ORIGINAL

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NINE MILE POINT NUCLEAR STATION Unit (1, 2 or 0=Both): 1 Discipline: STRUCTURAL

Title ACCEPTABLE CIRCUMFERENTIAL FLAW SIZE FOR RECIRCULATION PIPING SUCTION NOZZLE SAFE END-TO-ELBOW WELDS	Calculation No. S12.9-32WDNOZZLE			
	(Sub)system(s) 32	Building DW	Floor Elev. 259	Index No. S12.9

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Page 1a

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CALCULATION TITLE PAGE

Client	Niagara Mohawk Power Corporation	Page 1 of 12 plus 16 attachment pages
Project	NMP-1 Reactor Recirculation System Weld Indication Evaluation	Task No. 085-9905-325-0
Title	Acceptable Circumferential Flaw Size for NMP1 Recirculation Piping Suction Nozzle Safe End-to-Elbow Welds	Calculation No. 085-325-11

Preparer/Date	Checker/Date	Reviewer/Date	Rev. No.
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QUALITY ASSURANCE DOCUMENT

This document has been prepared, checked, and reviewed/approved in accordance with the Quality Assurance requirements of 10CFR50 Appendix B, as specified in the MPR Quality Assurance Manual.

RECORD OF REVISIONS

Calculation No.	Prepared By	Checked By	Page 2
085-325-11			

Revision	Description
0	Initial Issue.
1	Revised Pages 3, 6, 11 and 12, and added Appendix D, to evaluate flaw growth due to fatigue.

CERTIFICATE OF CONFORMANCE

This calculation was prepared in conformance with the applicable requirements of CSA PO 93-13319, Contract 99-23394 and the MPR Quality Assurance Manual.

5-11-99

Certification Signature Date

CONTENTS

Appendices

1.0 PURPOSE

This calculation determines the maximum depth for circumferentially oriented indications that can be accepted for one operating cycle (two years) by ASME Code Section XI evaluation for the NMP1 reactor recirculation system suction nozzle safe end-to-elbow welds. This will provide an acceptance criterion for any circumferential indications found in the suction nozzle safe end-to-elbow welds during inservice inspection.

2.0 SUMMARY OF RESULTS

Maximum Acceptable Circumferential Flaw Depth

Recirculation Pipe Loop	Weld ID	Allowable Depth
Loop 11	32-WD-003	0.42"
Loop 12	32-WD-046	0.43"
Loop 13	32-WD-086	0.43"
Loop 14	32-WD-126	0.42"
Loop 15	32-WD-168	0.42"

Allowable depths are calculated assuming the flaw has a uniform depth completely (360°) around the pipe ID circumference. Shorter flaws less than or equal to the maximum acceptable depths listed above at all points along the flaw length are acceptable.

3.0 APPROACH

This calculation provides acceptance criteria for circumferential flaws found during inservice inspection of the following welds in the reactor recirculation piping:

Reactor Recirculation Loop	Weld Identifier
Loop 11	32-WD-003
Loop 12	32-WD-046
Loop 13	32-WD-086
Loop 14	32-WD-126
Loop 15	32-WD-168

These are the suction nozzle safe end-to-elbow welds in each of the reactor recirculation loops (see Reference 1, NMPC Drawing F-45183-C, Sheet 7, Revision 5).

3.1 Basis for Circumferential Flaw Acceptance Criteria

Acceptance criteria for flaws found during inservice inspection program are documented in Section XI of the ASME Code (Reference 2). The NMP1 Inservice Inspection Program invokes the 1983 Edition with Summer 1983 addenda of Section XI.

Both NUREG-0313 Revision 2 (Reference 3) and Generic Letter 88-01 (Reference 4) refer to the 1986 Edition of ASME Code Section XI IWB-3600 for evaluation of flaws caused by intergranular stress corrosion cracking (IGSCC). The 1986 code edition provides detailed requirements for evaluation of IGSCC indications. Therefore, the 1986 edition (without addenda) of Section XI will be used in this calculation to evaluate the acceptability of indications.

Paragraph IWB-3132 of the 1986 Edition of Section XI states that components whose volumetric examination reveals flaws that do not meet the acceptance criteria of Table IWB-3410-1 shall be corrected either by repair or replacement, or accepted by analytical evaluation for service. Requirements for acceptance by analytical evaluation are provided in paragraphs IWB-3132.4, IWB-3600, and Appendix C to Section XI.

Specifically, rules for analytical evaluation of flaws are provided in Section XI, Appendix C. Flaws are evaluated by comparing the maximum flaw dimensions (determined by flaw growth analysis) at the end of a selected evaluation period with the maximum allowable flaw dimensions specified in the Code. Two different flaw growth mechanisms are considered: (1) flaw growth due to fatigue, and (2) flaw growth due to stress corrosion cracking (SCC). As shown in Appendix D, flaw growth due to fatigue, under the loads and cycles postulated for one refuel cycle, is insignificant, i.e., less than a few mils.

