Calculation Title Page

Project SONGS 1 Job Order No. ________ Discipline Nuclear

Subject SONGS1 Reactor Vessel Adjusted Reference Temperatures for 16 and 24 EFPY

Calculation No. DC 3115 QA Class I SR No. Pages 17

Responsible Engineer Phil Brashear (SIGNATURE) DC 8 12-8-88 Date 12/2/88

Independent Review Engineer [signature] (SIGNATURE) Date 12/5/88

ORIGINAL ISSUE

	NAME	DATE	SIGNATURE
Group Leader	Jerry L. Judd	12/6/88	Jerry L Judd
Discipline Sup. Engineer	Jerry L. Judd	12/6/88	Jerry L Judd
Professional Engineer (if required)			

RECORD OF REVISIONS

NO.	REASON FOR REVISION	DATE	RESP. ENGR.	IRE	GL	DSE	PE
1	Revise Fluences (per Reference 10) in Section 7.3. Correct error in Revision 0 (CF and ART for Plate W7601-9 in Tables 1 and 2).	3/10/90	P.F. Brashear	[initials]	JLJ	JJS 4/4/90	

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PROFESSIONAL ENGINEER'S SEAL

SCE 26-121 REV 10/84

DESIGN INPUT SHEET

☐ Design Requirements
☐ Design Input Change

DESIGN CALCULATION NO. DC 3115 Rev. 1

SUBJECT: SONGS 1 Reactor Vessel Adjusted Reference Temperatures For 16 and 24 EFPY.		PROJECT: SONGS 1
QUALITY CLASS: SR	SEISMIC CLASS: I	SPECIFICATION REFERENCE: ASME Code Section III, Class 1

Design Input

See Assumptions in Section 5, Page 6.

RESPONSIBLE ENGINEER	DATE	INDEPENDENT REVIEW ENGINEER	DATE	GROUP LEADER	DATE
P.F. Brashear	3/10/90	[illegible signature]	3/22/90	C.W. Bayles	3-29-90

SCE 26-88 REV 6/81

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1. PURPOSE

The current RCS Pressure-Temperature (P-T) operating limits (heatup and cooldown curves) are based on reactor vessel adjusted reference temperatures (adjusted RT_{NDT}) determined by Westinghouse and previously considered valid for 16 EFPY. Regulatory Guide 1.99 Revision 2 (Reference 1) introduces changes which significantly affect the methods used to predict irradiation induced shifts in adjusted RT_{NDT} values. Under the new regulation revision, the predicted adjusted RT_{NDT} values used in determining the current P-T limits may not be conservative; and therefore the heatup and cooldown limits (Technical Specification 3.1.3) may not be valid for the entire operating period considered. In accordance with NRC Generic Letter 88-11 (Reference 2), this design calculation determines SONGS1 adjusted RT_{NDT} values per Reference 1, and evaluates the validity of the existing P-T limits. In addition, Reg. Guide 1.99 Rev. 2 based adjusted RT_{NDT} values will be determined for 24 EFPY (end-of-life conditions) and compared with values predicted by Westinghouse.

2. METHODOLOGY

The adjusted RT_{NDT} is determined by adding the expected shift in Reference Temperature (ΔRT_{NDT}) due to neutron irradiation, to the initial unirradiated Reference Temperature (initial RT_{NDT}) for all reactor vessel beltline materials. These materials have previously been identified and their initial RT_{NDT} values are available (Reference 3). The Reference Temperature shifts are determined per the guidelines of Reference 1, Section 2.1, using SONGS 1 surveillance data, and evaluated at the operational periods (fluences) of interest (16 and 24 EFPY) for the vessel wall 1/4 thickness and 3/4 thickness locations. In accordance with Reference 1, a margin term M is determined and included in calculating adjusted RT_{NDT} values for conservatism.

The highest adjusted RT_{NDT} value calculated for all beltline materials determines the limiting material (or materials, since a different plate or weld can be limiting at different vessel wall thicknesses). These adjusted RT_{NDT} values for the limiting material(s) are then compared with the Westinghouse determined values (Reference 4) from which the existing P-T curves are based.

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3. RESULTS

The adjusted RT_{NDT}s for the reactor vessel beltline limiting materials at the vessel wall 1/4 and 3/4 thickness locations are shown below. Adjusted RT_{NDT} values for the limiting materials at operating periods of 16 and 24 EFPY using Reg. Guide 1.99 Rev. 2 methods are shown below. Values predicted using Westinghouse methods (References 9 and 11) are provided for comparison.

