VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

June 2, 2000

United States Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

Serial No.: 00-289
NL&OS/ETS: R0
Docket No.: 50-338
License No.: NPF-4

Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNIT 1
ASME SECTION XI RELIEF REQUEST NDE-16
WITHDRAWAL OF ASME SECTION XI RELIEF REQUEST NDE-9

By letter dated April 8, 1999 (Serial No. 99-169), Virginia Electric and Power Company submitted the Third Ten Year Inservice Inspection (ISI) Program for North Anna Power Station Unit 1, which included Relief Request NDE-9. This relief request was included to address through-wall leakage in the Service Water System as a result of microbiologically-induced corrosion (MIC), since it is anticipated that such through-wall leakage will occur during the third ten year ISI inspection interval.

Relief Request NDE-9 was revised and resubmitted on March 28, 2000. Relief Request NDE-9 was revised to address piping and welds, where flaw characterization cannot be conducted volumetrically or mechanically. A second relief request, NDE-15, was also prepared and submitted to address SW piping and welds that are accessible to flaw characterization. The NRC approved NDE-15 on April 29, 2000.

Since that time, we have re-evaluated the application and implementation of Relief Request NDE-9 and have decided to withdraw Relief Request NDE-9. However, to avoid placing the plant in more risk significant plant system configurations or initiating required transient as a result of declaring a component inoperable due to MIC indications on socket weld locations, we are requesting relief from the ASME Code, paragraph IWA-5250(a)(3) requirements for repair and replacement.

Pursuant to 10 CFR 50.55a (g)(5)(iii), relief is requested from requirements of ASME Section XI Code paragraph 5250(a)(3). Relief request NDE-16 is attached and provides the basis for the request. This relief request has been reviewed and approved by the Station Nuclear Safety and Operating Committee.

A047

If you have any questions or require additional information, please contact us.

Very truly yours,

Leslie N. Hartz
Vice President – Nuclear Engineering and Services

Commitments contained in this correspondence: None.

cc: U.S. Nuclear Regulatory Commission
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Mr. M. J. Morgan
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North Anna Power Station

Attachment 1

Relief Request NDE-16

North Anna Unit 1
Virginia Electric and Power Company

Virginia Electric and Power Company
North Anna Power Station Unit 1
Third Ten Year Interval

RELIEF REQUEST NDE-16
Revision 0

I. Identification of Components

All 3/4" to 2" socket welds (inclusive) and associated heat affected zones in the base metal, where flaw characterization is not practical, and also part of the Service Water System piping associated with the Microbiological Influenced Corrosion (MIC) attack on type 304 and 316 stainless steel.

II. Impractical Code Requirements

The code of reference for the third inspection interval is the 1989 Edition of ASME Section XI. This is an ASME Class 3 system.

Identification of additional through-wall leakage is anticipated as a result of continued MIC attack on the affected Service Water piping. Through-wall leakage must be located and evaluated in accordance with the requirements of IWA-5250. The specific Code requirement for which relief is requested is IWA-5250(a)(3).

"IWA-5250 Corrective Measures

(a) The source of leakage detected during the conduct of a system pressure test shall be located and evaluated by the Owner for corrective measures as follows:

(3) repairs or replacements of components shall be performed in accordance with IWA-4000 or IWA-7000, respectively."

Articles IWA-4000 and IWD-4000 of ASME Section XI Code repair requirements would require removal of the flaw and subsequent weld repair immediately.

Additionally, the use of ASME Code Case, N-513, "Evaluation Criteria for Temporary Acceptance of Flaws in Class 3 Piping," is not authorized for socket welds by 10 CFR 50.55a rulemaking.

III. Basis for Relief

Code repairs for through-wall leaks require the line to be isolated and drained. Taking a train of service water out of service in some instances is a major evolution and requires entering a Technical Specification action statement. The Service Water System is common to both units. As long as one unit is in Mode 1, 2, 3, or 4, both trains of service water must be operable. If both units are in Mode 5 or 6, then one train of service water must be operable. Imposing the Code requirements for repair and replacement on an immediate basis, considering the MIC damage mechanism being addressed, is considered impractical and an unnecessary burden.

Previously, the timeframe to adequately plan and make appropriate corrective actions (replacement of piping segment) on the system has been within 14 days of detection of MIC leakage (reference NDE-32, 2nd interval corresponding relief request in letter dated December 22, 1998 (TAC NOS. MA1222 and MA1223)). This timeframe for completion of repairs or replacements in our opinion is still deemed appropriate for the MIC damage mechanism with regard to socket welds. Besides the historical support for this conclusion, two evaluations have been provided to support the 14-day timeframe.

