth for the Alloy 182 material is conservatively used, in order to justify performing the volumetric examination of the SG DM welds in Fall 2021 refueling outage, which is 9 years (8.6 EFPY) from the previous November 2012 inspection.

Using the applicable stresses at the DM welds, the crack tip stress intensity factors can be determined based on the stress intensity factor expressions from NASA database [18] and API-579 2007 Edition [19]. Since the hoop welding residual stresses are best fitted with a 3rd order polynomial, the stress intensity factor expression for the axial flaws will be based on the NASA database from [18]. The axial residual stresses were fitted with a 4th order polynomial; therefore, the circumferential stress intensity factor expressions are from API-579 [19]. A 4th order polynomial stress distribution profile is defined as:

$$\sigma = \sigma_0 + \sigma_1 \left(x/t\right) + \sigma_2 \left(x/t\right)^2 + \sigma_3 \left(x/t\right)^3 + \sigma_4 \left(x/t\right)^4$$

Where:

σ_0, σ_1, σ_2, σ_3, and σ_4 are the stress profile curve fitting coefficients;

x is the distance from the wall surface where the crack initiates;

t is the wall thickness; and

σ is the stress perpendicular to the plane of the crack.

The stress intensity factor calculations for semi-elliptical inside surface axial and circumferential flaws are expressed in the general form as follows:

$$K_I = \sqrt{\frac{\pi a}{Q}} \sum_{j=0}^{n} G_j(a/c, a/t, t/R, \Phi)\sigma_j \left(\frac{a}{t}\right)^j$$

Where:

a	=	Crack depth
c	=	Half crack length along surface
t	=	Thickness of cylinder
R	=	Inside radius
Φ	=	Angular position of a point on the crack front
n	=	Order of polynomial fit
G_j	=	G_j is the influence coefficient for j^{th} stress distribution on crack surface (i.e., G_0, G_1, G_2, G_3, G_4)
σ_j	=	σ_j is stress profile curve fitting coefficient for j^{th} stress distribution (i.e., σ_0, σ_1, σ_2, σ_3, σ_4)
Q	=	The shape factor of an elliptical crack is approximated by: $Q = 1 + 1.464(a/c)^{1.65}$ for $a/c \leq 1$ or $Q = 1 + 1.464(c/a)^{1.65}$ for $a/c > 1$

Once the crack tip stress intensity factors are determined, PWSCC growth calculations can be performed using the crack growth rate discussed below with the applicable normal operating temperature.

The Point Beach SG inlet and outlet nozzle to safe end dissimilar metal weld regions are primarily made of nickel based alloys (Alloy 82) with an Alloy 52 inlay on the inside surface. The Alloy 52 inlays were installed as a protective barrier for the Alloy 82 weld against PWSCC. Alloy 52 weld metal is known to be more resistant to PWSCC than the lower chromium content Alloy 82. Current industry data, as discussed in the main body of this letter, suggests that the PWSCC crack growth for Alloy 52 has a factor of improvement of 100 over the PWSCC crack growth of Alloy 182 or better. However, for the evaluation contained herein, a conservative improvement factor of 18 over the Alloy 182 crack growth rate will be used to represent the crack growth rate of Alloy 52.

The PWSCC growth rate for the Alloy 82/182 material based on MRP-115 [11] is:

$$\frac{da}{dt} = \exp\left[-\frac{Q_g}{R}\left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right]\frac{\alpha}{FOI}(K)^{\beta}$$

Where:

$\frac{da}{dt}$	= Crack growth rate in m/sec (in/hr)
Q_g	= Thermal activation energy for crack growth = 130 kJ/mole (31.0 kcal/mole)
R	= Universal gas constant = 8.314 x 10^{-3} kJ/mole-K (1.103 x 10^{-3} kcal/mole-°R)
T	= Absolute operating temperature at the location of crack, K (°R)
T_{ref}	= Absolute reference temperature used to normalize data = 598.15 K (1076.67°R)
α	= Crack growth amplitude
	= 1.50 x 10^{-12} at 325°C (2.47 x 10^{-7} at 617°F)
β	= Exponent = 1.6
K	= Crack tip stress intensity factor MPa$\sqrt{m}$ (ksi$\sqrt{in}$)
FOI	= Improvement Factor = 2.6 for Alloy 82 (MRP-115),
	= 18 considered for Alloy 52 (see main body of letter report);

