ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNIT 3

TVA CALCULATION CD-Q3068-980061

See attached.

TVAN CALCULATION COVERSHEET

Title: Evaluation of IGSCC Indication at Weld GR-3-63	Plant: BFN Unit: 3
Preparing Organization: Site Engineering (Civil)	Key Nouns (For RIMS) Pipe Analysis, IGSCC, IGSCC Weld, Fracture Mechanics
Branch/Project Identifiers: CD-Q3068-980061	Each time these calculations are issued, preparer must ensure that the original (R0) RIMS accession number is filled in.

Rev	(for RIMS use)	RIMS Accession Number
Applicable Design Document(s): (see references)	R0	R14 981004 103
	R1	
SAR affected: ☐ Yes ■ No Section(s): N/A; UNID system(s): 068	R2	
	R3	

Revision 0	R1	R2	R3	Quality Related?	Yes	No
DCN No. N/A				Safety related?	■	☐
Prepared E.J. Fireveld 10-4-98				These calculations contain unverified assumption(s) that must be verified later?	☐	■
Checked J.C. Price 10-4-98				These calculations contain special requirements and/or limiting conditions?	☐	■
Reviewed J.C. Price 10-4-98				These calculations contain a design output attachment?	☐	■
Approved J.R. Glass/gjf 10-4-98				Calculation Revision: ☐ Entire Calculation ☐ Selected pages ■ Not Applicable		
Date 10-4-98						

Statement of Problem:

An IGSCC indication has been identified at weld GR-3-63. An evaluation must be performed to determine if the weld will be acceptable for one or more fuel (operating) cycles of Browns Ferry unit 3.

Abstract:

This calculation evaluates an IGSCC indication at weld GR-3-63. The weld is located on Reactor Water Recirculation loop B at the interface between valve 3-FCV-68-77 (downstream side) and the 28" diameter piping. This calculation utilizes the pc-CRACK computer program to calculate the IGSCC growth rate, the fatigue crack growth rate, and to perform an end-of-period flaw stability evaluation.

The results of this calculation demonstrate that the indication at weld GR-3-63 is acceptable for at least three additional operating cycles. The weld can also be considered acceptable for three additional cycles of operations after any future weld inspections if the crack is found not to have increased from its current size.

☐ Microfilm and return calculation to Calculation Library. Address:	☐ Microfilm and destroy.
☐ Microfilm and return calculation to:	

TVAN CALCULATION RECORD OF REVISION

Title: Evaluation of IGSCC Indication at Weld GR-3-63	CD-Q3068-980061

Revision No.	DESCRIPTION OF REVISION	Date Approved
0	Initial issue. Total pages: 20	10-4-98

TVAN CALCULATION DESIGN VERIFICATION (INDEPENDENT REVIEW) FORM

CD-Q3068-980061	0
Calculation No.	Revision

Method of design verification (independent review) used:	
1. Design Review	■
2. Alternate Calculation	□
3. Qualification Test	□

Comments:

The above noted calculation revision has been reviewed and determined to be technically adequate based on the use of accepted sound engineering practices and techniques.

Larry C. Ricca — Independent Reviewer

10/4/96 — Date

TVAN CALCULATION CLASSIFICATION FORM

CALCULATION INFORMATION:

Plant BFN Unit 3 Identifier CD-Q3068-980061 Rev. 0
Issue date 10-4-98

Title **Evaluation of IGSCC Indication at Weld GR-3-63**

System(s), Component, Feature or Subject of Calculation:

		SYSTEM/DESCRIPTION (AS NEEDED)
☒	Safety system	Reactor Water Recirculation System (068)
☐	Safety-related feature	
☐	Nonsafety system	
☐	Nonsafety-related feature	
☒	Quality-related system	
☐	Quality-related feature	
☐	Non Quality related system	
☐	Non Quality related feature	
☐	Plant environment (EQ, etc.)	
☐	Appendix R	
☐	Civil structures	
☐	Instrumentation (PAM, etc.)	
☐	Licensing	
☐	Other	

Calculation Category: B01, B06

Calculation Classification:

☒ Essential ☐ File Only ☐ Cancel ☐ Engineering Output
☐ Desirable ☐ Superseded ☐ Obsolete

Justification: This calculation documents acceptance of a weld flaw in a safety-related piping system. This calculation should therefore be classified as essential.

Concurrences:

Preparer Eric J. Treviol Date 10-1-98
Checker Terry C. Rivera Date 10-4-98
Verifier Terry C. Rivera Date 10-4-98

TABLE OF CONTENTS

SUBJECT: Evaluation of IGSCC Indication at Weld GR-3-63	BFN CALCULATION CD-Q3068-980061

PURPOSE

The purpose of this calculation is to determine whether weld GR-3-63, with an Intergranular Stress Corrosion Cracking (IGSCC) indication, will be acceptable for one or more fuel cycles without performing a weld repair.

REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section XI, IWB-3640, 1989 Edition
2. Generic Letter 88-01, "NRC Position on IGSCC in BWR Austenitic Stainless Steel Piping"
3. NUREG-0313 Rev. 2, "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping"
4. Computer Program "pc-CRACK", Version 2.1, Structural Integrity Associates, San Jose, California
5. EPRI Special Report NP-4690-SR, "Evaluation of Flaws in Austenitic Steel Piping"
6. Calculation CD-Q3068-922489 Rev. 11, "BFN Unit 3 Stress Report for Recirculation Piping Loop B, Stress Problem No. N1-368-2R"
7. Notice of Indication No. U3C8-0120
8. ASME Boiler and Pressure Vessel Code, Section III, 1989 Edition
9. Induction Heating Stress Improvement, Research Project T1113-1, Final Report, March 1983, General Electric, San Jose, California, page 4-95

ASSUMPTIONS

None.

SPECIAL REQUIREMENTS/LIMITING CONDITIONS

There are no special requirements or limiting conditions associated with this calculation.

