Omaha Public Power District
444 South 16th Street Mall
Omaha, NE 68102-2247

10 CFR 50.55a

LIC-14-0109

August 19, 2014

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

Fort Calhoun Station, Unit No. 1
Renewed Facility Operating License No. DPR-40
NRC Docket No. 50-285

Subject: Evaluation of a Through-Wall Leak in a Raw Water Elbow in Support of Relief Request RR-14

Reference: 1. Letter from OPPD (L. P. Cortopassi) to NRC (Document Control Desk), *Fort Calhoun Station Relief Request RR-14, Proposed Alternative, Request for Relief for Temporary Acceptance of a Pin Hole Leak in Raw Water (RW) System 20-inch Elbow Located in Room 19 of Auxiliary Building,* dated August 15, 2014 (LIC-14-0106)

In Reference 1, the Omaha Public Power District (OPPD) submitted a request for relief (RR-14) for a proposed alternative for Fort Calhoun Station, Unit No. 1. Attached is the evaluation of a through-wall leak in a raw water elbow, which has undergone owner-acceptance review by OPPD and supports the conclusion of the relief request.

There are no regulatory commitments contained in this submittal.

If you have any questions concerning this submittal, please contact Mr. Bill R. Hansher at (402) 533-6894.

Respectfully,

Edwin D. Dean III
Plant Manager

EDD/KGM/brh

Attachment: Evaluation of a Through-Wall Leak in a Raw Water Elbow

Evaluation of a Through-Wall Leak in a Raw Water Elbow
File No.: 1401013.301

Calculation Number: FC08390	**Page No.: i**
QA Category: [**X**] CQE [ ] Non-CQE [ ] LCQE	Total Pages: 23
Calculation Title: Evaluation of a Through Wall Leak in a Raw Water Elbow	Short Term Calc: [**X**] Yes [ ] No Vendor Calc. No.: 1401013.301 Associated Project::
Software Tracking No.: **N/A** (from PED-MEI-23, if applicable)	Responsible Dept No.: **356**
Owner Assignment (by Dept Head): **N/A** (Required only if there are affected documents to be changed)	
OPPD Engineer Assignment (by Dept Head): **Chris Hooker** (Required only for verification of vendor/contractor calculations)	
Verification of Vendor/Contractor Calc. assumptions, inputs and conclusions complete: OPPD Engineer: [signature] Employee ID: 13818 Date: 8/19/14	

APPROVALS - SIGNATURE AND DATE (Multiple preparers shall identify section prepared per PED-QP-3, Section 4.2.)						**Supersedes Calc No.**	**Confirmation Required?**	
Rev. No.	**Preparer(s)**	**Reviewer(s)**	**Employee ID**	**Required for CQE Independent Reviewer(s)**	**Responsible Department Head**		**Yes**	**No**
0	See cover page of vendor calculation for preparer, reviewer, and approver.				Carol Wolf 8/19/14	N/A		X

Calculation Number: FC08390	**Page No.: ii**
Applicable System(s)/Tag Number(s) Raw Water	
EA's and/or Calculations Used as input in this Calculation EA95-012, Rev. 3 FC06553, Rev. 1 FC01013, Rev. 0	

External Organization Distribution (Groups affected by this calculation)

Name and Location	Copy Sent (✓)	Name and Location	Copy Sent (✓)

CALCULATION REVISION SHEET

Calculation No.: FC08390	Page No.: iii

Rev. #	Description/Reason for Change
0	Original Issue

EAG Reviewed

Initial: [signature] Date: 8/19/14

Calculation No.: FC08390 Rev. 0

Page No.: iv

The Calculation Preparer is to identify documents affected by this Calculation. Markups are to be provided in an Attachment to the Calculation except those noted with an *. Changes not involving procedures should follow the associated change process. The preparer is to indicate below how the Calculation is to be processed by Document Control.	
	Not Required, Calculation supports EC No. ________ or is used to support EA-FC- - this form can be signed off by the Calculation Preparer. Calculation "As Built" follows direction given for modifications.
	EC, FLC, Preapproved NRC commitment change, or Condition Report need identified. Calculation is closed on receipt of the completed PED-QP-3.8 form.
	Change to a DBD, USAR, etc., without a change to plant procedures identified. Calculation is "As Built" on receipt of the completed PED-QP-3.8 form.
	Change to a DBD, USAR, etc., and plant procedures (no hardware) identified. Calculation is "As Built" on receipt of the completed PED-QP-3.8 form.
X	No document changes or other changes are required. Calculation "As Built" on receipt of the completed PED-QP-3.8 form.

