

**Southern California Edison
San Onofre Nuclear Generating Station, Unit 3
Response to Generic Letter 92-01**

(Non-Proprietary Version)

ATI Consulting

Sartrex Corporation

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

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CONTENTS

| <u>Section</u> | <u>Page</u> |
|---|-------------|
| 1 INTRODUCTION | 1-1 |
| 2 REACTOR PRESSURE VESSEL SURVEILLANCE PROGRAM-COMPLIANCE WITH APPENDIX H | 2-1 |
| 3 FRACTURE MECHANICS | 3-1 |
| 3.1 COMPLIANCE WITH APPENDIX G | 3-1 |
| 3.2 BELTLINE MATERIALS IN SONGS, UNIT 3 | 3-1 |
| 3.2.1 Location | 3-1 |
| 3.2.2 Heat Treatment | 3-1 |
| 3.2.3 Key Residual and Alloying Element Contents | 3-2 |
| 3.3 FRACTURE TOUGHNESS RELATED DATA | 3-3 |
| 3.3.1 Beltline Plate Material | 3-3 |
| 3.3.2 Beltline Welds | 3-4 |
| 4 ISSUES RELATED TO GENERIC LETTER 88-11 | 4-1 |
| 4.1 VESSEL TEMPERATURE DURING OPERATION | 4-1 |
| 4.2 APPLICABILITY OF SURVEILLANCE DATA | 4-1 |
| 4.3 SHIFTS AT THE CHARPY V-NOTCH 30 FT-LB ENERGY LEVEL | 4-2 |
| 4.4 UPPER SHELF ENERGY D_{KUP} | 4-3 |
| 5 REFERENCES | 5-1 |
| APPENDIX A SONGS, UNIT 3: EVALUATION OF COMPLIANCE WITH ASTM E185-73 AND E185-82 | A-1 |
| APPENDIX B SONGS, UNIT 3: BASES FOR PLATE CHEMISTRY MEASUREMENTS | B-1 |
| APPENDIX C SONGS, UNIT 3: MCRs FOR BELTLINE MATERIALS (Proprietary) | C-1 |

CONTENTS (cont'd)

| <u>Section</u> | | <u>Page</u> |
|----------------|---|-------------|
| APPENDIX D | SONGS, UNIT 3: UNIRRADIATED C_{VN} DATA FOR PLATES AND WELDS | D-1 |
| APPENDIX E | SONGS, UNIT 3: HAZ TEST RESULTS | E-1 |
| APPENDIX F | SONGS, UNIT 3: IRRADIATED C_{VN} DATA FROM CAPSULE 97 | F-1 |

ILLUSTRATIONS

| <u>Figure</u> | <u>Page</u> |
|---|-------------|
| 3-1 SONGS, Unit 3: Location and Identification of Beltline Plates and Welds | 3-6 |
| 3-2 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, TL Orientation, MCR Data | 3-7 |
| 3-3 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-2, TL Orientation, MCR Data | 3-8 |
| 3-4 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-3, TL Orientation, MCR Data | 3-9 |
| 3-5 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-4, TL Orientation, MCR Data | 3-10 |
| 3-6 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-5, TL Orientation, MCR Data | 3-11 |
| 3-7 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-6, TL Orientation, MCR Data | 3-12 |
| 3-8 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, TL Orientation, Surveillance Baseline Data | 3-13 |
| 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 | 3-14 |
| 3-10 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, LT Orientation, Surveillance Baseline Data | 3-15 |

ILLUSTRATIONS (cont'd)

| <u>Figure</u> | <u>Page</u> |
|--|-------------|
| 3-11 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, LT Orientation, MCR Data | 3-16 |
| 3-12 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Weld 3-203, FSAR Data | 3-17 |
| 3-13 SONGS, Unit 3: Data and Least Squares Fit Curve for Temperature, Weld 9-203, WMC Data | 3-18 |
| 3-14 SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Surveillance Weld, Surveillance Baseline Data | 3-19 |
| 4-1 SONGS, Unit 3: Comparison of Irradiated C_{VN} Data from Capsule 97 with Unirradiated Baseline Data, Plate C6802-1, LT Orientation | 4-4 |
| 4-2 SONGS, Unit 3: Comparison of Irradiated C_{VN} Data from Capsule 97 with Unirradiated Baseline Data, Plate C6802-1 TL Orientation | 4-5 |
| 4-3 SONGS, Unit 3: Comparison of Irradiated C_{VN} Data from Capsule 97 with Unirradiated Baseline Data, Surveillance Weld | 4-6 |

TABLES

| <u>Table</u> | | <u>Page</u> |
|--------------|--|-------------|
| 3.1 | SONGS, Unit 3: 10CFR50 Appendix G - Areas of Non-Compliance | 3-20 |
| 3.2 | SONGS, Unit 3: Plate and Corresponding Heat Numbers for Beltline Plates | 3-22 |
| 3.3 | SONGS, Unit 3: Weld Wire and Flux Combinations for Beltline and Surveillance Welds | 3-23 |
| 3.4 | SONGS, Unit 3: Key Residual and Alloying Element Contents for Beltline Plates | 3-24 |
| 3.5 | SONGS, Unit 3: Key Residual and Alloying Element Contents Beltline Welds | 3-25 |
| 3.6 | SONGS, Unit 3: Beltline Plate Material Unirradiated Fracture Toughness Tests Results Summary | 3-26 |
| 3.7 | SONGS, Unit 3: Charpy Absorbed Energy Values at 20F for Weld Seams 2-203 A, B, and C | 3-27 |
| 3.8 | SONGS, Unit 3: Beltline Weld Material Unirradiated Fracture Toughness Tests Results Summary | 3-28 |
| 4.1 | SONGS, Unit 3: Surveillance Capsule Shift Results | 4-7 |
| 4.2 | SONGS, Unit 3: ART Estimates for Beltline Materials on 12/16/91 and at 32 EFPY | 4-8 |
| 4.3 | SONGS, Unit 3: Surveillance Capsule Upper Shelf Results | 4-9 |
| 4.4 | SONGS, Unit 3: Upper Shelf Estimates for Beltline Materials on 12/16/91 and at 32 EFPY | 4-10 |

Section 1

INTRODUCTION

The Nuclear Regulatory Commission (NRC) in Generic Letter 92-01 (GL92-01) 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. This report has been prepared in response to GL92-01 for San Onofre Nuclear Generating Station (SONGS), Unit 3.

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 4.0 addresses embrittlement effects, including irradiation temperature and adjusted reference temperature for evaluation of the beltline materials relative to GL88-11 and 10CFR50.61.

Additional information is needed to complete the response to GL92-01 for SONGS, Unit 3. This information includes: (1) resolving inconsistencies in the residual and alloying element contents and Charpy impact properties reported for beltline weld 9-203 and the 8-203 weld, which have been reported to have been fabricated using some of the same components; (2) reviewing 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.

Section 2

REACTOR PRESSURE VESSEL SURVEILLANCE PROGRAM COMPLIANCE WITH APPENDIX H

The ASME Code of record for the San Onofre Nuclear Generating Station (SONGS), Unit 3 reactor pressure vessel is the 1971 Edition through the Summer 1971 Addenda. Consequently, the applicable version of 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 Appendix H requirements had to do with the method of attachment of the holders for the six surveillance capsules in each SONGS unit. Combustion Engineering (CE) was the vessel manufacturer and the nuclear steam supply system (NSSS) vendor; CE attached the capsule holders directly to the cladding on the inside of the vessel in the beltline region (as they did for all CE NSSS-designed vessels), and this approach violated the requirements in the early 1970's version of 10CFR50, Appendix H. The NRC reviewed a 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 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 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 (E185-92) 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 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.

Generally, the information presented in this section has been obtained from the materials certification reports (MCRs) and the FSAR for SONGS, Unit 3, and from additional information supplied by Combustion Engineering (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

Generally, the materials in the beltline region of SONGS, Unit 3 comply with the requirements of Appendix G, 10CFR50. Areas of non compliance with Appendix G, 10CFR50, 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 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.

3.2.2 Heat Treatment

The heat treatment for the plate materials consisted of austenitization at $1575 \pm 50^\circ\text{F}$ for 4 hours; water quenched and tempered at $1225 \pm 25^\circ\text{F}$ for 4 hours. For ASME Code qualification, the plates were stress relieved at $1150 \pm 25^\circ\text{F}$ 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 the 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 and Ni contents were obtained by averaging two measurements made by CE. The first measurement was made when CE received the plate from Lukens and the second measurement was made when the surveillance program was defined. The bases for the Cu and Ni contents reported by CE and listed in Table 3.4 are presented in Appendix B. The plate P and S contents were obtained from the MCRs, which are included as Appendix C.

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 in the FSAR for the beltline welds. Two additional chemistry measurements are reported for beltline weld 9-203. One additional value was obtained from the welding material certification (WMC) for Type Mil B-4 Wire, Heat No. 90069, Linde Type 124 Flux, Lot No. 0951 (see Appendix C), while a second preliminary value has been provided by CE^[4] for Type Mil B-4 Wire, Heat No. 90144, Linde Type 124 Flux, Lot No. 1061. 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]. Because Cu was not measured for beltline weld 8-203, a value of 0.35 wt% has been assumed (see Regulatory Guide 1.99, Revision 2). Because Ni was not measured for beltline welds 8-203 and 2-203, a value of 1.0 wt % has been assumed (see Regulatory Guide 1.99, Revision 2).

The surveillance weld was reported by CE to have been fabricated using one of the weld wire and flux combinations in weld 9-203 (see Table 3.3). The information in Table 3.5 indicates a distinct difference between the Cu and Ni contents reported for the surveillance weld and weld 9-203. Because of the differences in reported Cu and Ni contents and differences in the C_{VN} curves (see Section 3.3.2) the surveillance weld and beltline weld 9-203 are listed and evaluated separately in the report. CE is continuing their investigation to resolve these inconsistencies.

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 Charpy V-notch absorbed energy (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 E185-92 (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 plate were obtained from the MCRs (see Appendix C) and baseline surveillance program. The data for weld 9-203 were obtained from the WMC (see Appendix C). The fracture toughness data for the remaining beltline welds were obtained from the FSAR, 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 D.

As discussed earlier in Section 2, the results for heat affected zone (HAZ) material are not evaluated in this report because upcoming ASTM standard E185-92 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 E.

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 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 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 also is 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 E185-92 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 ($T @ 50 \text{ ft-lbs}$) is achieved consistent with the applicable method of ASME, Section III, NB 2331, and RT_{NDT} .

As part of the surveillance program additional Charpy absorbed energy 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. Because there was a relatively wide gap in the test temperatures near the 50 ft-lb level for the surveillance baseline data set in Figure 3-8, the graphical method of NB-2331 (a)(4) was used to determine RT_{NDT} . The 50 ft-lb temperature was determined by the intersection of the dashed line and the 50 ft-lb level as shown in Figure 3-8. The dashed line was drawn parallel to the least squares fit line at 50 ft-lb so that it was on, or to the right of, all data points in the transition region.

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 combined data set presented in Figure 3-9 was used to determine RT_{NDT} and the USE for the transverse orientation in Plate C6802-1. The average curve through the combined data set in Figure 3-9 also 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 transverse 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, while the second value was determined from the unirradiated baseline tests. The higher of these values 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 except for the combined data set of plate C6802-1 (see Figure 3-9), where the graphical method of NB-2331 (a)(4) was used because there is a relatively wide spread in the test temperatures near the 50 ft-lb level.

Figure 3-10 shows the data and least squares fit line for the longitudinal (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 indicate a significant difference in the C_{VN} versus temperature curves obtained from the MCR and surveillance program for the LT orientation for plate C6802-1. CE is continuing their investigation to resolve this inconsistency.

3.3.2 Beltline Welds

A full C_{VN} versus temperature curve was obtained for the material in weld seam 3-203, 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 combination in beltline weld seam 9-203; the C_{VN} data and least squares hyperbolic tangent fit through the data are presented in Figure 3-13. The material in beltline weld seam 2-203 was tested to obtain three C_{VN} data points at 20°F. The results from these tests are presented in Table 3.7.

Figure 3-14 presents the C_{VN} data and least squares hyperbolic tangent curve fit for the surveillance weld material. A comparison of Figures 3-13 and 3-14 indicates a significant difference in the C_{VN} versus temperature curves for the surveillance weld and beltline weld 9-203. This difference is not consistent with what would be expected from independent testing of the same weld wire heat. The source of this inconsistency is under investigation by CE.

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, 3-203, 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. No NDT data are available for weld 8-203, and RT_{NDT} was taken as the generic value of -56°F for CE fabricated vessels (see 10CFR50.61).

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 3-14.

