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Analysis of Capsule W from the South Texas Project Nuclear Operating Company South Texas Unit 1 Reactor Vessel Radiation Surveillance Program

Westinghouse

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Analysis of Capsule W from the South Texas Project Nuclear Operating Company South Texas Unit 1 Reactor

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EXECUTIVE SUMMARY

The purpose of this report is to document the testing results of surveillance Capsule W from South Texas Unit 1. Capsule W was removed at 18.21 effective full power years (EFPY) and post-irradiation mechanical tests of the Charpy V-notch and tensile specimens were performed. A fluence evaluation utilizing the neutron transport and dosimetry cross-section libraries was derived from the ENDF/B-VI database. Capsule W received a fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) after irradiation to 18.21 EFPY. The peak clad/base metal interface vessel fluence after 18.21 EFPY of plant operation was 1.44 x 10^{19} n/cm^2 (E > 1.0 MeV).

This evaluation led to the following conclusions: 1) The measured percent decreases in upper-shelf energy for all the surveillance materials contained in South Texas Unit 1 Capsule W are less than the Regulatory Guide 1.99, Revision 2 [Ref. 1] predictions. 2) The South Texas Unit 1 surveillance plate and weld data is judged to be credible. This credibility evaluation can be found in Appendix D. 3) All beltline materials exhibit a more than adequate upper-shelf energy level for continued safe plant operation and are predicted to maintain an upper-shelf energy greater than 50 ft-lb through end-of-license (34 EFPY) and end-of-license renewal (54 EFPY) as required by 10 CFR 50, Appendix G [Ref. 2]. The upper-shelf energy evaluation is presented in Appendix E.

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

1 SUMMARY OF RESULTS

The analysis of the reactor vessel materials contained in surveillance Capsule W, the fourth capsule removed and tested from the South Texas Unit 1 reactor pressure vessel, led to the following conclusions:

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

- Capsule W received an average fast neutron fluence (E > 1.0 MeV) of 4.365 x10^{19} n/cm^2 after 18.21 effective full power years (EFPY) of plant operation.

- Irradiation of the reactor vessel Intermediate Shell Plate R1606-2 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major working direction (longitudinal orientation), resulted in an irradiated 30 ft-lb transition temperature of 12.9°F and an irradiated 50 ft-lb transition temperature of 49.3°F. This results in a 30 ft-lb transition temperature increase of 64.9°F and a 50 ft-lb transition temperature increase of 69.6°F for the longitudinally oriented specimens.

- Irradiation of the reactor vessel Intermediate Shell Plate R1606-2 Charpy specimens, oriented with the longitudinal axis of the specimen perpendicular to the major working direction (transverse orientation), resulted in an irradiated 30 ft-lb transition temperature of 24.3°F and an irradiated 50 ft-lb transition temperature of 69.6°F. This results in a 30 ft-lb transition temperature increase of 30.4°F and a 50 ft-lb transition temperature increase of 42.6°F for the transversely oriented specimens.

- Irradiation of the Surveillance Program Weld Metal (Heat # 89476) Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of -12.4°F and an irradiated 50 ft-lb transition temperature of 21.1°F. This results in a 30 ft-lb transition temperature increase of 43.6°F and a 50 ft-lb transition temperature increase of 37.9°F.

- Irradiation of the Heat-Affected Zone (HAZ) Material Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of -52.5°F and an irradiated 50 ft-lb transition temperature of -34.8°F. This results in a 30 ft-lb transition temperature increase of 81.6°F and a 50 ft-lb transition temperature increase of 51.3°F.

- The average upper-shelf energy of Intermediate Shell Plate R1606-2 (longitudinal orientation) resulted in an average energy decrease of 17.0 ft-lb after irradiation. This results in an irradiated average upper-shelf energy of 121.0 ft-lb for the longitudinally oriented specimens.

- The average upper-shelf energy of Intermediate Shell Plate R1606-2 (transverse orientation) resulted in an average energy decrease of 11.0 ft-lb after irradiation. This results in an irradiated average upper-shelf energy of 102.0 ft-lb for the transversely oriented specimens.

- The average upper-shelf energy of the Surveillance Program Weld Metal (Heat # 89476) Charpy specimens resulted in an average energy increase of 1.0 ft-lb after irradiation. This results in an irradiated average upper-shelf energy of 87.0 ft-lb for the weld metal specimens.

- The average upper-shelf energy of the HAZ Material Charpy specimens resulted in an average energy increase of 3.0 ft-lb after irradiation. This results in an irradiated average upper-shelf energy of 108.0 ft-lb for the HAZ Material.

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

- Based on the credibility evaluation presented in Appendix D, the South Texas Unit 1 surveillance plate and weld data is credible.

- Based on the upper-shelf energy evaluation in Appendix E, all beltline materials contained in the South Texas Unit 1 reactor vessel exhibit a more than adequate upper-shelf energy level for continued safe plant operation and are predicted to maintain an upper-shelf energy greater than 50 ft-lb through end-of-license (34 EFPY) and end-of-license renewal (54 EFPY) as required by 10 CFR 50, Appendix G [Ref. 2].

- The calculated 34 EFPY (end-of-license) and 54 EFPY (end-of-license renewal) neutron fluence (E > 1.0 MeV) at the core mid-plane for the South Texas Unit 1 reactor vessel using the Regulatory Guide 1.99, Revision 2 attenuation formula (i.e., Equation #3 in the guide) are as follows:

Calculated (34 EFPY):	Vessel inner radius* = 2.51×10^{19} n/cm^2 (Taken from Table 6-2) Vessel 1/4 thickness = 1.50×10^{19} n/cm^2
Calculated (54 EFPY):	Vessel inner radius* = 3.88×10^{19} n/cm^2 (Taken from Table 6-2) Vessel 1/4 thickness = 2.31×10^{19} n/cm^2

* Clad/base metal interface.

2 INTRODUCTION

This report presents the results of the examination of Capsule W, the fourth capsule removed and tested in the continuing surveillance program, which monitors the effects of neutron irradiation on the South Texas Project South Texas Unit 1 reactor pressure vessel materials under actual operating conditions.

The surveillance program for the South Texas Unit 1 reactor pressure vessel materials was designed and recommended by the Westinghouse Electric Corporation. A description of the surveillance program and the pre-irradiation mechanical properties of the reactor vessel materials are presented in WCAP-9492 [Ref. 3], "South Texas Utilities South Texas Project Unit No. 1 Reactor Vessel Radiation Surveillance Program." The surveillance program was planned to cover the 40-year design life of the reactor pressure vessel and was based on ASTM E185-73 [Ref. 4], "Standard Recommended Practice for Surveillance Tests for Nuclear Reactor Vessels." Capsule W was removed from the reactor after 18.21 EFPY of exposure and shipped to the Westinghouse Research and Technology Unit (RTU) Hot Cell Facility, where the post-irradiation mechanical testing of the Charpy V-notch impact and tensile surveillance specimens was performed.

This report summarizes the testing of the post-irradiation data obtained from surveillance Capsule W removed from the South Texas Unit 1 reactor vessel and discusses the analysis of the data.

3 BACKGROUND

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

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

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

RT_{NDT} and, in turn, the operating limits of nuclear power plants can be adjusted to account for the effects of radiation on the reactor vessel material properties. The changes in mechanical properties of a given reactor pressure vessel steel, due to irradiation, can be monitored by a reactor vessel surveillance program, such as the South Texas Unit 1 reactor vessel radiation surveillance program, in which a surveillance capsule is periodically removed from the operating nuclear reactor and the encapsulated specimens are tested. The increase in the average Charpy V-notch 30 ft-lb temperature (ΔRT_{NDT}) due to irradiation is added to the initial RT_{NDT}, along with a margin (M) to cover uncertainties, to adjust the RT_{NDT} (ART) for radiation embrittlement. This ART (initial RT_{NDT} + M + ΔRT_{NDT}) is used to index the material to the K_{Ic} curve and, in turn, to set operating limits for the nuclear power plant that take into account the effects of irradiation on the reactor vessel materials.

4 DESCRIPTION OF PROGRAM

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

- Intermediate Shell Plate R1606-2 (longitudinal orientation)
- Intermediate Shell Plate R1606-2 (transverse orientation)
- Weld metal fabricated with Type B-4 weld wire, Heat Number 89476 Linde Type 124 flux, Lot Number 1061, which is identical to that used in the actual fabrication of the intermediate to lower shell circumferential weld seam
- Weld heat-affected zone (HAZ) material of Intermediate Shell Plate R1606-2

Test material obtained from the intermediate shell plate (after thermal heat treatment and forming of the plate) was taken at least one plate thickness from the quenched edges of the plate. All test specimens were machined from the ¼ thickness location of the plate after performing a simulated post-weld stress-relieving treatment on the test material. Test specimens were also removed from weld and heat-affected zone metal of a stress-relieved weldment joining Intermediate Shell Plate R1606-2 and adjacent Intermediate Shell Plate R1606-3. All heat-affected zone specimens were obtained from the weld heat-affected zone of Intermediate Shell Plate R1606-2.

Charpy V-notch impact specimens from Intermediate Shell Plate R1606-2 were machined in the longitudinal orientation (longitudinal axis of the specimen parallel to the major rolling direction) and also in the transverse orientation (longitudinal axis of the specimen perpendicular to the major rolling direction). The core-region weld Charpy impact specimens were machined from the weldment such that the long dimension of each Charpy specimen was perpendicular (normal) to the weld direction. The notch of the weld metal Charpy specimens was machined such that the direction of crack propagation in the specimen was in the welding direction.

Tensile specimens from Intermediate Shell Plate R1606-2 were machined in both the longitudinal and transverse orientations. Tensile specimens from the weld metal were oriented perpendicular to the welding direction.

Compact Tension (CT) specimens from Intermediate Shell Plate R1606-2 were machined in the longitudinal and transverse orientations. CT specimens from the weld metal were machined with the notch oriented in the direction of welding. All specimens were fatigue pre-cracked according to ASTM E399 [Ref. 7].

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

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

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

The chemical composition and heat treatment of the unirradiated surveillance materials is presented in Tables 4-1 and 4-2, respectively. The data in Tables 4-1 and 4-2 was obtained from the original surveillance program report, WCAP-9492 [Ref. 3], Appendix A.

Capsule W was removed after 18.21 effective full power years (EFPY) of plant operation. This capsule contained Charpy V-notch, tensile, 1/2T-CT fracture mechanics specimens, dosimeters, and thermal monitors.

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

Table 4-1 Chemical Composition (wt%) of South Texas Unit 1 Reactor Vessel Surveillance Materials (Unirradiated)[(a)]

Element	Intermediate Shell Plate R1606-2	Weld Metal[(b)]
C	0.19	0.12
S	0.013	0.010
N_2	0.008	0.004
Co	0.012	0.009
Cu	0.04	0.02
Si	0.19	0.42
Mo	0.53	0.53
Ni	0.61	0.09
Mn	1.18	1.36
Cr	0.03	0.02
V	0.004	0.003
P	0.008	0.009
Sn	0.002	0.003
B	< 0.001	0.001
Cb	< 0.01	< 0.01
Ti	< 0.01	< 0.01
W	< 0.01	0.02
As	0.003	0.004
Zr	< 0.001	< 0.001
Pb	Not Detected	< 0.001
Ar	0.017	0.008

Notes:

(a) Data obtained from WCAP-9492 [Ref. 3].

(b) Weld Wire Type B4, Heat Number 89476, Flux Type Linde 124, and Flux Lot Number 1061. Surveillance Weldment is from the weld between the Intermediate Shell Plates R1606-2 and R1606-3.

Table 4-2 Heat Treatment History of the South Texas Unit 1 Reactor Vessel Surveillance Materials[(a)]

Material	Temperature (°F)	Time	Cooling
Intermediate Shell Plate R1606-2	Austenitized @ 1600 ± 25 (871°C)	4 hrs.	Water-Quenched
	Tempered @ 1225 ± 25 (663°C)	4 hrs.	Air-Cooled
	Stress Relieved @ 1150 ± 50 (621°C)	14 hrs. 43 min.	Furnace-Cooled
Surveillance Program Weld Metal (Heat # 89476)	Stress Relieved @ 1150 ± 50 (621°C)	13 hrs. 15 min.	Furnace-Cooled

Note:
(a) Data obtained from WCAP-9492 [Ref. 3].

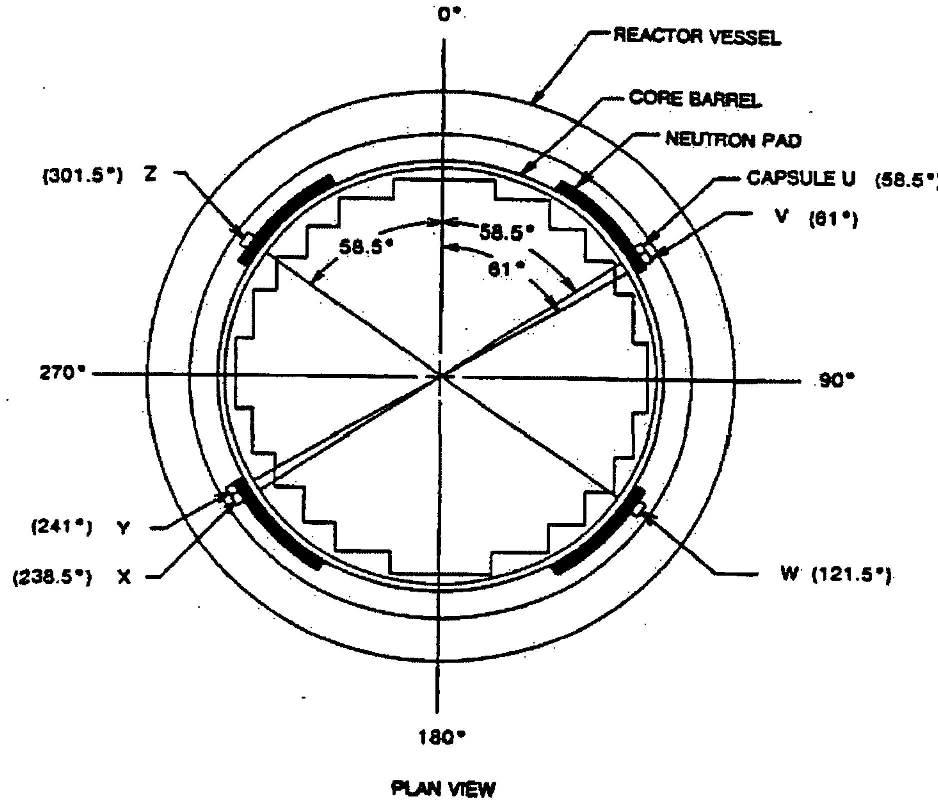


Figure 4-1 Arrangement of Surveillance Capsules in the South Texas Unit 1 Reactor Vessel

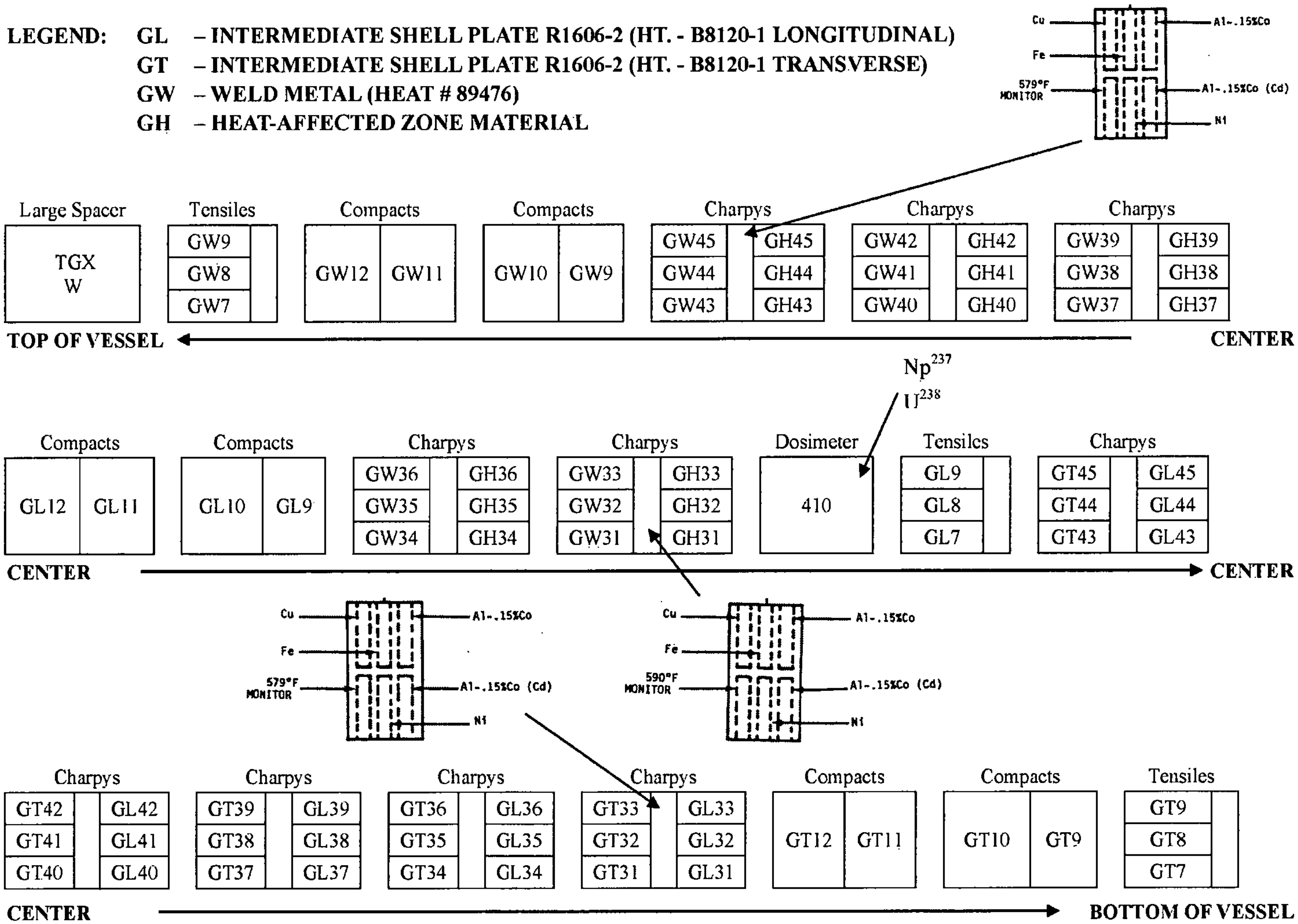


Figure 4-2 Capsule W Diagram Showing the Location of Specimens, Thermal Monitors, and Dosimeters

5 TESTING OF SPECIMENS FROM CAPSULE W

5.1 OVERVIEW

The post-irradiation mechanical testing of the Charpy V-notch impact specimens and tensile specimens was performed at the Hot Cell Facility at the Westinghouse Research and Technology Unit (RTU). Testing was performed in accordance with 10 CFR 50, Appendices G and H [Ref. 2] and ASTM Specification E185-82 [Ref. 8].

The capsule was opened upon receipt at the hot cell laboratory. The specimens and spacer blocks were carefully removed, inspected for identification number, and checked against the master list in WCAP-9492 [Ref. 3]. All items were in their proper locations.

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

The Charpy impact tests were performed per ASTM Specification E23-07a [Ref. 9] on a Tinius-Olsen Model 74, 358J machine. The Charpy machine striker was instrumented with an Instron Impulse system. Note that the instrumented Charpy data is for information only. The Instron Impulse system has not been calibrated to ASTM Standard E2298-09 [Ref. 10], so the instrumented energy, load, time, and stress data are considered for information only.

The instrumented striker load signal data acquisition rate was 819 kHz with data acquired for 10 ms. From the load-time curve, the load of general yielding (F_{gy}), the time to general yielding, the maximum load (F_m) and the time to maximum load were determined. Under some test conditions, a sharp drop in load indicative of fast fracture was observed. The load at which fast fracture was initiated is identified as the brittle fracture load (F_{bf}). The termination load after the fast load drop is identified as the arrest load (F_a). F_{gy}, F_m, F_{bf}, and F_a were determined per the guidance in ASTM Standard E2298-09 [Ref. 10].

The energy at maximum load (W_m) was determined by integrating the load-time record to the maximum load point. The energy at maximum load is approximately equivalent to the energy required to initiate a crack in the specimen. Therefore, the propagation energy for the crack (W_P) is the difference between the total energy (W_t) and the energy at maximum load (W_m). W_t is compared to the dial energy (KV). W_t derived from the instrumented striker were generally within 15% of the calibrated dial energy values as required in ASTM E2298-09 [Ref. 10], which indicates that the instrumented data is trustworthy.

Percent shear was determined from post-fracture photographs using the ratio-of-areas methods in compliance with ASTM E23-07a [Ref. 9] and A370-09 [Ref. 11]. The lateral expansion was measured using a dial gage rig similar to that shown in the same specifications.

Tensile tests were performed on a 250 KN Instron screw driven tensile machine (Model 5985). Testing met ASTM Specifications E8-09 [Ref. 12] and E21-09 [Ref. 13] except for some minor deviations that do not have any significant effect on the results provided in this report.

Elevated test temperatures were obtained with a three-zone electric resistance split-tube furnace with a 10-inch hot zone. Specimens were soaked at temperature (±5°F) for a minimum of 20 minutes before testing. All tests were conducted in air. The specimens were round 0.25-inch diameter with a 1.25-inch reduced section. Load was applied through a clevis and pin connection.

The yield load, ultimate load, fracture load, uniform elongation and elongation at fracture were determined directly from the load-extension curve. The yield strength (0.2% offset method), ultimate tensile strength and fracture strength were calculated using the original cross-sectional area. The final diameter and final gage length was determined from post-fracture photographs.

This final diameter measurement was used to calculate the fracture stress (true stress at fracture) and the percent reduction in area. The final gage length was used to calculate total elongation after fracture.

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 W, which received a fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) in 18.21 EFPY of operation, are presented in Tables 5-1 through 5-8 and are compared with the unirradiated and previously withdrawn capsule results as shown in Figures 5-1 through 5-12. The unirradiated and previously withdrawn capsule results were taken from WCAP-9492 [Ref. 3], WCAP-12629 [Ref. 14], WCAP-14847 [Ref. 15], and WCAP-16149 [Ref. 16].

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

- Irradiation of the reactor vessel Intermediate Shell Plate R1606-2 Charpy specimens, oriented with the longitudinal axis of the specimen parallel to the major working direction (longitudinal orientation), resulted in an irradiated 30 ft-lb transition temperature of 12.9°F and an irradiated 50 ft-lb transition temperature of 49.3°F. This results in a 30 ft-lb transition temperature increase of 64.9°F and a 50 ft-lb transition temperature increase of 69.6°F for the longitudinally oriented specimens.

- Irradiation of the reactor vessel Intermediate Shell Plate R1606-2 Charpy specimens, oriented with the longitudinal axis of the specimen perpendicular to the major working direction (transverse orientation), resulted in an irradiated 30 ft-lb transition temperature of 24.3°F and an irradiated 50 ft-lb transition temperature of 69.6°F. This results in a 30 ft-lb transition temperature increase of 30.4°F and a 50 ft-lb transition temperature increase of 42.6°F for the transversely oriented specimens.

- Irradiation of the Surveillance Program Weld Metal (Heat # 89476) Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of -12.4°F and an irradiated 50 ft-lb transition temperature of 21.1°F. This results in a 30 ft-lb transition temperature increase of 43.6°F and a 50 ft-lb transition temperature increase of 37.9°F.

- Irradiation of the Heat-Affected Zone (HAZ) Material Charpy specimens resulted in an irradiated 30 ft-lb transition temperature of -52.5°F and an irradiated 50 ft-lb transition temperature of -34.8°F.

This results in a 30 ft-lb transition temperature increase of 81.6°F and a 50 ft-lb transition temperature increase of 51.3°F.

- The average upper-shelf energy of the Intermediate Shell Plate R1606-2 (longitudinal orientation) resulted in an average energy decrease of 17.0 ft-lb after irradiation to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV). This results in an irradiated average upper-shelf energy of 121.0 ft-lb for the longitudinally oriented specimens.

- The average upper-shelf energy of the Intermediate Shell Plate R1606-2 (transverse orientation) resulted in an average energy decrease of 11.0 ft-lb after irradiation to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV). This results in an irradiated average upper-shelf energy of 102.0 ft-lb for the transversely oriented specimens.

- The average upper-shelf energy of the Surveillance Program Weld Metal (Heat # 89476) Charpy specimens resulted in an average energy increase of 1.0 ft-lb after irradiation to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV). This results in an irradiated average upper-shelf energy of 87.0 ft-lb for the weld metal specimens.

- The average upper-shelf energy of the HAZ Material Charpy specimens resulted in an average energy increase of 3.0 ft-lb after irradiation to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV). This results in an irradiated average upper-shelf energy of 108.0 ft-lb for the HAZ Material.

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

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

All beltline materials exhibit a more than adequate upper-shelf energy level for continued safe plant operation and are predicted to maintain an upper-shelf energy greater than 50 ft-lb through end-of-license (34 EFPY) and end-of-license renewal (54 EFPY) as required by 10 CFR 50, Appendix G [Ref. 2]. This evaluation can be found in Appendix E.

5.3 TENSILE TEST RESULTS

The results of the tensile tests performed on the various materials contained in Capsule W irradiated to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) are presented in Table 5-11 and are compared with unirradiated results as shown in Figures 5-17 through 5-19.

The results of the tensile tests performed on the Intermediate Shell Plate R1606-2 (longitudinal orientation) indicated that irradiation to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) caused increases in the 0.2 percent offset yield strength and the ultimate tensile strength when compared to unirradiated data [Ref. 3]. See Figure 5-17 and Table 5-11.

The results of the tensile tests performed on the Intermediate Shell Plate R1606-2 (transverse orientation) indicated that irradiation to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) caused increases in the 0.2 percent offset yield strength and the ultimate tensile strength when compared to unirradiated data [Ref. 3]. See Figure 5-18 and Table 5-11.

The results of the tensile tests performed on the Surveillance Program Weld Metal (Heat # 89476) indicated that irradiation to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) caused increases in the 0.2 percent offset yield strength and the ultimate tensile strength when compared to unirradiated data [Ref. 3]. See Figure 5-19 and Table 5-11.

The fractured tensile specimens for the Intermediate Shell Plate R1606-2 material are shown in Figures 5-20 and 5-21, while the fractured tensile specimens for the Surveillance Program Weld Metal (Heat # 89476) are shown in Figure 5-22. The engineering stress-strain curves for the tensile tests are shown in Figures 5-23 through 5-27.

5.4 1/2T COMPACT TENSION SPECIMEN TESTS

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

Table 5-1 Charpy V-notch Data for the South Texas Unit 1 Intermediate Shell Plate R1606-2 Irradiated to a Fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) (Longitudinal Orientation)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
GL31	-50	-46	3.5	5	4	0.10	2
GL44	0	-18	19	26	14	0.36	10
GL33	10	-12	51	69	38	0.97	15
GL43	15	-9	25	34	21	0.53	15
GL37	20	-7	19	26	15	0.38	15
GL41	30	-1	50	68	35	0.89	25
GL39	40	4	50	68	36	0.91	30
GL40	50	10	41	56	33	0.84	35
GL34	72	22	82	111	53	1.35	50
GL45	100	38	61	83	49	1.24	65
GL38	110	43	76	103	57	1.45	55
GL42	130	54	97	132	63	1.60	70
GL32	150	66	118	160	82	2.08	95
GL35	200	93	130	176	77	1.96	100
GL36	250	121	114	155	81	2.06	100

Table 5-2 Charpy V-notch Data for the South Texas Unit 1 Intermediate Shell Plate R1606-2 Irradiated to a Fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) (Transverse Orientation)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
GT43	-50	-46	5	7	4	0.10	0
GT32	0	-18	15	20	13	0.33	15
GT37	10	-12	22	30	20	0.51	15
GT42	20	-7	28	38	24	0.61	20
GT44	25	-4	43	58	34	0.86	30
GT45	30	-1	39	53	30	0.76	35
GT39	40	4	39	53	28	0.71	35
GT40	50	10	41	56	32	0.81	40
GT38	72	22	49	66	41	1.04	50
GT36	100	38	56	76	46	1.17	60
GT41	130	54	67	91	51	1.30	70
GT34	150	66	88	119	70	1.78	90
GT35	200	93	105	142	68	1.73	100
GT31	225	107	98	133	66	1.68	100
GT33	250	121	102	138	75	1.91	100

Table 5-3 Charpy V-notch Data for the South Texas Unit 1 Surveillance Program Weld Metal (Heat # 89476) Irradiated to a Fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
GW34	-90	-68	3	4	2	0.05	10
GW36	-70	-57	3	4	2	0.05	15
GW43	-50	-46	34	46	25	0.64	30
GW41	-45	-43	4	5	5	0.13	30
GW40	-40	-40	14	19	12	0.30	35
GW38	-35	-37	7	9	7	0.18	30
GW44	-30	-34	38	52	36	0.91	35
GW45	-15	-26	30	41	24	0.61	40
GW35	0	-18	38	52	36	0.91	50
GW31	30	-1	46	62	39	0.99	60
GW33	40	4	64	87	52	1.32	75
GW37	72	22	76	103	54	1.37	90
GW42	130	54	90	122	72	1.83	100
GW39	150	66	87	118	79	2.01	100
GW32	200	93	85	115	72	1.83	100

Table 5-4 Charpy V-notch Data for the South Texas Unit 1 Heat-Affected Zone (HAZ) Material Irradiated to a Fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV)

Sample Number	Temperature		Impact Energy		Lateral Expansion		Shear
	°F	°C	ft-lbs	Joules	mils	mm	%
GH37	-90	-68	15	20	7	0.18	5
GH44	-70	-57	34	46	16	0.41	10
GH39	-60	-51	66	89	42	1.07	30
GH33	-50	-46	18	24	12	0.30	20
GH31	-45	-43	46	62	24	0.61	15
GH40	-40	-40	29	39	16	0.41	20
GH34	-35	-37	25	34	15	0.38	25
GH43	-30	-34	64	87	14	0.36	35
GH41	-15	-26	34	46	23	0.58	40
GH32	0	-18	122	165	62	1.57	70
GH42	15	-9	115	156	75	1.91	100
GH36	40	4	145	197	73	1.85	100
GH38	72	22	139	188	73	1.85	100
GH35	130	54	49	66	43	1.09	95
GH45	200	93	90	122	72	1.83	100

Table 5-5 Instrumented Charpy Impact Test Results for the South Texas Unit 1 Intermediate Shell Plate R1606-2 Irradiated to a Fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) (Longitudinal Orientation)

Sample Number	Test Temp (°F)	Total Dial Energy, KV (ft-lb)	Total Instrumented Energy, W_t (ft-lb)	Difference, $(KV-W_t)/KV$ (%)	Energy to Max Load, W_m (ft-lb)	Maximum Load, F_m (lb)	Time to F_m (msec)	General Yield Load, F_{gy} (lb)	Time to F_{gy} (msec)	Fracture Load, F_{bf} (lb)	Arrest Load, F_a (lb)
GL31	-50	3.5	3.4	3	3	3610	0.08	3100	0.06	3600	NA
GL44	0	19	18	4	3	3820	0.09	3100	0.05	3710	NA
GL33	10	51	47	8	34	3990	0.61	3000	0.06	3820	NA
GL43	15	25	22	13	21	3740	0.40	3100	0.06	3660	NA
GL37	20	19	17	11	3	3720	0.09	3200	0.05	3450	NA
GL41	30	50	45	10	33	3940	0.61	3000	0.06	3850	40
GL39	40	50	44	12	32	3900	0.60	3100	0.06	3730	200
GL40	50	41	38	6	32	3840	0.60	3100	0.05	3750	300
GL34	72	82	77	6	43	3980	0.77	3200	0.05	3520	1100
GL45	100	61	57	6	31	3760	0.60	3000	0.06	3490	1400
GL38	110	76	68	10	32	3820	0.62	3100	0.07	3360	1200
GL42	130	97	81	17	31	3750	0.60	2800	0.06	2900	1600
GL32	150	118	110	7	31	3750	0.62	2500	0.06	2440	2100
GL35	200	130	119	9	39	3650	0.77	2900	0.05	NA	NA
GL36	250	114	104	9	28	3520	0.60	2700	0.05	NA	NA

Table 5-6 Instrumented Charpy Impact Test Results for the South Texas Unit 1 Intermediate Shell Plate R1606-2 Irradiated to a Fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV) (Transverse Orientation)

Sample Number	Test Temp (°F)	Total Dial Energy, KV (ft-lb)	Total Instrumented Energy, W_t (ft-lb)	Difference, $(KV-W_t)/KV$ (%)	Energy to Max Load, W_m (ft-lb)	Maximum Load, F_m (lb)	Time to F_m (msec)	General Yield Load, F_{gy} (lb)	Time to F_{gy} (msec)	Fracture Load, F_{br} (lb)	Arrest Load, F_a (lb)
GT43	-50	5	5	0	3	3920	0.09	3300	0.06	3300	NA
GT32	0	15	15	3	3	3640	0.09	3000	0.06	3010	NA
GT37	10	22	21	4	15	3600	0.32	3100	0.06	3470	NA
GT42	20	28	25	11	24	3650	0.48	3100	0.06	3580	NA
GT44	25	43	41	5	32	3820	0.60	3100	0.06	3710	300
GT45	30	39	37	5	31	3800	0.60	3200	0.08	3600	400
GT39	40	39	36	7	32	3740	0.60	3000	0.06	3540	300
GT40	50	41	39	5	33	3800	0.62	2900	0.07	3740	600
GT38	72	49	47	5	32	3800	0.60	3200	0.05	3770	1100
GT36	100	56	49	13	30	3650	0.60	2900	0.06	3330	1200
GT41	130	67	61	9	30	3620	0.60	2900	0.06	3240	1400
GT34	150	88	81	8	29	3600	0.60	2900	0.05	2420	1800
GT35	200	105	96	8	28	3520	0.61	2700	0.06	NA	NA
GT31	225	98	91	8	28	3460	0.60	2700	0.05	NA	NA
GT33	250	102	92	10	28	3440	0.60	2300	0.05	NA	NA

Table 5-7 Instrumented Charpy Impact Test Results for the South Texas Unit 1 Surveillance Program Weld Metal (Heat # 89476) Irradiated to a Fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV)

Sample Number	Test Temp (°F)	Total Dial Energy, KV (ft-lb)	Total Instrumented Energy, W_t (ft-lb)	Difference, $(KV-W_t)/KV$ (%)	Energy to Max Load, W_m (ft-lb)	Maximum Load, F_m (lb)	Time to F_m (msec)	General Yield Load, F_{gy} (lb)	Time to F_{gy} (msec)	Fracture Load, F_{br} (lb)	Arrest Load, F_a (lb)
GW34	-90	3	2.1	(a)	1	2110	0.05	2000	0.05	1910	NA
GW36	-70	3	2.1	(a)	1	3070	0.06	2600	0.05	3050	NA
GW43	-50	34	31	10	27	3830	0.09	3000	0.06	3600	NA
GW41	-45	4	3.6	10	2	3260	0.06	3300	0.06	3230	NA
GW40	-40	14	14	1	3	3800	0.09	3100	0.06	3350	NA
GW38	-35	7	6.5	7	3	3830	0.09	3200	0.05	3300	NA
GW44	-30	38	34	9	3	3780	0.09	3200	0.06	3540	NA
GW45	-15	30	25	15	14	3680	0.29	3100	0.06	3480	400
GW35	0	38	35	9	3	3690	0.50	3100	0.05	3660	900
GW31	30	46	40	14	31	3660	0.60	3000	0.06	3420	900
GW33	40	64	58	10	31	3660	0.60	3000	0.06	2970	1700
GW37	72	76	69	9	31	3730	0.60	3100	0.05	3220	2000
GW42	130	90	82	9	31	3610	0.62	2700	0.07	NA	NA
GW39	150	87	81	7	30	3590	0.60	2800	0.05	NA	NA
GW32	200	85	77	9	29	3470	0.60	2800	0.06	NA	NA

Note:
(a) Values are acceptable per ASTM E2298-09.

Table 5-8 Instrumented Charpy Impact Test Results for the South Texas Unit 1 Heat-Affected Zone (HAZ) Material Irradiated to a Fluence of 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV)

Sample Number	Test Temp (°F)	Total Dial Energy, KV (ft-lb)	Total Instrumented Energy, W_t (ft-lb)	Difference, (KV-W_t)/KV (%)	Energy to Max Load, W_m (ft-lb)	Maximum Load, F_m (lb)	Time to F_m (msec)	General Yield Load, F_{gy} (lb)	Time to F_{gy} (msec)	Fracture Load, F_{br} (lb)	Arrest Load, F_a (lb)
GH37	-90	15	14	5	4	4380	0.09	3400	0.07	3790	NA
GH44	-70	34	32	6	4	4330	0.09	3400	0.06	4270	NA
GH39	-60	66	62	7	38	4430	0.61	3400	0.06	4060	NA
GH33	-50	18	15	16	4	4190	0.09	3400	0.06	3870	NA
GH31	-45	46	44	5	38	4440	0.61	3400	0.06	4200	NA
GH40	-40	29	26	9	3	4220	0.09	3300	0.07	4100	NA
GH34	-35	25	23	8	4	4280	0.09	3500	0.06	3950	NA
GH43	-30	64	57	10	37	4290	0.61	3300	0.06	3850	600
GH41	-15	34	29	14	3	4100	0.09	3300	0.06	3910	200
GH32	0	122	111	9	36	4280	0.61	3400	0.06	2900	1300
GH42	15	115	109	5	35	4220	0.60	3300	0.06	NA	NA
GH36	40	145	134	8	35	4120	0.62	3300	0.06	NA	NA
GH38	72	139	129	7	35	4230	0.60	3300	0.05	NA	NA
GH35	130	49	45	9	18	3620	0.35	3200	0.05	3370	3000
GH45	200	90	83	8	32	3800	0.60	3000	0.05	NA	NA

Table 5-9 Effect of Irradiation to 4.365 x 1019 n/cm2 (E > 1.0 MeV) on the Charpy V-Notch Toughness Properties of the South Texas Unit 1 Reactor Vessel Surveillance Capsule W Materials

Material	Average 30 ft-lb Transition Temperature[(a)] (°F)			Average 35 mil Lateral Expansion Temperature[(a)] (°F)			Average 50 ft-lb Transition Temperature[(a)] (°F)			Average Energy Absorption at Full Shear[(a)] (ft-lb)		
	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔT	Unirradiated	Irradiated	ΔE
Intermediate Shell Plate R1606-2 (Longitudinal)	-52.0	12.9	64.9	-22.9	45.3	68.2	-20.3	49.3	69.6	138	121	-17
Intermediate Shell Plate R1606-2 (Transverse)	-6.1	24.3	30.4	19.7	56.0	36.3	27.0	69.6	42.6	113	102	-11
Surveillance Program Weld Metal (Heat # 89476)	-56.0	-12.4	43.6	-26.6	10.0	36.6	-16.8	21.1	37.9	86	87	+1
Heat-Affected Zone Material	-134.1	-52.5	81.6	-58.5	-20.7	37.8	-86.1	-34.8	51.3	105	108	+3

Note:

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

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

Material	Capsule	Capsule Fluence ($x10^{19}$ n/cm^2, E > 1.0 MeV)	30 ft-lb Transition Temperature Shift		Upper-Shelf Energy Decrease	
			Predicted(a) (°F)	Measured(b) (°F)	Predicted(a) (%)	Measured(b) (%)
Intermediate Shell Plate R1606-2 (Longitudinal)	U	0.2623	16.5	17.9	14	8
	Y	1.312	28.0	43.9	21	1
	V	2.680	32.8	39.7	24	5
	W	4.365	35.7	64.9	27	12
Intermediate Shell Plate R1606-2 (Transverse)	U	0.2623	16.5	23.3	14	8
	Y	1.312	28.0	13.3	21	4
	V	2.680	32.8	23.9	24	6
	W	4.365	35.7	30.4	27	10
Surveillance Program Weld Metal (Heat # 89476)	U	0.2623	14.8	33.5	14	0
	Y	1.312	25.1	37.9	21	---
	V	2.680	29.4	26.7	24	---
	W	4.365	32.0	43.6	27	---
Heat-Affected Zone Material	U	0.2623	---	0.0(c)	---	---
	Y	1.312	---	19.5	---	---
	V	2.680	---	61.7	---	---
	W	4.365	---	81.6	---	---

Notes:

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

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

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

Table 5-11 Tensile Properties of the South Texas Unit 1 Capsule W Reactor Vessel Surveillance Materials Irradiated to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV)

Material	Sample Number	Test Temp. (°F)	0.2% Yield Strength (ksi)	Ultimate Strength (ksi)	Fracture Load (kip)	Fracture Stress (ksi)	Fracture Strength (ksi)	Uniform Elongation (%)	Total Elongation (%)	Reduction in Area (%)
Intermediate Shell Plate R1606-2 (Longitudinal)	GL7	75	66.3	88.2	2.61	156	53.3	11.2	26.4	66
	GL8	300	---(a)	---(a)	---(a)	---(a)	---(a)	---(a)	---(a,b)	67
	GL9	550	61.7	84.5	2.81	135	57.2	10.2	22.1	57
Intermediate Shell Plate R1606-2 (Transverse)	GT7	75	64.5	89.5	2.51	135	51.1	12.2	25.5	62
	GT8	300	64.0	83.7	2.43	126	49.4	11.6	22.7	60
	GT9	550	62.9	85.6	2.97	175	60.5	10.3	20.8	65
Surveillance Program Weld Metal (Heat # 89476)	GW7	75	70.6	85.7	2.78	197	56.7	11.8	26.0	71
	GW8	300	---(a)	---(a)	---(a)	---(a)	---(a)	---(a)	---(a,c)	67
	GW9	550	66.9	88.6	3.07	165	62.5	10.1	21.3	62

Notes:

(a) Tensile data file was lost. This event has been documented in the Westinghouse corrective action database and an event investigation was conducted.

(b) Although the extensometer data was lost, post-fracture elongation measurements were made. Elongation after Fracture (%) = 30. This data is presented as information only.

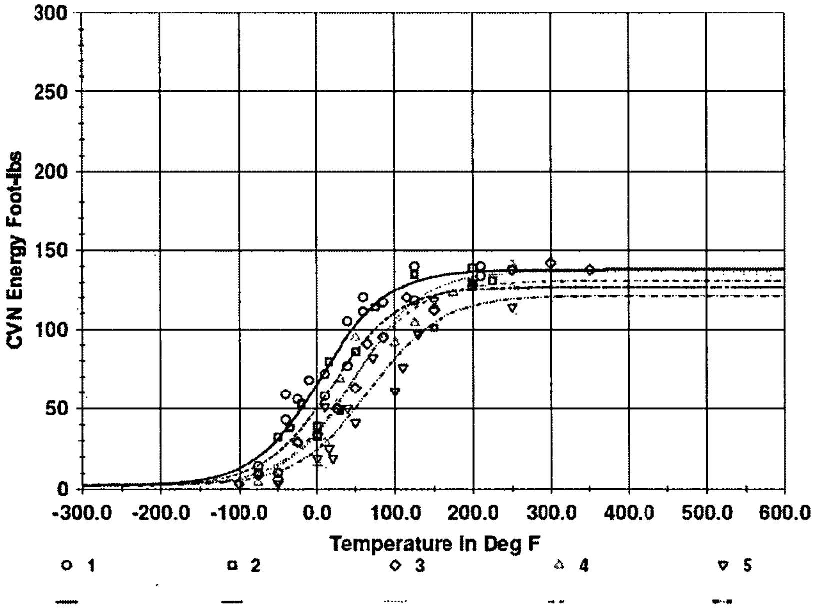
(c) Although the extensometer data was lost, post-fracture elongation measurements were made. Elongation after Fracture (%) = 27. This data is presented as information only.

