ENCLOSURE 3

Analytical Evaluation of Steam Generator B Upper Shell to Transition Cone Weld Indications

27 pages follow

Structural Integrity Associates, Inc.	CALCULATION PACKAGE	File No.: PBCH-14Q-303 Project No.: PBCH-14Q

PROJECT NAME: Point Beach Unit 1 Flaw Evaluation Fall 2005

Contract No.: P305817

CLIENT: Nuclear Management Company, LLC

PLANT: Point Beach Nuclear Plant

CALCULATION TITLE: Steam Generator A Flaw Evaluation

Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1-7 Appendices A, B, C	Initial Issue	H. L. Gustin 10/28/05	H. L. Gustin 10/28/05 S. S. Tang 10/28/05
1	5 Appendix C	Modified Reference 5, added e-mail reference to Appendix C	H. L. Gustin 11/28/05 [signature]	H. L. Gustin 11/17/05 [signature] J. E. Smith 11/28/05 [signature]

SI Form F2001R2a

1 INTRODUCTION

The 2005 inservice inspection of steam generator A at Point Beach Nuclear Plant Unit 1 identified several indications in the transition cone to upper shell weld region of the steam generator. The indications were assessed per the flaw proximity rules of ASME Boiler and Pressure Vessel Code Section XI, IWA-3300 [1]. Following assessment of flaw proximity, indication dimensions were compared to the flaw acceptance standards of Section XI, IWC-3510 [1] by the plant [4]. One indication did not meet the flaw acceptance standards of Section XI, IWC-3510 [1]. It is therefore necessary to conduct a flaw evaluation per Section XI, IWB-3600 (since IWC-3600 is in preparation) for this flaw. This calculation evaluates the flaw per the guidelines of Section XI, IWB-3610, which include acceptance criteria based on linear elastic fracture mechanics and consideration of potential flaw growth. This calculation does not apply to other flaws which may be identified, without further evaluation. Conservative assumptions have been used in this evaluation to demonstrate flaw acceptability per IWB-3610. This calculation has been design reviewed in accordance with the requirements of the Structural Integrity Associates Quality Assurance Program.

2 TECHNICAL APPROACH

Fracture mechanics methods consistent with the requirements of ASME Section XI have been applied in this flaw evaluation. The acceptance criterion is that the applied stress intensity factor due to the observed flaw, with consideration of flaw growth over the remaining life of the plant, remains below the material toughness, including applicable margins from Section XI. The flaw acceptance criteria, based on applied stress intensity factor, was determined based on Paragraph IWB-3612 of ASME Section XI [1]. The material toughness for the carbon/low alloy steel steam generator shell material at operating temperature is taken to be 200 ksi-√inch, consistent with Figure A-4200-1 from ASME Section XI Appendix A for K_{Ic}. A safety factor of $\sqrt{10}$ is applied, as required by IWB-3610. This gives an allowable stress intensity factor of $200/\sqrt{10} = 63.25$ ksi-√inch.

The fracture mechanics analysis was performed for the unacceptable flaw.

3 FLAW CHARACTERIZATION

A total of 24 flaw indications were observed. These flaws were compared to the flaw proximity rules of IWA-3300. Table 1 (which is based on data in [4]) lists all 24 flaw dimensions and their locations, and summarizes the results of the proximity rule assessment. None of the 24 indications had to be combined by the proximity rules. Plant personnel assessed all flaws to the IWC-3510 acceptance standards, and determined that only one flaw (number 19 in Table 1) required further evaluation. This flaw has length = 1.75 inch, and depth = 0.22 inch. It is located 1.03 inches below the outside surface.

The observed unacceptable flaw is entirely subsurface and not exposed to any fluid chemistry.

4 DESIGN INPUTS

The as-measured wall thickness is 3.68 inches in the transition cone region (from plant UT reports [4]).

The transition cone material is SA-533 Grade A, Class 2 [6] with specified yield stress = 70 ksi. The Upper Shell material has a yield stress of less than 50 ksi.

From [5], the combined membrane, bending and secondary stress (P_L+P_B+Q) at the affected weld location is 64.7 ksi.

Welding residual stresses at the flaw location are negligible since the vessel is a thick walled shell that has been stress relieved. Residual stresses are steady state secondary stresses.

5 ASSUMPTIONS

1. To be conservative, the limiting stress value reported in Section 4.0 is used, and treated as an applied membrane stress. This is conservative because membrane stresses are more severe than bending stresses at equal magnitude.
2. The service life is assumed to be 60 years.
3. The material toughness K_{Ic} is taken as 200 ksi- √inch, from Section XI Appendix A [1].

6 CALCULATIONS

6.1 Fracture mechanics evaluation

Linear elastic fracture mechanics and fatigue flaw growth evaluations of the flaw were performed. The flaw was modeled as a subsurface semi-elliptical flaw in an infinite plate subjected to membrane and bending stress as illustrated in Figure 1. This is a common fracture mechanics model applied to subsurface flaws in thick shells. Figure 1 refers to the 1986 Edition of ASME Section XI. This is the Edition to which the SI fracture mechanics program **pc-CRACK** [3] was developed. However, the flaw definition in that figure remains the same in subsequent Editions of the Code, including the committed Edition and Addenda for Point Beach [1]. For this subsurface flaw model, the flaw depth is defined as 2a. Therefore, the flaw depth, a, is half of the measured flaw depth as reported in the UT reports.