The PWSCC growth rate is highly dependent on the temperature at the location of the flaw, furthermore, the crack growth rate increases as the temperature increases. Therefore, during periods when the plant is not in operation, such as refueling outages or shutdowns, the temperature at the SG nozzles is low such that crack growth due to PWSCC is insignificant. Therefore, PWSCC growth calculation should be determined for the time interval when the plant is operating at full power. The amount of time when the plant is operating at full power is determined based on previous plant operation data and the anticipated outages scheduled until the next inspections. This operation duration at full power is referred to as Effective Full Power Years (EFPY). For Point Beach Unit 2, based on operational data, the time interval between the previous inspection in November 2012 and the proposed future inspection in Fall 2021, is conservatively set to 8.6 EFPY (9 calendar years). For Point Beach Unit 2, this translates to a power availability factor of 95.5% to account for the time the plant is operating at 100% power normal operating temperature of 611.1°F.

7.0 Technical Justification for Deferring the Volumetric Examination

Point Beach Unit 2 previously performed qualified automated phased array ultrasonic (PA-UT) and ECT inspections of these welds in November 2012 and no indications were identified during that inspection. Point Beach Unit 2 is seeking relaxation from the ASME Code Case N-770-2 [4] requirement in order to defer the volumetric examination of the SG primary nozzle DM welds planned during the March 2020 refueling outage to Fall 2021. Therefore, the technical basis herein is to justify acceptable PWSCC growth for an undetected postulated flaw for an operation duration of 8.6 EFPY (9 years) for the SG primary nozzle DM welds. A 1.5 mm (0.06") initial flaw depth is postulated for the flaw growth evaluation and an aspect ratio of 2 is used for the axial flaw and an aspect ratio of 10 for the circumferential flaw.

The PWSCC growth was calculated in two stages. The first stage is growth through the Alloy 52 inlay material. As discussed in Section 6.0 for Alloy 52 an improvement factor of 18 over the crack growth rate for Alloy 182 in MRP-115 is used for growth through the inlay. The second stage is growth through the Alloy 82 DM weld based on MRP-115. The crack growth through each material is then combined to determine the length of time it would take for the postulated initial flaw to grow to the maximum allowable end-of-evaluation period flaw size.

Deadweight, normal thermal expansion, and pressure (2.25 ksi) loadings along with through wall axial residual stresses were used to generate the through wall axial stresses used in the PWSCC analysis for the circumferential flaw. Since the axial welding residual stresses are compressive at locations through the wall, PWSCC analyses were performed with and without residual stress in order to determine the most limiting PWSCC growth results. Only through wall normal operating hoop residual stresses were used in the PWSCC analysis for the axial flaw. It should be noted that no fatigue crack growth calculation was performed since crack growth due to PWSCC is the controlling crack growth mechanism.

The PWSCC growth curves for an axial flaw and a circumferential flaw are shown in Figures 7-1 and 7-2 respectively for SG inlet nozzle. The horizontal axis displays service life in Effective Full Power Years (EFPY), and the vertical axis shows the flaw depth to wall thickness ratio (a/t). The maximum allowable end-of-evaluation period flaw sizes are also shown in these figures for the respective flaw configurations. The SG inlet nozzle crack growth results in terms of EFPY are based on a temperature of 611.1°F. Note that the PWSCC growth results for the SG outlet nozzle (temperature = 543°F) are not reported because they are bounded by the SG inlet nozzle results as the hot leg temperature results in faster PWSCC growth through the DM weld. Moreover, the consistency between the SG outlet and inlet nozzle geometry (Table 3-1) results in the same welding residual stresses between the two nozzle DM weld regions; furthermore, the piping loads between the two nozzles are similar in magnitude and do not have any significant difference on the PWSCC growth. Furthermore, the maximum end-of-evaluation flaw sizes (see Table 5-1) are the same for the SG inlet and outlet nozzle regions. As a result, the SG inlet nozzle PWSCC growth results in Figures 7-1 and 7-2 are bounding for the SG outlet nozzle DM weld region as well.