Flaw growth due to SCC is computed as a function of material condition, environment, stress intensity factor due to sustained loading, and total time that the flaw is exposed to the environment under sustained loading. The maximum allowable flaw dimensions specified in the Code provide a margin of safety for plastic limit load on the pipe section.

In 1988 NMPC obtained computer program SSFLAW, which was developed to evaluate the acceptability of SCC flaws in stainless steel piping per the requirements of ASME Section XI. Reference 5 describes SSFLAW, its development, and use, and provides a user manual.

SSFLAW uses the methodology of the 1986 Edition of Section XI to calculate the final flaw length and depth at the end of a service interval, given the initial flaw geometry, applied stresses and pressure loadings, weld characteristics, and key piping geometry and material properties. In brief, the program performs the following steps required by Section XI to evaluate the acceptability of flaws:

- SSFLAW calculates stresses on the pipe section resulting from residual stress due to welding (the major stress affecting flaw growth rate), and combines these stresses with stresses applied from normal operating and sustained upset mechanical loads on the pipe cross section. These stresses are used to calculate the instantaneous flaw growth rate. In addition to pressure stress, the applied loadings used to determine the sustained flaw growth rate are thermal expansion and deadweight.

- The flaw size is increased by integrating the calculated instantaneous flaw growth rate with time, until the end of the service interval is reached.

- SSFLAW compares the calculated flaw size at the end of the service interval to the allowable depth (from the tables in IWB-3640 of Section XI) for normal plus upset conditions (that is, pressure, thermal, and deadweight loads) and for emergency and faulted conditions (which include pressure, deadweight, thermal and seismic loads). For high toughness welds like the gas tungsten-arc welds (GTAW) in the recirculation system, the loads used for calculating acceptable flaw size do not include the effect of secondary loads (such as thermal expansion loads and residual stresses). This exclusion of secondary stresses is in accordance with paragraph IWB-3640 of Reference 2.

3.2 Method for Determining Flaw Depth Acceptance Criteria

The program SSFLAW is used in this calculation to determine the acceptable depth of a circumferentially oriented flaw in the suction nozzle safe end-to-elbow weld. The method is as follows:

- An initial guess is made for the flaw depth of the circumferential flaw. This flaw is assumed to be of uniform thickness around the entire inside diameter of the pipe.

- The flaw growth over a two year operating cycle is calculated using the program SSFLAW. Sustained stresses which cause the flaw to grow include stresses due to pressure, deadweight and thermal expansion, as described in the next section and in Appendix A to this calculation. Other inputs to program SSFLAW are defined in Appendix B to this calculation.

- The enlarged flaw size calculated for the end of the two year operating cycle is evaluated per the requirements of ASME Code Section XI, Tables IWB-3641-1 and IWB-3641-2. These tables are applicable to circumferential flaws in welds made using the GTAW or GMAW methods as defined in Paragraph IWB-3641.2(c) of Section XI. Stresses considered in these evaluations are described in the next section and in Appendix A.

- If the end-of-evaluation period flaw is less than the depths permitted by Tables IWB-3641-1 and IWB-3641-2, then the initial flaw depth is increased and the process is repeated.

This method is used to determine an initial flaw depth which will grow to the bounding allowable depth permitted by these Section XI tables.

3.3 Stresses Used as Input to Program SSFLAW

3.3.1 Source of Stress Inputs

Stresses in the recirculation system piping are obtained from Teledyne Technical Report TR-5828-1 (Reference 6). Appendix A to this calculation documents how stresses to be used as Program SSFLAW inputs are obtained using the Teledyne report results.

Note that Teledyne prepared two separate models of the recirculation system. One model represents Loop 12 of the recirculation system, which has no significant large bore branch piping. The other model represents Loop 15, which has large diameter branch lines on both the pump suction and discharge.

Loops which have large bore branch lines are identified in the table below (see Reference 7). The table also lists the Teledyne model which will be used to represent loops that were not modeled.

Reactor Recirculation Loop	Description of Branch Lines	Representative Model
Loops 11, 14 and 15	At least one large bore branch line	Loop 15
Loops 12 and 13	No large bore branch lines	Loop 12

3.3.2 Values for Stresses

There are three categories of stresses considered in this calculation, as follows:

- Sustained Stresses Which Act on the Weld for a Long Duration and Cause the Flaw to Grow. These stresses include welding residual stresses plus stresses due to pressure, deadweight and thermal expansion. SSFLAW calculates the pressure stress term based on the operating pressure of the piping system. SSFLAW also calculates the residual stresses in accordance with Appendix A of NUREG-0313, Revision 2 (Reference 3), as described in the SSFLAW program user's manual (Reference 5).

- Stresses used for Limit Load Evaluation for Normal and Upset Conditions. These stresses are used for evaluation per Table IWB-3641-1. These include primary membrane plus bending stresses due to the effects of pressure and deadweight. Thermal expansion effects are not required for consideration for welds made using GTAW per paragraph IWB-3640.

