April 15, 2020
L-2020-074
10 CFR 50.55a

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D. C. 20555-0001

Re: Turkey Point Unit 3
Docket Nos. 50-250
Subsequent Renewed License No. DPR-31
Response to Request for Additional Information for Relief Request No. 6

References:

1. Florida Power & Light Company (FPL) letter L-2020-056, Turkey Point Unit 3, Fifth Ten-Year Inservice Inspection Interval Relief Request No. 6, dated March 30, 2020. NRC's document management system (ADAMS) ML accession number: ML20090K520

2. Florida Power & Light Company (FPL) letter L-2020-073, Turkey Point Unit 3, Fifth Ten-Year Inservice Inspection Interval Revised Relief Request and Supplemental Information for Train B CCW Return Piping, dated April 13, 2020. NRC's document management system (ADAMS) ML accession numbers: ML20104B999 for the nonproprietary submission and ML20104C000 for the proprietary submission.

3. Electronic Mail, from NRC’s Senior Project Manager Turkey Point, Ms. Eva Brown to Mr. Robert Hess Licensing Manager Turkey Point, Titled DRAFT: Turkey Point Unit 3 - Relief Request Concerning CCW Header Weld Repairs (EPID L-2020-LLR-0040), dated April 14, 2020

In Reference 1, FPL requested relief from the applicable American Society of Mechanical Engineers Section XI Code (ASME Code) requirements to repair certain sections of the degraded Unit 3 Component Cooling Water (CCW) supply and return piping by installing a welded proprietary repair device, PMCap Restoration Method – US Patent 6,860,297 without removing the sections of degraded piping.

In Reference 2, FPL submitted the revised relief request and provided supplemental information regarding Train B CCW return piping and revised the relief request.

In Reference 3, NRC requested additional information.

FPL’s response to the request for additional information is provided in Attachment 1 herein.

If you have any questions or require additional information, please contact Robert J. Hess, Licensing Manager, at (305) 246-4112.

Sincerely,

Robert J. Hess
Licensing Manager
Turkey Point Nuclear Plant

Enclosure
Attachment

cc: USNRC Regional Administrator, Region II, USNRC
USNRC Senior Resident Inspector, USNRC, Turkey Point Nuclear Plant
USNRC Project Manager, Turkey Point Nuclear Plant

ATTACHMENT 1

L-2020-074

Response to NRC's Request for Additional Information

TURKEY POINT UNIT 3

RELIEF REQUEST No. 6

REQUEST FOR ADDITIONAL INFORMATION
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
FIFTH 10-YEAR INTERVAL RELIEF REQUEST NO. 6
COMPONENT COOLING WATER WELDED REPAIRS FOR EXTERNAL CORROSION
FLORIDA POWER & LIGHT COMPANY
TURKEY POINT, UNIT 3
DOCKET NO. 50-250

By letter dated March 30, 2020 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML20090K520), Florida Power & Light Company (FPL, the licensee), submitted Relief Request (RR) No. 6 which proposes an alternative to the requirements in Subarticle IWA-4421 of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 2007 Edition through 2008 Addenda, regarding removal of defects in accordance with IWA-4411, IWA-4461, or IWA-4462 on the subject piping identified in the request, prior to performing repair/replacement activities at Turkey Point, Unit 3 (TP3). The licensee is proposing to install a modification/repair of a welded proprietary repair device, PMCap Restoration Method – US Patent 6,860,297, hereafter referred to as PMCap, over the defect in the TP3 Component Cooling Water (CCW) system piping.

The licensee requested authorization to use the proposed alternative pursuant to Section 50.55a(z)(2) to Title 10 of the *Code of Federal Regulations* (10 CFR 50) on the basis that complying with the specified requirement would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

To complete its review, the Nuclear Regulatory Commission staff requests the following additional information relating to this relief request.

1. Section 5.0 of the March 30 submittal, in various locations, discusses the installation of the PMCap and that; 1) an ultrasonic testing thickness measurement shall also be performed to confirm that material thickness is adequate for the repair design, 2) locations where the PMCap is to be welded to the system pressure boundary shall be located sufficiently far from locations of identified wall thinning to preclude the growth of identified corrosion from challenging the integrity, and 3) with a full penetration weld at locations previously confirmed to have adequate material thickness.

   Define (i.e. provide a value for) the material thickness adequate for the repair design, the distance required to preclude the corrosion from challenging the integrity and adequate material thickness to allow a full penetration weld.

FPL Response to RAI No. 1:

The adequate material thickness to perform full penetration welds on CCW piping is a wall thickness equal to or greater than 0.25 inches without limitation of welding parameters and pressure. This was based on an evaluation considering potential for weld burn through and hydrogen cracking.
FPL's letter L-2020-073, Attachment 2 contains the ultrasonic thickness readings of the Train B CCW return piping and shows that in the areas of the weld (grid rows L and BB) the minimum measured wall thickness exceeded the minimum required thickness for welding.

The distance required to preclude corrosion from challenging the integrity and material thickness for a full penetration weld is considered to be that which meets the minimum wall thickness for welding, 0.25 inches.

As stated in the attached N-513 evaluation, t_{min} for the Train B CCW return piping is 0.109 inches. As shown in FPL's letter L-2020-073, Attachment 2, the areas where the wall thickness was measured below t_{min} are approximately in the center of the PMCap. Additionally, any effects of future corrosion are considered negligible due to the design which exposes the annulus between the 18'' CCW piping and the 20'' PMCap to CCW water that contains corrosion inhibitors to protect carbon steel (Ref UFSAR Section 9.3). Hence, the PMCap welds are located sufficiently far from the locations of identified wall thinning to preclude the growth of identified corrosion from challenging integrity and the full penetration welds are located in areas confirmed to have adequate material thickness.

2. Provide the Code Case N-513 evaluation performed to determine the structural integrity of the CCW system piping or a detailed discussion of the results of the evaluation.

FPL Response to RAI No. 2

The Code Case N-513 evaluation performed to determine the structural integrity of the Train B CCW return piping is enclosed herein as part of the attached Prompt Operability Determination documented in the Turkey Point Site Corrective Action Program, Condition report AR 2350581.

Turkey Point, Unit 3
Fifth 10-Year Interval Relief Request No. 6
FPL Responses to NRC RAIs
L-2020-074 Attachment 1

Enclosure

Prompt Operability Determination

PROMPT OPERABILITY DETERMINATION (POD) FORM

AR: 2350581 **AR Assignment Number: 01**

POD Title:	**18in Corroded CCW 3B Return Header**
NOTE:	**To ensure a complete POD, each of the following items shall be addressed to a level of detail commensurate with the affected SSC safety significance. Use instructions in EN-AA-203-1001 section 4.4 and Attachment 5 to complete this form.**

1. Describe affected SSC(s) (System #/ Comp #, etc.), considering the extent of the condition.

System: Component Cooling Water (CCW) / System #30

Affected Component(s): Sections of the U3 CCW B-Return Header Piping immediately below the U3 CCW Hx Room Floor penetrations which lead into the Aux Bldg 10' pipeway.

2. Identify Current Licensing Basis function(s) (include all safety and support functions) and performance requirements, including Technical Specifications, FSAR, NRC Commitments, or other appropriate information. (Section 6.1.3, Voluntary Action Item 7)

The CCW system is governed by TS. 3.7.2. CCW pumps and heat exchangers are specifically called out in TS 3.7.2. Individual headers are not called out in TS 3.7.2 and an inoperable CCW header would warrant entry into TS 3.0.3. The U3 B-Return Header Piping are corroded thereby potentially affecting the components to be cooled by the CCW system. The CCW piping and components shall be qualified for all loading conditions associated with a Class I structure. Those loads, per Discipline Standard CN-3.01 and FSAR, Appendix 5A are thermal expansion, deadweight, and pressure as well as seismic inertia. Applicable sections from the current licensing basis documents are as follows:

<u>Applicable Technical Specifications:</u>

3/4.7.2 COMPONENT COOLING WATER SYSTEM

LIMITING CONDITION FOR OPERATION

3.7.2 The Component Cooling Water System (CCW) shall be OPERABLE with:

a. Three CCW pumps, and
b. Two CCW heat exchangers.

APPLICABILITY: MODES 1, 2, 3, and 4.

ACTION:

a. With only two CCW pumps with independent power supplies OPERABLE, restore the inoperable CCW pump to OPERABLE status within 30 days or be in HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

b. With only one CCW pump OPERABLE or with two CCW pumps OPERABLE but not from independent power supplies, restore two pumps from independent power supplies to OPERABLE status within 72 hours or in accordance with the Risk Informed Completion Time Program, or be in HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

c. With less than two CCW heat exchangers OPERABLE, restore two heat exchangers to OPERABLE status within 1 hour or be in HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

3.5.2 The following Emergency Core Cooling System (ECCS) equipment and flow paths shall be OPERABLE:

a. Four Safety Injection (SI) pumps, each capable of being powered from its associated OPERABLE diesel generator#, with discharge flow paths aligned to the RCS cold legs,*
b. Two RHR heat exchangers,
c. Two RHR pumps with discharge flow paths aligned to the RCS cold legs,
d. A flow path capable of taking suction from the refueling water storage tank as defined in Specification 3.5.4, and
e. Two flow paths capable of taking suction from the containment sump.

APPLICABILITY: MODES 1, 2, and 3**

ACTION:

a. With one of the following components inoperable:

1. RHR heat exchanger,
2. RHR suction flow path from the containment sump,
3. RHR parallel injection flow path, or
4. SI parallel injection flow path

Restore the inoperable component to OPERABLE status within 72 hours or in accordance with the Risk Informed Completion Time Program, or be in at least HOT STANDBY within the next 6 hours and in HOT SHUTDOWN within the following 6 hours.

b. Deleted

c. With one of the four required Safety Injection pumps or its associated discharge flow path inoperable and the opposite unit in MODE 1, 2, or 3, restore the pump or flow path to OPERABLE status within 30 days or be in at least HOT STANDBY within the next 12 hours and in HOT SHUTDOWN within the following 6 hours.

---

*Only three Safety Injection (SI) pumps (two associated with the unit and one from the opposite unit), each capable of being powered from its associated OPERABLE diesel generator#, with discharge flow paths aligned to the RCS cold leg are required if the opposite unit is in MODE 4, 5, 6 or defueled.

**The provisions of Specification 4.0.4 are not applicable for entry into MODE 3 for the Safety Injection flow paths isolated pursuant to Specification 3.4.9.3 provided that the Safety Injection flow paths are restored to OPERABLE status prior to Tavg exceeding 380°F. Safety Injection flow paths may be isolated when Tavg is less than 380°F.

#Inoperability of the required diesel generators does not constitute inoperability of the associated Safety Injection pumps.

Applicable UFSAR Considerations:

The following excerpt regarding CCW seismic qualification is taken from Ch. 5, Appendix 5A.

12. Component Cooling System
    - Component cooling heat exchangers
    - Component cooling pumps and motors
    - Component cooling surge tanks
    - Component cooling head tank

This excerpt identifies that the affected portion of the CCW system is required to be seismically qualified.

The following excerpt regarding CCW leakage is taken from Ch. 9.

"Normally cross-connected, redundant component cooling water headers are provided for the unlikely event of a single failure in the component cooling water system following a loss of coolant accident. Header cross-connect valves are provided so that a passive failure (defined as 50 gpm leak) in the system can be isolated and cooling water flow can still be maintained to the necessary engineered safeguards equipment which require cooling water."

The excerpt defines a CCW design basis leak as 50 gpm with respect to header separation (no specific pipe).

Applicable CLB Considerations:

The following excerpts describing the basic functions of the CCW system are taken from the CCW design basis document, 5610-030-DB-002. Only information pertinent to this issue has been included. For the full design basis see Document 5610-030-DB-002.

BASIC FUNCTIONS (Section 4.1 of DBD 5610-030-DB-002)

Safety-Related Functions

1. Shall circulate component cooling water (CCW) through engineered safety features (ESF) heat loads during accident conditions, to support ESF equipment cooling, reactor heat removal and containment heat removal.
2. Shall circulate CCW through heat loads required to maintain safe shutdown (hot standby) at any time, including loss of offsite power and plant fires.
3. Shall passively maintain the CCW system pressure boundary integrity.

The following excerpt regarding CCW leakage is taken from the design basis document for the CCW system. Section 2.3.10 of 5610-030-DB-002 states:

> For the purposes of this design basis document, CCW pressure integrity is defined as follows:
>
> CCW pressure integrity is maintained whenever the total system out leakage does not exceed the capacity of the water makeup line.

The value of 50 gpm is used throughout the FSAR and DBD to quantify a limiting CCW leak. Although the DBD states that the origin of this value may be arbitrary, it provides reasonable maximum credible leak of 50 gpm which is consistent with ECCS passive failure assumption and allows about 20 minutes before make-up is required to prevent emptying the surge tank. For conservatism, the 50 gpm limit is considered to be an aggregate leak rate value of all the system leaks (seals, packing, pressure boundary, etc).

Excerpt from Section 49.3.2 of DBD 5610-030-DB-002:
*T-2 16 CCW Head Tank:

A. Parameter / Constraint: MINIMUM WATER LEVEL

B. Value: 138' 3" elevation

C. Source:
1. PC/M 96-093, "U4 Addition of CCW Head Tank"
2. Calculation PTN-BFSM-96-022, "CCW Post Accident Heat-up and Waterhammer Calculation"
3. Calculation PTN-BFSM-97-004, Rev 0, Miscellaneous CCW Head Tank Elevation Assessments"
4. PC/M 96-092, "U3 Addition of CCW Head Tank"

D. Background/Reason for Value:

To ensure compliance of the CCW System to all FSAR requirements, the head tank must provide adequate static pressure head to maintain the coolers in containment above saturation pressure during all design basis accident events. Per Source 2, that means that the head tank must maintain the ECCs, the most limiting case, above the saturation pressure for 270°F, which equates to maintaining 27.2 psig at an elevation of 73' 6" (see Source 1). At ambient temperature (100°F) that equates to a minimum water level of 136' 7-1/4", while at the design rating (200°F) a minimum level of 138'9-1/2" is required. Source 1 identifies 187°F as the maximum "Emergency" temperature, which equates to a minimum level of 138' 2- 1/2" per Source 3. The minimum level specified is based on the minimum level for the "Emergency" temperature which is essentially identical to the minimum head tank level and the lowest level measured by LT-*-614.

Several leakage and thermal contraction scenarios have been postulated that reduce the head tank level. Note that leakage scenarios do not have to be assumed coincident with a design basis accident. Head tank function is required only in response to a LOCA or MSLB. A subsequent leak will not impact its SR function. Thermal contraction that could reduce the level below the minimum would be associated with post-accident cooldown which is after the head tanks required SR function. The CCW system has been determined to be functional (operable).

3. Identify the established minimum design basis values necessary to satisfy the SSC specified safety function(s), including qualification requirements, and design/operating margins where applicable,

Pressure retaining piping and associated supports shall satisfy the acceptance criteria on ANSI B31.1 1973 (through Winter 1976 Addenda) as specified in Discipline Standard CN 3.01, Rev. 3. Additional consideration with regards to the minimum design basis values to ensure the operability of the CCW system after the area is cleaned is as follows:

1. Shall passively maintain the CCW system pressure boundary integrity.

Failure of the 18" piping would affect pressure boundary integrity.

The design basis of the Component Cooling Water System is to provide sufficient heat removal from the Engineered Safety Features to the ultimate heat sink (ICW System), post-accident.) The system, which is normally operated in an open configuration, is designed with sufficient capability to accommodate the failure of any single, active component without resulting in undue risk to the health and safety of the public following a Maximum Hypothetical Accident (MHA). The most limiting single active failure considered was the loss of one diesel, which results in only one CCW pump starting automatically to mitigate the consequences of the MHA. This assumed single failure also results in the loss of a complete train of engineered safety features, including the inability to open the CCW isolation valve associated with one RHR heat exchanger and one Emergency Containment Cooler (ECC).

4. Identify the Mode or other TS specified conditions of operation when the specified TS function(s) for the affected SSCs are required to be operable.

The affected CCW piping shall be operable for Modes 1 through 4 per TS 3.7.2.

- Technical Specifications for CCW operability are applicable in Modes 1-4.
- Post Design Basis Accident the CCW system is required to support the Post DBA mission statement: Cold Shutdown and maintenance of Cold Shutdown for 30 days.

5. Describe the degraded or nonconforming condition affecting the SSC(s).

Heavy surface corrosion (Approximately 12in longitudinally) on the external surface of the U3 CCW B-Return Header Piping. There is a through wall hole of 5/8”; which has caused an approximately 18gpm leak. Furthermore, there are (2) spots in the vicinity of the hole that are at or below the required minimum wall thicknesses screening value (t_{min} = 0.109”) per Structural Integrity Associates (SIA) Calculation 1901312.301.R0 (Attachment 1 – Thinning Handbook), Table 2.

Note that these other (2) values are t_{G23} = 0.109” & t_{E21} = 0.104” (See EDMS Folder for Nondestructive Examination (NDE) Report).

Note that during preparation of this POD, the 18 gpm leak had been mitigated by installing a proprietary pressure boundary restoring device (i.e. PMCap); which is being installed around the pipe per EC-DEC 291917.

6. Evaluate effects of condition, including potential failure modes, on the ability of the SSC to perform its specified safety function(s) and support function(s), if any. The following items shall be covered in the Evaluation.

A. Discuss why the degraded or nonconforming condition does or does not prevent the SSC from performing its specified safety function(s) or support function(s). Include known information that supports the specific evaluation, any adverse impact about the condition, related analysis, disposition of input data such as NDE results and observations, and items considered but discounted. (EN-AA-203-1001,Section 6.1.3,Voluntary Action Item 7)

Degraded condition does not prevent the U3 CCW B-Return Header Piping from performing its safety-related function during Modes 1-4 in as demonstrated per ASME XI, CC N-513-3 evaluation 1400949.301.R1(Attachment 2 – N-513-3 Evaluation).

Degraded condition does not prevent the U3 CCW B-Return Header Piping from performing its supporting functions during Modes 5 & 6 (Reference POD 2350581-02).

Note that during preparation of this POD, the 18 gpm leak had been mitigated by installing a proprietary pressure boundary restoring device (i.e. PMCap); which is being installed around the pipe per EC-DEC 291917. It should be noted that this PMCap repair has not been approved by the NRC; however, there is currently a Relief Request (L-2020-056) in place with the NRC, and it is understood that this PMCap repair is being installed at risk prior to NRC approval. Furthermore, Reg Guide 1.147, Rev. 18 postulated condition that “The repair or replacement activity temporarily deferred under the provisions of this Code Case (ASME XI, CC -513-3) shall be performed during the next scheduled outage" would entail that a repair/replacement activity needs to be performed/completed prior to entering Mode 2. Thus, NRC approval of the Relief Request (L-2020-056) is also needed prior to entering Mode 2 in order to credit the at risk installation of PMCap per EC-DEC 291917.

B. List and describe compensatory measures (e.g., procedure changes, facility changes, or substitution of manual actions for automatic functions) taken to restore, maintain, or enhance operability (compensatory actions involving changes to procedures or plant must be reviewed under 10 CFR 50.59).

