Vogtle Electric Generating Plant
Unit 2 Reactor Vessel Surveillance Capsule W Results

Enclosure 2

WCAP-17343-NP, Rev. 0, Analysis of Capsule Z from the Southern Nuclear Operating Company Vogtle Unit 2 Reactor Vessel Radiation Surveillance Program

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EXECUTIVE SUMMARY

The purpose of this report is to document the testing results of surveillance Capsule Z from Vogtle Unit 2. Capsule Z was removed at 18.48 effective full power years (EFPY) and post-irradiation mechanical tests of the Charpy V-notch and tensile specimens were performed, along with a fluence evaluation. Capsule Z received a fluence of 4.16×10^{19} n/cm^2 (E > 1.0 MeV) after irradiation to 18.48 EFPY. The peak clad/base metal interface vessel fluence after 18.48 EFPY of plant operation was 1.00×10^{19} n/cm^2 (E > 1.0 MeV).

This evaluation led to the following conclusions: 1) The measured percent decreases in upper-shelf energy for all the surveillance materials contained in Vogtle Unit 2 Capsule Z are less than the Regulatory Guide 1.99, Revision 2 [Ref. 1] predictions. 2) The Vogtle Unit 2 surveillance plate data is judged to be not credible; however, the weld data is judged to be credible. This credibility evaluation can be found in Appendix D. 3) All beltline 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 through end-of-license (36 EFPY) and end-of-license renewal (57 EFPY) as required by 10 CFR 50, Appendix G [Ref. 2]. 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 Z, the fifth capsule removed and tested from the Vogtle Unit 2 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 Z and previous capsules, along with the program input data.

- Capsule Z received an average fast neutron fluence (E > 1.0 MeV) of 4.16 x 10^{19} n/cm^2 after 18.48 EFPY of plant operation.

- Irradiation of the reactor vessel Lower Shell Plate B8628-1 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 67.8°F and an irradiated 50 ft-lb transition temperature of 106.8°F. This results in a 30 ft-lb transition temperature increase of 59.0°F and a 50 ft-lb transition temperature increase of 61.4°F for the longitudinally oriented specimens.

- Irradiation of the reactor vessel Lower Shell Plate B8628-1 Charpy specimens, oriented with the longitudinal axis of the specimen perpendicular to the major working direction (transverse orientation), resulted in an irradiated 30 ft-lb transition temperature of 103.9°F and an irradiated 50 ft-lb transition temperature of 140.1°F. This results in a 30 ft-lb transition temperature increase of 75.3°F and a 50 ft-lb transition temperature increase of 70.0°F for the transversely oriented specimens.

- Irradiation of the Surveillance Program Weld Metal (Heat # 87005) Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of 2.1°F and an irradiated 50 ft-lb transition temperature of 48.3°F. This results in a 30 ft-lb transition temperature increase of 21.3°F and a 50 ft-lb transition temperature increase of 37.2°F.

- Irradiation of the Heat-Affected Zone (HAZ) Material Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of -75.1°F and an irradiated 50 ft-lb transition temperature of -41.2°F. This results in a 30 ft-lb transition temperature increase of 8.6°F and a 50 ft-lb transition temperature increase of 11.2°F.

- The average upper-shelf energy of Lower Shell Plate B8628-1 (longitudinal orientation) did not change after irradiation. This results in an irradiated average upper-shelf energy of 89.0 ft-lb for the longitudinally oriented specimens.

- The average upper-shelf energy of Lower Shell Plate B8628-1 (transverse orientation) resulted in an average energy decrease of 2.0 ft-lb after irradiation. This results in an irradiated average upper-shelf energy of 68.0 ft-lb for the transversely oriented specimens.

- The average upper-shelf energy of the Surveillance Program Weld Metal Charpy specimens resulted in an average energy decrease of 2.0 ft-lb after irradiation. This results in an irradiated average upper-shelf energy of 90.0 ft-lb for the weld metal specimens.

- The average upper-shelf energy of the HAZ Material Charpy specimens resulted in an average energy increase of 6.0 ft-lb after irradiation. This results in an irradiated average upper-shelf energy of 112.0 ft-lb for the HAZ Material.

- Comparisons of the measured 30 ft-lb shift in transition temperature values and upper-shelf energy decreases to those predicted by Regulatory Guide 1.99, Revision 2 [Ref. 1] for the Vogtle Unit 2 reactor vessel surveillance materials are presented in Table 5-10.

- Based on the credibility evaluation presented in Appendix D, the Vogtle Unit 2 surveillance plate data is not credible but the surveillance weld data is credible.

- Based on the upper-shelf energy evaluation in Appendix E, all beltline 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 through end-of-license (36 EFPY) and end-of-license renewal (57 EFPY) as required by 10 CFR 50, Appendix G [Ref. 2].

- The calculated 36 EFPY (end-of-license) and 57 EFPY (end-of-license renewal) neutron fluence (E > 1.0 MeV) at the core mid-plane for the Vogtle Unit 2 reactor vessel using the Regulatory Guide 1.99, Revision 2 attenuation formula (i.e., Equation #3 in the guide) are as follows:

Calculated (36 EFPY):	Vessel inner radius* = 2.00×10^{19} n/cm^2 (Taken from Table 6-2) Vessel 1/4 thickness = 1.192×10^{19} n/cm^2
Calculated (57 EFPY):	Vessel inner radius* = 3.19×10^{19} n/cm^2 (Interpolated from Table 6-2) Vessel 1/4 thickness = 1.901×10^{19} n/cm^2

* Clad/base metal interface.

2 INTRODUCTION

This report presents the results of the examination of Capsule Z, the fifth capsule removed and tested in the continuing surveillance program, which monitors the effects of neutron irradiation on the Southern Nuclear Operating Company Vogtle Unit 2 reactor pressure vessel materials under actual operating conditions.

The surveillance program for the Vogtle Unit 2 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-11381 [Ref. 3], "Georgia Power Company Alvin W. Vogtle Unit No. 2 Reactor Vessel Radiation Surveillance Program." The surveillance program was planned to cover the 40-year design life of the reactor pressure vessel and was based on ASTM E185-82 [Ref. 4], "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels." Capsule Z was removed from the reactor after 18.48 EFPY of exposure and shipped to the Westinghouse Research and Technology Unit (RTU) 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 Z removed from the Vogtle Unit 2 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 SA533 Grade B Class 1 (base material of the Vogtle Unit 2 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 [Ref. 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 [Ref. 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 [Ref. 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 Vogtle Unit 2 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 (initial RT_{NDT} + M + ΔRT_{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 Vogtle Unit 2 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 neutron pads 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:

- Lower Shell Plate B8628-1 (longitudinal orientation)
- Lower Shell Plate B8628-1 (transverse orientation)
- Weld metal fabricated with 3/16-inch Mil B-4 weld filler wire, Heat Number 87005 Linde Type 124 flux, Lot Number 1061, which is identical to that used in the actual fabrication of the intermediate to lower shell circumferential weld seam
- Weld heat-affected zone (HAZ) material of Lower Shell Plate B8628-1

Test material obtained from the lower shell plate (after thermal heat treatment and forming of the plate) was taken at least one plate thickness from the quenched edges of the plate. All test specimens were machined from the ¼ and ¾ thickness locations of the plate after performing a simulated post-weld stress-relieving treatment on the test material. Test specimens were also removed from weld and heat-affected zone metal of a stress-relieved weldment joining Lower Shell Plate B8628-1 and adjacent Lower Shell Plate B8825-1. All heat-affected zone specimens were obtained from the weld heat-affected zone of Lower Shell Plate B8628-1.

Charpy V-notch impact specimens from Lower Shell Plate B8628-1 were machined in the longitudinal orientation (longitudinal axis of the specimen parallel to the major rolling direction) and also in the transverse orientation (longitudinal axis of the specimen perpendicular to the major rolling direction). The core-region weld Charpy impact specimens were machined from the weldment such that the long dimension of each Charpy specimen was perpendicular (normal) to the weld direction. The notch of the weld metal Charpy specimens was machined such that the direction of crack propagation in the specimen was in the welding direction.

Tensile specimens from Lower Shell Plate B8628-1 were machined in both the longitudinal and transverse orientations. Tensile specimens from the weld metal were oriented perpendicular to the welding direction.

Compact Test (CT) specimens from Lower Shell Plate B8628-1 were machined in the longitudinal and transverse orientations. CT specimens from the weld metal were machined with the notch oriented in the direction of welding. All specimens were fatigue pre-cracked according to ASTM E399 [Ref. 7].

All six capsules contained dosimeter wires of pure iron, copper, nickel, and aluminum-0.15 weight percent cobalt (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)
1.5% Ag, 1.0% Sn, 97.5% Pb	Melting Point: 590°F (310°C)

The chemical composition of the unirradiated surveillance materials is presented in Tables 4-1 and 4-2. Also contained in Tables 4-1 and 4-2 is the chemical composition of the surveillance materials that were irradiated in Capsule Y. The unirradiated data in Tables 4-1 and 4-2 was obtained from the original surveillance program report, WCAP-11381 [Ref. 3], Appendix A. The irradiated data in Tables 4-1 and 4-2 was obtained from the latest surveillance capsule report, WCAP-16382-NP [Ref. 8], and was originally documented in the Capsule Y report, WCAP-14532 [Ref. 9].

The heat treatment of the unirradiated surveillance materials is presented in Table 4-3. The data in Table 4-3 was obtained from the unirradiated surveillance program report, WCAP-11381 [Ref. 3], Appendix A.

Capsule Z was removed after 18.48 EFPY of plant operation. This capsule contained Charpy V-notch, tensile, 1/2T-CT fracture mechanics specimens, dosimeters, and thermal monitors.

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

Table 4-1 Chemical Composition (wt%) of Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1

Element	Combustion Engineering Analysis[(a)]	Westinghouse Analysis[(a)]	Capsule Y Analysis[(b)] (BL-62)
C	0.24	0.23	0.233
Mn	1.34	1.30	1.168
P	0.007	0.007	0.008
S	0.016	0.014	0.009
Si	0.25	0.23	0.185
Ni	0.59	0.59	0.549
Mo	0.59	0.50	0.51
Cr	0.02	0.07	0.064
Cu	0.05	0.05	0.049
Al	0.029	0.034	0.032
Co	0.004	0.008	0.008
Pb	Not detected	<0.07	- - -
W	<0.01	<0.05	- - -
Ti	<0.01	0.005	<0.002
Zr	<0.001	<0.03	<0.01
V	0.004	<0.005	<0.004
Sn	0.017	0.007	<0.01
As	0.007	0.008	<0.02
Cb	<0.01	<0.05	- - -
N_2	0.008	0.007	- - -
B	<0.001	0.008	0.009

Notes:

(a) The unirradiated data was obtained from Table 4-1 of WCAP-16382-NP [Ref. 8] and was originally documented in WCAP-11381 [Ref. 3], Appendix A.

(b) The Capsule Y data was obtained from Table 4-1 of WCAP-16382-NP [Ref. 8] and was originally documented in Table 4-4 of WCAP-14532 [Ref. 9].

Table 4-2 Chemical Composition (wt%) of the Vogtle Unit 2 Reactor Vessel Beltline Region Weld Materials

Element	Intermediate & Lower Shell Long. Welds[a,b]	Circ. Weld[a,c] (Combustion Engineering Analysis)	Circ. Weld[a,d] (Westinghouse Analysis)	Capsule Y Analysis[e] (BW-61)	Capsule Y Analysis[e] (BW-63)	Capsule Y Analysis[e] (BW-72)
C	0.15	0.075	0.099	0.084	0.089	0.097
Mn	1.34	1.27	1.25	1.046	0.983	1.110
P	0.007	0.007	0.008	0.010	0.008	0.011
S	0.011	0.010	0.013	0.006	0.006	0.008
Si	0.13	0.50	0.43	0.448	0.447	0.429
Ni	0.13	0.12	0.17	0.127	0.118	0.137
Mo	0.55	0.52	0.47	0.47	0.44	0.48
Cr	---	0.07	0.061	0.056	0.052	0.056
Cu	0.07	0.06	0.040	0.039	0.037	0.040
Al	---	---	0.015	<0.02	<0.02	<0.02
Co	---	---	0.002	0.008	0.008	0.009
Pb	---	---	<0.01	---	---	---
W	---	---	<0.01	---	---	---
Ti	---	---	<0.001	<0.002	<0.002	<0.002
Zr	---	---	<0.01	<0.01	<0.01	<0.01
V	0.005	0.004	<0.004	<0.004	<0.004	<0.004
Sn	---	---	<0.001	<0.01	<0.01	<0.01
As	---	---	0.003	<0.02	<0.02	<0.02
Cb	---	---	<0.002	---	---	---
N_2	---	---	0.002	---	---	---
B	---	---	0.009	0.009	0.008	0.008

Notes:

(a) The unirradiated data was obtained from Table 4-2 of WCAP-16382-NP [Ref. 8] and originally documented in WCAP-11381 [Ref. 3], Appendix A.
(b) Weld Wire Heat # 87005, Linde 0091 Flux, Lot # 0145.
(c) Weld Wire Heat # 87005, Linde 124 Flux, Lot # 1061.
(d) Westinghouse Analysis of surveillance program test plate "D", representative of the intermediate to lower shell circumferential weld.
(e) The Capsule Y data was obtained from Table 4-2 of WCAP-16382-NP [Ref. 8] and was originally documented in Table 4-4 of WCAP-14532 [Ref. 9]. Note that the NIST Standards are not reprinted herein.

Table 4-3 Heat Treatment History of the Vogtle Unit 2 Reactor Vessel Surveillance Materials[a]

Material	Temperature (°F)	Time (hours)	Cooling
Intermediate Shell Plates R4-1, R4-2, and R4-3	Austenitized @ 1600 ± 25 (871°C)	4	Water-Quenched
	Tempered @ 1225 ± 25 (663°C)	4	Air-Cooled
	Stress Relieved @ 1150 ± 50 (621°C)	16.5[b]	Furnace-Cooled
Lower Shell Plates B8825-1, R8-1, and B8628-1	Austenitized @ 1600 ± 25 (871°C)	4	Water-Quenched
	Tempered @ 1225 ± 25 (663°C)	4	Air-Cooled
	Stress Relieved @ 1150 ± 50 (621°C)	12.0[b]	Furnace-Cooled
Intermediate Shell Longitudinal Weld Seams	Stress Relieved @ 1150 ± 50 (621°C)	16.5[b]	Furnace-Cooled
Lower Shell Longitudinal Weld Seams	Stress Relieved @ 1150 ± 50 (621°C)	12.0[b]	Furnace-Cooled
Intermediate to Lower Shell Circumferential Weld Seam	Local Stress Relieved @ 1150 ± 50 (621°C)	5.0	Furnace-Cooled
Surveillance Program Test Material			
Surveillance Program Weldment Test Plate "D" (Representative of Closing Circ. Weld Seam)	Post Weld Stress Relieved @ 1150 ± 50 (621°C)	6.0[c]	Furnace-Cooled

Notes:

(a) This Table was reprinted from Table 4-3 of WCAP-16382-NP [Ref. 8] and originally documented in WCAP-11381 [Ref. 3], Appendix A.

(b) Stress relief includes the intermediate to lower shell closing circumferential seam post-weld heat treatment.

(c) The stress relief heat treatment received by the surveillance weldment test plate has been simulated.

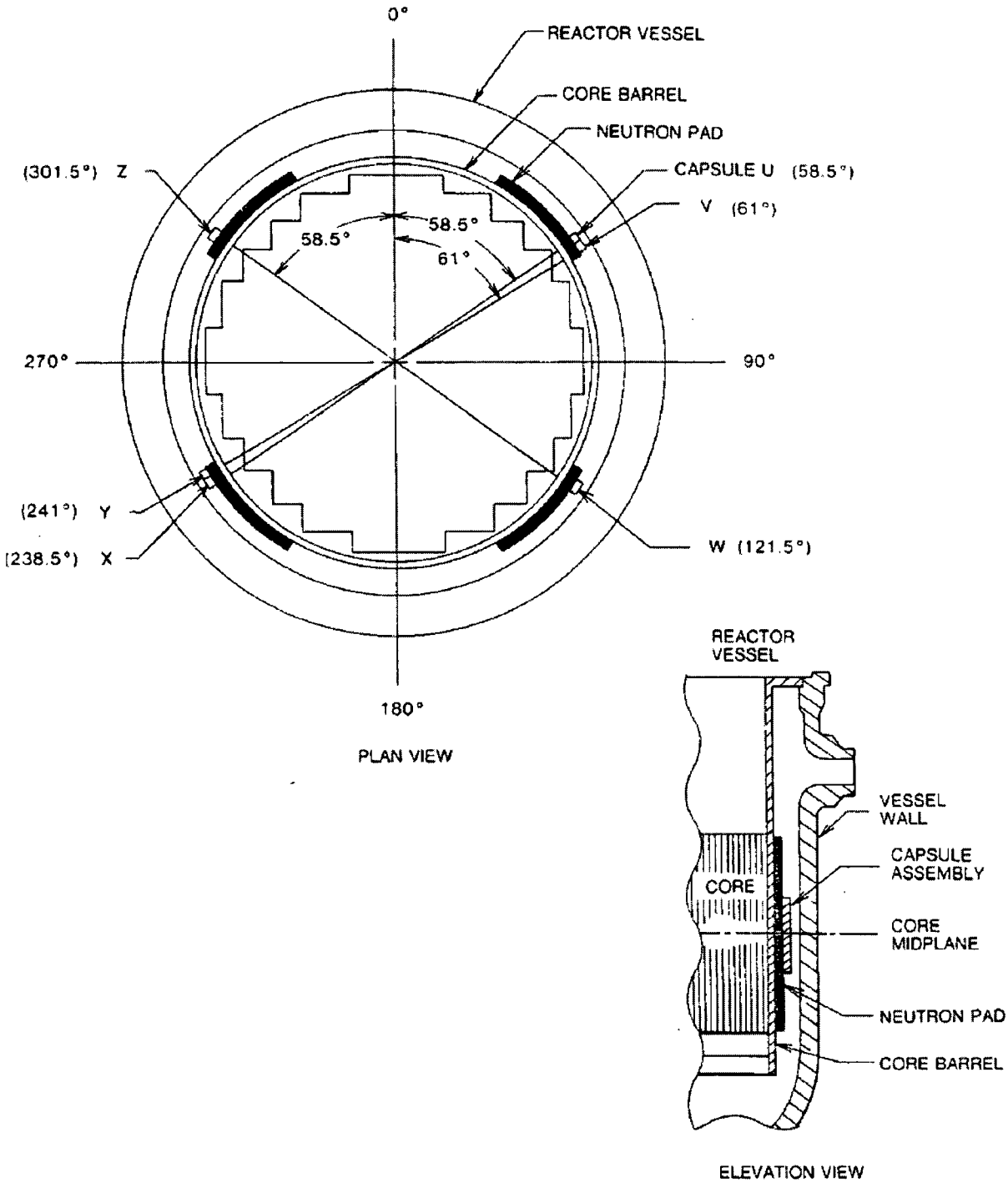


Figure 4-1 Arrangement of Surveillance Capsules in the Vogtle Unit 2 Reactor Vessel

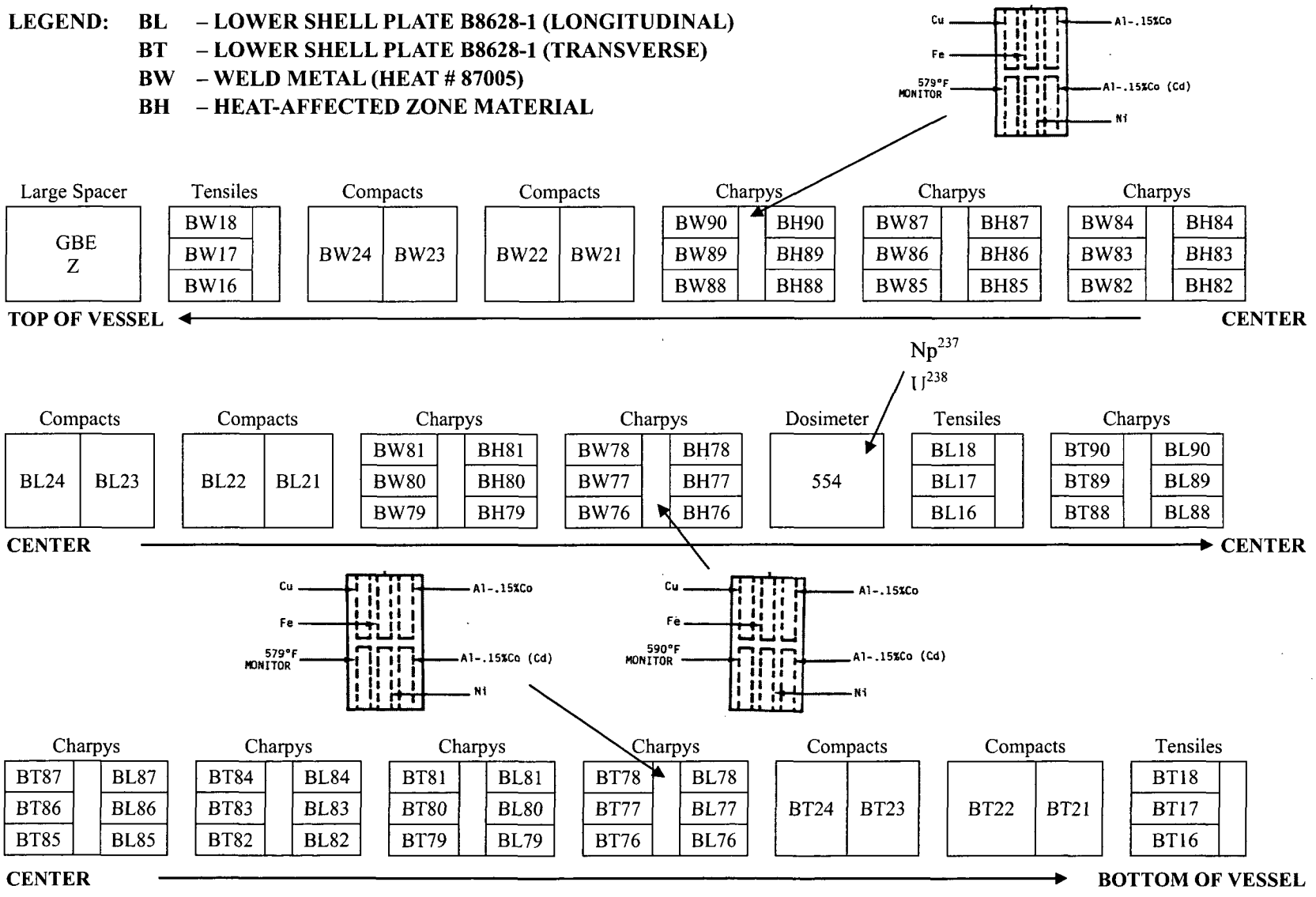


Figure 4-2 Capsule Z Diagram Showing the Location of Specimens, Thermal Monitors, and Dosimeters

5 TESTING OF SPECIMENS FROM CAPSULE Z

5.1 OVERVIEW

The post-irradiation mechanical testing of the Charpy V-notch impact specimens and tensile specimens was performed at the Hot Cell Facility at the Westinghouse Research and Technology Unit (RTU). Testing was performed in accordance with 10 CFR 50, Appendices G and H [Ref. 2] and ASTM Specification E185-82 [Ref. 4].

The capsule was opened upon receipt at the hot cell laboratory. The specimens and spacer blocks were carefully removed, inspected for identification number, and checked against the master list in WCAP-11381 [Ref. 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 E23-07a [Ref. 10] 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. Note that the instrumented Charpy data is for information only. The Instron Impulse system has not been calibrated to ASTM Standard E2298-09 [Ref. 11], so the instrumented energy, load, time, and stress data are considered for information only. With this system, load-time and energy-time signals can be recorded in addition to the standard measurement of Charpy energy. The load signal data acquisition rate was 819 kHz with data acquired for 10 ms. For some of the tests, a low-pass filter was used to condition the load signal. From the load-time curve, the load of general yielding (F_{gy}), the time to general yielding, the maximum load (F_m), and the time to maximum load 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 brittle fracture load (F_{bf}). The termination of the fast load drop is identified as the arrest load (F_a). F_{gy}, F_m, F_{bf}, and F_a were determined per the guidance in ASTM Standard E2298-09. Note that some of the signals were filtered for the instrumented Charpy testing. Although this is not recommended in ASTM Standard E2298-09, the instrumented Charpy data is reported for information only; thus, there is no significant effect on the results contained in this report.

The energy at maximum load (W_m) was determined by integrating 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 (W_P) is the difference between the total energy to fracture (W_t) and the energy at maximum load (W_m).

The yield stress (σ_Y) was calculated from the three-point bend formula having the following expression [Ref. 12]:

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

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 5-1 is valid with C = 1.21.

Therefore, (for L = 4W),

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

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

$$\sigma_Y = 33.3\ F_{gy} \qquad \text{(Eqn. 5-3)}$$

where σ_Y is in units of psi and F_{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.

Normalized energies for W_t, W_m, and W_P were calculated per the cross-sectional area (A) 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 E23-07a [Ref. 10] and A370-09 [Ref. 13]. 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 model 4400 screw-driven tensile machine (Model 1115). Testing met ASTM Specifications E8-09 [Ref. 14] and E21-09 [Ref. 15] except for some minor deviations that do not have any significant effect on the results provided in this report.

Elevated test temperatures were obtained with a three-zone electric resistance split-tube furnace with a 9-inch hot zone. Specimens were soaked at temperature (±5°F) for a minimum of 20 minutes before testing. All tests were conducted in air. The specimens were round 0.25-inch diameter with a 1.25-inch reduced section. Load was applied through a clevis and pin connection.

The yield load, ultimate load, fracture load, uniform elongation, and elongation at fracture were determined directly from the load-extension curve. The yield strength, ultimate tensile 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 Z, which received a fluence of 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV) in 18.48 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 unirradiated and previously withdrawn capsule results were taken from WCAP-11381 [Ref. 3], WCAP-13007 [Ref. 16], WCAP-14532 [Ref. 9], WCAP-15159 [Ref. 17], and WCAP-16382-NP [Ref. 8].

The transition temperature increases and changes in upper-shelf energies for the Capsule Z materials are summarized in Table 5-9 and led to the following results:

- Irradiation of the reactor vessel Lower Shell Plate B8628-1 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 67.8°F and an irradiated 50 ft-lb transition temperature of 106.8°F. This results in a 30 ft-lb transition temperature increase of 59.0°F and a 50 ft-lb transition temperature increase of 61.4°F for the longitudinally oriented specimens.

- Irradiation of the reactor vessel Lower Shell Plate B8628-1 Charpy specimens, oriented with the longitudinal axis of the specimen perpendicular to the major working direction (transverse orientation), resulted in an irradiated 30 ft-lb transition temperature of 103.9°F and an irradiated 50 ft-lb transition temperature of 140.1°F. This results in a 30 ft-lb transition temperature increase of 75.3°F and a 50 ft-lb transition temperature increase of 70.0°F for the transversely oriented specimens.

- Irradiation of the Surveillance Program Weld Metal (Heat # 87005) Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of 2.1°F and an irradiated 50 ft-lb transition temperature of 48.3°F. This results in a 30 ft-lb transition temperature increase of 21.3°F and a 50 ft-lb transition temperature increase of 37.2°F.

- Irradiation of the Heat-Affected Zone (HAZ) Material Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of -75.1°F and an irradiated 50 ft-lb transition temperature of -41.2°F. This results in a 30 ft-lb transition temperature increase of 8.6°F and a 50 ft-lb transition temperature increase of 11.2°F.

- The average upper-shelf energy of the Lower Shell Plate B8628-1 (longitudinal orientation) did not change after irradiation to 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV). This results in an irradiated average upper-shelf energy of 89.0 ft-lb for the longitudinally oriented specimens.

- The average upper-shelf energy of the Lower Shell Plate B8628-1 (transverse orientation) resulted in an average energy decrease of 2.0 ft-lb after irradiation to 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV). This results in an irradiated average upper-shelf energy of 68.0 ft-lb for the transversely oriented specimens.

- The average upper-shelf energy of the weld metal Charpy specimens resulted in an average energy decrease of 2.0 ft-lb after irradiation to 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV). This results in an irradiated average upper-shelf energy of 90.0 ft-lb for the weld metal specimens.

- The average upper-shelf energy of the HAZ Material Charpy specimens resulted in an average energy increase of 6.0 ft-lb after irradiation to 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV). This results in an irradiated average upper-shelf energy of 112.0 ft-lb for the HAZ Material.

- Comparisons of the measured 30 ft-lb shift in transition temperature values and upper-shelf energy decreases to those predicted by Regulatory Guide 1.99, Revision 2 [Ref. 1] for the Vogtle Unit 2 reactor vessel surveillance materials are presented in Table 5-10.

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 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 through end-of-license (36 EFPY) and end-of-license renewal (57 EFPY) as required by 10 CFR 50, Appendix G [Ref. 2]. This evaluation can be found in Appendix E.

5.3 TENSILE TEST RESULTS

The results of the tensile tests performed on the various materials contained in Capsule Z irradiated to 4.16×10^{19} n/cm^2 (E > 1.0 MeV) are presented in Table 5-11 and are compared with unirradiated results as shown in Figures 5-17 through 5-19.

The results of the tensile tests performed on the Lower Shell Plate B8628-1 (longitudinal orientation) indicated that irradiation to 4.16×10^{19} n/cm^2 (E > 1.0 MeV) caused increases in the 0.2 percent offset yield strength and the ultimate tensile strength when compared to unirradiated data [Ref. 3]. See Figure 5-17 and Table 5-11.

The results of the tensile tests performed on the Lower Shell Plate B8628-1 (transverse orientation) indicated that irradiation to 4.16×10^{19} n/cm^2 (E > 1.0 MeV) caused increases in the 0.2 percent offset yield strength and the ultimate tensile strength when compared to unirradiated data [Ref. 3]. See Figure 5-18 and Table 5-11.

The results of the tensile tests performed on the surveillance weld metal indicated that irradiation to 4.16×10^{19} n/cm^2 (E > 1.0 MeV) caused increases in the 0.2 percent offset yield strength and the ultimate tensile strength when compared to unirradiated data [Ref. 3]. See Figure 5-19 and Table 5-11.

The fractured tensile specimens for the Lower Shell Plate B8628-1 material are shown in Figures 5-20 and 5-21, while the fractured tensile specimens for the surveillance weld metal are shown in Figure 5-22. The engineering stress-strain curves for the tensile tests are shown in Figures 5-23 through 5-28.

5.4 1/2T COMPACT TENSION SPECIMEN TESTS

Per the surveillance capsule testing contract, the 1/2T Compact Tension Specimens were not tested and are being stored at the Westinghouse Research and Technology Unit.

Table 5-1 Charpy V-notch Data for the Vogtle Unit 2 Lower Shell Plate B8628-1 Irradiated to a Fluence of 4.16 x 10^{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	%
BL76	-50	-46	9	12	6	0.15	5
BL88	35	2	26	35	22	0.56	15
BL86	50	10	26	35	24	0.61	15
BL89	60	16	24	33	23	0.58	25
BL84	75	24	32	43	24	0.61	25
BL78	85	29	33	45	29	0.74	35
BL83	90	32	41	56	31	0.79	30
BL77	100	38	44	60	36	0.91	40
BL82	105	41	41	56	35	0.89	50
BL79	110	43	61	83	44	1.12	55
BL81	120	49	56	76	45	1.14	60
BL90	150	66	72	98	58	1.47	90
BL87	200	93	82	111	66	1.68	100
BL85	225	107	91	123	74	1.88	100
BL80	250	121	94	127	68	1.73	100

Table 5-2 Charpy V-notch Data for the Vogtle Unit 2 Lower Shell Plate B8628-1 Irradiated to a Fluence of 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV) (Transverse Orientation)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
BT89	-75	-59	4	5	4	0.10	5
BT85	75	24	17	23	21	0.53	25
BT87	90	32	26	35	27	0.69	35
BT80	100	38	29	39	30	0.76	30
BT88	110	43	33	45	32	0.81	40
BT83	115	46	33	45	34	0.86	40
BT90	125	52	44	60	38	0.97	50
BT81	135	57	42	57	42	1.07	70
BT78	140	60	48	65	47	1.19	65
BT77	145	63	44	60	45	1.14	65
BT76	150	66	66	89	55	1.40	90
BT84	175	79	64	87	60	1.52	100
BT82	210	99	76	103	59	1.50	100
BT86	250	121	62	84	56	1.42	100
BT79	275	135	69	94	56	1.42	100

Table 5-3 Charpy V-notch Data for the Vogtle Unit 2 Surveillance Weld Metal Irradiated to a Fluence of 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
BW90	-50	-46	7	9	5	0.13	10
BW79	0	-18	11	15	12	0.30	15
BW81	0	-18	37	50	28	0.71	20
BW76	5	-15	40	54	36	0.91	35
BW82	5	-15	23	31	20	0.51	20
BW86	10	-12	35	47	32	0.81	30
BW85	20	-7	54	73	47	1.19	50
BW84	25	-4	41	56	37	0.94	45
BW87	50	10	46	62	40	1.02	60
BW78	60	16	51	69	40	1.02	55
BW77	75	24	67	91	45	1.14	80
BW80	130	54	70	95	55	1.40	90
BW88	225	107	90	122	67	1.70	100
BW89	250	121	91	123	67	1.70	100
BW83	275	135	88	119	69	1.75	100

Table 5-4 Charpy V-notch Data for the Vogtle Unit 2 Heat-Affected Zone (HAZ) Material Irradiated to a Fluence of 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
BH85	-150	-101	9	12	4	0.10	10
BH84	-110	-79	20	27	11	0.28	15
BH76	-90	-68	33	45	18	0.46	20
BH88	-80	-62	23	31	15	0.38	20
BH77	-75	-59	29	39	19	0.48	25
BH82	-60	-51	38	52	21	0.53	30
BH78	-50	-46	52	71	34	0.86	40
BH79	-35	-37	58	79	34	0.86	50
BH89	-25	-32	38	52	30	0.76	50
BH90	0	-18	79	107	49	1.24	90
BH83	25	-4	90	122	51	1.30	85
BH81	60	16	115	156	70	1.78	100
BH86	110	43	114	155	71	1.80	100
BH80	150	66	106	144	66	1.68	100
BH87	175	79	111	151	72	1.83	100

Table 5-5 Instrumented Charpy Impact Test Results for the Vogtle Unit 2 Lower Shell Plate B8628-1 Irradiated to a Fluence of 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV) (Longitudinal Orientation)

Sample No.	Test Temp. (°F)	Charpy Energy, W_t (ft-lb)	Normalized Energies (ft-lb/in^2)			General Yield Load, F_{gy} (lb)	Time to F_{gy} (msec)	Max. Load, F_m (lb)	Time to F_m (msec)	Fract. Load, F_{bf} (lb)	Arrest Load, F_a (lb)	Yield Stress (ksi)	Flow Stress (ksi)
			Total W_t/A	At F_m W_m/A	Prop. W_P/A								
BL76	-50	9.0	73	41	31	3520	0.18	3720	0.18	3720	n/a	117	121
BL88	35	22.1	178	170	8	3000	0.05	3760	0.41	3760	n/a	100	113
BL86	50	26.2	211	127	85	2800	0.14	3760	0.36	3760	80	93	109
BL89	60	23.7	191	114	77	3000	0.05	3700	0.29	3700	80	100	112
BL84	75	30.9	249	170	79	3210	0.06	3700	0.41	3700	320	107	115
BL78	85	31.4	253	141	112	2890	0.05	3700	0.40	3700	750	96	110
BL83	90	38.4	309	197	112	3040	0.05	3640	0.47	3470	1010	101	111
BL77	100	40.7	328	197	131	2910	0.05	3640	0.50	3460	1070	97	109
BL82	105	38.8	313	198	114	2650	0.05	3770	0.48	3770	1030	88	107
BL79	110	56.1	452	257	195	2710	0.05	3920	0.60	3740	1490	90	110
BL81	120	51.5	415	194	221	2890	0.05	3600	0.48	3260	1100	96	108
BL90	150	68.0	548	191	357	2800	0.06	3570	0.48	2630	2160	93	106
BL87	200	74.3	599	201	398	2780	0.14	3690	0.53	n/a	n/a	93	108
BL85	225	83.2	670	245	425	3000	0.05	3690	0.60	n/a	n/a	100	111
BL80	250	86.1	694	244	450	2750	0.05	3650	0.60	n/a	n/a	92	107

Table 5-6 Instrumented Charpy Impact Test Results for the Vogtle Unit 2 Lower Shell Plate B8628-1 Irradiated to a Fluence of 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV) (Transverse Orientation)

Sample No.	Test Temp. (°F)	Charpy Energy, W_t (ft-lb)	Normalized Energies (ft-lb/in^2)			General Yield Load, F_{gy} (lb)	Time to F_{gy} (msec)	Max. Load, F_m (lb)	Time to F_m (msec)	Fract. Load, F_{bf} (lb)	Arrest Load, F_a (lb)	Yield Stress (ksi)	Flow Stress (ksi)
			Total W_t/A	At F_m W_m/A	Prop. W_P/A								
BT89	-75	4.3	35	18	17	2170	0.13	2190	0.13	2190	n/a	72	73
BT85	75	16.9	136	39	97	3140	0.15	3410	0.18	3410	660	105	109
BT87	90	24.4	197	110	86	2600	0.05	3670	0.29	3580	700	87	104
BT80	100	28.6	230	113	118	2780	0.05	3640	0.29	3600	820	93	107
BT88	110	31.0	250	139	110	2590	0.05	3630	0.35	3530	610	86	104
BT83	115	30.6	247	110	137	2500	0.05	3550	0.29	3400	1070	83	101
BT90	125	41.5	334	198	136	2580	0.05	3790	0.47	3450	1700	86	106
BT81	135	38.9	313	110	204	2860	0.05	3540	0.29	3320	2010	95	107
BT78	140	46.1	371	193	178	2570	0.05	3620	0.48	3450	2370	86	103
BT77	145	41.7	336	135	201	2650	0.05	3510	0.36	3360	1250	88	103
BT76	150	62.1	500	248	252	2570	0.05	3650	0.6	n/a	n/a	86	104
BT84	175	59.6	480	192	288	2330	0.05	3620	0.47	n/a	n/a	78	99
BT82	210	71.3	574	212	363	3130	0.05	3820	0.5	n/a	n/a	104	116
BT86	250	55.8	450	172	277	2680	0.14	3620	0.47	n/a	n/a	89	105
BT79	275	64.4	519	189	330	2500	0.05	3630	0.47	n/a	n/a	83	102

Table 5-7 Instrumented Charpy Impact Test Results for the Vogtle Unit 2 Surveillance Weld Metal Irradiated to a Fluence of 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV)

Sample No.	Test Temp. (°F)	Charpy Energy, W_t (ft-lb)	Normalized Energies (ft-lb/in^2)			General Yield Load, F_{gy} (lb)	Time to F_{gy} (msec)	Max. Load, F_m (lb)	Time to F_m (msec)	Fract. Load, F_{bf} (lb)	Arrest Load, F_a (lb)	Yield Stress (ksi)	Flow Stress (ksi)
			Total W_t/A	At F_m W_m/A	Prop. W_P/A								
BW90	-50	6.7	54	27	27	2840	0.14	2870	0.15	2870	n/a	95	95
BW79	0	12.1	97	27	70	2760	0.05	3840	0.09	3510	n/a	92	110
BW81	0	35.9	289	229	60	2800	0.05	4050	0.5	3810	n/a	93	114
BW76	5	38.8	313	226	87	2790	0.05	3930	0.5	3750	n/a	93	112
BW82	5	24.3	196	151	45	2360	0.05	3880	0.35	3620	n/a	79	104
BW86	10	33.8	272	220	52	2920	0.05	3830	0.5	3620	n/a	97	112
BW85	20	50.8	409	265	144	2620	0.05	3850	0.6	3340	720	87	108
BW84	25	37.7	304	212	92	3160	0.15	4010	0.52	3910	280	105	119
BW87	50	44.3	357	259	97	3030	0.05	3780	0.6	3670	1070	101	113
BW78	60	48.6	392	275	117	2790	0.05	3920	0.62	3590	800	93	112
BW77	75	62.8	506	225	281	3550	0.05	3950	0.5	3380	1830	118	125
BW80	130	64.6	521	255	265	2510	0.05	3760	0.6	2870	2030	84	104
BW88	225	83.1	670	257	413	2920	0.06	3780	0.62	n/a	n/a	97	112
BW89	250	82.2	662	272	390	2740	0.15	3750	0.68	n/a	n/a	91	108
BW83	275	81.8	659	247	413	3170	0.05	3670	0.6	n/a	n/a	106	114

Table 5-8 Instrumented Charpy Impact Test Results for the Vogtle Unit 2 Heat-Affected Zone (HAZ) Material Irradiated to a Fluence of 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV)

Sample No.	Test Temp. (°F)	Charpy Energy, W_t (ft-lb)	Normalized Energies (ft-lb/in^2)			General Yield Load, F_{gy} (lb)	Time to F_{gy} (msec)	Max. Load, F_m (lb)	Time to F_m (msec)	Fract. Load, F_{bf} (lb)	Arrest Load, F_a (lb)	Yield Stress (ksi)	Flow Stress (ksi)
			Total W_t/A	At F_m W_m/A	Prop. W_P/A								
BH85	-150	9.1	73	31	42	2600	0.05	4700	0.09	4350	n/a	87	122
BH84	-110	19.2	155	30	125	3240	0.05	4540	0.09	4340	n/a	108	130
BH76	-90	33.5	270	27	243	2360	0.04	4430	0.09	4260	n/a	79	113
BH88	-80	23.9	193	28	164	2830	0.05	4260	0.09	4040	n/a	94	118
BH77	-75	27.1	218	71	147	3610	0.15	4350	0.22	4310	250	120	133
BH82	-60	36.7	296	27	269	2730	0.05	4210	0.09	4050	510	91	116
BH78	-50	48.1	388	238	149	2800	0.05	4270	0.5	4050	1200	93	118
BH79	-35	54.9	442	298	144	2260	0.05	4330	0.62	3870	1790	75	110
BH89	-25	35.8	288	27	261	2980	0.05	4100	0.09	3930	1170	99	118
BH90	0	74.6	601	292	309	2500	0.05	4200	0.62	3400	2550	83	112
BH83	25	84.6	682	289	392	2450	0.05	4280	0.61	3470	2540	82	112
BH81	60	107.1	863	281	582	2970	0.05	4190	0.61	n/a	n/a	99	119
BH86	110	105.5	850	276	574	2500	0.05	4040	0.62	n/a	n/a	83	109
BH80	150	97.8	788	292	496	3000	0.15	4040	0.68	n/a	n/a	100	117
BH87	175	100.8	812	255	558	2550	0.05	3910	0.6	n/a	n/a	85	108

Table 5-9 Effect of Irradiation to 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV) on the Charpy V-Notch Toughness Properties of the Vogtle Unit 2 Reactor Vessel Surveillance Capsule Z Materials

Material	Average 30 ft-lb Transition Temperature[a] (°F)			Average 35 mil Lateral Expansion Temperature[a] (°F)			Average 50 ft-lb Transition Temperature[a] (°F)			Average Energy Absorption at Full Shear[a] (ft-lb)		
	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔE
Lower Shell Plate B8628-1 (LT)	8.8	67.8	59.0	36.4	94.4	58.0	45.4	106.8	61.4	89.0	89.0	0.0
Lower Shell Plate B8628-1 (TL)	28.6	103.9	75.3	44.0	111.7	67.7	70.1	140.1	70.0	70.0	68.0	-2.0
Surveillance Program Weld Metal (Heat # 87005)	-19.2	2.1	21.3	-1.0	30.2	31.2	11.1	48.3	37.2	92.0	90.0	-2.0
HAZ Material	-83.7	-75.1	8.6	-46.9	-30.5	16.4	-52.4	-41.2	11.2	106.0	112.0	6.0

Note:

(a) Average value is determined by CVGraph (see Appendix C).

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

Material	Capsule	Capsule Fluence ($\times 10^{19}$ n/cm^2, E > 1.0 MeV)	30 ft-lb Transition Temperature Shift		USE Decrease	
			Predicted (°F) [a]	Measured (°F) [b]	Predicted (%) [a]	Measured (%) [b]
Lower Shell Plate B8628-1 (Longitudinal)	U	0.356	22.2	2.0	15	---
	Y	1.12	32.0	5.8	19.5	---
	X	1.78	35.9	29.4	22	3
	W	2.98	40.0	39.0	25	6
	Z	4.16	42.3	59.0	26.5	0
Lower Shell Plate B8628-1 (Transverse)	U	0.356	22.2	0.0[c]	15	---
	Y	1.12	32.0	1.9	19.5	---
	X	1.78	35.9	29.8	22	7
	W	2.98	40.0	45.5	25	1
	Z	4.16	42.3	75.3	26.5	3
Surveillance Program Weld Metal	U	0.356	26.0	0.0[c]	15	---
	Y	1.12	37.6	18.7	19.5	7
	X	1.78	42.2	19.9	22	5
	W	2.98	46.9	31.4	25	5
	Z	4.16	49.7	21.3	26.5	2
Heat-Affected Zone Material	U	0.356	---	0.0[c]	---	---
	Y	1.12	---	0.0[c]	---	---
	X	1.78	---	0.0[c]	---	7
	W	2.98	---	3.2	---	6
	Z	4.16	---	8.6	---	---

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.

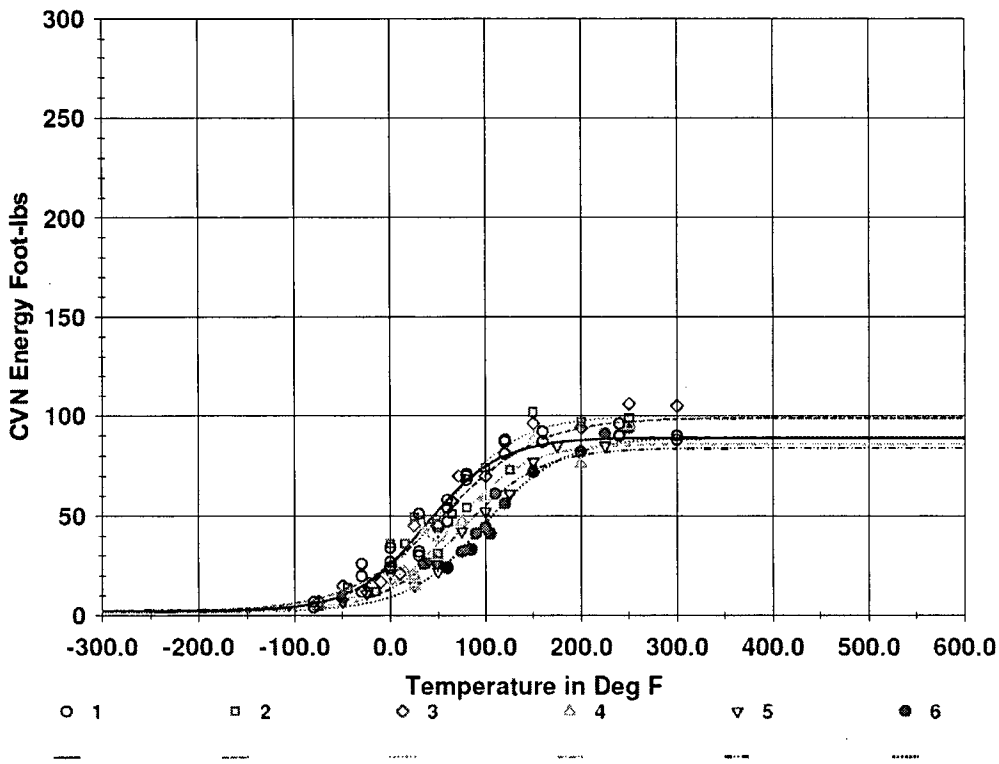
Table 5-11 Tensile Properties of the Vogtle Unit 2 Capsule Z Reactor Vessel Surveillance Materials Irradiated to 4.16×10^{19} n/cm^2 (E > 1.0 MeV)

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 (%)
Lower Shell Plate B8628-1 (Longitudinal)	BL16	75	77.8	97.8	3.28	185	66.7	11	24	64
	BL17	150	74.6	93.7	3.03	171	61.6	11	24	64
	BL18	550	68.4	92.7	3.30	164	67.2	11	21	59
Lower Shell Plate B8628-1 (Transverse)	BT16	75	77.0	96.8	3.33	146	67.7	11	22	54
	BT17	150	74.4	92.7	3.15	157	64.2	10	21	59
	BT18	550	68.9	92.7	3.83	135	77.9	11	18	42
Weld Metal (Heat # 87005)	BW16	25	78.4	93.3	3.15	205	64.2	12	25	69
	BW17	175	72.8	86.0	2.88	187	58.6	10	22	69
	BW18	550	69.7	88.0	3.15	157	64.2	10	21	59

Lower Shell Plate B8628-1 (LT)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 01:10 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	LT	C3500-2
2	Vogtle 2	U	SA533B1	LT	C3500-2
3	Vogtle 2	Y	SA533B1	LT	C3500-2
4	Vogtle 2	X	SA533B1	LT	C3500-2
5	Vogtle 2	W	SA533B1	LT	C3500-2
6	Vogtle 2	Z	SA533B1	LT	C3500-2



Results

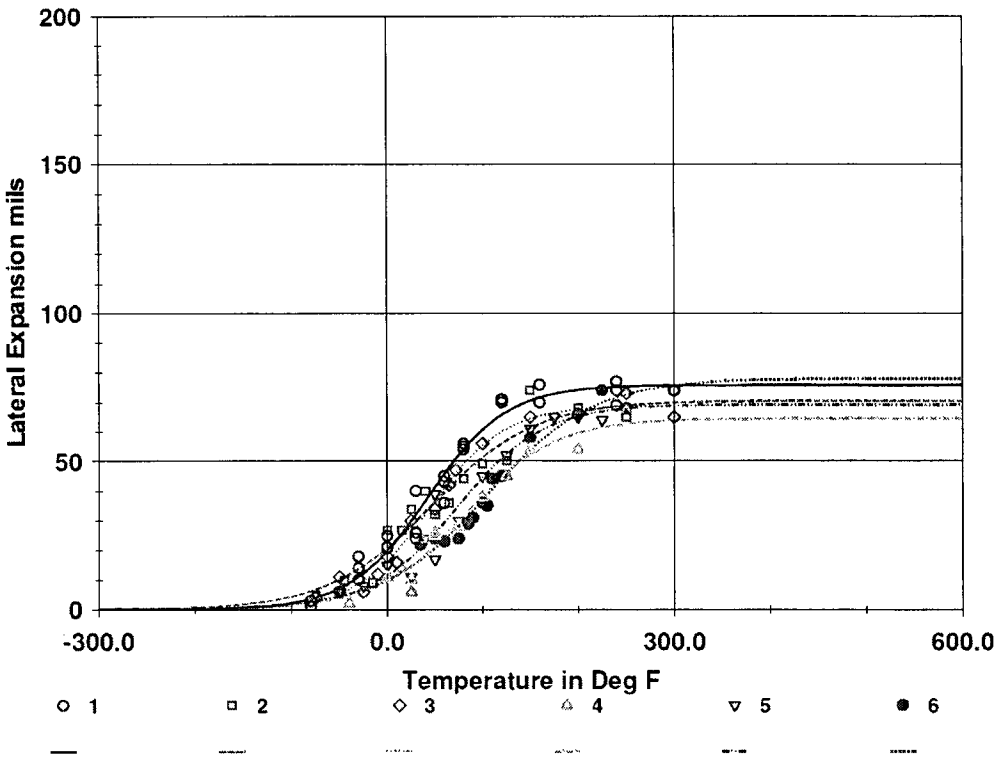
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	89.0	.0	8.8	.0	45.4	.0
2		2.2	99.0	10.0	10.8	2.0	54.9	9.5
3		2.2	100.0	11.0	14.6	5.8	50.5	5.1
4		2.2	86.0	-3.0	38.2	29.4	75.6	30.2
5		2.2	84.0	-5.0	47.8	39.0	89.0	43.6
6		2.2	89.0	.0	67.8	59.0	106.8	61.4

Figure 5-1 Charpy V-Notch Impact Energy vs. Temperature for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Longitudinal Orientation)

Lower Shell Plate B8628-1 (LT)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 01:26 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	LT	C3500-2
2	Vogtle 2	U	SA533B1	LT	C3500-2
3	Vogtle 2	Y	SA533B1	LT	C3500-2
4	Vogtle 2	X	SA533B1	LT	C3500-2
5	Vogtle 2	W	SA533B1	LT	C3500-2
6	Vogtle 2	Z	SA533B1	LT	C3500-2



Results

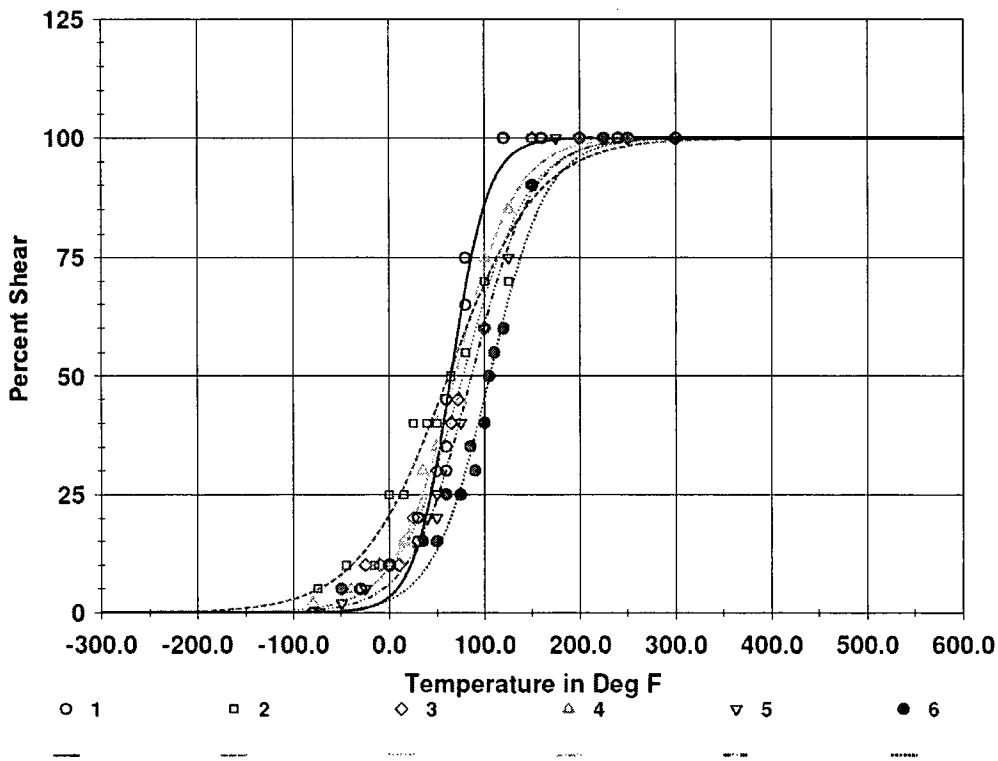
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		.0	75.9	.0	36.4	.0
2		.0	70.6	-5.3	45.8	9.4
3		.0	68.9	-7.1	46.8	10.4
4		.0	64.6	-11.4	90.0	53.6
5		.0	69.4	-6.6	74.7	38.3
6		.0	78.1	2.1	94.4	58.0

Figure 5-2 Charpy V-Notch Lateral Expansion vs. Temperature for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Longitudinal Orientation)

Lower Shell Plate B8628-1 (LT)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 01:30 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	LT	C3500-2
2	Vogtle 2	U	SA533B1	LT	C3500-2
3	Vogtle 2	Y	SA533B1	LT	C3500-2
4	Vogtle 2	X	SA533B1	LT	C3500-2
5	Vogtle 2	W	SA533B1	LT	C3500-2
6	Vogtle 2	Z	SA533B1	LT	C3500-2



Results

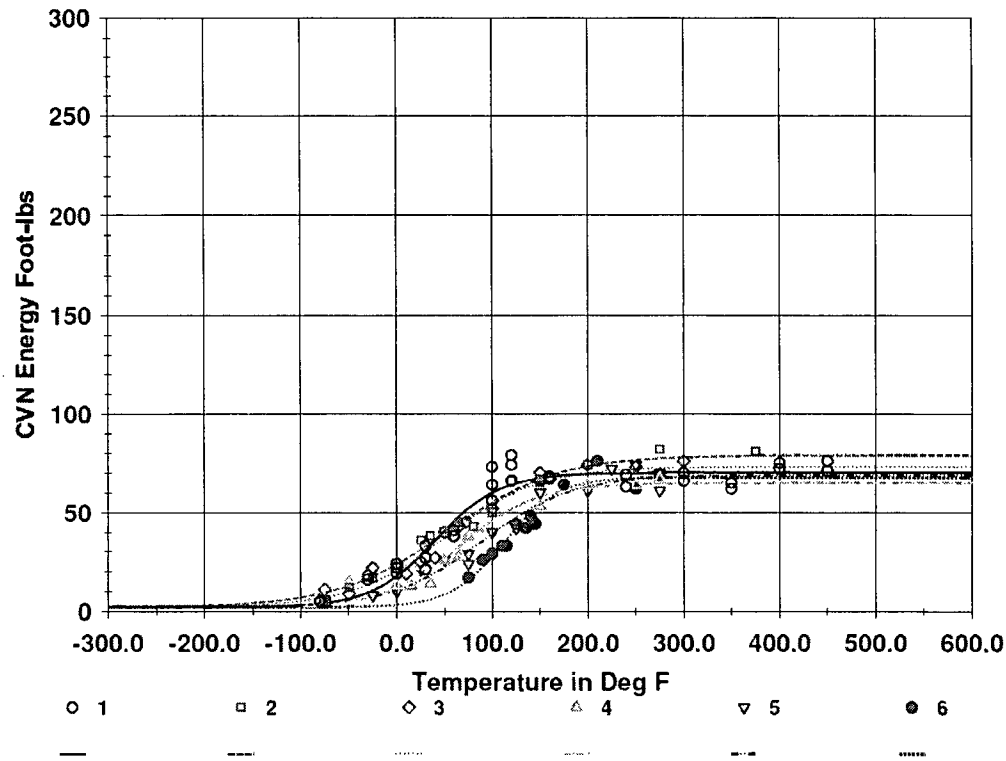
Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	65.0	.0
2		.0	100.0	.0	62.2	-2.8
3		.0	100.0	.0	77.8	12.8
4		.0	100.0	.0	69.3	4.3
5		.0	100.0	.0	86.5	21.5
6		.0	100.0	.0	105.4	40.4

Figure 5-3 Charpy V-Notch Percent Shear vs. Temperature for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Longitudinal Orientation)

Lower Shell Plate B8628-1 (TL)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 01:46 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	TL	C3500-2
2	Vogtle 2	U	SA533B1	TL	C3500-2
3	Vogtle 2	Y	SA533B1	TL	C3500-2
4	Vogtle 2	X	SA533B1	TL	C3500-2
5	Vogtle 2	W	SA533B1	TL	C3500-2
6	Vogtle 2	Z	SA533B1	TL	C3500-2



Results

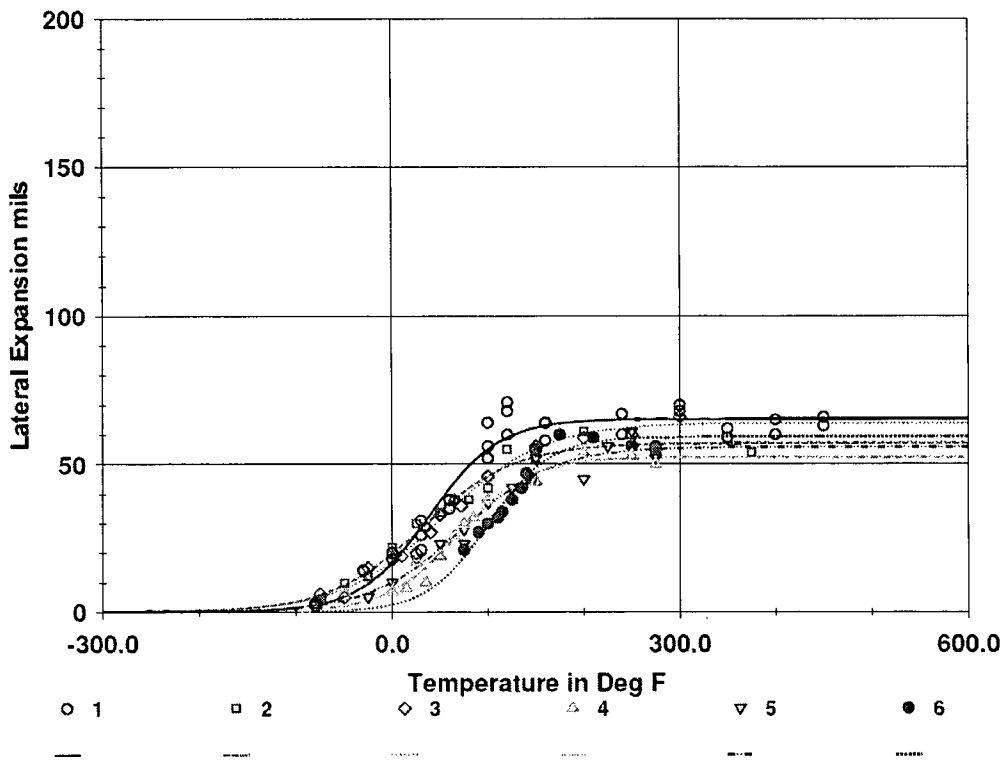
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2. 2	70. 0	. 0	28. 6	. 0	70. 1	. 0
2		2. 2	79. 0	9. 0	21. 5	- 7. 1	82. 6	12. 5
3		2. 2	73. 0	3. 0	30. 5	1. 9	87. 0	16. 9
4		2. 2	65. 0	- 5. 0	58. 4	29. 8	113. 5	43. 4
5		2. 2	69. 0	- 1. 0	74. 1	45. 5	133. 2	63. 1
6		2. 2	68. 0	- 2. 0	103. 9	75. 3	140. 1	70. 0

Figure 5-4 Charpy V-Notch Impact Energy vs. Temperature for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Transverse Orientation)

Lower Shell Plate B8628-1 (TL)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 01:47 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	TL	C3500-2
2	Vogtle 2	U	SA533B1	TL	C3500-2
3	Vogtle 2	Y	SA533B1	TL	C3500-2
4	Vogtle 2	X	SA533B1	TL	C3500-2
5	Vogtle 2	W	SA533B1	TL	C3500-2
6	Vogtle 2	Z	SA533B1	TL	C3500-2



Results

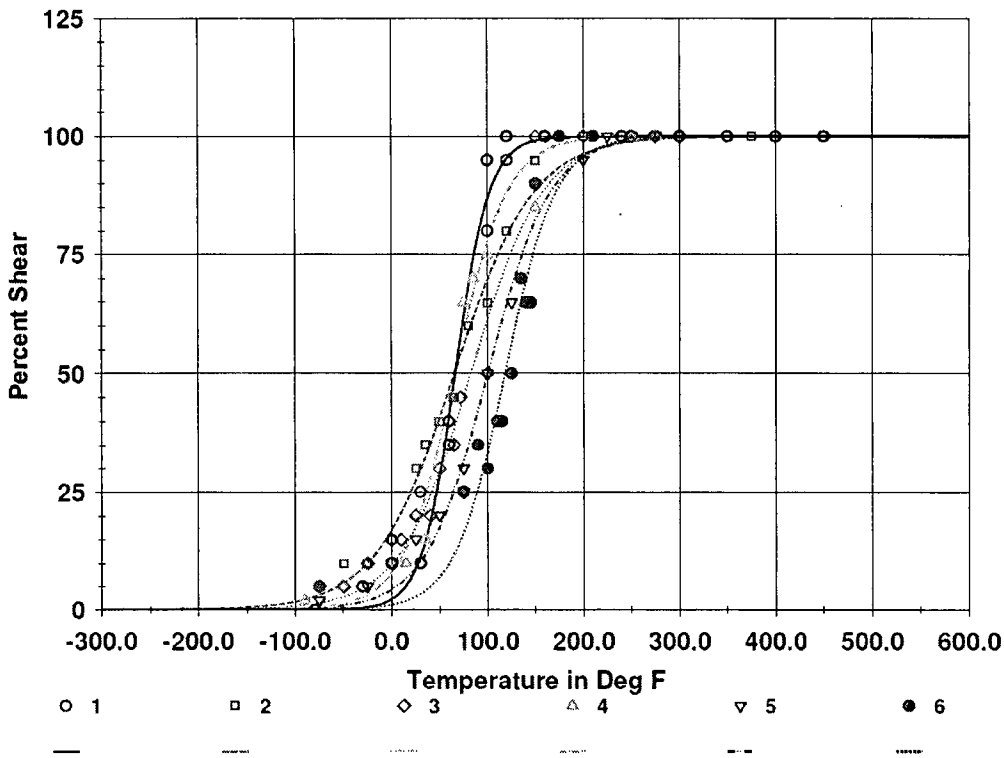
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		.0	65.3	.0	44.0	.0
2		.0	57.1	-8.2	53.1	9.1
3		.0	63.8	-1.5	62.9	18.9
4		.0	52.4	-12.9	94.3	50.3
5		.0	55.8	-9.5	97.1	53.1
6		.0	59.3	-6.1	111.7	67.7

Figure 5-5 Charpy V-Notch Lateral Expansion vs. Temperature for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Transverse Orientation)

Lower Shell Plate B8628-1 (TL)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 01:47 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	TL	C3500-2
2	Vogtle 2	U	SA533B1	TL	C3500-2
3	Vogtle 2	Y	SA533B1	TL	C3500-2
4	Vogtle 2	X	SA533B1	TL	C3500-2
5	Vogtle 2	W	SA533B1	TL	C3500-2
6	Vogtle 2	Z	SA533B1	TL	C3500-2



Results

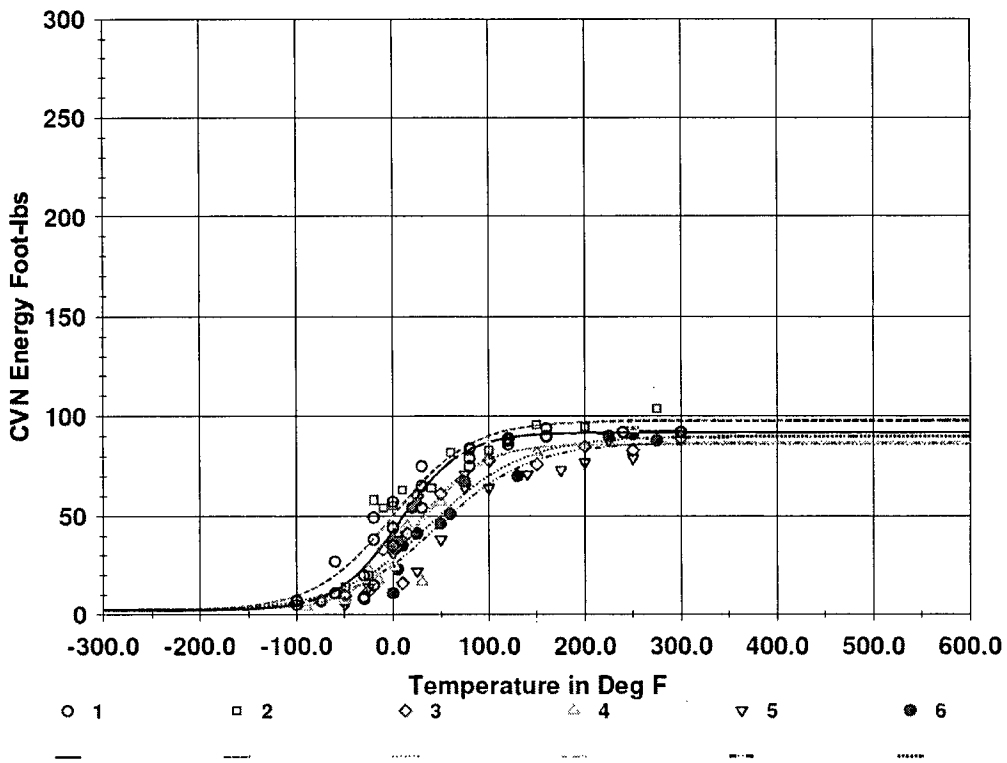
Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	66.5	.0
2		.0	100.0	.0	65.5	-1.0
3		.0	100.0	.0	83.0	16.5
4		.0	100.0	.0	66.2	-.3
5		.0	100.0	.0	100.4	33.9
6		.0	100.0	.0	118.1	51.6