Intermediate Shell Plate R1606-2 (LT)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 08:06 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	LT	B8120-1
2	South Texas 1	U	SA533B1	LT	B8120-1
3	South Texas 1	Y	SA533B1	LT	B8120-1
4	South Texas 1	V	SA533B1	LT	B8120-1
5	South Texas 1	W	SA533B1	LT	B8120-1



Results

Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	138.0	.0	-52.0	.0	-20.3	.0
2		2.2	127.0	-11.0	-34.1	17.9	-1.0	19.3
3		2.2	137.0	-1.0	-8.1	43.9	24.0	44.3
4		2.2	131.0	-7.0	-12.3	39.7	21.2	41.5
5		2.2	121.0	-17.0	12.9	64.9	49.3	69.6

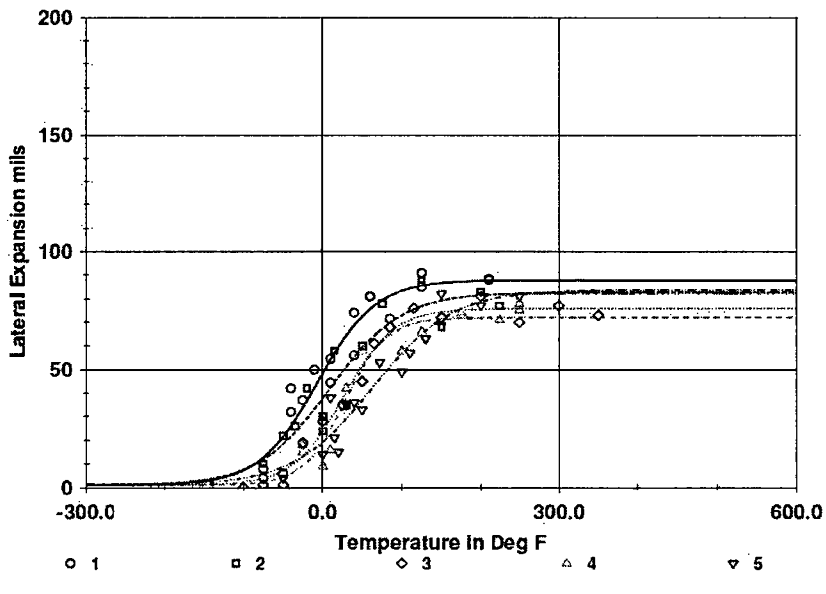
Figure 5-1 Charpy V-Notch Impact Energy vs. Temperature for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Longitudinal Orientation)

Intermediate Shell Plate R1606-2 (LT)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 08:13 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	LT	B8120-1
2	South Texas 1	U	SA533B1	LT	B8120-1
3	South Texas 1	Y	SA533B1	LT	B8120-1
4	South Texas 1	V	SA533B1	LT	B8120-1
5	South Texas 1	W	SA533B1	LT	B8120-1



Results

Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	87.9	.0	-22.9	.0
2		1.0	82.6	-5.3	-6.3	16.6
3		1.0	75.8	-12.2	21.0	43.9
4		1.0	72.0	-15.9	26.0	48.9
5		1.0	83.7	-4.2	45.3	68.2

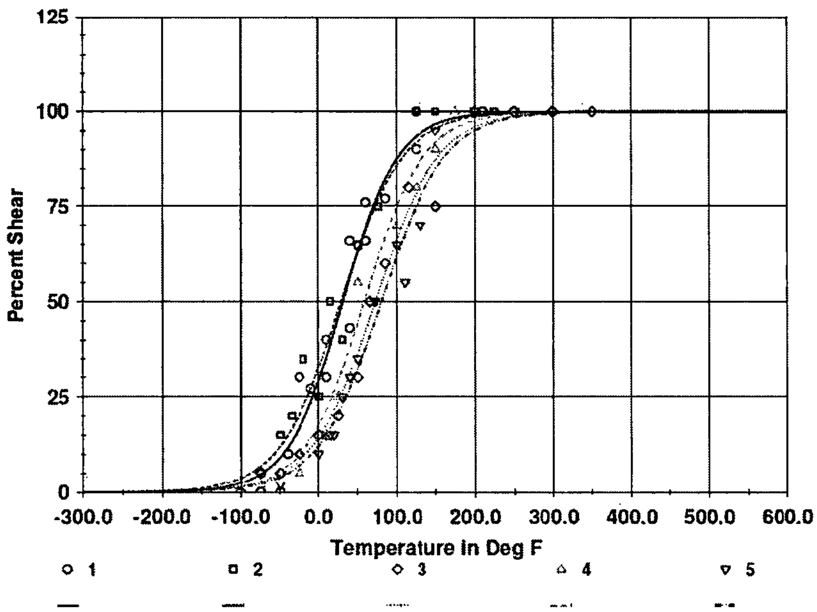
Figure 5-2 Charpy V-Notch Lateral Expansion vs. Temperature for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Longitudinal Orientation)

Intermediate Shell Plate R1606-2 (LT)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 08:07 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	LT	B8120-1
2	South Texas 1	U	SA533B1	LT	B8120-1
3	South Texas 1	Y	SA533B1	LT	B8120-1
4	South Texas 1	V	SA533B1	LT	B8120-1
5	South Texas 1	W	SA533B1	LT	B8120-1



Results

Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	31.2	.0
2		.0	100.0	.0	28.9	-2.3
3		.0	100.0	.0	72.8	41.6
4		.0	100.0	.0	58.5	27.3
5		.0	100.0	.0	80.2	49.0

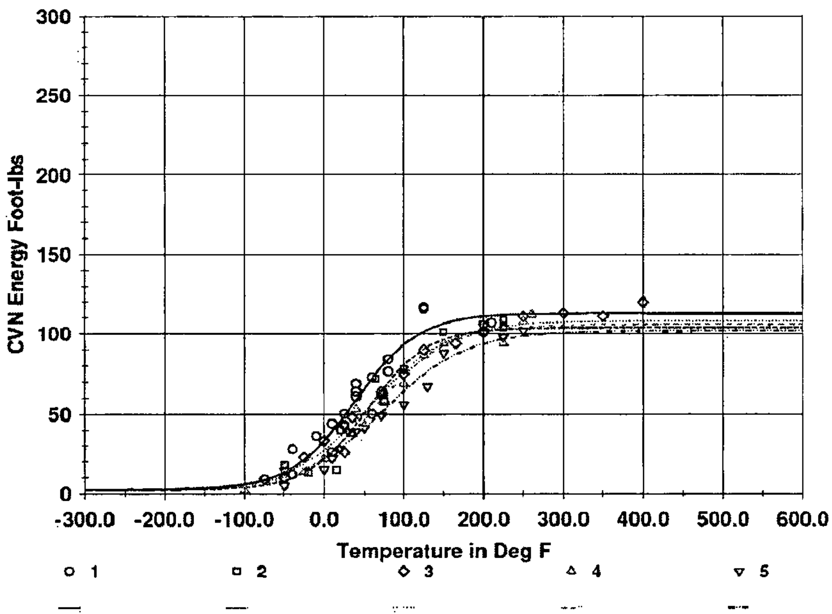
Figure 5-3 Charpy V-Notch Percent Shear vs. Temperature for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Longitudinal Orientation)

Intermediate Shell Plate R1606-2 (TL)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/27/2012 08:48 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	TL	B8120-1
2	South Texas 1	U	SA533B1	TL	B8120-1
3	South Texas 1	Y	SA533B1	TL	B8120-1
4	South Texas 1	V	SA533B1	TL	B8120-1
5	South Texas 1	W	SA533B1	TL	B8120-1



Results

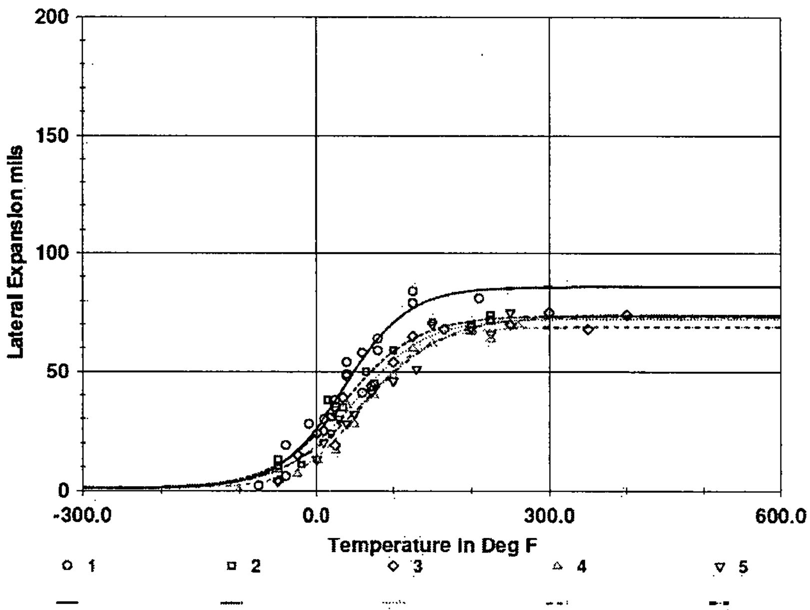
Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	113.0	.0	-6.1	.0	27.0	.0
2		2.2	104.0	-9.0	17.2	23.3	49.7	22.7
3		2.2	108.0	-5.0	7.2	13.3	48.3	21.3
4		2.2	106.0	-7.0	17.8	23.9	56.2	29.2
5		2.2	102.0	-11.0	24.3	30.4	69.6	42.6

Figure 5-4 Charpy V-Notch Impact Energy vs. Temperature for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Transverse Orientation)

Intermediate Shell Plate R1606-2 (TL)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 08:17 AM
Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	TL	B8120-1
2	South Texas 1	U	SA533B1	TL	B8120-1
3	South Texas 1	Y	SA533B1	TL	B8120-1
4	South Texas 1	V	SA533B1	TL	B8120-1
5	South Texas 1	W	SA533B1	TL	B8120-1



Results

Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	85.8	.0	19.7	.0
2		1.0	73.7	-12.1	30.7	11.0
3		1.0	72.3	-13.5	44.8	25.1
4		1.0	69.0	-16.8	59.7	40.0
5		1.0	73.6	-12.2	56.0	36.3

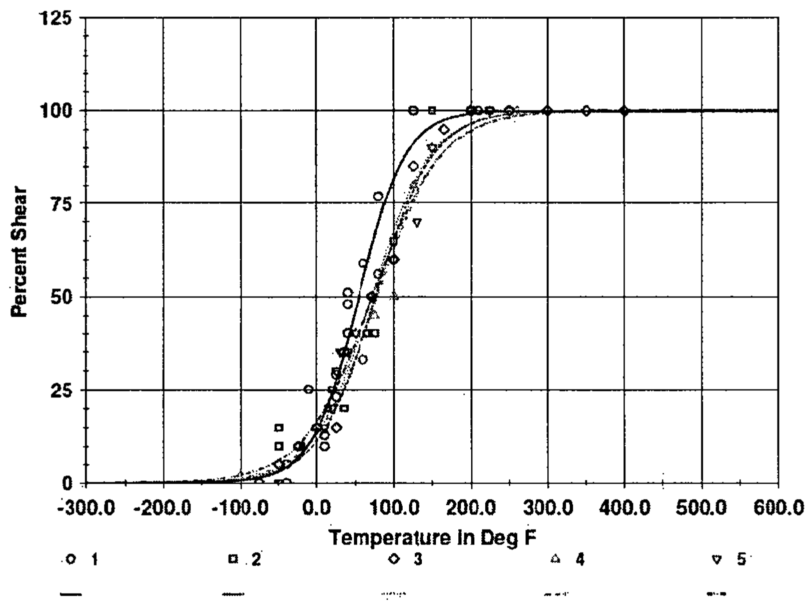
Figure 5-5 Charpy V-Notch Lateral Expansion vs. Temperature for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Transverse Orientation)

Intermediate Shell Plate R1606-2 (TL)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 08:16 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	TL	B8120-1
2	South Texas 1	U	SA533B1	TL	B8120-1
3	South Texas 1	Y	SA533B1	TL	B8120-1
4	South Texas 1	V	SA533B1	TL	B8120-1
5	South Texas 1	W	SA533B1	TL	B8120-1



Results

Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	54.6	.0
2		.0	100.0	.0	76.3	21.7
3		.0	100.0	.0	71.9	17.3
4		.0	100.0	.0	78.4	23.8
5		.0	100.0	.0	72.6	18.0

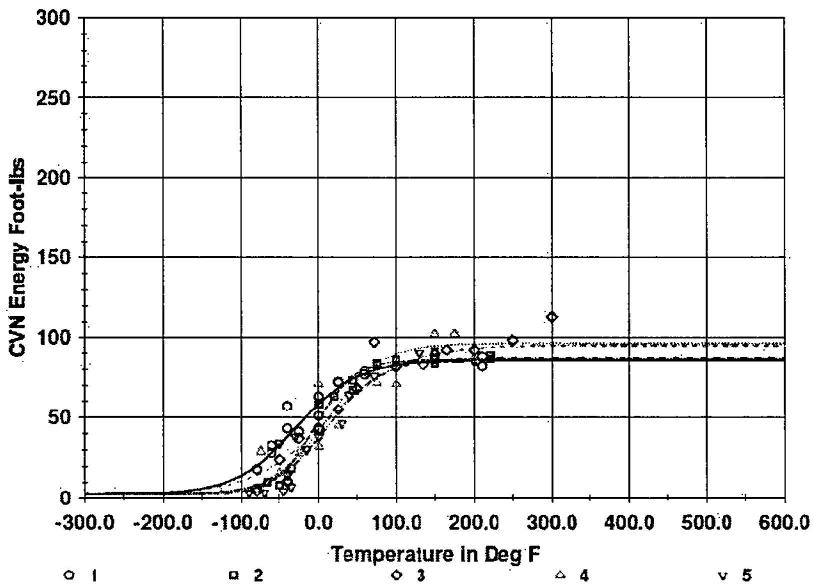
Figure 5-6 Charpy V-Notch Percent Shear vs. Temperature for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Transverse Orientation)

Surveillance Program Weld Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2012 03:15 PM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SAW	NA	89476
2	South Texas 1	U	SAW	NA	89476
3	South Texas 1	Y	SAW	NA	89476
4	South Texas 1	V	SAW	NA	89476
5	South Texas 1	W	SAW	NA	89476



Results

Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	86.0	.0	-56.0	.0	-16.8	.0
2		2.2	86.0	.0	-22.5	33.5	2.2	19.0
3		2.2	96.0	10.0	-18.1	37.9	12.9	29.7
4		2.2	95.0	9.0	-29.3	26.7	15.5	32.3
5		2.2	87.0	1.0	-12.4	43.6	21.1	37.9

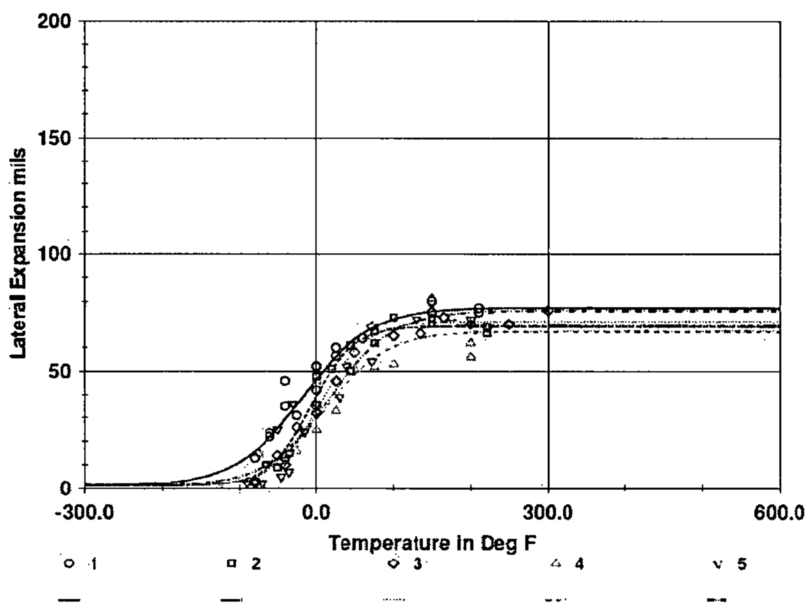
Figure 5-7 Charpy V-Notch Impact Energy vs. Temperature for the South Texas Unit 1 Reactor Vessel Surveillance Program Weld Metal (Heat # 89476)

Surveillance Program Weld Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 07:42 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SAW	NA	89476
2	South Texas 1	U	SAW	NA	89476
3	South Texas 1	Y	SAW	NA	89476
4	South Texas 1	V	SAW	NA	89476
5	South Texas 1	W	SAW	NA	89476



Results

Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	77.2	.0	-26.6	.0
2		1.0	69.1	-8.1	-7.0	19.6
3		1.0	71.2	-6.0	3.3	29.9
4		1.0	66.9	-10.3	14.5	41.1
5		1.0	76.0	-1.2	10.0	36.6

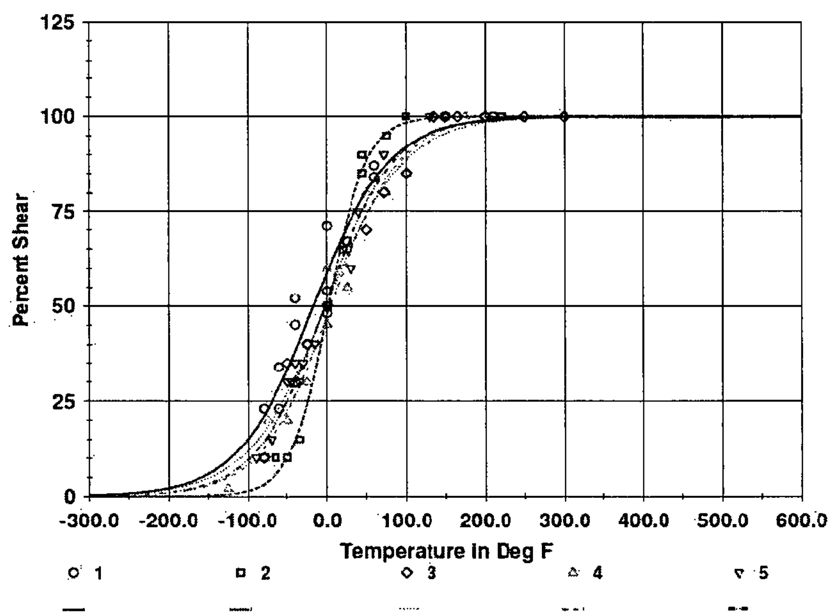
Figure 5-8 Charpy V-Notch Lateral Expansion vs. Temperature for the South Texas Unit 1 Reactor Vessel Surveillance Program Weld Metal (Heat # 89476)

Surveillance Program Weld Material

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 07:40 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SAW	NA	89476
2	South Texas 1	U	SAW	NA	89476
3	South Texas 1	Y	SAW	NA	89476
4	South Texas 1	V	SAW	NA	89476
5	South Texas 1	W	SAW	NA	89476



Results

Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	-17.1	.0
2		.0	100.0	.0	1.9	19.0
3		.0	100.0	.0	-1.1	16.0
4		.0	100.0	.0	4.2	21.3
5		.0	100.0	.0	-2.8	14.3

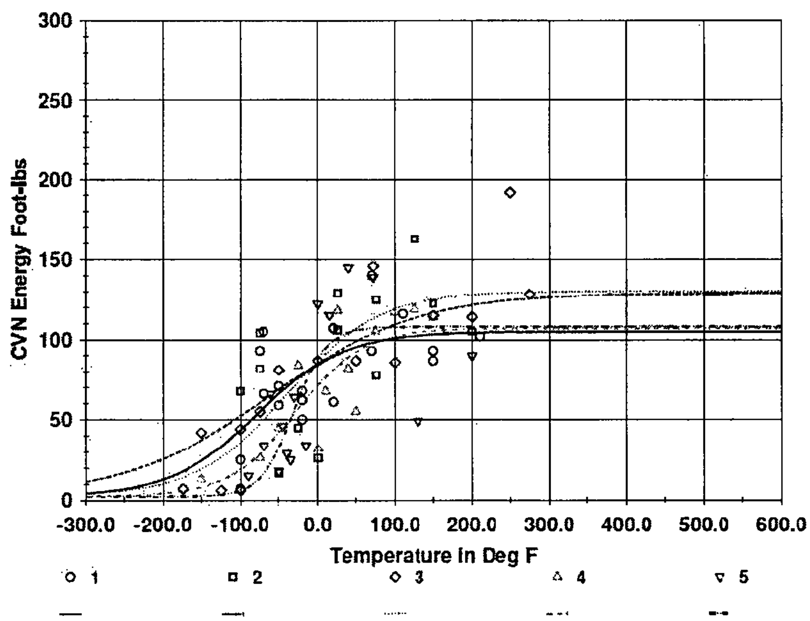
Figure 5-9 Charpy V-Notch Percent Shear vs. Temperature for the South Texas Unit 1 Reactor Vessel Surveillance Program Weld Metal (Heat # 89476)

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 02/08/2012 03:25 PM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	NA	B8120-1
2	South Texas 1	U	SA533B1	NA	B8120-1
3	South Texas 1	Y	SA533B1	NA	B8120-1
4	South Texas 1	V	SA533B1	NA	B8120-1
5	South Texas 1	W	SA533B1	NA	B8120-1



Results

Curve	Fluence	LSE	USE	d-USE	T @30	d-T @30	T @50	d-T @50
1		2.2	105.0	.0	-134.1	.0	-86.1	.0
2		2.2	129.0	24.0	-179.6	-45.5	-107.3	-21.2
3		2.2	130.0	25.0	-114.6	19.5	-69.3	16.8
4		2.2	107.0	2.0	-72.4	61.7	-36.1	50.0
5		2.2	108.0	3.0	-52.5	81.6	-34.8	51.3

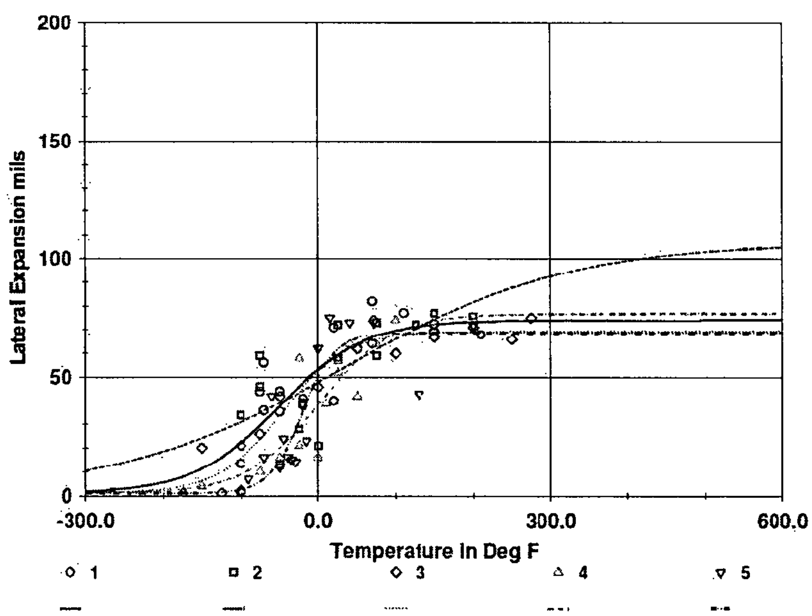
Figure 5-10 Charpy V-Notch Impact Energy vs. Temperature for the South Texas Unit 1 Reactor Vessel Heat-Affected Zone Material

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 07:50 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	NA	B8120-1
2	South Texas 1	U	SA533B1	NA	B8120-1
3	South Texas 1	Y	SA533B1	NA	B8120-1
4	South Texas 1	V	SA533B1	NA	B8120-1
5	South Texas 1	W	SA533B1	NA	B8120-1



Results

Curve	Fluence	LSE	USE	d-USE	T @35	d-T @35
1		1.0	74.1	.0	-58.5	.0
2		1.0	106.9	32.8	-75.1	-16.6
3		1.0	69.4	-4.7	-46.4	12.1
4		1.0	76.8	2.7	-8.5	50.0
5		1.0	68.7	-5.4	-20.7	37.8

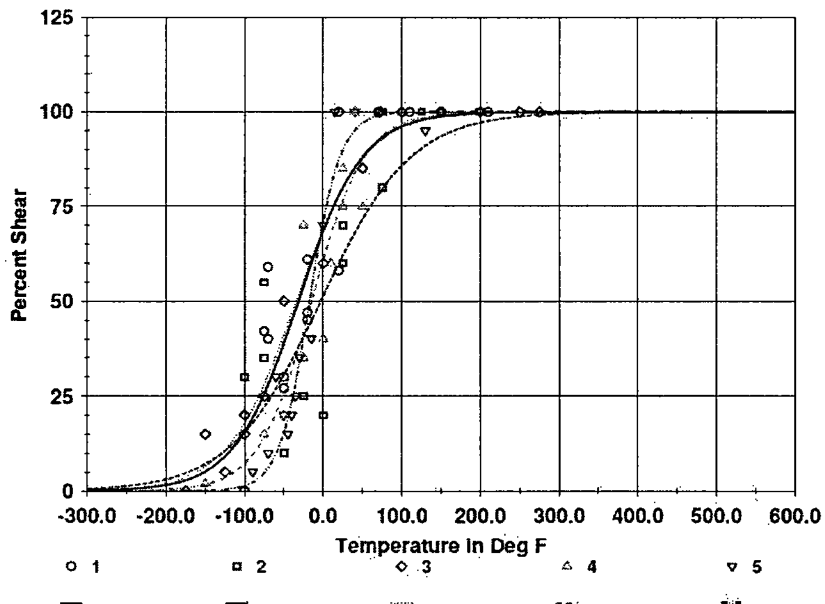
Figure 5-11 Charpy V-Notch Lateral Expansion vs. Temperature for the South Texas Unit 1 Reactor Vessel Heat-Affected Zone Material

Heat Affected Zone

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 07:49 AM

Data Set(s) Plotted

Curve	Plant	Capsule	Material	Ori.	Heat #
1	South Texas 1	UNIRR	SA533B1	NA	B8120-1
2	South Texas 1	U	SA533B1	NA	B8120-1
3	South Texas 1	Y	SA533B1	NA	B8120-1
4	South Texas 1	V	SA533B1	NA	B8120-1
5	South Texas 1	W	SA533B1	NA	B8120-1



Results

Curve	Fluence	LSE	USE	d-USE	T @50	d-T @50
1		.0	100.0	.0	-31.3	.0
2		.0	100.0	.0	-2.9	28.4
3		.0	100.0	.0	-34.0	-2.7
4		.0	100.0	.0	-14.6	16.7
5		.0	100.0	.0	-17.1	14.2

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

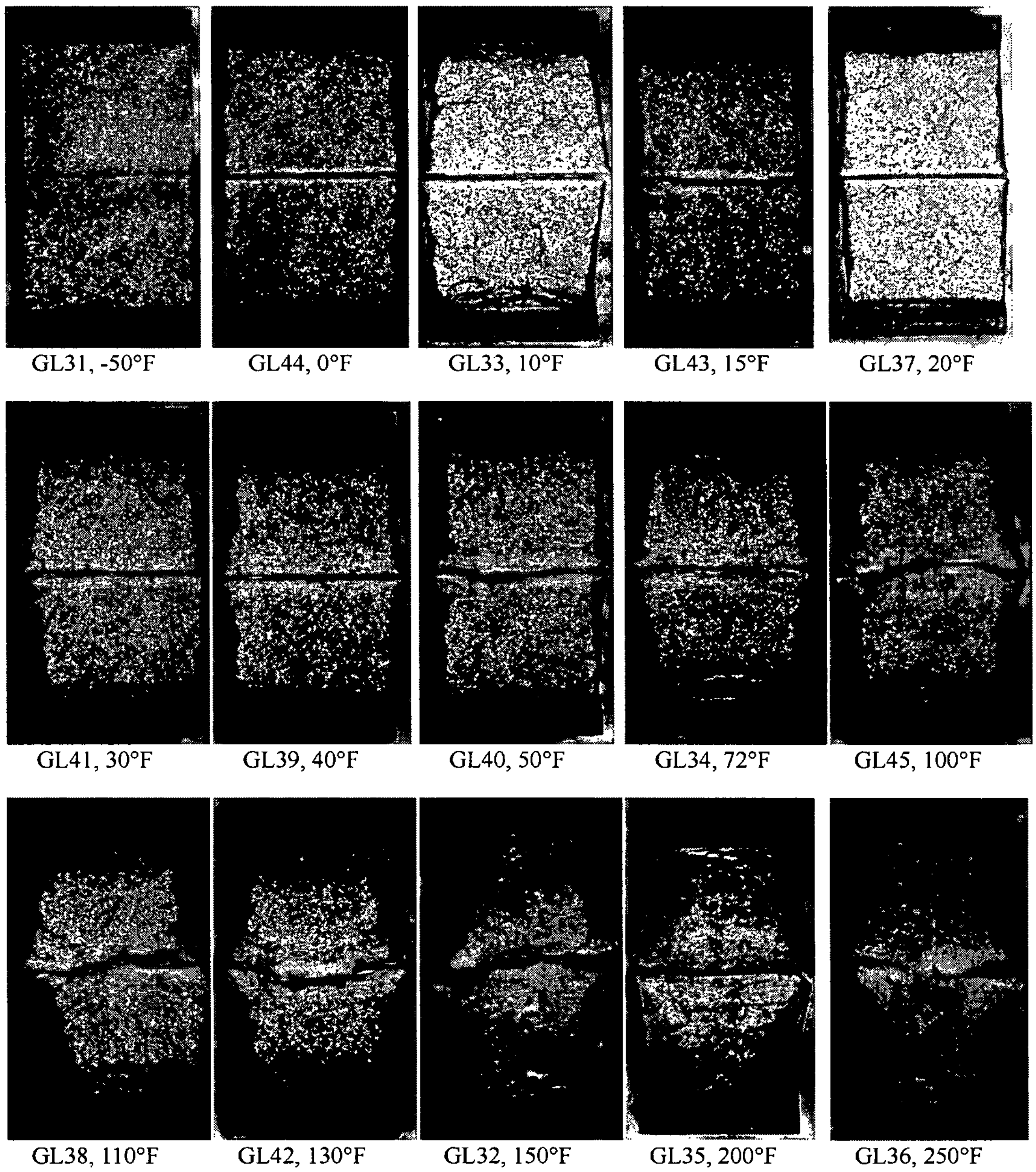


Figure 5-13 Charpy Impact Specimen Fracture Surfaces for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Longitudinal Orientation)

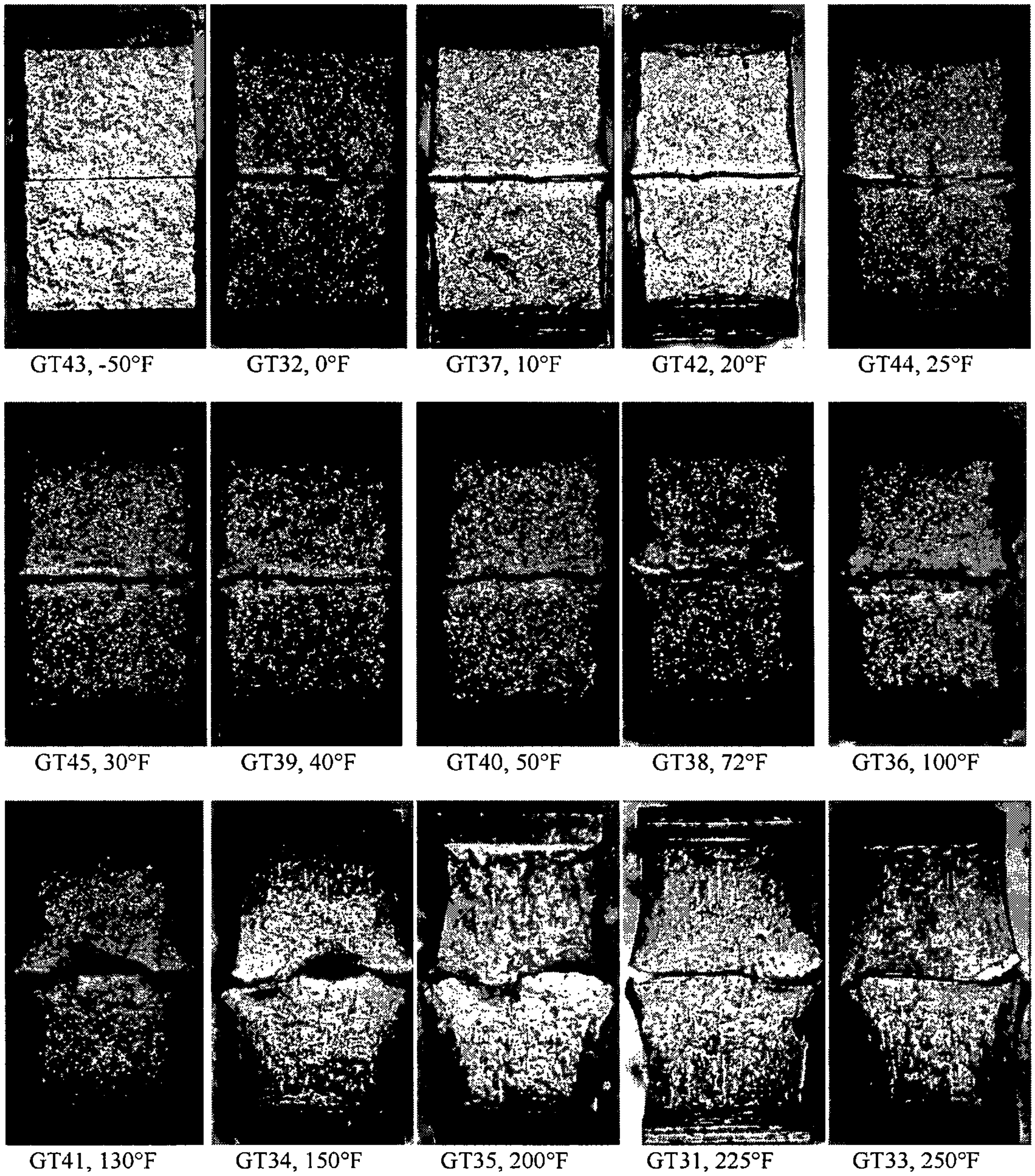


Figure 5-14 Charpy Impact Specimen Fracture Surfaces for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Transverse Orientation)

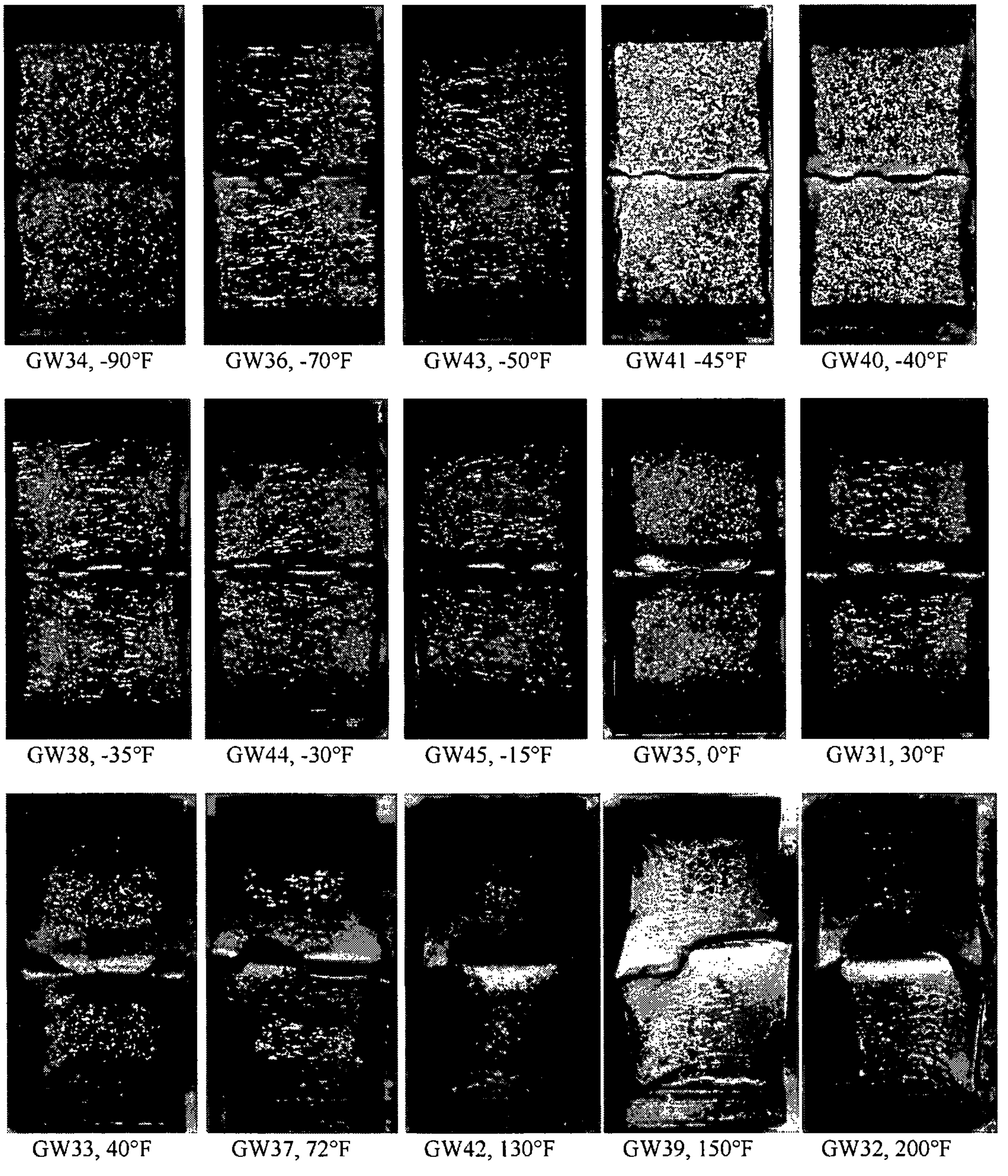


Figure 5-15 Charpy Impact Specimen Fracture Surfaces for the South Texas Unit 1 Reactor Vessel Surveillance Program Weld Metal (Heat # 89476)

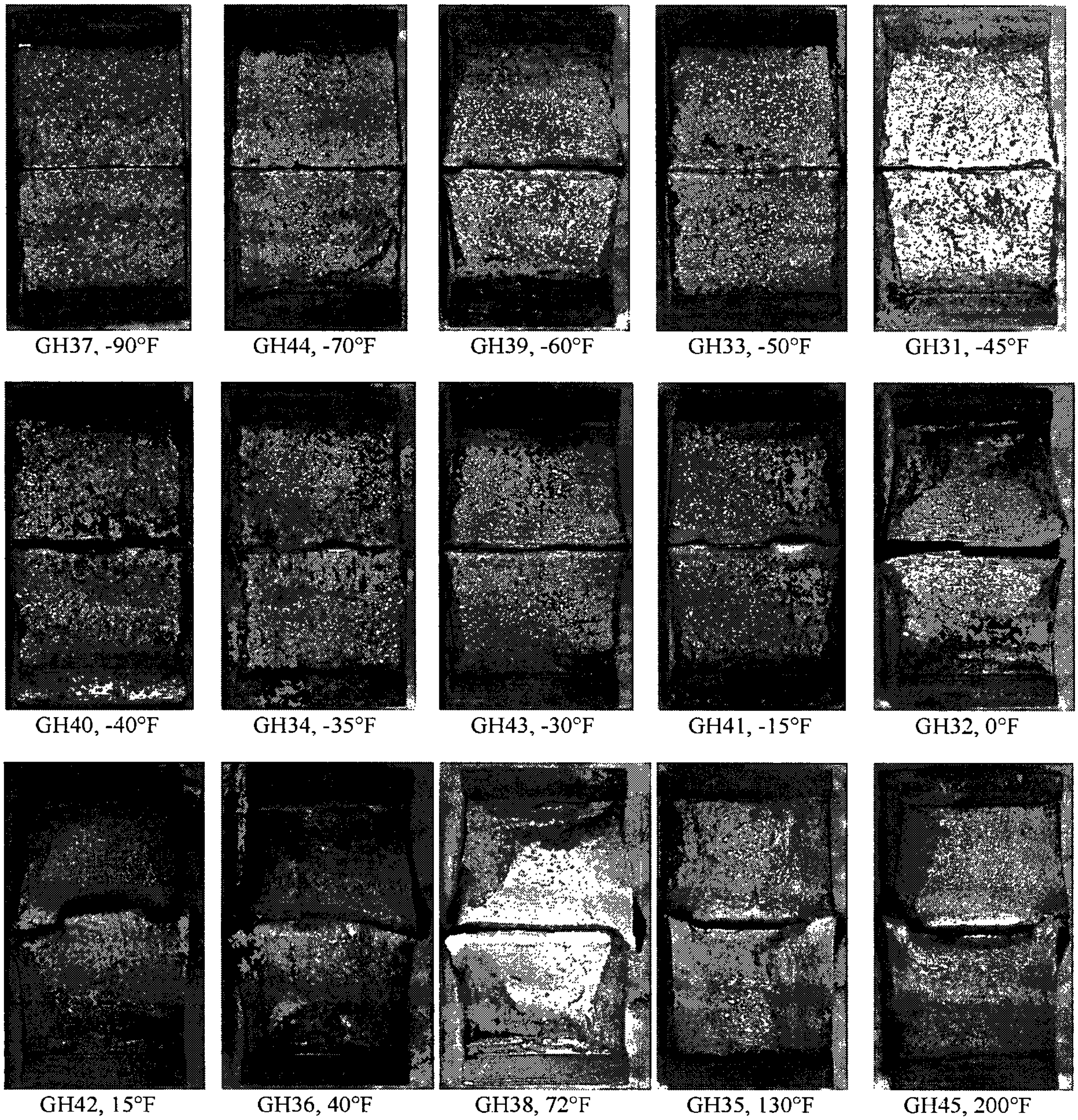
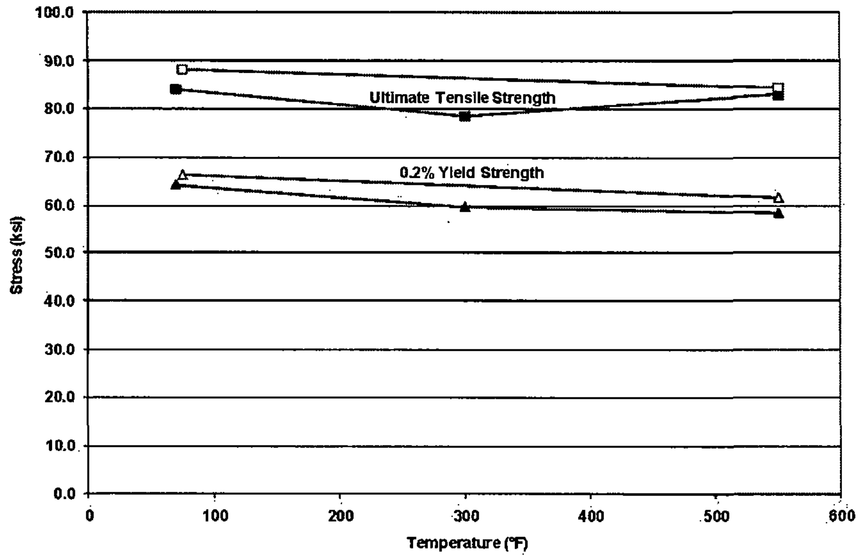


Figure 5-16 Charpy Impact Specimen Fracture Surfaces for the South Texas Unit 1 Reactor Vessel Heat-Affected Zone Material



Legend: ▲ and ● and ■ are unirradiated
Δ and ○ and □ are irradiated to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV)

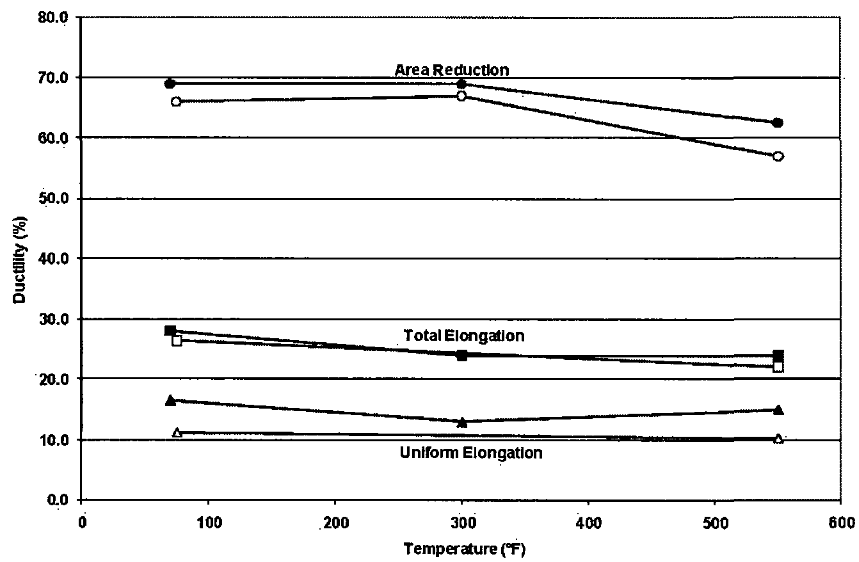
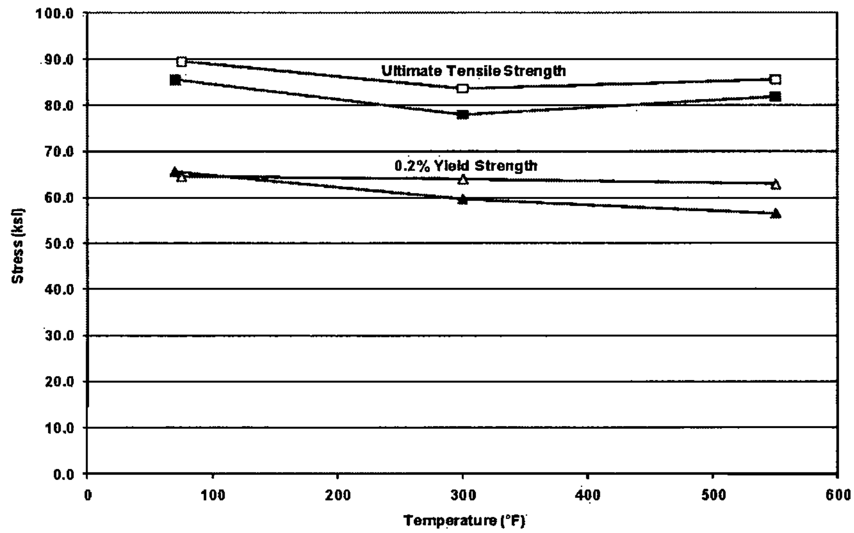