SONGS1 Adjusted RT_{NDT} (°F)

	16 EFPY		24 EFPY	
	R.G. 1.99 Rev. 2	W	R.G. 1.99 Rev. 2	W
1/4 T Location				
(Plate W7601-9)		217		235
(Plate W7601-1)	186		194	
3/4 T Location				
(Plate W7601-5)		163		172
(Plate W7601-1)	159		168	

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4. **REFERENCES**

1. Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," May 1988.

2. NRC Generic Letter 88-11, "Position on Radiation Embrittlement of Reactor Vessel Materials and It's Impact on Plant Operations", July 12, 1988.

3. K. P. Baskin (SCE) to H. R. Denton (NRC) Docket #50-206, "Heatup and Cooldown Curves SONGS Unit 1", April 18, 1980.

4. K. P. Baskin (SCE) to H. R. Denton (NRC) Docket #50-206, "Amendment Application No. 118 SONGS Unit 1", May 17, 1984.

5. ASTM Standard E208-87a, "Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels", Volume 03.01, 1988.

6. M. O. Medford (SCE) to G. E. Lear (NRC), "Pressurized Thermal Shock SONGS 1", January 23, 1986.

7. Southwest Research Institute, "Analysis of First Surveillance Material Capsule From San Onofre Unit 1", July, 1971

8. Southwest Research Institute, "SONGS1 Analysis of Second Surveillance Material Capsule From San Onofre Unit 1", July, 1972

9. Westinghouse Electric Corporation, "Analysis of Capsule F From The Southern California Edison Company, San Onofre Reactor Vessel Surveillance Program", May, 1979

10. Westinghouse Report, San Onofre Unit 1 Reactor Vessel Fluence Calculation, PTS Evaluation and Flux Reduction Factor Curves, March, 1990

11. K. P. Baskin to USNRC, "Docket No. 50-206 Pressurized Thermal Shock to Reactor Pressure Vessels SONGS Unit 1", January 25, 1982

12. Westinghouse Report, "Summary Report on Reactor Vessel Integrity for Westinghouse Operating Plants", WCAP-10019, December 1981

13. S. Anderson to P. F. Brashear, Westinghouse Letter #FSE-REA-90/941, "SCE Capsule Fluence Comparisons", April 6, 1990

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5. ASSUMPTIONS

1. Maximum expected vessel fast fluxes and fluences have been determined by Westinghouse (References 6, 10) using SONGS 1 surveillance capsule data. These values are conservative.

2. Initial RT_{NDT}s and material chemistry are taken from Reference 3. Where no chemistry analysis is available, conservative estimates are used (reference 6).

3. Techniques for determining RT_{NDT} shifts from plant surveillance data per Section 2 of Reference 1 are conservative; i.e., RT_{NDT} shifts for materials of different chemistry can be determined by correcting surveillance data using the ratio of chemistry factors.

4. Fast flux is attenuated through the vessel wall per Reference 1.

5. Maximum possible vessel initial crack depths are 1/4 thickness deep and occur at the vessel wall OD or ID.

6. Vessel EOL is 24 EFPY.

7. σ_i is 5°F for base metal as initial RT values were measured in accordance with ASTM standard E208-87a.

8. Margin M is 59°F for all welds per 10CFR50.61 (b.2.i). Mean generic values were used for these weld's initial RT_{NDT} and σ_i is unavailable; therefore, the recommended margin for the PTS rule is used and considered conservative.

9. SONGS1 reactor vessel wall thickness is 9.91 inches. This is the minimum plate thickness in the beltline region.

10. Nickel content for the vessel shell plate material is 0.20%. The nickel content was not directly measured, but is known to be less than 0.20 weight percent because this was the specification limit for the steel (SA302B) used.

11. The weld copper and nickel contents are not available, but are conservatively estimated as 0.27% and 0.20% (References 11, 12).

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6. NOMENCLATURE

ART - Reactor vessel limiting material adjusted reference temperature evaluated at vessel wall 1/4 thickness and/or 3/4 thickness location (°F).

CF - Chemistry factor per Reference 1.

ff - Fluence factor per Reference 1.

f_s - Fluence at reactor vessel ID surface (n/cm^2).

$f_{1/4T}$ - Fluence at reactor vessel 1/4 T flaw location (n/cm^2).