For the indication the flaw parameters were calculated as follows:

Depth [4]	2a = 0.22 inch
Length [4]	l = 1.75 inches
Aspect ratio:	a/l = 0.063
	a/t = 2.99%
Eccentricity ratio:	2e/t = 0.38

The applied stress intensity factors for the indication above were calculated using **pc-CRACK**, [3]. The aspect ratio of 0.1 was used in the evaluation for the indication (limit of the model). The applied stress intensity factor $K_{applied}$ at the limiting location on the flaw face was compared to an allowable value of $K_{Ic}/\sqrt{10}$, where K_{Ic} is the material toughness (assumed to be 200 ksi-$\sqrt{}$inch for the steam generator shell material at the service temperatures, from Section XI, Appendix A, Figure A-4200-1), and the factor of $\sqrt{10}$ represents the factor of safety that is imposed by ASME Section XI, IWB-3610 for Normal and Upset conditions. The allowable K is therefore 63.25 ksi-$\sqrt{}$inch. As long as the applied stress intensity factor remains below the allowable value for the flaw size, the flaw remains acceptable by Section XI criteria. **pc-CRACK** output for the fracture mechanics analysis is contained in Appendix A.

6.2 End of Life Fatigue Flaw Growth Calculation

Since the indication is subsurface and therefore not wetted, the end of life flaw size due to fatigue growth was calculated using the fatigue growth curves for carbon and low alloy ferritic steels exposed to air environments, Figure A-4300-1 of Appendix A of Section XI [1]. The flaw was conservatively assumed to experience cyclic stresses corresponding to a stress range from 0 to 64.7 ksi [5]. This is conservative because the latter value corresponds to the sum of the highest reported membrane plus bending plus secondary (P_L+P_B+Q) stress..

Fatigue growth results are contained in Appendix B.

7 RESULTS OF ANALYSIS

The fracture mechanics analysis shows that flaw 19 is acceptable per the criteria of ASME Section XI, IWB-3612. The calculated maximum stress intensity factor for the observed flaw is 40 ksi-$\sqrt{}$inch, as compared to the allowable value of 63.25 ksi-$\sqrt{}$inch, which includes required safety margins ($\sqrt{10}$) as noted in Section 2 of this calculation.

The fatigue growth calculation demonstrates that over more than 4800 cycles from 0 to 64.7 ksi, the resulting flaw growth of the flaw remains below the allowable flaw size. Most transients experienced by the component are much less severe than this transient, and would lead to negligible growth. Therefore, growth of the flaw to an unacceptable size over the remaining life of the plant is not predicted.

The flaw analyzed in this calculation is more severe than are any of the flaws in this weld that were accepted under the Acceptance Standards of IWC-3510. Therefore, although fracture mechanics evaluation of such acceptable flaws is not required, the fracture mechanics analysis in this calculation could conservatively be applied to such flaws, if necessary.

8 DEGRADATION MECHANISMS

The observed flaws are subsurface flaws that are remote from any surface (either the wetted inside surface or the air outside surface). Such a flaw is therefore not a result of chemistry-driven mechanisms such as stress corrosion cracking or corrosion. These factors lead to the conclusion that the observed flaws are in fact artifacts of original fabrication, and not due to an active degradation mechanism. The evaluation of the hypothetical flaw growth by a fatigue mechanism is therefore conservative.

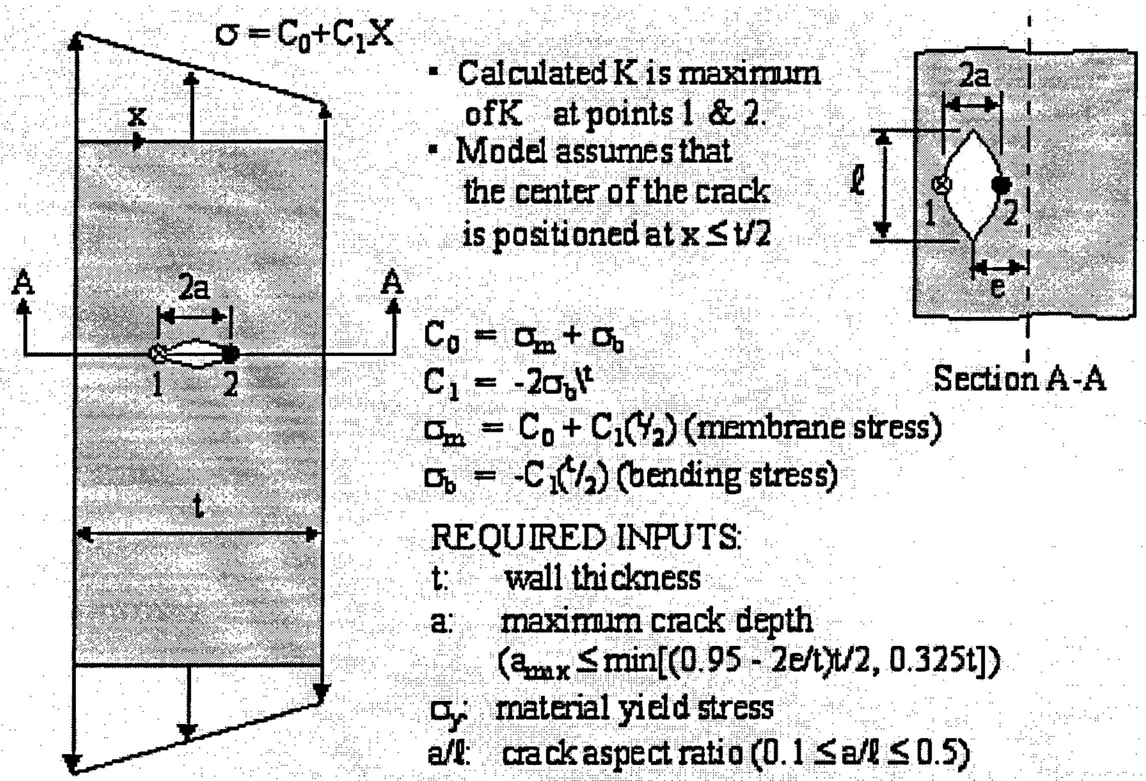
9 CONCLUSIONS AND DISCUSSIONS

Based on the results of the evaluation presented in this calculation package, the indications found during the inservice inspection of the steam generator A transition cone weld are acceptable and meet the requirement of ASME Code, Section XI, IWB-3610 [1].