Rev PD [signature] Date 10-1-98	Rev PD _____ Date _____	Rev PD _____ Date _____
0 CK [signature] Date 10-4-98	___ CK _____ Date _____	___ CK _____ Date _____

DESIGN INPUT DATA

Outside pipe diameter = 28.146"	(reference 6)
Pipe wall thickness = 1.2"	(reference 7)
Design pressure (N/U)= 1148 psi	(reference 6)
Peak pressure (E/F)= 1361 psi	(reference 6)
Pressure stress, design = 6249 psi	(reference 6)
Pressure stress, peak = 7409 psi	(reference 6)
Section modulus = 626.7 in^3	(reference 6)
Design temperature = 562°F	(reference 6)
Pipe material = A358 TP304 Cl 1	(reference 6)
S_m = 16.818 ksi (@ 562°F)	(reference 8)
Current flaw depth = 0.2"	(reference 7)
Current flaw length = 1.7"	(reference 7)

Applied bending moments (reference 6, microfiche TVA-F-N000757, node 322):

Load Case	My (ft-lb)	Mz (ft-lb)
Deadweight	10133	11037
Thermal (T1)	19137	6913
Thermal (T2)	11964	10060
Thermal (T3)	28132	21399
Thermal (T4)	21979	16754
Thermal (T5)	1898	3690
Thermal (T15)	15179	21967
Weld Overlay Shrinkage	344	1761
OBE SAM, X direction	50	954
OBE SAM, Z direction	5	419
OBE inertia, XY directions	11799	48627
OBE inertia, YZ directions	12973	28536

By using the above moments in the equation $12(My^2 + Mz^2)^{1/2} \div Z$, where Z = 626.7 in^3, the following stresses were calculated for use in the crack growth analysis:

Deadweight = 0.287 ksi	
Thermal = 0.677 ksi	(load case T3)
Weld shrinkage = 0.034 ksi	
OBE SAM = 0.026 psi	(summation of both SAM load cases)
OBE inertia = 0.958 ksi	

COMPUTATIONS AND ANALYSES

Stress Corrosion Crack Growth Analysis

The stress corrosion crack growth analysis was performed by the computer program pc-CRACK (reference 4) using the crack growth rate law parameters specified in Generic Letter 88-01 (i.e., $C = 3.59 \times 10^{-8}$ and $n = 2.161$). For analysis convenience, the maximum flaw depth of 0.2 inches was conservatively considered to extend 360° around the pipe circumference. Based on the ratio of pipe wall thickness to radius, Model C (Circumferential Crack in a Cylinder) was selected from the pc-CRACK Linear Elastic Crack Models. The stress considered in this analysis was the sum of the stresses due to internal pressure (design condition), deadweight, thermal expansion, weld overlay shrinkage, and OBE seismic anchor movements. The resulting stress value is 7.273 ksi.

Since this weld had been stress improved using the Induction Heating Stress Improvement Process (IHSI), residual stress was considered to be zero. This is justified since IHSI produces compressive axial residual stresses up to approximately 50% of wall thickness (reference 9). The indications in weld GR-3-63 are less than 20% of the wall thickness. The compressive residual stresses tend to inhibit IGSCC growth.

The pc-CRACK Stress Corrosion Crack Growth option, from the Linear Elastic Fracture Mechanics Module, was selected for evaluation of the IGSCC crack growth. An evaluation period of 52,560 hours (6 years or 3 fuel cycles) was used, with crack size calculated at increments of 730 hours (1 month). The results contained in Attachment B report a crack depth at the end of this evaluation period of 0.4078", which is below the ASME Section XI maximum allowable crack depth of 0.72" (60% of wall thickness).

Fatigue Crack Growth Analysis

The stress corrosion crack growth analysis discussed above determined the weld flaw size after three complete fuel cycles. The fatigue crack growth analysis was therefore also performed considering three fuel cycles of operation. Conservatively, the initial flaw size for the fatigue crack growth analysis was assumed to be equal to the end-of-period flaw size calculated in the stress corrosion crack growth analysis.

The stress value considered in the fatigue crack growth analysis was the same as that used in the corrosion crack growth analysis (7.273 ksi) which is conservative since it includes the noncyclic deadweight and weld shrinkage stresses. Based on review of reference 6, thirty stress cycles were considered sufficient to conservatively represent the number of stress cycles associated with the next three complete fuel cycles.

The loading profile and the stress intensity factors were determined using the Linear Elastic Fracture Mechanics Module of pc-CRACK. The stress intensities were used as input to the pc-CRACK Growth Evaluation Module using the Fatigue Crack Growth option. The crack model selected was Model C, Circumferential Crack in a Cylinder ($t/R = 0.1$). The Paris Law, Option A, was selected ($C = 1.589 \times 10^{-8}$ and $n = 3.3$). The fatigue crack law used is consistent with reference 5.

The pc-CRACK Fatigue Crack Growth Analysis option, from the Linear Elastic Fracture Mechanics Module, was selected for evaluating the crack growth due to fatigue. The results documented in Attachment C show that fatigue will produce an additional 0.0016" of crack growth, resulting in an end-of-period crack depth of 0.4094".