$f_{3/4T}$ - Fluence at reactor vessel 3/4 T flaw location (n/cm^2).

M - Margin to be used in determining ART to cover uncertainties per Reference 1 (°F).

RT_{NDT} - Reactor vessel material nil-ductility-transition reference temperature (or ART), (°F).

ΔRT_{NDT} - Shift in nil-ductility-transition reference temperature due to vessel irradiation (°F).

σ_i - Standard deviation for the initial RT_{NDT}, based on measured or generic data (°F).

σ_Δ - Standard deviation for ΔRT_{NDT}, (14°F for welds, 8.5°F for base metal, Reference 1).

T - Reactor vessel wall thickness (inches).

x - Reactor vessel wall radial position, measured from wall ID (inches).

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7. CALCULATIONS

7.1 Materials

The limiting reactor coolant pressure boundary material for irradiation embrittlement and fracture toughness considerations was previously determined to be intermediate shell plate W7601-9 for the 1/4 T location, and lower shell plate W7601-5 at the 3/4 T location, using the methodology presented in Reference 3. Due to changes in radiation damage correlations, Reference 1 must now be used to determine the ARTs for the vessel beltline weld, heat affected zone (HAZ), and plate metals. This will be done for fluences equivalent to 16 and 24 EFPY (EOL: 30 years @ 80% capacity). The largest resulting ART at the 1/4 T and 3/4 T locations will dictate the vessel limiting material.

The relative locations of the beltline materials considered are shown in Figure 1. Plate and weld reference numbers and material properties are listed in Tables 2 and 3. The methods used to determine the intermediate step parameters (summarized in Tables 2 & 3) are shown below.

7.2 Chemistry Factor (CF)

The Chemistry Factor for the various plates and weld metal is determined from Section C.2.1 of Reference 1.

Reference 1 states, "calculate the chemistry factor, CF, for the best fit by multiplying each adjusted ΔRT_{NDT} by its corresponding fluence factor, summing the products, and dividing by the sum of the squares of the fluence factors". This can be represented by the following equation:

$$CF = \Sigma(\Delta RT_{NDT} * ff) / \Sigma(ff^2)$$

and is the least squares fit of the surveillance data to the NRC correlation used in Section 7.4 of this calculation.

In addition, Reference 1 states if "the copper or nickel content of the surveillance weld (plate) differs from that of the vessel weld (plate), i.e., differs from the average of the weld wire heat number associated with the vessel weld and the surveillance weld, the measured values of ΔRT_{NDT} should be adjusted by multiplying them by the ratio of the chemistry factor (Reference 1, Table 2) for the vessel weld (plate) to that for the surveillance weld (plate). Copper and nickel content for the beltline materials are provided in Table 2.

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The surveillance capsule results needed for computation of the chemistry factors are summarized in Table 1 below. Shifts in RT_{NDT} are those values measured and reported in the surveillance capsule reports (References 7-9). Fast fluences provided result from a reanalysis (Reference 13) using the surveillance reports activation data and updated transport codes and a more detailed capsule geometric model.

Table 1

Capsule	Fluence n/cm^2	ff	ΔRT_{NDT} (°F) W7601-1	W7601-8	W7601-9	Weld	HAZ
A	1.8E19	1.161	-	-	100	80	80
D	3.4E19	1.320	140	110	130	-	-
F	4.9E19	1.398	-	120	-	145	115

where ff is the fluence factor as defined in Reference 1:

$$ff = fluence^{(0.28 - 0.10 \log fluence)}$$

Per Reference 1, at least 2 data points are needed to use in determining CF. For the plate material, plates W7601-8 and W7601-9 both meet this requirement. Furthermore, since these plates have the same copper and nickel content (Table 1), similar residual elements content (Reference 8), similar initial RT_{NDT}s, and the same heat treatment (microstructure), it is valid to group the 4 data points together and treat plates W7601-8 and W7601-9 as the same material (plate W7601-1 has slightly different copper content, and is therefore not included). The weld and HAZ metal have 2 valid surveillance data points, which are used in determining CF.