Figure 5-17 Tensile Properties for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Longitudinal Orientation)



Legend: ▲ and ● and ■ are unirradiated
Δ and ○ and □ are irradiated to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV)

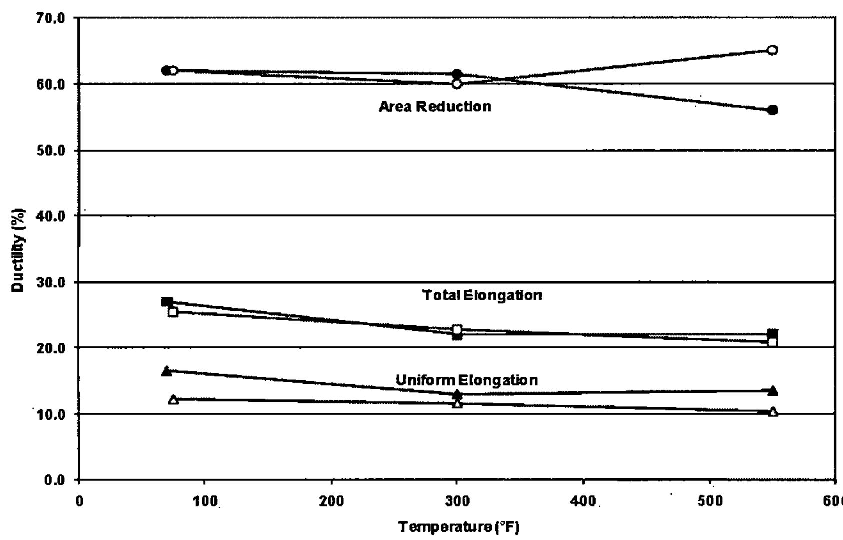
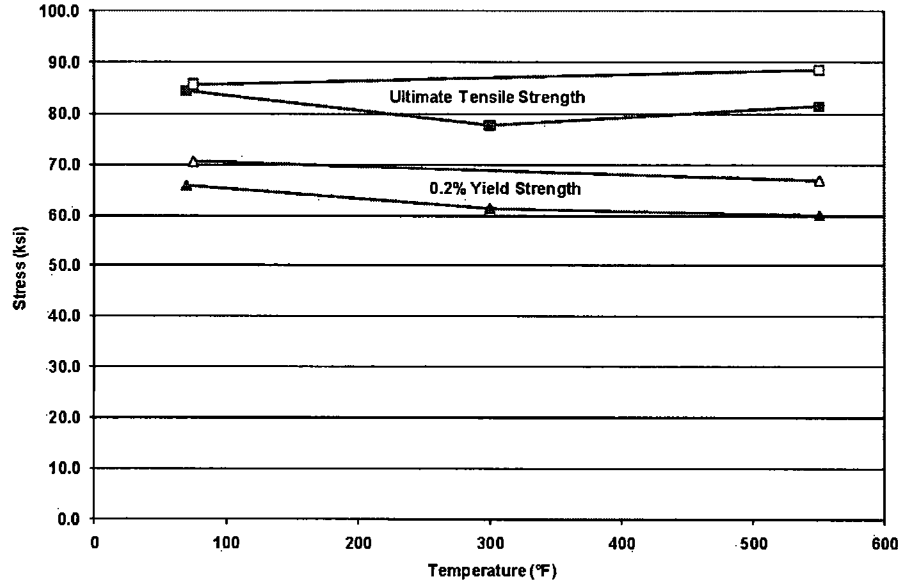


Figure 5-18 Tensile Properties for South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Transverse Orientation)



Legend: ▲ and ● and ■ are unirradiated
Δ and ○ and □ are irradiated to 4.365 x 10^{19} n/cm^2 (E > 1.0 MeV)

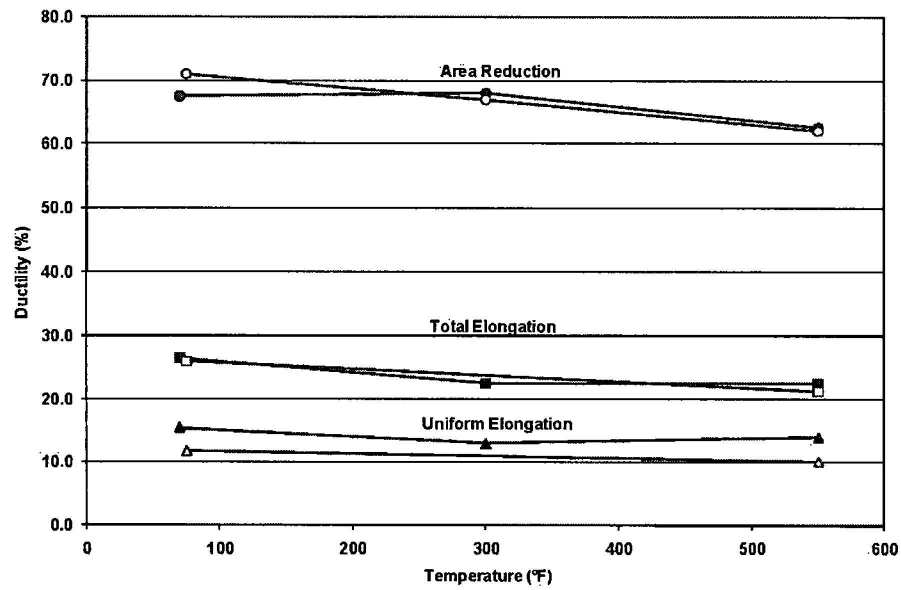
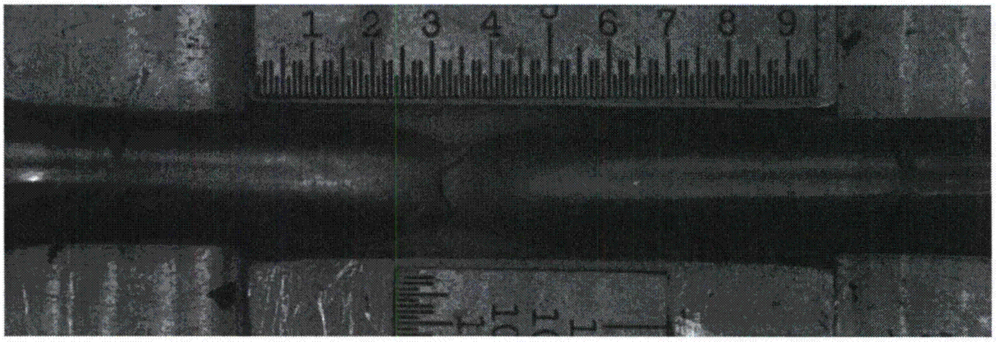
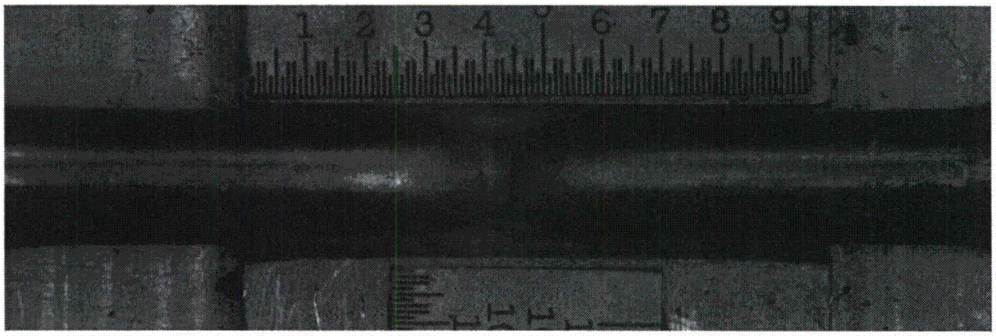


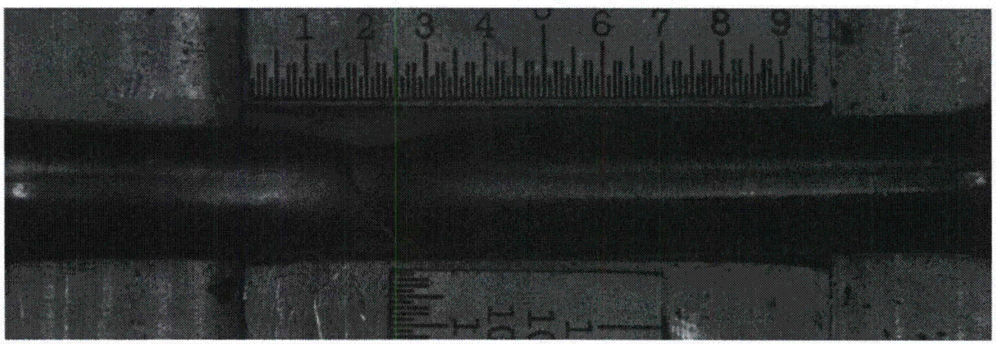
Figure 5-19 Tensile Properties for the South Texas Unit 1 Reactor Vessel Surveillance Program Weld Metal (Heat # 89476)



Specimen GL7- Tested at 75°F

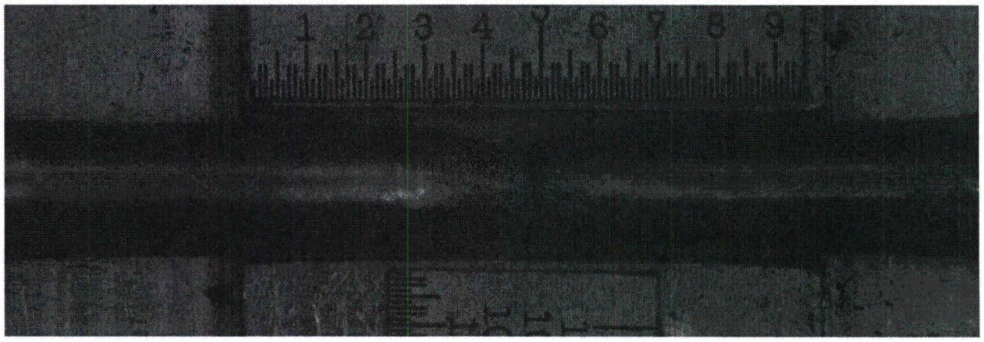


Specimen GL8 - Tested at 300°F

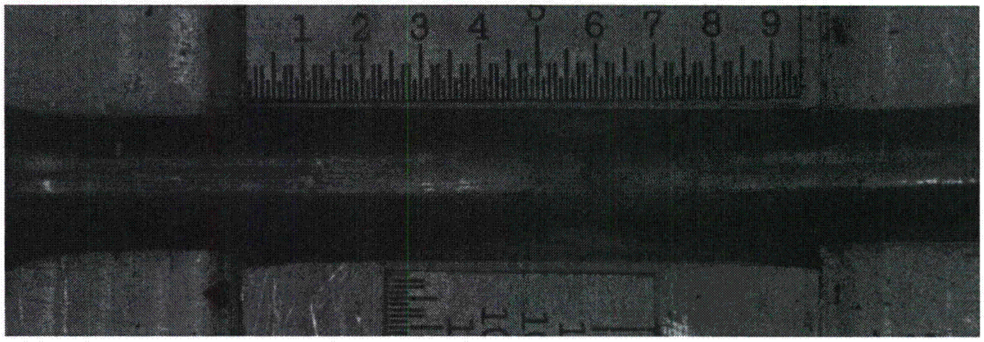


Specimen GL9 - Tested at 550°F

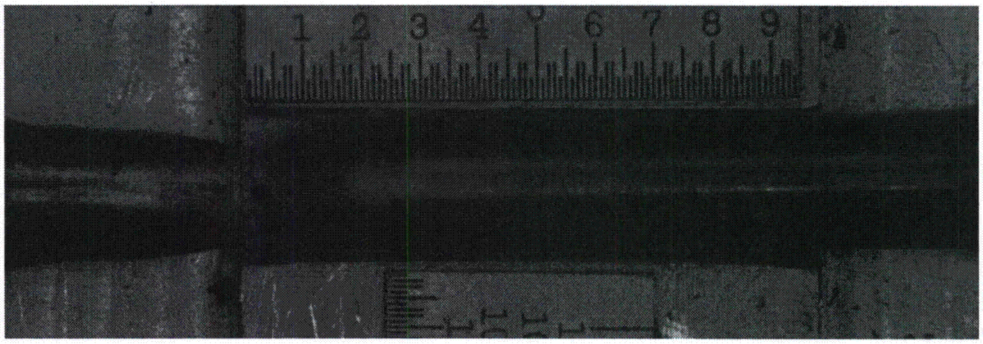
Figure 5-20 Fractured Tensile Specimens from South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Longitudinal Orientation)



Specimen GT7 - Tested at 75°F

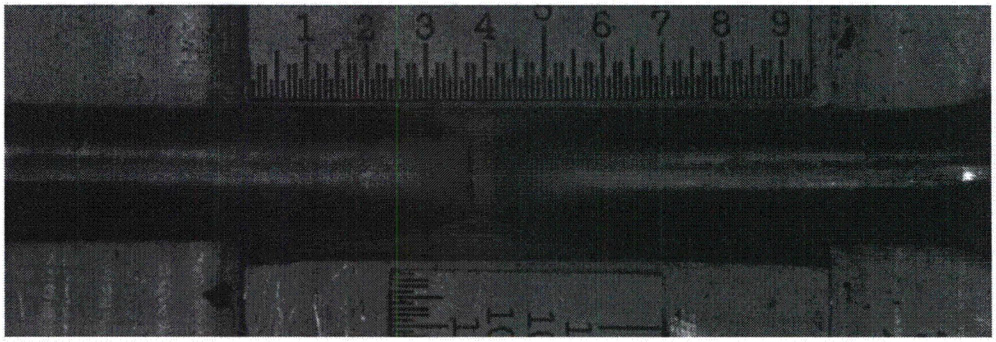


Specimen GT8 - Tested at 300°F

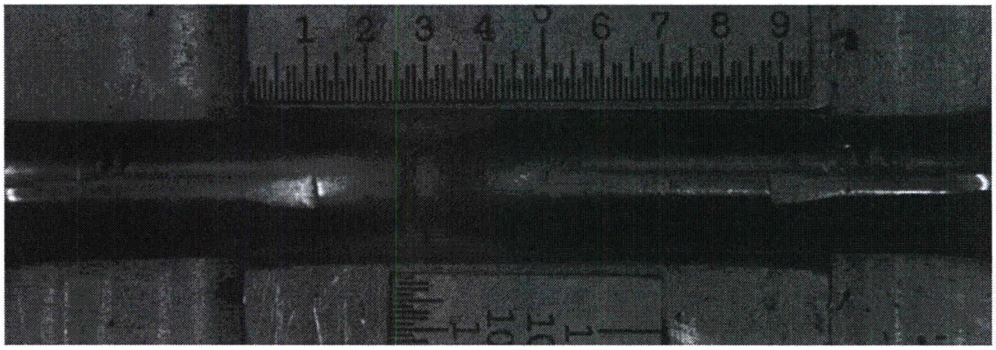


Specimen GT9 - Tested at 550°F

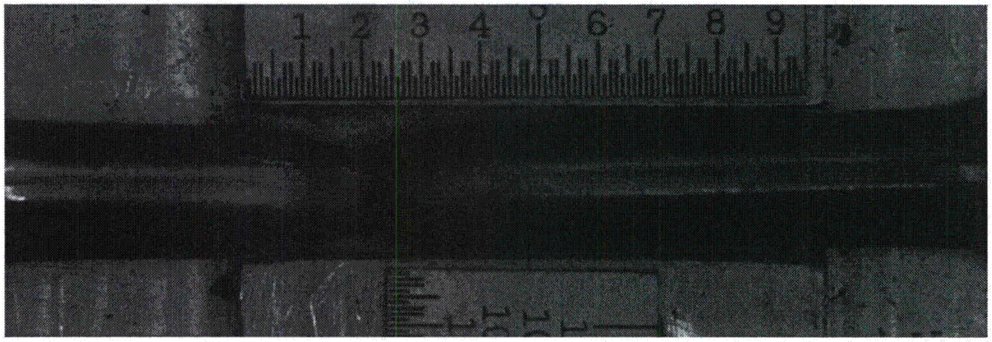
Figure 5-21 Fractured Tensile Specimens from South Texas Unit 1 Reactor Vessel Intermediate Shell Plate R1606-2 (Transverse Orientation)



Specimen GW7 - Tested at 75°F



Specimen GW8 - Tested at 300°F



Specimen GW9 - Tested at 550°F

Figure 5-22 Fractured Tensile Specimens from the South Texas Unit 1 Reactor Vessel Surveillance Program Weld Metal (Heat # 89476)

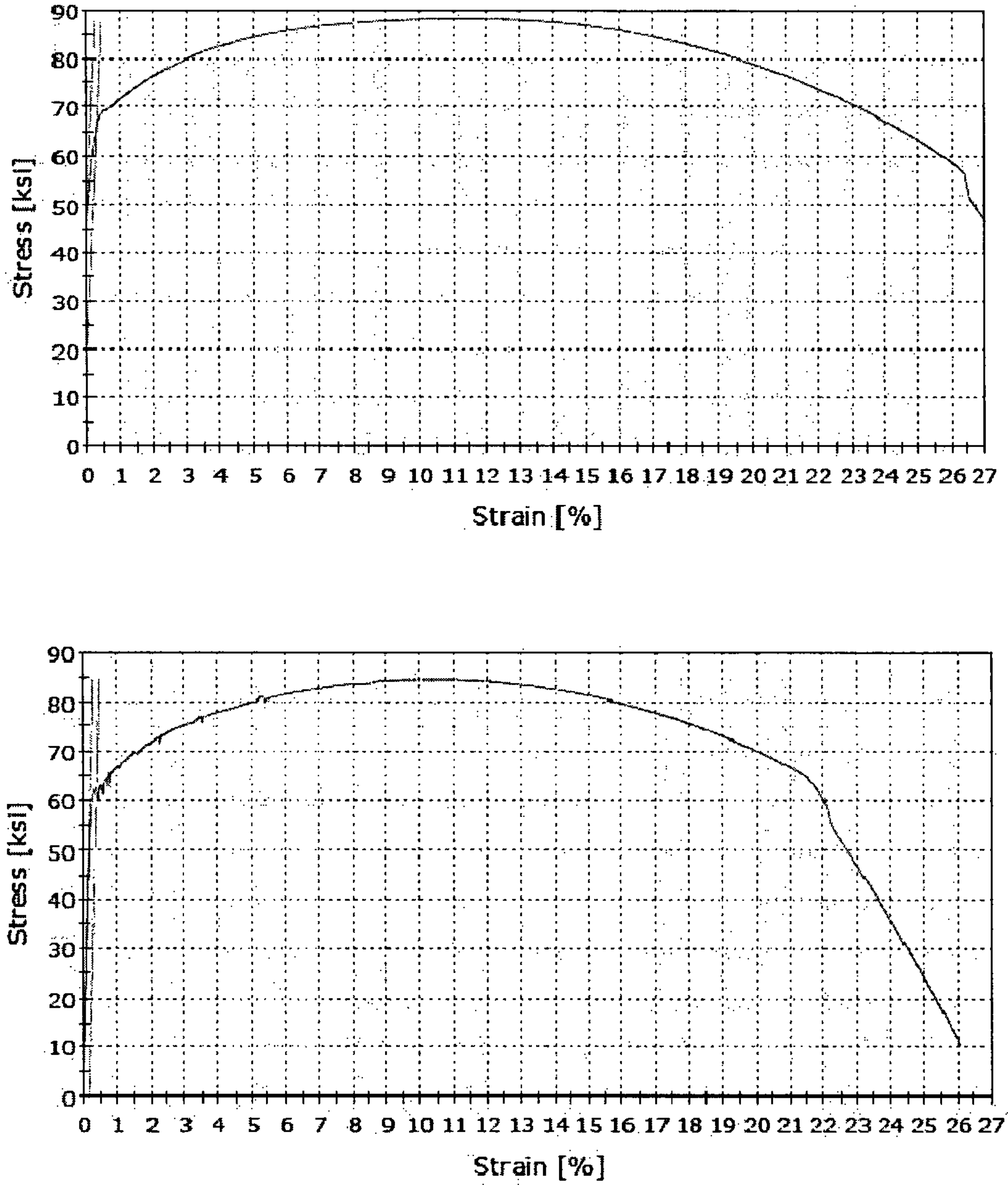
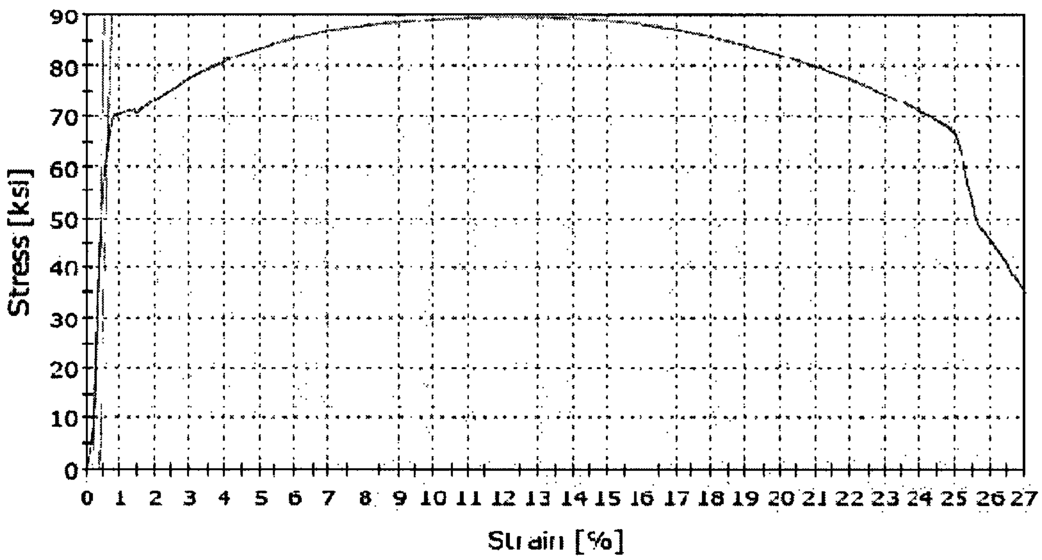


Figure 5-23 Engineering Stress-Strain Curves for South Texas Unit 1 Intermediate Shell Plate R1606-2 Tensile Specimens GL7 and GL9 (Longitudinal Orientation)



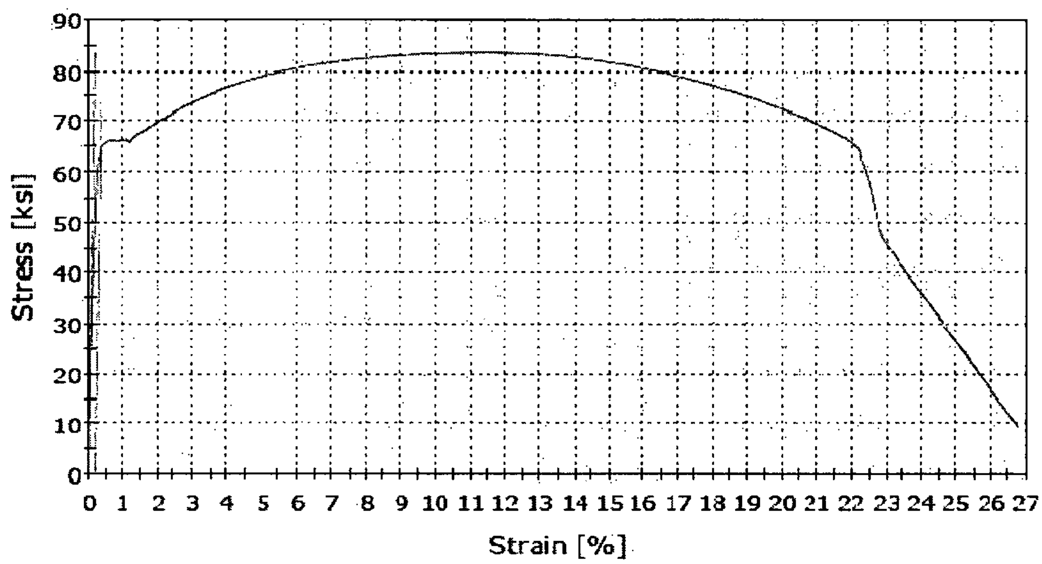


Figure 5-24 Engineering Stress-Strain Curves for South Texas Unit 1 Intermediate Shell Plate R1606-2 Tensile Specimens GT7 and GT8 (Transverse Orientation)

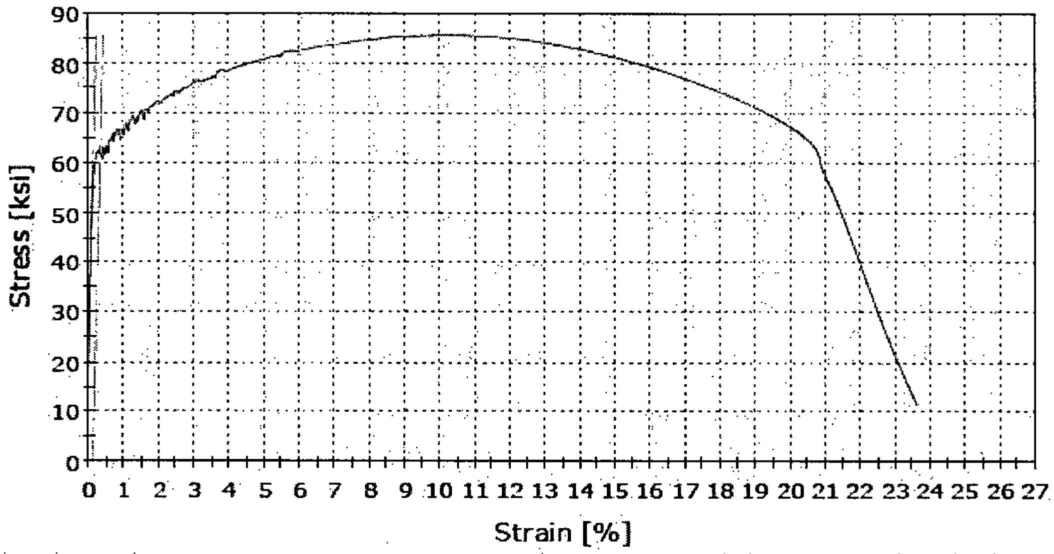


Figure 5-25 Engineering Stress-Strain Curve for South Texas Unit 1 Intermediate Shell Plate R1606-2 Tensile Specimen GT9 (Transverse Orientation)

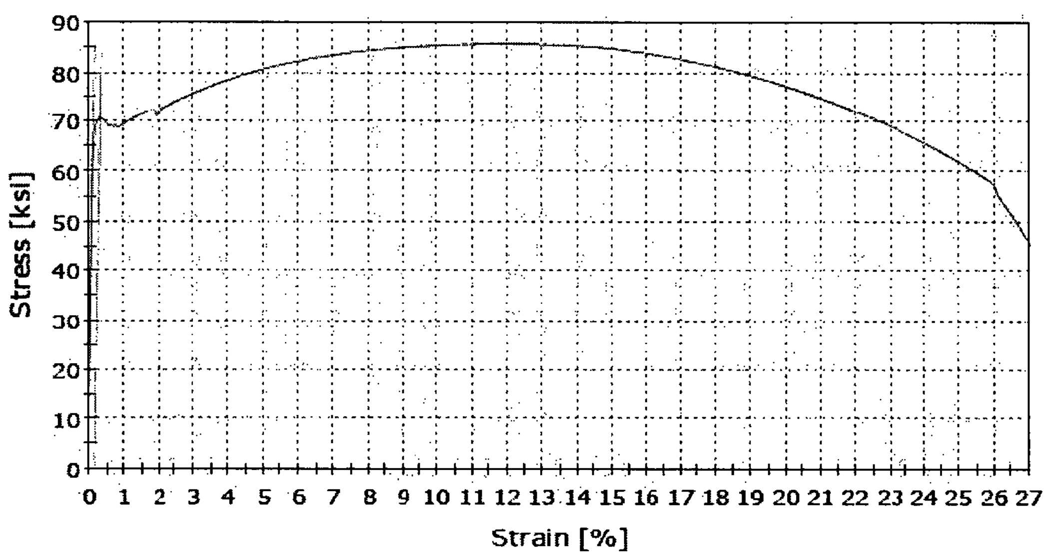


Figure 5-26 Engineering Stress-Strain Curve for South Texas Unit 1 Surveillance Program Weld Metal (Heat # 89476) Tensile Specimen GW7

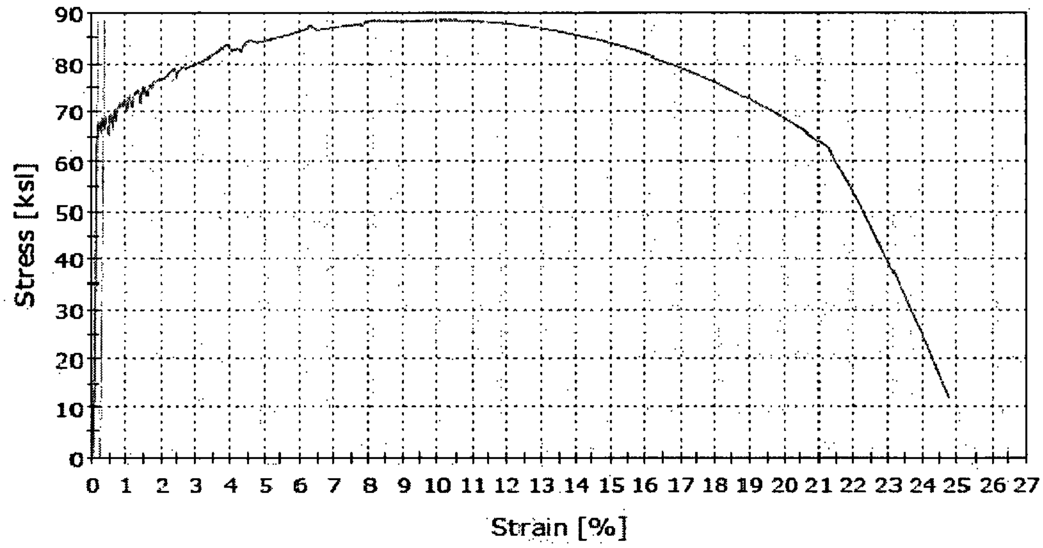


Figure 5-27 Engineering Stress-Strain Curve for South Texas Unit 1 Surveillance Program Weld Metal (Heat # 89476) Tensile Specimen GW9

6 RADIATION ANALYSIS AND NEUTRON DOSIMETRY

6.1 INTRODUCTION

This section describes a discrete ordinates S_n transport analysis performed for the South Texas Unit 1 reactor to determine the neutron radiation environment within the reactor pressure vessel and surveillance capsules. In this analysis, fast neutron exposure parameters in terms of fast neutron fluence (E > 1.0 MeV) and iron atom displacements (dpa) were established on a plant- and fuel-cycle-specific basis. An evaluation of the most recent dosimetry sensor set from Capsule W, withdrawn at the end of the sixteenth plant operating cycle, is provided. In addition, to provide an up-to-date data base applicable to the South Texas Unit 1 reactor, the sensor sets from the previously withdrawn capsules (U, Y, and V) are presented in Appendix A of this report. Comparisons of the results from these dosimetry evaluations with the analytical predictions served to validate the plant-specific neutron transport calculations. These validated calculations subsequently formed the basis for providing projections of the neutron exposure of the reactor pressure vessel for operating periods extending to 60 Effective Full Power Years (EFPY).

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

Because of this potential shift away from a threshold fluence toward an energy-dependent damage function for data correlation, ASTM Standard Practice E853-01, "Analysis and Interpretation of Light-Water Reactor Surveillance Results," [Ref. 17] recommends reporting displacements per iron atom (dpa) along with fluence (E > 1.0 MeV) to provide a database for future reference. The energy-dependent dpa function to be used for this evaluation is specified in ASTM Standard Practice E693-01, "Standard Practice for Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements per Atom" [Ref. 18]. The application of the dpa parameter to the assessment of embrittlement gradients through the thickness of the reactor vessel wall has already been promulgated in Revision 2 to Regulatory Guide 1.99, "Radiation Embrittlement of Reactor Vessel Materials" [Ref. 1].

All of the calculations and dosimetry evaluations described in this section and in Appendix A were based on the available nuclear cross-section data derived from ENDF/B-VI and made use of the latest available calculational tools. Furthermore, the neutron transport and dosimetry evaluation methodologies follow the guidance of Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence" [Ref. 19]. Additionally, the methods used to develop the calculated pressure vessel fluence are consistent with the NRC-approved methodology described in WCAP-14040-A, Revision 4, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves," May 2004 [Ref. 20].

6.2 DISCRETE ORDINATES ANALYSIS

The arrangement of the surveillance capsules in the South Texas Unit 1 reactor vessel is shown in Figure 4-1. Six irradiation capsules attached to the neutron pad are included in the reactor design that constitutes the reactor vessel surveillance program. The capsules are located at azimuthal angles of 58.5°, 61.0°, 121.5°, 238.5°, 241.0°, and 301.5° as shown in Figure 4-1. These full-core positions correspond to the following octant symmetric locations: Figure 6-1 shows the octants with no surveillance capsules with a 12.5° neutron pad, and 31.5° from the core cardinal axes is shown in Figure 6-2 for the 121.5° and 301.5° single surveillance capsule holder locations found in octants with a 20.0° neutron pad segment, and 29° from the core cardinal axes is shown in Figure 6-3 for the 61.0° and 241.0° dual surveillance capsule holder locations found in octants with a 22.5° neutron pad segment. On the same figure the 58.5° and the 238.5° dual surveillance capsule holder locations found in octants with a 22.5° neutron pad segment are also shown. The stainless steel specimen containers are 1.655-inch by 1.25-inch and are approximately 60.68 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 14-foot-high reactor core.

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

For the South Texas Unit 1 analysis, all of the transport calculations were carried out using the RAPTOR-M3G three-dimensional parallel discrete ordinates code Version 1.0 [Ref. 21] and the BUGLE-96 cross section library [Ref. 22]. The BUGLE-96 library provides a 67-group coupled neutron-gamma ray cross-section data set produced specifically for light water reactor applications. In these analyses, anisotropic scattering was treated with a P_3 legendre expansion and the angular discretization was modeled with an S_8 order of angular quadrature.

Three 3-dimensional r-θ-z geometry models were built for South Texas Unit 1. Plan views in the r, θ plane of the r-θ-z geometry of the South Texas Unit 1 reactor at the core midplane are shown in Figures 6-1, 6-2, and 6-3. In each of these figures, a single octant is depicted showing the arrangement of neutron pads and surveillance capsules as applicable. In regard to these three geometries, it should be noted that the maximum exposure of the pressure vessel occurs in octants with the 12.5° neutron pad span where no surveillance capsules are present. Further, the surveillance capsules with dual holders and ex-vessel neutron dosimetry are located in octants with the 22.5° neutron pad span. The surveillance capsules with single holders are located in octants with the 20° neutron pad span.

Section views in the r,z plane of the r-θ-z model with 22.5° neutron pad span of the South Texas Unit 1 reactor is shown in Figure 6-4 and Figure 6-5 for azimuthal angles at 35° and 29°, respectively. The surveillance capsule can be seen in Figure 6-5 for the azimuthal angle at 29°. In the r,z plane, the model 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 about three feet below the active fuel to about five-and-a-half feet above the active fuel. The important features in the r,z plane, such as the stainless steel former plates located between the core baffle and core barrel regions were explicitly included in the r-θ-z models.

Other features important to ex-vessel neutron dosimetry such as reactor pressure vessel insulation region and ex-core detector wells were also included in the models.

In developing the r-θ-z analytical models of the reactor geometry shown in Figures 6-1 through 6-5, nominal design dimensions were employed for the various structural components. Water temperatures and, hence, coolant densities in the reactor core, bypass, and downcomer regions were taken to be representative of full power operating conditions. These coolant temperatures were varied on a cycle-specific basis and are described in more detail later in this section. 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. These three 3-dimensional models have the same number of 208 radial by 197 azimuthal by 190 axial intervals with the same fine mesh boundaries. The differences between these three models are implemented by filling cells with different zone materials. 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-z calculations was set at a value of 0.001.

The core power distributions used in the plant-specific transport analysis for the South Texas Unit 1 reactor were taken from appropriate design documentation [Ref. 16, 23-28]. The data extracted included fuel assembly-specific initial enrichments, beginning-of-cycle burnups and end-of-cycle burnups. Appropriate axial power distributions were also obtained.

For each fuel cycle of operation, the fuel assembly-specific enrichment and burnup data were used to generate the spatially dependent neutron source throughout the reactor core. This source description included the spatial variation of isotope-dependent (U-235, U-238, Pu-239, Pu-240, Pu-241, and Pu-242) fission spectra, neutron emission rate per fission, and energy release per fission based on the burnup history of individual fuel assemblies. These fuel assembly-specific neutron source strengths derived from the detailed isotopics were then converted from fuel pin cartesian coordinates to the [r,θ,z] spatial mesh arrays used in the RAPTOR-M3G discrete ordinates calculations.

Selected results from the neutron transport analyses are provided in Tables 6-1 through 6-4. In Table 6-1, the calculated exposure rates and integrated exposures, expressed in terms of both neutron fluence (E > 1.0 MeV) and dpa, are given at the radial and azimuthal center of the octant symmetric surveillance capsule positions, i.e., for the 29.0° dual capsule, 31.5° dual capsule, and 31.5° single capsule. These results, representative of the axial midplane of the active core, establish the calculated exposure of the surveillance capsules withdrawn to date as well as projected into the future. Similar information is provided in Table 6-2 for the reactor vessel inner radius at five azimuthal locations. The vessel data given in Table 6-2 were taken at the clad/base metal interface, and thus, represent maximum calculated exposure levels on the vessel.

From the data provided in Table 6-2 it is noted that the peak clad/base metal interface vessel fluence (E > 1.0 MeV) at the end of the sixteenth fuel cycle (i.e., after 18.21 EFPY of plant operation) was 1.44×10^{19} n/cm^2.

Both calculated fluence (E > 1.0 MeV) and dpa data are provided in Tables 6-1 and 6-2. These data tabulations include both plant- and fuel-cycle-specific calculated neutron exposures at the end of the sixteenth fuel cycle as well as future projections to 26, 30, 34, 40, 44, 48, 54, and 60 EFPY. The calculations account for an uprate from 3800 MWt to 3853 MWt that occurred during Cycle 11. The

projections were based on the assumption that the core power distributions and associated plant operating characteristics from Cycle 17 [Ref. 28] were representative of future plant operation. The future projections are also based on the current reactor power level of 3853 MWt.

The calculated fast neutron exposures for the four surveillance capsules withdrawn from the South Texas Unit 1 reactor are provided in Table 6-3. These assigned neutron exposure levels are based on the plant- and fuel-cycle-specific neutron transport calculations performed for the South Texas Unit 1 reactor.

From the data provided in Table 6-3, Capsule W received a fluence (E > 1.0 MeV) of 4.37×10^{19} n/cm^2 after exposure through the end of the fourteenth fuel cycle (i.e., after 18.21 EFPY of plant operation).

Updated lead factors for the South Texas Unit 1 surveillance capsules are provided in Table 6-4. 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 6-4, the lead factors for capsules that have been withdrawn from the reactor (U, Y, V, and W) were based on the calculated fluence values for the irradiation period corresponding to the time of withdrawal for the individual capsules. Capsules X and Z are remained in the reactor, their lead factors have also been reported in Table 6-4, based on End-of-Cycle (EOC) 16, which is the last completed cycle.

6.3 NEUTRON DOSIMETRY

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

The direct comparison of measured versus calculated fast neutron threshold reaction rates for the sensors from Capsule W, that was withdrawn from South Texas Unit 1 at the end of the sixteenth fuel cycle, is summarized below.

Reaction	Reaction Rates (rps/atom)		M/C Ratio
	Measured	Calculated	
$^{63}Cu(n,\alpha)^{60}Co$	4.51E-17	4.32E-17	1.04
$^{54}Fe(n,p)^{54}Mn$	4.99E-15	4.69E-15	1.06
$^{58}Ni(n,p)^{58}Co$	7.23E-15	6.55E-15	1.10
$^{238}U(n,f)^{137}Cs$ (Cd)	2.78E-14	2.45E-14	1.13
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.50E-13	2.31E-13	1.08
		Average:	1.08
		% Standard Deviation:	3.2

The measured-to-calculated (M/C) reaction rate ratios for the Capsule W threshold reactions range from 1.04 to 1.13, and the average M/C ratio is 1.08 ± 3.2% (1σ). This direct comparison falls well within the ± 20% criterion specified in Regulatory Guide 1.190; furthermore, it is consistent with the full set of comparisons given in Appendix A for all measured dosimetry removed to date from the South Texas Unit 1 reactor. These comparisons validate the current analytical results described in Section 6.2; therefore, the calculations are deemed applicable for South Texas Unit 1.

6.4 CALCULATIONAL UNCERTAINTIES

The uncertainty associated with the calculated neutron exposure of the South Texas Unit 1 surveillance capsule and reactor pressure vessel is based on the recommended approach provided in Regulatory Guide 1.190. In particular, the qualification of the methodology was carried out in the following four stages:

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

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

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

4. Comparisons of the plant-specific calculations with all available dosimetry results from the South Texas Unit 1 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 South Texas Unit 1 analysis was established from results of these three phases of the methods qualification.

The fourth phase of the uncertainty assessment (comparisons with South Texas Unit 1 measurements) was used solely to demonstrate the validity of the transport calculations and to confirm the uncertainty estimates associated with the analytical results. The comparison was used only as a check and was not used in any way to modify the calculated surveillance capsule and pressure vessel neutron exposures previously described in Section 6.2. As such, the validation of the South Texas Unit 1 analytical model based on the measured plant dosimetry is completely described in Appendix A.

The following summarizes the uncertainties developed from the first three phases of the methodology qualification. Additional information pertinent to these evaluations is provided in Reference 20.

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

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

The plant-specific measurement comparisons described in Appendix A support these uncertainty assessments for South Texas Unit 1.

