CP&L

Carolina Power & Light Company

SERIAL: NLS-86-012

JAN 13 1986

Director of Nuclear Reactor Regulation
Attention: Mr. D. B. Vassallo, Chief
Operating Reactors Branch No. 2
Division of Licensing
United States Nuclear Regulatory Commission
Washington, DC 20555

BRUNSWICK STEAM ELECTRIC PLANT, UNIT NO. 1
DOCKET NO. 50-325 / LICENSE NO. DPR-62
INTERGRANULAR STRESS CORROSION CRACKING

Dear Mr. Vassallo:

On November 7, 1985, your staff requested additional information concerning intergranular stress corrosion cracking (IGSCC) inspections performed on Brunswick-1. Design reports regarding these inspections were submitted on June 14, 1985 and September 25, 1985. Enclosure 1 contains our responses to your staff's questions.

Please refer any further questions to Mr. Stephen D. Floyd at (919) 836-6901.

Yours very truly,

S.D. Floyd for

S. R. Zimmerman
Manager
Nuclear Licensing Section

SRZ/MAT/mf (3216MAT)

Enclosure

cc: Mr. W. H. Ruland (NRC-BNP)
Dr. J. Nelson Grace (NRC-RII)
Mr. M. Grotenhuis (NRC)

A047
1/1

ADD: EB (LIAW)

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ENCLOSURE 1
TO SERIAL NLS-86-012

RESPONSE TO NRC RAI REGARDING IGSCC INSPECTIONS
BRUNSWICK-1

(3216MAT/mf)

Request for Additional Information

Brunswick Unit 1

IGSCC Inspection

A. With respect to the design report transmitted on September 25, 1985 please provide the following information:

1. A detailed sample calculation for each kind of an overlay design used for the repair of cracked welds

2. The overlay inspection of welds repaired prior to October 1984.

B. With respect to the design report transmitted on June 14, 1985, please provide the following information:

1. The "as built" overlay thickness, including the first layer, for the 4-12" and 1-4" repaired welds (see Table 2.1 page 9)

2. The ultrasonic testing (UT) measured pipe wall thickness for the one unrepaired weld and the five repaired welds identified in B.1 above

3. The method of calculating the shrinkage stress for weld 12-AR-B4A (page 26)

4. The design menthod for the overlay for weld 1-RR-4A 10-A. Due to the accessibility constraint, the flaws in the subject weld were not sized.

5. A sample calculation for the overlay design for weld 12-13R-F4A

6. The data of the ferrite measurements made on the first layer of the overlay for the repaired welds identified in B.1 above

7. The stress information for welds 28 (table 4.1, page 21).

RESPONSE TO A.1

The following provides: (a) a sample calculation for a circumferentially flawed weld (12-AR-A3) and (b) a sample calculation for an axially flawed weld (12-BR-K3).

A. With respect to the design report transmitted on September 24, 1985 (NUTECH Report CPL-30-100, Revision 2), please provide the following information:

1. A detailed sample calculation for each kind of an overlay design used for the repair of cracked welds.

a. Typical weld overlay repair (WOR) design for a circumferentially flawed weld (12-AR-A3)

Weld Geometry/Configuration:

Outside Diameter = 12.75"

Pipe Wall Thickness (t_p) = 0.75"

Configuration = Elbow-to-Pipe

Measured Flaw Dimensions:

1.75" length x 35% depth circumferential flaw, elbow side.

Design Flaw Dimensions:

1.75" length x 100% depth circumferential flaw, elbow side.

Allowable Material Stress Intensity (at 550°F):

S_m = 16,950 psi

Stresses (unrepaired pipe):

$P_m + P_B$ = (Deadweight + Pressure + Seismic (OBE) Stresses)

= 8,493 psi

Assumed WOR Thickness:

$t_{ol} = 0.25"$

Stress after WOR:

$$\frac{t_p}{t_p + t_{ol}} \times 8{,}493 \text{ psi} = 6{,}370 \text{ psi}$$

Stress Ratio (SR):

SR = 6,370 psi/16,950 psi = 0.38

Non-Dimensional Flaw Length (FL):

FL = 1.75"/(12" X *)

= 0.046

Allowable Flaw Depth Ratio (a/t) from ASME Section XI, Table IWB-3641-1:

a/t = 0.75

Back Check Assumed vs. Allowable Flaw Depth Ratio:

$a/t = a/(t_p + t_{ol})$

= 0.75"/(0.75" + 0.25")

= 0.75 = Allowable a/t; O.K.

