Attachment D

San Onofre Nuclear Generating Station, Unit 2
Response to Generic Letter 92-01

Revision 2
May 19, 1994

Prepared by:

ATI Consulting
San Ramon, CA

and

Sartrex Corporation
Rockville, MD

Prepared for:

Southern California Edison
Irvine, CA

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Section 1

INTRODUCTION

The Nuclear Regulatory Commission (NRC) in Generic Letter 92-01 (GL 92-01) requested all holders of operating licenses or construction permits for nuclear power plants to submit information needed to assess compliance with requirements and commitments regarding reactor vessel integrity. Revision 0, June 24, 1992, of this report was prepared in response to GL 92-01 for San Onofre Nuclear Generating Station (SONGS), Unit 2. It identified additional information needed to resolve the following issues: (1) inconsistencies noted in copper (Cu) and nickel (Ni) contents for beltline Weld 9-203 and the surveillance weld, (2) locating material certification reports to confirm beltline weld properties, and (3) verifying the fluence at Weld 8-203.

Revision 1 of this report (dated January 22, 1993) incorporated additional materials data obtained from the SONGS, Unit 2 Nuclear Steam Supply System (NSSS) vendor, ABB-Combustion Engineering (ABB-CE), and the results of calculations performed by Southern California Edison Company (SCE) to better characterize fluence conditions at Weld 8-203, and the results from calculations performed to evaluate the upper shelf toughness for Weld 8-203. It also indicated that: (1) the beltline weld properties had been confirmed with the exception of beltline Welds 8-203 and 2-203 A, B, and C, and (2) additional information would be required to confirm heat numbers for the surveillance weld material and Welds 2-203 A, B, and C.

In previous versions of this report the initial RT_{NDT} for the vessel beltline material with the highest end of life adjusted reference temperature (i.e., the plate material used in the surveillance program) was determined using a combined data set obtained from the materials certification report (MCR) and the baseline surveillance program. In Revision 2, the initial RT_{NDT} for this material is determined using only the data from the MCR. This change was made to be consistent with SCE's interpretation of the Code requirement for defining initial RT_{NDT}, which is that data to be used in accordance with paragraph NB-2331 of Section III of the ASME Code are the data obtained by the vessel manufacturer to assess the toughness properties at the time of vessel fabrication. This MCR data thus established the initial RT_{NDT} by satisfying paragraph NB-2331(a)(3) of the ASME Code, Section III. This change also was made so that this initial RT_{NDT} is defined in a manner consistent with that for other beltline materials where surveillance baseline data were not available. Consistent with the previous revisions of this report, the combined set of MCR and surveillance data were used to establish the unirradiated upper shelf energy and the temperature at 30 ft-lb Charpy absorbed energy for purposes of assessing the irradiation effects on the surveillance plate material.

This revision (Revision 2) incorporates additional materials data and information obtained from the SONGS, Unit 2 NSSS vendor, ABB-CE. These data provide: (1) the heat number, chemistry and Charpy data for Welds 2-203 A, B, and C, (2) the weld wire and flux combinations, chemistry, and Charpy data for Weld 8-203, and (3) the weld wire and flux combinations for the surveillance weld. Based on a review of the information supplied by ABB-CE, the chemistry and

Charpy energies have been confirmed for the materials in the SONGS, Unit 2 pressure vessel beltline, and the response to GL 92-01 is now complete.

Section 2 of this report addresses compliance with 10 CFR Part 50 (10CFR50), Appendix H, for the surveillance program at SONGS, Unit 2. Compliance with 10CFR50, Appendix G, is described in Section 3 along with a description of the location, heat treatment, residual and alloying element contents, and upper shelf and transition temperature fracture toughness for the beltline materials in the SONGS, Unit 2, reactor vessel. Section 4 addresses embrittlement effects, including irradiation temperature and adjusted reference temperature for evaluation of the beltline materials relative to GL 88-11 and 10CFR50.61.

Section 2

REACTOR PRESSURE VESSEL SURVEILLANCE PROGRAM COMPLIANCE WITH APPENDIX H

The American Society of Mechanical Engineers (ASME) Code of record for the SONGS, Unit 2, reactor pressure vessel is the 1971 Edition through the Summer 1971 Addenda. Consequently, the applicable version of American Society for Testing and Materials (ASTM) E185 is the 1970 version (ASTM E185-70). However, the surveillance program for SONGS, Unit 2, was updated to the later 1973 version which is in more complete agreement with the intent of 10CFR50, Appendix H. Appendix A to this report provides a detailed review of ASTM E185-73 along with validation that ASTM E185-73 requirements were satisfied for the surveillance program design. With respect to capsule testing and reporting requirements, the latest version of ASTM E185 is required, and these requirements have been updated as listed in Appendix A following ASTM E185-82 (the current approved version).

As stated in the SONGS, Units 2 and 3 Final Safety Analysis Report (FSAR), Appendix H, requirements were met (with one exception) through compliance with ASTM E185-73. The one exception to meeting 10CFR50, Appendix H requirements had to do with the method of attachment of the holders for the six surveillance capsules in each SONGS unit. ABB-CE was the vessel manufacturer and the NSSS vendor; ABB-CE attached the capsule holders directly to the cladding on the inside of the vessel in the beltline region (as they did for all ABB-CE NSSS-designed vessels), and this approach violated the requirements in the early 1970's version of 10CFR50, Appendix H. NRC reviewed a ABB-CE Topical Report (CENPD-155-P, C-E Procedure for the Design, Fabrication, Installation, and Inspection of Surveillance Holder Assemblies) and found the practice and procedures acceptable.

The current version of 10CFR50, Appendix H does not treat this method of attachment of the capsule holders as a noncompliance issue. The wording in the current Appendix H, Section I.A.2, is:

> "If the capsule holders are attached to the vessel wall or to the vessel cladding, construction and in-service inspection of the attachments and the attachment welds must be done according to requirements for permanent structural attachments to reactor vessels given in Sections III and XI of the ASME Code. The design and location of the capsule holders shall permit insertion of replacement capsules."

This wording was derived from the ABB-CE Topical Report, and the SONGS units have met the additional ASME Code, Sections III and XI, design and inspection requirements. Therefore, there are no deviations or exceptions needed from the current Appendix H of 10CFR50.

The details of the SONGS, Unit 2, surveillance program have been described in the FSAR and subsequent surveillance program testing reports, baseline [1] and irradiated.[2] The first capsule results have been evaluated for a low fluence following ASTM E185-82 testing and reporting requirements. Later sections of this report will discuss these results as compared to regulatory prediction methods.

The update of ASTM E185 for 1992 (E185-93) is about to be approved and issued. One significant change from E185-82 is the removal of the requirements for testing heat-affected-zone (HAZ) material. This change has resulted from the difficulty in interpreting HAZ results due to the degree of scatter and the ability to define the usefulness of blunt notch Charpy V-notch absorbed energy (C_{VN}) HAZ data. NRC has been involved in making this change to E185 through ASTM standards participation. Because of this forthcoming change to ASTM E185, this report does not evaluate HAZ results for SONGS, Unit 2; however, the raw data from prior HAZ testing on the SONGS, Unit 2, beltline material has been reported previously,[1-2] and is provided for reference in a subsequent section of this report.

Section 3

FRACTURE MECHANICS

This section evaluates compliance with 10CFR50, Appendix G, and identifies the location, heat treatment, key residual and alloying element contents, and unirradiated fracture toughness properties for plates and welds in the SONGS, Unit 2, reactor pressure vessel beltline region.

The information presented in this section has been obtained from the materials certification reports (MCRs), welding materials certifications (WMCs), the FSAR for SONGS, Unit 2, and from additional information supplied by ABB-CE to prepare this response. In some instances, additional informatioı. was obtained from the unirradiated baseline surveillance material report,[1] and the irradiated material in the 97° location surveillance capsule (Capsule 97), which was removed from Unit 2 at the end of the third fuel cycle.[2]

3.1 COMPLIANCE WITH APPENDIX G

The materials in the beltline region of SONGS, Unit 2, comply with the requirements of Appendix G, 10CFR50. A summary of compliance with 10CFR50, Appendix G, as specified in the FSAR for SONGS, Units 2 and 3, and updated during preparation of this report, are listed in Table 3.1.

3.2 BELTLINE MATERIALS IN SONGS, UNIT 2

3.2.1 Location

Figure 3-1 is a representation of the SONGS, Unit 2, reactor pressure vessel, and identifies the plates and welds and their location in the beltline region.

The heat numbers for the beltline plates shown in Figure 3-1 are presented in Table 3.2. The weld wire and flux combination for the beltline welds shown in Figure 3-1 and the surveillance welds are presented in Table 3.3. Source documentation has been obtained to confirm the properties of all beltline plates and welds and the surveillance weld.

3.2.2 Heat Treatment

The heat treatment for the plate materials consisted of austenitization at 1575 ± 50°F for 4 hours; water quenched and tempered at 1225 ± 25°F for 4 hours. For ASME Code qualification, the plates were stress relieved at 1150 ± 25°F for 40 hours and then were furnace cooled to 600°F at a rate of 100°F/hr. The actual time at temperature for a specific weld or a plate in the vessel depended upon the sequence of vessel fabrication; intermediate and final stress relief times were selected such that the total did not exceed 40 hours for any particular portion of the vessel. Longitudinal weld seams would see stress relief times near the 40 hour maximum, while the closing girth weld in the beltline region would see approximately half this amount of time maximum. All of the testing of plate materials was performed on pieces with essentially an identical heat treatment as the actual reactor vessel. The surveillance weldment received a final 42-hour and 15-minute stress relief at 1100°F to 1150°F.

3.2.3 Key Residual and Alloying Element Contents

The copper (Cu), nickel (Ni), phosphorus (P), and sulfur (S) contents reported for each beltline plate are presented in Table 3.4. The plate Cu, Ni, P, and S contents were obtained by averaging two measurements made by ABB-CE. The first measurement was made when ABB-CE received the plate from Lukens, and the second measurement was made when the surveillance program was defined. The bases for the Cu, Ni, P, and S contents are presented in Appendix B.

A second set of data is included for Plate C6404-2. This set was obtained from broken surveillance specimens when the first irradiated surveillance capsule from Unit 2 was tested.[2]

Table 3.5 contains the Cu, Ni, P, and S contents for the beltline welds. The source documents for the information in Table 3.5 are presented in Appendix C. Additional information from the WMCs for Welds 3-203 A, B, C, 8-203, and 9-203 is presented in Appendix D. Because Ni was not measured for Weld Seam 8-203, a value of 1.0 wt% has been assumed (see Regulatory Guide 1.99, Rev. 2). Two chemistry measurements have been made for the surveillance weld and also are reported in Table 3.5. The first chemistry measurement was made as part of the original baseline[1], while the second was obtained from a broken Charpy specimen from Capsule 97[2].

Tables 3.4 and 3.5 also include the chemistry factors determined for each reported set of Cu and Ni contents using Regulatory Guide 1.99, Revision 2.

3.3 FRACTURE TOUGHNESS RELATED DATA

This section presents the results from the C_{VN} tests and summarizes the upper shelf energies (USEs) and the results from the drop weight nil ductility temperature (NDT) tests for the unirradiated beltline plate and weld materials in SONGS, Unit 2. The unirradiated reference temperature (RT_{NDT}) values were determined from the C_{VN} and NDT test results in accordance with the most recent version of ASME Section III, NB-2331. The USEs were determined using the definition specified in ASTM E185-94 (to be issued). The data included in the USE determination were the C_{VN} values for those tests (at least 3) where the percent shear on the fracture surfaces was equal to and greater than 95%.

The fracture toughness data for the plates were obtained from the MCRs (see Appendix E of this report) and baseline surveillance program.[1] The source documents for Welds 2-203 A, B, C, 3-203 A, B, C, 8-203, and 9-203 are presented in Appendix D of this report. The data for the surveillance weld were obtained from the baseline surveillance program. For convenience, the C_{VN}, lateral expansion, and fracture appearance (% shear) data for the unirradiated beltline and surveillance plate and weld materials are listed in tabular form in Appendix F of this report.

As discussed earlier in Section 2, the results for HAZ material are not evaluated in this report because upcoming ASTM standard E185-94 will not require HAZ material to be part of the surveillance program. The raw C_{VN} data for the past HAZ testing are attached in Appendix G of this report.

3.3.1 Beltline Plate Material

Because fracture toughness requirements for reactor pressure vessels are based on requirements to test specimens oriented transverse to the rolling direction, the data presented here are for the transverse (TL) orientation with one exception. The exception is for the beltline Plate C6404-2, which was included in the surveillance program. Because the surveillance program for SONGS, Unit 2, also contains longitudinally (LT) oriented specimens, the unirradiated C_{VN} data are presented for completeness for the LT orientation.

The transverse C_{VN} data as a function of test temperature for beltline Plate numbers C6404-1, -2, -3, -4, -5, and -6 are presented in Figures 3-2 through 3-7, respectively. For convenience, an average curve through the data is also shown in each figure. The average curves were determined using a least squares fit to the data and a hyperbolic tangent functional form, where the lower shelf was fixed at 2.2 ft-lb and the upper shelf was fixed at the value determined using the definition in ASTM E185-94 for specimens having fracture surfaces with 95% and greater shear. For convenience, the figures also indicate the values of NDT, USE, the temperature at which a minimum C_{VN} equal to 50 ft-lb (T @ 50 ft-lb) is achieved consistent with the applicable method of ASME, Section III, NB-2331, and RT_{NDT}. As part of the surveillance program, additional C_{VN} versus temperature data were generated for Plate C6404-2;[1] these data are presented in Figure 3-8 along with a least squares fit curve.

The data obtained when the plate material was purchased (Figure 3-3) and the surveillance baseline data (Figure 3-8) were combined as shown in Figure 3-9. The average curve through the combined data set in Figure 3-9 was used as the unirradiated baseline to evaluate the results for the irradiated surveillance tests (see Section 4).

Table 3.6 is a summary of the unirradiated NDT, RT_{NDT}, and USE values for the TL orientation for each of the beltline plates in SONGS, Unit 2. The NDT for Plate C6404-2 also was determined twice. One value was measured when the material was purchased (-20°F), while the second value was determined from the unirradiated baseline tests (+10°F). The value measured when the plate was purchased (i.e., the MCR data) is listed in Table 3.6.

The methods used to determine RT_{NDT} from the NDT and C_{VN} data also are identified in Table 3.6. The method of either NB-2331 (a)(2) or NB-2331 (a)(3) was used to determine RT_{NDT} for the plates.

Figure 3-10 shows the data and least squares fit line for the LT orientation for surveillance Plate C6404-2.[1] Figure 3-11 shows a comparison of the best fit line for the LT orientation for the surveillance plate (see Figure 3-10) with the data reported in the MCR for the LT orientation for Plate C6404-2. The information in Figure 3-11 indicates that the data for the LT orientation in Plate C6404-2 from the MCRs produce essentially the same C_{VN} versus temperature relationship as was obtained for the LT orientation surveillance plate material. Therefore, the baseline surveillance LT curve fit can be used to assess shift and upper shelf toughness changes.

3.3.2 Beltline Welds

A full C_{VN} versus temperature curve was obtained for the material in Weld Seam 9-203, and the data points and least squares hyperbolic tangent fit through the data are presented in Figure 3-12. The materials in the remaining beltline weld seams were tested to obtain three C_{VN} data points at 10°F. The results from these tests are presented in Table 3.7. Figure 3-13 presents the C_{VN} data and least squares hyperbolic tangent curve fit for the surveillance weld material. A comparison of the C_{VN} versus temperature curves for beltline Weld 9-203 and the surveillance weld in Figures 3-12 and 3-13, respectively, show that the impact energies as a function of temperature are essentially the same for both sets of data. Therefore, the baseline surveillance curve fit can be used to assess shift and upper shelf toughness changes.

Table 3.8 presents a summary of the unirradiated NDT, RT_{NDT}, and USE values for each of the beltline welds in SONGS, Unit 2. For Welds 3-203 A, B, C and 9-203, available C_{VN} data indicate that there is a minimum of 50 ft-lb absorbed energy at 60°F above NDT and, consequently, RT_{NDT} equals NDT. For Welds 2-203 A, B, C, the available C_{VN} data are 70°F above NDT; however, since the data all have absorbed energies greater than 100 ft-lb, RT_{NDT} was taken as equal to NDT because it is unlikely that the absorbed energy would be less than 50 ft-lb at 0°F when it is in excess of 100 ft-lb at 10°F. Since no NDT data are available for Weld 8-203, the initial RT_{NDT} was taken as the generic value of -56°F for ABB-CE fabricated vessels (see 10CFR50.61).

The USEs shown in Table 3.8 for Weld 9-203 and the surveillance weld were obtained by averaging the test results where 95% shear or greater was exhibited. The USEs for Welds 3-203 A, B, C and 8-203 were obtained from the data in Table 3.7 by averaging the three C_{VN} data points obtained at 10°F for each of the listed welds. The USEs for Welds 2-203 A, B, C were obtained from the data in Table 3.7 by averaging the nine C_{VN} data points obtained at 0 and 10°F.

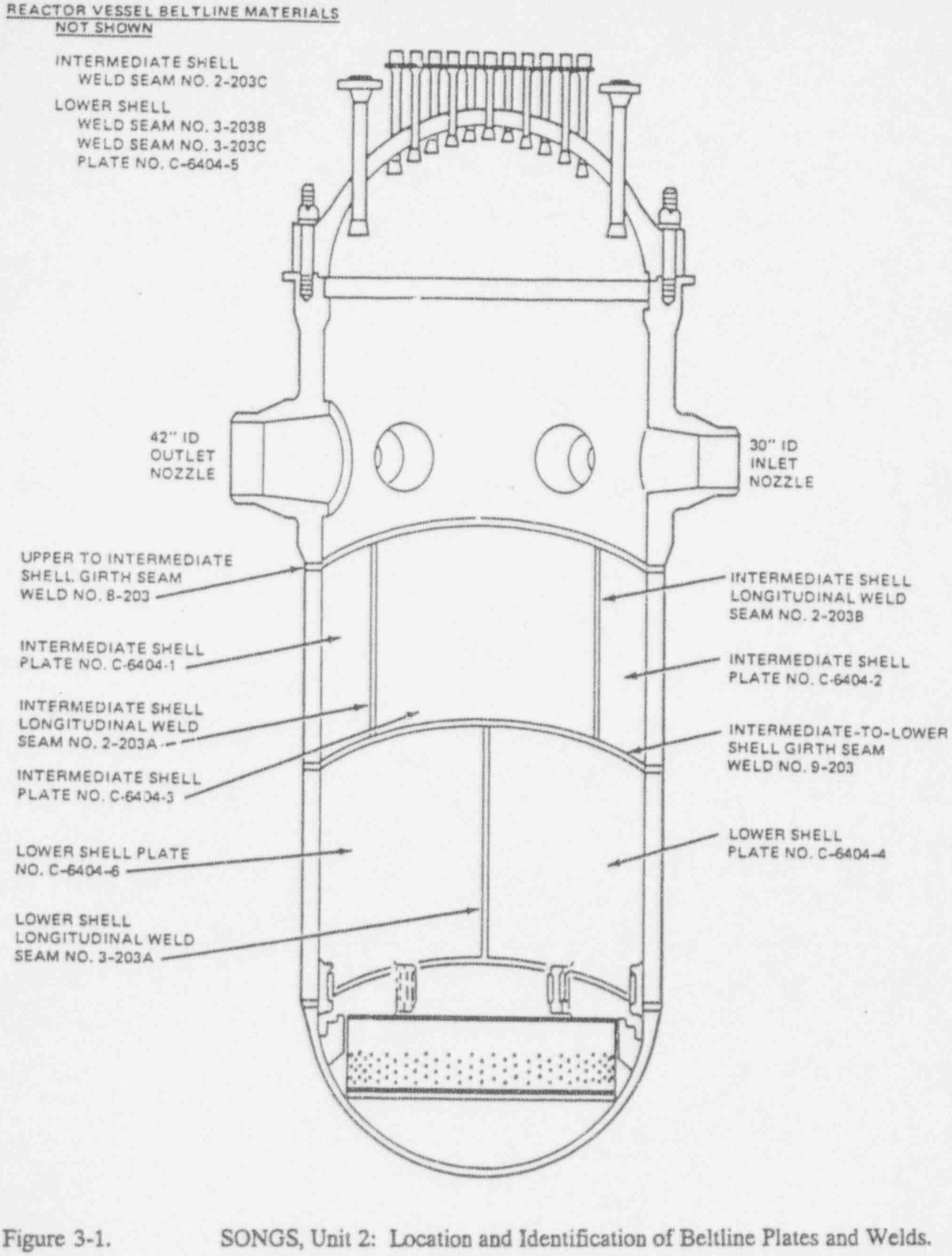

Figure 3-1. SONGS, Unit 2: Location and Identification of Beltline Plates and Welds.

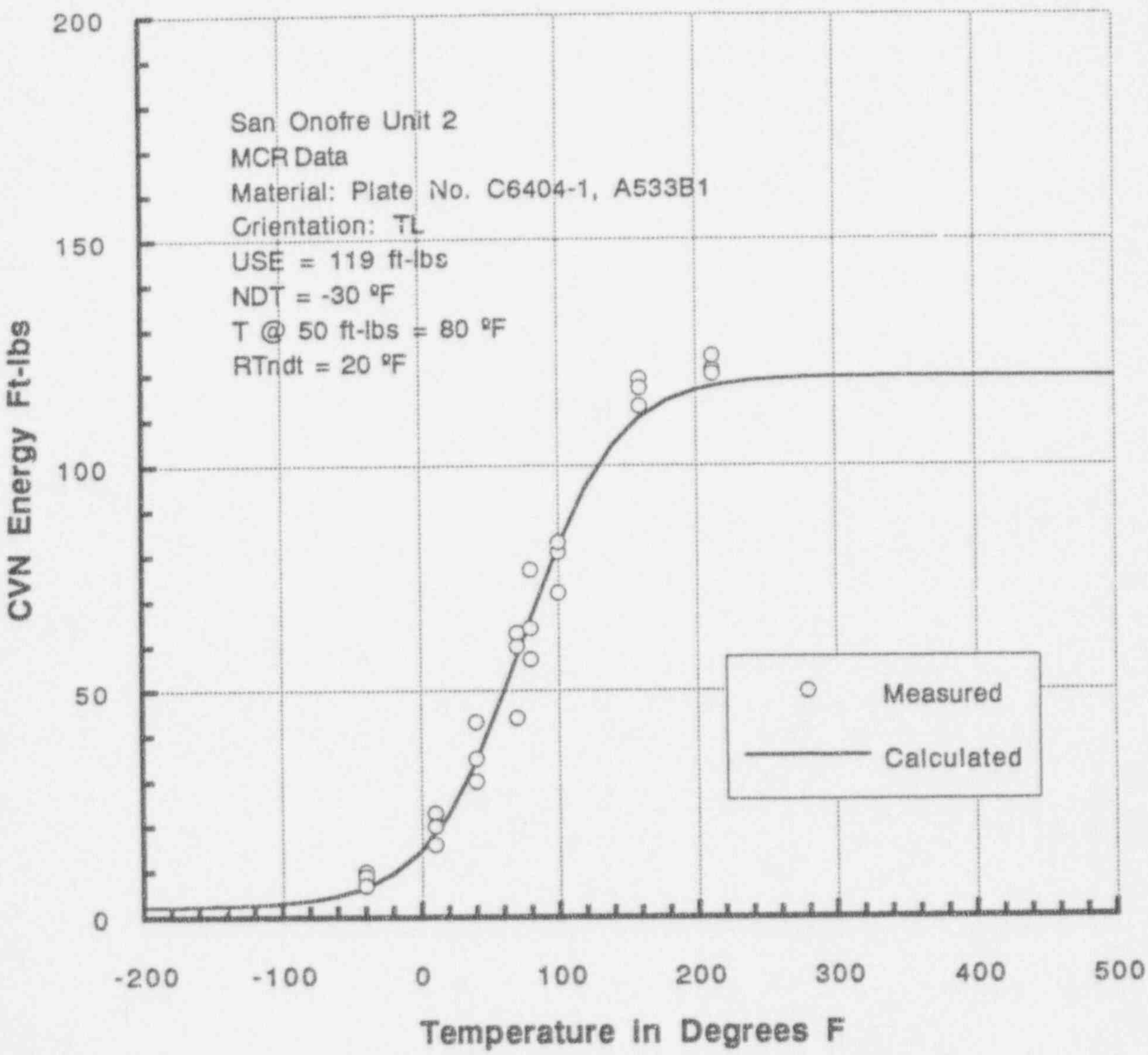

Figure 3-2. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-1, TL Orientation, MCR Data.

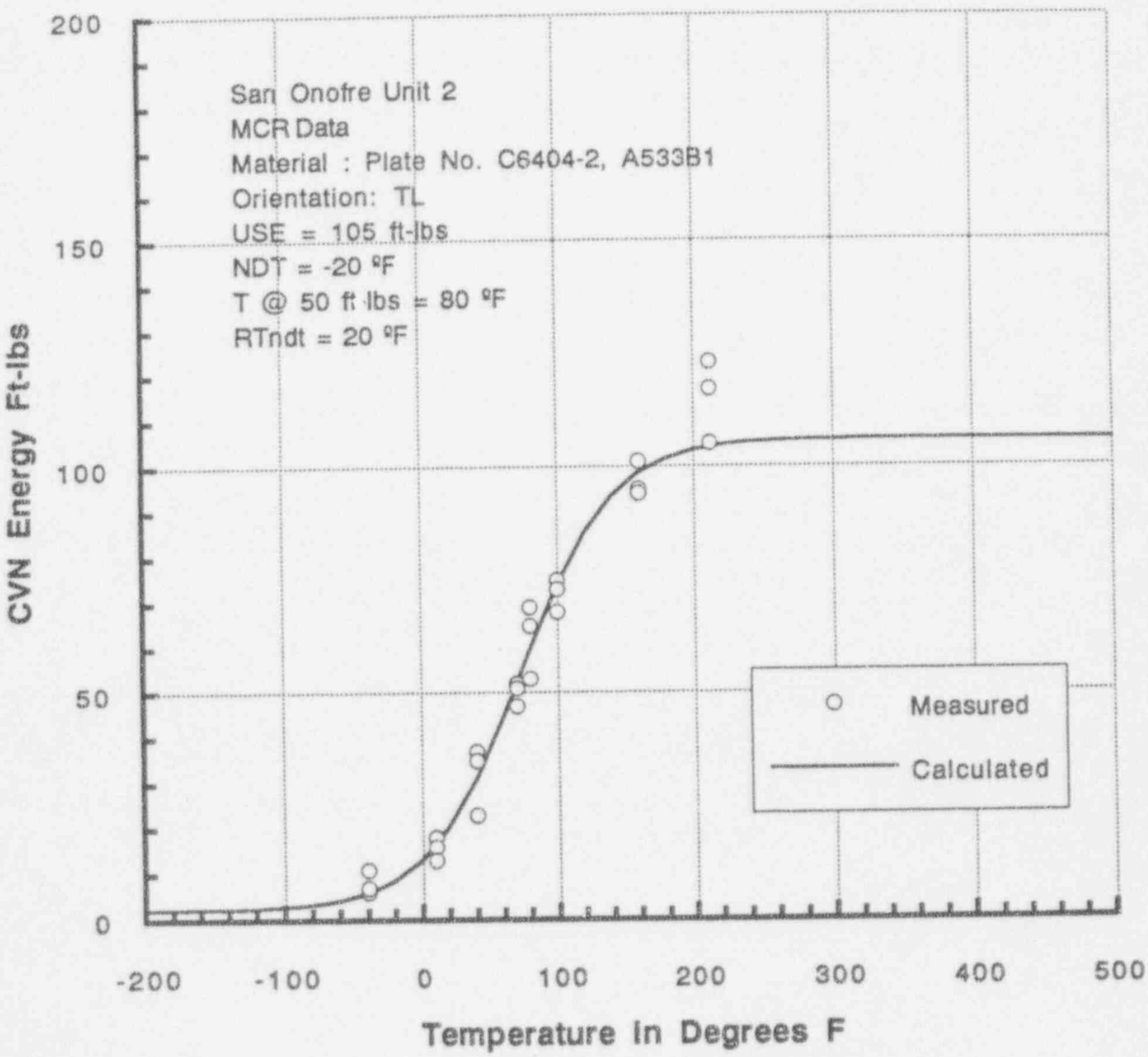

Figure 3-3. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-2, TL Orientation, MCR Data.

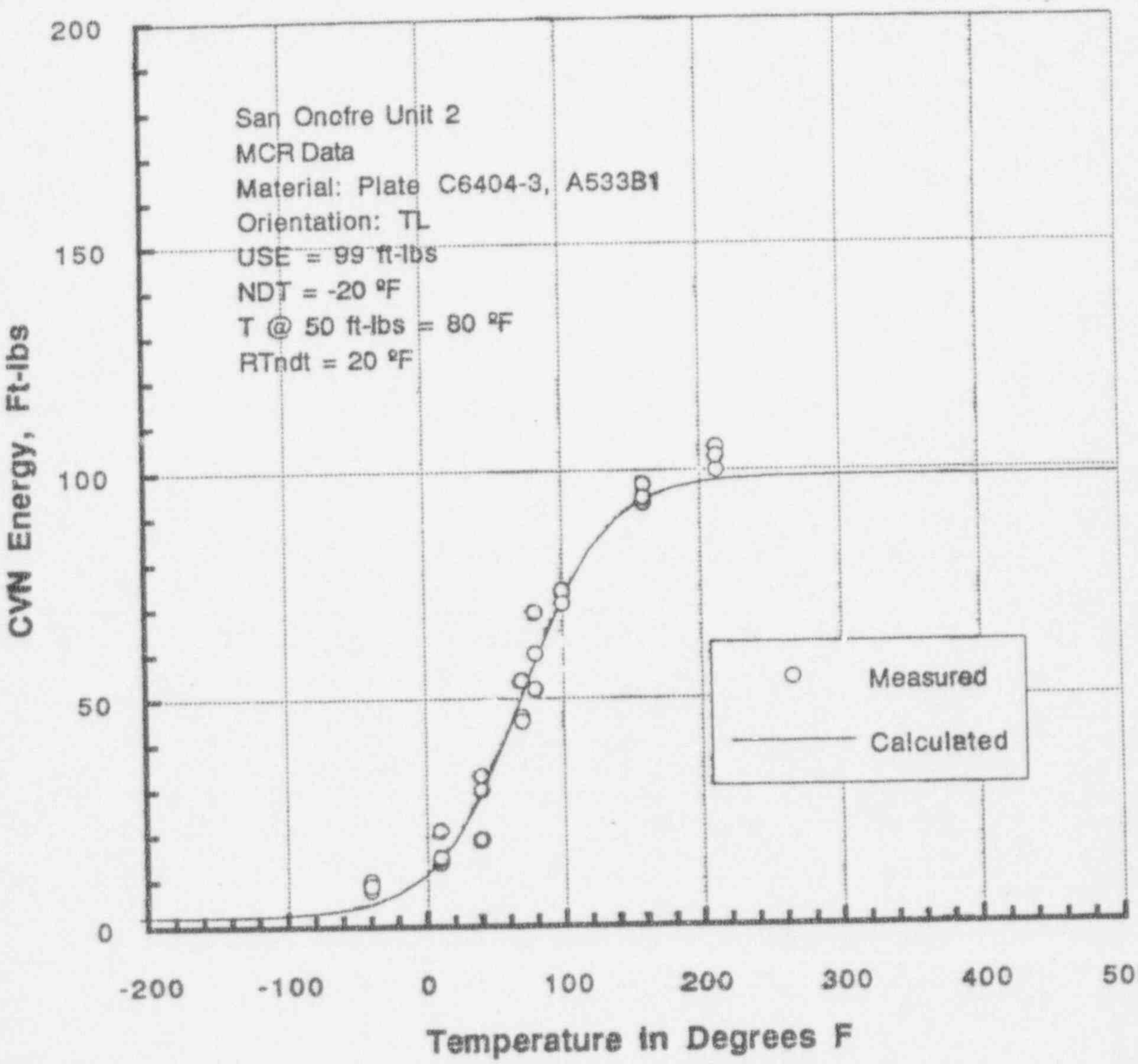

Figure 3-4. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-3, TL Orientation, MCR Data.

