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Analysis of Capsule N from the R. E. Ginna Reactor Vessel Radiation Surveillance Program

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The purpose of this report is to document the testing results of the surveillance Capsule N from R. E. Ginna. Capsule N was removed at 30.5 EFPY and post-irradiation mechanical tests of the Charpy V-notch and tensile specimens were performed. A fluence evaluation utilizing the neutron transport and dosimetry cross-section libraries was derived from the ENDF/B-VI database. Capsule N received a fluence of 5.80 x 10^{19} n/cm^2 (E > 1.0 MeV) after irradiation to 30.5 EFPY. The peak clad/base metal interface vessel fluence after 30.5 EFPY of plant operation was 3.20 x 10^{19} n/cm^2 (E > 1.0 MeV).

This evaluation led to the following conclusions: 1) The measured percent decrease in upper shelf energy for all surveillance materials contained in R. E. Ginna Capsule N is less than the Regulatory Guide 1.99, Revision 2 [1] prediction. 2) The R. E. Ginna surveillance data for both forgings (125S255 and 125P666) are judged to be not credible; however the weld data (heat #61782) is judged to be credible. This credibility evaluation can be found in Appendix D. 3) All beltline forging materials exhibit a more than adequate upper shelf energy level for continued safe plant operation and are predicted to maintain an upper shelf energy greater than 50 ft-lb throughout the 53 EFPY as required by 10 CFR 50, Appendix G [2]. The beltline welds (heat # 61782 and 71249) are predicted to fall below 50 ft-lb; however, an equivalent margin analysis has demonstrated they will remain acceptable through 53 EFPY. The upper shelf energy evaluation is presented in Appendix E.

Lastly, a brief summary of the Charpy V-notch testing can be found in Section 1. All Charpy V-notch data was plotted using a symmetric hyperbolic tangent curve fitting program.

1 SUMMARY OF RESULTS

The analysis of the reactor vessel materials contained in surveillance Capsule N, the fifth capsule removed and tested from the R. E. Ginna reactor pressure vessel, led to the following conclusions:

- Charpy V-notch test data were plotted using a symmetric hyperbolic tangent curve-fitting program. Appendix C presents the CVGRAPH, Version 5.3, Charpy V-notch plots for Capsule N and previous capsules, along with the program input data.

- Capsule N received an average fast neutron fluence (E > 1.0 MeV) of 5.80 $x10^{19}$ n/cm^2 after 30.5 effective full power years (EFPY) of plant operation.

- Irradiation of the reactor vessel Intermediate Shell Forging 125S255 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major working direction (longitudinal orientation), resulted in an irradiated 30 ft-lb transition temperature of 47.5°F and an irradiated 50 ft-lb transition temperature of 102.8°F. This results in a 30 ft-lb transition temperature increase of 76.4°F and a 50 ft-lb transition temperature increase of 100.0°F for the longitudinally oriented specimens.

- Irradiation of the reactor vessel Lower Shell Forging 125P666 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major working direction (longitudinal orientation), resulted in an irradiated 30 ft-lb transition temperature of 44.9°F and an irradiated 50 ft-lb transition temperature of 78.4°F. This results in a 30 ft-lb transition temperature increase of 91.1°F and a 50 ft-lb transition temperature increase of 93.3°F for the longitudinally oriented specimens.

- Irradiation of the Surveillance Program Weld Metal (Heat #61782) Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of 182.2°F and an irradiated 50 ft-lb transition temperature of 276.0°F. This results in a 30 ft-lb transition temperature increase of 216.9F and a 50 ft-lb transition temperature increase of 261.0°F.

- Irradiation of the Heat-Affected-Zone (HAZ) Material Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of 43.0°F and an irradiated 50 ft-lb transition temperature of 58.4°F. This results in a 30 ft-lb transition temperature increase of 107.7°F and a 50 ft-lb transition temperature increase of 74.5°F.

- The average upper shelf energy of the Intermediate Shell Forging 125S255 (longitudinal orientation) resulted in an average energy decrease of 5.7 ft-lb after irradiation. This results in an irradiated average upper shelf energy of 134.3 ft-lb for the longitudinally oriented specimens.

- The average upper shelf energy of the Lower Shell Forging 125P666 (longitudinal orientation) resulted in an average energy decrease of 32.3 ft-lb after irradiation. This results in an irradiated average upper shelf energy of 142.3 ft-lb for the longitudinally oriented specimens.

- The average upper shelf energy of the Surveillance Program Weld Metal Charpy specimens resulted in an average energy decrease of 27.1 ft-lb after irradiation. This results in an irradiated average upper shelf energy of 51.9 ft-lb for the weld metal specimens.

- The average upper shelf energy of the HAZ Material Charpy specimens resulted in an average energy decrease of 1.7 ft-lb after irradiation. This results in an irradiated average upper shelf energy of 88.3 ft-lb for the HAZ Material.

- A comparison, as presented in Table 5-10, of the R. E. Ginna reactor vessel surveillance material test results with the Regulatory Guide 1.99, Revision 2 predictions led to the following conclusions:

  - The measured 30 ft-lb shift in transition temperature values of the Intermediate Shell Forging 125S255 and Lower Shell Forging 125P666 specimens contained in Capsule N are greater than the Regulatory Guide 1.99, Revision 2 predictions.
  - The measured 30 ft-lb shift in transition temperature value of the Surveillance Weld Heat # 61782 specimens contained in Capsule N is less than the Regulatory Guide 1.99, Revision 2 prediction.
  - The measured percent decrease in upper shelf energy for all forging and weld surveillance materials in Capsule N are less that the Regulatory Guide 1.99, Revision 2 predictions.

- Based on the credibility evaluation presented in Appendix D, the R. E. Ginna surveillance data for forgings 125S255 and 125P666 are not credible, but the surveillance weld (heat #61782) data are credible. Sister plant data (from Turkey Point Unit 3) for weld heat #71249 is also credible.

- Based on the upper shelf energy evaluation in Appendix E, the beltline forging materials exhibit a more than adequate upper shelf energy level for continued safe plant operation and are predicted to maintain an upper shelf energy greater than 50 ft-lb throughout the end of the current license (53 EFPY) as required by 10 CFR 50, Appendix G [2].

- Based on the upper shelf energy evaluation in Appendix E, the beltline welds are predicted to fall below 50 ft-lb by the end of the current extended license (53 EFPY) but an equivalent margin analysis demonstrates acceptability through 53 EFPY.

- The calculated 53 EFPY (end-of-license renewal) neutron fluences (E > 1.0 MeV) at the core mid-plane for the R. E. Ginna reactor vessel using the Regulatory Guide 1.99, Revision 2 attenuation formula (i.e., Equation #3 in the guide) are as follows:

<u>Calculated (53 EFPY)</u>: Vessel inner radius* = 5.56×10^{19} n/cm^2 (Taken from Table 6-2A)
Vessel 1/4 thickness = 3.76×10^{19} n/cm^2
Vessel 3/4 thickness = 1.73×10^{19} n/cm^2

* Clad/base metal interface.

2 INTRODUCTION

This report presents the results of the examination of Capsule N, the fifth capsule removed from the reactor in the continuing surveillance program, which monitors the effects of neutron irradiation on the R. E. Ginna reactor pressure vessel materials under actual operating conditions.

The surveillance program for the R. E. Ginna reactor pressure vessel materials was designed and recommended by the Westinghouse Electric Corporation. A description of the surveillance program and the pre-irradiation mechanical properties of the reactor vessel materials are presented in WCAP-7254, "Rochester Gas and Electric Robert E. Ginna Unit No. 1 Reactor Vessel Radiation Surveillance Program" [3]. The surveillance program was planned to cover the 40-year design life of the reactor pressure vessel and was based on ASTM E185-66 [4], "Recommended Practice for Surveillance Tests on Structural Materials in Nuclear Reactors." Capsule N was removed from the reactor after Cycle 33, after 30.5 EFPY of exposure and shipped to the Westinghouse Science and Technology Department Hot Cell Facility, where the post-irradiation mechanical testing of the Charpy V-notch impact and tensile surveillance specimens was performed.

This report summarizes the testing of the post-irradiation data obtained from surveillance Capsule N removed from the R. E. Ginna reactor vessel and discusses the analysis of the data.

3 BACKGROUND

The ability of the large steel pressure vessel containing the reactor core and its primary coolant to resist fracture constitutes an important factor in ensuring safety in the nuclear industry. The beltline region of the reactor pressure vessel is the most critical region of the vessel because it is subjected to significant fast neutron bombardment. The overall effects of fast neutron irradiation on the mechanical properties of low alloy, ferritic pressure vessel steels such as ASTM A508 Class 2 (base material of the R. E. Ginna reactor pressure vessel beltline) are well documented in the literature. Generally, low alloy ferritic materials show an increase in hardness and tensile properties and a decrease in ductility and toughness during high-energy irradiation.

A method for ensuring the integrity of reactor pressure vessels has been presented in "Fracture Toughness Criteria for Protection Against Failure," Appendix G to Section XI of the ASME Boiler and Pressure Vessel Code [5]. The method uses fracture mechanics concepts and is based on the reference nil-ductility transition temperature (RT_{NDT}).

RT_{NDT} is defined as the greater of either the drop weight nil-ductility transition temperature (NDTT per ASTM E208 [6]) or the temperature 60°F less than the 50 ft-lb (and 35-mil lateral expansion) temperature as determined from Charpy specimens oriented perpendicular (transverse) to the major working direction of the plate. The RT_{NDT} of a given material is used to index that material to a reference stress intensity factor curve (K_{Ic} curve) which appears in Appendix G to Section XI of the ASME Code [5]. The K_{Ic} curve is a lower bound of static fracture toughness results obtained from several heats of pressure vessel steel. When a given material is indexed to the K_{Ic} curve, allowable stress intensity factors can be obtained for this material as a function of temperature. Allowable operating limits can then be determined using these allowable stress intensity factors.

RT_{NDT} and, in turn, the operating limits of nuclear power plants can be adjusted to account for the effects of radiation on the reactor vessel material properties. The changes in mechanical properties of a given reactor pressure vessel steel, due to irradiation, can be monitored by a reactor vessel surveillance program, such as the R. E. Ginna reactor vessel radiation surveillance program, in which a surveillance capsule is periodically removed from the operating nuclear reactor and the encapsulated specimens are tested. The increase in the average Charpy V-notch 30 ft-lb temperature (ΔRT_{NDT}) due to irradiation is added to the initial RT_{NDT}, along with a margin (M) to cover uncertainties, to adjust the RT_{NDT} (ART) for radiation embrittlement. This ART ($RT_{NDT\ Initial} + M + \Delta RT_{NDT}$) is used to index the material to the K_{Ic} curve and, in turn, to set operating limits for the nuclear power plant that take into account the effects of irradiation on the reactor vessel materials.

4 DESCRIPTION OF PROGRAM

Six surveillance capsules for monitoring the effects of neutron exposure on the R. E. Ginna reactor pressure vessel core region (beltline) materials were inserted in the reactor vessel prior to initial plant startup. The six capsules were positioned in the reactor vessel between the thermal shield and the vessel wall as shown in Figure 4-1. The vertical center of the capsules is opposite the vertical center of the core. The capsules contain specimens made from the following:

- Intermediate Shell Forging 125S255 (longitudinal orientation)
- Lower Shell Forging 125P666 (longitudinal orientation)
- Weld metal, Heat #61782 Linde Type 80 flux, which is the same wire used for the intermediate shell to lower shell girth weld.
- Weld heat-affected-zone (HAZ) material of Lower Shell Forging 125P666

Test material obtained from the Intermediate Shell Forging 125S255 and Lower Shell Forging 125P666 (after thermal heat treatment and prior to welding the two shells together) was taken at least one forging thickness from the quenched edges of the forgings. All test specimens were machined from the ¼ thickness location of the original forging thickness after stress-relieving. Test specimens from weld metal and heat-affected-zone (HAZ) metal of forging 125P666 were machined from a stress-relieved weldment joining Intermediate Shell Forging 125S255 and Lower Shell Forging 125P666.

Charpy V-notch impact specimens from Intermediate Shell Forging 125S255 and Lower Shell Forging 125P666 were machined in the "strong" direction (longitudinal). Specimens from the weld metal were oriented with the longitudinal axis of the specimen transverse to the welding direction.

Tensile specimens were machined with the longitudinal axis of the specimen parallel to the hoop direction of the forging. Tensile specimens from the weld metal were oriented with the longitudinal axis of the specimen parallel to the welding direction.

Wedge Opening Loading (WOL) test specimens from both forgings and the weld were machined with the simulated crack in the specimen perpendicular to the hoop direction and the major surfaces of the forgings.

All six capsules contained dosimeter wires of pure copper, nickel, and aluminum-cobalt wire (cadmium-shielded and unshielded). In addition, cadmium-shielded dosimeters of Neptunium (^{237}Np) and Uranium (^{238}U) were placed in the capsules to measure the integrated flux at specific neutron energy levels.

The capsules contained thermal monitors made from two low-melting-point eutectic alloys, which were sealed in Pyrex tubes. These thermal monitors were used to define the maximum temperature attained by the test specimens during irradiation. The composition of the two eutectic alloys and their melting points are as follows:

2.5% Ag, 97.5% Pb	Melting Point: 579°F (304°C)
1.75% Ag, 0.75% Sn, 97.5% Pb	Melting Point: 590°F (310°C)

The chemical composition and heat treatment of the unirradiated surveillance materials are presented in Tables 4-1 and 4-2, respectively. The data in Table 4-1 was obtained from WCAP-13902 [7], "Analysis of Capsule S from the Rochester Gas and Electric Corporation R. E. Ginna Reactor Vessel Radiation Surveillance Program," with copper and nickel values for the surveillance weld heat #61782 updated as noted. The data in Table 4-2 was obtained from the unirradiated surveillance program report, WCAP-7254 [3], Appendix A.

Capsule N was removed after 30.5 effective full power years (EFPY) of plant operation. This capsule contained Charpy V-notch, tensile, and WOL specimens, dosimeters, and thermal monitors.

The arrangement of the various mechanical specimens, dosimeters and thermal monitors contained in Capsule N is shown in Figure 4-2.

Table 4-1 Chemical Composition (wt%) of the R. E. Ginna Reactor Vessel Surveillance Materials (Unirradiated)[a]

Element	Forging 125P666	Forging 125S255	Weld Metal 61782
C	0.19	0.18	0.075
Mn	0.67	0.66	1.31
P	0.010	0.010	0.012
S	0.011	0.007	0.016
Si	0.20	0.23	0.59
Ni	0.69	0.69	0.53[b]
Cr	0.37	0.33	0.59
Co	0.013	0.015	0.001
Mo	0.57	0.58	0.36
V	0.02	0.02	0.001
Cu	0.05	0.07	0.23[b]
Al	0.004	0.003	0.020
N	- - -	- - -	0.015
Sn	0.01	0.01	- - -

Note:
(a) Data obtained from WCAP-13902 [7].
(b) Updated best estimate Cu / Ni for surveillance weld based on average of twelve unirradiated, Capsule T, and Capsule S specimen measurements.

Table 4-2 Heat Treatment History of the R. E. Ginna Reactor Vessel Surveillance Materials[a]

Material	Temperature (°F)	Time (hr)	Cooling
Lower Shell Forging 125P666	1550	9	Water-quenched
	1220	12	Air-cooled
	1100	11.25	Furnace-cooled
Intermediate Shell Forging 125S255	1550	15.5	Water-quenched
	1220	18	Air-cooled
	1100	11.25	Furnace-cooled
Weld Metal (Heat #61782)	1100	11.25	Furnace-cooled

Note:
(a) Data obtained from WCAP-7254 [3].

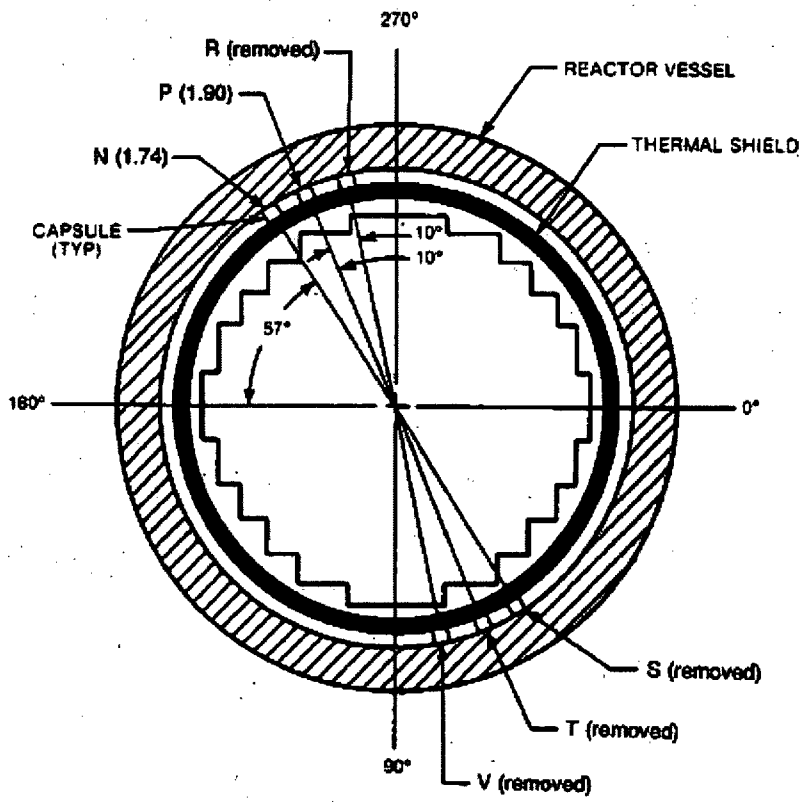


Figure 4-1 Arrangement of Surveillance Capsules in the R. E. Ginna Reactor Vessel

LEGEND: **P** – **LOWER SHELL FORGING 125P666**
S – **INTERMEDIATE SHELL FORGING 125S255**
W – **WELD METAL (HEAT # 61782)**
H – **HEAT AFFECTED ZONE MATERIAL**

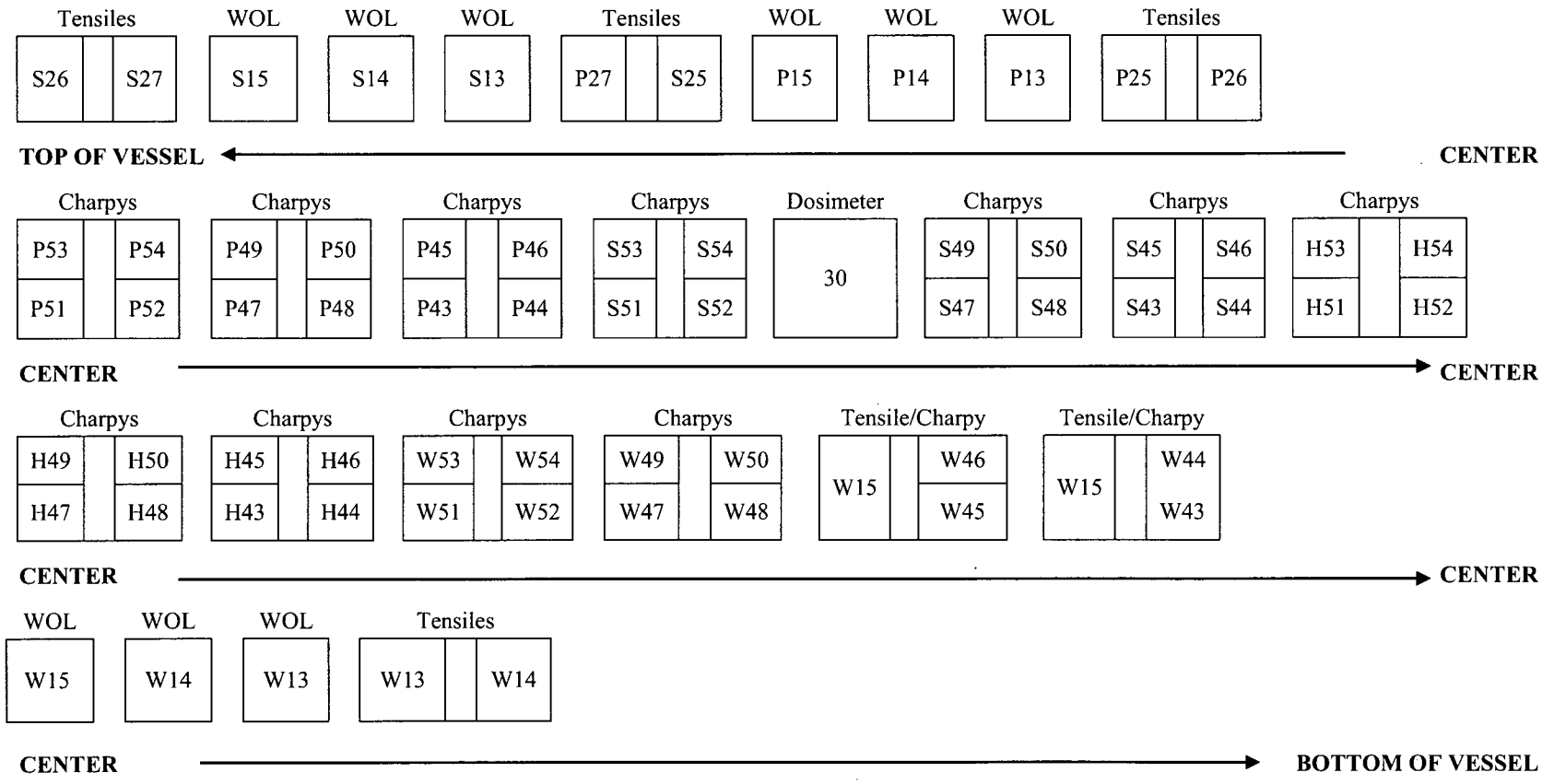


Figure 4-2 Capsule N Diagram Showing the Location of Specimens, Thermal Monitors, and Dosimeters

5 TESTING OF SPECIMENS FROM CAPSULE N

5.1 OVERVIEW

Capsule N contained test specimens from the lower shell forging (125P666), intermediate shell forging (125S255), intermediate shell to lower shell girth weld heat #61782, and heat-affected-zone (HAZ) metal from the 125P666 side of the 125P666/125S255 forgings joined by weld heat #61782. Charpy V-notch impact, tensile, and wedge opening loading (WOL) specimens were included. Per the surveillance capsule testing contract with R. E. Ginna, the Charpy V-notch impact and tensile specimens were tested. Per ASTM E185-82 [8], the testing of WOL specimens is optional. Therefore, the WOL specimens were not tested.

The post-irradiation mechanical testing of the Charpy V-notch impact specimens and tensile specimens was performed at the Westinghouse Science and Technology Department (STD) Remote Metallographic Facility. Testing was performed in accordance with 10 CFR 50, Appendices G and H [2], ASTM Specification E185-82 [8], and Westinghouse Procedure RMF 8402, Revision 3 [9] as detailed by Westinghouse RMF Procedures 8102, Revision 3 [10], and 8103, Revision 2 [11].

The capsule was opened upon receipt at the laboratory per Procedure RMF 8804, Revision 2 [12]. The specimens and spacer blocks were carefully removed, inspected for identification number, and checked against the master list in WCAP-7254 [3]. All items were in their proper locations.

Examination of the thermal monitors indicated that none of the melting point monitors had melted. Based on this examination, the maximum temperature to which the specimens were exposed was less than 579°F (304°C).

The Charpy impact tests were performed per ASTM Specification E23-06 [13] and Procedure RMF 8103 on a Tinius-Olsen Model 74, 358J machine. The tup (striker) of the Charpy machine is instrumented with an Instron Impulse instrumentation system, feeding information into a computer. With this system, load-time and energy-time signals can be recorded in addition to the standard measurement of Charpy energy (E_D). From the load-time curve, the load of general yielding (P_{GY}), the time to general yielding (T_{GY}), the maximum load (P_M), and the time to maximum load (T_M) can be determined. Under some test conditions, a sharp drop in load indicative of fast fracture was observed. The load at which fast fracture was initiated is identified as the fast fracture load (P_F). If the fast load drop terminates well above zero load, the termination load is identified as the arrest load (P_A).

The energy at maximum load (E_M) was determined by comparing the energy-time record and the load-time record. The energy at maximum load is approximately equivalent to the energy required to initiate a crack in the specimen. Therefore, the propagation energy for the crack (E_P) is the difference between the total energy to fracture (E_D) and the energy at maximum load (E_M).

The yield stress (σ_Y) was calculated from the three-point bend formula having the following expression [14]:

$$\sigma_Y = P_{GY} \frac{L}{B(W-a)^2\, C} \qquad \text{(Eqn. 5-1)}$$

where L = distance between the specimen supports in the impact testing machine; B = the width of the specimen measured parallel to the notch; W = height of the specimen, measured perpendicularly to the notch; a = notch depth. The constant C is dependent on the notch flank angle (φ), notch root radius (ρ) and the type of loading (i.e., pure bending or three-point bending). In three-point bending, for a Charpy specimen in which $\varphi = 45°$ and $\rho = 0.010$ in., Equation 1 is valid with C = 1.21.

Therefore, (for L = 4W),

$$\sigma_Y = P_{GY} \frac{L}{B(W-a)^2\, 1.21} = \frac{3.305\, P_{GY} W}{B(W-a)^2} \qquad \text{(Eqn. 5-2)}$$

For the Charpy specimen, B = 0.394 in., W = 0.394 in., and a = 0.079 in. Equation 5-2 then reduces to:

$$\sigma_Y = 33.3\, P_{GY} \qquad \text{(Eqn. 5-3)}$$

where σ_Y is in units of psi and P_{GY} is in units of lb. The flow stress was calculated from the average of the yield and maximum loads, also using the three-point bend formula.

Symbol A in columns 4, 5, and 6 of Tables 5-5 through 5-8 is the cross-section area under the notch of the Charpy specimens:

$$A = B(W-a) = 0.1241\ sq.\ in. \qquad \text{(Eqn. 5-4)}$$

Percent shear was determined from post-fracture photographs using the ratio-of-areas methods in compliance with ASTM E23-06 [13] and A370-07 [15]. The lateral expansion was measured using a dial gage rig similar to that shown in the same specifications.

Tensile tests were performed on a 20,000 pound Instron, split console test machine (Model 1115) per ASTM Specification E8-04 [16] and E21-05 [17] and Procedure RMF 8102 [10]. Extension measurements were made with a linear variable displacement transducer (LVDT) extensometer. The extensometer gage length was 1.00 inch. Elevated test temperatures were obtained with a three-zone electric resistance split-tube furnace with a 9-inch hot zone. All tests were conducted in air.

The yield load, ultimate load, fracture load, total elongation and uniform elongation were determined directly from the load-extension curve. The yield strength, ultimate strength and fracture strength were calculated using the original cross-sectional area. The final diameter was determined from post-fracture photographs. The fracture area used to calculate the fracture stress (true stress at fracture) and percent reduction in area were computed using the final diameter measurement.

5.2 CHARPY V-NOTCH IMPACT TEST RESULTS

The results of the Charpy V-notch impact tests performed on the various materials contained in Capsule N, which received a fluence of 5.80 x 10^{19} n/cm^2 (E > 1.0 MeV) in 30.5 EFPY of operation, are presented in Tables 5-1 through 5-8 and are compared with the unirradiated and previously withdrawn capsule results as shown in Figures 5-1 through 5-12.

The Charpy V-notch (CVN) test data from the Capsule N specimens were input into a hyperbolic tangent curve-fitting program, CVGraph Version 5.3 which was used to define the 30 ft-lb (41 J), 50 ft-lb (68 J), and 35 mil (0.89 mm) lateral expansion index temperatures on the transition temperature curve. The baseline (unirradiated) CVN data and the CVN data from all previously-tested capsules (V, R, T, and S) were likewise re-analyzed using CVGraph, to provided consistency of analytical method for all Ginna surveillance data results. The CVGraph data plots are provided in Appendix C. The unirradiated and previous capsule test data were taken from WCAP-7254 [3], FP-RA-1 [18], WCAP-8421 [19], WCAP-10086 [20], WCAP- 10496 [21] and WCAP-13902 [7].

The transition temperature increases and upper shelf energy decreases for the Capsule N materials are summarized in Table 5-9 and led to the following results for irradiation to 5.80 x 10^{19} n/cm^2 (E > 1.0 MeV):

- Irradiation of the reactor vessel Intermediate Shell Forging 125S255 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major working direction (longitudinal orientation), resulted in an irradiated 30 ft-lb transition temperature of 47.5°F and an irradiated 50 ft-lb transition temperature of 102.8°F. This results in a 30 ft-lb transition temperature increase of 76.4°F and a 50 ft-lb transition temperature increase of 100.0°F.

- Irradiation of the reactor vessel Lower Shell Forging 125P666 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major working direction (longitudinal orientation), resulted in an irradiated 30 ft-lb transition temperature of 44.9°F and an irradiated 50 ft-lb transition temperature of 78.4°F. This results in a 30 ft-lb transition temperature increase of 91.1°F and a 50 ft-lb transition temperature increase of 93.3°F.

- Irradiation of the weld metal (Heat #61782) Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of 182.2°F and an irradiated 50 ft-lb transition temperature of 276.0°F. This results in a 30 ft-lb transition temperature increase of 216.9°F and a 50 ft-lb transition temperature increase of 261.0°F.

- Irradiation of the weld Heat-Affected-Zone (HAZ) metal Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of 43.0°F and an irradiated 50 ft-lb transition temperature of 58.4°F. This results in a 30 ft-lb transition temperature increase of 107.7°F and a 50 ft-lb transition temperature increase of 74.5°F.

- The average upper shelf energy of the Intermediate Shell Forging 125S255 (longitudinal orientation) resulted in an average energy decrease of 5.7 ft-lb. This results in an irradiated average upper shelf energy of 134.3 ft-lb.

- The average upper shelf energy of the Lower Shell Forging 125P666 (longitudinal orientation) resulted in an average energy decrease of 32.3 ft-lb. This results in an irradiated average upper shelf energy of 142.3 ft-lb.

- The average upper shelf energy of the weld metal Charpy specimens resulted in an average energy decrease of 27.1 ft-lb. This results in an irradiated average upper shelf energy of 51.9 ft-lb for the weld metal specimens.

- The average upper shelf energy of the weld HAZ metal Charpy specimens resulted in an average energy decrease of 1.7 ft-lb. This results in an irradiated average upper shelf energy of 88.3 ft-lb for the weld HAZ metal.

- Comparisons of the measured 30 ft-lb shift in transition temperature values and upper shelf energy decreases to those predicted by Reg. Guide 1.99, Rev. 2 [1] are presented in Table 5-10. The 30 ft-lb shifts in transition temperature values vary in comparison to the previous R. E. Ginna capsule analyses. This variance is due to the increased accuracy of the hyperbolic tangent methodology contained in CVGRAPH Version 5.3 in comparison with previous methodologies.

The fracture appearance of each irradiated Charpy specimen from the various materials is shown in Figures 5-13 through 5-16. The fractures show an increasingly ductile or tougher appearance with increasing test temperature. Load-time records for the individual instrumented Charpy specimens are contained in Appendix B.

All beltline materials exhibit adequate upper shelf energy levels for continued safe plant operation. This evaluation can be found in Appendix E. Forgings 125S255 and 125P666 are predicted to maintain upper shelf energy values greater than 50 ft-lb throughout the end of the current license (53 EFPY) as required by 10 CFR 50, Appendix G [2]. Weld heat numbers 61782 and 71249 have projected USE values less than the 50 ft-lb screening criteria, but an equivalent margin analysis (EMA) has demonstrated that the weld materials remain acceptable. This is also discussed in Appendix E.

5.3 TENSILE TEST RESULTS

The results of the tensile tests performed on the various materials contained in Capsule N irradiated to 5.80E+19 n/cm^2 (E > 1.0 MeV) are presented in Table 5-11 and are compared with unirradiated results as shown in Figures 5-20 through 5-22.

The results of the tensile tests performed on the Intermediate Shell Forging 125S255 (longitudinal orientation) indicated that irradiation to 5.80E+19 n/cm^2 (E > 1.0 MeV) caused approximately a 17.7 ksi increase in the 0.2 percent offset yield strength and approximately a 11.3 ksi increase in the ultimate tensile strength at 550°F when compared to unirradiated data [3]. See Figure 5-20 and Table 5-11.

The results of the tensile tests performed on the Lower Shell Forging 125P666 (longitudinal orientation) indicated that irradiation to 5.80E+19 n/cm^2 (E > 1.0 MeV) caused approximately a 13.1 ksi increase in the 0.2 percent offset yield strength and approximately a 8.3 ksi increase in the ultimate tensile strength when compared to unirradiated data [3]. See Figure 5-21 and Table 5-11.

The results of the tensile tests performed on the surveillance weld heat #61782 indicated that irradiation to 5.80E+19 n/cm^2 (E > 1.0 MeV) caused approximately a 31.4 ksi increase in the 0.2 percent offset yield strength and approximately a 24.5 ksi increase in the ultimate tensile strength when compared to unirradiated data [3]. See Figure 5-22 and Table 5-11.

The fractured tensile specimens for Lower Shell Forging 125P666, Intermediate Shell Forging 125S255, and weld metal heat #61782 are shown in Figures 5-23, 5-24, and 5-25, respectively. The engineering stress-strain curves for the tensile tests are shown in Figures 5-26 through 5-31.

5.4 1/2T COMPACT TENSION SPECIMEN TESTS

Per ASTM E185-82 [8], the testing of 1/2T Compact Tension Specimens is optional. Therefore, the 1/2T Compact Tension Specimens were not tested and are being stored at the Westinghouse Research and Technology Department Hot Cell Facility.

Table 5-1 Charpy V-notch Data for the R. E. Ginna Intermediate Shell Forging 125S255 Irradiated to a Fluence of 5.80E+19 n/cm^2 (E > 1.0 MeV) (Longitudinal Orientation)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
S43	0	-18	6	8	6	0.15	0
S44	20	-7	32	43	28	0.71	5
S53	35	2	7	9	8	0.20	5
S52	40	4	5	7	6	0.15	5
S46	50	10	71	96	54	1.37	25
S54	60	16	13	18	13	0.33	5
S50	80	27	45	61	35	0.89	20
S48	90	32	72	98	51	1.30	30
S47	200	93	73	99	63	1.60	50
S49	350	177	148	201	90	2.29	100
S51	375	191	125	170	77	1.96	100
S45	390	199	130	176	83	2.11	100

Table 5-2 Charpy V-notch Data for the R. E. Ginna Lower Shell Forging 125P666 Irradiated to a Fluence of 5.80E+19 n/cm^2 (E > 1.0 MeV) (Longitudinal Orientation)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
P47	-25	-32	3	4	6	0.15	2
P50	20	-7	14	19	12	0.30	5
P53	30	-1	5	7	7	0.18	5
P51	40	4	4	5	7	0.18	5
P54	50	10	64	87	48	1.22	25
P44	55	13	49	66	40	1.02	20
P49	80	27	63	85	51	1.30	45
P45	90	32	74	100	56	1.42	45
P52	100	38	36	49	35	0.89	40
P46	350	177	145	197	88	2.24	100
P48	375	191	141	191	84	2.13	100
P43	390	199	141	191	83	2.11	100

Table 5-3 Charpy V-notch Data for the R. E. Ginna Surveillance Weld Metal Heat #61782 Irradiated to a Fluence of 5.80E+19 n/cm^2 (E > 1.0 MeV)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
W54	0	-18	4	5	7	0.18	5
W47	150	66	22	30	23	0.58	40
W48	200	93	26	35	25	0.64	50
W45	210	99	37	50	34	0.86	80
W43	220	104	46	62	39	0.99	90
W53	230	110	52	71	44	1.12	95
W49	240	116	52	71	43	1.09	95
W51	260	127	45	61	41	1.04	98
W50	280	138	51	69	45	1.14	98
W52	350	177	50	68	46	1.17	100
W44	375	191	64	87	85	2.16	100
W46	400	204	49	66	46	1.17	100

Table 5-4 Charpy V-notch Data for the R. E. Ginna Heat-Affected-Zone (HAZ) Material Irradiated to a Fluence of 5.80E+19 n/cm^2 (E > 1.0 MeV)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	Ft-lbs	Joules	mils	mm	%
H48	0	-18	8	11	8	0.20	20
H43	35	2	24	33	19	0.48	20
H50	40	4	34	46	25	0.64	20
H46	50	10	15	20	14	0.36	25
H52	55	13	38	52	33	0.84	30
H54	60	16	80	108	51	1.30	50
H53	80	27	66	89	48	1.22	50
H47	130	54	87	118	60	1.52	70
H45	350	177	124	168	64	1.63	100
H49	360	182	67	91	50	1.27	100
H51	375	191	90	122	52	1.32	100
H44	390	199	72	98	70	1.78	100

Table 5-5 Instrumented Charpy Impact Test Results for the R. E. Ginna Intermediate Shell Forging 125S255 Irradiated to a Fluence of 5.80E+19 n/cm^2 (E > 1.0 MeV) (Longitudinal Orientation)

Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Normalized Energies (ft-lb/in^2)			General Yield Load P_{GY} (lb)	Time to P_{GY} (msec)	Max. Load, P_M (lb)	Time to P_M (msec)	Fract. Load, P_F (lb)	Arrest Load, P_A (lb)	Yield Stress (ksi)	Flow Stress (ksi)
			Total E_D/A	At P_M E_M/A	Prop. Ep/A								
S43	0	6	46	23	23	2708	0.14	2714	0.14	2708	0	90	90
S44	20	32	259	206	53	3423	0.15	4431	0.47	4363	0	114	131
S53	35	7	57	30	27	3069	0.15	3097	0.16	3088	0	102	103
S42	40	5	41	20	21	2438	0.13	2472	0.14	2461	0	81	82
S46	50	69	552	326	226	3406	0.15	4367	0.7	4006	0	113	129
S54	60	12	98	55	43	3107	0.15	3910	0.21	3907	0	103	117
S50	80	44	350	296	54	3157	0.15	4140	0.68	4068	0	105	122
S48	90	67	536	316	220	3262	0.16	4310	0.7	3887	0	109	126
S47	200	66	531	302	228	3065	0.15	4221	0.69	3921	649	102	121
S49	350	137	1102	296	806	3164	0.3	3814	0.8	n/a	n/a	105	116
S51	375	115	927	288	640	2905	0.15	4042	0.68	n/a	n/a	97	116
S45	390	118	947	284	663	2754	0.15	3958	0.69	n/a	n/a	92	112

Table 5-6 Instrumented Charpy Impact Test Results for the R. E. Ginna Lower Shell Forging 125P666 Irradiated to a Fluence of 5.80E+19 n/cm^2 (E > 1.0 MeV) (Longitudinal Orientation)

Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Normalized Energies (ft-lb/in^2)			General Yield Load P_{GY} (lb)	Time to P_{GY} (msec)	Max. Load, P_M (lb)	Time to P_M (msec)	Fract. Load, P_F (lb)	Arrest Load, P_A (lb)	Yield Stress (ksi)	Flow Stress (ksi)
			Total E_D/A	At P_M E_M/A	Prop. Ep/A								
P47	-25	3	25	12	13	1526	0.1	1588	0.11	1574	0	51	52
P50	20	13	108	57	51	2995	0.14	3692	0.21	3672	0	100	111
P53	30	5	38	19	20	2211	0.12	2292	0.13	2290	0	74	75
P51	40	4	29	15	15	1800	0.12	1825	0.12	1825	0	60	60
P54	50	62	501	297	203	2973	0.15	4022	0.7	3823	0	99	116
P44	55	47	382	308	74	3178	0.15	4159	0.7	4081	0	106	122
P49	80	59	474	301	173	3006	0.15	4021	0.71	3841	0	100	117
P45	90	68	545	296	249	2996	0.15	4094	0.69	3668	0	100	118
P52	100	31	253	200	53	2828	0.14	3887	0.52	3878	0	94	112
P46	350	132	1061	254	807	2393	0.14	3552	0.69	n/a	n/a	80	99
P48	375	129	1043	268	775	2579	0.14	3721	0.69	n/a	n/a	86	105
P43	390	129	1038	269	769	2581	0.14	3777	0.68	n/a	n/a	86	106

Table 5-7 Instrumented Charpy Impact Test Results for the R. E. Ginna Surveillance Weld Metal Heat #61782 Irradiated to a Fluence of 5.80E+19 n/cm^2 (E > 1.0 MeV)

Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Normalized Energies (ft-lb/in^2)			General Yield Load P_{GY} (lb)	Time to P_{GY} (msec)	Max. Load, P_M (lb)	Time to P_M (msec)	Fract. Load, P_F (lb)	Arrest Load, P_A (lb)	Yield Stress (ksi)	Flow Stress (ksi)
			Total E_D/A	At P_M E_M/A	Prop. Ep/A								
W54	0	4	30	15	15	1865	0.12	1874	0.12	1874	0	62	62
W47	150	21	171	65	106	3057	0.14	3916	0.22	3742	739	102	116
W48	200	25	199	64	135	3099	0.15	3840	0.22	3773	1304	103	116
W45	210	35	282	67	214	3336	0.14	4176	0.22	3020	1002	111	125
W43	220	44	358	177	181	3329	0.14	4352	0.41	4232	2449	111	128
W53	230	49	392	179	213	3151	0.14	4146	0.43	3314	2367	105	122
W49	240	50	399	171	228	3011	0.14	4214	0.42	3348	2027	100	120
W51	260	43	344	156	188	3139	0.14	4043	0.39	2142	1666	105	120
W50	280	48	389	183	206	3019	0.15	4037	0.46	2941	2044	101	117
W52	350	47	379	159	221	2981	0.14	3838	0.42	n/a	n/a	99	114
W44	375	59	479	199	280	3145	0.14	4156	0.48	n/a	n/a	105	122
W46	400	46	374	153	221	2925	0.15	3742	0.42	n/a	n/a	97	111

Table 5-8 Instrumented Charpy Impact Test Results for the R. E. Ginna Heat-Affected-Zone (HAZ) Material Irradiated to a Fluence of 5.80E+19 n/cm^2 (E > 1.0 MeV)

Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Normalized Energies (ft-lb/in^2)			General Yield Load P_{GY} (lb)	Time to P_{GY} (msec)	Max. Load, P_M (lb)	Time to P_M (msec)	Fract. Load, P_F (lb)	Arrest Load, P_A (lb)	Yield Stress (ksi)	Flow Stress (ksi)
			Total E_D/A	At P_M E_M/A	Prop. Ep/A								
H48	0	7	53	28	25	2983	0.14	3011	0.15	3002	0	99	100
H43	35	24	192	68	124	3664	0.15	4384	0.22	4334	0	122	134
H50	40	31	253	199	54	3409	0.15	4498	0.45	4478	0	114	132
H46	50	13	105	58	46	3685	0.15	4335	0.2	4329	0	123	134
H52	55	35	285	211	74	3570	0.15	4603	0.47	4601	272	119	136
H54	60	73	591	344	248	3588	0.17	4643	0.7	4122	562	119	137
H53	80	64	515	338	176	3605	0.15	4601	0.69	4357	0	120	137
H47	130	80	648	244	404	3609	0.16	4519	0.53	3332	980	120	135
H45	350	115	925	312	614	2978	0.15	4278	0.71	n/a	n/a	99	121
H49	360	63	506	207	299	2978	0.15	4087	0.51	n/a	n/a	99	118
H51	375	81	656	307	349	3171	0.15	4324	0.68	n/a	n/a	106	125
H44	390	65	524	216	308	3084	0.14	4200	0.51	n/a	n/a	103	121

Table 5-9 Effect of Irradiation to 5.80E+19 n/cm^2 (E > 1.0 MeV) on the Charpy V-Notch Toughness Properties of the R. E. Ginna Reactor Vessel Surveillance Capsule N Materials

Material	Average 30 ft-lb[(a)] Transition Temperature (°F)			Average 35 mil Lateral[(b)] Expansion Temperature (°F)			Average 50 ft-lb[(a)] Transition Temperature (°F)			Average Energy Absorption[(a)] (ft-lb)		
	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔE
Intermediate Shell Forging 125S255 (Longitudinal)	-28.9	47.5	76.4	-6.6	79.7	86.3	2.8	102.8	100.0	140.0	134.3	-5.7
Lower Shell Forging 125P666 (Longitudinal)	-46.2	44.9	91.1	-28.2	64.4	92.6	-14.9	78.4	93.3	174.6	142.3	-32.3
Weld Metal (Heat # 61782)	-34.7	182.2	216.9	-21.4	208.5	229.9	15.0	276.0	261.0	79.0	51.9	-27.1
HAZ Material	-64.7	43.0	107.7	-31.7	56.5	88.2	-16.1	58.4	74.5	90.0	88.3	-1.7

Notes:

(a) "Average" is defined as the value mathematically determined by CVGRAPH from the data points of the Charpy tests (see Figures 5-1, 5-4, 5-7 and 5-10).
(b) "Average" is defined as the value mathematically determined by CVGRAPH from the data points of the Charpy tests (see Figures 5-2, 5-5, 5-8 and 5-11).

Table 5-10 Comparison of the R. E. Ginna Surveillance Material 30 ft-lb Transition Temperature Shifts and Upper Shelf Energy Decreases with Regulatory Guide 1.99, Revision 2, Predictions

Material	Capsule	Fluence (x 10^{19}n/cm^2, E > 1.0 MeV)	30 ft-lb Transition Temperature Shift		USE Decrease	
			Predicted (°F) [(a)]	Measured (°F) [(b)]	Predicted (%) [(a)]	Measured (%)
Intermediate Shell Forging 125S255 (Longitudinal)	V	0.587	37.4	0.0[(c)]	14.5	3.7
	R	1.02	44.2	20.1	16.5	-1.6
	T	1.69	50.4	0.0[(c)]	19	-8.8
	S	3.64	58.8	76.8	23	0.7
	N	5.8	62.9	76.4	26	4.1
Lower Shell Forging 125P666 (Longitudinal)	V	0.587	26.4	34.7	13	10.1
	R	1.02	31.2	57.5	15	15.4
	T	1.69	35.5	33.6	17	18.4
	S	3.64	41.4	45.8	21	18.4
	N	5.8	44.3	91.1	23	18.5
Weld Metal (Heat # 61782)	V	0.587	135.2	146.7	32.5	30.1
	R	1.02	159.7	156.2	37	38.1
	T	1.69	181.8	149.7	40.5	33.3
	S	3.64	212.1	212.2	49	33.9
	N	5.8	227.2	216.9	54	34.3
HAZ Material	V	0.587	- - -	30.7	- - -	-50.0
	R	1.02	- - -	58.6	- - -	8.0
	T	1.69	- - -	41.0	- - -	-30.8
	S	3.64	- - -	38.9	- - -	-15.0
	N	5.8	- - -	107.7	- - -	1.9

Notes:

(a) Based on Regulatory Guide 1.99, Revision 2, methodology using the mean weight percent values of copper and nickel of the surveillance material.

(b) Calculated by CVGraph Version 5.3 using measured Charpy data (See Appendix C).

(c) Measured ΔRT_{NDT} value was determined to be negative, but physically a reduction should not occur, therefore a conservative value of zero is used.

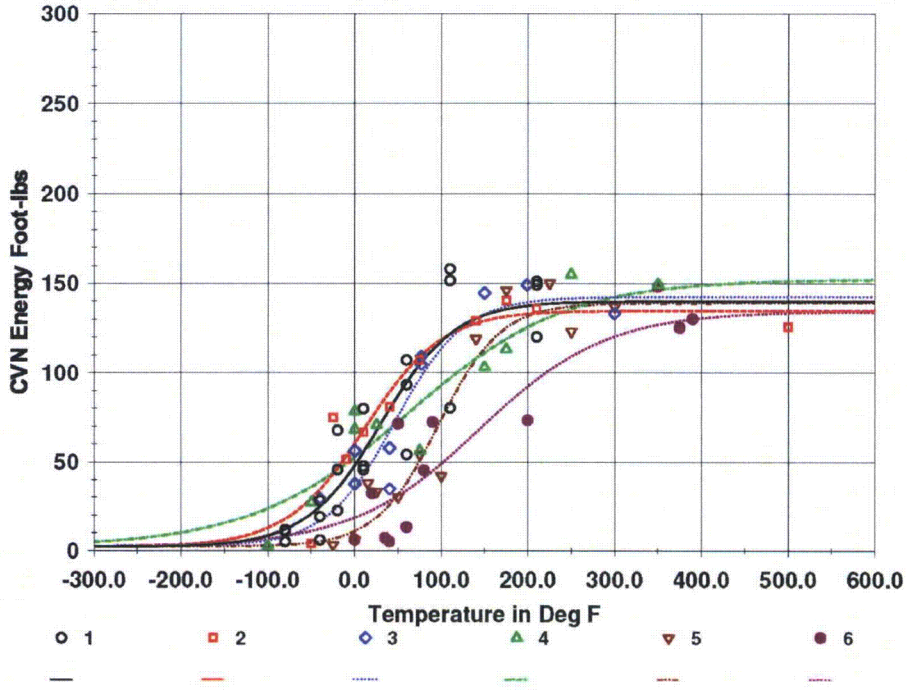
Table 5-11 Tensile Properties of the R. E. Ginna Capsule N Reactor Vessel Surveillance Materials Irradiated to 5.80E+19 n/cm^2 (E > 1.0 MeV)

Material	Sample Number	Test Temp. (°F)	0.2% Yield Strength (ksi)	Ultimate Strength (ksi)	Fracture Load (kip)	Fracture Stress (ksi)	Fracture Strength (ksi)	Uniform Elongation (%)	Total Elongation (%)	Reduction in Area (%)
Intermediate Shell Forging 125S255 (Longitudinal)	S25	125	93.2	109.0	3.75	188.9	76.4	8.4	19.6	60
	S26	300	79.5	94.2	3.00	161.1	61.1	8.3	21.5	62
	S27	550	86.6	104.9	3.90	223.7	79.5	7.5	18.2	64
Lower Shell Forging 125P666 (Longitudinal)	P25	150	73.8	91.7	2.75	189.3	56.0	9.6	23.3	70
	P26	325	69.5	86.1	2.70	177.9	55.0	8.6	21.6	69
	P27	550	69.8	88.6	3.03	146.8	61.6	7.8	18.6	58
Weld Metal (Heat #61782)	W13	125	102.9	111.0	4.05	184.9	82.5	9.0	21.2	55
	W14	260	96.8	104.9	3.90	184.6	79.5	9.0	19.8	57
	W15	550	92.7	105.4	4.15	189.5	84.5	8.3	17.3	55

Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/08/2009 09:31 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA508CL2	LC	125S255
2	Ginna	V	SA508CL2	LC	125S255
3	Ginna	R	SA508CL2	LC	125S255
4	Ginna	T	SA508CL2	LC	125S255
5	Ginna	S	SA508CL2	LC	125S255
6	Ginna	N	SA508CL2	LC	125S255



Results

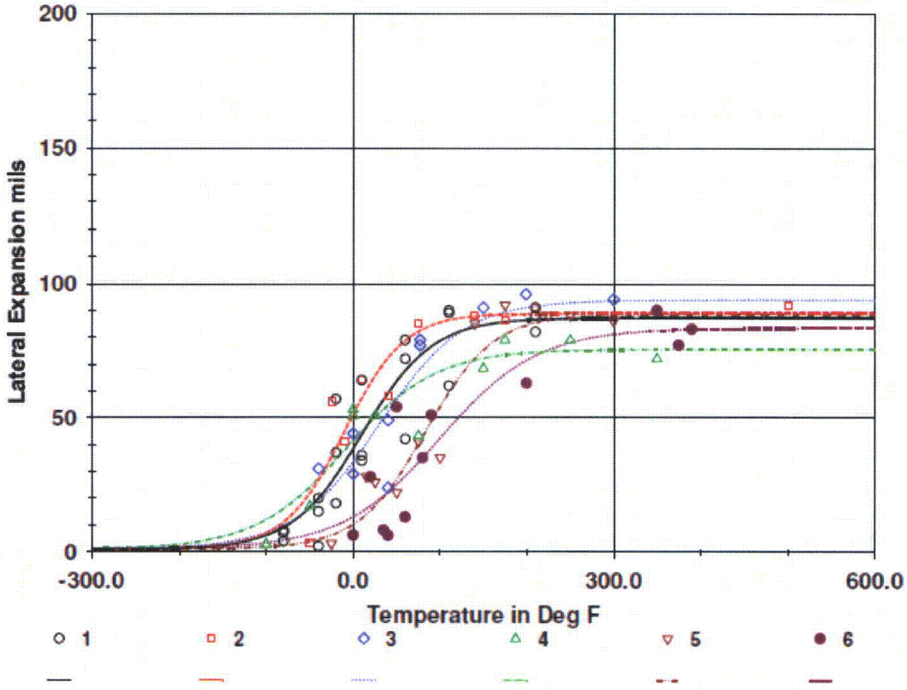
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	140.0	.0	-28.9	.0	2.8	.0
2		2.2	134.8	-5.2	-48.4	-19.5	-14.5	-17.3
3		2.2	142.2	2.2	-8.8	20.1	20.5	17.7
4		2.2	152.3	12.3	-71.5	-42.6	-6.4	-9.2
5		2.2	139.0	-1.0	47.9	76.8	74.7	71.9
6		2.2	134.3	-5.7	47.5	76.4	102.8	100.0

Figure 5-1 Charpy V-Notch Impact Energy vs. Temperature for R. E. Ginna Reactor Vessel Intermediate Shell Forging 125S255 (Longitudinal Orientation)

Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:55 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA508CL2	LC	125S255
2	Ginna	V	SA508CL2	LC	125S255
3	Ginna	R	SA508CL2	LC	125S255
4	Ginna	T	SA508CL2	LC	125S255
5	Ginna	S	SA508CL2	LC	125S255
6	Ginna	N	SA508CL2	LC	125S255



Results

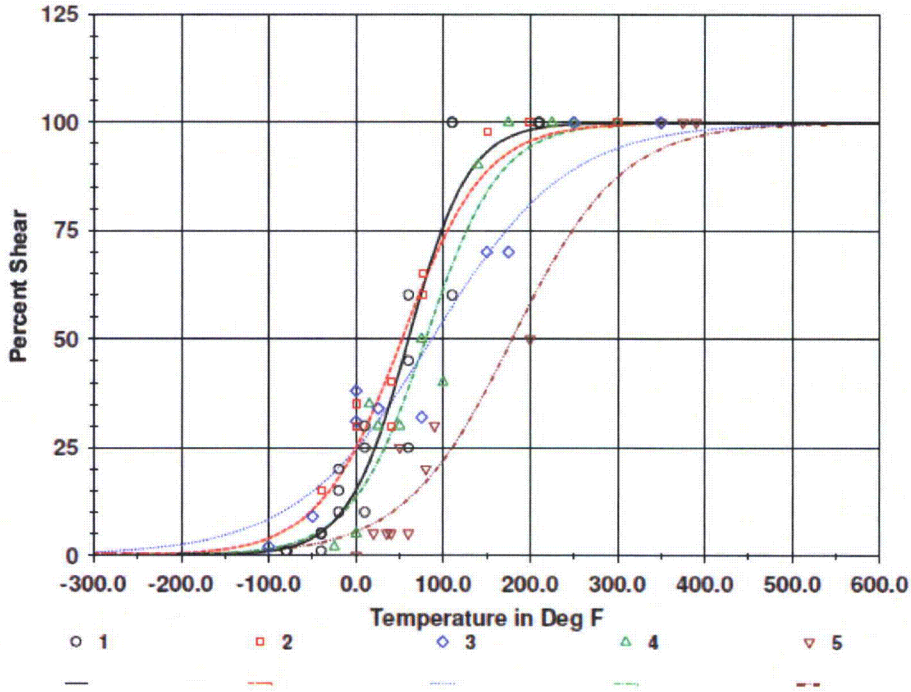
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	87.0	.0	-6.6	.0
2		1.0	88.8	1.8	-25.7	-19.1
3		1.0	93.7	6.7	3.5	10.1
4		1.0	75.5	-11.5	-17.9	-11.3
5		1.0	88.5	1.5	65.7	72.3
6		1.0	83.3	-3.7	79.7	86.3

Figure 5-2 Charpy V-Notch Lateral Expansion vs. Temperature for R. E. Ginna Reactor Vessel Intermediate Shell Forging 125S255 (Longitudinal Orientation)

Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:57 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA508CL2	LC	125S255
2	Ginna	R	SA508CL2	LC	125S255
3	Ginna	T	SA508CL2	LC	125S255
4	Ginna	S	SA508CL2	LC	125S255
5	Ginna	N	SA508CL2	LC	125S255



Results

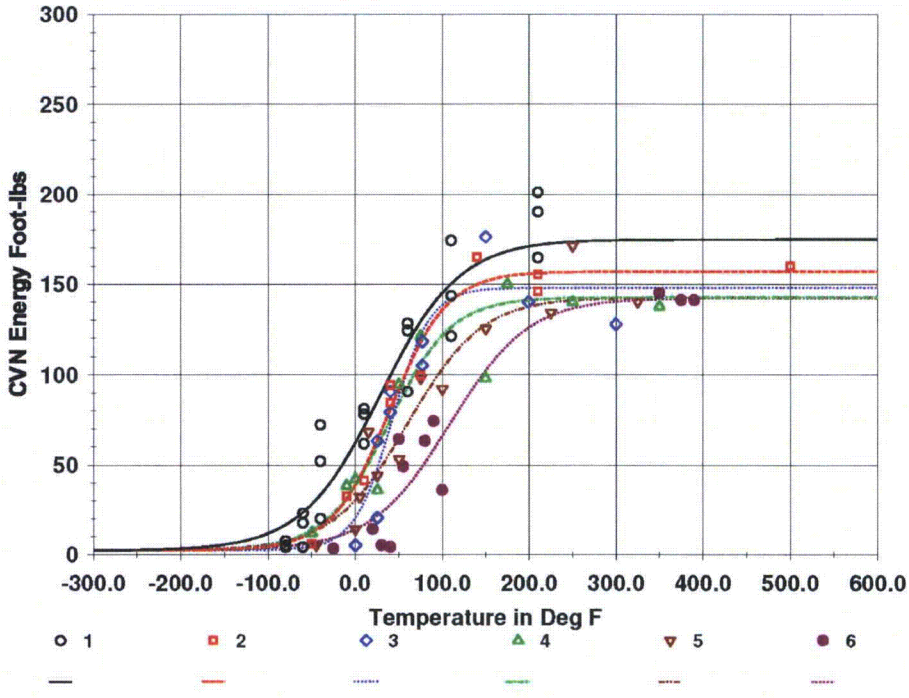
Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	60.0	.0
2		.0	100.0	.0	52.5	-7.5
3		.0	100.0	.0	87.4	27.4
4		.0	100.0	.0	80.0	20.0
5		.0	100.0	.0	179.4	119.4

Figure 5-3 Charpy V-Notch Percent Shear vs. Temperature for R. E. Ginna Reactor Vessel Intermediate Shell Forging 125S255 (Longitudinal Orientation)

Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/11/2009 09:05 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA508CL2	LC	125P666
2	Ginna	V	SA508CL2	LC	125P666
3	Ginna	R	SA508CL2	LC	125P666
4	Ginna	T	SA508CL2	LC	125P666
5	Ginna	S	SA508CL2	LC	125P666
6	Ginna	N	SA508CL2	LC	125P666



Results

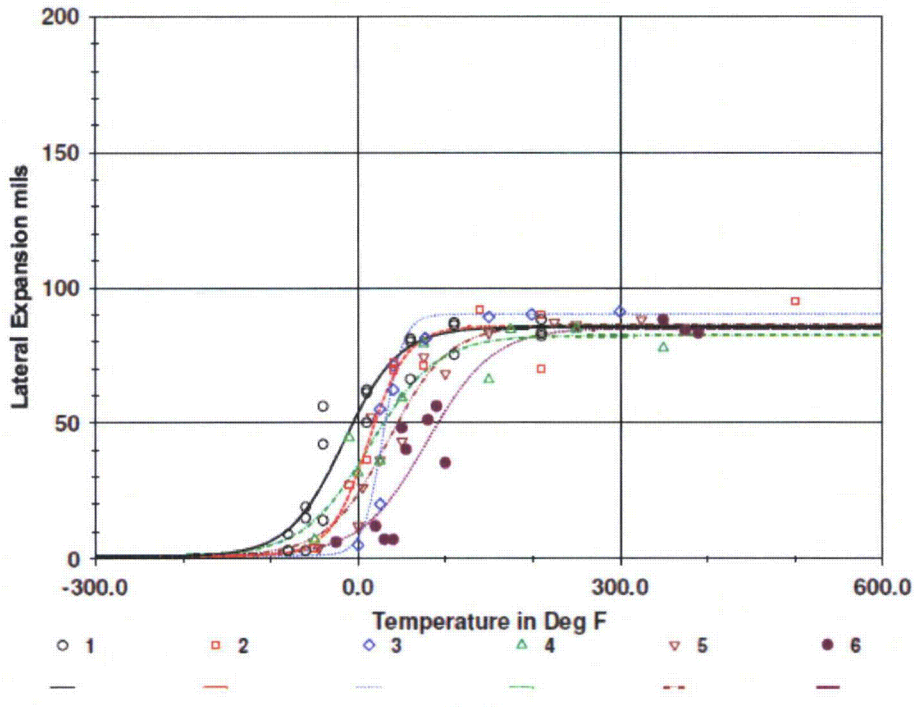
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	174.6	.0	-46.2	.0	-14.9	.0
2		2.2	157.0	-17.6	-11.5	34.7	12.3	27.2
3		2.2	147.8	-26.8	11.3	57.5	27.1	42.0
4		2.2	142.5	-32.1	-12.6	33.6	14.0	28.9
5		2.2	142.5	-32.1	-.4	45.8	31.3	46.2
6		2.2	142.3	-32.3	44.9	91.1	78.4	93.3

Figure 5-4 Charpy V-Notch Impact Energy vs. Temperature for R. E. Ginna Reactor Vessel Lower Shell Forging 125P666 (Longitudinal Orientation)

Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:42 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA508CL2	LC	125P666
2	Ginna	V	SA508CL2	LC	125P666
3	Ginna	R	SA508CL2	LC	125P666
4	Ginna	T	SA508CL2	LC	125P666
5	Ginna	S	SA508CL2	LC	125P666
6	Ginna	N	SA508CL2	LC	125P666



Results

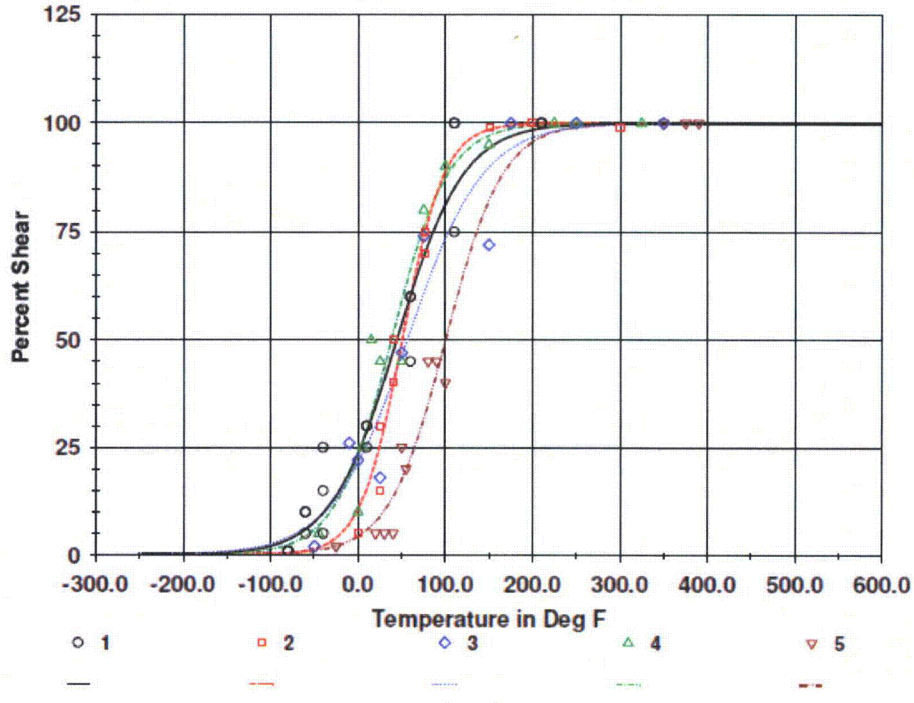
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	85.2	.0	-28.2	.0
2		1.0	85.5	.3	3.4	31.6
3		1.0	90.0	4.8	23.6	51.8
4		1.0	82.1	-3.1	1.1	29.3
5		1.0	86.0	.8	20.8	49.0
6		1.0	85.0	-.2	64.4	92.6

Figure 5-5 Charpy V-Notch Lateral Expansion vs. Temperature for R. E. Ginna Reactor Vessel Lower Shell Forging 125P666 (Longitudinal Orientation)

Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:49 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA508CL2	LC	125P666
2	Ginna	R	SA508CL2	LC	125P666
3	Ginna	T	SA508CL2	LC	125P666
4	Ginna	S	SA508CL2	LC	125P666
5	Ginna	N	SA508CL2	LC	125P666



Results

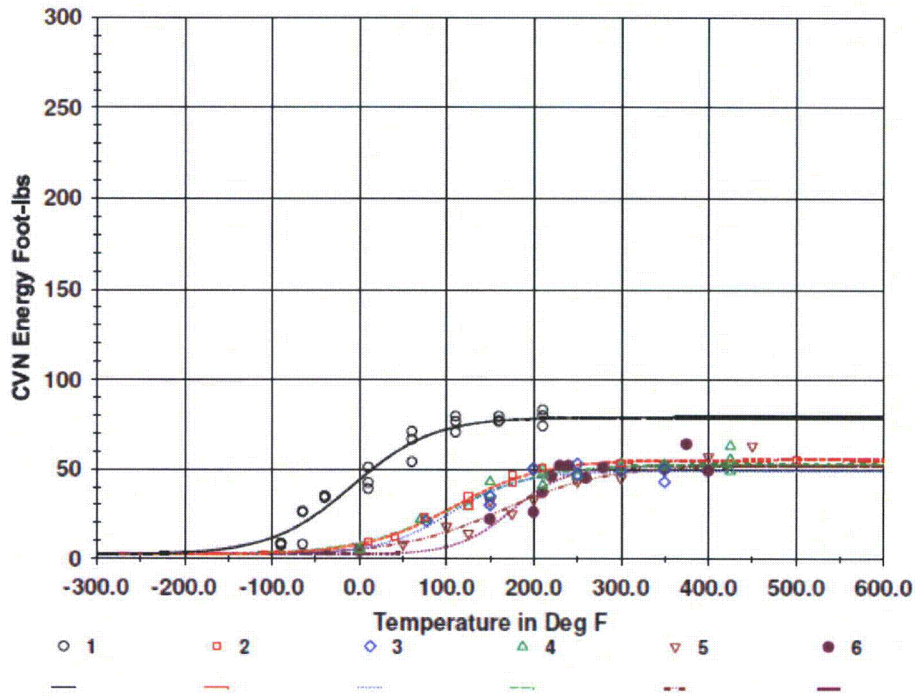
Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	44.3	.0
2		.0	100.0	.0	50.5	6.2
3		.0	100.0	.0	56.7	12.4
4		.0	100.0	.0	38.3	-6.0
5		.0	100.0	.0	100.3	56.0

Figure 5-6 Charpy V-Notch Percent Shear vs. Temperature for R. E. Ginna Reactor Vessel Lower Shell Forging 125P666 (Longitudinal Orientation)

Weld Heat #61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:07 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SAW	NA	61782
2	Ginna	V	SAW	NA	61782
3	Ginna	R	SAW	NA	61782
4	Ginna	T reco	SAW	NA	61782
5	Ginna	S	SAW	NA	61782
6	Ginna	N	SAW	NA	61782