The upper shelf energies listed in Table 3.8 for welds 3-203, 9-203 (Heat 90069), and the surveillance weld were obtained by averaging the test results where 95% shear or greater was exhibited. The upper shelf energy for weld 2-203 was obtained from the data in Table 3.7 by averaging the three C_{VN} data points obtained at 20°F. Currently, no C_{VN} data have been identified for welds 9-203 (Heat 90144) and 8-203, and CE is continuing their investigation to identify the C_{VN} values.

REACTOR VESSEL BELTLINE MATERIALS
NOT SHOWN

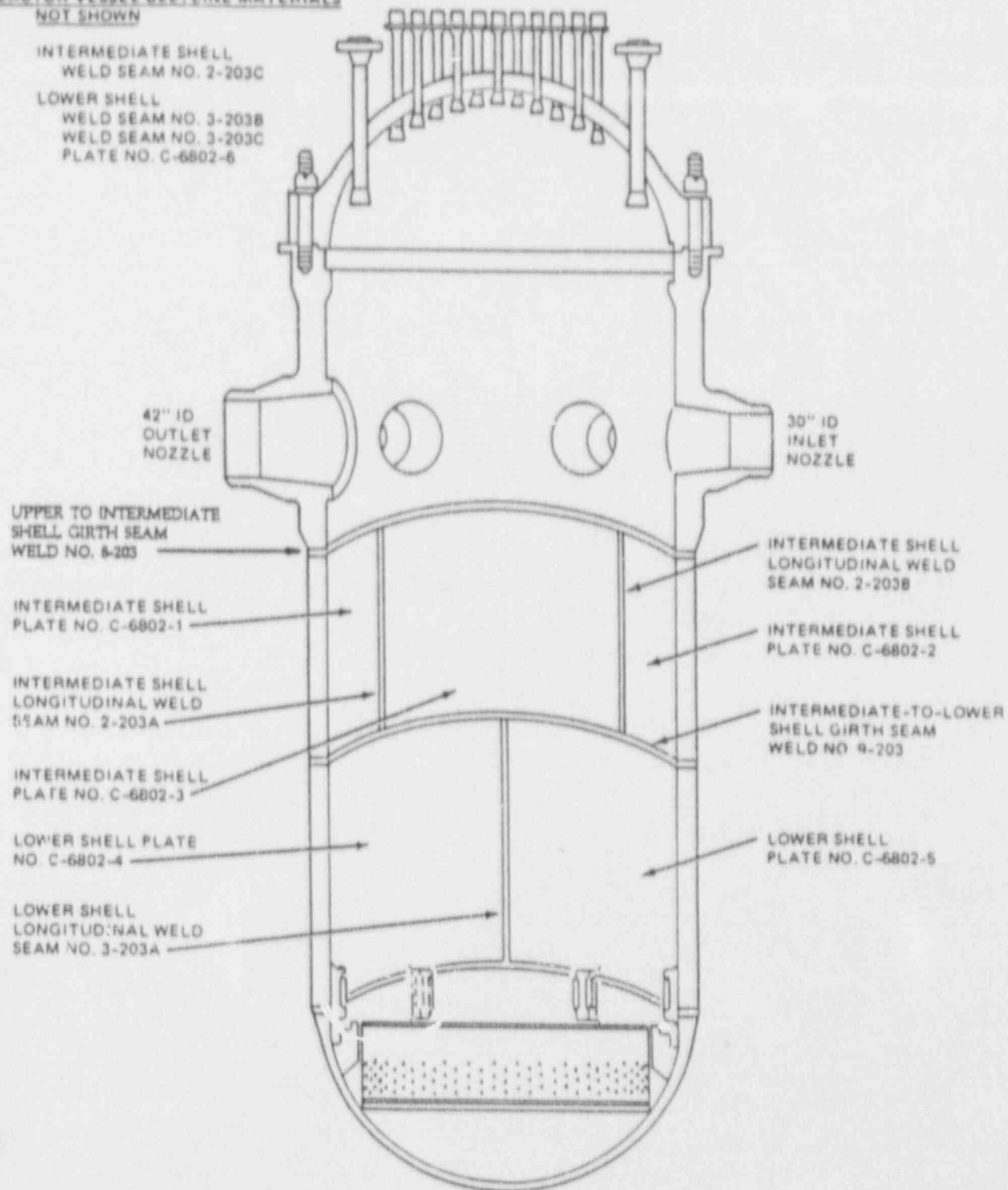


Figure 3-1. SONGS, Unit 3: Location and Identification of Beltline Plates and Welds.

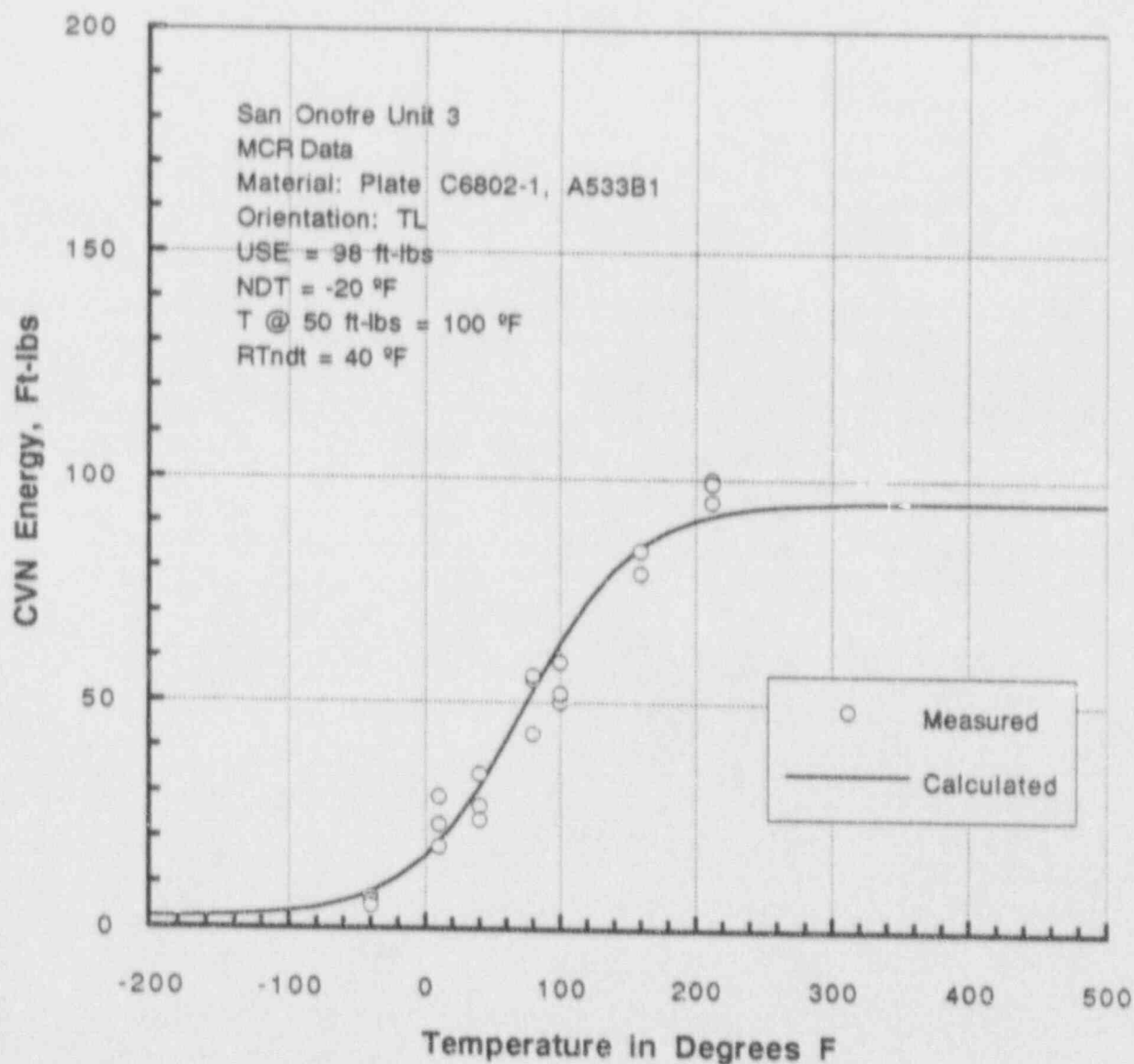


Figure 3-2. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, TL Orientation, MCR Data.

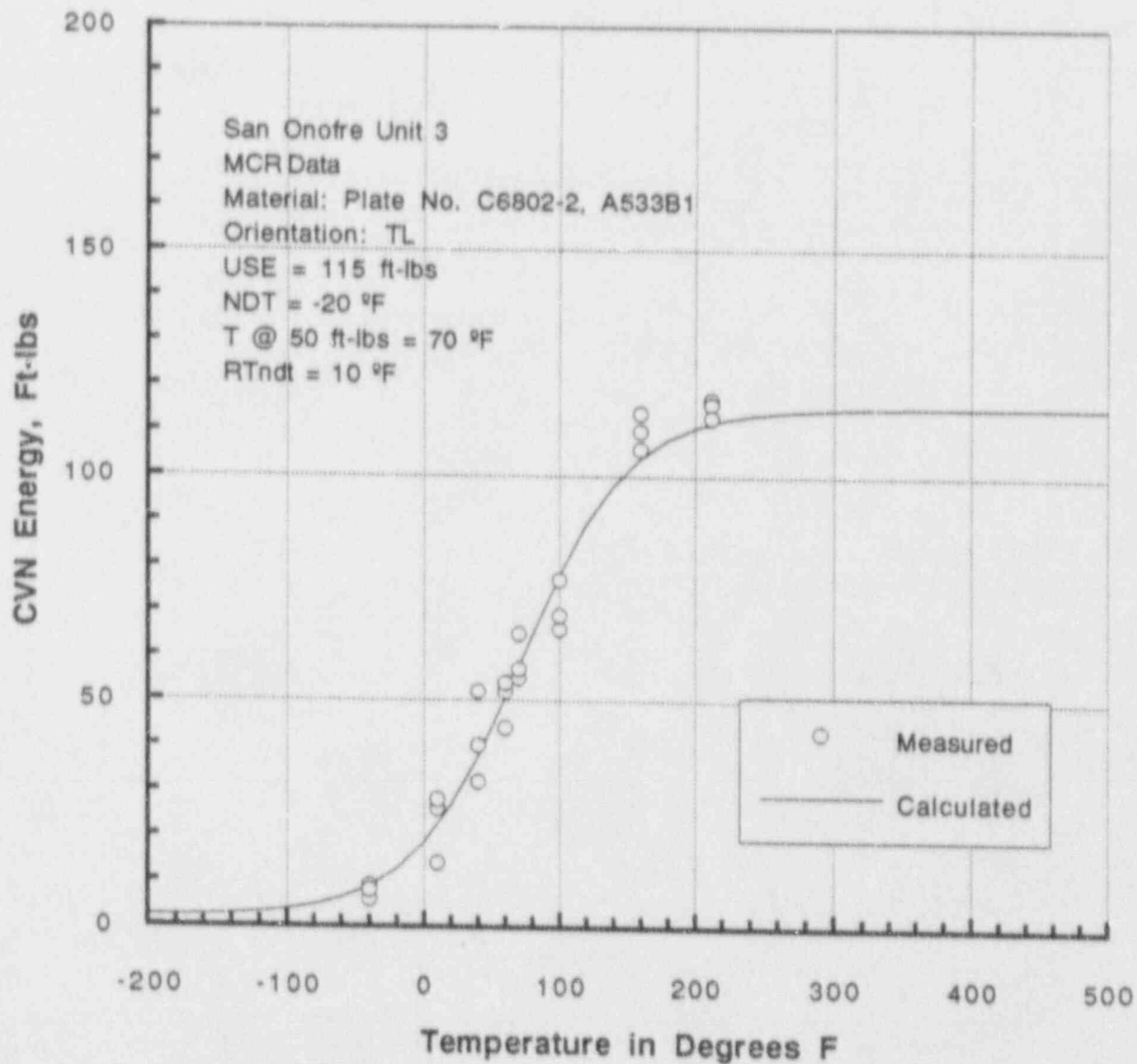


Figure 3-3. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-2, TL Orientation, MCR Data.

