NEXTera ENERGY
SEABROOK

February 6, 2017

10 CFR 50.55a

Docket No. 50-443
SBK-L-17027

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20582

Seabrook Station
Relief Request RA-17-002, Proposed Alternative in Accordance with 10 CFR 50.55a(z)(2)

Pursuant to 10 CFR 50.55a(z)(2) NextEra Energy Seabrook, LLC (NextEra Energy Seabrook) requests relief to allow performance of a temporary, non-ASME code repair to the Seabrook Station Unit 1 Service Water (SW) system. The circumstances regarding this request are included in the attachment to this letter. Justification for the temporary repair of the Seabrook Unit 1 SW piping is also provided in the attachment to this letter. NextEra requests prompt NRC review and approval of the proposed alternative to allow planned repairs on or before February 10, 2017.

Seabrook Station is in the third 10-year Inservice Inspection interval which ends August 18, 2020.

This request is similar to the relief granted to Southern Nuclear Operating Company, Inc., for the Edwin I. Hatch Nuclear Plant, Unit 1 (ML12058A413), Shearon Harris Nuclear Power Plant, Unit 1 (ML110601120) and McGuire Nuclear Station, Unit 1 (ML16266A026).

There are no commitments being made in this submittal.

If you have any questions regarding this submittal, please contact me at (603) 773-7932.

Sincerely,

NextEra Energy Seabrook, LLC

Christine Thomas for
Kenneth J. Browne
Licensing Manager

Attachment:

Request RA-17-002, Proposed Alternative in accordance with 10 CFR 50.55a(z)(2)

cc:

D. H. Dorman, NRC Region I Administrator
J. C. Poole, NRC Project Manager
P. C. Cataldo, NRC Senior Resident Inspector

Attachment to SBK-L-17027

Request RA-17-002

Proposed Alternative in accordance with 10 CFR 50.55a (z)(2)

## 1. ASME Code Components Affected

The affected piping is Service Water pipe 1-SW-1827-001-153-24", on the inlet to the A PCCW HX (1-CC-E-17-A), which supplies cooling water for the purpose of removing heat from systems and components during normal plant operations and emergency plant evolutions. The flaw is located in a Belzona-lined spool upstream of the 1-CC-E-17-A inlet isolation valve SW-V-14, adjacent to field weld FW-1827-F0905. Field weld FW-1827-F0905 is a transition location between cement lined and Belzona-lined piping which is covered internally by a WEKO seal.

### 1.1 System Details:

| | |
|---|---|
| ASME Code Class: | Class 3 |
| System: | Service Water System |
| Category: | Moderate Energy Piping |

### 1.2 Component Descriptions:

The component in question is 24-inch Nominal Pipe Size (NPS) SA 106 Grade B carbon steel piping with a Belzona lining and nominal wall thickness of 0.375-inch. The application of this alternative is to perform a temporary, non-Code repair to the SW piping. This non-Code repair will consist of the addition of a 6-inch nominal diameter weldolet, weld-neck flange, and blind flange over the identified localized flawed area. The general configuration for the repair is shown in Figure 1.

## 2. Applicable Code Edition and Addenda

Seabrook Station is currently in the third 10-year Inservice Inspection (ISI) interval. The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) of record for the current 10-year ISI interval is Section XI, 2004 Edition, with no Addenda for the Repair/Replacement Program.

## 3. Applicable Code Requirement

The applicable Code Section for which the relief is requested is ASME Code Section XI, 2004 Edition, with no Addenda, Section IWA-4412.

IWA-4412 states: "Defect removal shall be accomplished in accordance with the requirements of IWA-4420."

The identified defect will not be removed during operation of the "A" Train of Service Water because doing so would result in a significant leak rate through a larger area resulting from the removal of degraded pipe wall. Therefore relief is being requested to perform a temporary non-Code repair.

## 4. Reason for the Request

On January 21, 2017, with Seabrook Station in operation at 100% power, through-wall leakage was observed on the OD of pipe line 1-SW-1827-001. The present leak rate is approximately 12 drops per minute. Initial, best effort attempt, UT inspection of the reduced-wall area conservatively estimated an impacted area to be 1.75" axial x 2.5" circumferential. Subsequent UT identified the flaw area as being 0.72" axial by 0.953" circumferential. There was no visual sign of a through wall hole. The ASME Code required minimum pipe wall was calculated to be 0.105 inch based upon a system design pressure of 150 psi. In accordance with Code Case N-513-3 criteria, a value of 0.120 inch was calculated based upon maximum operating pressure of 171 psi. When the full circumference of the pipe was inspected in accordance with ASME Code Case N-513-3 requirements, in addition to the through wall flaw location, fourteen additional indications were discovered. All fifteen indications are essentially aligned in an axial band around the pipe that extends approximately 4.0 to 4.5 inches downstream of the field weld FW-1827-F0905. Of these fourteen additional locations, only two locations were identified to have resulting wall thickness values below the Code required minimums. These two are not through wall and have remaining wall values of 0.089 inch (flaw area 0.47 inch axial by 0.33 inch circumferential) and 0.117 inch (flaw area of 0.118 inch axial by 0.33 inch circumferential). The location around the pipe of the single through wall flaw and the locations of the two other non-through wall flaws are such that based upon N-513-3 criteria for multiple flaws the combination of these areas into a single equivalent area is not required. The pipe wall surrounding these has a minimum wall thickness of 0.328 inch.

The remaining wall thickness currently provides sufficient structural integrity to maintain operability of the SW system.

The temporary non-Code repair is to be applied over the existing through wall leak area.

## 5. Hardship of Repair

Section XI of the ASME Code specifies Code-acceptable repair methods for flaws that exceed Code acceptance limits for piping that is in service. A Code repair is required to restore the structural integrity of flawed ASME Code piping, independent of the operational mode of the plant when the flaw is detected. Repairs not in compliance with Section XI of the ASME Code are non-Code repairs. Seabrook Station Technical Specifications (TS) 3/4.7.4 requires that the Service Water System be operable with an Operable service water pumphouse and two service water loops with one Operable service water pump in each loop. Performing an ASME Code repair at the flaw location during power operation would require that the "A" Train of Service Water be taken out of service. While the Technical Specifications provide 24 hours for repair, doing so would result in the loss of one train of cooling water during the repair timeframe. The isolation and draining of the "A" train of Service Water during power operation is complex and would expend a significant portion of the 24 hours allowed. Shutting down the plant to perform a Code repair versus using the proposed temporary non-Code repair is considered by Seabrook Station to be a hardship.

## 6. Burden Caused by Compliance

It is impractical to complete a Code-acceptable repair to the identified SW leak at Seabrook Station without shutting the plant down. Shutting the plant down towards the end of cycle creates undue and unnecessary stress on plant systems, structures, and components.

## 7. Proposed Alternative and Basis for Use

Compliance with the specified requirements of the ASME Section XI Code would result in hardship without a compensating increase in the level of quality and safety.

NextEra Energy proposes a temporary, non-Code repair consisting of the encapsulation of the identified pipe through wall flaw by the addition of a 6-inch NPS weldolet, weld neck flange, and blind flange as depicted on Figure 1.

### 7.1 Flaw Sizing and Characterization

On 2/2/17 an Ultrasonic Test (UT) examination was performed at an identified through wall leak on line SW-1827-001-153-24" adjacent to field weld location FW-1827-F0905. The area was identified by discovery of a slow (several drops per minute) leak. The examination revealed that the through wall leak at this location was the result of a single isolated flaw that appears to be related to corrosion. In accordance with ASME Code Case N-513-3, the full circumference of the pipe was inspected at the leak location for additional flaws. A total of 15 wall loss indications were identified spread circumferentially around the pipe at the same axial distance (approximately 4.0 to 4.5 inches) from the centerline of field weld FW-1827-F0905. All are characterized as internal diameter initiated, non-planar indications with 3 characterized as flaws since they are below required minimum pipe wall (a value of 0.120 inch was calculated based upon maximum operating pressure of 171 psi). The relative size and location of the three flaws are as follows:

| Flaw | Centerline Distance Measured from top dead center ($0^o$) | | Minimum thickness | Size @ 0.120 in. Limit | |
|---|---|---|---|---|---|
| | Inches | Degrees | | Length circumferential | Width axial |
| 1 | 11.295 | 54 | 0.089 | 0.330 | 0.470 |
| 2 | 26.21 | 125.2 | 0.117 | 0.330 | 0.118 |
| 3 | 32.954 | 157.4 | 0.00 Through Wall | 0.953 | 0.720 |

Prior to the encoded UT data being collected at these locations, a best effort attempt UT was performed before the removal of paint. This initially resulted in a conservative bounded flaw area of 1.75" axial x 2.5" circumferential at the $157.4^o$ position. That flaw size was evaluated and found to be acceptable for structural integrity of the pipe.