The total of all indication areas is about 5.06 in^2. The area of the steam generator weld is about 1928 in^2, assuming a circumference of 524 inches [4], and a wall thickness of 3.68 inches. The transverse area reduction is less than 0.26% of the original area. This area reduction will have no significant affect on the hoop stress in the weld. Thus, the steam generator stress analysis based on ASME Boiler and Pressure Vessel Code Section III is not affected. Therefore, the requirement of IWB-3610 (d) (2) is satisfied.

10 REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section XI, 1998 Edition with Addenda through 2000.
2. Steam Generator Design Summary, E-mail from Brian Kemp (NMC) to Hal Gustin (SI), dated 10/19/05 SI File: PBCH-14Q-220
3. pc-CRACK for Windows, Version 3.1-98348, Structural Integrity Associates, 1998.
4. Point Beach Ultrasonic Examination Reports , SI File: PBCH-14Q-222
5. E-mail from Brian Kemp (NMC) to Hal Gustin (SI) dated 10/22/05, supplemented by e-mail from Brian Kemp (NMC) to Hal Gustin (SI) dated 11/10/05. SI File: PBCH-14Q-220
6. Telecon, Russell Turner (NMC) to Hal Gustin (SI) 10/25/05 SI File: PBCH-14Q-220



- Calculated K is maximum of K at points 1 & 2.
- Model assumes that the center of the crack is positioned at $x \leq t/2$

$C_0 = \sigma_m + \sigma_b$

$C_1 = -2\sigma_b/t$

$\sigma_m = C_0 + C_1(t/2)$ (membrane stress)

$\sigma_b = -C_1(t/2)$ (bending stress)

REQUIRED INPUTS:

t: wall thickness

a: maximum crack depth ($a_{max} \leq \min[(0.95 - 2e/t)t/2, 0.325t]$)

σ_y: material yield stress

a/ℓ: crack aspect ratio ($0.1 \leq a/\ell \leq 0.5$)

$2e/t$: eccentricity ratio ($0 \leq 2e/t \leq 0.6$)

Figure 1: ASME B&PV Code Section XI Subsurface Crack Model

Explanation of Terms Utilized for the Resolution of Indications

X = Distance from the vessel outside surface to the upper tip of the flaw

S = Distance from the vessel inside surface to the lower tip of the flaw

Thru-wall (2a or a) = Flaw depth size

Length (l) = Flaw length

Thickness = 3.68 inches

Lmax = Flaw circumferential location measured in inches clockwise from Vessel Zero.

Y = (S/t)(a/t) = S/a. If Y ≤ 0.40, the flaw is classified as surface. If Y > 1.0, then Y = 1.

Ind. No.	Angle	L1	L2	X	S	a	2a	l	Y	a/l	a/t Allowable	a/t	Section XI Allowable?
1	45	37.25	38.50	1.77	1.76	0.08	0.15	1.25	1.00	0.06	2.61%	2.04%	YES
2	45	61.00	62.50	2.26	1.32	0.05	0.10	1.50	1.00	0.03	2.39%	1.36%	YES
3	45	103.00	103.75	2.46	1.08	0.07	0.14	0.75	1.00	0.09	2.73%	1.88%	YES
4	45	109.50	110.50	3.16	0.40	0.06	0.12	1.00	1.00	0.06	2.61%	1.63%	YES
5	45	109.50	110.50	2.66	0.87	0.08	0.15	1.00	1.00	0.08	2.67%	2.04%	YES
6	45	255.25	256.50	2.67	0.85	0.08	0.16	1.25	1.00	0.06	2.61%	2.17%	YES
7	45	274.75	278.00	2.79	0.76	0.06	0.13	3.25	1.00	0.02	2.39%	1.77%	YES
8	45	278.00	279.88	2.45	1.06	0.09	0.17	1.88	1.00	0.05	2.48%	2.31%	YES
9	45	291.50	292.50	1.12	2.37	0.10	0.19	1.00	1.00	0.10	2.89%	2.58%	YES
10	45	307.00	309.75	2.06	1.45	0.09	0.17	2.75	1.00	0.03	2.43%	2.31%	YES
11	45	310.00	311.25	2.88	0.66	0.07	0.14	1.25	1.00	0.06	2.61%	1.90%	YES
12	45	324.25	325.25	1.71	1.81	0.08	0.16	1.00	1.00	0.08	2.73%	2.17%	YES
13	45	335.50	336.00	1.09	2.40	0.10	0.19	0.50	1.00	0.19	3.71%	2.58%	YES
14	45	341.38	343.25	2.04	1.55	0.04	0.09	1.88	1.00	0.02	2.39%	1.22%	YES
15	45	357.75	360.25	2.04	1.55	0.04	0.09	2.50	1.00	0.02	2.39%	1.22%	YES
16	45	370.25	371.00	2.39	1.21	0.04	0.08	0.75	1.00	0.05	2.54%	1.09%	YES
17	45	437.75	438.75	2.83	0.64	0.11	0.21	1.00	1.00	0.11	2.98%	2.85%	YES
18	60	472.25	473.75	1.76	1.76	0.08	0.16	1.00	1.00	0.08	2.73%	2.17%	YES
19	45	498.00	499.75	1.03	2.43	0.11	0.22	1.75	1.00	0.06	2.61%	2.99%	NO
20/21	45	499.75	504.00	2.45	1.06	0.09	0.17	4.25	1.00	0.02	2.39%	2.31%	YES
22	45	505.00	506.50	1.03	2.55	0.05	0.10	1.50	1.00	0.03	2.43%	1.36%	YES
23	45	517.00	518.00	1.12	2.44	0.06	0.12	1.00	1.00	0.06	2.61%	1.63%	YES
24	45	520.50	521.50	0.79	2.77	0.06	0.12	1.00	1.00	0.06	2.61%	1.63%	YES

Note: Indications 20 & 21 are the same detection indication recorded from two directions.