Results

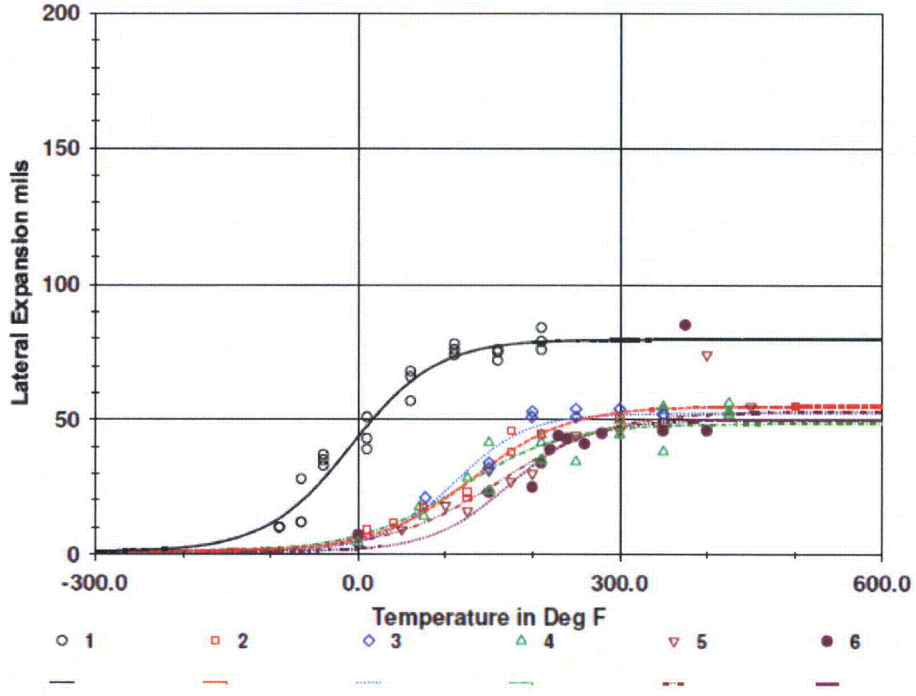
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	79.0	.0	-34.7	.0	15.0	.0
2		2.2	55.2	-23.8	112.0	146.7	219.4	204.4
3		2.2	48.9	-30.1	121.5	156.2		
4		2.2	52.7	-26.3	115.0	149.7	259.1	244.1
5		2.2	52.2	-26.8	177.5	212.2	346.5	331.5
6		2.2	51.9	-27.1	182.2	216.9	276.0	261.0

Figure 5-7 Charpy V-Notch Impact Energy vs. Temperature for the R. E. Ginna Reactor Vessel Surveillance Program Weld Metal

Weld Heat #61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:10 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SAW	NA	61782
2	Ginna	V	SAW	NA	61782
3	Ginna	R	SAW	NA	61782
4	Ginna	T reco	SAW	NA	61782
5	Ginna	S	SAW	NA	61782
6	Ginna	N	SAW	NA	61782



Results

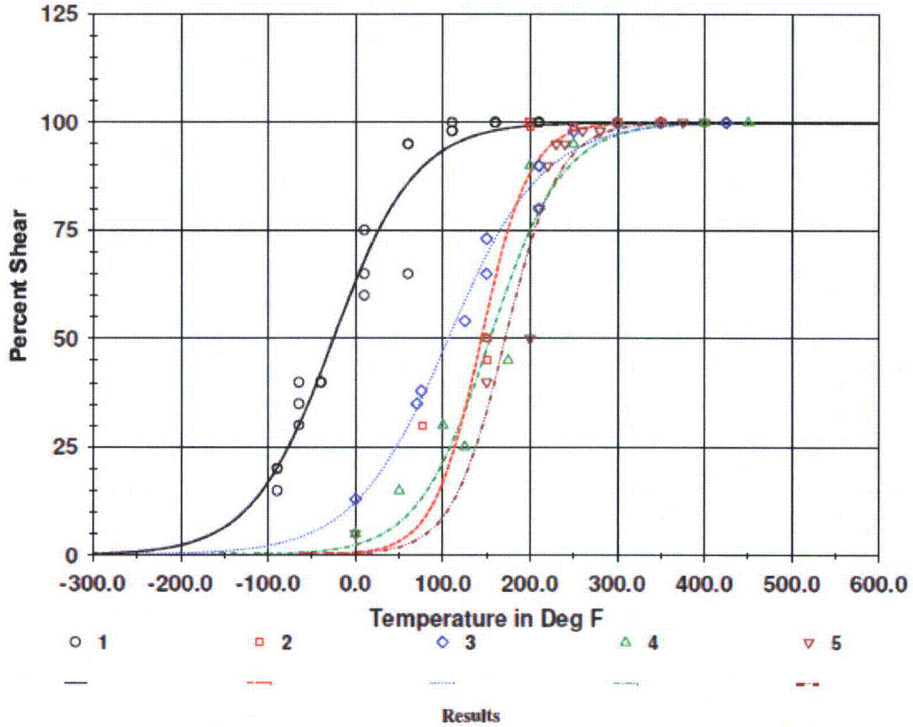
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	79.7	.0	-21.4	.0
2		1.0	55.2	-24.5	159.6	181.0
3		1.0	52.4	-27.3	138.8	160.2
4		1.0	48.6	-31.1	171.2	192.6
5		1.0	53.2	-26.5	201.7	223.1
6		1.0	50.0	-29.7	208.5	229.9

Figure 5-8 Charpy V-Notch Lateral Expansion vs. Temperature for the R. E. Ginna Reactor Vessel Surveillance Program Weld Metal

Weld Heat #61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:11 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SAW	NA	61782
2	Ginna	R	SAW	NA	61782
3	Ginna	T reco	SAW	NA	61782
4	Ginna	S	SAW	NA	61782
5	Ginna	N	SAW	NA	61782



Results

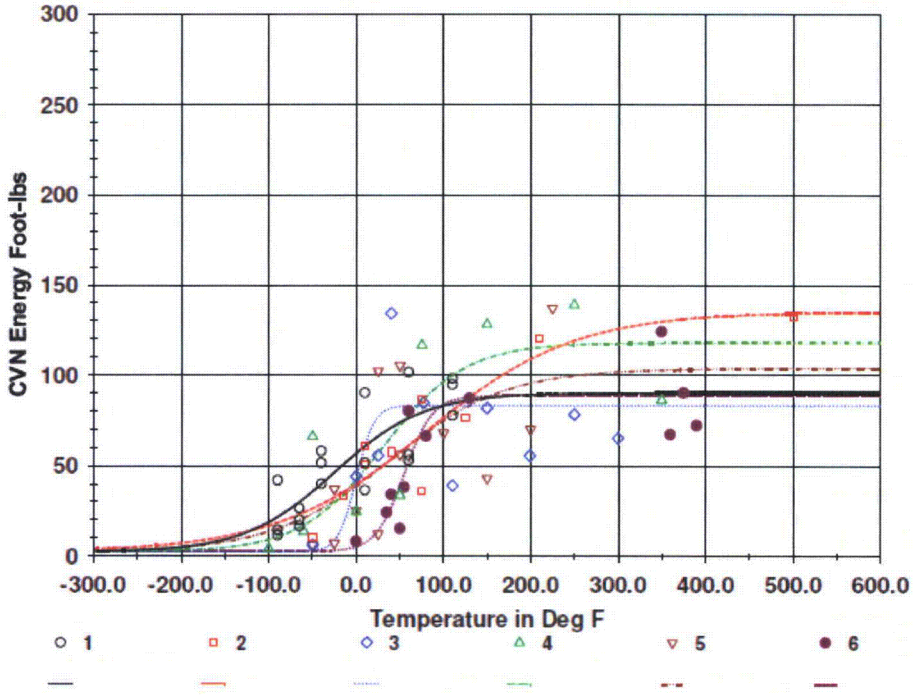
Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	-25.4	.0
2		.0	100.0	.0	143.8	169.2
3		.0	100.0	.0	106.5	131.9
4		.0	100.0	.0	154.2	179.6
5		.0	100.0	.0	171.5	196.9

Figure 5-9 Charpy V-Notch Percent Shear vs. Temperature for the R. E. Ginna Reactor Vessel Surveillance Program Weld Metal

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:20 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	GINNA	UNIRR	SAW	NA	125P666
2	Ginna	V	SAW	NA	125P666
3	Ginna	R	SAW	NA	125P666
4	Ginna	T	SAW	NA	125P666
5	Ginna	S	SAW	NA	125P666
6	Ginna	N	SAW	NA	125P666



Results

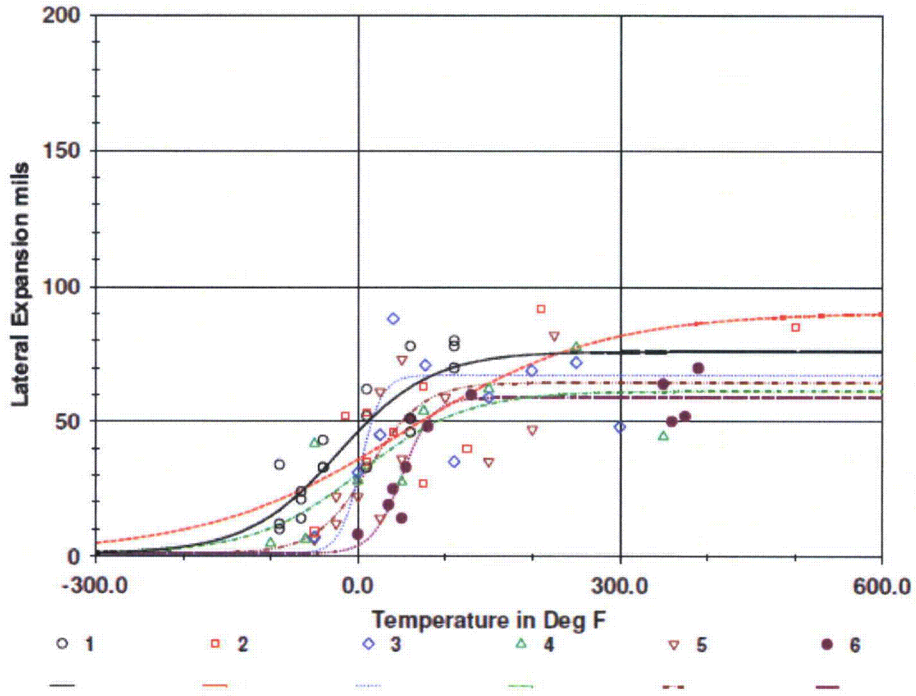
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	90.0	.0	-64.7	.0	-16.1	.0
2		2.2	135.0	45.0	-34.0	30.7	30.5	46.6
3		2.2	82.8	-7.2	-6.1	58.6	4.1	20.2
4		2.2	117.7	27.7	-23.7	41.0	14.1	30.2
5		2.2	103.5	13.5	-25.8	38.9	31.4	47.5
6		2.2	88.3	-1.7	43.0	107.7	58.4	74.5

Figure 5-10 Charpy V-Notch Impact Energy vs. Temperature for the R. E. Ginna Reactor Vessel Heat-Affected-Zone Material

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:24 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	GINNA	UNIRR	SAW	NA	125P666
2	Ginna	V	SAW	NA	125P666
3	Ginna	R	SAW	NA	125P666
4	Ginna	T	SAW	NA	125P666
5	Ginna	S	SAW	NA	125P666
6	Ginna	N	SAW	NA	125P666



Results

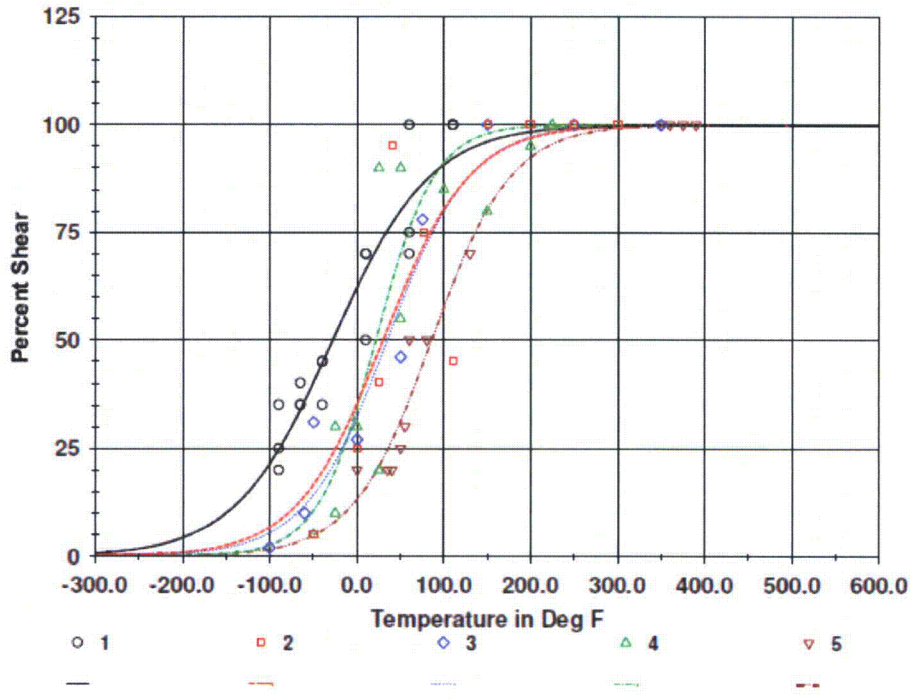
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	76.0	.0	-31.7	.0
2		1.0	90.6	14.6	-4.3	27.4
3		1.0	67.2	-8.8	4.3	36.0
4		1.0	61.4	-14.6	18.2	49.9
5		1.0	64.5	-11.5	17.5	49.2
6		1.0	59.0	-17.0	56.5	88.2

Figure 5-11 Charpy V-Notch Lateral Expansion vs. Temperature for the R. E. Ginna Reactor Vessel Heat-Affected-Zone Material

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:51 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	GINNA	UNIRR	SAW	NA	125P666
2	Ginna	R	SAW	NA	125P666
3	Ginna	T	SAW	NA	125P666
4	Ginna	S	SAW	NA	125P666
5	Ginna	N	SAW	NA	125P666



Results

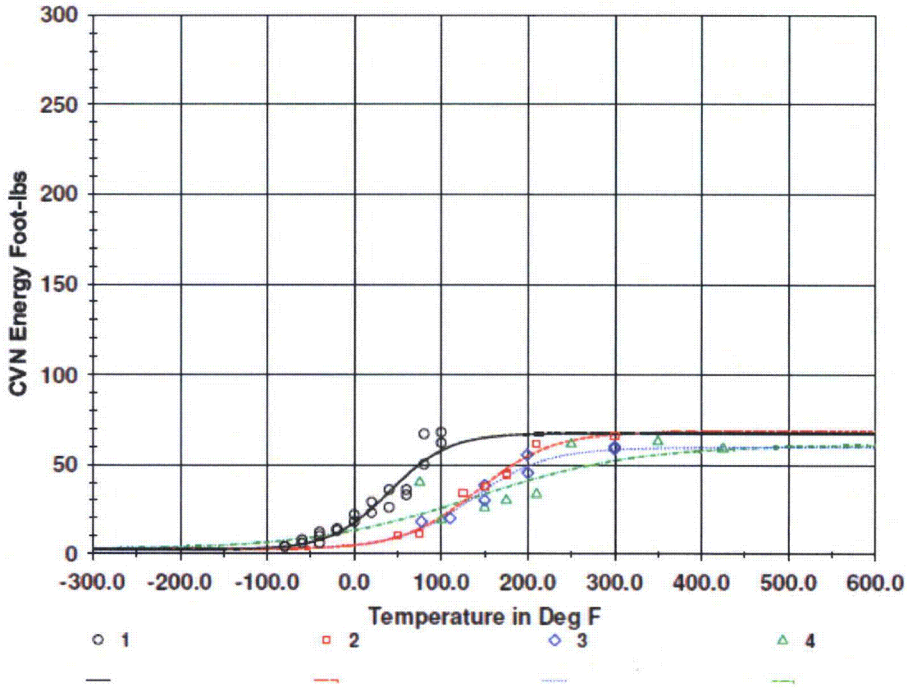
Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	-27.7	.0
2		.0	100.0	.0	29.9	57.6
3		.0	100.0	.0	35.3	63.0
4		.0	100.0	.0	21.8	49.5
5		.0	100.0	.0	86.0	113.7

Figure 5-12 Charpy V-Notch Percent Shear vs. Temperature for the R. E. Ginna Reactor Vessel Heat-Affected-Zone Material

Ginna Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/08/2009 09:44 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA302B	LT	A0421
2	Ginna	V	SA302B	LT	A0421
3	Ginna	R	SA302B	LT	A0421
4	Ginna	T	SA302B	LT	A0421



Results

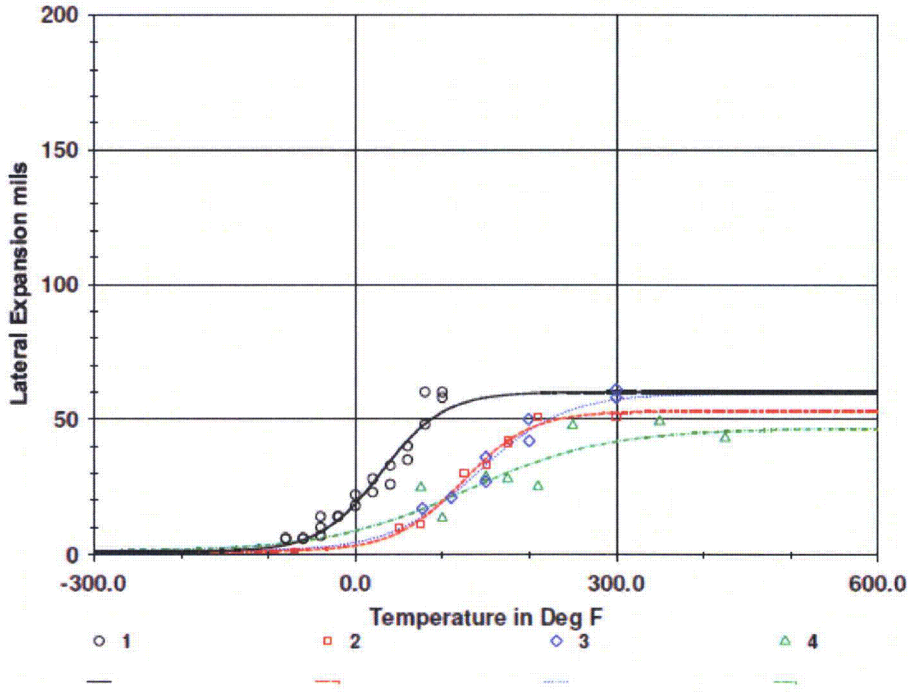
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	67.5	.0	30.2	.0	74.5	.0
2		2.2	68.6	1.1	127.2	97.0	182.7	108.2
3		2.2	59.5	-8.0	133.4	103.2	204.6	130.1
4		2.2	61.2	-6.3	128.0	97.8	274.3	199.8

Figure 5-13 Charpy V-Notch Impact Energy vs. Temperature for the R. E. Ginna Reactor Vessel Correlation Monitor Material

Ginna Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:17 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA302B	LT	A0421
2	Ginna	V	SA302B	LT	A0421
3	Ginna	R	SA302B	LT	A0421
4	Ginna	T	SA302B	LT	A0421



Results

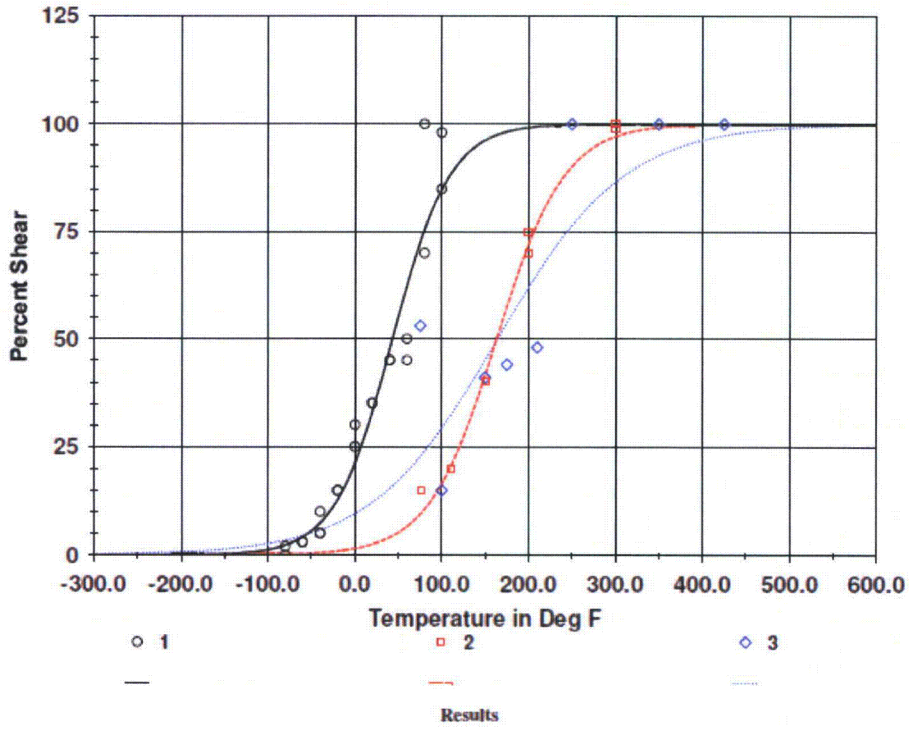
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	60.0	.0	41.0	.0
2		1.0	53.0	-7.0	148.2	107.2
3		1.0	59.5	-.5	157.2	116.2
4		1.0	46.6	-13.4	214.9	173.9

Figure 5-14 Charpy V-Notch Lateral Expansion vs. Temperature for the R. E. Ginna Reactor Vessel Correlation Monitor Material

Ginna Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/03/2009 08:19 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Ginna	UNIRR	SA302B	LT	A0421
2	Ginna	R	SA302B	LT	A0421
3	Ginna	T	SA302B	LT	A0421



Results

Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	43.2	.0
2		.0	100.0	.0	163.1	119.9
3		.0	100.0	.0	164.7	121.5

Figure 5-15 Charpy V-Notch Percent Shear vs. Temperature for the R. E. Ginna Reactor Vessel Correlation Monitor Material

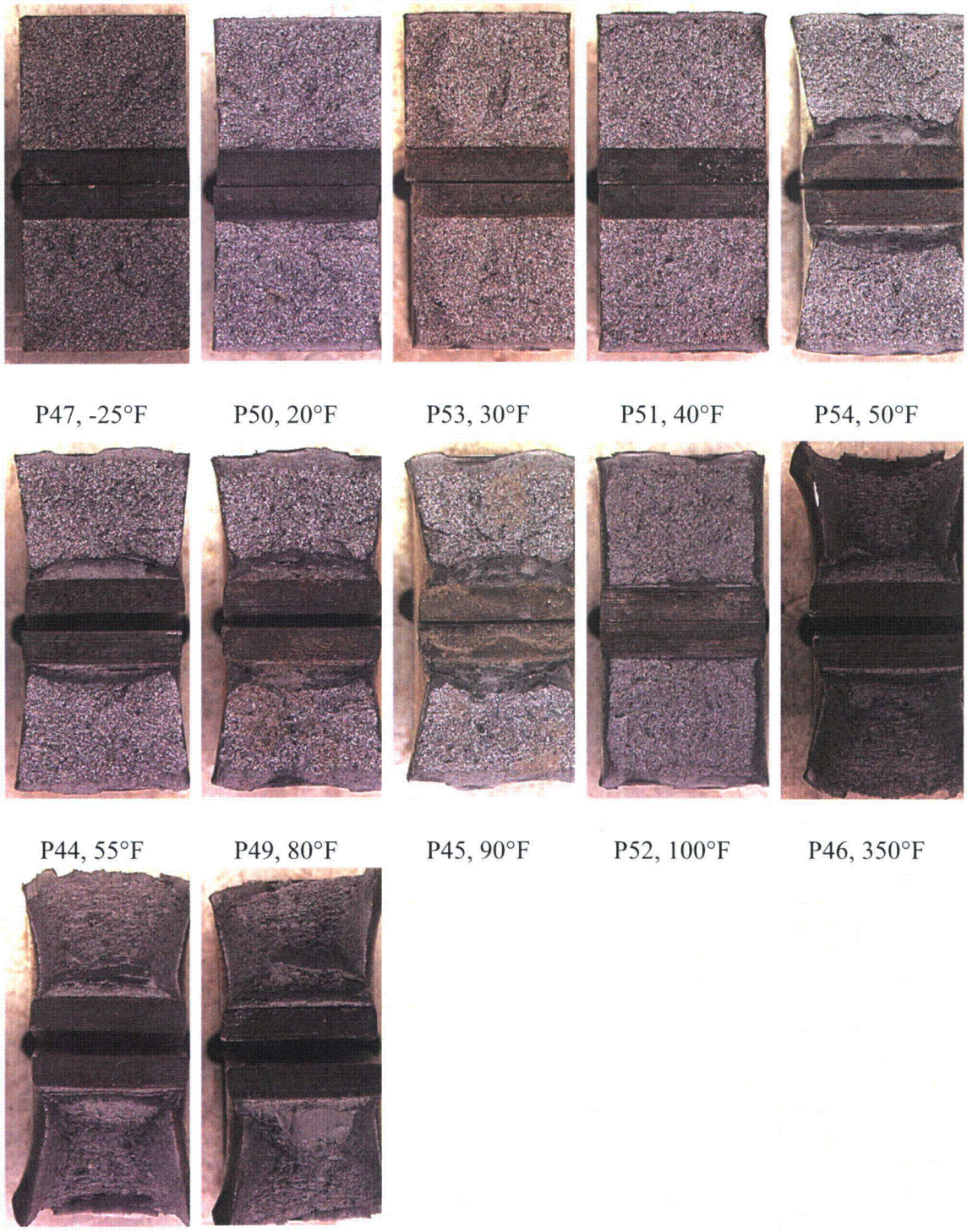


Figure 5-16 Charpy Impact Specimen Fracture Surfaces for R. E. Ginna Reactor Vessel Lower Shell Forging 125P666 (Longitudinal Orientation)

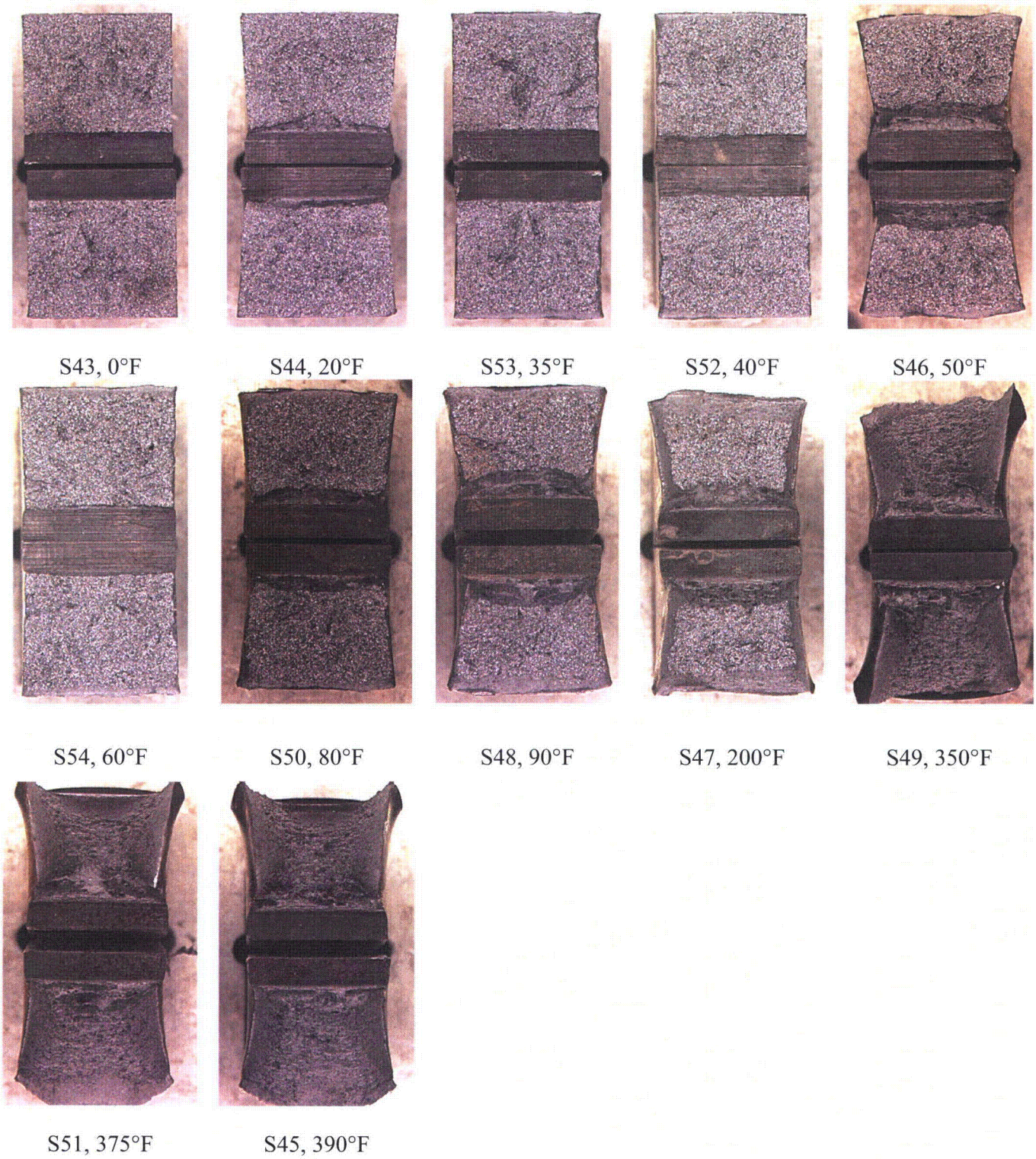


Figure 5-17 Charpy Impact Specimen Fracture Surfaces for R. E. Ginna Reactor Vessel Intermediate Shell Forging 125S255 (Longitudinal Orientation)

Figure 5-18 Charpy Impact Specimen Fracture Surfaces for the R. E. Ginna Reactor Vessel Surveillance Program Weld Metal

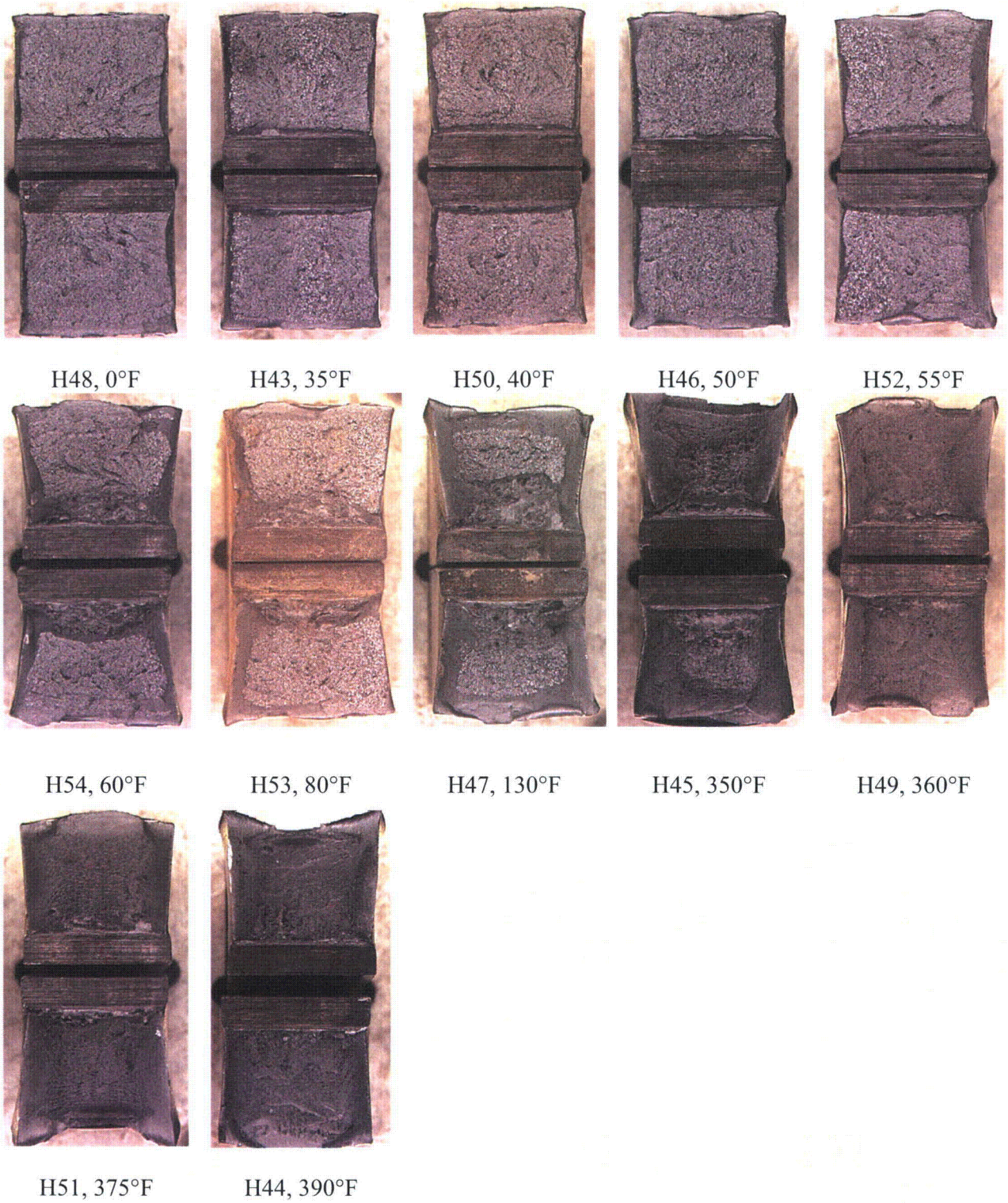
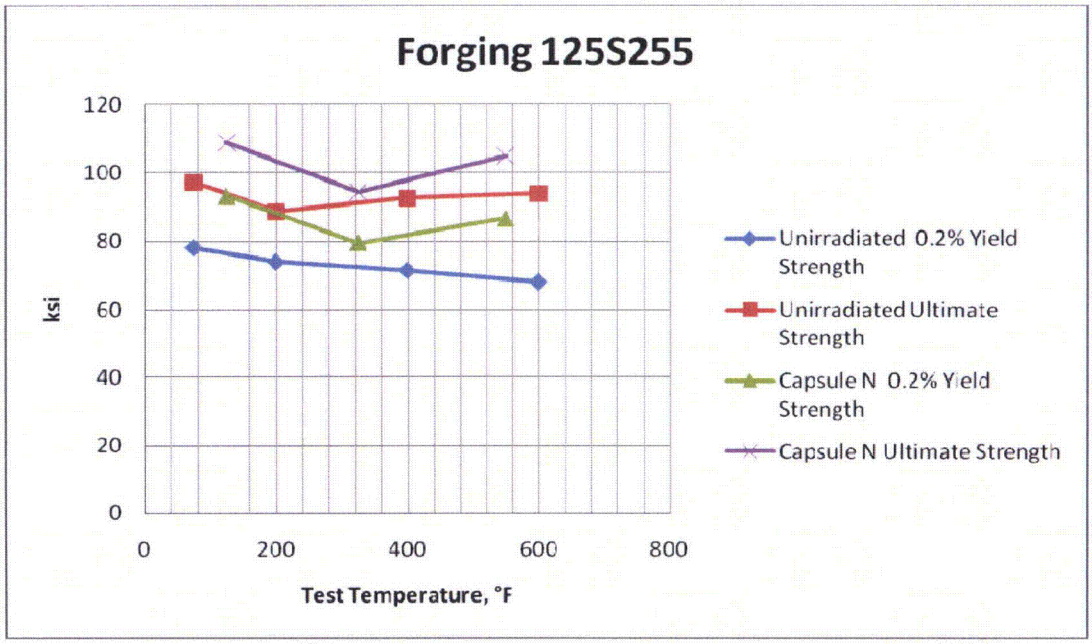


Figure 5-19 Charpy Impact Specimen Fracture Surfaces for the R. E. Ginna Reactor Vessel Heat-Affected-Zone Material



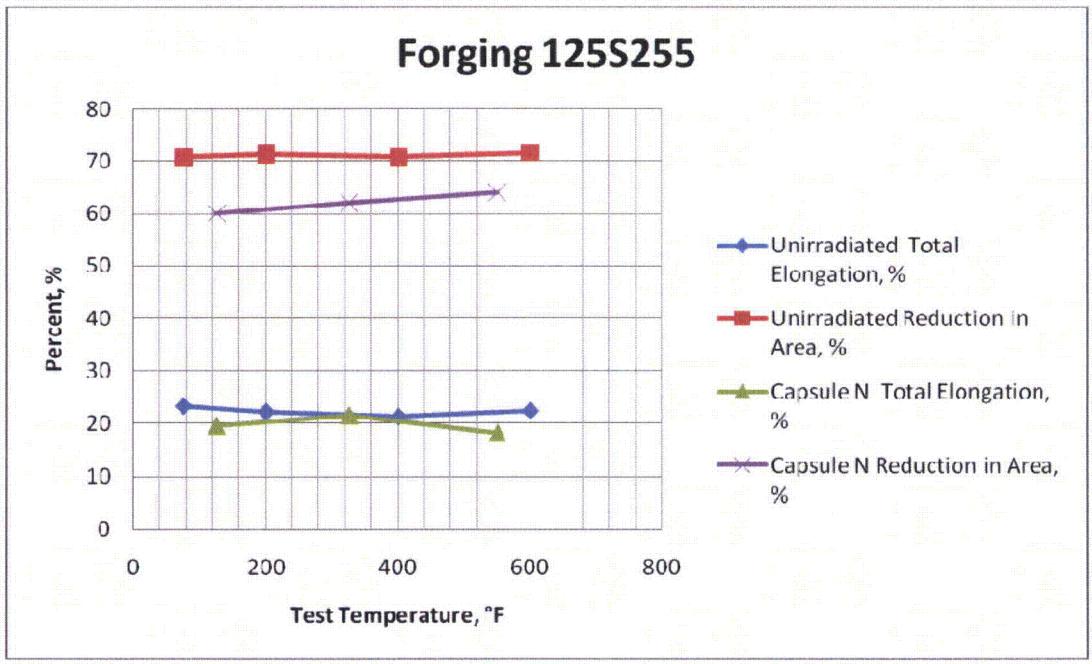
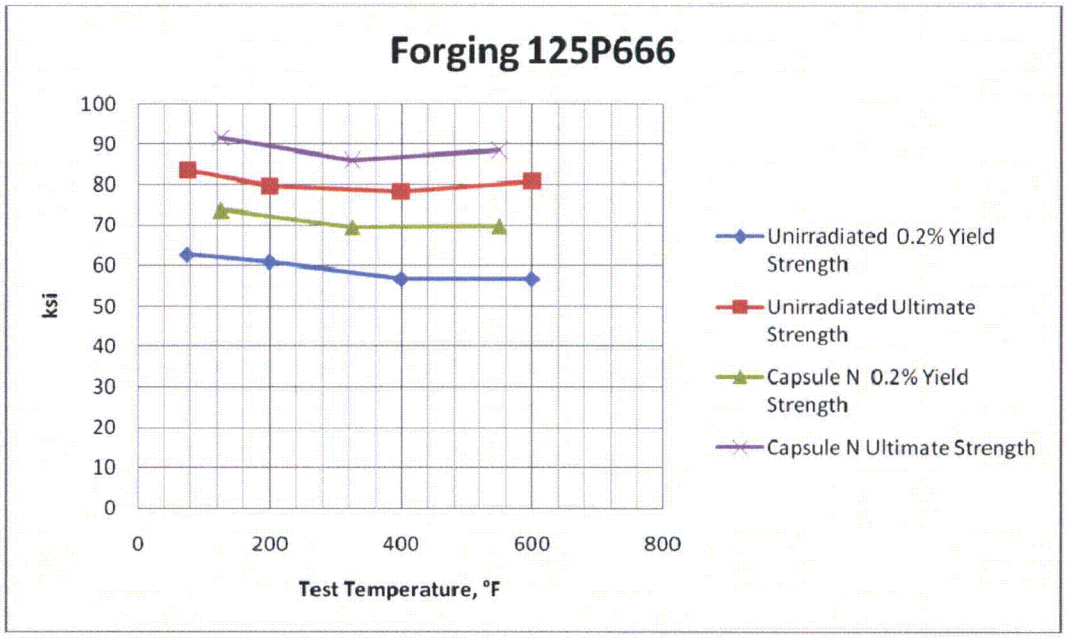


Figure 5-20 Tensile Properties for R. E. Ginna Reactor Vessel Intermediate Shell Forging 125S255 (Longitudinal Orientation)



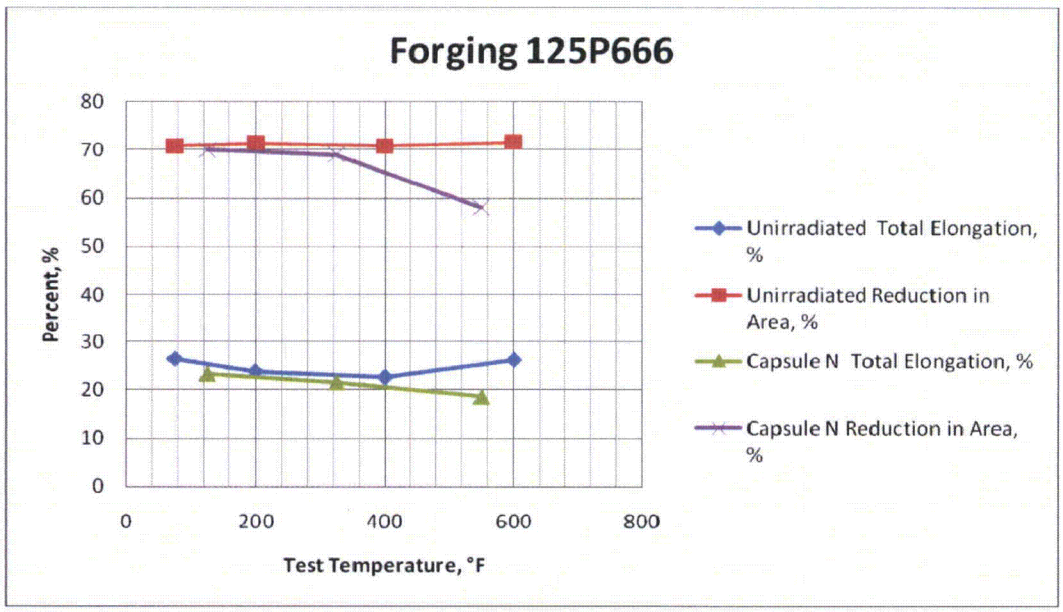
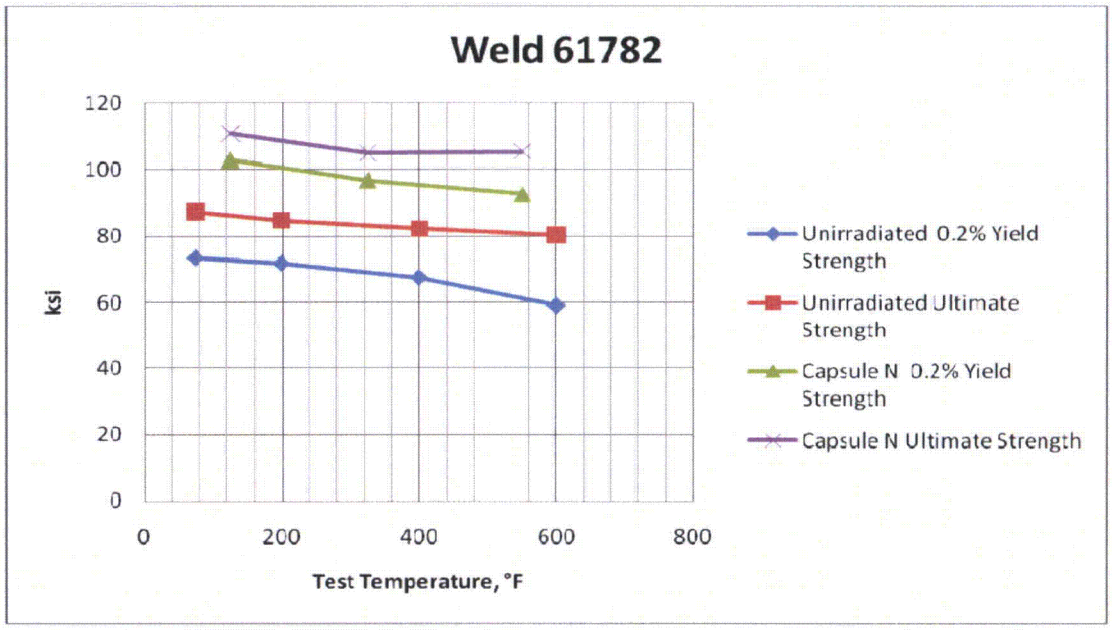


Figure 5-21 Tensile Properties for R. E. Ginna Reactor Vessel Lower Shell Forging 125P666 (Longitudinal Orientation)



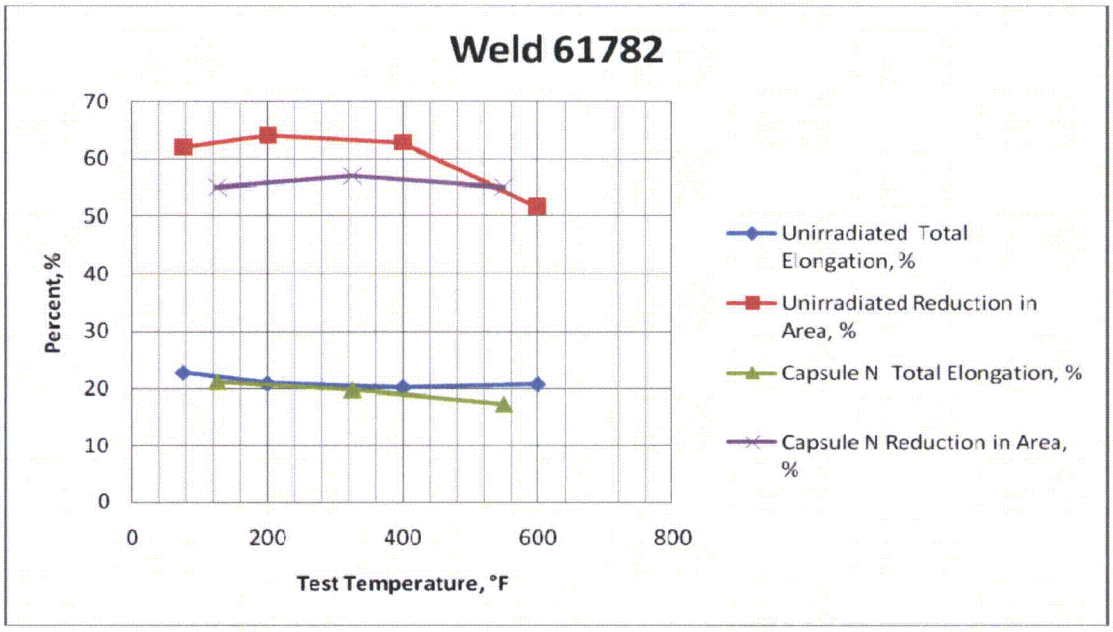
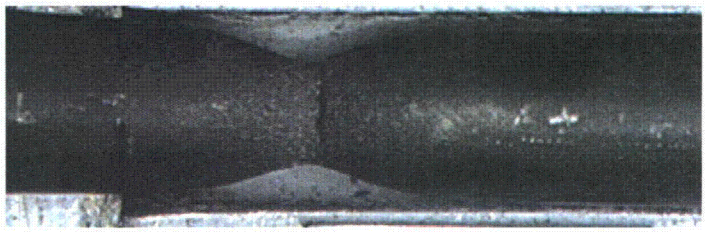
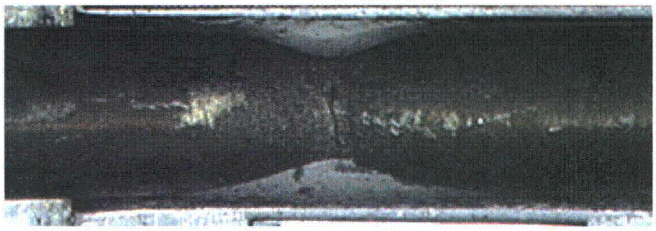


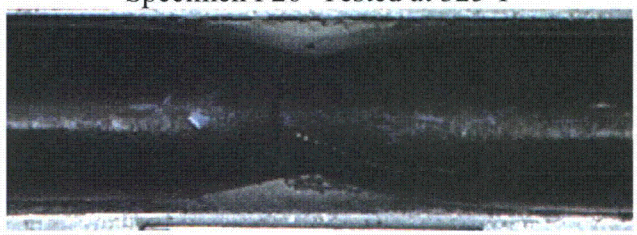
Figure 5-22 Tensile Properties for the R. E. Ginna Reactor Vessel Surveillance Program Weld Metal



Specimen P25- Tested at 150°F

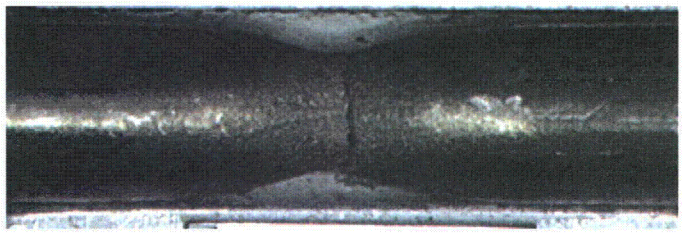


Specimen P26- Tested at 325°F

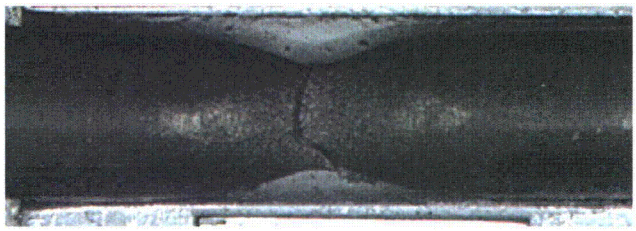


Specimen P27- Tested at 550°F

Figure 5-23 Fractured Tensile Specimens from R. E. Ginna Reactor Vessel Lower Shell Forging 125P666 (Longitudinal Orientation)



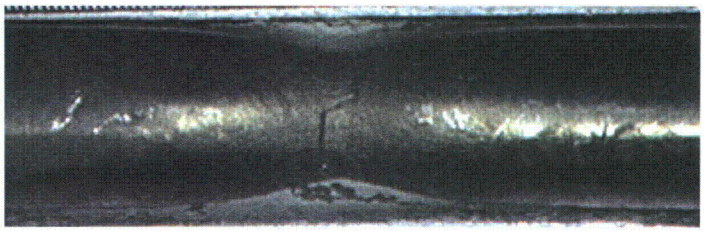
Specimen S25- Tested at 125°F



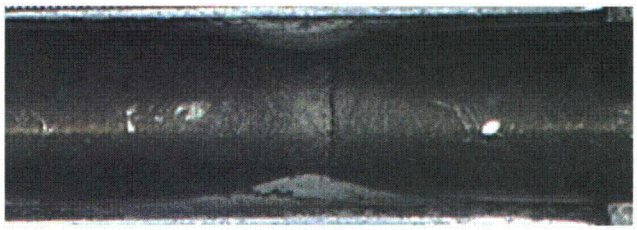
Specimen S26- Tested at 300°F

Specimen S27- Tested at 550°F

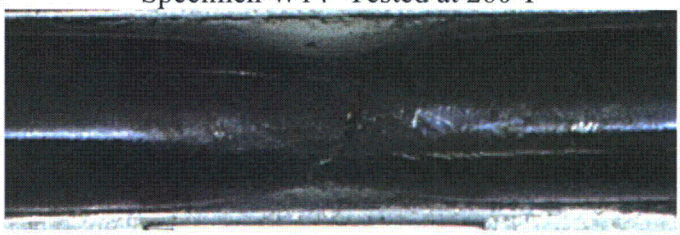
Figure 5-24 Fractured Tensile Specimens from R. E. Ginna Reactor Vessel Intermediate Shell Forging 125S255 (Longitudinal Orientation)



Specimen W13- Tested at 125°F

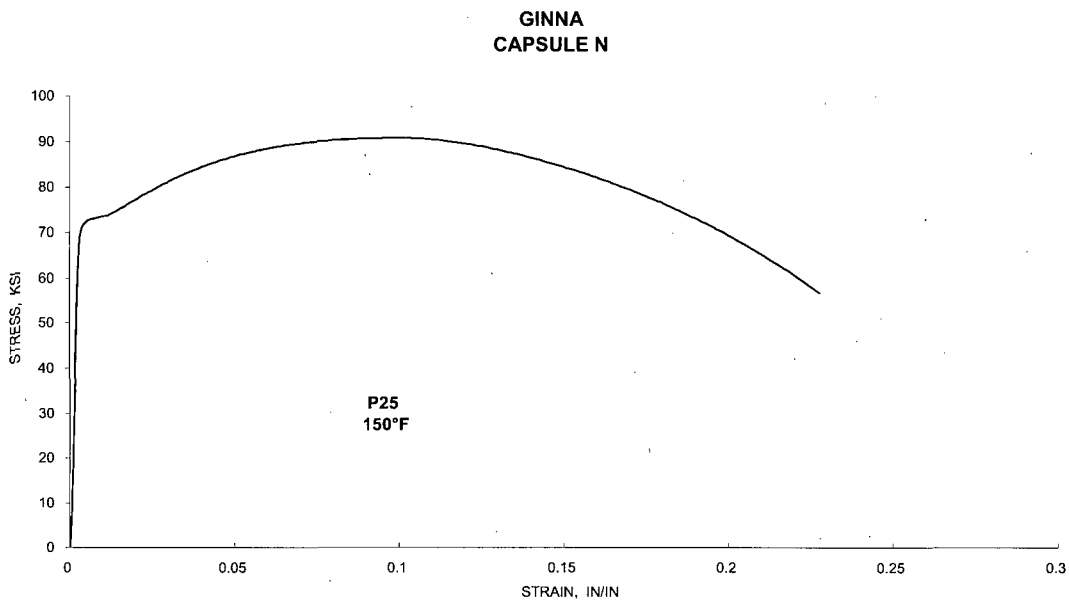


Specimen W14- Tested at 260°F



Specimen W15- Tested at 550°F

Figure 5-25 Fractured Tensile Specimens from the R. E. Ginna Reactor Vessel Surveillance Program Weld Metal Heat #61782



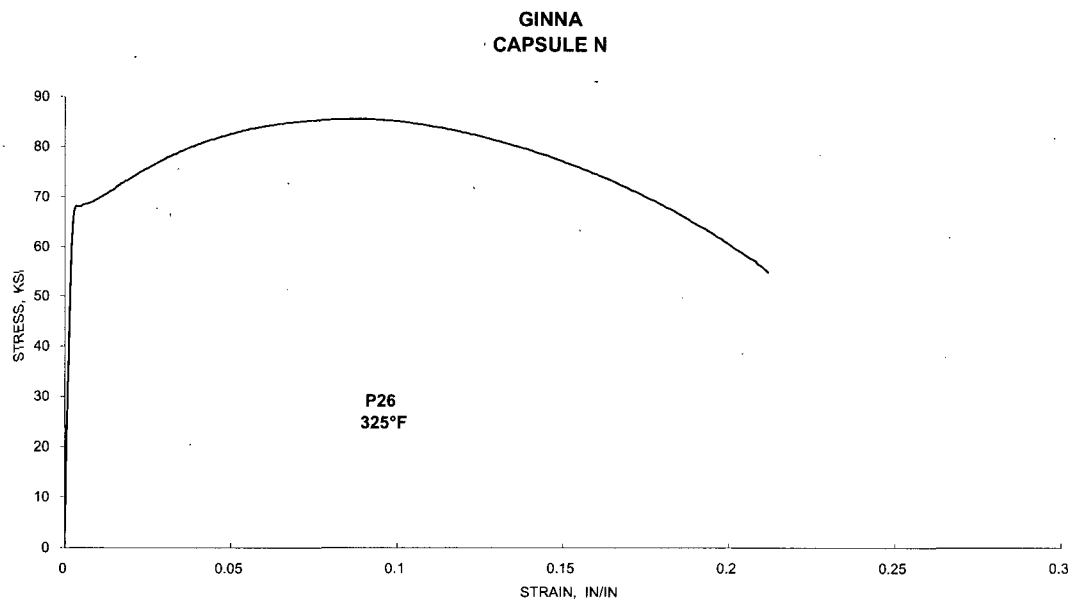


Figure 5-26 Engineering Stress-Strain Curves for R. E. Ginna Lower Shell Forging 125P666 Tensile Specimens P-25 and P-26 (Longitudinal Orientation)

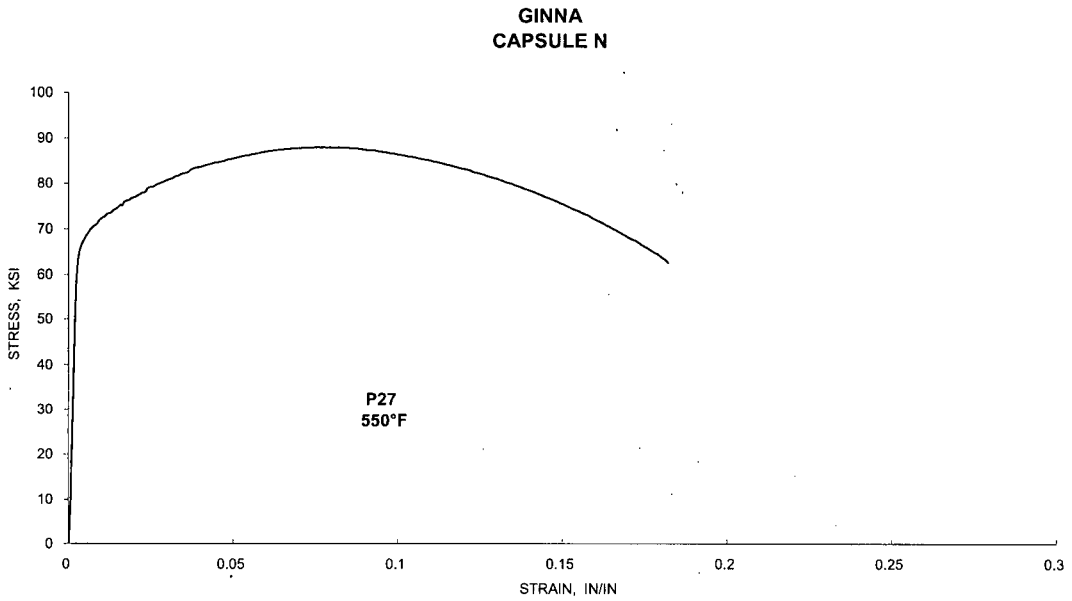
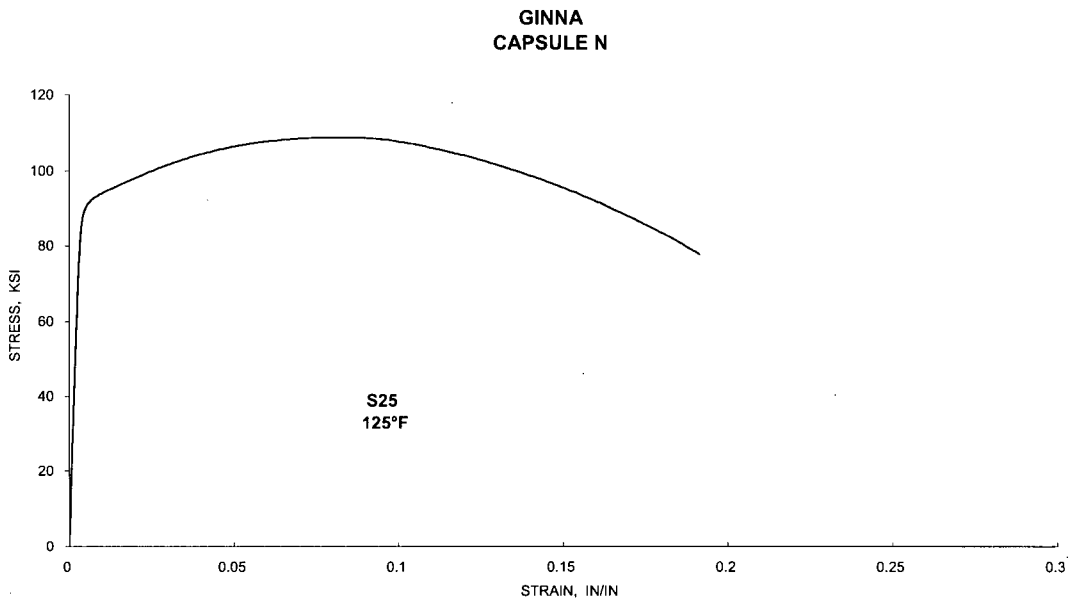


Figure 5-27 Engineering Stress-Strain Curve for R. E. Ginna Lower Shell Forging 125P666 Tensile Specimen P-27 (Longitudinal Orientation)



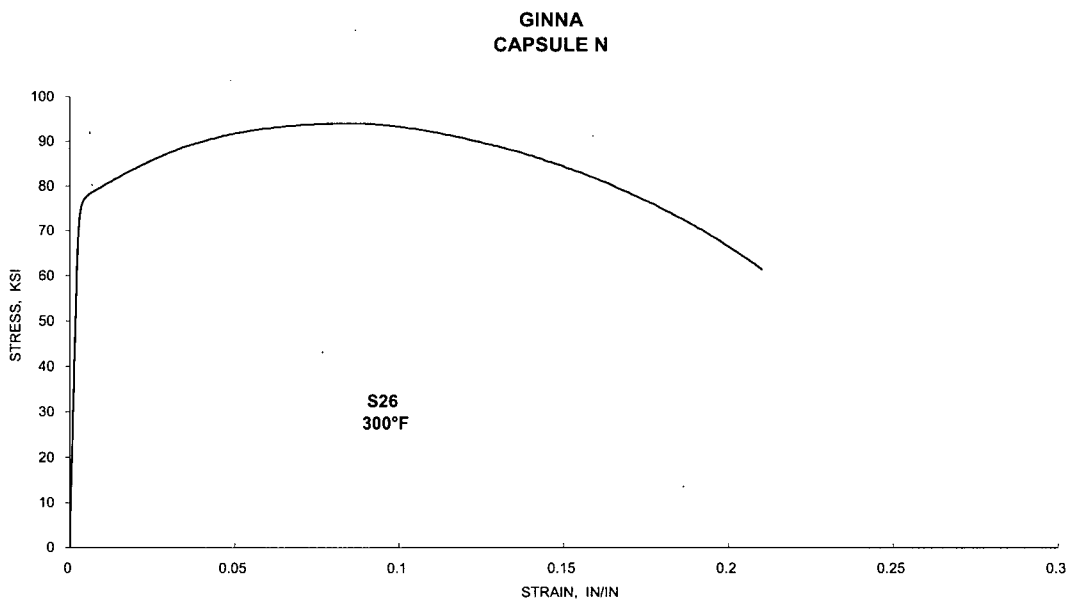


Figure 5-28 Engineering Stress-Strain Curves for R. E. Ginna Surveillance Program Intermediate Shell Forging 125S255 Tensile Specimens S-25 and S-26 (Longitudinal Orientation)

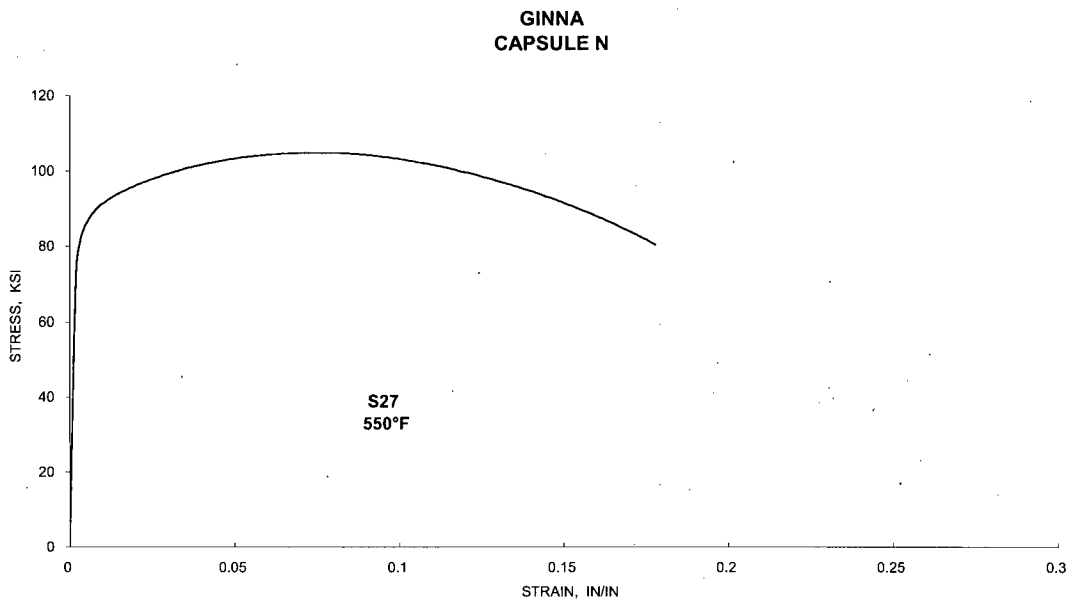
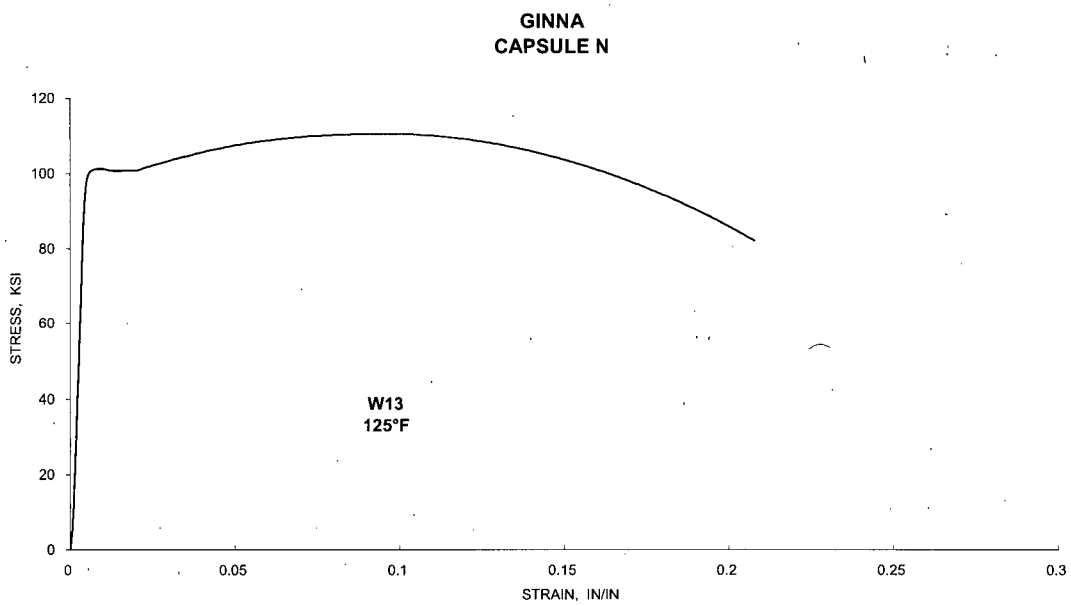


Figure 5-29 Engineering Stress-Strain Curve for R. E. Ginna Surveillance Program Intermediate Shell Forging 125S255 Tensile Specimen S-27



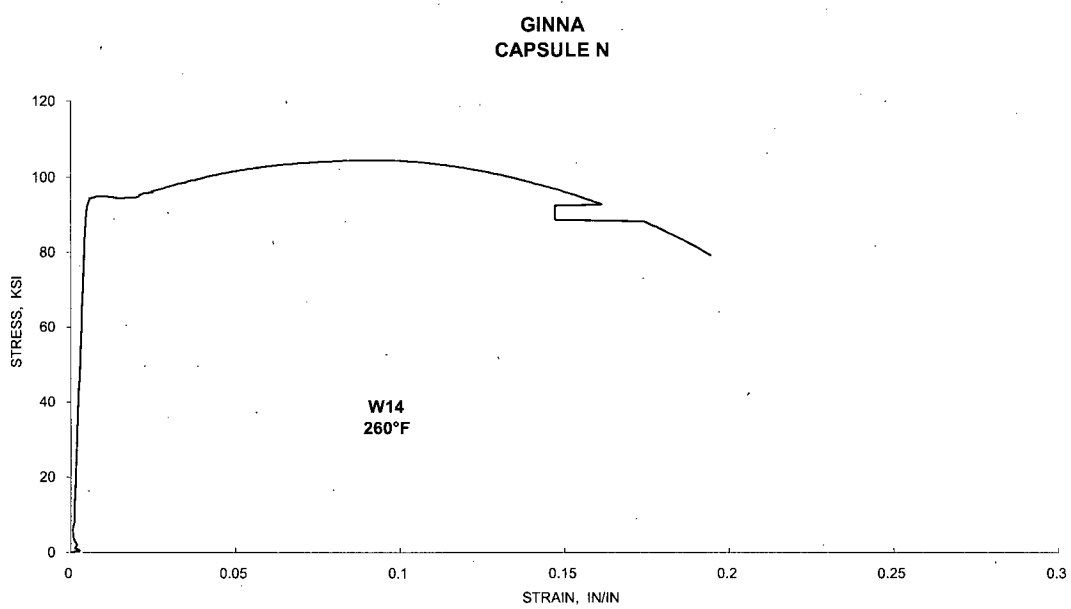


Figure 5-30 Engineering Stress-Strain Curves for R. E. Ginna Surveillance Program Weld Metal Heat 61782 Tensile Specimens W-13 and W-14

(Note: A temporary signal loss to the plotter occurred during the course of this test. This loss of data to the plotter had no adverse impact to tensile data analysis for specimen W-14)

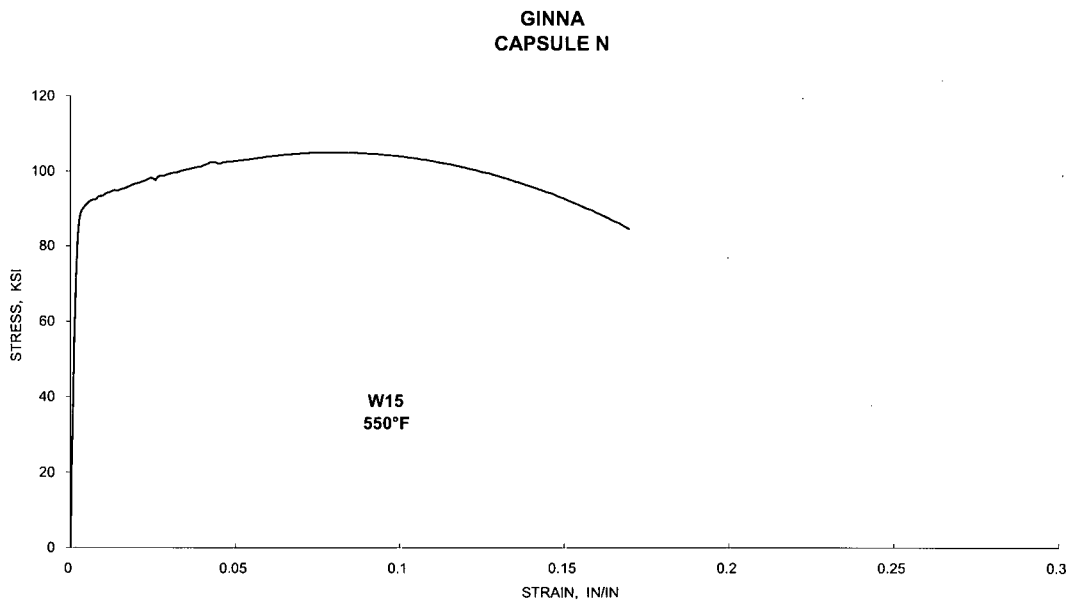


Figure 5-31 Engineering Stress-Strain Curve for R. E. Ginna Surveillance Program Weld Metal Heat 61782 Tensile Specimen W-15

6 RADIATION ANALYSIS AND NEUTRON DOSIMETRY

6.1 INTRODUCTION

This section describes a discrete ordinates S_n transport analysis performed for the R. E. Ginna reactor to determine the neutron radiation environment within the reactor pressure vessel and surveillance capsules. In this analysis, fast neutron exposure parameters in terms of fast neutron fluence (E > 1.0 MeV) and iron atom displacements (dpa) were established on a plant and fuel cycle specific basis. An evaluation of the most recent dosimetry sensor set from Capsule N, withdrawn at the end of the thirty-third plant operating cycle, is provided. In addition, dosimetry results of the sensor sets from the previously withdrawn capsules (V, R, T, and S) are also presented in Appendix A of this report. Comparisons of the results from these dosimetry evaluations with the analytical predictions served to validate the plant-specific neutron transport calculations. These validated calculations subsequently formed the basis for providing projections of the neutron exposure of the reactor pressure vessel for operating periods extending to 54 Effective Full Power Years (EFPY).

