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10 CFR 50.55a

W3F1-2019-0049

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U.S. Nuclear Regulatory Commission
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Washington, DC 20555-0001

Subject: Commitment Change Notification and Closure of Commitment Associated with Inservice Inspection Program Alternative WF3-RR-19-1 for Application of Dissimilar Metal Weld Full Structural Weld Overlay – Reactor Coolant System Cold Leg Drain Nozzles

Waterford Steam Electric Station, Unit 3 (Waterford 3)
NRC Docket No. 50-382
Renewed Facility Operating License No. NPF-38

This letter serves as notification by Entergy Operations, Inc. (Entergy) of revision to and completion of a Commitment associated with Relief Request WF3-RR-19-1 (Application of Dissimilar Metal Weld Full Structural Weld Overlay – Reactor Coolant System Cold Leg Drain Nozzles). This commitment was made in letter W3F1-2019-0009 (Reference 1), as supplemented by letter W3F1-2019-0011 (Reference 2). Information documenting the revision and supporting the closure is provided the Enclosure.

Closure of this commitment has been validated by Entergy's standard commitment closure verification process.

This submittal contains no new regulatory commitments.

If you have any questions or require additional information, please contact the Regulatory Assurance Manager, Paul Wood, (504) 464-3786.

Respectfully,

Paul Wood

PIW/mmz

References:

1. Entergy letter W3F1-2019-0009, "Proposed Inservice Inspection Program Alternative WF3-RR-19-1 for Application of Dissimilar Metal Weld Full Structural Weld Overlay – Reactor Coolant System Cold Leg Drain Nozzles," dated January 28, 2019 (ADAMS Accession Number ML19028A436)

2. Entergy letter W3F1-2019-0011, "Response to U. S. Nuclear Regulatory Commission Request for Additional Information Regarding Relief Request WF3-RR-19-1 for Application of Dissimilar Metal Weld Full Structural Weld Overlay," dated February 4, 2019 (ADAMS Accession Number ML19035A658)

3. NRR E-mail capture, NRC to Entergy, "Waterford 3 - FINAL Request for Information regarding Relief Request WF3-RR-19-001 for Application of Dissimilar Metal Weld Full Structural Weld Overlay," dated February 1, 2019

4. NRR E-mail capture, U.S. Nuclear Regulatory Commission (NRC) to Entergy Operations, Inc. (Entergy), "Verbal Authorization for Relief Request WF3-RR-19-1, Proposed Alternative for ASME Code Section XI, IWA-400 for Waterford Steam Electric Station, Unit 3 (EPID L-219-LLR-0003)," dated February 6, 2019

5. Entergy letter W3F1-2019-0017, "Closure of Commitment Associated with Inservice Inspection Program Alternative WF3-RR-19-1 for Application of Dissimilar Metal Weld Full Structural Weld Overlay – Reactor Coolant System Cold Leg Drain Nozzles," dated February 14, 2019 (ADAMS Accession Number ML19045A631)

Enclosure: Commitment Change Notification and Closure of Commitment Associated with Inservice Inspection Program Alternative WF3-RR-19-1 for Application of Dissimilar Metal Weld Full Structural Weld Overlay – Reactor Coolant System Cold Leg Drain Nozzles

cc: NRC Region IV Regional Administrator
NRC Senior Resident Inspector – Waterford Steam Electric Station, Unit 3
NRR Project Manager

ENCLOSURE

W3F1-2019-0049

Commitment Change Notification and Closure of Commitment Associated with Inservice Inspection Program Alternative WF3-RR-19-1 for Application of Dissimilar Metal Weld Full Structural Weld Overlay – Reactor Coolant System Cold Leg Drain Nozzles

Waterford Steam Electric Station, Unit 3
Commitment Change Notification and Closure of Commitment Associated with Inservice Inspection Program Alternative WF3-RR-19-1 for Application of Dissimilar Metal Weld Full Structural Weld Overlay – Reactor Coolant System Cold Leg Drain Nozzles

Background

By letter dated January 28, 2019, as supplemented by letter dated February 4, 2019, Entergy submitted Relief Request WF3-RR-19-1 (Application of Dissimilar Metal Weld Full Structural Weld Overlay – Reactor Coolant System Cold Leg Drain Nozzles). Verbal authorization was provided by the U.S. Nuclear Regulatory Commission (NRC) staff on February 6, 2019. The relief request included two commitments. Documentation of completion of the first commitment was provided by letter dated February 14, 2019.

