Form 01077 (R3-94)

ATTACHMENT 2

CERTIFICATION OF ENGINEERING CALCULATION

STATION AND UNIT NUMBER CNS 1+2

TITLE OF CALCULATION 90-05 Cal on RN stainless steel socket welds

CALCULATION NUMBER CNC 1206.00-02-0008

ORIGINALLY CONSISTING OF:

PAGES 1 THROUGH 2

TOTAL ATTACHMENTS ~~0~~ 4 TOTAL MICROFICHE ATTACHMENTS 0

TOTAL VOLUMES 1 TYPE I CALCULATION/ANALYSIS ~~☒~~ Yes ☒ No

TYPE I REVIEW FREQUENCY Type IV

THESE ENGINEERING CALCULATIONS COVER QA CONDITION 1 ITEMS. IN ACCORDANCE WITH ESTABLISHED PROCEDURES, THE QUALITY HAS BEEN ASSURED AND I CERTIFY THAT THE ABOVE CALCULATION HAS BEEN ORIGINATED, CHECKED OR APPROVED AS NOTED BELOW:

ORIGINATED BY EWMcElroy / J.F. Willis DATE 5/2/95

CHECKED BY [illegible] / BW Dennis / [illegible] DATE 5/2/95 5/2/95 / 5/2/95

APPROVED BY D. L. Ward DATE 5/2/95

ISSUED TO DOCUMENT MANAGEMENT D L Ward DATE 5/3/95

RECEIVED BY DOCUMENT MANAGEMENT ______ DATE ______

MICROFICHE ATTACHMENT LIST: ☐ Yes ☐ No SEE FORM 101.4

REV. NO.	CALCULATION PAGES (VOL)			ATTACHMENTS (VOL)			VOLUMES		ORIG	CHKD	APPR	ISSUE DATE
	REVISED	DELETED	ADDED	REVISED	DELETED	ADDED	DELETED	ADDED	DATE	DATE	DATE	REC'D-DATE

1.0 PROBLEM STATEMENT

This calculation evaluates a through wall crack located on RN stainless steel socket welded connections. The piping, is ASME Class 3 piping. This evaluation is required by NRC Generic Letter 90-05 and is referenced in PIP 0-C95-0527.

2.0 QA Condition

Piping addressed by this calculation is QA condition 1 and is a QA condition 1 calculation.

3.0 DESIGN METHOD

This calculation evaluates using the rules imposed by NRC Generic Letter 90-05, NSD 203 and ASME Section III.

4.0 APPLICABLE CODES AND STANDARDS

(1) ASME Section III 1974 Edition with addenda through summer 1974. (CNS Plant Base Code)
(2) Guidance For Performing Temporary Non-Code Repair of ASME Code Class 1,2, and 3 Piping (NRC Generic Letter 90-05)
(3) Duke Power Co. Nuclear Station Directive: 203. Operability
(4) ASME Code Case N-463
(5) Tech Spec 3/4.4.10 Structural Integrity

5.0 DESIGN INPUTS

Not Applicable

6.0 PSAR, FSAR CRITERIA

FSAR Volume 3, Table 3.2.2-3 identifies piping as complying with ASME & ANSI Codes.

7.0 ASSUMPTIONS

None

8.0 INFORMATION SOURCES

(1) Flow Diagram CN-1574
(2) Met Lab Report 1812
(3) PIP 0-C95-0527

9.0 EVALUATION

This calculation evaluates the through wall region identified at the fillet weld. The evaluation approach is the "through-wall flaw" per "NRC Generic Letter 90-05". Using NRC Generic Letter 90-05, attachment 3, the calculation meets the requirement of "K" less than 135 $ksi(in)^{0.5}$. This is consistent with the lower-bound fracture toughness property in ASME Code Case N-463. The characterized flaw, attachment 2A, uses 3/8" hole per pin hole found in the welds. This is approximately ¼" larger than could be seen on the pipe OD, Met Lab Report 1812. The actual examination of the crack with a magnifying glass while still installed was ~ 0.15". The pin hole weepage is less than 1 drop per minute. A walk down of all the RN stainless steel socket welded piping was completed by a Spoc team attachment 2 is a list of the socket weld leakers. The weld numbers are used for identification.

10.0 CONCLUSION

The characterized flaw of the RN stainless steel socket welds is acceptable per NRC Generic Letter 90-05 using the "Through-Wall Flaw" approach. The leaking RN connnections will be replaced or repaired per a repair plan. The repair plan will be initiated as soon as possible, but will not force the system availability. The RN socket welds are operable with these leaks.

Prepared By Ernie McElroy Date 5/2/95

Checked By TM Maulsbi Date 5/2/95

The pinhole leaks in the stainless steel portions of the RN system piping pose no threats from either a flooding or pipe rupture perspective. The flooding scenarios at the station are based on worst case pipe ruptures of various systems. These leaks are bounded by breaks already postulated. These leaks are all located in the heat affected zone of the welds. These weld locations were reviewed as part of the moderate energy piping water spray study for their potential affect on safety related equipment. A crack was postulated at each weld location in all moderate energy piping greater than 1" in diameter. These leaks are therefore also bounded by studies already in place at the plant. The only portions of piping which are excluded are those equal to or less than 1" in diameter. Since these are all located in areas of larger piping already reviewed for water spray effects, these leaks are also acceptable.

ACTUAL LEAKING WELDS OR SIGNS OF LEAKAGE

RN SS Socket Welds

Attachment 2

WELD #s	PIPE DIA.			
1RN 423-80	2"			
1RN 526-3	2"			
1RN 527-3	2"			
1RN 527-4	2"			
1RN 529-3	2"			
1RN 529-6	2"			
1RN 530-5	2"			
1RN 530-7	2"			
1RN 531-6	2"			
1RN 531-9	2"			
2RN 184-14	2"			
2RN 439-17	2"			
2RN 439-19	3/4"			
2RN 439-23	2"			
~~2RN 439-23~~	~~2"~~			EWM 5/2/95
2RN 440-22	1"			
2RN 441-1	2"			
2RN 442-13	2"			
2RN 442-15	2"			
2RN 442-17	2"			
2RN 442-19	2"			
2RN 442-21	2"			
2RN 442-25	2"			
2RN 442-26	2"			
2RN 442-7	2"			
2RN 443-11	2"			
2RN 445-1	2"			
2RN 445-5	2"			

Socket Weld Flaw Characterization

Eight socket welds were sectioned for flaw characterization. The general corrosion path traveled from the weld root outward through weld metal at a 45° angle. The typical geometry of the flaw was Wx DxL ,0.15" x 0.25" x 0.38"(max). This similar geometry is in seven of the eight welds sectioned welds. Weld 2RN442-15, 45 elbow, has a similar geometry as the above seven but has indication of sensitized pipe and forging. The elbow was sectioned in five locations 1/4" apart. The sectioned locations all showed some form of attack, but had no indication of linking. If assumed linked, the crack would be considered to be approximately 1.25". This is analyzed in case 4 of attachment 3 on 2" piping and is acceptable.