a) An analytical method described in Code Case N-513 is not allowed for socket welds due to the inability to characterize the flaw size and due to a lack of an acceptable analytical method. However, a type of bounding analysis assuming a 3/4" flaw (e.g., 3/4" long through-wall circumferential crack, a 3/4" long through-wall longitudinal crack, a 3/4" through-wall hole) as provided in appendix A, provides insights into the actual structural integrity. The assumed flaw sizes are bounding based upon our experiences to date (reference RAI response letter serial number 00166A, dated April 16, 2000). The analysis concludes for the assumed flaw sizes that the stainless steel socket welded joints for the above pipe sizes would maintain structural integrity, when subjected to pressure, dead weight, thermal expansion, seismic OBE and DBE loadings. The analysis is detailed in appendix A.

b) Additionally, an analysis was performed for core damage frequency (CDF) change by removing key pieces of equipment supported by the Service Water system for the 14-day time period in our Safety Monitor program. It concludes there is very little change in risk (CDF). The primary reason is that the conditional probability of a DBE within the 14-day time period is very small. The analysis is detailed in appendix B.

As such, relief is requested from the above Code requirements per 10 CFR 50.55a(g)(5)(iii) based upon the impracticality of the Code requirements given the basis above.

IV. Alternate Provisions

Code repairs or replacements in accordance with IWA-5250(a)(3) will be performed to the above identified socket welds and associated heat affected zones in the

Service Water System within 14 days. The timeframe proposed for repairs or replacements is considered adequate to maintain the overall structural integrity of the system.

Additionally, a walkdown of the affected areas will be performed at a frequency not to exceed 6 weeks to assure timely identification of through-wall leaks.

Appendix A

Structural Evaluation of Small Bore (3/4" NPS to 2" NPS) Stainless Steel Service Water Pipe with Bounding MIC Induced Through-Wall Flaws at Socket Welded Joints

Purpose:

The purpose of this evaluation is to establish a structural basis for operating the small bore (3/4" NPS to 2" NPS) stainless steel service water piping with a bounding size microbiologically influenced corrosion (MIC) induced through-wall flaw at socket welded joints for a 14-day time period.

Background:

The small-bore service water piping at North Anna is subjected to MIC. The station has various programs in place to reduce MIC, monitor and evaluate the degradation, and repair and/or replace piping in a planned manner before the degradation is large enough to render the system or components inoperable. NRC Generic Letters and ASME Code cases provide guidance for structural evaluations. However, no simplified guidelines are available for socket welded joints because of the complex configuration of the joints with the pipe fitting and the fillet weld. No easy method is available to characterize the flaw at the socket welded joint location where the flaw could extend from pipe through the weld to the fitting. Consequently, a flawed welded joint is not symmetric about any axis and will require a very detailed three-dimensional modeling technique for a quantitative evaluation of strength. Such an evaluation is time consuming and can not be performed quickly enough to ascertain structural integrity. In this situation, only two alternatives exist.

First, a mechanical clamping device designed per the guidance of ASME Code Case N-523 can be installed to control leakage through the pressure boundary and to restore the structural integrity of the degraded section. A properly designed installation like this with appropriate inspection schedule can be used till the next scheduled outage when a code repair can be performed. Adequate guidance is available in the code case to prepare the design of a mechanical clamping device. However, certain time is needed to conceptualize the design to fit to specific locations.

Secondly, a repair may be performed by temporarily isolating the system and by taking guidance from the plant technical specification for the period of the system isolation. This may not be practical for all locations. Additionally, the burden on planning and maintenance to make a quick repair to clear the Technical Specification LCO is not warranted as compared to the significance of a MIC induced flaw. In a low energy system like service water with minor breach of pressure boundary due to MIC, the risk of operating the system for a brief 14-day period may not be significant. Therefore, certain bounding type structural evaluation can be performed quickly to complement a risk evaluation. The following structural evaluation is performed to meet the above short-term objective.

Evaluation:

Material:

The material of the piping is ASTM 312 TP316L or ASTM 312 TP304 and the fittings are of ASTM A182-F316L or ASTM A182-F304. The piping is standard schedule and the fittings are ANSI class 150 lbs. rating. The design and fabrication of the system is per ANSI B31.7 Class 3 rules.

Loading:

The design pressure of the lines is 150 psig and the design temperature is 140° F. The pressure-temperature rating of the construction is significantly higher. The operating pressure and temperature at these locations is significantly lower than the design. The lines operate in a cold condition and therefore, do not experience any significant thermal expansion stress. Because of the size and temperature condition of the lines, the lines were not computer analyzed and were supported using the guidelines similar to the span chart of ANSI B31.1. Consequently, the basic deadweight stress in the lines is expected to be a maximum of 1500 psi. The lines basically service some small coolers for equipment and are located at elevation below grade and are subjected to very low amplitude seismic floor response spectra. The cold lines of this type are normally well supported and therefore, subjected to very low seismic stress. The plant experience indicates that these lines do not experience any other kind of mechanical loadings like water hammer or other transients.

