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WCAP-15067
Revision 0

Analysis of Capsule V from Southern Nuclear Vogtle Electric Generating Plant Unit 1 Reactor Vessel Radiation Surveillance Program

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Westinghouse Energy Systems

WCAP-15067

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PREFACE

This report has been technically reviewed and verified by:

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EXECUTIVE SUMMARY

The purpose of this report is to document the results of the testing of surveillance capsule V from Vogtle Electric Generating Plant Unit 1. Capsule V was removed at 8.57 EFPY and post irradiation mechanical tests of the Charpy V notch and tensile specimens was performed, along with a fluence evaluation. The peak clad base/metal vessel fluence after 8.57 EFPY of plant operation was 2.178×10^{19} n/cm^2. A brief summary of the Charpy V-notch testing can be found in Section 1 and the updated capsule removal schedule can be found in Section 7. A supplement to this report is a credibility evaluation, which can be found in Appendix D, that shows the Vogtle Electric Generating Plant Unit 1 surveillance data to be credible.

1 SUMMARY OF RESULTS

The analysis of the reactor vessel materials contained in surveillance capsule V, the third capsule to be removed from the Vogtle Electric Generating Plant Unit 1 reactor pressure vessel, led to the following conclusions:

- The Charpy V-notch data presented in WCAP-11011[3], WCAP-12256[42] and WCAP-13931 Rev. 1[43] were based on hand-fit Charpy curves using engineering judgment. However, the results presented in this report are based on a replot of all capsule data using CVGRAPH, Version 4.1, which is a hyperbolic tangent curve-fitting program. Appendix B presents a comparison of the Charpy V-Notch test results for each capsule based on hand fit vs. hyperbolic tangent fit. Appendix C presents the CVGRAPH, Version 4.1, Charpy V-notch plots and the program input data.

- Fluence projections for future operation were based on the assumption that the exposure rates averaged over Cycle 4 through 7 (low-leakage loading pattern) would continue to be applicable throughout plant life.

- The capsule received an average fast neutron fluence (E> 1.0 MeV) of 2.178×10^{19} n/cm^2 after 8.57 effective full power years (EFPY) of plant operation.

- Irradiation of the reactor vessel intermediate shell plate B8805-3 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major rolling direction (Longitudinal orientation), to 2.178×10^{19} n/cm^2 (E> 1.0MeV) resulted in a 30 ft-lb transition temperature increase of 43°F and a 50 ft-lb transition temperature increase of 59°F. This results in an irradiated 30 ft-lb transition temperature of 28°F and an irradiated 50 ft-lb transition temperature of 81°F for the Longitudinal oriented specimens.

- Irradiation of the reactor vessel intermediate shell plate B8805-3 Charpy specimens, oriented with the longitudinal axis of the specimen perpendicular to the major rolling direction of the plate (Transverse orientation), to 2.178×10^{19} n/cm^2 (E> 1.0 MeV) resulted in a 30 ft-lb transition temperature increase of 34°F and a 50 ft-lb transition temperature increase of 46°F. This results in an irradiated 30 ft-lb transition temperature of 51°F and an irradiated 50 ft-lb transition temperature of 108°F for Transverse oriented specimens.

- Irradiation of the weld metal Charpy specimens to 2.178×10^{19} n/cm^2 (E> 1.0MeV) resulted in a 30 ft-lb transition temperature decrease of 1°F and a 50 ft-lb transition temperature decrease of 8°F. This results in an irradiated 30 ft-lb transition temperature of -58°F and an irradiated 50 ft-lb transition temperature of -38°F.

- Irradiation of the weld Heat-Affected-Zone (HAZ) metal Charpy specimens to 2.178×10^{19} n/cm^2 (E> 1.0 MeV) resulted in a 30 ft-lb transition temperature increase of 42°F and a 50 ft-lb transition temperature increase of 43°F. This results in an irradiated 30 ft-lb transition temperature of -45°F and an irradiated 50 ft-lb transition temperature of -13°F.

- The average upper shelf energy of the intermediate shell plate B8805-3 (Longitudinal orientation) resulted in an average energy decrease of 4 ft-lb after irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV). This results in an irradiated average upper shelf energy of 118 ft-lb for the Longitudinal oriented specimens.

- The average upper shelf energy of the intermediate shell plate B8805-3 (Transverse orientation) resulted in an average energy decrease of 2 ft-lb after irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 94 ft-lb for the Transverse oriented specimens.

- The average upper shelf energy of the weld metal Charpy specimens resulted an average energy decrease of 3 ft-lb after irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 142 ft-lb for the weld metal specimens.

- The average upper shelf energy of the weld HAZ metal Charpy specimens resulted in an average energy decrease of 15 ft-lb after irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0MeV). This results in an irradiated average upper shelf energy of 121 ft-lb for the weld HAZ metal.

- A comparison of the Vogtle Electric Generating Plant Unit 1 reactor vessel beltline material test results with the Regulatory Guide 1.99, Revision 2[1] predictions led to the following conclusions:

  — The measured 30 ft-lb shift in transition temperature of the surveillance weld metal contained in capsule V is in good agreement with the Regulatory Guide 1.99, Revision 2, prediction. The measured 30 ft-lb shift in transition temperature values of all other surveillance materials are less than the Regulatory Guide 1.99, Revision 2, predictions.

  — The measured percent decrease in upper shelf energy for all surveillance materials is less than the Regulatory Guide 1.99, Revision 2, predictions.

- The calculated and best estimate end-of-license (36 EFPY) neutron fluence (E> 1.0 MeV) at the core midplane for the Vogtle Electric Generating Plant Unit 1 reactor vessel using the Regulatory Guide 1.99, Revision 2 attenuation formula (ie. Equation # 3) is as follows:

<u>Calculated:</u>

Vessel inner radius* = 2.09 x 10^{19} n/cm^2
Vessel 1/4 thickness = 1.25 x 10^{19} n/cm^2
Vessel 3/4 thickness = 4.42 x 10^{18} n/cm^2

<u>Best Estimate:</u>

Vessel inner radius* = 1.83 x 10^{19} n/cm^2
Vessel 1/4 thickness = 1.09 x 10^{19} n/cm^2
Vessel 3/4 thickness = 3.87 x 10^{18} n/cm^2

*Clad/base metal interface

- The credibility evaluation of the Vogtle Electric Generating Plant Unit 1 surveillance program presented in Appendix D of this report indicates that the surveillance results are credible.

- All beltline materials exhibit a more than adequate upper shelf energy level for continued safe plant operation and are expected to maintain an upper shelf energy greater than 50 ft-lb throughout the life of the vessel (36 EFPY) as required by 10CFR50, Appendix G[2].

2 INTRODUCTION

This report presents the results of the examination of Capsule V, the third capsule removed from the reactor in the continuing surveillance program which monitors the effects of neutron irradiation on Southern Nuclear Vogtle Electric Generating Plant Unit 1 reactor pressure vessel materials under actual operating conditions.

The surveillance program for Southern Nuclear Vogtle Electric Generating Plant Unit 1 reactor pressure vessel materials was designed and recommended by the Westinghouse Electric Company. A description of the surveillance program and the preirradiation mechanical properties of the reactor vessel materials is presented in WCAP-11011, "Georgia Power Company Vogtle Unit No. 1 Reactor Vessel Radiation Surveillance Program[3]. The surveillance program was planned to cover the 40-year design life of the reactor pressure vessel and was based on ASTM E185-82, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Reactor Vessels"[6]. Capsule V was removed from the reactor after 8.57 EFPY of exposure and shipped to the Westinghouse Science and Technology Center Hot Cell Facility, where the postirradiation mechanical testing of the Charpy V-notch impact and tensile surveillance specimens was performed.

The Charpy V-notch data presented in WCAP-11011[3], WCAP-12256[42] and WCAP-13931 Rev. 1[43] were based on hand-fit Charpy curves using engineering judgment. However, the results presented in this report are based on a replot of all capsule data using CVGRAPH, Version 4.1. which is a hyperbolic tangent curve-fitting program. Appendix B presents a comparison of the Charpy V-Notch test results for each capsule based on hand fit vs. hyperbolic tangent fit. Appendix C presents the CVGRAPH, Version 4.1, Charpy V-notch plots and the program input data.

This report summarizes the testing of and the post-irradiation data obtained from surveillance capsule V removed from the Southern Nuclear Vogtle Electric Generating Plant Unit 1 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 A533 Grade B Class 1 (base material of the Vogtle Electric Generating Plant Unit 1 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[4]. 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 E-208[5]) 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 rolling 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_{Ia} curve) which appears in Appendix G to the ASME Code[4]. The K_{Ia} curve is a lower bound of dynamic, crack arrest, and static fracture toughness results obtained from several heats of pressure vessel steel. When a given material is indexed to the K_{Ia} 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 surveillance program, such as the Vogtle Unit 1 reactor vessel radiation surveillance program[3], in which a surveillance capsule is periodically removed from the operating nuclear reactor and the encapsulated specimens tested. The increase in the average Charpy V-notch 30 ft-lb temperature (ΔRT_{NDT}) due to irradiation is added to the initial RT_{NDT}, along with a margin (M) to cover uncertainties, to adjust the RT_{NDT} (ART) for radiation embrittlement. This ART (RT_{NDT} initial + M + ΔRT_{NDT}) is used to index the material to the K_{Ia} 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 Electric Generating Plant Unit 1 reactor pressure vessel core region (beltline) materials were inserted in the reactor vessel prior to initial plant start-up. 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 intermediate shell plate B8805-3 (Heat No. C0623-1), weld metal fabricated with 3/16-inch Mil B-4 weld filler wire, heat number 83653 Linde 0091 flux, lot number 3536, which is identical to that used in the actual fabrication of the intermediate to lower shell girth weld and all longitudinal weld seams of both the intermediate and lower shell plates of the pressure vessel.

Capsule V was removed after 8.57 effective full power years (EFPY) of plant operation. This capsule contained Charpy V-notch, tensile, and 1/2T-CT fracture mechanics specimens made from intermediate shell plate B8805-3 and submerged arc weld metal identical to the closing girth and intermediate and lower shell longitudinal seams. In addition, this capsule contained Charpy V-notch specimens from the weld Heat-Affected-Zone (HAZ) of intermediate shell plate B8805-1.

Test material obtained from intermediate shell plate (after the thermal heat treatment and forming of the plate) was taken at least one plate thickness from the quenched ends of the plate. All test specimens were machined from the 1/4 and ¾ thickness locations of the plate after performing a simulated post-weld stress-relieving treatment on the test material. Specimens from weld metal and heat-affected-zone metal were machined from a stress-relieved weldment joining intermediate shell plate B8805-1 and adjacent lower shell plate B8606-3. All heat-affected-zone specimens were obtained from the weld heat-affected-zone of intermediate shell plate.B8805-1.

Charpy V-notch impact specimens from intermediate shell plate B8805-3 were machined both in the longitudinal orientation (longitudinal axis of the specimen parallel to the major rolling direction) and 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 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 intermediate shell plate B8805-3 were machined in both the longitudinal and transverse orientation. Tensile specimens from the weld metal were oriented with the long dimension of the specimen perpendicular to the weld direction.

Compact tension test specimens from plate B8805-3 were machined in both the longitudinal and transverse orientations. Compact tension test specimens from the weld metal were machined perpendicular to the weld direction with the notch oriented in the direction of the weld. All specimens were fatigue precracked according to ASTM E399.

The chemical composition and heat treatment of the surveillance material is presented in Tables 4-1 through 4-3. The chemical analysis reported in Table 4-1 was obtained from unirradiated material used in the surveillance program[3] and irradiated material from capsules U[42] and Y[43].

Capsule V contained dosimeter wires of pure copper, iron, nickel, and aluminum -0.15 weight percent cobalt (cadmium-shielded and unshielded). In addition, cadmium shielded dosimeters of neptunium (Np^{237}) and uranium (U^{238}) were placed in the capsule to measure the integrated flux at specific neutron energy levels

The capsule contained thermal monitors made from two low-melting-point eutectic alloys and 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 arrangement of the various mechanical specimens, dosimeters and thermal monitors contained in capsule V is shown in Figure 4-2.

Table 4-1 Chemical Composition (wt%) of the Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3[c]

Element	Westinghouse Analysis	CE Analysis	Capsule U[a] Analysis	Capsule Y[b] Analysis
C	0.220	0.250	--	0.225
Mn	1.320	1.320	1.262	1.277
P	0.017	0.003	0.010	<0.015
S	0.011	0.010	--	0.0139
Si	0.280	0.260	--	0.232
Ni	0.610	0.600	0.586	0.584
Mo	0.570	0.530	0.431	0.527
Cr	0.057	0.040	0.049	0.057
Cu	0.058	0.060	0.053	0.061
Al	0.030	0.029	--	0.032
Co	0.006	0.009	0.013	0.008
Pb	<0.001	<0.001	--	--
W	<0.010	<0.010	--	<0.037
Ti	0.004	<0.010	--	<0.008
Zr	<0.002	<0.001	--	<0.009
V	<0.002	0.003	<0.002	<0.001
Sn	0.019	0.017	--	<0.018
As	0.003	0.001	--	<0.015
Cb or Nb	<0.002	<0.010	--	0.013
N	0.006	0.008	--	--
B	<0.001	<0.001	--	0.004

Notes:

a. Chemical Analysis by Westinghouse on irradiated Charpy specimen AT-5 removed from Cap. U.
b. Chemical Analysis by Westinghouse on irradiated Charpy specimen AT-64 removed from Cap. Y.
c. Reprinted from WCAP-13931, Rev. 1.

Table 4-2(a) Chemical Composition (wt%) of the Vogtle Unit 1 Reactor Vessel Surveillance Weld Metal Weld Wire Heat No. 83653, Linde 0091 Flux, Lot No. 3536

Elmt.	Surveillance Program Test Weldment D	Wire Flux Test Weld Sample	Actual Production Weld (Girth Seam, 101-171)	Capsule U Analysis	Capsule Y Analysis	Capsule Y Analysis	Capsule Y Analysis
C	0.130	0.140	0.090	--	0.137	0.147	0.153
Mn	1.150	1.060	1.170	1.057	1.113	1.164	1.195
P	0.017	0.007	0.008	0.008	<0.014	<0.014	<0.016
S	0.010	0.009	0.009	--	0.0085	0.0112	0.0135
Si	0.190	0.160	0.170	--	0.174	0.123	0.102
Ni	0.100	--	0.100	0.091	0.101	0.117	0.105
Mo	0.610	0.520	0.630	0.475	0.553	0.561	0.584
Cr	0.052	--	0.050	0.044	0.053	0.053	0.055
Cu	0.037	0.030	0.040	0.035	0.048	0.040	0.041
Al	0.002	--	0.009	--	<0.019	<0.019	<0.021
Co	0.005	--	0.010	0.006	0.007	0.007	0.008
Pb	<0.001	--	<0.001	--	--	--	--
W	<0.010	--	0.020	--	<0.036	<0.036	<0.039
Ti	0.006	--	<0.010	--	0.011	0.011	0.012
Zr	<0.002	--	0.001	--	<0.009	<0.009	<0.010
V	0.003	0.005	0.007	0.006	0.001	0.001	0.001
Sn	<0.002	--	0.003	--	<0.019	<0.019	<0.020
As	0.004	--	0.006	--	<0.015	<0.015	<0.016
Cb or Nb	<0.002	--	0.010	--	0.013	0.013	0.014
N	0.003	--	0.021	--	--	--	--
B	<0.001	--	<0.001	--	0.004	0.004	0.003

Notes:

(a) Reprinted from Table 4-2 of WCAP-13931 Rev. 1.

(b) The NIST Standards are Not reprinted herein, they can be found in WCAP-13931 Rev. 1.

Table 4-3 Heat Treatment of the Vogtle Unit 1 Reactor Vessel Surveillance Material[3]

Material	Temperature (°F)	Time (hrs.)	Coolant
Surveillance Program Test Plate B8805-3	Austenitizing: 1600 ± 25	4	Water-quenched
	Tempered: 1225 ± 25	4	Air Cooled
	Stress Relief:(a) 1150± 50	17.5	Furnace Cooled
Weldment	1150 ± 50	12.75	Furnace Cooled

(a) The stress relief heat treatment received by the surveillance test plate and weldment have been simulated.

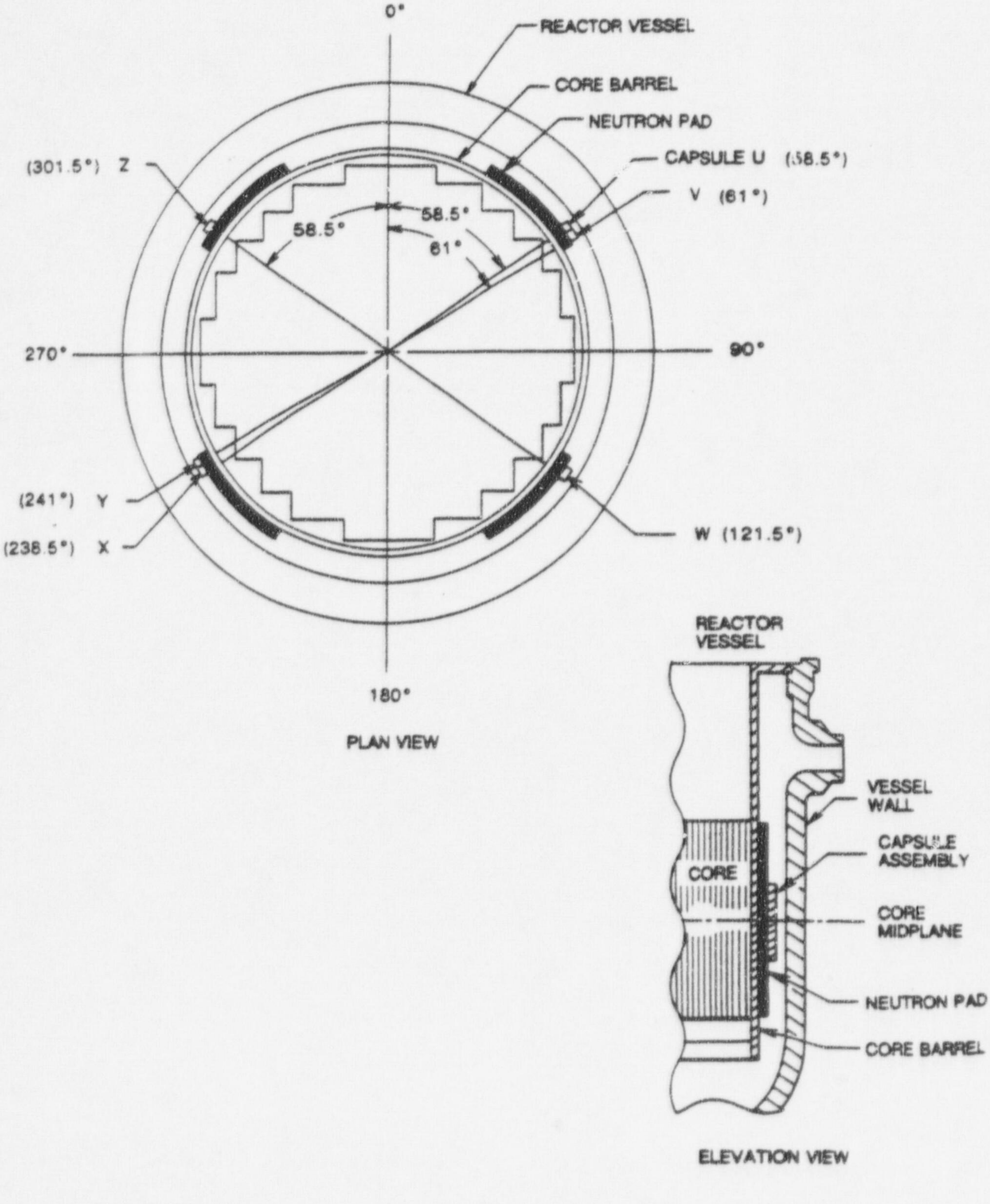


Figure 4-1 Arrangement of Surveillance Capsules in the Vogtle Unit 1 Reactor Vessel

LEGEND: AL - INTERMEDIATE SHELL PLATE B8805-3 (LONGITUDINAL)
AT - INTERMEDIATE SHELL PLATE B8805-3 (TRANSVERSE)
AW - WELD METAL
AH - HEAT-AFFECTED-ZONE MATERIAL

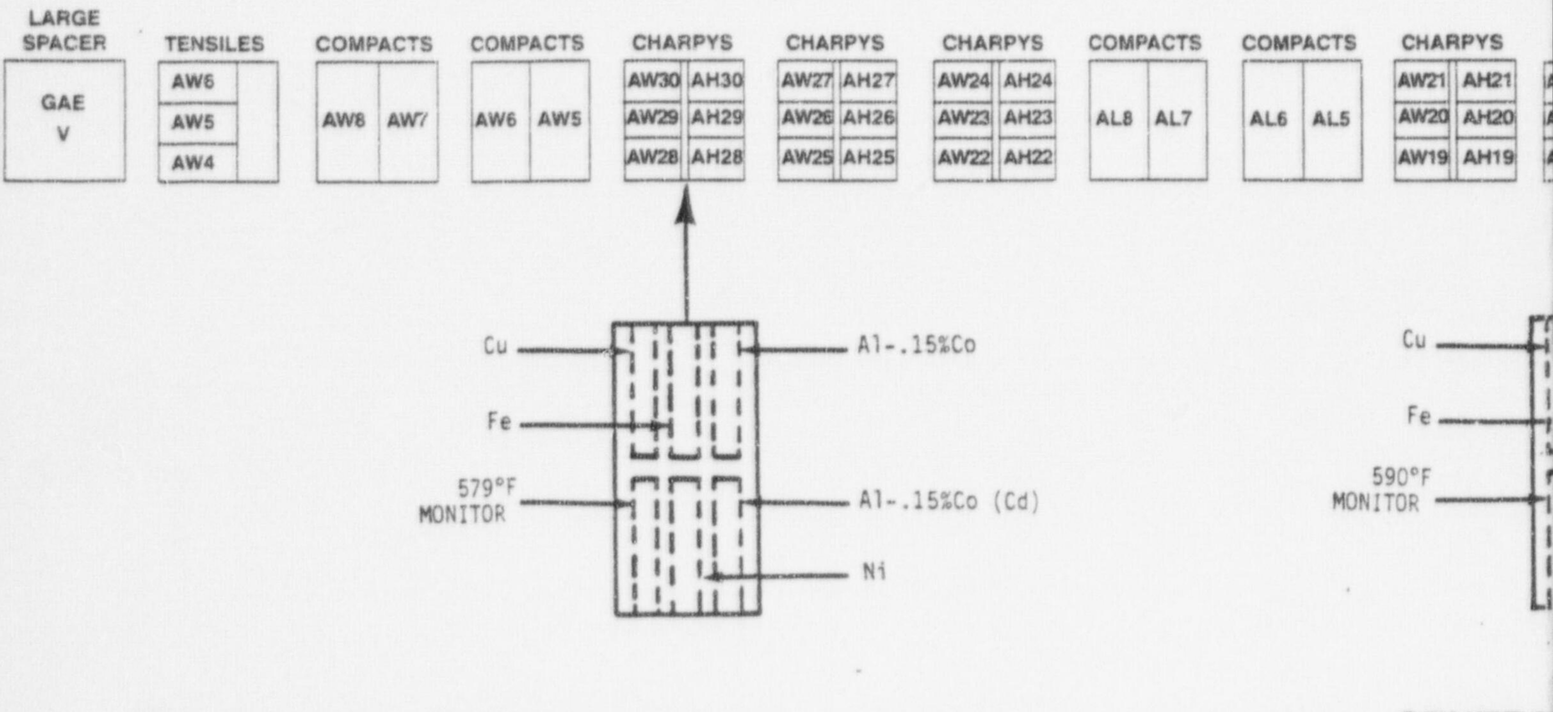
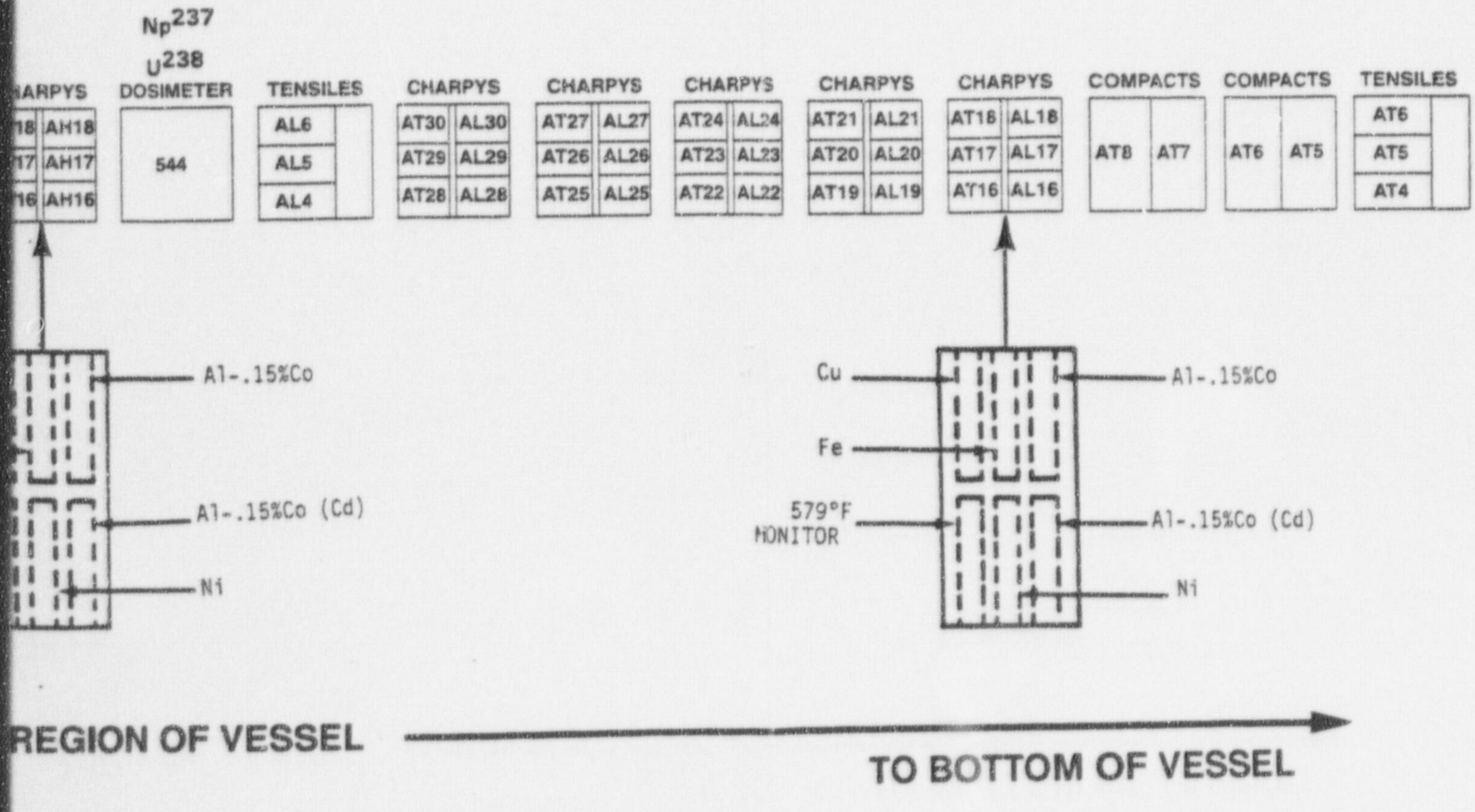


Figure 4-2 Capsule V Diagram Showing the Location of Specimens, Thermal Monitors, and Dosimeters



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5 TESTING OF SPECIMENS FROM CAPSULE V

5.1 OVERVIEW

The post-irradiation mechanical testing of the Charpy V-notch impact specimens and tensile specimens was performed in the Remote Metallographic Facility (RMF) at the Westinghouse Science and Technology Center. Testing was performed in accordance with 10CFR50, Appendices G and H[2], ASTM Specification E185-82[6], and Westinghouse Procedure RMF 8402, Revision 2 as modified by Westinghouse RMF Procedures 8102, Revision 1, and 8103, Revision 1.

Upon receipt of the capsule 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-11011[3]. No discrepancies were found.

Examination of the two low-melting point 579°F (304°C) and 590°F (310°C) eutectic alloys indicated no melting of either type of thermal monitor. Based on this examination, the maximum temperature to which the test specimens were exposed was less than 579°F (304°C).

The Charpy impact tests were performed per ASTM Specification E23-93a[7] and RMF Procedure 8103, Revision 1, on a Tinius-Olsen Model 74, 358J machine. The tup (striker) of the Charpy impact test machine is instrumented with a GRC 930-I instrumentation system, feeding information into an IBM compatible computer. With this system, load-time and energy-time signals can be recorded in addition to the standard measurement of Charpy energy (E_D). From the load-time curve (Appendix A), the load of general yielding (P_{GY}), the time to general yielding (t_{GY}), the maximum load (P_M), and the time to maximum load (t_M) can be determined. Under some test conditions, a sharp drop in load indicative of fast fracture was observed. The load at which fast fracture was initiated is identified as the fast fracture load (P_F), and the load at which fast fracture terminated is identified as the arrest load (P_A). The energy at maximum load (E_M) was determined by comparing the energy-time record and the load-time record. The energy at maximum load is approximately equivalent to the energy required to initiate a crack in the specimen. Therefore, the propagation energy for the crack (E_p) is the difference between the total energy to fracture (E_D) and the energy at maximum load (E_M).

The yield stress (s_Y) was calculated from the three-point bend formula having the following expression:

$$\sigma_Y = (P_{GY} * L) / [B * (W - a)^2 * C] \qquad (1)$$

where: L = distance between the specimen supports in the impact 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 $\phi = 45°$ and $\rho = 0.010$ inch, Equation 1 is valid with C = 1.21. Therefore, (for L = 4W),

$$\sigma_y=(P_{GY}*L)/[B*(W-a)^2*1.21]=(3.33*P_{GY}*W)/[B*(W-a)^2] \qquad (2)$$

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

$$\sigma_y=33.3*P_{GY} \qquad (3)$$

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

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

$$\mathrm{A=B*(W-a)=0.1241\,sq.in.} \qquad (4)$$

Percent shear was determined from post-fracture photographs using the ratio-of-areas methods in compliance with ASTM Specification A370-92[8]. The lateral expansion was measured using a dial gage rig similar to that shown in the same specification.

Tensile tests were performed on a 20,000-pound Instron, split-console test machine (Model 1115) per ASTM Specification E8-93[9] and E21-92[10], and WMF Procedure 8102, Revision 1. All pull rods, grips, and pins were made of Inconel 718. The upper pull rod was connected through a universal joint to improve axiality of loading. The tests were conducted at a constant crosshead speed of 0.05 inches per minute throughout the test.

Extension measurements were made with a linear variable displacement transducer extensometer. The extensometer knife edges were spring-loaded to the specimen and operated through specimen failure. The extensometer gage length was 1.00 inch. The extensometer is rated as Class B-2 per ASTM E83-93[11].

Elevated test temperatures were obtained with a three-zone electric resistance split-tube furnace with a 9-inch hot zone. All tests were conducted in air. Because of the difficulty in remotely attaching a thermocouple directly to the specimen, the following procedure was used to monitor specimen temperatures. Chromel-Alumel thermocouples were positioned at the center and at each end of the gage section of a dummy specimen and in each tensile machine griper. In the test configuration, with a slight load on the specimen, a plot of specimen temperature versus upper and lower tensile machine griper and controller temperatures was developed over the range from room temperature to 550°F. During the actual testing, the grip temperatures were used to obtain desired specimen temperatures. Experiments have indicated that this method is accurate to ±2°F.

The yield load, ultimate load, fracture load, total elongation, and uniform elongation were determined directly from the load-extension curve. The yield strength, ultimate strength, and fracture strength were calculated using the original cross-sectional area. The final diameter and final gage length were determined from post-fracture photographs. The fracture area used to calculate the fracture stress (true stress at fracture) and percent reduction in area was 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 V, which received a fluence of 2.178×10^{19} n/cm^2(E> 1.0 MeV) in 8.57 EFPY of operation, are presented in Tables 5-1 through 5-8 and are compared with unirradiated results[3] as shown in Figures 5-1 through 5-12.

The transition temperature increases and upper shelf energy decreases for the capsule V materials are summarized in Table 5-9. These results led to the following conclusions:

Irradiation of the reactor vessel intermediate shell plate B8805-3 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major rolling direction (Longitudinal orientation), to 2.178×10^{19} n/cm^2 (E> 1.0MeV) resulted in a 30 ft-lb transition temperature increase of 43°F and a 50 ft-lb transition temperature increase of 59°F. This results in an irradiated 30 ft-lb transition temperature of 28°F and an irradiated 50 ft-lb transition temperature of 81°F for the Longitudinal oriented specimens.

Irradiation of the reactor vessel intermediate shell plate B8805-3 Charpy specimens, oriented with the longitudinal axis of the specimen perpendicular to the major rolling direction of the plate (Transverse orientation), to 2.178×10^{19} n/cm^2 (E> 1.0 MeV) resulted in a 30 ft-lb transition temperature increase of 34°F and a 50 ft-lb transition temperature increase of 46°F. This results in an irradiated 30 ft-lb transition temperature of 51°F and an irradiated 50 ft-lb transition temperature of 108°F for Transverse oriented specimens.

Irradiation of the weld metal Charpy specimens to 2.178×10^{19} n/cm^2 (E> 1.0MeV) resulted in a 30 ft-lb transition temperature decrease of 1°F and a 50 ft-lb transition temperature decrease of 8°F. This results in an irradiated 30 ft-lb transition temperature of -58°F and an irradiated 50 ft-lb transition temperature of -38°F.

Irradiation of the weld Heat-Affected-Zone (HAZ) metal Charpy specimens to 2.178×10^{19} n/cm^2 (E> 1.0 MeV) resulted in a 30 ft-lb transition temperature increase of 42°F and a 50 ft-lb transition temperature increase of 43°F. This results in an irradiated 30 ft-lb transition temperature of -45°F and an irradiated 50 ft-lb transition temperature of -13°F.

The average upper shelf energy of the intermediate shell plate B8805-3 (Longitudinal orientation) resulted in an average energy decrease of 4 ft-lb after irradiation to 2.178×10^{19} n/cm^2 (E> 1.0 MeV). This results in an irradiated average upper shelf energy of 118 ft-lb for the Longitudinal oriented specimens.

The average upper shelf energy of the intermediate shell plate B8805-3 (Transverse orientation) resulted in an average energy decrease of 2 ft-lb after irradiation to 2.178×10^{19} n/cm^2 (E> 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 94 ft-lb for the Transverse oriented specimens.

The average upper shelf energy of the weld metal Charpy specimens resulted an average energy decrease of 3 ft-lb after irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 142 ft-lb for the weld metal specimens.

The average upper shelf energy of the weld HAZ metal Charpy specimens resulted in an average energy decrease of 15 ft-lb after irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0MeV). This results in an irradiated average upper shelf energy of 121 ft-lb for the weld HAZ metal.

A comparison of the Vogtle Unit 1 reactor vessel beltline material test results with the Regulatory Guide 1.99, Revision 2[1], predictions is presented in Table 5-10 and led to the following conclusions:

- The measured 30 ft-lb shift in transition temperature of the surveillance weld metal contained in capsule U is in good agreement with the Regulatory Guide 1.99, Revision 2, prediction. The measured 30 ft-lb shift in transition temperature values of all other surveillance materials are less than the Regulatory Guide 1.99, Revision 2, predictions.

- The measured percent decrease in upper shelf energy for all surveillance materials is less than the Regulatory Guide 1.99, Revision 2, predictions.

The fracture appearance of each irradiated Charpy specimen from the various surveillance capsule V materials is shown in Figures 5-13 through 5-16 and shows an increasingly ductile or tougher appearance with increasing test temperature.

All beltline materials exhibit a more than adequate upper shelf energy level for continued safe plant operation and are expected to maintain an upper shelf energy of no less than 50 ft-lb throughout the life of the vessel (36 EFPY) as required by 10CFR50, Appendix G[2].

The load-time records for individual instrumented Charpy specimen tests are shown in Appendix A.

The Charpy V-notch data presented in WCAP-11011[3], WCAP-12256[42] and WCAP-13931 Rev. 1[43] were based on hand-fit Charpy curves using engineering judgment. However, the results presented in this report are based on a replot of all capsule data using CVGRAPH, Version 4.1. which is a hyperbolic tangent curve-fitting program. Appendix B presents a comparison of the Charpy V-Notch test results for each capsule based on hand fit vs. hyperbolic tangent fit. Appendix C presents the CVGRAPH, Version 4.1, Charpy V-notch plots and the program input data.

5.3 TENSILE TEST RESULTS

The results of the tensile tests performed on the various materials contained in capsule V irradiated to 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV) are presented in Table 5-11 and are compared with unirradiated results[3] as shown in Figures 5-17 through 5-19.

The results of the tensile tests performed on the intermediate shell plate B8805-3 (Longitudinal orientation) indicated that irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV) caused approximately a 0 to 42 ksi increase in the 0.2 percent offset yield strength and approximately a 4 to 6 ksi increase in the ultimate tensile strength when compared to unirradiated data[3] (Figure 5-17).

The results of the tensile tests performed on the intermediate shell plate B8805-3 (Transverse orientation) indicated that irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV) caused an approximate increase of 4 ksi in the 0.2 percent offset yield strength and approximately a 5 to 6 ksi increase in the ultimate tensile strength when compared to unirradiated data[3] (Figure 5-18).

The results of the tensile tests performed on the surveillance weld metal indicated that irradiation to 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV) caused approximately a 3 ksi increase in the 0.2 percent offset yield strength and approximately a 2 to 4 ksi increase in the ultimate tensile strength when compared to unirradiated data[3] (Figure 5-19).

The fractured tensile specimens for the intermediate shell plate B8805-3 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 5-25.

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 Science and Technology Center Hot Cell facility.

Table 5-1 Charpy V-notch Data for the Vogtle Unit 1 Intermediate Shell Plate B8805-3 Irradiated to a Fluence of 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV) (Longitudinal Orientation)

Sample	Temperature		Impact Energy		Lateral Expansion		Shear
Number	F	C	ft-lbs	Joules	mils	mm	%
AL24	-80	-62	2	2	1	0.03	2
AL17	-50	-46	17	23	6	0.15	2
AL16	-25	-32	28	38	16	0.41	5
AL27	-15	-26	10	14	4	0.10	5
AL22	0	-18	9	12	4	0.10	10
AL25	5	-15	24	32	13	0.33	10
AL28	20	-7	34	46	22	0.56	20
AL18	50	10	49	66	31	0.79	20
AL20	100	38	59	79	38	0.97	45
AL29	150	66	65	88	45	1.14	65
AL19	175	79	90	123	61	1.55	80
AL26	200	93	95	129	69	1.75	90
AL30	250	121	112	152	74	1.88	100
AL21	300	149	123	167	76	1.93	100
AL23	375	191	118	160	72	1.83	100

Table 5-2 Charpy V-notch Data for the Vogtle Unit 1 Intermediate Shell Plate B8805-3 Irradiated to a Fluence of 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV) (Transverse Orientation)

Sample	Temperature		Impact Energy		Lateral Expansion		Shear
Number	F	C	ft-lbs	Joules	mils	mm	%
AT24	-25	-32	4	5	2	0.051	5
AT26	0	-18	19	26	14	0.357	10
AT23	25	-4	32	43	21	0.535	15
AT18	50	10	35	47	22	0.560	15
AT21	72	22	24	32	19	0.484	30
AT25	72	22	47	63	31	0.789	40
AT22	100	38	42	57	31	0.789	40
AT17	110	43	48	65	35	0.891	50
AT30	125	52	61	82	44	1.121	70
AT20	160	71	64	86	46	1.171	70
AT29	200	93	62	84	53	1.350	80
AT27	225	107	99	134	66	1.681	100
AT19	250	121	90	122	67	1.706	100
AT28	300	149	94	127	67	1.706	100
AT16	375	191	94	127	65	1.655	100

Table 5-3 Charpy V-notch Data for the Vogtle Unit I Surveillance Weld Metal Irradiated to a Fluence of 2.178 x 10^{19} n/cm^2 (E> 1.0 MeV)

Sample	Temperature		Impact Energy		Lateral Expansion		Shear
Number	F	C	ft-lbs	Joules	mils	mm	%
AW21	-125	-87	10	13	2	0.05	5
AW24	-100	-73	26	35	11	0.28	15
AW26	-75	-59	31	42	18	0.46	15
AW30	-60	-51	3	4	1	0.03	10
AW29	-50	-46	15	20	9	0.23	15
AW28	-45	-43	14	19	8	0.20	15
AW25	-40	-40	125	170	70	1.78	80
AW17	-25	-32	7	10	7	0.18	25
AW23	-25	-32	85	115	56	1.42	60
AW19	-10	-23	102	139	69	1.75	65
AW18	50	10	124	168	77	1.96	95
AW22	100	38	138	187	86	2.18	100
AW27	150	66	140	190	88	2.24	100
AW20	200	93	146	197	84	2.13	100
AW16	300	149	143	194	85	2.16	100

Table 5-4 Charpy V-notch Data for the Vogtle Unit 1 Heat Affected Zone Material Irradiated to a Fluence of 2.178×10^{19} n/cm^2 (E> 1.0 MeV)

Sample	Temperature		Impact Energy		Lateral Expansion		Shear
Number	F	C	ft-lbs	Joules	mils	mm	%
AH28	-100	-73	3	4	1	0.025	10
AH29	-75	-59	9	12	4	0.102	20
AH30	-50	-46	22	30	13	0.331	25
AH22	-40	-40	32	43	20	0.509	40
AH17	-35	-37	40	54	23	0.586	25
AH26	-25	-32	46	62	28	0.713	30
AH25	0	-18	70	95	41	1.044	40
AH19	25	-4	104	140	58	1.477	85
AH24	40	4	64	86	46	1.171	60
AH16	50	10	76	103	49	1.248	75
AH23	60	16	82	111	53	1.350	80
AH27	100	38	136	184	77	1.961	100
AH20	150	66	120	162	75	1.910	100
AH18	225	107	133	180	75	1.910	100
AH21	300	149	94	127	63	1.604	100

Table 5-5 Instrumented Charpy Impact Test Results for the Vogtle Unit 1 Intermediate Shell Plate B8805-3 Irradiated to a Fluence of 2.178 x 10^{19} n/cm^2 (E>1.0 MeV)(Longitudinal Orientation)

			Normalized Energies (ft-lb/in^2)										
Sample No.	**Test Temp. (°F)**	**Charpy Energy E_D (ft-lb)**	**Charpy E_P/A**	**Max. E_M/A**	**Prop. E_p/A**	**Yield Load P_{GY} (lb)**	**Time to Yield t_{GY} (msec)**	**Max. Load P_M (lb)**	**Time to Max. t_M (msec)**	**Fast Fract. Load P_F (lb)**	**Arrest Load P_A (lb)**	**Yield Stress S_Y (ksi)**	**Flow Stress (ksi)**
AL24	-80	1.83	15	7	8	984.78	0.1	984.78	0.1	984.78	0	33	33
AL17	-50	16.77	135	72	63	4150.5	0.17	4479.42	0.22	4440.47	0	138	143
AL16	-25	28.13	227	173	54	4011.35	0.16	4695.42	0.39	4688.93	0	133	145
AL27	-15	10.11	81	44	37	3839.61	0.16	3969.4	0.18	3943.44	0	128	130
AL22	0	9.16	74	39	35	3767.32	0.17	3769.49	0.17	3767.32	0	125	125
AL25	5	23.51	189	140	49	3728.52	0.16	4317.12	0.35	4312.79	0	124	134
AL23	20	34.23	276	221	55	3770.31	0.16	4588.91	0.49	4586.74	0	125	139
AL18	50	48.57	391	321	70	3651.83	0.16	4616.58	0.68	4536.72	0	121	137
AL20	100	58.54	471	318	153	3637.19	0.17	4537.27	0.68	4352.91	871.88	121	136
AL29	150	65.19	525	304	221	3399.11	0.16	4408.66	0.68	4241.84	1754.8	113	130
AL19	175	90.37	728	307	420	3395.66	0.16	4430.82	0.68	3731.33	1552.74	113	130
AL26	200	94.84	764	295	468	3149.56	0.16	4311.17	0.68	3151.72	1715.38	105	124
AL30	250	112.26	904	298	606	3195.94	0.16	4241.73	0.69	N/A	N/A	106	124
AL21	300	123.38	993	296	697	3204.13	0.16	4304.67	0.68	N/A	N/A	106	125
AL23	375	118.34	953	289	663	3120	0.16	4107.21	0.69	N/A	N/A	104	120

Table 5-6 Instrumented Charpy Impact Test Results for the Vogtle Unit 1 Intermediate Shell Plate B8805-3 Irradiated to a Fluence of 2.178 x 10^{19} n/cm^2 (E>1.0 MeV)(Transverse Orientation)

Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Normalized Energies (ft-lb/in^2)			Yield Load P_{GY} (lb)	Time to Yield t_{GY} (msec)	Max. Load P_M (lb)	Time to Max. t_M (msec)	Fast Fract. Load P_F (lb)	Arrest Load P_A (lb)	Yield Stress S_Y (ksi)	Flow Stress (ksi)
			Charpy E_D/A	Max. E_M/A	Prop. E_p/A								
AT24	-25	4.34	35	17	18	2166.14	0.12	2179.12	0.13	2166.14	0	72	72
AT26	0	20.61	166	69	97	4024.76	0.17	4365.4	0.22	4261.26	0	134	139
AT23	25	33.12	267	213	53	3723.18	0.16	4653.97	0.47	4638.78	0	124	139
AT18	50	33.98	274	219	55	3724.96	0.16	4616.18	0.49	4531.82	0	124	139
AT21	72	25.48	205	68	138	3761.4	0.16	4180.78	0.22	4091.69	886.57	125	132
AT25	72	48.3	389	253	136	3783.06	0.16	4842.5	0.53	4822.92	583.01	126	143
AT22	100	42.93	346	233	113	3619.28	0.16	4492.67	0.52	4431.99	721.69	120	135
AT17	110	49.83	401	238	164	3630.22	0.16	4556.25	0.53	4482.34	693.44	121	136
AT30	125	62.38	502	226	277	3641.53	0.17	4483.04	0.52	4036.26	1793.65	121	135
AT20	160	65.12	524	290	234	3311.79	0.16	4443.13	0.64	4421.5	1998.76	110	129
AT29	200	63.75	513	214	299	3395.27	0.16	4267.35	0.51	4087.74	2376.04	113	127
AT27	225	98.3	792	306	486	3344.59	0.16	4452.96	0.68	0	0	111	129
AT19	250	91.19	734	289	446	3383.05	0.17	4258.61	0.66	0	0	112	127
AT28	300	94.6	762	293	468	3364.44	0.17	4298.17	0.66	0	0	112	127
AT16	375	93.01	749	217	532	3170	0.16	4223.06	0.53	0	0	105	123

Table 5-7 Instrumented Charpy Impact Test Results for the Vogtle Unit 1 Surveillance Weld Metal Irradiated to a Fluence of 2.178 x 10^{19} n/cm^2 (E>1.0 MeV)

			Normalized Energies (ft-lb/in^2)										
Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Charpy E_D/A	Max. E_M/A	Prop. E_p/A	Yield Load P_{GY} (lb)	Time to Yield t_{GY} (msec)	Max. Load P_M (lb)	Time to Max. t_M (msec)	Fast Fract. Load P_F (lb)	Arrest Load P_A (lb)	Yield Stress S_Y (ksi)	Flow Stress (ksi)
AW21	-125	9.88	80	43	37	4193.19	0.16	4219.17	0.17	4193.19	0	139	140
AW24	-100	25.77	208	73	134	4276.56	0.16	4875.76	0.22	4566.43	0	142	152
AW26	-75	30.95	249	71	178	4433.3	0.17	4768.34	0.22	4690.53	0	147	153
AW30	-60	2.75	22	10	12	1393.01	0.11	1393.01	0.11	1393.01	0	46	46
AW29	-50	14.56	117	68	49	3898.78	0.17	4509.25	0.23	4504.92	0	130	140
AW28	-45	13.69	110	62	48	4055.14	0.16	4491.24	0.2	4486.91	0	135	142
AW25	-40	125.11	1007	346	661	3986.36	0.16	4735.29	0.69	2810.09	1241.02	132	145
AW17	-25	7.39	60	31	29	3318.54	0.15	3327.17	0.15	3318.54	0	110	110
AW23	-25	84.97	684	338	346	3978.21	0.16	4649.54	0.68	3947.89	1032.99	132	143
AW19	-10	102.41	825	329	495	3912.46	0.16	4604.93	0.67	3390.94	1270.25	130	141
AW18	50	124.16	1000	313	687	3620.15	0.16	4411.11	0.68	2648.84	1212.51	120	133
AW22	100	138.26	1113	316	797	3621.76	0.16	4381.73	0.69	N/A	N/A	120	133
AW27	150	139.96	1127	297	830	3428.15	0.16	4240.25	0.68	N/A	N/A	114	127
AW20	200	145.5	1172	299	873	3438.1	0.17	4159.52	0.69	N/A	N/A	114	126
AW16	300	142.72	1149	281	869	3085.98	0.16	4002.03	0.68	N/A	N/A	103	118

Table 5-8 Instrumented Charpy Impact Test Results for the Vogtle Unit 1 Heat-Affected-Zone (HAZ) Metal Irradiated to a Fluence of 2.178 x 10^{19} n/cm^2 (E>1.0 MeV)

Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Normalized Energies (ft-lb/in^2)			Yield Load P_{GY} (lb)	Time to Yield t_{GY} (msec)	Max. Load P_M (lb)	Time to Max. t_M (msec)	Fast Fract. Load P_F (lb)	Arrest Load P_A (lb)	Yield Stress S_Y (ksi)	Flow Stress (ksi)
			Charpy E_D/A	Max. E_M/A	Prop. E_p/A								
AH69	-25	8	64	36	28	4027	0.14	4027	0.14	4027	94	134	134
AH72	-10	6	48	26	23	3495	0.13	3495	0.13	3495	0	116	116
AH64	25	17	137	45	92	3932	0.14	4040	0.16	4040	1551	131	132
AH65	50	23	185	111	74	3877	0.15	4107	0.29	4107	1163	129	133
AH73	100	33	266	141	125	3742	0.16	4189	0.35	4189	1733	124	132
AH75	125	52	419	228	190	3680	0.16	4340	0.51	3109	970	122	133
AH62	125	54	435	226	209	3655	0.15	4208	0.51	4047	1117	121	131
AH66	150	29	234	130	103	3584	0.15	3976	0.34	3938	1499	119	126
AH67	150	31	250	133	116	3509	0.15	3990	0.35	3966	770	117	125
AH68	175	44	354	141	214	3586	0.15	4067	0.36	3813	2756	119	127
AH63	200	73	588	300	288	3515	0.15	4338	0.66	3846	2395	117	130
AH71	275	87	701	291	409	3364	0.16	4200	0.66	N/A	N/A	112	126
AH70	300	89	717	291	426	3261	0.14	4195	0.66	N/A	N/A	108	124
AH74	325	79	636	293	344	3244	0.15	4178	0.67	N/A	N/A	108	123
AH61	375	77	620	274	346	3078	0.15	3944	0.66	N/A	N/A	102	117

Table 5-9 Effect of Irradiation to 2.178×10^{19} n/cm^2 (E>1.0 MeV) on the Notch Toughness Properties of the Vogtle Unit 1 Reactor Vessel Surveillance Materials

Material	Average 30 (ft-lb)[a] Transition Temperature (°F)			Average 35 mil Lateral[b] Expansion Temperature (°F)			Average 50 ft-lb[a] Transition Temperature (°F)			Average Energy Absorption[a] at Full Shear (ft-lb)		
	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT
Inter. Shell Plate B8805-3 (Long.)	-15	28	43	19	88	69	22	81	59	122	118	-4
Inter. Shell Plate B8805-3 (Trans.)	17	51	34	54	106	52	62	108	46	96	94	-2
Weld Metal	-57	-58	-1	-33	-33	0	-30	-38	-8	145	142	-3
HAZ Metal	-87	-45	42	-50	-4	46	-56	-13	43	136	121	-15

a. "Average" is defined as the value read from the curve fit through the data points of the Charpy tests (see Figures 5-1, 5-4, 5-7 and 5-10).

b. "Average" is defined as the value read from the curve fit through the data points of the Charpy tests (see Figures 5-2, 5-5, 5-8 and 5-11)

Table 5-10 Comparison of the Vogtle Unit 1 Surveillance Material 30 ft-lb Transition Temperature Shifts and Upper Shelf Energy Decreases with Regulatory Guide 1.99, Revision 2, Predictions

Material	Capsule	Fluence (x 10^{19} n/cm^{2})	30 ft-lb Transition Temperature Shift		Upper Shelf Energy Decrease	
			Predicted (°F) (a)	Measured (°F) (b)	Predicted (°F) (a)	Measured (%)(c)
Intermediate Shell Plate B8805-3 (Longitudinal)	U	0.3691	27.8	13.6	15	0
	Y	1.276	41.0	31.9	20	0
	V	2.178	46.5	42.7	23	3
Intermediate Shell Plate B8805-3 (Transverse)	U	0.3691	27.8	0(d)	15	0
	Y	1.276	41.0	15.9	20	0
	V	2.178	46.5	33.8	23	2
Weld Metal	U	0.3691	25.0	25.5	15	0
	Y	1.276	36.8	8.2	20	1
	V	2.178	41.8	0(d)	23	2
HAZ Metal	U	0.3691	- -(e)	0(d)	- -(e)	5
	Y	1.276	- -(e)	20.8	- -(e)	9
	V	2.178	- -(e)	42.1	- -(e)	11

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 using measured Charpy data plotted using CVGRAPH, Version 4.1 (See Appendix C)

(c) Values are based on the definition of upper shelf energy given in ASTM E185-82.

(d) The actual measured value of ΔRT_{NDT} for the intermediate shell plate (capsule U) is -9.58, the actual measured value of ΔRT_{NDT} for the weld metal (capsule V) is -1.34 and the actual measured value of ΔRT_{NDT} for the HAZ metal (capsule U) is -19.35. This physically should not occur, therefore for conservatism a value of zero will be reported.

(e) Prediction methodology for HAZ material not available.

Table 5-11 Tensile Properties of the Vogtle Unit 1 Reactor Vessel Surveillance Materials Irradiated to 2.178 x 10^{19} n/cm^2 (E > 1.0 MeV)

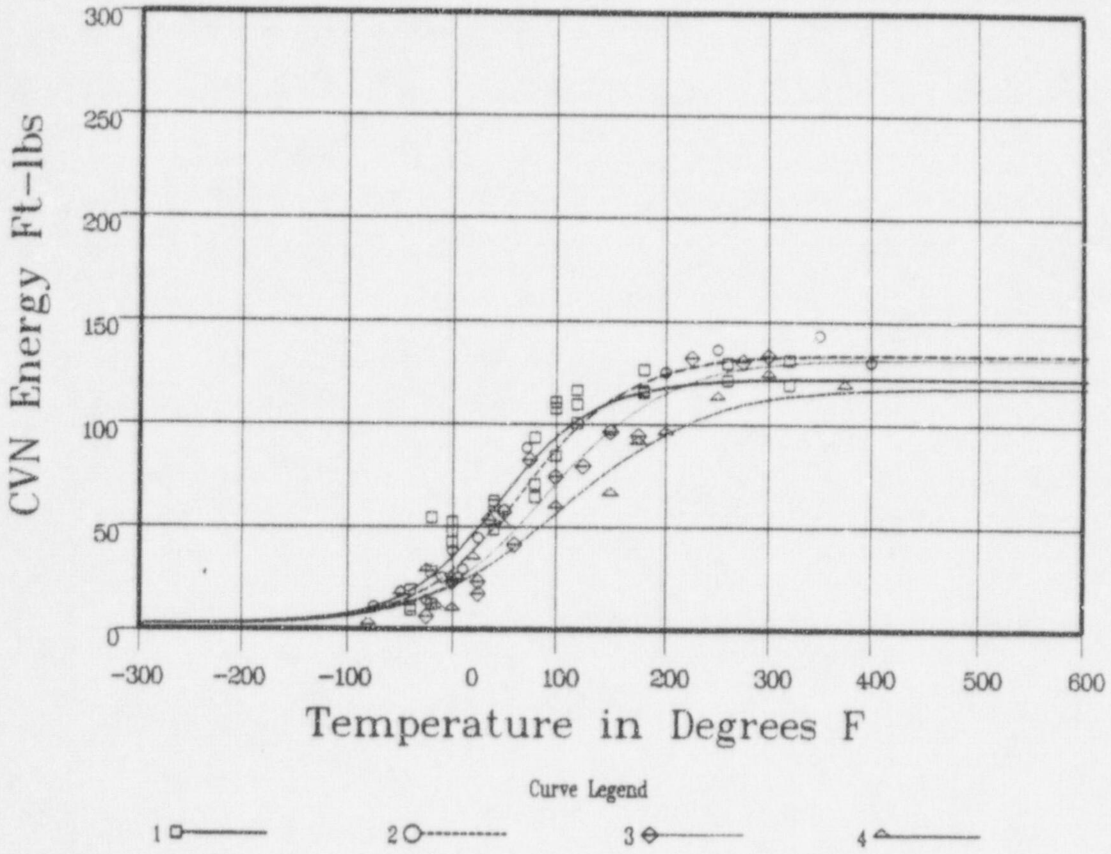
Material	Sample Number	Test Temp. (°F)	0.2% Yield Strength (ksi)	Ultimate Strength (ksi)	Fracture Load (kip)	Fracture Stress (ksi)	Fracture Strength (ksi)	Uniform Elongation (%)	Total Elongation (%)	Reduction in Area (%)
Intermediate Plate B8805-3 (Longitudinal)	AL4	74	74.9	98.0	3.25	196.8	66.2	10.5	23.4	66
	AL5	225	71.8	92.7	3.00	194.9	61.1	10.5	22.8	69
	AL6	550	68.2	95.7	3.25	183.9	66.2	9.8	20.4	64
Intermediate Plate B8805-3 (Transverse)	AT4	100	76.4	99.2	3.90	194.0	79.5	12.0	24.0	59
	AT5	225	71.3	92.7	3.30	168.3	67.2	10.5	21.3	60
	AT6	550	68.8	95.1	3.75	167.2	76.4	10.5	18.9	54
Weld Metal	AW4	-40	84.0	97.8	2.97	234.5	60.5	12.8	26.7	74
	AW5	74	75.9	87.6	2.70	216.5	55.0	10.5	24.3	75
	AW6	550	66.2	85.6	2.65	196.6	54.0	9.8	21.7	73

Intermediate Shell Plate B8805-3 (Long.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:17:11 on 05-08-1998

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	122	0	-15.06	0	21.87	0
2	0	2.19	0	133.5	11.5	-1.49	13.56	36.78	14.9
3	0	2.19	0	131.6	9.6	16.87	31.94	59.41	37.53
4	0	2.19	0	118	-4	27.6	42.66	80.63	58.75



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

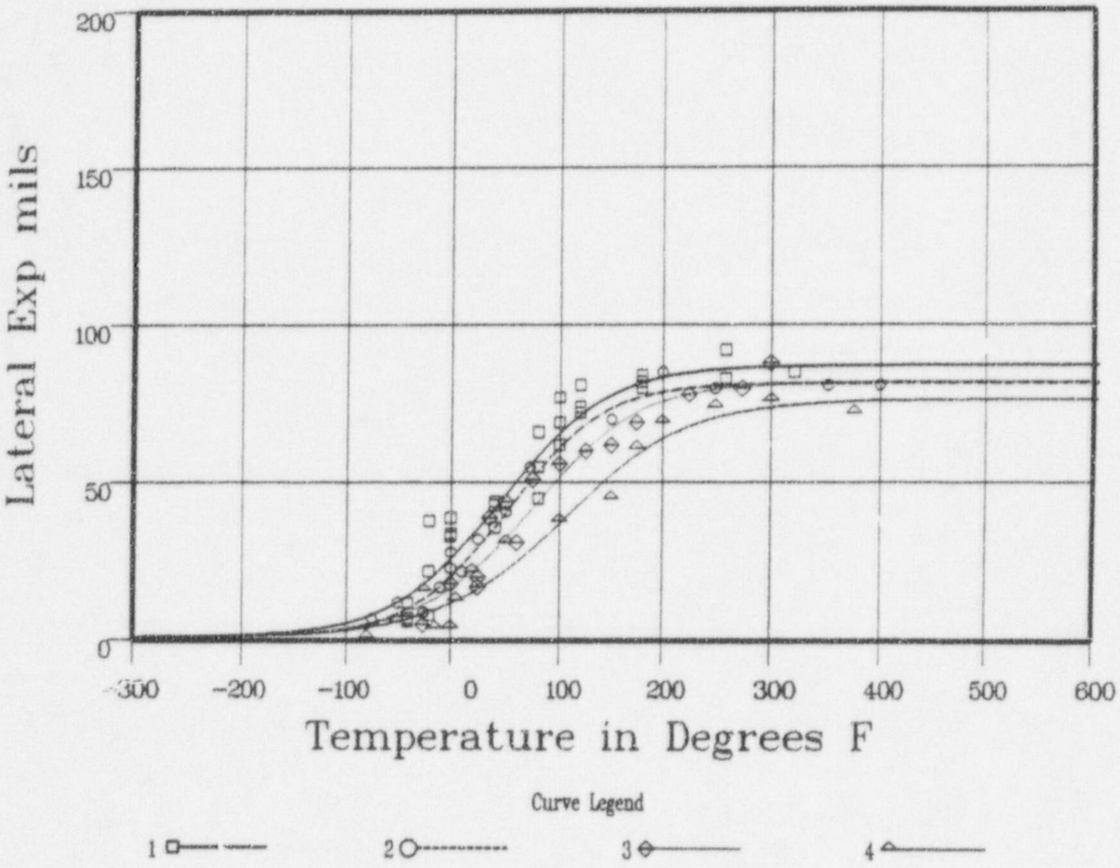
Figure 5-1 **Charpy V-Notch Impact Energy vs. Temperature for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Longitudinal Orientation)**

Intermediate Shell Plate B8805-3 (Long.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:50:47 on 05-08-1998

Results

Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	87.22	0	18.86	0
2	0	81.63	-5.58	32.95	14.08
3	0	82.21	-5	52.11	33.24
4	0	76.49	-10.72	88.45	69.58



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

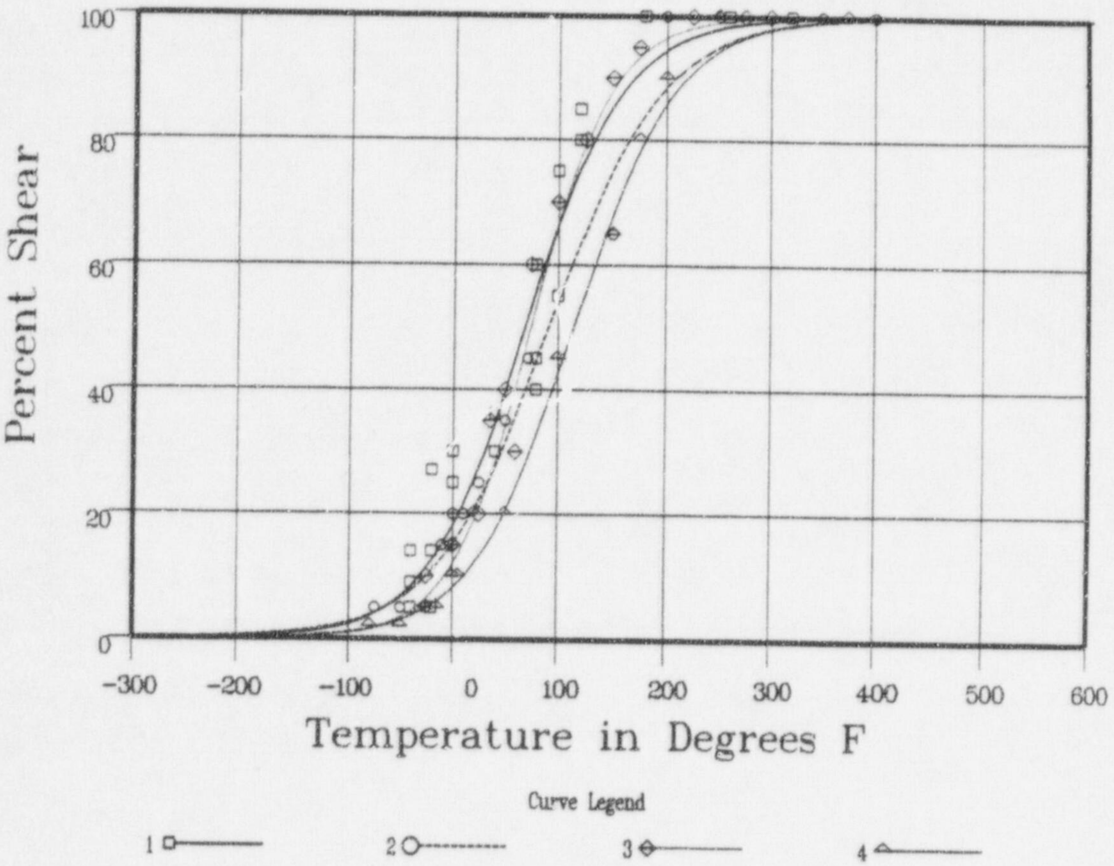
Figure 5-2 **Charpy V-Notch Lateral Expansion vs. Temperature for Vogtle Unit l Reactor Vessel Intermediate Shell Plate B8805-3 (Longitudinal Orientation)**

Intermediate Shell Plate B8805-3 (Long.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:39:42 on 05-08-1998

Results

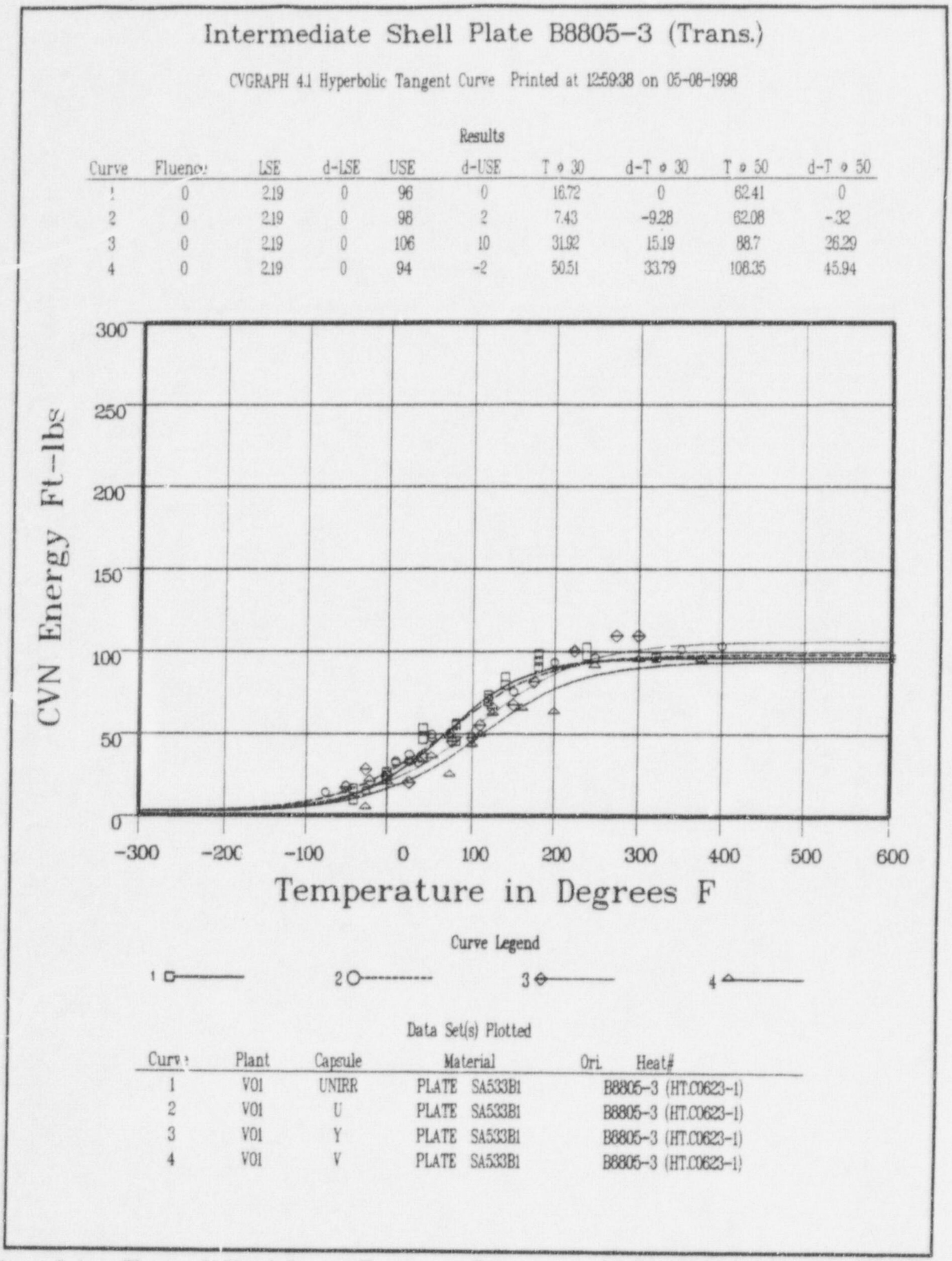
Curve	Fluence	T @ 50% Shear	d-T @ 50% Shear
1	0	64.46	0
2	0	86.71	22.24
3	0	70.03	5.56
4	0	109.86	45.39



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

Figure 5-3 **Charpy V-Notch Percent Shear vs. Temperature for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Longitudinal Orientation)**



Intermediate Shell Plate B8805-3 (Trans.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:59:38 on 05-08-1998

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	96	0	16.72	0	62.41	0
2	0	2.19	0	98	2	7.43	-9.28	62.08	-.32
3	0	2.19	0	106	10	31.92	15.19	88.7	26.29
4	0	2.19	0	94	-2	50.51	33.79	108.35	45.94

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

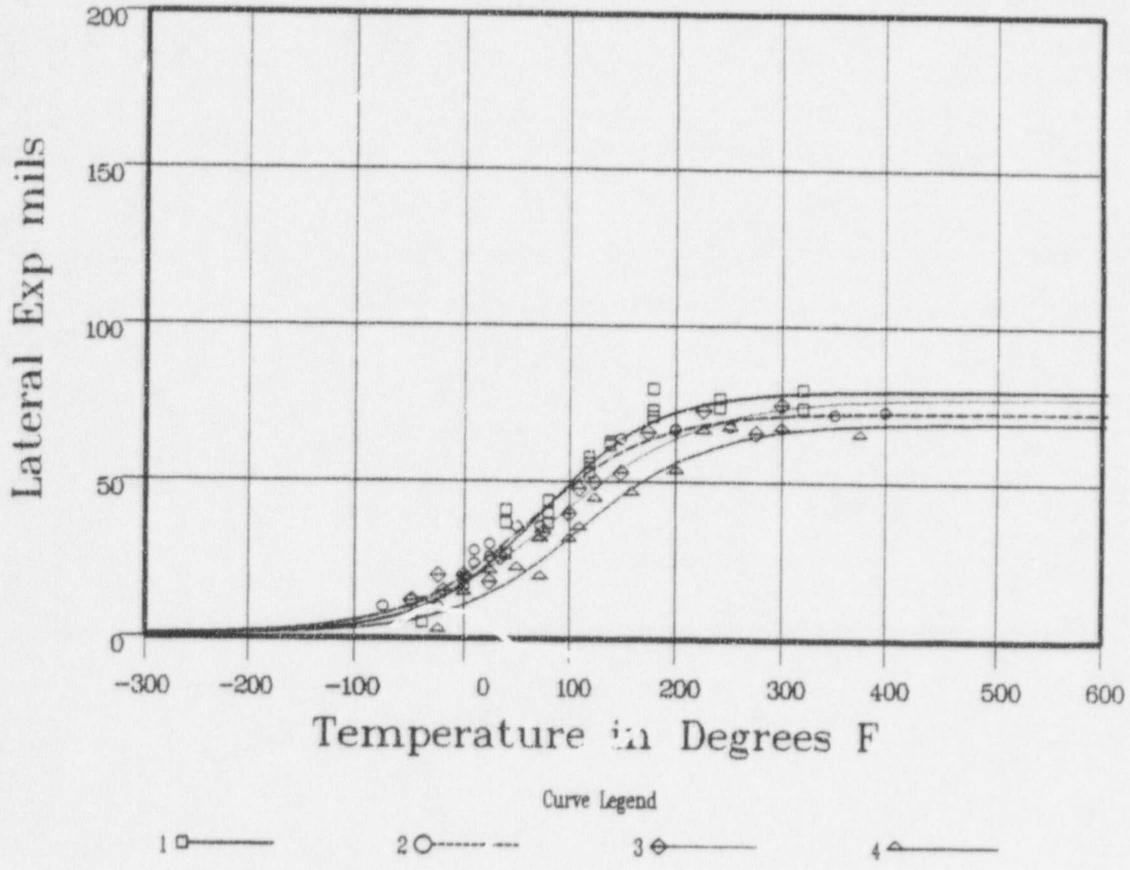
Figure 5-4 **Charpy V-Notch Impact Energy vs. Temperature for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Transverse Orientation)**

Intermediate Shell Plate B8805-3 (Trans.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 13:44:08 on 05-08-1998

Results

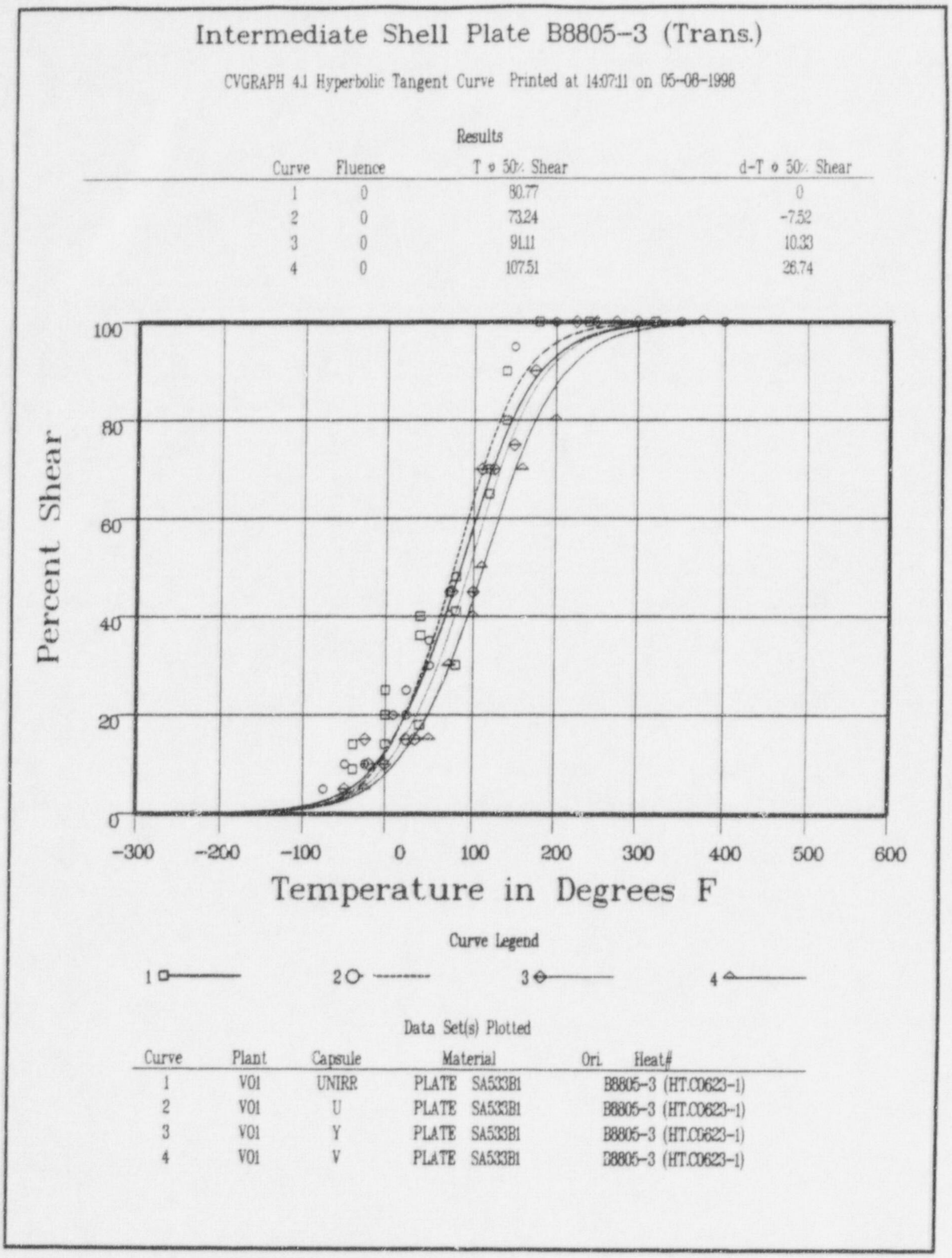
Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	79.81	0	54.01	0
2	0	72.73	-7.08	49.65	-4.35
3	0	77.56	-2.24	70.32	16.31
4	0	69.46	-10.34	105.8	51.78