The use of fast neutron fluence (E > 1.0 MeV) to correlate measured material property changes to the neutron exposure of the material has traditionally been accepted for the development of damage trend curves as well as for the implementation of trend curve data to assess the condition of the vessel. In recent years, however, it has been suggested that an exposure model that accounts for differences in neutron energy spectra between surveillance capsule locations and positions within the vessel wall could lead to an improvement in the uncertainties associated with damage trend curves and improved accuracy in the evaluation of damage gradients through the reactor vessel wall.

Because of this potential shift away from a threshold fluence toward an energy-dependent damage function for data correlation, ASTM Standard Practice E853-01, "Analysis and Interpretation of Light-Water Reactor Surveillance Results," [22] recommends reporting displacements per iron atom (dpa) along with fluence (E > 1.0 MeV) to provide a database for future reference. The energy-dependent dpa function to be used for this evaluation is specified in ASTM Standard Practice E693-01, "Standard Practice for Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements per Atom" [23]. The application of the dpa parameter to the assessment of embrittlement gradients through the thickness of the reactor vessel wall has already been promulgated in Revision 2 to Regulatory Guide 1.99, "Radiation Embrittlement of Reactor Vessel Materials" [1].

All of the calculations and dosimetry evaluations described in this section and in Appendix A were based on the latest available nuclear cross-section data derived from ENDF/B-VI and made use of the latest available calculational tools. Furthermore, the neutron transport and dosimetry evaluation methodologies follow the guidance of Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence" [24]. Additionally, the methods used to develop the calculated pressure vessel fluence are consistent with the NRC approved methodology described in WCAP-14040-A, Revision 4, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves," May 2004 [25].

6.2 DISCRETE ORDINATES ANALYSIS

A plan view of the R. E. Ginna reactor geometry at the core midplane is shown in Figure 4-1. Six irradiation capsules attached to the thermal shield are included in the reactor design that constitutes the reactor vessel surveillance program. The capsules are located at azimuthal angles of 57°, 67°, 77°, 237°, 247°, and 257° as shown in Figure 4-1. These full-core positions correspond to the following octant symmetric locations represented in Figure 6-1: 13° from the core cardinal axes (for the 77° and 257° surveillance capsule holder locations), 23° from the core cardinal axes (for the 67° and 247° surveillance capsule holder locations) and 33° from the core cardinal axes (for the 57° and the 237° surveillance capsule holder locations). The six capsules were positioned in the reactor vessel between the thermal shield and the vessel wall as shown in Figure 4-1. The vertical center of the capsule is opposite the vertical center of the core.

From a neutronic standpoint, the surveillance capsules and associated support structures are significant. The presence of these materials has a marked effect on both the spatial distribution of neutron flux and the neutron energy spectrum in the water annulus between the neutron pads and the reactor vessel. In order to determine the neutron environment at the test specimen location, the capsules themselves must be included in the analytical model.

In performing the fast neutron exposure evaluations for the R. E. Ginna reactor vessel and surveillance capsules, a series of fuel cycle specific forward transport calculations were carried out using the following three-dimensional flux synthesis technique:

$$\varphi(r,\theta,z) = \varphi(r,\theta) * \frac{\varphi(r,z)}{\varphi(r)}$$

where $\phi(r,\theta,z)$ is the synthesized three-dimensional neutron flux distribution, $\phi(r,\theta)$ is the transport solution in (r,θ) geometry, $\phi(r,z)$ is the two-dimensional solution for a cylindrical reactor model using the actual axial core power distribution, and $\phi(r)$ is the one-dimensional solution for a cylindrical reactor model using the same source per unit height as that used in the (r,θ) two-dimensional calculation. This synthesis procedure was carried out for each operating cycle at R. E. Ginna.

For the R. E. Ginna transport calculations, the (r,θ) model depicted in Figure 6-1 was utilized since the reactor is octant symmetric. The (r,θ) model includes the core, the reactor internals, the thermal shield – including explicit representations of surveillance capsules at 13°, 23° and 33°, the pressure vessel cladding and vessel wall, the insulation external to the pressure vessel, and the primary biological shield wall. This model formed the basis for the calculated results and enabled making comparisons to the surveillance capsule dosimetry evaluations. In developing these analytical models, nominal design dimensions were employed for the various structural components. Likewise, water temperatures, and hence, coolant densities in the reactor core and downcomer regions of the reactor were taken to be representative of full power operating conditions. The coolant densities were treated on a fuel cycle specific basis. The reactor core itself was treated as a homogeneous mixture of fuel, cladding, water, and miscellaneous core structures such as fuel assembly grids, guide tubes, et cetera. The geometric mesh description of the (r,θ) reactor model consisted of 148 radial by 105 azimuthal intervals. Mesh sizes were chosen to assure that proper convergence of the inner iterations was achieved on a pointwise basis. The pointwise inner iteration flux convergence criterion utilized in the (r,θ) calculations was set at a value of 0.001.

The (r,z) model used for the R. E. Ginna calculations is shown in Figure 6-2 and extends radially from the centerline of the reactor core out to a location interior to the primary biological shield and over an axial span from an elevation one foot below the active fuel to one foot above the active fuel. As in the case of the (r,θ) models, nominal design dimensions and full power coolant densities were employed in the calculations. In this case, the homogenous core region was treated as an equivalent cylinder with a volume equal to that of the active core zone. The stainless steel former plates located between the core baffle and core barrel regions were also explicitly included in the model. The (r,z) geometric mesh description of the reactor model consisted of 127 radial by 155 axial intervals. As in the case of the (r,θ) calculations, mesh sizes were chosen to assure that proper convergence of the inner iterations was achieved on a pointwise basis. The pointwise inner iteration flux convergence criterion utilized in the (r,z) calculations was also set at a value of 0.001.

The one-dimensional radial (r) model used in the synthesis procedure consisted of the same 127 radial mesh intervals included in the (r,z) model. Thus, radial synthesis factors could be determined on a meshwise basis throughout the entire geometry.

The core power distributions used in the plant-specific transport analysis were provided by the Nuclear Fuels Division of Westinghouse for each of the first thirty-three fuel cycles at R. E. Ginna. Specifically, the data utilized included cycle-dependent fuel assembly initial enrichments, burnups, and axial power distributions. This information was used to develop spatial and energy dependent core source distributions averaged over each individual fuel cycle. Therefore, the results from the neutron transport calculations provided data in terms of fuel cycle averaged neutron flux, which when multiplied by the appropriate fuel cycle length, generated the incremental fast neutron exposure for each fuel cycle. In constructing these core source distributions, the energy distribution of the source was based on an appropriate fission split for uranium and plutonium isotopes based on the initial enrichment and burnup history of individual fuel assemblies. From these assembly-dependent fission splits, composite values of energy release per fission, neutron yield per fission, and fission spectrum were determined.

All of the transport calculations supporting this analysis were carried out using the DORT discrete ordinates code Version 3.2 [26] and the BUGLE-96 cross-section library [27]. The BUGLE-96 library provides a 67-group coupled neutron-gamma ray cross-section data set produced specifically for light water reactor (LWR) applications. In these analyses, anisotropic scattering was treated with a P_5 legendre expansion and angular discretization was modeled with an S_{16} order of angular quadrature. Energy and space dependent core power distributions, as well as system operating temperatures, were treated on a fuel cycle specific basis.

Selected results from the neutron transport analyses are provided in Tables 6-1 through 6-6. In Table 6-1, the calculated integrated exposures, expressed in terms of both neutron fluence (E > 1.0 MeV) and dpa, are given at the radial and axial center of the surveillance capsule at each individual azimuthal position, i.e., at 13°, 23°, and 33°. These results, representative of the axial midplane of the active core, establish the calculated exposure of the surveillance capsules withdrawn to date as well as projected into the future. Similar information is provided in Table 6-2 for the reactor vessel inner radius at four azimuthal locations. The vessel data given in Table 6-2 were taken at the clad/base metal interface, and thus, represent maximum calculated exposure levels on the vessel.

From the data provided in Table 6-2, it is noted that the peak clad/base metal interface vessel fluence (E > 1.0 MeV) at the end of the thirty-third fuel cycle (i.e., after 30.5 EFPY of plant operation) was 3.20×10^{19} n/cm^2.

Both calculated fluence (E > 1.0 MeV) and dpa data are provided in Tables 6-1 and 6-2. These data tabulations include both plant and fuel cycle specific calculated neutron exposures at the end of the thirty-third fuel cycle as well as future projections to 31.8, 33.3, 36, 42, 48, 52, 53, and 54 EFPY. The calculations account for an uprate from 1520 MWt to 1775 MWt that occurred at the onset of Cycle 33. Projections for Cycles 35 and beyond were based on the conservative assumption that the core power distribution for Cycle 33 was applicable, along with a power level of 1811 MWt. Similar data applicable to the intermediate shell to nozzle shell circumferential weld are provided in Table 6-3.

Radial gradient information applicable to fast (E > 1.0 MeV) neutron fluence and dpa are given in Tables 6-4 and 6-5, respectively. The data, based on the cumulative integrated exposures from Cycles 1 through 33, are presented on a relative basis for each exposure parameter at several azimuthal locations. Exposure distributions through the vessel wall may be obtained by multiplying the calculated exposure at the vessel inner radius by the gradient data listed in Tables 6-4 and 6-5.

The calculated fast neutron exposures for the five surveillance capsules withdrawn from R. E. Ginna reactor are provided in Table 6-6. These assigned neutron exposure levels are based on the plant and fuel cycle-specific neutron transport calculations performed for the R. E. Ginna reactor.

From the data provided in Table 6-6, Capsule N received a fluence (E > 1.0 MeV) of 5.80×10^{19} n/cm^2 after exposure through the end of the thirty-third fuel cycle (i.e., after 30.5 EFPY of plant operation).

Lead factors for the R. E. Ginna surveillance capsules are provided in Table 6-7. The capsule lead factor is defined as the ratio of the calculated fluence (E > 1.0 MeV) at the geometric center of the surveillance capsule to the corresponding maximum calculated fluence at the pressure vessel clad/base metal interface. In Table 6-7, the lead factors for capsules that have been withdrawn from the reactor (V, R, T, S, and N) were based on the calculated fluence values for the irradiation period corresponding to the time of withdrawal for the individual capsules.

6.3 NEUTRON DOSIMETRY

The validity of the calculated neutron exposures previously reported in Section 6.2 is demonstrated by a direct comparison against the measured sensor reaction rates and via a least squares evaluation performed for each of the capsule dosimetry sets. However, since the neutron dosimetry measurement data merely serves to validate the calculated results, only the direct comparison of measured-to-calculated results for the most recent surveillance capsule removed from service is provided in this section of the report. For completeness, the assessment of all measured dosimetry removed to date, based on both direct and least squares evaluation comparisons, is documented in Appendix A.

The direct comparison of measured versus calculated fast neutron threshold reaction rates for the sensors from Capsule N, that was withdrawn from R. E. Ginna at the end of the thirty-third fuel cycle, is summarized below.

Reaction	Reaction Rates (rps/atom)		M/C Ratio
	Measured	Calculated	
$^{63}Cu(n,\alpha)^{60}Co$	4.06E-17	3.87E-17	1.05
$^{54}Fe(n,p)^{54}Mn$	3.37E-15	4.19E-15	0.80
$^{58}Ni(n,p)^{58}Co$	5.07E-15	5.77E-15	0.88
$^{238}U(n,f)^{137}Cs$ (Cd)	2.13E-14	2.08E-14	1.02
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.45E-13	1.67E-13	1.47
		Average:	1.04
		% Standard Deviation:	24.8

The measured-to-calculated (M/C) reaction rate ratios for the Capsule N threshold reactions range from 0.80 to 1.47, and the average M/C ratio is 1.04 ± 24.8% (1σ). This direct comparison falls outside the ± 20% criterion specified in Regulatory Guide 1.190; however, the overall average of all five extracted capsules is within the ± 20% criterion specified in the Regulatory Guide. As demonstrated in the full set of comparisons given in Appendix A for all measured dosimetry removed to date from the R. E. Ginna reactor, these comparisons validate the current analytical results described in Section 6.2; therefore, the calculations are deemed applicable for R. E. Ginna.

6.4 CALCULATIONAL UNCERTAINTIES

The uncertainty associated with the calculated neutron exposure of the R. E. Ginna surveillance capsule and reactor pressure vessel is based on the recommended approach provided in Regulatory Guide 1.190. In particular, the qualification of the methodology was carried out in the following four stages:

1. Comparison of calculations with benchmark measurements from the Pool Critical Assembly (PCA) simulator at the Oak Ridge National Laboratory (ORNL).

2. Comparisons of calculations with surveillance capsule and reactor cavity measurements from the H. B. Robinson power reactor benchmark experiment.

3. An analytical sensitivity study addressing the uncertainty components resulting from important input parameters applicable to the plant-specific transport calculations used in the neutron exposure assessments.

4. Comparisons of the plant-specific calculations with all available dosimetry results from the R. E. Ginna surveillance program.

The first phase of the methods qualification (PCA comparisons) addressed the adequacy of basic transport calculation and dosimetry evaluation techniques and associated cross-sections. This phase, however, did not test the accuracy of commercial core neutron source calculations nor did it address uncertainties in operational or geometric variables that impact power reactor calculations. The second phase of the qualification (H. B. Robinson comparisons) addressed uncertainties in these additional areas that are primarily methods related and would tend to apply generically to all fast neutron exposure evaluations. The third phase of the qualification (analytical sensitivity study) identified the potential uncertainties introduced into the overall evaluation due to calculational methods approximations as well as to a lack of knowledge relative to various plant-specific input parameters. The overall calculational uncertainty applicable to the R. E. Ginna analysis was established from results of these three phases of the methods qualification.

The fourth phase of the uncertainty assessment (comparisons with R. E. Ginna measurements) was used solely to demonstrate the validity of the transport calculations and to confirm the uncertainty estimates associated with the analytical results. The comparison was used only as a check and was not used in any way to modify the calculated surveillance capsule and pressure vessel neutron exposures previously described in Section 6.2. As such, the validation of the R. E. Ginna analytical model based on the measured plant dosimetry is completely described in Appendix A.

The following summarizes the uncertainties developed from the first three phases of the methodology qualification. Additional information pertinent to these evaluations is provided in [25].

	Capsule	**Vessel IR**
PCA Comparisons	3%	3%
H. B. Robinson Comparisons	3%	3%
Analytical Sensitivity Studies	10%	11%
Additional Uncertainty for Factors not Explicitly Evaluated	5%	5%
Net Calculational Uncertainty	12%	13%

The net calculational uncertainty was determined by combining the individual components in quadrature. Therefore, the resultant uncertainty was treated as random and no systematic bias was applied to the analytical results.

The R. E. Ginna plant-specific measurement comparisons in Appendix A support these assessments.

Table 6-1A
Calculated Neutron Fluence – Surveillance Capsule Center

Table 6-1A Calculated Neutron Fluence - Surveillance Capsule Center				
		Φ (E > 1.0 MeV) (n/cm^2)		
Cycle	EFPY	13°	23°	33°
1a	0.7	2.50E+18	1.47E+18	1.40E+18
1b	1.4	5.87E+18	3.37E+18	3.10E+18
2	1.6	6.83E+18	3.93E+18	3.64E+18
3	2.6	1.02E+19	5.86E+18	5.45E+18
4	3.2	1.26E+19	7.48E+18	7.06E+18
5	3.8	1.50E+19	8.89E+18	8.36E+18
6	4.6	1.84E+19	1.09E+19	1.02E+19
7	5.3	2.12E+19	1.27E+19	1.19E+19
8	6.0	2.45E+19	1.46E+19	1.37E+19
9	6.9	2.81E+19	1.69E+19	1.59E+19
10	7.7	3.12E+19	1.89E+19	1.79E+19
11	8.2	3.36E+19	2.02E+19	1.91E+19
12	9.0	3.68E+19	2.19E+19	2.06E+19
13	9.6	3.91E+19	2.34E+19	2.20E+19
14	10.4	4.16E+19	2.51E+19	2.36E+19
15	11.2	4.39E+19	2.68E+19	2.53E+19
16	12.0	4.65E+19	2.84E+19	2.69E+19
17	12.9	4.95E+19	3.02E+19	2.86E+19
18	13.9	5.22E+19	3.21E+19	3.04E+19
19	14.6	5.44E+19	3.36E+19	3.18E+19
20	15.4	5.69E+19	3.52E+19	3.33E+19
21	16.2	5.95E+19	3.69E+19	3.48E+19
22	17.0	6.21E+19	3.86E+19	3.64E+19
23	17.8	6.45E+19	4.01E+19	3.79E+19
24	18.6	6.70E+19	4.17E+19	3.94E+19
25	19.5	6.93E+19	4.32E+19	4.09E+19
26	20.7	7.23E+19	4.51E+19	4.27E+19
27	22.0	7.54E+19	4.70E+19	4.44E+19
28	23.4	7.88E+19	4.92E+19	4.65E+19
29	24.8	8.19E+19	5.13E+19	4.86E+19
30	26.1	8.51E+19	5.34E+19	5.06E+19
31	27.5	8.85E+19	5.55E+19	5.27E+19
32	29.0	9.31E+19	5.82E+19	5.54E+19
33	30.5	9.75E+19	6.09E+19	5.80E+19
34	31.8	1.01E+20	6.34E+19	6.05E+19
35	33.3	1.06E+20	6.62E+19	6.33E+19
future	36	1.14E+20	7.12E+19	6.82E+19
future	42	1.33E+20	8.22E+19	7.91E+19
future	48	1.51E+20	9.33E+19	9.00E+19
future	52	1.63E+20	1.01E+20	9.73E+19
future	53	1.66E+20	1.03E+20	9.91E+19
future	54	1.69E+20	1.04E+20	1.01E+20

Data in shaded area are estimates based on projected future operations.

Table 6-1B
Calculated Iron Atom Displacement at Surveillance Capsule Center

Table 6-1B Calculated Iron Atom Displacement at Surveillance Capsule Center				
		Iron atom displacement (dpa)		
Cycle	EFPY	13°	23°	33°
1a	0.7	4.56E-03	2.56E-03	2.46E-03
1b	1.4	1.07E-02	5.87E-03	5.44E-03
2	1.6	1.25E-02	6.86E-03	6.39E-03
3	2.6	1.85E-02	1.02E-02	9.58E-03
4	3.2	2.29E-02	1.30E-02	1.24E-02
5	3.8	2.73E-02	1.55E-02	1.47E-02
6	4.6	3.35E-02	1.91E-02	1.79E-02
7	5.3	3.87E-02	2.22E-02	2.09E-02
8	6.0	4.46E-02	2.55E-02	2.41E-02
9	6.9	5.12E-02	2.94E-02	2.80E-02
10	7.7	5.69E-02	3.29E-02	3.15E-02
11	8.2	6.12E-02	3.52E-02	3.36E-02
12	9.0	6.71E-02	3.82E-02	3.62E-02
13	9.6	7.13E-02	4.08E-02	3.86E-02
14	10.4	7.57E-02	4.37E-02	4.15E-02
15	11.2	7.99E-02	4.66E-02	4.44E-02
16	12.0	8.47E-02	4.95E-02	4.73E-02
17	12.9	9.00E-02	5.26E-02	5.02E-02
18	13.9	9.51E-02	5.59E-02	5.33E-02
19	14.6	9.90E-02	5.84E-02	5.58E-02
20	15.4	1.04E-01	6.12E-02	5.84E-02
21	16.2	1.08E-01	6.41E-02	6.11E-02
22	17.0	1.13E-01	6.70E-02	6.38E-02
23	17.8	1.17E-01	6.98E-02	6.65E-02
24	18.6	1.22E-01	7.25E-02	6.91E-02
25	19.5	1.26E-01	7.51E-02	7.17E-02
26	20.7	1.31E-01	7.84E-02	7.48E-02
27	22.0	1.37E-01	8.16E-02	7.79E-02
28	23.4	1.43E-01	8.54E-02	8.15E-02
29	24.8	1.49E-01	8.90E-02	8.51E-02
30	26.1	1.54E-01	9.26E-02	8.87E-02
31	27.5	1.60E-01	9.63E-02	9.23E-02
32	29.0	1.69E-01	1.01E-01	9.70E-02
33	30.5	1.77E-01	1.06E-01	1.02E-01
34	31.8	1.84E-01	1.10E-01	1.06E-01
35	33.3	1.92E-01	1.15E-01	1.11E-01
future	36	2.07E-01	1.23E-01	1.19E-01
future	42	2.40E-01	1.43E-01	1.38E-01
future	48	2.73E-01	1.62E-01	1.57E-01
future	52	2.95E-01	1.75E-01	1.70E-01
future	53	3.01E-01	1.78E-01	1.73E-01
future	54	3.06E-01	1.81E-01	1.76E-01

Data in shaded area are estimates based on projected future operations.

Table 6-2A
Calculated Maximum Fluence at the Vessel Clad/Base Metal Interface

Table 6-2A Calculated Maximum Fluence at the Vessel Clad/Base Metal Interface					
		Φ (E > 1.0 MeV) (n/cm^2)			
Cycle	EFPY	0°	15°	30°	45°
1a	0.7	8.46E+17	5.14E+17	3.57E+17	3.00E+17
1b	1.4	1.99E+18	1.20E+18	7.97E+17	6.64E+17
2	1.6	2.31E+18	1.40E+18	9.34E+17	7.84E+17
3	2.6	3.41E+18	2.08E+18	1.40E+18	1.19E+18
4	3.2	4.20E+18	2.60E+18	1.81E+18	1.55E+18
5	3.8	5.01E+18	3.09E+18	2.14E+18	1.82E+18
6	4.6	6.12E+18	3.79E+18	2.61E+18	2.19E+18
7	5.3	7.03E+18	4.38E+18	3.04E+18	2.54E+18
8	6.0	8.09E+18	5.02E+18	3.48E+18	2.92E+18
9	6.9	9.26E+18	5.75E+18	4.03E+18	3.40E+18
10	7.7	1.03E+19	6.39E+18	4.52E+18	3.82E+18
11	8.2	1.10E+19	6.86E+18	4.82E+18	4.11E+18
12	9.0	1.21E+19	7.50E+18	5.20E+18	4.46E+18
13	9.6	1.29E+19	7.98E+18	5.54E+18	4.75E+18
14	10.4	1.37E+19	8.49E+18	5.95E+18	5.14E+18
15	11.2	1.44E+19	8.98E+18	6.36E+18	5.56E+18
16	12.0	1.52E+19	9.52E+18	6.76E+18	5.98E+18
17	12.9	1.62E+19	1.01E+19	7.19E+18	6.37E+18
18	13.9	1.71E+19	1.07E+19	7.64E+18	6.76E+18
19	14.6	1.78E+19	1.12E+19	7.99E+18	7.09E+18
20	15.4	1.86E+19	1.17E+19	8.37E+18	7.42E+18
21	16.2	1.94E+19	1.23E+19	8.77E+18	7.77E+18
22	17.0	2.03E+19	1.28E+19	9.17E+18	8.12E+18
23	17.8	2.11E+19	1.33E+19	9.55E+18	8.48E+18
24	18.6	2.19E+19	1.38E+19	9.93E+18	8.82E+18
25	19.5	2.26E+19	1.43E+19	1.03E+19	9.15E+18
26	20.7	2.36E+19	1.49E+19	1.07E+19	9.56E+18
27	22.0	2.47E+19	1.56E+19	1.12E+19	9.98E+18
28	23.4	2.58E+19	1.63E+19	1.17E+19	1.04E+19
29	24.8	2.68E+19	1.69E+19	1.22E+19	1.09E+19
30	26.1	2.78E+19	1.76E+19	1.27E+19	1.14E+19
31	27.5	2.89E+19	1.83E+19	1.32E+19	1.18E+19
32	29.0	3.05E+19	1.92E+19	1.39E+19	1.25E+19
33	30.5	3.20E+19	2.01E+19	1.45E+19	1.31E+19
34	31.8	3.32E+19	2.09E+19	1.52E+19	1.37E+19
35	33.3	3.48E+19	2.18E+19	1.58E+19	1.44E+19
future	36	3.76E+19	2.35E+19	1.70E+19	1.56E+19
future	42	4.40E+19	2.73E+19	1.97E+19	1.82E+19
future	48	5.03E+19	3.10E+19	2.24E+19	2.08E+19
future	52	5.45E+19	3.35E+19	2.42E+19	2.26E+19
future	53	5.56E+19	3.42E+19	2.46E+19	2.30E+19
future	54	5.66E+19	3.48E+19	2.51E+19	2.35E+19

Data in shaded area are estimates based on projected future operations.

Table 6-2B
Calculated Maximum Iron Atom Displacement at Vessel Clad/Base Metal Interface

Table 6-2B Calculated Maximum Iron Atom Displacement at Vessel Clad/Base Metal Interface					
		Iron atom displacement (dpa)			
Cycle	EFPY	0°	15°	30°	45°
1a	0.7	1.38E-03	8.69E-04	5.87E-04	4.87E-04
1b	1.4	3.24E-03	2.04E-03	1.31E-03	1.08E-03
2	1.6	3.77E-03	2.37E-03	1.54E-03	1.27E-03
3	2.6	5.58E-03	3.52E-03	2.30E-03	1.93E-03
4	3.2	6.86E-03	4.39E-03	2.97E-03	2.51E-03
5	3.8	8.19E-03	5.23E-03	3.52E-03	2.96E-03
6	4.6	1.00E-02	6.40E-03	4.30E-03	3.55E-03
7	5.3	1.15E-02	7.39E-03	5.00E-03	4.12E-03
8	6.0	1.32E-02	8.48E-03	5.73E-03	4.74E-03
9	6.9	1.51E-02	9.72E-03	6.63E-03	5.52E-03
10	7.7	1.68E-02	1.08E-02	7.43E-03	6.21E-03
11	8.2	1.80E-02	1.16E-02	7.94E-03	6.68E-03
12	9.0	1.98E-02	1.27E-02	8.56E-03	7.24E-03
13	9.6	2.11E-02	1.35E-02	9.12E-03	7.71E-03
14	10.4	2.24E-02	1.43E-02	9.79E-03	8.35E-03
15	11.2	2.35E-02	1.52E-02	1.05E-02	9.03E-03
16	12.0	2.48E-02	1.61E-02	1.11E-02	9.71E-03
17	12.9	2.65E-02	1.71E-02	1.18E-02	1.04E-02
18	13.9	2.80E-02	1.81E-02	1.26E-02	1.10E-02
19	14.6	2.91E-02	1.89E-02	1.32E-02	1.15E-02
20	15.4	3.04E-02	1.98E-02	1.38E-02	1.21E-02
21	16.2	3.17E-02	2.07E-02	1.44E-02	1.26E-02
22	17.0	3.31E-02	2.16E-02	1.51E-02	1.32E-02
23	17.8	3.44E-02	2.25E-02	1.57E-02	1.38E-02
24	18.6	3.57E-02	2.33E-02	1.64E-02	1.43E-02
25	19.5	3.70E-02	2.42E-02	1.70E-02	1.49E-02
26	20.7	3.86E-02	2.52E-02	1.77E-02	1.55E-02
27	22.0	4.03E-02	2.63E-02	1.84E-02	1.62E-02
28	23.4	4.21E-02	2.74E-02	1.92E-02	1.69E-02
29	24.8	4.37E-02	2.85E-02	2.01E-02	1.77E-02
30	26.1	4.54E-02	2.96E-02	2.09E-02	1.84E-02
31	27.5	4.71E-02	3.08E-02	2.17E-02	1.92E-02
32	29.0	4.97E-02	3.23E-02	2.28E-02	2.02E-02
33	30.5	5.22E-02	3.39E-02	2.39E-02	2.13E-02
34	31.8	5.41E-02	3.52E-02	2.49E-02	2.22E-02
35	33.3	5.68E-02	3.68E-02	2.60E-02	2.33E-02
future	36	6.14E-02	3.96E-02	2.80E-02	2.52E-02
future	42	7.17E-02	4.59E-02	3.24E-02	2.95E-02
future	48	8.20E-02	5.23E-02	3.68E-02	3.37E-02
future	52	8.89E-02	5.65E-02	3.98E-02	3.66E-02
future	53	9.06E-02	5.75E-02	4.05E-02	3.73E-02
future	54	9.23E-02	5.86E-02	4.12E-02	3.80E-02

Data in shaded area are estimates based on projected future operations.

Table 6-3A
Calculated Maximum Fluence at the Pressure Vessel Intermediate Shell Course to Nozzle Shell Course Weld

Table 6-3A Calculated Maximum Fluence at the Pressure Vessel Intermediate Shell Course to Nozzle Shell Course Weld					
		Φ (E > 1.0 MeV) (n/cm^2)			
Cycle	EFPY	0°	15°	30°	45°
1a	0.7	3.15E+16	1.92E+16	1.33E+16	1.12E+16
1b	1.4	7.37E+16	4.47E+16	2.96E+16	2.47E+16
2	1.6	8.57E+16	5.20E+16	3.46E+16	2.91E+16
3	2.6	1.29E+17	7.84E+16	5.26E+16	4.48E+16
4	3.2	1.69E+17	1.05E+17	7.37E+16	6.32E+16
5	3.8	2.19E+17	1.35E+17	9.39E+16	8.01E+16
6	4.6	2.69E+17	1.67E+17	1.15E+17	9.67E+16
7	5.3	3.12E+17	1.95E+17	1.36E+17	1.13E+17
8	6.0	3.55E+17	2.20E+17	1.54E+17	1.29E+17
9	6.9	4.02E+17	2.50E+17	1.76E+17	1.48E+17
10	7.7	4.43E+17	2.76E+17	1.95E+17	1.65E+17
11	8.2	4.74E+17	2.95E+17	2.08E+17	1.77E+17
12	9.0	5.18E+17	3.21E+17	2.23E+17	1.91E+17
13	9.6	5.50E+17	3.41E+17	2.37E+17	2.03E+17
14	10.4	5.81E+17	3.61E+17	2.53E+17	2.18E+17
15	11.2	6.08E+17	3.80E+17	2.69E+17	2.35E+17
16	12.0	6.34E+17	3.97E+17	2.82E+17	2.48E+17
17	12.9	6.65E+17	4.16E+17	2.95E+17	2.60E+17
18	13.9	6.92E+17	4.33E+17	3.08E+17	2.71E+17
19	14.6	7.15E+17	4.49E+17	3.20E+17	2.82E+17
20	15.4	7.40E+17	4.65E+17	3.32E+17	2.93E+17
21	16.2	7.65E+17	4.82E+17	3.44E+17	3.04E+17
22	17.0	7.91E+17	4.99E+17	3.56E+17	3.14E+17
23	17.8	8.15E+17	5.14E+17	3.68E+17	3.25E+17
24	18.6	8.45E+17	5.33E+17	3.82E+17	3.38E+17
25	19.5	8.79E+17	5.55E+17	3.99E+17	3.53E+17
26	20.7	9.30E+17	5.87E+17	4.21E+17	3.73E+17
27	22.0	9.72E+17	6.12E+17	4.39E+17	3.90E+17
28	23.4	1.02E+18	6.39E+17	4.59E+17	4.08E+17
29	24.8	1.05E+18	6.64E+17	4.78E+17	4.26E+17
30	26.1	1.09E+18	6.89E+17	4.98E+17	4.43E+17
31	27.5	1.13E+18	7.16E+17	5.17E+17	4.62E+17
32	29.0	1.20E+18	7.52E+17	5.43E+17	4.87E+17
33	30.5	1.27E+18	7.94E+17	5.73E+17	5.17E+17
34	31.8	1.32E+18	8.32E+17	6.03E+17	5.44E+17
35	33.3	1.40E+18	8.76E+17	6.34E+17	5.76E+17
future	36	1.53E+18	9.54E+17	6.90E+17	6.31E+17
future	42	1.83E+18	1.13E+18	8.16E+17	7.54E+17
future	48	2.12E+18	1.30E+18	9.41E+17	8.77E+17
future	52	2.32E+18	1.42E+18	1.02E+18	9.59E+17
future	53	2.37E+18	1.45E+18	1.05E+18	9.79E+17
future	54	2.42E+18	1.48E+18	1.07E+18	1.00E+18

Data in shaded area are estimates based on projected future operations.

Table 6-3B
Calculated Maximum Iron Atom Displacement at the Pressure Vessel Intermediate Shell Course to Nozzle Shell Course Weld

Table 6-3B Calculated Maximum Iron Atom Displacement at the Pressure Vessel Intermediate Shell Course to Nozzle Shell Course Weld					
		Iron atom displacement (dpa)			
Cycle	EFPY	0°	15°	30°	45°
1a	0.7	5.47E-05	3.44E-05	2.33E-05	1.93E-05
1b	1.4	1.28E-04	8.03E-05	5.17E-05	4.25E-05
2	1.6	1.49E-04	9.34E-05	6.06E-05	5.02E-05
3	2.6	2.23E-04	1.41E-04	9.21E-05	7.72E-05
4	3.2	2.93E-04	1.88E-04	1.29E-04	1.09E-04
5	3.8	3.78E-04	2.42E-04	1.64E-04	1.38E-04
6	4.6	4.66E-04	2.99E-04	2.01E-04	1.66E-04
7	5.3	5.41E-04	3.49E-04	2.37E-04	1.95E-04
8	6.0	6.15E-04	3.95E-04	2.68E-04	2.22E-04
9	6.9	6.97E-04	4.48E-04	3.06E-04	2.55E-04
10	7.7	7.68E-04	4.95E-04	3.41E-04	2.85E-04
11	8.2	8.22E-04	5.30E-04	3.63E-04	3.05E-04
12	9.0	8.99E-04	5.76E-04	3.90E-04	3.29E-04
13	9.6	9.55E-04	6.12E-04	4.15E-04	3.50E-04
14	10.4	1.01E-03	6.47E-04	4.42E-04	3.76E-04
15	11.2	1.06E-03	6.82E-04	4.71E-04	4.05E-04
16	12.0	1.10E-03	7.13E-04	4.93E-04	4.28E-04
17	12.9	1.16E-03	7.47E-04	5.16E-04	4.49E-04
18	13.9	1.20E-03	7.79E-04	5.40E-04	4.69E-04
19	14.6	1.24E-03	8.06E-04	5.60E-04	4.87E-04
20	15.4	1.29E-03	8.36E-04	5.81E-04	5.06E-04
21	16.2	1.33E-03	8.67E-04	6.04E-04	5.25E-04
22	17.0	1.38E-03	8.96E-04	6.24E-04	5.43E-04
23	17.8	1.42E-03	9.25E-04	6.46E-04	5.62E-04
24	18.6	1.47E-03	9.59E-04	6.70E-04	5.84E-04
25	19.5	1.53E-03	9.99E-04	6.99E-04	6.10E-04
26	20.7	1.62E-03	1.05E-03	7.38E-04	6.45E-04
27	22.0	1.69E-03	1.10E-03	7.69E-04	6.74E-04
28	23.4	1.76E-03	1.15E-03	8.04E-04	7.05E-04
29	24.8	1.83E-03	1.19E-03	8.38E-04	7.35E-04
30	26.1	1.90E-03	1.24E-03	8.72E-04	7.66E-04
31	27.5	1.97E-03	1.29E-03	9.07E-04	7.98E-04
32	29.0	2.08E-03	1.35E-03	9.52E-04	8.42E-04
33	30.5	2.20E-03	1.43E-03	1.00E-03	8.92E-04
34	31.8	2.30E-03	1.49E-03	1.06E-03	9.40E-04
35	33.3	2.43E-03	1.57E-03	1.11E-03	9.94E-04
future	36	2.66E-03	1.71E-03	1.21E-03	1.09E-03
future	42	3.17E-03	2.02E-03	1.43E-03	1.30E-03
future	48	3.68E-03	2.34E-03	1.64E-03	1.51E-03
future	52	4.02E-03	2.54E-03	1.79E-03	1.65E-03
future	53	4.10E-03	2.60E-03	1.83E-03	1.68E-03
future	54	4.19E-03	2.65E-03	1.86E-03	1.72E-03

Data in shaded area are estimates based on projected future operations.

Table 6-4
Relative Radial Distribution of Fast Neutron Fluence (n/cm^2) Within the Reactor Vessel Wall

Table 6-4 Relative Radial Distribution of Fast Neutron Fluence (n/cm^2) Within the Reactor Vessel Wall				
Radius (cm)	**Azimuthal Angle**			
	0°	**15°**	**30°**	**45°**
168.04	1.000	1.000	1.000	1.000
172.25	0.638	0.645	0.635	0.645
176.46	0.364	0.374	0.366	0.372
180.66	0.200	0.210	0.205	0.208
184.87	0.103	0.116	0.114	0.113
Base Metal Inner Radius = 168.04 cm				
Base Metal 1/4T = 172.25 cm				
Base Metal 1/2T = 176.46 cm				
Base Metal 3/4T = 180.66 cm				
Base Metal Outer Radius = 184.87 cm				
Relative radial distribution based on the cumulative integrated exposures through plant life				

Table 6-5
Relative Radial Distribution of Iron Atom Displacements (dpa) Within the Reactor Vessel Wall

Table 6-5 Relative Radial Distribution of Iron Atom Displacements (dpa) Within the Reactor Vessel Wall				
Radius (cm)	Azimuthal Angle			
	0°	15°	30°	45°
168.04	1.000	1.000	1.000	1.000
172.25	0.708	0.724	0.712	0.715
176.46	0.472	0.497	0.486	0.484
180.66	0.304	0.333	0.326	0.320
184.87	0.179	0.212	0.213	0.204
Base Metal Inner Radius = 168.04 cm				
Base Metal 1/4T = 172.25 cm				
Base Metal 1/2T = 176.46 cm				
Base Metal 3/4T = 180.66 cm				
Base Metal Outer Radius = 184.87 cm				
Relative radial distribution based on the cumulative integrated exposures through plant life				

Table 6-6
Calculated Fast Neutron Exposure of Surveillance Capsules Withdrawn from R.E. Ginna

Table 6-6 Calculated Fast Neutron Exposure of Surveillance Capsules Withdrawn from R. E. Ginna			
Capsule	Irradiation Time [EFPY]	Fluence (E > 1.0 MeV) [n/cm^2]	Iron Displacements [dpa]
V	1.4	5.87E+18	1.07E-03
R	2.6	1.02E+19	1.85E-02
T	6.9	1.69E+19	2.94E-02
S	17.0	3.64E+19	6.38E-02
N	30.5	5.80E+19	1.02E-01

Table 6-7
Calculated Surveillance Capsule Lead Factors

Table 6-7 Calculated Surveillance Capsule Lead Factors		
Capsule ID And Location	**Status**	**Lead Factor**
V (13°)	Withdrawn EOC 1	2.96
R (13°)	Withdrawn EOC 3	2.97
T (23°)	Withdrawn EOC 9	1.82
S (33°)	Withdrawn EOC 22	1.79
N (33°)	Withdrawn EOC 33	1.82
P (23°)	In Reactor	1.90

Note: Capsule P lead factor is based on EOC33 fluence distribution.

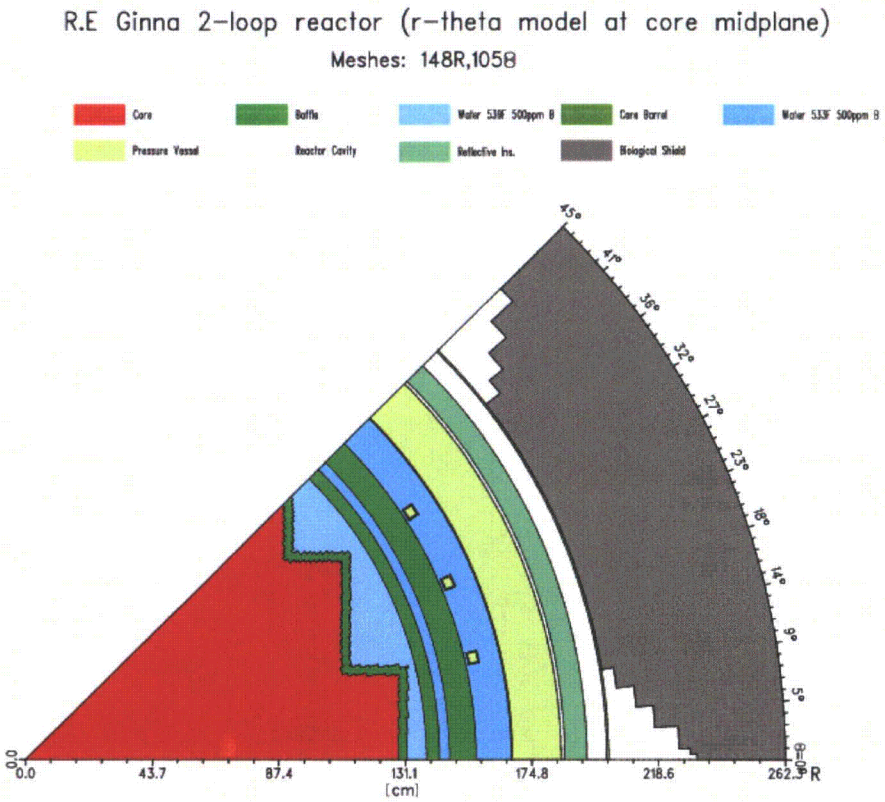


Figure 6-1 R.E. Ginna (r,θ) Reactor Geometry at the Core Midplane

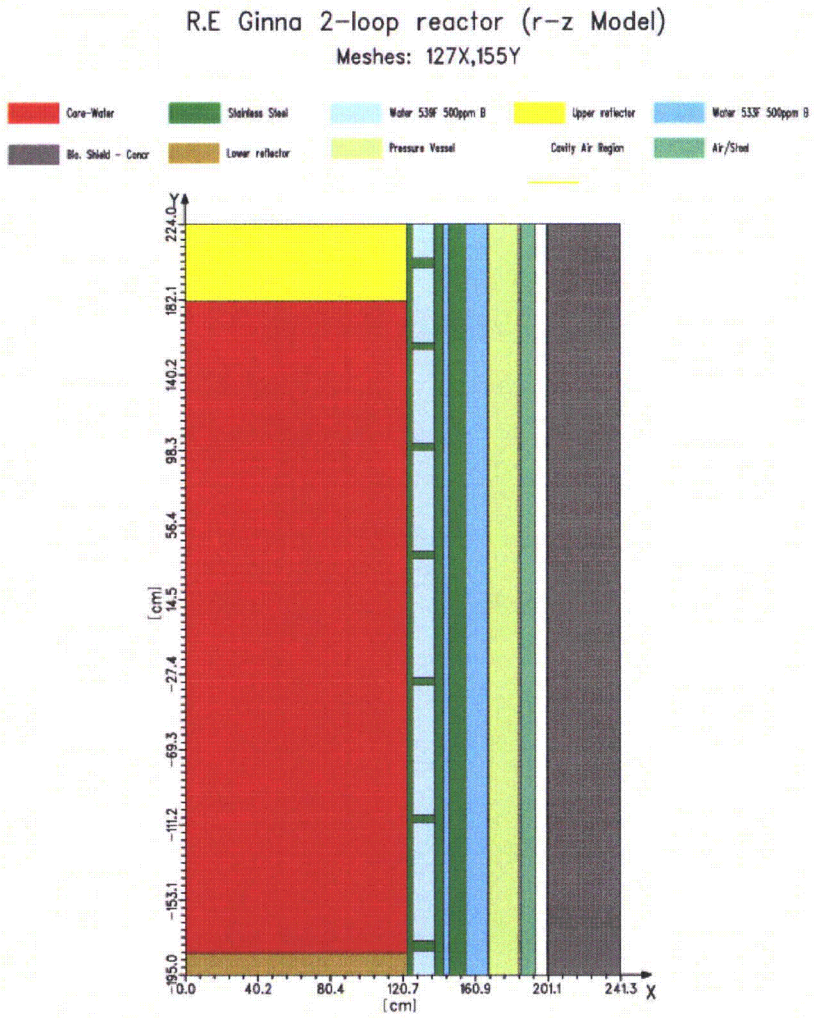


Figure 6-2 R.E. Ginna (r, z) Reactor Geometry

7 SURVEILLANCE CAPSULE REMOVAL SCHEDULE

The following surveillance capsule removal schedule meets the requirements of ASTM E185-82 [8] and is recommended for the future capsule to be removed from the R. E. Ginna reactor vessel. This recommended removal schedule is applicable to 53 EFPY of operation.

Table 7-1 Recommended Surveillance Capsule Withdrawal Schedule

Capsule	Capsule Location	Lead Factor[(a)]	Withdrawal EFPY[(b)]	Fluence (n/cm^2)[(a)]
V	77°	2.96	1.4	0.587×10^{19}
R	257°	2.97	2.6	1.02×10^{19}
T	67°	1.82	6.9	1.69×10^{19}
S	57°	1.79	17.0	3.64×10^{19}
N	237°	1.82	30.5	5.80×10^{19}
P	247°	1.90	In Reactor	(c)

Notes:
(a) Updated in Capsule N dosimetry analysis; see Table 6-6.
(b) EFPY from plant startup.
(c) Capsule P should be removed at about 33.9 EFPY to fulfill the commitment of [28] to remove the capsule shortly after it accumulates a fluence equivalent to 80 years of operation.

8 REFERENCES

1. Regulatory Guide 1.99, Revision 2, *Radiation Embrittlement of Reactor Vessel Materials*, U.S. Nuclear Regulatory Commission, May, 1988.

2. 10 CFR 50, Appendix G, *Fracture Toughness Requirements*, and Appendix H, *Reactor Vessel Material Surveillance Program Requirements*, Federal Register, Volume 60, No. 243, December 19, 1995.

3. WCAP-7254, Revision 0, *Rochester Gas and Electric Robert E. Ginna Unit No. 1 Reactor Vessel Radiation Surveillance Program*, S. E. Yanichko, May 1969.

4. ASTM E185-66, *Recommended Practice for Surveillance Tests on Structural Material in Nuclear Reactors,* American Society for Testing and Materials, 1966.

5. Section XI of the ASME Boiler and Pressure Vessel Code, Appendix G, *Fracture Toughness Criteria for Protection Against Failure.*

6. ASTM E208, *Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels*, in ASTM Standards, Section 3, American Society for Testing and Materials, Philadelphia, PA.

7. WCAP-13902, *Analysis of Capsule S from the Rochester Gas and Electric Corporation R. E. Ginna Reactor Vessel Radiation Surveillance Program*, J. M. Chicots, et. al., December 1993.

8. ASTM E185-82, *Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels, E706 (IF),* ASTM 1982.

9. Westinghouse Science and Technology Department Procedure RMF 8402, *Surveillance Capsule Testing Program*, Revision 3, June 6, 2005.

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APPENDIX A
VALIDATION OF THE RADIATION TRANSPORT MODELS BASED ON NEUTRON DOSIMETRY MEASUREMENTS

A.1 NEUTRON DOSIMETRY

Comparisons of measured dosimetry results to both the calculated and least squares adjusted values for all surveillance capsules withdrawn from service to date at R. E. Ginna are described herein. The sensor sets from these capsules have been analyzed in accordance with the current dosimetry evaluation methodology described in Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence" (Reference A-1). One of the main purposes for presenting this material is to demonstrate that the overall measurements agree with the calculated and least squares adjusted values to within ± 20% as specified by Regulatory Guide 1.190, thus serving to validate the calculated neutron exposures previously reported in Section 6.2 of this report.

A.1.1 Sensor Reaction Rate Determinations

In this section, the results of the evaluations of the five neutron sensor sets analyzed to date as part of the R. E. Ginna Reactor Vessel Materials Surveillance Program are presented. The capsule designation, location within the reactor, and time of withdrawal of each of these dosimetry sets were as follows:

Capsule ID	Azimuthal Location	Withdrawal Time	Irradiation Time [EFPY]
V	13°	End of Cycle 1	1.4
R	13°	End of Cycle 3	2.6
T	23°	End of Cycle 9	6.9
S	33°	End of Cycle 22	17.0
N	33°	End of Cycle 33	30.5

The azimuthal locations included in the above tabulation represent the first octant equivalent azimuthal angle of the geometric center of the respective surveillance capsules.

The passive neutron sensors included in the evaluations of Surveillance Capsules V, R, T, S, and N are summarized as follows:

Sensor Material	Reaction Of Interest	Capsule V	Capsule R	Capsule T	Capsule S	Capsule N
Copper	$^{63}Cu(n,\alpha)^{60}Co$	√	√	√	√	√
Iron+	$^{54}Fe(n,p)^{54}Mn$	√	√	√	√	√
Nickel	$^{58}Ni(n,p)^{58}Co$	√	√	√	√	√
Uranium-238	$^{238}U(n,f)^{137}Cs$	√	√	√	√	√
Neptunium-237	$^{237}Np(n,f)\ ^{137}Cs$	--	√	√	√	√
Cobalt-Aluminum*	$^{59}Co(n,\gamma)^{60}Co$	√	√	√	√	√

+The iron specimens were obtained from Charpy test material instead of dosimetry sensors.

*The cobalt-aluminum measurements for this plant include both bare wire and cadmium-covered sensors.

Since not all of the dosimetry monitors are located at the radial center of the material test specimen array, radial gradient corrections were made for these reaction rates. Pertinent physical and nuclear characteristics of the passive neutron sensors are listed in Table A-1.

The use of passive monitors such as those listed above does not yield a direct measure of the energy-dependent neutron flux at the point of interest. Rather, the activation or fission process is a measure of the integrated effect that the time and energy dependent neutron flux has on the target material over the course of the irradiation period. An accurate assessment of the average neutron flux level incident on the various monitors may be derived from the activation measurements only if the irradiation parameters are well known. In particular, the following variables are of interest:

- the measured specific activity of each monitor,
- the physical characteristics of each monitor,
- the operating history of the reactor,
- the energy response of each monitor, and
- the neutron energy spectrum at the monitor location.

Results from the radiometric counting of the neutron sensors from Capsules V, R, T, and S are documented in Reference A-2. The radiometric counting of the sensors from Capsule N was carried out by Pace Analytical Services, Inc. In all cases, the radiometric counting followed established ASTM procedures. Following sample preparation and weighing, the specific activity of each sensor was determined by means of a high-resolution gamma spectrometer. For the copper, iron, nickel, and cobalt-aluminum sensors, these analyses were performed by direct counting of each of the individual samples. In the case of the uranium and neptunium fission sensors, the analyses were carried out by direct counting preceded by dissolution and chemical separation of cesium from the sensor material.

The irradiation history of the reactor over the irradiation periods experienced by Capsules V, R, T, S, and N was based on the monthly power generation of R. E. Ginna from initial reactor criticality through the end of the dosimetry evaluation period. For the sensor sets utilized in the surveillance capsules, the half-

lives of the product isotopes are long enough that a monthly histogram describing reactor operation has proven to be an adequate representation for use in radioactive decay corrections for the reactions of interest in the exposure evaluations. The irradiation history for Capsule N encompassed thirty-three fuel cycles.

Having the measured specific activities, the physical characteristics of the sensors, and the operating history of the reactor, reaction rates referenced to full-power operation were determined from the following equation:

$$R = \frac{A}{N_0 F Y \sum \frac{P_j}{P_{ref}} C_j [1 - e^{-\lambda t_j}][e^{-\lambda t_d}]}$$

where:

R	=	Reaction rate averaged over the irradiation period and referenced to operation at a core power level of P_{ref} (rps/nucleus).
A	=	Measured specific activity (dps/gm).
N_0	=	Number of target element atoms per gram of sensor.
F	=	Atom fraction of the target isotope in the target element.
Y	=	Number of product atoms produced per reaction.
P_j	=	Average core power level during irradiation period j (MW).
P_{ref}	=	Maximum or reference power level of the reactor (MW).
C_j	=	Calculated ratio of $\phi(E > 1.0\ \text{MeV})$ during irradiation period j to the time weighted average $\phi(E > 1.0\ \text{MeV})$ over the entire irradiation period.
λ	=	Decay constant of the product isotope (1/sec).
t_j	=	Length of irradiation period j (sec).
t_d	=	Decay time following irradiation period j (sec).

and the summation is carried out over the total number of monthly intervals comprising the irradiation period.

In the equation describing the reaction rate calculation, the ratio $[P_j]/[P_{ref}]$ accounts for month-by-month variation of reactor core power level within any given fuel cycle as well as over multiple fuel cycles. The ratio C_j, which was calculated for each fuel cycle using the transport methodology discussed in Section 6.2, accounts for the change in sensor reaction rates caused by variations in flux level induced by

changes in core spatial power distributions from fuel cycle to fuel cycle. For a single-cycle irradiation, C_j is normally taken to be 1.0. However, for multiple-cycle irradiations, particularly those employing low leakage fuel management, the additional C_j term should be employed. The impact of changing flux levels for constant power operation can be quite significant for sensor sets that have been irradiated for many cycles in a reactor that has transitioned from non-low leakage to low leakage fuel management or for sensor sets contained in surveillance capsules that have been moved from one capsule location to another. The fuel cycle specific neutron flux values are listed in Table A-2. These flux values represent the cycle dependent results at the radial and azimuthal center of the respective capsules at the axial elevation of the active fuel midplane.

Prior to using the measured reaction rates in the least-squares evaluations of the dosimetry sensor sets, additional corrections were made to the ^{238}U measurements to account for the presence of ^{235}U impurities in the sensors as well as to adjust for the build-in of plutonium isotopes over the course of the irradiation. Corrections were also made to the ^{238}U and ^{237}Np sensor reaction rates to account for gamma ray induced fission reactions that occurred over the course of the capsule irradiations. The correction factors applied to the R. E. Ginna fission sensor reaction rates are summarized as follows:

Correction	Capsule V	Capsule R	Capsule T	Capsule S	Capsule N
^{235}U Impurity/Pu Build-in	0.861	0.820	0.845	0.755	0.689
$^{238}U(\gamma,f)$	0.950	0.955	0.950	0.953	0.953
Net ^{238}U Correction	0.818	0.783	0.803	0.720	0.657
$^{237}Np(\gamma,f)$	0.983	0.984	0.983	0.983	0.983

These factors were applied in a multiplicative fashion to the decay corrected uranium and neptunium fission sensor reaction rates.

Results of the sensor reaction rate determinations for Capsule N are given in Table A-3; results for Capsules V, R, T, and S are provided in Reference A-2. In Table A-3, the measured specific activities, decay corrected saturated specific activities, and computed reaction rates for each sensor indexed to the radial center of the capsule are listed. The fission sensor reaction rates are listed both with and without the applied corrections for ^{238}U impurities, plutonium build-in, and gamma ray induced fission effects.

A.1.2 Least Squares Evaluation of Sensor Sets

Least squares adjustment methods provide the capability of combining the measurement data with the corresponding neutron transport calculations resulting in a Best Estimate neutron energy spectrum with associated uncertainties. Best Estimates for key exposure parameters such as $\phi(E > 1.0\ MeV)$ or dpa/s along with their uncertainties are then easily obtained from the adjusted spectrum. In general, the least squares methods, as applied to surveillance capsule dosimetry evaluations, act to reconcile the measured sensor reaction rate data, dosimetry reaction cross-sections, and the calculated neutron energy spectrum within their respective uncertainties. For example,

$$R_i \pm \delta_{R_i} = \sum_g (\sigma_{ig} \pm \delta_{\sigma_{ig}})(\varphi_g \pm \delta_{\varphi_g})$$

relates a set of measured reaction rates, R_i, to a single neutron spectrum, ϕ_g, through the multigroup dosimeter reaction cross-section, σ_{ig}, each with an uncertainty δ. The primary objective of the least squares evaluation is to produce unbiased estimates of the neutron exposure parameters at the location of the measurement.

For the least squares evaluation of the R. E. Ginna surveillance capsule dosimetry, the FERRET code (Reference A-4) was employed to combine the results of the plant-specific neutron transport calculations and sensor set reaction rate measurements to determine best-estimate values of exposure parameters ($\phi(E > 1.0$ MeV) and dpa) along with associated uncertainties for the five in-vessel capsules analyzed to date.

The application of the least squares methodology requires the following input:

1. The calculated neutron energy spectrum and associated uncertainties at the measurement location.

2. The measured reaction rates and associated uncertainty for each sensor contained in the multiple foil set.

3. The energy dependent dosimetry reaction cross-sections and associated uncertainties for each sensor contained in the multiple foil sensor set.

For the R. E. Ginna application, the calculated neutron spectrum was obtained from the results of plant-specific neutron transport calculations described in Section 6.2 of this report. The sensor reaction rates were derived from the measured specific activities using the procedures described in Section A.1.1. The dosimetry reaction cross-sections and uncertainties were obtained from the SNLRML dosimetry cross-section library (Reference A-5). The SNLRML library is an evaluated dosimetry reaction cross-section compilation recommended for use in LWR evaluations by ASTM Standard E1018, "Application of ASTM Evaluated Cross-Section Data File, Matrix E 706 (IIB)."

The uncertainties associated with the measured reaction rates, dosimetry cross-sections, and calculated neutron spectrum were input to the least squares procedure in the form of variances and covariances. The assignment of the input uncertainties followed the guidance provided in ASTM Standard E 944, "Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance."

The following provides a summary of the uncertainties associated with the least squares evaluation of the R. E. Ginna surveillance capsule sensor sets.

Reaction Rate Uncertainties

The overall uncertainty associated with the measured reaction rates includes components due to the basic measurement process, irradiation history corrections, and corrections for competing reactions. A high level of accuracy in the reaction rate determinations is assured by utilizing laboratory procedures that

conform to the ASTM National Consensus Standards for reaction rate determinations for each sensor type.

After combining all of these uncertainty components, the sensor reaction rates derived from the counting and data evaluation procedures were assigned the following net uncertainties for input to the least squares evaluation:

Reaction	Uncertainty
$^{63}Cu(n,\alpha)^{60}Co$	5%
$^{54}Fe(n,p)^{54}Mn$	5%
$^{58}Ni(n,p)^{58}Co$	5%
$^{238}U(n,f)^{137}Cs$	10%
$^{237}Np(n,f)^{137}Cs$	10%
$^{59}Co(n,\gamma)^{60}Co$	5%

These uncertainties are given at the 1σ level.

Dosimetry Cross-Section Uncertainties

The reaction rate cross-sections used in the least squares evaluations were taken from the SNLRML library. This data library provides reaction cross-sections and associated uncertainties, including covariances, for 66 dosimetry sensors in common use. Both cross-sections and uncertainties are provided in a fine multigroup structure for use in least squares adjustment applications. These cross-sections were compiled from the most recent cross-section evaluations and they have been tested with respect to their accuracy and consistency for least squares evaluations. Further, the library has been empirically tested for use in fission spectra determination as well as in the fluence and energy characterization of 14 MeV neutron sources.

For sensors included in the R. E. Ginna surveillance program, the following uncertainties in the fission spectrum averaged cross-sections are provided in the SNLRML documentation package.

Reaction	Uncertainty
$^{63}Cu(n,\alpha)^{60}Co$	4.08-4.16%
$^{54}Fe(n,p)^{54}Mn$	3.05-3.11%
$^{58}Ni(n,p)^{58}Co$	4.49-4.56%
$^{238}U(n,f)^{137}Cs$	0.54-0.64%
$^{237}Np(n,f)^{137}Cs$	10.32-10.97%
$^{59}Co(n,\gamma)^{60}Co$	0.79-3.59%

These tabulated ranges provide an indication of the dosimetry cross-section uncertainties associated with the sensor sets used in LWR irradiations.

Calculated Neutron Spectrum

The neutron spectra input to the least squares adjustment procedure were obtained directly from the results of plant-specific transport calculations for each surveillance capsule irradiation period and location. The spectrum for each capsule was input in an absolute sense (rather than as simply a relative spectral shape). Therefore, within the constraints of the assigned uncertainties, the calculated data were treated equally with the measurements.

While the uncertainties associated with the reaction rates were obtained from the measurement procedures and counting benchmarks and the dosimetry cross-section uncertainties were supplied directly with the SNLRML library, the uncertainty matrix for the calculated spectrum was constructed from the following relationship:

$$M_{gg'} = R_n^2 + R_g * R_{g'} * P_{gg'}$$

where R_n specifies an overall fractional normalization uncertainty and the fractional uncertainties R_g and $R_{g'}$ specify additional random groupwise uncertainties that are correlated with a correlation matrix given by:

$$P_{gg'} = [1 - \theta]\delta_{gg'} + \theta\, e^{-H}$$

where

$$H = \frac{(g - g')^2}{2\gamma^2}$$

The first term in the correlation matrix equation specifies purely random uncertainties, while the second term describes the short-range correlations over a group range γ (θ specifies the strength of the latter term). The value of δ is 1.0 when g = g', and is 0.0 otherwise.

The set of parameters defining the input covariance matrix for the R. E. Ginna calculated spectra was as follows:

Flux Normalization Uncertainty (R_n)	15%
Flux Group Uncertainties (R_g, $R_{g'}$)	
(E > 0.0055 MeV)	15%
(0.68 eV < E < 0.0055 MeV)	25%
(E < 0.68 eV)	50%
Short Range Correlation (θ)	
(E > 0.0055 MeV)	0.9
(0.68 eV < E < 0.0055 MeV)	0.5
(E < 0.68 eV)	0.5
Flux Group Correlation Range (γ)	
(E > 0.0055 MeV)	6
(0.68 eV < E < 0.0055 MeV)	3
(E < 0.68 eV)	2

A.1.3 Comparisons of Measurements and Calculations

Results of the least squares evaluations of the dosimetry from the R. E. Ginna surveillance capsules withdrawn to date are provided in Tables A-4 and A-5. In Table A-4, measured, calculated, and best-estimate values for sensor reaction rates are given for each capsule. Also provided in this tabulation are ratios of the measured reaction rates to both the calculated and least squares adjusted reaction rates. These ratios of M/C and M/BE illustrate the consistency of the fit of the calculated neutron energy spectra to the measured reaction rates both before and after adjustment. In Table A-5, comparison of the calculated and best estimate values of neutron flux (E > 1.0 MeV) and iron atom displacement rate are tabulated along with the BE/C ratios observed for each of the capsules.

The data comparisons provided in Tables A-4 and A-5 show that the adjustments to the calculated spectra are relatively small and within the assigned uncertainties for the calculated spectra, measured sensor reaction rates, and dosimetry reaction cross-sections. Further, these results indicate that the use of the least squares evaluation results in a reduction in the uncertainties associated with the exposure of the surveillance capsules. From Section 6.4 of this report, it may be noted that the uncertainty associated with the unadjusted calculation of neutron fluence (E > 1.0 MeV) and iron atom displacements at the surveillance capsule locations is specified as 12% at the 1σ level. From Table A-5, it is noted that the corresponding uncertainties associated with the least squares adjusted exposure parameters have been reduced to 6% for neutron flux (E > 1.0 MeV) and 7-8% for iron atom displacement rate. Again, the uncertainties from the least squares evaluation are at the 1σ level.

Further comparisons of the measurement results (from Tables A-4 and A-5) with calculations are given in Tables A-6 and A-7. These comparisons are given on two levels. In Table A-6, calculations of individual threshold sensor reaction rates are compared directly with the corresponding measurements. These threshold reaction rate comparisons provide a good evaluation of the accuracy of the fast neutron portion of the calculated energy spectra. In Table A-7, calculations of fast neutron exposure rates in terms of ϕ(E > 1.0 MeV) and dpa/s are compared with the best estimate results obtained from the least squares evaluation of the capsule dosimetry results. These two levels of comparison yield consistent and similar

results with all measurement-to-calculation comparisons falling well within the 20% limits specified as the acceptance criteria in Regulatory Guide 1.190.

In the case of the direct comparison of measured and calculated sensor reaction rates, the M/C comparisons for fast neutron reactions range from 0.78 to 1.47 for the 24 samples included in the data set. The overall average M/C ratio for the entire set of R. E. Ginna data is 1.01 with an associated standard deviation of 17.1%.

In the comparisons of best estimate and calculated fast neutron exposure parameters, the corresponding BE/C comparisons for the capsule data sets range from 0.86 to 1.04 for neutron flux (E > 1.0 MeV) and from 0.85 to 1.03 for iron atom displacement rate. The overall average BE/C ratios for neutron flux (E > 1.0 MeV) and iron atom displacement rate are 0.98 with a standard deviation of 7.6% and 0.98 with a standard deviation of 7.6%, respectively.

Based on these comparisons, it is concluded that the calculated fast neutron exposures provided in Section 6.2 of this report are validated for use in the assessment of the condition of the materials comprising the beltline region of the R. E. Ginna reactor pressure vessel.