As previously discussed, in accordance with Code Case N-513-3 criteria, a value of 0.120 inch was calculated based upon a maximum operating pressure of 171 psi. The basis for the 171 psi

value is a Cooling Tower Pump operating at shut-off head in response to an Emergency/Faulted event. The original analysis assumed the pump shutoff head was 325 ft. which was subsequently reduced to 250 ft. or 107.2 psi. Conservatively neglecting the elevation difference between the pump discharge and the leak location, the maximum pressure the leak would experience in a shutoff condition is 107.2 psi. Conservatively using a value of 110 psi, the N-513-3 required minimum pipe wall for maximum operating pressure is 0.077 inch.

Reviewing the table above, the only indication less than 0.077 inch is the leaking through wall flaw location. Therefore in a worst case design basis event only the 157.4$^{o}$ location would achieve enough pressure to exacerbate the leak.

## 7.2 Degradation Mechanism

As discussed in Section 7.1 above, based upon the Non-Destructive Examination (NDE), the localized flaw appears to be seawater corrosion resulting from a loss of the pipe liner. See further discussion on this in Section 7.4.

## 7.3 Flaw Evaluation

A flaw evaluation, in accordance with ASME Code Case N-513-3, was performed with the through wall flaw size assumed to be the bounding area of 1.75-inches by 2.5-inches. The evaluation concluded that structural integrity is maintained. This evaluation is provided in Reference 2, a copy of which is attached. In accordance with Code Case N-513-3, augmented inspections will be performed. Considering the discovery of the 15 indications aligned in an axial band adjacent to a field weld with an installed WEKO seal, the augmented sample size will include locations potentially susceptible to the same condition.

## 7.4 Flaw Growth Rate

As previously stated in Section 7.2, the cause of the degradation is from localized corrosion. The typical corrosion rate used in Seabrook Station Service Water piping evaluations is 30 mils per year (mpy) under system flow conditions. The use of this number is conservative considering that the identified internal pipe wall indications can be assumed to be under the installed WEKO seal. The position of the Type “D” WEKO seal is over the centerline of the field weld FW-1827-F0905. The axial length of the EPDM portion of the seal is 11.125 inch. Considering the approximate 4 inch location from the field weld centerline, the UT identified indications reside under the EPDM portion of the seal. This explains the relative consistency of the indications all being four inches downstream of the field weld. Considering the 30 mils per year wall loss applied over the 57 days to the April 1, 2017, the N-513-3 derived required wall of 0.077 inch in Section 7.1 will not be challenged at the two non-through wall locations having thicknesses of 0.089 inch and 0.117 inch. Likewise while further degradation will occur within the bounding area, the surrounding area wall will not be violated during the duration of the proposed temporary non-Code repair. To provide further assurance, a 6-inch weldolet has been selected for use.

The sizing of the weldolet (6 inch nominal) was based upon the identified wall thickness of the piping and its installation position with respect to the conservative, bounded flaw size (1.75 by 2.5 inch). The weldolet will be welded to pipe wall thickness verified to be of a thickness of 0.328 inch or better. The typical corrosion rate used by Seabrook is 30 mils per year. To proactively address the corrosion potential within the bounded area, a factor of 4 is applied resulting in a rate of 120 mils per year. Although the installation duration is less than a year (next refueling outage is Spring 2017) 120 mils is used. The resulting pipe wall under the weldolet and weldment will therefore be reduced from to 0.328 – 0.120 = 0.208 inch. As the pipe wall with future metal loss, calculated to be 0.208 inch, exceeds the Code calculated minimum, structural integrity of the repair will be maintained. The 6.6875 inch inside diameter of the weldolet in relationship with the major axis dimension of the bounded flaw (2.5 inch) and actual flaw (0.953 inch) provides sufficient metal such that further corrosion will not affect the integrity of the repair.

### 7.5 Repair Components

The design pressure and temperature of the Service Water piping system is 150 psi and 200 degrees F. Normal operating pressure is 75 psi and Normal operating temperature is 65 degrees F maximum and 35 degrees F minimum. The repair components, weldolet, weld neck flange and blind flange design conforms to these temperature and pressure requirements. The existing 24 inch diameter piping is constructed from SA 106 Grade B material. The weldolet is constructed from ASME SA-105 material and meets the ASME Section III ND requirement for branch connections. The welding will be performed using the in-house General Welding Procedure, ES0815.002, a qualified procedure that meets the ASME Section IX requirements for an open root, full penetration weld. Water will be removed from the weld area via suction or wiping, as necessary. Impact to the Belzona lining on the pipe attributed to the heat from welding the weldolet will be minimal based on past experience at Seabrook. The EPDM seal material in the WEKO seal has a rated service temperature of $150^{o}$ C ($302^{o}$ F). Since the pipe will be water filled during installation, minimal damage to the seal is anticipated. In addition any lining/seal damage would exist for only two months until OR18 when the weldolet will be removed plus any corrosion in this area would be observed by the UTs being performed. The branch connection will meet the ASME Section III ND requirements for fabrication. The pre-installation NDE requirements for the weldolet consists of the verification of ASME material, the verification of proper weld joint fit-up and a final Visual and Penetrant Testing exam of the final weld. The post installation NDE requirements consist of a VT-2 for leakage in accordance Section XI, IWA-5000. The acceptance criteria are in accordance with the original construction code, ASME Section III ND, requirements. The NDE examination methods performed will meet the ASME Section XI, IWA-4500 requirements.

### 7.6 Piping System Impact

The addition of a weldolet results in the application of a stress intensification factor of 4.05. Application of this factor on the existing pipe stress levels does not impact the piping system qualification since the resulting stress increases have been reviewed and found to remain within the ASME Code allowable.

The weight of the repair components is determined as follows: 14.20 lbs. (weldolet) + 27 lbs. (weld neck flange with bolting) + 29 lbs. (blind flange) + 10 lbs. (water content) = 80.2 lbs.

The pipe support adjacent to the defective area is 1827-SG-03. A review of the pipe support design documentation has concluded that the existing pipe support scheme can accommodate the weight addition of 80.2 lbs.

## 8. Duration of Proposed Alternative

The temporary non-Code repair to the Seabrook Station SW system will remain in place until the next Refueling Outage (OR18) scheduled for Spring 2017. The relief request will expire at the end of the refueling outage. Should the ongoing NDE inspection identify that the flaw progresses outside the encapsulated area to the point that the Code required minimum thickness is challenged, the relief request would expire and the impact on system operability assessed.

## 9. Post Repair Monitoring

As discussed in Section 7.4, nominal pipe wall exists around the flaw area bounded by the repair. The proposed temporary non-Code repair will be installed on this nominal pipe wall. The two indication flaw locations presently have acceptable wall thickness based upon the N-513-3 required wall (0.077 inch) at the maximum operating pressure of 110 psi. Periodic UT inspections of no more than 30 day intervals around the installed weldolet will be performed to identify wall loss propagating outside the encompassed area. Likewise, periodic UT inspections of no more than 30 day intervals will be performed to identify further wall loss at the two indication areas. In addition daily walkdowns of the area in which the repair is located, presently performed by Operations personnel, will continue.

## 10. Precedents

1) NRC letter from N. Salgado to M. J. Ajluni of Southern Nuclear Operating Company, Inc., “Edwin I. Hatch Nuclear Plant, Unit 1, Safety Evaluation of Relief Request HNP-ISI-ALT-14, Version 2, for the Fourth 10-Year Inservice Inspection Interval, Temporary Non-Code Repair of Service Water Piping” (TAC No. ME7366)( (ML12058A413)
2) NRC letter from D. A. Broaddus to C. Burton of Shearon Harris, “Shearon Harris Nuclear Power Plant, Unit 1 – Relief Request 13R-08, Temporary Non-Code Repair of Service Water Supply System Piping” (TAC No. ME4750) (ML110601120)
3) NRC letter from M. Markley to S. Capps of McGuire Nuclear Station, “McGuire Nuclear Station, Unit1 – Proposed Relief Request Serial #16-MN-003 For Alternate Repair of Nuclear Service Water System Piping” (CAC No. MF8269) (ML16266A026).

## 11. References

1) American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section XI, 2004 Edition, no Addenda.
2) Seabrook Station Calculation C-S-1-45928-CALC Rev. 001 “Code Case N-513-3 Pipe Wall Flaw Evaluation for SW-1827-001 Spool” (attached).