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

Figure 5-5 **Charpy V-Notch Lateral Expansion vs. Temperature for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Transverse Orientation)**



Intermediate Shell Plate B8805-3 (Trans.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:07:11 on 05-08-1998

Results

Curve	Fluence	T @ 50% Shear	d-T @ 50% Shear
1	0	80.77	0
2	0	73.24	-7.52
3	0	91.11	10.33
4	0	107.51	26.74

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

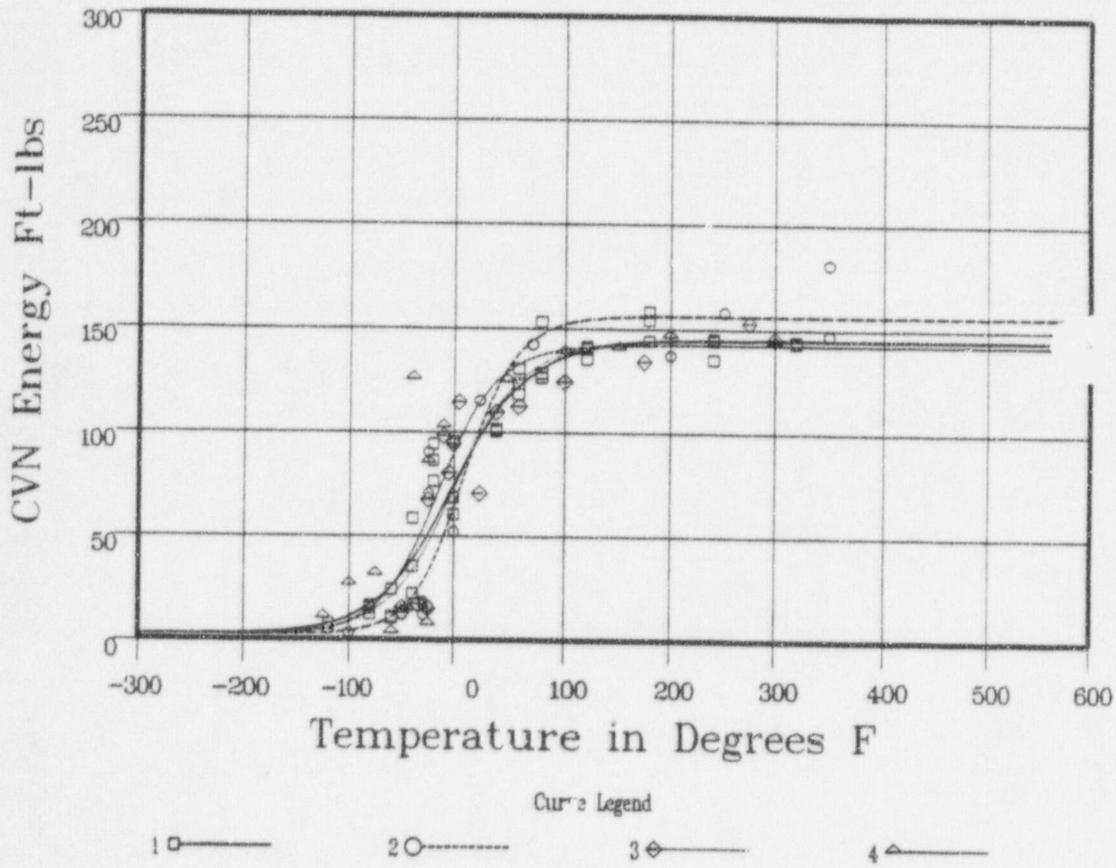
Figure 5-6 **Charpy V-Notch Percent Shear vs. Temperature for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Transverse Orientation)**

Weld Material

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:47:08 on 05-11-1998

Results

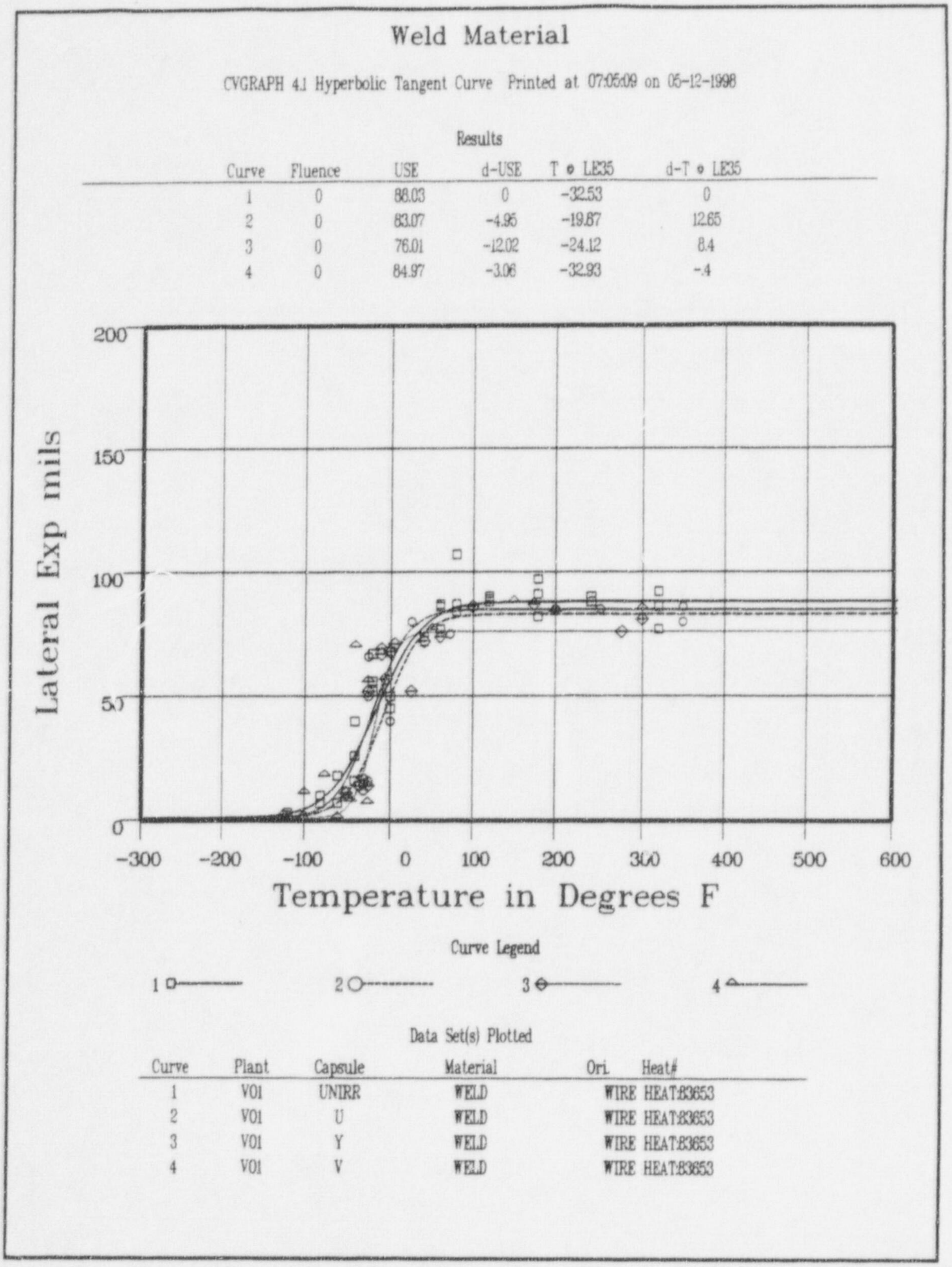
Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	144.5	0	-57.13	0	-30.42	0
2	0	2.19	0	156	11.5	-32.15	24.98	-14.28	16.14
3	0	2.19	0	144	-5	-49.42	7.7	-25.64	4.78
4	0	2.19	0	142	-2.5	-58.48	-1.34	-37.57	-7.14



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	WELD		WIRE HEAT:83653
2	V01	U	WELD		WIRE HEAT:83653
3	V01	Y	WELD		WIRE HEAT:83653
4	V01	V	WELD		WIRE HEAT:83653

Figure 5-7 Charpy V-Notch Impact Energy vs. Temperature for Vogtle Unit 1 Reactor Vessel Weld Metal



Weld Material

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:05:09 on 05-12-1998

Results

Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	86.03	0	-32.53	0
2	0	83.07	-4.95	-19.87	12.65
3	0	76.01	-12.02	-24.12	8.4
4	0	84.97	-3.06	-32.93	-.4

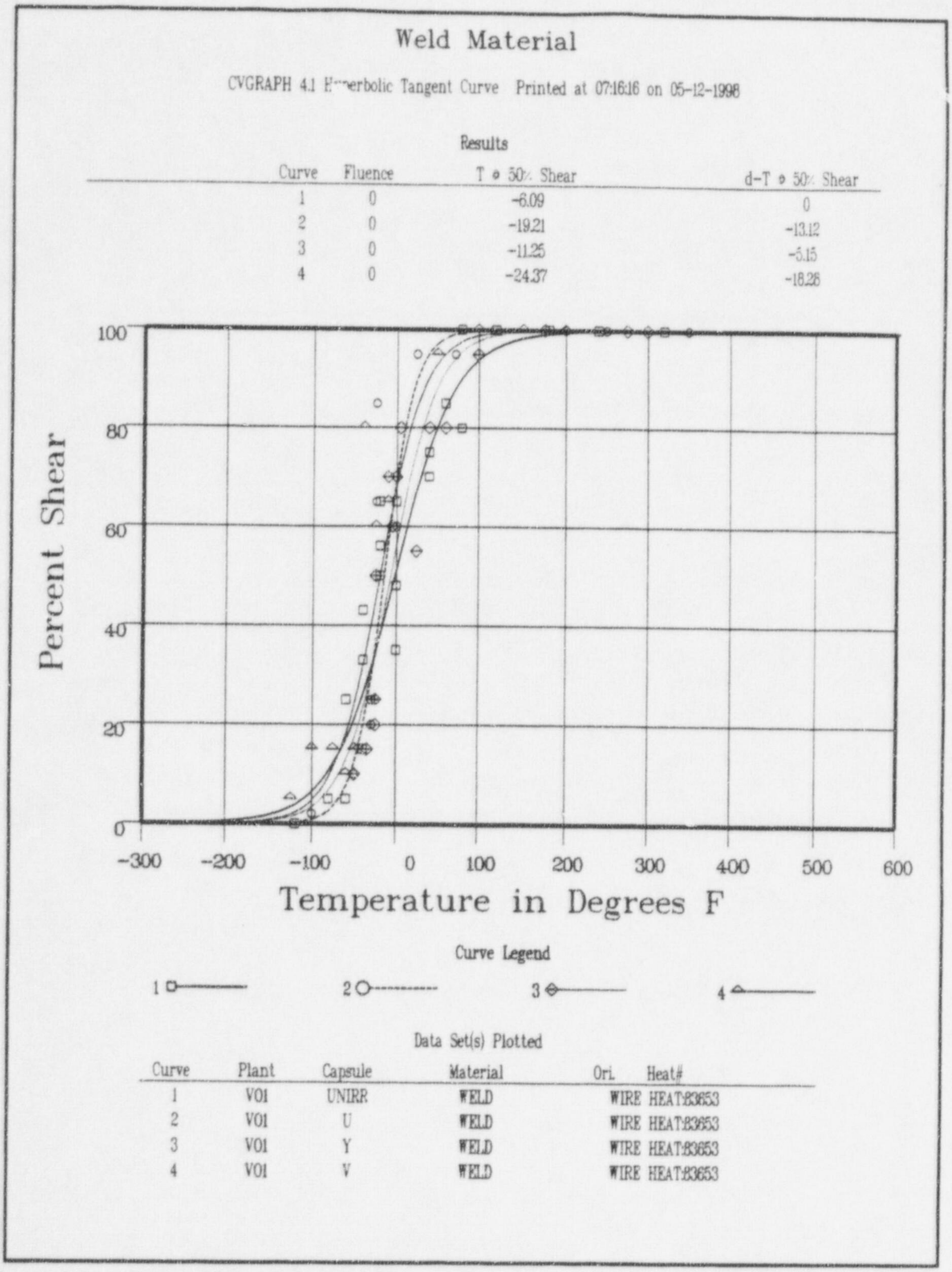
Curve Legend

1 □——— 2 ○------- 3 ◇——— 4 △———

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	WELD		WIRE HEAT:83653
2	V01	U	WELD		WIRE HEAT:83653
3	V01	Y	WELD		WIRE HEAT:83653
4	V01	V	WELD		WIRE HEAT:83653

Figure 5-8 Charpy V-Notch Lateral Expansion vs. Temperature for Vogtle Unit 1 Reactor Vessel Weld Metal



Weld Material

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:16:16 on 05-12-1998

Results

Curve	Fluence	T @ 50% Shear	d-T @ 50% Shear
1	0	-6.09	0
2	0	-19.21	-13.12
3	0	-11.25	-5.15
4	0	-24.37	-18.26

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	WELD		WIRE HEAT:83653
2	V01	U	WELD		WIRE HEAT:83653
3	V01	Y	WELD		WIRE HEAT:83653
4	V01	V	WELD		WIRE HEAT:83653

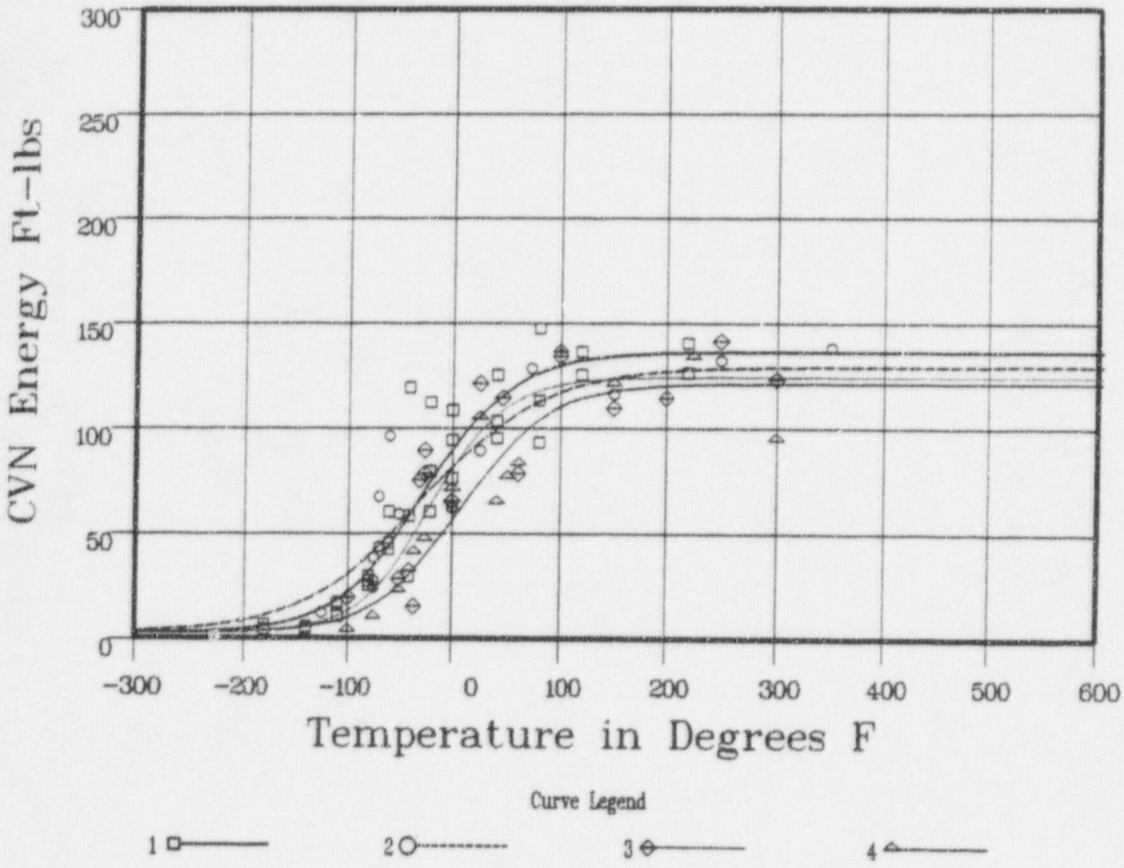
Figure 5-9 **Charpy V-Notch Percent Shear vs Temperature for Vogtle Unit 1 Reactor Vessel Weld Metal**

Heat Affected Zone

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:07:58 on 05-12-1998

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	136	0	-86.96	0	-55.52	0
2	0	2.19	0	129	-7	-106.31	-19.35	-62.32	-6.8
3	0	2.19	0	124	-12	-66.17	20.78	-39.36	16.15
4	0	2.19	0	121	-15	-44.87	42.08	-12.82	42.7



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	HEAT AFF'D ZONE	B8805-1	SIDE OF WELD
2	V01	U	HEAT AFF'D ZONE	B8805-1	SIDE OF WELD
3	V01	Y	HEAT AFF'D ZONE	B8805-1	SIDE OF WELD
4	V01	V	HEAT AFF'D ZONE	B8805-1	SIDE OF WELD

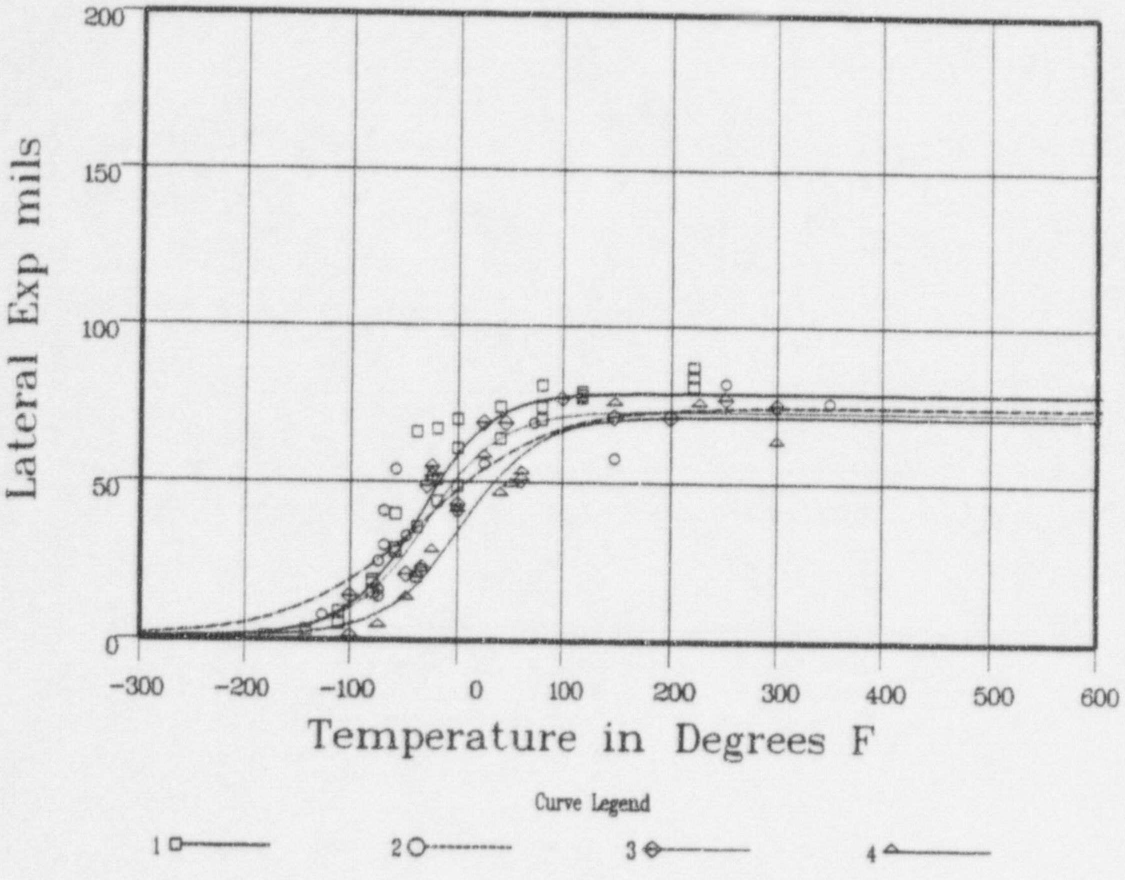
Figure 5-10 Charpy V-Notch Impact Energy vs. Temperature for Vogtle Unit 1 Reactor Vessel Heat-Affected-Zone Material

Heat Affected Zone

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:19:39 on 05-12-1998

Results

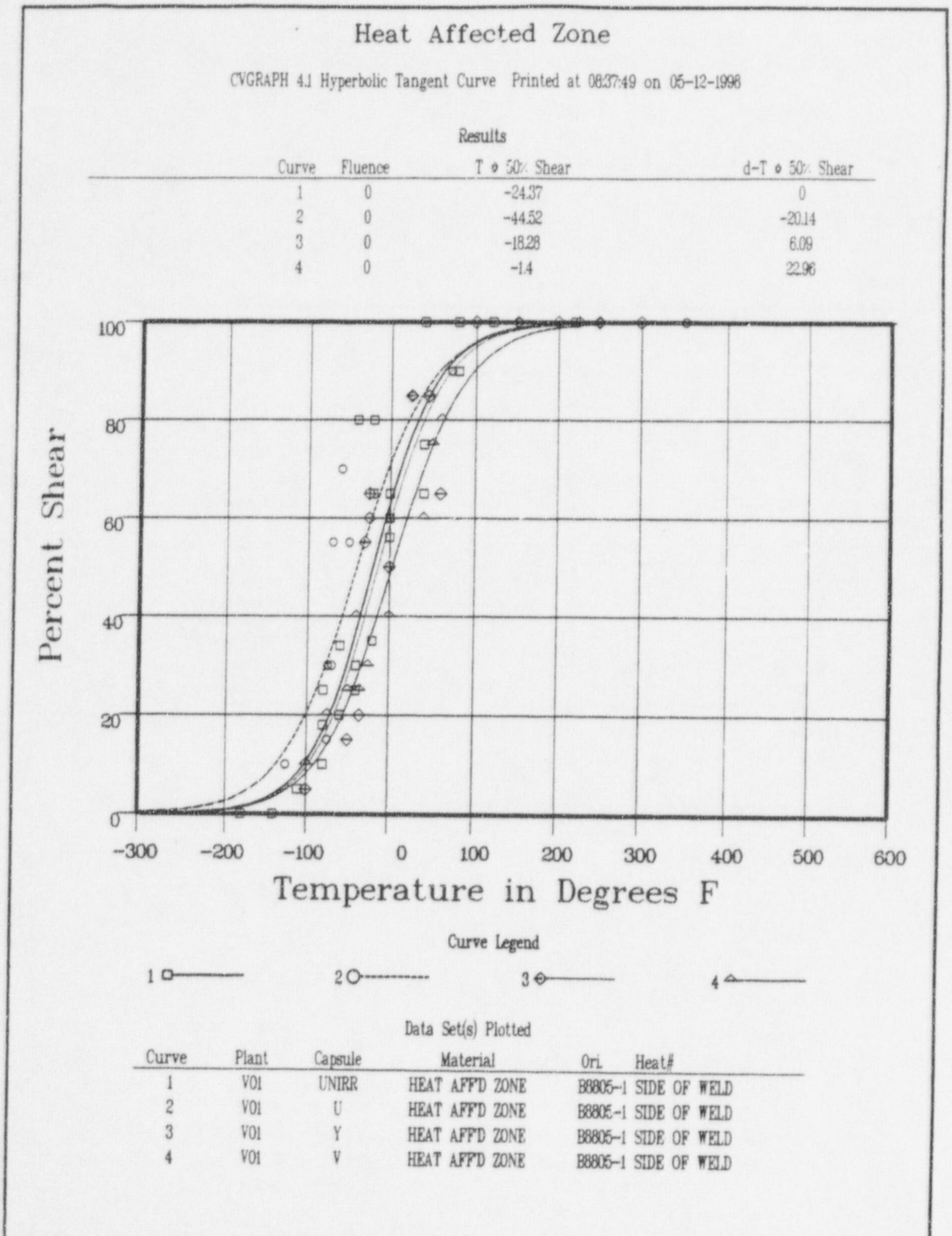
Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	78.79	0	-49.54	0
2	0	74.45	-4.33	-47.35	2.18
3	0	72.81	-5.98	-39.89	9.65
4	0	71.27	-7.51	-3.79	45.74



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
2	V01	U	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
3	V01	Y	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
4	V01	V	HEAT AFFD ZONE		B8805-1 SIDE OF WELD

Figure 5-11 **Charpy V-Notch Lateral Expansion vs. Temperature for Vogtle Unit 1 Reactor Vessel Heat-Affected-Zone Material**



Results

Curve	Fluence	T @ 50% Shear	d-T @ 50% Shear
1	0	-24.37	0
2	0	-44.52	-20.14
3	0	-18.28	6.09
4	0	-1.4	22.96

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
2	V01	U	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
3	V01	Y	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
4	V01	V	HEAT AFFD ZONE		B8805-1 SIDE OF WELD

Figure 5-12 **Charpy V-Notch Percent Shear vs. Temperature for Vogtle Unit 1 Reactor Vessel Heat-Affected-Zone Material**

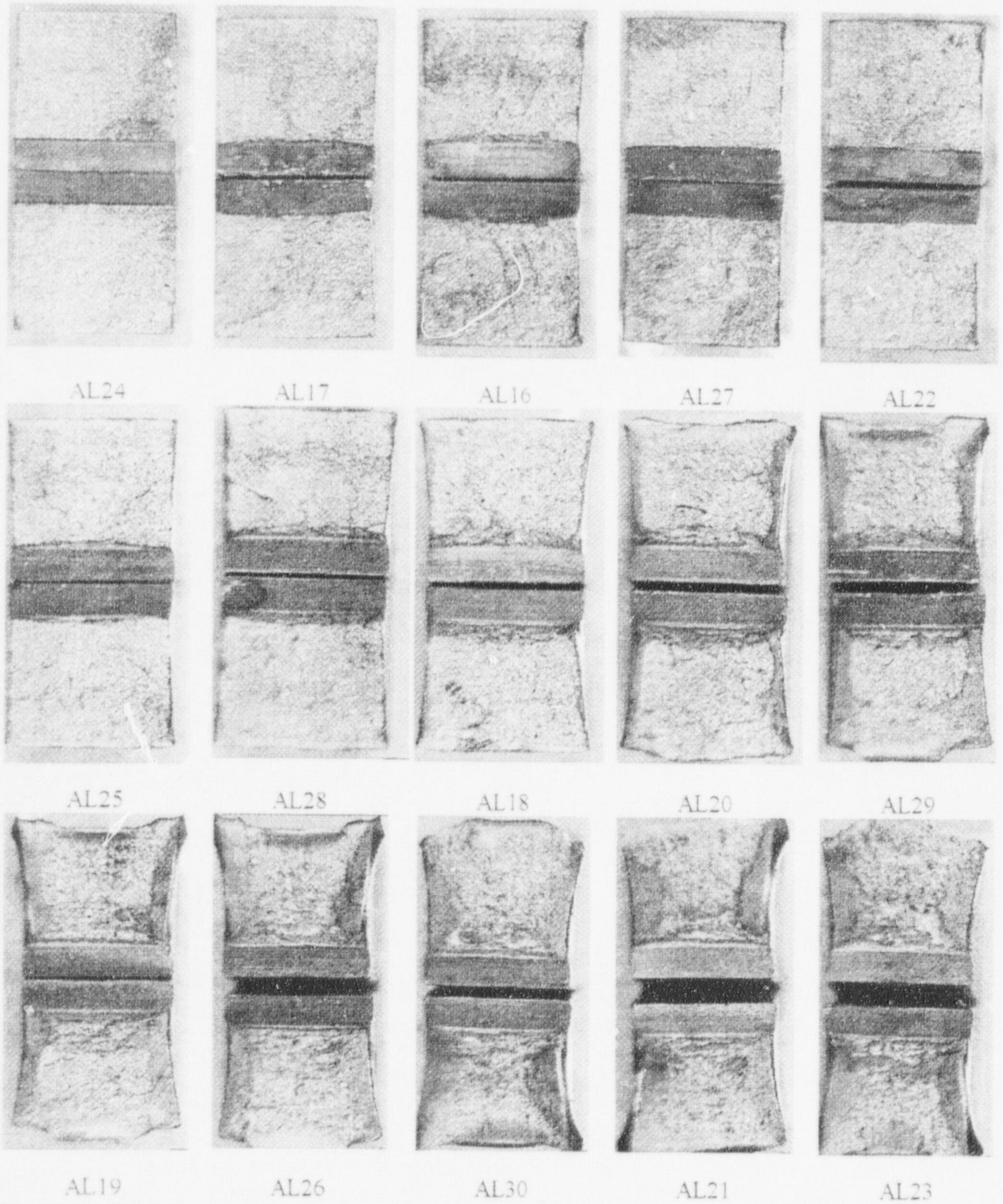


Figure 5-13 Charpy Impact Specimen Fracture Surfaces for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Longitudinal Orientation)

AT24 AT26 AT23 AT18 AT21

AT25 AT22 AT17 AT30 AT20

AT29 AT27 AT19 AT28 AT16

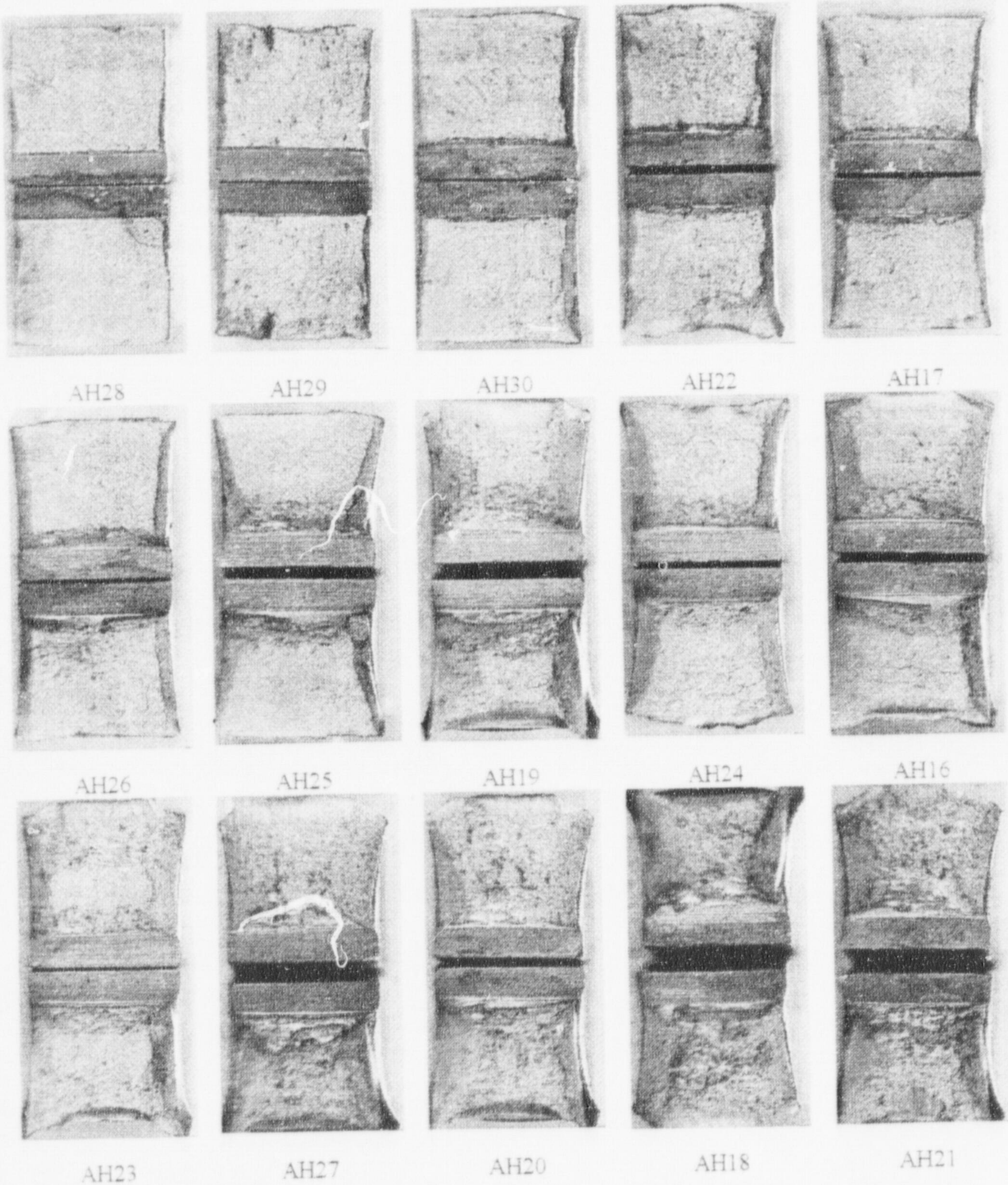
Figure 5-14 Charpy Impact Specimen Fracture Surfaces for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Transverse Orientation)

AW21 AW24 AW26 AW30 AW29

AW28 AW25 AW17 AW23 AW19

AW18 AW22 AW27 AW20 AW16

Figure 5-15 **Charpy Impact Specimen Fracture Surfaces for Vogtle Unit 1 Reactor Vessel Weld Metal**



AH28 AH29 AH30 AH22 AH17

AH26 AH25 AH19 AH24 AH16

AH23 AH27 AH20 AH18 AH21

Figure 5-16 **Charpy Impact Specimen Fracture Surfaces for Vogtle Unit 1 Reactor Vessel Heat-Affected-Zone Metal**

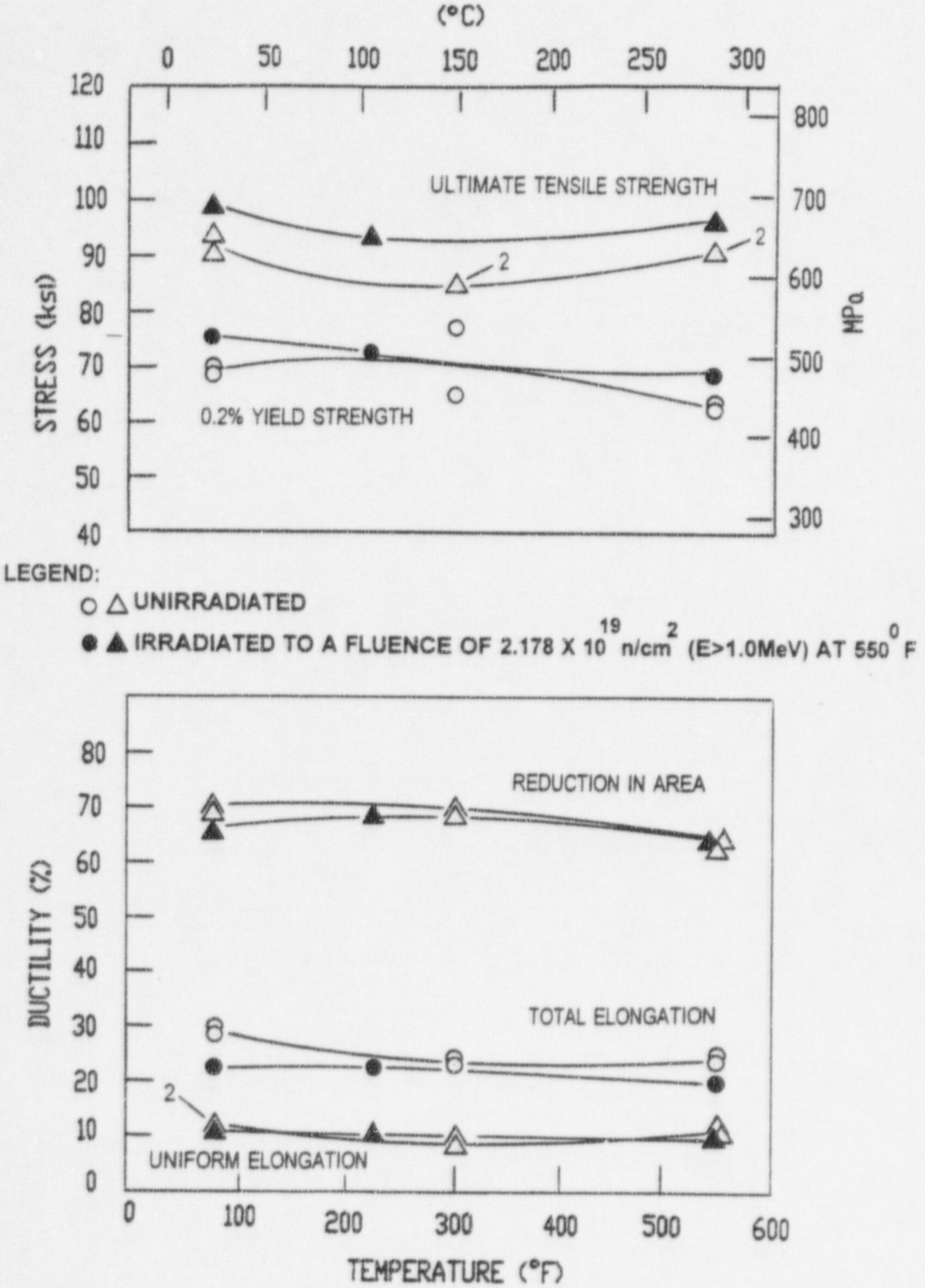


Figure 5-17 Tensile Properties for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Longitudinal Orientation)

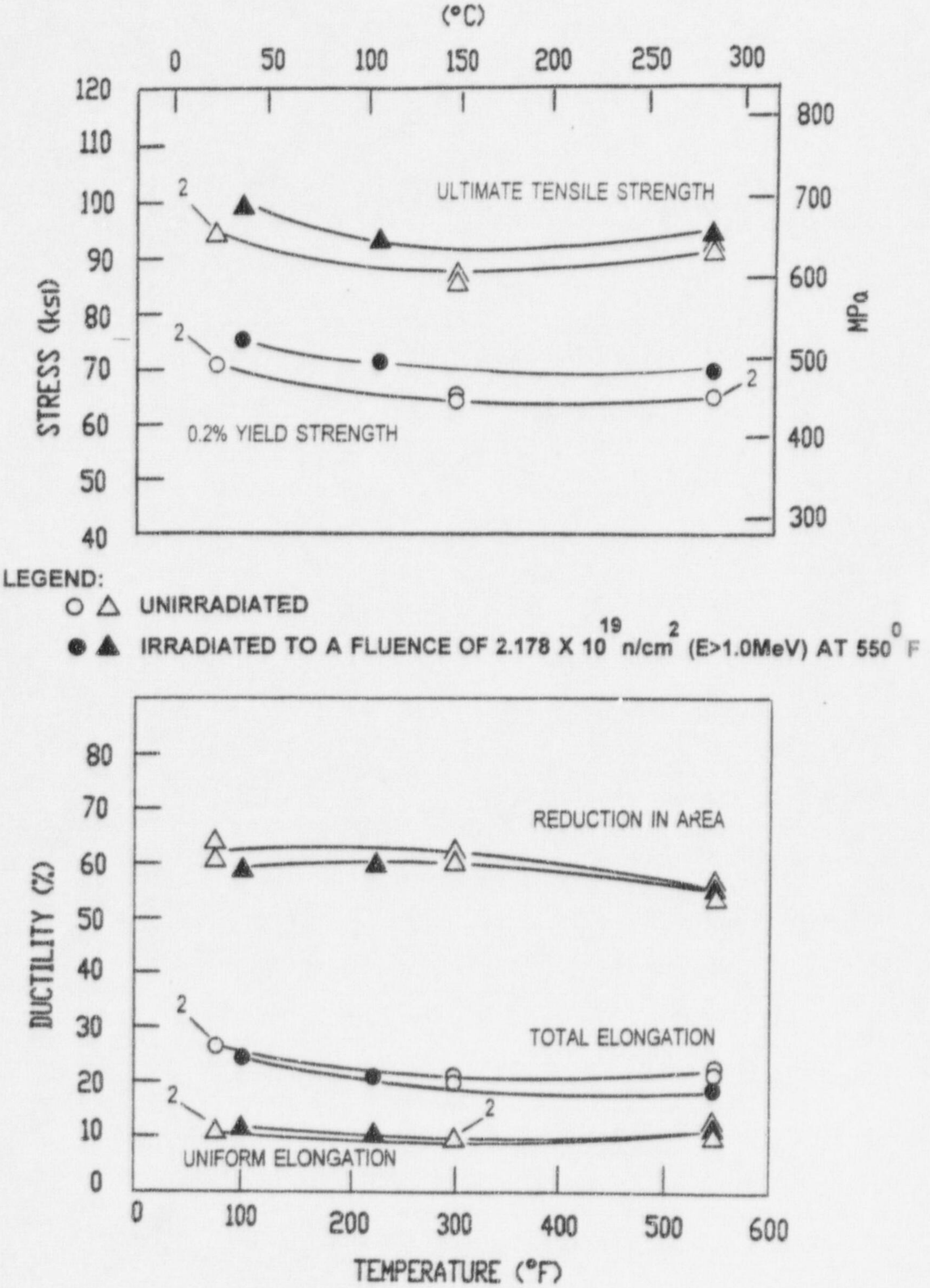


Figure 5-18 **Tensile Properties for Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Transverse Orientation)**

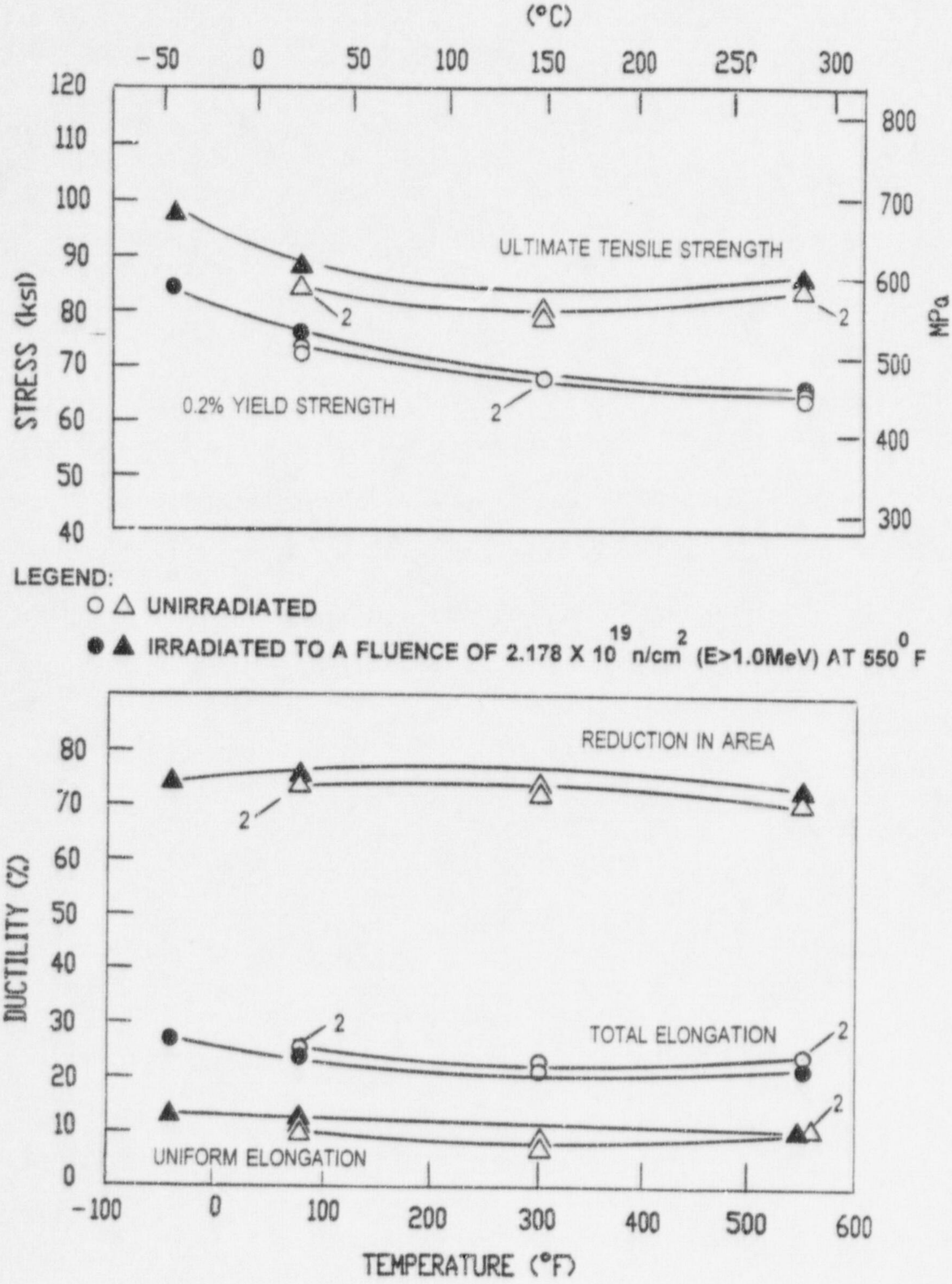
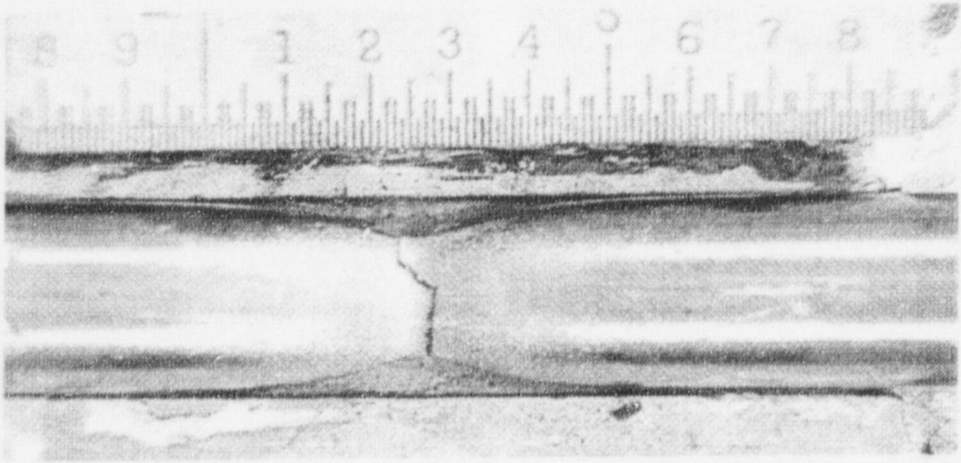
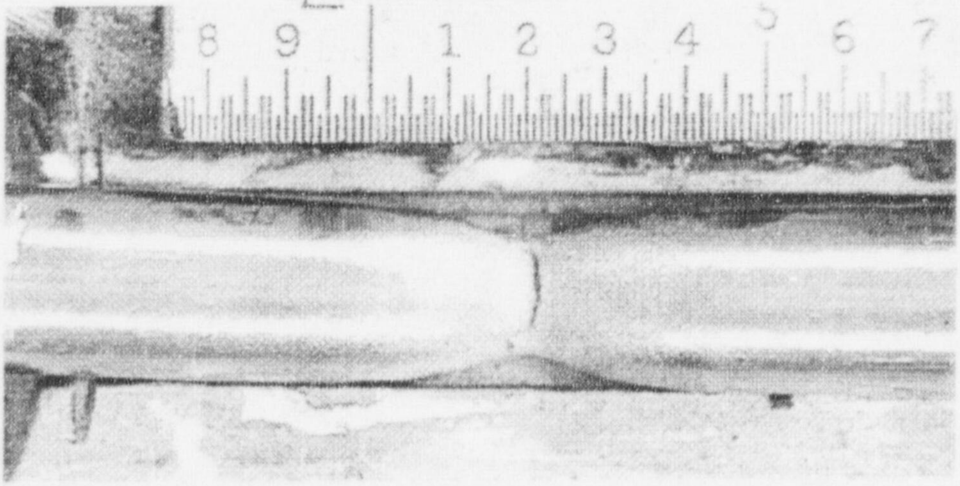


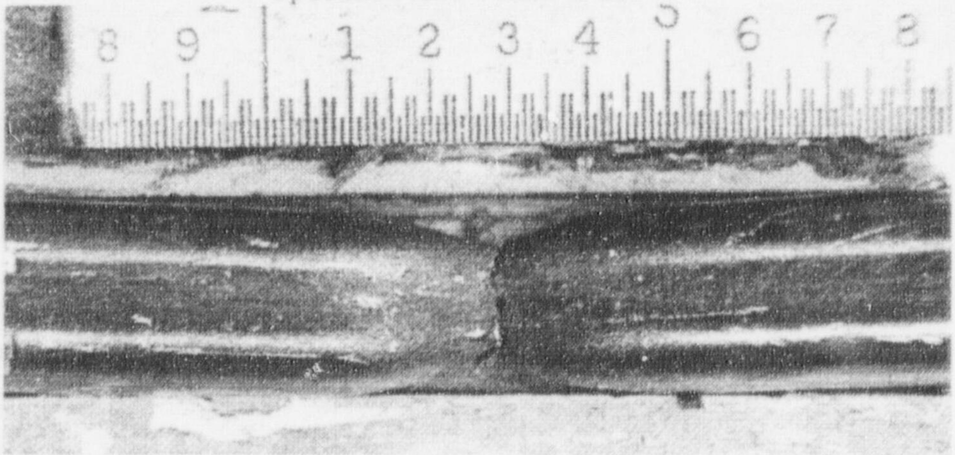
Figure 5-19 Tensile Properties for Vogtle Unit 1 Reactor Vessel Weld Metal



Specimen AL4 Tested at 74 °F

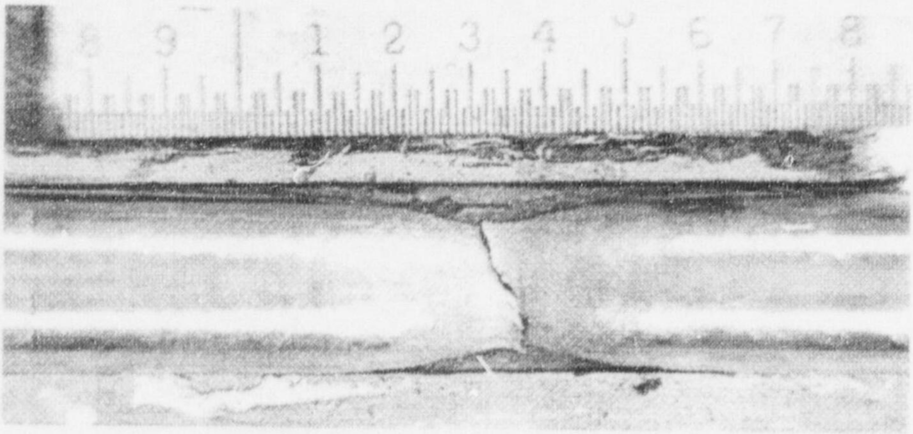


Specimen AL5 Tested at 225 °F

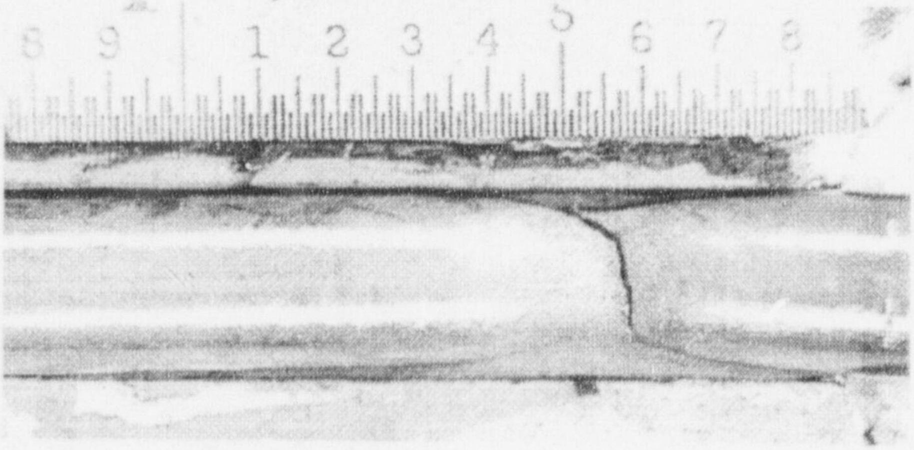


Specimen AL6 Tested at 550 °F

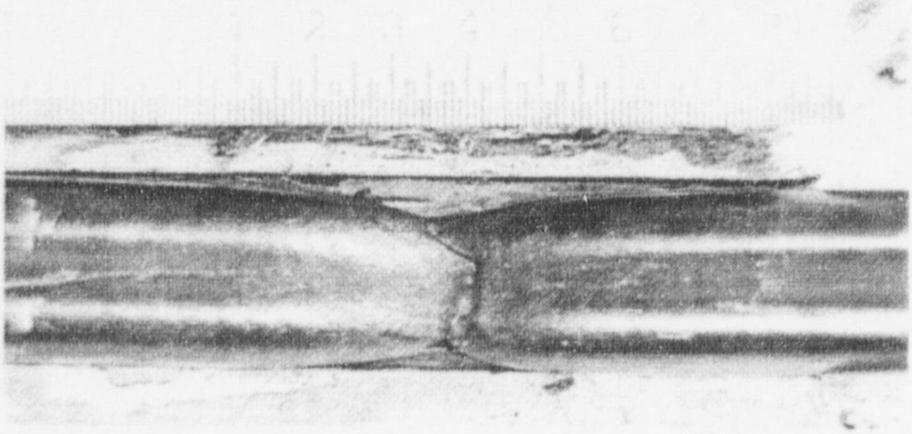
Figure 5-20 **Fractured Tensile Specimens from Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Longitudinal Orientation)**



Specimen AT4 Tested at 100 °F

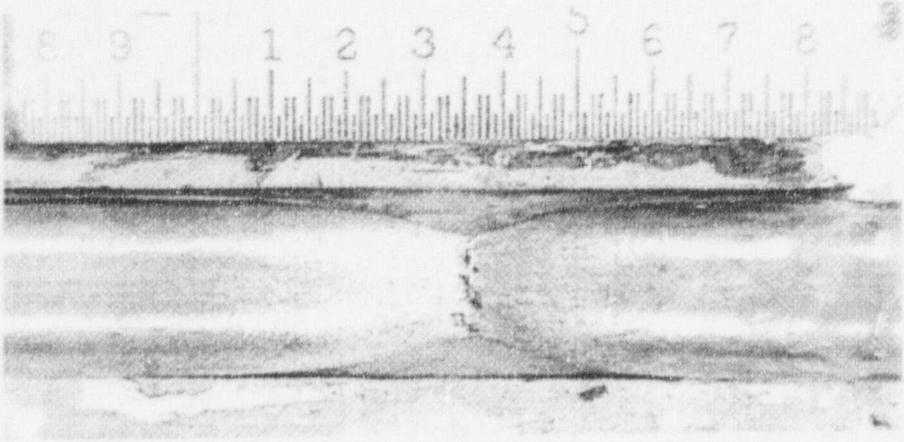


Specimen AT5 Tested at 225 °F

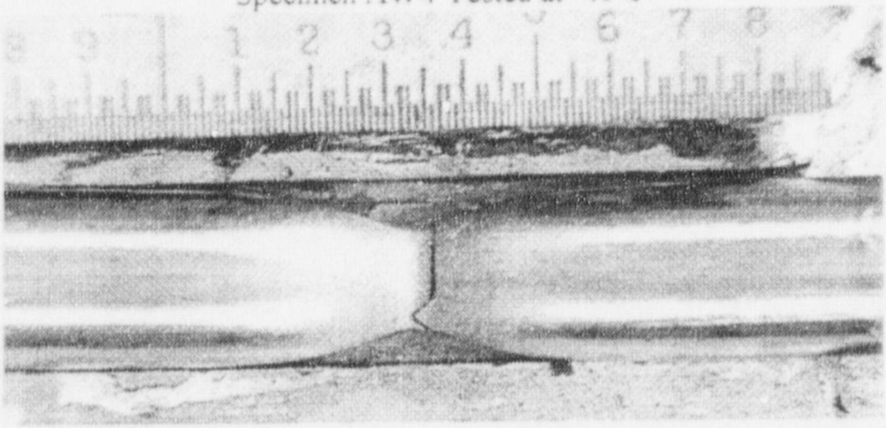


Specimen AT6 Tested at 550 °F

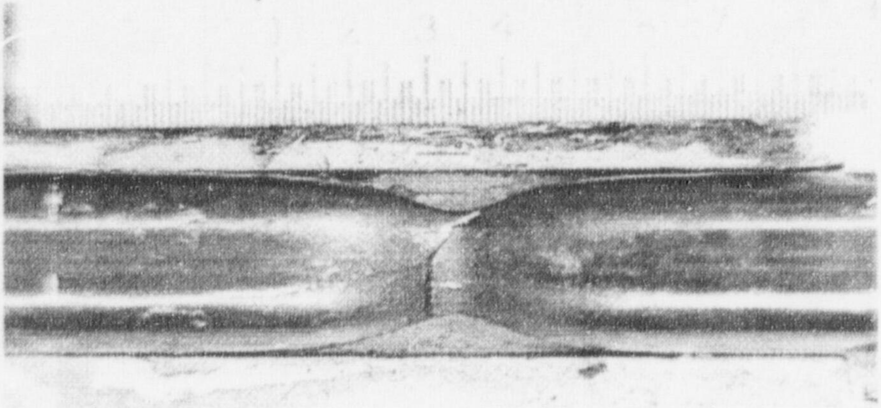
Figure 5-21 Fractured Tensile Specimens from Vogtle Unit 1 Reactor Vessel Intermediate Shell Plate B8805-3 (Transverse Orientation)



Specimen AW4 Tested at -40 °F



Specimen AW5 Tested at 74 °F



Specimen AW6 Tested at 550 °F

Figure 5-22 Fractured Tensile Specimens from Vogtle Unit 1 Reactor Vessel Weld Metal

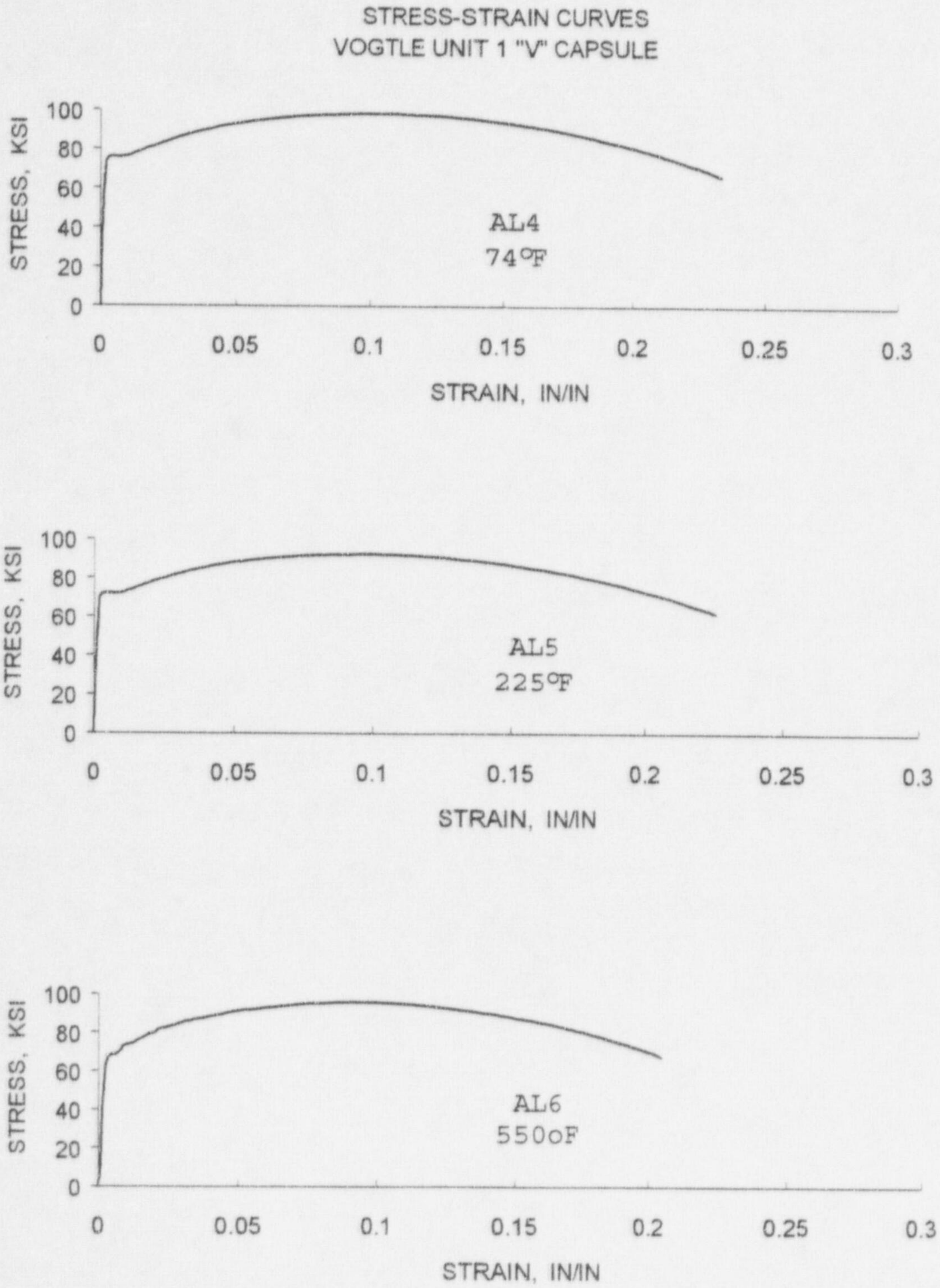


Figure 5-23 **Engineering Stress-Strain Curves for Intermediate Shell Plate B8805-3 Tensile Specimens AL4, AL5 and AL6 (Longitudinal Orientation)**

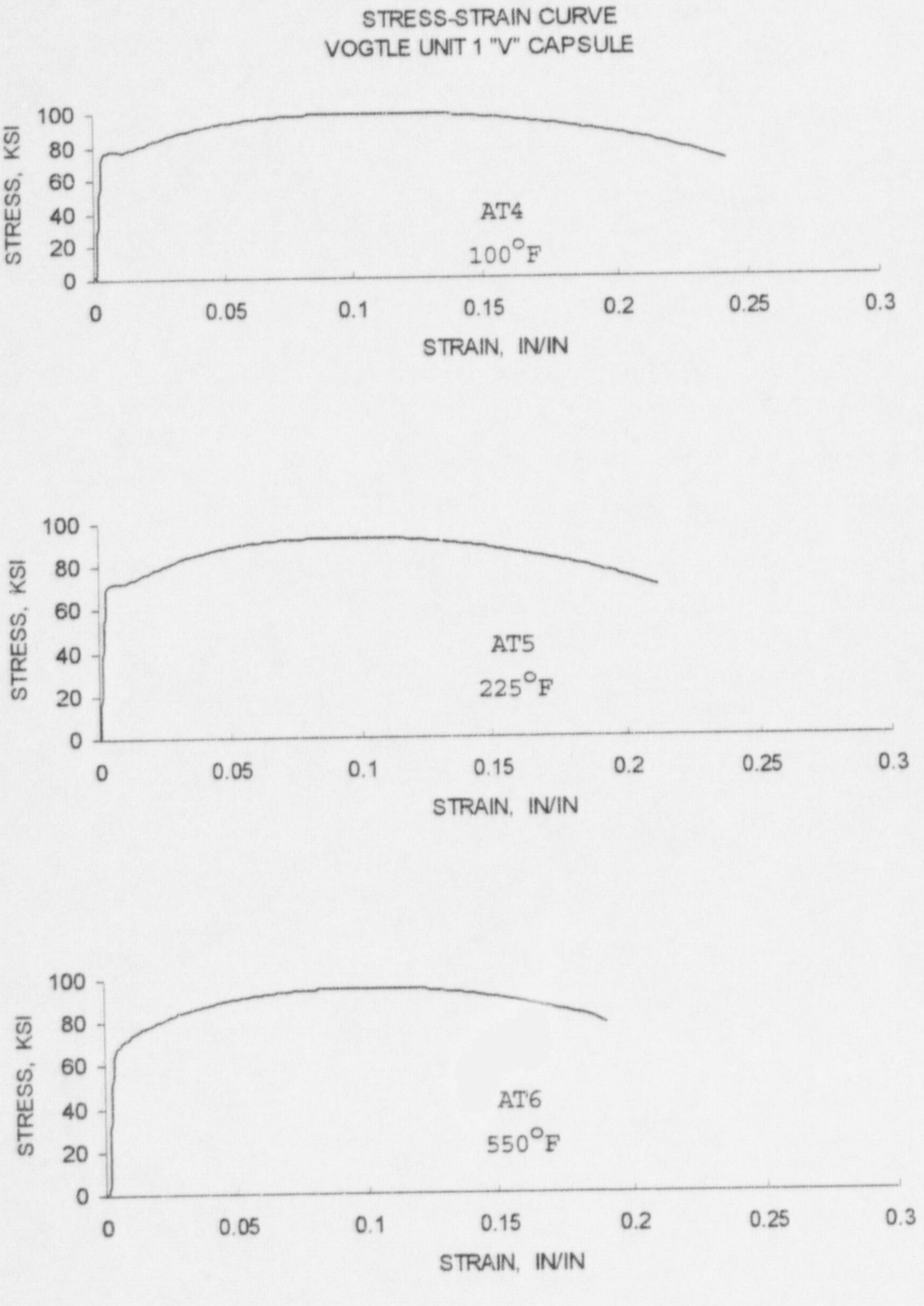


Figure 5-24 **Engineering Stress-Strain Curves for Intermediate Shell Plate B8805-3 Tensile Specimens AT4, AT5 and AT6 (Transverse Orientation)**

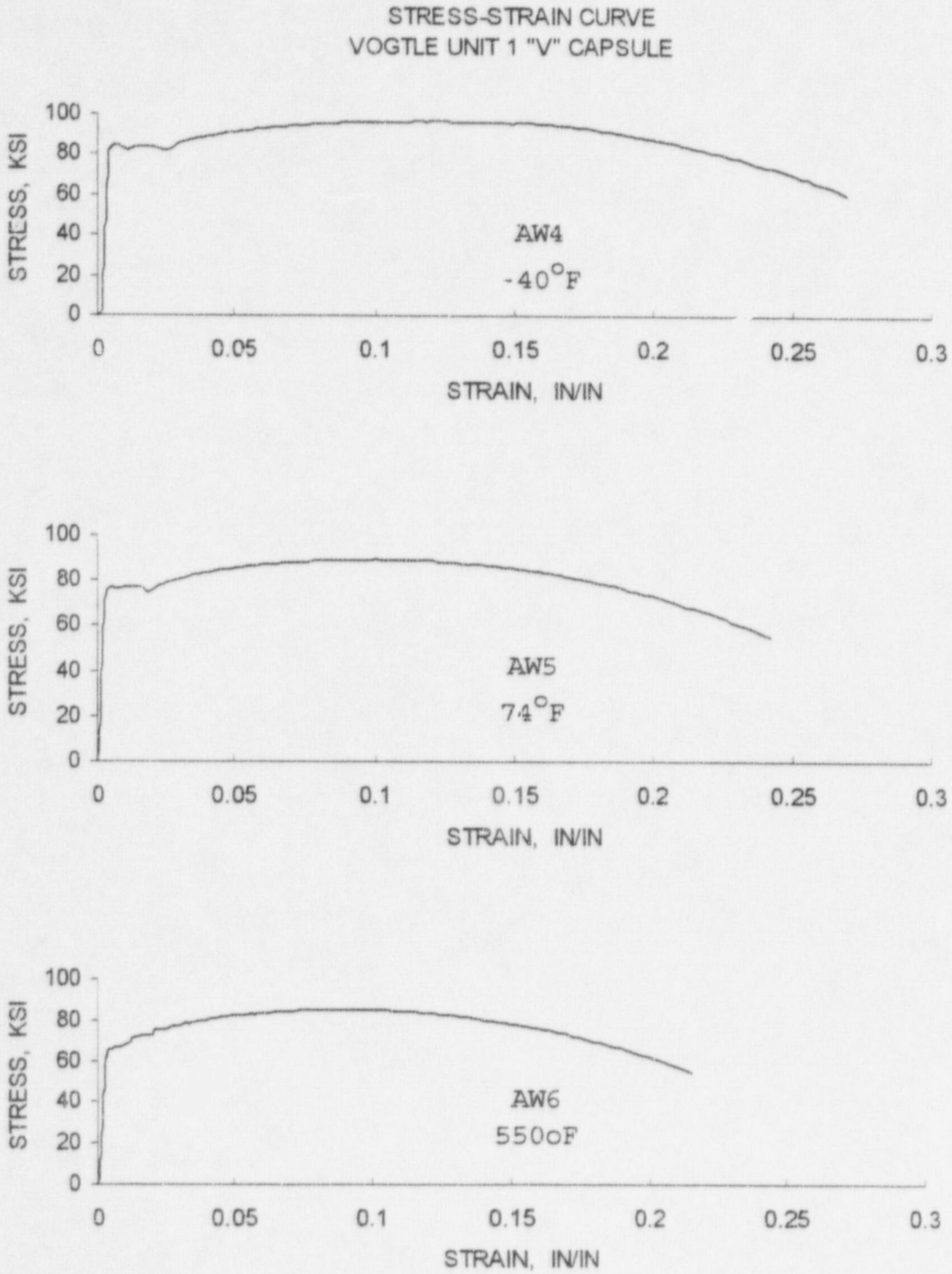


Figure 5-25 Engineering Stress-Strain Curves for Weld Metal Tensile Specimens AW4, AW5 and AW6

6 RADIATION ANALYSIS AND NEUTRON DOSIMETRY

6.1 INTRODUCTION

Knowledge of the neutron environment within the reactor vessel and surveillance capsule geometry is required as an integral part of LWR reactor vessel surveillance programs for two reasons. First, in order to interpret the neutron radiation induced material property changes observed in the test specimens, the neutron environment (energy spectrum, flux, fluence) to which the test specimens were exposed must be known. Second, in order to relate the changes observed in the test specimens to the present and future condition of the reactor vessel, a relationship must be established between the neutron environment at various positions within the reactor vessel and that experienced by the test specimens. The former requirement is normally met by employing a combination of rigorous analytical techniques and measurements obtained with passive neutron flux monitors contained in each of the surveillance capsules The latter information is generally derived solely from analysis.

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 development of damage trend curves as well as for the implementation of trend curve data to assess vessel condition. 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 as well as to a more accurate 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, "Analysis and Interpretation of Light-Water Reactor Surveillance Results," recommends reporting displacements per iron atom (dpa) along with fluence (E> 1.0 MeV) to provide a data base for future reference. The energy dependent dpa function to be used for this evaluation is specified in ASTM Standard Practice E693, "Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements per Atom." 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."

This section provides the results of the neutron dosimetry evaluations performed in conjunction with the analysis of test specimens contained in surveillance Capsules U, Y, and V which were withdrawn during the first, fourth, and seventh fuel cycles, respectively. This evaluation is based on current state-of-the-art methodology and nuclear data including recently released neutron transport and dosimetry cross-section libraries derived from the ENDF/B-VI data base. This report provides a consistent up-to-date neutron exposure data base for use in evaluating the material properties of the Vogtle Electric Generating Plant Unit 1 reactor vessel.

In each capsule dosimetry evaluation, fast neutron exposure parameters in terms of neutron fluence (E > 1.0 MeV), neutron fluence (E > 0.1 MeV), and iron atom displacements (dpa) are established for the capsule irradiation history. The analytical formalism relating the measured capsule exposure to the exposure of the vessel wall is described and used to project the integrated exposure of the vessel wall

Also, uncertainties associated with the derived exposure parameters at the surveillance capsules and with the projected exposure of the reactor vessel are provided.

6.2 DISCRETE ORDINATES ANALYSIS

A plan view of the reactor geometry at the core midplane is shown in Figure 4-1. Six irradiation capsules attached to the neutron pads are included in the reactor design to constitute the reactor vessel surveillance program. The capsules are located at azimuthal angles of 58.5°, 61°, 121.5°, 238.5°, 241°, and 301.5° relative to the core cardinal axis as shown in Figure 4-1.

A plan view of a dual surveillance capsule holder attached to the neutron pad is shown in Figure 6-1. The stainless steel specimen containers are 1.182 by 1-inch and 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 pad 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 surveillance capsules and reactor vessel, two distinct sets of transport calculations were carried out. The first, a single computation in the conventional forward mode, was used primarily to obtain relative neutron energy distributions throughout the reactor geometry as well as to establish relative radial distributions of exposure parameters {$\phi(E > 1.0\ \text{MeV})$, $\phi(E > 0.1\ \text{MeV})$, and dpa/sec} through the vessel wall. The neutron spectral information was required for the interpretation of neutron dosimetry withdrawn from the surveillance capsule as well as for the determination of exposure parameter ratios, i.e., [dpa/sec]/[$\phi(E > 1.0\ \text{MeV})$], within the reactor vessel geometry. The relative radial gradient information was required to permit the projection of measured exposure parameters to locations interior to the reactor vessel wall, i.e., the ¼T and ¾T locations.

The second set of calculations consisted of a series of adjoint analyses relating the fast neutron flux, $\phi(E > 1.0\ \text{MeV})$, at surveillance capsule positions and at several azimuthal locations on the reactor vessel inner radius to neutron source distributions within the reactor core. The source importance functions generated from these adjoint analyses provided the basis for all absolute exposure calculations and comparison with measurement. These importance functions, when combined with fuel cycle specific neutron source distributions, yielded absolute predictions of neutron exposure at the locations of interest for each cycle of irradiation. They also established the means to perform similar predictions and dosimetry evaluations for all subsequent fuel cycles. It is important to note that the cycle specific neutron source distributions utilized in these analyses included not only spatial variations of fission rates within the reactor core but also accounted for the effects of varying neutron yield per fission and fission spectrum introduced by the build-up of plutonium as the burnup of individual fuel assemblies increased.

The absolute cycle-specific data from the adjoint evaluations together with the relative neutron energy spectra and radial distribution information from the reference forward calculation provided the means to:

1 - Evaluate neutron dosimetry obtained from surveillance capsules,

2 - Relate dosimetry results to key locations at the inner radius and through the thickness of the reactor vessel wall,

3 - Enable a direct comparison of analytical prediction with measurement, and

4 - Establish a mechanism for projection of reactor vessel exposure as the design of each new fuel cycle evolves.

The forward transport calculation for the reactor model summarized in Figures 4-1 and 6-1 was carried out in R,θ geometry using the DORT two-dimensional discrete ordinates code Version 3.1[12] and the BUGLE-93 cross-section library [13]. The BUGLE-93 library is a 47 energy group ENDF/B-VI based data set produced specifically for light water reactor applications. In these analyses, anisotropic scattering was treated with a P_3 expansion of the scattering cross-sections and the angular discretization was modeled with an S_8 order of angular quadrature.