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

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Neutron Flux (E > 1.0 MeV) [n/cm²-s]		
				Dual 29.0°	Dual 31.5°	Single 31.5°
1	2.46E+07	2.46E+07	0.78	9.82E+10	1.06E+11	1.05E+11
2	1.23E+07	3.69E+07	1.17	7.64E+10	7.86E+10	7.72E+10
3	1.07E+07	4.77E+07	1.51	8.91E+10	9.63E+10	9.48E+10
4	4.26E+07	9.03E+07	2.86	8.08E+10	8.62E+10	8.48E+10
5	3.06E+07	1.21E+08	3.83	8.20E+10	8.43E+10	8.28E+10
6	3.38E+07	1.55E+08	4.90	8.45E+10	8.82E+10	8.67E+10
7	3.88E+07	1.93E+08	6.13	7.38E+10	8.02E+10	7.89E+10
8	4.54E+07	2.39E+08	7.57	6.74E+10	7.52E+10	7.41E+10
9	2.59E+07	2.65E+08	8.39	7.42E+10	8.39E+10	8.27E+10
10	4.35E+07	3.08E+08	9.77	6.71E+10	7.41E+10	7.30E+10
11	4.26E+07	3.51E+08	11.12	6.82E+10	7.19E+10	7.07E+10
12	4.86E+07	4.00E+08	12.66	6.64E+10	7.10E+10	6.98E+10
13	4.54E+07	4.45E+08	14.10	6.08E+10	6.49E+10	6.39E+10
14	4.32E+07	4.88E+08	15.47	6.57E+10	7.23E+10	7.12E+10
15	4.45E+07	5.33E+08	16.88	6.28E+10	6.90E+10	6.80E+10
16	4.20E+07	5.75E+08	18.21	6.25E+10	6.90E+10	6.80E+10
Future	2.46E+08	8.20E+08	26.00	5.78E+10	6.20E+10	6.10E+10
Future	1.26E+08	9.47E+08	30.00	5.78E+10	6.20E+10	6.10E+10
Future	1.26E+08	1.07E+09	34.00	5.78E+10	6.20E+10	6.10E+10
Future	1.89E+08	1.26E+09	40.00	5.78E+10	6.20E+10	6.10E+10
Future	1.26E+08	1.39E+09	44.00	5.78E+10	6.20E+10	6.10E+10
Future	1.26E+08	1.51E+09	48.00	5.78E+10	6.20E+10	6.10E+10
Future	1.89E+08	1.70E+09	54.00	5.78E+10	6.20E+10	6.10E+10
Future	1.89E+08	1.89E+09	60.00	5.78E+10	6.20E+10	6.10E+10

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

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

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Neutron Fluence (E > 1.0 MeV) [n/cm²]		
				Dual 29.0°	Dual 31.5°	Single 31.5°
1	2.46E+07	2.46E+07	0.78	2.43E+18	2.62E+18	2.58E+18
2	1.23E+07	3.69E+07	1.17	3.36E+18	3.59E+18	3.53E+18
3	1.07E+07	4.77E+07	1.51	4.32E+18	4.62E+18	4.55E+18
4	4.26E+07	9.03E+07	2.86	7.75E+18	8.28E+18	8.15E+18
5	3.06E+07	1.21E+08	3.83	1.03E+19	1.09E+19	1.07E+19
6	3.38E+07	1.55E+08	4.90	1.31E+19	1.38E+19	1.36E+19
7	3.88E+07	1.93E+08	6.13	1.60E+19	1.70E+19	1.67E+19
8	4.54E+07	2.39E+08	7.57	1.90E+19	2.04E+19	2.01E+19
9	2.59E+07	2.65E+08	8.39	2.10E+19	2.25E+19	2.22E+19
10	4.35E+07	3.08E+08	9.77	2.39E+19	2.58E+19	2.54E+19
11	4.26E+07	3.51E+08	11.12	2.68E+19	2.88E+19	2.84E+19
12	4.86E+07	4.00E+08	12.66	3.00E+19	3.23E+19	3.18E+19
13	4.54E+07	4.45E+08	14.10	3.28E+19	3.52E+19	3.47E+19
14	4.32E+07	4.88E+08	15.47	3.56E+19	3.84E+19	3.78E+19
15	4.45E+07	5.33E+08	16.88	3.84E+19	4.14E+19	4.08E+19
16	4.20E+07	5.75E+08	18.21	4.10E+19	4.43E+19	4.37E+19
Future	2.46E+08	8.20E+08	26.00	5.53E+19	5.96E+19	5.86E+19
Future	1.26E+08	9.47E+08	30.00	6.26E+19	6.74E+19	6.63E+19
Future	1.26E+08	1.07E+09	34.00	6.99E+19	7.52E+19	7.40E+19
Future	1.89E+08	1.26E+09	40.00	8.08E+19	8.70E+19	8.56E+19
Future	1.26E+08	1.39E+09	44.00	8.81E+19	9.48E+19	9.33E+19
Future	1.26E+08	1.51E+09	48.00	9.54E+19	1.03E+20	1.01E+20
Future	1.89E+08	1.70E+09	54.00	1.06E+20	1.14E+20	1.13E+20
Future	1.89E+08	1.89E+09	60.00	1.17E+20	1.26E+20	1.24E+20

Note:

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

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

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Iron Atom Displacement Rate [dpa/s]		
				Dual 29.0°	Dual 31.5°	Single 31.5°
1	2.46E+07	2.46E+07	0.78	1.91E-10	2.07E-10	2.03E-10
2	1.23E+07	3.69E+07	1.17	1.49E-10	1.53E-10	1.50E-10
3	1.07E+07	4.77E+07	1.51	1.73E-10	1.88E-10	1.84E-10
4	4.26E+07	9.03E+07	2.86	1.57E-10	1.67E-10	1.64E-10
5	3.06E+07	1.21E+08	3.83	1.59E-10	1.64E-10	1.60E-10
6	3.38E+07	1.55E+08	4.90	1.64E-10	1.71E-10	1.67E-10
7	3.88E+07	1.93E+08	6.13	1.43E-10	1.55E-10	1.52E-10
8	4.54E+07	2.39E+08	7.57	1.30E-10	1.45E-10	1.43E-10
9	2.59E+07	2.65E+08	8.39	1.43E-10	1.62E-10	1.59E-10
10	4.35E+07	3.08E+08	9.77	1.29E-10	1.43E-10	1.40E-10
11	4.26E+07	3.51E+08	11.12	1.32E-10	1.39E-10	1.36E-10
12	4.86E+07	4.00E+08	12.66	1.28E-10	1.37E-10	1.34E-10
13	4.54E+07	4.45E+08	14.10	1.17E-10	1.25E-10	1.23E-10
14	4.32E+07	4.88E+08	15.47	1.27E-10	1.39E-10	1.37E-10
15	4.45E+07	5.33E+08	16.88	1.21E-10	1.33E-10	1.31E-10
16	4.20E+07	5.75E+08	18.21	1.20E-10	1.33E-10	1.31E-10
Future	2.46E+08	8.20E+08	26.00	1.12E-10	1.20E-10	1.17E-10
Future	1.26E+08	9.47E+08	30.00	1.12E-10	1.20E-10	1.17E-10
Future	1.26E+08	1.07E+09	34.00	1.12E-10	1.20E-10	1.17E-10
Future	1.89E+08	1.26E+09	40.00	1.12E-10	1.20E-10	1.17E-10
Future	1.26E+08	1.39E+09	44.00	1.12E-10	1.20E-10	1.17E-10
Future	1.26E+08	1.51E+09	48.00	1.12E-10	1.20E-10	1.17E-10
Future	1.89E+08	1.70E+09	54.00	1.12E-10	1.20E-10	1.17E-10
Future	1.89E+08	1.89E+09	60.00	1.12E-10	1.20E-10	1.17E-10

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

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

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Iron Atom Displacement [dpa]		
				Dual 29.0°	Dual 31.5°	Single 31.5°
1	2.46E+07	2.46E+07	0.78	4.72E-03	5.12E-03	5.01E-03
2	1.23E+07	3.69E+07	1.17	6.55E-03	7.00E-03	6.86E-03
3	1.07E+07	4.77E+07	1.51	8.41E-03	9.01E-03	8.83E-03
4	4.26E+07	9.03E+07	2.86	1.51E-02	1.61E-02	1.58E-02
5	3.06E+07	1.21E+08	3.83	2.00E-02	2.12E-02	2.07E-02
6	3.38E+07	1.55E+08	4.90	2.55E-02	2.69E-02	2.63E-02
7	3.88E+07	1.93E+08	6.13	3.10E-02	3.30E-02	3.23E-02
8	4.54E+07	2.39E+08	7.57	3.69E-02	3.95E-02	3.87E-02
9	2.59E+07	2.65E+08	8.39	4.06E-02	4.37E-02	4.28E-02
10	4.35E+07	3.08E+08	9.77	4.63E-02	5.00E-02	4.90E-02
11	4.26E+07	3.51E+08	11.12	5.19E-02	5.59E-02	5.48E-02
12	4.86E+07	4.00E+08	12.66	5.81E-02	6.25E-02	6.13E-02
13	4.54E+07	4.45E+08	14.10	6.34E-02	6.82E-02	6.68E-02
14	4.32E+07	4.88E+08	15.47	6.89E-02	7.43E-02	7.28E-02
15	4.45E+07	5.33E+08	16.88	7.43E-02	8.02E-02	7.86E-02
16	4.20E+07	5.75E+08	18.21	7.93E-02	8.58E-02	8.41E-02
Future	2.46E+08	8.20E+08	26.00	1.07E-01	1.15E-01	1.13E-01
Future	1.26E+08	9.47E+08	30.00	1.21E-01	1.30E-01	1.28E-01
Future	1.26E+08	1.07E+09	34.00	1.35E-01	1.45E-01	1.43E-01
Future	1.89E+08	1.26E+09	40.00	1.56E-01	1.68E-01	1.65E-01
Future	1.26E+08	1.39E+09	44.00	1.70E-01	1.83E-01	1.80E-01
Future	1.26E+08	1.51E+09	48.00	1.84E-01	1.98E-01	1.94E-01
Future	1.89E+08	1.70E+09	54.00	2.05E-01	2.21E-01	2.17E-01
Future	1.89E+08	1.89E+09	60.00	2.27E-01	2.44E-01	2.39E-01

Note:

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

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

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Neutron Flux (E > 1.0 MeV) [n/cm²-s]				
				0°	15°	30°	43°	45°
1	2.46E+07	2.46E+07	0.78	1.32E+10	2.08E+10	2.52E+10	3.16E+10	3.15E+10
2	1.23E+07	3.69E+07	1.17	1.32E+10	2.01E+10	2.01E+10	2.65E+10	2.63E+10
3	1.07E+07	4.77E+07	1.51	1.17E+10	1.87E+10	2.22E+10	3.19E+10	3.19E+10
4	4.26E+07	9.03E+07	2.86	1.07E+10	1.76E+10	2.04E+10	2.65E+10	2.65E+10
5	3.06E+07	1.21E+08	3.83	1.24E+10	1.95E+10	2.04E+10	2.54E+10	2.53E+10
6	3.38E+07	1.55E+08	4.90	1.17E+10	1.85E+10	2.09E+10	2.58E+10	2.58E+10
7	3.88E+07	1.93E+08	6.13	9.33E+09	1.52E+10	1.84E+10	2.65E+10	2.65E+10
8	4.54E+07	2.39E+08	7.57	7.92E+09	1.22E+10	1.71E+10	2.38E+10	2.39E+10
9	2.59E+07	2.65E+08	8.39	8.60E+09	1.33E+10	1.88E+10	2.93E+10	2.93E+10
10	4.35E+07	3.08E+08	9.77	8.30E+09	1.29E+10	1.79E+10	2.67E+10	2.67E+10
11	4.26E+07	3.51E+08	11.12	9.59E+09	1.40E+10	1.74E+10	2.17E+10	2.16E+10
12	4.86E+07	4.00E+08	12.66	1.00E+10	1.42E+10	1.72E+10	2.27E+10	2.27E+10
13	4.54E+07	4.45E+08	14.10	9.13E+09	1.36E+10	1.61E+10	2.24E+10	2.23E+10
14	4.32E+07	4.88E+08	15.47	8.20E+09	1.24E+10	1.70E+10	2.40E+10	2.40E+10
15	4.45E+07	5.33E+08	16.88	7.64E+09	1.20E+10	1.67E+10	2.37E+10	2.37E+10
16	4.20E+07	5.75E+08	18.21	8.05E+09	1.20E+10	1.65E+10	2.34E+10	2.34E+10
Future	2.46E+08	8.20E+08	26.00	8.54E+09	1.31E+10	1.54E+10	2.16E+10	2.16E+10
Future	1.26E+08	9.47E+08	30.00	8.54E+09	1.31E+10	1.54E+10	2.16E+10	2.16E+10
Future	1.26E+08	1.07E+09	34.00	8.54E+09	1.31E+10	1.54E+10	2.16E+10	2.16E+10
Future	1.89E+08	1.26E+09	40.00	8.54E+09	1.31E+10	1.54E+10	2.16E+10	2.16E+10
Future	1.26E+08	1.39E+09	44.00	8.54E+09	1.31E+10	1.54E+10	2.16E+10	2.16E+10
Future	1.26E+08	1.51E+09	48.00	8.54E+09	1.31E+10	1.54E+10	2.16E+10	2.16E+10
Future	1.89E+08	1.70E+09	54.00	8.54E+09	1.31E+10	1.54E+10	2.16E+10	2.16E+10
Future	1.89E+08	1.89E+09	60.00	8.54E+09	1.31E+10	1.54E+10	2.16E+10	2.16E+10

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

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Neutron Fluence (E > 1.0 MeV) [n/cm²]				
				0°	15°	30°	43°	45°
1	2.46E+07	2.46E+07	0.78	3.27E+17	5.14E+17	6.22E+17	7.80E+17	7.78E+17
2	1.23E+07	3.69E+07	1.17	4.77E+17	7.42E+17	8.49E+17	1.11E+18	1.10E+18
3	1.07E+07	4.77E+07	1.51	6.02E+17	9.42E+17	1.09E+18	1.45E+18	1.44E+18
4	4.26E+07	9.03E+07	2.86	1.06E+18	1.69E+18	1.95E+18	2.57E+18	2.57E+18
5	3.06E+07	1.21E+08	3.83	1.44E+18	2.29E+18	2.58E+18	3.35E+18	3.35E+18
6	3.38E+07	1.55E+08	4.90	1.82E+18	2.89E+18	3.26E+18	4.22E+18	4.21E+18
7	3.88E+07	1.93E+08	6.13	2.19E+18	3.49E+18	3.98E+18	5.25E+18	5.24E+18
8	4.54E+07	2.39E+08	7.57	2.55E+18	4.04E+18	4.75E+18	6.33E+18	6.33E+18
9	2.59E+07	2.65E+08	8.39	2.77E+18	4.38E+18	5.24E+18	7.08E+18	7.08E+18
10	4.35E+07	3.08E+08	9.77	3.12E+18	4.93E+18	6.00E+18	8.24E+18	8.24E+18
11	4.26E+07	3.51E+08	11.12	3.53E+18	5.53E+18	6.73E+18	9.16E+18	9.16E+18
12	4.86E+07	4.00E+08	12.66	4.01E+18	6.21E+18	7.56E+18	1.03E+19	1.03E+19
13	4.54E+07	4.45E+08	14.10	4.42E+18	6.81E+18	8.26E+18	1.13E+19	1.13E+19
14	4.32E+07	4.88E+08	15.47	4.77E+18	7.34E+18	8.99E+18	1.23E+19	1.23E+19
15	4.45E+07	5.33E+08	16.88	5.10E+18	7.86E+18	9.71E+18	1.34E+19	1.34E+19
16	4.20E+07	5.75E+08	18.21	5.43E+18	8.35E+18	1.04E+19	1.44E+19	1.44E+19
Future	2.46E+08	8.20E+08	26.00	7.47E+18	1.15E+19	1.41E+19	1.97E+19	1.97E+19
Future	1.26E+08	9.47E+08	30.00	8.52E+18	1.31E+19	1.60E+19	2.24E+19	2.24E+19
Future	1.26E+08	1.07E+09	34.00	9.58E+18	1.47E+19	1.79E+19	2.51E+19	2.51E+19
Future	1.89E+08	1.26E+09	40.00	1.12E+19	1.72E+19	2.08E+19	2.92E+19	2.92E+19
Future	1.26E+08	1.39E+09	44.00	1.22E+19	1.88E+19	2.27E+19	3.20E+19	3.19E+19
Future	1.26E+08	1.51E+09	48.00	1.33E+19	2.04E+19	2.47E+19	3.47E+19	3.47E+19
Future	1.89E+08	1.70E+09	54.00	1.49E+19	2.29E+19	2.75E+19	3.88E+19	3.87E+19
Future	1.89E+08	1.89E+09	60.00	1.65E+19	2.53E+19	3.04E+19	4.29E+19	4.28E+19

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

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Iron Atom Displacement Rate [dpa/s]				
				0°	15°	30°	43°	45°
1	2.46E+07	2.46E+07	0.78	2.05E-11	3.20E-11	3.89E-11	4.81E-11	4.81E-11
2	1.23E+07	3.69E+07	1.17	2.05E-11	3.09E-11	3.10E-11	4.03E-11	4.02E-11
3	1.07E+07	4.77E+07	1.51	1.82E-11	2.87E-11	3.43E-11	4.86E-11	4.86E-11
4	4.26E+07	9.03E+07	2.86	1.66E-11	2.70E-11	3.15E-11	4.04E-11	4.04E-11
5	3.06E+07	1.21E+08	3.83	1.93E-11	3.00E-11	3.15E-11	3.87E-11	3.87E-11
6	3.38E+07	1.55E+08	4.90	1.82E-11	2.84E-11	3.22E-11	3.94E-11	3.94E-11
7	3.88E+07	1.93E+08	6.13	1.45E-11	2.34E-11	2.85E-11	4.03E-11	4.04E-11
8	4.54E+07	2.39E+08	7.57	1.23E-11	1.88E-11	2.64E-11	3.63E-11	3.64E-11
9	2.59E+07	2.65E+08	8.39	1.34E-11	2.05E-11	2.90E-11	4.44E-11	4.45E-11
10	4.35E+07	3.08E+08	9.77	1.29E-11	1.99E-11	2.76E-11	4.04E-11	4.06E-11
11	4.26E+07	3.51E+08	11.12	1.49E-11	2.15E-11	2.69E-11	3.30E-11	3.30E-11
12	4.86E+07	4.00E+08	12.66	1.55E-11	2.19E-11	2.65E-11	3.47E-11	3.46E-11
13	4.54E+07	4.45E+08	14.10	1.42E-11	2.09E-11	2.48E-11	3.41E-11	3.41E-11
14	4.32E+07	4.88E+08	15.47	1.28E-11	1.90E-11	2.62E-11	3.66E-11	3.67E-11
15	4.45E+07	5.33E+08	16.88	1.19E-11	1.85E-11	2.58E-11	3.61E-11	3.62E-11
16	4.20E+07	5.75E+08	18.21	1.25E-11	1.85E-11	2.55E-11	3.57E-11	3.58E-11
Future	2.46E+08	8.20E+08	26.00	1.33E-11	2.02E-11	2.38E-11	3.29E-11	3.30E-11
Future	1.26E+08	9.47E+08	30.00	1.33E-11	2.02E-11	2.38E-11	3.29E-11	3.30E-11
Future	1.26E+08	1.07E+09	34.00	1.33E-11	2.02E-11	2.38E-11	3.29E-11	3.30E-11
Future	1.89E+08	1.26E+09	40.00	1.33E-11	2.02E-11	2.38E-11	3.29E-11	3.30E-11
Future	1.26E+08	1.39E+09	44.00	1.33E-11	2.02E-11	2.38E-11	3.29E-11	3.30E-11
Future	1.26E+08	1.51E+09	48.00	1.33E-11	2.02E-11	2.38E-11	3.29E-11	3.30E-11
Future	1.89E+08	1.70E+09	54.00	1.33E-11	2.02E-11	2.38E-11	3.29E-11	3.30E-11
Future	1.89E+08	1.89E+09	60.00	1.33E-11	2.02E-11	2.38E-11	3.29E-11	3.30E-11

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

Cycle	Cycle Length [EFPS]	Cumulative Irradiation Time [EFPS]	Cumulative Irradiation Time [EFPY]	Iron Atom Displacements [dpa]				
				0°	15°	30°	43°	45°
1	2.46E+07	2.46E+07	0.78	5.07E-04	7.89E-04	9.60E-04	1.19E-03	1.19E-03
2	1.23E+07	3.69E+07	1.17	7.40E-04	1.14E-03	1.31E-03	1.68E-03	1.68E-03
3	1.07E+07	4.77E+07	1.51	9.34E-04	1.45E-03	1.68E-03	2.20E-03	2.20E-03
4	4.26E+07	9.03E+07	2.86	1.64E-03	2.59E-03	3.02E-03	3.92E-03	3.92E-03
5	3.06E+07	1.21E+08	3.83	2.24E-03	3.52E-03	3.99E-03	5.11E-03	5.11E-03
6	3.38E+07	1.55E+08	4.90	2.83E-03	4.45E-03	5.04E-03	6.43E-03	6.43E-03
7	3.88E+07	1.93E+08	6.13	3.40E-03	5.36E-03	6.15E-03	8.00E-03	8.01E-03
8	4.54E+07	2.39E+08	7.57	3.96E-03	6.21E-03	7.34E-03	9.65E-03	9.66E-03
9	2.59E+07	2.65E+08	8.39	4.30E-03	6.74E-03	8.09E-03	1.08E-02	1.08E-02
10	4.35E+07	3.08E+08	9.77	4.85E-03	7.59E-03	9.27E-03	1.26E-02	1.26E-02
11	4.26E+07	3.51E+08	11.12	5.49E-03	8.50E-03	1.04E-02	1.40E-02	1.40E-02
12	4.86E+07	4.00E+08	12.66	6.23E-03	9.55E-03	1.17E-02	1.56E-02	1.57E-02
13	4.54E+07	4.45E+08	14.10	6.86E-03	1.05E-02	1.28E-02	1.72E-02	1.72E-02
14	4.32E+07	4.88E+08	15.47	7.41E-03	1.13E-02	1.39E-02	1.88E-02	1.88E-02
15	4.45E+07	5.33E+08	16.88	7.92E-03	1.21E-02	1.50E-02	2.04E-02	2.04E-02
16	4.20E+07	5.75E+08	18.21	8.44E-03	1.28E-02	1.60E-02	2.19E-02	2.19E-02
Future	2.46E+08	8.20E+08	26.00	1.16E-02	1.77E-02	2.18E-02	3.00E-02	3.00E-02
Future	1.26E+08	9.47E+08	30.00	1.32E-02	2.02E-02	2.47E-02	3.41E-02	3.42E-02
Future	1.26E+08	1.07E+09	34.00	1.49E-02	2.27E-02	2.77E-02	3.83E-02	3.83E-02
Future	1.89E+08	1.26E+09	40.00	1.74E-02	2.64E-02	3.21E-02	4.45E-02	4.46E-02
Future	1.26E+08	1.39E+09	44.00	1.90E-02	2.89E-02	3.51E-02	4.87E-02	4.88E-02
Future	1.26E+08	1.51E+09	48.00	2.06E-02	3.14E-02	3.81E-02	5.29E-02	5.29E-02
Future	1.89E+08	1.70E+09	54.00	2.31E-02	3.52E-02	4.25E-02	5.91E-02	5.92E-02
Future	1.89E+08	1.89E+09	60.00	2.56E-02	3.89E-02	4.70E-02	6.53E-02	6.54E-02

Table 6-3 Calculated Fast Neutron Exposure of Surveillance Capsules Withdrawn from South Texas Unit 1

Capsule	Irradiation Time [EFPY]	Fluence (E > 1.0 MeV) [n/cm^2]	Iron Displacements [dpa]
U	0.78	2.623E+18	5.116E-03
Y	4.90	1.312E+19	2.546E-02
V	11.12	2.680E+19	5.187E-02
W	18.21	4.365E+19	8.407E-02

Table 6-4 Calculated Surveillance Capsule Lead Factors

Capsule ID And Location	Status	Lead Factor
U (58.5°)	Withdrawn EOC 1	3.36
Y (241.0°)	Withdrawn EOC 6	3.11
V (61°)	Withdrawn EOC 11	2.92
W (121.5°)	Withdrawn EOC 16	3.04
X (238.5°)	In Reactor	3.09*
Z (301.5°)	In Reactor	3.04*

* The lead factors for the capsules remaining in the reactor are calculated based on EOC 16, the last completed operating cycle.

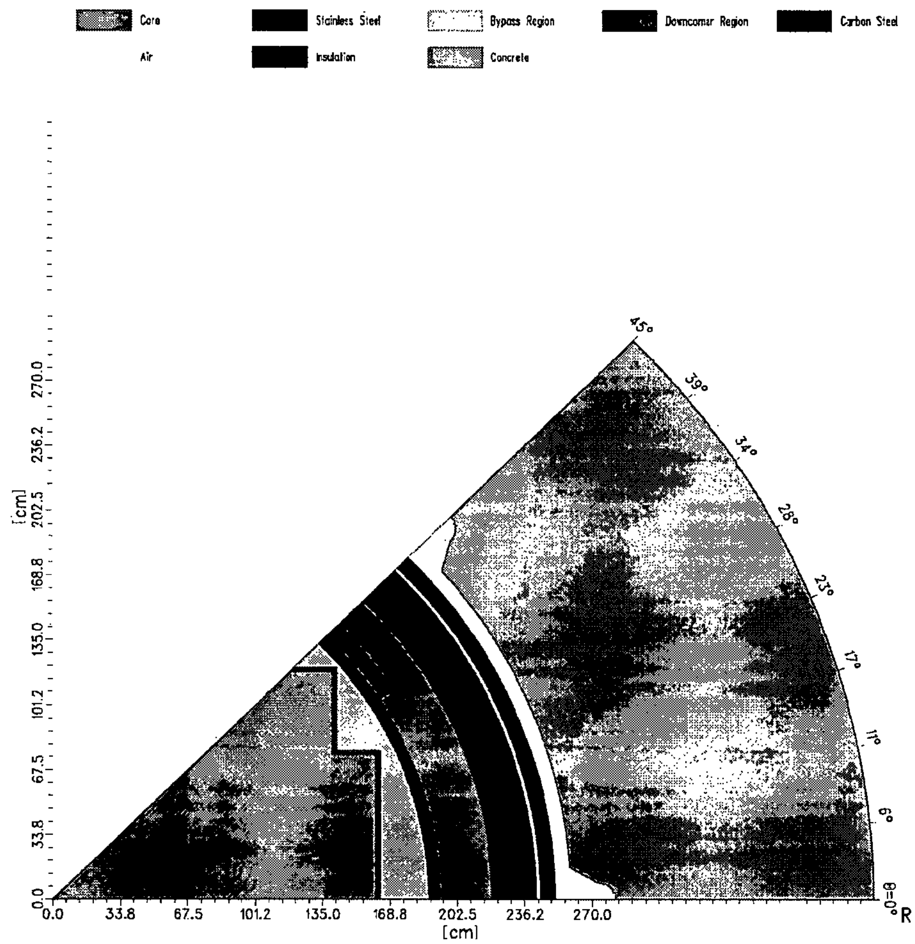


Figure 6-1 South Texas Unit 1 r,θ Reactor Geometry with a 12.5° Neutron Pad Span at the Core Midplane

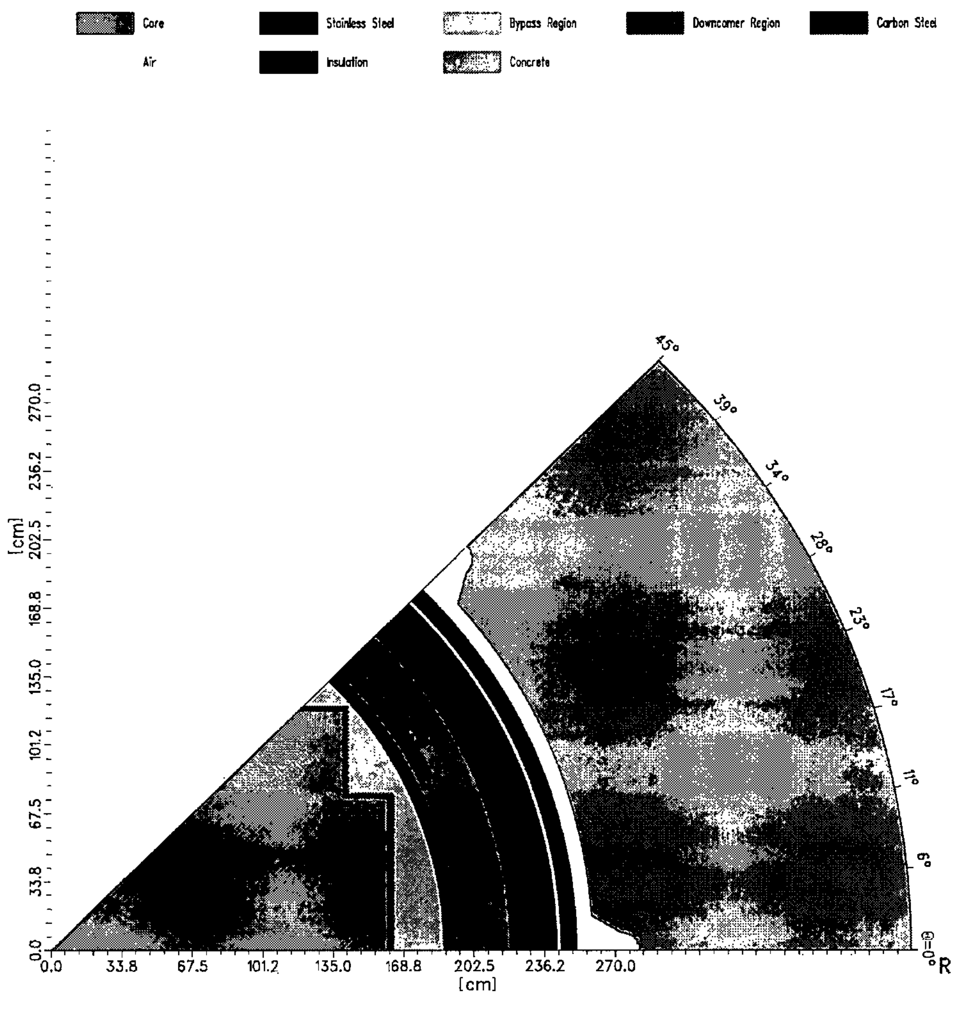


Figure 6-2 South Texas Unit 1 r,θ Reactor Geometry with a 20.0° Neutron Pad Span at the Core Midplane

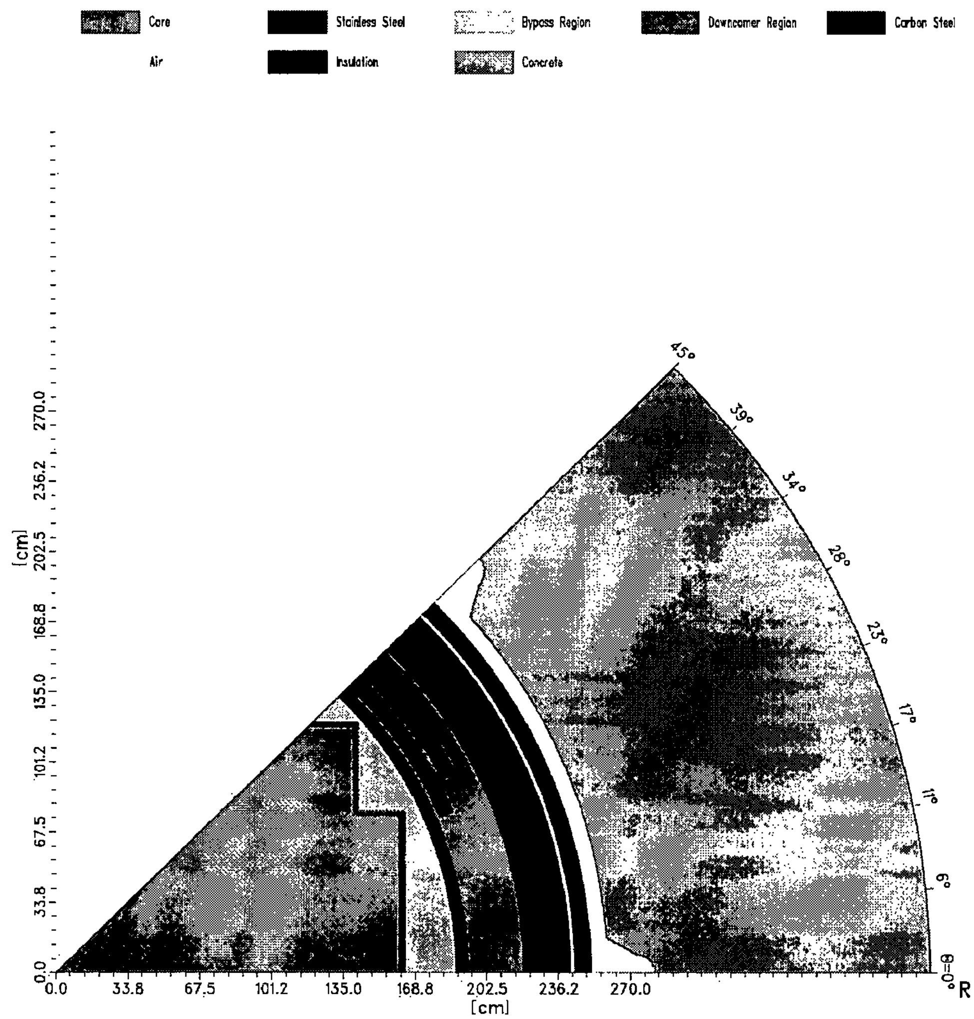


Figure 6-3 South Texas Unit 1 r,θ Reactor Geometry with a 22.5° Neutron Pad Span at the Core Midplane

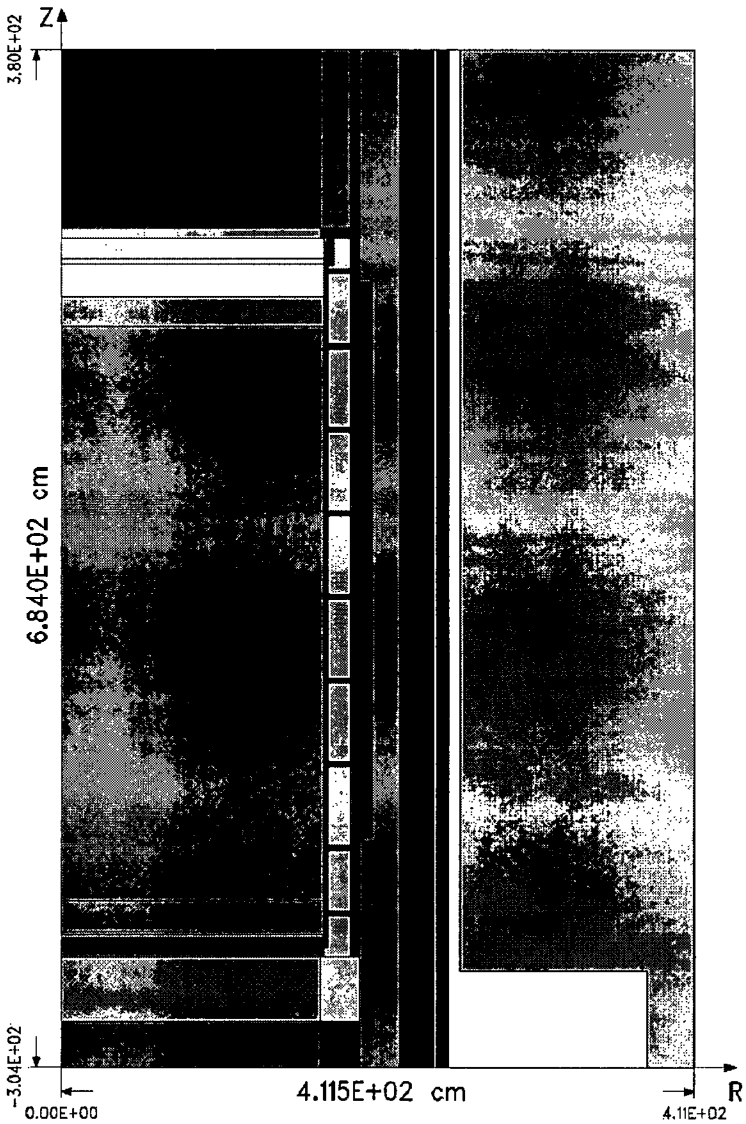


Figure 6-4 South Texas Unit 1 r,z Plane with Neutron Pad at 35° Azimuthal Angle

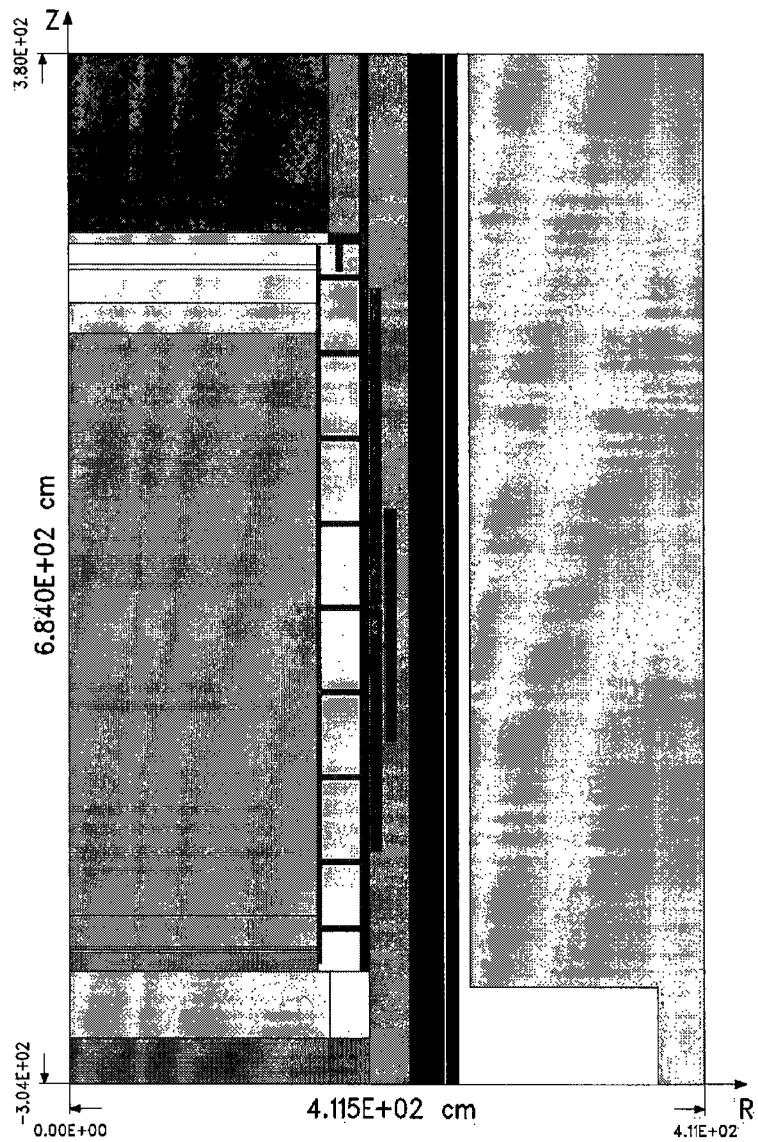


Figure 6-5 South Texas Unit 1 r,z Plane with Surveillance Capsule and Neutron Pad at 29° Azimuthal Angle

7 SURVEILLANCE CAPSULE REMOVAL SCHEDULE

The following surveillance capsule removal schedule (Table 7-1) meets the requirements of ASTM E185-82 [Ref. 8] and is recommended for future capsules to be removed from the South Texas Unit 1 reactor vessel.

Table 7-1 Surveillance Capsule Withdrawal Schedule

Capsule	Capsule Location	Status[(a)]	Capsule Lead Factor[(a)]	Withdrawal EFPY[(b,c)]	Capsule Fluence (n/cm^2, E > 1.0 MeV)[(c)]
U	58.5° (31.5°, dual)	Withdrawn (EOC 1)	3.36	0.78	2.623 x 10^{18}
Y	241.0° (29.0°, dual)	Withdrawn (EOC 6)	3.11	4.90	1.312 x 10^{19}
V	61° (29.0°, dual)	Withdrawn (EOC 11)	2.92	11.12	2.680 x 10^{19}
W	121.5° (31.5°, single)	Withdrawn (EOC 16)	3.04	18.21	4.365 x 10^{19}
X[(d)]	238.5° (31.5°, dual)	In Reactor	3.09	(e)	---
Z[(d)]	301.5° (31.5°, single)	In Reactor	3.04	(e)	---

Notes:

(a) Updated in Capsule W dosimetry analysis; see Table 6-4.

(b) EFPY from plant startup.

(c) Updated in Capsule W dosimetry analysis; see Table 6-3.

(d) If South Texas Unit 1 plans to pursue additional license renewals the two standby capsules located in the reactor vessel can serve as the 80-year and 100-year capsules. Capsules X and Z have approximately equivalent lead factors and per Table 6-1 have accumulated approximately equivalent fluence. Therefore, at this time, there is no advantage to pull one capsule over the other. Whichever capsule is pulled as the 80-year capsule, the other will serve as the 100-year capsule.

(e) Capsule X or Z should be withdrawn at the refueling outage after 26 EFPY of plant operation, which is after the first refueling outage when the fluence on the capsule will be greater than once but less than twice the peak 80-year vessel fluence. The withdrawal schedule of the remaining capsule, which could be considered a 100-year capsule, should be determined when the 80-year capsule is tested because predicted core operation and current regulations may change.

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

A.1 NEUTRON DOSIMETRY

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

A.1.1 Sensor Reaction Rate Determinations

In this section, the results of the evaluations of the four neutron sensor sets analyzed to date as part of the South Texas Unit 1 Reactor Vessel Materials Surveillance Program are presented. The capsule designation, location within the reactor, and time of withdrawal of each of these dosimetry sets were as follows:

Capsule ID	Azimuthal Location	Withdrawal Time	Irradiation Time [EFPY]
U	31.5° Dual	End of Cycle 1	0.78
Y	29.0° Dual	End of Cycle 6	4.90
V	29.0° Dual	End of Cycle 11	11.12
W	31.5° Single	End of Cycle 16	18.21

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

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

Sensor Material	Reaction Of Interest	Capsule U	Capsule Y	Capsule V	Capsule W
Copper-63	$^{63}Cu(n,\alpha)^{60}Co$	X	X	X	X
Iron-54	$^{54}Fe(n,p)^{54}Mn$	X	X	X	X
Nickel-58	$^{58}Ni(n,p)^{58}Co$	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 and cadmium-covered wire sensors.					

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

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

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

Results from the radiometric counting of the neutron sensors from Capsules U, Y, and V are documented in References A-2, A-3, and A-4, respectively, and re-evaluated in Reference A-5. The radiometric counting of the sensors from Capsule W was carried out by Pace Analytical Services, Inc. In all cases, the radiometric counting followed established ASTM procedures. Following sample preparation and weighing, the specific activity of each sensor was determined by means of a high-resolution gamma spectrometer. For the copper, iron, nickel, and cobalt-aluminum sensors, these analyses were performed by direct counting of each of the individual samples. In the case of the uranium and neptunium fission sensors, the analyses were carried out by direct counting preceded by dissolution and chemical separation of cesium from the sensor material.

The irradiation history of the reactor over the irradiation periods experienced by Capsules U, Y, V, and W was based on the monthly power generation of South Texas Unit 1 from initial reactor criticality through the end of the dosimetry evaluation period. For the sensor sets utilized in the surveillance capsules, the half-lives of the product isotopes are long enough that a monthly histogram describing reactor operation has proven to be an adequate representation for use in radioactive decay corrections for the reactions of

interest in the exposure evaluations. The irradiation history applicable to Capsules U, Y, V, and W is given in Table A-2.

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

$$R = \frac{A}{N_0 F Y \sum_{j=1}^{n} \frac{P_j}{P_{ref}} C_j \left[1 - e^{-\lambda t_j}\right] \left[e^{-\lambda t_{d,j}}\right]}$$

where:

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

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

In the equation describing the reaction rate calculation, the ratio $[P_j]/[P_{ref}]$ accounts for month-by-month variation of reactor core power level within any given fuel cycle as well as over multiple fuel cycles. The

ratio C_j, which was calculated for each fuel cycle using the transport methodology discussed in Section 6.2, accounts for the change in sensor reaction rates caused by variations in flux level induced by changes in core spatial power distributions from fuel cycle to fuel cycle. For a single-cycle irradiation, C_j is normally taken to be 1.0. However, for multiple-cycle irradiations, particularly those employing low-leakage fuel management, the additional C_j term should be employed. The impact of changing flux levels for constant power operation can be quite significant for sensor sets that have been irradiated for many cycles in a reactor that has transitioned from non-low-leakage to low-leakage fuel management or for sensor sets contained in surveillance capsules that have been moved from one capsule location to another. The fuel-cycle-specific neutron flux values along with the computed values for C_j are listed in Table A-3. These flux values represent the cycle-dependent results at the radial and azimuthal center of the respective capsules at the axial elevation of the active fuel midplane.

Prior to using the measured reaction rates in the least-squares evaluations of the dosimetry sensor sets, additional corrections were made to the ^{238}U measurements to account for the presence of ^{235}U impurities in the sensors as well as to adjust for the build-in of plutonium isotopes over the course of the irradiation. Corrections were also made to the ^{238}U and ^{237}Np sensor reaction rates to account for gamma-ray-induced fission reactions that occurred over the course of the capsule irradiations. The correction factors applied to the South Texas Unit 1 fission sensor reaction rates are summarized as follows:

Correction Factor	Capsule U	Capsule Y	Capsule V	Capsule W
^{235}U Impurity/Pu Build-in	0.874	0.833	0.787	0.731
$^{238}U(\gamma,f)$	0.966	0.968	0.968	0.969
Net ^{238}U Correction Factor	0.844	0.806	0.762	0.708
$^{237}Np(\gamma,f)$	0.990	0.990	0.990	0.990

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

Results of the sensor reaction rate determinations for Capsules U, Y, V, and W are given in Table A-4. In Table A-4, the measured specific activities, decay corrected saturated specific activities, and computed reaction rates for each sensor indexed to the radial center of the capsule are listed. The fission sensor reaction rates are listed both with and without the applied corrections for ^{238}U impurities, plutonium build-in, and gamma-ray-induced fission effects.

A.1.2 Least-Squares Evaluation of Sensor Sets

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

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

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

For the least-squares evaluation of the South Texas Unit 1 surveillance capsule dosimetry, the FERRET code [Ref. A-6] was employed to combine the results of the plant-specific neutron transport calculations and sensor set reaction rate measurements to determine best-estimate values of exposure parameters (ϕ(E > 1.0 MeV) and dpa) along with associated uncertainties for the four in-vessel capsules analyzed to date.