- Stresses used for Limit Load Evaluation for Emergency and Faulted Conditions. These stresses are used for evaluation per Table IWB-3641-2. These include primary membrane plus bending stresses due to the effects of earthquake as well as pressure and deadweight. Again, thermal expansion effects are not required for consideration for welds made using GTAW per paragraph IWB-3640.

Program SSFLAW stress inputs are calculated in Appendix A. Note that the stresses used for flaw growth are input as "normal condition" stresses, and therefore these stresses include stresses due to thermal expansion. SSFLAW does not use these thermal stresses for limit load evaluation when the welds made using GTAW are evaluated.

4.0 CALCULATION

The calculation method described above yields the following results:

- For Loop 12, the acceptance criterion for maximum allowable initial circumferential flaw depth is 0.43". A flaw of this depth around the entire pipe ID will grow to 0.570" by the end of a two year evaluation period; the allowable flaw depth under these circumstances is 0.577".

  This acceptance criterion applies to suction nozzle safe end-to-elbow welds in Loops 12 and 13 (Welds 32-WD-046 and 32-WD-086, respectively).

- For Loop 15, the acceptance criterion for maximum allowable initial circumferential flaw depth is 0.42". A flaw of this depth around the entire pipe ID will grow to 0.575" by the end of a two year evaluation period; the allowable flaw depth under these circumstances is 0.577".

  This acceptance criterion applies to suction nozzle safe end-to-elbow welds in Loops 11, 14 and 15 (Welds 32-WD-003, 32-WD-126, and 32-WD-168, respectively).

Program SSFLAW runs used in this calculation are presented in Appendix C to this calculation. The evaluation of flaw growth due to fatigue is presented in Appendix D. Flaw growth due to fatigue is insignificant.

5.0 REFERENCES

1. NMPC Drawing F-45183-C, Sheet 7, Revision 5.

2. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components.
   - --1983 Edition with Summer 1983 addenda
   - --1986 Edition without addenda

3. NUREG-0313, Revision 2, "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping -- Final Report," published January 1988.

4. Generic Letter 88-01, NRC Position on IGSCC in BWR Austenitic Stainless Steel Piping, January 25, 1988.

5. MPR Report MPR-1037, Revision 1, "SSFLAW -- A Computer Program to Evaluate Cracks in Stainless Steel Piping (Version 1.1)," April 1988.

6. Teledyne Engineering Services Technical Report TR-5828-1, "Reactor Recirculation Piping Replacement Analysis," 5/25/83.

7. NMPC Drawing C-26846-C, Sheet 2, Revision 9.

8. NMPC Document PSRS-32, Piping Specification Standard Record Set for System 32, Revision 4.

9. EPRI NP-6301-D, "Ductile Fracture Handbook," Volume 2, Chapter 4, October 1990.

Appendix A

Computation of Stresses For Input to SSFLAW

(Seven pages total)

The following spreadsheet pages show the calculation of the applied primary axial stress, primary bending stress and secondary (thermal) stress for normal plus upset conditions, and for emergency plus faulted conditions, for the NMP-1 recirculation piping at the location of the suction nozzle safe end-to-elbow welds. The method used is as follows:

- The Teledyne stress analyses (Reference 6) for Recirculation Loops 12 and 15 was reviewed to determine which node in the finite element model corresponds to the location of the safe end-to-elbow weld. This location was determined to be represented by nodes 100 and 101 for both Teledyne models.

- Forces and moments at these nodes were determined from the Teledyne computer run HX3SBIV (4/12/83) for Loop 12 (included in Volume 2 of Reference 6), and computer run HX3ZFIN for Loop 15 (in Volume 6). Reactions were obtained for the following load case:

  -- Deadweight;
  -- Thermal expansion of the piping system and reactor vessel (see discussion below);
  -- Seismic inertia loading in the X, Y and Z global directions;
  -- Seismic inertia end effect (building acceleration) loading in the X, Y and Z global directions

  (The seismic cases were run with varying stiffnesses for sway struts; only the most conservative case results are considered.)

- Forces and moments from these load cases were used to calculate the stresses for input to SSFLAW.

As described in the body of this calculation, there are three categories of stresses to consider: (1) sustained stresses that cause the flaw to grow over the service interval, (2) stresses for limit load evaluation for normal and upset conditions, and (3) stresses for limit load evaluation for emergency and faulted conditions. Stresses for Categories (1) and (2) are input to SSFLAW in the "Normal Operating" stresses field, and stresses for Category (3) are entered in the "Faulted Condition" field. Further, within each field, three types of stresses need to be entered: primary tensile stress, primary bending stress, and secondary (thermal) stress. These stresses are calculated as follows:

-- Primary Tensile (Axial) and Primary Bending Stress for Normal and Upset Conditions. Primary stresses are used to define the normal operating and upset condition sustained stress state at the weld location. These stresses contribute to crack growth throughout the service interval. The only sustained primary stress of this type that is entered into SSFLAW is due to deadweight because stress due to internal pressure is calculated by SSFLAW based on operating pressure and pipe geometry.