System Analysis:

Small bore lines were not computer analyzed. As a result, the forces and moments are not readily available at the socket-welded joints for the purpose of local structural integrity evaluation. The socket-welded joints are present in many different service water lines. Sample analyses were performed for three mathematical models of lines to determine bounding forces at the joints. The sample lines were selected based upon actual field walk-down of many different lines by a stress analyst experienced in the analysis and design of safety related piping system. The selected systems were analyzed using NUPIPE computer program for loading conditions stated above and forces and moments were determined at the socket-welded joints for the purpose of local structural analysis. The bounding values of stresses for different pipe sizes are listed in the attachment.

Local Structural Integrity Evaluation:

Our experience indicates that most of the through-wall leaks due to MIC are pin-hole type extending through the wall in an irregular fashion to cover about ¾". Therefore, for the purpose of local structural integrity, the section was evaluated with either a ¾" long through-wall circumferential crack, a ¾" long through-wall longitudinal crack, or a ¾" through-wall hole. An equivalent pipe section of equal size was used in the evaluation to get an assessment of short-term structural integrity without preparing a non-symmetric model of a flawed joint. The assessment was considered reasonable because in terms of overall strength the joint strength is nearly equal or better than pipe. A limit load analysis was performed for circumferential and axial flaws. A penalty factor 'Z' was used for compensating influence of weld. The analysis of the hole was done by using area-reinforcement method. The evaluation was performed for joints in each size of pipe. The details of evaluations are presented following the stress summary table. The results of the evaluation indicate that the structural integrity will be maintained.

Conclusion:

Based on the structural evaluation, it is concluded that the stainless steel socket welded joints with the postulated through-wall flaws in North Anna service water system will maintain structural integrity for a period 14 days or more without loss of structural integrity when subjected to pressure, dead weight, thermal expansion, seismic OBE and DBE loadings.

Specific conservatism used in the evaluation are listed below:

Minimum predicted factor of safety in OBE condition is 3.1 against required 2.77.

Minimum predicted factor of safety in DBE (SSE) condition is 1.59 against required 1.39.

The highest stress in the system is used in the analysis irrespective of location. The values of applied stresses were further bumped to create additional margin.

Enveloped Thermal Expansion stresses were bumped from 4,354 psi to 6,000 psi. Seismic OBE + Deadweight stresses were bumped from 2,504 psi to 5,000 psi. Seismic DBE + Deadweight stresses were bumped from 3,747 psi to 10,000 psi.

Lower bound material flow stress was used in the evaluation.

Bounding Evaluation of weld locations with flaws
Maximum Stress Summaries from Sample piping Analyses:

Three representative piping models containing ¾" – 2" diameter piping were analyzed for deadweight, thermal expansion, seismic OBE and DBE loadings. The maximum stress in each model is tabulated below irrespective of the location.

[1] Model- 1: 2" SW line to Charging Pump Lube Oil Cooler:

COL	CRITERIA	MAXIMUM CALCULATED STRESS (PSI)	ALLOWABLE STRESS(PSI)
1	$S_{lp} + S_{dl} + < S_h$	(468 + 305) = 773	17500
2	$S_{lp} + S_{dl} + S_{obei} + S_{obea} < 1.2S_h$	(468 + 623) = 1091	21000
3	$S_{lp} + S_{dl} + S_{dbei} + S_{dbea} < 1.8S_h$	(468 + 1053) = 1521	31500
4	$S_{th} < f(1.25S_c + 0.25S_h)$	3180	26250
FOR MATERIAL A 312 TP 316L or 304 S_c = 17500 psi, S_h = 17500 psi, T = 140 °F			

[2] Model- 2: 2" SW line to Charging Pump Lube Oil Cooler:

COL	CRITERIA	MAXIMUM CALCULATED STRESS (PSI)	ALLOWABLE STRESS(PSI)
1	$S_{lp} + S_{dl} + < S_h$	(468 + 1026) = 1494	17500
2	$S_{lp} + S_{dl} + S_{obei} + S_{obea} < 1.2S_h$	(468 + 2036) = 2504	21000
3	$S_{lp} + S_{dl} + S_{dbei} + S_{dbea} < 1.8S_h$	(468 + 3279) = 3747	31500
4	$S_{th} < f(1.25S_c + 0.25S_h)$	4259	26250
FOR MATERIAL A 312 TP 316L or 304 S_c = 17500 psi, S_h = 17500 psi, T = 140 °F			

[3] Model- 3: 2", 1" and ¾" SW lines to Air Compressors:

COL	CRITERIA	MAXIMUM CALCULATED STRESS (PSI)	ALLOWABLE STRESS(PSI)
1	$S_{lp} + S_{dl} + < S_h$	(468 + 669) = 1137	17500
2	$S_{lp} + S_{dl} + S_{obei} + S_{obea} < 1.2S_h$	(241 + 961) = 1202	21000
3	$S_{lp} + S_{dl} + S_{dbei} + S_{dbea} < 1.8S_h$	(241 + 1055) = 1296	31500
4	$S_{th} < f(1.25S_c + 0.25S_h)$	4354	26250
FOR MATERIAL A 312 TP 316L or 304 S_c = 17500 psi, S_h = 17500 psi, T = 140 °F			