WOR Design Length (L):

Rule-of-Thumb:

$1.5\sqrt{Rt} < L < 2.0\sqrt{Rt}$

$t = 0.75"$

$R = (12.75" - 0.75")/2 = 6.0"$

$3" < L < 4\ 1/4"$

b. Typical WOR design for an axially flawed weld (12-BR-K3)

Weld Geometry/Configuration:

Outside Diameter = 12.75"

Pipe Wall Thickness = 0.76"

Configuration = Elbow-to-Pipe

Measured/Design Flaw Dimensions:

0.75" Length x 100% Depth axial flaw, elbow side

Allowable Material Stress Intensity (at 550°):

$S_m = 16,950$ psi

Internal Pressure (P):

$P = 1,050$ psi

Stress Ratio (SR):

$$SR = PD/2tS_m$$

$$= 1{,}050 \text{ psi } (12.75")/[2(0.76")(16{,}950 \text{ psi})]$$

$$= 0.52$$

Non-Dimensional Flaw Length (FL):

$$FL = l_f // \sqrt{Rt}$$

$$= 0.75" // \sqrt{[(12.75" - 0.76")/2](0.76")}$$

$$= 0.35$$

From Table 1, Leakage Barrier (2 Layers) Only Required.

WOR Design Length (L):

Rule of Thumb:

L > Butt Weld Root Width + 2(Flaw Length) + 2(1/2" Cover)

= 3.0"

RESPONSE TO A.2

The 1983 overlays that were examined during the Unit 1 March 1985 outage are as follows:

12" B32 AR-E-2
12" B32 BR-H-4
28" B32 A-14
28" B32 A-15
28" B32 B-8

These welds were examined using the basic recommendations of the Electric Power Research Institute Interim Report dated April 1985, "Examination of Weld Overlayed Pipe Joints." The overlay bond integrity was examined manually with a 2.25 MHz 0° longitudinal transducer. The overlay weld metal and base material underneath were examined manually and with the automated General Electric SMART UT system using 2.0 MHZ refracted longitudinal 45° and 60° dual transducers. Calibration was accomplished utilizing "mock-up" overlayed pipe with a 1/16" side drilled hole and 75% EDM notch. Calibration encompassed reflectors from the tip and corner reflectors of the EDM notch for the examination of base metal and the 1/16" side drilled hole at the base metal/overlay interface for the overlay weld metal and weld overlay bond to pipe integrity. A minimum overlap of 50% search unit element size was utilized during manual examinations to assure complete examination coverage. The automated SMART system examination incorporated a minimum overlap of 25% search unit element size. The manual and automated exams of the subject weld overlays did not yield IGSCC indications.

RESPONSE TO B.1

The "as-built" overlay thickness, including first layer, for the four 12" and one 4" repaired welds listed in Table 2.1 of our June 14, 1985 submittal are as follows:

Weld ID	Thickness (inches)
12-AR-A4A	0.439
12-AR-B2A	0.272
12-AR-B4A	0.432
12-BR-F4A	0.40
1-RR-4A10-A	0.525

(3216MAT/1js)

RESPONSE TO B.2

The ultrasonic testing (UT) measured pipe wall thickness for the four 12" and one 4" repaired welds listed in Table 2.1 of our June 14, 1985 submittal and the unrepaired 28-A8 weld are as follows:

UT MEASURED PIPE WALL THICKNESS (inches)

	Location			
Weld ID	0°	90°	180°	270°
12-AR-A4A				
Upstream	0.638	0.608	0.684	0.639
Downstream	0.721	0.712	0.724	0.708
12-AR-B2A				
Upstream	0.625	0.624	0.630	0.624
Downstream	0.789	0.778	0.790	0.793
12-AR-B4A				
Upstream	0.622	0.615	0.629	0.626
Downstream	0.709	0.688	0.717	0.702
12-BR-F4A				
Upstream	NR	0.641	NR	0.639
Downstream	NR	0.717	NR	0.724
1-RR-4A10-A				
Weld-O-Let Side	0.32	0.32	0.33	0.33
28-A8				
Pipe Side	1.30*	NR	NR	NR