-- Primary Tensile (Axial) and Primary Bending Stress for Emergency and Faulted Conditions. These stresses are equal to the normal plus upset stresses, plus stresses due to earthquake.

-- Secondary Stresses for Normal Conditions. These stresses are due to thermal expansion and are assumed to be constant throughout the service interval. These stresses contribute to crack growth rate. Note that per the Section XI methodology these stresses need not be considered in the limit load evaluation for welds made using GTAW, as is the case for the safe end-to-elbow welds.

The Teledyne stress analysis considered two different thermal cases for Loop 12 and five cases for Loop 15. For Loop 12, the limiting thermal case represents an event in which the reactor is operating at full power and the recirculation loop is isolated. In this case, the loop operates at a lower temperature. This is a rare operating scenario. For conservatism, this case is considered to apply for Loop 12 for the entire two year flaw evaluation period.

For Loop 15, the Teledyne analysis considered five thermal cases. The most limiting case represents an event in which the reactor is operating at full temperature, the recirculation loop is valved out of service and shutdown cooling flow is initiated into the loop. This is considered a rare event and would occur only for a short duration. Therefore, these stresses are not used for flaw growth purposes. Instead, as described above for Loop 12, the stresses occurring during an isolation of the Loop 15 recirculation piping with the reactor at temperature are assumed for the flaw growth calculation for the two year service period, since these stresses bound all the remaining thermal cases considered in the Teledyne analysis for Loop 15.

Calculation of Stresses for Input to Program SSFLAW Loop 12 Suction Nozzle Safe End to Elbow Weld

Part 1: Reactions at the Weld Joint for Loop 12

Notes:

1. Forces and moments are from Teledyne computer runs HX3SBHR and HX3SBIV.
2. The values listed are the maximum absolute values from either Node 100 or 101 from computer run HX3SBIV. Run HX3SBIV was used because the total overall moments and forces were determined to bound the reactions from run HX3SBHR by inspection.

Case		FX (pounds)	FY (pounds)	FZ (pounds)	MX (inch-pounds)	MY (inch-pounds)	MZ (inch-pounds)
STATIC	DW	10	3,400	100	83,690	310	132,320
	TH-1	270	2,650	160	107,910	5,370	50,100
	TH-2	880	6,710	860	139,130	12,810	190,890
SEISMIC INERTIA	X	5,170	4,520	60	121,370	24,230	156,570
	Y	270	5,470	100	98,780	10,090	134,530
	Z	110	2,960	5,110	340,340	200,580	56,170
SRSS		5,178	7,688	5,111	374,592	202,290	213,934
SEISMIC END EFFECTS	X	3,870	5,440	3,870	357,630	182,880	171,680
	Y	700	1,710	680	43,090	34,010	51,950
	Z	3,690	4,660	4,000	337,540	204,980	187,220
SRSS		5,393	7,364	5,607	493,649	276,801	259,276
Total Seismic		10,571	15,053	10,718	868,241	479,091	473,210

SRSS Values	
FORCES (pounds)	MOMENTS (inch-pounds)
3,401	156,565
2,669	119,094
6,822	236,559
21,289	1,098,771

Geometry Data Used in Teledyne Report:

Outside Diameter (Do):	28.0 in
Nominal Thickness (tn):	1.05 in
Pipe Metal Area:	88.90 in^2
Section Modulus (Z):	598.96 in^3

Part 2: Stresses for SSFLAW Flaw Growth Calculation and Limit Load Evaluation for Loop 12

Primary Stress Calculation

Summary of Contributors to Primary Stresses

Case	Axial Force	Moment
DW	3,401	156,565
EQ	21,289	1,098,771
Sum	24,690	1,255,337
Units:	pounds	inch-pounds

Note: The forces and moments shown are SRSSed values. For conservatism, they are assumed to equal the applied axial force and overturning moment.

Normal and Upset Condition Primary Stresses (Deadweight Only)

Axial Force Due to Deadweight: 3,401.5 pounds
Pipe Area = pi * (Ro^2 - Ri^2): 88.90 in^2
Axial Stress (= F / Area): 38.3 psi

Bending Moment Due to Deadweight: 156,565.3 inch-pounds
Section Modulus (Z): 598.96 in^3
Bending Stress (= M / Z): 261.4 psi

Emergency and Faulted Condition Primary Stresses (DW + EQ)

Axial Force Due to Deadweight + EQ: 24,690.4 pounds
Pipe Area = pi * (Ro^2 - Ri^2): 88.90 in^2
Axial Stress (= F / Area): 277.7 psi

Bending Moment Due to Deadweight + EQ: 1,255,336.5 inch-pounds
Section Modulus (Z): 598.96 in^3
Bending Stress (= M / Z): 2095.9 psi

Secondary (Thermal) Stress Calculation

Worst Case Thermal Forces and Moments:

Case	Axial Force	Moment
TH-2	6,822	236,559
Units:	pounds	inch-pounds

Note: The forces and moments shown are SRSSed values. For conservatism, they are assumed to equal the applied axial force and overturning moment.