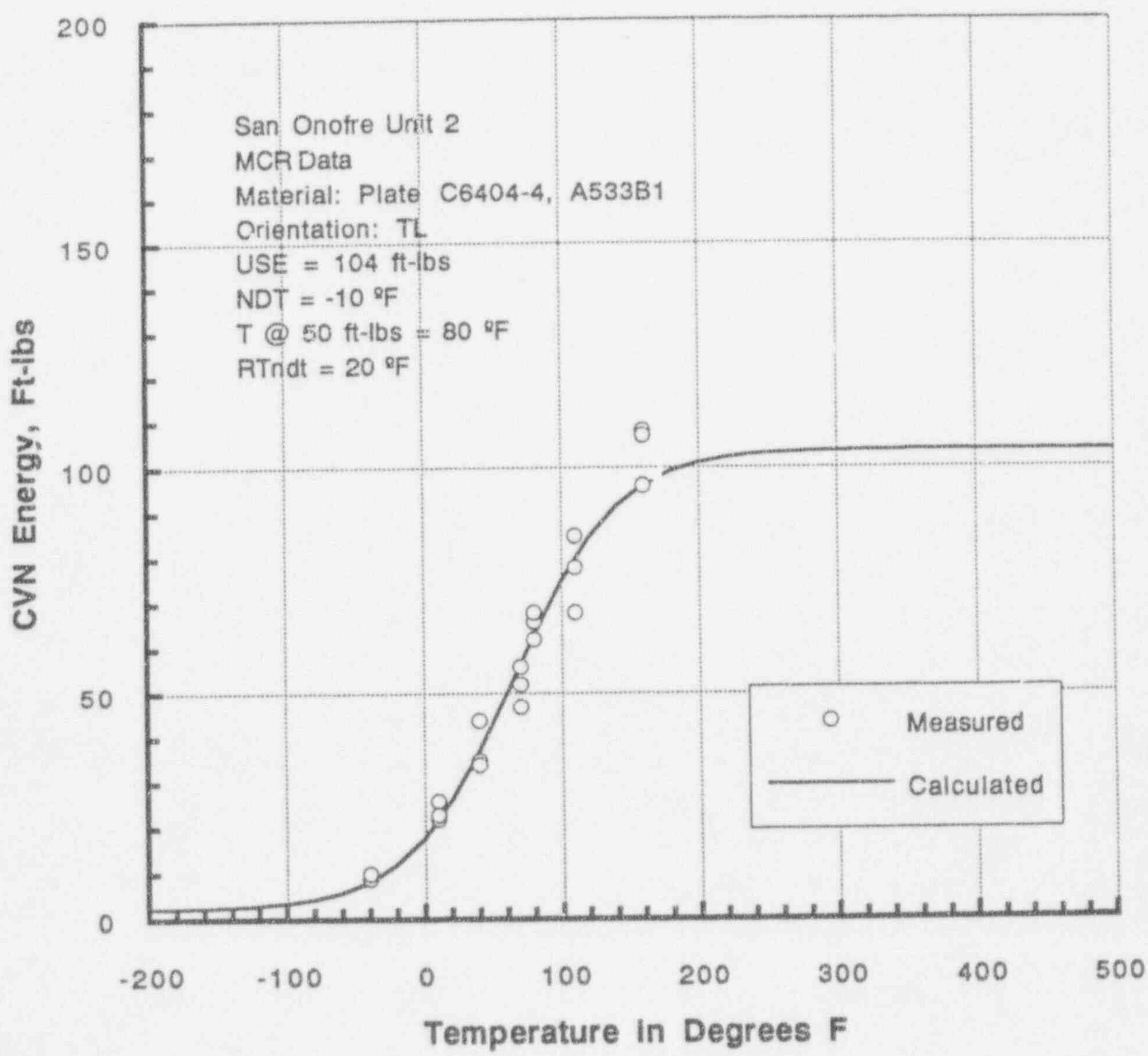

Figure 3-5. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-4, TL Orientation, MCR Data.

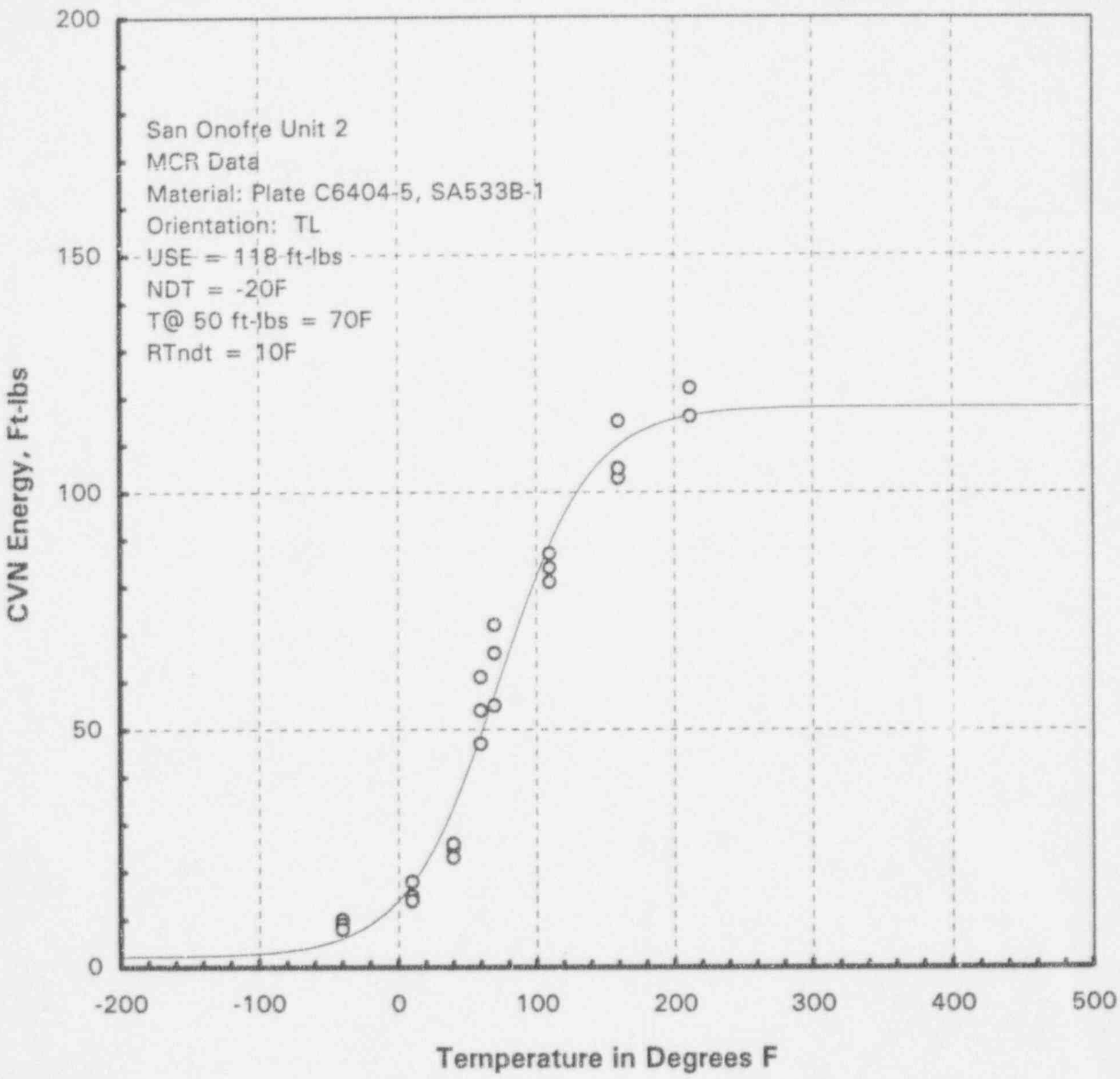

Figure 3-6. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-5, TL Orientation, MCR Data.

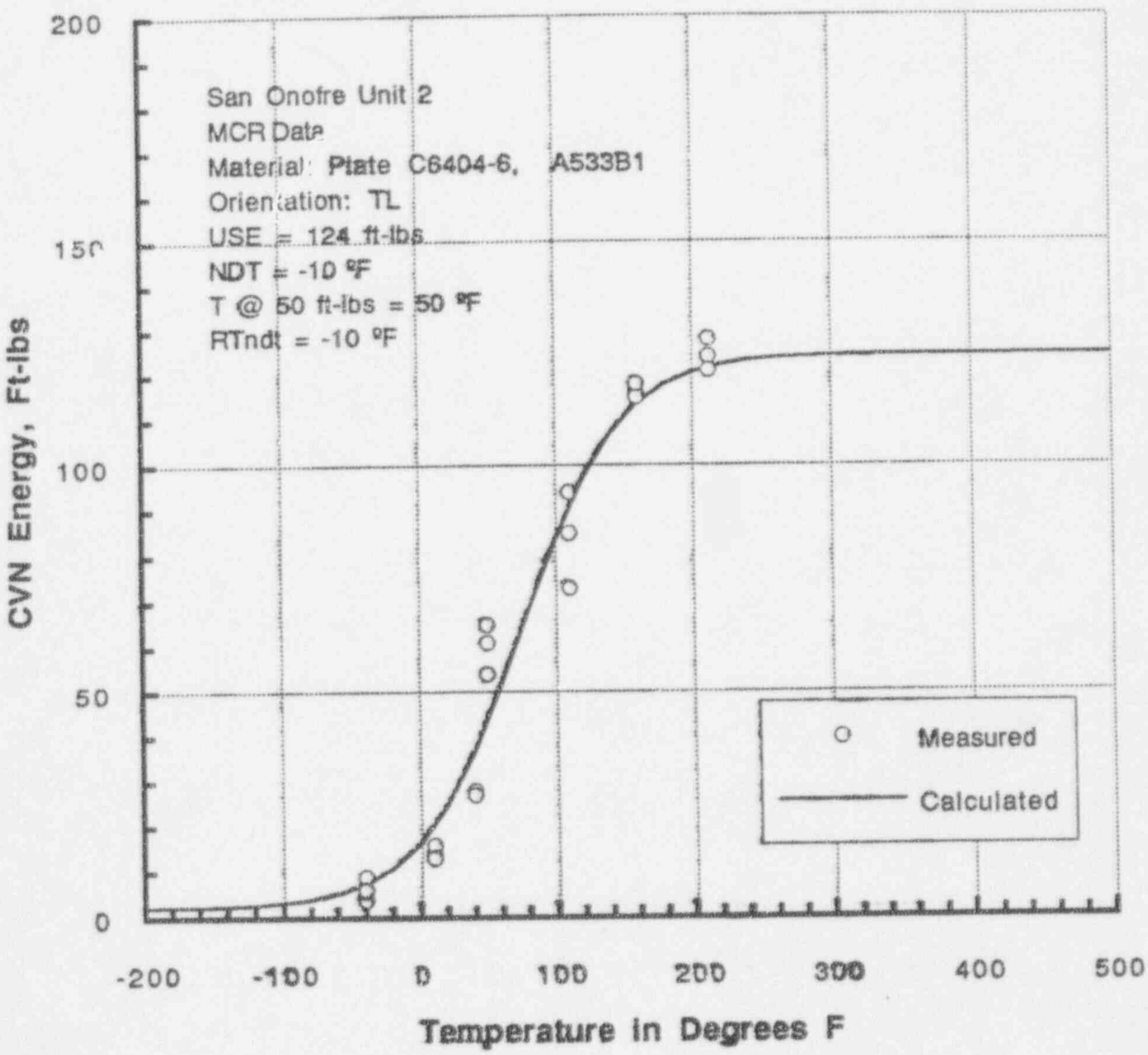

Figure 3-7. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-6, TL Orientation, MCR Data.

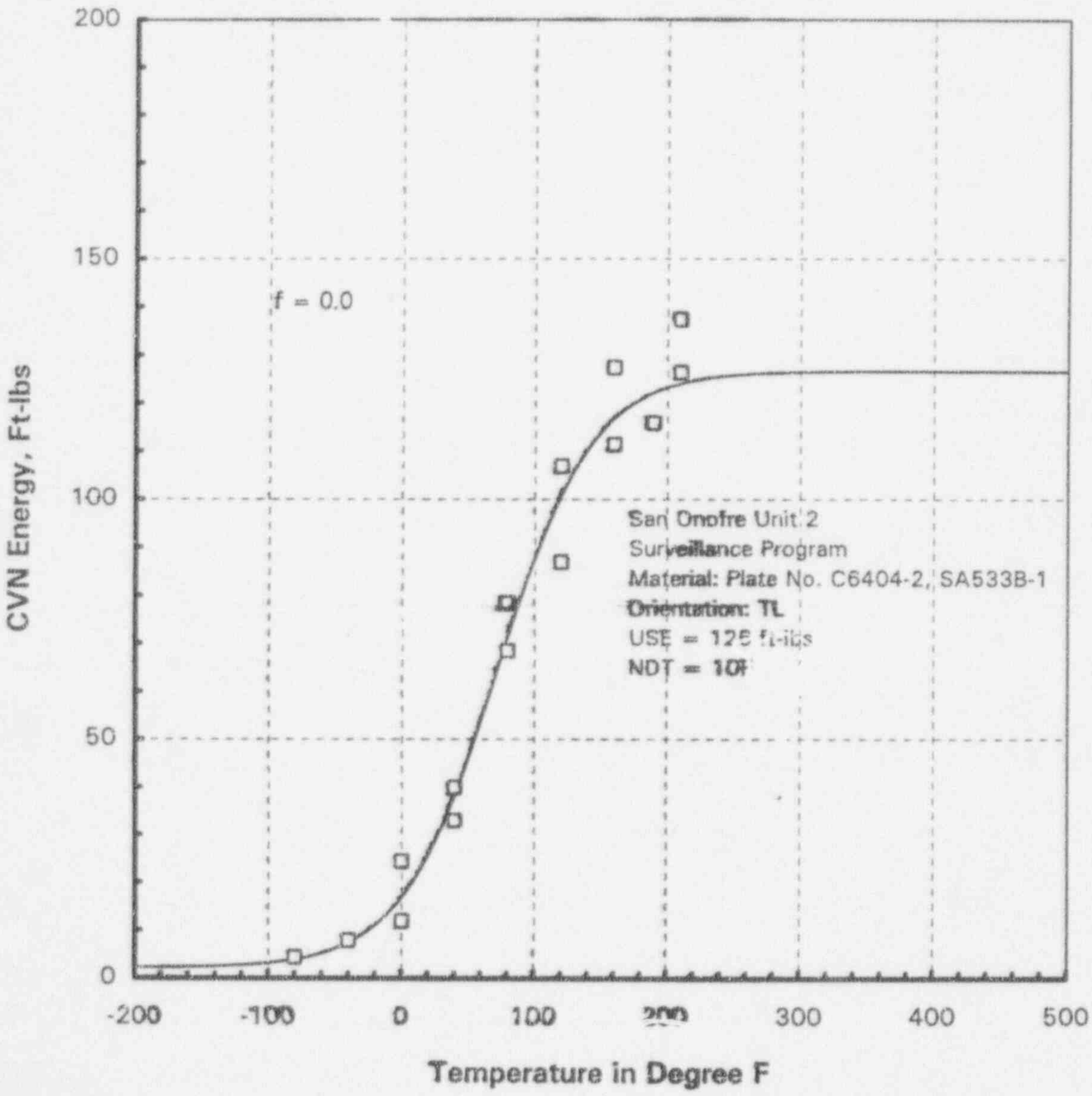

Figure 3-8. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-2, TL Orientation, Surveillance Baseline Data.

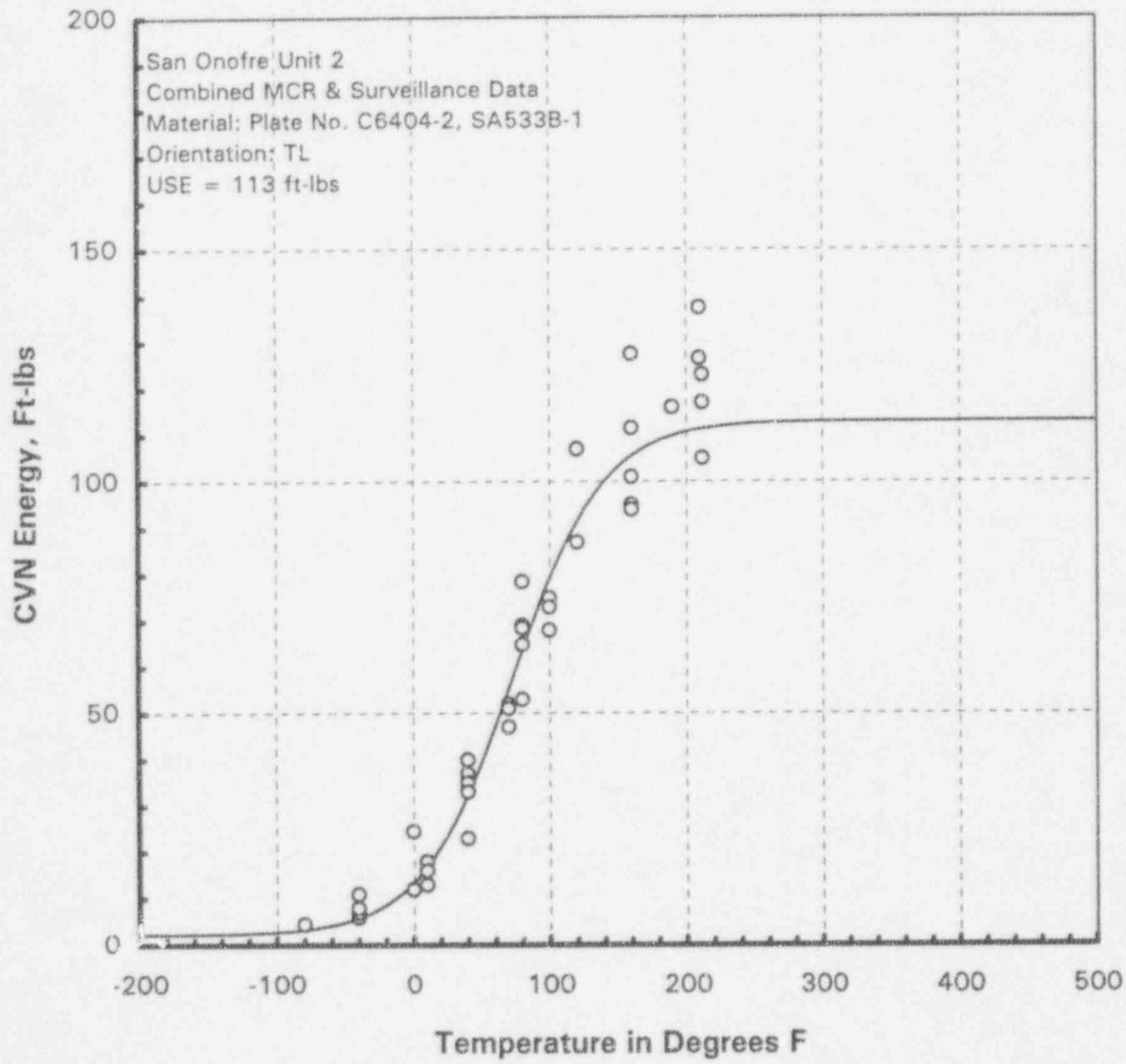

Figure 3-9. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-2, TL Orientation, Combined MCR and Surveillance Baseline Data.

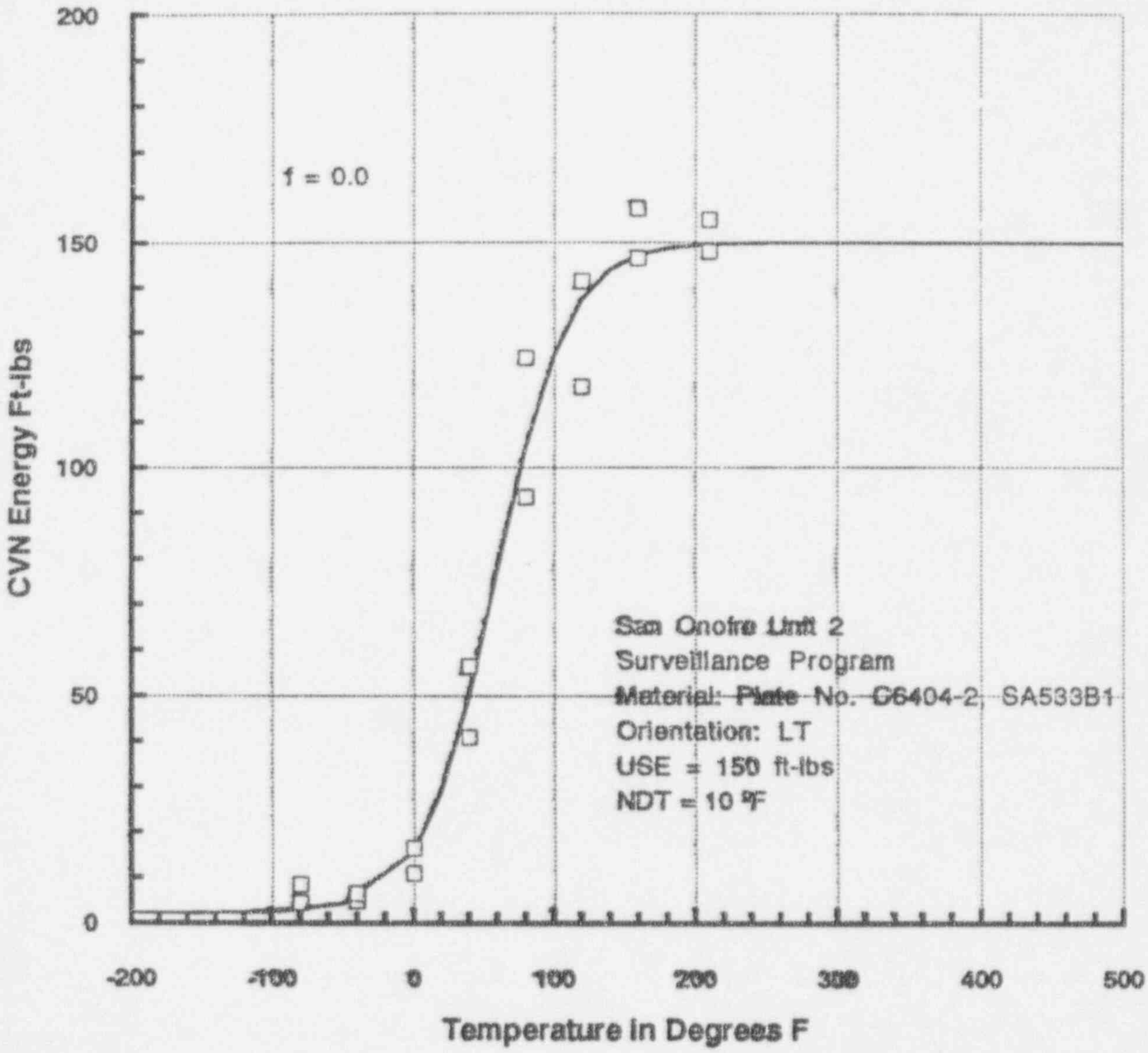

Figure 3-10. SONGS Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6404-2, LT Orientation, Surveillance Baseline Data.

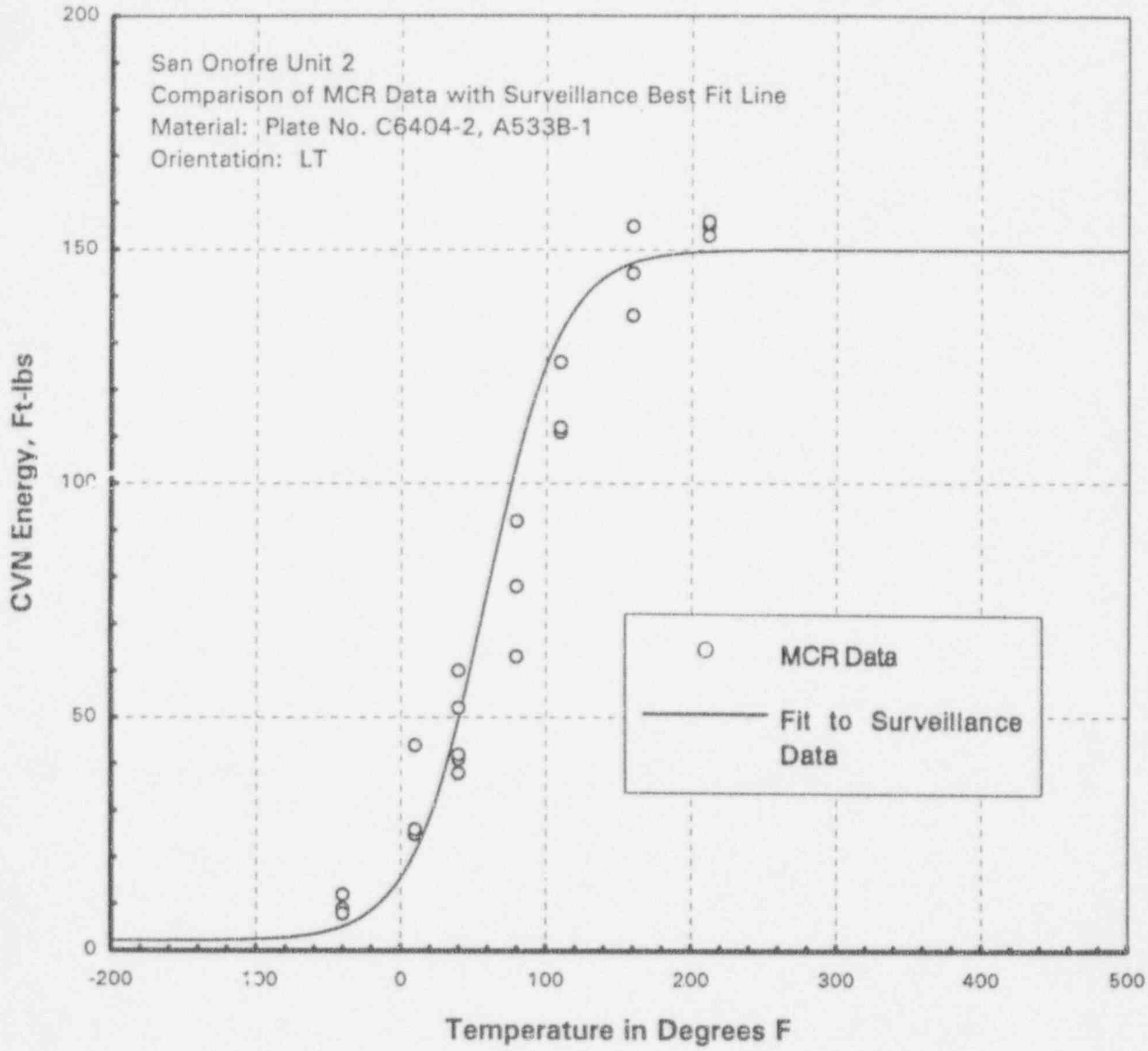

Figure 3-11. SONGS, Unit 2: Comparison of Least Squares Fit C_{VN} versus Temperature Curve for the Surveillance Plate with MCR Data for Plate C6404-2, LT Orientation.

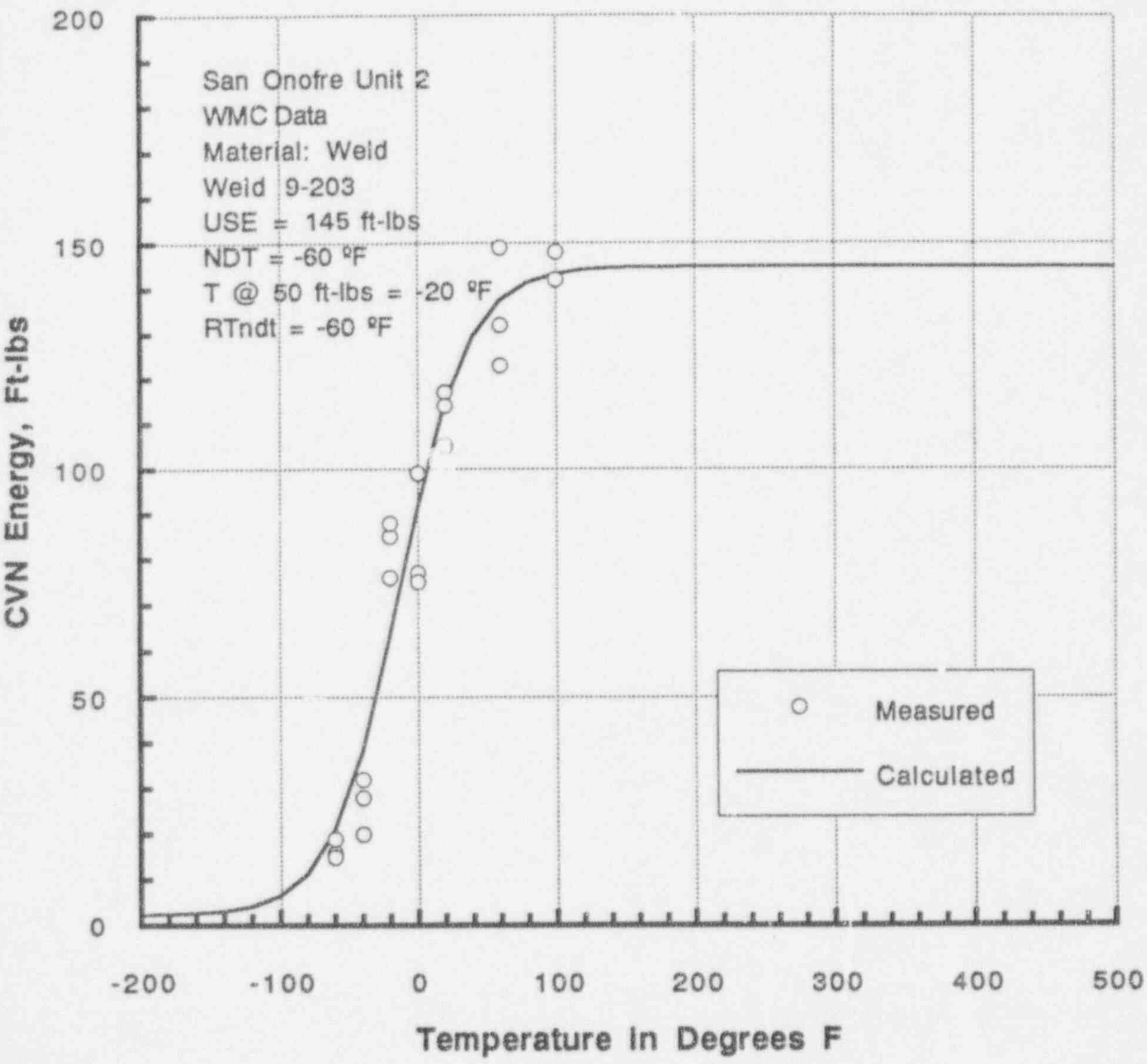

Figure 3-12. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Weld 9-203, WMC Data.

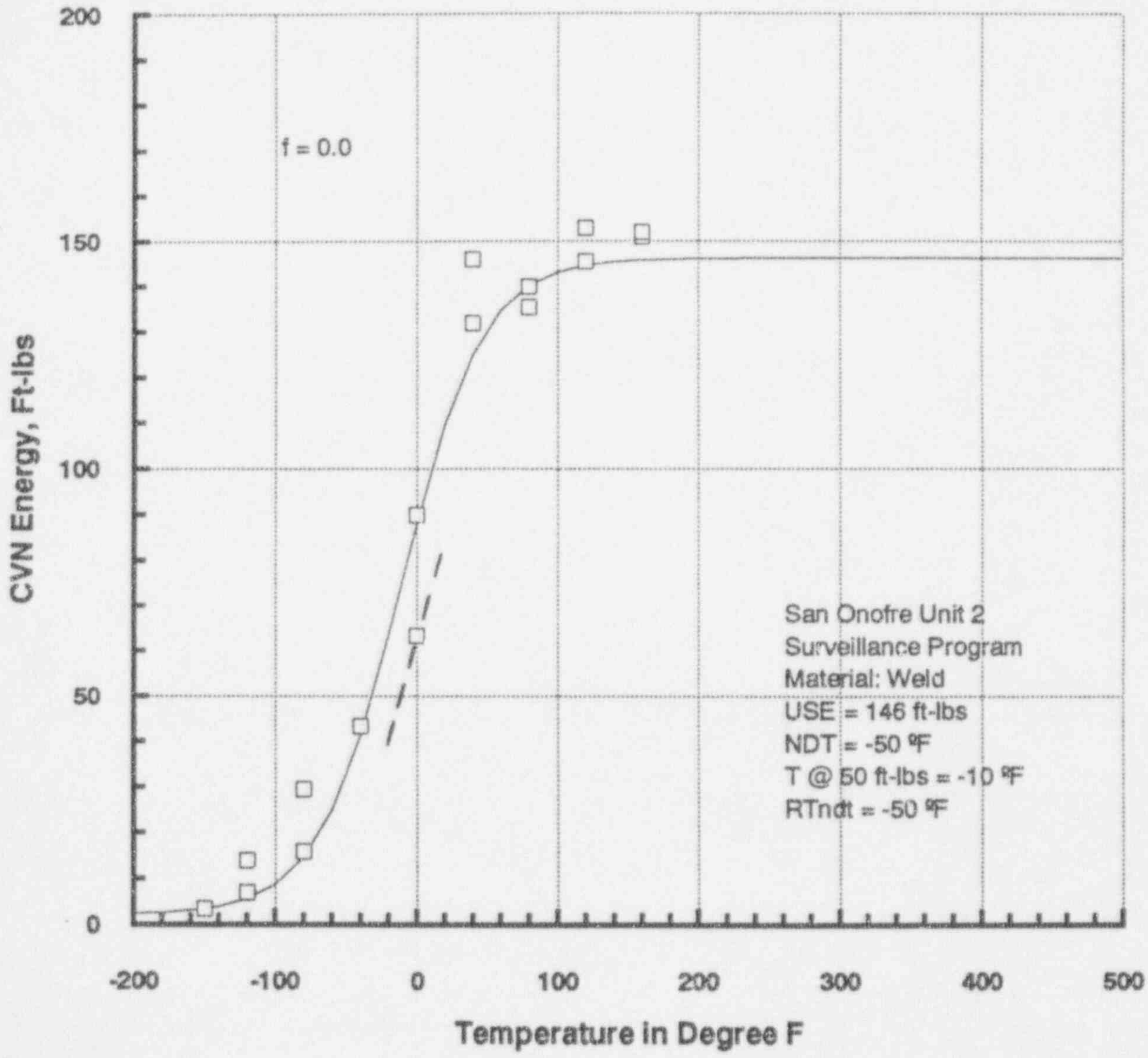

Figure 3-13. SONGS, Unit 2: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Surveillance Weld, Surveillance Baseline Data.

Table 3.1 SONGS, Unit 2: Compliance with 10CFR50, Appendix G.

Paragraph	Description of Non-Compliance	Comment
II.B	Series 4xx stainless steels are purchased and treated to Code requirements. No RT_{NDT} or drop weight T_{NDT} temperatures are determined.	Consistent with ASME Code in effect.
III.B.5.a	Records of fracture toughness testing do not include a certification that tests were performed in accordance with Appendix G.	Appendix G was not applicable at the time tests were performed. Certification to the applicable ASME Code is included. The intent of Appendix G is met.
III.C.	"Reactor Vessel Beltline", as defined by Paragraph II.H, includes the weld heat-affected-zones. Section III.C is not complied with in that only base plate and representative welds in the beltline region were considered for the required testing.	The baseline tests of the surveillance program include weld and HAZ material from the most limiting plate. Results available for SONGS Unit 2 indicate that the intent of Appendix G has been met. (Note: the HAZ results are not presented in this report)
III.C.1	Only single-temperature testing was performed for some weld materials. Only the heat-affected-zone from the most limiting plate was tested over an extended temperature range.	Consistent with ASME Code in effect.
III.C.2	Excess material for test specimen weldment is not necessarily from the actual production plate, although it is the same P-number. (Section IX, ASME Code)	The same combinations of a specific heat of filler wire and a specific lot of flux welded under the same production conditions as those used in joining the corresponding shell materials were used.