Allowable Flaw Size Evaluation

Following the methodology of reference 1, the allowable flaw depth to wall thickness ratios were calculated using the pc-CRACK Allowable Flaw Size option from the Codes and Standards Module. Under the Allowable Flaw Size option, Circumferential Crack/Stainless Steel, SMAW process, was selected. The following stress values were input into pc-CRACK for use in the weld flaw stability evaluation:

Pm = 6.249 ksi	(membrane stress due to internal pressure)
Pb = 1.245 ksi	(bending stress; deadweight plus OBE)
Pe = 0.737 ksi	(expansion stress; includes thermal, weld shrinkage and SAM)
Sm = 16.82 ksi	(material allowable stress)

The end-of-period flaw depth input for evaluation in pc-CRACK was 0.4094". This flaw depth represents the cumulative effects of crack growth due to IGSCC and fatigue for an evaluation period of 52,560 hours. The equation shown below, which is consistent with the requirements in reference 3, was used to determine the end-of-period flaw length. The resulting flaw length was determined to be 7.1234".

$$L_f = a_f(L_i / a_i)(a_f / a_i)$$

where L_f = final flaw length
a_f = final flaw depth
L_i = initial flaw length
a_i = initial flaw depth

SUMMARY OF RESULTS

The results of the analysis are provided in Attachment D. These results show that with an end-of-period flaw depth of 0.4094", and flaw length of 7.1234", the allowable flaw depth to wall thickness ratio will not be exceeded and the weld will remain stable. (Note: The evaluation was performed only for the normal/upset condition. This is justified since the normal/upset condition safety factor is double that of the emergency/faulted condition, whereas by inspection the stresses associated with the emergency/faulted condition will be considerably less than twice the normal/upset condition stresses.)

CONCLUSIONS

Results of this calculation demonstrate that weld GR-3-63 is acceptable for a minimum of three additional fuel cycles. The weld can also be considered acceptable for three additional fuel cycles after any future weld inspection if the crack is found not to have increased from its current size.

ASME SECTION XI
FOR INFORMATION ONLY
NOTIFICATION OF INDICATION FORM

BFN PART I - FINDINGS

NOI No. U3C8-010 Plant/Unit 3 ISI Dwg./Sh. No. 3-ISI-0328-C Rev.000 Sheet 2 of 2

Examination Report No. R-041 Component ID 28" Recirc Weld GR-3-63 Loop B

Description of Indication (Sketch/Photograph if Required for Clarification): Ultrasonic examination of above weld detected indications which don't meet Asme Section XI 1989 Edition, No Addenda Table IWB-3514-2 requirements. Reference the attached UT documentation. Exceeds IWB-3514-2 Fig 9 PSI 98

Signature of Examiner/Certification Level: /Date: 9/28/98
Signature of ISO Coordinator (Field Supervisor): /Date: 9/28/98
Signature of ISI Program Owner: /Date: 9/28/98

PART II - DISPOSITION

SEE ATTACHED SHEETS.

Administrative control document number (PER, WR/WO) if applicable:

Disposition Prepared/Recorded By: Kevin L. Groom (KEVIN L. GROOM) Org. SE MIN Date: 10/04/98

PART III - ADDITIONAL EXAMINATIONS

Additional Sample Required: ☐ Yes ☑ No * (KG) — ISI Program Owner — 10-5-98 Date
(Attach list of items in additional sample, if yes.)

Successive Examination Required: ☑ Yes (KG) ☐ No — ISI Program Owner — 10-5-98 Date

PART IV - VERIFICATION OF CLOSURE

Reexamination Report number, if Applicable: NA
Signature of ISO Coordinator: Date:

Comments: Weld GR-3-63 reclassified as Category E.

Verification of Complete Corrective Action Required by Disposition

Signature of ISI Program Owner: Date: 10-5-98

* 100% Category C welds scheduled for examination U3C8.
H.H 10-5-98

ATTACHMENT A

CD-Q3068-980061 R

TVA

WALL THICKNESS PROFILE SHEET

REPORT NO:

PROJECT: BFN

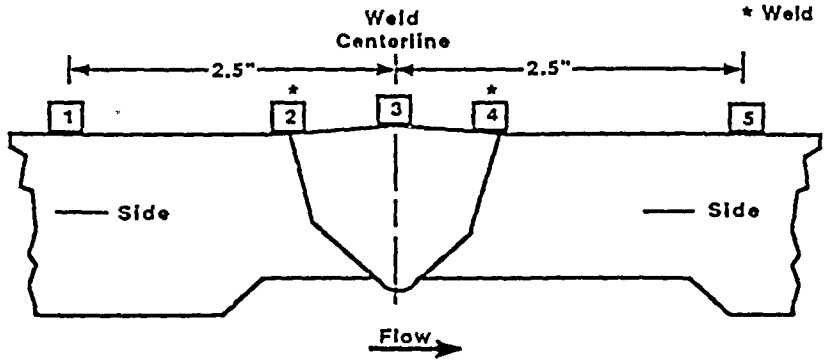
UNIT: U3 C8

WELD NO: GR-3-63

SYSTEM: RECIRC.

Record Thickness Measurements As Indicated, Including Weld Width, Edge-To-Edge At 0°

Position	0°	90°	180°	270°
1				
2				
3				
4				
5				



CROWN HEIGHT: _____ DIAMETER: _____

CROWN WIDTH: _____ WELD LENGTH: _____

FLAW LOCATED AT 34.5" - 36.2" = 1.7

FLAW THROUGH WALL DIMENSION IS 0.2"

FOR INFORMATION ONLY

PER ASME SECTION XI, 1989 EDITION, TABLE IWB-3514-2
THE MAXIMUM ALLOWED FLAW THROUGH WALL DIMENSION
FOR A THICKNESS OF 1.2" IS 0.13"

a = 0.2 a/ℓ = 0.12

ℓ = 1.7

a/t = 16.6% UNACCEPTABLE PER TABLE IWB-3514-
MAXIMUM ALLOWED FOR 1.2t IS 10.92

EXAMINER: [signature]

LEVEL: III

DATE: 9-28-98

REVIEWED BY: [signature]

LEVEL: III DATE: 9/28/98

ANII: NA

DATE: _____

PAGE _____ OF _____

TVA 19668 (NP-5-89)

ATTACHMENT A

CD-Q3068-980061 RO

TVA

WALL THICKNESS PROFILE SHEET

REPORT NO:

PROJECT: BFN

UNIT: 3 CYCLE-8

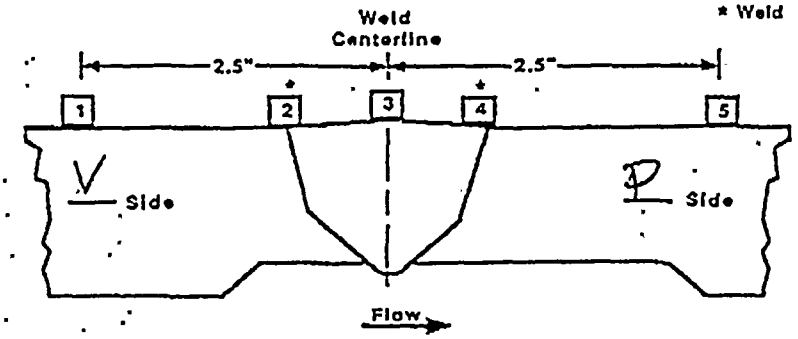
WELD NO: GR-3-63

SYSTEM: RECIRC

Record Thickness Measurements As Indicated, Including Weld Width, Edge-To-Edge At 0°

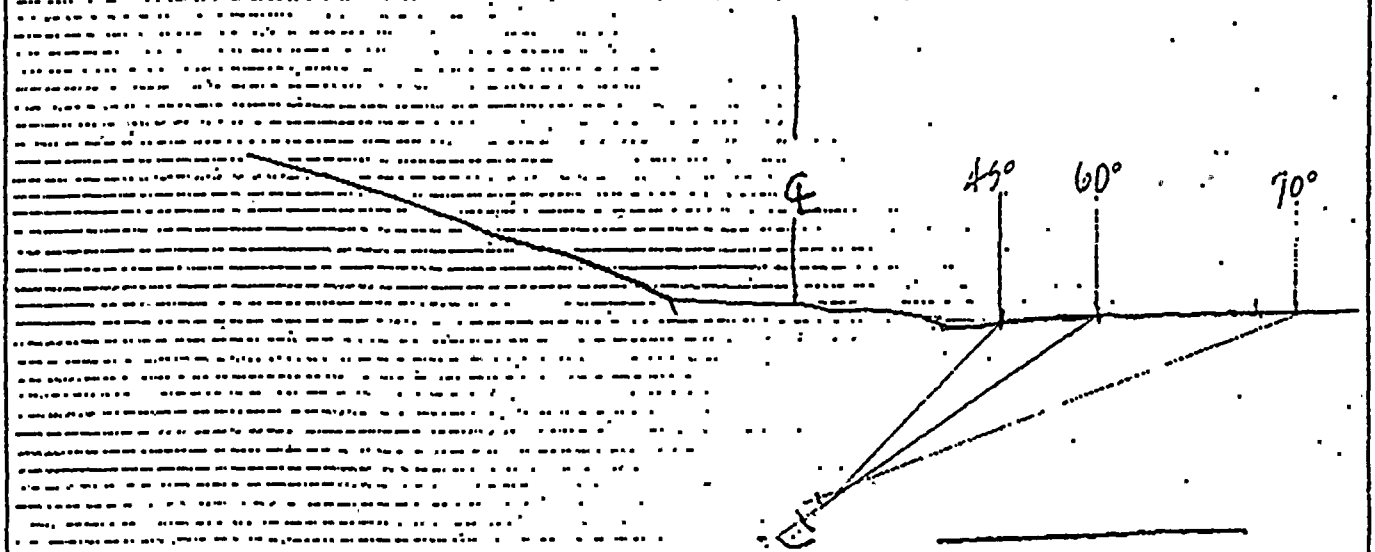
T&C 3/92

Position	0°	90°	180°	270°
1	N/A			
2	1.26			
3	1.37			
4	1.22			
5	1.20			



CROWN HEIGHT: _____ DIAMETER: _____

CROWN WIDTH: 1.5 WELD LENGTH: 89"



