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JAFP-17-0054
May 25, 2017

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D. C. 20555

Subject: Submittal of Stress Analysis Summary for the 24-10-130 Weld Overlay

James A. FitzPatrick Nuclear Power Plant
Docket No. 50-333
License No. DPR-59

Reference:

1. ENOI letter, Proposed Alternative to ASME Code Requirements for Weld Overlay Repair, RR-21 at James A. FitzPatrick Nuclear Power Plant, JAFP-17-0010, dated January 27, 2017
2. NRC letter, Summary of January 30, 2017, Teleconference with Entergy Nuclear Operations, Inc. Regarding Verbal Authorization for Relief Request RR-21 for the James A. FitzPatrick Nuclear Power Plant (CAC No. MF9128), ML17031A280, dated February 8, 2017
3. ENOI letter, Submittal of the Final Ultrasonic Test Results on the 24-10-130 Weld Overlay, JAFP-17-0023, dated March 9, 2017

Dear Sir or Madam:

During Refueling Outage R22, an indication was found by ultrasonic testing (UT) examination in "A" Residual Heat Removal Low Pressure Coolant Injection Loop weld number 24-10-130. Pursuant to 10 CFR 50.55a(z)(1), James A. FitzPatrick Nuclear Power Plant (JAF) proposed a repair in accordance with Relief Request RR-21 [Reference 1] and included a commitment to submit a stress analysis summary demonstrating that the repaired dissimilar metal weld (DMW) will perform its intended design function after the weld overlay installation. The Enclosure of this letter contains the summary of the stress analysis.

This letter contains no new regulatory commitments. Should you have any questions, please contact me at (315) 349-6562.

Very truly yours,

William C Drews

William C. Drews
Regulatory Assurance Manager

WCD/mh

Enclosure: Stress Analysis Summary for the 24-10-130 Weld Overlay

cc:
USNRC, Region I Administrator
USNRC, Project Manager
USNRC, Resident Inspector
NYSERDA
NYPSC

**JAFP-17-0054**

**Enclosure**

**Stress Analysis Summary for the 24-10-130 Weld Overlay**
**(14 pages)**

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May 24, 2017
Report No. 1700151.402.R0
Quality Program: ☒ Nuclear ☐ Commercial

Keith Schoales
James A. FitzPatrick Nuclear Power Plant
Exelon Corporation
P.O. Box 110
Lycoming, NY 13093-0110

Subject: Summary of Design and Analysis for Full Structural Weld Overlay Repair of James A. FitzPatrick Nuclear Power Plant (JAF), Loop "A" RHR LPCI Dissimilar Metal Weld – Tee-to-Gate Valve

Reference: Entergy Letter No. JAFP-17-0010 dated January 27, 2017, "Proposed Alternative to ASME Code Requirements for Weld Overlay Repair, RR-21 at James A. FitzPatrick Nuclear Power Plant"

Dear Mr. Schoales:

This letter report is being provided in support of JAF's response to a commitment in the above-referenced proposed alternative:

Commitment:

JAF will submit to the NRC a stress analysis summary demonstrating that the repaired dissimilar metal weld (DMW) will perform its intended design function after weld overlay installation. This information will be submitted to the NRC within 90 days of completing JAF's Refueling Outage 22.

The body of the referenced Entergy letter states the stress analysis report will include results showing that the requirements of NB-3200 and/or NB-3600 of the ASME Code, Section III are satisfied. The stress analysis will also include results showing that the requirements of IWB-3000 of the ASME Code, Section XI, are satisfied. The results will show that the as-found defect including its growth will not adversely affect the integrity of the overlaid welds.

Attachment A to this letter report provides the stress analysis summary to satisfy this commitment.

If you have any questions or comments regarding this summary, please contact one of the undersigned.

Prepared by:

05/24/17
Moses Taylor, Jr. Date
Senior Associate

Verified by:

05/24/17
Terry J. Herrmann Date
Senior Associate

Approved by:

05/24/17
Terry J. Herrmann Date
Senior Associate

Attachment

cc: Project File No. 1700151.402.R0 M. Lashley

**ATTACHMENT A**

Summary of Design and Analysis for Full Structural Weld Overlay Repair of James A. FitzPatrick Nuclear Plant, Residual Heat Removal Low Pressure Coolant Injection Loop "A" Weld Number 24-10-130.