The worst flaw in the sectioned areas is in weld 2RN442-25, ¾" socket weld. This weld had three pin hole leaks approximately 120° apart. These pin holes were far enough apart that they are considered as three different leaks, there was no evidence of cracking between the pin holes, linking. The corrosion in the 4" butt welds is described as propagating through pipe wall would start as a pin hole, enlarging, and neck down to a pin hole as it penetrate the pipe's outside diameter. A conservative estimation of the flaw size is to use the maximum enlargement of the cavity in the pipe wall, due to the changing geometry. One size, 3/8", per pin hole was used for butt welds and socket welds. This was the maximum cavity seen in the stainless steel RN piping. This is considered the worst case of all the observed leaking welds. The other analyzed cases are as follows:

Case 1: 3/4" piping with one 3/8" hole, with reduced section modulus the three hole 120° apart.
Case 2: 1" piping with one 3/8" hole, with reduced section modulus the three hole 120° apart.
Case 3: 2" piping with one 3/8" hole, with reduced section modulus the three hole 120° apart.

The maximum weepage from any of the pin holes is less than 1 drop per minute. Using this as the maximum leaking flaw found in SS socket weld in the RN system and the maximum stresses applied, this passes generic letter 90-05, using the through wall flaw approach.

90-05 Evaluation of Flawed Fillet Welds

(Attachment 3)

Statement of Problem/Purpose

The purpose of this calculation is to evaluate the structural integrity of the thru-wall leaking flaws that exist in the stainless steel fillet welds as listed in Table 3 (see sheet 5). The flaws were characterized in attachment 2A of this calculation. The characterized flaws will be covered by 4 cases.

Quality Assurance Condition

This calculation is QA condition 1 because it serves as the basis for the qualification of a QA condition 1 structure, system or component.

Analysis Methods Used

This condition will also be evaluated using Generic Letter 91-18 section 6.14 (Flaw Evaluation). Paragraph's 3 and 4 state that moderate energy Class 3 piping (maximum operating temperature less than 200 degrees F and a maximum operating pressure less than 275 psig) may be evaluated using Generic Letter 90-05.

References

1. 1974 ASME Code Section III, Subsection ND, Fig. ND-4427-1
2. 1989 ASME Code Section III (Winter Addenda), Subsection NB, Table NB-3681(a)-1 and NB-3683.4 (c)(2)
3. For Piping Analysis Calculations, see Table 1

References (cont.)

4. NRC Generic Letters 90-05 and 91-18
7. ASME Code Case N-480
8. NUREG/CR-4572
9. For weld isometric see Table 2
10. Vector Mechanics for Engineers: Statics & Dynamics, by Beer and Johnston

Assumptions

Listed as used in body of calculation

Characterization

The following 4 cases were considered based on attachment 2A of this calculation. In each case the flaw was assumed to be thru-wall for the entire length.

Case 1 - considers a 3/4" sch 40 pipe with 3-0.375" flaws located 120 degrees apart.

Case 2 - considers a 1" sch 40 pipe with 3-0.375" flaws located 120 degrees apart.

Case 3 - considers a 2" sch 40 pipe with 3-0.375" flaws located 120 degrees apart.

Case 4 - considers a 2" sch 40 pipe with 1-1.25" flaw.

Evaluation

Per section C, part 3, of generic letter 90-05, the structural integrity of a through wall crack like flaw may be evaluated using, part 3.a ("Through-Wall Flaw" Approach). The following is an evaluation using this method except as noted below.

Evaluation (cont.)

Since the flaw consists mainly of a subsurfa :e void, it was assumed to be thru-wall for the entire length, therefore the maximum diameter of the void will be used for "2a", and nominal thickness will be used for "tmin".

Based on the maximum size of the flaw (3/8"), and the minimum distance apart (120 degrees) on a 3/4" pipe, these flaws were considered far enough apart to be considered separately.

The flaw assumed for case 4 is 17% of the circumference of the nominal pipe, which exceed the limit of 15%. This is considered acceptable by engineering judgement due to the conservatism of assuming that all the small flaws would link together .

The stresses in the fillet weld, normal to the crack will be conservatively estimated by using the C1 and C2 primary plus secondary indices for a class 1 fillet weld. These indices, when applied to the nominal stress in the pipe, would yield the maximum primary plus secondary stress intensity in the weld. Per the 1989 ASME Section III Winter Addenda, Subsection NB, Table NB-3681(a)-1 the C1 and C2 indices would be 1.8 and 2.1 respectively. The existing stresses for each weld location are tabulated on sheet 6. These stresses were taken from the existing Superpipe Analysis Runs for the problems listed in Table 1 (see sheet 5). The maximum ASME Section III Equation's 8, 9, 10 and 9E stresses and ratio's are listed. The Equation 9E stresses at Catawba are used to evaluate functionality by comparing faulted stresses too and Emergency allowable. The stress to be used for the 90-05 evaluation will be the summation of the maximum thermal stress (EQ 10), plus the maximum pressure stress, gravity stress and SSE earthquake stress. The above 90-05 stresses (Eq 10 thermal + pressure + weight + SSE inertia + SSE SAM's) were then manipulated to determine the maximum bending moment. This moment times the C2 indices divided by the section modulus at the extreme fiber was then used to calculate the 90-05 bending stress. The 90-05 pressure stress was then conservatively calculated using the C1 indices times PD/2t. These stresses were added together to determine the total 90-05 stress. The above was repeated for each case using the maximum stress from all weld locations (see sheets 7 through 10).

Evaluation (cont.)

To qualify the existing ASME Section III stresses, the section modulus of the cracked section "Zc" and the area of the cracked section "Ac" was calculated for each pipe size (see sheets 16 through 19). The equations used to calculated the section properties are derived on sheets 11 through 13. The existing maximum stress ratio's for ASME Section III Equations 8, 9, and 9E were factored by the larger of (Zun "uncracked" / Zc "cracked") or (Aun "uncracked" / Ac "cracked") (see sheets 7 through 10 for calculations). The existing maximum ratio for ASME Section III Equation 10 was not factored since generic letter 90-05 requires that a code repair be performed at the next scheduled outage, making the evaluation of a secondary thermal stress of little concern, especially from a fatigue standpoint.

Conclusion

Since the piping is made of austenitic stainless steel, the critical stress intensity factor K will be 135.0 ksi(in)^0.5 (ref. Generic Letter 90-05). Since the stress intensity factor K for each case calculated on sheets 7 thru 10 are less than the critical value, the requirements of generic letter 90-05 have been meet, except as previously noted. The ASME Section III Equations for primary stresses are also acceptable since the factored ratio's are less than 1.0.