Notes: NR - Not Recorded
* - Preservice Baseline UT Data

RESPONSE TO B.3

The following provides the method of calculating the shrinkage stress for weld 12-AR-B4A:

B. With respect to the design report transmitted on June 14, 1985 (N .CH report CPL-21-103, Revision 1), please provide the following information:

3. The method of calculating the shrinkage stress for weld 12-AR-B4A (page 26).

Axial Load and Moments due to Shrinkage Stress (from PISTAR computer output):

F_{axial} = 3,282 lb

M_{xx} = 22,344 in-lb

M_{yy} = 21,988 in-lb

M_{zz} = -1,468,701 in-lb

Repaired Pipe Wall Thickness (t):

t = (pipe wall thickness) + (overlay thickness)

= 0.568 in + 0.262 in

= 0.830 in

Area and Section Modulus:

$A = \pi(OD^2 - ID^2)/4$

OD = 12.75" + 2 x (0.262") = 13.274"

ID = 12.75" - 2 x (0.568") = 11.614"

$A = 32.4\ in^2$

$Z = \pi(OD^4 - ID^4)/(32 \times OD)$

$= 95.1\ in^3$

Shrinkage Stress (σ_{sh}):

$$\sigma_{sh} = (F_{axial}/A) + (\sqrt{M_{xx}^2 + M_{yy}^2 + M_{zz}^2}/2)$$

$$= 15,517 \text{ psi}$$

RESPONSE TO B.4

The following provides the design method for the overlay weld 1-RR-4A 10-A:

B. With respect to the design report transmitted on June 14, 1985 (NUTECH report CPL-21-103, Revision 1), please provide the following information:

4. The design method for the overlay for weld 1-RR-4A10-A. Due to the accessibility constraint, the flaws in the subject weld were not sized.

Two Flaw Size Possibilities were Considered:

i. Flaw is Axially Oriented,
0.5" Length x 100% Depth

ii. Flaw is Circumferentially Oriented,
2.0" Length x 100% Depth

i. Axial Flaw

Weld Geometry/Configuration

Outside Diameter = 4.5"

Pipe Wall Thickness (t_p) = 0.337"

Configuration = Pipe-to-Weld-o-let

Stress Intensity/Internal Pressure

Allowable S_m (at 550°F) = 16,950 psi

Internal Pressure (P) = 1,050 psi

Stress Ratio (SR):

$$SR = PD/2t(S_m)$$

$$= (1{,}050 \text{ psi})(4.5")/[2(0.337")(16{,}950] \text{ psi})$$

$$= 0.414$$

Non-Dimensional Flaw Length (FL):

$$FL = l_f//\overline{Rt}$$

$$= 0.5"//\overline{[(4.5" - 0.337")/2](0.337")}$$

$$= 0.597$$

From Table 1, Leakage Barrier (2 Layer) Only Required.

WOR Design Length (L):

L > (Butt Weld Crown Width)/2 + (1/2" Cover) + (Distance from Weld Centerline to Weld-o-Let Transition)

ii. Circumferential Flaw

Stress information was not available, maximum allowable stresses in unrepaired pipe assumed:

Stress = 1.5 S_m

Assume a WOR thickness, reduce stress due to assumed WOR thickness, calculate stress ratio (SR):

$t_{ol} = 0.125"$

$$\text{Reduced Stress} = \frac{0.337"}{0.125" + 0.337"}(1.5\ S_m)$$

$$= 1.09\ S_m$$

$SR = 1.09$

Non-Dimensional Flaw Length (FL):

$FL = 2.0"/(4" \times \pi)$

$= 0.16$

Allowable Flaw Depth Ratio (a/t) from ASME Section XI Table IWB-3641-1:

$a/t = 0.74$

Back check assumed vs. allowable flaw depth ratio:

$a/t = a/(t_p + t_{ol})$

$= 0.337"/(0.337" + 0.125")$

$= 0.73 < 0.74$; O.K.