## 1.0 INTRODUCTION

James A. FitzPatrick Nuclear Plant (JAF) applied a full structural weld overlay (FSWOL) on dissimilar metal weld (DMW) 24-10-130 between the reactor water recirculation (RWR)/ residual heat removal (RHR) low pressure coolant injection (LPCI) Loop "A" tee-to-RHR gate valve.

The purpose of this overlay is to repair the as-found flaw and to mitigate any potential future intergranular stress corrosion cracking (IGSCC) in this weld. The overlay was installed using an IGSCC resistant weld filler material; Alloy 52M [4].

This report, which satisfies one of the JAF commitments of the Relief Request [1], summarizes the results of the component specific residual stress analyses and the fracture mechanics evaluations, and documents that all ASME Code, Section III stress and fatigue criteria are met. This information is to be submitted within 90 days of completing the refueling outage.

The requirements for design of the weld overlay repair are defined in the Relief Request [1], which is based upon ASME Code Cases N-504-4 [2] and N-638-4 [3], and ASME Code, Section XI, Nonmandatory Appendix Q [5]. The analytical basis for the design of the repair is in accordance with the requirements of ASME Code, Section XI [6], IWB-3640. Weld overlay repairs are acceptable long-term repairs for IGSCC-flawed weldments if they meet a conservative set of design assumptions, which qualify them as "full structural" weld overlays. The three principal design requirements that qualify a weld overlay as "full structural" are as follows:

1. The design basis for the repair is a circumferentially oriented flaw that extends 360° around the component, and is 100% through the original component wall. This conservative assumption eliminates concerns about IGSCC susceptibility of the original Alloy 82/182 DMW. In addition, potential concerns about the integrity of the original butt weld material are not applicable, since no credit is taken for the load carrying capability of this weld.
2. As required by ASME Code, Section XI [6], Appendix C, a combination of internal pressure, deadweight, seismic, and other dynamic stresses is used in the design of a weld overlay repair. Thermal and other secondary stresses are not required to be included for structural sizing calculations (since the repairs are applied using a GTAW process that produces a high toughness weld deposit), but they are addressed later in subsequent stress, fatigue, and stress corrosion cracking evaluations.
3. Following the repair, the surface finish of the overlay must be sufficiently smooth to allow preservice and future inservice ultrasonic examinations through the overlay material and into a portion of the original base metal. The purpose of these examinations is to demonstrate that the overlay design basis does not degrade with time due to flaw propagation.

ASME Code, Section III stress and fatigue usage evaluations are also performed to demonstrate that the overlaid components continue to meet ASME Code, Section III requirements. The original construction Code for the RWR / RHR LPCI Loop "A" tee-to-gate valve DMW was the B31.1 Power Piping Code [8]. However, the original construction Code has been reconciled to the ASME Code, Section III editions applicable to the stress and fatigue usage analyses [14], and as allowed by ASME Code, Section

XI [6], Subsection IWA-4222, Code Editions and Addenda later than the original construction Code may be used. ASME Code, Section III, 2001 Edition with Addenda through 2003 [7] was used for these analyses. In addition to providing structural reinforcement to the IGSCC susceptible locations with a resistant material, weld overlays have also been shown to produce beneficial residual stresses that mitigate IGSCC in the underlying DMWs. The weld overlay approach has been used to repair stress corrosion cracking in U.S. nuclear plants on hundreds of welds, and there have been no reports of subsequent crack extension after application of weld overlays. Thus, the compressive stresses caused by the weld overlay have been effective in mitigating new crack initiation and/or growth of existing cracks.

Finally, evaluations were performed, based on as-built measurements taken after the overlay was applied, to demonstrate that the overlay meet their design basis requirements, and that they will not have an adverse effect on the balance of the piping systems. These include comparison of overlay dimensions to design dimensions, evaluations of shrinkage and added weight effects on the piping systems.