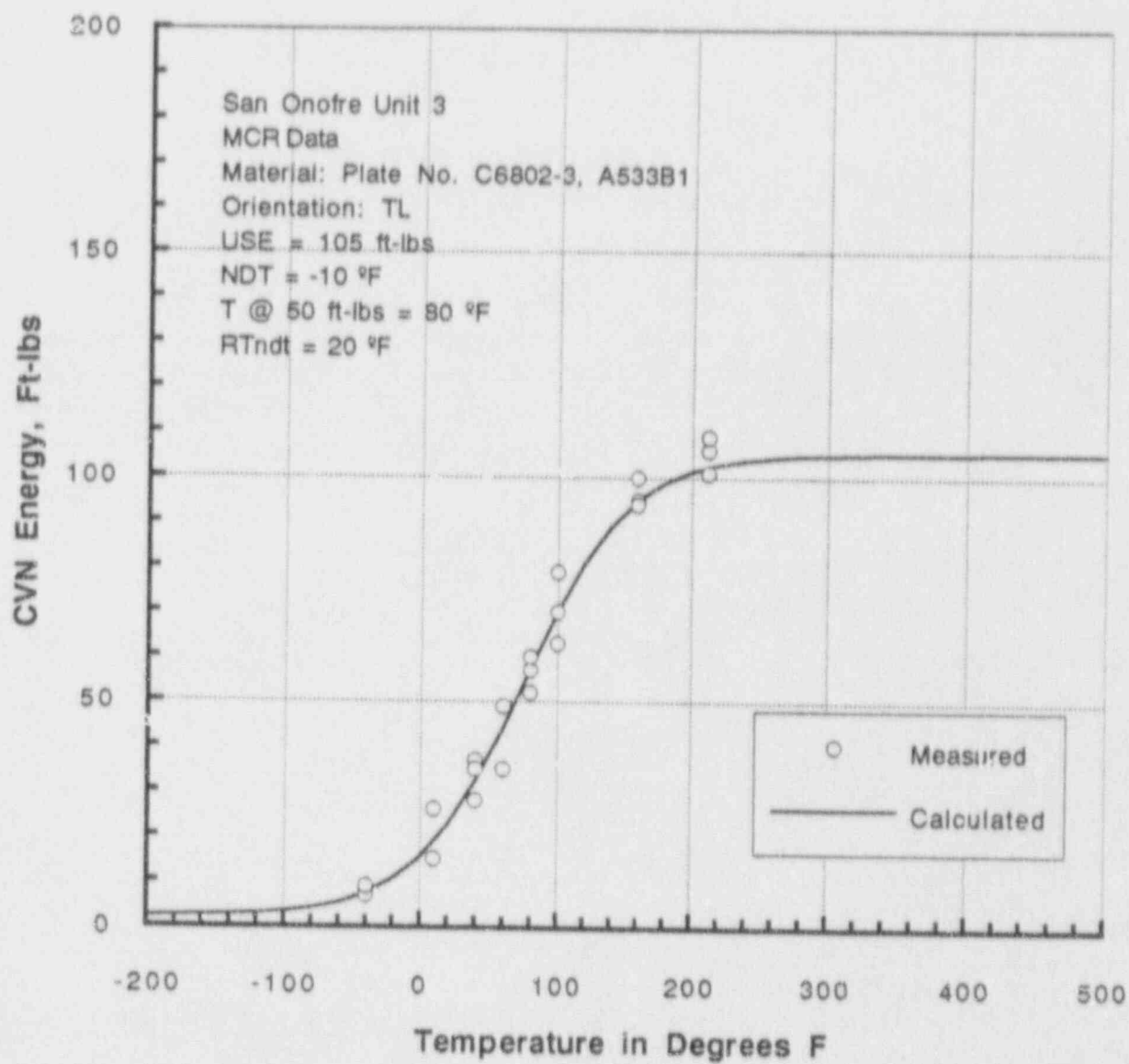


Figure 3-4. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-3, TL Orientation, MCR Data.

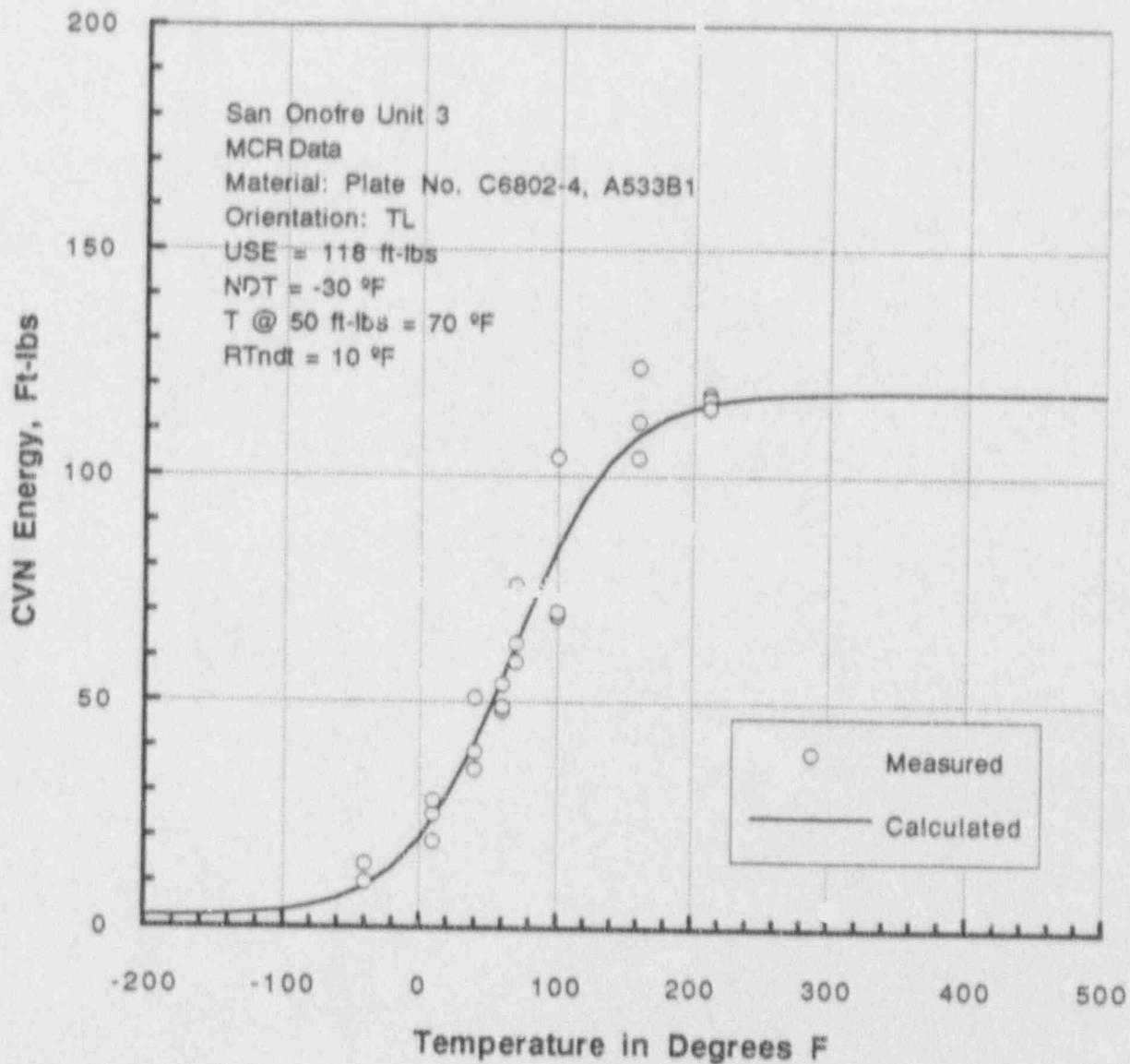


Figure 3-5. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-4, TL Orientation, MCR Data.

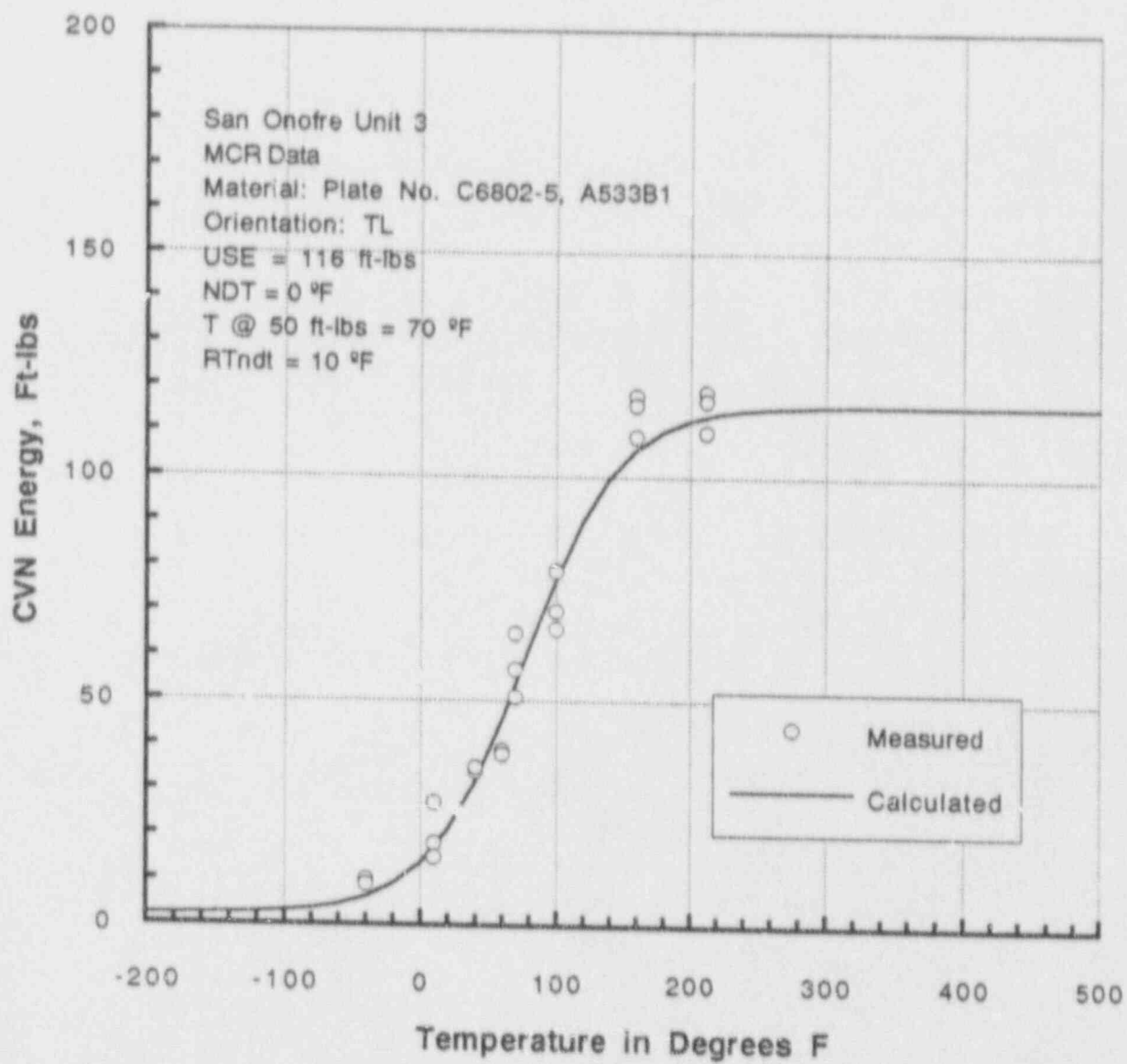


Figure 3-6. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-5, TL Orientation, MCR Data.