Table 1

Prob. No.	Micro Fiche Attach.	Superpipe Run Date	Superpipe Run Time	Calculation File No.	Calculation Rev. No.
RN076	M1	06-21-90	11:06:59	CNC-1206.12-34-2076	3
RN123	N/A	10-06-84	11:57:47	CNC-1206.12-34-2123	3
RN133	M3	09-04-90	08:38:09	CNC-1206.12-34-2133	7
RN144	M1	08-08-90	17:01:10	CNC-1206.12-34-2144	5
RN15	M2	08-09-88	14:39:07	CNC-1206.12-34-2015	9
RNS	M1	06-13-90	13:26:14	CNC-1206.02-84-2024	5

Table 3

Weld #'s	Nominal Diameter	Schedule	Wall Thickness
1RN 423-80	2"	40	0.154
1RN 526-3	2"	40	0.154
1RN 527-3	2"	40	0.154
1RN 527-4	2"	40	0.154
1RN 529-3	2"	40	0.154
1RN 529-6	2"	40	0.154
1RN 530-5	2"	40	0.154
1RN 530-7	2"	40	0.154
1RN 531-6	2"	40	0.154
1RN 531-9	2"	40	0.154
2RN 184-14	1"	40	0.133
2RN 439-17	2"	40	0.154
2RN 439-19	2"	40	0.154
2RN 439-23	2"	40	0.154
2RN 440-22	2"	40	0.154
2RN 441-1	2"	40	0.154
2RN 442-13	2"	40	0.154
2RN 442-15	2"	40	0.154
2RN 442-17	2"	40	0.154
2RN 442-19	2"	40	0.154
2RN 442-21	2"	40	0.154
2RN 442-25	2"	40	0.154
2RN 442-26	3/4"	40	0.113
2RN 442-7	2"	40	0.154
2RN 443-11	2"	40	0.154
2RN 445-1	2"	40	0.154
2RN 445-5	2"	40	0.154

Table 2

Weld Isomtric Drawing Numbers	Drawing Revision Number
CN-1RN 423	12
CN-1RN 526	0
CN-1RN 527	0
CN-1RN 529	1
CN-1RN 530	1
CN-1RN 531	0
CN-2RN 184	5
CN-2RN 439	1
CN-2RN 440	1
CN-2RN 441	0
CN-2RN 442	1
CN-2RN 443	0
CN-2RN 445	1

Existing Fillet Welded Stresses

Weld #'s	Prob. No.	Micro Fiche Attach.	Superpipe Run Date	Superpipe Run Time	DCP	SOP	Press. pd/d, pd4t	Press.	Section Modulus Mean/Extr	Eq 8 Stress Ratio	Eq 9 Stress Ratio	Eq 10 Stress Ratio	Eq 9E Stress Ratio	Thermal Eq 10 Stress	Pres+Wt +SSE Stress	Total Stress	SIF
2RN 445-1	RN133	M3	09-04-90	08:38:09	C06A	34W	pd/d	165	mean	0.065	0.070	0.121	0.056	3402	1841	5243	2.1
2RN 445-5	RN133	M3	09-04-90	08:38:09	BP3A	29W	pd/d	165	mean	0.023	0.023	0.015	0.018	422	579	1001	2.1
2RN 439-23	RN133	M3	09-04-90	08:38:09	*1	45W	pd/d	165	mean	0.145	0.196	0.360	0.175	10110	5748	15858	2.1
2RN 439-17	RN133	M3	09-04-90	08:38:09	C03A	50W	pd/d	165	mean	0.132	0.177	0.349	0.156	9804	5174	14978	2.1
2RN 439-19	RN133	M3	09-04-90	08:38:09	C04A	48W	pd/d	165	mean	0.194	0.231	0.243	0.194	6832	6405	13237	2.1
1RN 531-9	RN076	M1	06-21-90	11:06:59	BP1B	81W	pd/d	165	mean	0.028	0.028	0.000	0.022	0	705	705	2.1
1RN 531-6	RN076	M1	06-21-90	11:06:59	C10A	77W	pd/d	165	mean	0.100	0.203	0.098	0.206	2745	6757	9503	2.1
1RN 529-3	RN076	M1	06-21-90	11:06:59	C47B	38W	pd/d	165	mean	0.065	0.070	0.404	0.050	11348	1841	13190	2.1
2RN 442-7	RN144	M1	08-08-90	17:01:10	BP5B	111W	pd/d	165	mean	0.034	0.031	0.000	0.023	0	732	732	2.1
2RN 442-13	RN144	M1	08-08-90	17:01:10	C12B	121W	pd/d	165	mean	0.042	0.389	0.284	0.142	7962	15345	23307	2.1
2RN 442-17	RN144	M1	08-08-90	17:01:10	BP6C	149W	pd/d	165	mean	0.034	0.032	0.000	0.023	0	773	773	2.1
2RN 442-19	RN144	M1	08-08-90	17:01:10	BP6B	127W	pd/d	165	mean	0.035	0.289	0.403	0.081	11309	11339	22648	2.1
2RN 442-26	RN144	M1	08-08-90	17:01:10	RED4	135W	pd/d	165	mean	0.072	0.428	0.746	0.260	20952	16470	37422	2.1
2RN 442-25	RN144	M1	08-08-90	17:01:10	BP7B	134W	pd/d	165	mean	0.022	0.049	0.062	0.032	1738	1665	3403	2.1
1RN 423-80	RN15	M2	08-09-88	14:39:07	C03A	49W	pd4t	130	extr	0.037	0.035	0.014	0.026	387	849	1235	2.1
2RN 184-14	RN123	N/A	10-06-84	11:57:47	27	34W	pd/d	130	mean	0.028	0.119	0.035	0.135	975	4451	5427	2.1
1RN 529-6	RN076	M1	06-21-90	11:06:59	BP5B	43W	pd/d	165	mean	0.019	0.019	0.033	0.014	913	478	1391	2.1
1RN 530-7	RN076	M1	06-21-90	11:06:59	BP3B	109W	pd/d	165	mean	0.022	0.025	0.030	0.021	853	677	1530	2.1
1RN 530-5	RN076	M1	06-21-90	11:06:59	BP3C	140W	pd/d	165	mean	0.033	0.029	0.000	0.020	0	666	666	2.1
1RN 527-3	RNS	M1	06-13-90	13:26:14	BP5B	25W	pd/d	165	mean	0.022	0.056	0.112	0.059	3139	1954	5092	2.1
1RN 527-4	RNS	M1	06-13-90	13:26:14	BP5C	47W	pd/d	165	mean	0.033	0.030	0.000	0.021	0	707	707	2.1
1RN 526-3	RNS	M1	06-13-90	13:26:14	FL6B	11W	pd/d	165	mean	0.086	0.151	0.114	0.147	3201	4840	8042	2.1
2RN 441-1	RN144	M1	08-08-90	17:01:10	C06A	51W	pd/d	165	mean	0.073	0.089	0.034	0.073	946	2496	3442	2.1
2RN 440-22	RN144	M1	08-08-90	17:01:10	C05A	53W	pd/d	165	mean	0.063	0.079	0.134	0.065	3755	2244	5999	2.1
2RN 443-11	RN133	M3	09-04-90	08:38:09	BP6B	134W	pd/d	165	mean	0.034	0.033	0.000	0.025	0	814	814	2.1
2RN 442-15	RN144	M1	08-08-90	17:01:10	C13B	123W	pd/d	165	mean	0.049	0.367	0.229	0.154	6421	14327	20748	2.1
2RN 442-21	RN144	M1	08-08-90	17:01:10	C14B	129W	pd/d	165	mean	0.095	0.411	0.5[illegible]7	0.110	15645	15402	31047	2.1
									Max	0.194	0.428	0.746	0.260	Maximum Stress		37422	2.1
									SIF at Max	2.1	2.1	2.1	2.1	SOP number at location of maximum			

Pressure Term	pd/d	stress =	135W
Pressure	165	Thermal EQ 10	20952
Section Mod.	mean	Press+Wt+SSE	16470

Notes: *1. Weld is located between C06B and C05A.