Using the above equation, chemistry factors are determined for the beltline materials:

W7601-1

$$CF = (88/92)*(100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 84.7$$

W7601-8

$$CF = (100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 88.5$$

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<u>W7601-9</u>

$$CF = (100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 88.5$$

<u>W7601-3</u>

$$CF = (80/92)*(100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 77.0$$

<u>W7601-6</u>

$$CF = (84/92)*(100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 80.8$$

<u>W7601-7</u>

$$CF = (80/92)*(100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 77.0$$

<u>W7601-2</u>

$$CF = (88/92)*(100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 84.7$$

<u>W7601-4</u>

$$CF = (75/92)*(100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 72.1$$

<u>W7601-5</u>

$$CF = (75/92)*(100*1.161 + 110*1.320 + 130*1.320 + 120*1.398)/(1.161^2 + 1.320^2 + 1.398^2 + 1.320^2)$$

$$CF = 72.1$$

Chemistry factors for the welds are determined from the surveillance weld data. Since weld chemistry is assumed the same for all welds, no chemistry correction is necessary:

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Welds

$$CF = (80*1.161 + 145*1.398)/(1.161^2 + 1.398^2)$$
$$CF = 89.5$$

Chemistry factors for HAZ is determined from the surveillance HAZ data. Since the surveillance HAZ copper and nickel content (from plates W7601-8 and W7601-9) is the highest of any vessel HAZ material, the measured surveillance data does not need to be corrected for chemistry:

HAZ

$$CF = (80*1.161 + 115*1.398)/(1.161^2 + 1.398^2)$$
$$CF = 76.8$$

These chemistry factors are listed in Table 2 and 3.

7.3 Fluence

Fluences for the vessel beltline materials are determined below for the vessel wall I.D. surface, 1/4 T, and 3/4 T locations.

Surface Fluence (f_s)
I.D. surface fluences are obtained from References 10 and 11, and are considered conservative. Fast fluxes used to determine fluences for a given plate or weld were evaluated at the position of highest azimuthal and axial flux peaking.

The vessel peak fluence locations occur in intermediate shell plates (W7601-1, W7601-8, and W7601-9) and longitudinal weld 7-860A. The 16 and 24 EFPY maximum fluences for these materials are given in Reference 10 as 4.73E19 n/cm^2 and 6.84E19 n/cm^2.

The maximum fluences for the remaining beltline materials are obtained from Reference 11. Subsequent analysis (Reference 10) has shown the values determined in Reference 6 using Reference 11 overpredict the vessel fast fluxes and fluences. However, since Reference 10 did not explicitly determine the fluence for the remaining plates and welds, the values determined in Reference 6 will be used for these materials. This is conservative because the earlier analysis did not account for low leakage fuel patterns used since Cycle 7. This provides additional margin to the calculation of ΔRT_{NDT}. From Reference 6, these surface fast fluxes are:

Plates W7601-3, W7601-6, W7601-7 = 2.21E18 n/cm^2/EFPY
Plates W7601-2, W7601-4, W7601-5 = 1.11E18 n/cm^2/EFPY

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Longitudinal Weld 7-860B = 1.20E18 n/cm^2/EFPY
Longitudinal Weld 7-860C = 0.695E18 n/cm^2/EFPY
Longitudinal Weld 6-860A = 0.720E18 n/cm^2/EFPY
Longitudinal Weld 6-860B = 0.417E18 n/cm^2/EFPY
Longitudinal Weld 6-860C = 1.80E18 n/cm^2/EFPY
Longitudinal Weld 8-860A = 0.36E18 n/cm^2/EFPY
Longitudinal Weld 8-860B = 0.208E18 n/cm^2/EFPY
Longitudinal Weld 8-860C = 0.90E18 n/cm^2/EFPY
Circumferential Weld 1-860 = 1.11E18 n/cm^2/EFPY
Circumferential Weld 2-860 = 2.21E18 n/cm^2/EFPY

These fluxes are multiplied by 16 and 24 EFPY to obtain the fluences listed in Tables 2 and 3, respectively.

<u>Vessel wall 1/4 T Fluence ($f_{1/4T}$)</u>

Vessel wall 1/4T fluences are obtained by attenuating the surface fluences per Reference 1 (x as defined in the nomenclature):

$$f_x = f_s(e^{-0.24x})$$

For example, the 1/4 T fluence (16 EFPY) for shell plate W7601-1 is:

$$f_{1/4T} = (4.73E19)(e^{-0.24(9.91/4)})$$
$$f_{1/4T} = 2.61E19$$

1/4 T fluences at 16 and 24 EFPY for the remaining beltline materials are determine in the same manner and have been listed in Tables 2 and 3.