FOR INFORMATION ONLY

EXAMINER: [signature] Tech-II

LEVEL: II

DATE: 9-28-98

REVIEWED BY: _____

LEVEL: _____ DATE: _____

ANII: _____

DATE: _____

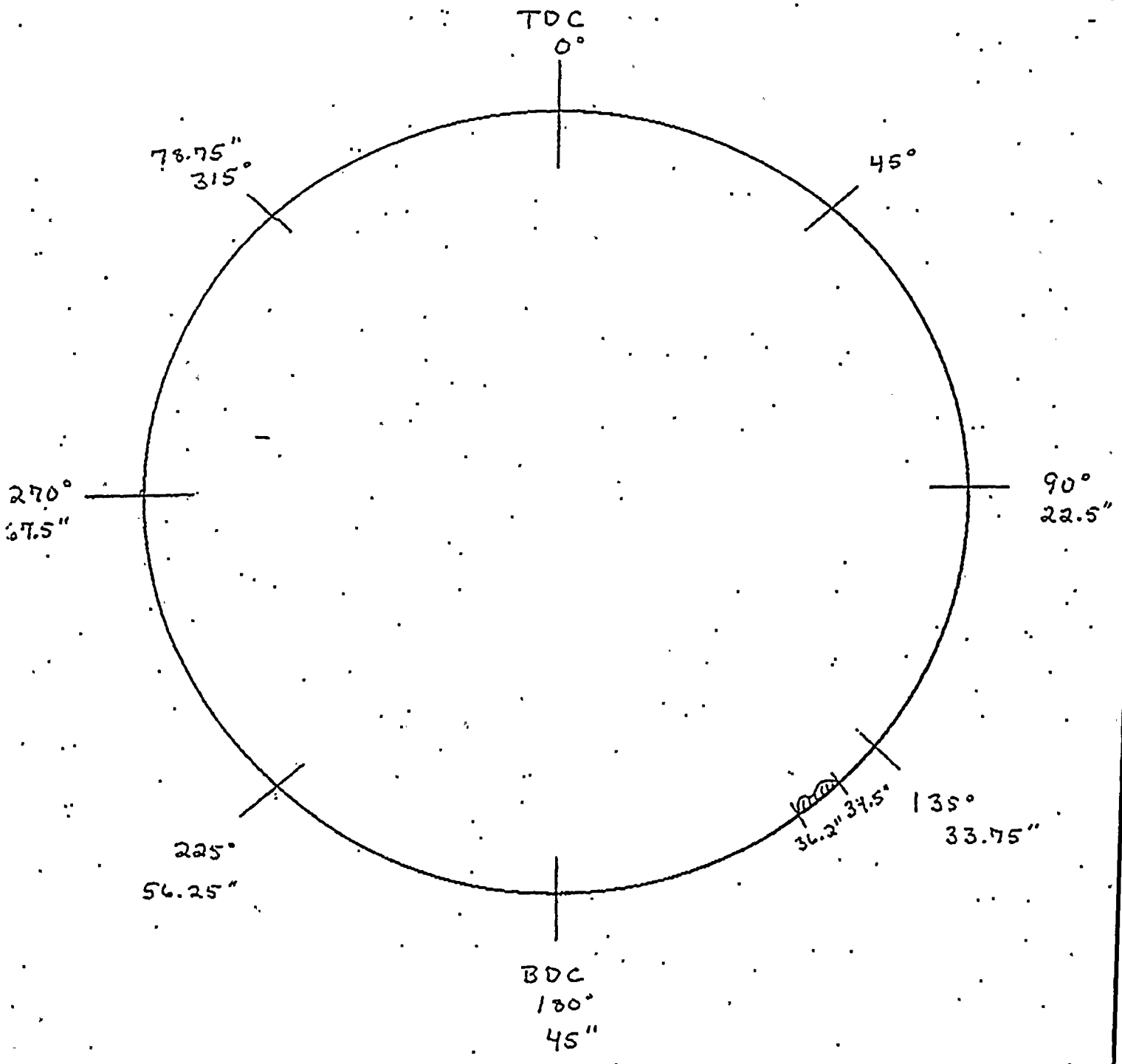
PAGE _____ OF _____

TVA 19448 (07-5-89)

ATTACHMENT A

CD-Q3068-980061 R

FLAW ORIENTATION
(VIEW FROM VALVE - LOOKING DOWN STREAM)



FOR INFORMATION ONLY

REV	DESIGN EQF	DATE 10-1-98
0	CHKD JCR	DATE 10-9-98

tm
pc-CRACK
(C) COPYRIGHT 1984, 1990
STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 2.1

Date: 1-Oct-1998
Time: 13:39: 4.36

STRESS CORROSION CRACK GROWTH ANALYSIS

IGSCC INDICATION AT WELD GR-3-63

INITIAL CRACK SIZE= 0.2000
WALL THICKNESS= 1.2000
MAX CRACK SIZE FOR SCCG= 0.7200

STRESS CORROSION CRACK GROWTH LAW

LAW ID	C	N	Kthres	K1C
NRC	3.590E-08	2.1610	0.0000	200.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
28PDWTH	7.2730	0.0000	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
28PDWTH	1.0000

TIME	TIME INCREMENT	PRINT INCREMENT
52560.0	730.0	730.0

crack model:CIRCUMFERENTIAL CRACK IN CYLINDER (T/R=0.1)

CRACK SIZE	STRESS INTENSITY FACTOR CASE 28PDWTH
0.0144	1.714
0.0288	2.432
0.0432	2.989
0.0576	3.463
0.0720	3.884
0.0864	4.269
0.1008	4.627
0.1152	4.962
0.1296	5.300
0.1440	5.636
0.1584	5.962
0.1728	6.281
0.1872	6.593
0.2016	6.900
0.2160	7.202
0.2304	7.500
0.2448	7.805
0.2592	8.130
0.2736	8.454
0.2880	8.777
0.3024	9.100
0.3168	9.423
0.3312	9.746

REV	DESIGN EQ Fr	DATE 10-1-98
0	CHKD LLE	DATE 10-1-98

0.3456	10.069
0.3600	10.393
0.3744	10.786
0.3888	11.183
0.4032	11.582
0.4176	11.985
0.4320	12.392
0.4464	12.801
0.4608	13.214
0.4752	13.630
0.4896	14.064
0.5040	14.510
0.5184	14.959
0.5328	15.412
0.5472	15.869
0.5616	16.330
0.5760	16.795
0.5904	17.264
0.6048	17.749
0.6192	18.263
0.6336	18.782
0.6480	19.306
0.6624	19.834
0.6768	20.366
0.6912	20.903
0.7056	21.445
0.7200	21.991

TIME	KMAX	DA/DT	DA	A	A/THK
730.0	6.87	2.308E-06	0.0017	0.2017	0.168
1460.0	6.90	2.334E-06	0.0017	0.2034	0.169
2190.0	6.94	2.360E-06	0.0017	0.2051	0.171
2920.0	6.97	2.387E-06	0.0017	0.2069	0.172
3650.0	7.01	2.414E-06	0.0018	0.2086	0.174
4380.0	7.05	2.441E-06	0.0018	0.2104	0.175
5110.0	7.08	2.469E-06	0.0018	0.2122	0.177
5840.0	7.12	2.498E-06	0.0018	0.2140	0.178
6570.0	7.16	2.527E-06	0.0018	0.2159	0.180
7300.0	7.20	2.557E-06	0.0019	0.2177	0.181
8030.0	7.24	2.586E-06	0.0019	0.2196	0.183
8760.0	7.28	2.617E-06	0.0019	0.2215	0.185
9490.0	7.32	2.647E-06	0.0019	0.2235	0.186
10220.0	7.36	2.679E-06	0.0020	0.2254	0.188
10950.0	7.40	2.711E-06	0.0020	0.2274	0.189
11680.0	7.44	2.743E-06	0.0020	0.2294	0.191
12410.0	7.48	2.776E-06	0.0020	0.2314	0.193
13140.0	7.52	2.811E-06	0.0021	0.2335	0.195
13870.0	7.56	2.846E-06	0.0021	0.2356	0.196
14600.0	7.61	2.882E-06	0.0021	0.2377	0.198
15330.0	7.65	2.918E-06	0.0021	0.2398	0.200
16060.0	7.70	2.956E-06	0.0022	0.2419	0.202
16790.0	7.74	2.994E-06	0.0022	0.2441	0.203
17520.0	7.79	3.033E-06	0.0022	0.2463	0.205
18250.0	7.84	3.074E-06	0.0022	0.2486	0.207
18980.0	7.89	3.117E-06	0.0023	0.2509	0.209
19710.0	7.94	3.161E-06	0.0023	0.2532	0.211
20440.0	7.99	3.206E-06	0.0023	0.2555	0.213
21170.0	8.05	3.252E-06	0.0024	0.2579	0.215
21900.0	8.10	3.299E-06	0.0024	0.2603	0.217
22630.0	8.15	3.347E-06	0.0024	0.2627	0.219
23360.0	8.21	3.396E-06	0.0025	0.2652	0.221
24090.0	8.27	3.446E-06	0.0025	0.2677	0.223