Figure 5-6 Charpy V-Notch Percent Shear vs. Temperature for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Transverse Orientation)

Surveillance Program Weld Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 01:50 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR		NA	87005
2	Vogtle 2	U		NA	87005
3	Vogtle 2	Y		NA	87005
4	Vogtle 2	X		NA	87005
5	Vogtle 2	W		NA	87005
6	Vogtle 2	Z		NA	87005



Results

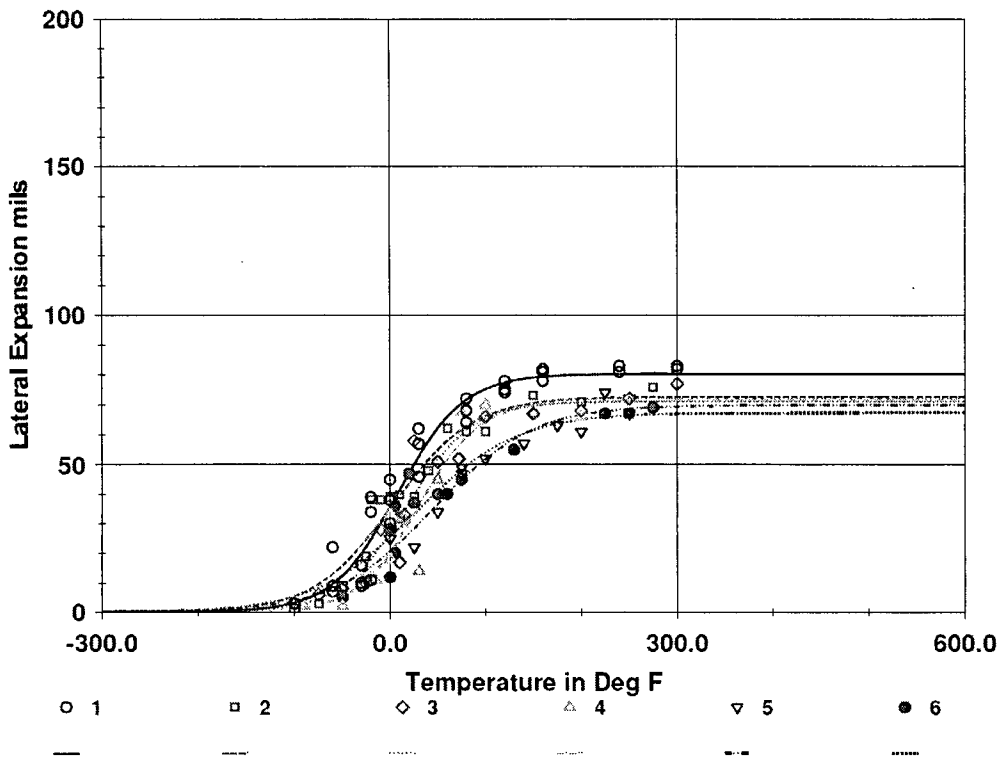
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	92.0	.0	-19.2	.0	11.1	.0
2		2.2	98.0	6.0	-36.5	-17.3	.0	-11.1
3		2.2	86.0	-6.0	-.5	18.7	32.0	20.9
4		2.2	87.0	-5.0	.7	19.9	34.7	23.6
5		2.2	87.0	-5.0	12.2	31.4	59.0	47.9
6		2.2	90.0	-2.0	2.1	21.3	48.3	37.2

Figure 5-7 Charpy V-Notch Impact Energy vs. Temperature for the Vogtle Unit 2 Reactor Vessel Surveillance Program Weld Metal

Surveillance Program Weld Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 02:13 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR		NA	87005
2	Vogtle 2	U		NA	87005
3	Vogtle 2	Y		NA	87005
4	Vogtle 2	X		NA	87005
5	Vogtle 2	W		NA	87005
6	Vogtle 2	Z		NA	87005



Results

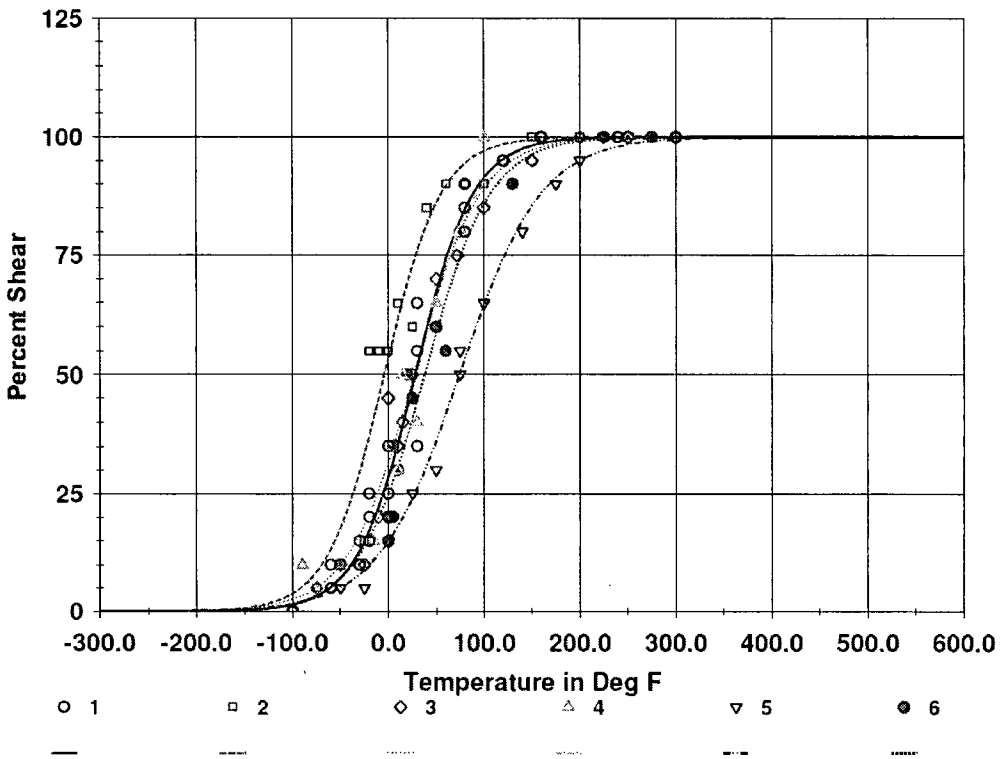
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		.0	80.4	.0	-1.0	.0
2		.0	72.6	-7.9	-.3	.7
3		.0	71.0	-9.4	16.2	17.2
4		.0	71.2	-9.2	28.1	29.1
5		.0	70.0	-10.5	45.0	46.0
6		.0	67.3	-13.1	30.2	31.2

Figure 5-8 Charpy V-Notch Lateral Expansion vs. Temperature for the Vogtle Unit 2 Reactor Vessel Surveillance Program Weld Metal

Surveillance Program Weld Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 02:13 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR		NA	87005
2	Vogtle 2	U		NA	87005
3	Vogtle 2	Y		NA	87005
4	Vogtle 2	X		NA	87005
5	Vogtle 2	W		NA	87005
6	Vogtle 2	Z		NA	87005



Results

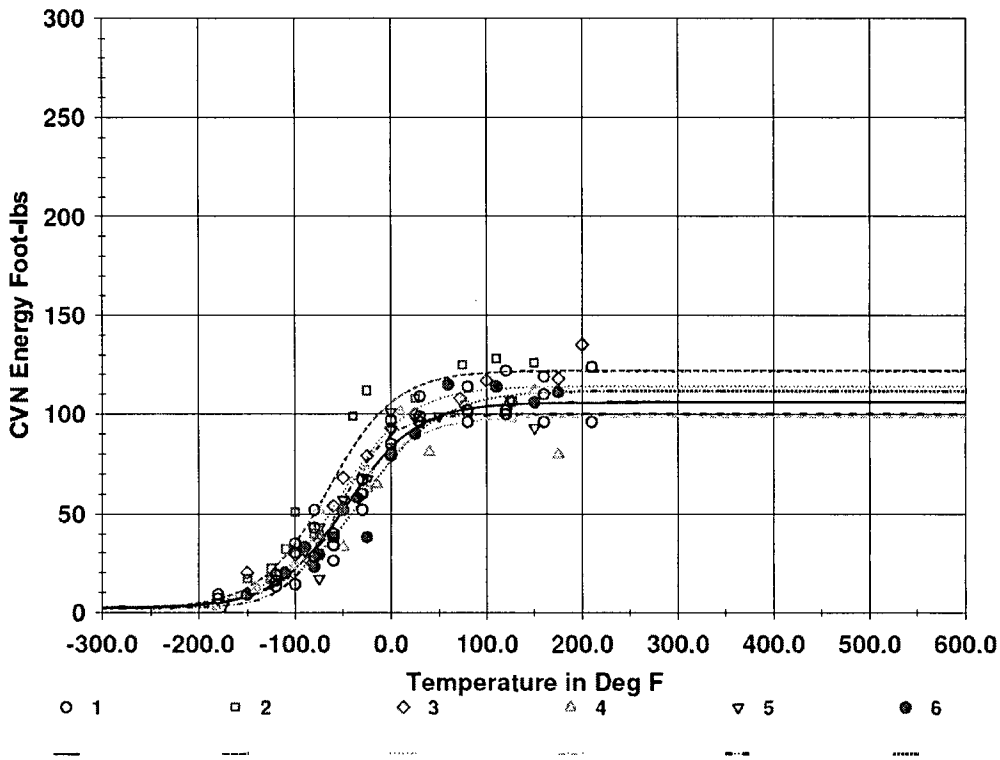
Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	28.1	.0
2		.0	100.0	.0	-4.1	-32.2
3		.0	100.0	.0	27.3	-.8
4		.0	100.0	.0	29.7	1.6
5		.0	100.0	.0	74.5	46.4
6		.0	100.0	.0	38.1	10.0

Figure 5-9 Charpy V-Notch Percent Shear vs. Temperature for the Vogtle Unit 2 Reactor Vessel Surveillance Program Weld Metal

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 02:22 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	NA	C3500-2
2	Vogtle 2	U	SA533B1	NA	C3500-2
3	Vogtle 2	Y	SA533B1	NA	C3500-2
4	Vogtle 2	X	SA533B1	NA	C3500-2
5	Vogtle 2	W	SA533B1	NA	C3500-2
6	Vogtle 2	Z	SA533B1	NA	C3500-2



Results

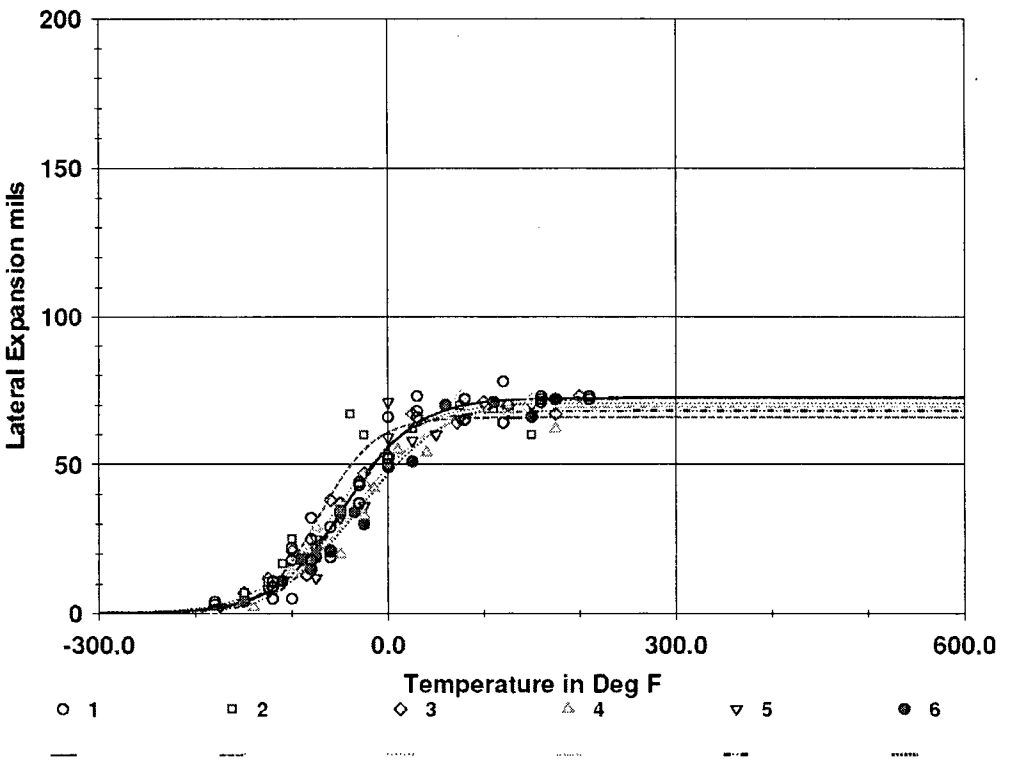
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2. 2	106. 0	. 0	- 83. 7	. 0	- 52. 4	. 0
2		2. 2	122. 0	16. 0	- 108. 0	- 24. 3	- 80. 2	- 27. 8
3		2. 2	114. 0	8. 0	- 93. 8	- 10. 1	- 63. 9	- 11. 5
4		2. 2	99. 0	- 7. 0	- 86. 2	- 2. 5	- 53. 2	-. 8
5		2. 2	100. 0	- 6. 0	- 80. 5	3. 2	- 57. 0	- 4. 6
6		2. 2	112. 0	6. 0	- 75. 1	8. 6	- 41. 2	11. 2

Figure 5-10 Charpy V-Notch Impact Energy vs. Temperature for the Vogtle Unit 2 Reactor Vessel Heat-Affected Zone Material

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 02:23 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	NA	C3500-2
2	Vogtle 2	U	SA533B1	NA	C3500-2
3	Vogtle 2	Y	SA533B1	NA	C3500-2
4	Vogtle 2	X	SA533B1	NA	C3500-2
5	Vogtle 2	W	SA533B1	NA	C3500-2
6	Vogtle 2	Z	SA533B1	NA	C3500-2



Results

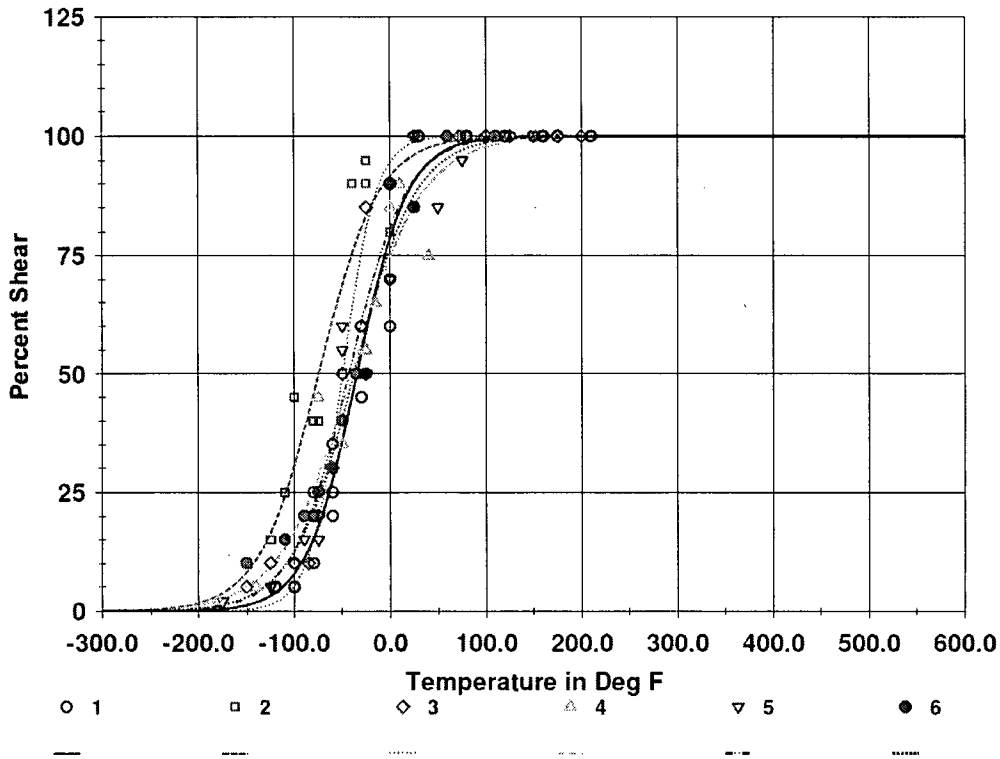
Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		.0	72.4	.0	-46.9	.0
2		.0	65.9	-6.5	-67.7	-20.8
3		.0	70.6	-1.9	-53.4	-6.5
4		.0	69.4	-3.0	-35.4	11.5
5		.0	68.0	-4.4	-46.5	.4
6		.0	72.4	.0	-30.5	16.4

Figure 5-11 Charpy V-Notch Lateral Expansion vs. Temperature for the Vogtle Unit 2 Reactor Vessel Heat-Affected Zone Material

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 02:24 PM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	Vogtle 2	UNIRR	SA533B1	NA	C3500-2
2	Vogtle 2	U	SA533B1	NA	C3500-2
3	Vogtle 2	Y	SA533B1	NA	C3500-2
4	Vogtle 2	X	SA533B1	NA	C3500-2
5	Vogtle 2	W	SA533B1	NA	C3500-2
6	Vogtle 2	Z	SA533B1	NA	C3500-2



Results

Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	-34.6	.0
2		.0	100.0	.0	-74.4	-39.8
3		.0	100.0	.0	-49.3	-14.7
4		.0	100.0	.0	-40.2	-5.6
5		.0	100.0	.0	-42.8	-8.2
6		.0	100.0	.0	-37.5	-2.9

Figure 5-12 Charpy V-Notch Percent Shear vs. Temperature for the Vogtle Unit 2 Reactor Vessel Heat-Affected Zone Material

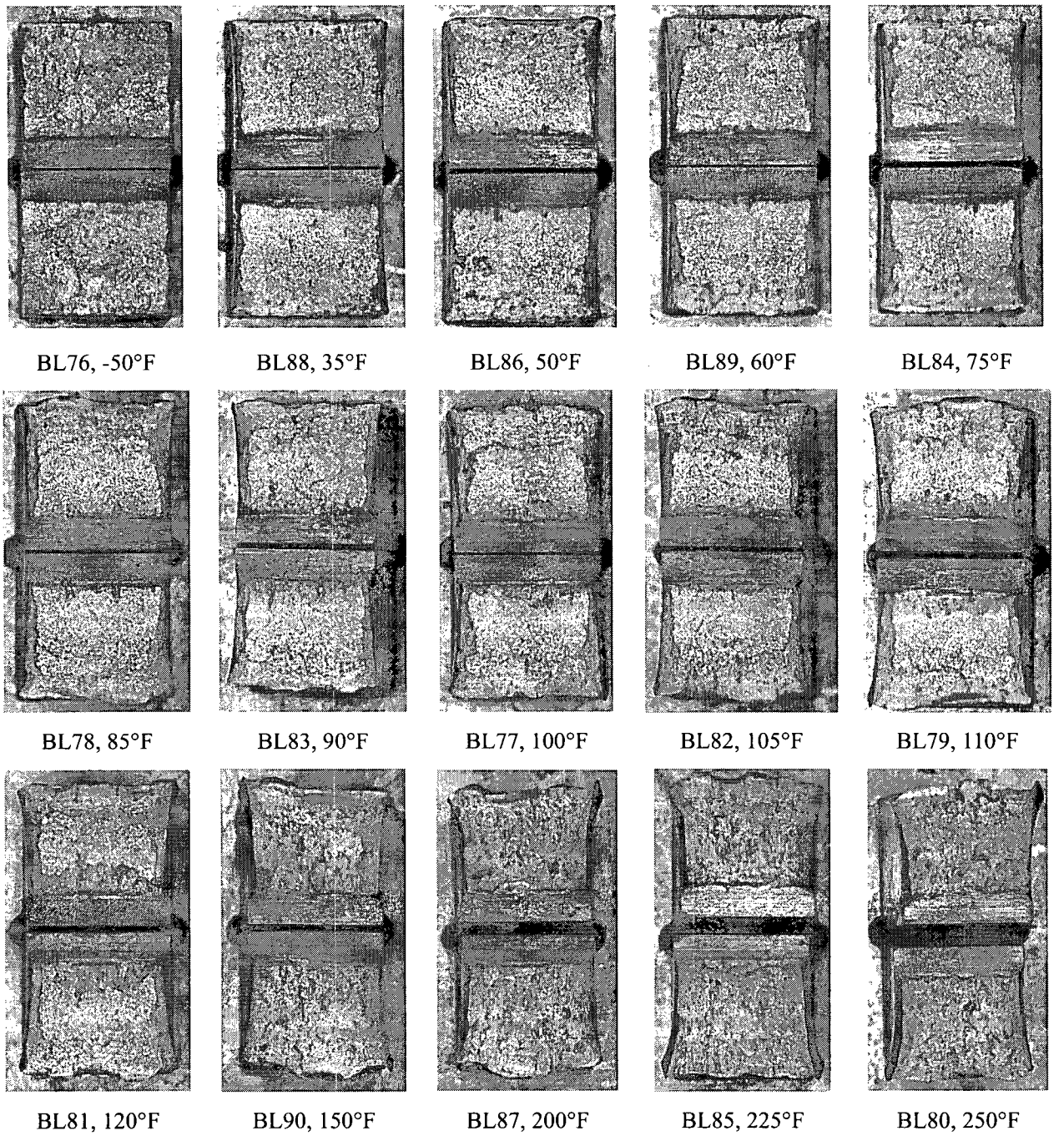


Figure 5-13 Charpy Impact Specimen Fracture Surfaces for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Longitudinal Orientation)

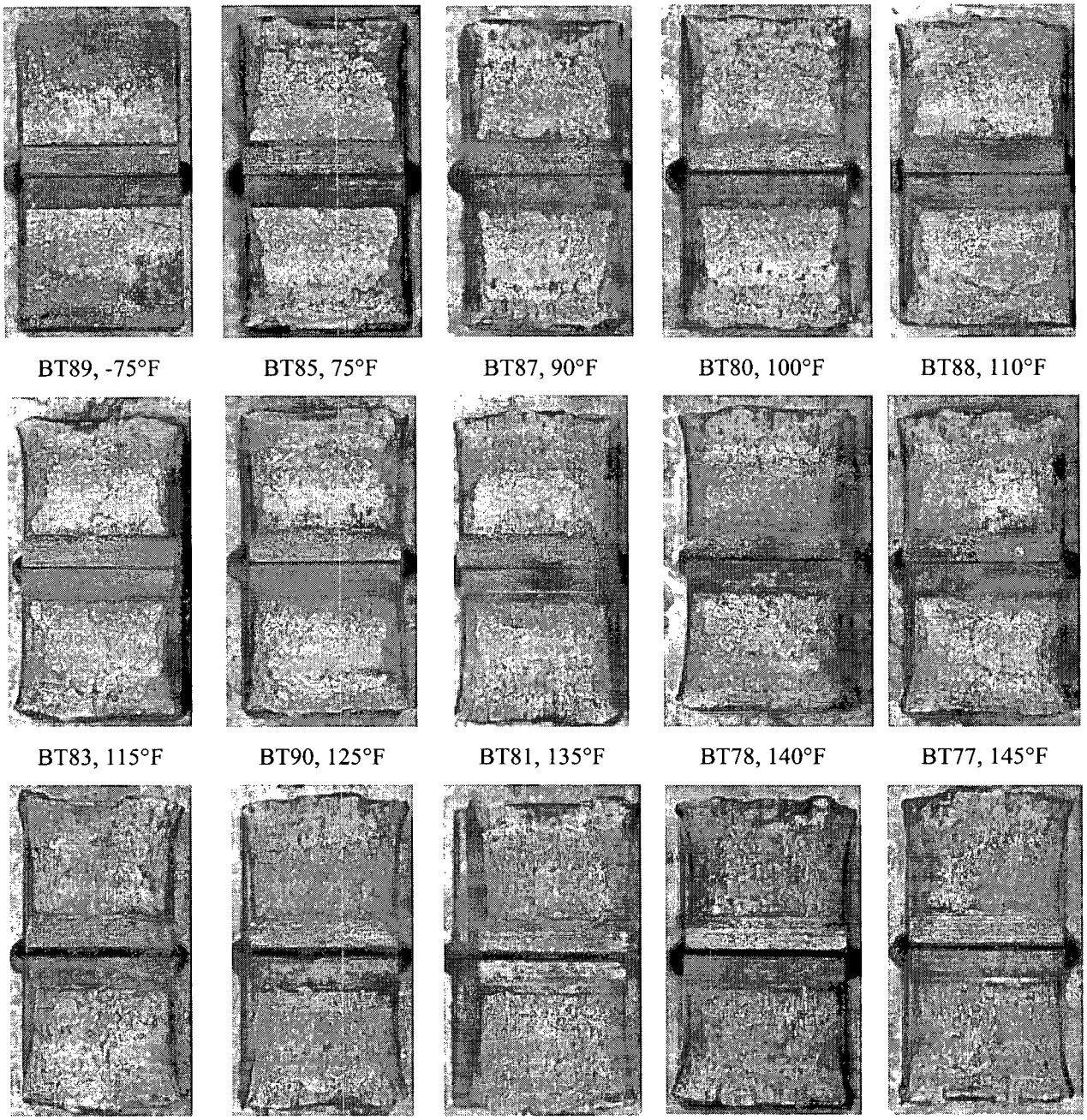


Figure 5-14 Charpy Impact Specimen Fracture Surfaces for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Transverse Orientation)

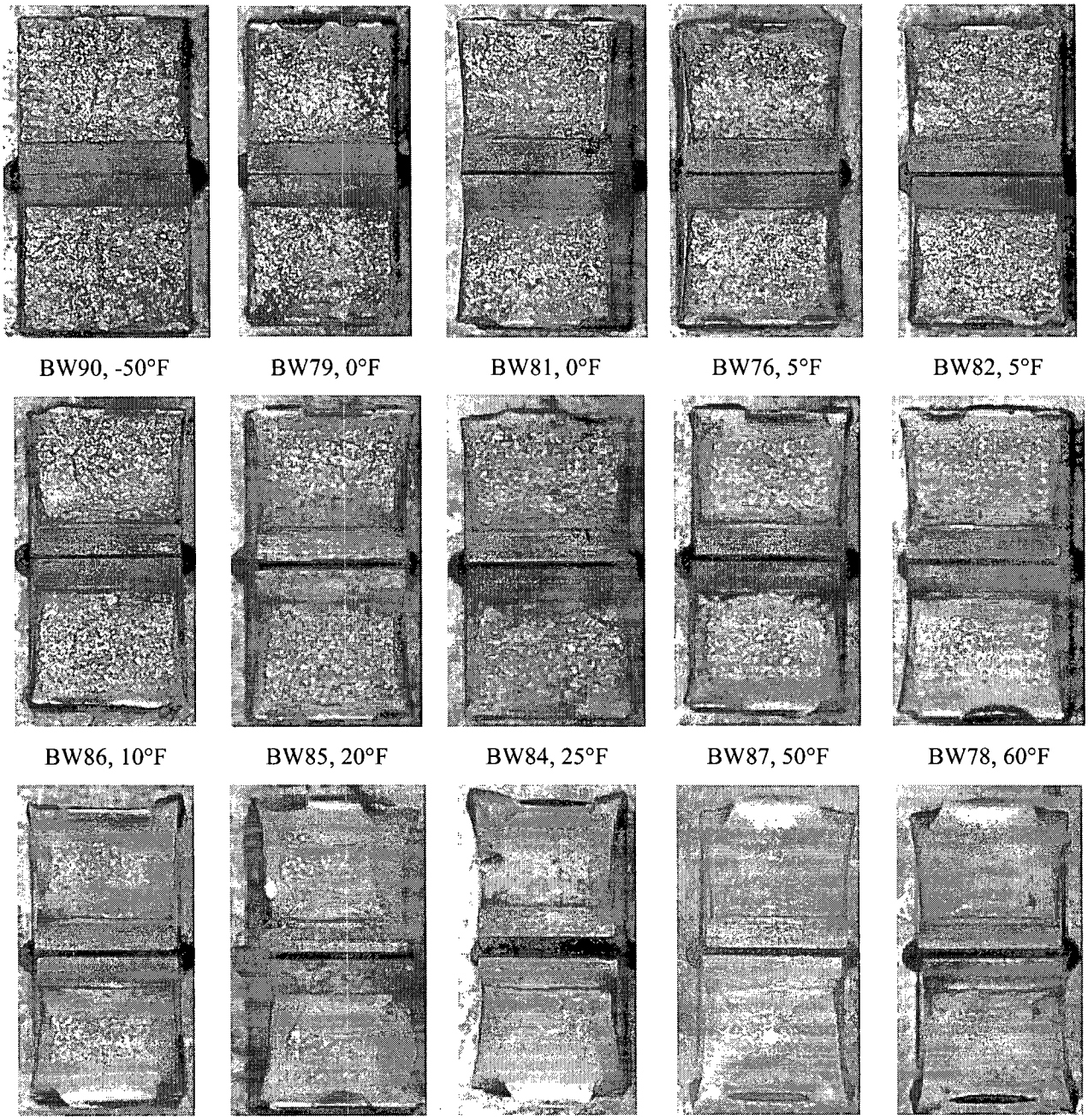


Figure 5-15 Charpy Impact Specimen Fracture Surfaces for the Vogtle Unit 2 Reactor Vessel Surveillance Program Weld Metal

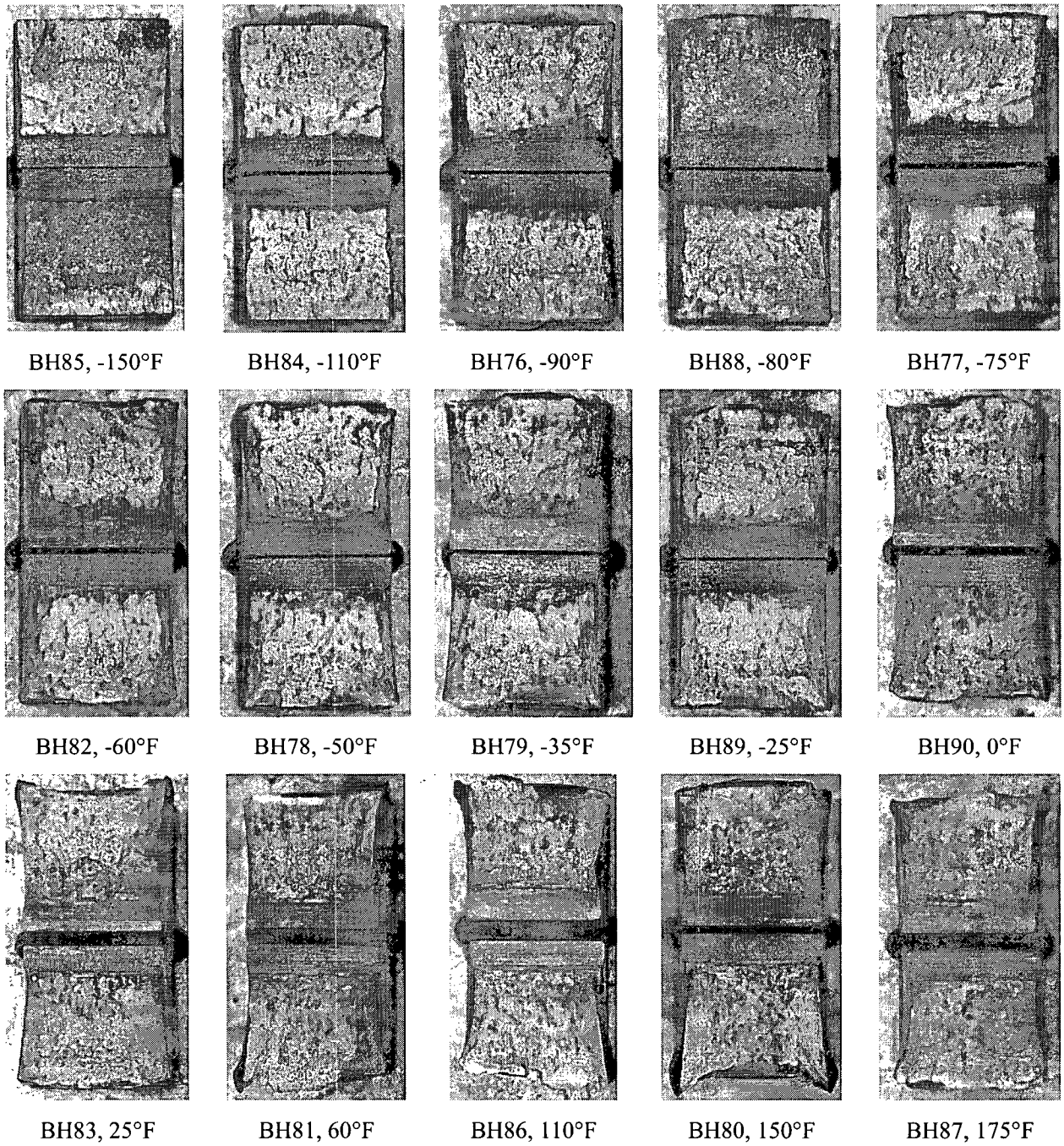
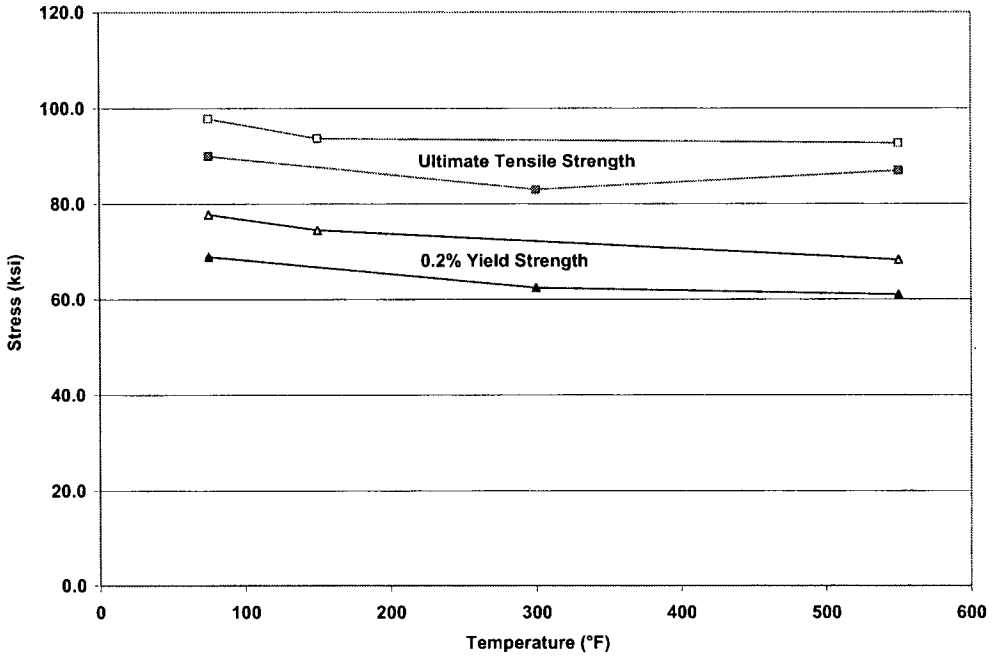


Figure 5-16 Charpy Impact Specimen Fracture Surfaces for the Vogtle Unit 2 Reactor Vessel Heat-Affected Zone Material



Legend: ▲ and ● and ■ are unirradiated
Δ and ○ and □ are irradiated to 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV)

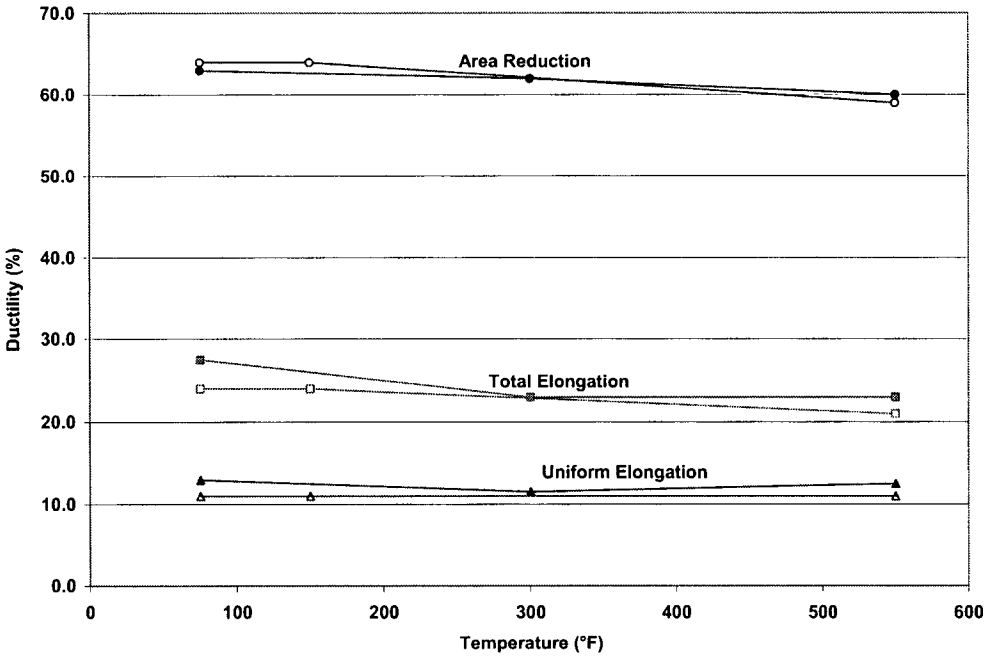
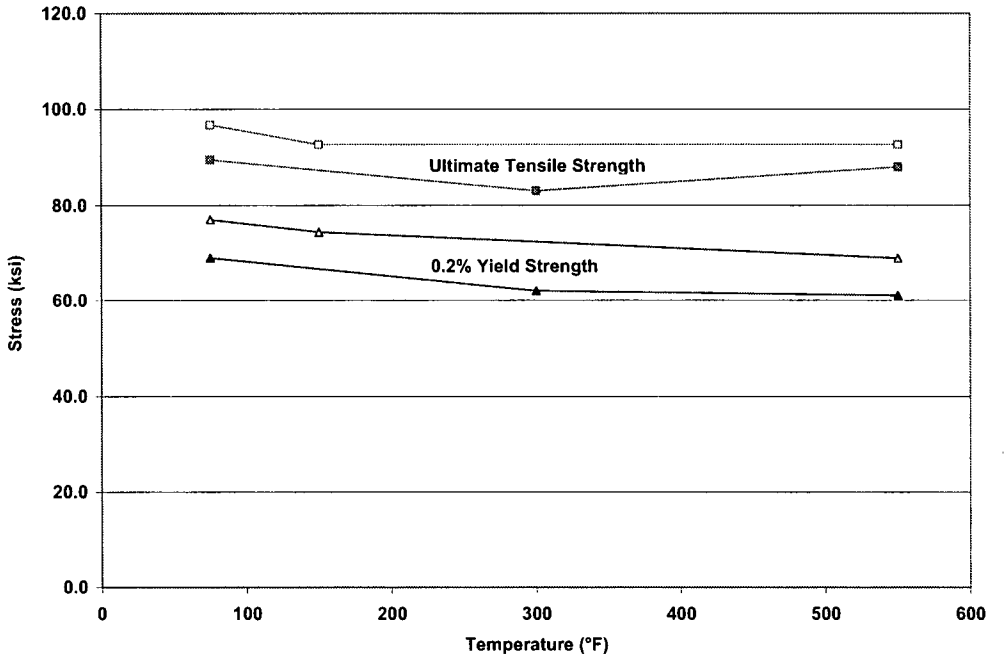


Figure 5-17 Tensile Properties for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Longitudinal Orientation)



Legend: ▲ and ● and ■ are unirradiated
Δ and ○ and □ are irradiated to 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV)

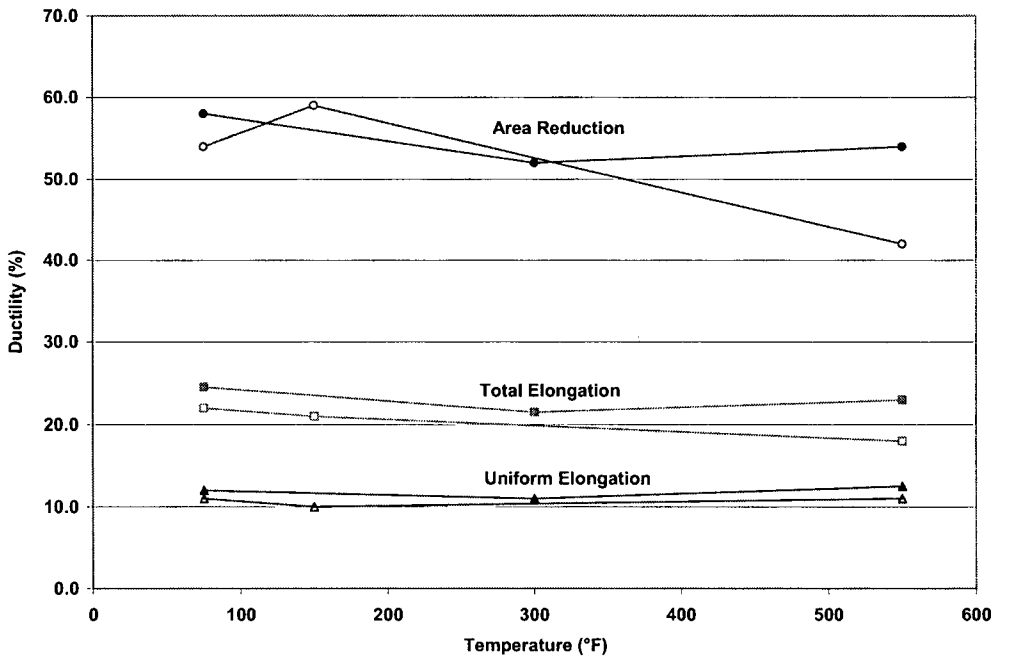
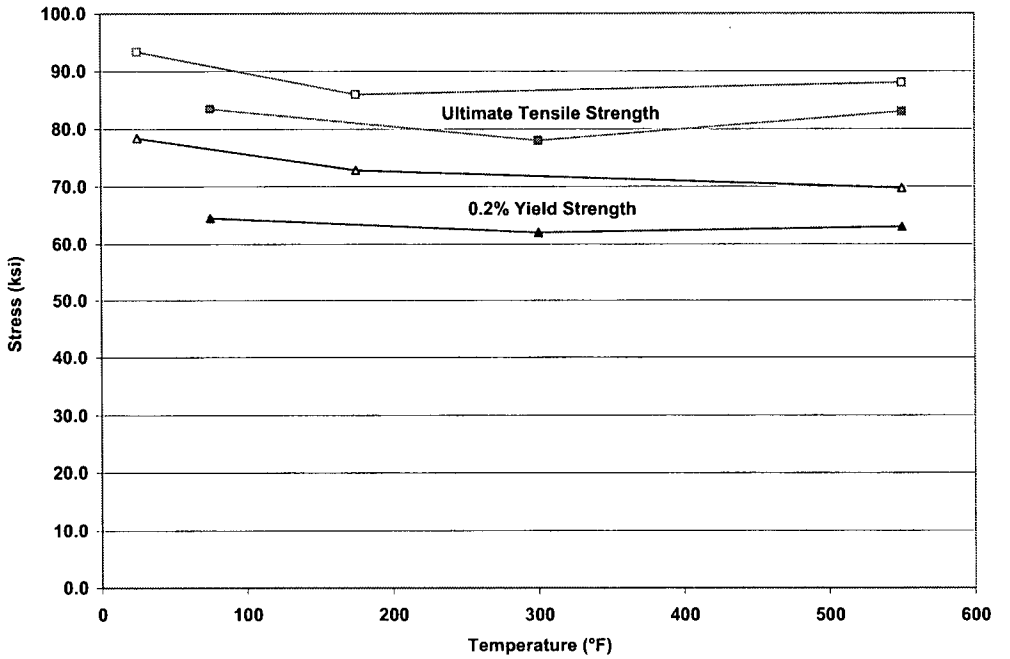


Figure 5-18 Tensile Properties for Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Transverse Orientation)



Legend: ▲ and ● and ■ are unirradiated
Δ and ○ and □ are irradiated to 4.16 x 10^{19} n/cm^2 (E > 1.0 MeV)

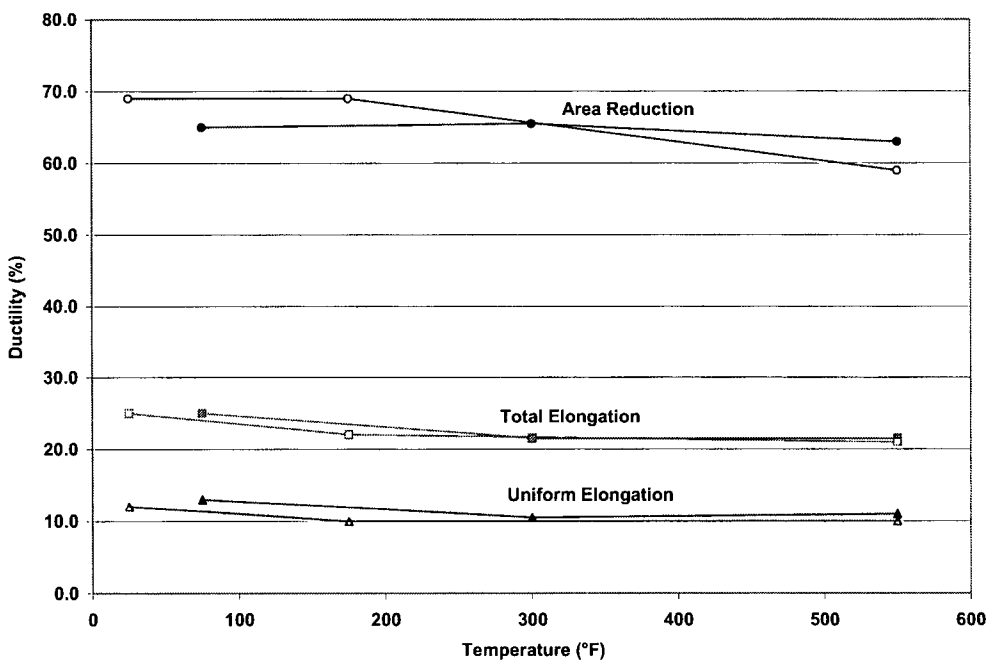
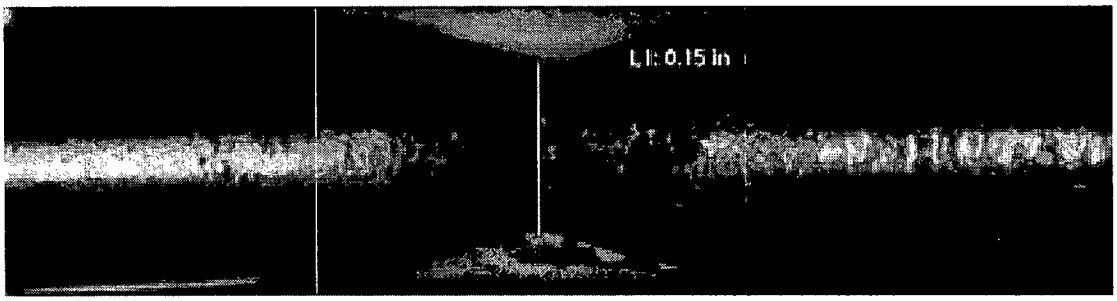
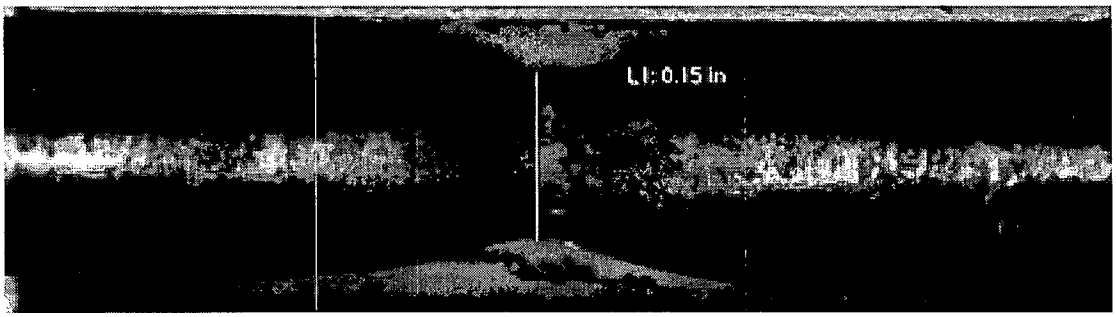


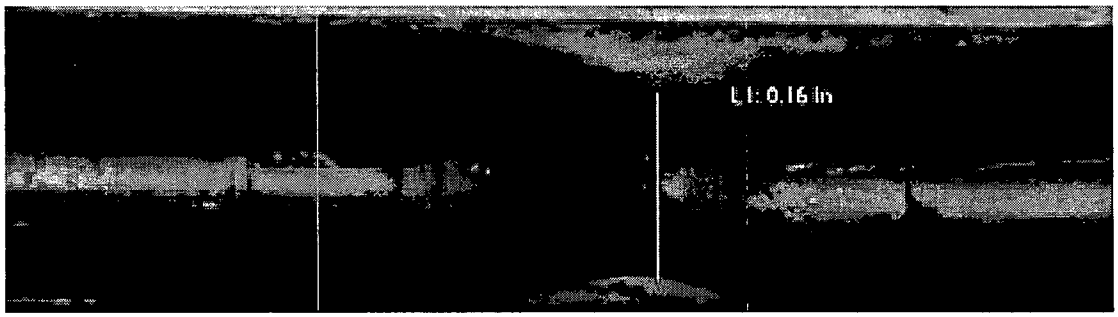
Figure 5-19 Tensile Properties for the Vogtle Unit 2 Reactor Vessel Surveillance Program Weld Metal



Specimen BL16 - Tested at 75°F

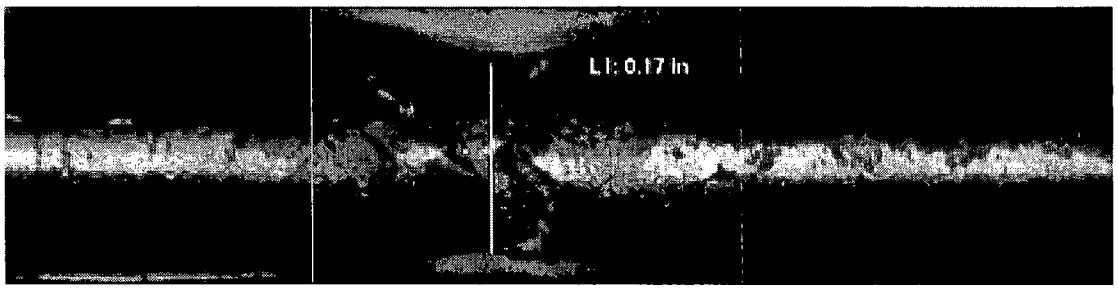


Specimen BL17 - Tested at 150°F



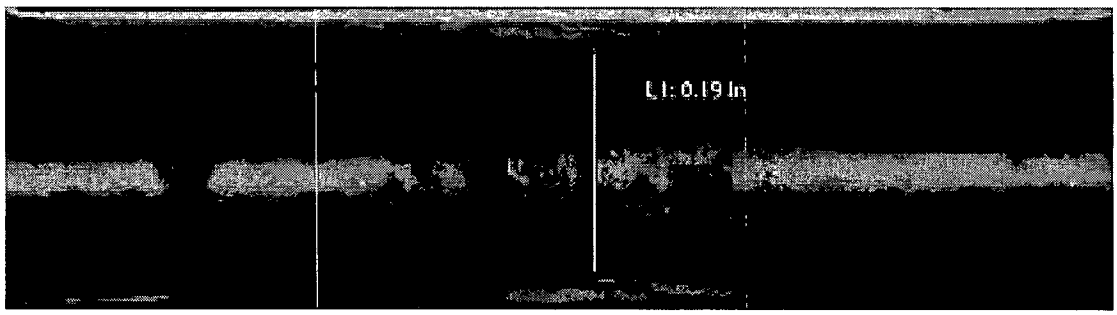
Specimen BL18 - Tested at 550°F

Figure 5-20 Fractured Tensile Specimens from Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Longitudinal Orientation)



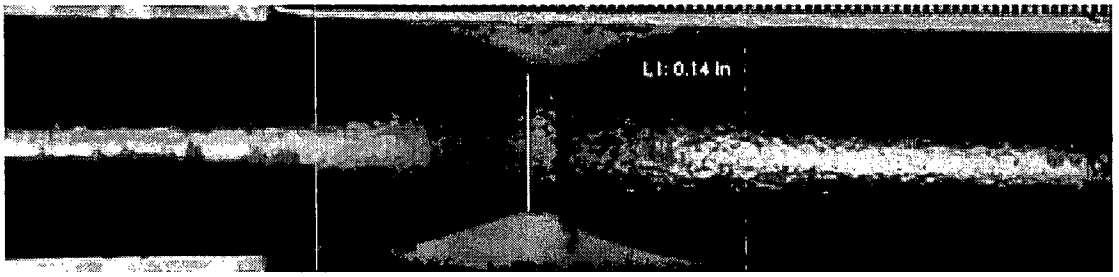
Specimen BT16 - Tested at 75°F

Specimen BT17 - Tested at 150°F

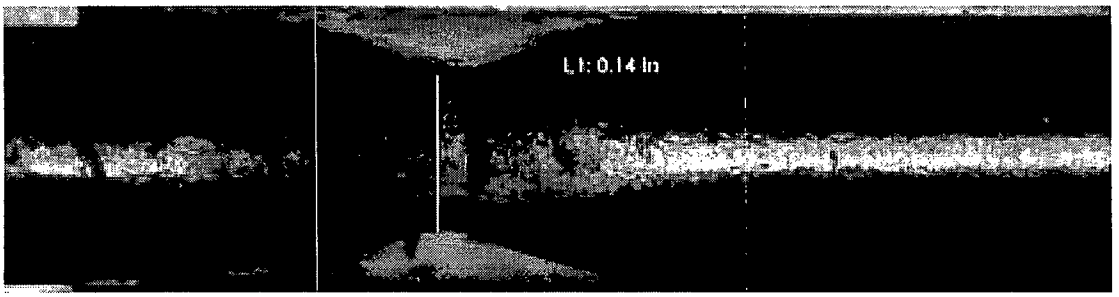


Specimen BT18 - Tested at 550°F

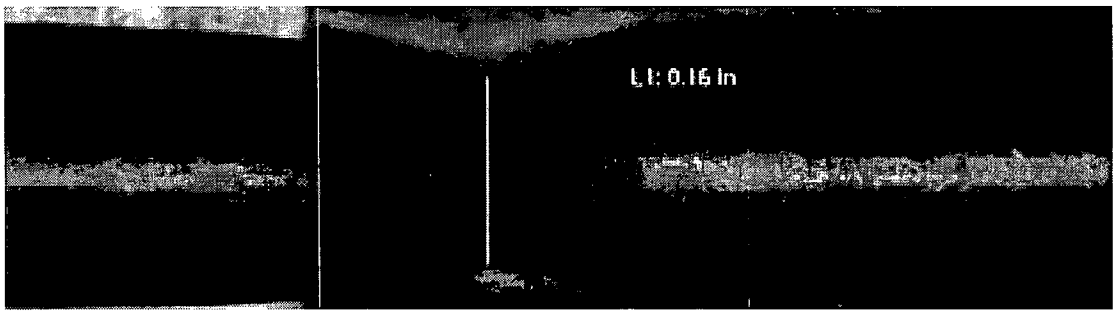
Figure 5-21 Fractured Tensile Specimens from Vogtle Unit 2 Reactor Vessel Lower Shell Plate B8628-1 (Transverse Orientation)



Specimen BW16 - Tested at 25°F

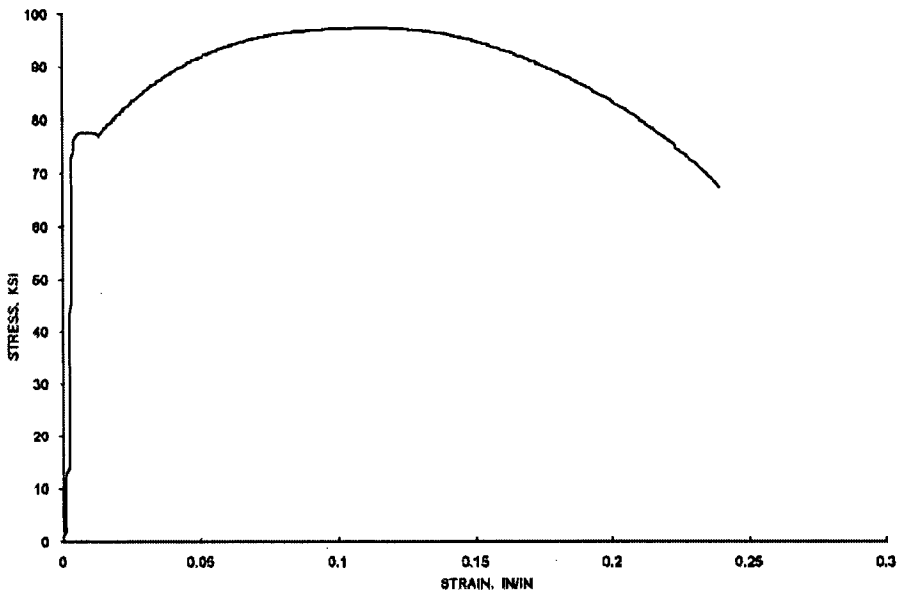


Specimen BW17 - Tested at 175°F



Specimen BW18 - Tested at 550°F

Figure 5-22 Fractured Tensile Specimens from the Vogtle Unit 2 Reactor Vessel Surveillance Program Weld Metal



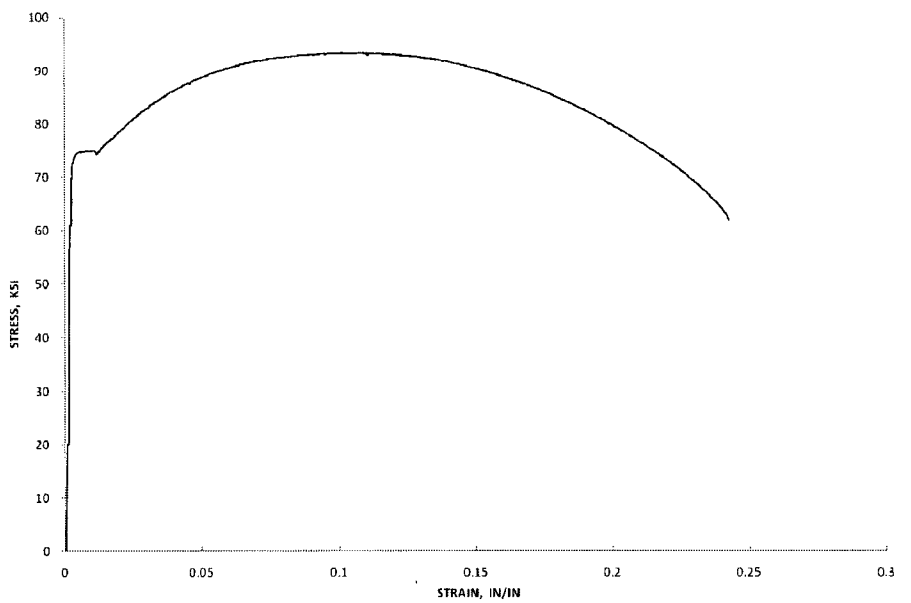


Figure 5-23 Engineering Stress-Strain Curves for Vogtle Unit 2 Lower Shell Plate B8628-1 Tensile Specimens BL16 and BL17 (Longitudinal Orientation)

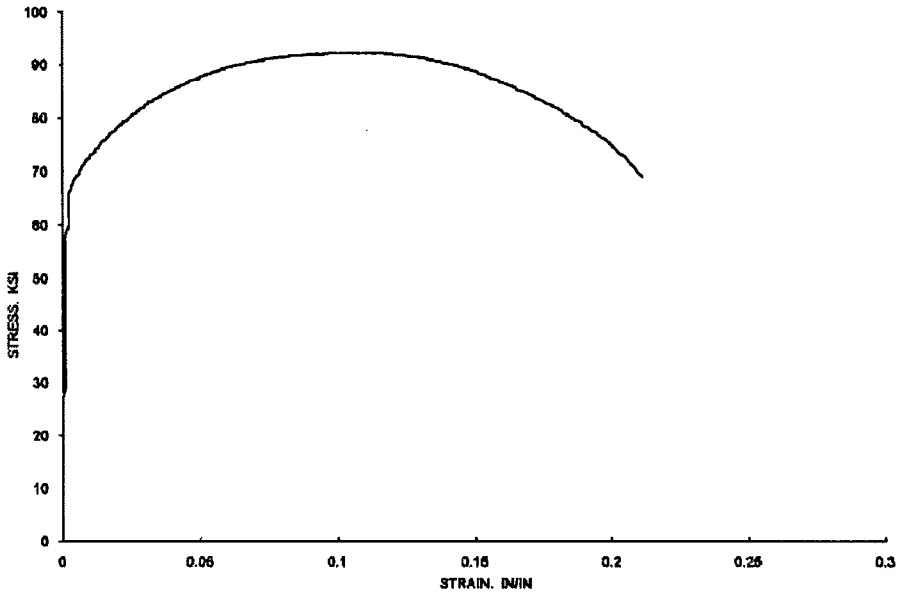


Figure 5-24 Engineering Stress-Strain Curve for Vogtle Unit 2 Lower Shell Plate B8628-1 Tensile Specimen BL18 (Longitudinal Orientation)

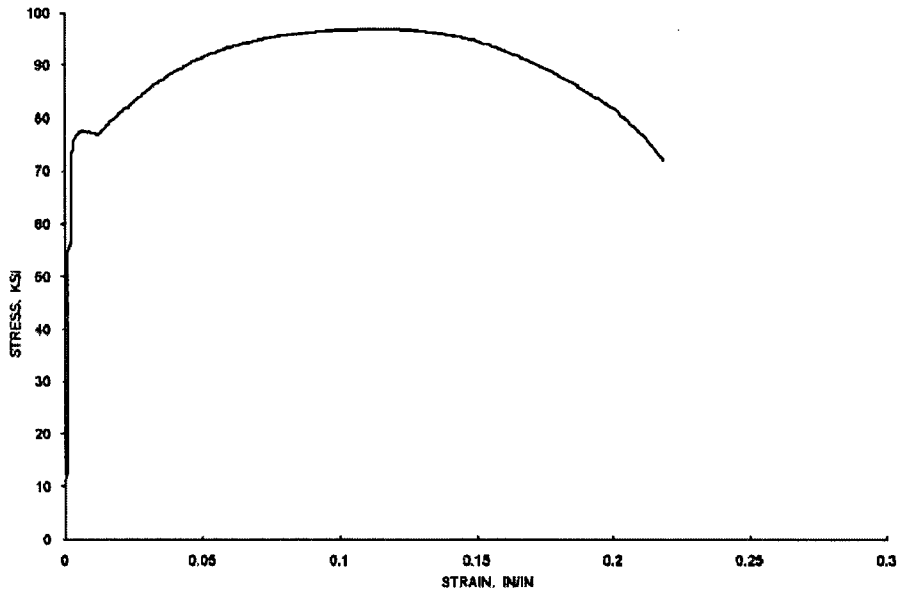
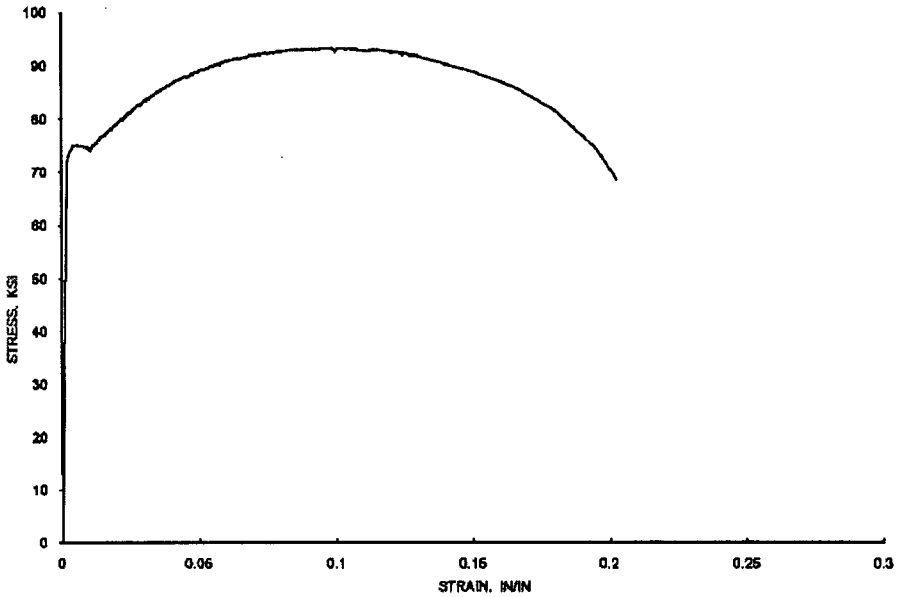


Figure 5-25 Engineering Stress-Strain Curve for Vogtle Unit 2 Lower Shell Plate B8628-1 Tensile Specimen BT16 (Transverse Orientation)



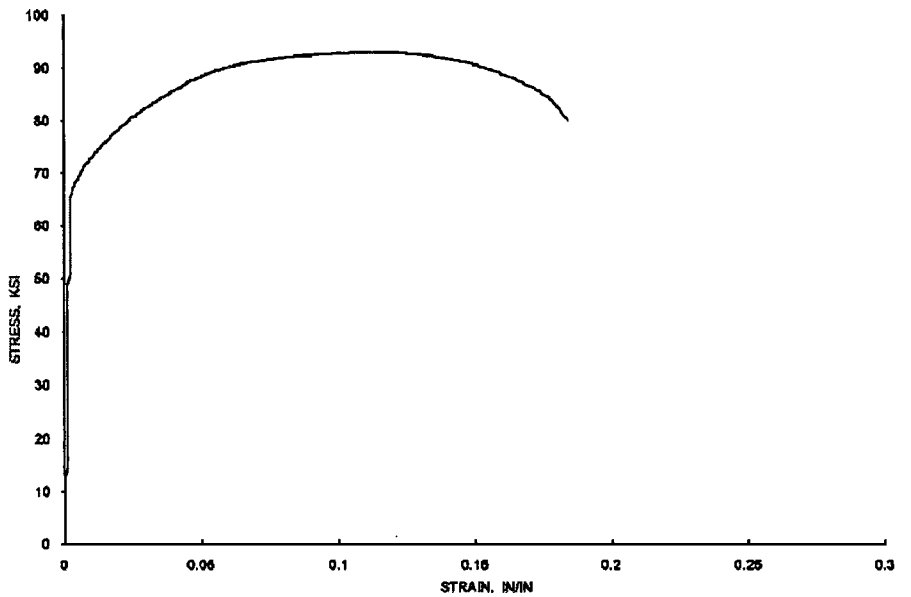
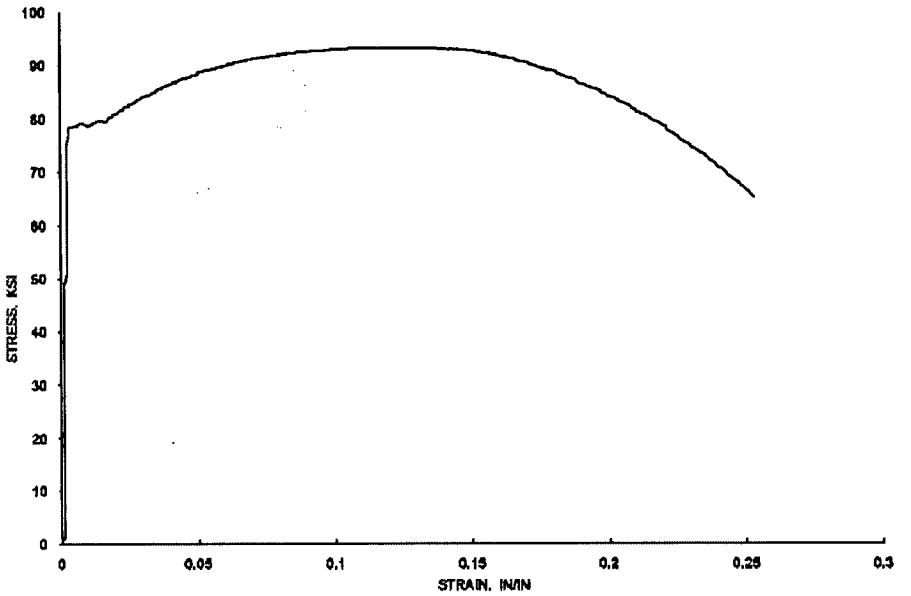


Figure 5-26 Engineering Stress-Strain Curves for Vogtle Unit 2 Lower Shell Plate B8628-1 Tensile Specimens BT17 and BT18 (Transverse Orientation)



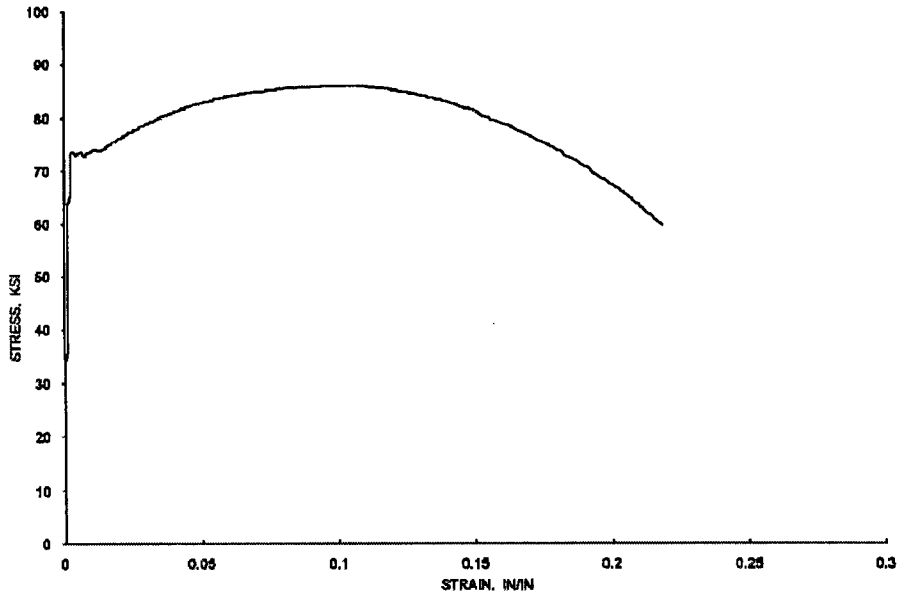


Figure 5-27 Engineering Stress-Strain Curves for Vogtle Unit 2 Surveillance Program Weld Metal Tensile Specimens BW16 and BW17

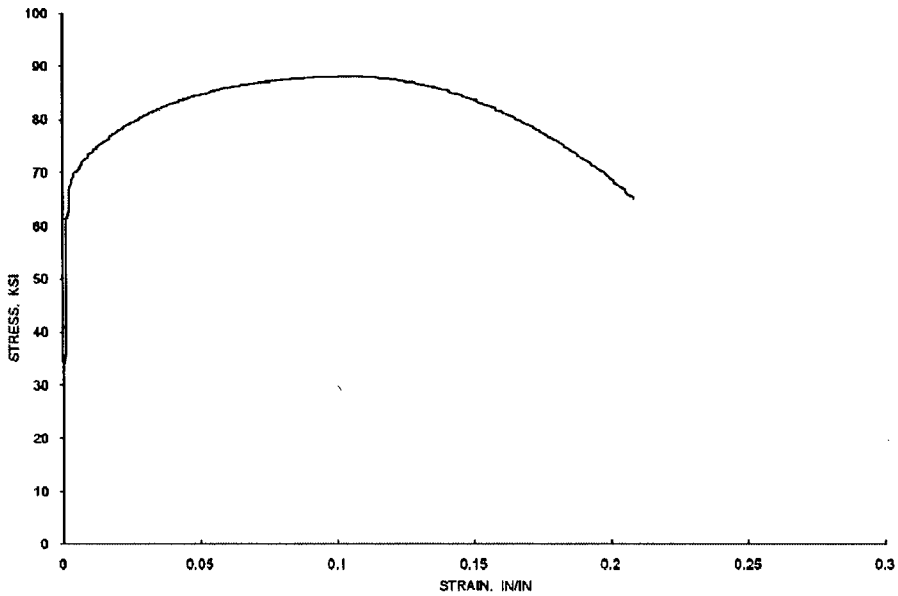


Figure 5-28 Engineering Stress-Strain Curve for Vogtle Unit 2 Surveillance Program Weld Metal Tensile Specimen BW18

6 RADIATION ANALYSIS AND NEUTRON DOSIMETRY

6.1 INTRODUCTION

This section describes a discrete ordinates S_n transport analysis performed for the Vogtle Unit 2 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 Z, withdrawn at the end of the fourteenth plant operating cycle, is provided. In addition, to provide an up-to-date data base applicable to the Vogtle Unit 2 reactor, the sensor sets from the previously withdrawn capsules (U, Y, X, and W) are 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 60 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," [Ref. 18] 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" [Ref. 19]. 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" [Ref. 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" [Ref. 20]. 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 [Ref. 21].