<u>Vessel wall 3/4 T Fluence ($f_{3/4T}$)</u>

Vessel wall 3/4T fluences are obtained by attenuating the surface fluences per Reference 1:

$$f_x = f_s(e^{-0.24x})$$

For example, the 3/4 T fluence (16 EFPY) for shell plate W7601-1 is:

$$f_{3/4T} = (4.73E19)(e^{-0.24(9.91*3/4)})$$
$$f_{3/4T} = 0.795E19$$

3/4 T fluences at 16 and 24 EFPY for the remaining beltline materials are determine in the same manner and have been listed in Tables 2 and 3.

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7.4 Nil-Ductility-Transition Temperature Shifts (ΔRT_{NDT})

The shift in RT_{NDT} is determined from Reference 1:

$$\Delta RT_{NDT} = CF * f^{(0.28 - 0.1 \log f)}$$

where f is the fluence ($x10^{19}$) evaluated at 1/4 T or 3/4 T, and at either 16 EFPY (Table 2) or 24 EFPY (Table 3). For example, ΔRT_{NDT} at 16 EFPY at 1/4 T for plate W7601-1 is:

$$\Delta RT_{NDT} = 84.7(2.61^{(0.28 - 0.1 \log(2.61))})$$
$$\Delta RT_{NDT} = 106.5\ ^{\circ}F$$

The remaining transition temperature shifts are determined in the same manner and have been listed in Tables 2 and 3.

7.5 ART Margin (M)

"Margin", M, is the quantity (°F) that must be added to obtain conservative, upper-bound values of adjusted reference temperature (ART) for the calculations necessary to meet the requirements of Appendix G to 10CFR50.

$$M = 2\sqrt{(\sigma_i^2 + \sigma_\Delta^2)}$$

σ_i is the standard deviation for the initial RT_{NDT}. The initial RT_{NDT}s for the beltline materials were measured values established in accordance with Reference 5. These values (listed in Tables 2 and 3) were determined through break/no-break specimen fracture tests conducted at 50 ft-lbs at 10°F increments. The initial RT_{NDT} is the highest tested temperature at which the specimen breaks for given loading conditions. σ_i is chosen as half of the test temperature increment, 5°F. σ_i for the welds is unknown because mean generic data was used in establishing the welds initial RT_{NDT}.

σ_Δ is the standard deviation for the shift in RT_{NDT}. Per Reference 1, based on generic data σ_Δ = 28°F for welds and 17°F for plates; however, half these values can be used when surveillance data is used in determining ΔRT_{NDT}.

Therefore, for base metal,

$$M = 2\sqrt{((5)^2 + (17/2)^2)}$$
$$M = 19.7^{\circ}F$$

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For welds, since there was no direct measurements for the vessel welds initial RT_{NDT} and σ_i for the generic data base is unknown, per 10CFR50.61(b)(2)(i), a conservative margin recommended which is consistant with the generic data base is:

$$M = 59^\circ F$$

7.6 Adjusted Reference Temperatures (ARTs)

The ART is the initial NDT Reference Temperature adjusted for material embrittlement (ΔRT_{NDT}) for the exposure period being considered, and includes a margin term:

$$ART = \text{initial } RT_{NDT} + \Delta RT_{NDT} + M$$

For shell plate W7601-1 at the 1/4 T location and 16 EFPY,

$$ART = 60 + 106.5 + 19.7\ ^\circ F$$
$$ART = 186.2^\circ F$$

ARTs for the remaining beltline materials at 1/4 T and 3/4 T locations and for 16 and 24 EFPY exposure conditions have been determined in a similar manner and are listed in Tables 2 and 3.

8. CONCLUSIONS

SONGS1 existing Technical Specification 3.1.3 (Heatup and Cooldown Curves) is based on ARTs of 217°F and 163°F at the 1/4 T and 3/4 T location, respectively. Reference 1 was used to determine ARTs for the limiting beltline materials under the new regulatory guidelines. The maximum ARTs for the beltline materials at 16 EFPY were found to occur for intermediate shell plate W7601-1, and are 186.2°F at 1/4 T, and 158.9°F at 3/4 T. These values are less than those used to develop the existing P-T limits (heatup and cooldown curves); therefore, it is concluded the existing curves continue to provide sufficient margin to account for neutron radiation damage through 16 EFPY of operation.