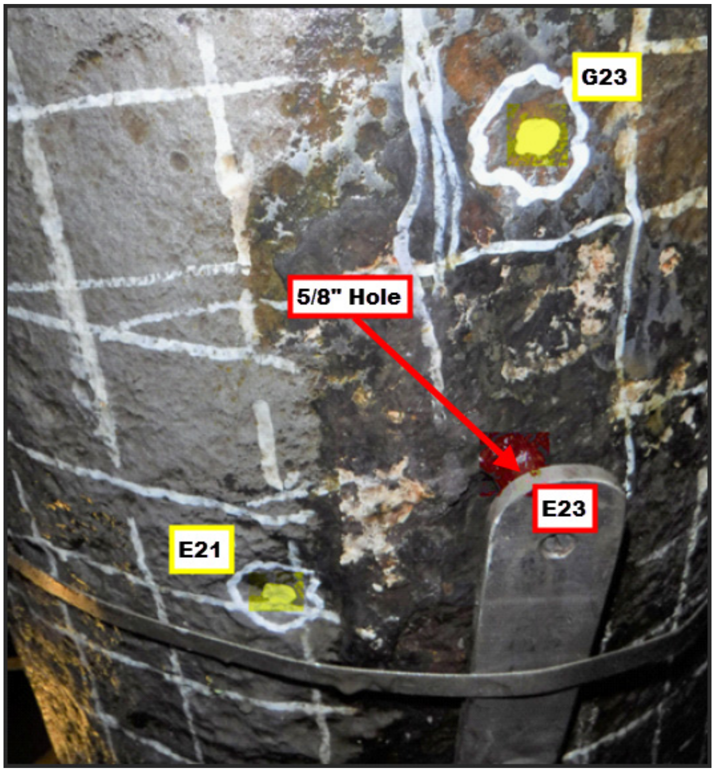
None.

C. Evaluate continued operability of the SSC should the degraded condition degrade further and describe the method used to monitor the degraded condition until corrected (e.g., operator rounds, system health trending/walkdowns, CAP monitoring action) or provide justification why monitoring is not required. (The POD must be forward looking to assess conditions that may impact the SSC during the period of operation until the condition is corrected, especially for PODs that rely on equipment performance information).

ASME XI, CC N-513-3 Evaluation was performed by SIA in order to determine the impact of the flaw with respect to the structural integrity of the piping section of concern (ASME XI, CC N-513-3 evaluation 1400949.301.R1(Attachment 2 – N-513-3 Evaluation)).

NDE Report data was used to characterize the defect (Through wall hole of 5/8" diameter) along with the other (2) spots (t_{G23} = 0.109" & t_{E21} = 0.104") in the vicinity of the hole that are at or below the required minimum wall thicknesses screening value of (t_{min} = 0.109") per SIA Calculation 1901312.301.R0 (Attachment 1 – Thinning Handbook), Table 2.

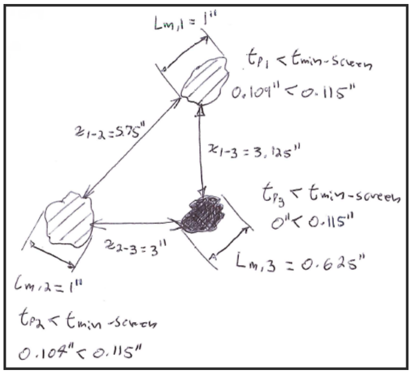
NDE Report was prepared in accordance with NDE Plan (Attachment 3 – 3B CCW Return NDE Plan, Rev.3), and characterization in accordance with ASME XI, CC N-513-3 was performed as follows:



ASME XI, CC 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…

$2.5 \cdot \sqrt{R \cdot t_{nom}}$ or $2 \cdot L_{m.avg}$

Where…



$R := 8.813\text{in}$

$t_{nom} := 0.375\text{in}$

$2.5 \cdot \sqrt{R \cdot t_{nom}} = 4.545\,\text{in}$

$L_{m.1} := 1\text{in}$

$L_{m.2} := 1\text{in}$

$L_{m.3} := 0.625\text{in}$

$$L_{m.avg} := \frac{L_{m.1} + L_{m.2} + L_{m.3}}{3}$$

$2 \cdot L_{m.avg} = 1.75\,\text{in}$

Due to the close proximity of the flaws (i.e. distance between flaws being less than 4.545”) in both circumferential (E21 to E23) and longitudinal directions (E23 to G23), it was required to evaluate them both as single flaws in both directions.

Note that even though t_{min} = 0.109”, a $t_{min\text{-}screen}$ = 0.115” was conservatively used during NDE.

Based on additional 1/2” micro-grids at these locations, additional readings were used to provide assurance on the extent of the flaw.

Circumferential Flaw (E21 to E23)

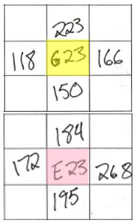
	E~~21~~ 222	
253	E21	121
	205	

	184	
172	E23	268
	195	

$L_C = X_{2-3} + L_{m.2} + L_{m.3}$ + 1/2” + 1/2” = 5.625 in

$t_{adj\text{-}avg(C)}$ = (0.253” + 0.268”)/2 = 0.261 in

Axial Flaw (E23 to G23)



	223	
118	G23	166
	150	

	184	
172	E23	268
	195	

Since there were no further readings that were below the t_{min} = 0.109” per SIA Calculation 1901312.301.R0 (Attachment 1 – Thinning Handbook), Table 2, it can be concluded that this flaw at location at G23 is not considered an actual defect. Therefore, it does not need to be accounted for in the ASME XI, CC N-513-3 evaluation. Thus the only flaw to be considered in the evaluation is the 5/8" hole.

L_A = 5/8" + 1/2" + 1/2" = 1.625 in

$t_{adj\text{-}avg(A)}$ = (0.195" + 0.184")/2 = 0.190 in

The above circumferential and axial flaws were compared to the results in ASME XI, CC N-513-3 evaluation 1400949.301.R1(Attachment 2 – N-513-3 Evaluation), Table 5 as follows:

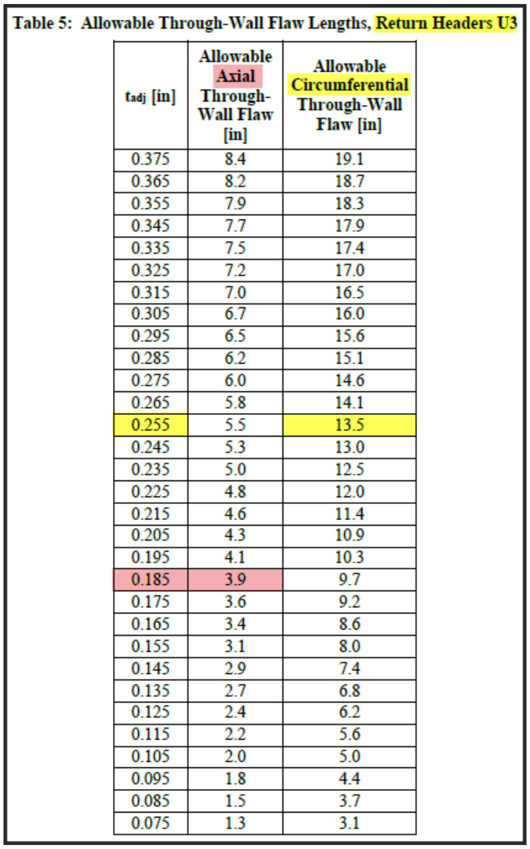


Table 5: Allowable Through-Wall Flaw Lengths, Return Headers U3

t_{adj} [in]	Allowable Axial Through-Wall Flaw [in]	Allowable Circumferential Through-Wall Flaw [in]
0.375	8.4	19.1
0.365	8.2	18.7
0.355	7.9	18.3
0.345	7.7	17.9
0.335	7.5	17.4
0.325	7.2	17.0
0.315	7.0	16.5
0.305	6.7	16.0
0.295	6.5	15.6
0.285	6.2	15.1
0.275	6.0	14.6
0.265	5.8	14.1
0.255	5.5	13.5
0.245	5.3	13.0
0.235	5.0	12.5
0.225	4.8	12.0
0.215	4.6	11.4
0.205	4.3	10.9
0.195	4.1	10.3
0.185	3.9	9.7
0.175	3.6	9.2
0.165	3.4	8.6
0.155	3.1	8.0
0.145	2.9	7.4
0.135	2.7	6.8
0.125	2.4	6.2
0.115	2.2	5.6
0.105	2.0	5.0
0.095	1.8	4.4
0.085	1.5	3.7
0.075	1.3	3.1

L_C = 4.625 in < 13.5 in … Therefore, ok

L_A = 1.625 in < 3.9 in … Therefore, ok

Based on evaluation in accordance with ASME XI, CC N-513-3 continued operability of the U3 CCW B-Return Header Piping is not challenged.

This condition is being restored/corrected to full design parameters by installing a proprietary pressure boundary restoring device (i.e. PMCap); which is being installed around the pipe per EC-DEC 291917 prior to entering Mode 4. Furthermore, note that the flaw and defect to be encased by the PMCap will be covered by CCW water (i.e. CCW pipe will be hot tapped in order to allow water to fill the cavity between CCW pipe exterior and PMCap underside); which will provide corrosion inhibiting chemistry into the area of concern (Ref. UFSAR 9.3-3). Therefore, future flaw/defect propagation due to external corrosion of the CCW pipe is negligible.

D. For SSC not fully qualified to perform its specified function(s), assess the aggregate impact on plant operations of the cumulative effect of this and other open operability and functionality issues, associated compensatory measures, (listed in Cognos Report AT-01.28) and relevant Engineering Changes (e.g., modifications) scheduled for implementation over the expected duration of the final corrective actions.

There is no adverse aggregate impact considering this degraded area in addition to the open operability and functional issues listed in Cognos Report AT-01.28. (See EDMS Folder).

E. Identify impacts on design and operating margins and limits.

The approximately 18 gpm CCW leak on the U3 CCW B-Return Header Piping is still below the allowable leakage of 50 gpm. Therefore, this provides an approximately 32 gpm margin.
Note that during preparation of this POD, the 18 gpm leak had been mitigated by installing a proprietary pressure boundary restoring device (i.e. PMCap); which is being installed around the pipe per EC-DEC 291917.

F. Identify assumptions used in evaluating the condition of the affected SSC(s).

Assumptions are from ASME XI, CC N-513-3 evaluation 1400949.301.R1 (Attachment 2 – N-513-3 Evaluation):

1. The material of the piping sections included in this evaluation is one of four variants of carbon steel, as described above, and are either welded or seamless. As the exact material is not known, it is conservatively assumed that the material is A-53 Grade A, welded, which has the lowest allowable stress.
2. Poisson's ratio is assumed to be 0.3.
3. Potential weld residual stress is assumed to be relieved as material is removed through the corrosion process.
4. A corrosion allowance is not considered (the ongoing inspection requirements in Code Case N-513-3 address the possibility of flaw growth during the temporary acceptance period).

7. Conclusion (address each SSC if conclusions are different)

Based on the evaluation above it is concluded that the U3 CCW B-Return Header Piping section of concern is considered operable but degraded. The basis for that recommendation comes from the CCW being capable of performing its specified safety function, and from procedure EN-AA-203-1001, Operability Determinations and Functionality Assessments, Attachment 3.
Note that during preparation of this POD, the 18 gpm leak had been mitigated by installing a proprietary pressure boundary restoring device (i.e. PMCap); which is being installed around the pipe per EC-DEC 291917. It should be noted that this PMCap repair has not been approved by the NRC; however, there is currently a Relief Request (L-2020-056) in place with the NRC, and it is understood that this PMCap repair is being installed at risk prior to NRC approval. Furthermore, Reg Guide 1.147, Rev. 18 postulated condition that "The repair or replacement activity temporarily deferred under the provisions of this Code Case (ASME XI, CC -513-3) shall be performed during the next scheduled outage" would entail that a repair/replacement activity needs to be performed/completed prior to entering Mode 2. Thus, NRC approval of the Relief Request (L-2020-056) is also needed prior to entering Mode 2 in order to credit the at risk installation of PMCap per EC-DEC 291917.

8. References:

1. PTN Technical Specifications, Rev. 420.
2. UFSAR, Rev. 430B
3. DBD 561 0-030-DB-002
4. FPL Discipline Standard CN-3.01, Rev. 3," Piping and Support Analysis Requirements for Turkey Point Units 3 & 4.
5. ANSI B31.1 1973 through summer 1976 Addenda, Power Piping
6. ASME XI, CC N-513-3

7. Reg Guide 1.147 Rev. 18
8. POD 1981540-01
9. POD 2350581-02
10. Relief Request L-2020-056

9. Attachments:

1. Attachment 1 – Thinning Handbook – SIA Calculation 1901312.301.R0
2. Attachment 2 – N-513-3 Evaluation – SIA Evaluation 1400949.301.R1
3. Attachment 3 – 3B CCW Return NDE Plan, Rev.3

10. MODE Restrictions (APPLICABILITY Restrictions for ISFSI Conditions):

(See Section 7, Conclusion)

11. Operability Recommendation

Relative Level of SSC Degradation

Check one	PROMPT OPERABILITY DETERMINATION (Use additional charts for SSCs with different determinations)	
	Operable and Fully Qualified	Meets all CLB, qualification, and design requirements, as described in drawings, specifications, procedures, etc.
Analyzed Design Limit		
	Operable and Fully Qualified with Reduced Design Margin	Meets all CLB and qualification requirements, but with reduced margin below some established design value in a design document.
Full Qualification As Described in CLB		
	Operable But Nonconforming	Meets CLB functional requirements, but is nonconforming due to inadequate design, testing, construction, modification, or documentation.(See procedure definition 2.0.18 for examples.)
CLB Functional Requirements		
X	Operable But Degraded	Does not meet all CLB requirements, but is capable of performing specified functions / mission time. (See procedure definition 2.0.6). Compensatory measures are ☐ or are not ☒ required.
Specified Function Capability		
	Not Operable	SSC is not capable of performing a specified safety function or completing its mission time. TS LCO is ☐ or is not ☐ met due to the SSC being inoperable

12. Resulting Actions

A. Is a past operability review (POR) required?	☐ Yes ☒ No	If yes, ensure POR type AR assignment is initiated.
B. Does the conclusion identify a new condition or identify a significant change of scope to the existing issue?	☐ Yes ☒ No	If yes, then initiate a new Condition Report AR and cross reference to this AR. New CR AR Number: ___________
C. Are there reduced design margins?	☐ Yes ☒ No	Initiate an RWA type AR assignment to the System Engineer (if exists) to notify for potential System Health Report discussion.
D. Are there compensatory measures or reduced operating margins?	☐ Yes ☒ No	If yes, ensure ACMP per OP-AA-100-1000 is implemented. List COMP Assignments created: ___________________
E. Do parameter limits or limitations established as a result of this POD or compensatory measures affect existing operating margins or alerts?	☐ Yes ☒ No	If yes, SM signature below attests that for any parameters that have limits/limitations established as a result of this POD or compensatory measures, adequate operating margins and alerts have been discussed, established, or exist to ensure operability and prevent exceeding the POD parameter limits.
F. Is any SSC not operable?	☐ Yes ☒ No	Initiate an MRFF type AR assignment to the System Engineer with a 30 day due date.

AR: 2350581 **AR Assignment Number: 01**

---

13. Signatures:

Prepared By: JUAN MILLAN / Date 4-12-20
Qual NUC ENG GEN 7011 required Print/Sign

Reviewed By: Mitch bett / Date: 4/12/20
Qual NUC ENG GEN 7011 required Print/Sign

Engr Supv/
Mgr Approval: alejandro Carrasquillo Date: 4/12/20
(Section 6.1.3, Voluntary Action Item 7) Print/Sign

SM Approval: A. Chomat A. Chomat Date: 4/12/20
(See Item 12.D, above) Print/Sign

After SM approval, preparer shall ensure the appropriate OBN, OBD, or ONOT type AR assignments are initiated to track final corrective actions, and COMP type AR assignments are initiated for compensatory actions, in accordance with EN-AA-203-1001 section 4.9.

Structural Integrity Associates, Inc.

File No.: 1901312.301
Project No.: 1901312
Quality Program Type: ☒ Nuclear ☐ Commercial

CALCULATION PACKAGE

PROJECT NAME:
Turkey Point CCW External Corrosion Engineering Support

CONTRACT NO.:
02404724

CLIENT:
FPL Group - NextEra Energy

PLANT:
Turkey Point Nuclear Plant Unit 3

CALCULATION TITLE:
Thinning Handbook Calculation for 18-inch Component Cooling Water Straight Piping

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 36 A-1 - A-2 Computer Files	Initial Issue	Stephen M Parker Stephen Parker 3/17/20	**Preparers:** Matt Santoro 3/10/20 Stephen M Parker Stephen Parker 3/10/20 **Checker:** Eric Houston 3/17/20

Table of Contents

1.0 OBJECTIVE 4
2.0 METHODOLOGY 4
  2.1 Criteria for Hoop Stress 5
  2.2 Criteria for Axial Stress 6
    2.2.1 Longitudinal Stresses Due to Sustained Loads 6
    2.2.2 Longitudinal Stresses Due to Occasional Loads 7
    2.2.3 Additive Stresses 9
  2.3 Local Primary Stress 10
  2.4 Separation Requirements 11
3.0 DESIGN INPUTS 11
  3.1 Geometry and Material 11
  3.2 Piping Loads 12
  3.3 Applicable Piping for Thinning Profiles 12
  3.4 Minimum Required Wall Thickness 16
4.0 ASSUMPTIONS 17
5.0 FINITE ELEMENT MODEL 18
  5.1 Geometry and Element Selection 18
  5.2 Boundary Conditions 21
  5.3 Internal Pressure 23
  5.4 Moment Loading 24
  5.5 Mesh Sensitivity Study 24
6.0 CALCULATIONS 25
  6.1 Hoop Stress Evaluation 25
  6.2 Axial Stress Evaluation 26
7.0 RESULTS OF ANALYSIS 28
8.0 GUIDANCE FOR USE 30
  8.1 Separation Requirements 30
  8.2 Sample Step-by-Step Evaluation 30
9.0 CONCLUSIONS 32
10.0 REFERENCES 33
APPENDIX A COMPUTER FILES A-1

List of Tables

Table 1. Bounding Moment Loading for 18-inch Piping at 150 psi 12
Table 2. Minimum Required Wall Thickness.. 17
Table 3. Calculated Limiting Stresses for 18-inch CCW Piping with External Thinning 29
Table 4. Minimum Thicknesses for 18-inch CCW Piping, External Thinning Profile A - 1/8" Grid 34
Table 5. Minimum Thicknesses for 18-inch CCW Piping, External Thinning Profile B - 1/8" Grid 35
Table 6. Minimum Thicknesses for 18-inch CCW Piping, External Thinning Profile C - 1/8" Grid 36

List of Figures

Figure 1. Isometric 5613-P-604-S Rev 1 Sheet 2 of 6... 13
Figure 2. Isometric 5613-P-604-S Rev 1 Sheet 6 of 6... 14
Figure 3. Isometric 5613-P-612-S Rev 2 Sheet 2 of 2... 15
Figure 4. Isometric 5613-P-614-S Rev 2 Sheet 2 of 3... 16
Figure 5. Typical External Thinning Profile Details 19
Figure 6. Finite Element Model Geometry, Global 20
Figure 7. Finite Element Model Geometry, Section View 20
Figure 8. Boundary Conditions Applied to the FEM 21
Figure 9. Pressure Load Application... 22
Figure 10. Moment Load Application 23
Figure 11. Axial Linearized Stress Paths 24
Figure 12. Circumferential Linearized Stress Paths 25
Figure 13. Typical Unit Pressure Hoop Stress Results 26
Figure 14. Typical Unit Pressure Axial Stress Results 27
Figure 15. Typical Unit Moment Axial Stress Results 27
Figure 16. Quarter Model of Thickness Profile with Grid Spacing 28

1.0 OBJECTIVE

The piping minimum required wall thickness, t_{min}, calculated in accordance with the Code of Construction assumes that the piping is uniformly thinned. Although conservative, this approach is not consistent with localized thinning that is typically observed in the Component Cooling Water (CCW) piping systems at Turkey Point Nuclear Plant (Turkey Point). In order to appropriately plan examinations of these systems, it is important to understand a more representative structural margin of the piping. Wall thickness profiles that meet the Code of Construction stress limits will be determined for the applicable CCW piping in order to understand the structural margin for typical localized thinning.