6.2 DISCRETE ORDINATES ANALYSIS

The arrangement of the surveillance capsules in the Vogtle Unit 2 reactor vessel is shown in Figure 4-1. Six irradiation capsules attached to the neutron pad are included in the reactor design that constitutes the reactor vessel surveillance program. The capsules are located at azimuthal angles of 58.5°, 61.0°, 121.5°, 238.5°, 241.0°, and 301.5° as shown in Figure 4-1. These full-core positions correspond to the following octant symmetric locations represented in Figures 6-2 and 6-3: 29° from the core cardinal axes (for the 61.0° and 241.0° dual surveillance capsule holder locations found in octants with a 22.5° neutron pad segment) and 31.5° from the core cardinal axes (for the 121.5° and 301.5° single surveillance capsule holder locations found in octants with a 20.0° neutron pad segment, and for the 58.5° and the 238.5° dual surveillance capsule holder locations found in octants with a 22.5° neutron pad segment). The stainless steel specimen containers are 1.182-inch by 1-inch and are approximately 56 inches in height. The containers are positioned axially such that the test specimens are centered on the core midplane, thus spanning the central 5 feet of the 12-foot-high reactor 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 Vogtle Unit 2 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:

$$\varphi(r,\theta,z) = \varphi(r,\theta) * \frac{\varphi(r,z)}{\varphi(r)} \qquad \text{(Eqn. 6-1)}$$

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 Vogtle Unit 2.

For the Vogtle Unit 2 transport calculations, the r,θ models depicted in Figures 6-1 through 6-3 were utilized since, with the exception of the neutron pads, the reactor is octant symmetric. These r,θ models include the core, the reactor internals, the neutron pads – including explicit representations of an octant not containing surveillance capsules and octants with surveillance capsules at 29.0° and 31.5°, the pressure vessel cladding and vessel wall, the insulation external to the pressure vessel, and the primary biological shield wall. These models 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 models consisted of 183 radial by 99 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 Vogtle Unit 2 calculations is shown in Figure 6-4 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 below the lower core plate to above the upper core plate. 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 these reactor models consisted of 153 radial by 188 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 model used in the synthesis procedure consisted of the same 153 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 fifteen fuel cycles at Vogtle Unit 2. 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 [Ref. 22] and the BUGLE-96 cross-section library [Ref. 23]. 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 exposure rates and integrated exposures, expressed in terms of both neutron fluence (E > 1.0 MeV) and dpa, are given at the radial and azimuthal center of the octant symmetric surveillance capsule positions, i.e., for the 29.0° dual capsule, 31.5° dual capsule, and 31.5° single capsule. 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 fourteenth fuel cycle (i.e., after 18.48 EFPY of plant operation) was 1.00×10^{19} n/cm^2 at the 45° azimuthal location. This peak clad/base metal interface vessel fluence of 1.00×10^{19} n/cm^2 was also reported in the Vogtle Unit 2 Cycle 14 ex-vessel neutron dosimetry analysis report [Ref. 24].

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 fourteenth fuel cycle as well as future projections to 19.94, 24, 28, 32, 36, 40, 44, 48, 54, and 60 EFPY. The calculations account for uprates from 3411 MWt to 3565 MWt that occurred at the onset of Cycle 4 and from 3565 MWt to 3626 MWt that occurred at the onset of Cycle 14. The projections were based on the assumption that the core power distributions and associated plant operating characteristics from Cycle 15 were representative of future plant operation. The future projections are also based on the current reactor power level of 3626 MWt.

Radial gradient information applicable to fast (E > 1.0 MeV) neutron fluence and dpa are given in Tables 6-3 and 6-4, respectively. The data, based on the cumulative integrated exposures from Cycles 1 through 14, 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 6-3 and 6-4.

The calculated fast neutron exposures for the five surveillance capsules withdrawn from the Vogtle Unit 2 reactor are provided in Table 6-5. These assigned neutron exposure levels are based on the plant- and fuel-cycle-specific neutron transport calculations performed for the Vogtle Unit 2 reactor.

From the data provided in Table 6-5, Capsule Z received a fluence (E > 1.0 MeV) of 4.16×10^{19} n/cm^2 after exposure through the end of the fourteenth fuel cycle (i.e., after 18.48 EFPY of plant operation).

Updated lead factors for the Vogtle Unit 2 surveillance capsules are provided in Table 6-6. 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 6-6, the lead factors for capsules that have been withdrawn from the reactor (U, Y, X, W, and Z) were based on the calculated fluence values for the irradiation period corresponding to the time of withdrawal for the individual capsules. The lead factor for Capsule V, which was withdrawn at the end of Cycle 14 and stored in the spent fuel pool, corresponds to the calculated fluence values at the end of Cycle 14, the last completed fuel cycle for Vogtle Unit 2.

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 serve 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 Z, that was withdrawn from Vogtle Unit 2 at the end of the fourteenth fuel cycle, is summarized below.

Reaction[a]	Reaction Rates (rps/atom)		M/C Ratio
	Measured	Calculated	
$^{63}Cu(n,\alpha)^{60}Co$	4.00E-17	3.96E-17	1.01
$^{54}Fe(n,p)^{54}Mn$	4.26E-15	4.30E-15	0.99
$^{58}Ni(n,p)^{58}Co$	5.75E-15	6.01E-15	0.96
$^{238}U(n,f)^{137}Cs$ (Cd)	1.81E-14	2.28E-14	0.80
$^{237}Np(n,f)^{137}Cs$ (Cd)	1.99E-13	2.21E-13	0.90
		Average:	0.93
		% Standard Deviation:	9.1

Note:
(a) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

The measured-to-calculated (M/C) reaction rate ratios for the Capsule Z threshold reactions range from 0.80 to 1.01, and the average M/C ratio is 0.93 ± 9.1% (1σ). This direct comparison falls well within the ± 20% criterion specified in Regulatory Guide 1.190; furthermore, it is consistent with the full set of comparisons given in Appendix A for all measured dosimetry removed to date from the Vogtle Unit 2 reactor. These comparisons validate the current analytical results described in Section 6.2; therefore, the calculations are deemed applicable for Vogtle Unit 2.

6.4 CALCULATIONAL UNCERTAINTIES

The uncertainty associated with the calculated neutron exposure of the Vogtle Unit 2 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 Vogtle Unit 2 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 Vogtle Unit 2 analysis was established from results of these three phases of the methods qualification.

The fourth phase of the uncertainty assessment (comparisons with Vogtle Unit 2 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 Vogtle Unit 2 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 Reference 21.

Description	Uncertainty	
	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 plant-specific measurement comparisons described in Appendix A support these uncertainty assessments for Vogtle Unit 2.

Table 6-1 Calculated Neutron Exposure Rates and Integrated Exposures at the Surveillance Capsule Center[(a)]

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Neutron Flux (E > 1.0 MeV) [n/cm²-s]		
				Dual 29.0°	Dual 31.5°	Single 31.5°
1	3.78E+07	3.78E+07	1.20	8.78E+10	9.43E+10	9.34E+10
2	3.86E+07	7.64E+07	2.42	7.30E+10	7.97E+10	7.89E+10
3	4.13E+07	1.18E+08	3.73	6.32E+10	6.82E+10	6.75E+10
4	3.96E+07	1.57E+08	4.98	6.08E+10	6.63E+10	6.57E+10
5	4.47E+07	2.02E+08	6.40	5.63E+10	6.17E+10	6.11E+10
6	4.35E+07	2.45E+08	7.78	6.27E+10	6.79E+10	6.73E+10
7	4.38E+07	2.89E+08	9.17	6.52E+10	7.08E+10	7.01E+10
8	4.43E+07	3.34E+08	10.57	6.53E+10	7.24E+10	7.17E+10
9	4.46E+07	3.78E+08	11.98	6.52E+10	6.95E+10	6.88E+10
10	4.11E+07	4.19E+08	13.29	6.41E+10	7.10E+10	7.04E+10
11	3.99E+07	4.59E+08	14.55	6.60E+10	7.06E+10	6.99E+10
12	3.97E+07	4.99E+08	15.81	6.65E+10	7.41E+10	7.35E+10
13	4.23E+07	5.41E+08	17.15	6.39E+10	7.15E+10	7.09E+10
14	4.20E+07	5.83E+08	18.48	6.66E+10	7.25E+10	7.18E+10
Future	4.60E+07	6.29E+08	19.94	6.86E+10	7.52E+10	7.45E+10
Future	1.28E+08	7.57E+08	24.00	6.86E+10	7.52E+10	7.45E+10
Future	1.26E+08	8.84E+08	28.00	6.86E+10	7.52E+10	7.45E+10
Future	1.26E+08	1.01E+09	32.00	6.86E+10	7.52E+10	7.45E+10
Future	1.26E+08	1.14E+09	36.00	6.86E+10	7.52E+10	7.45E+10
Future	1.26E+08	1.26E+09	40.00	6.86E+10	7.52E+10	7.45E+10
Future	1.26E+08	1.39E+09	44.00	6.86E+10	7.52E+10	7.45E+10
Future	1.26E+08	1.51E+09	48.00	6.86E+10	7.52E+10	7.45E+10
Future	1.89E+08	1.70E+09	54.00	6.86E+10	7.52E+10	7.45E+10
Future	1.89E+08	1.89E+09	60.00	6.86E+10	7.52E+10	7.45E+10

Note:

(a) Neutron exposure values reported for the surveillance capsules are centered at the core midplane.

Table 6-1 (Continued) Calculated Neutron Exposure Rates and Integrated Exposures at the Surveillance Capsule Center[(a)]

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Neutron Fluence (E > 1.0 MeV) [n/cm^2]		
				Dual 29.0°	Dual 31.5°	Single 31.5°
1	3.78E+07	3.78E+07	1.20	3.32E+18	3.56E+18	3.53E+18
2	3.86E+07	7.64E+07	2.42	6.14E+18	6.64E+18	6.58E+18
3	4.13E+07	1.18E+08	3.73	8.75E+18	9.45E+18	9.36E+18
4	3.96E+07	1.57E+08	4.98	1.12E+19	1.21E+19	1.20E+19
5	4.47E+07	2.02E+08	6.40	1.37E+19	1.48E+19	1.47E+19
6	4.35E+07	2.45E+08	7.78	1.64E+19	1.78E+19	1.76E+19
7	4.38E+07	2.89E+08	9.17	1.93E+19	2.09E+19	2.07E+19
8	4.43E+07	3.34E+08	10.57	2.22E+19	2.41E+19	2.39E+19
9	4.46E+07	3.78E+08	11.98	2.51E+19	2.72E+19	2.69E+19
10	4.11E+07	4.19E+08	13.29	2.77E+19	3.01E+19	2.98E+19
11	3.99E+07	4.59E+08	14.55	3.03E+19	3.29E+19	3.26E+19
12	3.97E+07	4.99E+08	15.81	3.30E+19	3.59E+19	3.56E+19
13	4.23E+07	5.41E+08	17.15	3.57E+19	3.89E+19	3.85E+19
14	4.20E+07	5.83E+08	18.48	3.85E+19	4.20E+19	4.16E+19
Future	4.60E+07	6.29E+08	19.94	4.16E+19	4.54E+19	4.50E+19
Future	1.28E+08	7.57E+08	24.00	5.04E+19	5.50E+19	5.45E+19
Future	1.26E+08	8.84E+08	28.00	5.91E+19	6.45E+19	6.39E+19
Future	1.26E+08	1.01E+09	32.00	6.77E+19	7.40E+19	7.33E+19
Future	1.26E+08	1.14E+09	36.00	7.64E+19	8.35E+19	8.28E+19
Future	1.26E+08	1.26E+09	40.00	8.51E+19	9.30E+19	9.22E+19
Future	1.26E+08	1.39E+09	44.00	9.37E+19	1.03E+20	1.02E+20
Future	1.26E+08	1.51E+09	48.00	1.02E+20	1.12E+20	1.11E+20
Future	1.89E+08	1.70E+09	54.00	1.15E+20	1.26E+20	1.25E+20
Future	1.89E+08	1.89E+09	60.00	1.28E+20	1.41E+20	1.39E+20

Note:

(a) Neutron exposure values reported for the surveillance capsules are centered at the core midplane.

Table 6-1 (Continued) Calculated Neutron Exposure Rates and Integrated Exposures at the Surveillance Capsule Center[a]

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Iron Atom Displacement Rate [dpa/s]		
				Dual 29.0°	Dual 31.5°	Single 31.5°
1	3.78E+07	3.78E+07	1.20	1.72E-10	1.84E-10	1.82E-10
2	3.86E+07	7.64E+07	2.42	1.42E-10	1.54E-10	1.53E-10
3	4.13E+07	1.18E+08	3.73	1.22E-10	1.32E-10	1.31E-10
4	3.96E+07	1.57E+08	4.98	1.18E-10	1.28E-10	1.27E-10
5	4.47E+07	2.02E+08	6.40	1.09E-10	1.19E-10	1.18E-10
6	4.35E+07	2.45E+08	7.78	1.22E-10	1.32E-10	1.30E-10
7	4.38E+07	2.89E+08	9.17	1.26E-10	1.37E-10	1.36E-10
8	4.43E+07	3.34E+08	10.57	1.27E-10	1.41E-10	1.39E-10
9	4.46E+07	3.78E+08	11.98	1.27E-10	1.35E-10	1.33E-10
10	4.11E+07	4.19E+08	13.29	1.24E-10	1.38E-10	1.37E-10
11	3.99E+07	4.59E+08	14.55	1.28E-10	1.37E-10	1.35E-10
12	3.97E+07	4.99E+08	15.81	1.29E-10	1.44E-10	1.42E-10
13	4.23E+07	5.41E+08	17.15	1.24E-10	1.39E-10	1.37E-10
14	4.20E+07	5.83E+08	18.48	1.29E-10	1.40E-10	1.39E-10
Future	4.60E+07	6.29E+08	19.94	1.33E-10	1.46E-10	1.44E-10
Future	1.28E+08	7.57E+08	24.00	1.33E-10	1.46E-10	1.44E-10
Future	1.26E+08	8.84E+08	28.00	1.33E-10	1.46E-10	1.44E-10
Future	1.26E+08	1.01E+09	32.00	1.33E-10	1.46E-10	1.44E-10
Future	1.26E+08	1.14E+09	36.00	1.33E-10	1.46E-10	1.44E-10
Future	1.26E+08	1.26E+09	40.00	1.33E-10	1.46E-10	1.44E-10
Future	1.26E+08	1.39E+09	44.00	1.33E-10	1.46E-10	1.44E-10
Future	1.26E+08	1.51E+09	48.00	1.33E-10	1.46E-10	1.44E-10
Future	1.89E+08	1.70E+09	54.00	1.33E-10	1.46E-10	1.44E-10
Future	1.89E+08	1.89E+09	60.00	1.33E-10	1.46E-10	1.44E-10

Note:

(a) Neutron exposure values reported for the surveillance capsules are centered at the core midplane.

Table 6-1 (Continued) Calculated Neutron Exposure Rates and Integrated Exposures at the Surveillance Capsule Center[a]

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Iron Atom Displacements [dpa]		
				Dual 29.0°	Dual 31.5°	Single 31.5°
1	3.78E+07	3.78E+07	1.20	6.49E-03	6.97E-03	6.89E-03
2	3.86E+07	7.64E+07	2.42	1.20E-02	1.29E-02	1.28E-02
3	4.13E+07	1.18E+08	3.73	1.70E-02	1.84E-02	1.82E-02
4	3.96E+07	1.57E+08	4.98	2.17E-02	2.35E-02	2.32E-02
5	4.47E+07	2.02E+08	6.40	2.66E-02	2.88E-02	2.85E-02
6	4.35E+07	2.45E+08	7.78	3.18E-02	3.45E-02	3.42E-02
7	4.38E+07	2.89E+08	9.17	3.74E-02	4.05E-02	4.01E-02
8	4.43E+07	3.34E+08	10.57	4.30E-02	4.67E-02	4.63E-02
9	4.46E+07	3.78E+08	11.98	4.86E-02	5.27E-02	5.22E-02
10	4.11E+07	4.19E+08	13.29	5.37E-02	5.84E-02	5.78E-02
11	3.99E+07	4.59E+08	14.55	5.88E-02	6.39E-02	6.32E-02
12	3.97E+07	4.99E+08	15.81	6.40E-02	6.96E-02	6.89E-02
13	4.23E+07	5.41E+08	17.15	6.92E-02	7.55E-02	7.47E-02
14	4.20E+07	5.83E+08	18.48	7.46E-02	8.13E-02	8.05E-02
Future	4.60E+07	6.29E+08	19.94	8.08E-02	8.80E-02	8.72E-02
Future	1.28E+08	7.57E+08	24.00	9.78E-02	1.07E-01	1.06E-01
Future	1.26E+08	8.84E+08	28.00	1.15E-01	1.25E-01	1.24E-01
Future	1.26E+08	1.01E+09	32.00	1.31E-01	1.44E-01	1.42E-01
Future	1.26E+08	1.14E+09	36.00	1.48E-01	1.62E-01	1.60E-01
Future	1.26E+08	1.26E+09	40.00	1.65E-01	1.80E-01	1.79E-01
Future	1.26E+08	1.39E+09	44.00	1.82E-01	1.99E-01	1.97E-01
Future	1.26E+08	1.51E+09	48.00	1.99E-01	2.17E-01	2.15E-01
Future	1.89E+08	1.70E+09	54.00	2.24E-01	2.45E-01	2.42E-01
Future	1.89E+08	1.89E+09	60.00	2.49E-01	2.72E-01	2.70E-01

Note:

(a) Neutron exposure values reported for the surveillance capsules are centered at the core midplane.

Table 6-2 Calculated Azimuthal Variation of Maximum Exposure Rates and Integrated Exposures at the Reactor Vessel Clad/Base Metal Interface

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Neutron Flux (E > 1.0 MeV) [n/cm²-s]			
				0°	15°	30°	45°
1	3.78E+07	3.78E+07	1.20	1.31E+10	1.94E+10	2.23E+10	2.30E+10
2	3.86E+07	7.64E+07	2.42	1.12E+10	1.53E+10	1.85E+10	1.78E+10
3	4.13E+07	1.18E+08	3.73	8.95E+09	1.36E+10	1.60E+10	1.60E+10
4	3.96E+07	1.57E+08	4.98	8.39E+09	1.24E+10	1.55E+10	1.58E+10
5	4.47E+07	2.02E+08	6.40	8.45E+09	1.23E+10	1.45E+10	1.47E+10
6	4.35E+07	2.45E+08	7.78	9.69E+09	1.39E+10	1.60E+10	1.62E+10
7	4.38E+07	2.89E+08	9.17	9.50E+09	1.42E+10	1.68E+10	1.70E+10
8	4.43E+07	3.34E+08	10.57	8.85E+09	1.35E+10	1.66E+10	1.84E+10
9	4.46E+07	3.78E+08	11.98	9.23E+09	1.40E+10	1.64E+10	1.62E+10
10	4.11E+07	4.19E+08	13.29	9.23E+09	1.34E+10	1.64E+10	1.78E+10
11	3.99E+07	4.59E+08	14.55	9.87E+09	1.47E+10	1.67E+10	1.65E+10
12	3.97E+07	4.99E+08	15.81	9.04E+09	1.27E+10	1.69E+10	1.78E+10
13	4.23E+07	5.41E+08	17.15	9.45E+09	1.35E+10	1.63E+10	1.81E+10
14	4.20E+07	5.83E+08	18.48	9.50E+09	1.36E+10	1.68E+10	1.72E+10
Future	4.60E+07	6.29E+08	19.94	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.28E+08	7.57E+08	24.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.26E+08	8.84E+08	28.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.26E+08	1.01E+09	32.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.26E+08	1.14E+09	36.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.26E+08	1.26E+09	40.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.26E+08	1.39E+09	44.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.26E+08	1.51E+09	48.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.89E+08	1.70E+09	54.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10
Future	1.89E+08	1.89E+09	60.00	9.25E+09	1.43E+10	1.73E+10	1.80E+10

Table 6-2 (Continued) Calculated Azimuthal Variation of Maximum Exposure Rates and Integrated Exposures at the Reactor Vessel Clad/Base Metal Interface

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Neutron Fluence (E > 1.0 MeV) [n/cm^2]			
				0°	15°	30°	45°
1	3.78E+07	3.78E+07	1.20	4.93E+17	7.31E+17	8.42E+17	8.69E+17
2	3.86E+07	7.64E+07	2.42	9.26E+17	1.32E+18	1.56E+18	1.56E+18
3	4.13E+07	1.18E+08	3.73	1.29E+18	1.87E+18	2.20E+18	2.20E+18
4	3.96E+07	1.57E+08	4.98	1.62E+18	2.36E+18	2.81E+18	2.83E+18
5	4.47E+07	2.02E+08	6.40	1.99E+18	2.91E+18	3.46E+18	3.48E+18
6	4.35E+07	2.45E+08	7.78	2.42E+18	3.52E+18	4.15E+18	4.19E+18
7	4.38E+07	2.89E+08	9.17	2.83E+18	4.14E+18	4.88E+18	4.93E+18
8	4.43E+07	3.34E+08	10.57	3.22E+18	4.74E+18	5.62E+18	5.74E+18
9	4.46E+07	3.78E+08	11.98	3.63E+18	5.36E+18	6.35E+18	6.46E+18
10	4.11E+07	4.19E+08	13.29	4.01E+18	5.91E+18	7.02E+18	7.20E+18
11	3.99E+07	4.59E+08	14.55	4.40E+18	6.49E+18	7.68E+18	7.85E+18
12	3.97E+07	4.99E+08	15.81	4.76E+18	6.99E+18	8.35E+18	8.55E+18
13	4.23E+07	5.41E+08	17.15	5.16E+18	7.56E+18	9.03E+18	9.31E+18
14	4.20E+07	5.83E+08	18.48	5.55E+18	8.12E+18	9.72E+18	1.00E+19
Future	4.60E+07	6.29E+08	19.94	5.97E+18	8.77E+18	1.05E+19	1.08E+19
Future	1.28E+08	7.57E+08	24.00	7.15E+18	1.06E+19	1.27E+19	1.32E+19
Future	1.26E+08	8.84E+08	28.00	8.32E+18	1.24E+19	1.49E+19	1.54E+19
Future	1.26E+08	1.01E+09	32.00	9.49E+18	1.42E+19	1.71E+19	1.77E+19
Future	1.26E+08	1.14E+09	36.00	1.07E+19	1.60E+19	1.93E+19	2.00E+19
Future	1.26E+08	1.26E+09	40.00	1.18E+19	1.78E+19	2.15E+19	2.22E+19
Future	1.26E+08	1.39E+09	44.00	1.30E+19	1.97E+19	2.37E+19	2.45E+19
Future	1.26E+08	1.51E+09	48.00	1.42E+19	2.15E+19	2.58E+19	2.68E+19
Future	1.89E+08	1.70E+09	54.00	1.59E+19	2.42E+19	2.91E+19	3.02E+19
Future	1.89E+08	1.89E+09	60.00	1.77E+19	2.69E+19	3.24E+19	3.36E+19

Table 6-2 (Continued) Calculated Azimuthal Variation of Maximum Exposure Rates and Integrated Exposures at the Reactor Vessel Clad/Base Metal Interface

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Iron Atom Displacement Rate [dpa/s]			
				0°	15°	30°	45°
1	3.78E+07	3.78E+07	1.20	2.03E-11	2.97E-11	3.43E-11	3.64E-11
2	3.86E+07	7.64E+07	2.42	1.74E-11	2.36E-11	2.85E-11	2.82E-11
3	4.13E+07	1.18E+08	3.73	1.39E-11	2.09E-11	2.47E-11	2.52E-11
4	3.96E+07	1.57E+08	4.98	1.31E-11	1.91E-11	2.39E-11	2.50E-11
5	4.47E+07	2.02E+08	6.40	1.31E-11	1.90E-11	2.23E-11	2.32E-11
6	4.35E+07	2.45E+08	7.78	1.51E-11	2.13E-11	2.47E-11	2.56E-11
7	4.38E+07	2.89E+08	9.17	1.48E-11	2.19E-11	2.59E-11	2.69E-11
8	4.43E+07	3.34E+08	10.57	1.38E-11	2.08E-11	2.56E-11	2.91E-11
9	4.46E+07	3.78E+08	11.98	1.44E-11	2.16E-11	2.52E-11	2.55E-11
10	4.11E+07	4.19E+08	13.29	1.44E-11	2.06E-11	2.53E-11	2.81E-11
11	3.99E+07	4.59E+08	14.55	1.54E-11	2.26E-11	2.57E-11	2.60E-11
12	3.97E+07	4.99E+08	15.81	1.41E-11	1.96E-11	2.61E-11	2.82E-11
13	4.23E+07	5.41E+08	17.15	1.47E-11	2.08E-11	2.52E-11	2.85E-11
14	4.20E+07	5.83E+08	18.48	1.48E-11	2.10E-11	2.59E-11	2.71E-11
Future	4.60E+07	6.29E+08	19.94	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.28E+08	7.57E+08	24.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.26E+08	8.84E+08	28.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.26E+08	1.01E+09	32.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.26E+08	1.14E+09	36.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.26E+08	1.26E+09	40.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.26E+08	1.39E+09	44.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.26E+08	1.51E+09	48.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.89E+08	1.70E+09	54.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11
Future	1.89E+08	1.89E+09	60.00	1.44E-11	2.21E-11	2.67E-11	2.85E-11

Table 6-2 (Continued) Calculated Azimuthal Variation of Maximum Exposure Rates and Integrated Exposures at the Reactor Vessel Clad/Base Metal Interface

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Iron Atom Displacements [dpa]			
				0°	15°	30°	45°
1	3.78E+07	3.78E+07	1.20	7.65E-04	1.12E-03	1.30E-03	1.37E-03
2	3.86E+07	7.64E+07	2.42	1.44E-03	2.04E-03	2.40E-03	2.46E-03
3	4.13E+07	1.18E+08	3.73	2.00E-03	2.88E-03	3.39E-03	3.48E-03
4	3.96E+07	1.57E+08	4.98	2.51E-03	3.64E-03	4.34E-03	4.47E-03
5	4.47E+07	2.02E+08	6.40	3.10E-03	4.48E-03	5.33E-03	5.50E-03
6	4.35E+07	2.45E+08	7.78	3.75E-03	5.41E-03	6.40E-03	6.61E-03
7	4.38E+07	2.89E+08	9.17	4.40E-03	6.37E-03	7.53E-03	7.79E-03
8	4.43E+07	3.34E+08	10.57	5.01E-03	7.29E-03	8.67E-03	9.07E-03
9	4.46E+07	3.78E+08	11.98	5.65E-03	8.25E-03	9.79E-03	1.02E-02
10	4.11E+07	4.19E+08	13.29	6.24E-03	9.10E-03	1.08E-02	1.14E-02
11	3.99E+07	4.59E+08	14.55	6.85E-03	9.99E-03	1.19E-02	1.24E-02
12	3.97E+07	4.99E+08	15.81	7.40E-03	1.08E-02	1.29E-02	1.35E-02
13	4.23E+07	5.41E+08	17.15	8.02E-03	1.16E-02	1.39E-02	1.47E-02
14	4.20E+07	5.83E+08	18.48	8.62E-03	1.25E-02	1.50E-02	1.58E-02
Future	4.60E+07	6.29E+08	19.94	9.28E-03	1.35E-02	1.62E-02	1.71E-02
Future	1.28E+08	7.57E+08	24.00	1.11E-02	1.63E-02	1.97E-02	2.08E-02
Future	1.26E+08	8.84E+08	28.00	1.29E-02	1.91E-02	2.30E-02	2.44E-02
Future	1.26E+08	1.01E+09	32.00	1.48E-02	2.19E-02	2.64E-02	2.79E-02
Future	1.26E+08	1.14E+09	36.00	1.66E-02	2.47E-02	2.98E-02	3.15E-02
Future	1.26E+08	1.26E+09	40.00	1.84E-02	2.75E-02	3.31E-02	3.51E-02
Future	1.26E+08	1.39E+09	44.00	2.02E-02	3.02E-02	3.65E-02	3.87E-02
Future	1.26E+08	1.51E+09	48.00	2.20E-02	3.30E-02	3.99E-02	4.23E-02
Future	1.89E+08	1.70E+09	54.00	2.48E-02	3.72E-02	4.49E-02	4.77E-02
Future	1.89E+08	1.89E+09	60.00	2.75E-02	4.14E-02	5.00E-02	5.31E-02

Table 6-3 Relative Radial Distribution of Neutron Fluence (E > 1.0 MeV) Within the Reactor Vessel Wall[a]

Radius (cm)	Relative Radial Distribution of Neutron Fluence Within the Vessel			
	0°	15°	30°	45°
220.11	1.000	1.000	1.000	1.000
225.59	0.571	0.566	0.561	0.558
231.06	0.282	0.277	0.272	0.269
236.54	0.134	0.130	0.127	0.125
242.01	0.064	0.059	0.057	0.056

Base Metal Inner Radius = 220.11 cm

Base Metal 1/4T = 225.59 cm

Base Metal 1/2T = 231.06 cm

Base Metal 3/4T = 236.54 cm

Base Metal Outer Radius = 242.01 cm

Note:

(a) Relative radial distribution data are based on the maximum cumulative integrated exposures from Cycles 1 through 14.

Table 6-4 Relative Radial Distribution of Iron Atom Displacements (dpa) Within the Reactor Vessel Wall[a]

Radius (cm)	Relative Radial Distribution of dpa Within the Vessel			
	0°	15°	30°	45°
220.11	1.000	1.000	1.000	1.000
225.59	0.642	0.637	0.635	0.644
231.06	0.389	0.381	0.381	0.392
236.54	0.236	0.226	0.227	0.234
242.01	0.141	0.127	0.127	0.130

Base Metal Inner Radius = 220.11 cm

Base Metal 1/4T = 225.59 cm

Base Metal 1/2T = 231.06 cm

Base Metal 3/4T = 236.54 cm

Base Metal Outer Radius = 242.01 cm

Note:

(a) Relative radial distribution data are based on the maximum cumulative integrated exposures from Cycles 1 through 14.

Table 6-5 Calculated Fast Neutron Exposure of Surveillance Capsules Withdrawn from Vogtle Unit 2

Capsule	Irradiation Time [EFPY]	Fluence (E > 1.0 MeV) [n/cm^2]	Iron Displacements [dpa]
U	1.20	3.56E+18	6.97E-03
Y	4.98	1.12E+19	2.17E-02
X	7.78	1.78E+19	3.45E-02
W	13.29	2.98E+19	5.78E-02
Z	18.48	4.16E+19	8.05E-02

Table 6-6 Calculated Surveillance Capsule Lead Factors

Capsule ID And Location	Status	Lead Factor
U (58.5°)	Withdrawn EOC 1	4.10
Y (241.0°)	Withdrawn EOC 4	3.95
X (238.5°)	Withdrawn EOC 6	4.25
W (121.5°)	Withdrawn EOC 10	4.14
Z (301.5°)	Withdrawn EOC 14	4.15
V (61.0°)	Withdrawn EOC 14 and Stored in Spent Fuel Pool	3.84

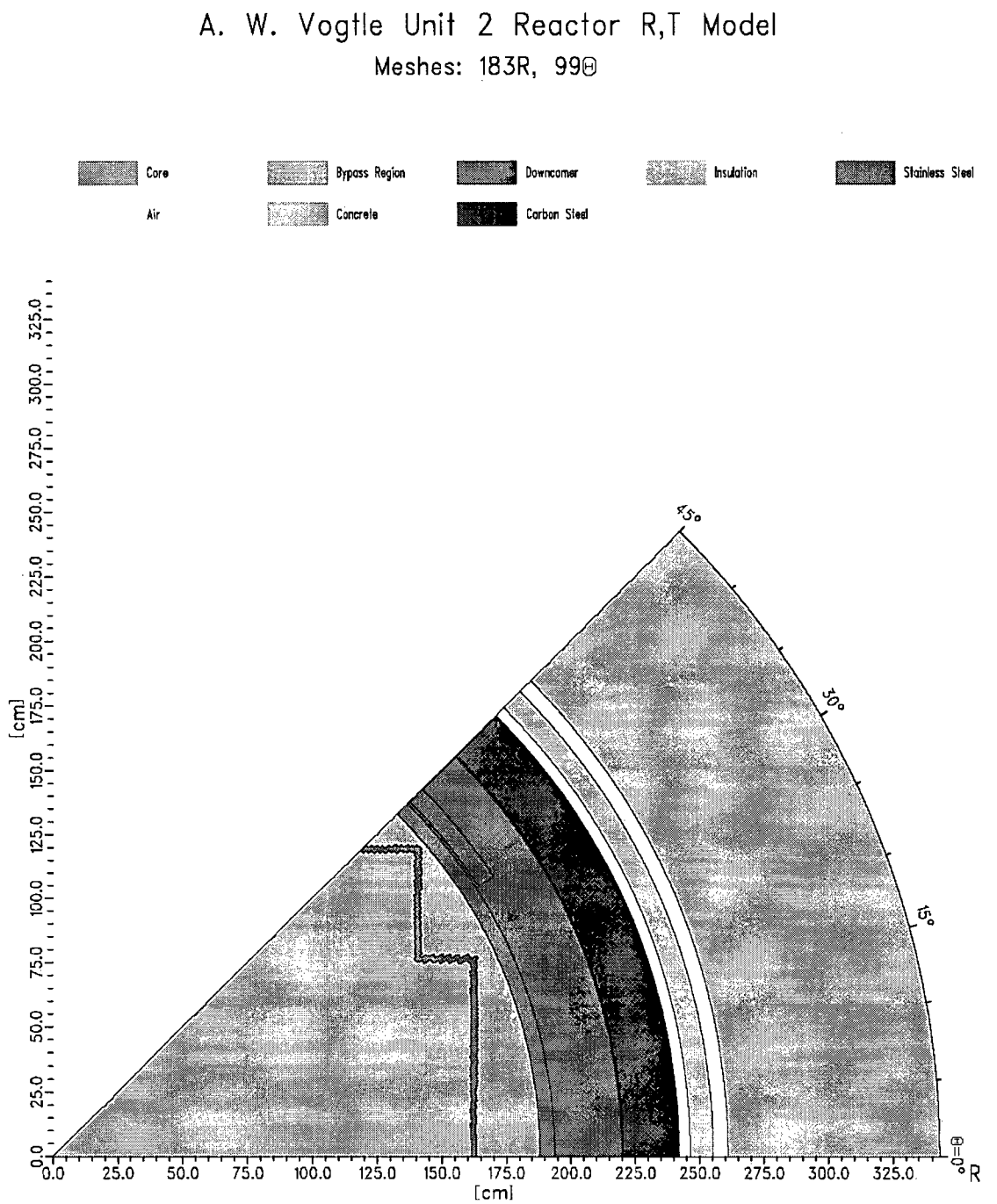


Figure 6-1 Vogtle Unit 2 r,θ Reactor Geometry with a 12.5° Neutron Pad Span at the Core Midplane

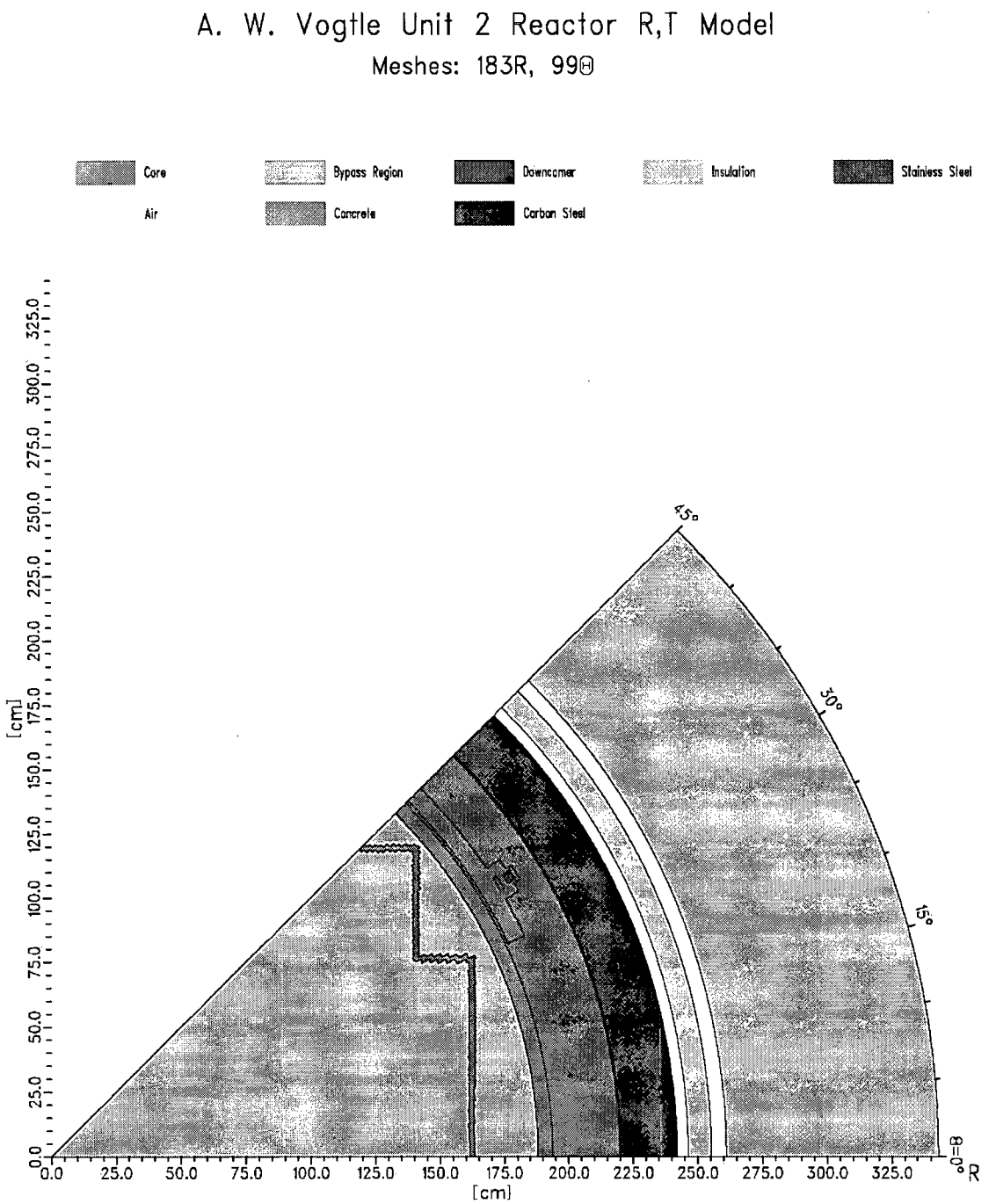


Figure 6-2 Vogtle Unit 2 r,θ Reactor Geometry with a 20.0° Neutron Pad Span at the Core Midplane

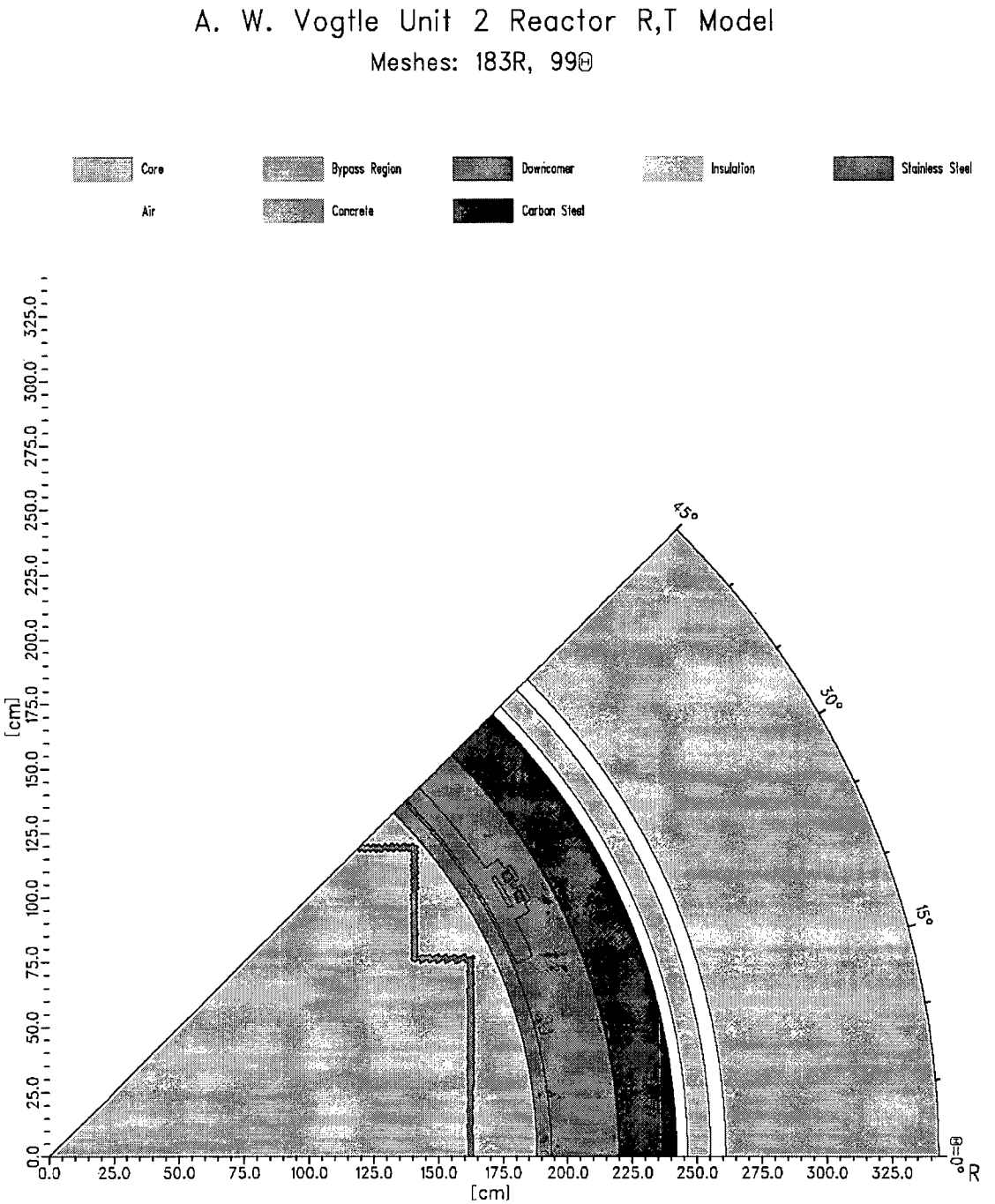


Figure 6-3 Vogtle Unit 2 r,θ Reactor Geometry with a 22.5° Neutron Pad Span at the Core Midplane

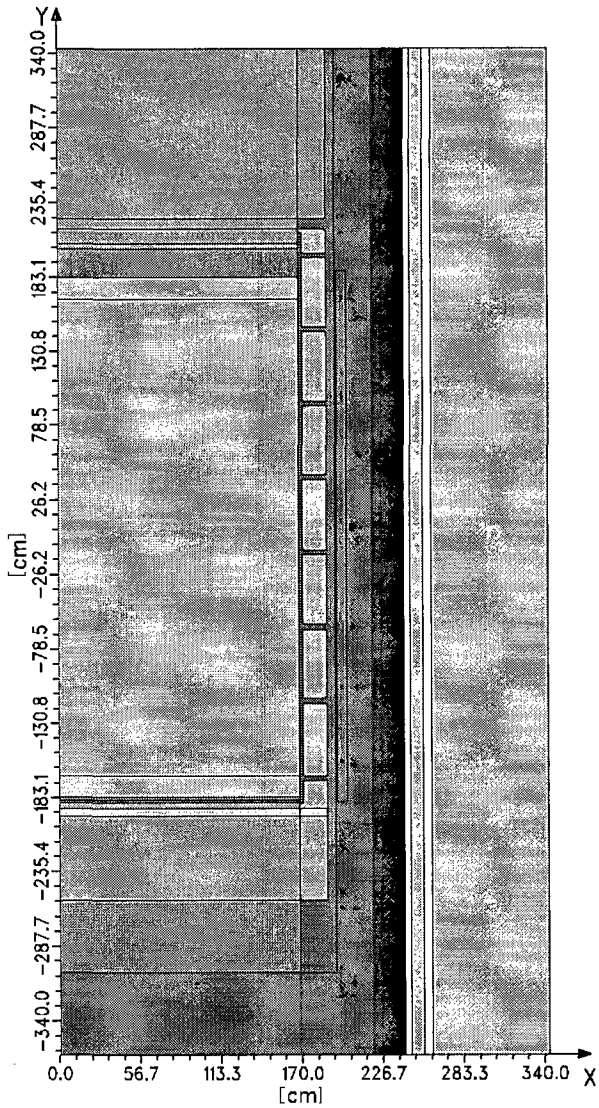


Figure 6-4 Vogtle Unit 2 r,z Reactor Geometry with Neutron Pad

7 SURVEILLANCE CAPSULE REMOVAL SCHEDULE

The following table summarizes the removal of the six surveillance capsules from the Vogtle Unit 2 reactor vessel, meeting the requirements of ASTM E185-82 [Ref. 4].

Table 7-1 Surveillance Capsule Withdrawal Summary

Capsule	Capsule Location	Lead Factor[a]	Withdrawal EFPY[b]	Fluence (n/cm^2)[c]
U	58.5°	4.10	1.20	0.356×10^{19}
Y	241°	3.95	4.98	1.12×10^{19}
X	238.5°	4.25	7.78	1.78×10^{19}
W	121.5°	4.14	13.29	2.98×10^{19}
Z	301.5°	4.15	18.48	4.16×10^{19}
V[d]	61°	3.84	18.48[d]	---

Notes:

(a) Updated in Capsule Z dosimetry analysis; see Table 6-6.

(b) EFPY from plant startup.

(c) Updated in Capsule Z dosimetry analysis; see Table 6-5.

(d) Standby Capsule V was removed and placed in the spent fuel pool. No testing or analysis has been performed on this capsule. Reinsertion of this capsule may be considered in the future, especially if Vogtle Unit 2 plans to pursue a 40-year license renewal (80 years). However, since the current regulations may change between now and then, it is recommended that the schedule for reinsertion and subsequent withdrawal of an 80-year license capsule be revisited at a later time.

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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 Vogtle Unit 2 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" [Ref. 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 Vogtle Unit 2 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]
U	31.5° Dual	End of Cycle 1	1.20
Y	29.0° Dual	End of Cycle 4	4.98
X	31.5° Dual	End of Cycle 6	7.78
W	31.5° Single	End of Cycle 10	13.29
Z	31.5° Single	End of Cycle 14	18.48

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 U, Y, X, W, and Z are summarized as follows:

Sensor Material	Reaction Of Interest	Capsule U	Capsule Y	Capsule X	Capsule W	Capsule Z
Copper	$^{63}Cu(n,\alpha)^{60}Co$	X	X	X	X	X
Iron	$^{54}Fe(n,p)^{54}Mn$	X	X	X	X	X
Nickel	$^{58}Ni(n,p)^{58}Co$	X	X	X	X	X
Uranium-238	$^{238}U(n,f)^{137}Cs$	X	X	X	X	X
Neptunium-237	$^{237}Np(n,f)\ ^{137}Cs$	X	X	X	X	X
Cobalt-Aluminum*	$^{59}Co(n,\gamma)^{60}Co$	X	X	X	X	X
*The cobalt-aluminum measurements for this plant include both bare wire and cadmium-covered sensors.						

Since all of the dosimetry monitors were located at the radial center of the material test specimen array, radial gradient corrections were not required 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 U, Y, X, and W are documented in References A-2 through A-5, respectively. The radiometric counting of the sensors from Capsule Z 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 U, Y, X, W, and Z was based on the monthly power generation of Vogtle Unit 2 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 applicable to Capsules U, Y, X, W, and Z is given in Table A-2.

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/g).
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 along with the computed values for C_j are listed in Table A-3. 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 Vogtle Unit 2 fission sensor reaction rates are summarized as follows:

Correction	Capsule U	Capsule Y	Capsule X	Capsule W	Capsule Z
^{235}U Impurity/Pu Build-in in ^{238}U	0.870	0.841	0.817	0.777	0.737
$^{238}U(\gamma,f)$	0.966	0.967	0.966	0.969	0.969
Net ^{238}U Correction	0.841	0.813	0.789	0.753	0.714
$^{237}Np(\gamma,f)$	0.990	0.990	0.990	0.991	0.991

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 Capsules U, Y, X, W, and Z are given in Table A-4. In Table A-4, 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 $\phi(E > 1.0\ \text{MeV})$ 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 Vogtle Unit 2 surveillance capsule dosimetry, the FERRET code [Ref. A-6] 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 Vogtle Unit 2 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 [Ref. A-7]. 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 E706 (IIB)" [Ref. A-8].

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 E944, "Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance" [Ref. A-9].

The following provides a summary of the uncertainties associated with the least squares evaluation of the Vogtle Unit 2 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 Vogtle Unit 2 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 Vogtle Unit 2 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 Vogtle Unit 2 surveillance capsules withdrawn to date are provided in Tables A-5 and A-6. In Table A-5, 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-6, 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-5 and A-6 show that the adjustments to the calculated spectra are relatively small and well 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-6, 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-5 and A-6) with calculations are given in Tables A-7 and A-8. These comparisons are given on two levels. In Table A-7, 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-8, calculations of fast neutron exposure rates in terms of $\phi(E > 1.0$ 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 0.80 to 1.27 for the 25 samples included in the data set. The overall average M/C ratio for the entire set of Vogtle Unit 2 data is 1.07 with an associated standard deviation of 11.6%.

In the comparisons of best-estimate and calculated fast neutron exposure parameters, the corresponding BE/C comparisons for the capsule data sets range from 0.92 to 1.20 for neutron flux ($E > 1.0$ MeV) and from 0.92 to 1.18 for iron atom displacement rate. The overall average BE/C ratios for neutron flux ($E > 1.0$ MeV) and iron atom displacement rate are 1.06 with a standard deviation of 10.2% and 1.05 with a standard deviation of 9.7%, 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 Vogtle Unit 2 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)[a]	Product Half-life	Fission Yield (%)
Copper	^{63}Cu (n,α)	0.6917	4.9 – 11.9	5.272 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	5.272 y	

Note:

(a) The 90% response range is defined such that, in the neutron spectrum characteristic of the Vogtle Unit 2 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 Monthly Thermal Generation During the First Fourteen Fuel Cycles of the Vogtle Unit 2 Reactor (Reactor Power of 3411 MWt from Startup Through the End of Cycle 3; 3565 MWt for Cycles 4 through 13; and, 3626 MWt for Cycle 14)

Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)
Mar-89	0	May-91	2276659	Jul-93	2629330	Sep-95	2565249
Apr-89	475504	Jun-91	2452835	Aug-93	2559359	Oct-95	2654328
May-89	617966	Jul-91	2534141	Sep-93	547977	Nov-95	2565212
Jun-89	2450888	Aug-91	2505776	Oct-93	903906	Dec-95	2624729
Jul-89	2452023	Sep-91	2359978	Nov-93	2564027	Jan-96	2650834
Aug-89	2526703	Oct-91	2508529	Dec-93	2588183	Feb-96	2479725
Sep-89	2439109	Nov-91	2433457	Jan-94	2429440	Mar-96	2650787
Oct-89	2034639	Dec-91	2535003	Feb-94	2393295	Apr-96	2565415
Nov-89	2350213	Jan-92	2534130	Mar-94	2639006	May-96	2650735
Dec-89	2335572	Feb-92	2299840	Apr-94	2533075	Jun-96	2565158
Jan-90	2503482	Mar-92	605707	May-94	2523585	Jul-96	2452545
Feb-90	2289775	Apr-92	0	Jun-94	1262082	Aug-96	2552746
Mar-90	2340854	May-92	1578601	Jul-94	1926053	Sep-96	489969
Apr-90	2396650	Jun-92	2447254	Aug-94	2341001	Oct-96	1241612
May-90	2424191	Jul-92	2532424	Sep-94	2564313	Nov-96	2564798
Jun-90	2181332	Aug-92	2534744	Oct-94	2653771	Dec-96	2650604
Jul-90	1854770	Sep-92	2452670	Nov-94	2564454	Jan-97	2650701
Aug-90	1534544	Oct-92	2539098	Dec-94	2649055	Feb-97	2393844
Sep-90	585194	Nov-92	2451426	Jan-95	2649874	Mar-97	2650728
Oct-90	0	Dec-92	2052686	Feb-95	2063517	Apr-97	2561147
Nov-90	1185372	Jan-93	2536193	Mar-95	10688	May-97	2630761
Dec-90	2395968	Feb-93	2291024	Apr-95	2438900	Jun-97	2564816
Jan-91	2023180	Mar-93	2536217	May-95	2650425	Jul-97	2650622
Feb-91	1953887	Apr-93	2450906	Jun-95	2565303	Aug-97	2650268
Mar-91	1827085	May-93	2577663	Jul-95	2456584	Sep-97	2564794
Apr-91	2149993	Jun-93	2406365	Aug-95	2650678	Oct-97	2654064

Table A-2 (Continued) Monthly Thermal Generation During the First Fourteen Fuel Cycles of the Vogtle Unit 2 Reactor (Reactor Power of 3411 MWt from Startup Through the End of Cycle 3; 3565 MWt for Cycles 4 through 13; and, 3626 MWt for Cycle 14)

Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)
Nov-97	2565321	Jan-00	2637192	Mar-02	2649969	May-04	1153034
Dec-97	2650576	Feb-00	2480228	Apr-02	2560911	Jun-04	2566084
Jan-98	2650913	Mar-00	2632679	May-02	2649576	Jul-04	2641609
Feb-98	2296803	Apr-00	2562046	Jun-02	2564442	Aug-04	2434483
Mar-98	491140	May-00	2651123	Jul-02	2649773	Sep-04	2560437
Apr-98	779588	Jun-00	2565774	Aug-02	2649969	Oct-04	2649641
May-98	2068679	Jul-00	2650927	Sep-02	2537763	Nov-04	2260026
Jun-98	2017178	Aug-00	2650534	Oct-02	386049	Dec-04	2641839
Jul-98	2630863	Sep-00	2565185	Nov-02	621071	Jan-05	2645016
Aug-98	2456507	Oct-00	2654654	Dec-02	1421414	Feb-05	2388895
Sep-98	2412869	Nov-00	2565381	Jan-03	2651478	Mar-05	2646305
Oct-98	2607668	Dec-00	2650338	Feb-03	2395041	Apr-05	2558066
Nov-98	2565406	Jan-01	2651123	Mar-03	2204085	May-05	1956212
Dec-98	2650912	Feb-01	2394487	Apr-03	2562629	Jun-05	1718861
Jan-99	2650519	Mar-01	2626793	May-03	2651185	Jul-05	2648418
Feb-99	2332866	Apr-01	541918	Jun-03	2565770	Aug-05	2648111
Mar-99	2503094	May-01	2212525	Jul-03	2651185	Sep-05	1442373
Apr-99	2561474	Jun-01	2566207	Aug-03	1785259	Oct-05	1310425
May-99	2650716	Jul-01	2651538	Sep-03	2246890	Nov-05	2565872
Jun-99	2501128	Aug-01	2651538	Oct-03	2654326	Dec-05	1790126
Jul-99	2650519	Sep-01	2536586	Nov-03	2565378	Jan-06	2649827
Aug-99	2648554	Oct-01	2654480	Dec-03	2650853	Feb-06	1248502
Sep-99	2508597	Nov-01	2564834	Jan-04	2629328	Mar-06	1678436
Oct-99	149981	Dec-01	2649576	Feb-04	2379233	Apr-06	2446888
Nov-99	2051716	Jan-02	2648988	Mar-04	2650596	May-06	2646007
Dec-99	2300308	Feb-02	2392406	Apr-04	1435551	Jun-06	2561341

Table A-2 (Continued) Monthly Thermal Generation During the First Fourteen Fuel Cycles of the Vogtle Unit 2 Reactor (Reactor Power of 3411 MWt from Startup Through the End of Cycle 3; 3565 MWt for Cycles 4 through 13; and, 3626 MWt for Cycle 14)

Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)
Jul-06	2646193	Jun-07	2543183	May-08	2602255	Aug-09	2694576
Aug-06	2243308	Jul-07	2624127	Jun-08	2517162	Sep-09	2550413
Sep-06	2455470	Aug-07	2620562	Jul-08	2600192	Oct-09	2694302
Oct-06	2644504	Sep-07	2532574	Aug-08	2602058	Nov-09	2549130
Nov-06	2557807	Oct-07	2614817	Sep-08	1050430	Dec-09	2441245
Dec-06	2643879	Nov-07	2496559	Oct-08	654939	Jan-10	2694240
Jan-07	2644076	Dec-07	2611400	Nov-08	2002080	Feb-10	2433005
Feb-07	2357699	Jan-08	2613056	Dec-08	2694367	Mar-10	519881
Mar-07	237033	Feb-08	2440492	Jan-09	2694412		
Apr-07	43611	Mar-08	2603709	Feb-09	2433837		
May-07	2283495	Apr-08	2519880	Mar-09	2637147		

Table A-3 Calculated C_j Factors at the Surveillance Capsule Center Core Midplane Elevation

Fuel Cycle	Cycle Length [EFPS]	φ(E > 1.0 MeV) [n/cm²-s]				
		Capsule U	Capsule Y	Capsule X	Capsule W	Capsule Z
1	3.78E+07	9.43E+10	8.78E+10	9.43E+10	9.34E+10	9.34E+10
2	3.86E+07		7.30E+10	7.97E+10	7.89E+10	7.89E+10
3	4.13E+07		6.32E+10	6.82E+10	6.75E+10	6.75E+10
4	3.96E+07		6.08E+10	6.63E+10	6.57E+10	6.57E+10
5	4.47E+07			6.17E+10	6.11E+10	6.11E+10
6	4.35E+07			6.79E+10	6.73E+10	6.73E+10
7	4.38E+07				7.01E+10	7.01E+10
8	4.43E+07				7.17E+10	7.17E+10
9	4.46E+07				6.88E+10	6.88E+10
10	4.11E+07				7.04E+10	7.04E+10
11	3.99E+07					6.99E+10
12	3.97E+07					7.35E+10
13	4.23E+07					7.09E+10
14	4.20E+07					7.18E+10
Average		9.43E+10	7.09E+10	7.25E+10	7.11E+10	7.13E+10

Fuel Cycle	Cycle Length [EFPS]	C_j				
		Capsule U	Capsule Y	Capsule X	Capsule W	Capsule Z
1	3.78E+07	1.000	1.238	1.302	1.313	1.311
2	3.86E+07		1.029	1.099	1.109	1.107
3	4.13E+07		0.891	0.941	0.949	0.947
4	3.96E+07		0.857	0.915	0.923	0.922
5	4.47E+07			0.851	0.859	0.858
6	4.35E+07			0.938	0.946	0.944
7	4.38E+07				0.986	0.984
8	4.43E+07				1.008	1.007
9	4.46E+07				0.967	0.966
10	4.11E+07				0.990	0.988
11	3.99E+07					0.981
12	3.97E+07					1.031
13	4.23E+07					0.994
14	4.20E+07					1.007
Average		1.000	1.000	1.000	1.000	1.000

Table A-4a Measured Sensor Activities and Reaction Rates Surveillance Capsule U

Reaction[e]	Location	Measured Activity[a] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate[d] (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	5.51E+04	3.96E+05	6.04E-17
	Middle	4.96E+04	3.56E+05	5.44E-17
	Bottom	4.86E+04	3.49E+05	5.33E-17
	Average			**5.60E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.88E+06	3.98E+06	6.31E-15
	Middle	1.65E+06	3.49E+06	5.54E-15
	Bottom	1.67E+06	3.53E+06	5.60E-15
	Average			**5.82E-15**
^{58}Ni (n,p) ^{58}Co	Top	1.86E+07	5.81E+07	8.32E-15
	Middle	1.70E+07	5.31E+07	7.60E-15
	Bottom	1.65E+07	5.16E+07	7.38E-15
	Average			**7.77E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	1.83E+05	6.78E+06	4.45E-14
	Including ^{235}U, ^{239}Pu, and (γ, fission) corrections:			**3.74E-14[b]**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	1.56E+06	5.78E+07	3.69E-13
	Including (γ, fission) corrections:			**3.65E-13[c]**
^{59}Co (n,γ) ^{60}Co	Top	1.13E+07	8.12E+07	5.30E-12
	Middle	1.26E+07	9.05E+07	5.91E-12
	Bottom	1.15E+07	8.26E+07	5.39E-12
	Average			**5.53E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	5.99E+06	4.30E+07	2.81E-12
	Middle	6.21E+06	4.46E+07	2.91E-12
	Bottom	6.19E+06	4.45E+07	2.90E-12
	Average			**2.87E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of December 12, 1990.

(b) The average ^{238}U (n,f) reaction rate of 3.74E-14 includes a correction factor of 0.870 to account for plutonium build-in and an additional factor of 0.966 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 3.65E-13 includes a correction factor of 0.990 to account for photo-fission effects in the sensor.

(d) Reaction rates referenced to the Cycle 1 Rated Reactor Power of 3411 MWt.