Normal Operating and Faulted Condition Thermal Stresses:

Axial Force Due to Worst Thermal Case: 6,822 pounds
Pipe Area = pi * (Ro^2 - Ri^2): 88.90 in^2
Axial Stress (= F / Area): 76.7 psi

Bending Moment Due to Worst Thermal Case: 236,559 inch-pounds
Section Modulus (Z): 598.96 in^3
Bending Stress (= M / Z): 395.0 psi

Total Secondary Stress (= Axial Plus Bending): 471.7 psi

Overall Summary of Stresses for Input to SSFLAW Flaw Growth Calculation and Limit Load Evaluation

			Stress	
Condition	Class	Type	(psi)	(ksi)
Normal and Upset	Primary	Axial	38.3	0.04
	Primary	Bending	261.4	0.26
	Secondary	Ax. + Bend	471.7	0.47
Emergency and Faulted	Primary	Axial	277.7	0.28
	Primary	Bending	2,095.9	2.10
	Secondary	Ax. + Bend	471.7	0.47

Calculation of Stresses for Input to Program SSFLAW
Loop 15 Suction Nozzle Safe End to Elbow Weld

Part 1: Reactions at the Weld Joint for Loop 15

Notes:

1. Forces and moments are from Teledyne computer runs HX3ZFHN and HX3ZFIN.
2. The values listed are the maximum absolute values from either Node 100 or 101 from computer run HX3ZFIN. Run HX3ZFIN was used because the total overall moments and forces were determined to bound the reactions from run HX3ZFHN by inspection.

Case		FX	FY	FZ	MX	MY	MZ	SRSS Values	
								FORCES	MOMENTS
		(pounds)	(pounds)	(pounds)	(inch-pounds)	(inch-pounds)	(inch-pounds)	(pounds)	(inch-pounds)
	DW	150	2,010	150	32,890	14,450	66,620	2,021	75,689
STATIC	TH-1	1,200	1,540	730	69,140	179,180	101,090	2,084	217,037
	TH-2	1,460	3,540	610	189,880	249,370	249,390	3,878	400,544
	TH-3	2,270	1,630	700	83,470	228,200	343,040	2,881	420,379
	TH-4	2,080	8,600	300	195,600	172,440	382,840	8,853	463,208
	TH-5	3,230	18,400	30	1,508,440	196,180	815,550	18,681	1,725,978

SEISMIC INERTIA	X	6,430	4,830	70	129,580	2,240	185,940
	Y	420	6,550	90	108,850	18,660	175,920
	Z	440	3,340	6,600	374,560	340,530	67,710
SRSS		6,459	8,797	6,601	411,016	341,048	264,776

SEISMIC END EFFECTS	X	4,930	4,910	3,850	260,910	302,190	201,170
	Y	1,180	2,420	1,220	81,990	87,780	72,670
	Z	2,950	3,740	5,720	337,480	426,740	228,750
SRSS		5,865	6,630	7,002	434,384	530,218	313,172

Total Seismic	12,324	15,427	13,603	845,400	871,266	577,948	23,977	1,344,556

Pressure and Geometry Data Used in Teledyne Report:

Outside Diameter (Do):	28.0 in
Nominal Thickness (tn):	1.05 in
Pipe Metal Area:	88.90 in^2
Section Modulus (Z):	598.96 in^3

Next B1

Part 2: Stresses for SSFLAW Flaw Growth Calculation and Limit Load Evaluation for Loop 15

Primary Stress Calculation

Summary of Contributors to Primary Stresses

Case	Axial Force	Moment
DW	2,021	75,689
EQ	23,977	1,344,556
Sum	25,998	1,420,244
Units:	pounds	inch-pounds

Note: The forces and moments shown are SRSSed values. For conservatism, they are assumed to equal the applied axial force and overturning moment.

Normal and Upset Condition Primary Stresses (Deadweight Only)

Axial Force Due to Deadweight:	2,021	pounds
Pipe Area = pi * (Ro^2 - Ri^2):	88.90	in^2
Axial Stress (= F / Area):	22.7	psi
Bending Moment Due to Deadweight:	75,689	inch-pounds
Section Modulus (Z):	598.96	in^3
Bending Stress (= M / Z):	126.4	psi

Emergency and Faulted Condition Primary Stresses (DW + EQ)

Axial Force Due to Deadweight + EQ:	25,998	pounds
Pipe Area = pi * (Ro^2 - Ri^2):	88.90	in^2
Axial Stress (= F / Area):	292.4	psi
Bending Moment Due to Deadweight + EQ:	1,420,244	inch-pounds
Section Modulus (Z):	598.96	in^3
Bending Stress (= M / Z):	2371.2	psi

Secondary (Thermal) Stress Calculation

Thermal Forces and Moments:

Case	Axial Force	Moment
Normal (TH-4)	8,853	463,208
Faulted (TH-5)	18,681	1,725,978
Units	pounds	inch-pounds

Note: The forces and moments shown are SRSSed values. For conservatism, they are assumed to equal the applied axial force and overturning moment.