	Rev.	Pref.	Date	Check	Date
Catawba Nuclear Station Units 1 & 2					
90-05 Eval. of Flawed RN Fillet Welds	0	JTW	5-1-95	BWD	5-1-95
Calc. File No. CNC-1206.00-02-0008					
Page 6 Attachment 3					

Thru-Wall Flaw Evaluation Using Generic Letter 90-05 for Socket Welding Pipe Case 1

Pipe Mean Radius (in)	Pipe O. D. (in)	Nom. Wall Thickness (in)	Code tmin See note 3 (in)	One Half Total Crack Length (in)	c	r	A	B
0.4685	1.050	0.113	0.113	0.1875	0.1274	4.146	1.9335	-1.9564
Enter 1 for carbon steel and 2 stainless steel					2			
C	Piping Stress ksi (Note 2)	F	Stress Intensity K	Allowble Stress Intensity	Ratio	The C1 and C2 indices were used in the 90-05 stress to estimate the discontinuity stress in the fillet weld.		
9.9071	48.39	1.0839	56.35	135	0.42			
Superpipe pressure stress-Enter 1 for Pd^2/(D^2-d^2) or 2 for PD/4t				1			Cls 1, C1 indice	1.8
Superpipe section modulus-enter 1 for mean or 2 extreme fiber				1	Existing SIF	2.1	Cls 1, C2 indice	2.1
Existing Superpipe EQ 10 Stress	Existing Superpipe EQ 9E stress	Existing Pressure (P)	Existing Pressure Stress	Exist. EQ 9E Bending Stress	Existing Bending Moment	90-05 Bending Stress	90-05 Pressure Stress	Total 90-05 Stress
20952	16470	165	264.52	16205.48	1579.13	47007.66	1379.87	48387.53
Is the total crack length less than 3".				Yes	N/A			
Is the total crack length less than 15 percent of the pipe circumference.				Yes	N/A			

Evaluation of Existing Stresses Using the Cracked Section

See sheet ___ for calculation of cracked section modulus (Zc).					Cracked Zc (in^3)	Uncracked Zun (in^3)	Ratio Zun/Zc	Cracked Area Ac (in^2)
r (in)	ri (in)	t (in)	I Cracked (in^4)	I Uncracked (in^4)				
0.4685	0.4120	0.1130	0.024	0.0370	0.046	0.0779	1.6939	0.219
Uncracked Area Aun (in^2)	Ratio Aun/Ac	Maximum Ratio	ASME Equation Number	Existing Ratio	Cracked Ratio			
0.3326	1.5189	1.6939	8	0.194	0.329			
			9	0.428	0.725			
			9E	0.26	0.440			

Notes
1. For acceptance see sheet N/A.
2. See sheet 6 for existing stresses.
3. Used pipe nominal wall thickness see sheet 3.
4. This evaluation assumed the flaw was thru-wall for the entire length.

Rev.	Orig	Date	Check	Date
0	[illegible]	5-1-95	JHG / [illegible]	5/1/95 / 5/1/95

Catawba Nuclear Station, Unit 1 & 2
90-05 Evaluation of Flawed RN Fillet Welds
Calc File # CNC-1206.00-02-0008
Page 7, Attachment 3

Thru-Wall Flaw Evaluation Using Generic Letter 90-05 for Socket Welding Pipe Case 2

Pipe Mean Radius (in)	Pipe O. D (in)	Nom. Wall Thickness (in)	Code tmin See note 3 (in)	One Half Total Crack Length (in)	c	r	A	B
0.5910	1.315	0.133	0.133	0.1875	0.1010	4.444	2.2287	-2.7128
Enter 1 for carbon steel and 2 stainless steel					2			
C	Piping Stress ksi (Note 2)	F	Stress Intensity K	Allowble Stress Intensity	Ratio	The C1 and C2 indices were used in the 90-05 stress to estimate the discontinuity stress in the fillet weld.		
10.6506	48.19	1.0662	55.21	135	0.41			
Superpipe pressure stress-Enter 1 for Pd^2/(D^2-d^2) or 2 for PD/4t				1			Cls 1, C1 indice	1.8
Superpipe section modulus-enter 1 for mean or 2 extreme fiber				1	Existing SIF	2.1	Cls 1, C2 indice	2.1
Existing Superpipe EQ 10 Stress	Existing Superpipe EQ 9E stress	Existing Pressure (P)	Existing Pressure Stress	Exist. EQ 9E Bending Stress	Existing Bending Moment	90-05 Bending Stress	90-05 Pressure Stress	Total 90-05 Stress
20952	16470	165	288.74	16181.26	2955.41	46720.16	1468.25	48188.41
Is the total crack length less than 3".				Yes	N/A			
Is the total crack length less than 15 percent of the pipe circumference.				Yes	N/A			

Evaluation of Existing Stresses Using the Cracked Section

See sheet for calculation of cracked section modulus (Zc).

r (in)	ri (in)	t (in)	I Cracked (in^4)	I Uncracked (in^4)	Cracked Zc (in^3)	Uncracked Zun (in^3)	Ratio Zun/Zc	Cracked Area Ac (in^2)
0.5910	0.5245	0.1330	0.063	0.0873	0.095	0.1459	1.5362	0.359

Uncracked Area Aun (in^2)	Ratio Aun/Ac	Maximum Ratio	ASME Equation Number	Existing Ratio	Cracked Ratio
0.4939	1.3757	1.5362	8	0.194	0.298
			9	0.428	0.658
			9E	0.26	0.399

Notes
1. For acceptance see sheet N/A.
2. See sheet 6 for existing stresses.
3. Used pipe nominal wall thickness see sheet 3.
4. This evaluation assumed the flaw was thru-wall for the entire length.