REV	DESIGN	DATE
0	CHKD	DATE

24820.0	8.32	3.497E-06	0.0026	0.2703	0.225
25550.0	8.38	3.549E-06	0.0026	0.2729	0.227
26280.0	8.44	3.603E-06	0.0026	0.2755	0.230
27010.0	8.50	3.657E-06	0.0027	0.2782	0.232
27740.0	8.56	3.713E-06	0.0027	0.2809	0.234
28470.0	8.62	3.771E-06	0.0028	0.2836	0.236
29200.0	8.68	3.829E-06	0.0028	0.2864	0.239
29930.0	8.74	3.890E-06	0.0028	0.2893	0.241
30660.0	8.81	3.951E-06	0.0029	0.2922	0.243
31390.0	8.87	4.014E-06	0.0029	0.2951	0.246
32120.0	8.94	4.079E-06	0.0030	0.2981	0.248
32850.0	9.00	4.145E-06	0.0030	0.3011	0.251
33580.0	9.07	4.213E-06	0.0031	0.3042	0.253
34310.0	9.14	4.282E-06	0.0031	0.3073	0.256
35040.0	9.21	4.354E-06	0.0032	0.3105	0.259
35770.0	9.28	4.427E-06	0.0032	0.3137	0.261
36500.0	9.35	4.502E-06	0.0033	0.3170	0.264
37230.0	9.43	4.579E-06	0.0033	0.3203	0.267
37960.0	9.50	4.658E-06	0.0034	0.3237	0.270
38690.0	9.58	4.739E-06	0.0035	0.3272	0.273
39420.0	9.66	4.822E-06	0.0035	0.3307	0.276
40150.0	9.74	4.908E-06	0.0036	0.3343	0.279
40880.0	9.82	4.996E-06	0.0036	0.3379	0.282
41610.0	9.90	5.087E-06	0.0037	0.3417	0.285
42340.0	9.98	5.180E-06	0.0038	0.3454	0.288
43070.0	10.07	5.275E-06	0.0039	0.3493	0.291
43800.0	10.15	5.374E-06	0.0039	0.3532	0.294
44530.0	10.24	5.475E-06	0.0040	0.3572	0.298
45260.0	10.33	5.579E-06	0.0041	0.3613	0.301
45990.0	10.43	5.694E-06	0.0042	0.3654	0.305
46720.0	10.54	5.829E-06	0.0043	0.3697	0.308
47450.0	10.66	5.969E-06	0.0044	0.3740	0.312
48180.0	10.78	6.114E-06	0.0045	0.3785	0.315
48910.0	10.90	6.265E-06	0.0046	0.3831	0.319
49640.0	11.03	6.423E-06	0.0047	0.3878	0.323
50370.0	11.15	6.586E-06	0.0048	0.3926	0.327
51100.0	11.29	6.757E-06	0.0049	0.3975	0.331
51830.0	11.42	6.936E-06	0.0051	0.4026	0.335
52560.0	11.57	7.121E-06	0.0052	0.4078	0.340

ATTACHMENT

CD-Q3068-980061 R0

REV	DESIGN	DATE
0	CHKD	DATE

tm
pc-CRACK
(C) COPYRIGHT 1984, 1990
STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 2.1

Date: 1-Oct-1998
Time: 13:15:36.67

FATIGUE CRACK GROWTH ANALYSIS

IGSCC INDICATION AT WELD GR-3-63

INITIAL CRACK SIZE= 0.4078
WALL THICKNESS= 1.2000
MAX CRACK SIZE FOR FCG= 0.7200

PARIS CRACK GROWTH LAW:
da/dN = C * (dK)^n
where
dK = Kmax - Kmin
dK > dKthres
Kmax < K1c

CURRENT LAWS:

LAW ID	C	n	dKthres	K1c
1	1.589E-08	3.300	0.000	200.000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
28PDWTH	7.2730	0.0000	0.0000	0.0000

NUMBER OF CYCLE BLOCKS= 1
PRINT INCREMENT OF CYCLE BLOCK= 1

SUBBLOCK	NUMBER OF CYCLES	CALCULATION INCREMENT	PRINT INCREMENT	FCG LAW ID
1	30	1	1	1

	Kmax		Kmin	
SUBBLOCK	CASE ID	SCALE FACTOR	CASE ID	SCALE FACTOR
1	28PDWTH	1.0000	28PDWTH	0.0000

crack model:CIRCUMFERENTIAL CRACK IN CYLINDER (T/R=0.1)

CRACK SIZE	STRESS INTENSITY FACTOR CASE 28PDWTH
0.0144	1.714
0.0288	2.432
0.0432	2.989
0.0576	3.463
0.0720	3.884
0.0864	4.269
0.1008	4.627
0.1152	4.962
0.1296	5.300
0.1440	5.636
0.1584	5.962