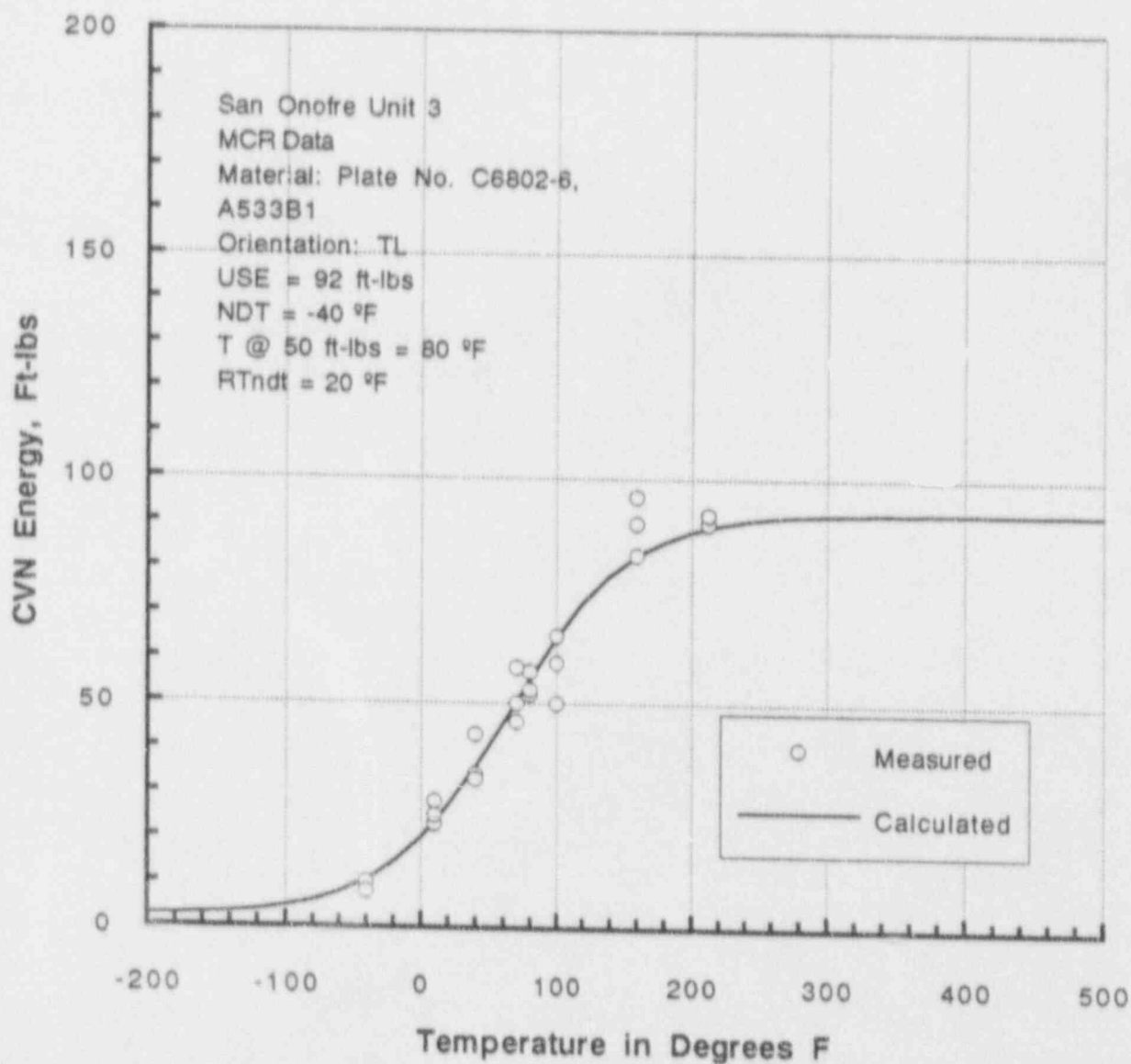


Figure 3-7. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-6, TL Orientation, MCR Data.

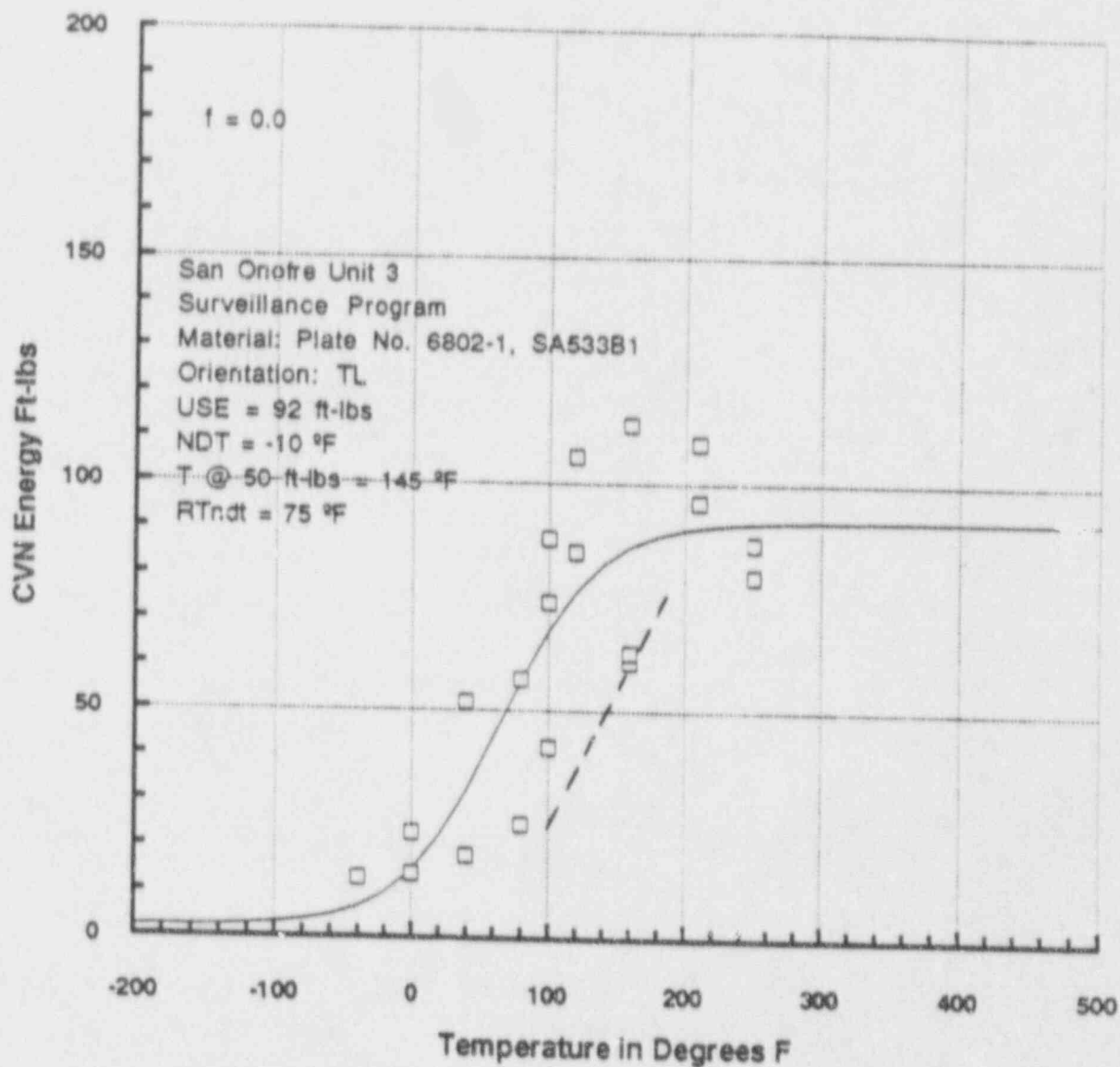


Figure 3-8. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, TL Orientation, Surveillance Baseline Data.

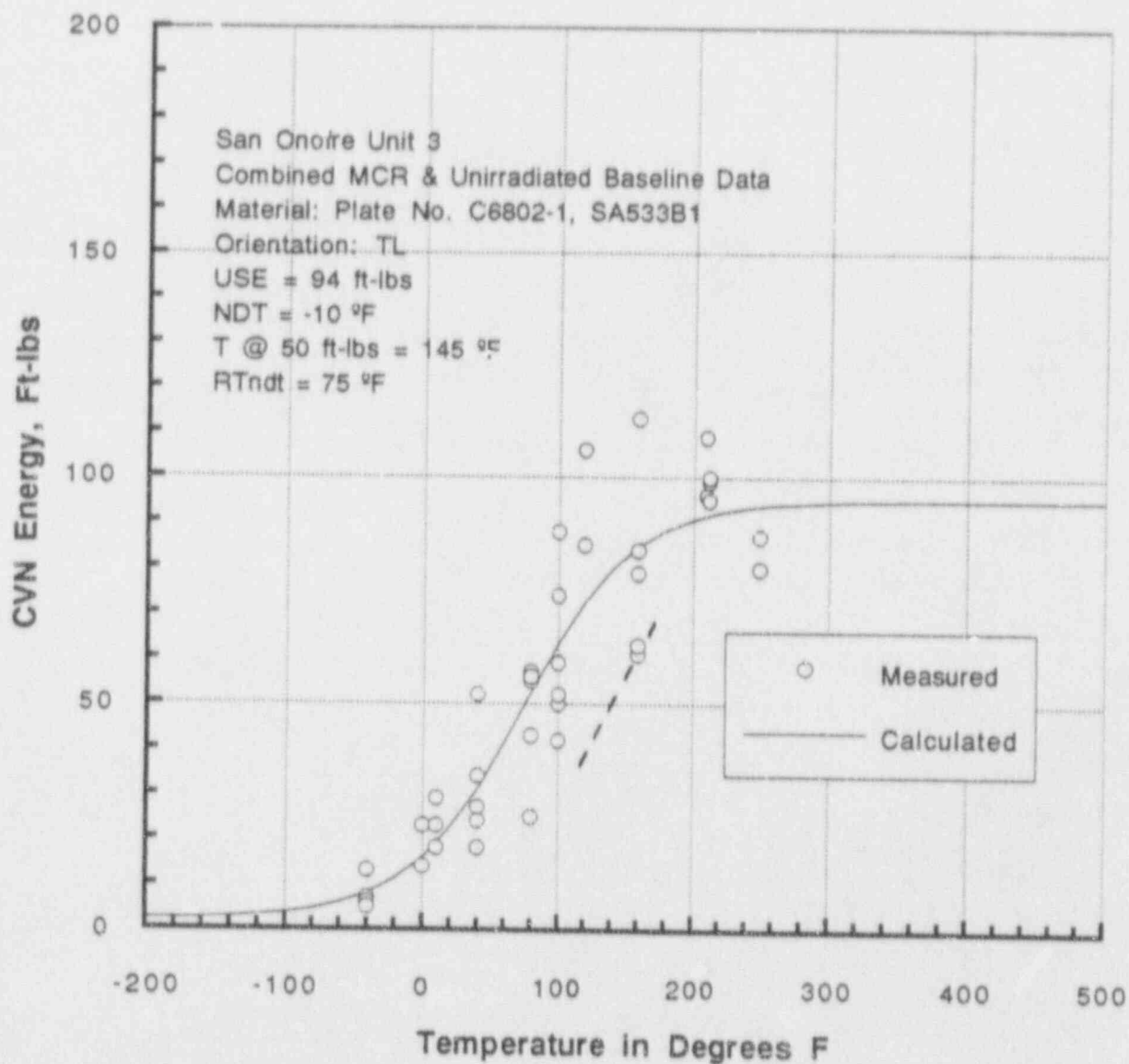


Figure 3-9. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, TL Orientation, Combined MCR and Surveillance Baseline Data.

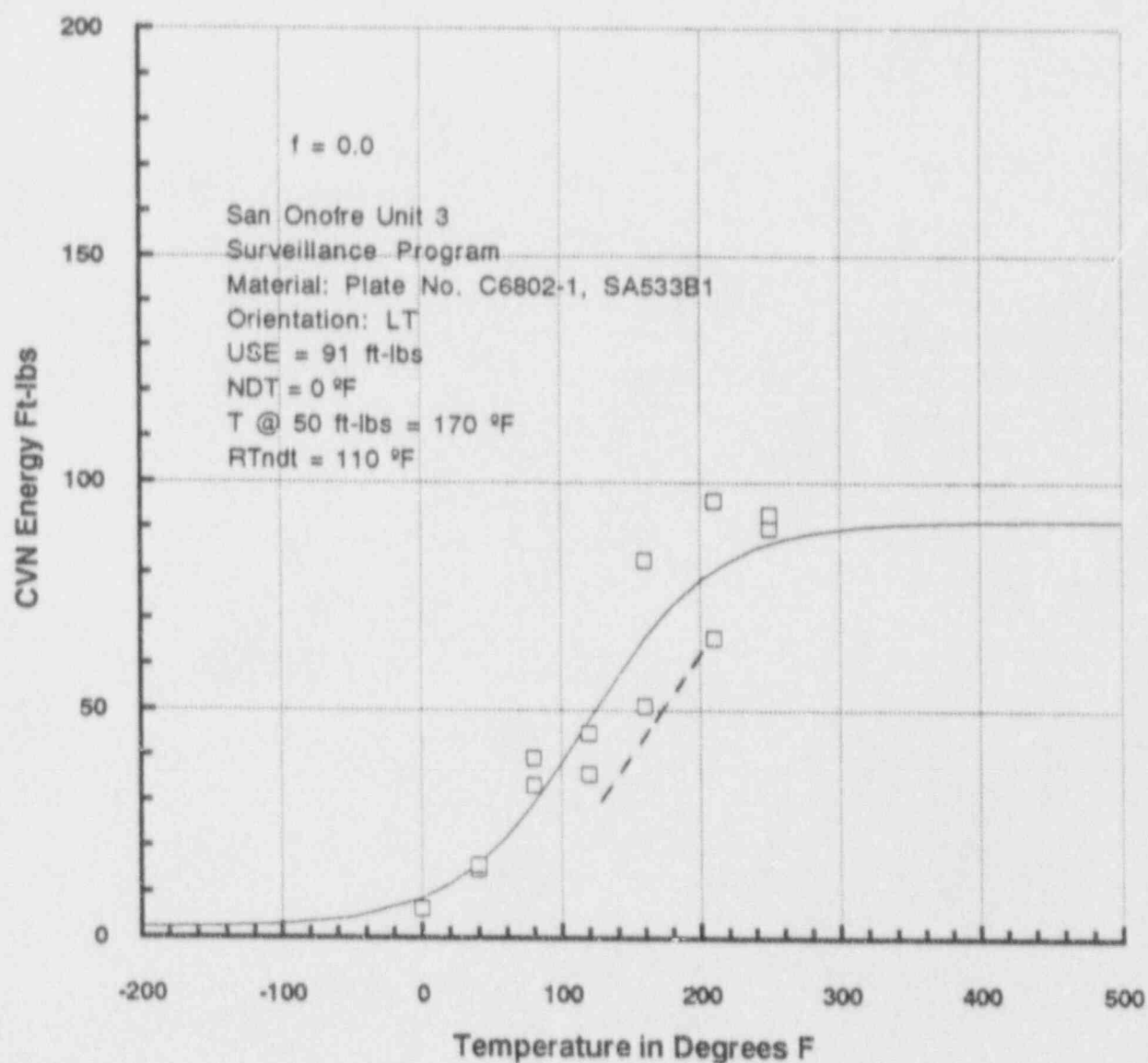


Figure 3-10. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, LT Orientation, Surveillance Baseline Data.