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

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

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

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

For the South Texas Unit 1 application, the calculated neutron spectrum was obtained from the results of plant-specific neutron transport calculations described in Section 6.2 of this report. The sensor reaction rates were derived from the measured specific activities using the procedures described in Section A.1.1. The dosimetry reaction cross sections and uncertainties were obtained from the SNLRML dosimetry cross-section library [Ref. A-7]. The SNLRML library is an evaluated dosimetry reaction cross-section compilation recommended for use in LWR evaluations by ASTM Standard E1018, "Application of ASTM Evaluated Cross-Section Data File, Matrix E706 (IIB)" [Ref. A-8].

The uncertainties associated with the measured reaction rates, dosimetry cross sections, and calculated neutron spectrum were input to the least-squares procedure in the form of variances and covariances. The assignment of the input uncertainties followed the guidance provided in ASTM Standard E944, "Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance" [Ref. A-9].

The following provides a summary of the uncertainties associated with the least-squares evaluation of the South Texas Unit 1 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 South Texas Unit 1 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 South Texas Unit 1 calculated spectra was as follows:

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

A.1.3 Comparisons of Measurements and Calculations

Results of the least-squares evaluations of the dosimetry from the South Texas Unit 1 surveillance capsules withdrawn to date are provided in Tables A-5 and A-6. In Table A-5, measured, calculated, and best-estimate values for sensor reaction rates are given for each capsule. Also provided in this tabulation are ratios of the measured reaction rates to both the calculated and least-squares adjusted reaction rates. These ratios of M/C and M/BE illustrate the consistency of the fit of the calculated neutron energy spectra to the measured reaction rates both before and after adjustment. In Table A-6, comparison of the calculated and best-estimate values of neutron flux (E > 1.0 MeV) and iron atom displacement rate are tabulated along with the BE/C ratios observed for each of the capsules.

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

Further comparisons of the measurement results (from Tables A-5 and A-6) with calculations are given in Tables A-7 and A-8. These comparisons are given on two levels. In Table A-7, calculations of individual threshold sensor reaction rates are compared directly with the corresponding measurements. These threshold reaction rate comparisons provide a good evaluation of the accuracy of the fast neutron portion of the calculated energy spectra. In Table A-8, calculations of fast neutron exposure rates in terms of $\phi(E > 1.0\ MeV)$ and dpa/s are compared with the best-estimate results obtained from the least-squares evaluation of the capsule dosimetry results. These two levels of comparison yield consistent and similar results with all measurement-to-calculation comparisons falling well within the 20% limits specified as the acceptance criteria in Regulatory Guide 1.190.

In the case of the direct comparison of measured and calculated sensor reaction rates, the M/C comparisons for fast neutron threshold reactions range from 0.91 to 1.16 for the 20 samples included in the data set. The overall average M/C ratio for the entire set of South Texas Unit 1 data is 1.05 with an associated standard deviation of 7.2%.

In the comparisons of best-estimate and calculated fast neutron exposure parameters, the corresponding BE/C comparisons for the capsule data sets range from 0.97 to 1.09 for neutron flux (E > 1.0 MeV) and from 0.99 to 1.08 for iron atom displacement rate. The overall average BE/C ratios for neutron flux (E > 1.0 MeV) and iron atom displacement rate are 1.03 with a standard deviation of 4.8% and 1.04 with a standard deviation of 3.6%, respectively.

Based on these comparisons, it is concluded that the calculated fast neutron exposures provided in Section 6.2 of this report are validated for use in the assessment of the condition of the materials comprising the beltline region of the South Texas Unit 1 reactor pressure vessel.

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

Monitor Material	Reaction of Interest	Target Atom Fraction	90% Response Range (MeV)[(a)]	Product Half-life	Fission Yield (%)
Copper-63	^{63}Cu (n,α)	0.6917	4.9 – 11.9	5.272 y	n/a
Iron-54	^{54}Fe (n,p)	0.0585	2.1 – 8.5	312.1 d	n/a
Nickel-58	^{58}Ni (n,p)	0.6808	1.5 – 8.3	70.82 d	n/a
Uranium-238	^{238}U (n,f)	1.0000	1.3 – 6.9	30.07 y	6.02
Neptunium-237	^{237}Np (n,f)	1.0000	0.3 – 3.8	30.07 y	6.17
Cobalt-Aluminum	^{59}Co (n,γ)	0.0015	non-threshold	5.272 y	n/a

(a) The 90% response range is defined such that, in the neutron spectrum characteristic of the South Texas Unit 1 surveillance capsules, approximately 90% of the sensor response is due to neutrons in the energy range specified with approximately 5% of the total response due to neutrons with energies below the lower limit and 5% of the total response due to neutrons with energies above the upper limit.

Table A-2 Monthly Thermal Generation During the First Sixteen Fuel Cycles of the South Texas Unit 1 Reactor (Reactor Power of 3800 MWt from Startup Through the End of Cycle 10; mid-cycle uprate from 3800 MWt to 3853 MWt for Cycle 11; and, 3853 MWt for Cycles 12 through 16)

Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)
Mar-88	3439	May-90	0	Jul-92	2817038	Sep-94	2410390
Apr-88	663115	Jun-90	357271	Aug-92	2728178	Oct-94	2843421
May-88	41693	Jul-90	2091044	Sep-92	1342973	Nov-94	2747874
Jun-88	443688	Aug-90	2615866	Oct-92	0	Dec-94	2833893
Jul-88	1543286	Sep-90	2174774	Nov-92	0	Jan-95	2476989
Aug-88	200458	Oct-90	1901324	Dec-92	49285	Feb-95	2518396
Sep-88	1828286	Nov-90	2157277	Jan-93	1765744	Mar-95	264197
Oct-88	1993115	Dec-90	0	Feb-93	309269	Apr-95	1266206
Nov-88	2506212	Jan-91	0	Mar-93	0	May-95	2839390
Dec-88	2277375	Feb-91	0	Apr-93	0	Jun-95	2748057
Jan-89	1368165	Mar-91	0	May-93	0	Jul-95	2839665
Feb-89	0	Apr-91	1648852	Jun-93	0	Aug-95	2650586
Mar-89	2502364	May-91	2827023	Jul-93	0	Sep-95	2747507
Apr-89	2625943	Jun-91	2674129	Aug-93	0	Oct-95	2843604
May-89	2671014	Jul-91	2837649	Sep-93	0	Nov-95	2733949
Jun-89	2736789	Aug-91	2782043	Oct-93	0	Dec-95	2394967
Jul-89	2372372	Sep-91	2458759	Nov-93	0	Jan-96	2783050
Aug-89	313757	Oct-91	1789196	Dec-93	0	Feb-96	2644490
Sep-89	0	Nov-91	2695565	Jan-94	0	Mar-96	2659793
Oct-89	783890	Dec-91	2762897	Feb-94	82814	Apr-96	2731768
Nov-89	2728544	Jan-92	2837741	Mar-94	463078	May-96	1540167
Dec-89	1761072	Feb-92	2651777	Apr-94	2614950	Jun-96	1797096
Jan-90	2526182	Mar-92	2470851	May-94	2735140	Jul-96	2827109
Feb-90	2561818	Apr-92	1965083	Jun-94	2746591	Aug-96	2827200
Mar-90	2614217	May-92	2833435	Jul-94	2839115	Sep-96	2736000
Apr-90	0	Jun-92	2739812	Aug-94	2839207	Oct-96	2831030

Table A-2 (Continued) Monthly Thermal Generation During the First Sixteen Fuel Cycles of the South Texas Unit 1 Reactor (Reactor Power of 3800 MWt from Startup Through the End of Cycle 10; mid-cycle uprate from 3800 MWt to 3853 MWt for Cycle 11; and, 3853 MWt for Cycles 12 through 16)

Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)
Nov-96	2734450	Jan-99	2826926	Mar-01	2826653	May-03	0
Dec-96	2827200	Feb-99	2553144	Apr-01	2731805	Jun-03	0
Jan-97	2591813	Mar-99	2144659	May-01	2826653	Jul-03	0
Feb-97	2553600	Apr-99	82354	Jun-01	2735179	Aug-03	1928348
Mar-97	2824646	May-99	2699976	Jul-01	2827018	Sep-03	2747324
Apr-97	2589442	Jun-99	2560622	Aug-01	2826926	Oct-03	2842596
May-97	2827109	Jul-99	2827109	Sep-01	2652278	Nov-03	2741827
Jun-97	2504990	Aug-99	2827109	Oct-01	735072	Dec-03	2839848
Jul-97	2826926	Sep-99	2512013	Nov-01	2736000	Jan-04	2527465
Aug-97	2826744	Oct-99	2830939	Dec-01	2827200	Feb-04	2656632
Sep-97	1081997	Nov-99	2735726	Jan-02	2827200	Mar-04	2839848
Oct-97	2170195	Dec-99	2826014	Feb-02	2548128	Apr-04	2743660
Nov-97	2324414	Jan-00	2825741	Mar-02	2827200	May-04	2839848
Dec-97	2826470	Feb-00	2538826	Apr-02	2731440	Jun-04	2748240
Jan-98	2826926	Mar-00	9	May-02	2808960	Jul-04	2839848
Feb-98	2553509	Apr-00	0	Jun-02	2735088	Aug-04	2839848
Mar-98	2827109	May-00	1379765	Jul-02	2827200	Sep-04	2747324
Apr-98	2732078	Jun-00	2732534	Aug-02	2827200	Oct-04	2843512
May-98	2827109	Jul-00	2826835	Sep-02	2736000	Nov-04	2747324
Jun-98	2690400	Aug-00	2827109	Oct-02	2830848	Dec-04	2739079
Jul-98	2827200	Sep-00	2735726	Nov-02	1989984	Jan-05	2839848
Aug-98	2787528	Oct-00	2830848	Dec-02	2827200	Feb-05	2413871
Sep-98	2554147	Nov-00	2735818	Jan-03	2827200	Mar-05	601865
Oct-98	2827474	Dec-00	2469514	Feb-03	2553600	Apr-05	1323736
Nov-98	2735818	Jan-01	2826562	Mar-03	1935264	May-05	2837191
Dec-98	2823643	Feb-01	2552779	Apr-03	0	Jun-05	2748240

Table A-2 (Continued) Monthly Thermal Generation During the First Sixteen Fuel Cycles of the South Texas Unit 1 Reactor (Reactor Power of 3800 MWt from Startup Through the End of Cycle 10; mid-cycle uprate from 3800 MWt to 3853 MWt for Cycle 11; and, 3853 MWt for Cycles 12 through 16)

Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)	Month-Year	Thermal Generation (MWt-hr)
Jul-05	2839482	Jan-07	2839848	Jul-08	2838016	Jan-10	2540021
Aug-05	2799632	Feb-07	2565024	Aug-08	2837466	Feb-10	2020698
Sep-05	2748057	Mar-07	2836000	Sep-08	2745675	Mar-10	2861639
Oct-05	2843512	Apr-07	2748148	Oct-08	2837649	Apr-10	2773050
Nov-05	2748148	May-07	2839665	Nov-08	2749889	May-10	2836671
Dec-05	2838932	Jun-07	2748057	Dec-08	2838016	Jun-10	2772865
Jan-06	2839482	Jul-07	2839482	Jan-09	2839573	Jul-10	2864690
Feb-06	2565024	Aug-07	2837191	Feb-09	2563925	Aug-10	2692970
Mar-06	2839848	Sep-07	2746957	Mar-09	2835268	Sep-10	2772311
Apr-06	2744026	Oct-07	2839848	Apr-09	2746408	Oct-10	2864783
May-06	2839848	Nov-07	2747232	May-09	2837924	Nov-10	2775640
Jun-06	2748240	Dec-07	2830229	Jun-09	2747690	Dec-10	2865060
Jul-06	2839848	Jan-08	2839482	Jul-09	2838840	Jan-11	2864320
Aug-06	2839848	Feb-08	2655349	Aug-09	2839024	Feb-11	2587089
Sep-06	2530030	Mar-08	2397198	Sep-09	2680542	Mar-11	2860621
Oct-06	0	Apr-08	299283	Oct-09	0	Apr-11	172645
Nov-06	2340584	May-08	2746866	Nov-09	1024682		
Dec-06	2839848	Jun-08	2747232	Dec-09	2866170		

Table A-3 Calculated Fast Neutron Flux (E > 1.0 MeV) and C_j Factors at the Surveillance Capsule Center, Core Midplane Elevation

Fuel Cycle	Cycle Length [EFPS]	φ(E > 1.0 MeV) [n/cm²-s]			
		Capsule U	Capsule Y	Capsule V	Capsule W
1	2.46E+07	1.06E+11	9.82E+10	9.82E+10	1.05E+11
2	1.23E+07		7.64E+10	7.64E+10	7.72E+10
3	1.07E+07		8.91E+10	8.91E+10	9.48E+10
4	4.26E+07		8.08E+10	8.08E+10	8.48E+10
5	3.06E+07		8.20E+10	8.20E+10	8.28E+10
6	3.38E+07		8.45E+10	8.45E+10	8.67E+10
7	3.88E+07			7.38E+10	7.89E+10
8	4.54E+07			6.74E+10	7.41E+10
9	2.59E+07			7.42E+10	8.27E+10
10	4.35E+07			6.71E+10	7.30E+10
11	4.26E+07			6.82E+10	7.07E+10
12	4.86E+07				6.98E+10
13	4.54E+07				6.39E+10
14	4.32E+07				7.12E+10
15	4.45E+07				6.80E+10
16	4.20E+07				6.80E+10
Time Weighted Average Flux		1.06E+11	8.48E+10	7.63E+10	7.60E+10

Table A-3 (continued) Calculated C_j Factors at the Surveillance Capsule Center, Core Midplane Elevation

Fuel Cycle	Cycle Length [EFPS]	C_j			
		Capsule U	Capsule Y	Capsule V	Capsule W
1	2.46E+07	1.00	1.16	1.29	1.38
2	1.23E+07		0.90	1.00	1.02
3	1.07E+07		1.05	1.17	1.25
4	4.26E+07		0.95	1.06	1.12
5	3.06E+07		0.97	1.07	1.09
6	3.38E+07		1.00	1.11	1.14
7	3.88E+07			0.97	1.04
8	4.54E+07			0.88	0.98
9	2.59E+07			0.97	1.09
10	4.35E+07			0.88	0.96
11	4.26E+07			0.89	0.93
12	4.86E+07				0.92
13	4.54E+07				0.84
14	4.32E+07				0.94
15	4.45E+07				0.89
16	4.20E+07				0.89
Average		1.00	1.00	1.00	1.00

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

Reaction	Location	Measured Activity[(a)] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate[(d)] (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	3.63E+04	4.20E+05	6.40E-17
	Middle	3.55E+04	4.10E+05	6.26E-17
	Bottom	3.64E+04	4.21E+05	6.42E-17
	Average			**6.36E-17**
^{54}Fe (n,p) ^{54}Mn	Top	9.06E+05	4.05E+06	6.42E-15
	Middle	8.69E+05	3.88E+06	6.16E-15
	Bottom	8.75E+05	3.91E+06	6.20E-15
	Average			**6.26E-15**
^{58}Ni (n,p) ^{58}Co	Top	2.61E+06	6.05E+07	8.67E-15
	Middle	2.55E+06	5.91E+07	8.47E-15
	Bottom	2.44E+06	5.66E+07	8.10E-15
	Average			**8.41E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	1.18E+05	6.74E+06	4.43E-14
	Including ^{235}U, ^{239}Pu, and γ fission corrections:			**3.74E-14**[(b)]
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	1.05E+06	6.00E+07	3.83E-13
	Including γ fission corrections:			**3.79E-13**[(c)]
^{59}Co (n,γ) ^{60}Co	Top	8.09E+06	9.35E+07	6.10E-12
		6.86E+06	7.93E+07	5.17E-12
	Middle	6.92E+06	8.00E+07	5.22E-12
		8.36E+06	9.66E+07	6.30E-12
	Bottom	7.54E+06	8.71E+07	5.69E-12
		8.61E+06	9.95E+07	6.49E-12
	Average			**5.83E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	4.20E+06	4.85E+07	3.17E-12
	Middle	4.33E+06	5.00E+07	3.27E-12
	Bottom	4.40E+06	5.09E+07	3.32E-12
	Average			**3.25E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of May 31, 1990.

(b) The average ^{238}U (n,f) reaction rate of 3.74E-14 includes a correction factor of 0.874 to account for plutonium build-in and an additional factor of 0.966 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 3.79E-13 includes a correction factor of 0.990 to account for photo-fission effects in the sensor.

(d) Reaction rates are referenced to the Cycle 1 rated reactor power of 3800 MWt.

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

Reaction	Location	Measured Activity[(a)] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate (rps/atom)[(d)]
^{63}Cu (n,α) ^{60}Co	Top	1.27E+05	3.30E+05	5.03E-17
	Middle	1.24E+05	3.22E+05	4.91E-17
	Bottom	1.19E+05	3.09E+05	4.71E-17
	Average			**4.88E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.65E+06	3.07E+06	4.87E-15
	Middle	1.59E+06	2.96E+06	4.69E-15
	Bottom	1.54E+06	2.86E+06	4.54E-15
	Average			**4.70E-15**
^{58}Ni (n,p) ^{58}Co	Top	7.99E+06	4.73E+07	6.77E-15
	Middle	7.64E+06	4.52E+07	6.47E-15
	Bottom	7.56E+06	4.47E+07	6.41E-15
	Average			**6.55E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	5.69E+05	5.56E+06	3.65E-14
	Including ^{235}U, ^{239}Pu, and γ fission corrections:			**2.94E-14[(b)]**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	4.50E+06	4.39E+07	2.80E-13
	Including γ fission corrections:			**2.78E-13[(c)]**
^{59}Co (n,γ) ^{60}Co	Top	2.31E+07	5.99E+07	3.91E-12
		2.08E+07	5.40E+07	3.52E-12
	Middle	2.41E+07	6.25E+07	4.08E-12
		2.46E+07	6.38E+07	4.17E-12
	Bottom	2.12E+07	5.50E+07	3.59E-12
	Average			**3.85E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	1.29E+07	3.35E+07	2.18E-12
	Middle	1.33E+07	3.45E+07	2.25E-12
	Bottom	1.35E+07	3.50E+07	2.29E-12
	Average			**2.24E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of November 11, 1996.

(b) The average ^{238}U (n,f) reaction rate of 2.94E-14 includes a correction factor of 0.833 to account for plutonium build-in and an additional factor of 0.968 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 2.78E-13 includes a correction factor of 0.990 to account for photo-fission effects in the sensor.

(d) Reaction rates are referenced to the Cycles 1-6 average rated reactor power of 3800 MWt.

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

Reaction	Location	Measured Activity[(a)] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate[(d)] (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	1.93E+05	2.92E+05	4.45E-17
	Middle	1.84E+05	2.78E+05	4.24E-17
	Bottom	1.77E+05	2.68E+05	4.08E-17
	Average			**4.26E-17**
^{54}Fe (n,p) ^{54}Mn	Top	2.16E+06	2.98E+06	4.72E-15
	Middle	2.07E+06	2.85E+06	4.53E-15
	Bottom	1.99E+06	2.74E+06	4.35E-15
	Average			**4.53E-15**
^{58}Ni (n,p) ^{58}Co	Top	2.15E+07	4.76E+07	6.82E-15
	Middle	2.08E+07	4.61E+07	6.60E-15
	Bottom	1.99E+07	4.41E+07	6.31E-15
	Average			**6.58E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	1.21E+06	5.54E+06	3.64E-14
	Including ^{235}U, ^{239}Pu, and γ fission corrections:			**2.77E-14[(b)]**
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	8.60E+06	3.94E+07	2.51E-13
	Including γ fission corrections:			**2.49E-13[(c)]**
^{59}Co (n,γ) ^{60}Co	Middle	3.08E+07	4.66E+07	3.04E-12
		3.59E+07	5.43E+07	3.54E-12
		3.14E+07	4.75E+07	3.10E-12
		3.72E+07	5.62E+07	3.67E-12
		3.08E+07	4.66E+07	3.04E-12
	Bottom	3.66E+07	5.53E+07	3.61E-12
	Average			**3.33E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Middle	1.96E+07	2.96E+07	1.93E-12
		2.00E+07	3.02E+07	1.97E-12
	Bottom	2.03E+07	3.07E+07	2.00E-12
	Average			**1.97E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of May 27, 2003.

(b) The average ^{238}U (n,f) reaction rate of 2.77E-14 includes a correction factor of 0.787 to account for plutonium build-in and an additional factor of 0.968 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 2.49E-13 includes a correction factor of 0.990 to account for photo-fission effects in the sensor.

(d) Reaction rates are referenced to the Cycles 1-11 average rated reactor power of 3804 MWt.

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

Reaction	Location	Measured Activity[(a)] (dps/g)	Saturated Activity (dps/g)	Adjusted Reaction Rate[(d)] (rps/atom)
^{63}Cu (n,α) ^{60}Co	Top	2.19E+05	3.07E+05	4.69E-17
	Middle	2.13E+05	2.99E+05	4.56E-17
	Bottom	2.00E+05	2.81E+05	4.28E-17
	Average			**4.51E-17**
^{54}Fe (n,p) ^{54}Mn	Top	1.58E+06	3.27E+06	5.19E-15
	Middle	1.52E+06	3.15E+06	5.00E-15
	Bottom	1.46E+06	3.02E+06	4.80E-15
	Average			**5.00E-15**
^{58}Ni (n,p) ^{58}Co	Top	3.93E+06	5.17E+07	7.40E-15
	Middle	3.88E+06	5.10E+07	7.30E-15
	Bottom	3.71E+06	4.88E+07	6.98E-15
	Average			**7.23E-15**
^{238}U (n,f) ^{137}Cs (Cd)	Middle	1.94E+06	5.99E+06	3.93E-14
	Including ^{235}U, ^{239}Pu, and γ fission corrections:			**2.78E-14**[(b)]
^{237}Np (n,f) ^{137}Cs (Cd)	Middle	1.28E+07	3.95E+07	2.52E-13
	Including γ fission corrections:			**2.50E-13**[(c)]
^{59}Co (n,γ) ^{60}Co	Top	3.99E+07	5.60E+07	3.65E-12
		3.40E+07	4.77E+07	3.11E-12
	Middle	4.08E+07	5.73E+07	3.74E-12
		3.26E+07	4.57E+07	2.98E-12
	Bottom	4.26E+07	5.98E+07	3.90E-12
		3.49E+07	4.90E+07	3.20E-12
	Average			**3.43E-12**
^{59}Co (n,γ) ^{60}Co (Cd)	Top	2.15E+07	3.02E+07	1.97E-12
	Middle	2.25E+07	3.16E+07	2.06E-12
	Bottom	2.18E+07	3.06E+07	2.00E-12
	Average			**2.01E-12**

Notes:

(a) Measured specific activities are indexed to a counting date of December 09, 2011.

(b) The average ^{238}U (n,f) reaction rate of 2.78E-14 includes a correction factor of 0.731 to account for plutonium build-in and an additional factor of 0.969 to account for photo-fission effects in the sensor.

(c) The average ^{237}Np (n,f) reaction rate of 2.50E-13 includes a correction factor of 0.990 to account for photo-fission effects in the sensor.

(d) Reaction rates are referenced to the Cycles 1-16 average rated reactor power of 3829 MWt.

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

Capsule U					
Reaction	Reaction Rate [rps/atom]			M/C	M/BE
	Measured	Calculated	Best-Estimate		
$^{63}Cu(n,\alpha)^{60}Co$	6.36E-17	5.54E-17	6.07E-17	1.15	1.04
$^{54}Fe(n,p)^{54}Mn$	6.26E-15	6.29E-15	6.42E-15	0.99	0.98
$^{58}Ni(n,p)^{58}Co$	8.41E-15	8.83E-15	8.87E-15	0.95	0.95
$^{238}U(n,f)^{137}Cs$ (Cd)	3.74E-14	3.39E-14	3.47E-14	1.10	1.08
$^{237}Np(n,f)^{137}Cs$ (Cd)	3.79E-13	3.26E-13	3.58E-13	1.16	1.06
$^{59}Co(n,\gamma)^{60}Co$	5.83E-12	4.82E-12	5.75E-12	1.21	1.01
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	3.25E-12	3.33E-12	3.29E-12	0.97	0.99

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

Capsule Y					
Reaction	Reaction Rate [rps/atom]			M/C	M/BE
	Measured	Calculated	Best-Estimate		
$^{63}Cu(n,\alpha)^{60}Co$	4.88E-17	4.68E-17	4.69E-17	1.04	1.04
$^{54}Fe(n,p)^{54}Mn$	4.70E-15	5.16E-15	4.89E-15	0.91	0.96
$^{58}Ni(n,p)^{58}Co$	6.55E-15	7.22E-15	6.81E-15	0.91	0.96
$^{238}U(n,f)^{137}Cs$ (Cd)	2.94E-14	2.74E-14	2.64E-14	1.07	1.11
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.78E-13	2.59E-13	2.66E-13	1.07	1.04
$^{59}Co(n,\gamma)^{60}Co$	3.85E-12	3.79E-12	3.82E-12	1.02	1.01
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	2.24E-12	2.64E-12	2.27E-12	0.85	0.99

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

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

Capsule V					
Reaction	Reaction Rate [rps/atom]			M/C	M/BE
	Measured	Calculated	Best-Estimate		
$^{63}Cu(n,\alpha)^{60}Co$	4.26E-17	4.31E-17	4.24E-17	0.99	1.00
$^{54}Fe(n,p)^{54}Mn$	4.53E-15	4.70E-15	4.66E-15	0.96	0.97
$^{58}Ni(n,p)^{58}Co$	6.57E-15	6.56E-15	6.58E-15	1.00	1.00
$^{238}U(n,f)^{137}Cs$ (Cd)	2.77E-14	2.47E-14	2.53E-14	1.12	1.10
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.49E-13	2.32E-13	2.45E-13	1.07	1.01
$^{59}Co(n,\gamma)^{60}Co$	3.33E-12	3.38E-12	3.30E-12	0.99	1.01
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	1.97E-12	2.35E-12	1.99E-12	0.84	0.99

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

Capsule W					
Reaction	Reaction Rate [rps/atom]			M/C	M/BE
	Measured	Calculated	Best-Estimate		
$^{63}Cu(n,\alpha)^{60}Co$	4.51E-17	4.32E-17	4.54E-17	1.04	0.99
$^{54}Fe(n,p)^{54}Mn$	4.99E-15	4.69E-15	5.05E-15	1.06	0.99
$^{58}Ni(n,p)^{58}Co$	7.23E-15	6.55E-15	7.12E-15	1.10	1.01
$^{238}U(n,f)^{137}Cs$ (Cd)	2.78E-14	2.45E-14	2.68E-14	1.13	1.04
$^{237}Np(n,f)^{137}Cs$ (Cd)	2.50E-13	2.31E-13	2.51E-13	1.08	1.00
$^{59}Co(n,\gamma)^{60}Co$	3.43E-12	3.24E-12	3.40E-12	1.06	1.01
$^{59}Co(n,\gamma)^{60}Co$ (Cd)	2.01E-12	2.23E-12	2.03E-12	0.90	0.99

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

Table A-6 Comparison of Calculated and Best-Estimate Exposure Rates at the Surveillance Capsule Center

Capsule ID	φ(E > 1.0 MeV) [n/cm^2-s]			
	Calculated	Best-Estimate	Uncertainty (1σ)	BE/C
U	1.066E+11	1.094E+11	6%	1.03
Y	8.518E+10	8.280E+10	6%	0.97
V	7.664E+10	7.940E+10	6%	1.04
W	7.624E+10	8.366E+10	6%	1.10

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

Capsule ID	Iron Atom Displacement Rate [dpa/s]			
	Calculated	Best-Estimate	Uncertainty (1σ)	BE/C
U	2.038E-10	2.141E-10	8%	1.05
Y	1.620E-10	1.611E-10	8%	0.99
V	1.453E-10	1.510E-10	7%	1.04
W	1.439E-10	1.563E-10	7%	1.09

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

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

Reaction	M/C Ratio			
	Capsule U	Capsule Y	Capsule V	Capsule W
$^{63}Cu(n,\alpha)^{60}Co$	1.15	1.04	0.99	1.04
$^{54}Fe(n,p)^{54}Mn$	0.99	0.91	0.96	1.06
$^{58}Ni(n,p)^{58}Co$	0.95	0.91	1.00	1.10
$^{238}U(n,f)^{137}Cs$ (Cd)	1.10	1.07	1.12	1.13
$^{237}Np(n,f)^{137}Cs$ (Cd)	1.16	1.07	1.07	1.08
Average	1.07	1.00	1.03	1.08
% Standard Deviation	8.9	8.3	6.4	3.2

Note:
The overall average M/C ratio for the set of 20 sensor measurements is 1.05 with an associated standard deviation of 7.2%.

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

Capsule ID	BE/C Ratio	
	$\phi(E > 1.0$ MeV)	dpa/s
U	1.02	1.05
Y	0.97	0.99
V	1.03	1.03
W	1.09	1.08
Average	1.03	1.04
% Standard Deviation	4.8	3.6

A.2 REFERENCES

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

A-2 WCAP-12629, Revision 0, *Analysis of Capsule U from the Houston Lighting and Power Company South Texas Unit 1 Reactor Vessel Radiation Surveillance Program*, August 1990.

A-3 WCAP-14847, Revision 0, *Analysis of Capsule Y from the Houston Lighting and Power Company South Texas Unit 1 Reactor Vessel Radiation Surveillance Program*, April 1997.

A-4 WCAP-16149-NP, Revision 2, *Analysis of Capsule V from the South Texas Project Nuclear Operating Company, South Texas Unit 1 Reactor Vessel Radiation Surveillance Program*, July 2007.

A-5 WCAP-17339-NP, Revision 0, *Ex-Vessel Neutron Dosimetry Program for South Texas Unit 1 Cycle 15*, J. Chen, April 2011.

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

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

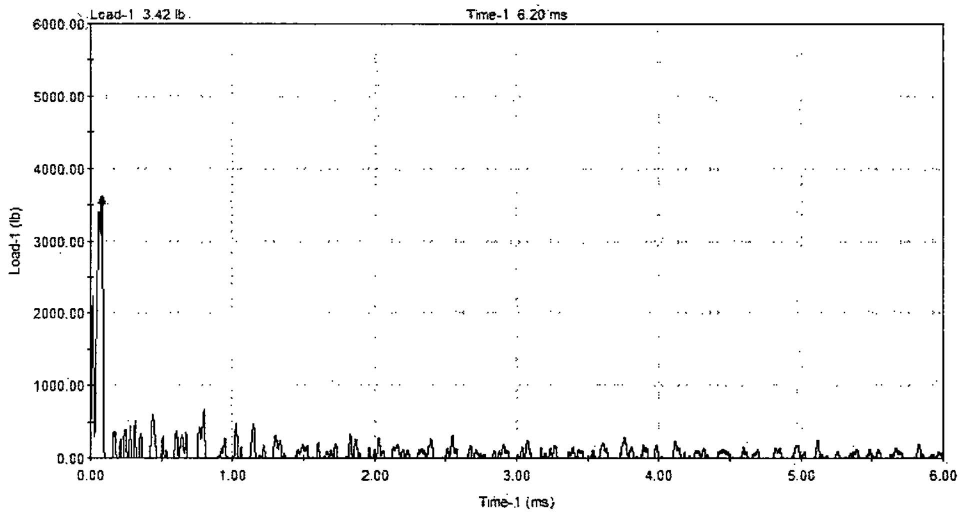
A-8 ASTM Standard E 1018-01, *Standard Guide for Application of ASTM Evaluated Cross Section Data File, Matrix E 706 (IIB)*, 2001.

A-9 ASTM Standard E 944-02, *Standard Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance, E 706 (IIA)*, 2002.

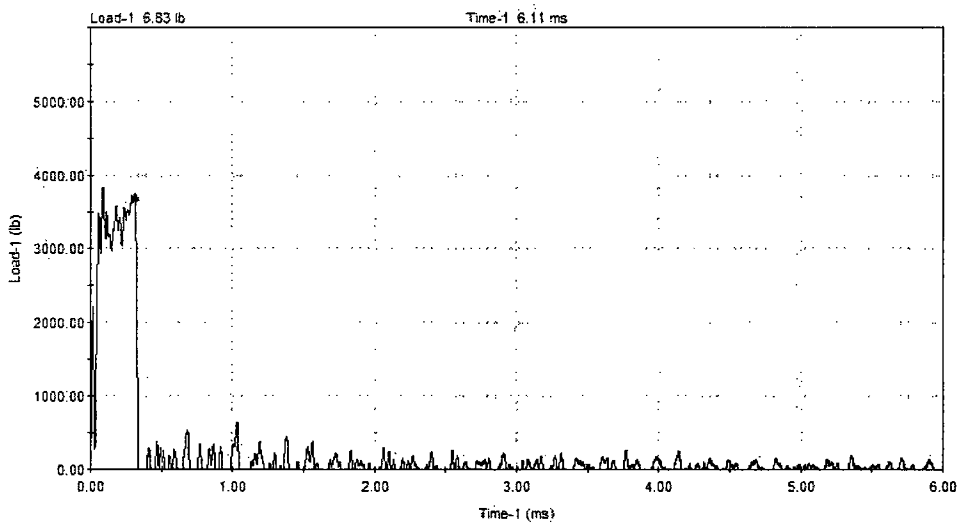
APPENDIX B
LOAD-TIME RECORDS FOR CHARPY SPECIMEN TESTS

- Specimen prefix "GL" denotes Intermediate Shell Plate R1606-2, Longitudinal Orientation
- Specimen prefix "GT" denotes Intermediate Shell Plate R1606-2, Transverse Orientation
- Specimen prefix "GW" denotes Surveillance Program Weld Metal (Heat # 89476)
- Specimen prefix "GH" denotes Heat-Affected Zone Material

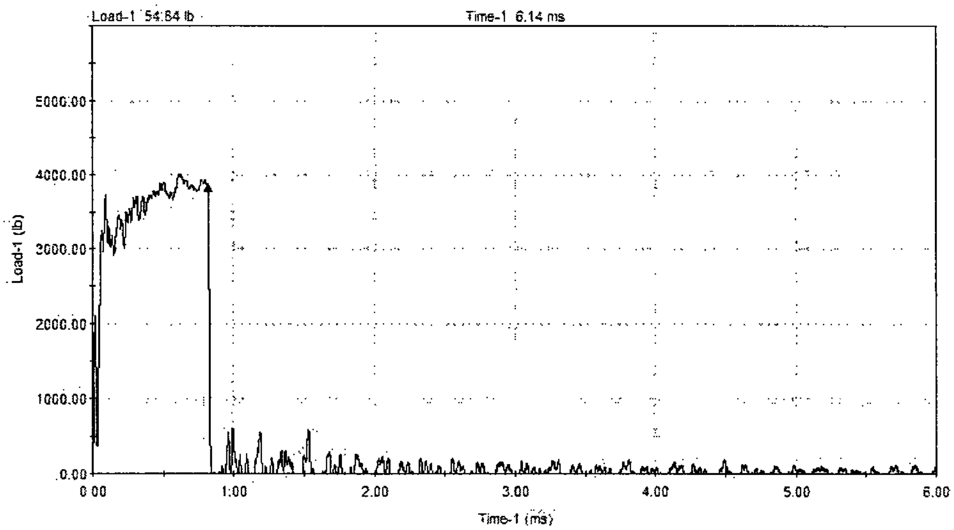
Note that the instrumented Charpy data is for information only. The instrumented tup was not calibrated per ASTM E2298-09.