In addition, ARTs were determined for end-of-life conditions (24 EFPY). At 1/4 T and 24 EFPY, the limiting material is intermediate shell plate W7601-9 with an ART of 193.6°F. At 3/4 T and 24 EFPY, the limiting material is intermediate shell plate W7601-1 with an ART of 167.7°F.

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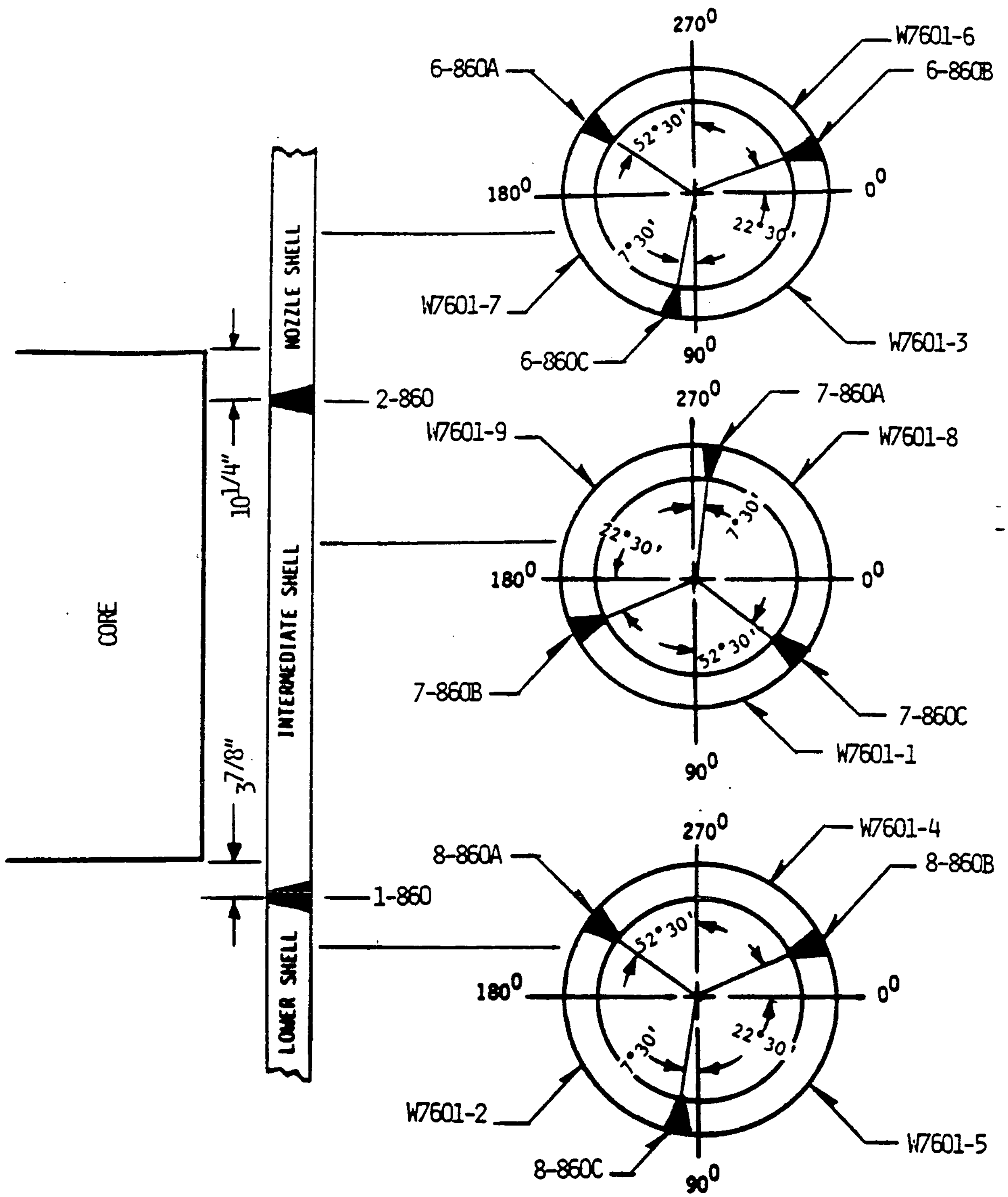

Figure 1. Identification and Location of Beltline Region Material of the San Onofre Unit 1 Reactor Vessel

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Table 2

Adjusted Reference Temperature (ART) for SONGS 1
Reactor Vessel Beltline Materials at 16 EFPY

