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June 18, 1990

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Gentlemen:

Subject: Docket No. 50-206
10 CFR 50 Appendix G, Fracture Toughness (GL 88-11)
San Onofre Nuclear Generating Station
Unit 1

The purpose of this letter is to provide our response regarding your March 13, 1990 request for additional information on the San Onofre Unit 1 reactor vessel material fracture toughness.

In a letter dated January 3, 1990, we provided clarification regarding the bases for San Onofre Unit 1 compliance with 10 CFR 50, Appendix G, Fracture Toughness Requirements. This matter and our response to Generic Letter 88-11 were later discussed with members of the NRC staff in a conference call on February 13, 1990. As a result of the discussion above, you required additional information to support your review of the reactor vessel material fracture toughness and our response to GL 88-11. The specific information required was identified in your March 13, 1990 letter.

We have also evaluated the three questions specified in our letter dated January 3, 1990. The questions addressed were: (1) Is a modification to the reactor vessel surveillance program appropriate in order to demonstrate continued compliance with 10 CFR 50, Appendix G. (2) What is the appropriate calculated Charpy Upper Shelf Energy. (3) Is any further action necessary to maintain compliance with 10 CFR 50, Appendix G, depending on plans for repair of the thermal shield. SCE has determined no modifications or additional actions are required at this time to maintain compliance with 10 CFR 50, Appendix G. This includes the reactor vessel surveillance program and the thermal shield repair. The appropriate calculated Charpy Upper Shelf Energy is provided in the enclosure.



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The responses to your request plus the supporting calculations are contained in the enclosure.

If you have any questions regarding this response, please feel free to call me.

Very truly yours,

cc: J. B. Martin, Regional Administrator, NRC Region V
C. Caldwell, NRC Senior Resident Inspector, San Onofre Units 1, 2 and 3

Enclosure

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION
REGARDING UNIT 1 RESPONSE TO GENERIC LETTER 88-11

Item 1

As discussed during the conference call, please provide the results of your revised calculations after making appropriate corrections for a transcription error that you identified and for reduced fluence data. Also, provide the basis for your reduced fluence determination.

Response

The results of the revised adjusted reference temperatures ($ART_{NTD}$) calculation are provided in Table 1. The calculation, "SONGS 1 Reactor Vessel Adjusted Reference Temperatures for 16 and 24 EFPY," is provided as Attachment 1. The calculation was done in accordance with Regulatory Guide 1.99, Radiation Embrittlement of Reactor Vessel Materials, Revision 2, Position C.2.1 which credits plant specific data. The limiting material for fluences equivalent to 16 EFPY of operation is intermediate shell plate W7601-1. The $ART_{NDT}$s for this material at 1/4 and 3/4 T locations are 186°F and 159°F, respectively. Since the existing SONGS 1 Technical Specification (3.1.3, Heatup and Cooldown Curves) is based on $ART_{NDT}$s of 217° at 1/4 T and 163°F at 3/4 T, the current limits continue to provide sufficient margin to account for neutron radiation damage through at least 16 EFPY of operation.

Our December 16, 1988 submittal provided the NRC results of calculating the reactor vessel material adjusted reference temperature in accordance with Regulatory Guide 1.99. The limiting beltline materials were plates W7601-9 and W7601-1 for 1/4 thickness location and W7601-1 for 3/4 thickness location. The $ART_{NDT}$s for the material at these locations was 188.7°F and 162.7°F.

Subsequently, an error was identified in the calculation. This was discussed in the conference call. An incorrect value for the material chemistry factor for plate W7601-9 was listed in the table attached to the December 16, 1988 letter. This incorrect value was used in determining the adjusted reference temperature for W7601-9. The correct chemistry factor has been included in Table 1 and Attachment 1, the $ART_{NDT}$ calculation. Also during the conference call it was indicated that new fluence data was available which would be included in the calculation for $ART_{NDT}$. The plant specific fluence evaluation is provided in the Westinghouse report, "San Onofre Unit 1 Reactor Vessel Fluence Calculation, PTS Evaluation and Flux Reduction Factors Curves," provided as Attachment 2. The new reduced fluence data is the result of updated neutron transport codes, a more detailed geometric model and updated power history data. The new reduced fluence data has been included in Attachment 1, the $ART_{NDT}$ calculation.