Rev.	Orig	Date	Check	Date
0	[signature]	5-1-95	JTG / [signature]	5/1/95 5/1/95

Catawba Nuclear Station, Unit 1 & 2
90-05 Evaluation of Flawed RN Fillet Welds
Calc File # CNC-1206.00-02-0008
Page 8, Attachment 3

Thru-Wall Flaw Evaluation Using Generic Letter 90-05 for Socket Welding Pipe Case 3

Pipe Mean Radius (in)	Pipe O. D. (in)	Nom. Wall Thickness (in)	Code tmin See note 3 (in)	One Half Total Crack Length (in)	c	r	A	B
1.1105	2.375	0.154	0.154	0.1875	0.0537	7.211	4.5720	-8.7169
Enter 1 for carbon steel and 2 stainless steel					2			
C	Piping Stress ksi (Note 2)	F	Stress Intensity K	Allowble Stress Intensity	Ratio	The C1 and C2 indices were used in the 90-05 stress to estimate the discontinuity stress in the fillet weld.		
16.5525	47.23	1.0517	53.37	135	0.40			
Superpipe pressure stress-Enter 1 for Pd^2/(D^2-d^2) or 2 for PD/4t				1			Cls 1, C1 indice	1.8
Superpipe section modulus-enter 1 for mean or 2 extreme fiber				1	Existing SIF	2.1	Cls 1, C2 indice	2.1
Existing Superpipe EQ 10 Stress	Existing Superpipe EQ 9E stress	Existing Pressure (P)	Existing Pressure Stress	Exist. EQ 9E Bending Stress	Existing Bending Moment	90-05 Bending Stress	90-05 Pressure Stress	Total 90-05 Stress
20952	16470	165	515.27	15954.73	11996.46	44936.23	2290.18	47226.41
Is the total crack length less than 3".				Yes	N/A			
Is the total crack length less than 15 percent of the pipe circumference.				Yes	N/A			

Evaluation of Existing Stresses Using the Cracked Section

See sheet for calculation of cracked section modulus (Zc).

r (in)	ri (in)	t (in)	I Cracked (in^4)	I Uncracked (in^4)	Cracked Zc (in^3)	Uncracked Zun (in^3)	Ratio Zun/Zc	Cracked Area Ac (in^2)
1.1105	1.0335	0.1540	0.563	0.6657	0.474	0.5966	1.2587	0.913

Uncracked Area Aun (in^2)	Ratio Aun/Ac	Maximum Ratio	ASME Equation Number	Existing Ratio	Cracked Ratio
1.0745	1.1769	1.2587	8	0.194	0.244
			9	0.428	0.539
			9E	0.26	0.327

Notes
1. For acceptance see sheet N/A.
2. See sheet 6 for existing stresses.
3. Used pipe nominal wall thickness see sheet 3.
4. This evaluation assumed the flaw was thru-wall for the entire length.

Rev.	Orig	Date	Check	Date
0	[signature]	5-1-95	JTG / [signature]	5/1/95 5/1/95

Catawba Nuclear Station, Unit 1 & 2
90-05 Evaluation of Flawed RN Fillet Welds
Calc File # CNC-1206.00-02-0008
Page 9, Attachment 3

Thru-Wall Flaw Evaluation Using Generic Letter 90-05 for Socket Welding Pipe Case 4

Pipe Mean Radius (in)	Pipe O. D. (in)	Nom. Wall Thickness (in)	Code tmin See note 3 (in)	One Half Total Crack Length (in)	c	r	A	B
1.1105	2.375	0.154	0.154	0.6250	0.1791	7.211	4.5720	-8.7169
Enter 1 for carbon steel and 2 stainless steel					2			
C	Piping Stress ksi (Note 2)	F	Stress Intensity K	Allowble Stress Intensity	Ratio	The C1 and C2 indices were used in the 90-05 stress to estimate the discontinuity stress in the fillet weld.		
16.5525	47.23	1.2685	117.53	135	0.87			
Superpipe pressure stress-Enter 1 for Pd^2/(D^2-d^2) or 2 for PD/4t				1			Cls 1, C1 indice	1.8
Superpipe section modulus-enter 1 for mean or 2 extreme fiber				1	Existing SIF	2.1	Cls 1, C2 indice	2.1
Existing Superpipe EQ 10 Stress	Existing Superpipe EQ 9E stress	Existing Pressure (P)	Existing Pressure Stress	Exist. EQ 9E Bending Stress	Existing Bending Moment	90-05 Bending Stress	90-05 Pressure Stress	Total 90-05 Stress
20952	16470	165	515.27	15954.73	11996.46	44936.23	2290.18	47226.41
Is the total crack length less than 3".				Yes	N/A			
Is the total crack length less than 15 percent of the pipe circumference.				Unacceptable	See note 1			

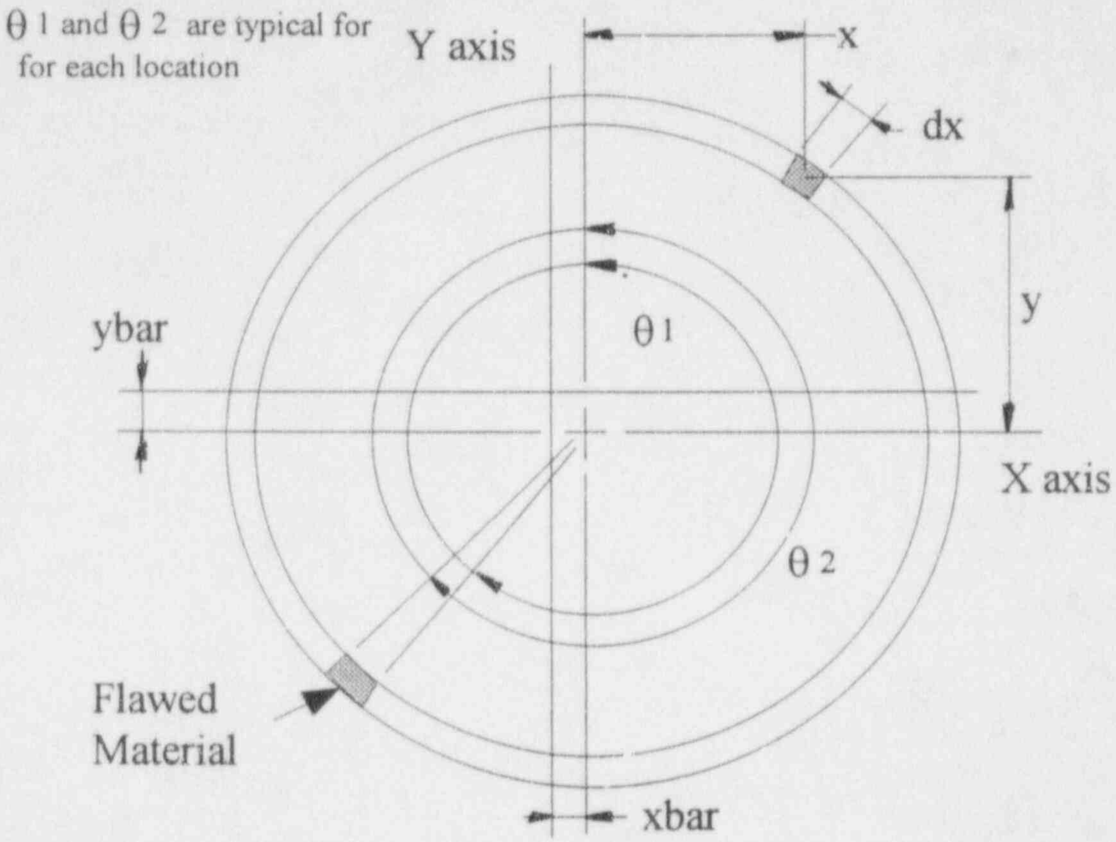
Evaluation of Existing Stresses Using the Cracked Section

See sheet for calculation of cracked section modulus (Zc).					Cracked Zc (in^3)	Uncracked Zun (in^3)	Ratio Zun/Zc	Cracked Area Ac (in^2)
r (in)	ri (in)	t (in)	I Cracked (in^4)	I Uncracked (in^4)				
1.1105	1.0335	0.1540	0.419	0.6657	0.299	0.5966	1.9954	0.895
Uncracked Area Aun (in^2)	Ratio Aun/Ac	Maximum Ratio	ASME Equation Number	Existing Ratio	Cracked Ratio			
1.0745	1.2006	1.9954	8	0.194	0.387			
			9	0.428	0.854			
			9E	0.26	0.519			

Notes
1. For acceptance see sheet 3.
2. See sheet 6 for existing stresses.
3. Used pipe nominal wall thickness see sheet 3.
4. This evaluation assumed the flaw was thru-wall for the entire length.