Table A-1 Nuclear Parameters Used in the Evaluation of Neutron Sensors

Monitor Material	Reaction of Interest	Target Atom Fraction	90% Response Range (MeV)	Product Half-life	Fission Yield (%)
Copper	^{63}Cu (n,α)	0.6917	4.9 – 11.9	5.271 y	
Iron	^{54}Fe (n,p)	0.0585	2.1 – 8.5	312.1 d	
Nickel	^{58}Ni (n,p)	0.6808	1.5 – 8.3	70.82 d	
Uranium-238	^{238}U (n,f)	1.0000	1.3 – 6.9	30.07 y	6.02
Neptunium-237	^{237}Np (n,f)	1.0000	0.3 – 3.8	30.07 y	6.17
Cobalt-Aluminum	^{59}Co (n,γ)	0.0015	non-threshold	5.271 y	

The 90% response range is defined such that, in the neutron spectrum characteristic of the R. E. Ginna surveillance capsules, approximately 90% of the sensor response is due to neutrons in the energy range specified with approximately 5% of the total response due to neutrons with energies below the lower limit and 5% of the total response due to neutrons with energies above the upper limit.

Table A-2 Calculated Flux at the Surveillance Capsule Center, Core Midplane Elevation						
		Φ (E > 1.0 MeV) (n/cm^2-s)				
Cycle	EFPY	Capsule V	Capsule R	Capsule T	Capsule S	Capsule N
1a	0.7	1.20E+11	1.20E+11	7.04E+10	6.70E+10	6.70E+10
1b	1.4	1.42E+11	1.42E+11	8.00E+10	7.15E+10	7.15E+10
2	1.6		1.37E+11	8.08E+10	7.70E+10	7.70E+10
3	2.6		1.15E+11	6.66E+10	6.29E+10	6.29E+10
4	3.2			7.45E+10	7.42E+10	7.42E+10
5	3.8			7.68E+10	7.06E+10	7.06E+10
6	4.6			8.47E+10	7.62E+10	7.62E+10
7	5.3			7.61E+10	7.12E+10	7.12E+10
8	6.0			8.58E+10	8.20E+10	8.20E+10
9	6.9			8.60E+10	8.48E+10	8.48E+10
10	7.7				7.92E+10	7.92E+10
11	8.2				6.60E+10	6.60E+10
12	9.0				6.49E+10	6.49E+10
13	9.6				6.37E+10	6.37E+10
14	10.4				7.04E+10	7.04E+10
15	11.2				6.72E+10	6.72E+10
16	12.0				6.08E+10	6.08E+10
17	12.9				6.07E+10	6.07E+10
18	13.9				5.96E+10	5.96E+10
19	14.6				6.02E+10	6.02E+10
20	15.4				5.89E+10	5.89E+10
21	16.2				6.10E+10	6.10E+10
22	17.0				6.19E+10	6.19E+10
23	17.8					6.13E+10
24	18.6					5.58E+10
25	19.5					5.33E+10
26	20.7					4.66E+10
27	22.0					4.47E+10
28	23.4					4.77E+10
29	24.8					4.64E+10
30	26.1					4.75E+10
31	27.5					4.65E+10
32	29.0					5.79E+10
33	30.5					5.69E+10
Average		**1.32E+11**	**1.26E+11**	**7.79E+10**	**6.78E+10**	**6.03E+10**

Data for Capsules V, R, T, S are from Reference A-2.

Table A-3 Measured Sensor Activities And Reaction Rates Surveillance Capsule N

Reaction	Location	Measured Activity (dps/g)	Saturated Activity (dps/g)	Radially Adjusted Saturated Activity (dps/g)	Radially Adjusted Reaction Rate (rps/atom)
$^{63}Cu(n,\alpha)^{60}Co$ (Cd)	Top	2.13E+05	2.89E+05	2.75E+05	4.16E-17
	TopMid	1.86E+05	2.52E+05	2.41E+05	3.63E-17
	BotMid	2.13E+05	2.89E+05	2.75E+05	4.16E-17
	Bottom	2.12E+05	2.87E+05	2.74E+05	4.14E-17
	Average				**4.02E-17**
$^{58}Ni(n,p)^{58}Co$	Middle	2.68E+06	3.72E+07	3.54E+07	5.00E-15
$^{238}U(n,f)^{137}Cs$ (Cd)	Cap	2.26E+06	4.90E+06	4.90E+06	3.24E-14
	Including ^{235}U, ^{239}Pu, and γ,fission corrections:				**2.13E-14**
$^{237}Np(n,f)^{137}Cs$ (Cd)	Cap	1.80E+07	3.90E+07	3.90E+07	2.49E-13
	Including ^{235}U, ^{239}Pu, and γ,fission corrections:				**2.45E-13**
$^{59}Co(n,\gamma)^{60}Co$	Top	3.55E+07	4.81E+07	4.61E+07	3.01E-12
	TopMid	3.11E+07	4.21E+07	4.04E+07	2.63E-12
	Middle	3.20E+07	4.34E+07	4.15E+07	2.71E-12
	BotMid	3.39E+07	4.59E+07	4.40E+07	2.87E-12
	Bottom	3.28E+07	4.45E+07	4.26E+07	2.78E-12
	Average				**2.80E-12**
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	Top	1.32E+07	1.79E+07	2.08E+07	1.36E-12
	TopMid	1.40E+07	1.90E+07	2.21E+07	1.44E-12
	Middle	1.29E+07	1.75E+07	2.03E+07	1.33E-12
	BotMid	1.40E+07	1.90E+07	2.21E+07	1.44E-12
	Bottom	1.32E+07	1.79E+07	2.08E+07	1.36E-12
	Average				**1.38E-12**

1. Measured specific activities are indexed to a counting date of January 23, 2009
2. The average $^{238}U(n,f)$ reaction rate of 2.13E-14 includes a correction factor of 0.689 to account for plutonium build-in and an additional factor of 0.953 to account for photo-fission effects in the sensor.
3. The average $^{237}Np(n,f)$ reaction rate of 2.45E-13 includes a correction factor of 0.983 to account for photo-fission effects in the sensor.

Table A-3 Measured Sensor Activities And Reaction Rates Surveillance Capsule N (Continued)

Reaction	Location	Measured Activity (dps/g)	Saturated Activity (dps/g)	Radially Adjusted Saturated Activity (dps/g)	Radially Adjusted Reaction Rate (rps/atom)
$^{54}Fe(n,p)^{54}Mn$	Core side Charpy	1.24E+06	2.28E+06	2.16E+06	3.43E-15
	Core side Charpy	1.17E+06	2.15E+06	2.04E+06	3.63E-17
	Core side Charpy	1.24E+06	2.28E+06	2.16E+06	3.24E-15
	Vessel side Charpy	1.02E+06	1.87E+06	2.17E+06	3.43E-15
	Vessel side Charpy	9.67E+05	1.77E+06	2.05E+06	3.25E-15
	Vessel side Charpy	1.02E+06	1.87E+06	2.17E+06	3.43E-15
	Average				**3.37E-15**

1. Measured specific activities are indexed to a counting date of January 23, 2009
2. The average 238U(n,f) reaction rate of 2.13E-14 includes a correction factor of 0.689 to account for plutonium build-in and an additional factor of 0.953 to account for photo fission effects in the sensor.
3. The average 237Np(n,f) reaction rate of 2.45E-13 includes a correction factor of 0.983 to account for photo fission effects in the sensor.

Table A-4 Comparison of Measured, Calculated, and Best Estimate Reaction Rates at Center of Surveillance Capsule N

Reaction	Reaction Rate (rps/atom)			M/C	M/BE
	Measured	Calculated	Best Estimate		
$^{63}Cu(n,\alpha)^{60}Co$	4.06E-17	3.87E-17	3.79E-17	1.05	1.08
$^{54}Fe(n,p)^{54}Mn$	3.37E-15	4.19E-15	3.73E-15	0.80	0.90
$^{58}Ni(n,p)^{58}Co$	5.07E-15	5.77E-15	5.25E-15	0.88	0.97
$^{238}U(n,f)^{137}Cs$ (Cd)	2.13E-14	2.08E-14	1.97E-14	1.02	1.08
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.45E-13	1.67E-13	2.04E-13	1.47	1.20
$^{59}Co(n,\gamma)^{60}Co$	2.80E-12	3.85E-12	2.84E-12	0.73	0.99
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	1.38E-12	1.50E-12	1.38E-12	0.92	1.00

Table A-5 Comparison of Calculated and Best Estimate Exposure Rates at the Surveillance Capsule Center

Capsule ID	φ(E > 1.0 MeV) [n/cm²-s]			
	Calculated	Best Estimate	Uncertainty (1σ)	BE/C
V	1.32E+11	1.13E+11	6%	0.86
R	1.26E+11	1.30E+11	6%	1.03
T	7.79E+10	8.12E+10	6%	1.04
S	6.79E+10	6.62E+10	6%	0.98
N	6.03E+10	5.92E+10	6%	0.98

Calculated results are based on the synthesized transport calculations taken at the core midplane following the completion of each respective capsule's irradiation period and are the average neutron exposure over the irradiation period for each capsule. See Section A.1.2 for details describing the Best Estimate (BE) exposure rates.

Capsule ID	Iron Atom Displacement Rate [dpa/s]			
	Calculated	Best Estimate	Uncertainty (1σ)	BE/C
V	2.40E-10	2.05E-10	8%	0.85
R	2.30E-10	2.36E-10	7%	1.03
T	1.36E-10	1.40E-10	8%	1.03
S	1.19E-10	1.16E-10	7%	0.97
N	9.93E-11	1.06E-10	7%	1.01

Calculated results are based on the synthesized transport calculations taken at the core midplane following the completion of each respective capsule's irradiation period and are the average neutron exposure over the irradiation period for each capsule. See Section A.1.2 for details describing the Best Estimate (BE) exposure rates.

Table A-6 Comparison of Measured/Calculated (M/C) Sensor Reaction Rate Ratios Including all Fast Neutron Threshold Reactions

Reaction	M/C Ratio						
	Capsule V	Capsule R	Capsule T	Capsule S	Capsule N	Average	% Standard Deviation
$^{63}Cu(n,\alpha)^{60}Co$	1.02	1.01	1.00	1.02	1.05	1.02	1.8
$^{54}Fe(n,p)^{54}Mn$	0.93	1.01	1.01	0.95	0.80	0.94	9.2
$^{58}Ni(n,p)^{58}Co$	0.78	0.93	0.95	0.90	0.88	0.89	7.4
$^{238}U(n,f)^{137}Cs$ (Cd)	0.89	0.98	1.01	0.94	1.02	0.97	5.5
$^{237}Np(n,f)^{137}Cs$ (Cd)	--	1.32	1.29	1.22	1.47	1.33	8.0

The overall average M/C ratio for the set of 24 sensor measurements is 1.01 with an associated standard deviation of 17.1%.

Table A-7 Comparison of Best Estimate/Calculated (BE/C) Exposure Rate Ratios

Capsule ID	BE/C Ratio	
	ϕ(E > 1.0 MeV)	dpa/s
V	0.86	0.85
R	1.03	1.03
T	1.04	1.03
S	0.98	0.97
N	0.98	1.01
Average	0.98	0.98
% Standard Deviation	7.6	7.6

A.2 REFERENCES

A-1. Regulatory Guide RG-1.190, *Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence*, U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, March 2001.

A-2. WCAP-15885, *R. E. Ginna Heatup and Cooldown Curves for Normal Operation*, Revision 0, July 2002.

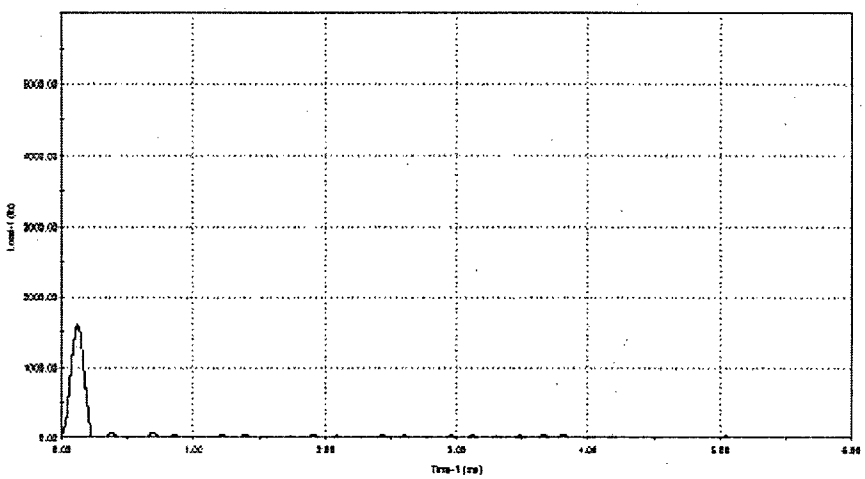
A-3 WCAP-7254, *Rochester Gas and Electric Robert E. Ginna Unit No. 1 Reactor Vessel Radiation Surveillance Program*, May 1969.

A-4. A. Schmittroth, *FERRET Data Analysis Core*, HEDL-TME 79-40, Hanford Engineering Development Laboratory, Richland, WA, September 1979.

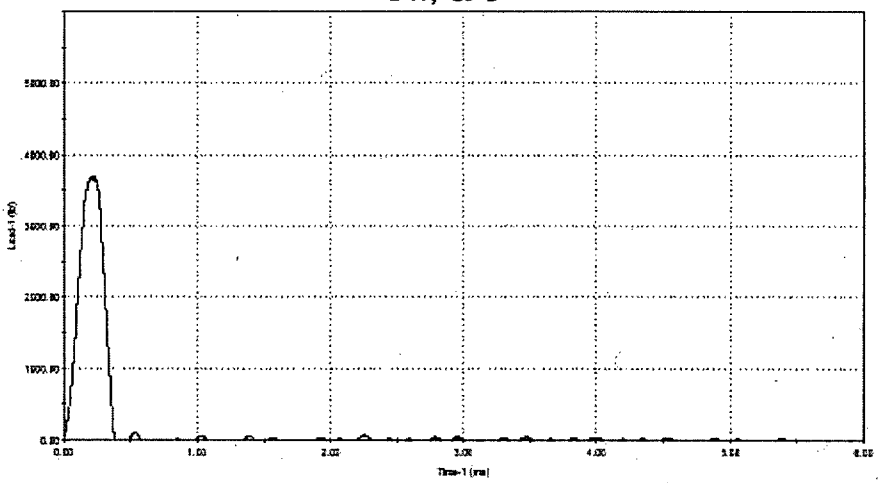
A-5. RSICC Data Library Collection DLC-178, *SNLRML Recommended Dosimetry Cross-Section Compendium*, July 1994.

APPENDIX B
LOAD-TIME RECORDS FOR CHARPY SPECIMEN TESTS

- Specimen prefix "P" denotes Forging 125P666, Longitudinal (Tangential) Orientation
- Specimen prefix "S" denotes Forging 125S255, Longitudinal (Tangential) Orientation
- Specimen prefix "W" denotes Surveillance Program Weld Metal
- Specimen prefix "H" denotes Heat-Affected Zone Material



P47, -25°F



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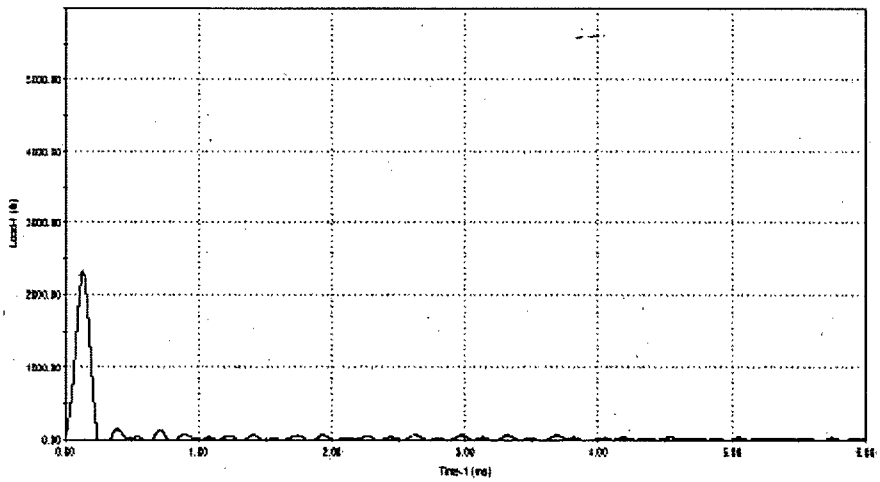
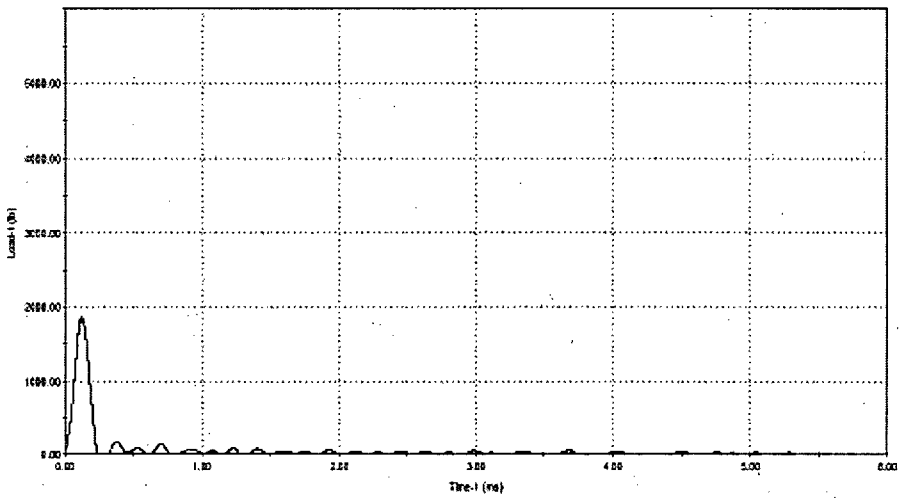
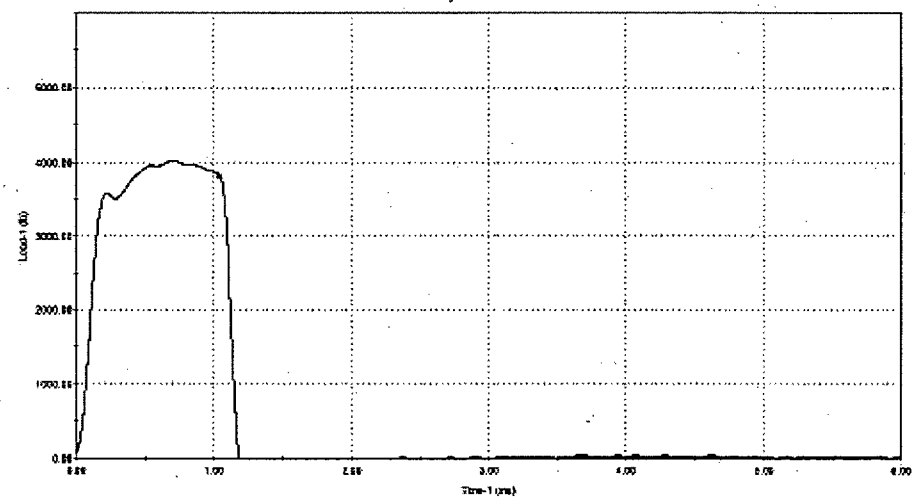


P53, 30°F



P51, 40°F



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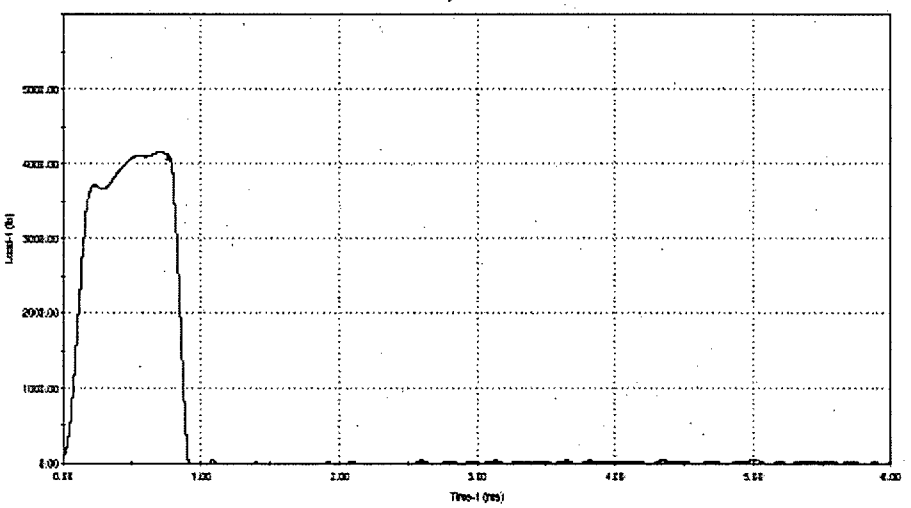
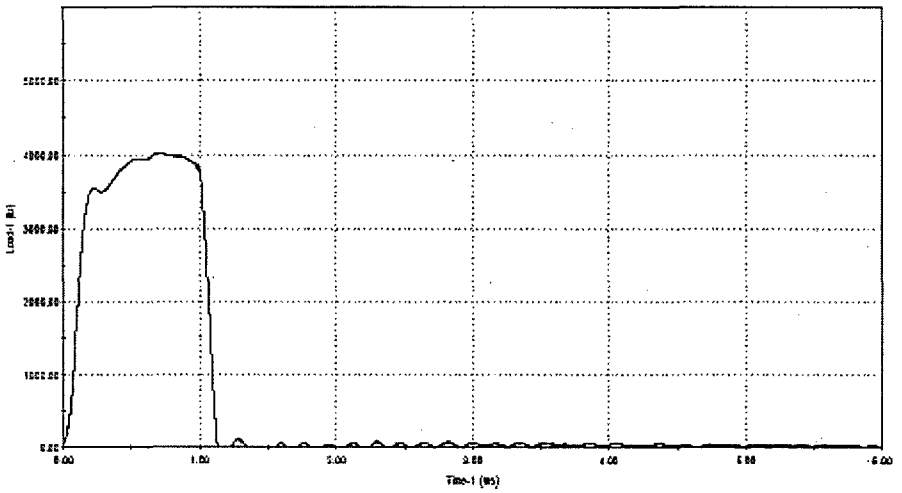


P44, 55°F



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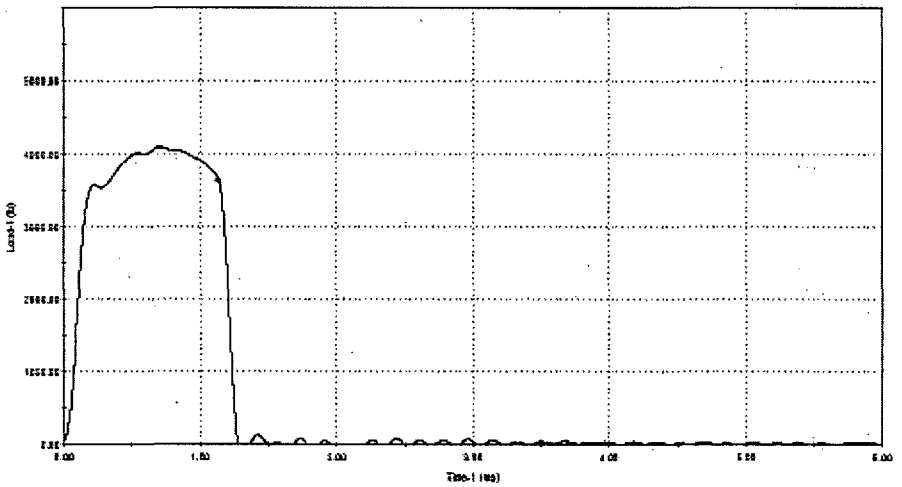

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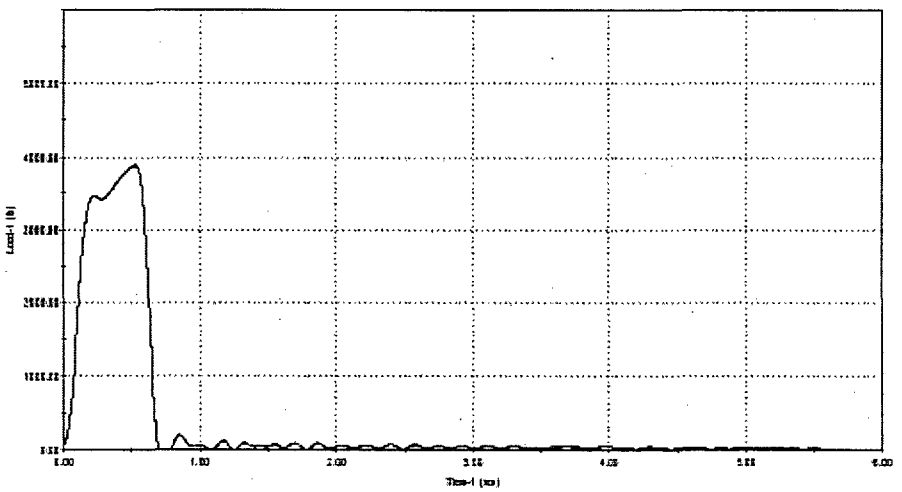
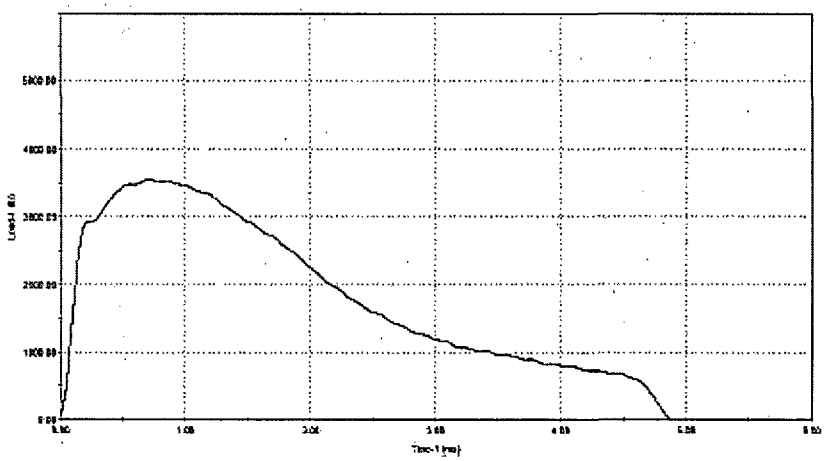


P52, 100°F



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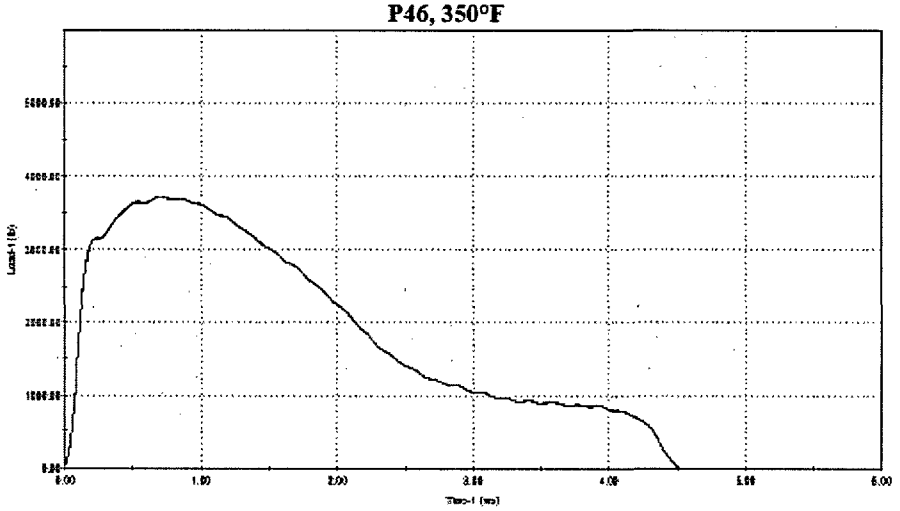

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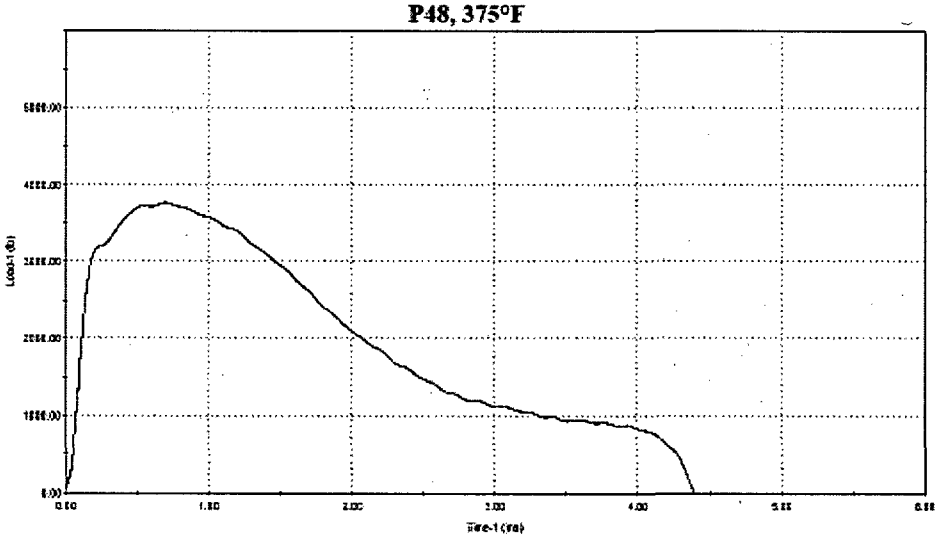

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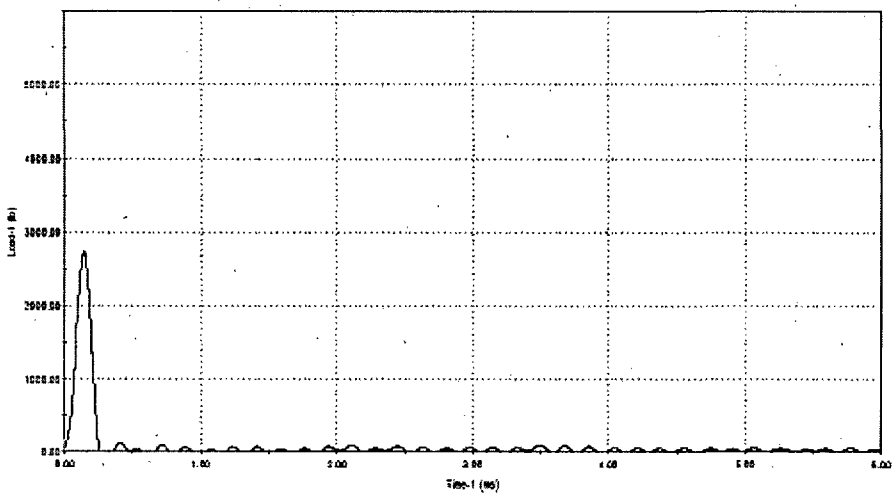

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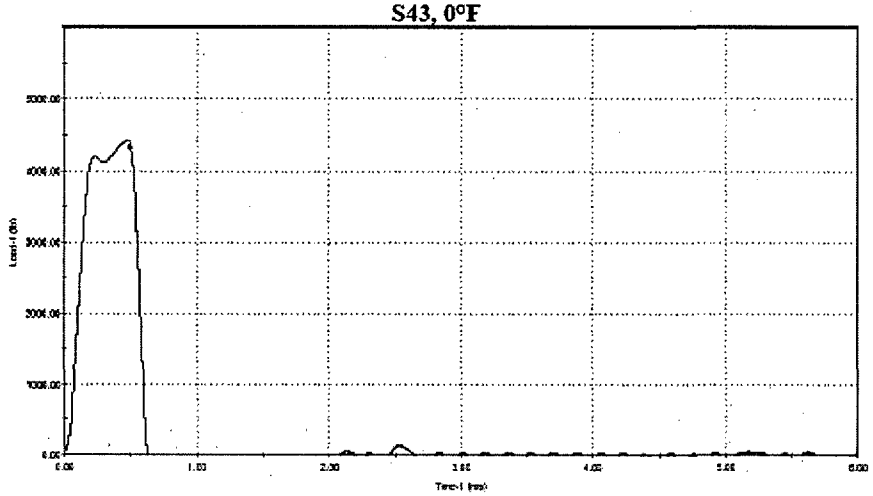

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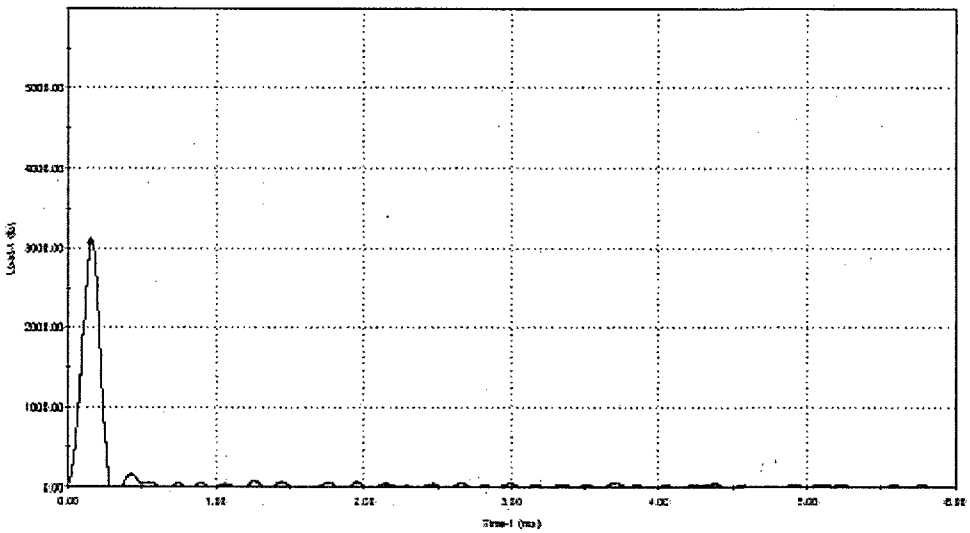

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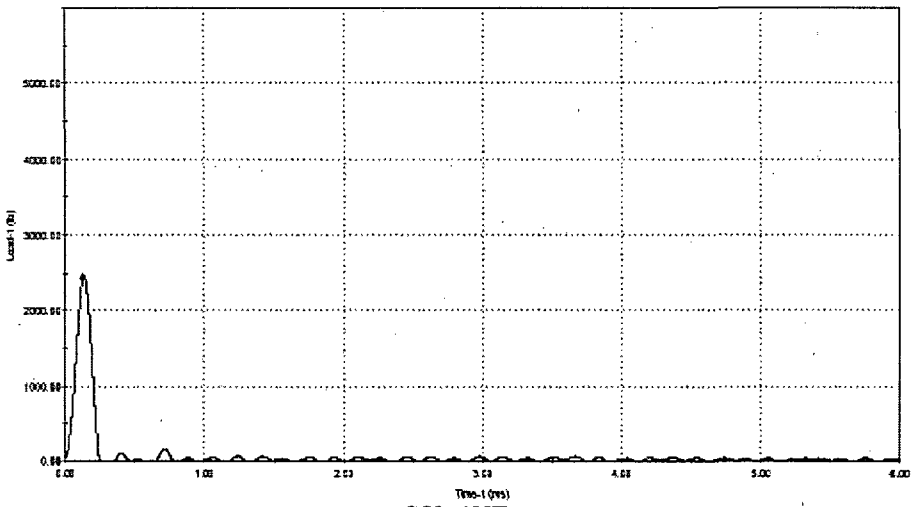

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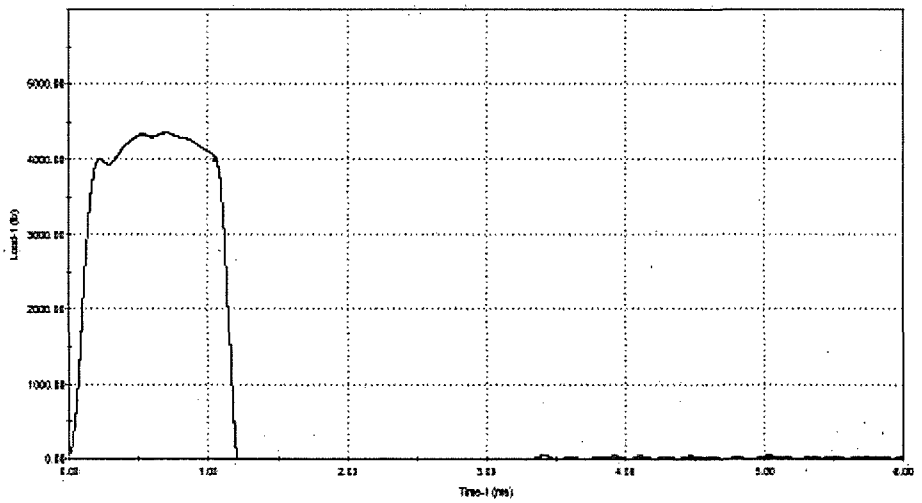

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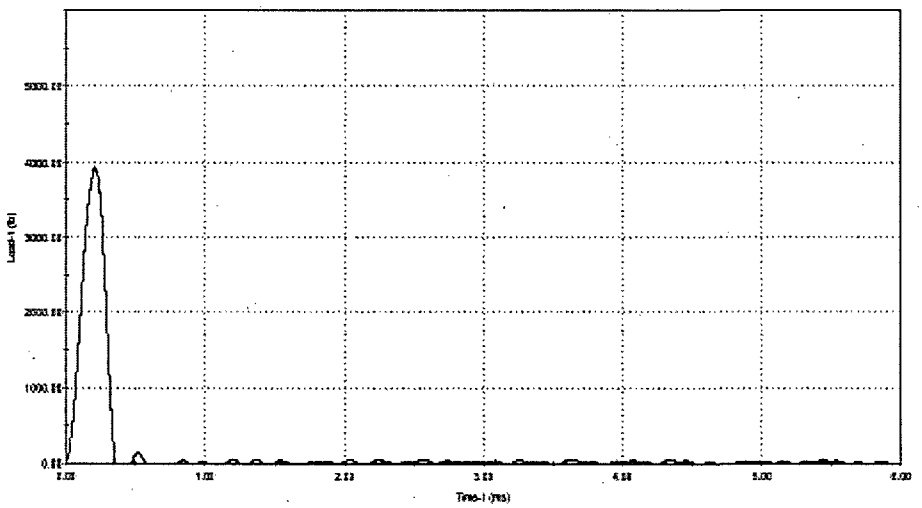

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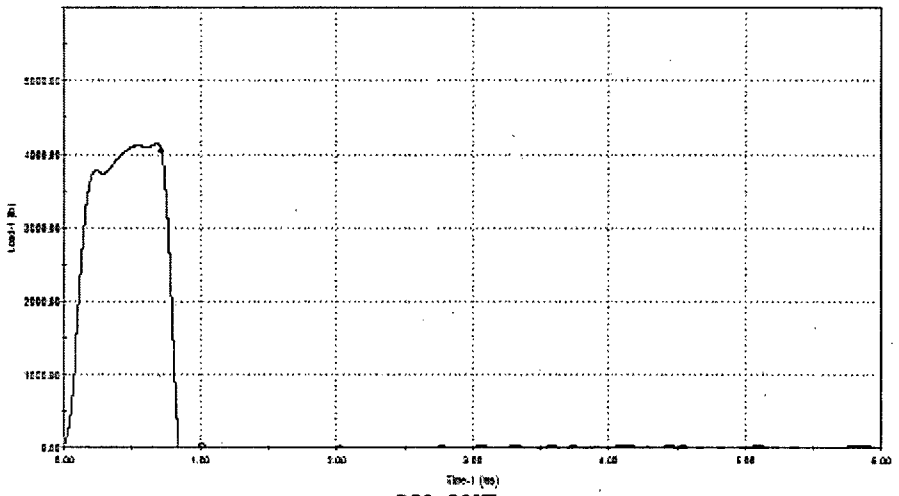

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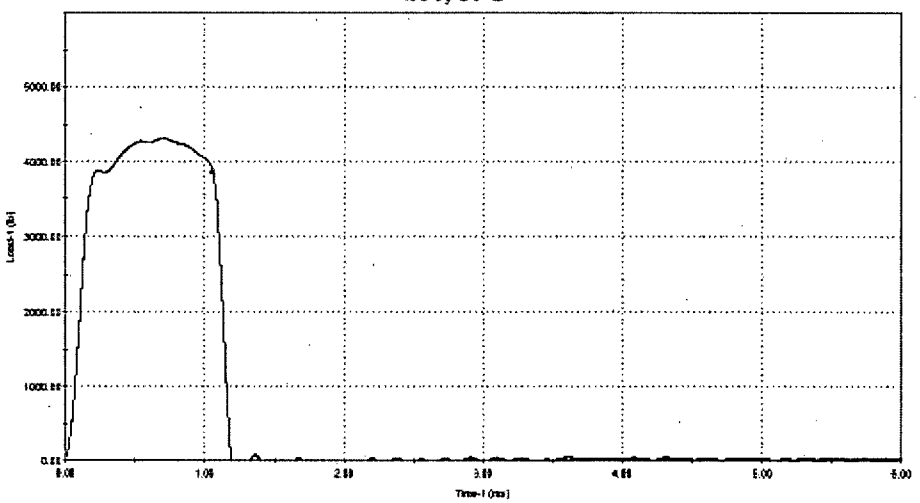

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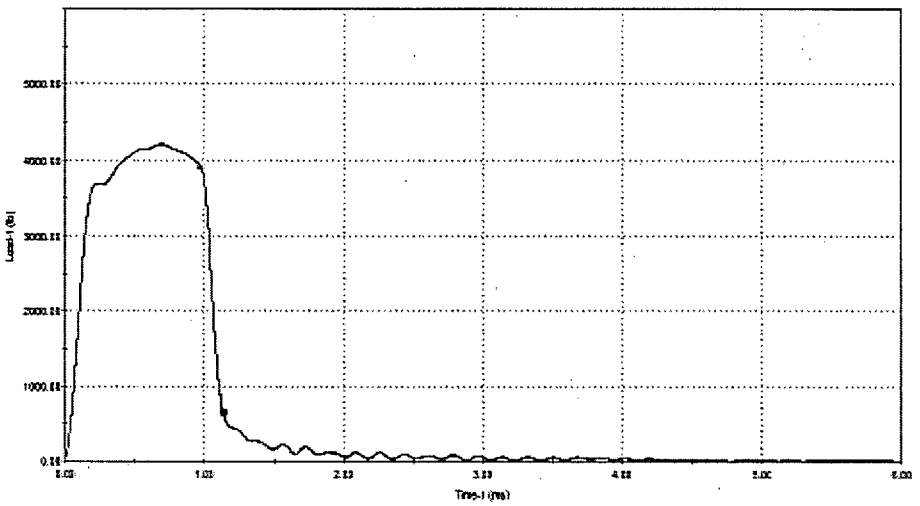

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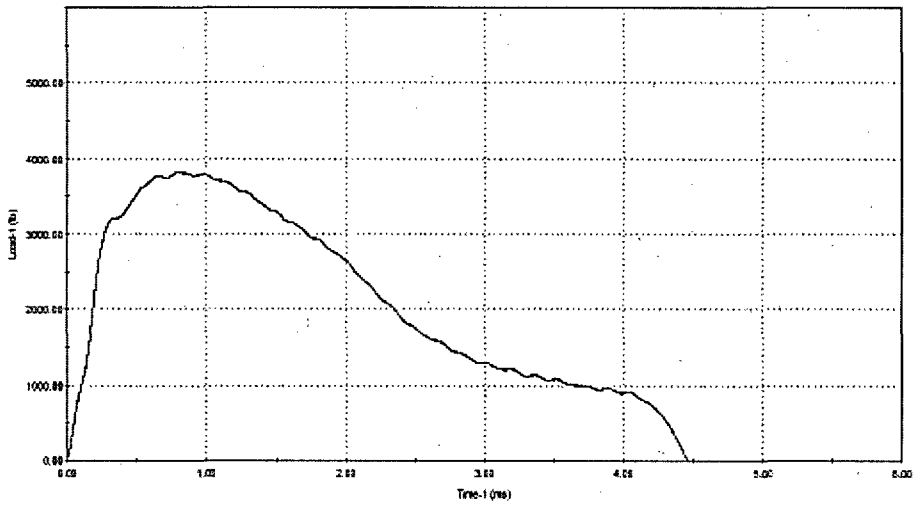

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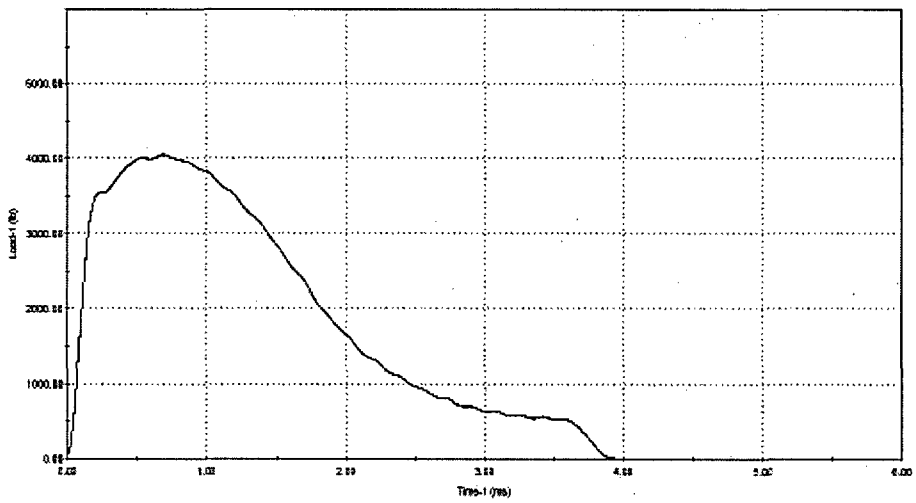

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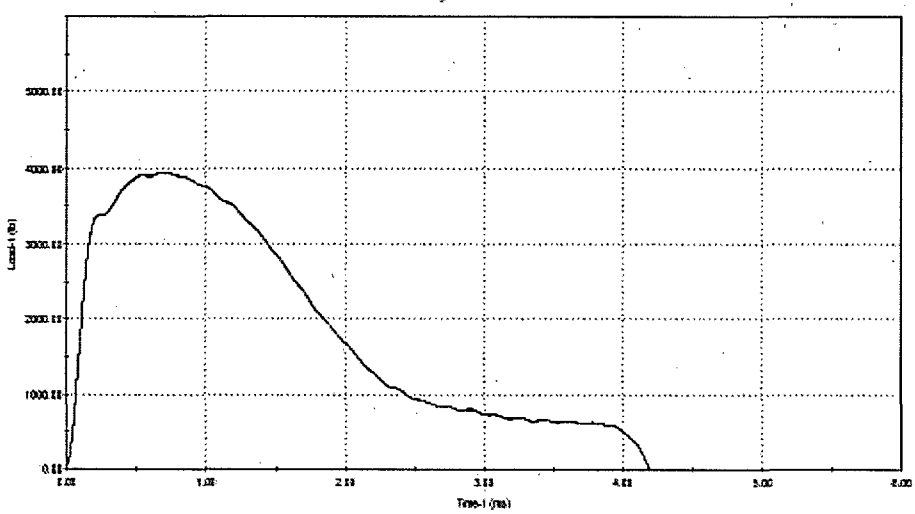

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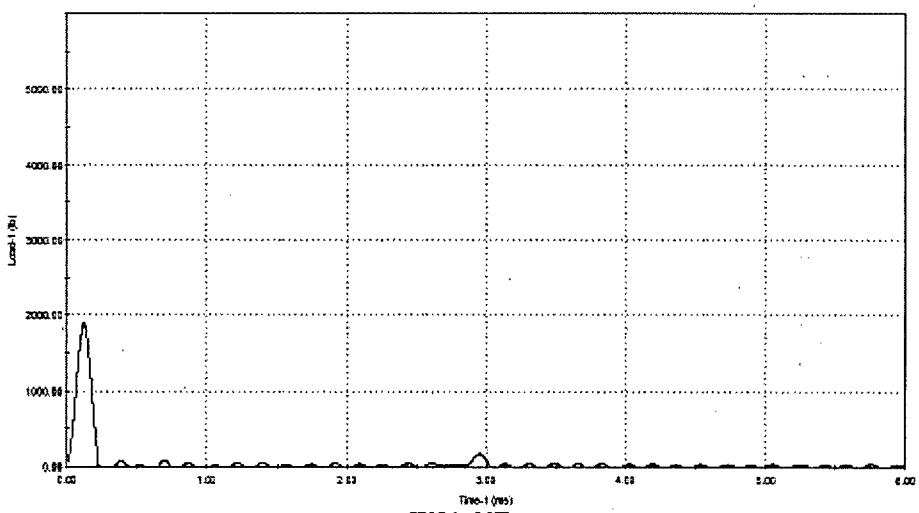

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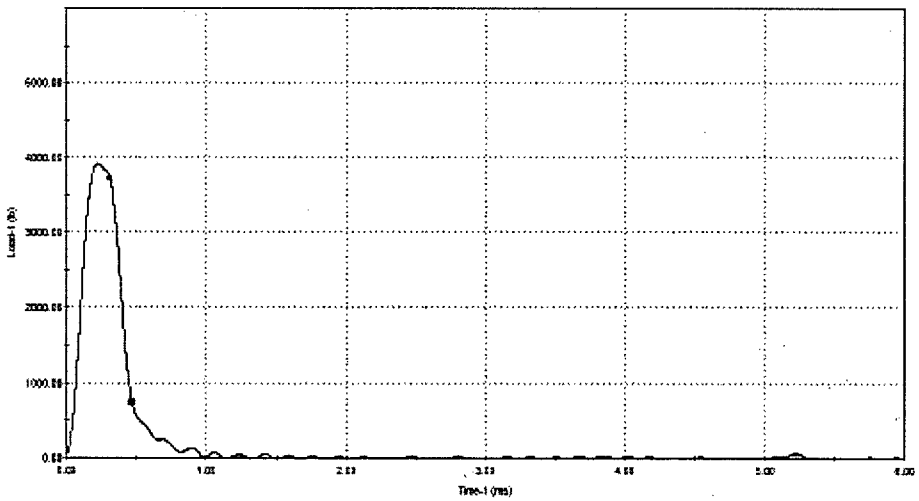

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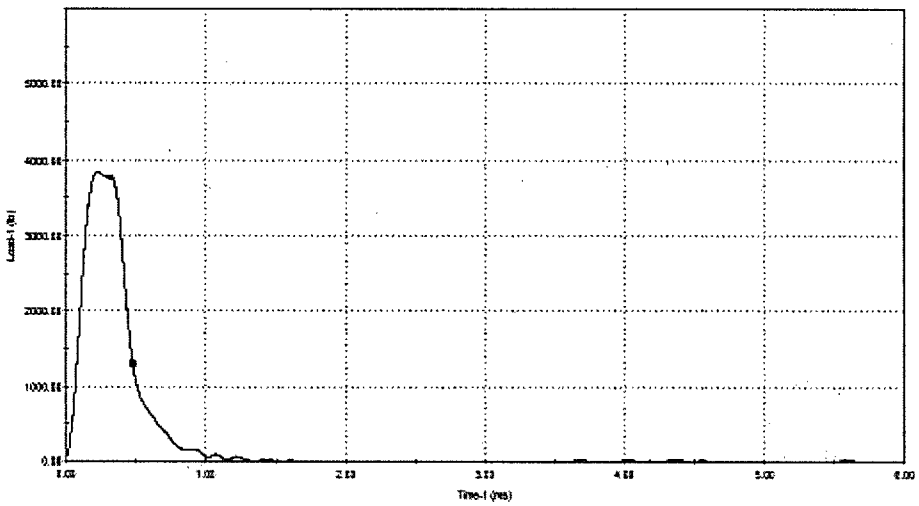

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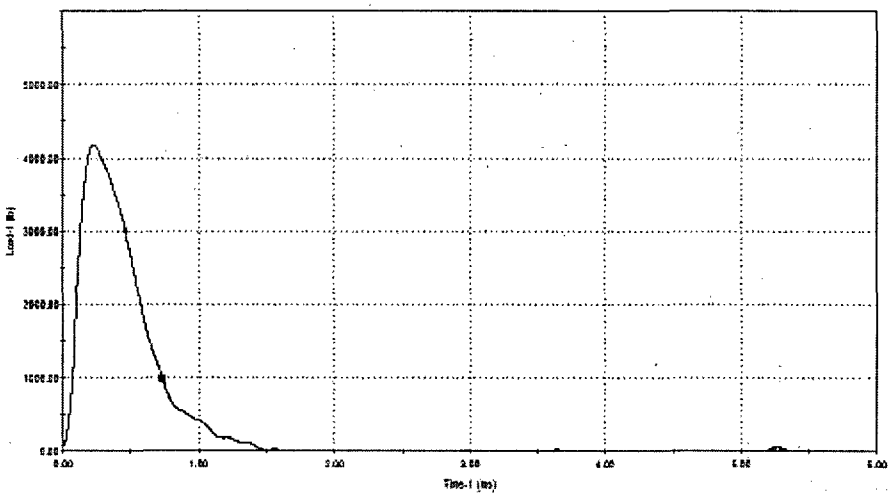

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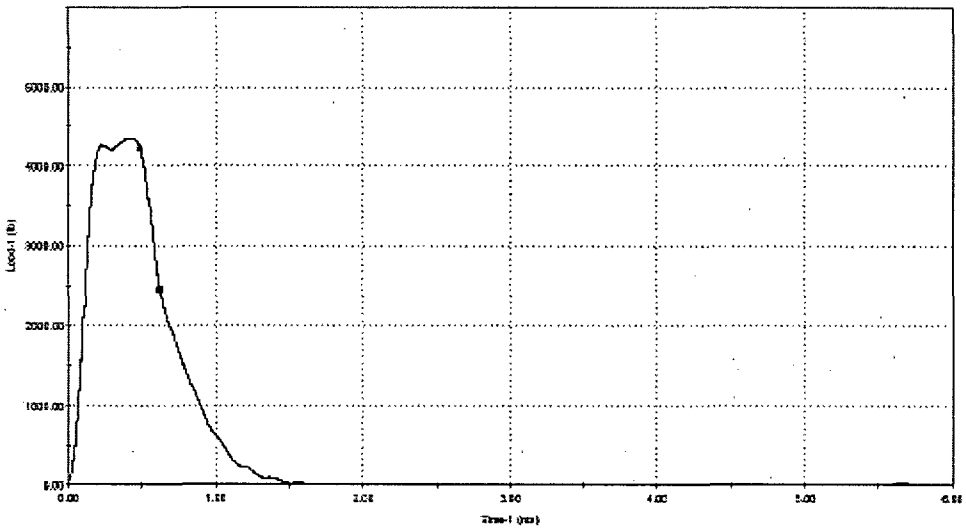

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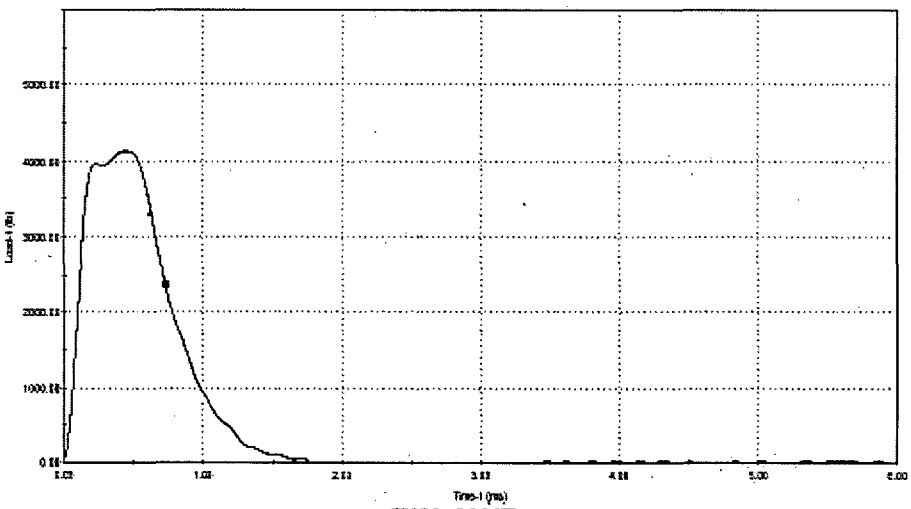

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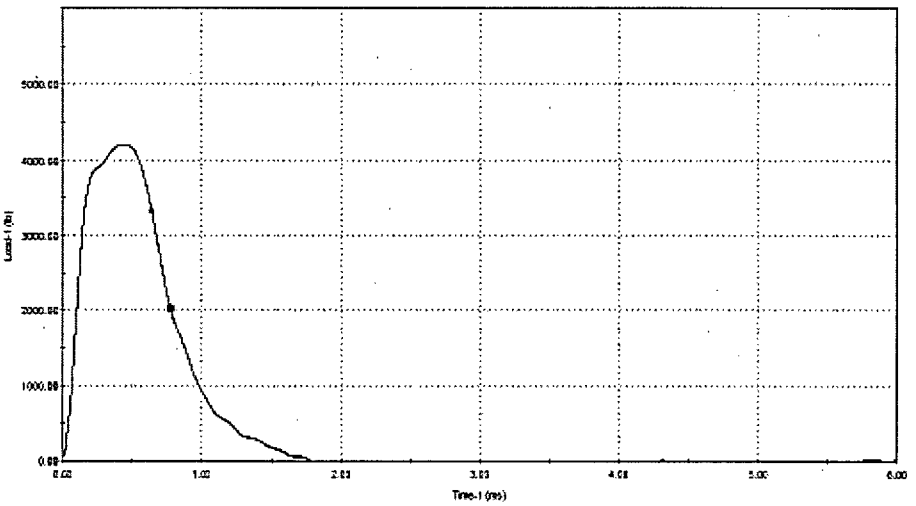

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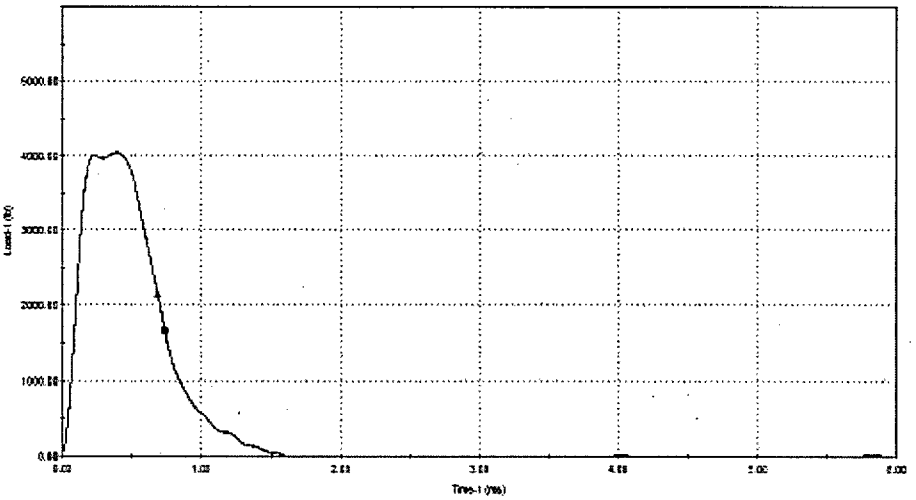

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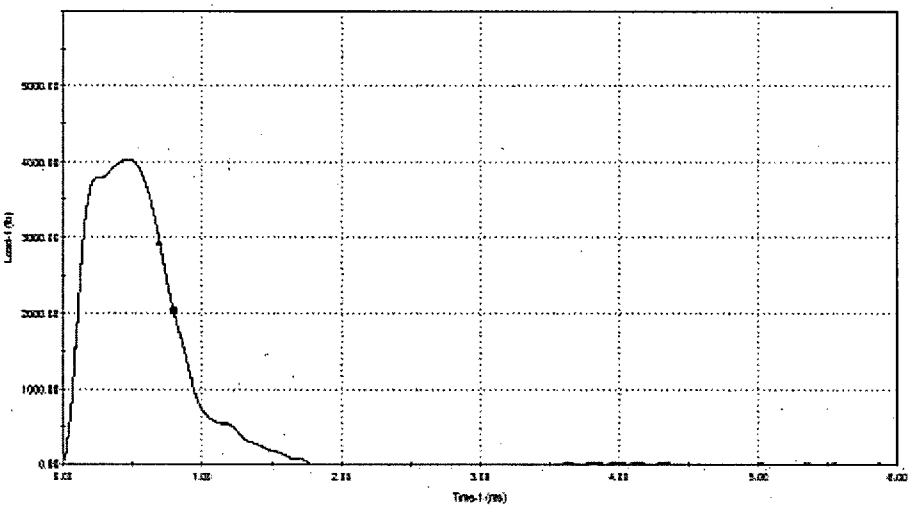

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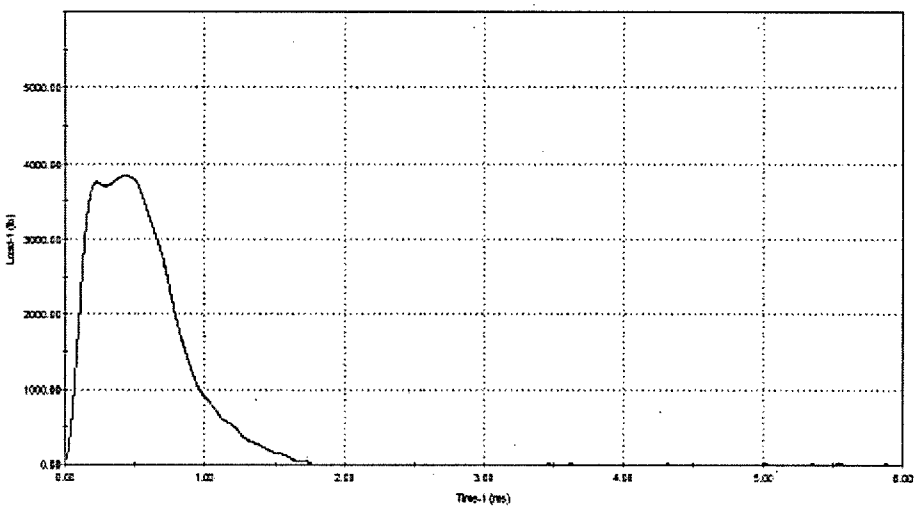

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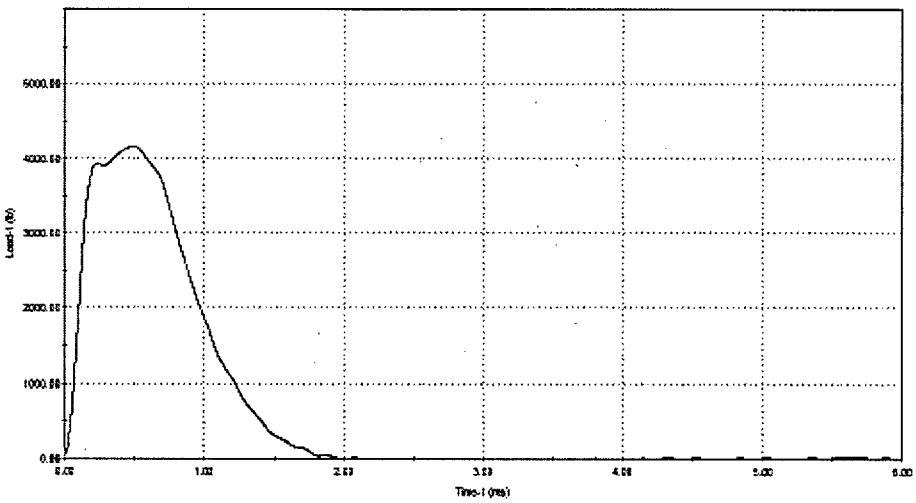

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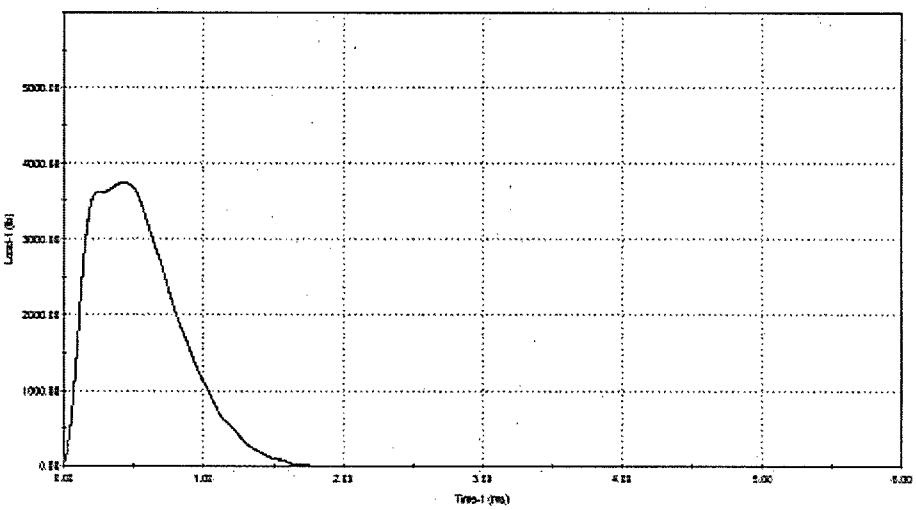

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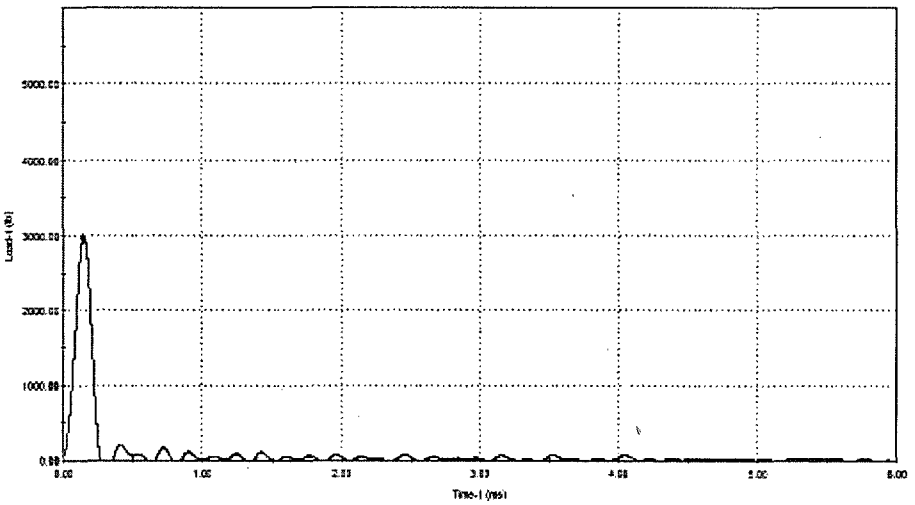

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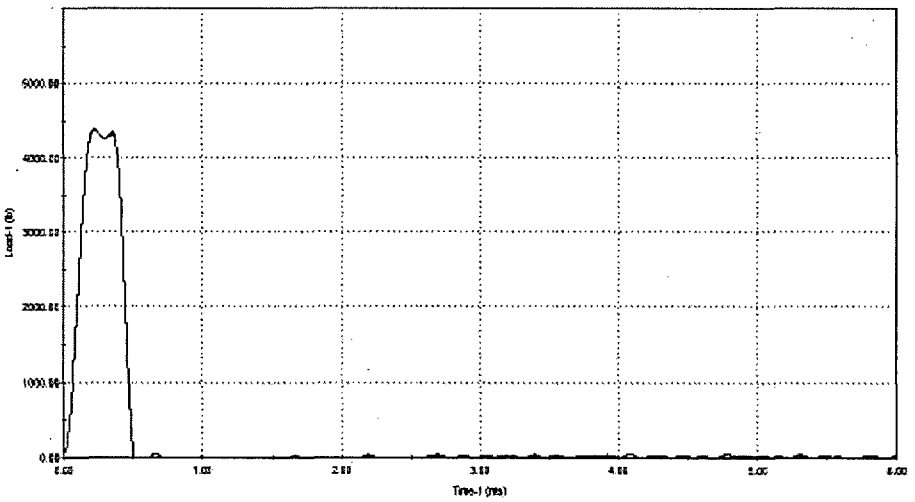