## 2.0 ANALYSIS SUMMARY AND RESULTS

### 2.1 Weld Overlay Structural Sizing Calculations

ASME Code Case N-504-3 [2], which incorporates ASME Code, Section XI [6], IWB-3640 evaluation methodology, was used to determine the thickness of the overlay. The FSWOL thickness design requirements in ASME Code Case N-504-3 are the same as Code Case N-504-4 which is referenced in the Relief Request [1] as the basis for the weld overlay installation. Equations from ASME Code, Section XI [6], Appendix C, and the maximum stresses at the DMW for any Service Level, were used to determine the design FSWOL thickness.

As stated in Section 1.0, a FSWOL was installed using Alloy 52M filler metal. However, Alloy 52M weld metal has demonstrated sensitivity to certain impurities, such as sulfur, when deposited onto austenitic stainless steel base materials. Therefore, buffer (transitional) layers of austenitic stainless steel filler metal were applied across the austenitic stainless steel base material. The austenitic stainless steel buffer layers are not part of the structural weld overlay thickness defined above.

The weld overlay length must consider: (1) sufficient distance on either side of the defect location to provide for effective load transfer across the defect location, (2) length required for access for preservice and inservice examinations of the overlaid weld, and (3) limitation on the area of the component that can be overlaid.

In accordance with the Relief Request [1], which is based on ASME Code Cases N-504-4 [2], the minimum weld overlay length required for structural reinforcement is the length which will provide adequate load transfer from one side of the flaw to the other. Per Reference [2], this criterion is generally satisfied if the overlay full thickness length extends axially at least $0.75\sqrt{Rt}$ on each side of susceptible material where R and t are the outer radius and nominal wall thickness of the overlaid components, prior to depositing the weld overlay.

For this location, with valve and tee transitions increasing sharply on either side of the butt weld the length of the weld overlay is dictated by its thickness and taper on the adjacent valve and tee. This configuration was demonstrated to achieve adequate load transfer and all Code primary stress intensity allowable values are met with overlays that directly tie into the adjacent component at the design minimum thickness of 0.75 inches. Figure 2-1 provides a general illustration of the analyzed configuration of the FSWOL.

The overlay length and profile must also be such that the required post-FSWOL examination volume can be inspected using Performance Demonstration Initiative (PDI) qualified nondestructive examination (NDE) techniques. The final configuration was reviewed by qualified NDE personnel to ensure that it meets inspectability requirements and the Relief Request [1].

ASME Code Case N-638-4 [3] limits the area of the ferritic valve covered by the FSWOL to below 500 square inches.

The as-built weld overlay thickness and length are provided in Table 2-1. These measurements exceed the minimum required structural design dimensions described above, thereby demonstrating the adequacy of the as-installed repair.

Table 2-1: Post-Weld Overlay As-Built Dimensions

| | **Location** | **Thickness or Length** |
|---|---|---|
| Minimum Thickness (in.) | Valve Side | 1.127 |
| Minimum Thickness (in.) | Tee Side | 1.055 |
| Minimum Length (in.) | Valve Side | NA* |
| Minimum Length (in.) | Tee Side | NA* |

*Minimum length dictated by weld overlay thickness and taper on the adjacent valve and tee.

## 2.2 ASME Code, Section III Stress Analyses

Stress intensities for the weld overlaid JAF DMW at the RHR LPCI Loop “A” tee-to-gate valve were determined from finite element analyses for the various specified load combinations and transients using the ANSYS software package [9]. Linearized stresses were evaluated at various stress locations using 3-dimensional solid models. A typical finite element model showing stress path locations is provided in Figure 2-2. The stress intensities at these locations were evaluated in accordance with ASME Code, Section III [7], Sub-articles NB-3200 and NB-3600, and compared to applicable Code limits. A summary of the stress and fatigue usage comparisons for the most limiting locations is provided in Table 2-2. The stresses and fatigue usage in the weld overlaid DMW are within the applicable Code limits.

Table 2-2: Limiting Stress Results for Weld

| Weld | Load Combination | Type | Calculated | Allowable |
|---|---|---|---|---|
| RHR LPCI “A” DMW between Gate Valve and Tee | Level A/B | Primary + Secondary (P +Q) (ksi)* | 45.0 | 50.5 |
| | ASME Code Fatigue | Cumulative Usage Factor | 0.20 | 1.00 |
| | Environmentally Assisted Fatigue (EAF) | Cumulative Usage Factor | 0.24 | 1.00 |

* - Primary stress acceptance criteria are met via the sizing calculations discussed in Section 2.1.