Rev.	Orig	Date	Check	Date
0	GJW	5-1-95	JTH / GWQ	5/1/95 / 5/1/95

Catawba Nuclear Station, Unit 1 & 2
90-05 Evaluation of Flawed RN Fillet Welds
Calc File # CNC-1206.00-02-0008
Page 10, Attachment 3



Derivation of formulas used to calculate Section Properties

dx = arc length for rotation $d\theta$

$da = t\,dx = tr\,d\theta$, where t = thickness, r = mean radius

θ_1 = angle in radians at the start of each flaw.

θ_2 = angle in radians at the end of each flaw.

∴ Area for the section from θ_2 to θ_1 = $\int_{\theta_1}^{\theta_2} tr\,d\theta = rt\theta_2 - rt\theta_1$

∴ first area moment about the x axis for the section from θ_2 to θ_1 = $\int y\,da = \int_{\theta_1}^{\theta_2} rt\,d\theta\, r\cos\theta = r^2 t \int_{\theta_1}^{\theta_2} \cos\theta\, d\theta$

(cont.)

Rev.	Perf.	Date	Check	Date
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(cont. from previous sheet)

$= r^2 t\left(\sin\theta_2 - \sin\theta_1\right)$

δ first area moment about the y axis for the section from θ_2 to θ_1 = $\int x\,da = \int_{\theta_1}^{\theta_2} rt\,d\theta\, r\sin\theta = r^2 t\int_{\theta_1}^{\theta_2} \sin\theta\,d\theta$

$= r^2 t\left(-\cos\theta_2 - \left(-\cos\theta_1\right)\right)$

Moment of Inertia about the X axis

δ I_x for the section from θ_2 to θ_1 = $\int y^2 da$

$= \int_{\theta_1}^{\theta_2} r^2\cos^2\theta\, tr\,d\theta = r^3 t\int_{\theta_1}^{\theta_2} \cos^2\theta\,d\theta$

$= r^3 t\left(\left(\frac{\theta_2}{2} + \frac{\sin\theta_2\cos\theta_2}{2}\right) - \left(\frac{\theta_1}{2} + \frac{\sin\theta_1 \cos_1}{2}\right)\right)$

Moment of Inertia about the Y axis

δI_y for the section from θ_2 to θ_1 = $\int x^2 da$

$= \int_{\theta_1}^{\theta_2} r^2\sin^2\theta\, tr\,d\theta = r^3 t\int_{\theta_1}^{\theta_2} \sin^2\theta\,d\theta$

$= r^3 t\left(\left(\frac{\theta_2}{2} - \frac{\sin\theta_2\cos\theta_2}{2}\right) - \left(\frac{\theta_1}{2} - \frac{\sin\theta_1\cos\theta_1}{2}\right)\right)$

Product of Inertia about the x-y axis

δI_{xy} for the section from θ_2 to θ_1 = $\int xy\,da$

$= \int_{\theta_1}^{\theta_2} r\sin\theta\, r\cos\theta\, tr\,d\theta = r^3 t\int_{\theta_1}^{\theta_2} \sin\theta\cos\theta\,d\theta$

$= r^3 t\left(\frac{\sin\theta_2^{\,2}}{2} - \frac{\sin\theta_1^{\,2}}{2}\right)$

Total Area = Summation of δ area's

(cont.)

(cont. from previous sheet)

First Area Moment x and y = summation of δ area moments

$$ybar = \frac{\text{First Area Moment about the x axis}}{\text{Total Area}}$$

$$xbar = \frac{\text{First Area Moment about the y axis}}{\text{Total Area}}$$

$$Ixbar = I_x - (\text{Total Area})(ybar)^2$$

$$Iybar = I_y - (\text{Total Area})(xbar)^2$$

$$Ixybar = Ixy - (\text{Total Area})(xbar)(ybar)$$

Principal Moments of Interia

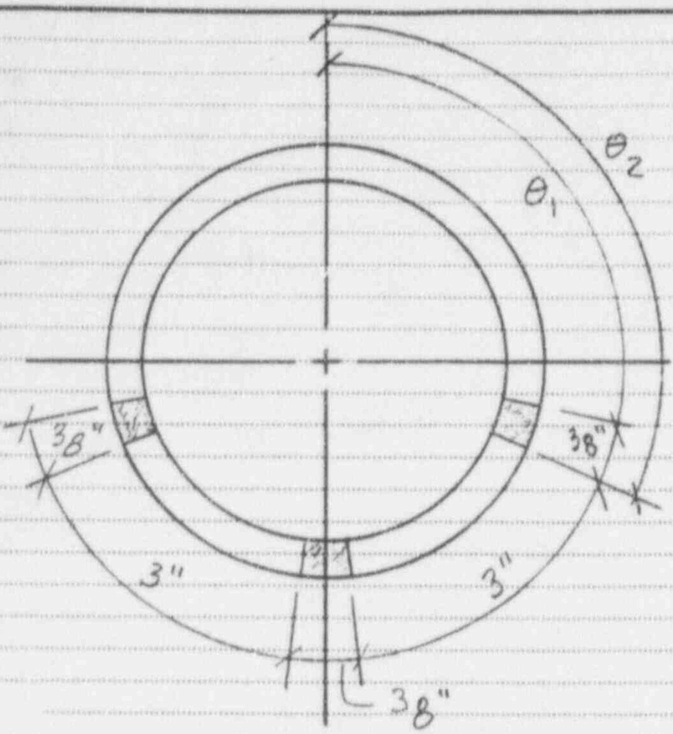
$$Imin, Imax = \frac{Ixbar + Iybar}{2} \pm \sqrt{\left(\frac{Ixbar - Iybar}{2}\right)^2 + (Ixybar)^2}$$