**Figure 1: Proposed 6-inch NPS Weldolet, Weld Neck Flange, and Blind Flange**

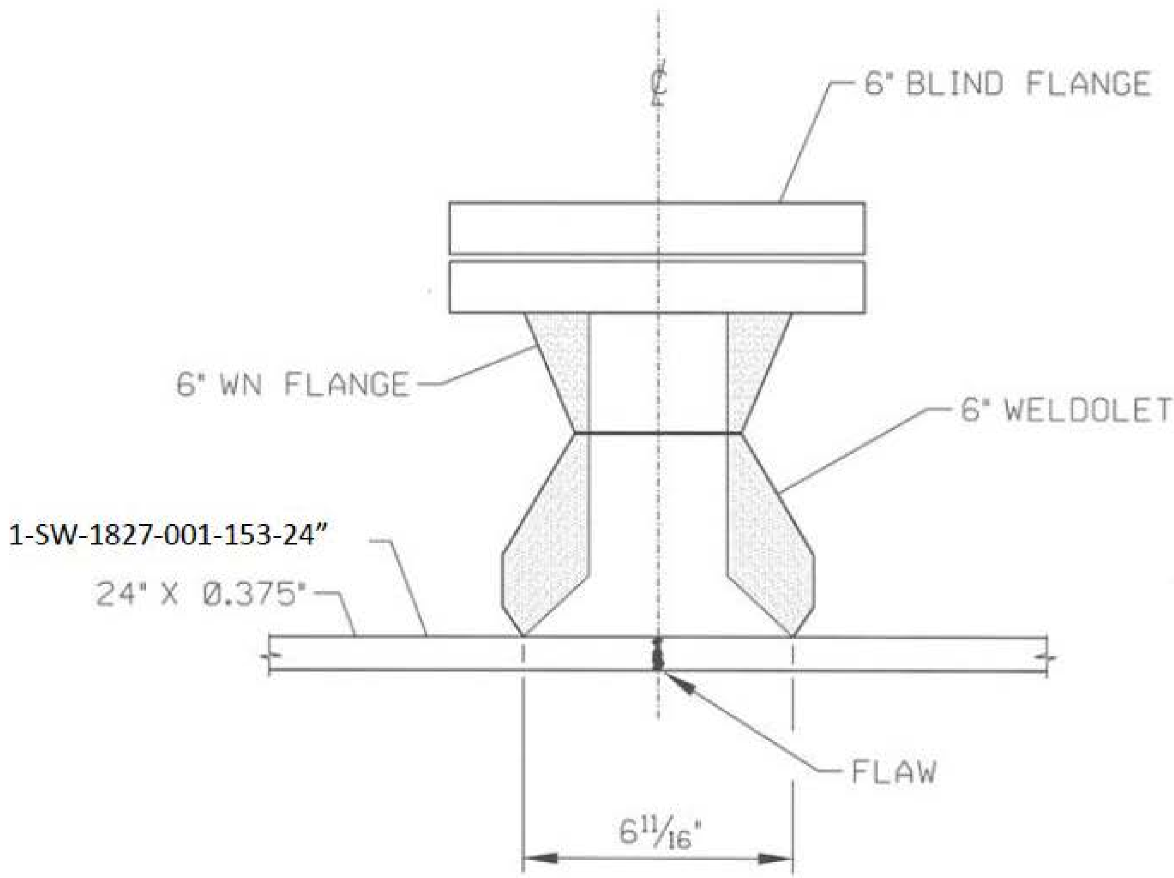



FIGURE 1

## Document Information:

| | |
|---|---|
| Calculation (Doc) No: **C-S-1-45928-CALC** | Controlled Documents Revision: 000 |
| Title: **Code Case N513-3 Pipe Wall Flaw Evaluation for SW-1827-001 Spool** | |
| Type: CALC Sub-Type: **CALC** Discipline: **Civil** | |
| Facility: **SEA** | Unit: **1** |
| Safety Class: ☒ SR ☐ Quality Related ☐ Non-Nuclear Safety ☐ Important to Safety ☐ Not Important to Safety | |
| Special Codes: ☐ Safeguards ☐ Proprietary | |
| Vendor Doc No: N/A | Vendor Name or Code: N/A |
| Executive Summary (optional): | |

## Review and Approval:

| | | |
|---|---|---|
| Associated EC Number: **288295**<br>AR/ Other Document Number: supports AR 02182856 POD | | EC Revision: 000 |
| Description of Calculation Revision: N/A | | EC Document Revision: 000 |
| Prepared by: Hy W. Mentel (signature) | Henry W. Mentel (Enercon) (print name) | Date: 2/1/2017 |
| Reviewed by: SAKenrick (signature) | SCOTT KENRICK (print name) | Date: 2/2/17 |
| Type of Review: ☒ Design Verification ☐ Review ☐ Owner Acceptance Review | | |
| Method Used (For DV Only): ☒ Design Review ☐ Alternate Calculation | | |
| Approved by: DJMcGonigle (signature) | DJMcGonigle (print name) | Date: 2/2/17 |

Calculation Number: C-S-1-45928-CALC Rev. 000

| Rev. | Affected Pages | Reason for Revision |
|---|---|---|
| 0 | 1 through 24<br>Attachment A – 2 Pages<br>Attachment B – 2 Pages<br><br>**Total Number of Pages = 28** | Original Issue |
| | | |
| | | |
| | | |

## CALCULATION FORMAT

## 1.0 PURPOSE

A through-wall flaw has been identified in pipe line SW-1827-001-153-24". The identification of this flaw has been entered into the Seabrook Station Corrective Action Program via Action Request (AR) 02182856.

The purpose of this calculation is to perform a wall thickness flaw evaluation in accordance with the ASME Boiler and Pressure Vessel Code Case N-513-3. This evaluation will determine whether or not the identified flaw is stable and provide input into the associated system operability determination. Furthermore this evaluation will identify recommended actions with regards to repair/replacement activities of the subject component.

The subject piping is classified as ANS Safety Class 3; Seismic Category I.

## 2.0 SUMMARY OF RESULTS

**EXECUTIVE SUMMARY:**

The through-wall pipe flaw identified and documented in AR# 02182856 has been evaluated in accordance with NRC CC N-513-3 and found to be stable. Calculated Stress Intensity Factors for all Service conditions are within the Code Case specified allowable with the applicable structural factors applied.
The ASME Code required minimum pipe wall thickness for both Design Pressure as well as mechanical loading is $t_m$ = 0.105 inch.
The N-513-3 derived minimum wall for the adjacent non-planar flaw region is 0.120 inch.

## 3.0 REFERENCES / DESIGN INPUTS

1) Action Request # 02182856
2) Code Case N-513-3 "Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping, Section XI, Division 1", Cases of ASME Boiler and Pressure Vessel Code, January 26, 2009.
3) ASME Boiler and Pressure Vessel Code, Section III 1983 Edition.
4) ASME Boiler and Pressure Vessel Code, Section XI, Appendix C, 2004 Edition
5) Regulatory Guide 1.147, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1", Revision 17, Nuclear Regulatory Commission, October 2010.
6) Y. Takahashi, "Evaluation of Leak-Before-Break Assessment of Pipes with a Circumferential Through-Wall Crack. Part 1: Stress Intensity Factor and Limit Load Solutions," International Journal of Pressure Vessels and Piping, 79, 2002.
7) Pipe Fracture Encyclopedia, US Nuclear Regulatory Commission, Volume 1, 1997.
8) Guidelines for Selection of Marine Materials, 2nd Edition, May, 1971 Copyright © 1966, The international Nickel Company, Inc.
9) FPL Energy Seabrook Structural Engineering Standard Technical Procedure DS36460, Rev. 3, Chg. 00 "Structural Evaluation of Flow Accelerated Corrosion (FAC) in Carbon Steel Piping and Piping Wall Flaws".
10) Code Case N-597-2 ""Requirements for Analytical Evaluation of Pipe Wall Thinning, Section XI, Division 1".
11) Nuclear Fleet Procedure EN-AA-203-1001 Rev. 22, "Operability Determinations / Functionality Assessments".
12) EN-AA-100-1004 Rev. 5, "Calculations"
13) EN-AA-204-1100 Rev. 6, "Document Change Request"
14) Piping Isometric: SW-1827-09 Rev. 7
15) "Piping Design and Engineering" Fourth Edition, Revised 1973 from ITT Grinnell Corporation.
16) Piping Stress Analysis of Record: C-S-1-45718-CALC Rev. 9
17) Piping Stress Analysis of Record Output: C-S-1-45718-CALC ATT-D Rev. 9
18) Pipe Stress Analysis isometric: SKM-020539-2001 DCN-2
19) Calculation 4.4.17.04F-CALC Rev. 6 SW Temp/Pressure Sheets

## 4.0 ASSUMPTIONS

Unless there is evidence of a base metal repair or other wall repair history and in consideration of low operating temperature, the stress intensity factor attributed to residual stresses ($K_{Ir}$) is assumed to be 0.00.

## 5.0 METHOD OF ANALYSIS

☒ Hand Calculation

Background:

The subject piping is SW-1827-001-153-24", and depicted on isometrics SW-1827-09 and SKM-020539-2001.

The current analysis of record for the piping is calculation C-S-1-45718-CALC Rev. 9.
Results from ADLPIPE Output SWONER5.000 dated 05/14/2015 are used. This ouput is available in NAMS as C-S-1-45718-CALC ATT-D Rev. 9.