NOTE: Markups are to include any inputs or assumptions which define plant configuration and/or operating practices that must be implemented to make the results of the Calculation valid. The Calculation may provide the basis for a 10 CFR 50.59 and/or 10 CFR 72.48 analysis or substantiate a 10 CFR 50.59 and/or 10 CFR 72.48 analysis.

Affected Documents

Document Type	Document Number (N/A = not applicable)	Procedure Change No., FLC No., etc.
Emergency Operating Procedure*	N/A	
Abnormal Operating Procedure*	N/A	
Annunciator Response Procedure	N/A	
Technical Data Book	N/A	
Surveillance Test Procedure	N/A	
Calibration Procedure	N/A	
Operating Procedure	N/A	
Maintenance Procedure	N/A	
PM Procedure	N/A	
PED Procedure	N/A	
EP/EPIP/RERP*	N/A	
Operating Instructions	N/A	
System Training Manuals	N/A	
Technical Specification*	N/A	

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Affected Documents		
Document Type	**Document Number (N/A = not applicable)**	**Procedure Change No., FLC No., etc.**
USAR	N/A	
Licensing Commitments	N/A	
Standing Order	N/A	
Security Procedures * (Safeguards)*	N/A	
Security Plan (Safeguards)	N/A	
CQE List	N/A	
Vendor Manual Changes	N/A	
Design Basis Documents	N/A	
Equipment Database	N/A	
Oil Spill Prevention, Control and Countermeasure (SPCC) Plan	N/A	
EEQ Manual	N/A	
ERFCS Computer Point Manual	N/A	
SE-PM-EX-0600	N/A	
Updated Fire Hazard Analysis	N/A	
EPIX	N/A	
Electrical Load Distribution Listing (ELDL)	N/A	
Station Equipment Labeling	N/A	
Engineering Analysis	N/A	
Calculations	N/A	
Drawing Number	N/A	
Drawing Number	N/A	
Other	N/A	

Completed by Owner (if Plant Procedure Changes Required or N/A): N/A Employee ID:	Date:
Completed by Preparer: Chris Hooker Employee ID: 13818	Date: 8/18/14

EAG Reviewed
JMC 8/19/14
Initial Date

EC No.: N/A Calculation No.: FC08390 Rev.: 0

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	Yes	No	N/A
1. Are the assumptions reasonable and have sufficient rationale?	X		
2. Are assumptions compatible with the way the plant is operated and with the licensing basis?	X		
3. Are design inputs/attributes correct for the calculation being performed and referenced to appropriate Design Basis and Licensing Basis Documents?	X		
4. Do the design inputs/attributes reflect the way the plant is operated?	X		
5. Are Engineering Judgments, if any, clearly documented and justified?	X		
6. Do the results and conclusions satisfy the purpose and objective of the design analysis?	X		
7. Is the Calculation prepared in a clear and understandable manner such that it will allow revision or review in the future without assistance from the preparer and uses reference documents or standards available to OPPD?	X		
8. Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?			X
Reviewer: Chris Hooker Employee ID: 13818 Date: 8/19/14			
Print/Sign: Chris Hooker			

Comments: A 50.59 review will not be completed for this calculation. Procedure PED-QP-3, Rev. 39, Calculation Preparation, Review and Approval indicates that the appropriate 50.59 review shall be included in the calculation package if the calculation is not being performed in support of a hardware configuration change to the facility. For this calculation, the appropriate review is no review for the following two reasons. First of all, this is not a design calculation; it is performed to determine operability of Raw Water piping from a structural integrity standpoint. Normally this calculation would be included as part of an operability evaluation and a 50.59 review would not be required for the calculation itself, only the required compensatory measures. Secondly, the code case used in this calculation required a relief request from the NRC. The ASME N-513-4 code case has not been generally accepted by the NRC which required a relief request to use it for determining operability of the Raw Water elbow. The purpose of a 50.59 review is to determine if prior NRC approval is required. In this case NRC verbal approval has already been granted (see attached), therefore a 50.59 review is not required.