Table 3.1 (Continued)

Paragraph	Description of Non-Compliance	Comment
IV.A.4	Charpy V-notch tests were not conducted at "the preload temperature or at the lowest service temperature, whichever is lower".	The ASME Code in effect required test temperature of 60°F below the lowest service temperature. All bolting material was tested at 10°F and met the 35 ft-lb minimum requirement of the applicable ASME Code. All beltline plate materials and one beltline weld were tested to meet the current (1989) Code requirements in NB-2331. The remaining beltline welds were tested at 10°F and/or 0°F and have an average C_{VN} in excess of 90 ft-lb. These results indicate that the intent of Appendix G has been met.

Table 3.2 SONGS, Unit 2: Plate and Corresponding Heat Numbers for the Beltline Plates.

Plate Number	Lukens Heat Number
C6404-1	C7596-1
C6404-2	C7595-2
C6404-3	C7595-1
C6404-4	A6735-1
C6404-5	C7585-1
C6404-6	C7596-2

Table 3.3 SONGS, Unit 2: Weld Wire and Flux Combinations for Beltline and Surveillance Welds.

Weld Seam	Weld Wire and Flux
2-203 A, B, C[a]	E8018 C-3 Electrodes, Lot No. BOLA
3-203 A, B, C[b]	Type Mil B-4 Wire, Heat No. 83637, Linde Type 0091 Flux, Lot No. 1122
8-203[c]	Combination of (1) Type Mil B-4 Wire, Heat No. 10137, Linde Type 0091 Flux, Lot No. 3999 and (2) Type Mil B-4 Wire, Heat No. 90136, Linde Type 0091 Flux, Lot. No. 3999
9-203[b]	Type Mil B-4 Wire, Heat No. 90130, Linde Type 0091 Flux, Lot No. 0842
Surveillance[a]	Same consumables as Weld 9-203

a. Weld wire heat number and flux type confirmed by ABB-CE letter dated November 4, 1993 contained in Appendix D.

b. Basis is SONGS Unit 2 FSAR and is consistent with handwritten note in Appendix D.

c. Weld wire heat number and flux type confirmed by ABB-CE letter dated January 4, 1994. The applicable data are contained in App. C and D.

Table 3.4 SONGS, Unit 2: Key Residual and Alloying Element Contents for Beltline Plates.[a]

Plate Number	ABB-CE Lab. No.	Cu	Ni	P	S	CF[b]
C6404-1	P14445 P16921	0.10	0.56	0.007	0.009	65
C6404-2	P14446 P16922	0.10	0.59	0.008	0.010	65
C6404-2[c]		0.10	0.59	0.011	N/A	65
C6404-3	P14447 P16923	0.10	0.56	0.008	0.011	65
C6404-4	P14105 P17110	0.10	0.62	0.006	0.009	65
C6404-5	P14068 P17405	0.11	0.64	0.007	0.010	75
C6404-6	P14106 P17111	0.10	0.58	0.006	0.010	65

a. Average values (see Appendix B)

b. Chemistry factors from Regulatory Guide 1.99, Revision 2

c. Measured when the surveillance tests were performed for Capsule 97[2]

Table 3.5 SONGS, Unit 2: Key Residual and Alloying Element Contents for Beltline Welds.

Weld Number	ABB-CE Lab No.	Cu	Ni	P	S	CF[a]
2-203A	D18153	0.03	0.90	0.009	0.017	41
2-203B	D18154	0.03	0.91	0.009	0.016	41
2-203C	D18155	0.03	0.95	0.010	0.016	41
3-203A	D17025	0.05	0.12	0.011	0.011	40
3-203B	D17026	0.04	0.06	0.010	0.011	30
3-203C	D17027	0.06	0.11	0.010	0.011	42
8-203 (90136)	D10255	0.31	1[b]	0.012	0.010	260
(10137)	D10600	0.23	1[b]	0.016	0.010	236
9-203	D23227	0.07	0.29	0.009	0.007	69
Surveillance[c]	D26761	0.03	0.12	0.003	0.009	30
Surveillance[d]		0.03	0.15	<0.005	N/A	32

a. Chemistry Factors determined from Regulatory Guide 1.99, Revision 2

b. Ni content was not obtained and 1.0 wt% has been assumed (per Regulatory Guide 1.99, Rev. 2)

c. Measured when surveillance program was developed[1]

d. Measured when the surveillance tests were performed for Capsule 97[2]

Table 3.6 SONGS, Unit 2: Beltline Plate Material Unirradiated Fracture Toughness Tests Results Summary, TL Orientation.

Plate Number	NDT (°F)	Initial RT_{NDT} (°F)	Procedure to Determine RT_{NDT}	USE (ft-lbs)
C6404-1	-30	20	NB-2331 (a)(3)	119
C6404-2[a]	-20[b]	20	NB-2331 (a)(3)	113
C6404-3	-20	20	NB-2331 (a)(3)	99
C6404-4	-10	20	NB-2331 (a)(3)	104
C6404-5	-20	10	NB-2331 (a)(3)	118
C6404-6	-10	-10	NB-2331 (a)(2)	124

a. This plate is included in the surveillance program. RT_{NDT} is based on the MCR data (see Figure 3-3) and the USE value is based on the combined data sets from the MCRs and unirradiated surveillance baseline (see Figure 3-9)

b. An NDT value of -20°F was determined when the plate was purchased (+10°F was determined from the surveillance baseline program).

Table 3.7 SONGS, Unit 2: Charpy Absorbed Energy Values for Weld Seams 2-203 A, B, and C; 3-203 A, B, and C; and 8-203.

Weld Seam	Test Temperature (°F)	Charpy Energy (ft-lb)
2-203 A, B, C	10	69, 87, 74
	10	106, 108, 105
	0	82, 101, 108
3-203 A, B, C	10	153, 131, 125
8-203 (90136)	10	108, 112, 119
(10137)	10	101, 108, 107

Table 3.8 SONGS, Unit 2: Beltline Weld Material Unirradiated Fracture Toughness Tests Results Summary.

Weld Seam	NDT (°F)	Initial RT_{NDT} (°F)	Procedure to Determine RT_{NDT}	USE (ft-lbs)
2-203 A, B, C	-60	-60	NB-2331 (a)(2)	93[b]
3-203 A, B, C	-50[a]	-50	NB-2331 (a)(2)	136[d]
8-203 (10137)	N/A	-56	c	105[d]
8-203 (90136)	N/A	-56	c	113[d]
9-203	-60[a]	-60	NB-2331 (a)(2)	145
Surveillance	-50	-50	NB-2331 (a)(4)	146

a. NDT values were obtained from the FSAR and documented in Appendix D

b. Estimated using the average of C_{VN} values obtained at +10°F and 0°F (see Table 3.7)

c. Generic value for ABB-CE fabricated vessels using Linde 0091, 1092, and 124 fluxes (see 10CFR50.61)

d. Estimated using the average of C_{VN} values obtained at +10°F (see Table 3.7)

Section 4

ISSUES RELATED TO GENERIC LETTER 88-11

NRC issued Generic Letter 88-11 (GL 88-11) in July 1988. GL 88-11 revised the methodology used for estimating radiation embrittlement of reactor pressure vessel materials to be consistent with the guidelines in Regulatory Guide 1.99, Revision 2. Several technical issues have recently emerged which indicate a need to address some of the application assumptions used in Regulatory Guide 1.99, Revision 2. The pertinent issues brought out in GL 92-01 are addressed in this section.

4.1 VESSEL TEMPERATURE DURING OPERATION

The methodology in Regulatory Guide 1.99, Revision 2, is specified to be applicable for operating temperatures in the range of 525 to 590°F. Concern is expressed in GL 92-01 that power operation may occur at temperatures below 525°F. For SONGS, Unit 2, the reactor coolant cold leg temperature (T_c) is maintained above the Technical Specification limiting condition for operation of 535°F which applies above 30% power. The normal operating band of T_c ranges from 545°F at zero power to 553°F at 100% power with a tolerance of $\pm$ 2°F. Thus, there is no time during normal power operation that the SONGS, Unit 2, vessel or surveillance capsules experience temperatures below 525°F.

4.2 APPLICABILITY OF SURVEILLANCE DATA

To properly assess the measured surveillance results and to project irradiation embrittlement trends for the vessel, fluence projections, validated through the dosimetry contained in the surveillance capsules tested to date, are needed. Both SONGS, Units 2 and 3, have identical core designs and essentially the same past and projected operation history. Therefore, the fluence projections from Units 2 and 3 surveillance data will be used for each unit. The fluence as a function of effective full power years (EFPY) was obtained from the results of the first capsules pulled from Units 2 and 3.

The Unit 2 capsule was pulled at the end of the third fuel cycle which corresponds to 2.85 EFPY.[2] These data represent the original core for both units, and the best estimate value of peak fluence at the vessel inner surface is 4.34×10^{18} n/cm^2 ($E > 1$ MeV); the capsule fluence was about 20% higher at 5.07×10^{18} n/cm^2.

At the start of the fourth cycle for each unit, the core was reconfigured in a low leakage loading pattern which reduced the vessel and capsule fluxes. The first capsule taken out of Unit 3 was after the fourth fuel cycle at 4.33 EFPY and represents the combined results of the standard and low leakage core designs.[3] The peak fluence value for the vessel inner surface is 6.6×10^{18} n/cm^2, and the associated capsule fluence is 8.0×10^{18} n/cm^2.

The projection of fluence forward in time is based upon an extrapolation of the dosimetry information obtained from the two SONGS capsules. The projected peak fluence at the vessel inner surface at the end of 32 EFPY is 4.2×10^{19} n/cm^2.[3] At the point in time of December 16, 1991, the estimated EFPY is 5.63, and the projected peak fluence at the vessel inner surface is 8.5×10^{18} n/cm^2.

As indicated in Figure 3-1, there is a weld identified as 8-203 which is well outside the core region of the vessel (i.e., approximately 2 feet above the top of the core). This weld is conservatively considered a beltline material because of a large chemistry factor associated with the high reported Cu content (0.31 wt%) in combination with a 1.0 wt% Ni content, which was conservatively assumed because Ni was not reported. The fluence at this location above the core was reported in the FSAR to be about 1/37 that of the peak fluence location within the vessel. Recent calculations performed at SCE[4] indicate that the fluence at Weld 8-203 is 1/108 that of the peak fluence location within the vessel. The SCE fluence calculations have been used in the evaluation of Weld 8-203.

Within Regulatory Guide 1.99, Revision 2, there are five credibility criteria that must be met in order to utilize surveillance data in adjusting the predicted embrittlement trends and/or reducing the assigned margin terms. Three of the criteria are met (proper limiting materials, definitive measurements of shift and upper shelf, and a match between the capsule and vessel temperatures within $\pm$25°F), but the other two have not been satisfied since only one capsule from each vessel has been pulled and evaluated. To satisfy these last two requirements, the second capsules (which will not be pulled until about 15 EFPY) must be evaluated to supply two valid data sets for the vessel surveillance materials, and testing of the correlation monitor material contained in the second capsules must be evaluated against the available data for that material.

In the subsequent portion of this section, the available results from the first capsules will be compared to the regulatory prediction approaches, and projections based upon the regulatory approaches will be made.

4.3 SHIFTS AT THE CHARPY V-NOTCH 30 FT-LB ENERGY LEVEL

Capsule 97 from the SONGS Unit 2 surveillance program was tested in 1988. The C_{VN} results from this capsule are shown in Figures 4-1 (Plate C6404-2/LT), 4-2 (Plate C6404-2/TL), and 4-3 (surveillance weld). Appendix H contains, in tabular form, the absorbed energy, lateral expansion, and fracture appearance (% shear) for the irradiated surveillance materials.

The results computed during this work for the shift at the 30 ft-lb energy level are tabulated in Table 4.1 as "current" and compared to the Regulatory Guide 1.99, Revision 2, mean shift predictions (RG1.99R2):

RG1.99R2 = CF (chemistry factor) x ff (fluence function).

The results obtained by Battelle[2] are also shown for comparison. The differences between the current values for shift versus those from Battelle are due to small differences in the curve fit to the C_{VN} data and the different data set used for unirradiated Plate C6404-2/TL (i.e., Figure 3-8 for Battelle and Figure 3-9 in the current study).

All of the measured shift results are less than the mean prediction from Regulatory Guide 1.99, Revision 2. Until another capsule is tested, there is no way to definitively evaluate that CFs should be adjusted to reflect measured behavior, rather than that predicted from the Regulatory Guide.

Table 4.2 lists the predicted estimates of adjusted RT_{NDT} (ART) at the vessel inner surface for the two time periods of December 16, 1991 (as requested in GL 92-01) and at the end of the current license (32 EFPY). Note that the Regulatory Guide 1.99, Revision 2, shift (CF x ff) with the appropriate margin terms have been used; the initial RT_{NDT}s were taken from Tables 3.6 and 3.8. The results in Table 4.2 show that the adjusted RT_{NDT} is essentially the same for all beltline plates, and that the plate material is the limiting material in the vessel beltline. Finally, the results in Table 4.2 show that the degree of radiation embrittlement in the SONGS, Unit 2, reactor vessel beltline materials is relatively low even at end-of-design life fluence.

4.4 UPPER SHELF ENERGY DROP

Capsule 97 from the SONGS, Unit 2, surveillance program was evaluated in 1988. The USE results are shown in Figures 4-1, 4-2, and 4-3, and are tabulated in Table 4.3 as absolute drop in USE (ft-lb). Also listed in Table 4.3 are the predicted drops from Regulatory Guide 1.99, Revision 2. All of the measured drops in USE are below those predicted by the Regulatory Guide.

Predictions of USE levels at the quarter-thickness location after neutron irradiation exposure are shown in Table 4.4 for all the SONGS, Unit 2, beltline materials. At the end of 32 EFPY, none of the materials are projected to even approach the NRC screening limit of 50 ft-lb specified in 10CFR50, Appendix G.

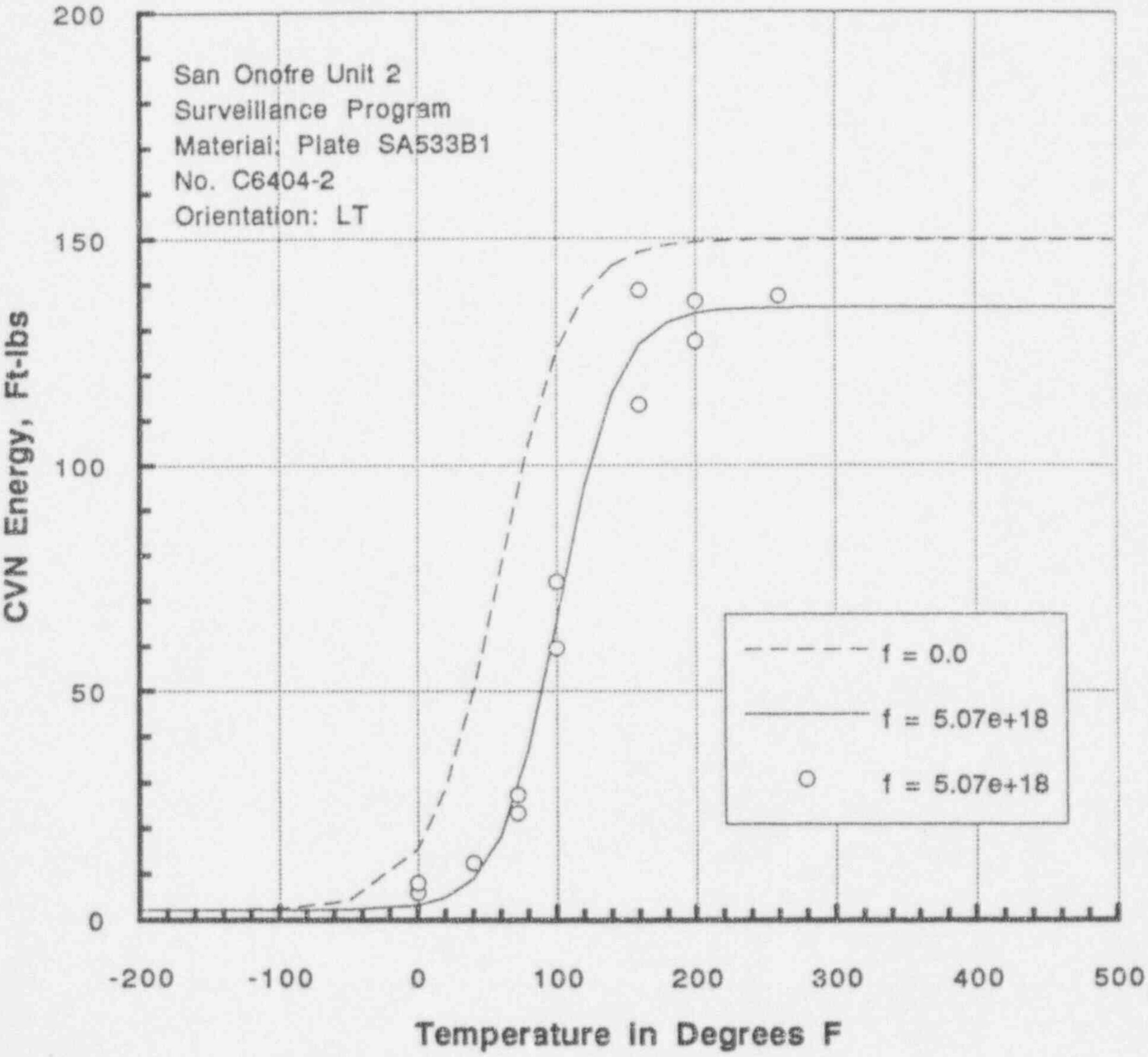

Figure 4-1. SONGS, Unit 2: Comparison of the Least Squares Fit for the Unirradiated Baseline Data with the Irradiated C_{VN} Data and Least Squares Fit for the Data from Capsule 97, Plate C6404-2, LT Orientation.

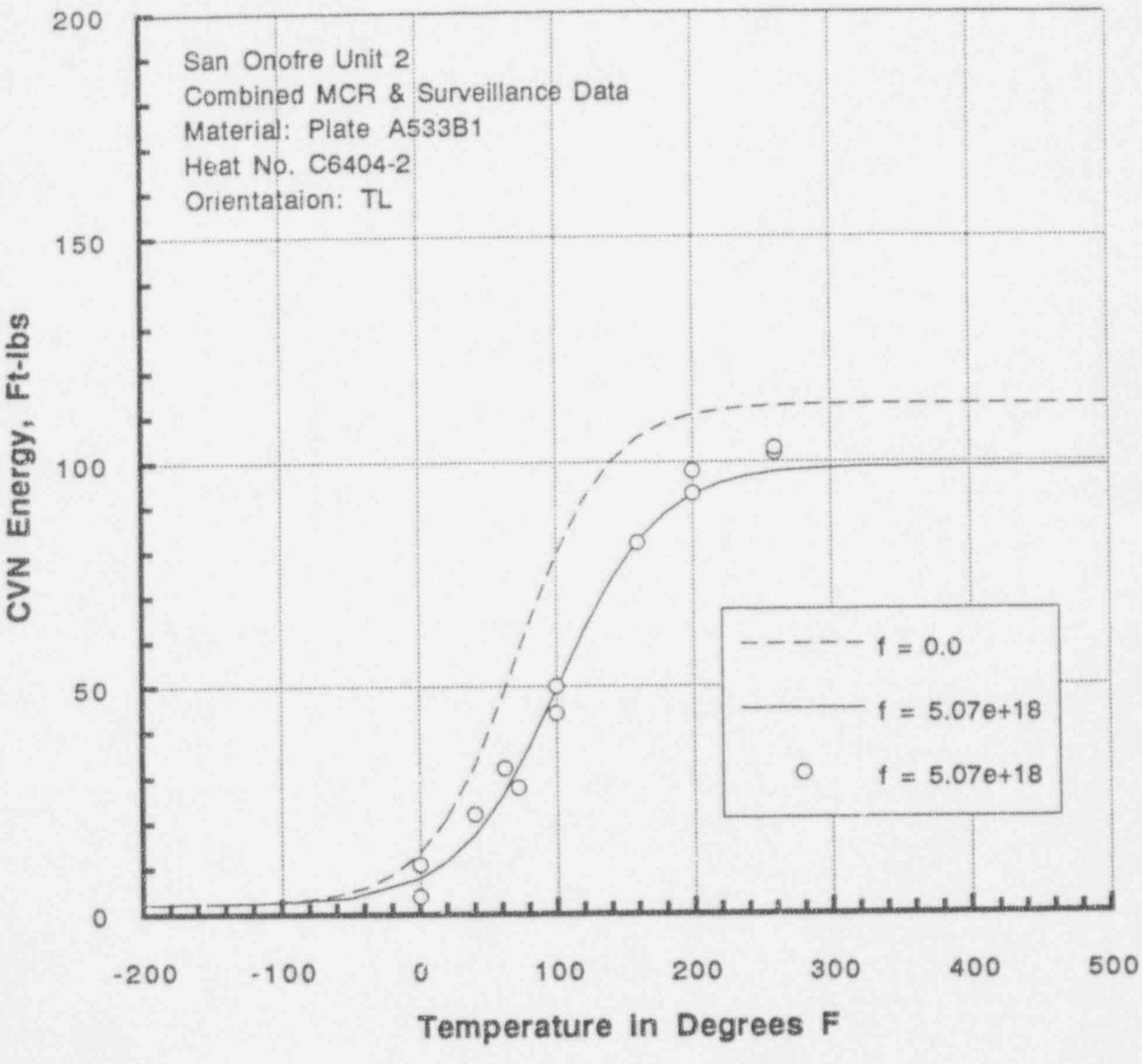

Figure 4-2. SONGS, Unit 2: Comparison of the Least Squares Fit for the Combined MCR and Unirradiated Baseline Data with the Irradiated C_{VN} Data and Least Squares Fit for the Data from Capsule 97, Plate C6404-2, TL Orientation.

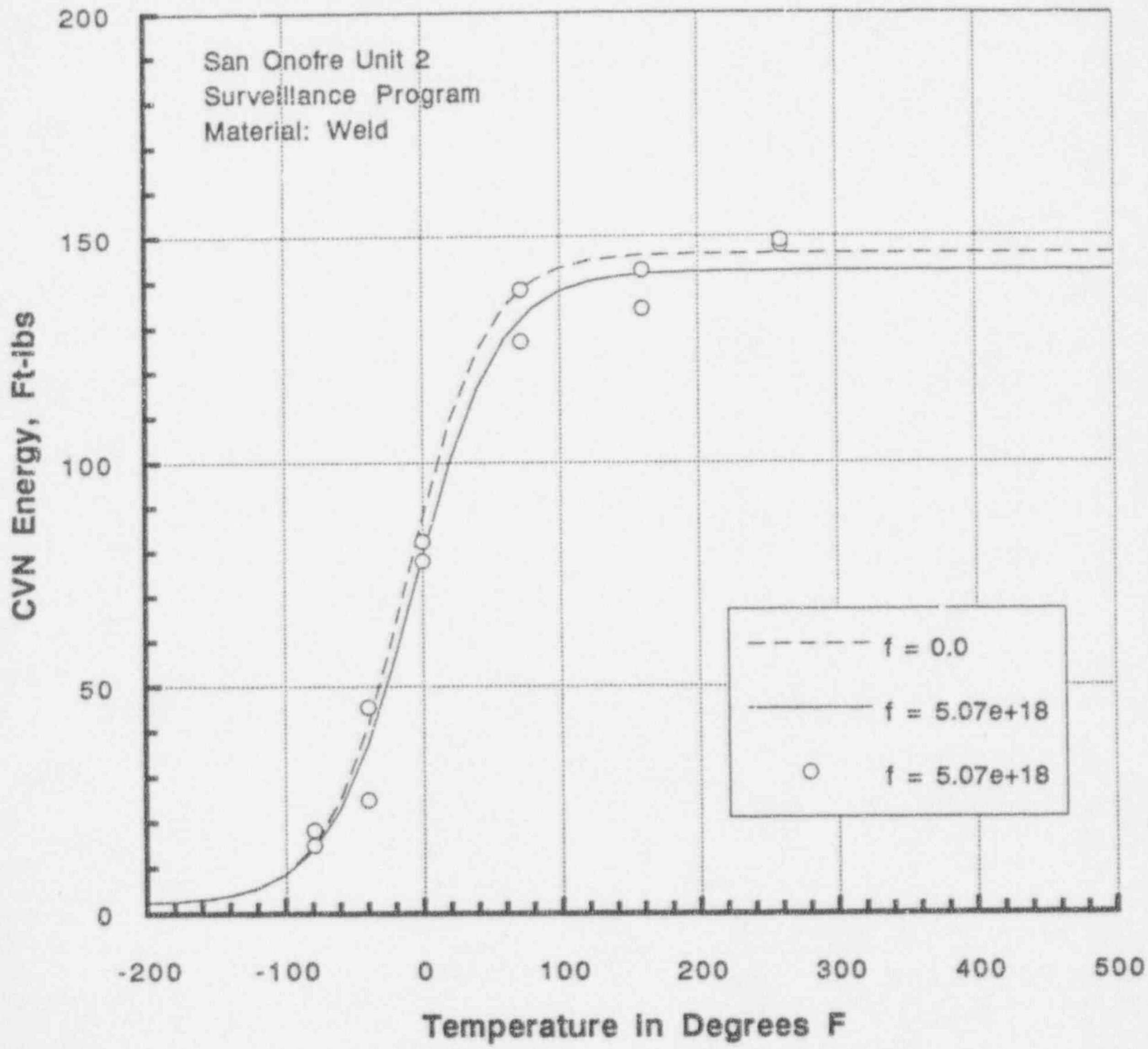

Figure 4-3. SONGS, Unit 2: Comparison of the Least Squares Fit for the Unirradiated Baseline Data with the Irradiated C_{VN} Data and Least Squares Fit for the Data from Capsule 97, Surveillance Weld.

Table 4.1. SONGS, Unit 2: Surveillance Capsule Shift Results.

Material/ Orientation	CF	ff	30 ft-lb Shift (°F)		
			Battelle	RG1.99R2	Current
C6404-2/LT	65[a]	0.81	51	53	52[c]
C6404-2/TL	65[a]	0.81	45	53	33[d]
Surveillance Weld	69[b]	0.81	7	56	4[e]

a. See Table 3.4 (Cu = .10; Ni = .59)

b. Based upon the conservative 9-203 weld chemistry -- see Table 3.5

c. Based on the baseline surveillance data, see Figure 3-10

d. Based on the combined data set from the MCR and baseline surveillance program, see Figure 3-9

e. Based on the baseline surveillance data, see Figure 3-13

Table 4.2. SONGS, Unit 2: ART Estimates at the Inner Surface Location for Beltline Materials on 12/16/91 and at 32 EFPY.

Plate No./ Weld Seam	CF	Fluence Function at the Inner Surface		ART (°F)[a] at the Inner Surface	
		12/16/91	32 EFPY	12/16/91	32 EFPY
C6404-1	65	0.95	1.37	116	143
C6404-2	65[b]	0.95	1.37	116	143
C6404-3	65	0.95	1.37	116	143
C6404-4	65	0.95	1.37	116	143
C6404-5	75	0.95	1.37	115	147
C6404-6	65	0.95	1.37	86	113
2-203 A, B, C	41[c]	0.95	1.37	18	52
3-203 A, B, C	38[d]	0.95	1.37	22	54
8-203 (10137)	236	0.09[e]	0.25[e]	5[f]	68[f]
8-203 (90136)	260	0.09[e]	0.25[e]	8[f]	74[f]
9-203	69	0.95	1.37	62	90

a. ART is the adjusted reference temperature equal to the predicted shift (CF x ff) plus the initial RT_{NDT} plus a margin term equal to 34°F for plates or 56°F for welds (unless the predicted shift is less than the margin term, in which case the margin is equal to the predicted shift)

b. Based upon average chemistries for this plate (.10 Cu/.59 Ni)--see Tables 3.4 and 4.1

c. Based upon average chemistries for these welds (.03 Cu/.92 Ni)--see Table 3.5

d. Based upon average chemistries for these welds (.05 Cu/.10 Ni)--see Table 3.5

e. Fluence function is based upon the peak vessel fluence divided by 108[4]

f. Since there is not a measured initial RT_{NDT}, an additional margin associated with the standard deviation (17°F) of the initial RT_{NDT} has been used as described in Regulatory Guide 1.99, Rev. 2

Table 4.3. SONGS, Unit 2: Surveillance Capsule Upper Shelf Results

Material/ Orientation	Cu (wt%)	Fluence (x 10^{19} n/cm^2)	Upper Shelf Drop (ft-lb)		
			Battelle	RG1.99R2	Current
C6404-2/LT	0.10[a]	0.507	17	24	15[d]
C6404-2/TL	0.10[a]	0.507	21	18	14[e]
Surveillance Weld	0.07[b]	0.507	5	26[c]	4[f]

a. See Table 3.4

b. See Table 3.5 for weld 9-203

c. Based upon interpolation of the Regulatory Guide 1.99, Rev. 2 curves.

d. Based on the baseline surveillance data, see Figure 3-10

e. Based on the combined data set from the MCR and baseline surveillance program, see Figure 3-9

f. Based on the baseline surveillance data, see Figure 3-13

Table 4.4. SONGS, Unit 2: Upper Shelf Estimates at the Quarter-Thickness Location for Beltline Materials on 12/16/91 and at 32 EFPY.

Plate No./ Weld Seam	Cu (wt%)	Fluence (x 10^{19} n/cm²) at Quarter-Thickness 12/16/91	32 EFPY	Upper Shelf Energy (ft-lb)[a] at Quarter-Thickness 12/16/91	32 EFPY
C6404-1	0.10	0.51	2.5	100	91
C6404-2	0.10[b]	0.51	2.5	95	87
C6404-3	0.10	0.51	2.5	83	76
C6404-4	0.10	0.51	2.5	87	80
C6404-5	0.11	0.51	2.5	98	89
C6404-6	0.10	0.51	2.5	104	95
2-203 A, B, C	0.03[c]	0.51	2.5	78	71
3-203 A, B, C	0.05[d]	0.51	2.5	114	103
8-203 (10137)	0.23	0.005	0.023	94[e]	89[e]
8-203 (90136)	0.31	).005	0.023	97[e]	88[e]
9-203	0.07	0.51	2.5	119	107

a. The upper shelf energy is estimated from Regulatory Guide 1.99, Rev. 2, taking into account the projected fluences and measured chemistry

b. Based upon average chemistry for this plate--see Table 3.4

c. Based upon average chemistry for this weld and the lowest measured upper shelf--see Tables 3.5 and 3.8

d. Based upon average chemistry for this weld--see Table 3.5

e. Based upon an extrapolation of the curves in Regulatory Guide 1.99, Rev. 2

Section 5

REFERENCES

[1] A. Ragl, Southern California Edison San Onofre Unit 2, Evaluation of Baseline Specimens, Reactor Vessel Materials Irradiation Surveillance Program, Combustion Engineering S-TR-MCS-002, May 27, 1978.

[2] M. P. Manahan, L. M. Lowry, and E. O. Fromm, Examination, Testing, and Evaluation of Irradiated Pressure Vessel Surveillance Specimens from the San Onofre Nuclear Generating Station Unit 2 (SONGS-2), Battelle Columbus, December 1988.

[3] E. Terek, E. P. Lippincott, A. Madeyski, and M. Ramirez, Analysis of the Southern California Edison Company San Onofre Unit 3 Reactor Vessel Surveillance Capsule Removed from the 97° Location, Westinghouse WCAP-12920, Revision 2, May 1994.

[4] R. Chang, "SONGS 2/3 RPV Fluence Ratio at Weld 8-203", SCE Calculation No. N-1020-065, December 1992.