As documented in the Relief Request, the original commitment stated the following:

> Commitment: For each nozzle with a Full Structural Weld Overlay (FSWOL) installed, the following items will be performed and submitted to the NRC:
>
> 1. Nozzle specific stress analyses will be performed to establish a residual stress profile in the Dissimilar Metal Weld (DMW). Inside diameter (ID) weld repairs will be assumed in these analyses to effectively bound any actual weld repairs that may have occurred in the DMW. The analysis shall then simulate application of the FSWOL to determine the final residual stress profile. Post weld overlay residual stresses at normal operating conditions will be shown to result in an improved stress state at the ID of the drain nozzle weld region that reduces the probability for further crack propagation due to stress corrosion cracking (SCC).
>
> 2. The analyses will demonstrate that the application of the FSWOL satisfies all ASME Code, Section III stress and fatigue criteria for the regions of the overlays remote from observed, or assumed, cracks.
>
> 3. Fracture mechanics analyses will be performed to predict crack growth. Crack growth due to SCC and fatigue in the original DMW shall be evaluated. These crack growth analyses will consider all design loads and transients, plus the post weld overlay through-wall residual stress distributions, and will demonstrate that the assumed cracks will not grow beyond the design bases for the weld overlay.
>
> 4. The total added weight on the piping system due to the overlay will be evaluated for the potential impact on nozzle stresses and dynamic characteristics.

The scheduled completion date is stated in the source documents as follows: "Submit a summary report within 120 days of completing the Waterford 3 refueling outage RF22, or outage in which the FSWOL is installed." The FSWOLs were installed on the affected components (weld numbers 07-009 and 11-007) during RF22, which ended on March 18, 2019.

Commitment Change

Entergy is revising part 1. of the commitment to the following:

1. A crack growth evaluation will be completed using a conservative weld residual stress (WRS) profile that will bound a nozzle specific residual stress profile in the dissimilar metal weld (DMW), with assumed inside diameter (ID) weld repairs that effectively bound any actual weld repairs that may have occurred in the DMW. The WRS profile will account for the application of the FSWOL at normal operating conditions. The WRS profile that will be used in the analysis will provide a conservative stress input for crack growth through the overlay and will ignore the beneficial compressive stresses near the ID surface that would be created by the FSWOL.

There is no change to parts 2, 3, and 4.

The basis for the change to the commitment is that the WRS used in the fatigue crack growth (FCG) analysis (summarized in the following section) is conservative and bounding of a detailed WRS simulation including an ID weld repair. The WRS profile for the FCG assumes zero stress from the ID up to 50% of the post-FSWOL thickness. This is conservative because it is higher in magnitude than the compressive welding stress typically observed at the inner half of the wall thickness. For the remaining 50%-100% post-FSWOL thickness, the WRS profile assumed a constant 60 ksi tensile stress (i.e. typical yield strength of the material). Justification for the 60 ksi bounding stress is provided in [17]. The use of typical yield strength of material is a conservative value used in the industry (see API-579 [18]) for welding residual stresses and crack growth analysis. API-579 recommends the use of the minimum specified yield strength of the material plus 10 ksi to be used to estimate WRS. The 60 ksi assumption bounds the API-579 guidance. Additionally, the 0-60 ksi step change WRS profile was compared to the WRS profile for a similar RCS drain nozzle FSWOL application with comparable geometry, material, loadings and determined to be bounding. Therefore, the WRS assumption is conservative and bounding.

Commitment Closure

Entergy has satisfied parts 1 through 4 of this regulatory commitment by completion of analyses for long term operation, including ASME Section III evaluations for the nozzle with the FSWOL, the impact of weld shrinkage on the drain line, and an ASME Section XI evaluation of postulated flaws on repair geometry. Provided below is a summary of the results and conclusions of the various analyses performed to qualify the FSWOL repair for operations.

ASME Section III Analysis

Methodology

A half symmetry, three dimensional (3D) model of the drain nozzle with the FSWOL was created using SolidWorks based on dimensions from [2, 3]. The finite element analysis (FEA) of the nozzle was performed in ANSYS Workbench [4] to extract path stresses generated during transient and static loadings at locations of interest for downstream ASME Section III [5] and Section XI [14] evaluations. ASME Code analyses were performed in the Westinghouse

proprietary code, WESTEMS [6], using the NB-3200 analysis model and transient stress result files created by ANSYS [4].