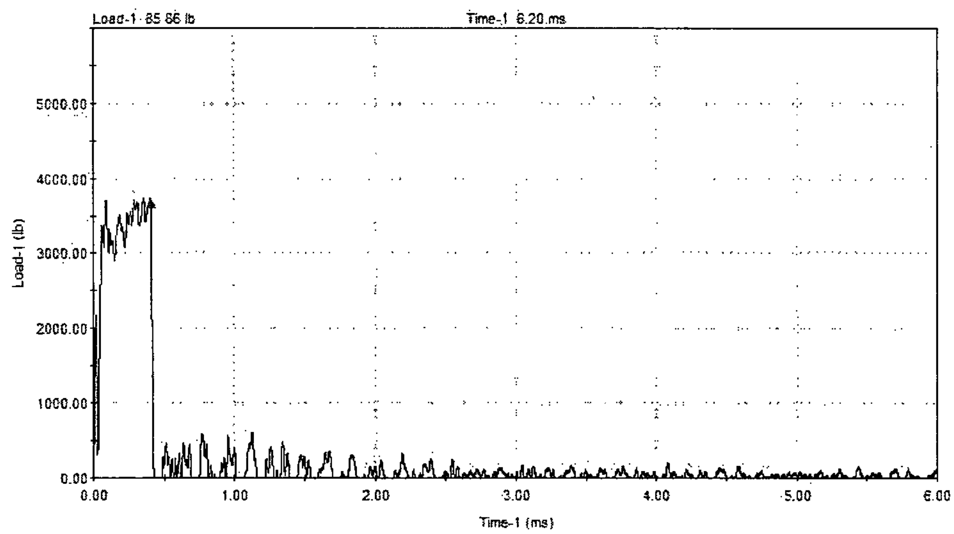
GL31, -50°F



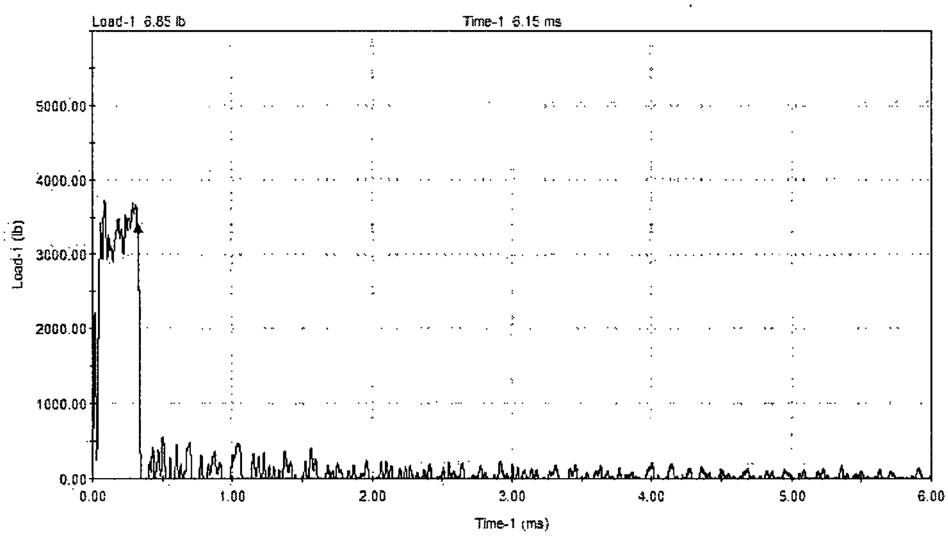
GL44, 0°F



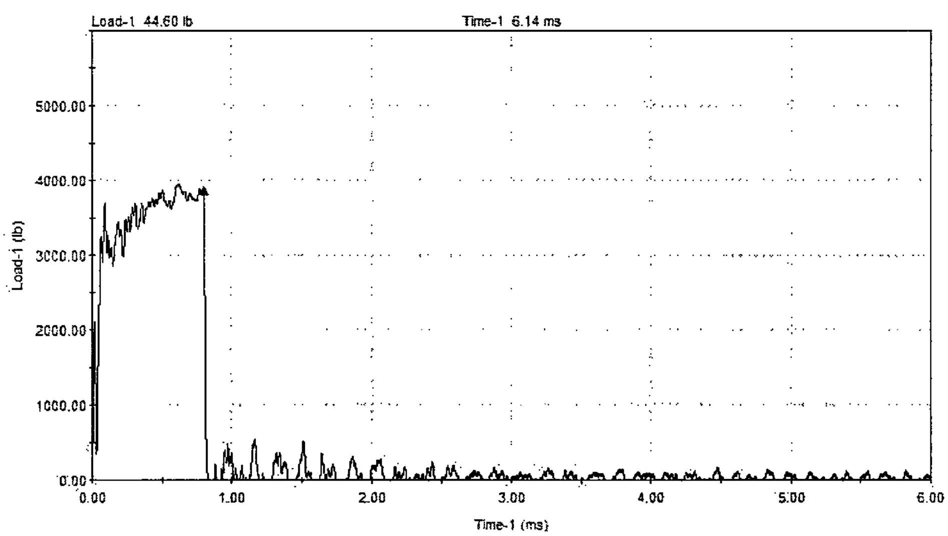
GL33, 10°F



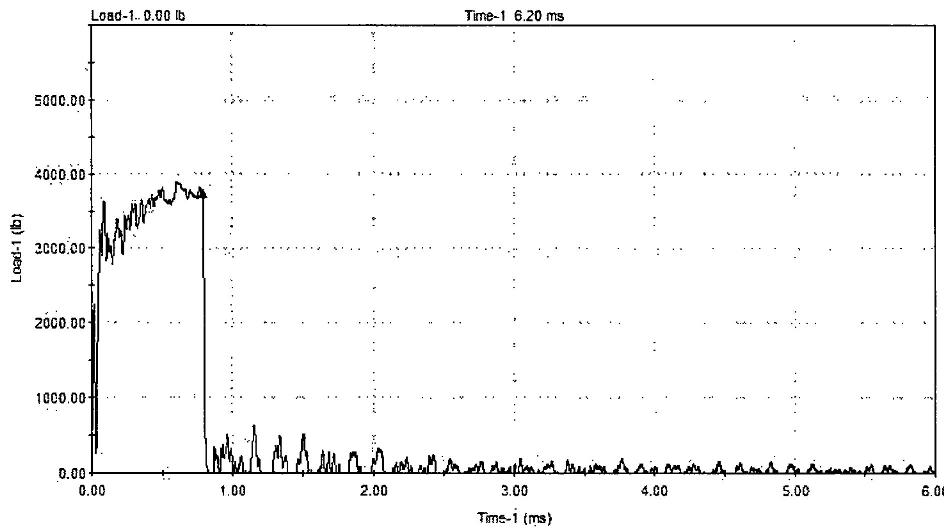
GL43, 15°F



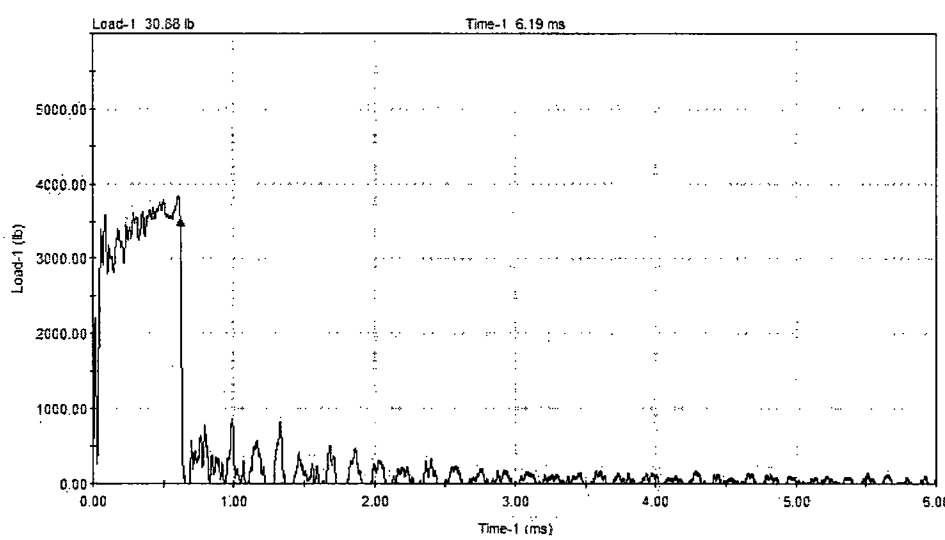
GL37, 20°F



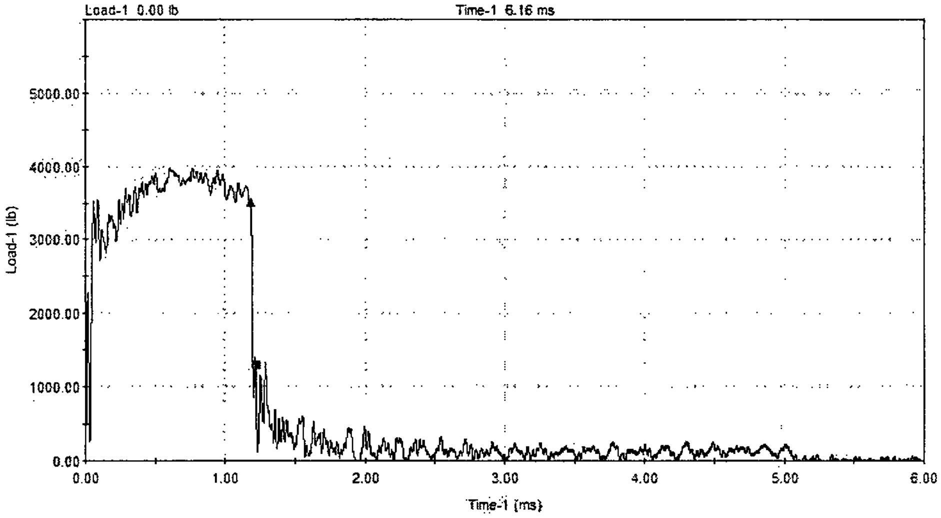
GL41, 30°F



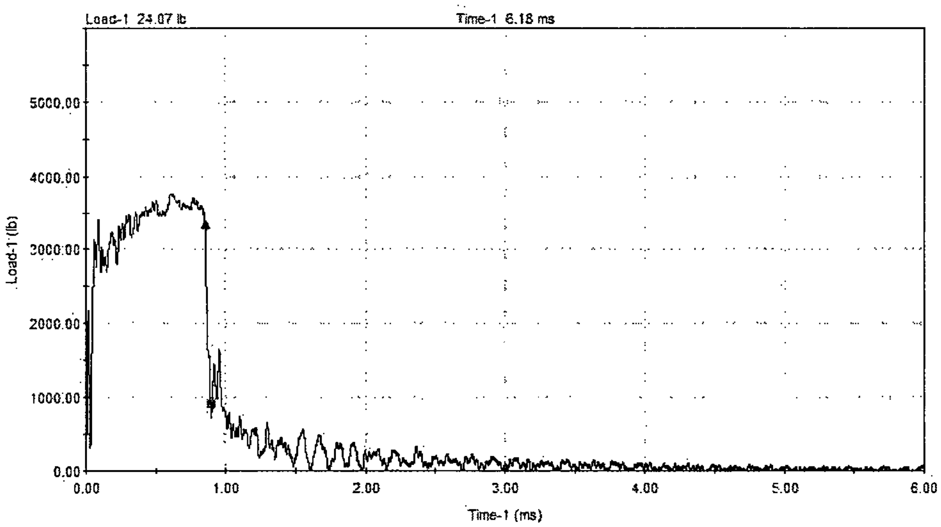
GL39, 40°F



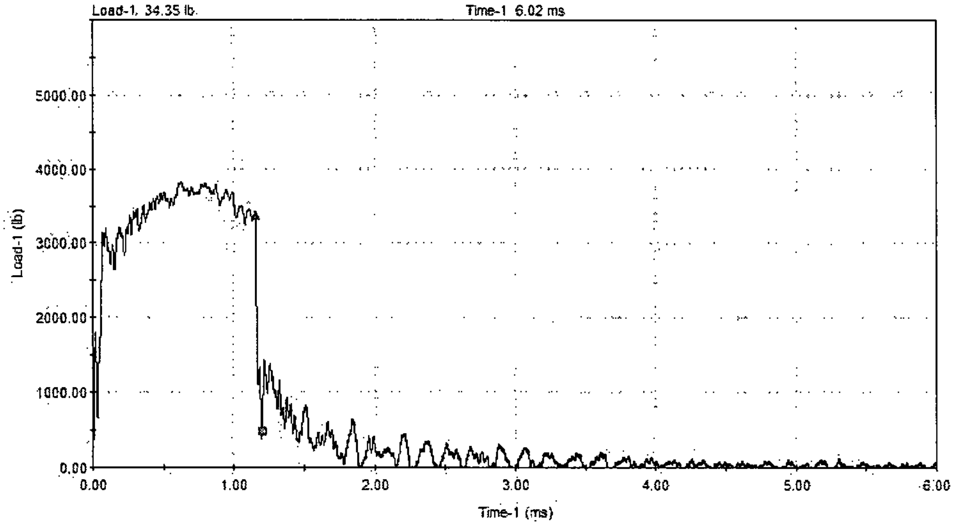
GL40, 50°F



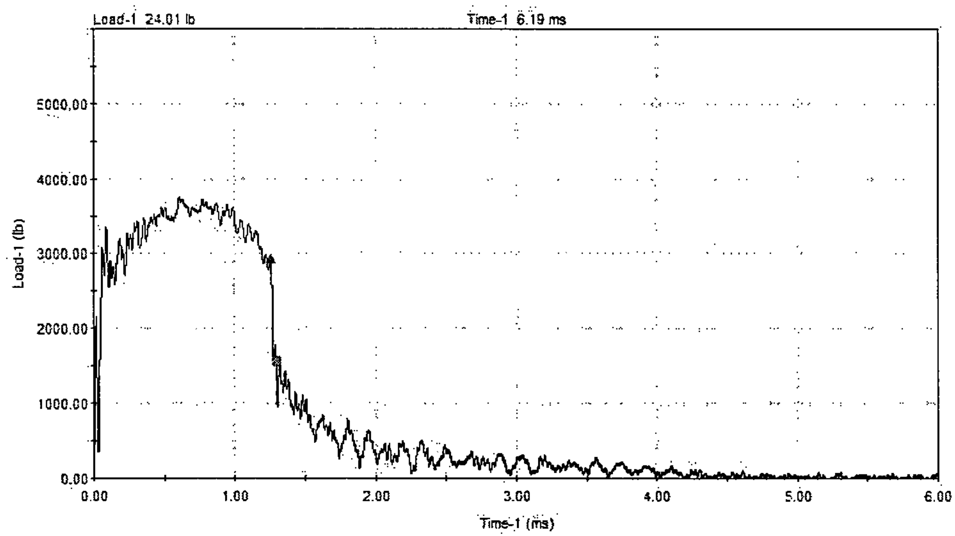
GL34, 72°F



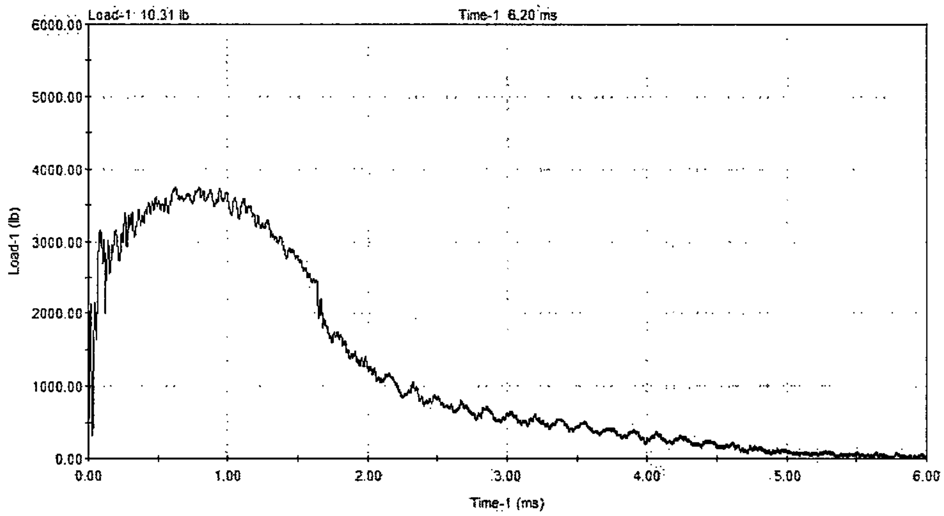
GL45, 100°F



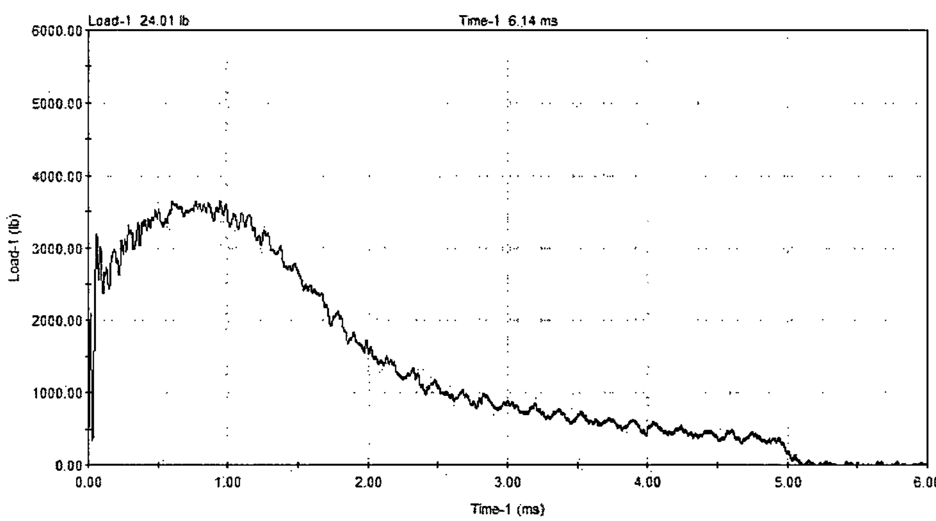
GL38, 110°F



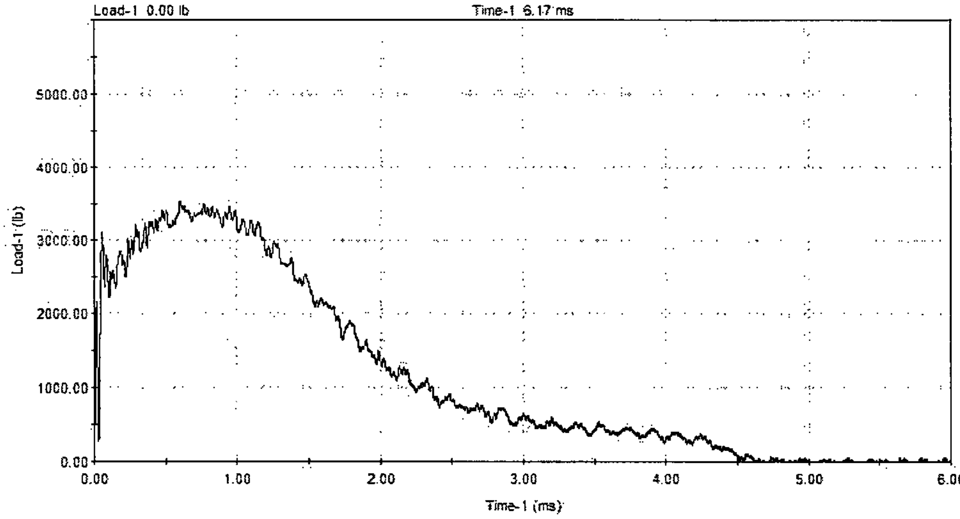
GL42, 130°F



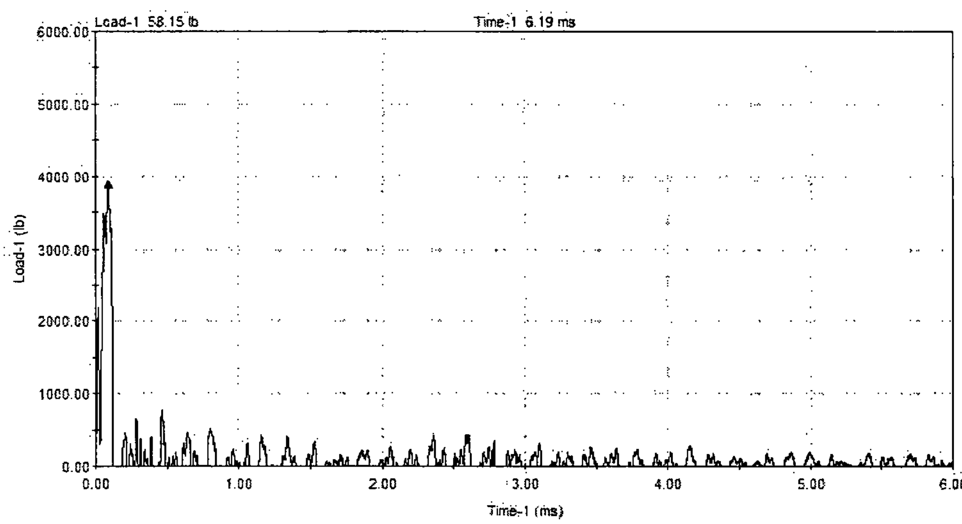
GL32, 150°F



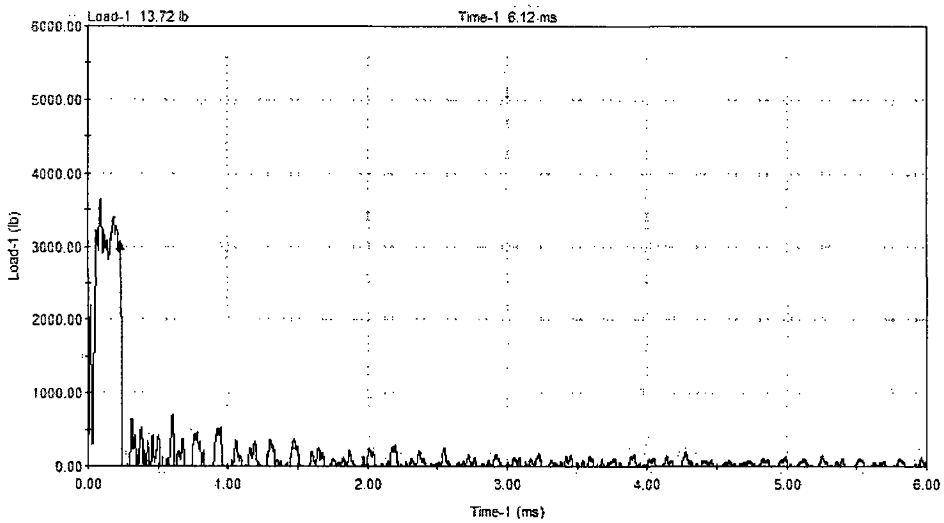
GL35, 200°F



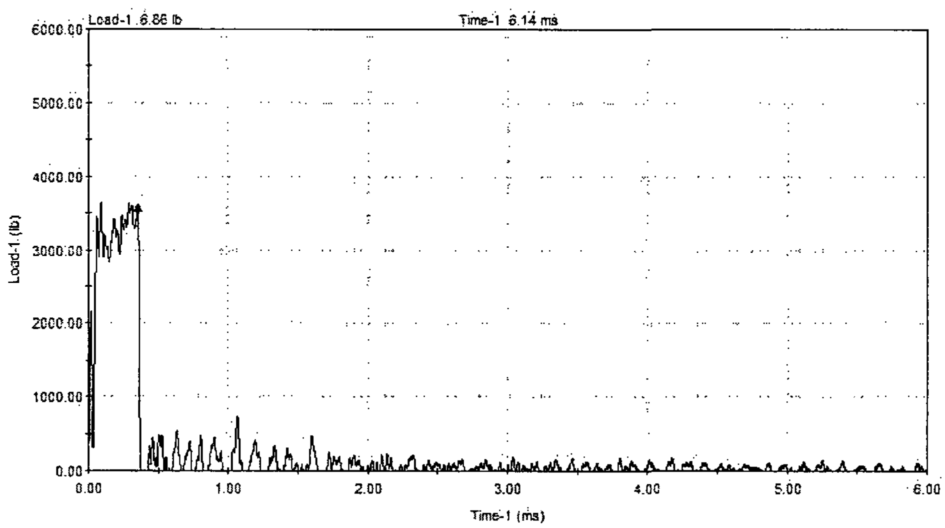
GL36, 250°F



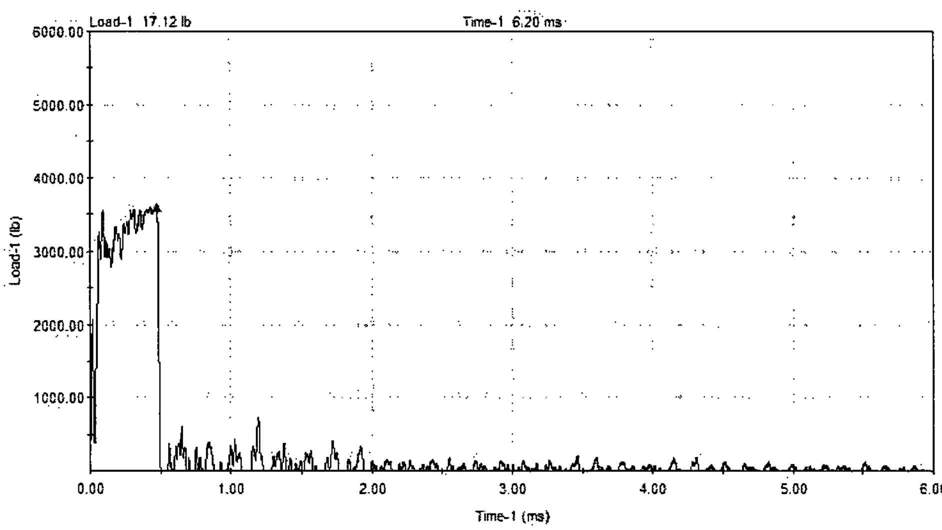
GT43, -50°F



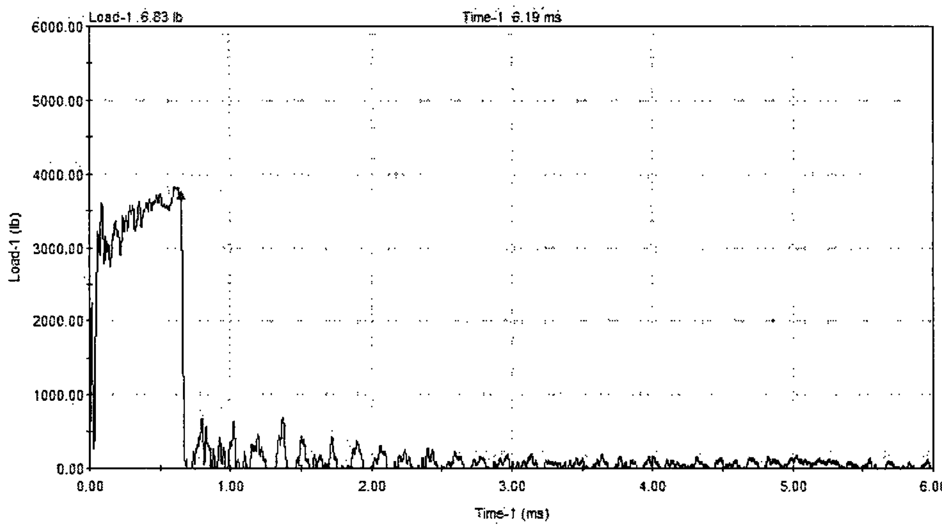
GT32, 0°F



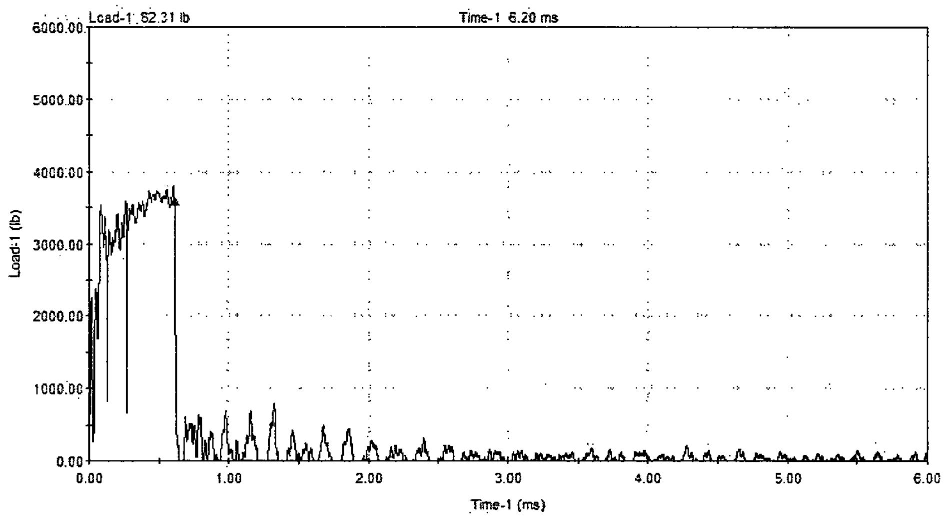
GT37, 10°F



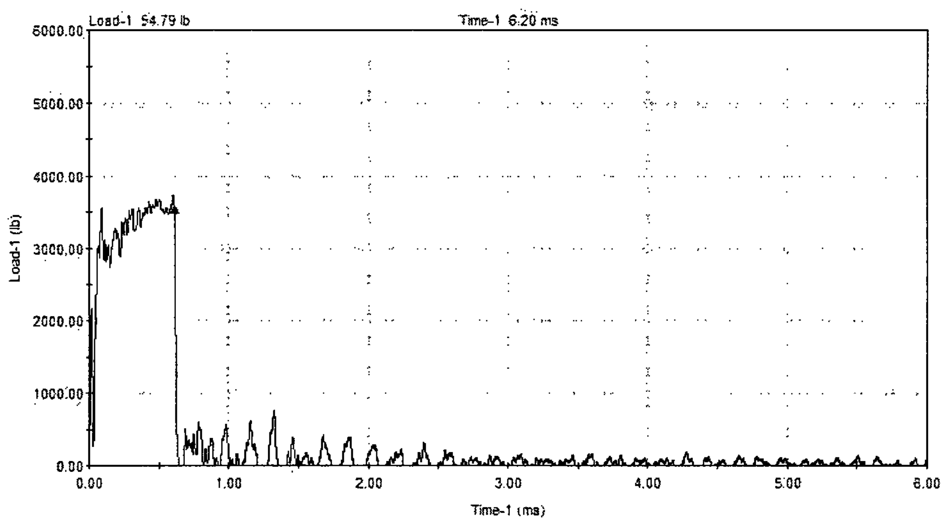
GT42, 20°F



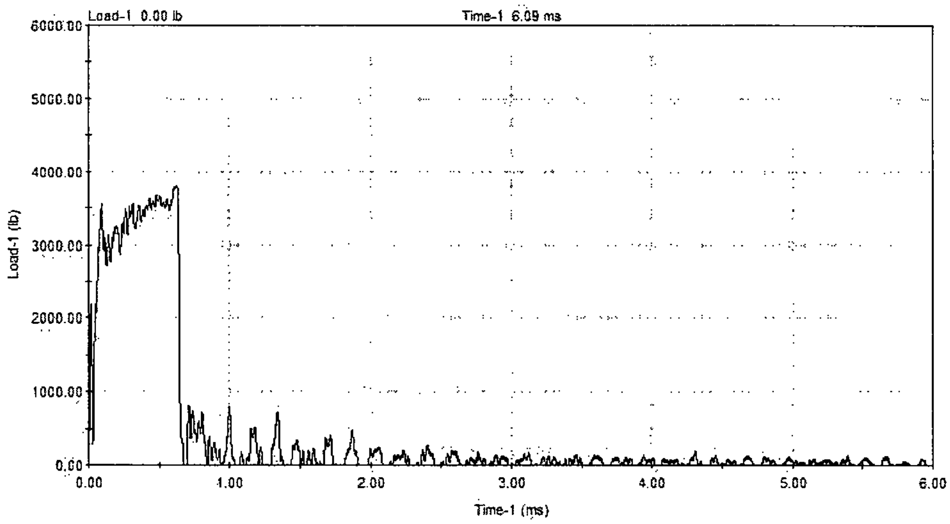
GT44, 25°F



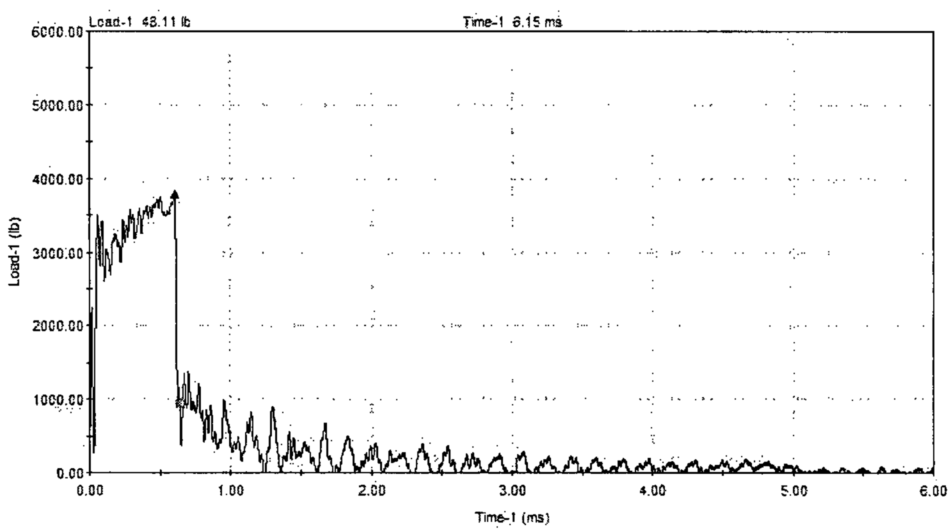
GT45, 30°F



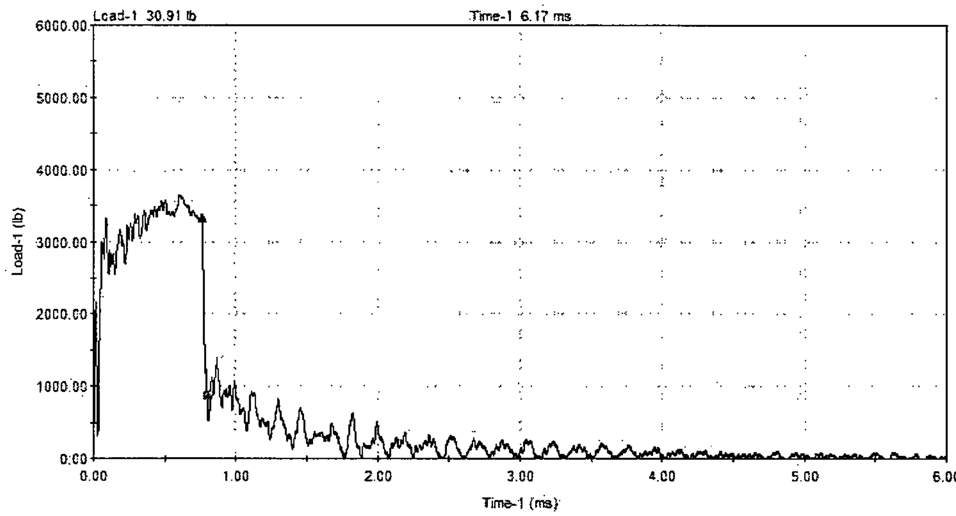
GT39, 40°F



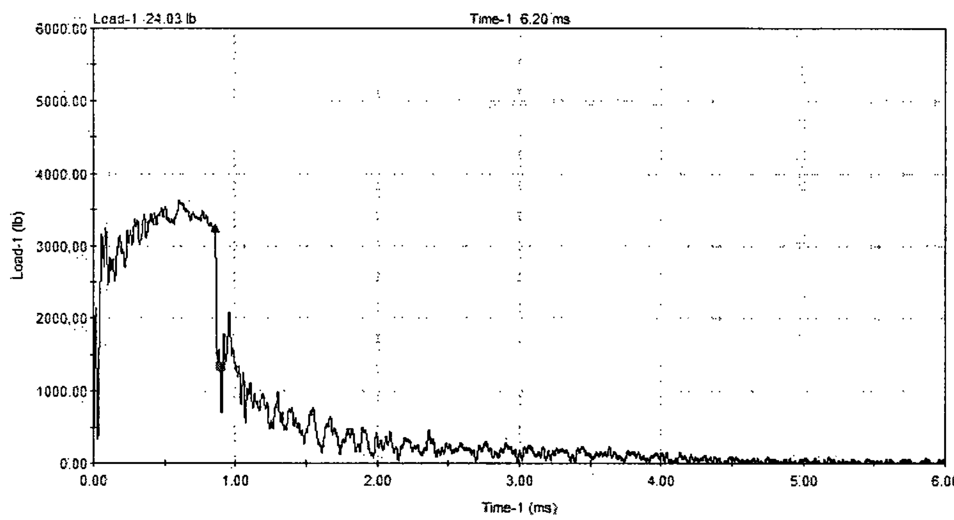
GT40, 50°F



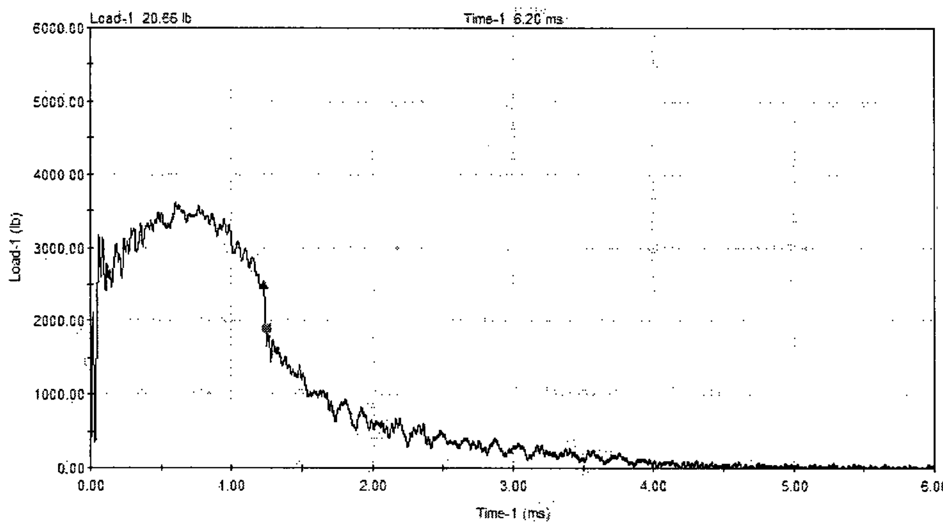
GT38, 72°F



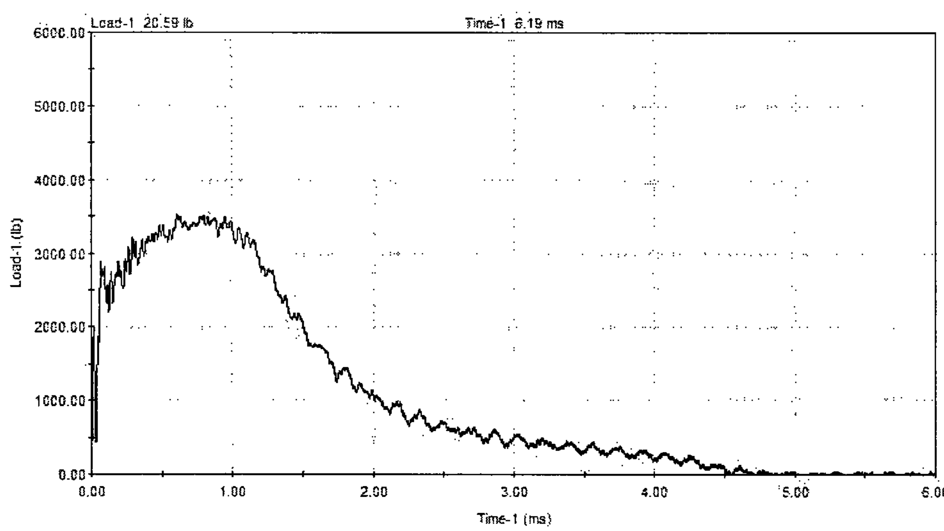
GT36, 100°F



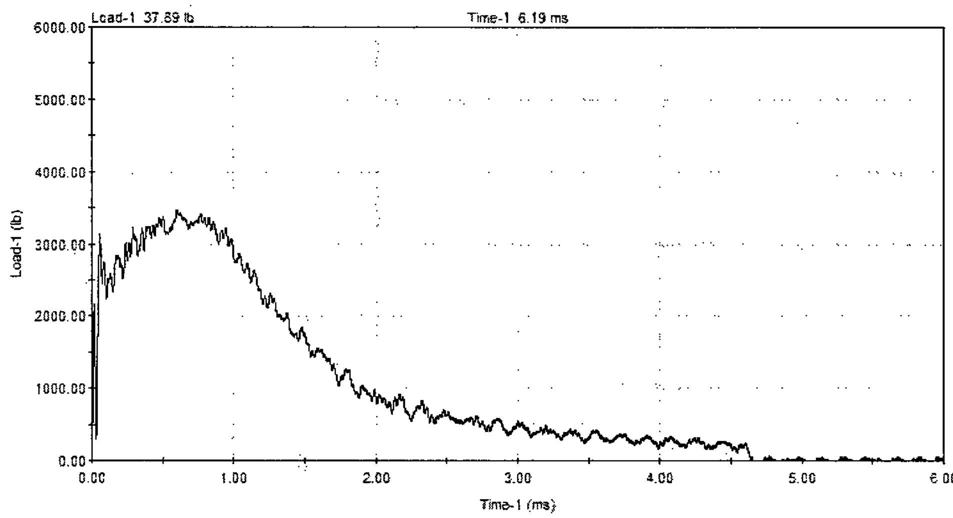
GT41, 130°F



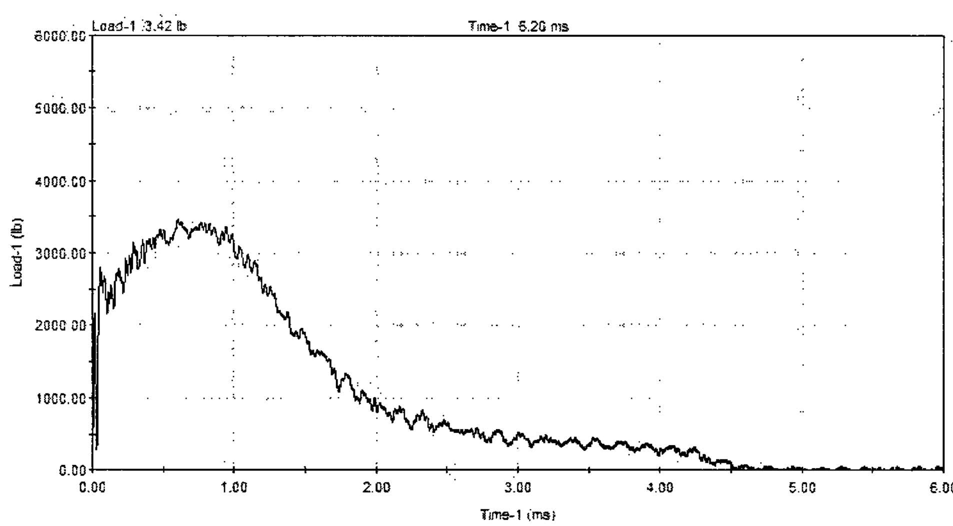
GT34, 150°F



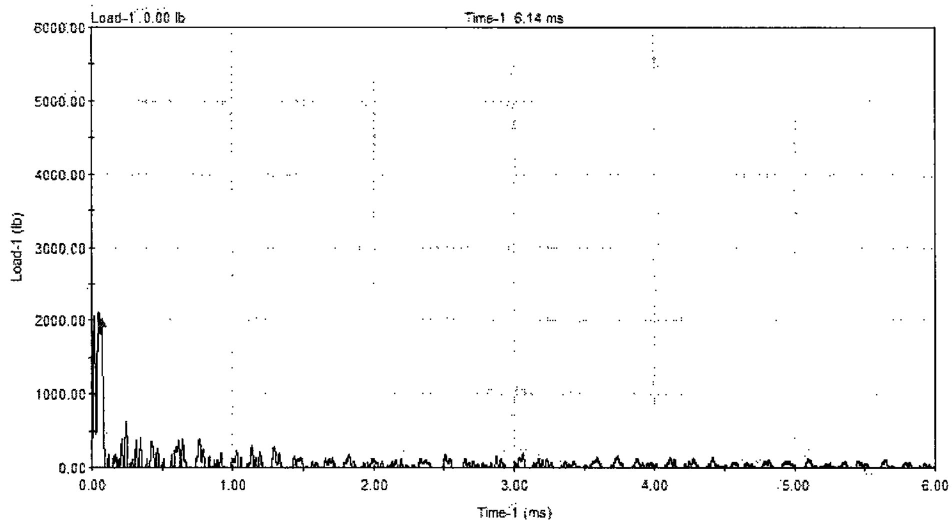
GT35, 200°F



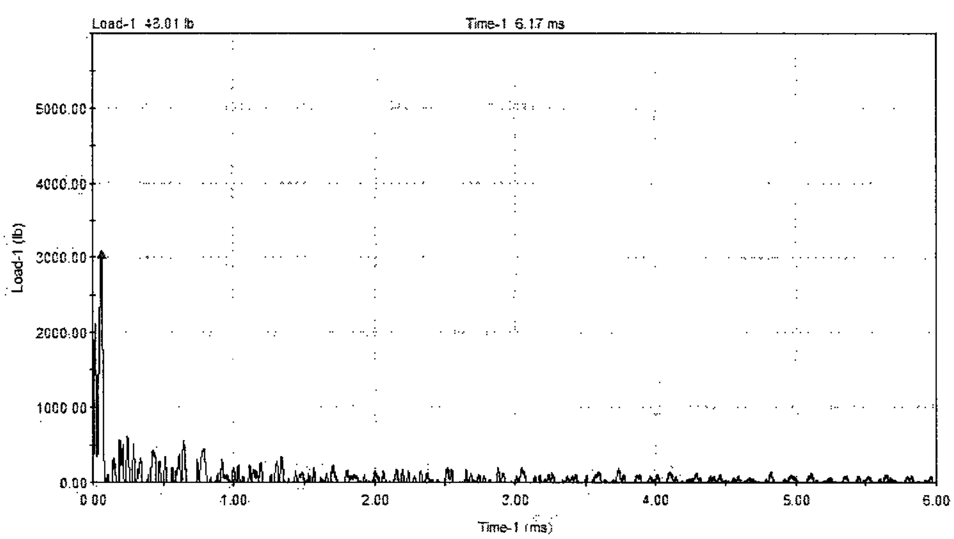
GT31, 225°F



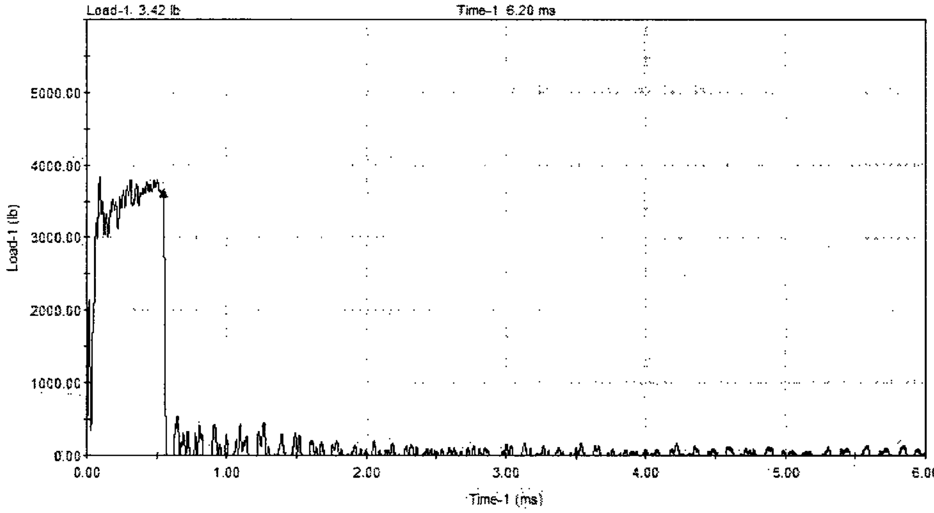
GT33, 250°F



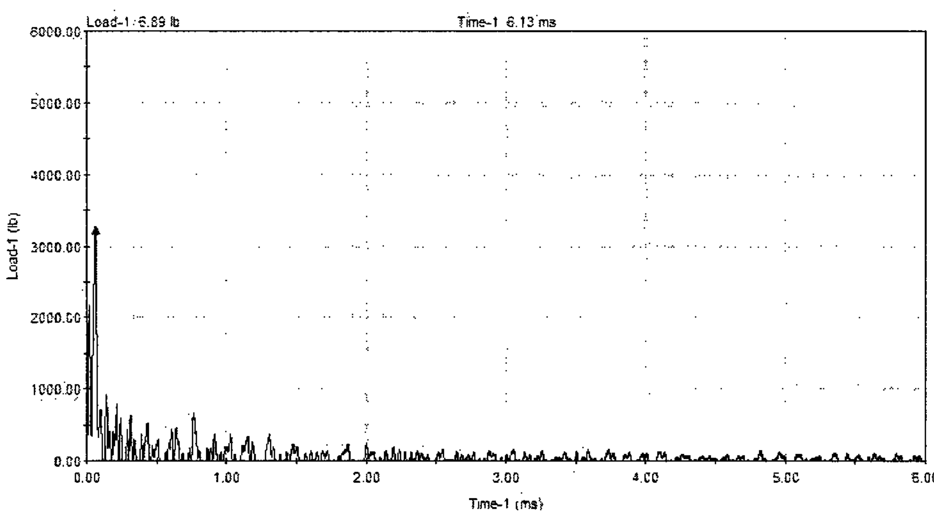
GW34, -90°F



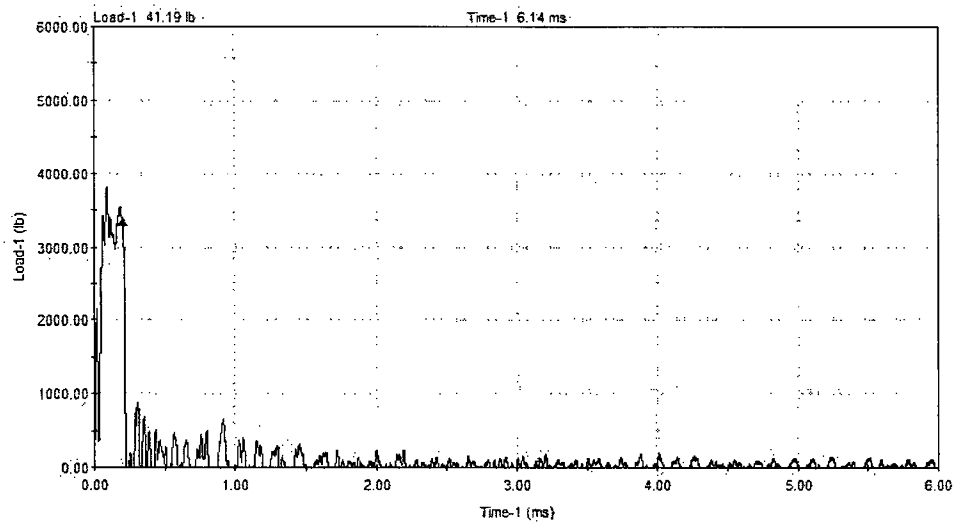
GW36, -70°F



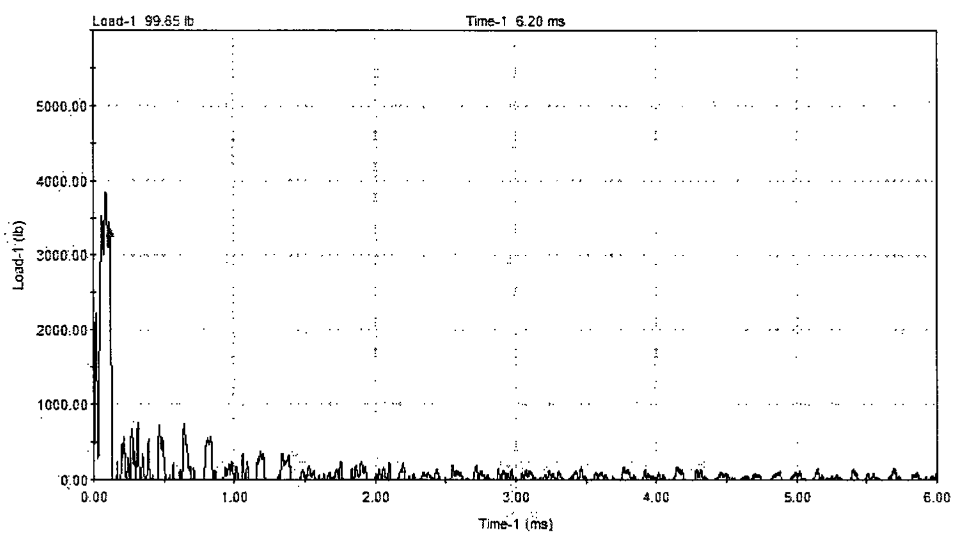
GW43, -50°F



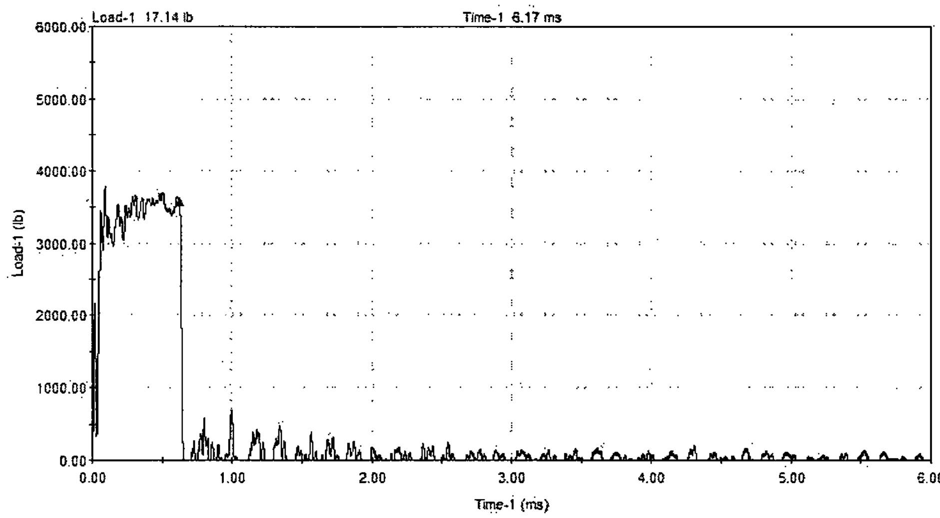
GW41, -45°F



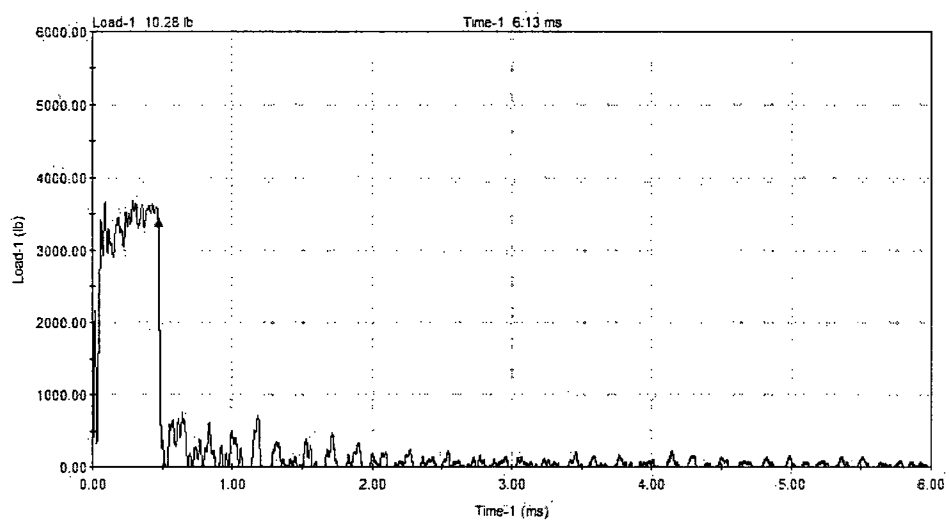
GW40, -40°F



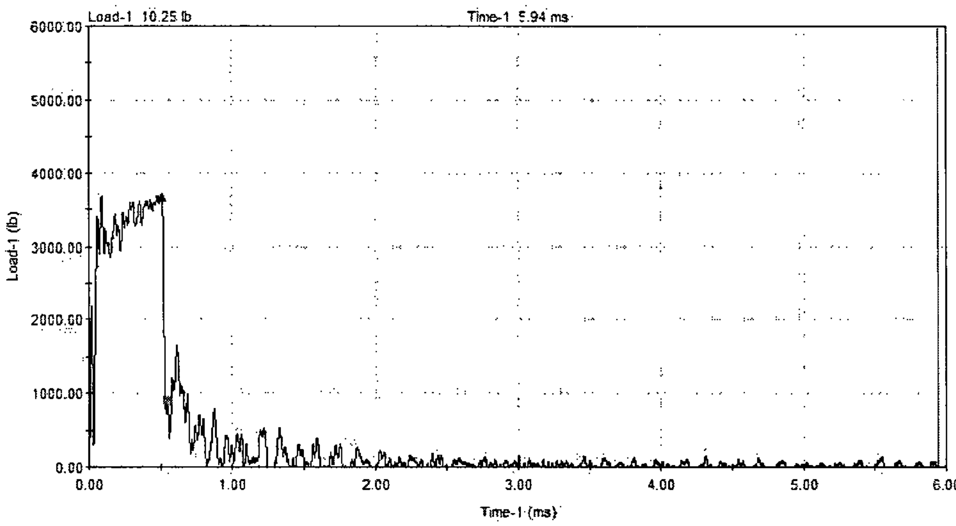
GW38, -35°F



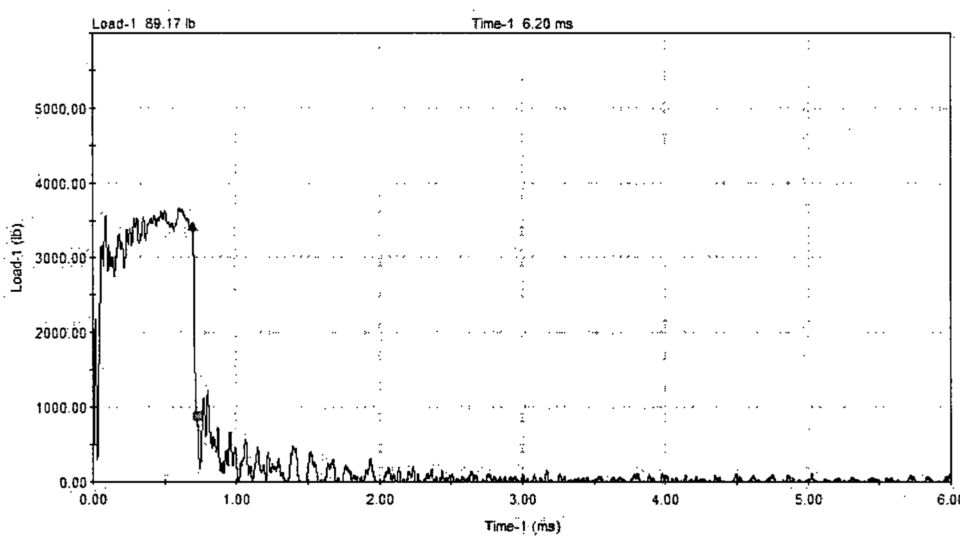
GW44, -30°F



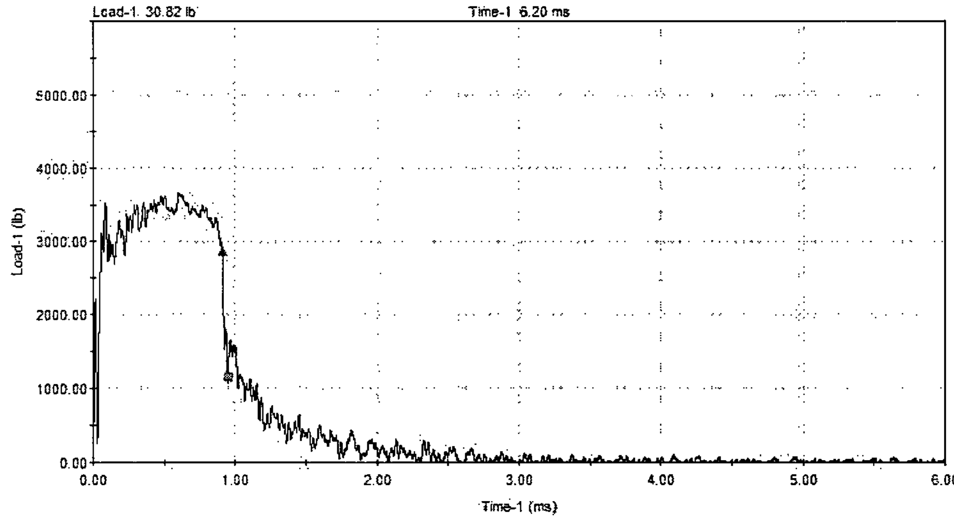
GW45, -15°F



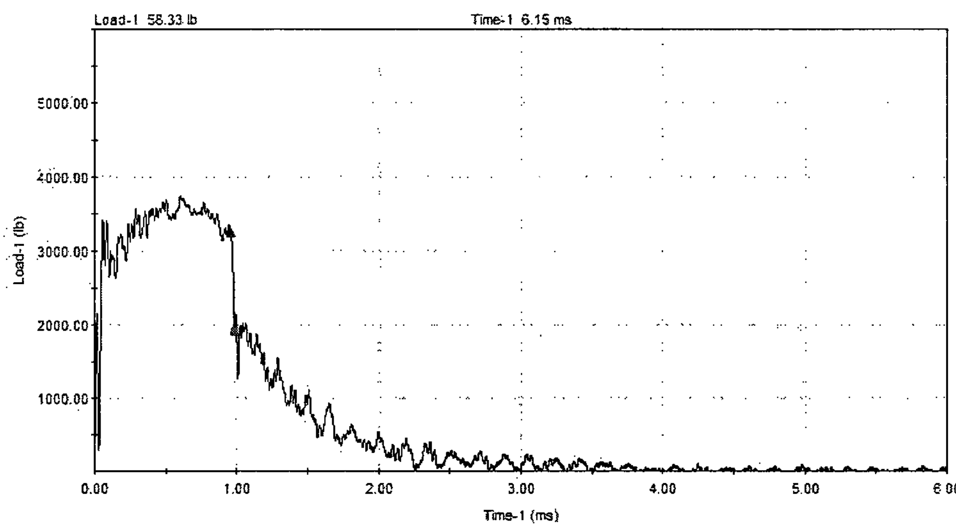
GW35, 0°F



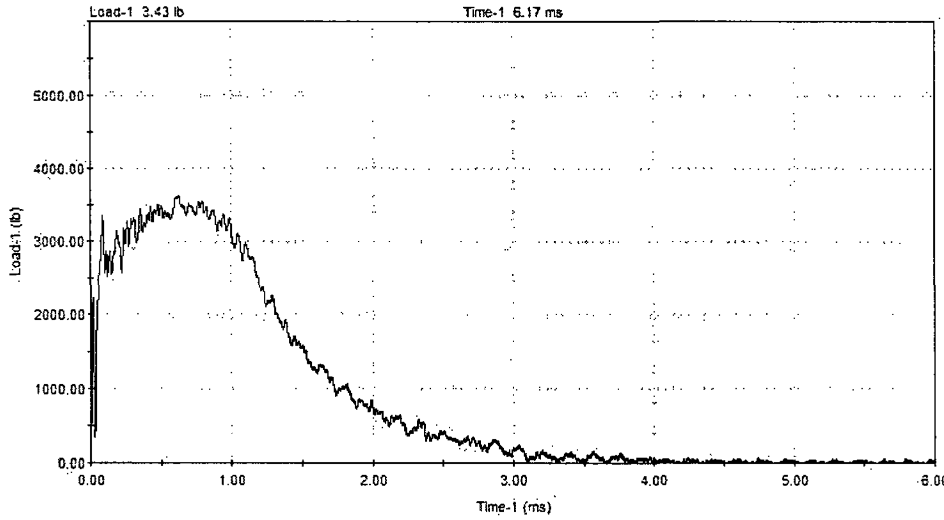
GW31, 30°F



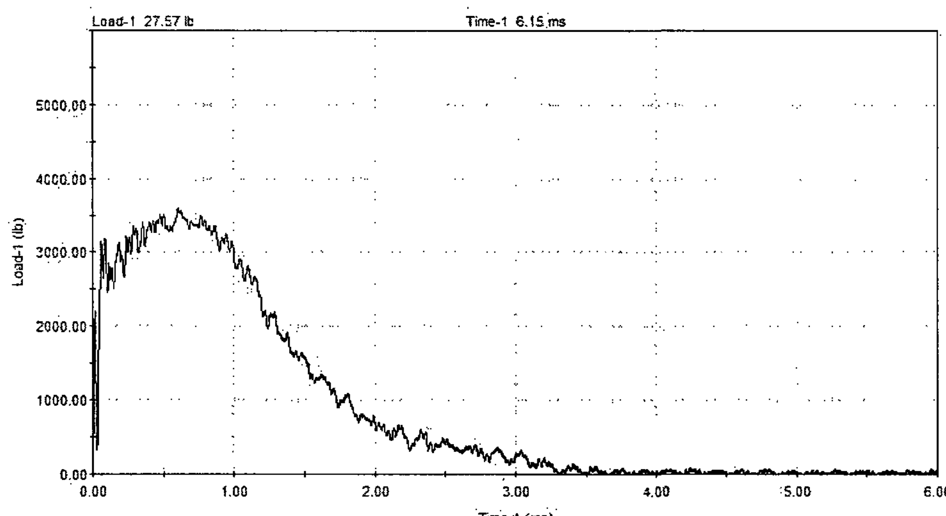
GW33, 40°F



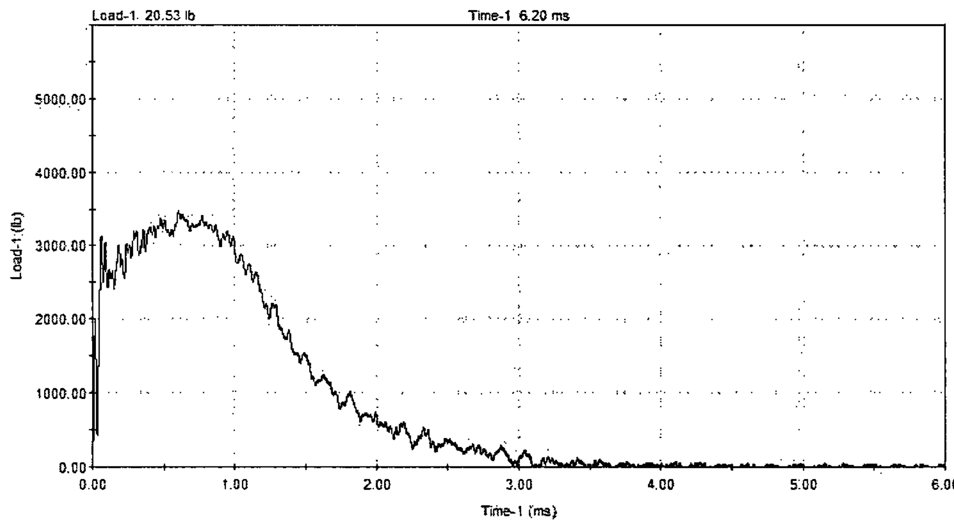
GW37, 72°F



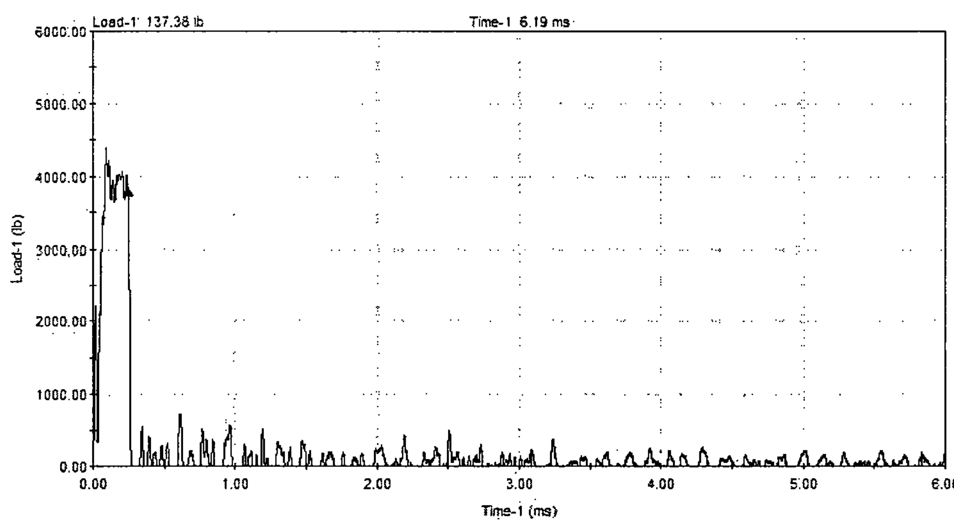
GW42, 130°F



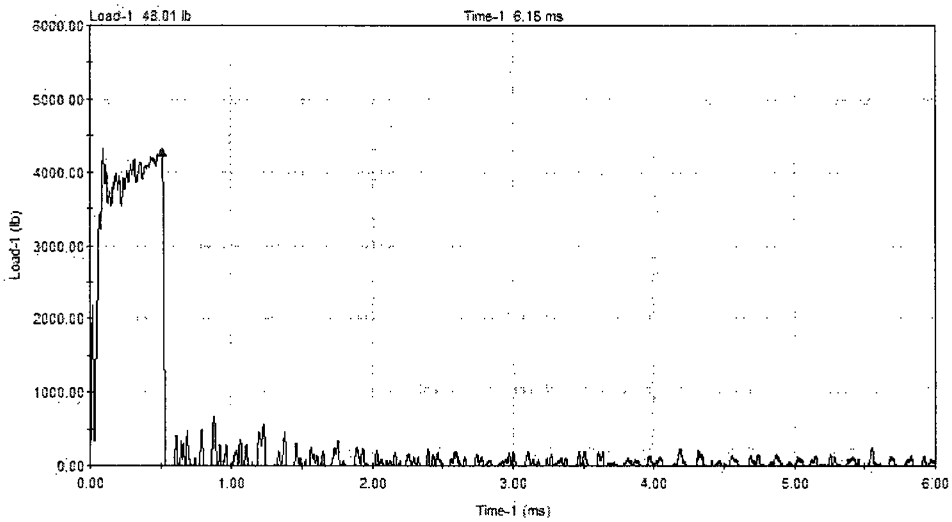
GW39, 150°F



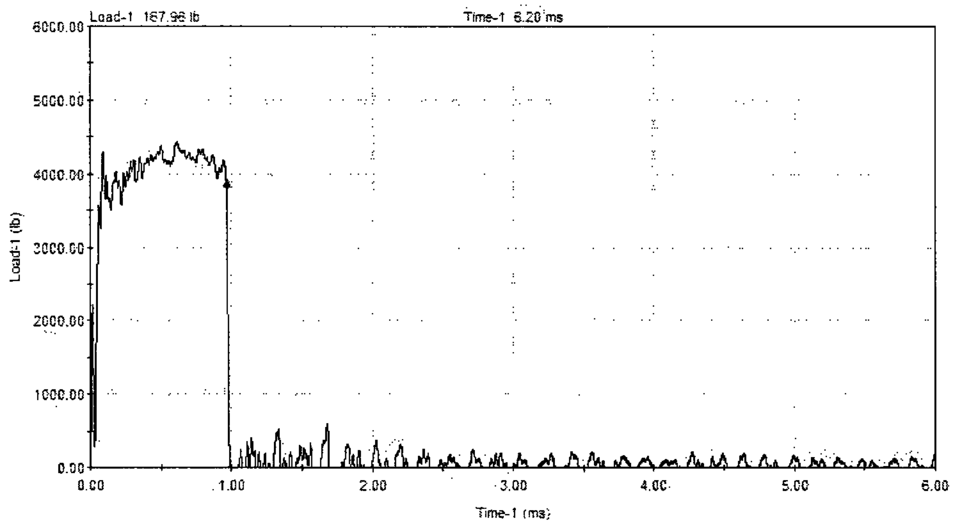
GW32, 200°F



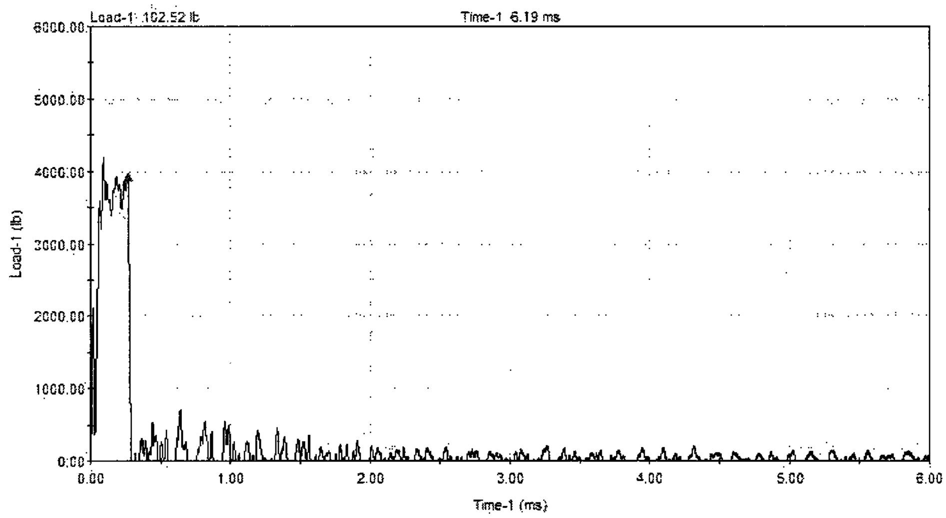
GH37, -90°F



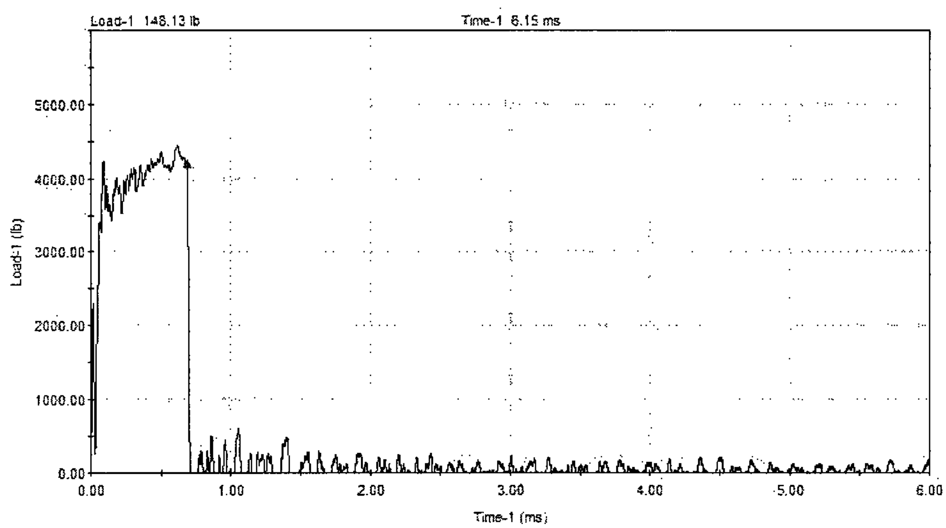
GH44, -70°F



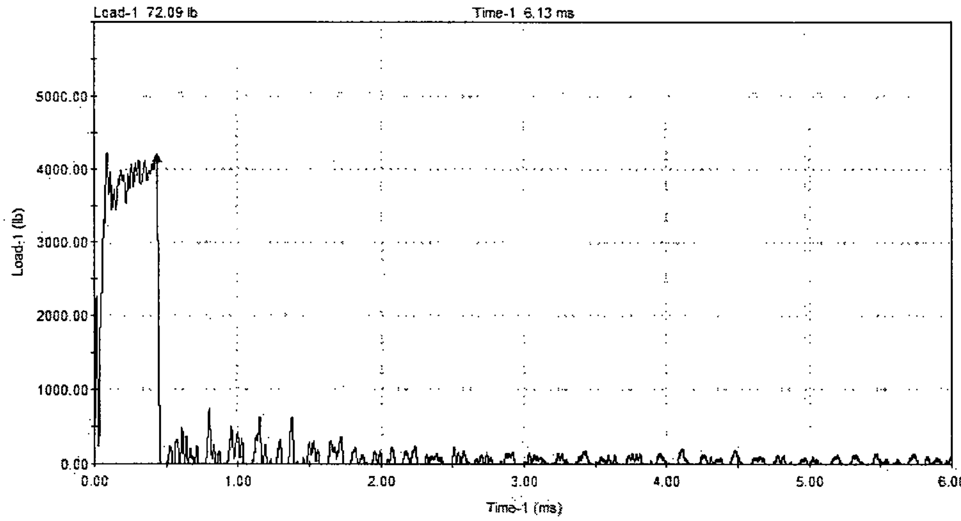
GH39, -60°F



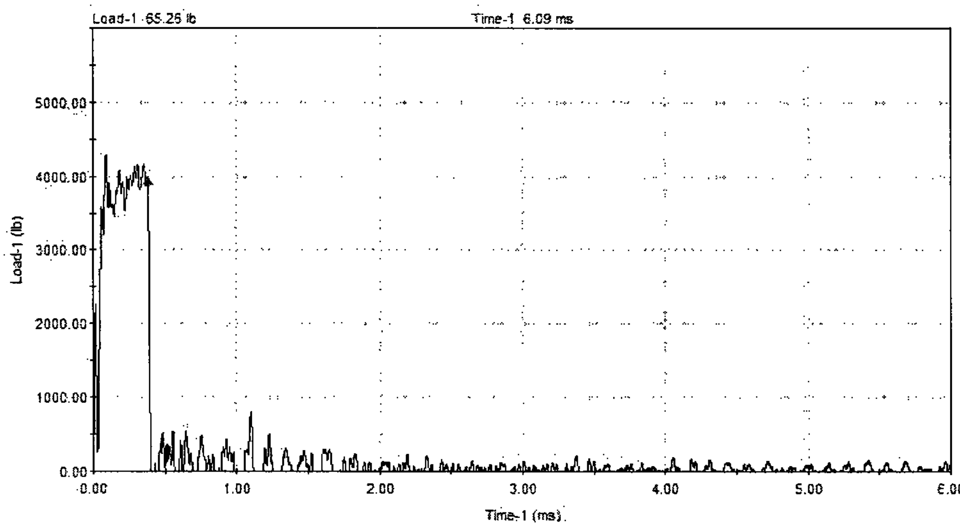
GH33, -50°F



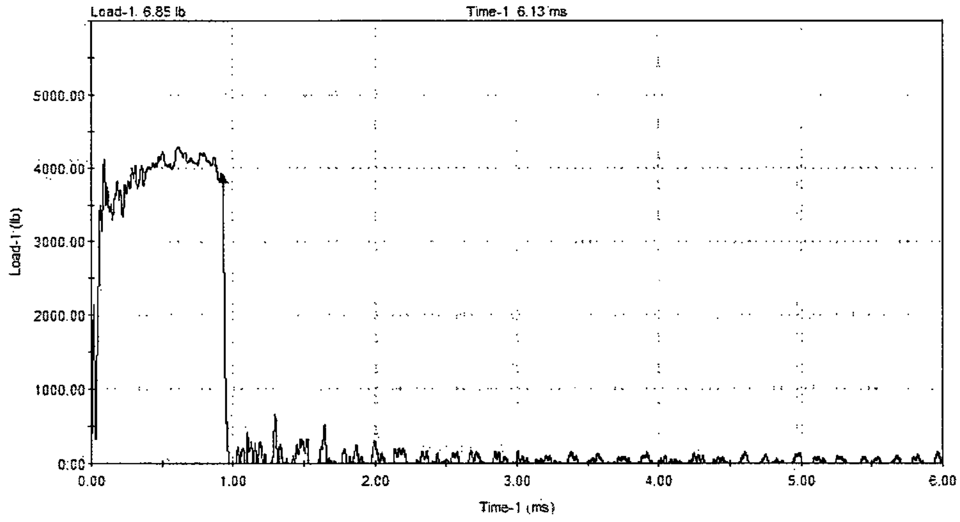
GH31, -45°F



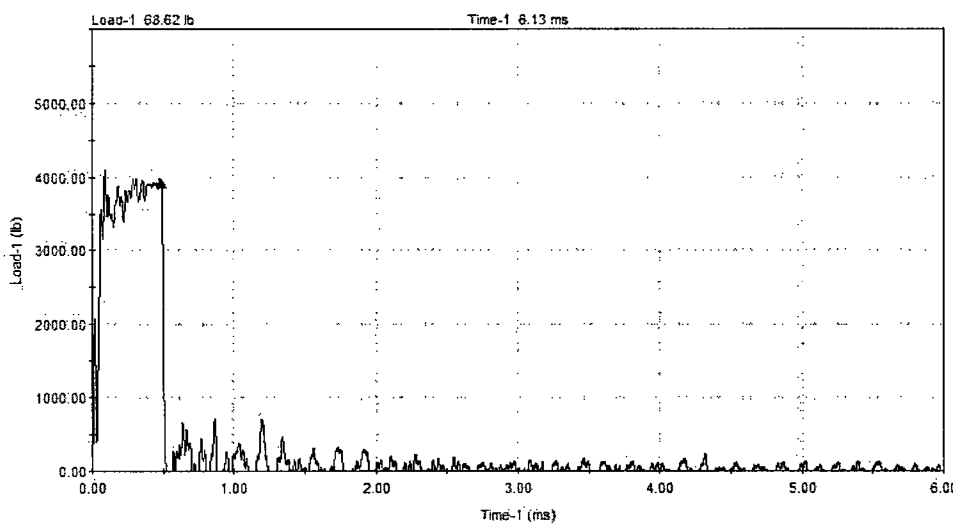
GH40, -40°F



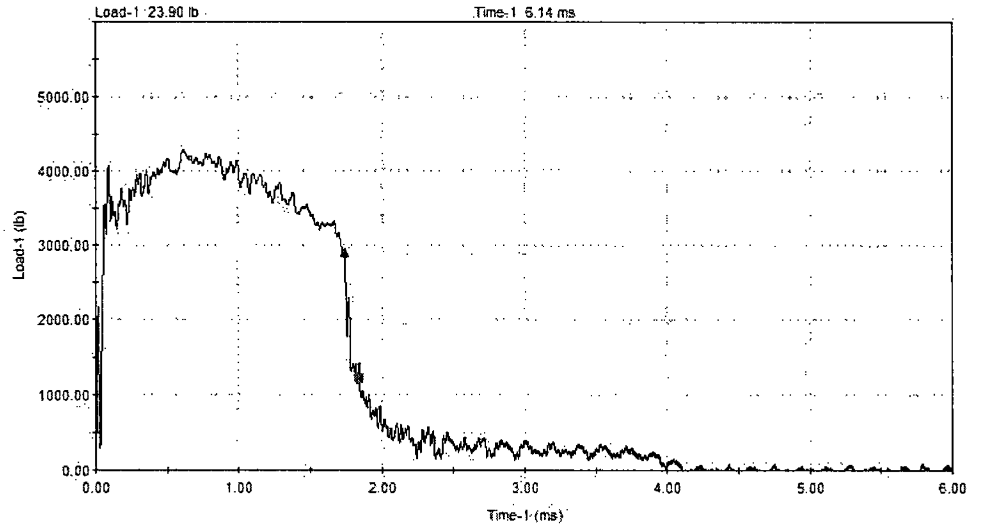
GH34, -35°F



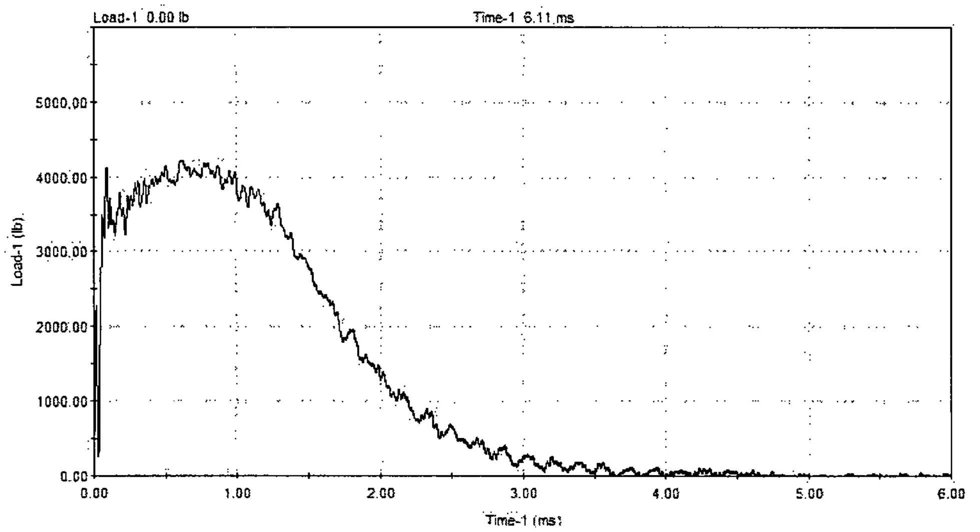
GH43, -30°F



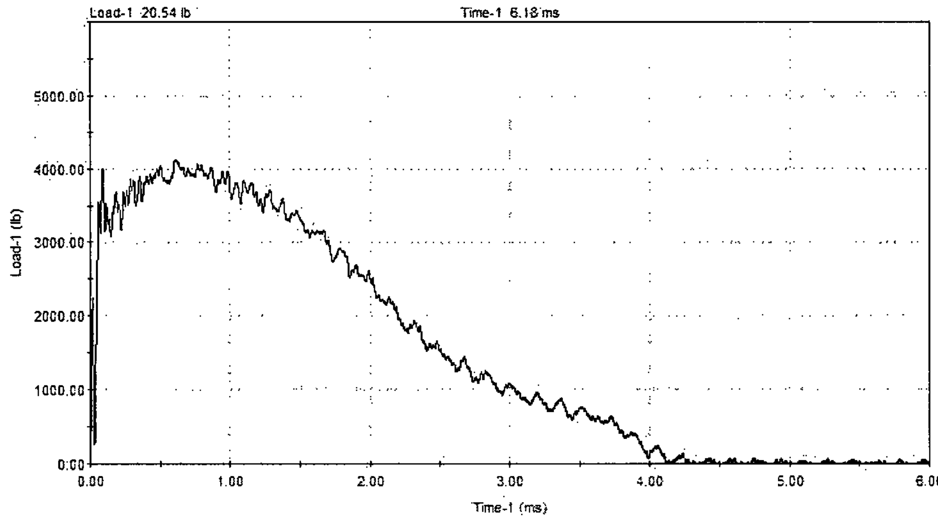