Worst Case Normal and Faulted Thermal Forces and Moments:

	Normal		Faulted	
Axial Force:	8,853	pounds	18,681	pounds
Pipe Area = pi * (Ro^2 - Ri^2):	88.90	in^2	88.90	in^2
Axial Stress (= F / Area):	99.6	psi	210.1	psi
Bending Moment:	463,208	inch-pounds	1,725,978	inch-pounds
Section Modulus (Z):	598.96	in^3	598.96	in^3
Bending Stress (= M / Z):	773.4	psi	2881.6	psi
Total Secondary Stress (= Axial Plus Bending):	872.9	psi	3091.8	psi

Overall Summary of Stresses for Input to SSFLAW Flaw Growth Calculation and Limit Load Evaluation

			Stress	
Condition	Class	Type	(psi)	(ksi)
Normal and Upset	Primary	Axial	22.7	0.02
	Primary	Bending	126.4	0.13
	Secondary	Ax. + Bend	872.9	0.87
Emergency and Faulted	Primary	Axial	292.4	0.29
	Primary	Bending	2,371.2	2.37
	Secondary	Ax. + Bend	3,091.8	3.09

Appendix B
Program SSFLAW Inputs

(Two pages total)

Appendix A to the SSFLAW user's manual (Reference 5) describes the inputs required to run the program. The required inputs are listed below, along with the values to be used for this calculation.

- Pipe Material. Per the Piping Specification Standard Record Set (Reference 8) for the recirculation system piping (System 32), the large bore recirculation system piping is made from Type 316 stainless steel.

- Material Design Stress Intensity (S_m) and Yield Strength (S_y). SSFLAW default values for these parameters are used. The program calculates these parameters for Type 316 material at the operating temperature of the system (discussed below).

- Weld Type. The recirculation system piping was replaced in 1983 with IGSCC resistant material. All circumferential welds made during this replacement were gas tungsten-arc welds (GTAW).

- Residual Stress State. The residual stress state in the vicinity of the weld will be considered "as-welded" rather than stress improved.

- Operating Temperature. Per Reference 6, the recirculation system piping operating temperature is 550°F.

- Operating Pressure. 1050 psig is used. This is slightly greater than the saturation pressure at 550°F.

- <u>Pipe Outside Diameter and Wall Thickness</u>. Reference 8 states that the large bore recirculation system piping is 28-inch OD, 1.05-inch minimum wall.

- <u>Flaw Orientation, Length and Depth.</u> Flaws are assumed to be circumferentially oriented and equal in length to the pipe circumference. The calculation will be iterated with varying depths to find the largest initial flaw size which can be accepted.

- <u>Service Interval.</u> This is the interval between inspections of the indication. Paragraphs IWB-3132.4(b) and IWB-2420(b) of Section XI require that flaws found acceptable for continued service by the evaluation criteria shall be re-examined during the next three inspection periods. NMP-1 performs inspections at each refueling outage; since the run cycles are two years long, the service interval is therefore considered to be two years (730 days).

- <u>Applied Stresses</u>. Stresses are calculated based on the results of stress analyses of the replaced piping (Reference 6). Appendix A to this report documents how the applied stresses used as input for SSFLAW were determined from the Teledyne stress results.

- <u>Reference Source for Allowable Flaw Size</u>. SSFLAW permits using either the Section XI Table IWB-3641 allowables for flaw size, or an alternate (less conservative) method based on the equations in Section XI Appendix C. For this evaluation, the more conservative tables will be specified as the reference source.

Appendix C

SSFLAW Computer Output

(Three pages total)

Note: Program SSFLAW was developed and used in accordance with the MPR Associates Quality Assurance Plan. Inputs used are described in Appendices A and B.

Calculation 085-'315-11
Appendix C

NMPC Calc. No. 512.9-32WDNOZZLE

Prepared by: 5/7/99
CHECKED BY:

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                              SSFLAW
                            Version 1.1
                          (April 5, 1988)

              IGSCC Crack Growth Calculation Results

   Loop 12(a=0.43) Normal

   Pipe Material: Type 316 Stainless Steel
    Sm= 17.50 ksi
    Sy= 19.35 ksi
    Weld Type: GTAW

   Pipe Geometry:                        System Operating Conditions:
     Outside Diameter= 28.000 in           Pressure= 1050.0 psig
     Wall Thickness=    1.050 in           Temperature= 550.0 F

   Initial Flaw Geometry:                Crack Growth Rate Parameters:
     Orientation- Circumferential          C= 0.359D-07 in/hr
     Depth=   0.430 in                     n= 2.161
     Length= 87.960 in                     Kth=  8.00 ksi√in

   Final Flaw Geometry:
     Service Interval=  730 days
     Depth=   0.570 in
     Length= 87.965 in


     ASME Code Section XI (1986 Edition), Section IWB-3640 Analysis
                          (Using IWB-3641 Tables)