The core power distribution utilized in the reference forward transport calculation was derived from statistical studies of long-term operation of Westinghouse 4-loop plants. Inherent in the development of this reference core power distribution is the use of an out-in fuel management strategy, i.e., fresh fuel on the core periphery. Furthermore, for the peripheral fuel assemblies, the neutron source was increased by a 2σ margin derived from the statistical evaluation of plant-to-plant and cycle-to-cycle variations in peripheral power. Since it is unlikely that any single reactor would exhibit power levels on the core periphery at the nominal + 2σ value for a large number of fuel cycles, the use of this reference distribution is expected to yield somewhat conservative results.

All adjoint calculations were also carried out using an S_8 order of angular quadrature and the P_3 cross-section approximation from the BUGLE-93 library. Adjoint source locations were chosen at several azimuthal locations along the reactor vessel inner radius as well as at the geometric center of each surveillance capsule. Again, these calculations were run in R,θ geometry to provide neutron source distribution importance functions for the exposure parameter of interest, in this case $\phi(E > 1.0\ \text{MeV})$.

Having the importance functions and appropriate core source distributions, the response of interest could be calculated as:

$$R(r,\theta) = \int_r \int_\theta \int_E I(r,\theta,E)\, S(r,\theta,E)\, r\, dr\, d\theta\, dE$$

where:

$R(r,\theta)$ $=\phi(E > 1.0\text{ MeV})$ at radius r and azimuthal angle θ.

$I(r,\theta,E)$=Adjoint source importance function at radius r, azimuthal angle θ, and neutron source energy E.

$S(r,\theta,E)$=Neutron source strength at core location r,θ and energy E.

Although the adjoint importance functions used in this analysis were based on a response function defined by the threshold neutron flux $\phi(E > 1.0\text{ MeV})$, prior calculations [14] have shown that, while the implementation of low leakage loading patterns significantly impacts both the magnitude and spatial distribution of the neutron field, changes in the relative neutron energy spectrum are of second order. Thus, for a given location, the ratio of $[\text{dpa/sec}]/[\phi(E > 1.0\text{ MeV})]$ is insensitive to changing core source distributions. In the application of these adjoint importance functions to the Vogtle Electric Generating Plant Unit 1 reactor, therefore, the iron atom displacement rates (dpa/sec) and the neutron flux $\phi(E > 0.1\text{ MeV})$ were computed on a cycle-specific basis by using $[\text{dpa/sec}]/[\phi(E > 1.0\text{ MeV})]$ and $[\phi(E > 0.1\text{ MeV})]/[\phi(E > 1.0\text{ MeV})]$ ratios from the forward analysis in conjunction with the cycle specific $\phi(E > 1.0\text{ MeV})$ solutions from the individual adjoint evaluations.

The reactor core power distributions used in the plant specific adjoint calculations were taken from the fuel cycle design reports for the first seven operating cycle of Vogtle Electric Generating Plant Unit 1 [15 through 22].

Selected results from the neutron transport analyses are provided in Tables 6-1 through 6-5. The data listed in these tables establish the means for absolute comparisons of analysis and measurement for the Capsules U, Y, and V irradiation periods and provide the means to correlate dosimetry results with the corresponding exposure of the reactor vessel wall.

In Table 6-1, the calculated exposure parameters [$\phi(E > 1.0\text{ MeV})$, $\phi(E > 0.1\text{ MeV})$, and dpa/sec] are given at the geometric center of the two azimuthally symmetric surveillance capsule positions (29° and 31.5°) for both the reference and the plant specific core power distributions. The plant-specific data, based on the adjoint transport analysis, are meant to establish the absolute comparison of measurement with analysis. The reference data derived from the forward calculation are provided as a conservative exposure evaluation against which plant specific fluence calculations can be compared. Similar data are given in Table 6-2 for the reactor vessel inner radius. Again, the three pertinent exposure parameters are listed for the reference and Cycles 1 to 7 plant specific power distributions.

It is important to note that the data for the vessel inner radius were taken at the clad/base metal interface, and, thus, represent the maximum predicted exposure levels of the vessel plates and welds.

Radial gradient information applicable to $\phi(E > 1.0\text{ MeV})$, $\phi(E > 0.1\text{ MeV})$, and dpa/sec is given in Tables 6-3, 6-4, and 6-5, respectively. The data, obtained from the reference forward neutron transport calculation, are presented on a relative basis for each exposure parameter at several azimuthal locations.

Exposure distributions through the vessel wall may be obtained by normalizing the calculated or projected exposure at the vessel inner radius to the gradient data listed in Tables 6-3 through 6-5.

For example, the neutron flux $\phi(E > 1.0 \text{ MeV})$ at the ¼T depth in the reactor vessel wall along the 0° azimuth is given by:

$$\phi_{1/4T}(0^\circ) = \phi(220.35, 0^\circ)\, F(225.87, 0^\circ)$$

where:

$\phi_{1/4T}(0^\circ)$ = Projected neutron flux at the ¼T position on the 0° azimuth.

$\phi(220.35, 0^\circ)$ = Projected or calculated neutron flux at the vessel inner radius on the 0° azimuth.

$F(225.87, 0^\circ)$ = Ratio of the neutron flux at the ¼T position to the flux at the vessel inner radius for the 0° azimuth. This data is obtained from Table 6-3.

Similar expressions apply for exposure parameters expressed in terms of $\phi(E > 0.1 \text{ MeV})$ and dpa/sec where the attenuation function F is obtained from Tables 6-4 and 6-5, respectively.

6.3 NEUTRON DOSIMETRY

The passive neutron sensors included in the Vogtle Electric Generating Plant Unit 1 surveillance program are listed in Table 6-6. Also given in Table 6-6 are the primary nuclear reactions and associated nuclear constants that were used in the evaluation of the neutron energy spectrum within the surveillance capsules and in the subsequent determination of the various exposure parameters of interest [$\phi(E > 1.0 \text{ MeV})$, $\phi(E > 0.1 \text{ MeV})$, dpa/sec]. The relative locations of the neutron sensors within the capsules are shown in Figure 4-2. The iron, nickel, copper, and cobalt-aluminum monitors, in wire form, were placed in holes drilled in spacers at several axial levels within the capsules. The cadmium shielded uranium and neptunium fission monitors were accommodated within the dosimeter block located near the center of the capsule.

The use of passive monitors such as those listed in Table 6-6 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 [23],
- The energy response of each monitor, and
- The neutron energy spectrum at the monitor location.

The specific activity of each of the neutron monitors was determined using established ASTM procedures [24 through 37]. Following sample preparation and weighing, the activity of each monitor was determined by means of a lithium-drifted germanium, Ge(Li), gamma spectrometer. The irradiation history of the Vogtle Electric Generating Plant Unit 1 reactor was obtained from Southern Nuclear personnel [23] as reported in NUREG-0020, "Licensed Operating Reactors Status Summary Report," for the Cycles 1 to 7 operating periods. The irradiation history applicable to the exposure of Capsules U, Y, and V is given in Table 6-7.

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:

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

where: R = Reaction rate averaged over the irradiation period and referenced to operation at a core power level of P_{ref} (rps/nucleus). Reaction rate averaged over the irradiation period and referenced to operation at a core power level of P_{ref} (rps/nucleus).

A = Measured specific activity (dps/gm).

N_0 = Number of target element atoms per gram of sensor.

F = Weight fraction of the target isotope in the sensor material.

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 can be calculated for each fuel cycle using the adjoint transport technology 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.

For the irradiation history of Capsule U, Y, and V the flux level term in the reaction rate calculations was set to 1.0 for Capsule U only. Measured and saturated reaction product specific activities as well as the derived full power reaction rates are listed in Table 6-8. The specific activities and reaction rates of the ^{238}U sensors provided in Table 6-8 include corrections for ^{235}U impurities, plutonium build-in, and gamma ray induced fissions. Corrections for gamma ray induced fissions were also included in the specific activities and reaction rates for the ^{237}Np sensors as well.

Values of key fast neutron exposure parameters were derived from the measured reaction rates using the FERRET least squares adjustment code [38]. The FERRET approach used the measured reaction rate data, sensor reaction cross-sections, and a calculated trial spectrum as input and proceeded to adjust the group fluxes from the trial spectrum to produce a best fit (in a least squares sense) within the constraints of the parameter uncertainties. The best estimate exposure parameters, along with the associated uncertainties, were then obtained from the best estimate spectrum.

In the FERRET evaluations, a log-normal least squares algorithm weights both the a priori values and the measured data in accordance with the assigned uncertainties and correlations. In general, the measured values, f, are linearly related to the flux, ϕ, by some response matrix, A:

$$f_i^{(s,\alpha)} = \sum_g A_{ig}^{(s)} \phi_g^{(\alpha)}$$

where i indexes the measured values belonging to a single data set s, g designates the energy group, and α delineates spectra that may be simultaneously adjusted. For example,

$$R_i = \sum_g \sigma_{ig} \phi_g$$

relates a set of measured reaction rates, R_i, to a single spectrum, ϕ_g, by the multi-group reaction cross-section, σ_{ig}. The log-normal approach automatically accounts for the physical constraint of positive fluxes, even with large assigned uncertainties.

In the least squares adjustment, the continuous quantities (i.e., neutron spectra and cross-sections) were approximated in a multi-group format consisting of 53 energy groups. The trial input spectrum was converted to the FERRET 53 group structure using the SAND-II code[39]. This procedure was carried out by first expanding the 47 group calculated spectrum into the SAND-II 620 group structure using a SPLINE interpolation procedure in regions where group boundaries do not coincide. The 620 point spectrum was then re-collapsed into the group structure used in FERRET.

The sensor set reaction cross-sections, obtained from the ENDF/B-VI dosimetry file [40], were also collapsed into the 53 energy group structure using the SAND-II code. In this instance, the trial spectrum, as expanded to 620 groups, was employed as a weighting function in the cross-section collapsing procedure. Reaction cross-section uncertainties in the form of a 53 × 53 covariance matrix for each sensor reaction were also constructed from the information contained on the ENDF/B-VI data files. These matrices included energy group to energy group uncertainty correlations for each of the individual reactions. However, correlations between cross-sections for different sensor reactions were not included. The omission of this additional uncertainty information does not significantly impact the results of the adjustment.

Due to the importance of providing a trial spectrum that exhibits a relative energy distribution close to the actual spectrum at the sensor set locations, the neutron spectrum input to the FERRET evaluation was taken from the center of the surveillance capsule modeled in the reference forward transport calculation. While the 53 × 53 group covariance matrices applicable to the sensor reaction cross-sections were developed from the ENDF/B-VI data files, the covariance matrix for the input trial spectrum was constructed from the following relation:

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

where R_n specifies an overall fractional normalization uncertainty (i.e., complete correlation) for the set of values. The fractional uncertainties, R_g, specify additional random uncertainties for group g 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 short range correlations over a group range γ (θ specifies the strength of the latter term). The value of δ is 1 when $g = g'$ and 0 otherwise. For the trial spectrum used in the current evaluations, a short range correlation of $\gamma = 6$ groups was used. This choice implies that neighboring groups are strongly correlated when θ is close to 1. Strong long-range correlations (or anti-correlations) were justified based on information presented by R. E. Maerker[41]. The uncertainties associated with the measured reaction rates included both statistical (counting) and systematic components. The systematic component of the overall uncertainty accounts for counter efficiency, counter calibrations, irradiation history corrections, and corrections for competing reactions in the individual sensors.

Results of the FERRET evaluation of the Capsule U, Y, and V dosimetry are given in Table 6-9. The data summarized in this table include fast neutron exposure evaluations in terms of $\Phi(E > 1.0\text{ MeV})$, $\Phi(E > 0.1\text{ MeV})$, and dpa. In general, excellent results were achieved in the fits of the best estimate spectra to the individual measured reaction rates. The measured, calculated and best estimate reaction rates for each reaction are given in Table 6-10. An examination of Table 6-10 shows that, in all cases, reaction rates calculated with the best estimate spectra match the measured reaction rates to better than 12%. The best estimate spectra from the least squares evaluation is given in Table 6-11 in the FERRET 53 energy group structure.

In Table 6-12, absolute comparisons of the best estimate and calculated fluence at the center of Capsules U, Y, and V are presented. The result for the Capsules U, Y, and V dosimetry evaluation (BE/C ratio of 0.876 for $\Phi(E > 1.0\text{ MeV})$) are consistent with results obtained from similar evaluations of dosimetry from other reactors using methodologies based on ENDF/B-VI cross-sections.

6.4 PROJECTIONS OF REACTOR VESSEL EXPOSURE

The best estimate exposure of the Vogtle Electric Generating Plant Unit 1 reactor vessel was developed using a combination of absolute plant specific transport calculations and all available plant specific measurement data. In the case of Vogtle Electric Generating Plant Unit 1, the measurement data base contains one surveillance capsule discussed in this report.

Combining this measurement data base with the plant-specific calculations, the best estimate vessel exposure is obtained from the following relationship:

$$\Phi_{Best\ Est.} = K\ \Phi_{Calc}$$

where:

$\Phi_{Best.\ Est.}$ = The best estimate fast neutron exposure at the location of interest.

K = The plant specific best estimate/calculation (BE/C) bias factor derived from the surveillance capsule dosimetry data.

$\Phi_{Calc.}$ = The absolute calculated fast neutron exposure at the location of interest.

The approach defined in the above equation is based on the premise that the measurement data represent the most accurate plant-specific information available at the locations of the dosimetry; and, further that the use of the measurement data on a plant-specific basis essentially removes biases present in the analytical approach and mitigates the uncertainties that would result from the use of analysis alone.

That is, at the measurement points the uncertainty in the best estimate exposure is dominated by the uncertainties in the measurement process. At locations within the reactor vessel wall, additional uncertainty is incurred due to the analytically determined relative ratios among the various measurement points and locations within the reactor vessel wall.

For Vogtle Unit 1, the derived plant specific bias factors were 0.876, 0.939, and 0.919 for $\Phi(E > 1.0\ MeV)$, $\Phi(E > 0.1\ MeV)$, and dpa, respectively. Bias factors of this magnitude are fully consistent with experience using the BUGLE-93 cross-section library.

The use of the bias factors derived from the measurement data base acts to remove plant-specific biases associated with the definition of the core source, actual versus assumed reactor dimensions, and operational variations in water density within the reactor. As a result, the overall uncertainty in the best estimate exposure projections within the vessel wall depends on the individual uncertainties in the measurement process, the uncertainty in the dosimetry location, and, in the uncertainty in the calculated ratio of the neutron exposure at the point of interest to that at the measurement location.

The uncertainty in the derived neutron flux for an individual measurement is obtained directly from the results of a least squares evaluation of dosimetry data. The least squares approach combines individual uncertainty in the calculated neutron energy spectrum, the uncertainties in dosimetry cross-sections, and the uncertainties in measured foil specific activities to produce a net uncertainty in the derived neutron flux at the measurement point. The associated uncertainty in the plant specific bias factor, K, derived from the BE/C data base, in turn, depends on the total number of available measurements as well as on the uncertainty of each measurement.

In developing the overall uncertainty associated with the reactor vessel exposure, the positioning uncertainties for dosimetry are taken from parametric studies of sensor position performed as part a series of analytical sensitivity studies included in the qualification of the methodology. The uncertainties in the exposure ratios relating dosimetry results to positions within the vessel wall are again based on the analytical sensitivity studies of the vessel thickness tolerance, downcomer water density variations, and vessel inner radius tolerance. Thus, this portion of the overall uncertainty is controlled entirely by dimensional tolerances associated with the reactor design and by the operational characteristics of the reactor.

The net uncertainty in the bias factor, K, is combined with the uncertainty from the analytical sensitivity study to define the overall fluence uncertainty at the reactor vessel wall. In the case of Vogtle Electric Generating Plant Unit 1, the derived uncertainties in the bias factor, K, and the additional uncertainty from the analytical sensitivity studies combine to yield a net uncertainty of ±9.2%.

Based on this best estimate approach, neutron exposure projections at key locations on the reactor vessel inner radius are given in Table 6-13; furthermore, calculated neutron exposure projections are also provided for comparison purposes. Along with the current (8.57 EFPY) exposure, projections are also provided for exposure periods of 16 EFPY, 32 EFPY, 36 EFPY and 54 EFPY. Projections for future operation were based on the assumption that the exposure rates averaged over Cycle 4 through 7 (low-leakage loading pattern) would continue to be applicable throughout plant life.

In the derivation of best estimate and calculated exposure gradients within the reactor vessel wall for the Vogtle Electric Generating Plant Unit 1 reactor vessel, exposure projections to 16, 32, 36 and 54 EFPY were also employed. Data based on both a $\Phi(E > 1.0\ \text{MeV})$ slope and a plant-specific dpa slope through the vessel wall are provided in Table 6-14.

In order to access RT_{NDT} versus fluence curves, dpa equivalent fast neutron fluence levels for the ¼T and ¾T positions were defined by the relations:

$$\phi(1/4T) = \phi(0T)\,\frac{dpa(1/4T)}{dpa(0T)}$$

and

$$\phi(^3\!/\!_4 T) = \phi(0T)\,\frac{dpa(^3\!/\!_4 T)}{dpa(0T)}$$

Using this approach results in the dpa equivalent fluence values listed in Table 6-14.

In Table 6-15, updated lead factors are listed for each of the Vogtle Electric Generating Plant Unit 1 surveillance capsules.

Figure 6-1

Plan View Of A Dual Reactor Vessel Surveillance Capsule

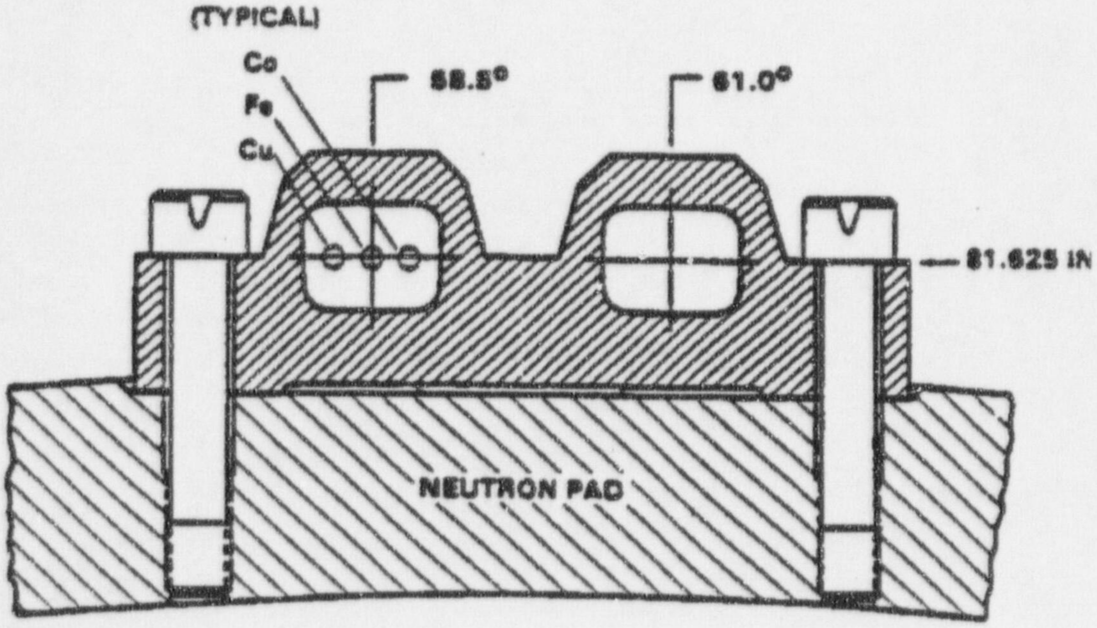


Table 6-1

Calculated Fast Neutron Exposure Rates And Iron Atom Displacement Rates At The Surveillance Capsule Center

	$\phi(E > 1.0 \text{ MeV})$ (n/cm^2-sec)	
Cycle No.	29°	31.5°
Reference	1.39E+11	1.48E+11
1	1.00E+11	1.07E+11
2	8.72E+10	9.29E+10
3	8.91E+10	9.77E+10
4	7.29E+10	7.86E+10
5	7.58E+10	8.17E+10
6	7.40E+10	7.91E+10
7	6.81E+10	7.33E+10

	$\phi(E > 0.1 \text{ MeV})$ (n/cm^2-sec)	
Cycle No.	29°	31.5°
Reference	5.96E+11	6.37E+11
1	4.308E+11	4.594E+11
2	3.740E+11	3.987E+11
3	3.824E+11	4.195E+11
4	3.129E+11	3.375E+11
5	3.254E+11	3.510E+11
6	3.176E+11	3.396E+11
7	2.924E+11	3.148E+11

	Displacement Rate (dpa/sec)	
Cycle No.	29°	31.5°
Reference	2.63E-10	2.80E-10
1	1.898E-10	2.023E-10
2	1.647E-10	1.755E-10
3	1.684E-10	1.847E-10
4	1.378E-10	1.486E-10
5	1.433E-10	1.545E-10
6	1.399E-10	1.495E-10
7	1.288E-10	1.386E-10

Table 6-2

Calculated Azimuthal Variation Of Fast Neutron Exposure Rates And Iron Atom Displacement Rates At The Reactor Vessel Clad/Base Metal Interface

$\phi(E > 1.0$ MeV$)$ (n/cm^2-sec)

Cycle No.	0°	15°	30°	45°
Reference	1.951E+10	2.929E+10	3.325E+10	3.409E+10
1	1.40E+10	2.08E+10	2.42E+10	2.45E+10
2	1.11E+10	1.74E+10	2.12E+10	1.99E+10
3	1.01E+10	1.58E+10	2.18E+10	2.14E+10
4	1.13E+10	1.54E+10	1.80E+10	1.83E+10
5	9.99E+09	1.52E+10	1.87E+10	1.83E+10
6	9.59E+09	1.51E+10	1.82E+10	1.76E+10
7	9.57E+09	1.36E+10	1.68E+10	1.63E+10

$\phi(E > 0.1$ MeV$)$ (n/cm^2-sec)

Cycle No.	0°	15°	30°	45°
Reference	4.104E+10	6.224E+10	7.226E+10	8.535E+10
1	2.953E+10	4.413E+10	5.254E+10	6.125E+10
2	2.333E+10	3.690E+10	4.601E+10	4.987E+10
3	2.122E+10	3.347E+10	4.727E+10	5.352E+10
4	2.377E+10	3.270E+10	3.912E+10	4.594E+10
5	2.103E+10	3.224E+10	4.057E+10	4.578E+10
6	2.018E+10	3.210E+10	3.957E+10	4.395E+10
7	2.014E+10	2.881E+10	3.647E+10	4.077E+10

Displacement Rate (dpa/sec)

Cycle No.	0°	15°	30°	45°
Reference	3.024E-11	4.496E-11	5.118E-11	5.384E-11
1	2.176E-11	3.188E-11	3.721E-11	3.862E-11
2	1.719E-11	2.666E-11	3.259E-11	3.145E-11
3	1.563E-11	2.418E-11	3.348E-11	3.375E-11
4	1.751E-11	2.362E-11	2.771E-11	2.897E-11
5	1.549E-11	2.329E-11	2.873E-11	2.887E-11
6	1.487E-11	2.319E-11	2.802E-11	2.771E-11
7	1.483E-11	2.081E-11	2.583E-11	2.571E-11

Table 6-3

Relative Radial Distribution Of ϕ (E > 1.0 Mev) Within The Reactor Vessel Wall

RADIUS (cm)	AZIMUTHAL ANGLE 0°	15°	30°	45°
220.35	1.000	1.000	1.000	1.000
221.00	0.959	0.958	0.956	0.957
222.30	0.852	0.851	0.844	0.846
223.60	0.739	0.736	0.729	0.729
224.89	0.634	0.630	0.623	0.622
225.87	0.561	0.557	0.549	0.547
227.01	0.486	0.482	0.473	0.472
228.63	0.395	0.390	0.382	0.380
230.09	0.325	0.320	0.314	0.311
231.39	0.273	0.269	0.263	0.260
232.68	0.229	0.225	0.219	0.217
234.14	0.188	0.184	0.179	0.176
235.76	0.150	0.146	0.142	0.140
236.90	0.128	0.124	0.121	0.118
237.88	0.111	0.107	0.105	0.102
239.18	0.092	0.089	0.086	0.084
240.47	0.076	0.072	0.071	0.069
241.77	0.063	0.058	0.057	0.055
242.42	0.060	0.055	0.054	0.052

Note: Base Metal Inner Radius = 220.35 cm
Base Metal ¼T = 225.87 cm
Base Metal ½T = 231.39 cm
Base Metal ¾T = 236.90 cm
Base Metal Outer Radius = 242.42 cm

Table 6-4

Relative Radial Distribution Of ϕ (E > 0.1 Mev)
Within The Reactor Vessel Wall

RADIUS (cm)	AZIMUTHAL ANGLE 0°	15°	30°	45°
220.35	1.000	1.000	1.000	1.000
221.00	1.014	1.012	1.011	1.009
222.30	1.003	0.997	0.993	0.989
223.60	0.968	0.958	0.953	0.946
224.89	0.923	0.909	0.904	0.894
225.87	0.886	0.870	0.865	0.852
227.01	0.840	0.821	0.816	0.802
228.63	0.775	0.754	0.749	0.733
230.09	0.716	0.693	0.689	0.672
231.39	0.664	0.639	0.636	0.618
232.68	0.612	0.587	0.584	0.566
234.14	0.556	0.530	0.528	0.509
235.76	0.496	0.469	0.468	0.449
236.90	0.455	0.428	0.427	0.409
237.88	0.419	0.392	0.391	0.373
239.18	0.374	0.346	0.346	0.328
240.47	0.330	0.301	0.301	0.284
241.77	0.286	0.254	0.255	0.238
242.42	0.276	0.244	0.245	0.228

Note: Base Metal Inner Radius = 220.35 cm
Base Metal ¼T = 225.87 cm
Base Metal ½T = 231.39 cm
Base Metal ¾T = 236.90 cm
Base Metal Outer Radius = 242.42 cm

Table 6-5

Relative Radial Distribution Of dpa/sec Within The Reactor Vessel Wall

RADIUS	AZIMUTHAL ANGLE			
(cm)	0°	15°	30°	45°
220.35	1.000	1.000	1.000	1.000
221.00	0.965	0.965	0.964	0.965
222.30	0.877	0.876	0.873	0.879
223.60	0.785	0.783	0.779	0.788
224.89	0.699	0.696	0.692	0.703
225.87	0.639	0.635	0.631	0.643
227.01	0.576	0.571	0.567	0.580
228.63	0.497	0.491	0.488	0.501
230.09	0.435	0.428	0.427	0.439
231.39	0.386	0.379	0.378	0.389
232.68	0.343	0.335	0.334	0.345
234.14	0.300	0.291	0.291	0.301
235.76	0.257	0.249	0.249	0.258
236.90	0.231	0.221	0.223	0.230
237.88	0.209	0.200	0.200	0.207
239.18	0.183	0.173	0.174	0.180
240.47	0.159	0.149	0.150	0.154
241.77	0.137	0.125	0.126	0.129
242.42	0.133	0.120	0.121	0.124

Note: Base Metal Inner Radius = 220.35 cm
Base Metal ¼T = 225.87 cm
Base Metal ½T = 231.39 cm
Base Metal ¾T = 236.90 cm
Base Metal Outer Radius = 242.42 cm

Table 6-6

Nuclear Parameters Used In The Evaluation Of Neutron Sensors

Monitor Material	Reaction of Interest	Target Atom Fraction	Response Range	Product Half-life	Fission Yield (%)
Copper	^{63}Cu (n,α)	0.6917	E > 4.7 MeV	5.271 y	
Iron	^{54}Fe (n,p)	0.0585	E > 1.0 MeV	312.1 d	
Nickel	^{58}Ni (n,p)	0.6808	E > 1.0 MeV	70.88 d	
Uranium-238	^{238}U (n,f)	1.0000	E > 0.4 MeV	30.07 y	6.02
Neptunium-237	^{237}Np (n,f)	1.0000	E > 0.08 MeV	30.07 y	6.17
Cobalt-Al	^{59}Co (n,γ)	0.0015	non-threshold	5.271 y	

Note: ^{238}U and ^{237}Np monitors are cadmium shielded.

Table 6-7

Monthly Thermal Generation During The First Seven Fuel Cycles Of The Vogtle Unit 1 Reactor

Y	Mo	Thermal Generat. (MW-hr)	Y	Mo	Thermal Generat. (MW-hr)	Y	Mo	Thermal Generat. (MW-hr)	Y	Mo	Thermal Generat. (MW-hr)
87	3	68766	89	11	2391716	92	7	2534681	95	3	2650182
87	4	797491	89	12	2535607	92	8	2535008	95	4	2561802
87	5	1044332	90	1	2374089	92	9	2188889	95	5	2630821
87	6	759746	90	2	1811171	92	10	2538900	95	6	2564944
87	7	1835718	90	3	0	92	11	2454211	95	7	2381719
87	8	2509822	90	4	591136	92	12	2536190	95	8	2650844
87	9	2452829	90	5	2311713	93	1	2536730	95	9	2519961
87	10	707673	90	6	2299026	93	2	2273143	95	10	2651520
87	11	1927388	90	7	2196834	93	3	849752	95	11	2564913
87	12	2467702	90	8	2512580	93	4	166750	95	12	2650729
88	1	1365280	90	9	2452206	93	5	2401502	96	1	2650608
88	2	1387377	90	10	2534258	93	6	2564437	96	2	2255312
88	3	2456340	90	11	2428733	93	7	2499130	96	3	130446
88	4	1907244	90	12	1692955	93	8	2645970	96	4	648324
88	5	2531355	91	1	2534837	93	9	2560140	96	5	2258085
88	6	2444967	91	2	2260779	93	10	2649962	96	6	1467397
88	7	2220349	91	3	2495386	93	11	2558233	96	7	2651000
88	8	2415264	91	4	2449552	93	12	2646046	96	8	2651013
88	9	2370737	91	5	2533685	94	1	2639758	96	9	2565318
88	10	483956	91	6	2449889	94	2	2156617	96	10	2654401
88	11	52233	91	7	2534501	94	3	2581209	96	11	2442399
88	12	2135007	91	8	2483204	94	4	2557372	96	12	2648271
89	1	1771903	91	9	969976	94	5	2554173	97	1	2648498
89	2	1905573	91	10	0	94	6	2561379	97	2	2393961
89	3	2533004	91	11	215953	94	7	2646904	97	3	2392019
89	4	2380073	91	12	2466013	94	8	2448946	97	4	1086834
89	5	2264902	92	1	2534684	94	9	629927	97	5	2489873
89	6	2452382	92	2	2371364	94	10	1099701	97	6	2565296
89	7	2443387	92	3	2528590	94	11	2564465	97	7	2645858
89	8	2286024	92	4	2239948	94	12	2631652	97	8	2650538
89	9	2450229	92	5	1866712	95	1	2650377	97	9	503695
89	10	2142954	92	6	2452840	95	2	2130621			

Table 6-8

Measured Sensor Activities And Reaction Rates

Surveillance Capsule U

Reaction	Location	Measured Activity (dps/gm)	Saturated Activity (dps/gm)	Reaction Rate (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	4.82E+04	3.84E+05	5.86E-17
	Middle	4.38E+04	3.49E+05	5.33E-17
	Bottom	4.44E+04	3.54E+05	5.40E-17
^{54}Fe (n,p) ^{54}Mn	Top	1.49E+06	3.72E+06	5.89E-15
	Middle	1.34E+06	3.34E+06	5.30E-15
	Bottom	1.36E+06	3.39E+06	5.38E-15
^{58}Ni (n,p) ^{58}Co	Top	1.26E+07	5.64E+07	8.07E-15
	Middle	1.16E+07	5.19E+07	7.43E-15
	Bottom	1.17E+07	5.23E+07	7.49E-15
^{59}Co (n,γ) ^{60}Co	Top	1.03E+07	8.21E+07	5.36E-12
	Middle	1.01E+07	8.05E+07	5.25E-12
	Bottom	1.05E+07	8.37E+07	5.46E-12
^{59}Co (n,γ) ^{60}Co (Cd)	Top	5.21E+06	4.15E+07	2.71E-12
	Middle	5.46E+06	4.35E+07	2.84E-12
	Bottom	5.58E+06	4.45E+07	2.90E-12
^{238}U (n,f) ^{137}Cs	Middle	1.29E+05	5.25E+06	3.44E-14
^{237}Np (n,f) ^{137}Cs	Middle	1.24E+06	5.04E+07	3.22E-13

Table 6-8 cont'd

Measured Sensor Activities And Reaction Rates

Surveillance Capsule Y

Reaction	Location	Measured Activity (dps/gm)	Saturated Activity (dps/gm)	Reaction Rate (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	1.38E+05	3.45E+05	5.26E-17
	Middle	1.21E+05	3.03E+05	4.62E-17
	Bottom	1.23E+05	3.08E+05	4.69E-17
^{54}Fe (n,p) ^{54}Mn	Top	1.63E+06	3.00E+06	4.76E-15
	Middle	1.47E+06	2.71E+06	4.30E-15
	Bottom	1.48E+06	2.73E+06	4.32E-15
^{58}Ni (n,p) ^{58}Co	Top	8.43E+06	4.67E+07	6.69E-15
	Middle	7.75E+06	4.29E+07	6.15E-15
	Bottom	7.63E+06	4.23E+07	6.05E-15
^{59}Co (n,γ) ^{60}Co	Top	2.34E+07	5.85E+07	3.82E-12
	Middle	2.35E+07	5.88E+07	3.83E-12
	Bottom	2.34E+07	5.85E+07	3.82E-12
^{59}Co (n,γ) ^{60}Co (Cd)	Top	1.20E+07	3.00E+07	1.96E-12
	Middle	1.29E+07	3.23E+07	2.10E-12
	Bottom	1.29E+07	3.23E+07	2.10E-12
^{238}U (n,f) ^{137}Cs	Middle	5.07E+05	5.13E+06	3.37E-14
^{237}Np (n,f) ^{137}Cs	Middle	3.38E+06	3.42E+07	2.18E-13

Table 6-8 cont'd

Measured Sensor Activities And Reaction Rates

Surveillance Capsule V

Reaction	Location	Measured Activity (dps/gm)	Saturated Activity (dps/gm)	Reaction Rate (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	1.75E+05	3.13E+05	4.78E-17
	Middle	1.55E+05	2.77E+05	4.23E-17
	Bottom	1.55E+05	2.77E+05	4.23E-17
^{54}Fe (n,p) ^{54}Mn	Top	1.35E+06	2.83E+06	4.49E-15
	Middle	1.24E+06	2.60E+06	4.12E-15
	Bottom	1.23E+06	2.58E+06	4.09E-15
^{58}Ni (n,p) ^{58}Co	Top	4.20E+06	4.46E+07	6.44E-15
	Middle	3.89E+06	4.13E+07	5.97E-15
	Bottom	3.88E+06	4.12E+07	5.95E-15
^{59}Co (n,γ) ^{60}Co	Top	2.88E+07	5.15E+07	3.36E-12
	Middle	2.88E+07	5.15E+07	3.36E-12
	Bottom	2.87E+07	5.14E+07	3.35E-12
^{59}Co (n,γ) ^{60}Co (Cd)	Top	1.45E+07	2.60E+07	1.69E-12
	Middle	1.50E+07	2.68E+07	1.75E-12
	Bottom	1.53E+07	2.74E+07	1.79E-12
^{238}U (n,f) ^{137}Cs	Middle	8.45E+05	4.89E+06	3.21E-14
^{237}Np (n,f) ^{137}Cs	Middle	6.27E+06	3.63E+07	2.32E-13

Table 6-9

Summary Of Neutron Dosimetry Results
Surveillance Capsules U, Y, and V

Best Estimate Flux and Fluence for Capsule U

Quantity	Flux [n/cm^2-sec]	Quantity	Fluence [n/cm^2]	Uncertainty
ϕ (E > 1.0 MeV)	9.332E+10	Φ (E > 1.0 MeV)	3.219E+18	7%
ϕ (E > 0.1 MeV)	4.477E+11	Φ (E > 0.1 MeV)	1.544E+19	15%
ϕ (E < 0.414 eV)	1.076E+11	Φ (E < 0.414 eV)	3.711E+18	28%
dpa/sec	1.899E-10	dpa	6.550E-03	11%

Best Estimate Flux and Fluence for Capsule Y

Quantity	Flux [n/cm^2-sec]	Quantity	Fluence [n/cm^2]	Uncertainty
ϕ (E > 1.0 MeV)	7.381E+10	Φ (E > 1.0 MeV)	1.080E+19	7%
ϕ (E > 0.1 MeV)	3.283E+11	Φ (E > 0.1 MeV)	4.805E+19	15%
ϕ (E < 0.414 eV)	7.589E+10	Φ (E < 0.414 eV)	1.111E+19	28%
dpa/sec	1.437E-10	dpa	2.103E-02	11%

Best Estimate Flux and Fluence for Capsule V

Quantity	Flux [n/cm^2-sec]	Quantity	Fluence [n/cm^2]	Uncertainty
ϕ (E > 1.0 MeV)	7.323E+10	F (E > 1.0 MeV)	1.9804E+19	7%
ϕ (E > 0.1 MeV)	3.339E+11	F (E > 0.1 MeV)	9.027E+19	15%
ϕ (E < 0.414 eV)	6.993E+10	F (E < 0.414 eV)	1.890E+19	28%
dpa/sec	1.441E-10	dpa	3.896E-02	11%

Table 6-10

Comparison Of Measured, Calculated, And Best Estimate Reaction Rates At The Surveillance Capsule Center

Surveillance Capsule U

Reaction	Measured	Calculated	Best Estimate	BE / Meas	BE/ Calc	Meas/Calc
^{63}Cu (n,a)	5.53E-17	5.53E-17	5.41E-17	0.98	0.98	1.00
^{54}Fe (n,p)	5.52E-15	6.32E-15	5.58E-15	1.01	0.88	0.87
^{58}Ni (n,p)	7.66E-15	8.87E-15	7.80E-15	1.02	0.88	0.86
^{238}U (n,f) (Cd)	2.90E-14	3.41E-14	2.94E-14	1.01	0.86	0.85
^{237}Np (n,f)	3.19E-13	3.27E-13	3.06E-13	0.96	0.94	0.98
^{59}Co (n,g)	5.36E-12	4.44E-12	5.33E-12	0.99	1.20	1.21
^{59}Co (n,g) (Cd)	2.82E-12	3.11E-12	2.83E-12	1.00	0.91	0.91

Surveillance Capsule Y

Reaction	Measured	Calculated	Best Estimate	BE / Meas	BE/ Calc	Meas/Calc
^{63}Cu (n,a)	4.86E-17	4.57E-17	4.69E-17	0.97	1.03	1.06
^{54}Fe (n,p)	4.46E-15	5.17E-15	4.64E-15	1.04	0.90	0.86
^{58}Ni (n,p)	6.30E-15	7.24E-15	6.46E-15	1.03	0.89	0.87
^{238}U (n,f) (Cd)	2.72E-14	2.77E-14	2.39E-14	0.88	0.86	0.98
^{237}Np (n,f)	2.16E-13	2.65E-13	2.22E-13	1.03	0.84	0.82
^{59}Co (n,g)	3.82E-12	3.54E-12	3.81E-12	1.00	1.08	1.08
^{59}Co (n,g) (Cd)	2.06E-12	2.50E-12	2.06E-12	1.00	0.82	0.82

Surveillance Capsule V

Reaction	Measured	Calculated	Best Estimate	BE / Meas	BE/ Calc	Meas/Calc
^{63}Cu (n,a)	4.42E-17	4.23E-17	4.29E-17	0.97	1.01	1.04
^{54}Fe (n,p)	4.23E-15	4.78E-15	4.40E-15	1.04	0.92	0.88
^{58}Ni (n,p)	6.12E-15	6.70E-15	6.16E-15	1.01	0.92	0.91
^{238}U (n,f) (Cd)	2.50E-14	2.57E-14	2.33E-14	0.93	0.91	0.97
^{237}Np (n,f)	2.29E-13	2.45E-13	2.28E-13	1.00	0.93	0.93
^{59}Co (n,g)	3.36E-12	3.28E-12	3.35E-12	1.00	1.02	1.02
^{59}Co (n,g) (Cd)	1.74E-12	2.31E-12	1.75E-12	1.01	0.76	0.75

Table 6-11

Best Estimate Neutron Energy Spectrum At The Center Of Surveillance Capsules

Capsule U

Group #	Energy (MeV)	Flux (n/cm^2-sec)	Group #	Energy (MeV)	Flux (n/cm^2-sec)
1	1.73E+01	7.70E+06	28	9.12E-03	2.20E+10
2	1.49E+01	1.64E+07	29	5.53E-03	2.82E+10
3	1.35E+01	6.01E+07	30	3.36E-03	8.75E+09
4	1.16E+01	1.63E+08	31	2.84E-03	8.33E+09
5	1.00E+01	3.62E+08	32	2.40E-03	8.05E+09
6	8.61E+00	6.17E+08	33	2.04E-03	2.34E+10
7	7.41E+00	1.46E+09	34	1.23E-03	2.24E+10
8	6.07E+00	2.17E+09	35	7.49E-04	2.03E+10
9	4.97E+00	4.41E+09	36	4.54E-04	1.81E+10
10	3.68E+00	5.10E+09	37	2.75E-04	1.98E+10
11	2.87E+00	9.92E+09	38	1.67E-04	1.97E+10
12	2.23E+00	1.37E+10	39	1.01E-04	2.07E+10
13	1.74E+00	1.91E+10	40	6.14E-05	2.07E+10
14	1.35E+00	2.26E+10	41	3.73E-05	2.04E+10
15	1.11E+00	4.01E+10	42	2.26E-05	2.00E+10
16	8.21E-01	4.79E+10	43	1.37E-05	1.94E+10
17	6.39E-01	5.34E+10	44	8.32E-06	1.86E+10
18	4.98E-01	3.71E+10	45	5.04E-06	1.78E+10
19	3.88E-01	5.73E+10	46	3.06E-06	1.76E+10
20	3.02E-01	6.12E+10	47	1.86E-06	1.74E+10
21	1.83E-01	6.15E+10	48	1.13E-06	1.22E+10
22	1.11E-01	4.56E+10	49	6.83E-07	1.41E+10
23	6.74E-02	3.58E+10	50	4.14E-07	1.99E+10
24	4.09E-02	1.95E+10	51	2.51E-07	1.94E+10
25	2.55E-02	2.27E+10	52	1.52E-07	1.83E+10
26	1.99E-02	1.09E+10	53	9.24E-08	5.00E+10
27	1.50E-02	1.92E+10			

Note: Tabulated energy levels represent the upper energy in each group.

Table 6-11 cont'd

Best Estimate Neutron Energy Spectrum At The
Center Of Surveillance Capsules

Capsule Y

Group #	Energy (MeV)	Flux (n/cm^2-sec)	Group #	Energy (MeV)	Flux (n/cm^2-sec)
1	1.73E+01	6.81E+06	28	9.12E-03	1.64E+10
2	1.49E+01	1.46E+07	29	5.53E-03	2.11E+10
3	1.35E+01	5.33E+07	30	3.36E-03	6.61E+09
4	1.16E+01	1.44E+08	31	2.84E-03	6.33E+09
5	1.00E+01	3.19E+08	32	2.40E-03	6.13E+09
6	8.61E+00	5.39E+08	33	2.04E-03	1.78E+10
7	7.41E+00	1.26E+09	34	1.23E-03	1.70E+10
8	6.07E+00	1.82E+09	35	7.49E-04	1.53E+10
9	4.97E+00	3.61E+09	36	4.54E-04	1.35E+10
10	3.68E+00	4.15E+09	37	2.75E-04	1.47E+10
11	2.87E+00	8.08E+09	38	1.67E-04	1.43E+10
12	2.23E+00	1.11E+10	39	1.01E-04	1.53E+10
13	1.74E+00	1.52E+10	40	6.14E-05	1.52E+10
14	1.35E+00	1.73E+10	41	3.73E-05	1.51E+10
15	1.11E+00	2.99E+10	42	2.26E-05	1.49E+10
16	8.21E-01	3.51E+10	43	1.37E-05	1.45E+10
17	6.39E-01	3.85E+10	44	8.32E-06	1.40E+10
18	4.98E-01	2.67E+10	45	5.04E-06	1.34E+10
19	3.88E-01	4.08E+10	46	3.06E-06	1.33E+10
20	3.02E-01	4.33E+10	47	1.86E-06	1.31E+10
21	1.83E-01	4.37E+10	48	1.13E-06	9.18E+09
22	1.11E-01	3.25E+10	49	6.83E-07	1.04E+10
23	6.74E-02	2.56E+10	50	4.14E-07	1.45E+10
24	4.09E-02	1.40E+10	51	2.51E-07	1.40E+10
25	2.55E-02	1.66E+10	52	1.52E-07	1.30E+10
26	1.99E-02	8.03E+09	53	9.24E-08	3.44E+10
27	1.50E-02	1.41E+10			

Note: Tabulated energy levels represent the upper energy in each group.

Table 6-11 cont'd

Best Estimate Neutron Energy Spectrum At The
Center Of Surveillance Capsules

Capsule V

Group #	Energy (MeV)	Flux (n/cm^2-sec)	Group #	Energy (MeV)	Flux (n/cm^2-sec)
1	1.73E+01	6.08E+06	28	9.12E-03	1.56E+10
2	1.49E+01	1.30E+07	29	5.53E-03	1.99E+10
3	1.35E+01	4.76E+07	30	3.36E-03	6.19E+09
4	1.16E+01	1.29E+08	31	2.84E-03	5.89E+09
5	1.00E+01	2.88E+08	32	2.40E-03	5.65E+09
6	8.61E+00	4.91E+08	33	2.04E-03	1.63E+10
7	7.41E+00	1.16E+09	34	1.23E-03	1.53E+10
8	6.07E+00	1.71E+09	35	7.49E-04	1.37E+10
9	4.97E+00	3.45E+09	36	4.54E-04	1.20E+10
10	3.68E+00	4.01E+09	37	2.75E-04	1.29E+10
11	2.87E+00	7.88E+09	38	1.67E-04	1.19E+10
12	2.23E+00	1.09E+10	39	1.01E-04	1.34E+10
13	1.74E+00	1.51E+10	40	6.14E-05	1.34E+10
14	1.35E+00	1.75E+10	41	3.73E-05	1.34E+10
15	1.11E+00	3.06E+10	42	2.26E-05	1.33E+10
16	8.21E-01	3.61E+10	43	1.37E-05	1.30E+10
17	6.39E-01	3.97E+10	44	8.32E-06	1.26E+10
18	4.98E-01	2.75E+10	45	5.04E-06	1.22E+10
19	3.88E-01	4.18E+10	46	3.06E-06	1.21E+10
20	3.02E-01	4.42E+10	47	1.86E-06	1.20E+10
21	1.83E-01	4.42E+10	48	1.13E-06	8.42E+09
22	1.11E-01	3.26E+10	49	6.83E-07	9.52E+09
23	6.74E-02	2.55E+10	50	4.14E-07	1.33E+10
24	4.09E-02	1.38E+10	51	2.51E-07	1.29E+10
25	2.55E-02	1.62E+10	52	1.52E-07	1.20E+10
26	1.99E-02	7.76E+09	53	9.24E-08	3.17E+10
27	1.50E-02	1.35E+10			

Note: Tabulated energy levels represent the upper energy in each group.

Table 6-12

Comparison Of Calculated And Best Estimate Integrated Neutron Exposure Of Vogtle Unit 1 Surveillance Capsules U, Y, and V

CAPSULE U

	Calculated	Best Estimate	BE/C
Φ(E > 1.0 MeV) [n/cm2]	3.691E+18	3.219E+18	0.87
Φ(E > 0.1 MeV) [n/cm2]	1.585E+19	1.544E+19	0.97
dpa	6.976E-03	6.550E-03	0.94

CAPSULE Y

	Calculated	Best Estimate	BE/C
Φ(E > 1.0 MeV) [n/cm2]	1.276E+19	1.080E+19	0.85
Φ(E > 0.1 MeV) [n/cm2]	5.474E+19	4.805E+19	0.88
dpa	2.411E-02	2.103E-02	0.87

CAPSULE V

	Calculated	Best Estimate	BE/C
Φ(E > 1.0 MeV) [n/cm2]	2.178E+19	1.980E+19	0.91
Φ(E > 0.1 MeV) [n/cm2]	9.344E+19	9.027E+19	0.97
dpa	4.116E-02	3.896E-02	0.95

AVERAGE BE/C RATIOS

	BE/C
Φ (E > 1.0 MeV) [n/cm^2]	0.876
Φ (E > 0.1 MeV) [n/cm^2]	0.939
dpa	0.919

Table 6-13

Azimuthal Variations Of The Neutron Exposure Projections On The Reactor Vessel Clad/Base Metal Interface At Core Midplane

Best Estimate

8.57 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	2.54E+18	3.80E+18	4.67E+18	3.06E+18	2.53E+18	4.58E+18
E>0.1 MeV	5.73E+18	8.65E+18	1.09E+19	1.04E+19	8.60E+18	1.23E+19
dpa	4.13E-03	6.12E-03	7.54E-03	5.59E-03	4.63E-03	7.59E-03

16 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	4.62E+18	6.84E+18	8.35E+18	5.47E+18	4.52E+18	8.20E+18
E>0.1 MeV	1.04E+19	1.56E+19	1.95E+19	1.85E+19	1.54E+19	2.20E+19
dpa	7.51E-03	1.10E-02	1.35E-02	1.00E-02	8.29E-03	1.36E-02

32 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	9.09E+18	1.34E+19	1.63E+19	1.07E+19	8.82E+18	1.60E+19
E>0.1 MeV	2.05E+19	3.05E+19	3.79E+19	3.61E+19	3.00E+19	4.29E+19
dpa	1.48E-02	2.16E-02	2.63E-02	1.95E-02	1.62E-02	2.65E-02

36 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	1.02E+19	1.50E+19	1.83E+19	1.20E+19	9.89E+18	1.79E+19
E>0.1 MeV	2.30E+19	3.42E+19	4.25E+19	4.05E+19	3.36E+19	4.82E+19
dpa	1.66E-02	2.42E-02	2.95E-02	2.19E-02	1.81E-02	2.97E-02

54 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	1.52E+19	2.24E+19	2.72E+19	1.78E+19	1.47E+19	2.67E+19
E>0.1 MeV	3.44E+19	5.10E+19	6.33E+19	6.03E+19	5.01E+19	7.17E+19
dpa	2.48E-02	3.61E-02	4.39E-02	3.26E-02	2.70E-02	4.42E-02

Table 6-13, cont'd

Azimuthal Variations Of The Neutron Exposure Projections On The Reactor Vessel Clad/Base Metal Interface At Core Midplane

Calculated

8.57 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	2.90E+18	4.33E+18	5.33E+18	3.49E+18	2.89E+18	5.23E+18
E>0.1 MeV	6.10E+18	9.21E+18	1.16E+19	1.10E+19	9.16E+18	1.31E+19
dpa	4.49E-03	6.65E-03	8.20E-03	6.08E-03	5.04E-03	8.25E-03

16 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	5.27E+18	7.81E+18	9.53E+18	6.24E+18	5.17E+18	9.36E+18
E>0.1 MeV	1.11E+19	1.66E+19	2.07E+19	1.97E+19	1.64E+19	2.34E+19
dpa	8.17E-03	1.20E-02	1.47E-02	1.09E-02	9.02E-03	1.48E-02

32 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	1.04E+19	1.53E+19	1.86E+19	1.22E+19	1.01E+19	1.83E+19
E>0.1 MeV	2.18E+19	3.25E+19	4.04E+19	3.84E+19	3.19E+19	4.57E+19
dpa	1.61E-02	2.35E-02	2.86E-02	2.12E-02	1.76E-02	2.88E-02

36 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	1.17E+19	1.72E+19	2.09E+19	1.36E+19	1.13E+19	2.05E+19
E>0.1 MeV	2.45E+19	3.65E+19	4.53E+19	4.31E+19	3.58E+19	5.13E+19
dpa	1.81E-02	2.63E-02	3.21E-02	2.38E-02	1.97E-02	3.23E-02

54 EFPY			12.5° NP	20° NP	22.5° NP	
	0°	15°	30°	30°	30°	45°
E>1.0 MeV	1.74E+19	2.56E+19	3.10E+19	2.03E+19	1.68E+19	3.05E+19
E>0.1 MeV	3.66E+19	5.43E+19	6.74E+19	6.42E+19	5.33E+19	7.63E+19
dpa	2.70E-02	3.92E-02	4.77E-02	3.54E-02	2.94E-02	4.81E-02

Table 6-14

Neutron Exposure Values Within The Vogtle Unit 1 Reactor Vessel

Best Estimate Fluence Based on E > 1.0 MeV Slope

				12.5° NP	20° NP	22.5° NP	
		0°	15°	30°	30°	30°	45°
	Surface	1	1	1	1	1	1
	1/4 T	0.561	0.557	0.549	0.549	0.549	0.547
	3/4 T	0.128	0.124	0.121	0.121	0.121	0.118
16 EFPY	Surface	4.62E+18	6.84E+18	8.35E+18	5.47E+18	4.52E+18	8.20E+18
	1/4 T	2.59E+18	3.81E+18	4.58E+18	3.00E+18	2.48E+18	4.49E+18
	3/4 T	5.91E+17	8.48E+17	1.01E+18	6.62E+17	5.47E+17	9.68E+17
32 EFPY	Surface	9.09E+18	1.34E+19	1.63E+19	1.07E+19	8.82E+18	1.60E+19
	1/4 T	5.10E+18	7.46E+18	8.93E+18	5.85E+18	4.84E+18	8.75E+18
	3/4 T	1.16E+18	1.66E+18	1.97E+18	1.29E+18	1.07E+18	1.89E+18
36 EFPY	Surface	1.02E+19	1.50E+19	1.83E+19	1.20E+19	9.89E+18	1.79E+19
	1/4 T	5.73E+18	8.37E+18	1.00E+19	6.56E+18	5.43E+18	9.81E+18
	3/4 T	1.31E+18	1.86E+18	2.21E+18	1.45E+18	1.20E+18	2.12E+18
54 EFPY	Surface	1.52E+19	2.24E+19	2.72E+19	1.78E+19	1.47E+19	2.67E+19
	1/4 T	8.55E+18	1.25E+19	1.49E+19	9.77E+18	8.08E+18	1.46E+19
	3/4 T	1.95E+18	2.78E+18	3.29E+18	2.15E+18	1.78E+18	3.15E+18

Table 6-14, cont'd

Neutron Exposure Values Within The
Vogtle Unit 1 Reactor Vessel

Best Estimate Fluence Based on dpa Slope

				12.5° NP	20° NP	22.5° NP	
		0°	15°	30°	30°	30°	45°
	Surface	1	1	1	1	1	1
	1/4 T	0.639	0.635	0.631	0.631	0.631	0.643
	3/4 T	0.231	0.221	0.223	0.223	0.223	0.230
16 EFPY	Surface	4.62E+18	6.84E+18	8.35E+18	5.47E+18	4.52E+18	8.20E+18
	1/4 T	2.95E+18	4.34E+18	5.27E+18	3.45E+18	2.86E+18	5.27E+18
	3/4 T	1.07E+18	1.51E+18	1.86E+18	1.22E+18	1.01E+18	1.89E+18
32 EFPY	Surface	9.09E+18	1.34E+19	1.63E+19	1.07E+19	8.82E+18	1.60E+19
	1/4 T	5.81E+18	8.50E+18	1.03E+19	6.73E+18	5.57E+18	1.03E+19
	3/4 T	2.10E+18	2.96E+18	3.63E+18	2.38E+18	1.97E+18	3.68E+18
36 EFPY	Surface	1.02E+19	1.50E+19	1.83E+19	1.20E+19	9.89E+18	1.79E+19
	1/4 T	6.52E+18	9.54E+18	1.15E+19	7.54E+18	6.24E+18	1.15E+19
	3/4 T	2.36E+18	3.32E+18	4.07E+18	2.67E+18	2.21E+18	4.13E+18
54 EFPY	Surface	1.52E+19	2.24E+19	2.72E+19	1.78E+19	1.47E+19	2.67E+19
	1/4 T	9.74E+18	1.42E+19	1.71E+19	1.12E+19	9.29E+18	1.72E+19
	3/4 T	3.52E+18	4.95E+18	6.06E+18	3.97E+18	3.28E+18	6.14E+18

Table 6-14, cont'd

Neutron Exposure Values Within The
Vogtle Unit 1 Reactor Vessel

Calculated Fluence Based on E > 1.0 MeV Slope

				12.5° NP	20° NP	22.5° NP	
		0°	15°	30°	30°	30°	45°
	Surface	1	1	1	1	1	1
	1/4 T	0.561	0.557	0.549	0.549	0.549	0.547
	3/4 T	0.128	0.124	0.121	0.121	0.121	0.118
16 EFPY	Surface	5.27E+18	7.81E+18	9.53E+18	6.24E+18	5.17E+18	9.36E+18
	1/4 T	2.96E+18	4.35E+18	5.23E+18	3.43E+18	2.84E+18	5.12E+18
	3/4 T	6.75E+17	9.68E+17	1.15E+18	7.55E+17	6.25E+17	1.10E+18
32 EFPY	Surface	1.04E+19	1.53E+19	1.86E+19	1.22E+19	1.01E+19	1.83E+19
	1/4 T	5.82E+18	8.51E+18	1.02E+19	6.68E+18	5.53E+18	9.99E+18
	3/4 T	1.33E+18	1.90E+18	2.25E+18	1.47E+18	1.22E+18	2.15E+18
36 EFPY	Surface	1.17E+19	1.72E+19	2.09E+19	1.36E+19	1.13E+19	2.05E+19
	1/4 T	6.54E+18	9.55E+18	1.14E+19	7.49E+18	6.20E+18	1.12E+19
	3/4 T	1.49E+18	2.13E+18	2.52E+18	1.65E+18	1.37E+18	2.42E+18
54 EFPY	Surface	1.74E+19	2.56E+19	3.10E+19	2.03E+19	1.68E+19	3.05E+19
	1/4 T	9.76E+18	1.42E+19	1.70E+19	1.12E+19	9.23E+18	1.67E+19
	3/4 T	2.23E+18	3.17E+18	3.75E+18	2.46E+18	2.03E+18	3.60E+18

Table 6-14, cont'd

Neutron Exposure Values Within The
Vogtle Unit 1 Reactor Vessel

Calculated Fluence Based on dpa Slope

				12.5° NP	20° NP	22.5° NP	
		0°	15°	30°	30°	30°	45°
	Surface	1	1	1	1	1	1
	1/4 T	0.639	0.635	0.631	0.631	0.631	0.643
	3/4 T	0.231	0.221	0.223	0.223	0.223	0.230
16 EFPY	Surface	5.27E+18	7.81E+18	9.53E+18	6.24E+18	5.17E+18	9.36E+18
	1/4 T	2.96E+18	4.35E+18	5.23E+18	3.43E+18	2.84E+18	5.12E+18
	3/4 T	6.75E+17	9.68E+17	1.15E+18	7.55E+17	6.25E+17	1.10E+18
32 EFPY	Surface	1.04E+19	1.53E+19	1.86E+19	1.22E+19	1.01E+19	1.83E+19
	1/4 T	5.82E+18	8.51E+18	1.02E+19	6.68E+18	5.53E+18	9.99E+18
	3/4 T	1.33E+18	1.90E+18	2.25E+18	1.47E+18	1.22E+18	2.15E+18
36 EFPY	Surface	1.17E+19	1.72E+19	2.09E+19	1.36E+19	1.13E+19	2.05E+19
	1/4 T	7.45E+18	1.09E+19	1.31E+19	8.61E+18	7.13E+18	1.32E+19
	3/4 T	2.69E+18	3.79E+18	4.65E+18	3.04E+18	2.52E+18	4.71E+18
54 EFPY	Surface	1.74E+19	2.56E+19	3.10E+19	2.03E+19	1.68E+19	3.05E+19
	1/4 T	1.11E+19	1.62E+19	1.96E+19	1.28E+19	1.06E+19	1.96E+19
	3/4 T	4.02E+18	5.65E+18	6.92E+18	4.53E+18	3.75E+18	7.01E+18

Table 6-15

Updated Lead Factors For Vogtle Unit 1
Surveillance Capsules

Capsule	Lead Factor
U[a]	4.38
Y[b]	4.11
V[c]	4.09
W[d]	4.40
X[d]	4.40
Z[d]	4.40

[a] - Withdrawn at the end of Cycle 1.
[b] - Withdrawn at the end of Cycle 4.
[c] - Withdrawn at the end of Cycle 7.
[d] - Not withdrawn; standby.

7 SURVEILLANCE CAPSULE REMOVAL SCHEDULE

The following surveillance capsule removal schedule meets the requirements of ASTM E185-82 and is recommended for future capsules to be removed from the Vogtle Unit 1 reactor vessel. This recommended removal schedule is applicable to 36 EFPY of operation.

Table 7-1 Vogtle Unit 1 Reactor Vessel Surveillance Capsule Withdrawal Schedule

Capsule	Location	Lead Factor[(a)]	Removal Time (EFPY)[(b)]	Fluence (n/cm^2, E>1.0 MeV)[(a)]
U	58.5°	4.38	1.14	3.691×10^{18} (c)
Y	241°	4.11	4.64	1.276×10^{19} (c)
V	61°	4.09	8.57	2.178×10^{19} (c)(f)
X	238.5°	4.40	12.5	3.10×10^{19} (d)
W	121.5°	4.40	Standby	(e)
Z	301.5°	4.40	Standby	(e)

Notes:

(a) Updated in Capsule V dosimetry analysis, see Table 6-15.

(b) Effective Full Power Years (EFPY) from plant startup.

(c) Plant specific evaluation.

(d) This fluence is not less than once or greater than twice the peak EOL fluence of 2.08×10^{19} n/cm^2, and is approximately equal to the peak vessel fluence at 54 EFPY.

(e) These capsules will reach a fluence of 3.10×10^{19} (54 EFPY Peak Fluence) at approximately 12.5 EFPY

(f) This capsule was withdrawn at approximately the current end-of-license, 36 EFPY, peak fluence.

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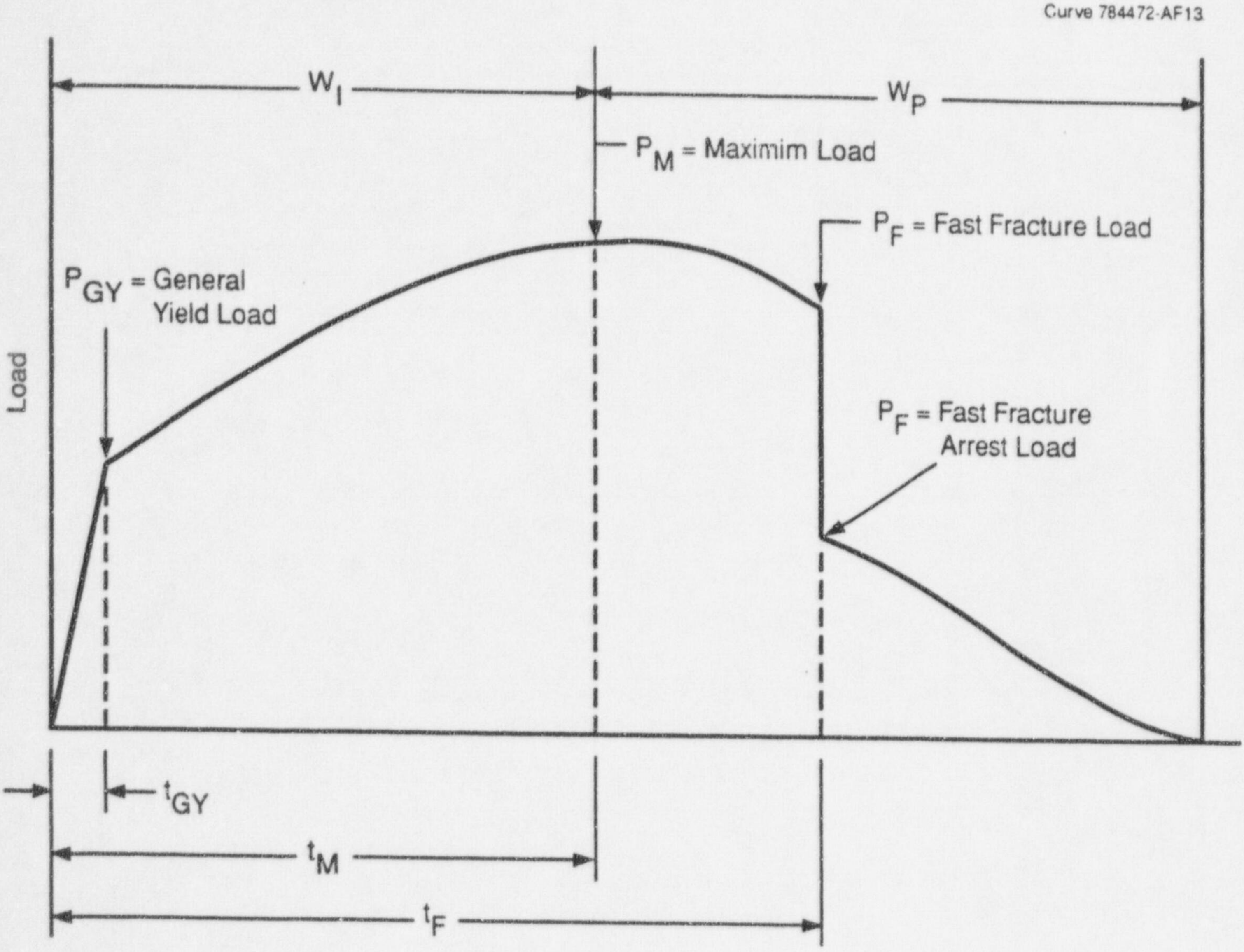
APPENDIX A