WOR Design Length (L):

Rule-of-Thumb: $1.5 \sqrt{Rt} < L < 2.0 \sqrt{Rt}$

$t = 0.337"$

$R = (4.5" - 0.337")/2$

$= 2.08"$

$1\ 1/4" < L < 1\ 5/8"$

WOR Design Assuming Circumferential Flaw is Bounding.

Therefore, it is Used.

RESPONSE TO B.5

The following is a sample calculation for the overlay design for weld 12-BR-F4A:

B. With respect to the design report transmitted on June 14, 1985 (NUTECH report CPL-21-103, Revision 1), please provide the following information:

5. A sample calculation for the Overlay Design for Weld 12-BR-F4A.

Weld Geometry/Configuration

Outside Diameter = 12.75"

Pipe Wall Thickness (t_p) = 0.568"

Configuration = Pipe-to-Safe end extension

Measured Flaw Dimensions:

4.0" length x 9% depth and 0.5" length x 23% depth circumferential flaws, pipe side

Design Flaw Dimensions:

4.5" length x 100% depth circumferential flaw, pipe side

Allowable Material Stress Intensity (at 550°F):

S_m = 16,950 psi

Stresses:

$P_m + P_B$ = (Deadweight + Pressure + Seismic (OBE) Stresses)

= 8,872 psi

Stress Ratio (SR):

$$SR = \frac{8,872 \text{ psi}}{16,950 \text{ psi}} = 0.52$$

Non-Dimensional Flaw Length (FL):

$$FL = 4.5"/(12" \times \pi)$$

$$= 0.12$$

Allowable Flaw Depth Ratio (a/t) from ASME Section XI Table IWB-3641-1:

$$a/t = 0.75$$

WOR thickness calculation:

$$0.568"/0.75 - 0.568" = 0.19"$$

WOR Design Length (L):

Rule-of-Thumb: $1.5\sqrt{Rt} < L < 2.0\sqrt{Rt}$

$t = 0.568"$

$R = (12.75" - 0.568")/2 = 6.1"$

$2\ 3/4" < L^* < 3\ 3/4"$

* WOR Length on Flawed Pipe Side of Weld = L/2. WOR Length on Unflawed Safe End Extension Side of Weld to Extend to within 1/4" of Inconel but Need not Exceed L/2.

Table 1

REPAIR CRITERIA FOR AXIAL IGSCC

STRESS RATIO	NONDIMENSIONAL FLAW LENGTH $\ell_4 / \sqrt{RT}$					
	0.00	0.25	0.50	1.00	2.00	.....
≤ 0.40	•	•	•	•	→	IWB-3640
0.50	•	•	•	•	→	
0.60	•	•	•	•	→	
0.70	•	•	•	•	→	
0.80	•	•	•	•	→	
0.90	•	•	•	→	→	
0.95	•	•	→	→	→	
1.00	→	→	→	→	→	

BCCM84.01

* LEAK BARRIER ONLY REQUIRED

ALL DEFINITIONS SAME AS IWB-3640

STRESS RATIO = PD / 2 T Sm

P = MAXIMUM PRESSURE FOR NORMAL OPERATING CONDITIONS

D = NOMINAL OUTSIDE DIAMETER OF THE PIPE

T = NOMINAL THICKNESS

ℓ_4 = END-OF-EVALUATION PERIOD FLAW LENGTH

R = NOMINAL RADIUS OF THE PIPE

Note: This table is contained in NUTECH Report COM-76-001, "Weld Overlay Design Criteria for Axial Cracks", Revision 0.

RESPONSE TO B.6

The ferrite measurements for the first layer of the overlays for the four 12" and one 4" repaired welds listed in Table 2.1 of our June 14, 1985 submittal are as follows:

Weld ID	Delta Ferrite Measurement
12-AR-A4A	7.5
12-AR-B2A	7.5 / 10 / 7.5 *
12-AR-B4A	7.5
12-BR-F4A	7.5 / 10 / 7.5 *
1-RR-4A10-A	7.5

* Measurements taken upstream / centerline / downstream

RESPONSE TO B.7

During a telephone conversation with members of your staff, it was determined that the stress information requested in B.7 pertains to weld 1-RR-4A10-A. This information can be found in our response to B.4.