The WESTEMS analysis performed the following primary stress evaluations as per NB-3200 of the ASME Code [5]:

- General Primary Membrane Stress Intensity (NB-3221.1)
- Local Membrane Stress Intensity (NB-3221.2)
- Primary Membrane Plus Primary Bending Stress Intensity (NB-3221.3)
- Triaxial Stress (NB-3227.4)

The analysis also included secondary stress and fatigue evaluations as per NB-3200 of the ASME Code:

- Primary plus secondary stress intensity range (NB-3222.2)
- Thermal stress ratchet (NB-3222.5)
- Simplified elastic-plastic (NB-3228.5) (performed only when the limits of NB-3222.2 are exceeded)

Results

Maximum bounding stresses were calculated for each of the primary and triaxial stress evaluations listed above. Stress ratios, defined as $\sigma_{max}/\sigma_{allow}$, where σ_{allow} is the maximum allowable stress based on material data appropriate for the load combination (i.e. design stress S_m, yield stress S_y, ultimate stress S_u), were calculated for each stress evaluation. The NB-3200 primary stress analyses demonstrated that the stress ratios, $\sigma_{max}/\sigma_{allow}$, were less than 1.0 for all the cases, indicating acceptance. The secondary stress evaluation showed that the range of primary plus secondary stress was less than $3S_m$, indicating acceptance. The cumulative usage factor for cyclic loading considering all primary and secondary stresses was less than 1.0, indicating acceptance.

Weld Shrinkage Evaluation

Methodology

The weld shrinkage impact was assessed using the PIPESTRESS Code [7] to calculate pipe displacements, pipe stresses, nozzle loads, and support loads. These results were linearly added to existing data documented in the analyses of records (AOR) [8, 9] to account for weld shrinkage effects. Two models were built:

1. For P12 drain line, the model covered the entire piping (lines 1RC2-48RL2A and 7BM2-318) up to the anchor BMA-404 at Node 22 (page 3.3 of [8]).

2. For P3 drain line, the model contained the main piping from the nozzle to the branch connection at Node 30 (Page 2.5 of [9], lines 1RC2-46L1A and 7BM2-315). To account for branch piping effects, the P3 drain line model was extended from Node 30 toward the

north to Node 425, from Node 30 toward the south to Node 9750, and from Node 2502 up to Node 155 (Page 2.5 of [9], lines 7BM2-324 and 7BM1-312).

The models were validated with a static thermal expansion run (case T2 in [8] and [9]). A static settlement analysis was executed for each model by applying an axial displacement to represent the weld shrinkage at the nozzle location. The analysis results of pipe stresses, nozzle loads, support loads, and pipe displacements were collected to assess the weld shrinkage impact. The analysis also considered the impact of the modified restraints and added weight of the FSWOL.

An assessment of the whip restraint gaps was also performed to ensure that the gaps remain open for all service levels, which was an assumption used in the original design analysis. The AOR [11] did not explicitly assess these locations, therefore, the extended power uprate (EPU) with replacement steam generator (RSG) hot gaps are calculated first prior to application of the weld shrinkage effect. The gaps were calculated by adding the nozzle motion due to EPU and RSG to the whip restraint location displacements from [8] and [9]. The newly calculated EPU and RSG hot gaps were then adjusted based on the weld shrinkage effect to ensure that no contact occurs between piping and whip restraints when not in a rupture scenario.

Results

The following list summarizes the assessment results:

- Class 1 Pipe Stress Code Compliance: Meet ASME NB-3600 criteria (1974 Edition + Summer 1975 Addenda [10]).
- Class 2/3 Pipe Stress Code Compliance: Meet ASME NC/ND-3600 criteria (1974 Edition + Summer 1975 Addenda).
- Drain Line Nozzle Loads: Loads are acceptable per downstream evaluation. (Loads due to weld shrinkage and added weld weight were provided for downstream evaluation.)
- Support Loads: Loads are acceptable. (New support loads vs. as-built loads.)
- Rupture Restraint Clearances: Pipe displacements due to combined FSWOL shrinkage and all operating cases are within the allowable clearances shown on whip restraint drawings V5.1.3-1008- 414_FCR 81756 [12] and V5.1.3-1008-416_FCR 81756 [13].

ASME Section XI Flaw Analysis

Methodology

Fatigue crack growth (FCG) analysis was performed for the drain nozzle FSWOL at the nozzle-to-safe end dissimilar metal weld (DMW) and the safe end to piping stainless steel weld as per the 2007 edition including 2008 Addenda of ASME Code, Section XI [14] and Code Case N-740-2 [15]. The Westinghouse proprietary program, WES_FRAMES [16], was used for the analysis. The welding residual stresses (WRS) used in the FCG analysis are conservative and bounding of a detailed WRS simulation including an ID weld repair. The WRS profile for the FCG assumes zero stress from the ID up to 50% of the post-FSWOL thickness. This is conservative because it is higher in magnitude than the compressive welding stress typically observed at the inner half of the wall thickness. For the remaining 50%-100% post-FSWOL

thickness, the WRS profile assumed a constant 60 ksi tensile stress (i.e. typical yield strength of the material). Justification for the 60 ksi bounding stress is provided in [17]. The use of typical yield strength of material is a conservative value used in the industry (see API-579 [18]) for welding residual stresses and crack growth analysis. API-579, recommends the use of the minimum specified yield strength of the material plus 10 ksi to be used to estimate WRS. The 60 ksi assumption bounds the API-579 guidance. Therefore, the WRS assumption is conservative and bounding.