The objective of this calculation is to demonstrate the suitability for continued operation of piping with localized thinning (i.e., pipe wall thickness below minimum design requirements (t_{min}) for a limited extent) using increased allowable stresses from later code editions than those from the ANSI B31.1, 1973 Edition Code of Construction [1]. The analyses show wall thickness profiles for which the Code of Construction criteria is met using guidance from NB-3200 and ND-3600 of the 2007 ASME Code with Addenda through 2008 [2]. This calculation is applicable to 18-inch straight pipe operating at 150 psig in the CCW system as discussed in Section 3.0. Thickness profiles presented in this calculation are applicable to past examinations and future examinations.

2.0 METHODOLOGY

The suitability for the continued operation of thinned pipe is based on two stress criteria: hoop stress and axial stress. The hoop stress limit is defined by the Code of Construction [1, Section 104.1.2 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 11, Longitudinal Stresses due to Sustained Loads [1, Section 104.8.1]
- Equation 12, Longitudinal Stresses due to Sustained and Occasional Loads [1, Section 104.8.2]
- Equation 13, Thermal Expansion Stresses [1, Section 104.8.3,A]
- Equation 14, Sustained Plus Thermal Expansion Stresses [1, Section 104.8.3,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 13 or 14 is required to be met, not both [1, Section 104.8.3]. Therefore, only Equation 13 is evaluated herein.

The B31.1 Design by Rule approach does not provide specific criteria for the evaluation of non-uniform wall thickness or local thinning. However, B31.1 was written to provide for flexibility in analysis as shown below [1, p. xi]:

> *"The specific design requirements of the Code usually revolve around a simplified engineering approach to a subject. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs and the evaluation of complex or combined stresses. In such cases the designer is responsible for demonstrating the validity of his approach."*

To evaluate non-uniform wall thickness/local thinning, or "complex or combined stresses," guidance for stress analysis is taken from the ASME Code Design by Analysis approach (Section III, NB-3200 [3]). Although NB-3200 is written for Class 1 components, applying the methods of NB-3200 to Class 3 piping is explicitly endorsed by ASME in ND-3611.3:

> *"The specific design requirements of ND-3600 are based on a simplified engineering approach. A more rigorous analysis such as described in NB-3600 or NB-3200 may be used to calculate the stresses required to satisfy these requirements. These calculated stresses must be compared to the allowable stresses in this Subsection. In such cases, the designer shall include appropriate justification for the approach taken in the Certified Design Report."*

Three-dimensional (3-D) finite element models will be utilized in subsequent evaluations to calculate the stress field associated with localized thinning, which is a more rigorous methodology than the Design by Rule approach in B31.1 and is consistent with the Design by Analysis approach of NB-3200. The resulting stresses extracted from the applicable 3-D finite element model will be compared to the allowable stresses in B31.1. Justification for this approach is detailed in the following sections. This evaluation does not invalidate the applicable Certified Design Report and should be considered supplemental to the report. Note that the NRC has reviewed ND-3611.3 and incorporated it by reference without condition in 10CFR50.55a.

The technical approach is based on the premise that while piping may have externally thinned locations that violate the conservative design t_{min} requirements, the thinning may still be shown to be of sufficiently limited extent such that the B31.1 Code design margin is maintained.

2.1 Criteria for Hoop Stress

The minimum thickness required based on hoop stress, Equation 3 [1, Section 104.1.2], assures against gross structural failure due to primary membrane pressure loading. Equation 3 is written as a design thickness calculation based on a maximum allowable stress. The minimum thickness required for design pressure, t_m, is defined as [1, Section 104.1.2, Equation 3]:

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

where,

P = Internal design pressure, psig
D_o = Outside pipe diameter, in
S = Maximum allowable stress at design temperature, psi
E = Longitudinal weld joint efficiency factor (welded pipe E = 0.85)
y = Pressure coefficient
= 0.4 for temperatures ≤ 900°F [1, Table 104.1.2.A]
A = Additional thickness to compensate for material removal or loss, in

Since subsequent analyses are for as-found conditions and not design, the additional thickness value, A, is taken as zero. The equation is then reordered to compare against the allowable stress, resulting in:

$$\frac{PD_o}{2t_m} - Py \leq S$$

For the wall thinning evaluation, the left side of the equation is a function of pressure that equates to the hand calculated value for hoop stress in a pipe. In order to change the equation above into a Design by Analysis evaluation (i.e., a stress comparison), the left side of the equation is modified to use the finite element-derived results to perform a primary stress check.

The finite element stresses in the non-uniform wall thickness region can be linearized through the thickness and extracted into component stresses (axial, radial and hoop) and then broken down into stress type (membrane, bending, membrane + bending, peak and total). Since the Code of Construction does not provide sufficient guidance to categorize the hoop stresses obtained from the analysis, guidance is taken from the ASME Code subarticle NB-3200 [2].

A discontinuity (or discontinuities) in a pipe is considered to be a gross structural discontinuity when it affects the through-wall stress distribution of the component. Localized non-uniform wall thickness affects the through-wall stress distribution and is, therefore, a gross structural discontinuity. Based on a component with a gross structural discontinuity, Table NB-3217-2 [2] indicates there would be both a primary and a secondary stress component due to pressure loading. Using guidance from Table NB-3217-2 [2], membrane stress in the hoop direction due to pressure is a primary stress and bending stress due to pressure in the hoop direction is a secondary stress. Therefore, the finite element-derived linearized membrane stresses in the hoop direction can be used to substitute into the left side of the above equation to derive:

$$(\sigma_{m\_h})_{pressure} \leq S$$

$(\sigma_{m\_h})_{pressure}$ = Linearized membrane stress in the hoop direction due to design pressure from finite element analysis.

2.2 Criteria for Axial Stress

Equations 11, 12, and 13 of B31.1 [1, Section 104.8] are intended to calculate axial stresses in the piping component due to pressure and piping loads, and meet the stress limits in the Code of Construction [1, Section 102.3]. In the original piping design process, the nominal uniform wall thickness is used to calculate the piping stresses which are compared to the allowable stresses. Rather than use the equations themselves, which are limited to uniform wall thickness, axial stresses are extracted from the finite element evaluations and substituted for the terms of the equations to perform a stress check for a non-uniform wall thickness. The resulting stresses are then added together and the results compared to the appropriate allowable stresses.

2.2.1 Longitudinal Stresses Due to Sustained Loads

The Longitudinal Stresses Due to Sustained Loads must satisfy the following requirement [1, Section 104.8.1, Equation 11]:

$$\frac{PD_o}{4t_n} + \frac{0.75iM_A}{Z} \leq 1.0S_h$$

where,

P = Internal design pressure, psig
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)
M_A = Resultant moment due to sustained loads, in-lbs
Z = Section modulus, in^3
S_h = Allowable stress at design temperature (equivalent to S for this evaluation), psi

Note that the finite element models automatically incorporate any shape-based intensification and thus, the stress intensification factor is not required. The Equation 11 loads are design pressure and piping moments due to deadweight and other sustained loads.

For the wall thinning evaluation, the first term of Equation 11 is a function of pressure that equates to the hand calculated value for axial membrane stress in a pipe. Consistent with the methodology outlined in Section 2.1, the finite element-derived linearized membrane stresses due to pressure in the axial direction can be used to substitute into the first term in Equation 11.

The second term in Equation 11 is the sustained mechanical load term, which is modified to use the finite element-derived results. The finite element stresses in the non-uniform wall thickness region can be linearized through the thickness and extracted into component stresses (axial, radial and hoop) and then broken down into stress type (membrane, bending, membrane + bending, peak and total). Since the Code of Construction does not provide sufficient guidance to categorize the axial stresses obtained from the analysis, guidance is taken from the ASME Code Subsection NB-3200 [2].

A discontinuity (or discontinuities) in a pipe is considered to be a gross structural discontinuity when it affects the through-wall stress distribution of the component. Localized non-uniform wall thickness affects the through-wall stress distribution and is, therefore, a gross structural discontinuity. Based on a component with a gross structural discontinuity, Table NB-3217-2 [2] indicates there would be both a primary and a secondary stress component due to sustained mechanical loading. Using guidance from Table NB-3217-2 [2], membrane stress in the axial direction due to sustained mechanical loading is a primary stress and bending stress due to sustained mechanical loading in the axial direction has characteristics of both a primary and a secondary stress. Therefore, the finite element-derived linearized membrane-plus-bending stresses in the axial direction due to mechanical loading is conservatively used to substitute into the second term of the above equation to yield:

$$(\sigma_{m\_a})_{pressure} + (\sigma_m + \sigma_b)_{moment\_A} \leq 1.0S_h$$

$(\sigma_{m\_a})_{pressure}$ = Axial linearized membrane stress due to pressure from finite element analysis
$(\sigma_{m+b})_{moment\_A}$ = Axial linearized membrane-plus-bending stress due to appropriate sustained moment loading from finite element analysis

2.2.2 Longitudinal Stresses Due to Occasional Loads

The Longitudinal Stresses Due to Occasional Loads must satisfy the following requirement [1, Section 104.8.2, Equation 12]:

$$\frac{PD_O}{4t_n} + \frac{0.75iM_A}{Z} + \frac{0.75iM_B}{Z} \leq kS_h$$

where,

P = Internal design pressure, psig
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)
M_A = Resultant moment due to sustained loads, in-lbs
M_B = Resultant moment due to occasional loads, in-lbs
Z = Section modulus, in^3
S_h = Allowable stress at design temperature (equivalent to S for this evaluation), psi
k = Allowable stress factor, defined below

Note that the finite element models automatically incorporate any shape-based intensification and thus, the stress intensification factor is not required. The Equation 12 loads are design pressure and piping moments due to sustained and occasional mechanical loads. Equation 12 is commonly broken down into three separate but similar equations to evaluate the different service levels (Service Level B would be referred to as Eq. 12B, Level C as Eq. 12C and Level D as Eq. 12D). The difference between 12B, 12C, and 12D is the occasional moment, M_B, and the multiplier prior to the allowable stress, k. Subsequent evaluations using this methodology are expected to use the following allowable stress values per Reference [3]:

- $1.2S_h$ (i.e., k = 1.2) for Equation 12B, which includes the occasional loading due to the operating basis earthquake (OBE)
- S_y for Equation 12D, which includes the occasional loading due to the safe shutdown earthquake (SSE)
- Service Level C loads are not expected to be defined for subsequent evaluations using this methodology; therefore, Service Level C is not required to be evaluated.

Note that each subsequent calculation that uses this methodology is required to verify that the allowable stress values (i.e., k multiplier) for the above service levels are applicable and that Service Level C is not defined. If the allowable stress values are different, then they shall be adjusted accordingly. If Service Level C is defined, then Service Level C shall be evaluated.

For the wall thinning evaluation, the far left side of Equation 12 is a function of pressure that equates to the hand calculated value for axial membrane stress in a pipe. Consistent with the methodology outlined in Section 2.1 the finite element-derived linearized membrane stresses due to pressure in the axial direction can be used to substitute into the far left side of Equation 12. Consistent with the methodology outlined above for Equation 11, the finite element-derived linearized membrane-plus-bending stresses in the axial direction due to sustained and occasional piping moment loads are conservatively used to substitute into the second term of the above equation to yield:

$$(\sigma_{m\_a})_{pressure} + (\sigma_m + \sigma_b)_{moment\_B} \leq 1.2S_h \qquad \text{for OBE (Eq. 12B)}$$

$$(\sigma_{m\_a})_{pressure} + (\sigma_m + \sigma_b)_{moment\_D} \leq S_y \qquad \text{for SSE (Eq. 12D)}$$

$(\sigma_m + \sigma_b)_{moment\_B}$ = Axial linearized membrane-plus-bending stress due to appropriate sustained and OBE moment loading from finite element analysis

$(\sigma_m + \sigma_b)_{moment\_D}$ = Axial linearized membrane-plus-bending stress due to appropriate sustained and SSE moment loading from finite element analysis

2.2.3 Additive Stresses

The Thermal Expansion Stresses, S_E, must satisfy the following requirement [1, 104.8.3,A Equation 13].

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

i = Stress intensification factor
M_C = Resultant moment due to thermal expansion, in-lbs
Z = Section modulus, in^3
S_A = Allowable stress range for expansion stresses, psi

Note that the finite element models automatically incorporate any shape-based intensification and thus, the stress intensification factor is not required. The Equation 13 loading is the range of resultant moment due to thermal expansion.

For the wall thinning evaluation, the left side of Equation 13 is modified to use the finite element derived results. The finite element stresses in the non-uniform wall thickness region can be linearized through the thickness and extracted into component stresses (axial, radial and hoop) and then broken down into stress type (membrane, bending, membrane + bending, peak and total). Since the Code of Construction does not provide sufficient guidance to categorize the axial stresses obtained from the analysis, guidance is taken from the ASME Code Subsection NB-3200 [2].

A discontinuity (or discontinuities) in a pipe is considered to be a gross structural discontinuity when it affects the through-wall stress distribution of the component. Localized non-uniform wall thickness affects the through-wall stress distribution and is, therefore, a gross structural discontinuity. Based on a component with a gross structural discontinuity, Table NB-3217-2 [2] indicates that the stress is a primary stress. However, the Equation 13 allowable stress is an allowable stress range and is, therefore, a limit on cyclical stresses. This requires peak stresses to be considered in the evaluation. The finite element-derived total stress in the axial direction (which includes membrane, bending, and peak stresses) due to thermal expansion loading is used to substitute into the left side of Equation 13 to yield:

$$(\sigma_T)_{moment\_C} \leq S_A$$

$(\sigma_T)_{moment\_C}$ = Axial total stress due to thermal moment loading from finite element analysis

The allowable stress range, S_A, is defined as $S_A = f(1.25S_c + 0.25S_h)$ [1, Section 102.3.2,C, Equation 1], where f is defined as the stress range reduction factor for cyclic conditions. S_c is the basic material allowable stress at minimum (cold) temperature. The reduction factor is assumed to be equal to 1.0, since the number of thermal expansion cycles is not anticipated to exceed 7,000 for subsequent evaluations using this methodology. In addition, S_c is expected to be equivalent to S_h for the materials and temperature ranges of the subsequent evaluations. Therefore, S_A is equal to $1.5S_h$ and the general stress limit for Equation 13 is:

$$(\sigma_T)_{moment\_C} \leq 1.5S_h$$

As stated in Section 2.0, Equation 14 is not explicitly evaluated since only Equation 13 or Equation 14 must be met.

2.3 Local Primary Stress

Section III of the ASME Code recognizes that a local increase in stress does not necessarily reduce the margin against burst pressure. Specifically, the Code allows local primary membrane stresses, P_L, to be up to 1.5 times the design stress intensity [3, NB-3221.2], provided that the region over which primary membrane stress intensity exceeds 1.1 times the design stress intensity, S_m, does not extend more than $\sqrt{Rt}$ in the meridional, or longitudinal, direction, where R is the minimum mid-surface radius of curvature and t is the minimum thickness in the region [3, NB-3213.10]. Additional requirements for local primary membrane stress pertaining to the proximity of multiple thinned locations are discussed in Section 2.4. Outside the local region described above, there is no limitation on the size of a region where the stress can be up to 1.1 S_m. This criterion recognizes that there can be a 10 percent increase in the basic stress intensity for regions associated with gross structural discontinuities.

It is noted that Section 2.2 describes bending stress due to sustained or occasional piping moment loads as having characteristics of both a primary and a secondary stress. The secondary stress due to sustained or occasional piping moment loads is conservatively included in the primary stress checks for regions of non-uniform wall thickness within the $\sqrt{Rt}$ distance.

Based on guidance from ND-3611.3 [3], the stress intensity, S_m, is replaced with the allowable stress, S, in the evaluations. The allowable stress associated with regions of non-uniform wall thickness within the $\sqrt{Rt}$ local region is allowed to increase by a factor of 1.5. The allowable stress may be increased to 1.1·S beyond the $\sqrt{Rt}$ local region of non-uniform wall thickness, but this additional increase is conservatively ignored. At locations remote from a discontinuity, the allowable stress is 1.0·S. To further clarify, the allowable stress for both the local and general (beyond $\sqrt{Rt}$) regions for each evaluated loading condition are presented below:

- Equation 3 allowable stress
  - Local - 1.5S
  - General - 1.0S (locations remote from a gross structural discontinuity)
- Equation 11 allowable stress
  - Local - 1.5S
  - General - 1.0S (locations remote from a gross structural discontinuity)

- Equation 12B (OBE) allowable stress
  - Local - 1.5S
  - General - 1.2S
- Equation 12D (SSE) allowable stress
  - Local - S_y
  - General - S_y
- Equation 13 allowable stress
  - Local - 1.5S
  - General - 1.5S
- Equation 14 allowable stress
  - Local - 3.0S
  - General - 2.5S

2.4 Separation Requirements

If multiple thinned locations are discovered, they must be separated by a sufficient distance in order to ensure that the stress fields do not interact. Based on the definition of local primary membrane stress in NB-3213.10 [3], thinned locations must be separated a distance of $2.5\sqrt{Rt}$ or greater. The mean radius, *R*, and thickness, *t*, are based on nominal pipe dimensions for the separation requirements. If thinned locations are within $2.5\sqrt{Rt}$ they must be analyzed as a combined single location.

3.0 DESIGN INPUTS

3.1 Geometry and Material

The following inputs for the sections of 18-inch CCW piping [4] are used in this analysis.

- Nominal pipe size: 18-inch [5]
- Outside diameter (O.D.): 18 inches [5]
- Nominal wall thickness: 0.375 inch [5]
- Straight Pipe Material type: A-53 Gr. A and B and A-106 Gr. A and B, welded and seamless [5, See Assumption 2]
- Young's Modulus: 27.9×10^6 psi (taken at 70°F) [1, Appendix C]
- Code of Construction: ANSI B31.1 1973 Edition through the 1976 Winter Addenda [1,5]
- Allowable stress in hot condition, S_h = 11,700 psi [6, Appendix A]
  - o The allowable stress is taken from a later Code edition as discussed in [7].
- Allowable stress in cold condition, S_c = 11,700 psi [6, Appendix A] (See Section 4.0, Assumption 3)
  - o The allowable stress is taken from a later Code edition as discussed in [7].
- Yield Stress, S_y = 30,000 psi for Grade A Carbon Steel (See Assumption 2) [7, Appendix A]

3.2 Piping Loads

The design stress report [8] applicable to the inspection locations for Turkey Point Unit 3 is examined to pull the respective moments used in Equations 11, 12, and 13. The maximum combined moment for a given node is used for this evaluation and is provided in Table 1. The design stress report only provides information for occasional moment loads due to SSE loading. Per guidance from FPL, the moment loading for OBE loading is conservatively assumed to be equal to the SSE moments divided by 2 [9].

Table 1. Bounding Moment Loading for 18-inch Piping at 150 psi

Loading Condition	SRSS Moment (ft-lbs)	SRSS Moment (in-lbs)	Location
Equation 11 - Sustained Loads (DW)	2,049	24,583	Node 174B (5613-P-604-s Rev 1 Sh 6 of 6 [4.d])
Equation 12B - Sustained + Occasional Loads (DW + OBE) (1)	17,594	211,126	Node 115 (5613-P-612-s Rev 2 Sh 2 of 2 [4.a])
Equation 12D - Sustained + Occasional Loads (DW + SSE)	35,062	420,748	Node 115 (5613-P-612-s Rev 2 Sh 2 of 2 [4.a])
Equation 13 - Thermal Expansion (THERM)	5,464	65,574	Node 115 (5613-P-612-s Rev 2 Sh 2 of 2 [4.a])

Note:

1. Based on OBE component moment loads, which are derived by dividing the SSE component moment loads by 2.

The design pressure and design temperature for the CCW line are 150 psig and 200°F, respectively [5].

3.3 Applicable Piping for Thinning Profiles

The 18-inch CCW examination locations for which this evaluation are applicable are highlighted in drawings reproduced in Figure 1 through Figure 4. These images are reproduced from the corresponding isometrics of Reference [4].