The ADLPIPE software model node at or adjacent to the through wall leak location is NODE 27, 27E.
The following forces and moment loading has been extracted for use in this calculation.
NOTE: Axial Force = Fx ; Torsional moment = Mx

| Load | Forces, (lbs.) Forces, (kips) | | | | Moments, (ft-lbs.) Moments, (in-kips) | | | |
|---|---|---|---|---|---|---|---|---|
| | Fx | Fy | Fz | $F_{R\text{-bending}}$ | Mx | My | Mz | $M_R$ |
| Deadweight (File 11) | 13 | -1845 | -5 | | 4520 | 70 | 5557 | 7163.49 |
| | 0.013 | | | | | | | 85.96 |
| OBE Inertia File (31) | 4512 | 4106 | 860 | | 7159 | 28189 | 10467 | 30910.02 |
| | 4.512 | | | | | | | 370.92 |
| SSE Inertia (File 41) | 6241 | 5558 | 1245 | | 9923 | 36752 | 14844 | 40859.76 |
| | 6.241 | | | | | | | 490.32 |
| Hydraulic Transient File (100) | 312 | 74 | 40 | | 284 | 1173 | 156 | 1216.93 |
| | 0.312 | | | | | | | 14.60 |

The Thermal stress at the node in question = Not Required (low temperature)

Applicable stress intensification factor, i = 1.0 .
Unintensified thermal stress = Not Applicable
Note: Due to the nature of the hydraulic transients (pump starts,re-starts) Hydraulic Transient loads need not be combined with seismic loading as they are not concurrent events. Also the Seismic loads envelope the transient loads.

Method:

Utilizing the mechanical loading shown above, the fracture toughness of the remaining pipe wall will be evaluated per the criteria presented in Code Case N-513-3, to determine the likelihood of further flaw propagation due to the subjective loading. Verification of flaw stability does not negate the requirement of addressing the potential for further degradation due to salt water intrusion.

## 6.0 BODY OF CALCULATION

### 1.0 Scope - Applicability:

(a) The Code Case requirements apply to ASME Section III, ANSI B31.1 and ANSI B31.7 piping classified as Class 2 or 3.

The subject piping is classified as: ASME Safety Class 3
The subject piping component is : straight pipe
Piping Material is: SA 106 Grade B

**CAUTION**

NOTE: Code Case is not applicable to the following:

(1) pumps, valves, expansion joints and heat exchangers;
(2) socket welds;
(3) leakage through a flange joint;
(4) threaded connections employing nonstructural seal welds for leakage protection.

(b) The Code Case applies to Class 2 or 3 piping whose maximum operating temperature does not exceed 200°F and whose maximum operating pressure does not exceed 275 psig.

The subject piping maximum operating temperature = 90°F $\leq$ 200°F
The subject piping maximum operating pressure = 171.0 psig $\leq$ 275 psig
Reference Source for temperature / pressure conditions: 4.4.17.04F-CALC T/P Sheet U-3

(c) Flaw Evaluation criteria are permitted for pipe and tube. It cannot be used for adjoining fittings and flanges as calculations are based upon round pipe. However the criteria is applicable to that portion of the fitting where it transitions from pipe up to a distance of $(R_o t)^{1/2}$ from the weld centerline.

Is the flaw location adjacent to a fitting / flange weld ? No

## 3.0 Flaw Evaluation:

### Background

Typically flaw evaluations are prepared for identified through wall flaws in ferritic piping.
Code Case N-513-3 provides criteria for the evaluation of nonplanar flaws (Section 3.2) and planar flaws in austenitic piping (Section 3.1(b)).

What follows is a review of the Code Case N-513-3 sections.

3.1(a) For planar flaws, the flaw shall be bounded by a rectangular or circumferential planar area in accordance with the methods described in ASME Section XI, Appendix C. Note that the flaw to be addressed should in most cases be a surface flaw on the interior diameter of the piping. Based upon Article C-2400 the flaw has to be characterized as axial, circumferential or a combination of both. The minimum wall thickness should first be determined as follows: (CC N-513-3 Eq. 4)

$$t_{min} = \frac{p D_o}{2(S + 0.4p)}$$

$P$ = maximum operating pressure at flaw location = 171 psi Ref. Source = 4.4.17.04F-CALC Rev. 6 U-3
$D_o$ = Piping outside diameter = 24 inches
$S$ = pipe material allowable stress at operating temperature = 17100 psi

$$t_{min} = \frac{(171)(24)}{2(17100 + 0.4(171))} = 0.120 \text{ inch}$$

Utilizing the derived value of $t_m$ envelope those area(s) mapped on the ES1807.012 Form A: Ultrasonic Thickness Examination Report. Based upon the Best Effort UT exam (See Email located in Attachment A) the surrounding areas are bounded by 0.375 inch wall; for calculation purposes a value of 0.875(0.375) = 0.328 inch (manufacturer's tolerance conservatively applied) is used.

Determine the applicable general flaw length dimension, L, in both the axial and circumferential directions.
Based upon the Best Effort UT exam (See Email located in Attachment A) a bounded area at the leak location is identified as 1.75 x 2.50 inches.

NOTE: It is very rare that identified flaws in SW system piping are purely axial or circumferential in nature.

The identified flaw is characterized as:
☒ AXIAL $L_{axial}$ = 1.75 inches
☒ CIRCUMFERENTIAL $L_{circ}$ = 2.50 inches

**2.0 Scope - Procedure:**

(a) The flaw geometry shall be characterized by volumetric inspection methods or by physical measurement. The full pipe circumference at the flaw location shall be inspected to characterize the length and depth of all flaws in the pipe section.

The subject flaw has been characterized by: Best Effort UT exam; See Email located in Attachment A

ES1807.012 Form A: Ultrasonic Thickness Examination Report not available; see photographs of area UT examined in the EDMS folder for AR 02182856

(b) Flaw Classification: Planar or Nonplanar
Ref: a) See N-513-3 Fig. 1 Through-wall flaw geometry - Planar
b)See N-513-3 Fig. 3 – Illustration of Non-planar flaw due to wall thinning
c) See N-513-3 Fig. 5–Illustration of through-wall Nonplanar flaw due to wall thinning
Based upon the AR# 02182856 photographs and the Best Effort UT exam (See Email located in Attachment A) the flaw is classified as being non-planar.

(c) Are multiple flaws present? **YES**
If the answer is yes, the interaction and combined area of loss of flaws in a given pipe section shall be accounted for in the flaw evaluation.
**The areas of wall loss are identified in the email in Attachment A. Visually the Azimuth locations are plotted on the diagram in Attachment A. The ASME Code required minimum pipe wall has been independently calculated to be 0.105 inch (See Attachment B). For N-513-3 a value of 0.120 inch is calculated on Sht. 9. The only locations below Code minimum wall are 45°, 160° (the through wall location) and 275°. Per N-513-3 Section 3.2(a)** ***"The evaluation shall consider the depth and extent of the affected area and require that the wall thickness exceed $t_{min}$ for a distance that is the greater of***

$$2.5\sqrt{Rt_{nom}} \quad or \quad 2L_{m,avg} \quad where \quad L_{m,avg} = 0.5(L_{m,i} + L_{m,j})$$

***between adjacent thinned regions,..."***

$$2.5\sqrt{11.8125 \; x \; 0.375} = 5.262 \; inches \qquad 2L_{m,avg} = 1.0\,(2.5 + 1.0) = 3.5 \; inches$$

**From the spatial diagram in Attachment A, the smaller arc distance is from 45° to 160° which has an arc length =** $R\theta = 24.086 \; inches$ **> 5.262 inches.** (Note that θ is 115° converted to radians.). **Based upon this the identified areas can be treated as single thinned regions.**

(d) A flaw evaluation shall be performed to determine the conditions for flaw acceptance.
Section 3.0 provides the accepted methods for conducting the required analysis.

If multiple planar flaws have been identified, discontinuous indications shall be considered as singular flaws if the distance between adjacent flaws is equal to or less than the dimension *S*, where *S* is determined in accordance with Section XI Fig. IWA-3330-1.

3.1(b) For planar flaws in austenitic piping. . . . . . . . . Not applicable to this evaluation.

3.1(c) For planar flaws in ferritic piping . . . . . .this section is addressed below.

3.2 For nonplanar flaws. . . . . . . .Not applicable to this evaluation, except as may be noted above.

3.2(c) When there is through-wall penetration along a portion of the thinned wall, as illustrated in N-513-3 Fig. 5, the flaw may be evaluated by the branch reinforcement method. This approach is practical when highly localized pinhole leaks are identified, but not utilized here.

3.2(d) The identified flaw may be evaluated as two independent planar through –wall flaws – one oriented in the axial direction and the other oriented in the circumferential direction. The through-wall lengths for each flaw are the lengths $L_{axial}$ and $L_{circ}$ where the local wall thickness is equal to $t_m$ as projected along the axial and circumferential planes. Conservatively in considering a flaw as both axial and circumferential, the larger determined length can be utilized. Hence the flaw is considered as circular with a diameter equal to *L*. Note that the flow area of the flaw, or the total of the flow areas of multiple flaws that are combined into a single flaw for the purpose of evaluation, shall not exceed the lesser of the flow area of the pipe or 20 in.$^2$.

