**Entergy Operations, Inc.**
1340 Echelon Parkway
Jackson, MS 39213
Tel 601-368-5138

**Ron Gaston**
Director, Nuclear Licensing

10 CFR 50.55a

W3F1-2019-0054

July 22, 2019

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

Subject: Response to U.S. Nuclear Regulatory Commission Request for Additional Information Regarding Relief Number WF3-RR-19-2, Proposed Alternative to Code Case N-666-1

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

By letter dated July 18, 2019 (Reference 1), Entergy Operations, Inc. (Entergy) requested relief from certain requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Code Case N-666-1, at Waterford Steam Electric Station, Unit 3 (Waterford 3). This request for alternative was submitted in accordance with Title 10 of the Code of Federal Regulations (CFR) 50.55a(z)(2), proposing to repair a through-wall flaw on a section of Chemical and Volume Control (CVC) system piping between two socket welds by performing a structural weld overlay.

By email correspondence dated July 19, 2019 (Reference 2), the NRC staff informed Entergy that they have reviewed the relief request and have determined that additional information is required to complete the review.

The additional information requested by the NRC in Reference 2 is provided in the Enclosure to this letter. In responding to the NRC's request for additional information, Entergy determined that changes to Relief Request WF3-RR-19-1 were necessary. Enclosure Attachment A includes the revised relief request.

This submittal contains no new regulatory commitments.

If you have any questions or require additional information, please contact the Waterford 3 Regulatory Assurance Manager, Paul Wood, at (504) 464-3786.

Respectfully,

Ron Gaston

RWG/rd

Enclosure: Response to NRC Request for Additional Information
Attachment A: Revision to Relief Number WF3-RR-19-2

References:

1. Entergy Operations, Inc. (Entergy) Letter W3F1-2019-0052, "10 CFR 50.55a Relief Number WF3-RR-19-2, Proposed Alternative to Code Case N-666-1, "Weld Overlay of Class 1, 2, and 3 Socket Welded Connections, Section XI, Division 1" in Accordance with 10 CFR 50.55a(z)(2)," Dated July 18, 2019 (ADAMS Accession Number ML19199A708)

2. NRC email correspondence to Entergy, "Waterford 3 – Final Request for Additional Information (RAIs) RE Relief Request WF3-RR-19-2: Alternate Repair of Degraded Drain Line of Chemical and Volume Control System," Dated July 19, 2019

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

**ENCLOSURE**
**W3F1-2019-0054**

**Response to NRC Request for Additional Information**

**Attachment A: Revision to Relief Request WF3-RR-19-2**

Additional Information Requested by the NRC:

Request 1:

Section 3, Applicable Code Requirement, of the proposed alternative does not discuss the fact that a flaw will remain inservice, which triggers certain provisions in the ASME Code, Section XI. The 2007 Edition through 2008 Addenda of the ASME Code, Section XI, IWA-4422, addresses defect evaluation and examination. In addition, IWC-3132.2 states that: "…A component containing relevant conditions is acceptable for continued service if the relevant conditions are corrected by a repair /replacement activity or by corrective measures to the extent necessary to meet the acceptance standards of Table IWC-3410-1.…" Please discuss if IWA-4422 and IWC-3132.2 should be applicable to the proposed relief request. If not, provide justification.

Entergy Response:

IWA-4422 and IWC-3132.2 are not applicable to the proposed relief request based on the justification below:

IWA-4000 of the ASME Section XI specifies requirements for performing repair/replacement activities such as welding, fabrication, installation, and defect removal. In general, IWA-4000 defers to the applicable Construction Code for performing these repair/replacement activities. However, as allowed by IWA-4411(a), Code Cases such as N-666-1 may be used in lieu of Construction Code requirements. The Waterford 3 relief request proposes an alternative to ASME Section XI Code Case N-666-1 which is conditionally approved by the NRC for use in Regulatory Guide 1.147, Revision 18. Code Case N-666-1 specifies requirements for restoring the structural integrity of cracked socket welds (if the failure is the result of vibration fatigue) by deposition of a weld overlay in lieu of removing the defect in accordance with IWA-4420. This point is made explicitly clear in the Inquiry and Reply of Code Case N-666-1. Since Code Case N-666-1 provides an explicit alternative to IWA-4420, the requirements of IWA-4422 do not apply. Therefore, proposed alternatives to IWA-4422 were not included in Section 3 of the request.

Regarding IWC-3132.2 and Table IWC-3410-1, these provisions only apply when performing visual examinations associated with ASME Section XI examinations and tests that are required by IWC-2500 (e.g., VT-2 associated with an ASME Section XI pressure test). Consistent with this point, IWC-3131 states in part:

> "The visual examinations required by IWC-2500... shall be evaluated by comparing the examination results with the acceptance standards specified in Table IWC-3410-1. Acceptance of components for continued service shall be in accordance with IWC-3132, IWC-3133, and IWC-3134."

Conversely, the requirements of IWA-3132.2 and Table IWC-3410-1 do not apply when flaws are identified during the performance of maintenance activities, plant walk-downs, or other inspection activities that are not under the jurisdiction of ASME Section XI. The inapplicability of the inservice inspection rules of ASME Section XI to flaws identified outside the performance of an ASME Section XI examination or test is further demonstrated by ASME Section XI interpretations such as XI-1-89-67, XI-1-92-03, and XI-1-92-19. Therefore, since the flaw in line 2CH1-30 was identified during a leakage investigation and not during the performance of an

ASME Section XI examination or test, the requirements of IWC-3132.2 and Table IWC-3410-1 do not apply.

Request 2:

Detail 3 of the proposed alternative provides a drawing of the proposed weld overlay.

(a) Provide dimensions of approximate thickness and longitudinal length of the weld overlay (Item No. 6 in the drawing). Specifically, provide the weld overlay thickness above the socket weld (Item No. 1 and the elbow (Item No. 3).
(b) Provide thickness of socket weld branch connection (Item No. 1), elbow (item no. 3), and seal weld (item No, 5).
(c) Provide the vertical length of the socket fillet weld (Item No. 4).

Approximate or estimated dimensions for these items is acceptable, if the as-built dimensions are not available.

Entergy Response:

A description of the overlay design and thickness requirements is provided, followed by answers to the specific RAI questions.