Resolution Performed By: / 10-26-05

Resolution Reviewed By: / II / 10-26-05

26-Oct-2005
14:13:13

WELD NUMBER: SG-A-4

APPENDIX A

pc-CRACK OUTPUT FILES: ALLOWABLE FLAW DETERMINATION

303SSF

pc-CRACK[tm] for Windows
Version 3.1-98348
(C) Copyright '84 - '98
Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
San Jose, CA 95118-1557
Voice: 408-978-8200
Fax: 408-978-8964
E-mail: pccrack@structint.com

Linear Elastic Fracture Mechanics

Date: Thu Oct 27 13:49:16 2005
Input Data and Results File: 303SSF.LFM

Title: PBCH-14Q: Steam Generator A Flaw Evaluation

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
PL+PB+Q	64.7	0	0	0	Coeff

------Through Wall Stresses for Load Cases With Stress Coeff-------

Wall Depth	Case PL+PB+Q
0.0000	64.7
0.0400	64.7
0.0800	64.7
0.1200	64.7
0.1600	64.7
0.2000	64.7
0.2400	64.7
0.2800	64.7
0.3200	64.7
0.3600	64.7
0.4000	64.7

Crack Model: Elliptical Subsurface Cracked Plate Under Membrane & Bending Stresses

Reference: ASME Boiler and Pressure Vessel Code, Section XI, '86 Ed.
WARNING: The stress intensity factor (K) is the maximum of
K at point 1 and K at point 2 as identified in Section XI.

Crack Parameters:
Wall thickness: 3.6800
Max. crack depth: 0.4000
Crack aspect ratio: 0.1000
Eccentricity ratio: 0.3800
Material yield strength: 70.0000
Co = Sigma(membrane) + Sigma(bending)
C1 = -2*Sigma(bending)/thickness

-------------------Stress Intensity Factor-------------------

Crack Size	Case PL+PB+Q
0.0080	10.6409
0.0160	15.0576
0.0240	18.4528
0.0320	21.3202
0.0400	23.8511
0.0480	26.1433
0.0560	28.2549
0.0640	30.2239
0.0720	32.0765
0.0800	33.8319
0.0880	35.5045
0.0960	37.1054
0.1040	38.6437
0.1120	40.1264
0.1200	41.5596
0.1280	42.9482
0.1360	44.2965
0.1440	45.6079
0.1520	46.8856
0.1600	48.1323
0.1680	49.3503
0.1760	50.5417
0.1840	51.7084
0.1920	52.8519
0.2000	53.9738
0.2080	55.0754
0.2160	56.1579
0.2240	57.2223
0.2320	58.2697
0.2400	59.3009
0.2480	60.3169
0.2560	61.3183
0.2640	62.3058
0.2720	63.2802
0.2800	64.2898
0.2880	65.3371
0.2960	66.3756
0.3040	67.4057
0.3120	68.4277
0.3200	69.4422
0.3280	70.4493
0.3360	71.4495
0.3440	72.4431
0.3520	73.4302
0.3600	74.4114
0.3680	75.3866
0.3760	76.3563
0.3840	77.3207
0.3920	78.2799
0.4000	79.2342

Material fracture toughness:

Material ID: SG Plate

Depth	K1c
0.0000	63.2500

1.0000	63.2500
3.0000	63.2500
4.0000	63.2500

Load combination for critical crack size:

Load Case	Scale Factor
PL+PB+Q	1.0000

Crack Size	Total K	K1c
0.008	10.6409	63.25
0.016	15.0576	63.25
0.024	18.4528	63.25
0.032	21.3202	63.25
0.04	23.8511	63.25
0.048	26.1433	63.25
0.056	28.2549	63.25
0.064	30.2239	63.25
0.072	32.0765	63.25
0.08	33.8319	63.25
0.088	35.5045	63.25
0.096	37.1054	63.25
0.104	38.6437	63.25
0.112	40.1264	63.25
0.12	41.5596	63.25
0.128	42.9482	63.25
0.136	44.2965	63.25
0.144	45.6079	63.25
0.152	46.8856	63.25
0.16	48.1323	63.25
0.168	49.3503	63.25
0.176	50.5417	63.25
0.184	51.7084	63.25
0.192	52.8519	63.25
0.2	53.9738	63.25
0.208	55.0754	63.25
0.216	56.1579	63.25
0.224	57.2223	63.25
0.232	58.2697	63.25
0.24	59.3009	63.25
0.248	60.3169	63.25
0.256	61.3183	63.25
0.264	62.3058	63.25
0.272	63.2802	63.25
0.28	64.2898	63.25
0.288	65.3371	63.25
0.296	66.3756	63.25
0.304	67.4057	63.25
0.312	68.4277	63.25
0.32	69.4422	63.25
0.328	70.4493	63.25
0.336	71.4495	63.25
0.344	72.4431	63.25
0.352	73.4302	63.25
0.36	74.4114	63.25
0.368	75.3866	63.25
0.376	76.3563	63.25
0.384	77.3207	63.25
0.392	78.2799	63.25
0.4	79.2342	63.25

303SSF

Critical crack size =   0.2716

End of pc-CRACK Output

APPENDIX B

pc-CRACK OUTPUT FILE: FATIGUE CRACK GROWTH

303FCG2

Linear Elastic Fracture Mechanics

Date: Thu Oct 27 13:51:18 2005
Input Data and Results File: 303FCG2.LFM

Title: PBCH-14Q: Steam Generator A Flaw Evaluation

Load Cases:

Case ID	Stress Coefficients C0	C1	C2	C3	Type
PL+PB+Q	64.7	0	0	0	Coeff

------Through Wall Stresses for Load Cases with Stress Coeff-------

Wall Depth	Case PL+PB+Q
0.0000	64.7
0.0400	64.7
0.0800	64.7
0.1200	64.7
0.1600	64.7
0.2000	64.7
0.2400	64.7
0.2800	64.7
0.3200	64.7
0.3600	64.7
0.4000	64.7

Crack Model: Elliptical Subsurface Cracked Plate Under Membrane & Bending Stresses

Reference: ASME Boiler and Pressure Vessel Code, Section XI, '86 Ed.
WARNING: The stress intensity factor (K) is the maximum of
K at point 1 and K at point 2 as identified in Section XI.