Based on the crack growth results from Figures 7-1 and 7-2, it is demonstrated that it would take more than 8.6 EFPY (9 years) for the postulated 1.5 mm (0.06 inch) deep axial and circumferential flaw in the Point Beach Unit 2 SG inlet nozzle DM weld inlay to grow to the maximum allowable end-of-evaluation period flaw sizes with consideration of Alloy 52 with a FOI of 18 over the Alloy 182 PWSCC rate from

MRP-115. It should be noted that for the SG outlet nozzle, the time duration is much longer than those provided in Figure 7-1 and 7-2 for the FOI of 18 for Alloy 52 due to the lower temperature at the outlet nozzle (T = 543°F) as compared to the inlet nozzle (T = 611.1°F) of the steam generator.

Therefore, the plant specific PWSCC growth results, in this appendix, justifies that Point Beach Unit 2 SG inlet and outlet nozzle DM welds can be examined after a duration of at least 8.6 EFPY (9 years) from the previous refueling outage inspections in November 2012.

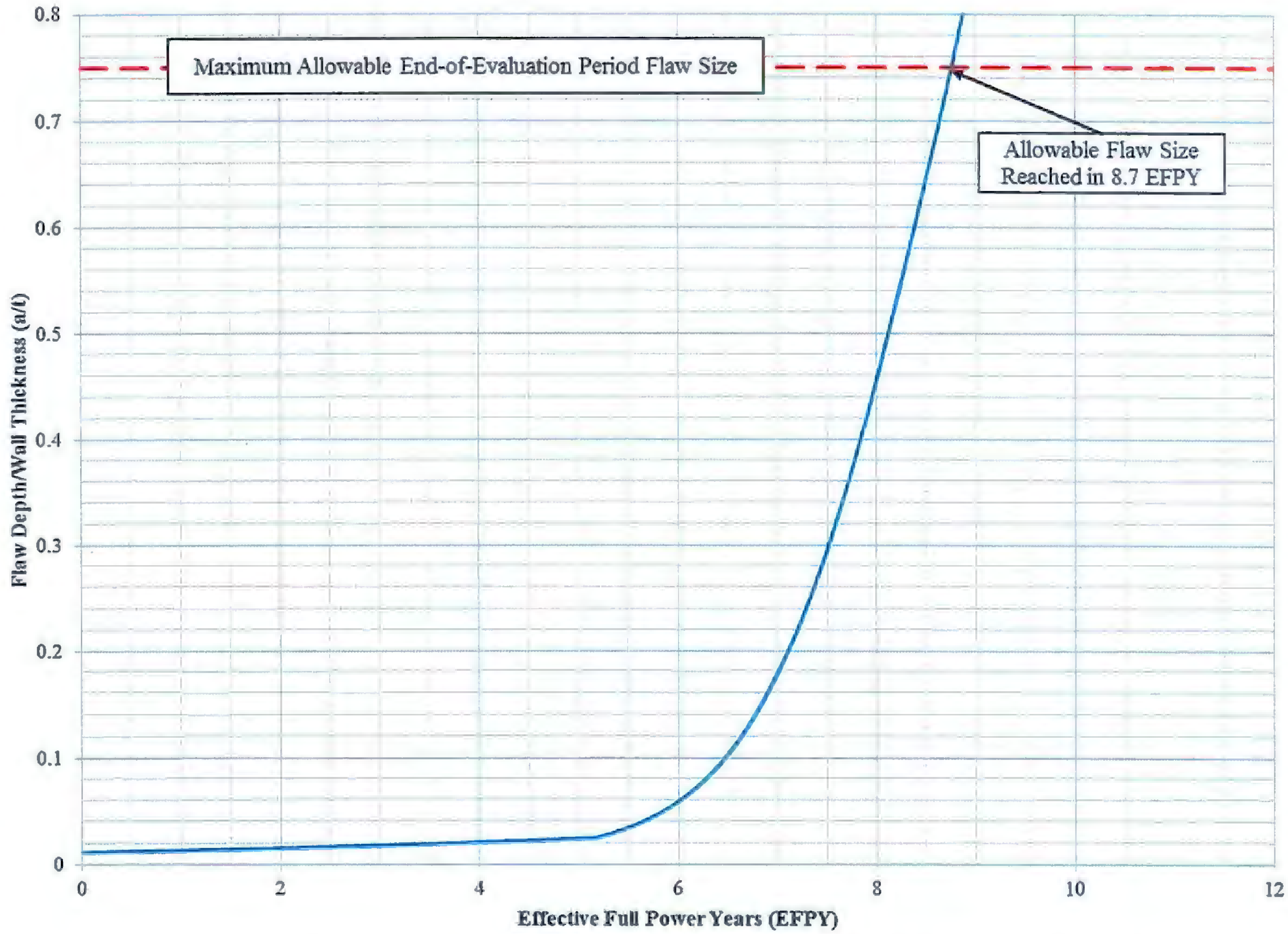

Figure 7-1 Flaw Growth Evaluation Chart for SG Inlet Nozzle (T = 611.1°F) Axial Flaw (AR=2)
For Alloy 52 PWSCC growth rate, a conservative FOI of 18 over the Alloy 182 crack growth rate is used