LOAD-TIME RECORDS FOR CHARPY SPECIMEN TESTS



W_I = Fracture Initiation Region

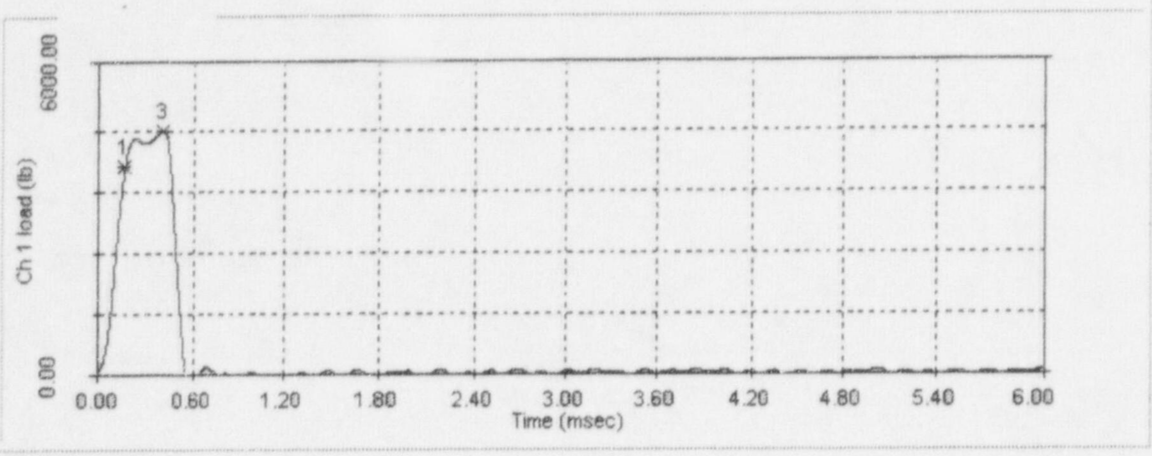
W_P = Fracture Propagation Region

t_{GY} = Time to General Yielding

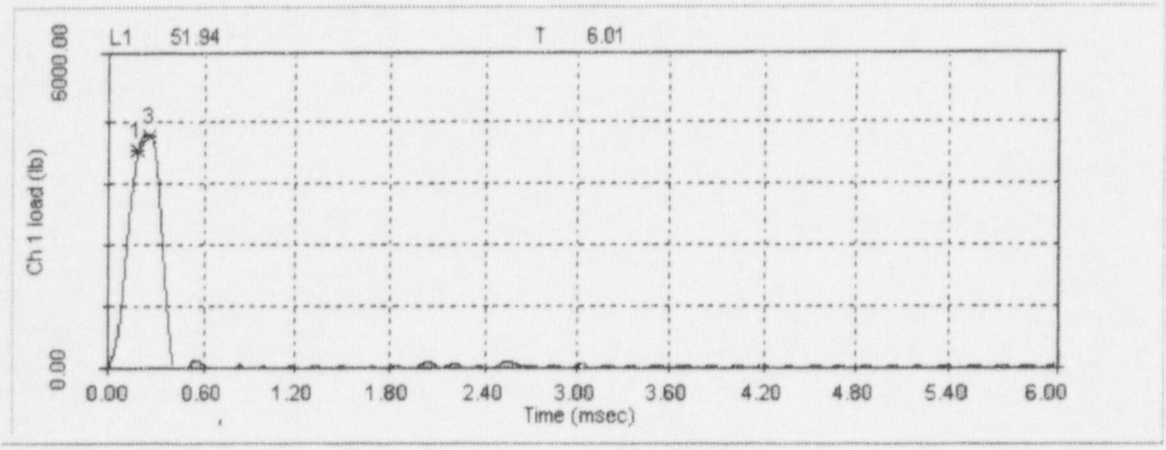
t_M = Time to Maximum Load

t_F = Time to Fast (Brittle) Fracture Start

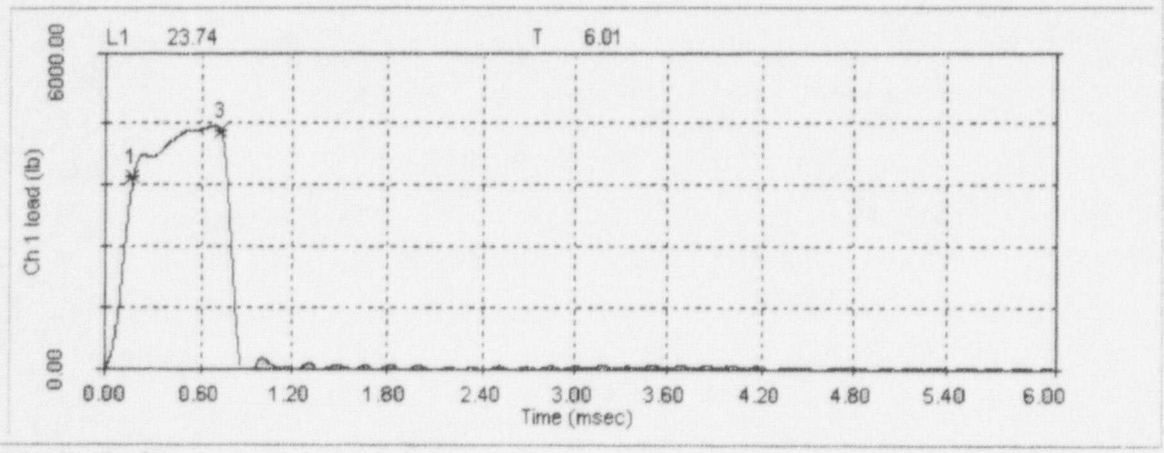
Fig. A-1-Idealized load-time record



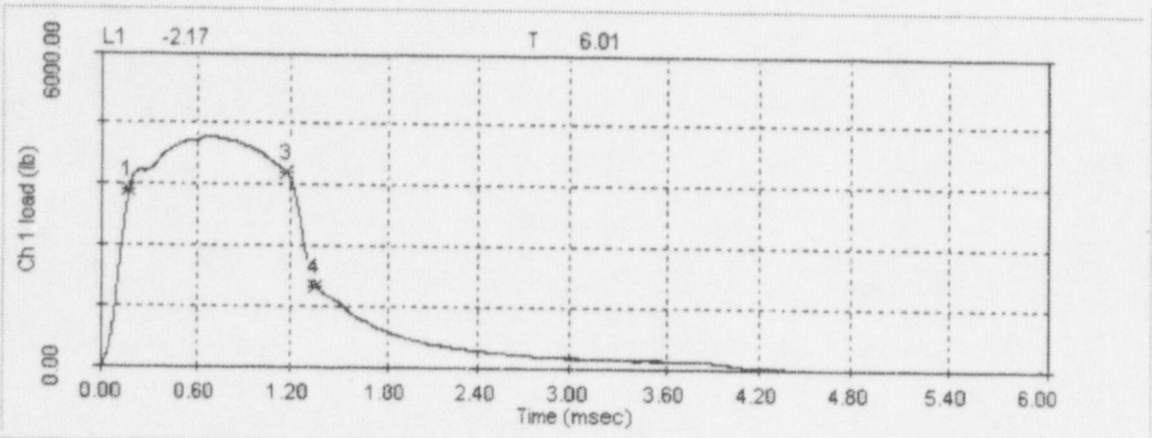
AL16, -25°F



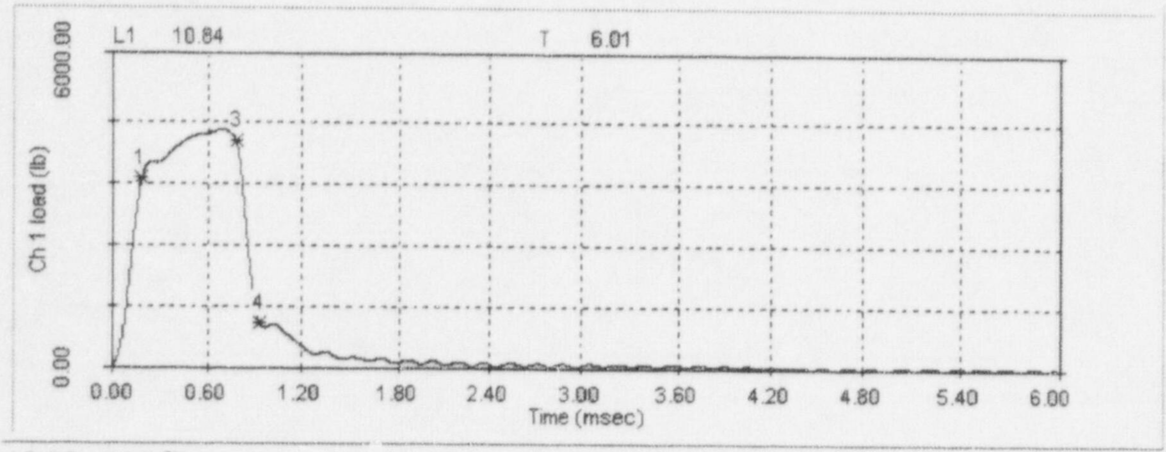
AL17, -50 °F



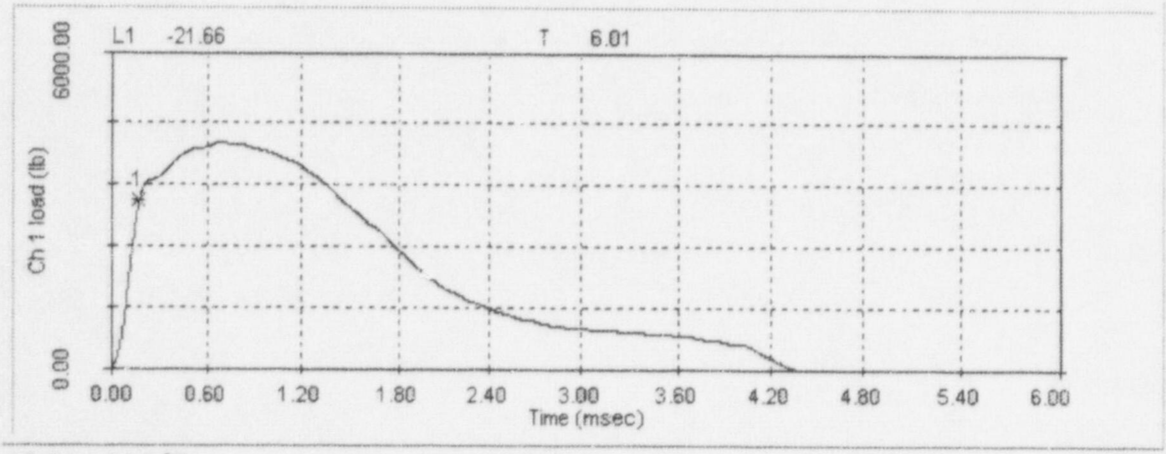
AL18, 50 °F



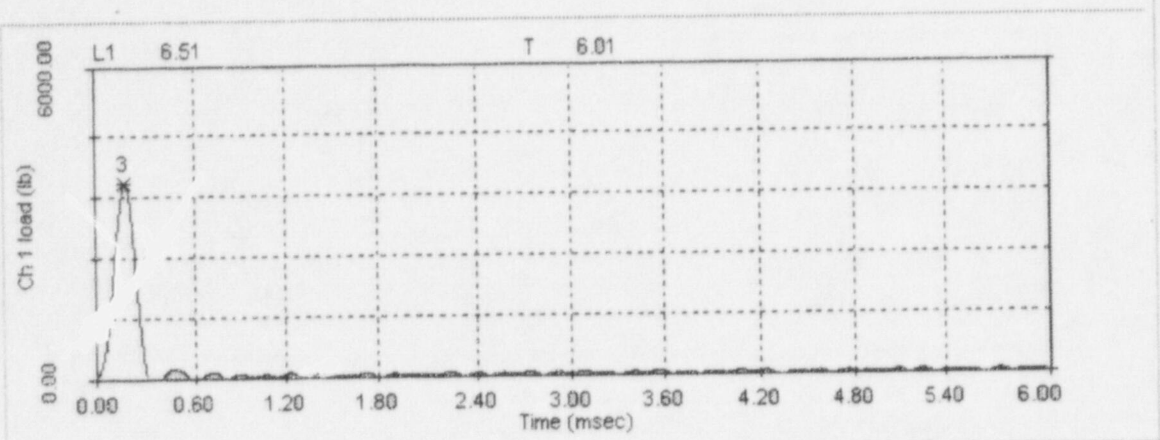
AL19, 175 °F



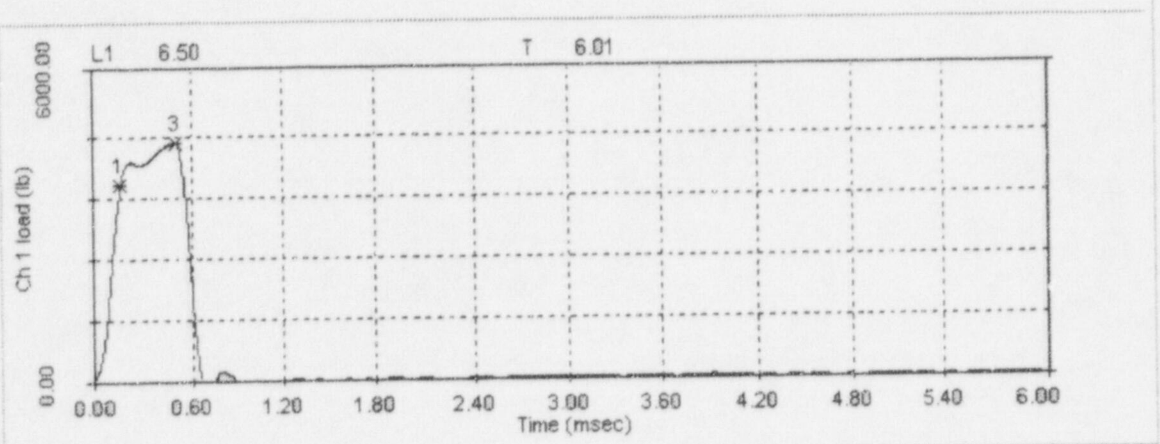
AL20, 100 °F



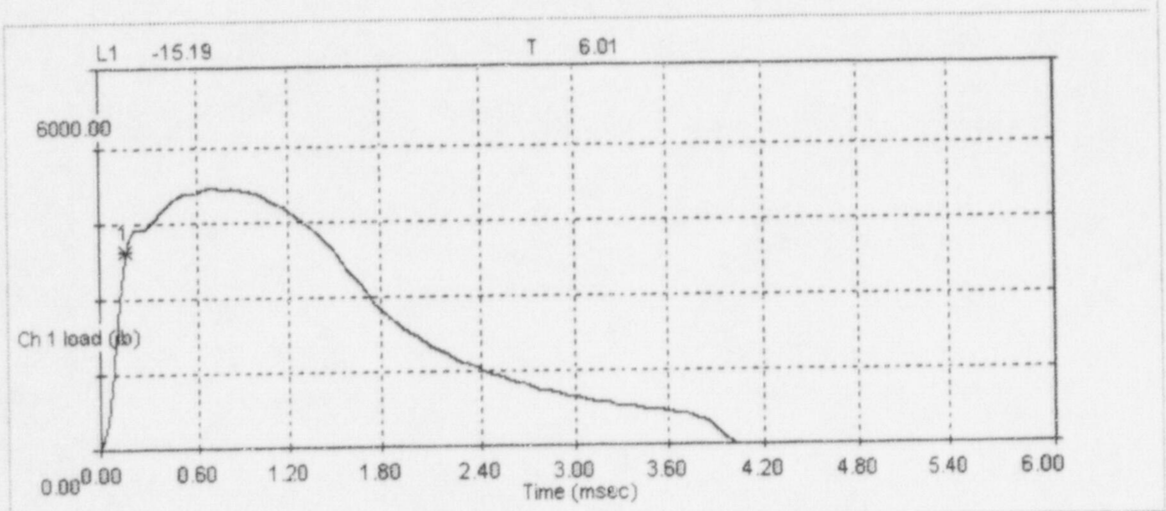
AL21, 300 °F



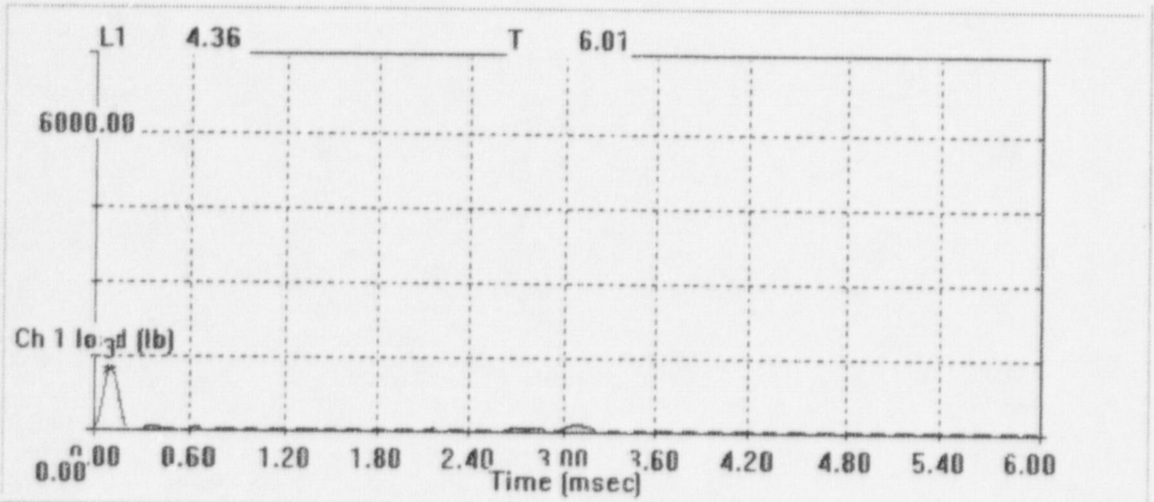
AL22, 0 °F



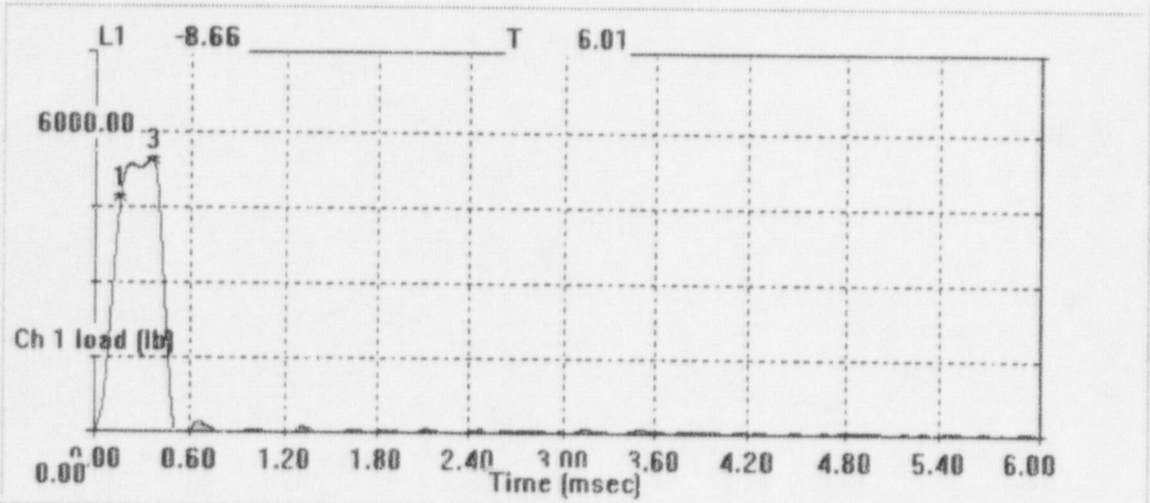
AL28, 20 °F



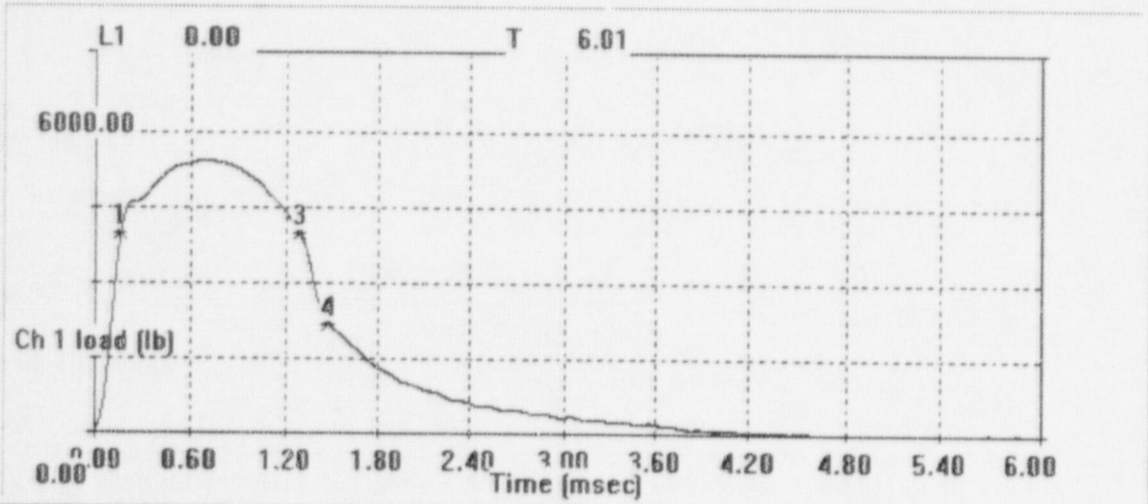
AL23, 375°F



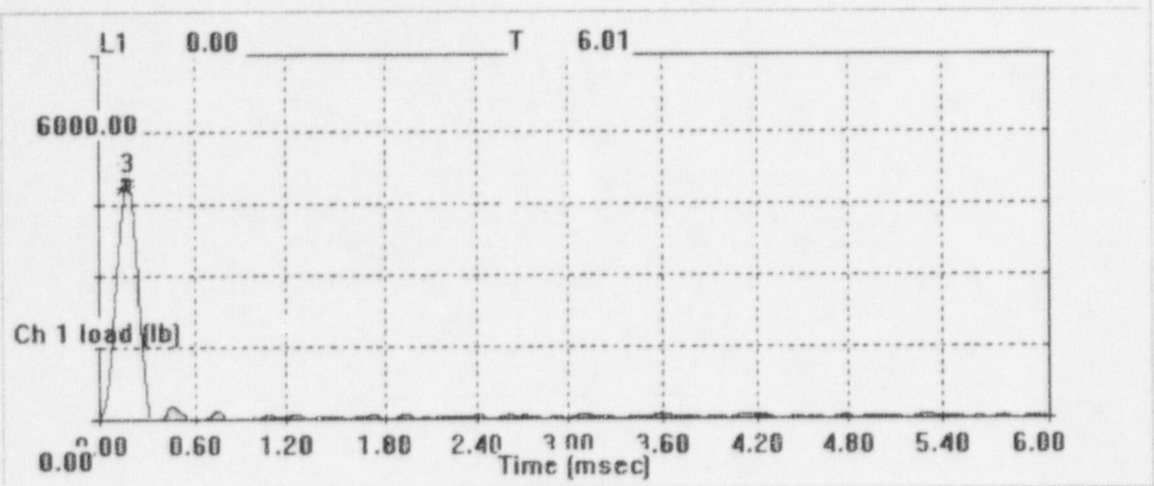
AL24, -80 °F



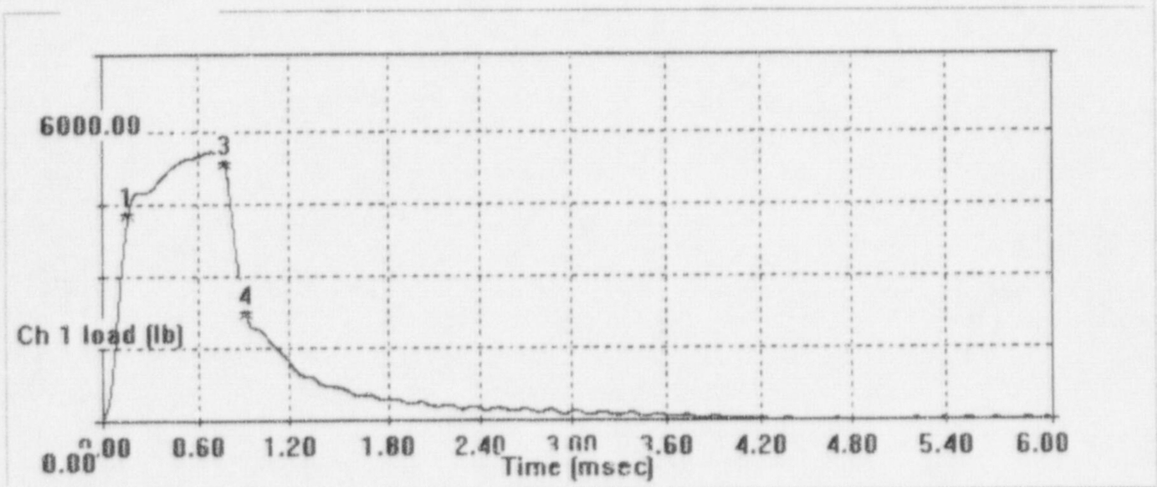
AL25, 5 °F



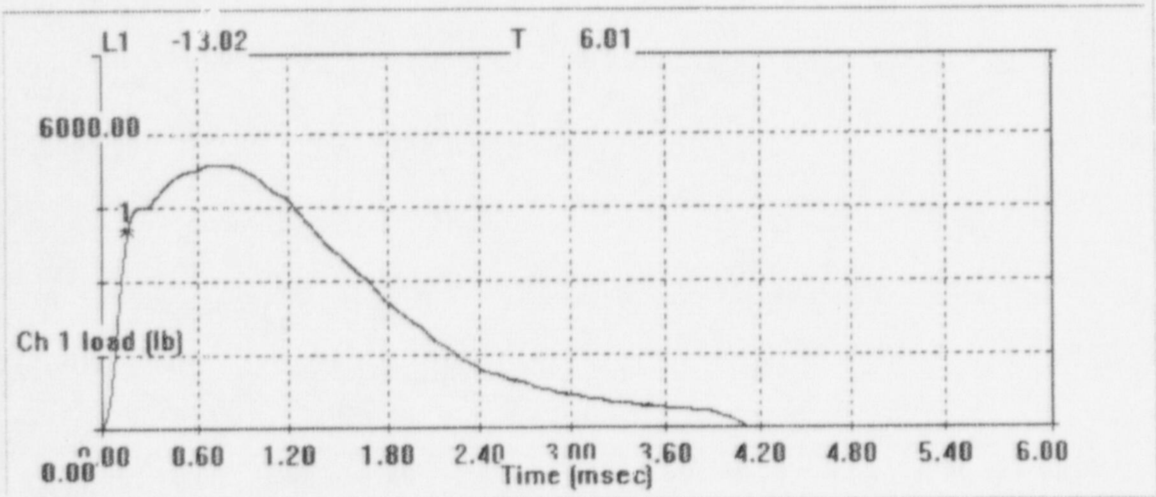
AL26, 200 °F



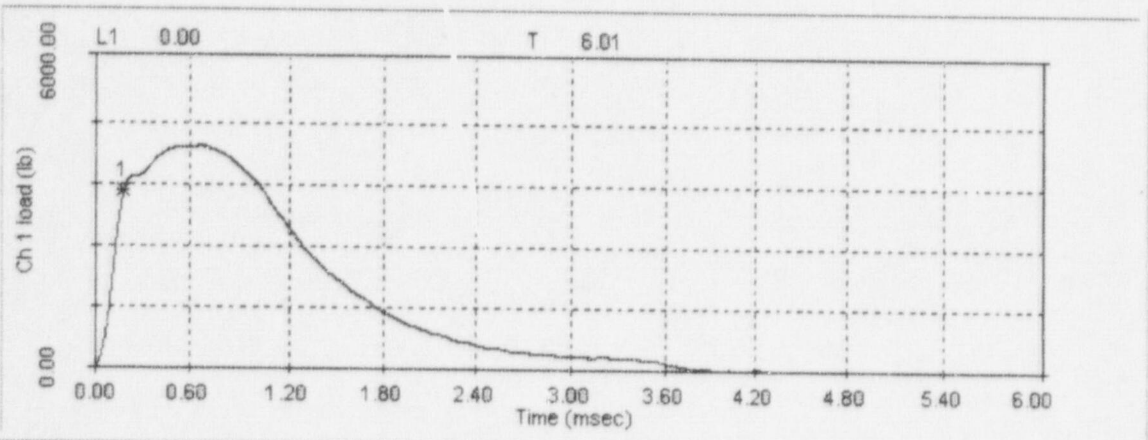
AL27, -15 °F



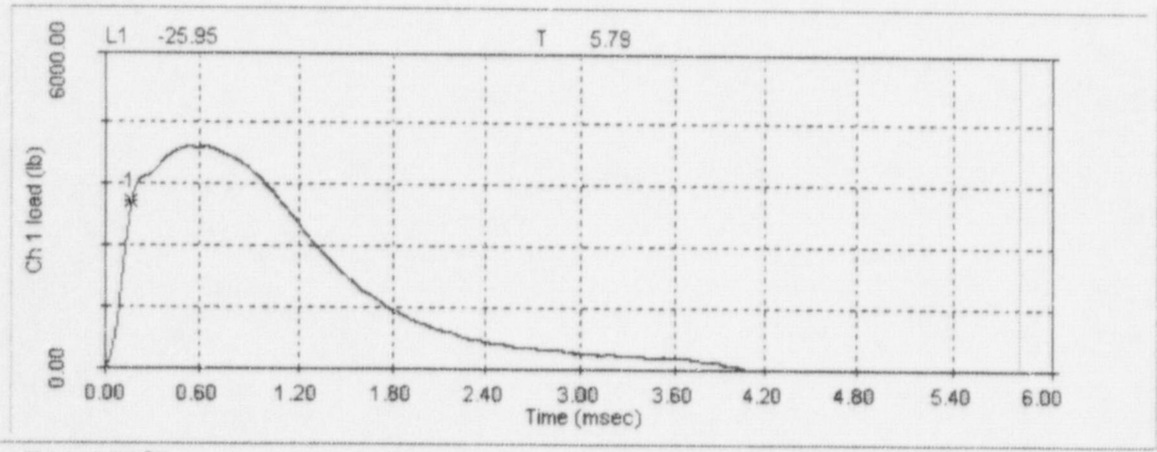
AL29, 150 °F



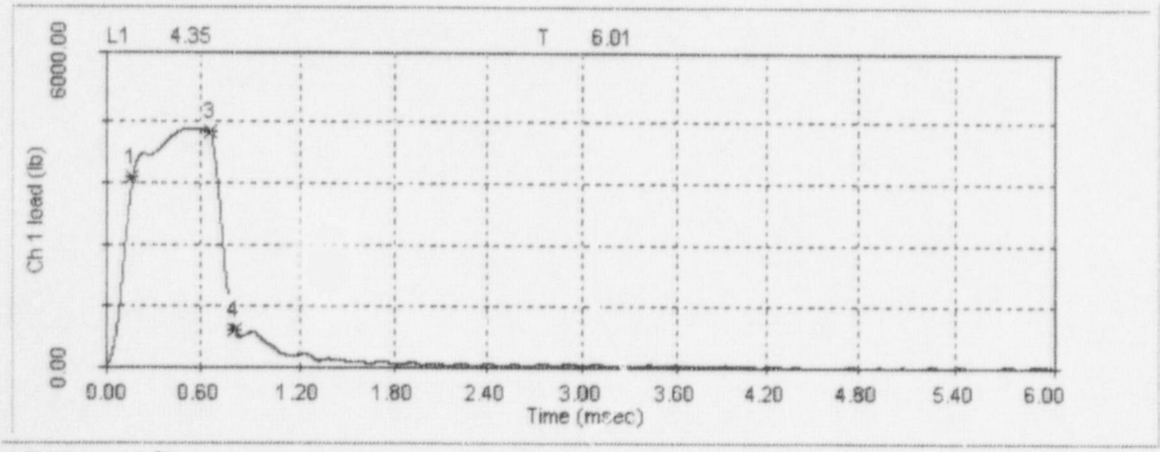
AL30, 250 °F



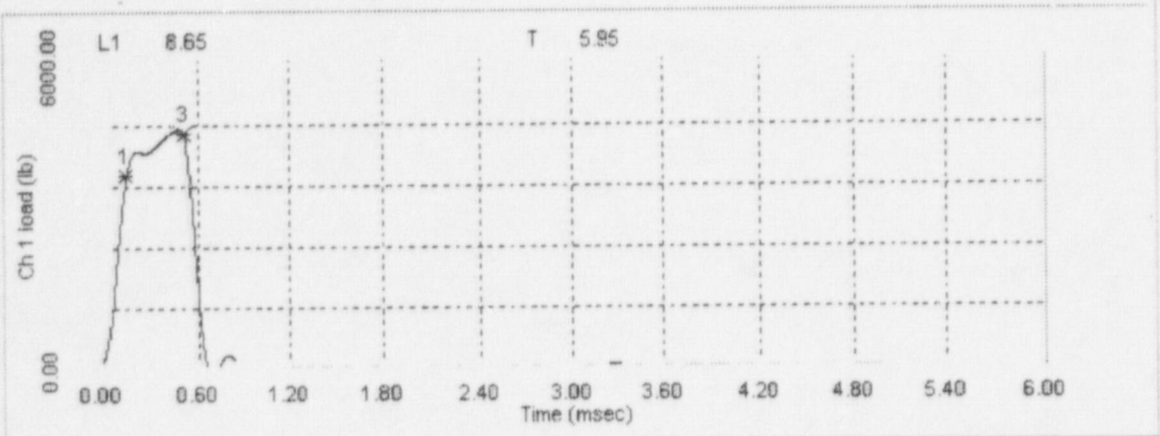
AT19, 250°F



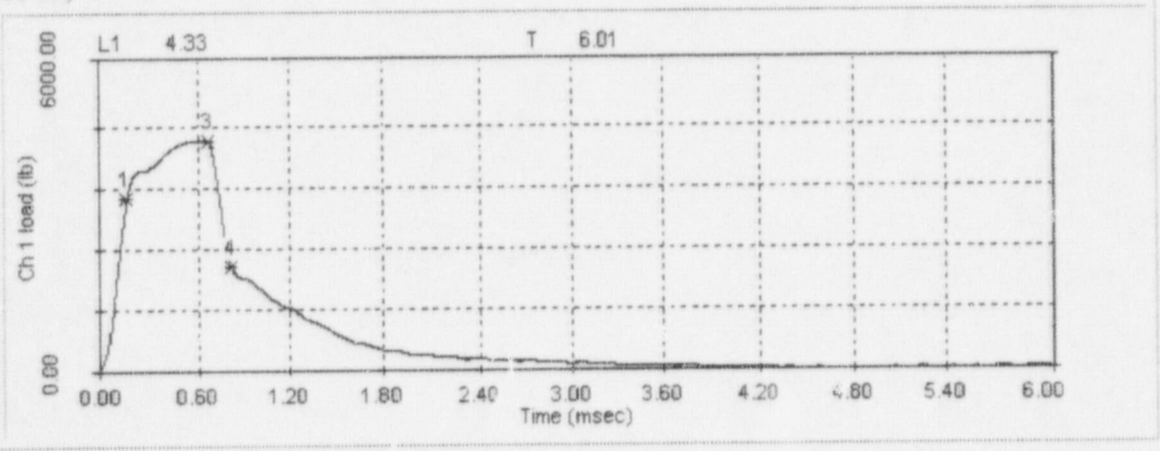
AT16, 375°F



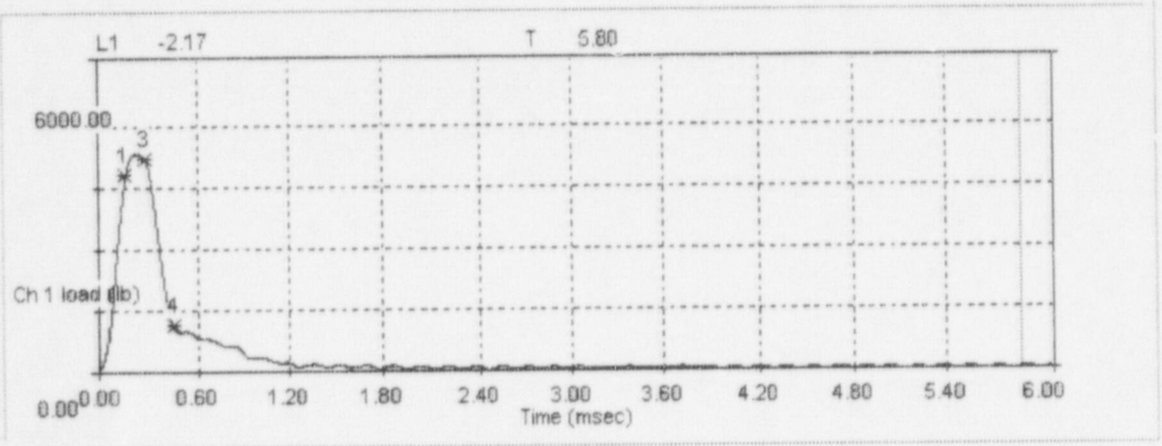
AT17, 110°F



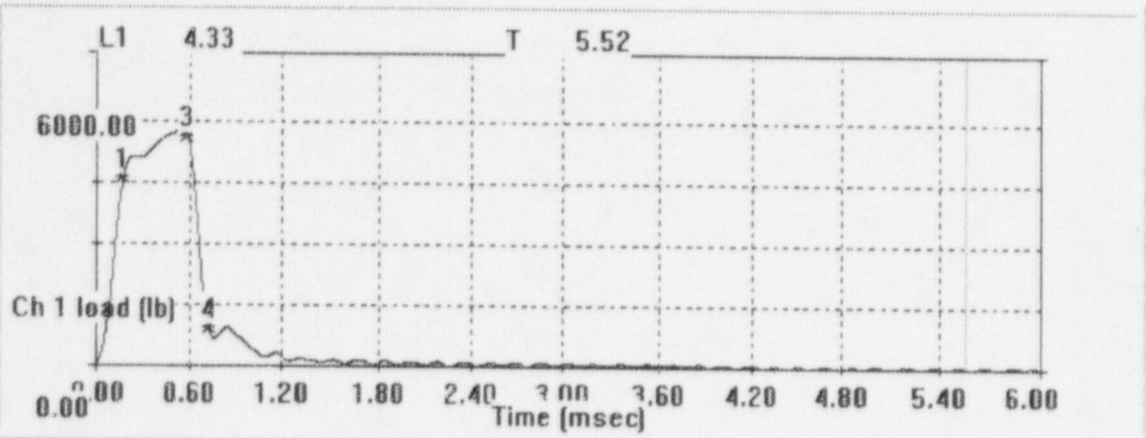
AT18, 50 °F



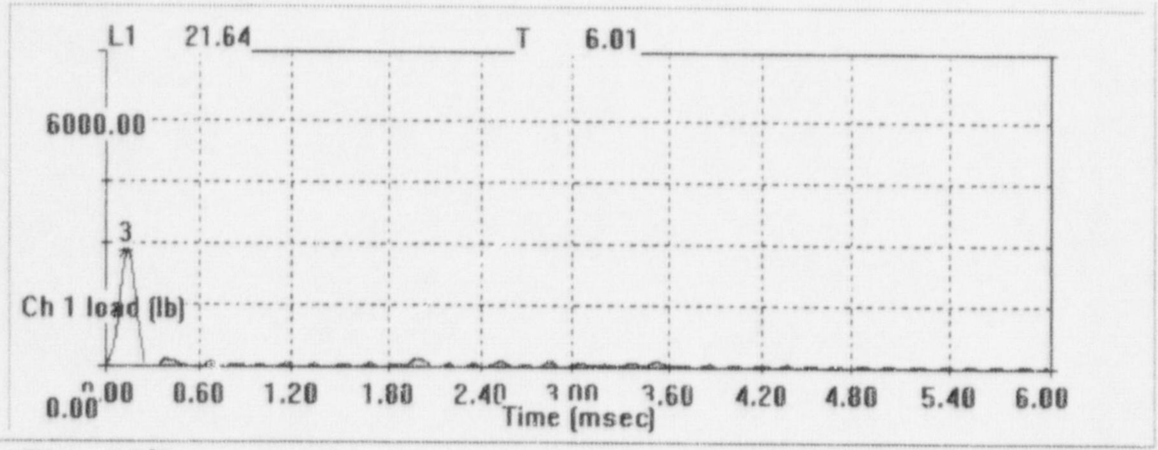
AT20, 160 °F



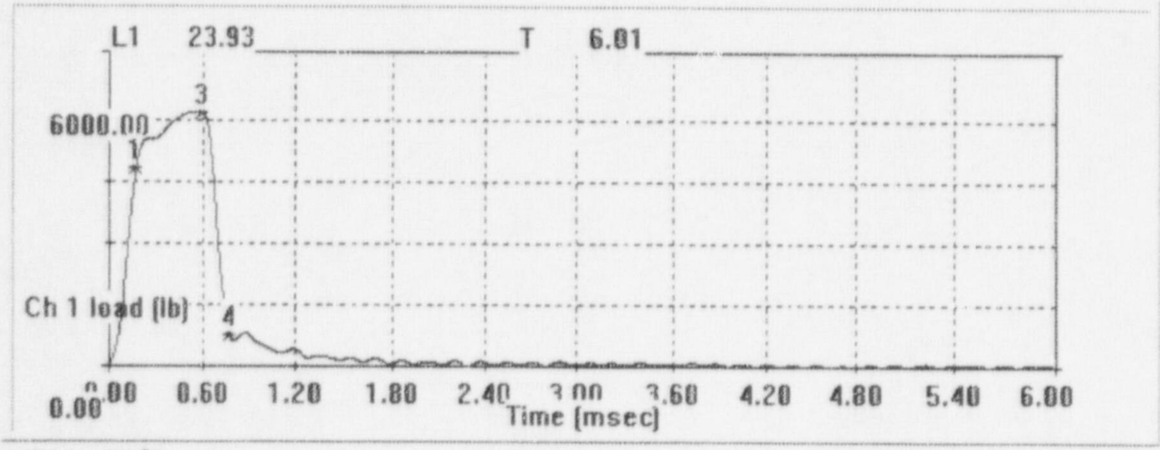
AT21, 72 °F



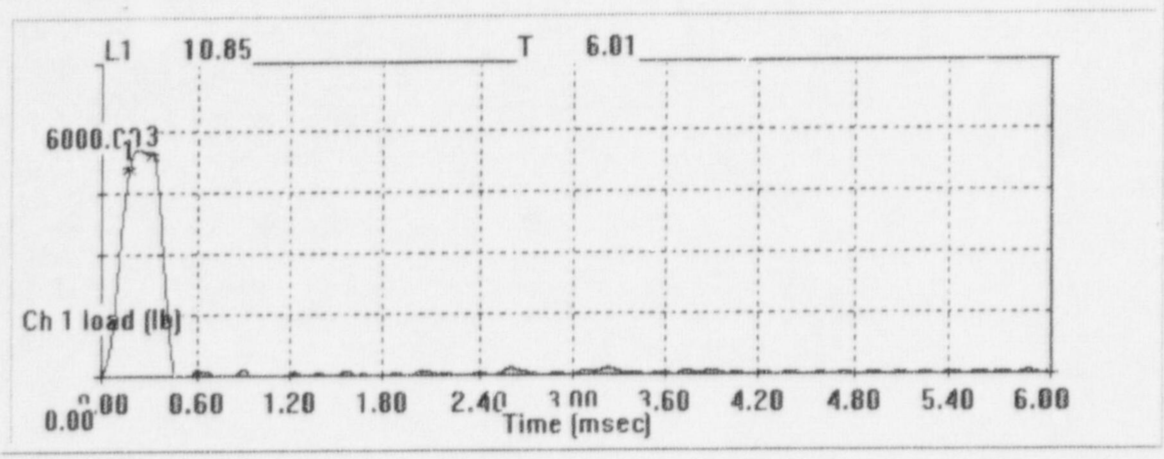
AT22, 100 °F



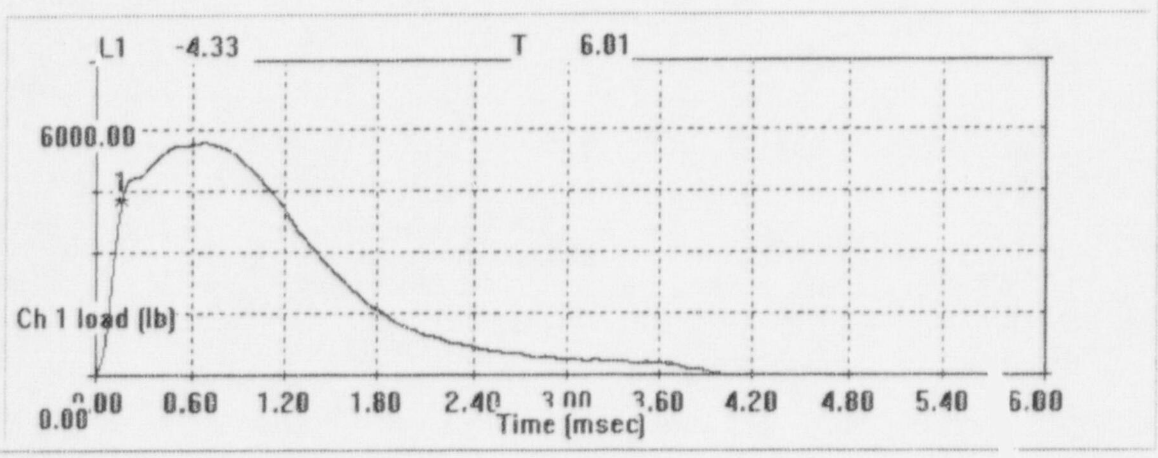
AT24, -25 °F



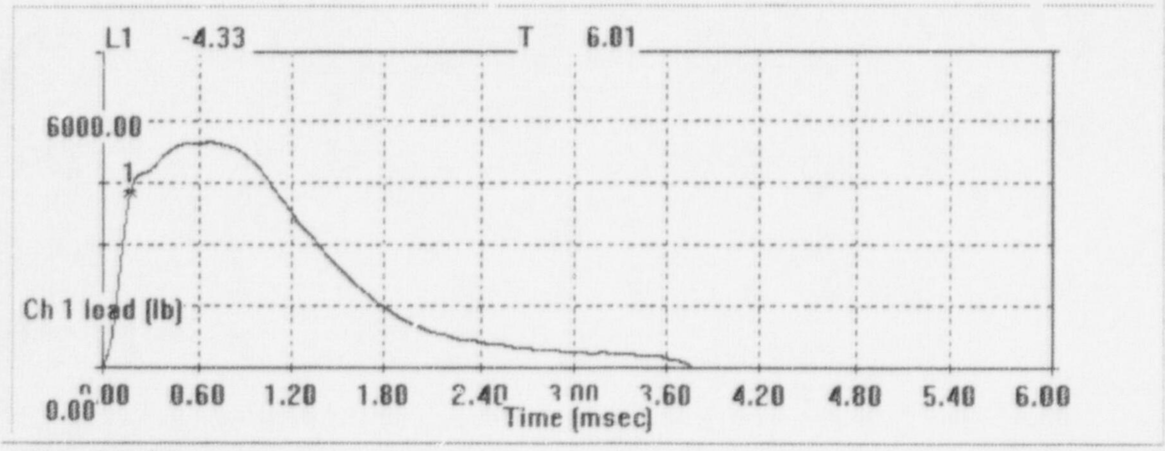
AT25, 72 °F



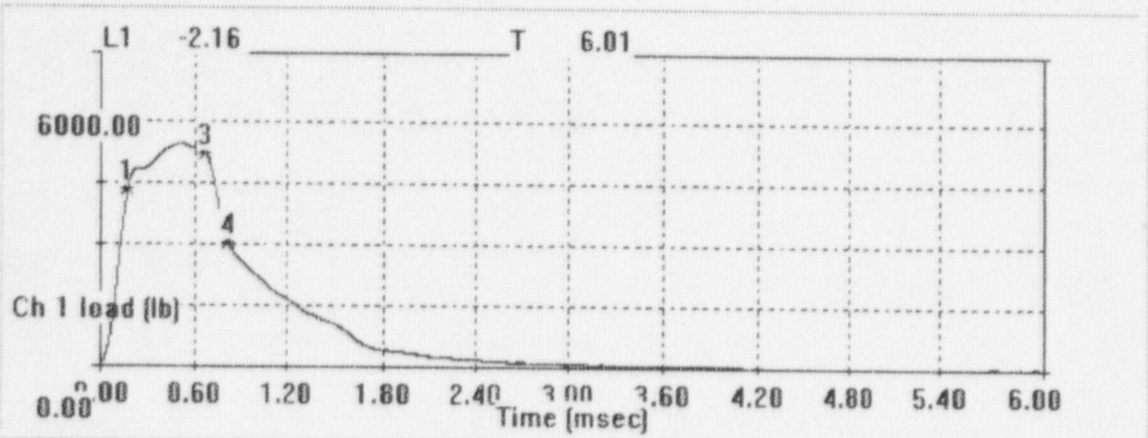
AT26, 0°F



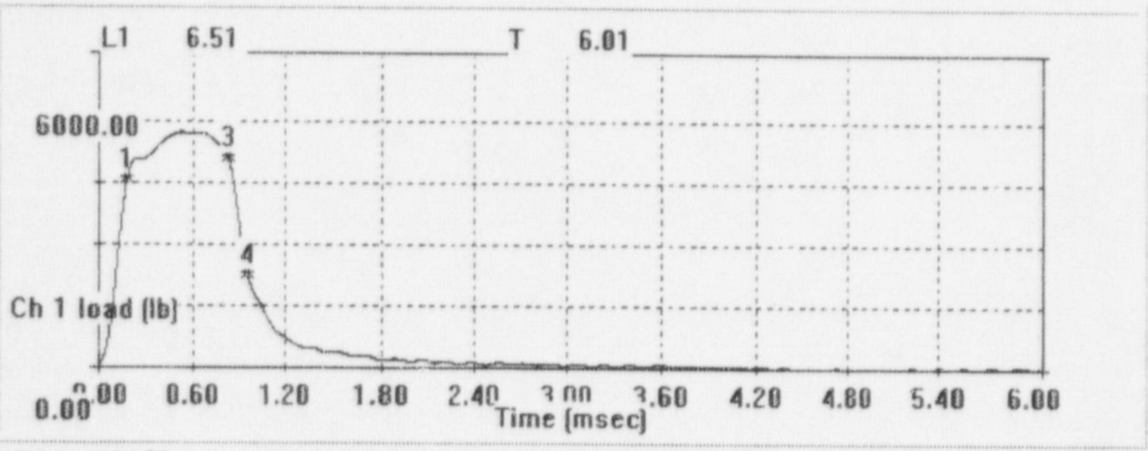
AT27, 225°F



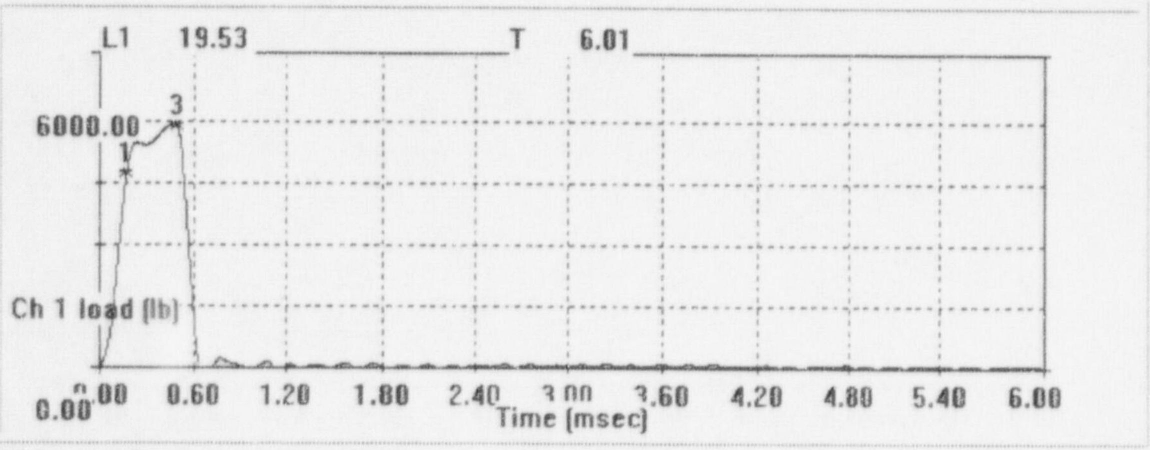
AT28, 300°F



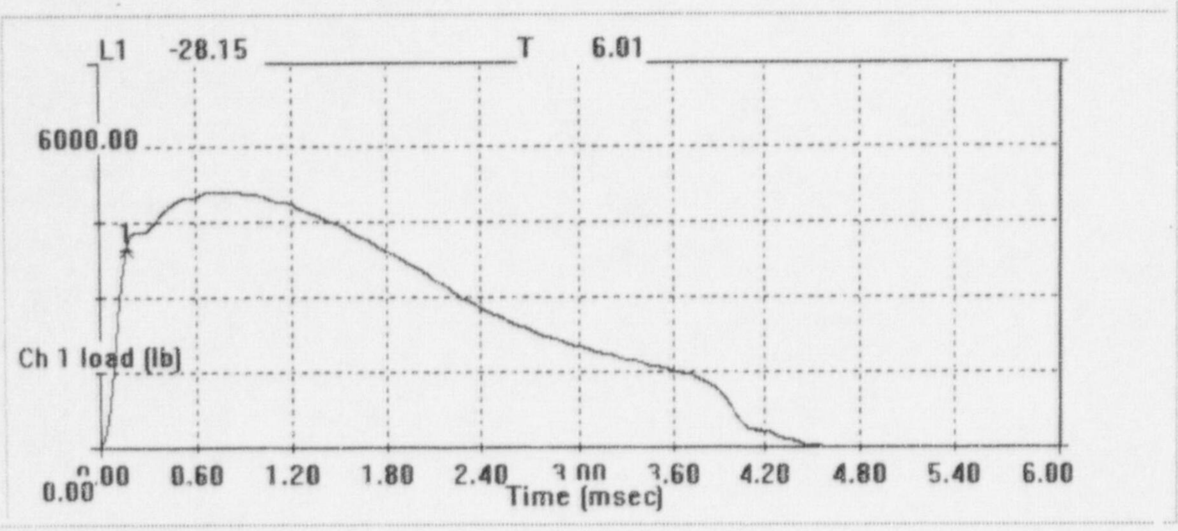
AT29, 200°F



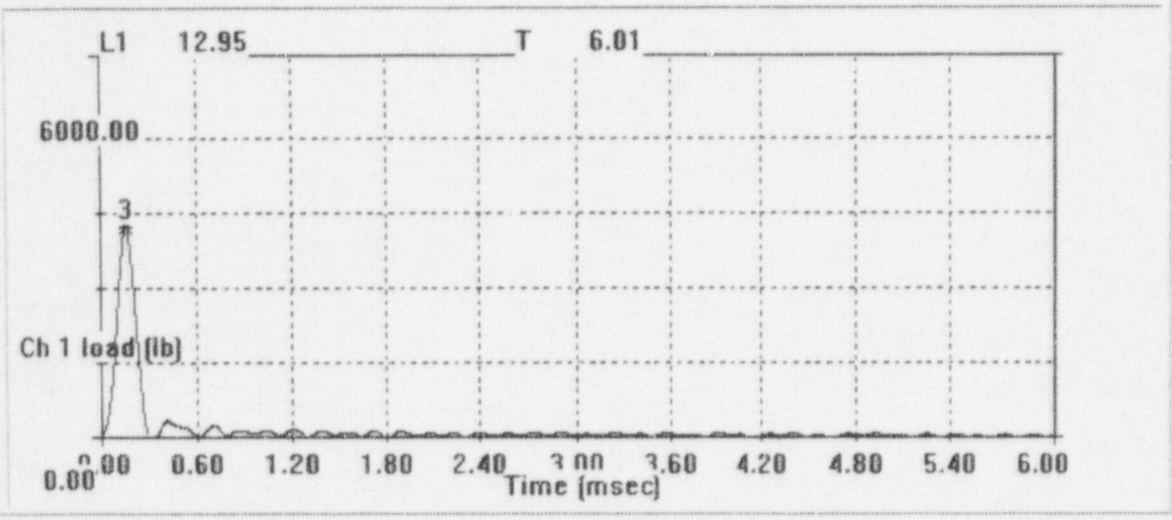
AT30, 125°F



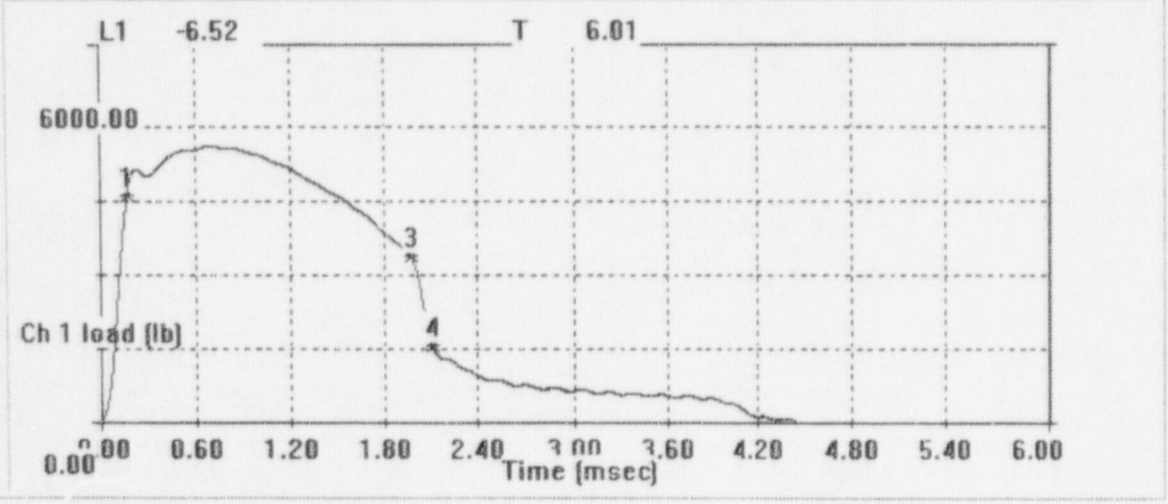
AT23, 25°F



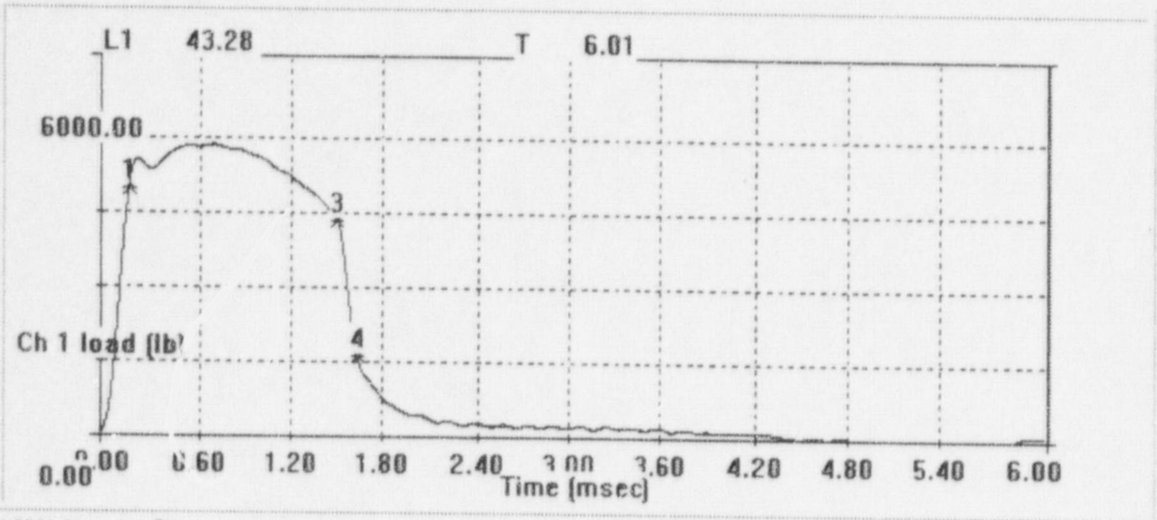
AW16, 300°F



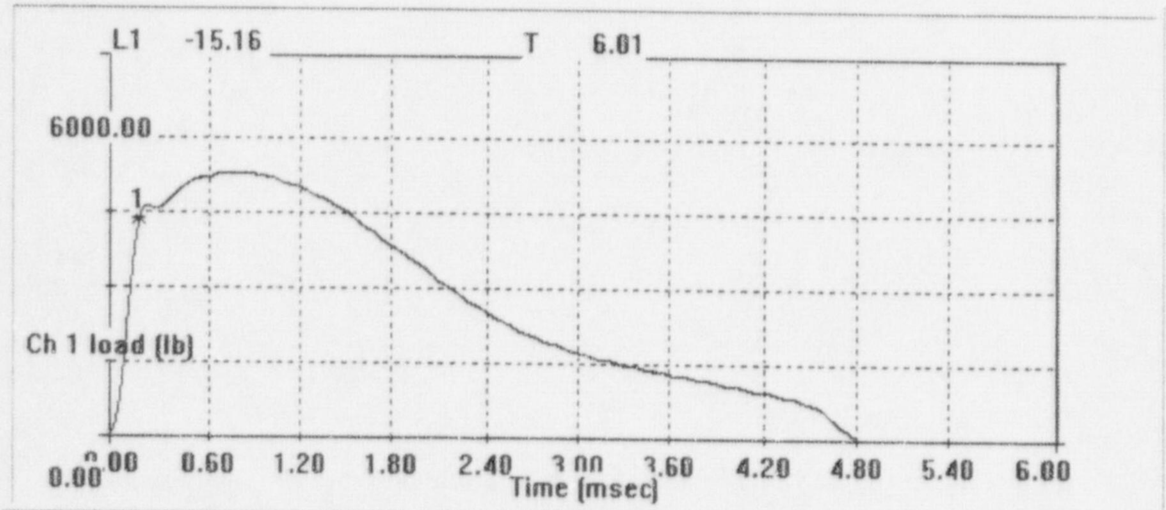
AW17, -25°F



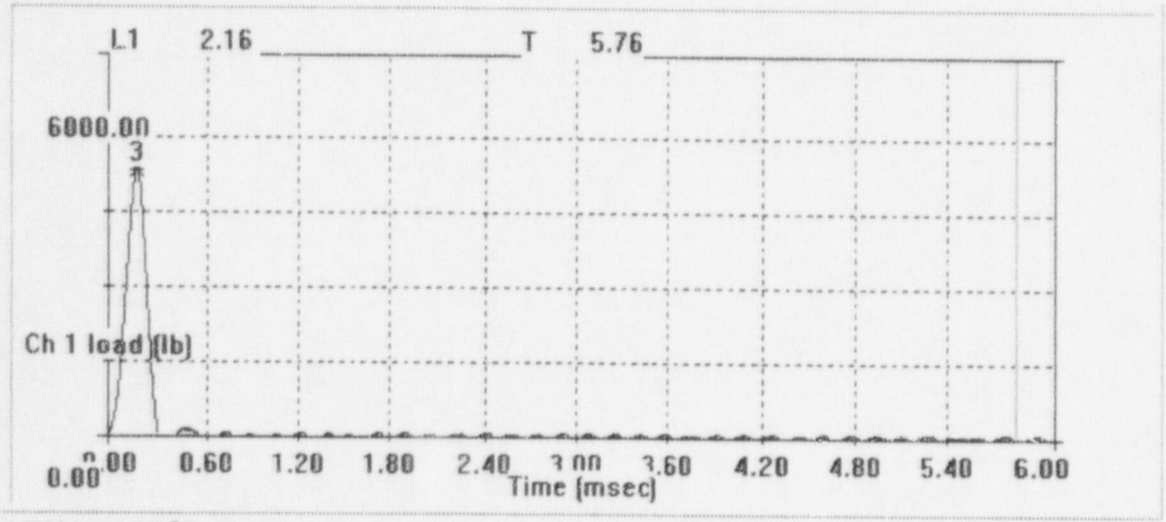
AW18, 50°F



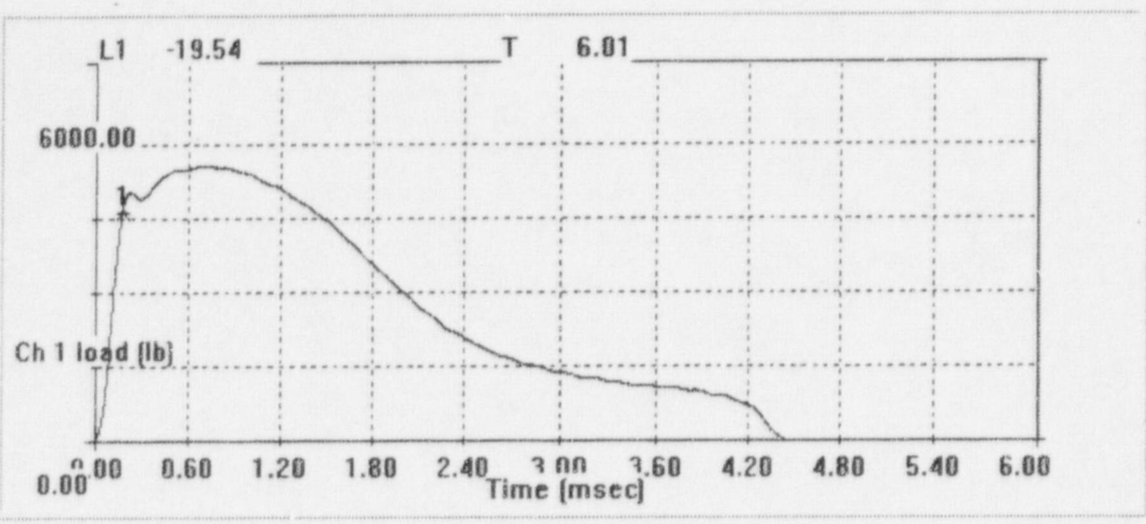
AW19, -10 °F



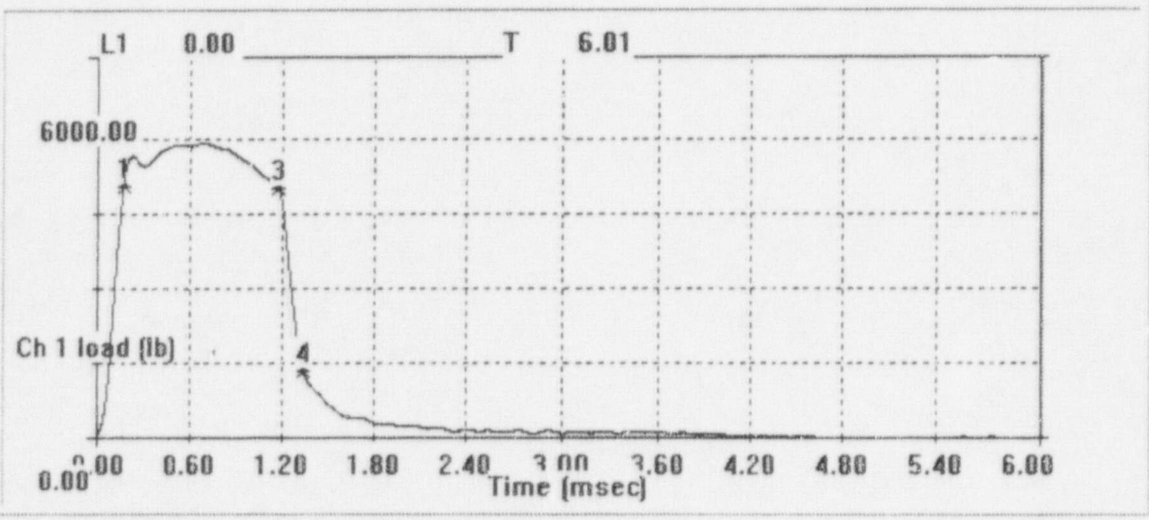
AW20, 200 °F



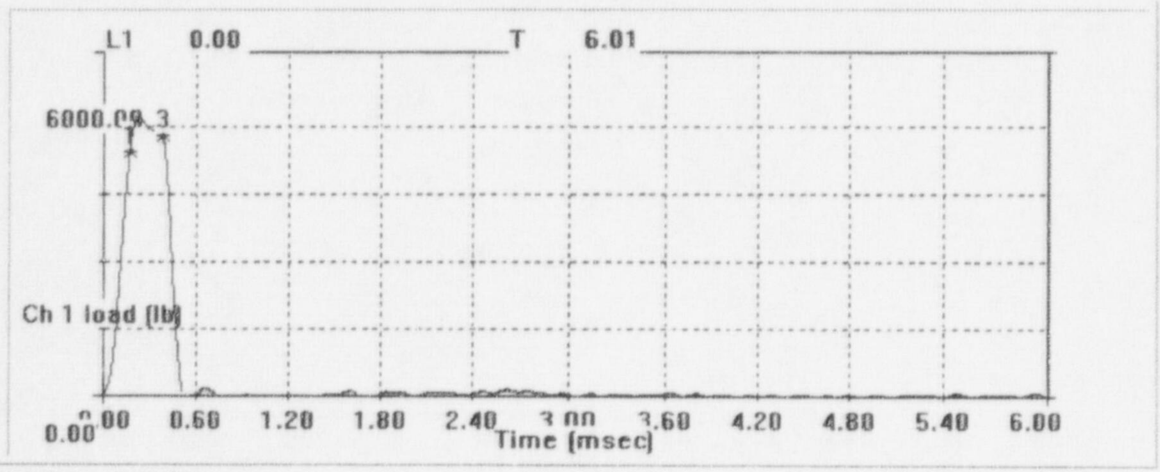
AW21, -125 °F



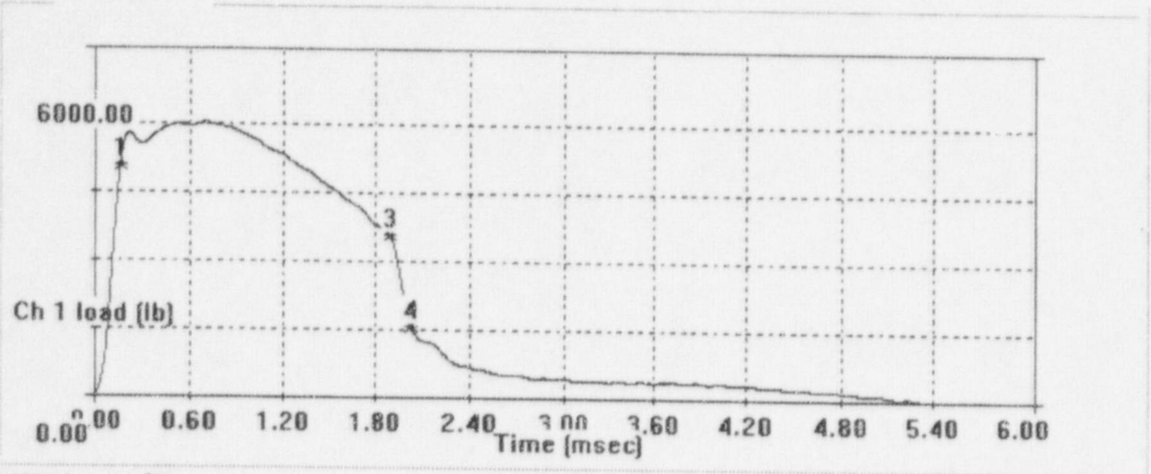
AW22, 100 °F



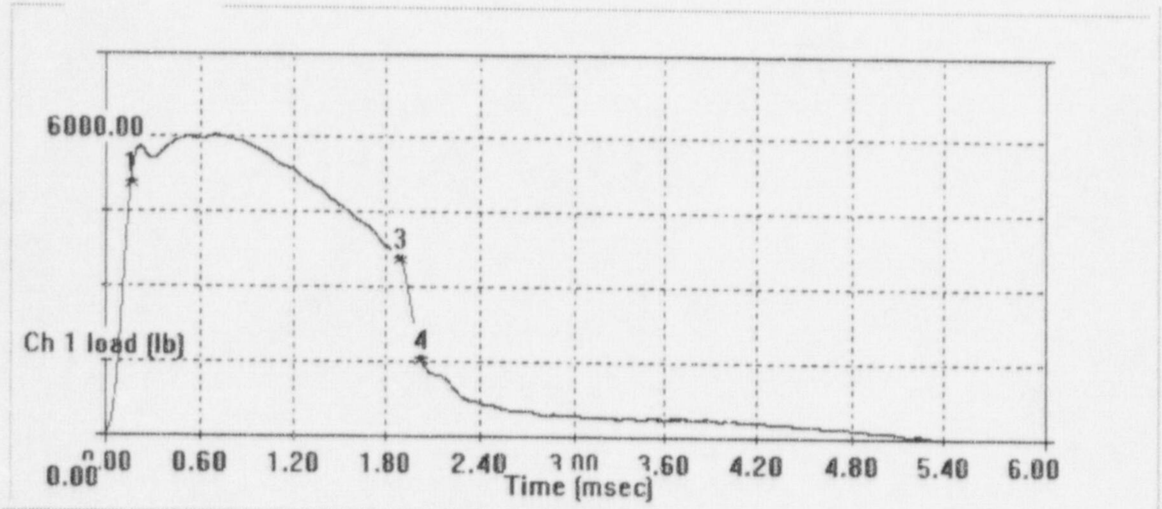
AW23, -25 °F



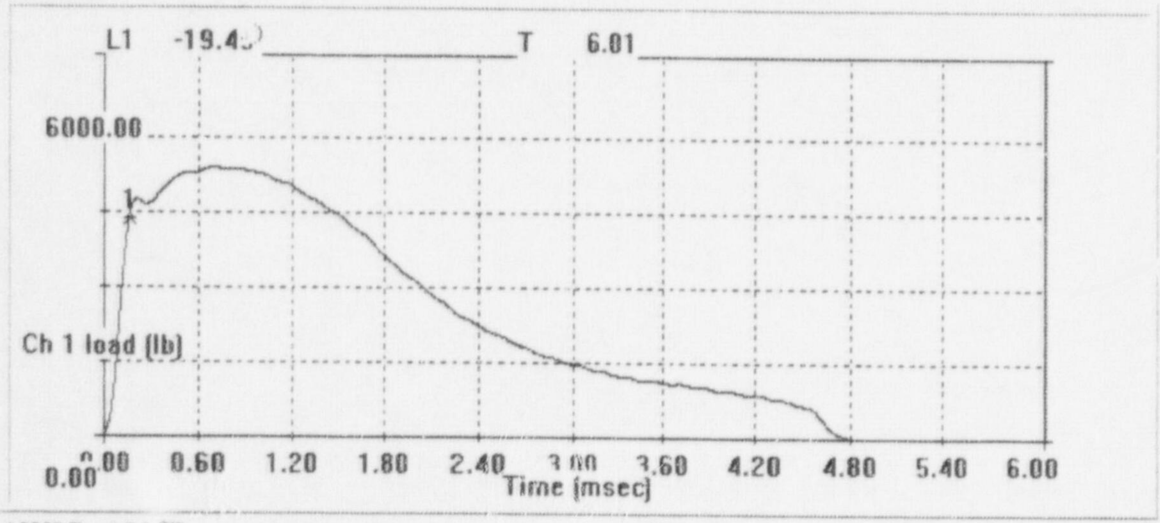
AW24, -100 °F



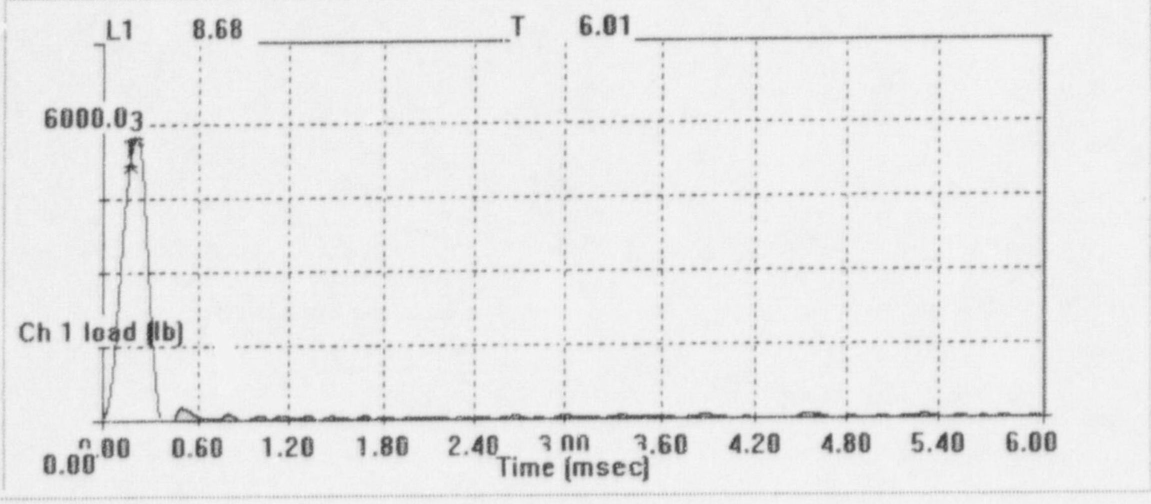
AW25, -40 °F



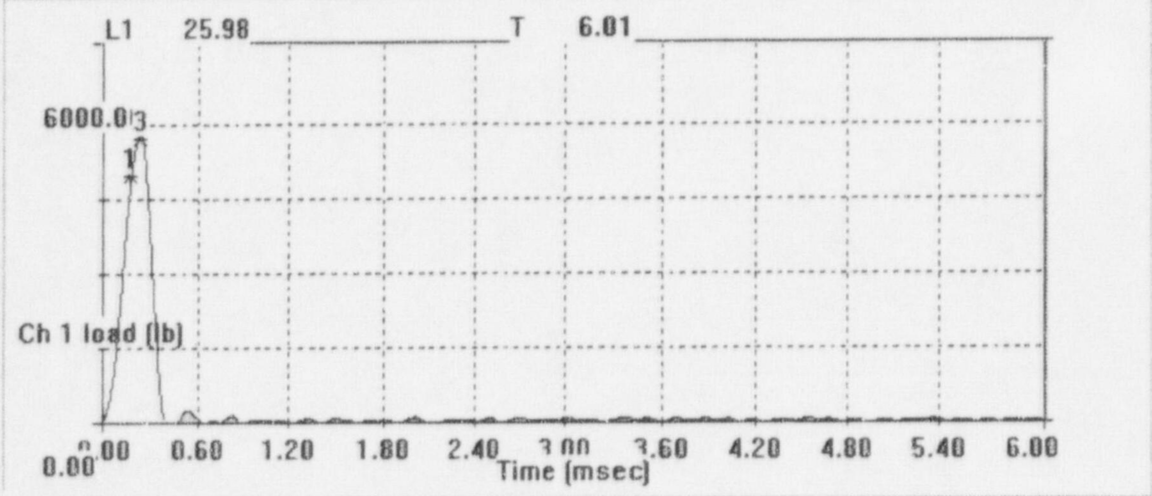
AW26, -75 °F



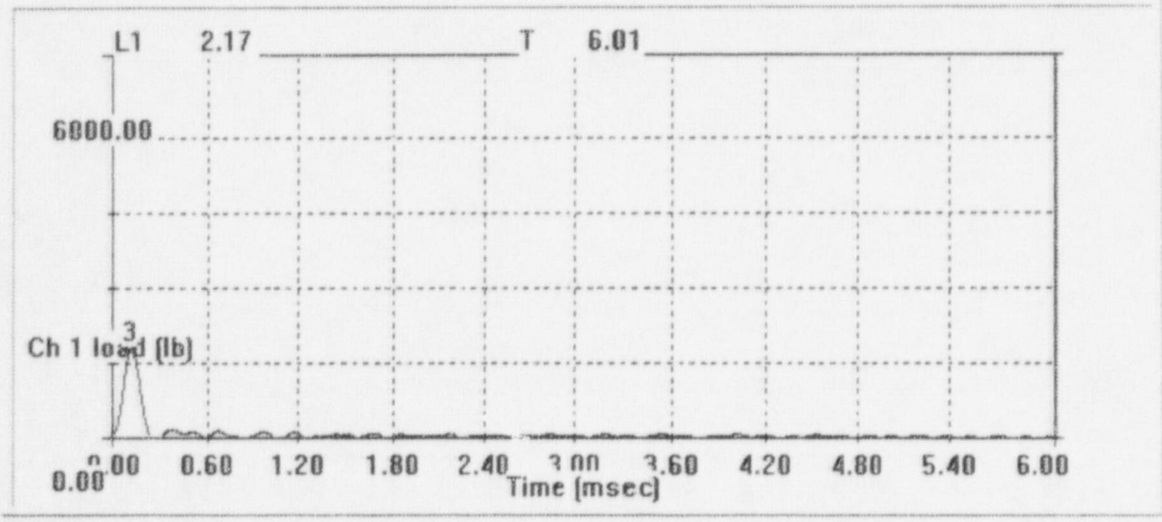
AW27, 150 °F



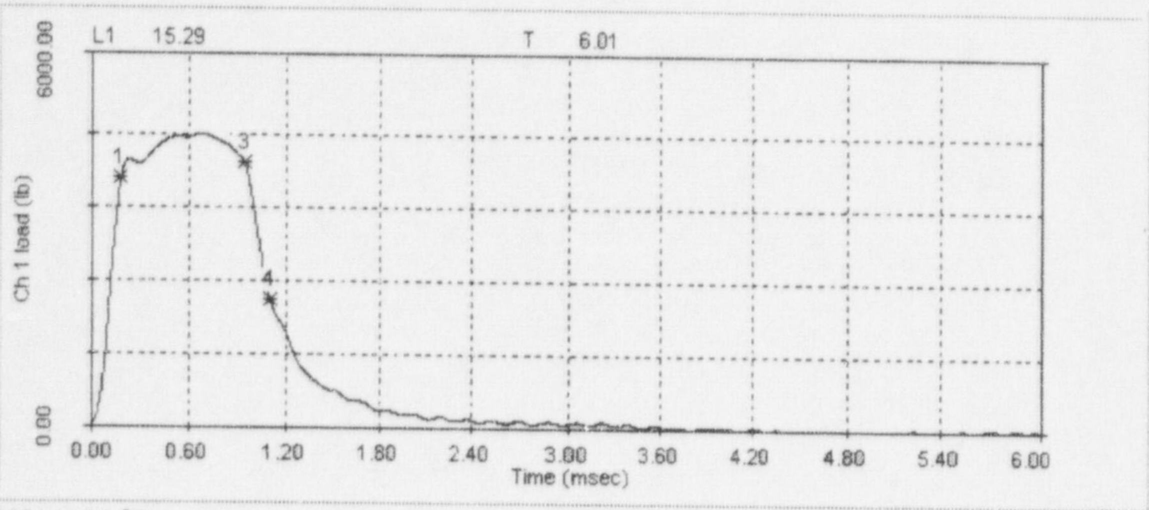
AW28, -45 °F



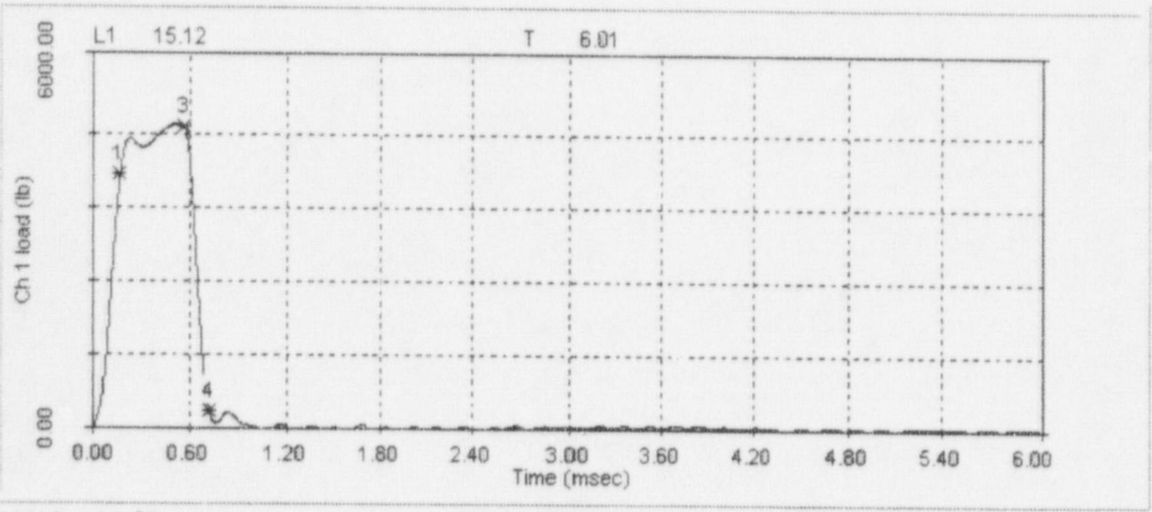
AW29, -50 °F



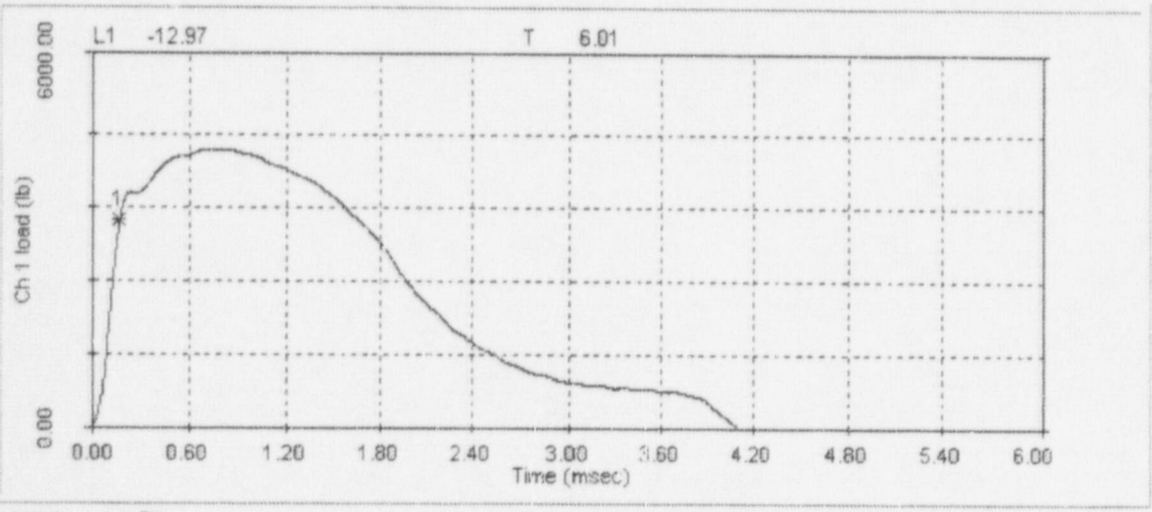
AW30, -60°F



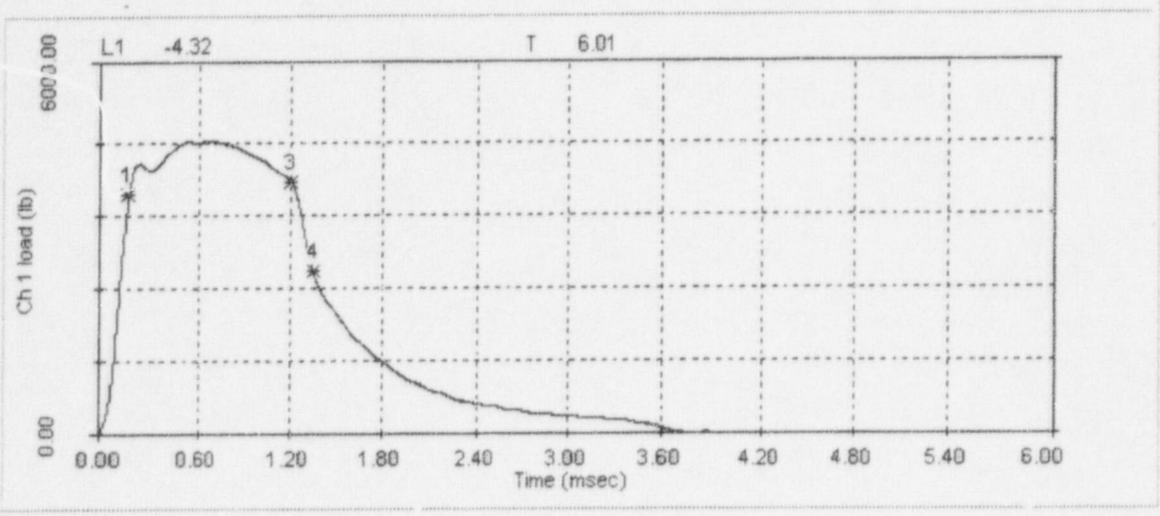
AH16, 50 °F



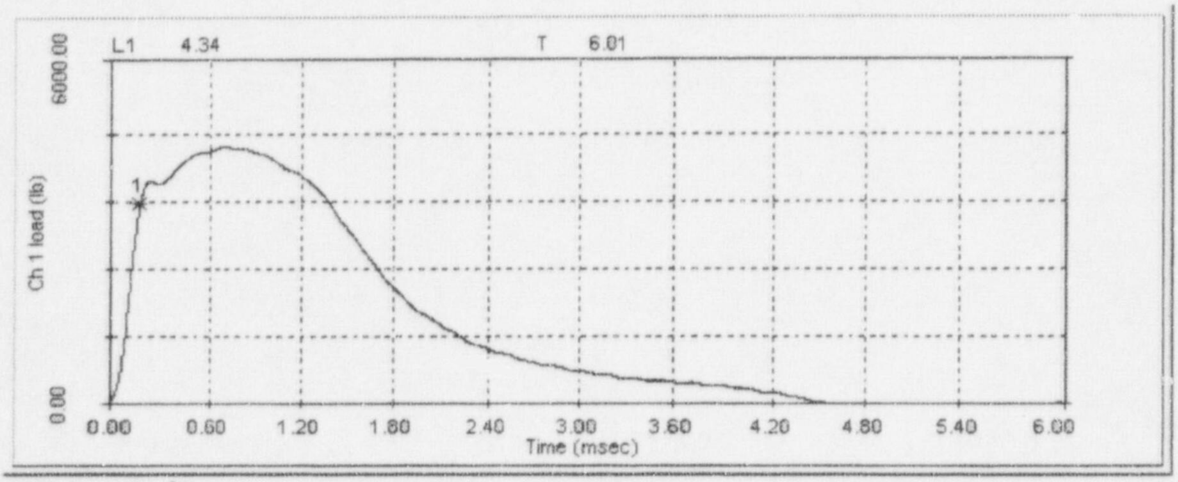
AH17, -35 °F



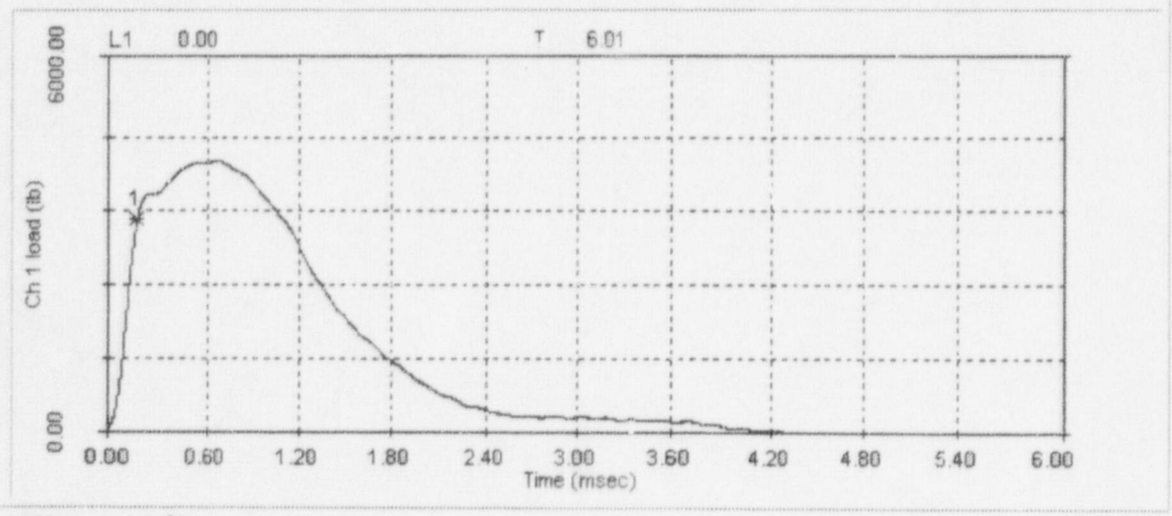
AH18, 225 °F



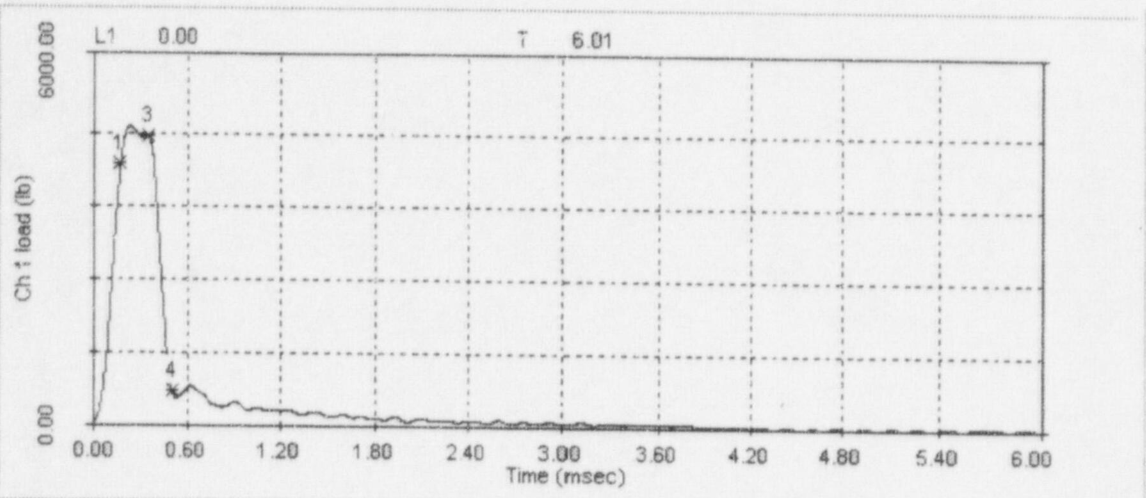
AH19, 25 °F



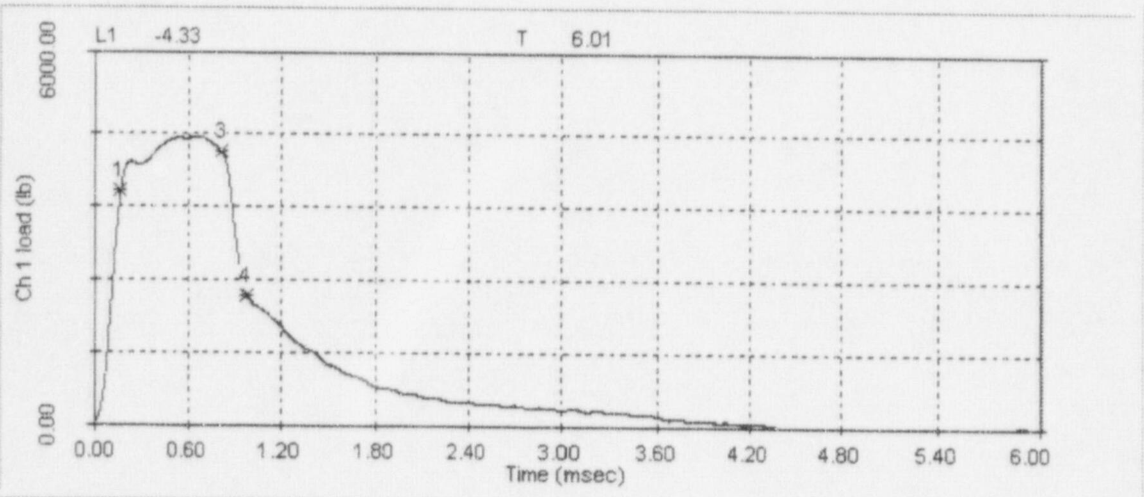
AH20, 150 °F



AH21, 300 °F



AH22, -40 °F



AH23, 60 °F

APPENDIX B

CHARPY V-NOTCH SHIFT RESULTS FOR EACH CAPSULE HAND-DRAWN VS. HYPERBOLIC TANGENT CURVE-FITTING METHOD (CVGRAPH VERSION 4.1)

Table B-1 30 ft-lb Transition Temperature Shifts (°F) for Intermediate Shell Plate B8805-3 (Long.)