Crack Parameters:
Wall thickness: 3.6800
Max. crack depth: 0.4000
Crack aspect ratio: 0.1000
Eccentricity ratio: 0.3800
Material yield strength: 70.0000
Co = Sigma(membrane) + Sigma(bending)
C1 = -2*Sigma(bending)/thickness

-------------------------Stress Intensity Factor-------------------

Crack Size	Case PL+PB+Q
0.0080	10.6409
0.0160	15.0576
0.0240	18.4528
0.0320	21.3202
0.0400	23.8511
0.0480	26.1433
0.0560	28.2549
0.0640	30.2239
0.0720	32.0765
0.0800	33.8319
0.0880	35.5045
0.0960	37.1054
0.1040	38.6437
0.1120	40.1264
0.1200	41.5596
0.1280	42.9482
0.1360	44.2965
0.1440	45.6079
0.1520	46.8856
0.1600	48.1323
0.1680	49.3503
0.1760	50.5417
0.1840	51.7084
0.1920	52.8519
0.2000	53.9738
0.2080	55.0754
0.2160	56.1579
0.2240	57.2223
0.2320	58.2697
0.2400	59.3009
0.2480	60.3169
0.2560	61.3183
0.2640	62.3058
0.2720	63.2802
0.2800	64.2898
0.2880	65.3371
0.2960	66.3756
0.3040	67.4057
0.3120	68.4277
0.3200	69.4422
0.3280	70.4493
0.3360	71.4495
0.3440	72.4431
0.3520	73.4302
0.3600	74.4114
0.3680	75.3866
0.3760	76.3563
0.3840	77.3207
0.3920	78.2799
0.4000	79.2342

Crack Growth Laws:

Law ID: SG subsurface
Model: ASME Section XI - ferritic steel in air environment

da/dN = C * S * dK^3.07

where

```
S = 25.72 * (2.88 - R')^(-3.07)
R = 0      for  R < 0
R'= R      for  R >= 0
dK = Kmax - Kmin
R = Kmin / Kmax
```

where:
  C = 1.9900e-010
is for the currently selected units of:
  force: kip
  length: inch

Material Fracture Toughness KIc:

Material ID: SG Plate

Depth	KIc
0.0000	63.2500
1.0000	63.2500
3.0000	63.2500
4.0000	63.2500

Initial crack size= 0.1100
Max. crack size= 0.4000

Number of blocks= 1
Print increment of block= 1

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. K1c
fcg303	10000	100	100	SG subsurface	SG Plate

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
fcg303	PL+PB+Q	1.0000	PL+PB+Q	0.0000

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block:	1								
100	100	3.98e+001	0.00e+000	3.98e+001	0.00	1.62e-005	1.62e-003	0.1116	0.03
200	200	4.01e+001	0.00e+000	4.01e+001	0.00	1.66e-005	1.66e-003	0.1133	0.03
300	300	4.04e+001	0.00e+000	4.04e+001	0.00	1.69e-005	1.69e-003	0.115	0.03
400	400	4.07e+001	0.00e+000	4.07e+001	0.00	1.73e-005	1.73e-003	0.1167	0.03
500	500	4.10e+001	0.00e+000	4.10e+001	0.00	1.77e-005	1.77e-003	0.1185	0.03
600	600	4.13e+001	0.00e+000	4.13e+001	0.00	1.82e-005	1.82e-003	0.1203	0.03
700	700	4.16e+001	0.00e+000	4.16e+001	0.00	1.86e-005	1.86e-003	0.1222	0.03
800	800	4.19e+001	0.00e+000	4.19e+001	0.00	1.91e-005	1.91e-003	0.1241	0.03
900	900	4.23e+001	0.00e+000	4.23e+001	0.00	1.95e-005	1.95e-003	0.126	0.03