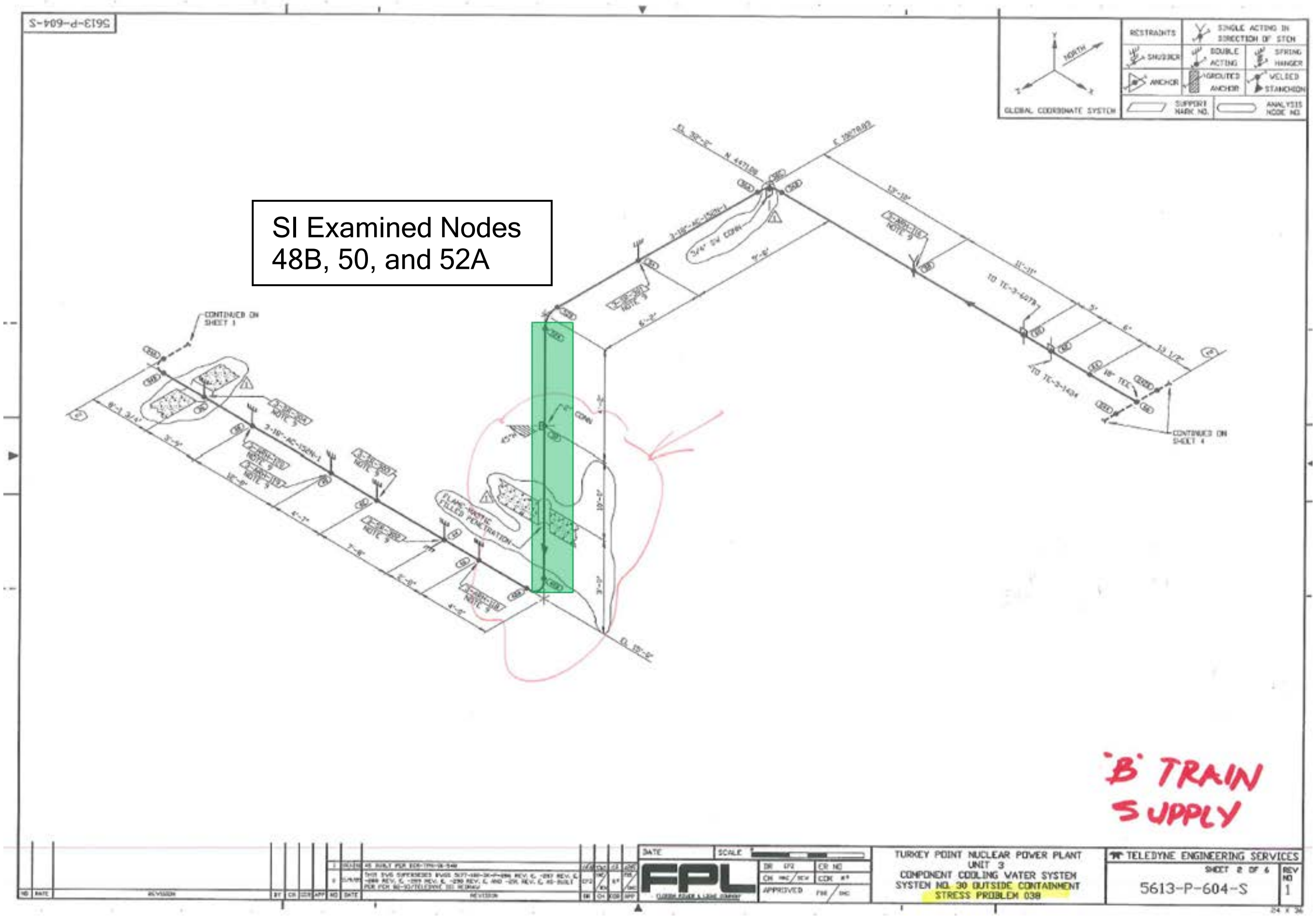


Figure 1. Isometric 5613-P-604-S Rev 1 Sheet 2 of 6

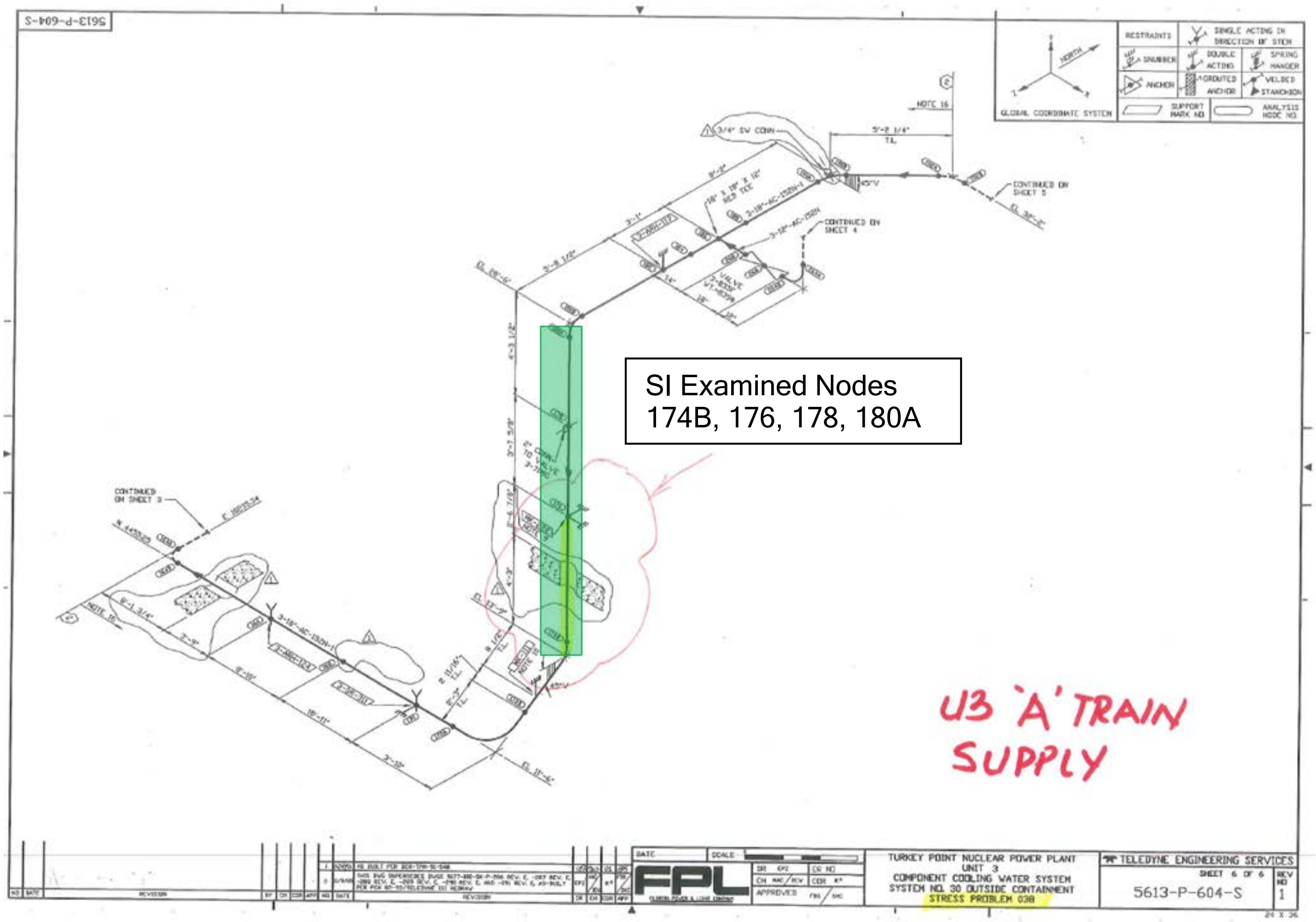


Figure 2. Isometric 5613-P-604-S Rev 1 Sheet 6 of 6

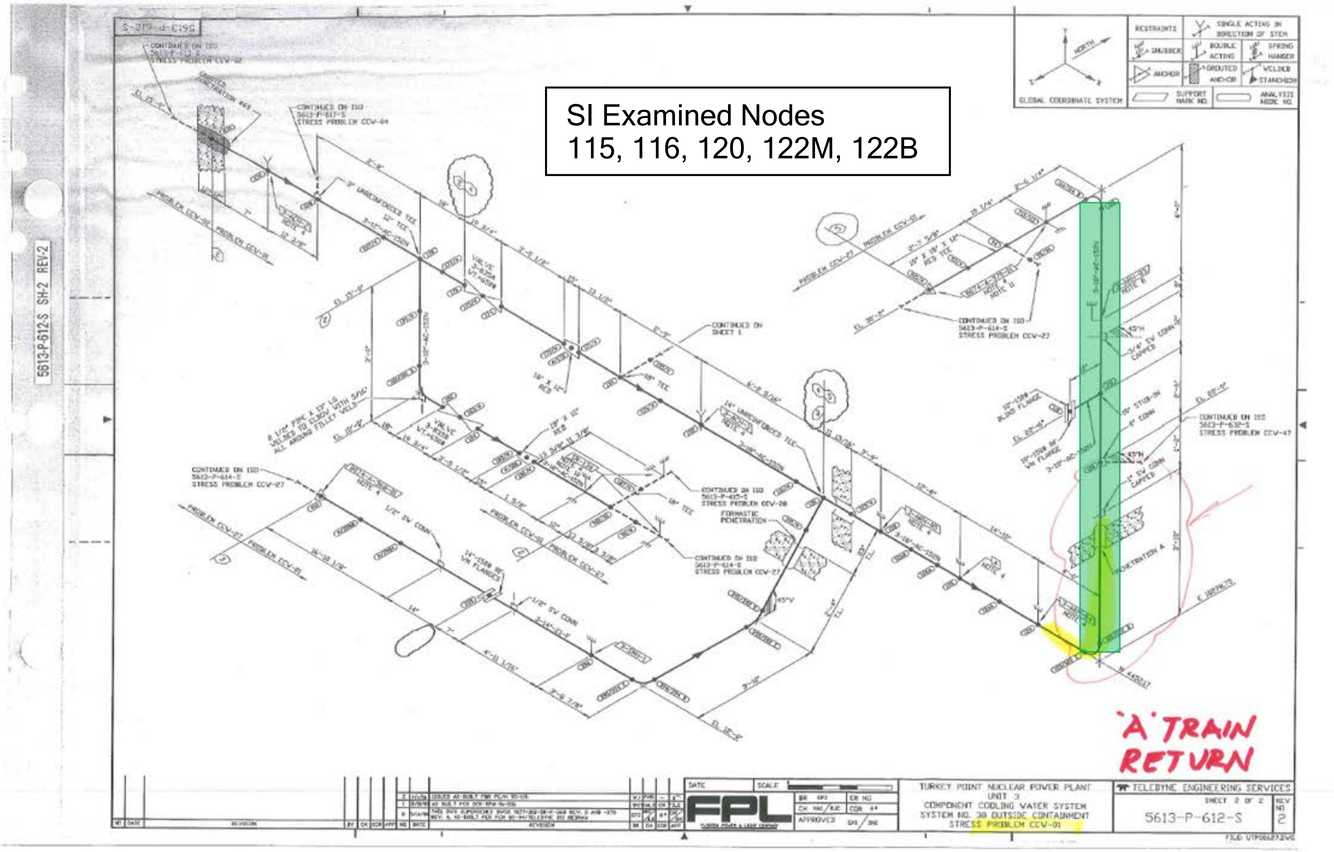


Figure 3. Isometric 5613-P-612-S Rev 2 Sheet 2 of 2

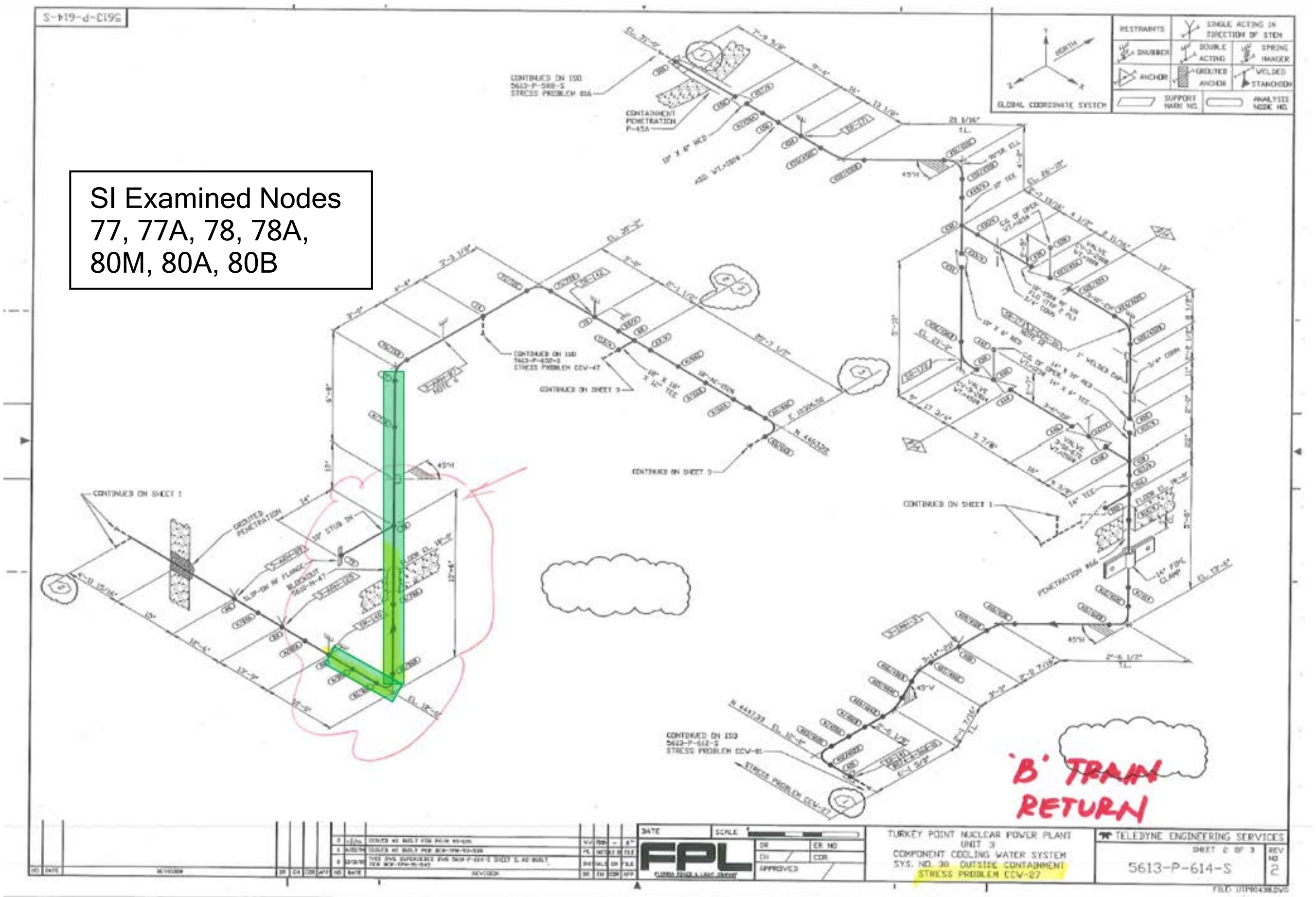


Figure 4. Isometric 5613-P-614-S Rev 2 Sheet 2 of 3

3.4 Minimum Required Wall Thickness

In a previous calculation [10], the minimum required wall thickness (t_{min}) for each of the locations identified in Figure 1 through Figure 4 was calculated. The results of this evaluation are provided in Table 2. These screening values are the minimum wall thicknesses that must exist for each piping segment to meet the Code of Construction stress requirements based on uniform thinning around the circumference of the pipe.

Table 2. Minimum Required Wall Thickness

Line, Train, Unit	Isometric Drawing	t_{min} [in]
CCW Supply, Train A, U3	Isometric 5613-P-604-S Rev 1 Sheet 6 of 6 [See Figure 2]	0.121
CCW Supply, Train B, U3	Isometric 5613-P-604-S Rev 1 Sheet 2 of 6 [See Figure 1]	0.167
CCW Return, Train A, U3	Isometric 5613-P-612-S Rev 2 Sheet 2 of 2 [See Figure 3]	0.170
CCW Return, Train B, U3	Isometric 5613-P-614-S Rev 2 Sheet 2 of 3 [See Figure 4]	0.109

4.0 ASSUMPTIONS

The following assumptions are used in the evaluation:

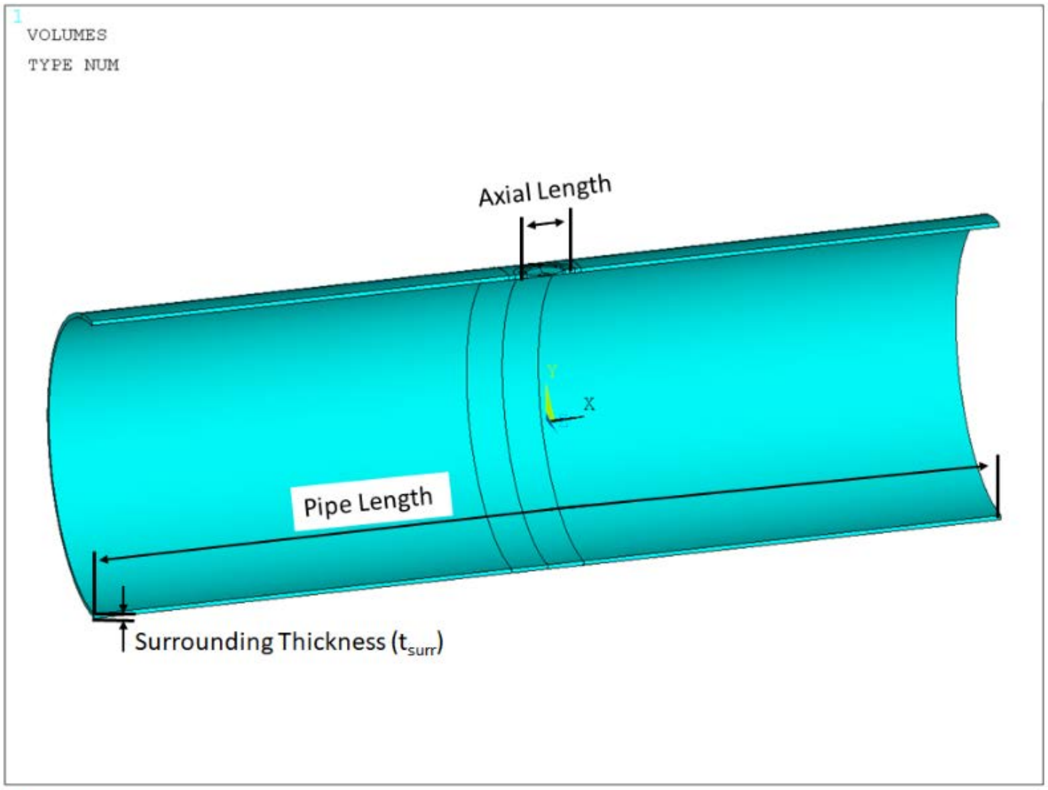
1. Poisson's ratio and density are assumed to be 0.30 and 0.283 lb/in^3, respectively, for carbon steel. These are typical values for carbon steel and do not affect the results of the evaluation.
2. The material of the piping sections included in this evaluation is one of four variants of carbon steel, as described in Section 3.0, and are either welded or seamless. As the exact material is not known, it is conservatively assumed that the material is A-53 Grade A, welded, which has the lowest allowable stress.
3. The minimum temperature at which S_c is taken is assumed to be 70°F. This assumption does not affect the results of the analysis as the minimum allowable stress value given in [6, Appendix A] is applicable up to a temperature of 650°F.
4. Each postulated thinning profile is assumed to be elliptical in shape. Thinning that is bounded by the selected thinning profile may be considered acceptable at the end of the examination interval, assuming potential future degradation is accounted for by the user.
5. All analyses performed herein are for the postulated as-found condition and do not account for additional potential thinning, such as thinning due to corrosion. It is assumed that the user will appropriately account for additional thinning to predict the wall thickness profile at the end of future examination intervals for comparison to the allowable wall thickness profiles determined in this evaluation.
6. The number of thermal expansion cycles is assumed to be low. This is typical for service water Class 3 piping, which does not experience significant thermal transients during operation. The number of thermal expansion cycles is not anticipated to exceed 7,000. Therefore, the stress range reduction factor, f, is assumed to be 1.0 [1, 102.3.2,C].