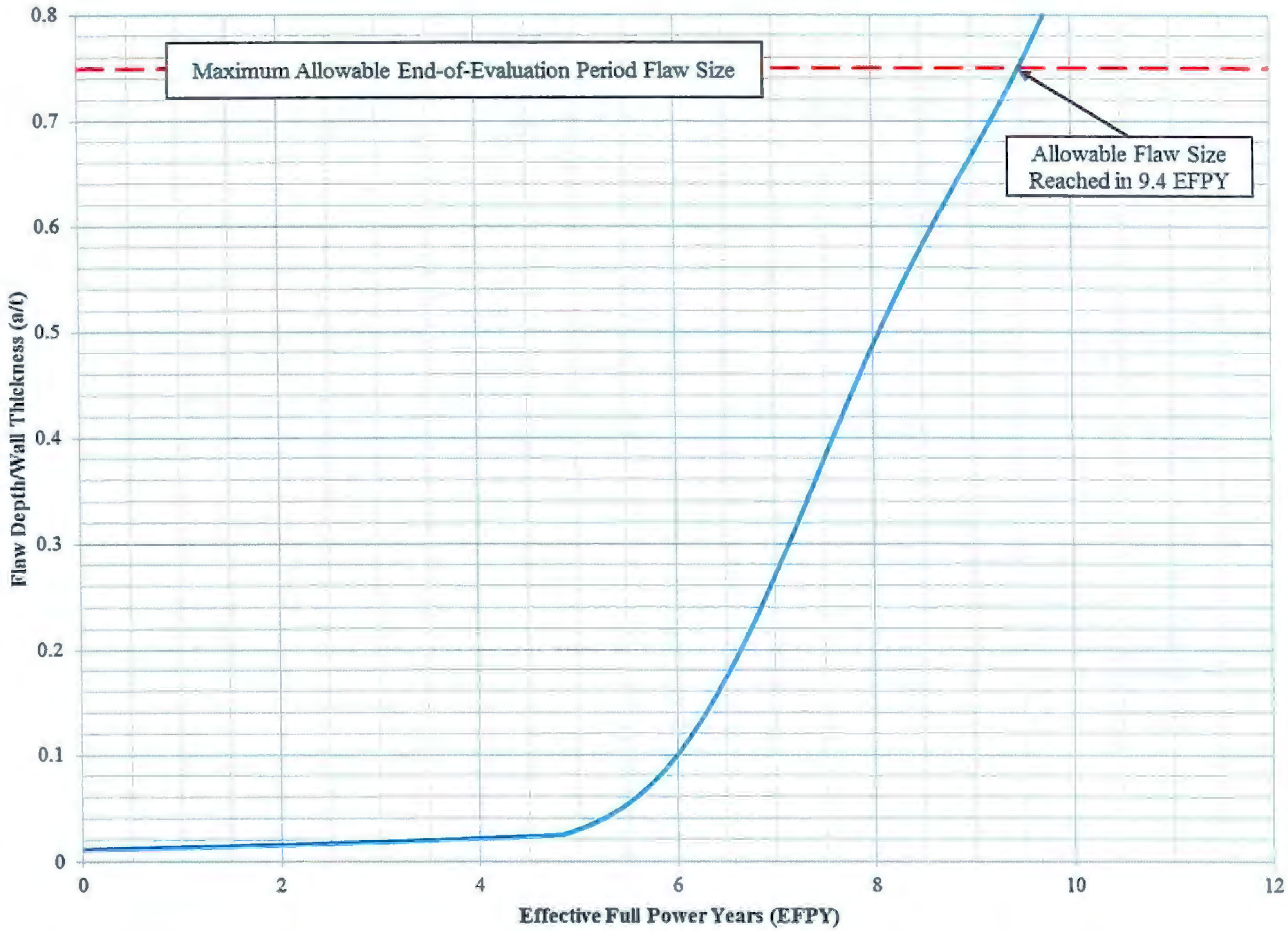

Figure 7-2 Flaw Growth Evaluation Chart for SG Inlet Nozzle (T = 611.1°F) Circumferential Flaw (AR=10)

For Alloy 52 PWSCC growth rate, a conservative FOI of 18 over the Alloy 182 crack growth rate is used

8.0 Summary and Conclusions

In August 2015, NextEra Energy submitted Relief Request 2-RR-11 in ML15225A104 [6] and ML15324A152 [7] to the NRC which included the Westinghouse PWSCC growth analysis in LTR-PAFM-15-11-P [5] of the SG inlet and outlet nozzle dissimilar metal welds. The PWSCC growth analysis extended the examination interval from 5 and 7 years for the steam generator inlet and outlet nozzle, respectively, to 7.5 EFPY. The Relief Request 2-RR-11 was approved by the NRC per ML16063A058 [8] in March 2016.

A volumetric examination and eddy current examination of the SG primary nozzle DM butt welds were performed in November 2012 at Point Beach Unit 2 with no indication on any of the four DM welds. The next required volumetric examination is planned during the March 2020 refueling outage, which is 7.5 EFPY past November 2012. Point Beach Unit 2 is seeking further relaxation from ASME Code Case N-770-2 [4], beyond the 7.5 EFPY to at least 8.6 EFPY (9 years) by performing a flaw evaluation to demonstrate that the SG DM welds possess adequate thickness to protect against failure due to PWSCC.

The PWSCC growth analysis herein is consistent with the methodology in ML101260554 [9] and the previous flaw evaluation LTR-PAFM-15-11-P [5]. A 1.5 mm (0.06 inch) inside surface flaw is postulated in the inlay and the amount of time is determined for the flaw to reach the maximum allowable end-of-evaluation period flaw size. This maximum