$$Z = \frac{I}{c}$$

Principal Section Modulus

$$Zmin, Zmax = \frac{I(min, max)}{O.D/2 + \sqrt{(ybar)^2 + (xbar)^2}}$$

Ref: Vector Mechanics For Engineers: Statics & Dynamics, by Beer & Johnston



4" Butt Weld Section

$arc = R\theta \quad R = D/2 \quad \theta = \frac{arc}{D/2}$

$\theta = \frac{2arc}{D}$

$\theta_{3/8"} = \frac{2 \times .375}{4.5} = 0.1667 \text{ rads}$

$\theta_{3"} = \frac{2 \times 3}{4.5} = 1.3333 \text{ rads}$

$\theta_1 = 0$

$= (2\pi - \theta_{3/8} \times 3 - \theta_3 \times 2)/2$

$\theta_2 = 1.5582 \text{ rad}$

$\theta_2 = 1.5582 + .1667 = 1.7249$

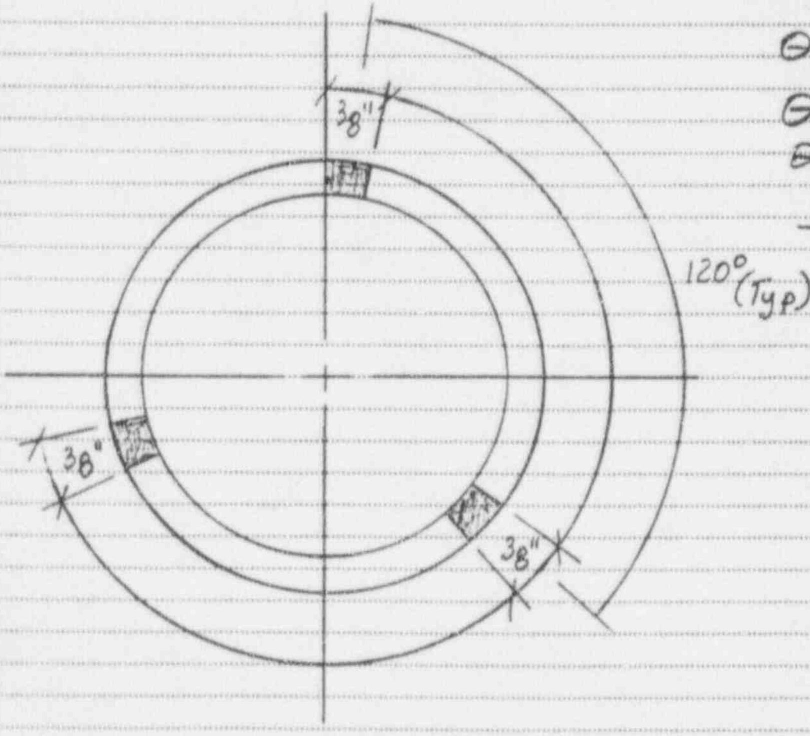
$\theta_2 = 1.7249 + 1.3333 = 3.0582$

$\theta_2 = 3.0582 + .1667 = 3.2249$

$\theta_2 = 3.2249 + 1.3333 = 4.5582$

$\theta_2 = 4.5582 + .1667 = 4.7249$

$\theta_2 = 4.7249 + 1.5582 = 6.2831$



Case-1 3/4" Socket Weld

$\theta_1 = 0$

$\theta_2 = \frac{0.375 \times 2}{1.05} = .7143 \text{ rad}$

$\theta_2 = (((2\pi - (3 \times .7143))/3) + .7143$

$= 2.0944 \text{ rad}$

$\theta_2 = 2.0944 + .7143 = 2.8087$

$\theta_2 = 2.8087 + 1.3801 = 4.1888$

$\theta_2 = 4.1888 + .7143 = 4.9031$

$\theta_2 = 4.9031 + 1.3801 = 6.2832$

Rev.	Perf.	Date	Check	Date
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Case-2 1" Socket Weld (See Case 1 for Sketch)

$\theta_1 = 0$

$\theta_2 = \frac{0.375 \times 2}{1.315} = 0.5703$ rad

$\theta_2 = (((2\pi - (3 \times .5703))/3) + .5703 = 2.0944$ rad

$\theta_2 = 2.0944 + .5703 = 2.6647$ rad

$\theta_2 = 2.6647 + 1.5241 = 4.1888$ rad

$\theta_2 = 4.1888 + .5703 = 4.7591$ rad

$\theta_2 = 4.7591 + 1.5241 = 6.2832$ rad

Case-3 2" Socket Weld (See Case 1 for Sketch)

$\theta_1 = 0$

$\theta_2 = \frac{.375 \times 2}{2.375} = 0.3158$ rad

$\theta_2 = (((2\pi - (3 \times .3158))/3) + .3158 = 2.094$ rad

$\theta_2 = 2.094 + .3158 = 2.4102$ rad

$\theta_2 = 2.4102 + 1.7786 = 4.1888$ rad

$\theta_2 = 4.1888 + .3158 = 4.5046$ rad

$\theta_2 = 4.5046 + 1.7786 = 6.2832$ rad

Case-4 2" Socket weld with 1-1.25" Flaw (Note this flaw was assumed be center at $\theta = \pi$

$\theta_1 = 0$

$\theta_2 = (\pi - ((\frac{1.25 \times 2}{2.375})/2)) = 2.6153$ rad

$\theta_2 = 2.6153 + (\frac{1.25 \times 2}{2.375}) = 3.6679$ rad

$\theta_2 = 3.6679 + 2.6153 = 6.2832$ rad

Calculation of Section Properties for Flawed Section Case 1

Angle 1 θ Radians Note 3	Angle 2 θ Radians Note 3	δ θ Radians	Wall Thick. (in)	O. D. (in)	Mean Radius (in)	δ Area (in)	δ First Area Moment x (in^3)	δ First Area Moment y (in^3)	δ Ix (in^4)	δ Iy (in^4)	δ Ixy (in^4)
0.000	0.714	0.714	0.000	1.050	0.525	0.000	0.000	0.000	0.000	0.000	0.000
0.714	2.094	1.380	0.113	1.050	0.469	0.073	0.005	0.031	0.003	0.013	0.002
2.094	2.809	0.714	0.000	1.050	0.525	0.000	0.000	0.000	0.000	0.000	0.000
2.809	4.189	1.380	0.113	1.050	0.469	0.073	-0.030	-0.011	0.012	0.004	0.004
4.189	4.903	0.714	0.000	1.050	0.525	0.000	0.000	0.000	0.000	0.000	0.000
4.903	6.283	1.380	0.113	1.050	0.469	0.073	0.024	-0.020	0.009	0.007	-0.006

Total Area (in)	First Area Moment x (in^3)	First Area Moment y (in^3)	Ix (in^4)	Iy (in^4)	Ixy (in^4)
0.219	0.000	0.000	0.024	0.024	0.000

ybar (in)	xbar (in)	Ixbar (in^4)	Iybar (in^4)	Ixybar (in^4)
0.000	0.000	0.024	0.024	0.000

Imin (in^4)	Imax (in^4)	Zmin (in^3)	Zmax (in^3)
0.024	0.024	0.046	0.046

Notes

1. Zmin. and Zmax. are calculated using Imin. and Imax with c equal to the radius to O. D. plus the resultant of ybar and xbar.
2. See sheet 11-13 for forumlas used in the above calculations.
3. Angle 1 represents the angle at the start of flaw and Angle 2 represent the angle to the end of the flaw, for each flaw, see sketch on sheet 14.