REV	DESIGN EOF	DATE 10-1-98
0	CHKD [illegible]	DATE 10-1-98

0.1728	6.281
0.1872	6.593
0.2016	6.900
0.2160	7.202
0.2304	7.500
0.2448	7.805
0.2592	8.130
0.2736	8.454
0.2880	8.777
0.3024	9.100
0.3168	9.423
0.3312	9.746
0.3456	10.069
0.3600	10.393
0.3744	10.786
0.3888	11.183
0.4032	11.582
0.4176	11.985
0.4320	12.392
0.4464	12.801
0.4608	13.214
0.4752	13.630
0.4896	14.064
0.5040	14.510
0.5184	14.959
0.5328	15.412
0.5472	15.869
0.5616	16.330
0.5760	16.795
0.5904	17.264
0.6048	17.749
0.6192	18.263
0.6336	18.782
0.6480	19.306
0.6624	19.834
0.6768	20.366
0.6912	20.903
0.7056	21.445
0.7200	21.991

TOTAL CYCLE	SUBBLOCK CYCLE	KMAX	KMIN	DELTAK	R	DADN	DA	A	A/T
BLOCK 1									
1	1	11.71	0.00	11.71	0.00	5.3E-05	0.0001	0.4079	0.34
2	2	11.71	0.00	11.71	0.00	5.3E-05	0.0001	0.4079	0.34
3	3	11.71	0.00	11.71	0.00	5.3E-05	0.0001	0.4080	0.34
4	4	11.72	0.00	11.72	0.00	5.3E-05	0.0001	0.4080	0.34
5	5	11.72	0.00	11.72	0.00	5.3E-05	0.0001	0.4081	0.34
6	6	11.72	0.00	11.72	0.00	5.4E-05	0.0001	0.4081	0.34
7	7	11.72	0.00	11.72	0.00	5.4E-05	0.0001	0.4082	0.34
8	8	11.72	0.00	11.72	0.00	5.4E-05	0.0001	0.4082	0.34
9	9	11.72	0.00	11.72	0.00	5.4E-05	0.0001	0.4083	0.34
10	10	11.72	0.00	11.72	0.00	5.4E-05	0.0001	0.4083	0.34
11	11	11.73	0.00	11.73	0.00	5.4E-05	0.0001	0.4084	0.34
12	12	11.73	0.00	11.73	0.00	5.4E-05	0.0001	0.4084	0.34
13	13	11.73	0.00	11.73	0.00	5.4E-05	0.0001	0.4085	0.34
14	14	11.73	0.00	11.73	0.00	5.4E-05	0.0001	0.4085	0.34
15	15	11.73	0.00	11.73	0.00	5.4E-05	0.0001	0.4086	0.34
16	16	11.73	0.00	11.73	0.00	5.4E-05	0.0001	0.4087	0.34
17	17	11.74	0.00	11.74	0.00	5.4E-05	0.0001	0.4087	0.34
18	18	11.74	0.00	11.74	0.00	5.4E-05	0.0001	0.4088	0.34
19	19	11.74	0.00	11.74	0.00	5.4E-05	0.0001	0.4088	0.34

20	20	11.74	0.00	11.74	0.00	5.4E-05	0.0001	0.4089	0.34
21	21	11.74	0.00	11.74	0.00	5.4E-05	0.0001	0.4089	0.34
22	22	11.74	0.00	11.74	0.00	5.4E-05	0.0001	0.4090	0.34
23	23	11.74	0.00	11.74	0.00	5.4E-05	0.0001	0.4090	0.34
24	24	11.75	0.00	11.75	0.00	5.4E-05	0.0001	0.4091	0.34
25	25	11.75	0.00	11.75	0.00	5.4E-05	0.0001	0.4091	0.34
26	26	11.75	0.00	11.75	0.00	5.4E-05	0.0001	0.4092	0.34
27	27	11.75	0.00	11.75	0.00	5.4E-05	0.0001	0.4092	0.34
28	28	11.75	0.00	11.75	0.00	5.4E-05	0.0001	0.4093	0.34
29	29	11.75	0.00	11.75	0.00	5.4E-05	0.0001	0.4094	0.34
30	30	11.75	0.00	11.75	0.00	5.4E-05	0.0001	0.4094	0.34

REV	DESIGN EJF	DATE 10-1-98
0	CHKD JLC	DATE 10-9-98

REV	DESIGN EJF	DATE 10-1-98
0	CHKD [illegible]	DATE 10-1-98

tm
pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 2.1

Date: 1-Oct-1998
Time: 13:49:41.28

ALLOWABLE FLAW SIZE EVALUATIONS
USING ASME SECTION XI, IWB-3640/50 PROCEDURES AND CRITERIA
FOR CIRCUMFERENTIAL CRACKS IN STAINLESS STEEL PIPING

MATERIAL IS SPECIFIED AS SHIELDED METAL ARC WELD
DEFAULT PROPERTIES:
  DESIGN STRESS = 16.95
  FLOW STRESS = 50.85

IGSCC INDICATION AT WELD FLAW GR-3-63

USER SUPPLIED MATERIAL PROPERTIES:
  DESIGN STRESS = 16.82
  FLOW STRESS = 50.46

PIPE GEOMETRY:
  OUTER DIAMETER = 28.1460
  WALL THICKNESS = 1.2000
CRACK GEOMETRY:
  CRACK DEPTH = 0.4094
  CRACK LENGTH = 7.1234

THE FLAWED PIPE IS ASSUMED TO FAIL DUE TO UNSTABLE DUCTILE TEARING (EPFM)

THE ALLOWABLE FLAW SIZE IS DETERMINED USING CODE TABLES
AND DEFAULT SAFETY FACTORS FOR NORMAL OPERATING (INCL. UPSET & TEST)
CONDITIONS

MEMBRANE STRESS (Pm)	=	6.2490	(SAFETY FACTOR = 2.770)
BENDING STRESS (Pb)	=	1.2450	(SAFETY FACTOR = 2.770)
EXPANSION STRESS (Pe)	=	0.7370	(SAFETY FACTOR = 1.000)
DESIGN STRESS	=	16.8200	
(Pm + Pb)/Sm	=	0.4455	
STRESS RATIO	=	0.4805	(DOES NOT INCLUDE S.F.)
M FACTOR	=	1.0415	
a/t	=	0.3412	
l/circumference	=	0.0806	
ALLOWABLE a/t	=	0.6000	