5.0 FINITE ELEMENT MODEL

Three dimensional (3-D), half-symmetry finite element models (FEMs) are developed for the analysis using the ANSYS finite element analysis program [11]. The half-pipe FEMs are symmetric with a locally thinned elliptical region in the exterior of the pipe. Internal thinning is not postulated in this analysis.

5.1 Geometry and Element Selection

Figure 5 shows the characteristic geometric dimensions for the external thinning models. The 3-D FEMs are constructed using 8-node SOLID45 structural solid elements. Figure 6 and Figure 7 show views of a typical finite element model for external thinning. For the thinning profiles in this evaluation, surrounding thicknesses (wall thickness outside of the locally thinned region) of 0.259 inch, 0.285 inch, and 0.325 inch are used.



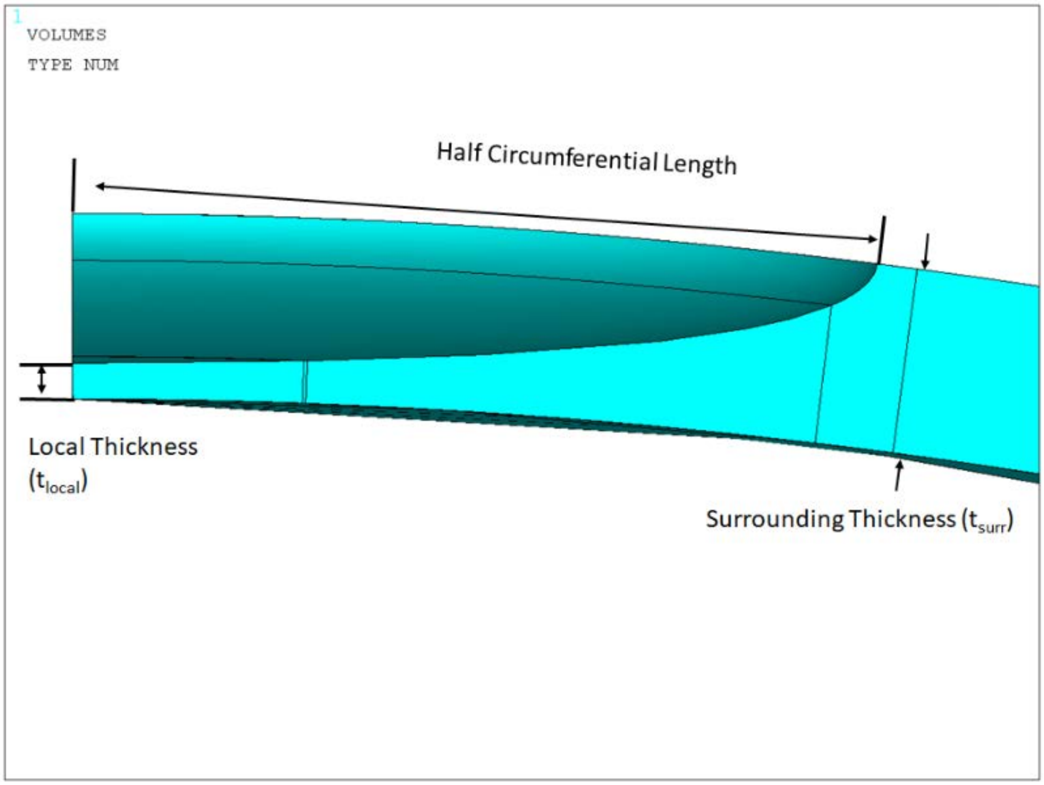


Figure 5. Typical External Thinning Profile Details

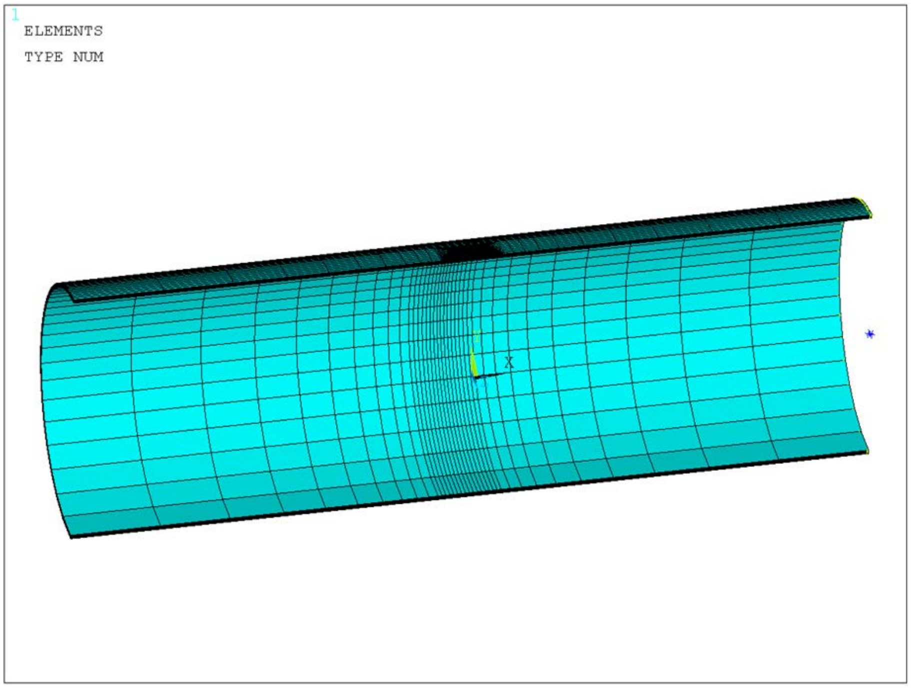


Figure 6. Finite Element Model Geometry, Global

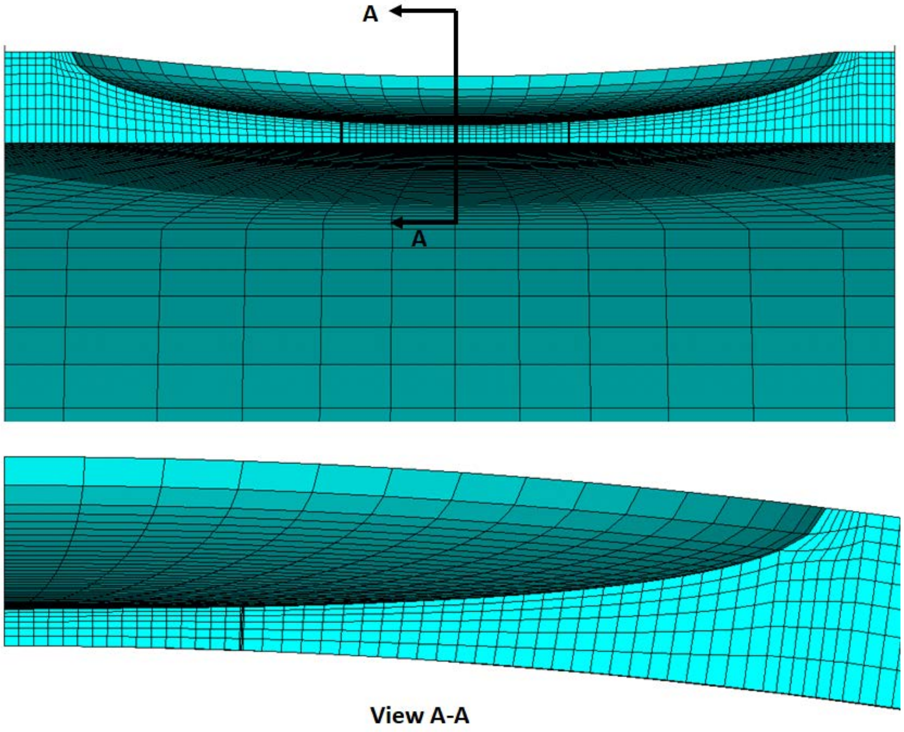


Figure 7. Finite Element Model Geometry, Section View

5.2 Boundary Conditions

Since a 180-degree half-symmetry section of the pipe is modeled, symmetric boundary conditions are applied to the nodes on the longitudinal "cut" plane of the piping. Two conditions of loading are applied to the FEM. One loading evaluates pressure and the other evaluates the piping moment loads.

For the pressure loading application, one end of the pipe is fixed in the axial and circumferential direction. The other end of the pipe has a corresponding cap load, discussed in the following section.

For the application of the moment loads, one end of the pipe is fixed in the axial and circumferential direction. On the other end of the pipe, CONTA175 and TARGE170 ANSYS elements are used for the generation of a pilot node to apply the moment load to the free end of the piping, discussed in the following section. Examples of the boundary conditions applied to the models are shown in Figure 8, Figure 9, and Figure 10.

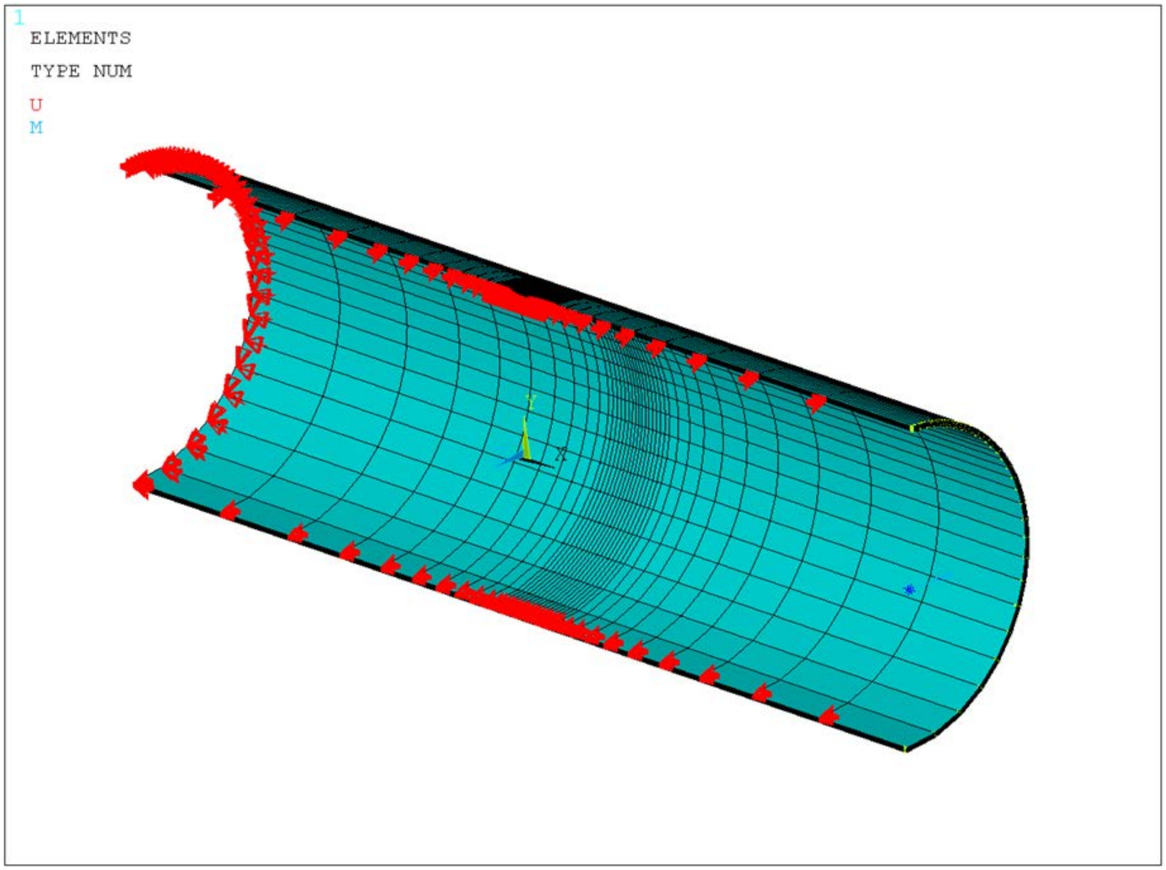


Figure 8. Boundary Conditions Applied to the FEM

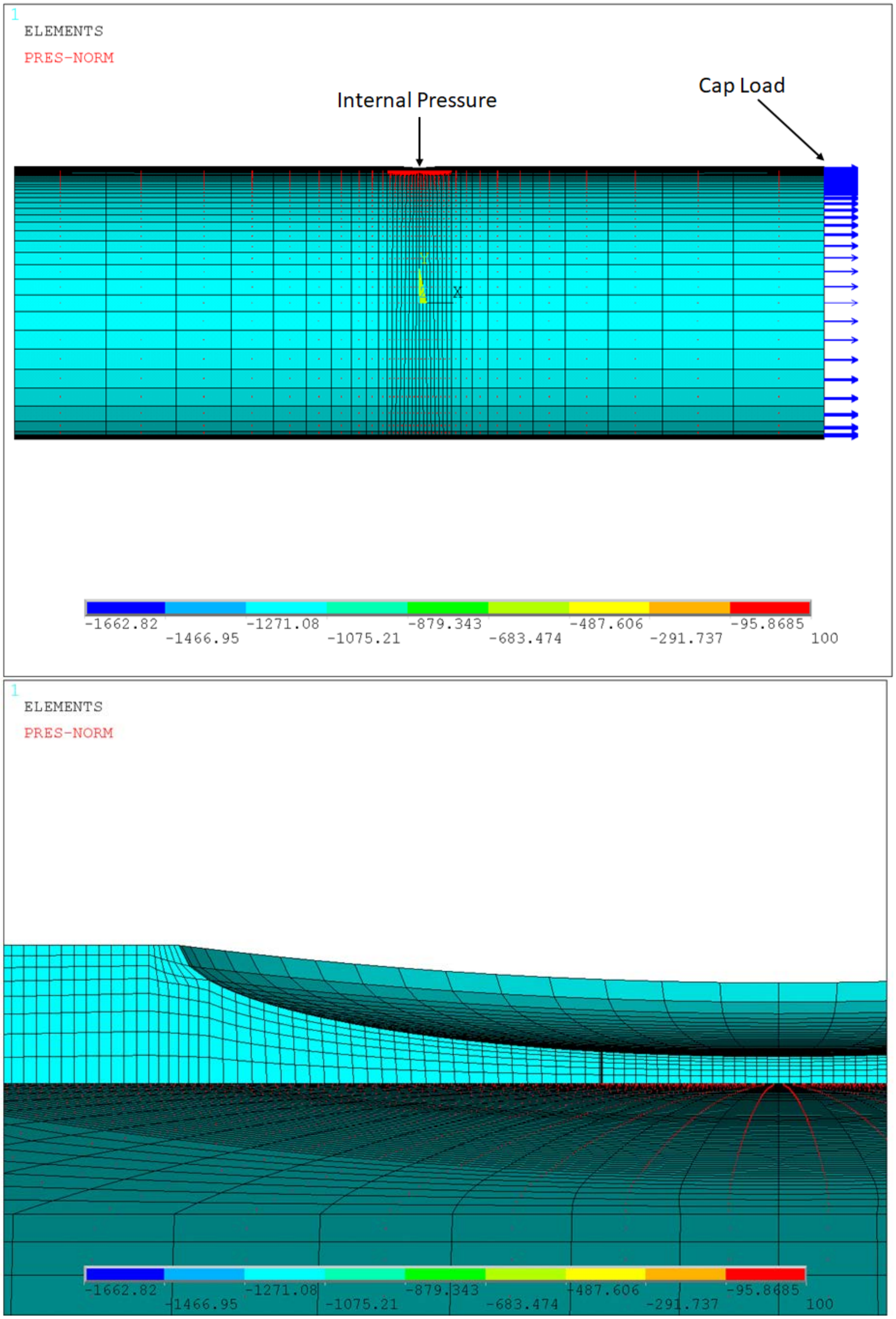


Figure 9. Pressure Load Application

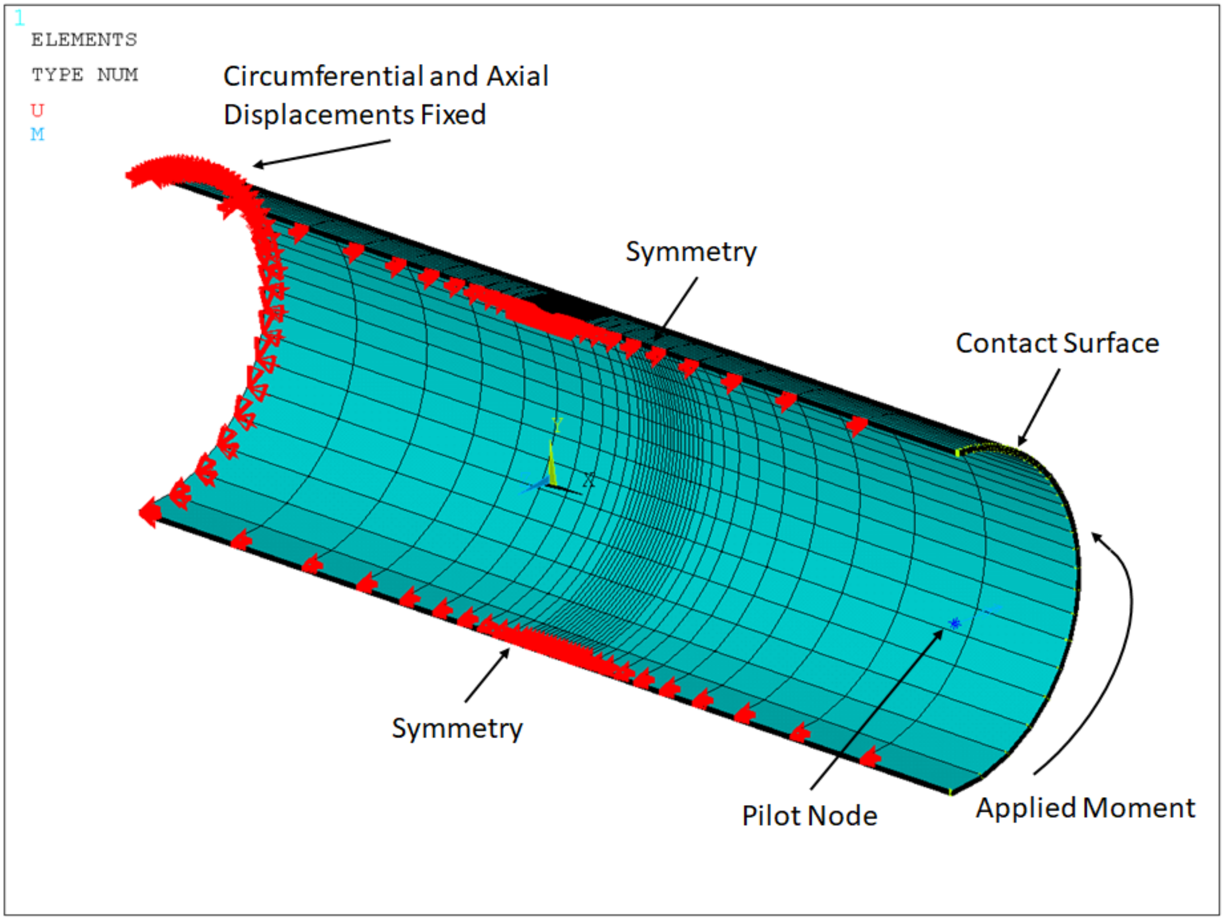


Figure 10. Moment Load Application

5.3 Internal Pressure

A unit pressure of 100 psi is applied to the internal surfaces of the model. An end cap pressure is also applied to the coupled free end of the modeled pipe section to account for the attached piping system. This end cap pressure, $P_{end\text{-}cap}$, is dependent upon the cross-sectional area it acts upon. The cap load is calculated as:

$$P_{end-cap} = \frac{P \times A_{flow}}{A_{wall}}$$

where,

$P_{end\text{-}cap}$ = End cap pressure on pipe free end (psi)
P = Unit Pressure (psi) = 100 psig
A_{flow} = Internal cross-sectional pipe area in which the water flows (in²)
A_{wall} = Cross-sectional area of pipe wall (in²)

Figure 9 depicts an example of the pressure and end cap loads applied to the model.