## 2.3 Residual Stress Analyses

Weld residual stresses for the JAF DMW at the RWR/RHR LPCI Loop “A” tee-to-gate valve weld overlay were determined by detailed elastic-plastic finite element analyses. The approach used in the analysis has been benchmarked and validated through multiple 2-dimensional and 3-dimensional ANSYS finite element analyses following the guidelines discussed in MRP-316 [10] and MRP-317 [11], and using the information provided in the problem statements for mock-up specimens [10, 12, 13] and experimental measurements [10]. A three-dimensional, non-axisymmetric finite element model was developed for the overlay configuration. The modeling of weld nuggets used in the analysis to lump the combined effects of several weld beads is illustrated in Figure 2-3. The model simulated an inside surface (ID) repair at the DMW location with a depth of approximately 50% of the original wall thickness. This ID weld repair is intended to meet the guidelines of the MRP-169 Safety Evaluation Report, Section 3.2.2, paragraph three [15], which states,

*“The residual stress analysis assumes a highly unfavorable, pre-overlay residual stress condition which would result from an inside diameter surface weld repair during construction.”*

An analysis is performed to simulate the welding process of the ID weld repair, the FSWOL welding process (including buffer layers and bridge bead), and finally, a slow heatup to operating temperature and pressure. The analysis consists of a thermal pass to determine the temperature response of the model to each individual lumped weld nugget as it is added in sequence, followed by a non-linear elastic-plastic stress pass to calculate the residual stress due to the temperature cycling from the application of each lumped weld pass. Since residual stress is a function of the welding history, the stress pass for each nugget is applied to the residual stress field induced from all previously applied weld nuggets.

After completion of the weld overlay simulation, the model was allowed to cool to a uniform steady state temperature of 70°F, and then five cycles of “shake down” with normal operating temperature and pressure were applied to stabilize the residual stress fluctuations due to stress distribution caused by normal operating loads.

The resulting residual stresses were evaluated on six paths through the DMW. These path definitions are shown in Figure 2-2. The resulting through wall residual stresses along these paths are shown in Figure 2-4.

## 2.4 Section XI Crack Growth Analyses

The residual stress calculations were then utilized, along with stresses due to applied loadings and thermal transients, to demonstrate that assumed cracks that could be missed by inspections or the as-found cracks in the weld will not exceed the overlay design basis during the ASME Section XI inservice inspection interval due to fatigue or IGSCC. In the fatigue crack growth analysis, the 60-year projected cycles for each applied transient was applied.

Given the short length of the overlay and the overall thickness on either side, the FSWOL is not expected to generate sufficient compression to halt IGSCC growth. Therefore, an initial flaw depth of 100% of the original base metal thickness is conservatively used for computing crack growth for an axial or circumferential flaw in the RWR/RHR LPCI Loop “A” tee-to-RHR gate valve DMW with a FSWOL.

Since the initial flaw depth (100% of the original base metal thickness) starts at the DMW to FSWOL material interface, crack growth rates for Alloy 52M, applicable to a BWR environment, are used to calculate the propagation in the thickness direction of the postulated cracks. The stress intensity factors are determined at 100% of the original base metal thickness for the circumferential and axial flaw. The analysis results showing the time it takes for an initial axial or circumferential flaw of 100% of the original base metal thickness to grow to 75% of the total thickness, including the FSWOL, are provided in Table 2-3 for the DMW.

Table 2-3: Crack Growth Results

| Flaw Type | Time for Initial Flaw Depth to Reach 75% of Total Thickness (Base Metal + FSWOL) |
|---|---|
| Circumferential Flaw | > 20 years |
| Axial Flaw | > 20 years |

## 2.5 Evaluation of As-Built Conditions

The Relief Request [1] and Code Case N-504-4 [2] require evaluation of the as-built weld overlays to determine the effects of any changes in applied loads, as a result of weld shrinkage from the entire overlay, on other items in the piping system. These evaluations were performed and are documented separately from this report. Calculations were performed based on design dimensions to confirm that the overlays would not adversely affect critical piping components. Specifically, the effect of the added weight of the overlays on the adjacent piping systems, based on maximum design dimensions, was evaluated and found to be insignificant.