Material	Cu (%)	Ni[a] (%)	Initial[b] RTndt (F)	M[c] (F)	ID Fluence[d] (10^{19} n/cm²)	CF[e]	1/4 T Fluence (10^{19} n/cm²)	1/4 T ΔRTndt (F)	1/4 T ART (F)	3/4 T Fluence (10^{19} n/cm²)	3/4 T ΔRTndt (F)	3/4 T ART (F)
Inter. Shell W7601-1	0.17	0.2	60	19.7	4.73	84.7	2.610	106.5	186.2	0.795	79.2	158.9
Inter. Shell W7601-8	0.18	0.2	40	19.7	4.73	88.5	2.610	111.2	170.9	0.795	82.8	142.5
Inter. Shell W7601-9	0.18	0.2	55	19.7	4.73	88.5	2.610	111.2	185.9	0.795	82.8	157.5
Upper Shell W7601-3	0.15	0.2	8	19.7	3.54	77.0	1.953	91.1	118.8	0.595	65.8	93.5
Upper Shell W7601-6	0.16	0.2	24	19.7	3.54	80.8	1.953	95.6	139.3	0.595	69.0	112.7
Upper Shell W7601-7	0.15	0.2	12	19.7	3.54	77.0	1.953	91.1	122.8	0.595	65.8	97.5
Lower Shell W7601-2	0.17	0.2	34	19.7	1.78	84.7	0.982	84.3	138.0	0.299	56.7	110.4
Lower Shell W7601-4	0.14	0.2	51	19.7	1.78	72.1	0.982	71.7	142.4	0.299	48.3	119.0
Lower Shell W7601-5	0.14	0.2	82	19.7	1.78	72.1	0.982	71.7	173.4	0.299	48.3	150.0
Long. Weld 7-860A	0.27[a]	0.2	-56	28.4	4.80	89.5	2.649	112.8	85.2	0.806	84.1	56.5
Long. Weld 7-860B	0.27[a]	0.2	-56	28.4	1.92	89.5	1.059	90.9	63.3	0.323	61.7	34.1
Long. Weld 7-860C	0.27[a]	0.2	-56	28.4	1.11	89.5	0.612	77.2	49.6	0.186	49.5	21.9
Long. Weld 6-860A	0.27[a]	0.2	-56	28.4	1.15	89.5	0.635	78.1	50.5	0.193	50.2	22.6
Long. Weld 6-860B	0.27[a]	0.2	-56	28.4	0.67	89.5	0.370	64.9	37.3	0.113	39.5	11.9
Long. Weld 6-860C	0.27[a]	0.2	-56	28.4	2.88	89.5	1.589	100.9	73.3	0.484	71.4	43.8
Long. Weld 8-860A	0.27[a]	0.2	-56	28.4	0.58	89.5	0.320	61.5	33.9	0.097	36.8	9.2
Long. Weld 8-860B	0.27[a]	0.2	-56	28.4	0.33	89.5	0.182	49.0	21.4	0.055	27.7	0.1
Long. Weld 8-860C	0.27[a]	0.2	-56	28.4	1.44	89.5	0.795	83.7	56.1	0.242	55.1	27.5
Circum. Weld 1-860	0.27[a]	0.2	-56	28.4	1.78	89.5	0.982	89.0	61.4	0.299	59.9	32.3
Circum. Weld 2-860	0.27[a]	0.2	-56	28.4	3.54	89.5	1.953	105.9	78.3	0.595	76.5	48.9
HAZ	0.18	0.2	0	19.7	4.73	76.8	2.610	96.5	116.2	0.795	71.8	91.5

(a) Conservative estimate - no analysis available.
(b) Initial Reference Temperature measured or generic mean value per 10CFR 50.61(b)(2)(i).
(c) Margin to be added to cover uncertainties per Regulatory Guide 1.99 Rev. 2, Section 2.1 for plates, 10CFR50.61(b)(2)(i) generic mean value margin for welds.
(d) Reference 6.
(e) Chemistry Factor determined per Regulatory Guide 1.99 Rev. 2, Section 2.1 using SONGS 1 surveillance data.

DWG. NO.