The overlay design fills in the area between the existing fillet welds from the pipe OD to the fitting socket OD, and then requires additional layers to create a uniform thickness from the elbow socket OD to the branch socket OD. The design does not take credit for the load carrying capacity of the weld metal between the pipe OD and the fitting socket OD. The structural required thickness of 0.021 inch (see RAI #6(a)) is smaller than the required thickness in Code Case N-666-1 of 0.77tnom (0.138 inch). The required thickness of the overlay at the socket connection is 0.138 inch. A minimum of two weld beads is required to achieve this thickness.

a) The requested dimensions are given, followed by discussion of how these dimensions are determined:
   - Approximate overlay thickness at crack location= 0.387 inch
   - Approximate overlay longitudinal length = 1 inch
   - Overlay thickness above the socket = 0.138 inch minimum

   Additional discussion of the overlay dimensions is provided. The OD of 1-inch NPS pipe is 1.315 inches. The OD of the elbow at the socket is assumed to be 1 13/16 inches based on vendor specification for a 3000# socket welded 90° elbow. The radial difference between the pipe OD and the elbow socket OD is approximately 0.249 inch. As stated above, no structural credit is taken for this 0.249 inch thickness. The minimum required wall thickness on the socket fitting OD is 0.138 inch. The total through thickness length of the weld repair at the crack is estimated to be 0.387 inch.

   The exact longitudinal length of the overlay shall be determined in the field and is not a parameter of the design. Minimum lengths that the overlay must extend onto the fittings are specified to maintain the required design thickness in accordance with Code Case N-666-1. The estimated longitudinal length of the overlay design is approximately 0.9 inch.

b) The requested dimensions are given, followed by discussion of how these dimensions are determined:
   - Socket branch connection thickness = less than 0.249 inch
   - Elbow branch connection thickness = less than 0.249 inch
   - Seal weld approximate thickness = 0.08 inch

   As stated in response (a), the radial distance from the pipe OD to the fitting OD is approximately 0.249 inch based on a vendor specification for a 3000# socket welded 90° elbow. Exact dimensions of the fittings are not readily available. The thickness of the elbow and branch connection fitting are likely to be slightly less than 0.249 inch to allow for fit up. The nominal thickness of the seal weld is anticipated to be 0.08 inch, with some variation due to individual welder technique. Code Case N-666-1 does not allow structural credit for the seal weld. As stated above, no structural credit is taken for the 0.249 inch thickness, which includes the thickness of the seal weld.

c) The requested dimensions are given, followed by discussion of how these dimensions are determined:
   - Approximate vertical length of socket fillet weld = 0.249 inch
   - Socket fillet weld as-built dimensions are not readily available.

   Based on the discussion in response (a), the radial distance from the pipe OD to the socket OD is approximately 0.249 inch. Pictures of the as-found condition indicate that the socket fillet weld extends to the shoulder of the fitting OD and that the weld profile is approximately 1:1. Therefore, the approximate length of each of the vertical socket fillet welds is 0.249 inch.

<u>Request 3:</u>

Page 4 of 9, under heading Structural evaluation, states that the allowable through-wall flaw is 1.7 inches (41% of the pipe circumference).

(a) Discuss either how the allowable flaw size is derived or submit the flaw evaluation.
(b) The NRC staff assumes that vibration in the drain line will continue after the weld overlay installation and the existing flaw may continue to grow. As such, discuss, in a qualitative manner, the crack growth of the existing pipe between now and refueling outage 23.

<u>Entergy Response:</u>

a) The allowable flaw size is derived from a structural evaluation performed in accordance with Code Case N-513-3 for a circumferentially oriented through-wall planar flaw. Code Case N-513-3 has been conditionally approved by the NRC in NRC Regulatory Guide 1.147 and allows the use of ASME Section XI, Appendix C for evaluation of flaws in piping. Because the material is austenitic stainless steel, the equations and correlations in C-5320 are used for fully-plastic fracture using limit load criteria. The evaluation considers both combined loading (membrane-plus-bending) and membrane only loading, as required by C-5320.

b) The through thickness length of the weld repair at the weld throat is estimated to be 0.387 inch (see RAI#2 response), which is more than double the thickness of the original pipe (0.179 inch).

The weld overlay is designed to be applied around the entire circumference of the pipe, increasing the wall thickness and section modulus, which provides additional material to support the mechanical, thermal, and vibration loading.

Based on leakage measurements and daily observation of the flaw, there are no indications that the as-found flaw has grown since initial discovery on July 2nd. Increasing the section modulus via weld overlay repair will reduce the crack driving force due to vibration loading. In addition, the weld overlay repair will provide approximately 0.387 inch of material over the crack tip, which is over 200% more material than the nominal wall thickness. It noted that the thickness of 0.387 inch includes the seal weld. However, the thickness of the weld bead used to seal the crack is a small portion of the 0.387 inch thickness. Application of the weld repair changes the crack growth model from a cylinder with an external circumferential crack (beginning as a part-wall flaw and growing through-wall) to one of a cylinder with an internal circumferential crack. In the repaired configuration, not only is the highest crack driving force (i.e., axial stress at the extreme fiber) reduced due to the increase in the moment of inertia, but the crack tip is no longer co-located on the outer surface of the pipe with the highest crack driving force.

It is reasonable to conclude that the repaired configuration will have a longer life than the original configuration. Therefore, the occurrence of any crack growth during the temporary acceptance period is not anticipated to challenge the structural integrity of the repaired configuration. Entergy is in the process of conducting crack growth analyses to confirm this conclusion.

Request 4:

Section 4, Reason for Request, states that the degradation mechanism is attributed to low cycle/high stress (vibration) fatigue. After the weld overlay is applied, the flaw may still grow based on vibration.

(a) Discuss whether compensatory measures will be taken to reduce the vibration of the drain line to minimize crack growth.
(b) Discuss the operational leakage limits in Technical Specifications for the drain line.
(c) Discuss the leakage detection system(s) that can detect potential leakage of the overlaid drain line in case the weld overlay degrades,
(d) Discuss whether the drain line is located inside or outside the containment.

Entergy Response:

a) Waterford 3 has entered the chemical and volume control system flaw into the 10 CFR 50 Appendix B corrective action program. A causal analysis is in progress which will identify the causal factors and corrective actions. Compensatory measures will be driven out of the causal factors and the vibration analysis. Since these are ongoing, the corrective actions to reduce vibration have not been finalized. The compensatory measures to reduce vibration are not required for the interim repair but would be needed if the repair were to be evaluated for use past the next cycle.

Based upon the data available at this time, Entergy has determined that the degradation mechanism which contributed to flaw initiation and growth is mostly likely low cycle/high stress fatigue (LCF) due to vibration. The degradation mechanism is supported based on review of vibration data and EPRI Report 3002010753. However, the possibility that the degradation mechanism could be high cycle/low stress fatigue (HCF) has not been eliminated because the vibration analysis is still ongoing. Differentiation between LCF and HCF is not required for the structural evaluation that determined the allowable flaw size and the weld repair design. The Code Case N-513-3 structural evaluation determines the allowable flaw size that could be tolerated by the piping system, including the structural factors in the ASME Code. Vibration loading contributes to flaw growth, but does not contribute to gross structural failure in ductile materials such as austenitic stainless steel. Failure of the remaining ligament would be anticipated to occur due to overload from primary loads (i.e., net section collapse). Therefore, determination of the allowable flaw size is not influenced by the specific degradation mechanism. Code Case N-666-1 only requires that the Owner verify the failure mechanism is vibration fatigue; differentiation between LCF and HCF is not required.

b) Waterford 3 Technical Specification 3.4.5.2 allowable unidentified leakage is 1 gpm and is applicable to the chemical and volume control system flaw leakage. Waterford 3 has instituted an operations decision making issue which limits the reactor coolant system unidentified leakage to below 0.6 gpm or requires a plant shutdown.

c) Waterford 3 Technical Specification Surveillance 4.4.5.2.1 requires that Reactor Coolant System leakages shall be demonstrated to be within the Technical Specification 3.4.5.2 limits by performance of a Reactor Coolant System water inventory balance in accordance with the Surveillance Frequency Control Program. The leakage detection system used will be the reactor water inventory balance.

d) The chemical and volume control system drain line containing the flaw is outside of containment.