$L_{circ}$ = 2.5 inches will be used for the circumferential direction
$L_{axial}$ = 1.75 inches will be used for the axial direction

Check the flow area of the mathematical representation of the flaw (circle, rectangle, or square):

$$Area = L_{\text{axial}}\, L_{\text{circ}} = (1.75)(2.5) = 4.375 \leq \textit{lesser of } 20\, in^2 \quad or \quad \textit{Pipe flow area}$$

3.3 In performing a flaw growth analysis, the procedures in C-3000 may be used as guidance. Relevant growth rate mechanisms shall be considered. Article C-3000 addresses flaw growth attributed to fatigue due to cyclic loading and SCC growth. For the SW system piping, the primary growth mechanism is the rate of wall loss due to exposure to seawater. Per Reference 8, the typical corrosion rate of carbon steel immersed in quiet seawater is 15 mils per year.

3.4 For non-ferrous materials, flaws may be evaluated. . . . . . . . . . . Not applicable to this evaluation.

3.1(c) For planar flaws in ferritic piping, the evaluation procedure of Appendix C shall be used. Per Article C-1000, Section C-1200(f) the screening procedure described in C-4000 should be used to determine the failure mechanism for the material and temperature for the identified flaw. However per Article C-4000, Section C-4222 the criteria for Classes 2 and 3 ferritic piping are in the course of preparation. The analyst shall establish the failure mode relevant for the flawed pipe under evaluation.

Considering the larger SC ($\geq$ 1.8) criteria (see Fig. C-4220-1) and the fact that NRC Generic Letter 90-05 recommended a LEFM approach for evaluating through-wall flaws in Class 3 piping, the Article C-7000 LEFM criteria is used. When through-wall flaws are evaluated in accordance with C-7300 or C-7400, the formulas for evaluation given in C-4300 may be used, but with values for $F_m$ , $F_b$ , and $F$ applicable to through-wall flaws. Relations for $F_m$ , $F_b$ , and $F$ that take into account flaw shape and pipe geometry (*R/t* ratio) shall be used. Appendix I to CC N-513-3 provides equations for $F_m$ , $F_b$ , and $F$ for a selected range of *R/t*. The $F_m$ and $F_b$ equations provided in CC N-513-3 are accurate in the range of R/t of 5 to 20. It is noted that alternative solutions for $F_m$ and $F_b$ may be used when the R/t ratio is greater than 20. The Takahashi relations presented in Reference 6 are applicable in the R/t range of 1.5 to 80.5 and will be used in this calculation.

## Evaluation

1) Determination of Flaw acceptance criteria. The stability of an identified through-wall flaw is considered acceptable provided the derived stress intensity factor, $K_I$ , is less than the critical fracture toughness for the material, which is based upon the measure of toughness of the material.

$$K_I \leq \left(J_{Ic}\, E'/1000\right)^{0.5}$$

For through-wall flaws, meeting the above criteria ensures the acceptability of the pipe for temporary service. Margin is provided by the use of the structural factors dictated by CC N-513-3.

Article C-8000, Section C-8321 addresses toughness properties for ferritic steel base metals subject to circumferentially and axial oriented flaws, with a minimum upper shelf temperature value given in the absence of specific data.
For this calculation a minimum $J_{Ic}$ value for SA-106 Grade B carbon steel base metal is obtained from Reference 7. Table B1 in Reference 7 provides a summary of all low temperature fracture testing conducted with SA-106 Grade B material in the database. The lowest value $J_{Ic}$ = 293 lbs. / in. has been conservatively selected for use in this CC N-513-3 evaluation.

Per C-1300, $E' = E/\left(1-\nu^2\right)$

$E$ = Young's Modulus at maximum operating temperature = 29,308 ksi @ 90°F

v = Poisson's ratio = 0.3

$$\therefore\ E' = 29308/\left(1-0.3^2\right) = 32207\ ksi$$

$$\therefore\ K_I = \left((293)\ 32207/1000\right)^{0.5} = 97.142\ \ ksi\sqrt{in.}$$

2) Determination of Load Relations $F_m$, $F_b$, and $F$ for through-wall flaws. For through-wall flaws, the crack depth ($a$) will be replaced with the half crack length ($c$) in the stress intensity factor equations used (per CC N-513-3 Appendix I, section I-1).

<u>Circumferential Flaw Load Relations</u> – From Reference 6 (NOTE: $F_t = F_m$ )

Geometrical factor for axial load:

$$F_t = \left[ A_t + B_t\left(\frac{\theta}{\pi}\right) + C_t\left(\frac{\theta}{\pi}\right)^2 + D_t\left(\frac{\theta}{\pi}\right)^3 + E_t\left(\frac{\theta}{\pi}\right)^4 \right]$$

$$A_t = 1$$
$$B_t = -1.040 - 3.1831(\xi) - 4.83(\xi)^2 - 2.369(\xi)^3$$
$$C_t = 16.71 + 23.10(\xi) + 50.82(\xi)^2 + 18.02(\xi)^3$$
$$D_t = -25.85 - 12.05(\xi) - 87.24(\xi)^2 - 30.39(\xi)^3$$
$$E_t = 24.70 - 54.18(\xi) + 18.09(\xi)^2 + 6.745(\xi)^3$$
$$\xi = \log\left(\frac{t}{R}\right)$$

Geometrical factor for bending moment:

$$F_b = \left(1 + \frac{t}{2R}\right) \left[ A_b + B_b\left(\frac{\theta}{\pi}\right) + C_b\left(\frac{\theta}{\pi}\right)^2 + D_b\left(\frac{\theta}{\pi}\right)^3 + E_b\left(\frac{\theta}{\pi}\right)^4 \right]$$

$$A_b = 0.65133 - 0.5774(\xi) - 0.3427(\xi)^2 - 0.0681(\xi)^3$$
$$B_b = 1.879 + 4.795(\xi) + 2.343(\xi)^2 - 0.6197(\xi)^3$$
$$C_b = -9.779 - 38.14(\xi) - 6.611(\xi)^2 + 3.972(\xi)^3$$
$$D_b = 34.56 + 129.9(\xi) + 50.55(\xi)^2 + 3.374(\xi)^3$$
$$E_b = -30.82 - 147.6(\xi) - 78.38(\xi)^2 - 15.54(\xi)^3$$
$$\xi = \log\left(\frac{t}{R}\right)$$

$L_{circ}$ = 2.50 inches
$c = L_{circ}/2$ = 1.25 inches
OD = 24 inches
$t$ = 0.328 inches (Note: surrounding "good" wall – not nominal)
$R$ = (OD – $t$) / 2 = 11.836 inches
$R/t$ = 36.085 NOTE: for R/t ratio > 20, the Equations for $F_t$ and $F_b$ become increasing conservative.
Θ = $c/R$ = 1.25/11.836 = 0.1056
Θ / π = 0.0336

$$\xi = \log\left(\frac{t}{R}\right) = \log\left(\frac{0.328}{11.836}\right) = -1.557$$

$$A_t = 1$$
$$B_t = -1.040 - 3.1831(-1.557) - 4.83(-1.557)^2 - 2.369(-1.557)^3 = 1.149$$
$$C_t = 16.71 + 23.10(-1.557) + 50.82(-1.557)^2 + 18.02(-1.557)^3 = 35.926$$
$$D_t = -25.85 - 12.05(-1.557) - 87.24(-1.557)^2 - 30.39(-1.557)^3 = -103.871$$
$$E_t = 24.70 - 54.18(-1.557) + 18.09(-1.557)^2 + 6.745(-1.557)^3 = 127.454$$

$$F_t = \left[1 + 1.149(0.0336) + 35.926(0.0336)^2 - 103.871(0.0336)^3 + 127.454(0.0336)^4\right] = 1.075$$

*Remember $F_t = F_m$*

$$A_b = 0.65133 - 0.5774(-1.557) - 0.3427(-1.557)^2 - 0.0681(-1.557)^3 = 0.977$$
$$B_b = 1.879 + 4.795(-1.557) + 2.343(-1.557)^2 - 0.6197(-1.557)^3 = 2.432$$
$$C_b = -9.779 - 38.14(-1.557) - 6.611(-1.557)^2 + 3.972(-1.557)^3 = 18.586$$
$$D_b = 34.56 + 129.9(-1.557) + 50.55(-1.557)^2 + 3.374(-1.557)^3 = -57.884$$
$$E_b = -30.82 - 147.6(-1.557) - 78.38(-1.557)^2 - 15.54(-1.557)^3 = 67.637$$

$$F_b = \left(1 + \frac{0.328}{2(11.836)}\right)\left[0.977 + 2.432(0.0336) + 18.586(0.0336)^2 - 57.884(0.0336)^3 + 67.637(0.0336)^4\right] =$$
$$F_b = 1.093$$

Axial Flaw Load Relation

$$F = 1 + 0.072449\lambda + 0.64856\lambda^2 - 0.2327\lambda^3 + 0.038154\lambda^4 - 0.0023487\lambda^5$$

