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U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

Gentlemen:

REACTOR VESSEL MATERIAL SURVEILLANCE PROGRAM
SURVEILLANCE SPECIMEN CAPSULE TEST REPORT
SALEM GENERATING STATION UNIT NO. 2
FACILITY OPERATING LICENSE NO. DPR-75
DOCKET NO. 50-311

PSEG Nuclear LLC hereby submits the report of test results (WCAP-15692) on the surveillance specimen capsule "Y" which was withdrawn from Salem Unit 2 during the October/November 2000 refueling outage in accordance with the requirements of 10CFR50, Appendix H, Section IV.A. The report of test results is included as the Attachment.

A comparison of the Salem Unit 2 reactor vessel beltline material test results with NRC Regulatory Guide 1.99 Revision 2, "Radiation Embrittlement of Reactor Vessel Materials" (RG 1.99) predictions led to a satisfactory assessment. This is based on the results being less than RG 1.99 allowances. A Technical Specification change is not required. PSEG Nuclear LLC concurs with the result and conclusions of the document.

Appendix E of WCAP-15692 provides new best estimate chemistry values for update of the computerized reactor vessel integrity database (RVID). The use of the RVID is discussed in NRC Generic Letter 92-01, Revision 1, Supplement 1, "Reactor Vessel Structural Integrity".

This letter is for submittal of test results and does not contain any regulatory commitments. Should you have any questions regarding this submittal, please contact Ken Buddenbohn at (856) 339-5653.

Sincerely,

G. Salamon
Manager - Nuclear Safety and Licensing

Attachment
WCAP-15692, Rev 0, Analysis of Capsule Y from the Public Service Electric and Gas Company Salem Unit 2 Reactor Vessel Radiation Surveillance program

A008

Distribution – (w/o attachment)

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Westinghouse Non-Proprietary Class 3

WCAP-15692
Revision 0

Analysis of Capsule Y from the Public Service Electric and Gas Company Salem Unit 2 Reactor Vessel Radiation Surveillance Program

Westinghouse Electric Company, LLC

WCAP-15692

Analysis of Capsule Y from Salem Unit 2 Reactor Vessel Radiation Surveillance Program

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PREFACE

This report has been technically reviewed and verified by:

Reviewer:

Sections 1 through 5, 7, 8, Appendices A, B, C and D	T. J. Laubham	T. J. Laubham
Section 6	S. L. Anderson	S L Anderson

EXECUTIVE SUMMARY

The purpose of this report is to document the results of the testing of surveillance Capsule Y from the Salem Unit 2 reactor vessel. Capsule Y was removed at 10.8 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 10.8 EFPY of plant operation was 5.20×10^{18} n/cm^2 (E> 1.0 MeV). A brief summary of the Charpy V-notch testing results 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, which shows the Salem Unit 2 surveillance data is credible. Appendix E shows supporting chemistry documentation used in the analysis of Capsule Y.

1 SUMMARY OF RESULTS

The analysis of the reactor vessel materials contained in surveillance Capsule Y, the fourth capsule to be removed from the Salem Unit 2 reactor pressure vessel, led to the following conclusions:

- The capsule received an average fast neutron fluence (E> 1.0 MeV) of 1.81 x 10^{19} n/cm^2 after 10.8 effective full power years (EFPY) of plant operation.

- Irradiation of the reactor vessel intermediate shell plate B4712-2 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major rolling direction (longitudinal orientation), to 1.81 x 10^{19} n/cm^2 (E> 1.0MeV) resulted in a 30 ft-lb transition temperature increase of 105.69°F and a 50 ft-lb transition temperature increase of 107.88°F. This results in an irradiated 30 ft-lb transition temperature of 132.77°F and an irradiated 50 ft-lb transition temperature of 164.32°F for the longitudinal oriented specimens.

- Irradiation of the reactor vessel intermediate shell plate B4712-2 Charpy specimens, oriented with the longitudinal axis of the specimen perpendicular to the major rolling direction of the plate (transverse orientation), to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV) resulted in a 30 ft-lb transition temperature increase of 129.33°F and a 50 ft-lb transition temperature increase of 121.09°F. This results in an irradiated 30 ft-lb transition temperature of 141.63°F and an irradiated 50 ft-lb transition temperature of 178.67°F for transverse oriented specimens.

- Irradiation of the weld metal Charpy specimens to 1.81 x 10^{19} n/cm^2 (E> 1.0MeV) resulted in a 30 ft-lb transition temperature increase of 200.9°F and a 50 ft-lb transition temperature increase of 202.38°F. This results in an irradiated 30 ft-lb transition temperature of 162.5°F and an irradiated 50 ft-lb transition temperature of 201.59°F.

- Irradiation of the weld Heat-Affected-Zone (HAZ) metal Charpy specimens to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV) resulted in a 30 ft-lb transition temperature increase of 162.93°F and a 50 ft-lb transition temperature increase of 179.18°F. This results in an irradiated 30 ft-lb transition temperature of 20.13°F and an irradiated 50 ft-lb transition temperature of 76.78°F.

- The average upper shelf energy of the intermediate shell plate B4712-2 (longitudinal orientation) resulted in an average energy decrease of 10 ft-lb after irradiation to 1.81 x 10^{19} n/cm^2 (E > 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 112 ft-lb for the longitudinal oriented specimens.

- The average upper shelf energy of the intermediate shell plate B4712-2 (transverse orientation) resulted in an average energy decrease of 13 ft-lb after irradiation to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 84 ft-lb for the transverse oriented specimens.

- The average upper shelf energy of the weld metal Charpy specimens resulted in an average energy decrease of 39 ft-lb after irradiation to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 72 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 20 after irradiation to 1.81×10^{19} n/cm^2 (E> 1.0MeV). This results in an irradiated average upper shelf energy of 100 ft-lb for the weld HAZ metal.

- A comparison of the Salem Unit 2 reactor vessel beltline material test results with the Regulatory Guide 1.99, Revision 2[3] predictions (See Table 5-10) led to the following conclusions:

  — The measured 30 ft-lb shift in transition temperature of the Intermediate Shell Plate B4712-2 contained in Capsule Y (Longitudinal and Transverse) is greater then the Regulatory Guide 1.99, Rev. 2 predictions. However, the shift value is less than two sigma allowance by Regulatory Guide 1.99, Rev. 2.

  — The measured 30 ft-lb shift in transition temperature of the Weld Metal in Capsule Y is less than the Regulatory Guide 1.99, Revision 2, predictions. However, the shift value is less than two sigma allowance by Regulatory Guide 1.99, Rev. 2.

  — The measured percent decrease in upper shelf energy (USE) of all the Capsule Y surveillance materials are less than the Regulatory Guide 1.99, Revision 2, predictions.

- The calculated and best estimate end-of-license (32 EFPY) neutron fluence (E> 1.0 MeV) at the core midplane for the Salem Unit 2 reactor vessel using the Regulatory Guide 1.99, Revision 2 attenuation formula (ie. Equation # 3 in the guide) is as follows:

  Calculated: Vessel inner radius* = 1.34×10^{19} n/cm^2

  Vessel 1/4 thickness = 7.98×10^{18} n/cm^2

  Vessel 3/4 thickness = 2.84×10^{18} n/cm^2

  *Clad/base metal interface

- The credibility evaluation of the Salem Unit 2 surveillance program presented in Appendix D of this report indicates that the surveillance results of the Salem Unit 2 surveillance program is 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 through end of license (32 EFPY) as shown in Appendix A of WCAP-15639[34] and as required by 10CFR50, Appendix G[4].

2 INTRODUCTION

This report presents the results of the examination of Capsule Y, the fourth capsule removed from the reactor in the continuing surveillance program which monitors the effects of neutron irradiation on the PSEG Nuclear LLC Salem Unit 2 reactor pressure vessel materials under actual operating conditions.

The surveillance program for the PSEG Salem Unit 2 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-8824, "Public Service Electric and Gas Company Salem Unit No. 2 Reactor Vessel Radiation Surveillance Program" [1]. The surveillance program was planned to cover the 40-year design life of the reactor pressure vessel and was based on ASTM E185-73, "Standard Recommended Practice for Surveillance Tests for Nuclear Reactor Vessels"[14]. Capsule Y was removed from the reactor after 10.8 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.

This report summarizes the testing of and the post-irradiation data obtained from surveillance Capsule Y removed from the PSEG Salem Unit 2 reactor vessel and discusses the analysis of the data.

3 BACKGROUND

The ability of the large steel pressure vessel containing the reactor core and its primary coolant to resist fracture constitutes an important factor in ensuring safety in the nuclear industry. The beltline region of the reactor pressure vessel is the most critical region of the vessel because it is subjected to significant fast neutron bombardment. The overall effects of fast neutron irradiation on the mechanical properties of low alloy, ferritic pressure vessel steels such as SA533 Grade B Class 1 plate (base material of the Salem Unit 2 reactor pressure vessel beltline) are well documented in the literature. Generally, low alloy ferritic materials show an increase in hardness and tensile properties and a decrease in ductility and toughness during high-energy irradiation.

A method for ensuring the integrity of reactor pressure vessels has been presented in "Fracture Toughness Criteria for Protection Against Failure," Appendix G to Section XI of the ASME Boiler and Pressure Vessel Code [6]. 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[7]) or the temperature 60°F less than the 50 ft-lb (and 35-mil lateral expansion) temperature as determined from Charpy specimens oriented normal (transverse) to the major working direction of the material. The RT_{NDT} of a given material is used to index that material to a reference stress intensity factor curve (K_{IC} curve) which appears in Appendix G to the ASME Code[6]. The K_{IC} curve is a lower bound of static fracture toughness results obtained from several heats of pressure vessel steel. When a given material is indexed to the K_{IC} curve, allowable stress intensity factors can be obtained for this material as a function of temperature. Allowable operating limits can then be determined using these allowable stress intensity factors.

RT_{NDT} and, in turn, the operating limits of nuclear power plants can be adjusted to account for the effects of radiation on the reactor vessel material properties. The changes in mechanical properties of a given reactor pressure vessel steel, due to irradiation, can be monitored by a reactor surveillance program, such as the Salem Unit 2 reactor vessel radiation surveillance program [1], 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_{IC} curve and, in turn, to set operating limits for the nuclear power plant that take into account the effects of irradiation on the reactor vessel materials.

4 DESCRIPTION OF PROGRAM

Eight surveillance capsules for monitoring the effects of neutron exposure on the Salem Unit 2 reactor pressure vessel core region (beltline) materials were inserted in the reactor vessel prior to initial plant start-up. The eight capsules were positioned in the reactor vessel between the thermal shield and the vessel wall as shown in Figure 4-1. The vertical center of the capsules is opposite the vertical center of the core.

Capsule Y was removed after 10.8 effective full power years (EFPY) of plant operation. This capsule contained Charpy V-notch, tensile, and wedge opening loading (WOL) specimens from the intermediate shell plate B4712-2, charpy V-notch and tensile specimens from submerged arc weld metal representative of the beltline region weld metal and charpy V-notch specimens from weld Heat-Affected-Zone (HAZ) of plate B4712-2. All heat-affected-zone specimens were obtained from within the HAZ of plate B4712-2 of the representative weld.

Test material obtained from Intermediate Shell Plate B4712-2 (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 ¼ thickness locations of the plate after performing a simulated post-weld stress-relieving treatment on the test material. Specimens were machined from weld metal and the heat-affected-zone (HAZ) metal of a stress-relieved weldment joining sections of the intermediate and lower shell plates. All heat-affected-zone specimens were obtained from the weld heat-affected-zone of intermediate shell plate B4712-2.

Charpy V-notch impact specimens from intermediate shell plate B4712-2 were machined in both the longitudinal orientation (longitudinal axis of specimen parallel to major working direction) and transverse orientation (longitudinal axis of specimen perpendicular to major working direction). The core region weld Charpy impact specimens were machined from the weldment such that the long dimension of the Charpy was normal to the weld direction; the notch was machined such that the direction of crack propagation in the specimen was in the weld direction.

The WOL specimens were machined such that the simulated crack in the specimen would propagate parallel to the major working direction for the plate specimen and parallel to the weld direction.

The chemical composition and heat treatment of the surveillance material is presented in Tables 4-1 and 4-2. The chemical analysis reported in Table 4-1 was obtained from unirradiated material used in the surveillance program[1]. In addition, a chemical analysis performed on four irradiated Charpy specimens from the weld and base metal plate B4712-2 is reported in Table 4-3. The chemistry results from the NIST standards are given in Table 4-4

Capsule Y contained dosimeter wires of pure copper, iron, nickel and aluminum-0.15 weight percent cobalt wire (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 Y is shown in Figure 4-2.

TABLE 4-1

Chemical Composition (wt%) of the Unirradiated Salem Unit 2 Reactor Vessel Surveillance Materials

Element	Intermediate Shell Plate B4712-2		Weld Metal
	Westinghouse Analysis	Lukens Steel Analysis	
C	0.23	0.22	0.10
Mn	1.34	1.37	1.27
P	0.015	0.011	0.017
S	0.010	0.015	0.011
Si	0.30	0.24	0.29
Ni	0.61	0.60	0.71
Mo	0.55	0.55	0.45
Cr	0.089	(a)	0.015
Cu	0.12	(a)	0.23
Al	0.030	(a)	0.007
Co	0.015	(a)	0.024
V	<0.010	(a)	0.001
Sn	0.008	(a)	0.005
N	0.004	(a)	0.007

Notes:
(a) Not measured.

Table 4-2

Heat Treatment of Salem Unit 2 Reactor Vessel Surveillance Materials[1]

Material	Temperature (°F)	Time (hrs.)	Coolant
Intermediate Shell Plate B4712-2	1550 - 1650	4	Water quenched
	1225 ± 25	4	Air cooled
	1150 ± 25	40	Furnace Cooled
Weldment	1150 ± 25	40	Furnace Cooled

Table 4-3
Chemical Composition of Four Salem Unit 2 Charpy Specimens Removed from Surveillance Capsule Y

Metals	JT-79 Base Metal	JW-84 Weld	JW-82 Weld	JW-75 Weld
	Concentration in Weight Percent			
C	0.24	0.11	0.11	0.11
Cr	0.106	0.0383	0.0447	0.0314
Cu	0.132	0.273	0.301	0.287
Fe	87.5	93.6	91.3	87.1
Mn	1.29	1.23	1.24	1.17
Mo	0.386	0.451	0.486	0.453
Ni	0.588	0.693	0.704	0.667
P	0.00576	0.0146	0.0158	0.0123
V	<0.0025	<0.0025	<0.0025	0.00254
S	0.014	0.01	0.012	0.011
Si	<0.05	<0.05	<0.05	<0.05

Table 4-4
Chemistry Results From the NBS Certified Reference Standards

Material ID	Low Alloy Steel: NBS Certified Reference Standards			
	Concentration in Weight Percent			
	NBS 361		NBS 362	
Metals	Measured	Certified	Measured	Certified
C	0.409	0.383	0.172	0.160
S	0.0136	0.0143	0.033	0.036
Si	0.220	0.222	0.35	0.39
Cr	0.616	0.694	0.27	0.3
Cu	0.047	0.042	0.51	0.50
Fe	93.1	95.6	91.3	95.3
Mn	0.64	0.66	0.995	1.04
Mo	0.20	0.19	0.070	0.068
Ni	1.88	2.00	0.53	0.59
P	0.015	0.014	0.034	0.041
V	0.009	0.011	0.036	0.040

Material ID	Low Alloy Steel: NBS Certified Reference Standards			
	Concentration in Weight Percent			
	NBS 363		NBS 364	
Metals	Measured	Certified	Measured	Certified
C	0.66	0.62	0.88	0.87
S	0.0071	0.0068	0.021	0.025
Si	0.76	0.74	0.058	0.065
Cr	1.11	1.31	0.065	0.063
Cu	0.098	0.10	0.26	0.249
Fe	87.3	94.4	98.6	96.7
Mn	1.4	1.5	0.242	0.255
Mo	0.032	0.028	0.49	0.49
Ni	0.27	0.3	0.129	0.144
P	0.026	0.029	0.009	0.01
V	0.29	0.31	0.101	0.105

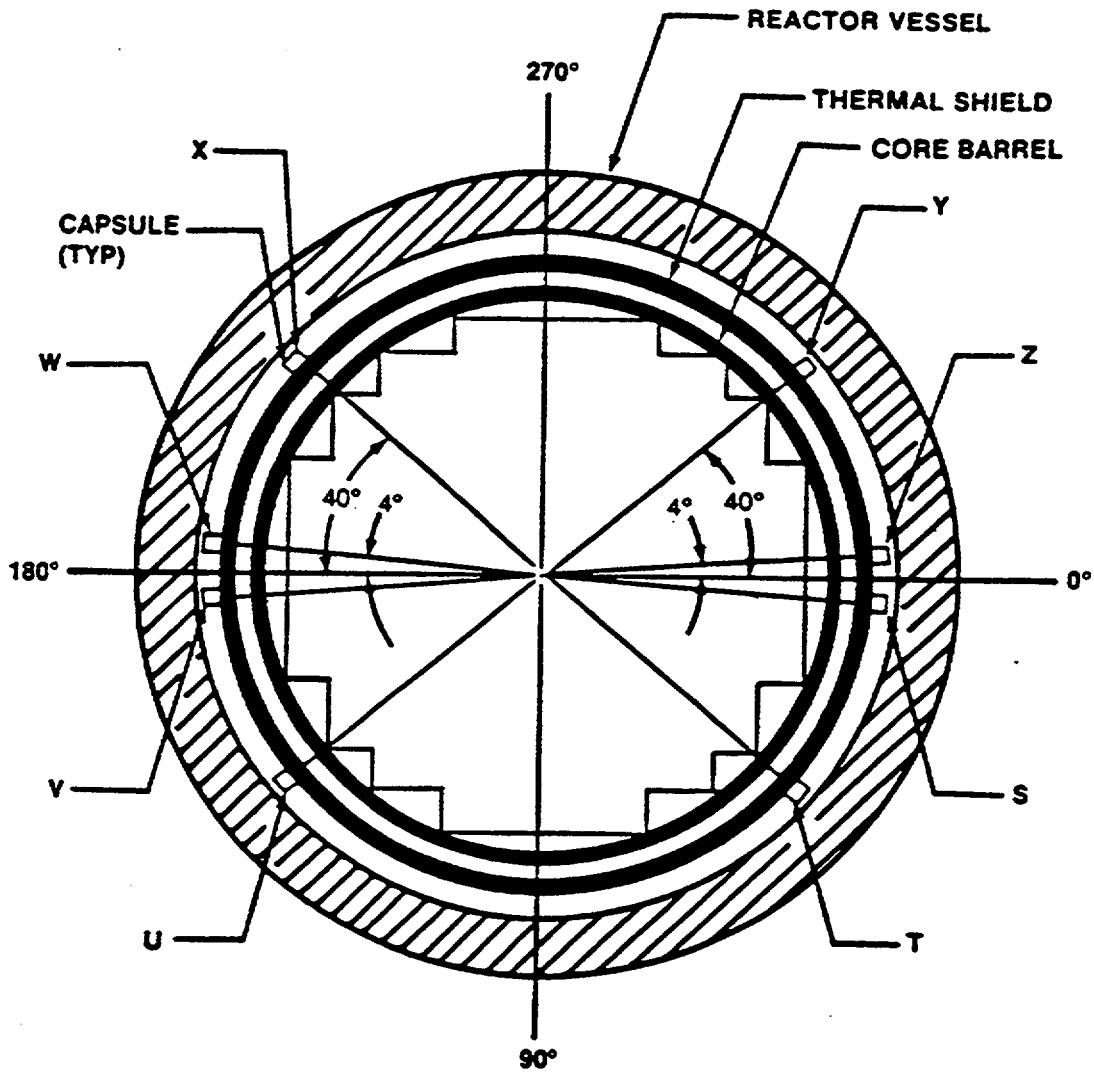


Figure 4-1 **Arrangement of Surveillance Capsules in the Salem Unit 2 Reactor Vessel**

SPECIMEN NUMBERING CODE:

JT PLATE B4712-2 (TRANVERSE)
JL PLATE B4712-2 (LONGITUDINAL)
JW WELD
JH HEAT-AFFECTED-ZONE

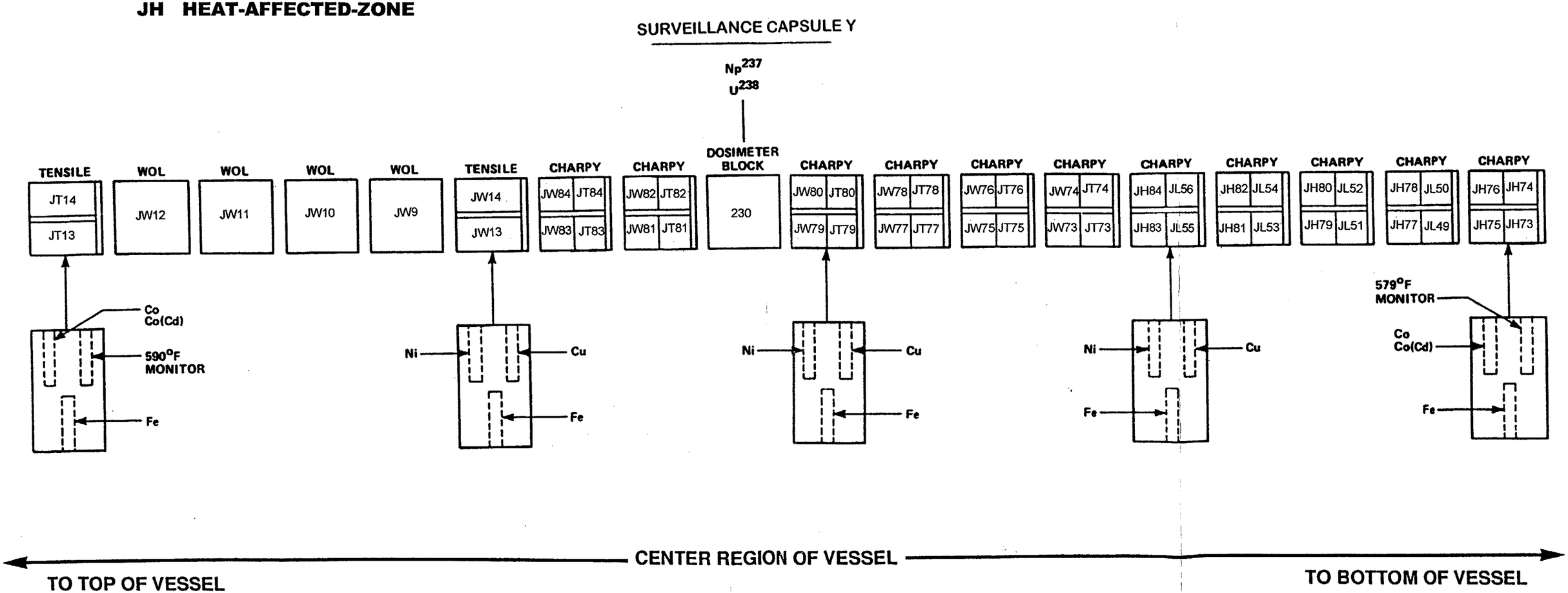


Figure 4-2 Capsule Y Diagram Showing the Location of Specimens, Thermal Monitors, and Dosimeters.

5 TESTING OF SPECIMENS FROM CAPSULE Y

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 (STC). Testing was performed in accordance with 10CFR50, Appendix H[8], ASTM Specification E185-82[5], and Westinghouse Procedure MHL 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-8824 [1]. 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 E23-98 [9] and Procedure RMF 8103, 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 (σ_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),

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

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

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

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:

$$A = B * (W - a) = 0.1241 \text{ sq.in.} \quad (4)$$

Percent shear was determined from post-fracture photographs using the ratio-of-areas methods in compliance with ASTM E23-98[9] and A370-97[10]. 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 E8-99[11] and E21-92[12], and RMF Procedure 8102, Revision 1.

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 E83-96[13].

Elevated test temperatures were obtained with a three-zone electric resistance split-tube furnace with a 9-inch hot zone. All tests were conducted in air.

The yield load, ultimate load, fracture load, total elongation, and uniform elongation were determined directly from the load-extension curve. The yield strength, ultimate strength, and fracture strength were calculated using the original cross-sectional area. The final diameter 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 Y, irradiated to a fluence of 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV) in 10.8 EFPY of operation are presented in Tables 5-1 through 5-8 and are compared with unirradiated results[1] in Figures 5-1 through 5-12. The transition temperature increases and upper shelf energy decreases for the Capsule Y materials are summarized in Table 5-10.

A comparison of the surveillance material 30 ft-lb transition temperature shifts and the upper shelf energy decreases with the Regulatory Guide 1.99, Revision 2, predictions is given in Table 5-10. These results led to the following conclusions:

- Irradiation of the reactor vessel intermediate shell plate B4712-2 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major rolling direction (longitudinal orientation), to 1.81 x 10^{19} n/cm^2 (E> 1.0MeV) resulted in a 30 ft-lb transition temperature increase of 105.69°F and a 50 ft-lb transition temperature increase of 107.88F. This results in an irradiated 30 ft-lb transition temperature of 132.77°F and an irradiated 50 ft-lb transition temperature of 164.32°F for the longitudinal oriented specimens.

- Irradiation of the reactor vessel intermediate shell plate B4712-2 Charpy specimens, oriented with the longitudinal axis of the specimen perpendicular to the major rolling direction of the plate (transverse orientation), to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV) resulted in a 30 ft-lb transition temperature increase of 129.33°F and a 50 ft-lb transition temperature increase of 121.09°F. This results in an irradiated 30 ft-lb transition temperature of 141.63°F and an irradiated 50 ft-lb transition temperature of 178.67°F for transverse oriented specimens.

- Irradiation of the weld metal Charpy specimens to 1.81 x 10^{19} n/cm^2 (E> 1.0MeV) resulted in a 30 ft-lb transition temperature increase of 200.9°F and a 50 ft-lb transition temperature increase of 202.38°F. This results in an irradiated 30 ft-lb transition temperature of 162.5°F and an irradiated 50 ft-lb transition temperature of 201.59°F.

- Irradiation of the weld Heat-Affected-Zone (HAZ) metal Charpy specimens to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV) resulted in a 30 ft-lb transition temperature increase of 162.93°F and a 50 ft-lb transition temperature increase of 179.18°F. This results in an irradiated 30 ft-lb transition temperature of 20.13°F and an irradiated 50 ft-lb transition temperature of 76.78°F.

- The average upper shelf energy of the intermediate shell plate B4712-2 (longitudinal orientation) resulted in an average energy decrease of 10 ft-lb after irradiation to 1.81 x 10^{19} n/cm^2 (E > 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 112 ft-lb for the longitudinal oriented specimens.

- The average upper shelf energy of the intermediate shell plate B4712-2 (transverse orientation) resulted in an average energy decrease of 13 ft-lb after irradiation to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 84 ft-lb for the transverse oriented specimens.

- The average upper shelf energy of the weld metal Charpy specimens resulted an average energy decrease of 39 ft-lb after irradiation to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV). Hence, this results in an irradiated average upper shelf energy of 72 ft-lb for the weld metal specimens.

- The average upper shelf energy of the weld HAZ metal Charpy specimens resulted an average energy decrease of 20 ft-lb after irradiation to 1.81 x 10^{19} n/cm^2 (E> 1.0MeV). This results in an irradiated average upper shelf energy of 100 ft-lb for the weld HAZ metal.

- A comparison of the Salem Unit 2 reactor vessel beltline material test results with the Regulatory Guide 1.99, Revision 2[3] predictions (See Table 5-10) led to the following conclusions:

  — The measured 30 ft-lb shift in transition temperature of the Intermediate Shell Plate B4712-2 contained in Capsule Y (Longitudinal and Transverse) is greater then the Regulatory Guide 1.99, Rev. 2 predictions. However, the shift value is less than two sigma allowance by Regulatory Guide 1.99, Rev. 2.

  — The measured 30 ft-lb shift in transition temperature of the Weld Metal in Capsule Y is Less then the Regulatory Guide 1.99, Revision 2, predictions.

  — The measured percent decrease in upper shelf energy (USE) of all the Capsule Y surveillance materials are less than the Regulatory Guide 1.99, Revision 2, predictions.

The fracture appearance of each irradiated Charpy specimen from the various surveillance Capsule Y materials is shown in Figures 5-13 through 5-16 and show 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 greater than 50 ft-lb through end of license (32 EFPY) as shown in Appendix A of WCAP-15639[34] and as required by 10CFR50, Appendix G[4].

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

Appendix D of this report contains a credibility evaluation of the surveillance data from the Salem Unit 2 reactor vessel surveillance program. This evaluation indicates that the surveillance results are credible.

5.3 TENSILE TEST RESULTS

The results of the tensile tests performed on the various materials contained in Capsule Y irradiated to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV) are presented in Table 5-11 and are compared with unirradiated results[1] as shown in Figures 5-17 and 5-18.

The results of the tensile tests performed on the intermediate shell plate B4712-2 (transverse orientation) indicated that irradiation to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV) caused approximately a 11 to 15 ksi increase in the 0.2 percent offset yield strength and approximately a 9 to 13 ksi increase in the ultimate tensile strength when compared to unirradiated data[1] (Figure 5-17).

The results of the tensile tests performed on the surveillance weld metal indicated that irradiation to 1.81 x 10^{19} n/cm^2 (E> 1.0 MeV) caused approximately a 20 to 24 ksi increase in the 0.2 percent offset yield strength and a 16 to 25 ksi increase in the ultimate tensile strength when compared to unirradiated data[1] (Figure 5-18).

The fractured tensile specimens for the intermediate shell plate B4712-2 material are shown in Figure 5-19, while the fractured tensile specimens for the surveillance weld metal are shown in Figure 5-20. The engineering stress-strain curves for the tensile tests are shown in Figures 5-21 and 5-22.

5.4 WEDGE OPENING LOADING SPECIMENS

Per the surveillance capsule testing contract with the Public Service Electric and Gas Company, the wedge opening loading fracture mechanics specimens will not be tested and will be stored at the Westinghouse Science and Technology Center.

Table 5-1 Charpy V-notch Data for the Salem Unit 2 Intermediate Shell Plate B4712-2 Irradiated to a Fluence of 1.81 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	%
JL56	50	10	9	12	4	0.10	5
JL52	75	24	15	20	10	0.25	10
JL50	130	54	30	41	22	0.56	25
JL51	150	66	39	53	29	0.74	45
JL55	190	88	64	87	47	1.19	50
JL53	225	107	88	119	60	1.52	90
JL49	270	132	107	145	69	1.75	100
JL54	290	143	116	157	72	1.83	100

Table 5-2 Charpy V-notch Data for the Salem Unit 2 Intermediate Shell Plate B4712-2 Irradiated to a Fluence of 1.81 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	%
JT80	0	-18	5	7	0	0.00	2
JT75	50	10	8	11	3	0.08	5
JT84	75	24	22	30	13	0.33	15
JT76	100	38	17	23	12	0.30	15
JT81	125	52	24	33	18	0.46	20
JT78	150	66	34	46	27	0.69	45
JT82	175	79	34	46	24	0.61	40
JT73	200	93	54	73	37	0.94	55
JT77	220	104	77	104	55	1.40	90
JT79	240	116	86	117	61	1.55	100
JT74	250	121	81	110	56	1.42	100
JT83	275	135	84	114	63	1.60	100

Table 5-3 Charpy V-notch Impact Data for Salem Unit 2 Surveillance Weld Metal Irradiated to a Fluence of 1.81 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	%
JW81	-50	-46	3	4	0	0.00	0
JW74	0	-18	4	5	0	0.00	0
JW83	75	24	16	22	8	0.20	10
JW84	100	38	17	23	12	0.30	20
JW82	125	52	15	20	12	0.30	20
JW76	180	82	32	43	24	0.61	55
JW77	200	93	38	52	28	0.71	50
JW73	225	107	74	100	55	1.40	95
JW75	250	121	73	99	54	1.37	100
JW78	275	135	71	96	51	1.30	95
JW79	300	149	75	102	54	1.37	100
JW80	320	160	66	89	52	1.32	100

Table 5-4 Charpy V-notch Impact Data for Salem Unit 2 Representative Heat Affected Zone Material Irradiated to a Fluence of 1.81 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	%
JH77	-75	-59	15	20	3	0.08	10
JH81	0	-18	31	42	8	0.20	15
JH76	25	-4	11	15	4	0.10	25
JH80	25	-4	33	45	22	0.56	25
JH84	50	10	41	56	21	0.53	40
JH78	75	24	76	103	46	1.17	70
JH74	100	38	56	76	36	0.91	60
JH79	125	52	43	58	29	0.74	50
JH82	175	79	83	113	40	1.02	70
JH73	225	107	107	145	66	1.68	100
JH83	250	121	88	119	48	1.22	100
JH75	275	135	105	142	69	1.75	100

Table 5-5 Instrumented Charpy Impact Test Results for the Salem Unit 2 Intermediate Shell Plate B4712-2 Irradiated to a Fluence of 1.81 x 10^{19} n/cm^2 (E>1.0 MeV) (Longitudinal Orientation)

Sample No.	Test Temp. (°F)	Charpy Energy E_D (ft-lb)	Normalized Energies (ft-lb/in^2)			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								
JL56	50	9	73	35	37	3578	0.16	3578	0.16	3578	0	119	119
JL52	75	15	121	59	61	4071	0.17	4318	0.20	4303	105.43	136	140
JL50	130	30	242	142	100	3798	0.17	4204	0.37	4179	855.48	126	133
JL51	150	39	314	186	128	3728	0.17	4362	0.45	4302	972	124	135
JL55	190	64	516	307	209	3673	0.17	4469	0.67	4220	1779	122	136
JL53	225	88	709	221	488	3595	0.17	4367	0.52	3546	2490	120	133
JL49	270	107	862	309	553	3602	0.17	4364	0.68	n/a	n/a	120	133
JL54	290	116	935	309	626	3548	0.17	4404	0.68	n/a	n/a	118	132

Table 5-6 Instrumented Charpy Impact Test Results for the Salem Unit 2 Intermediate Shell Plate B4712-2 Irradiated to a Fluence of 1.81 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								
JT80	0	5	40	18	23	2240	0.13	2258	0.13	2240	0	75	75
JT75	50	8	64	33	31	3400	0.17	3453	0.16	3400	0	113	114
JT84	75	22	177	74	103	4083	0.17	4387	0.23	4206	73	136	141
JT76	100	17	137	64	73	3909	0.17	4183	0.22	4177	203	130	135
JT81	125	24	193	65	129	3837	0.17	4075	0.22	4041	436	128	132
JT78	150	34	274	141	133	3733	0.17	4146	0.37	4142	1207	124	131
JT82	175	34	274	130	144	3637	0.17	4002	0.35	3960	1488	121	127
JT73	200	54	435	226	209	3692	0.17	4457	0.52	4358	1669	123	136
JT77	220	77	620	215	406	3784	0.17	4431	0.49	2872	1925	126	137
JT79	240	86	693	225	467	3664	0.17	4389	0.52	n/a	n/a	122	134
JT74	250	81	653	214	438	3617	0.17	4375	0.5	n/a	n/a	120	133
JT83	275	84	677	217	459	3612	0.17	4283	0.51	n/a	n/a	120	131

Table 5-7 Instrumented Charpy Impact Test Results for the Salem Unit 2 Surveillance Weld Metal Irradiated to a Fluence of 1.81 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								
JW81	-50	3	24	12	12	1612	0.11	1616	0.11	1612	0	54	54
JW74	0	4	32	17	15	2116	0.12	2121	0.13	2116	0	70	71
JW83	75	16	129	67	62	4249	0.17	4585	0.21	4580	0	141	147
JW84	100	17	137	58	79	4042	0.17	4295	0.2	4291	561	135	139
JW82	125	15	121	51	70	3966	0.17	4106	0.19	4100	364	132	134
JW76	180	32	258	66	192	3825	0.17	4083	0.22	3883	1774	127	132
JW77	200	38	306	180	126	3736	0.17	4201	0.44	4133	1335	124	132
JW73	225	74	596	214	383	3795	0.17	4342	0.49	3493	2535	126	135
JW75	250	73	588	213	375	3836	0.17	4450	0.48	n/a	n/a	128	138
JW78	275	71	572	205	367	3800	0.17	4310	0.47	3171	2215	127	135
JW79	300	75	604	206	398	3596	0.17	4214	0.49	n/a	n/a	120	130
JW80	320	66	532	191	341	3597	0.17	4155	0.47	n/a	n/a	120	129

Table 5-8 Instrumented Charpy Impact Test Results for the Salem Unit 2 Representative Heat-Affected-Zone (HAZ) Metal Irradiated to a Fluence of 1.81 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								
JH77	-75	15	121	68	53	4544	0.18	4888	0.22	0	0	151	157
JH81	0	31	250	191	58	4529	0.17	5091	0.40	5020	0	151	160
JH76	25	11	89	26	63	2792	0.15	2792	0.15	2792	708	93	93
JH80	25	33	266	178	88	4189	0.17	4596	0.4	4465	784	140	146
JH84	50	41	330	191	139	4398	0.17	4843	0.41	4789	1271	146	154
JH78	75	76	612	246	366	4214	0.17	4869	0.51	4365	958	140	151
JH74	100	56	451	208	243	4085	0.17	4443	0.47	4092	2002	136	142
JH79	125	43	346	207	140	3945	0.17	4502	0.47	4457	1507	131	141
JH82	175	83	669	351	318	4130	0.17	4950	0.68	4438	2034	138	151
JH73	225	107	862	320	542	3846	0.17	4524	0.68	N/A	N/A	128	139
JH83	250	88	709	251	458	4012	0.17	4830	0.53	N/A	N/A	134	147
JH75	275	105	846	311	535	3717	0.17	4424	0.67	N/A	N/A	124	136

Table 5-9 Effect of Irradiation to 1.81 x 10^{19} n/cm^2 (E>1.0 MeV) on the Notch Toughness Properties of the Salem Unit 2 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*	*ΔE*
Plate B4712-2 (Longitudinal)	27.07	132.77	105.69	51.69	162.29	110.6	56.53	164.32	107.88	122	112	-10
Plate B4712-2 (Transverse)	12.29	141.63	129.33	46.67	183.21	136.54	57.57	178.67	121.09	97	84	-13
Weld Metal	-38.4	162.5	200.9	-5.31	197.04	202.35	-0.79	201.59	202.38	111	72	-39
HAZ Metal	-142.8	20.13	162.93	-67.89	112.48	180.38	-102.39	76.78	179.18	120	160	-20

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 Salem Unit 2 Surveillance Material 30 ft-lb Transition Temperature Shifts and Upper Shelf Energy Decreases with Regulatory Guide 1.99, Revision 2, Predictions

Material	Capsule	Fluence ($x\ 10^{19}$ n/cm^2)	30 ft-lb Transition Temperature Shift		Upper Shelf Energy Decrease	
			Predicted (°F) [a]	Measured (°F) [b]	Predicted (%) [a]	Measured (%) [c]
Intermediate Shell Plate B4712-2 (Longitudinal)	T	0.278	54.1	61.7	15	6
	U	0.579	70.4	66.5	18	8
	X	1.12	85.8	93.8	21	2
	Y	1.81	96.7	105.7	23	8
Intermediate Shell Plate B4712-2 (Transverse)	T	0.278	54.1	74.8	15	8
	U	0.579	70.4	98.3	18	13
	X	1.12	85.8	125.2	21	8
	Y	1.81	96.7	129.3	23	13
Weld Metal	T	0.278	123.21	153.2	27	29
	U	0.579	160.3	185.9	32	33
	X	1.12	195.3	195.4	37	23
	Y	1.81	220.1	200.9	43	35
HAZ Metal	T	0.278	---	125.2	---	27
	U	0.579	---	164.1	---	13
	X	1.12	---	150.6	---	26
	Y	1.81	---	162.9	---	17

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.

Table 5-11 Tensile Properties of the Salem Unit 2 Reactor Vessel Surveillance Materials Irradiated to 1.81×10^{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 Shell Plate B4712-2 (Transverse)	JT13	250	77.9	96.9	3.60	166.1	73.2	8.9	17.9	56
	JT14	550	72.3	97.6	4.15	151.8	84.5	9.0	14.7	44
Surveillance Weld Metal	JW13	250	86.1	99.7	3.76	156.1	76.5	9.0	18.2	51
	JW14	550	80.0	96.9	3.70	170.7	75.3	8.6	17.3	56

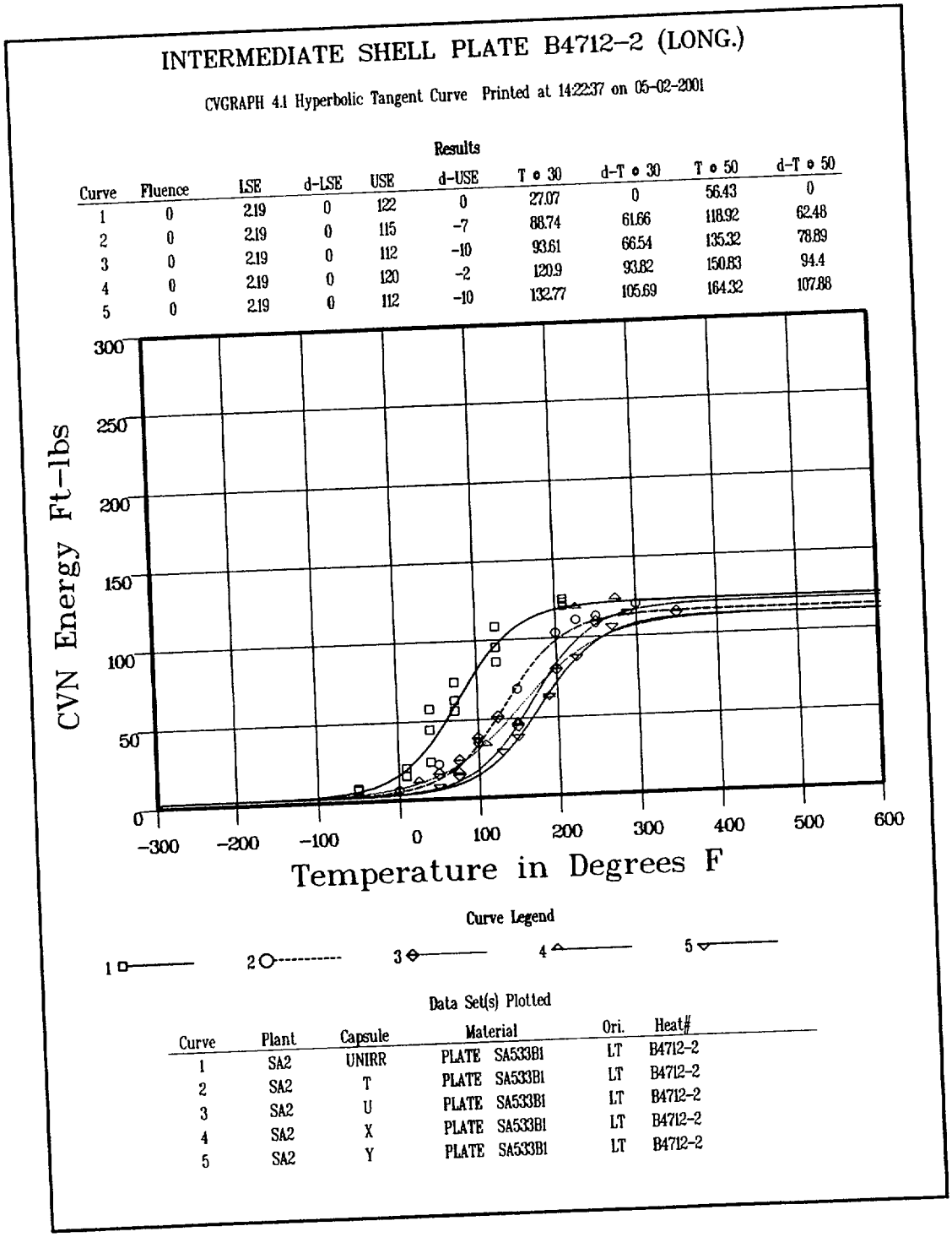


Figure 5-1 Charpy V-Notch Impact Energy vs. Temperature for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2(Longitudinal Orientation)

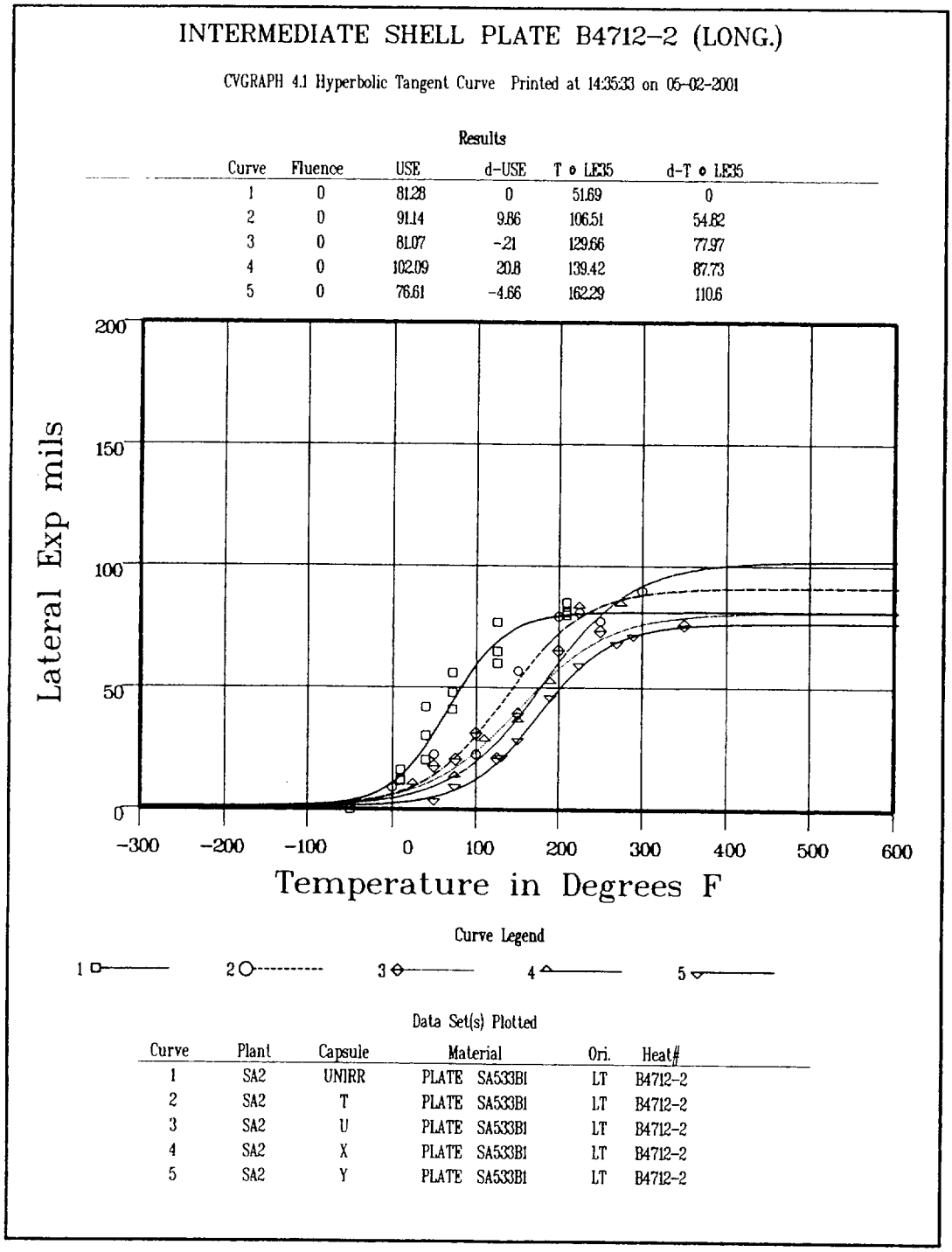


Figure 5-2 Charpy V-Notch Lateral Expansion vs. Temperature for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2(Longitudinal Orientation)

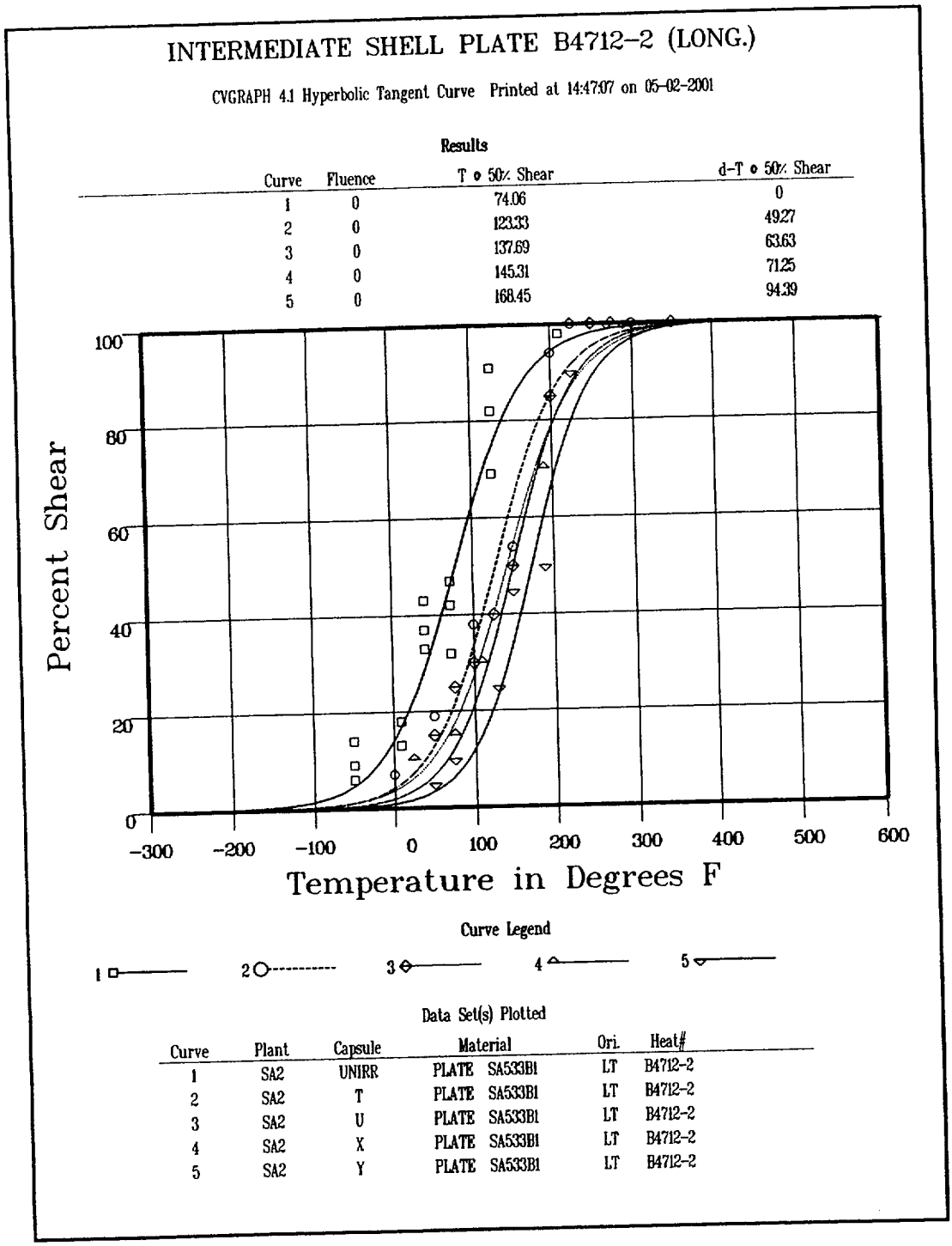


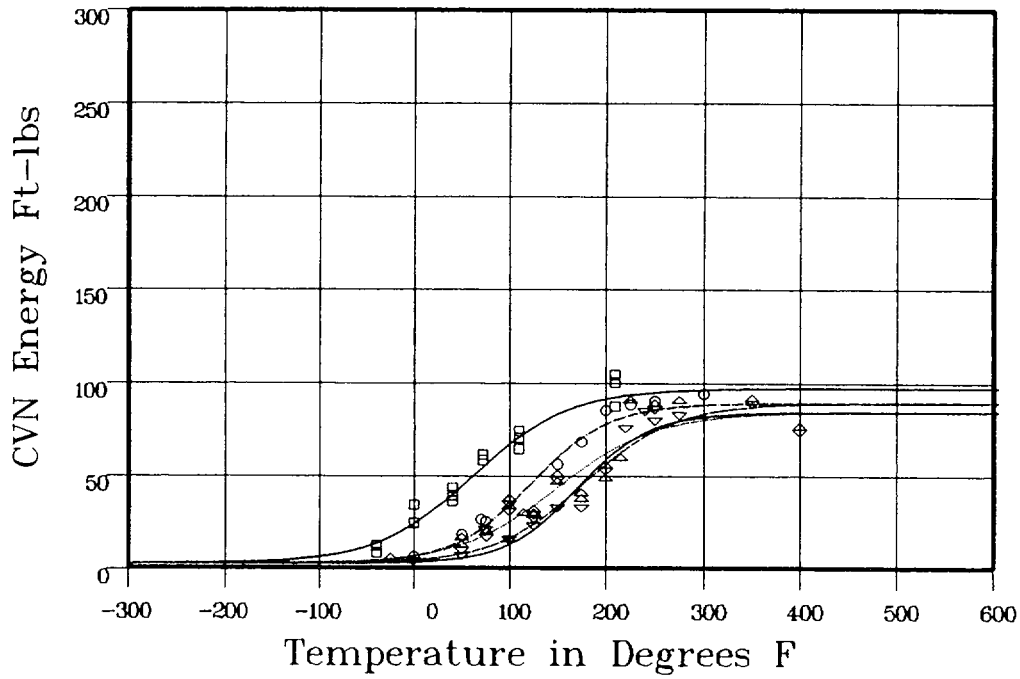
Figure 5-3 Charpy V-Notch Percent Shear vs. Temperature for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2(Longitudinal Orientation)

INTERMEDIATE SHELL PLATE B4712-2 (TRANS.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:06:48 on 05-03-2001

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T o 30	d-T o 30	T o 50	d-T o 50
1	0	2.19	0	97	0	12.29	0	57.57	0
2	0	2.19	0	89	-8	87.13	74.83	126.05	68.48
3	0	2.19	0	84	-13	110.56	98.26	161.8	104.23
4	0	2.19	0	89	-8	137.44	125.15	181.97	124.4
5	0	2.19	0	84	-13	141.63	129.33	178.67	121.09



Curve Legend

1 2 3 4 5

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	SA2	UNIRR	PLATE SA533B1	TL	B4712-2
2	SA2	T	PLATE SA533B1	TL	B4712-2
3	SA2	U	PLATE SA533B1	TL	B4712-2
4	SA2	X	PLATE SA533B1	TL	B4712-2
5	SA2	Y	PLATE SA533B1	TL	B4712-2

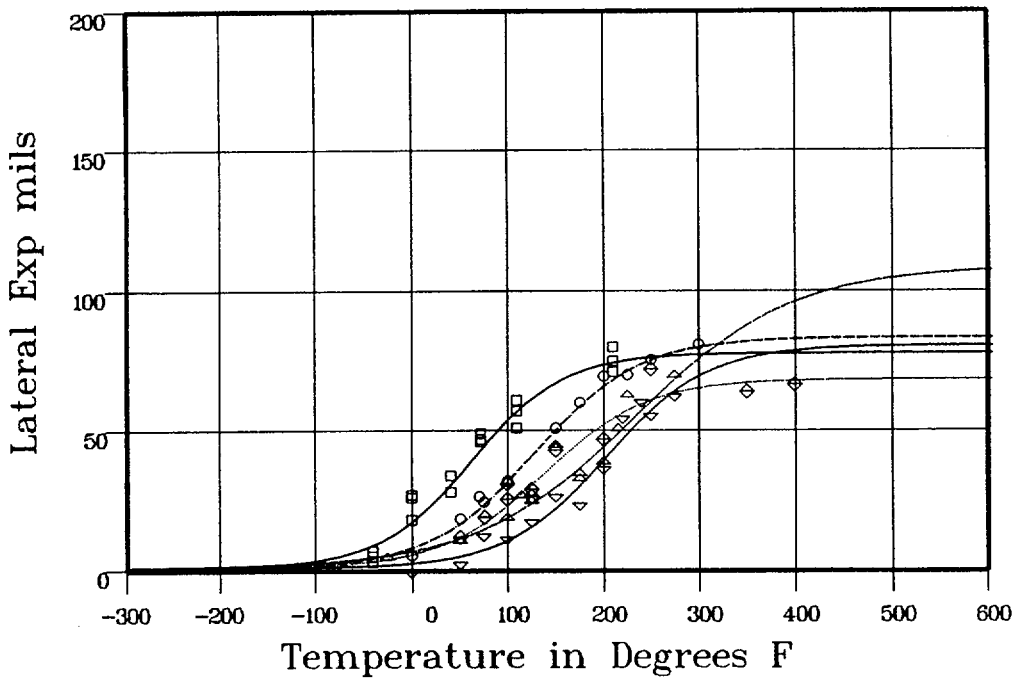
Figure 5-4 Charpy V-Notch Impact Energy vs. Temperature for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2(Transverse Orientation)

INTERMEDIATE SHELL PLATE B4712-2 (TRANS.)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:28:03 on 05-03-2001

Results

Curve	Fluence	USE	d-USE	T @ LE35	d-T @ LE35
1	0	77.75	0	46.67	0
2	0	83.44	5.69	104.38	57.7
3	0	68.36	-9.38	134.07	87.4
4	0	108.66	30.91	164.27	117.6
5	0	80.62	2.87	183.21	136.54



Curve Legend

1 2 3 4 5

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	SA2	UNIRR	PLATE SA533B1	TL	B4712-2
2	SA2	T	PLATE SA533B1	TL	B4712-2
3	SA2	U	PLATE SA533B1	TL	B4712-2
4	SA2	X	PLATE SA533B1	TL	B4712-2
5	SA2	Y	PLATE SA533B1	TL	B4712-2

Figure 5-5 Charpy V-Notch Lateral Expansion vs. Temperature for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2(Transverse Orientation)

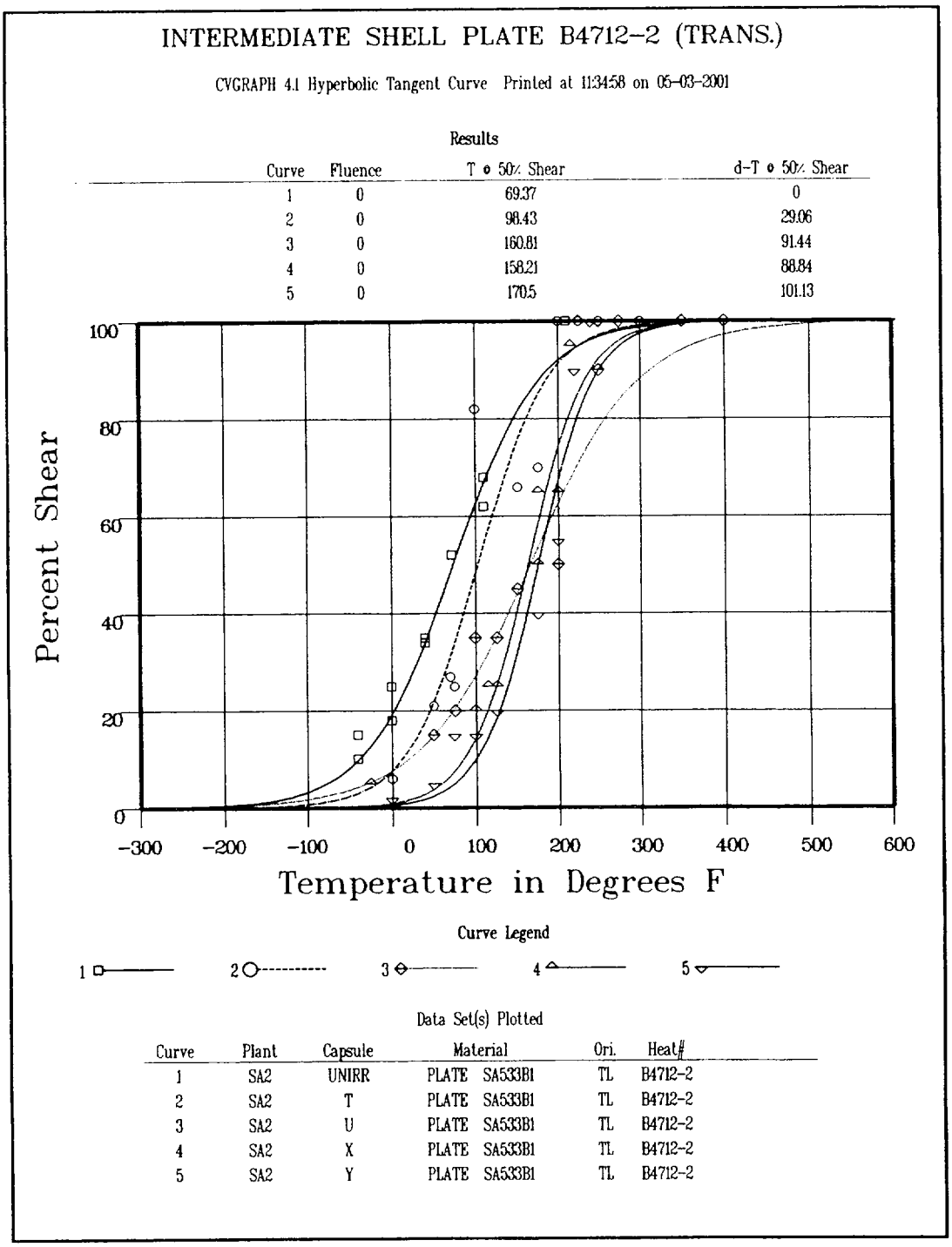


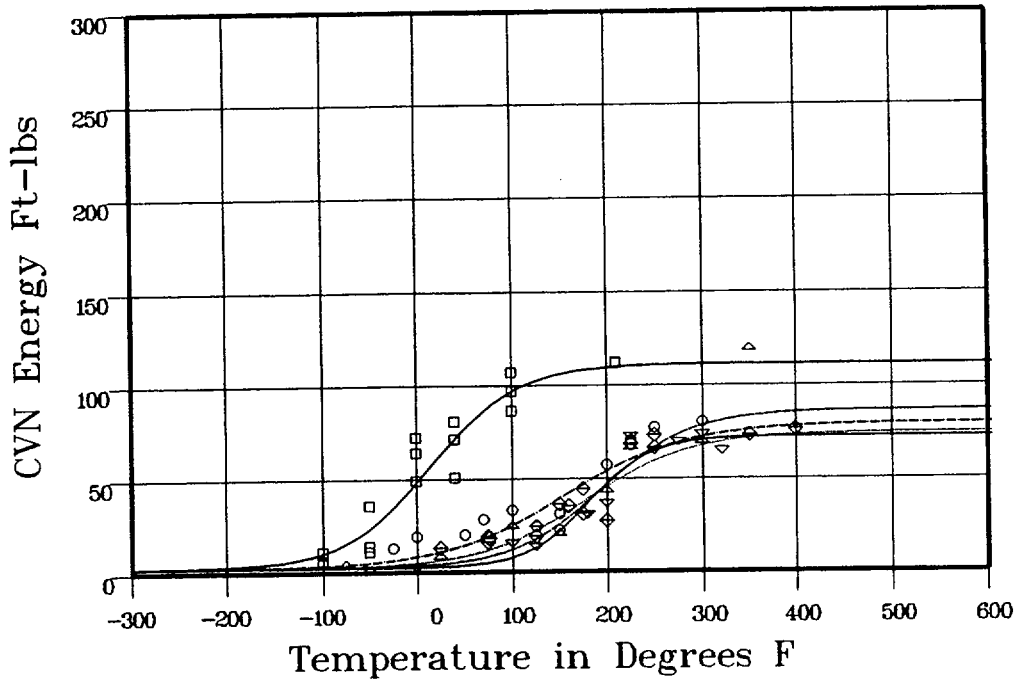
Figure 5-6 Charpy V-Notch Percent Shear vs. Temperature for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2(Transverse Orientation)

SURVIELLANCE PROGRAM WELD METAL

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:26:40 on 05-07-2001

Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	111	0	-38.4	0	-.79	0
2	0	2.19	0	79	-32	114.76	153.17	182.16	182.96
3	0	2.19	0	74	-37	147.54	185.94	210.09	210.89
4	0	2.19	0	86	-25	157.02	195.43	202.98	203.78
5	0	2.19	0	72	-39	162.5	200.9	201.59	202.38



Curve Legend

1 □——— 2 ○---------- 3 ◇——— 4 △——— 5 ▽———

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	SA2	UNIRR	WELD		13253
2	SA2	T	WELD		13253
3	SA2	U	WELD		13253
4	SA2	X	WELD		13253
5	SA2	Y	WELD SA533B1		13253

Figure 5-7 Charpy V-Notch Impact Energy vs. Temperature for Salem Unit 2 Reactor Vessel Weld Metal

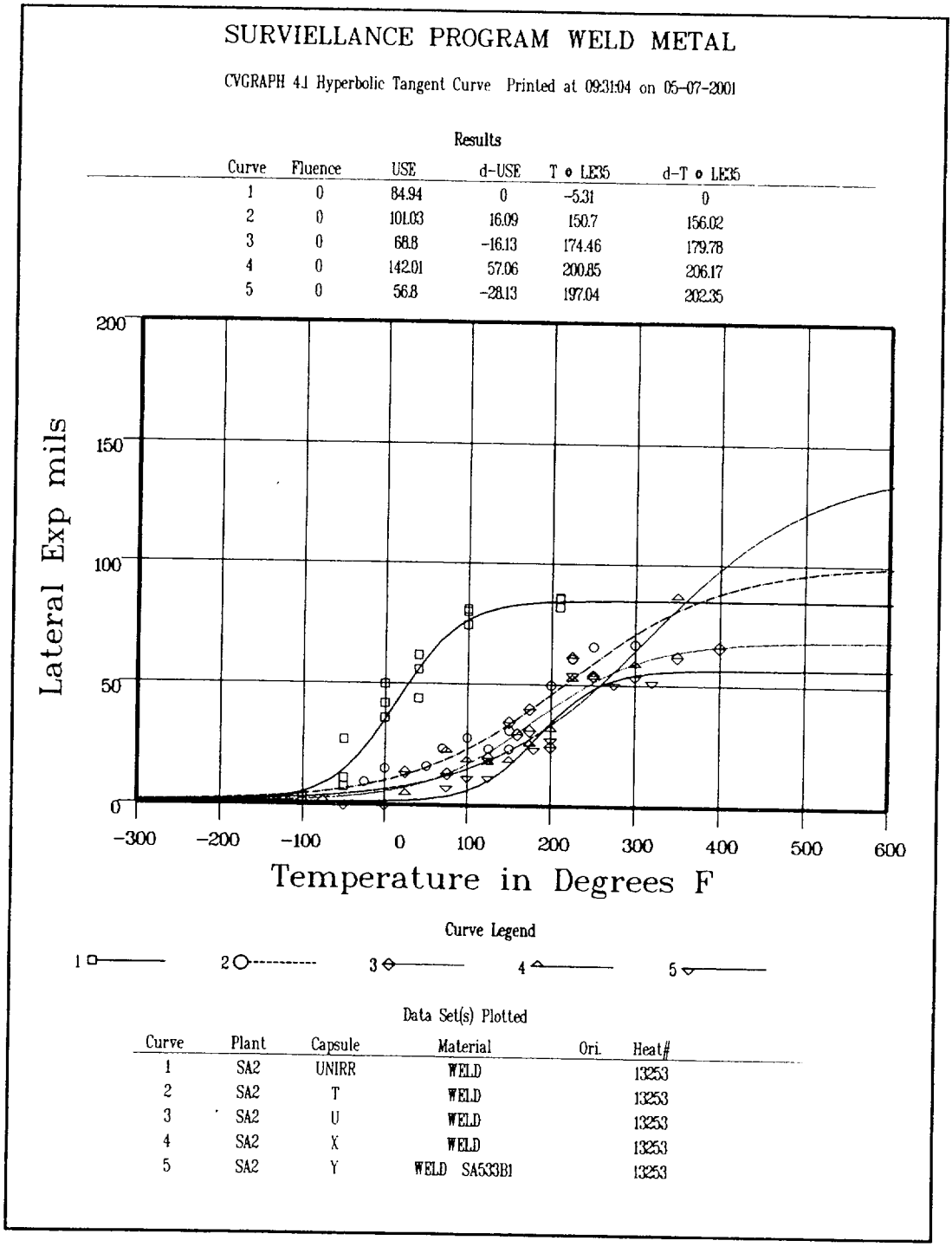


Figure 5-8 **Charpy V-Notch Lateral Expansion vs. Temperature for Salem Unit 2 Reactor Vessel Weld Metal**