(e) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

Table A-4b Measured Sensor Activities and Reaction Rates Surveillance Capsule Y

Reaction[e]	Location	Measured Activity[a] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate (rps/atom)[d]
^{63}Cu (n,α) ^{60}Co	Top	1.33E+05	3.14E+05	4.78E-17
	Middle	1.21E+05	2.85E+05	4.35E-17
	Bottom	1.21E+05	2.85E+05	4.35E-17
	Average			**4.50E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.54E+06	2.72E+06	4.32E-15
	Middle	1.41E+06	2.49E+06	3.95E-15
	Bottom	1.42E+06	2.51E+06	3.98E-15
	Average			**4.09E-15**
^{58}Ni (n,p) ^{58}Co	Top	7.80E+06	4.26E+07	6.09E-15
	Middle	7.18E+06	3.92E+07	5.61E-15
	Bottom	7.03E+06	3.84E+07	5.49E-15
	Average			**5.73E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	4.71E+05	4.45E+06	2.92E-14
	Including ^{235}U, ^{239}Pu, and (γ, fission) corrections:			**2.38E-14[b]**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	3.78E+06	3.57E+07	2.28E-13
	Including (γ, fission) corrections:			**2.25E-13[c]**
^{59}Co (n,γ) ^{60}Co	Top	2.39E+07	5.64E+07	3.68E-12
	Middle	2.37E+07	5.59E+07	3.65E-12
	Bottom	2.38E+07	5.61E+07	3.66E-12
	Average			**3.66E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	1.22E+07	2.88E+07	1.88E-12
	Middle	1.25E+07	2.95E+07	1.92E-12
	Bottom	1.27E+07	2.99E+07	1.95E-12
	Average			**1.92E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of August 1, 1995.

(b) The average ^{238}U (n,f) reaction rate of 2.38E-14 includes a correction factor of 0.841 to account for plutonium build-in and an additional factor of 0.967 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 2.25E-13 includes a correction factor of 0.990 to account for photo-fission effects in the sensor.

(d) Reaction rates referenced to the Cycles 1-4 Average Rated Reactor Power of 3450 MWt.

(e) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

Table A-4c Measured Sensor Activities and Reaction Rates Surveillance Capsule X

Reaction[e]	Location	Measured Activity[a] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate[d] (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	1.96E+05	3.59E+05	5.47E-17
	Middle	1.78E+05	3.26E+05	4.97E-17
	Bottom	1.74E+05	3.18E+05	4.86E-17
	Average			**5.10E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.78E+06	3.41E+06	5.40E-15
	Middle	1.62E+06	3.10E+06	4.92E-15
	Bottom	1.59E+06	3.05E+06	4.83E-15
	Average			**5.05E-15**
^{58}Ni (n,p) ^{58}Co	Top	4.96E+06	5.50E+07	7.87E-15
	Middle	4.41E+06	4.89E+07	7.00E-15
	Bottom	4.44E+06	4.92E+07	7.04E-15
	Average			**7.30E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	9.00E+05	5.66E+06	3.72E-14
	Including ^{235}U, ^{239}Pu, and (γ, fission) corrections:			**2.94E-14[b]**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	6.84E+06	4.30E+07	2.74E-13
	Including (γ, fission) corrections:			**2.72E-13[c]**
^{59}Co (n,γ) ^{60}Co	Middle	3.70E+07	6.77E+07	4.42E-12
	Bottom	3.66E+07	6.70E+07	4.37E-12
	Average			**4.39E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Middle	1.93E+07	3.53E+07	2.30E-12
	Bottom	1.97E+07	3.60E+07	2.35E-12
	Average			**2.33E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of November 1, 1998.

(b) The average ^{238}U (n,f) reaction rate of 2.93E-14 includes a correction factor of 0.817 to account for plutonium build-in and an additional factor of 0.966 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 2.72E-13 includes a correction factor of 0.990 to account for photo-fission effects in the sensor.

(d) Reaction rates referenced to the Cycles 1-6 Average Rated Reactor Power of 3491 MWt.

(e) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

Table A-4d Measured Sensor Activities and Reaction Rates Surveillance Capsule W

Reaction[e]	Location	Measured Activity[a] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate[d] (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	2.16E+05	2.98E+05	4.54E-17
	Middle	1.94E+05	2.67E+05	4.08E-17
	Bottom	1.90E+05	2.62E+05	4.00E-17
	Average			**4.21E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.83E+06	2.80E+06	4.43E-15
	Middle	1.67E+06	2.55E+06	4.05E-15
	Bottom	1.64E+06	2.51E+06	3.97E-15
	Average			**4.15E-15**
^{58}Ni (n,p) ^{58}Co	Top	1.00E+07	4.54E+07	6.50E-15
	Middle	9.22E+06	4.18E+07	5.99E-15
	Bottom	8.99E+06	4.08E+07	5.84E-15
	Average			**6.11E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	1.40E+06	5.47E+06	3.59E-14
	Including ^{235}U, ^{239}Pu, and (γ, fission) corrections:			**2.70E-14[b]**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	9.54E+06	3.72E+07	2.38E-13
	Including (γ, fission) corrections:			**2.35E-13[c]**
^{59}Co (n,γ) ^{60}Co	Top	4.00E+07	5.51E+07	3.60E-12
	Middle	4.00E+07	5.51E+07	3.60E-12
	Bottom	4.02E+07	5.54E+07	3.60E-12
	Average			**3.60E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	2.28E+07	3.14E+07	2.05E-12
	Middle	2.35E+07	3.24E+07	2.11E-12
	Bottom	2.29E+07	3.16E+07	2.06E-12
	Average			**2.08E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of September 16, 2004.

(b) The average ^{238}U (n,f) reaction rate of 2.70E-14 includes a correction factor of 0.777 to account for plutonium build-in and an additional factor of 0.969 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 2.35E-13 includes a correction factor of 0.991 to account for photo-fission effects in the sensor.

(d) Reaction rates referenced to the Cycles 1-10 Average Rated Reactor Power of 3522 MWt.

(e) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

Table A-4e Measured Sensor Activities and Reaction Rates Surveillance Capsule Z

Reaction[(e)]	Location	Measured Activity[(a)] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate[(d)] (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	2.22E+05	2.85E+05	4.34E-17
	Middle	1.95E+05	2.50E+05	3.81E-17
	Bottom	1.96E+05	2.51E+05	3.83E-17
	Average			**4.00E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.74E+06	2.88E+06	4.56E-15
	Middle	1.57E+06	2.60E+06	4.11E-15
	Bottom	1.57E+06	2.60E+06	4.11E-15
	Average			**4.26E-15**
^{58}Ni (n,p) ^{58}Co	Top	5.73E+06	4.26E+07	6.10E-15
	Middle	5.23E+06	3.89E+07	5.57E-15
	Bottom	5.25E+06	3.90E+07	5.59E-15
	Average			**5.75E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	1.29E+06	3.86E+06	2.54E-14
	Including ^{235}U, ^{239}Pu, and (γ, fission) corrections:			**1.81E-14[(b)]**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	1.05E+07	3.14E+07	2.01E-13
	Including (γ, fission) corrections:			**1.99E-13[(c)]**
^{59}Co (n,γ) ^{60}Co	Top	4.31E+07	5.53E+07	3.61E-12
	Middle	4.31E+07	5.53E+07	3.61E-12
	Bottom	4.32E+07	5.54E+07	3.61E-12
	Average			**3.61E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	2.40E+07	3.08E+07	2.01E-12
	Middle	2.65E+07	3.40E+07	2.22E-12
	Bottom	2.61E+07	3.35E+07	2.18E-12
	Average			**2.14E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of September 28, 2010.

(b) The average ^{238}U (n,f) reaction rate of 1.81E-14 includes a correction factor of 0.737 to account for plutonium build-in and an additional factor of 0.969 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 1.99E-13 includes a correction factor of 0.991 to account for photo-fission effects in the sensor.

(d) Reaction rates referenced to the Cycles 1-14 Average Rated Reactor Power of 3538 MWt.

(e) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

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

Capsule U					
	Reaction Rate [rps/atom]				
Reaction[a]	Measured	Calculated	Best-Estimate[b]	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	5.60E-17	4.90E-17	5.42E-17	1.14	1.03
$^{54}Fe(n,p)^{54}Mn$	5.82E-15	5.54E-15	5.93E-15	1.05	0.98
$^{58}Ni(n,p)^{58}Co$	7.77E-15	7.78E-15	8.21E-15	1.00	0.94
$^{238}U(n,f)^{137}Cs$ (Cd)	3.74E-14	3.00E-14	3.29E-14	1.25	1.14
$^{237}Np(n,f)^{137}Cs$ (Cd)	3.65E-13	2.95E-13	3.47E-13	1.24	1.05
$^{59}Co(n,\gamma)^{60}Co$	5.53E-12	4.23E-12	5.43E-12	1.31	1.02
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	2.87E-12	2.94E-12	2.92E-12	0.98	0.98

Notes:

(a) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

(b) See Section A.1.2 for details describing the Best-Estimate (BE) reaction rates.

Capsule Y					
	Reaction Rate [rps/atom]				
Reaction[a]	Measured	Calculated	Best-Estimate[b]	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	4.50E-17	3.92E-17	4.28E-17	1.15	1.05
$^{54}Fe(n,p)^{54}Mn$	4.09E-15	4.28E-15	4.25E-15	0.96	0.96
$^{58}Ni(n,p)^{58}Co$	5.73E-15	5.98E-15	5.91E-15	0.96	0.97
$^{238}U(n,f)^{137}Cs$ (Cd)	2.38E-14	2.27E-14	2.23E-14	1.05	1.06
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.25E-13	2.20E-13	2.21E-13	1.02	1.02
$^{59}Co(n,\gamma)^{60}Co$	3.66E-12	3.06E-12	3.59E-12	1.19	1.02
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	1.92E-12	2.15E-12	1.95E-12	0.89	0.98

Notes:

(a) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

(b) See Section A.1.2 for details describing the Best-Estimate (BE) reaction rates.

Table A-5 (Continued) Comparison of Measured, Calculated, and Best-Estimate Reaction Rates at the Surveillance Capsule Center

Capsule X					
	Reaction Rate [rps/atom]				
Reaction[a]	Measured	Calculated	Best-Estimate[b]	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	5.10E-17	4.02E-17	4.97E-17	1.27	1.03
$^{54}Fe(n,p)^{54}Mn$	5.05E-15	4.38E-15	5.21E-15	1.15	0.97
$^{58}Ni(n,p)^{58}Co$	7.30E-15	6.13E-15	7.33E-15	1.19	1.00
$^{238}U(n,f)^{137}Cs$ (Cd)	2.94E-14	2.33E-14	2.77E-14	1.26	1.06
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.72E-13	2.25E-13	2.68E-13	1.21	1.01
$^{59}Co(n,\gamma)^{60}Co$	4.39E-12	3.17E-12	4.31E-12	1.39	1.02
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	2.33E-12	2.20E-12	2.36E-12	1.06	0.99

Notes:

(a) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

(b) See Section A.1.2 for details describing the Best-Estimate (BE) reaction rates.

Capsule W					
	Reaction Rate [rps/atom]				
Reaction[a]	Measured	Calculated	Best-Estimate[b]	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	4.21E-17	3.94E-17	4.12E-17	1.07	1.02
$^{54}Fe(n,p)^{54}Mn$	4.15E-15	4.29E-15	4.35E-15	0.97	0.95
$^{58}Ni(n,p)^{58}Co$	6.11E-15	6.00E-15	6.17E-15	1.02	0.99
$^{238}U(n,f)^{137}Cs$ (Cd)	2.70E-14	2.27E-14	2.38E-14	1.19	1.14
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.35E-13	2.21E-13	2.36E-13	1.06	1.00
$^{59}Co(n,\gamma)^{60}Co$	3.60E-12	2.83E-12	3.54E-12	1.27	1.02
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	2.07E-12	2.00E-12	2.10E-12	1.04	0.99

Notes:

(a) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

(b) See Section A.1.2 for details describing the Best-Estimate (BE) reaction rates.

Table A-5 (Continued) Comparison of Measured, Calculated, and Best-Estimate Reaction Rates at the Surveillance Capsule Center

Capsule Z					
	Reaction Rate [rps/atom]				
Reaction[a]	Measured	Calculated	Best-Estimate[b]	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	4.00E-17	3.96E-17	3.98E-17	1.01	1.00
$^{54}Fe(n,p)^{54}Mn$	4.26E-15	4.30E-15	4.16E-15	0.99	1.02
$^{58}Ni(n,p)^{58}Co$	5.75E-15	6.01E-15	5.75E-15	0.96	1.00
$^{238}U(n,f)^{137}Cs$ (Cd)	1.81E-14	2.28E-14	2.11E-14	0.80	0.86
$^{237}Np(n,f)^{137}Cs$ (Cd)	1.99E-13	2.21E-13	2.01E-13	0.90	0.99
$^{59}Co(n,\gamma)^{60}Co$	3.61E-12	2.83E-12	3.54E-12	1.28	1.02
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	2.14E-12	2.00E-12	2.16E-12	1.07	0.99

Notes:

(a) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

(b) See Section A.1.2 for details describing the Best-Estimate (BE) reaction rates.

Table A-6 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
U	9.43E+10	1.06E+11	6%	1.12
Y	7.09E+10	6.99E+10	6%	0.99
X	7.25E+10	8.67E+10	6%	1.20
W	7.11E+10	7.57E+10	6%	1.06
Z	7.13E+10	6.57E+10	6%	0.92

Note:
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
U	1.84E-10	2.07E-10	8%	1.12
Y	1.38E-10	1.37E-10	8%	0.99
X	1.41E-10	1.65E-10	8%	1.18
W	1.38E-10	1.46E-10	8%	1.06
Z	1.38E-10	1.27E-10	8%	0.92

Note:
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-7 Comparison of Measured/Calculated (M/C) Sensor Reaction Rate Ratios Including all Fast Neutron Threshold Reactions

Reaction[b]	M/C Ratio[a]				
	Capsule U	Capsule Y	Capsule X	Capsule W	Capsule Z
$^{63}Cu(n,\alpha)^{60}Co$	1.14	1.15	1.27	1.07	1.01
$^{54}Fe(n,p)^{54}Mn$	1.05	0.96	1.15	0.97	0.99
$^{58}Ni(n,p)^{58}Co$	1.00	0.96	1.19	1.02	0.96
$^{238}U(n,f)^{137}Cs$ (Cd)	1.25	1.05	1.26	1.19	0.80
$^{237}Np(n,f)^{137}Cs$ (Cd)	1.24	1.02	1.21	1.06	0.90
Average	1.14	1.03	1.22	1.06	0.93
% Standard Deviation	9.8	7.6	4.1	7.7	9.1

Notes:

(a) The overall average M/C ratio for the set of 25 sensor measurements is 1.07 with an associated standard deviation of 11.6%.

(b) The "(Cd)" designation next to a reaction indicates that the sensor was cadmium-covered.

Table A-8 Comparison of Best-Estimate/Calculated (BE/C) Exposure Rate Ratios

Capsule ID	BE/C Ratio	
	$\phi(E > 1.0\ MeV)$	dpa/s
U	1.12	1.12
Y	0.99	0.99
X	1.20	1.18
W	1.06	1.06
Z	0.92	0.92
Average	1.06	1.05
% Standard Deviation	10.2	9.7

A.2 REFERENCES

A-1 Regulatory Guide 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-13007, Revision 0, *Analysis of Capsule U from the Georgia Power Company Vogtle Electric Generating Plant Unit 2 Reactor Vessel Radiation Surveillance Program*, E. Terek et al., August 1991.

A-3 WCAP-14532, Revision 0, *Analysis of Capsule Y from the Georgia Power Company Vogtle Electric Generating Plant (VEGP) Unit 2 Reactor Vessel Radiation Surveillance Program*, P. A. Grendys et al., February 1996.

A-4 WCAP-15159, Revision 0, *Analysis of Capsule X From the Southern Nuclear Vogtle Electric Generating Plant Unit 2 Reactor Vessel Radiation Surveillance Program*, T. J. Laubham et al., March 1999.

A-5 WCAP-16382-NP, Revision 0, *Analysis of Capsule W From the Southern Nuclear Operating Company, Vogtle Unit 2 Reactor Vessel Radiation Surveillance Program*, T. J. Laubham and R. J. Hagler, January 2005.

A-6 A. Schmittroth, *FERRET Data Analysis Core*, HEDL-TME 79-40, Hanford Engineering Development Laboratory, Richland, WA, September 1979.

A-7 RSICC Data Library Collection DLC-178, *SNLRML Recommended Dosimetry Cross-Section Compendium*, July 1994.

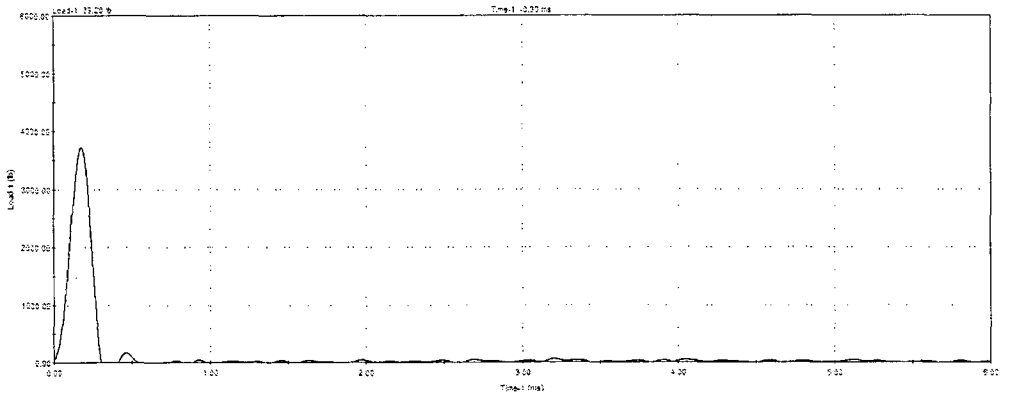
A-8 ASTM Standard E1018, *Application of ASTM Evaluated Cross-Section Data File, Matrix E706 (IIB).*

A-9 ASTM Standard E944, *Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance.*

APPENDIX B
LOAD-TIME RECORDS FOR CHARPY SPECIMEN TESTS

- Specimen prefix "BL" denotes Lower Shell Plate B8628-1, Longitudinal Orientation
- Specimen prefix "BT" denotes Lower Shell Plate B8628-1, Transverse Orientation
- Specimen prefix "BW" denotes Surveillance Program Weld Metal
- Specimen prefix "BH" denotes Heat-Affected Zone Material

Note that the instrumented Charpy data is for information only. The instrumented tup was not calibrated per ASTM E2298-09.



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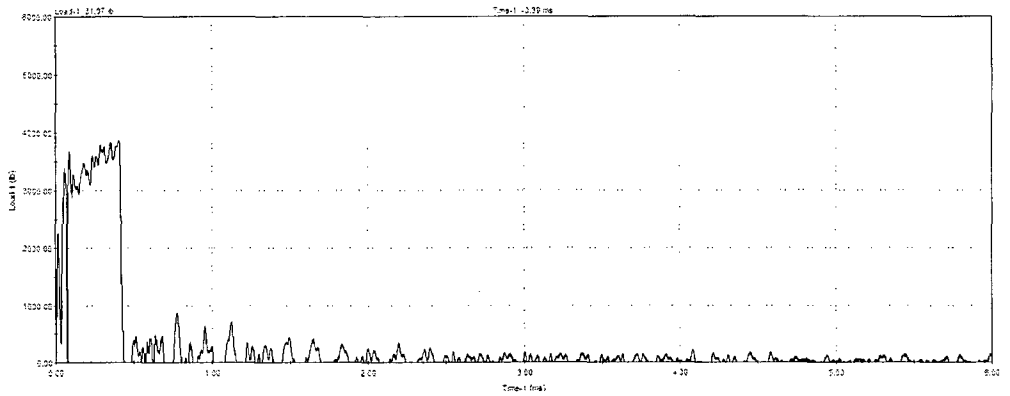

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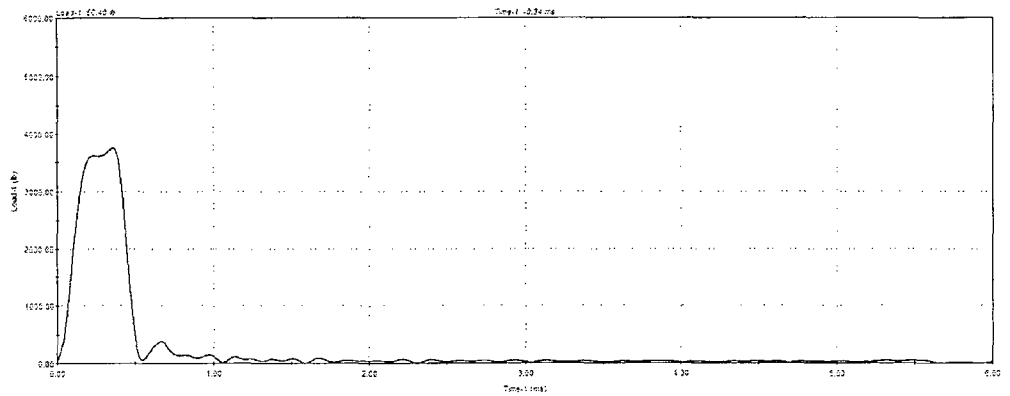

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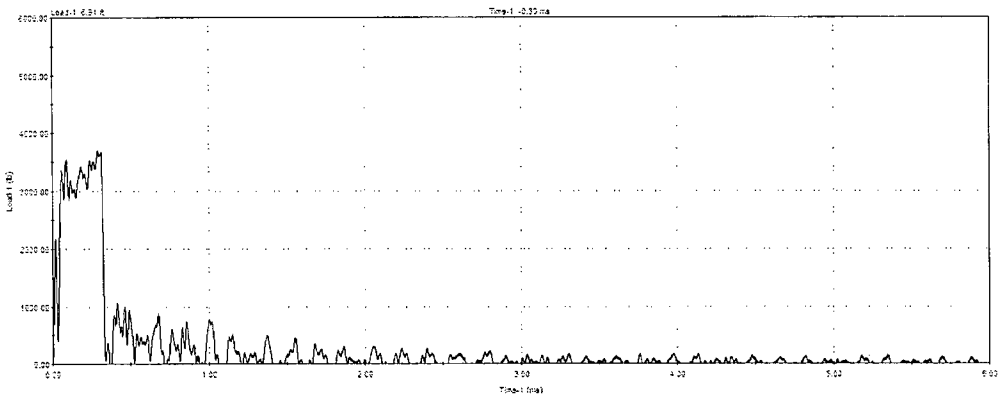

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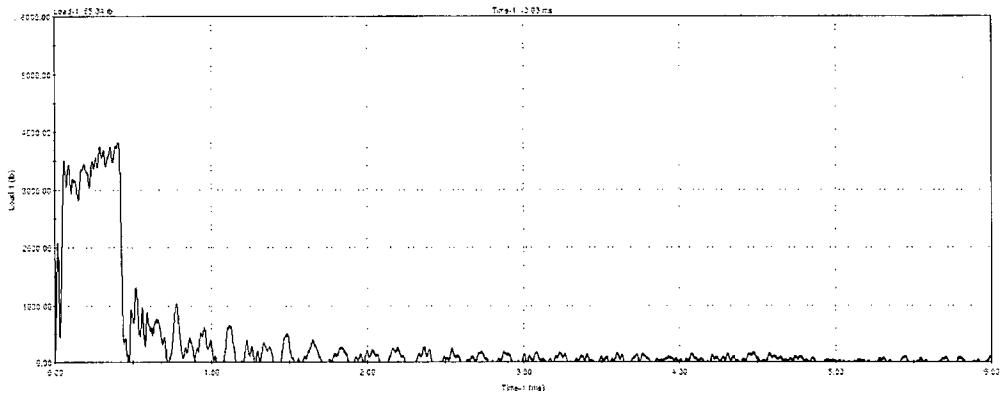

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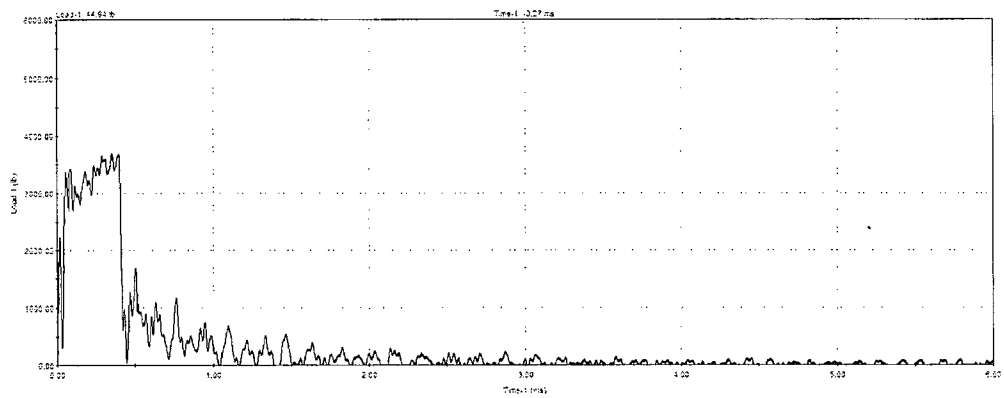

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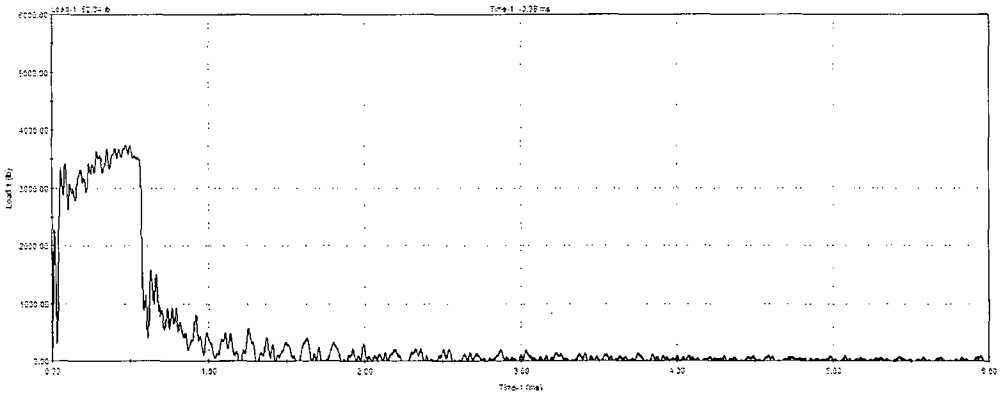
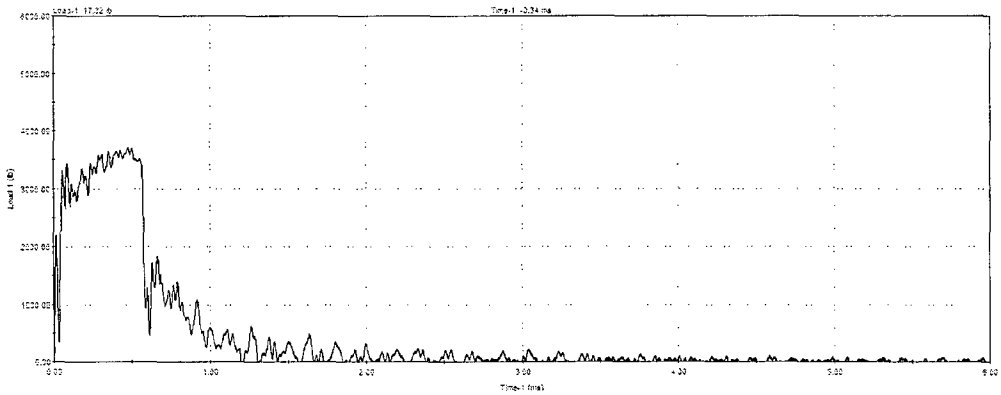
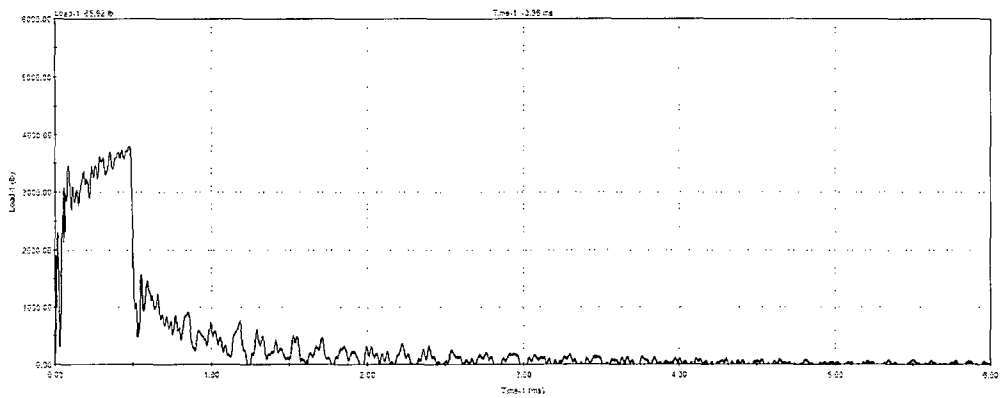


BL83, 90°F



BL77, 100°F



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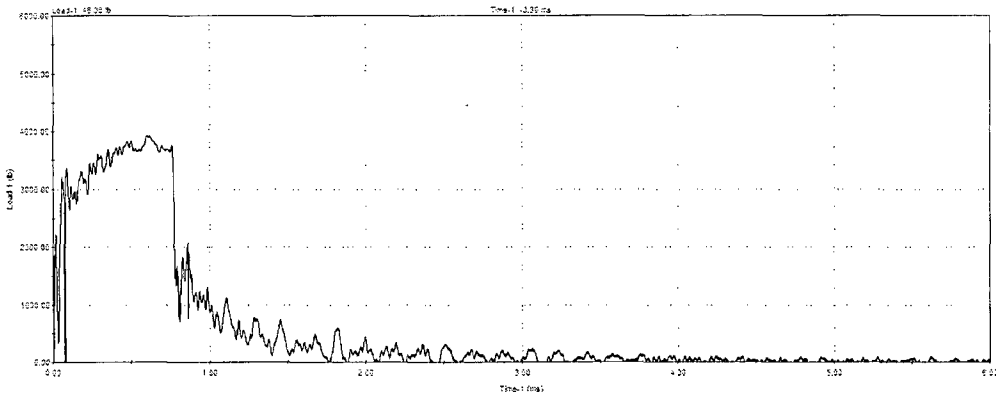

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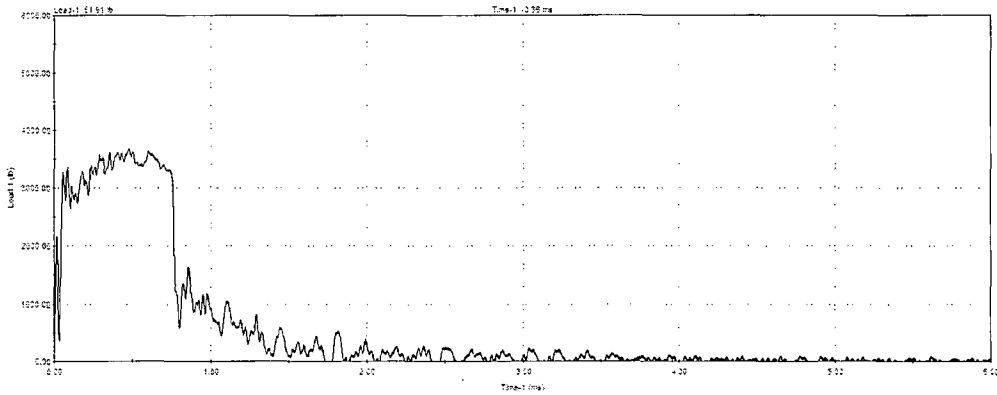

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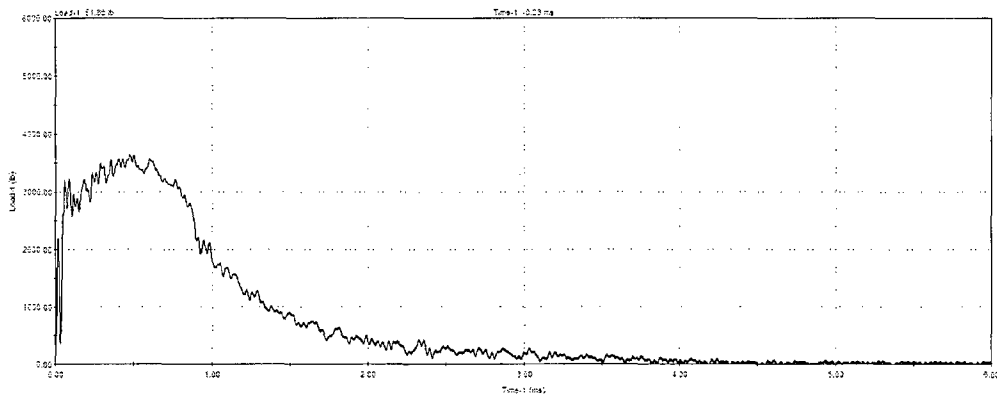

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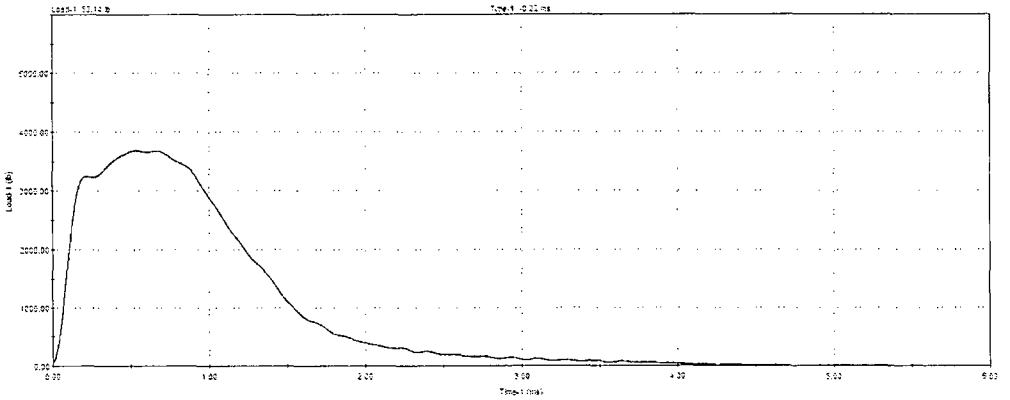

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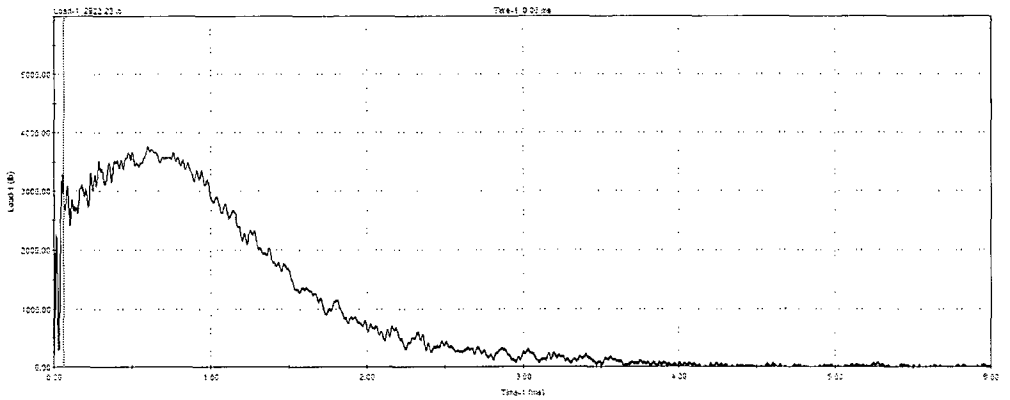

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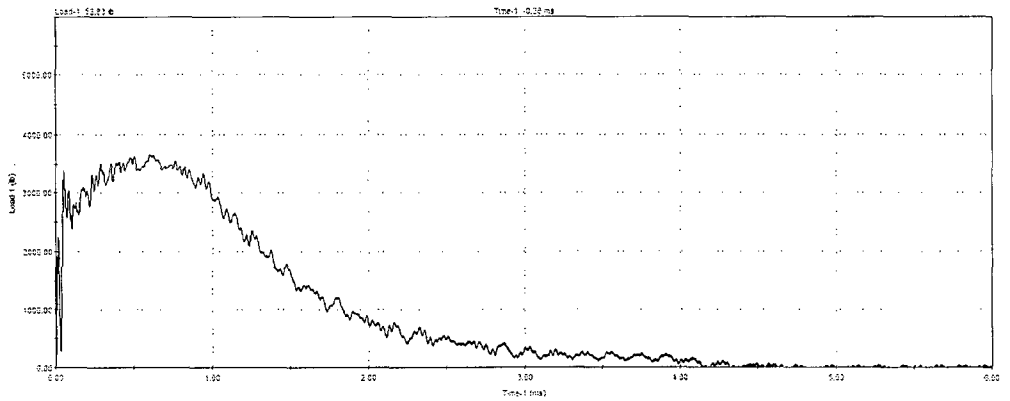

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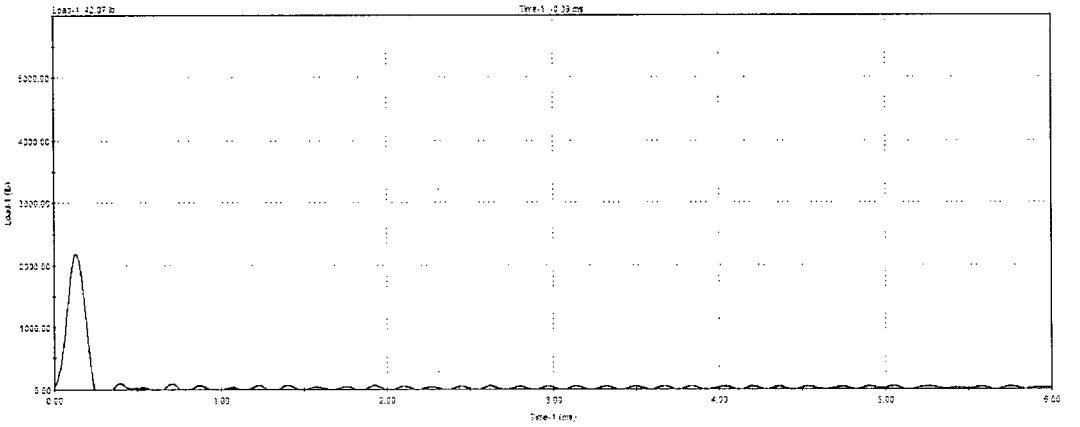

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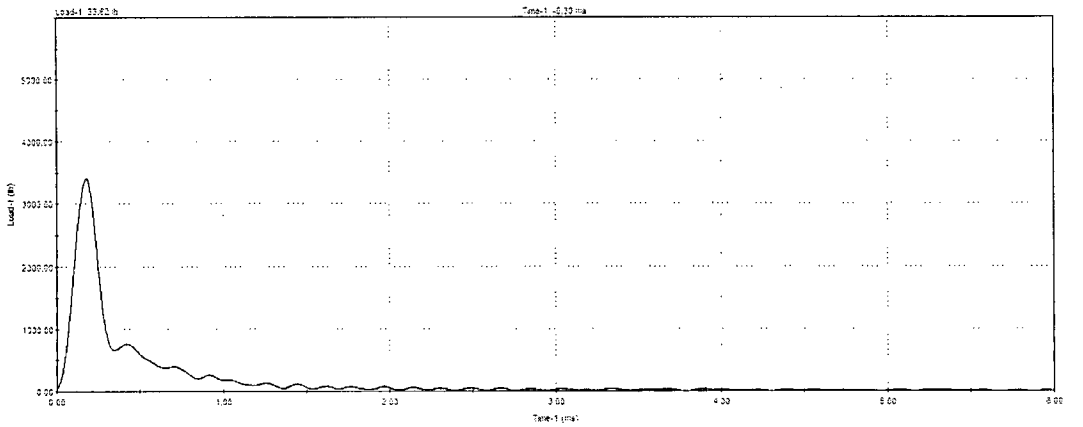

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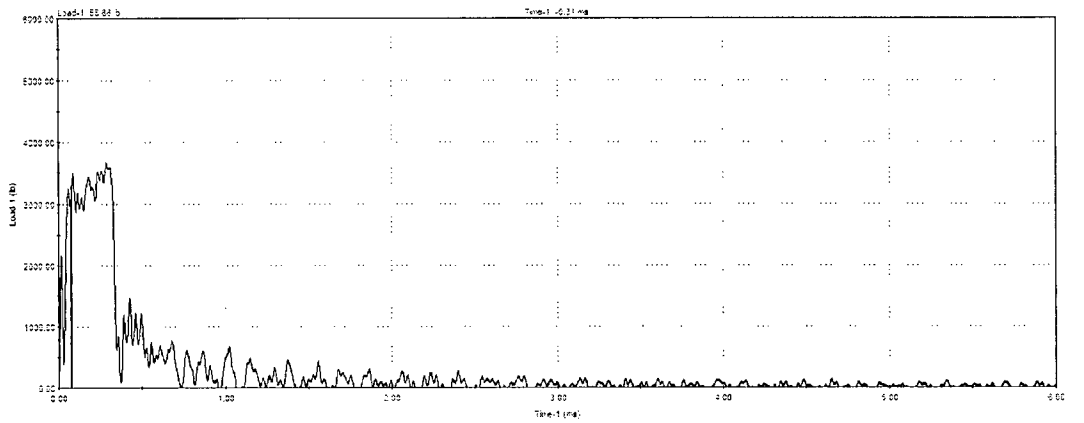

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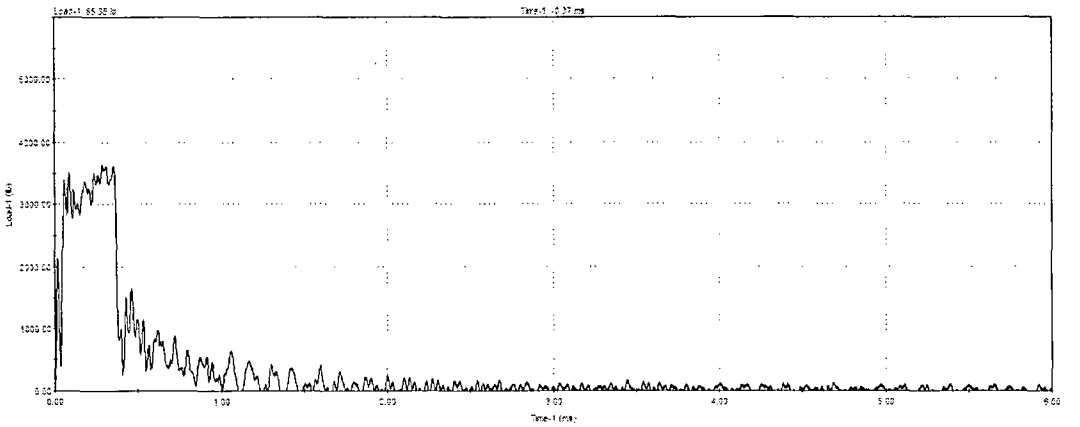

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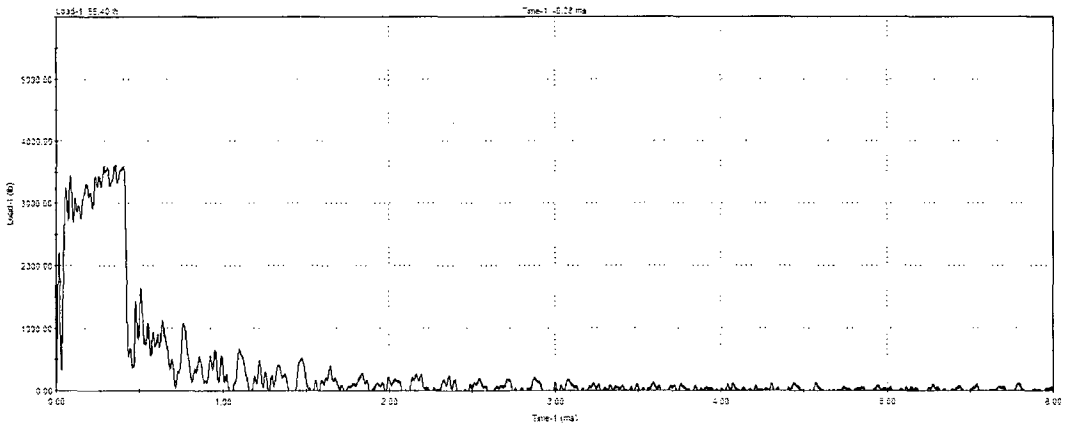

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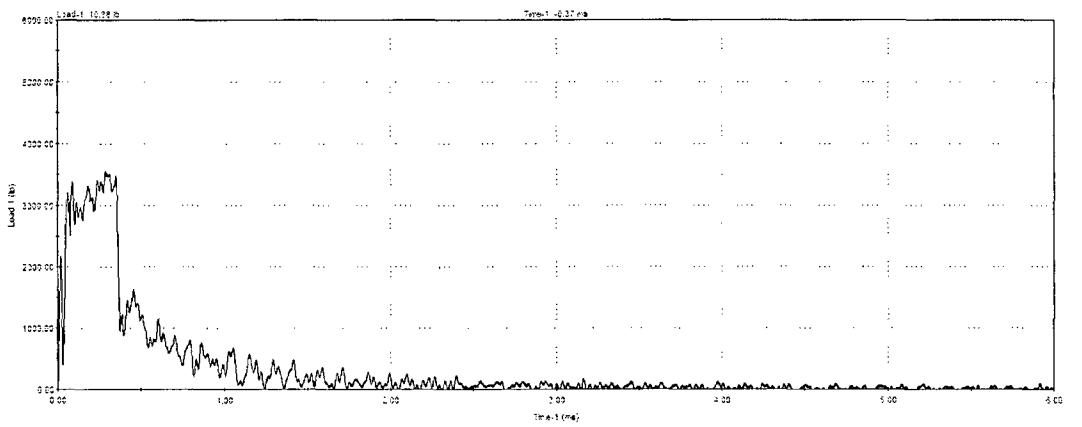

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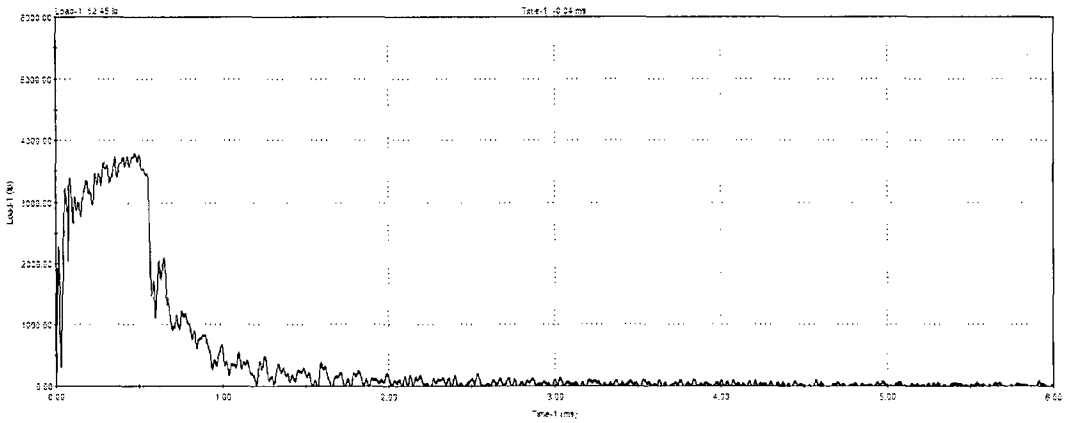

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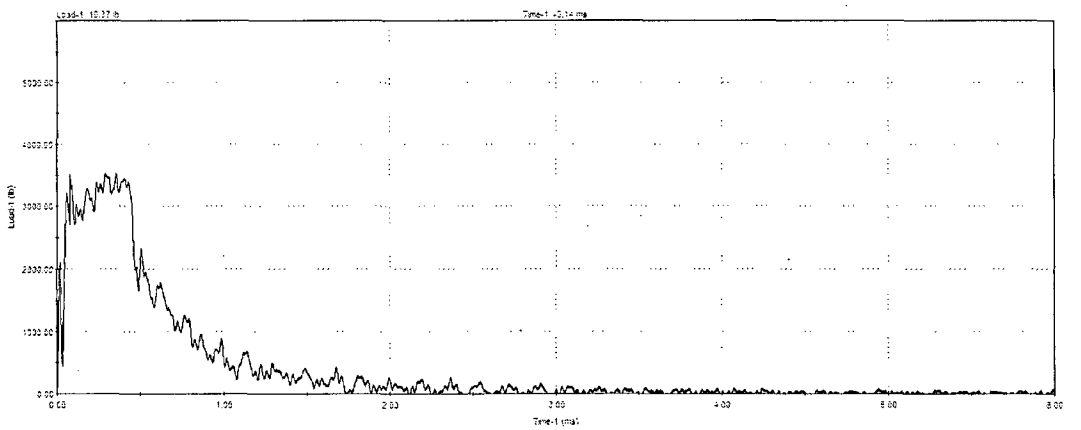

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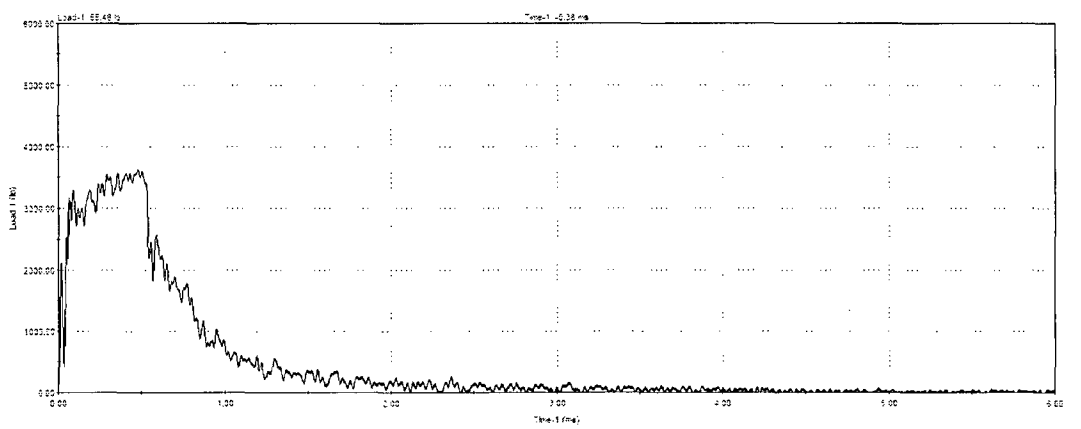

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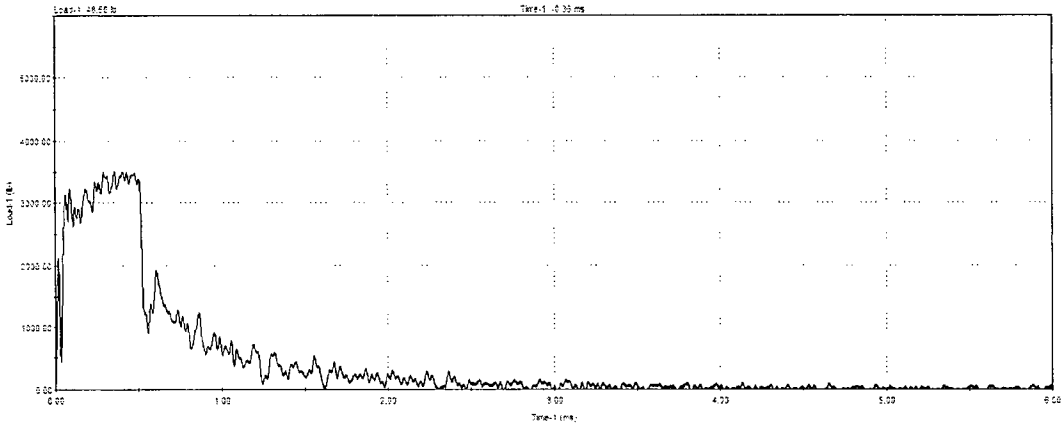

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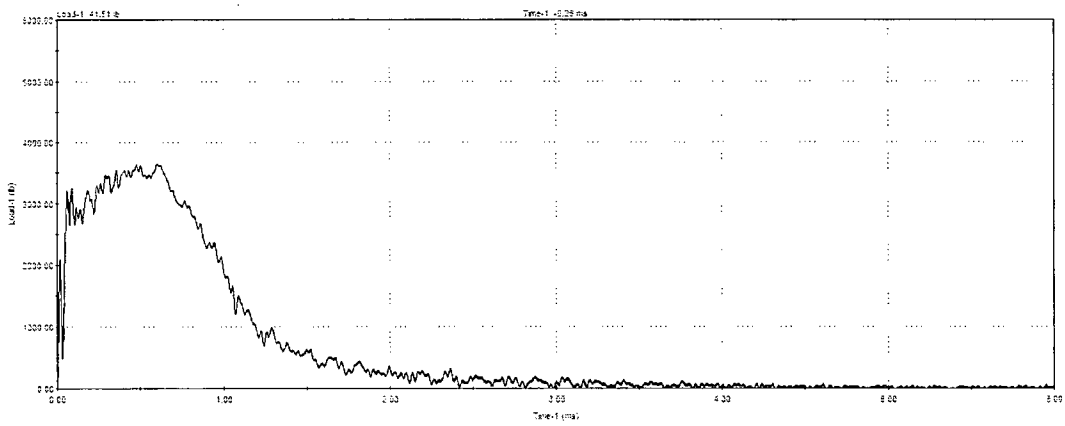
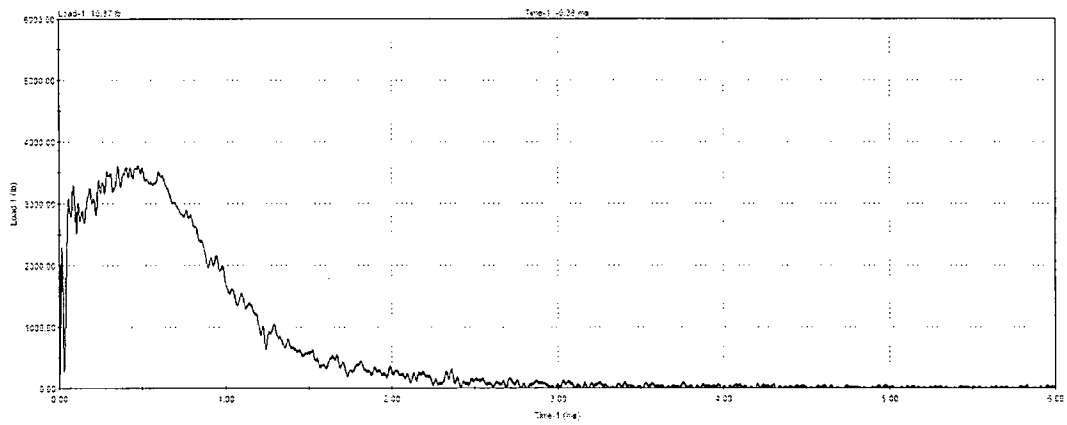
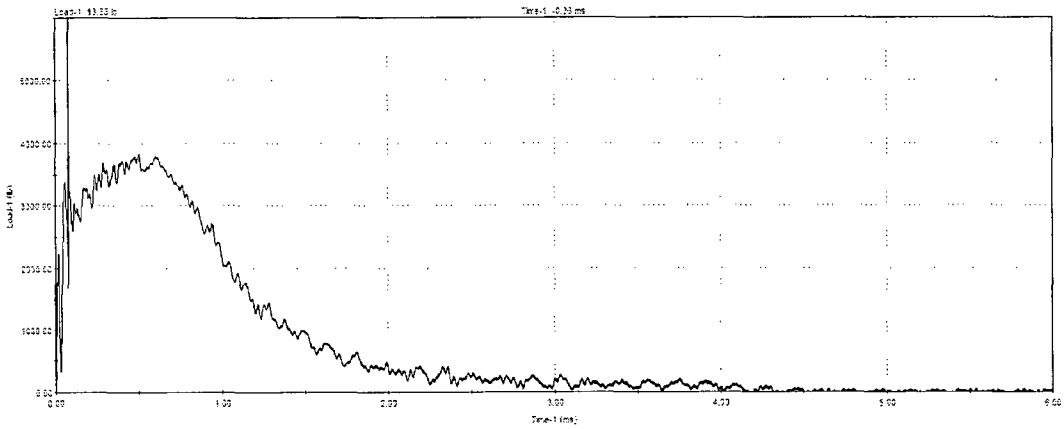