                                Normal Conditions        Faulted Conditions
   Tensile Stress  (ksi)              0.04                      0.28
   Bending Stress  (ksi)              0.26                      2.10
   Thermal Stress  (ksi)              0.47                      0.47
   Pressure Stress (ksi)              6.47                      6.47
   Stress Ratio                       0.39                      0.51

   Flaw Length Ratio                  1.00                      1.00
   Final Flaw Depth  (in)            0.570                     0.570
   Allowable Flaw Depth (in)         0.661                     0.577

                                 Flaw Allowable            Flaw Allowable
```

5/5/99

Calculation 085-325-11
Appendix C

NMPC Calc. No. S12.9-32WD NOZZLE

Prepared by 5/7/99
CHECKED BY:

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                          SSFLAW
                       Version 1.1
                     (April 5, 1988)

           IGSCC Crack Growth Calculation Results

 Loop 15 (a=0.42) Normal

 Pipe Material: Type 316 Stainless Steel
  Sm= 17.50 ksi
  Sy= 19.35 ksi
  Weld Type: GTAW

 Pipe Geometry:                       System Operating Conditions:
   Outside Diameter= 28.000 in          Pressure= 1050.0 psig
   Wall Thickness=    1.050 in          Temperature= 550.0 F

 Initial Flaw Geometry:               Crack Growth Rate Parameters:
   Orientation- Circumferential         C= 0.359D-07 in/hr
   Depth=   0.420 in                    n= 2.161
   Length= 87.960 in                    Kth=  8.00 ksi√in

 Final Flaw Geometry:
   Service Interval=  730 days
   Depth=   0.575 in
   Length= 87.965 in


     ASME Code Section XI (1986 Edition), Section IWB-3640 Analysis
                        (Using IWB-3641 Tables)

                               Normal Conditions       Faulted Conditions
 Tensile Stress   (ksi)               0.02                     0.29
 Bending Stress   (ksi)               0.13                     2.37
 Thermal Stress   (ksi)               0.87                     3.09
 Pressure Stress  (ksi)               6.47                     6.47
 Stress Ratio                         0.38                     0.52

 Flaw Length Ratio                    1.00                     1.00
 Final Flaw Depth  (in)              0.575                    0.575
 Allowable Flaw Depth (in)           0.661                    0.577

                                 Flaw Allowable          Flaw Allowable
```

5/7/99

Page C3
Next D1

Calculation No.	Prepared By	Checked By	Page D1
085-325-11			

Appendix D

Calculation of Circumferential Flaw Growth Due to Fatigue

(Four pages total)

Calculation of Circumferential Flaw Growth Due to Fatigue

Prepared by:
Checked by:

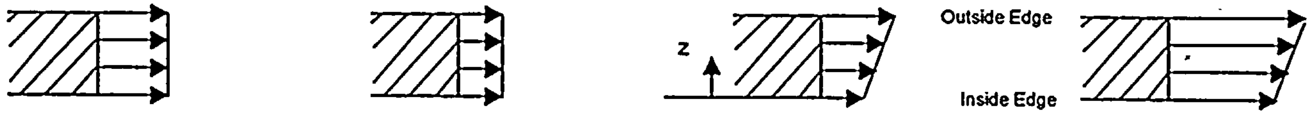
Initial Conditions:

Flaw Depth	$a =$	0.43 inch	Pipe Area	$A =$	88.90 in^2
Wall Thickness	$t_n =$	1.05 inch	Pipe Moment of Inertia	$I =$	8,083.22 in^4
Pipe OD	$D_o =$	28.00 inch	Flaw Depth to thickness ratio	$a/t_n =$	0.41
Pipe Inner Radius	$r_i =$	12.95 inch	Flaw Length	$L =$	87.96 in

Stress Distribution, Startup and Shutdown Cycles (Pressure and Thermal):

Design Pressure	$P_{max} =$	1,200 psig	(Reference 8)
Thermal Axial Load	$F =$	18,681 lb	(Loads from Appx. A
Thermal Bending Moment	$M =$	1,725,978 in-lb	for Loop 15)

Pressure Stress + **Thermal: Axial** + **Thermal: Bending** = **Total Stress**



$\sigma_P = P_{max}D_o / (4t_n)$ $\sigma_A = F / A$ $\sigma_B = M(r_i + z) / I$ $\sigma(z) = P_{max}D_o / (4t_n) + F / A + M(r_i + z) / I$

The general stress polynomial from Reference 9 expressed in terms of (z / t_n) is: $\sigma = \sigma_0 + \sigma_1(z / t_n) + \sigma_2(z / t_n)^2 + \sigma_3(z / t_n)^3$
Therefore, the stress polynomial can be expressed as follows:

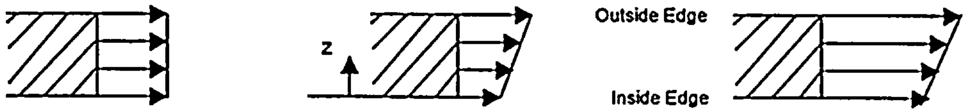
$\sigma(z) = [P_{max}D_o / (4t_n) + F / A + Mr_i / I] + [(Mt_n / I)(z / t_n)]$ where