1000	1000	4.26e+001	0.00e+000	4.26e+001	0.00	2.00e-005	2.00e-003	0.128	0.03
1100	1100	4.30e+001	0.00e+000	4.30e+001	0.00	2.05e-005	2.05e-003	0.1301	0.04
1200	1200	4.33e+001	0.00e+000	4.33e+001	0.00	2.10e-005	2.10e-003	0.1322	0.04
1300	1300	4.37e+001	0.00e+000	4.37e+001	0.00	2.16e-005	2.16e-003	0.1343	0.04
1400	1400	4.40e+001	0.00e+000	4.40e+001	0.00	2.21e-005	2.21e-003	0.1365	0.04
1500	1500	4.44e+001	0.00e+000	4.44e+001	0.00	2.27e-005	2.27e-003	0.1388	0.04
1600	1600	4.48e+001	0.00e+000	4.48e+001	0.00	2.33e-005	2.33e-003	0.1411	0.04
1700	1700	4.51e+001	0.00e+000	4.51e+001	0.00	2.39e-005	2.39e-003	0.1435	0.04
1800	1800	4.55e+001	0.00e+000	4.55e+001	0.00	2.45e-005	2.45e-003	0.146	0.04
1900	1900	4.59e+001	0.00e+000	4.59e+001	0.00	2.52e-005	2.52e-003	0.1485	0.04
2000	2000	4.63e+001	0.00e+000	4.63e+001	0.00	2.59e-005	2.59e-003	0.1511	0.04
2100	2100	4.67e+001	0.00e+000	4.67e+001	0.00	2.66e-005	2.66e-003	0.1537	0.04
2200	2200	4.72e+001	0.00e+000	4.72e+001	0.00	2.73e-005	2.73e-003	0.1565	0.04
2300	2300	4.76e+001	0.00e+000	4.76e+001	0.00	2.81e-005	2.81e-003	0.1593	0.04
2400	2400	4.80e+001	0.00e+000	4.80e+001	0.00	2.89e-005	2.89e-003	0.1622	0.04
2500	2500	4.85e+001	0.00e+000	4.85e+001	0.00	2.97e-005	2.97e-003	0.1651	0.04
2600	2600	4.89e+001	0.00e+000	4.89e+001	0.00	3.06e-005	3.06e-003	0.1682	0.05
2700	2700	4.94e+001	0.00e+000	4.94e+001	0.00	3.15e-005	3.15e-003	0.1713	0.05
2800	2800	4.98e+001	0.00e+000	4.98e+001	0.00	3.24e-005	3.24e-003	0.1746	0.05
2900	2900	5.03e+001	0.00e+000	5.03e+001	0.00	3.34e-005	3.34e-003	0.1779	0.05
3000	3000	5.08e+001	0.00e+000	5.08e+001	0.00	3.44e-005	3.44e-003	0.1814	0.05
3100	3100	5.13e+001	0.00e+000	5.13e+001	0.00	3.54e-005	3.54e-003	0.1849	0.05
3200	3200	5.18e+001	0.00e+000	5.18e+001	0.00	3.65e-005	3.65e-003	0.1886	0.05
3300	3300	5.24e+001	0.00e+000	5.24e+001	0.00	3.77e-005	3.77e-003	0.1923	0.05
3400	3400	5.29e+001	0.00e+000	5.29e+001	0.00	3.89e-005	3.89e-003	0.1962	0.05
3500	3500	5.34e+001	0.00e+000	5.34e+001	0.00	4.01e-005	4.01e-003	0.2002	0.05
3600	3600	5.40e+001	0.00e+000	5.40e+001	0.00	4.14e-005	4.14e-003	0.2044	0.06
3700	3700	5.46e+001	0.00e+000	5.46e+001	0.00	4.28e-005	4.28e-003	0.2086	0.06
3800	3800	5.52e+001	0.00e+000	5.52e+001	0.00	4.42e-005	4.42e-003	0.2131	0.06
3900	3900	5.58e+001	0.00e+000	5.58e+001	0.00	4.57e-005	4.57e-003	0.2176	0.06
4000	4000	5.64e+001	0.00e+000	5.64e+001	0.00	4.73e-005	4.73e-003	0.2224	0.06
4100	4100	5.70e+001	0.00e+000	5.70e+001	0.00	4.89e-005	4.89e-003	0.2273	0.06
4200	4200	5.76e+001	0.00e+000	5.76e+001	0.00	5.06e-005	5.06e-003	0.2323	0.06
4300	4300	5.83e+001	0.00e+000	5.83e+001	0.00	5.24e-005	5.24e-003	0.2376	0.06
4400	4400	5.90e+001	0.00e+000	5.90e+001	0.00	5.43e-005	5.43e-003	0.243	0.07
4500	4500	5.97e+001	0.00e+000	5.97e+001	0.00	5.63e-005	5.63e-003	0.2486	0.07
4600	4600	6.04e+001	0.00e+000	6.04e+001	0.00	5.84e-005	5.84e-003	0.2545	0.07
4700	4700	6.11e+001	0.00e+000	6.11e+001	0.00	6.06e-005	6.06e-003	0.2605	0.07
4800	4800	6.19e+001	0.00e+000	6.19e+001	0.00	6.29e-005	6.29e-003	0.2668	0.07
4900	4900	6.26e+001	0.00e+000	6.26e+001	0.00	6.54e-005	6.54e-003	0.2734	0.07
5000	5000	6.35e+001	0.00e+000	6.35e+001	0.00	6.80e-005	6.80e-003	0.2801	0.08

End of pc-CRACK Output

APPENDIX C

DESIGN INPUT MEMOS (E-MAIL) FROM NMC

Hal L. Gustin

From: Kemp, Brian [Brian.Kemp@nmcco.com]
Sent: Saturday, October 22, 2005 11:08 AM
To: Kemp, Brian; Hal L. Gustin
Subject: Additional PBNP Design Input

Hal,

The following information should be used as a design input for the U1R29 SG structural evaluation that SIA is performing.

This information is an exerpt from the Westinghouse Report titled "PBNP Power Uprate Project

NSSS Engineering Report Volume 1."

==

The PBNP Unit 1 Steam Generators (Westinghouse Model 44F) calculated stress for normal and abnormal conditions (PL+PB+Q) in the flaw region (upper shell to upper head weld) is 64.7 ksi.

==

Brian Kemp

Hal L. Gustin

From: Kemp, Brian [Brian.Kemp@nmcco.com]
Sent: Thursday, November 10, 2005 9:21 AM
To: Hal L. Gustin
Cc: Turner, Russell
Attachments: design paramters r1.doc

Hal,

As described in my email to you (dated October 22, 2005), the calculated stress for normal and abnormal conditions (P_L+P_B+Q) that should be used in the SIA analysis for the PBNP-1 SG flaw region (upper shell to upper head weld) is 64.7 ksi. This value was selected because it represented the highest stress values in the Model 44F SG transition cone region and is clearly referenced in the text of the Westinghouse SG Analysis[1]. This is a conservative value that is appropriate to use for the SIA analysis of upper shell to transition cone weld.

Additionally, the file that I forwarded to you October 19, 2005 titled "design parameters.doc" has a *.pdf to *.doc conversion error in it's note 1. The correct note should read "Parameters reflect Model Δ47 replacement steam generators but also bound operation with Model 44F in Unit 1." The note is corrected and the revised file is attached to this email.

Please call with questions.

Brian Kemp

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[1] "PBNP Power Uprate Project NSSS Engineering Report Volume 1."

Brian Kemp
NMC Fleet Lead - Materials
715-426-6960 (office)
612-202-9286 (cell)

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[1] "PBNP Power Uprate Project NSSS Engineering Report Volume 1."