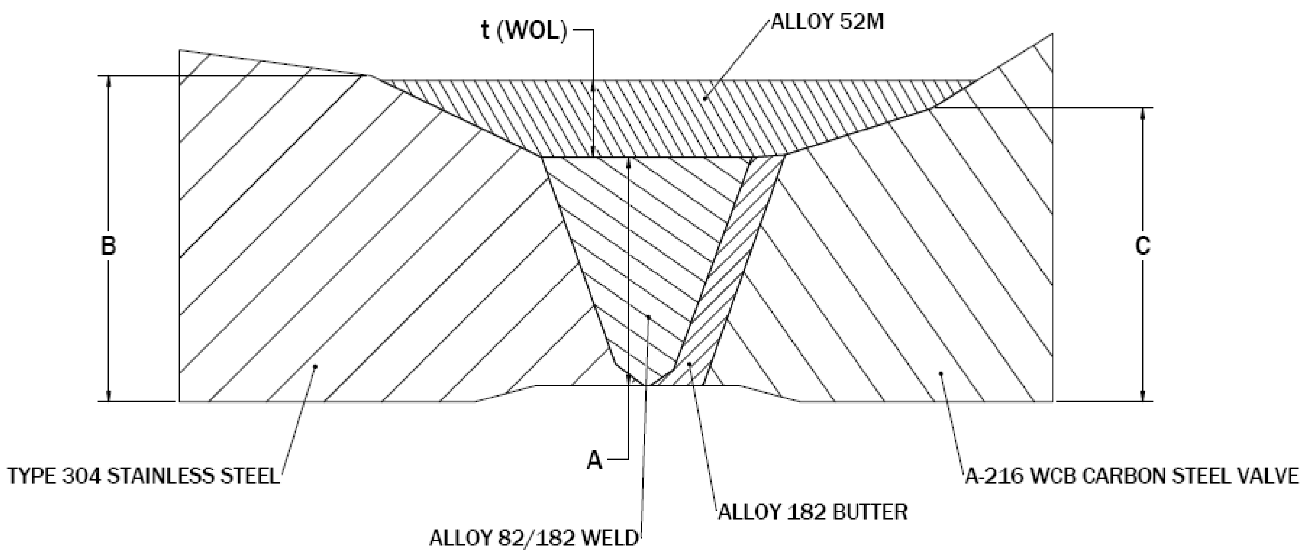
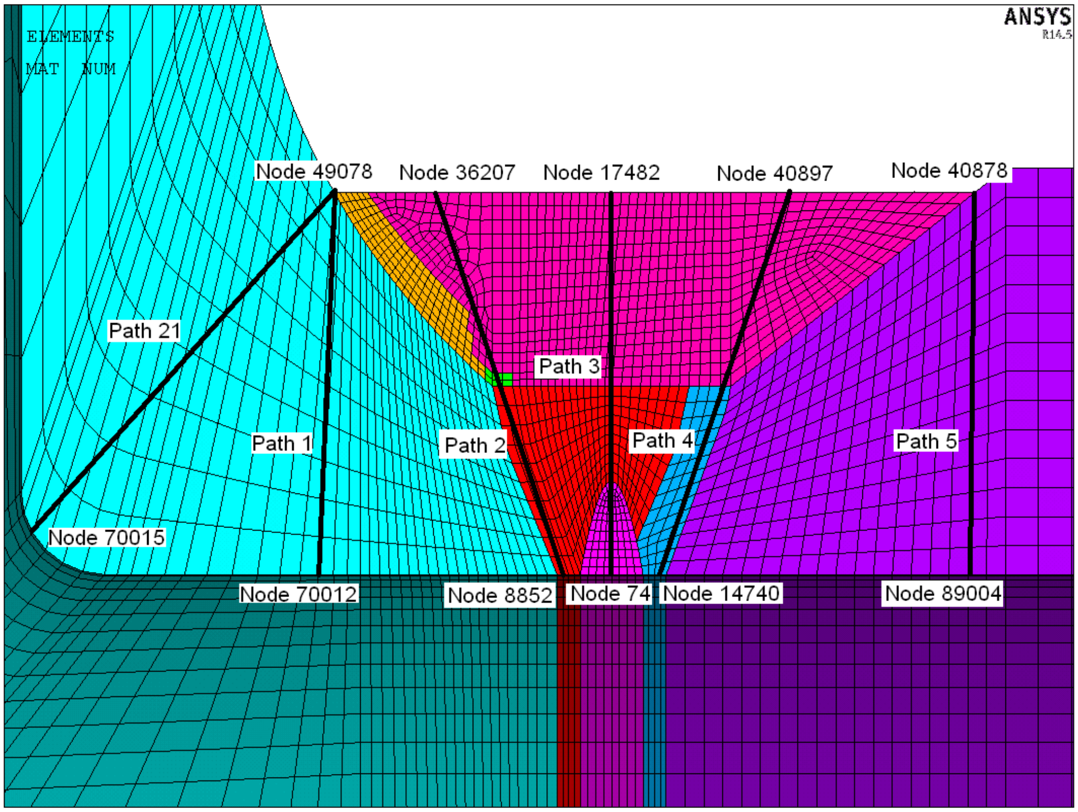