APPENDIX A

SONGS, UNIT 2: EVALUATION OF COMPLIANCE WITH ASTM E185-73 AND E185-82

Summary of Requirements per ASTM E185-73	San Onofre Unit 2 Program
1.2 Surveillance tests are divided according to application into two cases:	Compliance
1.2.1 Case A - Where both the predicted increase in transition temperature of the reactor vessel steel is 100°F or less and the calculated peak neutron fluence (E > 1 MeV) of the reactor vessel is 5×10^{18} n/cm^2 or less.	
1.2.2 Case B - Where the predicted increase in transition temperature of the reactor vessel steel is greater than 100°F or where the calculated peak neutron fluence (E > 1 MeV) of the reactor vessel is greater than 5×10^{18} n/cm^2	
4.1 Test Material - Test specimens shall be prepared from the actual materials used in fabricating the irradiated region of the reactor vessel.	Compliance
4.1 Samples shall represent a minimum of one heat of the base metal and one butt weld and one weld heat-affected-zone (HAZ) if a weld occurs in the irradiated region.	Compliance
4.1 The base metal and weld metal to be included in the program should represent the material that may limit the operation of the reactor during its lifetime.	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 2 Program
4.1.1 Vessel Material Sampling - A minimum test program shall consist of specimens taken from the following locations: (1) base metal of one heat used in the irradiated region, (2) weld metal, fully representative of the fabrication practice used for a weld in the irradiated region (weld wire of rod, must come from one of the heats used in the irradiated region of the reactor vessel) and the same type of flux, and (3) the heat-affected-zone associated with the base metal noted above.	Compliance
4.1.1 Representative test stock to provide two additional sets of test specimens of the base metal, weld and heat-affected-zone shall be retained with full documentation and identification.	Compliance
4.1.2 Fabrication History - The test material shall receive a fabrication history (austenitizing, quench and tempering, and post-weld heat treatment) fully representative of the fabrication received by the material in the irradiated region of the reactor vessel.	Compliance
4.1.3 Chemical Requirements - The chemical composition required by the material specifications for the test materials (base metal and as deposited weld metal) shall be obtained and include, but not be limited to phosphorus (P), sulfur (S), copper (Cu), and vanadium (V).	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 2 Program
4.2 Charpy V-notch impact specimens corresponding to the Type A specimen described in Methods E 23 shall be employed unless material thickness does not permit. Both irradiated and unirradiated types of specimens shall be of the same size and shape.	Compliance
4.3 Specimen Orientation and Location - For both tension and impact specimens from base metal, the major axis of the specimen shall be machined normal to the principal rolling direction for plates and normal to the major working direction for forgings. The length of the notch of the Charpy impact specimen shall be normal to the surface of the material. The recommended orientation of the impact and tension specimens with respect to the weld are shown in Fig. 1. Weld metal tension specimens may be oriented in the same direction as the Charpy specimens provided that the gage length consists of all weld metal. No specimens are to be removed within 1/2 in. of the root or the surfaces of the welds. Sections of the weldment shall be etched to define the weld heat affected zones. Care shall be taken that the impact specimens from the weld heat affected zones have their notch roots in the heat affected zone at a standard distance of approximately 1/32 in. from the fusion line. Specimens representing the base metal (tension and impact) and the weld heat-affected zone shall be removed from the quarter thickness location. (per NB2300 of ASME Code Section III)	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 2 Program
4.4 Number of Specimens - The minimum number of test specimens for each exposure shall be as follows:	Compliance

	Case A	Case B	
	Charpy	Charpy	Tension
Base Metal	12	12	2
Weld Metal	12	12	2
HAZ	12	12	-

4.4 At least 15 Charpy impact specimens shall be used to establish an unirradiated transition curve for each material.	Compliance
4.4 For Case B (see above), three tension test specimens shall be used to establish unirradiated tensile properties.	Not Applicable
5.1.1 Vessel Wall Specimens (Required) - Specimens shall be irradiated at a location in the reactor that duplicates as closely as possible the neutron-flux spectrum, temperature history, and maximum accumulated neutron fluence experienced by the reactor vessel.	Compliance
5.1.1 The instantaneous neutron flux at the location of the specimens shall not exceed three times the calculated maximum neutron flux at the inside wall of the reactor vessel.	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 2 Program
5.1.2 Accelerated Irradiation Specimens (Optional) - Test specimens may be positioned at locations other than (5.1.1) for accelerated irradiation at a rate exceeding three times the calculated maximum neutron flux at the inside wall of the reactor vessel.	Not Applicable
5.2 Flux Measurements - Provisions shall be made to measure the neutron fluence as follows: 5.2.1 Dosimeters with the vessel wall specimens (5.1.1).	Compliance
5.2.2 Where accelerated irradiation specimens are used (5.1.2), dosimeters with the test specimens and dosimeters either in a separate flux monitor capsule adjacent to the vessel wall or in a vessel wall capsule.	Compliance
5.3 Test Capsules - To prevent deterioration of the surface of the specimens during test, the specimens should be maintained in an inert environment within a corrosion-resistant capsule.	Compliance
5.3 The temperature history of the specimens shall duplicate as closely as possible the temperature experienced by the reactor vessel.	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 2 Program
5.3 Surveillance capsules should be sufficiently rigid to prevent damage to the capsules by coolant pressure or coolant flow thus hindering specimen removal or causing inadvertent deformation of the specimens.	Compliance
5.3 Irradiated capsules must not be bouyant to preclude serious radiation exposure to personnel if under water handling is employed.	Compliance
5.3 Consideration should be given to the design of the capsule and capsule attachments to permit insertion of replacement capsules into the reactor at a later time in the lifetime of the vessel.	Compliance
5.4 Specimen Withdrawal - A minimum surveillance program shall consist of three capsules for Case A and five capsules for Case B. It is recommended that capsules be withdrawn as described in Table 1. (See Table 1 of ASTM E185-73.)	Compliance
6.1 Radiation Environment - The neutron flux, neutron energy spectrum, and irradiation temperature of surveillance specimens and the method of determination shall be documented.	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 2 Program
6.2 Neutron Flux Dosimeters - Flux dosimeters for a particular program shall be determined by referring to Method E 261.	Corpliance
END	END

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
8.1 Temperature Environment - The maximum exposure temperature of the surveillance capsule materials shall be determined. If a discrepancy (>14°C or 25°F) occurs between the observed and the expected capsule exposure temperatures, an analysis of the operating conditions shall be conducted to determine the magnitude and duration of these differences.	Compliance
8.2 Neutron Irradiation Environment: 8.2.1 The neutron flux density, neutron energy spectrum, and neutron fluence of the surveillance specimens and the corresponding maximum values for the reactor vessel shall be determined in accordance with the guidelines in Guide E 482 and Recommended Practice E 560. 8.2.2 The specific method of determination shall be determined and recorded using both a calculated spectrum and an assumed fission spectrum.	Compliance
9.1 Tension Tests: 9.1.1 Method - Tension testing shall be conducted in accordance with Methods E 8 and Recommended Practice E 21. 9.1.2 Test Temperature: 9.1.2.1 Unirradiated - The test temperatures for each material shall include room temperature, service temperature, and one intermediate temperature to define the strength versus temperature relationship.	Compliance

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
9.1.2.2 Irradiated - One specimen from each material shall be tested at a temperature in the vicinity of the upper end of the Charpy energy transition region. The remaining specimens from each material shall be tested at the service temperature and the midtransition temperature.	Compliance
9.1.3 Measurements - For both unirradiated and irradiated materials, determine yield strength, tensile strength, fracture load, fracture strength, fracture stress, total and uniform elongation, and reduction of area.	Compliance
9.2 Charpy Tests: 9.2.1 Method - Charpy tests shall be conducted in accordance with Method E 23 and A370.	Compliance
9.2.2 Test Temperature: 9.2.2.1 Unirradiated - Test temperature for each material shall be selected to establish a full transition temperature curve. One specimen per test temperature may be used to define the overall shape of the curve. Additional tests should be performed in the region where the measurements described in 9.2.3 are made.	Compliance
9.2.2.2 Irradiated - Specimens for each material will be tested at temperatures selected to define the full energy transition curve. Particular emphasis should be placed on defining the 41-J (30 ft-lb), 68-J (50 ft-lb), and 0.89-mm (35 mil) lateral expansion index temperatures and the upper shelf energy.	Compliance

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
9.2.3 Measurements - For each test specimen, measure the impact energy, lateral expansion, and percent shear fracture appearance. From the unirradiated and irradiated transition temperature curves determine the 41-J (30 ft-lb), 68-J (50 ft-lb), and 0.89 mm (35 mil) lateral expansion index temperatures and the upper shelf energy. The index temperatures and the upper shelf energy shall be determined from the average curves.	Compliance
9.2.3.1 Obtain from the material qualification test report the initial reference temperature (RT_{NDT}) as defined in ASME Code, Section III, Subarticle NB 230 for unirradiated materials.	Compliance
9.3 Hardness Tests (Optional) - Hardness tests may be performed on unirradiated and irradiated Charpy specimens. The measurements shall be taken in areas away from the fracture zone or the edges of the specimens. The tests shall be conducted in accordance with Methods A 370.	Compliance
9.4 Supplemental Tests (Optional) - If supplemental fracture toughness tests are conducted (in addition to tests conducted on tension and Charpy specimens as described in 6.1) the test procedures shall be documented.	Not Applicable

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
9.5 Calibration of Equipment - Procedures shall be employed assuring that tools, gages, recording instruments, and other measuring and testing devices are calibrated and properly adjusted periodically to maintain accuracy within necessary limits. Whenever possible calibration shall be conducted with standards traceable to the National Bureau of Standards. Calibration status shall be maintained in records traceable to the equipment.	Compliance
10.1 Tension Test Data: 10.1.1 Determine the amount of radiation strengthening by comparing unirradiated test results with irradiated test results at the temperature specified in 9.1.2. 10.1.2 The tensile strength data can be verified using the results from the hardness test (optional) described in 9.3.	Compliance
10.2 Charpy Test Data: 10.2.1 Determine the radiation induced transition temperature shifts by measuring the difference in the 41-J (30 ft-lb), 68-J (50 ft-lb), and 0.89 mm (35 mil) lateral expansion index temperatures before and after irradiation. The index temperatures shall be obtained from the average curves.	Compliance

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
10.2.2 Determine the adjusted reference temperature by adding the shift corresponding to the 41-J (30 ft-lb) index determined in 10.2.1 to the initial reference temperature obtained in 9.2.3.1.	Compliance
10.2.3 Determine the radiation induced change in the upper shelf energy (USE) from the measurements made before and after irradiation using average value curves.	Compliance
10.2.4 (Optional) - Determine the radiation induced change in temperature corresponding to 50% of the upper shelf energy before and after irradiation from average value curves.	Not Applicable
10.3 Supplemental Test Data (Optional) - If additional, supplemental tests are performed (9.4), the data shall be recorded to supplement the information from the tensile and Charpy tests.	Not Applicable
10.4 Retention of Test Specimens - It is recommended that all broken test specimens be retained until released by the owner in the event that additional analyses are required to explain anomalous results.	Compliance
11.1 Where applicable, both SI units and conventional units shall be reported.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
11.2 Surveillance Program Description - Description of the reactor vessel including the following:	Compliance
11.2.1 Location of the surveillance capsules with respect to the reactor vessel, reactor vessel internals, and the reactor core.	
11.2.2 Location in the vessel of the plates or forgings and the welds.	
11.2.3 Location(s) of the peak vessel fluence.	
11.2.4 Lead factors between the specimen fluence and the peak vessel fluence at the I.D. and the 1/4T locations.	
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11.2.5 Surveillance Material Selection:	Compliance
11.2.5.1 Description of all beltline materials including chemical analysis, fabrication history, Charpy data, tensile data, drop-weight data, and initial RT_{NDT}.	
11.2.5.2 Describe the basis for selection of surveillance materials.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
11.3 Surveillance Material Characterization:	Compliance
11.3.1 Description of the surveillance material including fabrication history, material source (heat or lot), and any differences between the surveillance material history and that of the reactor vessel material history.	
11.3.2 Location and orientation of the test specimens in the parent material.	
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11.3.3 Test Specimen Design:	Compliance
11.3.3.1 Description of the test specimens (tension, Charpy, and any other types of specimens used), neutron dosimeters, and temperature monitors.	
11.3.3.2 Certification of calibration of all equipment and instruments used in conducting the tests.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
11.4.1 Tension Tests:	Compliance
11.4.1.1 Trade name and model of the testing machine, gripping devices, extensometer, and recording devices used in the test.	
11.4.1.2 Speed of testing and method of measuring the controlling testing speed.	
11.4.1.3 Complete stress-strain curve (if a group of specimens exhibits similar stress-strain curves, a typical curve may be reported for the group).	
1..4.1.4 Test Data from each specimen as follows: (1) Test temperature; (2) Yield strength or yield point and method of measurement; (3) Tensile strength; (4) Fracture load, fracture strength, and fracture stress; (5) Uniform elongation and method of measurement; (6) Total elongation; (7) Reduction of area; and (8) Specimen identification.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
11.4.2 Charpy Tests:	Compliance
11.4.2.1 Trade name and model of the testing machine, available hammer energy capacity and striking velocity, temperature conditioning and measuring devices, and a description of the procedure used in the inspection and calibration of the testing machine.	
11.4.2.2 Test data from each specimen as follows: (1) Temperature of test; (2) Energy absorbed by the specimen in breaking, reported in joules (and foot-pound-force); (3) Fracture appearance; (4) Lateral expansion; and (5) Specimen identification.	
11.4.2.3 Test data for each material as follows: (1) Charpy 41-J (30 ft-lb), 68-J (50 ft-lb), and 0.89 mm (35 mil) lateral expansion index temperature of unirradiated material and of each set of irradiated specimens, along with the corresponding temperature increases for these specimens; (2) Upper shelf energy (USE) absorbed before and after irradiation; (3) Initial reference temperature; and (4) Adjusted reference temperature.	
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11.4.3 Hardness Tests (Optional):	Compliance
11.4.3.1 Trade name and model of the testing machine.	
11.4.3.2 Hardness data.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
11.4.4 Other Fracture Toughness Tests: 11.4.4.1 If additional tests are performed, the test data shall be reported together with the procedure used for conducting the tests and analysis of the data.	Not Applicable
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11.4.5 Temperature and Neutron Radiation Environment Measurements: 11.4.5.1 Temperature monitor results and an estimate of maximum capsule exposure temperature. 11.4.5.2 Neutron dosimeter measurements, analysis techniques, and calculated results including the following: (1) Neutron flux density, neutron energy spectrum, and neutron fluence in terms of neutrons per square metre and neutrons per square centimetre (>0.1 and 1 MeV) for the surveillance specimens using both calculated spectrum and assumed fission spectrum assumptions. (2) Description of the methods used to verify the procedures including calibrations, cross sections, and other pertinent nuclear data.	Compliance

Summary of Requirements per ASTM E185-82	San Onofre Unit 2 Program
11.5 Application of Test Results:	Compliance
11.5.1 Extrapolation of the neutron flux and fluence results to the surface and 1/4T locations of the reactor vessel at the peak fluence location.	
11.5.2 Comparison of fluence determined from dosimetry analysis with original predicted values.	
11.5.3 Extrapolation of fracture toughness properties to the surface and 1/4T locations of the reactor vessel at the peak fluence location.	
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11.6 Deviations - Deviations or anomalies in procedure from this practice shall be identified and described fully in the report.	Compliance
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END	END

APPENDIX B

SONGS, UNIT 2: BASES FOR PLATE CHEMISTRY MEASUREMENTS (Proprietary)

APPENDIX C

SONGS, UNIT 2: BASES FOR WELD CHEMISTRY MEASUREMENTS (Proprietary)

APPENDIX D

SONGS, UNIT 2: WMCs FOR

BELTLINE MATERIALS (Proprietary)

APPENDIX E

SONGS, UNIT 2: MCRs FOR BELTLINE MATERIALS (Proprietary)

APPENDIX F

SONGS, UNIT 2: UNIRRADIATED C_{VN} DATA FOR PLATES AND WELDS

Table F-1 Charpy V-Notch Test Results For Unit 2 Plate C6404-1 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)	
1	-40.00	10.00	5.00	0.00	
2	-40.00	9.00	4.00	0.00	
3	-40.00	7.00	3.00	0.00	
4	10.00	23.00	19.00	10.00	
5	10.00	16.00	14.00	5.00	
6	10.00	20.00	15.00	10.00	
7	40.00	30.00	21.00	15.00	
8	40.00	35.00	25.00	15.00	
9	40.00	43.00	30.00	20.00	
10	70.00	63.00	~~35.00~~ 48.00	~~40.00~~ 35.00	BB 5/19/94
11	70.00	60.00	46.00	35.00	
12	70.00	44.00	31.00	20.00	
13	80.00	77.00	55.00	50.00	
14	80.00	64.00	44.00	40.00	
15	80.00	57.00	42.00	35.00	
16	100.00	81.00	58.00	50.00	
17	100.00	72.00	56.00	50.00	
18	100.00	83.00	62.00	50.00	
19	160.00	119.00	74.00	95.00	
20	160.00	113.00	76.00	95.00	
21	160.00	117.00	78.00	90.00	
22	212.00	121.00	75.00	100.00	
23	212.00	120.00	75.00	100.00	
24	212.00	124.00	79.00	100.00	

Table F-2 Charpy V-Notch Test Results
For Unit 2 Plate C6404-2 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	6.00	3.00	0.00
2	-40.00	7.00	3.00	0.00
3	-40.00	11.00	6.00	0.00
4	10.00	18.00	13.00	10.00
5	10.00	16.00	11.00	5.00
6	10.00	13.00	8.00	5.00
7	40.00	37.00	25.00	15.00
8	40.00	23.00	17.00	10.00
9	40.00	35.00	24.00	15.00
10	70.00	52.00	38.00	25.00
11	70.00	47.00	34.00	25.00
12	70.00	51.00	40.00	25.00
13	80.00	65.00	47.00	40.00
14	80.00	69.00	48.00	40.00
15	80.00	53.00	38.00	30.00
16	100.00	75.00	55.00	50.00
17	100.00	68.00	52.00	50.00
18	100.00	73.00	53.00	50.00
19	160.00	101.00	71.00	99.00
20	160.00	95.00	66.00	95.00
21	160.00	94.00	67.00	95.00
22	212.00	105.00	74.00	100.00
23	212.00	123.00	80.00	100.00
24	212.00	117.00	76.00	100.00

Table F-3 Charpy V-Notch Test Results
For Unit 2 Plate C6404-3 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)	
1	-40.00	8.00	5.00	0.00	
2	-40.00	10.00	6.00	0.00	
3	-40.00	9.00	~~8.00~~ 5.00	0.00	BB 5/19/94
4	10.00	14.00	9.00	5.00	
5	10.00	21.00	15.00	10.00	
6	10.00	15.00	13.00	5.00	
7	40.00	19.00	~~34.00~~ 19.00	~~30.00~~ 10.00	BB 5/19/94
8	40.00	33.00	22.00	20.00	
21	160.00	93.00	61.00	95.00	
10	70.00	46.00	35.00	25.00	
11	70.00	54.00	42.00	30.00	
12	70.00	45.00	35.00	25.00	
13	80.00	69.00	49.00	50.00	
14	80.00	60.00	44.00	50.00	
15	80.00	52.00	36.00	50.00	
16	100.00	73.00	55.00	50.00	
17	100.00	74.00	54.00	50.00	
18	100.00	71.00	50.00	50.00	
19	160.00	97.00	62.00	99.00	
20	160.00	94.00	64.00	95.00	
9	40.00	30.00	18.00	~~25.00~~ 15.00	BB 5/19/94
22	212.00	105.00	69.00	100.00	
23	212.00	100.00	66.00	100.00	
24	212.00	103.00	64.00	100.00	

Table F-4 Charpy V-Notch Test Results
For Unit 2 Plate C6404-4 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	9.00	6.00	0.00
2	-40.00	9.00	7.00	0.00
3	-40.00	10.00	8.00	0.00
4	10.00	26.00	20.00	15.00
5	10.00	22.00	17.00	10.00
6	10.00	23.00	20.00	10.00
7	40.00	35.00	25.00	15.00
8	40.00	34.00	25.00	15.00
9	40.00	44.00	33.00	20.00
10	70.00	47.00	36.00	30.00
11	70.00	52.00	40.00	35.00
12	70.00	56.00	41.00	40.00
13	80.00	62.00	48.00	40.00
14	80.00	66.00	50.00	40.00
15	80.00	68.00	53.00	40.00
16	110.00	68.00	51.00	50.00
17	110.00	78.00	56.00	50.00
18	110.00	85.00	60.00	60.00
19	160.00	108.00	78.00	100.00
20	160.00	107.00	75.00	100.00
21	160.00	96.00	71.00	100.00

Table F-5 Charpy V-Notch Test Results
For Unit 2 Plate C6404-5 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	10.00	5.00	0.00
2	-40.00	9.00	5.00	0.00
3	-40.00	8.00	4.00	0.00
4	10.00	18.00	18.00	5.00
5	10.00	15.00	13.00	5.00
6	10.00	14.00	14.00	5.00
7	40.00	25.00	20.00	15.00
8	40.00	26.00	22.00	15.00
9	40.00	23.00	19.00	15.00
10	60.00 ~~50.00~~	47.00	36.00	30.00
11	60.00 ~~50.00~~	54.00	42.00	35.00
12	60.00 ~~50.00~~	61.00	50.00	35.00
13	70.00	66.00	48.00	40.00
14	70.00	72.00	53.00	45.00
15	70.00	55.00	44.00	35.00
16	110.00	81.00	60.00	50.00
17	110.00	84.00	59.00	50.00
18	110.00	87.00	61.00	50.00
19	160.00	103.00	65.00	90.00
20	160.00	105.00	70.00	90.00
21	160.00	115.00	72.00	90.00
22	212.00	122.00	81.00	100.00
23	212.00	116.00	74.00	100.00
24	212.00	116.00	71.00 ~~70.00~~	100.00

BB 5/19/94

BB 5/19/94

Table F-6 Charpy V-Notch Test Results
For Unit 2 Plate C6404-6 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	4.00	4.00	0.00
2	-40.00	9.00	6.00	0.00
3	-40.00	6.00	5.00	0.00
4	10.00	14.00	13.00	5.00
5	10.00	16.00	14.00	5.00
6	10.00	13.00	12.00	5.00
7	40.00	28.00	23.00	15.00
8	40.00	27.00	22.00	15.00
9	40.00	27.00	24.00	15.00
10	50.00	61.00	46.00	30.00
11	50.00	54.00	40.00	25.00
12	50.00	65.00	47.00	30.00
13	110.00	85.00	61.00	60.00
14	110.00	73.00	52.00	50.00
15	110.00	94.00	59.00	70.00
16	160.00	116.00	78.00	90.00
17	160.00	115.00	75.00	90.00
18	160.00	118.00	78.00	90.00
19	212.00	128.00	80.00	100.00
20	212.00	124.00	76.00	100.00
21	212.00	121.00	77.00	100.00

Table F-7 Charpy V-Notch Test Results
For Unit 2 Weld Seam 9-203 (Heat #90130), ~~FSAR~~ WMC Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-60.00	16.00	9.00	0.00
2	-60.00	15.00	7.00	0.00
3	-60.00	19.00	11.00	0.00
4	-40.00	20.00	11.00	5.00
5	-40.00	28.00	16.00	10.00
6	-40.00	32.00	22.00	15.00
7	-20.00	85.00	53.00	50.00
8	-20.00	88.00	56.00	50.00
9	-20.00	76.00	47.00	40.00
10	0.00	77.00	47.00	40.00
11	0.00	75.00	45.00	40.00
12	0.00	99.00	52.00	60.00
13	20.00	117.00	74.00	70.00
14	20.00	105.00	65.00	60.00
15	20.00	114.00	74.00	70.00
16	60.00	132.00	77.00	80.00
17	60.00	149.00	84.00	100.00
18	60.00	123.00	74.00	80.00
19	100.00	142.00	82.00	100.00
20	100.00	148.00	84.00	100.00
21	100.00	140.00	82.00	100.00

Table F-8 Charpy V-Notch Test Results
For Unit 2 Plate C6404-2 (LT), CE Baseline Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
154	-80.00	4.50	2.00	0.00
136	-80.00	8.50	10.00	0.00
122	-40.00	5.00	6.00	0.00
132	-40.00	6.50	6.00	0.00
143	0.00	11.00	13.00	15.00
147	0.00	16.50	18.00	15.00
114	40.00	41.00	38.00	25.00
11A	40.00	56.50	48.00	25.00
12K	80.00	93.50	72.00	65.00
14A	80.00	124.50	83.00	75.00
156	120.00	118.00	78.00	80.00
11E	120.00	141.50	96.00	90.00
13T	160.00	146.50	90.00	100.00
11T	160.00	157.50	95.00	90.00
157	210.00	148.00	96.00	100.00
14L	210.00	155.00	94.00	100.00

Table F-9 Charpy V-Notch Test Results
For Unit 2 Plate C6404-2 (TL), CE Baseline Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
264	-80.00	4.50	2.00	0.00
25A	-40.00	8.00	8.00	0.00
23D	-40.00	8.00	9.00	0.00
21T	0.00	12.00	15.00	10.00
21Y	0.00	24.50	24.00	10.00
262	40.00	33.00	32.00	20.00
22B	40.00	40.00	35.00	25.00
24J	80.00	68.50	58.00	30.00
24E	80.00	78.50	62.00	40.00
21E	120.00	87.00	66.00	75.00
24A	120.00	107.00	72.00	80.00
245	160.00	111.50	78.00	85.00
24T	160.00	127.50	84.00	90.00
216	190.00	116.00	80.00	100.00
24U	210.00	126.50	87.00	100.00
231	210.00	137.50	91.00	100.00

Table F-10 Charpy V-Notch Test Results
For Unit 2 Surveillance Weld, CE Baseline Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
34P	-150.00	3.50	1.00	0.00
31M	-120.00	7.00	6.00	15.00
333	-120.00	14.00	12.00	15.00
346	-80.00	16.00	15.00	25.00
37A	-80.00	29.50	25.00	30.00
31K	-40.00	43.50	37.00	35.00
35T	0.00	63.50	53.00	65.00
34T	0.00	90.00	68.00	75.00
33B	40.00	132.00	90.00	90.00
324	40.00	146.00	97.00	100.00
35L	80.00	135.50	95.00	100.00
326	80.00	140.00	96.00	100.00
331	120.00	145.50	95.00	100.00
34J	120.00	153.00	98.00	100.00
35J	160.00	151.00	96.00	100.00
335	160.00	152.00	100.00	100.00

Table F-11 Charpy V-Notch Test Results
For Unit 2 Plate C6404-2 (LT), MCR Data

Test Temperature (°F)	Impact Energy (ft-lbs)	Lateral Expansion (mils)	Fracture Appearance (% Shear)
-40	9	11	0
-40	12	18	0
-40	8	10	0
10	25	19	10
10	44	30	25
10	26	21	15
40	42	31	25
40	60	44	40
40	52	46	30
110	126	85	80
110	111	78	70
110	112	74	70
160	145	85	95
160	136	84	90
160	155	90	100

APPENDIX G

SONGS, UNIT 2: HAZ TEST RESULTS

CE Baseline Tests[1]

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
45J	-150.00	5.00	3.00	0.00
43C	-120.00	9.50	6.00	0.00
41M	-80.00	23.50	19.00	25.00
415	-80.00	35.00	28.00	30.00
466	-40.00	30.00	24.00	30.00
46K	-40.00	40.00	34.00	30.00
47B	0.00	82.00	56.00	50.00
41Y	0.00	101.00	70.00	70.00
44C	40.00	104.50	71.00	90.00
432	40.00	115.50	88.00	100.00
461	80.00	135.50	86.00	90.00
42B	80.00	153.00	92.00	100.00
43K	120.00	108.00	79.00	90.00
421	120.00	144.50	88.00	100.00
451	160.00	139.00	85.00	100.00
442	160.00	151.50	86.00	100.00

Battelle Capsule 97[2]

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)	CHARPY FLUENCE (n/cm2)	IRRAD TEMP. (F)
476	-79.00	12.00	9.80	17.00	5.07E+18	580.00
41A	-79.00	14.10	10.20	13.00	5.07E+18	580.00
41C	-40.00	20.00	14.00	27.00	5.07E+18	580.00
413	-40.00	28.20	26.80	38.00	5.07E+18	580.00
43U	0.00	38.30	30.40	46.00	5.07E+18	580.00
42J	0.00	77.50	54.80	54.00	5.07E+18	580.00
42Y	72.00	103.80	81.20	89.00	5.07E+18	580.00
42C	72.00	114.20	84.40	93.00	5.07E+18	580.00
444	160.00	130.00	87.00	100.00	5.07E+18	580.00
412	160.00	132.60	85.60	100.00	5.07E+18	580.00
44P	260.00	133.70	02.20	100.00	5.07E+18	580.00
424	260.00	145.30	89.80	100.00	5.07E+18	580.00

APPENDIX H

SONGS, UNIT 2: IRRADIATED C_{VN} DATA FROM CAPSULE 97

Table H-1 Charpy V-Notch Test Results
For Unit 2 Plate C6404-2 (LT)
Irradiated ($f = 5.07 \times 10^{18}$)

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
141	0.00	6.00	6.80	4.00
111	0.00	8.10	6.40	5.00
15M	40.00	12.50	7.80	11.00
14T	72.00	23.50	23.60	9.00
13M	72.00	27.40	26.60	13.00
123	100.00	59.50	53.60	18.00
13E	100.00	74.70	58.80	20.00
11M	160.00	113.40	83.00	77.00
15E	160.00	138.50	99.40	100.00
11U	200.00	127.30	93.40	100.00
124	200.00	136.20	105.80	100.00
137	260.00	137.30	95.40	100.00

Table H-2 Charpy V-Notch Test Results
For Unit 2 Plate C6404-2 (TL)
Irradiated (f = 5.07 x 10^{18})

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
214	0.00	4.00	10.00	4.00
23J	0.00	11.00	11.00	6.00
223	40.00	22.00	19.60	11.00
22K	72.00	27.90	32.80	15.00
22T	62.00	32.10	31.80	15.00
25U	100.00	44.10	42.80	42.00
23P	100.00	50.00	44.00	49.00
21B	160.00	82.00	68.40	85.00
221	200.00	93.00	71.00	100.00
25L	200.00	98.00	68.60	100.00
256	260.00	101.90	83.40	100.00
211	260.00	103.00	83.80	100.00

Table H-3 Charpy V-Notch Test Results
For Unit 2 Surveillance Weld
Irradiated ($f = 5.07 \times 10^{18}$)

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
37M	-79.00	15.00	14.40	18.00
37L	-79.00	18.40	20.00	13.00
3A3	-40.00	25.00	23.60	36.00
36M	-40.00	45.40	36.60	40.00
36P	0.00	78.00	65.20	68.00
36K	0.00	82.40	64.60	70.00
31E	72.00	126.90	95.00	92.00
33P	72.00	138.20	102.20	100.00
342	160.00	134.00	99.80	100.00
36E	160.00	142.50	97.80	100.00
32P	260.00	147.90	97.60	100.00
341	260.00	149.00	100.40	100.00

Attachment E

San Onofre Nuclear Generating Station, Unit 3
Response to Generic Letter 92-01

Revision 2
May 19, 1994

Prepared by:

ATI Consulting
San Ramon, CA

and

Sartrex Corporation
Rockville, MD

Prepared for:

Southern California Edison
Irvine, CA

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Section 1

INTRODUCTION

The Nuclear Regulatory Commission (NRC) in Generic Letter 92-01 (GL 92-01) requested all holders of operating licenses or construction permits for nuclear power plants to submit information needed to assess compliance with requirements and commitments regarding reactor vessel integrity. Revision 0, June 24, 1992, of this report was prepared in response to GL 92-01 for San Onofre Nuclear Generating Station (SONGS), Unit 3. It identified additional information needed to resolve the following issues: (1) inconsistencies in copper (Cu) and nickel (Ni) contents and Charpy impact properties reported for beltline Weld 9-203 and the surveillance weld, (2) locating material certification reports to confirm beltline weld properties, (3) identifying the Charpy impact properties, chemistry, and fluence for Weld 8-203, and (4) resolving inconsistencies between Charpy impact properties reported in the materials certification report and the materials surveillance program for the longitudinal orientation in Plate C6802-1.

Revision 1, January 22, 1993, incorporated additional materials data obtained from the SONGS, Unit 3, Nuclear Steam Supply System (NSSS) vendor, ABB-Combustion Engineering (ABB-CE), the results of calculations performed by Southern California Edison Company (SCE) to better characterize fluence conditions at Weld 8-203, and the results from calculations performed to evaluate the upper shelf toughness for Weld 8-203. It also indicated that additional information was required to confirm heat numbers for the surveillance weld material and to identify the weld heat number for an unidentified girth weld chemistry.

This revision (Revision 2) incorporates additional materials data and information obtained from the SONGS Unit 3 NSSS Vendor, ABB-CE. These data provide the heat number for the surveillance weld, and the weld wire and flux combination, chemistry, and Charpy data for Weld 8-203. Based on a review of the information supplied by ABB-CE, the chemistry and Charpy energies have been confirmed for the materials in the SONGS, Unit 3 pressure vessel beltline, and the response to GL 92-01 is complete. There is still an inconsistency with regard to the surveillance weld data and its association with the weld seam 9-203. A comparison of the impact energy versus temperature curves in the transition and upper shelf regions for Weld 9-203 (wire heat 90069) with the surveillance weld data indicates a relatively large difference. But a comparison of the impact energy versus temperature curves for Weld 9-203 (wire heat 90144) with the surveillance weld data are in close proximity. Currently, no information is available to explain the difference in the impact data for the surveillance weld and Weld 9-203, wire heat 90069. However, based on the chemistry and impact properties of the surveillance weld, the surveillance weld does provide a conservative representation of Weld 9-203 overall, and is adequate to assess the shift in reference temperature and drop in upper shelf energy for the SONGS, Unit 3 surveillance program.

In previous versions of this report the initial RT_{NDT} for the vessel beltline material with the highest end of life adjusted reference temperature (i.e., the plate material used in the surveillance program) was determined using a combined data set obtained from the materials certification report (MCR) and the baseline surveillance program. In Revision 2, the initial RT_{NDT} for this material is determined using only the data from the MCR. This change was made to be consistent with SCE's interpretation of the Code requirement for defining initial RT_{NDT}, which is that data to be used in accordance with paragraph NB-2331 of Section III of the ASME Code are the data obtained by the vessel manufacturer to assess the toughness properties at the time of vessel fabrication. This MCR data thus established the initial RT_{NDT} by satisfying paragraph NB-2331(a)(3) of the ASME Code, Section III. This change also was made so that this initial RT_{NDT} is defined in a manner consistent with that for other beltline materials where surveillance baseline data were not available. Consistent with the previous revisions of this report, the combined set of MCR and surveillance data were used to establish the unirradiated upper shelf energy and the temperature at 30 ft-lb Charpy absorbed energy for purposes of assessing the irradiation effects on the surveillance plate material.

Section 2 of this report addresses compliance with 10 CFR Part 50 (10CFR50), Appendix H, for the surveillance program at SONGS, Unit 3. Compliance with 10CFR50, Appendix G, is described in Section 3 along with a description of the location, heat treatment, residual and alloying element contents, and upper shelf and transition temperature fracture toughness for the beltline materials in the SONGS, Unit 3, reactor vessel. Section 4 addresses embrittlement effects, including irradiation temperature and adjusted reference temperature for evaluation of the beltline materials relative to GL 88-11 and 10CFR50.61.

Section 2

REACTOR PRESSURE VESSEL SURVEILLANCE PROGRAM COMPLIANCE WITH APPENDIX H

The American Society of Mechanical Engineers (ASME) Code of record for the SONGS, Unit 3, reactor pressure vessel is the 1971 Edition through the Summer 1971 Addenda. Consequently, the applicable version of American Society for Testing and Materials (ASTM) E185 is the 1970 version (ASTM E185-70). However, the surveillance program for SONGS, Unit 3, was updated to the later 1973 version which is in more complete agreement with the intent of 10CFR50, Appendix H. Appendix A to this report provides a detailed review of ASTM E185-73 along with validation that ASTM E185-73 requirements were satisfied for the surveillance program design. With respect to capsule testing and reporting requirements, the latest version of ASTM E185 is required, and these requirements have been updated as listed in Appendix A following ASTM E185-82 (the current approved version).