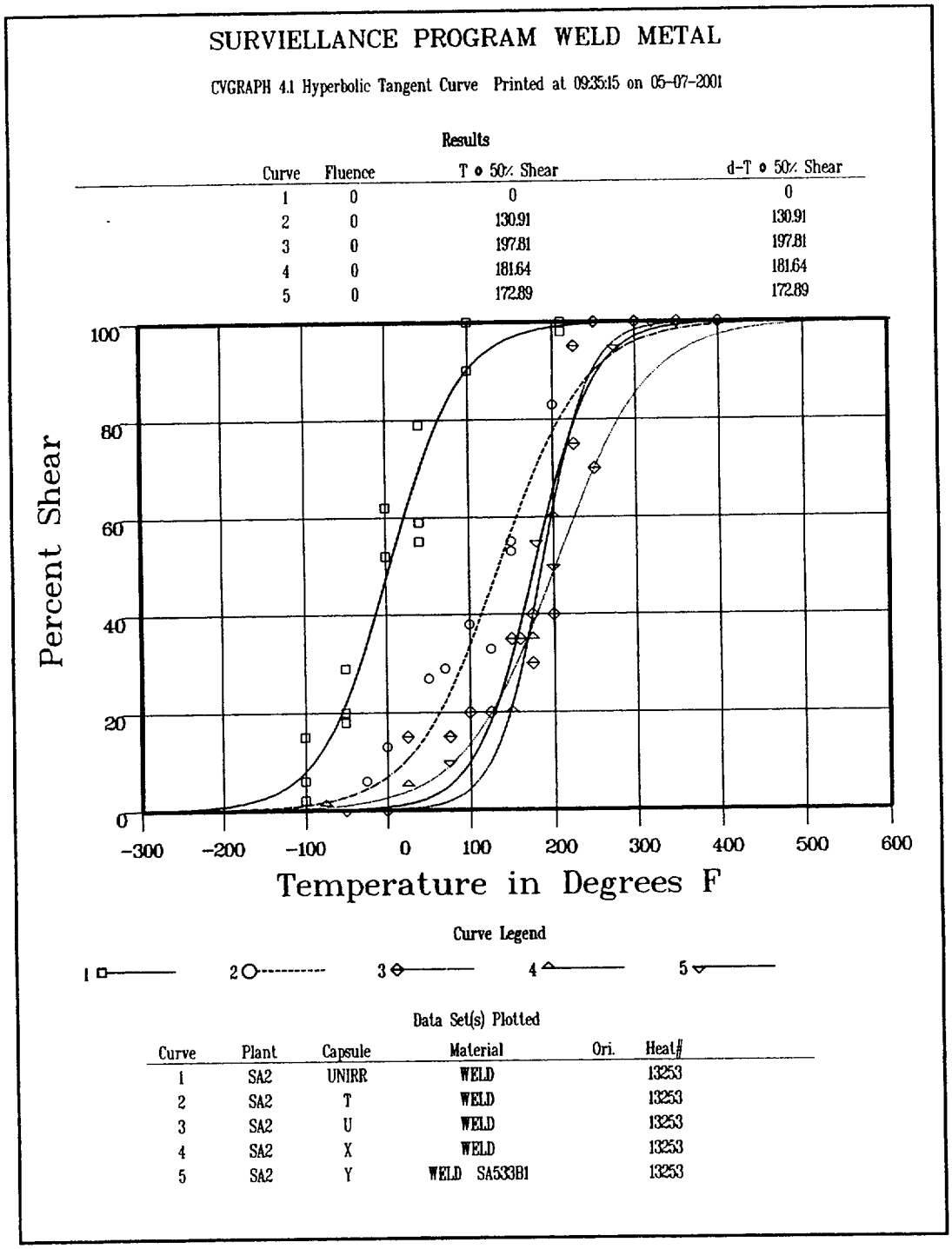
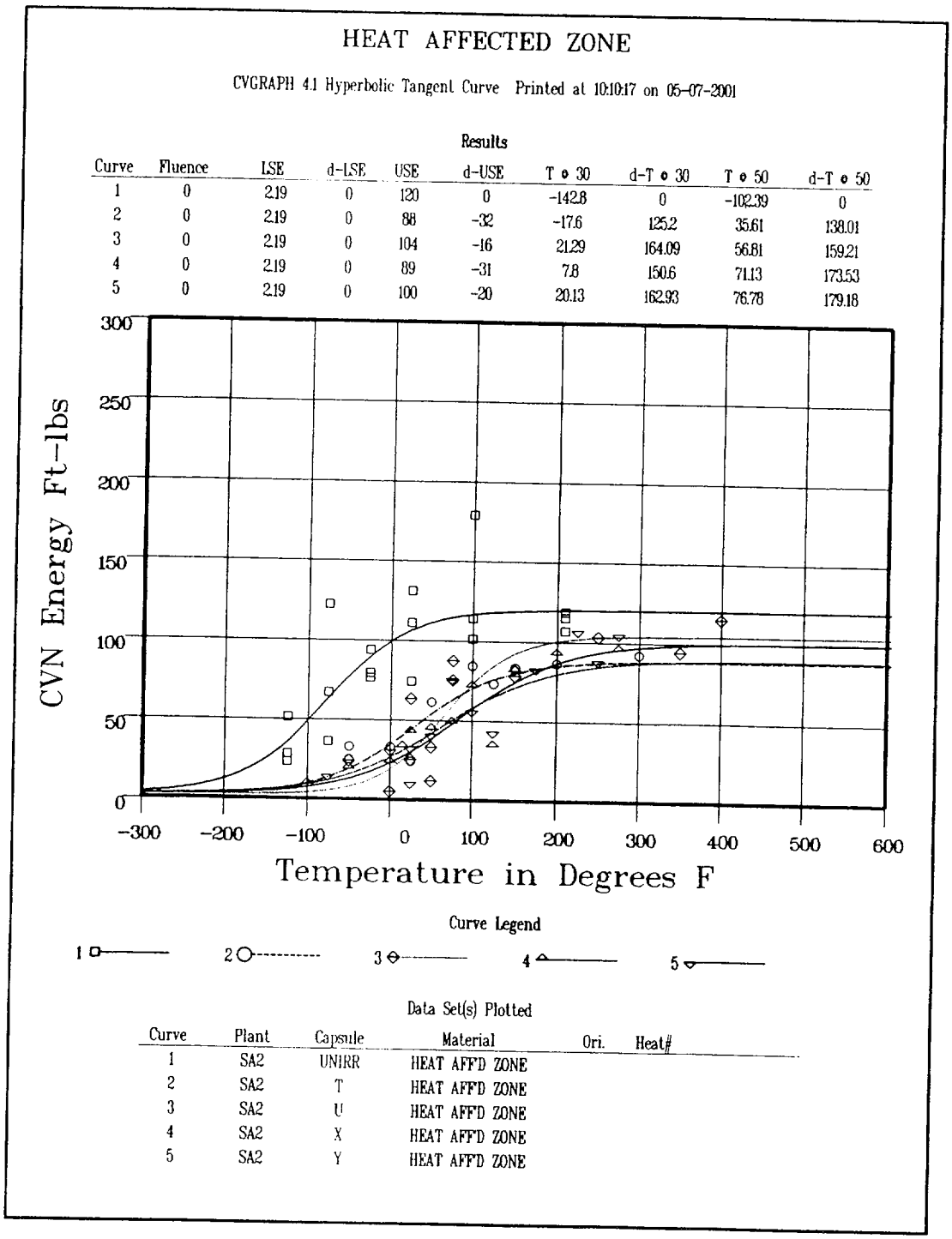


Figure 5-9 Charpy V-Notch Percent Shear vs Temperature for Salem Unit 2 Reactor Vessel Weld Metal



Results

Curve	Fluence	LSE	d-LSE	USE	d-USE	T @ 30	d-T @ 30	T @ 50	d-T @ 50
1	0	2.19	0	120	0	-142.8	0	-102.39	0
2	0	2.19	0	88	-32	-17.6	125.2	35.61	138.01
3	0	2.19	0	104	-16	21.29	164.09	56.81	159.21
4	0	2.19	0	89	-31	7.8	150.6	71.13	173.53
5	0	2.19	0	100	-20	20.13	162.93	76.78	179.18

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat#
1	SA2	UNIRR	HEAT AFF'D ZONE		
2	SA2	T	HEAT AFF'D ZONE		
3	SA2	U	HEAT AFF'D ZONE		
4	SA2	X	HEAT AFF'D ZONE		
5	SA2	Y	HEAT AFF'D ZONE		

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

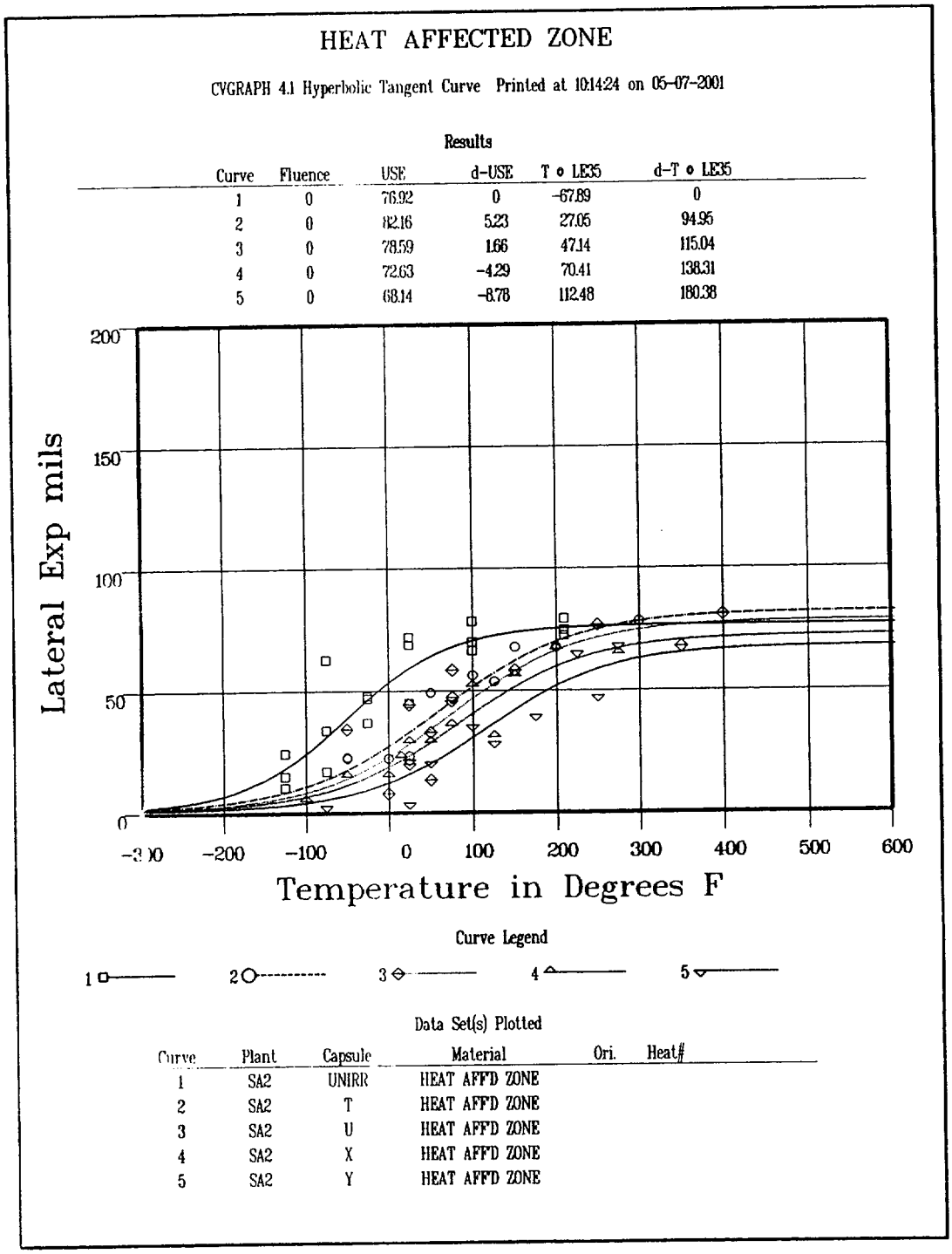


Figure 5-11 Charpy V-Notch Lateral Expansion vs. Temperature for Salem Unit 2 Reactor Vessel Heat-Affected-Zone Material

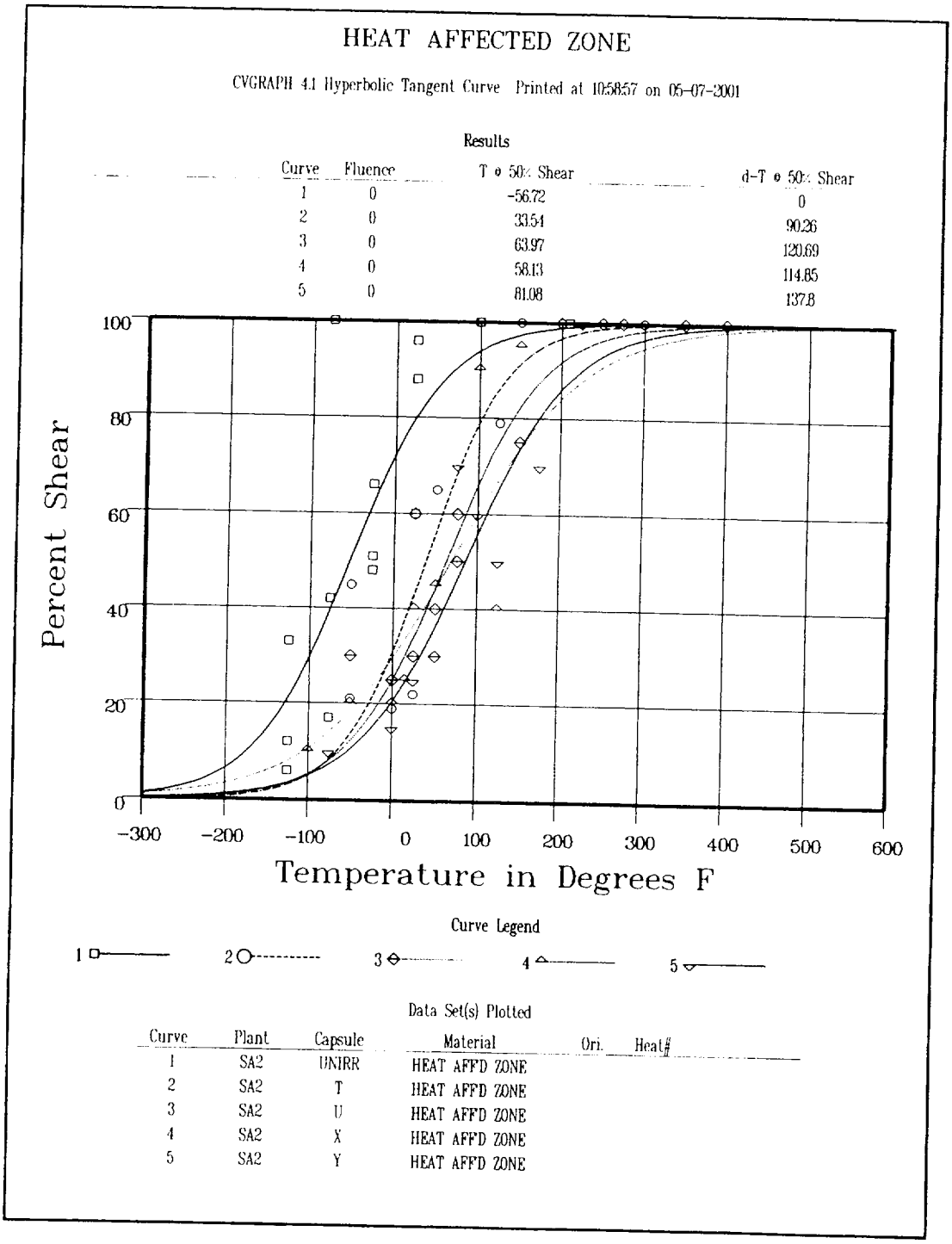
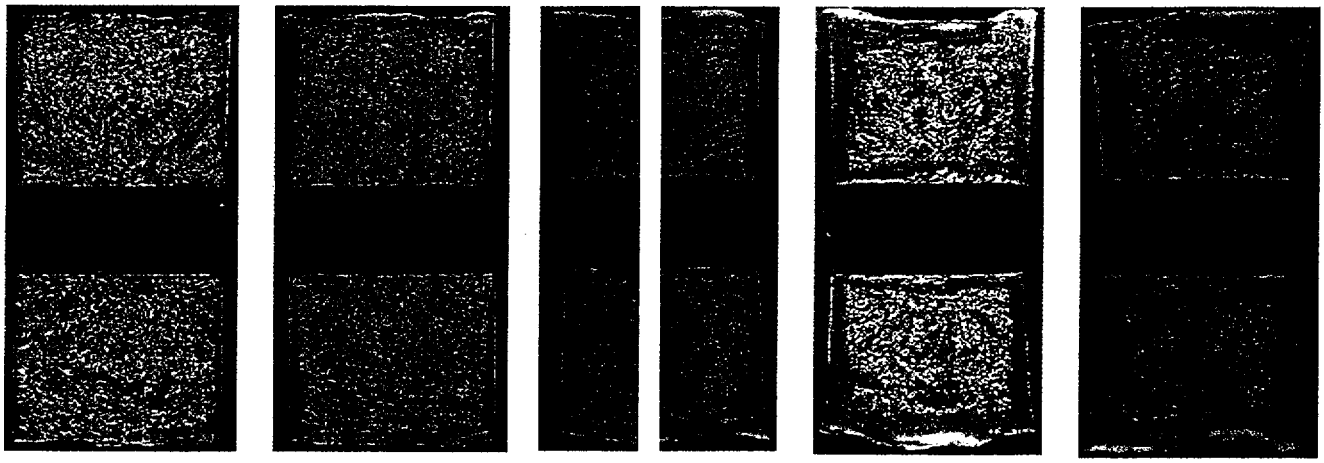


Figure 5-12 Charpy V-Notch Percent Shear vs. Temperature for Salem Unit 2 Reactor Vessel Heat-Affected-Zone Material



JL56, 50°F JL52, 75°F JL50 130°F JL51, 150°F JL55, 190°F

JL53, 225°F JL49, 270°F JL54 290°F

Figure 5-13 Charpy Impact Specimen Fracture Surfaces for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2(Longitudinal Orientation)

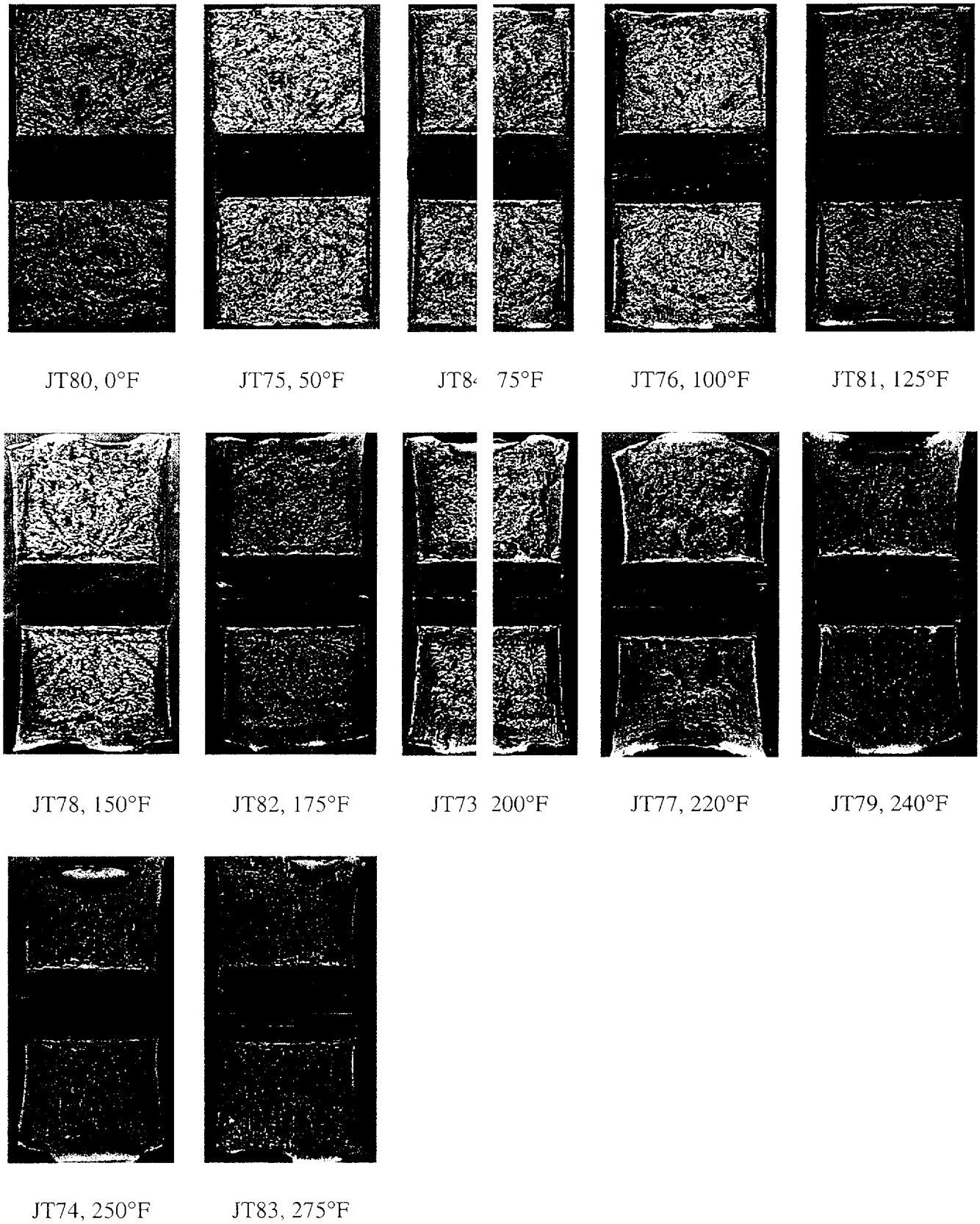


Figure 5-14 Charpy Impact Specimen Fracture Surfaces for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2 (Transverse Orientation)

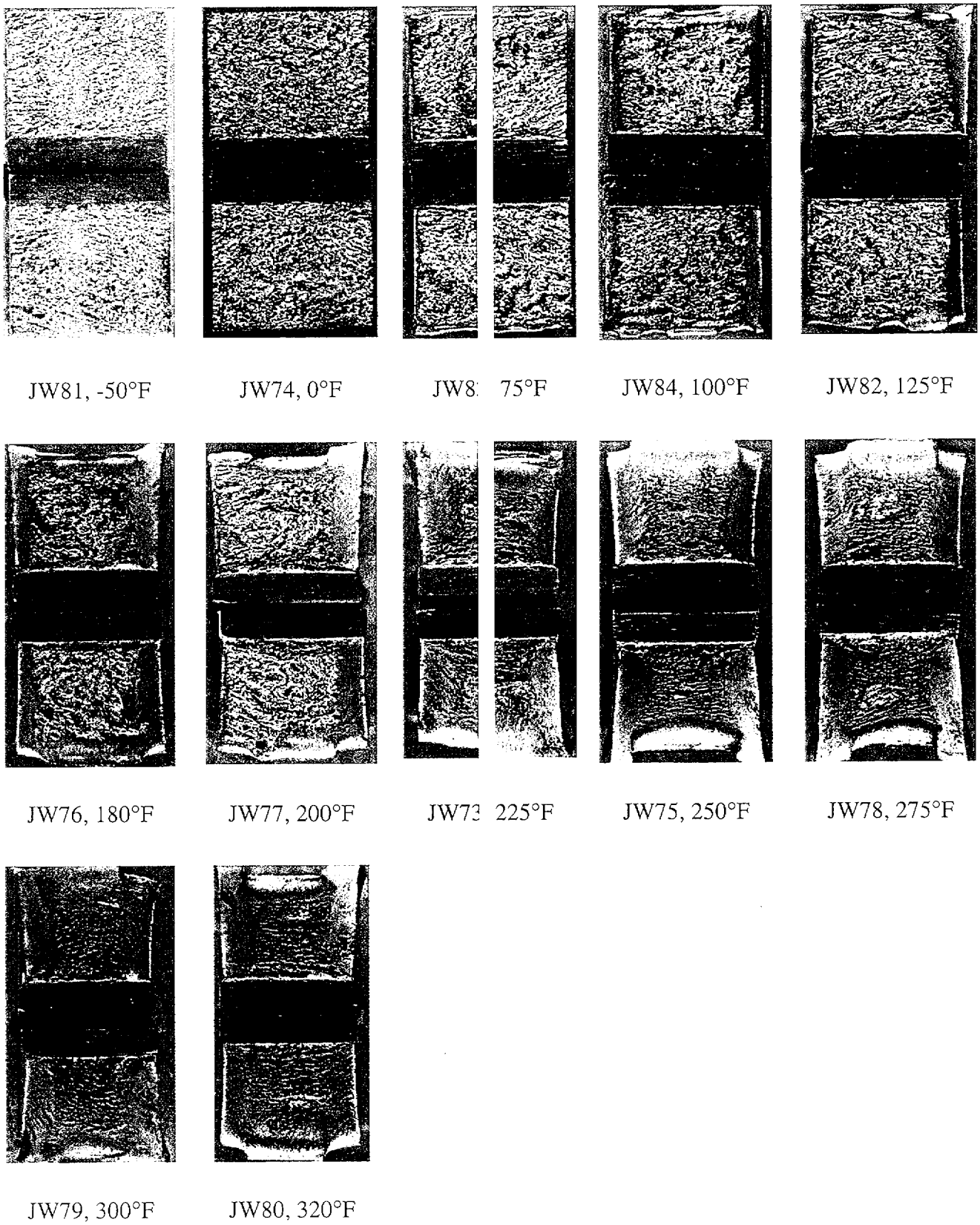


Figure 5-15 Charpy Impact Specimen Fracture Surfaces for Salem Unit 2 Reactor Vessel Weld Metal Specimen

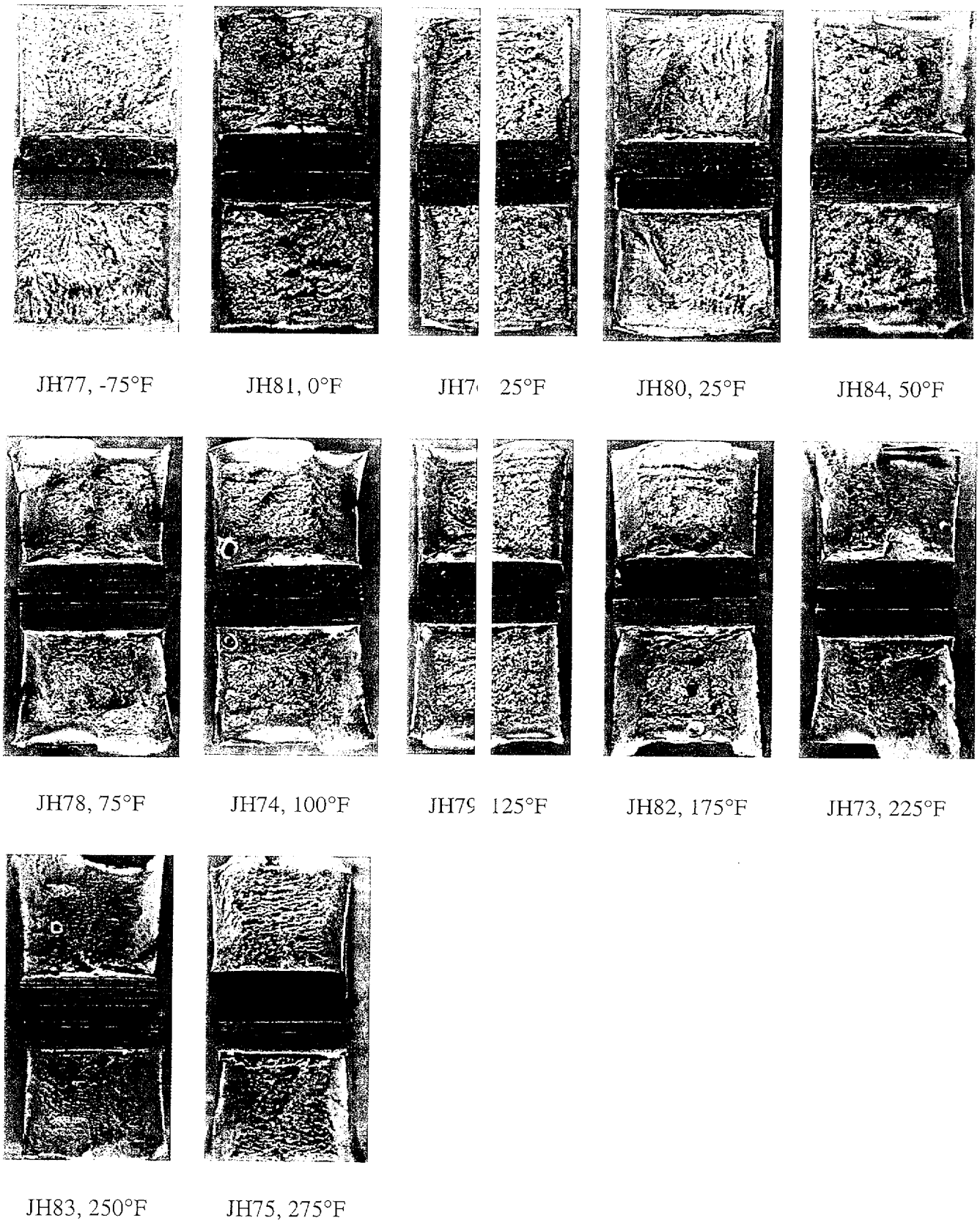
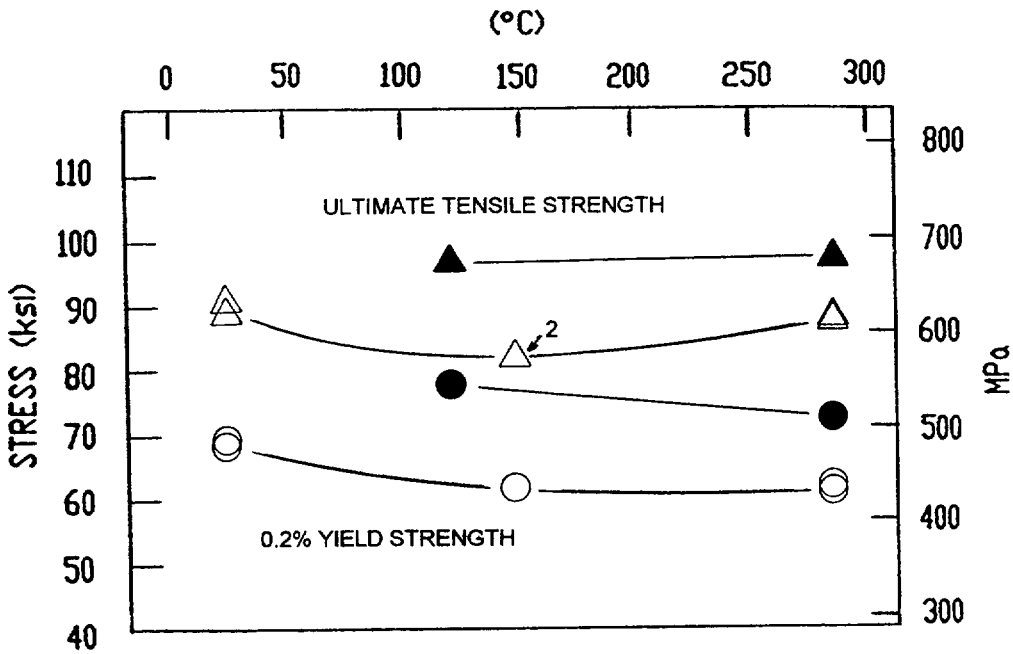


Figure 5-16 Charpy Impact Specimen Fracture Surfaces for Salem Unit 2 Reactor Vessel Heat-Affected-Zone Metal



LEGEND:
△ ○ **UNIRRADIATED**
▲ ● **IRRADIATED TO A FLUENCE OF 1.81 X 10^{19} n/cm^2 (E>1.0MeV) AT 550°F**

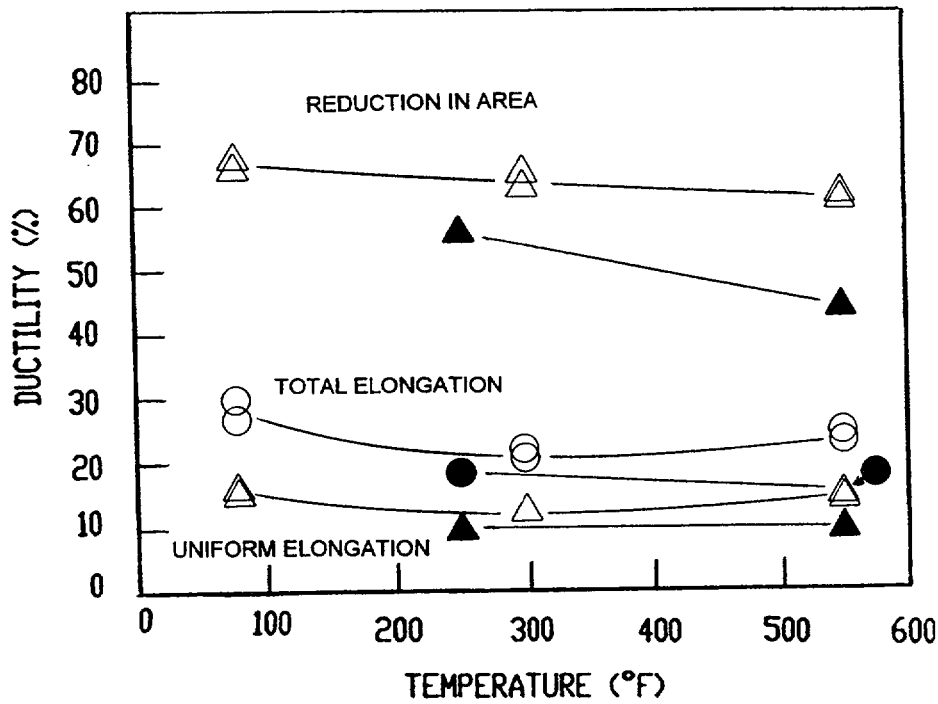
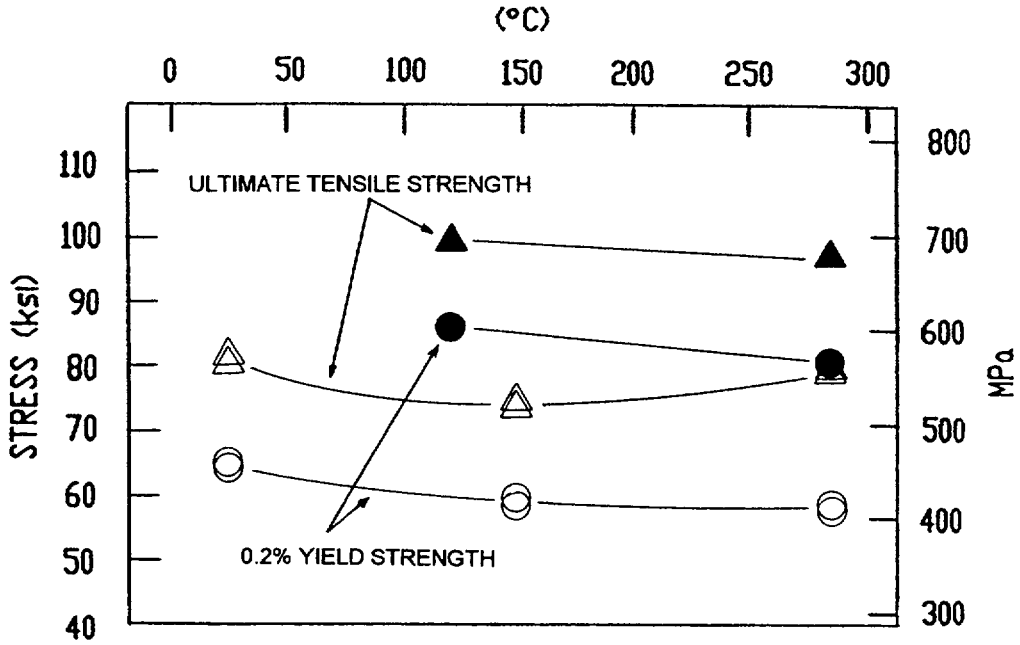


Figure 5-17 Tensile Properties for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2 (Transverse Orientation)



LEGEND:

△ ○ **UNIRRADIATED**

▲ ● **IRRADIATED TO A FLUENCE OF 1.81 X 10^{19} n/cm^2 (E>1.0MeV) AT 550°F**

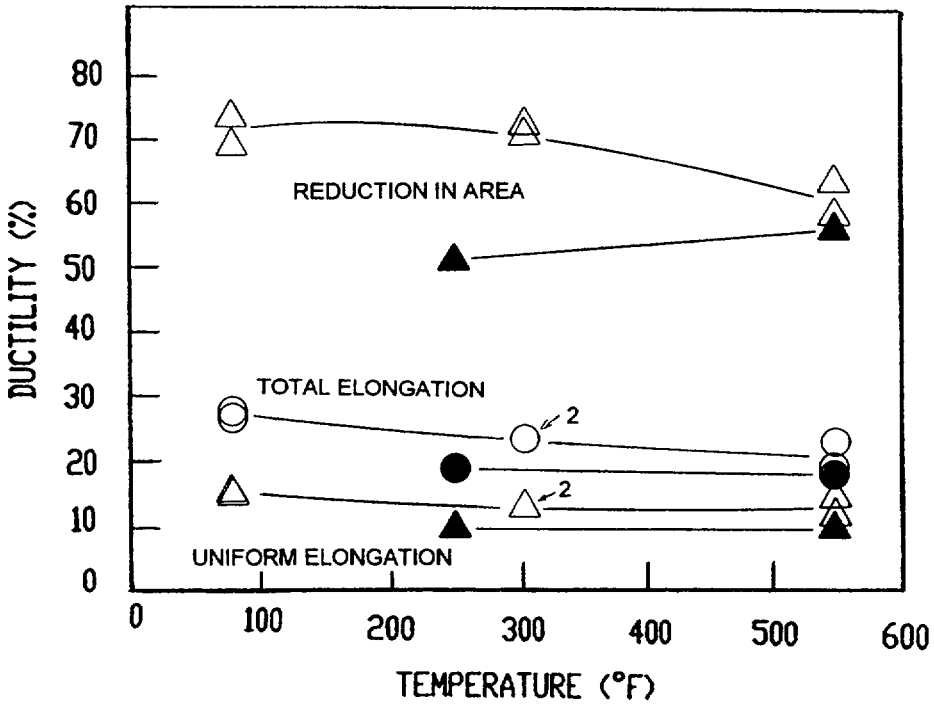
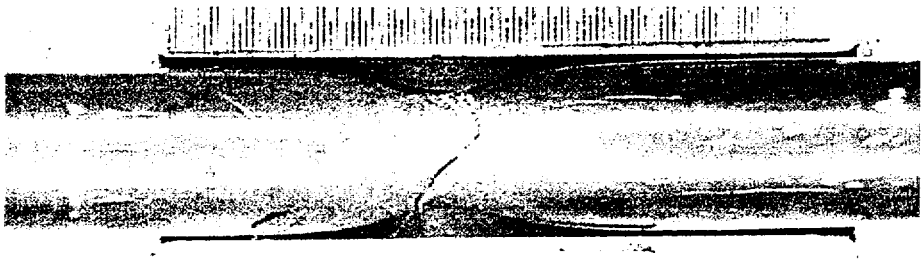
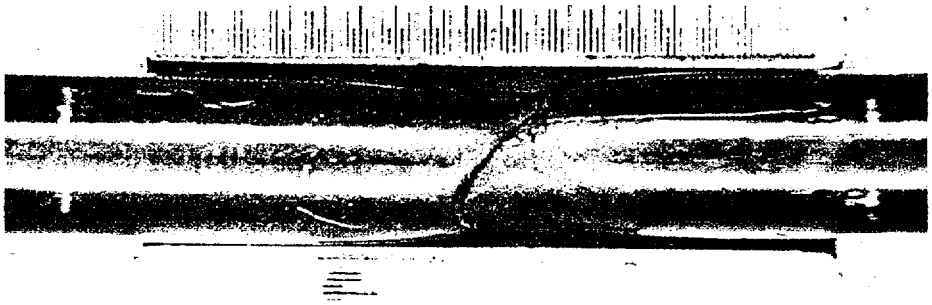


Figure 5-18 Tensile Properties for the Salem Unit 2 Reactor Vessel Weld Metal

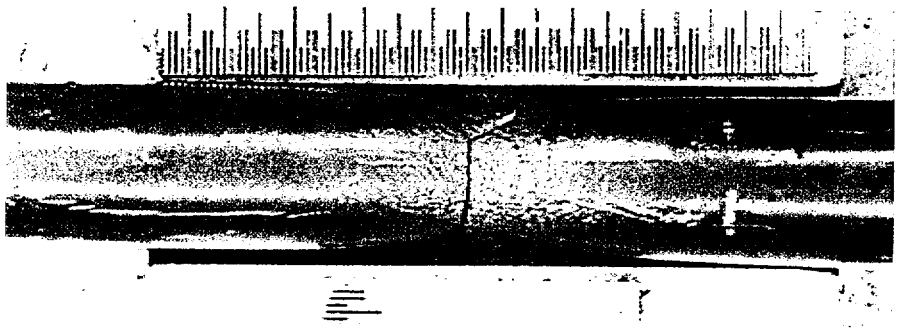


Specimen JT13 Tested at 250°F

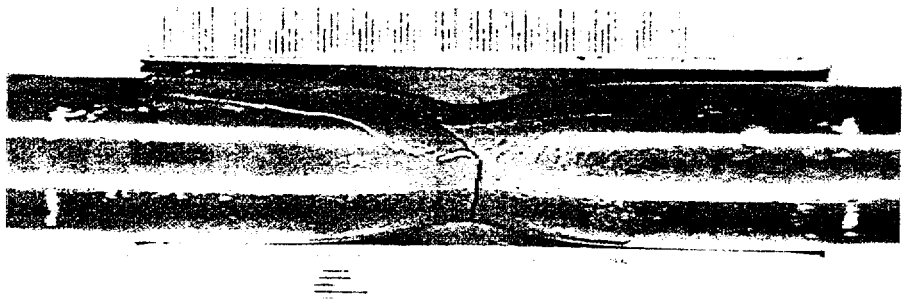


Specimen JT14 Tested at 550°F

Figure 5-19 Fractured Tensile Specimens from Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2(Transverse Orientation)

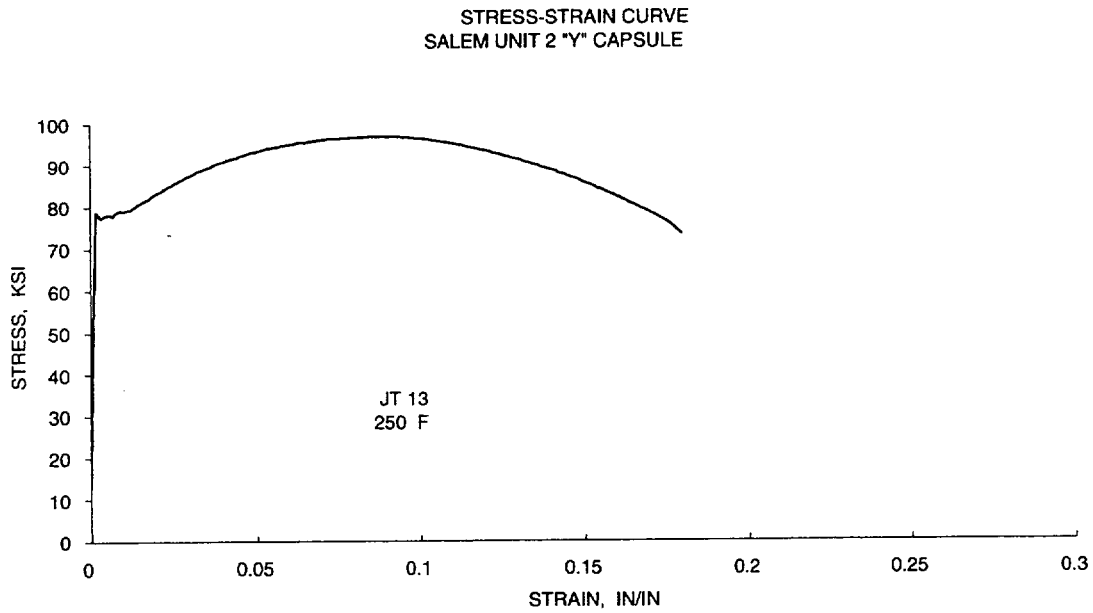


Specimen JW13 Tested at 250°F



Specimen JW14 Tested at 550°F

Figure 5-20 Fractured Tensile Specimens from Salem Unit 2 Reactor Vessel Weld Metal



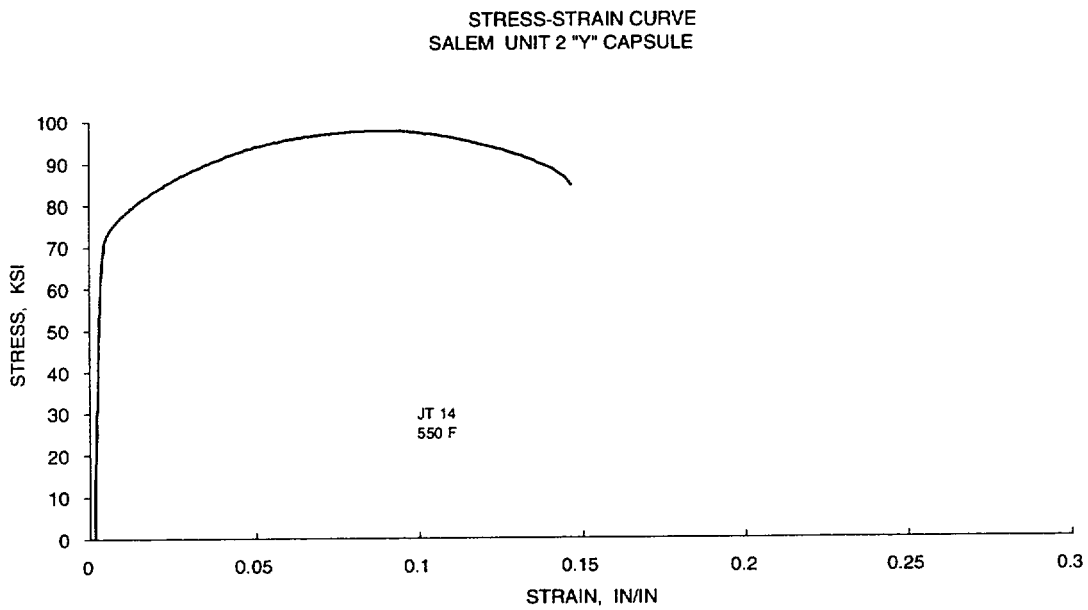
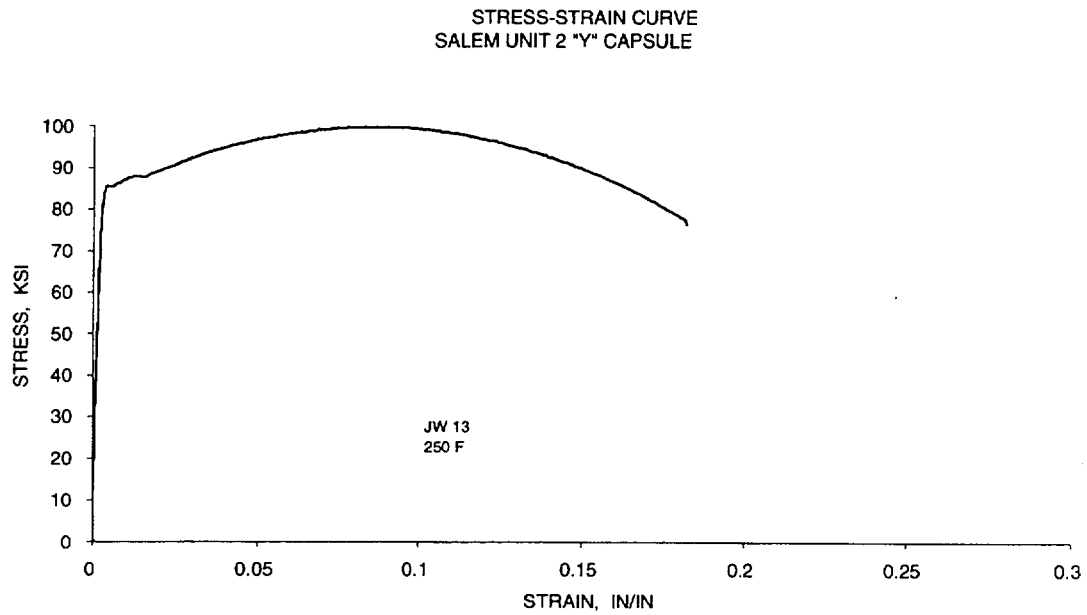


Figure 5-21 Engineering Stress-Strain Curves for Salem Unit 2 Reactor Vessel Intermediate Shell Plate B4712-2, Tensile Specimens JT13 and JT14.



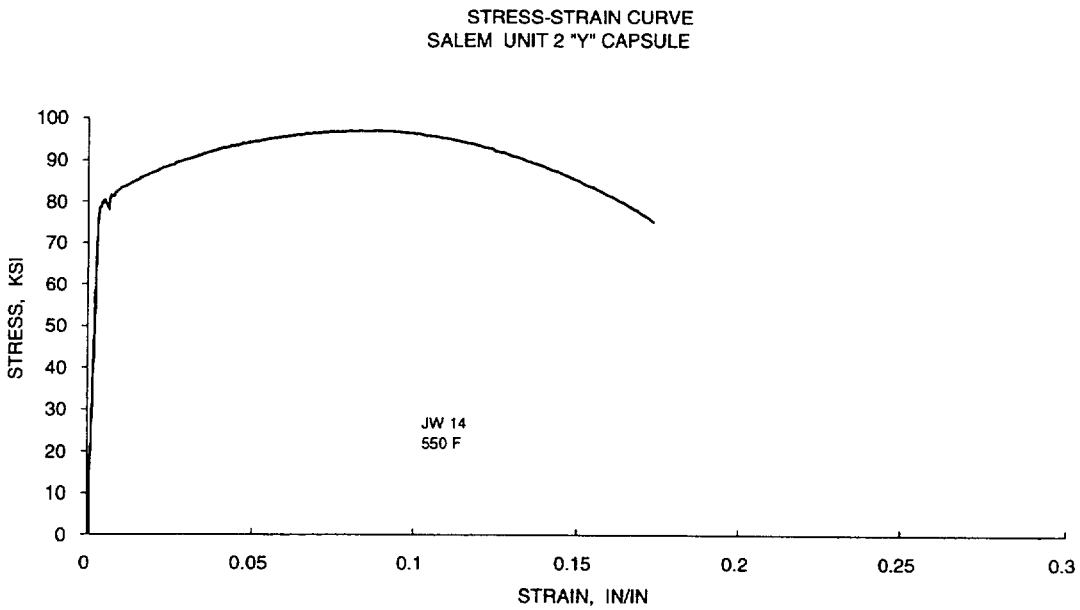


Figure 5-22 Engineering Stress-Strain Curves for Salem Unit 2 Reactor Vessel Weld Metal, Tensile Specimens JW13 and JW14.

6.0 RADIATION ANALYSIS AND NEUTRON DOSIMETRY

6.1 Introduction

This section describes a discrete ordinates S_n transport analysis performed for the Salem Unit 2 reactor to determine the neutron radiation environment within the reactor pressure vessel and surveillance capsules. In this evaluation, fast neutron exposure parameters in terms of fast neutron fluence (E > 1.0 MeV) and iron atom displacements (dpa) were established on a plant and fuel cycle specific basis for the first eleven reactor operating cycles. In addition, neutron dosimetry sensor sets from Surveillance Capsules T, U, X, and Y withdrawn from the Salem Unit 2 reactor at the conclusion of fuel cycles 1, 3, 6, and 11 were analyzed using current dosimetry evaluation methodology. Comparisons of the results of these dosimetry evaluations with the analytical predictions provided a validation of the plant specific neutron transport calculations. These validated calculations were then used to provide projections of the neutron exposure of the reactor pressure vessel for operating periods extending to 54 Effective Full Power Years (EFPY). These projections conservatively account for an assumed plant uprating, from 3411 MWt to 3459 MWt, beginning with the operation of the twelfth fuel cycle.

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

Because of this potential shift away from a threshold fluence toward an energy dependent damage function for data correlation, ASTM Standard Practice E853, "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 database 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."

All of the calculations and dosimetry evaluations described in this section were based on the latest available nuclear cross-section data derived from ENDF/B-VI and made use of the latest available calculational tools. Furthermore, the neutron transport and dosimetry evaluation methodologies follow the guidance and meet the requirements of Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence."[15] Additionally, the methods used to develop the calculated pressure vessel fluence are consistent with the NRC approved methodology described in WCAP-14040-NP-A, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves," January 1996.[16] The specific calculational methods applied are also consistent with those described in WCAP-15557, "Qualification of the Westinghouse Pressure Vessel Neutron Fluence Evaluation Methodology."[17]

6.2 Discrete Ordinates Analysis

A plan view of the Salem Unit 2 reactor geometry at the core midplane is shown in Figure 4-1. Eight irradiation capsules attached to the thermal shield are included in the reactor design that constitutes the reactor vessel surveillance program. The capsules are located at azimuthal angles of 4°, 176°,184°, 356° (4° from the core cardinal axes) and 40°, 140°, 220°, 320° (40° from the core cardinal axes) as shown in Figure 4-1. The stainless steel specimen containers are 1-inch square by 36 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 thermal shield 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.

The fast neutron exposure evaluations for the Salem Unit 2 surveillance capsules and reactor vessel were based on a series of fuel cycle specific forward transport calculations that were combined using the following three-dimensional flux synthesis technique:

$$\phi(r,\theta,z) = [\phi(r,\theta)] * [\phi(r,z)]/[\phi(r)]$$

where $\phi(r,\theta,z)$ is the synthesized three-dimensional neutron flux distribution, $\phi(r,\theta)$ is the transport solution in r,θ geometry, $\phi(r,z)$ is the two-dimensional solution for a cylindrical reactor model using the actual axial core power distribution, and $\phi(r)$ is the one-dimensional solution for a cylindrical reactor model using the same source per unit height as that used in the r,θ two-dimensional calculation. This synthesis procedure was carried out for each operating cycle at Salem Unit 2.

For the Salem Unit 2 calculations, one r,θ model was developed since the reactor is octant symmetric. This r,θ model includes the core, the reactor internals, the thermal shield -- including explicit representations of the surveillance capsules at 4° and 40°, the pressure vessel cladding and vessel wall, the insulation external to the pressure vessel, and the primary biological shield wall. The symmetric r,θ model was utilized to perform both the surveillance capsule dosimetry evaluations, and subsequent comparisons with calculated results, and to generate the maximum fluence levels at the pressure vessel wall. In developing this analytical model, nominal design dimensions were employed for the various structural components. Likewise, water temperatures, and hence, coolant densities in the reactor core and downcomer regions of the reactor were taken to be representative of full power operating conditions. The coolant densities were treated on a fuel cycle specific basis. The reactor core itself was treated as a homogeneous mixture of fuel, cladding, water, and miscellaneous core structures such as fuel assembly grids, guide tubes, et cetera. The r,θ geometric mesh description of the reactor model consisted of 170 radial by 67 azimuthal intervals. Mesh sizes were chosen to assure that proper convergence of the inner iterations was achieved on a pointwise basis. The pointwise inner iteration flux convergence criterion utilized in the r,θ calculations was set at a value of 0.001.

The r,z model used for the Salem Unit 2 calculations extended radially from the centerline of the reactor core out to a location interior to the primary biological shield and over an axial span from an elevation 1-foot below the active fuel to 1-foot above the active fuel. As in the case of the r,θ model, nominal design dimensions and full power coolant densities were employed in the calculations. In this case, the

homogenous core region was treated as an equivalent cylinder with a volume equal to that of the active core zone. The stainless steel former plates located between the core baffle and core barrel regions were also explicitly included in the model. The r,z geometric mesh description of the reactor model consisted of 153 radial by 90 axial intervals. As in the case of the r,θ calculations, mesh sizes were chosen to assure that proper convergence of the inner iterations was achieved on a pointwise basis. The pointwise inner iteration flux convergence criterion utilized in the r,z calculations was also set at a value of 0.001.

The one-dimensional radial model used in the synthesis procedure consisted of the same 153 radial mesh intervals included in the r,z model. Thus, radial synthesis factors could be determined on a meshwise basis throughout the entire geometry.

The core power distributions used in the plant specific transport analysis were taken from the appropriate Salem Unit 2 fuel cycle design reports.[18 through 29] The data extracted from the design reports represented cycle dependent fuel assembly enrichments, burnups, and axial power distributions. This information was used to develop spatial and energy dependent core source distributions averaged over each individual fuel cycle. Therefore, the results from the neutron transport calculations provided data in terms of fuel cycle averaged neutron flux, which when multiplied by the appropriate fuel cycle length, generated the incremental fast neutron exposure for each fuel cycle. In constructing these core source distributions, the energy distribution of the source was based on an appropriate fission split for uranium and plutonium isotopes based on the initial enrichment and burnup history of individual fuel assemblies. From these assembly dependent fission splits, composite values of energy release per fission, neutron yield per fission, and fission spectrum were determined.

All of the transport calculations supporting this analysis were carried out using the DORT discrete ordinates code Version 3.1[30] and the BUGLE-96 cross-section library.[31] The BUGLE-96 library provides a 67 group coupled neutron-gamma ray cross-section data set produced specifically for light water reactor (LWR) applications. In these analyses, anisotropic scattering was treated with a P_5 legendre expansion and angular discretization was modeled with an S_{16} order of angular quadrature. Energy and space dependent core power distributions, as well as system operating temperatures, were treated on a fuel cycle specific basis.

Selected results from the neutron transport analyses are provided in Tables 6-1 through 6-4. The data listed in these tables establish the means for absolute comparisons of analysis and measurement for the Capsules T, U, X, and Y irradiation and provide the calculated neutron exposure of the pressure vessel wall for the first eleven fuel cycles. In Table 6-1, the calculated exposure rates and integrated exposures, expressed in terms of both neutron fluence (E > 1.0 MeV) and dpa, are given at the radial and azimuthal center of the two azimuthally symmetric surveillance capsule positions (4° and 40°). These data, representative of the axial midplane of the active core, are meant to establish the exposure of the surveillance capsules withdrawn to date and to provide an absolute comparison of measurement with calculation. Similar information is provided in Table 6-2 for the reactor vessel inner radius. The vessel data given in Table 6-2 are representative of the axial location of the maximum neutron exposure at each of the four azimuthal locations. Again, both fluence (E > 1.0 MeV) and dpa data are provided. 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 calculated exposure levels of the vessel plates and welds.

Radial gradient information applicable to ϕ(E > 1.0 MeV) and dpa/sec are given in Tables 6-3 and 6-4, respectively. The data, based on the Cycles 1 through 11 cumulative fluence, are presented on a relative basis for each exposure parameter at several azimuthal locations. Exposure distributions through the

vessel wall may be obtained by multiplying the calculated exposure at the vessel inner radius by the gradient data listed in Tables 6-3 and 6-4.

6.3 Neutron Dosimetry

6.3.1 Sensor Reaction Rate Determinations

In this section, the results of the evaluations of the four neutron sensor sets withdrawn to date as a part of the Salem Unit 2 Reactor Vessel Materials Surveillance Program are presented. The capsule designation, location within the reactor, and time of withdrawal of each of these dosimetry sets were as follows:

Capsule ID	Azimuthal Location	Withdrawal Time	Irradiation Time [EFPY]
T	40°	End of Cycle 1	1.19
U	40°	End of Cycle 3	2.70
X	40°	End of Cycle 6	6.19
Y	40°	End of Cycle 11	10.80

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

The passive neutron sensors included in the evaluations of Surveillance Capsules T, U, X, and Y are summarized as follows:

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

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

** The bare cobalt-aluminum measurement for Capsule X was determined to be statistically different than similar measurement data obtained from the 4-loop, thermal-shield reactor plant database for 40° surveillance capsules. As a result, the Capsule X bare cobalt-aluminum measurement was not utilized in the least squares adjustment calculation for this capsule.

The copper, iron, nickel, and cobalt-aluminum monitors, in wire form, were placed in holes drilled in spacers at several radial locations within the test specimen array. As a result, gradient corrections were applied to these measured reaction rates in order to index all of the sensor measurements to the radial center of the respective surveillance capsules. Since the cadmium-shielded uranium and neptunium fission monitors were accommodated within the dosimeter block centered at the radial, azimuthal, and axial center of the material test specimen array, gradient corrections were not required for the fission monitor reaction rates. Pertinent physical and nuclear characteristics of the passive neutron sensors are listed in Table 6-5.

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

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

The radiometric counting of the neutron sensors from Capsules T, U, and X was carried out at the Westinghouse Analytical Services Laboratory at the Waltz Mill Site. The radiometric counting of the sensors from Capsule Y was completed at the Antech Analytical Laboratory, also located at the Waltz Mill Site. In all cases, the radiometric counting followed established ASTM procedures. Following sample preparation and weighing, the specific activity of each sensor was determined by means of a high-resolution gamma spectrometer. For the copper, iron, nickel, and cobalt-aluminum sensors, these analyses were performed by direct counting of each of the individual samples. In the case of the uranium and neptunium fission sensors, the analyses were carried out by direct counting preceded by dissolution and chemical separation of cesium from the sensor material.

The irradiation history of the reactor over the irradiation periods experienced by Capsules T, U, X, and Y was based on the reported monthly power generation of Salem Unit 2 from initial reactor startup through the end of the dosimetry evaluation period. For the sensor sets utilized in the surveillance capsules, the half-lives of the product isotopes are long enough that a monthly histogram describing reactor operation has proven to be an adequate representation for use in radioactive decay corrections for the reactions of interest in the exposure evaluations. The irradiation history applicable to Capsules T, U, X, and Y is given in Table 6-6.

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

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

where:

R	=	Reaction rate averaged over the irradiation period and referenced to operation at a core power level of P_{ref} (rps/nucleus).
A	=	Measured specific activity (dps/gm).
N_0	=	Number of target element atoms per gram of sensor.

F = 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 $\phi(E > 1.0\ MeV)$ during irradiation period j to the time weighted average $\phi(E > 1.0\ MeV)$ over the entire irradiation period.
λ = Decay constant of the product isotope (1/sec).
t_j = Length of irradiation period j (sec).
t_d = Decay time following irradiation period j (sec).

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

In the equation describing the reaction rate calculation, the ratio $[P_j]/[P_{ref}]$ accounts for month-by-month variation of reactor core power level within any given fuel cycle as well as over multiple fuel cycles. The ratio C_j, which was calculated for each fuel cycle using the transport methodology discussed in Section 6.2, accounts for the change in sensor reaction rates caused by variations in flux level induced by changes in core spatial power distributions from fuel cycle to fuel cycle. For a single-cycle irradiation, C_j is normally taken to be 1.0. However, for multiple-cycle irradiations, particularly those employing low leakage fuel management, the additional C_j term should be employed. The impact of changing flux levels for constant power operation can be quite significant for sensor sets that have been irradiated for many cycles in a reactor that has transitioned from non-low leakage to low leakage fuel management or for sensor sets contained in surveillance capsules that have been moved from one capsule location to another. The fuel cycle specific neutron flux values along with the computed values for C_j are listed in Table 6-7. These flux values represent the cycle dependent results at the radial and azimuthal center of the respective capsules at the axial elevation of the active fuel midplane.

Prior to using the measured reaction rates in the least-squares evaluations of the dosimetry sensor sets, additional corrections were made to the ^{238}U measurements to account for the presence of ^{235}U impurities in the sensors as well as to adjust for the build-in of plutonium isotopes over the course of the irradiation. Corrections were also made to the ^{238}U and ^{237}Np sensor reaction rates to account for gamma ray induced fission reactions that occurred over the course of the capsule irradiations. The correction factors applied to the Salem Unit 2 fission sensor reaction rates are summarized as follows:

Correction	Capsule T	Capsule U	Capsule X	Capsule Y
^{235}U Impurity/Pu Build-in	0.873	0.862	0.841	0.816
$^{238}U(\gamma,f)$	0.958	0.958	0.958	0.958
Net ^{238}U Correction	0.836	0.826	0.806	0.782
$^{237}Np(\gamma,f)$	0.985	0.985	0.985	0.985

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

Results of the sensor reaction rate determinations for Capsules T, U, X, and Y are given in Table 6-8. In Table 6-8, the measured specific activities, decay corrected saturated specific activities, and computed reaction rates for each sensor indexed to the radial center of the capsule are listed. The fission sensor

reaction rates are listed both with and without the applied corrections for ^{238}U impurities, plutonium build-in, and gamma ray induced fission effects.

6.3.2 Least Squares Evaluation of Sensor Sets

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

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

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

For the least squares evaluation of the Salem Unit 2 surveillance capsule dosimetry, the FERRET code[32] was employed to combine the results of the plant specific neutron transport calculations and sensor set reaction rate measurements to determine best-estimate values of exposure parameters ($\phi(E > 1.0\ MeV)$ and dpa) along with associated uncertainties for the four in-vessel capsules withdrawn to date.

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

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

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

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

For the Salem Unit 2 application, the calculated neutron spectrum was obtained from the results of plant specific neutron transport calculations described in Section 6.2 of this report. The sensor reaction rates were derived from the measured specific activities using the procedures described in Section 6.3.1. The dosimetry reaction cross-sections and uncertainties were obtained from the SNLRML dosimetry cross-section library[33]. The SNLRML library is an evaluated dosimetry reaction cross-section compilation recommended for use in LWR evaluations by ASTM Standard E1018, "Application of ASTM Evaluated Cross-Section Data File, Matrix E 706 (IIB)".

The uncertainties associated with the measured reaction rates, dosimetry cross-sections, and calculated neutron spectrums were input to the least squares procedure in the form of variances and covariances. The

assignment of the input uncertainties followed the guidance provided in ASTM Standard E 944, "Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance."

The following provides a summary of the uncertainties associated with the least squares evaluation of the Salem Unit 2 surveillance capsule sensor sets.

Reaction Rate Uncertainties

The overall uncertainty associated with the measured reaction rates includes components due to the basic measurement process, irradiation history corrections, and corrections for competing reactions. A high level of accuracy in the reaction rate determinations is assured by utilizing laboratory procedures that conform to the ASTM National Consensus Standards for reaction rate determinations for each sensor type.
After combining all of these uncertainty components, the sensor reaction rates derived from the counting and data evaluation procedures were assigned the following net uncertainties for input to the least squares evaluation:

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

These uncertainties are given at the 1σ level.

Dosimetry Cross-Section Uncertainties

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

For sensors included in the Salem Unit 2 surveillance program, the following uncertainties in the fission spectrum averaged cross-sections are provided in the SNLRML documentation package.