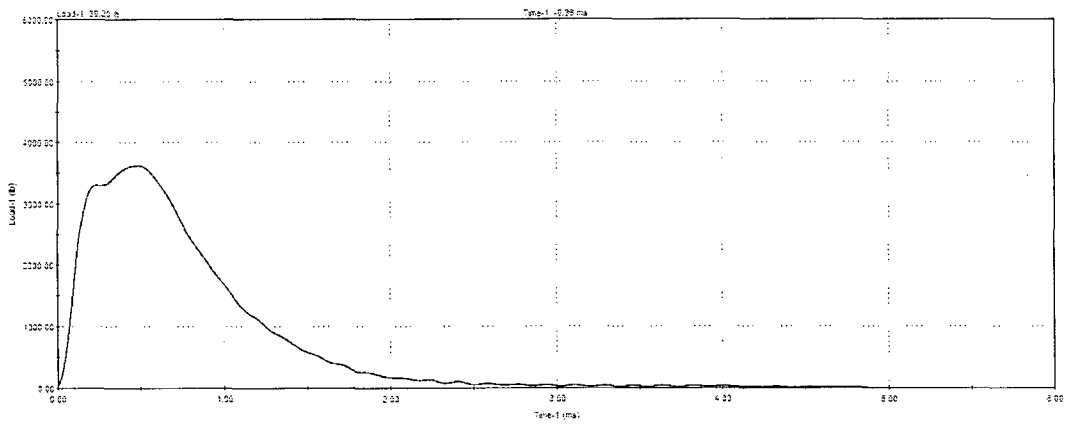
BT76, 150°F



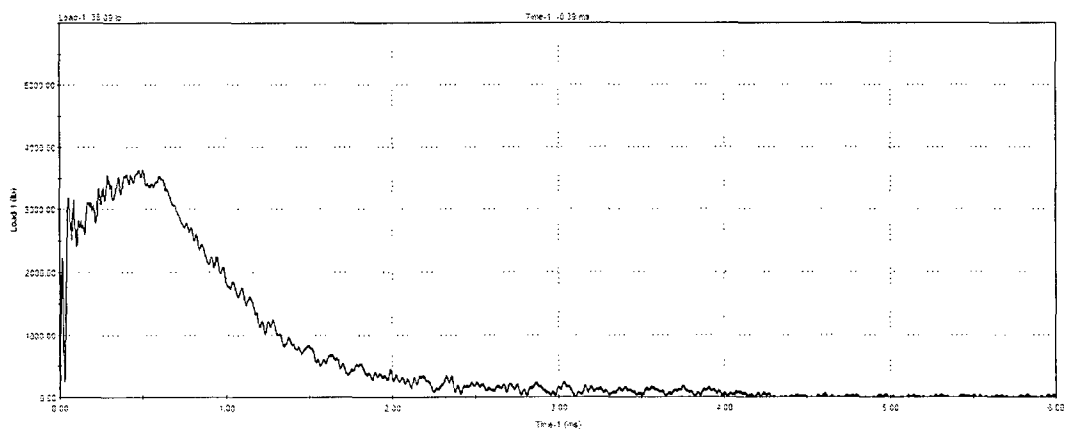
BT84, 175°F



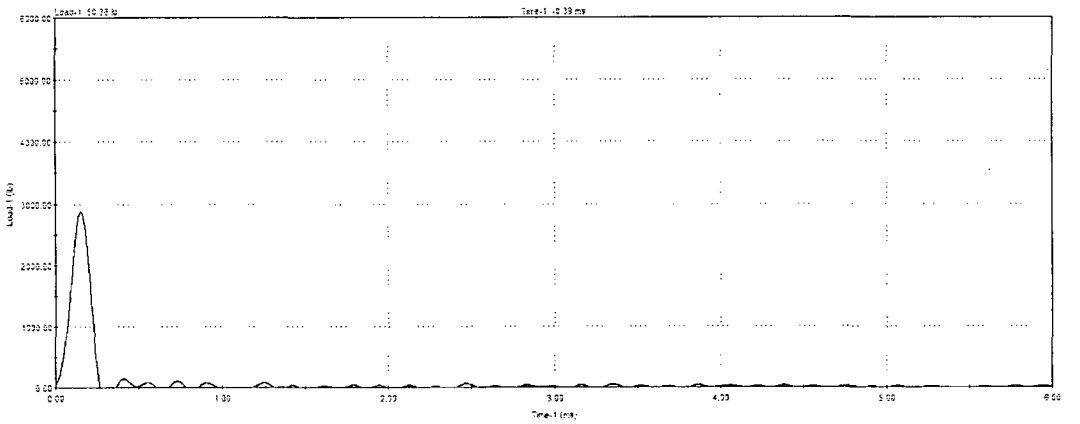
BT82, 210°F



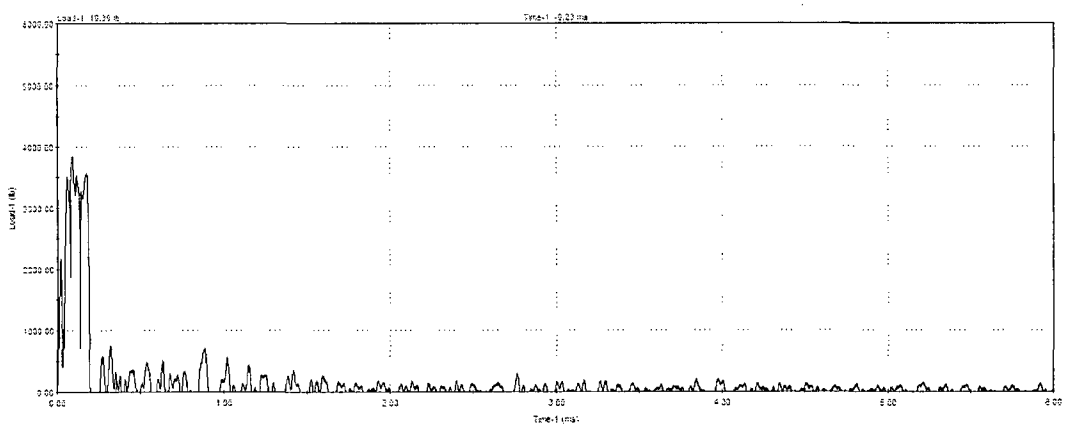
BT86, 250°F



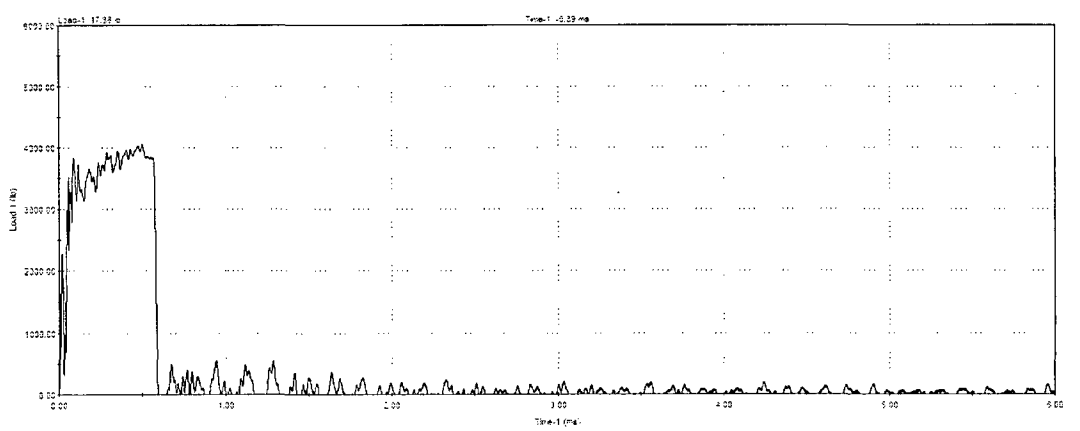
BT79, 275°F



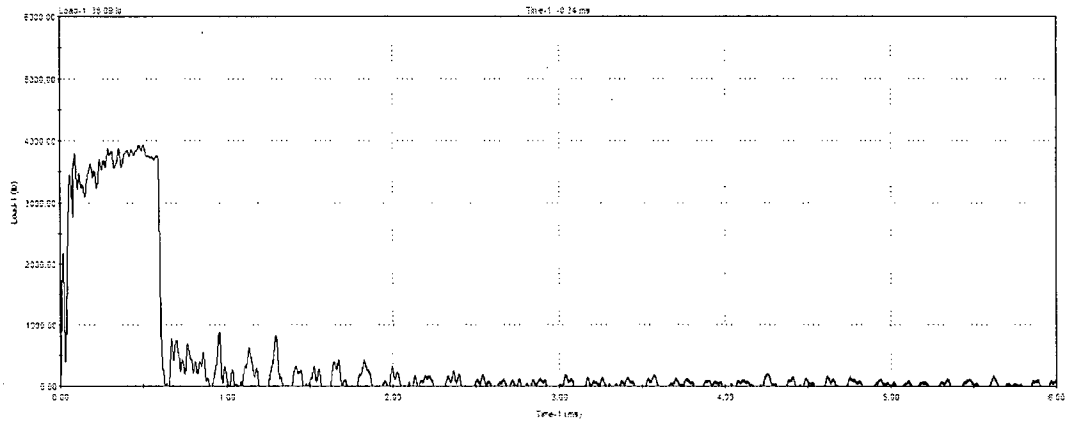
BW90, -50°F



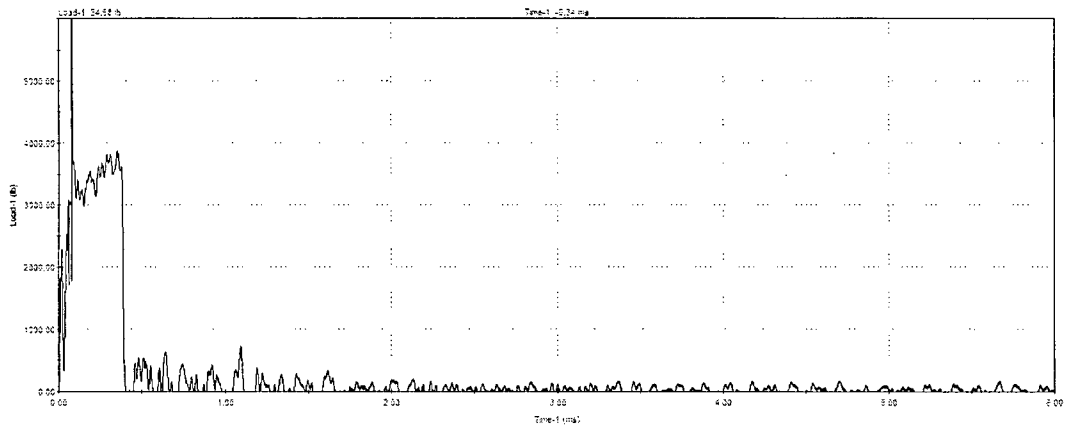
BW79, 0°F



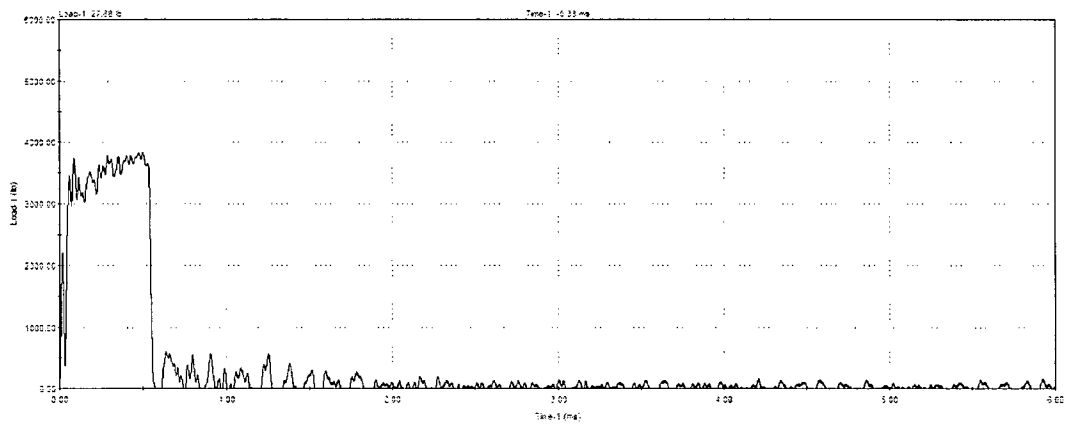
BW81, 0°F



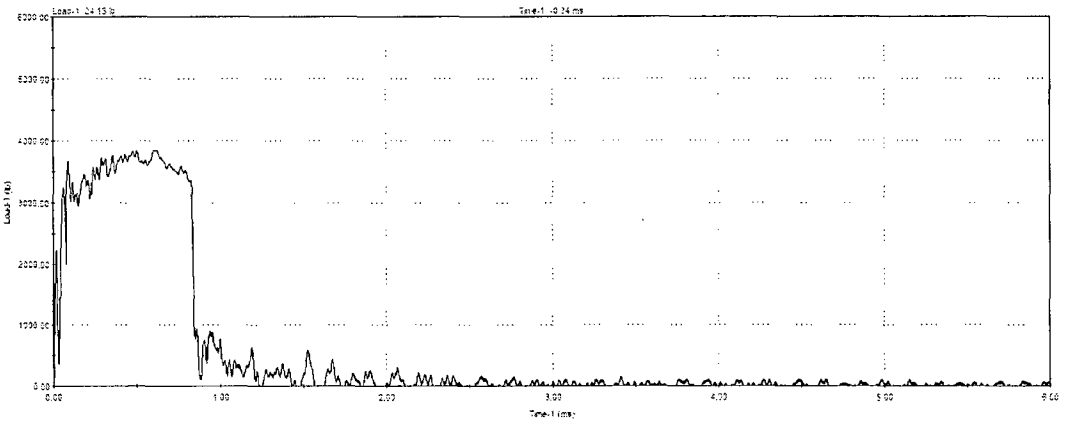
BW76, 5°F



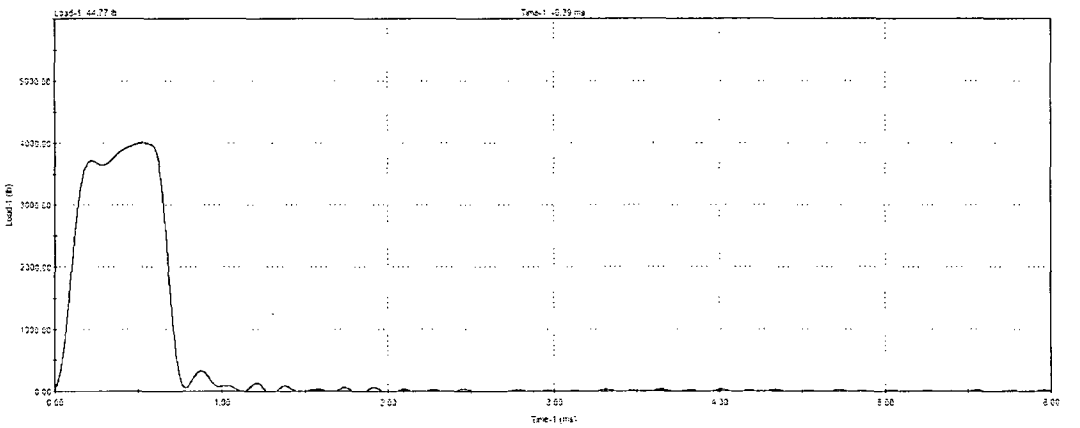
BW82, 5°F



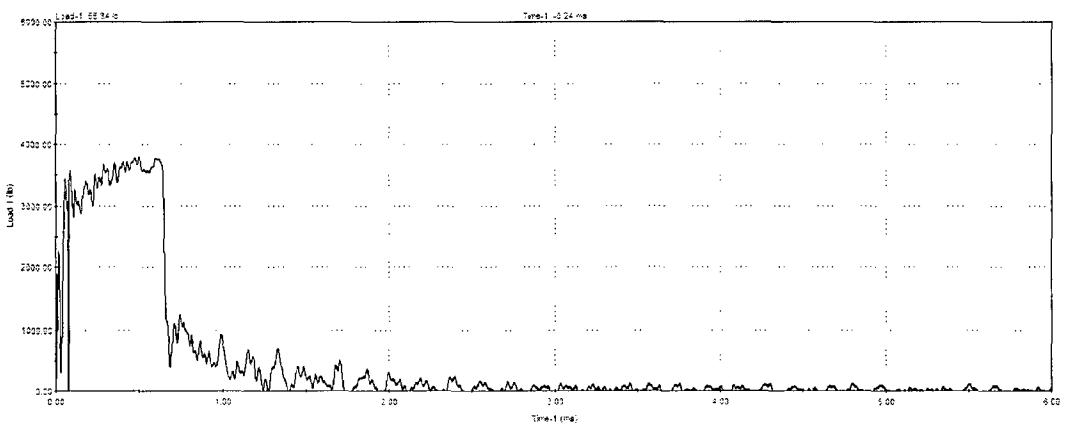
BW86, 10°F



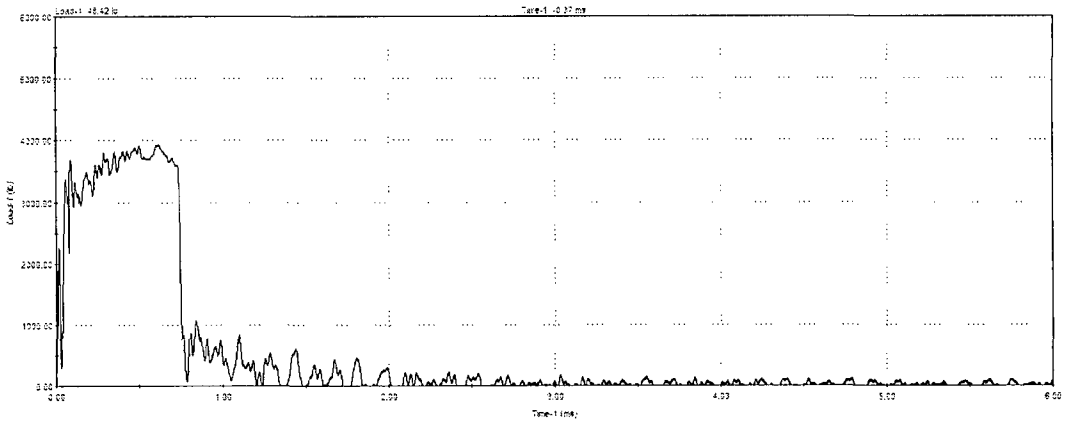
BW85, 20°F



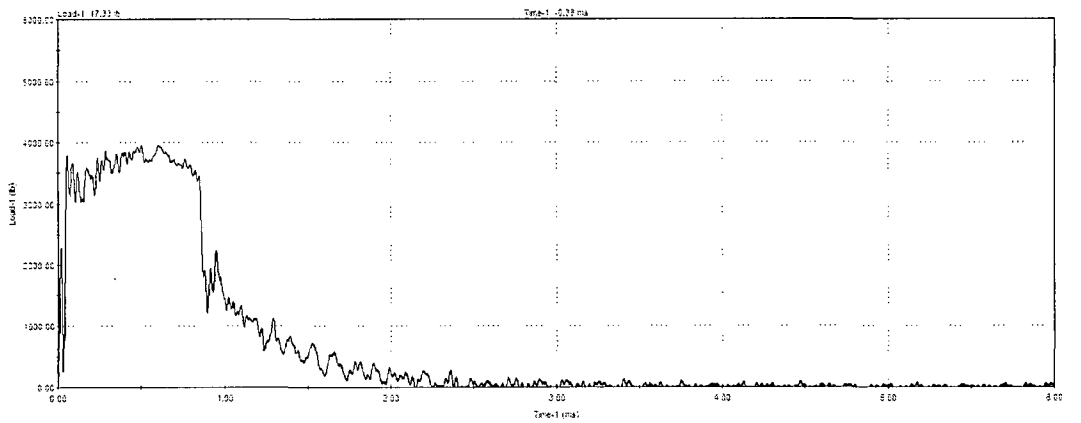
BW84, 25°F



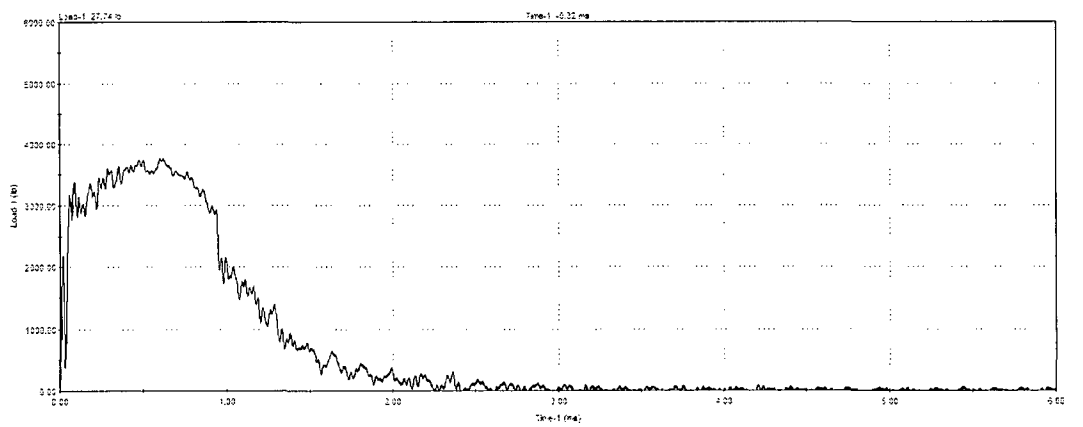
BW87, 50°F



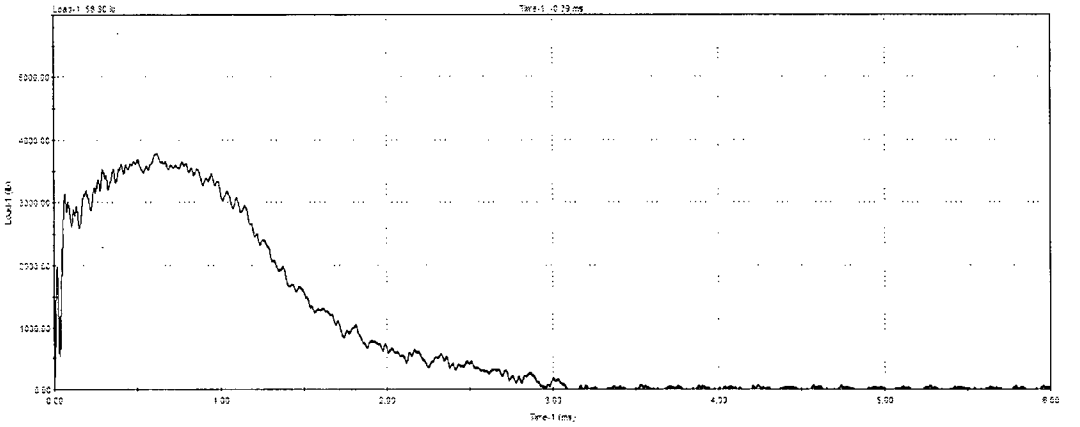
BW78, 60°F



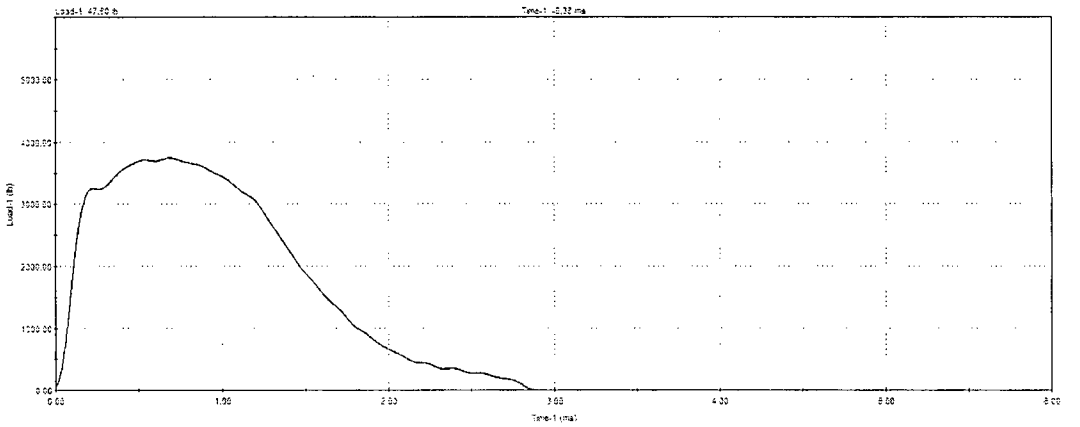
BW77, 75°F



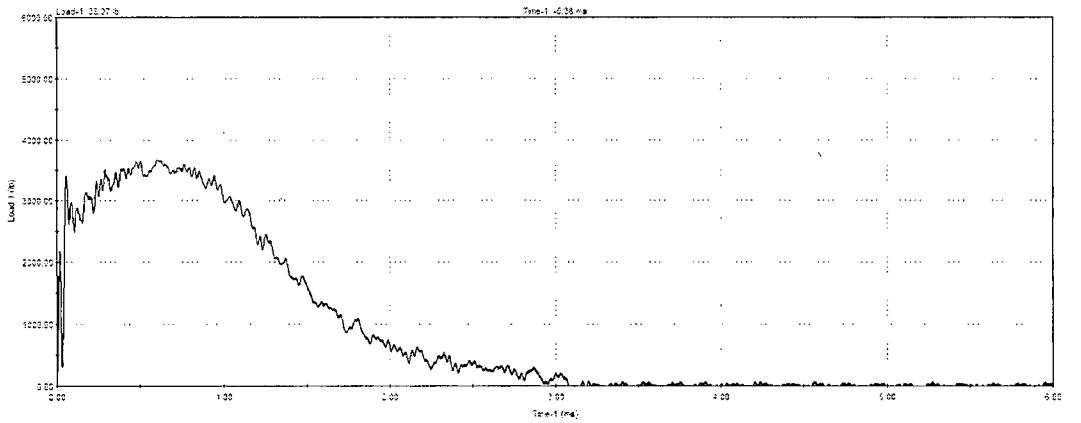
BW80, 130°F



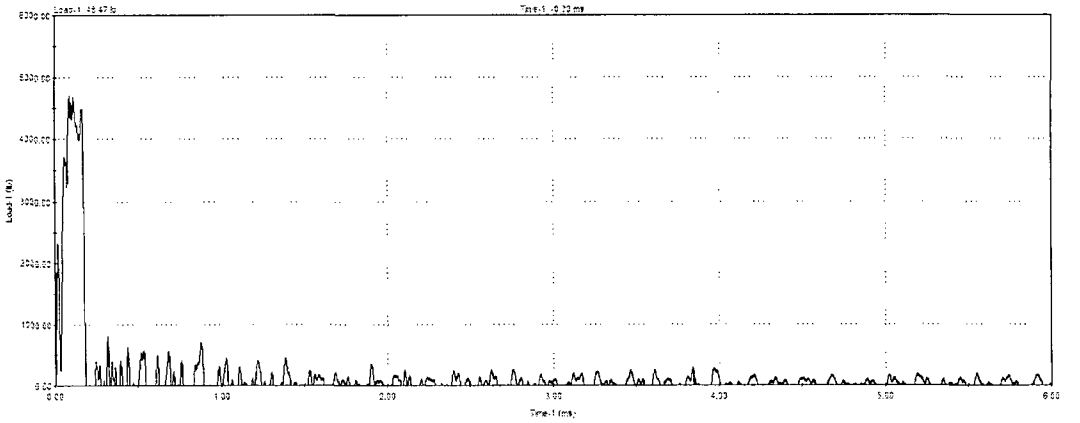
BW88, 225°F



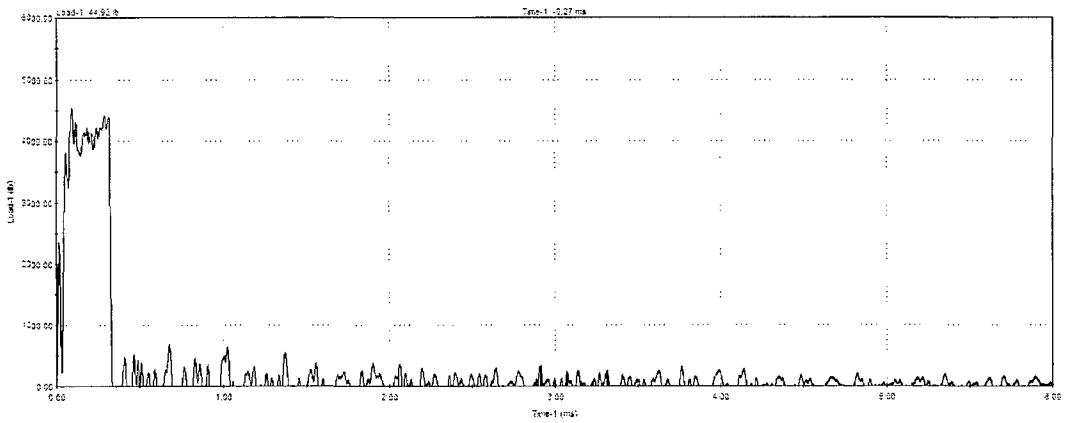
BW89, 250°F



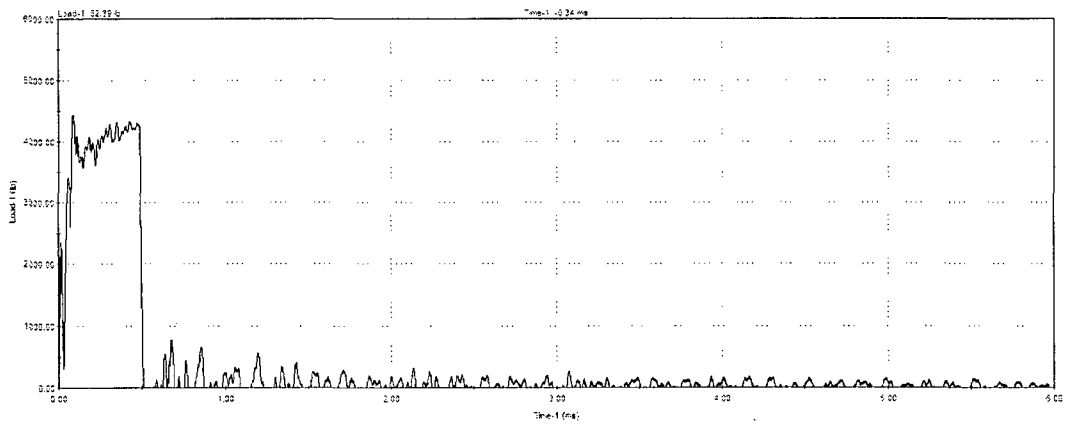
BW83, 275°F



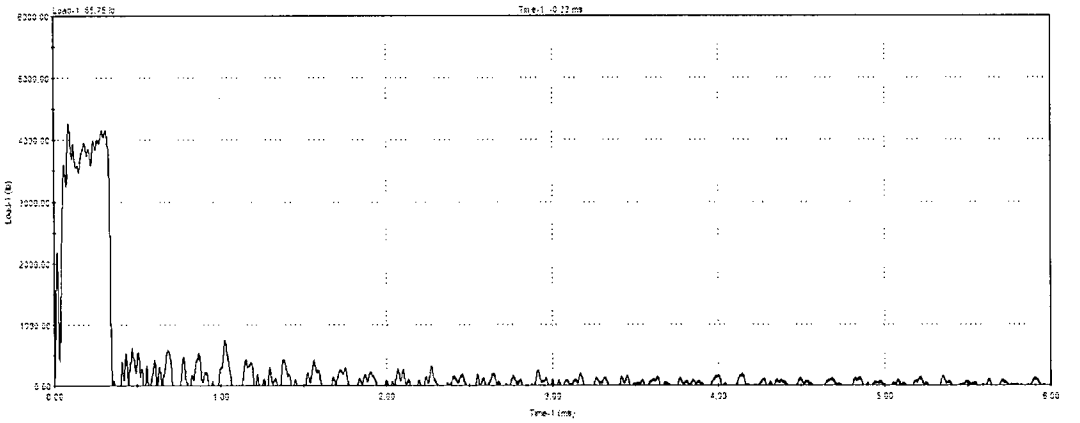
BH85, -150°F



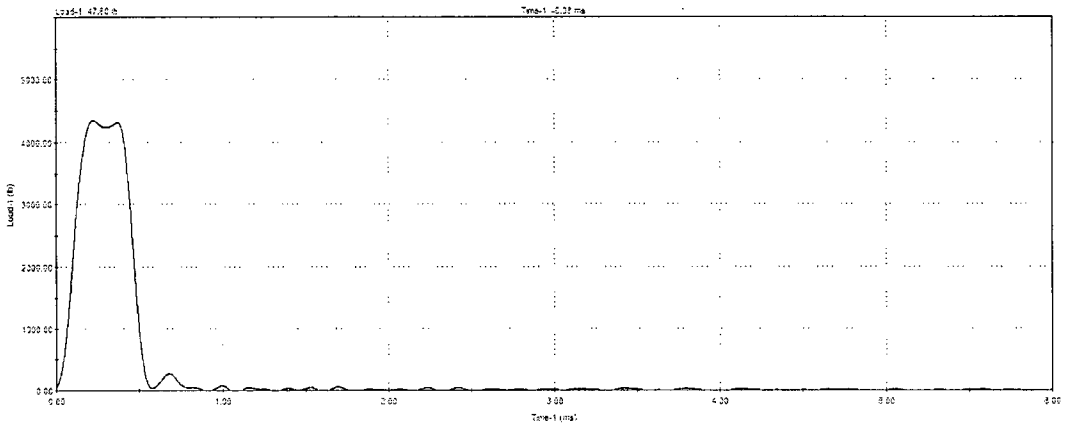
BH84, -110°F



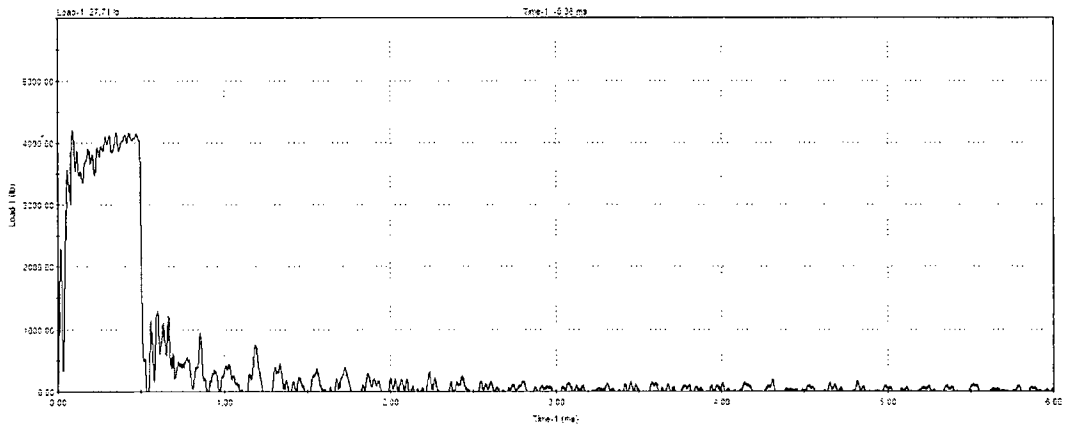
BH76, -90°F



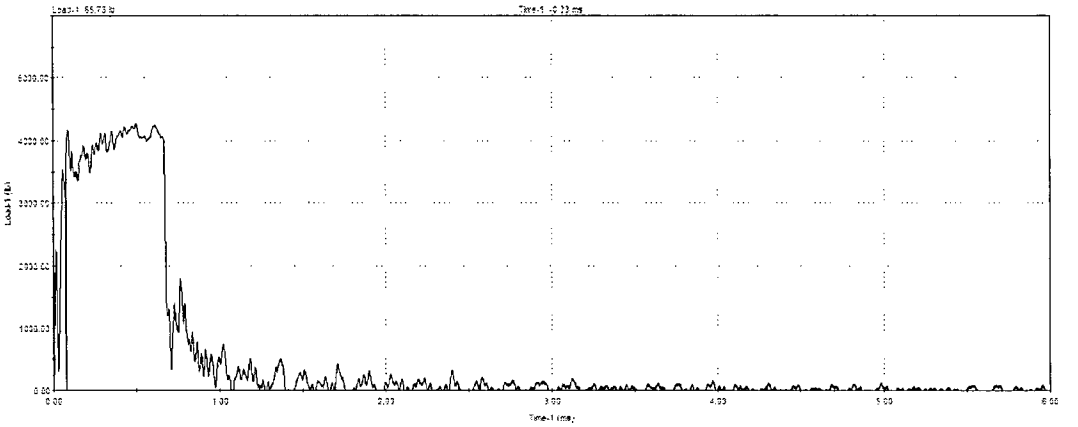
BH88, -80°F



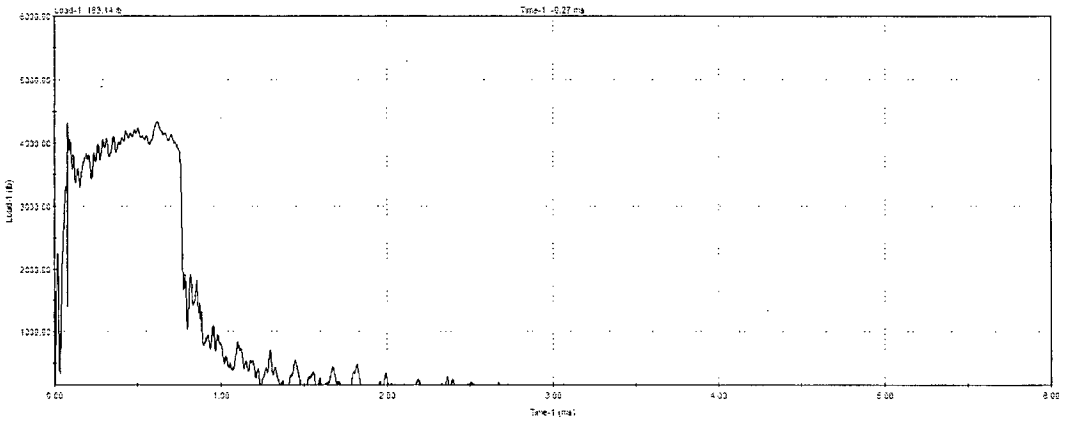
BH77, -75°F



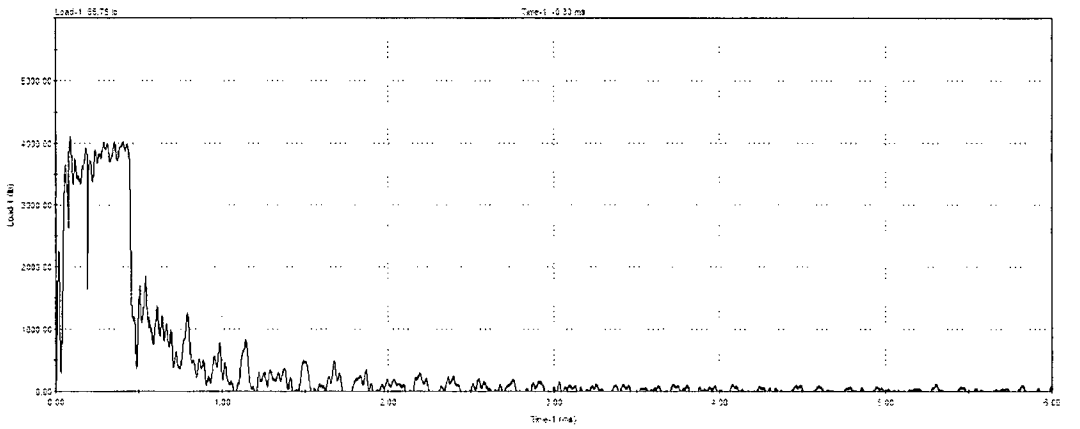
BH82, -60°F



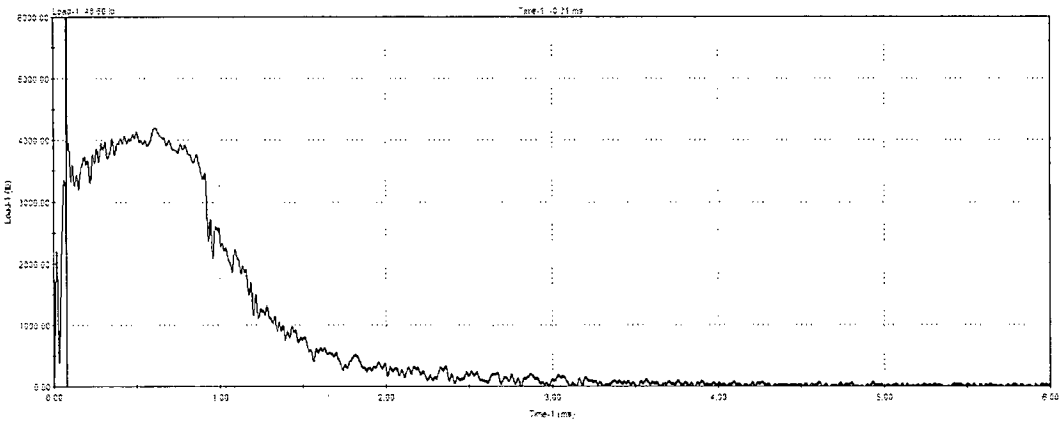
BH78, -50°F



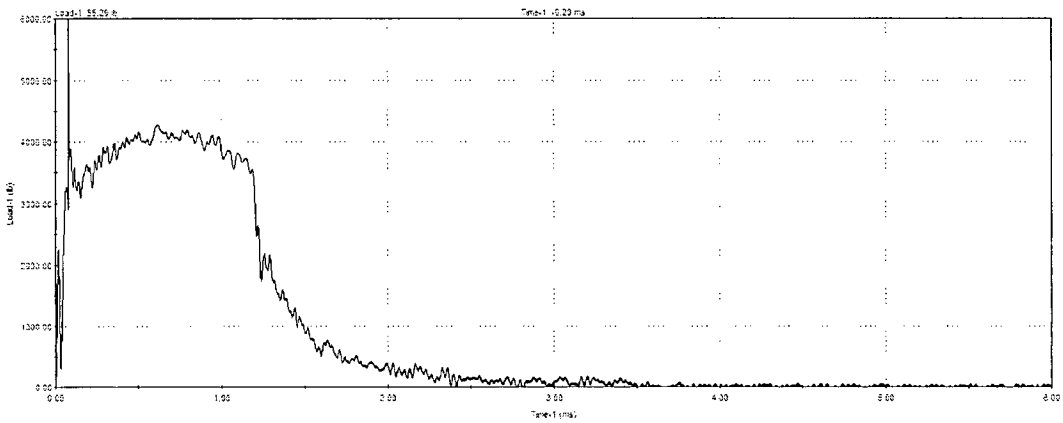
BH79, -35°F



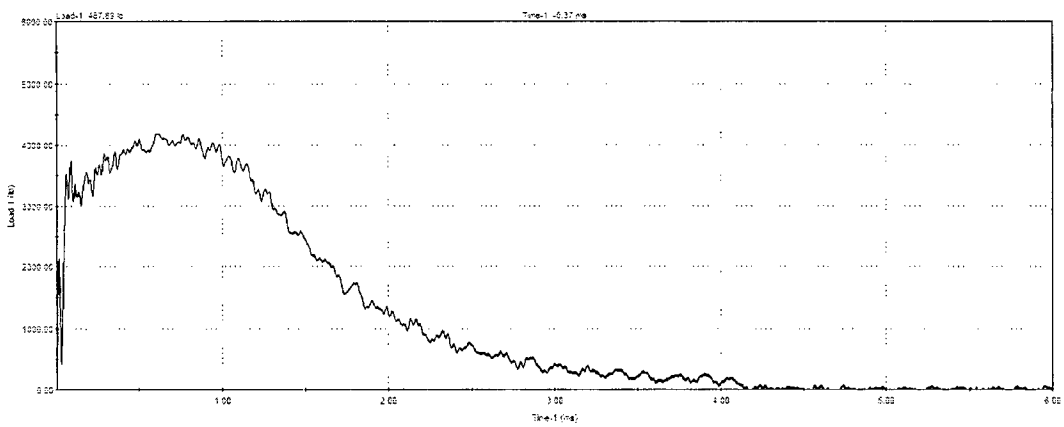
BH89, -25°F



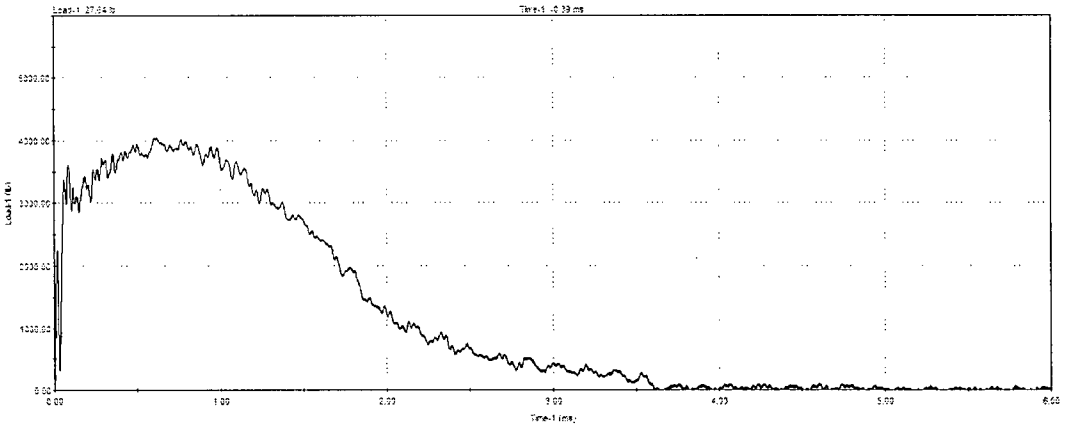
BH90, 0°F



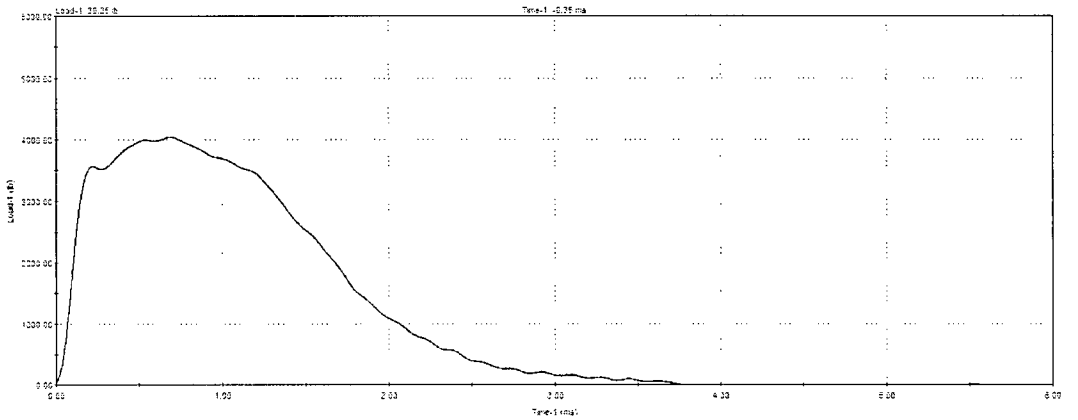
BH83, 25°F



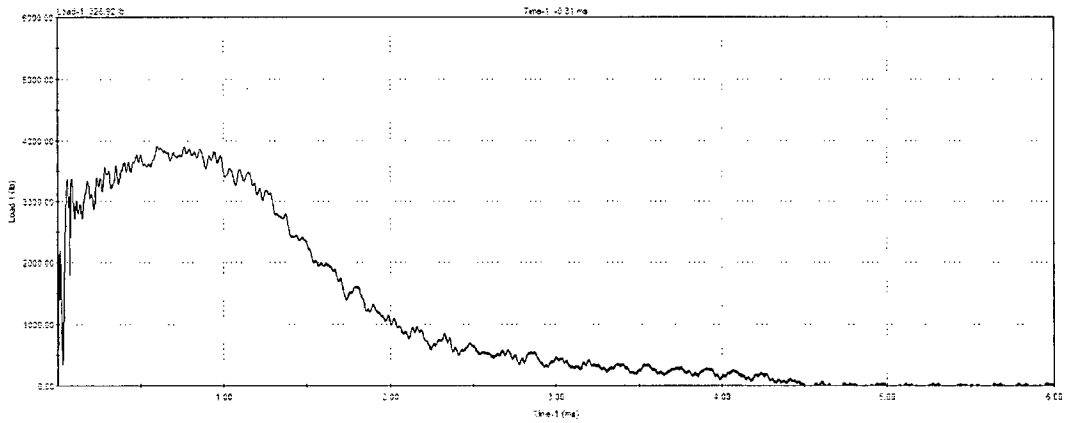
BH81, 60°F



BH86, 110°F



BH80, 150°F



BH87, 175°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 that are used as input for the generation of the Charpy V-notch plots using CVGRAPH, Version 5.3. The definition for USE is given in ASTM E185-82 [Ref. C-1], 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 typically 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 Capsule Z USE values reported in Table C-1 were determined by applying this methodology to the Charpy data tabulated in Tables 5-1 through 5-4 of this report. USE values documented in Table C-1 for the unirradiated material, as well as Capsules U, Y, X, and W, were imported directly from Reference C-2. The USE values reported in Table C-1 were used in generation of the Charpy V-notch curves.

The lower-shelf energy values were fixed at 2.2 ft-lb for all cases. The lower-shelf Lateral Expansion values were fixed at 0.0 mils in order to be consistent with the previous capsule analysis [Ref. C-2].

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

Material	Capsule					
	Unirradiated	U	Y	X	W	Z
Lower Shell Plate B8628-1 Longitudinal Orientation	89	99	100	86	84	89
Lower Shell Plate B8628-1 Transverse Orientation	70	79	73	65	69	68
Surveillance Program Weld Metal (Heat # 87005)	92	98	86	87	87	90
HAZ Material	106	122	114	99	100	112

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

C-2 WCAP-16382-NP, Revision 0, *Analysis of Capsule W from the Southern Nuclear Operating Company, Vogtle Unit 2 Reactor Vessel Radiation Surveillance Program*, T. J. Laubham and R. J. Hagler, January 2005.

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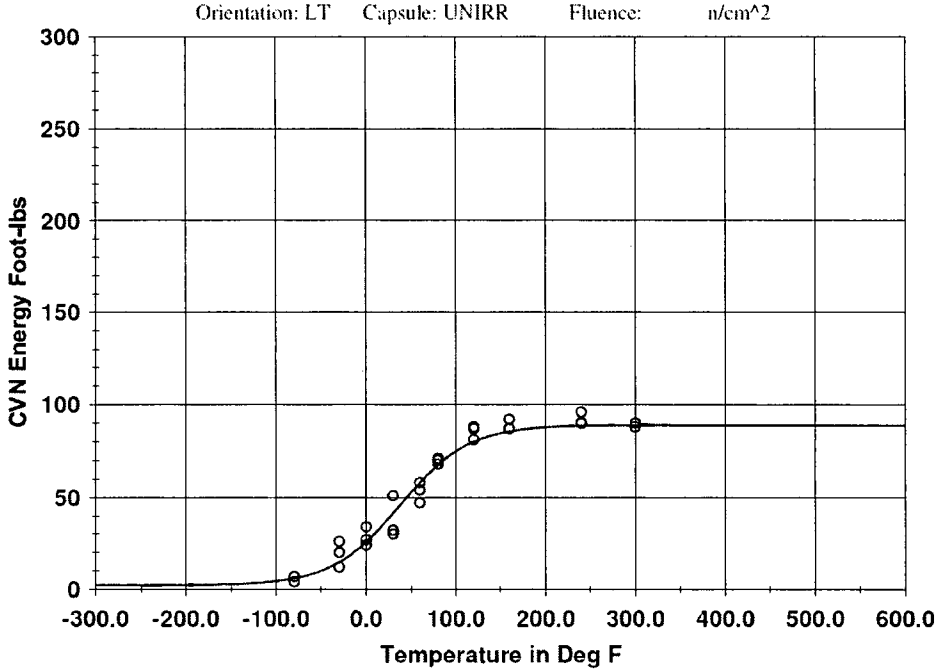
C.2 CVGRAPH VERSION 5.3 INDIVIDUAL PLOTS

Unirradiated Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:17 PM
Page 1
Coefficients of Curve 1
A = 45.6 B = 43.4 C = 76.43 T0 = 37.56 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=89.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=8.8 Deg F Temp@50 ft-lbs=45.4 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	4.00	6.03	-2.03
-80.00	7.00	6.03	.97
-30.00	12.00	14.86	-2.86
-30.00	20.00	14.86	5.14
-30.00	26.00	14.86	11.14
.00	24.00	25.84	-1.84
.00	27.00	25.84	1.16
.00	34.00	25.84	8.16
30.00	30.00	41.32	-11.32

Unirradiated Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

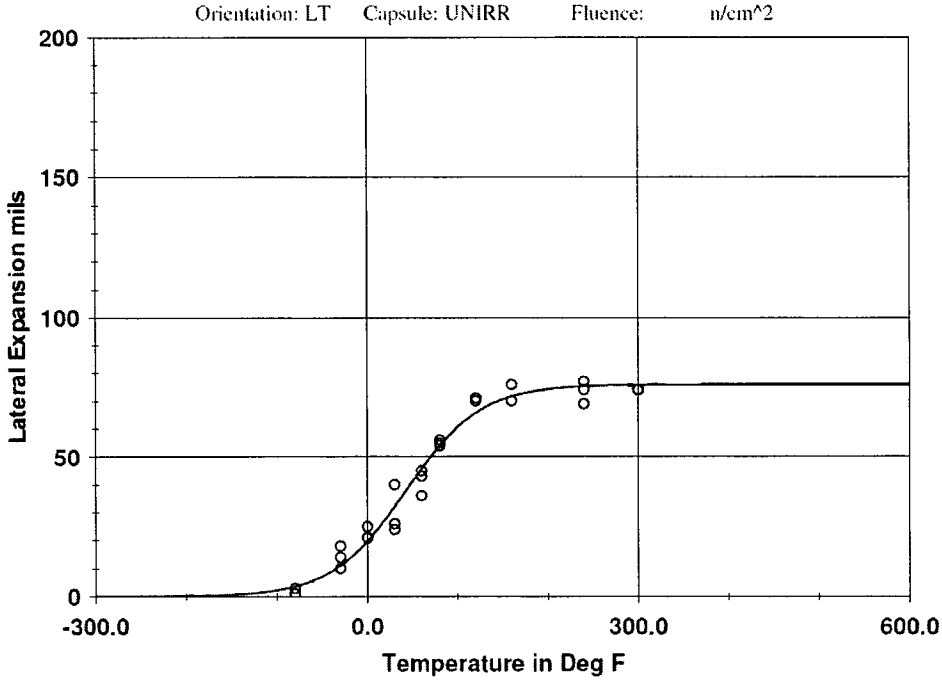
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
30.00	32.00	41.32	-9.32
30.00	51.00	41.32	9.68
60.00	47.00	57.99	-10.99
60.00	54.00	57.99	-3.99
60.00	58.00	57.99	.01
80.00	68.00	67.49	.51
80.00	71.00	67.49	3.51
80.00	70.00	67.49	2.51
120.00	81.00	80.00	1.00
120.00	87.00	80.00	7.00
120.00	88.00	80.00	8.00
160.00	87.00	85.61	1.39
160.00	92.00	85.61	6.39
240.00	90.00	88.57	1.43
240.00	90.00	88.57	1.43
240.00	96.00	88.57	7.43
300.00	88.00	88.91	-.91
300.00	90.00	88.91	1.09

Correlation Coefficient = .982

Unirradiated Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 12:36 PM
Page 1
Coefficients of Curve 1
A = 37.97 B = 37.97 C = 82.49 T0 = 42.82 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=75.9 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=36.4 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	1.00	3.68	-2.68
-80.00	3.00	3.68	-.68
-30.00	10.00	11.10	-1.10
-30.00	14.00	11.10	2.90
-30.00	18.00	11.10	6.90
.00	21.00	19.86	1.14
.00	21.00	19.86	1.14
.00	25.00	19.86	5.14
30.00	24.00	32.12	-8.12

Unirradiated Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

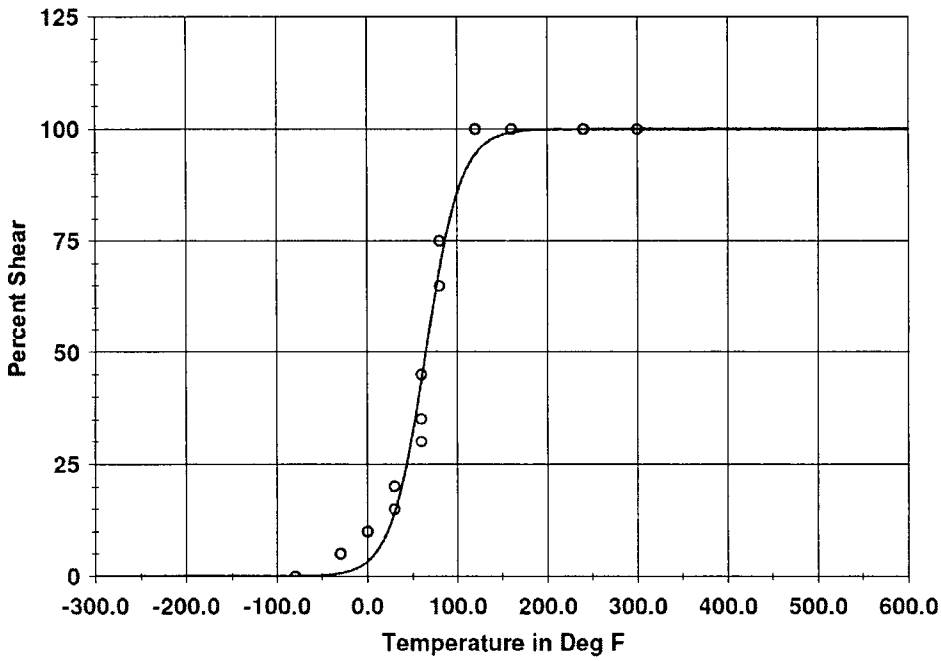
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
30.00	26.00	32.12	-6.12
30.00	40.00	32.12	7.88
60.00	36.00	45.77	-9.77
60.00	43.00	45.77	-2.77
60.00	45.00	45.77	-.77
80.00	56.00	54.01	1.99
80.00	54.00	54.01	-.01
80.00	55.00	54.01	.99
120.00	71.00	65.81	5.19
120.00	70.00	65.81	4.19
120.00	71.00	65.81	5.19
160.00	70.00	71.75	-1.75
160.00	76.00	71.75	4.25
240.00	77.00	75.31	1.69
240.00	74.00	75.31	-1.31
240.00	69.00	75.31	-6.31
300.00	74.00	75.79	-1.79
300.00	74.00	75.79	-1.79

Correlation Coefficient = .985

Unirradiated Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:18 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 38.73 T0 = 64.93 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 65.0
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	.00	.06	-.06
-80.00	.00	.06	-.06
-30.00	5.00	.74	4.26
-30.00	5.00	.74	4.26
-30.00	5.00	.74	4.26
.00	10.00	3.38	6.62
.00	10.00	3.38	6.62
.00	10.00	3.38	6.62
30.00	20.00	14.14	5.86

Unirradiated Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

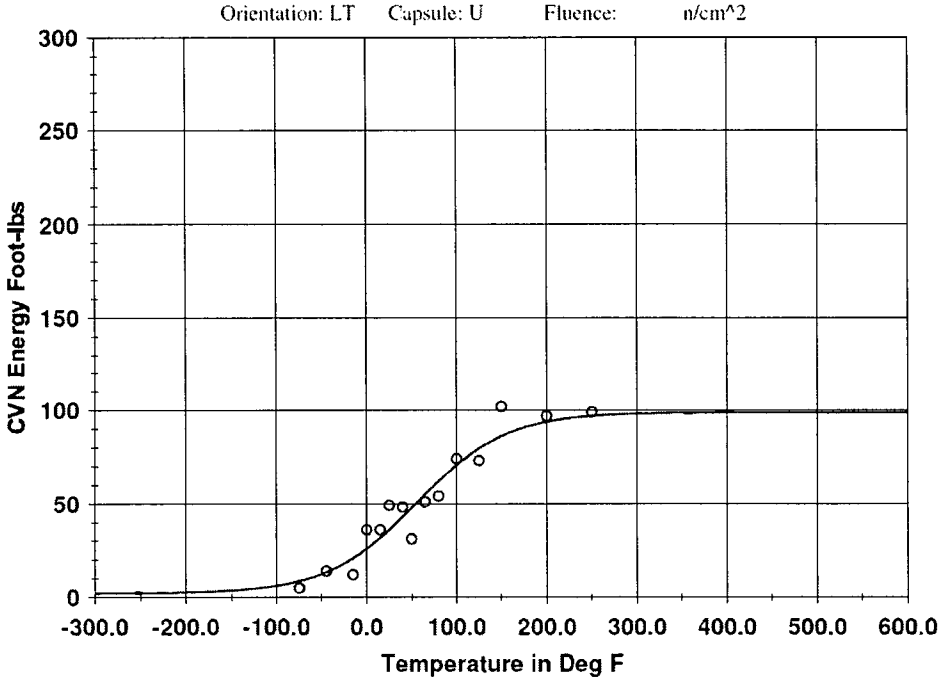
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
30.00	20.00	14.14	5.86
30.00	15.00	14.14	.86
60.00	30.00	43.67	-13.67
60.00	35.00	43.67	-8.67
60.00	45.00	43.67	1.33
80.00	75.00	68.53	6.47
80.00	75.00	68.53	6.47
80.00	65.00	68.53	-3.53
120.00	100.00	94.50	5.50
120.00	100.00	94.50	5.50
120.00	100.00	94.50	5.50
160.00	100.00	99.27	.73
160.00	100.00	99.27	.73
240.00	100.00	99.99	.01
240.00	100.00	99.99	.01
240.00	100.00	99.99	.01
300.00	100.00	100.00	.00
300.00	100.00	100.00	.00

Correlation Coefficient = .994

Capsule U Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:20 PM
Page 1
Coefficients of Curve 1
A = 50.6 B = 48.4 C = 99.74 T0 = 56.04 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=99.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=10.8 Deg F Temp@50 ft-lbs=54.9 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	5.00	8.72	-3.72
-45.00	14.00	13.48	.52
-15.00	12.00	20.98	-8.98
.00	36.00	25.95	10.05
15.00	36.00	31.74	4.26
25.00	49.00	36.01	12.99
40.00	48.00	42.88	5.12
50.00	31.00	47.67	-16.67
65.00	51.00	54.94	-3.94

Capsule U Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: U Fluence: n/cm^2

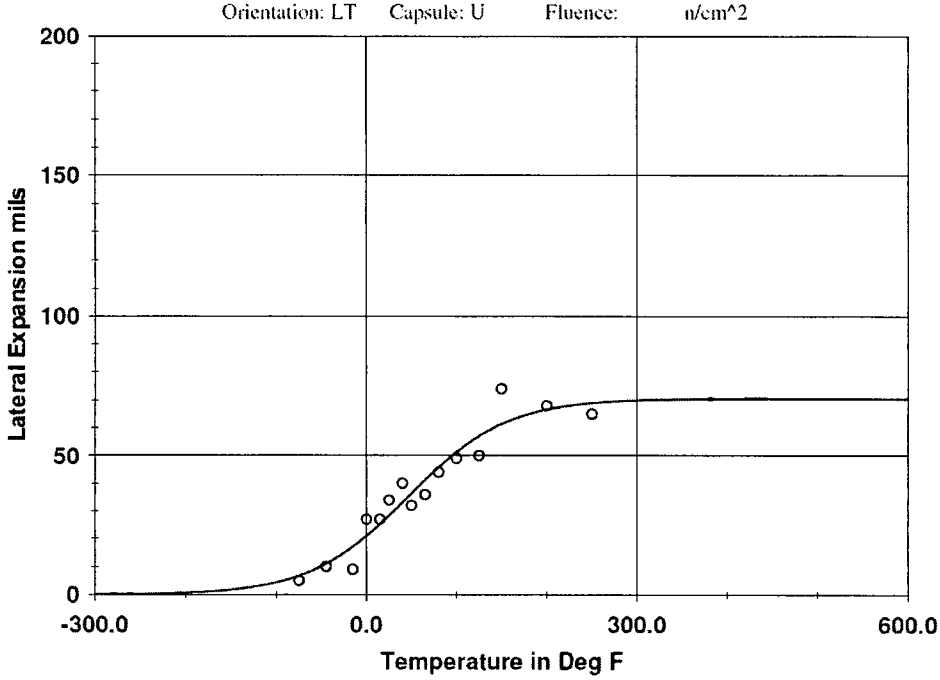
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
80.00	54.00	62.01	-8.01
100.00	74.00	70.65	3.35
125.00	73.00	79.58	-6.58
150.00	102.00	86.23	15.77
200.00	97.00	93.89	3.11
250.00	99.00	97.06	1.94

Correlation Coefficient = .961

Capsule U Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:27 PM
Page 1
Coefficients of Curve 1
A = 35.31 B = 35.31 C = 108.65 T0 = 46.71 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=70.6 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=45.8 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	5.00	6.79	-1.79
-45.00	10.00	11.02	-1.02
-15.00	9.00	17.16	-8.16
.00	27.00	21.00	6.00
15.00	27.00	25.28	1.72
25.00	34.00	28.34	5.66
40.00	40.00	33.13	6.87
50.00	32.00	36.37	-4.37
65.00	36.00	41.19	-5.19

Capsule U Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: U Fluence: n/cm^2

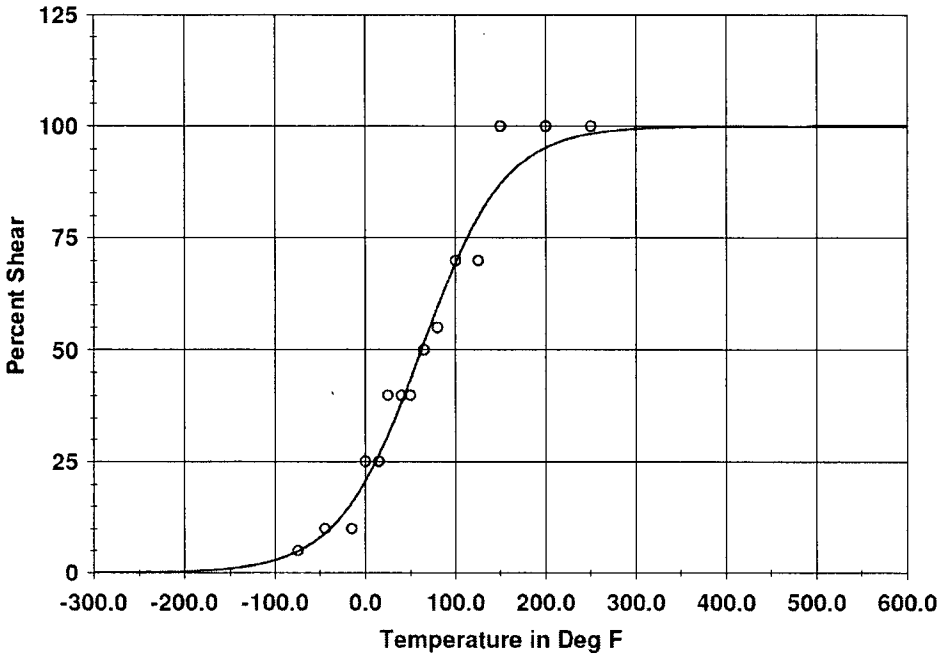
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
80.00	44.00	45.80	-1.80
100.00	49.00	51.36	-2.36
125.00	50.00	57.10	-7.10
150.00	74.00	61.44	12.56
200.00	68.00	66.65	1.35
250.00	65.00	68.98	-3.98

Correlation Coefficient = .962

Capsule U Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:25 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 92.4 T0 = 62.1 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 62.2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	5.00	4.89	.11
-45.00	10.00	8.96	1.04
-15.00	10.00	15.86	-5.86
.00	25.00	20.68	4.32
15.00	25.00	26.51	-1.51
25.00	40.00	30.94	9.06
40.00	40.00	38.26	1.74
50.00	40.00	43.49	-3.49
65.00	50.00	51.57	-1.57

Capsule U Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: U Fluence: n/cm^2

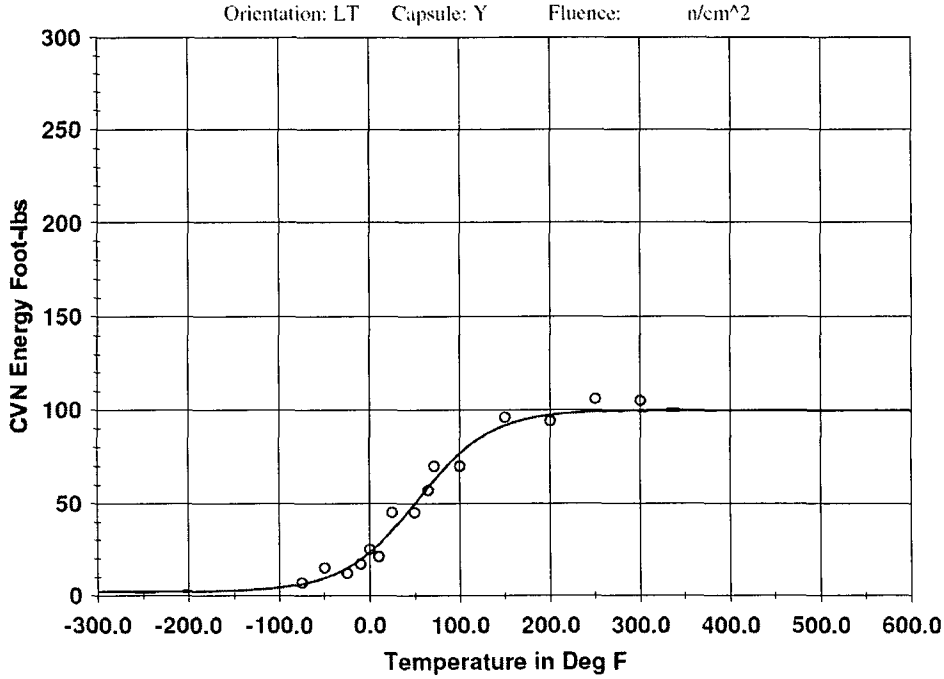
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
80.00	55.00	59.56	-4.56
100.00	70.00	69.43	.57
125.00	70.00	79.60	-9.60
150.00	100.00	87.02	12.98
200.00	100.00	95.19	4.81
250.00	100.00	98.32	1.68

Correlation Coefficient = .985

Capsule Y Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:26 PM
Page 1
Coefficients of Curve 1
A = 51.1 B = 48.9 C = 81.88 T0 = 52.33 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=100.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=14.6 Deg F Temp@50 ft-lbs=50.5 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	7.00	6.37	.63
-50.00	15.00	9.62	5.38
-25.00	12.00	15.05	-3.05
-10.00	17.00	19.72	-2.72
.00	25.00	23.51	1.49
10.00	21.00	27.85	-6.85
25.00	45.00	35.36	9.64
50.00	45.00	49.71	-4.71
65.00	57.00	58.61	-1.61

Capsule Y Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Y Fluence: n/cm^2

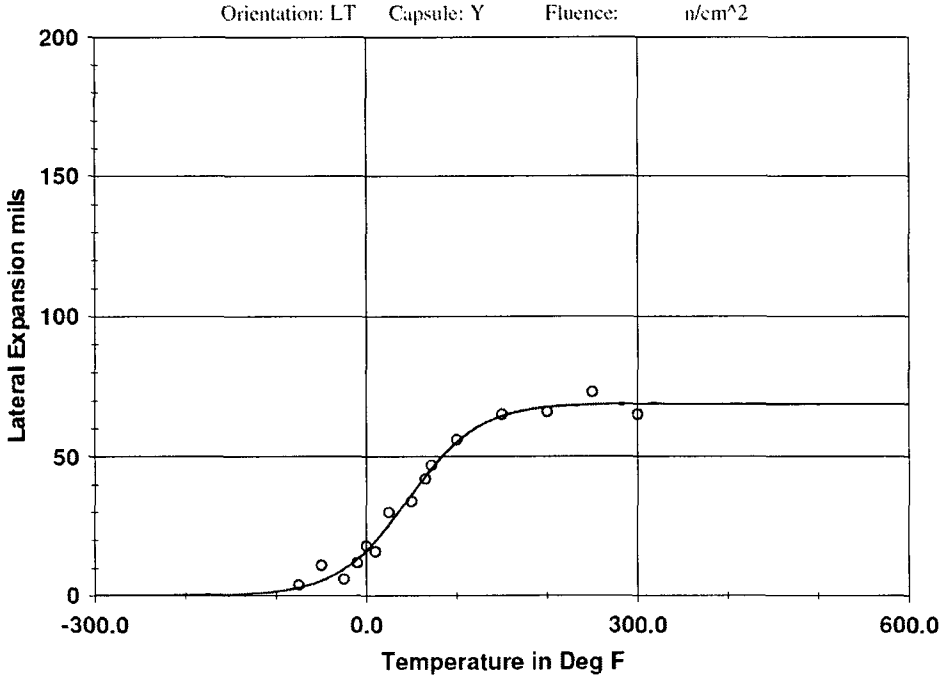
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
72.00	70.00	62.63	7.37
100.00	70.00	76.74	-6.74
150.00	96.00	91.76	4.24
200.00	94.00	97.42	-3.42
250.00	106.00	99.22	6.78
300.00	105.00	99.77	5.23

Correlation Coefficient = .989

Capsule Y Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 01:41 PM
Page 1
Coefficients of Curve 1
A = 34.43 B = 34.43 C = 77.76 T0 = 45.5 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=68.9 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=46.8 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	4.00	2.97	1.03
-50.00	11.00	5.44	5.56
-25.00	6.00	9.66	-3.66
-10.00	12.00	13.32	-1.32
.00	18.00	16.30	1.70
10.00	16.00	19.72	-3.72
25.00	30.00	25.55	4.45
50.00	34.00	36.42	-2.42
65.00	42.00	42.88	-.88

Capsule Y Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Y Fluence: n/cm^2

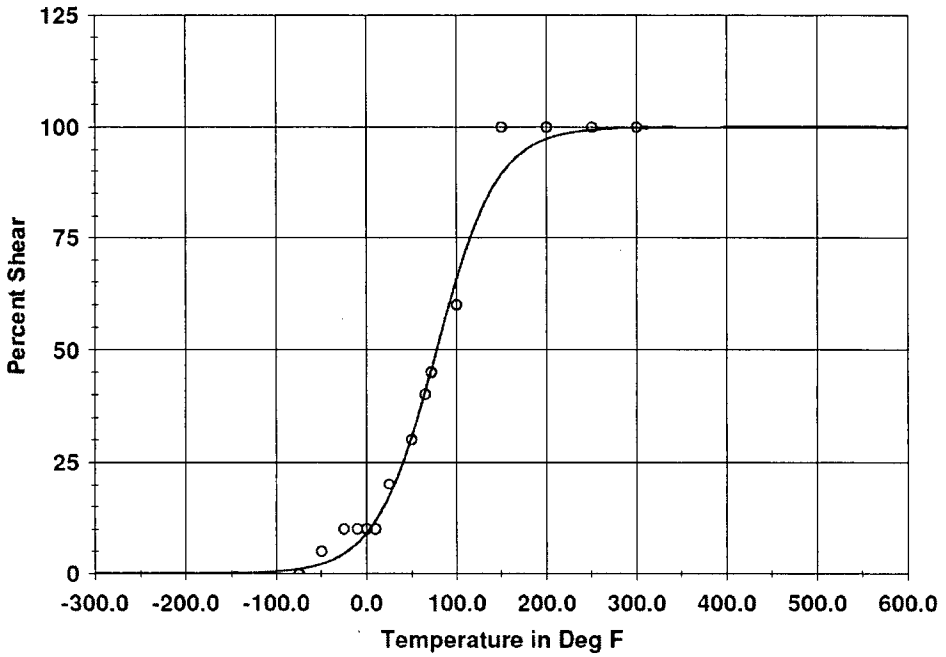
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
72.00	47.00	45.72	1.28
100.00	56.00	55.25	.75
150.00	65.00	64.47	.53
200.00	66.00	67.58	-1.58
250.00	73.00	68.50	4.50
300.00	65.00	68.75	-3.75

Correlation Coefficient = .992

Capsule Y Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:27 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 67.76 T0 = 77.75 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 77.8
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	.00	1.09	-1.09
-50.00	5.00	2.25	2.75
-25.00	10.00	4.60	5.40
-10.00	10.00	6.98	3.02
.00	10.00	9.15	.85
10.00	10.00	11.92	-1.92
25.00	20.00	17.41	2.59
50.00	30.00	30.59	-.59
65.00	40.00	40.70	-.70

Capsule Y Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Y Fluence: n/cm^2

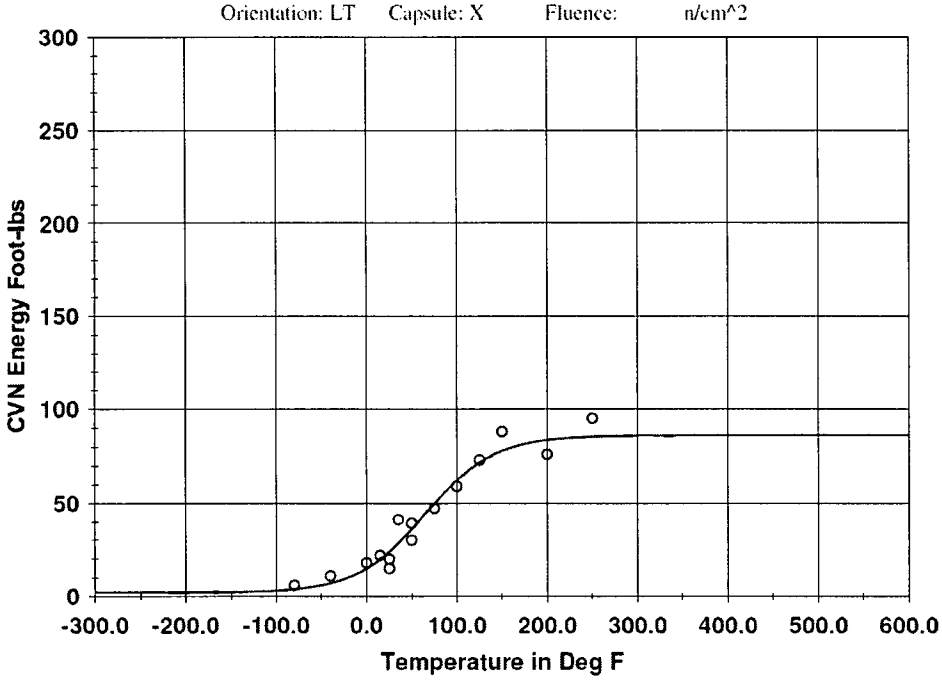
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
72.00	45.00	45.76	-.76
100.00	60.00	65.85	-5.85
150.00	100.00	89.40	10.60
200.00	100.00	97.36	2.64
250.00	100.00	99.38	.62
300.00	100.00	99.86	.14