As stated in the SONGS, Units 2 and 3 Final Safety Analysis Report (FSAR), Appendix H, requirements were met (with one exception) through compliance with ASTM E185-73. The one exception to meeting 10CFR50, Appendix H requirements had to do with the method of attachment of the holders for the six surveillance capsules in each SONGS unit. ABB-CE was the vessel manufacturer and the NSSS vendor; ABB-CE attached the capsule holders directly to the cladding on the inside of the vessel in the beltline region (as they did for all ABB-CE NSSS-designed vessels), and this approach violated the requirements in the early 1970's version of 10CFR50, Appendix H. NRC reviewed a ABB-CE Topical Report (CENPD-155-P, C-E Procedure for the Design, Fabrication, Installation, and Inspection of Surveillance Holder Assemblies) and found the practice and procedures acceptable.

The current version of 10CFR50, Appendix H does not treat this method of attachment of the capsule holders as a noncompliance issue. The wording in the current Appendix H, Section I.A.2, is:

> "If the capsule holders are attached to the vessel wall or to the vessel cladding, construction and in-service inspection of the attachments and the attachment welds must be done according to requirements for permanent structural attachments to reactor vessels given in Sections III and XI of the ASME Code. The design and location of the capsule holders shall permit insertion of replacement capsules."

This wording was derived from the ABB-CE Topical Report, and the SONGS units have met the additional ASME Code, Sections III and XI, design and inspection requirements. Therefore, there are no deviations or exceptions needed from the current Appendix H of 10CFR50.

The details of the SONGS, Unit 3, surveillance program have been described in the FSAR and subsequent surveillance program testing reports, baseline [1] and irradiated.[2] The first capsule results have been evaluated for a low fluence following ASTM E185-82 testing and reporting requirements. Later sections of this report will discuss these results as compared to regulatory prediction methods.

The update of ASTM E185 for 1992 (E185-93) is about to be approved and issued. One significant change from E185-82 is the removal of the requirements for testing heat-affected-zone (HAZ) material. This change has resulted from the difficulty in interpreting HAZ results due to the degree of scatter and the ability to define the usefulness of blunt notch Charpy V-notch absorbed energy (C_{VN}) HAZ data. NRC has been involved in making this change to E185 through ASTM standards participation. Because of this forthcoming change to ASTM E185, this report does not evaluate HAZ results for SONGS, Unit 3; however, the raw data from prior HAZ testing on the SONGS, Unit 3, beltline material has been reported previously,[1-3] and is provided for reference in a subsequent section of this report.

Section 3

FRACTURE MECHANICS

This section evaluates compliance with 10CFR50, Appendix G, and identifies the location, heat treatment, key residual and alloying element contents, and unirradiated fracture toughness properties for plates and welds in the SONGS, Unit 3, reactor pressure vessel beltline region.

The information presented in this section has been obtained from the materials certification reports (MCRs), welding materials certifications (WMCs), the FSAR for SONGS, Unit 3, and from additional information supplied by ABB-CE to prepare this response. In some instances, additional information was obtained from the unirradiated baseline surveillance material report,[1] and the irradiated material in the 97° location surveillance capsule (Capsule 97), which was removed from Unit 3 at the end of the fourth fuel cycle.[2]

3.1 COMPLIANCE WITH APPENDIX G

The materials in the beltline region of SONGS, Unit 3, comply with the requirements of Appendix G, 10CFR50. A summary of compliance with 10CFR50, Appendix G, as specified in the FSAR for SONGS, Units 2 and 3, and updated during preparation of this report, is listed in Table 3.1.

3.2 BELTLINE MATERIALS IN SONGS, UNIT 3

3.2.1 Location

Figure 3-1 is a representation of the SONGS, Unit 3, reactor pressure vessel, and identifies the plates and welds and their location in the beltline region.

The heat numbers for the beltline plates shown in Figure 3-1 are presented in Table 3.2. The weld wire and flux combination for the beltline welds shown in Figure 3-1 and the surveillance welds are presented in Table 3.3. Source documentation has been obtained to confirm the properties of all beltline plates and welds.

3.2.2 Heat Treatment

The heat treatment for the plate materials consisted of austenitization at 1575 $\pm$ 50°F for 4 hours; water quenched and tempered at 1225 $\pm$ 25°F for 4 hours. For ASME Code qualification, the plates were stress relieved at 1150 $\pm$ 25°F for 40 hours and then were furnace cooled to 600°F at a rate of 100°F/hr. The actual time at temperature for a specific weld or a plate in the vessel depended upon the sequence of vessel fabrication; intermediate and final stress relief times were selected such that the total did not exceed 40 hours for any particular portion of the vessel.

Longitudinal weld seams would see stress relief times near the 40 hour maximum, while the closing girth weld in the beltline region would see approximately half this amount of time maximum. All of the testing of plate materials was performed on pieces with essentially an identical heat treatment as the actual reactor vessel. The surveillance weldment received a final 41-hour and 45-minute stress relief at 1100°F to 1150°F.

3.2.3 Key Residual and Alloying Element Contents

The copper (Cu), nickel (Ni), phosphorus (P) and sulfur (S) contents reported for each beltline plate are presented in Table 3.4. The plate Cu, Ni, P, and S contents were obtained by averaging two measurements made by ABB-CE. The first measurement was made when ABB-CE received the plate from Lukens, and the second measurement was made when the surveillance program was defined. The bases for the Cu, Ni, P, and S contents reported by CE and listed in Table 3.4 are presented in Appendix B.

A second set of data is included for Plate C6802-1. This set was obtained from broken surveillance specimens when the first irradiated surveillance capsule from Unit 3 was tested.[2]

Table 3.5 contains the Cu, Ni, P, and S contents reported for the beltline welds. The source documents for the information in Table 3.5 are presented in Appendices C and D. Three chemistry measurements have been made for the surveillance weld and also are reported in Table 3.5. The first chemistry measurement was made as part of the original baseline[1], while the second and third were obtained from broken Charpy specimens from Capsule 97[2].

The surveillance weld was reported by ABB-CE to have been fabricated using one of the weld wire and flux combinations in Weld 9-203 (see Table 3.3).

Tables 3.4 and 3.5 also include the chemistry factors determined for each reported set of Cu and Ni contents using Regulatory Guide 1.99, Revision 2.

3.3 FRACTURE TOUGHNESS RELATED DATA

This section presents the results from the C_{VN} tests, and summarizes the upper shelf energies (USE) and the results from the drop weight nil ductility temperature (NDT) tests for the unirradiated beltline plate and weld materials in SONGS, Unit 3. The unirradiated reference temperature (RT_{NDT}) values were determined from the C_{VN} and NDT test results in accordance with the most recent version of ASME Section III, NB-2331. The upper shelf energies were determined using the definition specified in ASTM E185-93 (to be issued). The data included in the USE determination were the C_{VN} values for those tests (at least 3) where the percent shear on the fracture surfaces was equal to and greater than 95%.

The fracture toughness data for the plate were obtained from the MCRs (see Appendix E of this report) and baseline surveillance program.[1] The fracture toughness data for the beltline welds were obtained from the FSAR and confirmed by WMCs (see Appendix D of this report), and the data for the surveillance weld was obtained from the baseline surveillance program. For convenience, the C_{VN}, lateral expansion, and fracture appearance (% shear) data for the unirradiated beltline and surveillance plate and weld materials are listed in tabular form in Appendix F of this report.

As discussed earlier in Section 2, the results for HAZ material are not evaluated in this report because upcoming ASTM standard E185-93 will not require HAZ material to be part of the surveillance program. The raw C_{VN} data for the past HAZ testing are attached in Appendix G of this report.

3.3.1 Beltline Plate Material

Because fracture toughness requirements for reactor pressure vessels are based on requirements to test specimens oriented transverse to the rolling direction, the data presented here are for the transverse (TL) orientation with one exception. The exception is for the beltline Plate C6802-1, which was included in the surveillance program. Because the surveillance program for SONGS, Unit 3, was reported to contain longitudinally (LT) oriented specimens, data obtained from the MCRs and the baseline surveillance program for specimen reported to be in the LT orientation are presented for completeness.

The transverse C_{VN} data as a function of test temperature for beltline Plate numbers C6802-1, -2, -3, -4, -5, and -6 are presented in Figures 3-2 through 3-7, respectively. For convenience, an average curve through the data is also shown in each figure. The average curves were determined using a least squares fit to the data and a hyperbolic tangent functional form, where the lower shelf was fixed at 2.2 ft-lb and the upper shelf was fixed at the value determined using the definition in ASTM E185-93 for specimens having fracture surfaces with 95% and greater shear. For convenience, the figures also indicate the values of NDT, USE, the temperature at which a minimum C_{VN} equals to 50 ft-lb (T @ 50 ft-lbs) is achieved consistent with the applicable method of ASME, Section III, NB-2331, and RT_{NDT}. As part of the surveillance program, additional C_{VN} versus temperature data were generated for Plate C6802-1;[1] these data are presented in Figure 3-8 along with a least squares fit curve.

The data obtained when the plate material was purchased (Figure 3-2) and the surveillance baseline data (Figure 3-8) were combined as shown in Figure 3-9. The average curve through the combined data set in Figure 3-9 was used as the unirradiated baseline to evaluate the results for the irradiated surveillance tests (see Section 4).

Table 3.6 is a summary of the unirradiated NDT, RT_{NDT}, and USE values for the TL orientation for each of the beltline plates in SONGS, Unit 3. The NDT for Plate C6802-1 also was determined twice. One value was measured when the material was purchased (-20°F), while the second value was determined from the unirradiated baseline tests (-10°F). The value measured when the plate was purchased (i.e., the MCR data) is listed in Table 3.6.

The methods used to determine RT_{NDT} from the NDT and C_{VN} data also are identified in Table 3.6. The method of NB-2331 (a)(3) was used to determine RT_{NDT} for all plates.

Figure 3-10 shows the data and least squares fit line for the LT orientation for surveillance Plate C6802-1,[1] while Figure 3-11 shows the data and least squares fit line for the LT orientation reported in the MCR for Plate C6802-1. A comparison of the information in Figures 3-10 and 3-11 indicates a significant difference in the C_{VN} versus temperature curves obtained from the MCR and surveillance program in the LT orientation for Plate C6802-1. An additional review of the C_{VN} versus temperature curves for the beltline plates in SONGS, Unit 3, was performed to assess the source of the difference in the Charpy curves obtained in the LT orientation for Plate C6802-1 from the MCRs and surveillance program. A comparison of the data reported in the MCRs for the LT orientation for all other beltline plates indicated relatively large differences between the MCR and surveillance program data. This result indicates that the surveillance plate was not made from one of the other plates in the SONGS, Unit 3, beltline.

Based on these comparisons, the baseline and irradiated surveillance data for the LT orientation are not used for assessing the SONGS, Unit 3, beltline plate because: (1) source material indicate surveillance specimens reported to be in the LT orientation are not representative of the LT orientation of any of the beltline plates, and (2) adequate surveillance specimens for the required TL direction currently are available to satisfy Appendix H to 10CFR50. Although the results for the LT orientation are not used in Section 4 for assessing irradiation response, the tabulated data for irradiated LT data are included for reference in Appendix H to 10CFR50.

3.3.2 Beltline Welds

A full C_{VN} versus temperature curve was obtained for the material in Weld Seams 3-203 A, B, C, and the data points and least squares hyperbolic tangent fit through the data are presented in Figure 3-12. A full C_{VN} versus temperature curve was obtained for the Type Mil B-4 Wire, Heat No. 90069, Linde Type 124 Flux, Lot No. 0951 and Heat No. 90144, Linde Type 124 Flux, Lot No. 1061 in beltline Weld Seam 9-203; the C_{VN} data and least squares hyperbolic tangent fits through the data are presented in Figures 3-13 and 3-14, respectively. The material in beltline Weld Seams 2-203 A, B, C was tested to obtain three C_{VN} data points at 20°F. The results from these tests are presented in Table 3.7.

Figure 3-15 presents the C_{VN} data and least squares hyperbolic tangent curve fit for the surveillance weld material, which was reported by ABB-CE to be wire heat 90069 (see Table 3.3). However, a comparison of Figure 3-13 (Weld 9-203, wire heat 90069) with Figure 3-15 indicates a relatively large difference between the impact energy versus temperature curves in the transition and upper shelf regions. But a comparison of Figure 3-14 (Weld 9-203, wire heat 90144) with Figure 3-15 indicates the impact energy versus temperature curves are in close proximity. Currently, no information is available to explain the difference in the impact data for the surveillance weld and Weld 9-203, wire heat 90069. However, based on the chemistry and impact properties of the surveillance weld, the surveillance weld does provide a conservative representation of Weld 9-203 overall, and is adequate to assess the shift in reference temperature and drop in upper shelf energy for the SONGS, Unit 3 surveillance program.

Table 3.8 presents a summary of the unirradiated NDT, RT_{NDT}, and USE values for each of the beltline welds in SONGS, Unit 3. For Welds 2-203 A, B, C, 3-203 A, B, C, 8-203 and 9-203 (wire Heat Nos. 90069 and 90144), available C_{VN} data indicate that there is a minimum of 50 ft-lb absorbed energy at 60°F above NDT and, consequently, RT_{NDT} equals NDT.

Because fewer than three specimens were tested at each temperature, the graphical method of NB-2331 (a)(4) was used to determine RT_{NDT} for the surveillance weld as shown by the intersection of the dashed line and the 50 ft-lb C_{VN} level in Figure 3-15.

The upper shelf energies listed in Table 3.8 for Welds 3-203 A, B, C, 9-203, and the surveillance weld were obtained by averaging the test results where 95% shear or greater was exhibited. The USE for Welds 2-203 A, B, C was obtained from the data in Table 3.7 by averaging the three C_{VN} data points obtained at 20°F. The USE for Weld 8-203 was obtained from the data in Table 3.7 by averaging the three C_{VN} data points obtained at +10°F. It was determined that the CVN data at -10°F were not on the Upper Shelf.

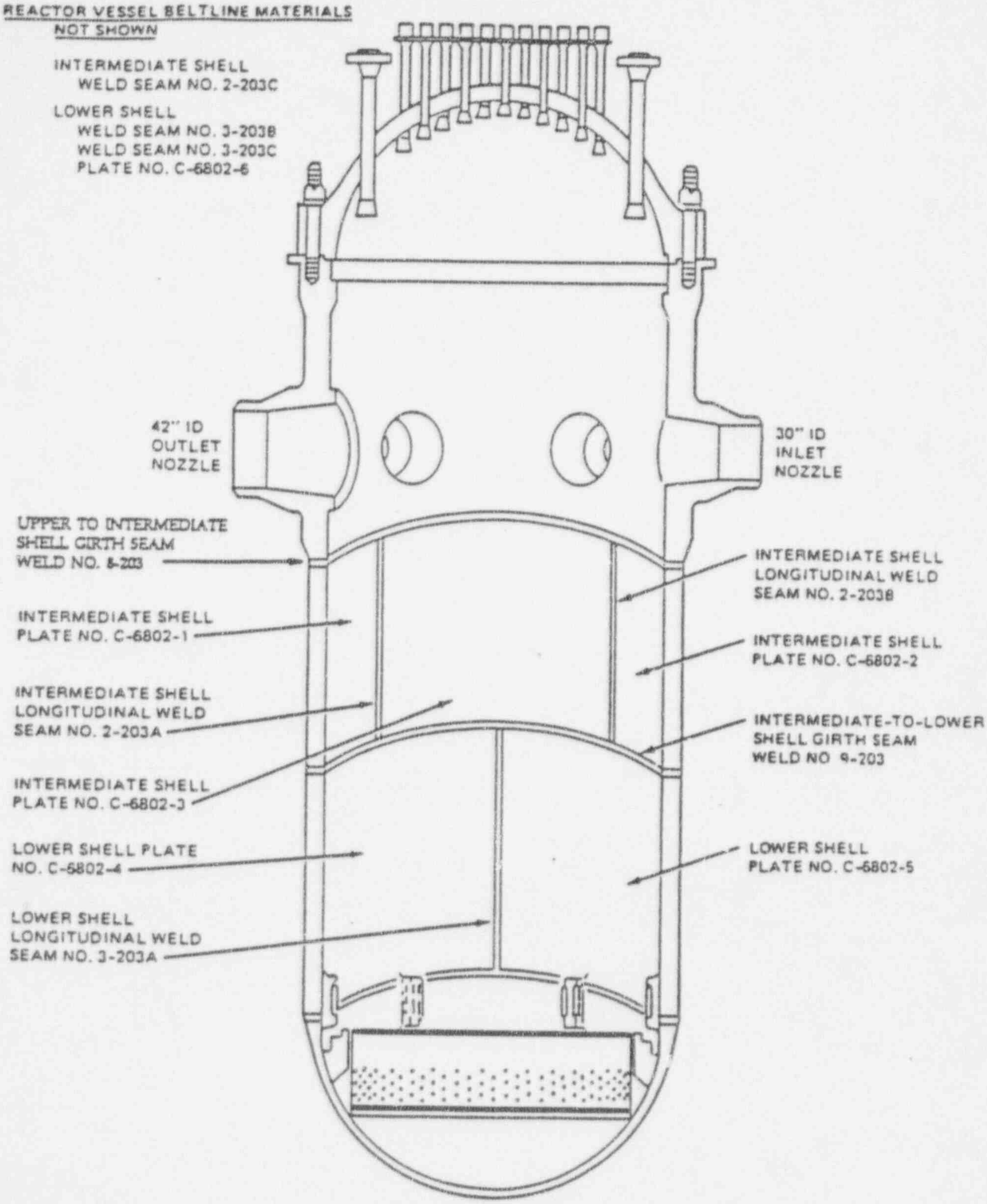

Figure 3-1. SONGS, Unit 3: Location and Identification of Beltline Plates and Welds.

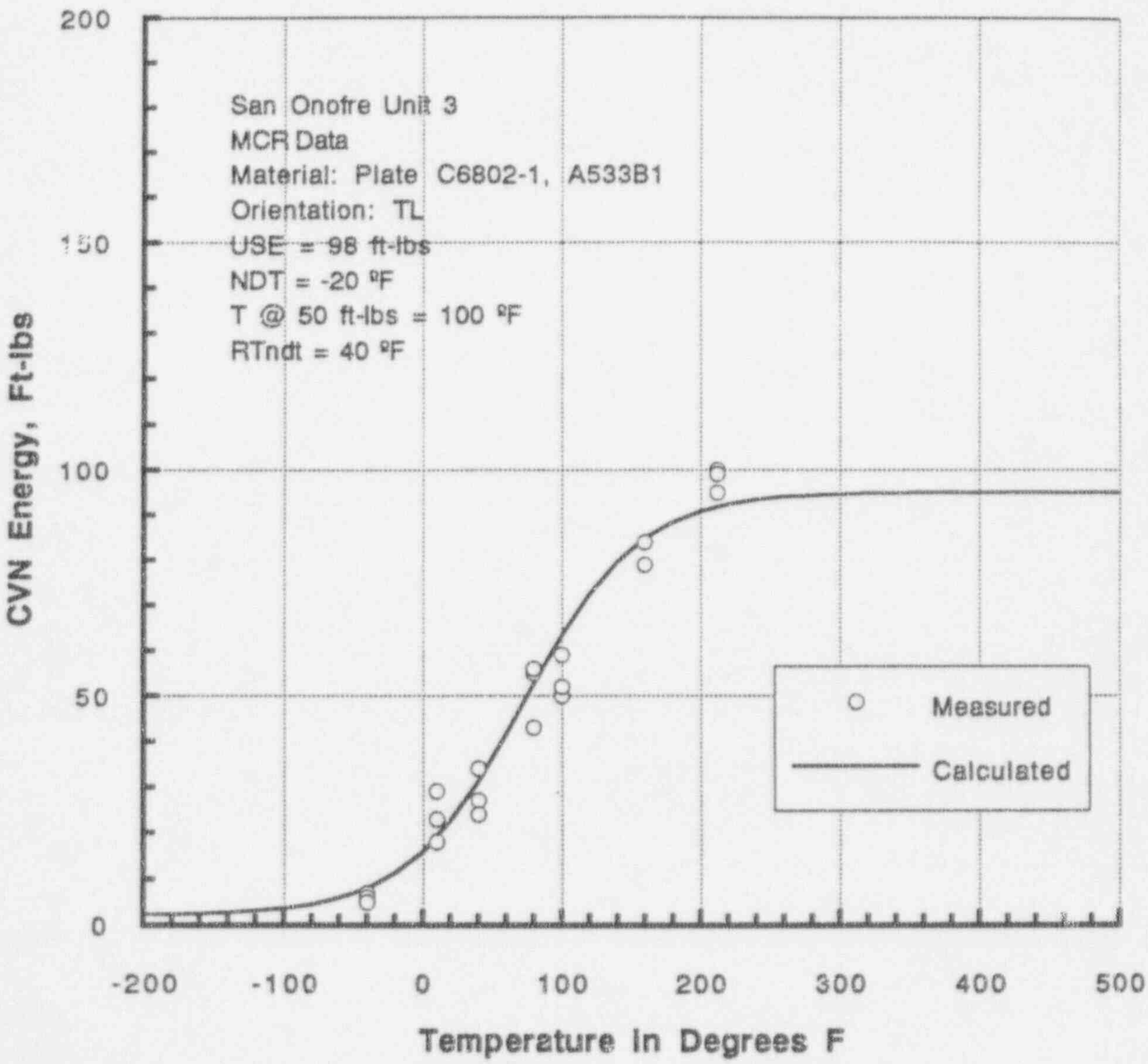

Figure 3-2. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, TL Orientation, MCR Data.

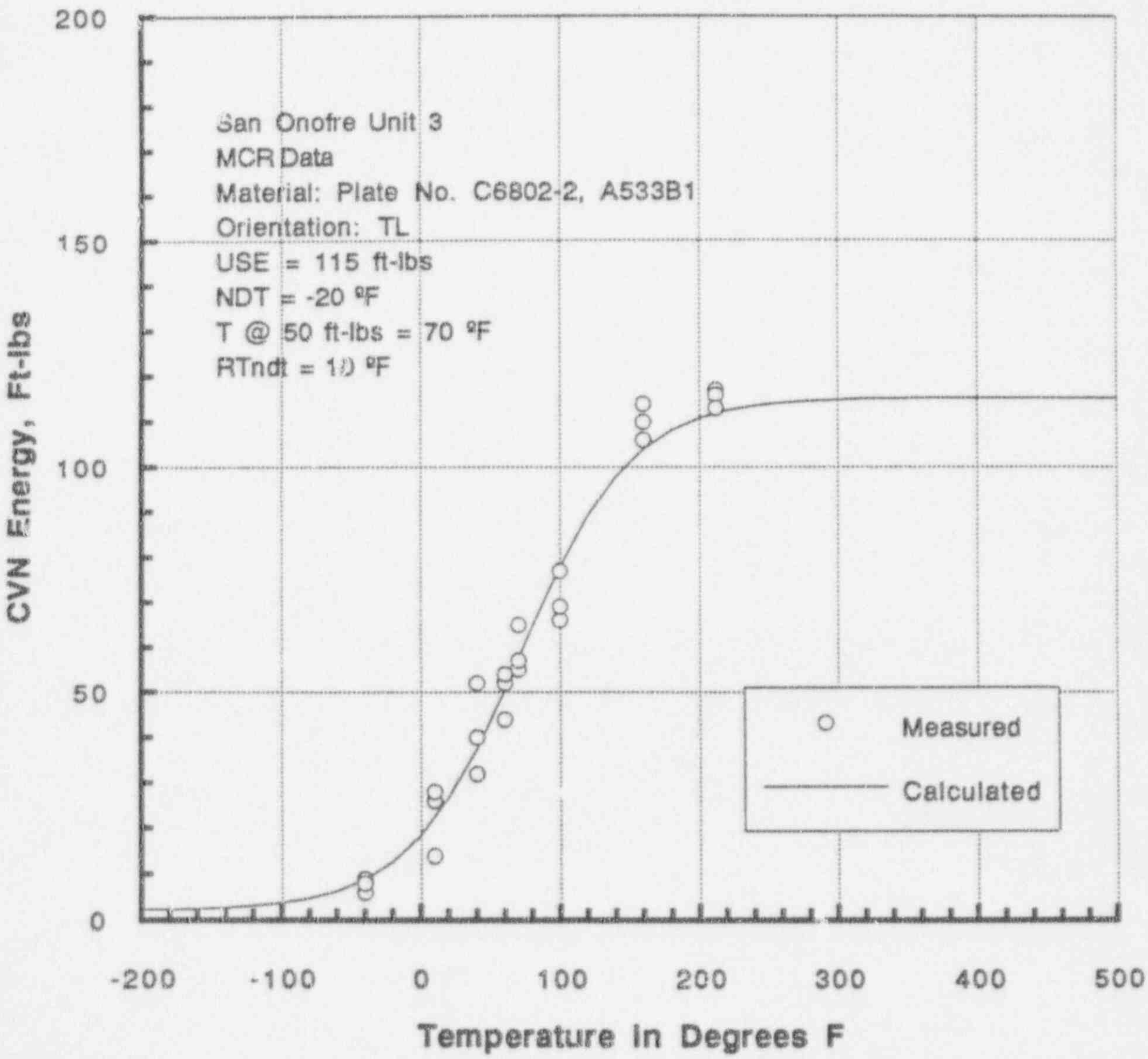

Figure 3-3. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-2, TL Orientation, MCR Data.

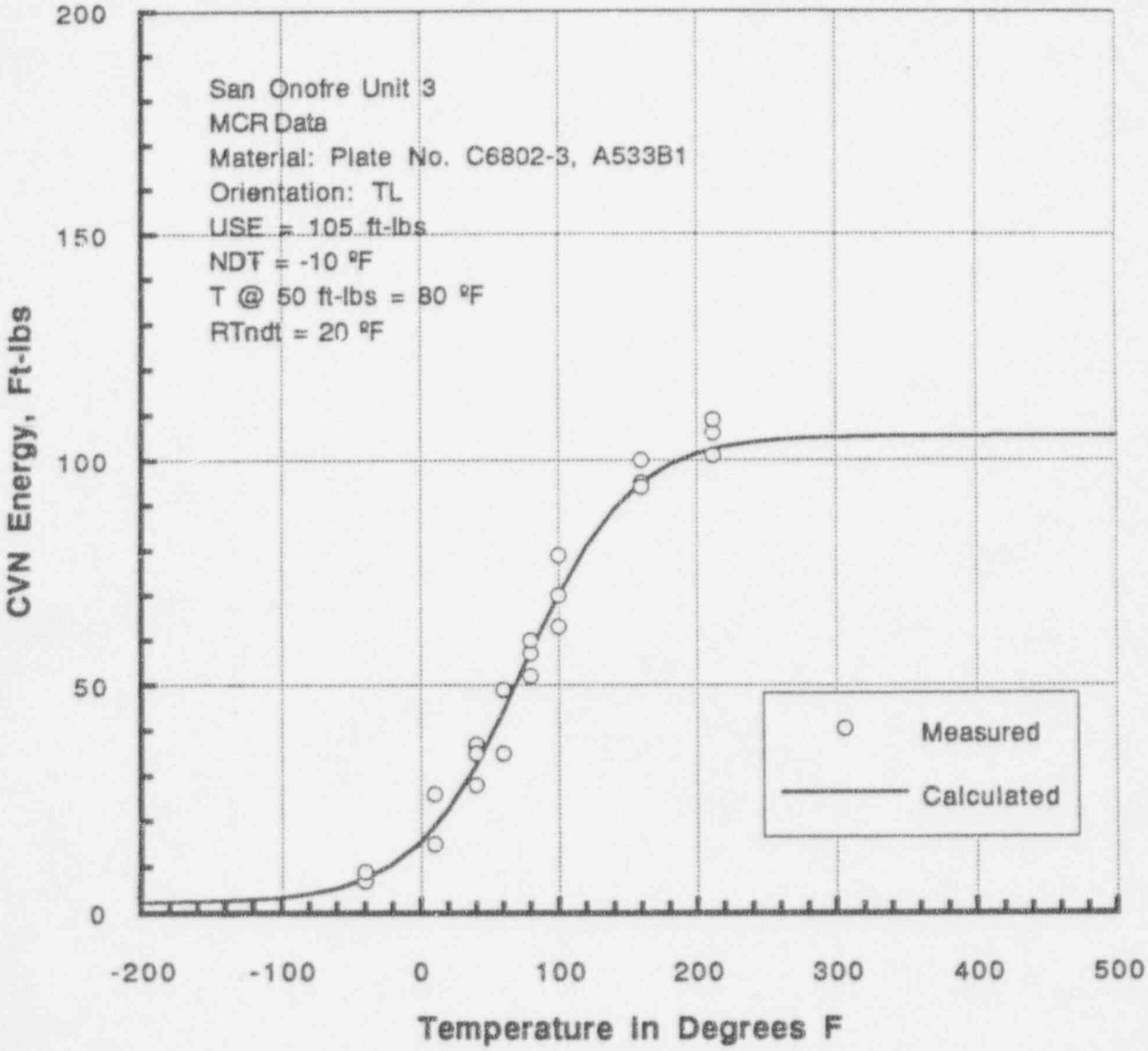

Figure 3-4. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-3, TL Orientation, MCR Data.

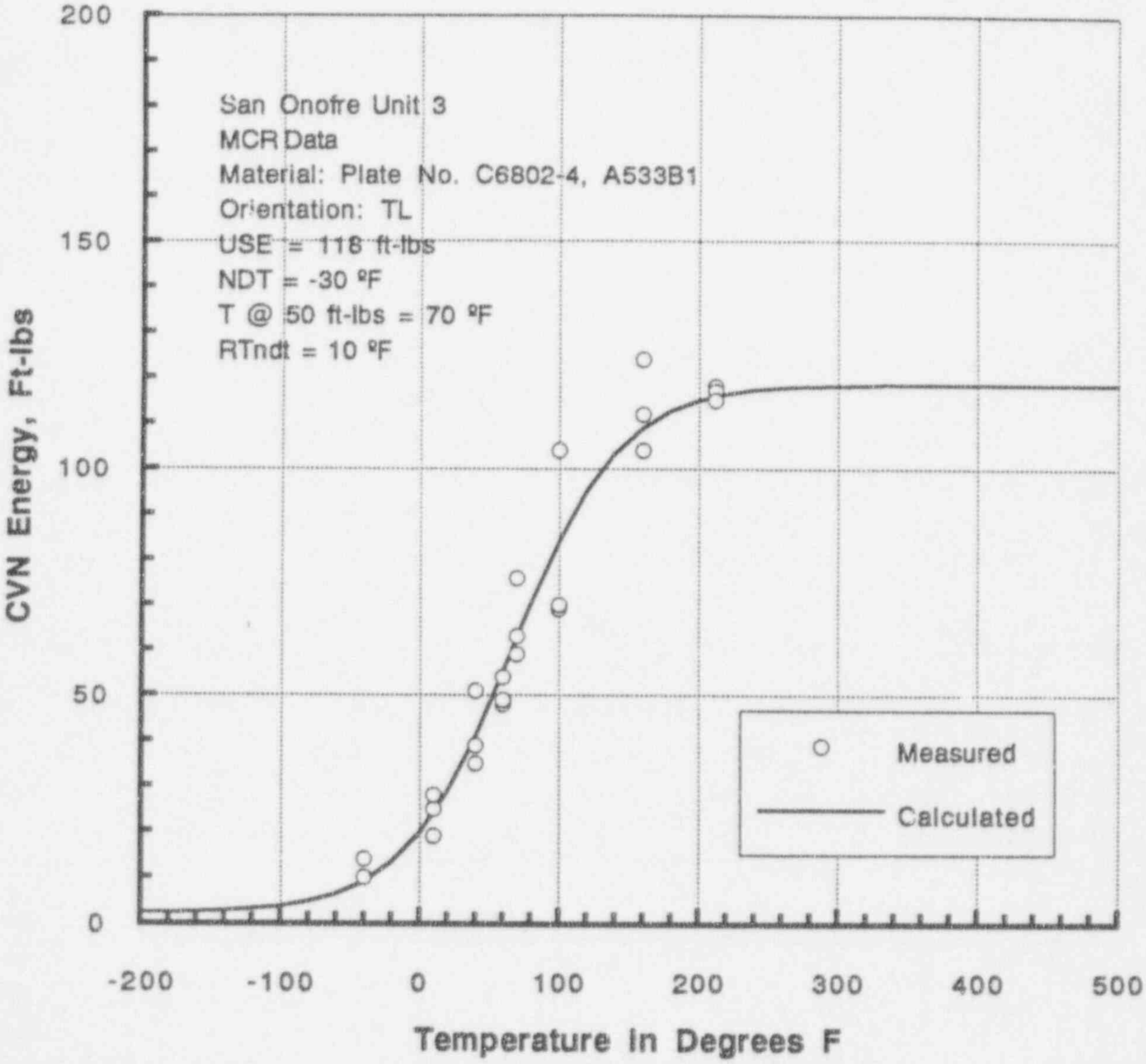

Figure 3-5. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-4, TL Orientation, MCR Data.