5.4 Moment Loading

A 1,000 in-lb unit piping interface moment is applied to the free end of the half-symmetry model via a pilot node. The pilot node and moment are applied using the CONTA175 and TARGE170 ANSYS element types. Since only half the piping is modeled, an equivalent unit moment load acting on the full piping model is used when scaling the results (i.e., an equivalent unit moment load of 2,000 in-lb acts on the full piping model). The moment is applied about the ANSYS global Z direction.

Figure 10 shows a typical moment loading case, along with typical boundary conditions discussed previously.

5.5 Mesh Sensitivity Study

In order to assure that the mesh density for the pipe thinning evaluations is sufficient in the region of interest (i.e., the mesh does not influence the analysis results), a mesh sensitivity analysis is performed for each finite element model. The mesh density is doubled in the thinned area and the extracted linearized results due to applied loads are compared. Linearized stress values are extracted through the paths shown in Figure 11 and Figure 12. Comparing the original mesh and the refined mesh for each finite element model, the maximum stress difference is less than 3%. This is judged to be within the accuracy of the finite element model. Thus, the choice of the original mesh is sufficient.

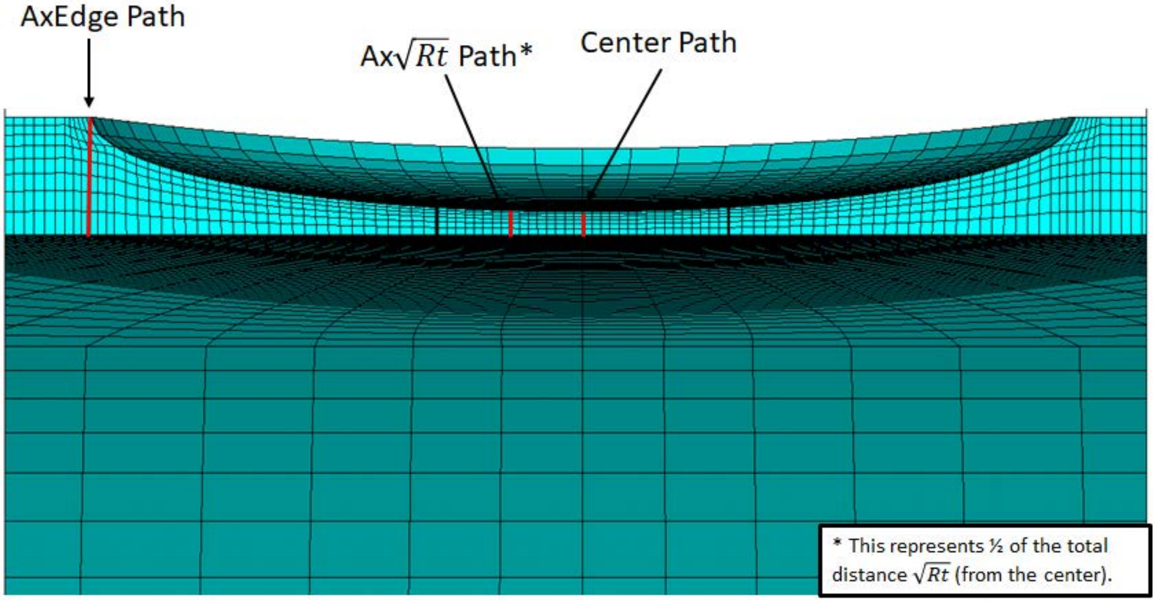
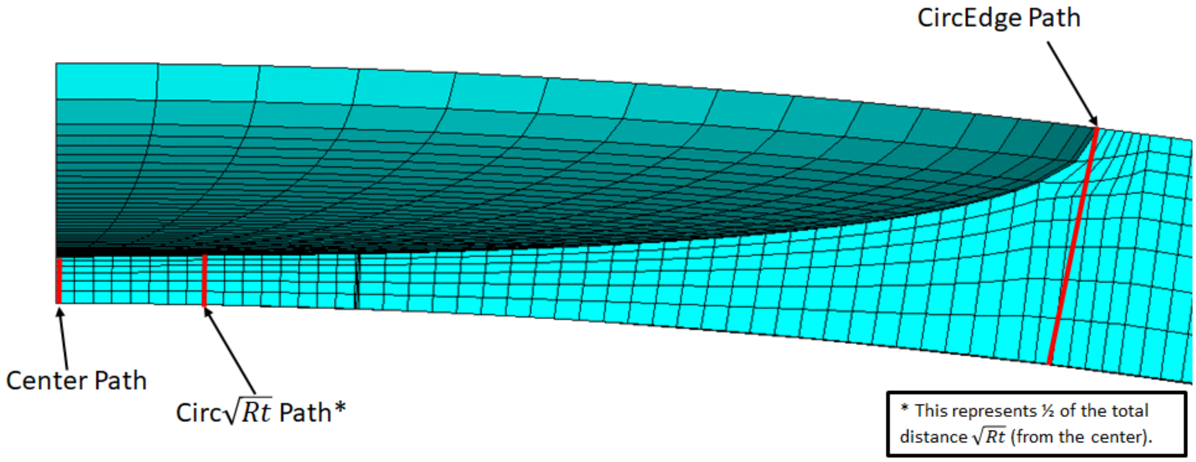


Figure 11. Axial Linearized Stress Paths



* This represents ½ of the total distance $\sqrt{Rt}$ (from the center).

Figure 12. Circumferential Linearized Stress Paths

6.0 CALCULATIONS

Pressure and moment loading stress analyses are performed using ANSYS [11] for the 18-inch CCW piping system with external wall thinning. All ANSYS input files are saved in the supporting files and are described in Appendix A.

6.1 Hoop Stress Evaluation

For the thinned wall hoop stress evaluations, linearized stresses are extracted at the thinnest location, as well as two paths at the edge of the locally-thinned region in the axial and circumferential directions. Linearized stresses at the axial and circumferential $\sqrt{Rt}$ locations are also extracted. Figure 11 and Figure 12 show typical axial and circumferential path locations for linearized stress extraction for the externally thinned model. Figure 13 shows the typical hoop stress contour due to pressure for external thinning. Note that this plot displays the total stress, which includes both the through-thickness bending and peak stresses.

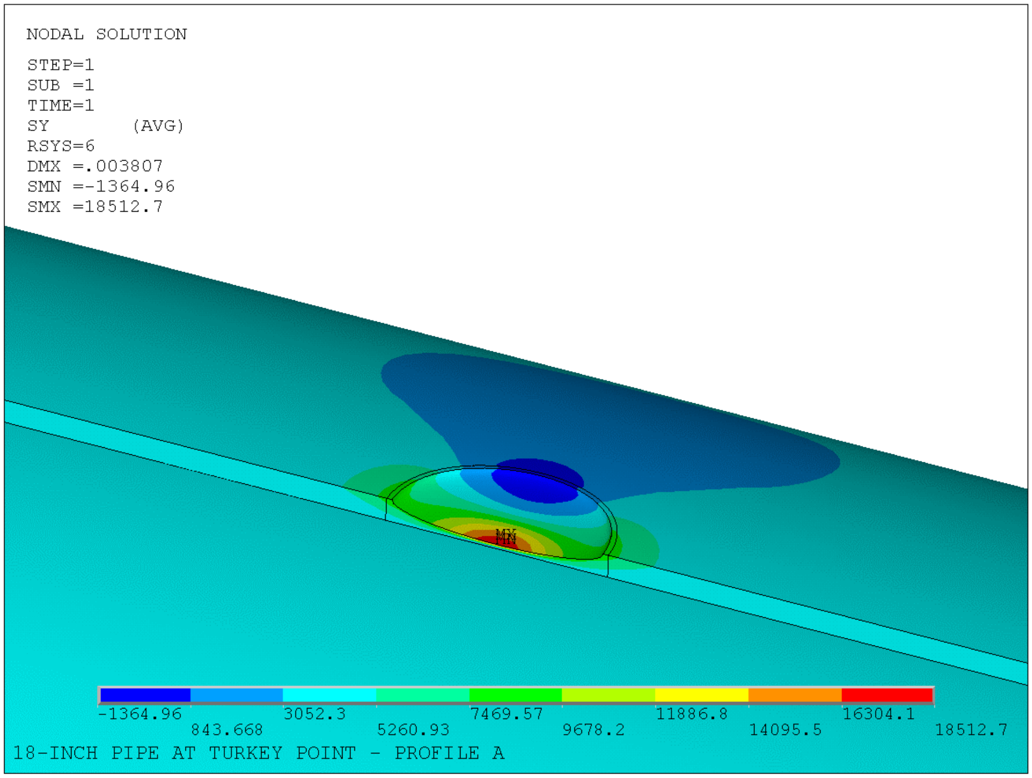


Figure 13. Typical Unit Pressure Hoop Stress Results

The linearized membrane stresses in the hoop direction at each path, for each thinning profile, are scaled by the ratio of the design pressure to the unit pressure, then compared to the allowable hoop stress criteria defined in Section 2.1. As described in Section 2.3, the allowable hoop stress may be increased to 1.5·S over a distance of $\sqrt{Rt}$ for locations associated with non-uniform wall thickness. Beyond the $\sqrt{Rt}$ distance, the allowable stress is 1.0·S. Stress results for the bounding acceptable external thinning profiles are given for the 18-inch CCW piping in Table 3.

6.2 Axial Stress Evaluation

For the thinned wall axial stress evaluations, linearized stresses are extracted as described in Section 6.1. Figure 14 and Figure 15 show the typical axial stress contour for external thinning due to pressure loading and moment loading, respectively. Note that these plots display the total stress, which includes both the through-thickness bending and peak stresses.

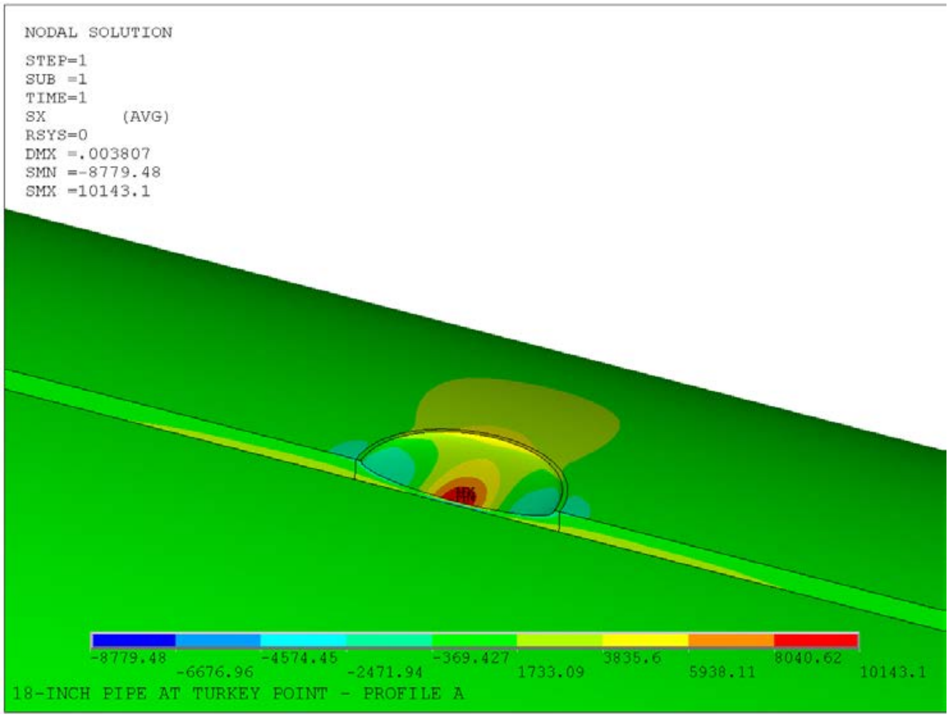


Figure 14. Typical Unit Pressure Axial Stress Results

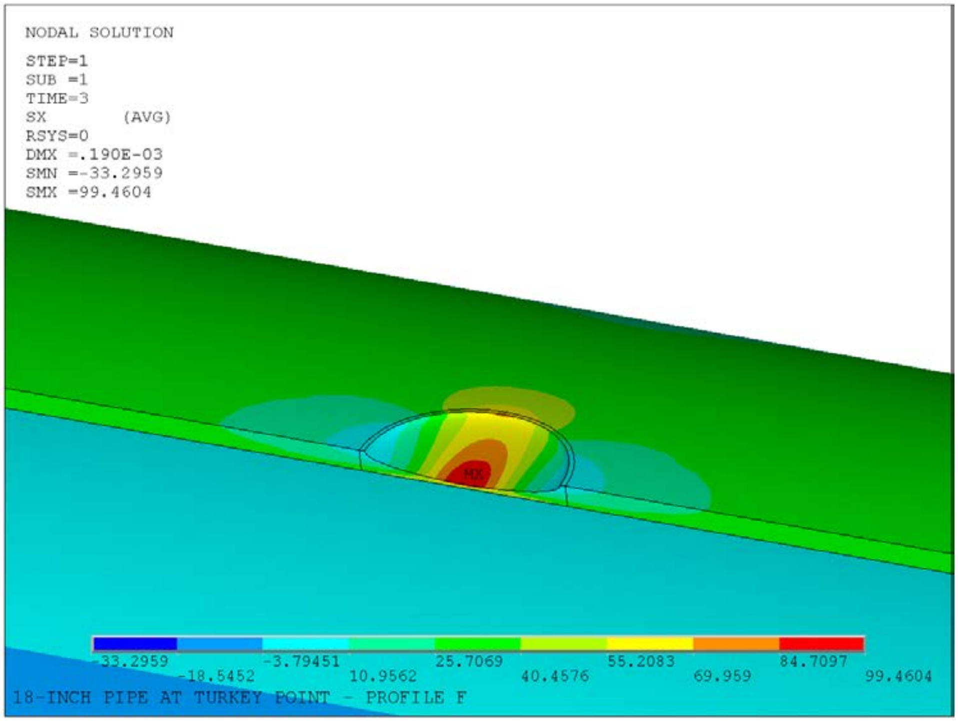


Figure 15. Typical Unit Moment Axial Stress Results

The component axial stresses due to moment loading are scaled by the ratio of the appropriate bounding moment load (See Table 1) to the unit moment load (2,000 in-lbs) and combined with the scaled component axial stresses due to pressure. The resulting axial stresses at each path, for each thinning profile, are compared to the allowable axial stress criteria described in Section 2.2. As described in Section 2.3, the allowable stress may be increased to 1.5·S over a distance of $\sqrt{Rt}$ for locations associated with non-uniform wall thickness. Beyond the $\sqrt{Rt}$ distance, the allowable stress is 1.0·S. Stress results for the bounding acceptable external thinning profiles are given for the 18-inch CCW piping in Table 3.

7.0 RESULTS OF ANALYSIS

The thickness profiles that have been shown to meet the Code of Construction stress limits are given in Table 3 for external thinning.

In order to ensure that observed thinning is bounded by the analyzed thinning, detailed allowable wall thickness profiles are presented in Table 4, Table 5, and Table 6 for external thinning. Due to symmetry of the analyzed thinning, only a quarter of the total thinning profiles are presented. The upper left-hand cell in the tables represents the center of thinning. Figure 16 illustrates how these tables are generated.

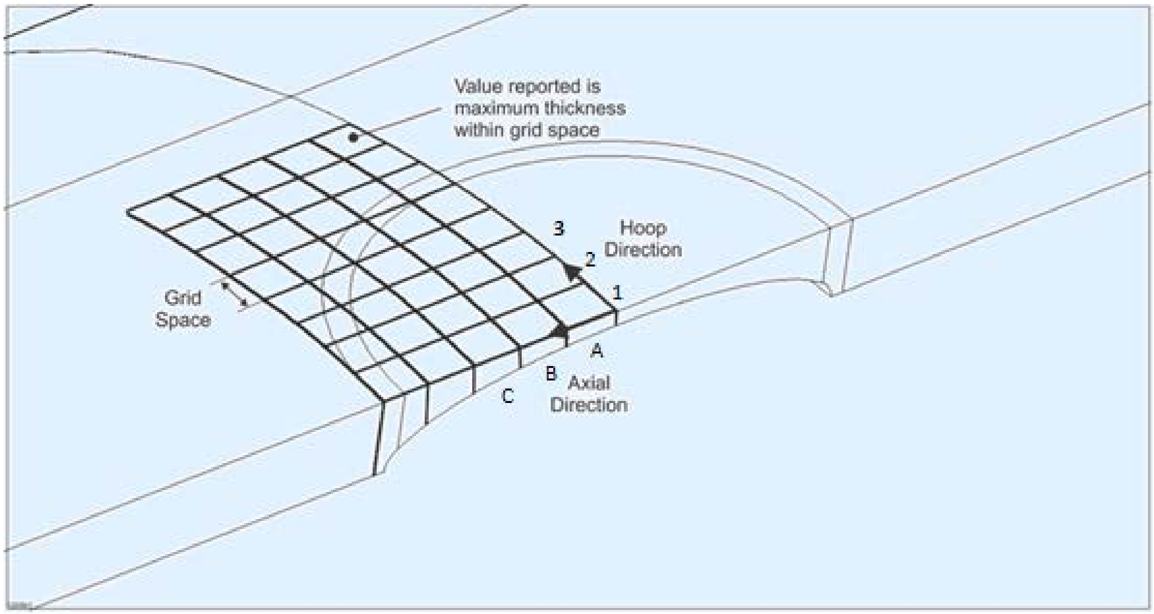


Figure 16. Quarter Model of Thickness Profile with Grid Spacing

Note: Figure 16 shows a model with internal thinning. The grid layout is identical for external thinning

Table 3. Calculated Limiting Stresses for 18-inch CCW Piping with External Thinning

Thinning Profile(1)					Path		Stress (psi)						Allowable Stress (psi)					
Profile Name	Full Axial (in)	Full Circ (in)	t_{surr} (in)	t_{local} (in)	Path Name(2)	ANSYS Nodes (ID/OD)	EQ 3	EQ 11	EQ 12B (OBE)	EQ 12D (SSE)	EQ 13	Local or General Path	EQ 3	EQ 11	EQ 12B (OBE)	EQ 12D (SSE)	EQ 13	Stress Less Than Allowable?
A	2.25	2.25	0.259	0.05	Center	24/1	12694	2191	11432	21815	3258	Local	17550	17550	17550	30000	17550	YES
					AxEdge	9855/9850	9625	1785	5297	9243	1277	General	11700	11700	14040	30000	17550	YES
					$\sqrt{Rt}$ Ax	18/2	11663	2078	8811	16376	2362	General	11700	11700	14040	30000	17550	YES
					$\sqrt{Rt}$ Circ	2941/2944	10942	2681	11107	20575	2969	General	11700	11700	14040	30000	17550	YES
					CircEdge	9911/9906	3433	5461	12168	19705	2392	General	11700	11700	14040	30000	17550	YES
B	2.25	3.5	0.285	0.075	Center	24/1	10987	4520	14741	26227	3701	Local	17550	17550	17550	30000	17550	YES
					AxEdge	9162/9157	7609	1804	5796	10283	1470	General	11700	11700	14040	30000	17550	YES
					$\sqrt{Rt}$ Ax	2920/2925	9763	3577	9978	17172	2261	General	11700	11700	14040	30000	17550	YES
					$\sqrt{Rt}$ Circ	120/136	10430	4502	14006	24687	3352	General	11700	11700	14040	30000	17550	YES
					CircEdge	9218/9213	3942	5116	11208	18053	2187	General	11700	11700	14040	30000	17550	YES
C	3.5	4.25	0.325	0.089	Center	26/1	12257	4678	12428	21136	2772	Local	17550	17550	17550	30000	17550	YES
					AxEdge	11778/11773	6517	1748	5020	8698	1154	General	11700	11700	14040	30000	17550	YES
					$\sqrt{Rt}$ Ax	3754/3755	11271	4171	10609	17844	2266	General	11700	11700	14040	30000	17550	YES
					$\sqrt{Rt}$ Circ	154/170	11681	4562	11840	20018	2563	General	11700	11700	14040	30000	17550	YES
					CircEdge	11846/11841	3756	4170	8712	13817	1622	General	11700	11700	14040	30000	17550	YES

Notes:
1. These dimensions are shown in Figure 5
2. See Figure 11 and Figure 12 for path locations

8.0 GUIDANCE FOR USE

The thinning handbook profiles can be used to justify thinning beyond the applicable minimum thickness screening values presented in Table 2. The wall thickness in the area of observed thinning, minus potential additional thinning occurring through the end of the examination interval, must not be less than the thickness values presented in Table 4, Table 5, and Table 6. The average wall thickness surrounding the localized thinning, minus potential additional thinning occurring through the end of the examination interval, must not be less than the evaluated surrounding thickness, t_{surr}. It is not necessary for the wall thickness in the area of observed thinning to meet the thickness requirements of each of the thinning profiles. If the wall thickness in the area of observed thinning, minus potential additional thinning, is bounded by any of the wall thickness requirements in Table 4, Table 5, or Table 6, the observed thinning may be considered acceptable until the end of the examination interval.