GH41, -15°F



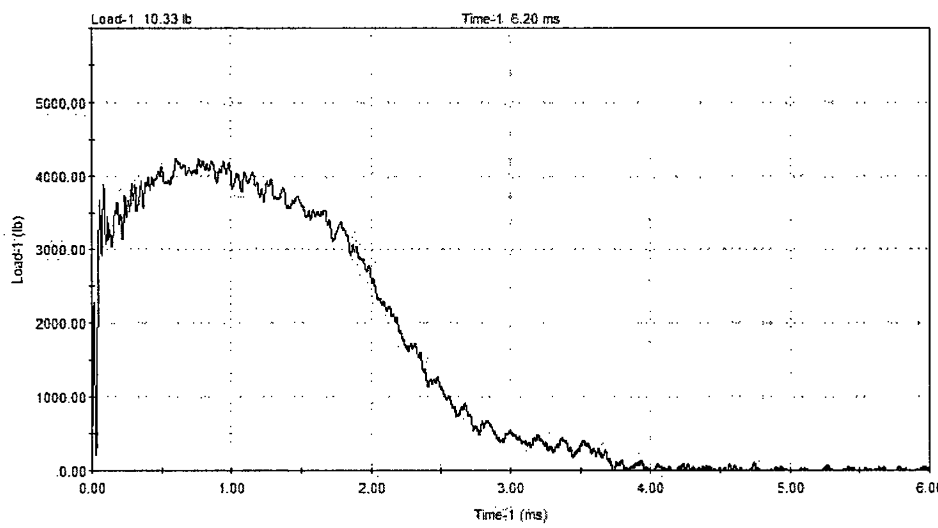
GH32, 0°F



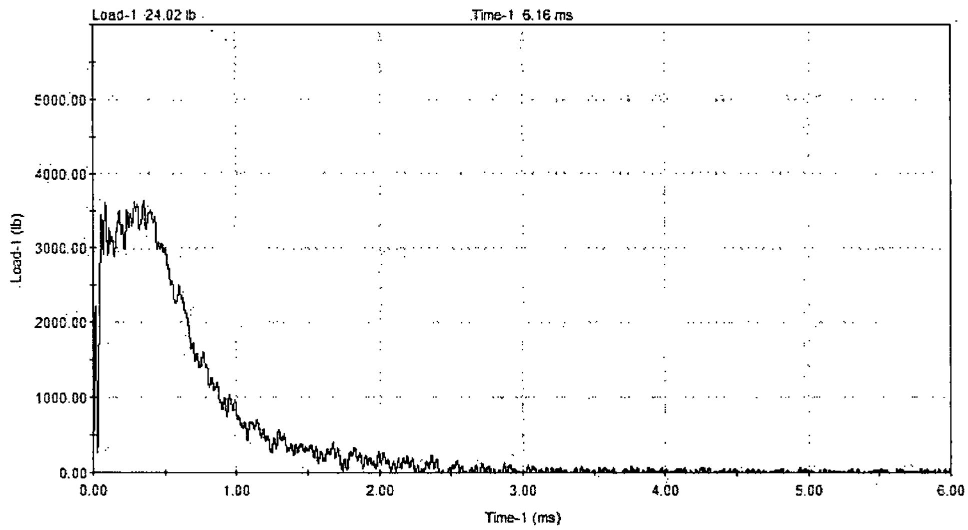
GH42, 15°F



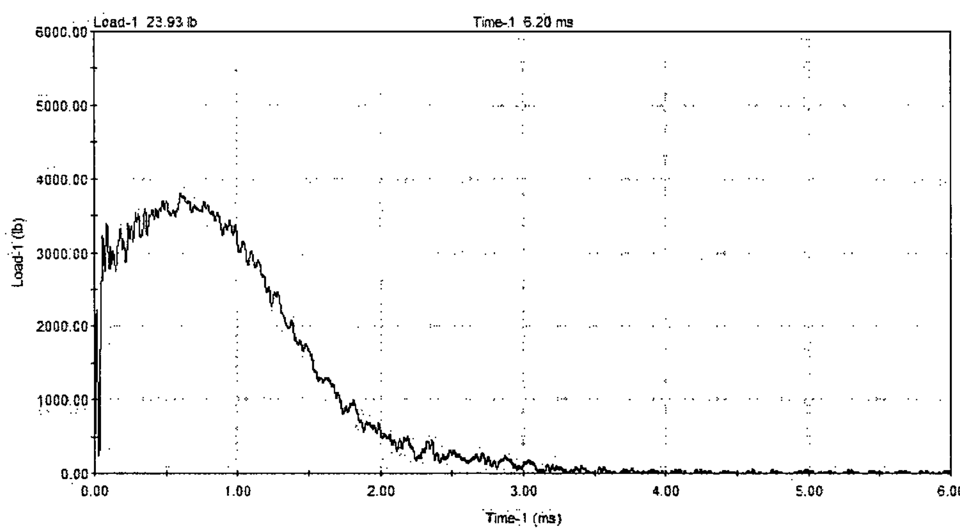
GH36, 40°F



GH38, 72°F



GH35, 130°F



GH45, 200°F

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

Contained in Table C-1 are the upper-shelf energy (USE) values that are used as input for the generation of the Charpy V-notch plots using CVGRAPH, Version 5.3. The definition for USE is given in ASTM E185-82 [Ref. C-1], Section 4.18, and reads as follows:

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

If there are specimens tested in sets of three at each temperature, Westinghouse typically reports the set having the highest average energy as the USE (usually unirradiated material). If the specimens were not tested in sets of three at each temperature, Westinghouse reports the average of all Charpy data (≥ 95% shear) as the USE, excluding any values that are deemed outliers using engineering judgment. Hence, the Capsule W USE values reported in Table C-1 were determined by applying this methodology to the Charpy data tabulated in Tables 5-1 through 5-4 of this report. USE values documented in Table C-1 for the unirradiated material, as well as Capsules U, Y, and V, were also determined by applying the methodology described above to the Charpy impact data reported in WCAP-9492 [Ref. C-2], WCAP-12629 [Ref. C-3], WCAP-14847 [Ref. C-4], and WCAP-16149 [Ref. C-5]. The USE values reported in Table C-1 were used in generation of the Charpy V-notch curves.

The lower-shelf energy values were fixed at 2.2 ft-lb for all cases. The lower-shelf Lateral Expansion values were fixed at 1.0 mils in order to be consistent with the previous capsule analysis [Ref. C-5].

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

Material	Capsule				
	Unirradiated	U	Y	V	W
Intermediate Shell Plate R1606-2 Longitudinal Orientation	138	127	137	131	121
Intermediate Shell Plate R1606-2 Transverse Orientation	113	104	108	106	102
Surveillance Program Weld Metal (Heat # 89476)	86	86	96	95	87
Heat-Affected Zone (HAZ) Material	105	129	130	107	108

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

C.1 REFERENCES

C-1 ASTM E185-82, *Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels, E706(IF)*, ASTM, 1982.

C-2 WCAP-9492, Revision 0, *South Texas Utilities South Texas Project Unit 1 Reactor Vessel Radiation Surveillance Program*, June 1979.

C-3 WCAP-12629, Revision 0, *Analysis of Capsule U from the Houston Lighting and Power Company South Texas Unit 1 Reactor Vessel Radiation Surveillance Program*, August 1990.

C-4 WCAP-14847, Revision 0, *Analysis of Capsule Y from the Houston Lighting and Power Company South Texas Unit 1 Reactor Vessel Radiation Surveillance Program*, April 1997.

C-5 WCAP-16149-NP, Revision 2, *Analysis of Capsule V from the South Texas Project Nuclear Operating Company, South Texas Unit 1 Reactor Vessel Radiation Surveillance Program*, July 2007.