*where*

$c$ = half crack length

$\lambda = c/(R\,t)^{1/2}$

---

$L_{axial}$ = 1.75 inches
$c = L_{axial}/2$ = 0.875 inches
OD = 24 inches
$t$ = 0.328 inches (Note: surrounding "good" wall – not nominal)
$R = (OD - t)/2$ = 11.836 inches
$\lambda = c/(Rt)^{1/2} = 0.875/(11.836 \times 0.328)^{1/2} = 0.444$

$$F = 1 + 0.072449(0.444) + 0.64856(0.444)^2 - 0.2327(0.444)^3 + 0.038154(0.444)^4 - 0.0023487(0.444)^5$$
$$= 1.141$$

3) Determination of actual flaw stress intensity factor $K_I$ for Circumferential Flaws (Ref. C-7300 / C-4311)

$$K_I = K_{Im} + K_{Ib} + K_{Ir}$$

*where*

$$K_{Im} = (SF_m)\left(P/(2\pi R_m t)\right)(\pi a)^{0.5}(F_m)$$

$$K_{Ib} = \left[(SF_b)\left(M/\pi R_m^2 t\right) + \sigma_e\right](\pi a)^{0.5}(F_b)$$

$$K_{Ir} = K_I \text{ from residual stresses at the flaw location}$$

*where*

$SF_m$ and $SF_b$ are structural factors from C - 2621 - see below

$a$ is flaw depth which for through - wall flaws is equal to $c$ the half crack length

$P$ is the total axial load on pipe including pressure, kips

$R_m, t, F_m, F_b$ previously defined/derived

$M$ is applied moment on the pipe, in - kips

$\sigma_e$ secondary bending stress (unintensified), thermal expansion

The Structural Factors for Circumferential Flaws per C-2621 are as follows:

| Service Level | Membrane Stress, $SF_m$ | Bending Stress, $SF_b$ |
|---|---|---|
| A | 2.7 | 2.3 |
| B | 2.4 | 2.0 |
| C | 1.8 | 1.6 |
| D | 1.3 | 1.4 |

General Notes:

1) Unless there is evidence of a base metal repair or other wall repair history and in consideration of low operating temperature, $K_{Ir}$ is assumed to be 0.00.
2) $K_{Im}$ and $K_{Ib}$ will be calculated for Service Levels A (Normal), B (Upset), C (Emergency) and D (Faulted).

*P* and *M* determination for Service Levels A, B, C & D

NOTE: OBESAD and SSESAD loads are not applicable; TR loads not used as they are enveloped by seismic loading and not considered concurrently.

$$P_{pressure} = \left(p_{\max .operating\ pressure}\right) A_{FLOW} / 1000 \quad where \quad A_{FLOW} = \pi\left(\frac{OD-2(t)}{2}\right)^2 = \pi\left(\frac{24-2(0.375)}{2}\right)^2 = 424.6$$

$$P_{normal} = P_{DW} + P_{pressure}$$

$$P_{upset} = P_{DW} + P_{pressure} + \sqrt{P_{OBEI}^2 + P_{OBESAD}^2} + P_{TR}$$

$$P_{emergency} = P_{DW} + P_{pressure} + P_{TR}$$

$$P_{faulted} = P_{DW} + P_{pressure} + \sqrt{P_{SSEI}^2 + P_{SSESAD}^2} + P_{TR}$$

$$M_{normal} = M_{DW}$$

$$M_{upset} = M_{DW} + \sqrt{M_{OBEI}^2 + M_{OBESAD}^2} + M_{TR}$$

$$M_{emergency} = M_{DW} + M_{TR}$$

$$M_{faulted} = M_{DW} + \sqrt{M_{SSEI}^2 + M_{SSESAD}^2} + M_{TR}$$

Normal Loads:

$$P_{pressure} = \left(p_{\max .operating\ pressure}\right) A_{FLOW} / 1000 = (171)(424.6) / 1000 = 72.61\ kips$$

$$P_{normal} = P_{DW} + P_{pressure} = (0.013) + (72.61) = 72.623 \quad kips$$

$$M_{normal} = M_{DW} = 85.96 \quad in-kips$$

Upset Loads:

$$P_{upset} = P_{DW} + P_{pressure} + \sqrt{P_{OBEI}^2 + P_{OBESAD}^2} + P_{TR}$$

$$= (0.013) + (72.61) + \sqrt{(4.512)^2 + (0.0)^2} + (0.0) = \quad 77.135 kips$$

$$M_{upset} = M_{DW} + \sqrt{M_{OBEI}^2 + M_{OBESAD}^2} + M_{TR}$$

$$= (85.96) + \sqrt{(370.92)^2 + (0.0)^2} + (0.0) = \quad 456.88 in-kips$$

Emergency Loads:

$$P_{emergency} = P_{DW} + P_{pressure} + P_{TR}$$
$$= (0.013) + (72.61) + (0.312) = 72.935 \quad kips$$
$$M_{emergency} = M_{DW} + M_{TR}$$
$$= (85.96) + (14.60) = 100.56 \; in-kips$$

Faulted Loads:

$$P_{faulted} = P_{DW} + P_{pressure} + \sqrt{P_{SSEI}^2 + P_{SSESAD}^2} + P_{TR}$$
$$= (0.013) + (72.61) + \sqrt{(6.241)^2 + (0.0)^2} + (0.0) = 78.864 \; kips$$
$$M_{faulted} = M_{DW} + \sqrt{M_{SSEI}^2 + M_{SSESAD}^2} + M_{TR}$$
$$= (85.96) + \sqrt{(490.32)^2 + (0.0)^2} + (0.0) = 576.28 \; in-kips$$

Determination of actual flaw stress intensity factor $K_I$ for Circumferential Flaws

$$K_I = K_{Im} + K_{Ib} + K_{Ir}$$

***where***

$$K_{Im} = (S\,F_m)\left(P/(2\,\pi\,R_m\,t)\right)(\pi\,a)^{0.5}\,(F_m)$$
$$K_{Ib} = \left[(S\,F_b)\left(M/\pi\,R_m^2\,t\right) + \sigma_e\right](\pi\,a)^{0.5}\,(F_b)$$
$$K_{Ir} = 0.0$$

Normal $K_I$ Determination (All equation terms previously derived)

$$K_I = K_{Im} + K_{Ib}$$

$$K_I = (S\,F_m)\left(P_{normal} / (2\pi\,R_m\,t)\right)(\pi\,a)^{0.5}\,(F_m) \quad + \quad \left[(S\,F_b)\left(M_{normal} / \pi\,R_m^2\,t\right) + \sigma_e\right](\pi\,a)^{0.5}\,(F_b)$$

$$K_I = (2.7)\left((72.623) / (2\pi(11.836)(0.328))\right)(\pi(1.25))^{0.5}\,(1.075) \quad + \left[(2.3)\left((85.96) / \pi(11.836)^2\,(0.328)\right) + (0.00)\right](\pi(1.25))^{0.5}\,(1.093) =$$

$$K_I = 17.124 + 2.966 = 20.090 ksi\sqrt{in.}$$

Upset $K_I$ Determination (All equation terms previously derived)

$$K_I = K_{Im} + K_{Ib}$$

$$K_I = (S\,F_m)\left(P_{upset} / (2\pi\,R_m\,t)\right)(\pi\,a)^{0.5}\,(F_m) \quad + \quad \left[(S\,F_b)\left(M_{upset} / \pi\,R_m^2\,t\right) + \sigma_e\right](\pi\,a)^{0.5}\,(F_b)$$

$$K_I = (2.4)\left(77.135 / (2\pi(11.836)(0.328))\right)(\pi(1.25))^{0.5}\,(1.075) \quad + \left[(2.0)\left((456.88) / \pi(11.836)^2\,(0.328)\right) + (0.0)\right](\pi(1.25))^{0.5}\,(1.093) =$$

$$K_I = 16.167 + 13.710 = 28.877\,ksi\sqrt{in.}$$

Emergency $K_I$ Determination (All equation terms previously derived)

$$K_I = K_{Im} + K_{Ib}$$

$$K_I = (S\,F_m)\left(\frac{P_{emergency}}{2\pi R_m t}\right)(\pi a)^{0.5}(F_m) + \left[(S\,F_b)\left(\frac{M_{emergency}}{\pi R_m^2 t}\right) + \sigma_e\right](\pi a)^{0.5}(F_b)$$

$$K_I = (1.8)\left(\frac{(72.935)}{(2\pi(11.836)(0.328))}\right)(\pi(1.25))^{0.5}(1.075) + \left[(1.6)\left(\frac{(100.56)}{\pi(11.836)^2(0.328)}\right) + (0.0)\right](\pi(1.25))^{0.5}(1.093) =$$

$$K_I = 11.465 + 2.414 = 13.879\, ksi\sqrt{in.}$$

Faulted $K_I$ Determination (All equation terms previously derived)

$$K_I = K_{Im} + K_{Ib}$$

$$K_I = (S\,F_m)\left(\frac{P_{faulted}}{2\pi R_m t}\right)(\pi a)^{0.5}(F_m) + \left[(S\,F_b)\left(\frac{M_{faulted}}{\pi R_m^2 t}\right) + \sigma_e\right](\pi a)^{0.5}(F_b)$$

$$K_I = (1.3)\left(\frac{(78.864)}{(2\pi(11.836)(0.328))}\right)(\pi(1.25))^{0.5}(1.075) + \left[(1.4)\left(\frac{(576.28)}{\pi(11.836)^2(0.328)}\right) + (0.0)\right](\pi(1.25))^{0.5}(1.093) =$$

$$K_I = 8.954 + 12.105 = 21.059\, ksi\sqrt{in.}$$

Summary of calculated $K_I$ values for the identified Circumferential through-wall flaw

| | Normal | Upset | Emergency | Faulted |
|---|---|---|---|---|
| $K_I$ $ksi\sqrt{in.}$ | 20.090 | 28.877 | 13.879 | 21.059 |