This calculation is applicable to girth welds because the stress intensification factor in the Code of Construction is 1.0 [1]. As a result, welds are treated as base metal and therefore, this calculation is valid for circumferential welds.

8.1 Separation Requirements

If multiple thinned locations are discovered, they must be separated by a sufficient distance in order to ensure that the stress fields do not interact. Based on the definition of local primary membrane stress in NB-3213.10 [3], thinned locations must be separated a distance of $2.5\sqrt{Rt}$. The mean radius, R, and thickness, t, are based on nominal pipe dimensions for the separation requirements. This results in a minimum separation length of 4.54 inches between the edge of adjacent thinned locations. If thinned locations are within $2.5\sqrt{Rt}$ they must be analyzed as a combined single location. If the combined thinning is bounded by at least one of the acceptable thinning profiles, then the combined thinning is considered acceptable for continued operation. If both internal and external wall thinning is observed within $2.5\sqrt{Rt}$, the evaluation herein is not valid. In this situation, a case specific analysis may be performed.

8.2 Sample Step-by-Step Evaluation

This section is intended to be a guided example of potentially discovered thinning. Note that this example does not correspond to actual discovered thinning.

Problem definition:

Localized external thinning is discovered on the 18-inch CCW piping having an axial extent of 2.00 inches, a circumferential extent of 2.00 inches, and a minimum remaining thickness of 0.070 inch. The profile of the thinning is smooth and semi-elliptical in both the axial and circumferential directions. This area of thinning is far from other local thinning and other structural discontinuities. The surrounding thickness is 0.300 inch with an estimated corrosion rate of 0.005 inch/year. If the next inspection is scheduled for one year (i.e., the inspection interval), comment on the acceptability for continued operation.

Step 1:

Identify the current dimensions of the localized thinning. For this example, external corrosion was discovered having an axial extent of 2.00 inches and a circumferential extent of 2.00 inches. The remaining wall thickness at the center of the thinning, which is also the deepest point, is 0.070 inch. This thickness is less than the minimum thickness screening value for uniform thinning as presented in Table 2, therefore, the thinning handbook profiles can be compared to the as-found thinning as a means of disposition.

Step 2:

Confirm that the nearest distance between any adjacent localized thinning is greater than or equal to 2.5 $\sqrt{Rt}$ in the meridional and axial directions. As previously calculated in Section 8.1, 2.5 $\sqrt{Rt}$ = 4.54 inches. If this criterion is not met, adjacent thinning must be analyzed as a single location using a conservative bounding thinning profile. In this example, adjacent thinned locations are far from each other, thereby meeting this criterion.

Step 3:

Identify the future dimensions of the thinning at the next inspection. Considering the corrosion rate of 0.005 inch/year, and the minimum remaining thickness of 0.070 inch, the predicted minimum remaining wall thickness will be 0.065 inch. This process is carried out for each thickness reading within the thinned location. Similarly, the predicted surrounding thickness, t_{surr} is conservatively estimated to be 0.295 inch at the end of the inspection interval. The axial and circumferential lengths are not predicted to grow significantly during the inspection interval.

Step 4:

Evaluate the predicted state of the localized thinning in comparison to the analyzed thinning profiles presented in Table 3. For one of the analyzed thinning profiles to bound the predicted thinning, both the predicted minimum remaining thickness and the predicted surrounding thickness must be greater than those thickness values associated with the evaluated thinning profile. In addition, both the axial and circumferential extents of the localized thinning must be less than those values associated with the analyzed thinning profile. In this case, Profile A appears to bound the predicted thinning and is selected for evaluation in the next step.

Step 5:

Evaluate the predicted state of the localized thinning for acceptance. The predicted thickness profile is compared with the thicknesses shown in Table 4 (for Profile A). Note that the analyzed thicknesses in Table 4 must be mirrored twice in order to perform the comparison as the Table 4 grid is only a quarter of the analyzed thickness profile. In this case, none of the grids in the predicted thickness profile is less than the corresponding grid in Table 4.

Since the criteria in Step 5 are met, the thinning is acceptable until the end of the next inspection schedule.

9.0 CONCLUSIONS

In order to appropriately plan examinations of the 18-inch CCW system at Turkey Point Unit 3, several postulated external thickness profiles are developed, herein, in an attempt to bound potentially thinned locations discovered during examinations (past or future). This evaluation is applicable to the 18-inch CCW straight piping operating at 150 psi highlighted in the isometric drawings shown in Figure 1 through Figure 4.

The analysis shows that the Code of Construction [1] design criteria are met using guidance from NB-3200 [2] for measured external thinning bounded by the profiles in Table 4, Table 5, and Table 6. Thinning (which includes projected additional wear) that is bounded by any one of these profiles may be considered acceptable at the end of the next examination interval.

10.0 REFERENCES

1. American National Standard, ANSI B31.1 - 1973, “Power Piping,” 1973 Edition through the Winter 1976 Addenda.
2. ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Facility Components, 2007 Edition with Addenda through 2008.
3. Enercon Design Information Transmittal, EC 291917, “Input Data for PMCap Design & Fabrication,” SI File No. 1901312.202.
4. Turkey Point Component Cooling Water Piping Isometric Drawings, SI File No. 1901312.205:
    a. 5613-P-612-S Revision 2, sheet 2 of 2
    b. 5613-P-614-S Revision 2, sheet 2 of 3
    c. 5613-P-604-S Revision 1, sheet 2 of 6
    d. 5613-P-604-S Revision 1, sheet 6 of 6
5. SI Data Input Request, 1901312.202, Revision 0, “Turkey Point 18-inch Component Cooling Water External Corrosion Engineering Support,” January 3, 2020.
6. ASME B31.1-2016, “Power Piping,” 2016 Edition.
7. SI Letter Report, 1901312.403, Revision 0, “Technical Basis for Increased Allowable Design Stress,” March 10, 2020.
8. PTN Engineering Design Information Transmittal, AR 01981540, “Heavily Corroded CCW Piping in the 10’ Radioactive Pipeway,” August 8, 2014, SI File No. 1901312.202.
9. Email from J. Milan (FPL) to S. Parker (SI), “RE: Estimated time for SR-GWT Exams,” February 13, 2020, SI File No. 1901312.208.
10. SI Calculation Package, 1400949.302, Revision 0, “Evaluation of Postulated CCW Line Minimum Required Wall Thickness and Through-Wall Flaw in Elbow,” August 12, 2014.
11. ANSYS Mechanical APDL, (UP20170403) and Workbench (March 31, 2017), Release 18.1 SAS IP, Inc.

Table 4. Minimum Thicknesses for 18-inch CCW Piping, External Thinning Profile A - 1/8” Grid

Axial Direction →

Hoop Direction ↓

	A	B	C	D	E	F	G	H	I
1	0.053	0.057	0.063	0.073	0.087	0.105	0.130	0.166	0.259
2	0.057	0.061	0.068	0.078	0.092	0.110	0.136	0.175	0.259
3	0.063	0.068	0.075	0.085	0.100	0.120	0.148	0.193	0.259
4	0.073	0.078	0.085	0.096	0.112	0.134	0.166	0.236	0.259
5	0.087	0.092	0.100	0.112	0.130	0.155	0.198	0.259	0.259
6	0.105	0.110	0.120	0.134	0.155	0.189	0.259	0.259	0.259
7	0.130	0.136	0.148	0.166	0.198	0.259	0.259	0.259	0.259
8	0.166	0.175	0.193	0.236	0.259	0.259	0.259	0.259	0.259
9	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259	0.259

Notes:

1. Allowable thickness profile applicable to 18-inch straight piping in referenced stress report as discussed in Section 3.0.
2. Profile consists of 1/8” x 1/8” grid spacing (See Figure 16).

Table 5. Minimum Thicknesses for 18-inch CCW Piping, External Thinning Profile B - 1/8" Grid

Axial Direction →

Hoop Direction ↓

	A	B	C	D	E	F	G	H	I
1	0.077	0.081	0.088	0.097	0.111	0.129	0.154	0.190	0.285
2	0.078	0.082	0.089	0.099	0.113	0.131	0.156	0.194	0.285
3	0.081	0.085	0.092	0.102	0.116	0.135	0.161	0.200	0.285
4	0.085	0.089	0.096	0.107	0.121	0.140	0.167	0.210	0.285
5	0.090	0.094	0.102	0.112	0.127	0.148	0.176	0.225	0.285
6	0.097	0.101	0.109	0.120	0.135	0.157	0.188	0.251	0.285
7	0.105	0.109	0.117	0.129	0.145	0.169	0.205	0.285	0.285
8	0.114	0.119	0.128	0.140	0.158	0.185	0.230	0.285	0.285
9	0.126	0.131	0.140	0.154	0.174	0.206	0.285	0.285	0.285
10	0.140	0.146	0.156	0.171	0.196	0.240	0.285	0.285	0.285
11	0.157	0.164	0.176	0.195	0.228	0.285	0.285	0.285	0.285
12	0.179	0.187	0.203	0.230	0.285	0.285	0.285	0.285	0.285
13	0.211	0.223	0.251	0.285	0.285	0.285	0.285	0.285	0.285
14	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285	0.285

Notes:

1. Allowable thickness profile applicable to 18-inch straight piping in referenced stress report as discussed in Section 4.0.
2. Profile consists of 1/8" x 1/8" grid spacing (See Figure 16).

Table 6. Minimum Thicknesses for 18-inch CCW Piping, External Thinning Profile C - 1/8” Grid

Axial Direction →

Hoop Direction ↓

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	0.090	0.092	0.095	0.099	0.105	0.112	0.121	0.132	0.145	0.160	0.180	0.204	0.239	0.325
2	0.091	0.093	0.096	0.101	0.106	0.114	0.123	0.133	0.146	0.162	0.182	0.207	0.242	0.325
3	0.093	0.095	0.098	0.103	0.109	0.116	0.125	0.136	0.149	0.165	0.185	0.211	0.248	0.325
4	0.096	0.098	0.101	0.106	0.112	0.119	0.128	0.139	0.153	0.169	0.190	0.217	0.257	0.325
5	0.100	0.102	0.105	0.110	0.116	0.123	0.133	0.144	0.158	0.175	0.197	0.225	0.272	0.325
6	0.105	0.107	0.110	0.115	0.121	0.129	0.138	0.150	0.165	0.182	0.205	0.236	0.298	0.325
7	0.111	0.113	0.116	0.121	0.127	0.135	0.145	0.157	0.173	0.191	0.216	0.252	0.325	0.325
8	0.117	0.120	0.123	0.128	0.135	0.143	0.153	0.166	0.182	0.203	0.230	0.276	0.325	0.325
9	0.125	0.128	0.131	0.136	0.143	0.152	0.163	0.177	0.194	0.217	0.249	0.325	0.325	0.325
10	0.135	0.137	0.141	0.146	0.154	0.163	0.175	0.190	0.209	0.236	0.280	0.325	0.325	0.325
11	0.146	0.148	0.152	0.158	0.166	0.176	0.189	0.206	0.228	0.262	0.325	0.325	0.325	0.325
12	0.159	0.161	0.166	0.172	0.181	0.192	0.207	0.226	0.255	0.325	0.325	0.325	0.325	0.325
13	0.174	0.177	0.182	0.189	0.198	0.211	0.229	0.255	0.315	0.325	0.325	0.325	0.325	0.325
14	0.192	0.195	0.201	0.209	0.221	0.237	0.262	0.325	0.325	0.325	0.325	0.325	0.325	0.325
15	0.215	0.219	0.226	0.237	0.253	0.279	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325
16	0.247	0.253	0.263	0.282	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325
17	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325	0.325

Notes:

1. Allowable thickness profile applicable to 18-inch straight piping in referenced stress report as discussed in Section 4.0.
2. Profile consists of 1/8” x 1/8” grid spacing (See Figure 16).

APPENDIX A

COMPUTER FILES

The following files were created for this calculation:

ANSYS Input Files

TP-18-inch_Profile_A.inp	- Input deck that calculates pressure and moment linearized stresses for the 18-inch CCW piping with external thinning (Profile A, t_{surr} = 0.259”, t_{local} = 0.05”)
TP-18-inch_Profile_B.inp	- Input deck that calculates pressure and moment linearized stresses for the 18-inch CCW piping with external thinning (Profile B, t_{surr} = 0.285”, t_{local} = 0.075”)
TP-18-inch_Profile_C.inp	- Input deck that calculates pressure and moment linearized stresses for the 18-inch CCW piping with external thinning (Profile C, t_{surr} = 0.325”, t_{local} = 0.089”)

ANSYS Output Files

One set of the following files for each thickness profile, where ### is the surrounding thickness:

CenterPath_18_0.###_0.txt	- Output file containing pressure and moment load linearized stress results for the externally thinned piping, Center path
CircEdgePath_18_0.###_0.txt	- Output file containing pressure and moment load linearized stress results for the externally thinned piping, CircEdge path
CircROOTrtPath_18_0.###_0.txt	- Output file containing pressure and moment load linearized stress results for the externally thinned piping, Circ $\sqrt{Rt}$ path
EdgePath_18_0.###_0.txt	- Output file containing pressure and moment load linearized stress results for the externally thinned piping, AxEdge path
ROOTrtPath_18_0.###_0.txt	- Output file containing pressure and moment load linearized stress results for the externally thinned piping, Axial $\sqrt{Rt}$

Structural Integrity Associates, Inc.®

CALCULATION PACKAGE

File No.: 1400949.301

Project No.: 2000327
Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Turkey Point U3 CCW 513-3 Evaluation

CONTRACT NO.:
2410713

CLIENT:
Florida Power & Light

PLANT:
Turkey Point Nuclear Plant, Unit 3

CALCULATION TITLE:
Evaluation of Postulated CCW Line Through-Wall Flaw

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
1	1 - 13	Incorporated higher material toughness and various updates	Stephen M Parker Stephen Parker 4/7/30	Eric Houston 4/7/20 Stephen M Parker Stephen Parker 4/7/30
0	1-12	Initial Issue	Eric J. Houston [EJH] 8/12/14	Eric J. Houston [EJH] 8/12/14 Shawn M. McFarland [SMM] 8/12/14

Table of Contents

1.0 INTRODUCTION 3
2.0 TECHNICAL APPROACH 3
3.0 DESIGN INPUTS AND ASSUMPTIONS 3
4.0 CALCULATIONS..4
  4.1 Applied Loads..5
  4.2 Stress Intensity Factor Calculations..5
  4.3 Critical Fracture Toughness Determination..6
5.0 RESULTS..7
6.0 CONCLUSIONS 7
7.0 REFERENCES 8

List of Tables

Table 1: Applied Moment Loading 10
Table 2: Axial and Circumferential Structural Factors [3]..10
Table 3: Load Combinations for Circumferential Flaw Analyses..10
Table 4: Allowable Through-Wall Flaw Lengths, Supply Headers U3 11
Table 5: Allowable Through-Wall Flaw Lengths, Return Headers U3..12
Table 6: Pressure Blowout Check..13

1.0 INTRODUCTION

Turkey Point Unit 3 has identified external corrosion on each train of the Component Cooling Water (CCW) System supply and return headers. The 18-inch carbon steel lines are safety related ANSI B31.1 piping. However, the safety significance and quality class of ANSI B31.1 piping at Turkey Point, Unit 3 is equivalent to ASME Code, Section III, Class 3 piping at later vintage plants [18, 19, 20]. Thus, in this analysis, the CCW piping is treated as ASME Code, Section III, Class 3 piping. The objective of this calculation is to determine the allowable through-wall flaw lengths in accordance with ASME Code Case N-513-3 [1].

2.0 TECHNICAL APPROACH

The flaw evaluation herein is based on the criteria prescribed in ASME Code Case N-513-3. This Code Case allows for the temporary acceptance of through-wall flaws in moderate energy Class 2 or Class 3 piping. N-513-3 has been conditionally accepted by the NRC with the stipulation that, “The repair or replacement activity temporarily deferred under the provisions of this Code Case shall be performed during the next scheduled outage,” and is published in Regulatory Guide 1.147, Revision 18 [2]. N-513-3 allows non-planar, through-wall flaws to be characterized and evaluated as planar (i.e., crack-like), through-wall flaws in the axial and circumferential directions.

Code Case N-513-3 evaluation criteria rely on the methods given in ASME Section XI, Appendix C [3]. Linear Elastic Fracture Mechanics (LEFM) criteria are conservatively employed as described in Article C-7000. Equations for through-wall stress intensity factor parameters F_m, F_b and F are given in the appendix to the Code Case, although the Code Case allows for alternate stress intensity factor parameters to be used. For circumferential through-wall flaws, the Code Case stress intensity factor parameters are valid over a range of mean pipe radius to thickness (R_m/t) ratios from 5 to 20 and become increasingly conservative for $R_m/t>20$. Takahashi has proposed alternate stress intensity factor parameters, which are valid over the range of 1.5 to 80.5 [4]. Since the R_m/t ratios in the present analysis are greater than 20, the Takahashi parameters are appropriate to use. Therefore, for the circumferential through-wall analysis, the Takahashi stress intensity factor parameters are used in place of the Code Case stress intensity factor parameters. Axial through-wall flaws are evaluated using the stress intensity factor parameter from the Code Case, Appendix I.

Allowable flaw lengths are determined through iteration comparing calculated stress intensity factors to a critical fracture toughness defined in C-7200 of Section XI, Appendix C.

3.0 DESIGN INPUTS AND ASSUMPTIONS

For Turkey Point, the original piping Construction Code was ASA B31.1-1955. However, ANSI B31.1, 1973 Edition with Addenda through winter 1976 [5] is used for piping analysis at Turkey Point [21].

The following design inputs are used in this calculation:

1. Material type = A-53, Grade A or B and A-106 Grade A or B [7, See Assumption 1]

2. Outside diameter = 18 inches (based on standard pipe size) [8, 9, 10]
3. Nominal wall thickness = 0.375 inch [11, Appendix D, Page 7 of 28]
4. Design pressure = 150 psig [7]
5. Design temperature = 200°F [7]
6. Material stress allowable = 11.7 ksi [12]
    - The allowable stress is taken from a later Code edition as discussed in [13]
7. Material yield strength = 30 ksi for Grade A Carbon Steel (See Assumption 1) [13]
8. Young's modulus = 27,700 ksi [5, Table C-1 at 200°F]

The design stress report [14] applicable to the inspection locations for Turkey Point Unit 3 is examined to pull the respective moments used in Equations 11, 12, and 13. The maximum combined moment for a given node is used for this evaluation and is provided in Table 1. The design stress report only provides information for occasional moment loads due to SSE loading. Per guidance from FPL, the moment loading for OBE loading is conservatively assumed to be equal to the SSE moments divided by 2 [15].