allowable end-of-evaluation period flaw size would be the largest flaw size that could exist in the DM welds and be acceptable according to the ASME Section XI Code [10]. Crack growth was calculated based on the PWSCC growth mechanism through both the Alloy 52 inlay and the Alloy 82 DM weld. The evaluation herein considered the PWSCC crack growth through the Alloy 82 DM weld based on MRP-115 [11], while for the PWSCC growth though the Alloy 52 weld inlay, a factor of improvement of 18 over the crack growth rate for Alloy 182 based on MRP-115 [11] was used. The justification for the factor of improvement of 18 for the Alloy 52 weld material is provided in numerous laboratory data as discussed in the main body of this letter report.

The results in Figures 7-1 and 7-2 demonstrate that it would take more than 8.6 EFPY (9 years) for the postulated 1.5 mm (0.06 inch) deep axial and circumferential flaw in the Point Beach Unit 2 SG inlet nozzle DM weld inlay to grow to the maximum allowable end-of-evaluation period flaw size. The PWSCC growth results for the SG outlet nozzle DM weld are bounded by the results in Figures 7-1 and 7-2 for the SG inlet nozzle, because the outlet nozzle is operating at a lower temperature of 543°F as compared to the inlet nozzle which is at 611.1°F. Furthermore, all other geometric inputs, welding residual stresses, loading, and maximum end-of-evaluation period flaw sizes are consistent between the SG inlet and outlet nozzles; thus, the results for the SG inlet nozzle DM weld conservatively bound the SG outlet nozzle. Therefore, in conclusion, the Point Beach Unit 2 plant specific analysis performed herein justifies an examination interval of 8.6 EFPY (9 years).