Request 5:

Section 6, Duration of Proposed Alternative, provide the approximate scheduled start date for Refueling Outage 23.

Entergy Response:

Refueling Outage 23 is scheduled during the Fall of 2020.

Request 6:

Table 2 of the calculation in the relief request shows the following minimum required thickness for the weld overlay:

| Loading Condition | Minimum Required Thickness (inch) |
|---|---|
| Equation 3- Hoop Stress, Pressure | 0.004 |
| Equation 8- Sustained Load-Deadweight | 0.008 |
| Equation 9- Occasional Load – OBE, Seismic | 0.013 |
| Equation 10- Thermal Expansion | 0.021 |

(a) The licensee's analysis shows that the minimum required thickness for the weld overlay is 0.021 inches. The licensee did not calculate the minimum required thickness caused by mechanical vibration. Discuss why the minimum required thickness was not calculated based on mechanical vibration.

(b) The licensee states that the ASME Code, Section III, NC-3652.3 requires only Equation 10 or Equation 11 to be met, not both. The licensee did not calculate the minimum required thickness per Equation 11. If the minimum required thickness per Equation 11 is greater than Equation 10, it seems that the thickness calculated from Equation 11 should be used as the minimum required thickness. Discuss why the minimum required thickness was not calculated using Equation 11.

(c) During the plant normal operation, the drain line will experience stresses caused by pressure, deadweight, temperature, and occasional vibration. It seems that the minimum required thickness of the weld overlay should include the contribution of the required thickness from pressure, deadweight, thermal expansion and vibration. Discuss whether the minimum weld overlay thickness should be 0.046 inches (0.004 + 0.008 + 0.013 + 0.021).

<u>Entergy Response:</u>

a) Mechanical vibration was not specifically included in the minimum required wall thickness. The conclusion of the RAI 3(b) response is that crack growth during the temporary acceptance period is not anticipated to challenge the structural integrity of the repaired configuration. In addition, the RAI 2(a) response demonstrates the significant margin between the Code of Construction required wall thickness of 0.021 inch and the approximate overlay thickness of 0.387 inch at the crack location.

b) The minimum thickness was not calculated using Equation 11 because Section NC-3652.3 of the Code required Equation 10 or Equation 11 to be evaluated:

*The requirements of either Equation (10) or Equation (11) must be met.*

Equation 10 accounts for the range of resultant moments due to thermal expansion and is compared to the allowable stress range for expansion stresses. Equation 11 accounts for pressure, weight, other sustained loads, and thermal expansion in comparison to the sum of the allowable stress at maximum temperature and the allowable stress range for expansion stresses. Evaluation of Equation 11 results in a smaller required wall thickness (0.016-inch), which is less than Equation 10.

c) Equations 3, 8, 9, and 10 of the Code of Construction are used to evaluate the minimum required wall thickness. Equations 8 and 9 account for sustained axial loads and occasional axial loads, respectively. These equations each account for the axial stress due to pressure loading and deadweight loads. Addition of the minimum required wall thickness calculated using these equations is not appropriate as it would account for the same loading multiple times. As discussed in response to RAI 3(b), the overlay design is more than 200% thicker than the nominal pipe thickness. The overlay design is significantly thicker (0.387 inch) than the Code of Construction required wall thickness (0.021 inch). Therefore, additional wall thickness to resist vibration loading is available, providing implicit margin in the repair design.

Request 7:

Code Case N-666-1, paragraph 5(c) states that:" A system leakage test shall be performed in accordance with IWA-4540…" The licensee did not take exception to this provision; therefore, the NRC staff assumes that the licensee will perform the system leakage test. However, the NRC staff is not clear how a system leakage test can be performed in accordance with IWA-4540 while the plant is online. Discuss how a system leakage test can be performed in accordance with IWA-4540.

Entergy Response:

As noted by the NRC staff, Entergy did not take an exception to paragraph 5(c) of Code Case N-666-1 and will perform a system leakage test in accordance with IWA-4540. Regarding the NRC concern, system leakage tests associated with repair/ replacement activities are normally performed as part of returning a system to service. This is consistent with requirements in IWA-4540 and IWA-5211(a). In fact, IWC-5221 states in part: "The system leakage test shall be conducted at the system pressure obtained while the system, or portion of the system, is in service performing its normal operating function…"

**ENCLOSURE, ATTACHMENT A**
**W3F1-2019-0054**

**Revision to Relief Request WF3-RR-19-2**

**Entergy Operations, Inc.**
**10 CFR 50.55a Request Number WF3-RR-19-2**
**Proposed Alternative to Code Case N-666-1, "Weld Overlay of Class 1, 2, and 3 Socket Welded Connections, Section XI, Division 1"**

## 1. ASME Code Component(s) Affected:

Component: Chemical and Volume Control (CVC) System line 2CH1-30, Volume Control Tank Outlet Header Drain to Equipment Drain Tank Sump

Code Class: 2

Unit: Waterford Steam Electric Station, Unit 3 (Waterford 3)

Interval: Fourth ($4^{th}$) Interval beginning December 1, 2017 and ending November 30, 2027

## 2. Applicable Code Edition and Addenda:

ASME Section XI, 2007 Edition through 2008 Addenda

ASME Section III, Subsection NC, 1971 Edition/1972 Winter Addenda (Original Construction Code)

ASME Section III, Subsection NC, 1992 Edition/No Addenda

ASME Section XI Code Case N-666-1 (approved for use by the NRC in Regulatory Guide 1.147)

## 3. Applicable Code Requirement:

American Society of Mechanical Engineers (ASME) Section XI Code includes the following applicable requirements:

- IWA-4411 states: "Welding, brazing, fabrication, and installation shall be performed in accordance with the Owner’s Requirements and, except as modified below, in accordance with the Construction Code of the item."

- IWA-4411(a) states in part: "Later editions and addenda of the Construction Code, or a later different Construction Code, either in its entirety or portions thereof, and Code Cases may be used, provided the substitution is as listed in IWA-4221(c)."

As an alternative to the IWA-4000 requirements specified above, ASME Section XI Code Case N-666-1 specifies requirements for restoring the structural integrity of socket welded connections with root or toe cracks by deposition of a weld overlay on the outside surface of the pipe, socket weld, and fitting. The Code Case N-666-1 requirements specified below are those for which relief is being requested.