(Notes on following page)

S_{lp} = Longitudinal Pressure Stress
S_{dl} = Dead Load Stress
S_{obei} = Operational Basis Earthquake stress
S_{dbei} = Design Basis Earthquake Stress
S_{obea} = Operating Basis Earthquake Anchor Movements
S_{dbea} = Design Basis Earthquake Anchor Movements
S_{th} = Thermal Expansion Stress
S_c = Allowable Stress at Ambient Temperature
S_h = Allowable Stress at Design Temperature

The results show that the typical piping of low energy system like these are not highly stressed.

P_e = Maximum Thermal expansion Stress range = 4,354 psi

Pb_{OBE} = Maximum deadweight + Seismic OBE stress = 2,504 psi

Pb_{DBE} = Maximum deadweight + Seismic DBE stress = 3,747 psi

In order to produce conservative results, the calculated stresses were increased and the following values were used for local evaluation.

P_e = Maximum Thermal expansion Stress range = 6,000 psi

Pb_{OBE} = Maximum deadweight + Seismic OBE stress = 5,000 psi

Pb_{DBE} = Maximum deadweight + Seismic DBE stress = 10,000 psi

Limit Load Analysis of an Equivalent Pipe Section Representing a Socket Welded Joint:

3/4" Diameter Service Water pipe:

Material: ASTM A 312 TP 316L, A 312 TP 304, A182-F316L, A182-F304

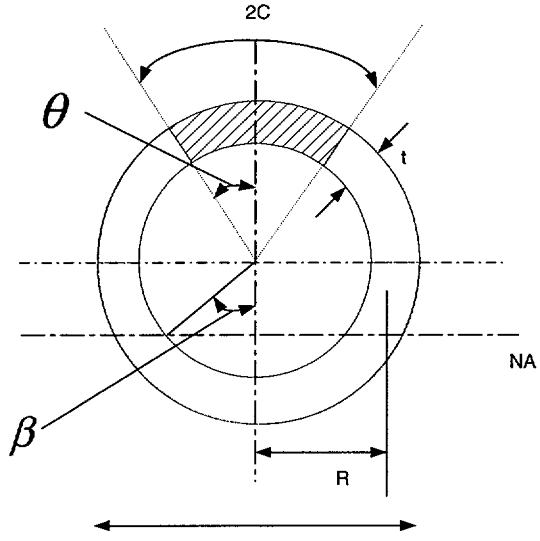

Figure 1
Circumferential Flaw

Yield Stress $Sy := 25000$ psi   Ultimate Stress $Su := 65000$ psi

Lower bound properties are used for all four materials

Flow Stress $\sigma_f := 0.5 \cdot (Sy + Su)$ psi

$\sigma_f = 4.5 \cdot 10^4$ psi

Outside diameter of pipe = $D := 1.05$ in

Pipe wall thickness = $t := 0.113$ in

Mean radius of pipe = $R := \frac{D - t}{2}$ in $R = 0.469$ in

Inside diameter of pipe = $d := D - 2 \cdot t$ in $d = 0.824$ in

Design pressure = $p := 150$ psig

Primary membrane Stress = $P_m := \frac{p \cdot d^2}{D^2 - d^2}$ psi

$P_m = 240.474$ psi

Half Crack length = $c := 0.375$ in

Half Crack angle $\theta := \frac{c}{R}$ $\theta = 0.8$

Angle to neutral axis from the bottom of pipe =

$$\beta := \frac{1}{2} \cdot \left[(\pi) - \theta - \frac{\pi \cdot P_m}{\sigma_f} \right] \qquad \beta = 1.162$$

$\theta + \beta = 1.963$ $< \pi$ OK

Limit failure bending stress = $P_b := \frac{2 \cdot \sigma_f}{\pi} \cdot ((2) \cdot \sin(\beta) - \sin(\theta))$

$P_b = 3.202 \cdot 10^4$ psi

Determination of Factor of Safety based upon quality of material and welding: (SMAW)

Penalty factor 'Z' is used to conservatively account for the influence of weld.

$D := 24.0$

For SMAW $Z_{SMAW} := 1.15 \cdot (1 + 0.013 \cdot (D - 4))$ $Z_{SMAW} = 1.449$

Note: For 'D' <= 24.0, use D = 24.0

Factor of Safety in OBE condition:

Bounding values of stresses from piping analysis are used for conservative evaluation.