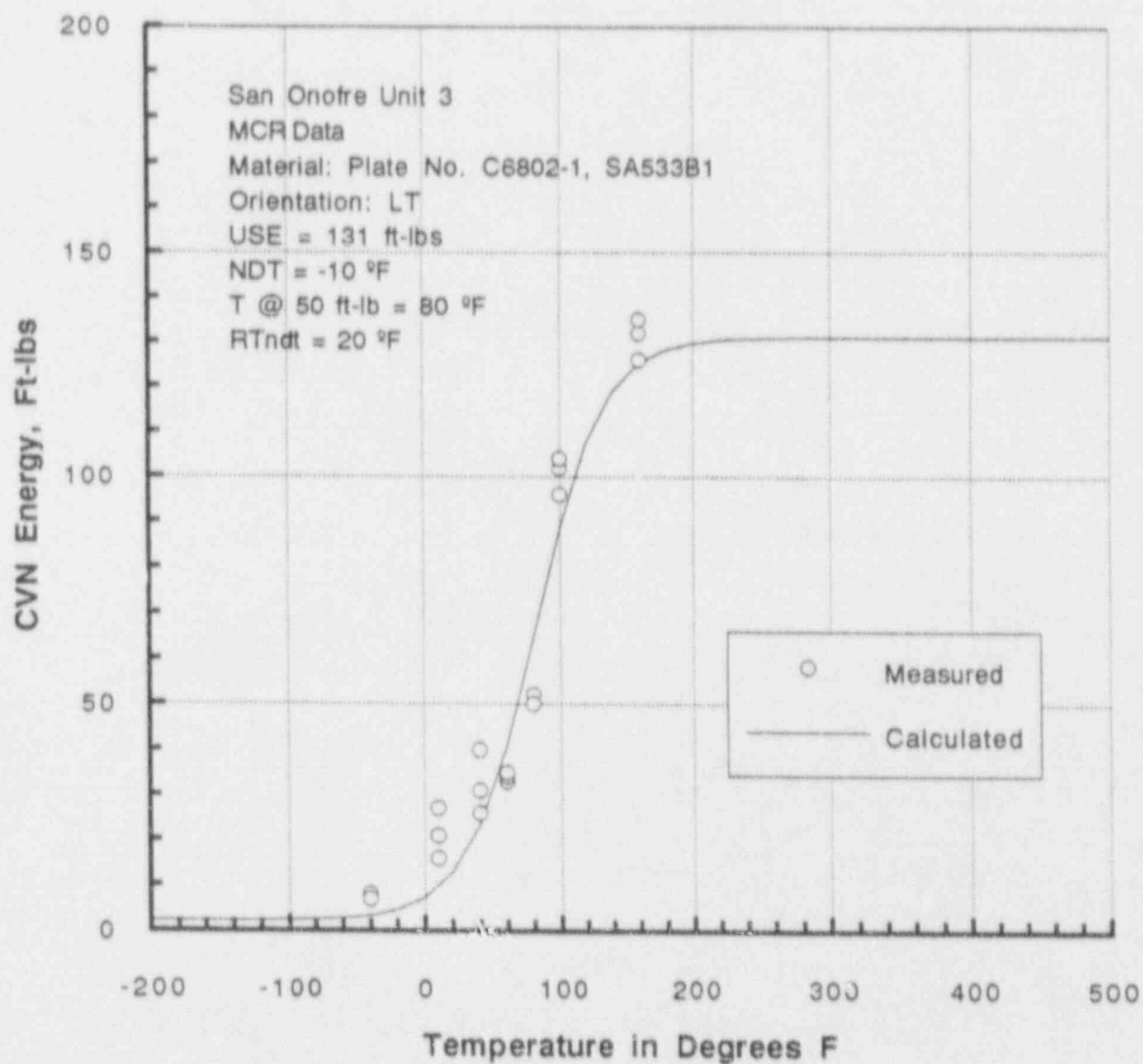


Figure 3-11. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Plate C6802-1, LT Orientation, MCR Data.

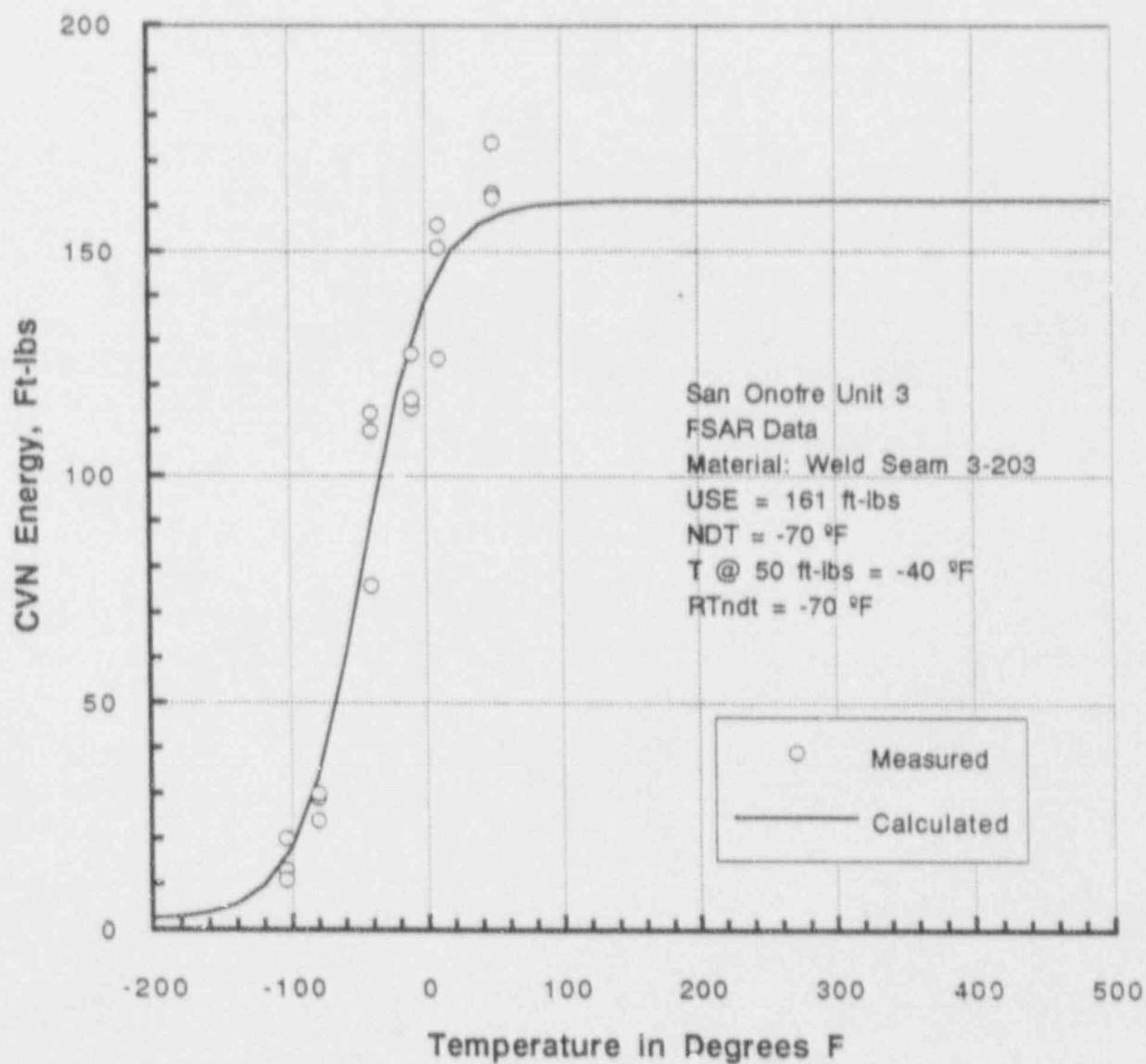


Figure 3-12. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Weld 3-203, FSAR Data

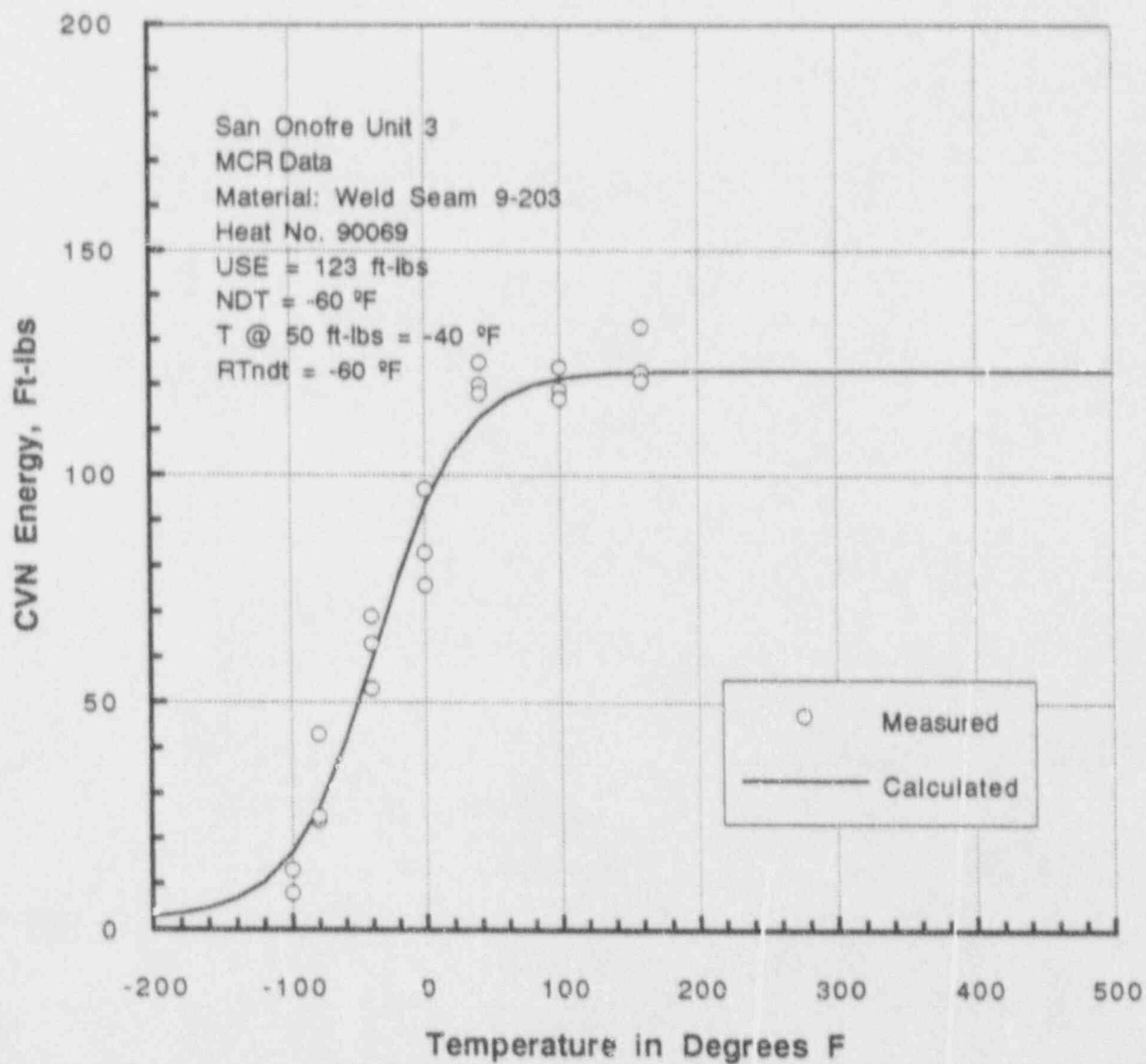


Figure 3-13. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Weld 9-203, MCR Data.