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

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

Calculated Neutron Spectrum

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

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

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

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

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

where

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

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

The set of parameters defining the input covariance matrix for the Salem Unit 2 calculated spectra was as follows:

Flux Normalization Uncertainty (R_n)	15%
Flux Group Uncertainties (R_g, $R_{g'}$)	
(E > 0.0055 MeV)	15%
(0.68 eV < E < 0.0055 MeV)	29%
(E < 0.68 eV)	52%
Short Range Correlation (θ)	
(E > 0.0055 MeV)	0.9
(0.68 eV < E < 0.0055 MeV)	0.5
(E < 0.68 eV)	0.5

Flux Group Correlation Range (γ)	
(E > 0.0055 MeV)	6
(0.68 eV < E < 0.0055 MeV)	3
(E < 0.68 eV)	2

6.3.3 Comparisons of Measurements and Calculations

Results of the least squares evaluations of the dosimetry from the four Salem Unit 2 surveillance capsules withdrawn to date are provided in Tables 6-9 and 6-10. In Table 6-9, measured, calculated, and best-estimate values for sensor reaction rates are given for each capsule. Also provided in this tabulation are ratios of the measured reaction rates to both the calculated and least squares adjusted reaction rates. These ratios of M/C and M/BE illustrate the consistency of the fit of the calculated neutron energy spectra to the measured reaction rates both before and after adjustment. In Table 6-10, comparison of the calculated and best estimate values of neutron flux (E > 1.0 MeV) and iron atom displacement rate are tabulated along with the BE/C ratios observed for each of the capsules.

The data comparisons provided in Tables 6-9 and 6-10 show that the adjustments to the calculated spectra are relatively small and well within the assigned uncertainties for the calculated spectra, measured sensor reaction rates, and dosimetry reaction cross-sections. Further, these results indicate that the use of the least squares evaluation results in a reduction in the uncertainties associated with the exposure of the surveillance capsules. From Section 6.4 of this report, it may be noted that the uncertainty associated with the unadjusted calculation of neutron fluence (E > 1.0 MeV) and iron atom displacements at the surveillance capsule locations is specified as 12% at the 1σ level. From Table 6-10, it is noted that the corresponding uncertainties associated with the least squares adjusted exposure parameters have been reduced to 6% for neutron flux (E > 1.0 MeV) and 7% for iron atom displacement rate. Again, the uncertainties from the least squares evaluation are at the 1σ level.

Further comparisons of the measurement results with calculations are given in Tables 6-11 and 6-12. These comparisons are given on two levels. In Table 6-11, calculations of individual threshold sensor reaction rates are compared directly with the corresponding measurements. These threshold reaction rate comparisons provide a good evaluation of the accuracy of the fast neutron portion of the calculated energy spectra. In Table 6-12, calculations of fast neutron exposure rates in terms of ϕ(E > 1.0 MeV) and dpa/s are compared with the best estimate results obtained from the least squares evaluation of the four capsule dosimetry results. These two levels of comparison yield consistent and similar results with all measurement-to-calculation comparisons falling well within the 20% limits specified as the acceptance criteria in Regulatory Guide 1.190.

In the case of the direct comparison of measured and calculated sensor reaction rates, the M/C comparisons for fast neutron reactions range from 0.92–1.14 for the 20 samples included in the data set. The overall average M/C ratio for the entire set of Salem Unit 2 data is 1.00 with an associated standard deviation of 6.7%.

In the comparisons of best estimate and calculated fast neutron exposure parameters, the corresponding BE/C comparisons for the four capsule data set range from 0.96–1.01 for neutron flux (E > 1.0 MeV) and from 0.96 to 1.01 for iron atom displacement rate. The overall average BE/C ratios for neutron flux (E > 1.0 MeV) and iron atom displacement rate are 0.98 with a standard deviation of 2.4% and 0.98 with a standard deviation of 2.5%, respectively.

Based on these comparisons, it is concluded that the calculated fast neutron exposures provided in Section 6.4 of this report are validated for use in the assessment of the condition of the materials comprising the beltline region of the Salem Unit 2 reactor pressure vessel.

6.4 Projections of Reactor Vessel Exposure

The final results of the fluence evaluations performed for the four surveillance capsules withdrawn from the Salem Unit 2 reactor are provided in Table 6-13. These assigned neutron exposure levels are based on the plant and fuel cycle specific neutron transport calculations performed for the Salem Unit 2 reactor. As shown by the comparisons provided in Tables 6-11 and 6-12, the validity of these calculated fluence levels is demonstrated both by a direct comparison with measured sensor reaction rates as well by comparison with the least squares evaluation performed for each of the capsule dosimetry sets.

The corresponding calculated fast neutron fluence (E > 1.0 MeV) and dpa exposure values for the Salem Unit 2 pressure vessel are provided in Table 6-14. As presented, these data represent the maximum exposure of the clad/base metal interface at azimuthal angles of 0, 15, 30, and 45 degrees relative to the core cardinal axes. The data tabulation includes the plant and fuel cycle specific calculated fluence at the end of the eleventh operating fuel cycle as well as projections for future operation to 16, 32, 48, and 54 effective full power years. The projections were based on the assumption that the spatial power distributions averaged over fuel cycles 10 through 12 were representative of future plant operation. The future projections also account for a power uprate from 3411 MWt to 3459 MWt.

Updated lead factors for the Salem Unit 2 surveillance capsules are provided in Table 6-15. The capsule lead factor is defined as the ratio of the calculated fluence (E > 1.0 MeV) at the geometric center of the surveillance capsule to the corresponding maximum calculated fluence at the pressure vessel clad/base metal interface. In Table 6-15, the lead factors for capsules that have been withdrawn from the reactor (T, U, X, and Y) were based on the calculated fluence values for the irradiation period corresponding to the time of withdrawal for the individual capsules. For the capsules remaining in the reactor (S, V, W, and Z), the lead factors correspond to the calculated fluence values at the end of cycle 11, the last fuel cycle for which fuel cycle specific transport calculations have been completed.

The uncertainty associated with the calculated neutron exposure of the Salem Unit 2 surveillance capsule and reactor pressure vessel is based on the recommended approach provided in Regulatory Guide 1.190. In particular, the qualification of the methodology was carried out in the following four stages:

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

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

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

4 - Comparisons of the plant specific calculations with all available dosimetry results from the Salem Unit 2 surveillance program.

The first phase of the methods qualification (PCA comparisons) addressed the adequacy of basic transport calculation and dosimetry evaluation techniques and associated cross-sections. This phase, however, did not test the accuracy of commercial core neutron source calculations nor did it address uncertainties in operational or geometric variables that impact power reactor calculations. The second phase of the qualification (H. B. Robinson comparisons) addressed uncertainties in these additional areas that are primarily methods related and would tend to apply generically to all fast neutron exposure evaluations. The third phase of the qualification (analytical sensitivity study) identified the potential uncertainties introduced into the overall evaluation due to calculational methods approximations as well as to a lack of knowledge relative to various plant specific input parameters. The overall calculational uncertainty applicable to the Salem Unit 2 analysis was established from results of these three phases of the methods qualification.

The fourth phase of the uncertainty assessment (comparisons with Salem Unit 2 measurements) was used solely to demonstrate the validity of the transport calculations and to confirm the uncertainty estimates associated with the analytical results. The comparison was used only as a check and was not used in any way to modify the calculated surveillance capsule and pressure vessel neutron exposures.

The following summarizes the uncertainties developed from the first three phases of the methodology qualification. Additional information pertinent to these evaluations is provided in Reference 17.

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

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

The plant specific measurement comparisons provided in Tables 6-11 and 6-12 support these uncertainty assessments for Salem Unit 2.

Table 6-1

Calculated Neutron Exposure Rates and Integrated Exposures
at the Surveillance Capsule Center

Neutrons (E > 1.0 MeV)

Cycle	Cycle Length [EFPY]	Total Irradiation Time [EFPY]	Neutron Flux (E > 1.0 MeV) [n/cm^2-s]		Neutron Fluence (E > 1.0 MeV) [n/cm^2]	
			4 Degrees	40 Degrees	4 Degrees	40 Degrees
1	1.19	1.19	2.29E+10	7.40E+10	8.60E+17	2.78E+18
2	0.40	1.60	2.48E+10	8.58E+10	1.18E+18	3.88E+18
3	1.11	2.70	2.28E+10	5.49E+10	1.97E+18	5.79E+18
4	1.29	3.99	2.01E+10	5.35E+10	2.79E+18	7.96E+18
5	1.05	5.04	2.17E+10	4.62E+10	3.51E+18	9.50E+18
6	1.15	6.19	2.08E+10	4.78E+10	4.27E+18	1.12E+19
7	0.69	6.88	2.11E+10	5.08E+10	4.72E+18	1.23E+19
8	1.01	7.89	2.14E+10	5.30E+10	5.41E+18	1.40E+19
9	0.23	8.12	2.00E+10	4.11E+10	5.55E+18	1.43E+19
10	1.34	9.46	2.26E+10	4.87E+10	6.51E+18	1.64E+19
11	1.34	10.80	1.62E+10	3.95E+10	7.20E+18	1.81E+19

Iron Atom Displacements

Cycle	Cycle Length [EFPY]	Total Irradiation Time [EFPY]	Displacement Rate [dpa/s]		Displacements [dpa]	
			4 Degrees	40 Degrees	4 Degrees	40 Degrees
1	1.19	1.19	3.69E-11	1.25E-10	1.39E-03	4.70E-03
2	0.40	1.60	4.00E-11	1.45E-10	1.90E-03	6.55E-03
3	1.11	2.70	3.67E-11	9.22E-11	3.18E-03	9.77E-03
4	1.29	3.99	3.24E-11	9.01E-11	4.49E-03	1.34E-02
5	1.05	5.04	3.49E-11	7.76E-11	5.65E-03	1.60E-02
6	1.15	6.19	3.35E-11	8.03E-11	6.87E-03	1.89E-02
7	0.69	6.88	3.41E-11	8.54E-11	7.61E-03	2.08E-02
8	1.01	7.89	3.45E-11	8.91E-11	8.72E-03	2.36E-02
9	0.23	8.12	3.21E-11	6.91E-11	8.95E-03	2.41E-02
10	1.34	9.46	3.64E-11	8.18E-11	1.05E-02	2.76E-02
11	1.34	10.80	2.62E-11	6.64E-11	1.16E-02	3.04E-02

Table 6-2

Calculated Azimuthal Variation of Maximum Exposure Rates
And Integrated Exposures at The Reactor Vessel
Clad/Base Metal Interface

Cycle	Cycle Length [EFPY]	Total Irradiation Time [EFPY]	Neutron Flux (E > 1.0 MeV) [n/cm^2-s]			
			0 Degrees	15 Degrees	30 Degrees	45 Degrees
1	1.19	1.19	7.00E+09	1.11E+10	1.41E+10	2.17E+10
2	0.40	1.60	7.40E+09	1.20E+10	1.51E+10	2.44E+10
3	1.11	2.70	6.83E+09	1.06E+10	1.18E+10	1.58E+10
4	1.29	3.99	6.07E+09	9.43E+09	1.07E+10	1.55E+10
5	1.05	5.04	6.53E+09	1.00E+10	1.01E+10	1.34E+10
6	1.15	6.19	6.30E+09	9.37E+09	1.04E+10	1.38E+10
7	0.69	6.88	6.46E+09	9.20E+09	1.06E+10	1.47E+10
8	1.01	7.89	6.48E+09	9.14E+09	1.04E+10	1.53E+10
9	0.23	8.12	6.10E+09	7.52E+09	8.03E+09	1.19E+10
10	1.34	9.46	6.92E+09	9.17E+09	1.02E+10	1.42E+10
11	1.34	10.80	4.95E+09	7.19E+09	8.60E+09	1.14E+10

Cycle	Cycle Length [EFPY]	Total Irradiation Time [EFPY]	Neutron Fluence (E > 1.0 MeV) [n/cm^2]			
			0 Degrees	15 Degrees	30 Degrees	45 Degrees
1	1.19	1.19	2.63E+17	4.17E+17	5.29E+17	8.15E+17
2	0.40	1.60	3.57E+17	5.70E+17	7.22E+17	1.13E+18
3	1.11	2.70	5.96E+17	9.39E+17	1.13E+18	1.68E+18
4	1.29	3.99	8.38E+17	1.31E+18	1.56E+18	2.29E+18
5	1.05	5.04	1.05E+18	1.65E+18	1.90E+18	2.74E+18
6	1.15	6.19	1.28E+18	1.98E+18	2.27E+18	3.23E+18
7	0.69	6.88	1.42E+18	2.18E+18	2.50E+18	3.55E+18
8	1.01	7.89	1.63E+18	2.47E+18	2.83E+18	4.04E+18
9	0.23	8.12	1.67E+18	2.53E+18	2.88E+18	4.12E+18
10	1.34	9.46	1.96E+18	2.91E+18	3.31E+18	4.72E+18
11	1.34	10.80	2.17E+18	3.21E+18	3.67E+18	5.20E+18

Note: At the end of Cycle 11, the maximum fast (E > 1.0 MeV) neutron fluence at the pressure vessel wall occurs at an axial elevation 9.1 cm above the midplane of the active fuel for the 0° and 15° azimuths and at 39.7 cm below the midplane of the active fuel for the 30° and 45° azimuths.

Table 6-2 cont'd

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

Cycle	Cycle Length [EFPY]	Total Irradiation Time [EFPY]	Iron Atom Displacement Rate [dpa/s]			
			0 Degrees	15 Degrees	30 Degrees	45 Degrees
1	1.19	1.19	1.14E-11	1.78E-11	2.27E-11	3.51E-11
2	0.40	1.60	1.20E-11	1.92E-11	2.44E-11	3.94E-11
3	1.11	2.70	1.11E-11	1.69E-11	1.90E-11	2.55E-11
4	1.29	3.99	9.83E-12	1.51E-11	1.73E-11	2.50E-11
5	1.05	5.04	1.06E-11	1.60E-11	1.62E-11	2.16E-11
6	1.15	6.19	1.02E-11	1.50E-11	1.67E-11	2.23E-11
7	0.69	6.88	1.05E-11	1.47E-11	1.71E-11	2.38E-11
8	1.01	7.89	1.05E-11	1.46E-11	1.67E-11	2.48E-11
9	0.23	8.12	9.85E-12	1.20E-11	1.30E-11	1.93E-11
10	1.34	9.46	1.12E-11	1.47E-11	1.64E-11	2.29E-11
11	1.34	10.80	8.02E-12	1.15E-11	1.38E-11	1.84E-11

Cycle	Cycle Length [EFPY]	Total Irradiation Time [EFPY]	Iron Atom Displacements [dpa]			
			0 Degrees	15 Degrees	30 Degrees	45 Degrees
1	1.19	1.19	4.26E-04	6.68E-04	8.54E-04	1.32E-03
2	0.40	1.60	5.80E-04	9.12E-04	1.17E-03	1.82E-03
3	1.11	2.70	9.66E-04	1.50E-03	1.83E-03	2.71E-03
4	1.29	3.99	1.36E-03	2.10E-03	2.52E-03	3.71E-03
5	1.05	5.04	1.71E-03	2.64E-03	3.06E-03	4.42E-03
6	1.15	6.19	2.07E-03	3.17E-03	3.65E-03	5.22E-03
7	0.69	6.88	2.30E-03	3.49E-03	4.02E-03	5.73E-03
8	1.01	7.89	2.63E-03	3.96E-03	4.56E-03	6.52E-03
9	0.23	8.12	2.71E-03	4.05E-03	4.65E-03	6.66E-03
10	1.34	9.46	3.18E-03	4.66E-03	5.34E-03	7.62E-03
11	1.34	10.80	3.51E-03	5.14E-03	5.92E-03	8.40E-03

Note: At the end of Cycle 11, the maximum iron atom displacements at the pressure vessel wall occur at an axial elevation 39.7 cm below the midplane of the active fuel for the 0°, 15°, 30° and 45° azimuths.

Table 6-3

Relative Radial Distribution of Neutron Fluence (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
225.87	0.544	0.546	0.551	0.540
231.39	0.261	0.262	0.267	0.256
236.90	0.121	0.121	0.124	0.116
242.42	0.055	0.054	0.056	0.049

Note:
Base Metal Inner Radius = 220.35 cm
Base Metal 1/4T = 225.87 cm
Base Metal 1/2T = 231.39 cm
Base Metal 3/4T = 236.90 cm
Base Metal Outer Radius = 242.42 cm

Table 6-4

Relative Radial Distribution of Iron Atom Displacements (dpa)
Within The Reactor Vessel Wall

RADIUS (cm)	AZIMUTHAL ANGLE			
	0°	15°	30°	45°
220.35	1.000	1.000	1.000	1.000
225.87	0.640	0.639	0.651	0.638
231.39	0.393	0.391	0.405	0.387
236.90	0.237	0.236	0.248	0.227
242.42	0.134	0.133	0.142	0.118

Note:
Base Metal Inner Radius = 220.35 cm
Base Metal 1/4T = 225.87 cm
Base Metal 1/2T = 231.39 cm
Base Metal 3/4T = 236.90 cm
Base Metal Outer Radius = 242.42 cm

Table 6-5

Nuclear Parameters Used in the Evaluation of Neutron Sensors

Monitor Material	Reaction of Interest	Target Atom Fraction	90% Response Range (MeV)	Product Half-life	Fission Yield (%)
Copper	^{63}Cu (n,α)	0.6917	4.9 – 11.8	5.271 y	
Iron	^{54}Fe (n,p)	0.0585	2.1 – 8.3	312.3 d	
Nickel	^{58}Ni (n,p)	0.6808	1.5 – 8.1	70.82 d	
Uranium-238	^{238}U (n,f)	0.9996	1.2 – 6.7	30.07 y	6.02
Neptunium-237	^{237}Np (n,f)	1.0000	0.4 – 3.5	30.07 y	6.17
Cobalt-Aluminum	^{59}Co (n,γ)	0.0015	non-threshold	5.271 y	

Note: The 90% response range is defined such that, in the neutron spectrum characteristic of the Salem Unit 2 surveillance capsules, approximately 90% of the sensor response is due to neutrons in the energy range specified with approximately 5% of the total response due to neutrons with energies below the lower limit and 5% of the total response due to neutrons with energies above the upper limit.

Table 6-6

Monthly Thermal Generation During The First Eleven Fuel Cycles
Of The Salem Unit 2 Reactor
(Reactor Power of 3411 MWt)

Year	Month	Thermal Generation (MWt-hr)	Year	Month	Thermal Generation (MWt-hr)	Year	Month	Thermal Generation (MWt-hr)
81	6	78098	84	3	2059562	86	12	326002
81	7	737059	84	4	406510	87	1	2346533
81	8	1906942	84	5	1927080	87	2	2288412
81	9	1252728	84	6	1345678	87	3	1863264
81	10	1260696	84	7	399636	87	4	1431199
81	11	1805837	84	8	1823350	87	5	2139360
81	12	2041486	84	9	2013103	87	6	1766332
82	1	2238970	84	10	276166	87	7	1571339
82	2	2182846	84	11	0	87	8	788479
82	3	2481187	84	12	0	87	9	2434121
82	4	2174431	85	1	0	87	10	1882250
82	5	2508634	85	2	0	87	11	0
82	6	2448542	85	3	0	87	12	1135051
82	7	1887012	85	4	407818	88	1	2490826
82	8	2066801	85	5	1867901	88	2	2298118
82	9	1640998	85	6	2210338	88	3	2532218
82	10	1989686	85	7	1485823	88	4	2249256
82	11	1916650	85	8	2128176	88	5	2323214
82	12	1872773	85	9	2346017	88	6	2170375
83	1	1109383	85	10	2306441	88	7	2388288
83	2	0	85	11	2455831	88	8	2012440
83	3	0	85	12	810317	88	9	0
83	4	0	86	1	1108313	88	10	0
83	5	0	86	2	2066002	88	11	10756
83	6	0	86	3	2477746	88	12	539083
83	7	53664	86	4	2257325	89	1	1512676
83	8	816137	86	5	2324078	89	2	1708567
83	9	447922	86	6	2429813	89	3	2150445
83	10	527417	86	7	2147440	89	4	1978951
83	11	0	86	8	1397742	89	5	2170394
83	12	0	86	9	728568	89	6	2070988
84	1	0	86	10	110662	89	7	2475830
84	2	4879	86	11	0	89	8	2384116

Table 6-6 Cont'd

Monthly Thermal Generation During The First Eleven Fuel Cycles
Of The Salem Unit 2 Reactor
(Reactor Power of 3411 MWt)

Year	Month	Thermal Generation (MWt-hr)	Year	Month	Thermal Generation (MWt-hr)	Year	Month	Thermal Generation (MWt-hr)
89	9	2429035	92	6	1306414	95	3	1275559
89	10	983484	92	7	957403	95	4	2422169
89	11	1997556	92	8	2523355	95	5	2443757
89	12	2524596	92	9	2032075	95	6	528850
90	1	1874868	92	10	2522004	95	7	0
90	2	2262746	92	11	2165482	95	8	0
90	3	2418187	92	12	2506930	95	9	0
90	4	0	93	1	2239932	95	10	0
90	5	0	93	2	2095738	95	11	0
90	6	125880	93	3	1255075	95	12	0
90	7	1798	93	4	0	96	1	0
90	8	908050	93	5	0	96	2	0
90	9	1990867	93	6	8506	96	3	0
90	10	2470128	93	7	2121233	96	4	0
90	11	2403902	93	8	2534410	96	5	0
90	12	2485303	93	9	2349696	96	6	0
91	1	2526556	93	10	2156220	96	7	0
91	2	2260361	93	11	2375899	96	8	0
91	3	2428037	93	12	230542	96	9	0
91	4	2456870	94	1	1917542	96	10	0
91	5	1585037	94	2	1848480	96	11	0
91	6	2410973	94	3	2427636	96	12	0
91	7	2540352	94	4	1540894	97	1	0
91	8	2529274	94	5	2335673	97	2	0
91	9	2372525	94	6	1846246	97	3	0
91	10	2318374	94	7	1582258	97	4	0
91	11	689894	94	8	2452858	97	5	0
91	12	0	94	9	1617274	97	6	0
92	1	0	94	10	941986	97	7	0
92	2	0	94	11	0	97	8	75146
92	3	0	94	12	0	97	9	1612547
92	4	20839	95	1	0	97	10	1853218
92	5	949466	95	2	136886	97	11	2448156

Table 6-6 Cont'd

Monthly Thermal Generation During The First Eleven Fuel Cycles
Of The Salem Unit 2 Reactor
(Reactor Power of 3411 MWt)

Year	Month	Thermal Generation (MWt-hr)	Year	Month	Thermal Generation (MWt-hr)	Year	Month	Thermal Generation (MWt-hr)
97	12	2335319	98	12	1592133	99	12	2527031
98	1	2465071	99	1	2535310	2000	1	2528623
98	2	882054	99	2	2282946	2000	2	2350601
98	3	1266229	99	3	2479349	2000	3	2534978
98	4	2180552	99	4	83186	2000	4	2388591
98	5	2518200	99	5	124037	2000	5	2535224
98	6	2406597	99	6	2341761	2000	6	2422455
98	7	1958635	99	7	2533277	2000	7	2513592
98	8	1766743	99	8	2492363	2000	8	2536235
98	9	2450808	99	9	2452872	2000	9	2396354
98	10	2480253	99	10	2536096	2000	10	349266
98	11	2423563	99	11	2415060			

Table 6-7

Calculated $\phi(E > 1.0\ MeV)$ and C_j Factors at the Surveillance Capsule Center
Core Midplane Elevation

Fuel Cycle	$\phi(E > 1.0\ MeV)$ [n/cm^2-s]				C_j			
	Capsule T	Capsule U	Capsule X	Capsule Y	T	U	X	Y
1	7.40E+10	7.40E+10	7.40E+10	7.40E+10	1.000	1.090	1.288	1.398
2		8.58E+10	8.58E+10	8.58E+10		1.262	1.492	1.620
3		5.49E+10	5.49E+10	5.49E+10		0.807	0.954	1.036
4			5.35E+10	5.35E+10			0.931	1.010
5			4.62E+10	4.62E+10			0.803	0.872
6			4.78E+10	4.78E+10			0.831	0.902
7				5.08E+10				0.959
8				5.30E+10				1.000
9				4.11E+10				0.776
10				4.87E+10				0.919
11				3.95E+10				0.746
Average	7.40E+10	6.80E+10	5.75E+10	5.30E+10	1.000	1.000	1.000	1.000

Table 6-8

Measured Sensor Activities and Reaction Rates

Surveillance Capsule T

Reaction	Location	Measured Activity (dps/g)	Saturated Activity (dps/g)	Radially Adjusted Saturated Activity (dps/g)	Radially Adjusted Reaction Rate (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top Middle	4.03E+04	3.23E+05	3.08E+05	4.70E-17
	Middle	4.06E+04	3.25E+05	3.11E+05	4.74E-17
	Bottom Middle	4.16E+04	3.33E+05	3.18E+05	4.85E-17
	Average				**4.76E-17**
^{54}Fe (n,p) ^{54}Mn	Top	7.67E+05	3.06E+06	3.21E+06	5.09E-15
	Top Middle	7.67E+05	3.06E+06	3.21E+06	5.09E-15
	Middle	7.35E+05	2.93E+06	3.07E+06	4.87E-15
	Bottom Middle	7.56E+05	3.01E+06	3.16E+06	5.01E-15
	Bottom	7.56E+05	3.01E+06	3.16E+06	5.01E-15
	Average				**5.01E-15**
^{58}Ni (n,p) ^{58}Co	Top Middle	9.30E+05	4.19E+07	4.84E+07	6.93E-15
	Middle	9.23E+05	4.15E+07	4.81E+07	6.88E-15
	Bottom Middle	9.34E+05	4.20E+07	4.86E+07	6.96E-15
	Average				**6.93E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	1.23E+05	4.66E+06	4.66E+06	3.06E-14
^{238}U (n,f) ^{137}Cs (Cd)		Including ^{235}U, ^{239}Pu, and γ,fission corrections:			**2.56E-14**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	9.49E+05	3.60E+07	3.60E+07	2.30E-13
^{237}Np (n,f) ^{137}Cs (Cd)			Including γ,fission correction:		**2.26E-13**
^{59}Co (n,γ) ^{60}Co	Top	7.05E+06	5.65E+07	5.50E+07	3.59E-12
	Bottom	6.90E+06	5.53E+07	5.38E+07	3.51E-12
	Average				**3.55E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	2.84E+06	2.27E+07	2.62E+07	1.71E-12
	Bottom	2.69E+06	2.15E+07	2.48E+07	1.62E-12
	Average				**1.66E-12**

Note: Measured specific activities are indexed to a counting date of January 16, 1984.

Table 6-8 cont'd

Measured Sensor Activities and Reaction Rates

Surveillance Capsule U

Reaction	Location	Measured Activity (dps/g)	Saturated Activity (dps/g)	Radially Adjusted Saturated Activity (dps/g)	Radially Adjusted Reaction Rate (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top Middle	7.17E+04	2.99E+05	2.85E+05	4.35E-17
	Middle	7.40E+04	3.08E+05	2.94E+05	4.49E-17
	Bottom Middle	7.59E+04	3.16E+05	3.02E+05	4.61E-17
	Average				**4.48E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.00E+06	2.58E+06	2.71E+06	4.29E-15
	Top Middle	1.01E+06	2.60E+06	2.73E+06	4.34E-15
	Bottom Middle	1.06E+06	2.73E+06	2.87E+06	4.55E-15
	Bottom	1.06E+06	2.73E+06	2.87E+06	4.55E-15
	Average				**4.43E-15**
^{58}Ni (n,p) ^{58}Co	Top Middle	5.65E+06	3.54E+07	4.09E+07	5.86E-15
	Middle	5.76E+06	3.61E+07	4.17E+07	5.98E-15
	Bottom Middle	5.90E+06	3.70E+07	4.28E+07	6.12E-15
	Average				**5.99E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	2.65E+05	4.58E+06	4.58E+06	3.00E-14
^{238}U (n,f) ^{137}Cs (Cd)		Including ^{235}U, ^{239}Pu, and γ,fission corrections:			**2.48E-14**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	1.94E+06	3.35E+07	3.35E+07	2.14E-13
^{237}Np (n,f) ^{137}Cs (Cd)			Including γ,fission correction:		**2.10E-13**
^{59}Co (n,γ) ^{60}Co	Top	1.17E+07	4.87E+07	4.75E+07	3.10E-12
	Bottom	1.12E+07	4.67E+07	4.54E+07	2.96E-12
	Average				**3.03E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	4.57E+06	1.90E+07	2.19E+07	1.43E-12
	Bottom	4.45E+06	1.85E+07	2.14E+07	1.39E-12
	Average				**1.41E-12**

Note: Measured specific activities are indexed to a counting date of February 2, 1987.

Table 6-8 cont'd

Measured Sensor Activities and Reaction Rates

Surveillance Capsule X

Reaction	Location	Measured Activity (dps/g)	Saturated Activity (dps/g)	Radially Adjusted Saturated Activity (dps/g)	Radially Adjusted Reaction Rate (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top Middle	1.11E+05	2.61E+05	2.49E+05	3.80E-17
	Middle	1.13E+05	2.65E+05	2.53E+05	3.86E-17
	Bottom Middle	1.15E+05	2.70E+05	2.58E+05	3.93E-17
	Average				**3.86E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.24E+06	2.43E+06	2.55E+06	4.04E-15
	Top Middle	1.15E+06	2.25E+06	2.36E+06	3.75E-15
	Middle	1.14E+06	2.23E+06	2.34E+06	3.71E-15
	Bottom Middle	1.18E+06	2.31E+06	2.43E+06	3.84E-15
	Bottom	1.13E+06	2.21E+06	2.32E+06	3.68E-15
	Average				**3.81E-15**
^{58}Ni (n,p) ^{58}Co	Top Middle	7.90E+06	3.17E+07	3.67E+07	5.25E-15
	Middle	7.97E+06	3.20E+07	3.70E+07	5.30E-15
	Bottom Middle	7.75E+06	3.11E+07	3.60E+07	5.15E-15
	Average				**5.24E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	4.62E+05	3.67E+06	3.67E+06	2.41E-14
^{238}U (n,f) ^{137}Cs (Cd)		Including ^{235}U, ^{239}Pu, and γ,fission corrections:			**1.94E-14**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	3.38E+06	2.69E+07	2.69E+07	1.71E-13
^{237}Np (n,f) ^{137}Cs (Cd)			Including γ,fission correction:		**1.69E-13**
^{59}Co (n,γ) ^{60}Co	Top	7.13E+06	1.67E+07	1.63E+07	1.06E-12
	Bottom	6.03E+06	1.42E+07	1.38E+07	8.99E-13
	Average				**9.81E-13**
^{59}Co (n,γ) ^{60}Co (Cd)	Bottom	6.71E+06	1.58E+07	1.81E+07	1.18E-12
	Average				**1.18E-12**

Note: Measured specific activities are indexed to a counting date of March 4, 1992.

Table 6-8 cont'd

Measured Sensor Activities and Reaction Rates

Surveillance Capsule Y

Reaction	Location	Measured Activity (dps/g)	Saturated Activity (dps/g)	Radially Adjusted Saturated Activity (dps/g)	Radially Adjusted Reaction Rate (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top Middle	1.09E+05	2.38E+05	2.27E+05	3.46E-17
	Middle	1.11E+05	2.42E+05	2.31E+05	3.53E-17
	Bottom Middle	1.14E+05	2.49E+05	2.38E+05	3.62E-17
	Average				**3.54E-17**
^{54}Fe (n,p) ^{54}Mn	Top	9.23E+05	2.03E+06	2.13E+06	3.37E-15
	Top Middle	9.33E+05	2.05E+06	2.15E+06	3.41E-15
	Middle	9.44E+05	2.07E+06	2.18E+06	3.45E-15
	Bottom Middle	9.66E+05	2.12E+06	2.23E+06	3.53E-15
	Bottom	9.56E+05	2.10E+06	2.20E+06	3.49E-15
	Average				**3.45E-15**
^{58}Ni (n,p) ^{58}Co	Top Middle	4.12E+06	3.04E+07	3.51E+07	5.03E-15
	Middle	4.07E+06	3.00E+07	3.47E+07	4.97E-15
	Bottom Middle	4.05E+06	2.99E+07	3.45E+07	4.94E-15
	Average				**4.98E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	6.47E+05	3.30E+06	3.30E+06	2.17E-14
^{238}U (n,f) ^{137}Cs (Cd)		Including ^{235}U, ^{239}Pu, and γ,fission corrections:			**1.70E-14**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	4.71E+06	2.41E+07	2.41E+07	1.53E-13
^{237}Np (n,f) ^{137}Cs (Cd)			Including γ,fission correction:		**1.51E-13**
^{59}Co (n,γ) ^{60}Co	Top	1.59E+07	3.47E+07	3.38E+07	2.20E-12
	Bottom	1.57E+07	3.43E+07	3.34E+07	2.18E-12
	Average				**2.19E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	6.86E+06	1.50E+07	1.72E+07	1.13E-12
	Top	6.88E+06	1.50E+07	1.73E+07	1.13E-12
	Bottom	6.51E+06	1.42E+07	1.64E+07	1.07E-12
	Bottom	6.57E+06	1.43E+07	1.65E+07	1.08E-12
	Average				**1.10E-12**

Note: Measured specific activities are indexed to a counting date of March 26, 2001.

Table 6-9

Comparison of Measured, Calculated, and Best Estimate
Reaction Rates at the Surveillance Capsule Center

Capsule T

	Reaction Rate [rps/atom]				
Reaction	Measured	Calculated	Best Estimate	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	4.76E-17	4.56E-17	4.67E-17	1.04	1.02
$^{54}Fe(n,p)^{54}Mn$	5.01E-15	5.12E-15	5.10E-15	0.98	0.98
$^{58}Ni(n,p)^{58}Co$	6.93E-15	7.07E-15	7.03E-15	0.98	0.99
$^{238}U(n,f)^{137}Cs$ (Cd)	2.56E-14	2.56E-14	2.57E-14	1.00	1.00
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.26E-13	2.01E-13	2.15E-13	1.12	1.05
$^{59}Co(n,\gamma)^{60}Co$	3.55E-12	3.01E-12	3.53E-12	1.18	1.01
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	1.66E-12	1.57E-12	1.67E-12	1.06	1.00

Capsule U

	Reaction Rate [rps/atom]				
Reaction	Measured	Calculated	Best Estimate	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	4.48E-17	4.25E-17	4.32E-17	1.05	1.04
$^{54}Fe(n,p)^{54}Mn$	4.43E-15	4.74E-15	4.56E-15	0.94	0.97
$^{58}Ni(n,p)^{58}Co$	5.99E-15	6.53E-15	6.25E-15	0.92	0.96
$^{238}U(n,f)^{137}Cs$ (Cd)	2.48E-14	2.35E-14	2.31E-14	1.05	1.08
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.10E-13	1.85E-13	1.97E-13	1.14	1.06
$^{59}Co(n,\gamma)^{60}Co$	3.03E-12	2.74E-12	3.02E-12	1.11	1.00
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	1.41E-12	1.43E-12	1.42E-12	0.99	1.00

Table 6-9 cont'd

Comparison of Measured, Calculated, and Best Estimate
Reaction Rates at the Surveillance Capsule Center

Capsule X

	Reaction Rate [rps/atom]				
Reaction	Measured	Calculated	Best Estimate	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	3.86E-17	3.68E-17	3.75E-17	1.05	1.03
$^{54}Fe(n,p)^{54}Mn$	3.81E-15	4.05E-15	3.90E-15	0.94	0.98
$^{58}Ni(n,p)^{58}Co$	5.24E-15	5.57E-15	5.35E-15	0.94	0.98
$^{238}U(n,f)^{137}Cs$ (Cd)	1.94E-14	2.00E-14	1.93E-14	0.97	1.01
$^{237}Np(n,f)^{137}Cs$ (Cd)	1.69E-13	1.56E-13	1.60E-13	1.08	1.05
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	1.18E-12	1.20E-12	1.19E-12	0.99	1.00

Capsule Y

	Reaction Rate [rps/atom]				
Reaction	Measured	Calculated	Best Estimate	M/C	M/BE
$^{63}Cu(n,\alpha)^{60}Co$	3.54E-17	3.44E-17	3.45E-17	1.03	1.02
$^{54}Fe(n,p)^{54}Mn$	3.45E-15	3.75E-15	3.57E-15	0.92	0.97
$^{58}Ni(n,p)^{58}Co$	4.98E-15	5.16E-15	4.96E-15	0.96	1.00
$^{238}U(n,f)^{137}Cs$ (Cd)	1.69E-14	1.84E-14	1.76E-14	0.92	0.96
$^{237}Np(n,f)^{137}Cs$ (Cd)	1.51E-13	1.43E-13	1.44E-13	1.05	1.04
$^{59}Co(n,\gamma)^{60}Co$	2.19E-12	2.11E-12	2.19E-12	1.04	1.00
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	1.10E-12	1.10E-12	1.10E-12	1.00	1.00

Table 6-10

Comparison of Calculated and Best Estimate Exposure Rates
At The Surveillance Capsule Center

Capsule ID	ϕ(E > 1.0 MeV) [n/cm^2-s]			
	Calculated	Best Estimate	Uncertainty (1σ)	BE/C
T	7.40E+10	7.49E+10	6%	1.01
U	6.80E+10	6.74E+10	6%	0.99
X	5.75E+10	5.58E+10	6%	0.97
Y	5.30E+10	5.07E+10	6%	0.96

Capsule ID	Iron Atom Displacement Rate [dpa/s]			
	Calculated	Best Estimate	Uncertainty (1σ)	BE/C
T	1.25E-10	1.26E-10	7%	1.01
U	1.15E-10	1.14E-10	7%	1.00
X	9.69E-11	9.40E-11	7%	0.97
Y	8.91E-11	8.54E-11	7%	0.96

Table 6-11

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

Reaction	M/C Ratio			
	Capsule T	Capsule U	Capsule X	Capsule Y
$^{63}Cu(n,\alpha)^{60}Co$	1.04	1.05	1.05	1.03
$^{54}Fe(n,p)^{54}Mn$	0.98	0.94	0.94	0.92
$^{58}Ni(n,p)^{58}Co$	0.98	0.92	0.94	0.96
$^{238}U(n,p)^{137}Cs$ (Cd)	1.00	1.05	0.97	0.92
$^{237}Np(n,f)^{137}Cs$ (Cd)	1.12	1.14	1.08	1.05
Average	1.02	1.02	1.00	0.98
% Standard Deviation	5.8	8.9	6.5	6.3

Note: The overall average M/C ratio for the set of 20 sensor measurements is 1.00 with an associated standard deviation of 6.7%.

Table 6-12

Comparison of Best Estimate/Calculated (BE/C) Exposure Rate Ratios

Capsule ID	BE/C Ratio	
	$\phi(E > 1.0$ MeV)	dpa/s
T	1.01	1.01
U	0.99	1.00
X	0.97	0.97
Y	0.96	0.96
Average	0.98	0.98
% Standard Deviation	2.4	2.5

Table 6-13

Calculated Fast Neutron Exposure of Surveillance Capsules
Withdrawn from Salem Unit 2

Capsule	Irradiation Time [EFPY]	Fluence (E > 1.0 MeV) [n/cm^2]	Iron Displacements [dpa]
T	1.19	2.78E+18	4.70E-03
U	2.70	5.79E+18	9.77E-03
X	6.19	1.12E+19	1.89E-02
Y	10.80	1.81E+19	3.04E-02

Table 6-14

Calculated Maximum Fast Neutron Exposure of the Salem Unit 2
Reactor Pressure Vessel at the Clad/Base Metal Interface

Neutron Fluence [E > 1.0 MeV]

Cumulative Operating Time [EFPY]	Neutron Fluence [n/cm^2]			
	0.0 Degrees	15.0 Degrees	30.0 Degrees	45.0 Degrees
10.80 (EOC 11)	2.17E+18	3.21E+18	3.67E+18	5.20E+18
16.00	3.08E+18	4.49E+18	5.17E+18	7.20E+18
32.00	5.87E+18	8.41E+18	9.76E+18	1.34E+19
48.00	8.65E+18	1.23E+19	1.44E+19	1.95E+19
54.00	9.70E+18	1.38E+19	1.61E+19	2.18E+19

Iron Atom Displacements

Cumulative Operating Time [EFPY]	Iron Atom Displacements [dpa]			
	0.0 Degrees	15.0 Degrees	30.0 Degrees	45.0 Degrees
10.80 (EOC 11)	3.51E-03	5.14E-03	5.92E-03	8.40E-03
16.00	4.98E-03	7.19E-03	8.32E-03	1.16E-02
32.00	9.49E-03	1.35E-02	1.57E-02	2.16E-02
48.00	1.40E-02	1.92E-02	2.31E-02	3.15E-02
54.00	1.57E-02	2.21E-02	2.59E-02	3.52E-02

Note: For all future projections, i.e., beyond the end of Cycle 11, the maximum fast (E > 1.0 MeV) neutron fluences and iron atom displacements at the pressure vessel wall occur at an axial elevation 39.7 cm below the midplane of the active fuel for the 0°, 15°, 30° and 45° azimuths. The future projections also account for a plant uprating from 3411 MWt to 3459 MWt.

Table 6-15

Calculated Surveillance Capsule Lead Factors

Capsule ID And Location	Status	Lead Factor
T (40°)	Withdrawn EOC 1	3.41
U (40°)	Withdrawn EOC 3	3.45
X (40°)	Withdrawn EOC 6	3.48
Y (40°)	Withdrawn EOC 11	3.47
S (4°)	In Reactor	1.38
V (4°)	In Reactor	1.38
W (4°)	In Reactor	1.38
Z (4°)	In Reactor	1.38

Note: Lead factors for capsules remaining in the reactor are based on cycle specific exposure calculations through fuel cycle 11.

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 Salem Unit 2 reactor vessel.

Table 7-1 Salem Unit 2 Reactor Vessel Surveillance Capsule Withdrawal Schedule

Capsule	Location	Lead Factor[a]	Removal Time (EFPY)[b]	Fluence (n/cm^2,E>1.0 MeV)[a]
T	40°	Withdrawn	1.19	2.78×10^{18} (c)
U	140°	Withdrawn	2.70	5.79×10^{18} (c)
X	220°	Withdrawn	6.19	1.12×10^{19} (c)
Y	320°	Withdrawn	10.80	1.81×10^{19} (c)
S	4°	1.38	Standby	(d)
V	176°	1.38	Standby	(d)
W	184°	1.38	Standby	(d)
Z	356°	1.38	Standby	(d)

Notes:

(a) Updated in Capsule Y dosimetry analysis.
(b) Effective Full Power Years (EFPY) from plant startup.
(c) Actual plant evaluation calculated fluence.
(d) No further capsules are required to be withdrawn from the Salem Unit 2 Nuclear Reactor. However, to obtain "meaningful" metallurgical data these capsules should be withdrawn prior to the end of license renewal. These capsules will reach a fluence of approximately 1.95×10^{19} (48 EFPY Peak Fluence) at approximately 34 EFPY. If further data is needed to support license renewal prior to 34 EFPY, then the remaining capsules could be moved to higher lead factor locations.

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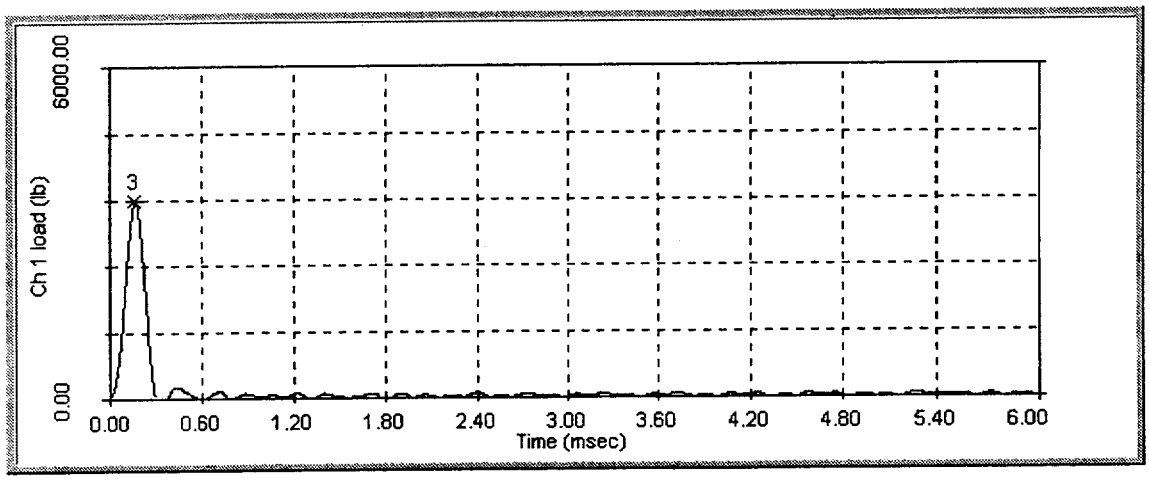
APPENDIX A

LOAD-TIME RECORDS FOR CHARPY SPECIMEN TESTS



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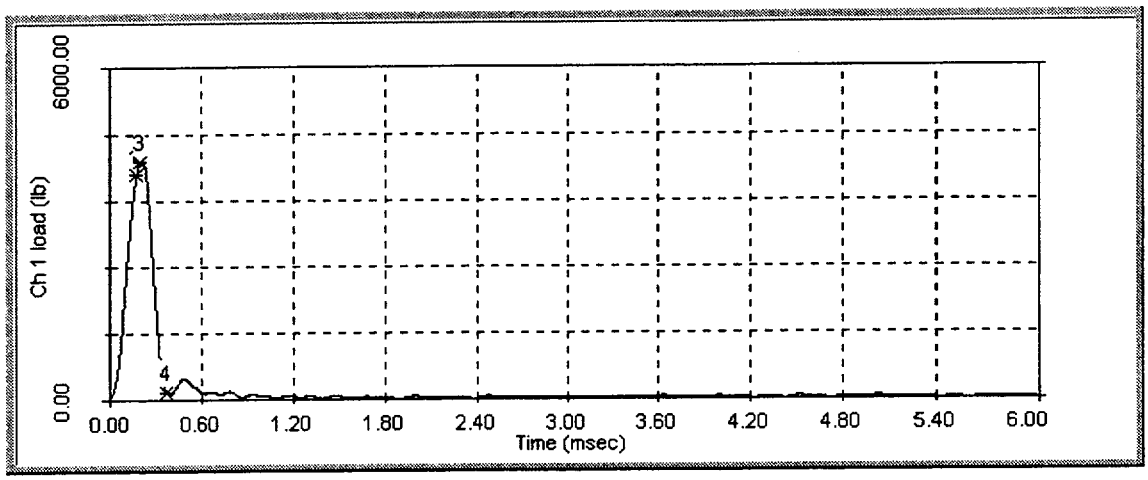

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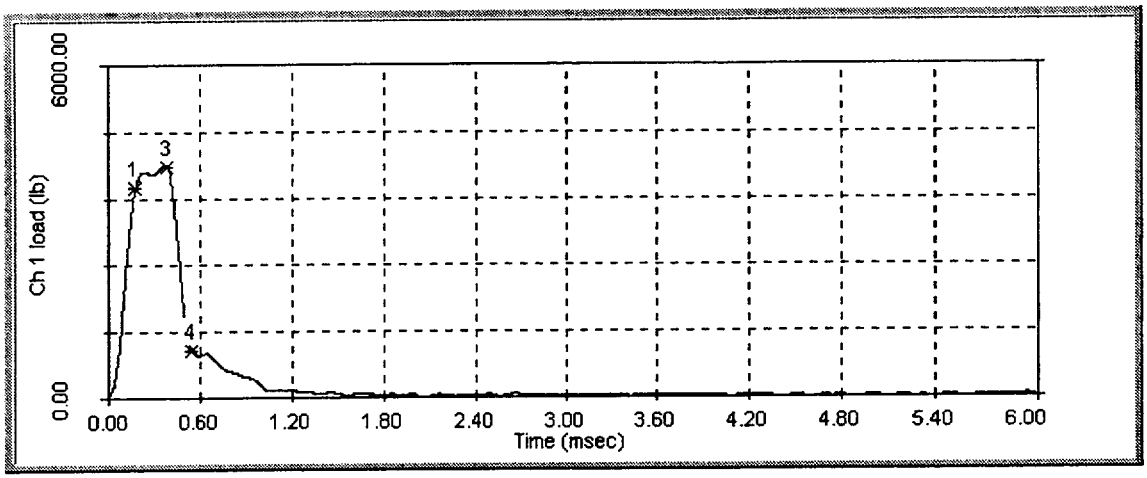

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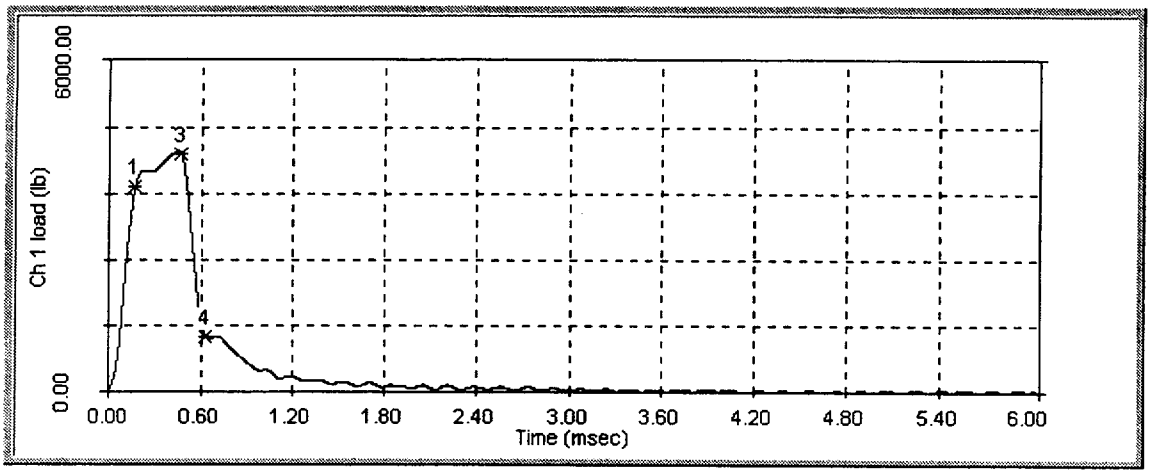

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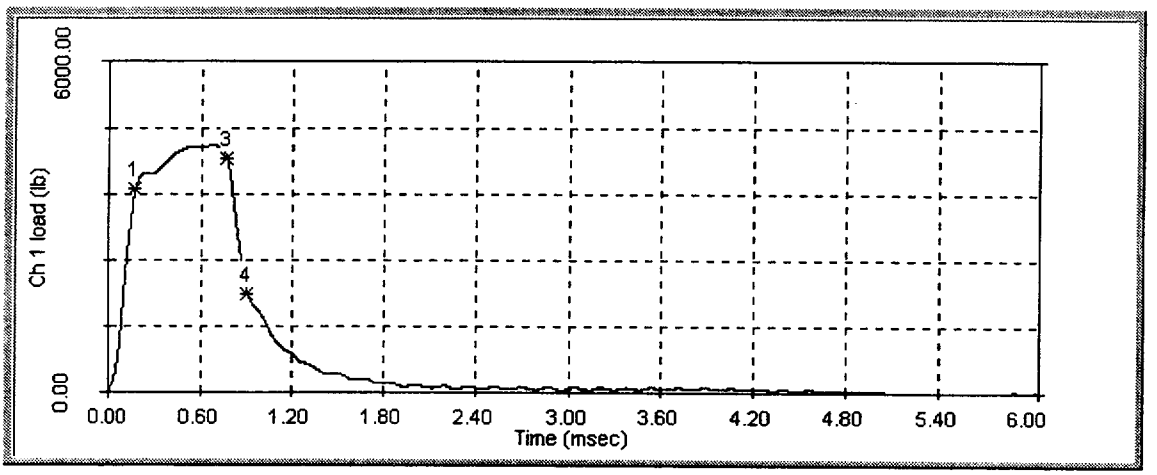

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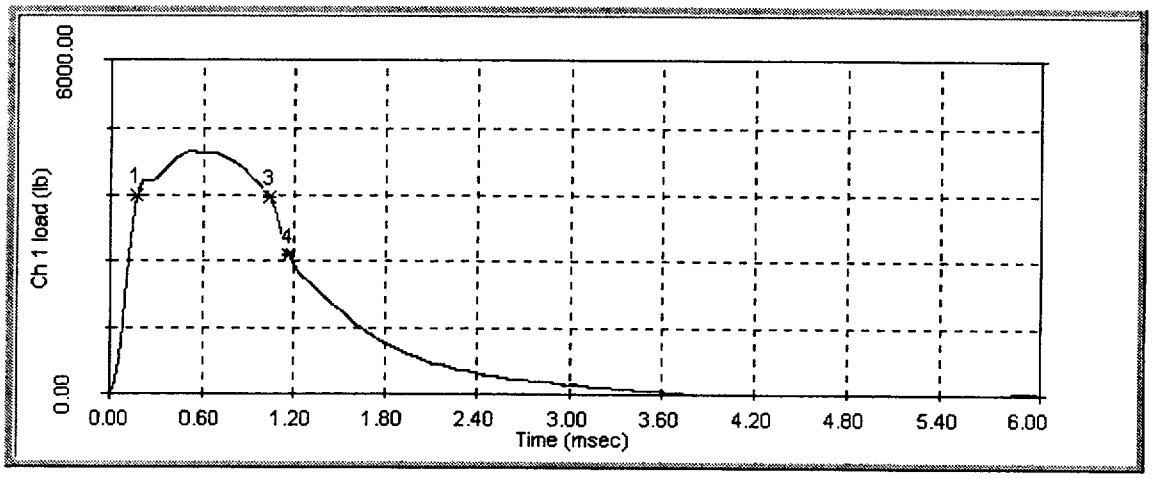

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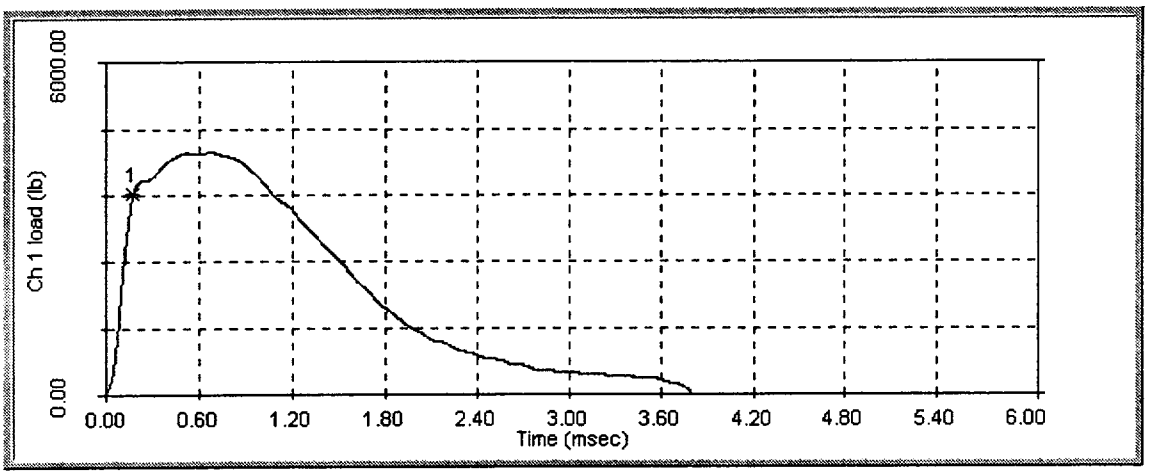

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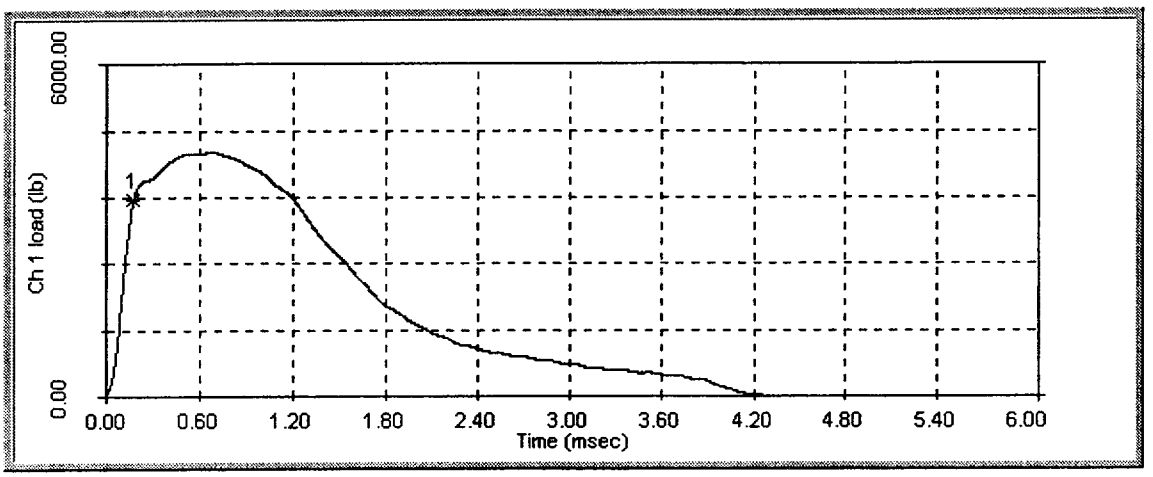

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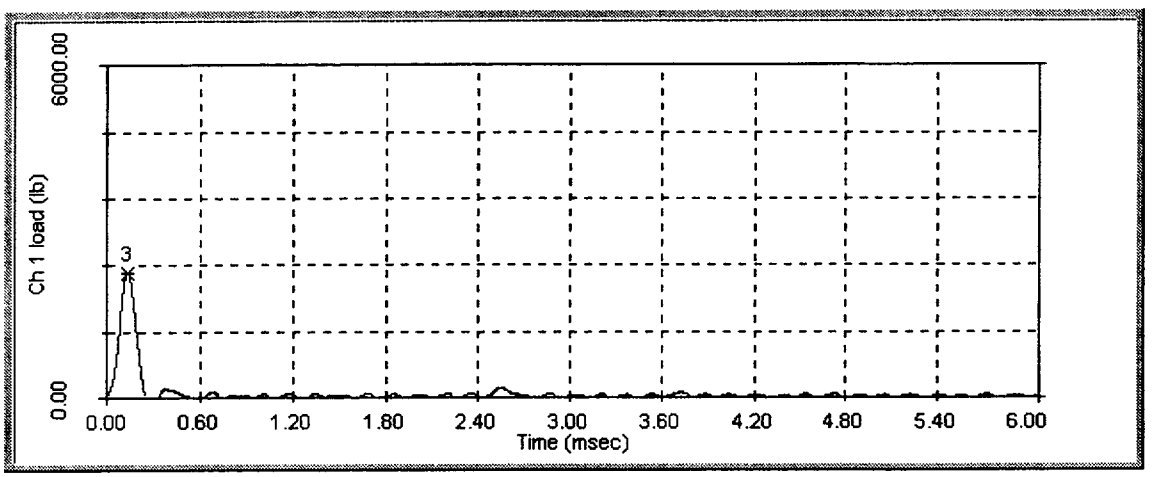

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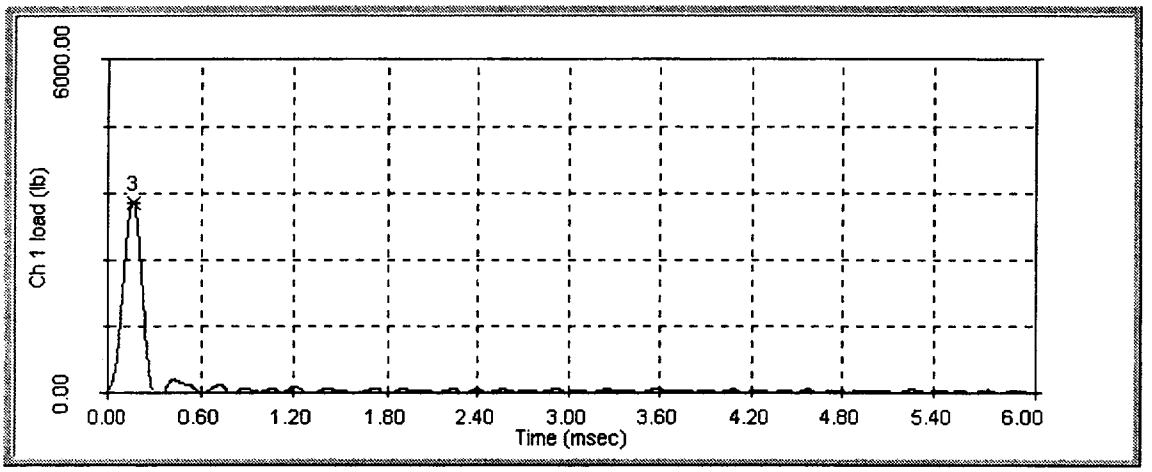

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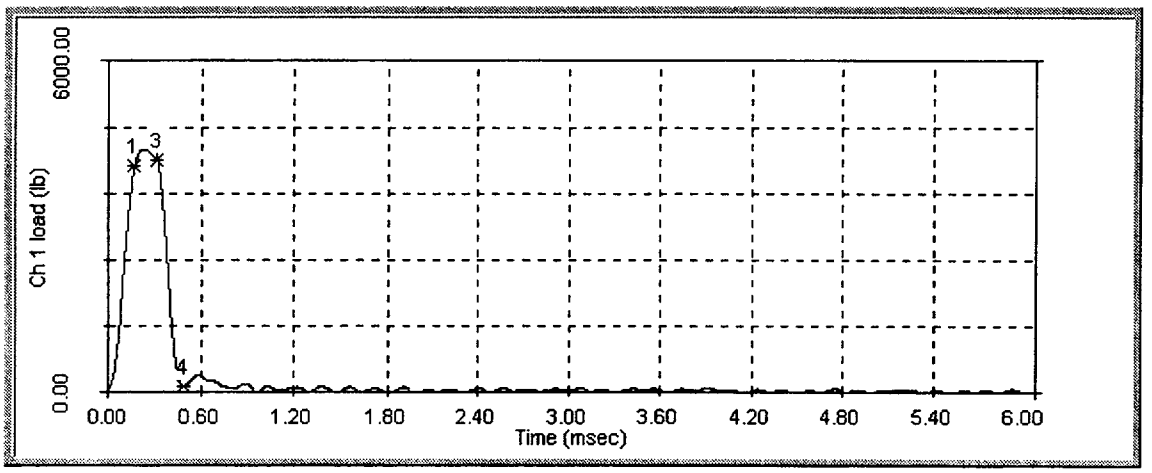

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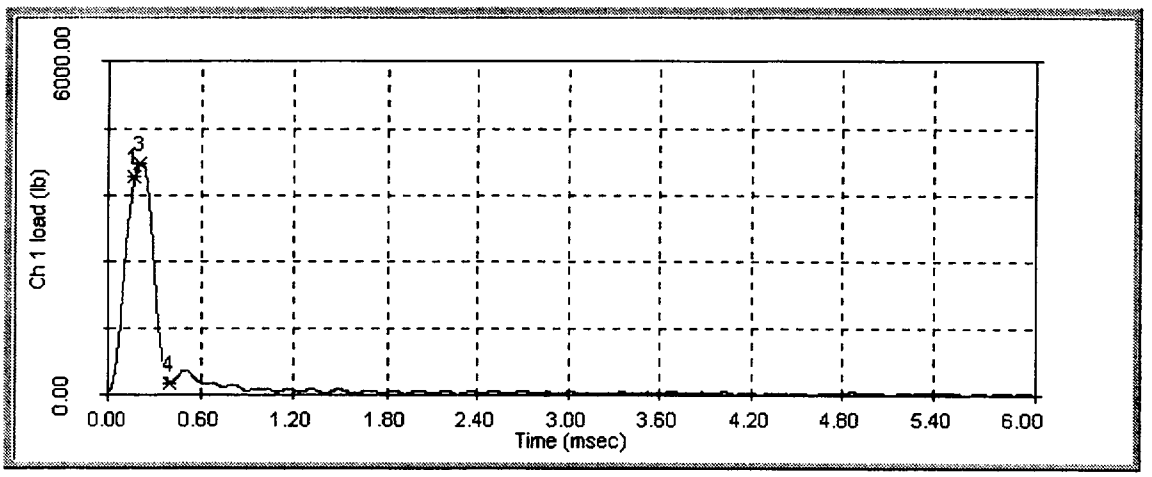

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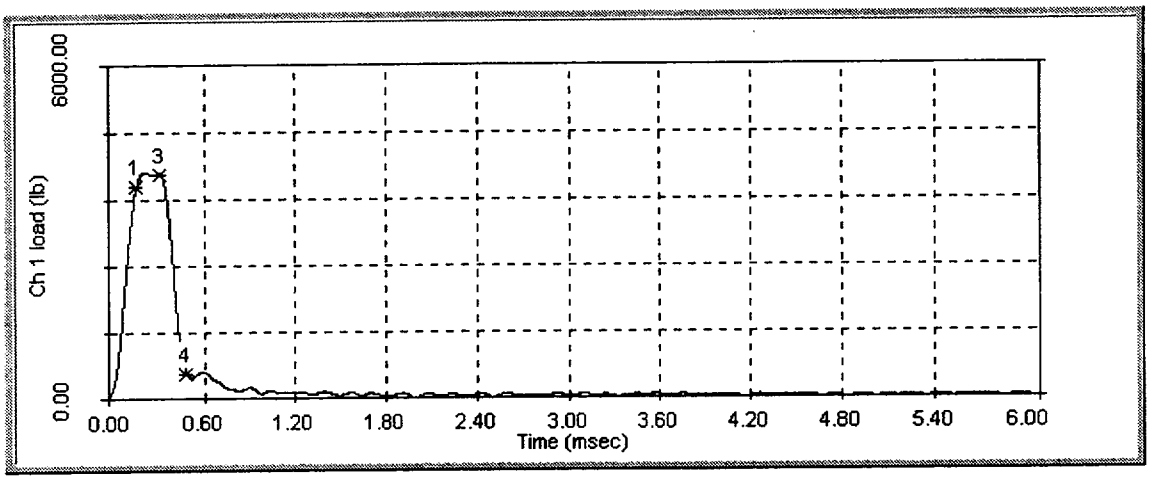

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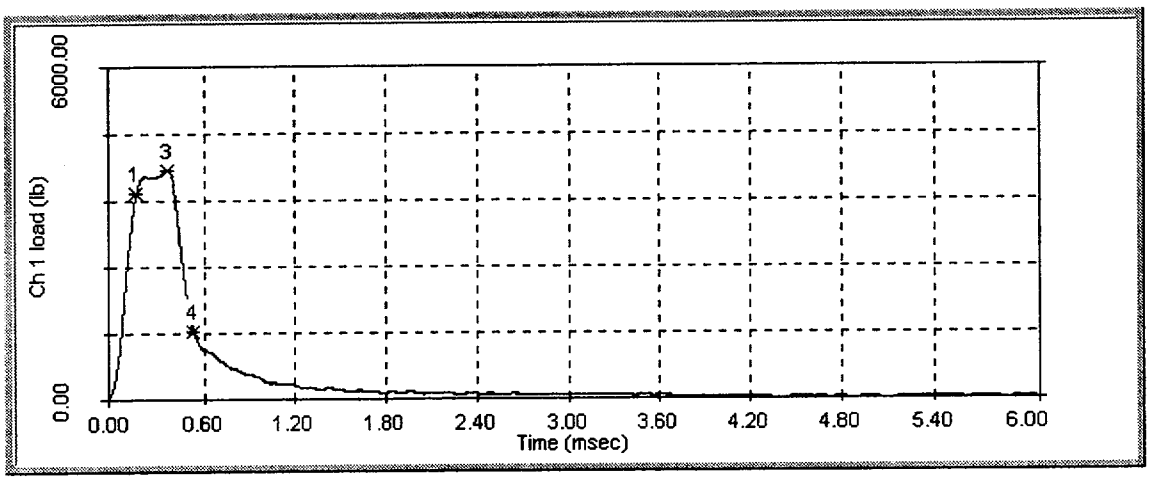