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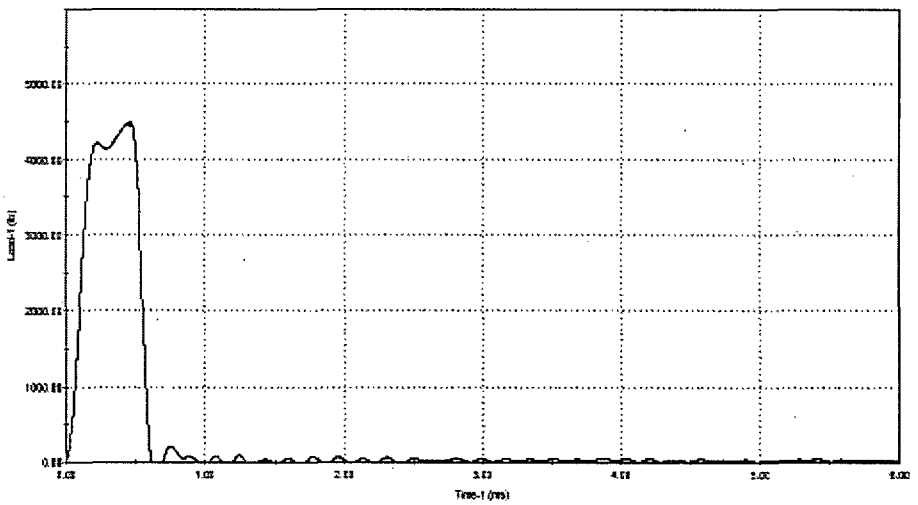

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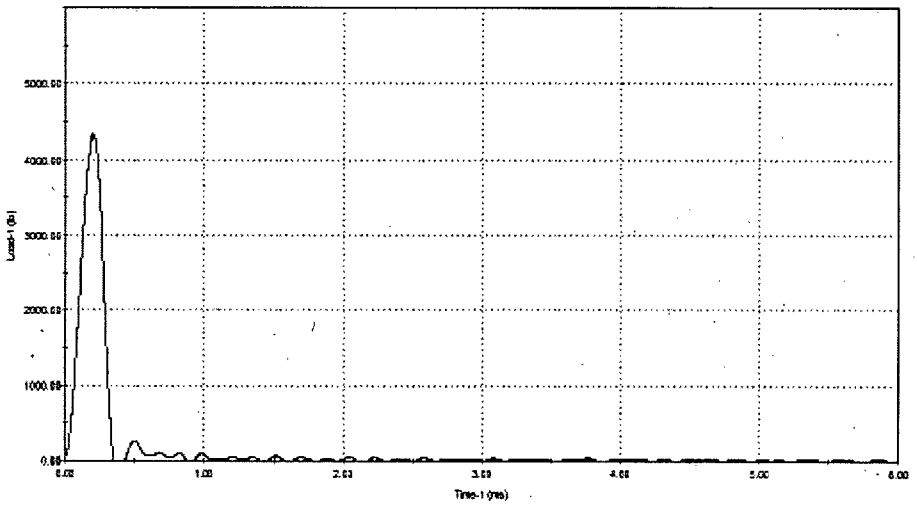

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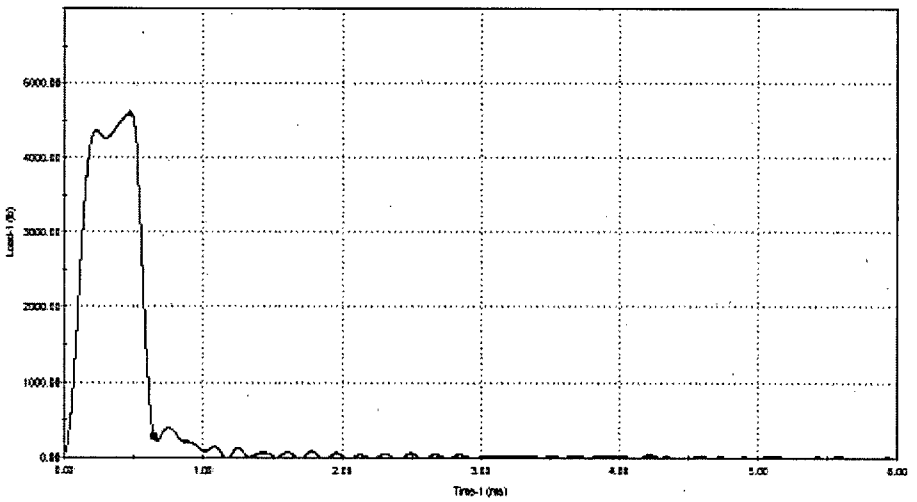

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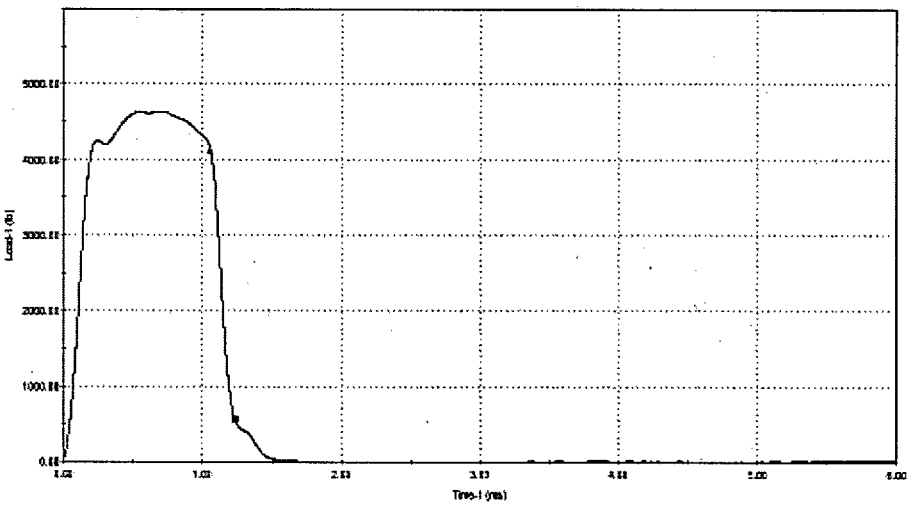

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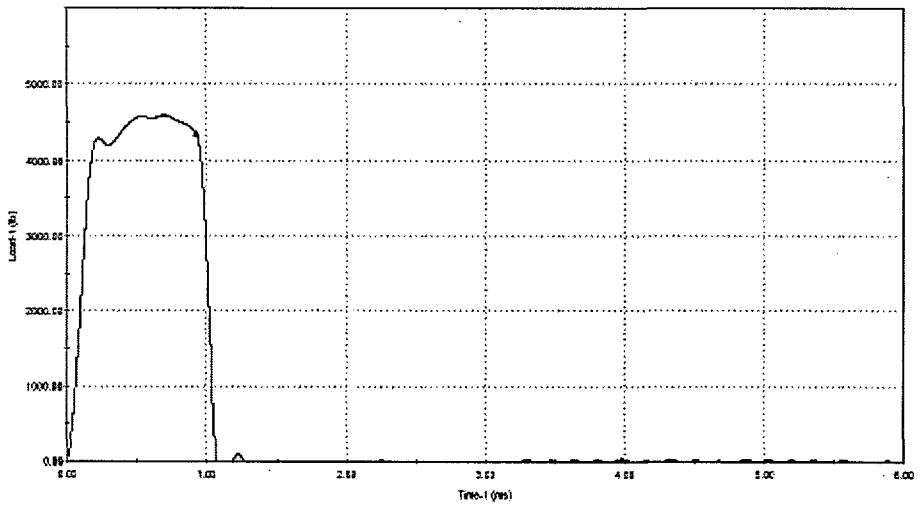

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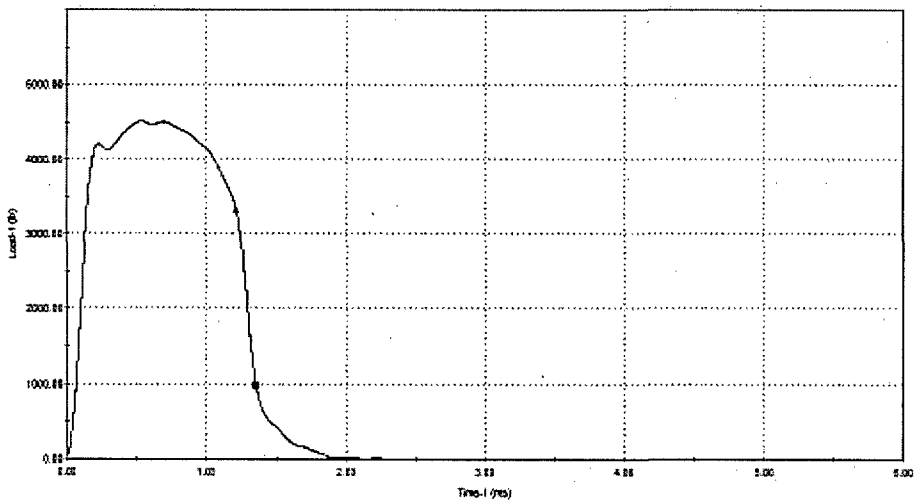

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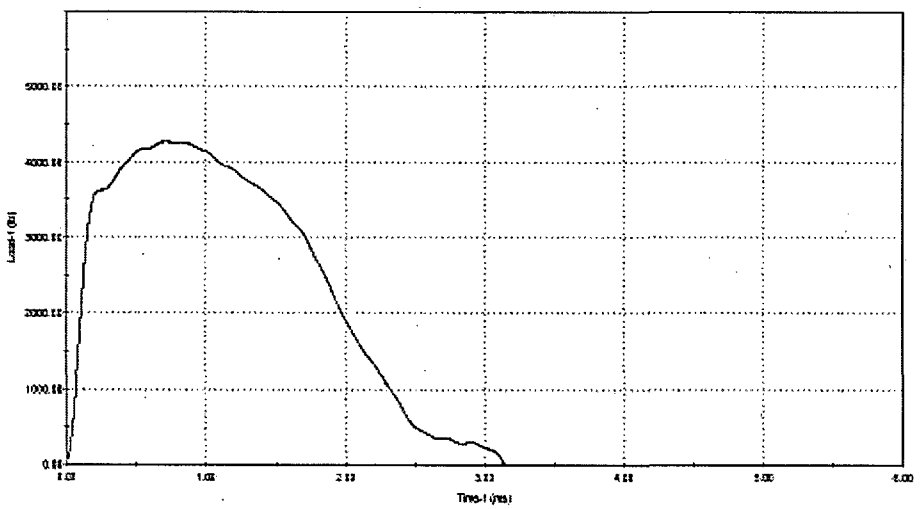

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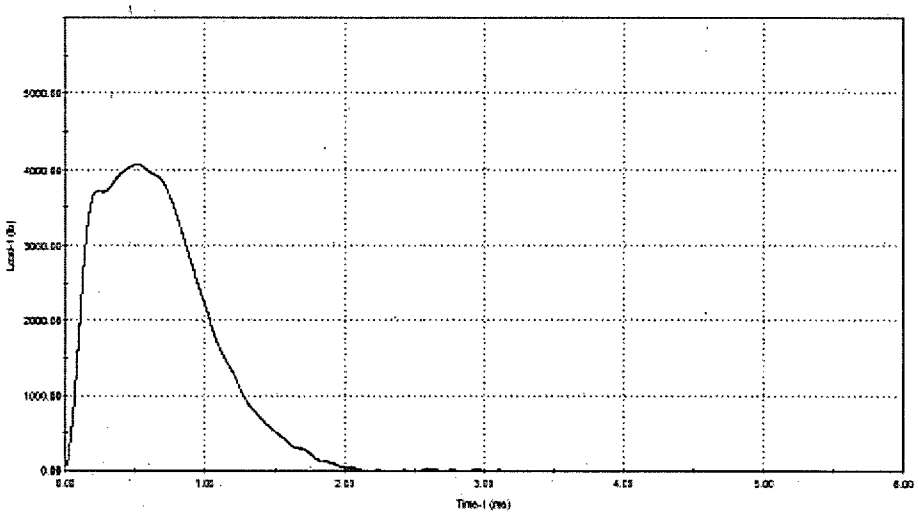
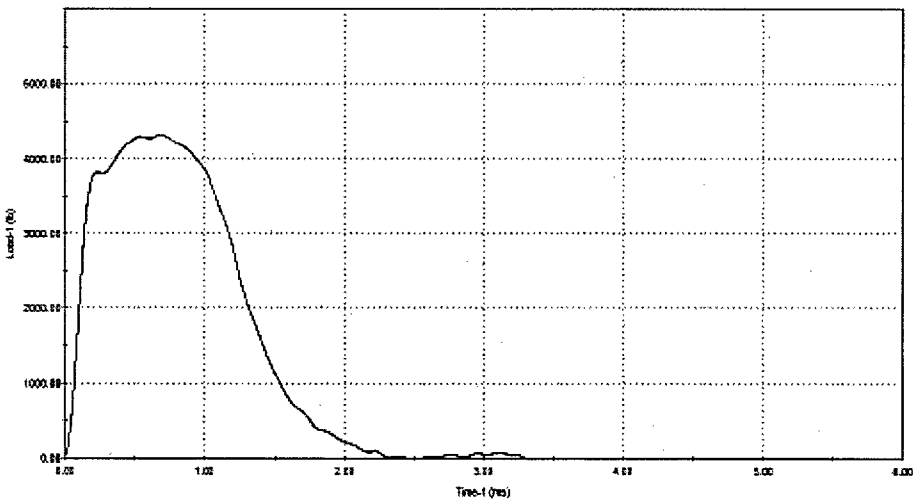
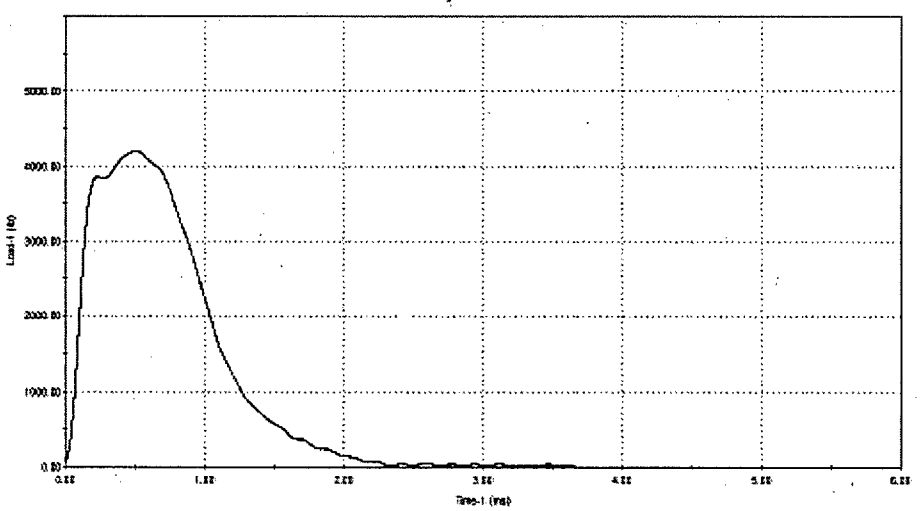


H49, 360°F



H51, 375°F



H44, 390°F

APPENDIX C
CHARPY V-NOTCH PLOTS FOR EACH CAPSULE USING SYMMETRIC HYPERBOLIC TANGENT CURVE-FITTING METHOD

Contained in Table C-1 are the upper shelf energy (USE) values used as input for the generation of the Charpy V-notch plots using CVGRAPH, Version 5.3 [C-1]. Per Reference C-1, CVGRAPH, Version 5.3 meets the Westinghouse QA program requirements. The use of CVGARPH 5.3 to fit the Charpy V-notch impact energy data for all capsules and baseline testing is the most accurate and consistent methodology available. Previous capsules relied upon manual free hand fits that are still valid today, but not necessarily the most consistent approach when comparing all of the capsule test data. Therefore, all previous testing and analyses are valid, but the new CVGARPH 5.3 results presented in this report, coupled with the updated fluence values for each capsule, provide the best representation of the total surveillance results for the R. E. Ginna surveillance program.

The definition for USE is given in ASTM E185-82 [C-2], Section 4.18, and reads as follows:

> "*upper shelf energy level* – the average energy value for all Charpy specimens (normally three) whose test temperature is above the upper end of the transition region. For specimens tested in sets of three at each test temperature, the set having the highest average may be regarded as defining the upper shelf energy."

If there are specimens tested in sets of three at each temperature, Westinghouse reports the set having the highest average energy as the USE (usually unirradiated material). If the specimens were not tested in sets of three at each temperature, Westinghouse reports the average of all Charpy data (≥ 95% shear) as the USE, excluding any values that are deemed outliers using engineering judgment. Hence, the USE values reported in Table C-1, which were used to generate the Charpy V-notch curves, were determined utilizing this methodology.

The lower shelf energy values were fixed at 2.2 ft-lb for all cases.

Table C-1 Upper Shelf Energy Values (ft-lb) Fixed in CVGRAPH

Material	Capsule					
	Unirradiated	V	R	T	S	N
Lower Shell Forging 125P666 (L-C)	174.6	(a)	147.8	142.5	142.5	142.3
Intermediate Shell Forging 125S255 (L-C)	140.0	(a)	142.2	152.3	139.0	134.3
Weld Metal (Heat # 61782)	79.0	(a)	48.9	52.7	52.2	51.9
HAZ Material	90.0	(a)	82.8	117.7	103.5	88.3

Note:

(a) No shear data was reported for Capsule V; therefore, the upper shelf was left free for CVGRAPH to determine from the tanh fit of the data.

CVGRAPH Version 5.3 plots of all surveillance data are provided in this appendix, on the pages following the reference list.

C.1 REFERENCES

C-1 CVGRAPH, Hyperbolic Tangent Curve-Fitting Program, Version 5.3, developed by ATI Consulting, December 2007. Sub-References:

(a) Westinghouse Calculation Note CN-PCAM-07-10, Revision 0, "CVGRAPH Version 5.3 Validation and Verification," December 2007.

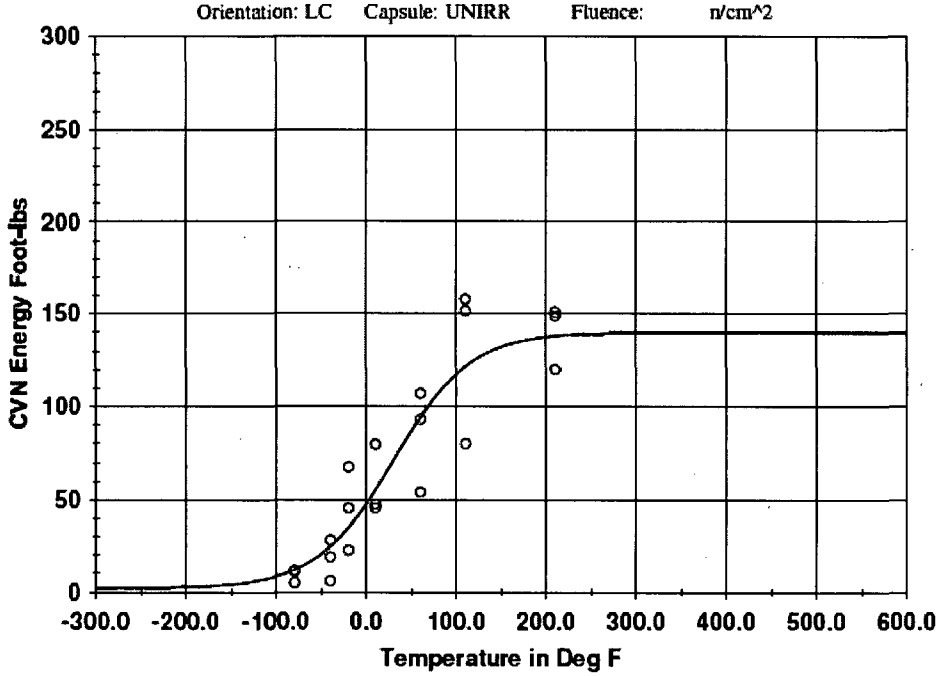
(b) WCAP-14370, Revision 0, "Use of the Hyperbolic Tangent Function for Fitting Transition Temperature Toughness Data," T. R. Mager, et al., May 1995.

(c) Westinghouse Letter LTR-PCAM-07-105, "Release of Program CVGraph 5.3 for Production Use," December 19, 2007.

C-2 ASTM E185-82, *Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels, E706 (IF),* ASTM, 1982.

Unirradiated Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/08/2009 10:19 PM
Page 1
Coefficients of Curve 1
A = 71.1 B = 68.9 C = 85.45 T0 = 29.82 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=140.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-28.9 Deg F Temp@50 ft-lbs=2.8 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	5.00	11.99	-6.99
-80.00	11.50	11.99	-.49
-80.00	11.00	11.99	-.99
-40.00	6.00	24.70	-18.70
-40.00	28.00	24.70	3.30
-40.00	19.00	24.70	-5.70
-20.00	45.50	34.94	10.56
-20.00	67.50	34.94	32.56
-20.00	22.50	34.94	-12.44

Unirradiated Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: UNIRR Fluence: n/cm^2

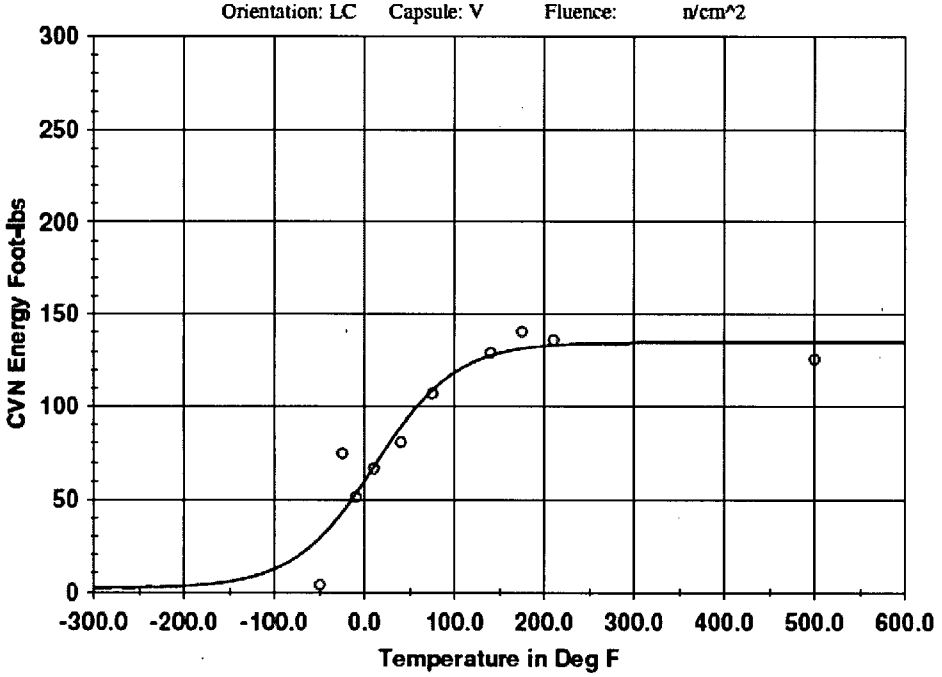
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
10.00	47.50	55.40	-7.90
10.00	79.50	55.40	24.10
10.00	45.50	55.40	-9.90
60.00	107.00	94.47	12.53
60.00	54.00	94.47	-40.47
60.00	93.00	94.47	-1.47
110.00	158.00	121.71	36.29
110.00	151.50	121.71	29.79
110.00	80.00	121.71	-41.71
210.00	151.00	138.00	13.00
210.00	120.00	138.00	-18.00
210.00	149.00	138.00	11.00

Correlation Coefficient = .917

Capsule V Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:12 AM
Page 1
Coefficients of Curve 1
A = 68.49 B = 66.29 C = 90.07 T0 = 11.28 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=134.8 Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-48.4 Deg F Temp@50 ft-lbs=-14.5 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	3.80	29.26	-25.46
-25.00	74.50	43.14	31.36
-10.00	51.30	53.11	-1.81
10.00	66.50	67.55	-1.05
40.00	80.50	88.94	-8.44
75.00	107.00	108.86	-1.86
140.00	129.00	127.58	1.42
175.00	140.50	131.37	9.13
210.00	136.00	133.19	2.81

Capsule V Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: V Fluence: n/cm^2

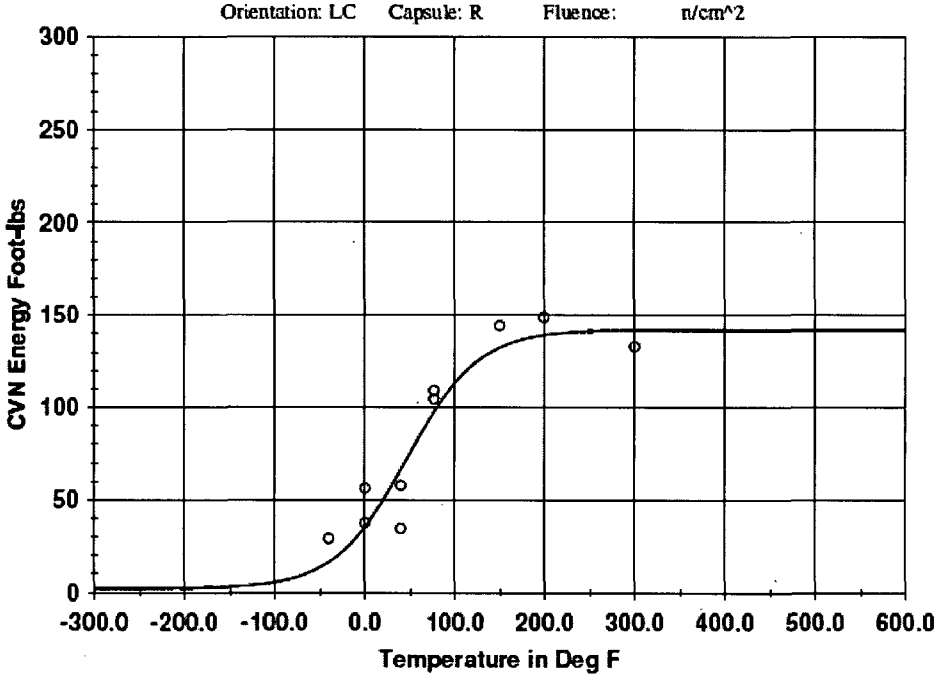
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
500.00	125.50	134.77	-9.27

Correlation Coefficient = .945

Capsule R Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:17 AM
Page 1
Coefficients of Curve 1
A = 72.2 B = 70. C = 79.49 T0 = 46.59 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=142.2(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-8.8 Deg F Temp@50 ft-lbs=20.5 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-40.00	29.00	16.44	12.56
.00	56.00	35.31	20.69
.00	37.50	35.31	2.19
40.00	57.50	66.41	-8.91
40.00	34.50	66.41	-31.91
77.00	109.00	97.75	11.25
77.00	104.50	97.75	6.75
150.00	144.50	132.54	11.96
199.00	149.00	139.24	9.76

Capsule R Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: R Fluence: n/cm^2

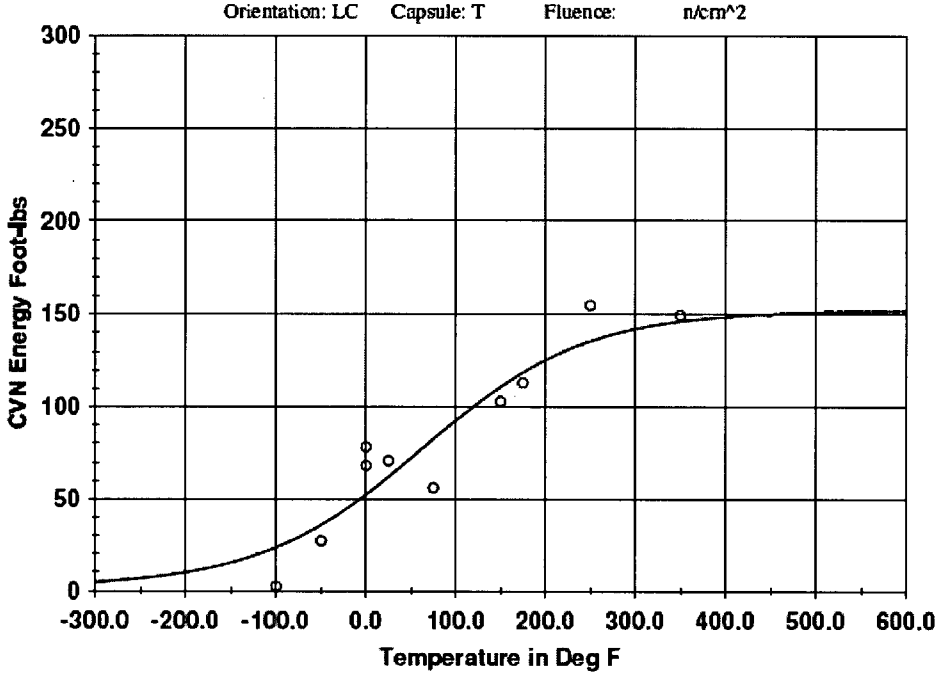
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
300.00	133.00	141.96	-8.96

Correlation Coefficient = .947

Capsule T Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:52 PM
Page 1
Coefficients of Curve 1
A = 77.22 B = 75.03 C = 180.72 T0 = 62.3 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=152.3(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-71.5 Deg F Temp@50 ft-lbs=-6.4 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: T Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	2.50	23.56	-21.06
-50.00	27.00	35.80	-8.80
.00	68.00	52.34	15.66
.00	78.00	52.34	25.66
25.00	70.50	61.96	8.54
75.00	56.00	82.49	-26.49
150.00	103.00	111.02	-8.02
175.00	113.00	118.76	-5.76
250.00	155.00	135.55	19.45

Capsule T Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: T Fluence: n/cm^2

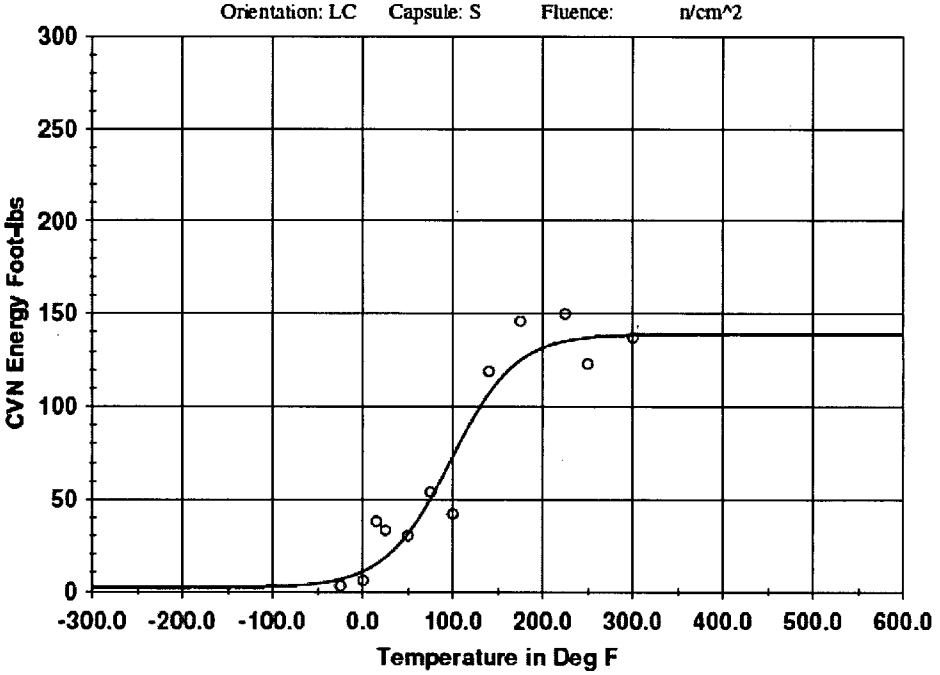
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
350.00	149.50	146.28	3.22

Correlation Coefficient = .937

Capsule S Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:57 PM
Page 1
Coefficients of Curve 1
A = 70.6 B = 68.4 C = 71.81 T0 = 96.92 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=139.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=47.9 Deg F Temp@50 ft-lbs=74.7 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-25.00	3.00	6.64	-3.64
.00	6.00	10.82	-4.82
15.00	38.00	14.88	23.12
25.00	33.00	18.46	14.54
50.00	30.00	31.34	-1.34
75.00	54.00	50.35	3.65
100.00	42.00	73.53	-31.53
140.00	119.00	107.33	11.67
175.00	146.00	125.04	20.96

Capsule S Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: S Fluence: n/cm^2

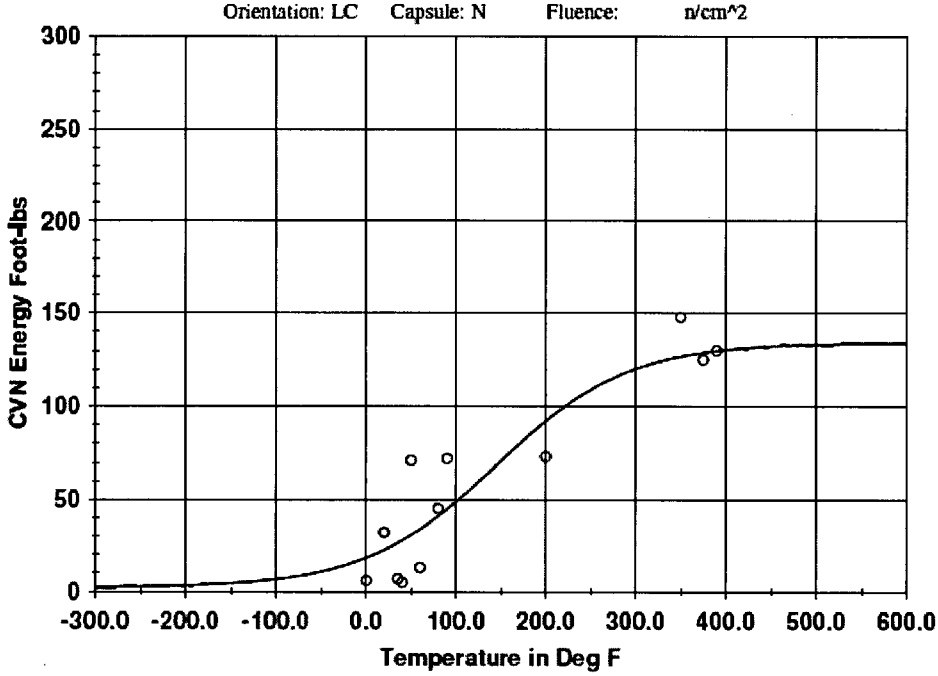
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
225.00	150.00	135.24	14.76
250.00	123.00	137.10	-14.10
300.00	137.00	138.52	-1.52

Correlation Coefficient = .961

Capsule N Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/05/2009 09:18 AM
Page 1
Coefficients of Curve 1
A = 68.25 B = 66.05 C = 146.43 T0 = 144.29 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=134.3(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=47.5 Deg F Temp@50 ft-lbs=102.8 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	6.00	18.36	-12.36
20.00	32.00	22.65	9.35
35.00	7.00	26.44	-19.44
40.00	5.00	27.82	-22.82
50.00	71.00	30.76	40.24
60.00	13.00	33.94	-20.94
80.00	45.00	40.98	4.02
90.00	72.00	44.83	27.17
200.00	73.00	92.23	-19.23

Capsule N Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: N Fluence: n/cm^2

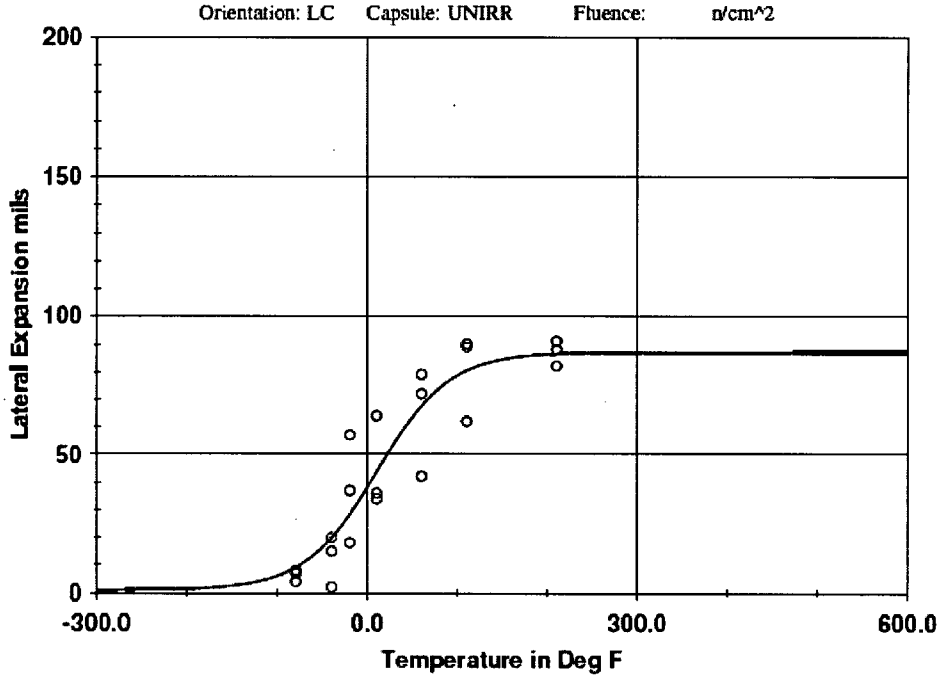
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
350.00	148.00	126.80	21.20
375.00	125.00	128.88	-3.88
390.00	130.00	129.85	.15

Correlation Coefficient = .915

Unirradiated Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/08/2009 10:20 PM
Page 1
Coefficients of Curve 1
A = 44. B = 43. C = 79.95 T0 = 10.36 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=87.0(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-6.6 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	4.00	9.12	-5.12
-80.00	7.00	9.12	-2.12
-80.00	8.00	9.12	-1.12
-40.00	2.00	20.01	-18.01
-40.00	20.00	20.01	-.01
-40.00	15.00	20.01	-5.01
-20.00	37.00	28.41	8.59
-20.00	57.00	28.41	28.59
-20.00	18.00	28.41	-10.41

Unirradiated Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: UNIRR Fluence: n/cm^2

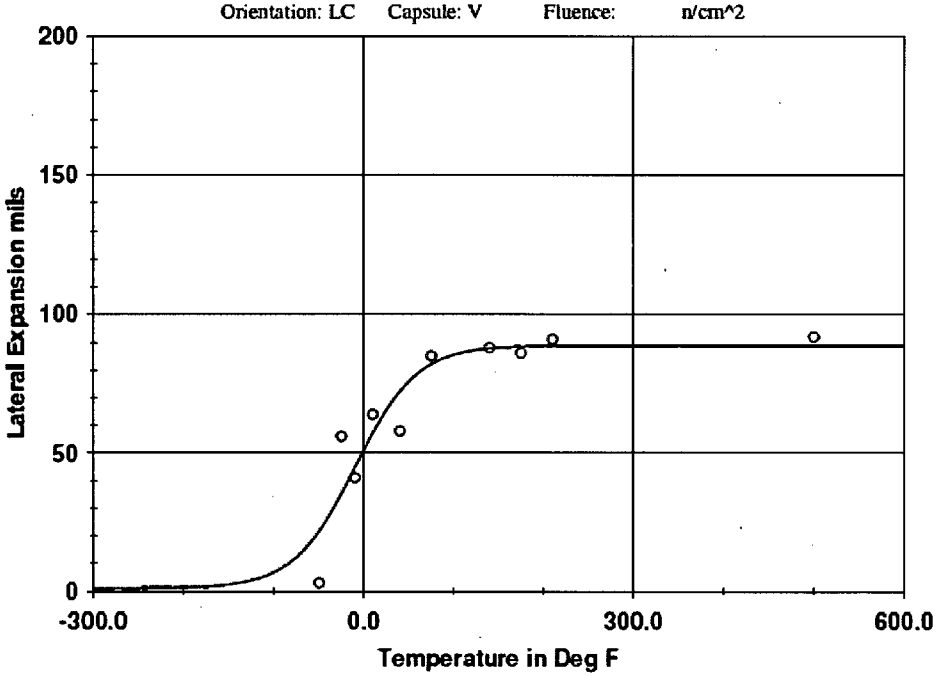
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
10.00	34.00	43.81	-9.81
10.00	64.00	43.81	20.19
10.00	36.00	43.81	-7.81
60.00	79.00	67.72	11.28
60.00	42.00	67.72	-25.72
60.00	72.00	67.72	4.28
110.00	89.00	80.43	8.57
110.00	90.00	80.43	9.57
110.00	62.00	80.43	-18.43
210.00	91.00	86.42	4.58
210.00	82.00	86.42	-4.42
210.00	88.00	86.42	1.58

Correlation Coefficient = .917

Capsule V Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:12 AM
Page 1
Coefficients of Curve 1
A = 44.92 B = 43.92 C = 68.36 T0 = -10.08 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=88.8 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-25.7 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	3.00	21.84	-18.84
-25.00	56.00	35.48	20.52
-10.00	41.00	44.97	-3.97
10.00	64.00	57.47	6.53
40.00	58.00	72.36	-14.36
75.00	85.00	82.12	2.88
140.00	88.00	87.77	.23
175.00	86.00	88.46	-2.46
210.00	91.00	88.71	2.29

Capsule V Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: V Fluence: n/cm^2

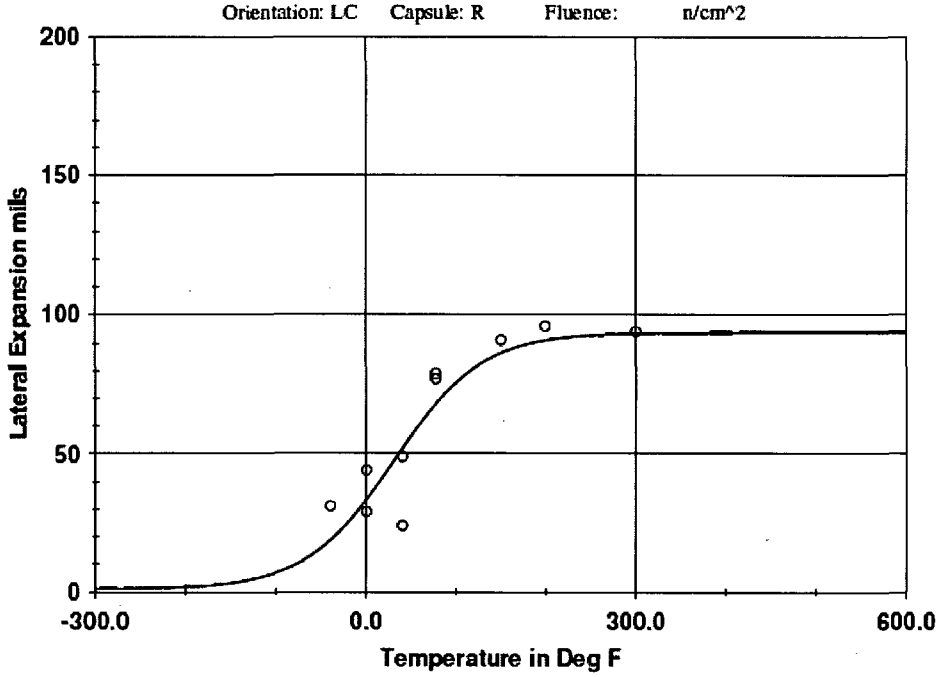
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
500.00	92.00	88.85	3.15

Correlation Coefficient = .925

Capsule R Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:18 AM
Page 1
Coefficients of Curve 1
A = 47.35 B = 46.35 C = 97.33 T0 = 30.06 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=93.7(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=3.5 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-40.00	31.00	18.76	12.24
.00	44.00	33.47	10.53
.00	29.00	33.47	-4.47
40.00	49.00	52.07	-3.07
40.00	24.00	52.07	-28.07
77.00	79.00	68.12	10.88
77.00	77.00	68.12	8.88
150.00	91.00	86.43	4.57
199.00	96.00	90.91	5.09

Capsule R Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: R Fluence: n/cm^2

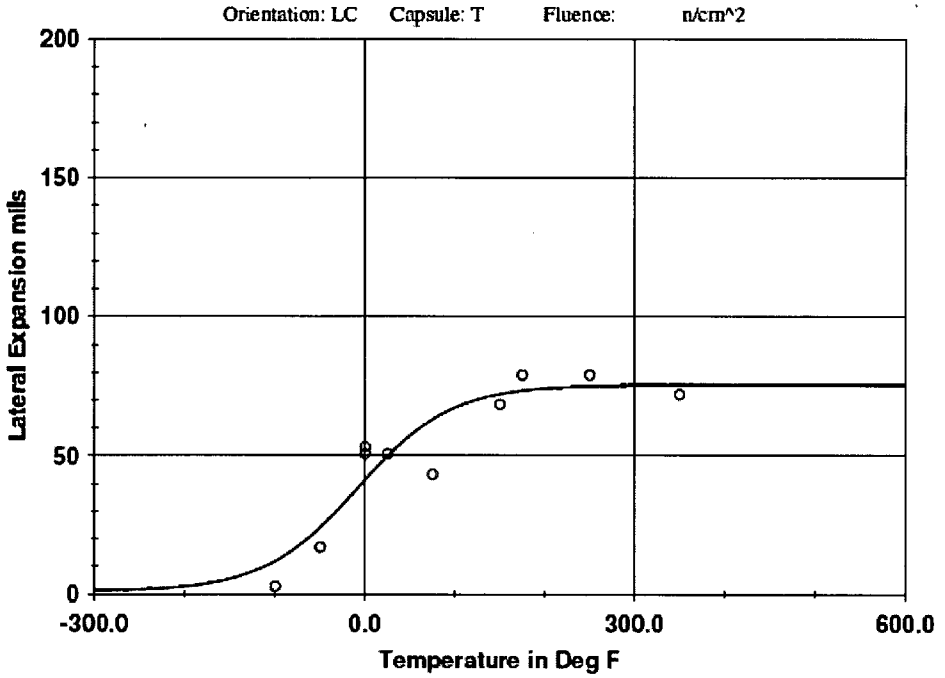
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
300.00	94.00	93.34	.66

Correlation Coefficient = .910

Capsule T Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:54 PM
Page 1
Coefficients of Curve 1
A = 38.25 B = 37.25 C = 103.65 T0 = -8.84 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=75.5(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-17.9 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: T Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-100.00	2.80	11.94	-9.14
-50.00	16.90	24.19	-7.29
.00	50.80	41.42	9.38
.00	53.20	41.42	11.78
25.00	50.80	50.00	.80
75.00	43.30	63.17	-19.87
150.00	68.50	72.18	-3.68
175.00	79.00	73.41	5.59
250.00	79.00	75.00	4.00

Capsule T Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: T Fluence: n/cm^2

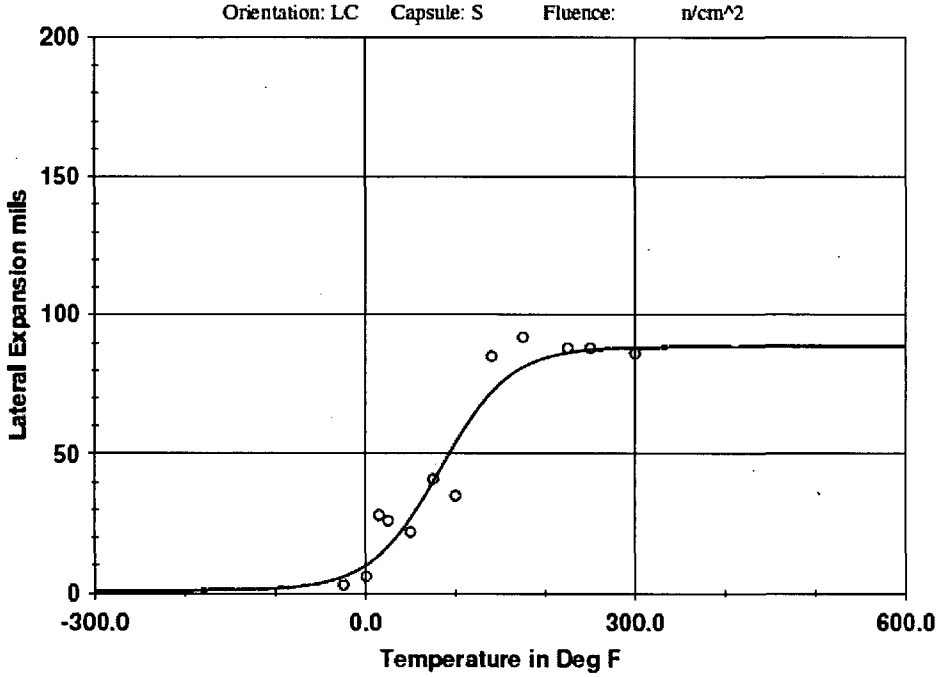
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
350.00	72.00	75.43	-3.43

Correlation Coefficient = .928

Capsule S Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:57 PM
Page 1
Coefficients of Curve 1
A = 44.75 B = 43.75 C = 77.23 T0 = 83.14 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=88.5(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=65.7 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-25.00	3.00	6.01	-3.01
.00	6.00	10.10	-4.10
15.00	28.00	13.79	14.21
25.00	26.00	16.89	9.11
50.00	22.00	27.05	-5.05
75.00	41.00	40.16	.84
100.00	35.00	54.15	-19.15
140.00	85.00	72.18	12.82
175.00	92.00	81.08	10.92

Capsule S Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: S Fluence: n/cm^2

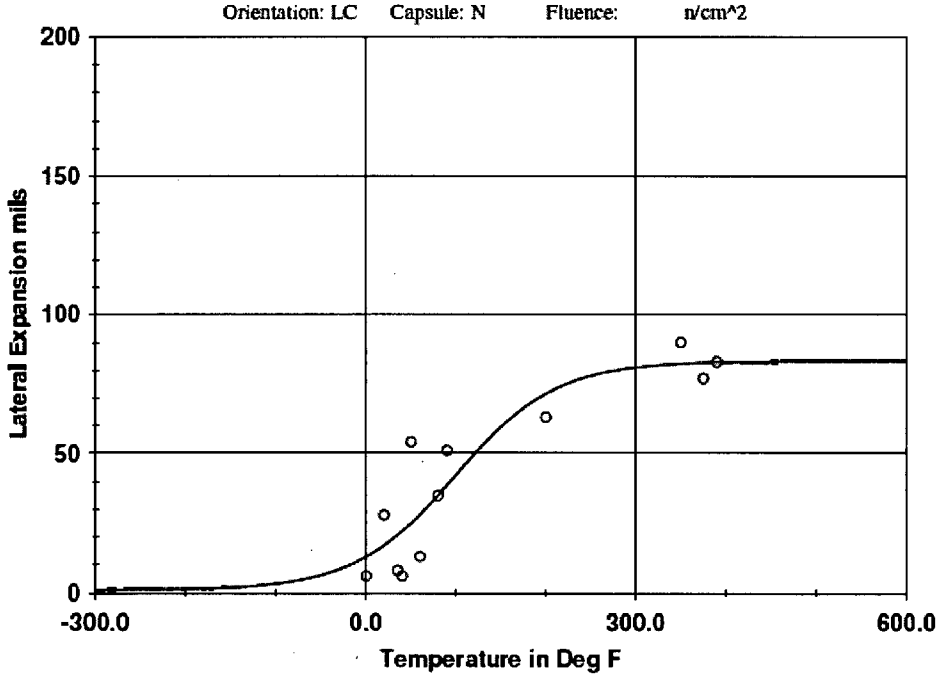
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
225.00	88.00	86.33	1.67
250.00	88.00	87.35	.65
300.00	86.00	88.18	-2.18

Correlation Coefficient = .963

Capsule N Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/05/2009 09:19 AM
Page 1
Coefficients of Curve 1
A = 42.15 B = 41.15 C = 112.11 T0 = 99.29 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=83.3(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=79.7 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	6.00	12.96	-6.96
20.00	28.00	17.09	10.91
35.00	8.00	20.84	-12.84
40.00	6.00	22.21	-16.21
50.00	54.00	25.14	28.86
60.00	13.00	28.29	-15.29
80.00	35.00	35.14	-.14
90.00	51.00	38.75	12.25
200.00	63.00	71.59	-8.59

Capsule N Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: N Fluence: n/cm^2

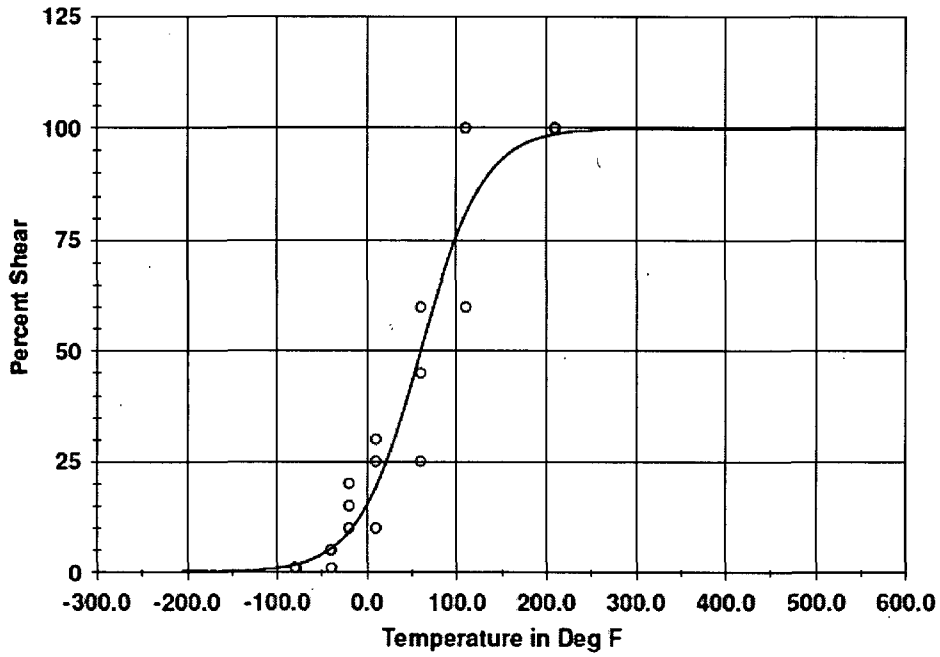
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
350.00	90.00	82.37	7.63
375.00	77.00	82.70	-5.70
390.00	83.00	82.84	.16

Correlation Coefficient = .903

Unirradiated Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:07 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 69.54 T0 = 59.9 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 60.0
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	1.00	1.76	-.76
-80.00	1.00	1.76	-.76
-80.00	1.00	1.76	-.76
-40.00	1.00	5.35	-4.35
-40.00	5.00	5.35	-.35
-40.00	5.00	5.35	-.35
-20.00	15.00	9.13	5.87
-20.00	20.00	9.13	10.87
-20.00	10.00	9.13	.87

Unirradiated Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: UNIRR Fluence: n/cm^2

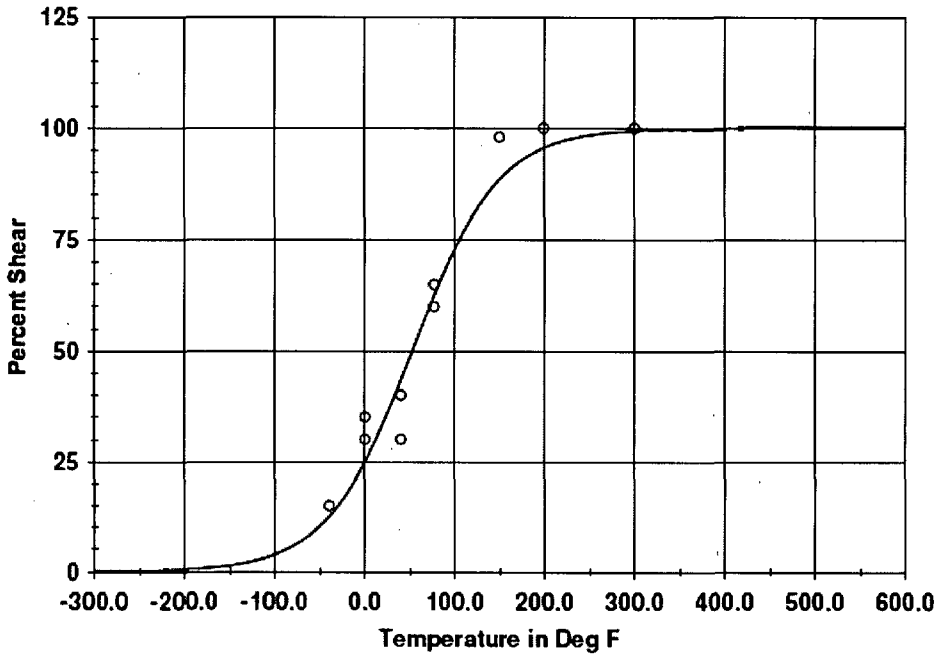
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
10.00	25.00	19.23	5.77
10.00	30.00	19.23	10.77
10.00	10.00	19.23	-9.23
60.00	60.00	50.07	9.93
60.00	25.00	50.07	-25.07
60.00	45.00	50.07	-5.07
110.00	100.00	80.86	19.14
110.00	100.00	80.86	19.14
110.00	60.00	80.86	-20.86
210.00	100.00	98.68	1.32
210.00	100.00	98.68	1.32
210.00	100.00	98.68	1.32

Correlation Coefficient = .962

Capsule R Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:18 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 95.37 T0 = 52.44 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 52.5
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-40.00	15.00	12.58	2.42
.00	35.00	24.98	10.02
.00	30.00	24.98	5.02
40.00	40.00	43.52	-3.52
40.00	30.00	43.52	-13.52
77.00	65.00	62.60	2.40
77.00	60.00	62.60	-2.60
150.00	98.00	88.55	9.45
199.00	100.00	95.58	4.42

Capsule R Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: R Fluence: n/cm^2

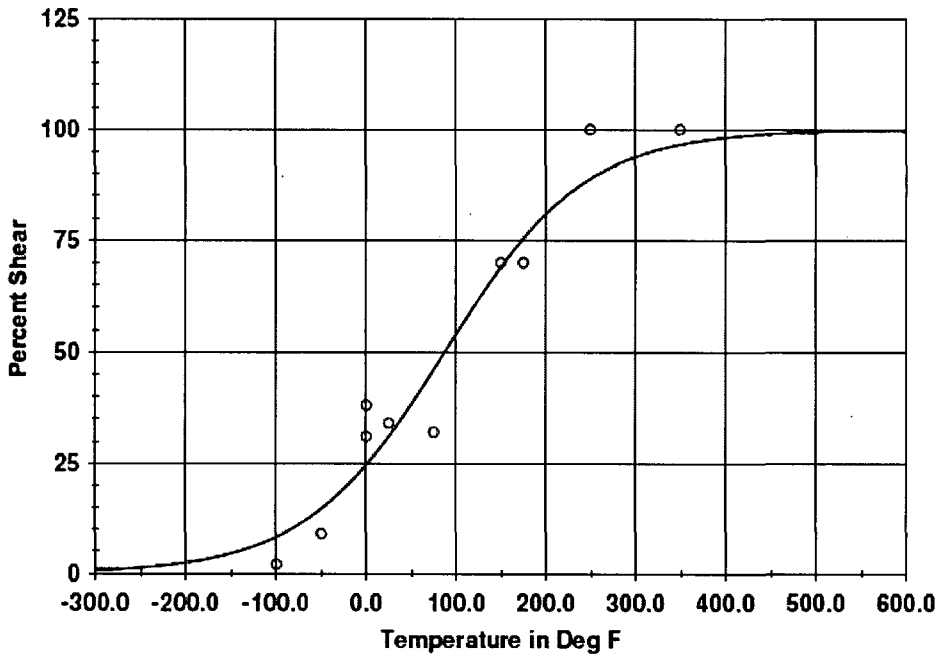
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
300.00	100.00	99.45	.55

Correlation Coefficient = .977

Capsule T Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:54 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 156.06 T0 = 87.32 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 87.4
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: T Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100.00	2.00	8.31	-6.31
-50.00	9.00	14.68	-5.68
.00	31.00	24.62	6.38
.00	38.00	24.62	13.38
25.00	34.00	31.03	2.97
75.00	32.00	46.06	-14.06
150.00	70.00	69.07	.93
175.00	70.00	75.47	-5.47
250.00	100.00	88.94	11.06

Capsule T Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: T Fluence: n/cm^2

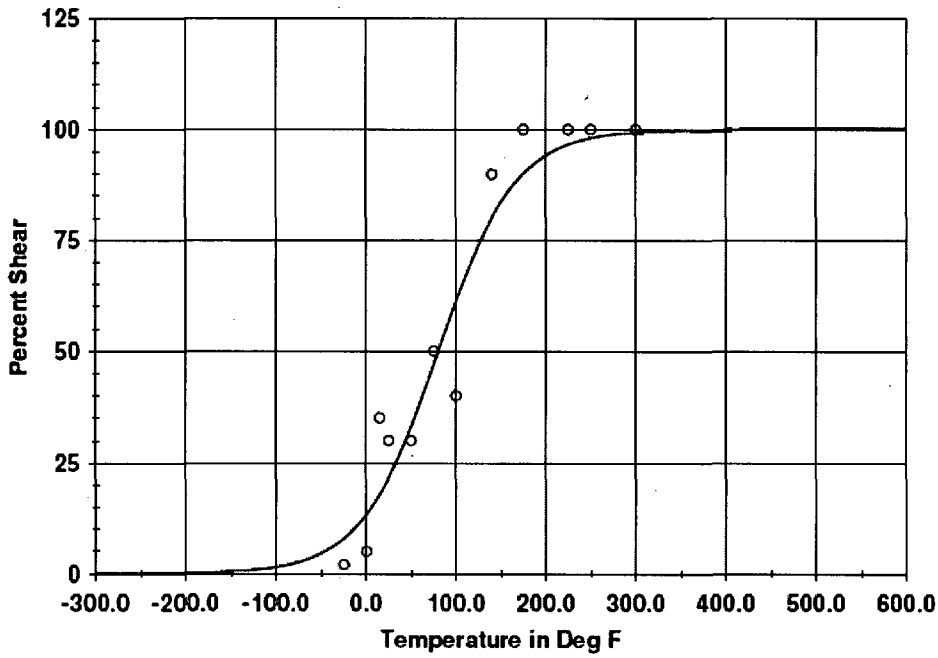
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
350.00	100.00	96.66	3.34

Correlation Coefficient = .970

Capsule S Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/09/2009 08:58 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 85.92 T0 = 79.99 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 80.0
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-25.00	2.00	7.99	-5.99
.00	5.00	13.45	-8.45
15.00	35.00	18.05	16.95
25.00	30.00	21.75	8.25
50.00	30.00	33.22	-3.22
75.00	50.00	47.10	2.90
100.00	40.00	61.44	-21.44
140.00	90.00	80.17	9.83
175.00	100.00	90.13	9.87

Capsule S Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: S Fluence: n/cm^2

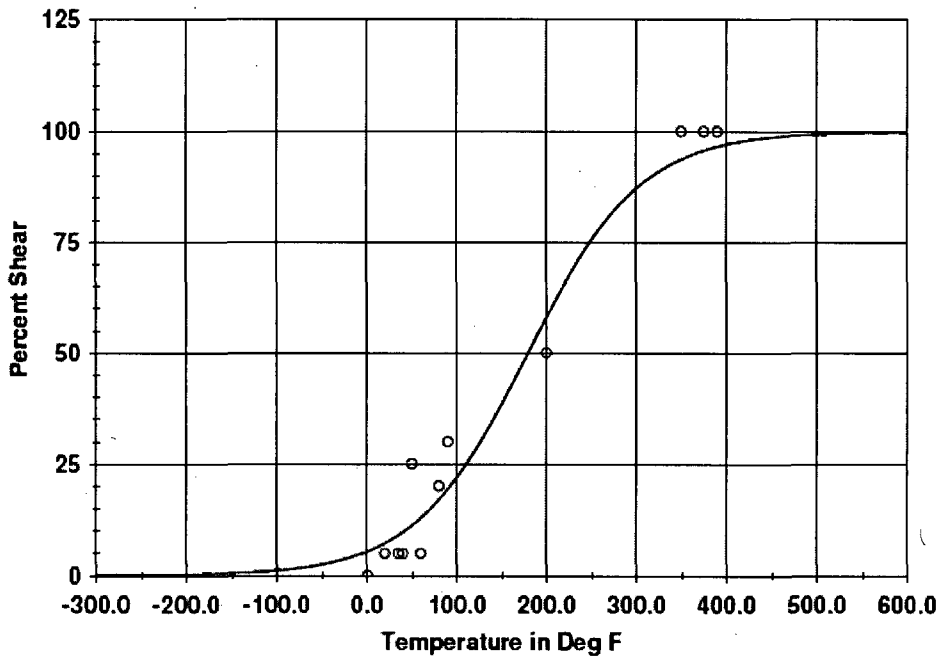
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
225.00	100.00	96.69	3.31
250.00	100.00	98.13	1.87
300.00	100.00	99.41	.59

Correlation Coefficient = .966

Capsule N Intermediate Shell Forging 125S255

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/05/2009 09:20 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 125.47 T0 = 179.32 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 179.4
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	.00	5.42	-5.42
20.00	5.00	7.31	-2.31
35.00	5.00	9.11	-4.11
40.00	5.00	9.79	-4.79
50.00	25.00	11.29	13.71
60.00	5.00	12.99	-7.99
80.00	20.00	17.03	2.97
90.00	30.00	19.41	10.59
200.00	50.00	58.17	-8.17

Capsule N Intermediate Shell Forging 125S255

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125S255
Orientation: LC Capsule: N Fluence: n/cm^2

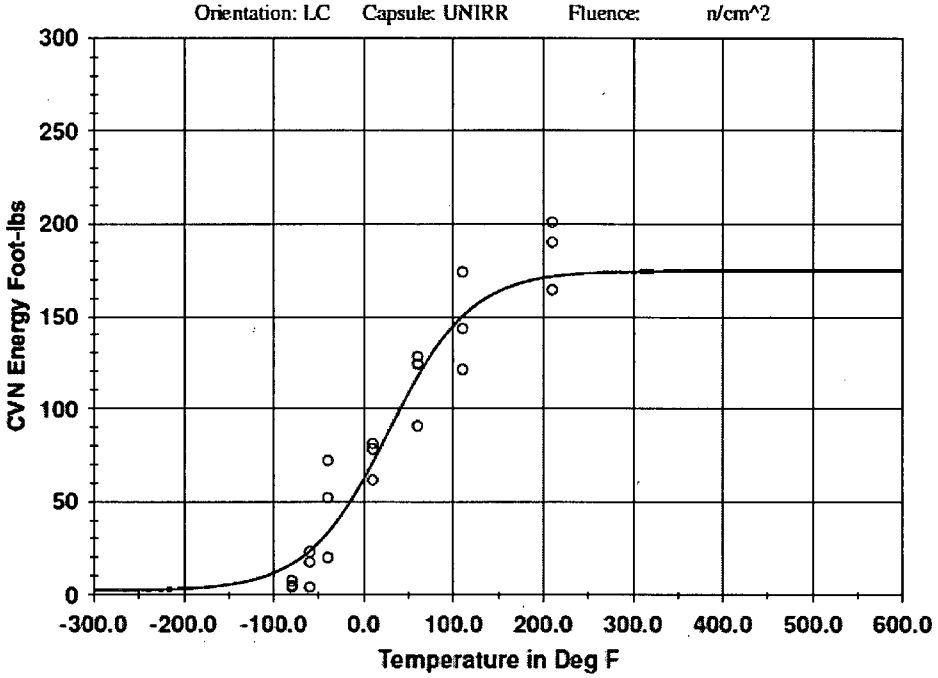
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
350.00	100.00	93.82	6.18
375.00	100.00	95.77	4.23
390.00	100.00	96.64	3.36

Correlation Coefficient = .985

Unirradiated Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:10 AM
Page 1
Coefficients of Curve 1
A = 88.4 B = 86.2 C = 90.59 T0 = 28.44 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=174.6(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-46.2 Deg F Temp@50 ft-lbs=-14.9 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	7.50	16.62	-9.12
-80.00	4.00	16.62	-12.62
-80.00	5.00	16.62	-11.62
-60.00	23.00	23.62	-.62
-60.00	4.00	23.62	-19.62
-60.00	17.50	23.62	-6.12
-40.00	20.00	33.37	-13.37
-40.00	52.00	33.37	18.63
-40.00	72.00	33.37	38.63

Unirradiated Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: UNIRR Fluence: n/cm^2