Correlation Coefficient = .996

Capsule X Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:28 PM
Page 1
Coefficients of Curve 1
A = 44.1 B = 41.9 C = 75.94 T0 = 64.75 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=86.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=38.2 Deg F Temp@50 ft-lbs=75.6 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	6.00	4.01	1.99
-40.00	11.00	7.19	3.81
.00	18.00	15.09	2.91
15.00	22.00	20.00	2.00
25.00	15.00	23.97	-8.97
25.00	20.00	23.97	-3.97
35.00	41.00	28.48	12.52
50.00	30.00	36.06	-6.06
50.00	39.00	36.06	2.94

Capsule X Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: X Fluence: n/cm^2

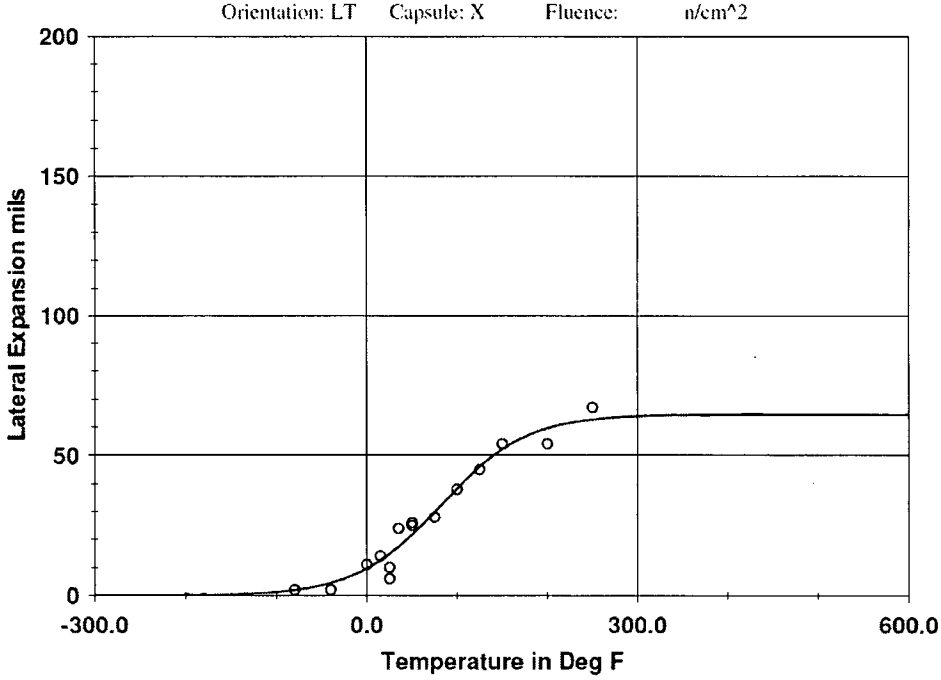
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
75.00	47.00	49.72	-2.72
100.00	59.00	62.26	-3.26
125.00	73.00	71.77	1.23
150.00	88.00	77.97	10.03
200.00	76.00	83.69	-7.69
250.00	95.00	85.37	9.63

Correlation Coefficient = .975

Capsule X Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:28 PM
Page 1
Coefficients of Curve 1
A = 32.28 B = 32.28 C = 94.48 T0 = 82. D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=64.6 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=90.0 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	2.00	2.03	-.03
-40.00	2.00	4.54	-2.54
.00	11.00	9.67	1.33
15.00	14.00	12.58	1.42
25.00	6.00	14.87	-8.87
25.00	10.00	14.87	-4.87
35.00	24.00	17.42	6.58
50.00	26.00	21.74	4.26
50.00	25.00	21.74	3.26

Capsule X Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: X Fluence: n/cm^2

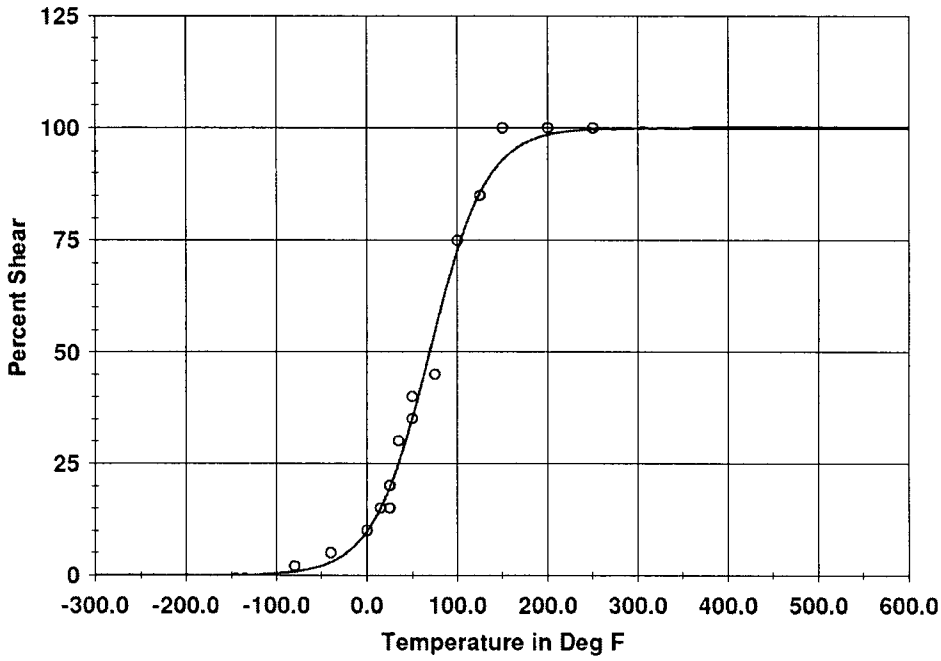
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
75.00	28.00	29.89	-1.89
100.00	38.00	38.35	-.35
125.00	45.00	46.03	-1.03
150.00	54.00	52.18	1.82
200.00	54.00	59.64	-5.64
250.00	67.00	62.76	4.24

Correlation Coefficient = .979

Capsule X Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:29 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 62.44 T0 = 69.29 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 69.3
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	2.00	.83	1.17
-40.00	5.00	2.93	2.07
.00	10.00	9.80	.20
15.00	15.00	14.95	.05
25.00	15.00	19.49	-4.49
25.00	20.00	19.49	.51
35.00	30.00	25.01	4.99
50.00	35.00	35.03	-.03
50.00	40.00	35.03	4.97

Capsule X Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: X Fluence: n/cm^2

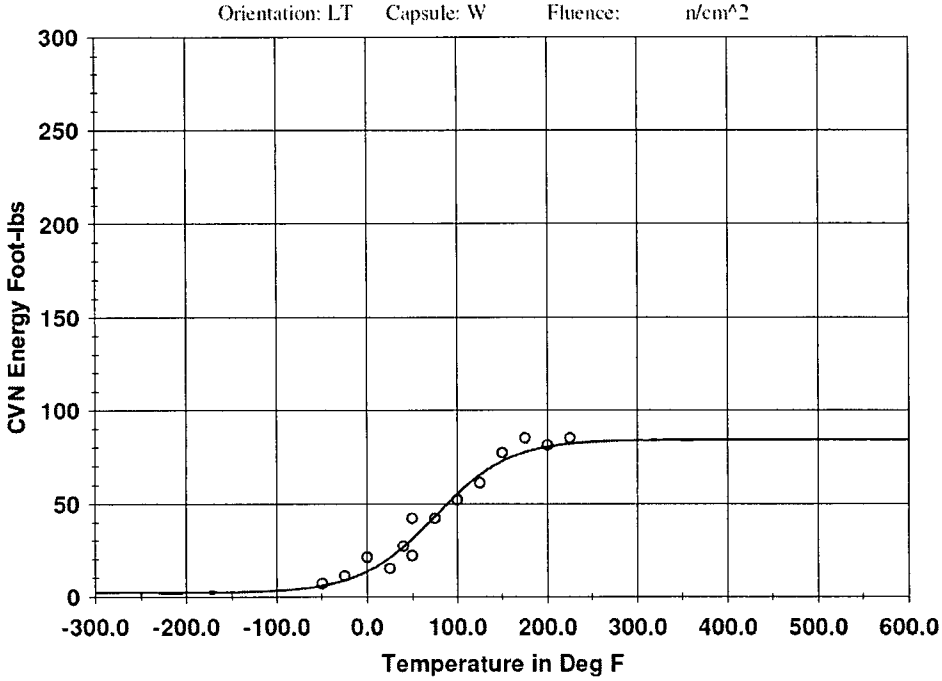
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
75.00	45.00	54.56	-9.56
100.00	75.00	72.78	2.22
125.00	85.00	85.62	-.62
150.00	100.00	92.99	7.01
200.00	100.00	98.50	1.50
250.00	100.00	99.69	.31

Correlation Coefficient = .994

Capsule W Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:30 PM
Page 1
Coefficients of Curve 1
A = 43.1 B = 40.9 C = 81.94 T0 = 74.98 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=84.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=47.8 Deg F Temp@50 ft-lbs=89.0 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	7.00	5.90	1.10
-25.00	11.00	8.76	2.24
.00	21.00	13.51	7.49
25.00	15.00	20.85	-5.85
40.00	27.00	26.63	.37
50.00	42.00	31.00	11.00
50.00	22.00	31.00	-9.00
75.00	42.00	43.11	-1.11
100.00	52.00	55.22	-3.22

Capsule W Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: W Fluence: n/cm^2

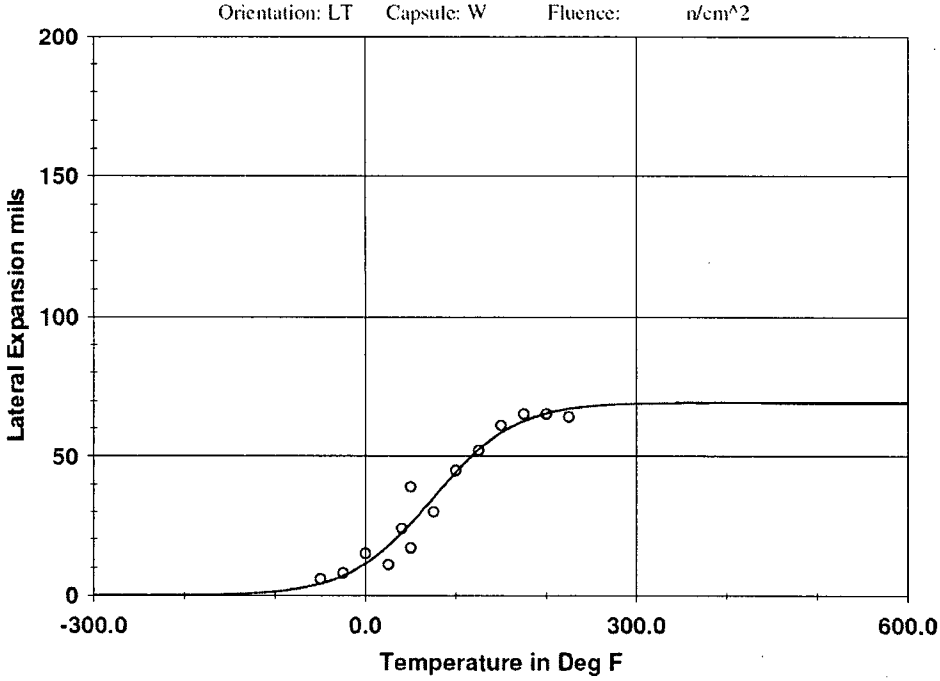
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
125.00	61.00	65.37	-4.37
150.00	77.00	72.70	4.30
175.00	85.00	77.45	7.55
200.00	81.00	80.31	.69
225.00	85.00	81.95	3.05

Correlation Coefficient = .981

Capsule W Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 01:42 PM
Page 1
Coefficients of Curve 1
A = 34.69 B = 34.69 C = 91.2 T0 = 73.83 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=69.4 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=74.7 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	6.00	4.31	1.69
-25.00	8.00	7.13	.87
.00	15.00	11.47	3.53
25.00	11.00	17.71	-6.71
40.00	24.00	22.38	1.62
50.00	39.00	25.83	13.17
50.00	17.00	25.83	-8.83
75.00	30.00	35.14	-5.14
100.00	45.00	44.38	.62

Capsule W Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: W Fluence: n/cm^2

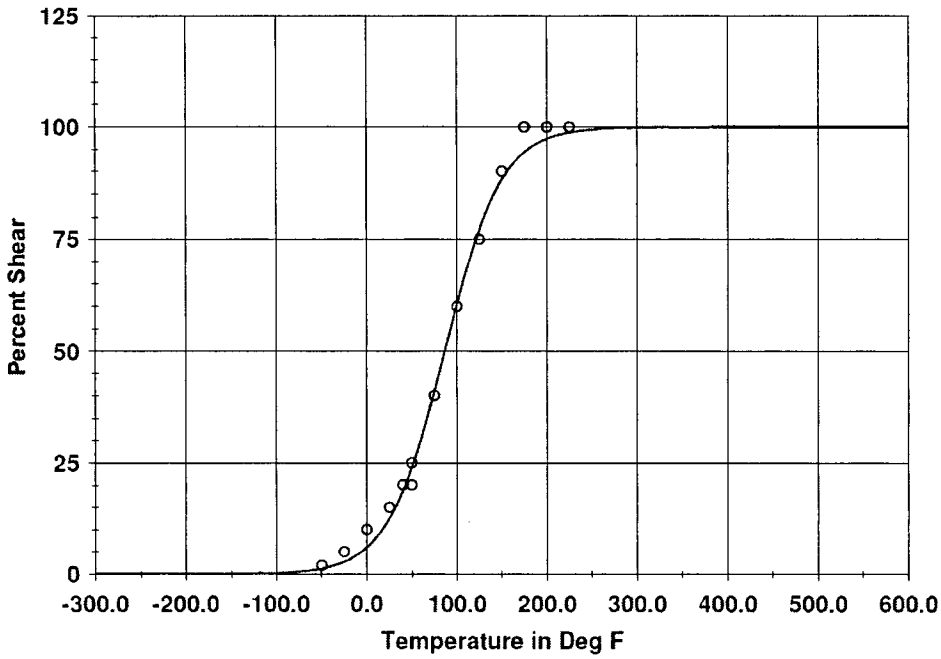
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
125.00	52.00	52.34	-.34
150.00	61.00	58.40	2.60
175.00	65.00	62.58	2.42
200.00	65.00	65.28	-.28
225.00	64.00	66.95	-2.95

Correlation Coefficient = .973

Capsule W Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/26/2010 04:31 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 63.08 T0 = 86.41 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 86.5
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	2.00	1.31	.69
-25.00	5.00	2.84	2.16
.00	10.00	6.07	3.93
25.00	15.00	12.49	2.51
40.00	20.00	18.67	1.33
50.00	25.00	23.97	1.03
50.00	20.00	23.97	-3.97
75.00	40.00	41.06	-1.06
100.00	60.00	60.61	-.61

Capsule W Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: W Fluence: n/cm^2

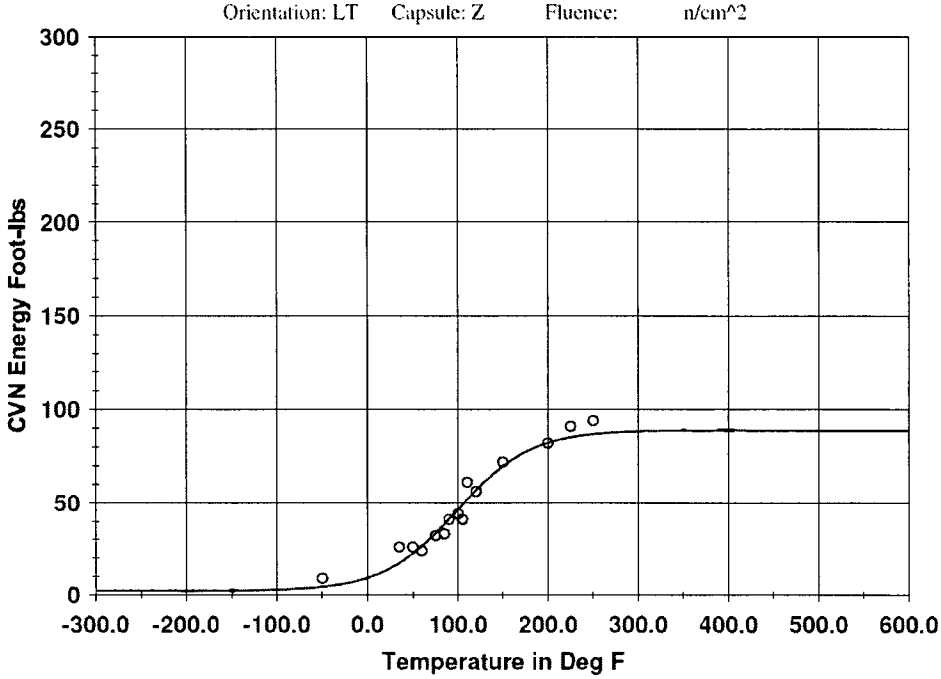
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
125.00	75.00	77.27	-2.27
150.00	90.00	88.25	1.75
175.00	100.00	94.32	5.68
200.00	100.00	97.34	2.66
225.00	100.00	98.78	1.22

Correlation Coefficient = .998

Capsule Z Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 01:19 PM
Page 1
Coefficients of Curve 1
A = 45.6 B = 43.4 C = 81.71 T0 = 98.46 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=89.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=67.8 Deg F Temp@50 ft-lbs=106.8 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	9.00	4.43	4.57
35.00	26.00	17.36	8.64
50.00	26.00	22.51	3.49
60.00	24.00	26.56	-2.56
75.00	32.00	33.47	-1.47
85.00	33.00	38.52	-5.52
90.00	41.00	41.12	-.12
100.00	44.00	46.42	-2.42
105.00	41.00	49.07	-8.07

Capsule Z Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Z Fluence: n/cm^2

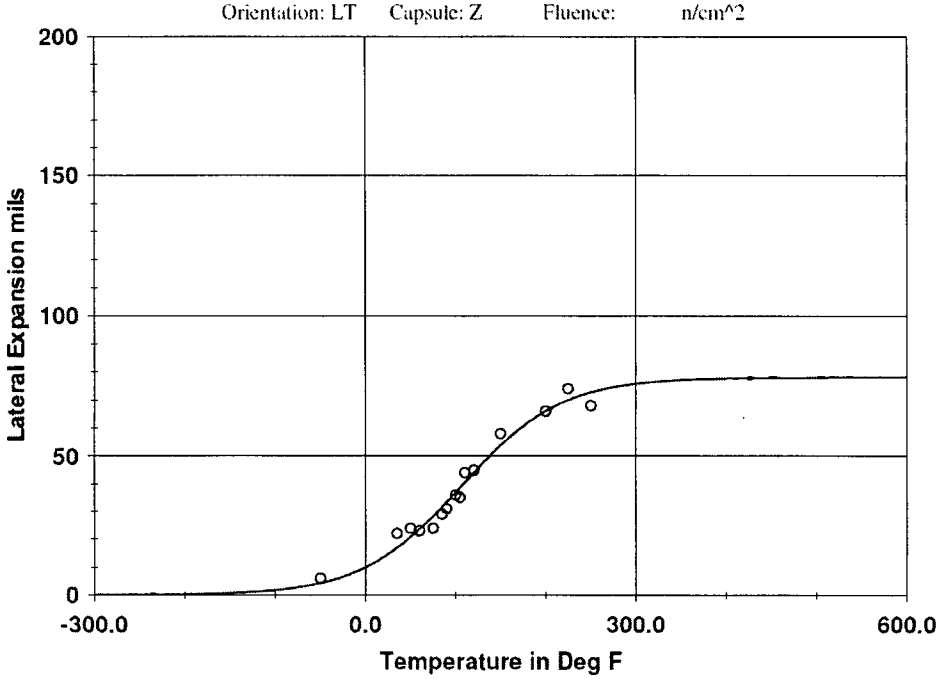
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
110.00	61.00	51.69	9.31
120.00	56.00	56.78	-.78
150.00	72.00	69.84	2.16
200.00	82.00	82.33	-.33
225.00	91.00	85.25	5.75
250.00	94.00	86.92	7.08

Correlation Coefficient = .981

Capsule Z Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:29 PM
Page 1
Coefficients of Curve 1
A = 39.04 B = 39.04 C = 110.35 T0 = 105.85 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=78.1 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=94.4 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	6.00	4.37	1.63
35.00	22.00	16.93	5.07
50.00	24.00	20.81	3.19
60.00	23.00	23.70	-.70
75.00	24.00	28.41	-4.41
85.00	29.00	31.75	-2.75
90.00	31.00	33.47	-2.47
100.00	36.00	36.98	-.98
105.00	35.00	38.74	-3.74

Capsule Z Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Z Fluence: n/cm^2

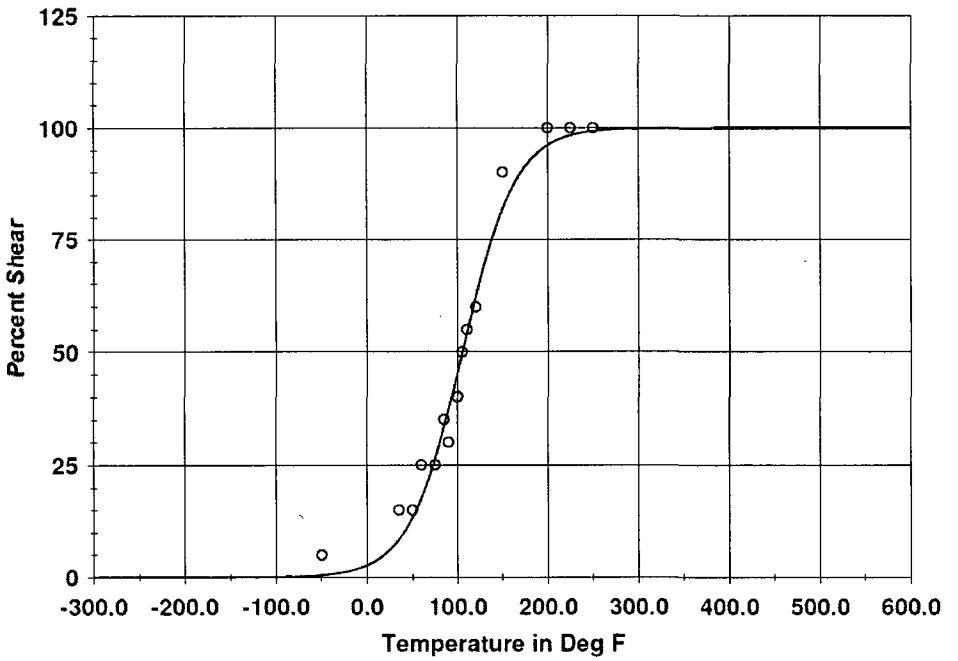
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
110.00	44.00	40.51	3.49
120.00	45.00	44.02	.98
150.00	58.00	53.88	4.12
200.00	66.00	66.09	-.09
225.00	74.00	70.01	3.99
250.00	68.00	72.75	-4.75

Correlation Coefficient = .986

Capsule Z Lower Shell Plate B8628-1 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 01:21 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 58.97 T0 = 105.33 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 105.4
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	5.00	.51	4.49
35.00	15.00	8.43	6.57
50.00	15.00	13.28	1.72
60.00	25.00	17.69	7.31
75.00	25.00	26.33	-1.33
85.00	35.00	33.41	1.59
90.00	30.00	37.29	-7.29
100.00	40.00	45.49	-5.49
105.00	50.00	49.72	.28

Capsule Z Lower Shell Plate B8628-1 (Longitudinal)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: LT Capsule: Z Fluence: n/cm^2

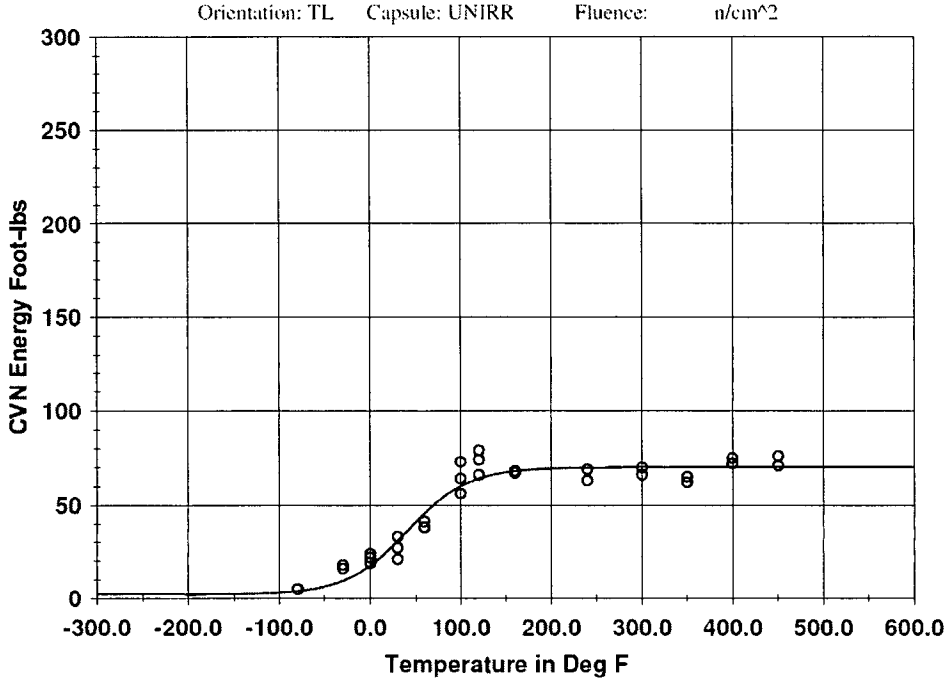
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
110.00	55.00	53.95	1.05
120.00	60.00	62.19	-2.19
150.00	90.00	81.98	8.02
200.00	100.00	96.12	3.88
225.00	100.00	98.30	1.70
250.00	100.00	99.27	.73

Correlation Coefficient = .991

Unirradiated Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 04:30 PM
Page 1
Coefficients of Curve 1
A = 36.1 B = 33.9 C = 67.14 T0 = 40.81 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=70.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=28.6 Deg F Temp@50 ft-lbs=70.1 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	5.00	4.01	.99
-80.00	5.00	4.01	.99
-30.00	16.00	9.54	6.46
-30.00	18.00	9.54	8.46
.00	19.00	17.71	1.29
.00	22.00	17.71	4.29
.00	24.00	17.71	6.29
30.00	21.00	30.69	-9.69
30.00	27.00	30.69	-3.69

Unirradiated Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: UNIRR Fluence: n/cm^2

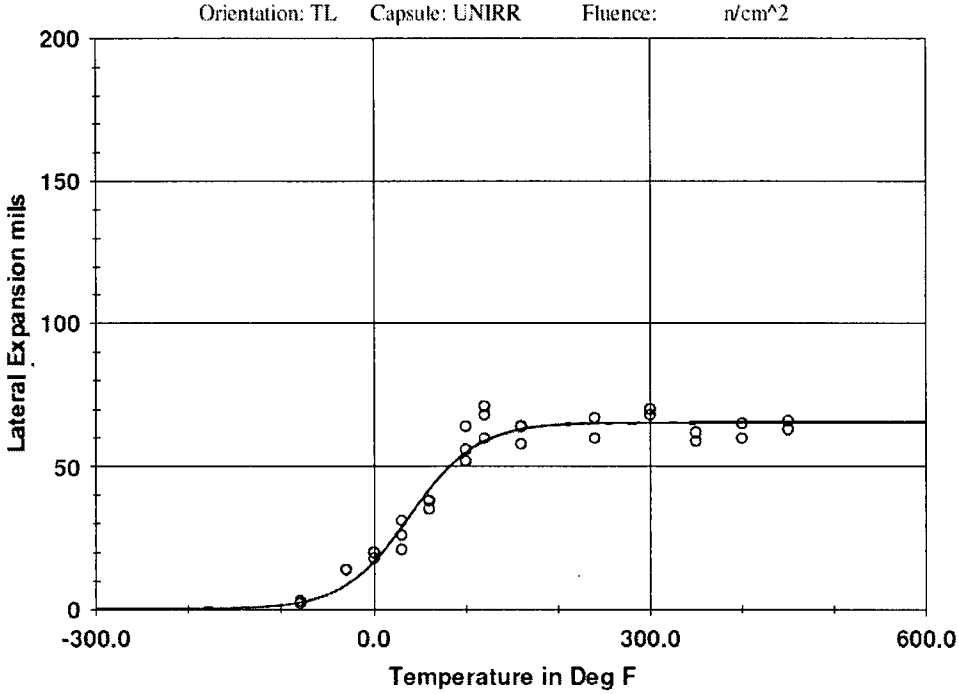
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
30.00	33.00	30.69	2.31
60.00	38.00	45.54	-7.54
60.00	38.00	45.54	-7.54
60.00	41.00	45.54	-4.54
100.00	56.00	60.08	-4.08
100.00	64.00	60.08	3.92
100.00	73.00	60.08	12.92
120.00	66.00	64.15	1.85
120.00	74.00	64.15	9.85
120.00	79.00	64.15	14.85
160.00	67.00	68.11	-1.11
160.00	68.00	68.11	-.11
160.00	68.00	68.11	-.11
240.00	63.00	69.82	-6.82
240.00	69.00	69.82	-.82
300.00	66.00	69.97	-3.97
300.00	70.00	69.97	.03
350.00	62.00	69.99	-7.99
350.00	65.00	69.99	-4.99
400.00	72.00	70.00	2.00
400.00	75.00	70.00	5.00
450.00	71.00	70.00	1.00
450.00	76.00	70.00	6.00

Correlation Coefficient = .968

Unirradiated Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/03/2011 05:20 PM
Page 1
Coefficients of Curve 1
A = 32.67 B = 32.67 C = 72.88 T0 = 38.79 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=65.3 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=44.0 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	2.00	2.42	-.42
-80.00	3.00	2.42	.58
-30.00	14.00	8.59	5.41
-30.00	14.00	8.59	5.41
.00	18.00	16.76	1.24
.00	20.00	16.76	3.24
.00	20.00	16.76	3.24
30.00	21.00	28.75	-7.75
30.00	26.00	28.75	-2.75

Unirradiated Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: UNIRR Fluence: n/cm^2

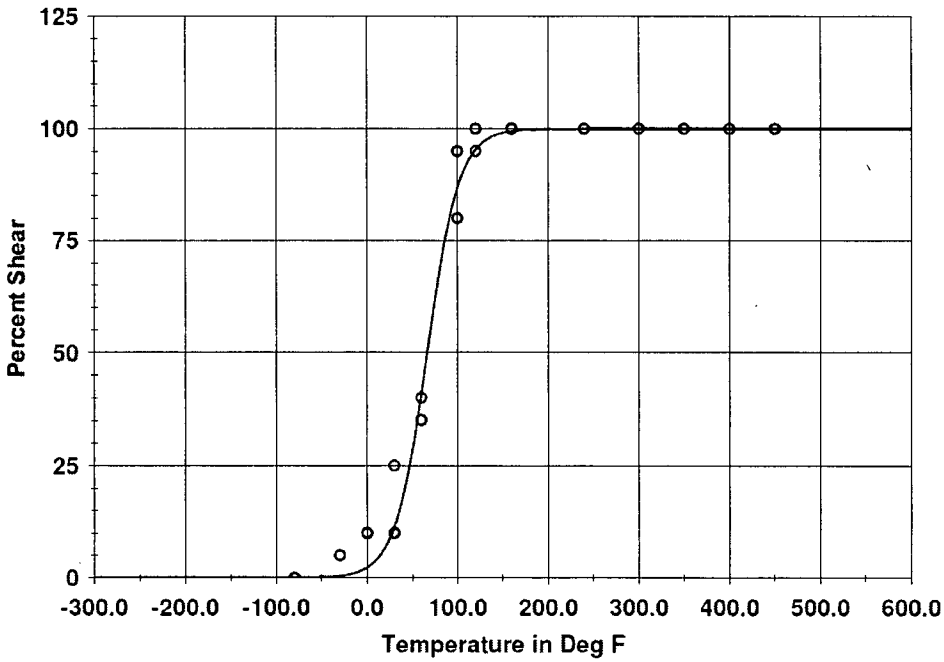
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
30.00	31.00	28.75	2.25
60.00	35.00	41.92	-6.92
60.00	38.00	41.92	-3.92
60.00	38.00	41.92	-3.92
100.00	52.00	55.08	-3.08
100.00	56.00	55.08	.92
100.00	64.00	55.08	8.92
120.00	60.00	58.99	1.01
120.00	68.00	58.99	9.01
120.00	71.00	58.99	12.01
160.00	58.00	63.08	-5.08
160.00	64.00	63.08	.92
160.00	64.00	63.08	.92
240.00	60.00	65.08	-5.08
240.00	67.00	65.08	1.92
300.00	68.00	65.29	2.71
300.00	70.00	65.29	4.71
350.00	59.00	65.33	-6.33
350.00	62.00	65.33	-3.33
400.00	65.00	65.34	-.34
400.00	60.00	65.34	-5.34
450.00	63.00	65.34	-2.34
450.00	66.00	65.34	.66

Correlation Coefficient = .977

Unirradiated Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 04:34 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 35.5 T0 = 66.46 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 66.5
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	.00	.03	-.03
-80.00	.00	.03	-.03
-30.00	5.00	.43	4.57
-30.00	5.00	.43	4.57
.00	10.00	2.31	7.69
.00	10.00	2.31	7.69
.00	10.00	2.31	7.69
30.00	25.00	11.36	13.64
30.00	10.00	11.36	-1.36

Unirradiated Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: UNIRR Fluence: n/cm^2

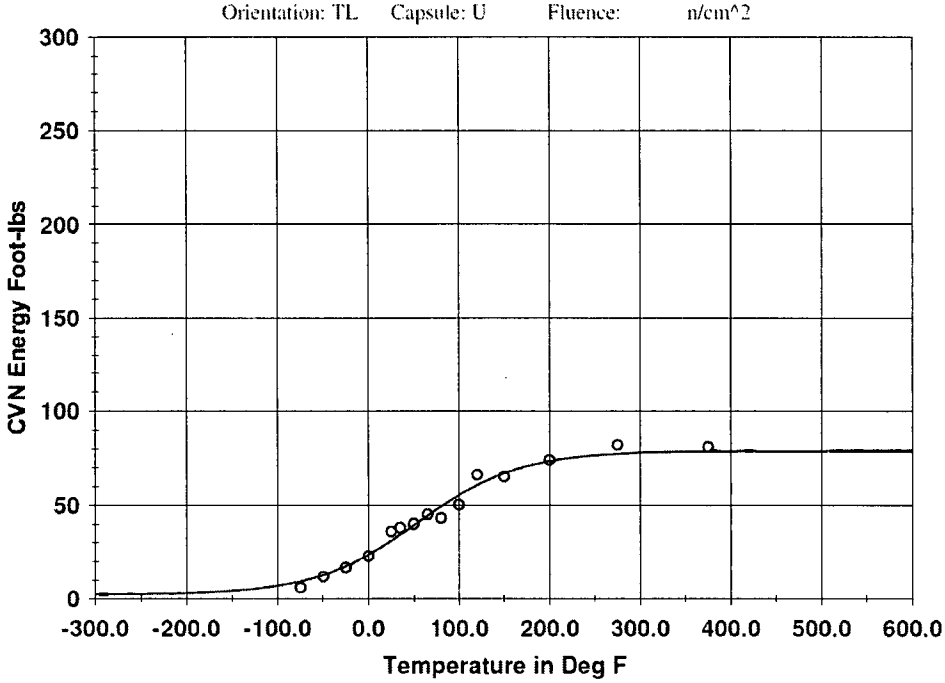
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
30.00	10.00	11.36	-1.36
60.00	35.00	40.99	-5.99
60.00	40.00	40.99	-.99
60.00	35.00	40.99	-5.99
100.00	80.00	86.87	-6.87
100.00	95.00	86.87	8.13
100.00	95.00	86.87	8.13
120.00	95.00	95.33	-.33
120.00	100.00	95.33	4.67
120.00	100.00	95.33	4.67
160.00	100.00	99.49	.51
160.00	100.00	99.49	.51
160.00	100.00	99.49	.51
240.00	100.00	99.99	.01
240.00	100.00	99.99	.01
300.00	100.00	100.00	.00
300.00	100.00	100.00	.00
350.00	100.00	100.00	.00
350.00	100.00	100.00	.00
400.00	100.00	100.00	.00
400.00	100.00	100.00	.00
450.00	100.00	100.00	.00
450.00	100.00	100.00	.00

Correlation Coefficient = .995

Capsule U Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 04:39 PM
Page 1
Coefficients of Curve 1
A = 40.6 B = 38.4 C = 114.68 T0 = 53.93 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=21.5 Deg F Temp@50 ft-lbs=82.6 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	6.00	9.53	-3.53
-50.00	12.00	12.98	-.98
-25.00	17.00	17.68	-.68
.00	23.00	23.77	-.77
25.00	36.00	31.11	4.89
35.00	38.00	34.32	3.68
50.00	40.00	39.29	.71
65.00	45.00	44.30	.70
80.00	43.00	49.18	-6.18

Capsule U Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: U Fluence: n/cm^2

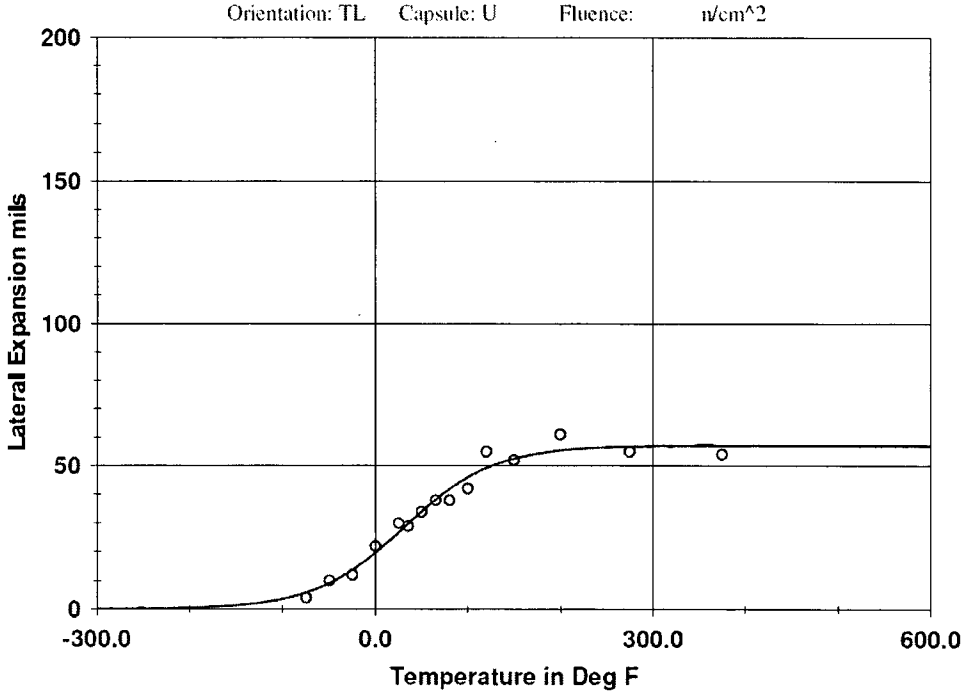
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
100.00	50.00	55.25	-5.25
120.00	66.00	60.56	5.44
150.00	65.00	66.89	-1.89
200.00	74.00	73.43	.57
275.00	82.00	77.41	4.59
375.00	81.00	78.72	2.28

Correlation Coefficient = .990

Capsule U Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/03/2011 05:22 PM
Page 1
Coefficients of Curve 1
A = 28.55 B = 28.55 C = 97.06 T0 = 30.7 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=57.1 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=53.1 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	4.00	5.81	-1.81
-50.00	10.00	9.10	.90
-25.00	12.00	13.76	-1.76
.00	22.00	19.81	2.19
25.00	30.00	26.88	3.12
35.00	29.00	29.81	-.81
50.00	34.00	34.15	-.15
65.00	38.00	38.24	-.24
80.00	38.00	41.92	-3.92

Capsule U Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: U Fluence: n/cm^2

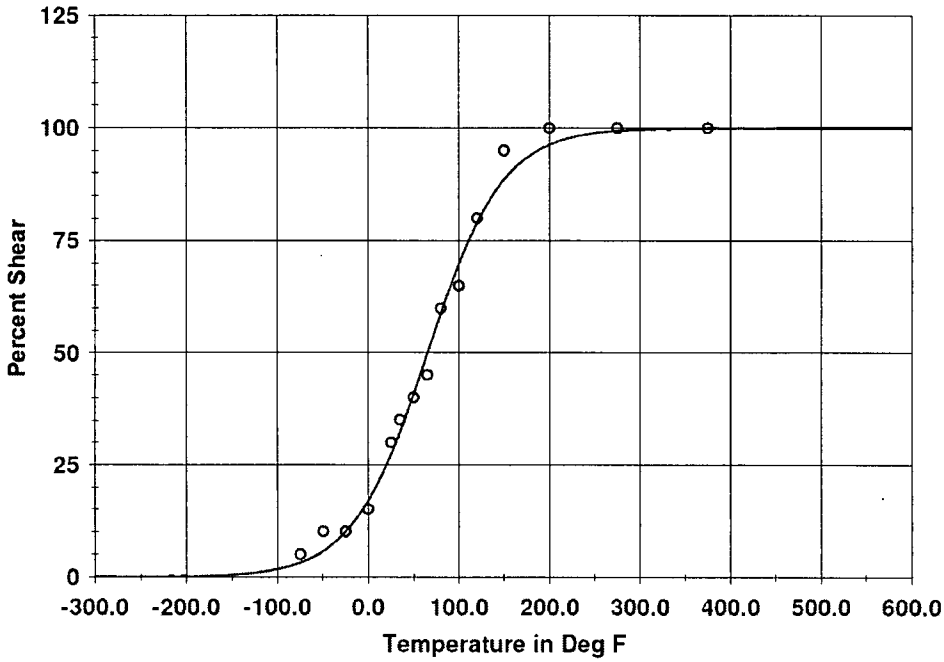
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
100.00	42.00	46.05	-4.05
120.00	55.00	49.27	5.73
150.00	52.00	52.60	-.60
200.00	61.00	55.41	5.59
275.00	55.00	56.73	-1.73
375.00	54.00	57.05	-3.05

Correlation Coefficient = .985

Capsule U Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 04:43 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 82.49 T0 = 65.43 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 65.5
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	5.00	3.21	1.79
-50.00	10.00	5.74	4.26
-25.00	10.00	10.04	-.04
.00	15.00	16.99	-1.99
25.00	30.00	27.28	2.72
35.00	35.00	32.35	2.65
50.00	40.00	40.75	-.75
65.00	45.00	49.74	-4.74
80.00	60.00	58.74	1.26

Capsule U Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: U Fluence: n/cm^2

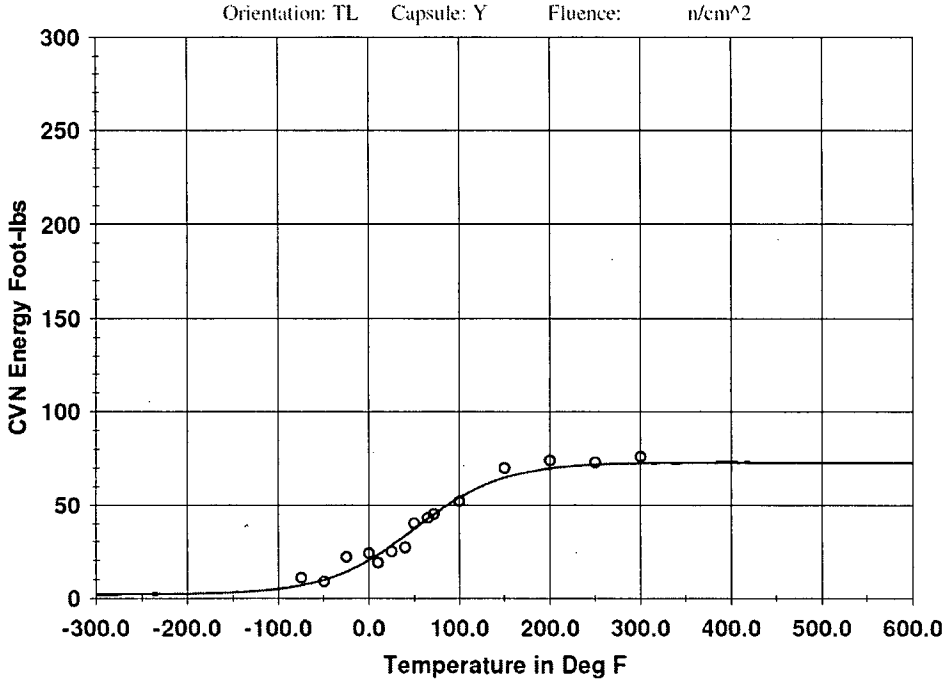
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
100.00	65.00	69.81	-4.81
120.00	80.00	78.97	1.03
150.00	95.00	88.60	6.40
200.00	100.00	96.31	3.69
275.00	100.00	99.38	.62
375.00	100.00	99.95	.05

Correlation Coefficient = .996

Capsule Y Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 04:45 PM
Page 1
Coefficients of Curve 1
A = 37.6 B = 35.4 C = 96.69 T0 = 51.57 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=73.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=30.5 Deg F Temp@50 ft-lbs=87.0 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	11.00	7.01	3.99
-50.00	9.00	9.92	-.92
-25.00	22.00	14.26	7.74
.00	24.00	20.33	3.67
10.00	19.00	23.26	-4.26
25.00	25.00	28.11	-3.11
40.00	27.00	33.39	-6.39
50.00	40.00	37.03	2.97
65.00	43.00	42.49	.51

Capsule Y Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Y Fluence: n/cm^2

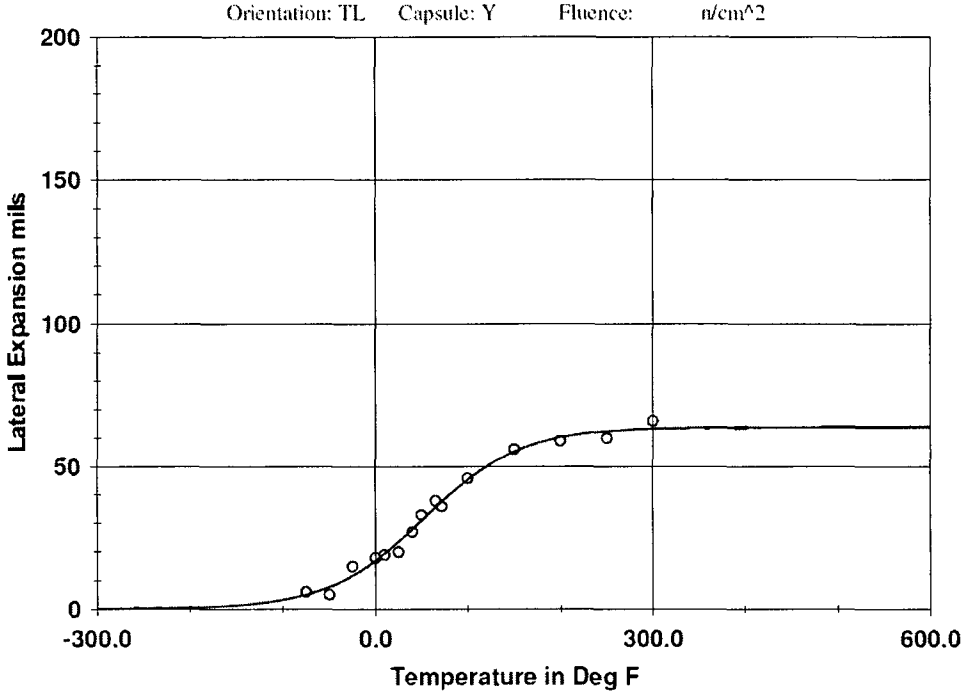
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
72.00	45.00	44.97	.03
100.00	52.00	53.98	-1.98
150.00	70.00	64.82	5.18
200.00	74.00	69.86	4.14
250.00	73.00	71.85	1.15
300.00	76.00	72.59	3.41

Correlation Coefficient = .987

Capsule Y Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/03/2011 05:23 PM
Page 1
Coefficients of Curve 1
A = 31.92 B = 31.92 C = 104.1 T0 = 52.77 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=63.8 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=62.9 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	6.00	5.05	.95
-50.00	5.00	7.78	-2.78
-25.00	15.00	11.70	3.30
.00	18.00	16.99	1.01
10.00	19.00	19.49	-.49
25.00	20.00	23.60	-3.60
40.00	27.00	28.02	-1.02
50.00	33.00	31.07	1.93
65.00	38.00	35.65	2.35

Capsule Y Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Y Fluence: n/cm^2

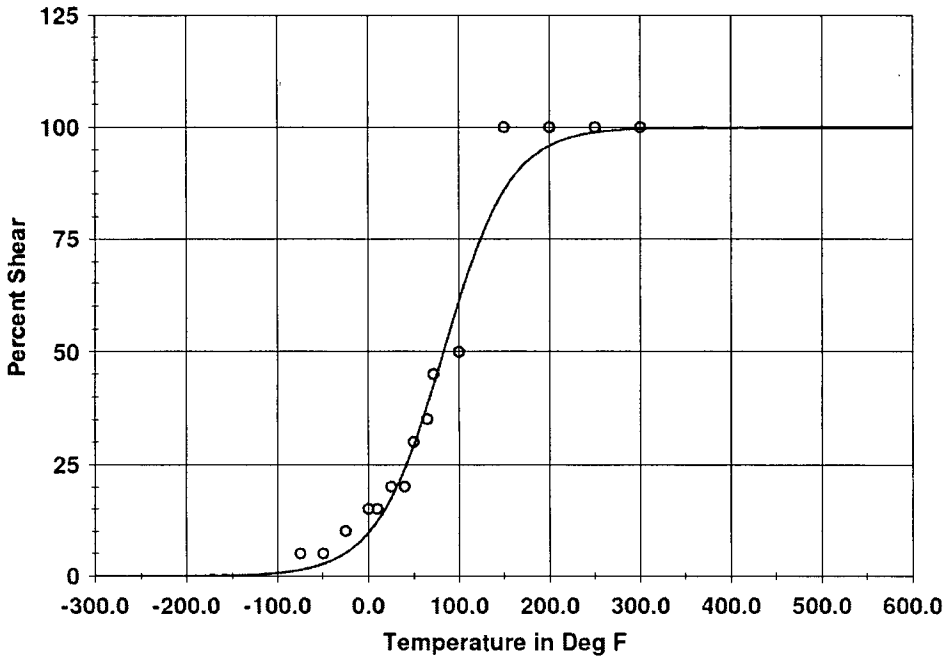
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
72.00	36.00	37.75	-1.75
100.00	46.00	45.48	.52
150.00	56.00	55.30	.70
200.00	59.00	60.27	-1.27
250.00	60.00	62.42	-2.42
300.00	66.00	63.29	2.71

Correlation Coefficient = .994

Capsule Y Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 04:49 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 74.35 T0 = 83. D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 83.0
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	5.00	1.41	3.59
-50.00	5.00	2.72	2.28
-25.00	10.00	5.19	4.81
.00	15.00	9.69	5.31
10.00	15.00	12.31	2.69
25.00	20.00	17.36	2.64
40.00	20.00	23.93	-3.93
50.00	30.00	29.16	.84
65.00	35.00	38.13	-3.13

Capsule Y Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Y Fluence: n/cm^2

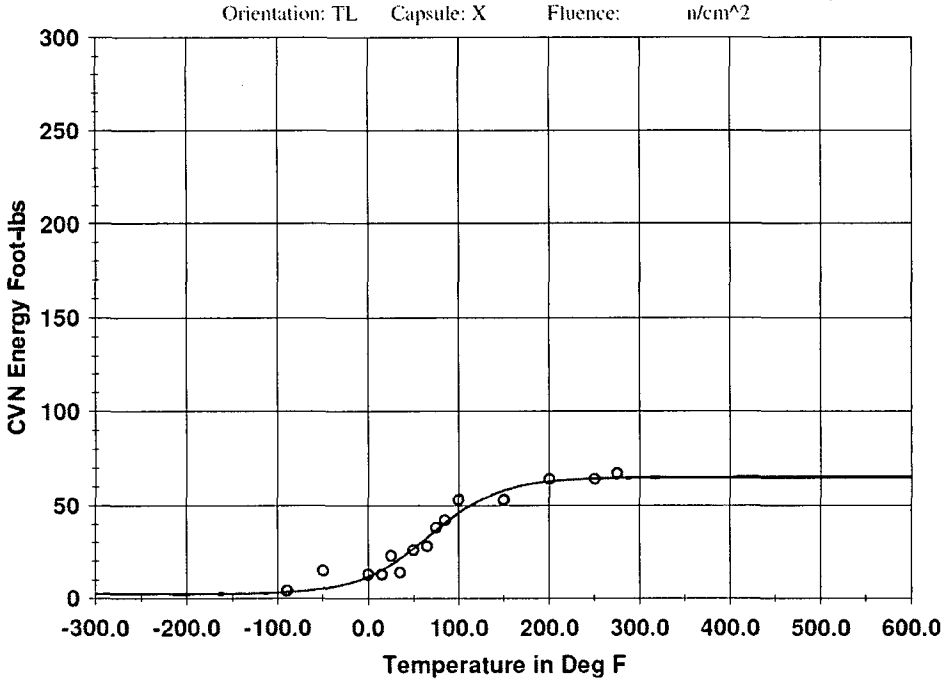
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
72.00	45.00	42.66	2.34
100.00	50.00	61.24	-11.24
150.00	100.00	85.84	14.16
200.00	100.00	95.88	4.12
250.00	100.00	98.89	1.11
300.00	100.00	99.71	.29

Correlation Coefficient = .990

Capsule X Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 05:06 PM
Page 1
Coefficients of Curve 1
A = 33.6 B = 31.4 C = 79.36 T0 = 67.47 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=65.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=58.4 Deg F Temp@50 ft-lbs=113.5 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-90.00	4.00	3.36	.64
-50.00	15.00	5.29	9.71
.00	13.00	11.90	1.10
15.00	13.00	15.42	-2.42
25.00	23.00	18.24	4.76
35.00	14.00	21.43	-7.43
50.00	26.00	26.80	-.80
65.00	28.00	32.62	-4.62
75.00	38.00	36.57	1.43

Capsule X Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: X Fluence: n/cm^2

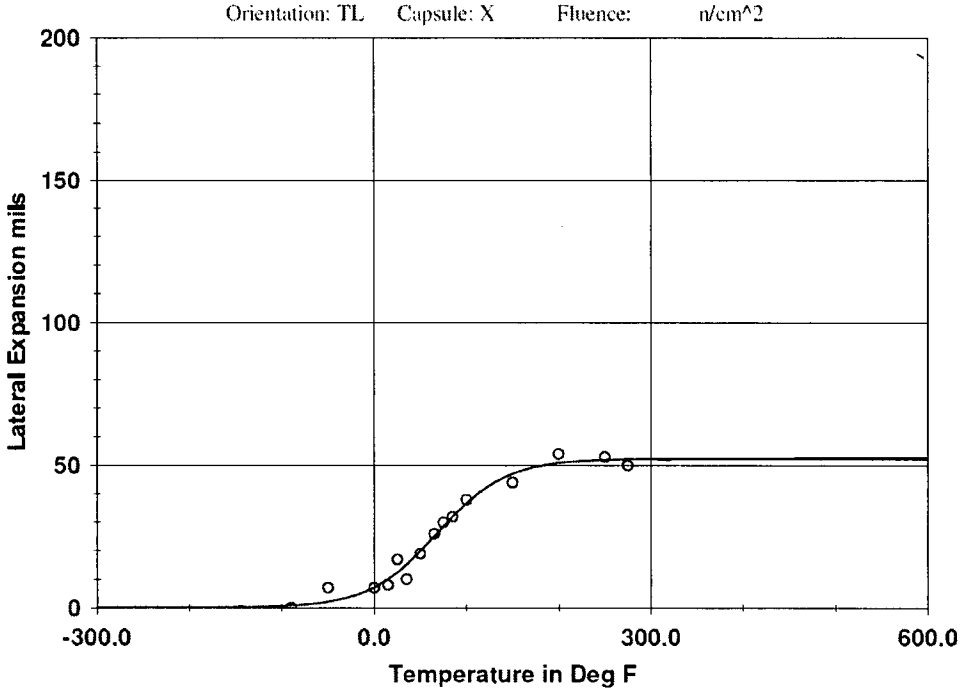
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
85.00	42.00	40.43	1.57
100.00	53.00	45.80	7.20
150.00	53.00	58.03	-5.03
200.00	64.00	62.85	1.15
250.00	64.00	64.38	-.38
275.00	67.00	64.67	2.33

Correlation Coefficient = .978

Capsule X Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/03/2011 05:24 PM
Page 1
Coefficients of Curve 1
A = 26.2 B = 26.2 C = 74.38 T0 = 68.23 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=52.4 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=94.3 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-90.00	.00	.73	-.73
-50.00	7.00	2.09	4.91
.00	7.00	7.21	-.21
15.00	8.00	10.11	-2.11
25.00	17.00	12.48	4.52
35.00	10.00	15.22	-5.22
50.00	19.00	19.90	-.90
65.00	26.00	25.06	.94
75.00	30.00	28.58	1.42

Capsule X Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: X Fluence: n/cm^2

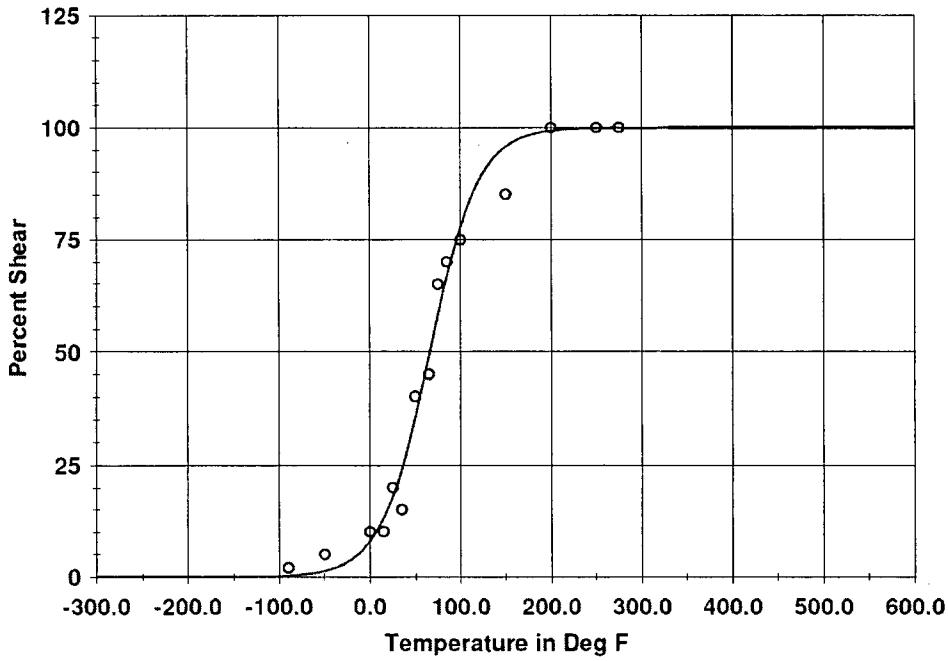
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
85.00	32.00	32.01	-.01
100.00	38.00	36.76	1.24
150.00	44.00	47.16	-3.16
200.00	54.00	50.92	3.08
250.00	53.00	52.01	.99
275.00	50.00	52.20	-2.20

Correlation Coefficient = .989

Capsule X Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 05:07 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 53.99 T0 = 66.11 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 66.2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-90.00	2.00	.31	1.69
-50.00	5.00	1.34	3.66
.00	10.00	7.95	2.05
15.00	10.00	13.09	-3.09
25.00	20.00	17.90	2.10
35.00	15.00	24.01	-9.01
50.00	40.00	35.51	4.49
65.00	45.00	48.98	-3.98
75.00	65.00	58.16	6.84

Capsule X Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: X Fluence: n/cm^2

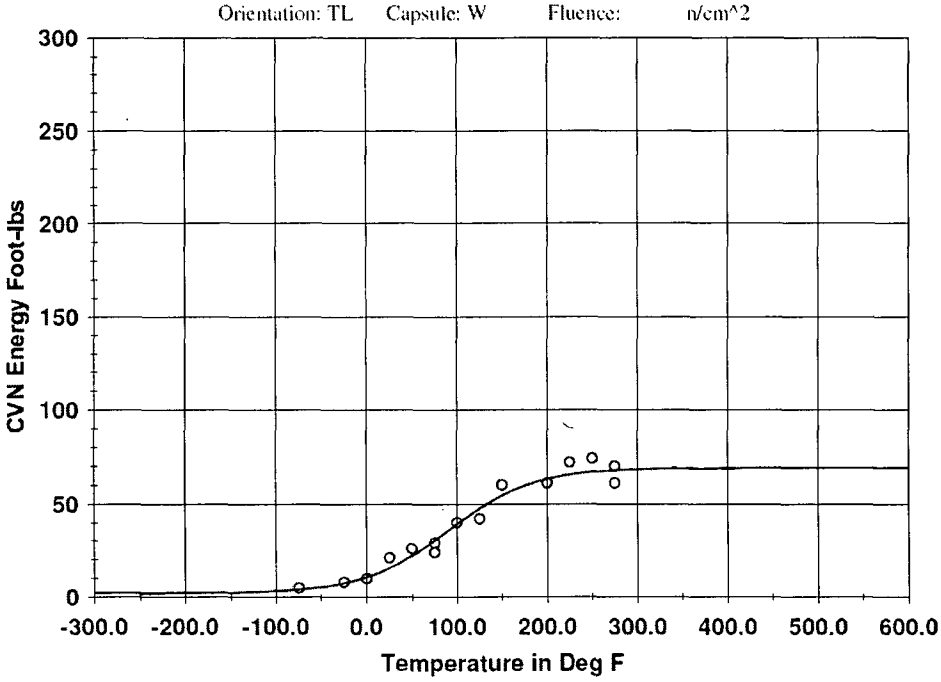
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
85.00	70.00	66.82	3.18
100.00	75.00	77.83	-2.83
150.00	85.00	95.72	-10.72
200.00	100.00	99.30	.70
250.00	100.00	99.89	.11
275.00	100.00	99.96	.04

Correlation Coefficient = .992

Capsule W Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/30/2010 11:41 AM
Page 1
Coefficients of Curve 1
A = 35.6 B = 33.4 C = 93.76 T0 = 89.91 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=69.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=74.1 Deg F Temp@50 ft-lbs=133.2 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	5.00	4.12	.88
-25.00	8.00	7.50	.50
.00	10.00	10.76	-.76
25.00	21.00	15.58	5.42
50.00	26.00	22.18	3.82
75.00	29.00	30.33	-1.33
75.00	24.00	30.33	-6.33
100.00	40.00	39.18	.82
125.00	42.00	47.55	-5.55

Capsule W Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: W Fluence: n/cm^2

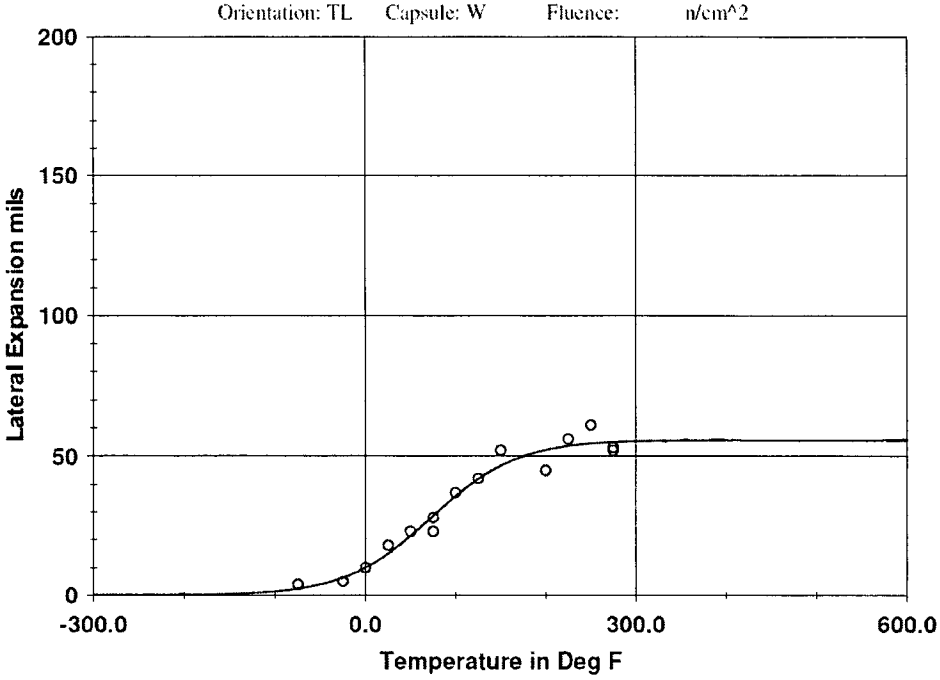
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
150.00	60.00	54.49	5.51
200.00	61.00	63.18	-2.18
225.00	72.00	65.46	6.54
250.00	74.00	66.87	7.13
275.00	61.00	67.74	-6.74
275.00	70.00	67.74	2.26

Correlation Coefficient = .983

Capsule W Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 12:35 PM
Page 1
Coefficients of Curve 1
A = 27.92 B = 27.92 C = 95.34 T0 = 72.36 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=55.8 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=97.1 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	4.00	2.43	1.57
-25.00	5.00	6.41	-1.41
.00	10.00	10.04	-.04
25.00	18.00	15.09	2.91
50.00	23.00	21.49	1.51
75.00	28.00	28.69	-.69
75.00	23.00	28.69	-5.69
100.00	37.00	35.80	1.20
125.00	42.00	41.94	.06

Capsule W Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: W Fluence: n/cm^2

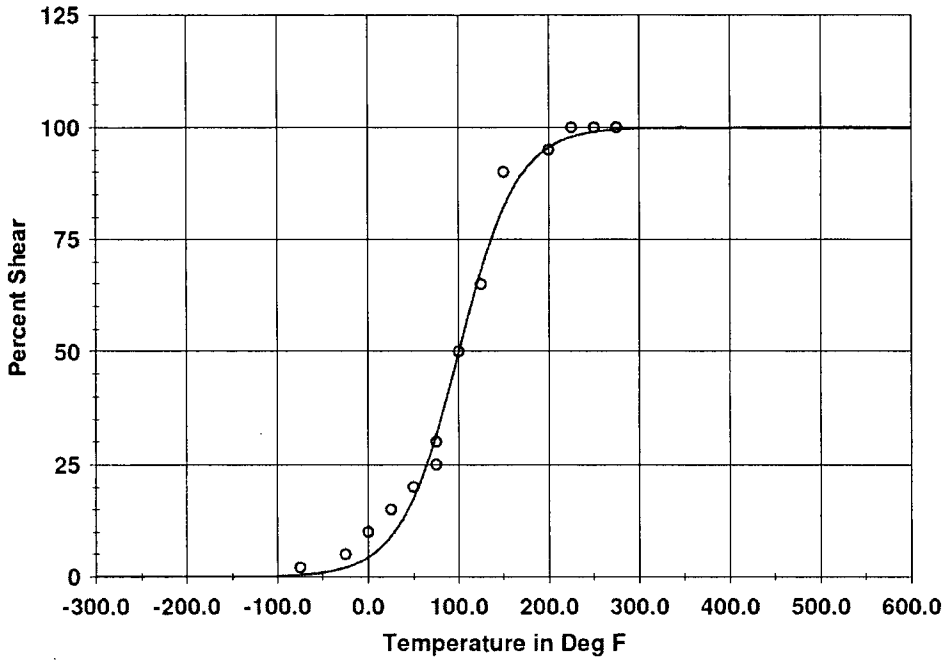
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
150.00	52.00	46.68	5.32
200.00	45.00	52.25	-7.25
225.00	56.00	53.66	2.34
250.00	61.00	54.53	6.47
275.00	53.00	55.06	-2.06
275.00	52.00	55.06	-3.06