Figure 2-1: General Illustration of Weld Overlay Design

**0° and 180° Cross Sections**




**90º and 270º Cross Sections**

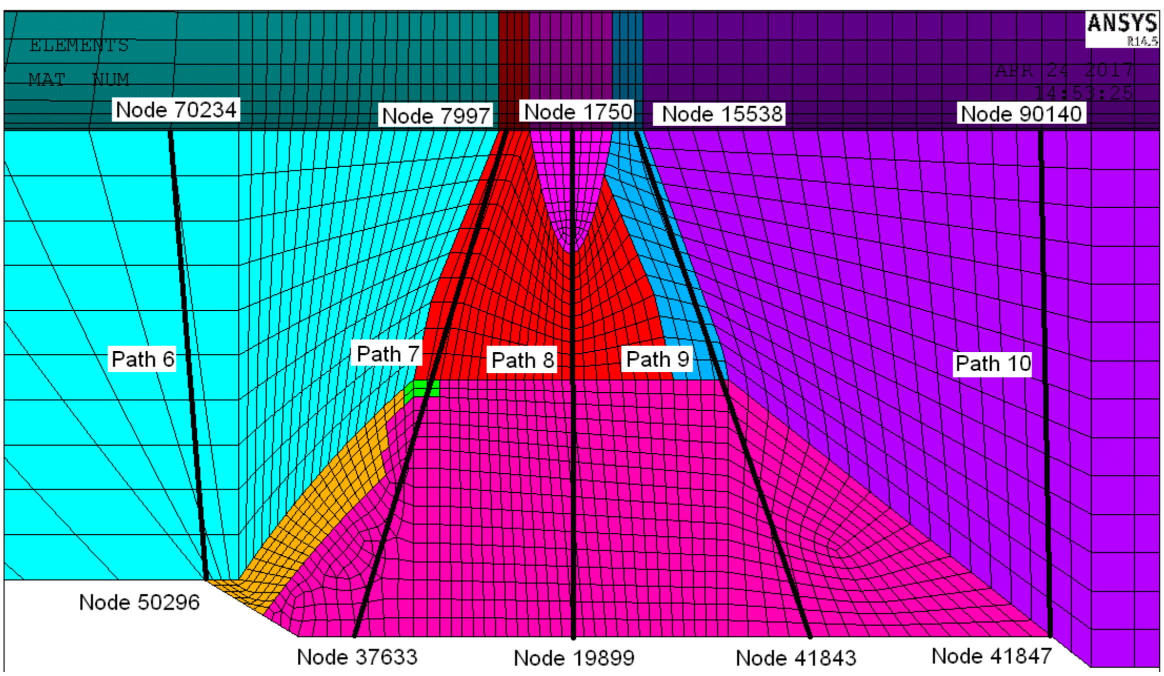



Figure 2-2: Finite Element Model for Section III Stress Evaluation showing Stress Paths (RWR/RHR tee on the left – RHR valve on the right)