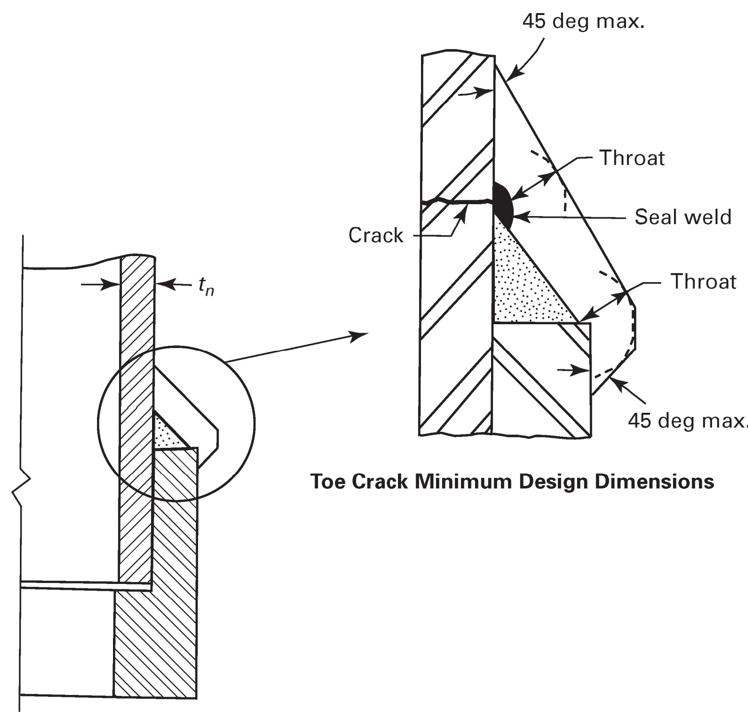
- Paragraph 1(d) of the Code Case states in part: "…the Owner shall verify that the pipe base material adjacent to the socket weld requiring overlay meets the required minimum wall thickness."

- Paragraph 3(a) of Code Case N-666-1 states in part:

  "The completed weld overlay shall meet the dimensional requirements of Figure 1."

  "When the fatigue crack is located in the base metal adjacent to the toe of the socket weld, the minimum throat dimensions shall be measured from the location of the crack farthest from the weld toe."

- Figure 1 of Code Case N-666-1 provides weld overlay design details for toe cracks. According to Figure 1, the included angle of the weld overlay along the axis of the pipe shall not exceed 45°.



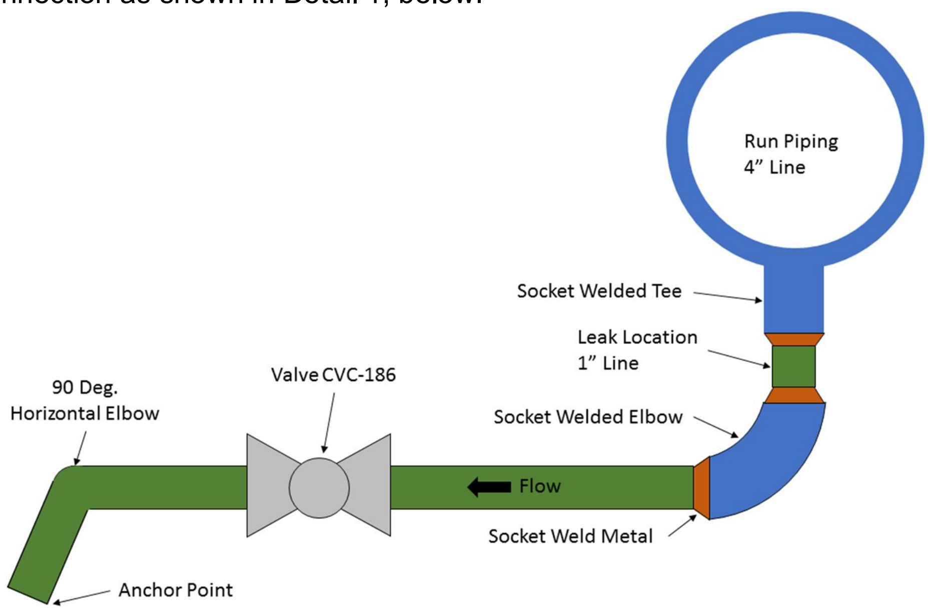

**Toe Crack Minimum Design Dimensions**

- Paragraph 4(d) of the Code Case states in part: "The weld sequence shall be from the fitting to the pipe for the overlay of toe cracks… The completed weld overlay shall meet the dimensional requirements of Figure 1."

Code Case N-666-1 has been approved for use in Regulatory Guide 1.147 with the following condition: "A surface examination (magnetic particle or liquid penetrant) must be performed after installation of the weld overlay on Class 1 and 2 piping socket welds. Fabrication defects, if detected, must be dispositioned using the surface examination acceptance criteria of the Construction Code identified in the Repair/Replacement Plan."

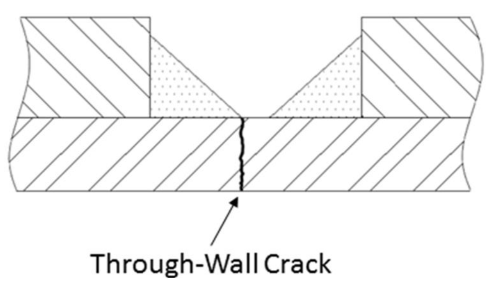
**4. Reason for Request:**

On July 2, 2019, a leaking flaw was discovered at Waterford 3 in the CVC system. The leakage was initially identified while performing surveillances for TS 3.4.5.2 for UNIDENTIFIED Reactor Coolant System (RCS) leakage. Subsequent investigations identified the actual source of leakage as being from CVC system in line 2CH1-30. The Class 2 leaking pipe is upstream of valve CVC-186. More specifically, the leak is located in a short section of straight pipe in between a socket welded tee and a socket welded elbow in a 1-inch Nominal Pipe Size (NPS) drain line connection as shown in Detail 1, below.




Detail 1: Pipe Configuration Around Line 2CH1-30

The leak is due to a vibration-induced flaw through the straight section of pipe at the toe of a socket welded tee branch. Detail 2 provides an example cross section of the piping configuration with the through-wall leak. Due to the proximity of a socket welded elbow, there is not a sufficient length of straight pipe to overlay the socket weld toe crack following the dimensional requirements of Figure 1 in the Code Case N-666-1. The distance between the toes of the socket welds is 1/8" or less.