Correlation Coefficient = .982

Capsule W Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/21/2010 05:13 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 64.89 T0 = 100.3 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 100.4
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	2.00	.45	1.55
-25.00	5.00	2.06	2.94
.00	10.00	4.35	5.65
25.00	15.00	8.94	6.06
50.00	20.00	17.50	2.50
75.00	30.00	31.43	-1.43
75.00	25.00	31.43	-6.43
100.00	50.00	49.77	.23
125.00	65.00	68.16	-3.16

Capsule W Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: W Fluence: n/cm^2

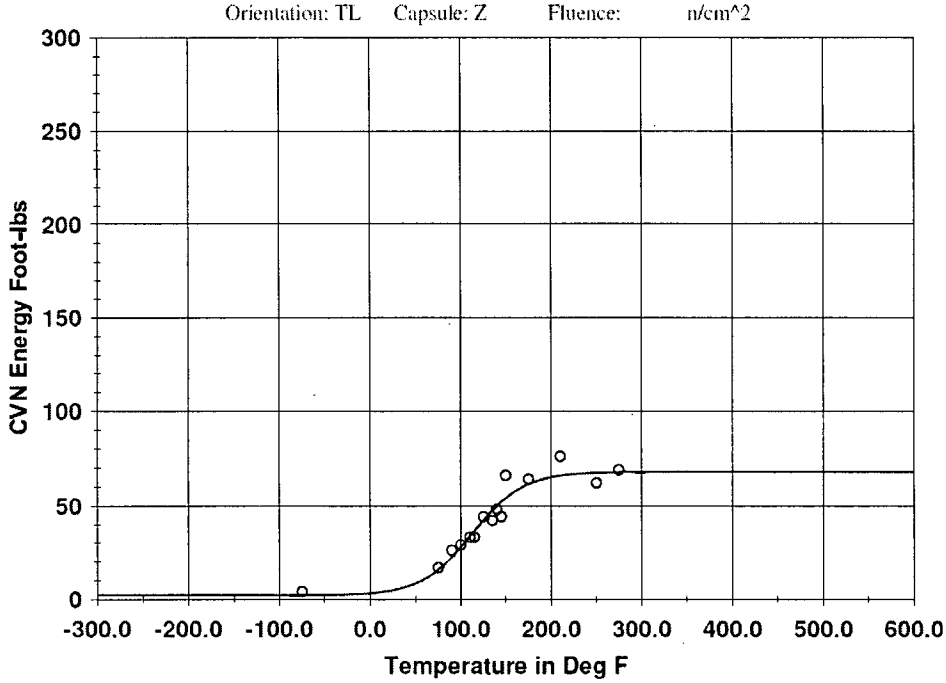
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
150.00	90.00	82.22	7.78
200.00	95.00	95.58	-.58
225.00	100.00	97.90	2.10
250.00	100.00	99.02	.98
275.00	100.00	99.54	.46
275.00	100.00	99.54	.46

Correlation Coefficient = .996

Capsule Z Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 01:23 PM
Page 1
Coefficients of Curve 1
A = 35.1 B = 32.9 C = 56.19 T0 = 112.66 D = 0.00E+00
Equation is A + B * [Tanh(/T-To)/(C+DT))]
Upper Shelf Energy=68.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=103.9 Deg F Temp@50 ft-lbs=140.1 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	4.00	2.28	1.72
75.00	17.00	15.85	1.15
90.00	26.00	22.51	3.49
100.00	29.00	27.81	1.19
110.00	33.00	33.54	-.54
115.00	33.00	36.47	-3.47
125.00	44.00	42.21	1.79
135.00	42.00	47.53	-5.53
140.00	48.00	49.95	-1.95

Capsule Z Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Z Fluence: n/cm^2

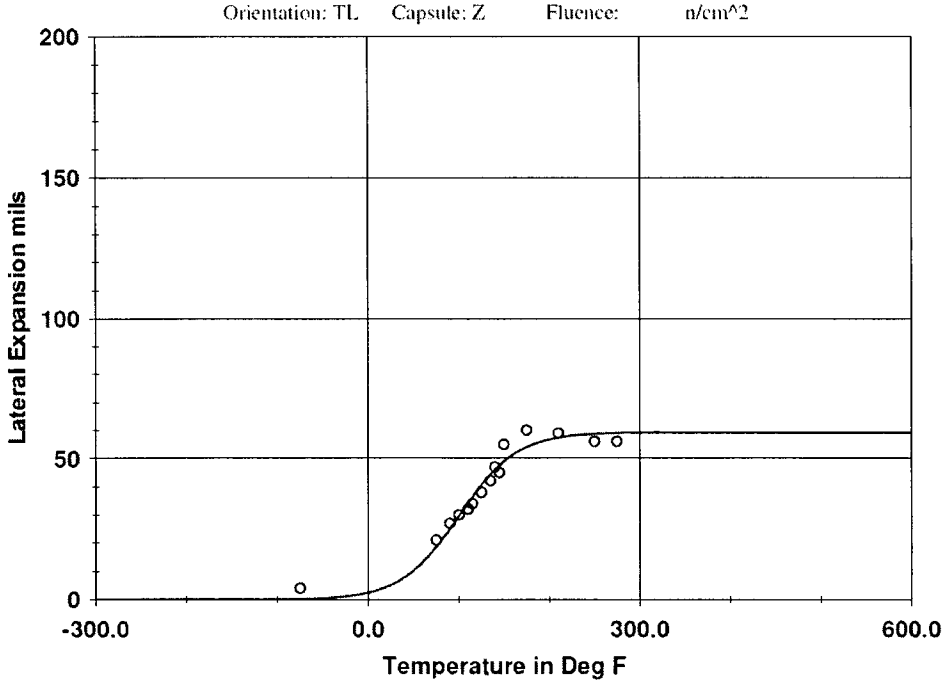
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
145.00	44.00	52.19	-8.19
150.00	66.00	54.23	11.77
175.00	64.00	61.55	2.45
210.00	76.00	66.00	10.00
250.00	62.00	67.51	-5.51
275.00	69.00	67.80	1.20

Correlation Coefficient = .966

Capsule Z Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/30/2010 10:32 AM
Page 1
Coefficients of Curve 1
A = 29.64 B = 29.64 C = 63.95 T0 = 99.96 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=59.3 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=111.7 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	4.00	.25	3.75
75.00	21.00	18.62	2.38
90.00	27.00	25.06	1.94
100.00	30.00	29.65	.35
110.00	32.00	34.25	-2.25
115.00	34.00	36.48	-2.48
125.00	38.00	40.68	-2.68
135.00	42.00	44.42	-2.42
140.00	47.00	46.09	.91

Capsule Z Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Z Fluence: n/cm^2

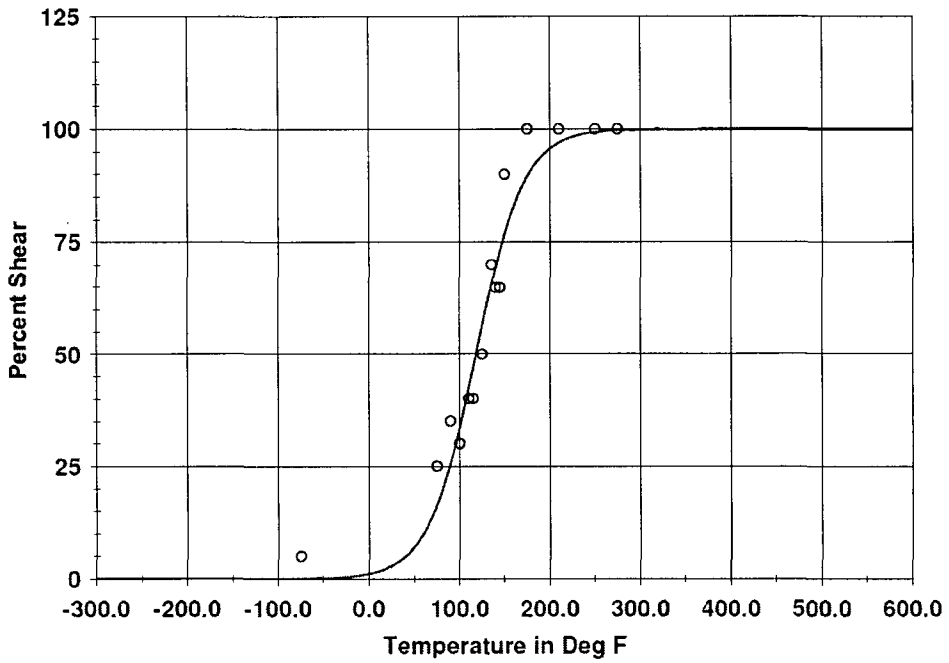
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
145.00	45.00	47.63	-2.63
150.00	55.00	49.02	5.98
175.00	60.00	54.10	5.90
210.00	59.00	57.43	1.57
250.00	56.00	58.73	-2.73
275.00	56.00	59.02	-3.02

Correlation Coefficient = .981

Capsule Z Lower Shell Plate B8628-1 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 01:24 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 52.8 T0 = 118.1 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 118.1
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	5.00	.07	4.93
75.00	25.00	16.35	8.65
90.00	35.00	25.65	9.35
100.00	30.00	33.50	-3.50
110.00	40.00	42.39	-2.39
115.00	40.00	47.07	-7.07
125.00	50.00	56.50	-6.50
135.00	70.00	65.48	4.52
140.00	65.00	69.63	-4.63

Capsule Z Lower Shell Plate B8628-1 (Transverse)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: TL Capsule: Z Fluence: n/cm^2

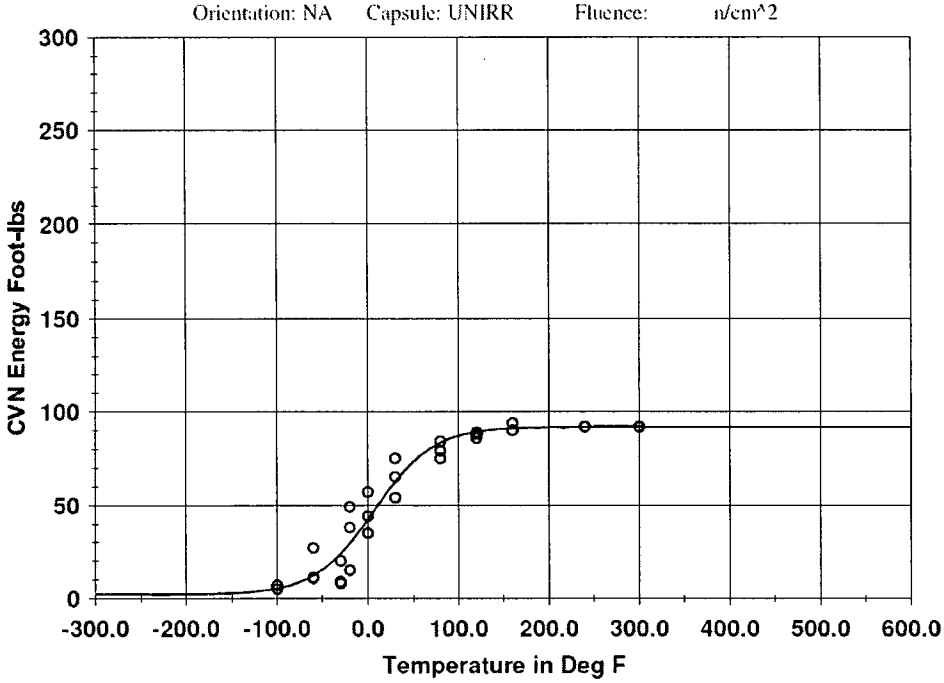
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
145.00	65.00	73.48	-8.48
150.00	90.00	77.00	13.00
175.00	100.00	89.62	10.38
210.00	100.00	97.01	2.99
250.00	100.00	99.33	.67
275.00	100.00	99.74	.26

Correlation Coefficient = .976

Unirradiated (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 02:29 PM
Page 1
Coefficients of Curve 1
A = 47.1 B = 44.9 C = 65.02 T0 = 6.8 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=92.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-19.2 Deg F Temp@50 ft-lbs=11.1 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	5.00	5.44	-.44
-100.00	7.00	5.44	1.56
-100.00	7.00	5.44	1.56
-60.00	11.00	12.40	-1.40
-60.00	11.00	12.40	-1.40
-60.00	27.00	12.40	14.60
-30.00	8.00	24.09	-16.09
-30.00	9.00	24.09	-15.09
-30.00	20.00	24.09	-4.09

Unirradiated (Weld) .

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

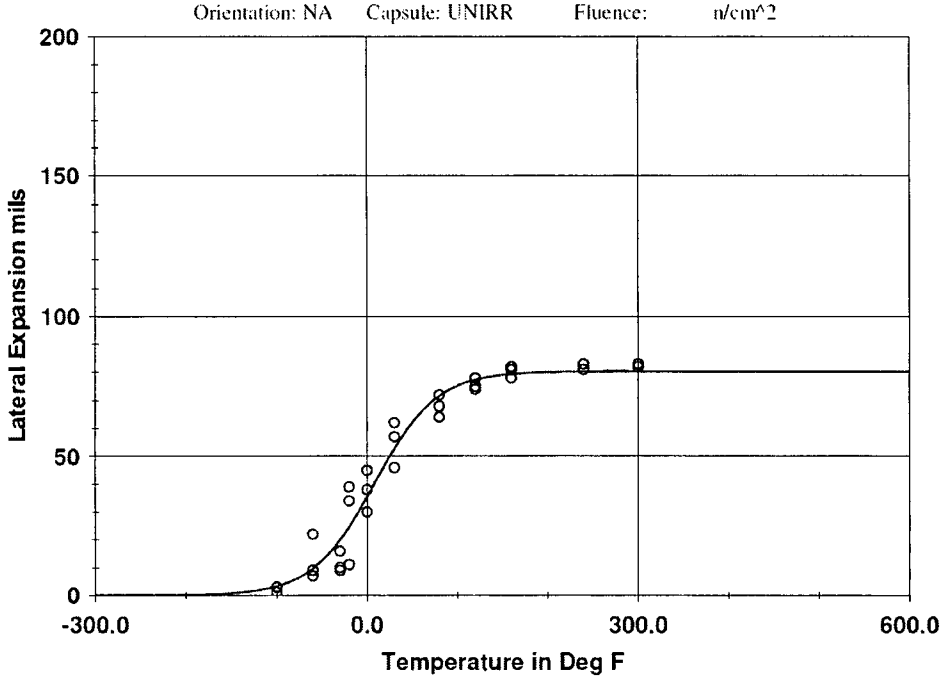
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-20.00	15.00	29.57	-14.57
-20.00	38.00	29.57	8.43
-20.00	49.00	29.57	19.43
.00	35.00	42.42	-7.42
.00	44.00	42.42	1.58
.00	57.00	42.42	14.58
30.00	54.00	62.47	-8.47
30.00	65.00	62.47	2.53
30.00	75.00	62.47	12.53
80.00	75.00	83.45	-8.45
80.00	79.00	83.45	-4.45
80.00	84.00	83.45	.55
120.00	86.00	89.32	-3.32
120.00	88.00	89.32	-1.32
120.00	89.00	89.32	-.32
160.00	90.00	91.20	-1.20
160.00	90.00	91.20	-1.20
160.00	94.00	91.20	2.80
240.00	92.00	91.93	.07
240.00	92.00	91.93	.07
300.00	92.00	91.99	.01
300.00	92.00	91.99	.01

Correlation Coefficient = .971

Unirradiated (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:39 PM
Page 1
Coefficients of Curve 1
A = 40.21 B = 40.21 C = 68.68 T0 = 7.85 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=80.4 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=-1.0 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-100.00	1.00	3.33	-2.33
-100.00	3.00	3.33	-.33
-100.00	3.00	3.33	-.33
-60.00	9.00	9.79	-.79
-60.00	7.00	9.79	-2.79
-60.00	22.00	9.79	12.21
-30.00	9.00	20.05	-11.05
-30.00	10.00	20.05	-10.05
-30.00	16.00	20.05	-4.05

Unirradiated (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

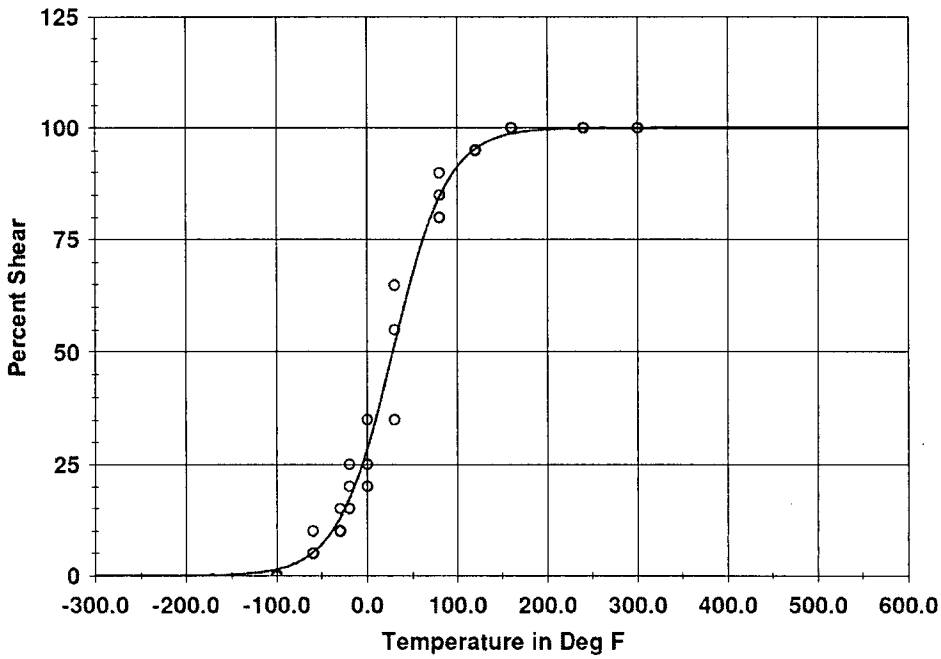
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-20.00	11.00	24.74	-13.74
-20.00	34.00	24.74	9.26
-20.00	39.00	24.74	14.26
.00	30.00	35.63	-5.63
.00	38.00	35.63	2.37
.00	45.00	35.63	9.37
30.00	46.00	52.74	-6.74
30.00	57.00	52.74	4.26
30.00	62.00	52.74	9.26
80.00	64.00	71.65	-7.65
80.00	68.00	71.65	-3.65
80.00	72.00	71.65	.35
120.00	74.00	77.46	-3.46
120.00	75.00	77.46	-2.46
120.00	78.00	77.46	.54
160.00	81.00	79.47	1.53
160.00	78.00	79.47	-1.47
160.00	82.00	79.47	2.53
240.00	81.00	80.32	.68
240.00	83.00	80.32	2.68
300.00	82.00	80.40	1.60
300.00	83.00	80.40	2.60

Correlation Coefficient = .977

Unirradiated (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 08:23 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 61.01 T0 = 28.04 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 28.1
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100.00	.00	1.48	-1.48
-100.00	.00	1.48	-1.48
-100.00	.00	1.48	-1.48
-60.00	5.00	5.28	-.28
-60.00	5.00	5.28	-.28
-60.00	10.00	5.28	4.72
-30.00	10.00	12.98	-2.98
-30.00	15.00	12.98	2.02
-30.00	10.00	12.98	-2.98

Unirradiated (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

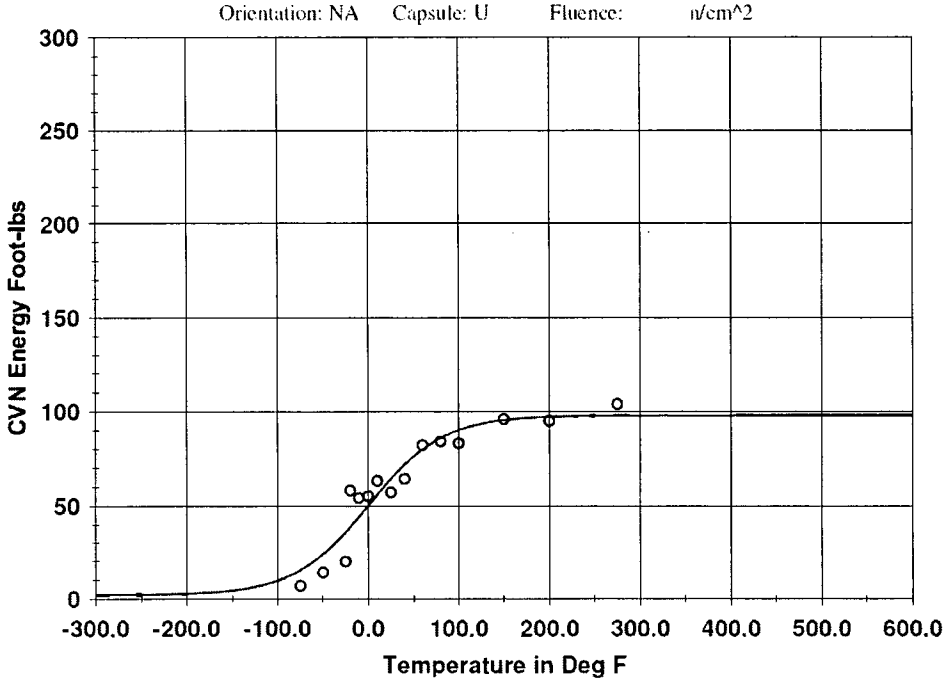
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-20.00	15.00	17.15	-2.15
-20.00	20.00	17.15	2.85
-20.00	25.00	17.15	7.85
.00	25.00	28.51	-3.51
.00	20.00	28.51	-8.51
.00	35.00	28.51	6.49
30.00	35.00	51.60	-16.60
30.00	55.00	51.60	3.40
30.00	65.00	51.60	13.40
80.00	80.00	84.60	-4.60
80.00	85.00	84.60	.40
80.00	90.00	84.60	5.40
120.00	95.00	95.32	-.32
120.00	95.00	95.32	-.32
120.00	95.00	95.32	-.32
160.00	100.00	98.70	1.30
160.00	100.00	98.70	1.30
160.00	100.00	98.70	1.30
240.00	100.00	99.90	.10
240.00	100.00	99.90	.10
300.00	100.00	99.99	.01
300.00	100.00	99.99	.01

Correlation Coefficient = .992

Capsule U (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 02:35 PM
Page 1
Coefficients of Curve 1
A = 50.1 B = 47.9 C = 82.01 T0 = .14 D = 0.00E+00
Equation is A + B * |Tanh((T-To)/(C+DT))|
Upper Shelf Energy=98.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-36.5 Deg F Temp@50 ft-lbs=.0 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	7.00	15.42	-8.42
-50.00	14.00	23.99	-9.99
-25.00	20.00	35.86	-15.86
-20.00	58.00	38.57	19.43
-10.00	54.00	44.21	9.79
.00	55.00	50.02	4.98
10.00	63.00	55.83	7.17
25.00	57.00	64.19	-7.19
40.00	64.00	71.71	-7.71

Capsule U (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: U Fluence: n/cm^2

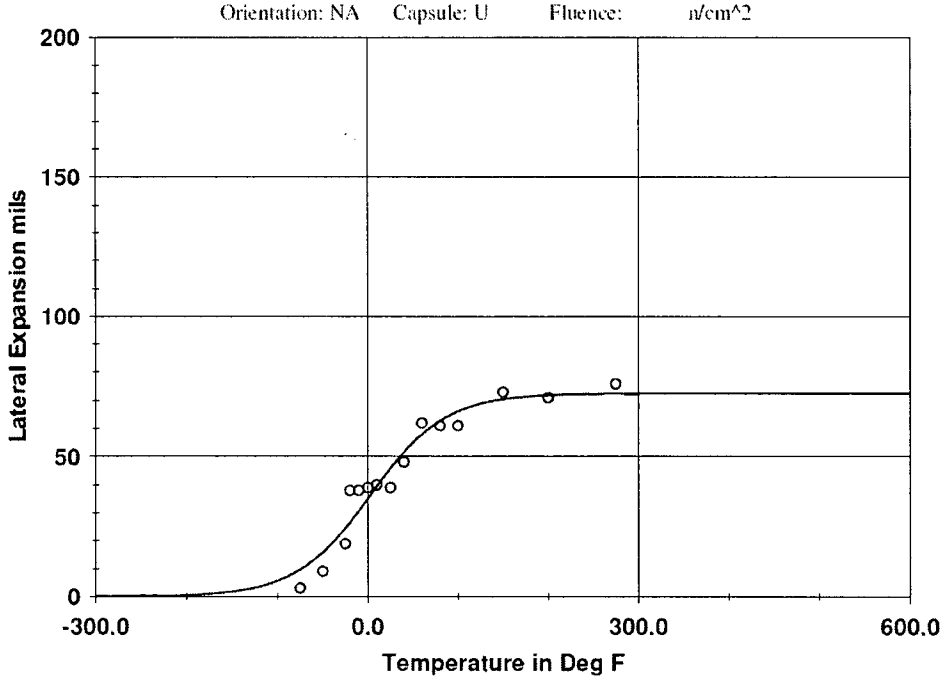
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
60.00	82.00	79.94	2.06
80.00	84.00	86.04	-2.04
100.00	83.00	90.29	-7.29
150.00	96.00	95.58	.42
200.00	95.00	97.27	-2.27
275.00	104.00	97.88	6.12

Correlation Coefficient = .952

Capsule U (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:43 PM
Page 1
Coefficients of Curve 1
A = 36.28 B = 36.28 C = 82.97 T0 = 2.59 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=72.6 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=-.3 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	3.00	9.69	-6.69
-50.00	9.00	15.94	-6.94
-25.00	19.00	24.64	-5.64
-20.00	38.00	26.64	11.36
-10.00	38.00	30.81	7.19
.00	39.00	35.14	3.86
10.00	40.00	39.51	.49
25.00	39.00	45.84	-6.84
40.00	48.00	51.61	-3.61

Capsule U (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: U Fluence: n/cm^2

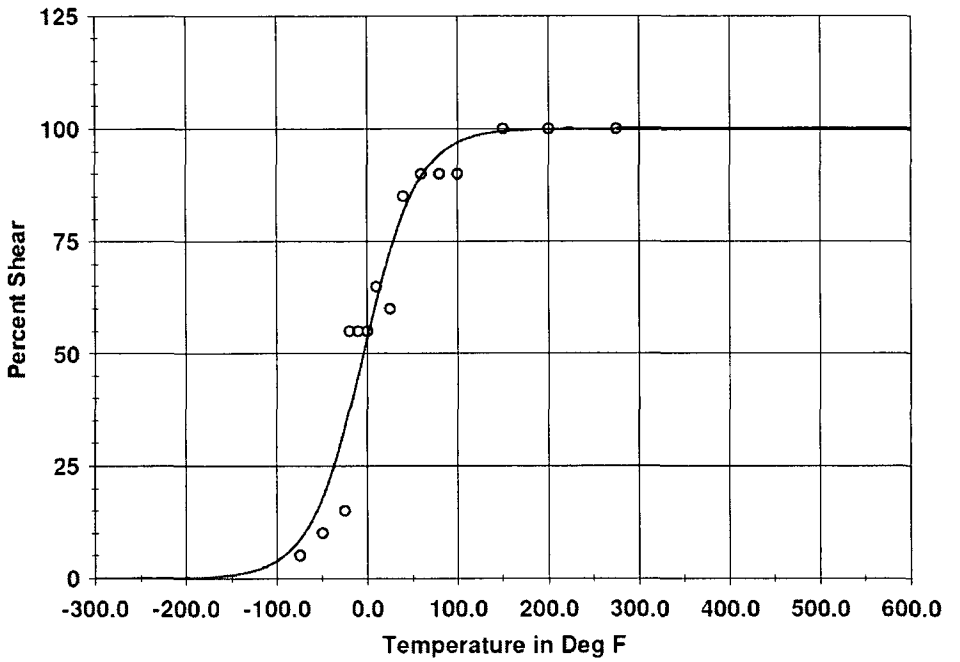
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
60.00	62.00	58.01	3.99
80.00	61.00	62.83	-1.83
100.00	61.00	66.22	-5.22
150.00	73.00	70.53	2.47
200.00	71.00	71.93	-.93
275.00	76.00	72.45	3.55

Correlation Coefficient = .969

Capsule U (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 02:36 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 59.67 T0 = -4.16 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -4.1
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	5.00	8.52	-3.52
-50.00	10.00	17.71	-7.71
-25.00	15.00	33.21	-18.21
-20.00	55.00	37.03	17.97
-10.00	55.00	45.12	9.88
.00	55.00	53.48	1.52
10.00	65.00	61.65	3.35
25.00	60.00	72.66	-12.66
40.00	85.00	81.46	3.54

Capsule U (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: U Fluence: n/cm^2

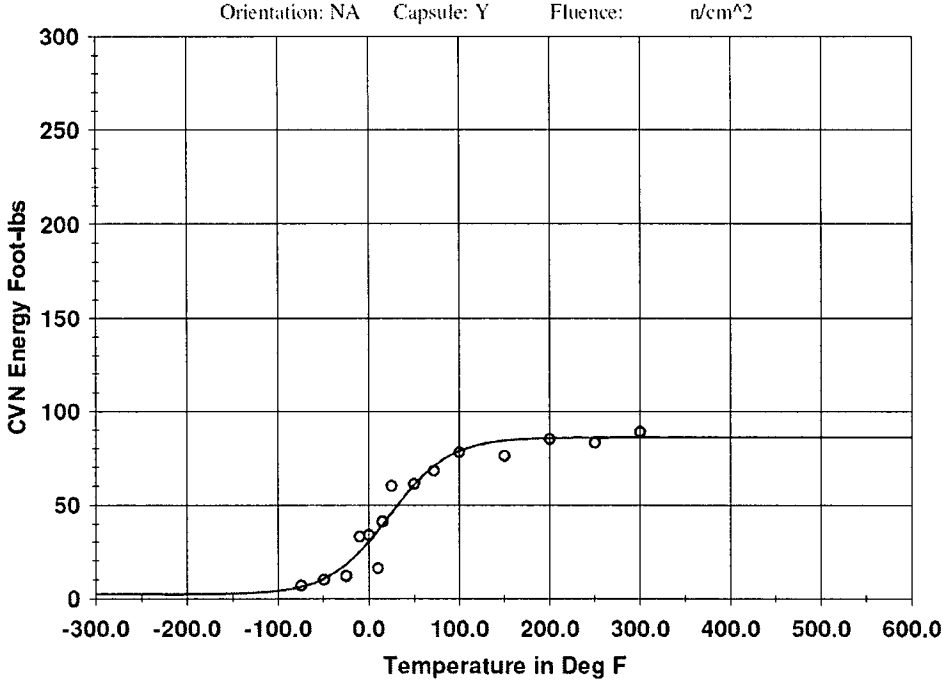
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
60.00	90.00	89.57	.43
80.00	90.00	94.38	-4.38
100.00	90.00	97.04	-7.04
150.00	100.00	99.43	.57
200.00	100.00	99.89	.11
275.00	100.00	99.99	.01

Correlation Coefficient = .965

Capsule Y (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 02:50 PM
Page 1
Coefficients of Curve 1
A = 44.1 B = 41.9 C = 66.07 T0 = 22.56 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=86.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-.5 Deg F Temp@50 ft-lbs=32.0 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	7.00	6.36	.64
-50.00	10.00	10.59	-.59
-25.00	12.00	18.26	-6.26
-10.00	33.00	24.98	8.02
.00	34.00	30.32	3.68
10.00	16.00	36.23	-20.23
15.00	41.00	39.33	1.67
25.00	60.00	45.65	14.35
50.00	61.00	60.57	.43

Capsule Y (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Y Fluence: n/cm^2

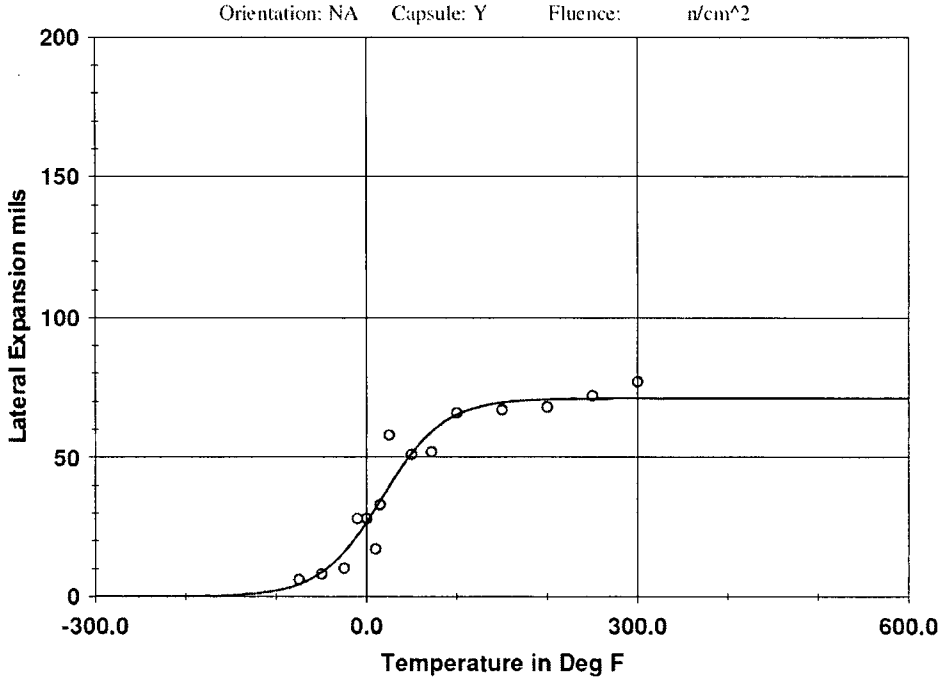
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
72.00	68.00	70.67	-2.67
100.00	78.00	78.67	-.67
150.00	76.00	84.27	-8.27
200.00	85.00	85.61	-.61
250.00	83.00	85.91	-2.91
300.00	89.00	85.98	3.02

Correlation Coefficient = .967

Capsule Y (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:46 PM
Page 1
Coefficients of Curve 1
A = 35.51 B = 35.51 C = 67.92 T0 = 17.15 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=71.0 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=16.2 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	6.00	4.42	1.58
-50.00	8.00	8.64	-.64
-25.00	10.00	15.93	-5.93
-10.00	28.00	22.03	5.97
.00	28.00	26.73	1.27
10.00	17.00	31.79	-14.79
15.00	33.00	34.39	-1.39
25.00	58.00	39.60	18.40
50.00	51.00	51.46	-.46

Capsule Y (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Y Fluence: n/cm^2

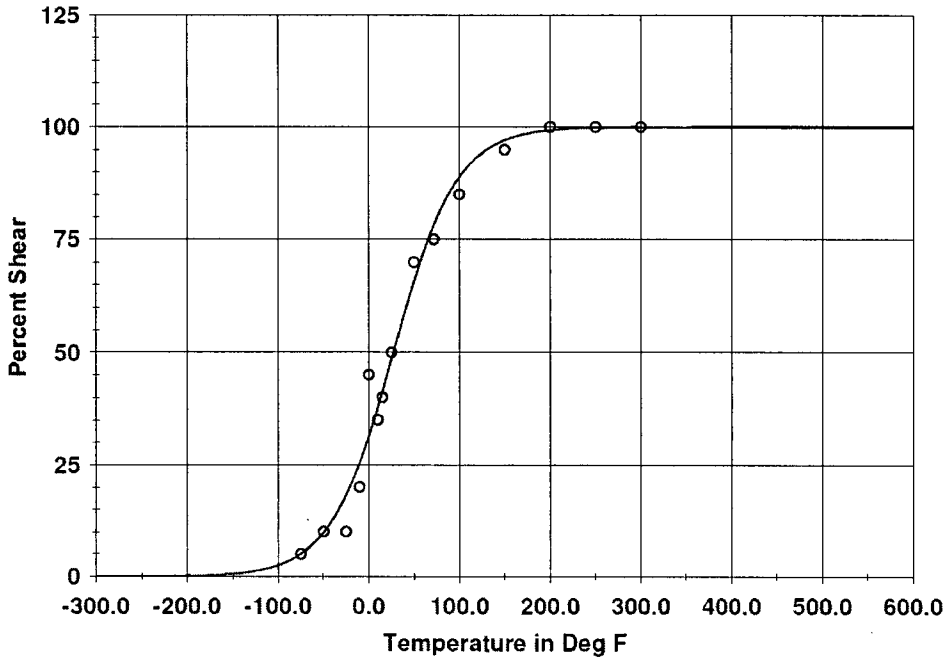
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
72.00	52.00	59.24	-7.24
100.00	66.00	65.33	.67
150.00	67.00	69.63	-2.63
200.00	68.00	70.70	-2.70
250.00	72.00	70.95	1.05
300.00	77.00	71.01	5.99

Correlation Coefficient = .958

Capsule Y (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 02:51 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 69.74 T0 = 27.24 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 27.3
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	5.00	5.06	-.06
-50.00	10.00	9.84	.16
-25.00	10.00	18.27	-8.27
-10.00	20.00	25.58	-5.58
.00	45.00	31.40	13.60
10.00	35.00	37.88	-2.88
15.00	40.00	41.31	-1.31
25.00	50.00	48.39	1.61
50.00	70.00	65.76	4.24

Capsule Y (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Y Fluence: n/cm^2

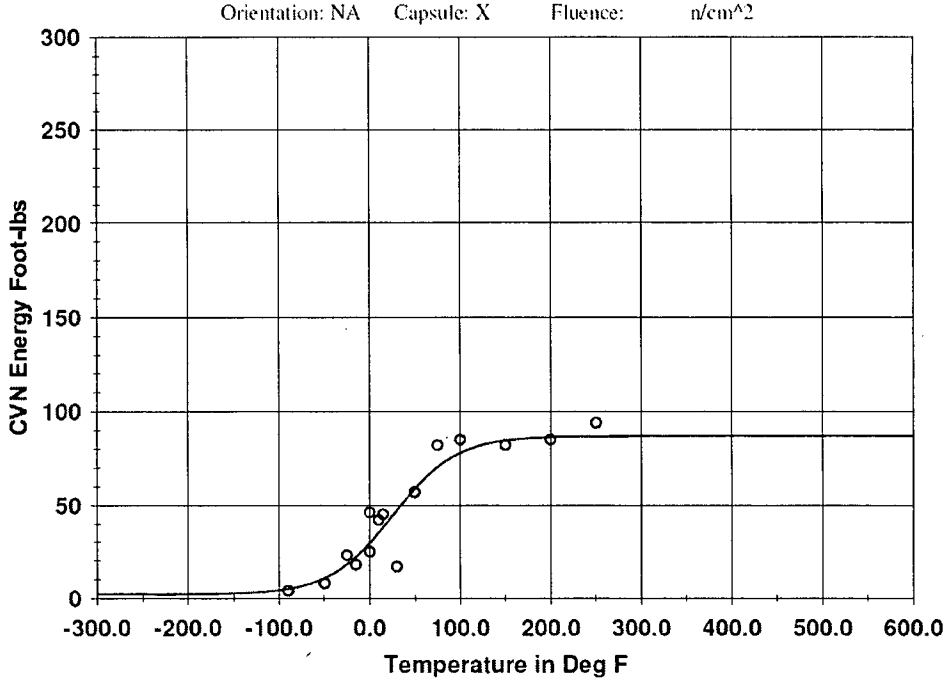
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
72.00	75.00	78.31	-3.31
100.00	85.00	88.96	-3.96
150.00	95.00	97.13	-2.13
200.00	100.00	99.30	.70
250.00	100.00	99.83	.17
300.00	100.00	99.96	.04

Correlation Coefficient = .990

Capsule X (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 02:52 PM
Page 1
Coefficients of Curve 1
A = 44.6 B = 42.4 C = 69.77 T0 = 25.72 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=87.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=.7 Deg F Temp@50 ft-lbs=34.7 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-90.00	4.00	5.17	-1.17
-50.00	8.00	10.89	-2.89
-25.00	23.00	18.26	4.74
-15.00	18.00	22.33	-4.33
.00	25.00	29.64	-4.64
.00	46.00	29.64	16.36
10.00	42.00	35.21	6.79
15.00	45.00	38.14	6.86
30.00	17.00	47.20	-30.20

Capsule X (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: X Fluence: n/cm^2

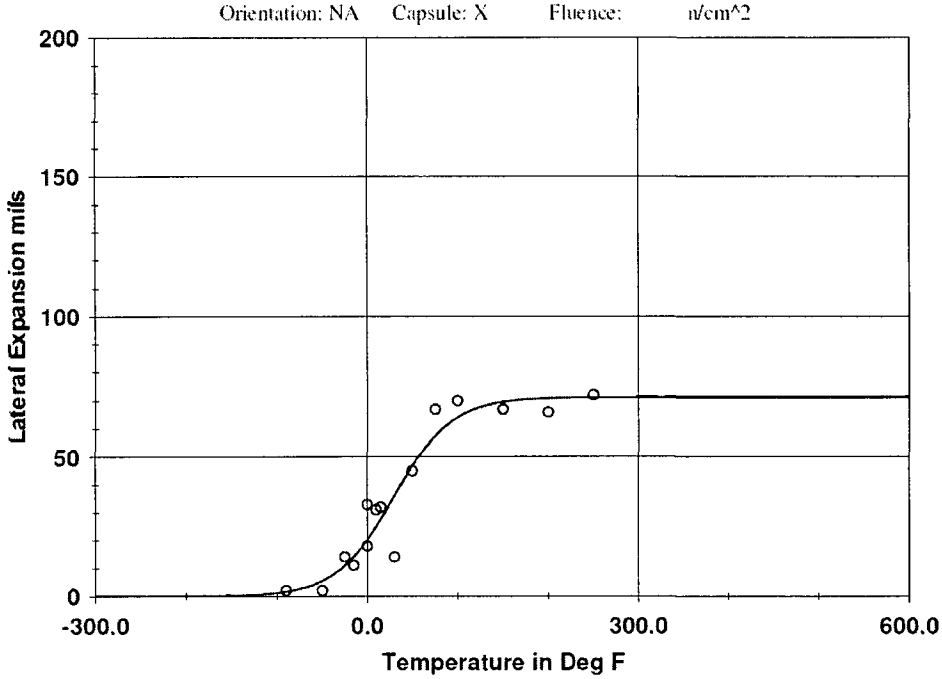
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
50.00	57.00	58.79	-1.79
75.00	82.00	70.40	11.60
100.00	85.00	77.99	7.01
150.00	82.00	84.66	-2.66
200.00	85.00	86.43	-1.43
250.00	94.00	86.86	7.14

Correlation Coefficient = .942

Capsule X (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:40 PM
Page 1
Coefficients of Curve 1
A = 35.61 B = 35.61 C = 63.83 T0 = 29.18 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=71.2 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=28.1 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-90.00	2.00	1.66	.34
-50.00	2.00	5.50	-3.50
-25.00	14.00	11.02	2.98
-15.00	11.00	14.27	-3.27
.00	18.00	20.38	-2.38
.00	33.00	20.38	12.62
10.00	31.00	25.22	5.78
15.00	32.00	27.83	4.17
30.00	14.00	36.07	-22.07

Capsule X (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: X Fluence: n/cm^2

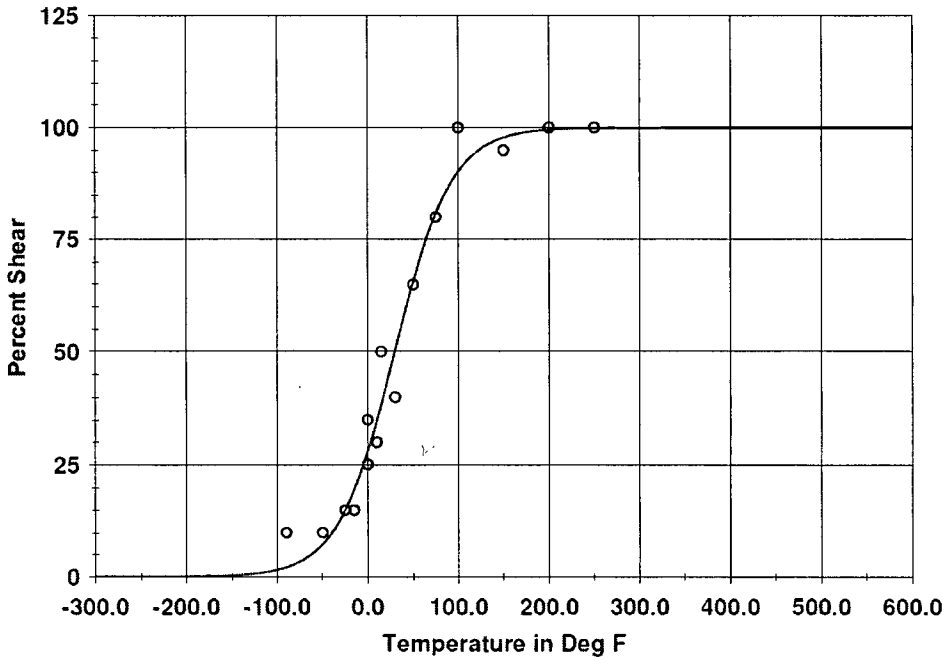
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
50.00	45.00	46.83	-1.83
75.00	67.00	57.53	9.47
100.00	70.00	64.24	5.76
150.00	67.00	69.64	-2.64
200.00	66.00	70.89	-4.89
250.00	72.00	71.15	.85

Correlation Coefficient = .953

Capsule X (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 02:54 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 63.06 T0 = 29.69 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 29.7
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-90.00	10.00	2.20	7.80
-50.00	10.00	7.40	2.60
-25.00	15.00	15.00	.00
-15.00	15.00	19.51	-4.51
.00	25.00	28.06	-3.06
.00	35.00	28.06	6.94
10.00	30.00	34.88	-4.88
15.00	50.00	38.56	11.44
30.00	40.00	50.25	-10.25

Capsule X (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: X Fluence: n/cm^2

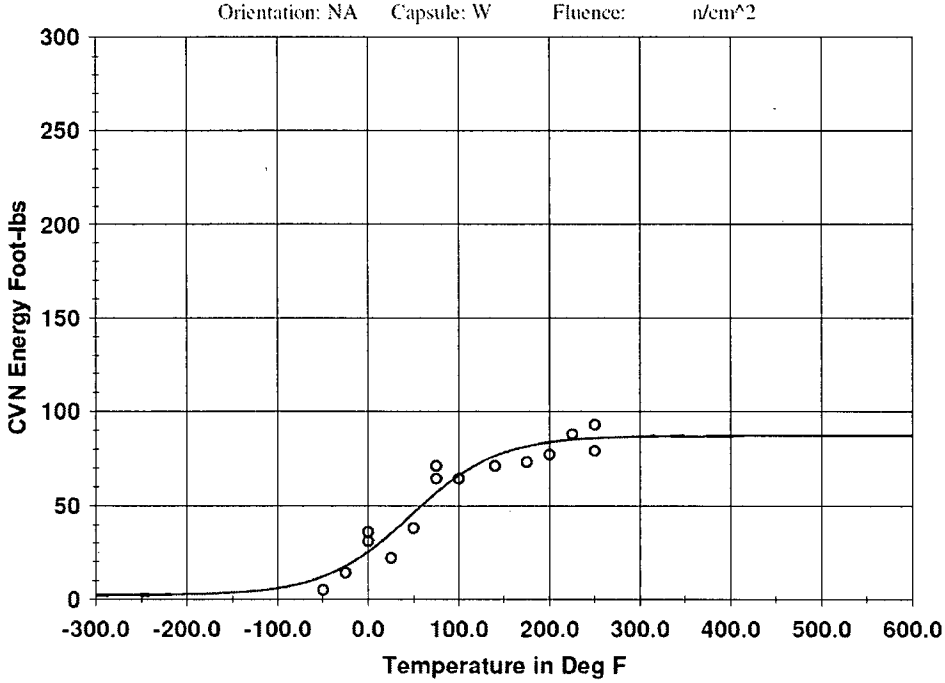
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
50.00	65.00	65.57	-.57
75.00	80.00	80.80	-.80
100.00	100.00	90.29	9.71
150.00	95.00	97.85	-2.85
200.00	100.00	99.55	.45
250.00	100.00	99.91	.09

Correlation Coefficient = .986

Capsule W (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:06 PM
Page 1
Coefficients of Curve 1
A = 44.6 B = 42.4 C = 96.14 T0 = 46.66 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=87.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=12.2 Deg F Temp@50 ft-lbs=59.0 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	5.00	12.21	-7.21
-25.00	14.00	17.79	-3.79
.00	36.00	25.50	10.50
.00	31.00	25.50	5.50
25.00	22.00	35.21	-13.21
50.00	38.00	46.07	-8.07
75.00	71.00	56.75	14.25
75.00	64.00	56.75	7.25
100.00	64.00	65.98	-1.98

Capsule W (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: W Fluence: n/cm^2

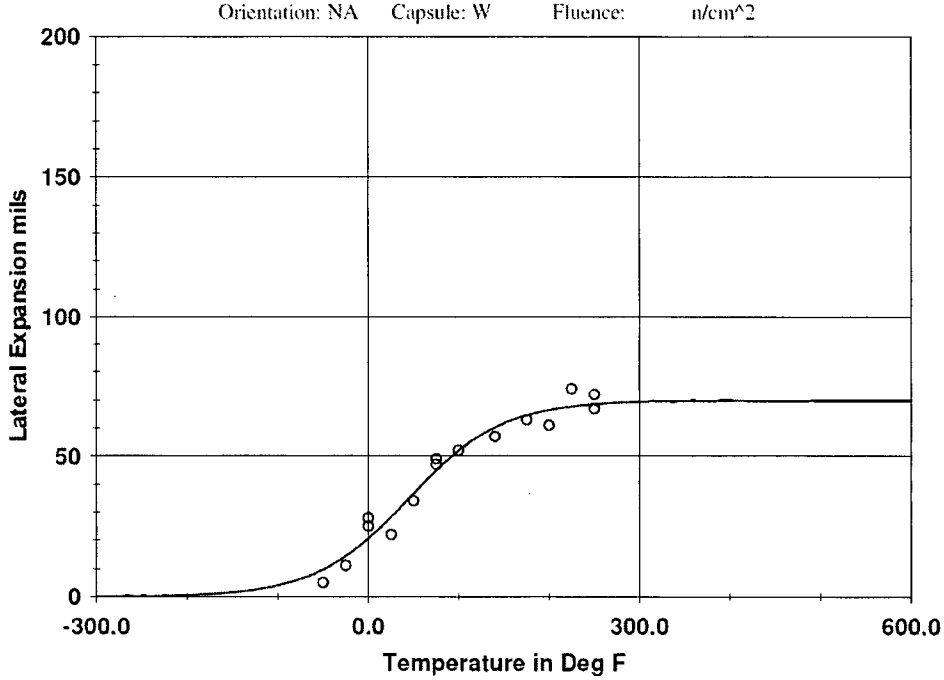
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
140.00	71.00	76.36	-5.36
175.00	73.00	81.51	-8.51
200.00	77.00	83.65	-6.65
225.00	88.00	84.97	3.03
250.00	79.00	85.78	-6.78
250.00	93.00	85.78	7.22

Correlation Coefficient = .956

Capsule W (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:42 PM
Page 1
Coefficients of Curve 1
A = 34.98 B = 34.98 C = 103.68 T0 = 44.94 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=70.0 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=45.0 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	5.00	9.66	-4.66
-25.00	11.00	14.41	-3.41
.00	28.00	20.70	7.30
.00	25.00	20.70	4.30
25.00	22.00	28.34	-6.34
50.00	34.00	36.69	-2.69
75.00	47.00	44.85	2.15
75.00	49.00	44.85	4.15
100.00	52.00	51.99	.01

Capsule W (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: W Fluence: n/cm^2

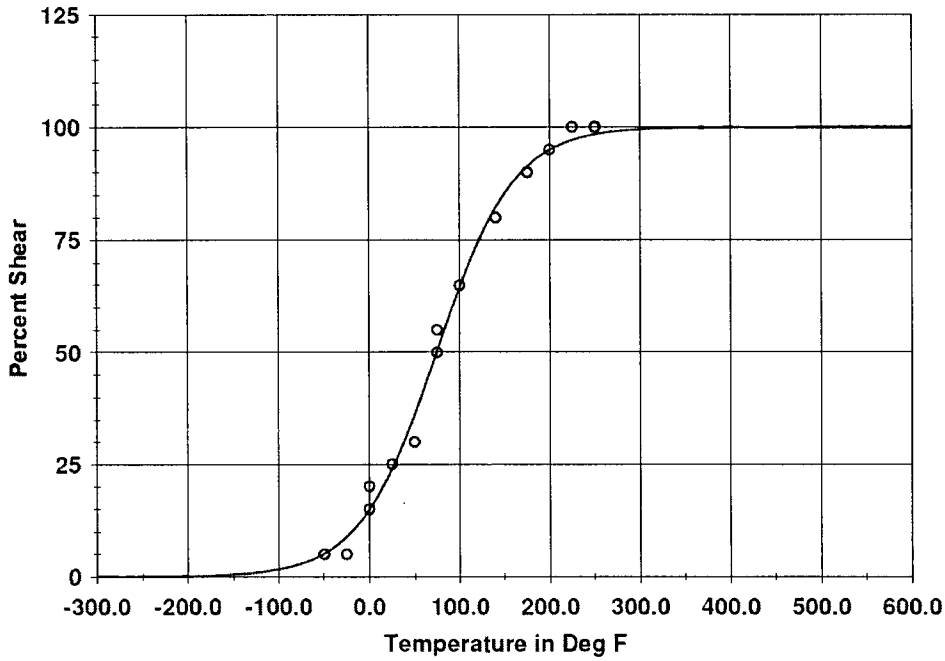
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
140.00	57.00	60.32	-3.32
175.00	63.00	64.70	-1.70
200.00	61.00	66.62	-5.62
225.00	74.00	67.86	6.14
250.00	67.00	68.65	-1.65
250.00	72.00	68.65	3.35

Correlation Coefficient = .980

Capsule W (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:09 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 85.44 T0 = 74.41 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 74.5
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	5.00	5.16	-.16
-25.00	5.00	8.89	-3.89
.00	15.00	14.91	.09
.00	20.00	14.91	5.09
25.00	25.00	23.93	1.07
50.00	30.00	36.09	-6.09
75.00	55.00	50.35	4.65
75.00	50.00	50.35	-.35
100.00	65.00	64.54	.46

Capsule W (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: W Fluence: n/cm^2

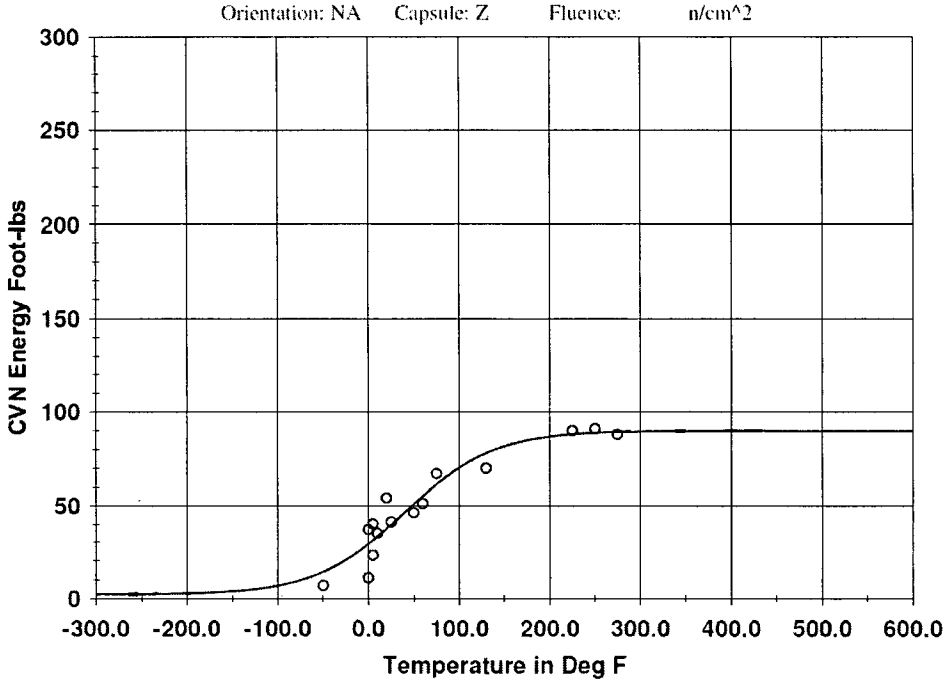
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
140.00	80.00	82.28	-2.28
175.00	90.00	91.33	-1.33
200.00	95.00	94.98	.02
225.00	100.00	97.14	2.86
250.00	100.00	98.39	1.61
250.00	100.00	98.39	1.61

Correlation Coefficient = .997

Capsule Z (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 01:28 PM
Page 1
Coefficients of Curve 1
A = 46.1 B = 43.9 C = 97.5 T0 = 39.58 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=2.1 Deg F Temp@50 ft-lbs=48.3 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	7.00	14.26	-7.26
.00	11.00	29.20	-18.20
.00	37.00	29.20	7.80
5.00	40.00	31.15	8.85
5.00	23.00	31.15	-8.15
10.00	35.00	33.17	1.83
20.00	54.00	37.40	16.60
25.00	41.00	39.58	1.42
50.00	46.00	50.77	-4.77

Capsule Z (Weld)

Page 2

Plant: Vogtle 2 Material: Heat: 87005

Orientation: NA Capsule: Z Fluence: n/cm^2

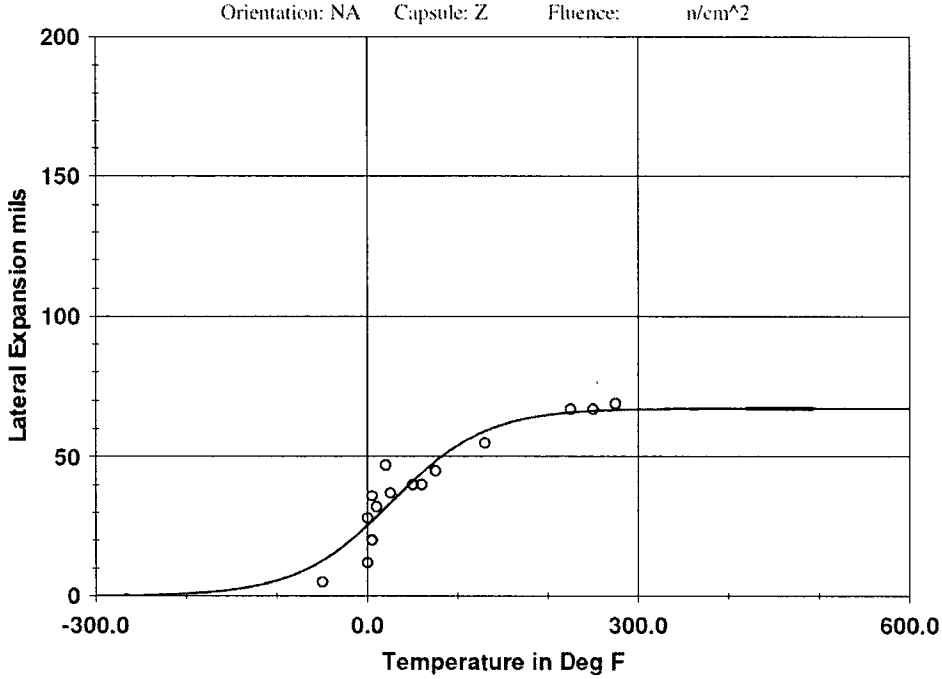
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
60.00	51.00	55.16	-4.16
75.00	67.00	61.38	5.62
130.00	70.00	78.12	-8.12
225.00	90.00	88.09	1.91
250.00	91.00	88.84	2.16
275.00	88.00	89.30	-1.30

Correlation Coefficient = .949

Capsule Z (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 03:45 PM
Page 1
Coefficients of Curve 1
A = 33.65 B = 33.65 C = 104.29 T0 = 26. D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=67.3 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=30.2 Deg F
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	5.00	12.71	-7.71
.00	12.00	25.43	-13.43
.00	28.00	25.43	2.57
5.00	36.00	26.97	9.03
5.00	20.00	26.97	-6.97
10.00	32.00	28.53	3.47
20.00	47.00	31.72	15.28
25.00	37.00	33.33	3.67
50.00	40.00	41.26	-1.26

Capsule Z (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Z Fluence: n/cm^2

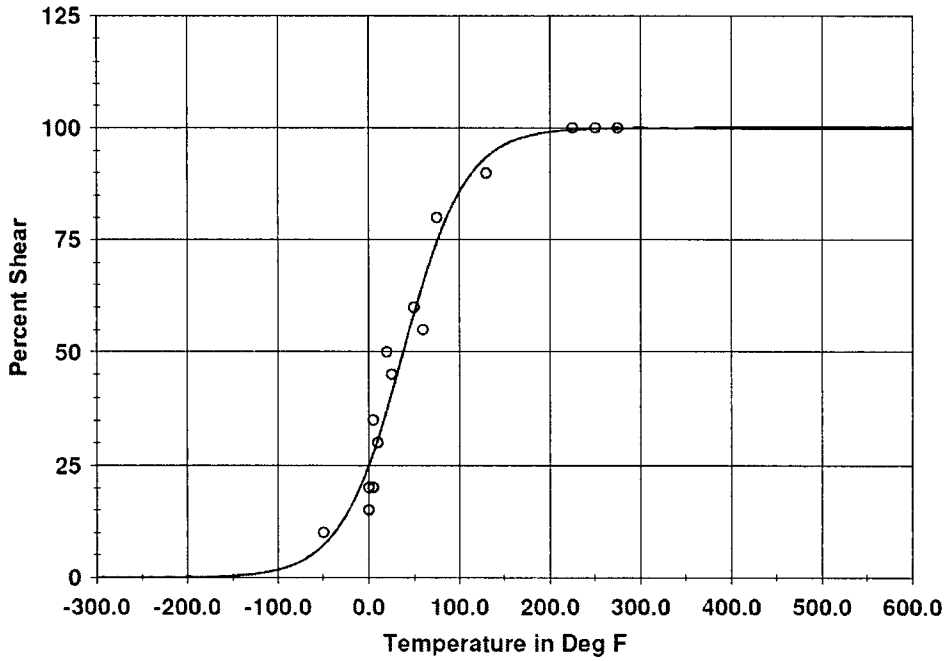
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
60.00	40.00	44.25	-4.25
75.00	45.00	48.39	-3.39
130.00	55.00	59.24	-4.24
225.00	67.00	65.85	1.15
250.00	67.00	66.39	.61
275.00	69.00	66.73	2.27

Correlation Coefficient = .932

Capsule Z (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 01:31 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 68.88 T0 = 38. D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 38.1
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	10.00	7.21	2.79
.00	15.00	24.91	-9.91
.00	20.00	24.91	-4.91
5.00	35.00	27.72	7.28
5.00	20.00	27.72	-7.72
10.00	30.00	30.72	-.72
20.00	50.00	37.22	12.78
25.00	45.00	40.67	4.33
50.00	60.00	58.62	1.38

Capsule Z (Weld)

Page 2
Plant: Vogtle 2 Material: Heat: 87005
Orientation: NA Capsule: Z Fluence: n/cm^2

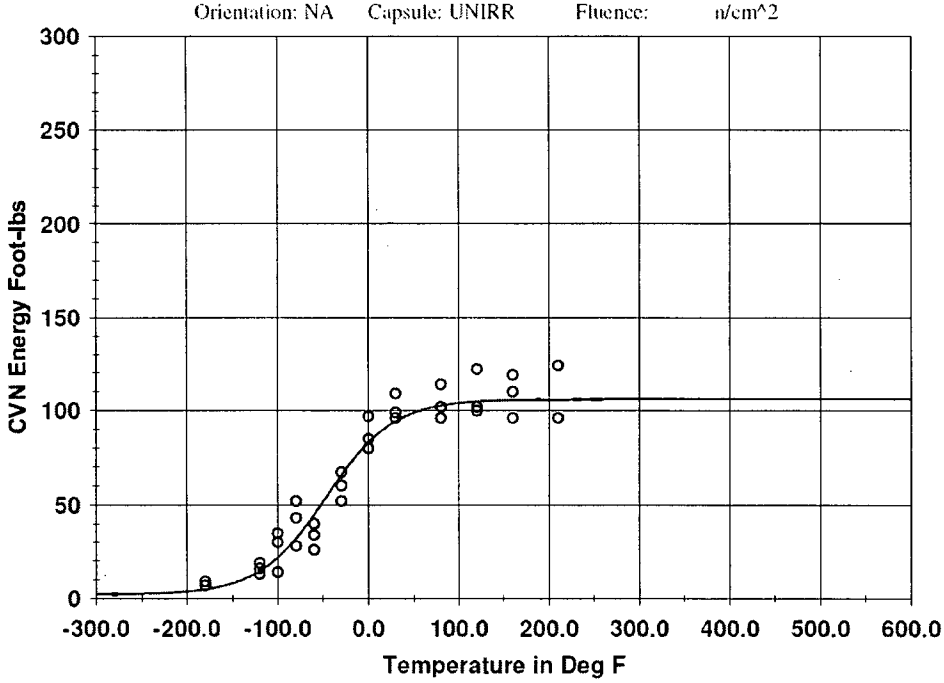
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
60.00	55.00	65.45	-10.45
75.00	80.00	74.54	5.46
130.00	90.00	93.53	-3.53
225.00	100.00	99.56	.44
250.00	100.00	99.79	.21
275.00	100.00	99.90	.10

Correlation Coefficient = .981

Unirradiated (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:15 PM
Page 1
Coefficients of Curve 1
A = 54.1 B = 51.9 C = 73.88 T0 = -46.61 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=106.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-83.7 Deg F Temp@50 ft-lbs=-52.4 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-180.00	7.00	4.93	2.07
-180.00	9.00	4.93	4.07
-120.00	13.00	14.72	-1.72
-120.00	16.00	14.72	1.28
-120.00	19.00	14.72	4.28
-100.00	14.00	22.00	-8.00
-100.00	30.00	22.00	8.00
-100.00	35.00	22.00	13.00
-80.00	28.00	32.12	-4.12