Hal L. Gustin

From: Kemp, Brian [Brian.Kemp@nmcco.com]
Sent: Wednesday, October 19, 2005 9:30 AM
To: Hal L. Gustin
Subject: PBNP design input

Attachments: design paramters.doc; load cycles.doc; Pzr Fatigue Usage.doc; SG Design Information.doc; Transition Cone Region Figure.doc; Transition Cone Region Figure - Thicknesses.doc

design aramters.doc (70 KE load cycles.doc (68 KB) Pzr Fatigue Usage.doc (43 KB) SG Design ıformation.doc (37 . Transition Cone Region Figure.... Transition Cone Region Figure ...

Hal,

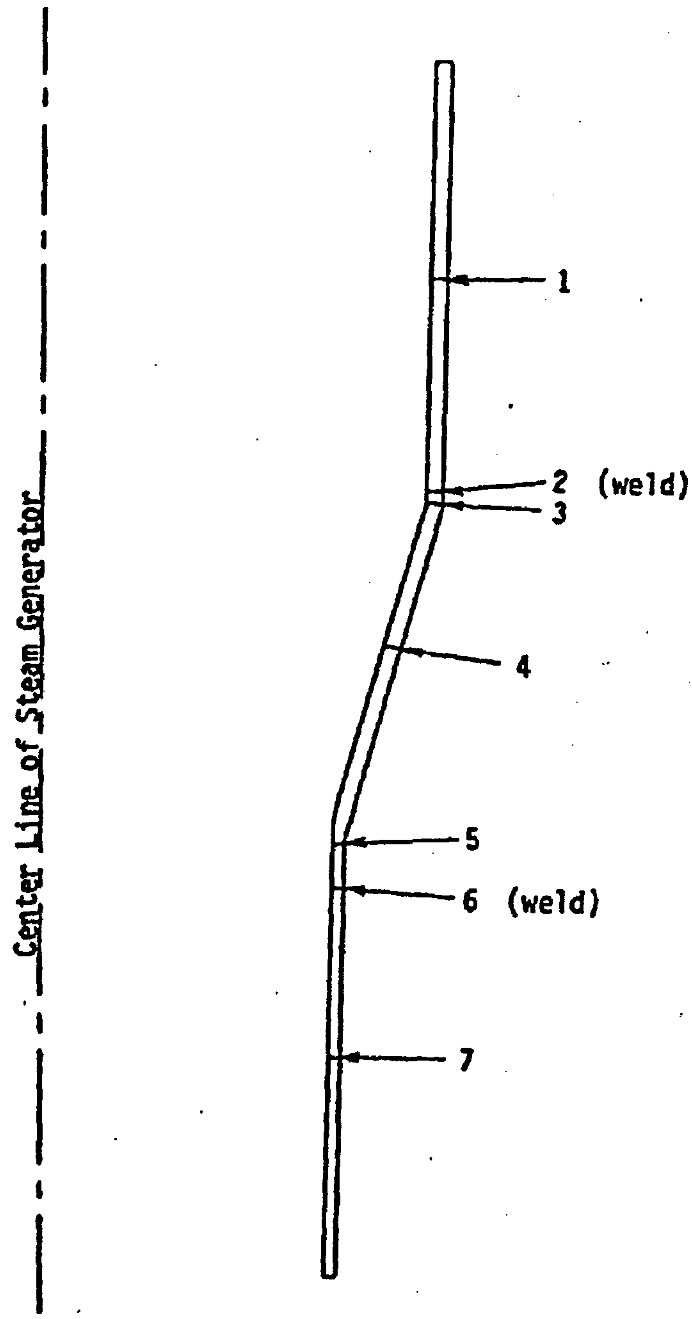
The attached information should be used as design inputs for the U1R29 SG & PZR structural evaluations that SIA is performing.

This information is non-proprietary exerpts from the Westinghouse Report titled "PBNP Power Uprate Project

NSSS Engineering Report Volume 1."

Please call with questions.

Brian Kemp



Transition Cone Region

PBNP Unit 1 Model 44F And Δ47 Steam Generator Loading Cycles				
Description of Loading Conditions	Number of Load Cycles			
	44F Design Spec. (Ref. 1)	Δ47 Design Spec. (Ref. 2)	Sect. 3.1	60-Year Transients
Heatup/Cooldown	200	200		200
Hot Standby at No Power	--			--
Feedwater Cycling at HSB	25,000	10,000		25,000
Loading/Unloading @5% PWR/min	14,500	18,300		18,300
Steady-state at Full Load	--	--		--
10% Step-Load Increase	2,000	2,000		2,000
10% Step-Load Decrease	2,000	2,000		2,000
Large Step-Load Decrease (50% Step-Load Decrease)	200	200		200
Reactor Trip	400	400		400
Loss of Load	80	80		80
Partial Loss of Flow	80	80		80
Loss of Power (Power Blackout)	40	40		40
Inadvertent Auxiliary Spray		10		10
Primary Hydrotest @ 3106 psig	1	5		5
Primary Pressure Test @ 2485 psig	50	120	94 (100)	100
Secondary Hydrotest @ 1356 psig	1	10		10
Secondary Pressure Test @ 1085 psig	50	10		50
Prim-to-Sec Leak Tests	5		27 (30)	30
Sec-to-Prim Leak Tests	5	120	128 (130)	130

PBNP Power Uprate Project (Bounding 10.5% Core Power Uprate)
NSSS Design Parameters[1,2] Used for Systems, Components & Accident Analyses

Parameter	Case 1 Low T_{avg} 0% SGTP	Case 2 Low T_{avg} 10% SGTP	Case 3 High T_{avg} 0% SGTP	Case 4 High T_{avg} 10% SGTP
Steam Generator				
Steam Pressure (psia)	662[3,4]	637[3,4]	764[4]	737[3,4]
Steam Temperature (°F)	496.8[3]	492.7[3]	512.9	508.8[3]
Steam Flow, Total (10^6 lb_m/hr)	7.37	7.37	7.39[5]	7.39[5]
Feedwater Temperature (°F)	442.9	442.9	442.9	442.9
Tube Plugging (%)	0	10	0	10

Notes:

1. Parameters reflect Model Δ47 replacement steam generators but also bound operation with Model 44F in Unit 1
2. Systems and components analyses have been performed using the parameters identified in Table 1-1.
3. Steam pressure/temperature must be greater than 745.7 psia/510.0°F due to the steam generator design pressure differential requirements.
4. Steam pressure at the outlet of the steam generator nozzle.
5. A maximum moisture carry over of 0.10% was assumed; however, this value cannot be warranted at this high power level and low steam pressure. The maximum moisture carry over for the Model 44F steam generators is 0.25% and the maximum steam flow associated with this value is 7.40x10^6 lb/hr.