Capsule	Hand Fit Plots			CVGRAPH Plots		
	Unirradiated	Irradiated	a T_{30}	Unirradiated	Irradiated	a T_{30}
U	-15	0	15	-15	-1	14
Y	-15	25	40	-15	17	32
V	-15	- - -	- - -	-15	28	43

Table B-2 50 ft-lb Transition Temperature Shifts (°F) for Intermediate Shell Plate B8805-3 (Long.)

Capsule	Hand Fit Plots			CVGRAPH Plots		
	Unirradiated	Irradiated	a T_{50}	Unirradiated	Irradiated	a T_{50}
U	20	35	15	22	37	15
Y	20	55	35	22	59	37
V	20	- - -	- - -	22	81	59

Table B-3 35 mil Lateral Expansion Temperature Shifts (°F) for Intermediate Shell Plate B8805-3 (Long.)

Capsule	Hand Fit Plots			CVGRAPH Plots		
	Unirradiated	Irradiated	a T_{35}	Unirradiated	Irradiated	a T_{35}
U	10	25	15	19	33	14
Y	10	45	35	19	52	33
V	10	- - -	- - -	19	88	69

Table B-4 Upper Shelf Energy Shifts (ft-lb) for Intermediate Shell Plate B8805-3 (Long.)

Capsule	Hand Fit Plots			CVGRAPH Plots		
	Unirradiated	Irradiated	a E	Unirradiated	Irradiated	a E
U	122	134	12	122	134	12
Y	122	132	10	122	132	10
V	122	- - -	- - -	122	118	-4

Table B-5 30 ft-lb Transition Temperature Shifts (°F) for Intermediate Shell Plate B8805-3 (Trans.)

	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{30}	Unirradiated	Irradiated	ΔT_{30}
U	15	15	0	17	8	-9
Y	15	35	20	17	32	15
V	15	---	---	17	51	34

Table B-6 50 ft-lb Transition Temperature Shifts (°F) for Intermediate Shell Plate B8805-3 (Trans.)

	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{50}	Unirradiated	Irradiated	ΔT_{50}
U	65	65	0	62	62	0
Y	65	95	30	62	88	26
V	65	---	---	62	108	46

Table B-7 35 mil Lateral Expansion Temperature Shifts (°F) for Intermediate Shell Plate B8805-3 (Trans.)

	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{35}	Unirradiated	Irradiated	ΔT_{35}
U	55	55	0	54	50	-4
Y	55	75	20	54	70	16
V	55	---	---	54	106	52

Table B-8 Upper Shelf Energy Shifts (ft-lb) for Intermediate Shell Plate B8805-3 (Trans.)

	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔE	Unirradiated	Irradiated	ΔE
U	96	98	2	96	98	2
Y	96	106	10	96	106	10
V	96	---	---	96	94	-2

Table B-9 30 ft-lb Transition Temperature Shifts (°F) for Weld Material

	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{30}	Unirradiated	Irradiated	ΔT_{30}
U	-40	-25	15	-57	-32	25
Y	-40	-40	0	-57	-49	8
V	-40	---	---	-57	-58	-1

Table B-10 50 ft-lb Transition Temperature Shifts (°F) for Weld Material

	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{50}	Unirradiated	Irradiated	ΔT_{50}
U	-25	-10	15	-30	-14	16
Y	-25	-25	0	-30	-26	4
V	-25	---	---	-30	-38	-8

Table B-11 35 mil Lateral Expansion Temperature Shifts (°F) for Weld Material

	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{35}	Unirradiated	Irradiated	ΔT_{35}
U	-35	-20	15	-33	-20	13
Y	-35	-25	10	-33	-24	9
V	-35	---	---	-33	-33	0

Table B-12 Upper Shelf Energy Shifts (ft-lb) for Weld Material

	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔE	Unirradiated	Irradiated	ΔE
U	145	156	11	145	156	11
Y	145	144	-1	145	144	-1
V	145	---	---	145	142	-3

Table B-13 30 ft-lb Transition Temperature Shifts (°F) for Heat Affected Zone Material						
	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{30}	Unirradiated	Irradiated	ΔT_{30}
U	-75	-75	0	-87	-106	-19
Y	-75	-50	25	-87	-66	21
V	-75	- - -	- - -	-87	-45	42

Table B-14 50 ft-lb Transition Temperature Shifts (°F) for Heat Affected Zone Material						
	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{50}	Unirradiated	Irradiated	ΔT_{50}
U	-50	-50	0	-56	-62	-6
Y	-50	-25	25	-56	-39	17
V	-50	- - -	- - -	-56	-13	43

Table B-15 35 mil Lateral Expansion Temperature Shifts (°F) for Heat Affected Zone Material						
	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔT_{35}	Unirradiated	Irradiated	ΔT_{35}
U	-45	-45	0	-50	-47	3
Y	-45	-45	0	-50	-40	10
V	-45	- - -	- - -	-50	-4	46

Table B-16 Upper Shelf Energy Shifts (ft-lb) for Heat Affected Zone Material						
	Hand Fit Plots			CVGRAPH Plots		
Capsule	Unirradiated	Irradiated	ΔE	Unirradiated	Irradiated	ΔE
U	136	128	-8	136	129	-7
Y	136	124	-12	136	124	-12
V	136	- - -	- - -	136	121	-15

APPENDIX C

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

Contained in Table C-1 are the upper shelf energy values used as input for the generation of the Charpy V-notch plots using CVGRAPH, Version 4.1. Lower shelf energy values were fixed at 2.2 ft-lb. The unirradiated and irradiated upper shelf energy values were calculated per the ASTM El 85-82 definition of upper shelf energy.

Table C-1 Upper Shelf Energy Values Fixed in CVGRAPH

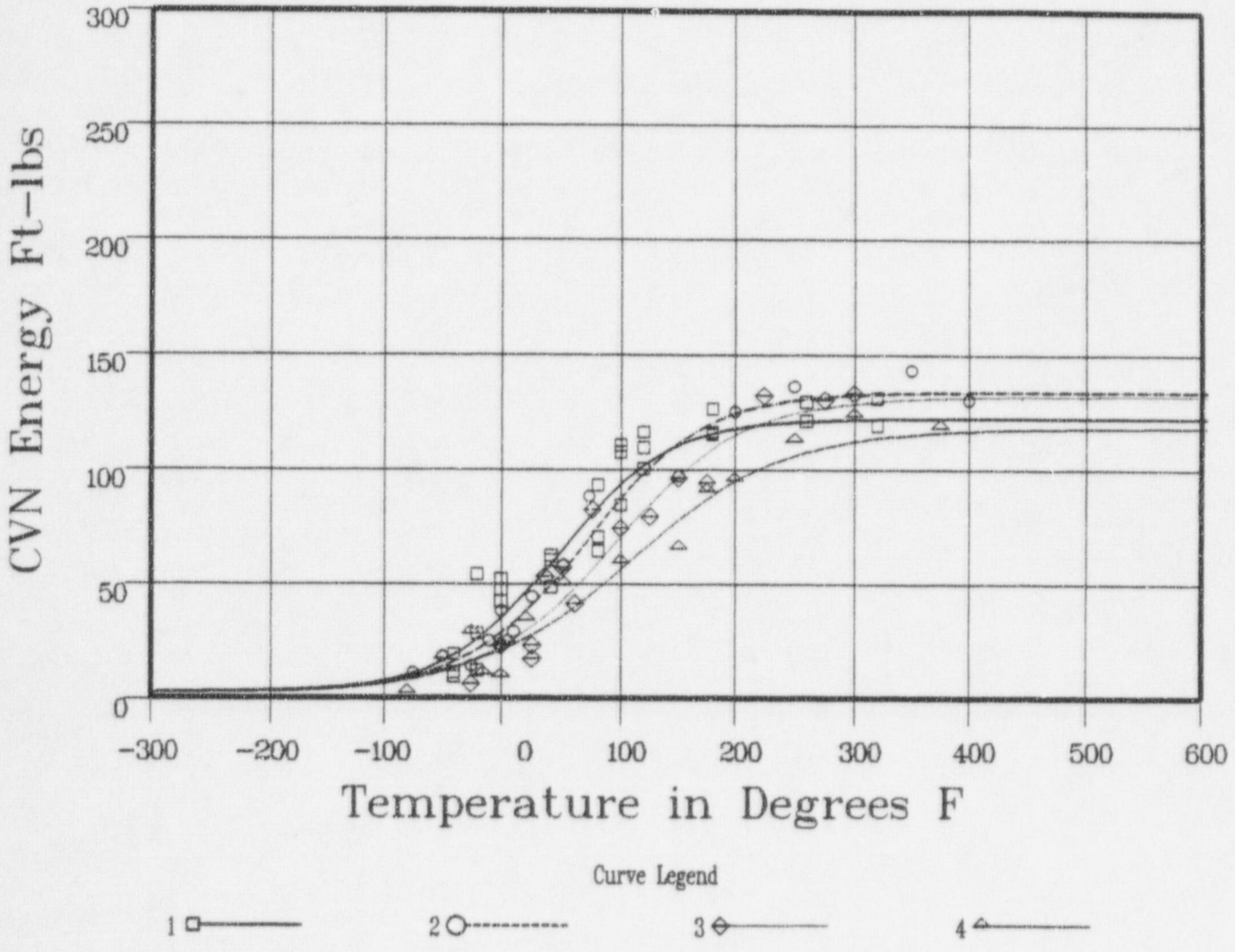
Material	Unirradiated	Capsule U	Capsule Y	Capsule V
Intermediate Shell Plate B8805-3 (Longitudinal Orientation)	122 ft-lb	134 ft-lb	132 ft-lb	118 ft-lb
Intermediate Shell Plate B8805-3 (Transverse Orientation)	96 ft-lb	98 ft-lb	106 ft-lb	94 ft-lb
Weld Metal (Heat # 895075)	145 ft-lb	156 ft-lb	144 ft-lb	142 ft-lb
HAZ Material	136 ft-lb	129 ft-lb	124 ft-lb	121 ft-lb

Intermediate Shell Plate B8805-3 (Long.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:17:11 on 05-08-1998

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	122	0	-15.06	0	21.87	0
2	0	2.19	0	133.5	11.5	-1.49	13.56	36.78	14.9
3	0	2.19	0	131.6	9.6	16.87	31.94	59.41	37.53
4	0	2.19	0	118	-4	27.6	42.66	80.63	58.75



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:26:21 on 05-08-1998

Page 1

Coefficients of Curve 1

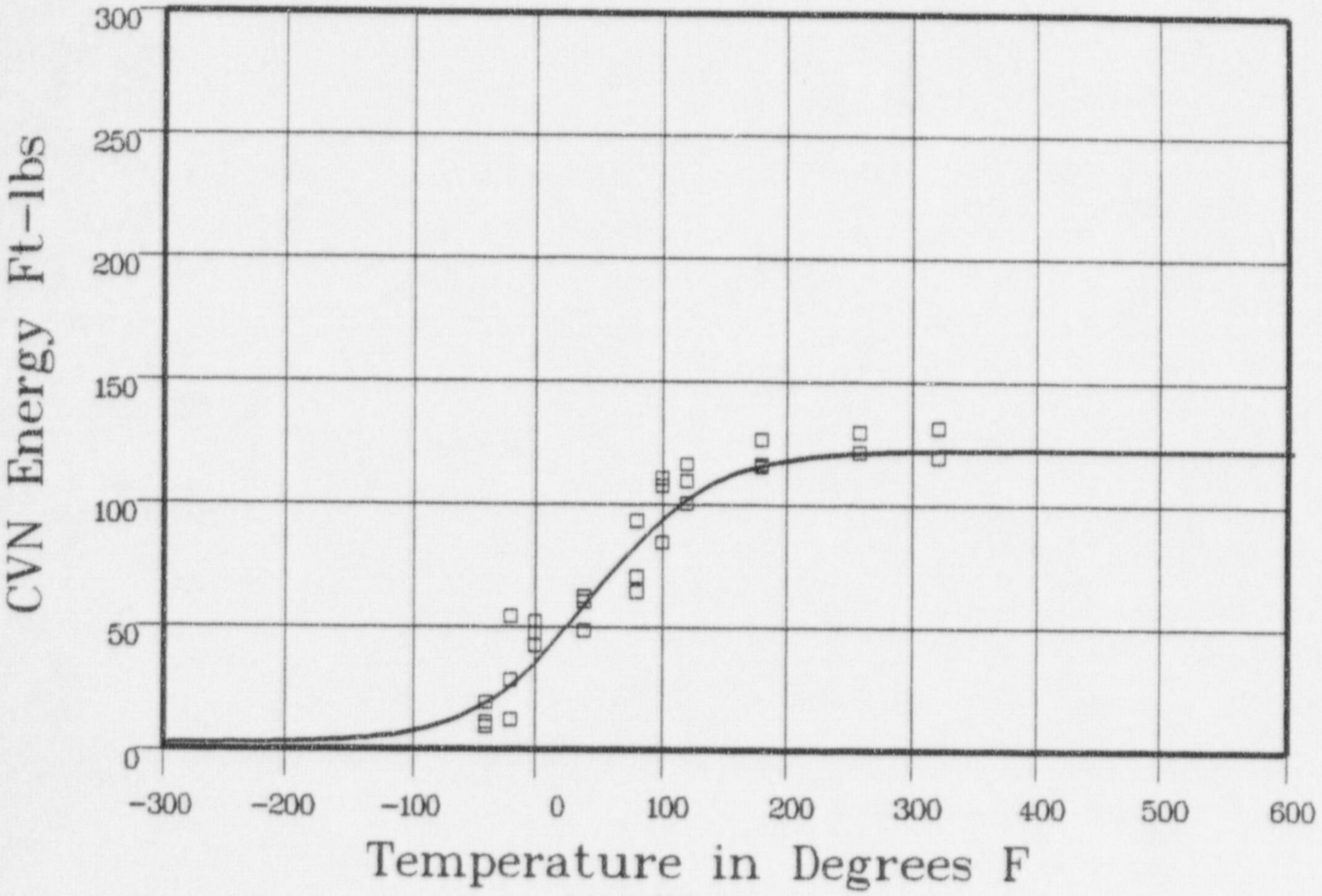
A = 62.09	B = 59.9	C = 93.86	T0 = 41.09

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 122 Fixed Temp. at 30 ft-lbs: -15 Temp. at 50 ft-lbs: 21.8 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-40	11	20.26	-9.26
-40	19	20.26	-1.26
-40	9	20.26	-11.26
-20	54	27.81	26.18
-20	28	27.81	.18
-20	12	27.81	-15.81
0	52	37.42	14.57
0	47	37.42	9.57
0	42	37.42	4.57

**** Data continued on next page ****

Unirradiated

Page 2

Material: PLATE SA533B1　　Heat Number: CODE B8805-3 (HT.C0623-1)　　Orientation: LT

Capsule: UNIRR　　Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
40	48	61.39	-13.39
40	62	61.39	.6
40	60	61.39	-1.39
80	93	85.59	7.4
80	64	85.59	-21.59
80	70	85.59	-15.59
100	84	95.42	-11.42
100	107	95.42	11.57
100	110	95.42	14.57
120	100	103.19	-3.19
120	116	103.19	12.8
120	109	103.19	5.8
180	126	116.09	9.9
180	115	116.09	-1.09
180	116	116.09	-.09
260	129	120.88	8.11
260	121	120.88	.11
320	131	121.68	9.31
320	119	121.68	-2.68

SUM of RESIDUALS = 27.17

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:26:21 on 05-08-1998

Page 1

Coefficients of Curve 2

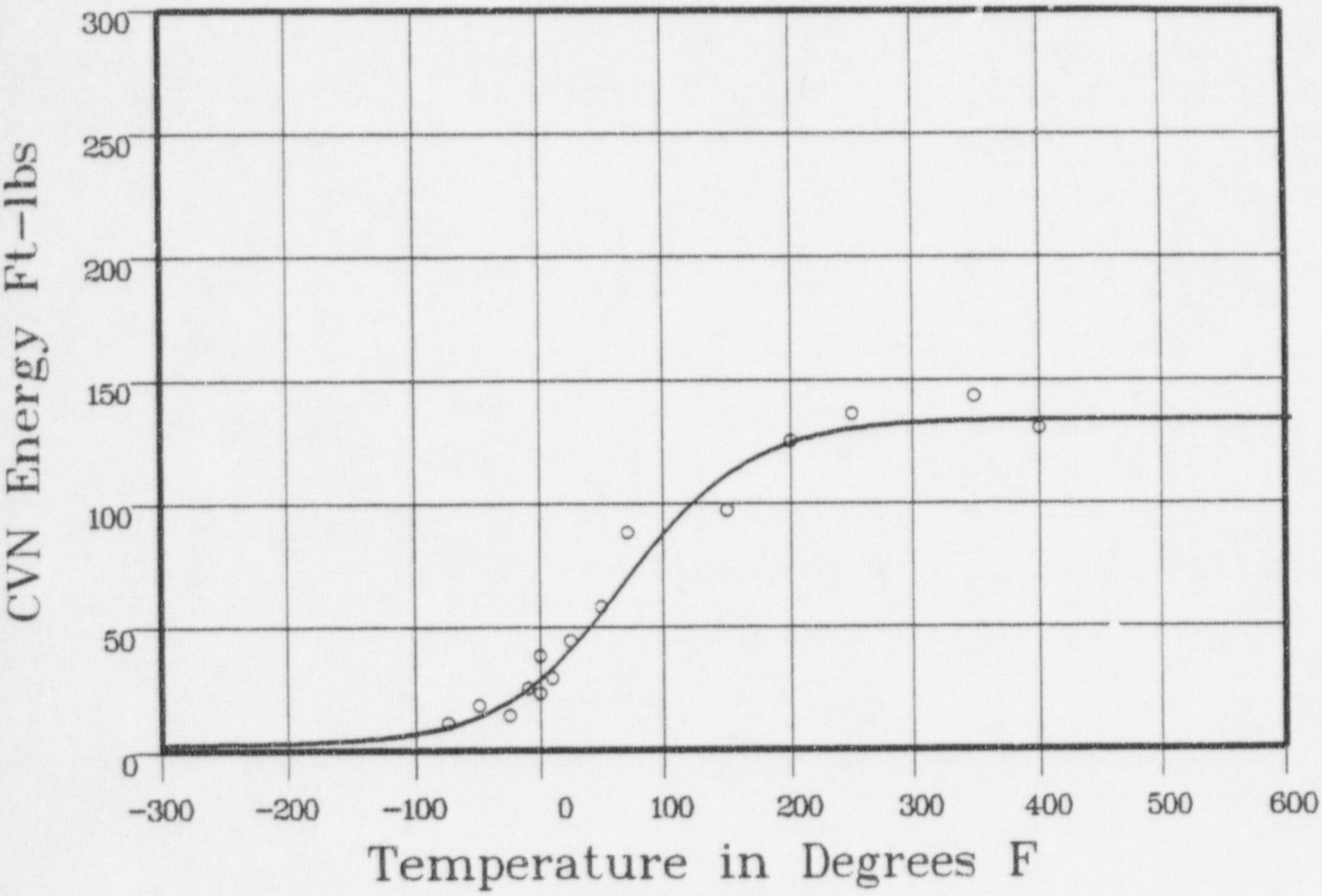
A = 67.84	B = 65.65	C = 101.16	T0 = 65

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 133.5 Fixed Temp. at 30 ft-lbs: -1.4 Temp. at 50 ft-lbs: 36.7 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: U Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-75	11	9.95	1.04
-50	18	14.45	3.54
-25	14	21.16	-7.16
-10	25	26.49	-1.49
0	23	30.65	-7.65
0	38	30.65	7.34
10	29	35.3	-6.3
25	44	43.16	.83

**** Data continued on next page ****

Capsule U

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
50	58	58.18	-.18
72	88	72.38	15.61
150	97	112.87	-15.87
200	125	124.98	.01
250	136	130.19	5.8
350	143	133.03	9.96
400	130	133.32	-3.32

SUM of RESIDUALS = 2.15

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:17:11 on 05-08-1998

Page 1

Coefficients of Curve 3

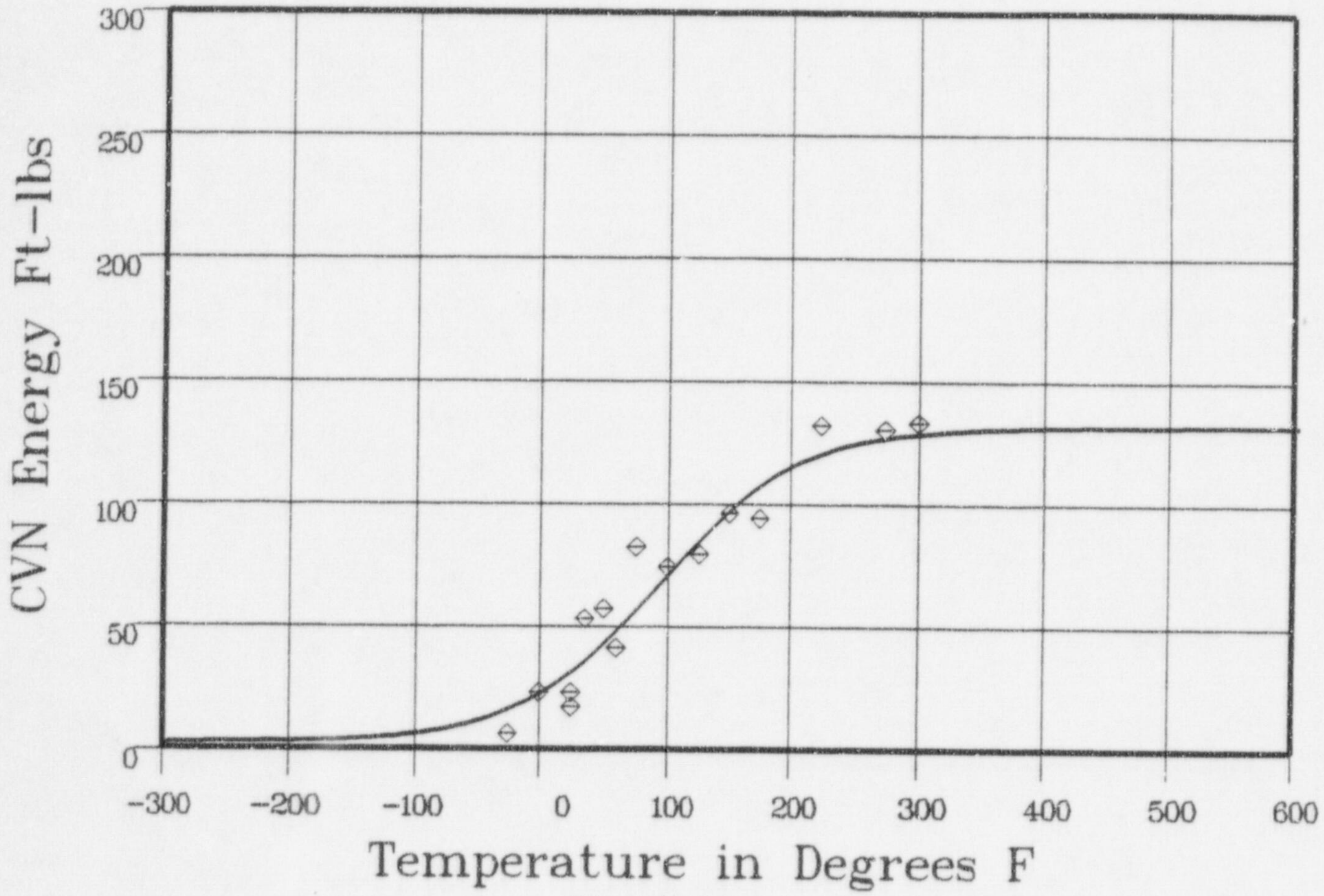
A = 66.9	B = 64.7	C = 111.75	T0 = 89.29

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 131.6 Fixed Temp. at 30 ft-lbs: 16.8 Temp. at 50 ft-lbs: 59.4 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-25	6	17.01	-11.01
0	23	23.97	-.97
25	17	33.3	-16.3
25	23	33.3	-10.3
35	53	37.72	15.27
50	57	45.04	11.95
60	41	50.31	-9.31
75	82	58.66	23.33

**** Data continued on next page ****

Capsule Y

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
100	74	73.07	.92
125	79	86.89	-7.89
150	96	98.95	-2.95
175	94	108.63	-14.63
225	132	121.11	10.88
275	130	127.09	2.9
300	133	128.68	4.31

SUM of RESIDUALS = -3.8

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:17:11 on 05-08-1998
Page 1
Coefficients of Curve 4

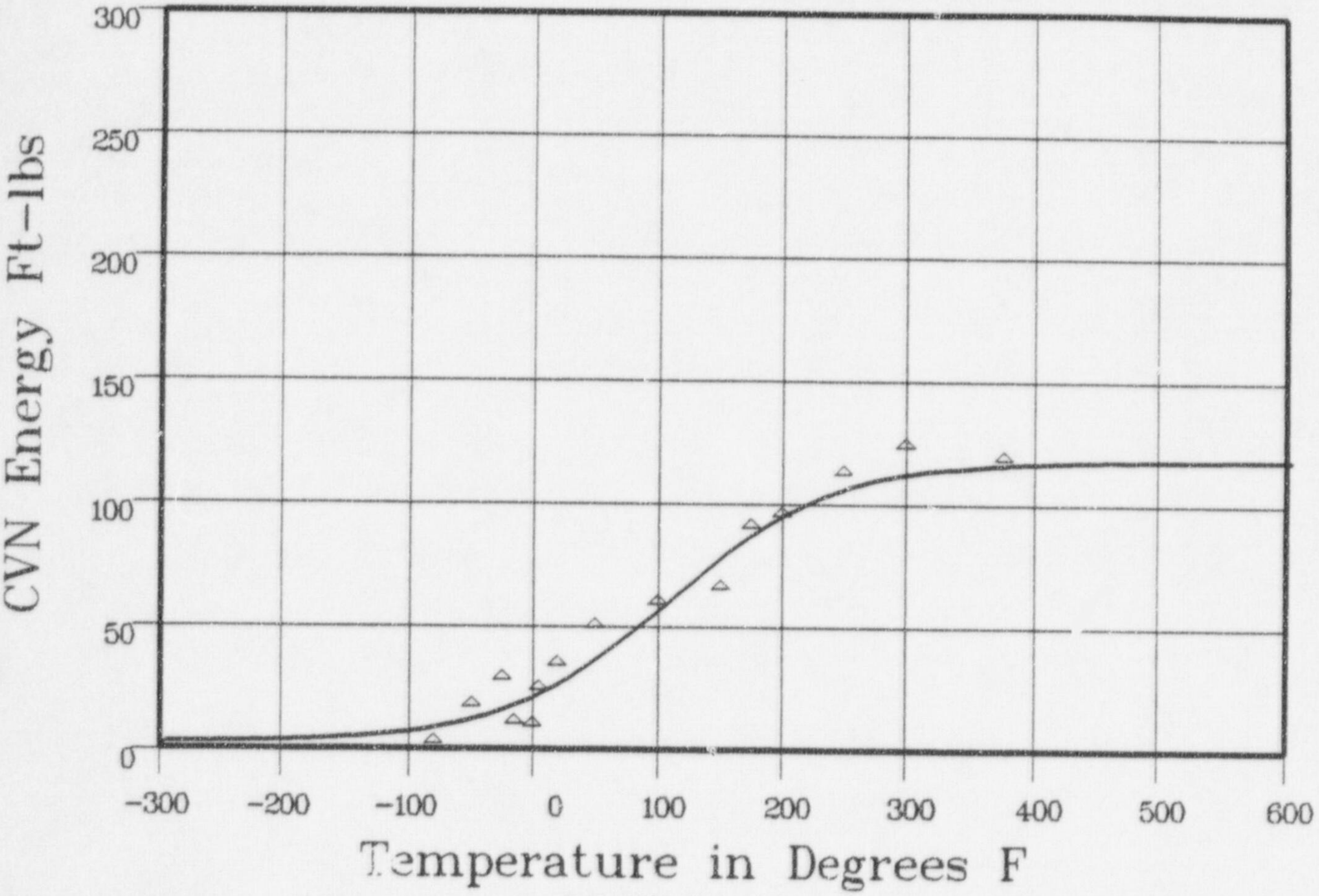
A = 60.09	B = 57.9	C = 132.61	T0 = 104

Equation is: $CVN = A + B * [\tanh((T - T0)/C)]$

Upper Shelf Energy: 118 Fixed Temp. at 30 ft-lbs: 27.6 Temp. at 50 ft-lbs: 80.6 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: V Total Fluence:



Data Set(s) Plotted
Plant: V01 Cap.: V Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-80	2	8.99	-6.99
-50	17	12.53	4.46
-25	28	16.67	11.32
-15	10	18.69	-8.69
0	9	22.16	-13.16
5	24	23.44	.55
20	34	27.65	6.34

**** Data continued on next page ****

Capsule V

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
50	49	37.74	11.25
100	59	58.35	.64
150	65	79.41	-14.41
175	90	88.44	1.55
200	95	95.95	-.95
250	112	106.46	5.53
300	123	112.27	10.72
375	118	116.08	1.91

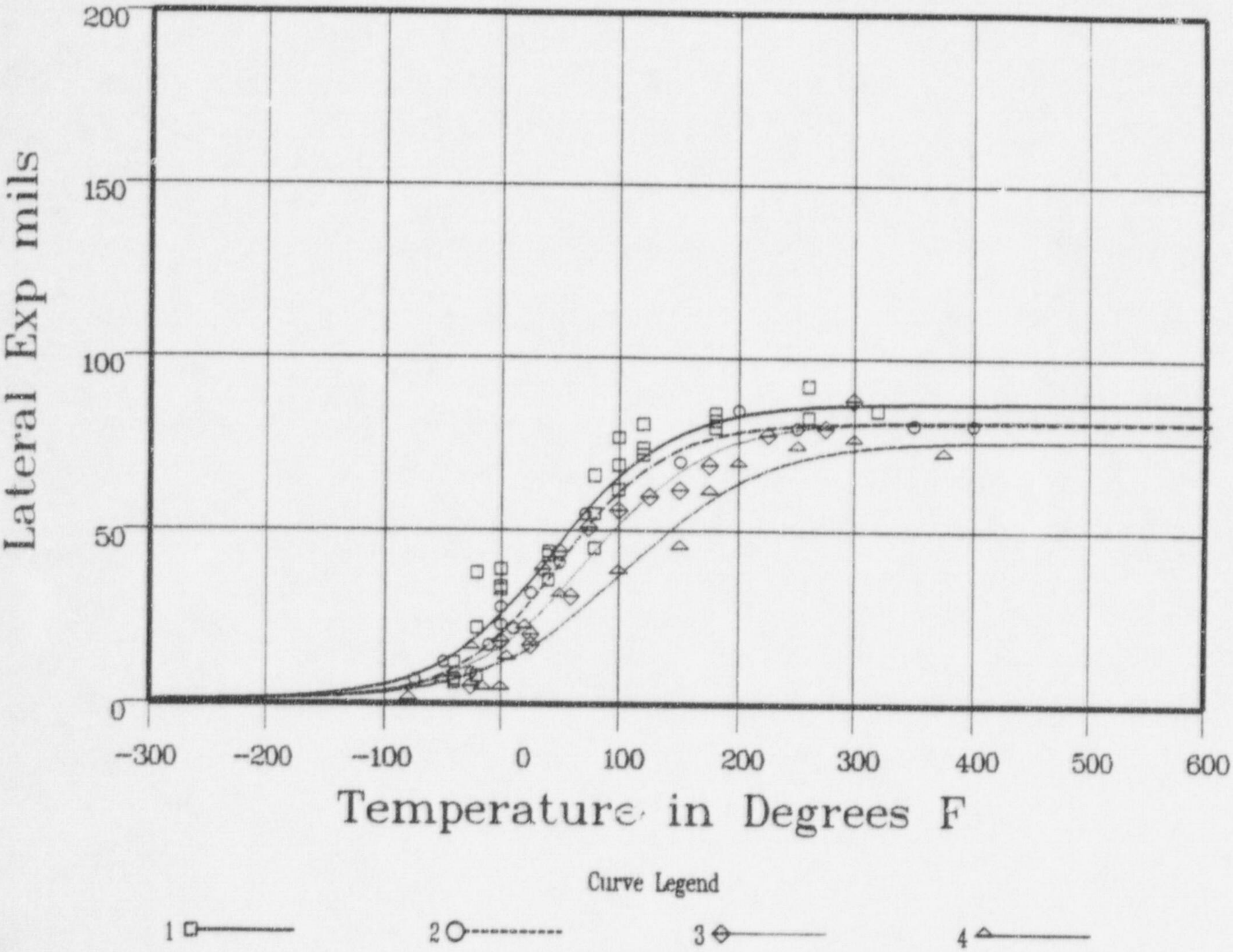
SUM of RESIDUALS = 10.08

Intermediate Shell Plate B8805-3 (Long.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:50:47 on 05-08-1998

Results

Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	87.22	0	18.86	0
2	0	81.63	-5.58	32.95	14.08
3	0	82.21	-5	52.11	33.24
4	0	76.49	-10.72	88.45	69.58



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:50:47 on 05-08-1998

Page 1

Coefficients of Curve 1

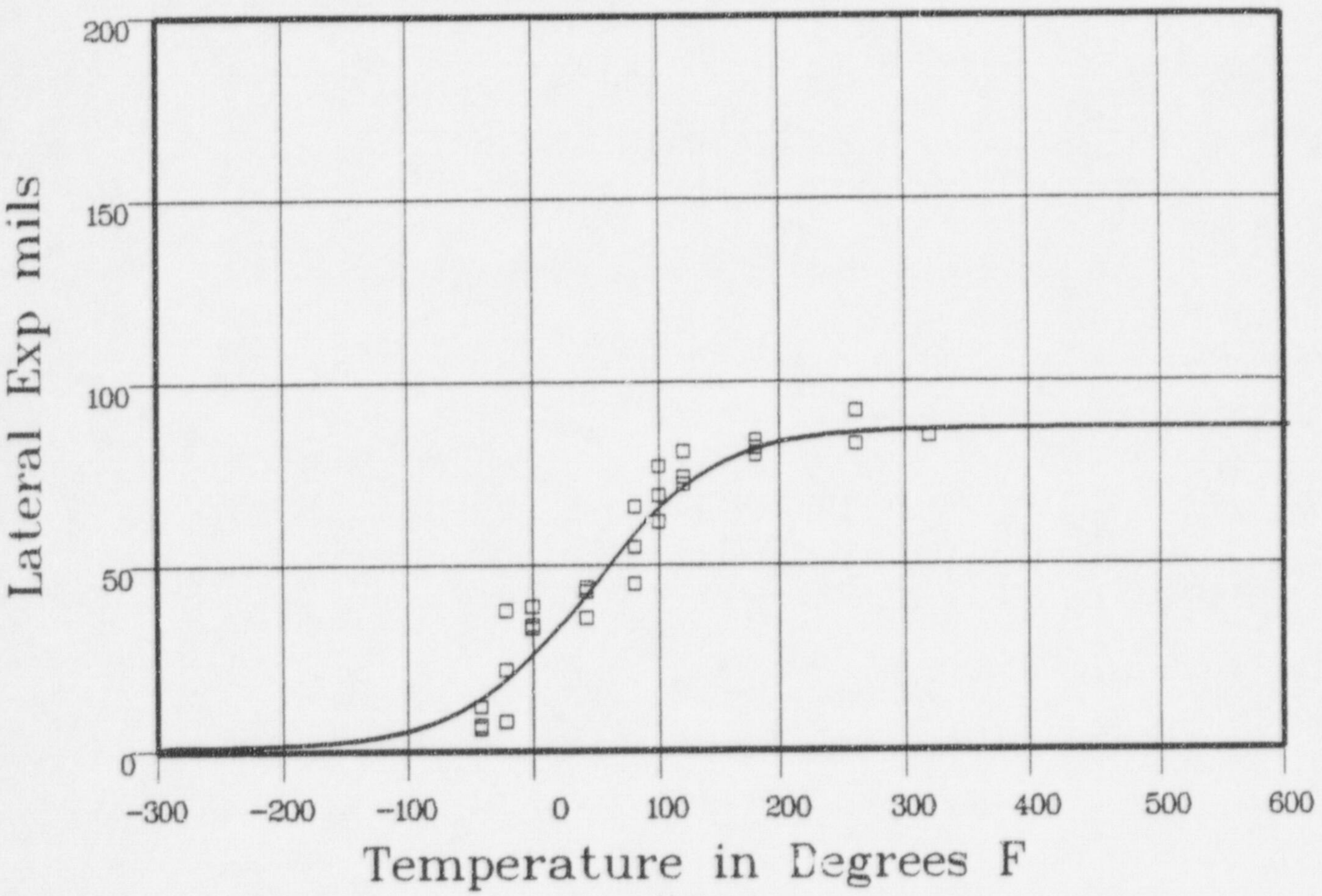
A = 44.11	B = 43.11	C = 99.93	T0 = 40.31

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 87.22 Temperature at L.E. 35: 18.8 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-40	7	15.39	-8.39
-40	12	15.39	-3.39
-40	6	15.39	-9.39
-20	38	20.85	17.14
-20	22	20.85	1.14
-20	8	20.85	-12.85
0	39	27.6	11.39
0	34	27.6	6.39
0	33	27.6	5.39

**** Data continued on next page ****

Unirradiated

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
40	36	43.97	-7.97
40	43	43.97	-.97
40	44	43.97	.02
80	66	60.38	5.61
80	45	60.38	-15.38
80	55	60.38	-5.38
100	62	67.17	-5.17
100	69	67.17	1.82
100	77	67.17	9.82
120	72	72.67	-.67
120	81	72.67	8.32
120	74	72.67	1.32
180	84	82.25	1.74
180	82	82.25	-.25
180	80	82.25	-2.25
260	92	86.17	5.82
260	83	86.17	-3.17
320	85	86.9	-1.9
320	85	86.9	-1.9

SUM of RESIDUALS = -3.12

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:50:47 on 05-08-1998

Page 1

Coefficients of Curve 2

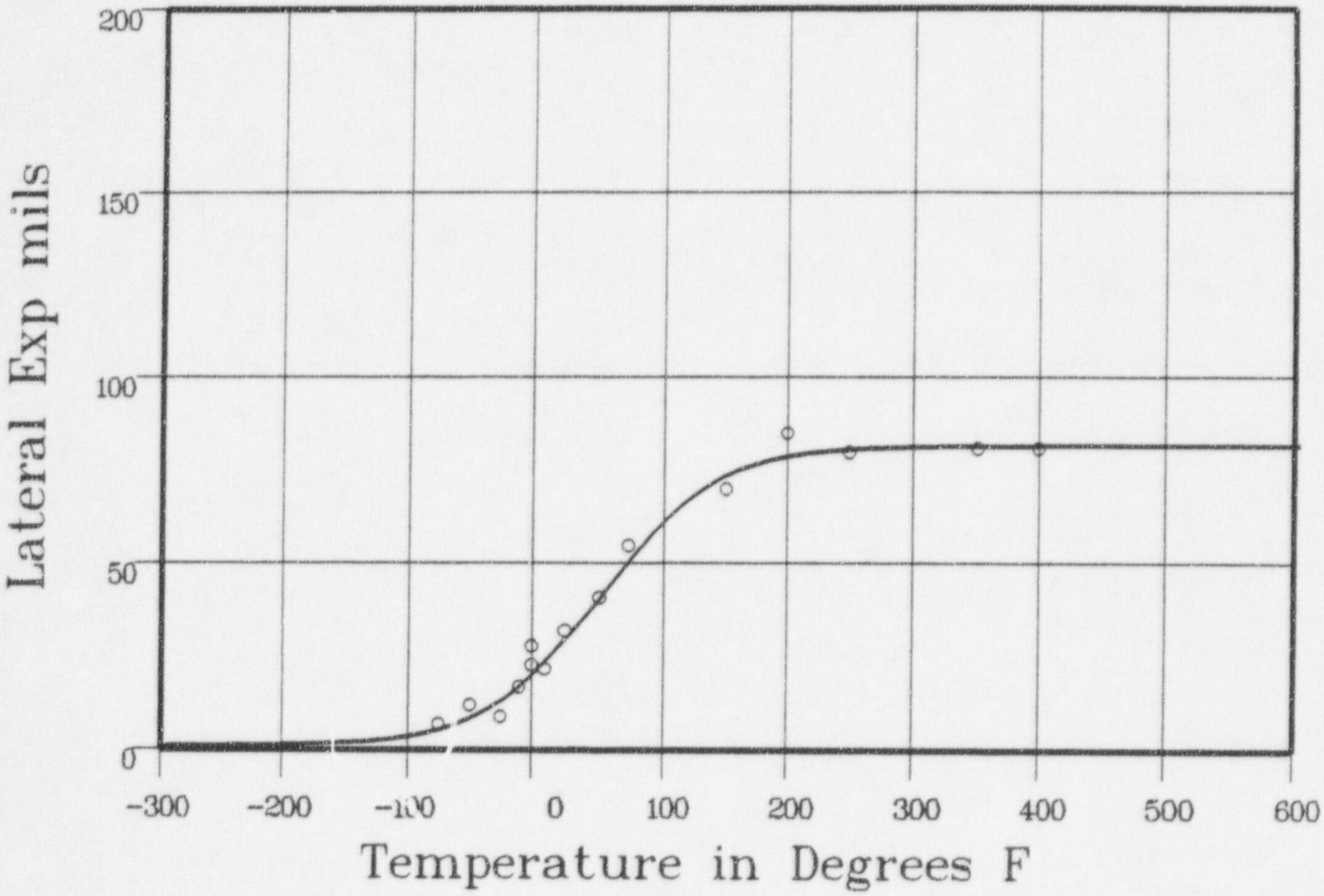
A = 41.31 B = 40.31 C = 89.31 T0 = 47.06

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 81.63 Temperature at L.E. 35: 32.9 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: U Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-75	7	5.92	1.07
-50	12	9.23	2.76
-25	9	14.39	-5.39
-10	17	18.57	-1.57
0	23	21.84	1.15
0	28	21.84	6.15
10	22	25.48	-3.48
25	32	31.55	.44

**** Data continued on next page ****

Capsule U

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
50	41	42.64	-1.64
72	55	52.29	2.7
150	70	74.32	-4.32
200	85	79.09	5.9
250	80	80.79	-.79
350	81	81.54	-.54
400	81	81.6	-.6

SUM of RESIDUALS = 1.84

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve   Printed at 10:50:47 on 05-08-1998
Page 1
Coefficients of Curve 3

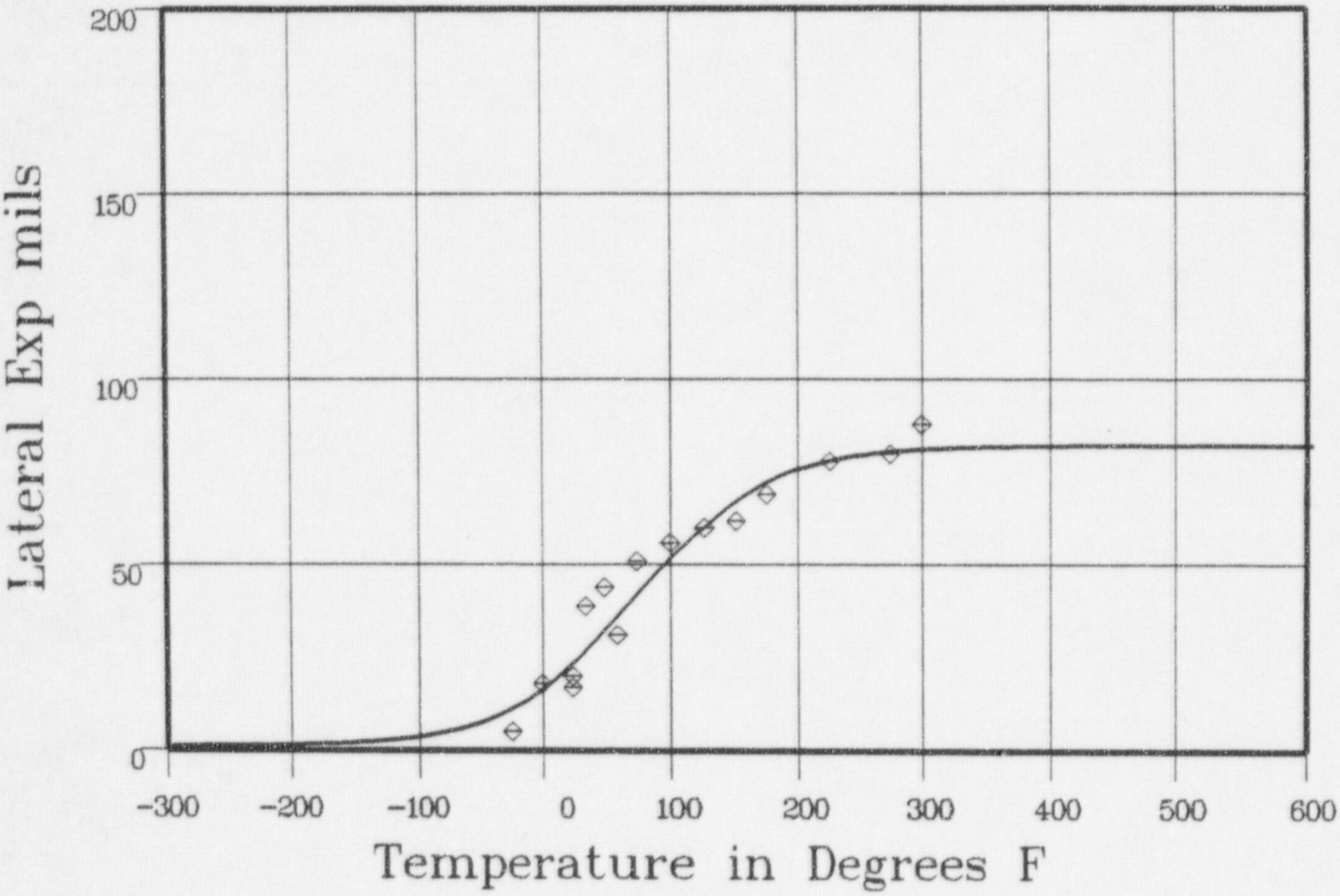
A = 41.6	B = 40.6	C = 102.63	T0 = 68.96

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 82.21   Temperature at L.E. 35: 52.1   Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1   Heat Number: CODE B8805-3 (HT.C0623-1)   Orientation: LT

Capsule: Y   Total Fluence:



Data Set(s) Plotted
Plant: V01   Cap.: Y   Material: PLATE SA533B1   Ori.: LT   Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-25	5	12.21	-7.21
0	18	17.8	.19
25	17	25.2	-8.2
25	20	25.2	-5.2
35	39	28.63	10.36
50	44	34.18	9.81
60	31	38.06	-7.06
75	51	43.99	7

***** Data continued on next page *****

Capsule Y

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
100	56	53.52	2.47
125	60	61.81	-1.81
150	62	68.33	-6.33
175	69	73.08	-4.08
225	78	78.51	-.51
275	80	80.77	-.77
300	88	81.32	6.67

SUM of RESIDUALS = -4.68

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:50:47 on 05-08-1998

Page 1

Coefficients of Curve 4

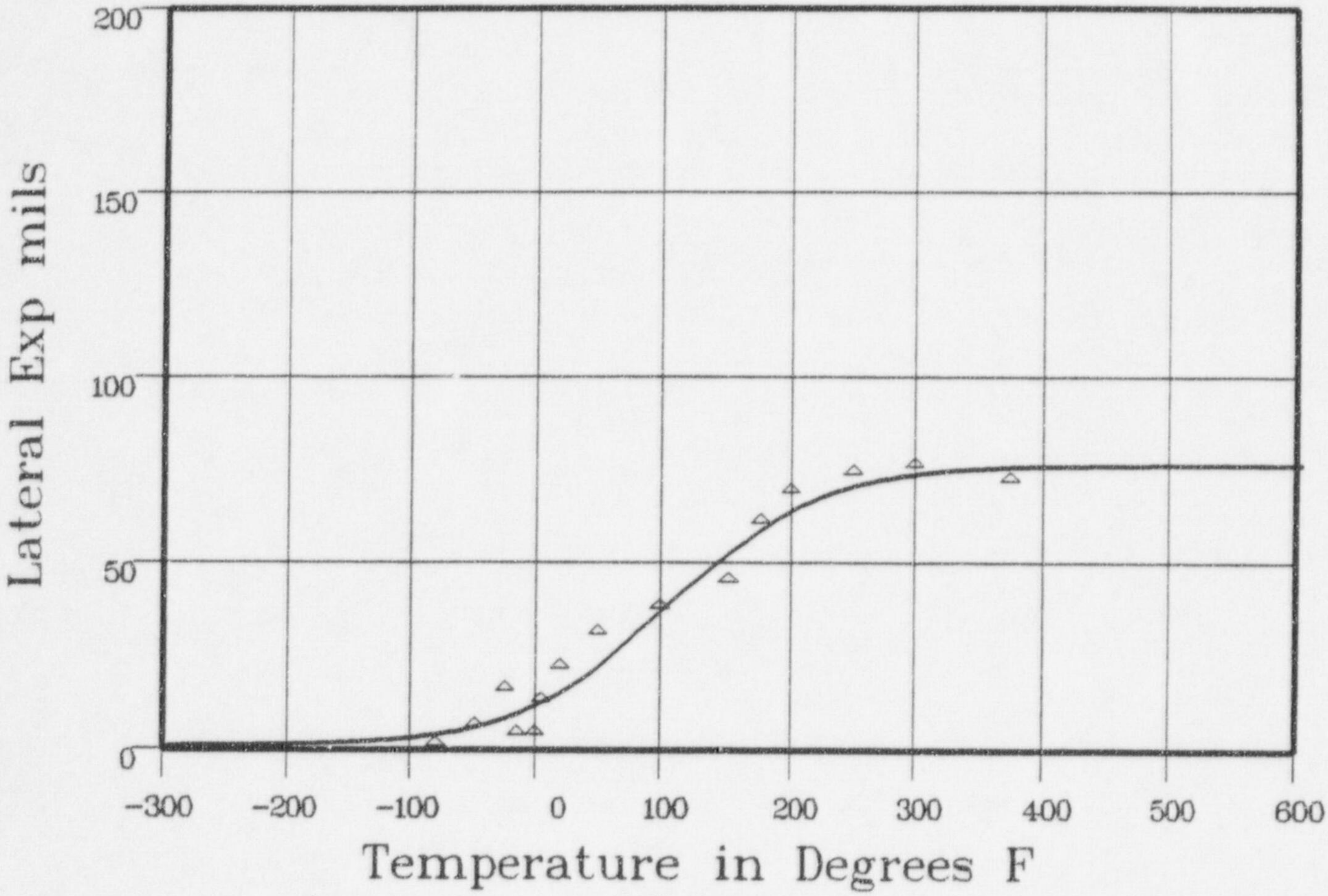
A = 38.74	B = 37.74	C = 117.81	T0 = 100.19

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 76.49 Temperature at L.E. 35: 88.4 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: V Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: V Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-80	1	4.38	-3.38
-50	6	6.46	-.46
-25	16	9.05	6.94
-15	4	10.35	-6.35
0	4	12.65	-8.65
5	13	13.51	-.51
20	22	16.4	5.59

**** Data continued on next page ****

Capsule V

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: V Total Fluence:

Charpy V--Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
50	31	23.57	7.42
100	38	38.68	-.68
150	45	53.82	-8.82
175	61	59.94	1.05
200	69	64.78	4.21
250	74	70.99	3
300	76	74.04	1.95
375	72	75.79	-3.79

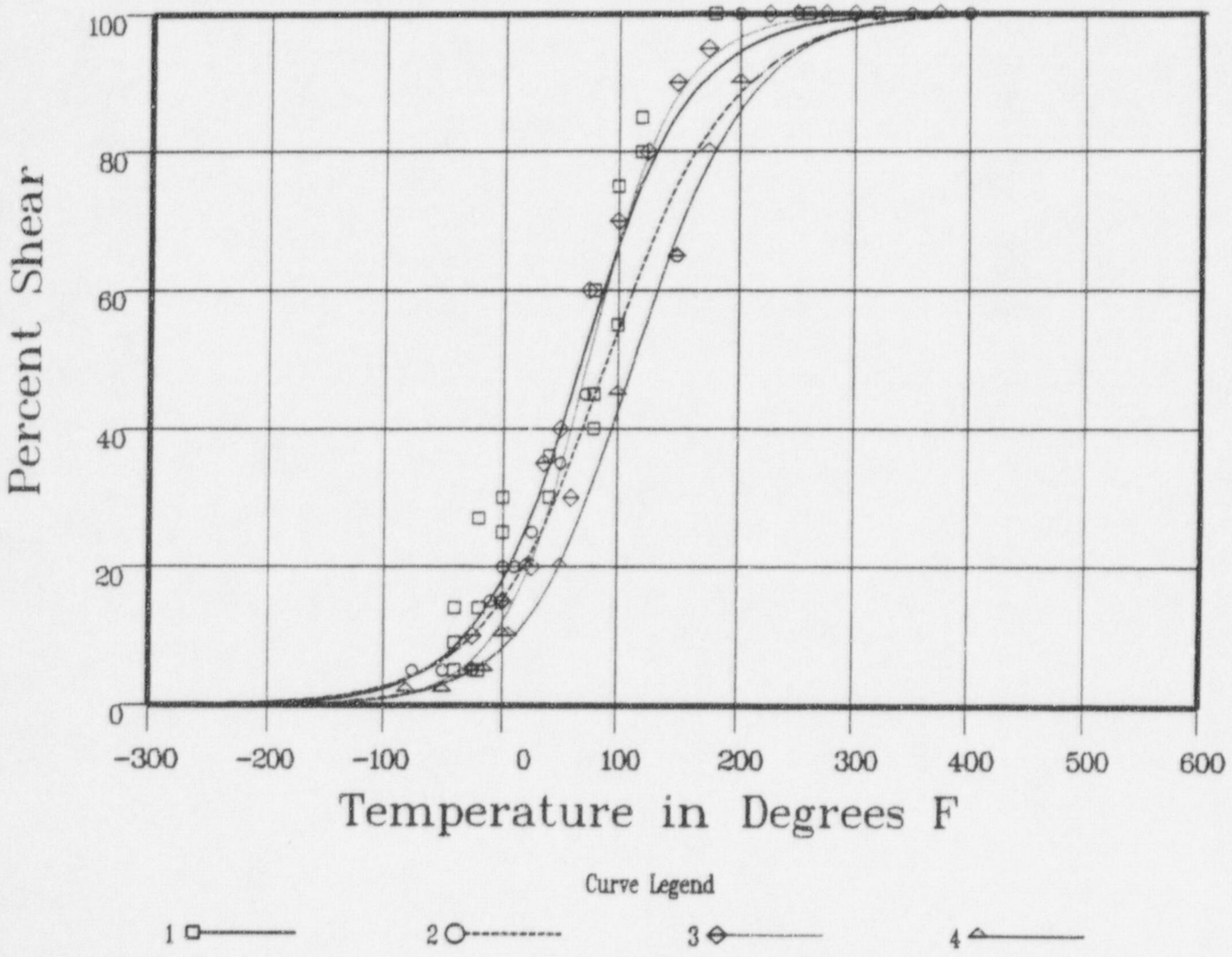
SUM of RESIDUALS = -2.46

Intermediate Shell Plate B8805-3 (Long.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:39:42 on 05-08-1998

Results

Curve	Fluence	T @ 50% Shear	d-T @ 50% Shear
1	0	64.46	0
2	0	86.71	22.24
3	0	70.03	5.56
4	0	109.86	45.39



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:39:42 on 05-08-1998

Page 1

Coefficients of Curve 1

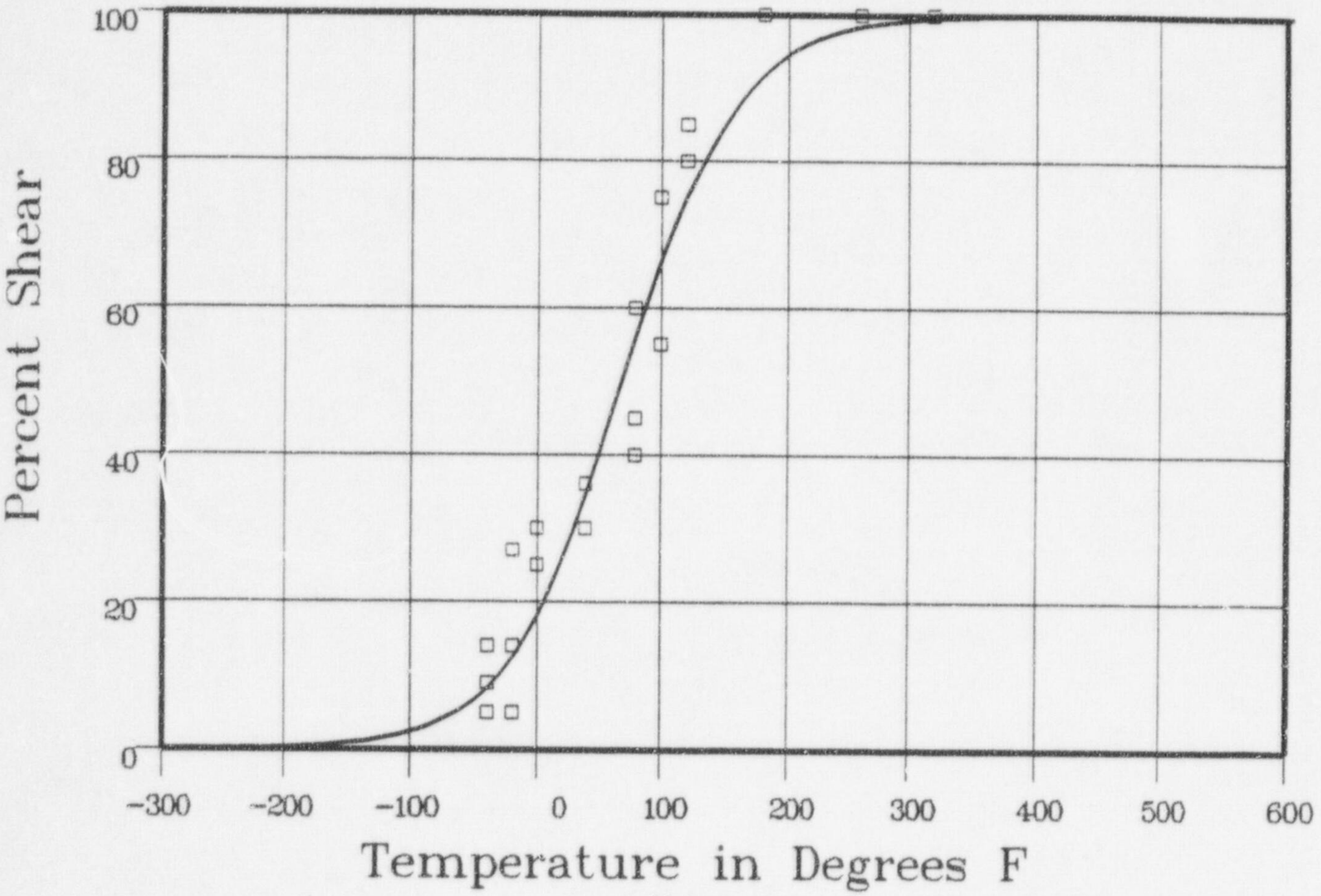
A = 50 B = 50 C = 91.61 T0 = 64.46

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: 64.4

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-40	5	9.27	-4.27
-40	14	9.27	4.72
-40	9	9.27	-.27
-20	27	13.65	13.34
-20	14	13.65	.34
-20	5	13.65	-8.65
0	30	19.66	10.33
0	30	19.66	10.33
0	25	19.66	5.33

**** Data continued on next page ****

Unirradiated

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
40	30	36.95	-6.95
40	36	36.95	-.95
40	36	36.95	-.95
80	60	58.39	1.6
80	45	58.39	-13.39
80	40	58.39	-18.39
100	55	68.47	-13.47
100	75	68.47	6.52
100	75	68.47	6.52
120	80	77.07	2.92
120	85	77.07	7.92
120	85	77.07	7.92
180	100	92.56	7.43
180	100	92.56	7.43
180	100	92.56	7.43
260	100	98.61	1.38
260	100	98.61	1.38
320	100	99.62	.37
320	100	99.62	.37

SUM of RESIDUALS = 36.34

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:39:42 on 05-08-1998

Page 1

Coefficients of Curve 2

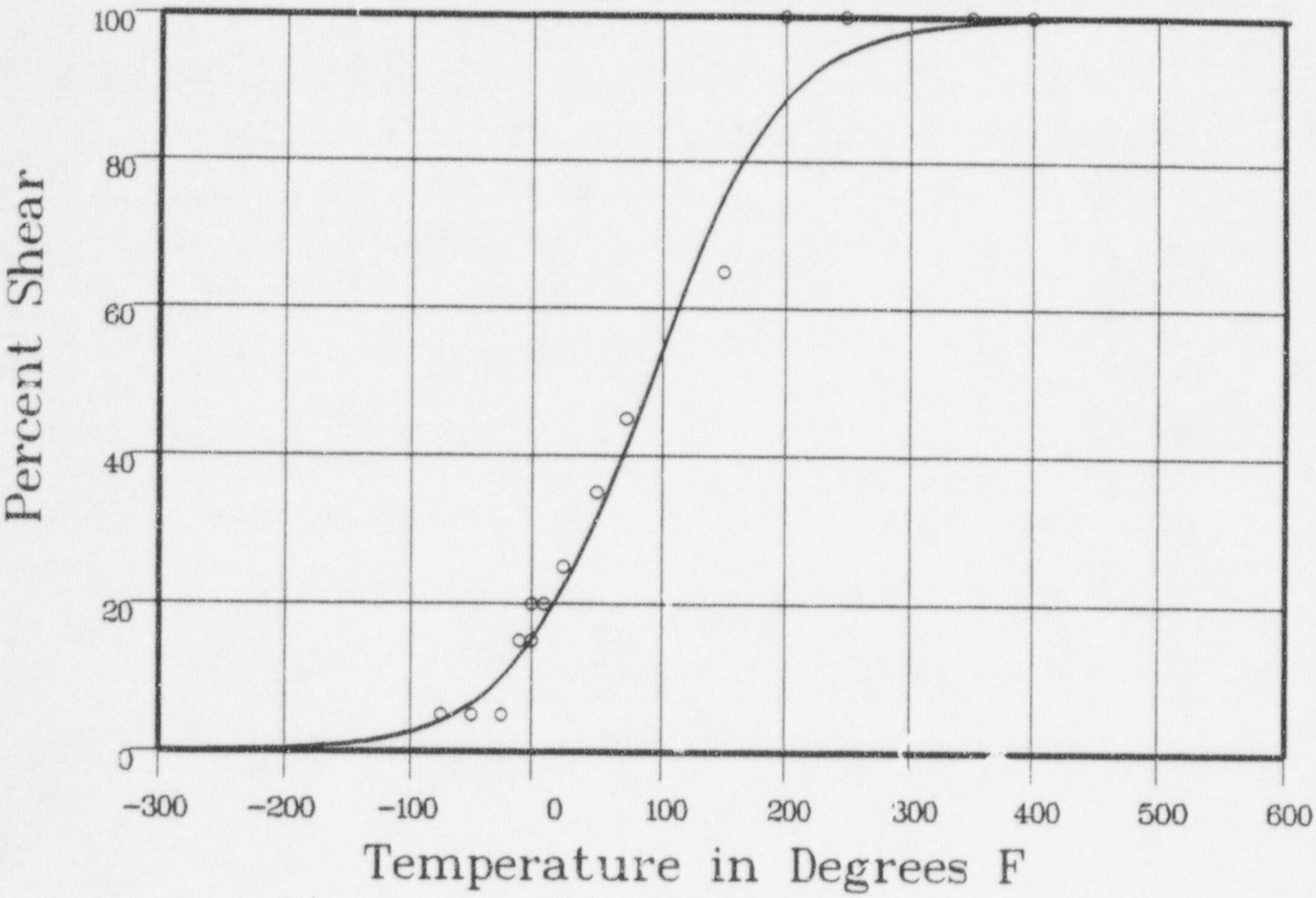
A = 50	B = 50	C = 106.38	T0 = 86.71

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: 86.7

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: U Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75	5	4.56	.43
-50	5	7.1	-2.1
-25	5	10.9	-5.9
-10	15	13.96	1.03
0	15	16.37	-1.37
0	20	16.37	3.62
10	20	19.11	.88
25	25	23.86	1.13

**** Data continued on next page ****

Capsule U

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
50	35	33.39	1.6
72	45	43.12	1.87
150	65	76.66	-11.66
200	100	89.37	10.62
250	100	95.56	4.43
350	100	99.29	.7
400	100	99.72	.27

SUM of RESIDUALS = 5.57

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:39:42 on 05-08-1998
Page 1
Coefficients of Curve 3