Additionally assumption number 2 in the calculation was verified. The flaw and subsequent leak were found in the middle of the elbow and is not near (within 5 inches) of any welds.

HOOKER, CHRISTOPHER T

From:	SIMPKIN, TERRENCE W
Sent:	Monday, August 18, 2014 12:59 PM
To:	HOOKER, CHRISTOPHER T
Subject:	FW: Verbal Authorization RR-14

-----Original Message-----
From: Lyon, Fred [mailto:Fred.Lyon@nrc.gov]
Sent: Friday, August 15, 2014 10:06 PM
To: SIMPKIN, TERRENCE W; HANSHER, BILL R
Cc: EDWARDS, MICHAEL L; Oesterle, Eric; Alley, David; Tsao, John; Hay, Michael
Subject: Verbal Authorization RR-14

VERBAL AUTHORIZATION FOR RELIEF REQUEST RR-14 TEMPORARY NON-CODE REPAIR OF RAW WATER PIPING FORT CALHOUN STATION, UNIT 1 August 15, 2014

By letter dated August 15, 2014, Omaha Public Power District (the licensee) requested relief from the requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, IWD-3120(b), at at Fort Calhoun Station, Unit 1.

Pursuant to Title 10 of the Code of Federal Regulations (10 CFR) 50.55a(a)(3)(ii), the licensee submitted Relief Request RR-14 and proposed to use an alternative methodology to ASME Code Case N-513-3 to disposition a pin hole leak in lieu of performing a repair on the leaking elbow of the raw water system piping immediately.

The licensee states that it will perform daily walkdown and measurement of the leakage to confirm that the analysis supported by the ultrasonic testing remains valid. The licensee calculated an allowable axial through wall flaw size of 4 inches and allowable circumferential through wall flaw size of 10 inches. The leaking flaw is of pin hole size. There is a substantial margin between the pin hole flaw size and the allowable flaw size. The NRC staff finds that the probability of pipe failure would be unlikely.

The NRC finds that the licensee has provided a adequate justification that Relief Request RR-14 will provide a reasonable assurance of the structural integrity of the subject raw water piping.

The NRC staff determines that the proposed alternative provides a reasonable assurance of structural integrity of the subject raw water piping. The NRC staff finds that complying with IWA-4000 of the ASME Code, Section XI, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. Accordingly, the NRC staff concludes that the licensee has adequately addressed all of the regulatory requirements set forth in 10 CFR 50.55a(a)(3)(ii). Therefore, on August 15, 2014, Eric Oesterle, Acting Chief, NRR/DORL/LPL4-1, and David Alley, Chief, NRR/ DE/EPNB, verbally authorize the use of Relief Request RR-14 at Fort Calhoun Station, Unit 1 until September 5, 2014, or when the leakage flaw size exceeds the allowable flaw size discussed above, whichever occurs first.

All other requirements in ASME Code, Section XI, for which relief was not specifically requested and approved in this relief request remain applicable, including third-party review by the Authorized Nuclear Inservice Inspector.

This verbal authorization does not preclude the NRC staff from asking additional clarification questions regarding the Relief Request while preparing the subsequent written safety evaluation.