Bending Stress due to dead weight + seismic OBET = $Pb_{OBE} := 5000$ psi

Bending Stress due to thermal expansion = $P_e := 6000$ psi

$$S_F := \frac{(P_b + P_m) - Z_{SMAW} \cdot P_e}{Z_{SMAW} \cdot (Pb_{OBE} + P_m)} \qquad S_F = 3.103 \qquad > 2.77 \quad \text{OK}$$

Factor of Safety in DBE condition:

Bending Stress due to dead weight + seismic DBET = $Pb_{DBE} := 10000$ psi

Bending Stress due to thermal expansion = $P_e := 6000$ psi

$$S_F := \frac{(P_b + P_m) - Z_{SMAW} \cdot P_e}{Z_{SMAW} \cdot (Pb_{DBE} + P_m)}$$ $S_F = 1.588$ > 1.39 OK

Through wall Axial Flaw:

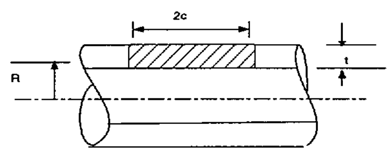

Figure 2
Axial Flaw

Inspected length of Flaw = l = 0.75 in Allowable length of axial flaw = l_{all} in

$D := 1.05$ Hoop Stress $\sigma_h := \frac{p \cdot D}{2 \cdot t}$

$$l_{all} := 1.58 \cdot \sqrt{R \cdot t} \cdot \left[\left(\frac{\sigma_f}{3 \cdot \sigma_h} \right)^2 - 1 \right]^{\frac{1}{2}}$$ $l_{all} = 7.816$ > 0.75 OK

<u>Area Reinforcement Evaluation for 3/4" SW pipe with 0.75" hole:</u>

Pipe Minimum required wall thickness for design Pressure:

Design Pressure $P := 150$ psig

Outside Diameter $D_o := 1.05$ inch

Material A 312 TP 304L or 316L

Allowable Stress at 120 deg F $S_E := 17500$ psig

Coefficient $y := 0.4$

$$t_m := \frac{P \cdot D_o}{2 \cdot (S_E + P \cdot y)}$$ $t_m = 4.485 \cdot 10^{-3}$ in

Area reinforcement evaluation:

Area required $= A_r$ in^2 Area Available $= A_a$ in^2

diameter (hole) = $d := 0.75$ in $\alpha := 90 \cdot deg$

Minimum required thickness of run pipe $t_r := 0.0045$ in

Thickness of the run pipe $T_r := 0.113$ in

$A_r := \left[d \cdot t_r \cdot (2 - \sin(\alpha))\right] \cdot 1.07$ $A_r = 3.611 \cdot 10^{-3}$ in^2

$A_a := d \cdot \left(T_r - t_r\right)$ $A_a = 0.081$ in^2

$A_a > A_r$ OK

Reference: ANSI B31.7

Limit Load Analysis of an Equivalent Pipe Section Representing a Socket Welded Joint:

1" Diameter Service Water pipe:

Material: ASTM A 312 TP 316L, A 312 TP 304, A182-F316L, A182-F304

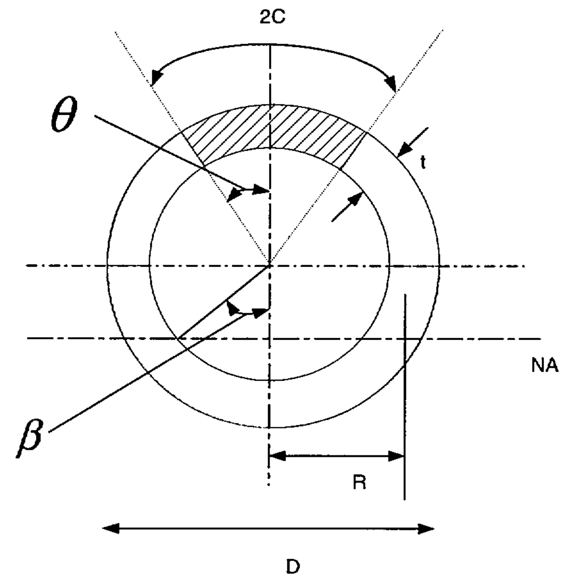

Figure 1
Circumferential Flaw

Yield Stress $Sy := 25000$ psi Ultimate Stress $Su := 65000$ psi

Lower bound properties are used for all four materials

Flow Stress $\sigma_f := 0.5 \cdot (Sy + Su)$ psi

$\sigma_f = 4.5 \cdot 10^4$ psi

Outside diameter of pipe = $D := 1.315$ in

Pipe wall thickness = $t := 0.133$ in

Mean radius of pipe = $R := \frac{D - t}{2}$ in $R = 0.591$ in

Inside diameter of pipe = $d := D - 2 \cdot t$ in $d = 1.049$ in

Design pressure = $p := 150$ psig

Primary membrane Stress = $P_m := \frac{p \cdot d^2}{D^2 - d^2}$ psi

$P_m = 262.49$ psi

Half Crack length = $c := 0.375$ in

Half Crack angle $\theta := \frac{c}{R}$ $\theta = 0.635$

Angle to neutral axis from the bottom of pipe =

$$\beta := \frac{1}{2} \cdot \left[(\pi) - \theta - \frac{\pi \cdot P_m}{\sigma_f} \right] \qquad \beta = 1.244$$

$\theta + \beta = 1.879$ $< \pi$ OK

Limit failure bending stress = $P_b := \frac{2 \cdot \sigma_f}{\pi} \cdot ((2) \cdot \sin(\beta) - \sin(\theta))$

$P_b = 3.729 \cdot 10^4$ psi

Determination of Factor of Safety based upon quality of material and welding: (SMAW)

Penalty factor 'Z' is used to conservatively account for influence weld.