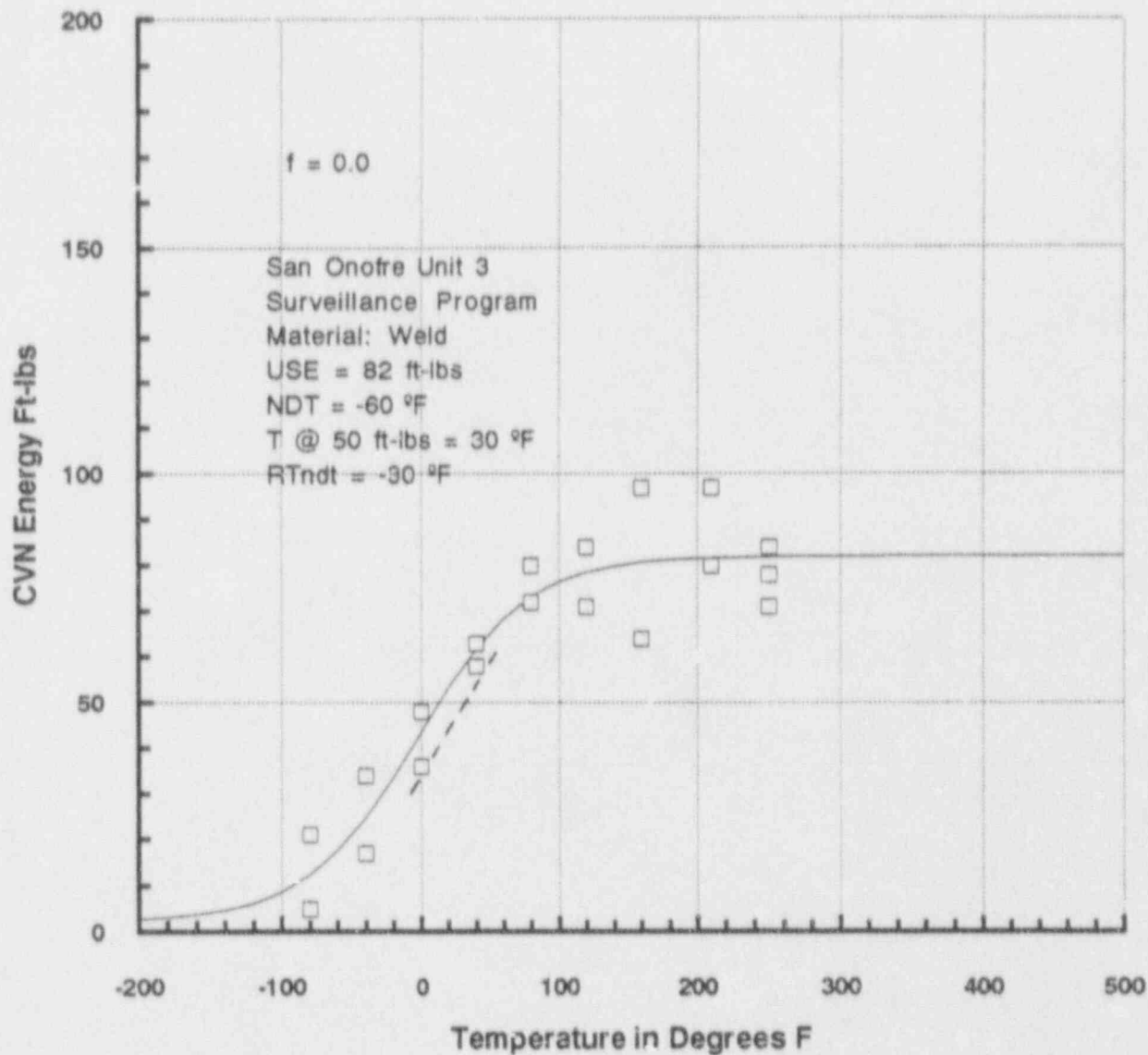


Figure 3-14. SONGS, Unit 3: Data and Least Squares Fit Curve for C_{VN} versus Temperature, Surveillance Weld, Surveillance Baseline Data.

Table 3.1 SONGS, Unit 3: 10CFR50 Appendix G - Areas of Non-Compliance.

| 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 (Continue)

| Paragraph | Description of Non-Compliance | Comment |
|-----------|---|---|
| IV.A.4 | Charpy V-notch test were not conducted at "the preload temperature or at the lowest service temperature, whichever is lower". | <p>The ASME Code in effect required test temperature of 60F below the lowest service temperature. All beltline material was tested at 10F 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 as tested at 20F and has C_{VN} in excess of 100 ft-lb. These results indicate that the intent of Appendix G has been met. One weld located away from the core region has been classified as a beltline weld because the Cu and Ni contents are currently not documented and high values have been assumed; these assumed Cu and Ni values result in the second largest shift, for the beltline materials. In addition, no C_{VN} data are currently available for this weld. Additional chemistry, fluence, and C_{VN} energy data will be required to complete the evaluation of weld 8-203 for compliance with Appendix G.</p> |

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, and C | Type Mil B-4 Wire, Heat No. 83650 Linde Type 0091 Flux, Lot No. 1122 |
| 3-203 A, B, and C | Type Mil B-4 Wire, Heat No. 88114, Linde Type 0091 Flux, Lot No. 0145 |
| 9-203 | 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 | Presently not available |
| Surveillance | Presently not available. Currently reported by CE to be one of the weld wire heats used to fabricate beltline weld 9-203 ⁽⁴⁾ . |

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

| Plate Number | Cu ^a | Ni ^a | P ^b | S ^b | CF ^c |
|--------------|-------------------|-------------------|--------------------|--------------------|-----------------|
| C6802-1 | 0.06 | 0.58 | 0.011 | 0.013 | 37 |
| C6802-1 | 0.06 ^d | 0.58 ^d | 0.009 ^d | 0.014 ^d | 37 |
| C6802-2 | 0.04 | 0.57 | 0.010 | 0.013 | 26 |
| C6802-3 | 0.06 | 0.58 | 0.011 | 0.012 | 37 |
| C6802-4 | 0.05 | 0.56 | 0.011 | 0.013 | 31 |
| C6802-5 | 0.04 | 0.55 | 0.012 | 0.013 | 26 |
| C6802-6 | 0.06 | 0.62 | 0.011 | 0.014 | 37 |

a. Average values reported by CE in Appendix B.

b. Values reported in the MCR.

c. Chemistry factors from Regulatory Guide 1.99, Revision 2

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

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

| Weld Seam | Cu | Ni | P | S | CF ^a |
|---------------------------|-------------------|----------------|-------|-------|-----------------|
| 2-203A,B,C ^b | 0.05 | 1 ^c | 0.006 | 0.010 | 68 |
| 3-203A,B,C ^b | 0.04 | 0.16 | 0.007 | 0.005 | 39 |
| 9-203 ^b | 0.05 | 0.04 | 0.007 | 0.011 | 31 |
| 9-203 ^d | 0.06 | 0.04 | 0.010 | 0.009 | 34 |
| 9-203 ^e | 0.05 | 0.04 | N/A | N/A | 31 |
| 8-203 | 0.35 ^f | 1 ^c | N/A | N/A | 272 |
| Surveillance ^g | 0.03 | 0.08 | 0.004 | 0.009 | 27 |
| Surveillance ^h | 0.03 | 0.11 | 0.014 | 0.008 | 29 |
| Surveillance ^h | 0.03 | 0.09 | 0.011 | 0.008 | 28 |

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

b. Values from FSAR

c. Ni content was not measured and 1 wt% has been assumed

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

e. Preliminary information from CE for Type Mil B-4 Wire, Heat No. 90144, Linde Type 124 Flux, Lot No. 1061^[4].

f. Cu content was not measured and 0.35% has been assumed

g. Measured when surveillance program was developed^[1]

h. 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 | -10 ^b | 75 | NB2331 (a)(4) | 94 |
| 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} and USE values are based on the combined data sets from the MCRs and unirradiated surveillance baseline (see Figure 3-9)
- b. Higher of 2 transverse values (i.e., -20°F determined when plate was purchased, and -10°F from surveillance baseline)

Table 3.7 SONGS, Unit 3: Charpy Absorbed Energy Values at 20°F for Weld Seams 2-203 A, B and C.

| Weld Seam | Charpy Energy (ft-lb) |
|-------------------|--------------------------|
| 2-203 A, B, and C | 125, 138, 145 |

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 | N/A | -56 | c | N/A |
| 9-203 | -60 ^d | -60 | NB-2331 (a)(2) | 123 |
| 9-203 ^e | -50 | -50 | -- | N/A |
| Surveillance | -60 | -30 | NB-2331 (a)(4) | 82 |

a. Values obtained from the FSAR

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

c. Generic value for CE fabricated vessels using Linde 009, 1097, and 124 fluxes (see 10CFR50.61)

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

e. Preliminary values obtained from CE for Type Mil B-4 Wire, Heat No. 90144, Linde Type 124 Flux, Lot No. 1061⁽⁴⁾.

Section 4

ISSUES RELATED TO GENERIC LETTER 88-11

NRC issued Generic Letter 88-11 (GL88-11) in July 1988. GL88-11 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 Generic Letter 92-01 (GL92-01) 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 from 525 to 590°F. Concern is expressed in GL92-01 that power operation may occur at temperatures below 525°F. For SONGS, Unit 3 the reactor coolant cold leg temperature (T_c) is never below 545°F during power operation and rises to about 553°F at full power. Thus, there is no time during normal power operation that the SONGS, Unit 3 vessel or surveillance capsules experience temperatures below 545°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 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/cm² ($E > 1$ MeV); the capsule fluence was about 20% higher at 5.07×10^{18} n/cm².

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/cm², and the associated capsule fluence is 8.0×10^{18} n/cm².

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/cm².^[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/cm².

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 considered a beltline material because of a large chemistry factor associated with the unreported Cu and Ni contents. Because Cu was not reported, 0.35 wt % was conservatively assumed; and, because Ni was not reported, Ni was assumed at 1 wt %. The fluence at this location above the core has reported in the FSAR to be about 1/37 that of the peak fluence location within the vessel. Preliminary calculations performed at SCE indicate that the fluence at this weld location may be considerably lower than that indicated in the FSAR. Prior to final verification of the SCE fluence calculation at weld 8-203, the factor of 1/37 has been assumed to perform the evaluations in this report.

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 $\pm 25^\circ\text{F}$), 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/LT), 4-2 (Plate C6802-1/TL), and 4-3 (surveillance weld). Appendix F 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):

$$\text{RG1.99R2} = \text{CF (chemistry factor)} \times \text{ff (fluence function)}.$$

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 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 45 - 58°F). The measured shift for the surveillance weld is much less than 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 chemistry factors (CF) 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 GL92-01) 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. For weld seam 9-203 the properties from the weld wire heat 90069 was used for the predictions in Table 4-2; if the other weld wire heat (90144) was evaluated, the results would be 10°F higher due to the higher initial RT_{NDT} . 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 upper shelf energy results are shown in Figures 4-1, 4-2, and 4-3, and are tabulated in Table 4.3 as an absolute drop in upper shelf energy (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 two measured upper shelf drops for plate C6802-1 are slightly higher than those predicted using the regulatory guide. The difference will be reassessed when additional surveillance capsule results are available (at about 15 EFPY); however, as shown in the following paragraph, current trends indicate an USE well above 50 ft-lb at 32 EFPY.

Predictions of upper shelf energy 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. Because there are no upper shelf values for welds 8-203 and 9-203 (Heat 90144), these welds were not evaluated for drop in upper shelf. Since both of these welds were fabricated by CE using materials and procedures which produce initial upper shelves above 80 ft-lb, the upper shelf is projected to never drop below 50 ft-lb.