Item 2

Please state your basis for using the methodology of Regulatory Guide (R.G.) 1.99, Revision 2, paragraph C.2, in your calculations along with supporting details/analyses (i.e., "same heat" argument).

Response

The methodology of Regulatory Guide (R.G.) 1.99, Revision 2, Position C.2, Surveillance Data Available, credits the use of reactor vessel surveillance data for calculation of adjusted reference temperature and Charpy upper shelf energy. This position requires two or more surveillance data sets from the reactor vessel for use in determining the adjusted reference temperature and Charpy upper shelf energy for the beltline materials.

Three surveillance capsules have been removed from the SONGS 1 reactor vessel and evaluated. From these surveillance capsules, five data points for the reactor vessel beltline materials are available: two data points for plates W7601-8 and W7601-9 each, and one data point for plate W7601-1. These data are provided in Table 2 and have also been plotted on Figure 2 from R.G. 1.99, which predicts the decrease in upper shelf energy. This plot is provided as Figure 1.

The use of these data to determine adjusted reference temperatures and Charpy upper shelf energy (USE) for the intermediate shell plates W7601-1, W7601-8 and W7601-9 in accordance with Position C.2 is based on the similarity of the three intermediate shell plates. These plates have the same heat treatment, exposure conditions and similar chemistry including residual elements such as copper (see Table 4). In addition, mechanical properties such as unirradiated longitudinal and transverse upper shelf energies and initial reference temperatures are close for the three plates. Based on this, it is concluded that the microstructures of the plates are approximately equivalent and therefore the plates can be considered equivalent.

Measurable differences in mechanical properties for these three plates due to variances in plate chemistry are considered negligible with respect to data scatter. This is demonstrated in the surveillance test results. Plate W7601-1 has slightly lower copper content (0.17%) than the other 2 plates (0.18%), and hence should theoretically have less radiation damage per the trends presented in R.G. 1.99, Rev. 2. However, the data show that plate W7601-1 has slightly higher radiation damage (decrease in USE) than the two other plates. This is contrary to the prediction resulting from the R.G. 1.99, Rev. 2 correlation. This contradiction demonstrates that the data scatter is larger than the difference between the plates as evaluated by R.G. 1.99, Rev. 2 methodology. Since margin terms used in R.G. 1.99 already account for data scatter, grouping these data points in predicting the beltline material properties is acceptable.

Item 3

With regard to charpy upper shelf energy, please provide the results of your calculations using:

a. The methods of R.G. 1.99, Rev. 2
b. The alternate method that was discussed which credits saturation effects. In this case, also provide supporting details for your conclusions.

Response

At the request of the NRC, the beltline USE was also evaluated using R.G. 1.99, Rev. 2. SCE used Section C.2 which credits surveillance data for determining the USE. Updated fluence data, surveillance data from the SONGS 1 program, and the methodology of Section C.2 were used for determination of USE. SONGS 1 surveillance data is listed in Table 2. Data for all 3 surveillance capsules have been grouped and plotted in Figure 1.

Bounding the data in Figure 1 and using the lowest unirradiated transverse USE (71.5 ft-lbs), plate W7601-9 is limiting and would be predicted to currently have an USE of 53.1 ft-lbs. USE for this plate would be predicted to drop below 50 ft-lbs at 24.7 EFPY (see Table 3) based on R.G. 1.99, Rev. 2, which is beyond the current projected plant EOL.