$D := 24.0$

For SMAW $Z_{SMAW} := 1.15 \cdot (1 + 0.013 \cdot (D - 4))$ $Z_{SMAW} = 1.449$

Note: For 'D' <= 24.0, use D = 24.0

Factor of Safety in OBE condition:

Bounding values of stresses from piping analysis are used for conservative evaluation.

Bending Stress due to dead weight + seismic OBET = $Pb_{OBE} := 5000$ psi

Bending Stress due to thermal expansion = $P_e := 6000$ psi

$$S_F := \frac{(P_b + P_m) - Z_{SMAW} \cdot P_e}{Z_{SMAW} \cdot (Pb_{OBE} + P_m)} \qquad S_F = 3.784 \qquad > 2.77 \quad \text{OK}$$

Factor of Safety in DBE condition:

Bending Stress due to dead weight + seismic DBET = $Pb_{DBE} := 10000$ psi

Bending Stress due to thermal expansion = $P_e := 6000$ psi

$$S_F := \frac{(P_b + P_m) - Z_{SMAW} \cdot P_e}{Z_{SMAW} \cdot (Pb_{DBE} + P_m)}$$ $S_F = 1.941$ > 1.39 OK

Through wall Axial Flaw:

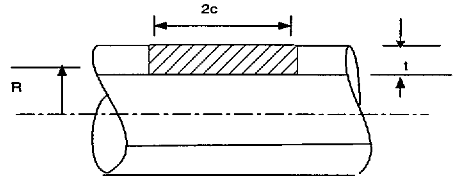

Figure 2
Axial Flaw

Inspected length of Flaw = l = 0.75 in   Allowable length of axial flaw = l_{all} in

$D := 1.315$ Hoop Stress $\sigma_h := \frac{p \cdot D}{2 \cdot t}$

$$l_{all} := 1.58 \cdot \sqrt{R \cdot t} \cdot \left[\left(\frac{\sigma_f}{3 \cdot \sigma_h} \right)^2 - 1 \right]^{\frac{1}{2}}$$ $l_{all} = 8.95$ > 0.75 OK

<u>Area Reinforcement Evaluation for 1" SW pipe with 0.75" hole:</u>

Pipe Minimum required wall thickness for design Pressure:

Design Pressure $P := 150$ psig

Outside Diameter $D_o := 1.315$ inch

Material A 312 TP 304L or 316L

Allowable Stress at 120 deg F $S_E := 17500$ psig

Coefficient $y := 0.4$

$$t_m := \frac{P \cdot D_o}{2 \cdot (S_E + P \cdot y)}$$ $t_m = 5.616 \cdot 10^{-3}$ in

Area reinforcement evaluation:

Area required $= A_r$ in^2 Area Available $= A_a$ in^2

diameter (hole) = $d := 0.75$ in $\alpha := 90 \cdot deg$

Minimum required thickness of run pipe $t_r := 0.00562$ in

Thickness of the run pipe $T_r := 0.133$ in

$A_r := \left[d \cdot t_r \cdot (2 - \sin(\alpha)) \right] \cdot 1.07$ $A_r = 4.51 \cdot 10^{-3}$ in^2

$A_a := d \cdot (T_r - t_r)$ $A_a = 0.096$ in^2

$A_a > A_r$ OK

Reference: ANSI B31.7

Limit Load Analysis of an Equivalent Pipe Section Representing a Socket Welded Joint:

2" Diameter Service Water pipe:

Material: ASTM A 312 TP 316L, A 312 TP 304, A182-F316L, A182-F304

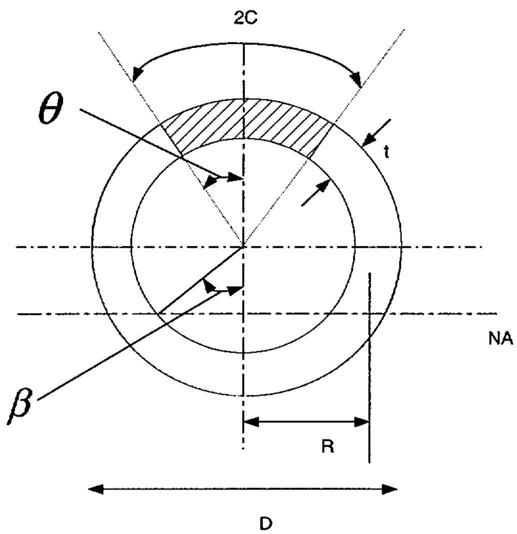

Figure 1
Circumferential Flaw

Yield Stress $Sy := 25000$ psi Ultimate Stress $Su := 65000$ psi

Lower bound properties are used for all four materials

Flow Stress $\sigma_f := 0.5 \cdot (Sy + Su)$ psi

$\sigma_f = 4.5 \cdot 10^4$ psi

Outside diameter of pipe = $D := 2.375$ in

Pipe wall thickness = $t := 0.154$ in

Mean radius of pipe = $R := \frac{D - t}{2}$ in $R = 1.111$ in

Inside diameter of pipe = $d := D - 2 \cdot t$ in $d = 2.067$ in

Design pressure = $p := 150$ psig

Primary membrane Stress = $P_m := \frac{p \cdot d^2}{D^2 - d^2}$ psi

$P_m = 468.428$ psi

Half Crack length = $c := 0.375$ in

Half Crack angle $\theta := \frac{c}{R}$ $\theta = 0.338$

Angle to neutral axis from the bottom of pipe =

$$\beta := \frac{1}{2}\cdot\left[(\pi) - \theta - \frac{\pi \cdot P_m}{\sigma_f}\right] \qquad \beta = 1.386$$

$\theta + \beta = 1.723$ $< \pi$ OK

Limit failure bending stress = $P_b := \frac{2\cdot\sigma_f}{\pi}\cdot((2)\cdot\sin(\beta) - \sin(\theta))$

$P_b = 4.682 \cdot 10^4$ psi

Determination of Factor of Safety based upon quality of material and welding: (SMAW)

Penalty factor 'Z' is used to conservatively account for the influence of weld.

$D := 24.0$

For SMAW $Z_{SMAW} := 1.15\cdot(1 + 0.013\cdot(D - 4))$ $Z_{SMAW} = 1.449$

Note: For 'D' <= 24.0, use D = 24.0

Factor of Safety in OBE condition:

Bounding values of stresses from piping analyses were used for conservative evaluation.

Bending Stress due to dead weight + seismic OBET = $Pb_{OBE} := 5000$ psi

Bending Stress due to thermal expansion = $P_e := 6000$ psi

$$S_F := \frac{(P_b + P_m) - Z_{SMAW}\cdot P_e}{Z_{SMAW}\cdot(Pb_{OBE} + P_m)} \qquad S_F = 4.871 \qquad > 2.77 \quad \text{OK}$$

Factor of Safety in DBE condition:

Bending Stress due to dead weight + seismic DBET = $Pb_{DBE} := 10000$ psi

Bending Stress due to thermal expansion = $P_e := 6000$ psi

$$S_F := \frac{(P_b + P_m) - Z_{SMAW} \cdot P_e}{Z_{SMAW} \cdot (Pb_{DBE} + P_m)}$$ $S_F = 2.545$ > 1.39 OK

Through wall Axial Flaw:

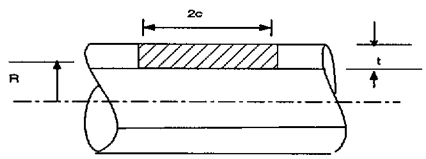

Figure 2
Axial Flaw

Inspected length of Flaw = l = 0.75 in   Allowable length of axial flaw = l_{all} in

$D := 2.375$ Hoop Stress $\sigma_h := \frac{p \cdot D}{2 \cdot t}$

$$l_{all} := 1.58 \cdot \sqrt{R \cdot t} \cdot \left[\left(\frac{\sigma_f}{3 \cdot \sigma_h} \right)^2 - 1 \right]^{\frac{1}{2}}$$ $l_{all} = 8.448$ > 0.75 OK

Area Reinforcement Evaluation for 2" SW pipe with 0.75" hole:

Pipe Minimum required wall thickness for design Pressure:

Design Pressure $P := 150$ psig

Outside Diameter $D_o := 2.375$ inch

Material A 312 TP 304L or 316L

Allowable Stress at 120 deg F $S_E := 17500$ psig

Coefficient $y := 0.4$

$$t_m := \frac{P \cdot D_o}{2 \cdot (S_E + P \cdot y)}$$ $t_m = 0.01$ in

Area reinforcement evaluation:

Area required $= A_r$ in^2 Area Available $= A_a$ in^2

diameter (hole) = $d := 0.75$ in $\alpha := 90 \cdot deg$

Minimum required thickness of run pipe $t_r := 0.01$ in

Thickness of the run pipe $T_r := 0.154$ in

$A_r := \left[d \cdot t_r \cdot (2 - \sin(\alpha)) \right] \cdot 1.07$ $A_r = 8.025 \cdot 10^{-3}$ in^2

$A_a := d \cdot \left(T_r - t_r \right)$ $A_a = 0.108$ in^2

$A_a > A_r$ OK

Reference: ANSI B31.7

Appendix B
PRA Risk Assessment of SW Piping Degradation

Purpose
To document the PRA risk assessment of the SW piping degradation at North Anna.