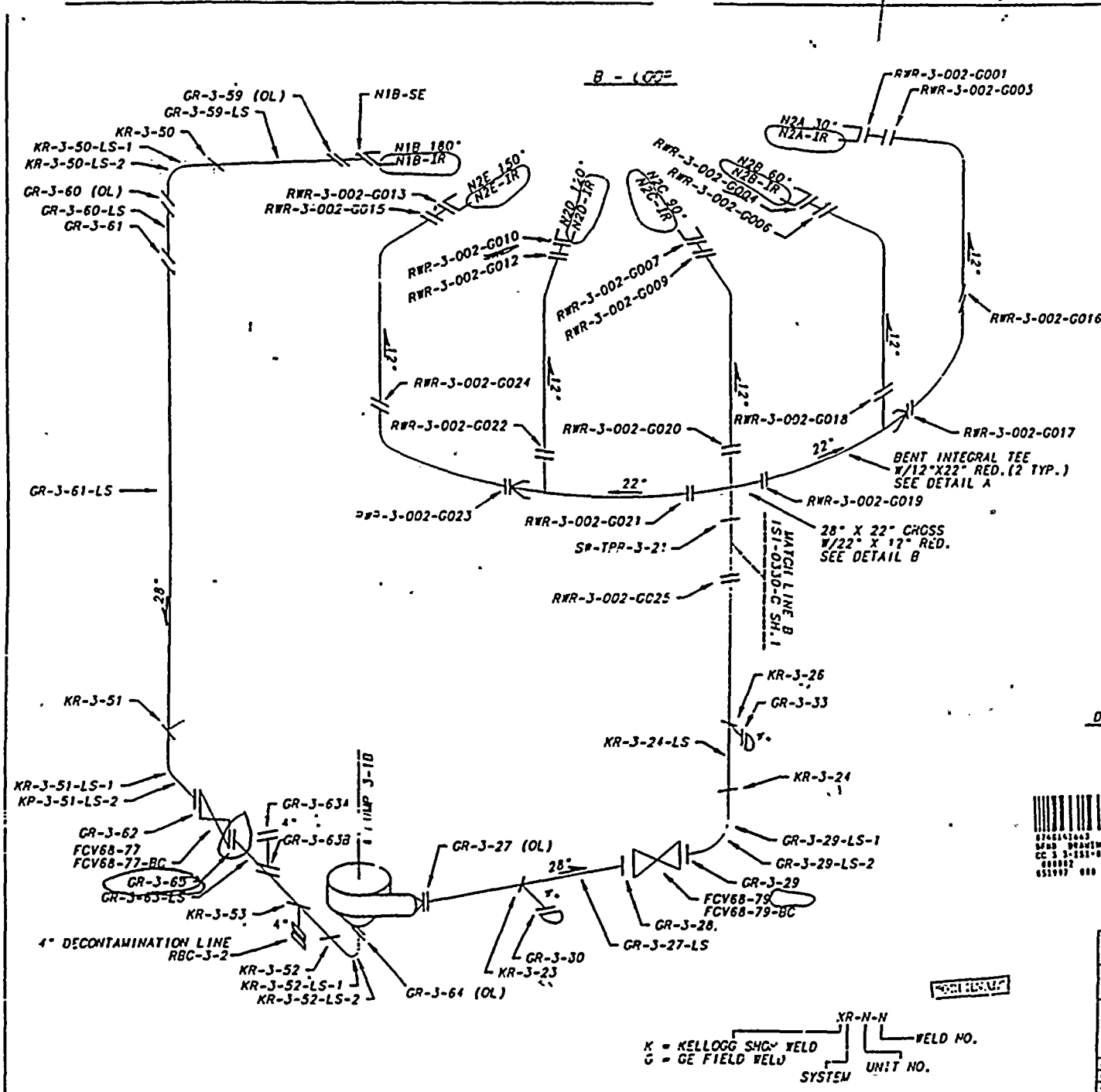
	l/circumference					
	0.00	0.10	0.20	0.30	0.40	0.50
ALLOWABLE a/t	0.6000	0.6000	0.6000	0.6000	0.6000	0.4900

ENCLOSURE 3

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNIT 3

3-ISI-0328-0

See Attached.



REFERENCE DRAWI.

TVA 47K1544-3
GE 153F754
KELLOGG BF 2-180
NOTE: THIS DRAWING SUPERSEDES CHW-2139-C ALL SHEETS

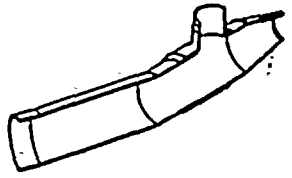
MATERIAL SPECIFICATIONS:

A378, TP 304
4" X 0.337" NOM WALL THK. (SS)
28" X 1.138" NOM. WALL THK. (SS) SUCT
28" X 1.322" NOM. WALL THK. (SS) DISCHA

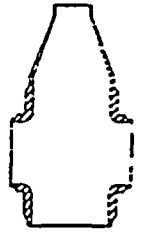
SA403 WP316NG

12" X 0.602" MIN. WALL
22" INTEGRAL RED. TEE 0.980" MIN. WAL
28" X 22" CROSS 0.980" MIN. WALL
28" X 24" INEGRAL TEE X 1.272" MIN.

ASME CC-1 (EQUIVALENT)



DETAIL A - ONE PEICE SPECIAL FORGING



DETAIL B - ONE PEICE SPECIAL FORGING

TENNESSEE VALLEY AUTHORITY

BROWNS FERRY NUCLEAR PLANT
UNIT 3
RECIRCULATION SYSTEM
WELD LOCATIONS

CCD

ALL A/D HISTORY RESEARCHED AT ROOO