An alternate method which credited saturation affects was also used to determine USE's. While R.G. 1.99, Revision 2, methodology was not used in performing this evaluation, we do not believe the Regulatory Guide methodology for predicting USE is appropriate for Unit 1. It is believed that radiation damage rates and mechanisms occurring for the San Onofre Unit 1-type plate material and exposure conditions are not accurately reflected in R.G. 1.99, Revision 2. This is because the USE correlation provided in R.G. 1.99, Rev. 2 does not take into account material saturation affects and is unchanged from the previous revision. This correlation was derived from test reactor data obtained through accelerated fluence programs which used high-flux irradiation and steel with higher nickel content which is not representative of the San Onofre environment. PWR surveillance data for Unit 1 plate material clearly support a radiation damage saturation effect which occurs at a fluence near $1x10^{19}$ n/cm$^2$. As a result of this phenomenon, USEs for the vessel plate materials are not expected to decrease with additional fluence. This is presented in the Westinghouse WCAP 12514, "A Review of the Upper Shelf Charpy Energy Behavior of the Materials in the San Onofre Unit 1 Rector Vessel," included as Attachment 3.

It is our position that Unit 1 will continue to meet 10CFR50 Appendix G requirements through the currently projected End-of-Life. This is supported by surveillance data. The projected EOL fluence at 1/4 T is $3.88x10^{19}$ n/cm$^2$. This fluence coincides with the Capsule D fluence, for which surveillance data on all three intermediate shell plates were evaluated and indicated transverse orientation USEs were above 50 ft-lbs.

Table 1

## 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/cm$^2$) | CF[e] | 1/4 T Fluence ($10^{19}$ n/cm$^2$) | 1/4 T ΔRTndt (F) | 1/4 T ART (F) | 3/4 T Fluence ($10^{19}$ n/cm$^2$) | 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.

Table 2
Charpy Upper Shelf Energy
Surveillance Data For SONGS1

| Material | Fast Fluence (n/cm²) | Upper Shelf Energy[1] (ft-lb) | Decrease in USE (%) |
|---|---|---|---|
| W7601-1 | 0 | 86.3 (75.0) | |
| | 3.40E19 | 60.9 | 29.4 |
| W7601-8 | 0 | 94.3 (75.9) | |
| | 3.40E19 | 69.4 | 26.4 |
| | 4.90E19 | 71.8 | 23.9 |
| W7601-9 | 0 | 92.3 (71.5) | |
| | 1.80E19 | 70.4 | 23.7 |
| | 3.40E19 | 70.4 | 23.7 |

**Table 3**
Charpy Upper Shelf Energy
For SONGS1 Reactor Vessel (@ ¼T)
Using Regulatory Guide 1.99 Revision 2

| EFPY | Fast Fluence (n/cm²) | Upper Shelf Energy[2] (ft-lb) | Decrease in USE (%) |
|---|---|---|---|
| 12.0 (EOC10) | 2.03E19 | 53.1 | 25.8 |
| 24.7 (~EOL) | 3.88E19 | 50.0 | 30.0 |

[1]Values given are for longitudinal (transverse) orientations.

[2]Values projected are for transverse orientation based on unirradiated transverse data and curve fit (Figure 1) for longitudinal surveillance results.

TABLE 4

Chemistries and Heat Treatment
of Surveillance Materials
(SCE Pressure Vessel Plates)

| Plate Number | Lukens Heat Number | Chemistry (percent) C | Mn | P | S | Mo | Si | Cu |
|---|---|---|---|---|---|---|---|---|
| W7601-1 | 19585 | 0.22 | 1.36 | 0.013 | 0.025 | 0.46 | 0.24 | 0.17 |
| W7601-8 | A3099 | 0.20 | 1.34 | 0.012 | 0.020 | 0.47 | 0.20 | 0.18 |
| W7601-9 | A3119 | 0.19 | 1.36 | 0.014 | 0.026 | 0.47 | 0.23 | 0.18 |

Heat Treatment

Plates W7601-1, W7601-8 and W7601-9 were heat treated at 1550 to 1600°F and held at temperature for 4 hr and dip-quenched, tempered at 1225°F for 4 hr, and furnace-cooled. Material cut from this plate was then stress-relieved at 1150°F for 24 hr and furnace-cooled at WPAD.