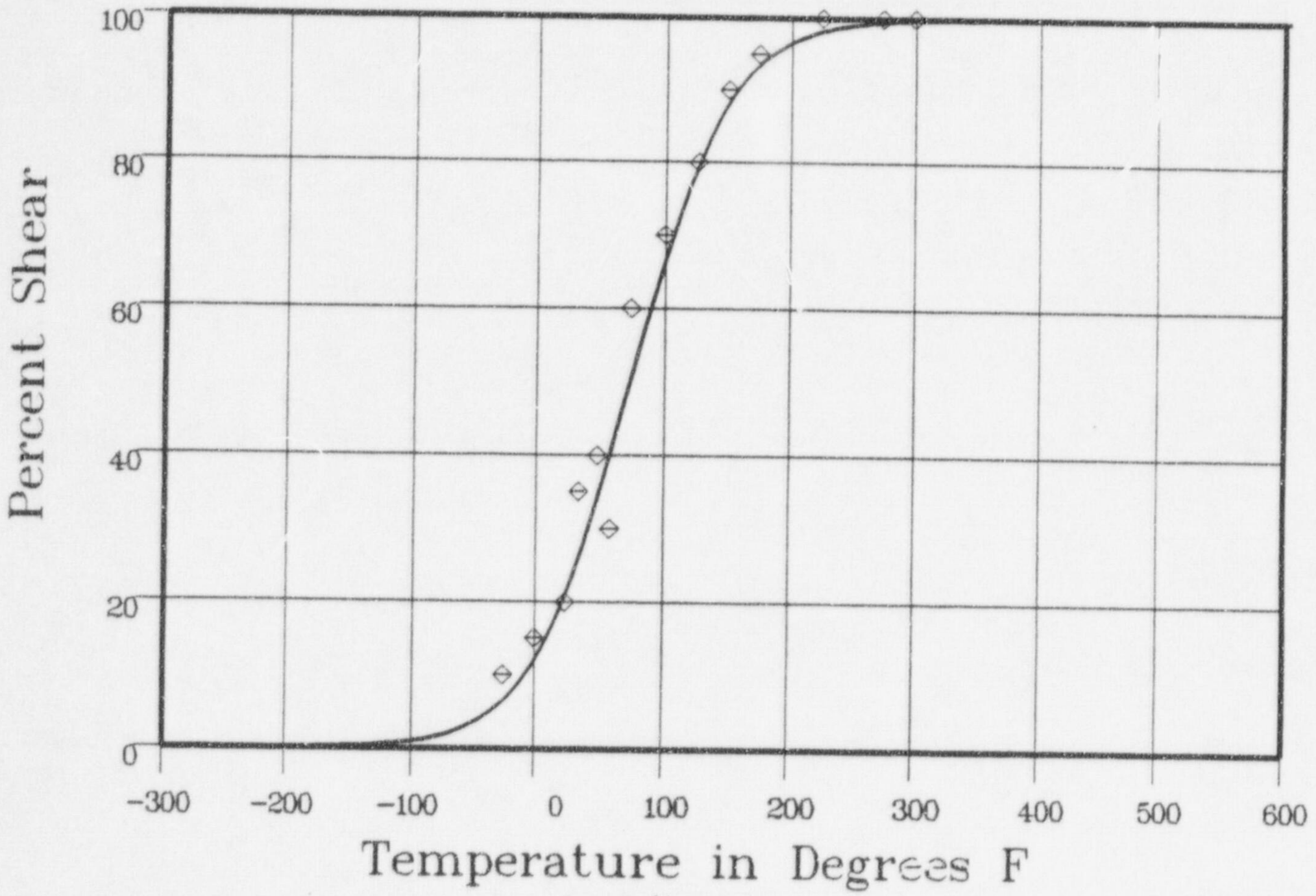
A = 50 B = 50 C = 75.06 T0 = 70.03

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: 70

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: Y Total Fluence:



Data Set(s) Plotted
Plant: V01 Cap.: Y Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-25	10	7.36	2.63
0	15	13.4	1.59
25	20	23.14	-3.14
25	20	23.14	-3.14
35	35	28.22	6.77
50	40	36.96	3.03
60	30	43.35	-13.35
75	60	53.3	6.69

**** Data continued on next page ****

Capsule Y

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
100	70	68.96	1.03
125	80	81.21	-1.21
150	90	89.38	.61
175	95	94.24	.75
225	100	98.41	1.58
275	100	99.57	.42
300	100	99.78	.21

SUM of RESIDUALS = 4.51

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:39:42 on 05-08-1998
Page 1
Coefficients of Curve 4

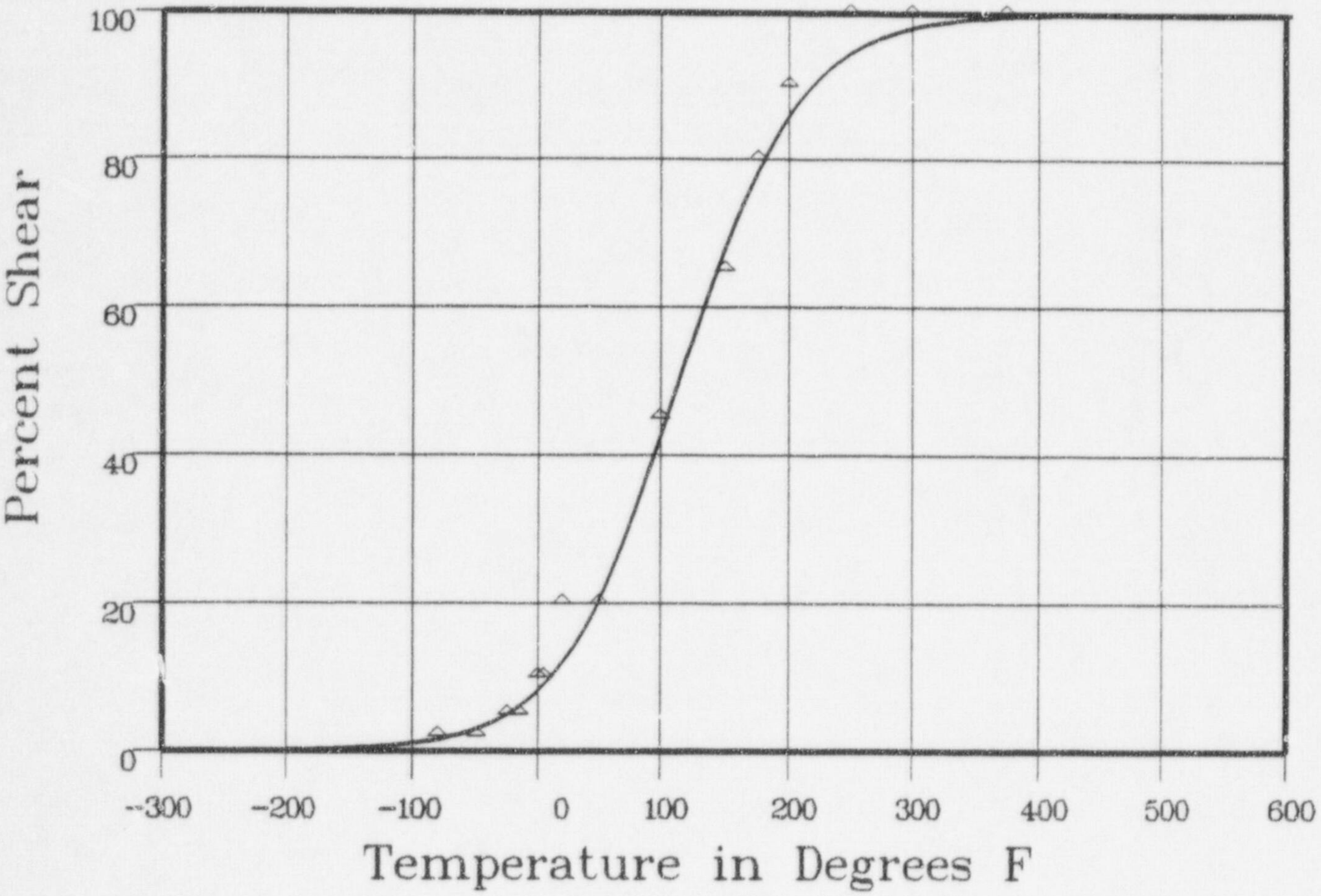
A = 50	B = 50	C = 94.99	T0 = 109.86

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: 109.8

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: V Total Fluence:



Data Set(s) Plotted
Plant: V01 Cap.: V Material: PLATE SA533B1 Ori.: LT Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80	2	1.8	.19
-50	2	3.33	-1.33
-25	5	5.52	-.52
-15	5	6.73	-1.73
0	10	9	.99
5	10	9.9	.09
20	20	13.1	6.89

**** Data continued on next page ****

Capsule V

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: LT

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
50	20	22.09	-2.09
100	45	44.82	.17
150	65	69.95	-4.95
175	80	79.75	.24
200	90	86.96	3.03
250	100	95.02	4.97
300	100	98.2	1.79
375	100	99.62	.37

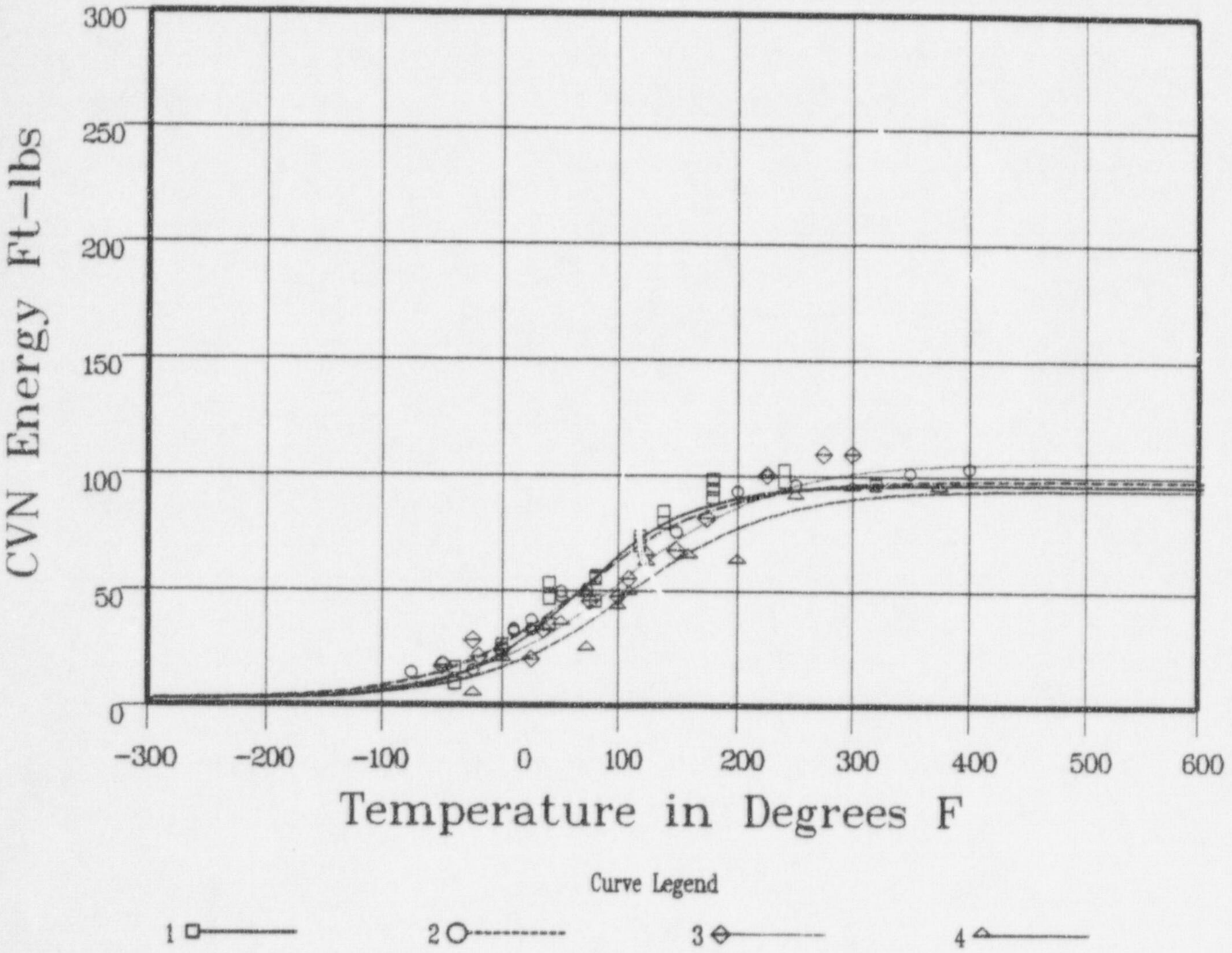
SUM of RESIDUALS = 8.13

Intermediate Shell Plate B8805-3 (Trans.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:59:38 on 05-08-1998

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	96	0	16.72	0	62.41	0
2	0	2.19	0	98	2	7.43	-9.28	62.08	-.32
3	0	2.19	0	106	10	31.92	15.19	88.7	26.29
4	0	2.19	0	94	-2	50.51	33.79	108.35	45.94



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:59:38 on 05-08-1998
Page 1
Coefficients of Curve 1

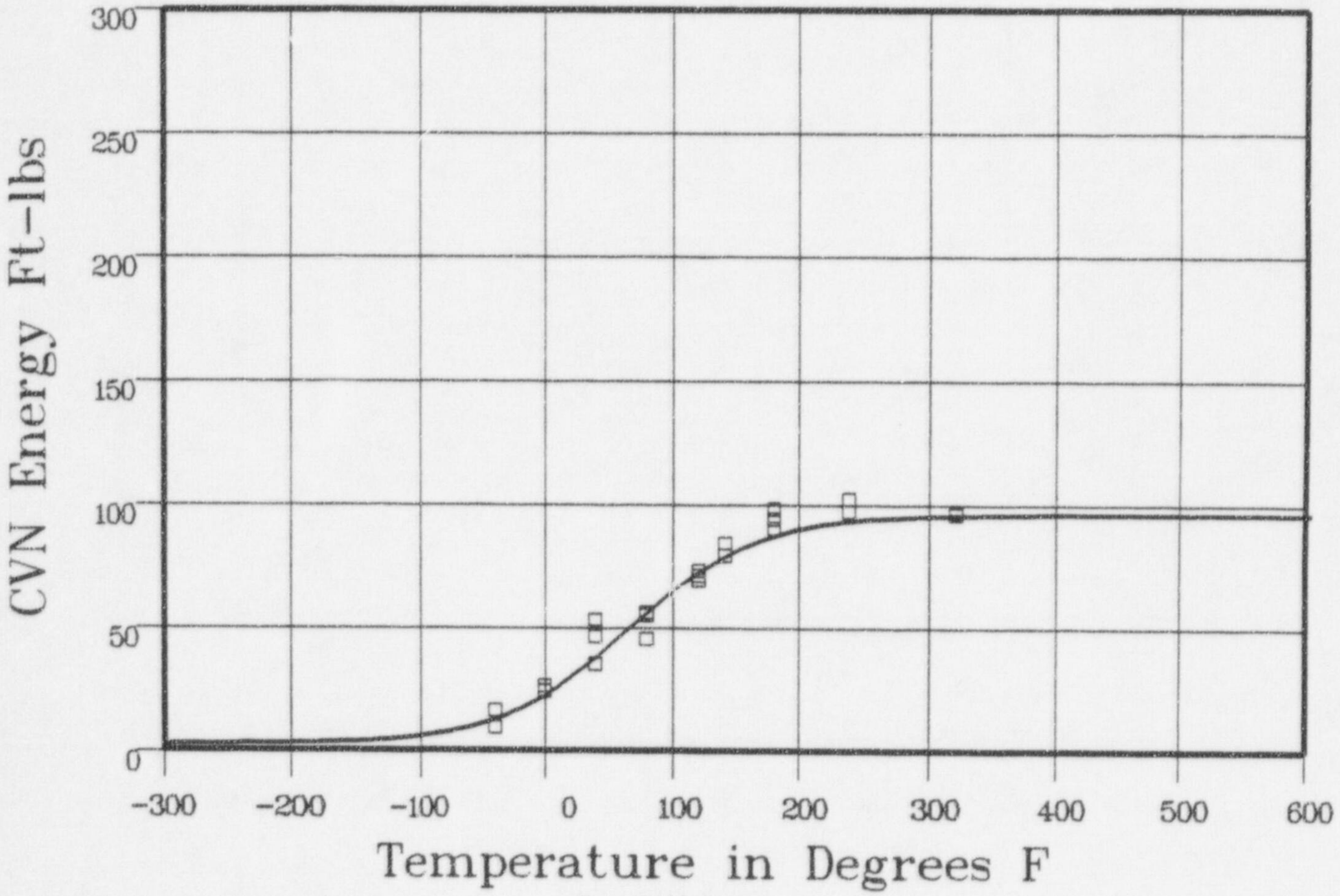
A = 49.09	B = 46.9	C = 101.19	T0 = 60.46

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 96 Fixed Temp. at 30 ft-lbs: 16.7 Temp. at 50 ft-lbs: 62.4 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted
Plant: V01 Cap.: UNIRR Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-40	9	13.52	-4.52
-40	16	13.52	2.47
0	26	23.99	2
0	24	23.99	0
0	24	23.99	0
40	35	39.74	-4.74
40	46	39.74	6.25
40	53	39.74	13.25
80	55	58.04	-3.04

**** Data continued on next page ****

Unirradiated

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
80	45	58.04	-13.04
80	56	58.04	-2.04
120	69	73.89	-4.89
120	73	73.89	-.89
120	71	73.89	-2.89
140	84	79.87	4.12
140	79	79.87	-.87
180	94	87.92	6.07
180	98	87.92	10.07
180	90	87.92	2.07
240	97	93.37	3.62
240	102	93.37	8.62
320	97	95.44	1.55
320	96	95.44	.55

SUM of RESIDUALS = 23.77

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:59:38 on 05-08-1998

Page 1

Coefficients of Curve 2

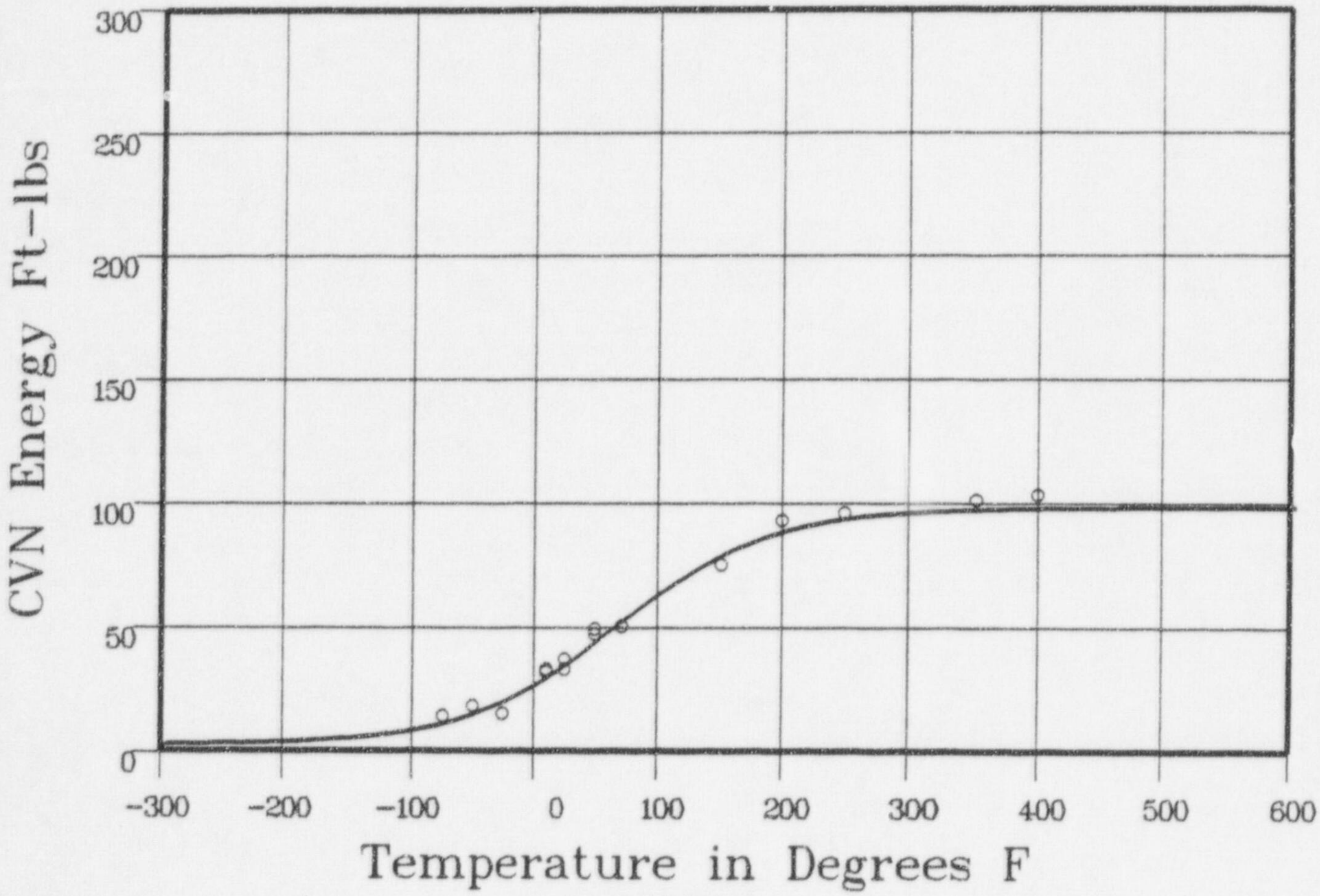
A = 50.09 B = 47.9 C = 122.77 T0 = 62.34

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 98 Fixed Temp. at 30 ft-lbs: 7.4 Temp. at 50 ft-lbs: 62 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: U Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-75	14	11.43	2.56
-50	18	15.44	2.55
-25	15	20.8	-5.8
10	32	30.83	1.16
10	33	30.83	2.16
25	37	35.96	1.03
25	33	35.96	-2.96
50	49	45.3	3.69

**** Data continued on next page ****

Capsule U

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
50	47	45.3	1.69
72	50	53.85	-3.85
150	75	79.47	-4.47
200	93	88.8	4.19
250	96	93.69	2.3
350	101	97.12	3.87
400	103	97.61	5.38

SUM of RESIDUALS = 13.55

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:59:38 on 05-08-1998

Page 1

Coefficients of Curve 3

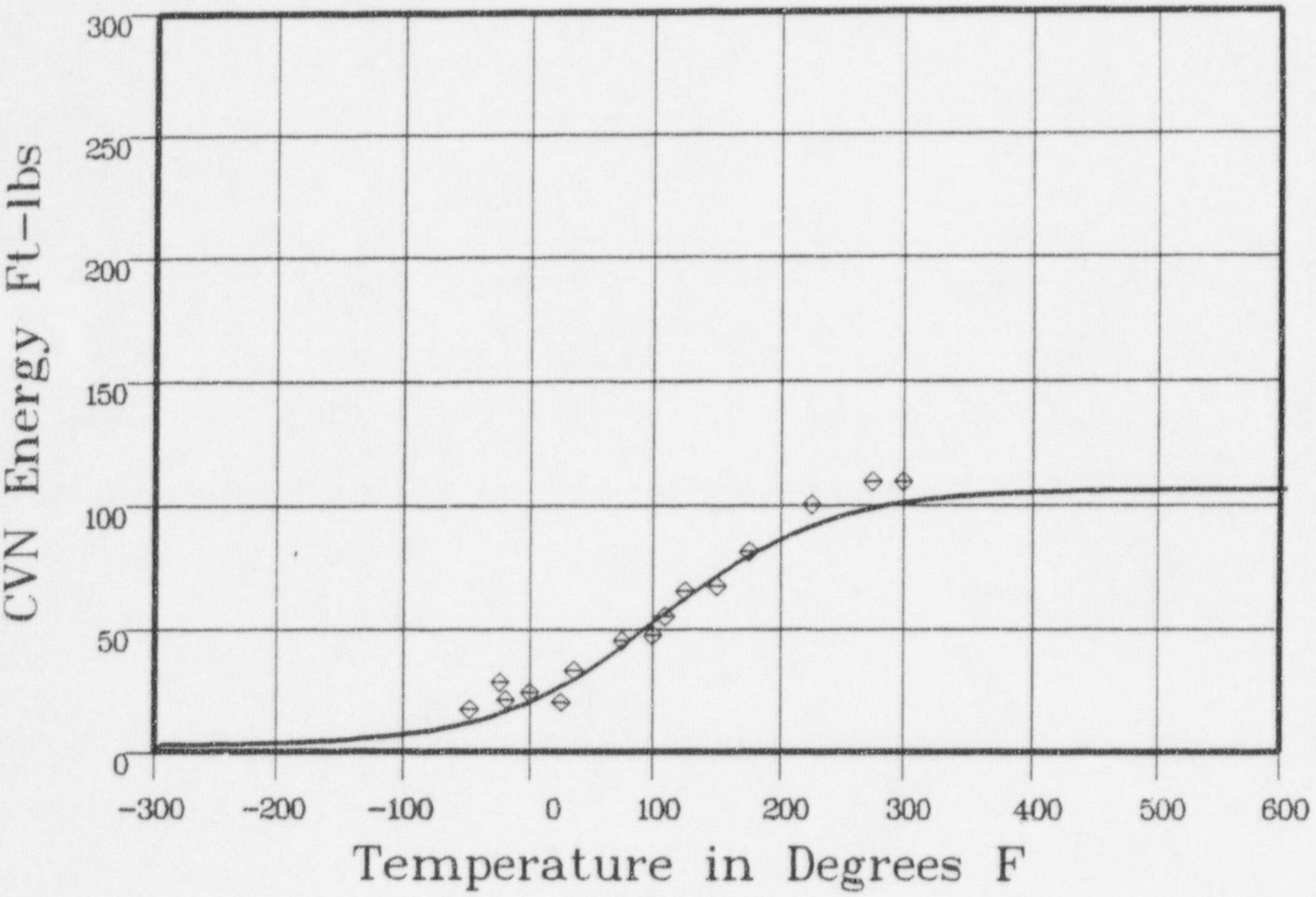
A = 54.09	B = 51.9	C = 134.02	T0 = 99.31

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 106 Fixed Temp. at 30 ft-lbs: 31.9 Temp. at 50 ft-lbs: 88.7 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-50	17	12.29	4.7
-25	28	16.24	11.75
-20	21	17.17	3.82
0	24	21.41	2.58
25	20	27.94	-7.94
35	33	30.94	2.05
75	45	44.78	.21
100	47	54.36	-7.36

**** Data continued on next page ****

Capsule Y

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
110	55	58.22	-3.22
125	65	63.92	1.07
150	67	72.84	-5.84
175	81	80.64	.35
225	100	92.2	7.79
275	109	98.96	10.03
300	109	101.05	7.94

SUM of RESIDUALS = 27.96

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 12:59:38 on 05-08-1998

Page 1

Coefficients of Curve 4

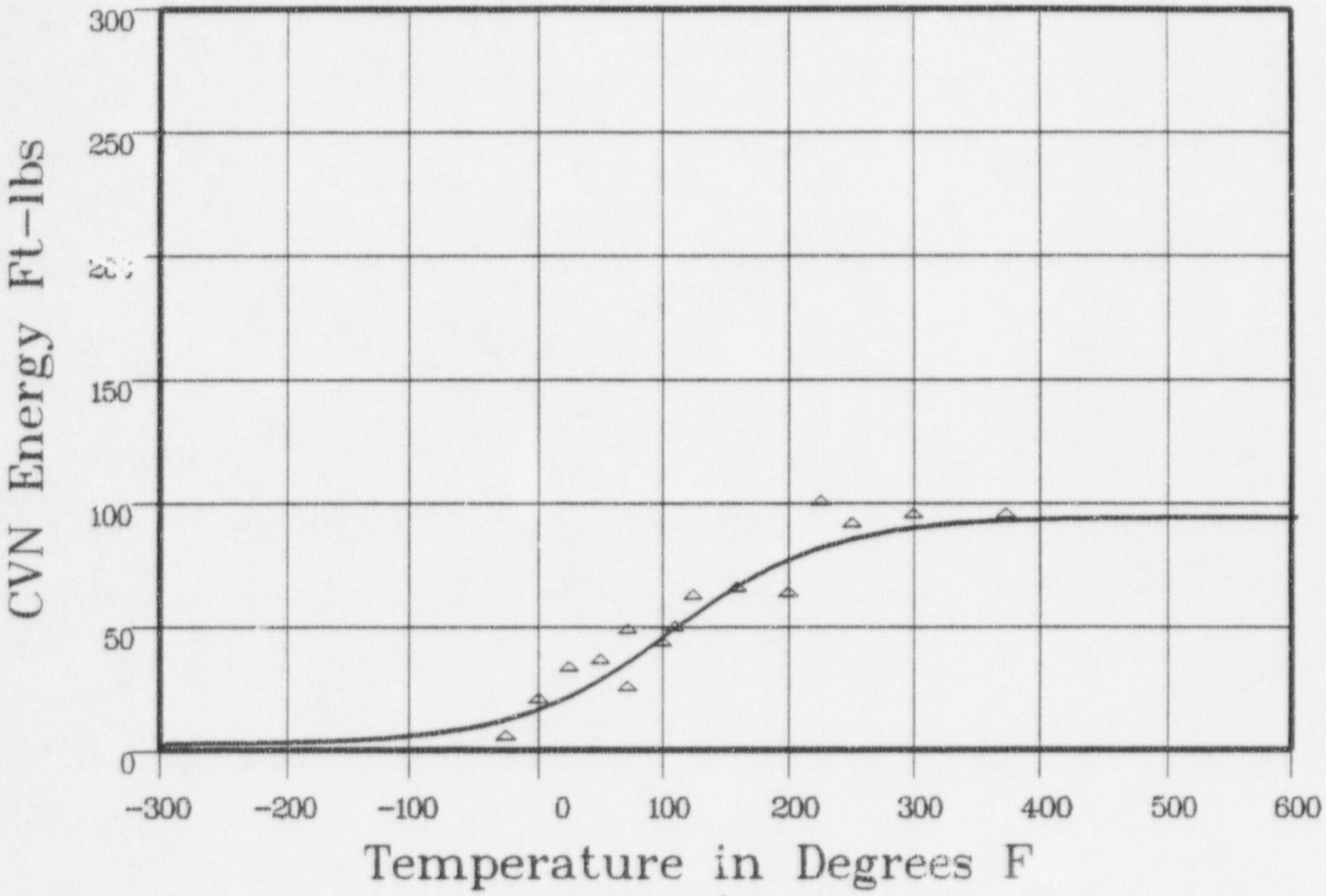
A = 48.09	B = 45.9	C = 126.17	T0 = 103.12

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 94 Fixed Temp. at 30 ft-lbs: 50.5 Temp. at 50 ft-lbs: 108.3 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: V Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: V Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-25	4	12.84	-8.84
0	19	17.18	1.81
25	32	22.83	9.16
50	35	29.84	5.15
72	47	37	9.99
72	24	37	-13
100	42	46.96	-4.96

**** Data continued on next page ****

Capsule V

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
110	48	50.59	-2.59
125	61	55.97	5.02
160	64	67.49	-3.49
200	62	77.73	-15.73
225	99	82.38	16.61
250	90	85.84	4.15
300	94	90.11	3.88
375	94	92.78	1.21

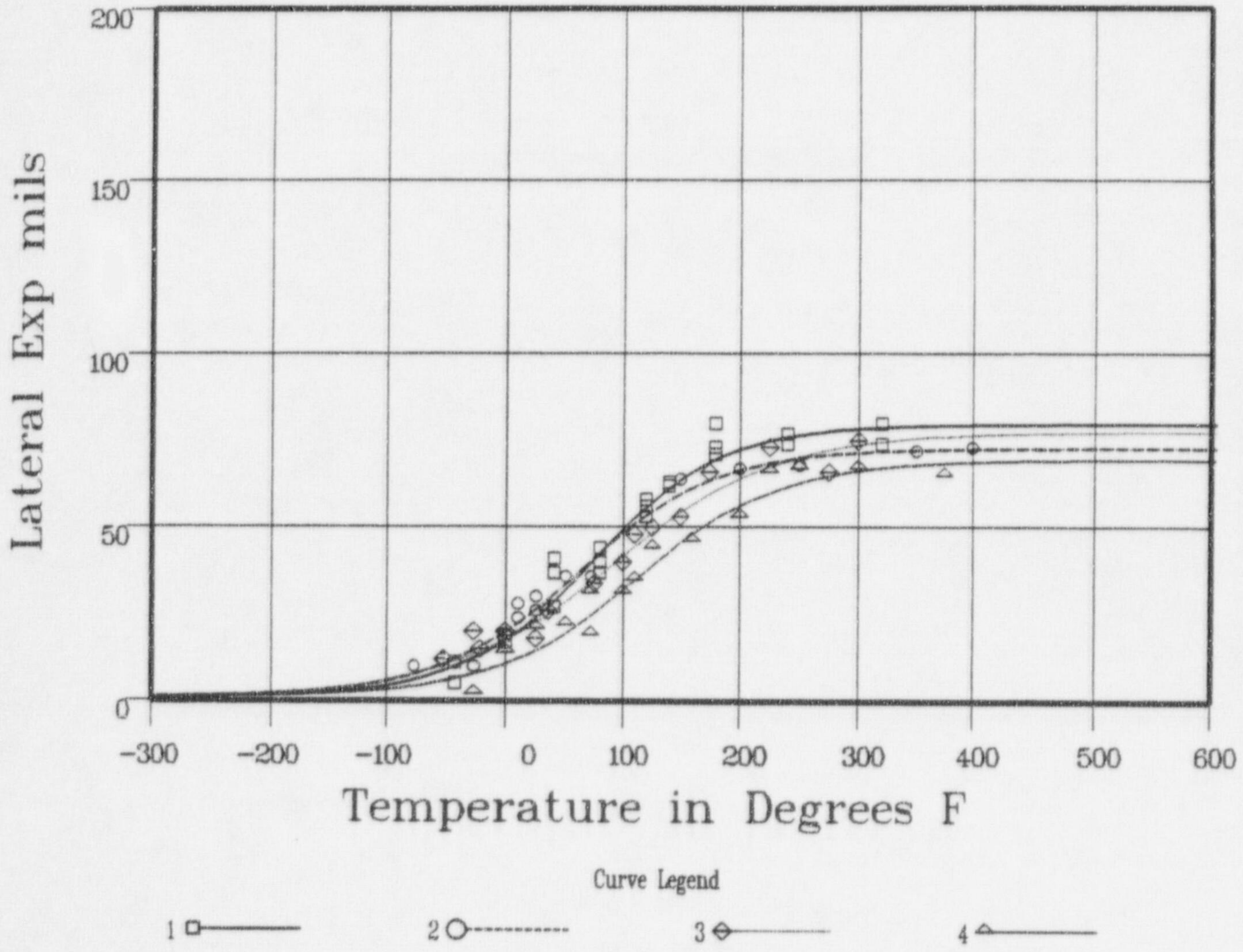
SUM of RESIDUALS = 8.39

Intermediate Shell Plate B8805-3 (Trans.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 13:44:08 on 05-08-1998

Results

Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	79.81	0	54.01	0
2	0	72.73	-7.08	49.65	-4.35
3	0	77.56	-2.24	70.32	16.31
4	0	69.46	-10.34	105.8	51.78



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 13:44:08 on 05-08-1998

Page 1

Coefficients of Curve 1

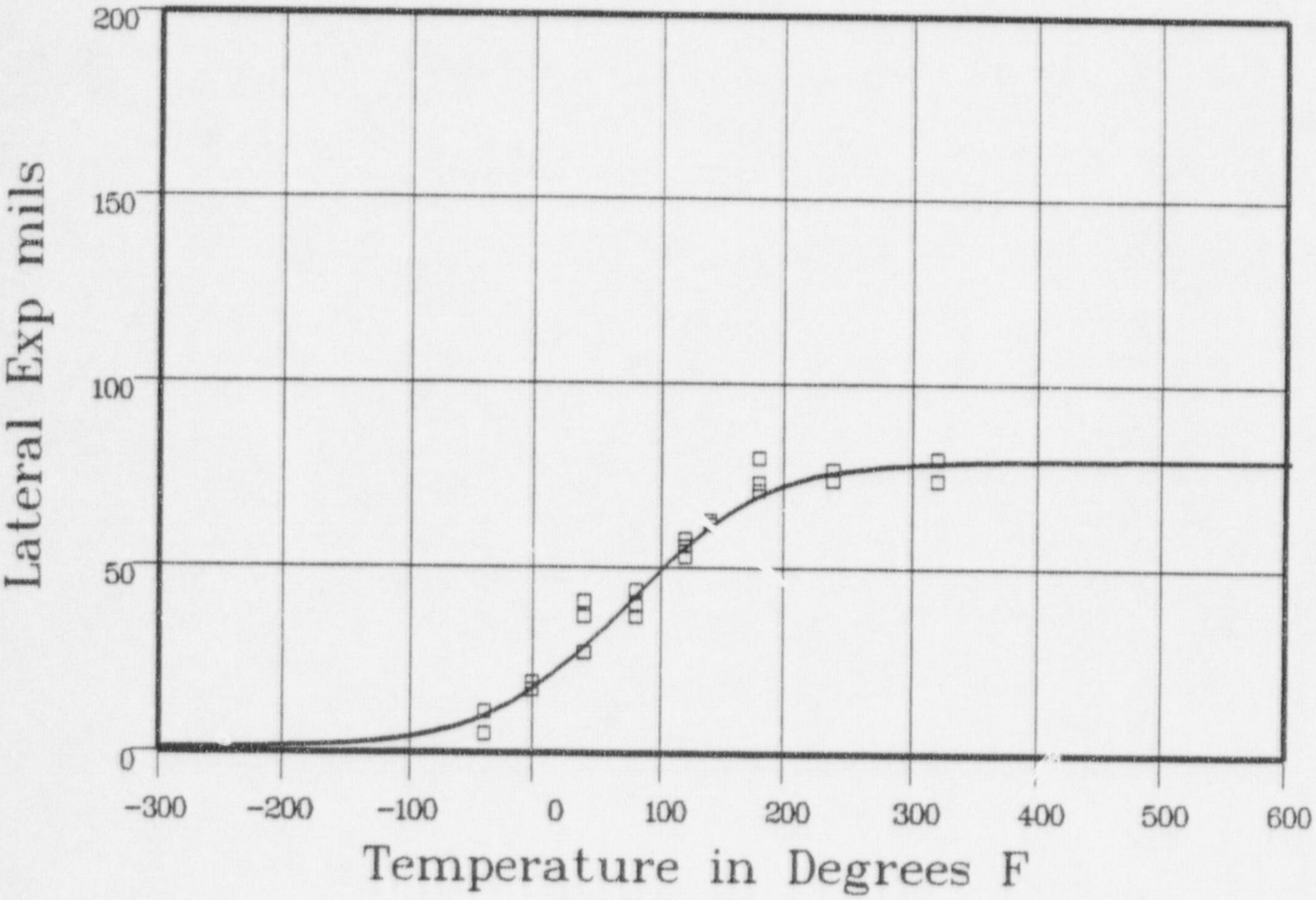
A = 40.4	B = 39.4	C = 111.28	T0 = 69.37

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 79.81 Temperature at L.E. 35: 54 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-40	5	10.68	-5.68
-40	11	10.68	.31
0	19	18.59	.4
0	17	18.59	-1.59
0	19	18.59	.4
40	27	30.23	-3.23
40	37	30.23	6.76
40	41	30.23	10.76
80	40	44.15	-4.15

**** Data continued on next page ****

Unirradiated

Page 2

Material: PLATE SA533B1　　Heat Number: CODE B8805-3 (HT:C0623-1)　　Orientation: TL

Capsule: UNIRR　　Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
80	37	44.15	-7.15
80	44	44.15	-.15
120	53	57.18	-4.18
120	56	57.18	-1.18
120	58	57.18	.81
140	63	62.52	.47
140	62	62.52	-.52
180	73	70.31	2.68
180	71	70.31	.68
180	80	70.31	9.68
240	77	76.3	.69
240	74	76.3	-2.3
320	80	78.94	1.05
320	74	78.94	-4.94

SUM of RESIDUALS = -.4

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 13:44:08 on 05-08-1998
Page 1
Coefficients of Curve 2

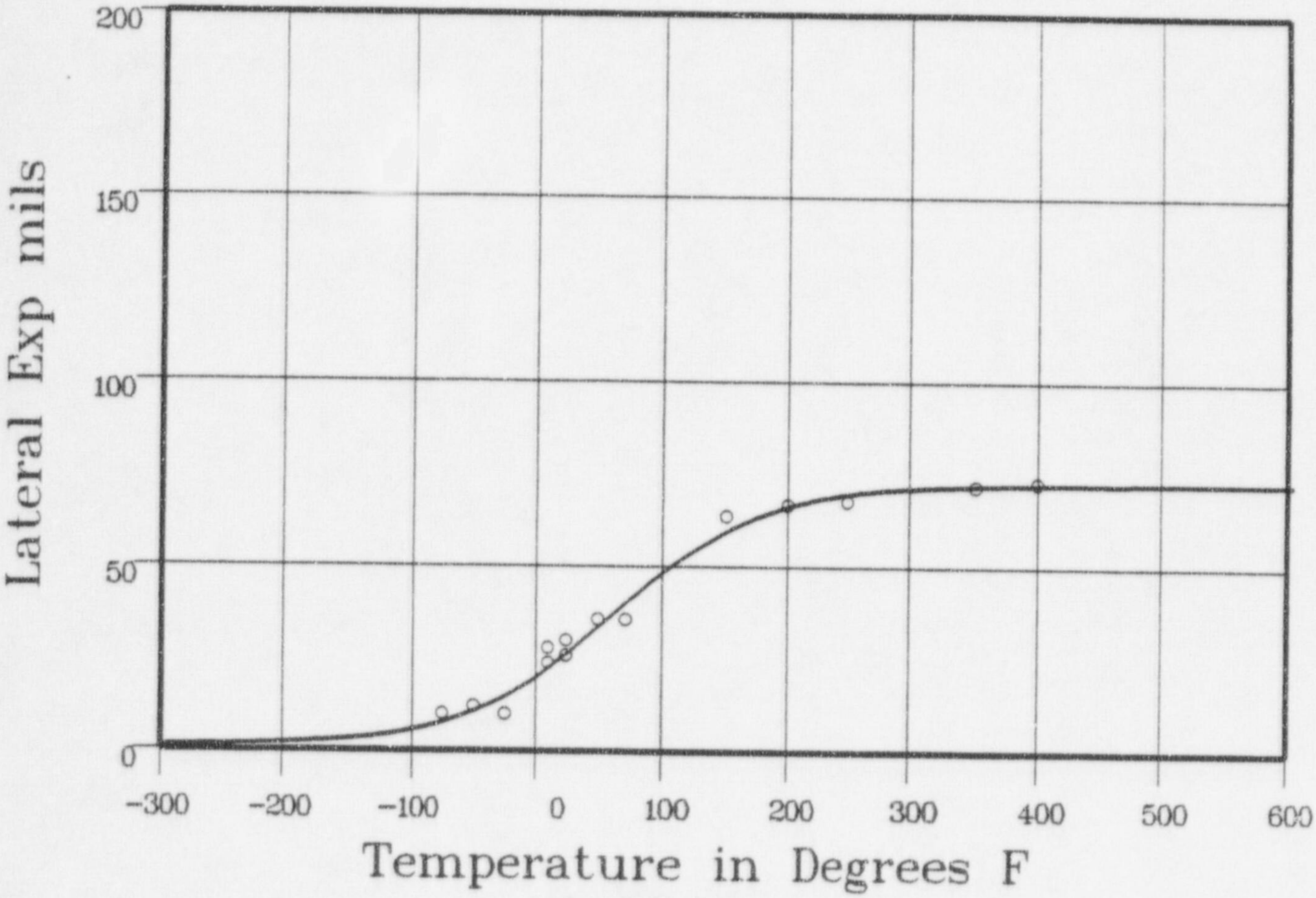
A = 36.86	B = 35.86	C = 118.88	T0 = 55.84

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 72.73 Temperature at L.E. 35: 49.6 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: U Total Fluence:



Data Set(s) Plotted
Plant: V01 Cap.: U Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-75	10	8.14	1.85
-50	12	11.34	.65
-25	10	15.64	-5.64
10	28	23.68	4.31
10	24	23.68	.31
25	30	27.76	2.23
25	26	27.76	-1.76
50	36	35.1	.89

**** Data continued on next page ****

Capsule U

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
50	36	35.1	.89
72	36	41.7	-5.7
150	64	60.51	3.48
200	67	66.89	.1
250	68	70.09	-2.09
350	72	72.22	-.22
400	73	72.51	.48

SUM of RESIDUALS = -.19

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 13:44:08 on 05-08-1998

Page 1

Coefficients of Curve 3

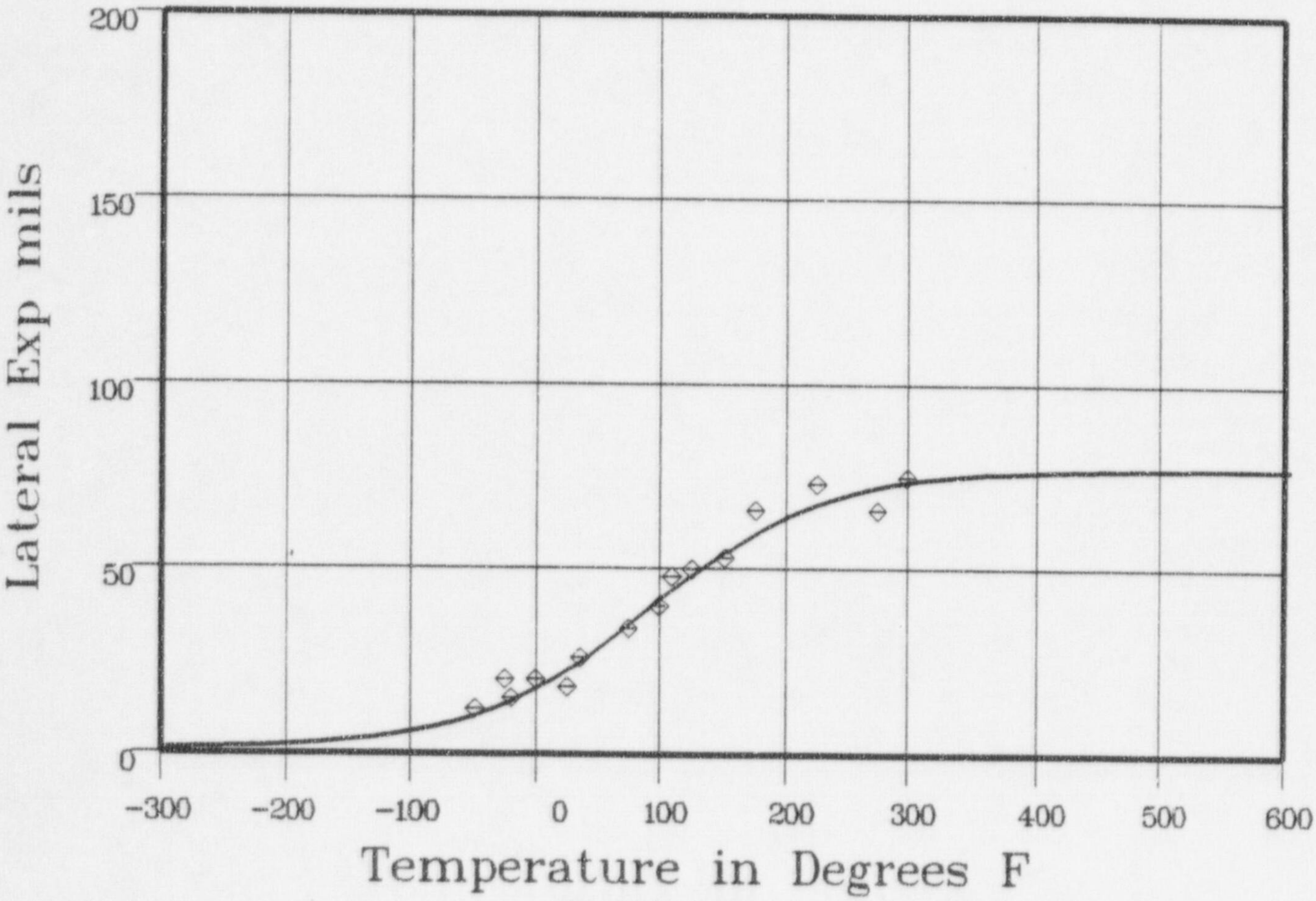
A = 39.28	B = 38.28	C = 141.81	T0 = 86.25

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 77.56 Temperature at L.E. 35: 70.3 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-50	12	10.77	1.22
-25	20	14.19	5.8
-20	15	14.98	.01
0	20	18.5	1.49
25	18	23.7	-5.7
35	26	26.01	-.01
75	34	36.25	-2.25
100	40	42.98	-2.98

**** Data continued on next page ****

Capsule Y

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
110	48	45.63	2.36
125	50	49.48	.51
150	53	55.41	-2.41
175	66	60.53	5.46
225	73	68.08	4.91
275	66	72.56	-6.56
300	75	73.98	1.01

SUM of RESIDUALS = 2.88

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 13:44:08 on 05-08-1998

Page 1

Coefficients of Curve 4

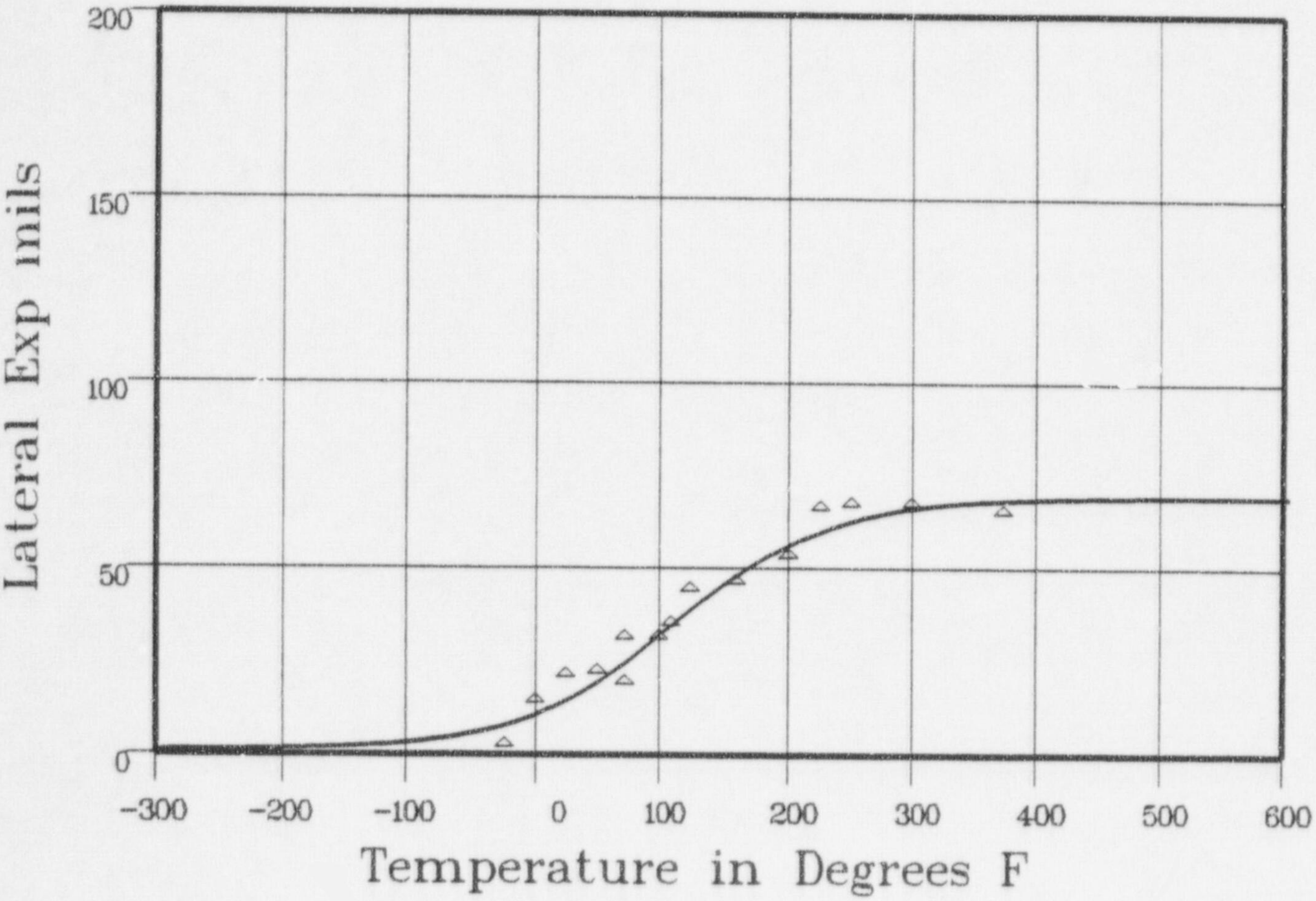
A = 35.23	B = 34.23	C = 123.89	T0 = 106.64

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 69.46 Temperature at L.E. 35: 105.8 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: V Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: V Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT/.0623-1)

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-25	2	8.3	-6.3
0	14	11.38	2.61
25	21	15.45	5.54
50	22	20.58	1.41
72	31	25.9	5.09
72	19	25.9	-6.9
100	31	33.39	-2.39

**** Data continued on next page ****

Capsule V

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
110	35	36.15	-1.15
125	44	40.26	3.73
160	46	49.12	-3.12
200	53	57.04	-4.04
225	66	60.63	5.36
250	67	63.3	3.69
300	67	66.57	.42
375	65	68.57	-3.57

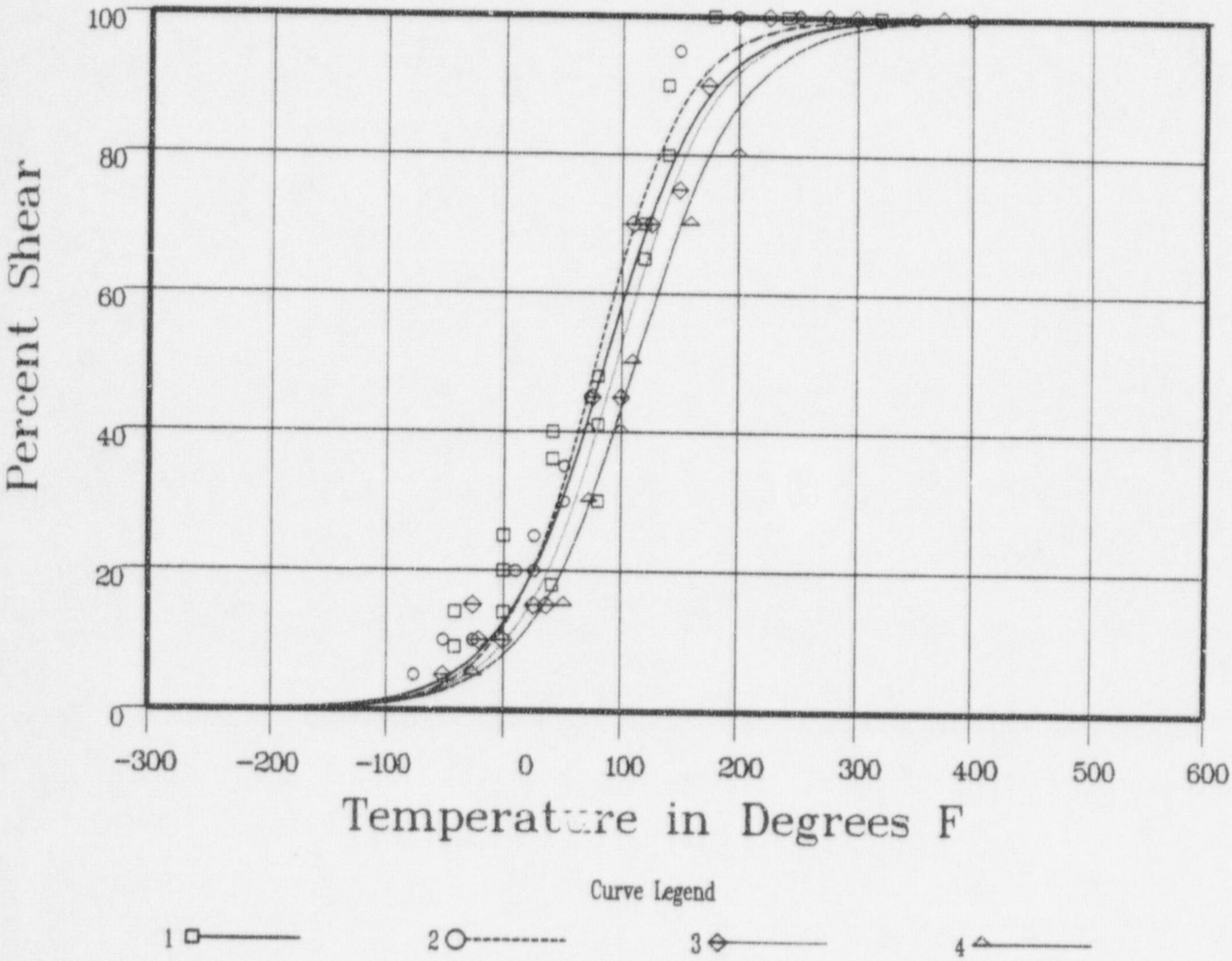
SUM of RESIDUALS = .37

Intermediate Shell Plate B8805-3 (Trans.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:07:11 on 05-08-1998

Results

Curve	Fluence	T @ 50% Shear	d-T @ 50% Shear
1	0	80.77	0
2	0	73.24	-7.52
3	0	91.11	10.33
4	0	107.51	26.74



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	PLATE SA533B1		B8805-3 (HT.C0623-1)
2	V01	U	PLATE SA533B1		B8805-3 (HT.C0623-1)
3	V01	Y	PLATE SA533B1		B8805-3 (HT.C0623-1)
4	V01	V	PLATE SA533B1		B8805-3 (HT.C0623-1)

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:07:11 on 05-08-1998
Page 1
Coefficients of Curve 1

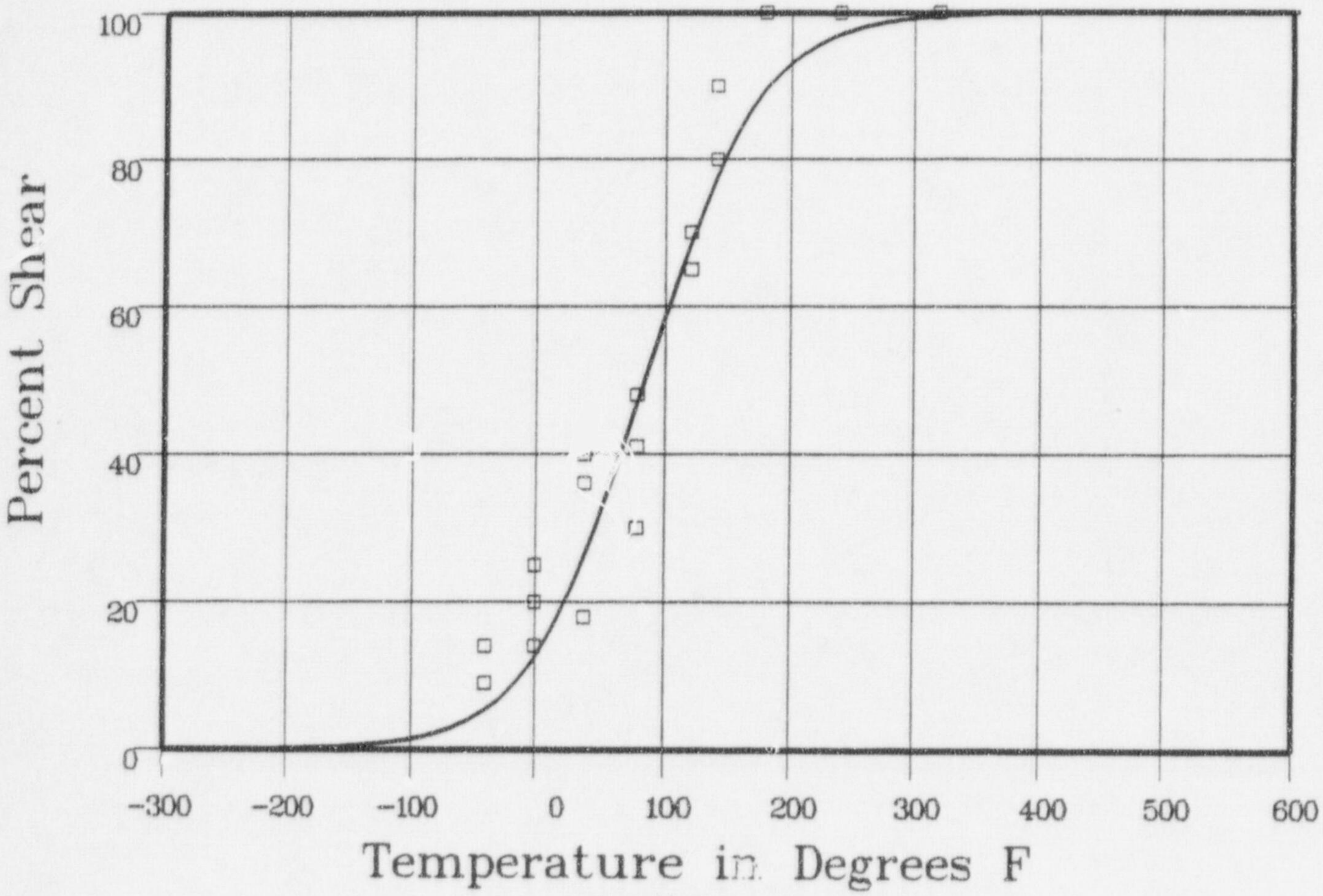
A = 50	B = 50	C = 87.93	T0 = 80.77

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: 80.7

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-40	9	6.02	2.97
-40	14	6.02	7.97
0	20	13.73	6.26
0	14	13.73	.26
0	25	13.73	11.26
40	18	28.34	-10.34
40	36	28.34	7.65
40	40	28.34	11.65
80	30	49.55	-19.55

**** Data continued on next page ****

Unirradiated

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
80	41	49.55	-8.55
80	48	49.55	-1.55
120	65	70.93	-5.93
120	70	70.93	-.93
120	70	70.93	-.93
140	90	79.36	10.63
140	80	79.36	.63
180	100	90.52	9.47
180	100	90.52	9.47
180	100	90.52	9.47
240	100	97.39	2.6
240	100	97.39	2.6
320	100	99.56	.43
320	100	99.56	.43

SUM of RESIDUALS = 46

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:07:11 on 05-08-1998
Page 1
Coefficients of Curve 2

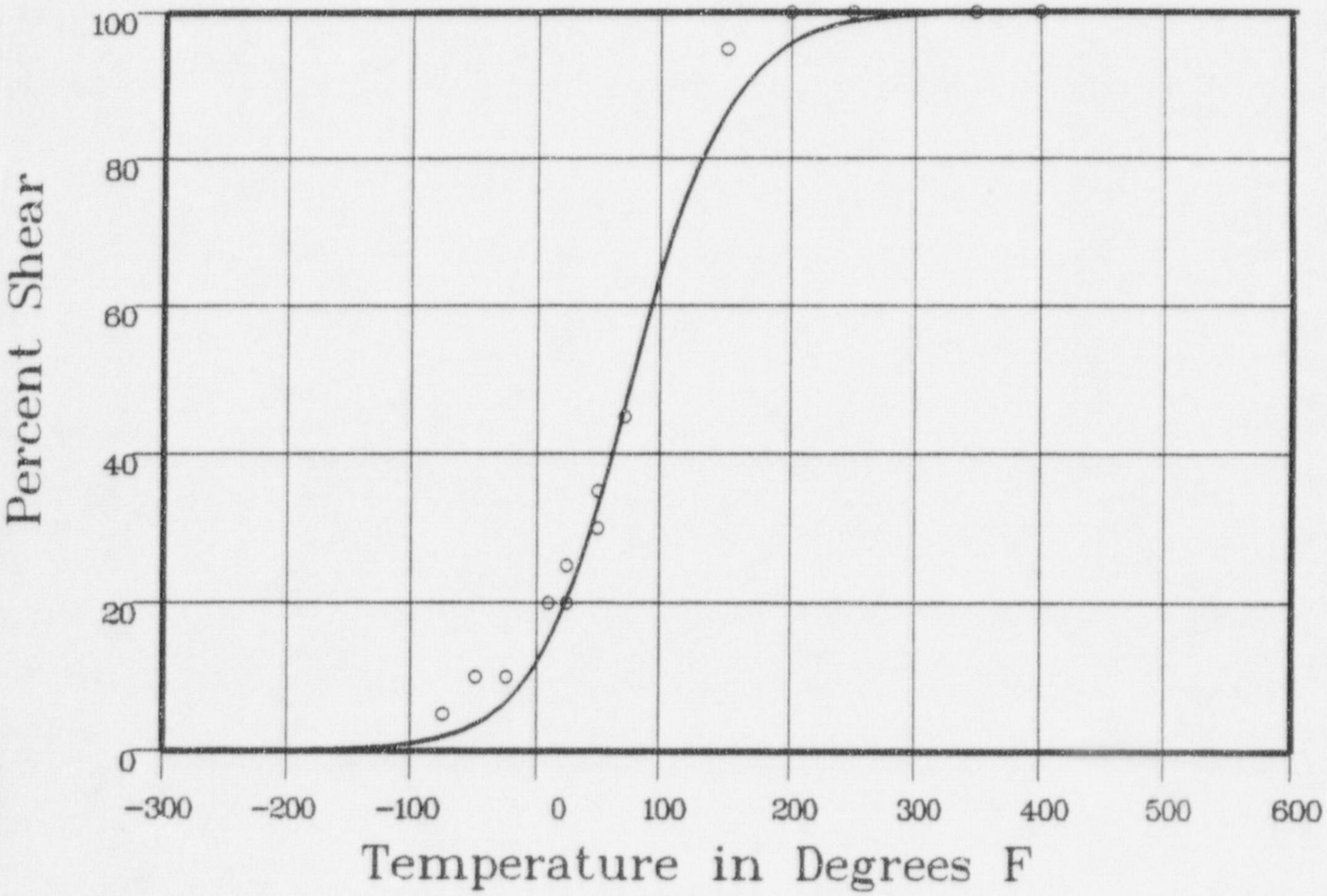
A = 50	B = 50	C = 77.97	T0 = 73.24

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: 73.2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: U Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75	5	2.18	2.81
-50	10	4.06	5.93
-25	10	7.44	2.55
10	20	16.48	3.51
10	20	16.48	3.51
25	25	22.48	2.51
25	20	22.48	-2.48
50	35	35.51	-.51

**** Data continued on next page ****

Capsule U

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
50	30	35.51	-5.51
72	45	49.19	-4.19
150	95	87.74	7.25
200	100	96.27	3.72
250	100	98.93	1.06
350	100	99.91	.08
400	100	99.97	.02

SUM of RESIDUALS = 20.26

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:07:11 on 05-08-1998

Page 1

Coefficients of Curve 3

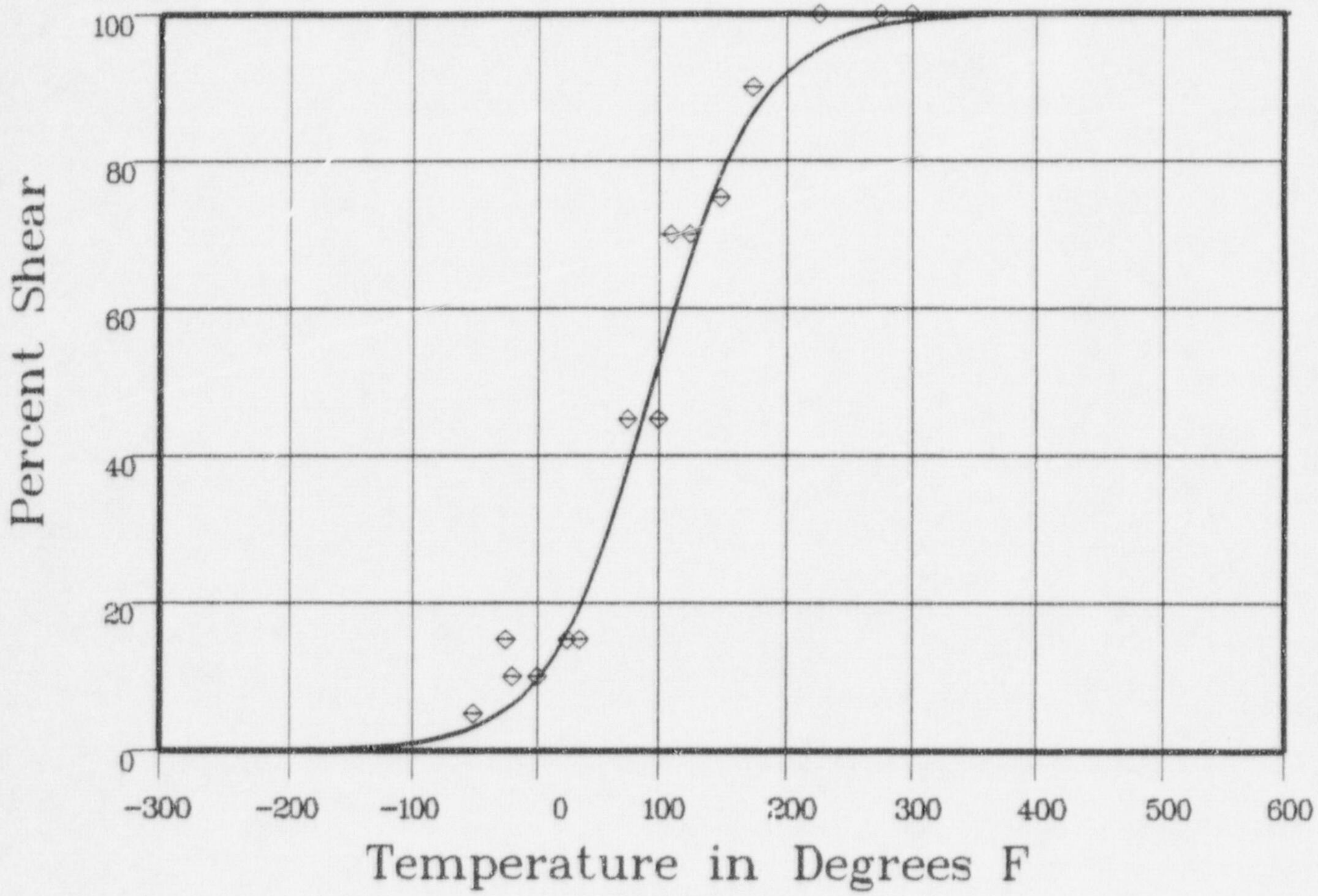
A = 50	B = 50	C = 85.43	T0 = 91.11

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: 91.1

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50	5	3.54	1.45
-25	15	6.19	8.8
-20	10	6.9	3.09
0	10	10.59	-.59
25	15	17.54	-2.54
35	15	21.18	-6.18
75	45	40.67	4.32
100	45	55.18	-10.18

**** Data continued on next page ****

Capsule Y

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
110	70	60.87	9.12
125	70	68.85	1.14
150	75	79.87	-4.87
175	90	87.69	2.3
225	100	95.82	4.17
275	100	98.66	1.33
300	100	99.25	.74

SUM of RESIDUALS = 12.12

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:07:11 on 05-08-1998

Page 1

Coefficients of Curve 4

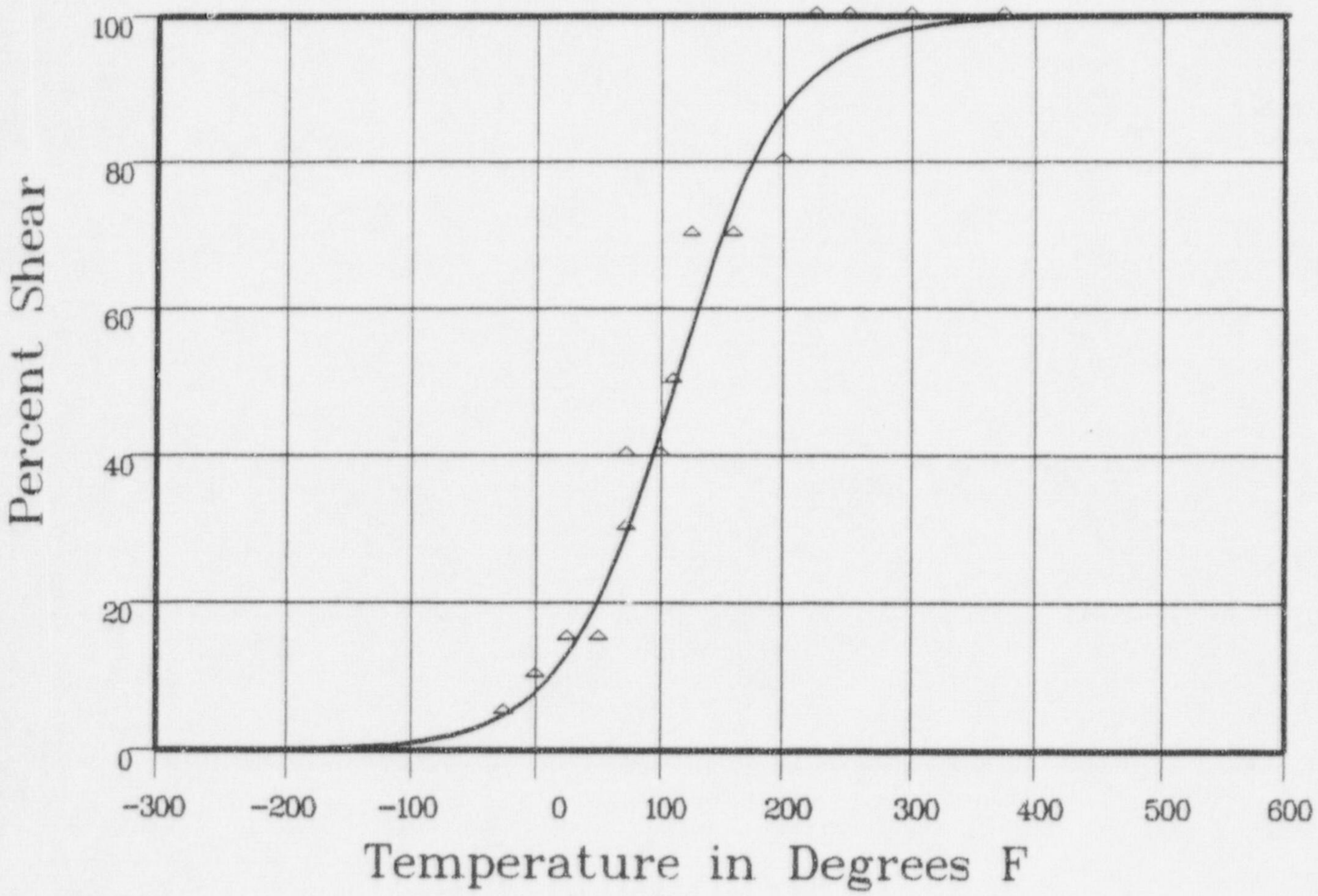
A = 50 B = 50 C = 91.72 T0 = 107.51

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: 107.5

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: V Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: V Material: PLATE SA533B1 Ori.: TL Heat #: CODE B8805-3 (HT.C0623-1)

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-25	5	5.26	-.26
0	10	8.75	1.24
25	15	14.19	.8
50	15	22.19	-7.19
72	40	31.55	8.44
72	30	31.55	-1.55
100	40	45.91	-5.91

**** Data continued on next page ****

Capsule V

Page 2

Material: PLATE SA533B1 Heat Number: CODE B8805-3 (HT.C0623-1) Orientation: TL

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
110	50	51.35	-1.35
125	70	59.41	10.58
160	70	75.84	-5.84
200	80	88.25	-8.25
225	100	92.83	7.16
250	100	95.71	4.28
300	100	98.51	1.48
375	100	99.7	.29