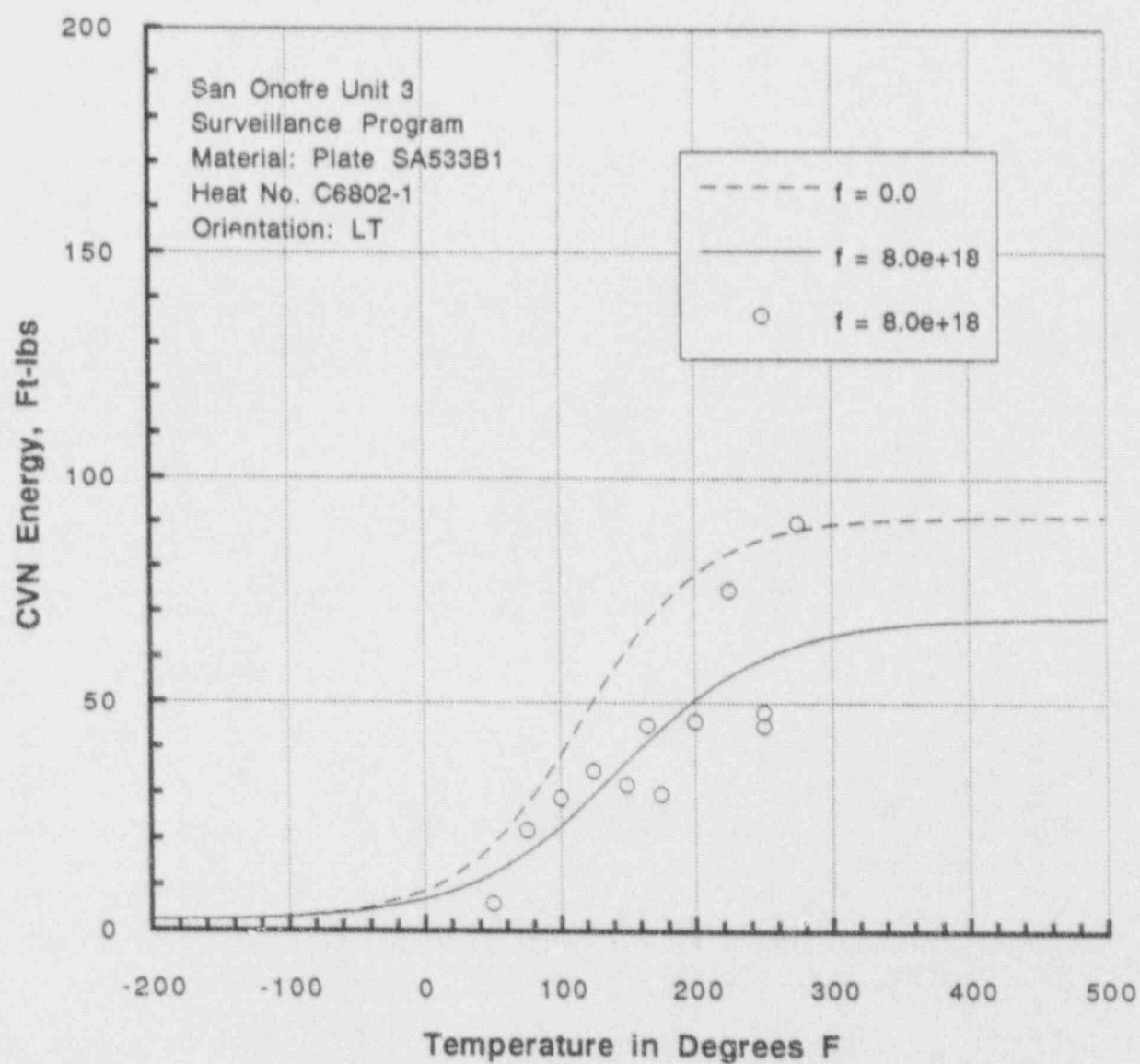


Figure 4-1. SONGS, Unit 3: Comparison of Irradiated C_{VN} Data from Capsule 97 with Unirradiated Baseline Data, Plate C6802-1, LT Orientation.

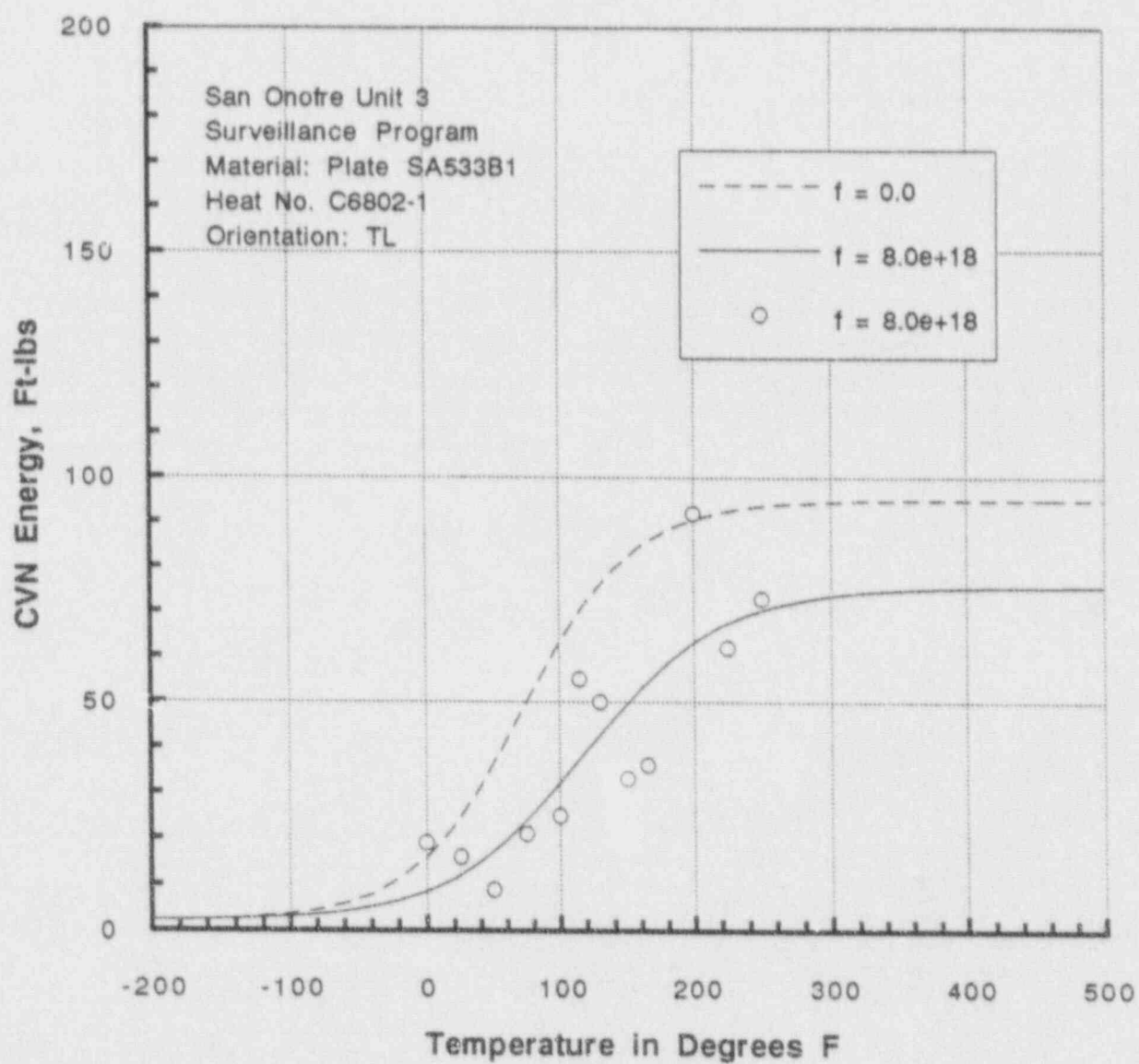


Figure 4-2. SONGS, Unit 3: Comparison of Irradiated C_{VN} Data from Capsule 97 with Unirradiated Baseline Data, Plate C6802-1, TL Orientation.

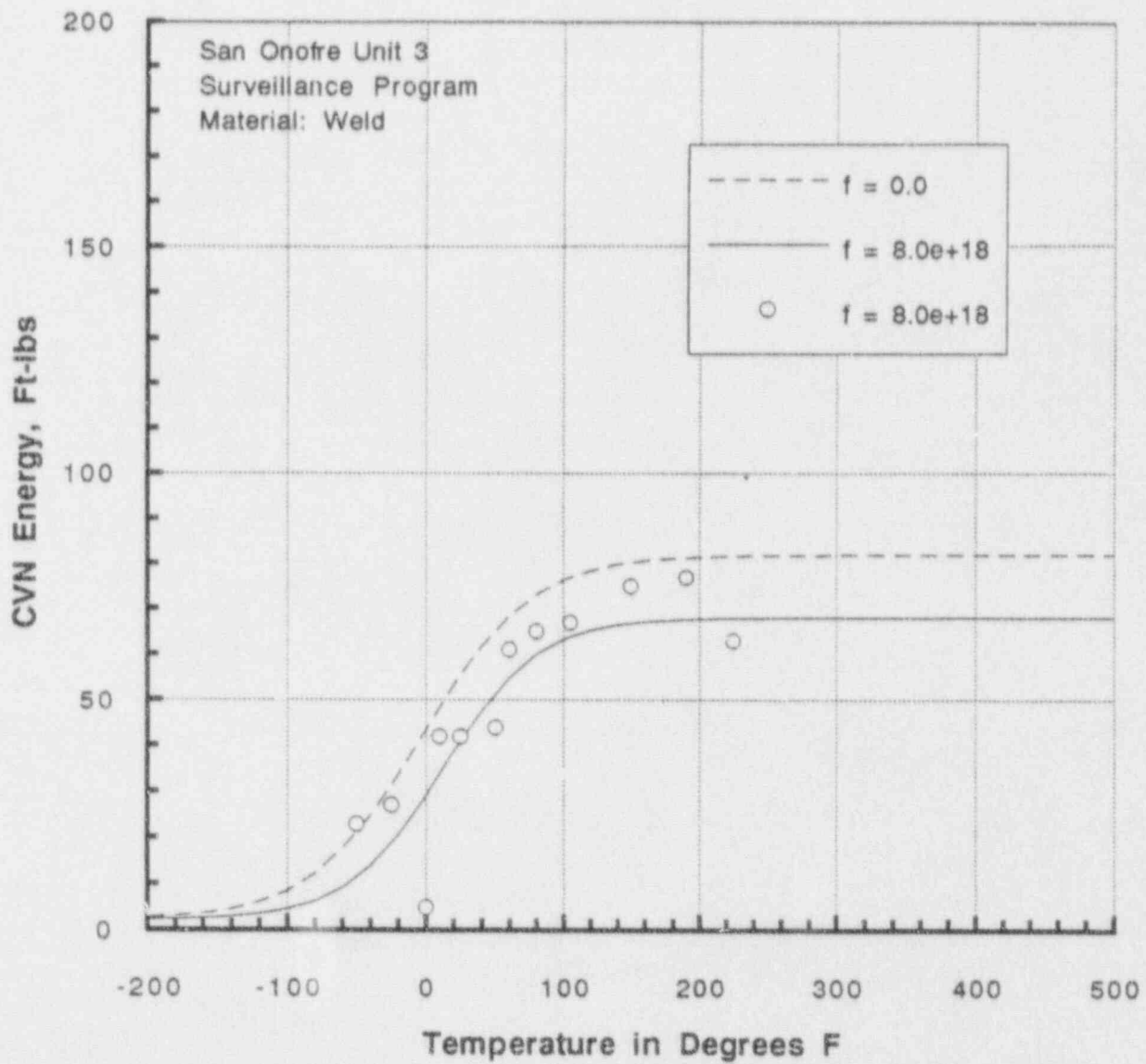


Figure 4-3. SONGS, Unit 3: Comparison of Irradiated C_{VN} data from Capsule 97 with Unirradiated Baseline Data, Surveillance Weld.

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

| Material/ Orientation | CF | ff | 30 ft-lb Shift (°F) | | |
|--------------------------|-----------------|------|---------------------|----------|-----------------|
| | | | <u>W</u> | RG1.99R2 | Current |
| C6802-1/LT | 37 ^a | 0.94 | 50 | 35 | 45 ^c |
| C6802-1/TL | 37 ^a | 0.94 | 55 | 35 | 58 ^d |
| Surveillance Weld | 28 ^b | 0.94 | 32 | 26 | 2 ^e |

^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 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 3-14.