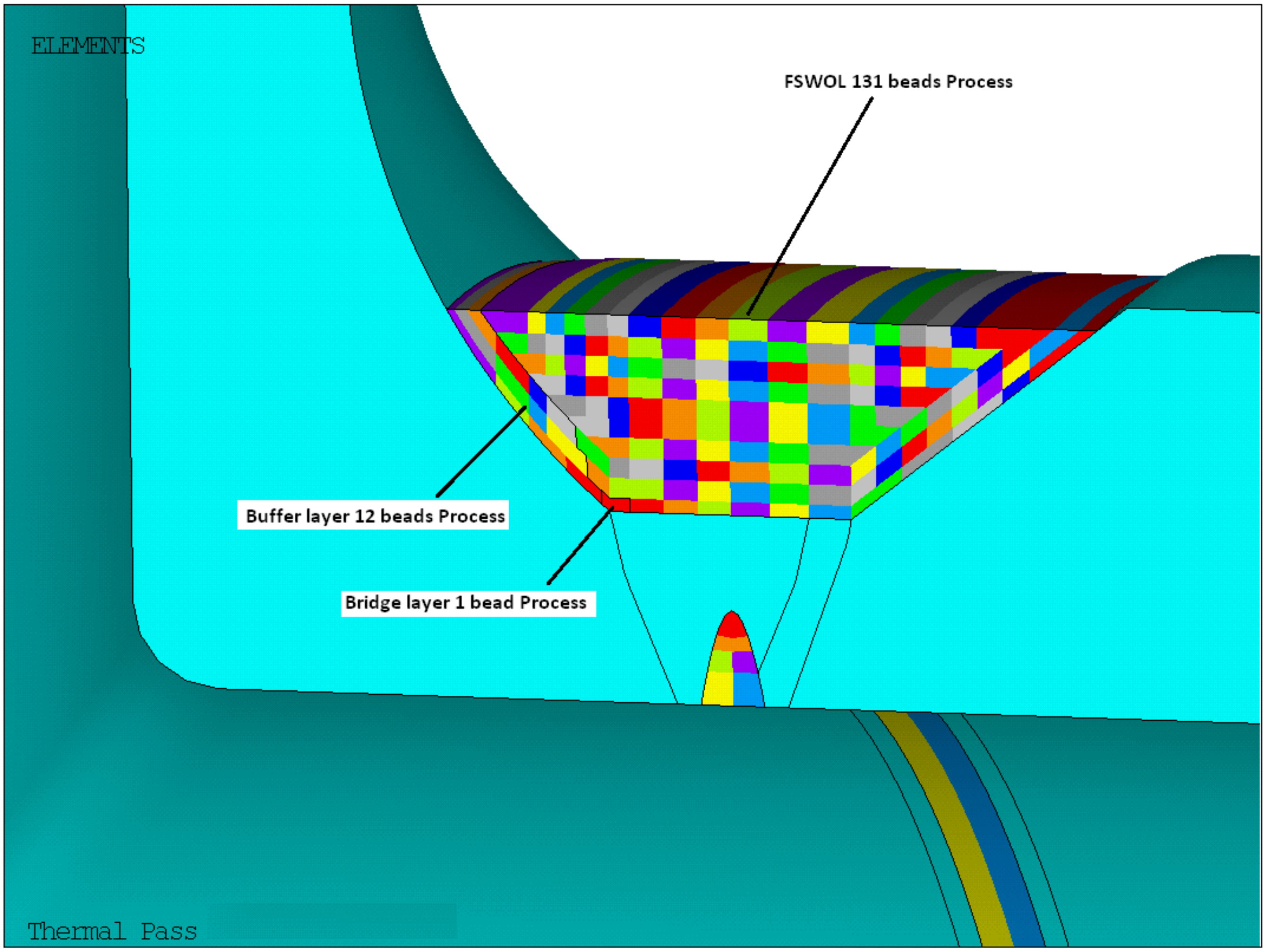



Figure 2-3: Finite Element Model for Residual Stress Analysis showing Nuggets used for Welding Simulations
(RWR/RHR tee on the left – RHR valve on the right)


Figure 2-4: Residual Stress Results along Stress Paths through the DMW

## 3.0 CONCLUSIONS

The design of the JAF weld overlay was performed in accordance with the requirements of the Relief Request [1], which is based on ASME Code Case N-504-4 [2] and N-638-4 [3], and ASME Code, Section XI, Nonmandatory Appendix Q [5]. The weld overlay design is demonstrated to be a long-term repair and provide mitigation of IGSCC in this weld based on the following:

- In accordance with ASME Code Case N-504-4, structural design of the overlay was performed to meet the requirements of ASME Code, Section XI, IWB-3640 based on an assumed circumferential flaw 100% through-wall, and 360° around the original weld. The resulting full structural weld overlay thus restores the original safety margins of the original weld, with no credit taken for the underlying IGSCC-susceptible material.