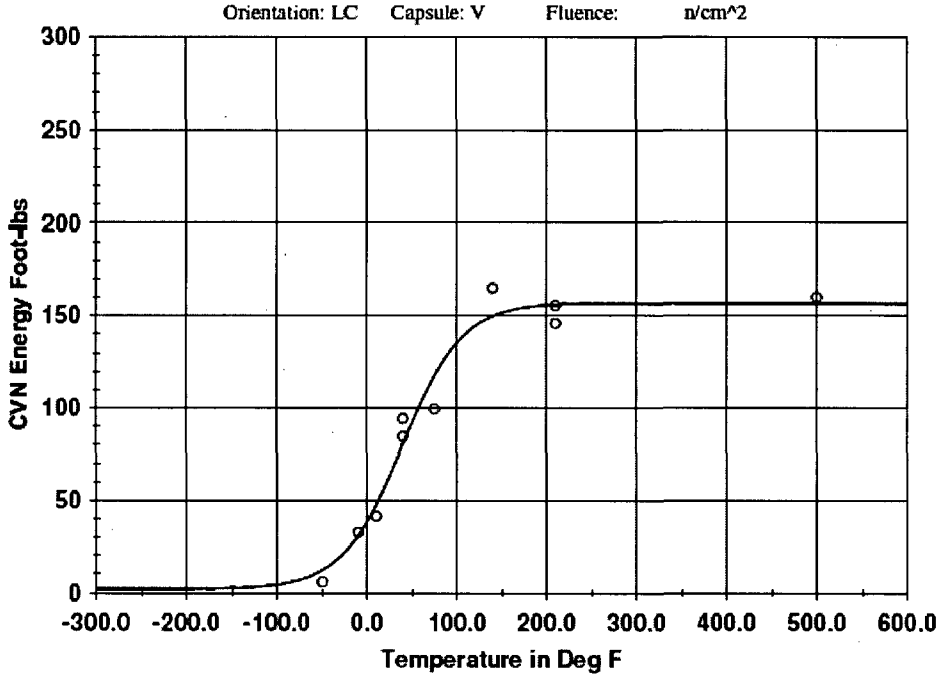
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
10.00	61.50	71.09	-9.59
10.00	81.00	71.09	9.91
10.00	78.00	71.09	6.91
60.00	128.00	117.27	10.73
60.00	90.50	117.27	-26.77
60.00	124.00	117.27	6.73
110.00	121.00	150.16	-29.16
110.00	174.00	150.16	23.84
110.00	143.50	150.16	-6.66
210.00	190.00	171.53	18.47
210.00	164.50	171.53	-7.03
210.00	201.00	171.53	29.47

Correlation Coefficient = .962

Capsule V Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 11:56 AM
Page 1
Coefficients of Curve 1
A = 79.61 B = 77.41 C = 66.66 T0 = 39.09 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=157.0 Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-11.5 Deg F Temp@50 ft-lbs=12.3 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	5.80	12.20	-6.40
-10.00	32.50	31.07	1.43
10.00	41.30	47.82	-6.52
40.00	84.50	80.66	3.84
40.00	94.30	80.66	13.64
75.00	99.50	117.69	-18.19
140.00	165.00	149.86	15.14
210.00	146.00	156.10	-10.10
210.00	155.50	156.10	-.60

Capsule V Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: V Fluence: n/cm^2

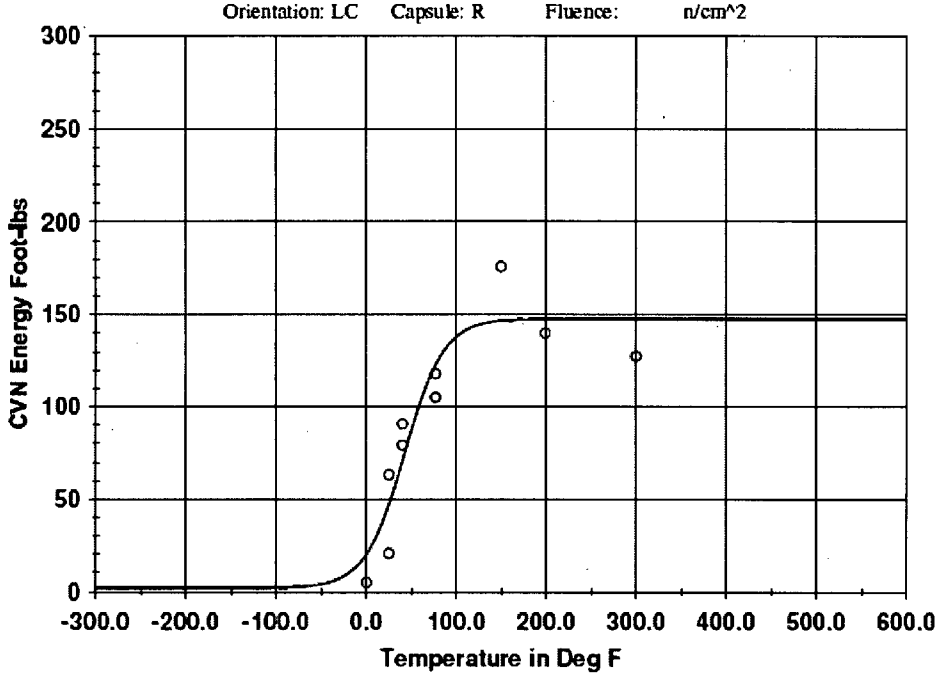
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
500.00	160.00	157.02	2.98

Correlation Coefficient = .984

Capsule R Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:06 PM
Page 1
Coefficients of Curve 1
A = 75. B = 72.8 C = 43.38 T0 = 42.54 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=147.8(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=11.3 Deg F Temp@50 ft-lbs=27.1 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	5.00	20.16	-15.16
25.00	63.00	47.07	15.93
25.00	20.50	47.07	-26.57
40.00	79.00	70.74	8.26
40.00	90.50	70.74	19.76
77.00	105.00	123.11	-18.11
77.00	118.00	123.11	-5.11
150.00	176.00	146.78	29.22
199.00	140.00	147.69	-7.69

Capsule R Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: R Fluence: n/cm^2

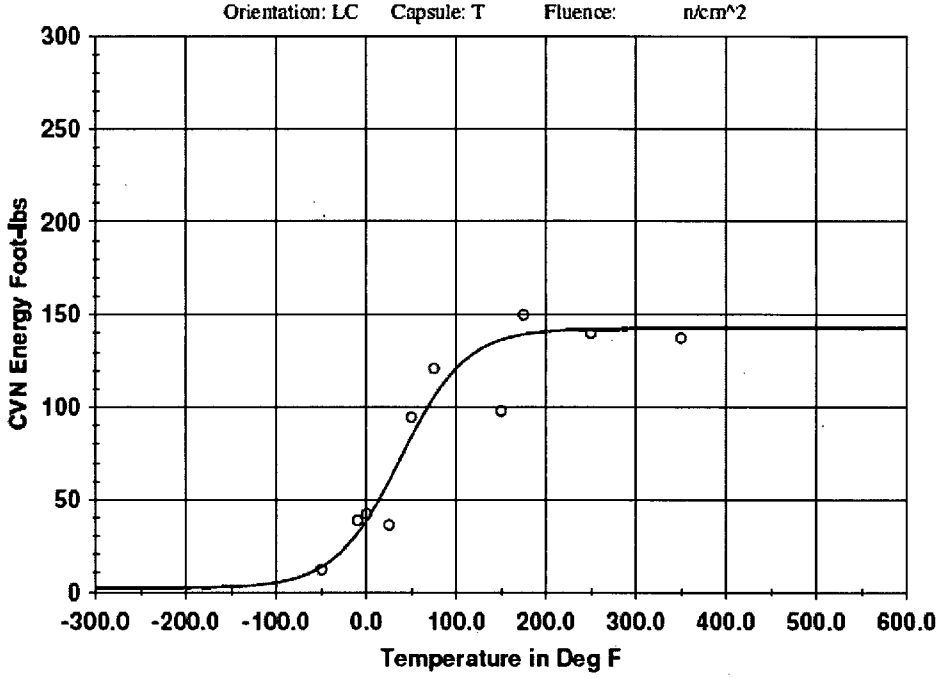
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
300.00	127.50	147.80	-20.30

Correlation Coefficient = .932

Capsule T Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:09 PM
Page 1
Coefficients of Curve 1
A = 72.35 B = 70.15 C = 72.13 T0 = 37.8 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=142.5(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-12.6 Deg F Temp@50 ft-lbs=14.0 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: T Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	12.00	13.51	-1.51
-10.00	38.50	31.65	6.85
.00	42.00	38.62	3.38
25.00	36.00	60.03	-24.03
50.00	94.50	84.10	10.40
75.00	121.00	105.63	15.37
150.00	98.00	136.51	-38.51
175.00	150.00	139.44	10.56
250.00	140.00	142.11	-2.11

Capsule T Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: T Fluence: n/cm^2

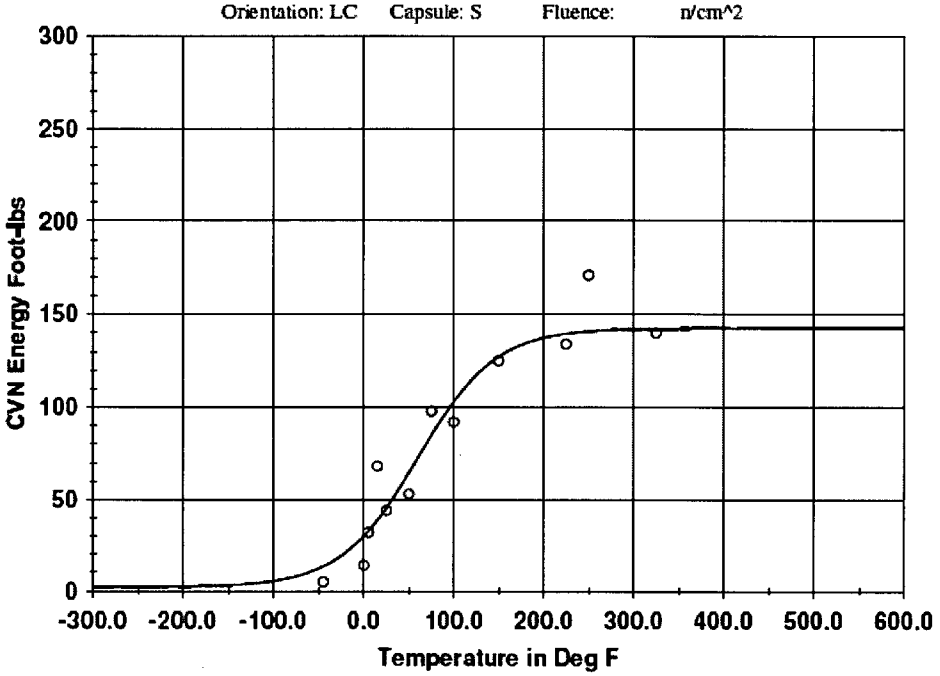
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
350.00	137.50	142.48	-4.98

Correlation Coefficient = .945

Capsule S Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:13 PM
Page 1
Coefficients of Curve 1
A = 72.35 B = 70.15 C = 85.77 T0 = 59.55 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=142.5(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-.4 Deg F Temp@50 ft-lbs=31.3 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-45.00	5.00	13.47	-8.47
.00	14.00	30.21	-16.21
5.00	32.00	32.92	-.92
15.00	68.00	38.87	29.13
25.00	44.00	45.53	-1.53
50.00	53.00	64.57	-11.57
75.00	98.00	84.85	13.15
100.00	92.00	103.18	-11.18
150.00	125.00	127.32	-2.32

Capsule S Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: S Fluence: n/cm^2

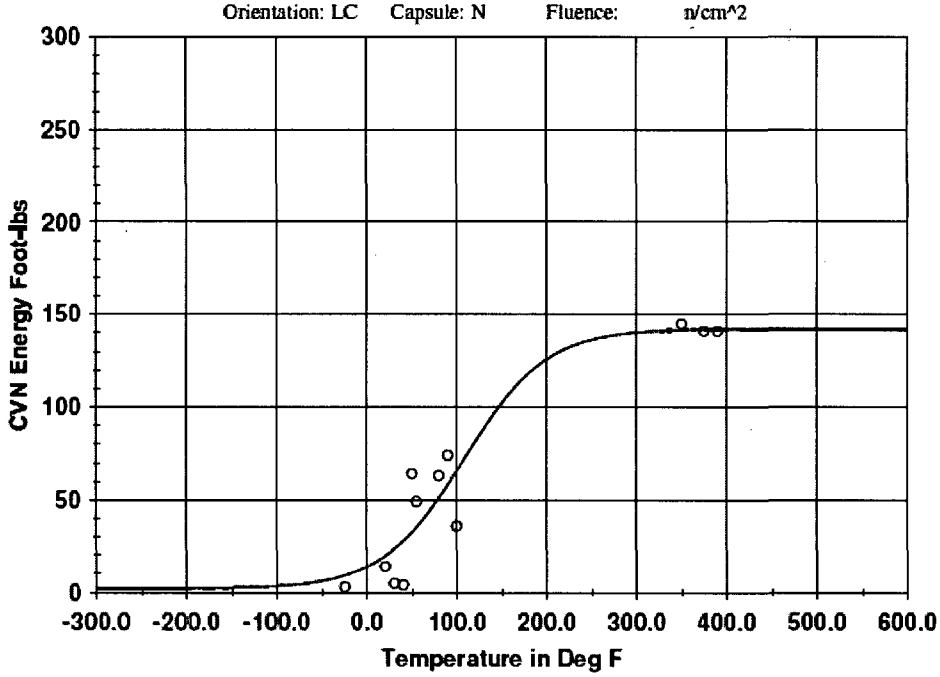
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
225.00	134.00	139.60	-5.60
250.00	171.00	140.87	30.13
325.00	140.00	142.21	-2.21

Correlation Coefficient = .960

Capsule N Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/11/2009 09:09 AM
Page 1
Coefficients of Curve 1
A = 72.25 B = 70.05 C = 90.88 T0 = 108.24 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=142.3(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=44.9 Deg F Temp@50 ft-lbs=78.4 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-25.00	3.00	9.29	-6.29
20.00	14.00	19.77	-5.77
30.00	5.00	23.44	-18.44
40.00	4.00	27.72	-23.72
50.00	64.00	32.64	31.36
55.00	49.00	35.34	13.66
80.00	63.00	51.16	11.84
90.00	74.00	58.37	15.63
100.00	36.00	65.91	-29.91

Capsule N Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: N Fluence: n/cm^2

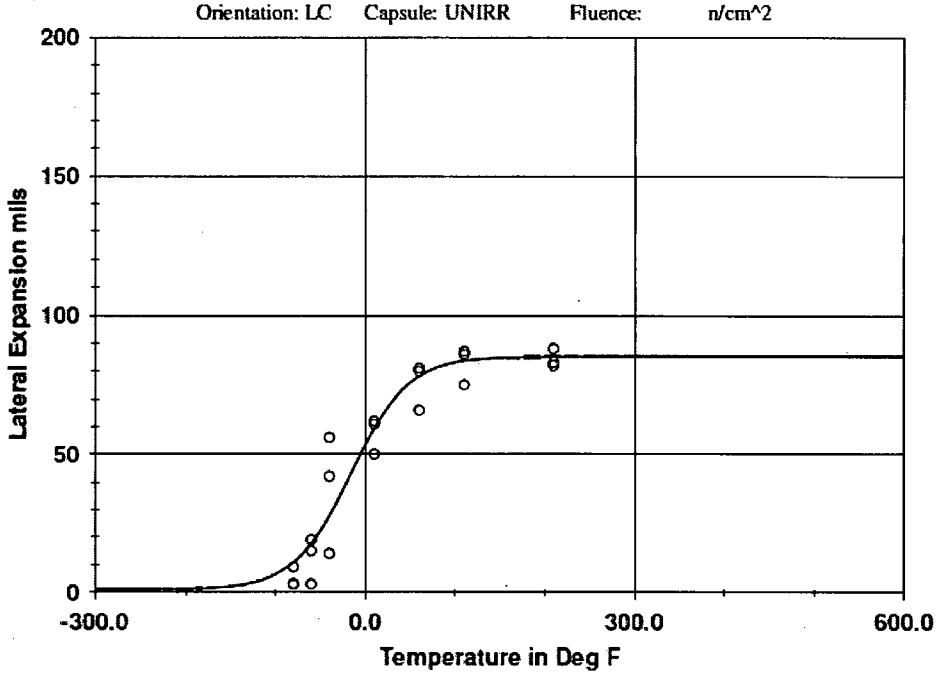
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
350.00	145.00	141.62	3.38
375.00	141.00	141.91	-.91
390.00	141.00	142.02	-1.02

Correlation Coefficient = .946

Unirradiated Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:12 AM
Page 1
Coefficients of Curve 1
A = 43.1 B = 42.1 C = 63.27 T0 = -15.97 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=85.2(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-28.2 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	9.00	10.83	-1.83
-80.00	3.00	10.83	-7.83
-80.00	3.00	10.83	-7.83
-60.00	19.00	17.77	1.23
-60.00	3.00	17.77	-14.77
-60.00	15.00	17.77	-2.77
-40.00	14.00	27.84	-13.84
-40.00	42.00	27.84	14.16
-40.00	56.00	27.84	28.16

Unirradiated Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: UNIRR Fluence: n/cm^2

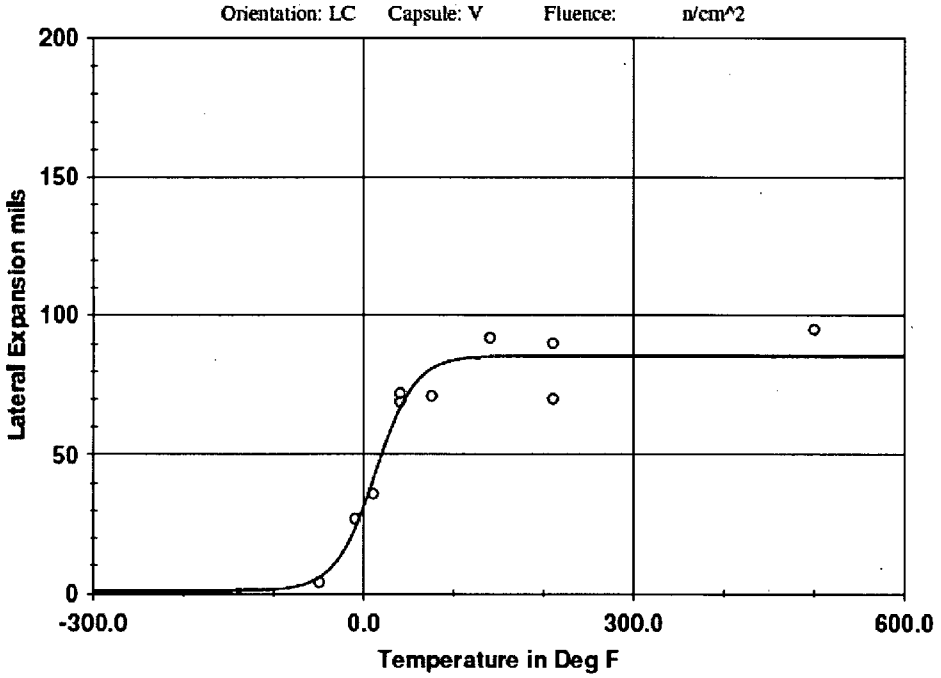
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
10.00	50.00	59.47	-9.47
10.00	62.00	59.47	2.53
10.00	61.00	59.47	1.53
60.00	81.00	78.21	2.79
60.00	66.00	78.21	-12.21
60.00	80.00	78.21	1.79
110.00	75.00	83.66	-8.66
110.00	86.00	83.66	2.34
110.00	87.00	83.66	3.34
210.00	88.00	85.13	2.87
210.00	82.00	85.13	-3.13
210.00	83.00	85.13	-2.13

Correlation Coefficient = .954

Capsule V Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:01 PM
Page 1
Coefficients of Curve 1
A = 43.24 B = 42.24 C = 44.25 T0 = 12.09 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=85.5 Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=3.4 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	4.00	5.81	-1.81
-10.00	27.00	23.75	3.25
10.00	36.00	41.25	-5.25
40.00	69.00	66.84	2.16
40.00	72.00	66.84	5.16
75.00	71.00	80.84	-9.84
140.00	92.00	85.23	6.77
210.00	70.00	85.47	-15.47
210.00	90.00	85.47	4.53

Capsule V Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: V Fluence: n/cm^2

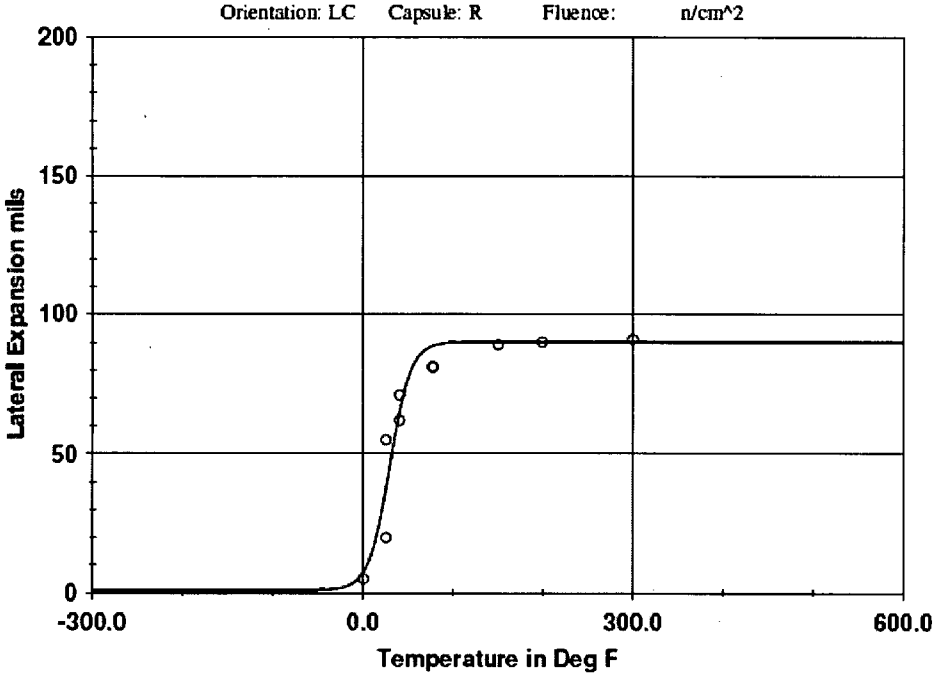
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
500.00	95.00	85.49	9.51

Correlation Coefficient = .965

Capsule R Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:07 PM
Page 1
Coefficients of Curve 1
A = 45.5 B = 44.5 C = 22.93 T0 = 29.06 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=90.0(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=23.6 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	5.00	7.54	-2.54
25.00	55.00	37.70	17.30
25.00	20.00	37.70	-17.70
40.00	62.00	65.26	-3.26
40.00	71.00	65.26	5.74
77.00	81.00	88.66	-7.66
77.00	81.00	88.66	-7.66
150.00	89.00	90.00	-1.00
199.00	90.00	90.00	.00

Capsule R Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: R Fluence: n/cm^2

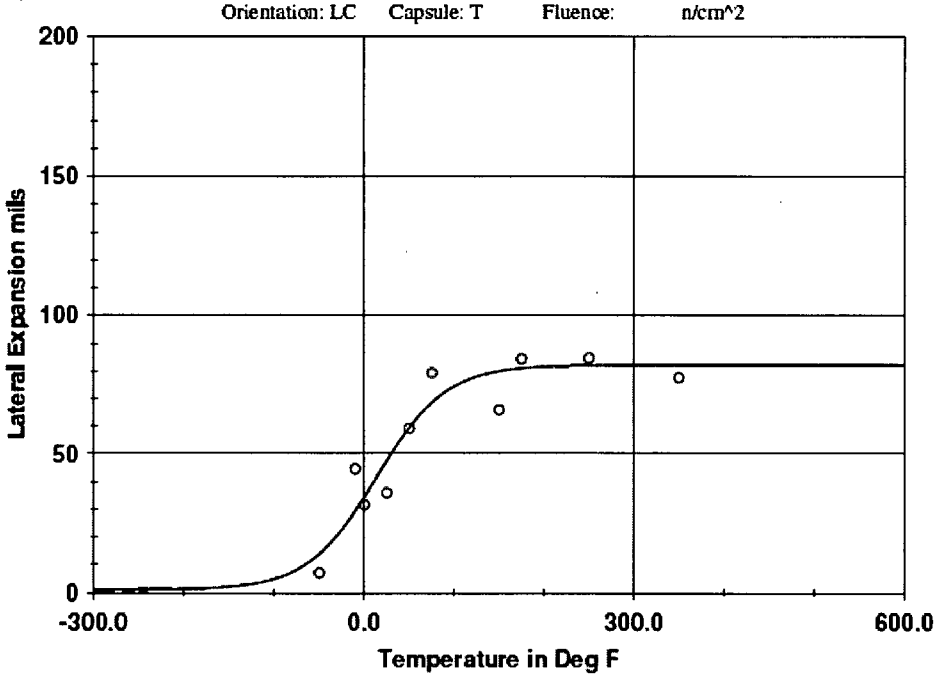
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
300.00	91.00	90.00	1.00

Correlation Coefficient = .953

Capsule T Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:10 PM
Page 1
Coefficients of Curve 1
A = 41.55 B = 40.55 C = 76.65 T0 = 13.59 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=82.1(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=1.1 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: T Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	7.10	13.97	-6.87
-10.00	44.50	29.45	15.05
.00	31.50	34.43	-2.93
25.00	35.80	47.54	-11.74
50.00	59.10	59.48	-.38
75.00	79.10	68.50	10.60
150.00	65.80	79.86	-14.06
175.00	84.30	80.92	3.38
250.00	84.50	81.93	2.57

Capsule T Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: T Fluence: n/cm^2

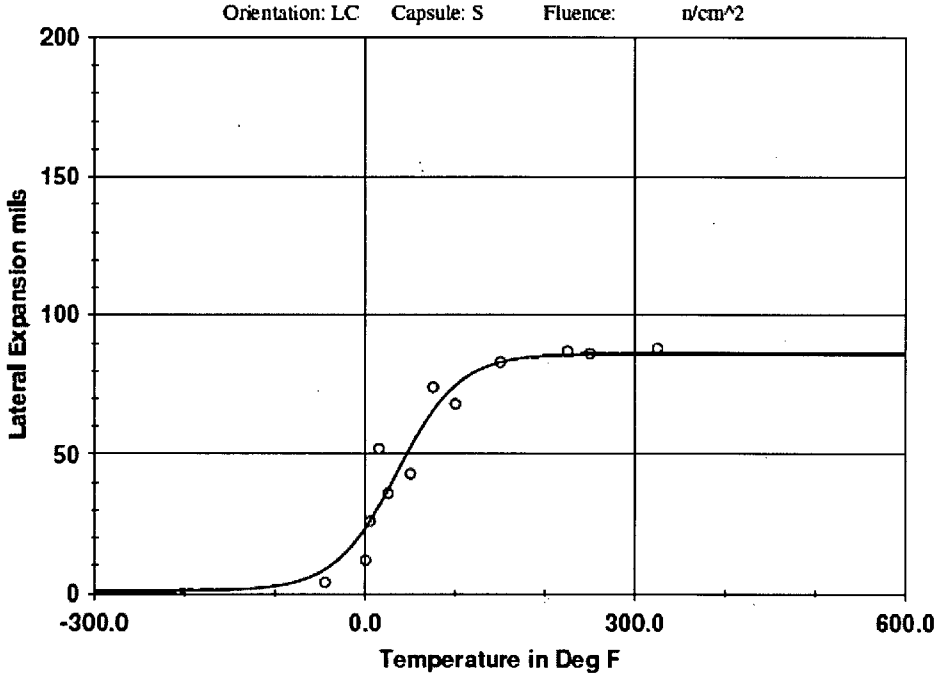
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
350.00	77.50	82.09	-4.59

Correlation Coefficient = .937

Capsule S Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/11/2009 08:33 AM
Page 1
Coefficients of Curve 1
A = 43.5 B = 42.5 C = 69.3 T0 = 34.83 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=86.0(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=20.8 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-45.00	4.00	8.72	-4.72
.00	12.00	23.77	-11.77
5.00	26.00	26.26	-.26
15.00	52.00	31.66	20.34
25.00	36.00	37.51	-1.51
50.00	43.00	52.66	-9.66
75.00	74.00	65.70	8.30
100.00	68.00	74.76	-6.76
150.00	83.00	83.05	-.05

Capsule S Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: S Fluence: n/cm^2

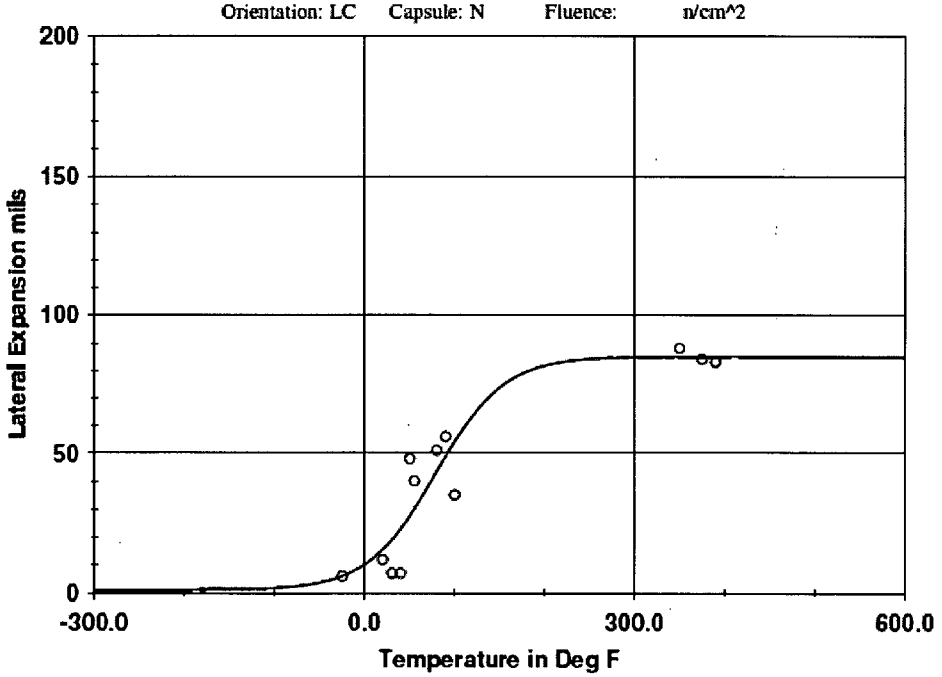
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
225.00	87.00	85.65	1.35
250.00	86.00	85.83	.17
325.00	88.00	85.98	2.02

Correlation Coefficient = .961

Capsule N Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/05/2009 09:16 AM
Page 1
Coefficients of Curve 1
A = 43. B = 42. C = 75.92 T0 = 78.99 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=85.0(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=64.4 Deg F
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-25.00	6.00	6.10	-.10
20.00	12.00	15.66	-3.66
30.00	7.00	19.12	-12.12
40.00	7.00	23.14	-16.14
50.00	48.00	27.70	20.30
55.00	40.00	30.15	9.85
80.00	51.00	43.56	7.44
90.00	56.00	49.05	6.95
100.00	35.00	54.33	-19.33

Capsule N Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: N Fluence: n/cm^2

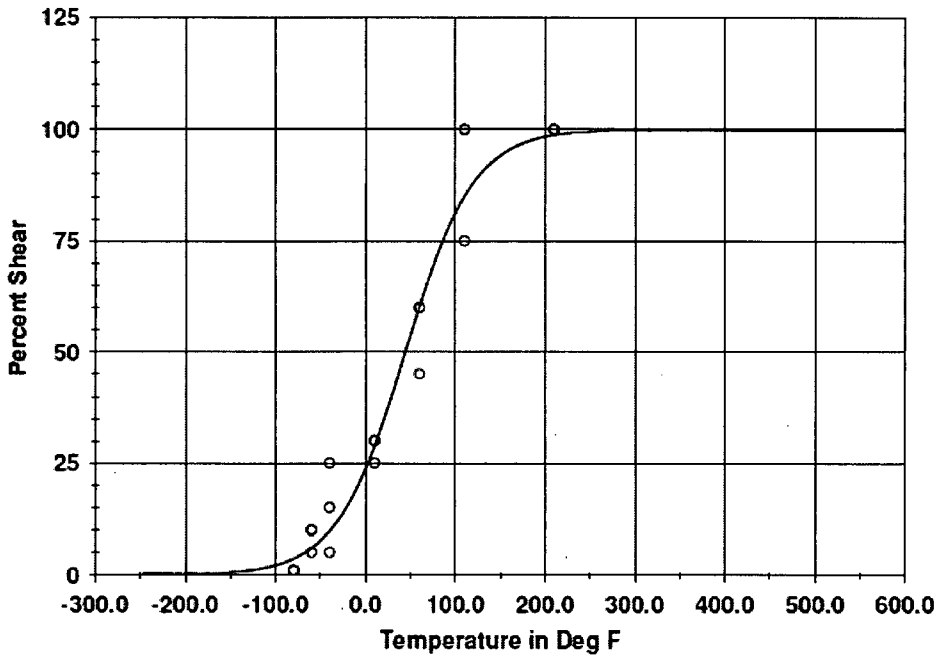
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
350.00	88.00	84.93	3.07
375.00	84.00	84.97	-.97
390.00	83.00	84.98	-1.98

Correlation Coefficient = .930

Unirradiated Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:13 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 75.69 T0 = 44.23 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 44.3
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	1.00	3.62	-2.62
-80.00	1.00	3.62	-2.62
-80.00	1.00	3.62	-2.62
-60.00	10.00	5.98	4.02
-60.00	5.00	5.98	-.98
-60.00	10.00	5.98	4.02
-40.00	5.00	9.75	-4.75
-40.00	15.00	9.75	5.25
-40.00	25.00	9.75	15.25

Unirradiated Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: UNIRR Fluence: n/cm^2

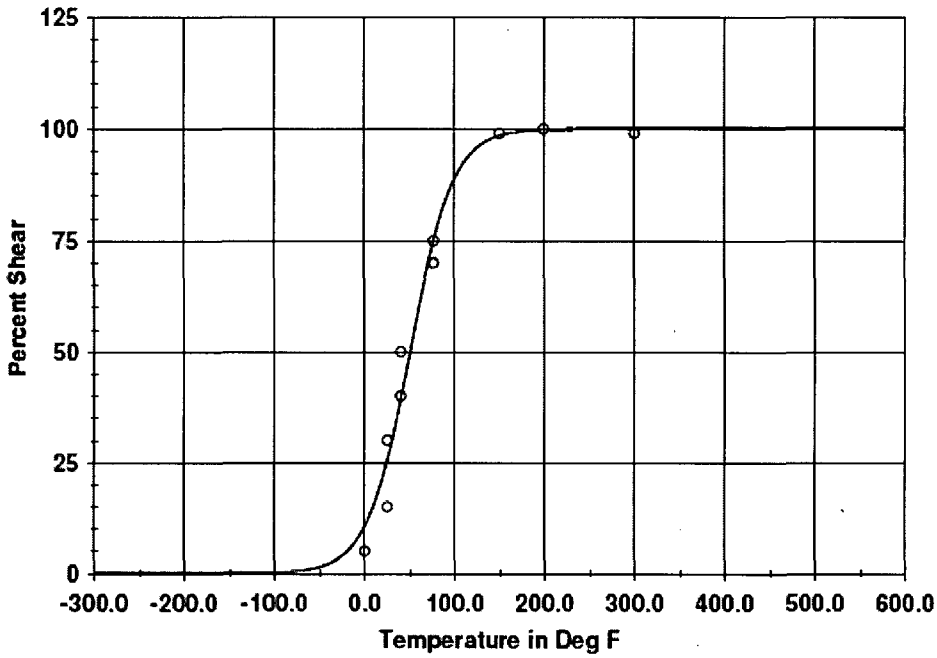
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
10.00	25.00	28.81	-3.81
10.00	30.00	28.81	1.19
10.00	30.00	28.81	1.19
60.00	60.00	60.27	-.27
60.00	45.00	60.27	-15.27
60.00	60.00	60.27	-.27
110.00	75.00	85.04	-10.04
110.00	100.00	85.04	14.96
110.00	100.00	85.04	14.96
210.00	100.00	98.76	1.24
210.00	100.00	98.76	1.24
210.00	100.00	98.76	1.24

Correlation Coefficient = .981

Capsule R Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:08 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 47.48 T0 = 50.41 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 50.5
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	5.00	10.68	-5.68
25.00	30.00	25.53	4.47
25.00	15.00	25.53	-10.53
40.00	40.00	39.21	.79
40.00	50.00	39.21	10.79
77.00	70.00	75.40	-5.40
77.00	75.00	75.40	-.40
150.00	99.00	98.52	.48
199.00	100.00	99.81	.19

Capsule R Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: R Fluence: n/cm^2

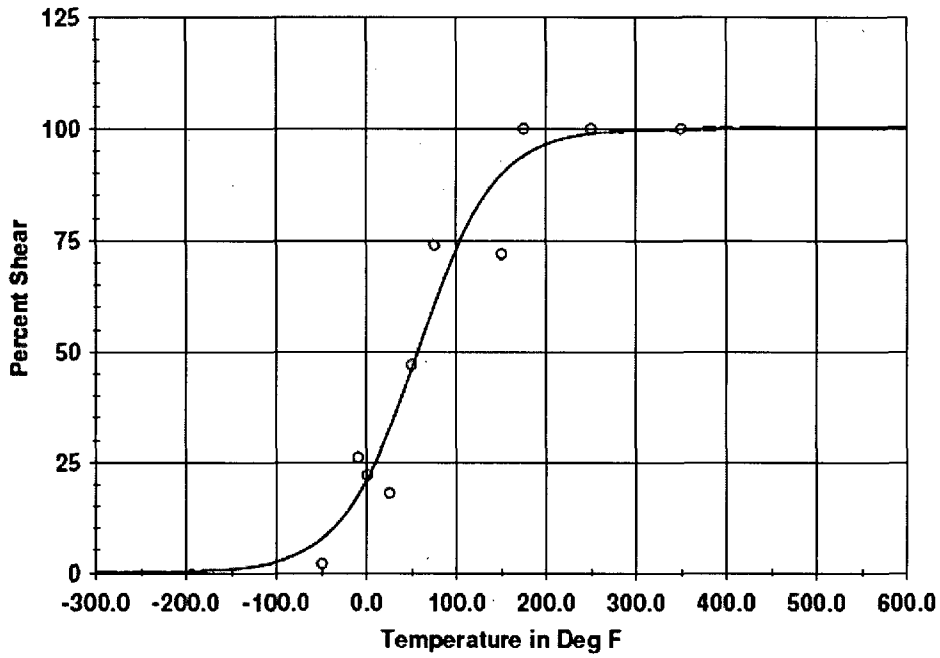
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
300.00	99.00	100.00	-1.00

Correlation Coefficient = .987

Capsule T Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:11 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 85.95 T0 = 56.7 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 56.7
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: T Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	2.00	7.71	-5.71
-10.00	26.00	17.48	8.52
.00	22.00	21.09	.91
25.00	18.00	32.35	-14.35
50.00	47.00	46.11	.89
75.00	74.00	60.49	13.51
150.00	72.00	89.76	-17.76
175.00	100.00	94.01	5.99
250.00	100.00	98.90	1.10

Capsule T Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: T Fluence: n/cm^2

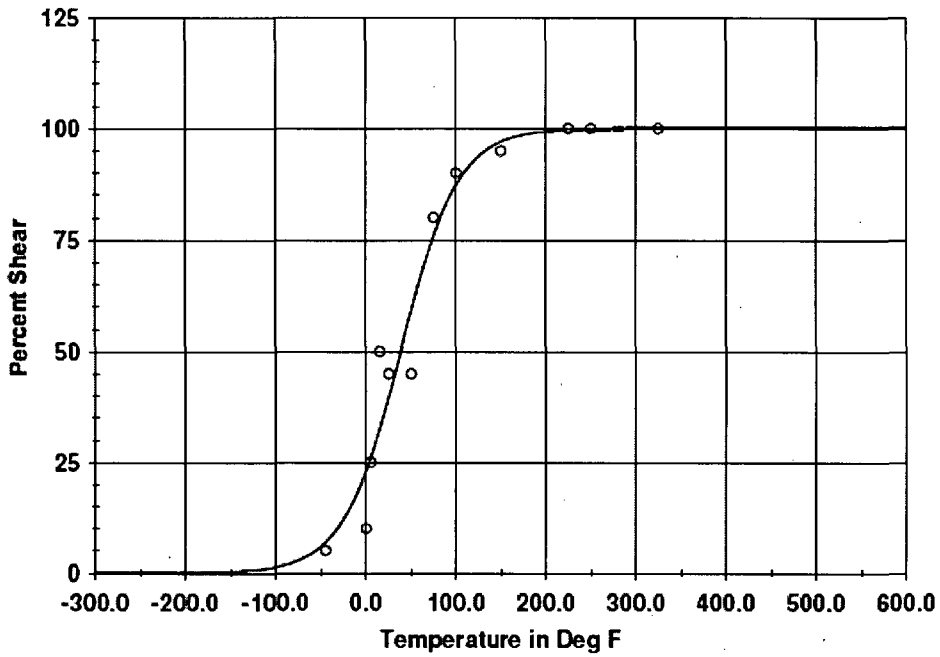
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
350.00	100.00	99.89	.11

Correlation Coefficient = .967

Capsule S Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2009 12:15 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 63.9 T0 = 38.29 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 38.3
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-45.00	5.00	6.87	-1.87
.00	10.00	23.17	-13.17
5.00	25.00	26.08	-1.08
15.00	50.00	32.54	17.46
25.00	45.00	39.75	5.25
50.00	45.00	59.06	-14.06
75.00	80.00	75.93	4.07
100.00	90.00	87.34	2.66
150.00	95.00	97.06	-2.06

Capsule S Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: S Fluence: n/cm^2

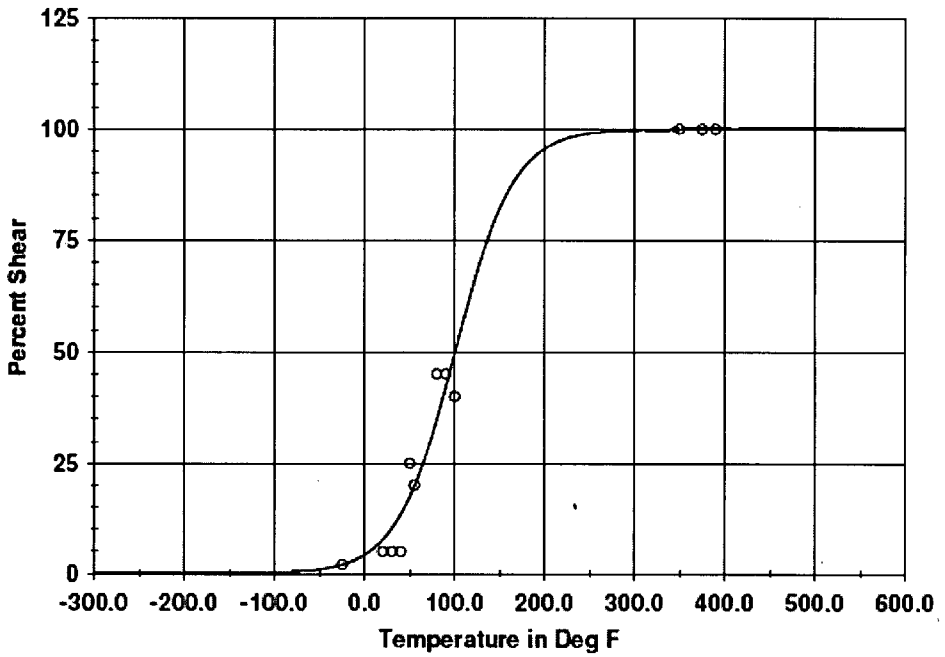
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
225.00	100.00	99.71	.29
250.00	100.00	99.87	.13
325.00	100.00	99.99	.01

Correlation Coefficient = .974

Capsule N Lower Shell Forging 125P666

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/05/2009 09:16 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 64.75 T0 = 100.25 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 100.3
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-25.00	2.00	2.05	-.05
20.00	5.00	7.73	-2.73
30.00	5.00	10.25	-5.25
40.00	5.00	13.46	-8.46
50.00	25.00	17.48	7.52
55.00	20.00	19.82	.18
80.00	45.00	34.85	10.15
90.00	45.00	42.15	2.85
100.00	40.00	49.80	-9.80

Capsule N Lower Shell Forging 125P666

Page 2
Plant: Ginna Material: SA508CL2 Heat: 125P666
Orientation: LC Capsule: N Fluence: n/cm^2

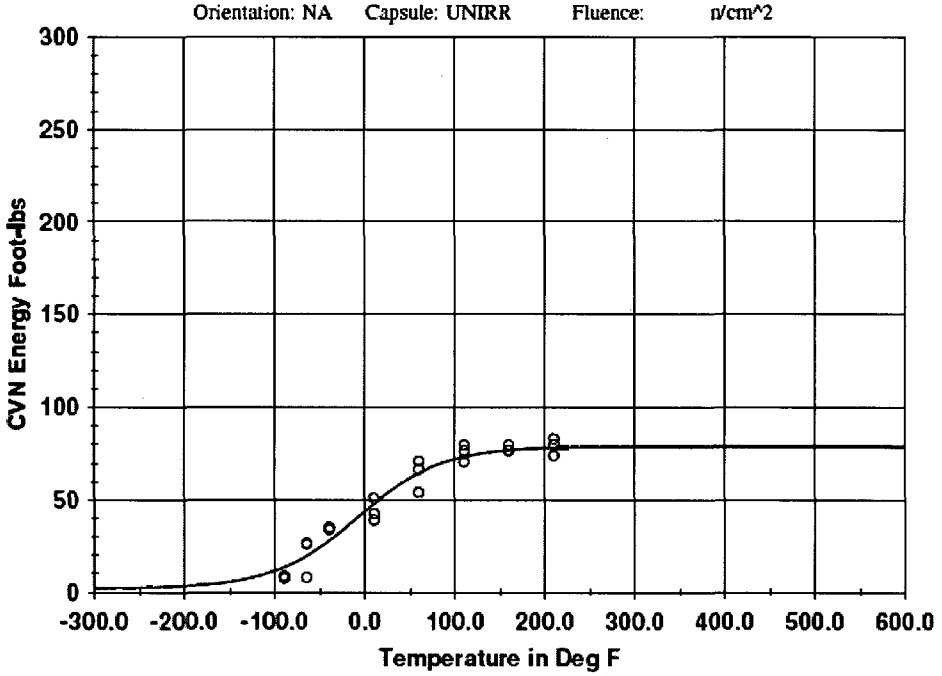
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
350.00	100.00	99.96	.04
375.00	100.00	99.98	.02
390.00	100.00	99.99	.01

Correlation Coefficient = .989

Unirradiated Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/10/2009 10:34 PM
Page 1
Coefficients of Curve 1
A = 40.6 B = 38.4 C = 93.15 T0 = -8.3 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=79.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-34.7 Deg F Temp@50 ft-lbs=15.0 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-90.00	7.50	13.53	-6.03
-90.00	8.50	13.53	-5.03
-90.00	8.50	13.53	-5.03
-65.00	26.00	19.74	6.26
-65.00	26.50	19.74	6.76
-65.00	8.00	19.74	-11.74
-40.00	34.00	28.02	5.98
-40.00	35.00	28.02	6.98
-40.00	35.00	28.02	6.98

Unirradiated Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

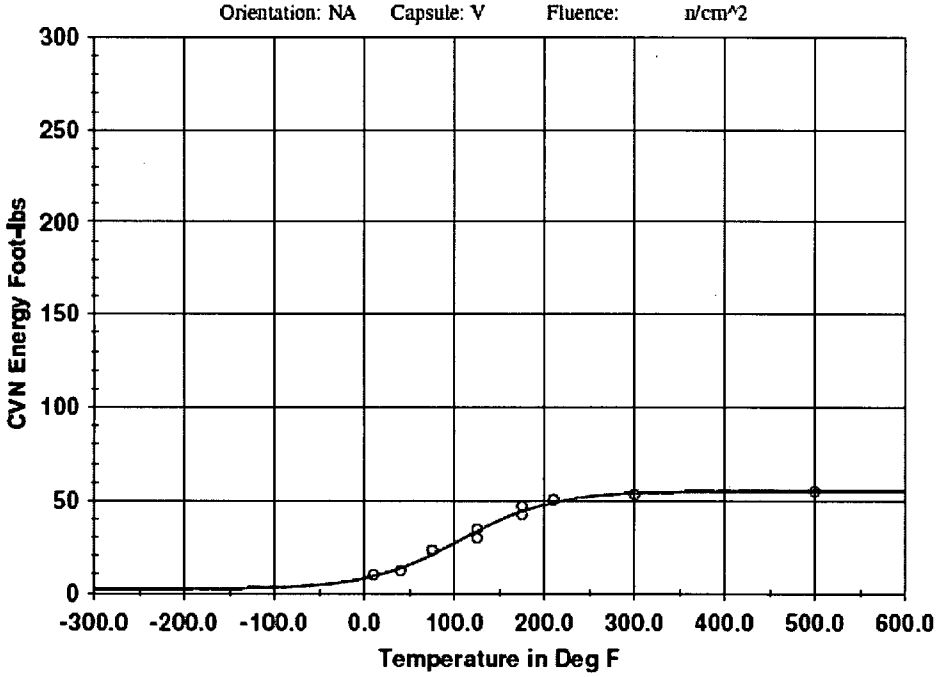
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
10.00	51.00	48.05	2.95
10.00	42.50	48.05	-5.55
10.00	39.00	48.05	-9.05
60.00	54.00	64.60	-10.60
60.00	66.50	64.60	1.90
60.00	71.00	64.60	6.40
110.00	79.50	73.39	6.11
110.00	70.50	73.39	-2.89
110.00	76.50	73.39	3.11
160.00	77.00	76.98	.02
160.00	79.50	76.98	2.52
160.00	76.50	76.98	-.48
210.00	80.00	78.30	1.70
210.00	74.00	78.30	-4.30
210.00	83.00	78.30	4.70

Correlation Coefficient = .975

Capsule V Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/11/2009 08:38 AM
Page 1
Coefficients of Curve 1
A = 28.72 B = 26.52 C = 101.65 T0 = 107. D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=55.2 Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=112.0 Deg F Temp@50 ft-lbs=219.4 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
10.00	9.80	9.05	.75
40.00	12.00	13.40	-1.40
75.00	23.00	20.64	2.36
125.00	29.50	33.37	-3.87
125.00	34.50	33.37	1.13
175.00	47.00	44.21	2.79
175.00	42.30	44.21	-1.91
210.00	50.50	49.06	1.44
300.00	53.30	54.08	-.78

Capsule V Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: V Fluence: n/cm^2

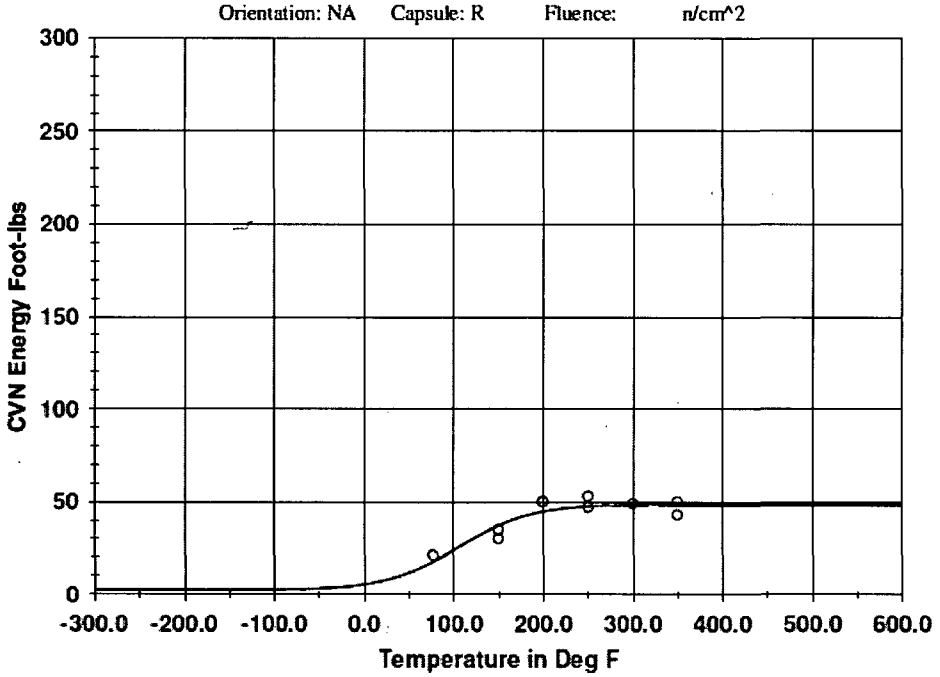
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
500.00	55.00	55.22	-.22

Correlation Coefficient = .992

Capsule R Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:27 AM
Page 1
Coefficients of Curve 1
A = 25.55 B = 23.35 C = 81.21 T0 = 105.77 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=48.9(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=121.5Deg F Temp@50 ft-lbs= NA
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
77.00	21.00	17.61	3.39
150.00	35.00	37.14	-2.14
150.00	30.00	37.14	-7.14
199.00	50.00	44.63	5.37
200.00	50.00	44.72	5.28
250.00	53.00	47.60	5.40
250.00	47.00	47.60	-.60
300.00	49.00	48.51	.49
350.00	43.00	48.79	-5.79

Capsule R Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: R Fluence: n/cm^2

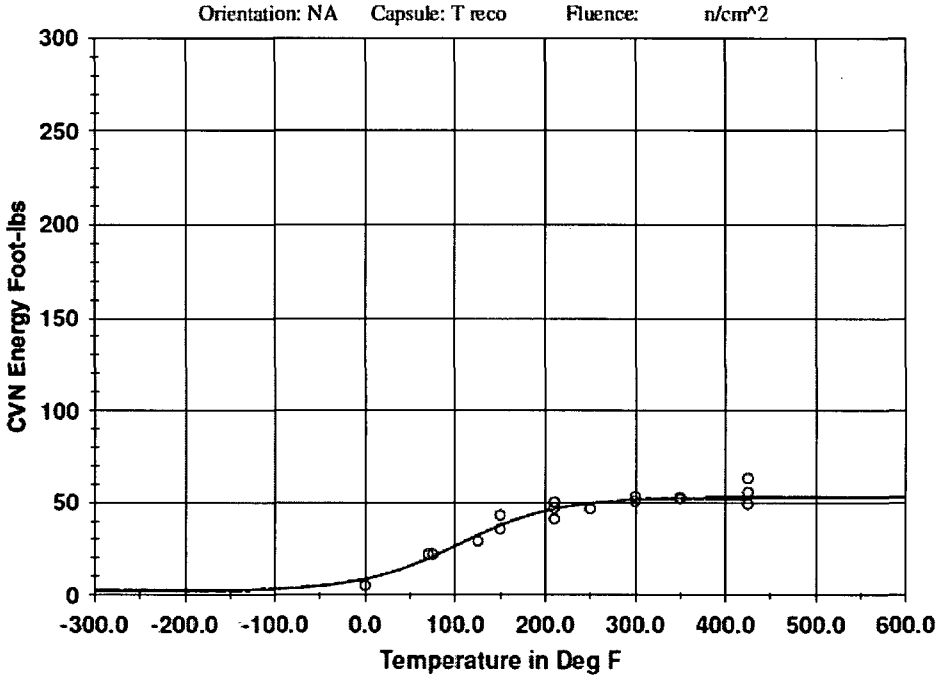
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
350.00	50.00	48.79	1.21

Correlation Coefficient = .904

Capsule T Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:34 AM
Page 1
Coefficients of Curve 1
A = 27.45 B = 25.25 C = 107.87 T0 = 104.06 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=52.7(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=115.0 Deg F Temp@50 ft-lbs=259.1 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: T reco Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	5.00	8.60	-3.60
75.00	22.00	20.81	1.19
125.00	29.00	32.29	-3.29
150.00	35.50	37.60	-2.10
210.00	41.00	46.49	-5.49
250.00	46.50	49.54	-3.04
300.00	50.50	51.40	-.90
350.00	52.50	52.18	.32
425.00	55.50	52.57	2.93

Capsule T Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: T reco Fluence: n/cm^2

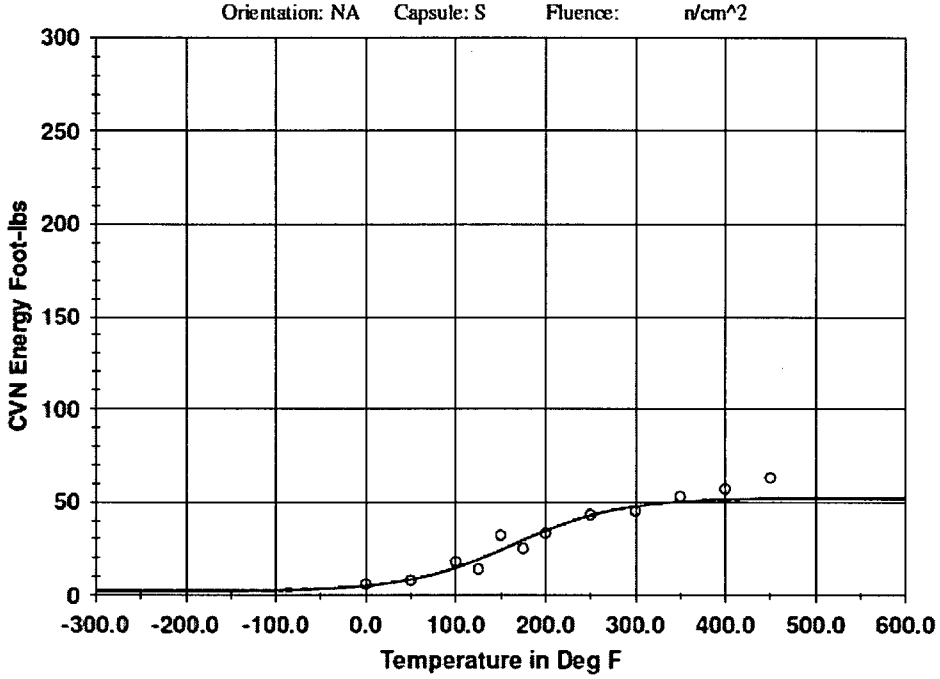
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
425.00	63.00	52.57	10.43
70.00	22.00	19.73	2.27
150.00	43.00	37.60	5.40
210.00	47.00	46.49	.51
210.00	50.00	46.49	3.51
300.00	53.00	51.40	1.60
350.00	52.00	52.18	-.18
350.00	52.00	52.18	-.18
425.00	49.00	52.57	-3.57

Correlation Coefficient = .966

Capsule S Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:38 AM
Page 1
Coefficients of Curve 1
A = 27.2 B = 25. C = 118.42 T0 = 164.17 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=52.2(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=177.5 Deg F Temp@50 ft-lbs=346.5 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	6.00	5.14	.86
50.00	8.00	8.55	-.55
100.00	18.00	14.84	3.16
125.00	14.00	19.22	-5.22
150.00	32.00	24.22	7.78
175.00	25.00	29.48	-4.48
200.00	33.00	34.54	-1.54
250.00	43.00	42.70	.30
300.00	45.00	47.62	-2.62

Capsule S Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: S Fluence: n/cm^2

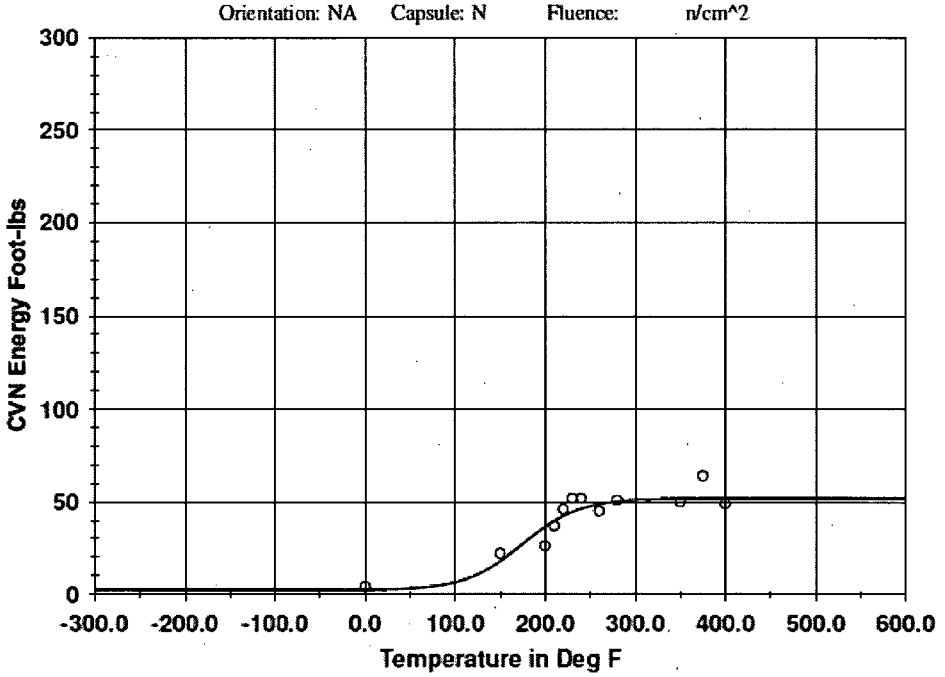
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
350.00	53.00	50.12	2.88
400.00	57.00	51.29	5.71
450.00	63.00	51.80	11.20

Correlation Coefficient = .970

Capsule N Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:42 AM
Page 1
Coefficients of Curve 1
A = 27.05 B = 24.85 C = 62.8 T0 = 174.64 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=51.9(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=182.2 Deg F Temp@50 ft-lbs=276.0 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	4.00	2.39	1.61
150.00	22.00	17.77	4.23
200.00	26.00	36.57	-10.57
210.00	37.00	39.73	-2.73
220.00	46.00	42.41	3.59
230.00	52.00	44.62	7.38
240.00	52.00	46.39	5.61
260.00	45.00	48.82	-3.82
280.00	51.00	50.22	.78

Capsule N Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: N Fluence: n/cm^2

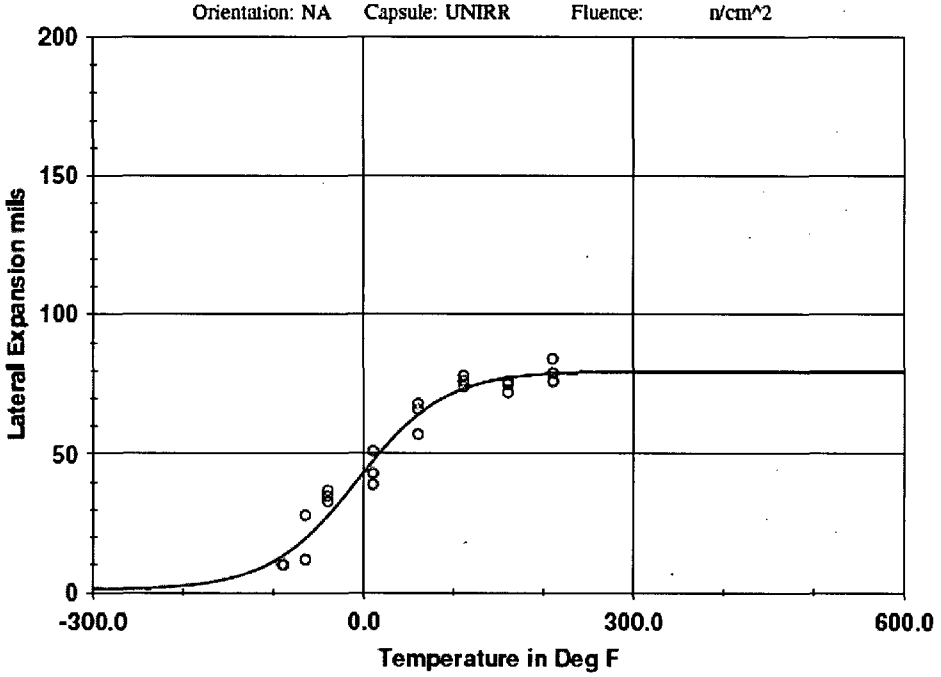
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
350.00	50.00	51.71	-1.71
375.00	64.00	51.82	12.18
400.00	49.00	51.86	-2.86

Correlation Coefficient = .932

Unirradiated Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/10/2009 10:36 PM
Page 1
Coefficients of Curve 1
A = 40.35 B = 39.35 C = 97.25 T0 = -8.12 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=79.7(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-21.4 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-90.00	10.00	13.32	-3.32
-90.00	10.00	13.32	-3.32
-90.00	10.00	13.32	-3.32
-65.00	28.00	19.64	8.36
-65.00	12.00	19.64	-7.64
-65.00	12.00	19.64	-7.64
-40.00	33.00	27.89	5.11
-40.00	37.00	27.89	9.11
-40.00	35.00	27.89	7.11

Unirradiated Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

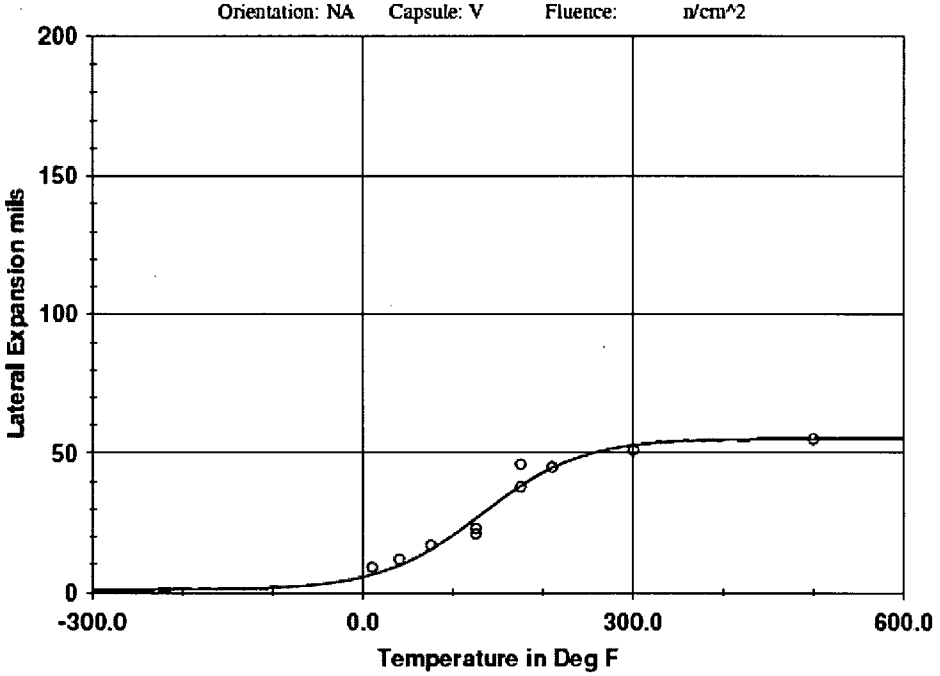
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
10.00	51.00	47.60	3.40
10.00	43.00	47.60	-4.60
10.00	39.00	47.60	-8.60
60.00	57.00	64.14	-7.14
60.00	66.00	64.14	1.86
60.00	68.00	64.14	3.86
110.00	76.00	73.33	2.67
110.00	74.00	73.33	.67
110.00	78.00	73.33	4.67
160.00	75.00	77.30	-2.30
160.00	76.00	77.30	-1.30
160.00	72.00	77.30	-5.30
210.00	79.00	78.82	.18
210.00	76.00	78.82	-2.82
210.00	84.00	78.82	5.18

Correlation Coefficient = .980

Capsule V Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/11/2009 08:41 AM
Page 1
Coefficients of Curve 1
A = 28.08 B = 27.08 C = 110.38 T0 = 130.69 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=55.2 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=159.6 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
10.00	9.00	6.47	2.53
40.00	12.00	9.77	2.23
75.00	17.00	15.47	1.53
125.00	21.00	26.68	-5.68
125.00	23.00	26.68	-3.68
175.00	38.00	38.40	-.40
175.00	46.00	38.40	7.60
210.00	45.00	44.76	.24
300.00	51.00	52.75	-1.75

Capsule V Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: V Fluence: n/cm^2

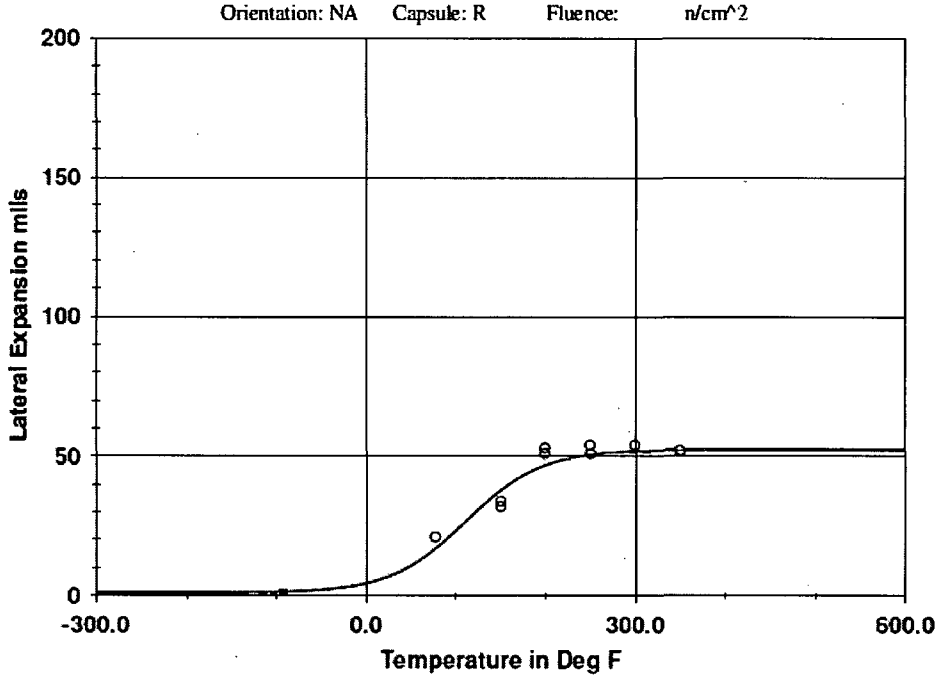
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
500.00	55.00	55.09	-.09