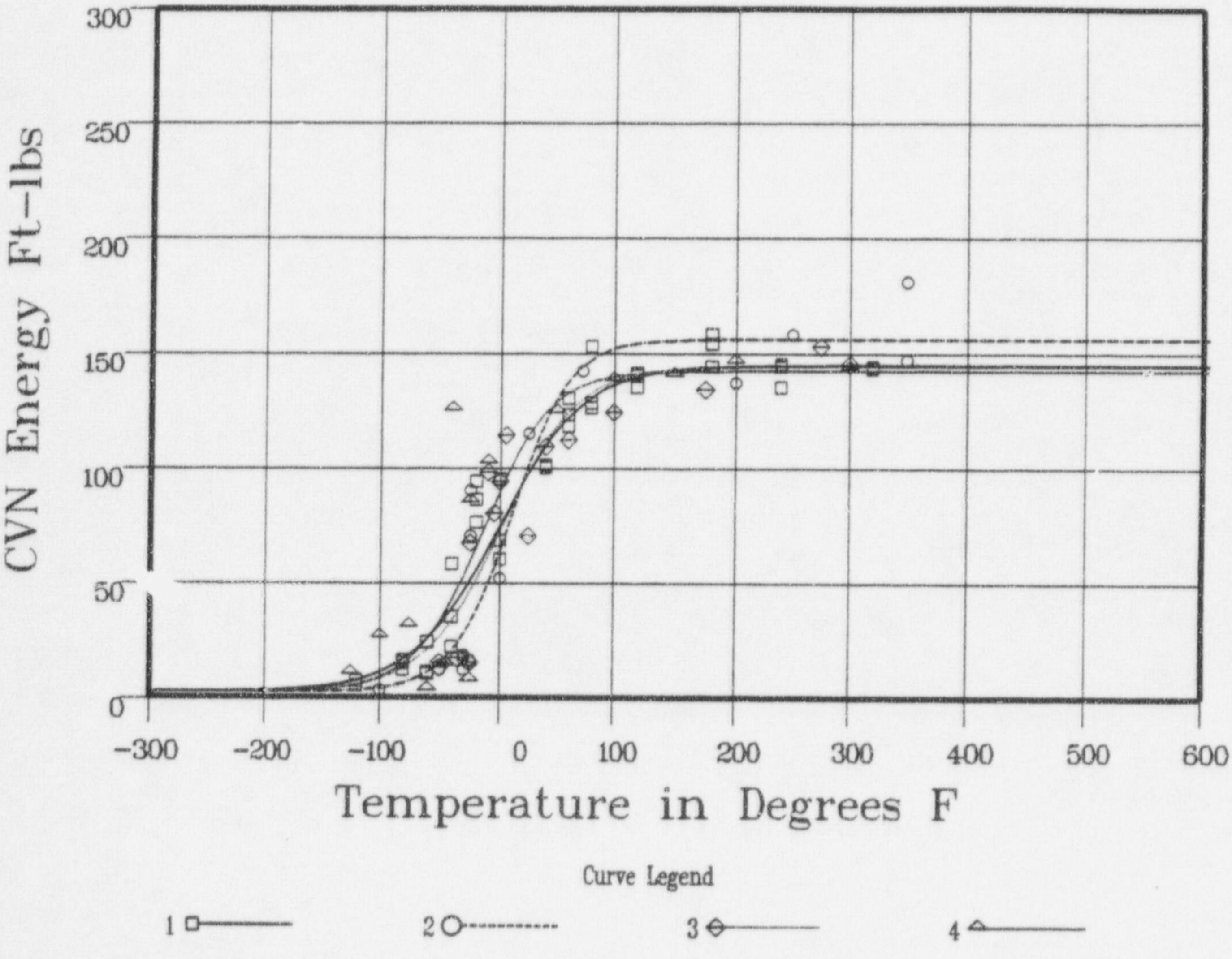
SUM of RESIDUALS = 3.93

Weld Material

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:47:08 on 05-11-1998

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	144.5	0	-57.13	0	-30.42	0
2	0	2.19	0	156	11.5	-32.15	24.98	-14.28	16.14
3	0	2.19	0	144	-.5	-49.42	7.7	-25.64	4.78
4	0	2.19	0	142	-2.5	-58.48	-1.34	-37.57	-7.14



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	WELD		WIRE HEAT:83653
2	V01	U	WELD		WIRE HEAT:83653
3	V01	Y	WELD		WIRE HEAT:83653
4	V01	V	WELD		WIRE HEAT:83653

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:47:08 on 05-11-1998

Page 1

Coefficients of Curve 1

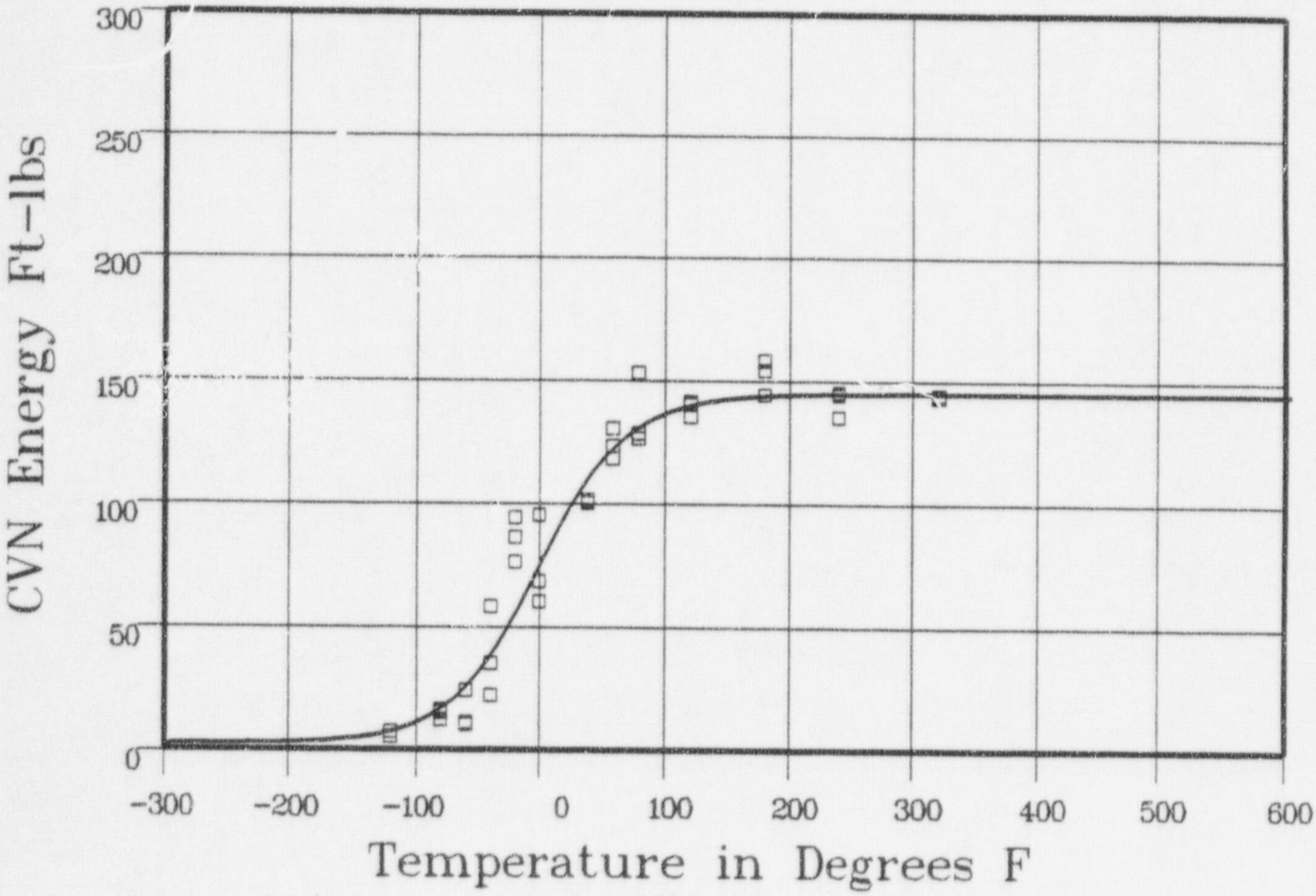
A = 73.34 B = 71.15 C = 72.78 T0 = -5.62

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 144.5 Fixed Temp. at 30 ft-lbs: -57.1 Temp. at 50 ft-lbs: -30.4 Lower Shelf Energy: 2.19 Fixed

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-120	7	8.08	-1.08
-120	5	8.08	-3.08
-80	12	18.52	-6.52
-80	15	18.52	-3.52
-80	16	18.52	-2.52
-60	10	28.28	-18.28
-60	11	28.28	-17.28
-60	24	28.28	-4.28
-40	58	42.04	15.95

**** Data continued on next page ****

Unirradiated

Page 2

Material: WELD   Heat Number: WIRE HEAT:83653   Orientation:

Capsule: UNIRR   Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-40	22	42.04	-20.04
-40	35	42.04	-7.04
-20	94	59.47	34.52
-20	76	59.47	16.52
-20	86	59.47	26.52
0	68	78.83	-10.83
0	95	78.83	16.16
0	60	78.83	-18.83
40	101	112.9	-11.9
40	101	112.9	-11.9
40	100	112.9	-12.9
60	130	124.37	5.62
60	118	124.37	-6.37
60	123	124.37	-1.37
80	128	132.14	-4.14
80	126	132.14	-6.14
80	153	132.14	20.85
120	141	140.13	.86
120	140	140.13	-.13
120	135	140.13	-5.13
180	144	143.63	.36
180	158	143.63	14.36
180	154	143.63	10.36
240	144	144.33	-.33
240	135	144.33	-9.33
240	145	144.33	.66
320	144	144.48	-.48
320	143	144.48	-1.48
320	143	144.48	-1.48

SUM of RESIDUALS = -23.65

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:47:08 on 05-11-1998

Page 1

Coefficients of Curve 2

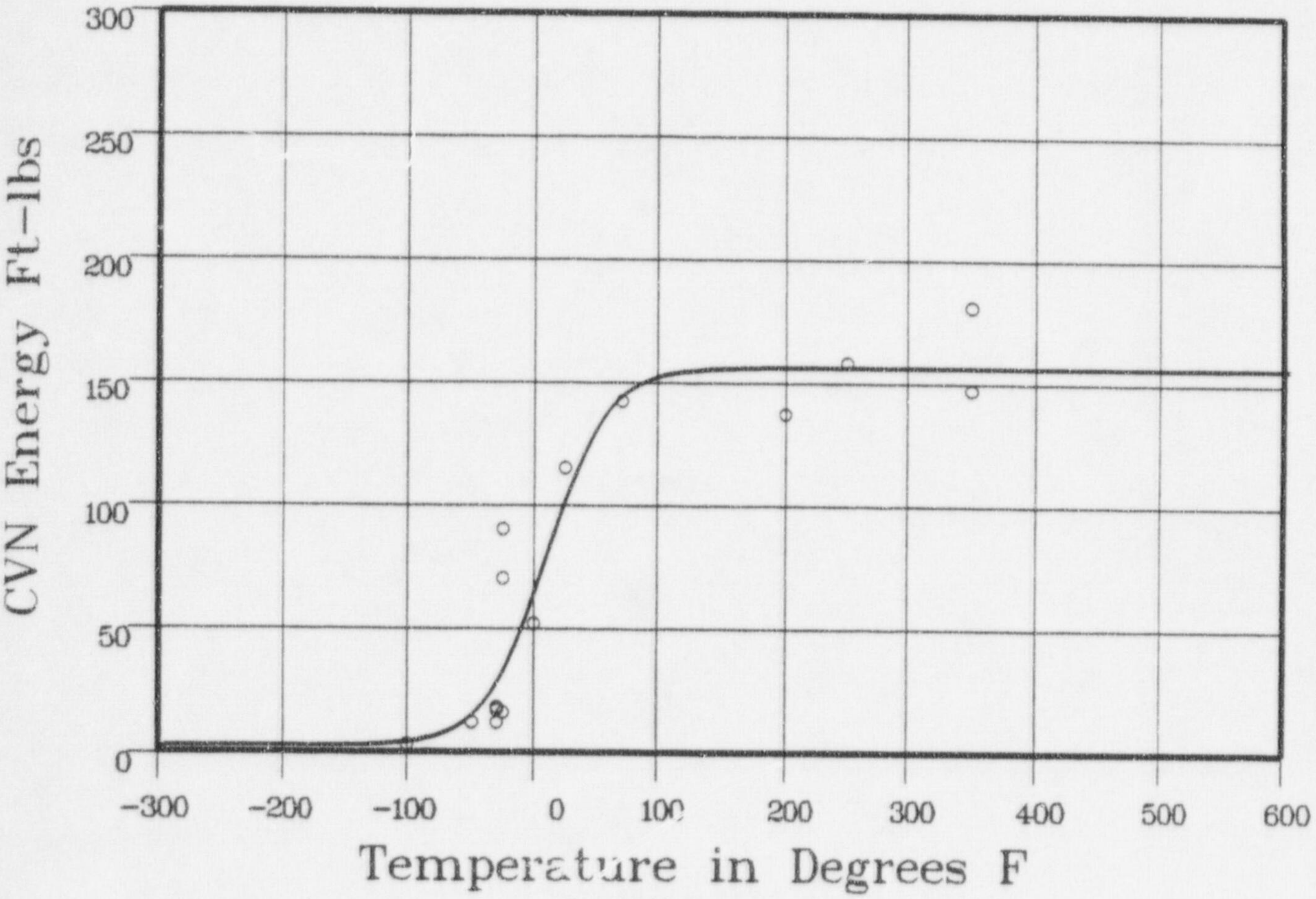
A = 79.09	B = 76.9	C = 49.99	T0 = 5.62

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 156 Fixed   Temp. at 30 ft-lbs: -32.1   Temp. at 50 ft-lbs: -14.2   Lower Shelf Energy: 2.19 Fixed

Material: WELD   Heat Number: WIRE HEAT:83653   Orientation:

Capsule: U   Total Fluence:



Data Set(s) Plotted

Plant: V01   Cap.: U   Material: WELD   Ori.:   Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-100	3	4.41	-1.41
-50	12	17.19	-5.19
-30	12	32.01	-20.01
-30	17	32.01	-15.01
-30	18	32.01	-14.01
-25	70	37.11	32.88
-25	16	37.11	-21.11
-25	90	37.11	52.88

**** Data continued on next page ****

Capsule U

Page 2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
0	52	70.48	-18.48
25	115	107.49	7.5
72	142	145.9	-3.9
200	137	155.93	-18.93
250	158	155.99	2
350	181	155.99	25
350	147	155.99	-8.99

SUM of RESIDUALS = -6.82

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:47:08 on 05-11-1998

Page 1

Coefficients of Curve 3

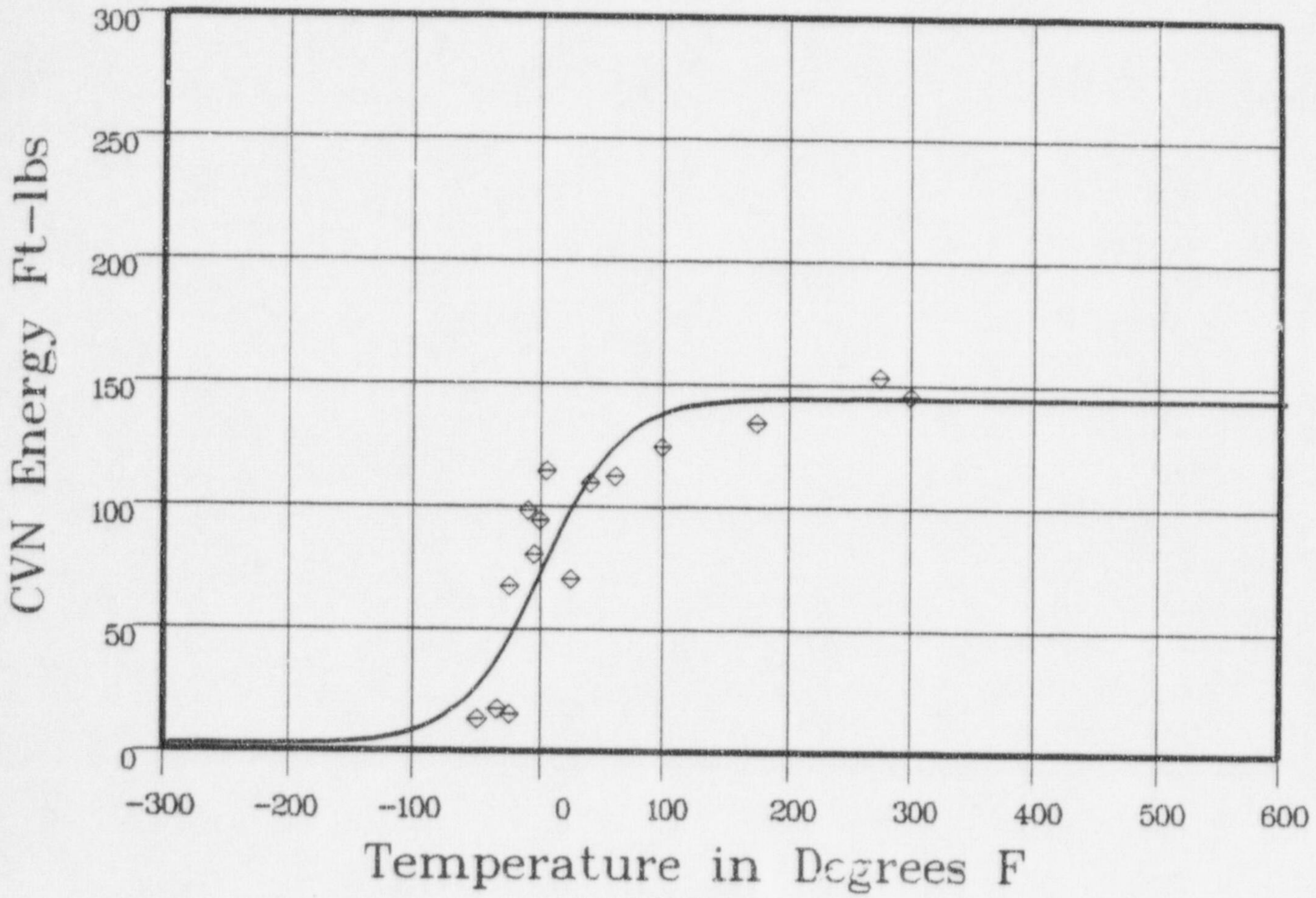
A = 73.09	B = 70.9	C = 64.74	T0 = -3.75

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 144 Fixed Temp. at 30 ft-lbs: -49.4 Temp. at 50 ft-lbs: -25.6 Lower Shelf Energy: 2.19 Fixed

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-50	13	29.6	-16.6
-35	17	41.3	-24.3
-25	15	50.62	-35.62
-25	67	50.62	16.37
-10	98	66.27	31.72
-5	80	71.73	8.26
0	94	77.2	16.79
5	114	82.62	31.37

**** Data continued on next page ****

Capsule Y

Page 2

Material: WELD　　Heat Number: WIRE HEAT:83653　　Orientation:

Capsule: Y　　Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
25	70	102.66	-32.66
40	109	114.84	-5.84
60	112	126.63	-14.63
100	124	138.47	-14.47
175	134	143.43	-9.43
275	153	143.97	9.02
300	145	143.98	1.01

SUM of RESIDUALS = -39.02

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:47:08 on 05-11-1998

Page 1

Coefficients of Curve 4

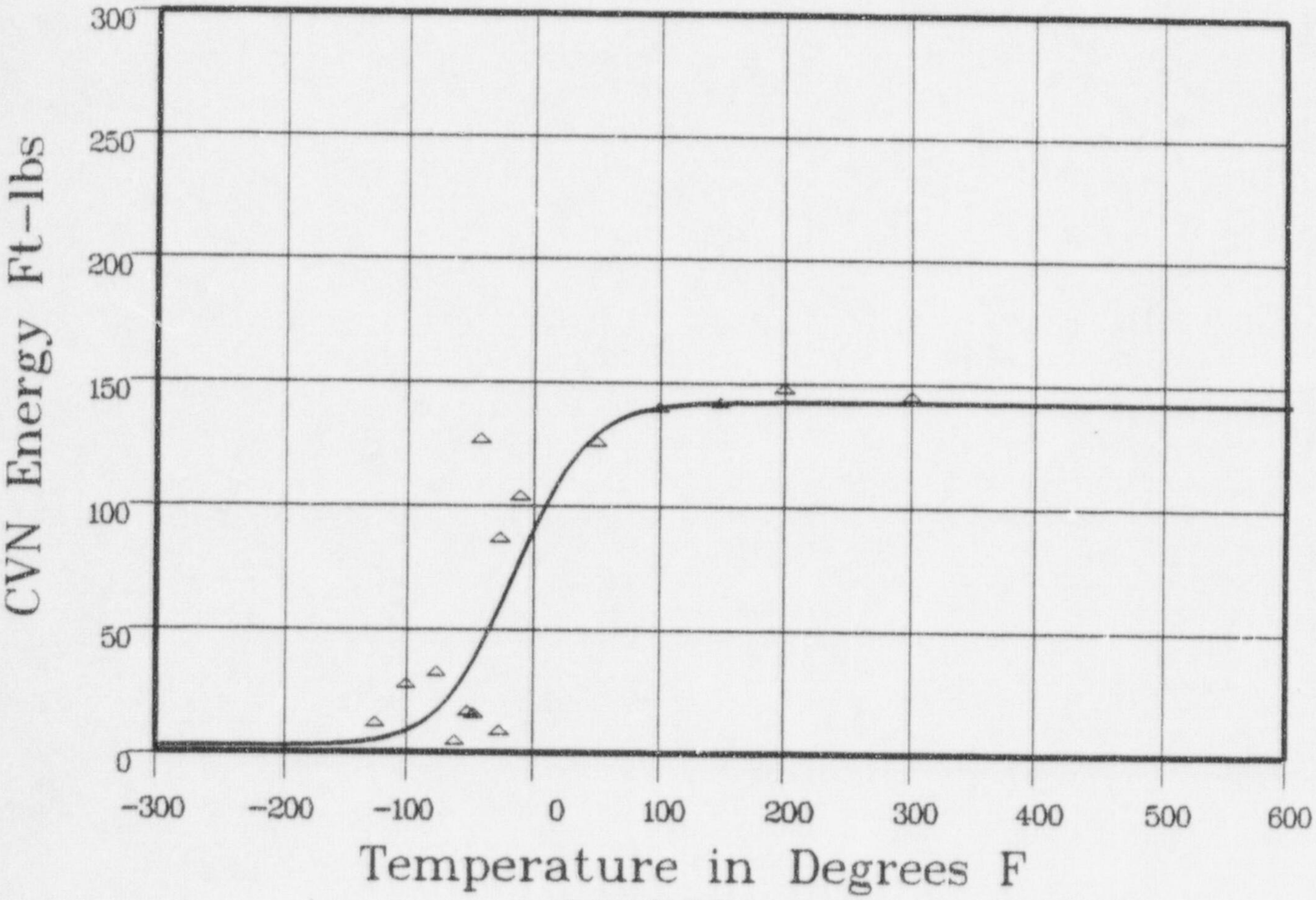
A = 72.09	B = 69.9	C = 56.61	T0 = -19.04

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 142 Fixed Temp. at 30 ft-lbs: -58.4 Temp. at 50 ft-lbs: -37.5 Lower Shelf Energy: 2.19 Fixed

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: V Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: V Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-125	10	5.43	4.56
-100	26	9.77	16.22
-75	31	19.2	11.79
-60	3	28.82	-25.82
-50	15	37.28	-22.28
-45	14	42.12	-28.12
-40	125	47.34	77.65

**** Data continued on next page ****

Capsule V

Page 2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-25	85	64.77	20.22
-25	7	64.77	-57.77
-10	102	83.17	18.82
50	124	130.78	-6.78
100	138	139.94	-1.94
150	140	141.64	-1.64
200	146	141.93	4.06
300	143	141.99	1

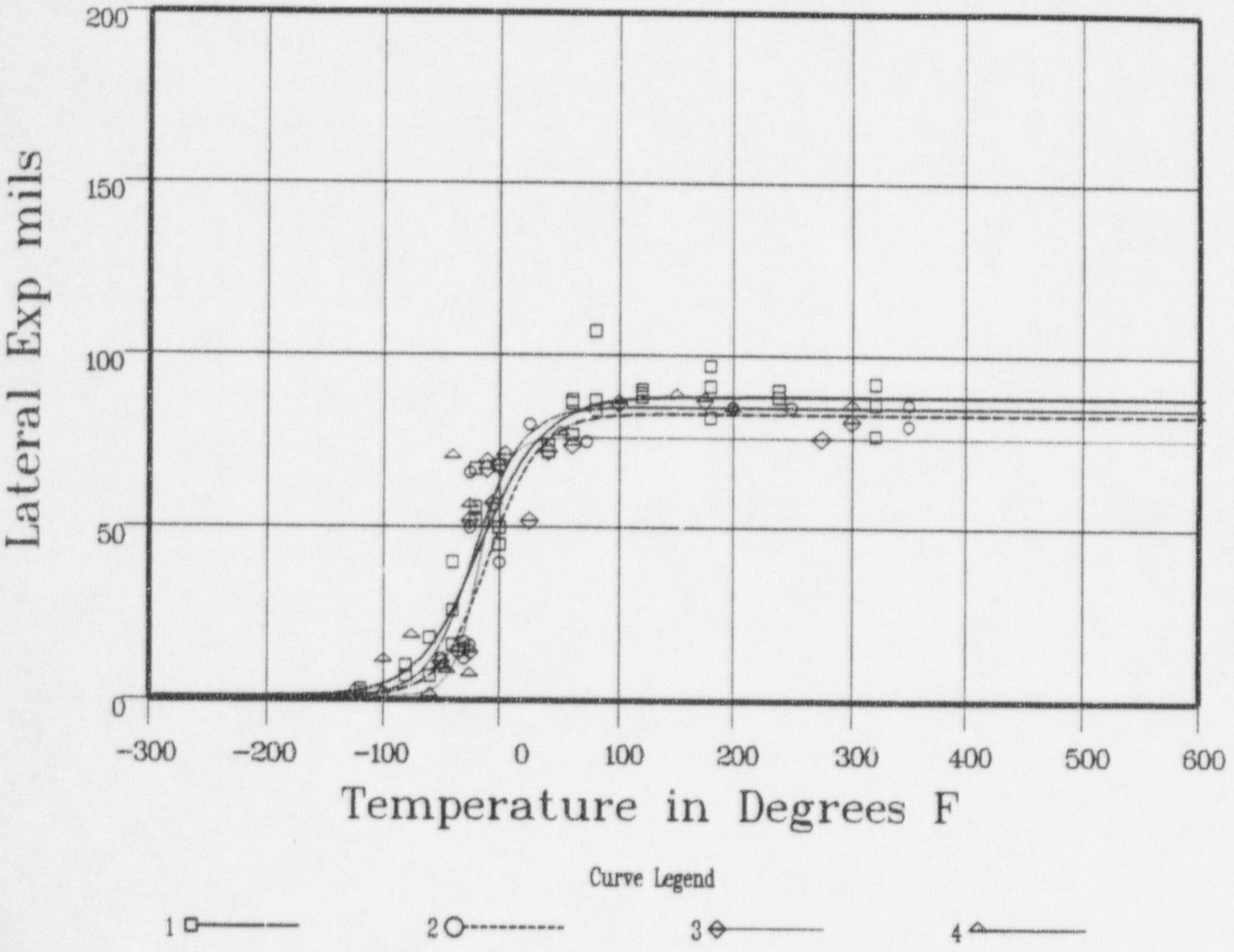
SUM of RESIDUALS = 9.98

Weld Material

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:05:09 on 05-12-1998

Results

Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	88.03	0	-32.53	0
2	0	83.07	-4.95	-19.87	12.65
3	0	76.01	-12.02	-24.12	8.4
4	0	84.97	-3.06	-32.93	-.4



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	WELD		WIRE HEAT:83653
2	V01	U	WELD		WIRE HEAT:83653
3	V01	Y	WELD		WIRE HEAT:83653
4	V01	V	WELD		WIRE HEAT:83653

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:05:09 on 05-12-1998

Page 1

Coefficients of Curve 1

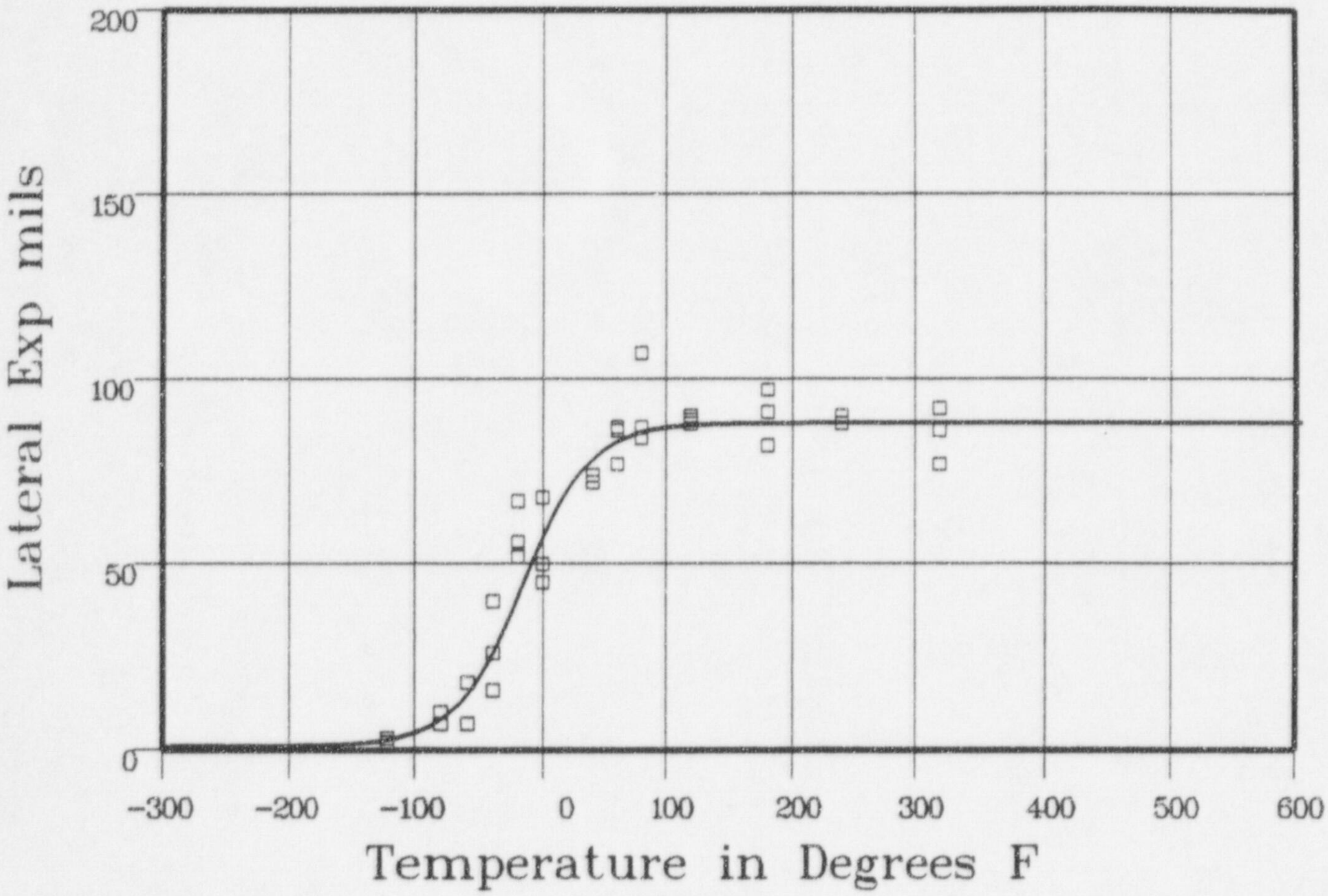
A = 44.51	B = 43.51	C = 53.55	T0 = -20.62

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 88.03 Temperature at L.E. 35: -32.5 Lower Shelf L.E.: 1 Fixed

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-120	3	3.07	-.07
-120	2	3.07	-1.07
-80	7	9.54	-2.54
-80	10	9.54	.45
-80	10	9.54	.45
-60	7	17.26	-10.26
-60	7	17.26	-10.26
-60	18	17.26	.73
-40	40	29.42	10.57

**** Data continued on next page ****

Unirradiated

Page 2

Material: WELD　Heat Number: WIRE HEAT:83653　Orientation:

Capsule: UNIRR　Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-40	16	29.42	-13.42
-40	26	29.42	-3.42
-20	67	45.02	21.97
-20	56	45.02	10.97
-20	52	45.02	6.97
0	50	60.49	-10.49
0	68	60.49	7.5
0	45	60.49	-15.49
40	72	79.84	-7.84
40	74	79.84	-5.84
40	72	79.84	-7.84
60	87	83.95	3.04
60	77	83.95	-6.95
60	86	83.95	2.04
80	87	86.05	.94
80	84	86.05	-2.05
80	107	86.05	20.94
120	90	87.58	2.41
120	88	87.58	.41
120	89	87.58	1.41
180	97	87.98	9.01
180	82	87.98	-5.98
180	91	87.98	3.01
240	90	88.03	1.96
240	88	88.03	-.03
240	88	88.03	-.03
320	86	88.03	-2.03
320	92	88.03	3.96
320	77	88.03	-11.03

SUM of RESIDUALS = -7.93

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:05:09 on 05-12-1998

Page 1

Coefficients of Curve 2

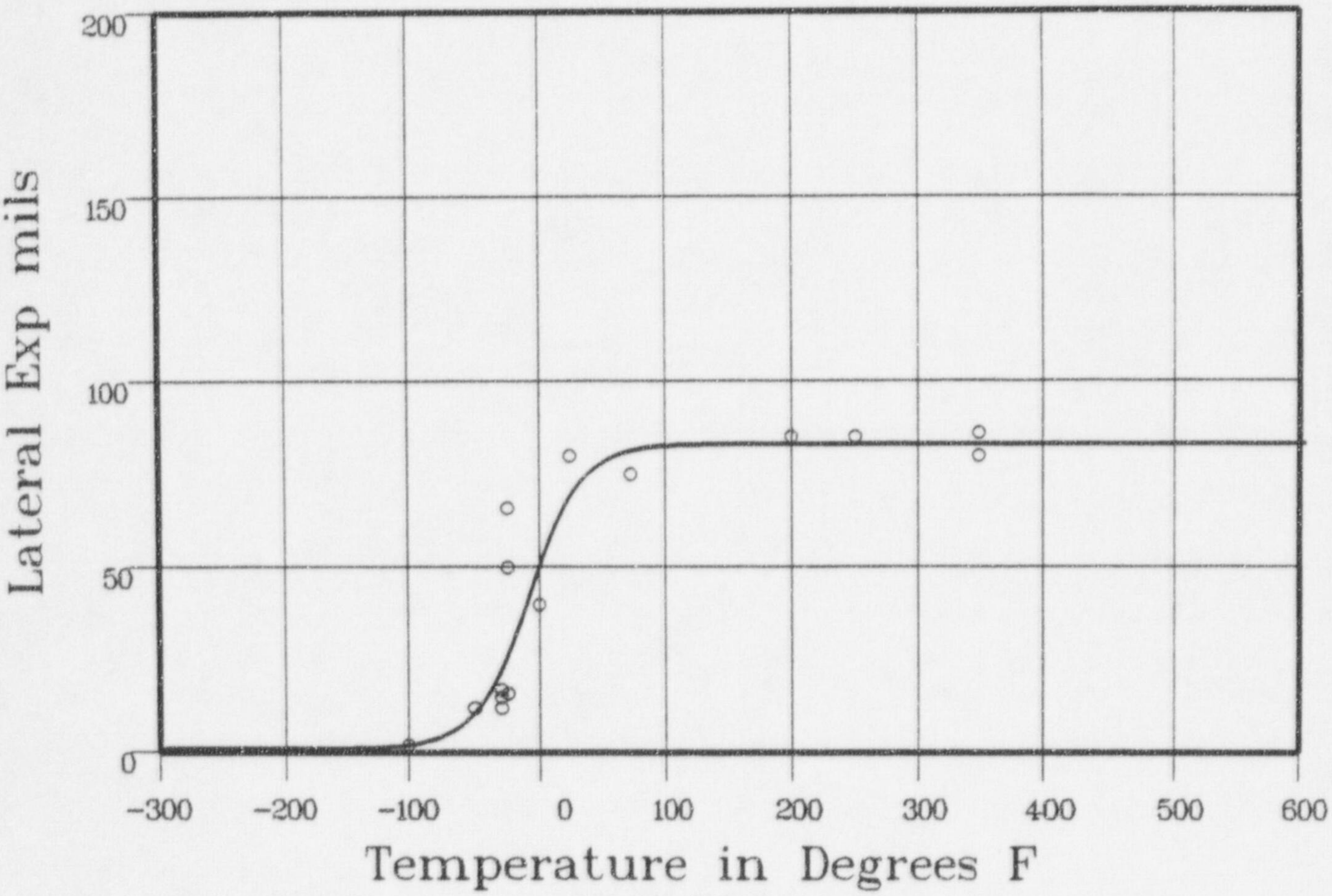
A = 42.03	B = 41.03	C = 41.68	T0 = -12.65

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 83.07 Temperature at L.E. 35: -19.8 Lower Shelf L.E.: 1 Fixed

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: U Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-100	2	2.22	-.22
-50	12	12.72	-.72
-30	12	25.88	-13.88
-30	17	25.88	-8.88
-30	15	25.88	-10.88
-25	50	30.23	19.76
-25	16	30.23	-14.23
-25	66	30.23	35.76

**** Data continued on next page ****

Capsule U

Page 2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
0	40	54.12	-14.12
25	80	71.5	8.49
72	75	81.68	-6.68
200	85	83.07	1.92
250	85	83.07	1.92
350	80	83.07	-3.07
350	86	83.07	2.92

SUM of RESIDUALS = -1.93

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:05:09 on 05-12-1998

Page 1

Coefficients of Curve 3

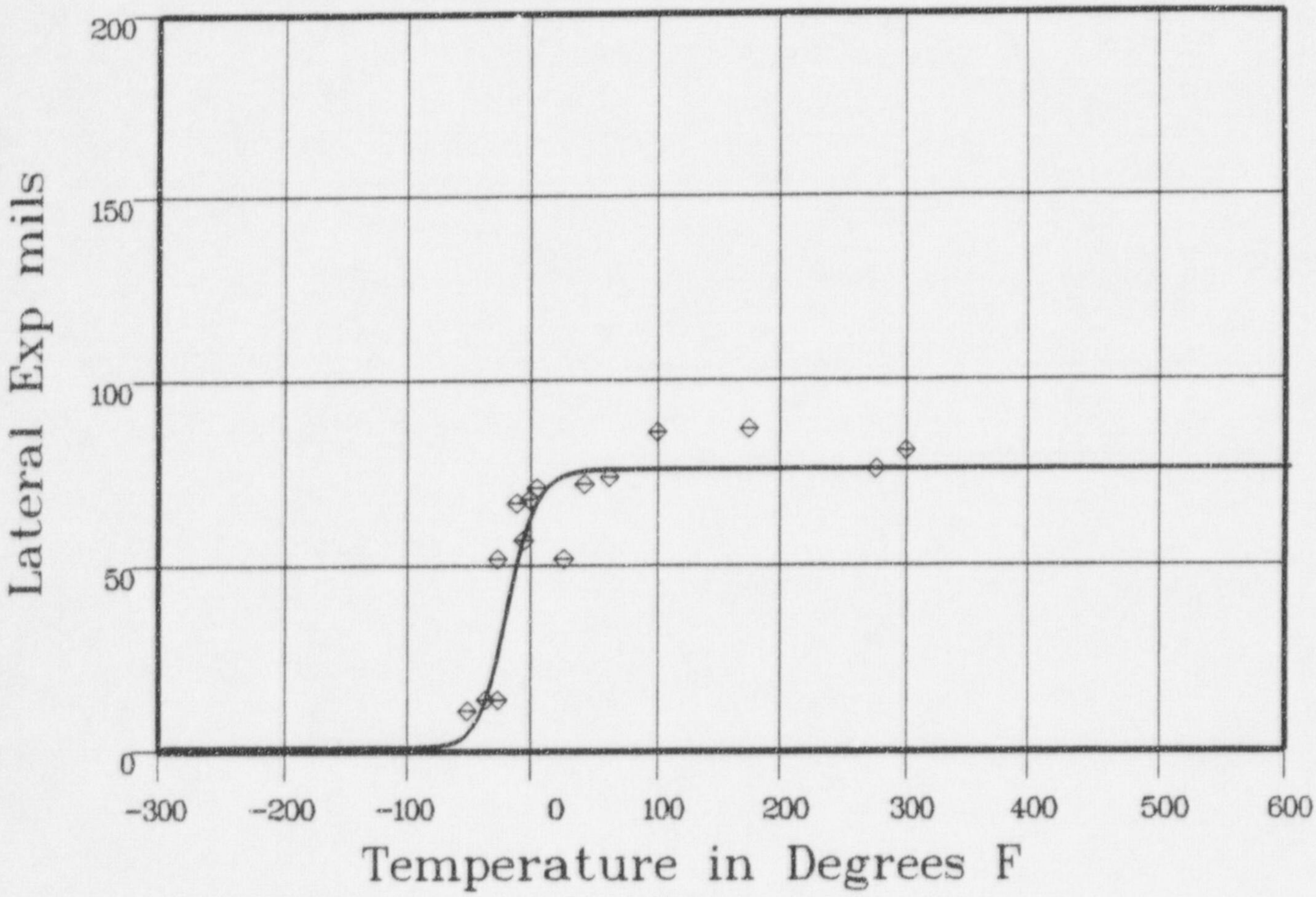
A = 38.5	B = 37.5	C = 22.33	T0 = -22.03

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 76.01 Temperature at L.E. 35: -24.1 Lower Shelf L.E.: 1 Fixed

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-50	11	6.66	4.33
-35	14	18.88	-4.88
-25	14	33.55	-19.55
-25	52	33.55	18.44
-10	67	56.96	10.03
-5	57	62.61	-5.61
0	68	66.85	1.14
5	71	69.89	1.1

**** Data continued on next page ****

Capsule Y

Page 2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
25	52	74.92	-22.92
40	72	75.72	-3.72
60	74	75.96	-1.96
100	86	76.01	9.98
175	87	76.01	10.98
275	76	76.01	-.01
300	81	76.01	4.98

SUM of RESIDUALS = 2.33

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:05:09 on 05-12-1998

Page 1

Coefficients of Curve 4

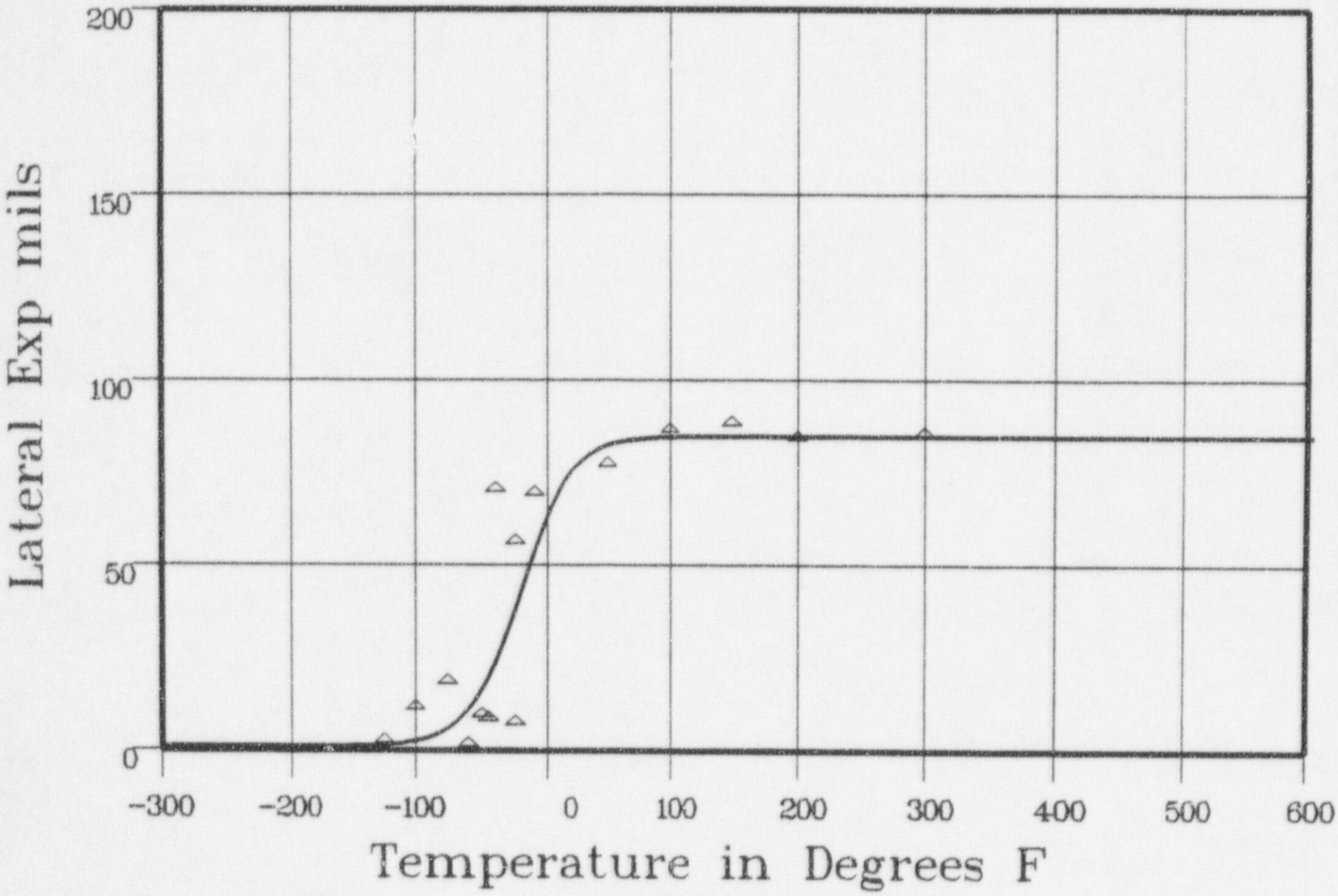
A = 42.98	B = 41.98	C = 39.57	T0 = -25.31

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 84.97 Temperature at L.E. 35: -32.9 Lower Shelf L.E.: 1 Fixed

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: V Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: V Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-125	2	1.54	.45
-100	11	2.88	8.11
-75	18	7.3	10.69
-60	1	13.4	-12.4
-50	9	19.73	-10.73
-45	8	23.66	-15.66
-40	70	28.08	41.91

**** Data continued on next page ****

Capsule V

Page 2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-25	56	43.31	12.68
-25	7	43.31	-36.31
-10	69	58.46	10.53
50	77	83.14	-6.14
100	86	84.82	1.17
150	88	84.95	3.04
200	84	84.96	-.96
300	85	84.97	.02

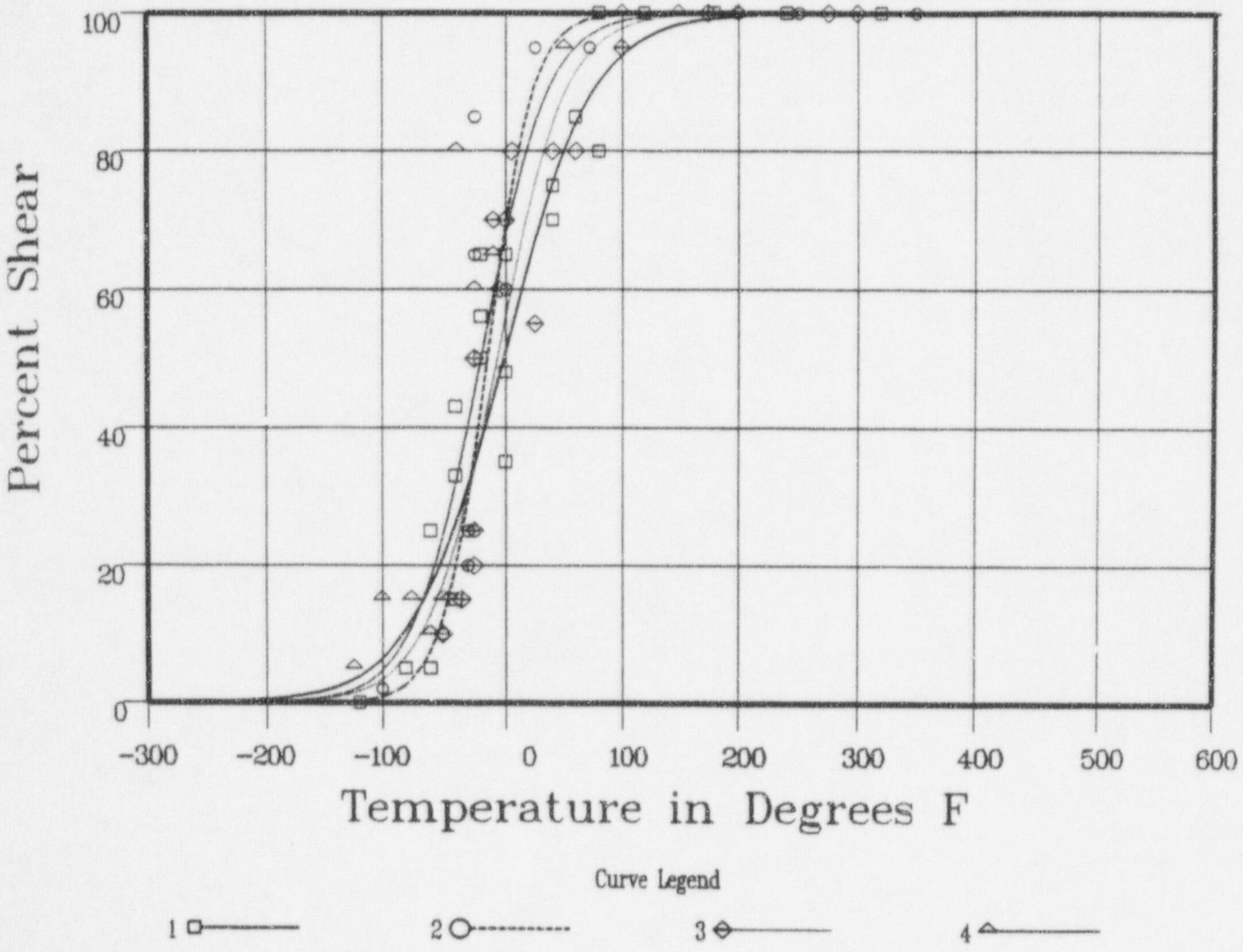
SUM of RESIDUALS = 6.42

Weld Material

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:16:16 on 05-12-1998

Results

Curve	Fluence	T @ 50% Shear	d-T @ 50% Shear
1	0	-6.09	0
2	0	-19.21	-13.12
3	0	-11.25	-5.15
4	0	-24.37	-18.28



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	WELD		WIRE HEAT:83653
2	V01	U	WELD		WIRE HEAT:83653
3	V01	Y	WELD		WIRE HEAT:83653
4	V01	V	WELD		WIRE HEAT:83653

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:16:16 on 05-12-1998

Page 1

Coefficients of Curve 1

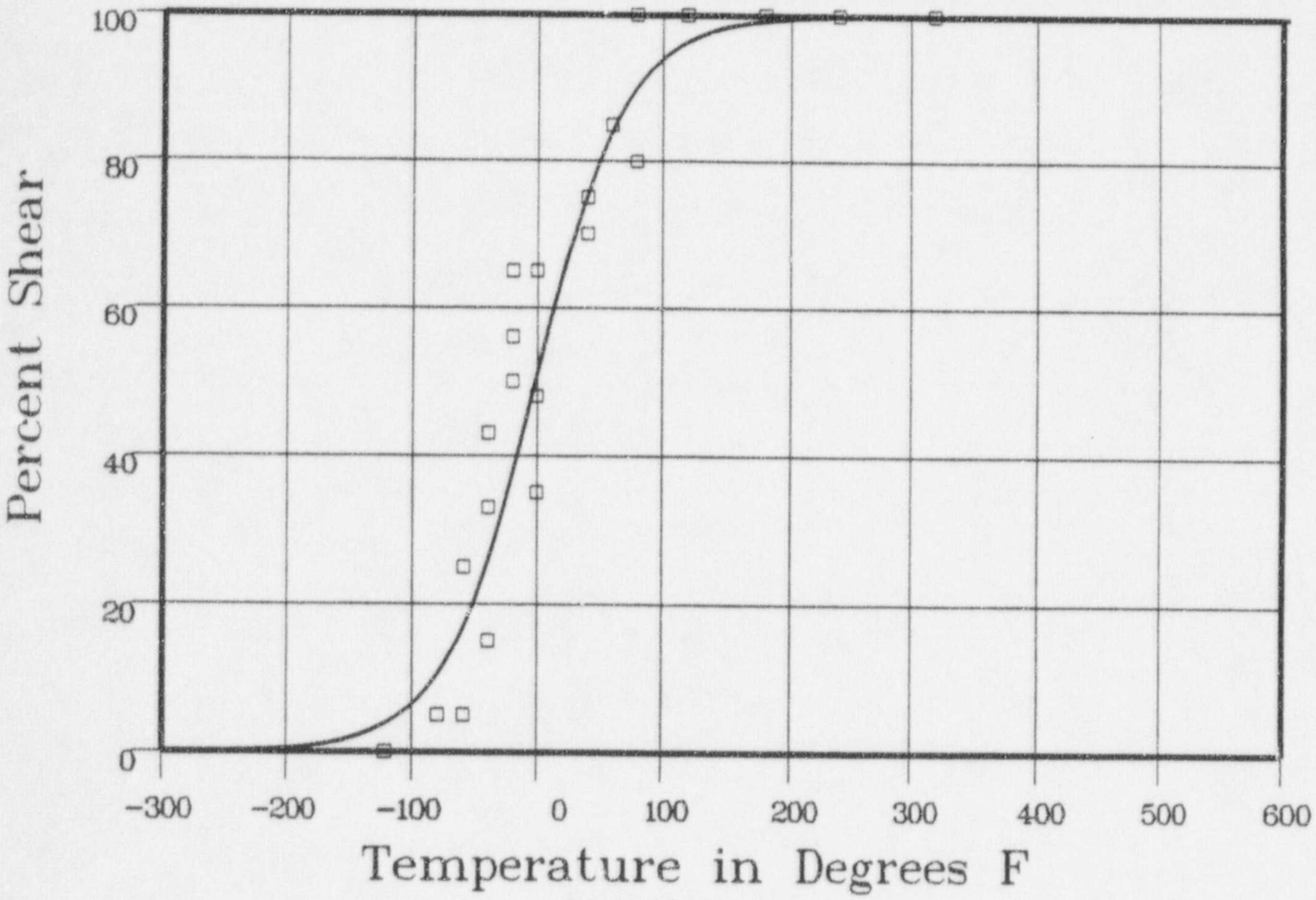
A = 50	B = 50	C = 73.82	T0 = -6.09

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: -6

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-120	0	4.36	-4.36
-120	0	4.36	-4.36
-80	5	11.89	-6.89
-80	5	11.89	-6.89
-80	5	11.89	-6.89
-60	5	18.84	-13.84
-60	5	18.84	-13.84
-60	25	18.84	6.15
-40	43	28.52	14.47

**** Data continued on next page ****

Unirradiated

Page 2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: UNIRR Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-40	15	28.52	-13.52
-40	33	28.52	4.47
-20	65	40.69	24.3
-20	56	40.69	15.3
-20	50	40.69	9.3
0	48	54.11	-6.11
0	65	54.11	10.88
0	35	54.11	-19.11
40	75	77.7	-2.7
40	70	77.7	-7.7
40	75	77.7	-2.7
60	85	85.69	-.69
60	85	85.69	-.69
60	85	85.69	-.69
80	80	91.15	-11.15
80	30	91.15	-11.15
80	100	91.15	8.84
120	100	96.82	3.17
120	100	96.82	3.17
120	100	96.82	3.17
180	100	99.35	.64
180	100	99.35	.64
180	100	99.35	.64
240	100	99.87	.12
240	100	99.87	.12
240	100	99.87	.12
320	100	99.98	.01
320	100	99.98	.01
320	100	99.98	.01

SUM of RESIDUALS = -27.74

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:16:16 on 05-12-1998

Page 1

Coefficients of Curve 2

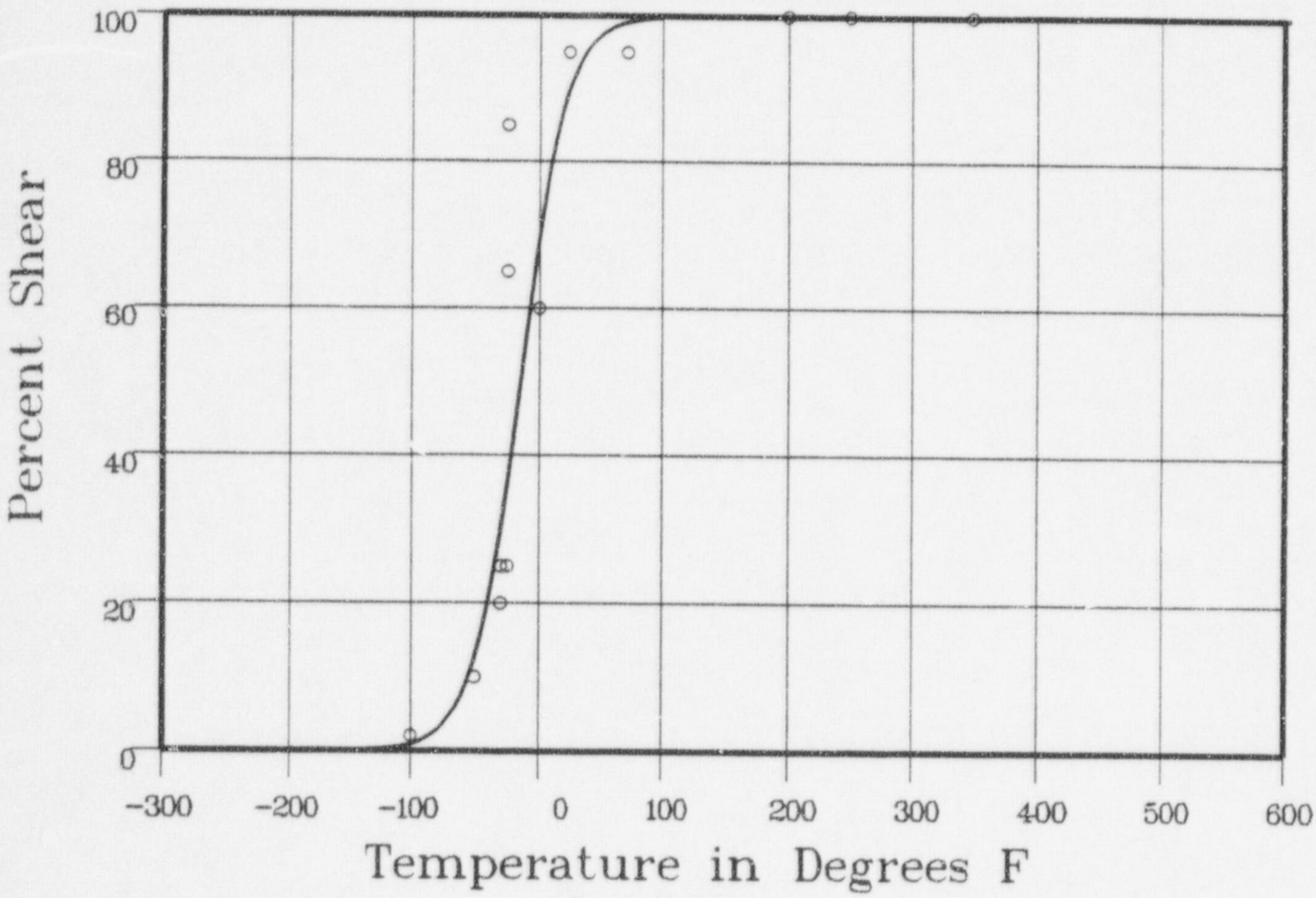
A = 50	B = 50	C = 36.35	T0 = -19.21

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: -19.2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: U Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100	2	1.16	.83
-50	10	15.53	-5.53
-30	20	35.59	-15.59
-30	25	35.59	-10.59
-30	25	35.59	-10.59
-25	65	42.11	22.88
-25	25	42.11	-17.11
-25	85	42.11	42.88

**** Data continued on next page ****

Capsule U

Page 2

Material: WELD   Heat Number: WIRE HEAT:83653   Orientation:

Capsule: U   Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
0	60	74.21	-14.21
25	95	91.92	3.07
72	95	99.34	-4.34
200	100	99.99	0
250	100	99.99	0
350	100	100	0
350	100	100	0

SUM of RESIDUALS = -8.3

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:16:16 on 05-12-1998

Page 1

Coefficients of Curve 3

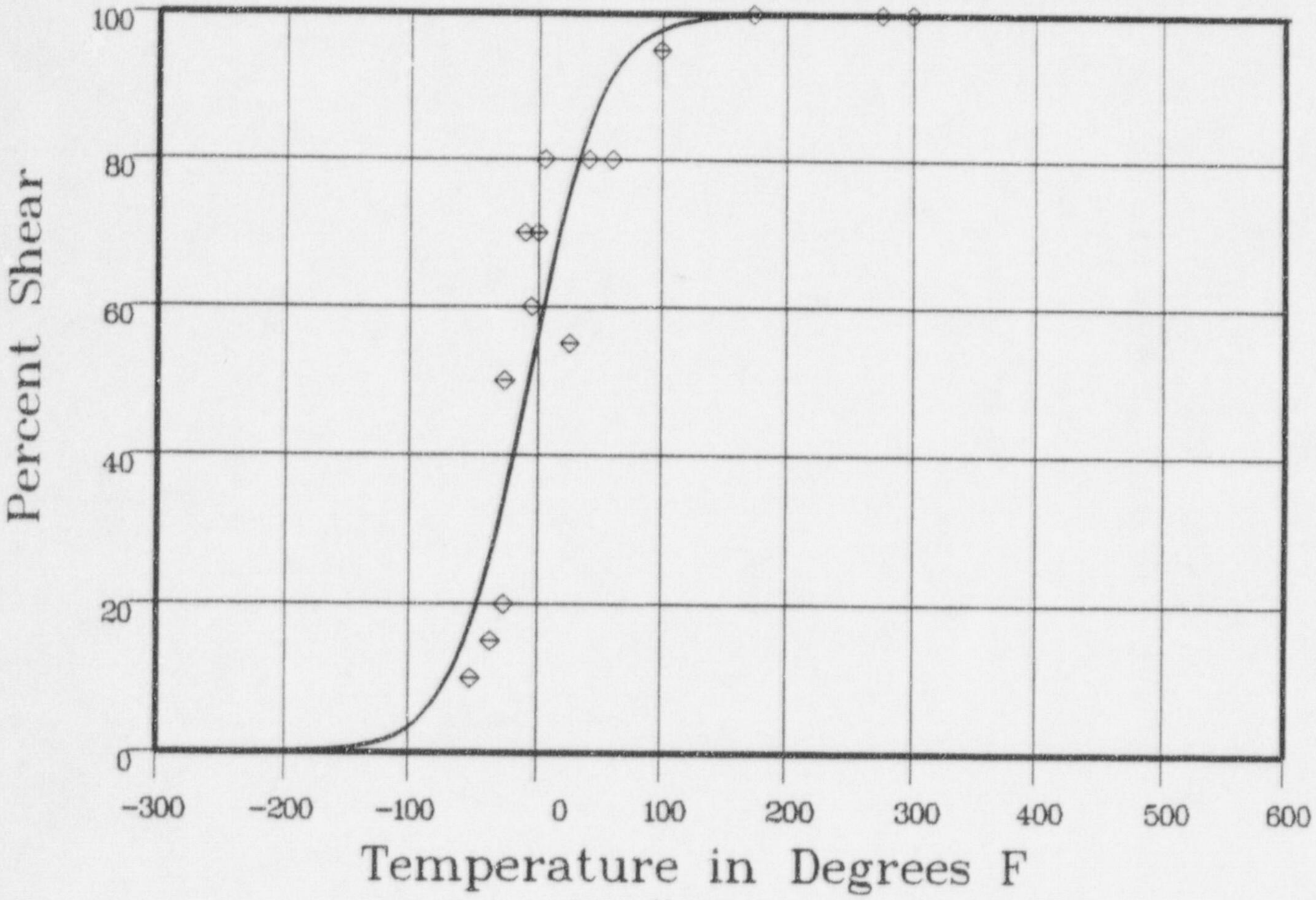
A = 50	B = 50	C = 55.85	T0 = -11.25

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: -11.2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50	10	19.97	-9.97
-35	15	29.93	-14.93
-25	20	37.93	-17.93
-25	50	37.93	12.06
-10	70	51.11	18.88
-5	60	55.57	4.42
0	70	59.93	10.06
5	80	64.15	15.84

**** Data continued on next page ****

Capsule Y

Page 2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
25	55	78.55	-23.55
40	80	86.23	-6.23
60	80	92.76	-12.76
100	95	98.17	-3.17
175	100	99.87	.12
275	100	99.99	0
300	100	99.99	0

SUM of RESIDUALS = -27.15

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 07:16:16 on 05-12-1998
Page 1
Coefficients of Curve 4

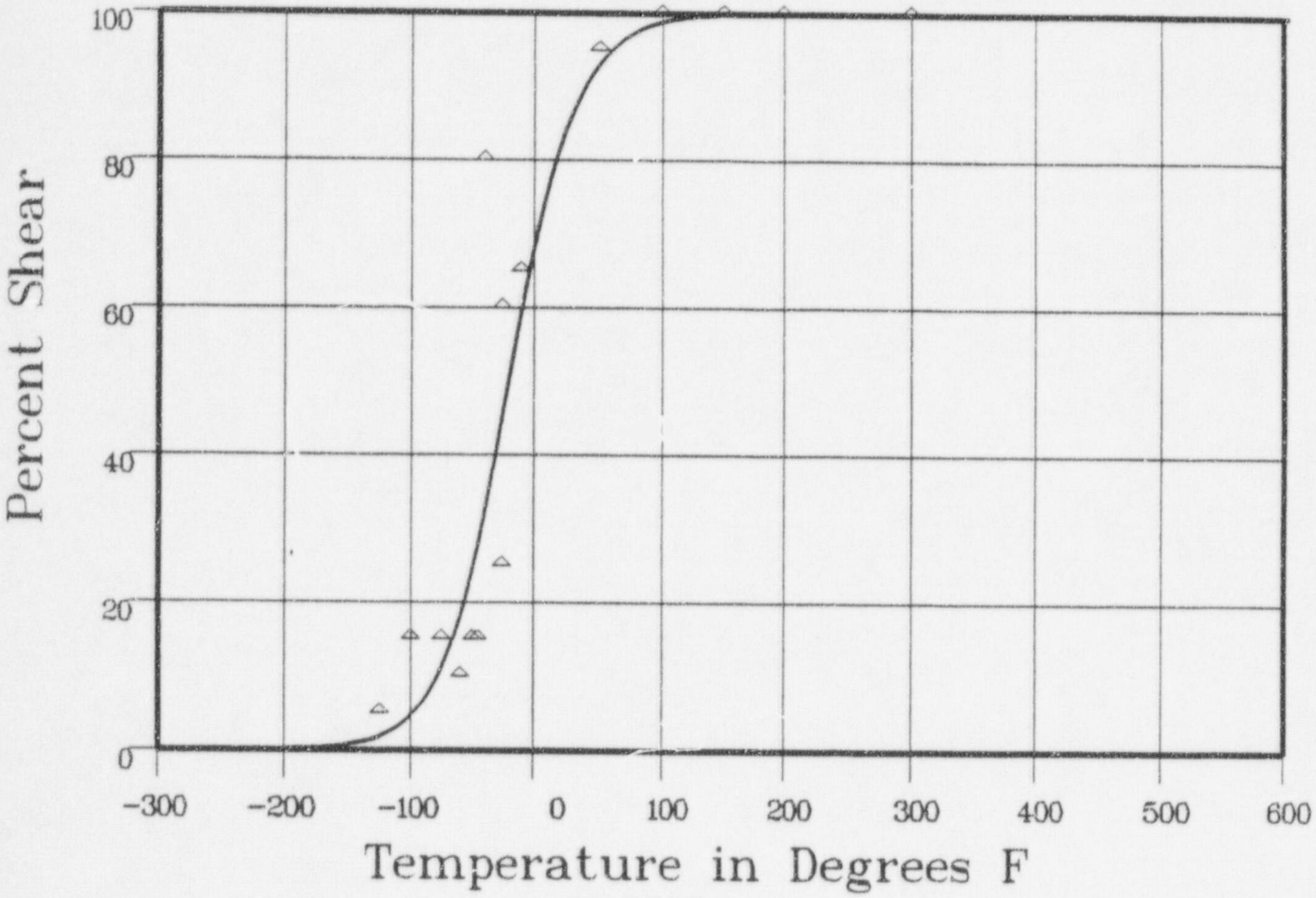
A = 50	B = 50	C = 53.36	T0 = -24.37

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: -24.3

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: V Total Fluence:



Data Set(s) Plotted
Plant: V01 Cap.: V Material: WELD Ori.: Heat #: WIRE HEAT:83653

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-125	5	2.25	2.74
-100	15	5.54	9.45
-75	15	13.04	1.95
-60	10	20.83	-10.83
-50	15	27.68	-12.68
-45	15	31.58	-16.58
-40	80	35.76	44.23

**** Data continued on next page ****

Capsule V

Page 2

Material: WELD Heat Number: WIRE HEAT:83653 Orientation:

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-25	60	49.41	10.58
-25	25	49.41	-24.41
-10	65	63.15	1.84
50	95	94.19	.8
100	100	99.06	.93
150	100	99.85	.14
200	100	99.97	.02
300	100	99.99	0

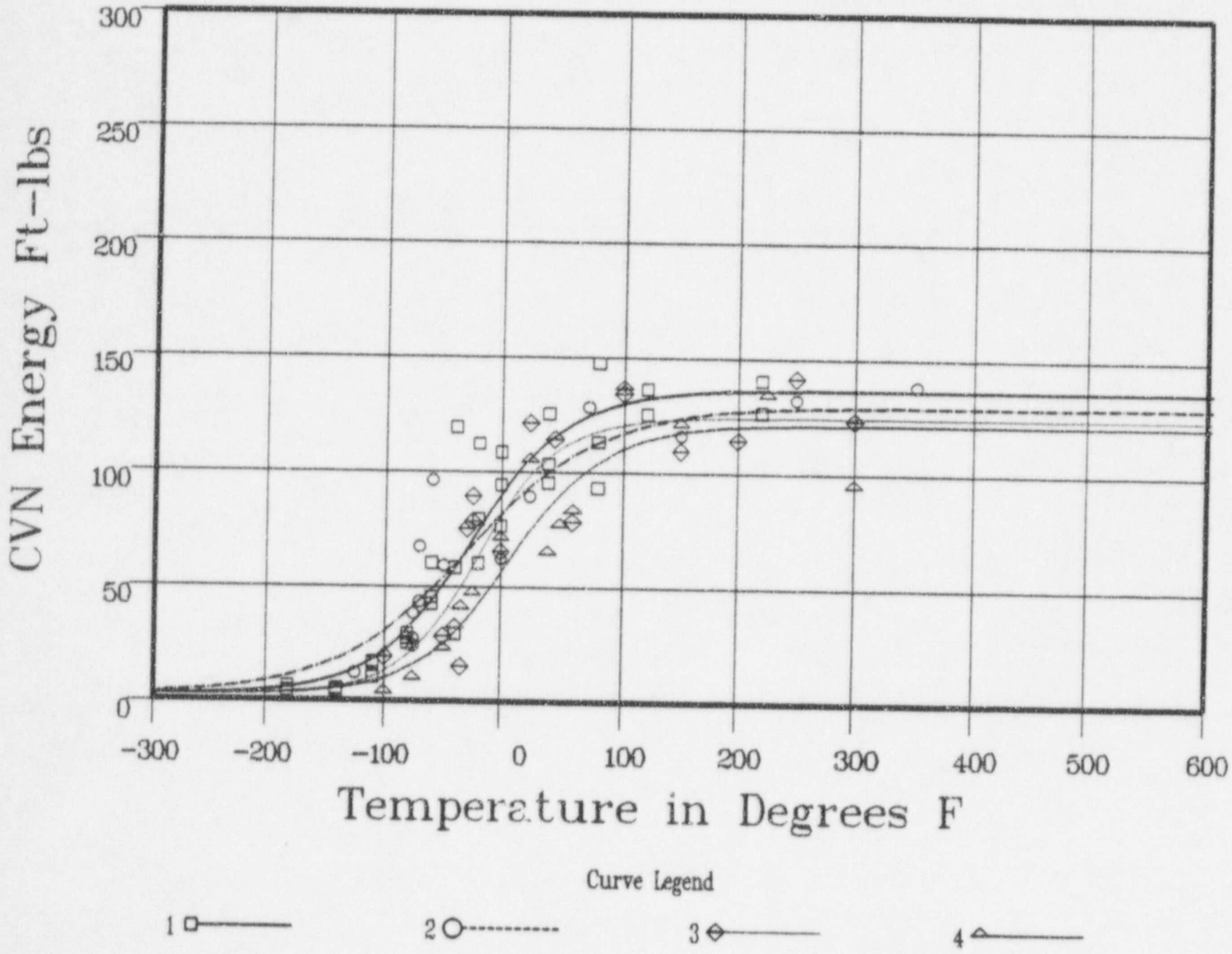
SUM of RESIDUALS = 8.22

Heat Affected Zone

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:07:58 on 05-12-1998

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	136	0	-86.96	0	-55.52	0
2	0	2.19	0	129	-7	-106.31	-19.35	-62.32	-6.8
3	0	2.19	0	124	-12	-66.17	20.78	-39.36	16.15
4	0	2.19	0	121	-15	-44.87	42.08	-12.82	42.7



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
2	V01	U	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
3	V01	Y	HEAT AFFD ZONE		B8805-1 SIDE OF WELD
4	V01	V	HEAT AFFD ZONE		B8805-1 SIDE OF WELD

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:07:58 on 05-12-1998

Page 1

Coefficients of Curve 1

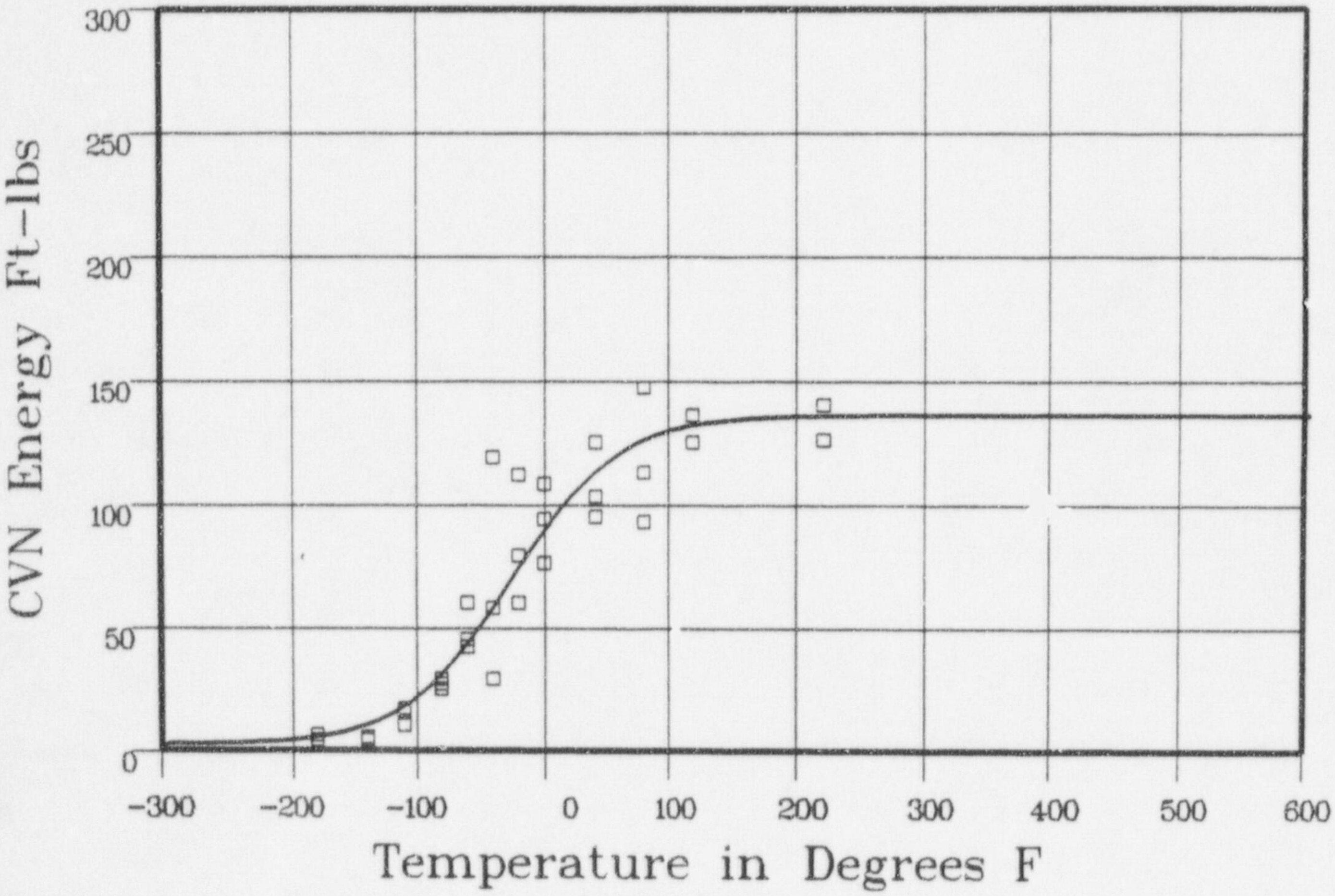
A = 69.09	B = 66.9	C = 83.7	T0 = -30.94

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 136 Fixed Temp. at 30 ft-lbs: -86.9 Temp. at 50 ft-lbs: -55.5 Lower Shelf Energy: 2.19 Fixed