Unirradiated (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

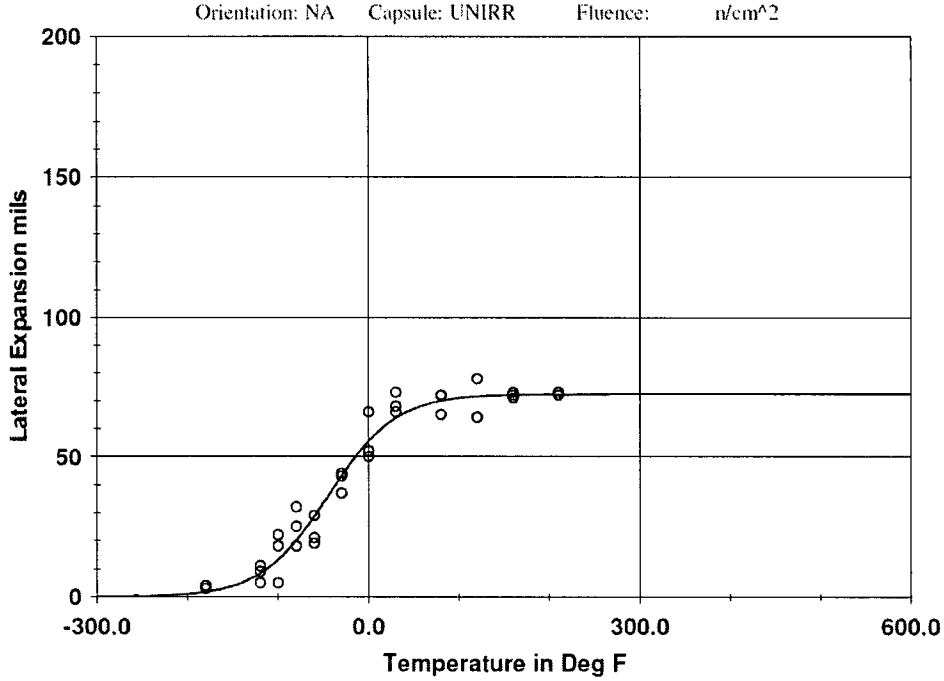
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	43.00	32.12	10.88
-80.00	52.00	32.12	19.88
-60.00	26.00	44.80	-18.80
-60.00	34.00	44.80	-10.80
-60.00	40.00	44.80	-4.80
-30.00	52.00	65.58	-13.58
-30.00	60.00	65.58	-5.58
-30.00	67.00	65.58	1.42
.00	80.00	83.10	-3.10
.00	85.00	83.10	1.90
.00	97.00	83.10	13.90
30.00	96.00	94.41	1.59
30.00	99.00	94.41	4.59
30.00	109.00	94.41	14.59
80.00	96.00	102.74	-6.74
80.00	102.00	102.74	-.74
80.00	114.00	102.74	11.26
120.00	100.00	104.87	-4.87
120.00	102.00	104.87	-2.87
120.00	122.00	104.87	17.13
160.00	96.00	105.62	-9.62
160.00	110.00	105.62	4.38
160.00	119.00	105.62	13.38
210.00	96.00	105.90	-9.90
210.00	124.00	105.90	18.10

Correlation Coefficient = .968

Unirradiated (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 12/14/2010 10:41 AM
Page 1
Coefficients of Curve 1
A = 36.21 B = 36.21 C = 74.44 T0 = -44.47 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=72.4 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=-46.9 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-180.00	4.00	1.85	2.15
-180.00	3.00	1.85	1.15
-120.00	5.00	8.41	-3.41
-120.00	9.00	8.41	.59
-120.00	11.00	8.41	2.59
-100.00	5.00	13.30	-8.30
-100.00	18.00	13.30	4.70
-100.00	22.00	13.30	8.70
-80.00	18.00	20.13	-2.13

Unirradiated (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

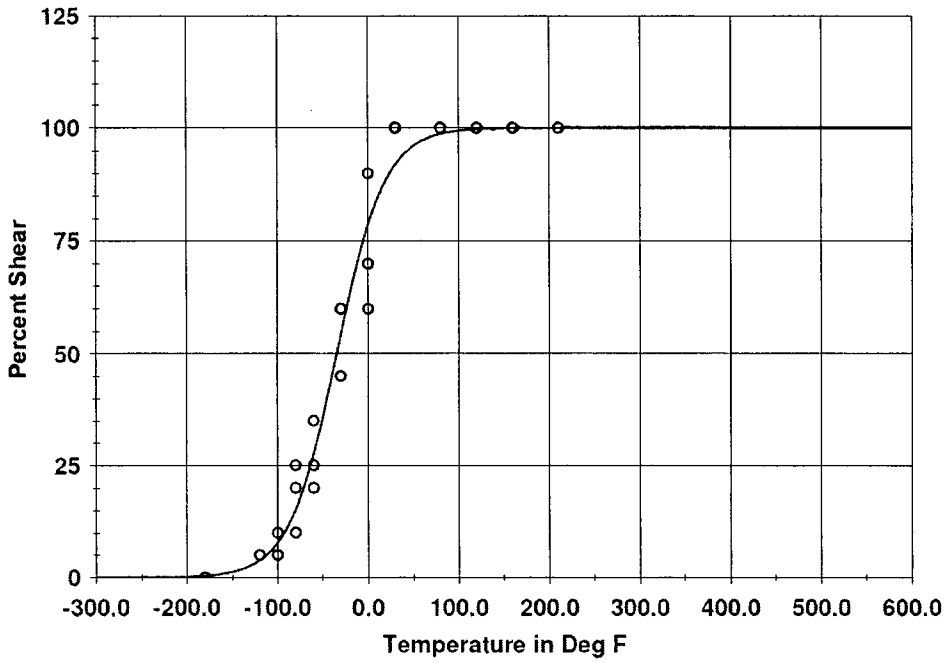
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	25.00	20.13	4.87
-80.00	32.00	20.13	11.87
-60.00	19.00	28.77	-9.77
-60.00	21.00	28.77	-7.77
-60.00	29.00	28.77	.23
-30.00	37.00	43.17	-6.17
-30.00	43.00	43.17	-.17
-30.00	44.00	43.17	.83
.00	52.00	55.60	-3.60
.00	50.00	55.60	-5.60
.00	66.00	55.60	10.40
30.00	68.00	63.80	4.20
30.00	66.00	63.80	2.20
30.00	73.00	63.80	9.20
80.00	72.00	69.96	2.04
80.00	65.00	69.96	-4.96
80.00	72.00	69.96	2.04
120.00	64.00	71.57	-7.57
120.00	64.00	71.57	-7.57
120.00	78.00	71.57	6.43
160.00	73.00	72.13	.87
160.00	71.00	72.13	-1.13
160.00	72.00	72.13	-.13
210.00	72.00	72.35	-.35
210.00	73.00	72.35	.65

Correlation Coefficient = .978

Unirradiated (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:16 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 53.04 T0 = -34.64 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -34.6
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-180.00	.00	.41	-.41
-180.00	.00	.41	-.41
-120.00	5.00	3.85	1.15
-120.00	5.00	3.85	1.15
-120.00	5.00	3.85	1.15
-100.00	5.00	7.84	-2.84
-100.00	5.00	7.84	-2.84
-100.00	10.00	7.84	2.16
-80.00	10.00	15.31	-5.31

Unirradiated (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

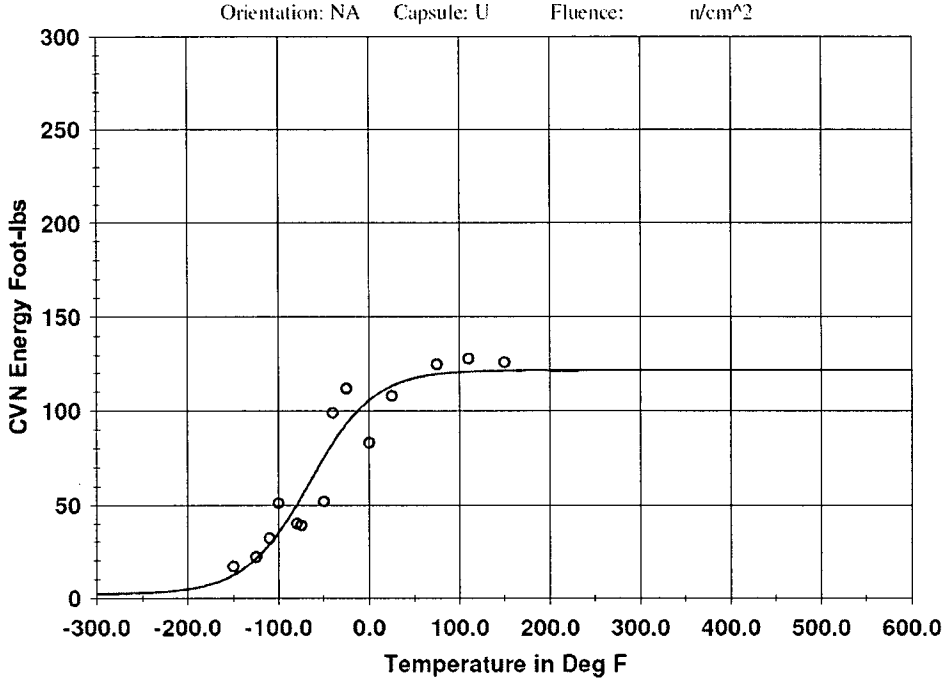
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	20.00	15.31	4.69
-80.00	25.00	15.31	9.69
-60.00	20.00	27.77	-7.77
-60.00	25.00	27.77	-2.77
-60.00	35.00	27.77	7.23
-30.00	60.00	54.36	5.64
-30.00	45.00	54.36	-9.36
-30.00	60.00	54.36	5.64
.00	70.00	78.69	-8.69
.00	60.00	78.69	-18.69
.00	90.00	78.69	11.31
30.00	100.00	91.96	8.04
30.00	100.00	91.96	8.04
30.00	100.00	91.96	8.04
80.00	100.00	98.69	1.31
80.00	100.00	98.69	1.31
80.00	100.00	98.69	1.31
120.00	100.00	99.71	.29
120.00	100.00	99.71	.29
120.00	100.00	99.71	.29
160.00	100.00	99.94	.06
160.00	100.00	99.94	.06
160.00	100.00	99.94	.06
210.00	100.00	99.99	.01
210.00	100.00	99.99	.01

Correlation Coefficient = .990

Capsule U (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:17 PM
Page 1
Coefficients of Curve 1
A = 62.1 B = 59.9 C = 70.83 T0 = -65.7 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=122.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-108.0 Deg F Temp@50 ft-lbs=-80.2 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-150.00	17.00	12.35	4.65
-125.00	22.00	21.11	.89
-110.00	32.00	28.86	3.14
-100.00	51.00	35.17	15.83
-80.00	40.00	50.17	-10.17
-75.00	39.00	54.28	-15.28
-50.00	52.00	75.17	-23.17
-40.00	99.00	82.93	16.07
-25.00	112.00	93.18	18.82

Capsule U (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: U Fluence: n/cm^2

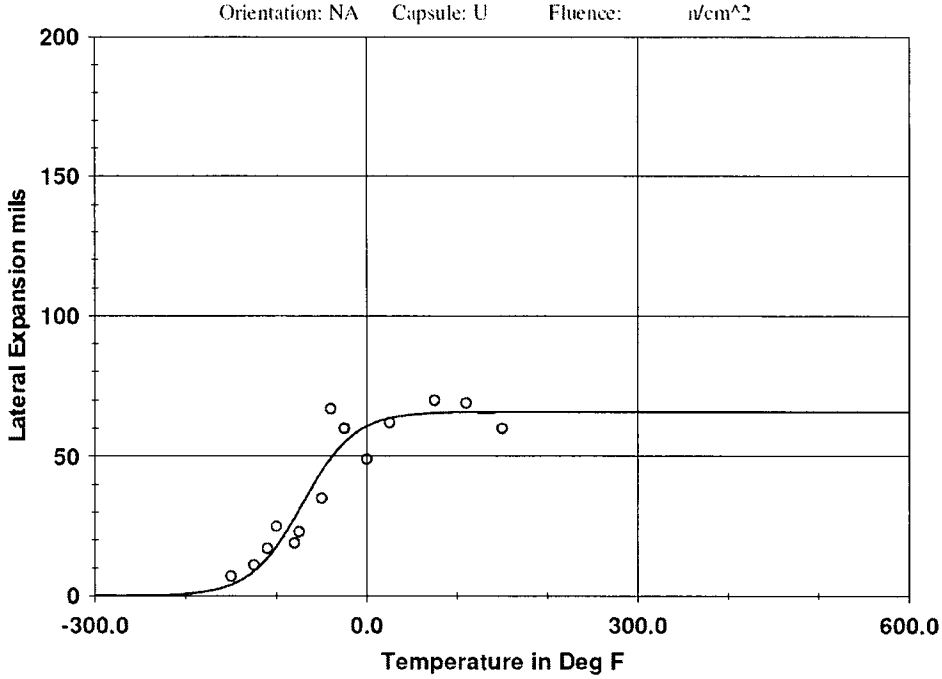
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-25.00	112.00	93.18	18.82
.00	83.00	105.80	-22.80
25.00	108.00	113.41	-5.41
75.00	125.00	119.79	5.21
110.00	128.00	121.17	6.83
150.00	126.00	121.73	4.27

Correlation Coefficient = .941

Capsule U (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 02:52 PM
Page 1
Coefficients of Curve 1
A = 32.95 B = 32.95 C = 57.44 T0 = -71.33 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=65.9 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=-67.7 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-150.00	7.00	4.00	3.00
-125.00	11.00	8.81	2.19
-110.00	17.00	13.61	3.39
-100.00	25.00	17.75	7.25
-80.00	19.00	28.02	-9.02
-75.00	23.00	30.85	-7.85
-50.00	35.00	44.65	-9.65
-40.00	67.00	49.33	17.67
-25.00	60.00	54.95	5.05

Capsule U (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: U Fluence: n/cm^2

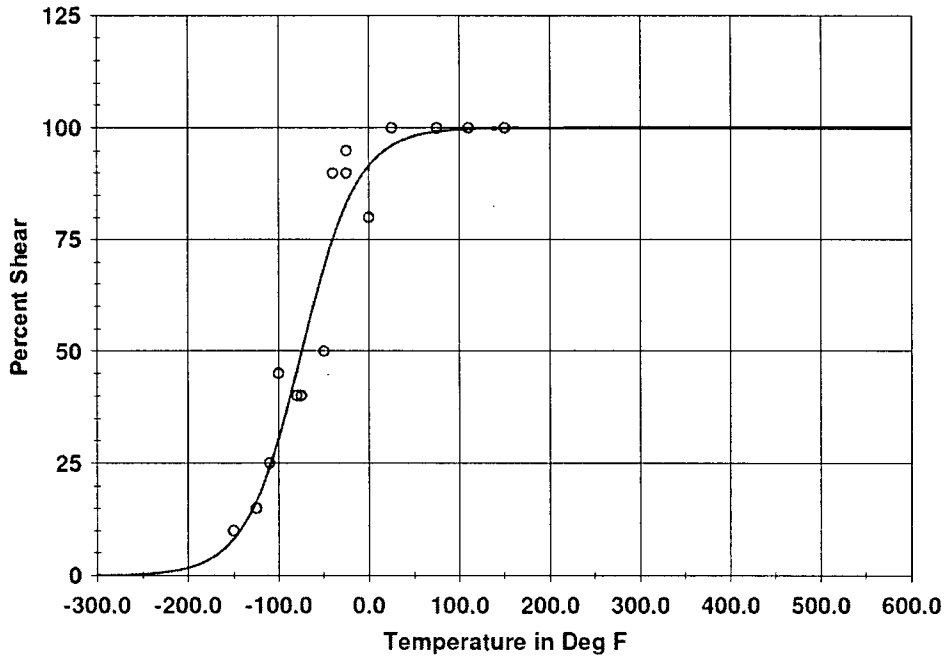
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-25.00	60.00	54.95	5.05
.00	49.00	60.83	-11.83
25.00	62.00	63.68	-1.68
75.00	70.00	65.50	4.50
110.00	69.00	65.78	3.22
150.00	60.00	65.87	-5.87

Correlation Coefficient = .941

Capsule U (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 08:56 AM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 62.09 T0 = -74.49 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -74.4
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-150.00	10.00	8.08	1.92
-125.00	15.00	16.43	-1.43
-110.00	25.00	24.17	.83
-100.00	45.00	30.54	14.46
-80.00	40.00	45.58	-5.58
-75.00	40.00	49.59	-9.59
-50.00	50.00	68.76	-18.76
-40.00	90.00	75.23	14.77
-25.00	95.00	83.12	11.88

Capsule U (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: U Fluence: n/cm^2

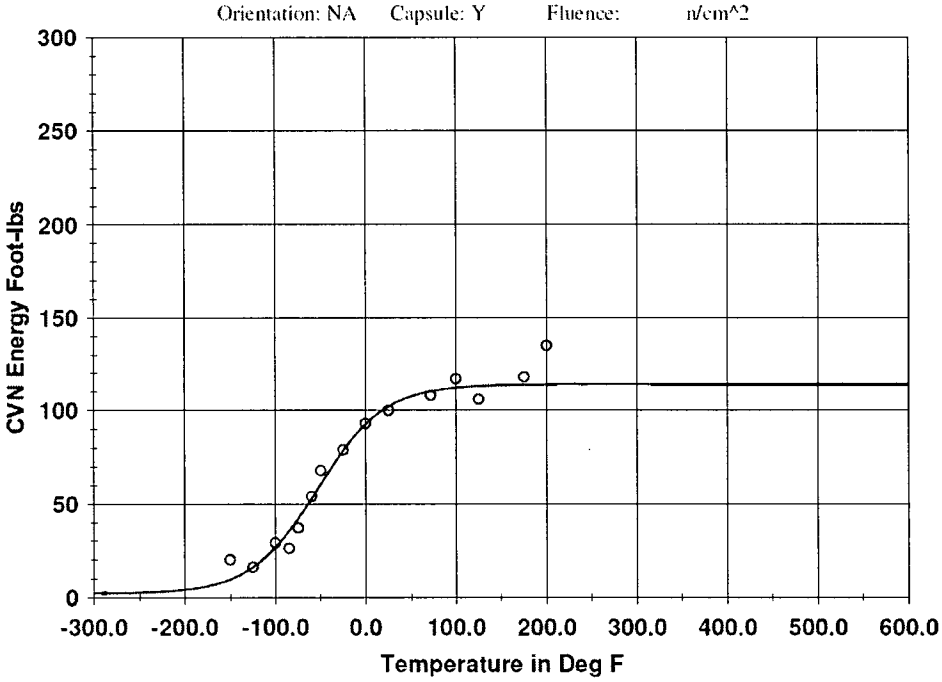
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-25.00	90.00	83.12	6.88
.00	80.00	91.68	-11.68
25.00	100.00	96.10	3.90
75.00	100.00	99.20	.80
110.00	100.00	99.74	.26
150.00	100.00	99.93	.07

Correlation Coefficient = .961

Capsule Y (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/27/2010 08:58 AM
Page 1
Coefficients of Curve 1
A = 58.1 B = 55.9 C = 73.59 T0 = -53.18 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=114.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-93.8 Deg F Temp@50 ft-lbs=-63.9 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-150.00	20.00	9.71	10.29
-125.00	16.00	16.10	-.10
-100.00	29.00	26.67	2.33
-85.00	26.00	35.33	-9.33
-75.00	37.00	42.00	-5.00
-60.00	54.00	52.94	1.06
-50.00	68.00	60.52	7.48
-25.00	79.00	78.52	.48
.00	93.00	92.68	.32

Capsule Y (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Y Fluence: n/cm^2

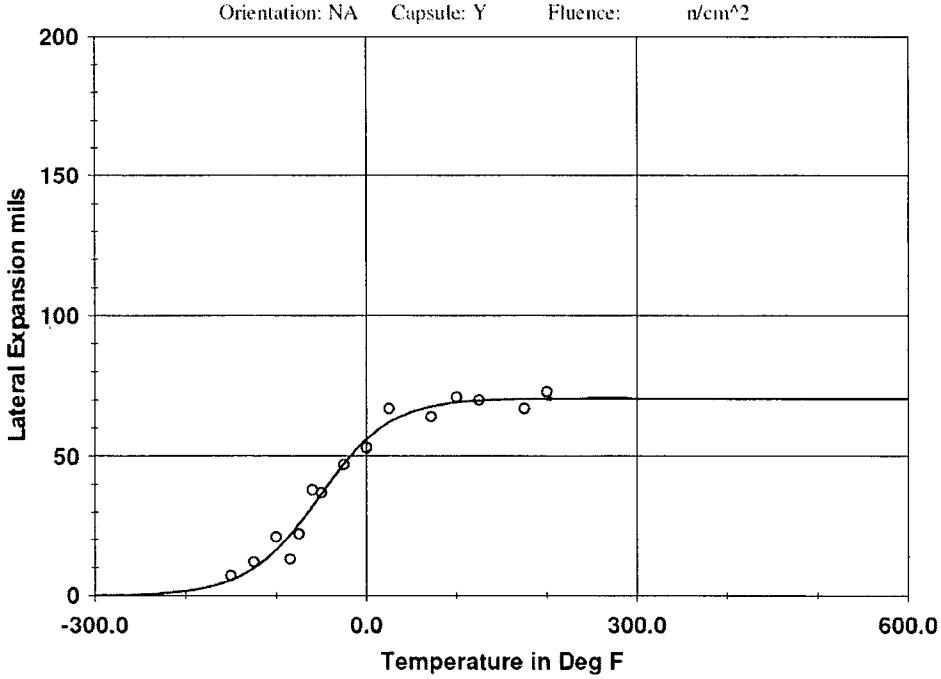
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
25.00	100.00	102.07	-2.07
72.00	108.00	110.40	-2.40
100.00	117.00	112.29	4.71
125.00	106.00	113.13	-7.13
175.00	118.00	113.77	4.23
200.00	135.00	113.89	21.11

Correlation Coefficient = .983

Capsule Y (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/30/2010 11:23 AM
Page 1
Coefficients of Curve 1
A = 35.29 B = 35.29 C = 78.8 T0 = -52.82 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=70.6 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=-53.4 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-150.00	7.00	5.52	1.48
-125.00	12.00	9.74	2.26
-100.00	21.00	16.37	4.63
-85.00	13.00	21.63	-8.63
-75.00	22.00	25.61	-3.61
-60.00	38.00	32.08	5.92
-50.00	37.00	36.55	.45
-25.00	47.00	47.25	-.25
.00	53.00	55.94	-2.94

Capsule Y (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Y Fluence: n/cm^2

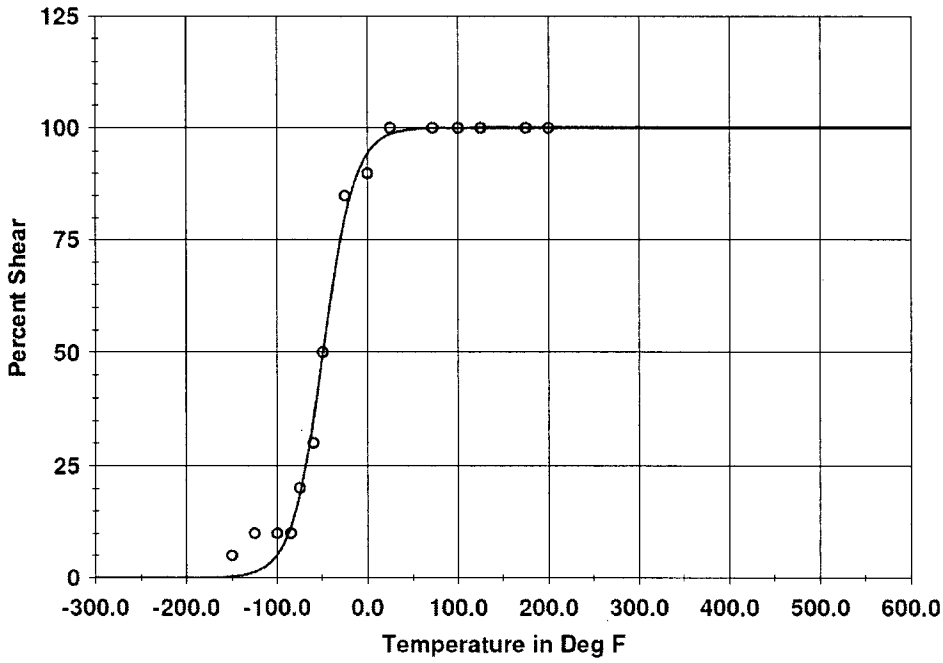
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
25.00	67.00	61.98	5.02
72.00	64.00	67.73	-3.73
100.00	71.00	69.15	1.85
125.00	70.00	69.81	.19
175.00	67.00	70.36	-3.36
200.00	73.00	70.46	2.54

Correlation Coefficient = .987

Capsule Y (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:34 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 34.94 T0 = -49.36 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -49.3
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-150.00	5.00	.31	4.69
-125.00	10.00	1.30	8.70
-100.00	10.00	5.22	4.78
-85.00	10.00	11.51	-1.51
-75.00	20.00	18.73	1.27
-60.00	30.00	35.23	-5.23
-50.00	50.00	49.08	.92
-25.00	85.00	80.13	4.87
.00	90.00	94.40	-4.40

Capsule Y (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Y Fluence: n/cm^2

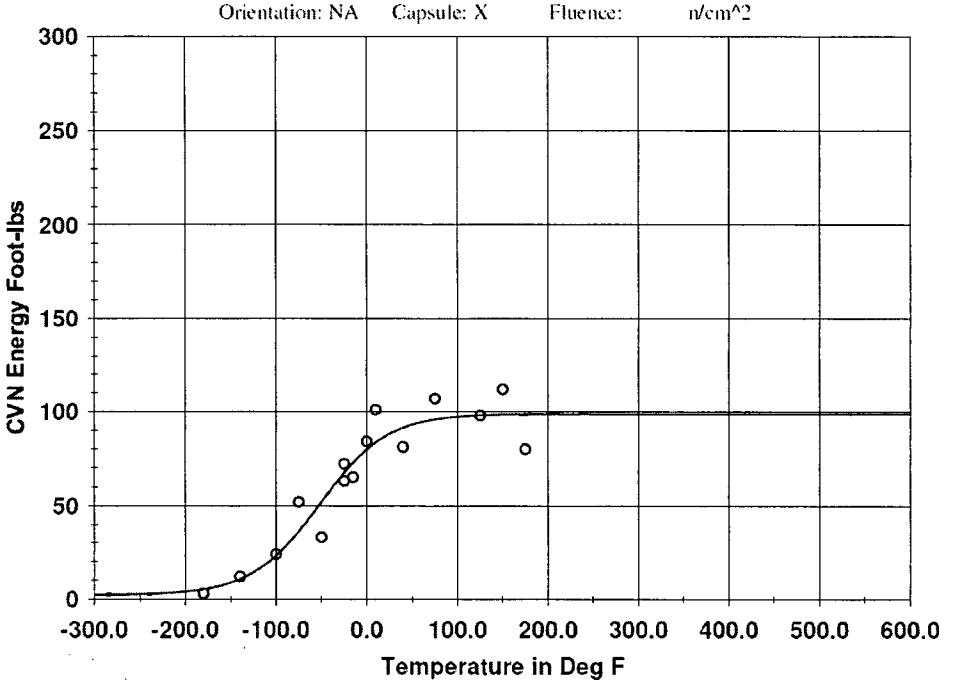
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
25.00	100.00	98.60	1.40
72.00	100.00	99.90	.10
100.00	100.00	99.98	.02
125.00	100.00	100.00	.00
175.00	100.00	100.00	.00
200.00	100.00	100.00	.00

Correlation Coefficient = .997

Capsule X (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:36 PM
Page 1
Coefficients of Curve 1
A = 50.6 B = 48.4 C = 74.79 T0 = -52.28 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=99.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-86.2 Deg F Temp@50 ft-lbs=-53.2 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-180.00	3.00	5.28	-2.28
-140.00	12.00	10.66	1.34
-100.00	24.00	23.32	.68
-75.00	52.00	36.33	15.67
-50.00	33.00	52.08	-19.08
-25.00	72.00	67.51	4.49
-25.00	63.00	67.51	-4.51
-15.00	65.00	72.91	-7.91
.00	84.00	79.82	4.18

Capsule X (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: X Fluence: n/cm^2

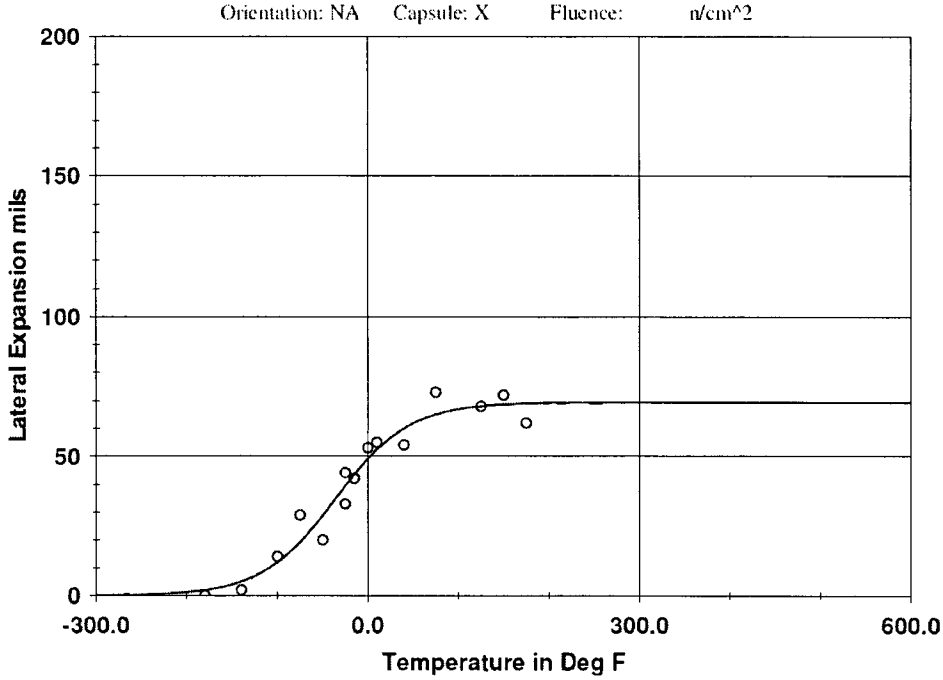
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
10.00	101.00	83.61	17.39
40.00	81.00	91.44	-10.44
75.00	107.00	95.89	11.11
125.00	98.00	98.16	-.16
150.00	112.00	98.57	13.43
175.00	80.00	98.78	-18.78

Correlation Coefficient = .945

Capsule X (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 03:05 PM
Page 1
Coefficients of Curve 1
A = 34.72 B = 34.72 C = 81.9 T0 = -36.15 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=69.4 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=-35.4 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-180.00	.00	2.01	-2.01
-140.00	2.00	5.09	-3.09
-100.00	14.00	12.07	1.93
-75.00	29.00	19.38	9.62
-50.00	20.00	28.90	-8.90
-25.00	44.00	39.42	4.58
-25.00	33.00	39.42	-6.42
-15.00	42.00	43.49	-1.49
.00	53.00	49.12	3.88

Capsule X (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: X Fluence: n/cm^2

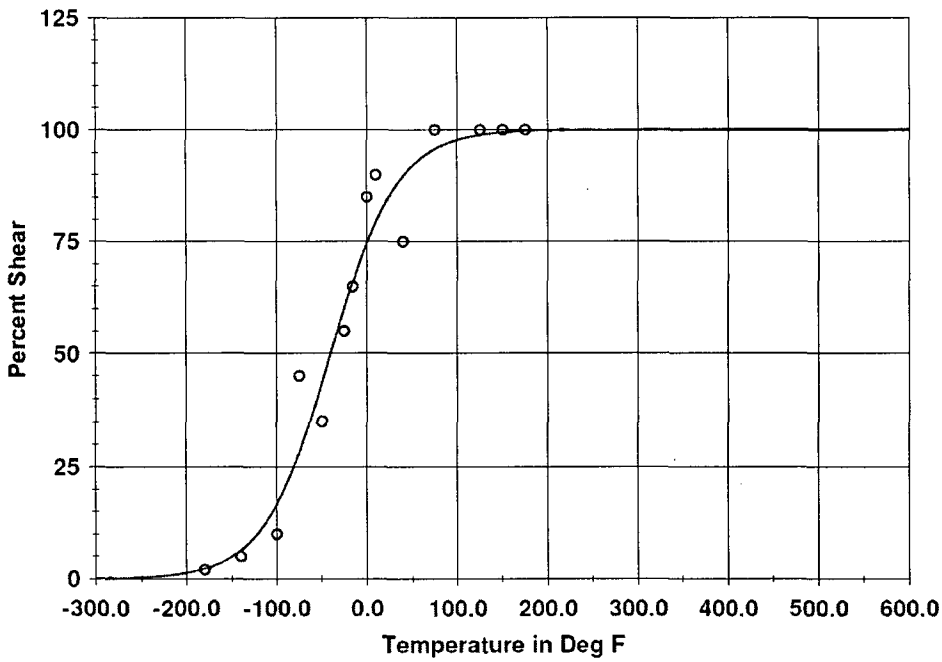
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
10.00	55.00	52.45	2.55
40.00	54.00	60.08	-6.08
75.00	73.00	65.12	7.88
125.00	68.00	68.11	-.11
150.00	72.00	68.71	3.29
175.00	62.00	69.04	-7.04

Correlation Coefficient = .973

Capsule X (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:37 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 74.29 T0 = -40.29 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -40.2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: X Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-180.00	2.00	2.27	-.27
-140.00	5.00	6.39	-1.39
-100.00	10.00	16.70	-6.70
-75.00	45.00	28.20	16.80
-50.00	35.00	43.50	-8.50
-25.00	55.00	60.15	-5.15
-25.00	55.00	60.15	-5.15
-15.00	65.00	66.39	-1.39
.00	85.00	74.74	10.26

Capsule X (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: X Fluence: n/cm^2

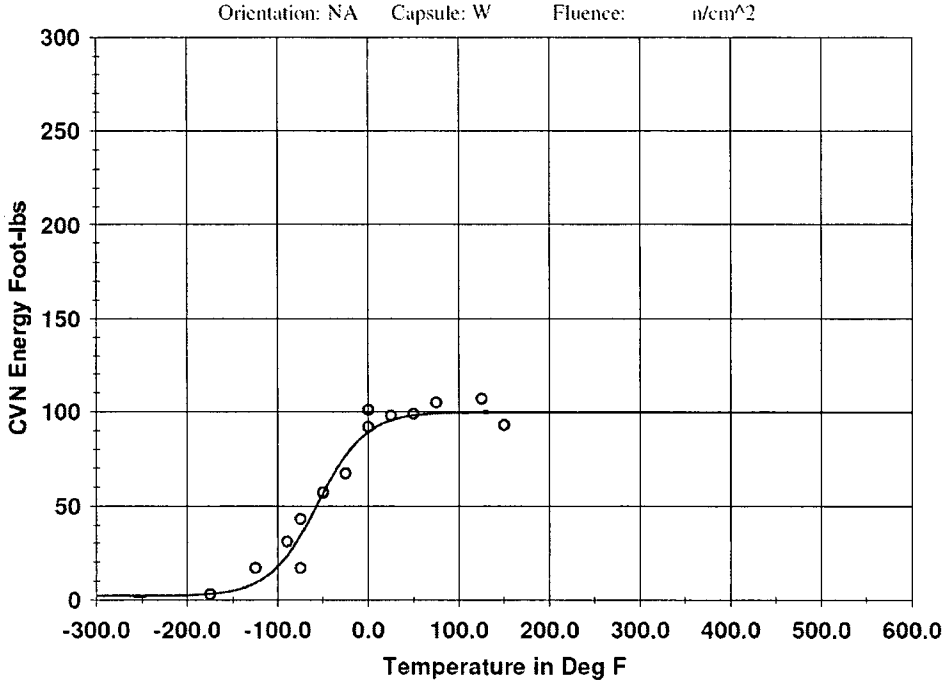
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
10.00	90.00	79.48	10.52
40.00	75.00	89.68	-14.68
75.00	100.00	95.71	4.29
125.00	100.00	98.85	1.15
150.00	100.00	99.41	.59
175.00	100.00	99.70	.30

Correlation Coefficient = .974

Capsule W (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:40 PM
Page 1
Coefficients of Curve 1
A = 51.1 B = 48.9 C = 53.34 T0 = -55.88 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=100.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-80.5 Deg F Temp@50 ft-lbs=-57.0 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-175.00	3.00	3.31	-.31
-125.00	17.00	9.01	7.99
-90.00	31.00	23.49	7.51
-75.00	43.00	34.28	8.72
-75.00	17.00	34.28	-17.28
-50.00	57.00	56.46	.54
-50.00	57.00	56.46	.54
-25.00	67.00	76.62	-9.62
.00	101.00	89.28	11.72

Capsule W (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: W Fluence: n/cm^2

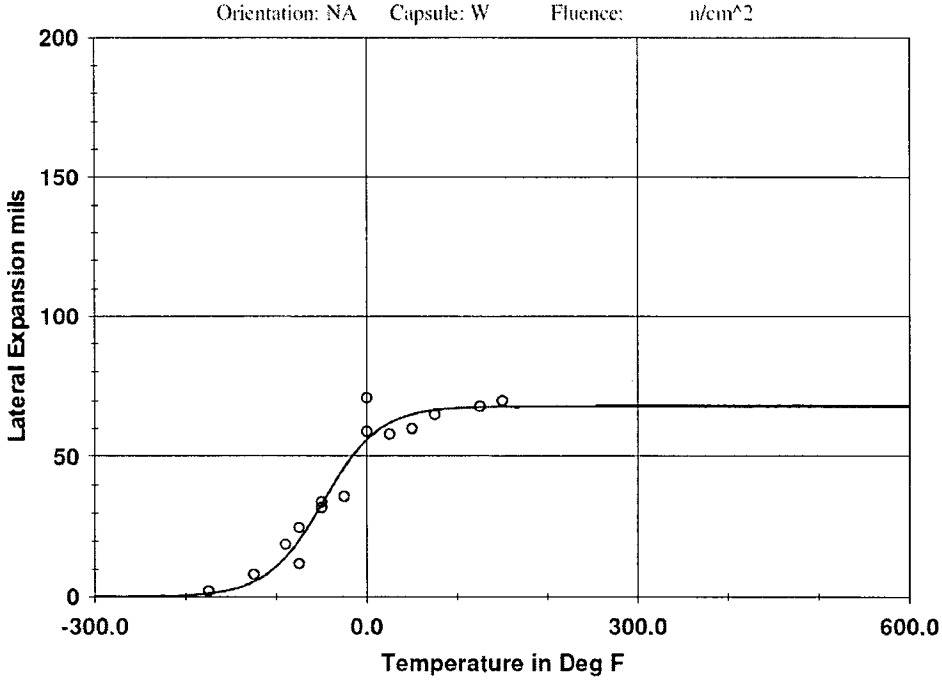
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	92.00	89.28	2.72
25.00	98.00	95.50	2.50
50.00	99.00	98.19	.81
75.00	105.00	99.28	5.72
125.00	107.00	99.89	7.11
150.00	93.00	99.96	-6.96

Correlation Coefficient = .977

Capsule W (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 03:12 PM
Page 1
Coefficients of Curve 1
A = 34.01 B = 34.01 C = 62.8 T0 = -48.33 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=68.0 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=-46.5 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-175.00	2.00	1.18	.82
-125.00	8.00	5.45	2.55
-90.00	19.00	14.26	4.74
-75.00	25.00	20.38	4.62
-75.00	12.00	20.38	-8.38
-50.00	32.00	33.11	-1.11
-50.00	34.00	33.11	.89
-25.00	36.00	46.09	-10.09
.00	71.00	56.00	15.00

Capsule W (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: W Fluence: n/cm^2

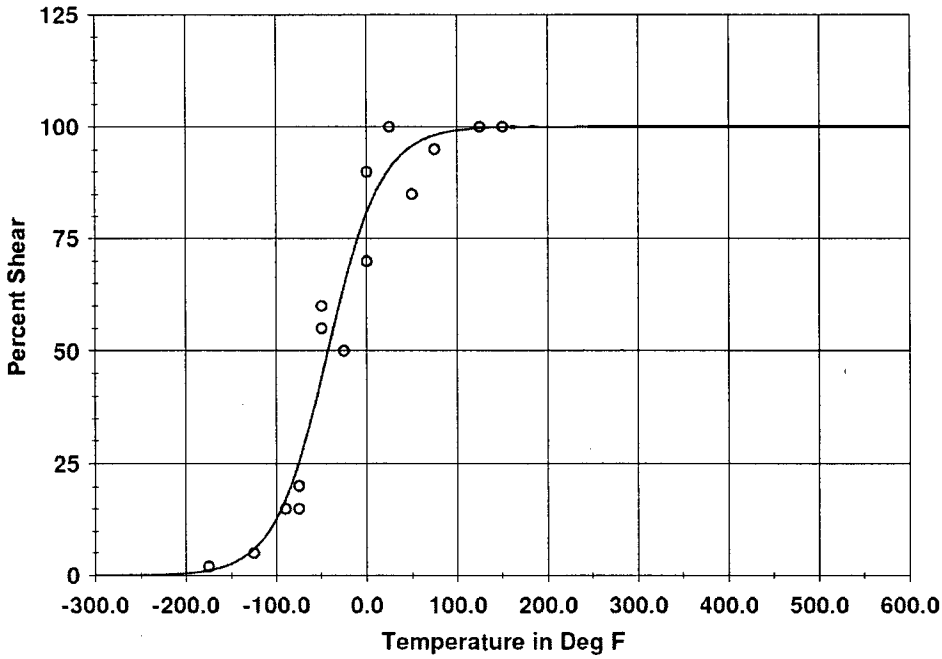
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	59.00	56.00	3.00
25.00	58.00	62.02	-4.02
50.00	60.00	65.18	-5.18
75.00	65.00	66.71	-1.71
125.00	68.00	67.75	.25
150.00	70.00	67.90	2.10

Correlation Coefficient = .969

Capsule W (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 03:46 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 59.52 T0 = -42.89 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -42.8
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-175.00	2.00	1.17	.83
-125.00	5.00	5.96	-.96
-90.00	15.00	17.04	-2.04
-75.00	20.00	25.37	-5.37
-75.00	15.00	25.37	-10.37
-50.00	55.00	44.05	10.95
-50.00	60.00	44.05	15.95
-25.00	50.00	64.59	-14.59
.00	90.00	80.86	9.14

Capsule W (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: W Fluence: n/cm^2

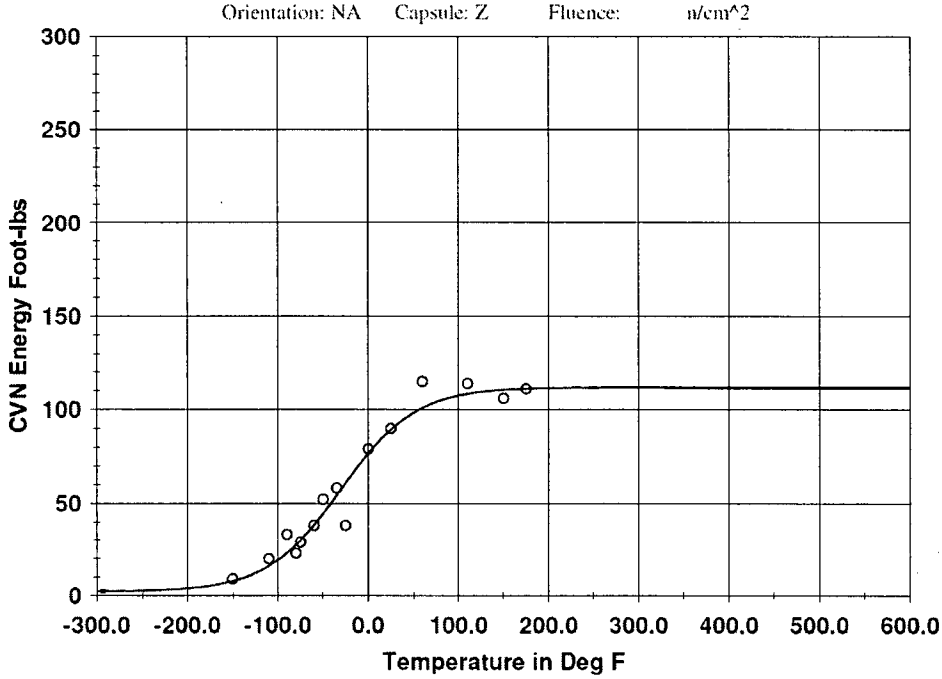
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	70.00	80.86	-10.86
25.00	100.00	90.73	9.27
50.00	85.00	95.78	-10.78
75.00	95.00	98.13	-3.13
125.00	100.00	99.65	.35
150.00	100.00	99.85	.15

Correlation Coefficient = .971

Capsule Z (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 04:00 PM
Page 1
Coefficients of Curve 1
A = 57.1 B = 54.9 C = 82.44 T0 = -30.56 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=112.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-75.1 Deg F Temp@50 ft-lbs=-41.2 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-150.00	9.00	7.94	1.06
-110.00	20.00	16.15	3.85
-90.00	33.00	23.20	9.80
-80.00	23.00	27.63	-4.63
-75.00	29.00	30.08	-1.08
-60.00	38.00	38.29	-.29
-50.00	52.00	44.39	7.61
-35.00	58.00	54.15	3.85
-25.00	38.00	60.80	-22.80

Capsule Z (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Z Fluence: n/cm^2

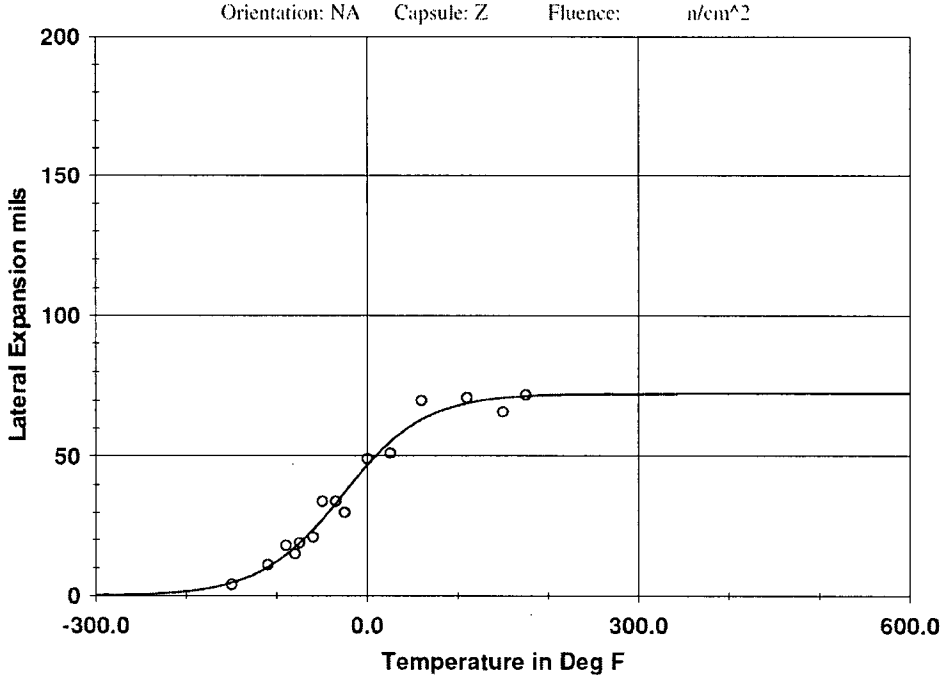
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	79.00	76.57	2.43
25.00	90.00	89.36	.64
60.00	115.00	101.02	13.98
110.00	114.00	108.49	5.51
150.00	106.00	110.64	-4.64
175.00	111.00	111.26	-.26

Correlation Coefficient = .976

Capsule Z (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 11/02/2010 04:03 PM
Page 1
Coefficients of Curve 1
A = 36.22 B = 36.22 C = 91.05 T0 = -27.52 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=72.4 Lower Shelf L.E.=.0(Fixed)
Temp.@L.E. 35 mils=-30.5 Deg F
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-150.00	4.00	4.60	-.60
-110.00	11.00	10.17	.83
-90.00	18.00	14.65	3.35
-80.00	15.00	17.38	-2.38
-75.00	19.00	18.87	.13
-60.00	21.00	23.82	-2.82
-50.00	34.00	27.45	6.55
-35.00	34.00	33.25	.75
-25.00	30.00	37.22	-7.22

Capsule Z (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Z Fluence: n/cm^2

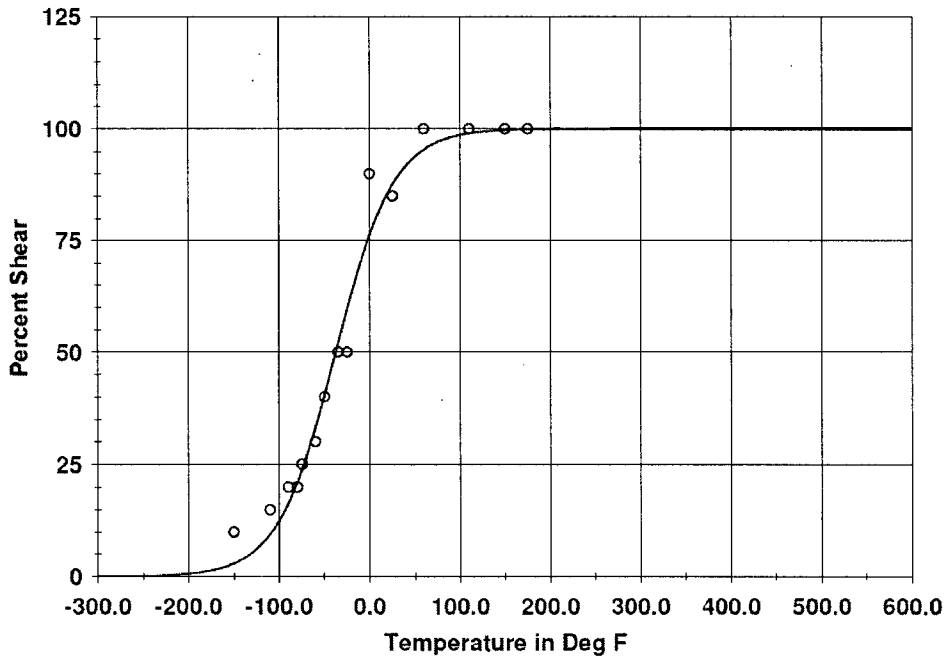
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	49.00	46.84	2.16
25.00	51.00	55.06	-4.06
60.00	70.00	63.19	6.81
110.00	71.00	69.07	1.93
150.00	66.00	71.00	-5.00
175.00	72.00	71.60	.40

Correlation Coefficient = .986

Capsule Z (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 10/25/2010 01:45 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 64.25 T0 = -37.56 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -37.5
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Z Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-150.00	10.00	2.93	7.07
-110.00	15.00	9.49	5.51
-90.00	20.00	16.35	3.65
-80.00	20.00	21.06	-1.06
-75.00	25.00	23.77	1.23
-60.00	30.00	33.21	-3.21
-50.00	40.00	40.44	-.44
-35.00	50.00	51.99	-1.99
-25.00	50.00	59.65	-9.65

Capsule Z (Heat Affected Zone)

Page 2
Plant: Vogtle 2 Material: SA533B1 Heat: C3500-2
Orientation: NA Capsule: Z Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	90.00	76.30	13.70
25.00	85.00	87.51	-2.51
60.00	100.00	95.42	4.58
110.00	100.00	99.00	1.00
150.00	100.00	99.71	.29
175.00	100.00	99.87	.13

Correlation Coefficient = .989

APPENDIX D
VOGTLE UNIT 2 SURVEILLANCE PROGRAM CREDIBILITY EVALUATION

D.1 INTRODUCTION

Regulatory Guide 1.99, Revision 2 [Ref. 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. Positions 2.1 and 2.2 of Regulatory Guide 1.99, Revision 2, describe the method for calculating the adjusted reference temperature and Charpy upper-shelf energy of reactor vessel beltline materials using surveillance capsule data. The methods of Positions 2.1 and 2.2 can only be applied when two or more credible surveillance data sets become available from the reactor in question.

To date there have been five surveillance capsules removed from the Vogtle Unit 2 reactor vessel and tested. To use these surveillance data sets, they must be shown to be credible. 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 Vogtle Unit 2 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" [Ref. D-2], as follows:

> *"the region of 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 Vogtle Unit 2 reactor vessel consists of the following beltline region materials:

- Intermediate Shell Plates R4-1, R4-2, and R4-3
- Lower Shell Plates B8825-1, R8-1, and B8628-1
- Intermediate Shell Longitudinal Weld Seams 101-124 A, B, and C (fabricated with weld wire Heat # 87005, Linde 0091 flux, Lot # 0145)
- Lower Shell Longitudinal Weld Seams 101-142 A, B, and C (fabricated with weld wire Heat # 87005, Linde 0091 flux, Lot # 0145)
- Intermediate to Lower Shell Circumferential Weld Seam 101-171 (fabricated with weld wire Heat # 87005, Linde 124 flux, Lot # 1061)

The Vogtle Unit 2 surveillance program utilizes longitudinal and transverse test specimens from Lower Shell Plate B8628-1. The surveillance weld metal was fabricated with weld wire Heat # 87005, Linde 124 flux, Lot # 1061.

At the time when the surveillance program material was selected, it was believed that copper and phosphorus were the elements most important to embrittlement of reactor vessel steels. Lower Shell Plate B8628-1 had the highest initial RT_{NDT} and one of the lowest initial USE values of all plate materials in the beltline region. In addition, Lower Shell Plate B8628-1 had approximately the same copper and phosphorus content of the other beltline plate materials. Based on the highest initial RT_{NDT} and one of the lowest initial USE values of all plate materials in the beltline region, Lower Shell Plate B8628-1 was chosen for the surveillance program.

The circumferential weld has the same heat number as all the beltline longitudinal welds, but a different flux. The circumferential weld had the lower initial RT_{NDT} of the two flux types. However, both welds had low initial RT_{NDT} values and approximately the same copper and phosphorus content. The initial USE of the circumferential weld was approximately 60 ft-lbs lower than the initial USE of the beltline longitudinal weld seams. Thus, the circumferential weld was selected based on the lower USE value.

Based on the above discussion and the methodology in use at the time the program was developed, the Vogtle Unit 2 surveillance material meets the intent of Criterion 1.

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 Vogtle Unit 2 surveillance materials unambiguously. Hence, the Vogtle Unit 2 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 should normally 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 [Ref. D-3].

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 welds and less than 17°F for the plate.

The Vogtle Unit 2 Lower Shell Plate B8628-1 and surveillance weld material will be evaluated for credibility. The weld is made from weld wire Heat # 87005; Vogtle Unit 2 does not have a sister plant that shares the same weld wire heat and thus does not utilize data from other surveillance programs. Therefore, the method of Regulatory Guide 1.99, Revision 2 will be followed for determining credibility of the weld as well as the plate material.

Credibility Assessment:

Since all surveillance data is from one vessel (Vogtle Unit 2), the measured ΔRT_{NDT} and fluence factor (FF) should be used to calculate the chemistry factors to determine if the Vogtle Unit 2 surveillance material test results are credible.

The chemistry factors for the Vogtle Unit 2 surveillance plate 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 Interim Chemistry Factors for the Credibility Evaluation using Vogtle Unit 2 Surveillance Capsule Data

Material	Capsule	Capsule f ($x\ 10^{19}$ n/cm^2)	FF	ΔRT_{NDT} (°F)	$FF*\Delta RT_{NDT}$ (°F)	FF^2
Lower Shell Plate B8628-1 (Longitudinal)	U	0.356	0.715	2.0	1.43	0.511
	Y	1.12	1.032	5.8	5.98	1.064
	X	1.78	1.158	29.4	34.06	1.342
	W	2.98	1.289	39.0	50.28	1.662
	Z	4.16	1.365	59.0	80.51	1.862
Lower Shell Plate B8628-1 (Transverse)	U	0.356	0.715	0.0[a]	0.00	0.511
	Y	1.12	1.032	1.9	1.96	1.064
	X	1.78	1.158	29.8	34.52	1.342
	W	2.98	1.289	45.5	58.65	1.662
	Z	4.16	1.365	75.3	102.76	1.862
	SUM:				370.15	12.883
	$CF_{B8628-1} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (370.15) \div (12.883) = 28.7°F$					
Surveillance Weld Material	U	0.356	0.715	0.0[a]	0.00	0.511
	Y	1.12	1.032	18.7	19.29	1.064
	X	1.78	1.158	19.9	23.05	1.342
	W	2.98	1.289	31.4	40.48	1.662
	Z	4.16	1.365	21.3	29.07	1.862
	SUM:				111.89	6.441
	$CF_{Surv.\ Weld} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (111.89) \div (6.441) = 17.4°F$					

Note:

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

Table D-2 Vogtle Unit 2 Surveillance Capsule Data Scatter about the Best-Fit Line

Material	Capsule	CF ($Slope_{best\ fit}$) (°F)	Capsule f ($x\ 10^{19}$ n/cm^2)	FF	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	Scatter ΔRT_{NDT} (°F)	<17°F (Base Metal) <28°F (Weld)
Lower Shell Plate B8628-1 (Longitudinal)	U	28.7	0.356	0.715	2.0	20.5	18.5	no
	Y	28.7	1.12	1.032	5.8	29.6	23.8	no
	X	28.7	1.78	1.158	29.4	33.3	3.9	yes
	W	28.7	2.98	1.289	39.0	37.0	2.0	yes
	Z	28.7	4.16	1.365	59.0	39.2	19.8	no
Lower Shell Plate B8628-1 (Transverse)	U	28.7	0.356	0.715	0.0	20.5	20.5	no
	Y	28.7	1.12	1.032	1.9	29.6	27.7	no
	X	28.7	1.78	1.158	29.8	33.3	3.5	yes
	W	28.7	2.98	1.289	45.5	37.0	8.5	yes
	Z	28.7	4.16	1.365	75.3	39.2	36.1	no
Surveillance Weld Material	U	17.4	0.356	0.715	0.0	12.4	12.4	yes
	Y	17.4	1.12	1.032	18.7	17.9	0.8	yes
	X	17.4	1.78	1.158	19.9	20.1	0.2	yes
	W	17.4	2.98	1.289	31.4	22.4	9.0	yes
	Z	17.4	4.16	1.365	21.3	23.7	2.4	yes

From a statistical point of view, +/- 1σ would be expected to encompass 68% of the data. Table D-2 indicates that six of the ten surveillance data points fall outside the +/- 1σ of 17°F scatter band for surveillance base metals; therefore, the plate data is deemed "not credible" per the third criterion.

Table D-2 indicates that zero of the five surveillance data points falls outside the +/- 1σ of 28°F scatter band for surveillance weld materials; therefore, the surveillance weld data is deemed "credible" per the third criterion.

Note that although Lower Shell Plate B8628-1 did not meet Criterion 3, both materials (Lower Shell Plate B8628-1 and the surveillance weld material) may still be used in determining the upper-shelf energy decrease in accordance with Regulatory Guide 1.99, Revision 2, Position 2.2.

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 pads. 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 Vogtle Unit 2 surveillance program does not contain correlation monitor material. Therefore, this criterion is not applicable to the Vogtle Unit 2 surveillance program.

D.3 CONCLUSION

Based on the preceding responses to all five criteria of Regulatory Guide 1.99, Revision 2, Section B, the Vogtle Unit 2 surveillance data is deemed credible for the weld specimens and non-credible for the plate specimens.

D.4 REFERENCES

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

D-2 10 CFR 50, Appendix G, *Fracture Toughness Requirements*, Federal Register, Volume 60, No. 243, December 19, 1995.

D-3 ASTM E185-82, *Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels, E706(IF)*, ASTM, 1982.

APPENDIX E
VOGTLE UNIT 2 UPPER-SHELF ENERGY EVALUATION

Per Regulatory Guide 1.99, Revision 2 [Ref. 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.

The 36 EFPY (end-of-license) and 57 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 36 and 57 EFPY. Note that the maximum fluence value associated with 57 EFPY was calculated based on the linear interpolation of the maximum fluence values at 54 EFPY and 60 EFPY.

The Vogtle Unit 2 reactor vessel beltline region minimum thickness is 8.625 inches. Calculation of the 1/4T vessel surface fluence values at 36 and 57 EFPY for the beltline materials is shown as follows:

$$\text{Maximum Vessel Fluence @ 36 EFPY} = 2.00 \times 10^{19}\ \text{n/cm}^2\ (E > 1.0\ \text{MeV})$$

$$\text{1/4T Fluence @ 36 EFPY} = (2.00 \times 10^{19}\ \text{n/cm}^2) * e^{(-0.24 * (8.625 / 4))}$$

$$= 1.192 \times 10^{19}\ \text{n/cm}^2\ (E > 1.0\ \text{MeV})$$

$$\text{Maximum Vessel Fluence @ 57 EFPY} = 3.19 \times 10^{19}\ \text{n/cm}^2\ (E > 1.0\ \text{MeV})$$

$$\text{1/4T Fluence @ 57 EFPY} = (3.19 \times 10^{19}\ \text{n/cm}^2) * e^{(-0.24 * (8.625 / 4))}$$

$$= 1.901 \times 10^{19}\ \text{n/cm}^2\ (E > 1.0\ \text{MeV})$$

The following pages present the Vogtle Unit 2 upper-shelf energy evaluation. Figure E-1, as indicated above, is used in making predictions in accordance with Regulatory Guide 1.99, Revision 2. Table E-1 provides the predicted upper-shelf energy values for 36 EFPY (end-of-license). Table E-2 provides the predicted upper-shelf energy values for 57 EFPY (end-of-license renewal).

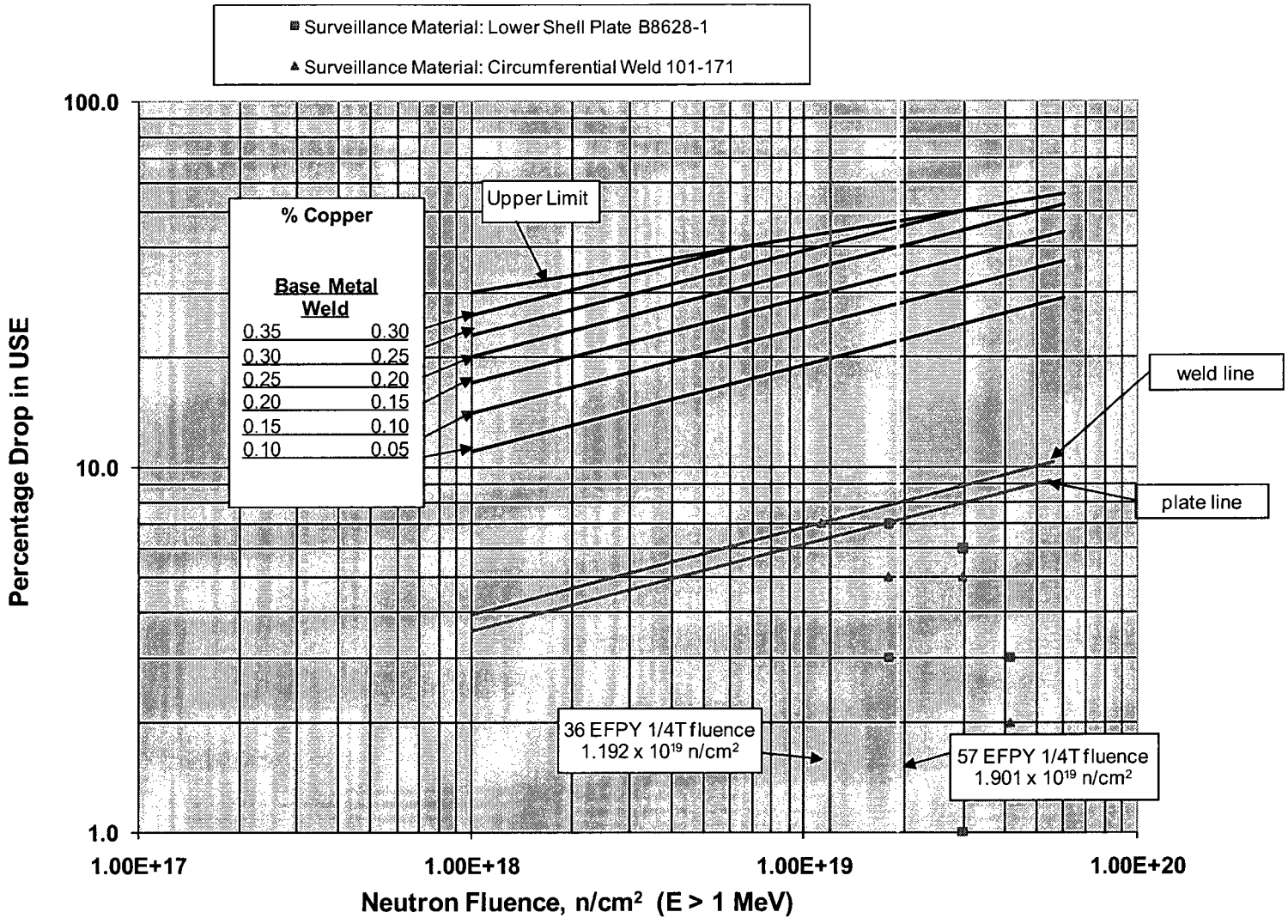


Figure E-1 **Regulatory Guide 1.99, Revision 2 Predicted Decrease in Upper-Shelf Energy as a Function of Copper and Fluence**

Table E-1 Predicted Positions 1.2 and 2.2 Upper-Shelf Energy Values at 36 EFPY

Material	Weight % of Cu	1/4T EOL Fluence (x 10^{19} n/cm^2, E > 1.0 MeV)	Unirradiated USE (ft-lb)	Projected USE Decrease (%)	Projected EOL USE (ft-lb)
Position 1.2					
Intermediate Shell Plate R4-1	0.07	1.192	95	20	76
Intermediate Shell Plate R4-2	0.06	1.192	104	20	83
Intermediate Shell Plate R4-3	0.05	1.192	84	20	67
Lower Shell Plate B8825-1	0.06	1.192	83	20	66
Lower Shell Plate R8-1	0.07	1.192	87	20	70
Lower Shell Plate B8628-1	0.05	1.192	85	20	68
Intermediate Shell Longitudinal Weld Seams 101-124 A, B, C (Heat # 87005)	0.05	1.192[a]	152	20	122
Lower Shell Longitudinal Weld Seams 101-142 A, B, C (Heat # 87005)	0.05	1.192[a]	152	20	122
Intermediate to Lower Shell Circumferential Weld Seam 101-171 (Heat # 87005)	0.05	1.192	90	20	72
Position 2.2[b]					
Lower Shell Plate B8628-1	0.05	1.192	85	6.4	80
Intermediate & Lower Shell Longitudinal Welds (Heat # 87005)	0.05	1.192[a]	152	7.2	141
Intermediate to Lower Shell Circumferential Weld (Heat # 87005)	0.05	1.192	90	7.2	84

Notes:

(a) The fluence values listed for the intermediate and lower shell longitudinal welds conservatively pertain to the maximum vessel fluence value, though the welds vary in location.

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

Table E-2 Predicted Positions 1.2 and 2.2 Upper-Shelf Energy Values at 57 EFPY

Material	Weight % of Cu	1/4T EOLR Fluence (x 10^{19} n/cm^2, E > 1.0 MeV)	Unirradiated USE (ft-lb)	Projected USE Decrease (%)	Projected EOLR USE (ft-lb)
Position 1.2					
Intermediate Shell Plate R4-1	0.07	1.901	95	22	74
Intermediate Shell Plate R4-2	0.06	1.901	104	22	81
Intermediate Shell Plate R4-3	0.05	1.901	84	22	66
Lower Shell Plate B8825-1	0.06	1.901	83	22	65
Lower Shell Plate R8-1	0.07	1.901	87	22	68
Lower Shell Plate B8628-1	0.05	1.901	85	22	66
Intermediate Shell Longitudinal Weld Seams 101-124 A, B, C (Heat # 87005)	0.05	1.901[(a)]	152	22	119
Lower Shell Longitudinal Weld Seams 101-142 A, B, C (Heat # 87005)	0.05	1.901[(a)]	152	22	119
Intermediate to Lower Shell Circumferential Weld Seam 101-171 (Heat # 87005)	0.05	1.901	90	22	70
Position 2.2[(b)]					
Lower Shell Plate B8628-1	0.05	1.901	85	7	79
Intermediate & Lower Shell Longitudinal Welds (Heat # 87005)	0.05	1.901[(a)]	152	8.2	140
Intermediate to Lower Shell Circumferential Weld (Heat # 87005)	0.05	1.901	90	8.2	83

Notes:

(a) The fluence values listed for the intermediate and lower shell longitudinal welds conservatively pertain to the maximum vessel fluence value, though the welds vary in location.

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

USE Conclusion

All of the beltline materials in the Vogtle Unit 2 reactor vessel are projected to remain above the USE screening criterion value of 50 ft-lb (per 10 CFR 50, Appendix G) at 36 and 57 EFPY.

E.1 REFERENCES

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