ENGINEERING DEPARTMENT

CALCULATION SHEET

SUBJECT: SONGS 1 Reactor Vessel Adjusted Reference Temperature For 16 & 24 EFPY DESIGN CALCULATION NO. DC 3115 REVISION 1

J.O. NO. ______ MADE BY P. Brashear DATE 3/10/90 CHK. BY [signature] DATE 3/22/90

Table 3

Adjusted Reference Temperature (ART) for SONGS 1 Reactor Vessel Beltline Materials at 24 EFPY

Material	Cu (%)	Ni[a] (%)	Initial[b] RTndt (F)	M[c] (F)	ID Fluence[d] (10^{19} n/cm²)	CF[e]	1/4 T Fluence (10^{19} n/cm²)	1/4 T ΔRTndt (F)	1/4 T ART (F)	3/4 T Fluence (10^{19} n/cm²)	3/4 T ΔRTndt (F)	3/4 T ART (F)
Inter. Shell W7601-1	0.17	0.2	60	19.7	6.84	84.7	3.774	113.8	193.5	1.149	88.0	167.7
Inter. Shell W7601-8	0.18	0.2	40	19.7	6.84	88.5	3.774	118.9	178.6	1.149	91.9	151.6
Inter. Shell W7601-9	0.18	0.2	55	19.7	6.84	88.5	3.774	118.9	193.6	1.149	91.9	166.6
Upper Shell W7601-3	0.15	0.2	8	19.7	5.30	77.0	2.925	98.9	126.6	0.890	74.5	102.2
Upper Shell W7601-6	0.16	0.2	24	19.7	5.30	80.8	2.925	103.8	147.5	0.890	78.2	121.9
Upper Shell W7601-7	0.15	0.2	12	19.7	5.30	77.0	2.925	98.9	130.6	0.890	74.5	106.2
Lower Shell W7601-2	0.17	0.2	34	19.7	2.66	84.7	1.468	93.7	147.4	0.447	65.7	119.4
Lower Shell W7601-4	0.14	0.2	51	19.7	2.66	72.1	1.468	79.8	150.5	0.447	55.9	126.6
Lower Shell W7601-5	0.14	0.2	82	19.7	2.66	72.1	1.468	79.8	181.5	0.447	55.9	157.6
Long. Weld 7-860A	0.27[a]	0.2	-56	28.4	6.84	89.5	3.774	120.2	92.6	1.149	93.0	65.4
Long. Weld 7-860B	0.27[a]	0.2	-56	28.4	2.88	89.5	1.589	100.9	73.3	0.484	71.4	43.8
Long. Weld 7-860C	0.27[a]	0.2	-56	28.4	1.67	89.5	0.922	87.4	59.8	0.281	58.5	30.9
Long. Weld 6-860A	0.27[a]	0.2	-56	28.4	1.73	89.5	0.955	88.3	60.7	0.291	59.3	31.7
Long. Weld 6-860B	0.27[a]	0.2	-56	28.4	1.00	89.5	0.552	74.6	47.0	0.168	47.3	19.7
Long. Weld 6-860C	0.27[a]	0.2	-56	28.4	4.32	89.5	2.384	110.5	82.9	0.726	81.5	53.9
Long. Weld 8-860A	0.27[a]	0.2	-56	28.4	0.86	89.5	0.477	71.0	43.4	0.145	44.3	16.7
Long. Weld 8-860B	0.27[a]	0.2	-56	28.4	0.50	89.5	0.276	58.1	30.5	0.084	34.3	6.7
Long. Weld 8-860C	0.27[a]	0.2	-56	28.4	2.16	89.5	1.192	93.9	66.3	0.363	64.4	36.8
Circum. Weld 1-860	0.27[a]	0.2	-56	28.4	2.66	89.5	1.468	99.0	71.4	0.447	69.4	41.8
Circum. Weld 2-860	0.27[a]	0.2	-56	28.4	5.30	89.5	2.925	115.0	87.4	0.890	86.6	59.0
HAZ	0.18	0.2	0	19.7	6.84	76.8	3.774	103.2	122.9	1.149	79.8	99.5

(a) Conservative estimate - no analysis available.
(b) Initial Reference Temperature measured or generic mean value per 10CFR 50.61(b)(2)(i).
(c) Margin to be added to cover uncertainties per Regulatory Guide 1.99 Rev. 2, Section 2.1 for plates, 10CFR50.61(b)(2)(i) generic mean value margin for welds.
(d) Reference 6.
(e) Chemistry Factor determined per Regulatory Guide 1.99 Rev. 2, Section 2.1 using SONGS 1 surveillance data.

DWG. NO.

ATTACHMENT 2