Material: HEAT AFF'D ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: HEAT AFF'D ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-180	4	5.89	-1.89
-180	6	5.89	.1
-140	4	11.4	-7.4
-140	5	11.4	-6.4
-110	17	19.77	-2.77
-110	10	19.77	-9.77
-110	16	19.77	-3.77
-80	25	33.84	-8.84
-80	29	33.84	-4.84

**** Data continued on next page ****

Unirradiated

Page 2

Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-80	27	33.84	-6.84
-60	45	46.76	-1.76
-60	60	46.76	13.23
-60	42	46.76	-4.76
-40	29	61.89	-32.89
-40	58	61.89	-3.89
-40	119	61.89	57.1
-20	112	77.79	34.2
-20	60	77.79	-17.79
-20	79	77.79	1.2
0	76	92.76	-16.76
0	94	92.76	1.23
0	108	92.76	15.23
40	125	115.24	9.75
40	95	115.24	-20.24
40	103	115.24	-12.24
80	147	127.17	19.82
80	113	127.17	-14.17
80	93	127.17	-34.17
120	136	132.46	3.53
120	125	132.46	-7.46
120	136	132.46	3.53
220	140	135.66	4.33
220	126	135.66	-9.66
220	140	135.66	4.33

SUM of RESIDUALS = -60.77

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:07:58 on 05-12-1998

Page 1

Coefficients of Curve 2

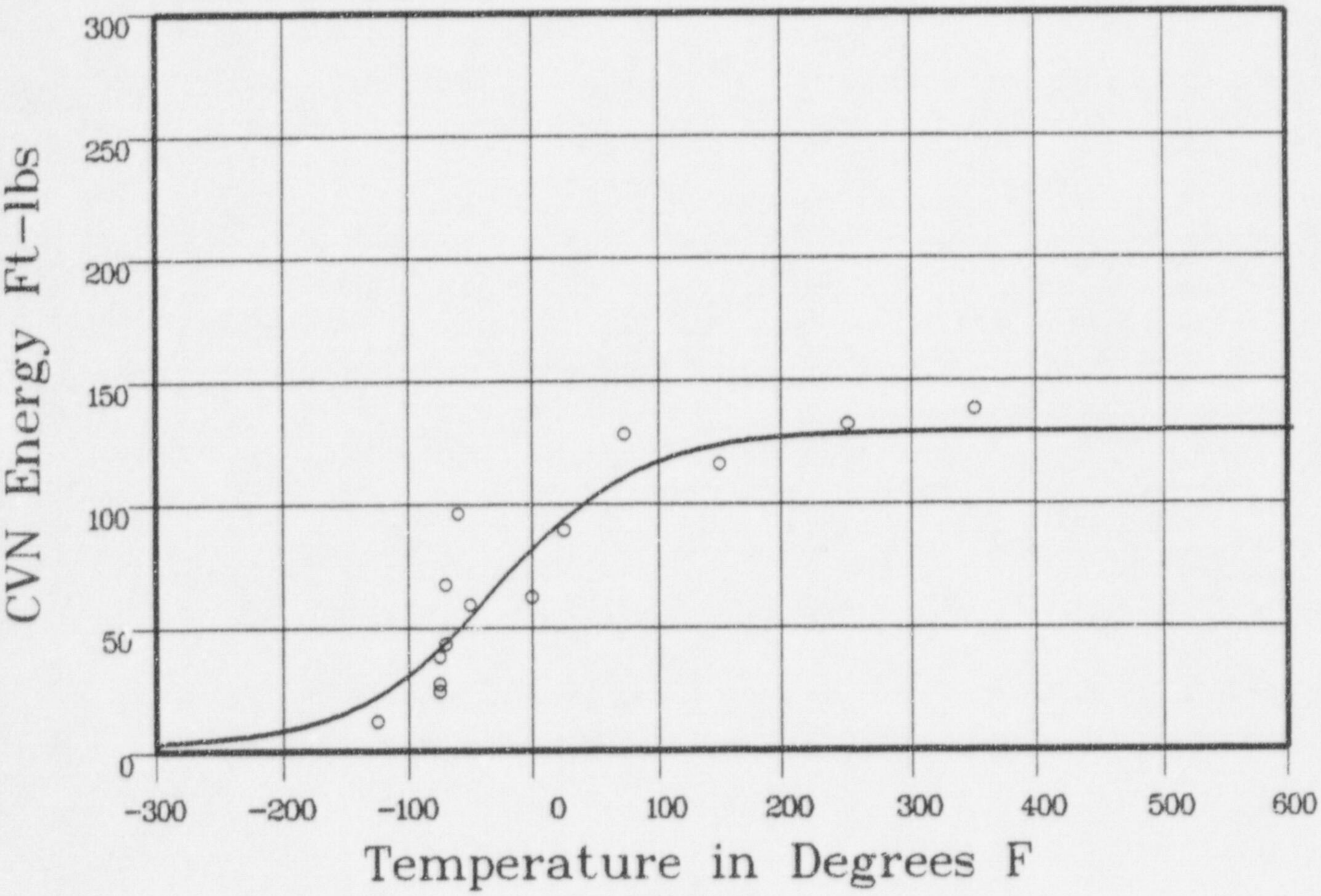
A = 65.59	B = 63.4	C = 114.59	T0 = -33.54

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 129 Fixed Temp. at 30 ft-lbs: -106.3 Temp. at 50 ft-lbs: -62.3 Lower Shelf Energy: 2.19 Fixed

Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: U Material: HEAT AFFD ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-125	12	23.56	-11.56
-75	27	43.61	-16.61
-75	24	43.61	-19.61
-75	38	43.61	-5.61
-70	67	46.08	20.91
-70	43	46.08	-3.08
-60	96	51.21	44.78
-50	59	56.55	2.44

**** Data continued on next page ****

Capsule U

Page 2

Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
0	62	83.64	-21.64
25	89	95.43	-6.43
72	128	111.65	16.34
150	116	124.04	-8.04
250	132	128.1	3.89
350	138	128.84	9.15

SUM of RESIDUALS = 4.91

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:07:58 on 05-12-1998

Page 1

Coefficients of Curve 3

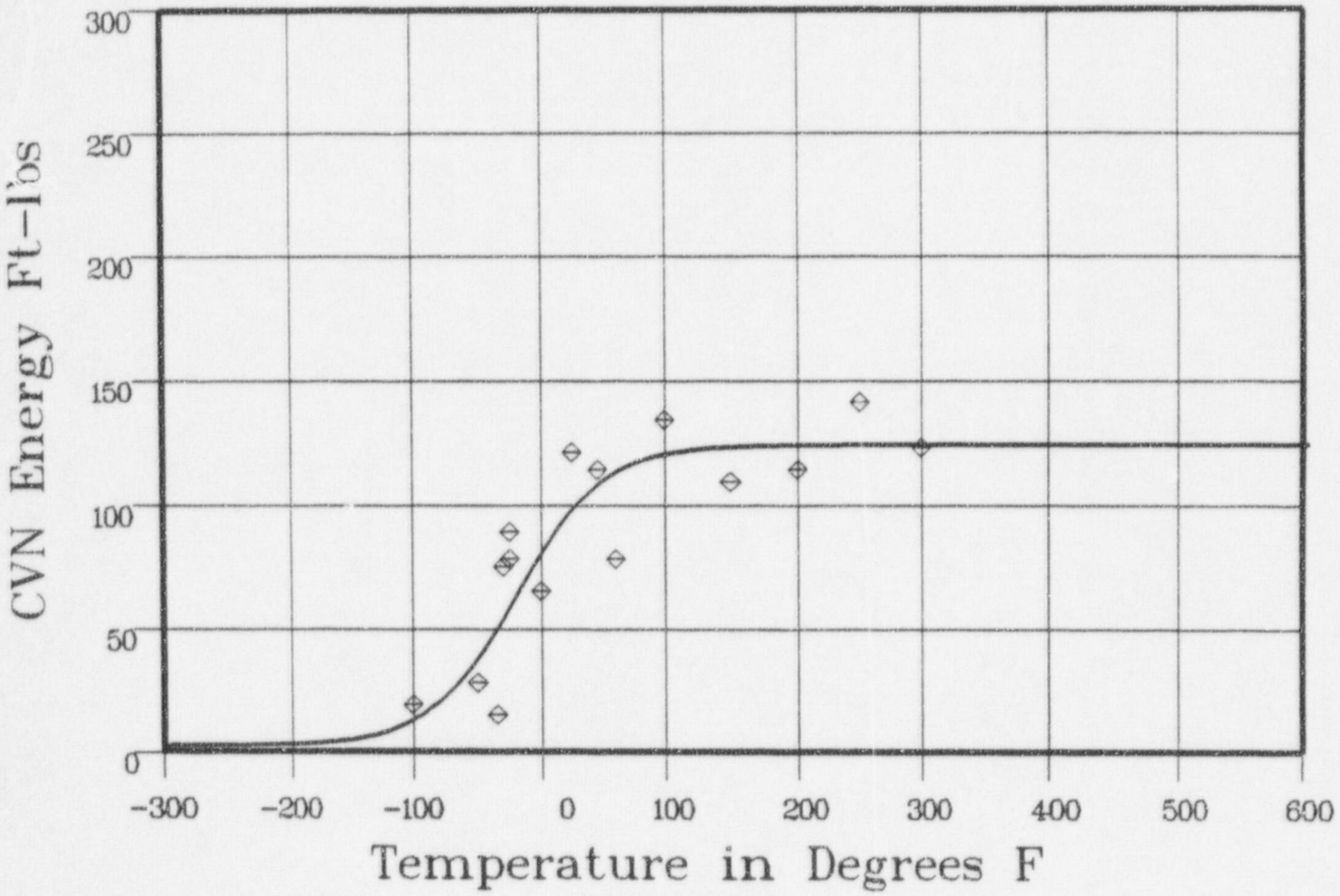
A = 63.09	B = 60.9	C = 68.61	T0 = -24.37

Equation is: CVN = A + B * [tanh((T - T0)/C)]

Upper Shelf Energy: 124 Fixed Temp. at 30 ft-lbs: -66.1 Temp. at 50 ft-lbs: -39.3 Lower Shelf Energy: 2.19 Fixed

Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: HEAT AFFD ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-100	19	14.3	4.69
-50	28	41.35	-13.35
-35	15	53.74	-38.74
-30	75	58.11	16.88
-25	89	62.54	26.45
-25	78	62.54	15.45
0	65	83.86	-18.86
25	121	100.65	20.34

**** Data continued on next page ****

Capsule Y

Page 2

Material: HEAT AFF'D ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:

Capsule: Y   Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
45	114	109.76	4.23
60	78	114.4	-36.4
100	134	120.83	13.16
150	109	123.24	-14.24
200	114	123.82	-9.82
250	141	123.95	17.04
300	123	123.99	-.99

SUM of RESIDUALS = -14.16

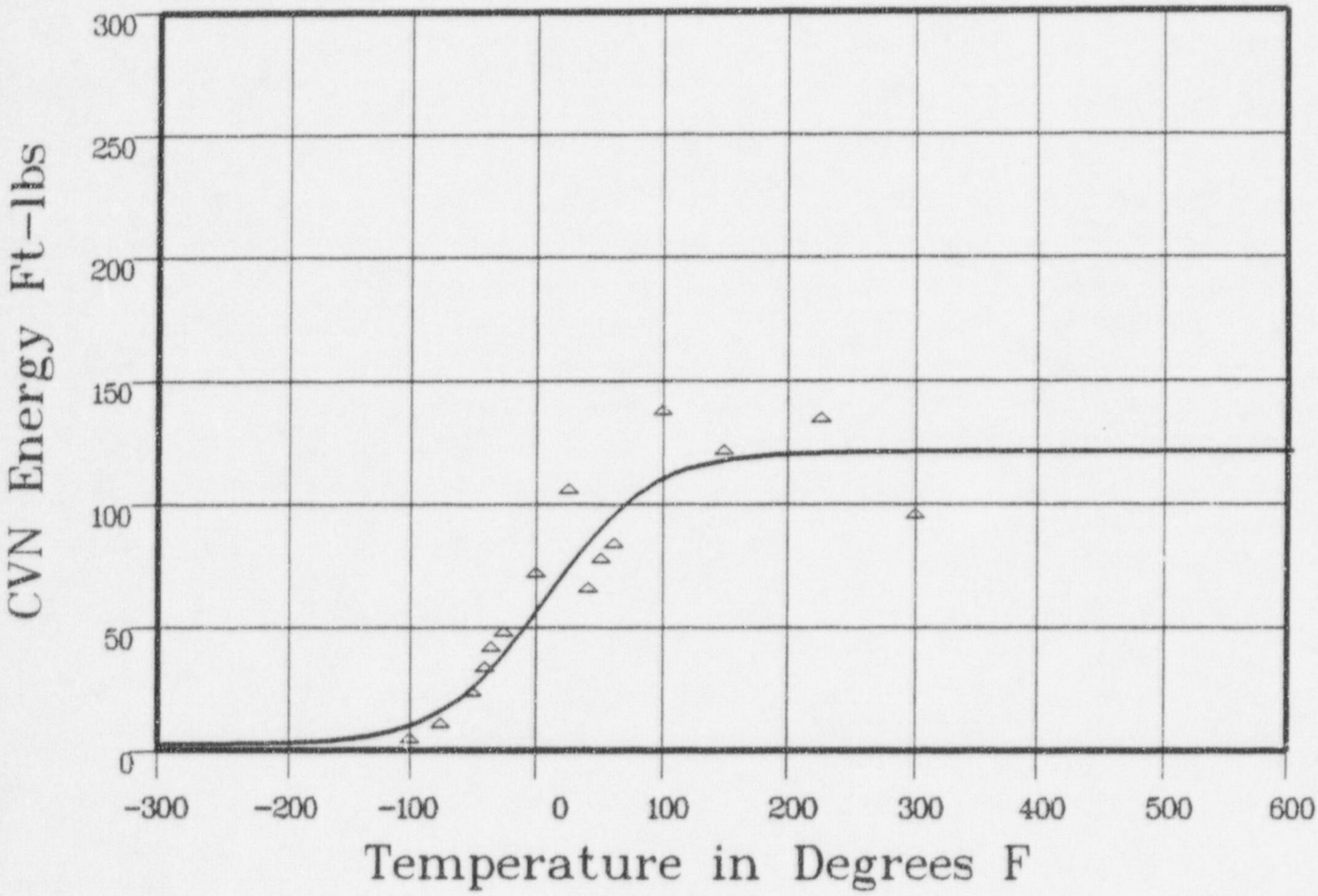
Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:07:58 on 05-12-1998
Page 1
Coefficients of Curve 4

A = 61.59   B = 59.4   C = 81.13   T0 = 3.22

Equation is: $CVN = A + B * [\tanh((T - T0)/C)]$

Upper Shelf Energy: 121 Fixed   Temp. at 30 ft-lbs: -44.8   Temp. at 50 ft-lbs: -12.8   Lower Shelf Energy: 2.19 Fixed
Material: HEAT AFFD ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:
Capsule: V   Total Fluence:



Data Set(s) Plotted
Plant: V01   Cap.: V   Material: HEAT AFFD ZONE   Ori.:   Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-100	3	10.84	-7.84
-75	9	17.27	-8.27
-50	22	27.4	-5.4
-40	32	32.64	-.64
-35	40	35.51	4.48
-25	46	41.72	4.27
0	70	59.23	10.76

**** Data continued on next page ****

Capsule V

Page 2

Material: HEAT AFFD ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:

Capsule: V   Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
25	104	77.16	26.83
40	64	86.81	-22.81
50	76	92.49	-16.49
60	82	97.48	-15.48
100	136	110.98	25.01
150	120	117.89	2.1
225	133	120.5	12.49
300	94	120.92	-26.92

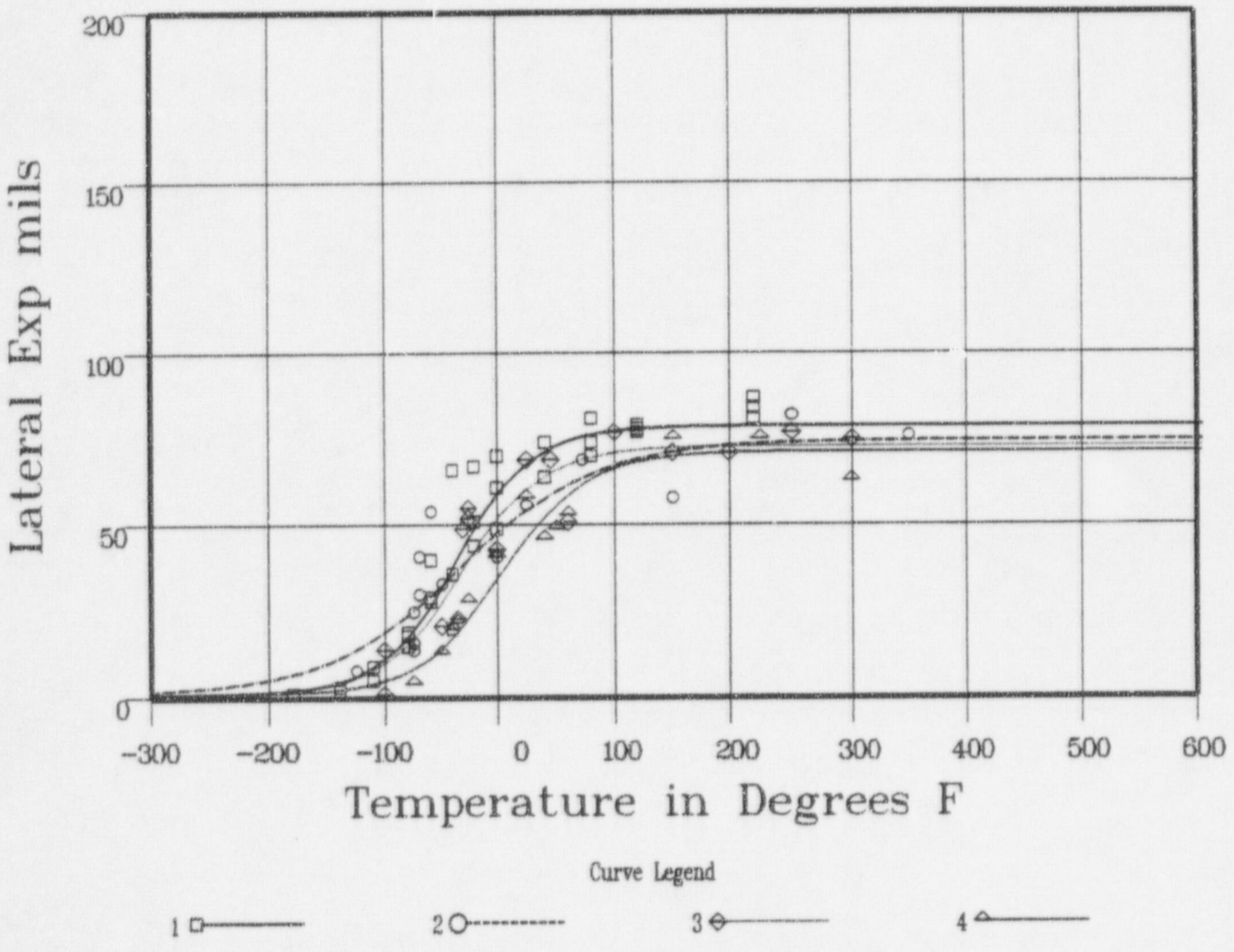
SUM of RESIDUALS = -17.91

Heat Affected Zone

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:19:39 on 05-12-1998

Results

Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	78.79	0	-49.54	0
2	0	74.45	-4.33	-47.35	2.18
3	0	72.81	-5.98	-39.89	9.65
4	0	71.27	-7.51	-3.79	45.74



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	HEAT AFF'D ZONE		B8805-1 SIDE OF WELD
2	V01	U	HEAT AFF'D ZONE		B8805-1 SIDE OF WELD
3	V01	Y	HEAT AFF'D ZONE		B8805-1 SIDE OF WELD
4	V01	V	HEAT AFF'D ZONE		B8805-1 SIDE OF WELD

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:19:39 on 05-12-1998

Page 1

Coefficients of Curve 1

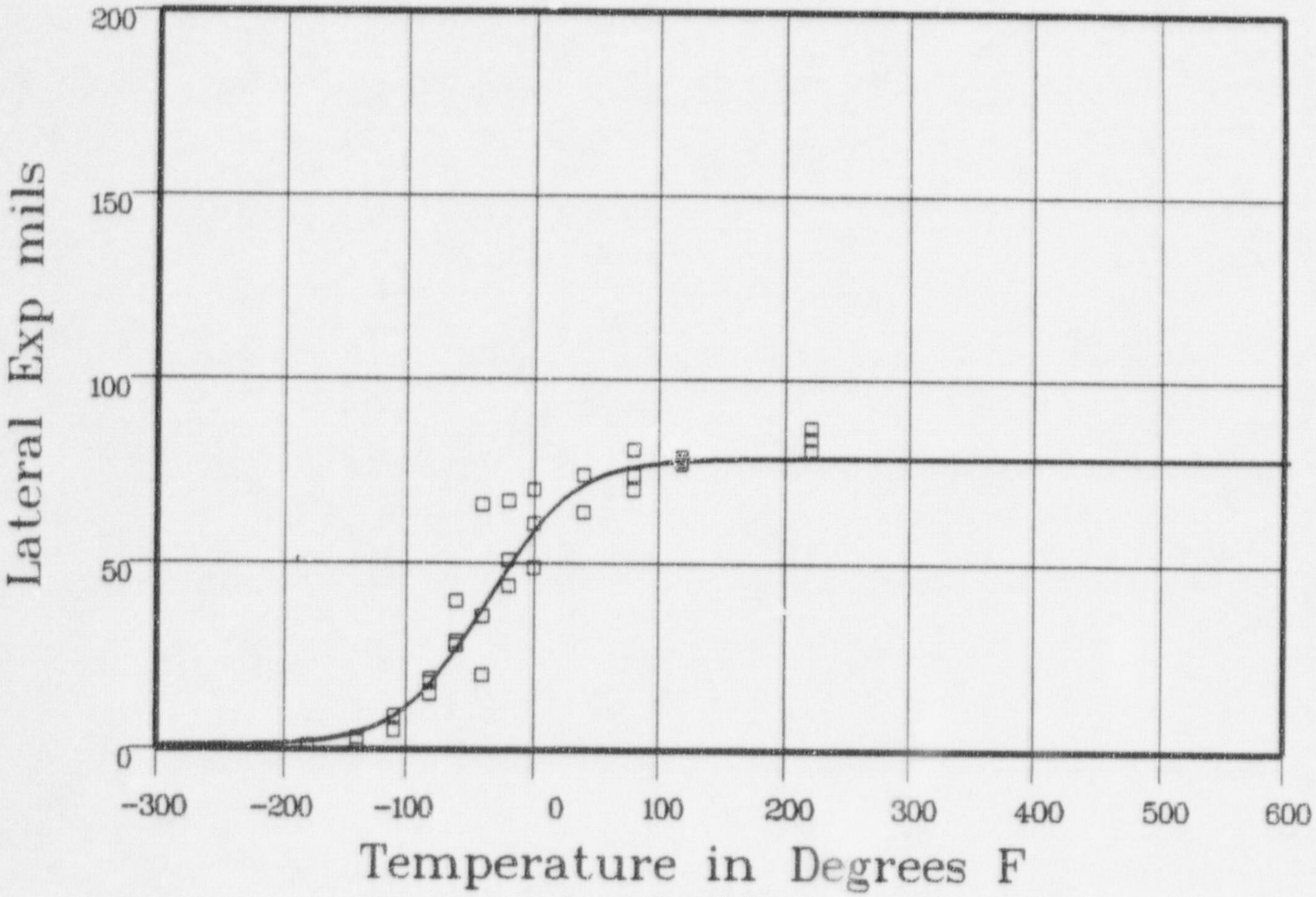
A = 39.89	B = 38.89	C = 68.15	T0 = -40.92

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 78.79 Temperature at L.E. 35: -49.5 Lower Shelf L.E.: 1 Fixed

Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: HEAT AFFD ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-180	1	2.29	-1.29
-180	1	2.29	-1.29
-140	2	5.02	-3.02
-140	3	5.02	-2.02
-110	9	10.05	-1.05
-110	5	10.05	-5.05
-110	9	10.05	-1.05
-80	15	19.75	-4.75
-80	18	19.75	-1.75

**** Data continued on next page ****

Unirradiated

Page 2

Material: HEAT AFF'D ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:

Capsule: UNIRR   Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-80	19	19.75	-.75
-60	28	29.28	-1.28
-60	40	29.28	10.71
-60	29	29.28	-.28
-40	20	40.42	-20.42
-40	36	40.42	-4.42
-40	66	40.42	25.57
-20	67	51.47	15.52
-20	44	51.47	-7.47
-20	51	51.47	-.47
0	49	60.79	-11.79
0	61	60.79	2
0	70	60.79	9.2
40	74	72.17	1.82
40	64	72.17	-8.17
40	64	72.17	-8.17
80	81	76.61	4.38
80	74	76.61	-2.61
80	70	76.61	-6.61
120	79	78.1	.89
120	77	78.1	-1.1
120	78	78.1	-.1
220	84	78.75	5.24
220	81	78.75	2.24
220	87	78.75	8.24

SUM of RESIDUALS = -10.95

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:19:39 on 05-12-1998

Page 1

Coefficients of Curve 2

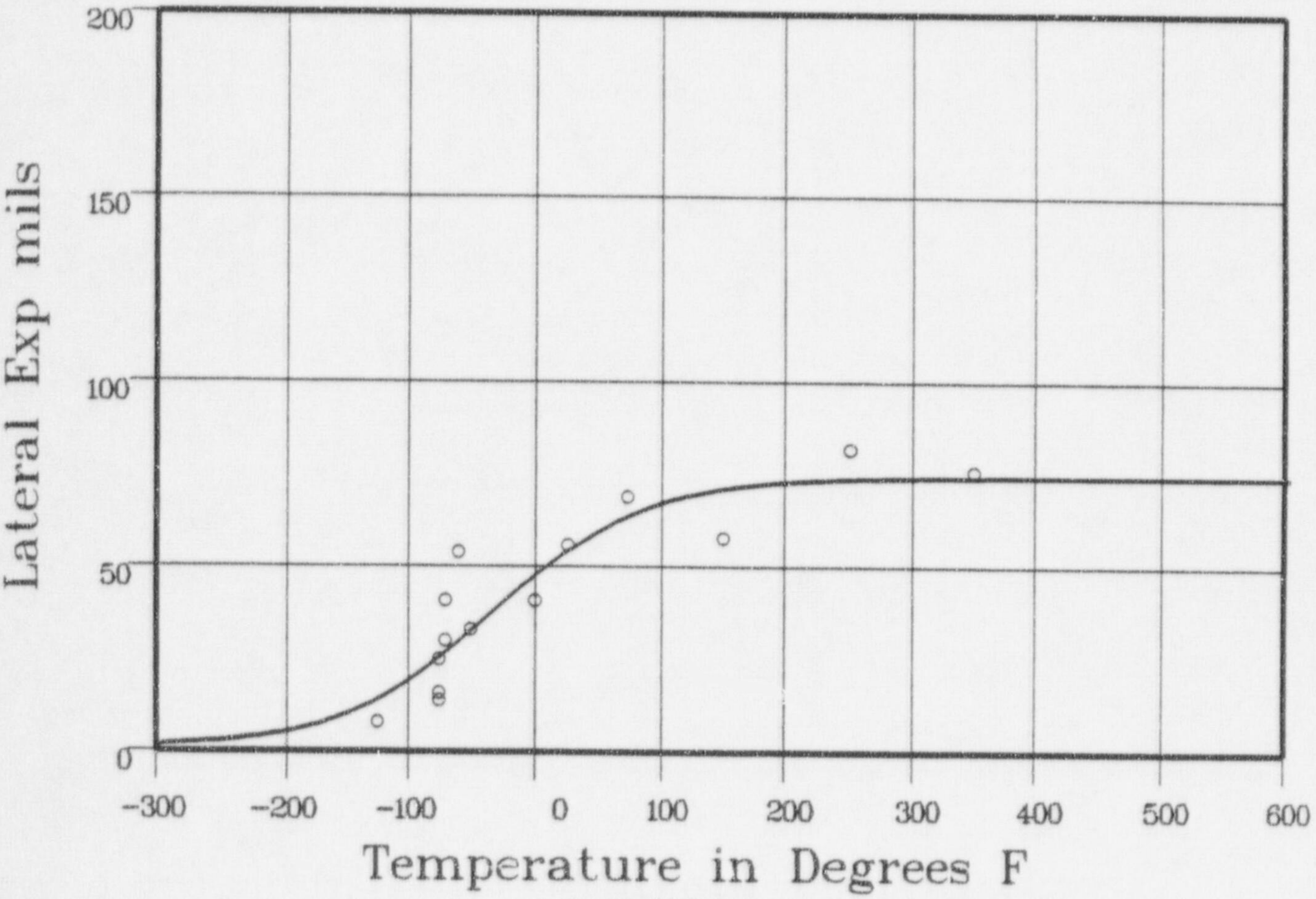
A = 37.72 B = 36.72 C = 119.85 T0 = -38.43

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 74.45 Temperature at L.E. 35: -47.3 Lower Shelf L.E.: 1 Fixed

Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap: U Material: HEAT AFFD ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-125	8	15.02	-7.02
-75	14	26.85	-12.85
-75	16	26.85	-10.85
-75	25	26.85	-1.85
-70	41	28.27	12.72
-70	30	28.27	1.72
-60	54	31.19	22.8
-50	33	34.19	-1.19

**** Data continued on next page ****

Capsule U

Page 2

Material: HEAT AFF'D ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:

Capsule: U   Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
0	41	49.11	-8.11
25	56	55.53	.46
72	69	64.41	4.58
150	58	71.42	-13.42
250	82	73.86	8.13
350	76	74.34	1.65

SUM of RESIDUALS = -3.23

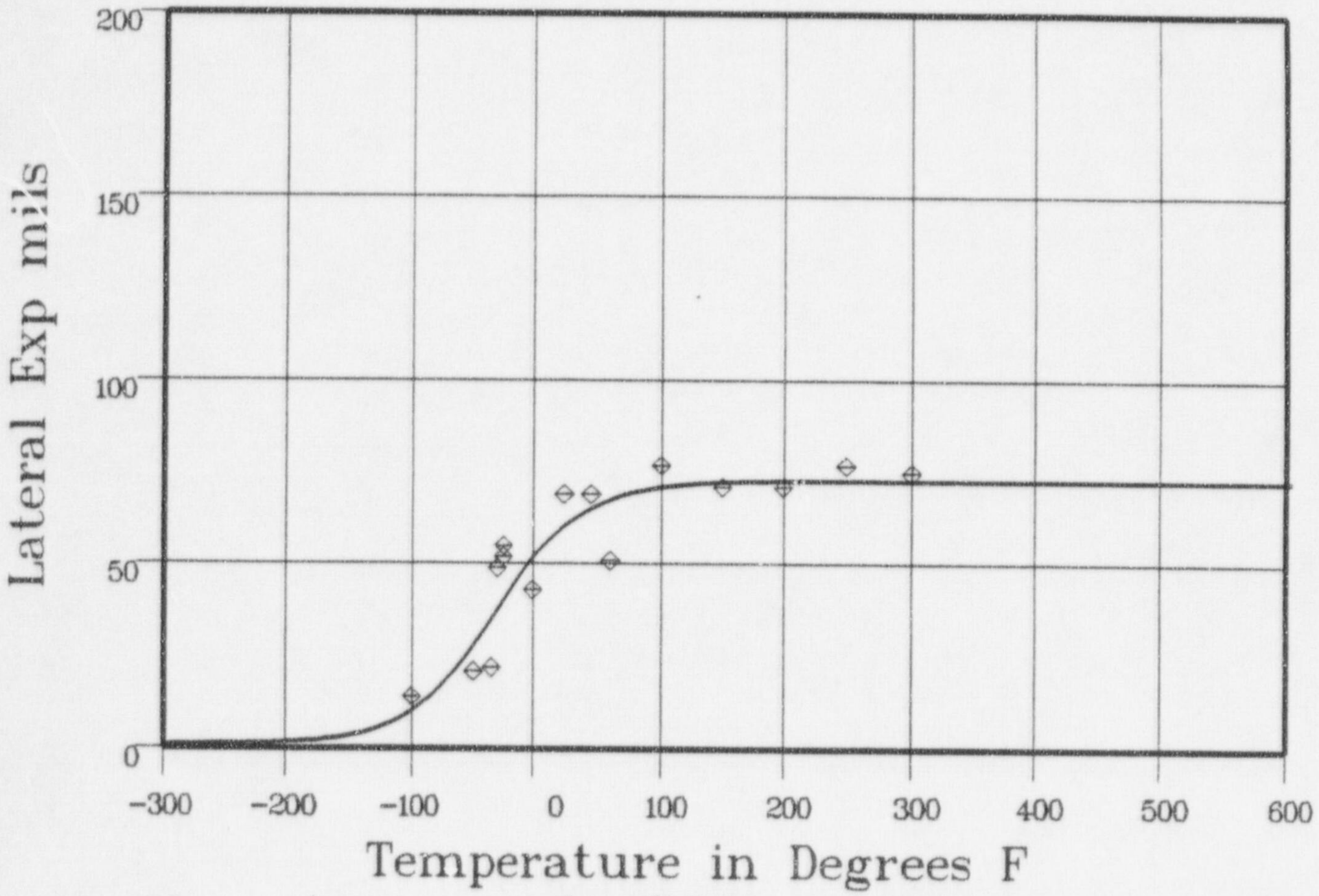
Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:19:39 on 05-12-1998
Page 1
Coefficients of Curve 3

A = 36.9 B = 35.9 C = 71.56 T0 = -36.09

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 72.81 Temperature at L.E. 35: -39.8 Lower Shelf L.E.: 1 Fixed
Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:
Capsule: Y Total Fluence:



Data Set(s) Plotted
Plant: V01 Cap.: Y Material: HEAT AFFD ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-100	14	11.31	2.68
-50	21	30.01	-9.01
-35	22	37.45	-15.45
-30	49	39.95	9.04
-25	55	42.42	12.57
-25	52	42.42	9.57
0	43	53.61	-10.61
25	69	61.78	7.21

**** Data continued on next page ****

Capsule Y

Page 2

Material: HEAT AFF'D ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
45	69	66.06	2.93
60	51	68.22	-17.22
100	77	71.24	5.75
150	71	72.41	-1.41
200	71	72.71	-1.71
250	77	72.78	4.21
300	75	72.8	2.19

SUM of RESIDUALS = .75

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:19:39 on 05-12-1998

Page 1

Coefficients of Curve 4

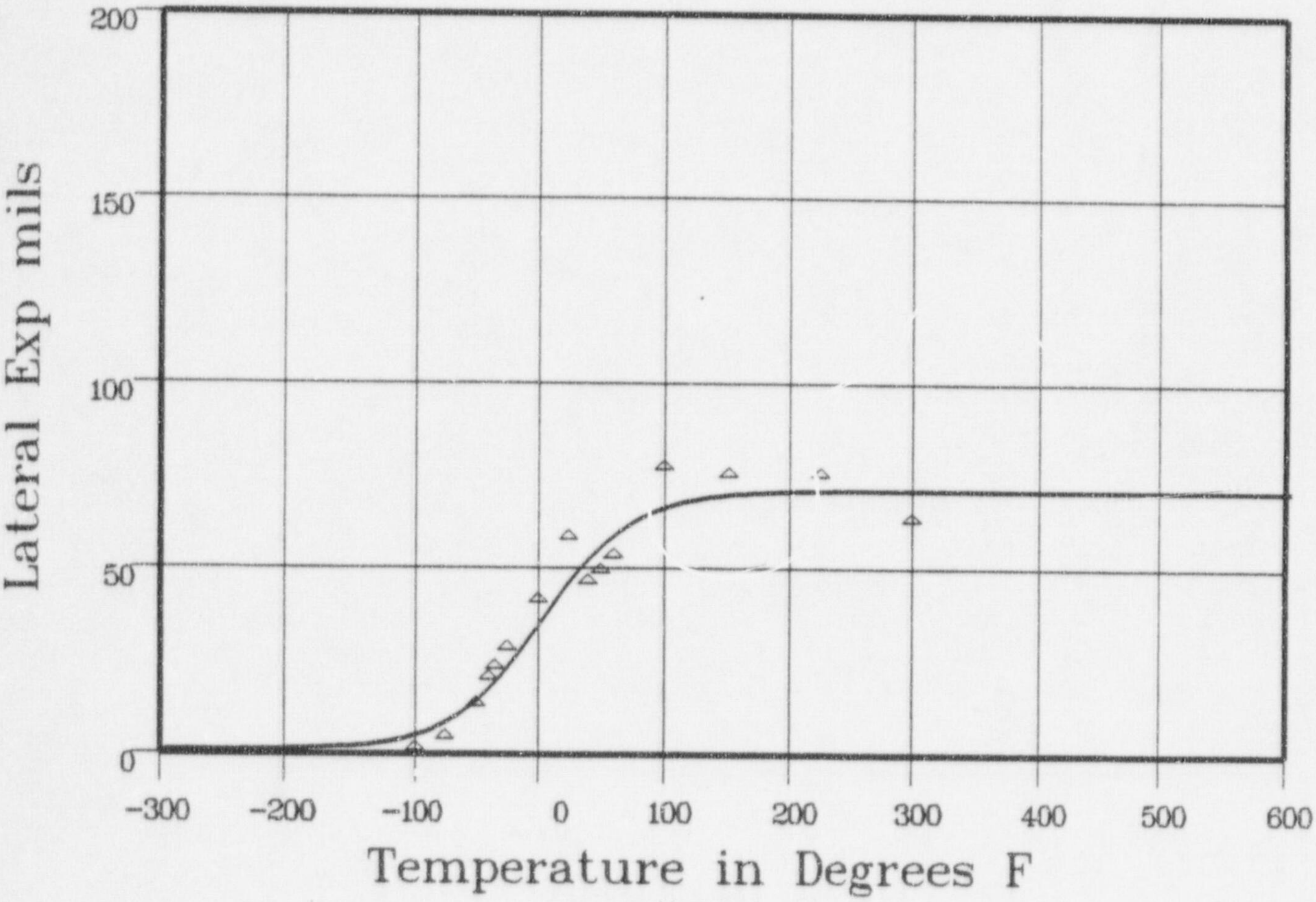
A = 36.13	B = 35.13	C = 73.76	T0 = -1.4

Equation is: L.E. = A + B * [tanh((T - T0)/C)]

Upper Shelf L.E.: 71.27 Temperature at L.E. 35: -3.7 Lower Shelf L.E.: 1 Fixed

Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: V Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: V Material: HEAT AFFD ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-100	1	5.53	-4.53
-75	4	9.41	-5.41
-50	13	15.84	-2.84
-40	20	19.26	.73
-35	23	21.15	1.84
-25	28	25.26	2.73
0	41	36.8	4.19

**** Data continued on next page ****

Capsule V

Page 2

Material: HEAT AFF'D ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:

Capsule: V   Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
25	58	48.2	9.79
40	46	54.02	-8.02
50	49	57.3	-8.3
60	53	60.09	-7.09
100	77	67.05	9.94
150	75	70.13	4.86
225	75	71.12	3.87
300	63	71.25	-8.25

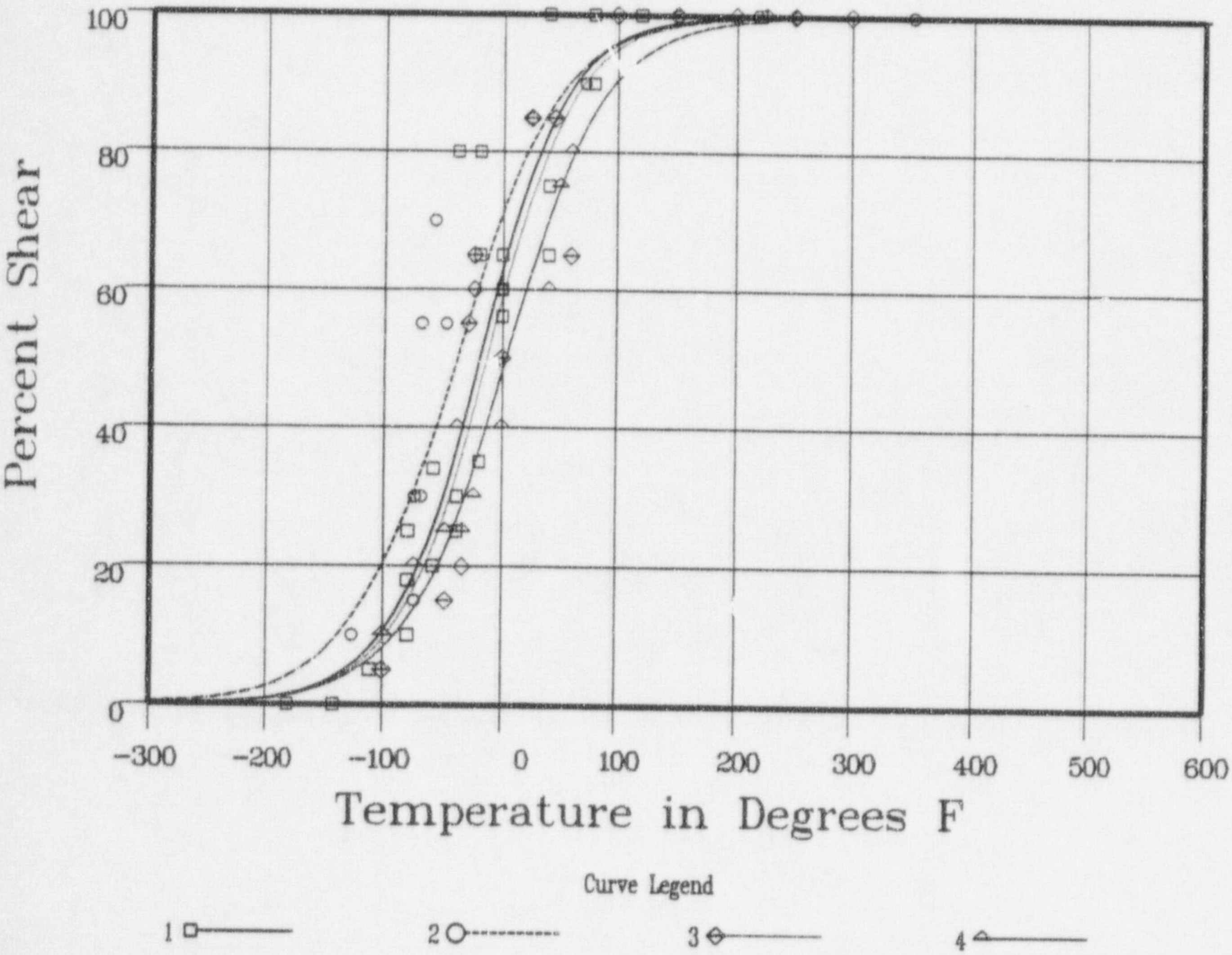
SUM of RESIDUALS = -6.48

Heat Affected Zone

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:37:49 on 05-12-1998

Results

Curve	Fluence	T @ 50% Shear	d-T @ 50% Shear
1	0	-24.37	0
2	0	-44.52	-20.14
3	0	-18.28	6.09
4	0	-1.4	22.96



Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	V01	UNIRR	HEAT AFF'D ZONE		B8805-1 SIDE OF WELD
2	V01	U	HEAT AFF'D ZONE		B8805-1 SIDE OF WELD
3	V01	Y	HEAT AFF'D ZONE		B8805-1 SIDE OF WELD
4	V01	V	HEAT AFF'D ZONE		B8805-1 SIDE OF WELD

Unirradiated

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:37:49 on 05-12-1998

Page 1

Coefficients of Curve 1

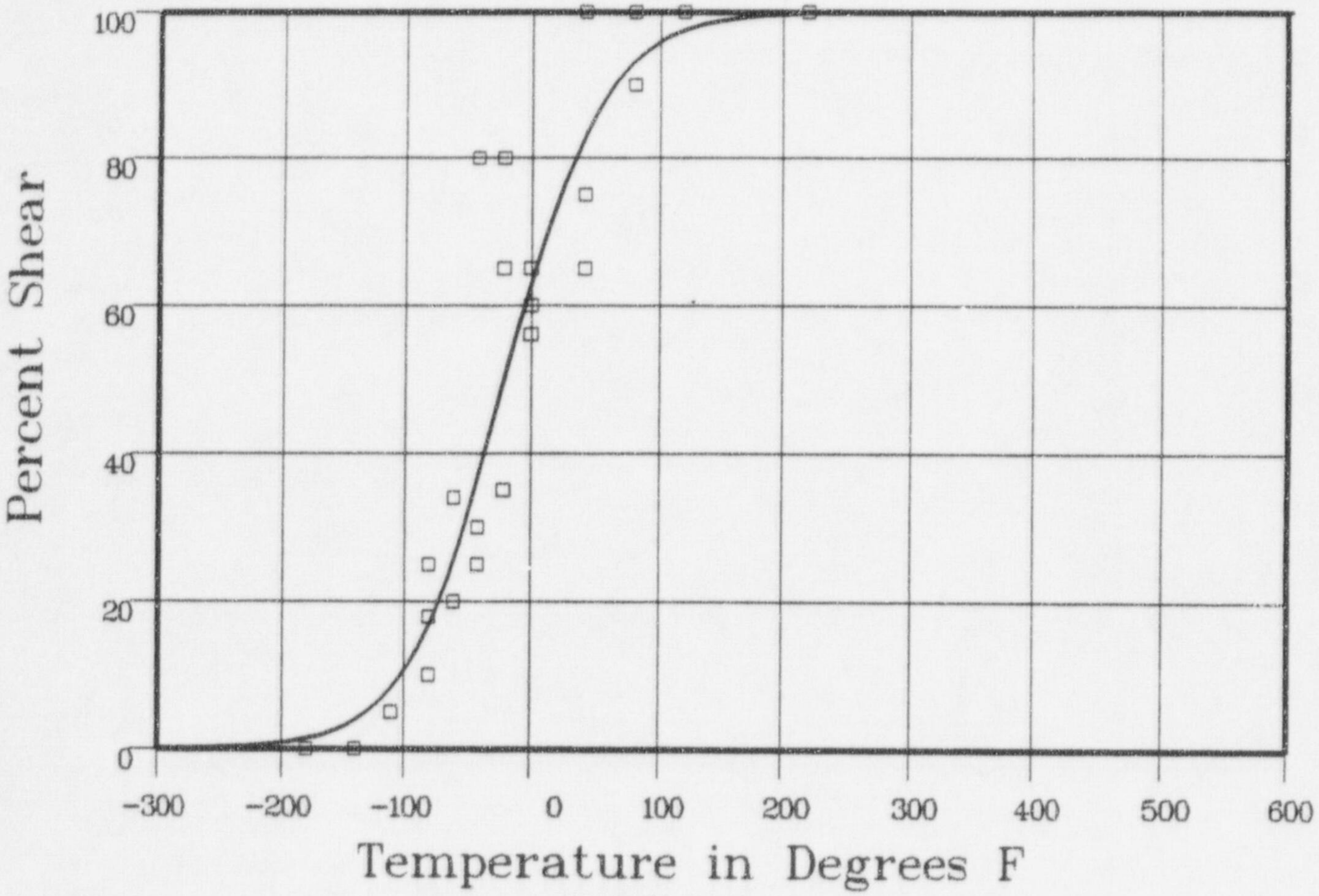
A = 50	B = 50	C = 75.45	T0 = -24.37

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: -24.3

Material: HEAT AFFD ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: UNIRR Material: HEAT AFFD ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-180	0	1.59	-1.59
-180	0	1.59	-1.59
-140	0	4.45	-4.45
-140	0	4.45	-4.45
-110	5	9.36	-4.36
-110	5	9.36	-4.36
-110	5	9.36	-4.36
-80	10	18.63	-8.63
-80	25	18.63	6.36

**** Data continued on next page ****

Unirradiated

Page 2

Material: HEAT AFFD ZONE　　Heat Number: B8805-1 SIDE OF WELD　　Orientation:

Capsule: UNIRR　　Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80	18	18.63	-.63
-60	20	28	-8
-60	34	28	5.99
-60	20	28	-8
-40	25	39.79	-14.79
-40	30	39.79	-9.79
-40	80	39.79	40.2
-20	80	52.89	27.1
-20	35	52.89	-17.89
-20	65	52.89	12.1
0	65	65.61	-.61
0	60	65.61	-5.61
0	56	65.61	-9.61
40	100	84.63	15.36
40	65	84.63	-19.63
40	75	84.63	-9.63
80	100	94.08	5.91
80	90	94.08	-4.08
80	90	94.08	-4.08
120	100	97.86	2.13
120	100	97.86	2.13
120	100	97.86	2.13
220	100	99.84	.15
220	100	99.84	.15
220	100	99.84	.15

SUM of RESIDUALS = -26.35

Capsule U

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:37:49 on 05-12-1998

Page 1

Coefficients of Curve 2

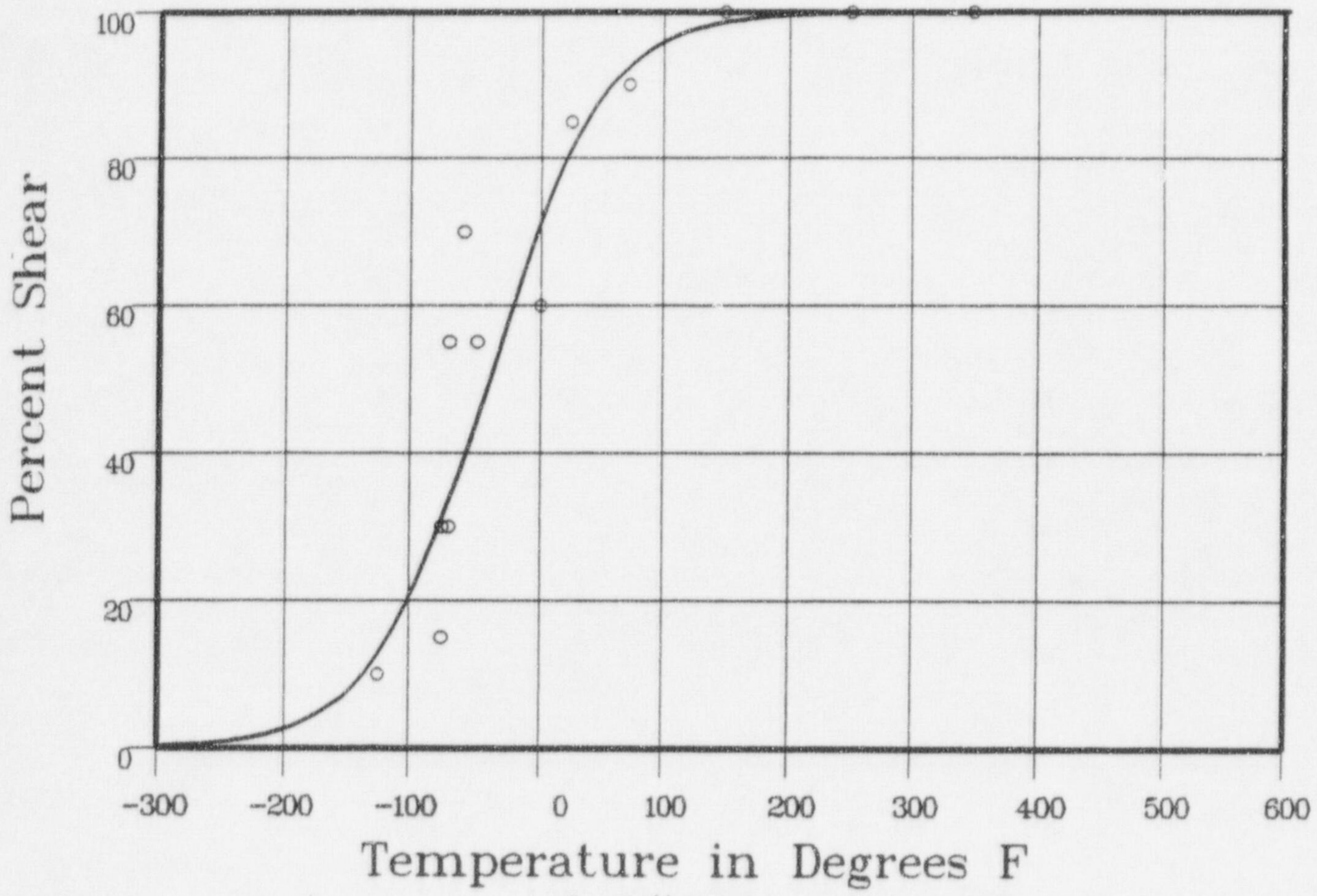
A = 50	B = 50	C = 88.56	T0 = -44.52

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: -44.5

Material: HEAT AFF'D ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:

Capsule: U   Total Fluence:



Data Set(s) Plotted

Plant: V01   Cap.: U   Material: HEAT AFF'D ZONE   Ori.:   Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-125	10	13.97	-3.97
-75	15	33.44	-18.44
-75	15	33.44	-18.44
-75	30	33.44	-3.44
-70	55	36	18.99
-70	30	36	-6
-60	70	41.35	28.64
-50	55	46.91	8.08

**** Data continued on next page ****

Capsule U

Page 2

Material: HEAT AFF'D ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:

Capsule: U   Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
0	60	73.21	-13.21
25	85	82.77	2.22
72	90	93.28	-3.28
150	100	98.77	1.22
250	100	99.87	.12
350	100	99.98	.01

SUM of RESIDUALS = -7.51

Capsule Y

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:37:49 on 05-12-1998

Page 1

Coefficients of Curve 3

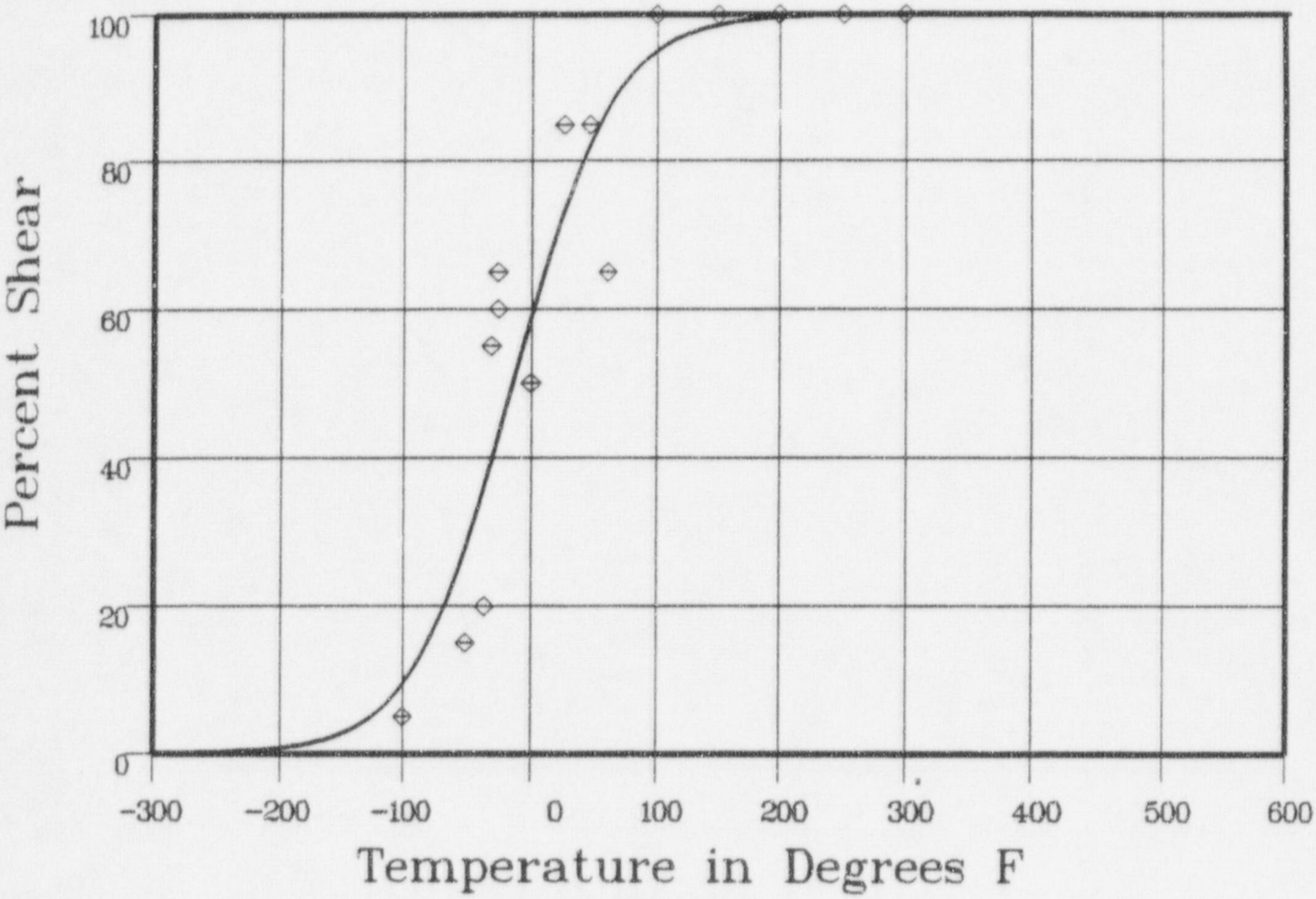
A = 50 B = 50 C = 76.75 T0 = -18.28

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: -18.2

Material: HEAT AFF'D ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: V01 Cap.: Y Material: HEAT AFF'D ZONE Ori.: Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100	5	10.62	-5.62
-50	15	30.43	-15.43
-35	20	39.27	-19.27
-30	55	42.42	12.57
-25	65	45.63	19.36
-25	60	45.63	14.36
0	50	61.68	-11.68
25	85	75.54	9.45

**** Data continued on next page ****

Capsule Y

Page 2

Material: HEAT AFF'D ZONE　　Heat Number: B8805-1 SIDE OF WELD　　Orientation:

Capsule: Y　　Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
45	85	83.87	1.12
60	65	88.49	-23.49
100	100	95.61	4.38
150	100	98.76	1.23
200	100	99.66	.33
250	100	99.9	.09
300	100	99.97	.02

SUM of RESIDUALS = -12.55

Capsule V

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 08:37:49 on 05-12-1998

Page 1

Coefficients of Curve 4

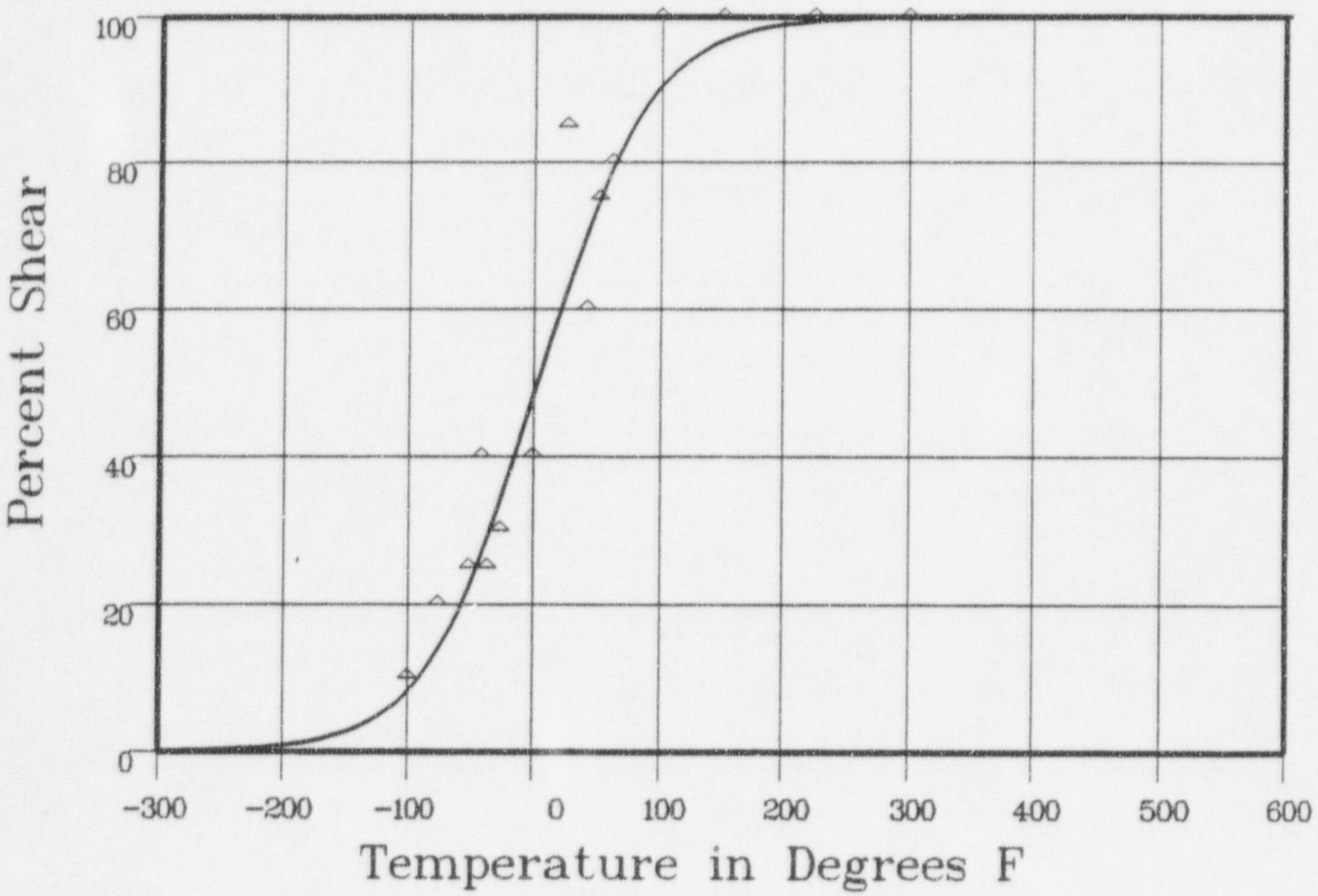
A = 50	B = 50	C = 85.83	T0 = -1.4

Equation is: Shear% = A + B * [tanh((T - T0)/C)]

Temperature at 50% Shear: -1.4

Material: HEAT AFFD ZONE   Heat Number: B8805-1 SIDE OF WELD   Orientation:

Capsule: V   Total Fluence:



Data Set(s) Plotted

Plant: V01   Cap.: V   Material: HEAT AFFD ZONE   Ori.:   Heat #: B8805-1 SIDE OF WELD

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100	10	9.13	.86
-75	20	15.25	4.74
-50	25	24.37	.62
-40	40	28.92	11.07
-35	25	31.37	-6.37
-25	30	36.59	-6.59
0	40	50.82	-10.82

**** Data continued on next page ****

Capsule V

Page 2

Material: HEAT AFF'D ZONE Heat Number: B8805-1 SIDE OF WELD Orientation:

Capsule: V Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
25	85	64.91	20.08
40	60	72.41	-12.41
50	75	76.81	-1.81
60	80	80.7	-.7
100	100	91.39	8.6
150	100	97.14	2.85
225	100	99.49	.5
300	100	99.91	.08

SUM of RESIDUALS = 10.73

APPENDIX D

VOGTLE UNIT 1 SURVEILLANCE PROGRAM CREDIBILITY ANALYSIS

INTRODUCTION:

Regulatory Guide 1.99, Revision 2, 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. Position C.2 of Regulatory Guide 1.99, Revision 2, describes 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 Position c.2 can only be applied when two or more credible surveillance data sets becomes available from the reactor in question.

To date there has been three surveillance capsules removed from the Vogtle Electric Generating Plant Unit 1 reactor vessel. To use these surveillance data sets, they must be shown to be credible. In accordance with the discussion of Regulatory Guide 1.99, Revision 2, there are five requirements that must be met for the surveillance data to be judged credible.

The purpose of this evaluation is to apply the credibility requirements of Regulatory Guide 1.99, Revision 2, to the Vogtle Electric Generating Plant Unit 1 reactor vessel surveillance data and determine if the Vogtle Electric Generating Plant Unit 1 surveillance data is credible.

EVALUATION:

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

The beltline region of the reactor vessel is defined in Appendix G to 10CFR Part 50, "Frature Toughness Requirements", as follows:

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

The Vogtle Electric Generating Plant Unit 1 reactor vessel consists of the following beltline region materials:

- Intermediate Shell Plate B8805-1, 2 and 3 (Heat No. C0613-1, -2 and C0623-1)
- Lower Shell Plate B8806-1, 2 and 3 (Heat No. C2146-1, -2 and C2085-2)
- Intermediate Shell Longitudinal Weld Seams 101-124A, B, C, Lower Shell Longitudinal Weld Seams 101-142A, B, C and Girth Weld Seam 101-171.

The Vogtle Electric Generating Plant Unit 1 surveillance program utilizes longitudinal and transverse test specimens from the intermediate shell plate B8805-3. The surveillance weld metal was fabricated with weld wire heat number 83653, Linde 0091 Flux, Lot 3536, which represents all the welds in the beltline region.

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. Intermediate shell plate B8805-3 had the highest initial RT_{NDT} and one of the lowest initial USE of all the plate materials in the beltline region. In addition, intermediate shell plate B8805-3 had approximately the same copper and phosphorus content as the other beltline plate materials. Therefore, based on having the highest initial RT_{NDT} and one of the lowest USE of all the plate materials, the intermediate shell plate B8805-3 was chosen for the surveillance program. The weld, on the other hand, represents all of the beltline welds.

Based on the above discussion, the Vogtle Electric Generating Plant Unit 1 surveillance material meets the intent of this criteria.

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 upper shelf energy unambiguously.

Plots of the Charpy energy versus temperature for the unirradiated and irradiated condition are presented in Section 5 and Appendix C of this Report.

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 upper shelf energy of the Vogtle Electric Generating Plant Unit 1 surveillance materials unambiguously. Therefore, the Vogtle Electric Generating Plant Unit 1 surveillance program meets the intent of this criterion.

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

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.

Following is the calculation of the best-fit line as described in Regulatory Position 2.1 of Regulatory Guide 1.99, Revision 2.

TABLE D-1: Vogtle Unit 1 Surveillance Capsule Data Chemistry Factor Calculation

Material	Capsule	Capsule $f^{(a)}$	$FF^{(b)}$	$\Delta RT_{NDT}{}^{(c)}$	$FF * \Delta RT_{NDT}$	FF^2
Intermediate Shell Plate B8805-3 (Longitudinal)	U	0.3691	0.725	13.6	9.9	0.526
	Y	1.276	1.068	31.9	34.1	1.141
	V	2.178	1.211	42.7	51.7	1.467
Intermediate Shell Plate B8805-3 (Transverse)	U	0.3691	0.725	-9.3	-6.7	0.526
	Y	1.276	1.068	15.9	17.0	1.141
	V	2.178	1.211	33.8	40.9	1.467
				SUM:	146.1	6.268
	$CF_{B8805-3} = \Sigma(FF*RT_{NDT}) \div \Sigma(FF^2) = (146.1) \div (6.268) = 23.3°F$					
Surveillance Weld Material	U	0.3691	0.725	25	18.1	0.526
	Y	1.276	1.068	8	8.5	1.141
	V	2.178	1.211	-1.3	-1.6	1.467
				SUM:	24.7	3.134
	$CF_{Weld} = \Sigma(FF*RT_{NDT}) \div \Sigma(FF^2) = (24.7) \div (3.134) = 7.9°F$					

NOTES:

(a) f = Measured fluence from Capsule V dosimetry analysis results per Section 6 (x 10^{19} n/cm^2, E > 1.0 MeV).

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values (See Section 5 and Appendix C) and does not include an adjustment per the ratio procedure of Reg. Guide 1.99 Rev. 2, Position 2.1, since this calculation is based on the actual surveillance base and weld metal measured shift values.

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-2: Best-Fit Evaluation for Vogtle Unit 1 Surveillance Materials

Base Material	**CF (°F)**	**FF**	**Measured ΔRT_{NDT} (30 ft-lb) (°F)**	**Best-Fit [a] ΔRT_{NDT} (°F)**	**Scatter of ΔRT_{NDT} (°F)**	**< 17°F (Base Metals) < 28°F (Weld Metals)**
Intermediate Shell	23.3	0.725	13.6	16.9	-3.3	Yes
Plate B8805-3	23.3	1.068	31.9	24.9	7.0	Yes
(Longitudinal)	23.3	1.211	42.7	28.2	14.5	Yes
Intermediate Shell	23.3	0.725	-9.3	16.9	-26.2	No[b]
Plate B8805-3	23.3	1.068	15.9	24.9	-9.0	Yes
(Transverse)	23.3	1.211	33.8	28.2	5.6	Yes
Surveillance Weld	7.9	0.725	25	5.7	-19.3	Yes
Metal	7.9	1.068	8	8.4	-0.4	Yes
	7.9	1.211	-1.3	9.6	-10.9	Yes

NOTES:

(a) Best-fit Line Per Equation 2 of Reg. Guide 1.99, Rev. 2, Position 1.1.

(b) See Discussion Below.

From Table D-2 above, it can be seen that one of six points for the surveillance plate material falls outside the scatter band (+/- 17°F) on the low side, meaning that the Best-Fit Line over predicts the a RT_{NDT}. Based on guidance from the NRC, when only one point out of six or more is outside the scatter band (especially on the low side), then it should be considered credible. As for the weld material, Table D-2 indicates all the scatter is within the acceptable range for credible data.

Based on this discussion the Vogtle Electric Generating Plant Unit 1 surveillance materials meet the intent of this criteria.

Figure D-1

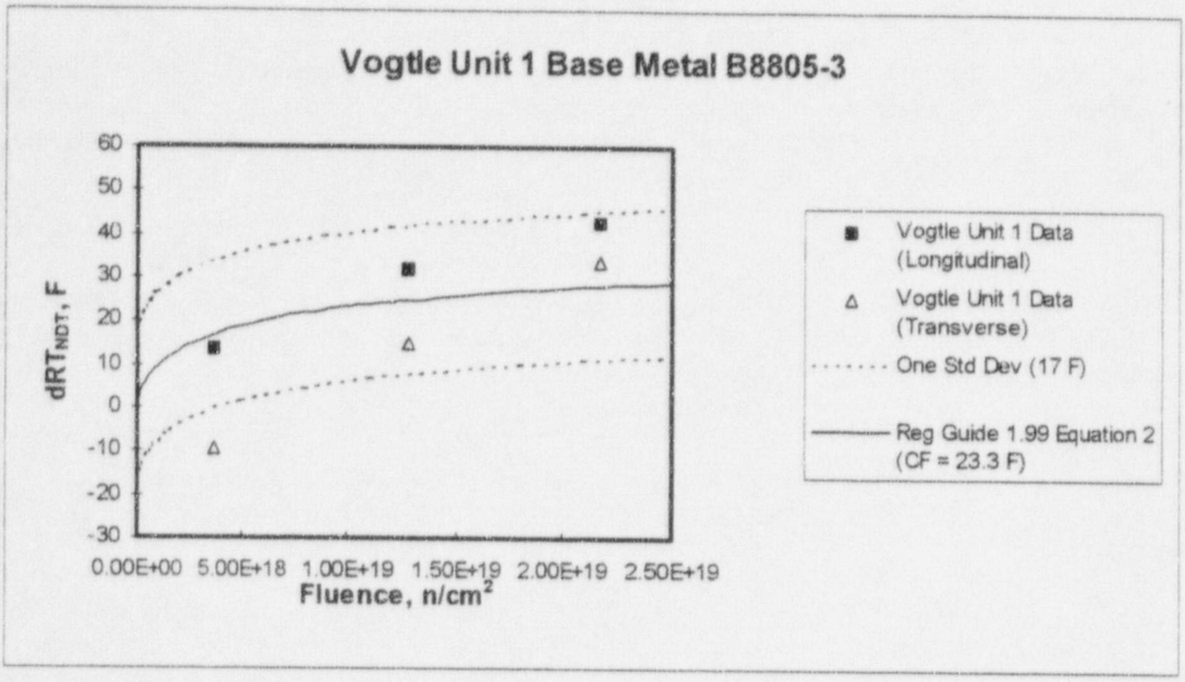
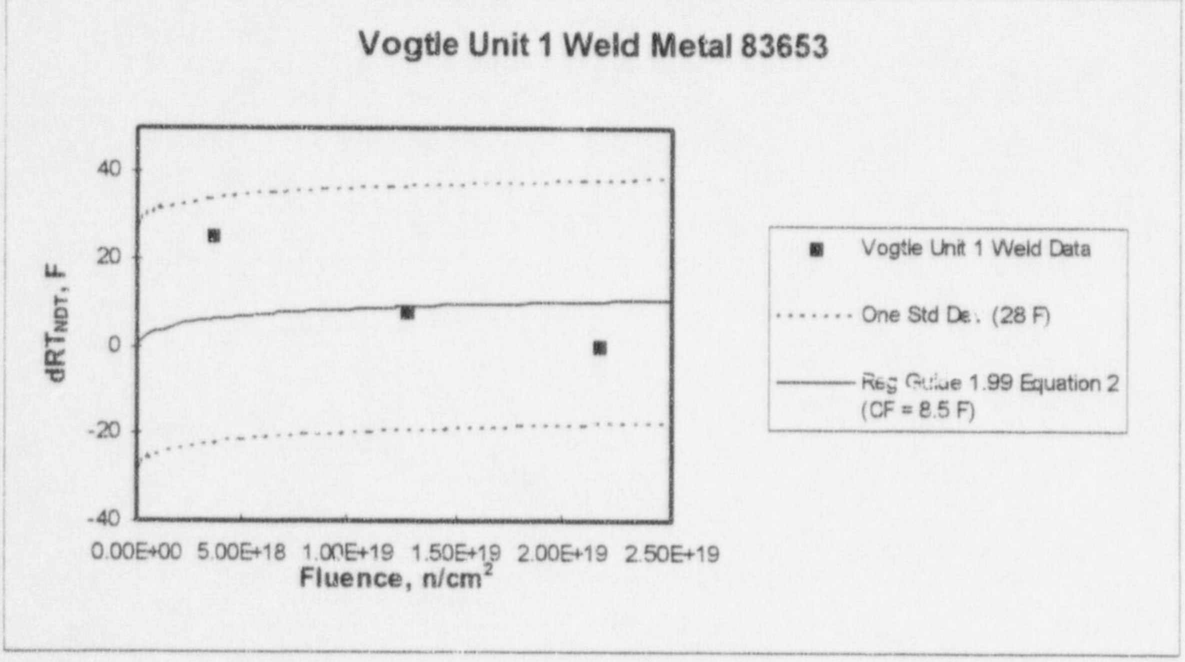


Figure D-2



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 core barrel 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 temperature will not differ by more than 25°F. Hence, this criteria is met.

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

The Vogtle Electric Generating Plant Unit 1 surveillance program does not contain correlation monitor material. Therefore, this criterion is not applicable to the Vogtle Electric Generating Plant Unit 1 surveillance program.

CONCLUSION:

Based on the preceding responses to all five criteria of Regulatory Guide 1.99, Revision 2, Section B and 10CFR 50.61, the Vogtle Electric Generating Plant Unit 1 surveillance data is Credible.