- The weld metal used for the overlay is Alloy 52M, which has been shown to be resistant to IGSCC [4], thus providing an IGSCC resistant barrier. Therefore, little if any IGSCC crack growth is expected to occur in the overlay.
- Application of the weld overlay does not impact the conclusions of the existing system Stress Report. Following application of the overlay, all ASME Code, Section III stress and fatigue criteria are met.
- A weld specific residual stress analysis was performed by first simulating a severe ID weld repair in the DMW, prior to applying the weld overlay. The post weld overlay residual stresses were shown to result in reduced tensile stresses into the thickness of the original DMW.
- A fracture mechanics analysis was performed to determine the amount of future crack growth which would be predicted in the FSWOL, assuming that the initial depth was 100% through wall of the original base material. Both fatigue and IGSCC crack growth were considered, and found to be acceptable.
- A walk down focusing on support H10-347 and review of associated pipe support locations and configurations (EC 619794) indicated that all hangers and other supports were within design dimensional tolerances.

Based on the above observations and the fact that weld overlays have been applied to other plants since 1986 with no subsequent problems identified, it is concluded that the JAF Loop "A" RWR/RHR low pressure coolant injection tee-to RHR gate valve DMW has received long term resistance to IGSCC.

## 4.0 REFERENCES


1. Relief Request No. JAFP-17-0010 (Relief Request RR 21), "Proposed Alternative to ASME Code Requirements for Weld Overlay Repair, RR-21 at James A. FitzPatrick Nuclear Power Plant" Docket No. 50-333, dated January 27, 2017. ADAMS Accession No. ML17028A011.
2. ASME Boiler and Pressure Vessel Code, Code Case N-504-3/4, "Alternate Rules for Repair of Classes 1, 2 and 3 Austenitic Stainless Steel Piping," Section XI, Division 1.
3. ASME Boiler and Pressure Vessel Code, Code Case N-638-4, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique," Section XI, Division 1.
4. Peter L. Andresen, et al., GE Global Research Center, "SCC of High Cr Alloys in BWR Environments," 15th International Conference on Environmental Degradation, TMS (The Minerals, Metals & Materials Society), 2011.
5. ASME Code, Section XI, 2004 Edition with Addenda through 2005, Nonmandatory Appendix Q, "Weld Overlay Repairs of Classes 1, 2, and 3 Austenitic Stainless Steel Piping Weldments."
6. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 2001 Edition with Addenda through 2003.
7. ASME Boiler and Pressure Vessel Code, Section III, 2001 Edition with Addenda through 2003.
8. USAS B31.1.0 Power Piping, 1967 Edition/1969 Addenda.
9. ANSYS Mechanical APDL, Release 14.5 (w/ Service Pack 1 UP20120918), ANSYS, Inc., September 2012.
10. *Materials Reliability Program: Finite-Element Model Validation for Dissimilar Metal Butt-Welds (MRP-316, Revision 1): Volumes 1 and 2*. EPRI, Palo Alto, CA: 2015. 3002005498.
11. *Materials Reliability Program: Welding Residual Stress Dissimilar Metal Butt-Weld Finite Element Modeling Handbook (MRP-317, Revision 1)*. EPRI, Palo Alto, CA: 2015. 3002005499.
12. U.S. NRC, "International Weld Residual Stress Round Robin Problem Statement," Version 1.0, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Division of Engineering, Component Integrity Branch, December 2009.
13. U.S. NRC, "International Weld Residual Stress Round Robin Problem Statement: Phase 2b of the NRC/EPRI WRS Validation Program," Version 3.0, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Division of Engineering, Component Integrity Branch, December 2013
14. James A. FitzPatrick Nuclear Change EC No. 66827, Revision 0.
15. *Materials Reliability Program: Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in Pressurized Water Reactors (PWRs) (MRP-169), Revision 1-A*, EPRI, Palo Alto, CA: 2010. 1021014.