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

| Plate No./ Weld Seam | CF | ff | | ART (F) ^a | |
|-------------------------|-----------------|----------------------------------|-------------------|----------------------------------|------------------|
| | | at the Inner Surface 12/16/91 | 32 EFY | at the Inner Surface 12/16/91 | 32 EFY |
| C6802-1 | 37 ^b | 0.95 | 1.37 | 144 | 160 |
| 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 | 69 | 86 |
| C6802-5 | 26 | 0.95 | 1.37 | 60 | 80 |
| C6802-6 | 37 | 0.95 | 1.37 | 89 | 105 |
| 2-203 | 68 | 0.95 | 1.37 | 81 | 109 |
| 3-203 | 39 | 0.95 | 1.37 | 4 | 37 |
| 8-203 | 272 | 0.19 ^c | 0.42 ^c | 56 ^d | 130 ^d |
| 9-203 | 34 | 0.95 | 1.37 | 5 | 33 |

^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 34F for plates or 56F 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 ff is based upon the peak vessel fluence divided by 37 (as indicated in the FSAR)

^d Since there is no 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 3: Surveillance Capsule Upper Shelf Results

| Material/ Orientation | Cu (wt%) | Fluence ($\times 10^{19}$ n/cm) | Upper Shelf Drop (ft-lb) | | |
|--------------------------|-------------------|-------------------------------------|--------------------------|-----------------|-----------------|
| | | | Battelle | RG1.99R2 | Current |
| C6802-1/LT | 0.06 ^a | 0.80 | 22 | 17 | 22 ^d |
| C6802-1/TL | 0.06 ^a | 0.80 | 16 | 17 | 18 ^e |
| Surveillance Weld | 0.03 ^b | 0.80 | 12 | 15 ^e | 14 ^f |

^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 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 3-14

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

| Plate No./ Weld Seam | Cu (wt%) | fluence ($\times 10^{19}$ n/cm) at Quarter-Thickness | | Upper Shelf Energy (ft-lb) ^a at Quarter-Thickness | |
|-------------------------|-------------------|--|---------|---|---------|
| | | 12/16/91 | 32 EFPY | 12/16/91 | 32 EFPY |
| C6802-1 | 0.06 ^b | 0.51 | 2.5 | 79 | 72 |
| C6802-2 | 0.04 | 0.51 | 2.5 | 96 | 88 |
| C6802-3 | 0.06 | 0.51 | 2.5 | 88 | 80 |
| C6802-4 | 0.05 | 0.51 | 2.5 | 99 | 90 |
| C6802-5 | 0.04 | 0.51 | 2.5 | 97 | 89 |
| C6802-6 | 0.06 | 0.51 | 2.5 | 77 | 70 |
| 2-203 | 0.05 | 0.51 | 2.5 | 114 | 104 |
| 3-203 | 0.04 | 0.51 | 2.5 | 135 | 123 |
| 9-203 | 0.06 | 0.51 | 2.5 | 102 | 92 |

^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

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 1, November 1991.
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, 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.

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 5×10^{18} n/cm² 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/cm²

4.1 Test Material - Test specimens shall be prepared from the actual materials used in fabricating the irradiated region of the reactor vessel.

To be confirmed based on resolving inconsistencies in: (1) Cu and Ni contents and C_{VN} curves reported for beltline and surveillance welds, and (2) C_{VN} curves reported for the LT orientation in beltline and surveillance plate materials.

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 or 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.

To be confirmed based on resolving inconsistencies in: (1) Cu and Ni contents reported for beltline and surveillance welds, and (2) C_{VN} curves reported for the LT orientation in beltline and surveillance plates.

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

Compliance

obtained and include, but not be limited to phosphorus (P), sulfur (S), copper (Cu), and vanadium (V).

Compliance

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

Compliance

Summary of Requirements
per ASTM E185-73

San Onofre Unit 3 Program

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)

4.4 Number of Specimens - The minimum number of test specimens for each exposure shall be as follows:

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

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

Compliance

Summary of Requirements
per ASTM E185-73

San Onofre Unit 3 Program

closely as possible the neutron-flux spectrum, temperature history, and maximum accumulated neutron fluence experienced by the reactor vessel.

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

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:

Compliance

5.2.1 Dosimeters with the vessel wall specimens (5.1.1).

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

Compliance

Summary of Requirements
per ASTM E185-73

San Onofre Unit 3 Program

capsule.

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

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.)

6.1 Radiation Environment - The neutron flux, neutron energy spectrum, and irradiation temperature of surveillance specimens and the method of determination shall be documented.

6.2 Neutron Flux Dosimeters - Flux dosimeters for a particular program shall be determined by referring to Method E 261.

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
($>14^{\circ}\text{C}$ 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:

Compliance

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.

9.1 Tension Tests:

Compliance

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

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

define the strength versus temperature relationship.

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:

Compliance

9.2.1 Method - Charpy tests shall be conducted in accordance with Method E 23 and A370.

9.2.2 Test Temperature:

Compliance

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

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

where the measurements
described in 9.2.3 are made.

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

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) -

Compliance

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

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

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:

Compliance

10.1.1 Determine the amount of radiation strengthening by comparing unirradiated test results with irradiated test results at the temperature

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

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.

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.

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.

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.

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.

Compliance

Compliance

Compliance

Not Applicable

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

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.

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

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

the 1/4T locations.

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.

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.

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

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

and instruments used in
conducting the tests.

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.

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

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

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.

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.

11.4.4 Other Fracture Toughness Tests:

Not Applicable

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

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:

Compliance

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.

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

Summary of Requirements
per ASTM E185-82

San Onofre Unit 3 Program

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

APPENDIX B

SONGS, UNIT 3: BASES FOR PLATE

CHEMISTRY MEASUREMENTS

June 8, 1992
S-MECH-92-050

Mr. Steve Gosselin
Southern California Edison
23 Parker Street
Irvine, CA 92718

SUBJECT: VESSEL PLATE CHEMICAL ANALYSIS SOURCES

Dear Mr. Gosselin:

The purpose of this letter is to provide background information pertaining to beltline material chemistry data for the plates which were used in the fabrication of the SONGS Units 2 and 3 reactor vessel. Recently, differences were noted in the chemical analysis results reported for the SONGS 2 and 3 reactor vessel beltline plates. A review has been performed which identified that these differences arose from the fact that different source information was used. The source information is noted below:

SONGS 2

"CMTR" - Lukens Steel Mill analysis
"PSAR" and "CEN-189" - Chattanooga analyses dated 3/20/70 and 11/26/73

SONGS 3

"CMTR" - Lukens Steel Mill analysis
"PSAR" - Chattanooga analysis dated 1/25/74 and 3/20/74
"CEN-189" - RPV surveillance program Chattanooga analyses dated 7/16/75 and 5/4/78

In order to respond to the plate chemistry questions of NRC Generic Letter 92-01, pertinent background information is provided followed by a specific recommendation.

First, the Lukens chemical analysis data was provided with the CMTR for information only, whereas Chattanooga analyses were used as the basis for licensing transmittals. This was done as a matter of C-E practice to maintain consistency of results. (Lukens used both different equipment and analysis standards, which could yield different reported chemical contents than the Chattanooga laboratory.)

ABB Combustion Engineering Nuclear Power

Combustion Engineering, Inc.

1000 Prosper Hill Road
Post Office Box 500
Windsor, Connecticut 06095-0500

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Telex 902077 COMENR USPP

Mr. Steve Gosselin
June 8, 1992

8-MECH-92-050
Page 2 of 3

Secondly, for both SONGS Unit 2 and 3, chemical analyses were required by both the C-E reactor pressure vessel specification and C-E surveillance program specification. Since these analyses were performed in two separate instances by the Chattanooga facility on the same material, it is ABB C-E's position that the average of these two analyses would be most representative of the plate chemical content. (Note: For both units, the 'CE Analysis' value is an average of the chemical contents acquired in accordance with the vessel and surveillance program specification.)

Therefore, the recommended chemical composition for both SONGS vessels is the average of the two Chattanooga chemical analyses, provided in Table 1, and titled 'CE Analysis'.

Should there be any additional questions, please do not hesitate to contact me at (203) 285-3469.

Sincerely,

COMBUSTION ENGINEERING, INC.

Craig D. Stewart for

S. T. Byrne
Supervisor, Reactor Vessel Integrity

STB/CDS:ods

cc: D. Pilmer (SCK)
B. Chang
W. Gahviller
C. Stewart
M. Wade

STB060.WP

TABLE 1

| U23 RV BELTLINE REGION PLATE COPPER AND NICKEL CONTENT | | | | |
|--|-------------------|-------------|-------------------|-------------|
| Plate No. | Cu Content (wt %) | | Ni Content (wt %) | |
| | CMTR | CE Analysis | CMTR | CE Analysis |
| Unit 2 | | | | |
| C-6404-1 | 0.11 | 0.10 | 0.51 | 0.56 |
| C-6404-2 | 0.12 | 0.10 | 0.61 | 0.59 |
| C-6404-3 | 0.12 | 0.10 | 0.62 | 0.56 |
| C-6404-4 | 0.12 | 0.10 | 0.63 | 0.62 |
| C-6404-5 | 0.12 | 0.11 | 0.63 | 0.64 |
| C-6404-6 | 0.12 | 0.10 | 0.54 | 0.58 |
| Unit 3 | | | | |
| C-6802-1 | 0.06 | 0.06 | 0.58 | 0.58 |
| C-6802-2 | 0.04 | 0.04 | 0.58 | 0.57 |
| C-6802-3 | 0.06 | 0.06 | 0.57 | 0.58 |
| C-6802-4 | 0.05 | 0.05 | 0.58 | 0.56 |
| C-6802-5 | 0.04 | 0.04 | 0.52 | 0.55 |
| C-6802-6 | 0.06 | 0.06 | 0.65 | 0.62 |

APPENDIX C

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

APPENDIX D

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

Table D-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 D-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 | 4.00 | 0.6 |
| 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 | 40.00 | 44.00 | 34.00 | 25.00 |
| 11 | 40.00 | 52.00 | 36.00 | 30.00 |
| 12 | 40.00 | 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 | 40.00 |
| 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 D-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 | 4.00 | 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 | 104.00 | 76.00 | 100.00 |
| 23 | 212.00 | 109.00 | 78.00 | 100.00 |
| 24 | 212.00 | 101.00 | 72.00 | 100.00 |

Table D-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 | 124.00 | 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 D-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 | 35.00 | 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 | 45.00 | 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 |

Table D-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 D-7 Charpy V-Notch Test Results
For Unit 3 Weld Seam 9-203 (Heat #90067), 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 D-8 Charpy V-Notch Test Results
For Unit 3 Weld Seam 3-203 (Heat #88114), FSAR 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 D-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 | 5.00 |
| 22P | 40.00 | 18.00 | 17.00 | 10.00 |
| 260 | 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 D-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 EXP (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 |
| 13H | 80.00 | 39.30 | 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 | 63.00 | 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 D-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 |
| 36H | -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 |
| 34H | 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 D-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 |

APPENDIX E

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 | 67.00 | 72.00 | 90.00 |
| 46K | 210.00 | 57.00 | 57.00 | 70.00 |
| 444 | 210.00 | 103.00 | 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/cm ²) | 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 |
| 465 | 50.00 | 33.00 | 33.00 | 50.00 | 8.00E+18 | 550.00 |
| 466 | 75.00 | 43.00 | 44.00 | 75.00 | 8.00E+18 | 550.00 |
| 467 | 100.00 | 41.00 | 38.00 | 70.00 | 8.00E+18 | 550.00 |
| 468 | 125.00 | 45.00 | 44.00 | 80.00 | 8.00E+18 | 550.00 |
| 469 | 150.00 | 63.00 | 61.00 | 100.00 | 8.00E+18 | 550.00 |
| 470 | 175.00 | 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 (%) |
|----------------|---------------------|-----------------------------|-------------------------|------------------------|
| 3S1 | -120.00 | 7.50 | 5.00 | 11.00 |
| 3S3 | -120.00 | 9.50 | 3.20 | 9.30 |
| 1S11 | -80.00 | 23.50 | 13.00 | 12.40 |
| 1S12 | -80.00 | 26.00 | 16.60 | 17.80 |
| 1S17 | -40.00 | 27.50 | 21.80 | 13.10 |
| 3S4 | -40.00 | 57.00 | 36.20 | 31.10 |
| 3S5 | 0.00 | 39.50 | 31.80 | 49.20 |
| 1S9 | 0.00 | 64.50 | 43.20 | 55.40 |
| 1S16 | 20.00 | 61.50 | 46.60 | 52.00 |
| 1S5 | 20.00 | 76.00 | 49.80 | 54.70 |
| 1S3 | 20.00 | 82.00 | 50.60 | 56.30 |
| 1S18 | 40.00 | 93.00 | 63.80 | 63.10 |
| 1S1C | 40.00 | 99.00 | 64.00 | 73.40 |
| 1S13 | 40.00 | 105.00 | 64.40 | 72.90 |
| 1S8 | 80.00 | 113.00 | 72.60 | 100.00 |
| 1S6 | 80.00 | 115.00 | 65.00 | 100.00 |
| 1S4 | 120.00 | 122.00 | 83.40 | 100.00 |
| 1S14 | 120.00 | 160.00 | 86.60 | 100.00 |
| 1S7 | 160.00 | 128.00 | 87.20 | 100.00 |
| 1S2 | 160.00 | 153.00 | 82.20 | 100.00 |
| 3S6 | 210.00 | 118.00 | 78.80 | 100.00 |
| 1S15 | 210.00 | 132.00 | 75.80 | 100.00 |

APPENDIX F

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

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

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

| 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 | 41.00 | 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 F-3 Charpy V-Notch Test Results
 For Unit 3 Surveillance Weld
 Irradiated ($\phi = 8 \times 10^{18}$ n/cm²)

| 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 |