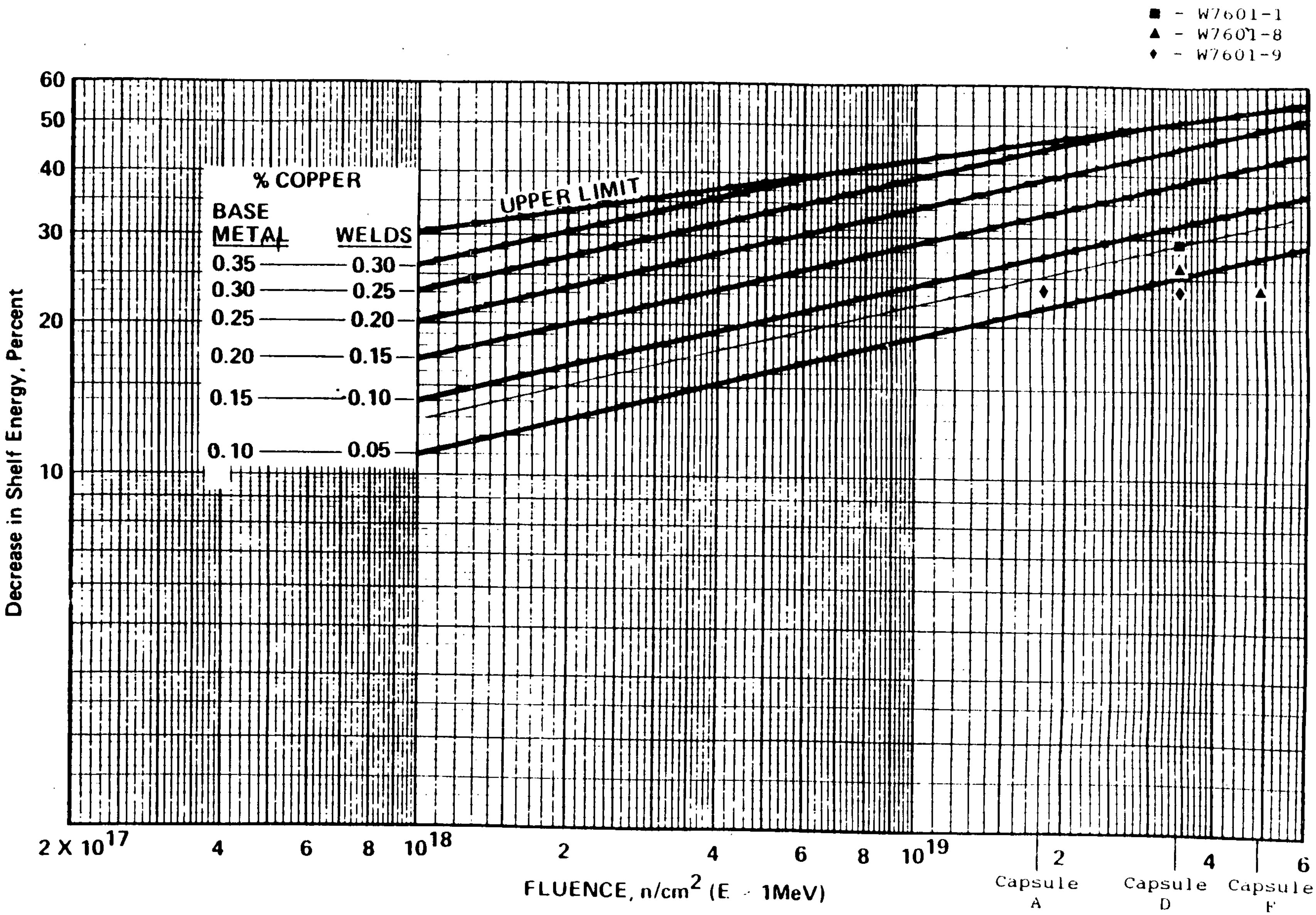


FIGURE 1. Predicted Decrease In Upper Shelf Energy For SONGS1 Per Regulatory Guide 1.99 Rev. 2

ATTACHMENT 1