Detail 2: Low Cycle/High Stress Flaw Configuration

Entergy has determined that the degradation mechanism which contributed to flaw initiation and growth is most likely low cycle/high stress (vibration) fatigue. This is consistent with information provided by the Electric Power Research Institute (EPRI) in EPRI Report 3002010753, "Welding and Repair Technology Center: Practical Guideline to Socket Welding," (Reference 2) which provides information of fatigue mechanisms and their contributions to failures of socket welded connections. Section 3.4 of this report states in part:

> "The results of socket weld tests performed… indicate that, in general, failures at a lower cycle/higher stress (i.e., LCF) tended to originate at the toe, while the higher cycle/lower stress (i.e., HCF) failures tended to occur at the root. The majority of test failures occurred due to cracks that initiated at weld roots (i.e., HCF). Toe related (i.e., LCF) failures occurred in tests at higher stress levels that were premature with identical tests in which root failures prevailed."

The location and appearance of the flaw (circumferential orientation, at the toe of the fillet weld) is indicative of a fatigue failure. Since September 2014, Entergy has typically operated the Waterford 3 CVC system in an alignment where two (2) of the three (3) charging pumps are running simultaneously (hereinafter, the “nominal” configuration), with an exception of primarily running one charging pump from February 2016 to March 2017. Prior to September 2014, the CVC system alignment generally only included one (1) operating pump (resulting in several permutations of “alternate” configurations).

On July 8, 2019, following identification of the failure, Entergy obtained vibration data in the nominal configuration from several locations on the 1-inch drain line as well as the 4-inch CVC header to which it attaches. The resulting data demonstrated relatively low baseline levels coupled with regular "pulses" wherein significantly increased amplitudes are observed for short periods (2-5 seconds). The pulses appear to be driven by acoustic imbalance between the two positive-displacement charging pumps operating in parallel. The pulses are of sufficient amplitude to have imparted fatigue damage; however, given their occasional nature and low frequency, result in slower accumulation of cycles than is typical for branch lines. This evidence supports the conclusion that the failure originated due to vibration.

<u>Structural Evaluation</u>

An evaluation of the structural stability of the circumferentially oriented through-wall flaw was performed following the criteria prescribed in ASME Code Case N-513-3. This evaluation calculates the allowable through-wall flaw in the circumferential direction for the affected piping to be 1.7 inches (41% of pipe circumference), which is bounding for the actual through-wall flaw which was determined to be 1.162" in length when characterized by a volumetric examination method (radiography). Based on the Code Case N-513-3 structural evaluation, it was determined that the leaking pipe is structurally stable.

<u>Risk Impact</u>

The risk impact of the identified flaw has been evaluated. An evaluation of the CVC drain line determined that structural integrity of the pipe would be maintained with a flaw larger than currently identified, which demonstrates that the nuclear safety risk is minimal. The leakage does not impact any specified safety functions and remains within the Technical Specification operational leakage limits. Plant operations personnel have conservative decision-making triggers to ensure actions are taken in advance of reaching the Technical Specification limits. Radiological and Industrial Safety risk is minimal because the leakage is in the low pressure suction side of the charging system. The CVC drain line is not specifically modeled in the station Probabilistic Risk Analysis (PRA) model but the impact would be to the boric acid inventory through the charging system. The loss of the boric acid makeup tank capacity would result in a change in the core damage frequency (ΔCDF) of 1.7E-7/year. This change in core damage frequency falls within the Regulatory Guide 1.174 acceptance guidelines (Reference 1) for very small changes to CDF.

Hardship to Repair

The location of this leak on 2CH1-30 is a common CVC line which is downstream of both the Boric Acid Makeup pump discharge and Boric Acid Gravity Feed Valves and upstream of the suction of all three CVC charging pumps.

The CVC system is designed to maintain the chemistry and purity of the reactor coolant during normal operation and shutdowns, maintain the required volume of water in the RCS compensating for reactor coolant contraction or expansion resulting from changes in reactor coolant temperature and for other coolant losses or additions, and control the boron concentration in the RCS to compensate for reactivity changes.

Two independent charging pumps are required to be operable per Technical Specification LCO 3.1.2.4 in Modes 1-4. There is no action statement if more than one of the independent pumps are inoperable. Two boron injection paths to the RCS via the charging pumps are required to be Operable per Technical Specification LCO 3.1.2.2. With no action statement for more than one flow path inoperable, LCO 3.0.3 requires shutdown within 1 hour.

An ASME Section XI, IWA-4000 repair of the leak in drain line 2CH1-30 cannot be performed without shutting down the plant should such a repair become necessary. As an alternative to IWA-4000, Entergy proposes to perform a weld overlay repair of the subject through-wall flaw based on ASME Section XI Code Case N-666-1. Code Case N-666 was originally approved by the ASME in April 2006. Since that time, the weld overlay methodology of this code case has been used across the industry to restore structural integrity of degraded socket weld connections.

Entergy intends to use Code Case N-666-1 to perform a weld overlay repair of the leaking through-wall flaw on drain line 2CH1-30. To do this, Entergy has initiated this relief request to propose alternatives to certain requirements in Code Case N-666-1.

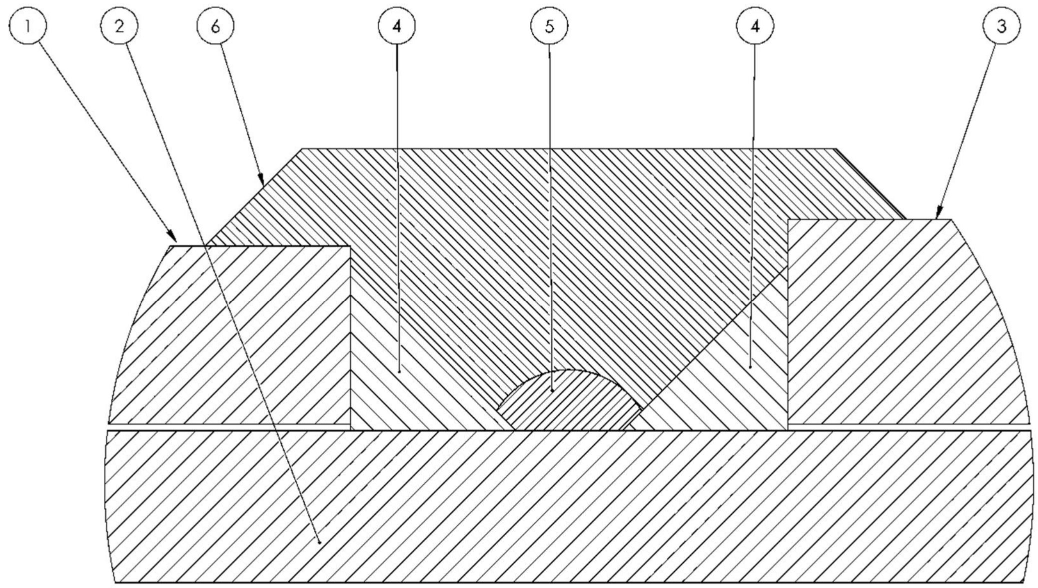
**5. Proposed Alternative and Basis for Use:**

Pursuant to 10 CFR 50.55a(z)(2), Entergy is proposing an alternative to specific ASME Section XI Code requirements in Code Case N-666-1 as conditionally approved for use by the NRC in Regulatory Guide 1.147. Entergy's proposed alternative and bases is provided below:

A. Code Case N-666-1, paragraph 1(d) requires that the pipe base material adjacent to the socket weld requiring overlay be verified to meet the required minimum wall thickness. However, the close proximity of the adjacent socket weld does not permit access to the pipe base material for verification that the pipe meets the minimum wall thickness. Therefore, as an alternative, Entergy proposes to install the weld overlay across both socket welded joints, the pipe, and on the outer surfaces of the socket weld fittings. The weld overlay thickness will be designed to meet the minimum required wall thickness.