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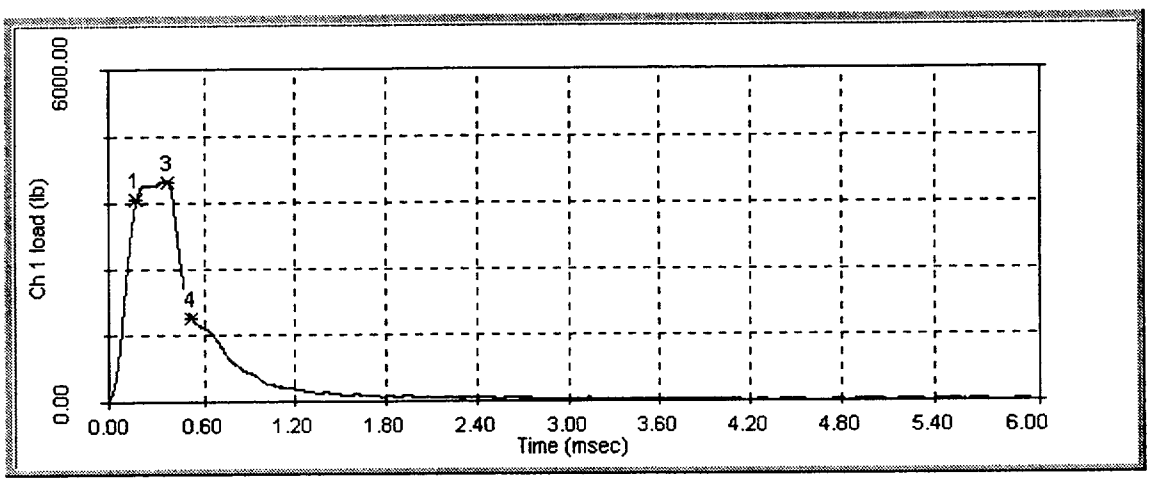

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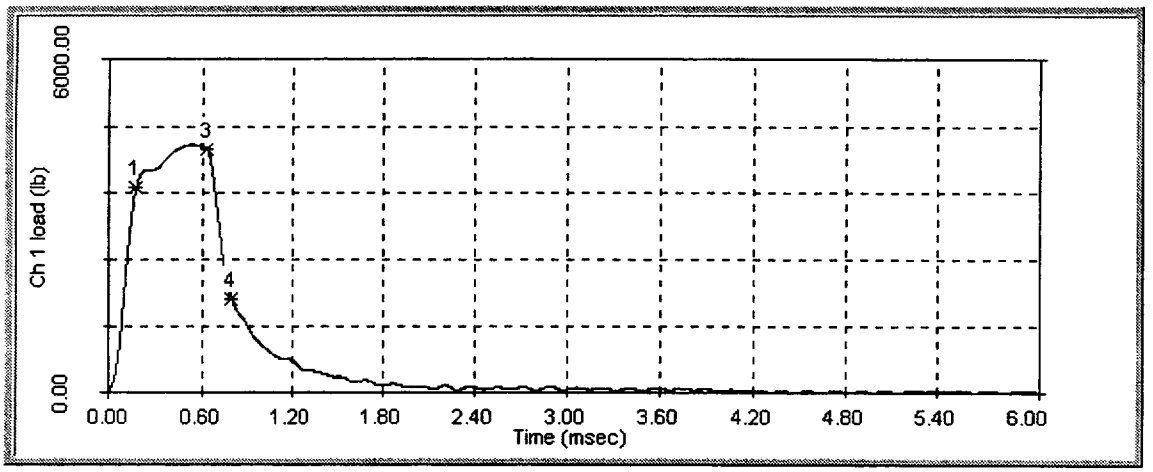

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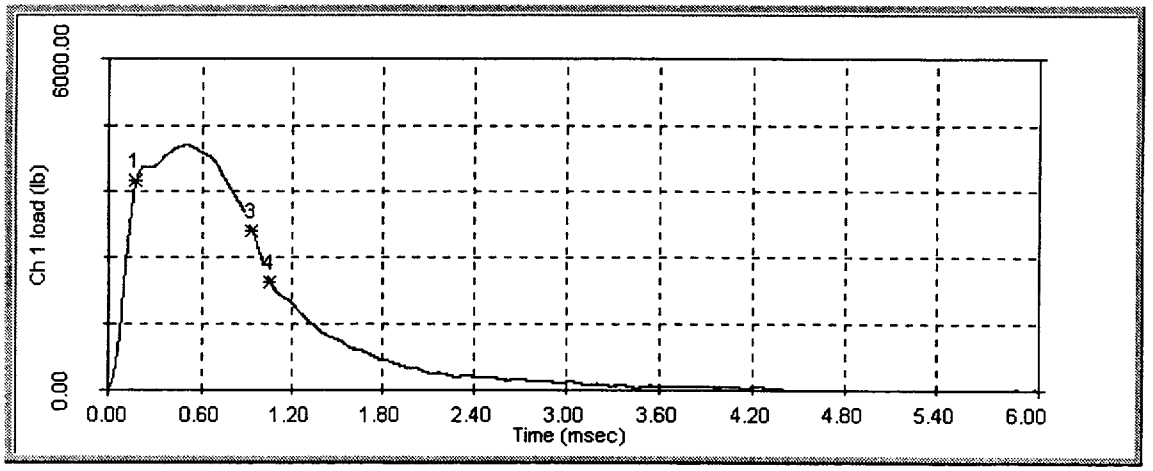

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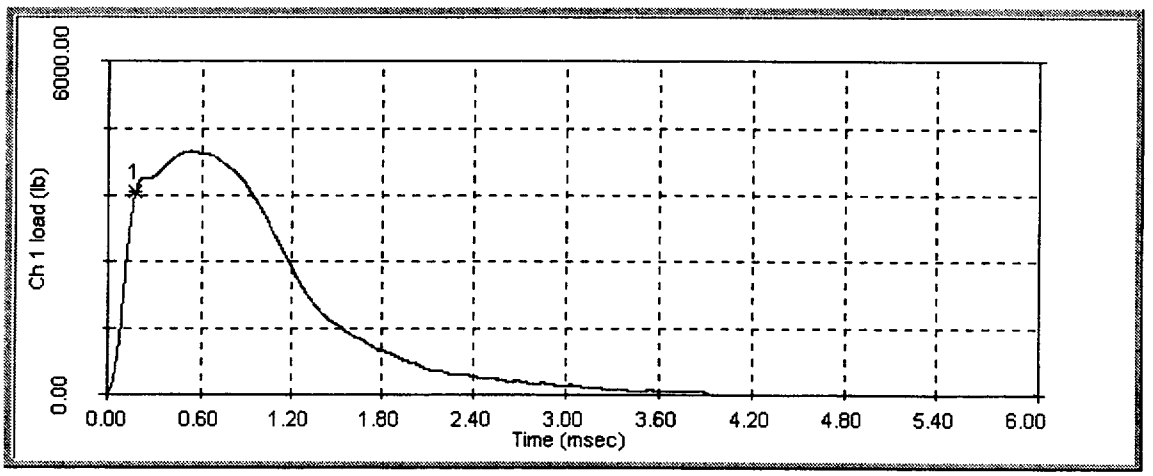

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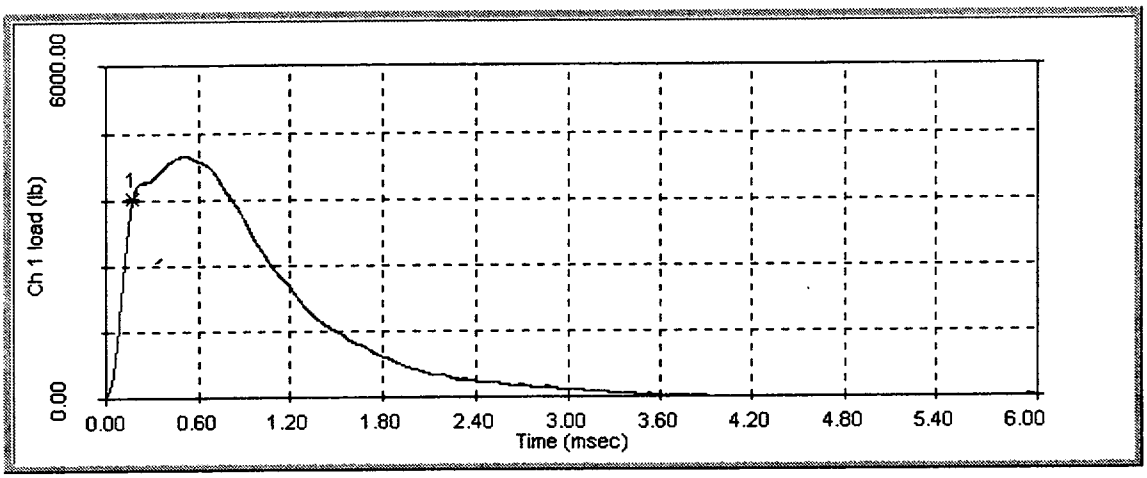

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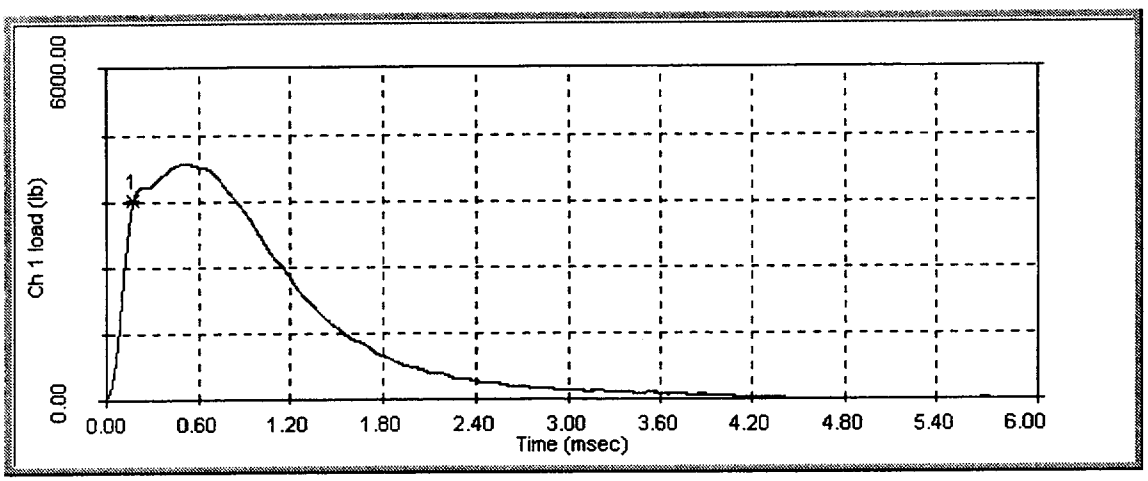

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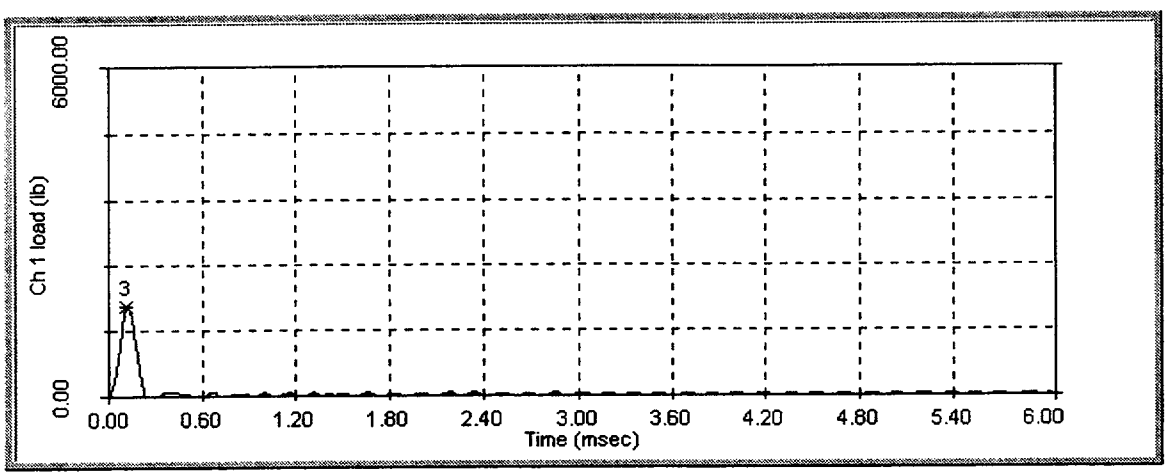

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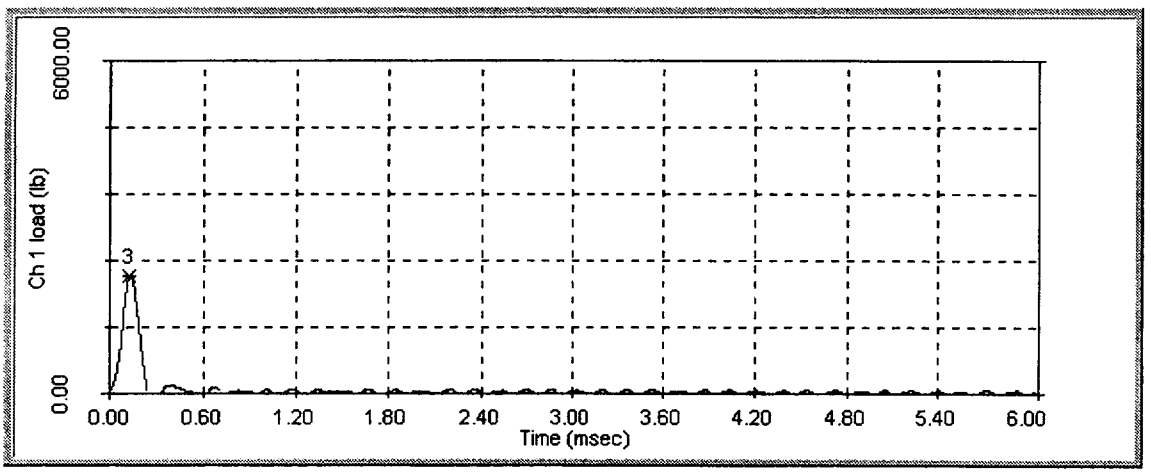

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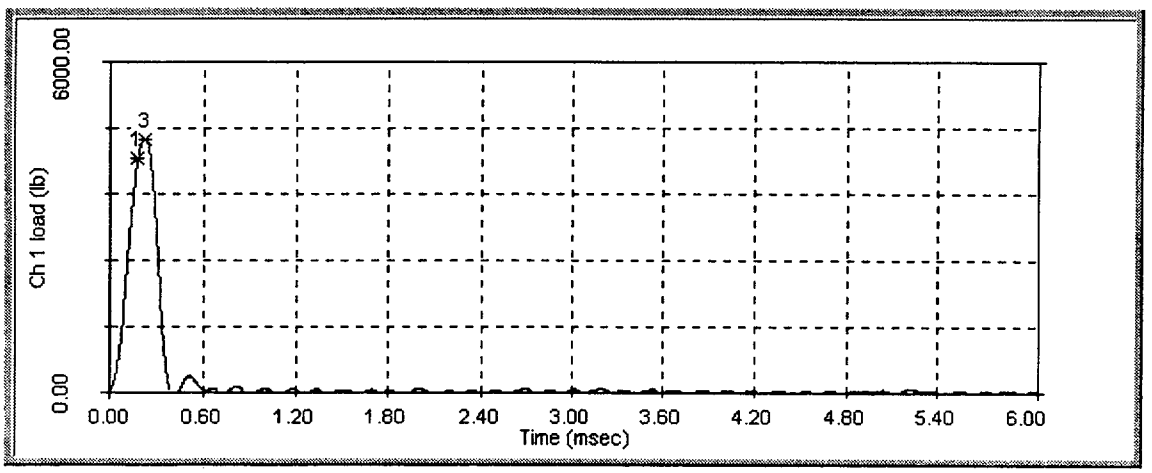

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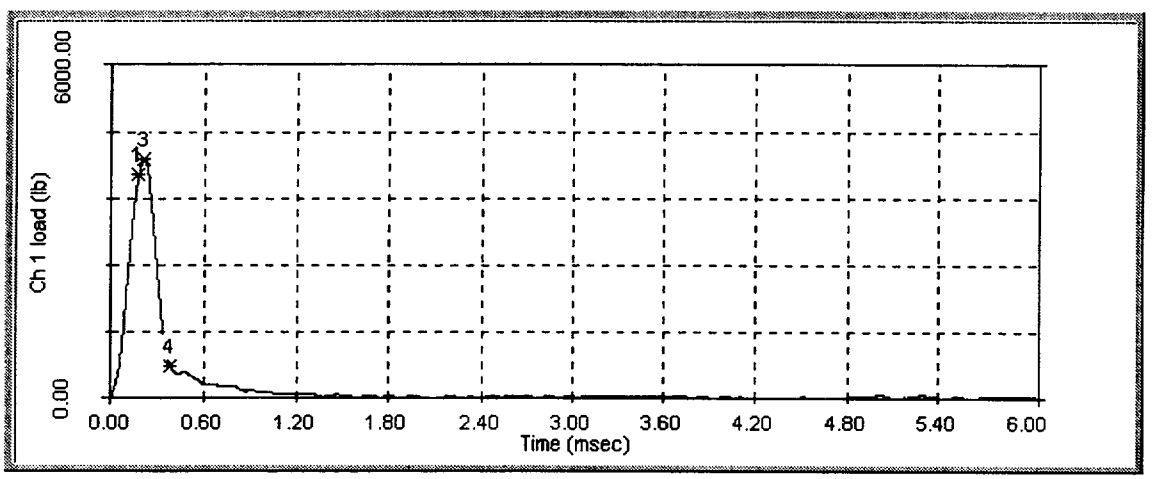

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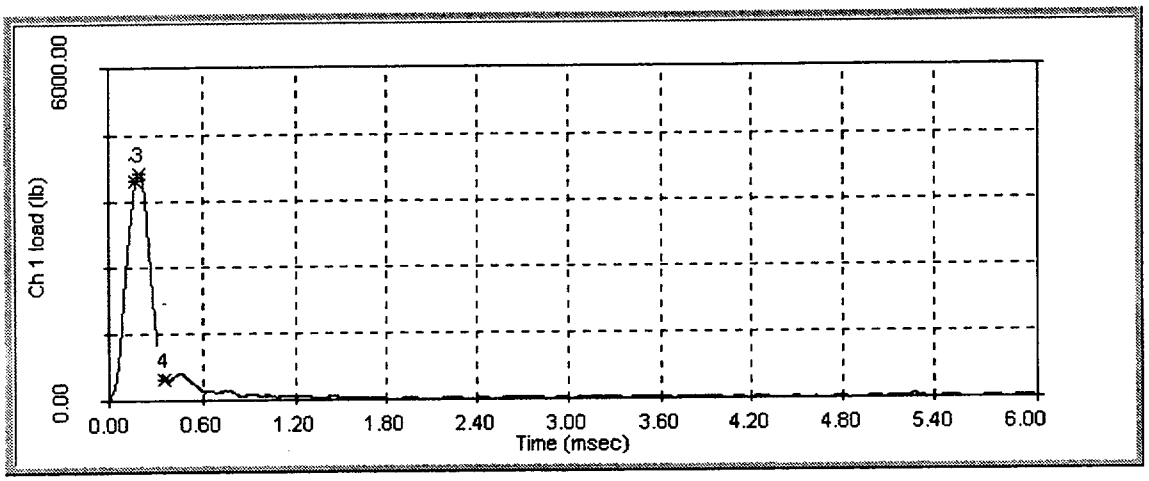

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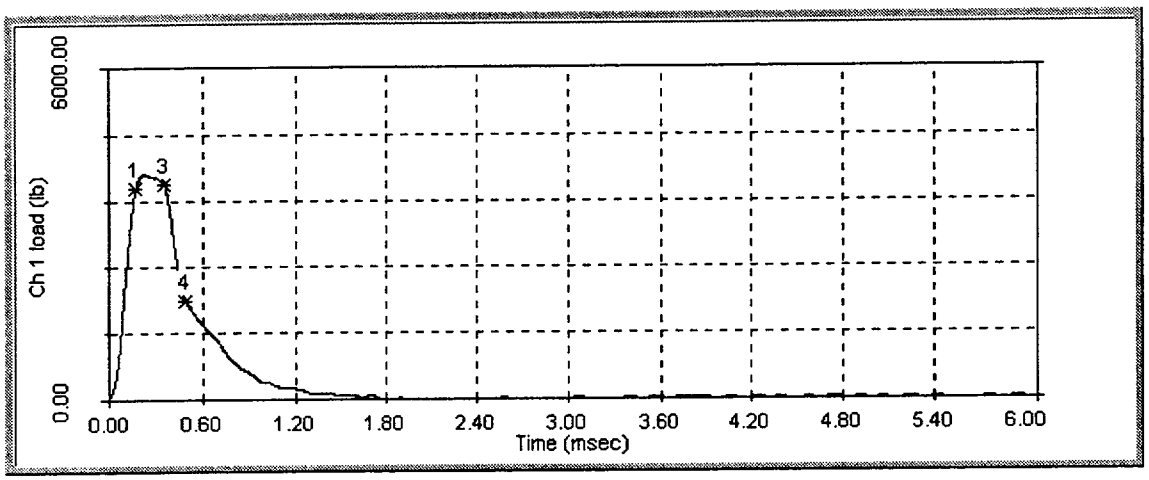

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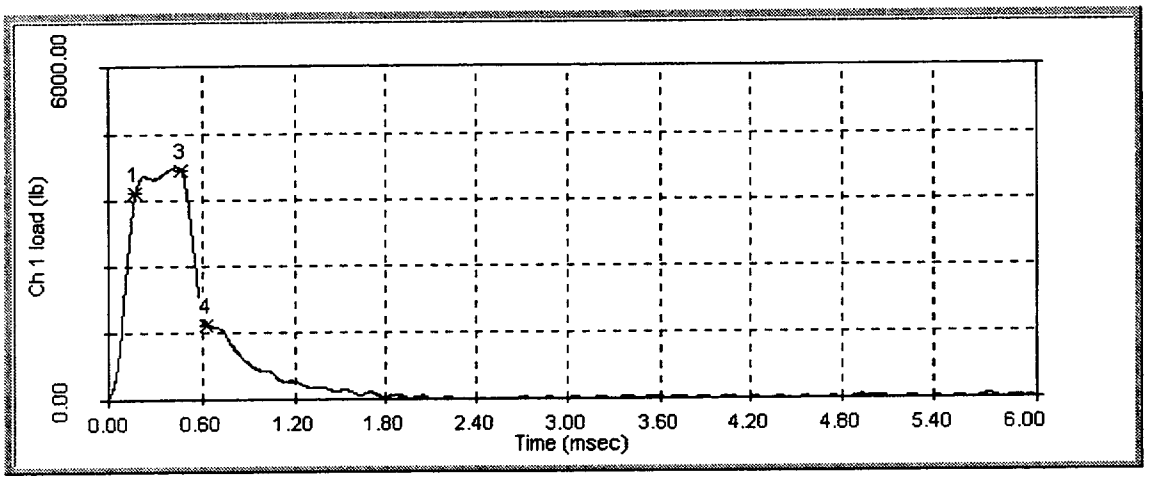

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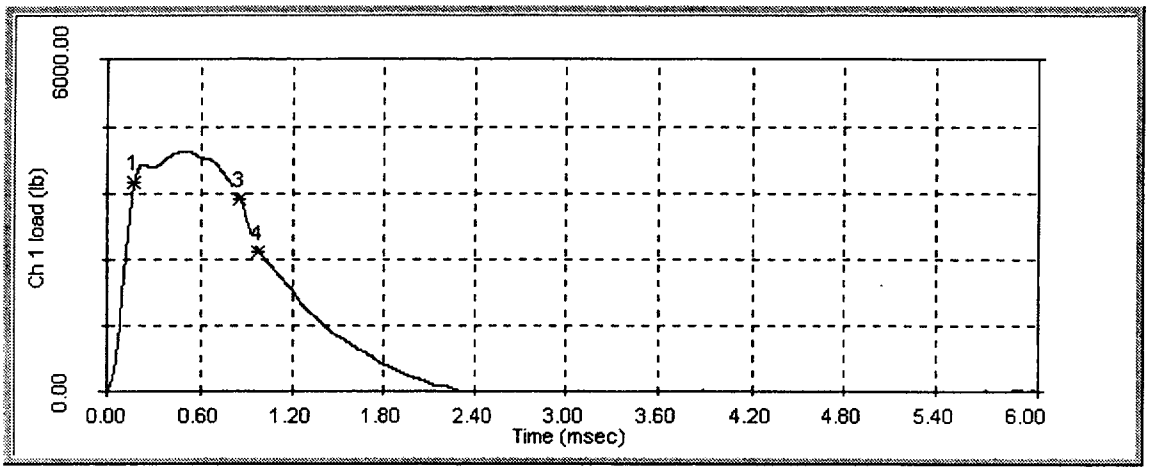

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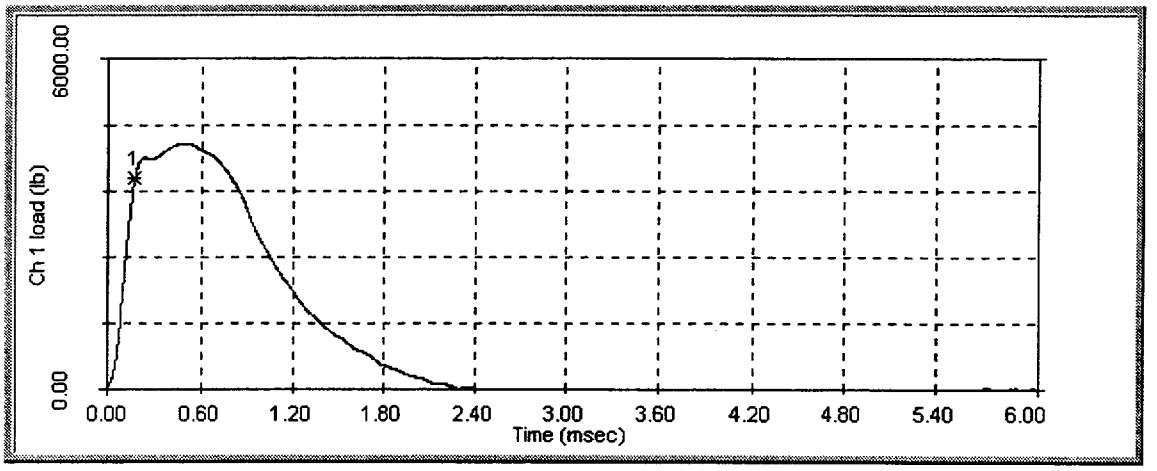

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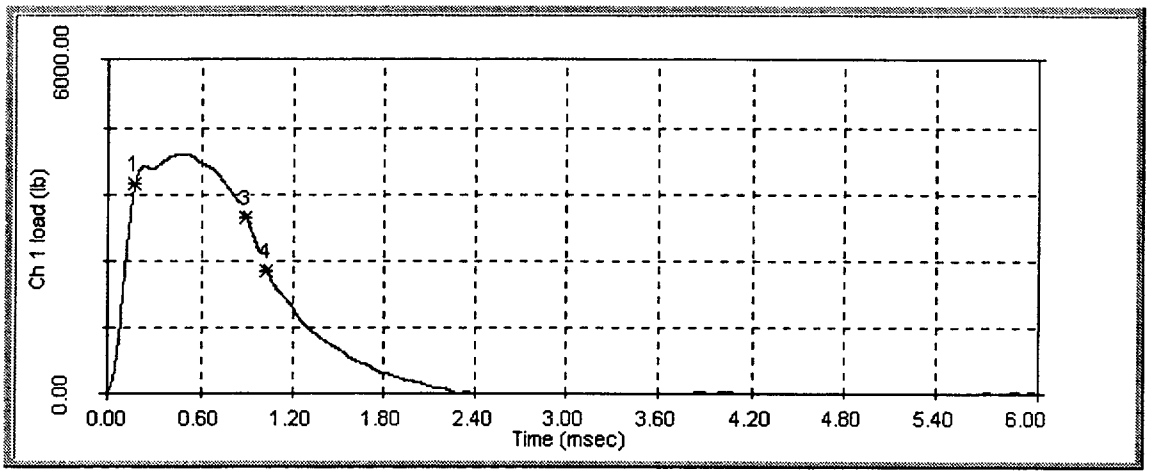

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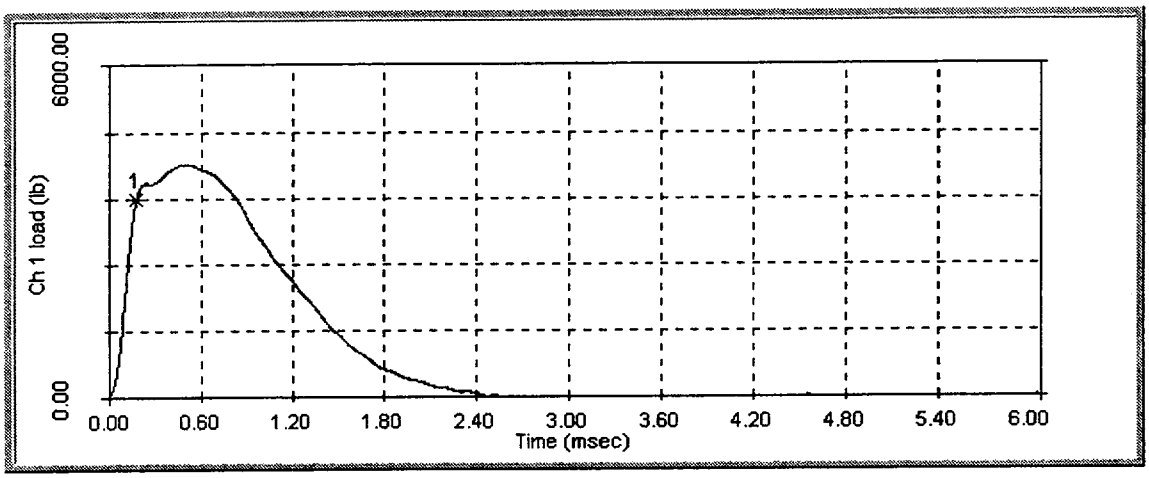

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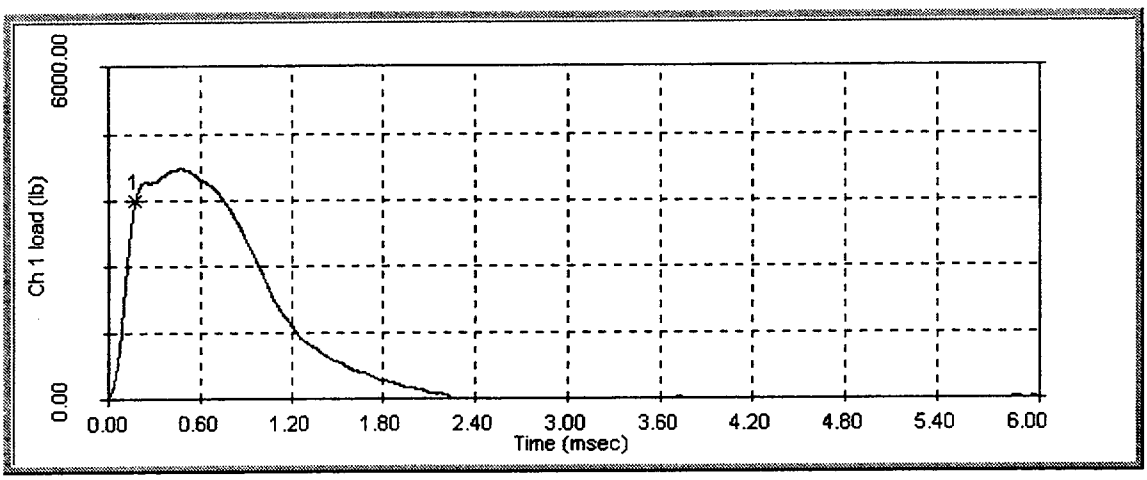

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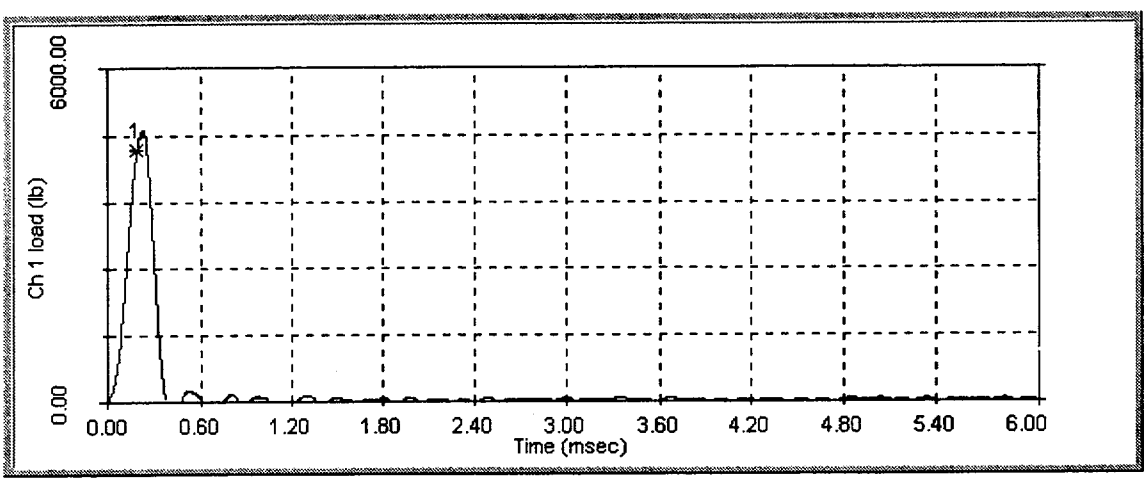

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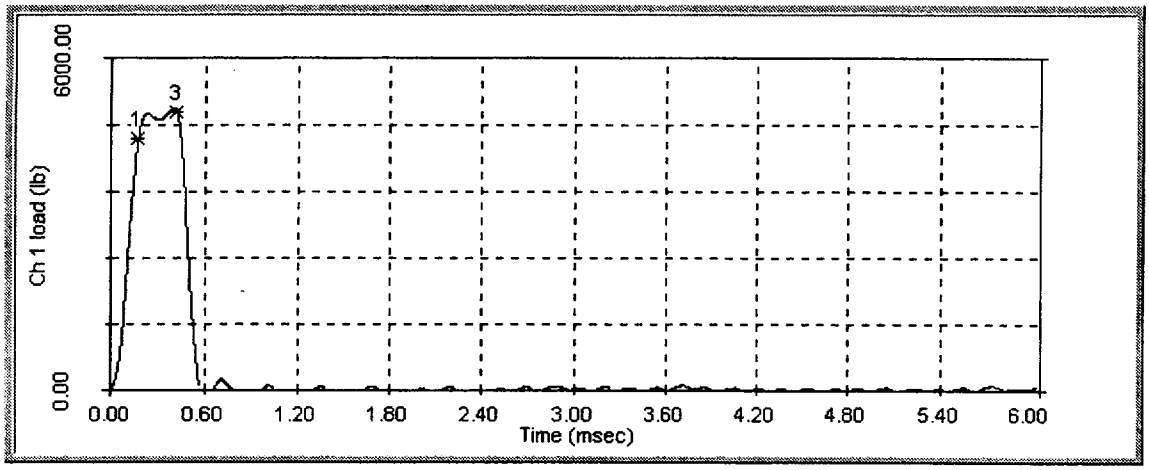

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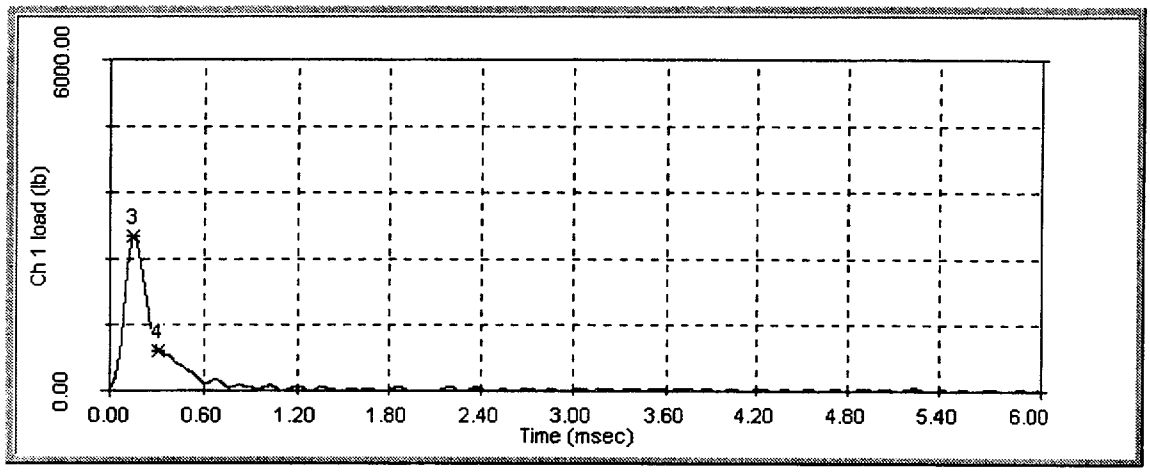

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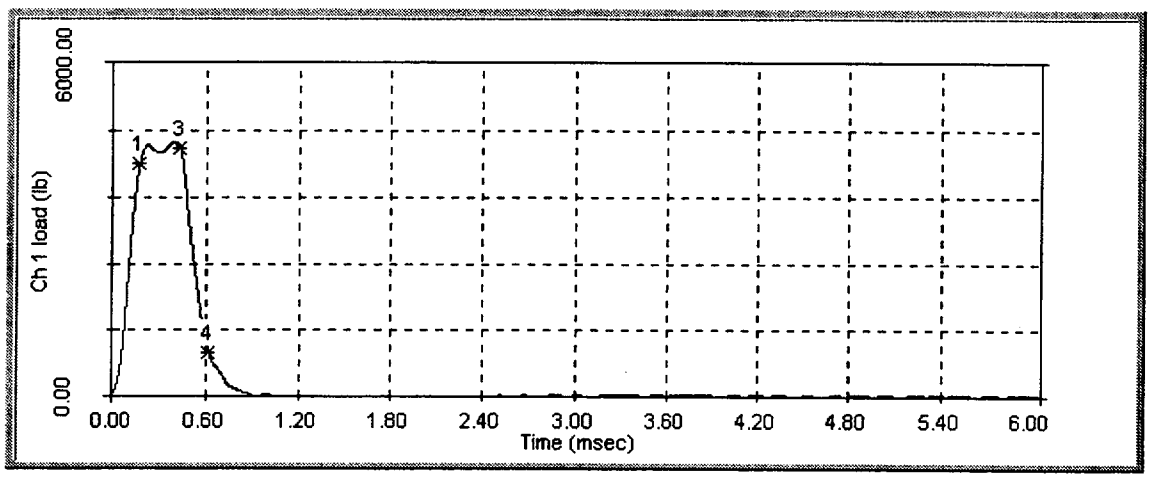
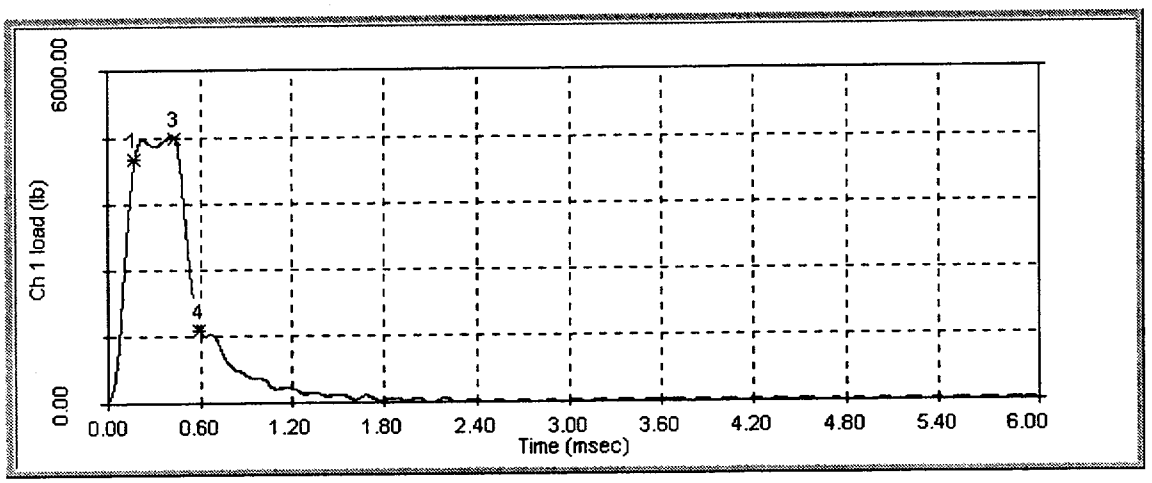
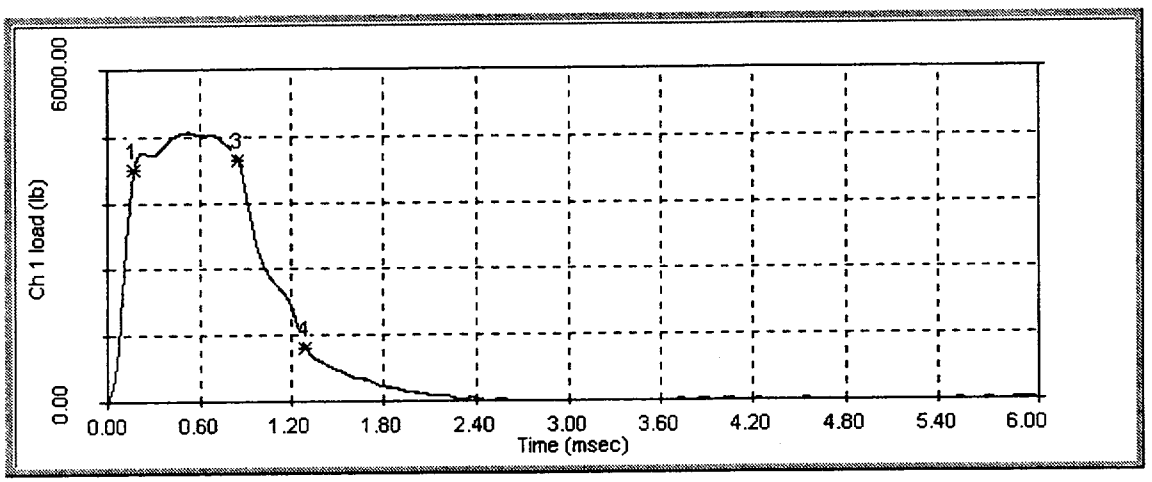


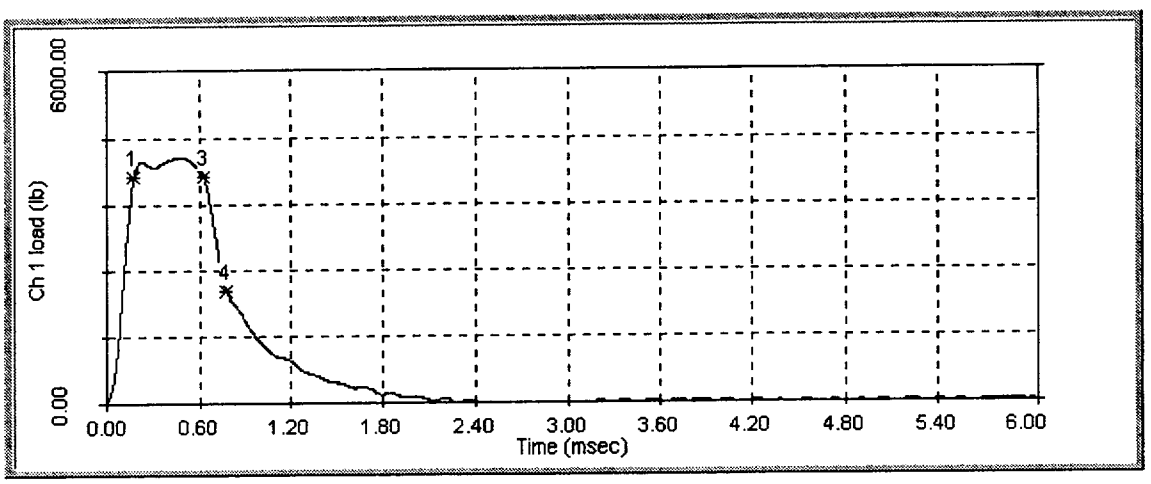
JH80, 25°F



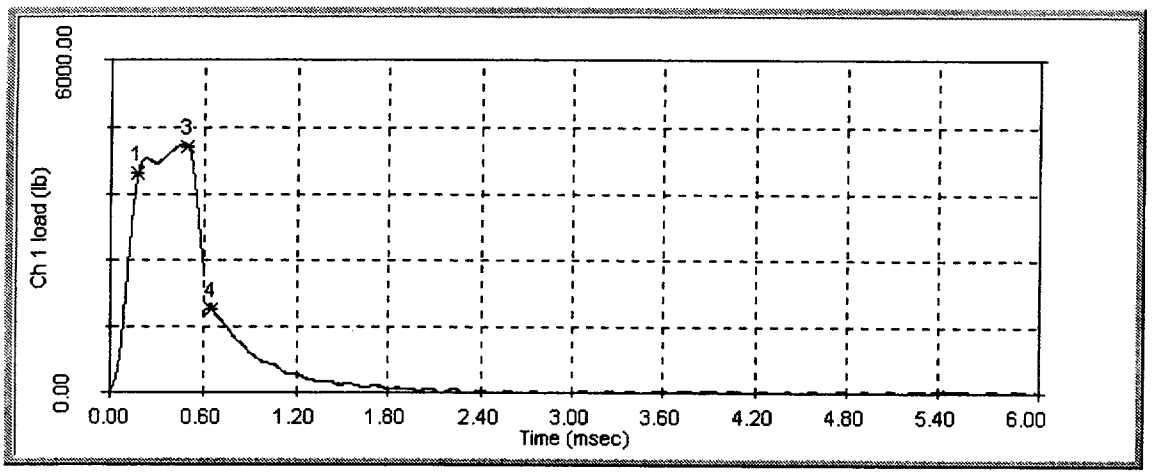
JH84, 50°F



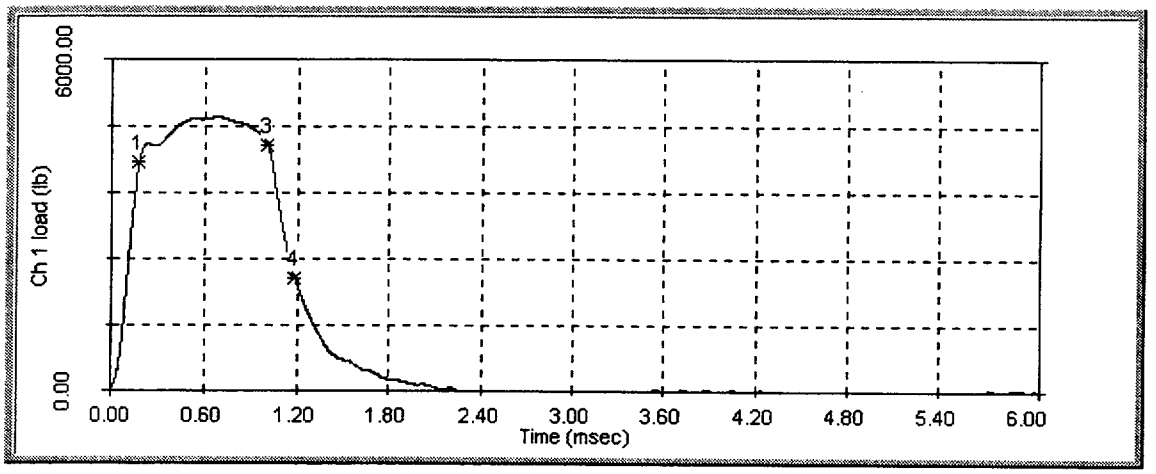
JH78, 75°F



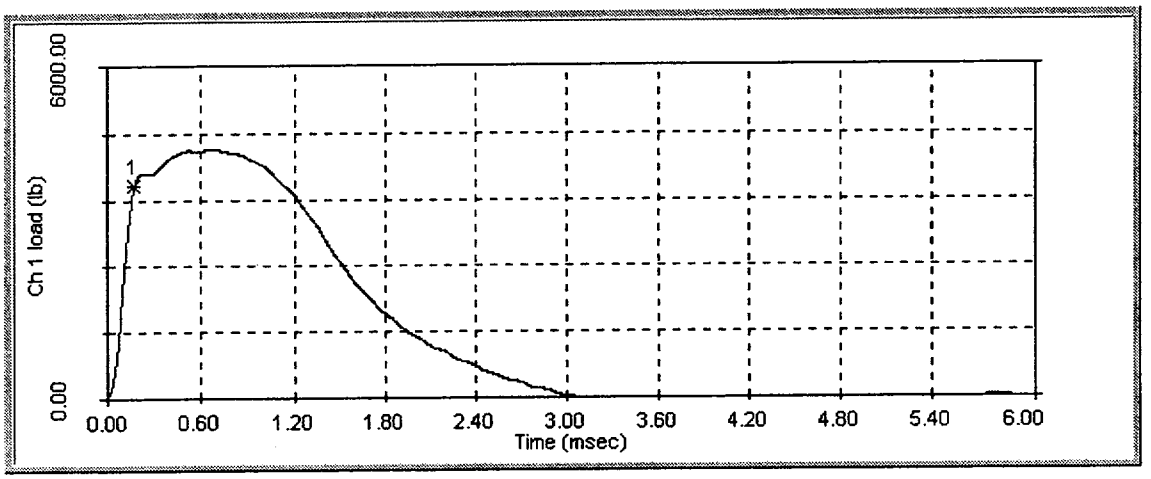
JH74, 100°F



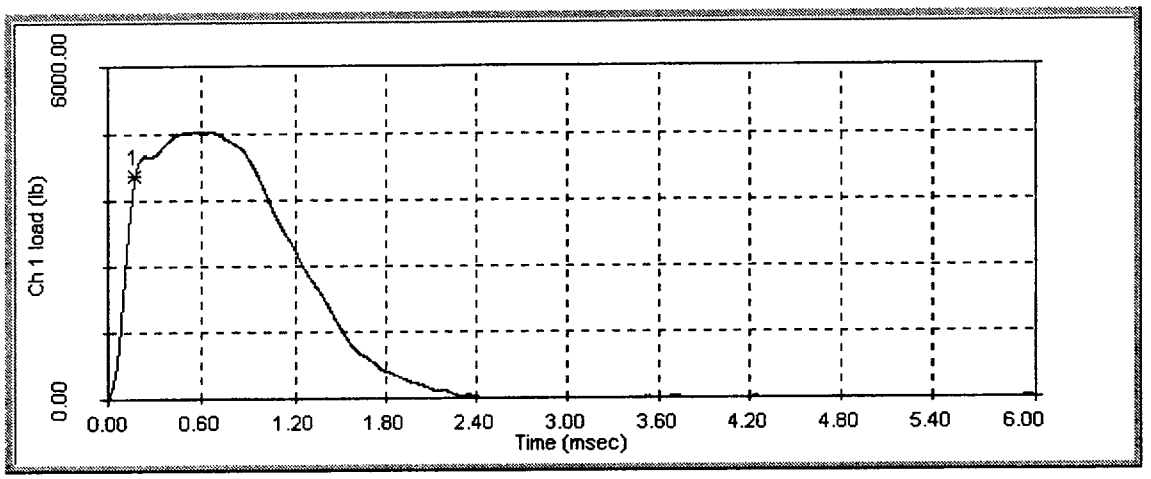
JH79, 125°F



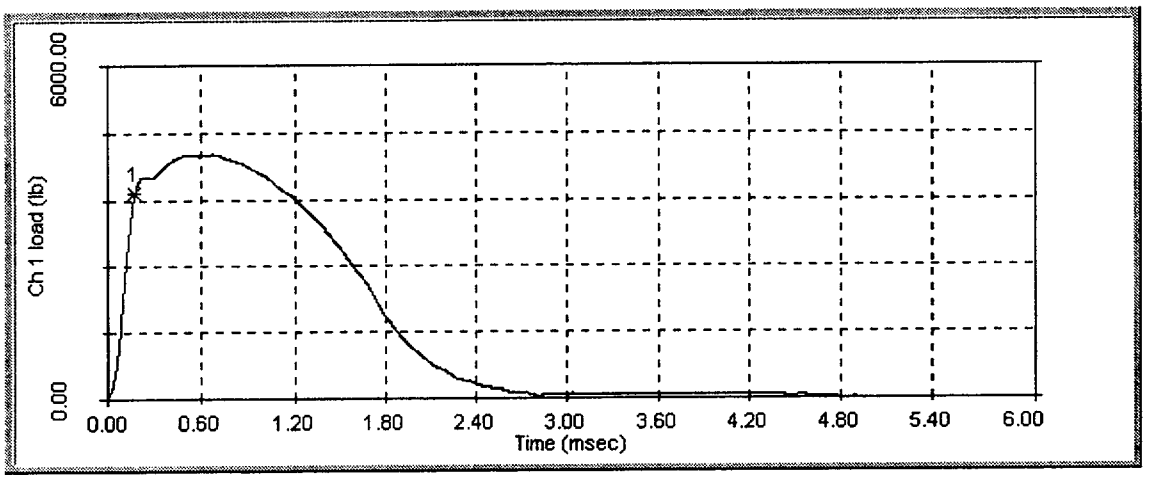
JH82, 175°F



JH73, 225°F



JH83, 250°F



JH75, 275°F

APPENDIX B

Comparison of the Salem Unit 2 Charpy V-Notch Data in Previous Capsule Analyses (Plotted by Hand) and the Charpy V-Notch Data Obtained from CVGRAPH Version 4.1

TABLE B-1
Changes in Average 30 ft-lb Temperatures for Intermediate Shell Plate B4712-2
(Longitudinal Orientation)
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{30}	Unirradiated	CVGRAPH Fit	ΔT_{30}
T	30	80	50	27.07	88.74	61.66
U	30	100	70	27.07	93.61	66.54
X	30	110	80	27.07	120.9	93.82
Y	30	- -	- -	27.07	132.77	105.69

TABLE B-2
Changes in Average 50 ft-lb Temperatures for Intermediate Shell Plate B4712-2
(Longitudinal Orientation)
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{50}	Unirradiated	CVGRAPH Fit	ΔT_{50}
T	55	115	60	56.43	118.92	62.48
U	55	140	85	56.43	135.32	78.89
X	55	165	110	56.43	150.83	94.4
Y	55	- -	- -	56.43	164.32	107.88

TABLE B-3
Changes in Average 35 mil Lateral Expansion Temperatures for Intermediate Shell Plate B4712-2
(Longitudinal Orientation)
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{35}	Unirradiated	CVGRAPH Fit	ΔT_{35}
T	45	90	45	51.69	106.51	54.82
U	45	130	85	51.69	129.66	77.97
X	45	150	105	51.69	139.42	87.73
Y	45	- -	- -	51.69	162.29	110.6

TABLE B-4
Changes in Average Energy Absorption at Full Shear for Intermediate Shell Plate B4712-2
(Longitudinal Orientation)
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔE	Unirradiated	CVGRAPH Fit	ΔE
T	122	115	-7	122	115	-7
U	122	112	-10	122	112	-10
X	122	120	-2	122	120	-2
Y	122	- -	- -	122	112	-10

TABLE B-5
Changes in Average 30 ft-lb Temperatures for Intermediate Shell Plate B4712-2
(Transverse Orientation)
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{30}	Unirradiated	CVGRAPH Fit	ΔT_{30}
T	10	80	70	12.29	87.13	74.83
U	10	105	95	12.29	110.56	98.26
X	10	135	125	12.29	137.44	125.15
Y	10	- -	- -	12.29	141.63	129.33

TABLE B-6
Changes in Average 50 ft-lb Temperatures for Intermediate Shell Plate B4712-2
(Transverse Orientation)
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{50}	Unirradiated	CVGRAPH Fit	ΔT_{50}
T	60	125	65	57.57	126.05	68.48
U	60	155	95	57.57	161.8	104.23
X	60	190	130	57.57	181.97	124.4
Y	60	- -	- -	57.57	178.67	121.09

TABLE B-7
Changes in Average 35 mil Lateral Expansion Temperatures for Intermediate Shell Plate B4712-2
(Transverse Orientation)
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{35}	Unirradiated	CVGRAPH Fit	ΔT_{35}
T	40	105	65	46.67	104.38	57.7
U	40	140	100	46.67	134.07	87.4
X	40	170	130	46.67	164.27	117.6
Y	40	- -	- -	46.67	183.21	136.54

TABLE B-8
Changes in Average Energy Absorption at Full Shear for Intermediate Shell Plate B4712-2
(Transverse Orientation)
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔE	Unirradiated	CVGRAPH Fit	ΔE
T	97	89	-8	97	89	-8
U	97	84	-13	97	84	-13
X	97	89	-8	97	89	-8
Y	97	- -	- -	97	84	-13

TABLE B-9
Changes in Average 30 ft-lb Temperatures for Surveillance Weld Material
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{30}	Unirradiated	CVGRAPH Fit	ΔT_{30}
T	-30	125	155	-38.4	114.76	153.17
U	-30	160	190	-38.4	147.54	185.94
X	-30	165	195	-38.4	157.02	195.43
Y	-30	- -	- -	-38.4	162.5	200.9

TABLE B-10
Changes in Average 50 ft-lb Temperatures for Surveillance Weld Material
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{50}	Unirradiated	CVGRAPH Fit	ΔT_{50}
T	0	180	180	-0.79	182.16	182.96
U	0	200	200	-0.79	210.09	210.89
X	0	205	205	-0.79	202.98	203.78
Y	0	- -	- -	-0.79	201.59	202.38

TABLE B-11
Changes in Average 35 mil Lateral Expansion Temperatures for Surveillance Weld Material
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{35}	Unirradiated	CVGRAPH Fit	ΔT_{35}
T	-10	140	150	-5.31	150.7	156.02
U	-10	180	190	-5.31	174.46	179.78
X	-10	205	215	-5.31	200.85	206.17
Y	-10	- -	- -	-5.31	197.04	202.35

TABLE B-12
Changes in Average Energy Absorption at Full Shear for Surveillance Weld Material
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔE	Unirradiated	CVGRAPH Fit	ΔE
T	111	79	32	111	79	-32
U	111	74	-37	111	74	-37
X	111	86	-25	111	86	-25
Y	111	- -	- -	111	72	-39

TABLE B-13
Changes in Average 30 ft-lb Temperatures for the Weld Heat Affected Zone
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{30}	Unirradiated	CVGRAPH Fit	ΔT_{30}
T	-125	-10	115	-142.8	-17.6	125.2
U	-125	25	150	-142.8	21.29	164.09
X	-125	25	150	-142.8	7.8	150.6
Y	-125	- -	- -	-142.8	20.13	162.93

TABLE B-14
Changes in Average 50 ft-lb Temperatures for the Weld Heat Affected Zone
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{50}	Unirradiated	CVGRAPH Fit	ΔT_{50}
T	-95	30	125	-102.39	35.61	138.01
U	-95	55	150	-102.39	56.81	159.21
X	-95	80	175	-102.39	71.13	173.53
Y	-95	- -	- -	-102.39	76.78	179.18

TABLE B-15
Changes in Average 35 mil Lateral Expansion Temperatures for the Weld Heat Affected Zone
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔT_{35}	Unirradiated	CVGRAPH Fit	ΔT_{35}
T	-65	45	110	-67.89	27.05	94.95
U	-65	55	120	-67.89	47.14	115.04
X	-65	65	130	-67.89	70.41	138.31
Y	-65	- -	- -	-67.89	112.48	180.38

TABLE B-16
Changes in Average Energy Absorption at Full Shear for the Weld Heat Affected Zone
Hand Fit vs. CVGRAPH 4.1

Capsule	Unirradiated	Hand Fit	ΔE	Unirradiated	CVGRAPH Fit	ΔE
T	120	88	-32	120	88	-32
U	120	104	-16	120	104	-16
X	120	89	-31	120	89	-31
Y	120	- -	- -	120	100	-20

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[2]. Lower shelf energy values were fixed at 2.2 ft-lb The unirradiated and irradiated upper shelf energy values were calculated per the ASTM E185-82 definition of upper shelf energy.