The residual stress was applied with the transient stresses developed from the WESTEMS NB-3200 analysis. The FCG analysis postulated both an axial and circumferential flaw that is 100% of the original DMW (Alloy 182). Since the FSWOL material, Alloy 52, is highly resistant to primary water stress corrosion cracking (PWSCC), FCG is the only crack propagation mechanism. The Alloy 690 fatigue crack growth rate (CGR) is conservatively assumed to be 10 times faster than the Alloy 600 in air since there is no published Alloy 690 CGR for Pressurized Water Reactor water environment [19]. Various aspect ratios (length/depth) for both axial and circumferential flaws were analyzed. FCG was also performed for the safe end to piping stainless steel weld (SSW).

Results

The fatigue crack growth on both the dissimilar metal weld between the nozzle and safe end and the stainless steel weld between the safe end and piping due to design transients are acceptable for the remaining life of the plant.

Overall Conclusions

The ASME Section III stress and fatigue evaluation, Section XI flaw evaluation, and the weld shrinkage evaluation demonstrate that the application of the FSWOL satisfies the ASME Code criteria.

References

[1] Westinghouse Calculation Note, CN-SDA-19-40, Rev. 0, “Summary of Analysis for Waterford Unit 3 Drain Line Structural Weld Overlay Analysis,” July 10, 2019.

[2] Entergy Correspondence, W3C1-2019-0002, Rev. 0, “Transmittal of Data to Support Design and Qualification of Structural Weld Overlay at Waterford 3,” April 29, 2019.

[3] Combustion Engineering Drawing, 74470-728-008, Rev. 05, “Nozzle Cladding & Machining.”

[4] Westinghouse Correspondence, LTR-ANSYS-18-7, Rev. 0, “Software Release Letter for ANSYS Structural Mechanics (Mechanical APDL and Workbench) Versions 18.2 and 19.1 and Fluid Dynamics (FLUENT and CFX) Versions 18.2 and 19.1 on the Windows 10 System State,” December 11, 2018.

[5] ASME Boiler & Pressure Vessel Code, Section II and Section III Division 1, 2007 Edition up to 2008 Addenda.

[6] Westinghouse Correspondence, LTR-SDA-II-19-17, Rev. 0, “Software Release Letter for WESTEMS Version 5.3 on Windows 7 System State,” May 2, 2019.

[7] Westinghouse Correspondence, LTR-SST-19-11, Rev. 0, “Software Release Letter for PepS 6.0 on the Windows 10 System State,” May 21, 2019.

[8] Impell Calculation, IM-2696 Including DRN 03-433, Rev. 0, “Piping Analysis of the Reactor Coolant Loop Drains,” February 26, 2004.

[9] Impell Calculation, IM-2695 Including DRN 03-431, Rev. 0, “Piping Analysis of the Reactor Coolant Loop Drains,” February 9, 2004.

[10] ASME Boiler & Pressure Vessel Code, Section III, 1974 Edition plus Summer 1975 Addenda.

[11] Westinghouse Calculation Note, CN-MRCDA-10-15, Rev. 0, “Waterford Unit 3 (3716 MWt) with RSGs: Structural Evaluation of Reactor Coolant System (RCS) Drain Line Piping and Supports,” March 25, 2010.

[12] Waterford SES Unit 3 Whip Restraints Modification Drawing, V5.1.3-1008-414_FCR 81756.

[13] Waterford SES Unit 3 Whip Restraints Modification Drawing, V5.1.3-1008-416_FCR 81756.14.ASME Boiler and Pressure Vessel Code Section XI, 2007 Edition with 2008 Addenda.

[14] ASME Boiler and Pressure Vessel Code Case, N-740-2, “Full Structural Dissimilar Metal Weld Overlay for Repair or Mitigation of Class 1, 2, and 3 Items Section XI, Division 1,” November 10, 2008.

[15] Westinghouse Correspondence, LTR-PAFM-14-108, “Software Release Letter WES_FRAMES Version 4.2,” November 12, 2014.

[16] ASME Codes and Standards (C&S Connect) Record No. 13-1419, “Weld Residual Stress Distributions for Use in Crack Growth Calculations for Nickel-Base Alloy Dissimilar Metal Welds,” Working Group on Flaw Evaluation Reference Curves, Project Manager: Anees Udyawar and John Broussard, June 2019.

[17] API 579-1/ASME FFS-1, “Fitness-For-Service,” The American Society of Mechanical Engineers, American Petroleum Institute, June 2016.

[18] NUREG/CR-6907, ANL-04/3, “Crack Growth Rates of Nickel Alloy Welds in a PWR Environment,” May 2006.