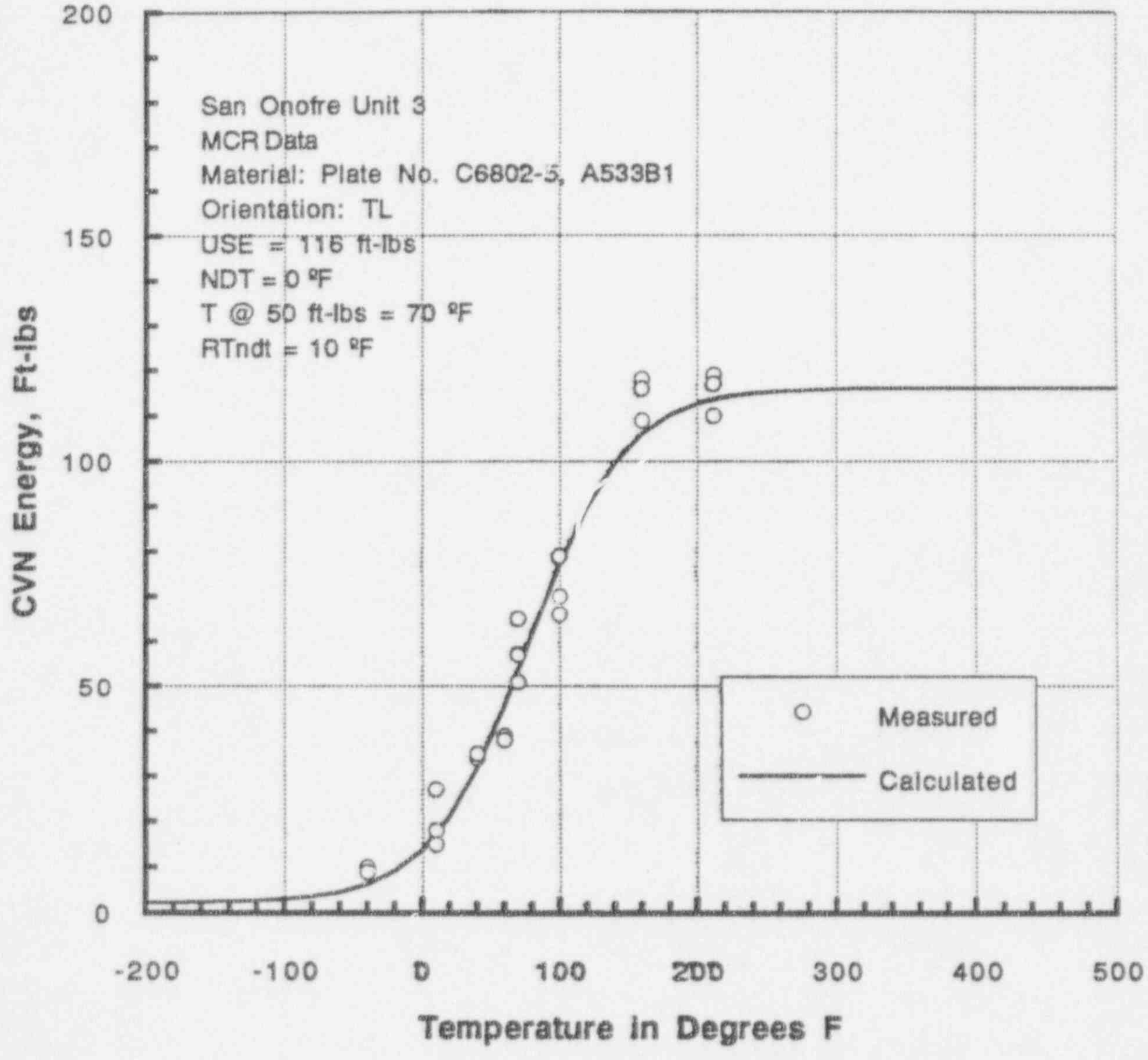

Figure 3-6. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-5, TL Orientation, MCR Data.

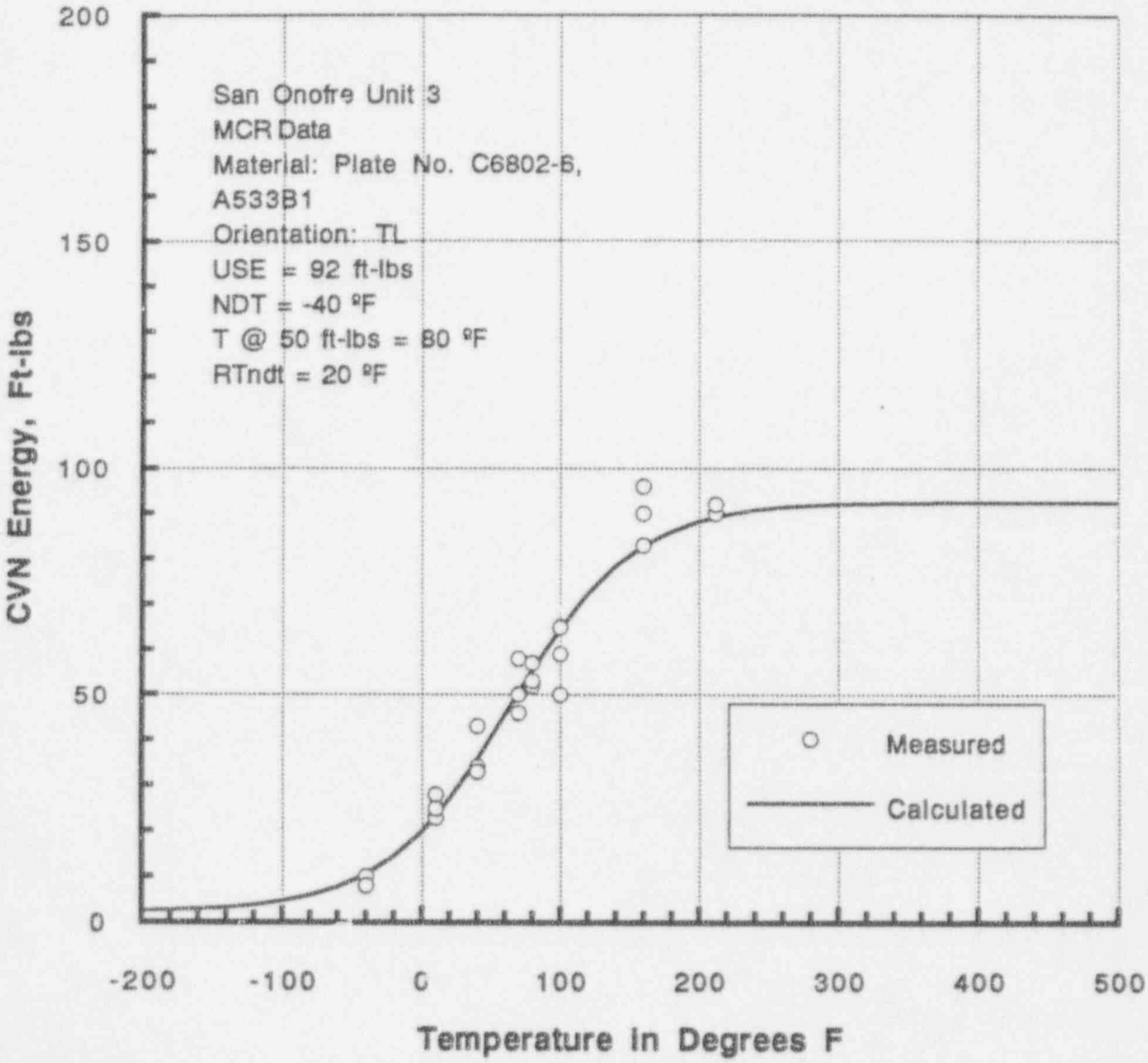

Figure 3-7. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-6, TL Orientation, MCR Data.

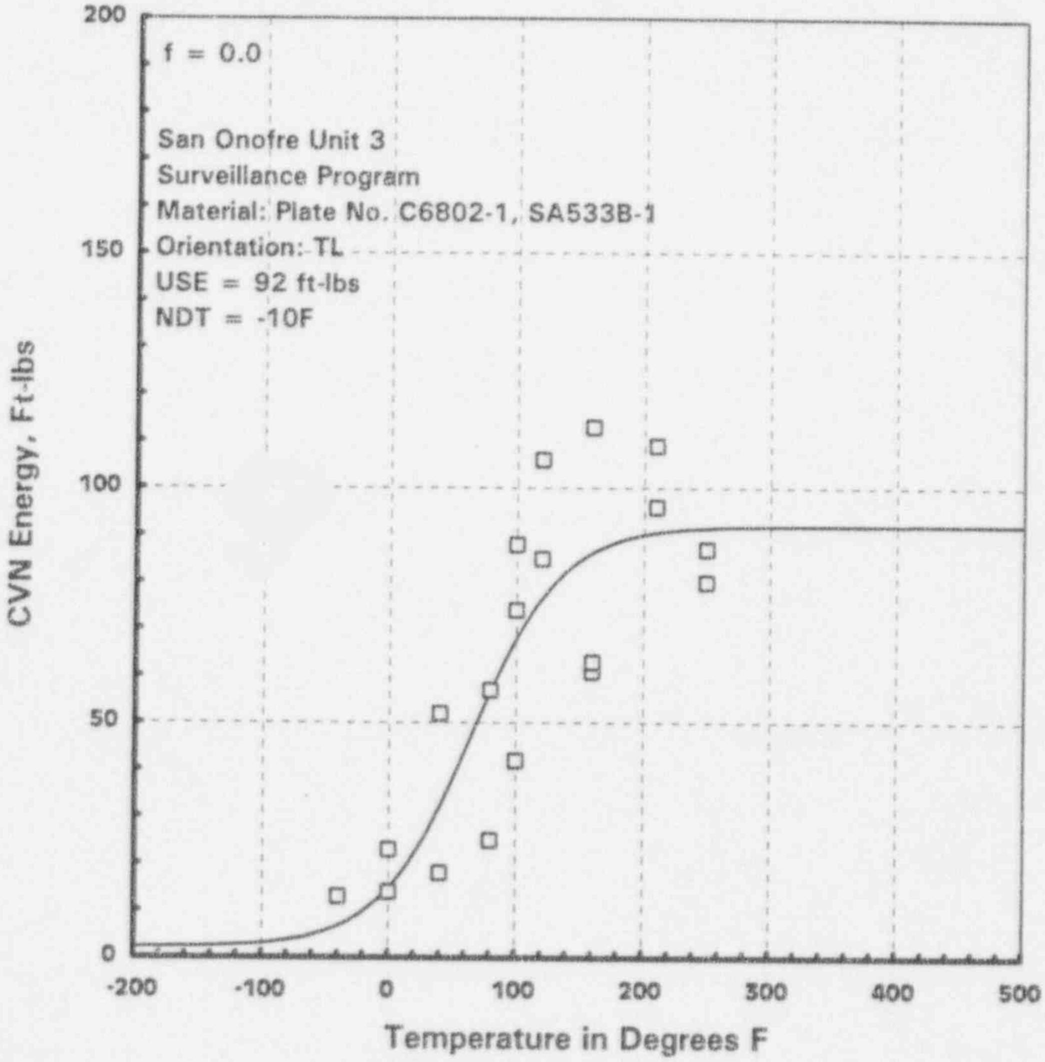

Figure 3-8. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, TL Orientation, Surveillance Baseline Data.

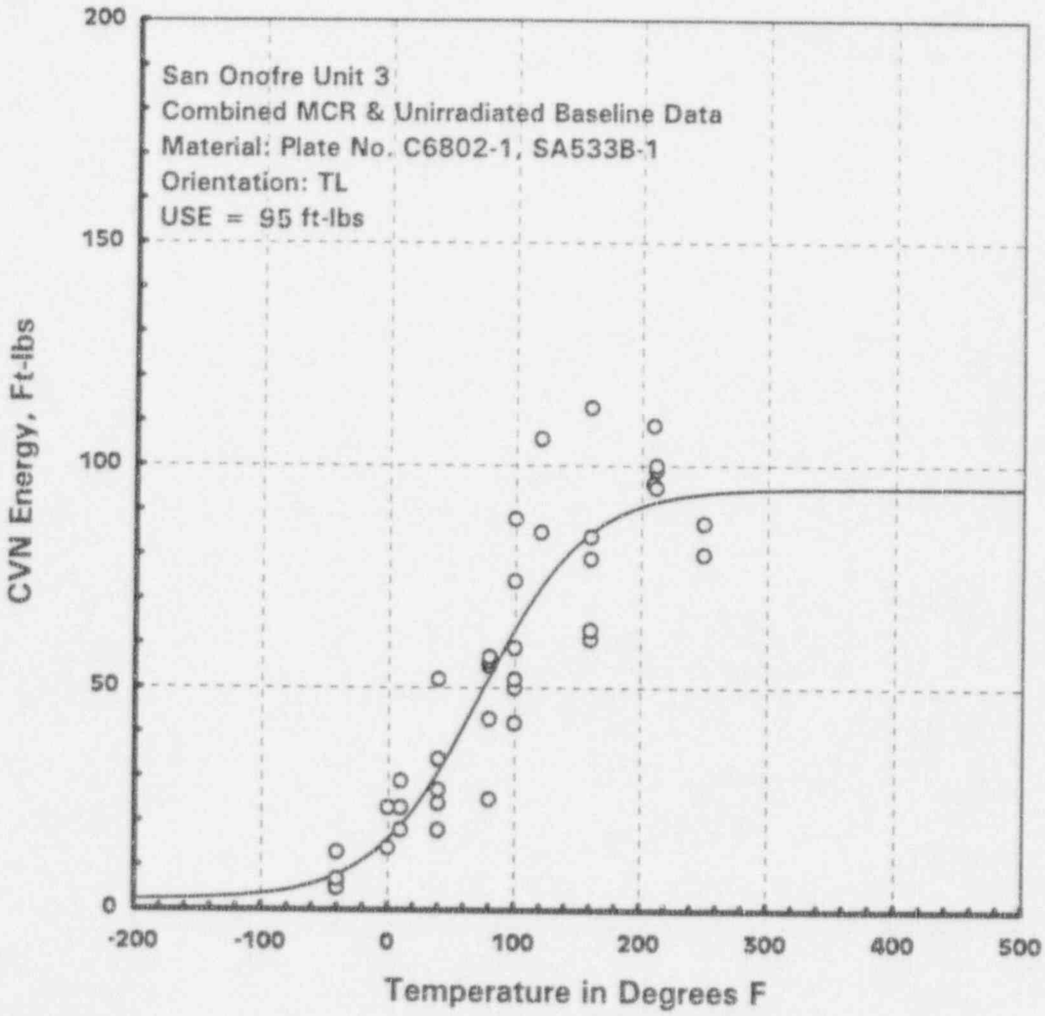

Figure 3-9. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, TL Orientation, Combined MCR and Surveillance Baseline Data.

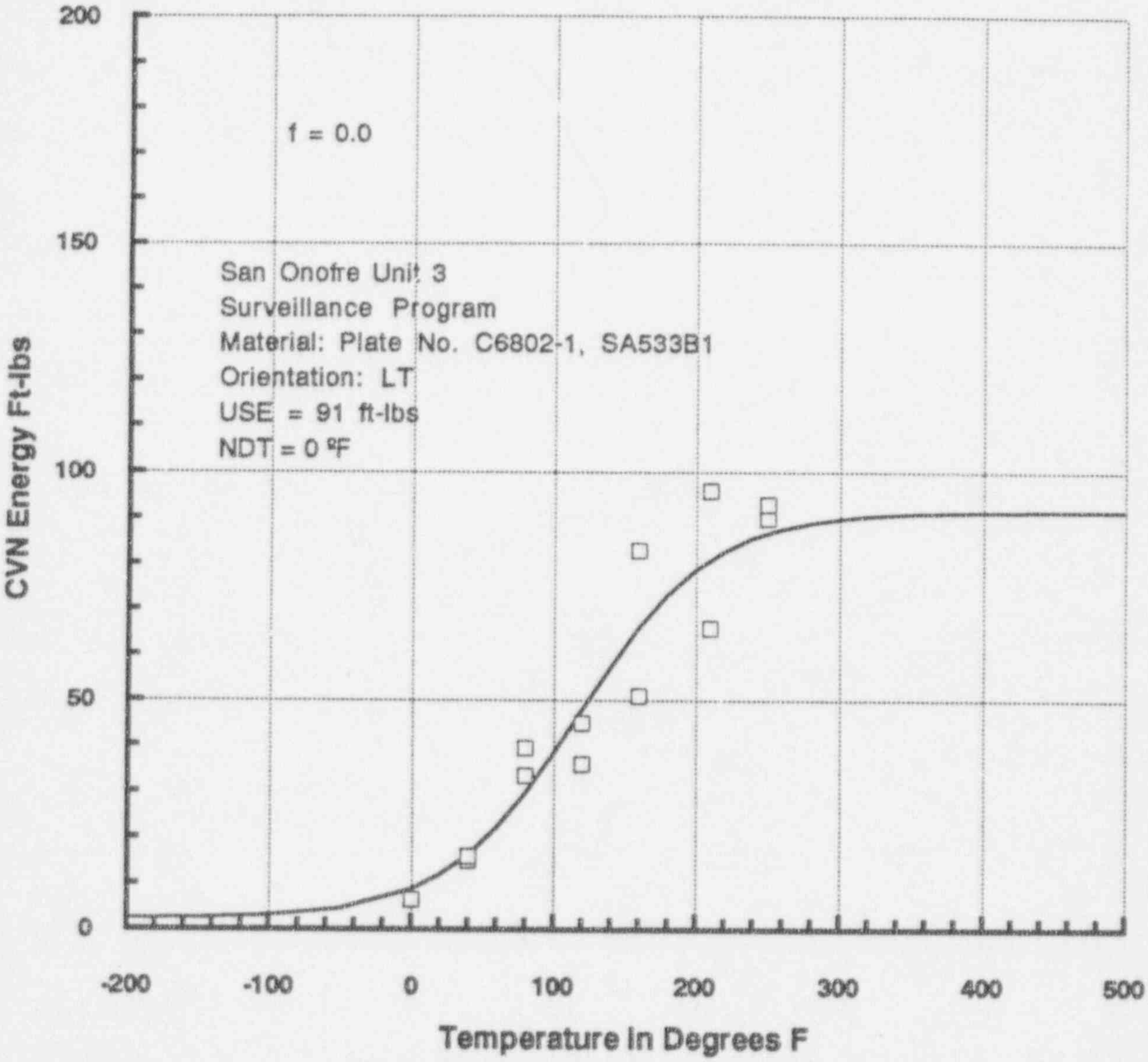

Figure 3-10. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, LT Orientation, Surveillance Baseline Data.

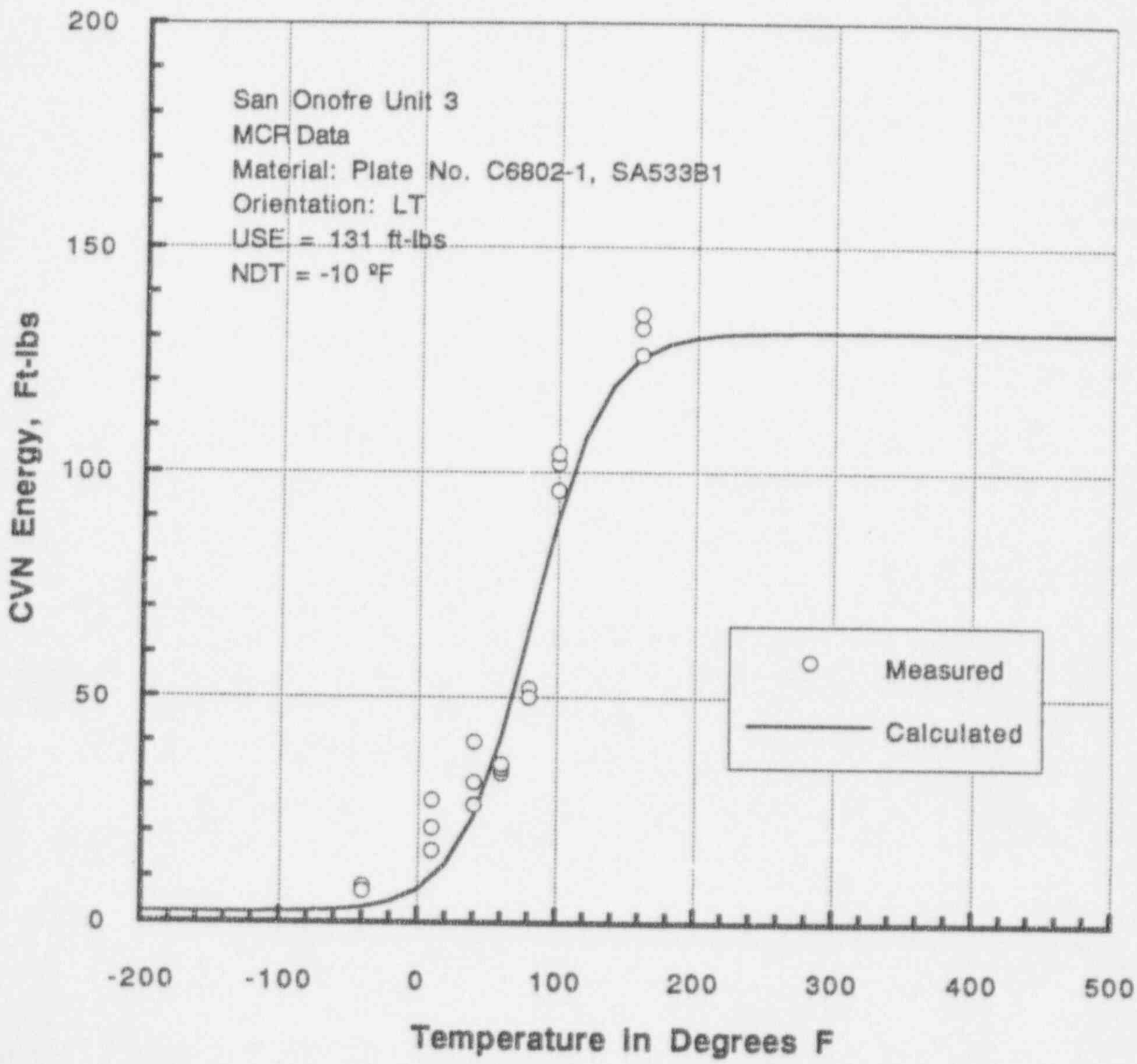

Figure 3-11. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, LT Orientation, MCR Data.

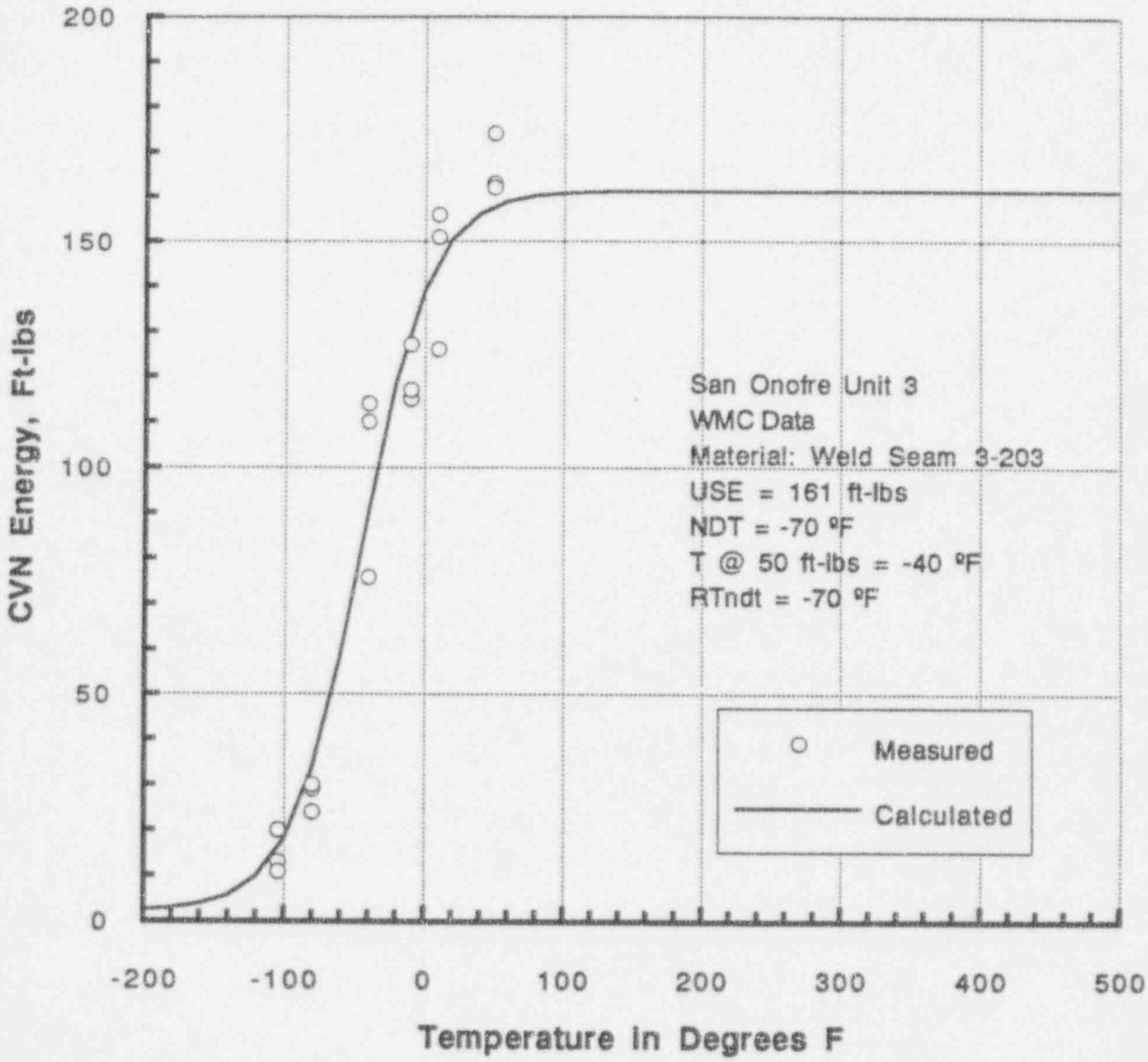

Figure 3-12. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Weld 3-203, WMC Data

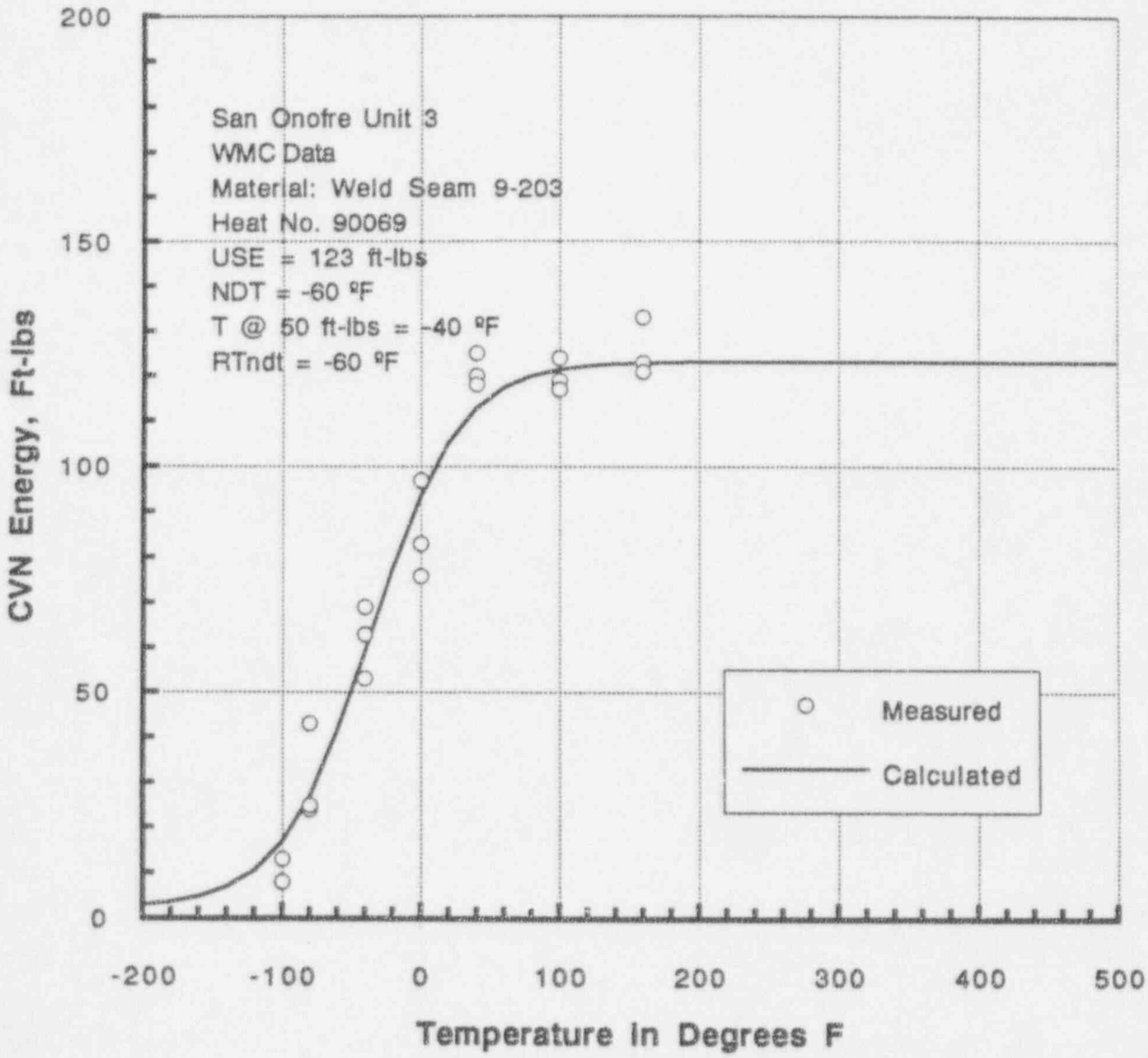

Figure 3-13. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Weld 9-203 (Heat No. 90069), WMC Data.

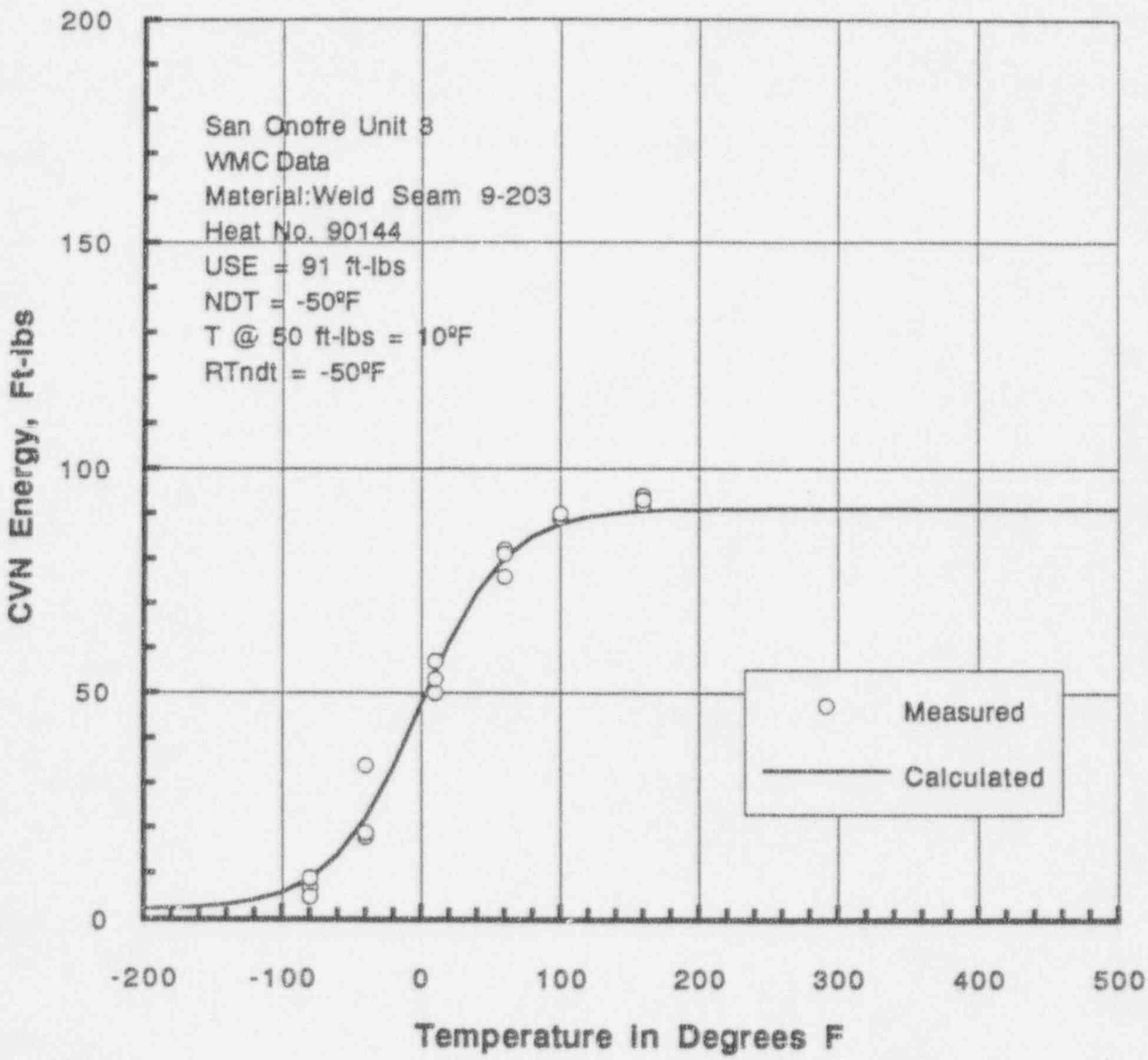

Figure 3-14. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Weld 9-203 (Heat 90144), WMC Data.