DOCUMENT REVIEW FORM				Project:	
Document(s) Reviewed:			FC08390, Rev. 0		
Date Reviewed:		8/18/2014		Date Resolved:	
No.	**Reviewer**	**Section or Ref.**	**Comment**	**Resolution**	**Acceptance**
1	C. Hooker	Assumptions, page 4 and 5	I would like to remove the assumption regarding the long radius elbow and add it to the inputs section. This assumption was verifed by a field walkdown and will bt added to rev. of the Design Input Transmittal (DIT).	Will remove assumption after receiving revised DIT.	Y
2	C. Hooker	Technical Approach, page 3	What is the basis for using Takahashi's SIFs instead of the code values? Is this acceptable per the code and code case? If so, where is this stated? More basis needs to be provided as to why this is acceptable to use with the code and code case. If sufficient basis cannot be provided the code SIFs should be used.	The third sentence in the last paragraph of pg. 3 explains that "the Code Case allows for alternate stress intensity factor parameters to be used." To make this more clear, we will add an additional sentence as follows: "...1.5 to 80.5 [5]. **The Code Case states that alternative solutions for Fm and Fb may be used when R/t is greater than 20 [1, Appendix I-2].** Takahashi has proposed..."	Y
3	C. Hooker				
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20	C. Hooker				

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CALCULATION PACKAGE

File No.: 1401013.301

Project No.: 1401013

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Ft Calhoun Evaluation of Leaking Elbow

CONTRACT NO.:
165134 Release 10

CLIENT:
Omaha Public Power District

PLANT:
Fort Calhoun Station

CALCULATION TITLE:
Evaluation of a Through-Wall Leak in a Raw Water Elbow

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 12 A1 - A-3	Initial Issue	Eric J. Houston 8/19/2014	**Preparer:** Matthew C. Walter 8/19/2014 **Checker:** Brad P. Dawson 8/19/2014

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1.0 INTRODUCTION

Fort Calhoun Station has identified a pinhole leak in a 20-inch elbow in the raw water system. The system is safety related, and therefore requires an evaluation to demonstrate operability. The objective of this calculation is to determine the allowable through-wall flaw lengths in accordance with an upcoming revision of ASME Code Case N-513-3 [1].

2.0 TECHNICAL APPROACH

The flaw evaluation herein is based on the criteria prescribed in an upcoming revision of 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 the latest revision of Regulatory Guide 1.147 [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.

The evaluation criteria provided in N-513-3 are only for straight pipe since the technical approach relies on ASME Section XI, Appendix C [3] methods. A new revision of the Code Case (N-513-4) includes rules for the evaluation of piping components such as elbows, branch tees and reducers. Flaws in these components may be evaluated as if in straight pipe provided the stresses used in the evaluation are adjusted to account for geometric differences. For elbows, hoop stress is adjusted by considering flaw location and through-wall bending that results from elbow ovalization due to in-plane or out-of-plane bending moment. For axial stresses, the stress scaling follows the same approach given in ASME Section III, ND-3600 [4] design by rule using stress indices and stress intensification factors for the adjustment. Details are provided in N-513-4 for determining these adjusted stresses.

N-513-4 has been approved by ASME and is pending publication. It is recognized in ASME committee that the technical approach is very conservative. Simple treatment of piping component flaw evaluation using hand calculations was an important objective in the development of the approach recognizing the trade-off being conservative results. N-513-4 allows for alternative methods to calculate the stresses used in the analysis to reduce conservatism. N-513-4 has not been generically reviewed by the NRC.

As stated above, Code Case N-513-3 evaluation criteria rely on the methods given in ASME Section XI, Appendix C. 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 $R_m/t>20$. The Code Case states that alternative solutions for F_m and F_b may be used when R/t is greater than 20 [1, Appendix I-2]. Takahashi has proposed alternate stress intensity factor parameters, which are valid over the range of 1.5 to 80.5 [5]. 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.

Details of the Code Case N-513-4 evaluation procedure for elbows are given in Appendix A.

3.0 DESIGN INPUTS AND ASSUMPTIONS

The piping design Code of Construction is USAS B31.7, 1968 Draft Edition [6] as specified in Reference [7].

The elbow material is ASME A234 WPB [7] carbon steel. For the analysis, A106 Gr. B carbon steel is judged to have equivalent material properties. The nominal composition of the two materials is essentially the same and the minimum yield and tensile strengths are the same for both materials.

The following design inputs are used in this calculation:

1. Outside diameter = 20 inches [7]
2. Nominal wall thickness = 0.375 inch (based on standard pipe size) [7]
3. Elbow bend radius = 30 inches [7]
4. Maximum normal operating pressure = 54 psig [7]
5. Design temperature = 500°F [7]
6. Maximum operating temperature = 200°F [7]
7. Material stress allowable = 15 ksi [6]
8. Young's modulus = 26,400 ksi [6]
9. NDE inspection results [7]

The moment loadings applied to the piping are obtained from the design input transmittal [7] for element C15. The bounding moments are shown in Table 1.