9.0 Appendix A References

1. NextEra Energy Point Beach, LLC Letter to NRC, dated December 27, 2013, "10 CFR 50.55a Request, Relief Request 2-RR-7 Re-categorization of Unit 2 Steam Generator Nozzle to Safe-End Welds." [ML13365A310]
2. NextEra Energy Point Beach Unit 2 Letter to NRC, "10 CFR 50.55a Request, Relief Request 2-RR-7, Re-Categorization of Unit 2 Steam Generator Nozzle to Safe-End Welds, Response to Request for Additional Information," July 24, 2014. [ML14206A929]
3. ASME Code Case N-770-1, "Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated with UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities, Section XI, Division 1," Approval Date December 25, 2009.
4. ASME Code Case N-770-2, Section XI Division 1, "Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities Section XI, Division 1," Approval Date June 9, 2011.
5. Westinghouse Letter LTR-PAFM-15-11-P, Revision 0, "Point Beach Unit 2 Steam Generator Primary Nozzle to Safe-end Weld Crack Growth Analysis," June 2015.
6. NextEra Energy Point Beach Unit 2 Letter to NRC, "10 CFR 50.55a Request, Relief Request 2-RR-11, Unit 2 Steam Generator Nozzle to Safe-End Dissimilar Metal (DM) Weld Inspection," August 13, 2015. [ML15225A104]
7. NextEra Energy Point Beach Unit 2 Letter to NRC, "Point Beach Nuclear Plant Unit 2 – Request for Additional Information for Relief Request 2-RR-11 – MF6615," November 19, 2015. [ML15324A152]
8. NRC letter to NextEra Energy Point Beach Unit 2, "Point Beach Nuclear Plant, Unit 2 – Approval of Relief Request 2-RR-11; Steam Generator Nozzle to Safe-End Dissimilar Metal (DM) Weld Inspection RE: (CAC No. MF6615)," March 22, 2016. [ML16063A058]
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10. ASME Boiler & Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 2007 Edition with 2008 Addenda.
11. *Materials Reliability Program: Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Alloy 82, 182, and 132 Welds (MRP-115)*, EPRI, Palo Alto, CA: 2004. 1006696.
12. Westinghouse Drawing 6147E62, Revision 3, Sheets 1 through 6. "Point Beach Unit 2 Model 47F Replacement Steam Generator Channel Head Welding Machining and Assembly."
13. Westinghouse Document, WCAP-16983-P, Revision 1. "Point Beach Units 1 and 2 Extended Power Uprate (EPU) Engineering Report," October 2014.

14. Technical Manual No. TM 1440-C370, Revision 1. "Vertical Steam Generator Instructions for Wisconsin Electric Power Company Point Beach Nuclear Plant – Unit 2." Westinghouse General Order No. MK-77054. June 2012.

15. Dominion Engineering, Inc., Document C-8850-00-01, Revision 0, "Welding Residual Stress Calculation for Steam Generator Nozzle DMW."

16. *Materials Reliability Program: Primary Water Stress Corrosion Cracking (PWSCC) Flaw Evaluation Guidance (MRP-287).* EPRI, Palo Alto, CA: 2010, 1021023.

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18. S. R. Mettu, I. S. Raju, "Stress Intensity Factors for Part-through Surface Cracks in Hollow Cylinders," Jointly developed under Grants NASA-JSC 25685 and Lockheed ESC 30124, Job Order number 85-130, Call number 96N72214 (NASA-TM-111707), July 1992.

19. American Petroleum Institute, API 579-1/ASME FFS-1 (API 579 Second Edition), "Fitness-For-Service," June 2007.

Attachment 3
Westinghouse CAW-19-4934
Affidavit, Proprietary Information Notice, Copyright Notice

(4 pages follow)

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:
COUNTY OF BUTLER:

(1) I, Korey L. Hosack, 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 LTR-SDA-19-071-P 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 to meet NRC requirements for licensing documentation without purchasing the right to use the information.

AFFIDAVIT

(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.

(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

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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: 20190826

Korey L. Hosack, Manager
Product Line Regulatory Support

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and non-proprietary versions of a document, furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary 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 (4)(ii)(a) through (4)(ii)(f) of the Affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).