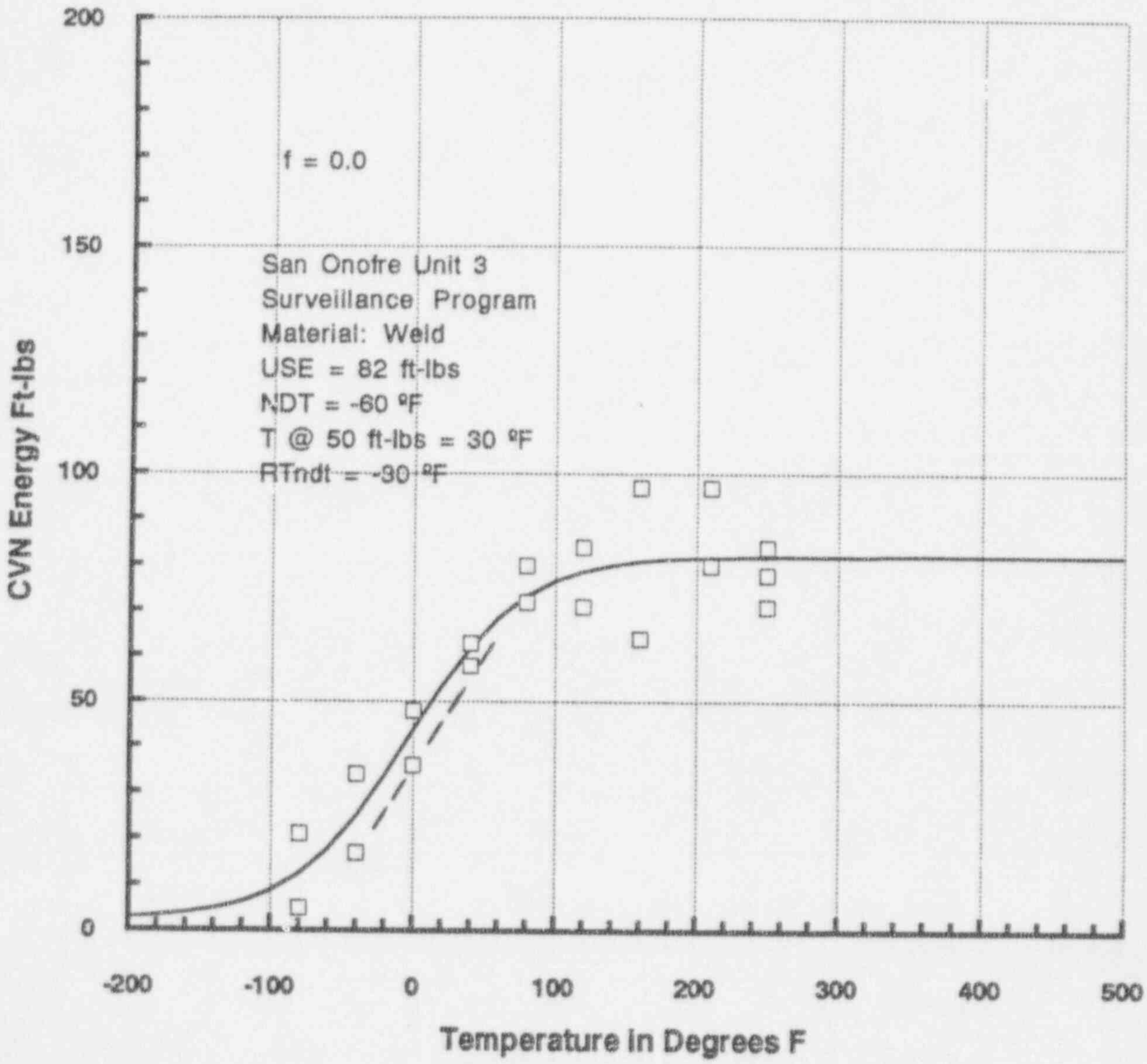

Figure 3-15. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Surveillance Weld, Surveillance Baseline Data.

Table 3.1 SONGS, Unit 3: Compliance with 10CFR50, Appendix G.

Paragraph	Description of Non-Compliance	Comment
II.B	Series 4xx stainless steels are purchased and treated to Code requirements. No RT_{NDT} or drop weight T_{NDT} temperatures are determined.	Consistent with ASME Code in effect.
III.B.5.a	Records of fracture toughness testing do not include a certification that tests were performed in accordance with Appendix G.	Appendix G was not applicable at the time tests were performed. Certification to the applicable ASME Code is included. The intent of Appendix G is met.
III.C.	"Reactor Vessel Beltline", as defined by Paragraph II.H, includes the weld heat-affected-zones. Section III.C is not complied with in that only base plate and represent-active welds in the beltline region were considered for the required testing.	The baseline tests of the surveillance program include weld and HAZ material from the most limiting plate. Results available for SONGS Unit 3 indicate that the intent of Appendix G has been met (Note: the HAZ results are not presented in this report)
III.C.1	Only single-temperature testing was performed for some weld materials. Only the heat-affected-zone from the most limiting plate was tested over an extended temperature range.	Consistent with ASME Code in effect.
III.C.2	Excess material for test specimen weldment is not necessarily from the actual production plate, although it is the same P-number. (Section IX, ASME Code)	The same combinations of a specific heat of filler wire and a specific lot of flux welded under the same production conditions as those used in joining the corresponding shell materials were used.

Table 3.1 (Continued)

Paragraph	Description of Non-Compliance	Comment
IV.A.4	Charpy V-notch tests were not conducted at "the preload temperature or at the lowest service temperature, whichever is lower".	The ASME Code in effect required test temperature of 60°F below the lowest service temperature. All bolting material was tested at 10°F and met the 35 ft-lb minimum requirement of the applicable ASME Code. All beltline plate materials and two beltline welds were tested to meet the current (1989) Code requirements in NB-2331. One beltline weld was tested at 10°F and another at 20°F and both had C_{VN} in excess of 100 ft-lb. These results indicate that the intent of Appendix G has been met.

Table 3.2 SONGS, Unit 3: Plate and Corresponding Heat Numbers for the Beltline Plates.

Plate Number	Lukens Heat Number
C6802-1	C9195-2
C6802-2	C9218-2
C6802-3	C9195-1
C6802-4	C9220-1
C6802-5	C9218-1
C6802-6	B3388-1

Table 3.3 SONGS, Unit 3: Weld Wire and Flux Combinations for Beltline and Surveillance Welds.

Weld Seam	Weld Wire and Flux
2-203 A, B, C[a]	Type Mil B-4 Wire, Heat No. 83650, Linde Type 0091 Flux, Lot No. 1122
3-203 A, B, C[a]	Type Mil B-4 Wire, Heat No. 88114, Linde Type 0091 Flux, Lot No. 0145
9-203[b]	Combination of (1) Type Mil B-4 Wire, Heat No. 90069, Linde Type 124 Flux, Lot No. 0951, and (2) Type Mil B-4 Wire, Heat No. 90144, Linde Type 124 Flux, Lot No. 1061
8-203[c]	Type Mil B-4 Wire, Heat No. 88118, Linde Type 0091 Flux, Lot No. 0145
Surveillance[c]	Type Mil B-4 Wire, Heat No. 90069, Linde Type 124 Flux, Lot No. 0951

a. Basis is SONGS Unit 3 FSAR and is consistent with handwritten note in Appendix D.

b. Basis is SONGS Unit 3 FSAR for weld wire heat 90069 and is consistent with handwritten note in Appendix D. Weld wire heat 90144 was provided by CE as the second weld wire used to fabricate this seam.

c. Weld wire heat number and flux type confirmed by ABB-CE letter dated November 4, 1993 contained in Appendix D.

Table 3.4 SONGS, Unit 3: Key Residual and Alloying Element Contents for Beltline Plates.[a]

Plate Number	ABB-CE Lab No.	Cu	Ni	P	S	CF[b]
C6802-1	P14214 P18195	0.06	0.58	0.005	0.013	37
C6802-1[c]		0.06	0.58	0.009	0.014	37
C6802-2	P14244 P18196	0.04	0.57	0.009	0.013	26
C6802-3	P14223 P18197	0.06	0.58	0.005	0.012	37
C6802-4	P14452 P15391	0.05	0.56	0.007	0.010	31
C6802-5	P14453 P15392	0.04	0.55	0.011	0.013	26
C6802-6	P14454 P15393	0.06	0.62	0.007	0.013	37

a. Average values (see Appendix B)

b. Chemistry factors from Regulatory Guide 1.99, Revision 2

c. Measured when the surveillance tests were performed for Capsule 97[2]

Table 3.5 SONGS, Unit 3: Key Residual and Alloying Element Contents for Beltline Welds.

Weld Seam	ABB-CE Lab No.	Cu	Ni	P	S	CF[a]
2-203A	D17360	0.04	0.17	0.011	0.012	40
2-203B	D17361	0.05	0.21	0.011	0.013	50
2-203C	D17362	0.04	0.08	0.010	0.012	32
3-203A	D22245	0.04	0.21	0.012	0.008	44
3-203B	D22246	0.04	0.19	0.012	0.008	42
3-203C	D22247	0.04	0.21	0.011	0.008	44
9-203[b]	D23985	0.06	0.04	0.010	0.009	34
9-203[c]	D28503	0.05	0.04	0.007	0.011	31
8-203	D17888	0.05	0.17	0.009	0.008	46
Surveillance[d]	D30342	0.03	0.08	0.004	0.009	27
Surveillance[e]		0.03	0.11	0.014	0.008	29
Surveillance[e]		0.03	0.09	0.011	0.008	28

a. Chemistry Factors determined from Regulatory Guide 1.99, Revision 2

b. Values from WMC for Type Mil B-4 Wire, Heat No. 90069, Linde Type 124 Flux, Lot No. 0951--see Appendix D

c. Values from WMC for Type Mil B-4 Wire, Heat No. 90144, Linde Type 124 Flux, Lot No. 1061--see Appendix D

d. Measured when surveillance program was developed[1]

e. Measured when the surveillance tests were performed for Capsule 97[2]

Table 3.6 SONGS, Unit 3: Beltline Plate Material Unirradiated Fracture Toughness Tests Results Summary, TL Orientation.

Plate Number	NDT (°F)	Initial RT_{NDT} (°F)	Procedure to Determine RT_{NDT}	USE (ft-lbs)
C6802-1[a]	-20[b]	40	NB2331 (a)(3)	95
C6802-2	-20	10	NB2331 (a)(3)	115
C6802-3	-10	20	NB2331 (a)(3)	105
C6802-4	-30	10	NB2331 (a)(3)	118
C6802-5	0	10	NB2331 (a)(3)	116
C6802-6	-40	20	NB2331 (a)(3)	92

a. This plate is included in the surveillance program. RT_{NDT} is based on the MCR data (see Figure 3-2), and the USE value is based on the combined data sets from the MCRs and unirradiated surveillance baseline (see Figure 3-9)

b. An NDT value of -20°F was determined when the plate was purchased (-10°F was determined from the baseline surveillance program).

Table 3.7 SONGS, Unit 3: Charpy Absorbed Energy Values for Weld Seams 2-203 A, B and C, and Weld Seam 8-203.

Weld Seam	Test Temperature (°F)	Charpy Energy (ft-lb)
2-203 A, B, C	+20	125, 138, 145
8-203	-10	95, 84, 94
	+10	137, 118, 119

Table 3.8 SONGS, Unit 3: Beltline Weld Material Unirradiated Fracture Toughness Tests Results Summary.

Weld Seam	NDT (°F)	Initial RT_{NDT} (°F)	Procedure to Determine RT_{NDT}	USE (ft-lbs)
2-203 A, B, C	-40[a]	-40	NB-2331 (a)(2)	136[b]
3-203 A, B, C	-70[a]	-70	NB-2331 (a)(2)	161
8-203	-70	-70	NB-2331 (a)(2)	125[c]
9-203 (90069)	-60[d]	-60	NB-2331 (a)(2)	123
9-203 (90144)	-50[e]	-50	NB-2331 (a)(2)	91
Surveillance	-60	-30	NB-2331 (a)(4)	82

a. NDT values obtained from the FSAR and documented in Appendix D

b. Estimated using the average of C_{VN} values obtained at +20°F (see Table 3.7)

c. Estimated using the average of C_{VN} values obtained at +10°F (see Table 3.7)

d. Value obtained from the WMC, for Type Mil B-4 Wire, Heat No. 90069, Linde Type 124 Flux, Lot No. 0951 -- see Appendix D

e. Value obtained from the WMC for Type Mil B-4 Wire, Heat No. 90144, Linde Type 124 Flux, Lot No. 1061 -- see Appendix D

Section 4

ISSUES RELATED TO GENERIC LETTER 88-11

NRC issued Generic Letter 88-11 (GL 88-11) in July 1988. GL 88-11 letter revised the methodology used for estimating radiation embrittlement of reactor pressure vessel materials to be consistent with the guidelines in Regulatory Guide 1.99, Revision 2. Several technical issues have recently emerged which indicate a need to address some of the application assumptions used in Regulatory Guide 1.99, Revision 2. The pertinent issues brought out in GL 92-01 are addressed in this section.

4.1 VESSEL TEMPERATURE DURING OPERATION

The methodology in Regulatory Guide 1.99, Revision 2, is specified to be applicable for operating temperatures in the range of 525 to 590°F. Concern is expressed in GL 92-01 that power operation may occur at temperatures below 525°F. For SONGS, Unit 3, the reactor coolant cold leg temperature (T_c) is maintained above the Technical Specification limiting condition for operation of 535°F which applies above 30% power. The normal operating band of T_c ranges from 545°F at zero power to 553°F at 100% power with a tolerance of $\pm$ 2°F. Thus, there is no time during normal power operation that the SONGS, Unit 3, vessel or surveillance capsules experience temperatures below 525°F.

4.2 APPLICABILITY OF SURVEILLANCE DATA

To properly assess the measured surveillance results and to project irradiation embrittlement trends for the vessel, fluence projections, validated through the dosimetry contained in the surveillance capsules tested to date, are needed. Both SONGS, Units 2 and 3, have identical core designs and essentially the same past and projected operation history. Therefore, the fluence projections from Units 2 and 3 surveillance data will be used for each unit. The fluence as a function of effective full power years (EFPY) was obtained from the results of the first capsules pulled from Units 2 and 3.

The Unit 2 capsule was pulled at the end of the third fuel cycle which corresponds to 2.85 EFPY.[5] These data represent the original core for both units, and the best estimate value of peak fluence at the vessel inner surface is 4.34×10^{18} n/cm^2 (E > 1 MeV); the capsule fluence was about 20% higher at 5.07×10^{18} n/cm^2.

At the start of the fourth cycle for each unit, the core was reconfigured in a low leakage loading pattern which reduced the vessel and capsule fluxes. The first capsule taken out of Unit 3 was after the fourth fuel cycle at 4.33 EFPY and represents the combined results of the standard and low leakage core designs.[2] The peak fluence value at the vessel inner surface is 6.6×10^{18} n/cm^2, and the associated capsule fluence is 8.0×10^{18} n/cm^2.

The projection of fluence forward in time is based upon an extrapolation of the dosimetry information obtained from the two SONGS capsules. The projected peak fluence at the vessel inner surface at the end of 32 EFPY is 4.2×10^{19} n/cm^2.[2] At the point in time of December 16, 1991, the estimated EFPY is 5.63, and the projected peak fluence at the vessel inner surface is 8.5×10^{18} n/cm^2.

As indicated in Figure 3-1, there is a weld identified as 8-203 which is well outside the core region of the vessel (i.e., approximately 2 feet above the top of the core). In earlier versions of the report, Weld 8-203 was conservatively considered a beltline material because the Cu and Ni contents were unreported. Therefore, conservative values were assumed resulting in a very high chemistry factor. In addition, the fluence at Weld 8-203 had been reported in the FSAR to be about 1/37 that of the peak fluence in the vessel. This fluence, in combination with the high assumed chemistry factor, resulted in predicted shifts in reference temperature as high as those for materials directly surrounding the core. However, recently obtained documentation indicates that the Cu and Ni contents are 0.05 wt% and 0.17 wt%, respectively (see Table 3-5). Also, recent calculations performed at SCE[6] indicate that the fluence at Weld 8-203 is 1/108 that of the peak fluence location within the vessel. The SCE fluence calculations have been used in the evaluation of Weld 8-203. Based on the revised chemistry and fluence values, Weld 8-203 need not be considered a beltline weld for SONGS, Unit 3, although shift in reference temperature and drop in upper shelf energy are provided for reference later in this section.

Within Regulatory Guide 1.99, Revision 2, there are five credibility criteria that must be met in order to utilize surveillance data in adjusting the predicted embrittlement trends and/or reducing the assigned margin terms. Three of the criteria are met (proper limiting materials, definitive measurements of shift and upper shelf, and a match between the capsule and vessel temperatures within $\pm 25°F$), but the other two have not been satisfied since only one capsule from each vessel has been pulled and evaluated. To satisfy these last two requirements, the second capsules (which will not be pulled until about 15 EFPY) must be evaluated to supply two valid data sets for the vessel surveillance materials, and testing of the correlation monitor material contained in the second capsules must be evaluated against the available data for that material.

In the subsequent portion of this section, the available results from the first capsules will be compared to the regulatory prediction approaches, and projections based upon the regulatory approaches will be made.

4.3 SHIFTS AT THE CHARPY V-NOTCH 30 FT-LB ENERGY LEVEL

Capsule 97 from the SONGS Unit 3 surveillance program was tested in 1991. The C_{VN} results from this capsule are shown in Figures 4-1 (Plate C6802-1/TL), and 4-2 (surveillance weld). Appendix H contains, in tabular form, the absorbed energy, lateral expansion, and fracture appearance (% shear) for the irradiated surveillance materials.

The results computed during this work for the shift at the 30 ft-lb energy level are tabulated in Table 4.1 as "current" and compared to the Regulatory Guide 1.99, Revision 2, mean shift predictions (RG1.99R2):

RG1.99R2 = CF (chemistry factor) x ff (fluence function).

The results obtained by Westinghouse[2] are also shown for comparison. The differences between the current values for shift versus those from Westinghouse are due to small differences in the curve fit to the C_{VN} data and the different data set used for unirradiated Plate C6802-1/TL (i.e., Figure 3-8 for Westinghouse and Figure 3-9 in the current study).

The measured shift result for Plate C6802-1 are higher than the mean prediction from Regulatory Guide 1.99, Revision 2, but are within the mean plus two standard deviation value of 69°F (i.e., 35°F + 34°F = 69°F as compared to 55 - 58°F). The measured shift for the surveillance weld is essentially the same as the mean shift prediction using Regulatory Guide 1.99, Revision 2. Until another capsule is tested, there is no way to definitively evaluate that the CFs should be adjusted to reflect measured behavior, rather than that predicted from the Regulatory Guide.

Table 4.2 lists the predicted estimates of adjusted RT_{NDT} (ART) at the vessel inner surface for the two time periods of December 16, 1991 (as requested in GL 92-01) and at the end of the current license (32 EFPY). Note that the Regulatory Guide 1.99, Revision 2, shift (CF x ff) with the appropriate margin terms have been used; the initial RT_{NDT}s were taken from Tables 3.6 and 3.8. The results in Table 4.2 show that the plate material C6802-1, which is the plate material in the surveillance program, is the limiting material in the vessel beltline. Note the low levels of ART for all welds. The results in Table 4.2 show that the degree of radiation embrittlement in the SONGS, Unit 3 reactor vessel beltline materials is relatively low even at end-of-design life fluence.

4.4 UPPER SHELF ENERGY DROP

Capsule 97 from the SONGS, Unit 3, surveillance program was evaluated in 1991. The USE results are shown in Figures 4-1 and 4-2, and are tabulated in Table 4.3 as an absolute drop in USE (ft-lb). Also listed in Table 4.3 are the predicted drops from Regulatory Guide 1.99, Revision 2. The measured drop for the surveillance weld is slightly below the value predicted using Regulatory Guide 1.99, Revision 2. The measured upper shelf drop for Plate C6802-1 is essentially the same as that predicted using the Regulatory Guide.

Predictions of USE levels at the quarter-thickness location after neutron irradiation exposure are shown in Table 4.4 for all the SONGS, Unit 3, beltline materials. At the end of 32 EFPY, none of the materials are projected to even approach the NRC screening limit of 50 ft-lb specified in 10CFR50, Appendix G.

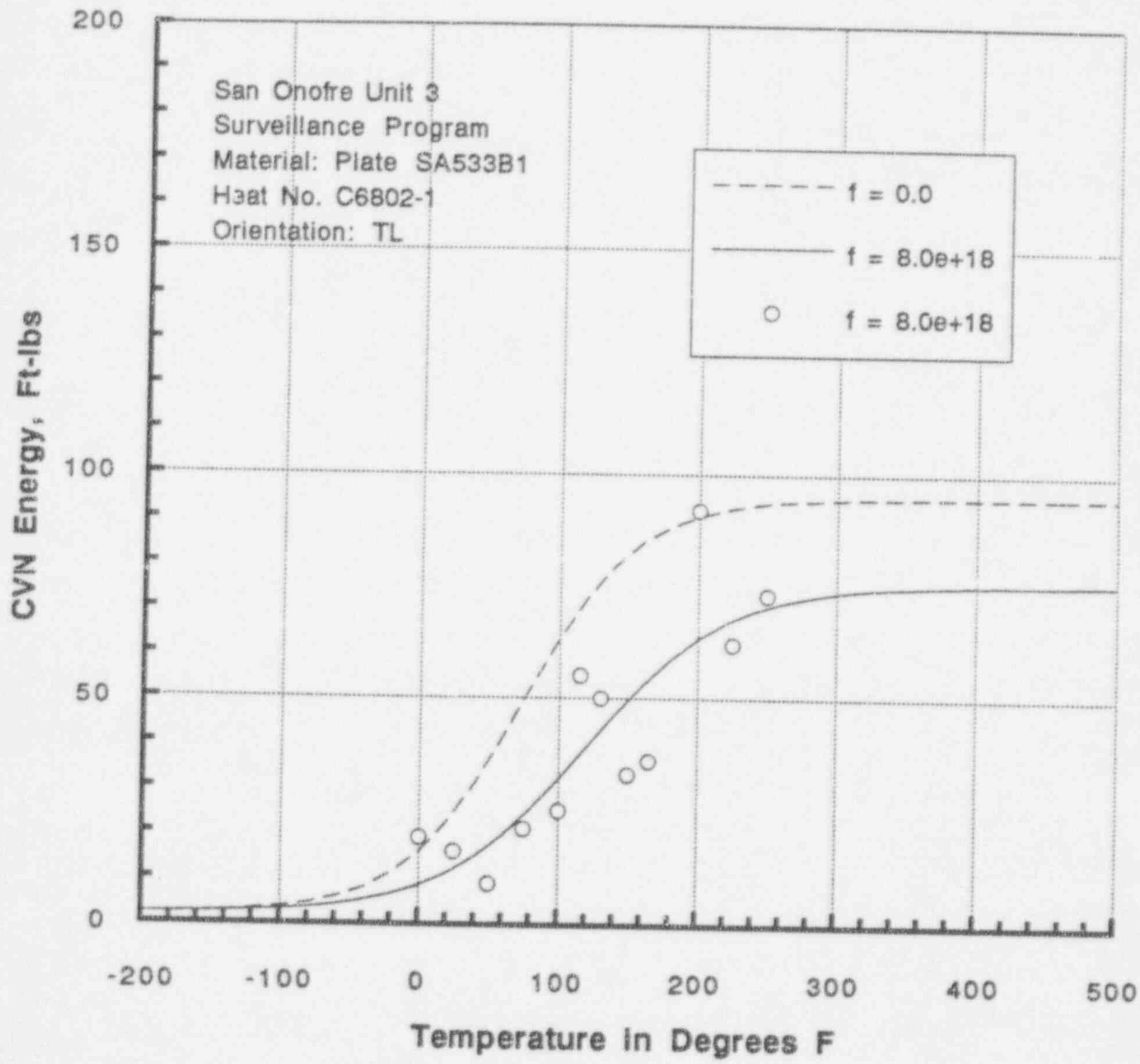

Figure 4-1. SONGS, Unit 3: Comparison of the Least Squares Fit for the Combined MCR And Unirradiated Baseline Data with the Irradiated C_{VN} Data and Least Squares Fit for the Data from Capsule 97, Pl[illegible] [illegible]6802-1, TL Orientation.

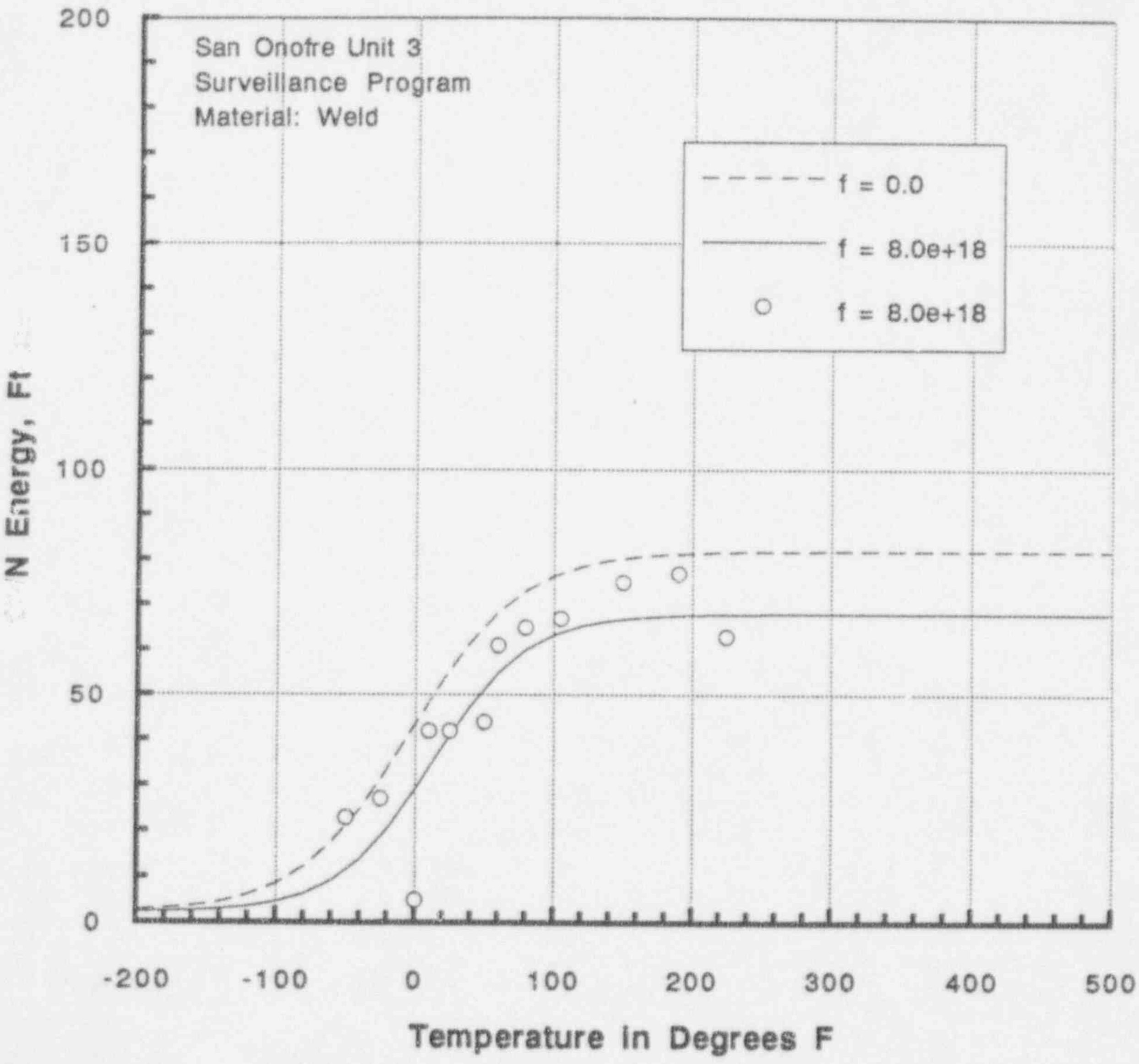

Figure 4-2. SONGS, Unit 3: Comparison of the Least Squares Fit for the Unirradiated Baseline Data with the Irradiated C_{VN} Data and Least Squares Fit for the Data from Capsule 97, Surveillance Weld.

Table 4.1. SONGS, Unit 3: Surveillance Capsule Shift Results.

Material/ Orientation	CF	ff	30 ft-lb Shift (°F)		
			W	RG1.99R2	Current
C6802-1/TL	37[a]	0.94	55	35	58[c]
Surveillance Weld	28[b]	0.94	32	26	30[d]

a. See Table 3.4 (Cu = .06; Ni = .58)

b. Based upon the average chemistries -- see Table 3.5 (Cu = .03; Ni = .09)

c. Based on the combined data set from the MCR and baseline surveillance program, see Figure 3-9

d. Based on the baseline surveillance data, see Figure 3-15

Table 4.2. SONGS, Unit 3: ART Estimates at the Inner Surface Location for Beltline Materials on 12/16/91 and at 32 EFPY.

Plate No./ Weld Seam	CF	Fluence Function at the Inner Surface		ART (°F)[a] at the Inner Surface	
		12/16/91	32 EFPY	12/16/91	32 EFPY
C6802-1	37[b]	0.95	1.37	109	125
C6802-2	26	0.95	1.37	60	80
C6802-3	37	0.95	1.37	89	105
C6802-4	31	0.95	1.37	68	86
C6802-5	26	0.95	1.37	60	80
C6802-6	37	0.95	1.37	89	105
2-203 A, B, C	39[c]	0.95	1.37	34	66
3-203 A, B, C	43[d]	0.95	1.37	12	45
8-203	46	0.09[e]	0.25[e]	-62	-48
9-203 (90069)	34	0.95	1.37	4	34
9-203 (90144)	31	0.95	1.37	8	34

a. ART is the adjusted reference temperature equal to the predicted shift (CF x ff) plus the initial RT_{NDT} plus a margin term equal to 34°F for plates or 56°F for welds (unless the predicted shift is less than the margin term, in which case the margin is equal to the predicted shift)

b. Based upon measured chemistries for this plate (.06 Cu / .58 Ni) -- see Tables 3.4 and 4.1

c. Based upon average chemistries for these welds (.04 Cu/.15 Ni) -- see Table 3.5

d. Based upon average chemistries for these welds (.04 Cu/.20 Ni) -- see Table 3.5

e. Fluence function is based upon the peak vessel fluence divided by 108[6]

Table 4.3. SONGS, Unit 3: Surveillance Capsule Upper Shelf Results.

Material/ Orientation	Cu (wt%)	Fluence (x 10^{19} n/cm²)	Upper Shelf Drop (ft-lb)		
			W	RG1.99R2	Current
C6802-1/TL	0.06[a]	0.80	16	17	19[d]
Surveillance Weld	0.03[b]	0.80	12	15[c]	14[e]

a. See Table 3.4

b. See Table 3.5

c. Based upon the Regulatory Guide 1.99, Rev. 2, lowest percentage drop (18%) curve at the specified fluence times the measured unirradiated upper shelf determined in this report

d. Based on the combined data set from the MCR and baseline surveillance program, see Figure 3-9

e. Based on the baseline surveillance data, see Figure 3-15

Table 4.4. SONGS, Unit 3: Upper Shelf Estimates at the Quarter-Thickness Location for Beltline Materials on 12/16/91 and at 32 EFPY.

Plate No./ Weld Seam	Cu (wt%)	fluence (x 10^{19} n/cm^2) at Quarter-Thickness 12/16/91	32 EFPY	Upper Shelf Energy (ft-lb)[a] at Quarter-Thickness 12/16/91	32 EFPY
C6802-1	0.06[b]	0.51	2.5	80	73
C6802-2	0.04	0.51	2.5	97	89
C6802-3	0.06	0.51	2.5	88	81
C6802-4	0.05	0.51	2.5	99	91
C6802-5	0.04	0.51	2.5	97	89
C6802-6	0.06	0.51	2.5	77	71
2-203 A, B, C	0.05[c]	0.51	2.5	114	105
3-203 A, B, C	0.04[c]	0.51	2.5	135	122
8-203	0.05	0.005	0.023	119[d]	115[d]
9-203 (90069)	0.06	0.51	2.5	102	92
9-203 (90144)	0.05	0.51	2.5	76	70

a. The upper shelf energy is estimated from Regulatory Guide 1.99, Rev. 2, taking into account the projected fluences and measured chemistry

b. Based upon measured chemistry for this plate -- see Table 3.4

c. Based upon average chemistries for these welds -- see Table 3.5

d. Based upon an extrapolation of the curves in Regulatory Guide 1.99, Rev. 2

Section 5

REFERENCES

[1] A. Ragl, Southern California Edison San Onofre Unit 3, Evaluation of Baseline Specimens, Reactor Vessel Materials Irradiation Surveillance Program, Combustion Engineering TR-S-MCS-004, November 30, 1979.

[2] E. Terek, E. P. Lippincott, A. Madeyski, and M. Ramirez, Analysis of the Southern California Edison Company San Onofre Unit 3 Reactor Vessel Surveillance Capsule Removed from the 97° Location, Westinghouse WCAP-12920, Revision 2, May 1994.

[3] M. P. Manahan and J. Garrabrandt, Testing and Analysis of Unirradiated Heat Effected-Zone (HAZ) Material from the San Onofre Nuclear Generating Station Unit 3 (SONGS-3), Battelle Columbus, May 31, 1989.

[4] Telephone communication between S. Byrne and C. Stewart, ABB-CE, and D. Pilmer and S. Gosselin, SCE, June 15, 1992.

[5] M. P. Manahan, L. M. Lowry, and E. O. Fromm, Examination, Testing, and Evaluation of Irradiated Pressure Vessel Surveillance Specimens from the San Onofre Nuclear Generating Station Unit 2 (SONGS-2), Battelle Columbus, December 1988.

[6] R. Chang, "SONGS 2/3 RPV Fluence Ratio at Weld 8-203", SCE Calculation No. N-1020-065, December 1992.