Rev.	Perf.	Date	Check	Date
0	9 Jw	5-1-95	JTG	5/1/95

Calculation of Section Properties for Flawed Section Case 2

Angle 1 θ Radians Note 3	Angle 2 θ Radians Note 3	δ θ Radians	Wall Thick. (in)	O. D. (in)	Mean Radius (in)	δ Area (in)	δ First Area Moment x (in^3)	δ First Area Moment y (in^3)	δ Ix (in^4)	δ Iy (in^4)	δ Ixy (in^4)
0.000	0.570	0.570	0.000	1.315	0.658	0.000	0.000	0.000	0.000	0.000	0.000
0.570	2.094	1.524	0.133	1.315	0.591	0.120	0.015	0.062	0.009	0.033	0.006
2.094	2.665	0.570	0.000	1.315	0.658	0.000	0.000	0.000	0.000	0.000	0.000
2.665	4.189	1.524	0.133	1.315	0.591	0.120	-0.062	-0.018	0.032	0.009	0.007
4.189	4.759	0.570	0.000	1.315	0.658	0.000	0.000	0.000	0.000	0.000	0.000
4.759	6.283	1.524	0.133	1.315	0.591	0.120	0.046	-0.044	0.022	0.020	-0.014

Total Area (in)	First Area Moment x (in^3)	First Area Moment y (in^3)	Ix (in^4)	Iy (in^4)	Ixy (in^4)
0.359	0.000	0.000	0.063	0.063	0.000

ybar (in)	xbar (in)	Ixbar (in^4)	Iybar (in^4)	Ixybar (in^4)
0.000	0.000	0.063	0.063	0.000

Imin (in^4)	Imax (in^4)	Zmin (in^3)	Zmax (in^3)
0.063	0.063	0.095	0.095

Notes

1. Zmin. and Zmax. are calculated using Imin. and Imax with c equal to the radius to O. D. plus the resultant of ybar and xbar.
2. See sheet 11-13 for forumlas used in the above calculations.
3. Angle 1 represents the angle at the start of flaw and Angle 2 represent the angle to the end of the flaw, for each flaw, see sketch on sheet 14.

Rev.	Perf.	Date	Check	Date
0	97W	5-1-95	JTG	5/1/95

Catawba Nuclear Station Units 1 & 2
90-05 Evaluation of Flawed RN Fillet Welds
Calc. File No. CNC-1206.00-02-0008
Page 17 Attachment 3

Calculation of Section Properties for Flawed Section Case 3

Angle 1 θ Radians Note 3	Angle 2 θ Radians Note 3	δ θ Radians	Wall Thick. (in)	O. D. (in)	Mean Radius (in)	δ Area (in)	δ First Area Moment x (in^3)	δ First Area Moment y (in^3)	δ Ix (in^4)	δ Iy (in^4)	δ Ixy (in^4)
0.000	0.316	0.316	0.000	2.375	1.188	0.000	0.000	0.000	0.000	0.000	0.000
0.316	2.094	1.779	0.154	2.375	1.111	0.304	0.105	0.275	0.111	0.264	0.069
2.094	2.410	0.316	0.000	2.375	1.188	0.000	0.000	0.000	0.000	0.000	0.000
2.410	4.189	1.779	0.154	2.375	1.111	0.304	-0.291	-0.046	0.286	0.089	0.032
4.189	4.505	0.316	0.000	2.375	1.188	0.000	0.000	0.000	0.000	0.000	0.000
4.505	6.283	1.779	0.154	2.375	1.111	0.304	0.186	-0.229	0.166	0.209	-0.101

Total Area (in)	First Area Moment x (in^3)	First Area Moment y (in^3)	Ix (in^4)	Iy (in^4)	Ixy (in^4)
0.913	0.000	0.000	0.563	0.563	0.000

ybar (in)	xbar (in)	Ixbar (in^4)	Iybar (in^4)	Ixybar (in^4)
0.000	0.000	0.563	0.563	0.000

Imin (in^4)	Imax (in^4)	Zmin (in^3)	Zmax (in^3)
0.563	0.563	0.474	0.474

Notes

1. Zmin. and Zmax. are calculated using Imin. and Imax with c equal to the radius to O. D. plus the resultant of ybar and xbar.
2. See sheet 11-13 for forumlas used in the above calculations.
3. Angle 1 represents the angle at the start of flaw and Angle 2 represent the angle to the end of the flaw, for each flaw, see sketch on sheet 14

Rev.	Perf.	Date	Check	Date
0	GJW	5-1-95	JTh	5/1/95

Calculation of Section Properties for Flawed Section Case 4

Angle 1 θ Radians Note 3	Angle 2 θ Radians Note 3	δ θ Radians	Wall Thick. (in)	O. D. (in)	Mean Radius (in)	δ Area (in)	δ First Area Moment x (in^3)	δ First Area Moment y (in^3)	δ Ix (in^4)	δ Iy (in^4)	δ Ixy (in^4)
0.000	2.615	2.615	0.154	2.375	1.111	0.447	0.095	0.354	0.230	0.322	0.027
2.615	3.668	1.053	0.000	2.375	1.188	0.000	0.000	0.000	0.000	0.000	0.000
3.668	6.283	2.615	0.154	2.375	1.111	0.447	0.095	-0.354	0.230	0.322	-0.027

Total Area (in)	First Area Moment x (in^3)	First Area Moment y (in^3)	Ix (in^4)	Iy (in^4)	Ixy (in^4)
0.895	0.191	0.000	0.460	0.643	-0.000

ybar (in)	xbar (in)	Ixbar (in^4)	Iybar (in^4)	Ixybar (in^4)
0.213	0.000	0.419	0.643	-0.000

Imin (in^4)	Imax (in^4)	Zmin (in^3)	Zmax (in^3)
0.419	0.643	0.299	0.459

Notes

1. Zmin. and Zmax. are calculated using Imin. and Imax with c equal to the radius to O. D. plus the resultant of ybar and xbar.
2. See sheet[redacted] s 11-13 for forumlas used in the above calculations.
3. Angle 1 represents the angle at the start of flaw and Angle 2 represent the angle to the end of the flaw, for each flaw, see [redacted] sheet 15.

Rev.	Perf.	Date	Check	Date
0	gfm	5/1/95	JR	5/1/95

(Revision 7)

DESIGN ENGINEERING DEPARTMENT

OPERABILITY EVALUATION

Station: Catawba Unit: 1&2 PIR Number: 0-C95-0527

Structure, system, or component (SSC) in question: RN Stainless Steel socket welds

Design basis reference application: FSAR volume 3, Table 3.2.2-3

Technical Specification section applicable: 3/4.4.10

Structural Integrity

The SSC in question is recommended to be:

X OPERABLE ___ CONDITIONALLY OPERABLE ___ INOPERABLE

Operability Evaluation expiration date: ______

FSAR change required _YesXNo 10 CFR 50.59 Evaluation required_YesXNo

Summary/Comments:

The RN Stainless Steel socket welds had no safety significance issues during the investigation period of the pin hole leaks, per NRC 90-05 calculation, CNC-1206.00-02-0008. The leaking RN connnections will be replaced or repaired per a repair plan. The repair plan will be initiated as soon as possible, but will not force the system availability. The RN socket welds are operable with these leaks.

Originated by: Ernie McElroy Date: 05-02-95

Reviewed by: TM Marcolini Date: 5/2/95

Approved by: ______ Date: ______