Correlation Coefficient = .977

Capsule R Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:30 AM
Page 1
Coefficients of Curve 1
A = 26.7 B = 25.7 C = 83.77 T0 = 110.68 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=52.4(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=138.8 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
77.00	21.00	16.89	4.11
150.00	34.00	37.95	-3.95
150.00	32.00	37.95	-5.95
199.00	51.00	46.84	4.16
200.00	53.00	46.95	6.05
250.00	54.00	50.62	3.38
250.00	51.00	50.62	.38
300.00	54.00	51.85	2.15
350.00	52.00	52.23	-.23

Capsule R Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: R Fluence: n/cm^2

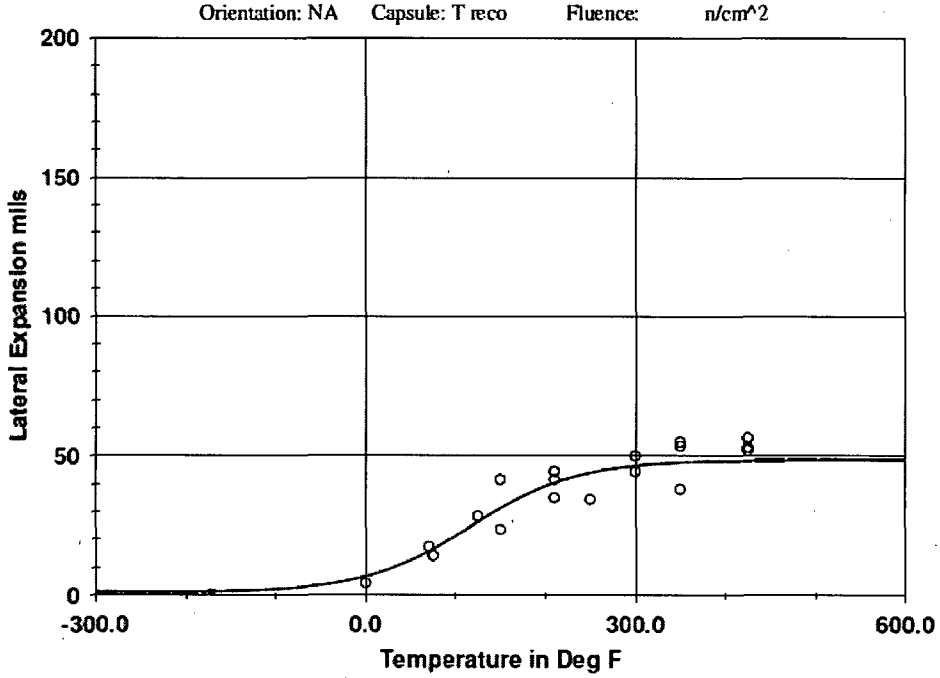
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
350.00	52.00	52.23	-.23

Correlation Coefficient = .948

Capsule T Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:36 AM
Page 1
Coefficients of Curve 1
A = 24.8 B = 23.8 C = 118.13 T0 = 117.06 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=48.6(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=171.2 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: T reco Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	4.30	6.77	-2.47
75.00	14.20	16.67	-2.47
125.00	28.40	26.40	2.00
150.00	23.60	31.27	-7.67
210.00	35.00	40.43	-5.43
250.00	34.50	44.06	-9.56
300.00	44.50	46.54	-2.04
350.00	38.20	47.70	-9.50
425.00	52.00	48.34	3.66

Capsule T Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: T reco Fluence: n/cm^2

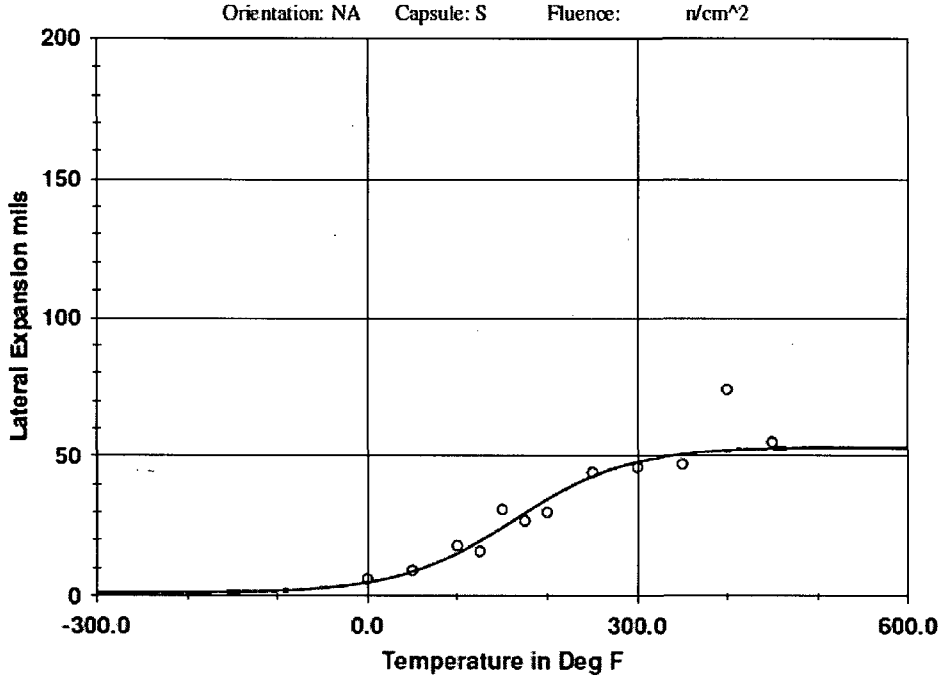
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
425.00	56.30	48.34	7.96
70.00	17.50	15.79	1.71
150.00	41.50	31.27	10.23
210.00	41.50	40.43	1.07
210.00	44.50	40.43	4.07
300.00	50.00	46.54	3.46
350.00	53.50	47.70	5.80
350.00	55.00	47.70	7.30
425.00	53.00	48.34	4.66

Correlation Coefficient = .923

Capsule S Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:39 AM
Page 1
Coefficients of Curve 1
A = 27.1 B = 26.1 C = 127.22 T0 = 161.94 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=53.2(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=201.7 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	6.00	4.80	1.20
50.00	9.00	8.66	.34
100.00	18.00	15.31	2.69
125.00	16.00	19.73	-3.73
150.00	31.00	24.66	6.34
175.00	27.00	29.77	-2.77
200.00	30.00	34.68	-4.68
250.00	44.00	42.74	1.26
300.00	46.00	47.85	-1.85

Capsule S Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: S Fluence: n/cm^2

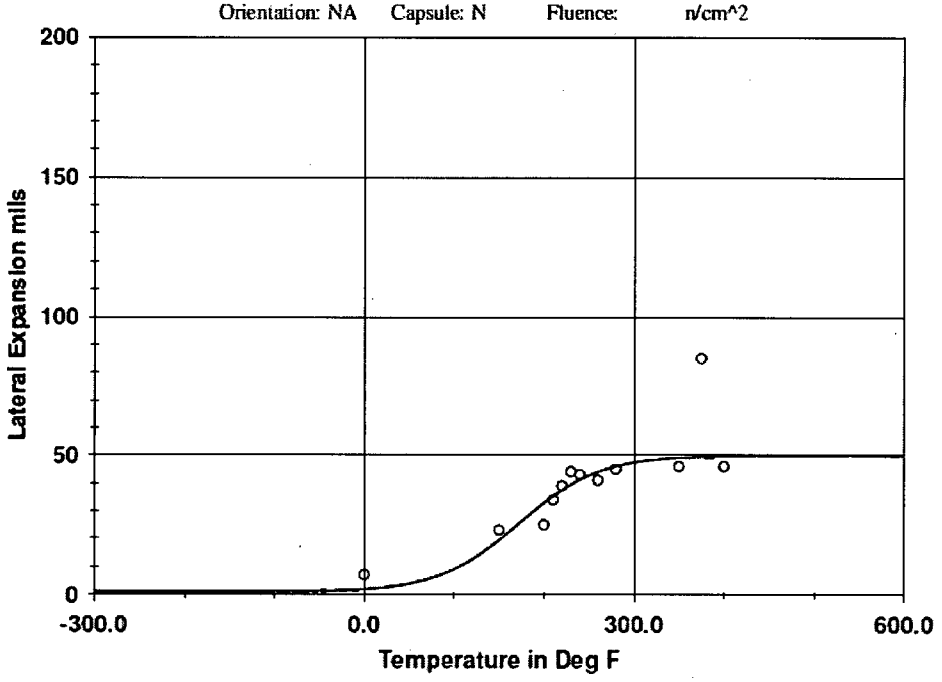
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
350.00	47.00	50.62	-3.62
400.00	74.00	51.99	22.01
450.00	55.00	52.64	2.36

Correlation Coefficient = .938

Capsule N Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:43 AM
Page 1
Coefficients of Curve 1
A = 25.5 B = 24.5 C = 88.93 T0 = 172.11 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=50.0(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=208.5 Deg F
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	7.00	2.00	5.00
150.00	23.00	19.53	3.47
200.00	25.00	32.94	-7.94
210.00	34.00	35.35	-1.35
220.00	39.00	37.55	1.45
230.00	44.00	39.52	4.48
240.00	43.00	41.25	1.75
260.00	41.00	44.04	-3.04
280.00	45.00	46.02	-1.02

Capsule N Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: N Fluence: n/cm^2

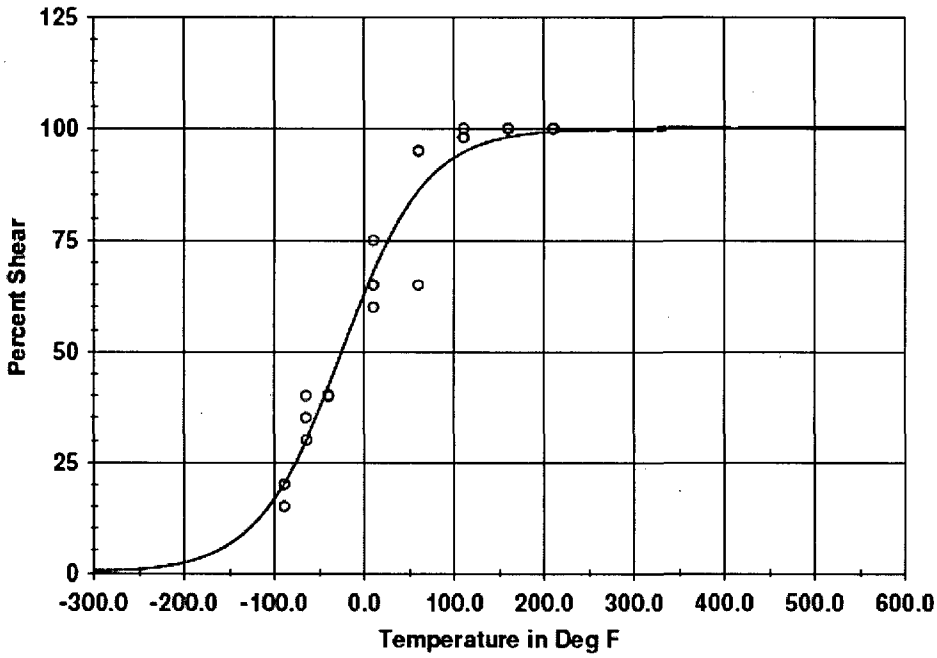
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
350.00	46.00	49.12	-3.12
375.00	85.00	49.49	35.51
400.00	46.00	49.71	-3.71

Correlation Coefficient = .806

Unirradiated Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/10/2009 10:44 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 93.94 T0 = -25.4 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -25.4
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-90.00	15.00	20.18	-5.18
-90.00	20.00	20.18	-.18
-90.00	20.00	20.18	-.18
-65.00	40.00	30.09	9.91
-65.00	35.00	30.09	4.91
-65.00	30.00	30.09	-.09
-40.00	40.00	42.29	-2.29
-40.00	40.00	42.29	-2.29
-40.00	40.00	42.29	-2.29

Unirradiated Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

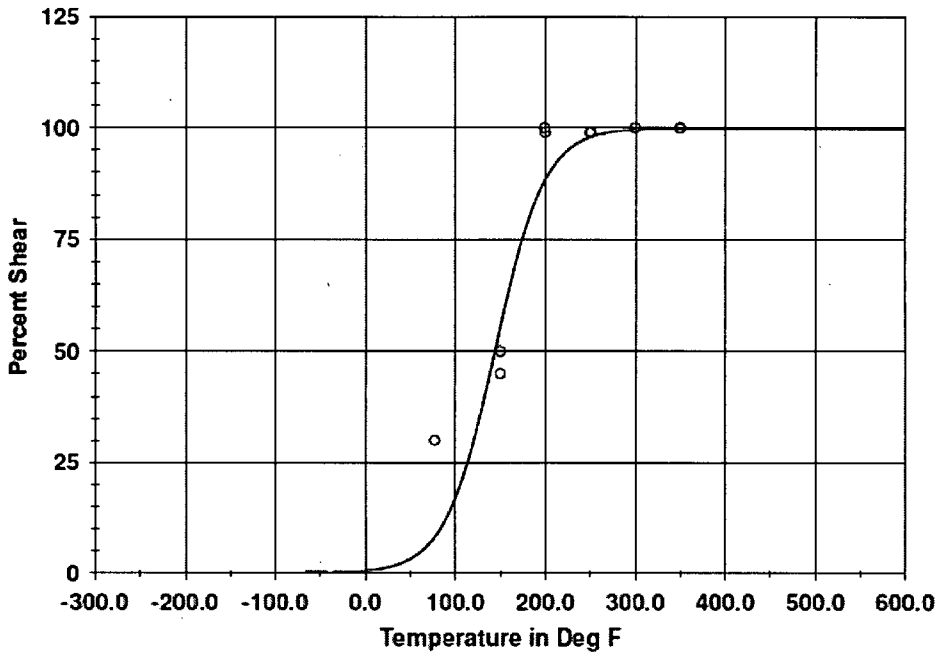
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
10.00	75.00	68.00	7.00
10.00	65.00	68.00	-3.00
10.00	60.00	68.00	-8.00
60.00	65.00	86.04	-21.04
60.00	95.00	86.04	8.96
60.00	95.00	86.04	8.96
110.00	98.00	94.70	3.30
110.00	100.00	94.70	5.30
110.00	98.00	94.70	3.30
160.00	100.00	98.11	1.89
160.00	100.00	98.11	1.89
160.00	100.00	98.11	1.89
210.00	100.00	99.34	.66
210.00	100.00	99.34	.66
210.00	100.00	99.34	.66

Correlation Coefficient = .980

Capsule R Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:31 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 55.19 T0 = 143.78 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 143.8
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
77.00	30.00	8.17	21.83
150.00	50.00	55.61	-5.61
150.00	45.00	55.61	-10.61
199.00	100.00	88.09	11.91
200.00	99.00	88.47	10.53
250.00	99.00	97.92	1.08
250.00	99.00	97.92	1.08
300.00	100.00	99.65	.35
350.00	100.00	99.94	.06

Capsule R Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: R Fluence: n/cm^2

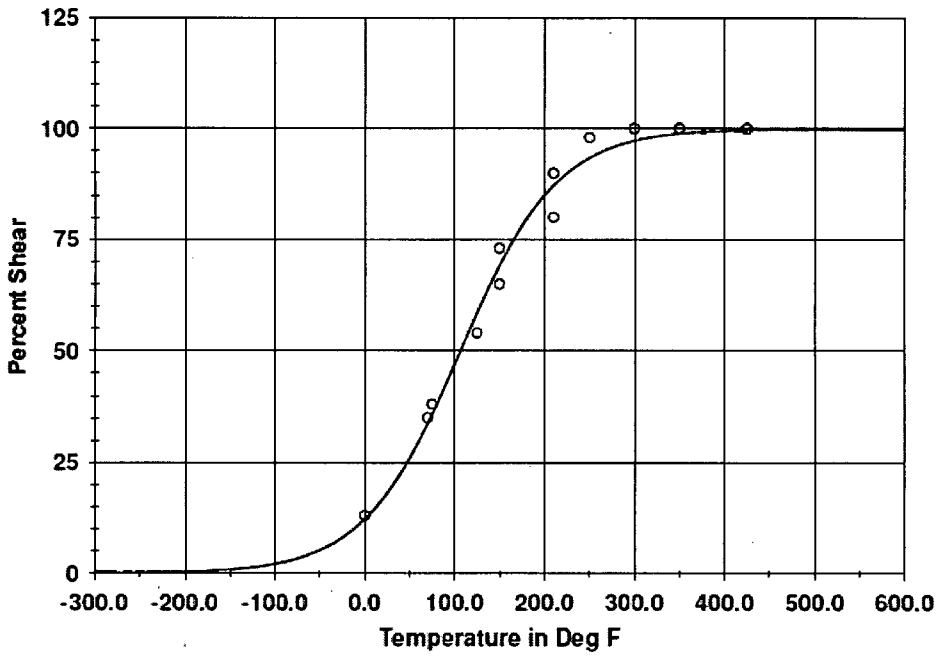
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
350.00	100.00	99.94	.06

Correlation Coefficient = .952

Capsule T Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:37 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 107.93 T0 = 106.47 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 106.5
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: T reco Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	13.00	12.21	.79
75.00	38.00	35.82	2.18
125.00	54.00	58.50	-4.50
150.00	73.00	69.14	3.86
210.00	90.00	87.20	2.80
250.00	98.00	93.46	4.54
300.00	100.00	97.30	2.70
350.00	100.00	98.91	1.09
425.00	100.00	99.73	.27

Capsule T Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: T reco Fluence: n/cm^2

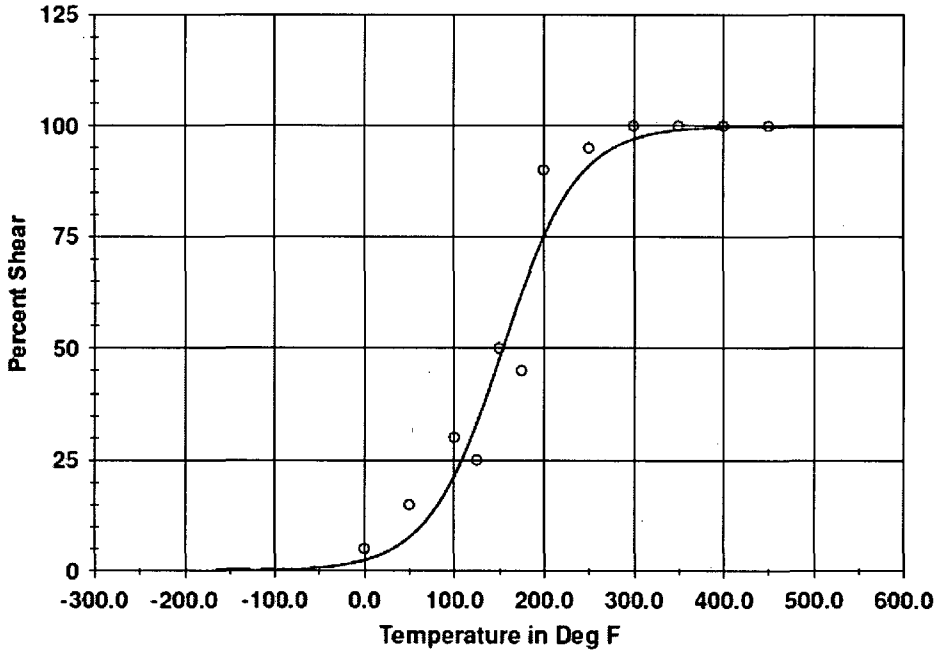
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
425.00	100.00	99.73	.27
70.00	35.00	33.72	1.28
150.00	65.00	69.14	-4.14
210.00	80.00	87.20	-7.20
210.00	90.00	87.20	2.80
300.00	100.00	97.30	2.70
350.00	100.00	98.91	1.09
350.00	100.00	98.91	1.09
425.00	100.00	99.73	.27

Correlation Coefficient = .994

Capsule S Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:40 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 83.42 T0 = 154.13 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 154.2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	5.00	2.42	2.58
50.00	15.00	7.61	7.39
100.00	30.00	21.45	8.55
125.00	25.00	33.22	-8.22
150.00	50.00	47.53	2.47
175.00	45.00	62.26	-17.26
200.00	90.00	75.02	14.98
250.00	95.00	90.88	4.12
300.00	100.00	97.06	2.94

Capsule S Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: S Fluence: n/cm^2

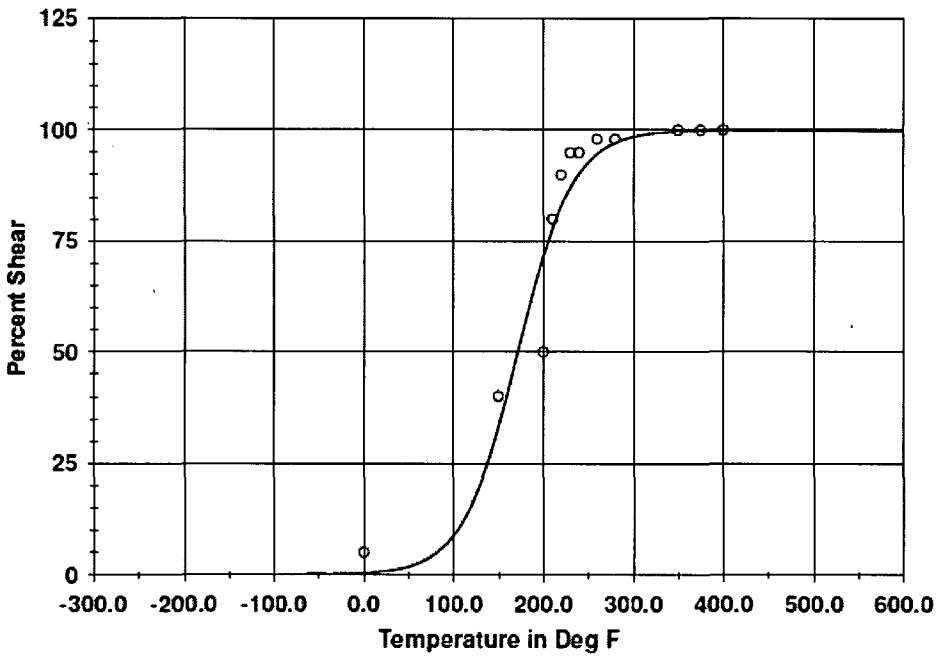
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
350.00	100.00	99.10	.90
400.00	100.00	99.73	.27
450.00	100.00	99.92	.08

Correlation Coefficient = .977

Capsule N Weld Heat 61782

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:43 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 61.4 T0 = 171.48 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 171.5
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	5.00	.37	4.63
150.00	40.00	33.19	6.81
200.00	50.00	71.69	-21.69
210.00	80.00	77.81	2.19
220.00	90.00	82.93	7.07
230.00	95.00	87.06	7.94
240.00	95.00	90.31	4.69
260.00	98.00	94.70	3.30
280.00	98.00	97.17	.83

Capsule N Weld Heat 61782

Page 2
Plant: Ginna Material: SAW Heat: 61782
Orientation: NA Capsule: N Fluence: n/cm^2

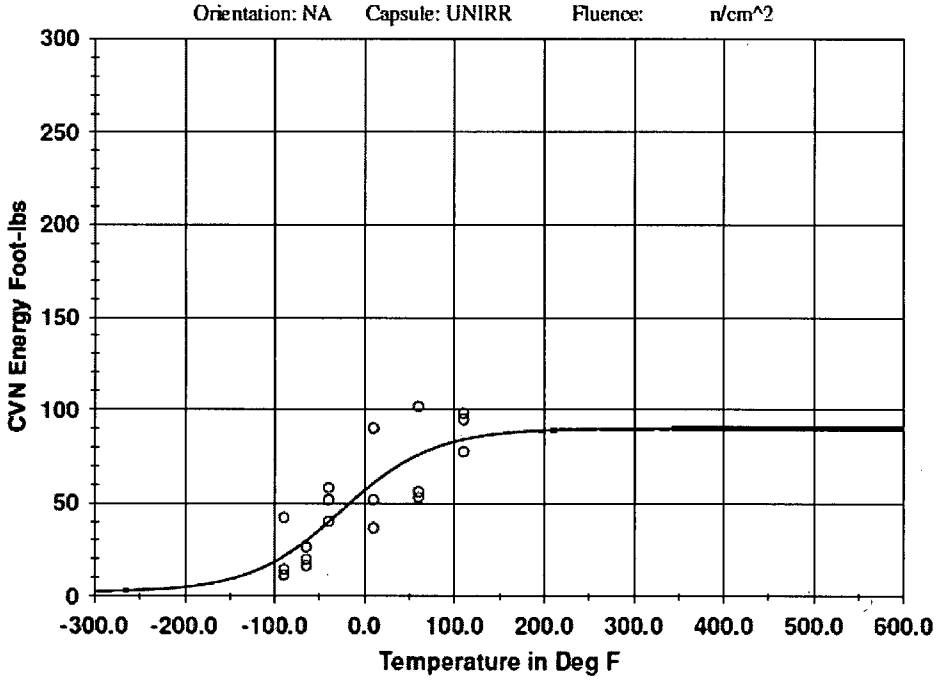
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
350.00	100.00	99.70	.30
375.00	100.00	99.87	.13
400.00	100.00	99.94	.06

Correlation Coefficient = .968

Unirradiated Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:21 AM
Page 1
Coefficients of Curve 1
A = 46.1 B = 43.9 C = 102.49 T0 = -25.3 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=90.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-64.7 Deg F Temp@50 ft-lbs=-16.1 Deg F
Plant: GINNA Material: SAW Heat: 125P666
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-90.00	14.50	21.56	-7.06
-90.00	42.00	21.56	20.44
-90.00	11.50	21.56	-10.06
-65.00	26.50	29.90	-3.40
-65.00	16.50	29.90	-13.40
-65.00	20.00	29.90	-9.90
-40.00	40.00	39.85	.15
-40.00	58.00	39.85	18.15
-40.00	51.50	39.85	11.65

Unirradiated Heat Affected Zone

Page 2
Plant: GINNA Material: SAW Heat: 125P666
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

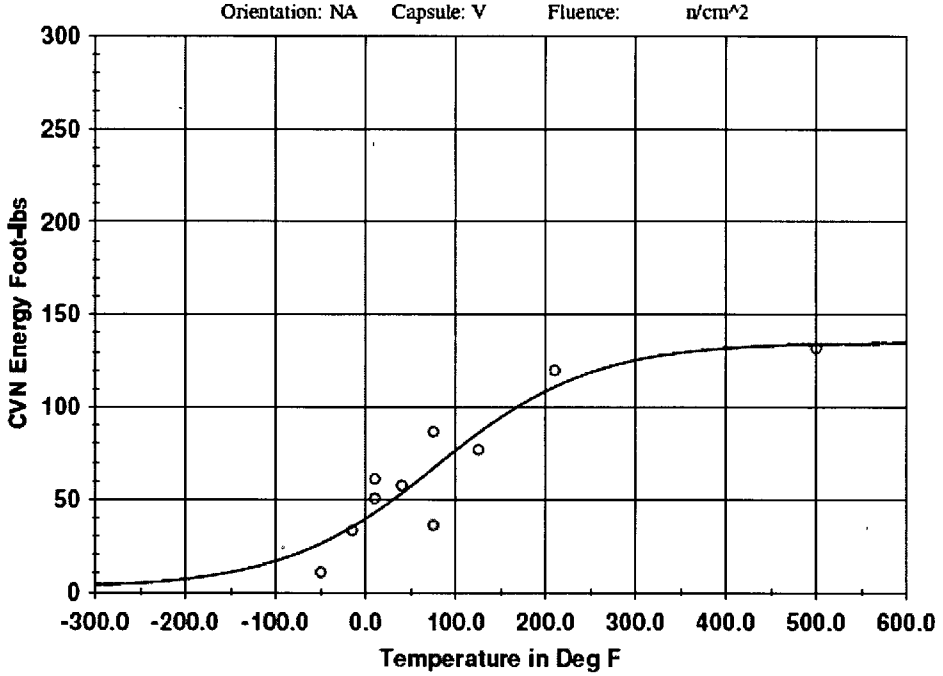
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
10.00	90.00	60.65	29.35
10.00	36.50	60.65	-24.15
10.00	51.50	60.65	-9.15
60.00	56.00	76.03	-20.03
60.00	53.00	76.03	-23.03
60.00	101.50	76.03	25.47
110.00	94.50	84.15	10.35
110.00	98.00	84.15	13.85
110.00	77.50	84.15	-6.65

Correlation Coefficient = .826

Capsule V Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/11/2009 12:40 PM
Page 1
Coefficients of Curve 1
A = 68.6 B = 66.4 C = 171.32 T0 = 79.76 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=135.0 Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-34.0 Deg F Temp@50 ft-lbs=30.5 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	10.50	26.13	-15.63
-15.00	33.00	35.21	-2.21
10.00	50.50	42.96	7.54
10.00	61.00	42.96	18.04
40.00	57.50	53.46	4.04
75.00	36.00	66.76	-30.76
75.00	86.30	66.76	19.54
125.00	76.50	85.74	-9.24
210.00	120.00	111.18	8.82

Capsule V Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: V Fluence: n/cm^2

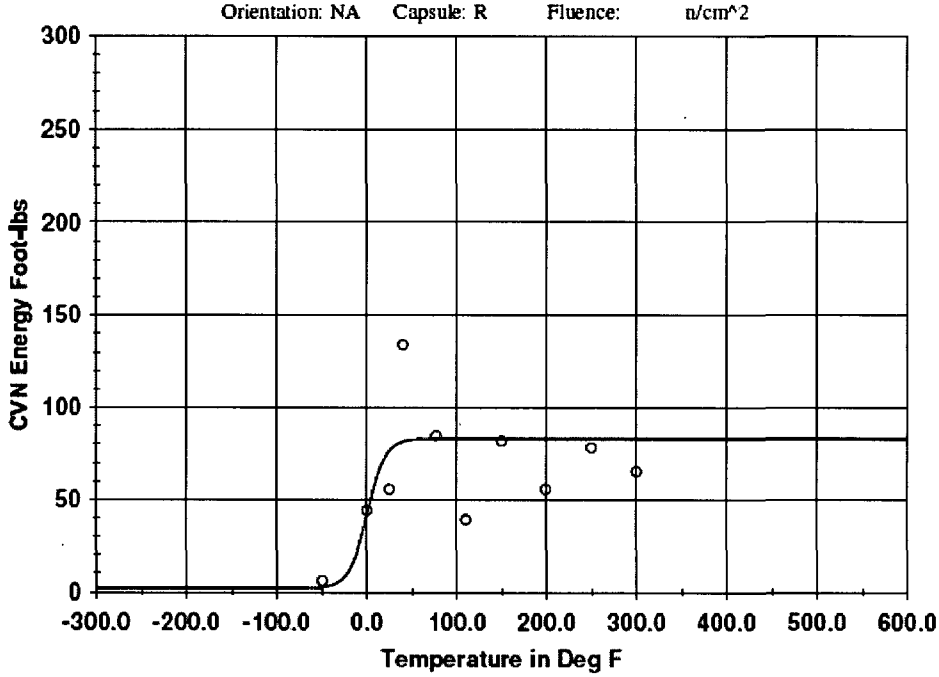
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
500.00	132.00	134.03	-2.03

Correlation Coefficient = .915

Capsule R Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/11/2009 12:45 PM
Page 1
Coefficients of Curve 1
A = 42.5 B = 40.3 C = 20.12 T0 = .29 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=82.8(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-6.1 Deg F Temp@50 ft-lbs=4.1 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	6.00	2.74	3.26
.00	44.00	41.91	2.09
25.00	55.50	76.43	-20.93
40.00	134.00	81.27	52.73
77.00	84.50	82.76	1.74
110.00	39.00	82.80	-43.80
150.00	81.50	82.80	-1.30
199.00	55.50	82.80	-27.30
250.00	78.00	82.80	-4.80

Capsule R Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: R Fluence: n/cm^2

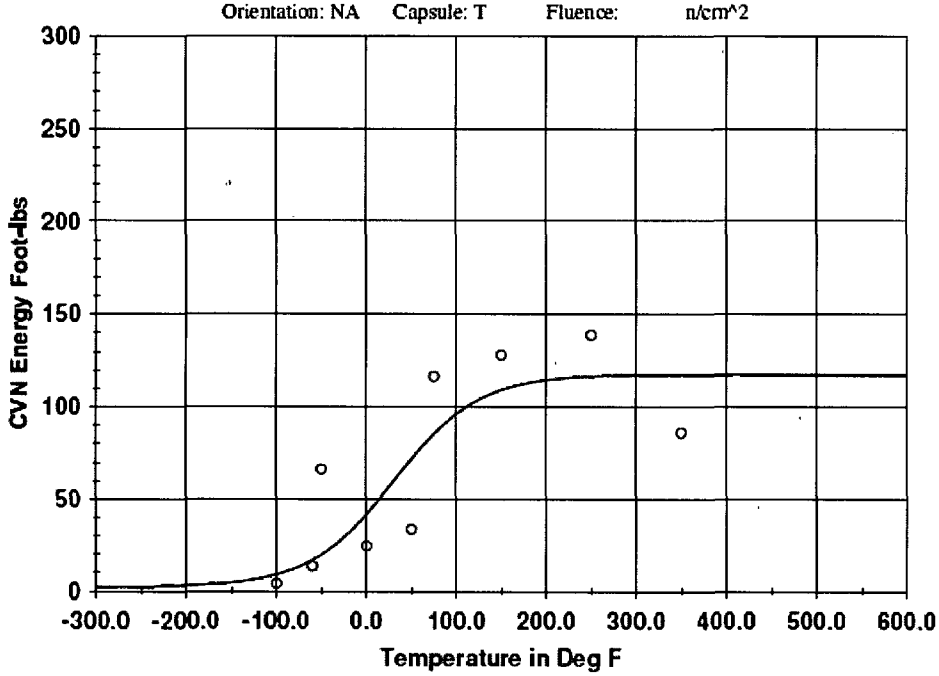
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
300.00	65.00	82.80	-17.80

Correlation Coefficient = .666

Capsule T Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/11/2009 12:51 PM
Page 1
Coefficients of Curve 1
A = 59.95 B = 57.75 C = 94.46 T0 = 30.53 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=117.7(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-23.7 Deg F Temp@50 ft-lbs=14.1 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: T Fluence: n/cm^2



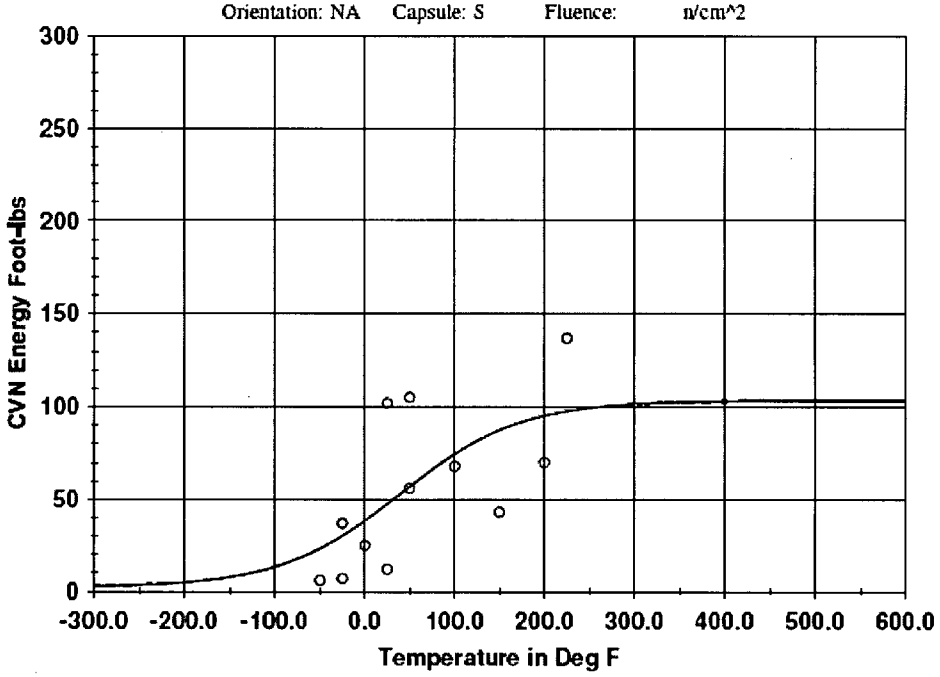
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	4.00	9.05	-5.05
-60.00	13.50	17.01	-3.51
-50.00	66.00	19.96	46.04
.00	24.50	41.91	-17.41
50.00	33.50	71.69	-38.19
75.00	116.50	85.29	31.21
150.00	128.00	109.17	18.83
250.00	139.00	116.60	22.40
350.00	86.00	117.57	-31.57

Correlation Coefficient = .830

Capsule S Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/16/2009 07:53 AM
Page 1
Coefficients of Curve 1
A = 52.85 B = 50.65 C = 133.03 T0 = 38.86 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=103.5(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-25.8 Deg F Temp@50 ft-lbs=31.4 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	6.00	23.29	-17.29
-25.00	7.00	30.25	-23.25
-25.00	37.00	30.25	6.75
.00	25.00	38.46	-13.46
25.00	12.00	47.59	-35.59
25.00	102.00	47.59	54.41
50.00	56.00	57.08	-1.08
50.00	105.00	57.08	47.92
100.00	68.00	74.62	-6.62

Capsule S Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: S Fluence: n/cm^2

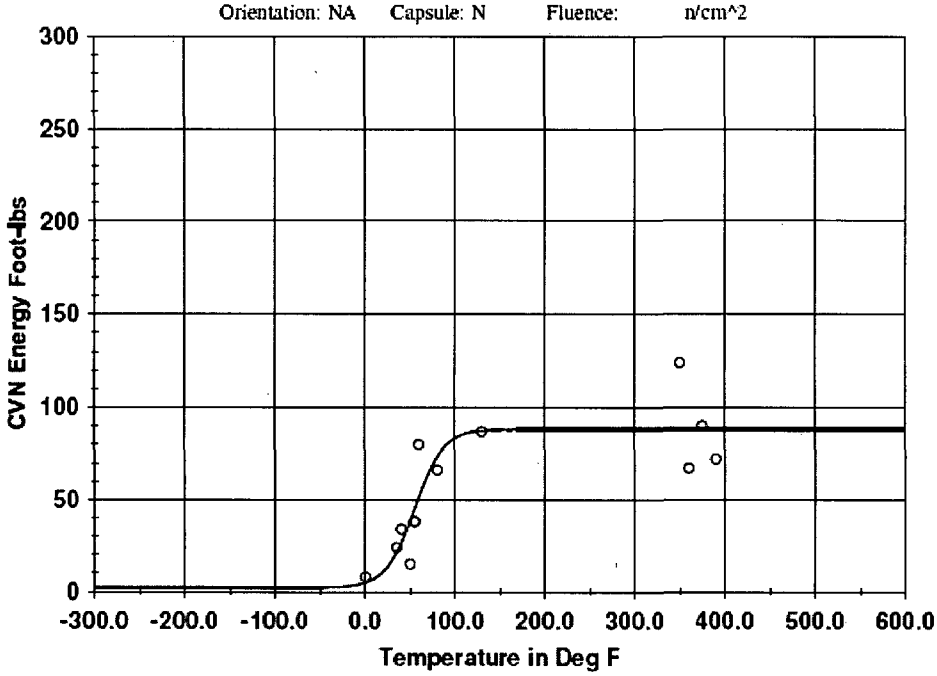
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
150.00	43.00	87.46	-44.46
200.00	70.00	95.25	-25.25
225.00	137.00	97.68	39.32

Correlation Coefficient = .636

Capsule N Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/06/2009 09:28 AM
Page 1
Coefficients of Curve 1
A = 45.22 B = 43.03 C = 32. T0 = 54.78 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=88.3(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=43.0 Deg F Temp@50 ft-lbs=58.4 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	8.00	4.92	3.08
35.00	24.00	21.57	2.43
40.00	34.00	26.66	7.34
50.00	15.00	38.85	-23.85
55.00	38.00	45.52	-7.52
60.00	80.00	52.18	27.82
80.00	66.00	73.51	-7.51
130.00	87.00	87.48	-.48
350.00	124.00	88.25	35.75

Capsule N Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: N Fluence: n/cm^2

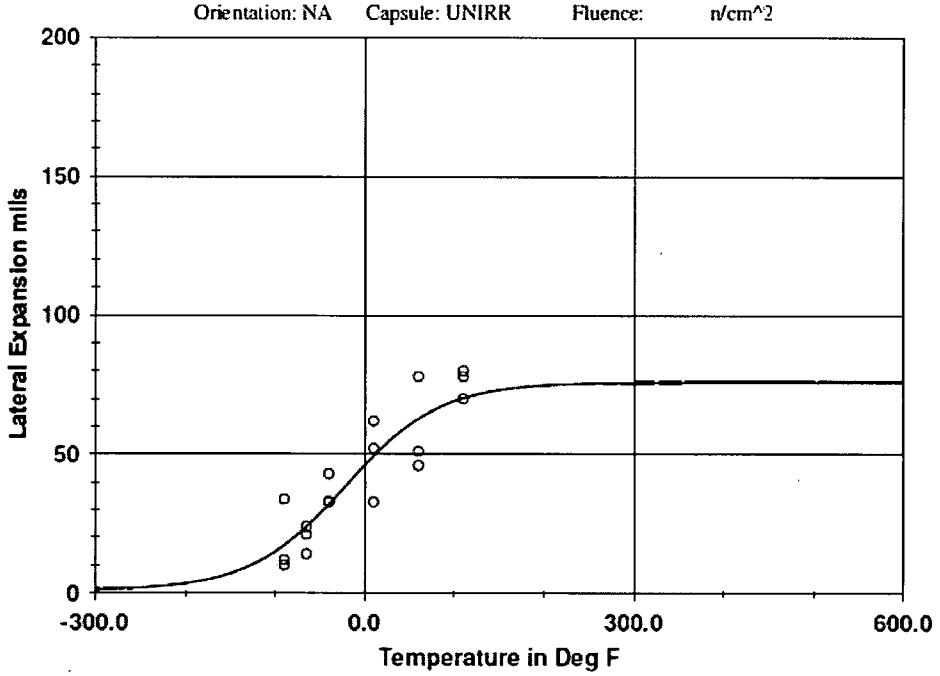
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
360.00	67.00	88.25	-21.25
375.00	90.00	88.25	1.75
390.00	72.00	88.25	-16.25

Correlation Coefficient = .860

Unirradiated Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:23 AM
Page 1
Coefficients of Curve 1
A = 38.5 B = 37.5 C = 105.67 T0 = -21.83 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=76.0(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-31.7 Deg F
Plant: GINNA Material: SAW Heat: 125P666
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-90.00	10.00	17.19	-7.19
-90.00	34.00	17.19	16.81
-90.00	12.00	17.19	-5.19
-65.00	24.00	23.98	.02
-65.00	14.00	23.98	-9.98
-65.00	21.00	23.98	-2.98
-40.00	33.00	32.12	.88
-40.00	43.00	32.12	10.88
-40.00	33.00	32.12	.88

Unirradiated Heat Affected Zone

Page 2
Plant: GINNA Material: SAW Heat: 125P666
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

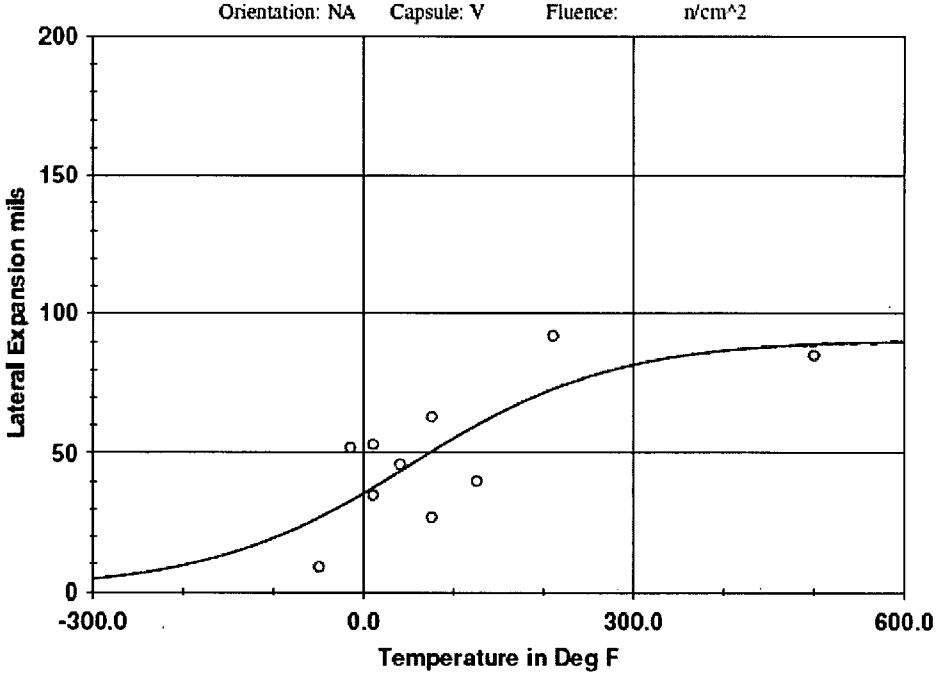
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
10.00	62.00	49.47	12.53
10.00	33.00	49.47	-16.47
10.00	52.00	49.47	2.53
60.00	51.00	62.86	-11.86
60.00	46.00	62.86	-16.86
60.00	78.00	62.86	15.14
110.00	80.00	70.29	9.71
110.00	78.00	70.29	7.71
110.00	70.00	70.29	-.29

Correlation Coefficient = .895

Capsule V Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/11/2009 12:41 PM
Page 1
Coefficients of Curve 1
A = 45.79 B = 44.79 C = 225.29 T0 = 51.04 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=90.6 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-4.3 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	9.00	26.95	-17.95
-15.00	52.00	33.02	18.98
10.00	35.00	37.72	-2.72
10.00	53.00	37.72	15.28
40.00	46.00	43.59	2.41
75.00	27.00	50.53	-23.53
75.00	63.00	50.53	12.47
125.00	40.00	59.98	-19.98
210.00	92.00	73.01	18.99

Capsule V Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: V Fluence: n/cm^2

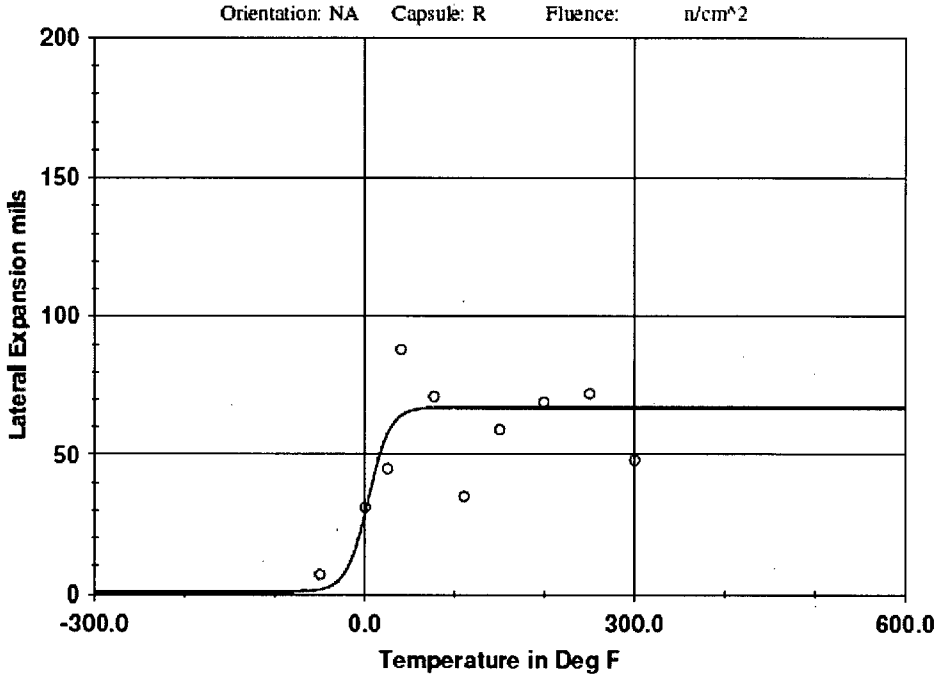
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
500.00	85.00	88.94	-3.94

Correlation Coefficient = .760

Capsule R Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/11/2009 12:46 PM
Page 1
Coefficients of Curve 1
A = 34.1 B = 33.1 C = 23.99 T0 = 3.62 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=67.2(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=4.3 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	7.00	1.75	5.25
.00	31.00	29.15	1.85
25.00	45.00	57.67	-12.67
40.00	88.00	64.16	23.84
77.00	71.00	67.05	3.95
110.00	35.00	67.19	-32.19
150.00	59.00	67.20	-8.20
199.00	69.00	67.20	1.80
250.00	72.00	67.20	4.80

Capsule R Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: R Fluence: n/cm^2

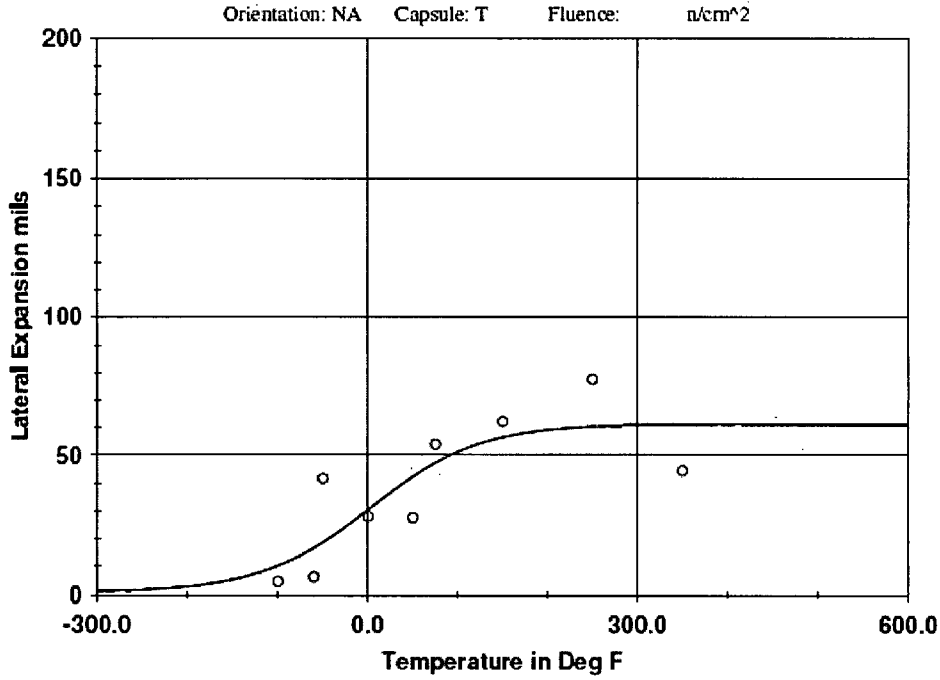
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
300.00	48.00	67.20	-19.20

Correlation Coefficient = .777

Capsule T Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/11/2009 12:52 PM
Page 1
Coefficients of Curve 1
A = 31.2 B = 30.2 C = 121.03 T0 = 2.82 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=61.4(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=18.2 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: T Fluence: n/cm^2



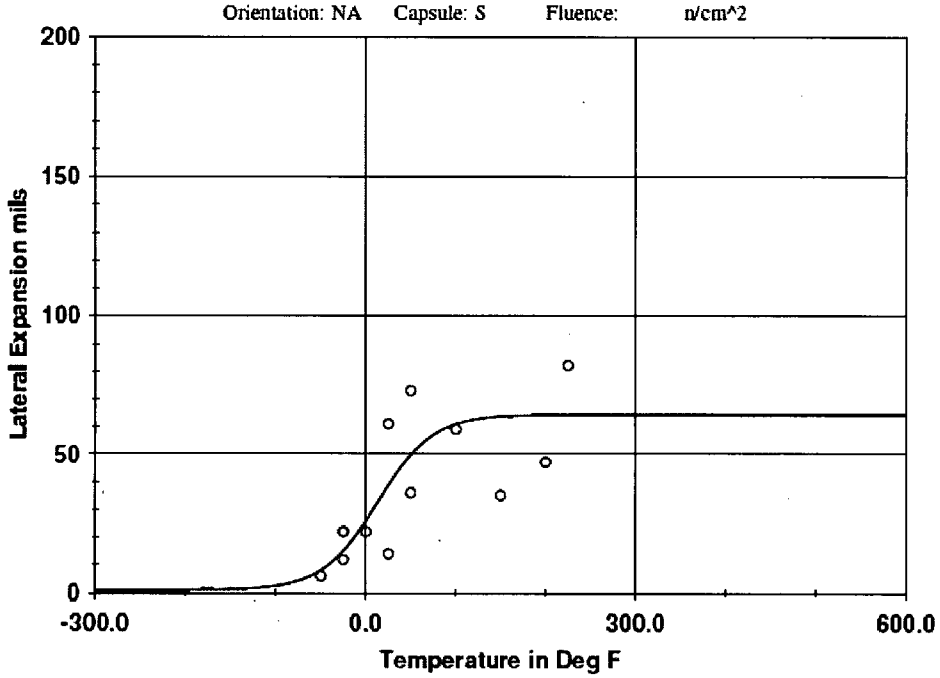
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-100.00	4.70	10.34	-5.64
-60.00	6.30	16.80	-10.50
-50.00	41.70	18.80	22.90
.00	28.00	30.50	-2.50
50.00	27.60	42.41	-14.81
75.00	53.90	47.34	6.56
150.00	62.20	56.52	5.68
250.00	77.60	60.40	17.20
350.00	44.50	61.21	-16.71

Correlation Coefficient = .823

Capsule S Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/16/2009 07:54 AM
Page 1
Coefficients of Curve 1
A = 32.75 B = 31.75 C = 61.39 T0 = 13.12 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=64.5(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=17.5 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	6.00	8.20	-2.20
-25.00	12.00	15.23	-3.23
-25.00	22.00	15.23	6.77
.00	22.00	26.07	-4.07
25.00	14.00	38.82	-24.82
25.00	61.00	38.82	22.18
50.00	36.00	49.82	-13.82
50.00	73.00	49.82	23.18
100.00	59.00	60.96	-1.96

Capsule S Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: S Fluence: n/cm^2

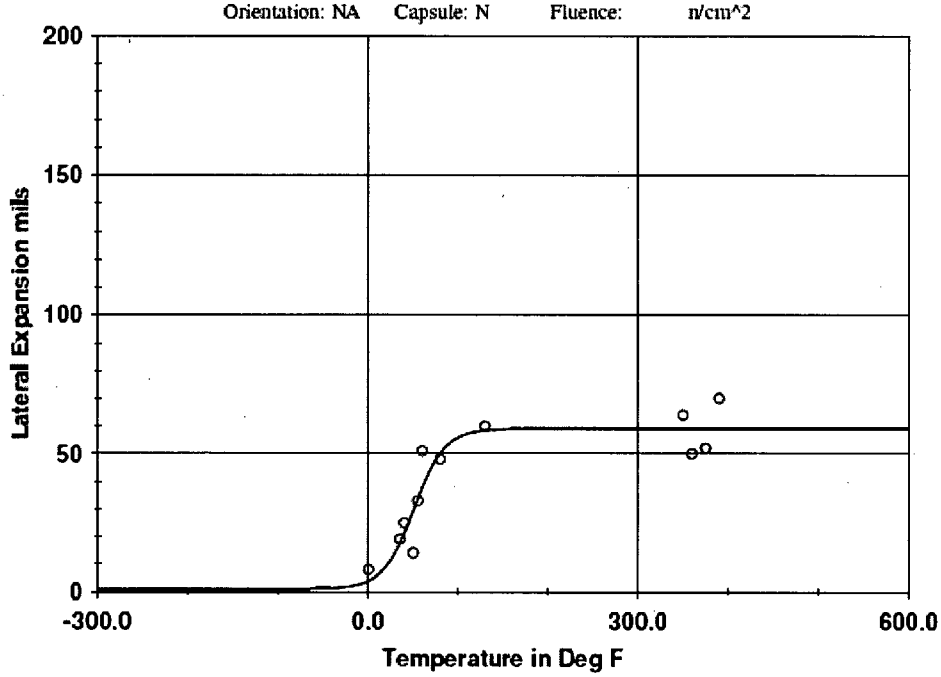
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
150.00	35.00	63.77	-28.77
200.00	47.00	64.36	-17.36
225.00	82.00	64.44	17.56

Correlation Coefficient = .733

Capsule N Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/06/2009 09:29 AM
Page 1
Coefficients of Curve 1
A = 30. B = 29. C = 34.18 T0 = 50.52 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=59.0(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp. @L.E. 35 mils=56.5 Deg F
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	8.00	3.87	4.13
35.00	19.00	17.67	1.33
40.00	25.00	21.34	3.66
50.00	14.00	29.56	-15.56
55.00	33.00	33.78	-.78
60.00	51.00	37.84	13.16
80.00	48.00	50.23	-2.23
130.00	60.00	58.45	1.55
350.00	64.00	59.00	5.00

Capsule N Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: N Fluence: n/cm^2

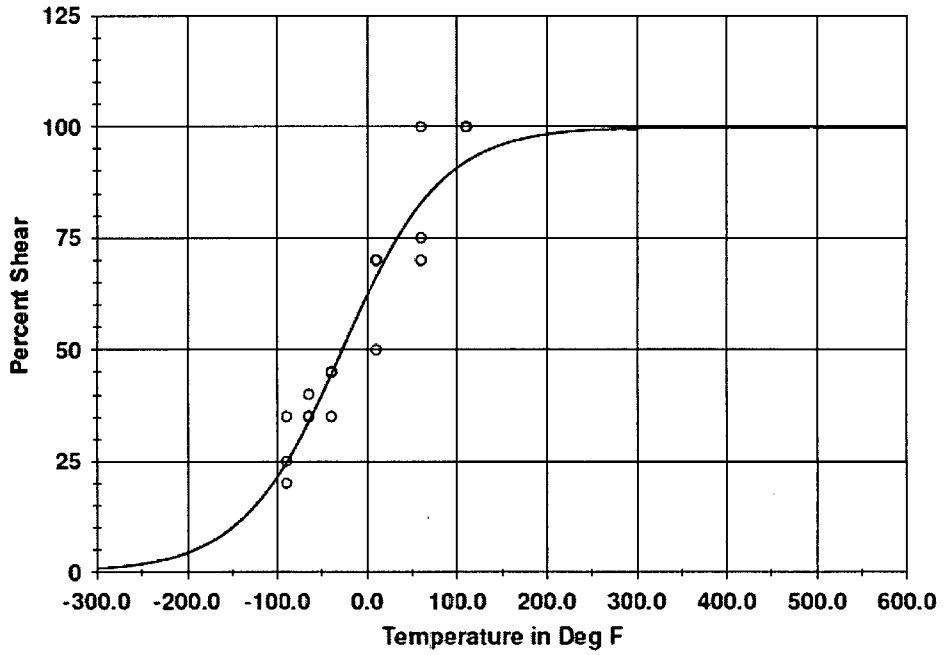
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
360.00	50.00	59.00	-9.00
375.00	52.00	59.00	-7.00
390.00	70.00	59.00	11.00

Correlation Coefficient = .920

Unirradiated Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/27/2009 09:23 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 111.53 T0 = -27.79 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -27.7
Plant: GINNA Material: SAW Heat: 125P666
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-90.00	20.00	24.68	-4.68
-90.00	35.00	24.68	10.32
-90.00	25.00	24.68	.32
-65.00	40.00	33.91	6.09
-65.00	35.00	33.91	1.09
-65.00	35.00	33.91	1.09
-40.00	45.00	44.55	.45
-40.00	45.00	44.55	.45
-40.00	35.00	44.55	-9.55

Unirradiated Heat Affected Zone

Page 2
Plant: GINNA Material: SAW Heat: 125P666
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

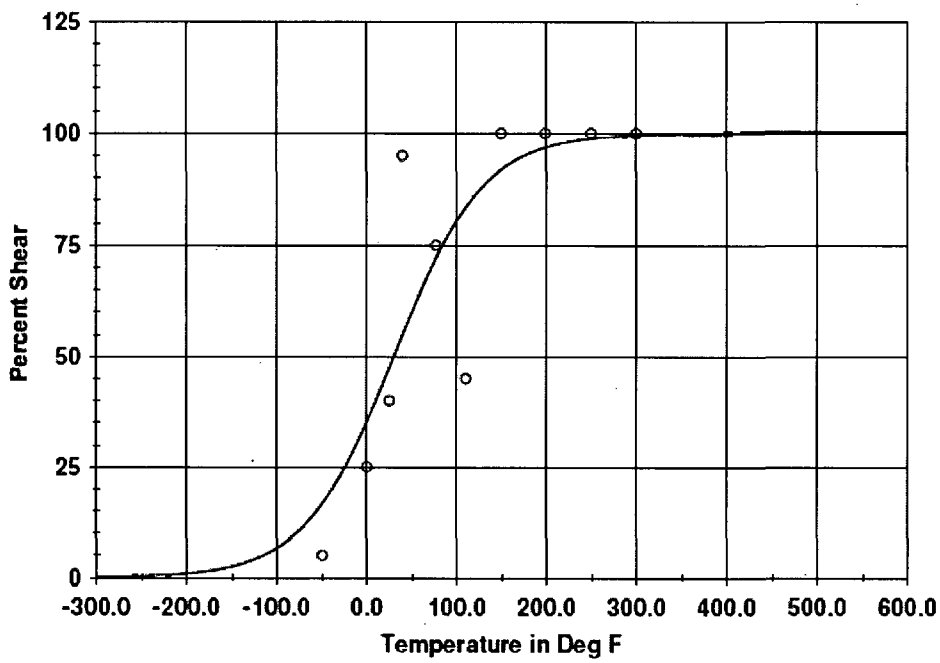
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
10.00	70.00	66.32	3.68
10.00	50.00	66.32	-16.32
10.00	70.00	66.32	3.68
60.00	75.00	82.84	-7.84
60.00	70.00	82.84	-12.84
60.00	100.00	82.84	17.16
110.00	100.00	92.21	7.79
110.00	100.00	92.21	7.79
110.00	100.00	92.21	7.79

Correlation Coefficient = .952

Capsule R Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/11/2009 12:47 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 98.74 T0 = 29.86 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 29.9
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: R Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	5.00	16.55	-11.55
.00	25.00	35.32	-10.32
25.00	40.00	47.54	-7.54
40.00	95.00	55.12	39.88
77.00	75.00	72.21	2.79
110.00	45.00	83.52	-38.52
150.00	100.00	91.93	8.07
199.00	100.00	96.85	3.15
250.00	100.00	98.86	1.14

Capsule R Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: R Fluence: n/cm^2

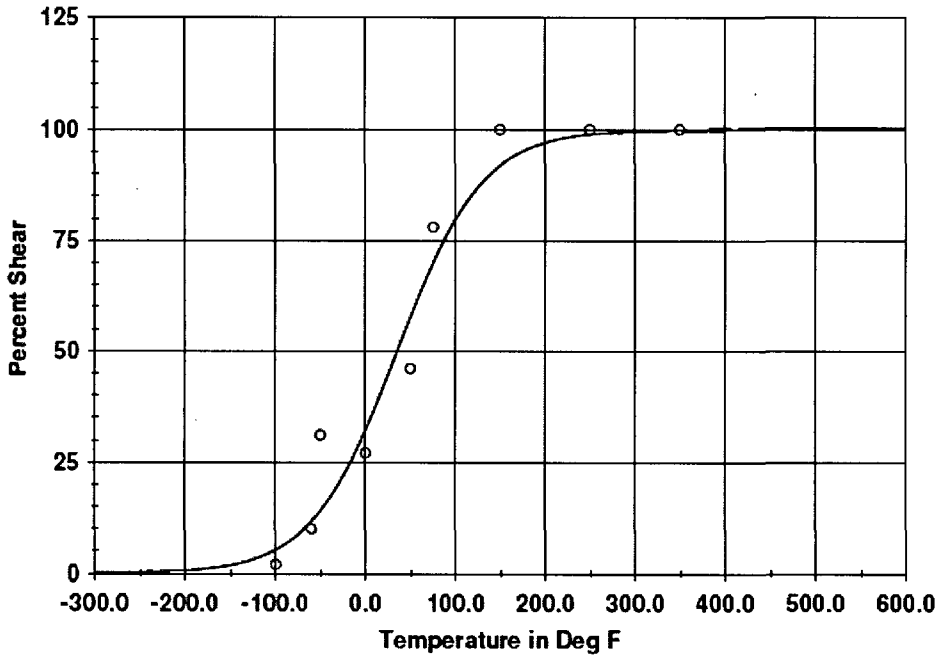
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
300.00	100.00	99.58	.42

Correlation Coefficient = .845

Capsule T Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/11/2009 12:53 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 94.19 T0 = 35.2 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 35.3
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: T Fluence: n/cm^2



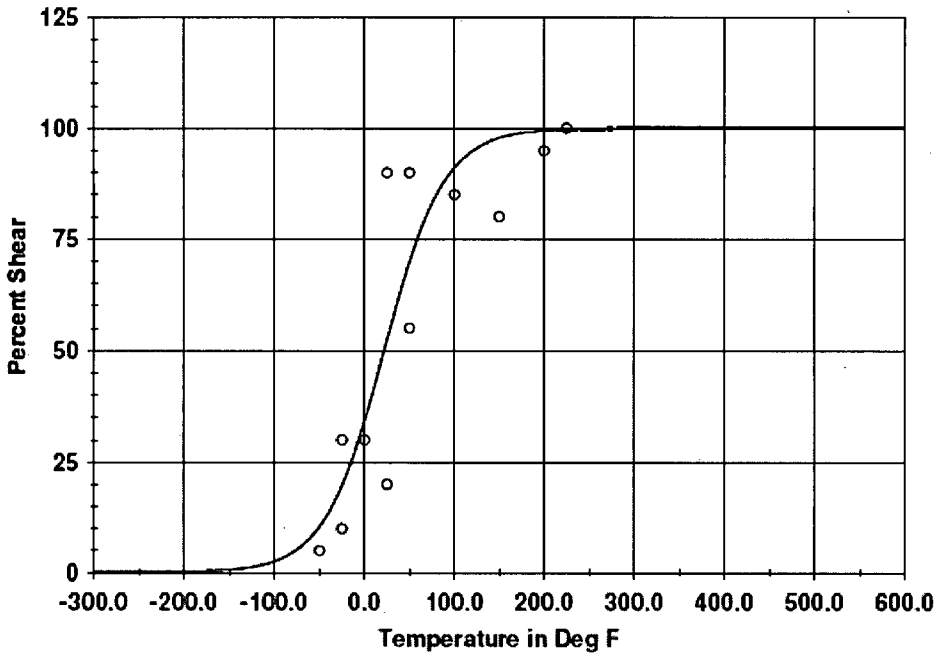
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100.00	2.00	5.36	-3.36
-60.00	10.00	11.70	-1.70
-50.00	31.00	14.07	16.93
.00	27.00	32.14	-5.14
50.00	46.00	57.79	-11.79
75.00	78.00	69.95	8.05
150.00	100.00	91.97	8.03
250.00	100.00	98.97	1.03
350.00	100.00	99.88	.12

Correlation Coefficient = .977

Capsule S Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/16/2009 07:55 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 66.92 T0 = 21.71 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 21.8
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: S Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	5.00	10.50	-5.50
-25.00	10.00	19.85	-9.85
-25.00	30.00	19.85	10.15
.00	30.00	34.33	-4.33
25.00	20.00	52.46	-32.46
25.00	90.00	52.46	37.54
50.00	55.00	69.96	-14.96
50.00	90.00	69.96	20.04
100.00	85.00	91.21	-6.21

Capsule S Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: S Fluence: n/cm^2