$\sigma_0 = P_{max}D_o / (4t_n) + F / A + Mr_i / I = 10.98$ ksi
$\sigma_1 = Mt_n / I = 0.22$ ksi
$\sigma_2 = \sigma_3 = 0$ for this linear stress distribution

Stress Distribution, Seismic Cycles:

Seismic Axial Load	$F =$	23,977 lb	(Loads from Appx. A
Seismic Bending Moment	$M =$	1,344,556 in-lb	for Loop 15)

Seismic: Load + **Seismic: Bending** = **Total Stress**



$\sigma_A = F / A$ $\sigma_B = M(r_i + z) / I$ $\sigma(z) = F / A + M(r_i + z) / I$

The general stress polynomial from Reference 9 expressed in terms of (z / t_n) is: $\sigma = \sigma_0 + \sigma_1(z / t_n) + \sigma_2(z / t_n)^2 + \sigma_3(z / t_n)^3$
Therefore, the stress polynomial can be expressed as follows:

$\sigma(z) = [F / A + Mr_i / I] + [(Mt_n / I)(z / t_n)]$ where

$\sigma_0 = F / A + Mr_i / I = 2.42$ ksi
$\sigma_1 = Mt_n / I = 0.17$ ksi
$\sigma_2 = \sigma_3 = 0$ for this linear stress distribution

Prepared by:
Checked by:

Case I: Startup and Shutdown Cycles

Cycle Number	Flaw Size at Start of Cycle (inch)		Stress Polynomial Coefficients (ksi)		Influence Coefficients Ref. 9 Sec. 4.1.4, R/t = 10		Delta K (ksi - root inch)	ASME Section XI Figure A-4300-1		da/dN (inch per cycle)	End of Cycle Flaw Depth (inch)
	Depth	Length	σ_0	σ_1	G_0	G_1		Co	n		
1	0.4300000	87.96	10.98	0.22	1.5508	0.3414	19.87	2.52E-07	1.95	8.57E-05	0.4300857
2	0.4300857	87.96	10.98	0.22	1.5509	0.3415	19.88	2.52E-07	1.95	8.57E-05	0.4301714
3	0.4301714	87.96	10.98	0.22	1.5511	0.3416	19.88	2.52E-07	1.95	8.58E-05	0.4302572
4	0.4302572	87.96	10.98	0.22	1.5513	0.3417	19.88	2.52E-07	1.95	8.58E-05	0.4303430
5	0.4303430	87.96	10.98	0.22	1.5514	0.3418	19.89	2.52E-07	1.95	8.58E-05	0.4304288
6	0.4304288	87.96	10.98	0.22	1.5516	0.3419	19.89	2.52E-07	1.95	8.59E-05	0.4305147
7	0.4305147	87.96	10.98	0.22	1.5518	0.3420	19.90	2.52E-07	1.95	8.59E-05	0.4306006
8	0.4306006	87.96	10.98	0.22	1.5519	0.3421	19.90	2.52E-07	1.95	8.59E-05	0.4306865
9	0.4306865	87.96	10.98	0.22	1.5521	0.3422	19.90	2.52E-07	1.95	8.60E-05	0.4307725
10	0.4307725	87.96	10.98	0.22	1.5523	0.3423	19.91	2.52E-07	1.95	8.60E-05	0.4308585
11	0.4308585	87.96	10.98	0.22	1.5524	0.3423	19.91	2.52E-07	1.95	8.60E-05	0.4309445
12	0.4309445	87.96	10.98	0.22	1.5526	0.3424	19.92	2.52E-07	1.95	8.61E-05	0.4310306
13	0.4310306	87.96	10.98	0.22	1.5528	0.3425	19.92	2.52E-07	1.95	8.61E-05	0.4311167
14	0.4311167	87.96	10.98	0.22	1.5530	0.3426	19.93	2.52E-07	1.95	8.61E-05	0.4312028

Prepared by:
Checked by:

Flaw Size Increment for Each Cycle (Continued)

Case II: Seismic Cycles (Following 14 Startup/Shutdown Cycles)

Cycle Number	Flaw Size at Start of Cycle (inch)		Stress Polynomial Coefficients (ksi)		Influence Coefficients Ref. 9 Sec. 4.1.4, R/t = 10		Delta K (ksi - root inch)	ASME Section XI Figure A-4300-1		da/dN (inch per cycle)	End of Cycle Flaw Depth (inch)
	Depth	Length	σ_0	σ_1	G_0	G_1		Co	n		
1	0.4312028	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312029
2	0.4312029	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312030
3	0.4312030	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312031
4	0.4312031	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312032
5	0.4312032	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312033
6	0.4312033	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312034
7	0.4312034	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312034
8	0.4312034	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312035
9	0.4312035	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312036
10	0.4312036	87.96	2.42	0.17	1.5531	0.3427	4.45	1.20E-11	5.95	8.66E-08	0.4312037

Final Flaw Depth: 0.43120 inches