Structural

The critical steam generator components that were evaluated for structural adequacy are:

Primary side: Primary chamber, tubesheet, primary nozzles, primary manway, divider plate, and tube-to-tubesheet weld. The primary side of the replacement steam generators was evaluated as a whole through a review of the uprating transients that affect the primary side of the steam generator, i.e., RCS transients.

Secondary side: Upper shell, transition cone, lower shell, junction of tubesheet and stub barrel, main and auxiliary feedwater and spray nozzles, secondary manway opening and bolts, inspection ports, and minor shell taps.

These components were evaluated for the effects of the uprate on the steady-state and transient conditions for the normal and upset loads in the design specifications, References 1 (Model 44F) and Reference 2 (Model Δ47). The test, emergency, and faulted loading conditions are unaffected by the uprate. The structural acceptance criteria for both steam generator models are given in the 1965 Edition through Summer 1966 Addenda of the ASME B&PV, Section III, Reference 3. Details of the actual acceptance criteria employed in the structural evaluation of both the 44F and Δ47 are given in Section 4 of Volume 1 of Reference 4.

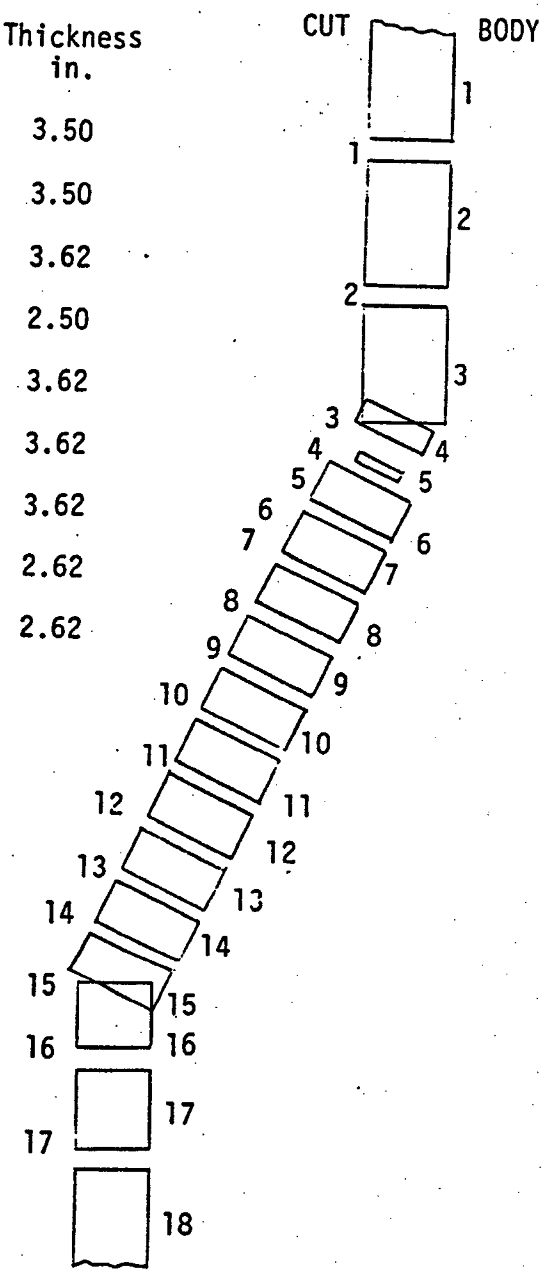
Secondary Shell – Model 44F

Summary stress results for the secondary shell transition cone are given in Table 7-44 of Reference 5 for current power rating. These results, shown in Table 5.6-9, remain bounding for the uprated conditions since a reduction in secondary pressure will reduce the stresses in the shell. Citical sections in the transition cone region are depicted in Figure 5.6-3. The results in Table 5.6-9 show that all stress limits are satisfied. For fatigue, Section BB, shown in Figure 5.6-1, is the overall governing location for the secondary shell and has been considered above in the evaluation for the channel head, the tubesheet and the tubesheet to shell junctions. The structural evaluation of the relocated PBNP Unit 1 level taps in the secondary shell is discussed below.

Upper Shell Remnant – Model 44F

The upper shell (along with its manway) and the steam outlet nozzle are remnant components from the original 44 Series steam generator. The remnant components were evaluated for continued use in Model 44F replacement steam generators in Section 7.20 of Reference 5. Figure 5.6-5 shows the locations in the upper shell remnant evaluated in Reference 5. Section DD in Figure 5.6-5 refers to the manway pad. The feedwater nozzle is evaluated above as a separate item. As discussed previously, the power uprate results in reduced secondary (steam) pressures and temperatures. Therefore, the specified loads, considered in Reference 5, bound the structural evaluation. The calculated fatigue usage factor for 40 years is less than 1.0 at the limiting location, Section BB in Figure 5.6-5. Since the maximum usage in the remnant based on 40 years is very low, extension to 60 years and ASME Code compliance within the usage limit of one are obvious.

Body No.	Meridional length, in.	Thickness in.
1	∞	3.50
2,3	8.43	3.50
4	5.15	3.62
5	1.00	2.50
6-8	7.24	3.62
9	7.29	3.62
10-15	7.24	3.62
16, 17	6.38	2.62
18	∞	2.62



Transition Cone Region – Model 44F