4) Determination of actual flaw stress intensity factor $K_I$ for Axial Flaws (Ref. C-7400 / C-4312)

$$K_I = K_{Im} + K_{Ir}$$

*where*

$$K_{Im} = (SF_m)(pR_m/t)(\pi a/Q)^{0.5}(F)$$

$K_{Ir}$ = $K_I$ from residual stresses at the flaw location

*where*

$F$ is the structural factor from C - 2622 - see below

$a$ is flaw depth which for through - wall flaws is equal to $c$ the half crack length

$p$ is the maximum operating pressure, kips

$SF_m, R_m, t$ previously defined/derived

$Q = 1 + 4.593(a/l)^{1.65}$ = 1.0 (set to unity per CC N - 513 - 3 Appendix I for through - wall flaws)

The Structural Factor for Axial Flaws per C-2622 are as follows:

| Service Level | Membrane Stress, $SF_m$ |
|---|---|
| A | 2.7 |
| B | 2.4 |
| C | 1.8 |
| D | 1.3 |

General Notes:

3) Unless there is evidence of a base metal repair or other wall repair history and in consideration of low operating temperature, $K_{Ir}$ is assumed to be 0.00.
4) $K_{Im}$ will be calculated for Service Levels A (Normal), B (Upset), C (Emergency) and D (Faulted).

Determination of actual flaw stress intensity factor $K_I$ for Axial Flaws

$$K_I = K_{Im} + K_{Ir}$$

*where*

$$K_{Im} = (S\,F_m)(p\,R_m/t)(\pi\,a/1.0)^{0.5}(F)$$

$$K_{Ir} = 0.0$$

Normal $K_I$ Determination (All equation terms previously derived)

$$K_I = K_{Im} = (S\,F_m)(p\,R_m/t)(\pi\,a/1.0)^{0.5}(F)$$

$$= (2.7)((0.171)(11.836)/(0.328))(\pi\,(0.875))^{0.5}\,(1.141)$$

$$K_I = 31.518\ ksi\sqrt{in.}$$

Upset $K_I$ Determination (All equation terms previously derived)

$$K_I = K_{Im} = (S\,F_m)(p\,R_m/t)(\pi\,a/1.0)^{0.5}(F)$$

$$= (2.4)((0.171)(11.836)/(0.328))(\pi\,(0.875))^{0.5}\,(1.141)$$

$$K_I = 28.016\ ksi\sqrt{in.}$$

Emergency $K_I$ Determination (All equation terms previously derived)

$$K_I = K_{Im} = (S\,F_m)(p\,R_m/t)(\pi\,a/1.0)^{0.5}(F)$$

$$= (1.8)((0.171)(11.836)/(0.328))(\pi\,(0.875))^{0.5}\,(1.141)$$

$$K_I = 21.012\ ksi\sqrt{in.}$$

Faulted $K_I$ Determination (All equation terms previously derived)

$$K_I = K_{Im} = (S\,F_m)(p\,R_m/t)(\pi\,a/1.0)^{0.5}(F)$$

$$= (1.3)((0.171)(11.836)/(0.328))(\pi\,(0.875))^{0.5}(1.141)$$

$$K_I = 15.175\ ksi\sqrt{in.}$$

Summary of calculated $K_I$ values for the identified Axial through-wall flaw

| | Normal | Upset | Emergency | Faulted |
|---|---|---|---|---|
| $K_I$ $ksi\sqrt{in.}$ | 31.518 | 28.016 | 21.012 | 15.175 |

5) CONCLUSION - Prepared input for use in the Operability Determination

| FLAW STABILITY CHECK | | | | |
|---|---|---|---|---|
| Flaw Type | Service Load | Stress Intensity Factor $K_I\left(ksi\sqrt{in}\right)$ | | Allowable / Calculated |
| | | Calculated | Allowable | |
| Circumferential | Normal | 20.090 | 97.142 | 4.84 |
| | Upset | 28.877 | 97.142 | 3.36 |
| | Emergency | 13.879 | 97.142 | 7.00 |
| | Faulted | 21.059 | 97.142 | 4.61 |
| Axial | Normal | 31.518 | 97.142 | 3.08 |
| | Upset | 28.016 | 97.142 | 3.47 |
| | Emergency | 21.012 | 97.142 | 4.62 |
| | Faulted | 15.175 | 97.142 | 6.40 |

The calculated Stress Intensity Factors include the required structural factors prescribed by Code Case N-513-3 and ASME Section XI, Division 1 Article C-2620. The acceptable calculated stress intensity factors ensures the acceptability of the pipe for temporary service.

The Structural Factors for Circumferential Flaws per C-2621 are as follows:

| Service Level | Membrane Stress, $SF_m$ | Bending Stress, $SF_b$ |
|---|---|---|
| A | 2.7 | 2.3 |
| B | 2.4 | 2.0 |
| C | 1.8 | 1.6 |
| D | 1.3 | 1.4 |

The Structural Factor for Axial Flaws per C-2622 are as follows:

| Service Level | Membrane Stress, $SF_m$ |
|---|---|
| A | 2.7 |
| B | 2.4 |
| C | 1.8 |
| D | 1.3 |

The Best Estimate UT email identified a boundary pipe wall thickness on 0.375 inch (nominal wall). For this evaluation a remaining pipe wall ($t_p$) of 0.328 inch was used. This is a non-planar flaw and per CC N-513-3 must be greater than the N-513-3 derived minimum wall.

$$t_p = (0.328) \geq t_{\min} = (0.120)(\text{calculated on sht. } 9)$$

## 7.0 REVIEWERS COMMENTS AND RESOLUTIONS

Line by line check performed.

Any and all reviewer comments, corrections, and changes have been reviewed by the Cognizant Design Engineer and have, with the mutual consent of the reviewer, been incorporated.

## 8.0 ATTACHMENTS

**Attachment A – Best Estimate UT email/Spatial projection of area locations – 2 Sheets**

**Attachment B – ASME Code Minimum Wall Thickness Determination – 2 Sheets**

**Mentel, Henry**

**Subject:** FW: Best Effort UT Numbers from SW-V-14

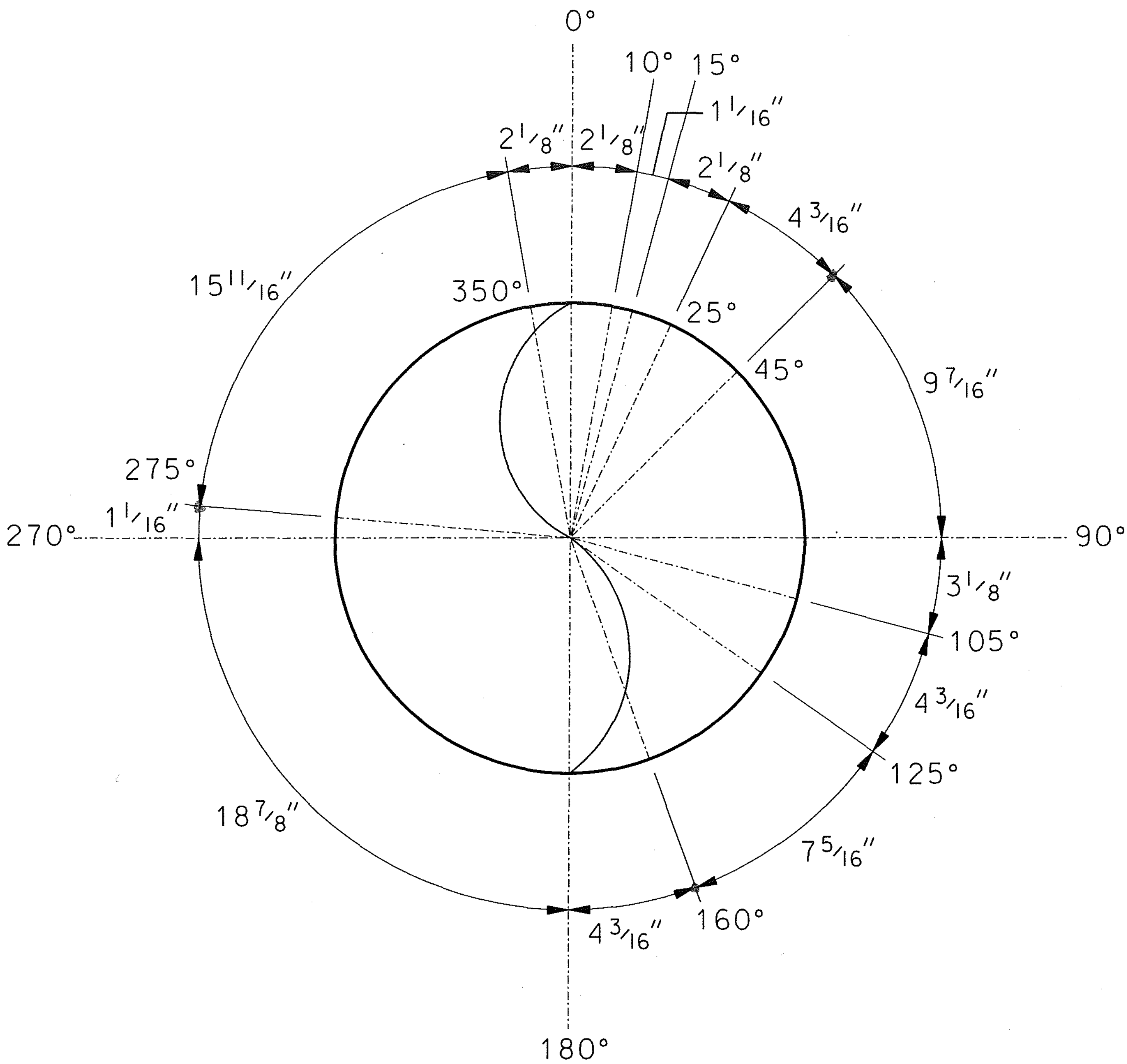
**From:** Hamel, Scott
**Sent:** Wednesday, February 01, 2017 2:05 PM
**To:** Mentel, Henry
**Cc:** Belanger, Richard; Alexander, Donald; Parry, Robert; Collins, Michael; Tremblay, Leonard; Sobotka, Jeffrey; McGonigle, David
**Subject:** Best Effort UT Numbers from SW-V-14