TABLE C-1
Upper Shelf Energy Values Fixed in CVGRAPH

Material	Unirradiated	Capsule T	Capsule U	Capsule X	Capsule Y
Intermediate Shell Plate B4712-2 (Longitudinal Orientation)	122	115	112	120	112
Intermediate Shell Plate B4712-2 (Transverse Orientation)	97	89	84	89	84
Weld Metal (Heat # 13253)	111	79	74	86	72
HAZ Material	120	88	104	89	100

UNIRRADIATED (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:30:38 on 05-07-2001

Page 1

Coefficients of Curve 1

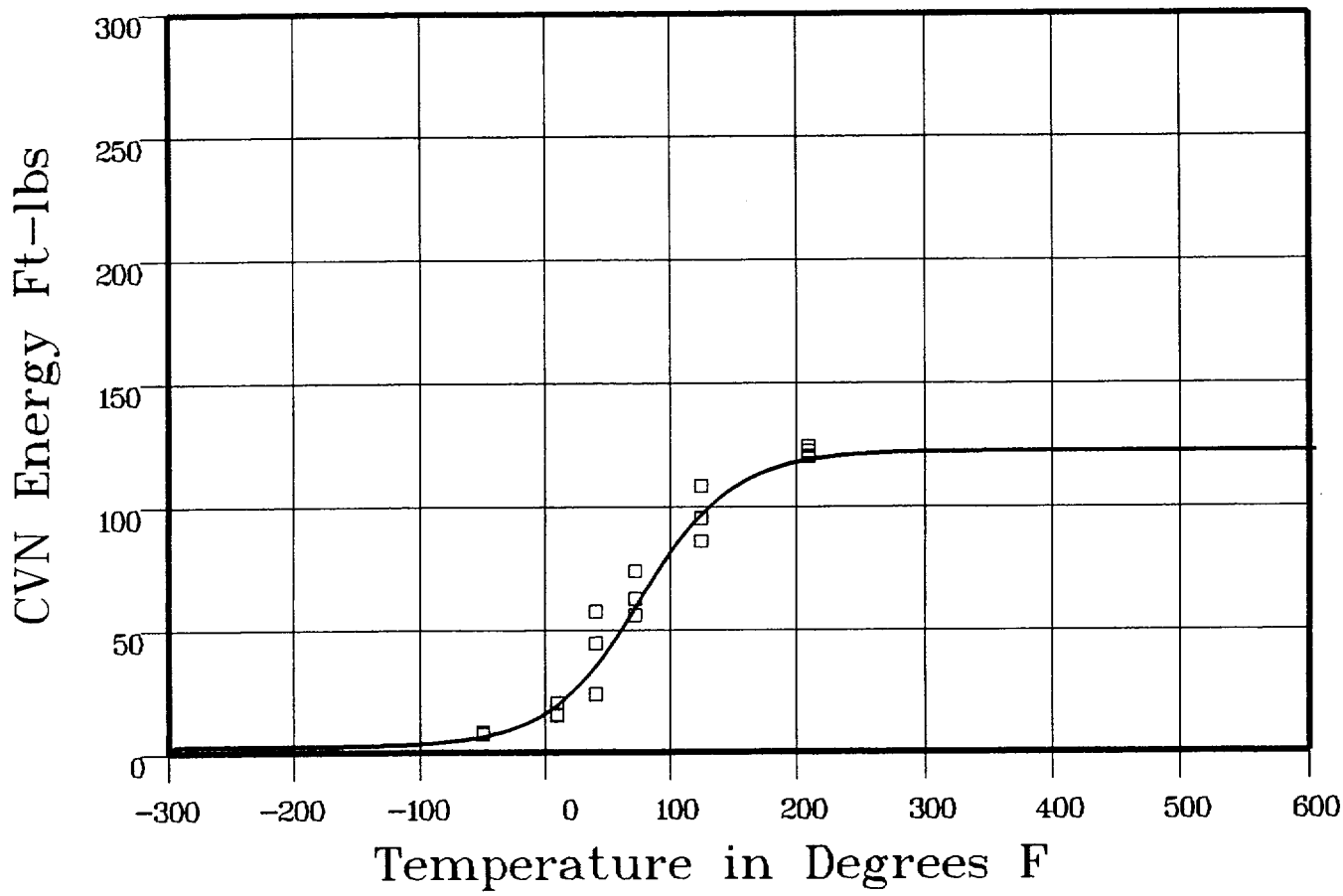
A = 62.09	B = 59.9	C = 74.6	T0 = 71.71

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

Upper Shelf Energy: 122 Fixed Temp. at 30 ft-lbs: 27 Temp. at 50 ft-lbs: 56.4 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-50	7.5	6.61	.88
-50	7	6.61	.38
-50	8	6.61	1.38
10	15.5	21.42	-5.92
10	15	21.42	-6.42
10	20	21.42	-1.42
40	44	38.06	5.93
40	23.5	38.06	-14.56
40	57	38.06	18.93

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

UNIRRADIATED (LONGITUDINAL ORIENTATION)

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
72	62	62.32	-.32
72	55.5	62.32	-6.82
72	73.5	62.32	11.17
125	108	98.83	9.16
125	85.5	98.83	-13.33
125	95	98.83	-3.83
210	120	119.12	.87
210	124	119.12	4.87
210	122	119.12	2.87
		SUM of RESIDUALS =	3.8

CAPSULE T (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:22:37 on 05-02-2001

Page 1

Coefficients of Curve 2

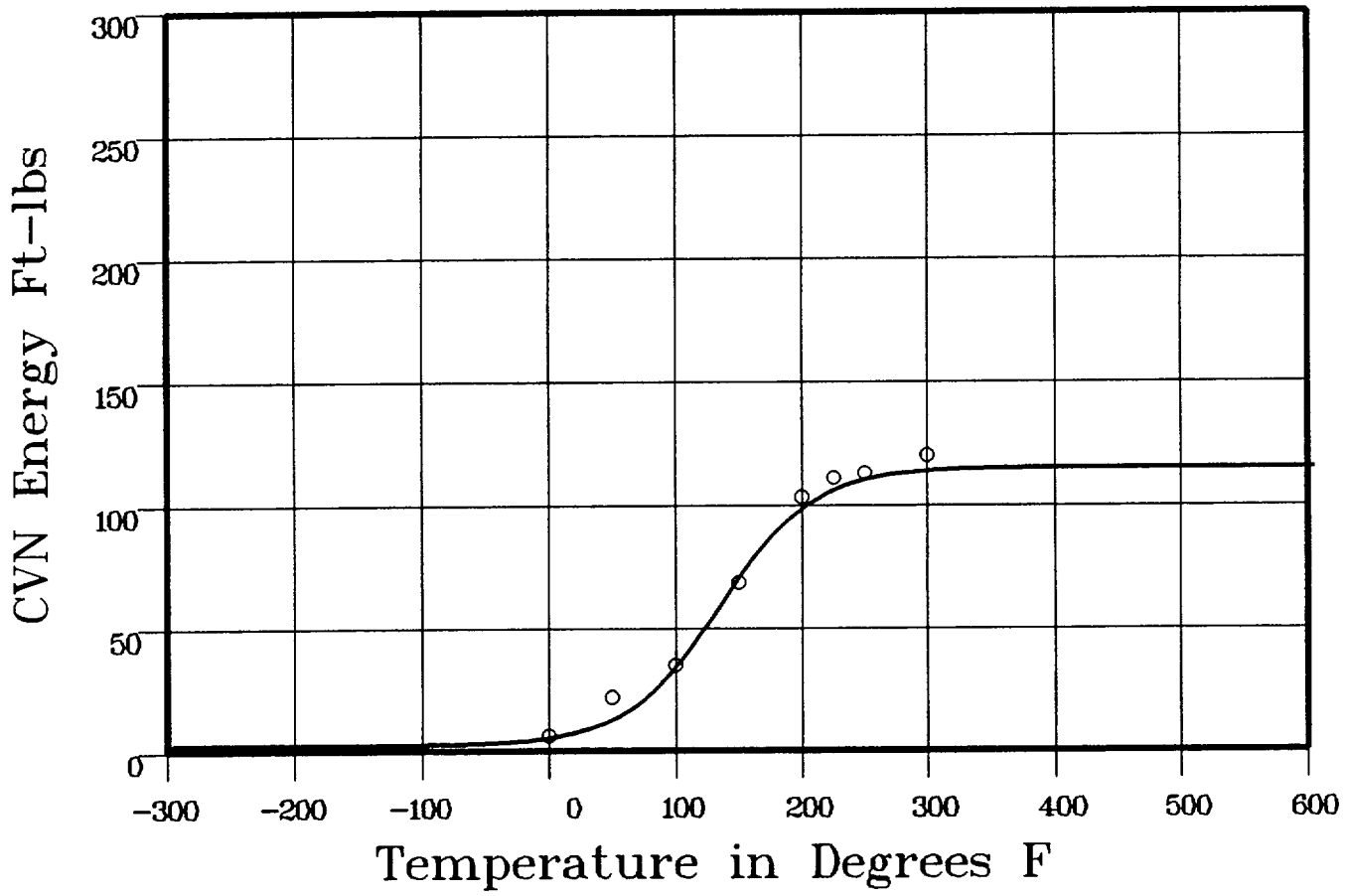
A = 58.59	B = 56.4	C = 74.49	T0 = 130.37

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

Upper Shelf Energy: 115 Fixed Temp. at 30 ft-lbs: 88.7 Temp. at 50 ft-lbs: 118.9 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
0	6	5.5	.49
50	22	13.88	8.11
100	35	36.8	-1.8
150	68	73.12	-5.12
200	103	99.92	3.07
225	111	106.75	4.24
250	113	110.63	2.36
300	120	113.82	6.17

SUM of RESIDUALS = 17.53

CAPSULE U (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:22:37 on 05-02-2001

Page 1

Coefficients of Curve 3

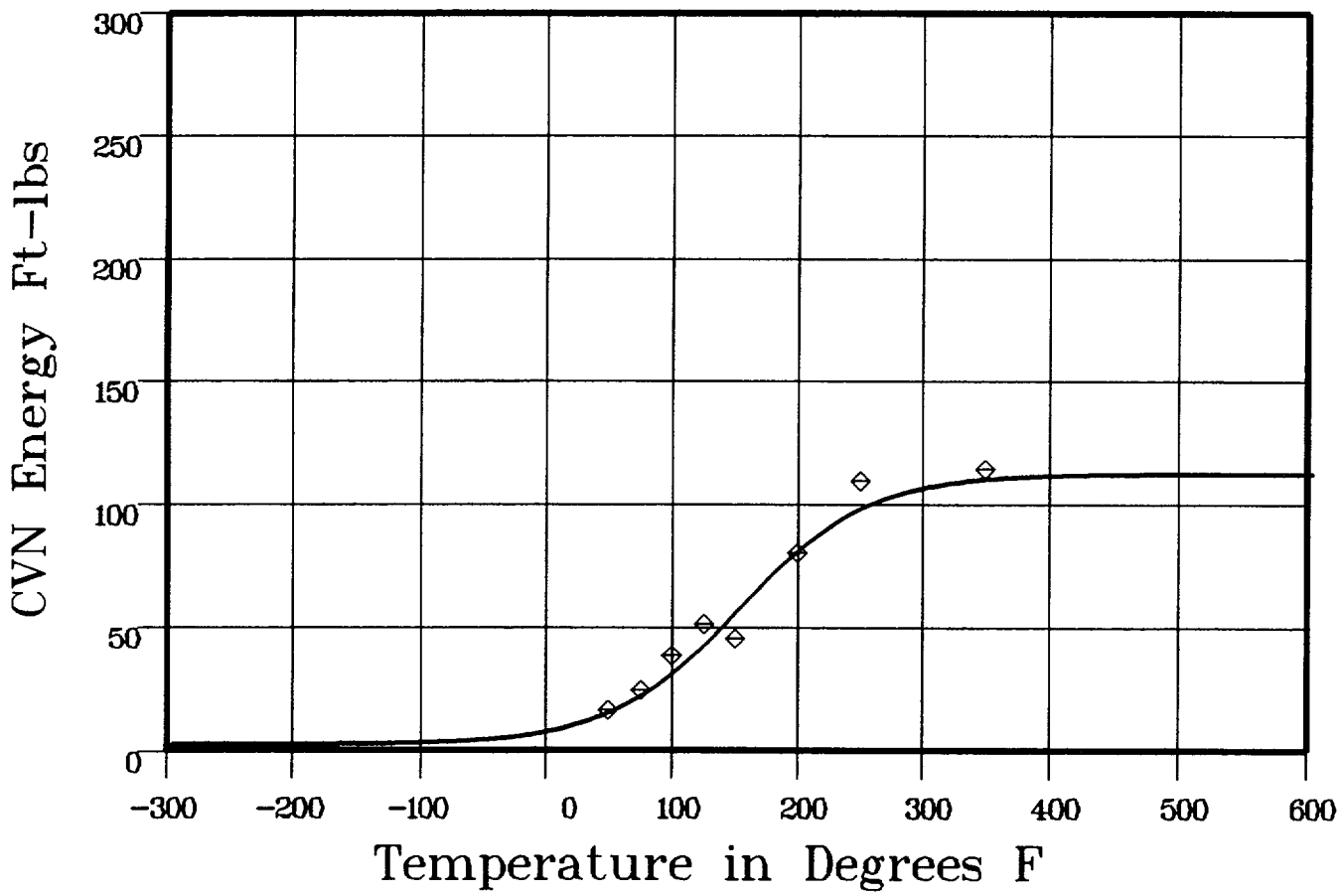
A = 57.09	B = 54.9	C = 101.53	T0 = 148.53

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

Upper Shelf Energy: 112 Fixed Temp. at 30 ft-lbs: 93.6 Temp. at 50 ft-lbs: 135.3 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
50	16	15.98	.01
76	24	23.42	.57
100	38	32.68	5.31
125	51	44.59	6.4
150	45	57.89	-12.89
200	80	82.76	-2.76
250	109	98.89	10.1
350	114	109.96	4.03

SUM of RESIDUALS = 10.78

CAPSULE X (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:22:37 on 05-02-2001

Page 1

Coefficients of Curve 4

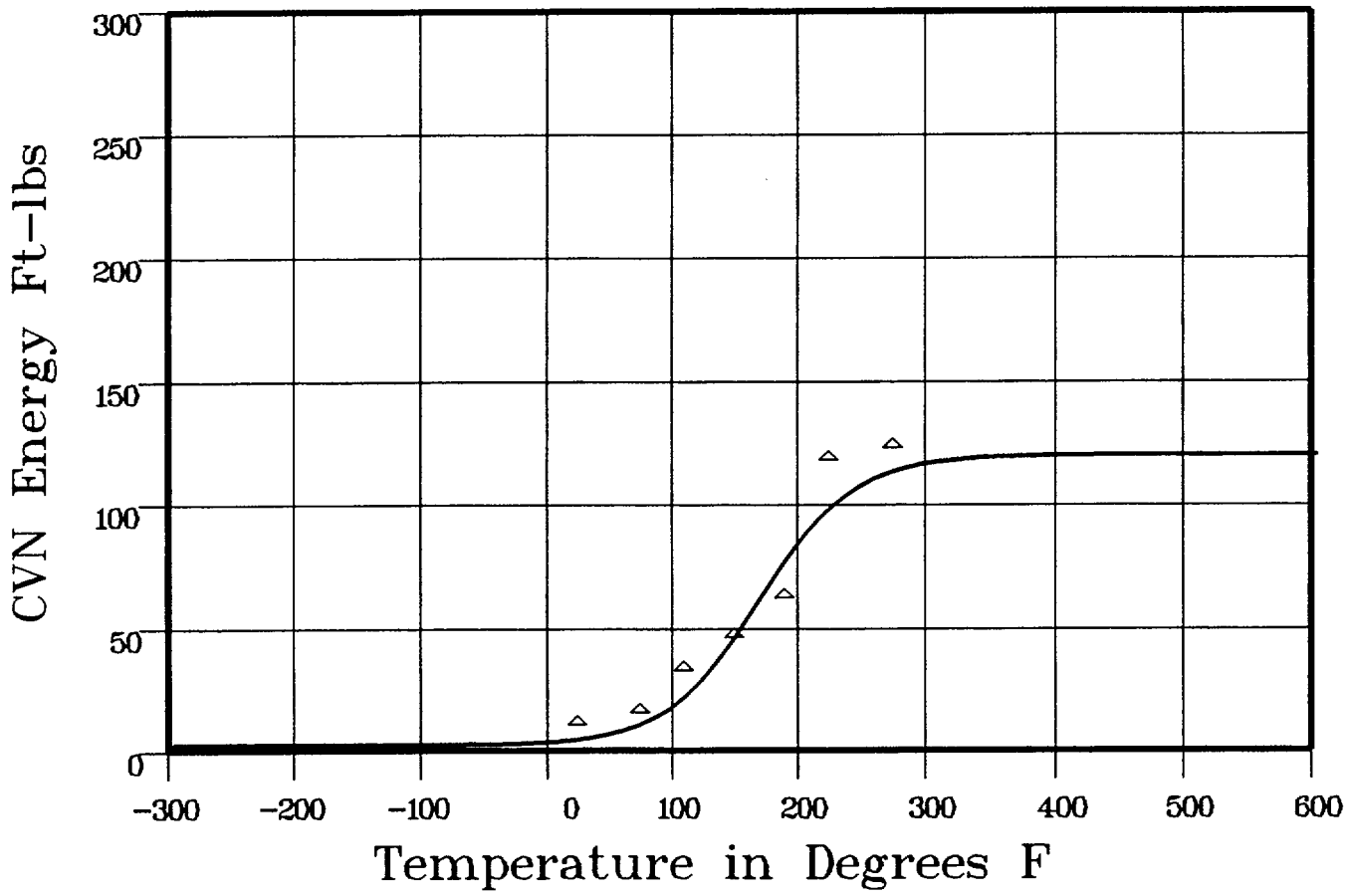
A = 61.09	B = 58.9	C = 75.46	T0 = 165.23

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

Upper Shelf Energy: 120 Fixed Temp. at 30 ft-lbs: 120.9 Temp. at 50 ft-lbs: 150.8 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: X Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
25	11	4.99	6
75	16	12.07	3.92
110	33	24.33	8.66
150	46	49.36	-3.36
190	62	79.76	-17.76
225	118	99.94	18.05
275	123	113.9	9.09

SUM of RESIDUALS = 24.6

CAPSULE Y (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:22:37 on 05-02-2001

Page 1

Coefficients of Curve 5

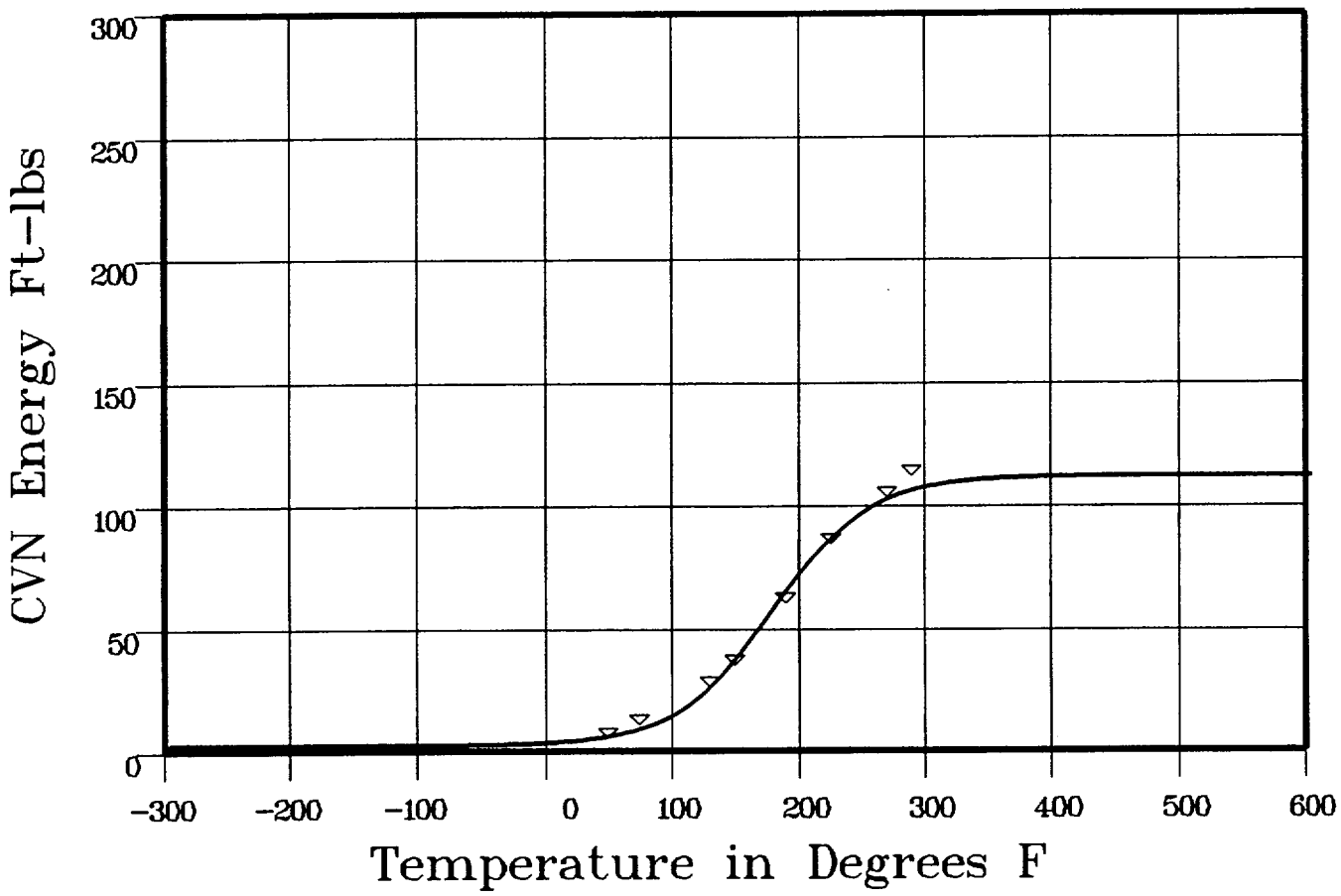
A = 57.09	B = 54.9	C = 76.8	T0 = 174.31

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

Upper Shelf Energy: 112 Fixed Temp. at 30 ft-lbs: 132.7 Temp. at 50 ft-lbs: 164.3 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: Y Material: PLATE SA533B1 Ori: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
50	9	6.34	2.65
75	15	9.89	5.1
130	30	28.52	1.47
150	39	40.27	-1.27
190	64	68.15	-4.15
225	88	88.84	-.84

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

CAPSULE Y (LONGITUDINAL ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
270	107	103.6	3.39
290	116	106.85	9.14

SUM of RESIDUALS = 15.49

UNIRRADIATED (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:35:33 on 05-02-2001

Page 1

Coefficients of Curve 1

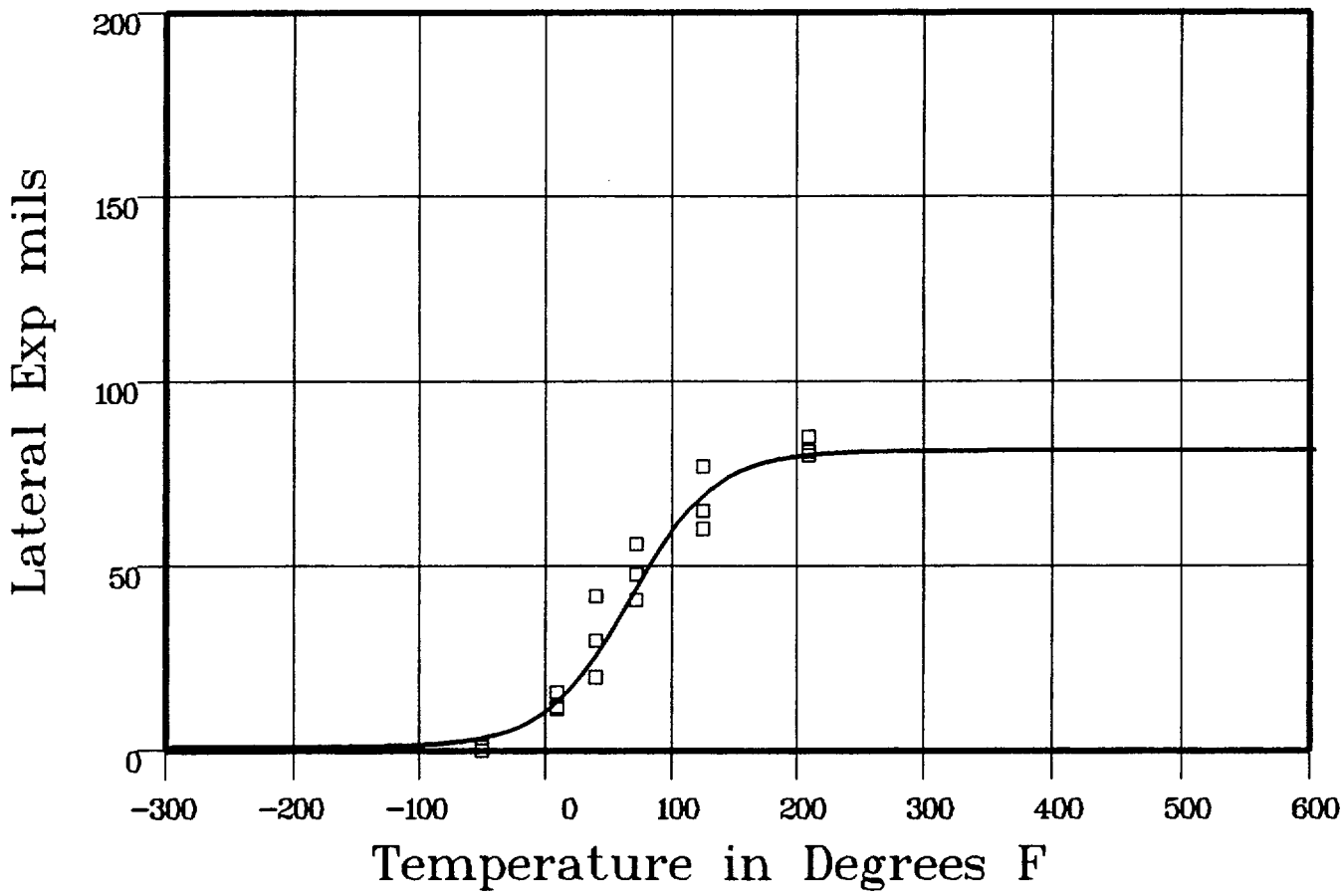
A = 41.14	B = 40.14	C = 67.55	T0 = 62.1

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

Upper Shelf L.E.: 81.28 Temperature at L.E. 35: 51.6 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-50	1.5	3.8	-2.3
-50	0	3.8	-3.8
-50	1	3.8	-2.8
10	16	15.14	.85
10	12	15.14	-3.14
10	11.5	15.14	-3.64
40	42	28.45	13.54
40	30	28.45	1.54
40	20	28.45	-8.45

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

UNIRRADIATED (LONGITUDINAL ORIENTATION)

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
72	41	46.97	-5.97
72	56	46.97	9.02
72	48	46.97	1.02
125	65	70.48	-5.48
125	60	70.48	-10.48
125	77	70.48	6.51
210	80	80.28	-.28
210	81	80.28	.71
210	85	80.28	4.71

SUM of RESIDUALS = -8.46

CAPSULE T (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:35:33 on 05-02-2001

Page 1

Coefficients of Curve 2

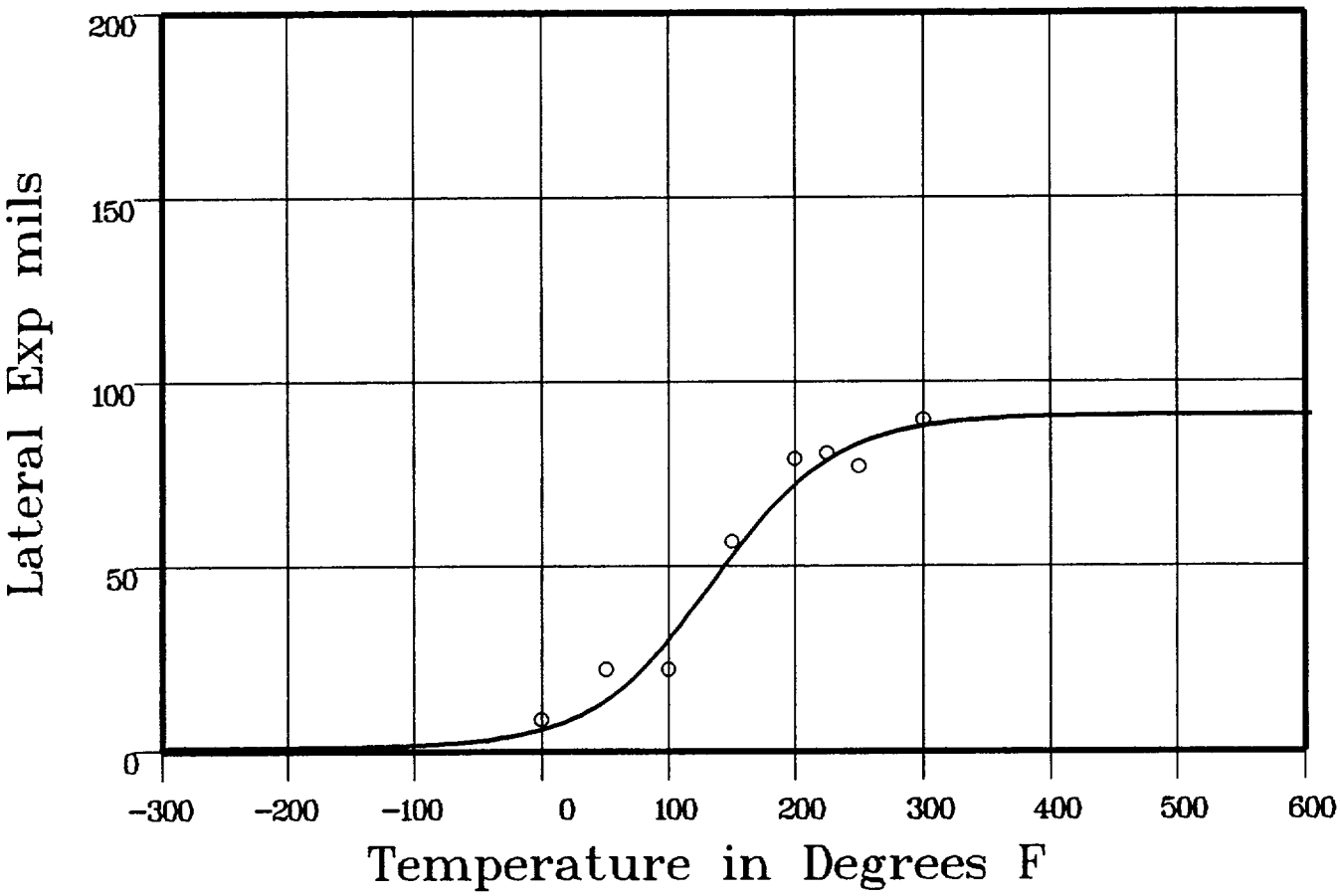
A = 46.07	B = 45.07	C = 96.29	T0 = 130.66

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

Upper Shelf L.E.: 91.14 Temperature at L.E. 35: 106.5 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: T Material: PLATE SA533B1 Ori: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
0	9	6.6	2.39
50	22.5	15.21	7.28
100	22.5	32.18	-9.68
150	57	55	1.99
200	79.5	73.88	5.61
225	81	80.01	.98
250	77.5	84.17	-6.67
300	90	88.54	1.45

SUM of RESIDUALS = 3.37

CAPSULE U (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:35:33 on 05-02-2001

Page 1

Coefficients of Curve 3

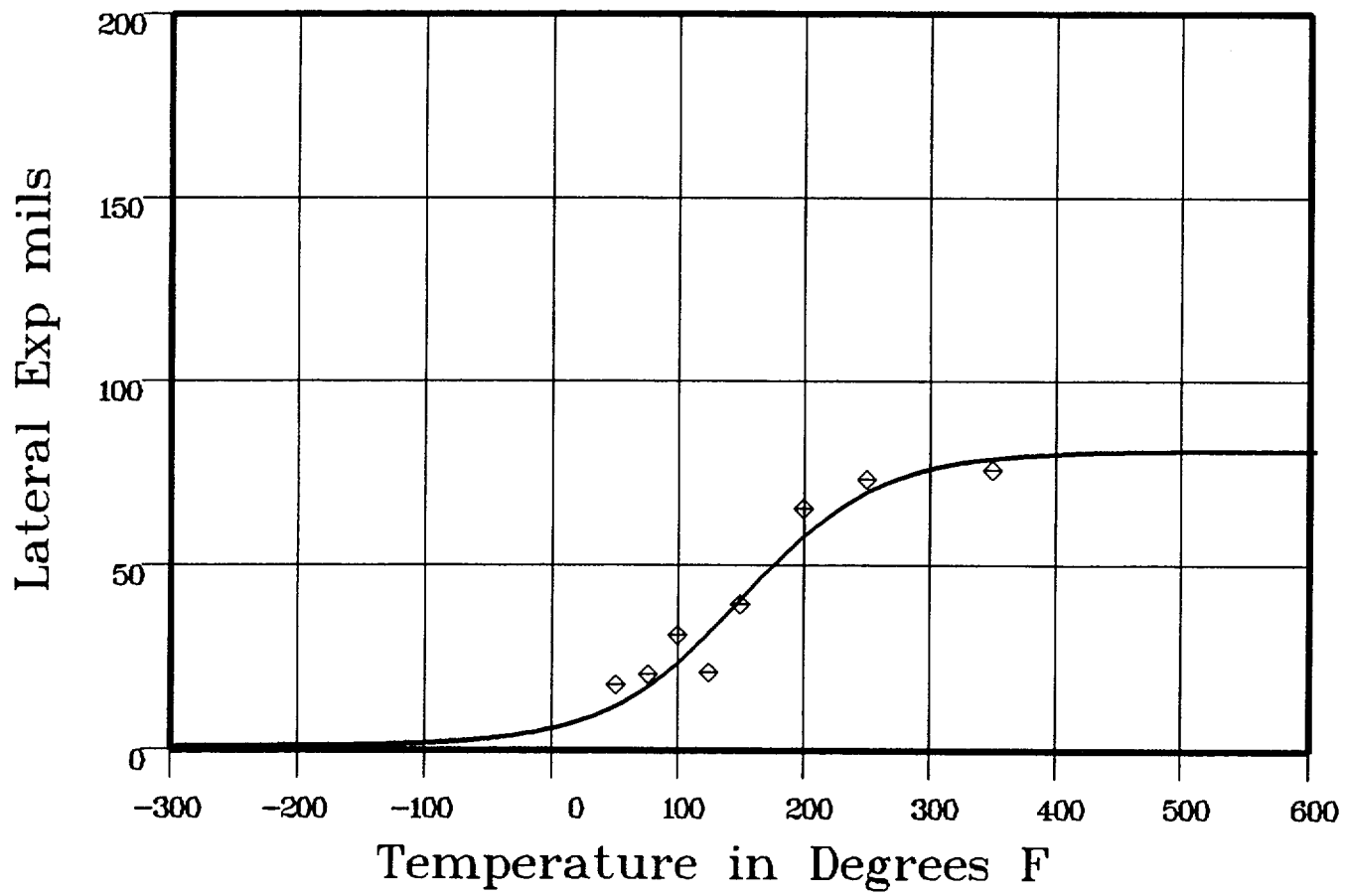
A = 41.03	B = 40.03	C = 109.1	T0 = 146.24

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

Upper Shelf L.E.: 81.07 Temperature at L.E. 35: 129.6 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
50	17.5	12.71	4.78
76	20.5	18.31	2.18
100	31	25.01	5.98
125	21	33.33	-12.33
150	39.5	42.41	-2.91
200	65.5	59.3	6.19
250	73.5	70.67	2.82
350	76	79.2	-3.2

SUM of RESIDUALS = 3.5

CAPSULE X (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:35:33 on 05-02-2001

Page 1

Coefficients of Curve 4

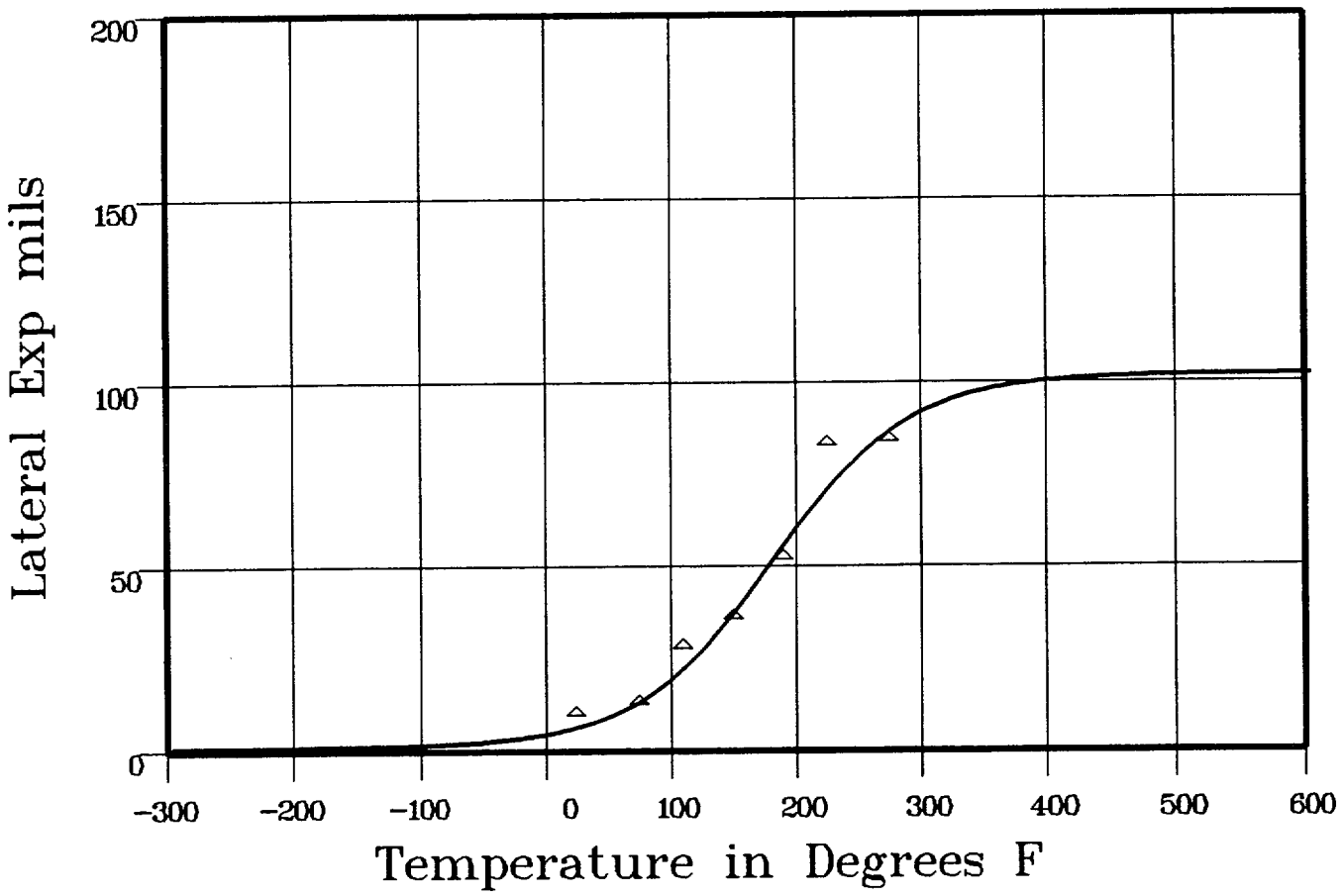
A = 51.54	B = 50.54	C = 108.35	T0 = 176.25

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

Upper Shelf L.E.: 102.09 Temperature at L.E. 35: 139.4 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: X Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
25	10	6.84	3.15
75	13	14.51	-1.51
110	28	23.99	4
150	36	39.53	-3.53
190	52	57.92	-5.92
225	83	72.86	10.13
275	84	88.02	-4.02

SUM of RESIDUALS = 2.29

CAPSULE Y (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:35:33 on 05-02-2001

Page 1

Coefficients of Curve 5

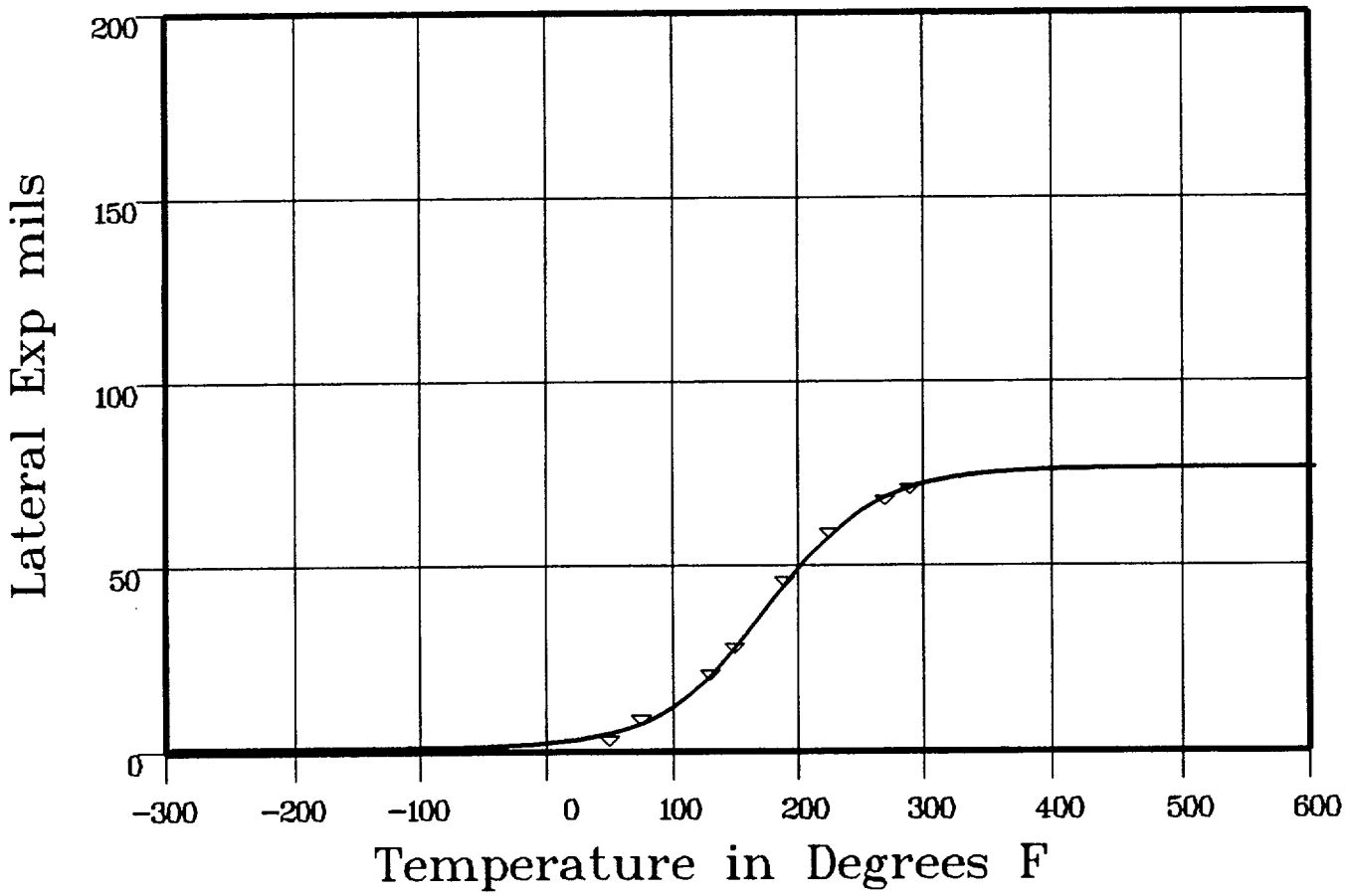
A = 38.8	B = 37.8	C = 87.06	T0 = 171.09

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

Upper Shelf L.E.: 76.61 Temperature at L.E. 35: 162.2 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: Y Material: PLATE SA533B1 Ori: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
50	4	5.41	-1.41
75	10	8.49	1.5
130	22	22.18	-.18
150	29	29.82	-.82
190	47	46.89	.1
225	60	59.62	.37

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

CAPSULE Y (LONGITUDINAL ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
270	69	69.54	-.54
290	72	71.99	0

SUM of RESIDUALS = -.96

UNIRRADIATED (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:47:07 on 05-02-2001

Page 1

Coefficients of Curve 1

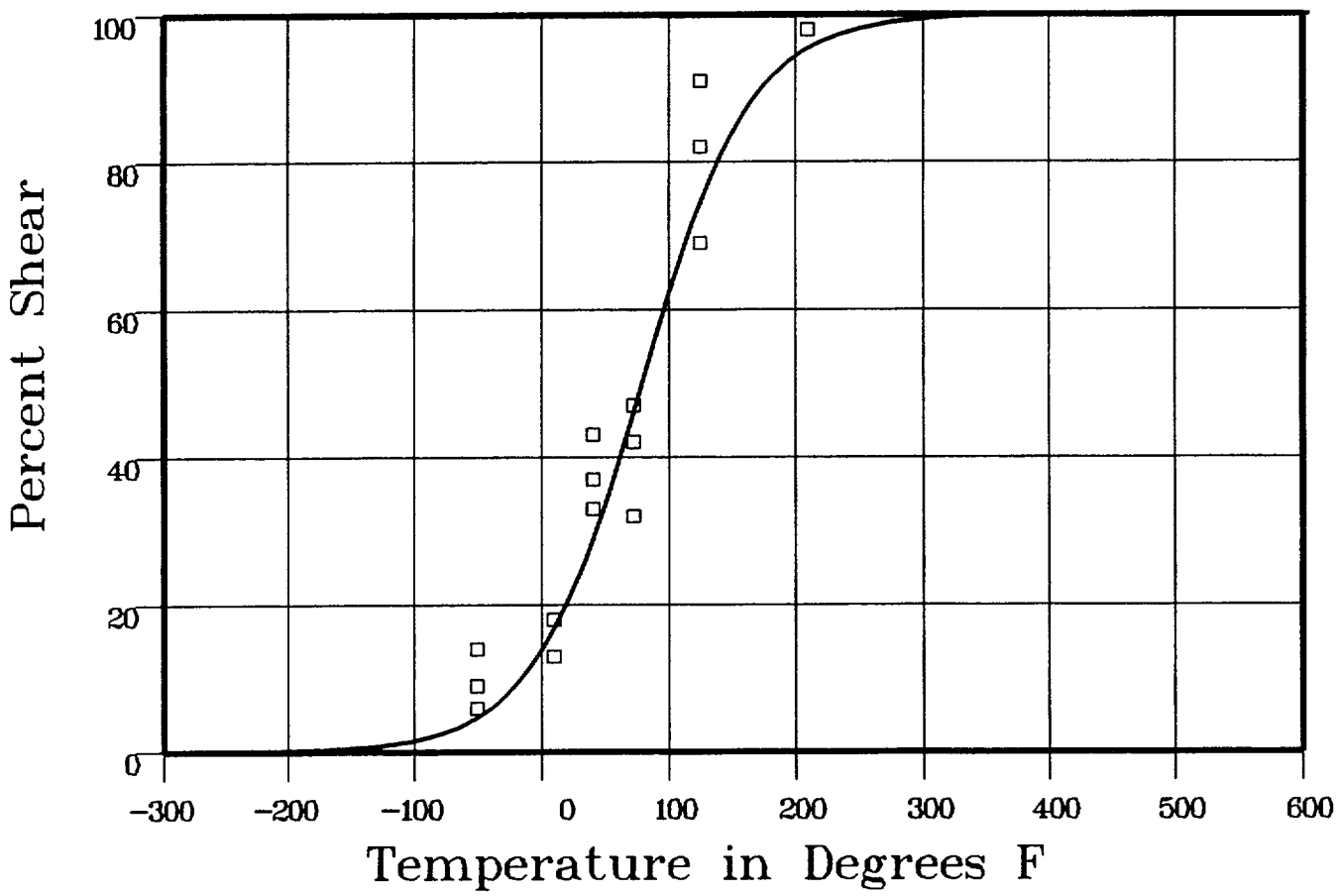
A = 50	B = 50	C = 86.18	T0 = 74.06

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

Temperature at 50% Shear: 74

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50	14	5.32	8.67
-50	6	5.32	.67
-50	9	5.32	3.67
10	13	18.44	-5.44
10	18	18.44	-.44
10	18	18.44	-.44
40	43	31.2	11.79
40	33	31.2	1.79
40	37	31.2	5.79

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

UNIRRADIATED (LONGITUDINAL ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
72	47	48.8	-1.8
72	32	48.8	-16.8
72	42	48.8	-6.8
125	82	76.53	5.46
125	69	76.53	-7.53
125	91	76.53	14.46
210	98	95.9	2.09
210	98	95.9	2.09
210	98	95.9	2.09

SUM of RESIDUALS = 19.35

CAPSULE T (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:47:07 on 05-02-2001

Page 1

Coefficients of Curve 2

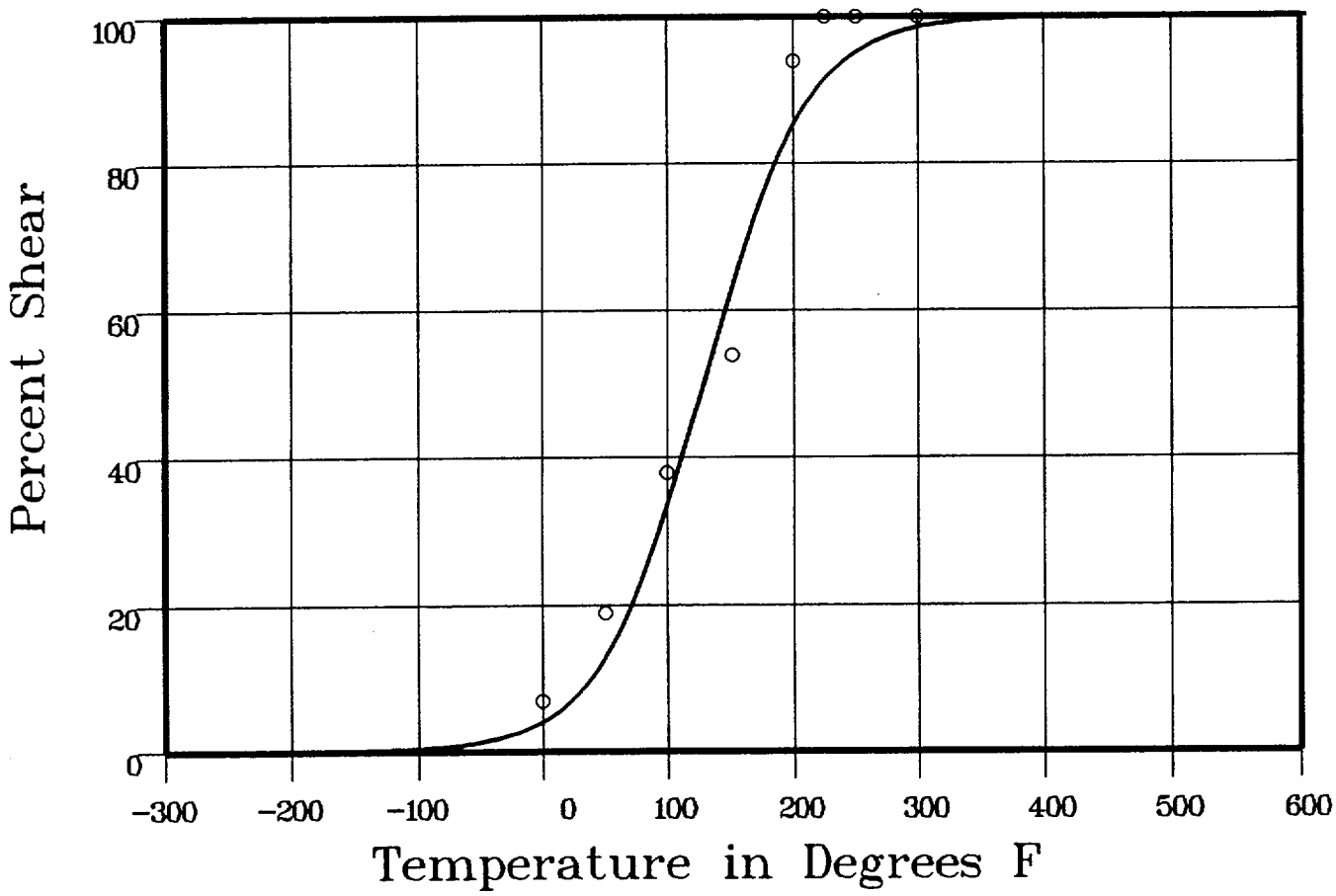
A = 50	B = 50	C = 81.63	T0 = 123.33

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

Temperature at 50% Shear: 123.3

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
0	7	4.64	2.35
50	19	14.22	4.77
100	38	36.08	1.91
150	54	65.77	-11.77
200	94	86.73	7.26
225	100	92.34	7.65
250	100	95.7	4.29
300	100	98.69	1.3

SUM of RESIDUALS = 17.78

CAPSULE U (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:47:07 on 05-02-2001

Page 1

Coefficients of Curve 3

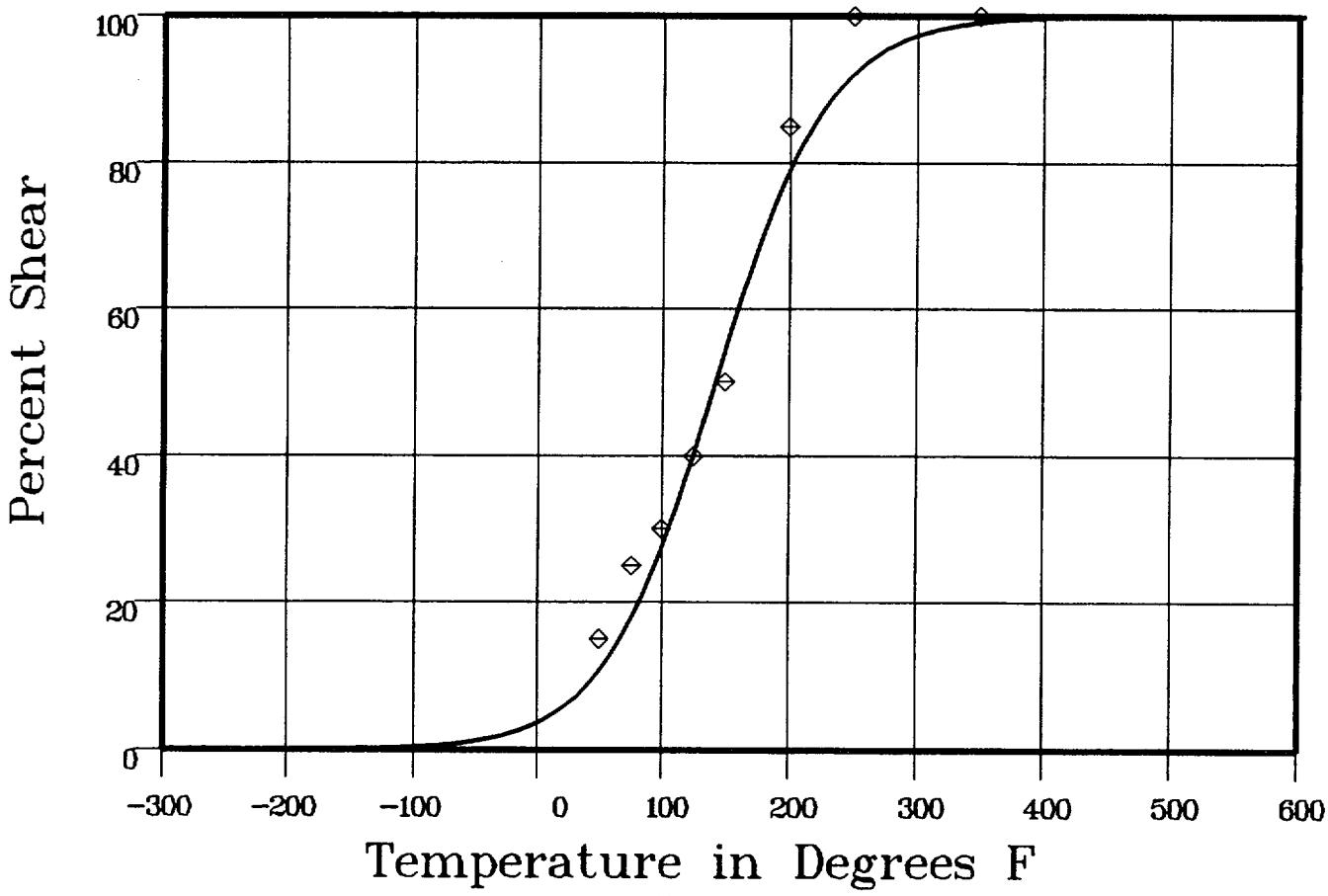
A = 50	B = 50	C = 87.21	T0 = 137.69

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

Temperature at 50% Shear: 137.6

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: U Material: PLATE SA533B1 Ori: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
50	15	11.8	3.19
76	25	19.54	5.45
100	30	29.64	.35
125	40	42.77	-2.77
150	50	57	-7
200	85	80.67	4.32
250	100	92.92	7.07
350	100	99.23	.76

SUM of RESIDUALS = 11.39

CAPSULE X (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:47:07 on 05-02-2001

Page 1

Coefficients of Curve 4

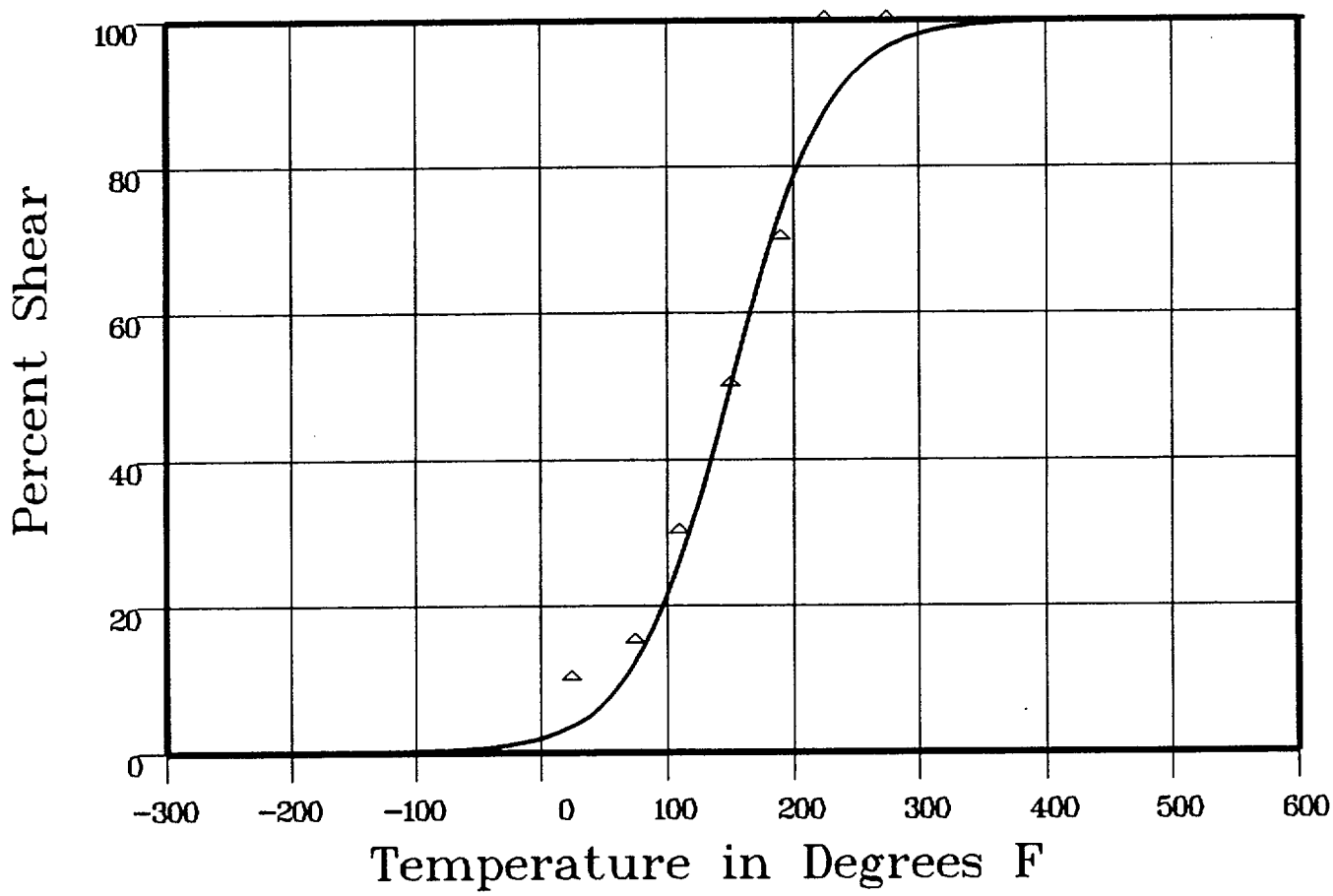
A = 50	B = 50	C = 76.83	T0 = 145.31

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

Temperature at 50% Shear: 145.3

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: X Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
25	10	4.18	5.81
75	15	13.82	1.17
110	30	28.51	1.48
150	50	53.04	-3.04
190	70	76.19	-6.19
225	100	88.83	11.16
275	100	96.69	3.3

SUM of RESIDUALS = 13.71

CAPSULE Y (LONGITUDINAL ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 14:47:07 on 05-02-2001

Page 1

Coefficients of Curve 5

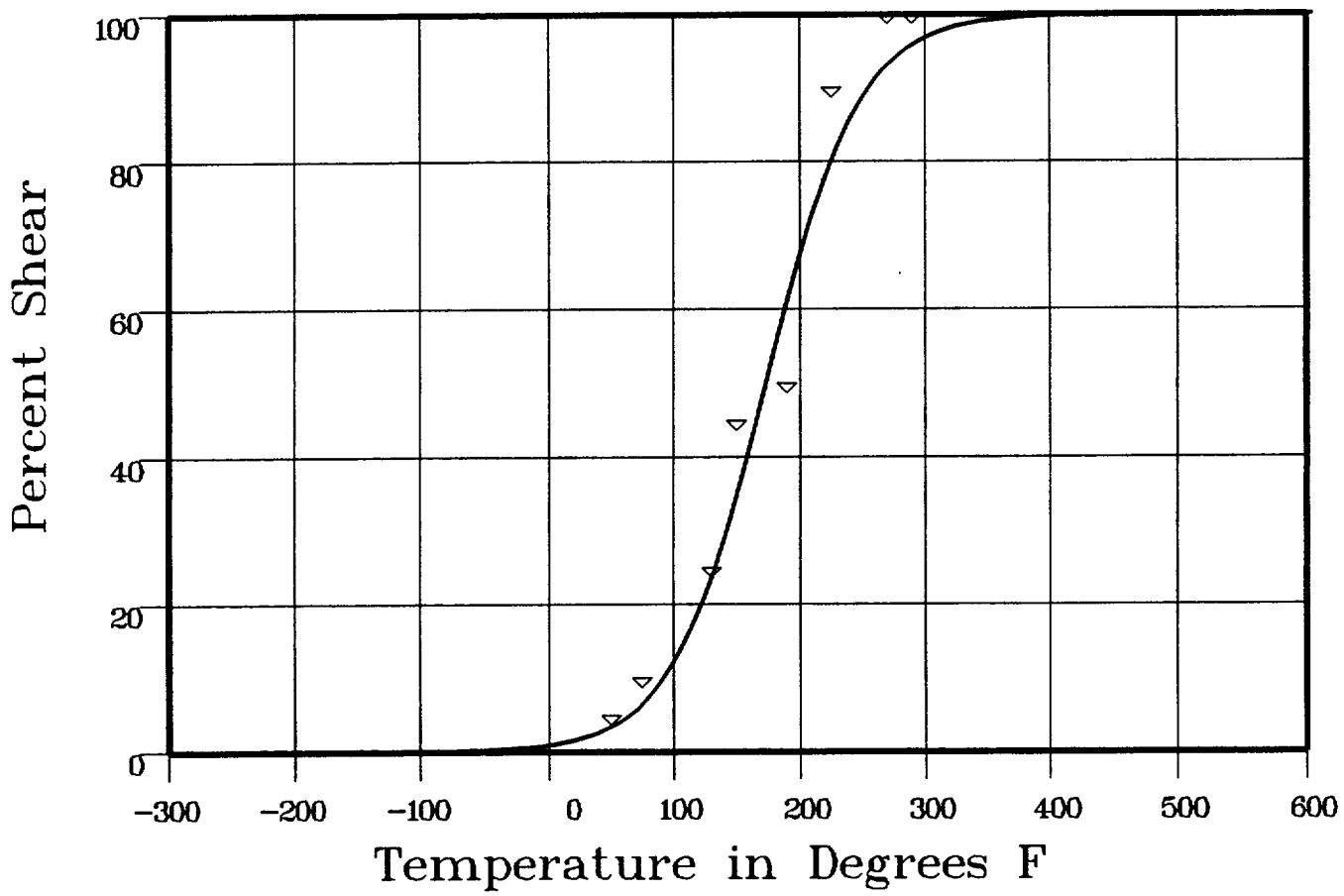
A = 50	B = 50	C = 73.98	T0 = 168.45

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

Temperature at 50% Shear: 168.4

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: Y Material: PLATE SA533B1 Ori.: LT Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
50	5	3.9	1.09
75	10	7.4	2.59
130	25	26.12	-1.12
150	45	37.77	7.22
190	50	64.16	-14.16
225	90	82.17	7.82

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

CAPSULE Y (LONGITUDINAL ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: LT

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
270	100	93.96	6.03
290	100	96.39	3.6

SUM of RESIDUALS = 13.09

UNIRRADIATED (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:06:48 on 05-03-2001

Page 1

Coefficients of Curve 1

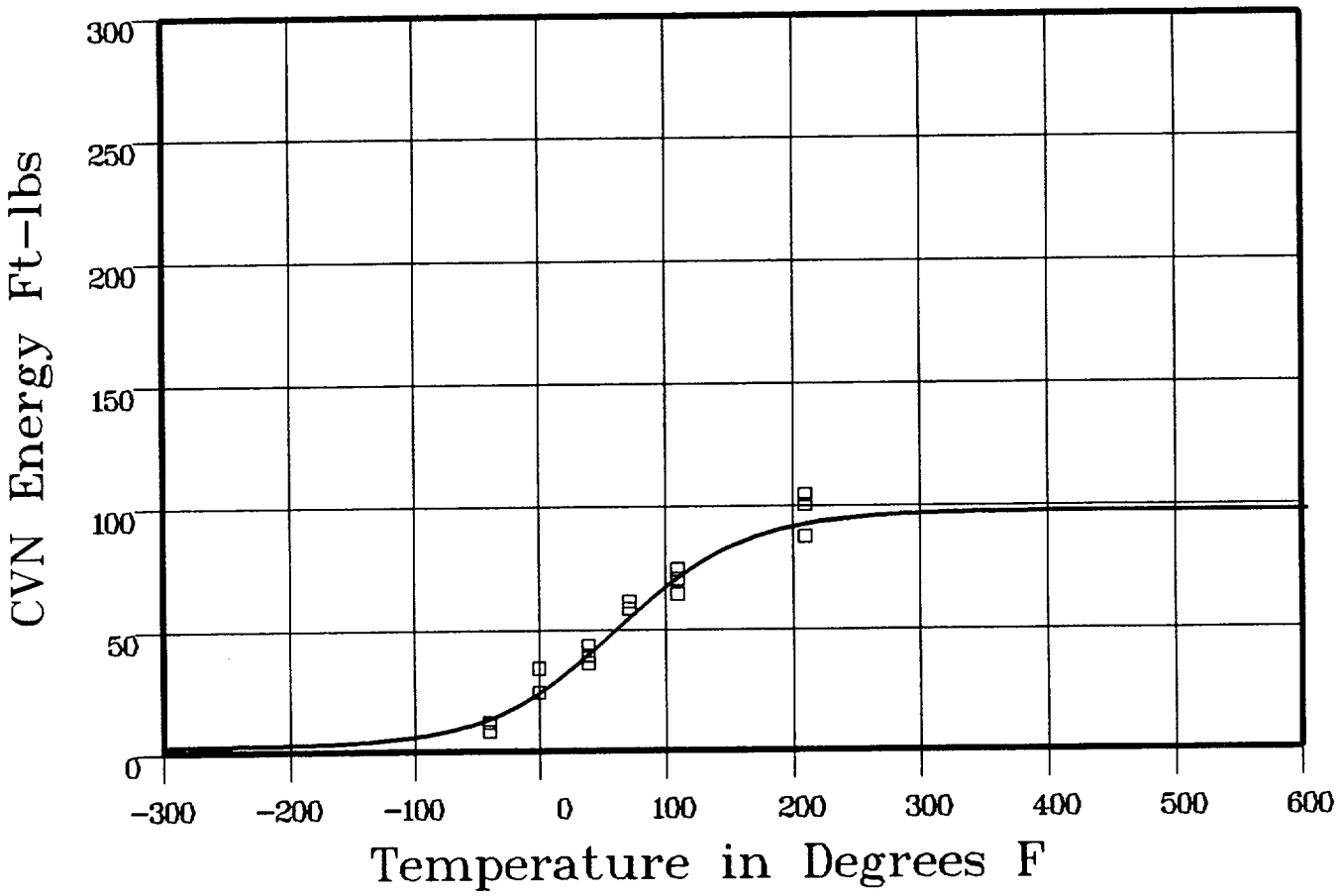
A = 49.59	B = 47.4	C = 100.99	T0 = 56.71

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

Upper Shelf Energy: 97 Fixed Temp. at 30 ft-lbs: 12.2 Temp. at 50 ft-lbs: 57.5 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: UNIRR Material: PLATE SA533B1 Ori: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-40	8	14.37	-6.37
-40	12	14.37	-2.37
-40	12	14.37	-2.37
0	34	25.46	8.53
0	34	25.46	8.53
0	24	25.46	-1.46
40	39	41.82	-2.82
40	36	41.82	-5.82
40	43	41.82	1.17

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

UNIRRADIATED (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
72	58	56.71	1.28
72	61	56.71	4.28
72	58	56.71	1.28
110	70	72.51	-2.51
110	74	72.51	1.48
110	64	72.51	-8.51
210	104	92.65	11.34
210	87	92.65	-5.65
210	100	92.65	7.34

SUM of RESIDUALS = 7.34

CAPSULE T (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:06:48 on 05-03-2001

Page 1

Coefficients of Curve 2

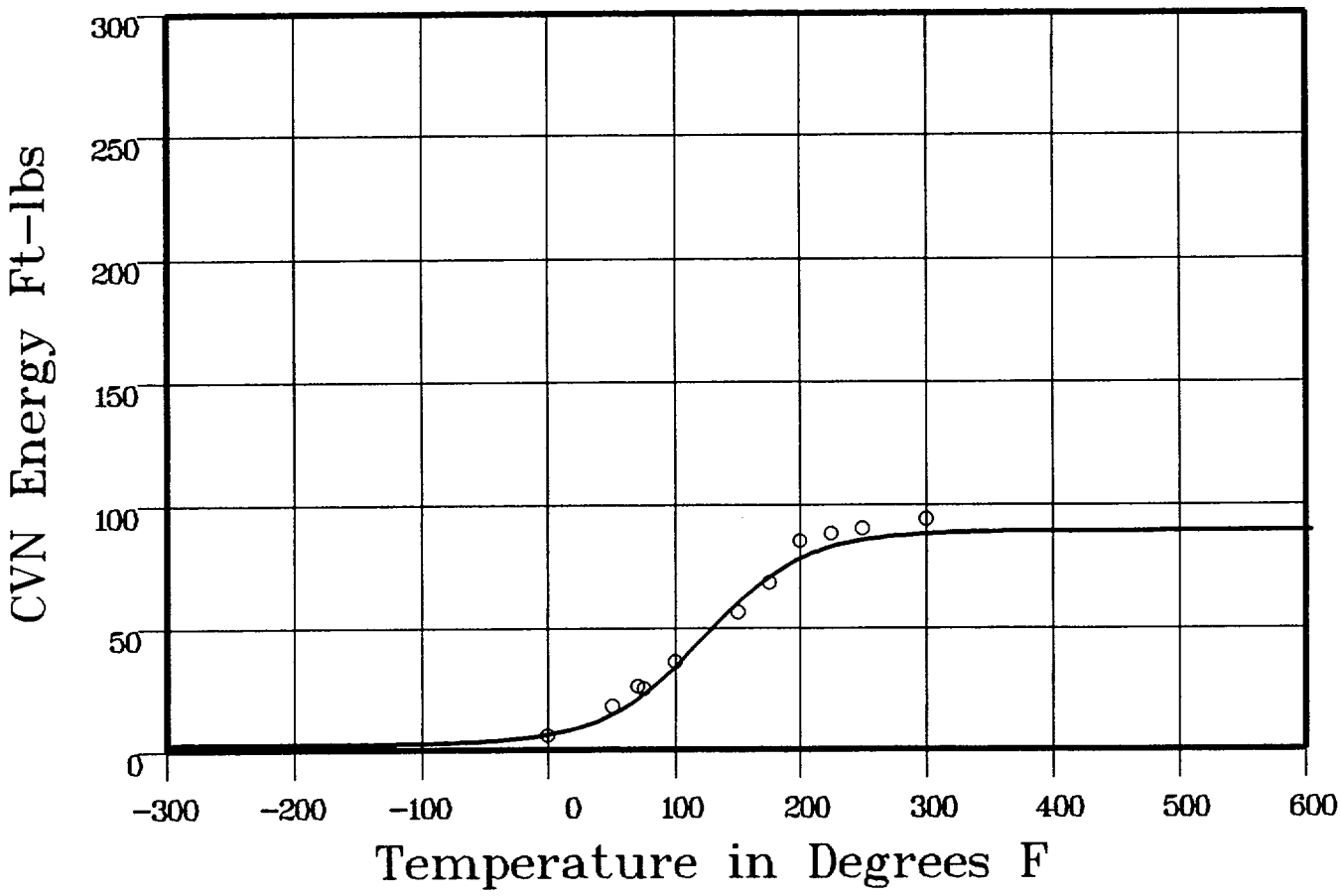
A = 45.59	B = 43.4	C = 81.42	T0 = 117.77

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

Upper Shelf Energy: 89 Fixed Temp. at 30 ft-lbs: 87.1 Temp. at 50 ft-lbs: 126 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
0	6	6.75	-.75
50	18	16.01	1.98
70	26	22.7	3.29
75	25	24.69	.3
100	36	36.27	-.27
150	56	61.93	-5.93
175	68	71.9	-3.9
200	85	78.83	6.16

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

CAPSULE T (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
225	88	83.18	4.81
250	90	85.75	4.24
300	94	88.02	5.97

SUM of RESIDUALS = 15.92

CAPSULE U (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:06:48 on 05-03-2001