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}. The NRC's Pipe Fracture Encyclopedia [8] contains numerous CVN test results for A106 Gr. B carbon steel at low temperature, which are reproduced in Table 2. The minimum reported value of 293 in-lb/in^2 is used in the analysis.

The following assumptions are used in this calculation:

1. Poisson's ratio is assumed to be 0.3.
2. The leak is remote from a weld, so the residual stress is assumed to be negligible.

3. 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 for a surrounding wall thickness of 0.225 inches.

4.1 Applied Loads

Axial and circumferential (i.e., hoop) stresses are calculated from the moment loads in Table 1 and the maximum operating pressure. The surrounding wall thickness, t_{adj}, is used to determine the section properties. The nominal wall thickness, t_{nom}, is used to calculate the flexibility characteristic 'h' in accordance with the guidance of N-513-4 (see Appendix A).

4.1.1 Hoop Stress

For the allowable axial flaw length, the hoop stress, σ_h, due to internal pressure and elbow ovalization from the axial moments may be determined from Equation 9 of N-513-4 (see Appendix A):

$$\sigma_h = \left(\frac{pD_o}{2t_{adj}}\right)\left[\frac{2R_{bend} + R_o \sin\phi}{2(R_{bend} + R_o \sin\phi)}\right] + \left(\frac{1.95}{h^{2/3}}\right)\frac{R_o M_b}{I} \quad (1)$$

where:

p = internal maximum operating pressure, psig
D_o = outside diameter, in
t_{adj} = surrounding (adjacent) wall thickness, in
R_{bend} = elbow bend radius
R_o = outside radius, in
ϕ = circumferential angle from elbow flank (see Figure 7 in Appendix A)
h = flexibility characteristic = $t_{nom} * R_{bend} / (R_{mean})^2$ [6, section D-402]
t_{nom} = nominal wall thickness = 0.375 in (Section 3.0)
R_{mean} = elbow mean radius, in
M_b = primary bending moment, in-lbs
I = moment of inertia, in^4.

Note that the first term of Equation 1 accounts for the hoop stress due to internal pressure and includes a scaling factor to account for the circumferential location of the flaw (assuming uniform thickness, pressure based hoop stress is a maximum at the elbow intrados, while a minimum at the elbow extrados). At the flank, the pressure based hoop stress is equal to that of straight pipe. For the analysis herein, it is conservative to set $\phi = 1.5\pi$ since this maximizes the hoop stress.

The second term of Equation 1 accounts for the through-wall bending stress resulting from the axial moments acting to ovalize the elbow. The basis for this factor comes from Reference [9].

Finally, N-513-4 limits the use of Equation 1 for $h \geq 0.1$. For this elbow, h is greater than 0.1.

4.1.2 Axial Stresses

For the allowable circumferential flaw length, the axial stress due to pressure, deadweight and seismic loading is presented below. For axial membrane stress due to pressure, σ_m, Equation 10 of N-513-4 is used:

$$\sigma_m = B_1\left(\frac{pD_o}{2t}\right) \quad (2)$$

where:

B_1 is an ASME Section III primary stress index for internal pressure (N-513-4 sets this value to 0.5).

For axial bending stress, σ_b, due to deadweight and seismic moments, Equation 11 of N-513-4 may be used:

$$\sigma_b = B_2\left(\frac{R_o M_b}{I}\right) \quad (3)$$

where:

B_2 is an ASME Section III primary stress index for moment loading (from Figure ND-3673.2(b)-1 of Reference [4], $B_2 = 1.30/h^{2/3}$).

For axial bending stress, σ_e, due to thermal expansion, Equation 12 of N-513-4 may be used:

$$\sigma_e = i\left(\frac{R_o M_c}{I}\right) \quad (4)$$

where:

i = stress intensification factor
M_c = resultant thermal expansion moment, in-lbs.