The below values represent the ***best effort attempt*** to characterize the flaw at the leak location and the 360° circumferential band, 3" up and down stream of the leak.

All indications are essentially at the same axial distance from the weld centerline, 4.0" downstream.

The coating will need to be removed in order to obtain official UT results.

| UT Values, Leak UPST of SW-V-14 | | | |
|---|---|---|---|
| Az in Degrees | Thickness | Size | Comments |
| 10 | 0.19 | 1" x 1" | At the boundary of the size listed the thickness is ~ Tnom or 0.375". The flawed area is assumed to be no larger than size listed. However the marginal surface condition is inhibiting reliable wall measurements. |
| 15 | 0.18 | 1" x 1" | |
| 25 | 0.2 | 1" x 1" | |
| 45 | 0.08 | 1" x 1" | |
| 90 | 0.2 | 1" x 1" | |
| 105 | 0.19 | 1" x 1" | |
| 125 | 0.19 | 1" x 1" | |
| 160 | Leak | 1.75" x 2.5" | Assumed to be no larger than size listed. However the marginal surface condition is inhibiting reliable wall measurements |
| 275 | 0.09 | 1" x 1" | At the boundary of the size listed the thickness is ~ Tnom or 0.375". The flawed area is assumed to be no larger than size listed. However the marginal surface condition is inhibiting reliable wall measurements. |
| 350 | 0.2 | 1" x 1" | |



0°
10°
15°
1 1/16"
2 1/8"
2 1/8"
2 1/8"
4 3/16"
15 11/16"
350°
25°
45°
9 7/16"
275°
1 1/16"
270°
90°
3 1/8"
105°
4 3/16"
125°
18 7/8"
7 5/16"
160°
4 3/16"
180°


24" DIA. PIPE

| REV | PREPARER / DATE | CHECKER / DATE |
|---|---|---|
| 0 | [signature] 2/1/17 | JMH 2-1-2017 |
| | | |

CALC SET NO: C-S-1-45928-CALC REFERENCE AR 02182856

ATTACHMENT B PAGE 1 OF 2

**CODE MINIMUM WALL THICKNESS DETERMINATION – Safety Class 2 or 3 Component**

Inspection Location: 1827-FW-F0905 Line Number: SW-1827-001-153-24" Isometric: SKM-020539-2001 DCN-2
Leak location is just north of the field weld; SW-1827-09 Rev. 7
SKM-020539-2001 DCN-2 is Sheet 13 in calculation C-S-1-45718-CALC Rev. 9

Component Type: ☒ Straight Pipe ☐ Elbow ☐ Bend ☐ Reducer ☐ large end ☐ small end ☐ Tee ☐ run end ☐ branch end ☐ Other ________

Component Material: SA-106 Grade B Design Pressure(P): 150 psi Design Temperature($T_D$): 200 °F
Temperature/Pressure Reference: 4.4.17.04F-CALC Rev. 6 Sheet U-3

Allowable Stress (S) @ $T_D$ = 17100 psi Component Outside Diameter ($D_o$): 24.0 in.

Component Nominal Wall Thickness ($t_{nom}$): 0.375 in.

Construction Code factor (y) = 0.4 except where $D_o < 6\ (t_{min})$ [Note: use 0.4 then verify that this value is acceptable]

Design Pressure Minimum Wall Thickness Determination

$D_o < 6\ (t_{min})$
24.0 < 0.630

$$t_{min} = \frac{P D_o}{2(S + yP)} = 0.105 \text{ in.} \qquad y = 0.4 \text{ used.}$$

Piping Stress Evaluation: (Simplified Analysis Approach)

The effect on piping stresses at the reduced wall location must be evaluated with consideration given to changes in the pipe metal area, pipe inside area, section modulus and stress intensification factor.

$EQ.\ 8 = P D_o / 4 t_{pred} + 0.75 i [ ( M_b + P A_o \delta ) / Z_{min} ] \leq 1.143 S$

with $M_b$ based upon deadweight loads only.

$EQ.\ 9 = P D_o / 4 t_{pred} + 0.75 i [ ( M_b + P A_o \delta ) / Z_{min} ] \leq 1.143 \times 1.2 S = 1.372 S$

with $M_b$ based upon deadweight, OBE seismic and transient loads, as applicable.

Terms P, $D_o$, defined above. (Note: use Design Pressure $t_{min} = t_{PRED}$)

| REV | PREPARER / DATE | CHECKER / DATE |
|---|---|---|
| 0 | [illegible] 2/1/17 | JMH 2-1-2017 |
| | | |

CALC SET NO: C-S-1-45928-CALC REFERENCE AR 02182856

ATTACHMENT B PAGE 2 OF 2

For the following evaluation t used = 0.105in.

$A_o$ = total cross-sectional area of pipe based on nominal outside diameter, $\pi D_o^2 / 4 = 452.389$ in.$^2$

$\delta$ = nominal distance between the center of the pipe and the neutral axis of the thinned piping section $= t_{nom} - t_{pred} = 0.375 - 0.105 = 0.270$ in.

$Z_{min} = I_{min} / R_{max}$ where $R_{max} = (D_o / 2) + \delta = 12.270$ in.
where $I_{min} = 0.0491 [ D_o^4 - (D_o - 2 t_{pred})^4 ] = 562.717$ in.$^4$

$Z_{min} = 45.861$ in.$^3$

Pipe Stress analysis of record: C-S-1-45718-CALC Rev. 9 ADLPIPE Output SWONER5.000 dated: 5/14/2015
Applicable Nodes: Node 27 is applicable to 1827-FW-F0905; Use 27, 27End (north side)

| Node | Load | Moments (ft.-lbs.) **T**orsional or **B**ending | | | $M_b$ (Resultant) |
|---|---|---|---|---|---|
| | | $M_x$ ( T ) | $M_y$ (B ) | $M_z$ ( B ) | |
| 27 | Deadweight File 11 | 4520 | 70 | 5557 | 5557 |
| 27E | OBEI File 31 | 7159 | 28189 | 10467 | 30070 |
| | OBEA(NA) | | | | |
| 27 | TR File 100 | 284 | 1173 | 156 | Not Used (see note) |

**Note:** For Service Water, TR loads need not be combined with OBEI loads – Use Maximum Value of TR or OBEI.

For Deadweight $M_b$ = (12) 5557 = 66684 in-lbs.
For Total $M_b$ = Deadweight + SRSS (OBEI & OBEA) + TR = (12) (5557 + 30070) = 427,524 in.-lbs.

Intensification factor = 1.0 for straight pipe; not impacted by wall thinning.
NOTE 0.75i = 0.75(1.0) = 1.0 cannot by Code be lower than 1.0.

EQ. 8 = $P D_o / 4 t_{pred} + 0.75 i [ ( M_b + P A_o \delta ) / Z_{min} ) ] \leq 1.143 S$

EQ. 8 = $8571 + 1854 = 10425 \leq 1.143 ( 17100 ) = 19545$ ✓

EQ. 9 = $P D_o / 4 t_{pred} + 0.75 i [ ( M_b + P A_o \delta ) / Z_{min} ) ] \leq 1.143 \times 1.2 S = 1.372 S$

EQ. 9 = $8571 + 9722 = 18293 \leq 1.372 ( 17100 ) = 23461$ ✓

**CONCLUSION: ASME Code required minimum pipe wall thickness = 0.105 inch**