Page 1

Coefficients of Curve 3

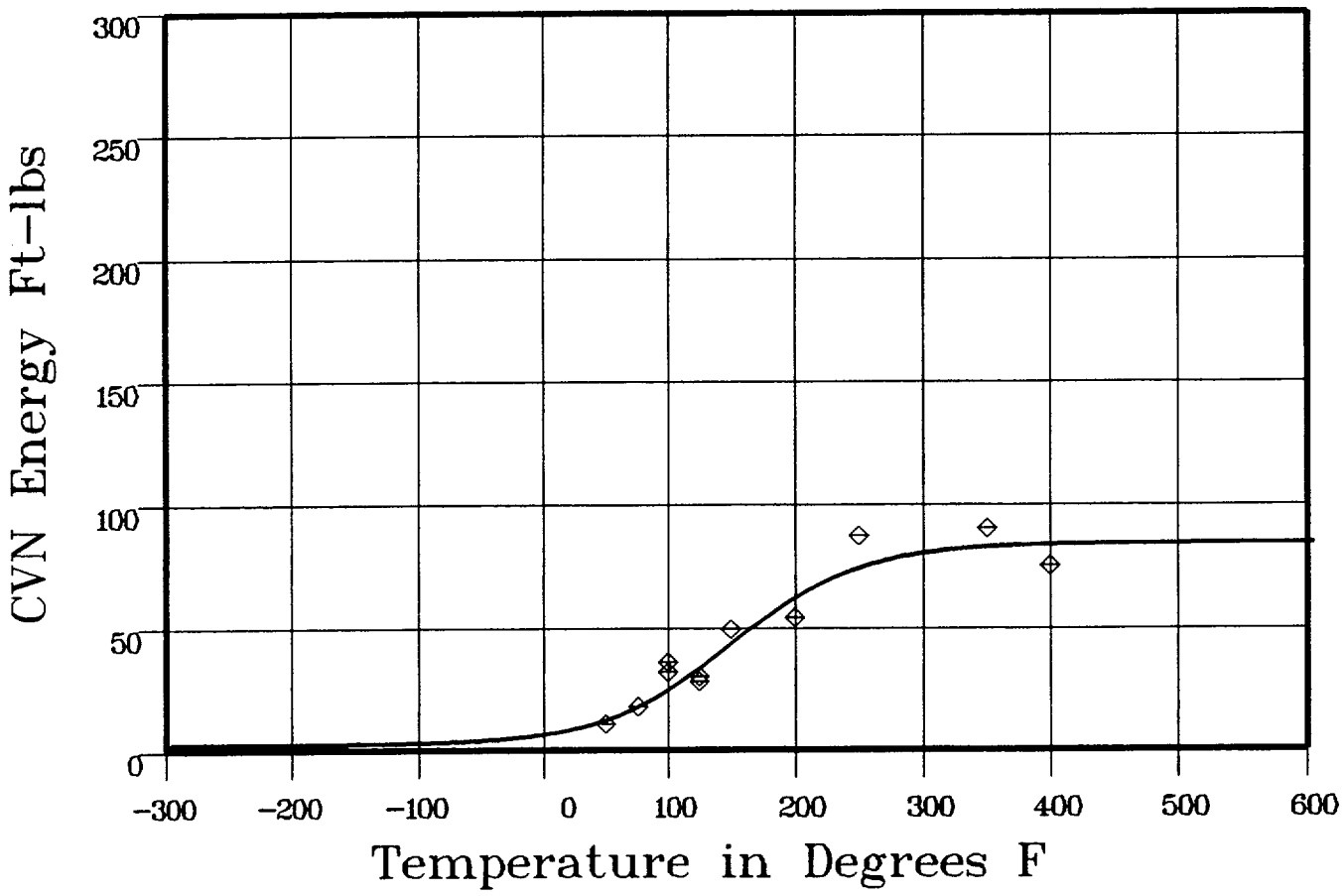
A = 43.09	B = 40.9	C = 102.01	T0 = 144.43

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

Upper Shelf Energy: 84 Fixed Temp. at 30 ft-lbs: 110.5 Temp. at 50 ft-lbs: 161.8 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
50	11	13.3	-2.3
76	18	19.15	-1.15
100	36	26.33	9.66
100	32	26.33	5.66
125	28	35.4	-7.4
125	30	35.4	-5.4
150	49	45.32	3.67
200	54	63.4	-9.4

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

CAPSULE U (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
250	87	74.83	12.16
350	90	82.57	7.42
400	75	83.45	-8.45

SUM of RESIDUALS = 4.48

CAPSULE X (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:06:48 on 05-03-2001

Page 1

Coefficients of Curve 4

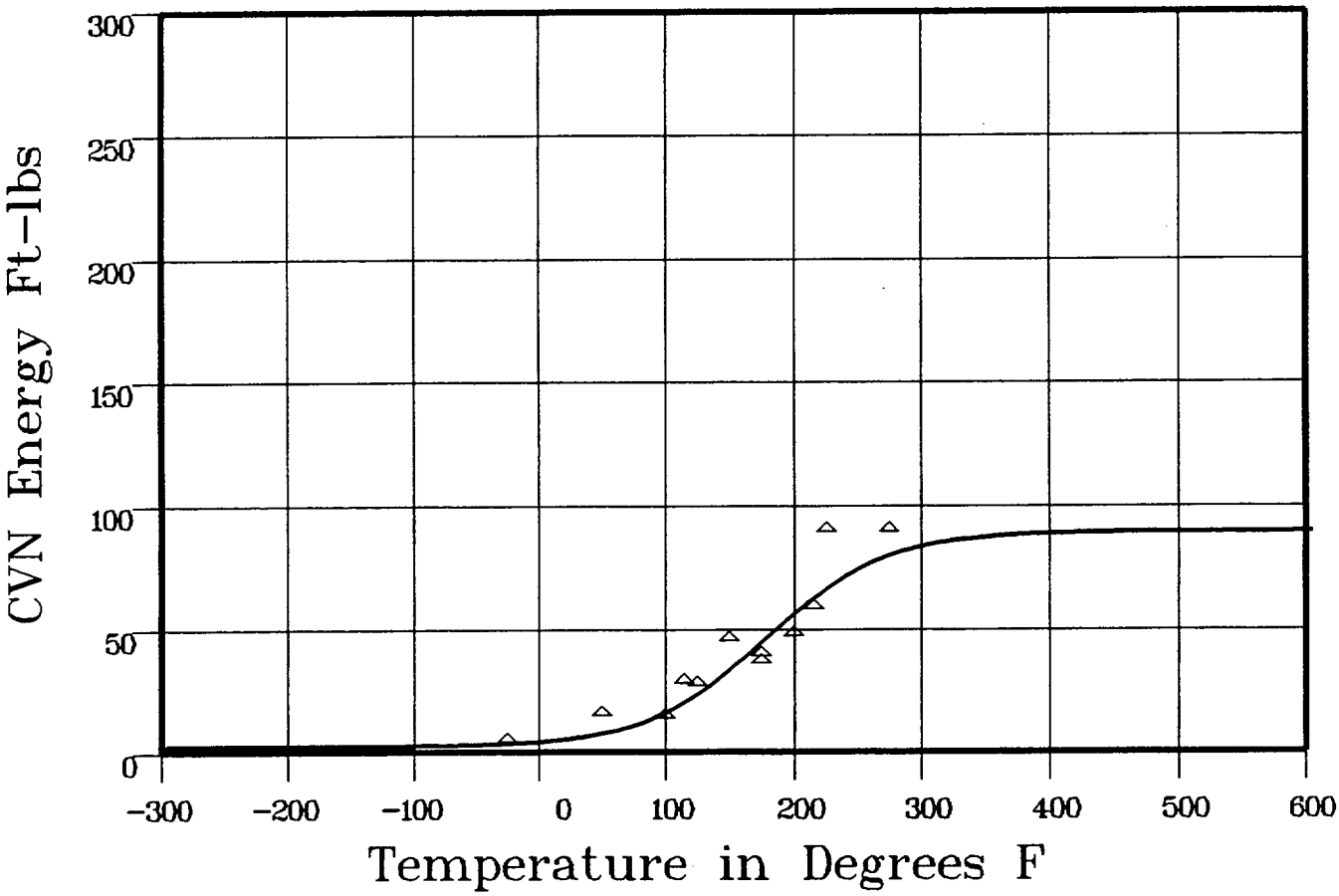
A = 45.59	B = 43.4	C = 93.15	T0 = 172.5

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

Upper Shelf Energy: 89 Fixed Temp. at 30 ft-lbs: 137.4 Temp. at 50 ft-lbs: 181.9 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: X Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-25	4	3.43	.56
50	15	8.03	6.96
100	14	17.31	-3.31
115	28	21.76	6.23
125	27	25.2	1.79
150	45	35.31	9.68
175	36	46.76	-10.76

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

CAPSULE X (TRANSVERSE ORIENTATION)

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: X Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
175	39	46.76	-7.76
200	47	58.05	-11.05
215	58	64.13	-6.13
225	89	67.76	21.23
275	89	80.34	8.65

SUM of RESIDUALS = 16.1

CAPSULE Y (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:06:48 on 05-03-2001

Page 1

Coefficients of Curve 5

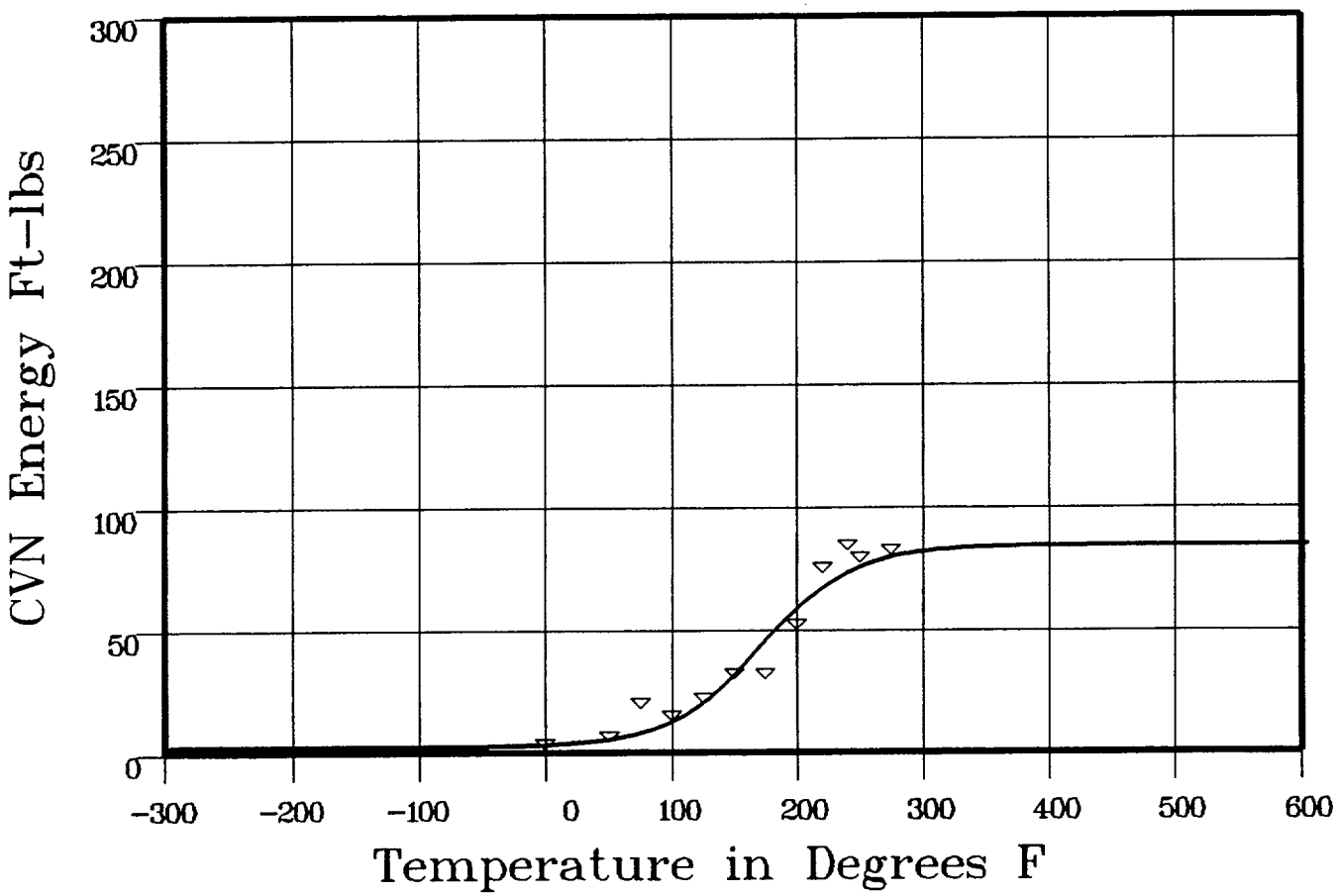
A = 43.09	B = 40.9	C = 73.72	T0 = 166.11

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

Upper Shelf Energy: 84 Fixed Temp. at 30 ft-lbs: 141.6 Temp. at 50 ft-lbs: 178.6 Lower Shelf Energy: 2.19 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: Y Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
0	5	3.09	1.9
50	8	5.56	2.43
75	22	8.56	13.43
100	17	13.86	3.13
125	24	22.39	1.6
150	34	34.3	-.3

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

CAPSULE Y (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
175	34	48	-14
200	54	60.67	-6.67
220	77	68.6	8.39
240	86	74.28	11.71
250	81	76.37	4.62
275	84	79.94	4.05

SUM of RESIDUALS = 30.3

UNIRRADIATED (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:28:03 on 05-03-2001

Page 1

Coefficients of Curve 1

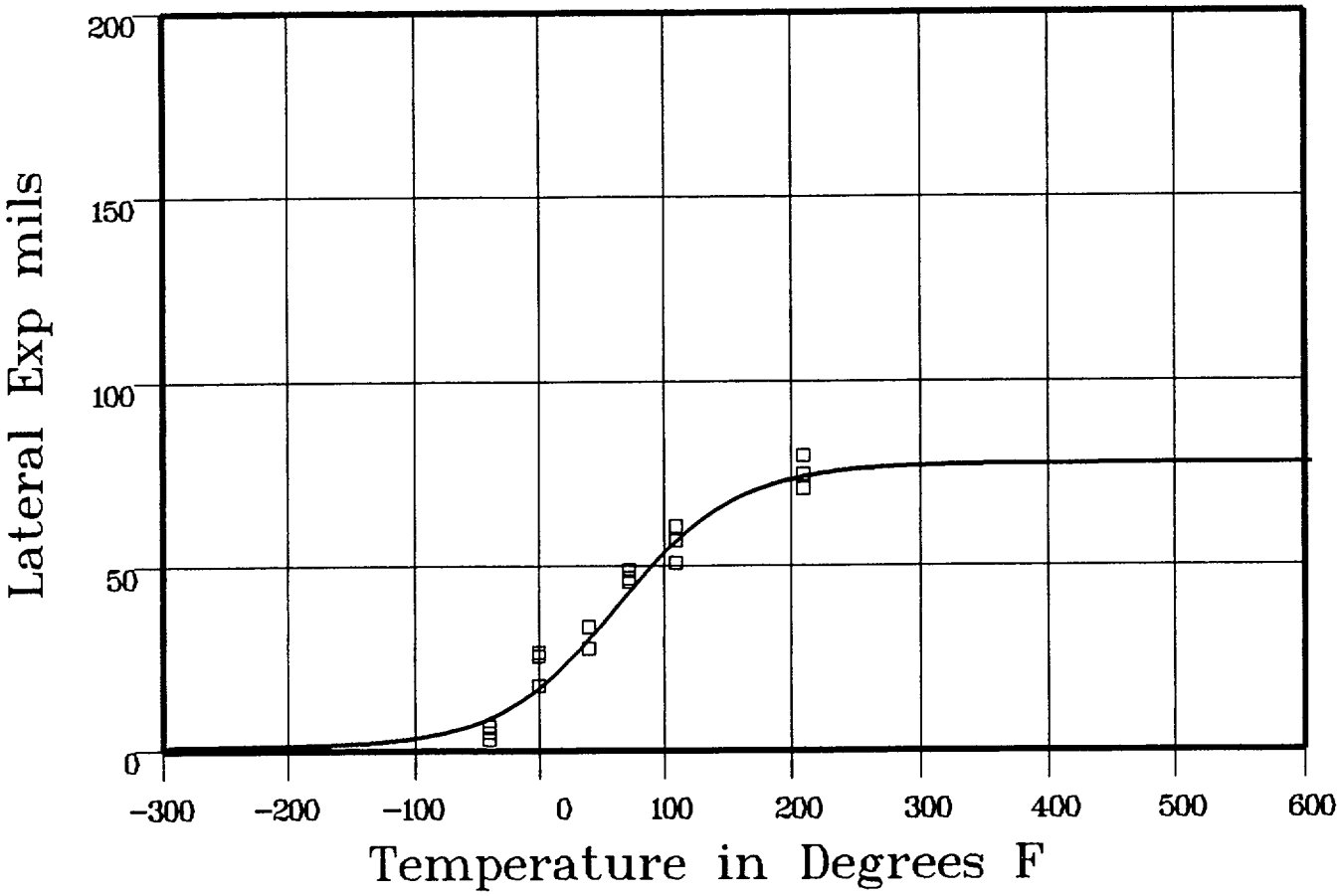
A = 39.37	B = 38.37	C = 95.89	T0 = 57.65

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

Upper Shelf L.E.: 77.75 Temperature at L.E. 35: 46.6 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-40	3	9.85	-6.85
-40	7	9.85	-2.85
-40	5	9.85	-4.85
0	27	18.73	8.26
0	26	18.73	7.26
0	18	18.73	-.73
40	28	32.38	-4.38
40	28	32.38	-4.38
40	34	32.38	1.61

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

UNIRRADIATED (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
72	47	45.07	1.92
72	49	45.07	3.92
72	46	45.07	.92
110	57	58.46	-1.46
110	61	58.46	2.53
110	51	58.46	-7.46
210	75	74.67	.32
210	71	74.67	-3.67
210	80	74.67	5.32

SUM of RESIDUALS = -4.57

CAPSULE T (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:28:03 on 05-03-2001

Page 1

Coefficients of Curve 2

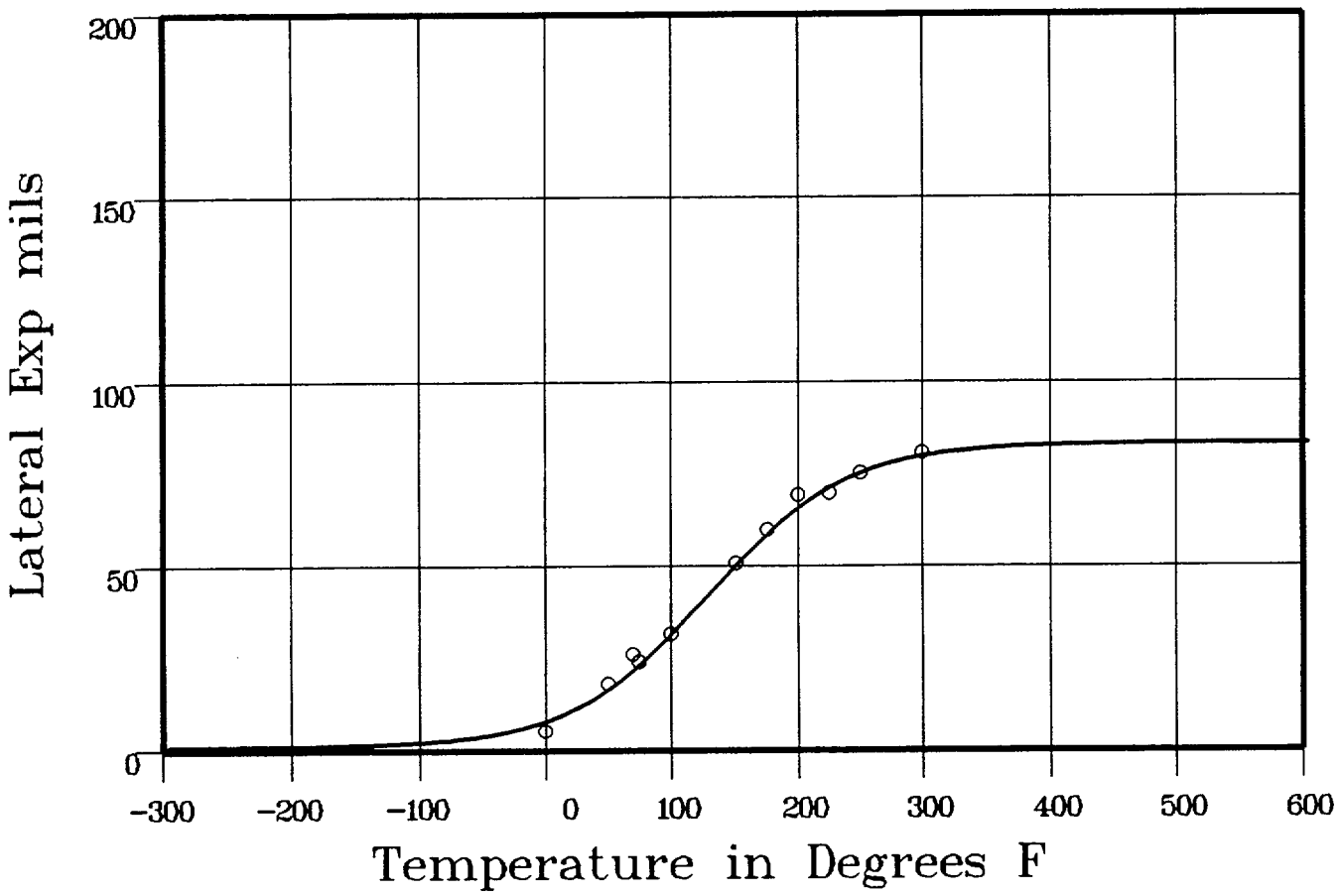
A = 42.22	B = 41.22	C = 109.4	T0 = 123.75

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

Upper Shelf L.E.: 83.44 Temperature at L.E. 35: 104.3 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
0	5.5	8.77	-3.27
50	18.5	17.99	.5
70	26.5	23.45	3.04
75	24.5	24.97	-.47
100	32	33.41	-1.41
150	51	51.92	-.92
175	60	60.23	-.23
200	69.5	67.05	2.44

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

CAPSULE T (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
225	70	72.24	-2.24
250	75.5	75.98	-.48
300	81	80.28	.71

SUM of RESIDUALS = -2.34

CAPSULE U (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:28:03 on 05-03-2001

Page 1

Coefficients of Curve 3

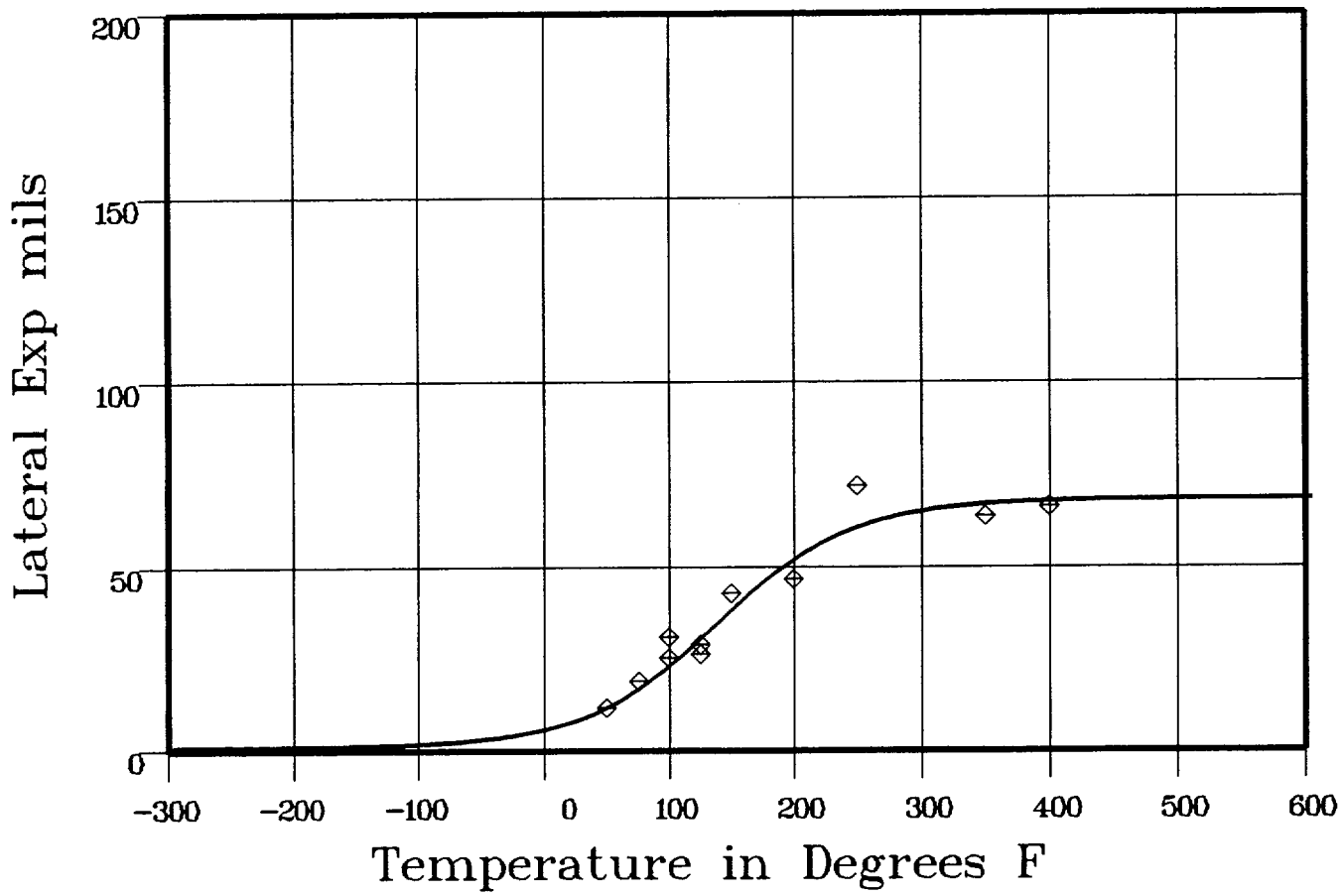
A = 34.68	B = 33.68	C = 107.33	T0 = 133.07

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

Upper Shelf L.E.: 68.36 Temperature at L.E. 35: 134 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
50	12	12.81	-.81
76	19	18.29	.7
100	31	24.62	6.37
100	25.5	24.62	.87
125	26.5	32.15	-5.65
125	29	32.15	-3.15
150	43	39.95	3.04
200	47	53.33	-6.33

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

CAPSULE U (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
250	72	61.51	10.48
350	64	67.2	-3.2
400	66.5	67.9	-1.4

SUM of RESIDUALS = .92

CAPSULE X (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:28:03 on 05-03-2001

Page 1

Coefficients of Curve 4

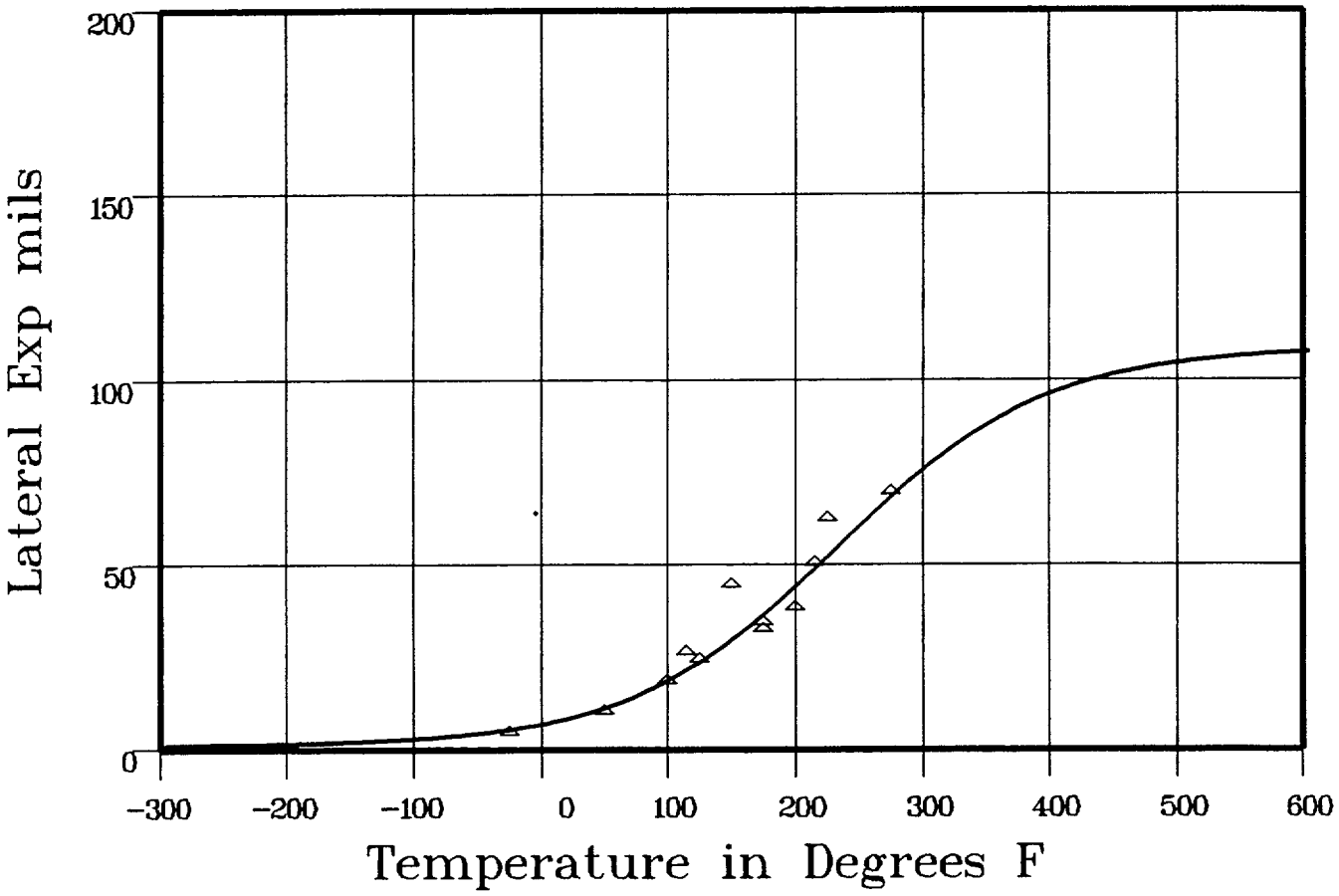
A = 54.83	B = 53.83	C = 164.33	T0 = 227.81

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

Upper Shelf L.E.: 108.66 Temperature at L.E. 35: 164.2 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: X Material: PLATE SA533B1 Ori: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-25	4	5.74	-1.74
50	10	12.09	-2.09
100	18	19.76	-1.76
115	26	22.76	3.23
125	24	24.95	-.95
150	44	31.09	12.9
175	32	38.1	-6.1

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

CAPSULE X (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: X Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
175	34	38.1	-4.1
200	38	45.8	-7.8
215	50	50.64	-.64
225	62	53.91	8.08
275	69	69.88	-.88

SUM of RESIDUALS = -1.87

CAPSULE Y (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:28:03 on 05-03-2001

Page 1

Coefficients of Curve 5

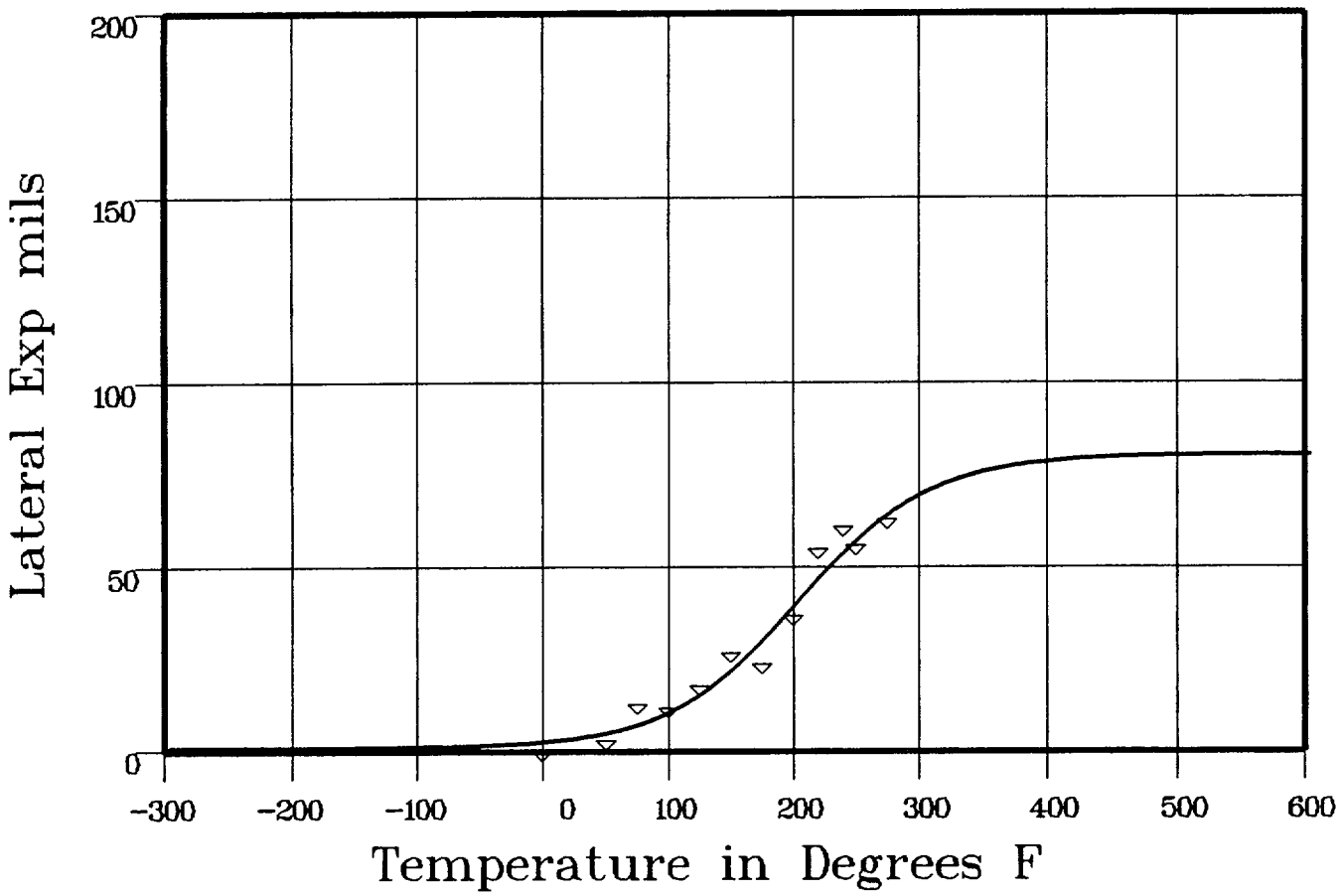
A = 40.81	B = 39.81	C = 105.72	T0 = 198.76

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

Upper Shelf L.E.: 80.62 Temperature at L.E. 35: 183.2 Lower Shelf L.E.: 1 Fixed

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: Y Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
0	0	2.81	-2.81
50	3	5.5	-2.5
75	13	7.98	5.01
100	12	11.64	.35
125	18	16.8	1.19
150	27	23.64	3.35

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

CAPSULE Y (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
175	24	32.01	-8.01
200	37	41.27	-4.27
220	55	48.7	6.29
240	61	55.59	5.4
250	56	58.72	-2.72
275	63	65.4	-2.4

SUM of RESIDUALS = -1.13

UNIRRADIATED (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:34:58 on 05-03-2001

Page 1

Coefficients of Curve 1

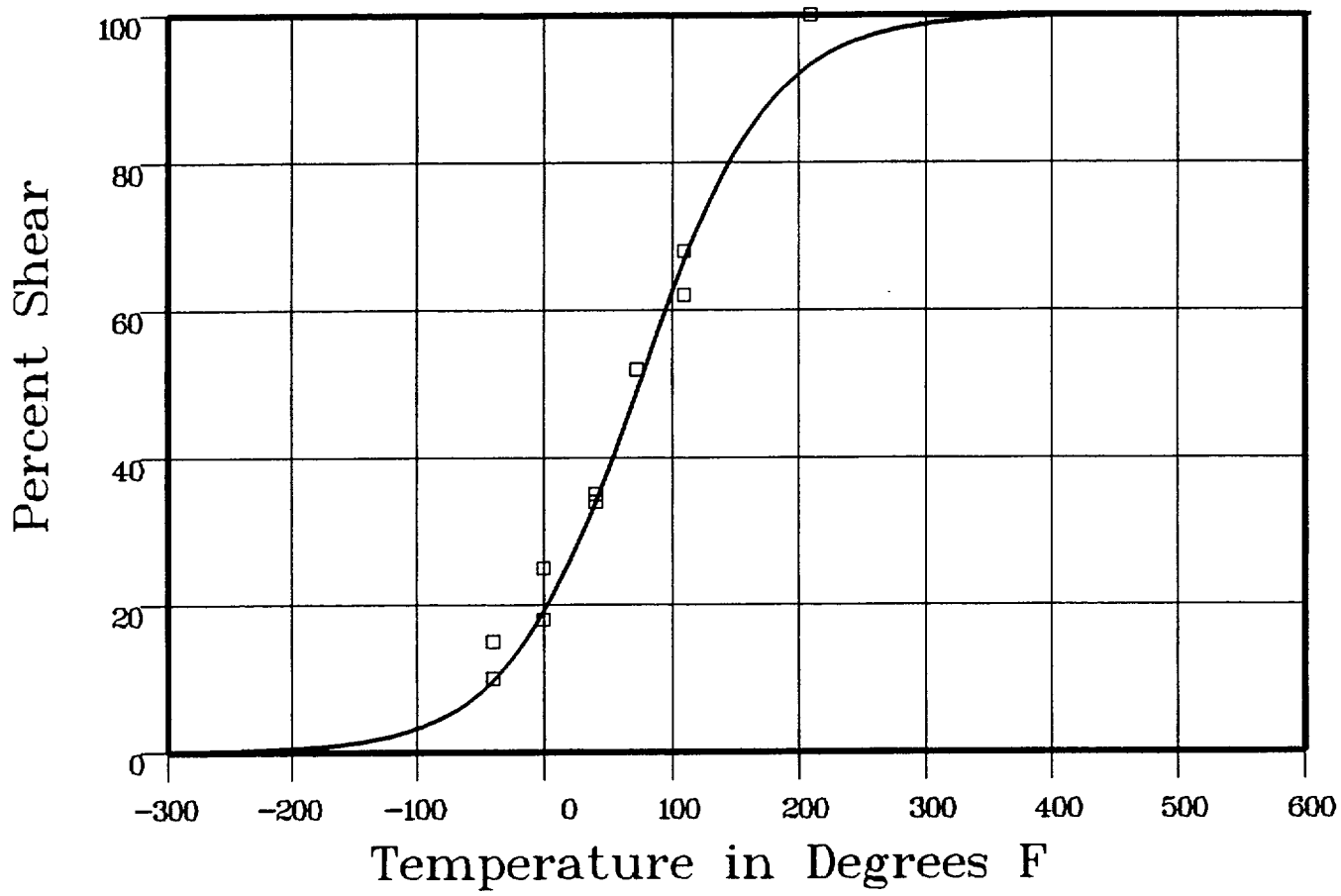
A = 50	B = 50	C = 102.81	T0 = 69.37

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

Temperature at 50% Shear: 69.3

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-40	15	10.64	4.35
-40	10	10.64	-.64
-40	10	10.64	-.64
0	25	20.59	4.4
0	25	20.59	4.4
0	18	20.59	-2.59
40	35	36.09	-1.09
40	34	36.09	-2.09
40	34	36.09	-2.09

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

UNIRRADIATED (TRANSVERSE ORIENTATION)

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
72	52	51.27	.72
72	52	51.27	.72
72	52	51.27	.72
110	68	68.78	-.78
110	68	68.78	-.78
110	62	68.78	-6.78
210	100	93.9	6.09
210	100	93.9	6.09
210	100	93.9	6.09

SUM of RESIDUALS = 16.08

CAPSULE T (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:34:58 on 05-03-2001

Page 1

Coefficients of Curve 2

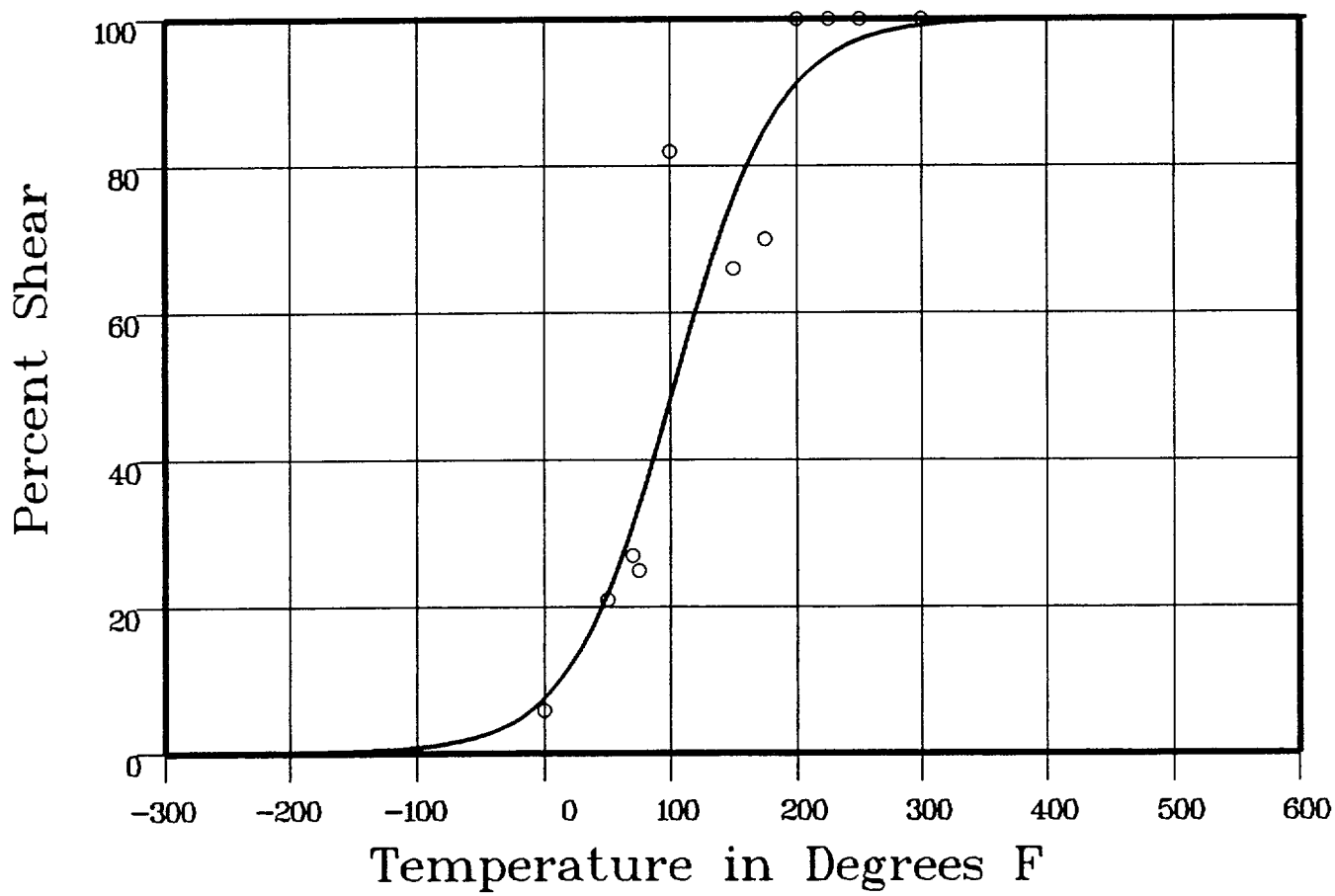
A = 50	B = 50	C = 82.93	T0 = 98.43

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

Temperature at 50% Shear: 98.4

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
0	6	8.51	-2.51
50	21	23.72	-2.72
70	27	33.49	-6.49
75	25	36.23	-11.23
100	82	50.94	31.05
150	66	77.61	-11.61
175	70	86.36	-16.36
200	100	92.04	7.95

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

CAPSULE T (TRANSVERSE ORIENTATION)

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
225	100	95.48	4.51
250	100	97.47	2.52
300	100	99.23	.76

SUM of RESIDUALS = -4.14

CAPSULE U (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:34:58 on 05-03-2001

Page 1

Coefficients of Curve 3

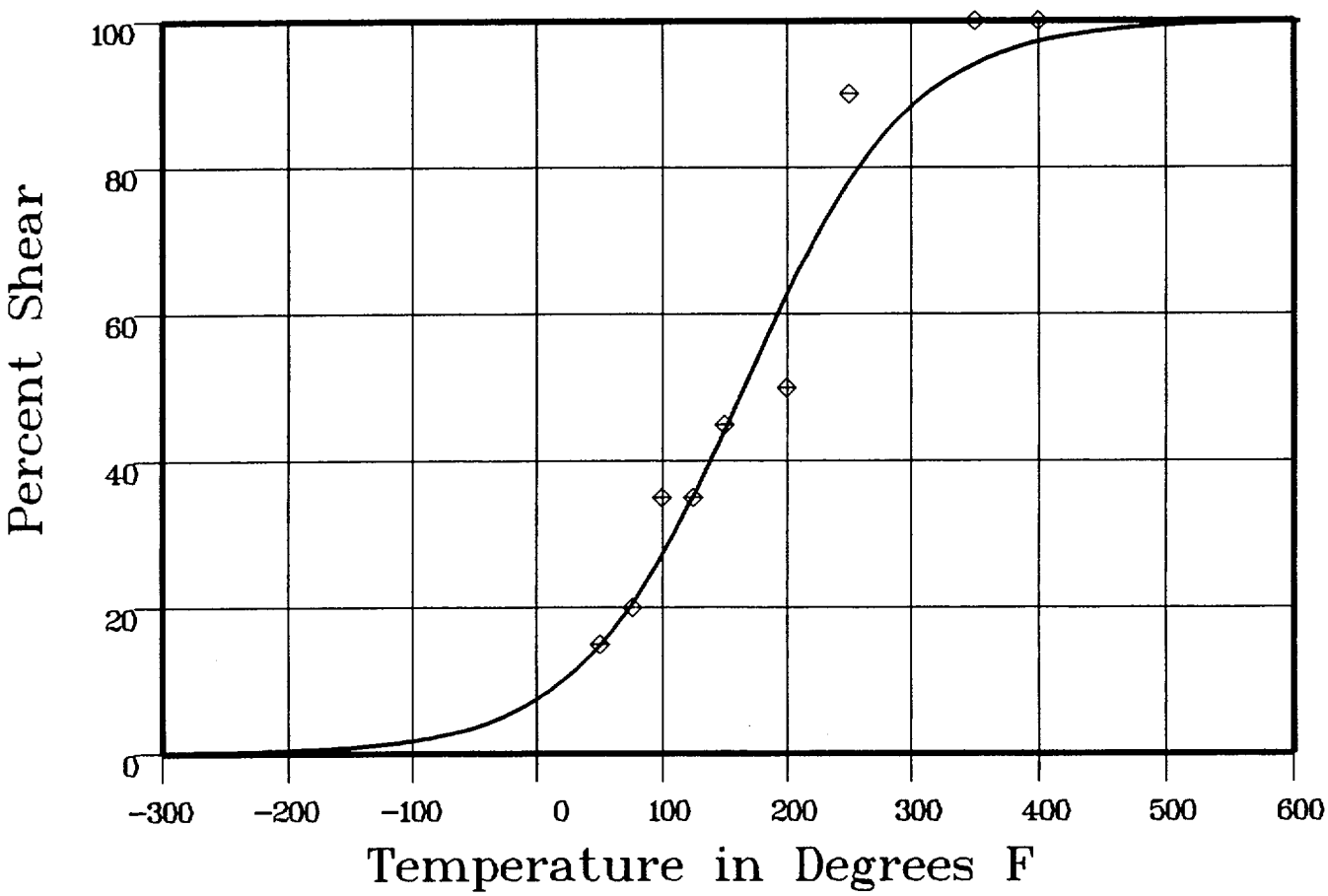
A = 50	B = 50	C = 132.76	T0 = 160.81

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

Temperature at 50% Shear: 160.8

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: PLATE SA533B1 Ori.: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
50	15	15.85	-.85
76	20	21.79	-1.79
100	35	28.57	6.42
100	35	28.57	6.42
125	35	36.82	-1.82
125	35	36.82	-1.82
150	45	45.93	-.93
200	50	64.34	-14.34

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

CAPSULE U (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
250	90	79.3	10.69
350	100	94.53	5.46
400	100	97.34	2.65

SUM of RESIDUALS = 10.08

CAPSULE X (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:34:58 on 05-03-2001

Page 1

Coefficients of Curve 4

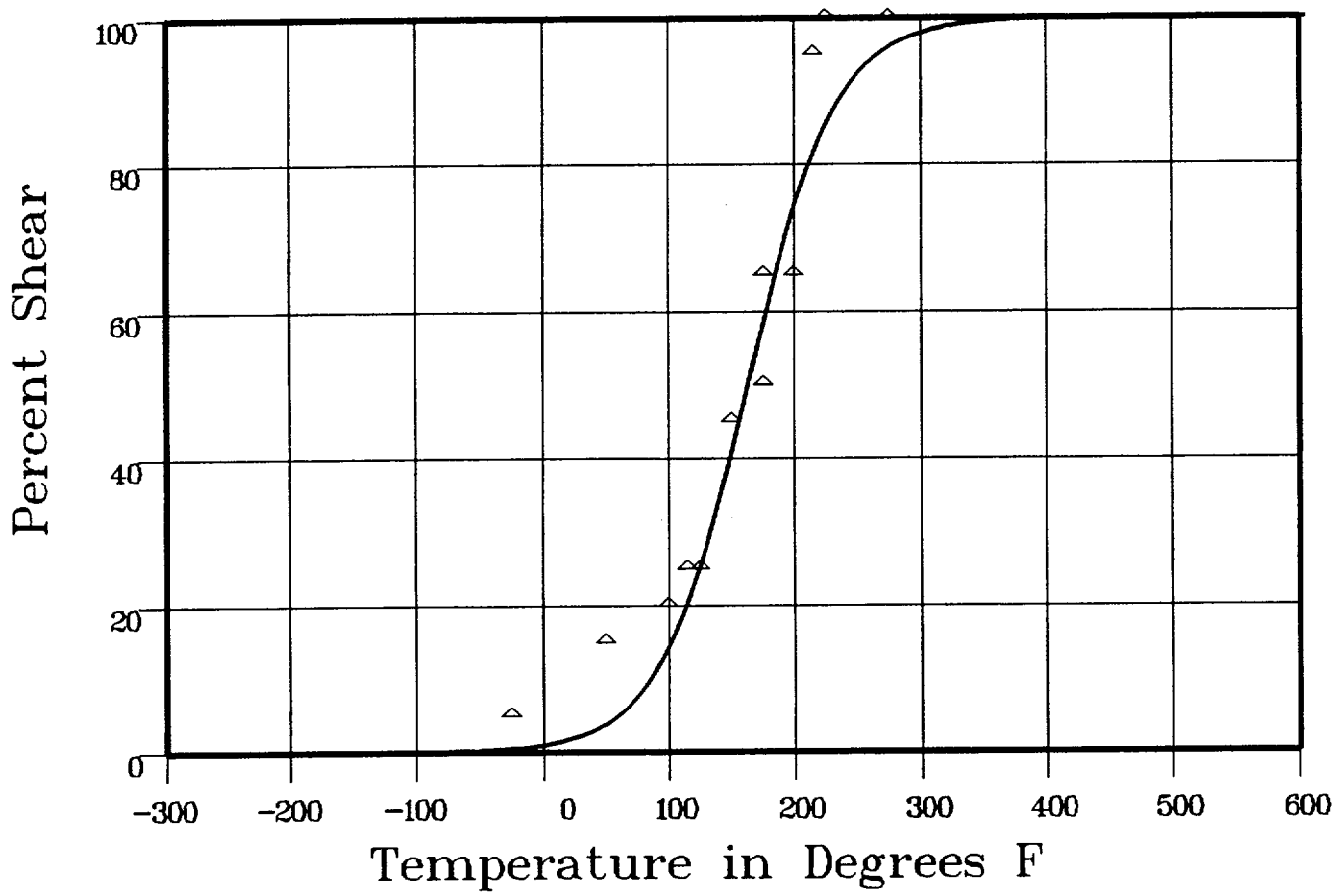
A = 50	B = 50	C = 70.25	T0 = 158.21

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

Temperature at 50% Shear: 158.2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: X Material: PLATE SA533B1 Ori: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-25	5	.53	4.46
50	15	4.39	10.6
100	20	16.01	3.98
115	25	22.61	2.38
125	25	27.97	-2.97
150	45	44.17	.82
175	50	61.72	-11.72

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

CAPSULE X (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: X Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
175	65	61.72	3.27
200	65	76.66	-11.66
215	95	83.43	11.56
225	100	87	12.99
275	100	96.52	3.47

SUM of RESIDUALS = 27.22

CAPSULE Y (TRANSVERSE ORIENTATION)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 11:34:58 on 05-03-2001

Page 1

Coefficients of Curve 5

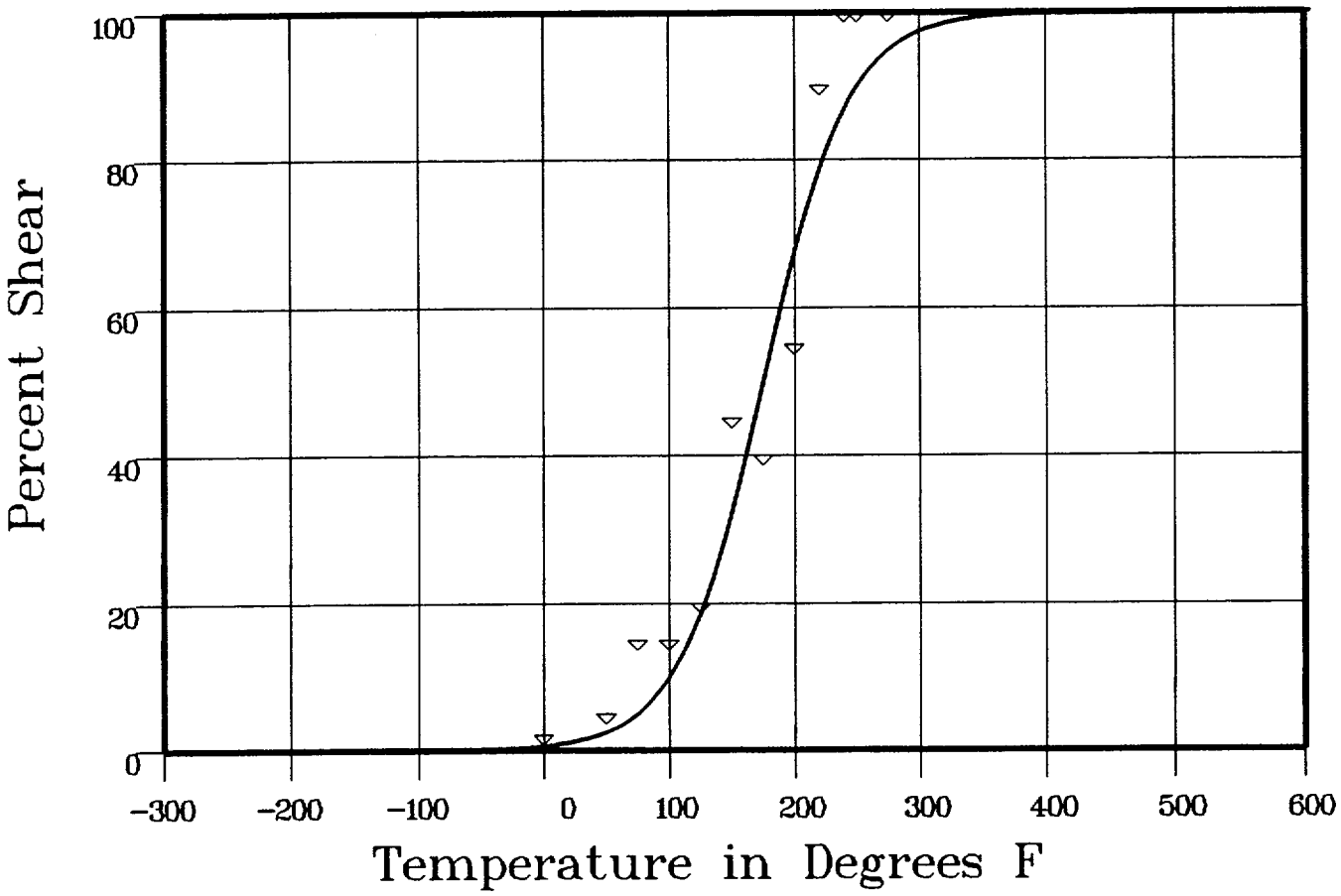
A = 50	B = 50	C = 68.34	T0 = 170.5

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

Temperature at 50% Shear: 170.5

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: Y Material: PLATE SA533B1 Ori: TL Heat #: B4712-2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
0	2	.67	1.32
50	5	2.85	2.14
75	15	5.76	9.23
100	15	11.27	3.72
125	20	20.88	-.88
150	45	35.43	9.56

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

CAPSULE Y (TRANSVERSE ORIENTATION)

Page 2

Material: PLATE SA533B1 Heat Number: B4712-2 Orientation: TL

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
175	40	53.28	-13.28
200	55	70.32	-15.32
220	90	80.97	9.02
240	100	88.42	11.57
250	100	91.1	8.89
275	100	95.51	4.48

SUM of RESIDUALS = 30.48

UNIRRADIATED (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:26:40 on 05-07-2001

Page 1

Coefficients of Curve 1

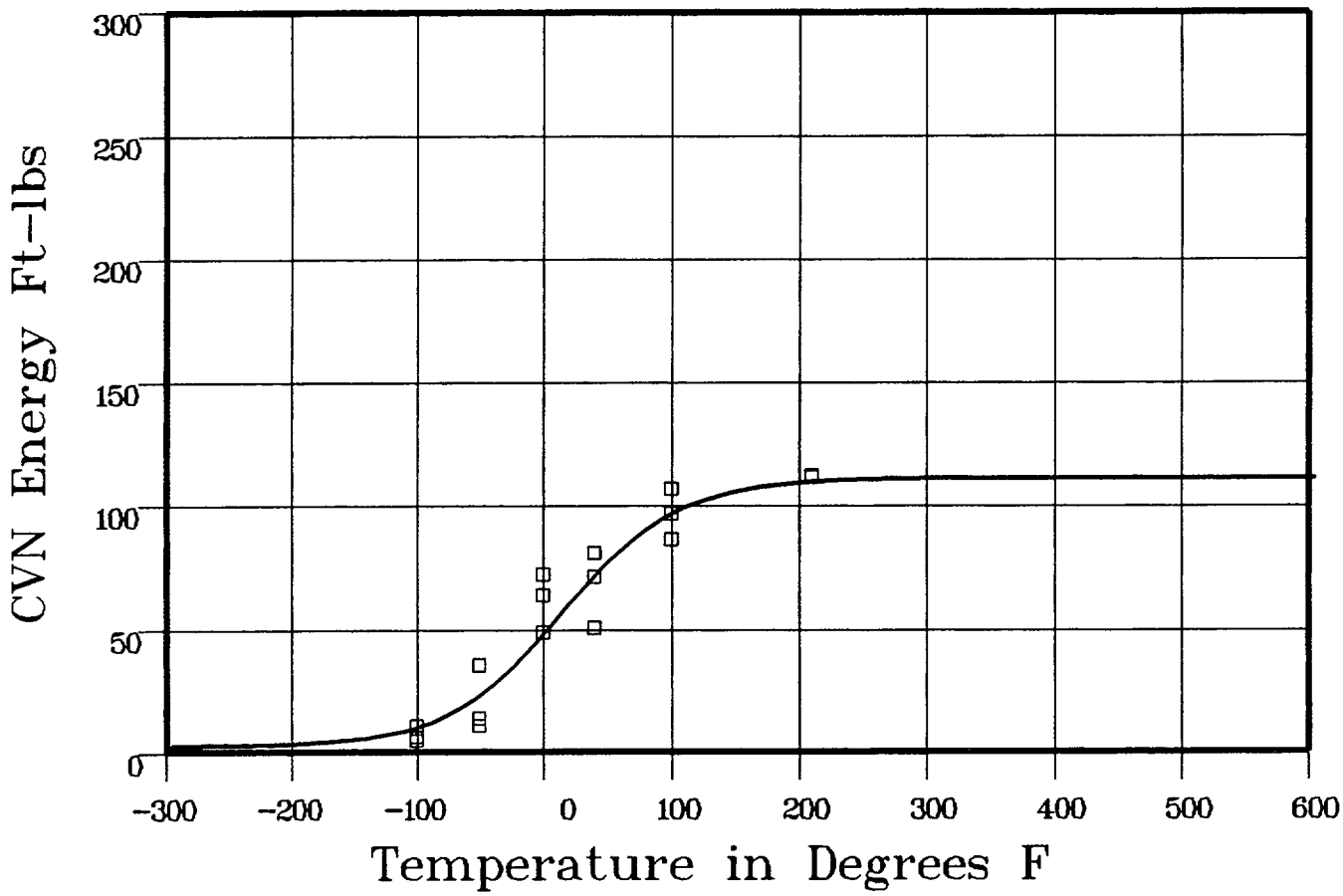
A = 56.59	B = 54.4	C = 91.11	T0 = 10.31

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

Upper Shelf Energy: 111 Fixed Temp. at 30 ft-lbs: -38.4 Temp. at 50 ft-lbs: -7 Lower Shelf Energy: 2.19 Fixed

Material: WELD Heat Number: 13253 Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-100	11	11.07	-.07
-100	6	11.07	-5.07
-100	4.5	11.07	-6.57
-50	14	25.06	-11.06
-50	35.5	25.06	10.43
-50	11	25.06	-14.06
0	72	50.46	21.53
0	63.5	50.46	13.03
0	48.5	50.46	-1.96

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

UNIRRADIATED (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
40	50.5	73.72	-23.22
40	80.5	73.72	6.77
40	71	73.72	-2.72
100	106.5	97.66	8.83
100	86	97.66	-11.66
100	96.5	97.66	-1.16
210	111.5	109.65	1.84
210	111.5	109.65	1.84
210	112	109.65	2.34

SUM of RESIDUALS = -10.97

CAPSULE T (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:26:40 on 05-07-2001

Page 1

Coefficients of Curve 2

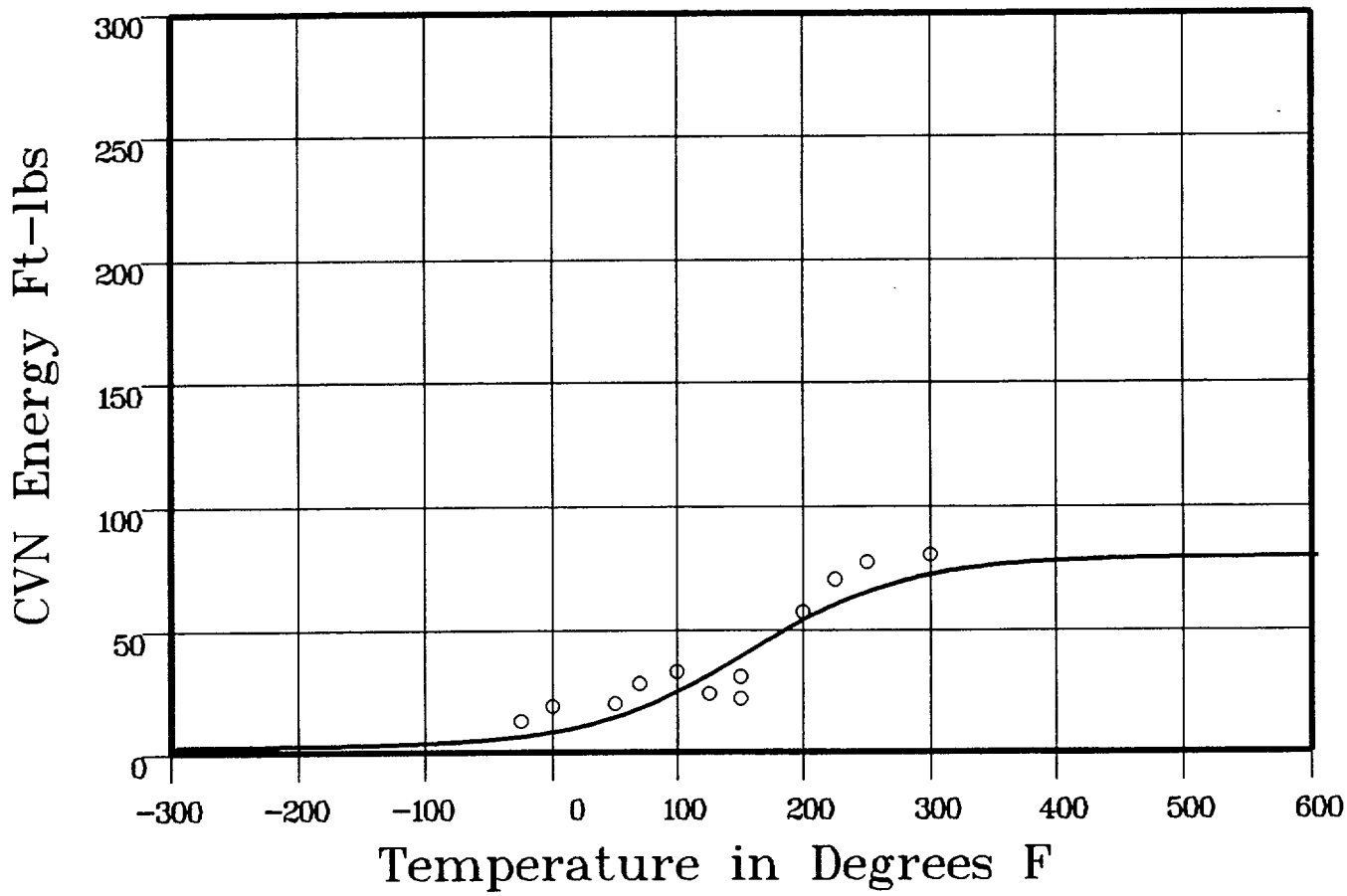
A = 40.59	B = 38.4	C = 126.39	T0 = 150.58

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

Upper Shelf Energy: 79 Fixed Temp. at 30 ft-lbs: 114.7 Temp. at 50 ft-lbs: 182.1 Lower Shelf Energy: 2.19 Fixed

Material: WELD Heat Number: 13253 Orientation:

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-25	13	6.69	6.3
0	19	8.68	10.31
50	20	15.19	4.8
70	28	18.97	9.02
100	33	26	6.99
125	24	32.93	-8.93
150	22	40.42	-18.42
150	31	40.42	-9.42

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

CAPSULE T (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
200	57	54.89	2.1
225	70	60.91	9.08
250	77	65.8	11.19
300	80	72.39	7.6

SUM of RESIDUALS = 30.66

CAPSULE U (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:26:40 on 05-07-2001

Page 1

Coefficients of Curve 3

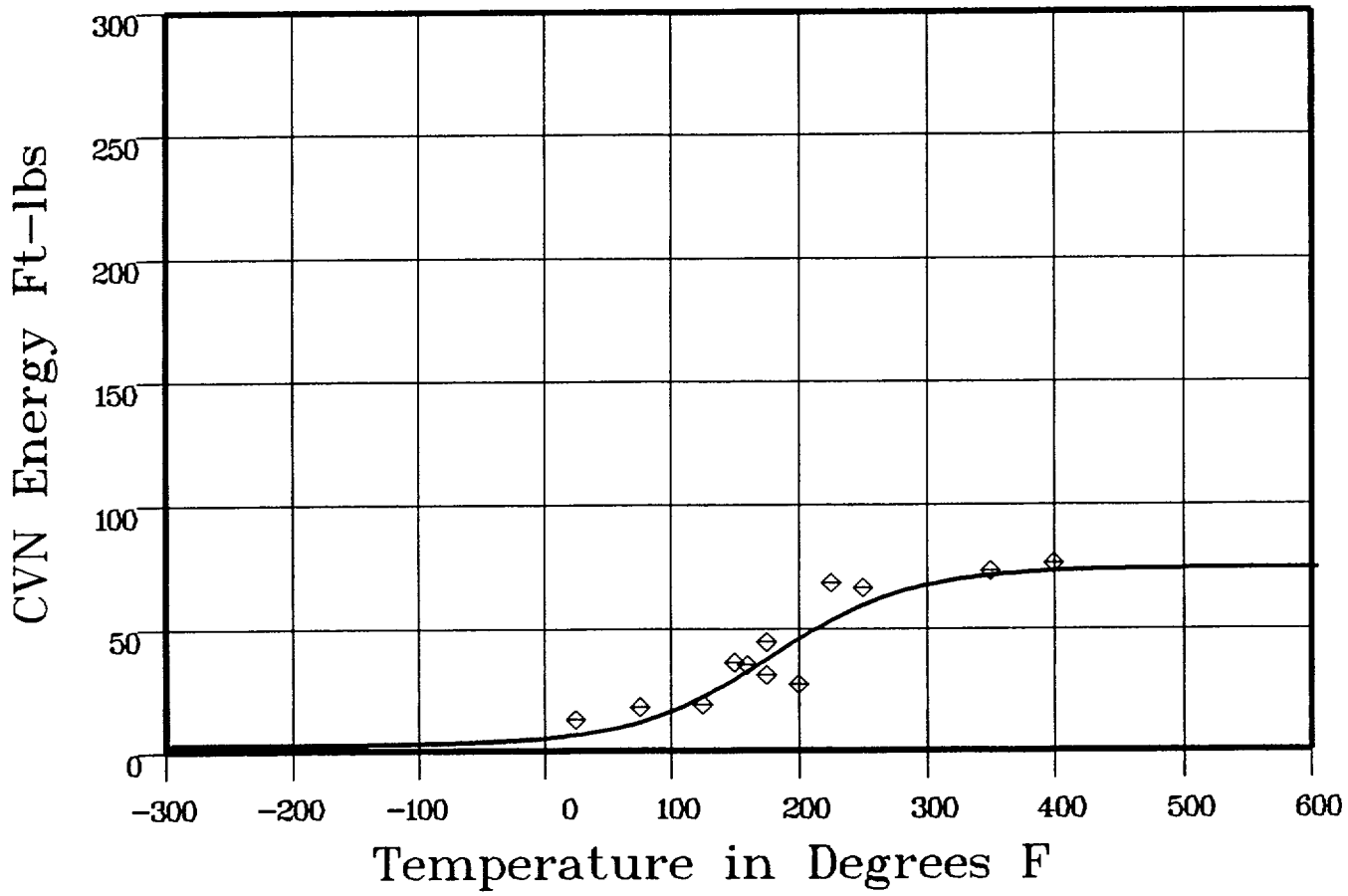
A = 38.09	B = 35.9	C = 108.96	T0 = 172.55