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:

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

where:

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

SF_m = structural factor for membrane stress (see Table 3)
F = through-wall stress intensity factor parameter 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)

Only the hoop stress influences the allowable axial flaw length, which is a function of pressure and primary bending stress.

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:

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

where:

$K_{Im} = (SF_m)F_m\sigma_m(\pi a)^{0.5}$
F_m = through-wall stress intensity factor parameter for a circumferential flaw under membrane stress [5]
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 3)
σ_b = bending stress, ksi
σ_e = thermal stress, ksi
F_b = through-wall stress intensity factor parameter for a circumferential flaw under bending stress [5]
K_{Ir} = K_I from residual stresses at flaw location (assumed negligible)

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

Table 4 shows the specific load combinations considered herein for the allowable circumferential flaw calculations.

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} = 92.2 ksi-in$^{0.5}$. 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

Based on inputs in Section 3.0, moments in Table 1 and using equations from Section 4.0, the allowable through-wall flaw in the axial direction is 4 inches. The allowable through-wall flaw in the circumferential direction is 10 inches. These flaw lengths are for a 0.225 inch surrounding wall thickness. Based on the inspection data given in Reference [7], the analyzed thickness and flaw lengths easily bound the observed thinning. Thus, the acceptance criteria of Code Case N-513-4 are met.

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 5 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}. Based on the inspection data given in Reference [7], the values in Table 5 easily bound the observed thinning. Thus, the Code Case requirement is met.

Note that the through-wall flaw evaluations and the pressure blowout evaluation are separate analyses.

6.0 CONCLUSIONS

Fort Calhoun Station has identified a pinhole leak in a 20-inch elbow in the raw water system. Allowable through-wall flaw lengths have been calculated in accordance with an upcoming revision of ASME Code Case N-513-3 (designated N-513-4) for the elbow identified with node point C15. N-513-4 has been approved by ASME and is pending publication. It is recognized in ASME committee that the technical approach is very conservative. Simple treatment of piping component flaw evaluation using hand calculations was an important objective in the development of the approach recognizing the trade-off being conservative results. N-513-4 has not been generically reviewed by the NRC.

The allowable through-wall flaw in the axial direction is 4 inches. The allowable through-wall flaw in the circumferential direction is 10 inches. These flaw lengths are for a 0.225 inch surrounding wall thickness. Table 5 shows the requirements to resist pressure blowout.

The observed pinhole leak flaw is easily bounded by the results of the analysis; thus, the acceptance criteria of Code Case N-513-4 are met. The system should be considered operable but degraded.

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 16, Nuclear Regulatory Commission, October, 2010.
3. ASME Boiler and Pressure Vessel Code, Section XI, Appendix C, 2004 Edition.
4. ASME Boiler and Pressure Vessel Code, Section III, 2004 Edition.
5. 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.
6. USAS B31.7 "Nuclear Power Piping," 1968 Draft Edition.
7. OPPD Design Input Transmittal NED-14-108, Revision 1, "Design Information Transmittal for Evaluation of the Raw Water Through-wall Leak (CR 2014-10078)," SI File No 1401013.201.
8. Pipe Fracture Encyclopedia, US Nuclear Regulatory Commission, Volume 1, 1997.
9. Moore, S.E., and Rodabaugh, E.C., "Background for Changes in the 1981 Edition of the ASME Nuclear Power Plant Components Code for Controlling Primary Loads in Piping Systems," Journal of Pressure Vessel Technology, Volume 104, pp. 351 – 361, November 1982.

Table 1: Applied Moment Loading for Bounding Moments [7]

Deadweight [in-lbs]	Thermal [in-lbs]	OBE [in-lbs]	SSE [in-lbs]
22,320	38,647	22,812	36,937

Notes:

1. Square Root Sum of the Squares (SRSS) is used to calculate moments from Reference [7].
2. Moments are from the bounding location on the elbow, which is at node 113.