B. Code Case N-666-1, paragraph 3(a) requires that the completed weld overlay comply with the dimensional requirements of Figure 1 and that the minimum throat dimension of the weld overlay be measured from the location of the crack farthest from the weld toe. However, the weld overlay cannot be designed to meet the dimensional requirements of paragraph 3(a) or Figure 1 as the installed piping configuration and the location of the leak is on a section of straight pipe in between a socket welded tee and a socket welded elbow. Furthermore, the distance between the two socket welds does not permit the weld overlay to be terminated on the pipe while meeting the 45° (maximum) requirement between the pipe and weld overlay contour.

   Entergy's weld overlay design proposes an alternative design to the dimensional requirements of Figure 1 of Code Case N-666-1. The proposed repair design maintains the required wall thickness and throat dimensions as defined in paragraph 3(a) of Code Case N-666-1, and also maintains the wall thickness requirements per the Code of Construction requirements (ASME Section III, 1971 Edition with Addenda through Winter 1972). Detail 3, below, provides a schematic of the proposed repair design. The weld overlay design applies weld metal across both socket welded joints, the pipe, and on the outer surface of the socket weld fittings. The throat dimension of this design, measured from the leak seal weld surface, is greater than 0.138-inch (77 percent of the nominal wall thickness of the pipe or 0.179-inch) and meets the Code Case's design throat dimension.




| Item | Description | Material |
|---|---|---|
| 1 | SOCKET WELD BRANCH CONNECTION | SA-182 F304 |
| 2 | 1-inch SCH 80S PIPE | SA-376 TP304 |
| 3 | ELBOW | SA-182 F304 |
| 4 | SOCKET WELD | E308 / ER308 |
| 5 | SEAL WELD | E308L / ER308L |
| 6 | WELD OVERLAY | E308L / ER308L |

Detail 3: Weld Overlay Design

A structural evaluation of the repair design is provided in Enclosure 1. This evaluation uses the hoop and axial stress limits of the 1971 Edition/Winter 1972 Addenda of ASME Section III to determine the minimum required wall thickness of the repaired pipe configuration. This evaluation is based on operating loads and conservatively does not include the thickness provided by the 1-inch NPS, Schedule 80 socket welded pipe that contains the through-wall crack. The results of this evaluation show that the minimum required wall thickness for the weld overlay repair is 0.021-inch. Compared to the required throat dimension of the repair weld at the location of the toe crack, an additional 0.117-inch of thickness margin is available. The actual configuration results in additional material being applied over the seal weld.

C. Code Case N-666-1, paragraph 4(d) requires that the weld sequence shall be from the fitting to the pipe for overlay of toe cracks and that the completed weld overlay comply with Figure 1. However, the close proximity of the adjacent socket welds does not facilitate deposition of weld metal using this weld sequence. Therefore, as an alternative, Entergy proposes to implement the proposed weld overlay design as follows:

- The crack will be seal welded in accordance with Code Case N-666-1, paragraph 4(b). Afterwards, the seal weld, remaining socket welds, and adjacent base materials to be overlaid shall be visually examined using VT-1 criteria in accordance with Code Case N-666-1, paragraph 4(c).

- Due to the configuration of the repair design, weld beads will be deposited in individual layers until the V-groove cavity is filled and flush with the shoulders of the fittings. The weld overlay build-up is completed as shown schematically in Detail 3 by applying a minimum of two structural layers. Weld sequence shall be from fitting to fitting.

- As required by Code Case N-666-1, paragraph 4(d), the weld overlay design will consist of at least two structural overlay layers deposited around the entire circumference of the filled V-groove cavity and fittings. The throat dimensions of this design take no structural credit for the seal weld layers.

- The completed weld overlay will be examined and tested in accordance with Code Case N-666-1, Section 5. However, final dimensions of the completed weld overlay will comply with Entergy's proposed weld overlay design described in Section 5.B of this relief request.

All other requirements of Code Case N-666-1, including the conditional acceptance requirement in Regulatory Guide 1.147 will be met.

## 6. Duration of Proposed Alternative:

Entergy's intention is to perform an ASME Section XI, IWA-4000 repair on CVC system line 2CH1-30 during the next refueling outage. The proposed alternative is applicable until repair is performed during Refueling Outage 23, which is scheduled during the Fall of 2020.

## 7. Precedents:

None

## 8. References:

1. NRC Regulatory Guide 1.174, Revision 3, "An Approach for Using Probabilistic Risk Assessment in Risk-informed Decisions on Plant-Specific Changes to the Licensing Basis," January 2018, ADAMS Accession No. ML17317A256.

2. EPRI Report 3002010753, Welding and Repair Technology Center: Practical Guideline to Socket Welding, EPRI, Palo Alto, CA: 2017.

**9. Attachments:**

1. Structural Integrity Calculation Package 1900769.302, Revision 0, "Evaluation of Weld Overlay Repair of Socket Weld Region," July 18, 2019

2. List of Regulatory Commitments

**ATTACHMENT 1**
**W3F1-2019-0054**

**Structural Integrity Calculation Package 1900769.302, Revision 0, "Evaluation of Weld Overlay Repair of Socket Weld Region," July 18, 2019**

**File No.: 1900769.302**
**Project No.: 1900769**
Quality Program Type: ☒ Nuclear ☐ Commercial

Structural Integrity Associates, Inc.

# CALCULATION PACKAGE

**PROJECT NAME:**
Waterford Code Case N-513 Evaluation of Leaking Class 2 Line

**CONTRACT NO.:**
10585075

**CLIENT:**
Entergy Nuclear

**PLANT:**
Waterford Steam Electric Station, Unit 3

**CALCULATION TITLE:**
Evaluation of Weld Overlay Repair of Socket Weld Region

| Document Revision | Affected Pages | Revision Description | Project Manager Approval Signature & Date | Preparer(s) & Checker(s) Signatures & Date |
|---|---|---|---|---|
| 0 | 1 - 8 | Initial Issue | Eric Houston<br>7/18/19 | Preparer:<br>Andrew Collins<br>7/18/19<br>Checker:<br>.Stephen Parker<br>7/18/19 |
| | | | | |

## Table of Contents



## List of Tables

## 1.0 OBJECTIVE

A leaking flaw was recently discovered at the Waterford Steam Electric Station, Unit 3 (Waterford) in the Chemical and Volume Control (CVC) system. The Class 2 leaking pipe is upstream of valve CVCMVAAA186 (CVC-186). The objective of this calculation is to determine the minimum required wall thickness for the repaired section of piping with a weld overlay repair.