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

Upper Shelf Energy: 74 Fixed Temp. at 30 ft-lbs: 147.5 Temp. at 50 ft-lbs: 210 Lower Shelf Energy: 2.19 Fixed

Material: WELD Heat Number: 13253 Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
25	13	6.68	6.31
76	18	12.63	5.36
125	19	23.35	-4.35
150	36	30.77	5.22
160	35	33.98	1.01
175	31	38.9	-7.9
175	44	38.9	5.09
200	27	46.95	-19.95

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

CAPSULE U (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
225	68	54.15	13.84
250	66	60.03	5.96
350	73	71.33	1.66
400	76	72.91	3.08

SUM of RESIDUALS = 15.36

CAPSULE X (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:26:40 on 05-07-2001

Page 1

Coefficients of Curve 4

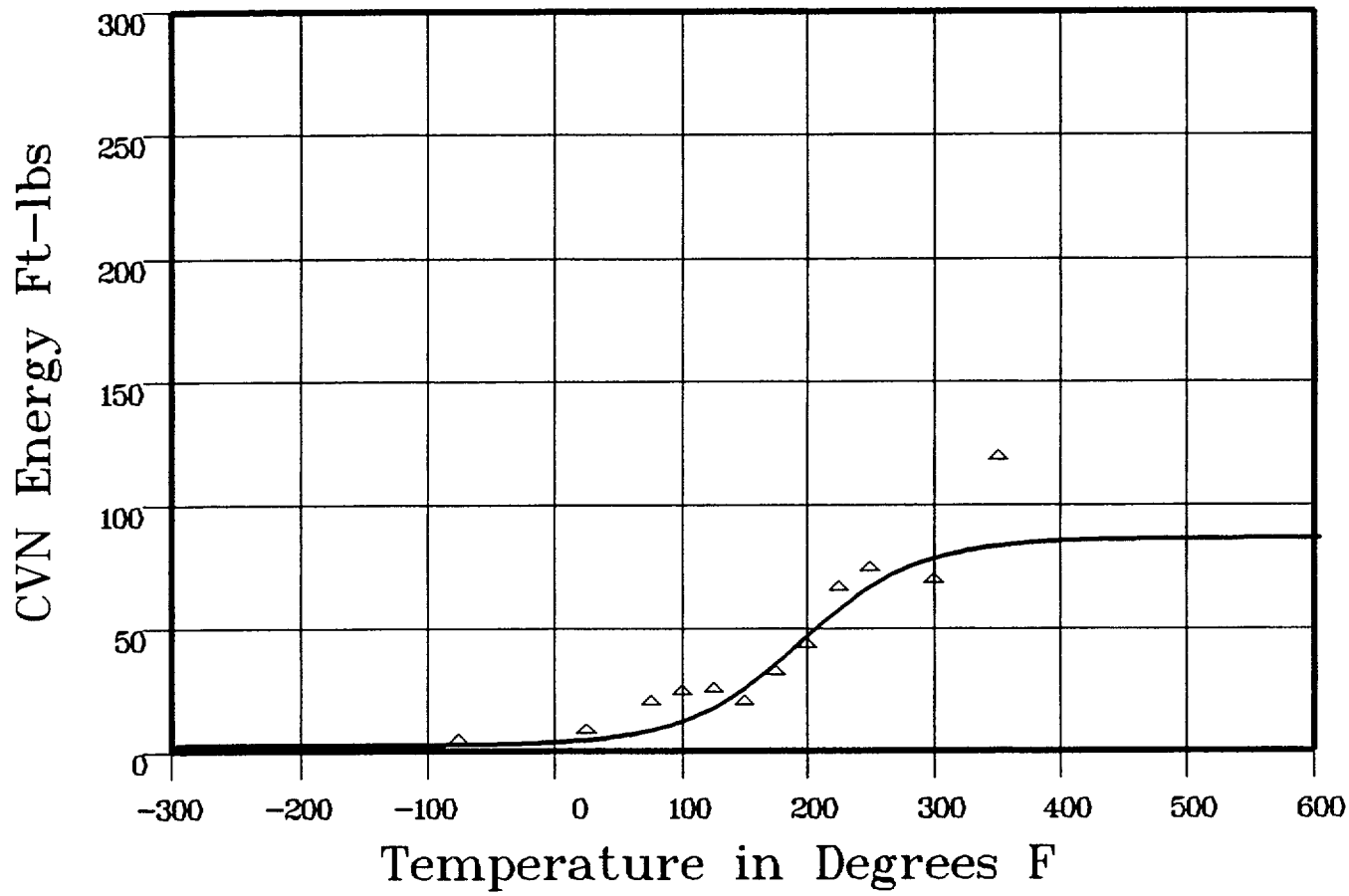
A = 44.09	B = 41.9	C = 93.43	T0 = 189.74

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

Upper Shelf Energy: 86 Fixed Temp. at 30 ft-lbs: 157 Temp. at 50 ft-lbs: 202.9 Lower Shelf Energy: 2.19 Fixed

Material: WELD Heat Number: 13253 Orientation:

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: X Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-75	3	2.48	.51
25	7	4.59	2.4
75	19	8.81	10.18
100	23	12.9	10.09
125	24	18.96	5.03
150	19	27.27	-8.27
175	31	37.54	-6.54

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

CAPSULE X (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: X Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
200	42	48.68	-6.68
225	65	59.19	5.8
250	73	67.9	5.09
300	68	78.77	-10.77
350	118	83.37	34.62

SUM of RESIDUALS = 41.47

CAPSULE Y (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:26:40 on 05-07-2001

Page 1

Coefficients of Curve 5

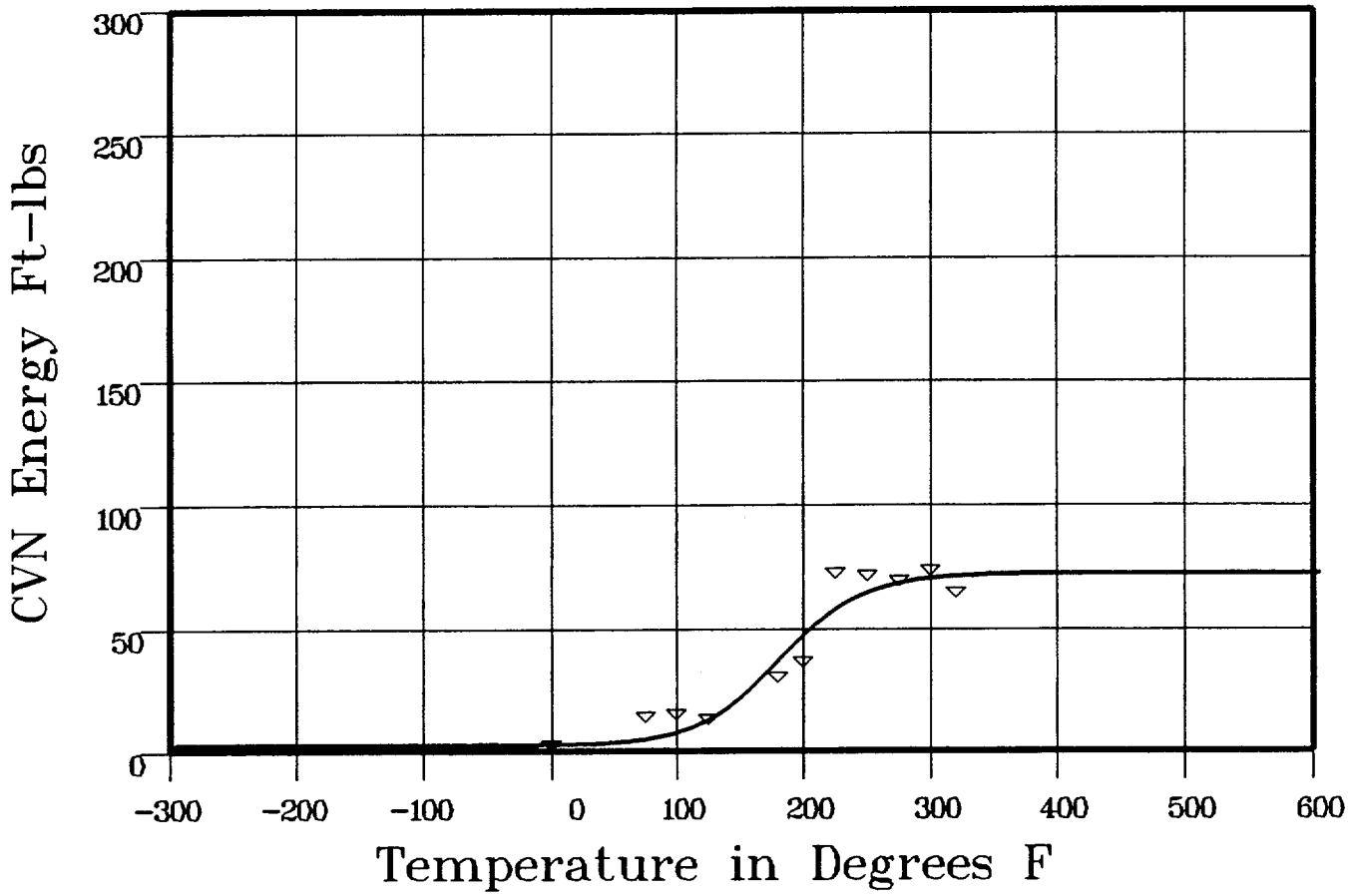
A = 37.09	B = 34.9	C = 65.77	T0 = 176.07

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

Upper Shelf Energy: 72 Fixed Temp. at 30 ft-lbs: 162.5 Temp. at 50 ft-lbs: 201.5 Lower Shelf Energy: 2.19 Fixed

Material: WELD SA533B1 Heat Number: 13253 Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: Y Material: WELD SA533B1 Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-50	3	2.27	.72
0	4	2.52	1.47
75	16	5.28	10.71
100	17	8.48	8.51
125	15	14.39	.6
180	32	39.18	-7.18

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

CAPSULE Y (WELD)

Page 2

Material: WELD SA533B1 Heat Number: 13253 Orientation:

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
200	38	49.26	-11.26
225	74	59.13	14.86
250	73	65.33	7.66
275	71	68.71	2.28
300	75	70.42	4.57
320	66	71.13	-5.13

SUM of RESIDUALS = 27.85

UNIRRADIATED (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:31:04 on 05-07-2001

Page 1

Coefficients of Curve 1

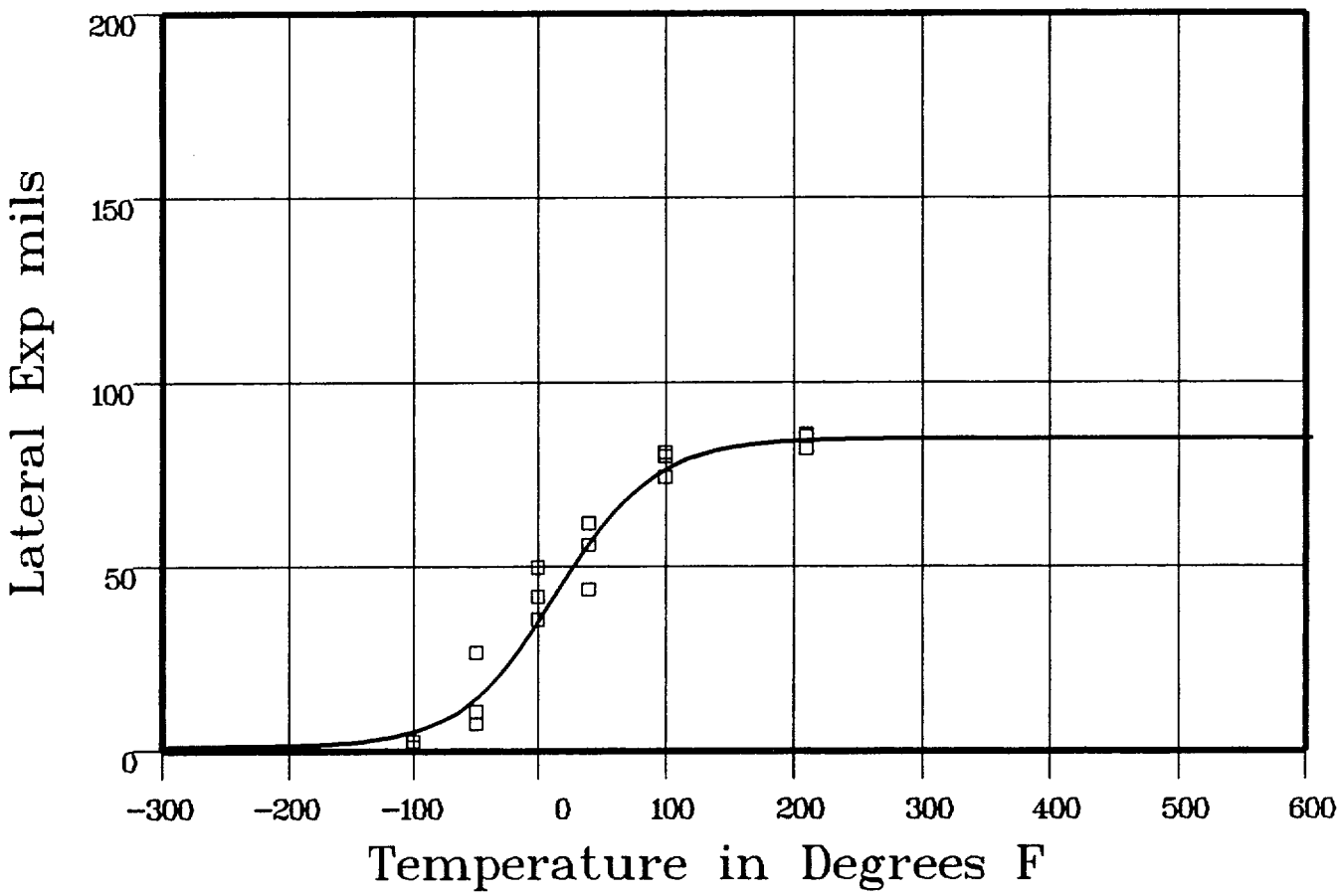
A = 42.97	B = 41.97	C = 78.33	T0 = 9.74

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

Upper Shelf L.E.: 84.94 Temperature at L.E. 35: -5.3 Lower Shelf L.E.: 1 Fixed

Material: WELD Heat Number: 13253 Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-100	2.5	5.8	-3.3
-100	1	5.8	-4.8
-100	1	5.8	-4.8
-50	11	15.99	-4.99
-50	27	15.99	11
-50	7.5	15.99	-8.49
0	36	37.77	-1.77
0	50	37.77	12.22
0	42	37.77	4.22

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

UNIRRADIATED (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
40	44	58.42	-14.42
40	62	58.42	3.57
40	56	58.42	-2.42
100	80	77.32	2.67
100	81	77.32	3.67
100	74.5	77.32	-2.82
210	86	84.43	1.56
210	85.5	84.43	1.06
210	82	84.43	-2.43

SUM of RESIDUALS = -10.3

CAPSULE T (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:31:04 on 05-07-2001

Page 1

Coefficients of Curve 2

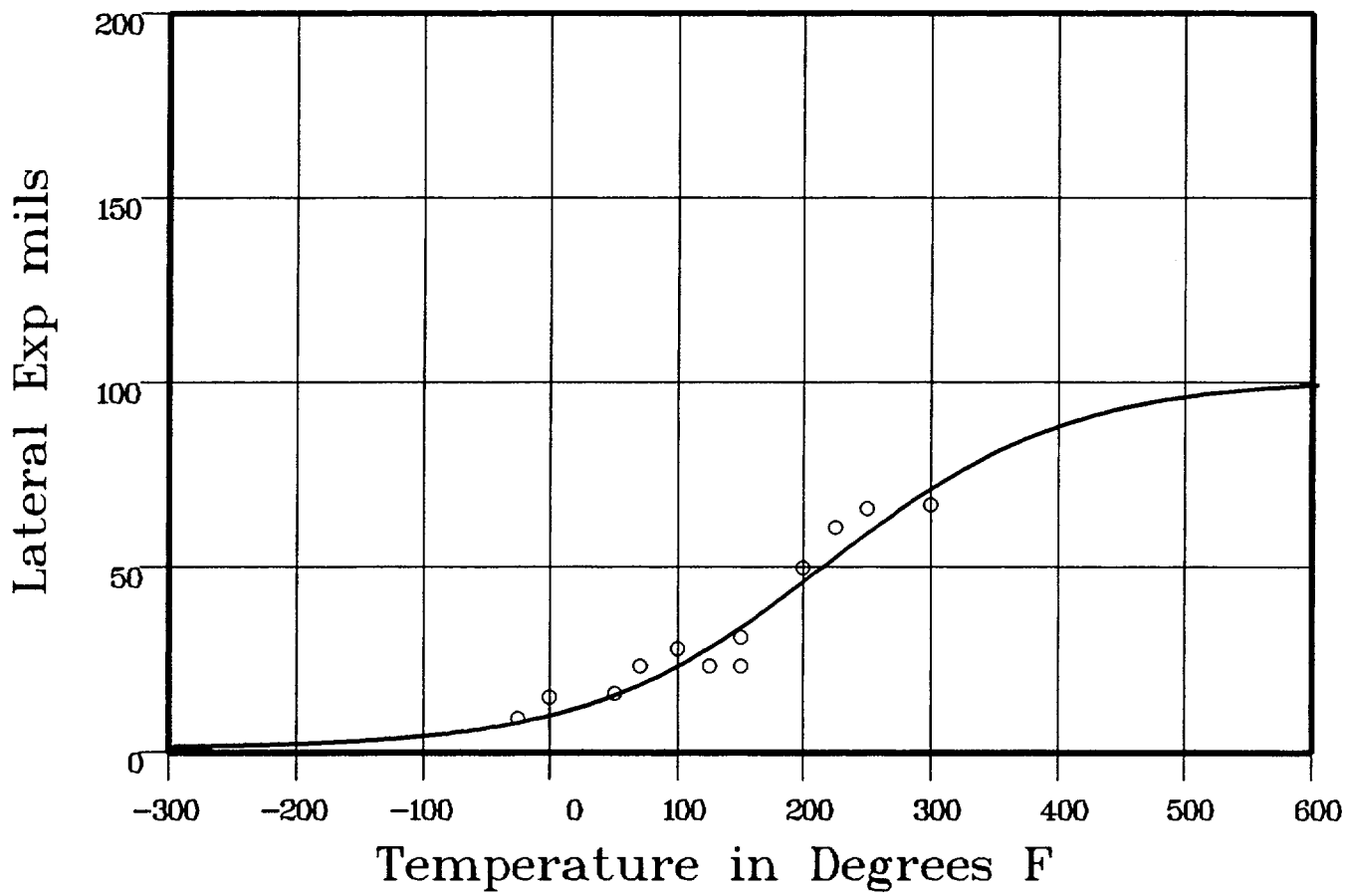
A = 51.01	B = 50.01	C = 189.94	T0 = 213.75

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

Upper Shelf L.E: 101.03 Temperature at L.E. 35: 150.7 Lower Shelf L.E: 1 Fixed

Material: WELD Heat Number: 13253 Orientation:

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: T Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-25	9.5	8.49	1
0	15	10.53	4.46
50	16	16.13	-.13
70	23.5	19.04	4.45
100	28	24.19	3.8
125	23.5	29.21	-5.71
150	23.5	34.83	-11.33
150	31	34.83	-3.83

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

CAPSULE T (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
200	50	47.4	2.59
225	61	53.97	7.02
250	66	60.44	5.55
300	67	72.28	-5.28

SUM of RESIDUALS = 2.6

CAPSULE U (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:31:04 on 05-07-2001

Page 1

Coefficients of Curve 3

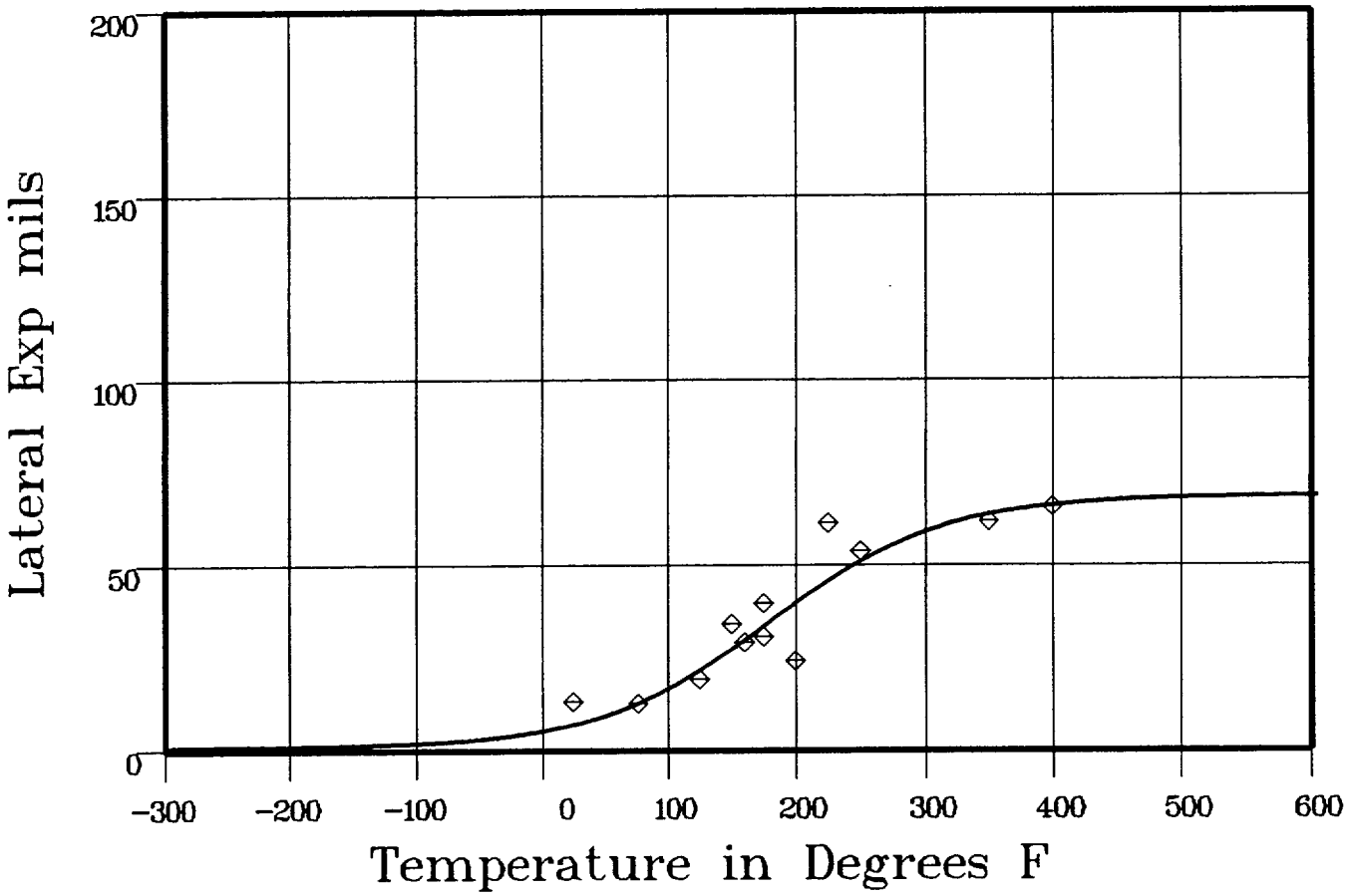
A = 34.9	B = 33.9	C = 134.61	T0 = 174.07

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

Upper Shelf L.E.: 68.8 Temperature at L.E. 35: 174.4 Lower Shelf L.E.: 1 Fixed

Material: WELD Heat Number: 13253 Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
25	13.5	7.67	5.82
76	13	13.8	-.8
125	19.5	23.06	-3.56
150	34.5	28.9	5.59
160	29.5	31.37	-1.87
175	31	35.13	-4.13
175	40	35.13	4.86
200	24.5	41.35	-16.85

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

CAPSULE U (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
225	61.5	47.14	14.35
250	54	52.22	1.77
350	62	64.17	-2.17
400	66	66.51	-.51

SUM of RESIDUALS = 2.49

CAPSULE X (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:31:04 on 05-07-2001

Page 1

Coefficients of Curve 4

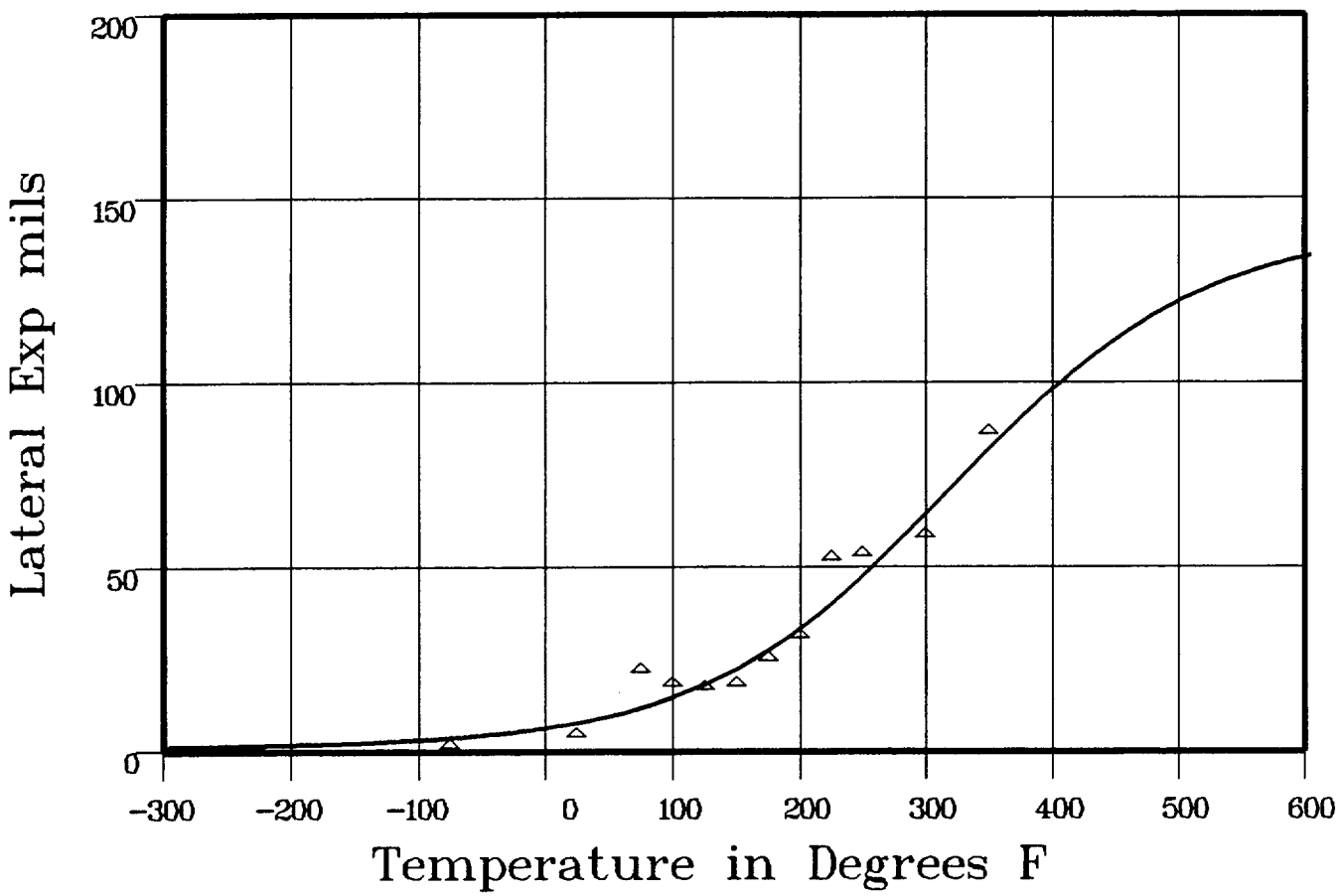
A = 71.5	B = 70.5	C = 199.92	T0 = 315.46

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

Upper Shelf L.E.: 142.01 Temperature at L.E. 35: 200.8 Lower Shelf L.E.: 1 Fixed

Material: WELD Heat Number: 13253 Orientation:

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: X Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-75	1	3.78	-2.78
25	4	8.31	-4.31
75	22	12.66	9.33
100	18	15.63	2.36
125	17	19.26	-2.26
150	18	23.61	-5.61
175	25	28.77	-3.77

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

CAPSULE X (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: X Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
200	31	34.78	-3.78
225	52	41.61	10.38
250	53	49.2	3.79
300	58	66.06	-8.06
350	86	83.56	2.43

SUM of RESIDUALS = -2.28

CAPSULE Y (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:31:04 on 05-07-2001

Page 1

Coefficients of Curve 5

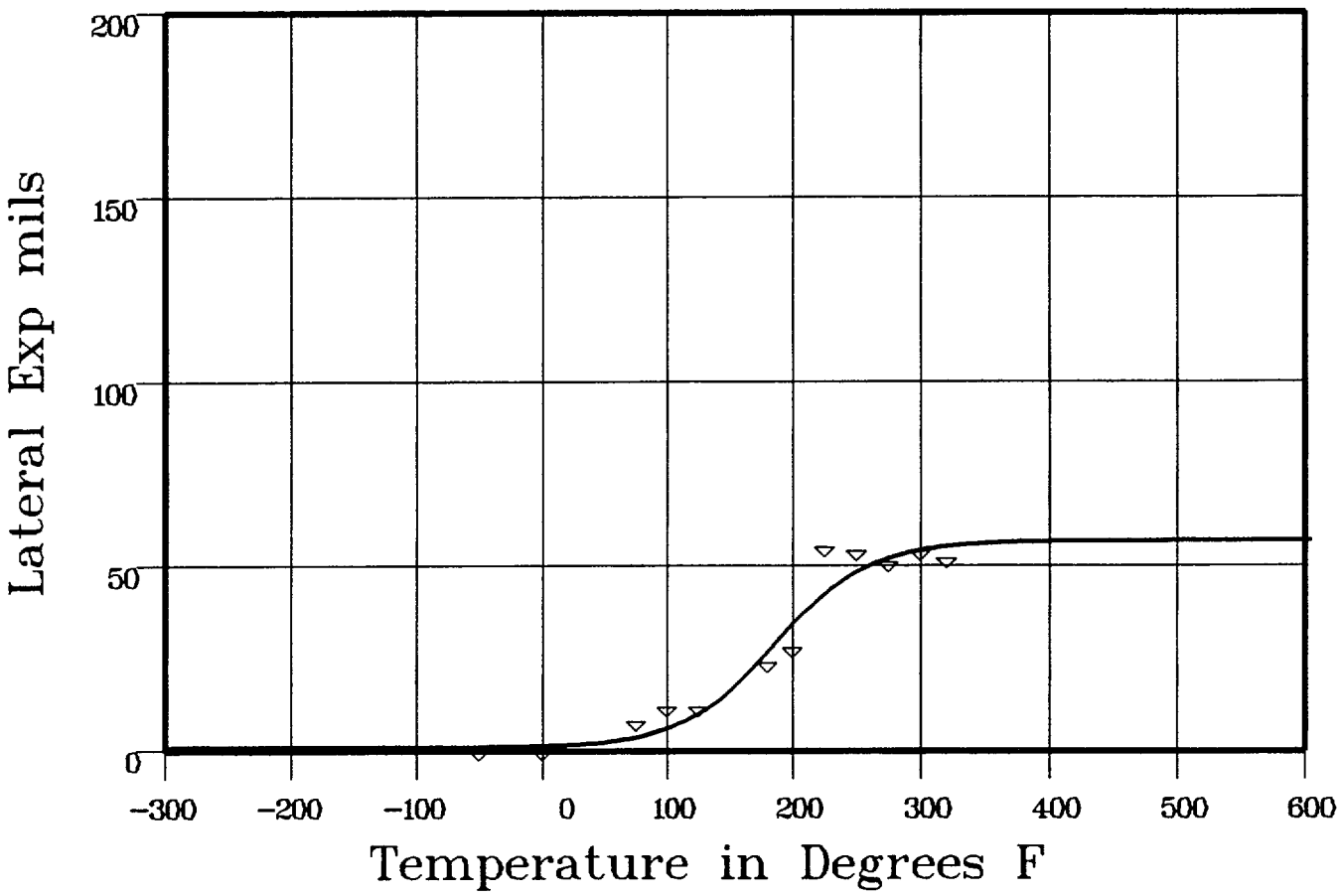
A = 28.9	B = 27.9	C = 74.63	T0 = 180.46

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

Upper Shelf L.E.: 56.8 Temperature at L.E. 35: 197 Lower Shelf L.E.: 1 Fixed

Material: WELD SA533B1 Heat Number: 13253 Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: Y Material: WELD SA533B1 Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-50	0	1.11	-1.11
0	0	1.43	-1.43
75	8	4.12	3.87
100	12	6.78	5.21
125	12	11.29	.7
180	24	28.72	-4.72

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

CAPSULE Y (WELD)

Page 2

Material: WELD SA533B1 Heat Number: 13253 Orientation:

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
200	28	36.04	-8.04
225	55	43.82	11.17
250	54	49.31	4.68
275	51	52.7	-1.7
300	54	54.62	-.62
320	52	55.51	-3.51

SUM of RESIDUALS = 4.48

UNIRRADIATED (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:35:15 on 05-07-2001

Page 1

Coefficients of Curve 1

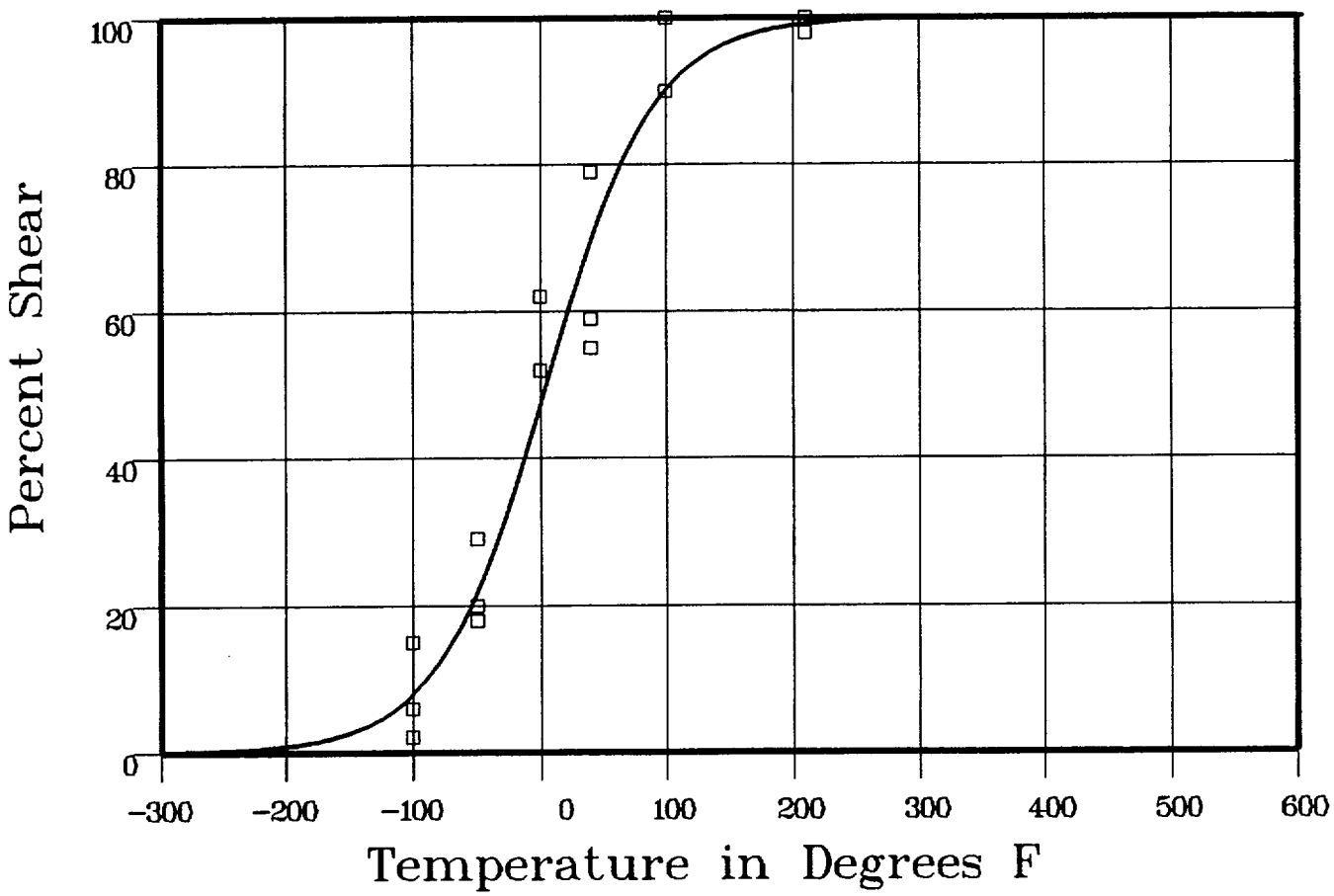
A = 50	B = 50	C = 85.63	T0 = 0

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

Temperature at 50% Shear: 0

Material: WELD Heat Number: 13253 Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100	6	8.82	-2.82
-100	15	8.82	6.17
-100	2	8.82	-6.82
-50	20	23.72	-3.72
-50	29	23.72	5.27
-50	18	23.72	-5.72
0	52	50	2
0	62	50	12
0	52	50	2

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

UNIRRADIATED (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
40	55	71.79	-16.79
40	79	71.79	7.2
40	59	71.79	-12.79
100	100	91.17	8.82
100	100	91.17	8.82
100	90	91.17	-1.17
210	100	99.26	.73
210	100	99.26	.73
210	98	99.26	-1.26

SUM of RESIDUALS = 2.65

CAPSULE T (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:35:15 on 05-07-2001

Page 1

Coefficients of Curve 2

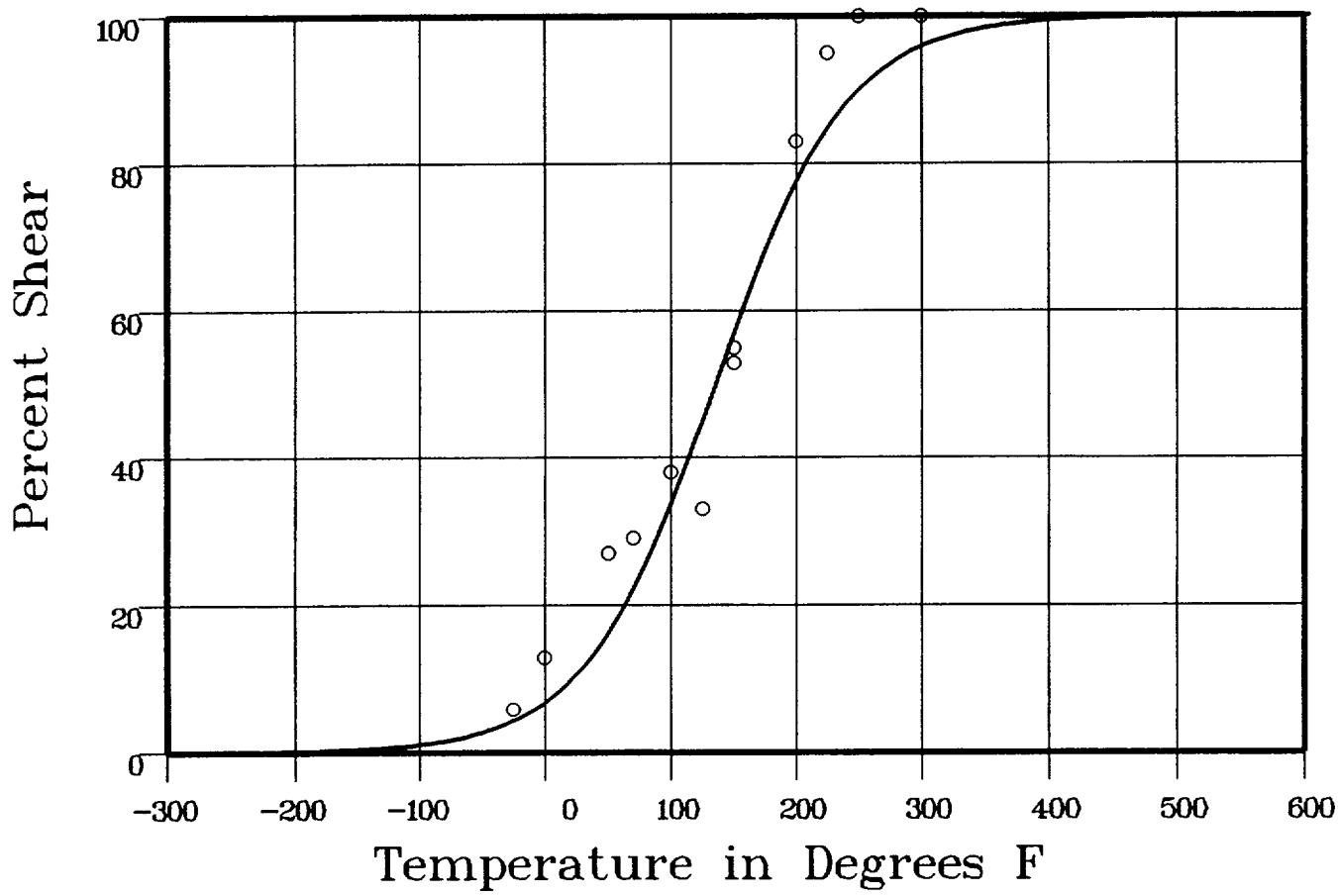
A = 50	B = 50	C = 104.11	T0 = 130.91

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

Temperature at 50% Shear: 130.9

Material: WELD Heat Number: 13253 Orientation:

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-25	6	4.76	1.23
0	13	7.48	5.51
50	27	17.44	9.55
70	29	23.68	5.31
100	38	35.57	2.42
125	33	47.16	-14.16
150	53	59.06	-6.06
150	55	59.06	-4.06

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

CAPSULE T (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
200	83	79.03	3.96
225	95	85.9	9.09
250	100	90.78	9.21
300	100	96.25	3.74

SUM of RESIDUALS = 25.78

CAPSULE U (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:35:15 on 05-07-2001

Page 1

Coefficients of Curve 3

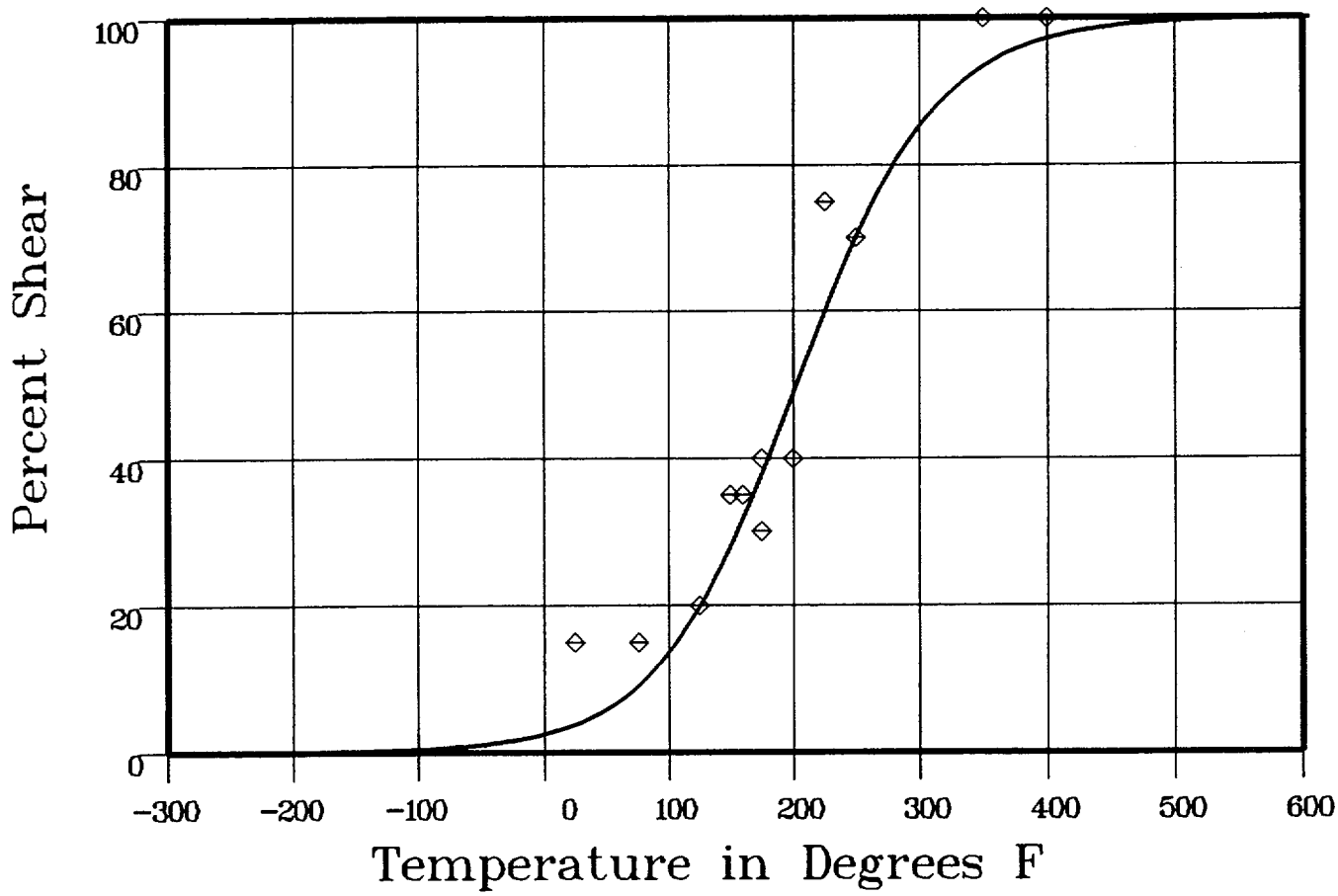
A = 50	B = 50	C = 110.94	T0 = 197.81

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

Temperature at 50% Shear: 197.8

Material: WELD Heat Number: 13253 Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: WELD Ori.: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
25	15	4.24	10.75
76	15	10.01	4.98
125	20	21.2	-1.2
150	35	29.69	5.3
160	35	33.58	1.41
175	30	39.86	-9.86
175	40	39.86	.13
200	40	50.98	-10.98

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

CAPSULE U (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: U Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
225	75	62.01	12.98
250	70	71.92	-1.92
350	100	93.95	6.04
400	100	97.45	2.54

SUM of RESIDUALS = 20.19

CAPSULE X (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:35:15 on 05-07-2001

Page 1

Coefficients of Curve 4

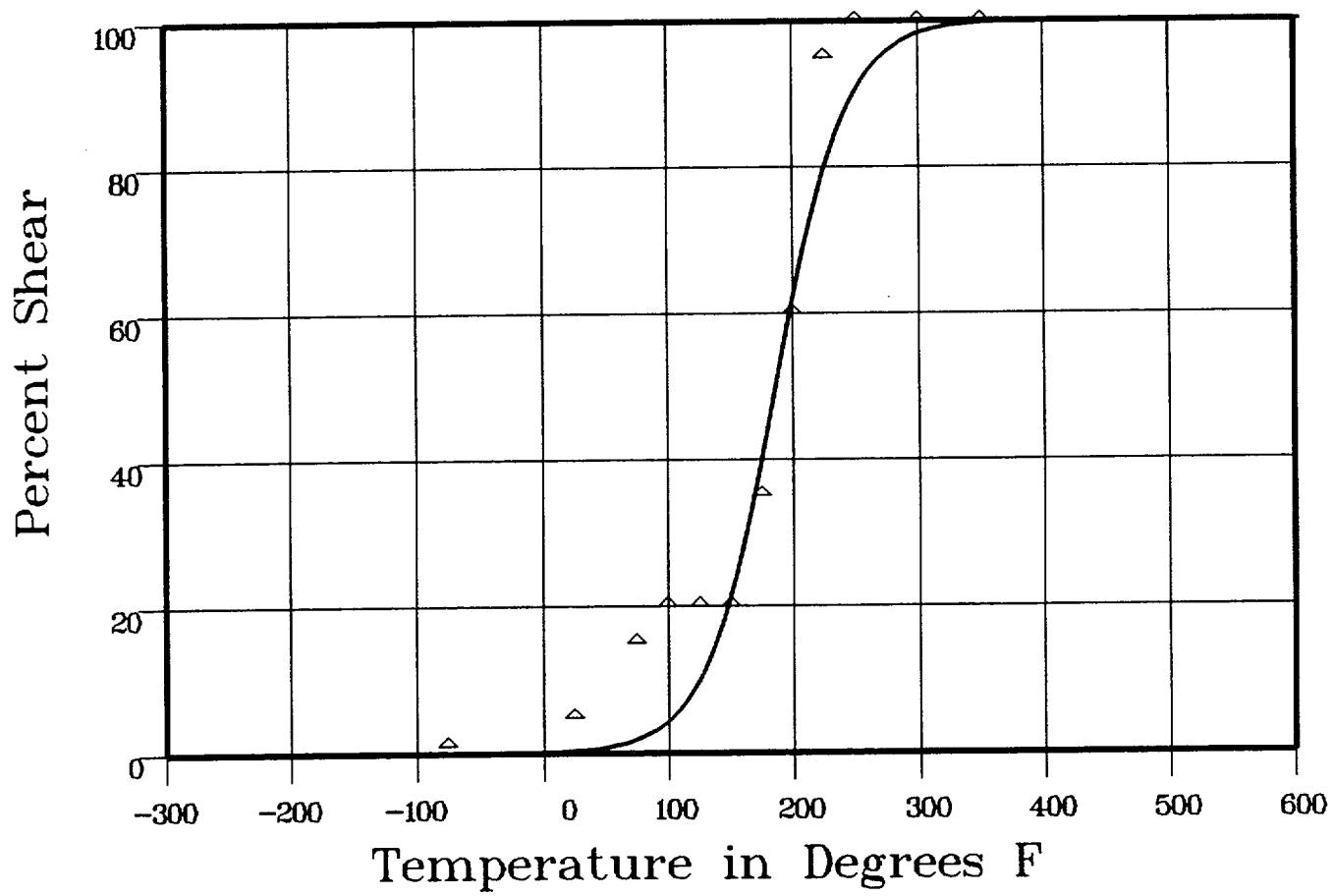
A = 50	B = 50	C = 55.95	T0 = 181.64

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

Temperature at 50% Shear: 181.6

Material: WELD Heat Number: 13253 Orientation:

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: X Material: WELD Ori: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75	1	.01	.98
25	5	.36	4.63
75	15	2.16	12.83
100	20	5.12	14.87
125	20	11.66	8.33
150	20	24.4	-4.4
175	35	44.09	-9.09

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

CAPSULE X (WELD)

Page 2

Material: WELD Heat Number: 13253 Orientation:

Capsule: X Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
200	60	65.84	-5.84
225	95	82.48	12.51
250	100	92	7.99
300	100	98.56	1.43
350	100	99.75	.24

SUM of RESIDUALS = 44.51

CAPSULE Y (WELD)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 09:35:15 on 05-07-2001

Page 1

Coefficients of Curve 5

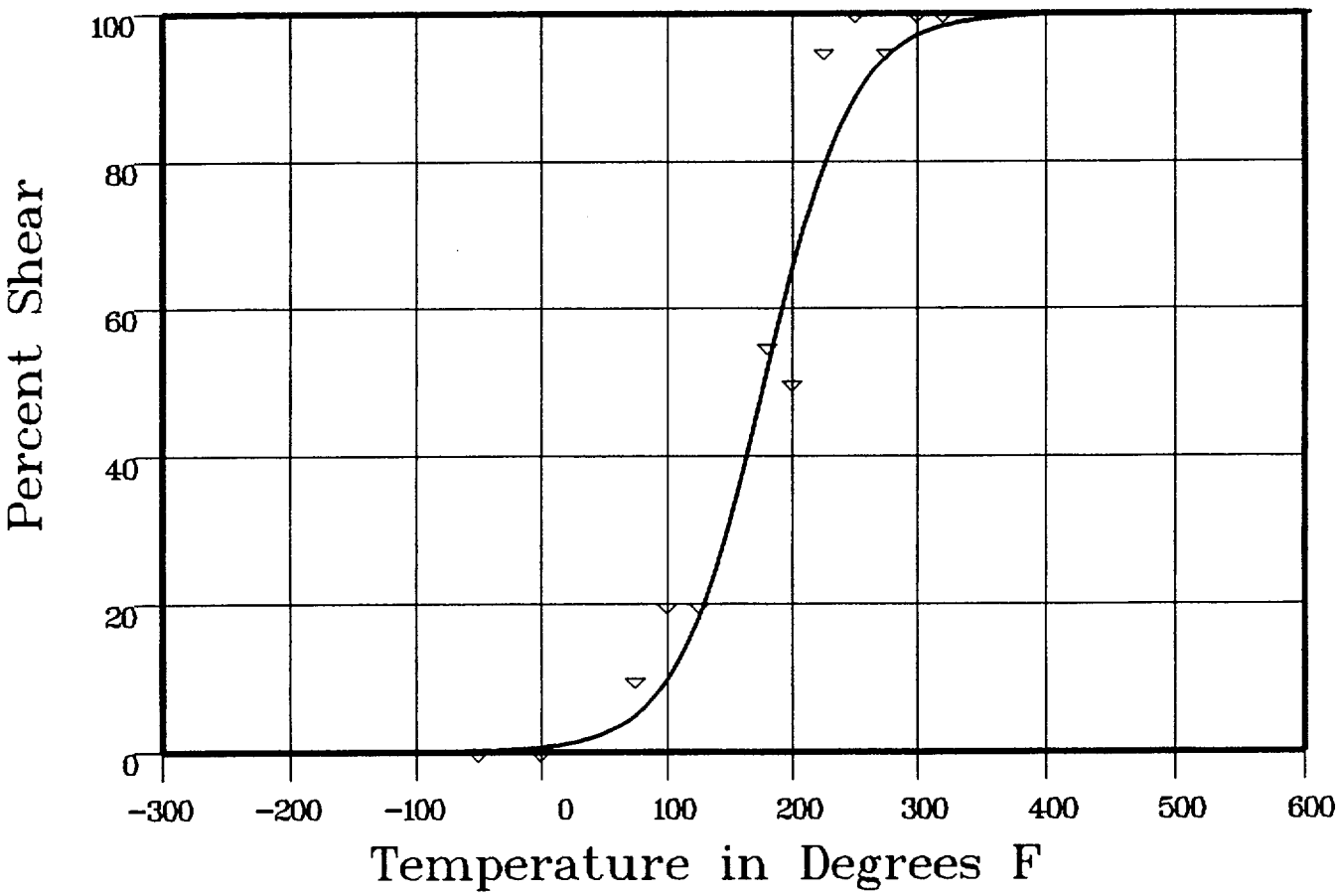
A = 50	B = 50	C = 70.2	T0 = 172.89

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

Temperature at 50% Shear: 172.8

Material: WELD SA533B1 Heat Number: 13253 Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: Y Material: WELD SA533B1 Ori: Heat #: 13253

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50	0	.17	-.17
0	0	.72	-.72
75	10	5.79	4.2
100	20	11.13	8.86
125	20	20.35	-.35
180	55	55.04	-.04

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

CAPSULE Y (WELD)

Page 2

Material: WELD SA533B1 Heat Number: 13253 Orientation:

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
200	50	68.39	-18.39
225	95	81.52	13.47
250	100	89.99	10
275	95	94.82	.17
300	100	97.39	2.6
320	100	98.5	1.49

SUM of RESIDUALS = 21.13

UNIRRADIATED (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:10:17 on 05-07-2001

Page 1

Coefficients of Curve 1

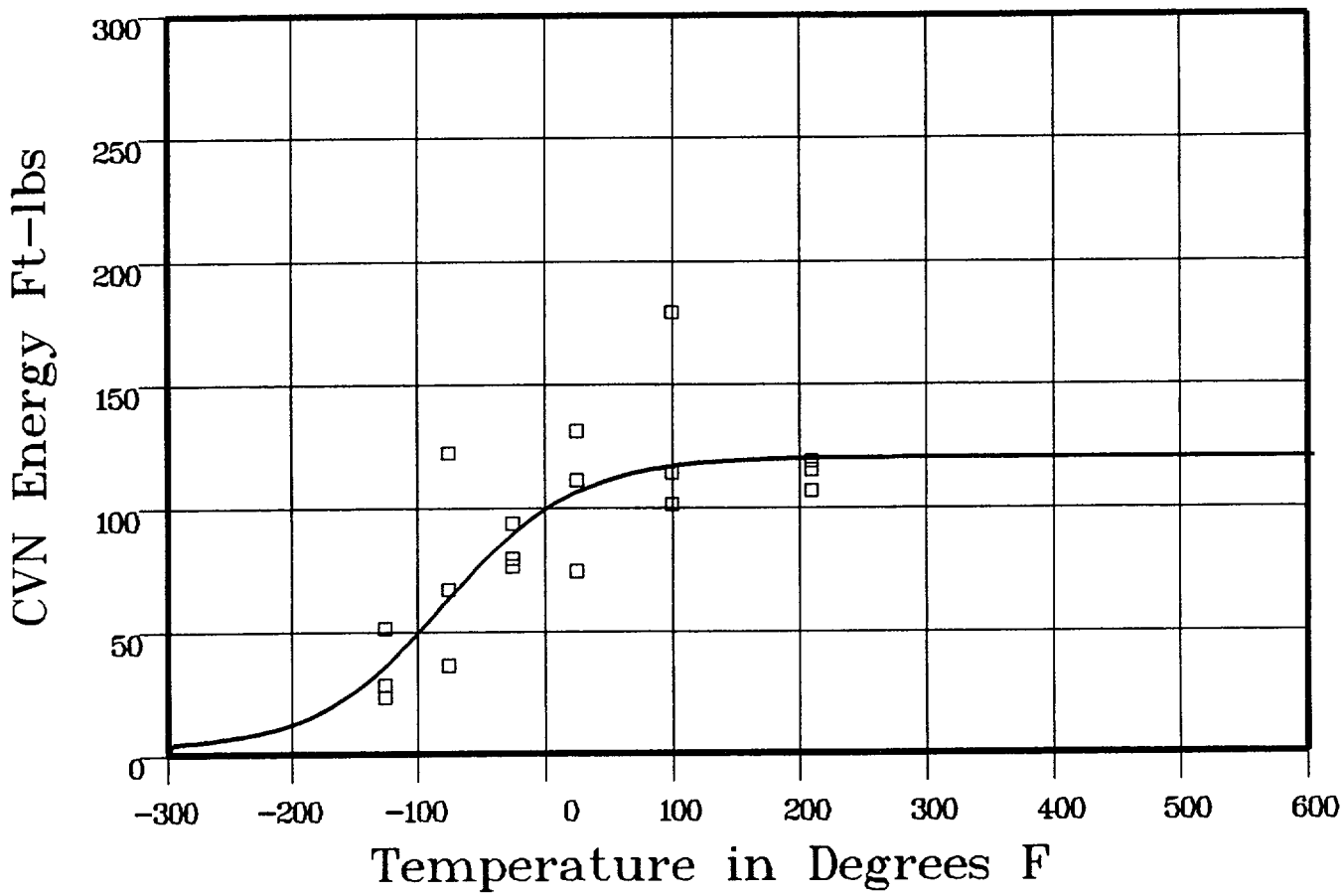
A = 61.09	B = 58.9	C = 101.86	T0 = -82.96

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

Upper Shelf Energy: 120 Fixed Temp. at 30 ft-lbs: -142.8 Temp. at 50 ft-lbs: -102.3 Lower Shelf Energy: 2.19 Fixed

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-125	23	38.08	-15.08
-125	28	38.08	-10.08
-125	51	38.08	12.91
-75	36	65.69	-29.69
-75	66.5	65.69	.8
-75	122	65.69	56.3
-25	93.5	91.41	2.08
-25	76	91.41	-15.41
-25	79	91.41	-12.41

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

UNIRRADIATED (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: UNIRR Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
25	111	107.37	3.62
25	131	107.37	23.62
25	74	107.37	-33.37
100	114	116.84	-2.84
100	179	116.84	62.15
100	101	116.84	-15.84
210	106.5	119.62	-13.12
210	115	119.62	-4.62
210	118.5	119.62	-1.12

SUM of RESIDUALS = 7.86

CAPSULE T (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:10:17 on 05-07-2001

Page 1

Coefficients of Curve 2

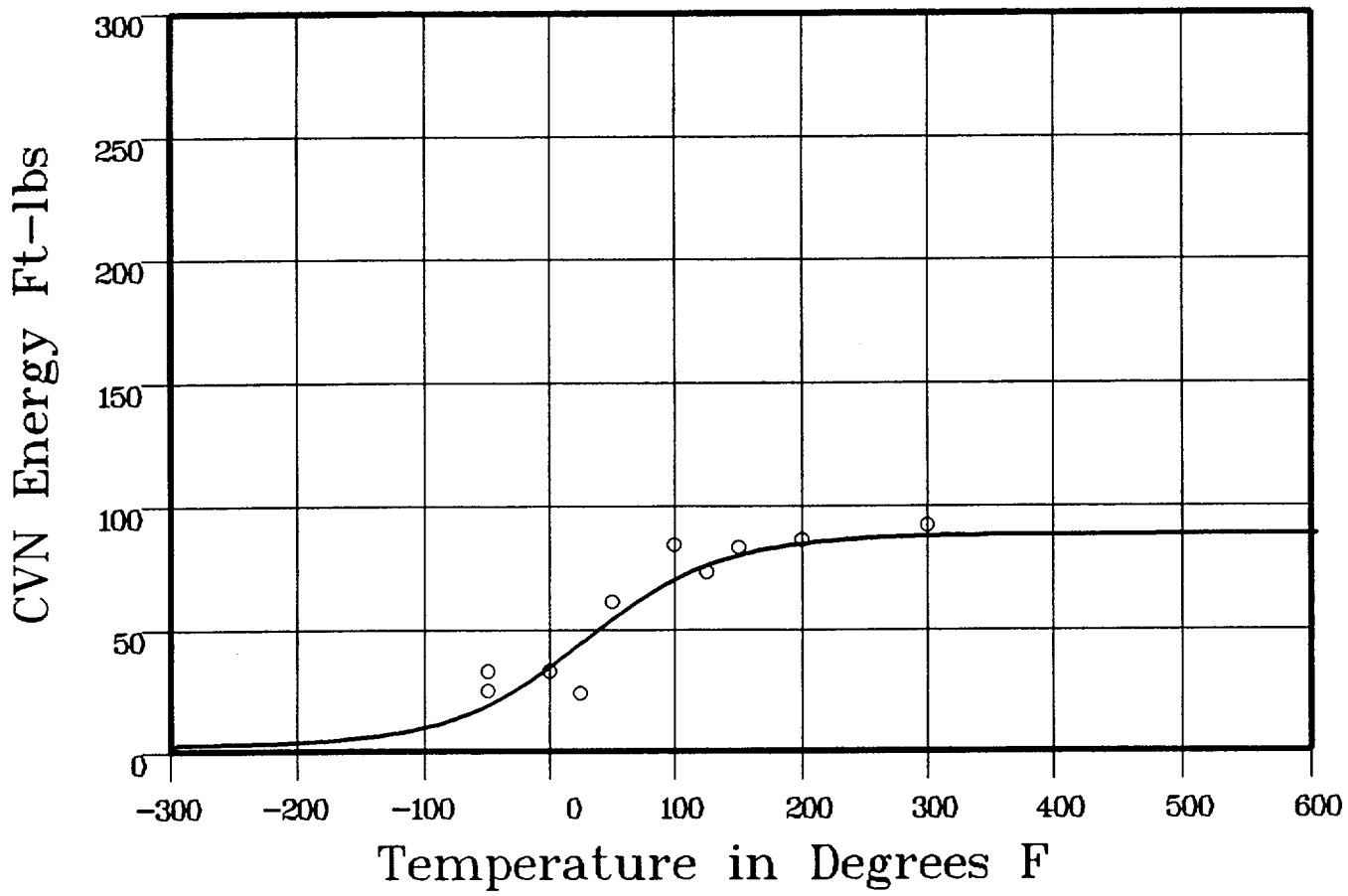
A = 45.09	B = 42.9	C = 110.31	T0 = 22.96

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

Upper Shelf Energy: 88 Fixed Temp. at 30 ft-lbs: -17.6 Temp. at 50 ft-lbs: 35.6 Lower Shelf Energy: 2.19 Fixed

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-50	33	20.24	12.75
-50	25	20.24	4.75
0	33	36.29	-3.29
25	24	45.89	-21.89
50	61	55.4	5.59
100	84	70.98	13.01
125	73	76.34	-3.34
150	83	80.2	2.79

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

CAPSULE T (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
200	86	84.67	1.32
300	92	87.43	4.56

SUM of RESIDUALS = 16.26

CAPSULE U (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:10:17 on 05-07-2001

Page 1

Coefficients of Curve 3

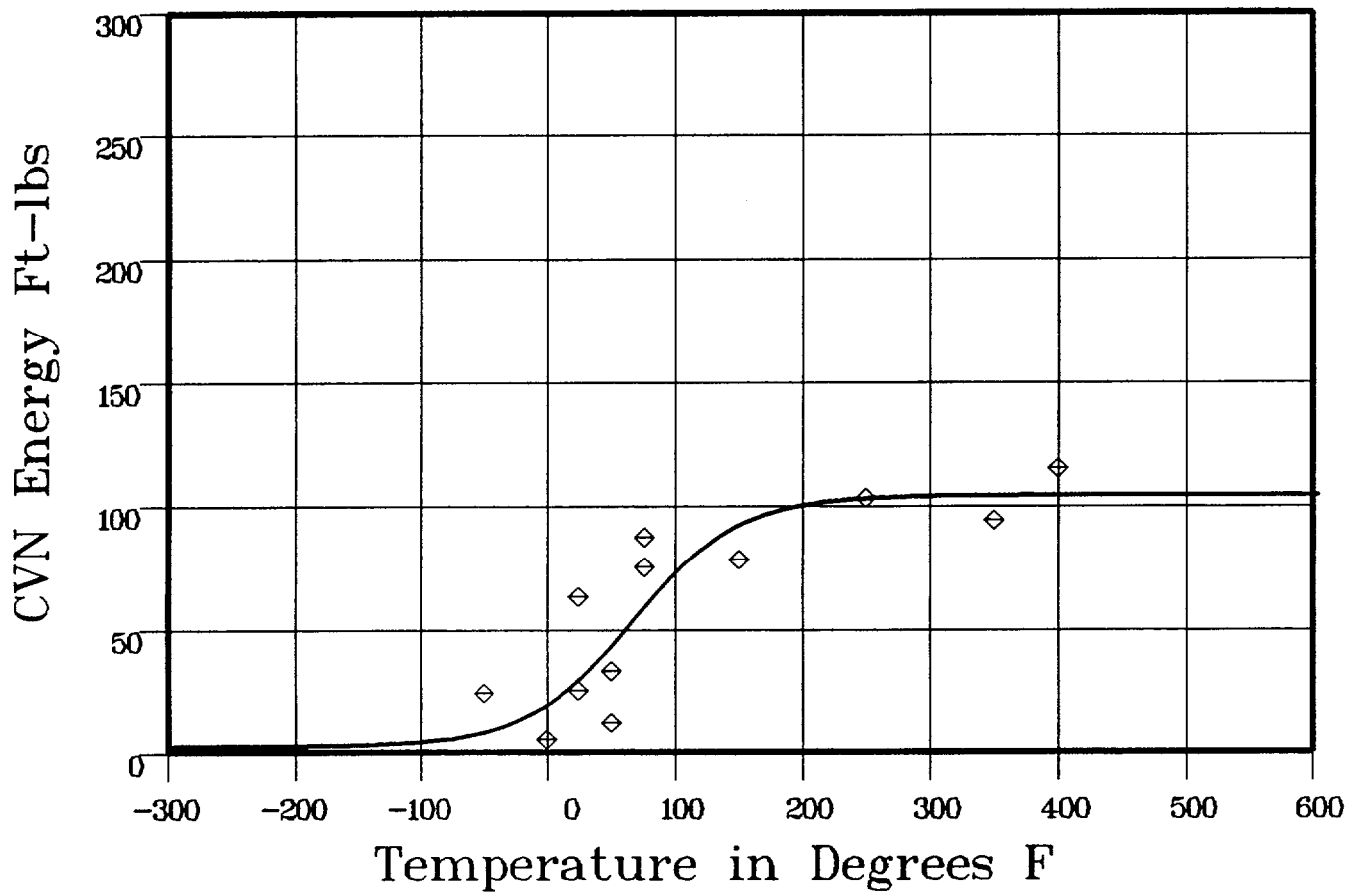
A = 53.09	B = 50.9	C = 82.9	T0 = 61.87

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

Upper Shelf Energy: 104 Fixed Temp. at 30 ft-lbs: 21.2 Temp. at 50 ft-lbs: 56.8 Lower Shelf Energy: 2.19 Fixed