APPENDIX A

SONGS, UNIT 3: EVALUATION OF COMPLIANCE

WITH ASTM E185-73 AND E185-82

Summary of Requirements per ASTM E185-73	San Onofre Unit 3 Program
1.2 Surveillance tests are divided according to application into two cases:	Compliance
1.2.1 Case A - Where both the predicted increase in transition temperature of the reactor vessel steel is 100°F or less and the calculated peak neutron fluence (E > 1 MeV) of the reactor vessel is 5 X 10^{18} n/cm^2 or less.	
1.2.2 Case B - Where the predicted increase in transition temperature of the reactor vessel steel is greater than 100°F or where the calculated peak neutron fluence (E > 1 MeV) of the reactor vessel is greater than 5 X 10^{18} n/cm^2	
4.1 Test Material - Test specimens shall be prepared from the actual materials used in fabricating the irradiated region of the reactor vessel.	Compliance
4.1 Samples shall represent a minimum of one heat of the base metal and one butt weld and one weld heat-affected-zone (HAZ) if a weld occurs in the irradiated region.	Compliance
4.1 The base metal and weld metal to be included in the program should represent the material that may limit the operation of the reactor during its lifetime.	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 3 Program
4.1.1 Vessel Material Sampling - A minimum test program shall consist of specimens taken from the following locations: (1) base metal of one heat used in the irradiated region, (2) weld metal, fully representative of the fabrication practice used for a weld in the irradiated region (weld wire of rod, must come from one of the heats used in the irradiated region of the reactor vessel) and the same type of flux, and (3) the heat-affected-zone associated with the base metal noted above.	Compliance
4.1.1 Representative test stock to provide two additional sets of test specimens of the base metal, weld and heat-affected-zone shall be retained with full documentation and identification.	Compliance
4.1.2 Fabrication History - The test material shall receive a fabrication history (austenitizing, quench and tempering, and post-weld heat treatment) fully representative of the fabrication received by the material in the irradiated region of the reactor vessel.	Compliance
4.1.3 Chemical Requirements - The chemical composition required by the material specifications for the test materials (base metal and as deposited weld metal) shall be obtained and include, but not be limited to phosphorus (P), sulfur (S), copper (Cu), and vanadium (V).	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 3 Program
4.2 Charpy V-notch impact specimens corresponding to the Type A specimen described in Methods E 23 shall be employed unless material thickness does not permit. Both irradiated and unirradiated types of specimens shall be of the same size and shape.	Compliance
4.3 Specimen Orientation and Location - For both tension and impact specimens from base metal, the major axis of the specimen shall be machined normal to the principal rolling direction for plates and normal to the major working direction for forgings. The length of the notch of the Charpy impact specimen shall be normal to the surface of the material. The recommended orientation of the impact and tension specimens with respect to the weld are shown in Fig. 1. Weld metal tension specimens may be oriented in the same direction as the Charpy specimens provided that the gage length consists of all weld metal. No specimens are to be removed within 1/2 in. of the root or the surfaces of the welds. Sections of the weldment shall be etched to define the weld heat affected zones. Care shall be taken that the impact specimens from the weld heat affected zones have their notch roots in the heat affected zone at a standard distance of approximately 1/32 in. from the fusion line. Specimens representing the base metal (tension and impact) and the weld heat-affected zone shall be removed from the quarter thickness location. (per NB2300 of ASME Code Section III)	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 3 Program
4.4 Number of Specimens - The minimum number of test specimens for each exposure shall be as follows:	Compliance
4.4 At least 15 Charpy impact specimens shall be used to establish an unirradiated transition curve for each material.	Compliance
4.4 For Case B (see above), three tension test specimens shall be used to establish unirradiated tensile properties.	Not Applicable
5.1.1 Vessel Wall Specimens (Required) - Specimens shall be irradiated at a location in the reactor that duplicates as closely as possible the neutron-flux spectrum, temperature history, and maximum accumulated neutron fluence experienced by the reactor vessel.	Compliance
5.1.1 The instantaneous neutron flux at the location of the specimens shall not exceed three times the calculated maximum neutron flux at the inside wall of the reactor vessel.	Compliance

The minimum-specimen table under the first 4.4 requirement:

	Case A	Case B	
	Charpy	Charpy	Tension
Base Metal	12	12	2
Weld Metal	12	12	2
HAZ	12	12	-

Summary of Requirements per ASTM E185-73	San Onofre Unit 3 Program
5.1.2 Accelerated Irradiation Specimens (Optional) - Test specimens may be positioned at locations other than (5.1.1) for accelerated irradiation at a rate exceeding three times the calculated maximum neutron flux at the inside wall of the reactor vessel.	Not Applicable
5.2 Flux Measurements - Provisions shall be made to measure the neutron fluence as follows: 5.2.1 Dosimeters with the vessel wall specimens (5.1.1).	Compliance
5.2.2 Where accelerated irradiation specimens are used (5.1.2), dosimeters with the test specimens and dosimeters either in a separate flux monitor capsule adjacent to the vessel wall or in a vessel wall capsule.	Compliance
5.3 Test Capsules - To prevent deterioration of the surface of the specimens during test, the specimens should be maintained in an inert environment within a corrosion-resistant capsule.	The specimens from the 97° Capsule Location had corroded. Metallurgical evaluation by SCE concluded the corrosion (in the form of pitting) to be insignificant, with a maximum depth of 0.8 mils. The results of the Charpy testing were deemed credible, and are therefore in compliance.
5.3 The temperature history of the specimens shall duplicate as closely as possible the temperature experienced by the reactor vessel.	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 3 Program
5.3 Surveillance capsules should be sufficiently rigid to prevent damage to the capsules by coolant pressure or coolant flow thus hindering specimen removal or causing inadvertent deformation of the specimens.	Compliance
5.3 Irradiated capsules must not be bouyant to preclude serious radiation exposure to personnel if under water handling is employed.	Compliance
5.3 Consideration should be given to the design of the capsule and capsule attachments to permit insertion of replacement capsules into the reactor at a later time in the lifetime of the vessel.	Compliance
5.4 Specimen Withdrawal - A minimum surveillance program shall consist of three capsules for Case A and five capsules for Case B. It is recommended that capsules be withdrawn as described in Table 1. (See Table 1 of ASTM E185-73.)	Compliance
6.1 Radiation Environment - The neutron flux, neutron energy spectrum, and irradiation temperature of surveillance specimens and the method of determination shall be documented.	Compliance

Summary of Requirements per ASTM E185-73	San Onofre Unit 3 Program
6.2 Neutron Flux Dosimeters - Flux dosimeters for a particular program shall be determined by referring to Method E 261.	Compliance

END

END

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
8.1 Temperature Environment - The maximum exposure temperature of the surveillance capsule materials shall be determined. If a discrepancy (>14°C or 25°F) occurs between the observed and the expected capsule exposure temperatures, an analysis of the operating conditions shall be conducted to determine the magnitude and duration of these differences.	Compliance
8.2 Neutron Irradiation Environment: 8.2.1 The neutron flux density, neutron energy spectrum, and neutron fluence of the surveillance specimens and the corresponding maximum values for the reactor vessel shall be determined in accordance with the guidelines in Guide E 482 and Recommended Practice E 560. 8.2.2 The specific method of determination shall be determined and recorded using both a calculated spectrum and an assumed fission spectrum.	Compliance
9.1 Tension Tests: 9.1.1 Method - Tension testing shall be conducted in accordance with Methods E 8 and Recommended Practice E 21. 9.1.2 Test Temperature: 9.1.2.1 Unirradiated - The test temperatures for each material shall include room temperature, service temperature, and one intermediate temperature to define the strength versus temperature relationship.	Compliance

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
9.1.2.2 Irradiated - One specimen from each material shall be tested at a temperature in the vicinity of the upper end of the Charpy energy transition region. The remaining specimens from each material shall be tested at the service temperature and the midtransition temperature.	Compliance
9.1.3 Measurements - For both unirradiated and irradiated materials, determine yield strength, tensile strength, fracture load, fracture strength, fracture stress, total and uniform elongation, and reduction of area.	Compliance
9.2 Charpy Tests: 9.2.1 Method - Charpy tests shall be conducted in accordance with Method E 23 and A370.	Compliance
9.2.2 Test Temperature: 9.2.2.1 Unirradiated - Test temperature for each material shall be selected to establish a full transition temperature curve. One specimen per test temperature may be used to define the overall shape of the curve. Additional tests should be performed in the region where the measurements described in 9.2.3 are made.	Compliance
9.2.2.2 Irradiated - Specimens for each material will be tested at temperatures selected to define the full energy transition curve. Particular emphasis should be placed on defining the 41-J (30 ft-lb), 68-J (50 ft-lb), and 0.89-mm (35 mil) lateral expansion index temperatures and the upper shelf energy.	Compliance

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
9.2.3 Measurements - For each test specimen, measure the impact energy, lateral expansion, and percent shear fracture appearance. From the unirradiated and irradiated transition temperature curves determine the 41-J (30 ft-lb), 68-J (50 ft-lb), and 0.89 mm (35 mil) lateral expansion index temperatures and the upper shelf energy. The index temperatures and the upper shelf energy shall be determined from the average curves.	Compliance
9.2.3.1 Obtain from the material qualification test report the initial reference temperature (RT_{NDT}) as defined in ASME Code, Section III, Subarticle NB 230 for unirradiated materials.	Compliance
9.3 Hardness Tests (Optional) - Hardness tests may be performed on unirradiated and irradiated Charpy specimens. The measurements shall be taken in areas away from the fracture zone or the edges of the specimens. The tests shall be conducted in accordance with Methods A 370.	Compliance
9.4 Supplemental Tests (Optional) - If supplemental fracture toughness tests are conducted (in addition to tests conducted on tension and Charpy specimens as described in 6.1) the test procedures shall be documented.	Not Applicable

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
9.5 Calibration of Equipment - Procedures shall be employed assuring that tools, gages, recording instruments, and other measuring and testing devices are calibrated and properly adjusted periodically to maintain accuracy within necessary limits. Whenever possible calibration shall be conducted with standards traceable to the National Bureau of Standards. Calibration status shall be maintained in records traceable to the equipment.	Compliance
10.1 Tension Test Data: 10.1.1 Determine the amount of radiation strengthening by comparing unirradiated test results with irradiated test results at the temperature specified in 9.1.2. 10.1.2 The tensile strength data can be verified using the results from the hardness test (optional) described in 9.3.	Compliance
10.2 Charpy Test Data: 10.2.1 Determine the radiation induced transition temperature shifts by measuring the difference in the 41-J (30 ft-lb), 68-J (50 ft-lb), and 0.89 mm (35 mil) lateral expansion index temperatures before and after irradiation. The index temperatures shall be obtained from the average curves.	Compliance

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
10.2.2 Determine the adjusted reference temperature by adding the shift corresponding to the 41-J (30 ft-lb) index determined in 10.2.1 to the initial reference temperature obtained in 9.2.3.1.	Compliance
10.2.3 Determine the radiation induced change in the upper shelf energy (USE) from the measurements made before and after irradiation using average value curves.	Compliance
10.2.4 (Optional) - Determine the radiation induced change in temperature corresponding to 50% of the upper shelf energy before and after irradiation from average value curves.	Not Applicable
10.3 Supplemental Test Data (Optional) - If additional, supplemental tests are performed (9.4), the data shall be recorded to supplement the information from the tensile and Charpy tests.	Not Applicable
10.4 Retention of Test Specimens - It is recommended that all broken test specimens be retained until released by the owner in the event that additional analyses are required to explain anomalous results.	Compliance
11.1 Where applicable, both SI units and conventional units shall be reported.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
11.2 Surveillance Program Description - Description of the reactor vessel including the following:	Compliance
11.2.1 Location of the surveillance capsules with respect to the reactor vessel, reactor vessel internals, and the reactor core.	
11.2.2 Location in the vessel of the plates or forgings and the welds.	
11.2.3 Location(s) of the peak vessel fluence.	
11.2.4 Lead factors between the specimen fluence and the peak vessel fluence at the I.D. and the 1/4T locations.	
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11.2.5 Surveillance Material Selection:	Compliance
11.2.5.1 Description of all beltline materials including chemical analysis, fabrication history, Charpy data, tensile data, drop-weight data, and initial RT_{NDT}.	
11.2.5.2 Describe the basis for selection of surveillance materials.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
11.3 Surveillance Material Characterization:	Compliance
11.3.1 Description of the surveillance material including fabrication history, material source (heat or lot), and any differences between the surveillance material history and that of the reactor vessel material history.	
11.3.2 Location and orientation of the test specimens in the parent material.	
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11.3.3 Test Specimen Design:	Compliance
11.3.3.1 Description of the test specimens (tension, Charpy, and any other types of specimens used), neutron dosimeters, and temperature monitors.	
11.3.3.2 Certification of calibration of all equipment and instruments used in conducting the tests.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
11.4.1 Tension Tests:	Compliance
11.4.1.1 Trade name and model of the testing machine, gripping devices, extensometer, and recording devices used in the test.	
11.4.1.2 Speed of testing and method of measuring the controlling testing speed.	
11.4.1.3 Complete stress-strain curve (if a group of specimens exhibits similar stress-strain curves, a typical curve may be reported for the group).	
11.4.1.4 Test Data from each specimen as follows: (1) Test temperature; (2) Yield strength or yield point and method of measurement; (3) Tensile strength; (4) Fracture load, fracture strength, and fracture stress; (5) Uniform elongation and method of measurement; (6) Total elongation; (7) Reduction of area; and (8) Specimen identification.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
11.4.2 Charpy Tests:	Compliance
11.4.2.1 Trade name and model of the testing machine, available hammer energy capacity and striking velocity, temperature conditioning and measuring devices, and a description of the procedure used in the inspection and calibration of the testing machine.	
11.4.2.2 Test data from each specimen as follows: (1) Temperature of test; (2) Energy absorbed by the specimen in breaking, reported in joules (and foot-pound-force); (3) Fracture appearance; (4) Lateral expansion; and (5) Specimen identification.	
11.4.2.3 Test data for each material as follows: (1) Charpy 41-J (30 ft-lb), 68-J (50 ft-lb), and 0.89 mm (35 mil) lateral expansion index temperature of unirradiated material and of each set of irradiated specimens, along with the corresponding temperature increases for these specimens; (2) Upper shelf energy (USE) absorbed before and after irradiation; (3) Initial reference temperature; and (4) Adjusted reference temperature.	
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11.4.3 Hardness Tests (Optional):	Compliance
11.4.3.1 Trade name and model of the testing machine.	
11.4.3.2 Hardness data.	

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
11.4.4 Other Fracture Toughness Tests: 11.4.4.1 If additional tests are performed, the test data shall be reported together with the procedure used for conducting the tests and analysis of the data.	Not Applicable
11.4.5 Temperature and Neutron Radiation Environment Measurements: 11.4.5.1 Temperature monitor results and an estimate of maximum capsule exposure temperature. 11.4.5.2 Neutron dosimeter measurements, analysis techniques, and calculated results including the following: (1) Neutron flux density, neutron energy spectrum, and neutron fluence in terms of neutrons per square metre and neutrons per square centimetre (>0.1 and 1 MeV) for the surveillance specimens using both calculated spectrum and assumed fission spectrum assumptions. (2) Description of the methods used to verify the procedures including calibrations, cross sections, and other pertinent nuclear data.	Compliance

Summary of Requirements per ASTM E185-82	San Onofre Unit 3 Program
11.5 Application of Test Results:	Compliance
11.5.1 Extrapolation of the neutron flux and fluence results to the surface and 1/4T locations of the reactor vessel at the peak fluence location.	
11.5.2 Comparison of fluence determined from dosimetry analysis with original predicted values.	
11.5.3 Extrapolation of fracture toughness properties to the surface and 1/4T locations of the reactor vessel at the peak fluence location.	
11.6 Deviations - Deviations or anomalies in procedure from this practice shall be identified and described fully in the report.	Compliance
END	END

APPENDIX B

SONGS, UNIT 3: BASES FOR PLATE CHEMISTRY MEASUREMENTS (Proprietary)

APPENDIX C

SONGS, UNIT 3: BASES FOR WELD

CHEMISTRY MEASUREMENTS (Proprietary)

APPENDIX D

SONGS, UNIT 3: WMCs FOR BELTLINE MATERIALS (Proprietary)

APPENDIX E

SONGS, UNIT 3: MCRs FOR BELTLINE MATERIALS (Proprietary)

APPENDIX F

SONGS, UNIT 3: UNIRRADIATED C_{VN} DATA FOR PLATES AND WELDS

Table F-1 Charpy V-Notch Test Results
For Unit 3 Plate C6802-1 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	7.00	5.00	0.00
2	-40.00	6.00	4.00	0.00
3	-40.00	5.00	4.00	0.00
4	10.00	29.00	20.00	10.00
5	10.00	23.00	17.00	10.00
6	10.00	18.00	14.00	5.00
7	40.00	34.00	21.00	15.00
8	40.00	27.00	19.00	10.00
9	40.00	24.00	17.00	5.00
10	80.00	43.00	34.00	25.00
11	80.00	55.00	45.00	30.00
12	80.00	56.00	44.00	30.00
13	100.00	50.00	37.00	25.00
14	100.00	52.00	40.00	25.00
15	100.00	59.00	45.00	30.00
16	160.00	79.00	60.00	80.00
17	160.00	79.00	63.00	80.00
18	212.00	95.00	70.00	100.00
19	212.00	99.00	72.00	100.00
20	160.00	84.00	62.00	80.00
21	212.00	100.00	74.00	100.00

Table F-2 Charpy V-Notch Test Results
For Unit 3 Plate C6802-2 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	9.00	6.00	0.00
2	-40.00	6.00	3.00	0.00
3	-40.00	8.00	4.00	0.00
4	10.00	26.00	19.00	10.00
5	10.00	14.00	11.00	5.00
6	10.00	28.00	24.00	10.00
7	40.00	32.00	26.00	15.00
8	40.00	40.00	30.00	20.00
9	40.00	52.00	37.00	25.00
10	60.00	44.00	34.00	25.00
11	60.00	52.00	36.00	30.00
12	60.00	54.00	37.00	30.00
13	70.00	55.00	38.00	30.00
14	70.00	57.00	39.00	35.00
15	70.00	65.00	45.00	40.00
16	100.00	66.00	50.00	40.00
17	100.00	77.00	59.00	50.00
18	100.00	69.00	54.00	60.00
19	160.00	114.00	77.00	90.00
20	160.00	110.00	75.00	90.00
21	160.00	106.00	75.00	90.00
22	212.00	117.00	80.00	100.00
23	212.00	116.00	82.00	100.00
24	212.00	113.00	79.00	100.00

Table F-3 Charpy V-Notch Test Results
For Unit 3 Plate C6802-3 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	8.00	4.00	0.00
2	-40.00	7.00	3.00	0.00
3	-40.00	9.00	5.00	0.00
4	10.00	26.00	20.00	10.00
5	10.00	26.00	20.00	10.00
6	10.00	15.00	11.00	5.00
7	40.00	37.00	27.00	15.00
8	40.00	28.00	22.00	10.00
9	40.00	35.00	26.00	15.00
10	60.00	35.00	26.00	15.00
11	60.00	49.00	34.00	25.00
12	60.00	35.00	30.00	20.00
13	80.00	57.00	47.00	30.00
14	80.00	52.00	40.00	25.00
15	80.00	60.00	46.00	40.00
16	100.00	79.00	60.00	60.00
17	100.00	70.00	54.00	50.00
18	100.00	63.00	46.00	40.00
19	160.00	100.00	71.00	90.00
20	160.00	95.00	69.00	90.00
21	160.00	94.00	67.00	90.00
22	212.00	106.00	76.00	100.00
23	212.00	109.00	78.00	100.00
24	212.00	101.00	72.00	100.00

Table F-4 Charpy V-Notch Test Results
For Unit 3 Plate C6802-4 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	10.00	6.00	0.00
2	-40.00	14.00	8.00	0.00
3	-40.00	10.00	6.00	0.00
4	10.00	25.00	18.00	10.00
5	10.00	28.00	20.00	10.00
6	10.00	19.00	13.00	5.00
7	40.00	35.00	30.00	20.00
8	40.00	39.00	32.00	20.00
9	40.00	51.00	37.00	25.00
10	60.00	48.00	35.00	20.00
11	60.00	54.00	39.00	25.00
12	60.00	49.00	34.00	20.00
13	70.00	76.00	53.00	50.00
14	70.00	63.00	47.00	40.00
15	70.00	59.00	44.00	35.00
16	100.00	104.00	65.00	60.00
17	100.00	69.00	52.00	40.00
18	100.00	70.00	54.00	40.00
19	160.00	126.00	80.00	95.00
20	160.00	112.00	71.00	90.00
21	160.00	104.00	70.00	90.00
22	212.00	118.00	78.00	100.00
23	212.00	117.00	81.00	100.00
24	212.00	115.00	77.00	100.00

Table F-5 Charpy V-Notch Test Results For Unit 3 Plate C6802-5 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	9.00	4.00	0.00
2	-40.00	10.00	5.00	0.00
3	-40.00	9.00	3.00	0.00
4	10.00	18.00	12.00	5.00
5	10.00	27.00	20.00	10.00
6	10.00	15.00	11.00	5.00
7	40.00	34.00	23.00	15.00
8	40.00	~~33.00~~ 34.02	24.00	15.00
9	40.00	35.00	25.00	15.00
10	60.00	39.00	26.00	15.00
11	60.00	39.00	28.00	15.00
12	60.00	38.00	27.00	15.00
13	70.00	65.00	43.00	30.00
14	70.00	57.00	40.00	30.00
15	70.00	51.00	37.00	25.00
16	100.00	66.00	47.00	30.00
17	100.00	70.00	49.00	35.00
18	100.00	79.00	56.00	40.00
19	160.00	118.00	78.00	100.00
20	160.00	116.00	75.00	100.00
21	160.00	109.00	65.00	90.00
22	212.00	119.00	78.00	100.00
23	212.00	110.00	72.00	100.00
24	212.00	117.00	74.00	100.00

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Table F-6 Charpy V-Notch Test Results
For Unit 3 Plate C6802-6 (TL), MCR Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-40.00	10.00	5.00	0.00
2	-40.00	10.00	4.00	0.00
3	-40.00	8.00	4.00	0.00
4	10.00	23.00	17.00	10.00
5	10.00	28.00	20.00	10.00
6	10.00	25.00	18.00	10.00
7	40.00	34.00	26.00	15.00
8	40.00	43.00	34.00	20.00
9	40.00	33.00	26.00	15.00
10	70.00	50.00	39.00	25.00
11	70.00	46.00	35.00	20.00
12	70.00	58.00	45.00	30.00
13	80.00	52.00	40.00	25.00
14	80.00	57.00	45.00	30.00
15	80.00	53.00	41.00	25.00
16	100.00	50.00	42.00	30.00
17	100.00	65.00	51.00	50.00
18	100.00	59.00	46.00	40.00
19	160.00	96.00	72.00	95.00
20	160.00	90.00	69.00	90.00
21	160.00	83.00	65.00	90.00
22	212.00	90.00	70.00	100.00
23	212.00	92.00	71.00	100.00
24	212.00	92.00	70.00	100.00

Table F-7 Charpy V-Notch Test Results
For Unit 3 Weld Seam 9-203 (Heat #90069), WMC Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-100.00	13.00	8.00	0.00
2	-100.00	8.00	4.00	0.00
3	-100.00	13.00	5.00	0.00
4	-80.00	24.00	15.00	5.00
5	-80.00	43.00	31.00	20.00
6	-80.00	25.00	17.00	5.00
7	-40.00	53.00	36.00	25.00
8	-40.00	69.00	50.00	40.00
9	-40.00	63.00	44.00	35.00
10	0.00	83.00	60.00	50.00
11	0.00	76.00	52.00	40.00
12	0.00	97.00	67.00	60.00
13	40.00	120.00	82.00	90.00
14	40.00	118.00	80.00	90.00
15	40.00	125.00	82.00	100.00
16	100.00	119.00	78.00	100.00
17	100.00	117.00	78.00	100.00
18	100.00	124.00	83.00	100.00
19	160.00	123.00	82.00	100.00
20	160.00	121.00	81.00	100.00
21	160.00	133.00	82.00	100.00

Table F-8 Charpy V-Notch Test Results For Unit 3 Weld Seam 3-203 (Heat #88114), ~~FSAR~~ WMC Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-104.00	13.00	7.00	0.00
2	-104.00	11.00	6.00	0.00
3	-104.00	20.00	13.00	5.00
4	-80.00	29.00	22.00	10.00
5	-80.00	30.00	21.00	10.00
6	-80.00	24.00	13.00	10.00
7	-40.00	110.00	66.00	60.00
8	-40.00	76.00	48.00	40.00
9	-40.00	114.00	68.00	60.00
10	-10.00	127.00	70.00	80.00
11	-10.00	115.00	64.00	70.00
12	-10.00	117.00	68.00	70.00
13	10.00	126.00	78.00	80.00
14	10.00	151.00	81.00	100.00
15	10.00	156.00	84.00	100.00
16	50.00	174.00	86.00	100.00
17	50.00	163.00	85.00	100.00
18	50.00	162.00	83.00	100.00

Table F-9 Charpy V-Notch Test Results
For Unit 3 Plate C6802-1 (TL), CE Baseline Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
252	-40.00	13.00	12.00	0.00
23E	0.00	14.00	12.00	10.00
26J	0.00	23.00	24.00	0.00
22P	40.00	18.00	17.00	10.00
26D	40.00	52.00	45.00	20.00
22K	80.00	25.00	25.00	20.00
263	80.00	57.00	50.00	40.00
23Y	100.00	42.00	40.00	30.00
25M	100.00	74.00	60.00	40.00
24T	100.00	88.00	65.00	50.00
25E	120.00	85.00	73.00	50.00
267	120.00	106.00	80.00	80.00
23A	160.00	61.00	60.00	60.00
221	160.00	63.00	58.00	70.00
25Y	160.00	113.00	81.00	90.00
23P	210.00	96.00	74.00	90.00
255	210.00	109.00	82.00	100.00
21K	250.00	80.00	71.00	100.00
22A	250.00	87.00	73.00	100.00

Table F-10 Charpy V-Notch Test Result For Unit 3 Plate C6802-1 (LT), CE Baseline Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EKP (mil)	FRACT APPEAR (%)
151	0.00	6.50	5.00	0.00
146	40.00	15.00	13.00	10.00
127	40.00	16.00	15.00	10.00
11U	80.00	33.50	30.00	30.00
13M	80.00	39.50	36.00	30.00
14C	120.00	36.00	37.00	40.00
126	120.00	45.00	41.00	40.00
14B	160.00	51.00	47.00	60.00
13U	160.00	83.00	70.00	80.00
13E	210.00	66.00	62.00	70.00
14T	210.00	96.00	81.00	80.00
11L	250.00	90.00	80.00	100.00
11C	250.00	93.00	87.00	100.00

Table F-11 Charpy V-Notch Test Results
For Unit 3 Surveillance Weld, CE Baseline Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
31Y	-80.00	5.00	5.00	0.00
37C	-80.00	21.00	19.00	20.00
32C	-40.00	17.00	18.00	20.00
36M	-40.00	34.00	31.00	30.00
36C	0.00	36.00	34.00	30.00
36T	0.00	48.00	45.00	40.00
37E	40.00	58.00	53.00	40.00
3A2	40.00	63.00	56.00	60.00
35Y	80.00	72.00	65.00	80.00
34M	80.00	80.00	82.00	100.00
376	120.00	71.00	65.00	80.00
33K	120.00	84.00	79.00	90.00
316	160.00	64.00	67.00	70.00
344	160.00	97.00	90.00	100.00
32K	210.00	80.00	85.00	90.00
31C	210.00	97.00	84.00	90.00
35M	250.00	71.00	69.00	100.00
372	250.00	78.00	73.00	100.00
34E	250.00	84.00	82.00	100.00

Table F-12 Charpy V-Notch Test Results
For Unit 3 Plate C6802-1 (LT), MCR Data

Test Temperature (°F)	Impact Energy (ft-lbs)	Lateral Expansion (mils)	Fracture Appearance (% Shear)
-40	8	3	0
-40	7	2	0
-40	7	2	0
10	16	10	5
10	21	13	5
10	27	18	10
40	40	27	15
40	26	17	10
40	31	23	10
60	33	25	15
60	34	25	15
60	35	24	15
80	50	39	20
80	52	40	25
80	50	38	20
100	102	65	70
100	104	61	70
100	96	63	60
160	126	81	100
160	132	84	100
160	135	83	100

Table F-13 Charpy V-Notch Test Results
For Unit 3 Weld Seam 9-203 (Heat #90144), WMC Data

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
1	-80.00	7.00	3.00	0.00
2	-80.00	9.00	6.00	0.00
3	-80.00	5.00	3.00	0.00
4	-40.00	18.00	13.00	0.00
5	-40.00	19.00	13.00	0.00
6	-40.00	34.00	26.00	15.00
7	10.00	57.00	41.00	35.00
8	10.00	50.00	36.00	25.00
9	10.00	53.00	40.00	30.00
10	60.00	82.00	60.00	80.00
11	60.00	81.00	60.00	80.00
12	60.00	76.00	54.00	80.00
13	100.00	90.00	67.00	100.00
14	100.00	89.00	71.00	100.00
15	100.00	90.00	70.00	100.00
16	160.00	94.00	79.00	100.00
17	160.00	92.00	77.00	100.00
18	160.00	93.00	72.00	100.00

APPENDIX G

SONGS, UNIT 3: HAZ TEST RESULTS

CE Baseline Tests[1]

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
47L	-80.00	6.00	4.00	0.00
45B	-80.00	6.00	4.00	0.00
42Y	-40.00	30.00	26.00	10.00
436	-40.00	30.00	26.00	10.00
45J	0.00	30.00	25.00	20.00
45Y	0.00	46.00	37.00	30.00
42J	40.00	33.00	34.00	20.00
42K	40.00	35.00	32.00	20.00
42U	80.00	73.00	48.00	80.00
454	80.00	79.00	63.00	50.00
471	120.00	42.00	41.00	60.00
475	120.00	50.00	49.00	70.00
43C	160.00	61.00	62.00	80.00
43K	160.00	87.00	72.00	90.00
46K	210.00	57.00	57.00	70.00
444	210.00	105.00	73.00	100.00
46A	250.00	63.00	66.00	100.00
42T	250.00	75.00	68.00	100.00
46Y	250.00	98.00	80.00	100.00

Westinghouse Capsule 97[2]

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)	CHARPY FLUENCE (n/cm2)	IRRAD TEMP. (F)
441	-75.00	9.00	8.00	5.00	8.00E+18	550.00
42L	-50.00	18.00	16.00	15.00	8.00E+18	550.00
45C	-20.00	3.00	4.00	5.00	8.00E+18	550.00
43P	0.00	26.00	23.00	35.00	8.00E+18	550.00
464	25.00	35.00	37.00	45.00	8.00E+18	550.00
41C	60.00	33.00	33.00	50.00	8.00E+18	550.00
47E	95.00	43.00	44.00	75.00	8.00E+18	550.00
46T	125.00	41.00	38.00	70.00	8.00E+18	550.00
45M	145.00	45.00	44.00	80.00	8.00E+18	550.00
437	165.00	63.00	61.00	100.00	8.00E+18	550.00
45P	200.00	84.00	68.00	100.00	8.00E+18	550.00
434	250.00	75.00	65.00	100.00	8.00E+18	550.00

Battelle Columbus Additional Unirradiated HAZ Results[3]

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
3B1	-120.00	7.50	5.00	11.00
3B3	-120.00	9.50	3.20	9.30
1B11	-80.00	23.50	13.00	12.40
1B12	-80.00	26.00	16.60	17.80
1B17	-40.00	27.50	21.80	13.10
3B4	-40.00	57.00	36.20	31.10
3B5	0.00	39.50	31.80	49.20
1B9	0.00	64.50	43.20	55.40
1B16	20.00	61.50	46.60	52.00
1B5	20.00	76.00	49.80	54.70
1B3	20.00	82.00	50.60	56.30
1B18	40.00	93.00	63.80	63.10
1B10	40.00	99.00	64.00	73.40
1B13	40.00	105.00	64.40	72.90
1B8	80.00	113.00	72.60	100.00
1B6	80.00	115.00	65.00	100.00
1B4	120.00	122.00	83.40	100.00
1B14	120.00	160.00	86.60	100.00
1B7	160.00	128.00	87.20	100.00
1B2	160.00	153.00	82.20	100.00
3B6	210.00	118.00	78.80	100.00
1B15	210.00	132.00	75.80	100.00

APPENDIX H

SONGS, UNIT 3: IRRADIATED C_{VN} DATA FROM CAPSULE 97

Table H-1 Charpy V-Notch Test Results
For Unit 3 Plate C6802-1 (LT)
Irradiated (f = 8 x 10^{18} n/cm^2)

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
147	50.00	6.00	5.00	5.00
153	75.00	22.00	15.00	15.00
15K	100.00	29.00	24.00	25.00
113	125.00	35.00	32.00	30.00
14Y	150.00	32.00	26.00	30.00
15B	165.00	45.00	43.00	45.00
14A	175.00	30.00	27.00	45.00
14E	200.00	46.00	46.00	55.00
11T	225.00	75.00	66.00	80.00
12K	250.00	45.00	48.00	80.00
12L	250.00	48.00	46.00	95.00
14M	275.00	90.00	76.00	100.00

Table H-2 Charpy V-Notch Test Results
For Unit 3 Plate C6802-1 (TL)
Irradiated ($f = 8 \times 10^{18}\ n/cm^2$)

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
25U	0.00	19.00	18.00	10.00
23K	25.00	16.00	11.00	10.00
21A	50.00	9.00	12.00	10.00
23L	75.00	21.00	20.00	15.00
22B	100.00	25.00	25.00	20.00
25J	115.00	55.00	48.00	45.00
25L	130.00	50.00	44.00	50.00
247	150.00	33.00	33.00	50.00
223	165.00	36.00	37.00	65.00
25C	200.00	92.00	73.00	100.00
245	225.00	62.00	59.00	100.00
23M	250.00	73.00	77.00	100.00

Table H-3 Charpy V-Notch Test Results
For Unit 3 Surveillance Weld
Irradiated ($f = 8 \times 10^{18}$ n/cm^2)

SPECIMEN ID	TEMP TEST (F)	ENERGY IMPACT (ft-lb)	LATERAL EXP (mil)	FRACT APPEAR (%)
363	-50.00	23.00	20.00	15.00
33L	-25.00	27.00	25.00	20.00
31D	0.00	5.00	6.00	5.00
37B	10.00	42.00	34.00	60.00
367	25.00	42.00	44.00	65.00
331	50.00	44.00	44.00	70.00
37U	60.00	61.00	57.00	95.00
371	80.00	65.00	59.00	95.00
365	105.00	67.00	60.00	100.00
34P	150.00	75.00	73.00	100.00
33D	190.00	77.00	76.00	100.00
377	225.00	63.00	58.00	100.00