## 2.0 METHODOLOGY

The structural suitability of a weld overlay repair is accomplished by verifying that the thickness of the weld buildup meets the required minimum thickness for the operational condition. The methodology of this calculation uses the equations for hoop stress and axial stress along with allowable stresses from Section III, 1971 Edition with Addenda through Winter 1972 Code of Construction [1].

The hoop stress limit is defined by the Code of Construction [1, NC-3641.1 Equation 3] and calculates the minimum required wall thickness due to internal pressure, $t_m$. The axial stress limits are defined as a series of stress limits based on pressure and piping loads:

- Equation 8, Longitudinal Stresses due to Sustained Loads [1, NC-3652.1]
- Equation 9, Longitudinal Stresses due to Occasional Loads [1, NC-3652.2]
- Equation 10, Longitudinal Thermal Expansion Stresses [1, NC-3652.3(a)]
- Equation 11, Longitudinal Thermal Expansion and Sustained Loads Stress [1, NC-3652.3(b)]

The smallest wall thickness that satisfies both the hoop and axial stress limits is defined as the minimum wall thickness, $t_{min}$. Note that only Equation 10 or Equation 11 is required to be met, not both [1, NC-3652.3]. Therefore, only Equation 10 is evaluated herein. For this evaluation, the $t_{min}$ value will be conservatively calculated using the dimensions of the weld buildup over the socket welded connections and ignoring the structural benefit of the unflawed existing base pipe material.

### 2.1 Criteria for Hoop Stress

The minimum thickness required based on hoop stress, Equation 3 [1, NC-3641.1], assures against gross structural failure due to primary membrane pressure loading. Equation 3 is written as a design thickness calculation based on the maximum allowable stress. The minimum thickness required for design pressure, $t_m$, is defined by Equation 3 as:

$$t_m = \frac{PD_o}{2(SE + Py)} + A$$

| | | |
|---|---|---|
| P | = | Internal design pressure, psi |
| $D_o$ | = | Outside pipe diameter, in |
| S | = | Maximum allowable stress at design temperature, psi |
| E | = | Longitudinal weld joint efficiency factor (1.0 for seamless pipe) |
| y | = | Pressure coefficient |
| | = | 0.4 [1, NB-3641.1] |
| A | = | Additional thickness, in |

The additional thickness value, A, is taken as zero.

## 2.2 Criteria for Axial Stress

Equations 8, 9, and 10 [1, NC-3652] are intended to show that the calculated axial stresses in the piping component, due to pressure and piping loads, meet the Code of Construction stress limits. An iterated uniform wall thickness is used to calculate the piping stresses in these equations, which are compared to an allowable stress for design purposes. The thickness that results in a stress equal to the allowable stress is taken as the minimum thickness for that condition.

The Longitudinal Stresses Due to Sustained Loads, $S_{SL}$, must satisfy the following requirement [1, NC-3652.1, Equation 8]:

$$S_{\mathrm{SL}} = \frac{\mathrm{PD}_o}{4\mathrm{t}_n} + \frac{0.75\mathrm{iM}_A}{Z} \leq 1.0\mathrm{S}_h$$

| | | |
|---|---|---|
| P | = | Internal design pressure, psi |
| $D_o$ | = | Outside pipe diameter, in |
| $t_n$ | = | Nominal wall thickness, in |
| i | = | Stress intensification factor (Note: 0.75i may not be less than 1.0) (see [1, NC-3673.2(b)]) |
| $M_A$ | = | Resultant moment due to sustained loads, in-lb (see [1, NC-3654]) |
| Z | = | Section modulus, $in^3$ (see [1, NC-3654]) |
| $S_h$ | = | Allowable stress at design temperature (equivalent to S for this evaluation), psi |

The Longitudinal Stresses Due to Occasional Loads, $S_{OL}$, must satisfy the following requirement 1, NC-3652.2, Equation 9]:

$$S_{\mathrm{OL}} = \frac{P_{max} D_o}{4\mathrm{t}_n} + 0.75\mathrm{i}\frac{(M_A + M_R)}{Z} \leq 1.2 S_h$$

| | | |
|---|---|---|
| $P_{max}$ | = | Peak pressure (taken as operating pressure), psi |
| $D_o$ | = | Outside pipe diameter, in |
| $t_n$ | = | Nominal wall thickness, in |
| i | = | Stress intensification factor (Note: 0.75i may not be less than 1.0) (see [1, NC-3673.2(b)]) |
| $M_A$ | = | Resultant moment due to sustained loads, in-lb (see [1, NC-3654]) |
| $M_R$ | = | Resultant moment due to occasional loads, in-lb (see [1, NC-3652.4]) |
| Z | = | Section modulus, $in^3$ (see [1, NC-3654]) |
| $S_h$ | = | Allowable stress at design temperature (equivalent to S for this evaluation), psi |

The Thermal Expansion Stresses, $S_E$, must satisfy the following requirement [1, NC-3652.3(a), Equation 10]:

$$\frac{iM_C}{Z} \leq S_A$$

| | | |
|---|---|---|
| i | = | Stress intensification factor |
| $M_C$ | = | Range of resultant moment due to thermal expansion, in-lb (see [1, NC-3652.2]) |
| Z | = | Section modulus, $in^3$ (see [1, NC-3654]) |
| $S_A$ | = | Allowable stress range for expansion stresses, psi |

The allowable stress range, $S_A$, is defined as $S_A$=f $(1.25S_c+0.25S_h)$ [1, NC-3611.1(b)(3)], where f is defined as the stress range reduction factor for full temperature thermal cycles. $S_c$ is the basic material allowable stress at minimum (cold) temperature. For this evaluation, the reduction factor is assumed to be equal to 1.0 since the number of thermal expansion cycles is expected to be below 7,000 (see Section 4.0, Assumption No. 2). Therefore, $S_A$ is equal to $1.5S_h$ as $S_c$ and $S_h$ are equivalent for this evaluation.

## 3.0 DESIGN INPUTS

The following design inputs were provided by Entergy personnel to be used in the analysis:

1. Pipe Material = SA-376, TP-304 [2]
2. Pipe Nominal Size = 1-inch Schedule 80 [2]
3. Maximum Operating Temperature = 120°F [3]
4. Design Temperature = 250°F [3]
5. Maximum Operating Pressure = 85 psig [3]
6. System Code of Construction = ASME Section III, 1971 Edition with Addenda through Winter 1972 [3]
7. Code Allowable Stress, interpolated at 120°F, = 18.6 ksi [1, Table I-7.2]
8. Material Yield Strength = 30 ksi [1, Table I-7.2]
9. Material Ultimate Strength = 75 ksi [1, Table I-7.2]

The pipe outside diameter (1.315 inches) and nominal thickness (0.179 inch) are obtained from readily available industry information based on the pipe size and schedule.