Method
To assess the risk due to the small pipe leaks in the Service Water (SW) supply to the Charging (CH) pumps and Instrument Air (IA) compressors, the North Anna Safety Monitor (SM) was used to quantify the change in Core Damage Frequency (CDF) for various plant configurations of CH pumps and/or IA compressors either failed or degraded. The Safety Monitor was modified for this analysis to add factors for degraded IA compressors and CH pumps. To simulate the degraded condition, it was assumed that a SW pipe with a leak would fail during a Design Basis Earthquake (DBE). The probability of the failure within a 14-day period was taken from the mean frequency of a DBE and converting it to a 14-day conditional probability. Based on input from Corporate Mechanical Engineering, the mean frequency of a DBE is 0.46E-3, which converts to a 14-day conditional probability of 0.18E-4. This value was added to the failure probabilities of the IA compressors and CH pumps to simulate the component being degraded.

The Safety Monitor Indirect Effects table was modified to add degraded factors for the IA compressor and B CH pump. The SM was run for several different configurations with SW supply lines failed or with the component, which is supplied by the SW lines failed. The individual components (e.g. a CH pump or IA compressor) were failed since it is possible to have a leak in the common line coming from both headers. Table 1 summarizes the results. The results show that there is little risk increase when one entire SW header is unavailable. Also, there is little increase in risk with one CH pump failed by itself or with a second CH pump degraded. With one IA compressor failed, the CDF increases approximately 90%, however, the risk recommended Allowed Configuration Time (ACT) is greater than 14 days. With one IA compressor failed and the other degraded, there is no change in risk from that of one compressor failed.

The cumulative risk impact of multiple component unavailabilities during a year is monitored by the Maintenance Rule program. For the SW system, there is significant margin in the cumulative risk as documented in the Performance Criteria Sensitivity Study to allow for multiple repairs to the SW pipes.

Conclusion
In conclusion, there is very little change in risk due to the SW pipe leaking and ultimately failing its affected component. The primary reason is that the conditional probability of a DBE within the 14-day period is very small.

Appendix B Table 1
Safety Monitor Results Summary

Configuration		Unit 1	Unit 2
Baseline - Nothing OOS	CDF ACT(hrs)	2.68E-5 8760	2.69E-5 8760
"A" 4" SW header to CH pumps & IA compressors failed	CDF ACT (hrs) Risk Color	2.78e-5 8760 Green	2.72E-5 8760 Green
"B" 4" SW header to CH pumps & IA compressors failed	CDF ACT (hrs) Risk Color	2.72E-5 8760 Green	2.77E-5 8760 Green
1-IA-C-1 failed	CDF ACT (hrs) Risk Color	4.94E-5 393 Green	5.09E-5 373 Green
2-IA-C-1 failed	CDF ACT (hrs) Risk Color	5.09E-5 369 Green	5.00E-5 388 Green
1-CH-P-1B failed	CDF ACT (hrs) Risk Color	2.68E-5 8760 Green	2.69E-5 8760 Green
2-CH-P-1B failed	CDF ACT (hrs) Risk Color	2.68E-5 8760 Green	2.82E-5 8760 Green
1-CH-P-1B failed 1-CH-P-1C failed	CDF ACT (hrs) Risk Color	3.00E-5 3166 Green	2.69E-5 8760 Green
1-CH-P-1B degraded 1-CH-P-1C failed	CDF ACT (hrs) Risk Color	2.68E-5 8760 Green	2.69E-5 8760 Green
2-CH-P-1B failed 2-CH-P-1C failed	CDF ACT (hrs) Risk Color	2.68E-5 8760 Green	3.0E-5 3180 Green
2-CH-P-1B degraded 2-CH-P-1C failed	CDF ACT (hrs) Risk Color	2.68E-5 8760 Green	2.69E-5 8760 Green
1-IA-C-1 failed 2-IA-C-1 failed	CDF ACT (hrs) Risk Color	6.29E-4 14 Red	6.24E-4 14 Red
1-IA-C-1 degraded 2-IA-C-1 failed	CDF ACT (hrs) Risk Color	5.09E-5 369 Green	5.00E-5 387 Green
1-IA-C-1 failed 2-IA-C-1 degraded	CDF ACT (hrs) Risk Color	4.95E-5 393 Green	5.09E-5 373 Green
1-IA-C-1 degraded	CDF ACT (hrs) Risk Color	2.68E-5 8760 Green	2.69E-5 8760 Green
2-IA-C-1 degraded	CDF ACT (hrs) Risk Color	2.68E-5 8760 Green	2.69E-5 8760 Green