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: U Material: HEAT AFF'D ZONE Ori: Heat #:

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-50	24	8.61	15.38
0	5	20.88	-15.88
25	63	31.84	31.15
25	25	31.84	-6.84
50	12	45.85	-33.85
50	33	45.85	-12.85
76	75	61.68	13.31
76	87	61.68	25.31

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

CAPSULE U (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFFD ZONE Heat Number: Orientation:

Capsule: U Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
150	78	93.14	-15.14
250	103	102.92	.07
350	94	103.9	-9.9
400	115	103.97	11.02

SUM of RESIDUALS = 1.77

CAPSULE X (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:10:17 on 05-07-2001

Page 1

Coefficients of Curve 4

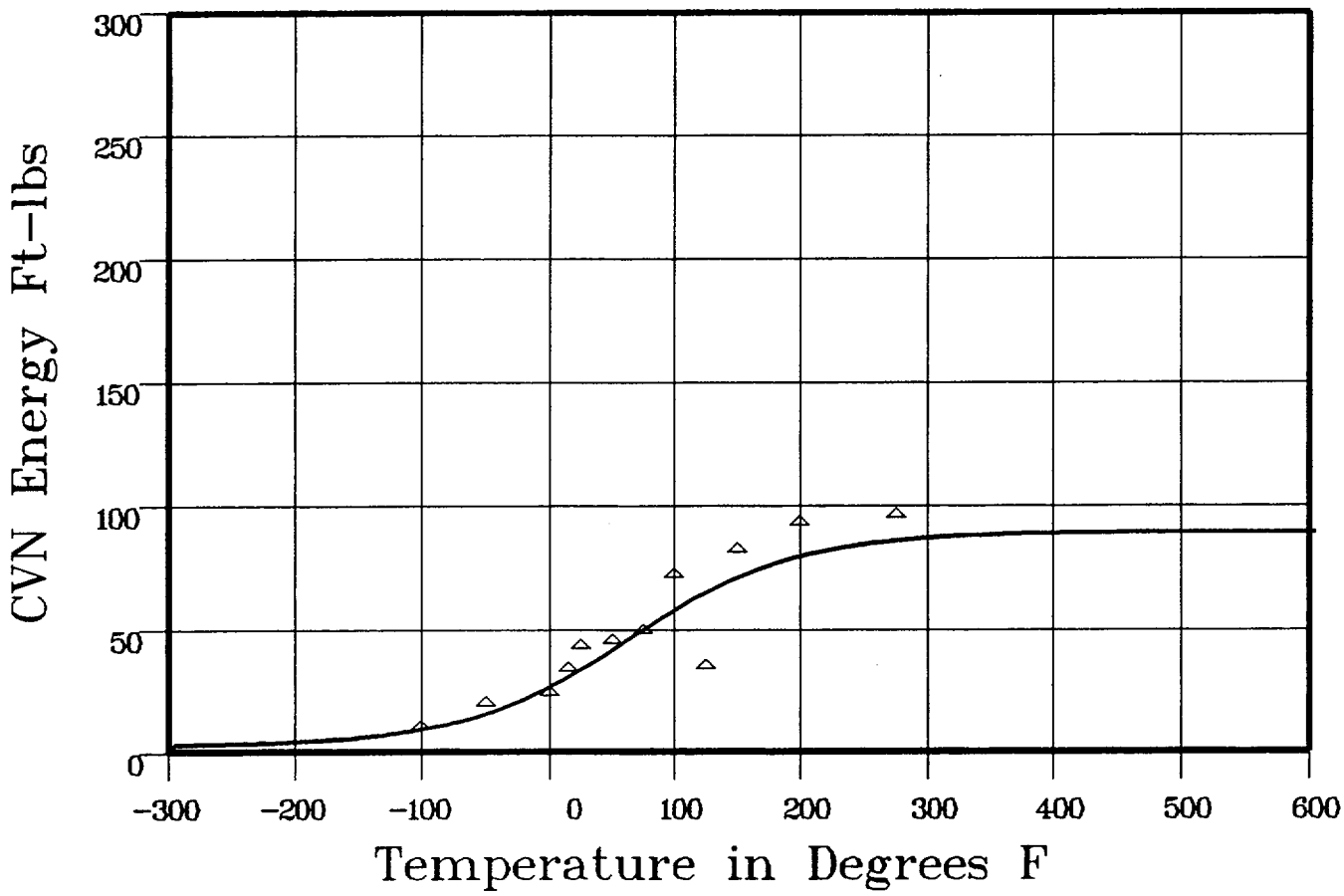
A = 45.59	B = 43.4	C = 132.5	T0 = 57.65

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

Upper Shelf Energy: 89 Fixed Temp. at 30 ft-lbs: 7.8 Temp. at 50 ft-lbs: 71.1 Lower Shelf Energy: 2.19 Fixed

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: X Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-100	9	9.55	-.55
-50	19	16.48	2.51
0	23	27.82	-4.82
15	33	32.09	.9
25	42	35.11	6.88
50	44	43.09	.9
75	48	51.24	-3.24

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

CAPSULE X (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: X Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
100	71	59.01	11.98
125	34	65.93	-31.93
150	81	71.74	9.25
200	92	79.93	12.06
275	95	85.85	9.14
		SUM of RESIDUALS =	13.1

CAPSULE Y (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:10:17 on 05-07-2001

Page 1

Coefficients of Curve 5

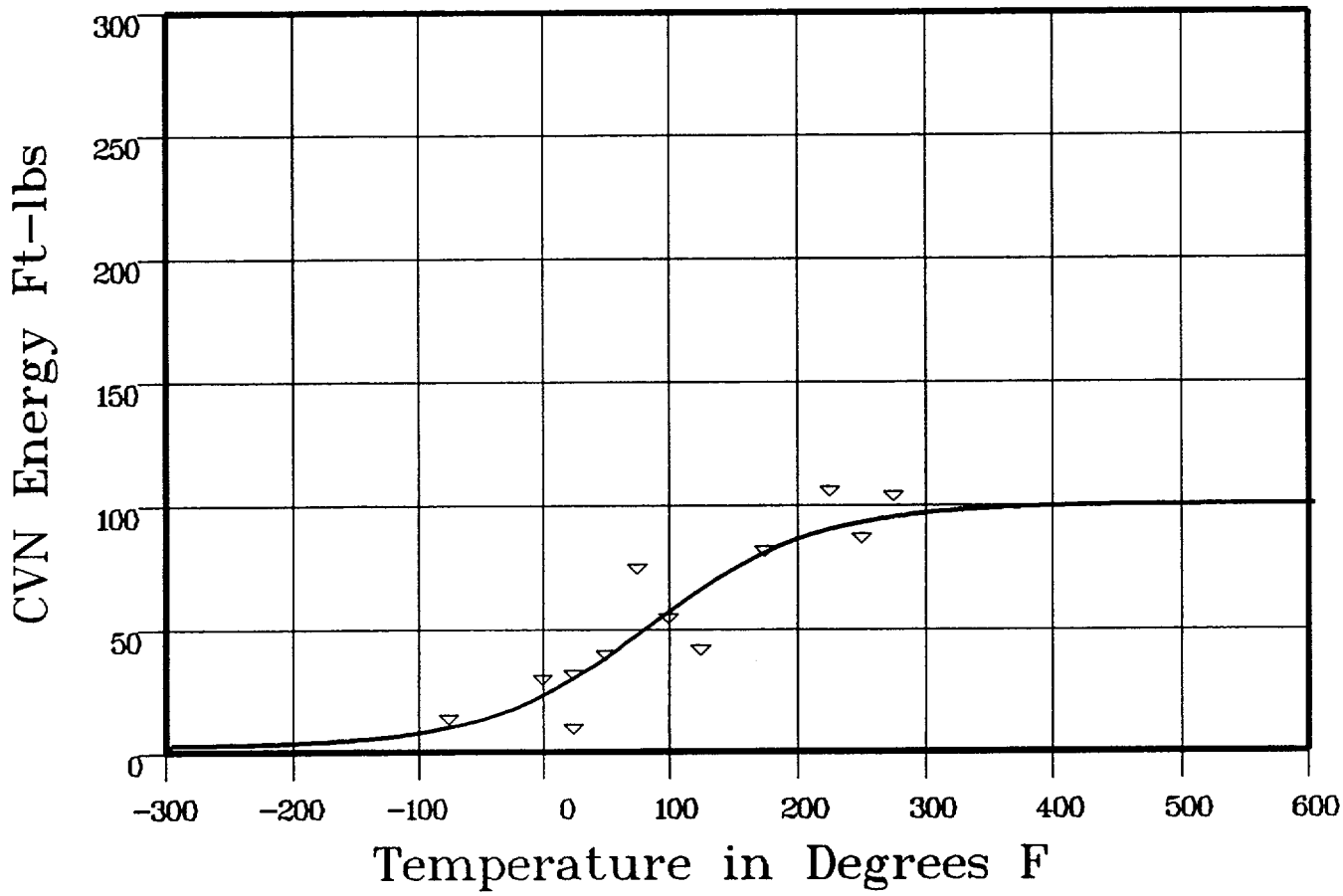
A = 51.09	B = 48.9	C = 128.97	T0 = 79.68

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

Upper Shelf Energy: 100 Fixed Temp. at 30 ft-lbs: 20.1 Temp. at 50 ft-lbs: 76.7 Lower Shelf Energy: 2.19 Fixed

Material: HEAT AFFD ZONE Heat Number: Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: Y Material: HEAT AFFD ZONE Ori: Heat #:

Charpy V-Notch Data

Temperature	Input CVN Energy	Computed CVN Energy	Differential
-75	15	10.34	4.65
0	31	24.22	6.77
25	11	31.52	-20.52
25	33	31.52	1.47
50	41	40.03	.96
75	76	49.32	26.67

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

CAPSULE Y (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFFD ZONE Heat Number: Orientation:

Capsule: Y Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input CVN Energy	Computed CVN Energy	Differential
100	56	58.73	-2.73
125	43	67.6	-24.6
175	83	81.83	1.16
225	107	90.7	16.29
250	88	93.49	-5.49
275	105	95.48	9.51

SUM of RESIDUALS = 14.15

UNIRRADIATED (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:14:24 on 05-07-2001

Page 1

Coefficients of Curve 1

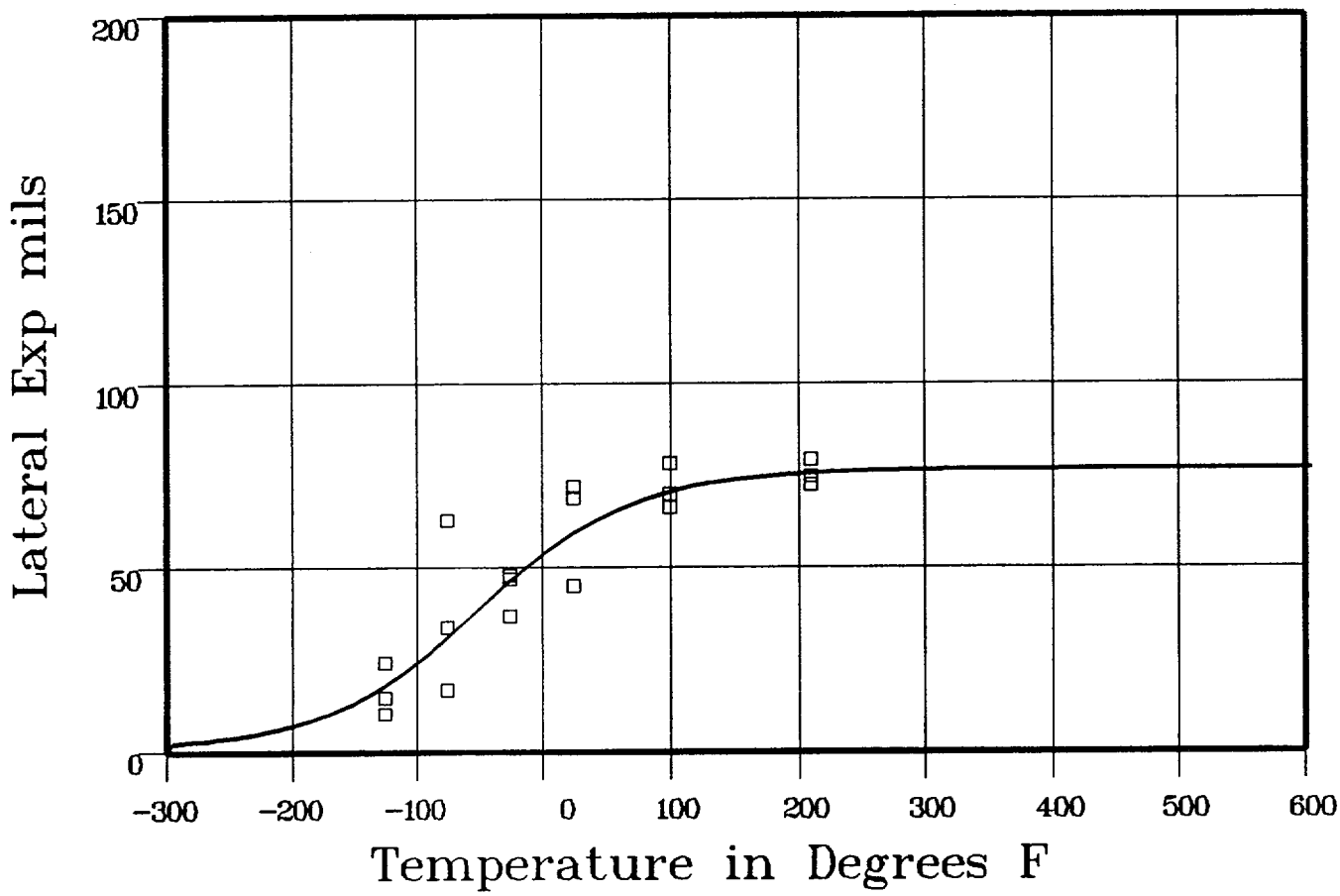
A = 38.96	B = 37.96	C = 123.72	T0 = -54.93

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

Upper Shelf L.E: 76.92 Temperature at L.E. 35: -67.8 Lower Shelf L.E: 1 Fixed

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: UNIRR Material: HEAT AFF'D ZONE Ori: Heat #:

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-125	15	19.5	-4.5
-125	10.5	19.5	-9
-125	24.5	19.5	4.99
-75	17	32.85	-15.85
-75	34	32.85	1.14
-75	63	32.85	30.14
-25	47	47.97	-.97
-25	37	47.97	-10.97
-25	48	47.97	.02

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

UNIRRADIATED (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
25	72	60.56	11.43
25	69	60.56	8.43
25	45	60.56	-15.56
100	70	71.19	-1.19
100	78.5	71.19	7.3
100	66.5	71.19	-4.69
210	75	75.89	-.89
210	72.5	75.89	-3.39
210	79.5	75.89	3.6

SUM of RESIDUALS = .04

CAPSULE T (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:14:24 on 05-07-2001

Page 1

Coefficients of Curve 2

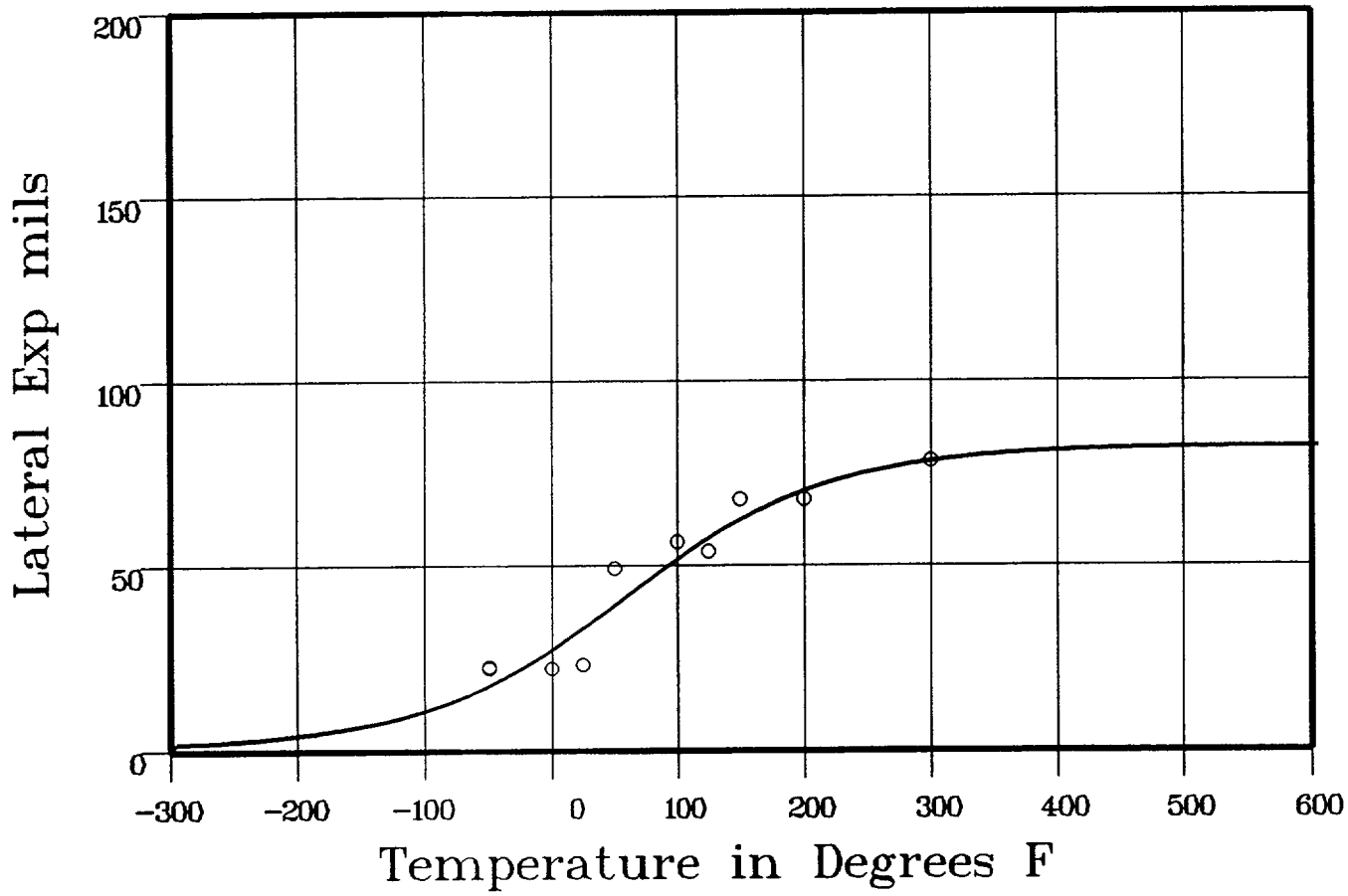
A = 41.58	B = 40.58	C = 161.21	T0 = 53.43

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

Upper Shelf L.E.: 82.16 Temperature at L.E. 35: 27 Lower Shelf L.E.: 1 Fixed

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-50	23	18.61	4.38
-50	22.5	18.61	3.88
0	22.5	28.6	-6.1
25	23.5	34.49	-10.99
50	49.5	40.71	8.78
100	56.5	52.98	3.51
125	54	58.5	-4.5
150	68	63.34	4.65

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

CAPSULE T (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
200	68	70.83	-2.83
300	78.5	78.52	-.02

SUM of RESIDUALS = .76

CAPSULE U (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:14:24 on 05-07-2001

Page 1

Coefficients of Curve 3

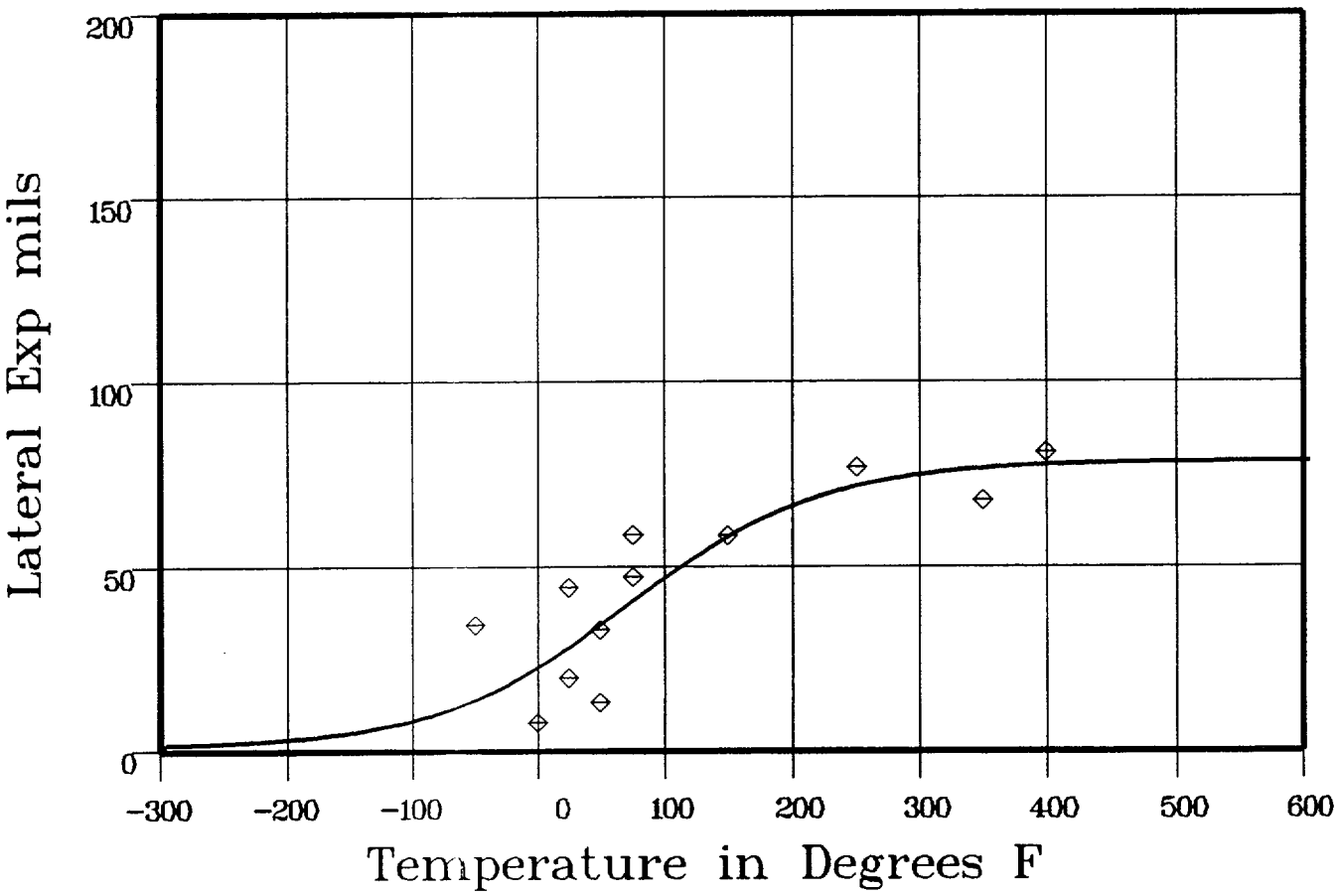
A = 39.79	B = 38.79	C = 152.47	T0 = 66.09

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

Upper Shelf L.E.: 78.59 Temperature at L.E. 35: 47.1 Lower Shelf L.E.: 1 Fixed

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-50	31.5	14.89	19.6
0	8	23.95	-15.95
25	44.5	29.58	14.91
25	20	29.58	-9.58
50	13.5	35.71	-22.21
50	33	35.71	-2.71
76	47.5	42.31	5.18
76	58.79	42.31	16.48

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

CAPSULE U (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: U Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
150	58.5	59.22	–.72
250	77	72.21	4.78
350	68	76.76	–8.76
400	81	77.63	3.36
		SUM of RESIDUALS =	4.38

CAPSULE X (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:14:24 on 05-07-2001

Page 1

Coefficients of Curve 4

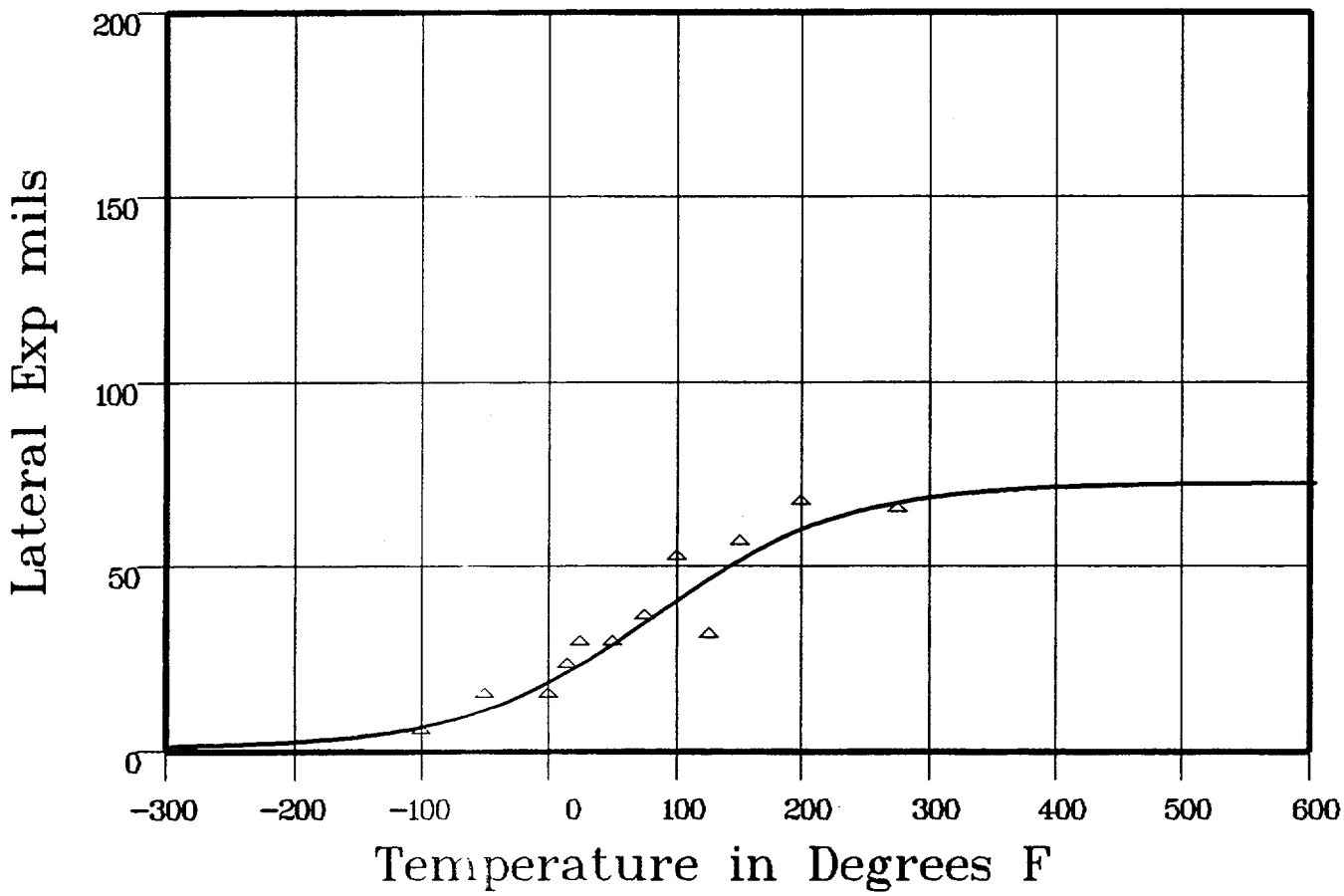
A = 36.81	B = 35.81	C = 150.96	T0 = 78.07

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

Upper Shelf L.E.: 72.63 Temperature at L.E. 35: 70.4 Lower Shelf L.E.: 1 Fixed

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap: X Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-100	5	7.18	-2.18
-50	15	12.09	2.9
0	15	19.78	-4.78
15	23	22.66	.33
25	29	24.71	4.28
50	29	30.22	-1.22
75	36	36.08	-.08

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

CAPSULE X (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: X Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
100	52	41.98	10.01
125	31	47.6	-16.6
150	56	52.69	3.3
200	67	60.75	6.24
275	65	67.71	-2.71

SUM of RESIDUALS = -.5

CAPSULE Y (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:14:24 on 05-07-2001

Page 1

Coefficients of Curve 5

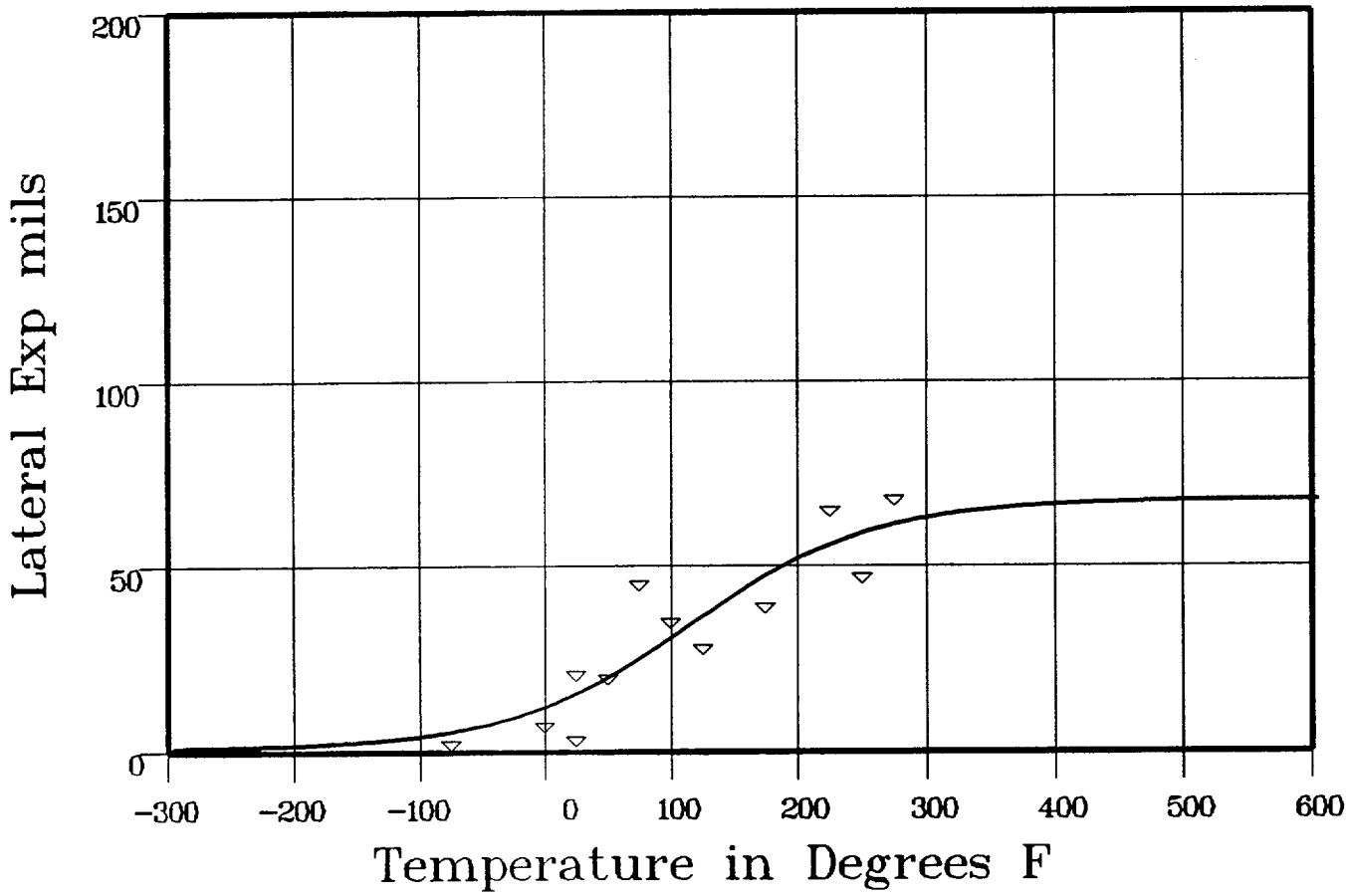
A = 34.57	B = 33.57	C = 145.58	T0 = 110.62

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

Upper Shelf L.E: 68.14 Temperature at L.E. 35: 112.4 Lower Shelf L.E: 1 Fixed

Material: HEAT AFFD ZONE Heat Number: Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: Y Material: HEAT AFFD ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Lateral Expansion	Computed L.E.	Differential
-75	3	5.86	-2.86
0	8	13.05	-5.05
25	4	16.82	-12.82
25	22	16.82	5.17
50	21	21.34	-.34
75	46	26.51	19.48

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

CAPSULE Y (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: Y Total Fluence:

Charpy V–Notch Data (Continued)

Temperature	Input Lateral Expansion	Computed L.E.	Differential
100	36	32.12	3.87
125	29	37.87	-8.87
175	40	48.51	-8.51
225	66	56.59	9.4
250	48	59.51	-11.51
275	69	61.78	7.21

SUM of RESIDUALS = -4.84

UNIRRADIATED (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:58:57 on 05-07-2001

Page 1

Coefficients of Curve 1

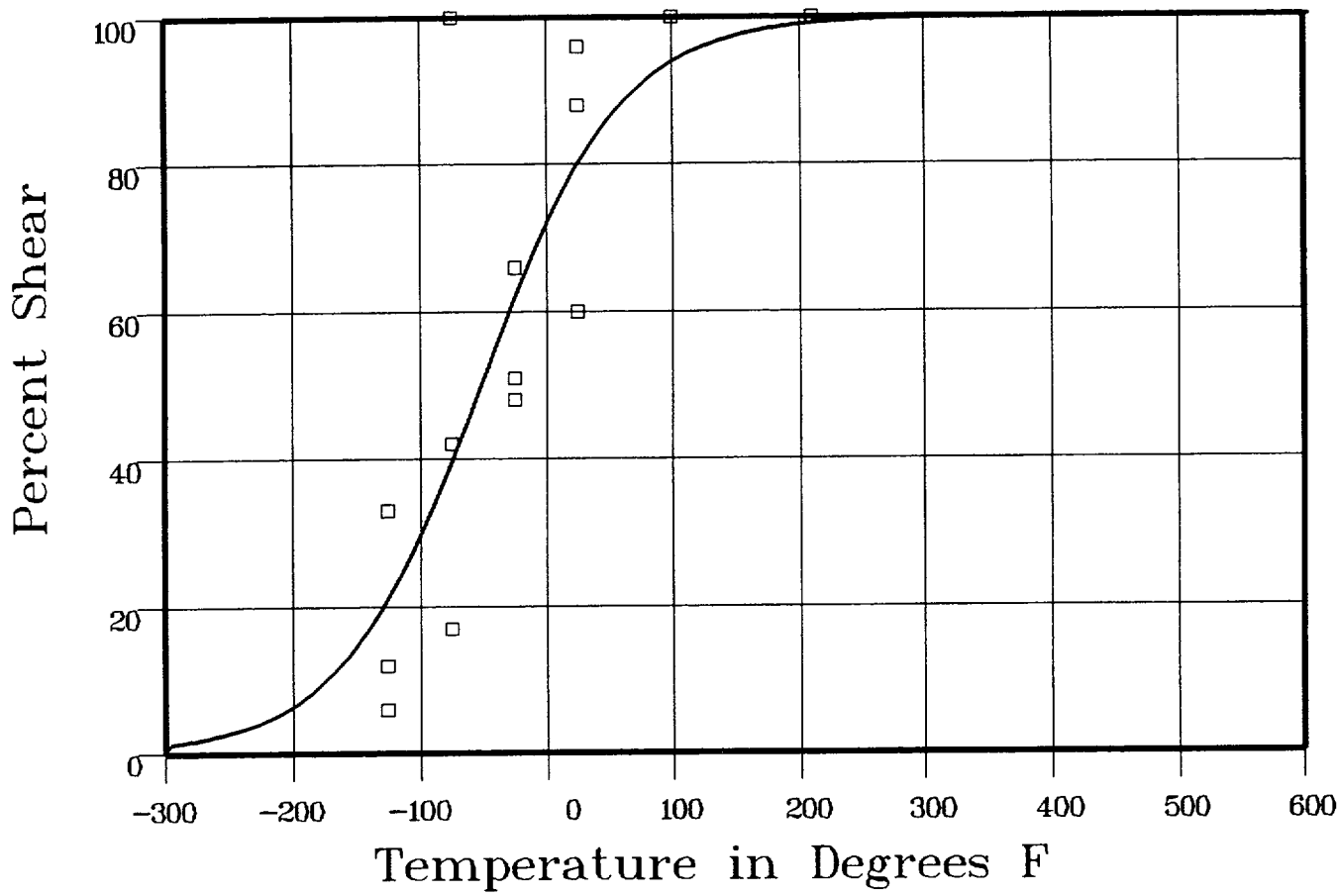
A = 50	B = 50	C = 110.48	T0 = -56.72

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

Temperature at 50% Shear: -56.7

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: UNIRR Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: UNIRR Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-125	6	22.51	-16.51
-125	12	22.51	-10.51
-125	33	22.51	10.48
-75	17	41.8	-24.8
-75	42	41.8	.19
-75	100	41.8	58.19
-25	48	63.97	-15.97
-25	51	63.97	-12.97
-25	66	63.97	2.02

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

UNIRRADIATED (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: UNIRR Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
25	88	81.44	6.55
25	96	81.44	14.55
25	60	81.44	-21.44
100	100	94.46	5.53
100	100	94.46	5.53
100	100	94.46	5.53
210	100	99.2	.79
210	100	99.2	.79
210	100	99.2	.79

SUM of RESIDUALS = 8.78

CAPSULE T (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:58:57 on 05-07-2001

Page 1

Coefficients of Curve 2

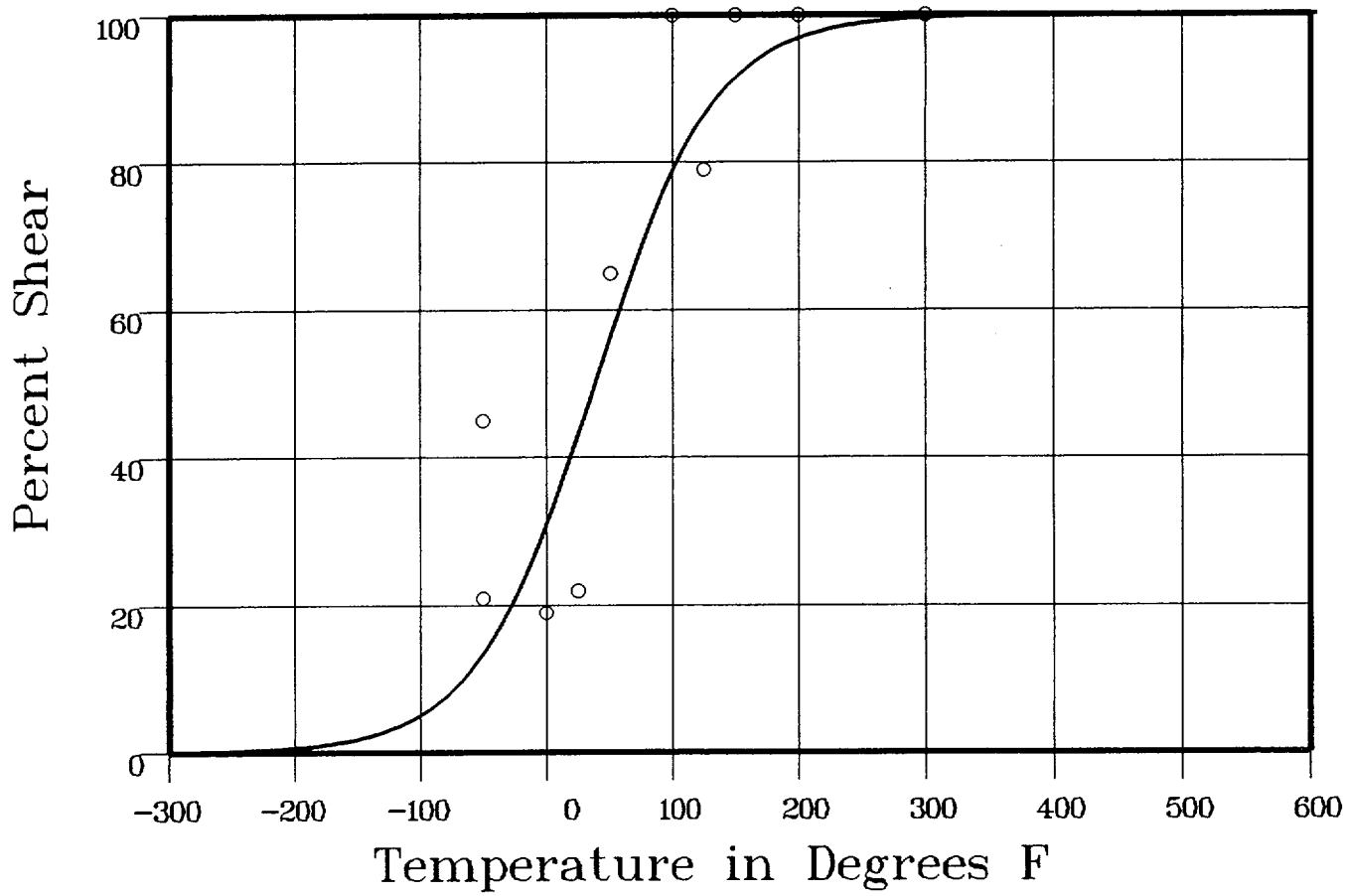
A = 50	B = 50	C = 94.41	T0 = 33.54

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

Temperature at 50% Shear: 33.5

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: T Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: T Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50	45	14.55	30.44
-50	21	14.55	6.44
0	19	32.95	-13.95
25	22	45.48	-23.48
50	65	58.62	6.37
100	100	80.34	19.65
125	79	87.4	-8.4
150	100	92.17	7.82

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

CAPSULE T (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: T Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
200	100	97.14	2.85
300	100	99.64	.35

SUM of RESIDUALS = 28.09

CAPSULE U (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:58:57 on 05-07-2001

Page 1

Coefficients of Curve 3

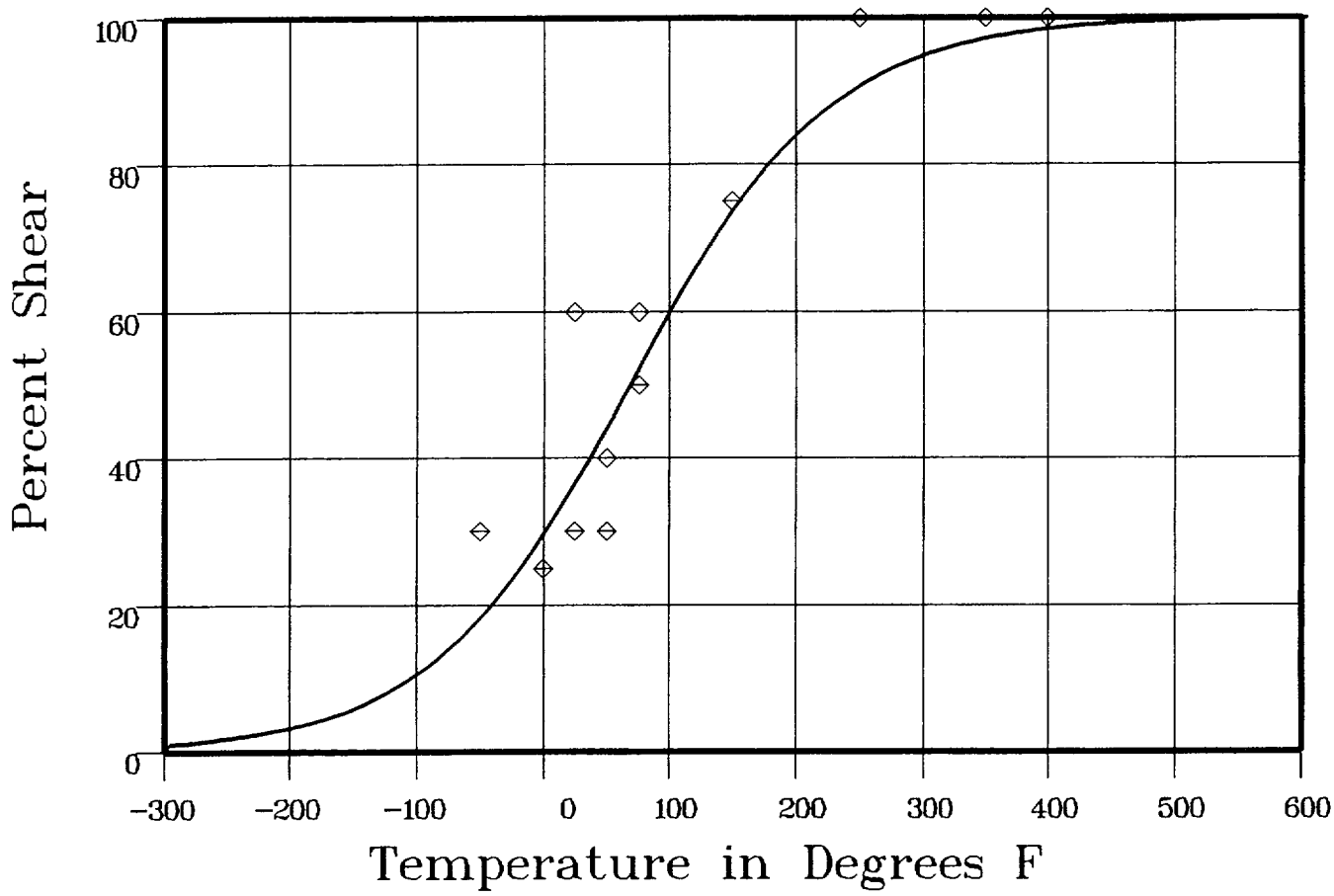
A = 50	B = 50	C = 158.46	T0 = 63.97

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

Temperature at 50% Shear: 63.9

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: U Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: U Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50	30	19.17	10.82
0	25	30.84	-5.84
25	60	37.94	22.05
25	30	37.94	-7.94
50	30	45.6	-15.6
50	40	45.6	-5.6
76	60	53.78	6.21
76	50	53.78	-3.78

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

CAPSULE U (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: U Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
150	75	74.75	.24
250	100	91.27	8.72
350	100	97.36	2.63
400	100	98.58	1.41

SUM of RESIDUALS = 13.31

CAPSULE X (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:58:57 on 05-07-2001

Page 1

Coefficients of Curve 4

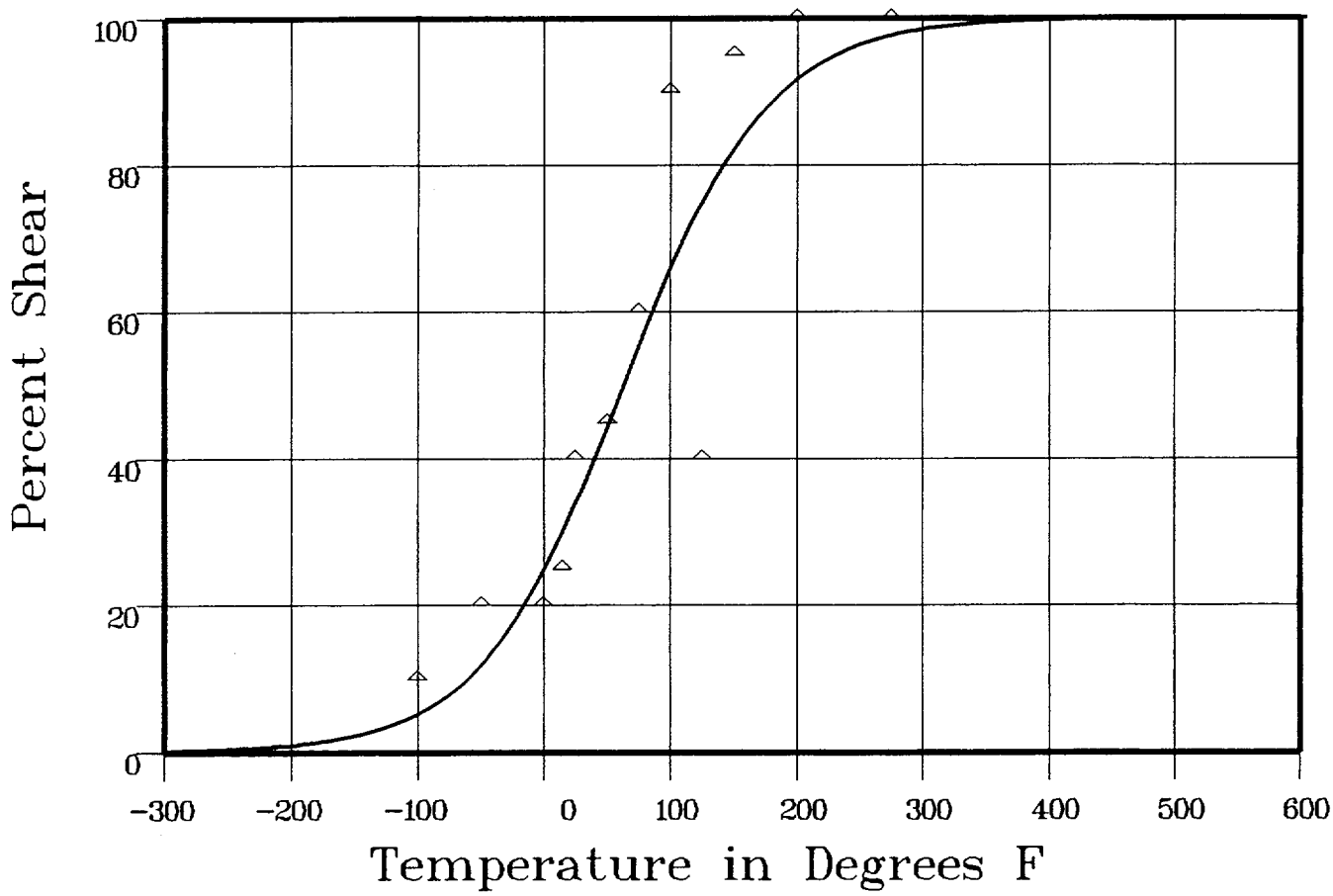
A = 50	B = 50	C = 113.44	T0 = 58.13

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

Temperature at 50% Shear: 58.1

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: X Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: X Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100	10	5.79	4.2
-50	20	12.94	7.05
0	20	26.4	-6.4
15	25	31.85	-6.85
25	40	35.8	4.19
50	45	46.42	-1.42
75	60	57.38	2.61

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

CAPSULE X (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: X Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
100	90	67.65	22.34
125	40	76.47	-36.47
150	95	83.47	11.52
200	100	92.42	7.57
275	100	97.86	2.13

SUM of RESIDUALS = 10.5

CAPSULE Y (HEAT AFFECTED ZONE)

CVGRAPH 4.1 Hyperbolic Tangent Curve Printed at 10:58:57 on 05-07-2001

Page 1

Coefficients of Curve 5

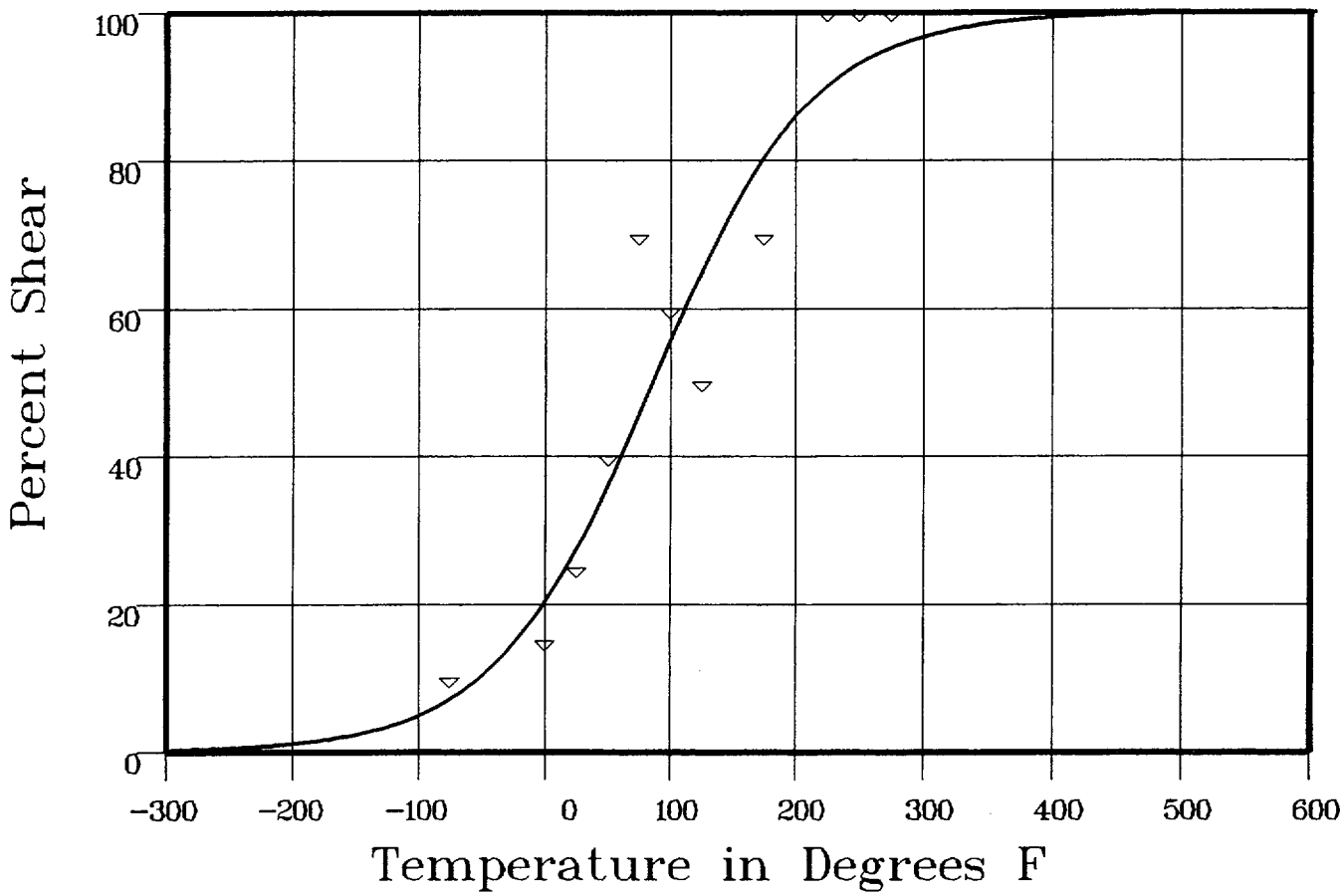
A = 50	B = 50	C = 126.22	T0 = 81.08

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

Temperature at 50% Shear: 81

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: Y Total Fluence:



Data Set(s) Plotted

Plant: SA2 Cap.: Y Material: HEAT AFF'D ZONE Ori.: Heat #:

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75	10	7.77	2.22
0	15	21.67	-6.67
25	25	29.13	-4.13
25	25	29.13	-4.13
50	40	37.92	2.07
75	70	47.58	22.41

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

CAPSULE Y (HEAT AFFECTED ZONE)

Page 2

Material: HEAT AFF'D ZONE Heat Number: Orientation:

Capsule: Y Total Fluence:

Charpy V-Notch Data (Continued)

Temperature	Input Percent Shear	Computed Percent Shear	Differential
100	60	57.43	2.56
125	50	66.72	-16.72
175	70	81.57	-11.57
225	100	90.72	9.27
250	100	93.56	6.43
275	100	95.57	4.42

SUM of RESIDUALS = 6.16

APPENDIX D

SALEM UNIT 2 SURVEILLANCE PROGRAM CREDIBILITY ANALYSIS

SURVEILLANCE DATA CREDIBLITY EVALUATION

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 methodology 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 become available from the reactor in question.

To date there have been four surveillance capsules removed from Salem Unit 2. To use these surveillance data sets, they must be shown to be credible. In accordance with 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 these credibility requirements to the reactor vessel surveillance data obtained from Salem Unit 2 and determine if these surveillance data sets are credible.

EVALUATION

Criterion 1: ***Materials in the capsules should be those judged most likely to be controlling with regard to radiation embrittlement. The beltline region of the reactor vessel is defined in Appendix G to 10 CFR Part 50, "Fracture Toughness Requirements", December 19, 1995 to be:***

"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 Salem Unit 2 reactor vessel consists of the following beltline region materials:

- Intermediate shell plates: B4712-1, B4712-2, and B4713-3,
- Lower shell plates: B4713-1, B4713-2, and B4713-3,
- Intermediate shell longitudinal weld seams: 2-442A, 2-442B, and 2-442C, heat 13253/12008, Linde 1092 flux, lot 3833,

- Lower shell longitudinal weld seams 3-442A, 3-442B, and 3-442C, heat 21935/12008, Linde 1092 flux, lot 3889, and

- Circumferential weld seam 9-442, heat #90099, Linde 0091 flux, lot 3977

The Salem Unit 2 surveillance program was based on ASTM E185-73[14], "Standard Recommended Practice for Surveillance Tests for Nuclear Reactor Vessels". Per Annex A1, Section A1.1.1, from the standpoint of IRT_{NDT} and phosphorous content values, the beltline plate materials are considered to be equivalent. Intermediate shell plate B4712-2 had the highest Cu content (0.14%) and was selected as the surveillance program base and HAZ metal.

The surveillance weld was fabricated with weld wire heat #13253, flux 1092, lot #3774 and was fabricated utilizing the same fabrication process as was used in the fabrication of the beltline welds. This heat and flux are of the same type as that used in the fabrication of the irradiated region of the vessel. Hence, the surveillance weld is fully representative of the fabrication practice used for the welds in the irradiated region.

Based on the above evaluation and engineering judgment the Salem Unit 2 surveillance program meets this criterion.

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 Charpy energy versus temperature for the unirradiated condition are presented in WCAP-8824, "Public Service Electric and Gas Company Salem Unit 2 Reactor Vessel Surveillance Program," dated January 1977. Plots of Charpy energy versus temperature for the irradiated condition are presented in the WCAP reports for Capsules: T (WCAP-10492), U (WCAP-11554), X (WCAP-13366) and Y (WCAP-15692). 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 Salem Unit 2 surveillance materials unambiguously. Therefore, the Salem Unit 2 surveillance program meets this criterion.

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

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 this criterion is met.

Table D-1:
Salem Unit 2 Surveillance Capsule Calculation of Best-Fit Line as Described in Position 2.1 of Regulatory Guide 1.99, Revision 2.

Material	Capsule	Capsule f [(a)]	FF [(b)]	ΔRT_{NDT} [(c)]	$FF*\Delta RT_{NDT}$	FF^2
Intermediate Shell B4712-2 (Longitudinal)	T	0.278	0.651	61.66	40.14	0.42
	U	0.579	0.847	66.54	56.36	0.72
	X	1.12	1.032	93.82	96.82	1.07
	Y	1.81	1.163	105.69	122.92	1.35
Intermediate Shell B4712-2 (Transverse)	T	0.278	0.651	74.83	48.71	0.42
	U	0.579	0.847	98.26	83.23	0.72
	X	1.12	1.032	125.15	129.15	1.07
	Y	1.81	1.163	129.33	150.41	1.35
	Sum =				727.74	7.12
	$CF = \Sigma(FF * RT_{NDT}) + \Sigma(FF^2) = (727.74) + (7.12) = 102.21$ °F					
Surveillance Program Weld Material	T	0.278	0.651	153.17	99.71	0.42
	U	0.579	0.847	185.94	157.49	0.72
	X	1.12	1.032	195.43	201.68	1.07
	Y	1.81	1.163	200.9	233.65	1.35
	Sum =				692.53	3.56
	$CF = \Sigma(FF * RT_{NDT}) + \Sigma(FF^2) = (692.53) + (3.56) = 194.53$ °F					

Notes:
(a) f = Best-estimate fluence
(b) FF = fluence factor = $f^{(0.28 - 0.1*\log f)}$
(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values taken from App. B.
(d) $CF = \Sigma(FF * RT_{NDT}) + \Sigma(FF^2)$

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:
Salem Unit 2 Surveillance Capsule Data Scatter about the Best-Fit Line for Surveillance Materials.

Material	Capsule	CF[a] ($Slope_{best\ fit}$)	FF[b]	ΔRT_{NDT}[c]	Best Fit ΔRT_{NDT} (°F)	Scatter ΔRT_{NDT} (°F)	<17°F (Base Metals) <28°F (Weld)
Intermediate Shell Plate B4712-2 (Longitudinal)	T	102.21	0.651	61.66	66.54	-4.88	Yes
	U	102.21	0.847	66.54	86.57	-20.03	No
	X	102.21	1.032	93.82	105.48	-11.66	Yes
	Y	102.21	1.163	105.69	118.87	-13.18	Yes
Intermediate Shell Plate B4712-2 (Transverse)	T	102.21	0.651	74.83	66.54	8.29	Yes
	U	102.21	0.847	98.26	86.57	11.69	Yes
	X	102.21	1.032	125.15	105.48	19.67	No
	Y	102.21	1.163	129.33	118.87	10.46	Yes
Surveillance Weld Metal (Heat 13253)	T	194.53	0.651	153.17	126.64	26.53	Yes
	U	194.53	0.847	185.94	164.77	21.17	Yes
	X	194.53	1.032	195.43	200.75	-5.32	Yes
	Y	194.53	1.163	200.9	226.24	-25.34	Yes

Notes:
(a) f = Measured fluence from capsule Y dosimetry analysis results (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 (Appendix C) and do not include the adjustment ratio procedure of Reg. Guide 1.99 Revision 2, Position 2.1, since this calculation is based on the actual surveillance weld metal measured shift values.

$$\text{Best Fit } \Delta RT_{NDT} = (Slope_{best\ fit}) * (\text{Fluence Factor})$$

Plates:

Table B-2 indicates that one of the measured plate ΔRT_{NDT} values is below the lower bound 1σ of 17°F. This indicates that the best-fit line would slightly over predict this measured ΔRT_{NDT} value. Table B-2 also indicates that one of the measured ΔRT_{NDT} values is above the upper bound 1σ of 17°F. From a statistical point of view ± 1σ (17°F) would be expected to encompass approximately 68% of the data. It is still statistically acceptable to have two of the data points fall outside the ± 1σ bounds. The fact that two of the measured ΔRT_{NDT} values are outside of the 1σ bound of 17°F can be attributed to several factors, such as 1) the inherent uncertainty in Charpy test data, 2) the use of a symmetric hyperbolic tangent Charpy curve fitting curve fitting program versus an asymmetric hyperbolic tangent Charpy curve fitting program versus a hand drawn curve using engineering judgment, and/or 3) rounding errors.

Welds:

All weld metal data points are well within the 1σ scatter band. Hence, the plate and weld data meet this criterion.

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 Salem Unit 2 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 temperatures will not differ by more than 25°F.

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

The Salem Unit 2 surveillance program does not include correlation monitor material. Therefore, this criterion is not applicable to Salem Unit 2.

CONCLUSION:

Based on the preceding responses to all five criteria of Regulatory Guide 1.99, Revision 2, Section B, and the application of engineering judgment, the Salem Unit 2 surveillance data is credible.

APPENDIX E

SUPPORTING DOCUMENTATION

As part of the Capsule Y analysis for Salem Unit 2, tests provide new chemistry values for the Intermediate Shell Plate B4712-2 and the Surveillance Weld Material (Heat 13253). This new data needs to be considered for calculating the Best Estimate %Cu and %Ni for both of the previously mentioned materials. Intermediate Shell Plate B4712-2 Best Estimate Calculations are shown in Table E-1. The Best Estimate for the Intermediate Shell Longitudinal Weld Seam 2-442 A, B & C was determined by averaging the Best Estimates from two Heats (13253 and 20291). Heat 13253 contained the Surveillance data Best Estimate under Tag "a" of CE NPSD-1039, Rev 2 Heat 13253[35]. Since new chemistry has been tested from Capsule Y (Specimen Numbers JW-84, JW-82 and JW-75), Tag "a" Best Estimate and the overall Best Estimate %Cu and %Ni must be determined. Table E-2 contains the new Surveillance Weld Best Estimate (i.e. Tag "a") and Table E-3 contains the calculation of the overall Best Estimate for Heat 13253. Table E-4 contains the Best Estimate for Intermediate Shell Longitudinal Weld Seam 2-442 A, B & C (Heat numbers 13253 and 20291).

Table E-1

Determination of the Best Estimate of % Cu and % Ni for Intermediate Shell Plate B4712-2 from the Salem Unit 2 Reactor Vessel

Reference	% Cu	% Ni
WCAP-10492	0.10	0.61
WCAP-10492	- - -	0.60
WCAP-11554 (JL46)	0.129	0.634
WCAP-13366 (JT-42)	0.122	0.625
WCAP-15692 (JT-79)	0.132 *	0.588 *
Best Estimate	**0.12**	**0.61**

* Indicates new specimen.

Table E-2

Determination of the Best Estimate of % Cu and % Ni for the Surveillance Weld Material (Heat 13253 Tag "a") from the Salem Unit 2 Reactor Vessel

Reference	Average % Cu	Average % Ni
Tag "a" (WCAP-10492)	0.23	0.71
Tag "a" (WCAP-13366)	0.247	0.728
Tag "a" (WCAP-13366)	0.267	0.728
Tag "a" (WCAP-11554)	0.283	0.732
Tag "a" (WCAP-13366)	0.244	0.734
JW-84	0.273 *	0.693 *
JW-82	0.301 *	0.704 *
JW-75	0.287 *	0.667 *
Best Estimate (Heat 13253 Tag "a")	**0.267**	**0.712**

* Indicates new specimen.

Table E-3

Determination of the Best Estimate of % Cu and % Ni Weld Material (Heat 13253) from the Salem Unit 2 Reactor Vessel

Reference	Average % Cu	Average % Ni
Heat 13253 Updated Tag "a"	0.267 *	0.712 *
Heat 13253 Tag "b"	0.14	0.73
Heat 13253 Tag "c"	0.27	0.74
Overall Best Estimate (Heat 13253)	**0.225**	**0.727**

* Results of Table E-2.

Table E-4

Determination of the Best Estimate of % Cu and % Ni for Intermediate Shell Longitudinal Weld Seam 2-442 A, B & C from the Salem Unit 2 Reactor Vessel

Reference	Average % Cu	Average % Ni
Best Estimate (Heat 13253)	0.225 *	0.727 *
Heat 20291	0.216	0.737
Overall Best Estimate (Heat 13253/20291)	**0.221**	**0.732**

* Results of Table E-3.