The OD of the socket welded elbow and coupling are assumed to be those of 3000 lb fittings from [5], which have a maximum fitting OD of 1.8125 inches.

Piping loads are taken from the design basis stress report [4]. The location of interest is at Node 403, but the bounding loads used in the evaluation are taken from Node 402, which is the branch of the socket welded connection to the 4-inch run piping. The methodology requires moment loads as input, which are obtained from the Reference [4] nodal outputs for each load case. Three load cases are utilized: thermal expansion (TH), sustained (DW), and operating basis earthquake (OBE). OBE is the only seismic loading evaluated in the stress report and is, therefore, the only seismic loading evaluated herein. The component moments at Node 402 are taken from each load case in the Reference [4] output. The square root sum of squares (SRSS) moments are calculated for each load.

Constrained thermal expansion stress in a simple system is roughly linear over small ranges of changes in temperature ($\Delta T$), with slight non-linearities introduced due to temperature depended material properties. Complex systems, such as piping systems, are not strictly linear due to geometric effects and the potential influence of mixed metals. The design basis stress report only evaluates thermal expansion loading for the design temperature of 250°F. If the reference temperature for thermal expansion stress is taken as 70°F (see Assumption 1), the evaluated $\Delta T$ is 180°F. The maximum operating temperature is only 120°F, which represents a $\Delta T$ of 50°F. Rather than use the thermal expansion loading for the full 180°F $\Delta T$, the thermal expansion loads are scaled by a factor of 0.5. This represents an evaluated $\Delta T$ of approximately 90°F, which is still considered conservative when the actual $\Delta T$ is nearly half that amount.

To conservatively account for the stress intensification due to the weld overlay repair, a stress intensification factor (SIF) of 1.3 is used in the analysis. This SIF is consistent with Figure NC-3672.9(a)-1 from the Code of Construction for socket welded connections [1]. Application of this SIF to the analysis is conservative as the stress intensification created by the original socket welded joint will be reduced with the addition of the repair weld metal. The geometric configuration of the weld overlay will result in a design that is similar to a butt welded connection, which have an SIF of 1.0 per Figure NC-3672.9(a)-1 from the Code of Construction [1].

The loads for the analysis, derived from Reference [4], are shown in Table 1.

**Table 1: Applied Moment Loads**

| | From Stress Report (ft-lbs) | | | Resultant | ΔT Scale Factor Applied | Evaluated Loads |
|---|---|---|---|---|---|---|
| | X | Y | Z | (in-lbs) | (in-lbs) | (in-lbs) |
| DW | 19 | 1 | 8 | 248 | --- | 248 |
| OBE | 21 | 13 | 16 | 353 | --- | 353 |
| TH | 53 | 170 | 42 | 2195 | 1098 | 1098 |

## 4.0 ASSUMPTIONS

The following assumptions are used in the evaluation.

1. It is assumed that 70°F is used as the reference temperature (i.e., the zero-stress state) in the design basis thermal expansion stress analysis [4]. The stress report then evaluates the change in temperature from 70°F to 250°F. Use of 70°F is typical for such an evaluation. Use of a different reference temperature would result in a change in the resulting stress (higher stress for a lower reference temperature, lower stress for a higher reference temperature). However, use of a significantly different reference temperature does not have a meaningful impact on the results of the analysis, and there is no basis for evaluating from a different reference temperature.
2. It is assumed that the full thermal cycles for the piping system total less than 7,000 cycles. Given the operation of the system, this assumption is appropriate for determining the stress range reduction factor (f) for this analysis.
3. The evaluation assumes no structural benefits from the existing base pipe material. This is reasonable and conservative for analyzing the acceptance of the weld overlay buildup.

## 5.0 CALCULATIONS

For longitudinal stresses, the thickness, $t_n$, is iterated for Equations 8, 9, and 10 until the calculated stress is equal to the allowable stress, as defined for each equation. This calculation provides a resulting minimum thickness necessary that meets the Code of Construction requirements based on the dimensions of the added weld overlay material. The section modulus of the weld overlay cross section is also iterated as function of the evaluated thickness. The minimum thickness necessary for hoop stresses is calculated directly from Equation 3.

## 6.0 RESULTS OF ANALYSIS

The resulting $t_{min}$ for each loading condition is shown in Table 2.

**Table 2: Minimum Thickness Results**

| Loading Condition | Minimum Required Thickness (inch) |
|---|---|
| Equation 3 - Hoop Stress | 0.004 |
| Equation 8 - Sustained Load - Deadweight | 0.008 |
| Equation 9 - Occasional Load - OBE | 0.013 |
| Equation 10 - Thermal Expansion | **0.021** |

The Code of Construction minimum required wall thickness for these conditions is taken as the maximum of the resulting thicknesses tabulated in Table 2. Therefore, the minimum required wall thickness for the weld overlay design is 0.021 inch and is limited by thermal expansion.

## 7.0 CONCLUSIONS

This evaluation calculates the minimum required thicknesses of the Waterford Steam Electric Station, Unit 3 CVC system Class 2 piping region upstream of valve CVCMVAAA186 (CVC-186) in support of a Code Case N-666-1 weld overlay repair. The Code of Construction minimum required wall thickness for the weld overlay repair is 0.021-inch. This minimum thickness is based on the dimensions of the socket welded fittings and the resulting weld overlay and conservatively ignores the structural benefit of the existing unflawed base pipe material.

## 8.0 REFERENCES


1. ASME Boiler and Pressure Vessel Code, Section III, 1971 Edition with Addenda through Winter 1972.
2. Waterford Drawing No. 4305-3913, SI File No. 1900769.205.
3. Email from T. House (Entergy) to E. Houston (SI), Subject "RE: SI Contact Information," July 2, 2019, SI File No. 1900769.208.
4. Waterford Stress Report No. SA-2869-2, Revision 2, "Stress Analysis of CH-Piping per SMP-1743 'As-Built'," SI File No. 1900769.201.
5. Ladish General Catalog No. 55, Forged and Seamless Welding Pipe Fittings,1954, SI File No. 1900769.209.

**ENCLOSURE, ATTACHMENT 2**
**W3F1-2019-0054**

**List of Regulatory Commitments**

**Attachment 2**
**List of Regulatory Commitments**

This table identifies actions discussed in this letter for which Entergy commits to perform. Any other actions discussed in this submittal are described for the NRC's information and are **not** commitments.

| COMMITMENT | TYPE (Check one) | | SCHEDULED COMPLETION DATE (If Required) |
|---|---|---|---|
| | ONE-TIME ACTION | CONTINUING COMPLIANCE | |
| Perform an ASME Section XI, IWA-4000 repair during the next refueling outage. | X | | RF 23 |