Table 2: J_{IC} Values for A106 Gr. B Carbon Steel from NRC's Pipe Fracture Database [8]

A106 Grade B					
Database Reference	Temperature (°C)	Temperature (°F)	JIC (kJ/m^2)	JIC (lb-in/in^2)	KIC (ksi-in$^{0.5}$)
2	24	75	97	552	133
2	24	75	336	1919	249
16	25	77	81	464	122
16	25	77	418	2386	277
16	25	77	270	1542	223
16	25	77	193	1104	189
22	24	75	224	1278	203
22	20	68	112	641	144
22	20	68	117	668	147
22	23	73	214	1223	199
22	20	68	167	954	175
22	20	68	223	1271	202
22	20	68	108	617	141
23	52	126	116	663	146
23	23	73	103	590	138
23	23	73	105	600	139
23	23	73	93	528	131
24	23	73	76	431	118
24	23	73	82	469	123
24	57	135	51	293	97
25	23	73	77	439	119
25	23	73	70	400	114
25	57	135	62	356	107
90	20	68	235	1342	208
90	20	68	219	1251	201
90	20	68	255	1456	217
90	20	68	281	1605	228
90	20	68	281	1605	228
90	20	68	335	1913	248
90	20	68	421	2404	279
90	20	68	385	2198	266
90	20	68	175	999	180
90	20	68	172	982	178
90	20	68	178	1016	181
90	20	68	214	1222	199
90	20	68	275	1570	225
90	20	68	133	759	157
90	20	68	140	799	161
90	20	68	174	994	179
90	20	68	111	634	143
90	20	68	190	1085	187
90	20	68	71	405	114
90	20	68	110	628	142
90	20	68	104	594	138
90	20	68	104	594	138
90	20	68	97	554	134
90	20	68	89	508	128
90	20	68	88	502	127
90	20	68	267	1525	222

Table 3: 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 4: Load Combinations for Circumferential Flaw Analyses

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

Table 5: Pressure Blowout Check

d_{adj} [in]	$t_{c,avg}$ [in]
0.25	0.01
0.75	0.02
1.25	0.03
1.75	0.04
2.25	0.05
2.75	0.06
3.25	0.07
3.75	0.08
4.25	0.09
4.75	0.10
5.25	0.11

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Appendix A

CODE CASE N-513-4 PROCEDURES FOR ELBOW FLAW EVALUATION

3.3 Through-wall Flaws in Elbows and Bent Pipe

Through-wall flaws in elbows and bent pipe may be evaluated using the straight pipe procedures given in 3.1 or 3.2(d) provided the stresses used in the evaluation are adjusted as described below to account for the geometry differences. Alternate methods may be used to calculate the stresses used in evaluation.

The hoop stress, σ_h, for elbow and bent pipe evaluation shall be:

$$\sigma_h = \left(\frac{pD_o}{2t}\right)\left[\frac{2R_{bend} + R_o \sin\phi}{2(R_{bend} + R_o \sin\phi)}\right] + \left(\frac{1.95}{h^{2/3}}\right)\frac{R_o M_b}{I} \quad (9)$$

where

R_{bend} = elbow or bent pipe bend radius
ϕ = circumferential angle defined in Figure 7
h = flexibility characteristic
M_b = resultant primary bending moment
I = moment of inertia based on evaluation wall thickness, t

Equation 9 is only applicable for elbows and bent pipe where $h \geq 0.1$.

The axial membrane pressure stress, σ_m, for elbow and bent pipe evaluation shall be:

$$\sigma_m = B_1\left(\frac{pD_o}{2t}\right) \quad (10)$$

where B_1 is a primary stress index as defined in ASME Section III for the piping item. B_1 shall be equal to 0.5 for elbows and bent pipe.

The axial bending stress, σ_b, for elbow and bent pipe evaluation shall be:

$$\sigma_b = B_2\left(\frac{R_o M_b}{I}\right) \quad (11)$$

where B_2 is a primary stress index as defined in ASME Section III for the piping item.

The thermal expansion stress, σ_e, for elbow and bent pipe evaluation shall be:

$$\sigma_e = i\left(\frac{R_o M_e}{I}\right) \quad (12)$$

where

i = stress intensification factor as defined in the Code of Record for the piping item
M_e = resultant thermal expansion moment

Figure 7 from N-513-4:

FIG. 7 CIRCUMFERENTIAL ANGLE DEFINED