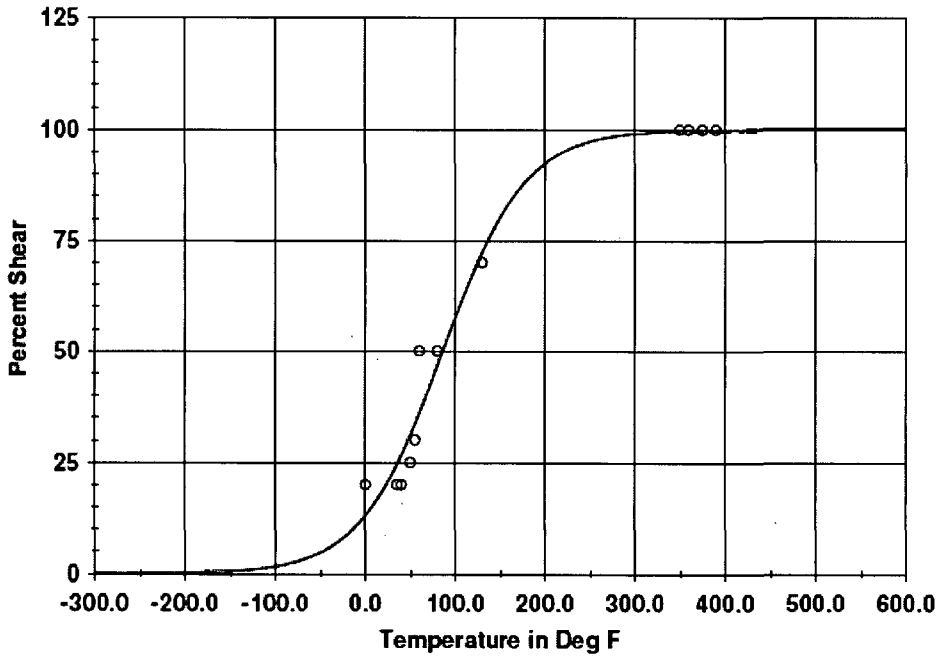
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
150.00	80.00	97.88	-17.88
200.00	95.00	99.52	-4.52
225.00	100.00	99.77	.23

Correlation Coefficient = .867

Capsule N Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 03/06/2009 09:30 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 90.97 T0 = 85.94 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 86.0
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: N Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	20.00	13.13	6.87
35.00	20.00	24.60	-4.60
40.00	20.00	26.70	-6.70
50.00	25.00	31.21	-6.21
55.00	30.00	33.62	-3.62
60.00	50.00	36.12	13.88
80.00	50.00	46.74	3.26
130.00	70.00	72.48	-2.48
350.00	100.00	99.70	.30

Capsule N Heat Affected Zone

Page 2
Plant: Ginna Material: SAW Heat: 125P666
Orientation: NA Capsule: N Fluence: n/cm^2

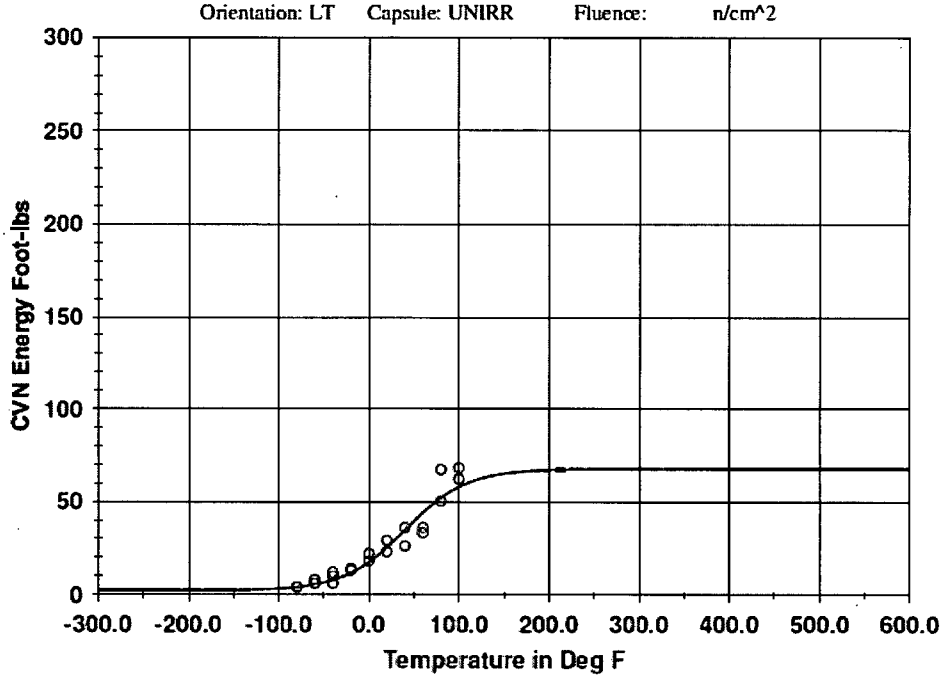
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
360.00	100.00	99.76	.24
375.00	100.00	99.83	.17
390.00	100.00	99.88	.12

Correlation Coefficient = .986

Unirradiated Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 10:46 AM
Page 1
Coefficients of Curve 1
A = 34.85 B = 32.65 C = 67.92 T0 = 40.28 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=67.5(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=30.2 Deg F Temp@50 ft-lbs=74.5 Deg F
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	4.00	4.04	-.04
-80.00	4.00	4.04	-.04
-60.00	8.00	5.44	2.56
-60.00	6.00	5.44	.56
-40.00	12.00	7.81	4.19
-40.00	10.00	7.81	2.19
-40.00	6.00	7.81	-1.81
-20.00	14.00	11.66	2.34
-20.00	13.00	11.66	1.34

Unirradiated Correlation Monitor Material

Page 2
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

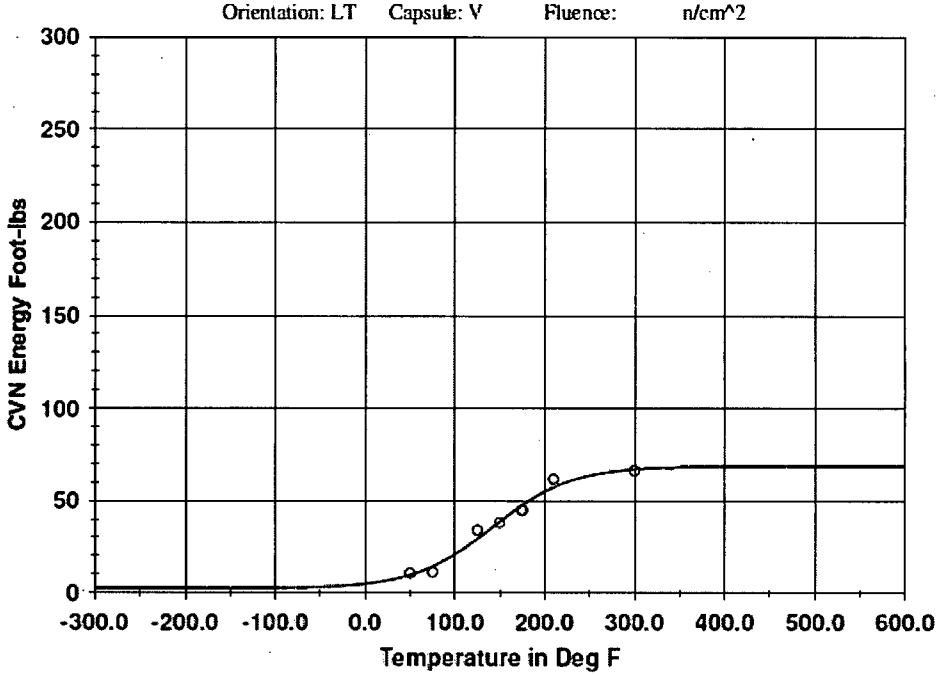
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	22.00	17.48	4.52
.00	18.00	17.48	.52
20.00	29.00	25.38	3.62
20.00	23.00	25.38	-2.38
40.00	36.00	34.72	1.28
40.00	26.00	34.72	-8.72
60.00	36.00	44.07	-8.07
60.00	33.00	44.07	-11.07
80.00	67.00	52.03	14.97
80.00	50.00	52.03	-2.03
100.00	68.00	57.90	10.10
100.00	62.00	57.90	4.10

Correlation Coefficient = .960

Capsule V Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 10:52 AM
Page 1
Coefficients of Curve 1
A = 35.4 B = 33.2 C = 87.23 T0 = 141.45 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=68.6 Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=127.2 Deg F Temp@50 ft-lbs=182.7 Deg F
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: V Fluence: n/cm^2



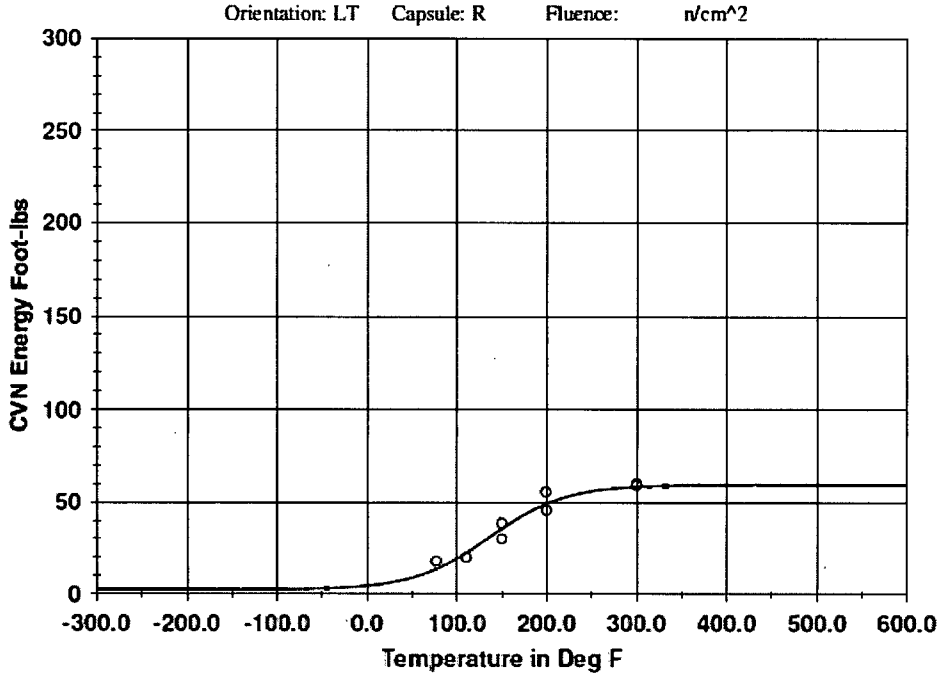
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
50.00	10.30	9.46	.84
75.00	11.00	14.08	-3.08
125.00	34.00	29.21	4.79
150.00	38.00	38.64	-.64
175.00	45.00	47.57	-2.57
175.00	44.50	47.57	-3.07
210.00	61.50	57.18	4.32
300.00	66.00	66.89	-.89

Correlation Coefficient = .988

Capsule R Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 10:44 AM
Page 1
Coefficients of Curve 1
A = 30.85 B = 28.65 C = 84.99 T0 = 135.85 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=59.5(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=133.4 Deg F Temp@50 ft-lbs=204.6 Deg F
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: R Fluence: n/cm^2



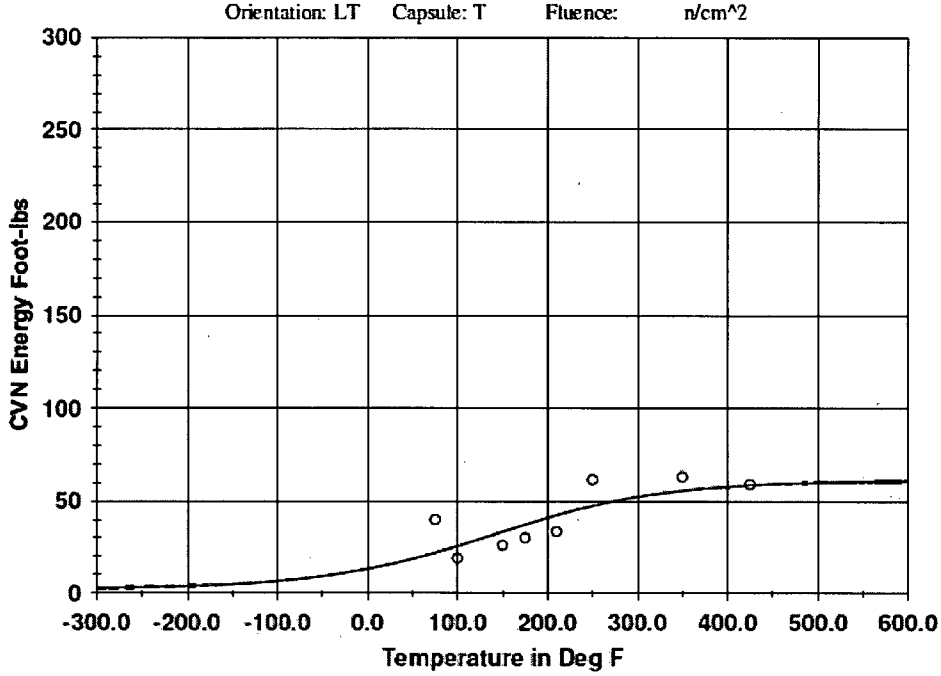
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
77.00	18.00	13.67	4.33
110.00	20.00	22.40	-2.40
150.00	38.50	35.58	2.92
150.00	30.00	35.58	-5.58
199.00	55.50	48.93	6.57
200.00	45.50	49.13	-3.63
300.00	59.00	58.32	.68
300.00	60.00	58.32	1.68

Correlation Coefficient = .969

Capsule T Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 10:51 AM
Page 1
Coefficients of Curve 1
A = 31.7 B = 29.5 C = 186.75 T0 = 138.74 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=61.2(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=128.0 Deg F Temp@50 ft-lbs=274.3 Deg F
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: T Fluence: n/cm^2



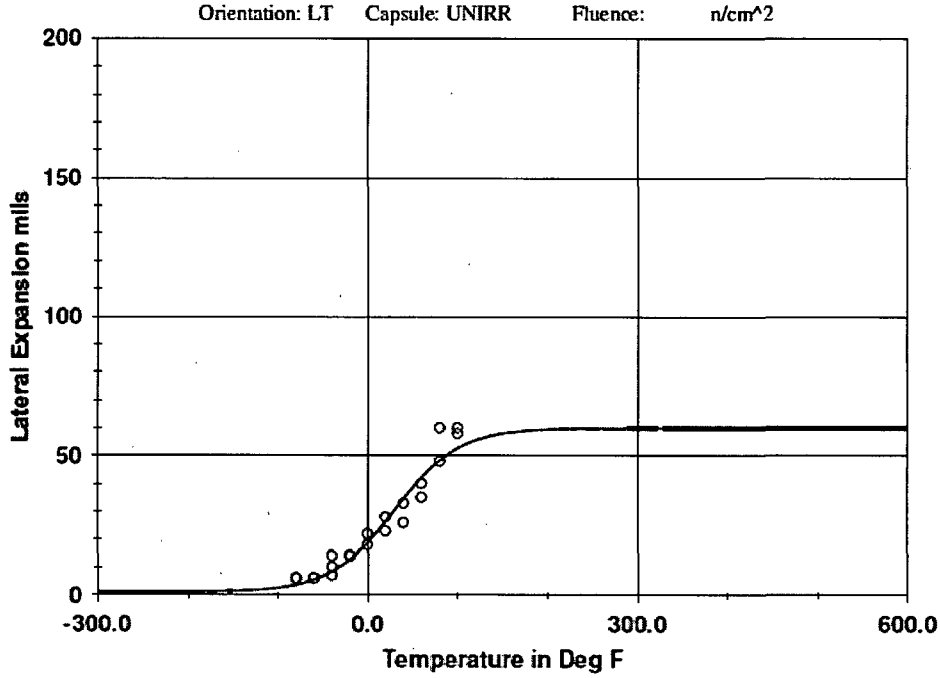
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
75.00	40.00	22.00	18.00
100.00	19.00	25.67	-6.67
150.00	26.00	33.48	-7.48
175.00	30.00	37.36	-7.36
210.00	33.50	42.44	-8.94
250.00	61.50	47.45	14.05
350.00	63.00	55.64	7.36
425.00	59.00	58.57	.43

Correlation Coefficient = .789

Unirradiated Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 01:59 PM
Page 1
Coefficients of Curve 1
A = 30.5 B = 29.5 C = 71.82 T0 = 29.87 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=60.0(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=41.0 Deg F
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	6.00	3.64	2.36
-80.00	6.00	3.64	2.36
-60.00	6.00	5.46	.54
-60.00	6.00	5.46	.54
-40.00	14.00	8.38	5.62
-40.00	10.00	8.38	1.62
-40.00	7.00	8.38	-1.38
-20.00	14.00	12.78	1.22
-20.00	14.00	12.78	1.22

Unirradiated Correlation Monitor Material

Page 2
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

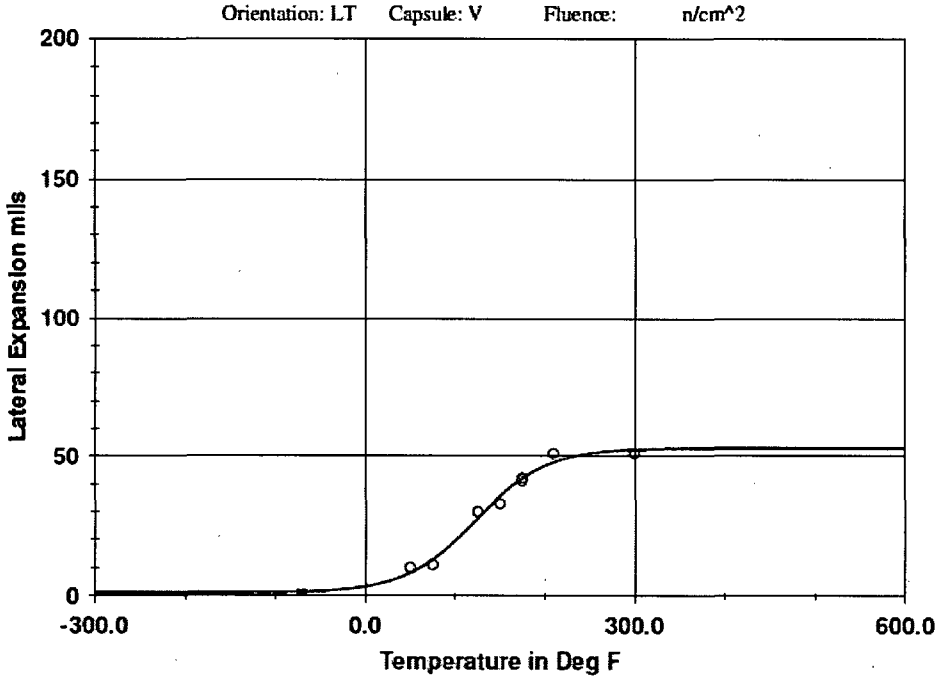
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	22.00	18.89	3.11
.00	18.00	18.89	-.89
20.00	28.00	26.47	1.53
20.00	23.00	26.47	-3.47
40.00	33.00	34.63	-1.63
40.00	26.00	34.63	-8.63
60.00	40.00	42.20	-2.20
60.00	35.00	42.20	-7.20
80.00	60.00	48.29	11.71
80.00	48.00	48.29	-.29
100.00	60.00	52.67	7.33
100.00	58.00	52.67	5.33

Correlation Coefficient = .970

Capsule V Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 02:01 PM
Page 1
Coefficients of Curve 1
A = 27.02 B = 26.02 C = 79.33 T0 = 122.99 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=53.0 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=148.2 Deg F
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: V Fluence: n/cm^2



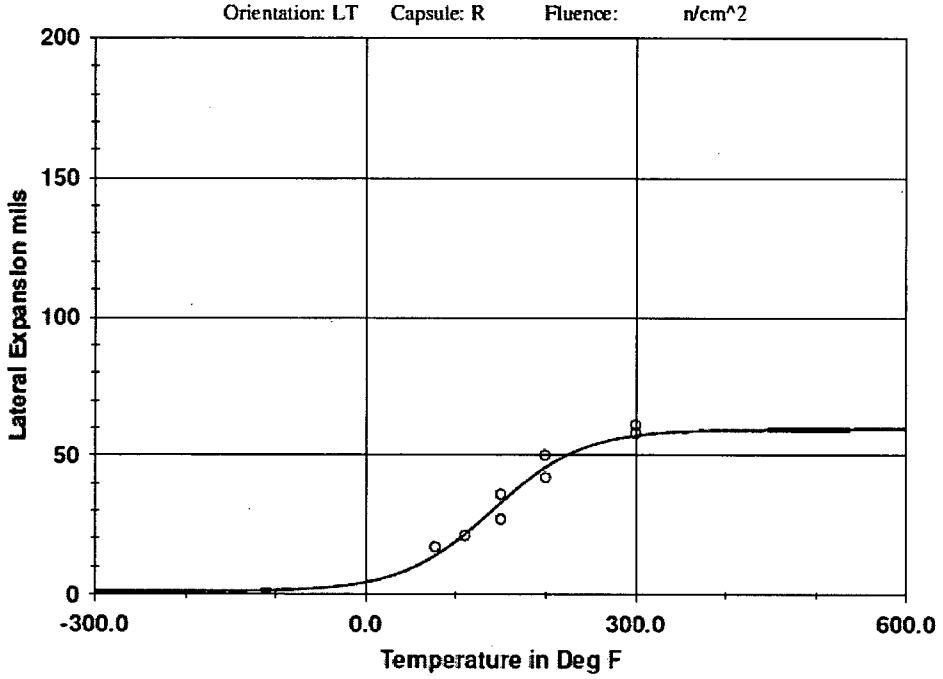
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
50.00	10.00	8.13	1.87
75.00	11.00	12.95	-1.95
125.00	30.00	27.67	2.33
150.00	33.00	35.54	-2.54
175.00	42.00	41.98	.02
175.00	41.00	41.98	-.98
210.00	51.00	47.81	3.19
300.00	51.00	52.44	-1.44

Correlation Coefficient = .991

Capsule R Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 02:00 PM
Page 1
Coefficients of Curve 1
A = 30.25 B = 29.25 C = 100.63 T0 = 140.66 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=59.5(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=157.2 Deg F
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: R Fluence: n/cm^2



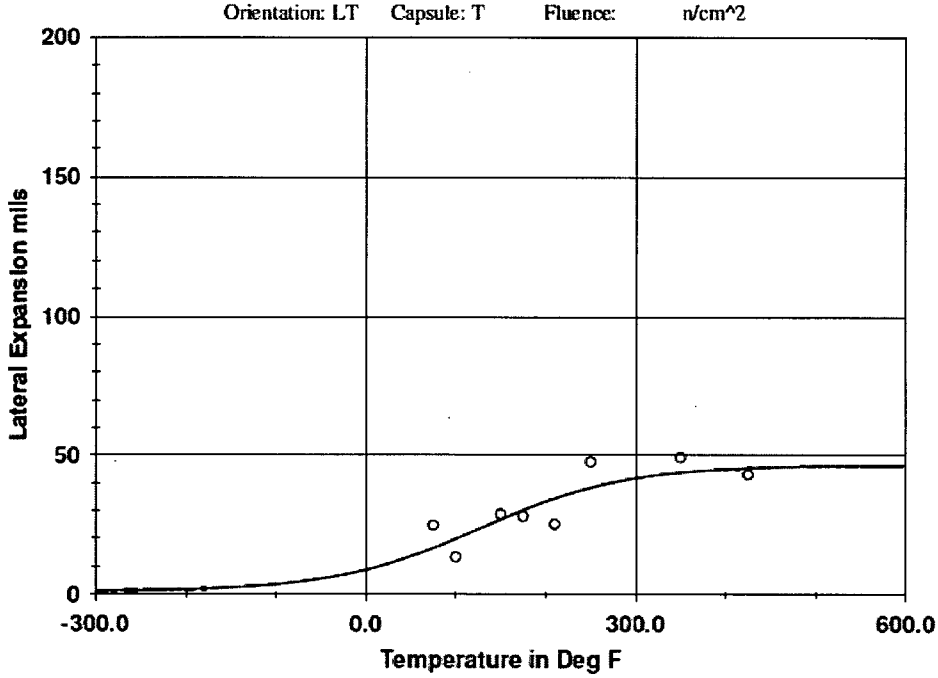
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
77.00	17.00	13.87	3.13
110.00	21.00	21.60	-.60
150.00	36.00	32.96	3.04
150.00	27.00	32.96	-5.96
199.00	50.00	45.53	4.47
200.00	42.00	45.74	-3.74
300.00	61.00	57.13	3.87
300.00	58.00	57.13	.87

Correlation Coefficient = .974

Capsule T Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 02:01 PM
Page 1
Coefficients of Curve 1
A = 23.8 B = 22.8 C = 161.67 T0 = 127.94 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=46.6(Fixed) Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=214.9 Deg F
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: T Fluence: n/cm^2



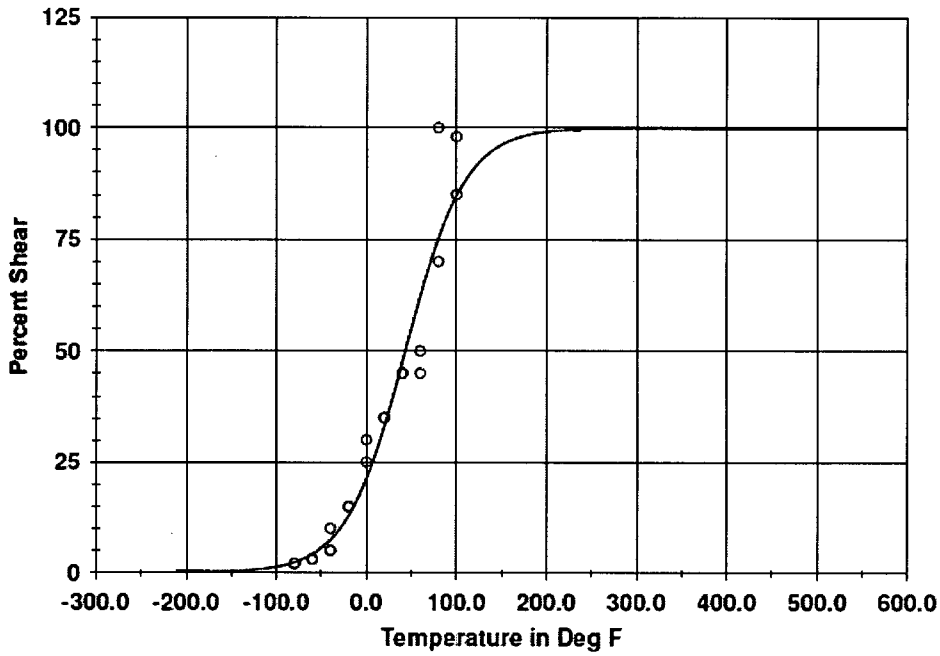
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
75.00	24.80	16.59	8.21
100.00	13.40	19.90	-6.50
150.00	28.70	26.89	1.81
175.00	28.00	30.25	-2.25
210.00	25.20	34.47	-9.27
250.00	47.60	38.35	9.25
350.00	49.20	43.85	5.35
425.00	43.00	45.47	-2.47

Correlation Coefficient = .846

Unirradiated Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 03:09 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 65.95 T0 = 43.1 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 43.2
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	2.00	2.34	-.34
-80.00	2.00	2.34	-.34
-60.00	3.00	4.20	-1.20
-60.00	3.00	4.20	-1.20
-40.00	10.00	7.45	2.55
-40.00	5.00	7.45	-2.45
-40.00	5.00	7.45	-2.45
-20.00	15.00	12.86	2.14
-20.00	15.00	12.86	2.14

Unirradiated Correlation Monitor Material

Page 2
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

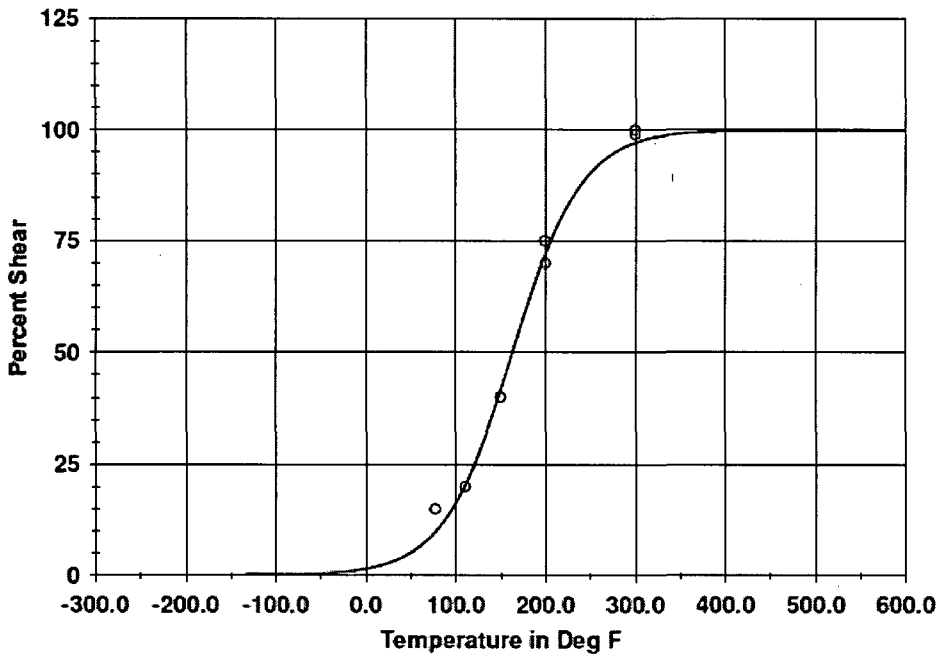
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	30.00	21.30	8.70
.00	25.00	21.30	3.70
20.00	35.00	33.17	1.83
20.00	35.00	33.17	1.83
40.00	45.00	47.65	-2.65
40.00	45.00	47.65	-2.65
60.00	50.00	62.54	-12.54
60.00	45.00	62.54	-17.54
80.00	100.00	75.38	24.62
80.00	70.00	75.38	-5.38
100.00	98.00	84.88	13.12
100.00	85.00	84.88	.12

Correlation Coefficient = .965

Capsule R Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 10:40 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 77.59 T0 = 163.09 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 163.1
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: R Fluence: n/cm^2



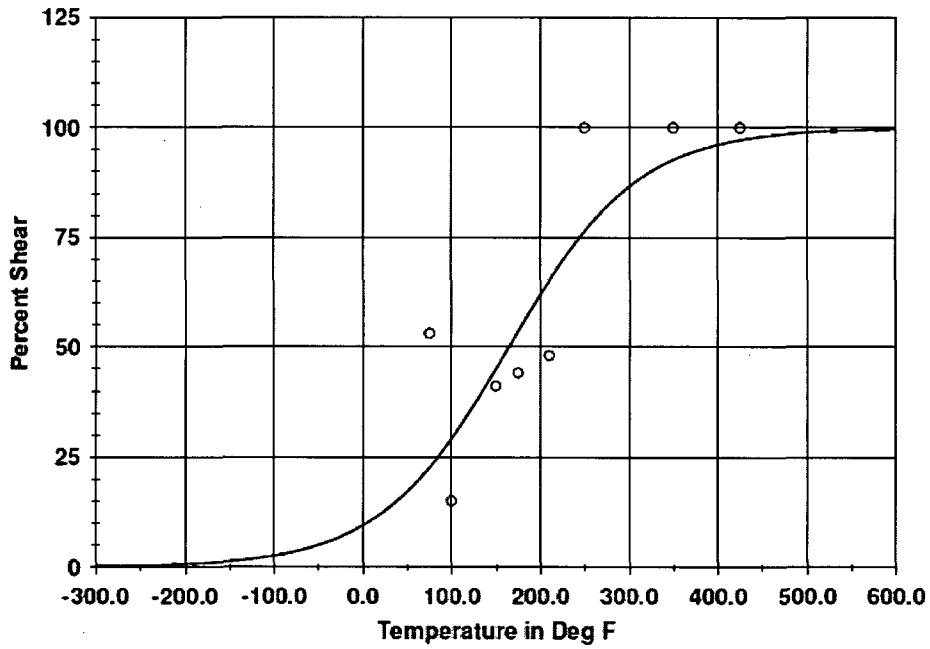
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
77.00	15.00	9.81	5.19
110.00	20.00	20.29	-.29
150.00	40.00	41.65	-1.65
150.00	40.00	41.65	-1.65
199.00	75.00	71.62	3.38
200.00	70.00	72.14	-2.14
300.00	99.00	97.15	1.85
300.00	100.00	97.15	2.85

Correlation Coefficient = .997

Capsule T Correlation Monitor Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 04/15/2009 10:51 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 145.59 T0 = 164.7 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 164.7
Plant: Ginna Material: SA302B Heat: A0421
Orientation: LT Capsule: T Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
75.00	53.00	22.58	30.42
100.00	15.00	29.14	-14.14
150.00	41.00	44.97	-3.97
175.00	44.00	53.53	-9.53
210.00	48.00	65.07	-17.07
250.00	100.00	76.35	23.65
350.00	100.00	92.73	7.27
425.00	100.00	97.28	2.72

Correlation Coefficient = .851

APPENDIX D
SURVEILLANCE PROGRAM CREDIBILITY EVALUATION

D.1 INTRODUCTION

Regulatory Guide 1.99, Revision 2 [D-1] describes general procedures acceptable to the NRC staff for calculating the effects of neutron radiation embrittlement of the low-alloy steels currently used for light-water-cooled reactor vessels. Regulatory Positions 2.1 and 2.2 of Regulatory Guide 1.99, Revision 2, describe the methods for calculating the adjusted reference temperature (ART) and Charpy upper shelf energy (USE) of reactor vessel beltline materials using surveillance capsule data.

To date there have been five surveillance capsules removed from the R. E. Ginna reactor vessel. To use these surveillance data sets to reduce the margin term (σ_Δ) that is used to calculate ART according to Position 2.1, or to obtain the projected decrease in USE per Position 2.2, the data must be shown to be credible. However, even if the data is not shown to be credible, the projected decrease in USE per Position 2.2 may still be obtained if the upper shelf can be clearly determined, following the definition given in ASTM E185-82 [D-2]. In accordance with Regulatory Guide 1.99, Revision 2, the credibility of the surveillance data will be judged based on five criteria.

The purpose of this evaluation is to apply the credibility requirements of Regulatory Guide 1.99, Revision 2, to the R. E. Ginna reactor vessel surveillance data and determine if that surveillance data is credible.

D.2 EVALUATION

Criterion 1: Materials in the capsules should be those judged most likely to be controlling with regard to radiation embrittlement.

The beltline region of the reactor vessel is defined in Appendix G to 10 CFR Part 50, "Fracture Toughness Requirements" [D-3], as follows:

> *"the reactor vessel (shell material including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage."*

The R. E. Ginna reactor vessel consists of the following beltline region materials:

- Nozzle shell forging 123P118
- Intermediate shell forging 125S255
- Lower shell forging 125P666
- Nozzle to Intermediate shell girth weld seam (heat # 71249)
- Intermediate to lower shell girth weld seam (heat # 61782)

Per WCAP-7254, the R. E. Ginna surveillance program was based on ASTM E185-66 [D-4], "Recommended Practice for Surveillance Tests on Structural Materials in Nuclear Reactors". Per Section 3.1 of ASTM E185-66, "Samples shall represent one heat of the base metal and one butt weld if a weld occurs in the irradiated region." R. E. Ginna included the intermediate and lower shell forging materials as well as the intermediate to lower shell girth weld metal in the surveillance program. At the time the surveillance program was developed, the nozzle area (weld and forging) was thought to be outside the beltline region; thus, it was left out of the surveillance program. All beltline region materials were included. Hence, Criterion 1 is met for the R. E. Ginna reactor vessel.

Criterion 2: Scatter in the plots of Charpy energy versus temperature for the irradiated and unirradiated conditions should be small enough to permit the determination of the 30 ft-lb temperature and USE unambiguously.

Based on engineering judgment, the scatter in the data presented in these plots is small enough to permit the determination of the 30 ft-lb temperature and the USE of the R. E. Ginna surveillance materials unambiguously. Hence, the R. E. Ginna surveillance program meets this criterion.

Criterion 3: When there are two or more sets of surveillance data from one reactor, the scatter of ΔRT_{NDT} values about a best-fit line drawn as described in Regulatory Position 2.1 normally should be less than 28°F for welds and 17°F for base metal. Even if the fluence range is large (two or more orders of magnitude), the scatter should not exceed twice those values. Even if the data fail this criterion for use in shift calculations, they may be credible for determining decrease in USE if the upper shelf can be clearly determined, following the definition given in ASTM E185-82 [D-2].

The functional form of the least squares method as described in Regulatory Position 2.1 will be utilized to determine a best-fit line for this data and to determine if the scatter of these ΔRT_{NDT} values about this line is less than 28°F for surveillance welds and less than 17°F for surveillance forgings.

Following is the calculation of the best fit line as described in Regulatory Position 2.1 of Regulatory Guide 1.99, Revision 2. There are three cases to be evaluated for this criterion, and they are:

- Case A: Surveillance weld data for the Intermediate to Lower Shell Girth Weld Heat #61782. Charpy specimens of weld heat #61782 are contained in the R. E. Ginna surveillance capsule program and will be evaluated for the R. E. Ginna reactor vessel.
- Case B: Surveillance weld data for Nozzle to Intermediate Shell Girth Weld Heat #71249. This weld is not included in the R. E. Ginna surveillance program but surveillance data are available from Turkey Point Units 3 and 4 and Davis-Besse.
- Case C: Surveillance forging data from the Intermediate and Lower Shell forgings. Data for these forgings are contained only in the R. E. Ginna surveillance program.

The recommended NRC methods for determining credibility will be followed. The NRC methods were presented to industry at a meeting held by the NRC on February 12 and 13, 1998 [D-5]. At this meeting the NRC presented five cases. Of the five cases, NRC Case 1 most closely represents R. E. Ginna Cases A and C. NRC Case 1 is "Surveillance Data Available From Plant But No Other Source". This is identical to the credibility calculation of Regulatory Guide 1.99, Revision 2. R. E. Ginna Case B corresponds to NRC Case 5, "Surveillance Data from Other Plants Only".

Credibility Assessment (Cases A and C):

The chemistry factors for the R. E. Ginna surveillance forging and weld material contained in the surveillance program were calculated in accordance with Regulatory Guide 1.99, Revision 2, Position 2.1 and are presented in Table D-1. The scatter of ΔRT_{NDT} values about the functional form of a best-fit line drawn as described in Regulatory Position 2.1 is presented in Table D-2.

Table D-1 Calculation of Chemistry Factors using R. E. Ginna Surveillance Capsule Data

Material	Capsule	Capsule f [(a)]	FF[(b)]	ΔRT_{NDT}[(c)]	$FF*\Delta RT_{NDT}$	FF^2
Intermediate Shell Forging 125S255 (L-C)	V	0.587	0.851	0[(d)]	0	0.724
	R	1.02	1.006	20.1	20.2	1.011
	T	1.69	1.144	0[(d)]	0	1.310
	S	3.64	1.335	76.8	102.6	1.783
	N	5.8	1.430	76.4	109.3	2.046
				SUM:	232.1	6.875
	$CF_{125S255} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (232.1) \div (6.875) =$ **33.8°F**					
Lower Shell Forging 125P666 (L-C)	V	0.587	0.851	34.7	29.5	0.724
	R	1.02	1.006	57.5	57.8	1.011
	T	1.69	1.144	33.6	38.5	1.310
	S	3.64	1.335	45.8	61.2	1.783
	N	5.8	1.430	91.1	130.3	2.046
				SUM:	317.3	6.875
	$CF_{125P666} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (317.3) \div (6.875) =$ **46.2°F**					
Surveillance Weld Material Heat # 61782	V	0.587	0.851	146.7	124.8	0.724
	R	1.02	1.006	156.2	157.1	1.011
	T	1.69	1.144	149.7	171.3	1.310
	S	3.64	1.335	212.2	283.4	1.783
	N	5.8	1.430	216.9	310.3	2.046
				SUM:	1046.9	6.875
	$CF_{Ht.\#61782} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (1046.9) \div (6.875) =$ **152.3°F**					

Notes:

(a) f = fluence (x 10^{19} n/cm^2, E > 1.0 MeV). See Section 6.

(b) FF = fluence factor = $f^{(0.28 - 0.1*\log(f))}$.

(c) ΔRT_{NDT} (°F) values are the measured 30 ft-lb shift values taken from Section 5.

(d) Measured ΔRT_{NDT} value was determined to be negative, but physically a reduction should not occur. Therefore, a conservative value of zero is used.

Table D-2 R. E. Ginna Surveillance Capsule Data Scatter about the Best-Fit Line

Material	Capsule	CF ($Slope_{best\ fit}$) (°F)	Capsule f ($x10^{19}$ n/cm^2)	FF	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	Scatter ΔRT_{NDT} (°F)	<17°F (Base Metal) <28°F (Weld)
Intermediate Shell Forging 125S255 (Longitudinal)	V	33.8	0.587	0.851	0	28.7	28.7	No
	R	33.8	1.02	1.006	20.1	33.9	13.8	Yes
	T	33.8	1.69	1.144	0	38.6	38.6	No
	S	33.8	3.64	1.335	76.8	45.1	-31.7	No
	N	33.8	5.8	1.430	76.4	48.3	-28.1	No
Lower Shell Forging 125P666 (Longitudinal)	V	46.2	0.587	0.851	34.7	39.3	4.6	Yes
	R	46.2	1.02	1.006	57.5	46.4	-11.1	Yes
	T	46.2	1.69	1.144	33.6	52.8	19.2	No
	S	46.2	3.64	1.335	45.8	61.6	15.8	Yes
	N	46.2	5.8	1.430	91.1	66.0	-25.1	No
Surveillance Weld Material Heat # 61782	V	152.3	0.587	0.851	146.7	129.57	-17.1	Yes
	R	152.3	1.02	1.006	156.2	153.12	-3.1	Yes
	T	152.3	1.69	1.144	149.7	174.28	24.6	Yes
	S	152.3	3.64	1.335	212.2	203.36	-8.8	Yes
	N	152.3	5.8	1.430	216.9	217.83	0.9	Yes

Conclusions (Cases A and C)

- R. E. Ginna Intermediate Shell Forging 125S255 has 4 of 5 data points outside the 17°F scatter band and is therefore deemed NOT CREDIBLE;
- R. E. Ginna Lower Shell Forging 125P666 has 2 of 5 data points outside the 17°F scatter band and is therefore deemed NOT CREDIBLE;
- R. E. Ginna Surveillance Weld Heat # 61782 has 5 of 5 data points within the 28°F scatter band and is credible if the other Criteria are satisfied.

It should be noted that the CF calculated for Heat #61782 in Table D-1 is applicable only to the surveillance weld; to apply the R. E. Ginna surveillance data for weld heat #61782 to the R. E. Ginna vessel heat #61782 (e.g., to calculate a regulatory Position 2.1 CF for vessel heat #61782), the shift data must be adjusted for chemical composition differences between the surveillance weld and the vessel weld of that same heat. This evaluation is not contained in this Appendix.

Credibility Assessment (Case B)

Surveillance weld Heat #71249 is contained in the Turkey Point Units 3 and 4 (TP3, TP4) surveillance programs. It was also contained in a supplemental surveillance capsule irradiated in the Davis Besse reactor vessel.

In order to adapt sister plant surveillance data to a particular plant, the data must be adjusted for (1) differences in irradiation temperature and (2) differences between the surveillance material chemistry and the target plant vessel material chemistry. The adjustment is described later in this Appendix.

Like R. E. Ginna, Turkey Point is a Westinghouse plant (NSSS vendor). Davis Besse is a B&W plant. The irradiation environment of Turkey Point Unit 3 is judged closer to R. E. Ginna than that of Davis Besse, so Turkey Point Unit 3 will be evaluated first.

Three capsules containing weld heat #71249 have been tested at Turkey Point Unit 3. A fitted chemistry factor considering only the Turkey Point Unit 3 data is calculated in the table below. For this case, no adjustment of ΔRT_{NDT} is required.

Table D-3 Calculation of Chemistry Factor using Turkey Point Unit 3 Surveillance Data for Weld Heat #71249

Material	Capsule	Capsule f [(a)]	FF[(b)]	ΔRT_{NDT}[(c)]	$FF*\Delta RT_{NDT}$	FF^2
Surveillance Weld Heat #71249	T (TP3)	0.599	0.856	163.87	140.4	0.734
	V (TP3)	1.223	1.056	180.77	190.9	1.115
	X (TP3)	2.897	1.282	191.06	245.0	1.644
				SUM:	576.3	3.493
	$CF_{Ht.\#71249} = \sum(FF * \Delta RT_{NDT}) \div \sum(FF^2) = (576.3) \div (3.493) =$ **165.0°F**					

Notes:

(a) f = fluence (x 10^{19} n/cm^2, E > 1.0 MeV).

(b) FF = fluence factor = $f^{(0.28 - 0.1*\log(f))}$.

(c) ΔRT_{NDT} (°F) values are the measured 30 ft-lb shift values taken from [D-6].

The fitted CF calculated in Table D-3 is used to calculate a predicted shift, which is then compared to the measured shift. If the scatter is less than 28°F (the scatter criteria for welds), then the data are considered to be credible.

Table D-4 Predicted Versus Best-Estimate ΔRT_{NDT} Values using Turkey Point Unit 3 Surveillance Data for Weld Heat #71249

Material	Capsule	CF	FF	Best Estimate ΔRT_{NDT} (°F)	Measured ΔRT_{NDT} (°F)	Scatter in ΔRT_{NDT} (B. E. - Measured)
Surveillance Weld Heat # 71249	T (TP3)	165.0°F	0.856	141.3	163.87	-22.58
	V (TP3)		1.056	174.2	180.77	-6.55
	X (TP3)		1.282	211.5	191.06	20.48

The scatter for all capsules is less than 28°F. Therefore, the surveillance data for weld heat #71249 from Turkey Point Unit 3 are credible.

When the Turkey Point Unit 3 data are considered with the Turkey Point Unit 4 data and the Davis Besse data, the scatter exceeds 28°F for two of the data points; therefore that data is not credible. Only the Turkey Point Unit 3 data should be used for R. E. Ginna.

The next step is to apply the credible Turkey Point Unit 3 data to the R. E. Ginna vessel weld Heat # 71249 in order to calculate a Position 2.1 CF for the R. E. Ginna vessel weld. For this calculation, the surveillance data must be adjusted for the irradiation temperature and vessel weld chemistry. These adjustments are shown below:

Adjusted ΔRT_{NDT} = ((Measured Shift * [CF_{VW} / CF_{SW}]) + [$T_{Capsule} - T_{plant}$])

where,

CF_{VW} / CF_{SW} is the ratio of the Regulatory Guide 1.99, Revision 2 Table chemistry factors (vessel weld CF to surveillance weld CF)

$T_{Capsule}$ - T_{Plant} is the adjustment for irradiation temperature.

For the application of the Turkey Point Unit 3 data to the R. E. Ginna vessel weld Heat # 71249:

CF_{VW} = 167.6°F

CF_{SW} = 194.1°F

CF_{VW} / CF_{SW} = 167.6°F / 194.1°F = 0.863

$T_{Capsule} - T_{Plant}$ = 6°F

Table D-5 Calculated Regulatory Position 2.1 Chemistry Factor for the R. E. Ginna Vessel Heat #71249 Using Credible Surveillance Data from Turkey Point Unit 3

Material	Capsule	Capsule f [(a)]	FF[(b)]	ΔRT_{NDT}[(c)]	Adjusted ΔRT_{NDT}[(d)]	$FF*\Delta RT_{NDT}$	FF^2
Surveillance Weld Heat #71249	T (TP3)	0.599	0.856	163.87	147.5	126.3	0.734
	V (TP3)	1.223	1.056	180.77	162.09	171.2	1.115
	X (TP3)	2.897	1.282	191.06	170.98	219.2	1.644
					SUM:	516.8	3.493
	$CF_{Ht.\#71249} = \sum(FF * \Delta RT_{NDT}) \div \sum(FF^2) = (516.8) \div (3.493) =$ **147.9°F**						

Notes:

(a) f = fluence (x 10^{19} n/cm^2, E > 1.0 MeV).

(b) FF = fluence factor = $f^{(0.28 - 0.1*\log(f))}$.

(c) ΔRT_{NDT} (°F) values are the measured 30 ft-lb shift values taken from [D-6].

(d) Adjusted for irradiation temperature and chemical composition differences.

Conclusion (Case B)

Per Table D-5, the Regulatory Position 2.1 Chemistry Factor for R. E. Ginna vessel weld Heat #71249 is 147.9°F, based on credible Turkey Point Unit 3 surveillance data.

Criterion 4: The irradiation temperature of the Charpy specimens in the capsule should match the vessel wall temperature at the cladding/base metal interface within +/- 25°F.

The capsule specimens are located in the reactor between the neutron pad and the vessel wall and are positioned opposite the center of the core. The test capsules are in baskets attached to the neutron pad. The location of the specimens with respect to the reactor vessel beltline provides assurance that the reactor vessel wall and the specimens experience equivalent operating conditions such that the temperatures will not differ by more than 25°F. Hence, this criterion is met.

Criterion 5: The surveillance data for the correlation monitor material in the capsule should fall within the scatter band of the database for that material.

The R. E. Ginna surveillance program does have Correlation Monitor Material. NUREG/CR-6413, ORNL/TM-13133 [D-7] contains a plot of residual vs. Fast Fluence for the SRM (Figure 10 in the NUREG report) and shows a 2σ uncertainty of 50°F. The data used for the plot is contained in Table 15 (in the NUREG Report). However, the data in the NUREG Report has not been considered for the recalculated fluences as documented herein. Thus, Table D-6 contains an updated calculation of Residual vs. Fast fluence.

Table D-6 Calculation of Residual vs. Fast Fluence

Capsule	Fluence ($x\ 10^{19}$ n/cm^2)	Fluence Factor (FF)	Measured ΔRT_{NDT}[(a)]	RG 1.99 Rev. 2 Shift (CF*FF)[(b)]	Residual (Measured –RG Shift)
V	0.587	0.851	97.0	85.1	11.9
R	1.02	1.006	103.2	100.6	2.6
T	1.69	1.144	97.8	114.4	-16.6

Notes:

(a) ΔRT_{NDT} (°F) values are the measured 30 ft-lb shift values obtained from Section 5.

(b) Per NUREG/CR-6413, ORNL/TM-13133, the Cu and Ni values for the Correlation Monitor Material are 0.20 Cu and 0.18 Ni. This equates to a Chemistry Factor of 100°F from Reg. Guide 1.99 Rev. 2.

Table D-6 shows a 2σ uncertainty of less than 50°F, which is the allowable scatter in NUREG/CR-6413, ORNL/TM-13133 [D-7]. Hence, this criterion is met.

D.3 CONCLUSION

Based on the preceding responses to all five criteria of Regulatory Guide 1.99, Revision 2, Section B and 10 CFR 50.61 [D-8], the R. E. Ginna surveillance weld (heat # 61782) data meet the credibility criteria of Regulatory Guide 1.99, Revision 2 and are deemed CREDIBLE. The surveillance forging data for the lower shell and intermediate shell forgings do not meet Criterion #3 and are deemed NOT CREDIBLE for use in the shift calculations of Regulatory Position 2.1; however, the upper shelf energy levels of the forgings can be clearly determined, and thus the data are credible for use in determining decrease in USE per Regulatory Position 2.2.

The weld data of heat # 71249 from Turkey Point Unit 3 is credible and results in an adjusted Regulatory Position 2.1 Chemistry Factor for R. E. Ginna beltline weld heat # 71249 of 147.9°F.

D.4 REFERENCES

D-1 Regulatory Guide 1.99, Revision 2, *Radiation Embrittlement of Reactor Vessel Materials*, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, May 1998.

D-2 ASTM E185-82, *Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels,* American Society for Testing and Materials.

D-3 10 CFR 50, Appendix G, *Fracture Toughness Requirements*, Federal Register, Volume 60, No. 243, December 19, 1995.

D-4 ASTM E185-66, *Recommended Practice for Surveillance Tests on Structural Material in Nuclear Reactors,* American Society for Testing and Materials, 1966

D-5 K. Wichman, M. Mitchell, and A. Hiser, USNRC, Generic Letter 92-01 and RPV Integrity Workshop Handouts, NRC/Industry Workshop on RPV Integrity Issues, February 12, 1998.

D-6 WCAP-15916, Revision 0, *Analysis of Capsule X from Florida Power and Light Company Turkey Point Unit 3 Reactor Vessel Radiation Surveillance Program*, J. H. Ledger et. al., September 2002.

D-7 ORNL/TM-13133; NUREG/CR-6413, *Analysis of the Irradiation Data for A302B and A533B Correlation Monitor Materials,* J. A. Wang, Oak Ridge National Laboratory, Oak Ridge, TN, April 1996.

D-8 10 CFR Part 50.61, *Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events*, Federal Register, Volume 60, No. 143, dated December 19, 1995, as amended at 61 FR 39300, July 29, 1996; 72 FR 49500, Aug. 28, 2007; 73 FR 5722, Jan. 31, 2008.

APPENDIX E
UPPER SHELF ENERGY EVALUATION

Per Regulatory Guide 1.99, Revision 2 [E-1], the Charpy upper shelf energy (USE) is assumed to decrease as a function of fluence and copper content as indicated in Figure 2 of the Guide (Figure E-1 of this appendix) when surveillance data is not used. Linear interpolation is permitted. In addition, if surveillance data is to be used, the decrease in upper shelf energy may be obtained by plotting the reduced plant surveillance data on Figure 2 of the Guide (Figure E-1 of this appendix) and fitting the data with a line drawn parallel to the existing lines as the upper bound of all the data. This line should be used in preference to the existing graph. Even if the surveillance data are not credible for use in the shift calculations per Regulatory Position 2.1, they may be credible for determining decrease in USE per Regulatory Position 2.2 if the upper shelf can be clearly determined, following the definition given in ASTM E185-82 [E-2].

The 53 EFPY (end-of-license renewal) upper shelf energy of the vessel materials can be predicted using the corresponding 1/4T fluence projection, the copper content of the beltline materials and/or the results of the capsules tested to date using Figure 2 in Regulatory Guide 1.99, Revision 2. The maximum vessel clad/base metal interface fluence value was used to determine the corresponding 1/4T fluence value at 53 EFPY.

The R. E. Ginna reactor vessel beltline region minimum thickness is 6.50 inches. Calculation of the 1/4T vessel fluence values at 53 EFPY for the intermediate shell and lower shell forgings and the intermediate shell to lower shell girth weld is shown as follows:

$$\text{Maximum Vessel Fluence @ 53 EFPY} = 5.56 \times 10^{19}\ \text{n/cm}^2\ (E > 1.0\ \text{MeV})$$

$$\text{1/4T Fluence @ 53 EFPY} = (5.56 \times 10^{19}\ \text{n/cm}^2) * e^{(-0.24 * (6.50 / 4))}$$

$$= 3.76 \times 10^{19}\ \text{n/cm}^2\ (E > 1.0\ \text{MeV})$$

Calculation of the 1/4T vessel fluence values at 53 EFPY for the nozzle shell forging and the nozzle to intermediate shell girth weld:

$$\text{Maximum Vessel Fluence @ 53 EFPY} = 2.37 \times 10^{18}\ \text{n/cm}^2\ (E > 1.0\ \text{MeV})$$

$$\text{1/4T Fluence @ 53 EFPY} = (2.37 \times 10^{18}\ \text{n/cm}^2) * e^{(-0.24 * (6.50 / 4))}$$

$$= 1.60 \times 10^{18}\ \text{n/cm}^2\ (E > 1.0\ \text{MeV})$$

However, based on the conservative approach that the NRC requested R. E. Ginna to take in DA-ME-2003-024 [E-3], the fluence for the Nozzle Shell Area materials will be doubled:

Max. Vessel Fluence @ 53 EFPY * 2	=	4.74×10^{18} n/cm^2 (E > 1.0 MeV)
1/4T Fluence @ 53 EFPY	=	$(4.74 \times 10^{18}$ n/cm$^2) * e^{(-0.24 * (6.50 / 4))}$
	=	3.2×10^{18} n/cm^2 (E > 1.0 MeV)

The following pages present the R. E. Ginna upper shelf energy evaluation. Figure E-1, as indicated above, as well as Figure E-2, are used in making predictions in accordance with Regulatory Guide 1.99, Revision 2. Note that in Figure E-2, only two red data points are displayed, pertaining to Capsules V and N. Capsules R, T, and S have measured USE decreases of less than one percent. Therefore, the data points pertaining to these capsules do not appear on Figure E-2. Table E-1 provides the predicted upper shelf energy values for 53 EFPY (end-of-license renewal).

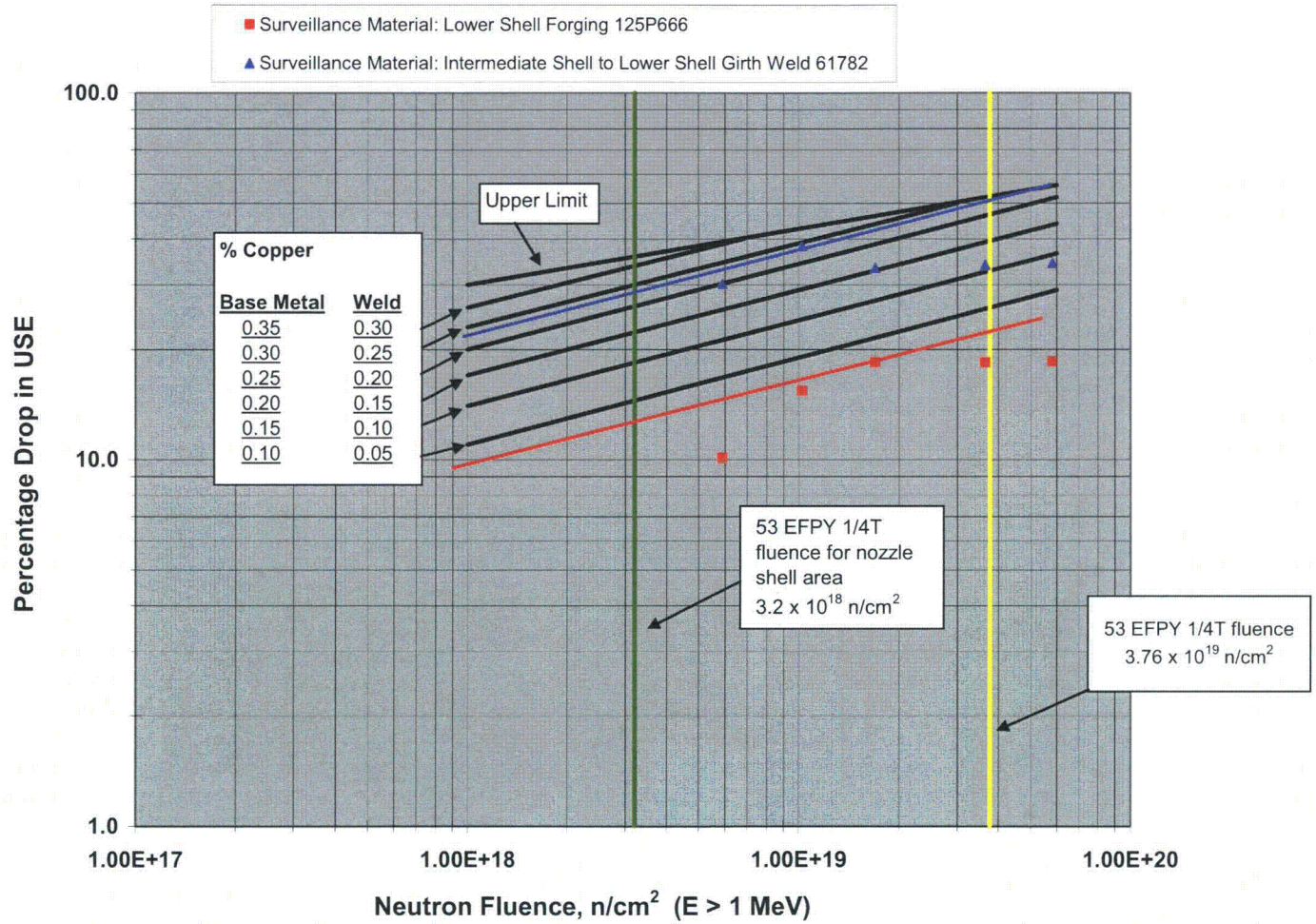


Figure E-1 **Regulatory Guide 1.99, Revision 2 Predicted Decrease in Upper Shelf Energy as a Function of Copper and Fluence for Lower Shell Forging 125P666 and Weld Heat # 61782**

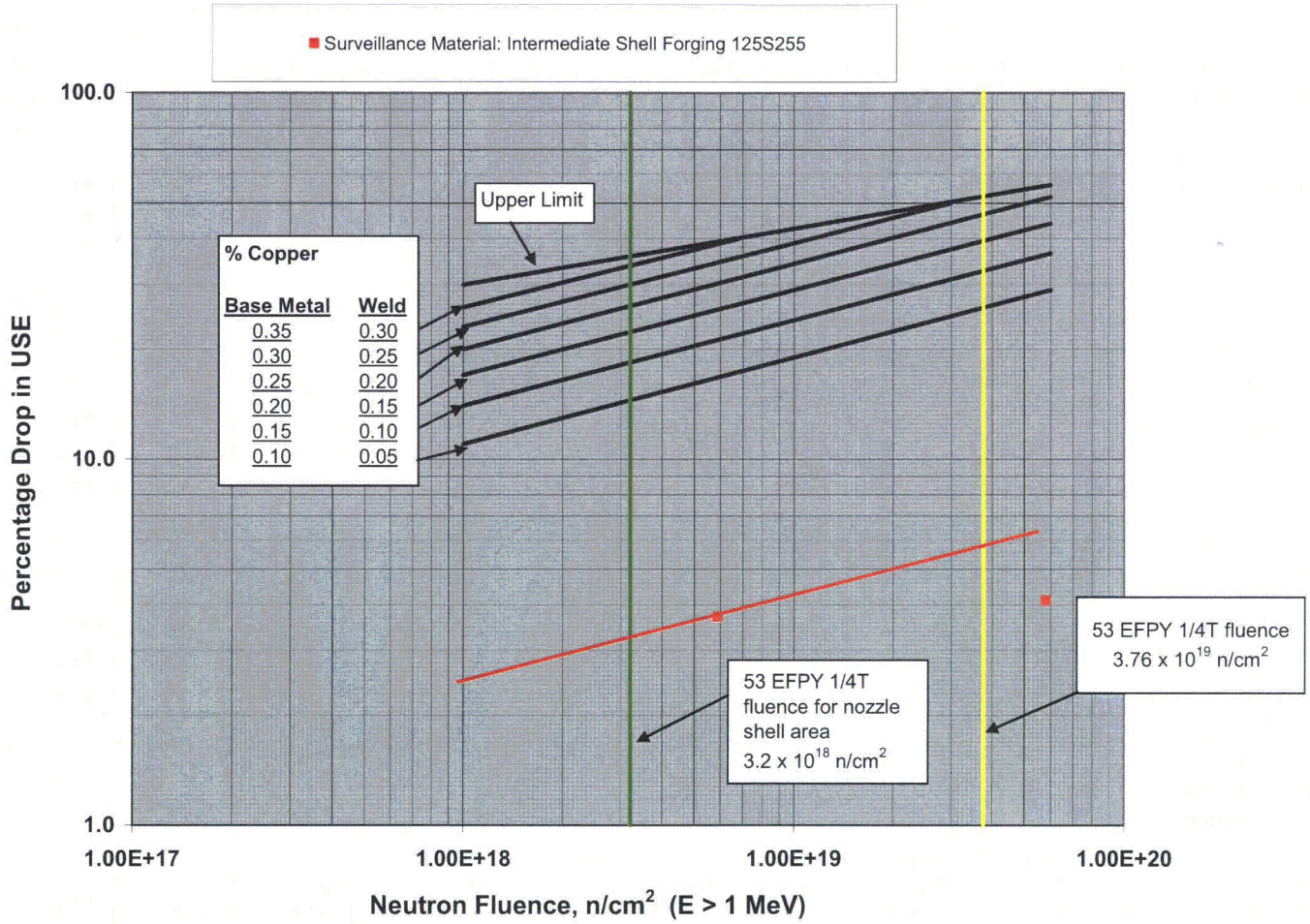


Figure E-2 **Regulatory Guide 1.99, Revision 2 Predicted Decrease in Upper Shelf Energy as a Function of Copper and Fluence for Intermediate Shell Forging 125S255**

Table E-1 Predicted Positions 1.2 and 2.2 Upper Shelf Energy Values at 53 EFPY

Material	Weight % of Cu	1/4T EOLE Fluence (x 10^{19} n/cm^2, E > 1.0 MeV)	Unirradiated USE (ft-lb)	Projected USE Decrease (%)	Projected EOLE USE (ft-lb)
Position 1.2					
Nozzle Shell Forging 123P118	0.17	0.32[(b)]	117	21	92
Intermediate Shell Forging 125S255	0.07	3.76	91	23	70
Lower Shell Forging 125P666	0.05	3.76	114	21	90
Nozzle to Intermediate Shell Girth Weld (Heat # 71249)	0.23	0.32[(b)]	65	29	46
Intermediate Shell to Lower Shell Girth Weld (Heat # 61782)	0.25	3.76	80	52	38
Position 2.2[(a)]					
Intermediate Shell Forging 125S255	0.07	3.76	91	6	85.5
Lower Shell Forging 125P666	0.05	3.76	114	23	88
Intermediate Shell to Lower Shell Girth Weld (Heat # 61782)	0.25	3.76	80	51	39

Notes:

(a) Calculated using surveillance capsule measured percent decrease in USE from Table 5-10 and Regulatory Guide 1.99, Revision 2, Position 2.2; see Figures E-1 and E-2.

(b) Based on the conservative approach that the NRC requested R. E. Ginna to take in DA-ME-2003-024 [E-3], the fluence values for the Nozzle Shell Area materials have been doubled.

The projected EOLE USE value for the Intermediate Shell to Lower Shell Girth Weld (Heat #61782) is 39 ft-lbs. This is below the acceptable level of 50 ft-lbs. The projected EOLE USE value for the Nozzle to Intermediate Shell Girth Weld (Heat #71249) is 46 ft-lbs. This too is below the acceptable level of 50 ft-lbs.

An equivalent margin analysis was performed in BAW-2425, Revision 1 [E-4] which showed weld heat #61782 is acceptable even with a USE value below 50 ft-lbs. However, this analysis was performed for an EOLE (53 EFPY) inside surface fluence of 5.01 x 10^{19} n/cm^2. Thus, the calculation was checked for a revised EOLE (53 EFPY) fluence of 5.56 x 10^{19} n/cm^2.

In BAW-2425, Revision 1, the applied J-integral was compared to the J-integral resistance to determine the acceptable margin for USE. The applied J-integral, which is not a function of fluence, must be lower than the J-integral resistance, which is a function of fluence. Thus, J-integral resistance was calculated and confirmed to be greater than the applied J-integral for an EOLE inside surface fluence of 5.56 x 10^{19} n/cm^2. For Service Levels A, B, C and D, the Intermediate to Lower Shell Girth Weld and the Nozzle to Intermediate Shell Girth Weld show more than sufficient margin for USE.

E.1 REFERENCES

E-1 U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Regulatory Guide 1.99, Revision 2, *Radiation Embrittlement of Reactor Vessel Materials,* May 1988.

E-2 ASTM E185-82, *Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels,* American Society for Testing and Materials.

E-3 Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 97 to Renewed Facility Operating License No. DPR-18 R. E. Ginna Nuclear Power Plant, Docket No. 50-244.

E-4 Framatome ANP Report BAW-2425, Rev. 1, *Low Upper-Shelf Toughness Fracture Mechanics Analysis of Reactor Vessel of R. E. Ginna for Extended Life through 54 Effective Full Power Years*, H. P. Gunawardane, June 2002.

ATTACHMENT 2

List of Regulatory Commitments

ATTACHMENT 2

List of Regulatory Commitments

The following table identifies those actions committed to by Ginna LLC in this document. Any other statements made in this licensing submittal are provided for informational purposes only and are not to be considered regulatory commitments. Please direct any questions you have in this matter to Mr. Thomas Harding at (585)771-5219.

COMMITMENT	COMPLETION DATE
An updated Pressure Temperature Limits Report (PTLR) incorporating the Capsule "N" test results will be submitted.	February 19, 2010