Determination of the fracture toughness, J_{IC}, used in the evaluation is based on Section XI, Appendix C, C-8320 [3], which specifies that "reasonable lower bound fracture toughness data" may be used to determine the allowable stress intensity factor, K_{Ic}. Beginning with the 2013 Edition, Section XI, Appendix C contains additional guidance for the temperature for the onset of upper-shelf behavior [16, Table C-8321-2]. Note that the NRC has approved the 2013 Edition of Section XI, Appendix C without exception [17]. Based on the guidance in [16, Table C-8321-2], upper shelf material toughness is expected at temperatures greater than 49°F for wall thicknesses less than or equal to 0.375-inch. Therefore, J_{IC} is taken as 350 in-lb/in^2 for the circumferential direction [3, Table C-8321-1] and 300 in-lb/in^2 for the axial direction [3, Table C-8322-1].

The following assumptions are used in this calculation:

1. The material of the piping sections included in this evaluation is one of four variants of carbon steel, as described above, and are either welded or seamless. As the exact material is not known, it is conservatively assumed that the material is A-53 Grade A, welded, which has the lowest allowable stress.
2. Poisson's ratio is assumed to be 0.3.
3. Potential weld residual stress is assumed to be relieved as material is removed through the corrosion process.
4. A corrosion allowance is not considered (the ongoing inspection requirements in Code Case N-513-3 address the possibility of flaw growth during the temporary acceptance period).

4.0 CALCULATIONS

The applied stresses and resulting stress intensity factors are evaluated over a range of surrounding wall thicknesses.

4.1 Applied Loads

Axial and circumferential (i.e., hoop) stresses are calculated from the bounding moment loads in Table 1 and the design pressure. The surrounding wall thickness, t_{adj}, is used to determine the section properties. Because the thinning is externally initiated, the outside diameter is taken as the thinned diameter (i.e., the evaluated outside diameter is less than the nominal outside diameter). The axial membrane pressure stress, σ_m, may be determined from:

$$\sigma_m = \frac{pD_o}{4t_{adj}}$$

where:

p = internal design pressure, psig
D_o = outside diameter, in
t_{adj} = wall thickness, in

The bending stress, σ_b, may be determined from:

$$\sigma_b = \frac{M}{Z}$$

$$Z = \frac{\pi}{4}\frac{R_o^4 - R_i^4}{R_o}$$

where:

M = bending moment, in-lbs
Z = section modulus, in^3
R_o = outside radius, in
R_i = inside radius, in

Hoop stress, σ_h, due to internal design pressure may be determined from:

$$\sigma_h = \left(\frac{pD_o}{2t_{adj}}\right)$$

4.2 Stress Intensity Factor Calculations

For LEFM analysis, the stress intensity factor, K_I, for an axial flaw is taken from Article C-7000 [3] as prescribed by N-513-3 and is given below:

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

where:

$K_{Im} = (SF_m)F\sigma_h(\pi a/Q)^{0.5}$
SF_m = structural factor for membrane stress (see Table 2)
F = through-wall stress intensity factor parameters for an axial flaw under hoop stress (given in Appendix I of N-513-3)
σ_h = hoop stress, ksi
a = flaw depth (taken as half flaw length for through-wall flaw per Appendix I of N-513-3), in
Q = flaw shape parameter (unity per Appendix I of N-513-3)
K_{Ir} = K_I from residual stresses at flaw location (assumed negligible).

For LEFM analysis, the stress intensity factor, K_I, for a circumferential flaw is taken from Article C-7000 [3] as prescribed by N-513-3 and is given below:

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

where:
$K_{Im} = (SF_m)F_m\sigma_m(\pi a)^{0.5}$
F_m = through-wall stress intensity factor parameters for a circumferential flaw under membrane stress [4]
σ_m = membrane stress, ksi
$K_{Ib} = [(SF_b)\sigma_b + \sigma_e]F_b(\pi a)^{0.5}$
SF_b = structural factor for bending stress (see Table 2)
σ_b = bending stress, ksi
σ_e = thermal stress, ksi
F_b = through-wall stress intensity factor parameters for a circumferential flaw under bending stress [4].

Note that the through-wall flaw stress intensity factor parameters are a function of flaw length.

Table 3 shows the specific load combinations considered herein for the allowable circumferential flaw calculations. Note that SSE is conservatively evaluated using Service Level C structural factors. Thus, Service Level D is not evaluated.

4.3 Critical Fracture Toughness Determination

For LEFM analysis, the static fracture toughness for crack initiation under plane strain conditions, K_{Ic}, is taken from Article C-7000 [3] as prescribed by N-513-3 and is given below:

$$K_{Ic} = \sqrt{\frac{J_{Ic}E'}{1000}}$$

where:
J_{Ic} = material toughness, in-lb/in^2
$E' = E/(1-\nu^2)$
E = Young’s modulus, ksi
ν = Poisson’s ratio.

Based on the design input listed above, K_{Ic} = 95.6 ksi-in$^{0.5}$ for axial flaws and K_{Ic} = 103.2 ksi-in$^{0.5}$ for circumferential flaws. The allowable flaw lengths are determined iteratively by increasing flaw length until the stress intensity factor is equal to the static fracture toughness.

5.0 RESULTS

The bounding moments for each train, shown in Table 1, are used in the evaluation. Table 4 shows the allowable through-wall flaw lengths for the Unit 3 supply headers. Table 5 shows the allowable through-wall flaw lengths results for the Unit 3 return headers.

Code Case N-513-3, Paragraph 3.2(d) requires that the remaining ligament average thickness over the degraded area be sufficient to resist pressure blowout [1, Equation 9]. Table 6 shows the required average thickness, $t_{c,avg}$, as a function of the equivalent diameter of the circular region, d_{adj}, for which the wall thickness is less than t_{adj}.

6.0 CONCLUSIONS

Turkey Point Unit 3 has identified external corrosion on each train of the Component Cooling Water (CCW) System supply and return headers. Allowable through-wall flaw lengths have been calculated in accordance with ASME Code Case N-513-3 for Unit 3 CCW piping. Code Case N-513-3 has been conditionally accepted by the NRC in RG 1.147.

Table 4 shows the allowable through-wall flaw lengths for the Unit 3 supply headers, Train A and Train B. Table 5 shows the allowable through-wall flaw lengths results for the Unit 3 return headers, Train A and Train B. Table 6 shows the requirements to resist pressure blowout.

7.0 REFERENCES

1. ASME 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.
2. Regulatory Guide 1.147, “Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1,” Revision 18, Nuclear Regulatory Commission, March, 2017.
3. ASME Boiler and Pressure Vessel Code, Section XI, Appendix C, 2007 Edition with 2008 Addenda.
4. Y. Takahashi, “Evaluation of Leak-Before-Break Assessment Methodology for Pipes With a Circumferential Through-Wall Crack. Part I: Stress Intensity Factor and Limit Load Solutions,” International Journal of Pressure Vessels and Piping, 79, 2002, pp. 385-392, SI File No. 0801508.204.
5. ANSI B31.1 “Power Piping,” 1973 Edition with Addenda through winter 1976.
6. FPL Document No. EC-249147, Revision 0, “Component Cooling Water (CCW) Pipe Supports,” SI File No. 1400949.202.
7. SI Data Input Request, 1901312.202, Revision 0, “Turkey Point 18-inch Component Cooling Water External Corrosion Engineering Support,” January 3, 2020.
8. FPL Drawing No. 5613-P-612-S, Sheet 2 of 2, Revision 2, “Turkey Point Nuclear Power Plant Unit 3 Component Cooling Water System, System No. 30 Outside Containment Stress Problem CCW-01,” SI File No. 1400949.201.
9. FPL Drawing No. 5613-P-614-S, Sheet 2 of 3, Revision 2, “Turkey Point Nuclear Power Plant Unit 3 Component Cooling Water System, System No. 30 Outside Containment Stress Problem CCW-27,” SI File No. 1400949.201.
10. FPL Drawing No. 5613-P-604-S, Sheets 2 and 6 of 6, Revision 1, “Turkey Point Nuclear Power Plant Unit 3 Component Cooling Water System, System No. 30 Outside Containment Stress Problem 038,” SI File No. 1400949.201.
11. Turkey Point Specification No. MN-3.11, Revision 18, “Piping Class Sheets,” SI File No. 1400949.202.
12. ASME B31.1-2016, “Power Piping,” 2016 Edition.
13. SI Letter Report, 1901312.403, Revision 0, “Technical Basis for Increased Allowable Design Stress,” March 10, 2020.
14. PTN Engineering Design Information Transmittal, AR 01981540, “Heavily Corroded CCW Piping in the 10’ Radioactive Pipeway,” August 8, 2014, SI File No. 1901312.202.
15. Email from J. Millan (FPL) to S. Parker (SI), “RE: Estimated time for SR-GWT Exams,” February 13, 2020, SI File No. 1901312.208.
16. ASME Boiler and Pressure Vessel Code, Section XI, Appendix C, 2013 Edition.

17. Code of Federal Regulations, 10CFR 50.55a, Codes and standards, (December 30, 2019).
18. Regulatory Guide 1.26, “Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants,” Revision 3, Nuclear Regulatory Commission, February 1976.
19. NextEra Energy Engineering Design Standard, STD-M-027, Rev. 6, “ASME Section XI Repair and Replacement,” SI File No. 2000327.206.
20. Turkey Point, Unit 3 UFSAR, Section 1.1.4, SI File No. 2000327.211.
21. FPL Standard CN-3.01, Revision 3, “Piping and Support Analysis Requirements, Turkey Point Units 3 & 4,” SI File No. 2000327.206.

Table 1: Applied Moment Loading

Line, Train, Unit	Bounding Stress Problem / Node	Deadweight [in-lbs]	Thermal [in-lbs]	OBE [in-lbs]	SSE [in-lbs]
CCW Supply U3	Problem 37, 38, CCW-12 Node 48B	11,029	33,603	96,738	193,477
CCW Return U3	Problem CCW-27 Node 122B	13,008	65,574	69,765	139,530

Table 2: Axial and Circumferential Structural Factors [3]

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

Table 3: Load Combinations for Circumferential Flaw Analyses

Load Combination	Service Level
P+DW+TH	A
P+DW+TH+OBE	B
P+DW+TH+SSE	C

Table 4: Allowable Through-Wall Flaw Lengths, Supply Headers U3

t_{adj} [in]	Allowable Axial Through-Wall Flaw [in]	Allowable Circumferential Through-Wall Flaw [in]
0.375	8.4	18.8
0.365	8.2	18.4
0.355	7.9	18.0
0.345	7.7	17.5
0.335	7.5	17.1
0.325	7.2	16.6
0.315	7.0	16.2
0.305	6.7	15.7
0.295	6.5	15.2
0.285	6.2	14.7
0.275	6.0	14.2
0.265	5.8	13.7
0.255	5.5	13.2
0.245	5.3	12.7
0.235	5.0	12.1
0.225	4.8	11.6
0.215	4.6	11.1
0.205	4.3	10.5
0.195	4.1	10.0
0.185	3.9	9.4
0.175	3.6	8.8
0.165	3.4	8.3
0.155	3.1	7.7
0.145	2.9	7.1
0.135	2.7	6.5
0.125	2.4	5.9
0.115	2.2	5.3
0.105	2.0	4.7
0.095	1.8	4.1
0.085	1.5	3.5
0.075	1.3	2.9

Table 5: Allowable Through-Wall Flaw Lengths, Return Headers U3

t_{adj} [in]	Allowable Axial Through-Wall Flaw [in]	Allowable Circumferential Through-Wall Flaw [in]
0.375	8.4	19.1
0.365	8.2	18.7
0.355	7.9	18.3
0.345	7.7	17.9
0.335	7.5	17.4
0.325	7.2	17.0
0.315	7.0	16.5
0.305	6.7	16.0
0.295	6.5	15.6
0.285	6.2	15.1
0.275	6.0	14.6
0.265	5.8	14.1
0.255	5.5	13.5
0.245	5.3	13.0
0.235	5.0	12.5
0.225	4.8	12.0
0.215	4.6	11.4
0.205	4.3	10.9
0.195	4.1	10.3
0.185	3.9	9.7
0.175	3.6	9.2
0.165	3.4	8.6
0.155	3.1	8.0
0.145	2.9	7.4
0.135	2.7	6.8
0.125	2.4	6.2
0.115	2.2	5.6
0.105	2.0	5.0
0.095	1.8	4.4
0.085	1.5	3.7
0.075	1.3	3.1

Table 6: Pressure Blowout Check

d_{adj} [in]	$t_{c,avg}$ [in]
0.25	0.01
0.50	0.02
0.75	0.03
1.00	0.04
1.25	0.05
1.50	0.06
1.75	0.07
2.00	0.08
2.25	0.09
2.50	0.10
2.75	0.11
3.00	0.12
3.25	0.13
3.50	0.14
3.75	0.15
4.00	0.16
4.25	0.17
4.50	0.18
4.75	0.19
5.00	0.20

If the pipe IS leaking:

Purpose of NDE

Obtain sufficient data to meet requirements of Code Case N-513-3 for past operability and demonstrate operability to move into Mode 4 and 3, even if relief request hasn't been approved or if PMCap installation is not complete.

- Characterize the flaw by direct measurement
- Inspect full circumference at the flaw location and characterize the length and depth of all flaws in the pipe section.
- If multiple flaws are detected, obtain sufficient data for analysis to account for multiple flaws.

Extent of NDE (Figure 2)

1. NDE inspector identify any areas that require specific cautions when performing surface prep and mark areas avoid with a pipe marker.
2. NDE inspector mark pipe 2" above and 2" below area where concrete slab had been for extent of prep area (nominally 12" apart)
3. BHI will clean / prep the areas of pipe as identified by NDE following any special precautions set by NDE.
    a. If during surface prep it appears cleaning may compromise the integrity of the pipe, STOP and notify Eng. / NDE.
4. NDE inspector perform visual inspection and scan edges of prep area to confirm that the prep area encompasses all areas of degraded pipe surface (above 0.195").
5. IF the surface prep area does not encompass the degraded areas, THEN NDE to provide direction to BHI for guidance to expand the surface prep area.
6. BHI will perform surface prep sufficient for UT around entire circumference of pipe between the markings.
7. BHI to perform surface prep sufficient for UT in regions of location where PMCap will be welded to the CCW pipe.
8. Perform UT per following plan. Steps may be performed out of sequence at discretion of inspector or craft.
    a. Grid pipe in 2" x 2" gridlines
    b. Perform 100% scan and record minimum wall thickness within each 2"x2" square.
    c. If any squares have readings less than 0.115", then mark location and record minimum thickness within each square.
    d. Perform UT scan to identify extent of wall thickness less than 0.115" and measure La and Lc per Figure 2.
    e. For each 2"x2" square with a minimum thickness less than 0.115", record wall thickness 0.5" away in both axial directions and 0.5" away in both circumferential directions (reference Figure 2).
    f. NDE inspector characterize through-wall leak area by direct measurement of the projection in both the axial (La) and circumferential (Lc) directions.
    g. Measure distance from edge of each area less than 0.115" (L_{1-2}, L_{2-3}, L_{1-3}).
    h. At discretion of ENG, additional readings may be taken to validate acceptance criteria.
9. NDE to validate that locations bands of where PMCaps are welded to CCW pipe are at least 0.25".

Acceptance Criteria

Flaws bounded by SIA calculation, pass N-513-3 acceptance criteria, and the pipe can be considered operable for purposes of releasing Mode 4 hold, even if relief request hasn't been approved or if PMCap installation & testing is not complete. New mode 2 hold required to ensure both relief request approval and PMCap installation & testing are complete.

Flaws not bounded by SIA calculation, do not pass N-513-3 and prior to releasing mode 4 hold, both the relief request approval and full PMCap installation & testing are required.

CCW pipe wall thickness in area of PMCap welds is at least 0.25".

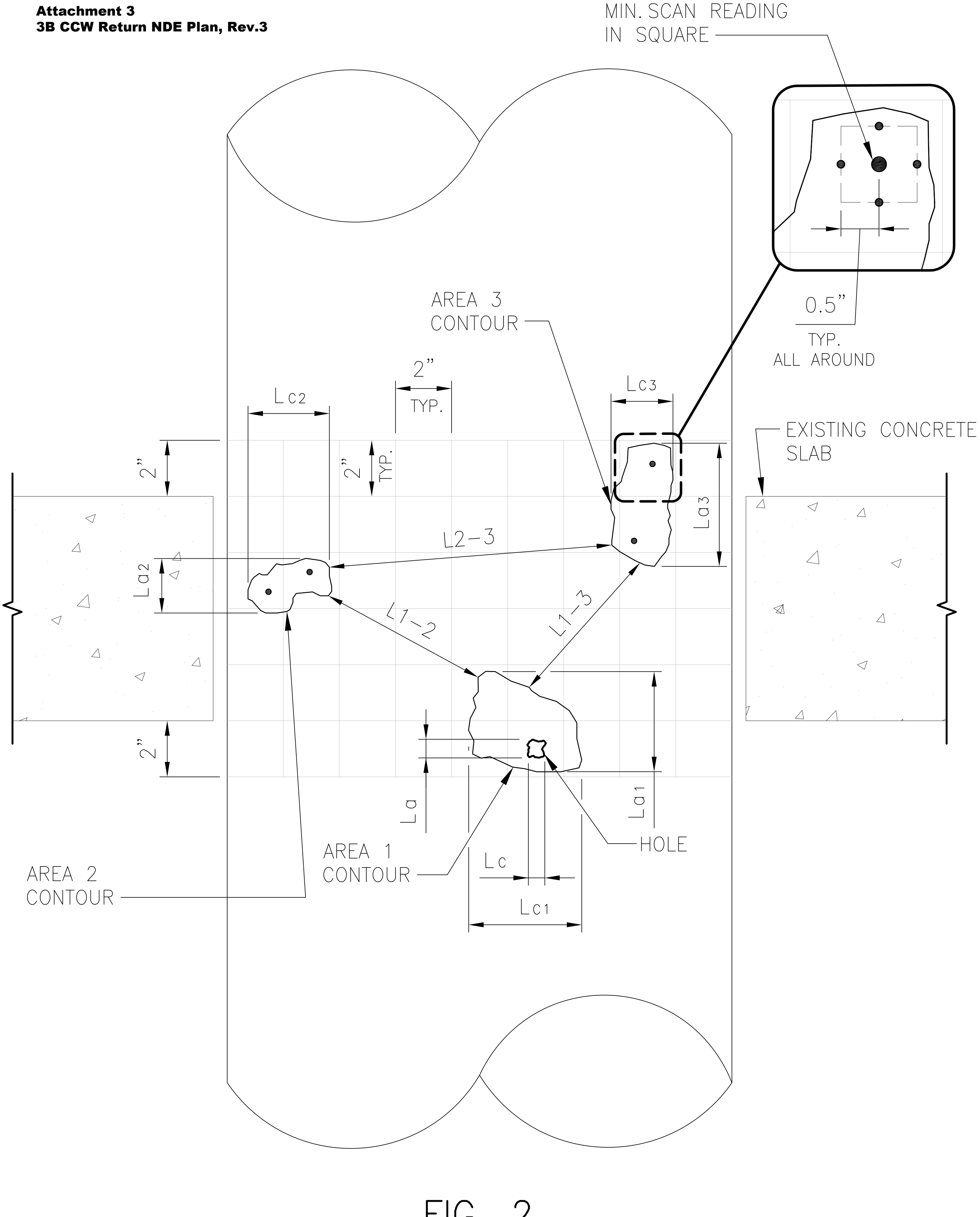


FIG. 2

IF PIPE IS LEAKING