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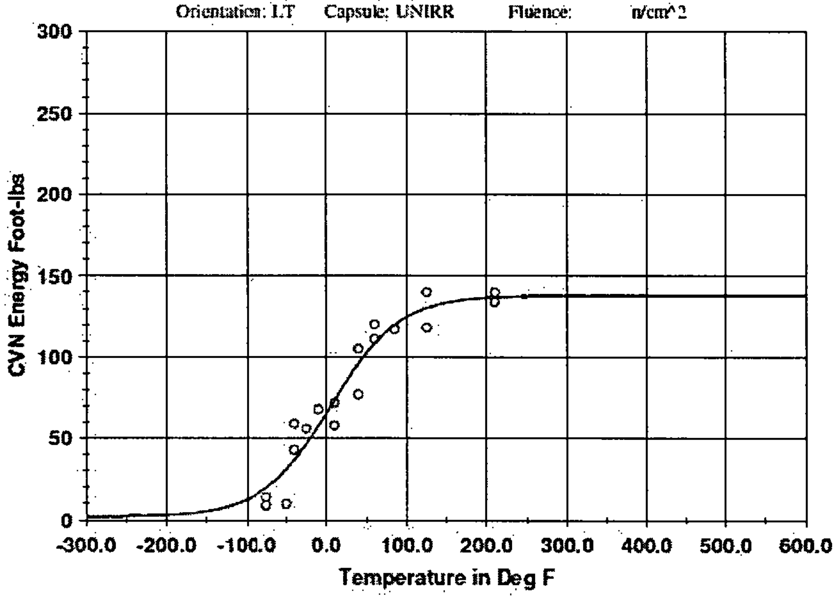
C.2 CVGRAPH VERSION 5.3 INDIVIDUAL PLOTS

Unirradiated Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:44 PM
Page 1
Coefficients of Curve 1
A = 70.1 B = 67.9 C = 85.1 T0 = 5.66 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=138.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-52.0 Deg F Temp@50 ft-lbs=-20.3 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	14.00	19.94	-5.94
-75.00	9.00	19.94	-10.94
-50.00	10.00	31.10	-21.10
-40.00	43.00	36.80	6.20
-40.00	59.00	36.80	22.20
-25.00	56.00	46.64	9.36
-10.00	68.00	57.75	10.25
10.00	58.00	73.56	-15.56
10.00	72.00	73.56	-1.56

Unirradiated Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
40.00	77.00	96.11	-19.11
40.00	105.00	96.11	8.89
60.00	120.00	108.39	11.61
60.00	111.00	108.39	2.61
85.00	117.00	119.78	-2.78
125.00	140.00	130.25	9.75
125.00	118.00	130.25	-12.25
210.00	140.00	136.89	3.11
210.00	134.00	136.89	-2.89

Correlation Coefficient = .963

Unirradiated Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:34 PM

Page 1

Coefficients of Curve 1

A = 44.47 B = 43.47 C = 73.65 T0 = -6.6 D = 0.00E+00

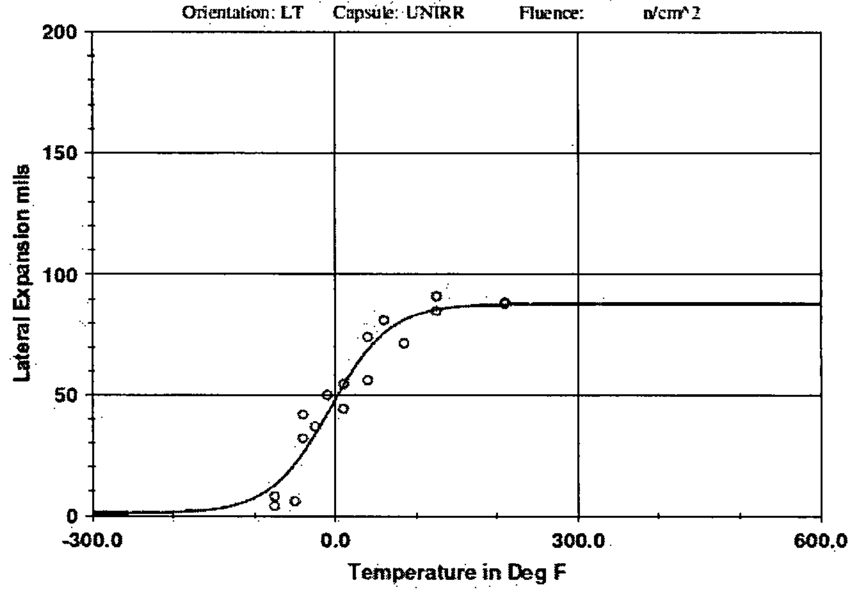
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf L.E.=87.9 Lower Shelf L.E.=1.0(Fixed)

Temp.@L.E. 35 mils=-22.9 Deg F

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	8.00	12.74	-4.74
-75.00	4.00	12.74	-8.74
-50.00	6.00	21.46	-15.46
-40.00	32.00	26.00	6.00
-40.00	42.00	26.00	16.00
-25.00	37.00	33.83	3.17
-10.00	50.00	42.47	7.53
10.00	44.50	54.11	-9.61
10.00	54.50	54.11	.39

Unirradiated Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

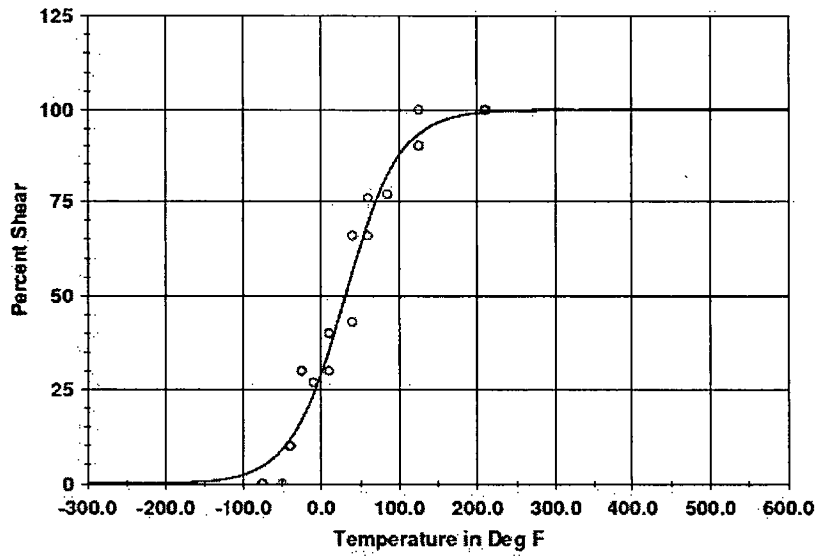
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
40.00	56.00	68.81	-12.81
40.00	74.00	68.81	5.19
60.00	81.00	75.70	5.30
60.00	81.00	75.70	5.30
85.00	71.50	81.27	-9.77
125.00	91.00	85.57	5.43
125.00	85.00	85.57	-.57
210.00	88.00	87.70	.30
210.00	88.50	87.70	.80

Correlation Coefficient = .960

Unirradiated Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:14 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 70.6 T0 = 31.19 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 31.2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	.00	4.71	-4.71
-75.00	.00	4.71	-4.71
-50.00	.00	9.11	-9.11
-40.00	10.00	11.75	-1.75
-40.00	10.00	11.75	-1.75
-25.00	30.00	16.91	13.09
-10.00	27.00	23.74	3.26
10.00	40.00	35.43	4.57
10.00	30.00	35.43	-5.43

Unirradiated Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: UNIRR Fluence: n/cm^2

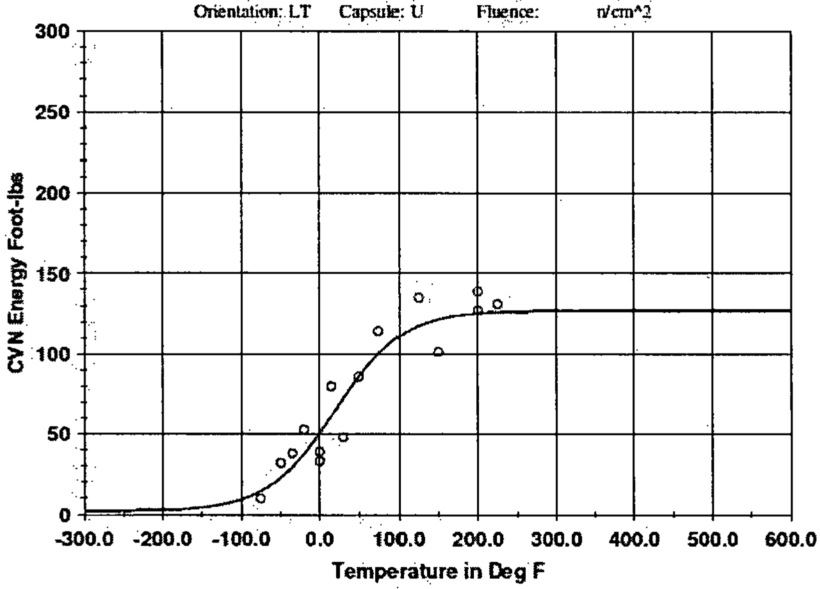
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
40.00	43.00	56.21	-13.21
40.00	66.00	56.21	9.79
60.00	76.00	69.34	6.66
60.00	66.00	69.34	-3.34
85.00	77.00	82.12	-5.12
125.00	100.00	93.45	6.55
125.00	90.00	93.45	-3.45
210.00	100.00	99.37	.63
210.00	100.00	99.37	.63

Correlation Coefficient = .983

Capsule U Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:41 PM
Page 1
Coefficients of Curve 1
A = 64.6 B = 62.4 C = 85.64 T0 = 19.34 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=127.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-34.1 Deg F Temp@50 ft-lbs=1.0 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	10.00	14.61	-4.61
-50.00	32.00	22.83	9.17
-35.00	38.00	29.58	8.42
-20.00	53.00	37.79	15.21
.00	39.00	50.74	-11.74
.00	33.00	50.74	-17.74
15.00	80.00	61.44	18.56
30.00	48.00	72.32	-24.32
50.00	86.00	86.03	-.03

Capsule U Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: U Fluence: n/cm^2

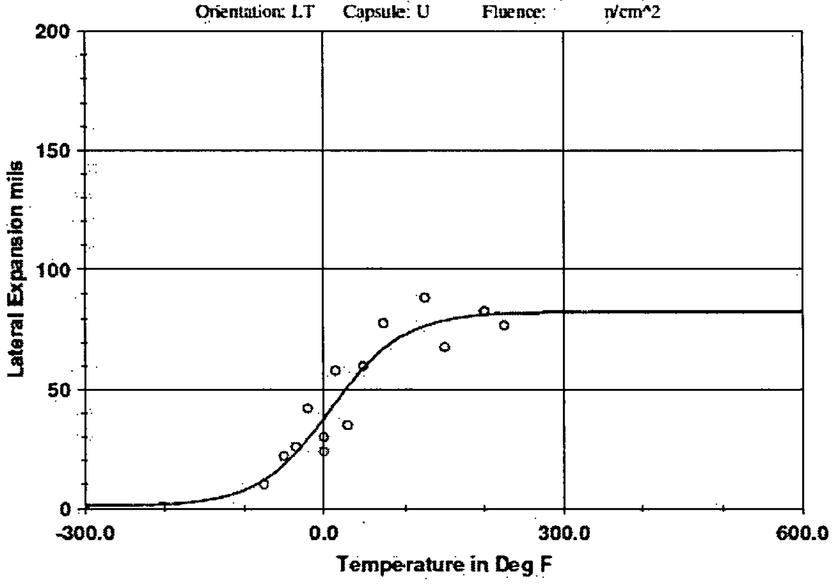
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
75.00	114.00	100.27	13.73
125.00	135.00	117.24	17.76
150.00	101.00	121.36	-20.36
200.00	139.00	125.19	13.81
200.00	127.00	125.19	1.81
225.00	131.00	125.98	5.02

Correlation Coefficient = .946

Capsule U Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:31 PM
Page 1
Coefficients of Curve 1
A = 41.82 B = 40.82 C = 90.25 T0 = 8.88 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=82.6 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-6.3 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	10.00	12.01	-2.01
-50.00	22.00	18.42	3.58
-35.00	26.00	23.40	2.60
-20.00	42.00	29.19	12.81
.00	30.00	37.82	-7.82
.00	24.00	37.82	-13.82
15.00	58.00	44.58	13.42
30.00	35.00	51.20	-16.20
50.00	60.00	59.23	.77

Capsule U Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: U Fluence: n/cm^2

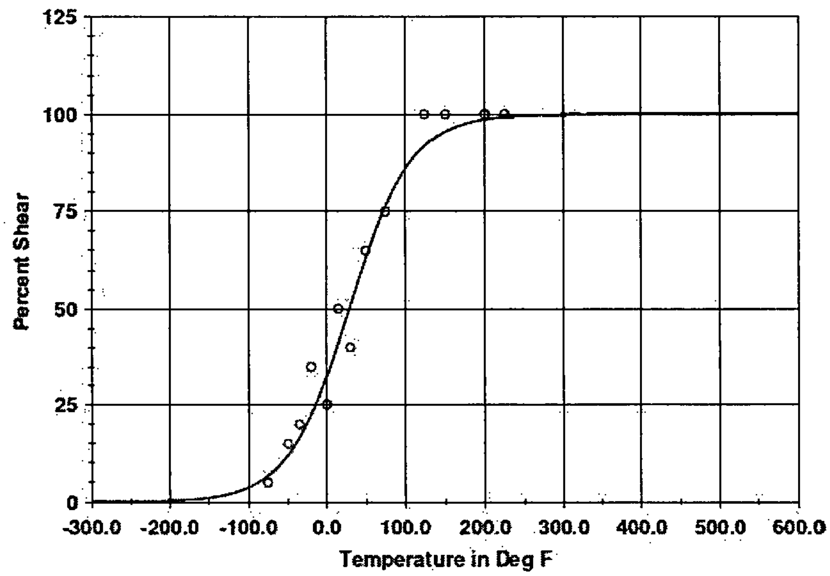
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
75.00	78.00	67.32	10.68
125.00	88.00	76.85	11.15
150.00	68.00	79.21	-11.21
200.00	83.00	81.48	1.52
200.00	83.00	81.48	1.52
225.00	77.00	81.97	-4.97

Correlation Coefficient = .933

Capsule U Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:11 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 79.11 T0 = 28.83 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 28.9
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	5.00	6.76	-1.76
-50.00	15.00	12.00	3.00
-35.00	20.00	16.61	3.39
-20.00	35.00	22.54	12.46
.00	25.00	32.55	-7.55
.00	25.00	32.55	-7.55
15.00	50.00	41.35	8.65
30.00	40.00	50.74	-10.74
50.00	65.00	63.07	1.93

Capsule U Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: U Fluence: n/cm^2

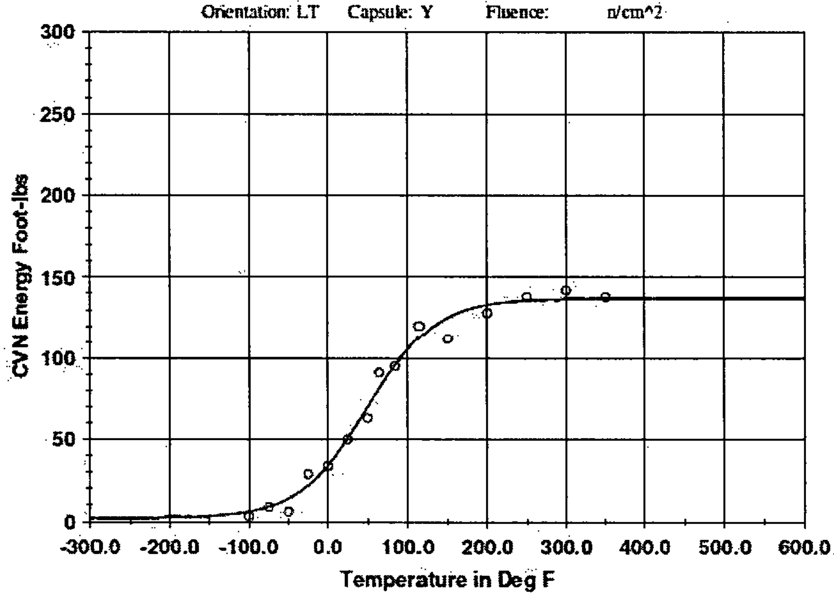
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
75.00	75.00	76.27	-1.27
125.00	100.00	91.92	8.08
150.00	100.00	95.54	4.46
200.00	100.00	98.70	1.30
200.00	100.00	98.70	1.30
225.00	100.00	99.30	.70

Correlation Coefficient = .985

Capsule Y Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:42 PM
Page 1
Coefficients of Curve 1
A = 69.6 B = 67.4 C = 85.59 T0 = 49.54 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=137.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-8.1 Deg F Temp@50 ft-lbs=24.0 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	3.00	6.17	-3.17
-75.00	9.00	9.16	-.16
-50.00	6.00	14.20	-8.20
-25.00	29.00	22.30	6.70
.00	34.00	34.43	-.43
25.00	50.00	50.79	-.79
50.00	63.00	69.96	-6.96
65.00	91.00	81.64	9.36
85.00	95.00	96.03	-1.03

Capsule Y Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: Y Fluence: n/cm^2

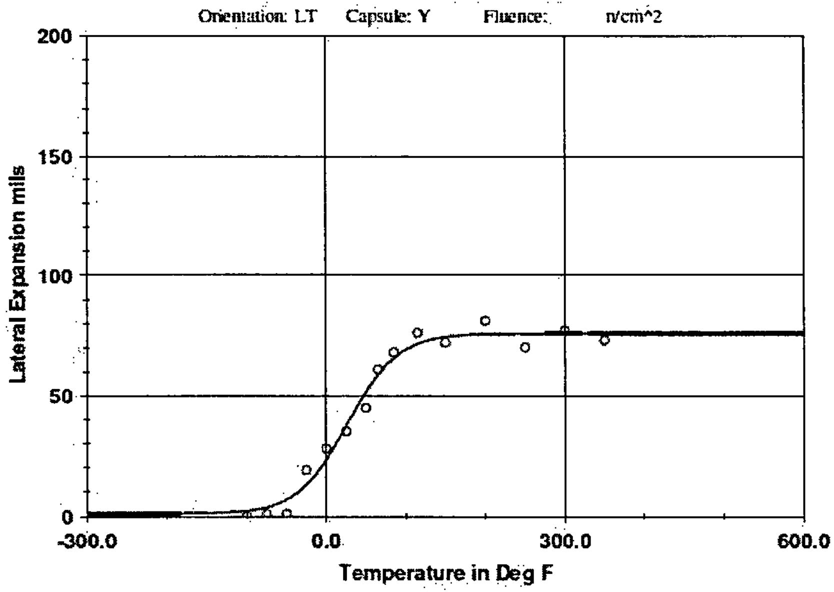
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
115.00	120.00	113.00	7.00
150.00	112.00	125.23	-13.23
200.00	128.00	133.11	-5.11
250.00	138.00	135.77	2.23
300.00	142.00	136.61	5.39
350.00	138.00	136.88	1.12

Correlation Coefficient = .993

Capsule Y Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:32 PM
Page 1
Coefficients of Curve 1
A = 38.39 B = 37.39 C = 62.92 T0 = 26.65 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=75.8 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=21.0 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-100.00	.00	2.31	-2.31
-75.00	1.00	3.84	-2.84
-50.00	1.00	7.02	-6.02
-25.00	19.00	13.13	5.87
.00	28.00	23.44	4.56
25.00	35.00	37.41	-2.41
50.00	45.00	51.66	-6.66
65.00	61.00	58.72	2.28
85.00	68.00	65.66	2.34

Capsule Y Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: Y Fluence: n/cm^2

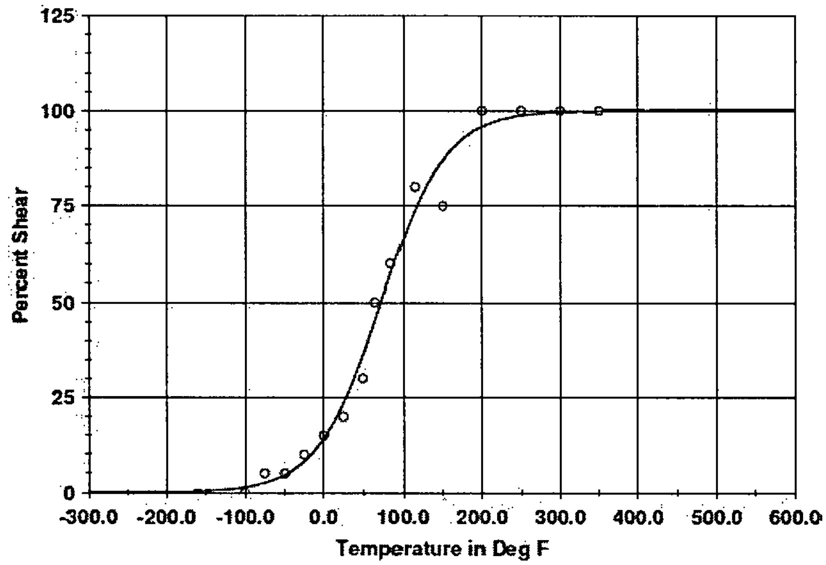
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
115.00	76.00	71.52	4.48
150.00	72.00	74.32	-2.32
200.00	81.00	75.47	5.53
250.00	70.00	75.71	-5.71
300.00	77.00	75.76	1.24
350.00	73.00	75.77	-2.77

Correlation Coefficient = .990

Capsule Y Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:11 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 80.84 T0 = 72.77 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 72.8
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100.00	.00	1.37	-1.37
-75.00	5.00	2.52	2.48
-50.00	5.00	4.58	.42
-25.00	10.00	8.17	1.83
.00	15.00	14.18	.82
25.00	20.00	23.47	-3.47
50.00	30.00	36.28	-6.28
65.00	50.00	45.21	4.79
85.00	60.00	57.50	2.50

Capsule Y Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: Y Fluence: n/cm^2

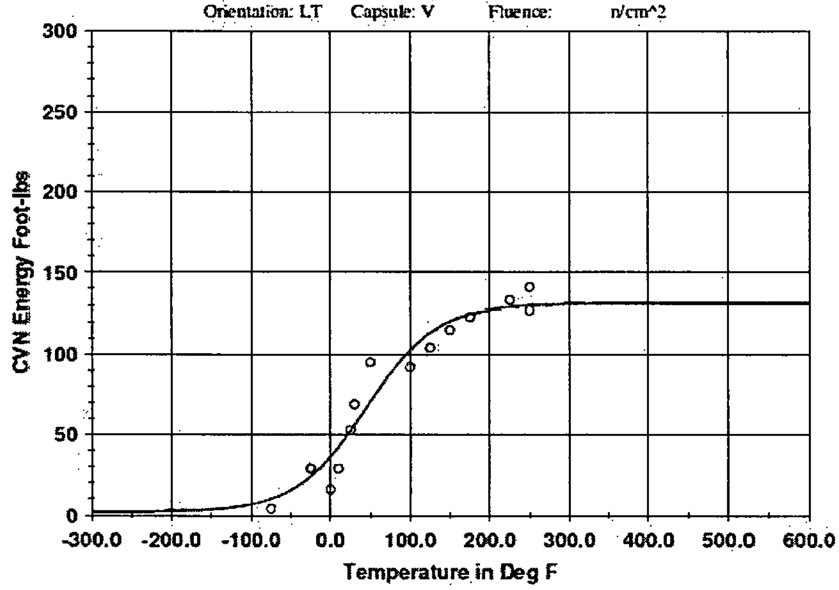
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
115.00	80.00	73.97	6.03
150.00	75.00	87.11	-12.11
200.00	100.00	95.88	4.12
250.00	100.00	98.77	1.23
300.00	100.00	99.64	.36
350.00	100.00	99.90	.10

Correlation Coefficient = .993

Capsule V Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:43 PM
Page 1
Coefficients of Curve 1
A = 66.6 B = 64.4 C = 87.89 T0 = 44.36 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=131.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-12.3 Deg F Temp@50 ft-lbs=21.2 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	4.00	10.19	-6.19
-25.00	29.00	24.23	4.77
-25.00	29.00	24.23	4.77
.00	16.00	36.60	-20.60
10.00	29.00	42.63	-13.63
25.00	53.00	52.64	.36
30.00	69.00	56.17	12.83
50.00	95.00	70.73	24.27
100.00	92.00	102.67	-10.67

Capsule V Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: V Fluence: n/cm^2

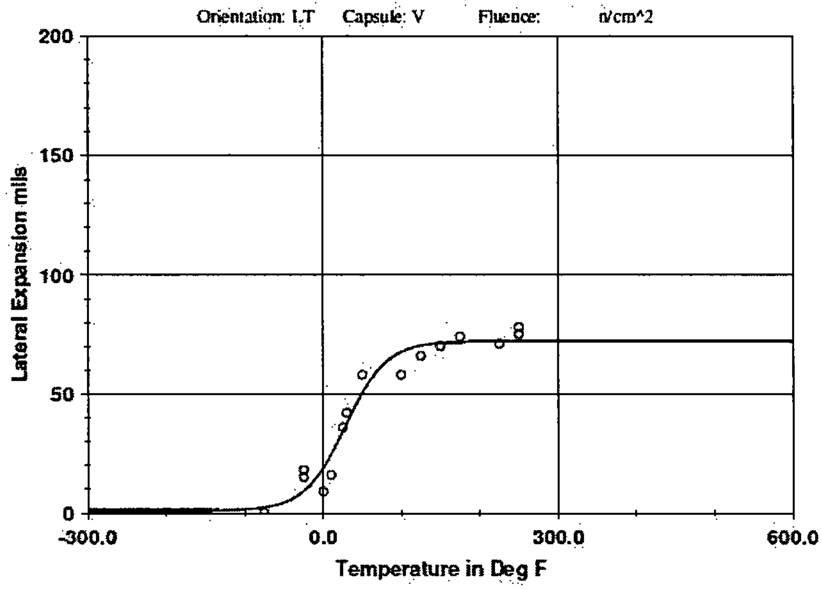
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
125.00	104.00	113.27	-9.27
150.00	115.00	120.32	-5.32
175.00	123.00	124.73	-1.73
225.00	133.00	128.92	4.08
250.00	141.00	129.82	11.18
250.00	127.00	129.82	-2.82

Correlation Coefficient = .970

Capsule V Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:33 PM
Page 1
Coefficients of Curve 1
A = 36.51 B = 35.51 C = 52.43 T0 = 28.17 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=72.0 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=26.0 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	.00	2.36	-2.36
-25.00	15.00	9.26	5.74
-25.00	18.00	9.26	8.74
.00	9.00	19.08	-10.08
10.00	16.00	24.67	-8.67
25.00	36.00	34.37	1.63
30.00	42.00	37.75	4.25
50.00	58.00	50.50	7.50
100.00	58.00	67.71	-9.71

Capsule V Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: V Fluence: n/cm^2

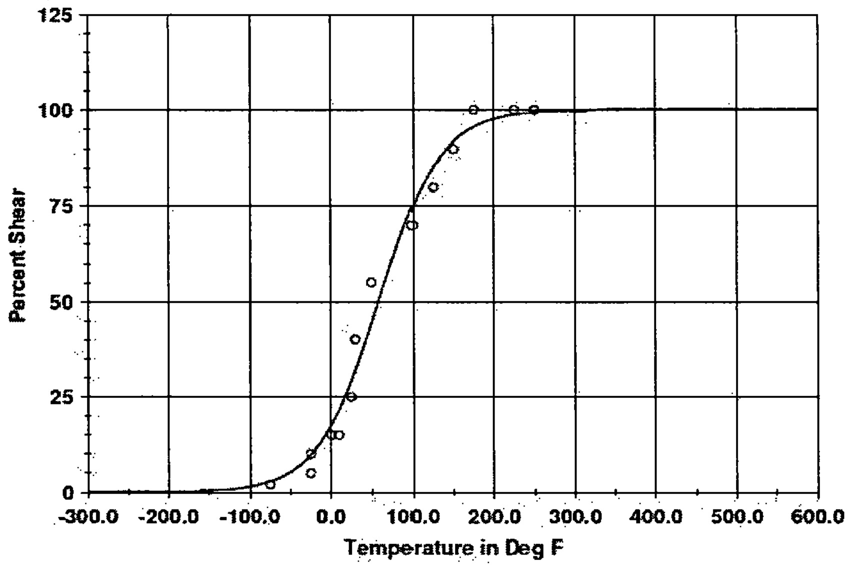
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
125.00	66.00	70.29	-4.29
150.00	70.00	71.34	-1.34
175.00	74.00	71.75	2.25
225.00	71.00	71.98	-.98
250.00	75.00	72.00	3.00
250.00	78.00	72.00	6.00

Correlation Coefficient = .975

Capsule V Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:12 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 75.47 T0 = 58.47 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 58.5
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	2.00	2.83	-.83
-25.00	10.00	9.87	.13
-25.00	5.00	9.87	-4.87
.00	15.00	17.52	-2.52
10.00	15.00	21.68	-6.68
25.00	25.00	29.18	-4.18
30.00	40.00	31.99	8.01
50.00	55.00	44.42	10.58
100.00	70.00	75.04	-5.04

Capsule V Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: V Fluence: n/cm^2

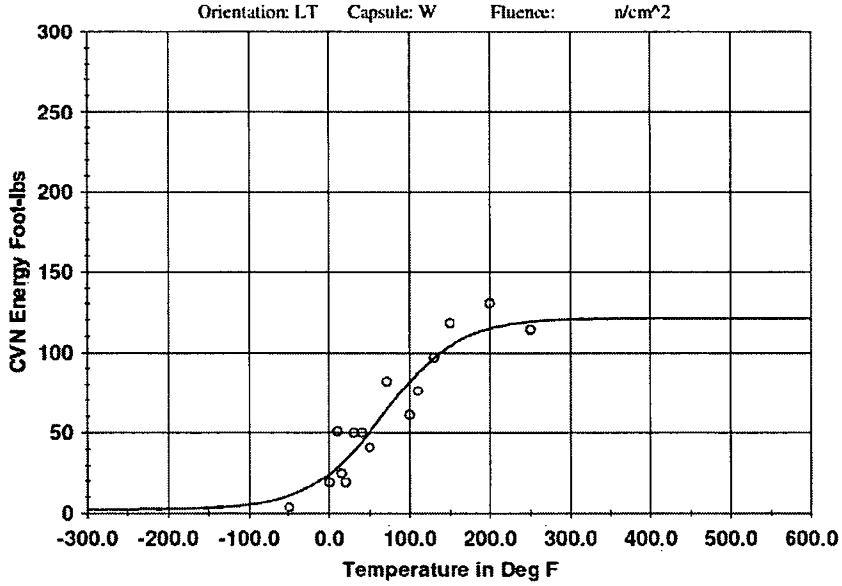
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
125.00	80.00	85.36	-5.36
150.00	90.00	91.88	-1.88
175.00	100.00	95.64	4.36
225.00	100.00	98.80	1.20
250.00	100.00	99.38	.62
250.00	100.00	99.38	.62

Correlation Coefficient = .992

Capsule W Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 08:24 AM
Page 1
Coefficients of Curve 1
A = 61.6 B = 59.4 C = 92.09 T0 = 67.49 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=121.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=12.9 Deg F Temp@50 ft-lbs=49.3 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	3.50	10.79	-7.29
.00	19.00	24.48	-5.48
10.00	51.00	28.69	22.31
15.00	25.00	30.99	-5.99
20.00	19.00	33.42	-14.42
30.00	50.00	38.67	11.33
40.00	50.00	44.38	5.62
50.00	41.00	50.45	-9.45
72.00	82.00	64.51	17.49

Capsule W Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: W Fluence: n/cm^2

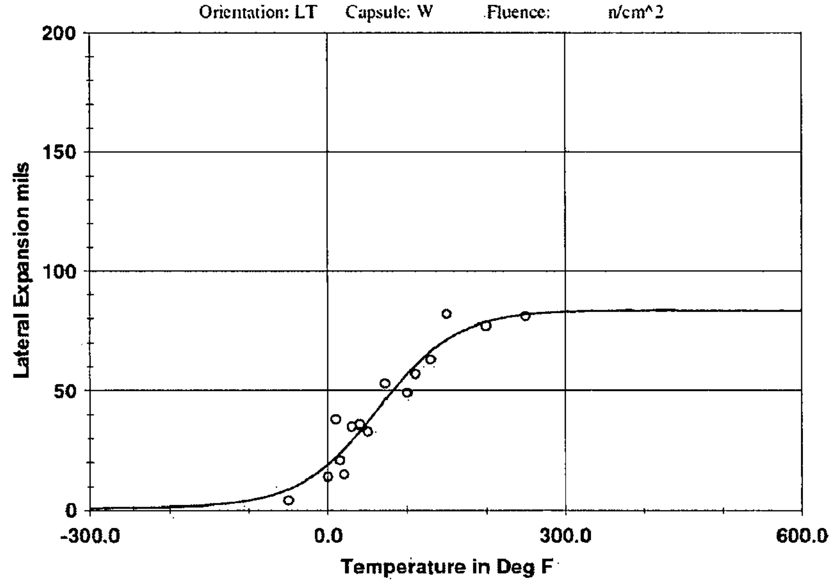
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
100.00	61.00	81.74	-20.74
110.00	76.00	87.23	-11.23
130.00	97.00	96.69	.31
150.00	118.00	104.03	13.97
200.00	130.00	114.67	15.33
250.00	114.00	118.79	-4.79

Correlation Coefficient = .944

Capsule W Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 03:44 PM
Page 1
Coefficients of Curve 1
A = 42.36 B = 41.36 C = 100.04 T0 = 63.19 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=83.7 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=45.3 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	4.00	8.80	-4.80
.00	14.00	19.23	-5.23
10.00	38.00	22.23	15.77
15.00	21.00	23.85	-2.85
20.00	15.00	25.53	-10.53
30.00	35.00	29.12	5.88
40.00	36.00	32.94	3.06
50.00	33.00	36.93	-3.93
72.00	53.00	45.99	7.01

Capsule W Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: W Fluence: n/cm^2

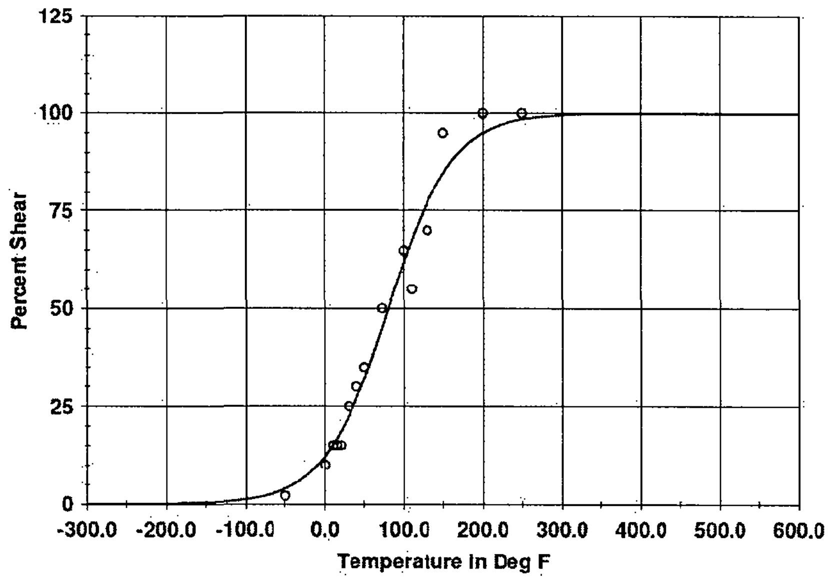
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
100.00	49.00	56.92	-7.92
110.00	57.00	60.41	-3.41
130.00	63.00	66.49	-3.49
150.00	82.00	71.31	10.69
200.00	77.00	78.67	-1.67
250.00	81.00	81.78	-.78

Correlation Coefficient = .957

Capsule W Intermediate Shell Plate R1606-2 (Longitudinal)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/25/2012 04:26 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 81.42 T0 = 80.19 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 80.2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	2.00	3.92	-1.92
.00	10.00	12.24	-2.24
10.00	15.00	15.13	-.13
15.00	15.00	16.78	-1.78
20.00	15.00	18.56	-3.56
30.00	25.00	22.57	2.43
40.00	30.00	27.14	2.86
50.00	35.00	32.26	2.74
72.00	50.00	44.98	5.02

Capsule W Intermediate Shell Plate R1606-2 (Longitudinal)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: LT Capsule: W Fluence: n/cm^2

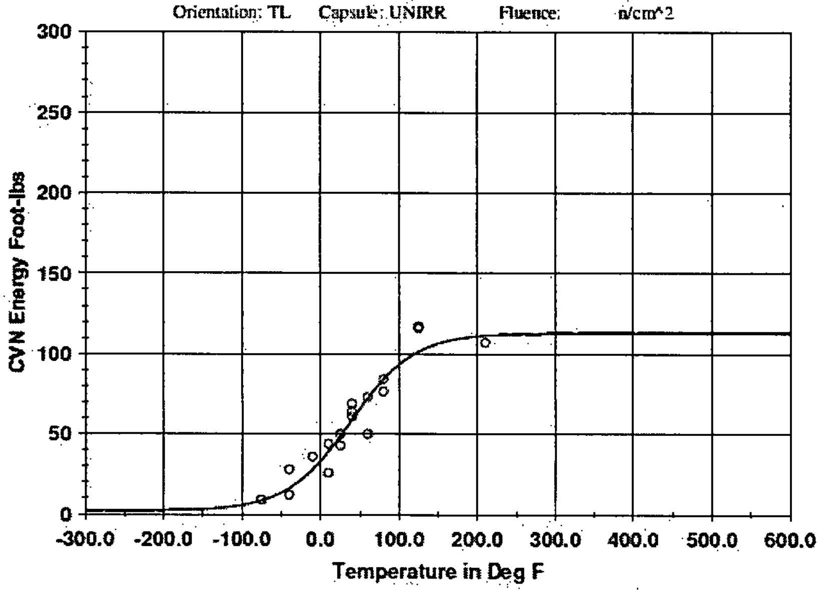
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
100.00	65.00	61.93	3.07
110.00	55.00	67.53	-12.53
130.00	70.00	77.27	-7.27
150.00	95.00	84.75	10.25
200.00	100.00	94.99	5.01
250.00	100.00	98.48	1.52

Correlation Coefficient = .987

Unirradiated Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:51 PM
Page 1
Coefficients of Curve 1
A = 57.6 B = 55.4 C = 80.82 T0 = 38.09 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=113.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=6.1 Deg F Temp@50 ft-lbs=27.0 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.00	9.00	8.56	.44
-40.00	12.00	16.21	-4.21
-40.00	28.00	16.21	11.79
-10.00	36.00	28.04	7.96
10.00	44.00	39.09	4.91
10.00	26.00	39.09	-13.09
25.00	50.00	48.71	1.29
25.00	43.00	48.71	-5.71
40.00	61.00	58.91	2.09

Unirradiated Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: UNIRR Fluence: n/cm^2

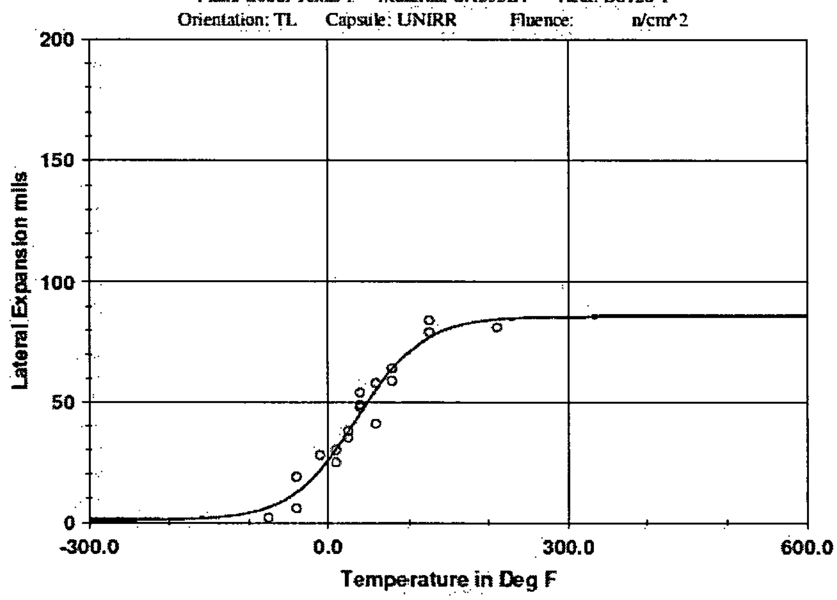
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
40.00	69.00	58.91	10.09
40.00	64.00	58.91	5.09
60.00	50.00	72.26	-22.26
60.00	73.00	72.26	.74
80.00	84.00	84.01	-.01
80.00	76.50	84.01	-7.51
125.00	117.00	101.45	15.55
125.00	116.00	101.45	14.55
210.00	107.00	111.45	-4.45

Correlation Coefficient = .955

Unirradiated Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:59 PM
Page 1
Coefficients of Curve 1
A = 43.41 B = 42.41 C = 82.95 T0 = 36.32 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=85.8 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=19.7 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-75.00	2.00	6.42	-4.42
-40.00	6.00	12.62	-6.62
-40.00	19.00	12.62	6.38
-10.00	28.00	21.92	6.08
10.00	30.00	30.39	-.39
10.00	25.00	30.39	-5.39
25.00	38.00	37.66	.34
25.00	35.00	37.66	-2.66
40.00	48.00	45.29	2.71

Unirradiated Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: UNIRR Fluence: n/cm^2

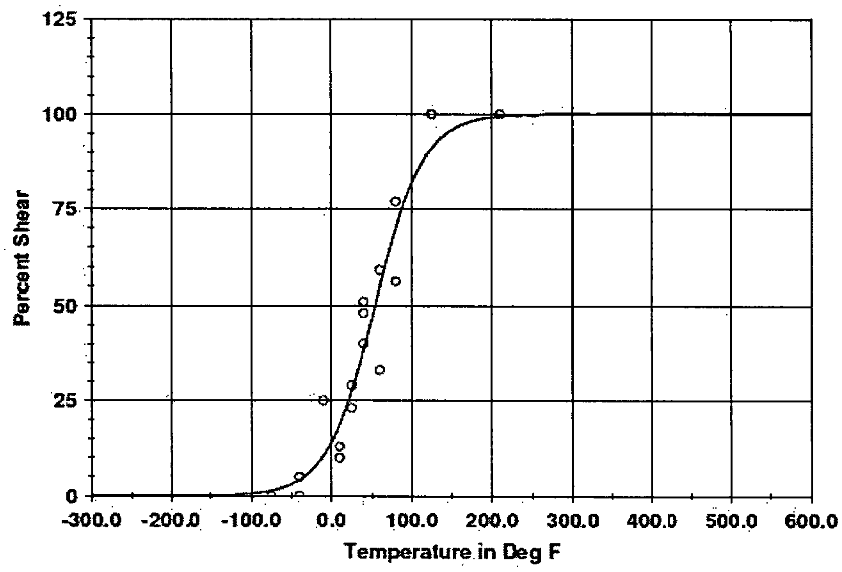
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
40.00	54.00	45.29	8.71
40.00	49.00	45.29	3.71
60.00	41.00	55.20	-14.20
60.00	58.00	55.20	2.80
80.00	64.00	63.89	.11
80.00	59.00	63.89	-4.89
125.00	84.00	76.88	7.12
125.00	79.00	76.88	2.12
210.00	81.00	84.56	-3.56

Correlation Coefficient = .971

Unirradiated Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:17 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 60.54 T0 = 54.52 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 54.6
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-75.00	.00	1.37	-1.37
-40.00	.00	4.22	-4.22
-40.00	5.00	4.22	.78
-10.00	25.00	10.61	14.39
10.00	13.00	18.69	-5.69
10.00	10.00	18.69	-8.69
25.00	29.00	27.39	1.61
25.00	23.00	27.39	-4.39
40.00	40.00	38.24	1.76

Unirradiated Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: UNIRR Fluence: n/cm^2

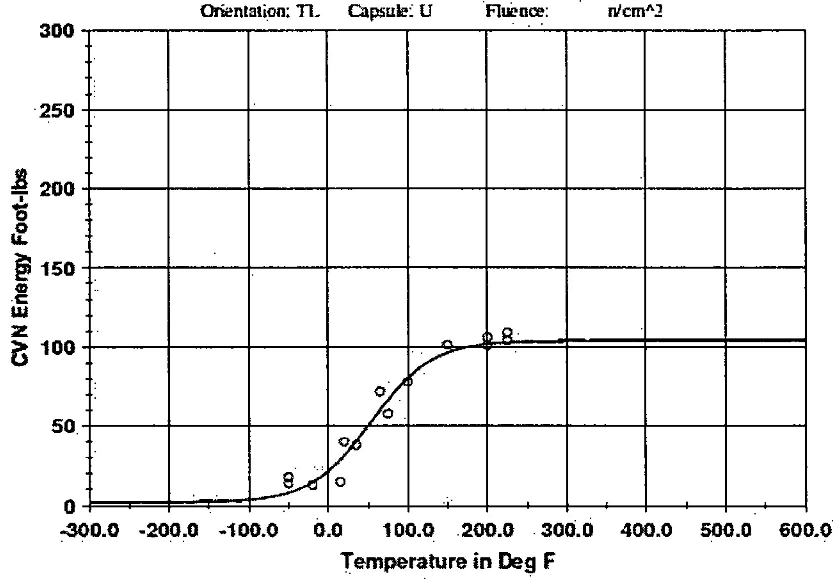
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
40.00	51.00	38.24	12.76
40.00	48.00	38.24	9.76
60.00	33.00	54.52	-21.52
60.00	59.00	54.52	4.48
80.00	77.00	69.89	7.11
80.00	56.00	69.89	-13.89
125.00	100.00	91.12	8.88
125.00	100.00	91.12	8.88
210.00	100.00	99.42	.58

Correlation Coefficient = .961

Capsule U Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:47 PM
Page 1
Coefficients of Curve 1
A = 53.1 B = 50.9 C = 75.67 T0 = 54.23 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=104.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=17.2 Deg F Temp@50 ft-lbs=49.7 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	14.00	8.29	5.71
-50.00	18.00	8.29	9.71
-20.00	13.00	14.75	-1.75
15.00	15.00	28.85	-13.85
20.00	40.00	31.53	8.47
35.00	38.00	40.44	-2.44
65.00	72.00	60.29	11.71
75.00	58.00	66.73	-8.73
100.00	78.00	80.61	-2.61

Capsule U Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: U Fluence: n/cm^2

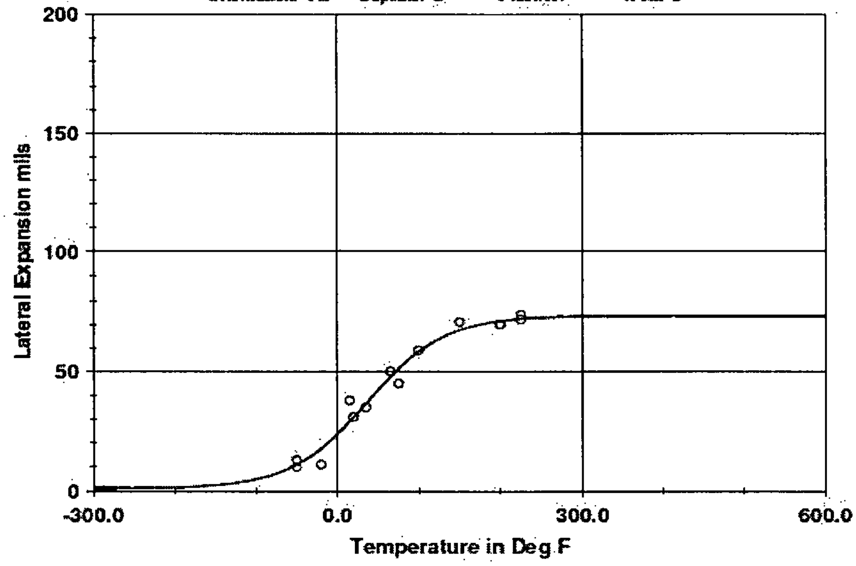
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
150.00	101.00	96.50	4.50
200.00	106.00	101.88	4.12
200.00	101.00	101.88	-.88
225.00	104.00	102.90	1.10
225.00	109.00	102.90	6.10

Correlation Coefficient = .983

Capsule U Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:57 PM
Page 1
Coefficients of Curve 1
A = 37.36 B = 36.36 C = 94.65 T0 = 36.78 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=73.7 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=30.7 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	10.00	11.02	-1.02
-50.00	13.00	11.02	1.98
-20.00	11.00	17.83	-6.83
15.00	38.00	29.13	8.87
20.00	31.00	30.97	.03
35.00	35.00	36.67	-1.67
65.00	50.00	47.88	2.12
75.00	45.00	51.29	-6.29
100.00	59.00	58.57	.43

Capsule U Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: U Fluence: n/cm^2

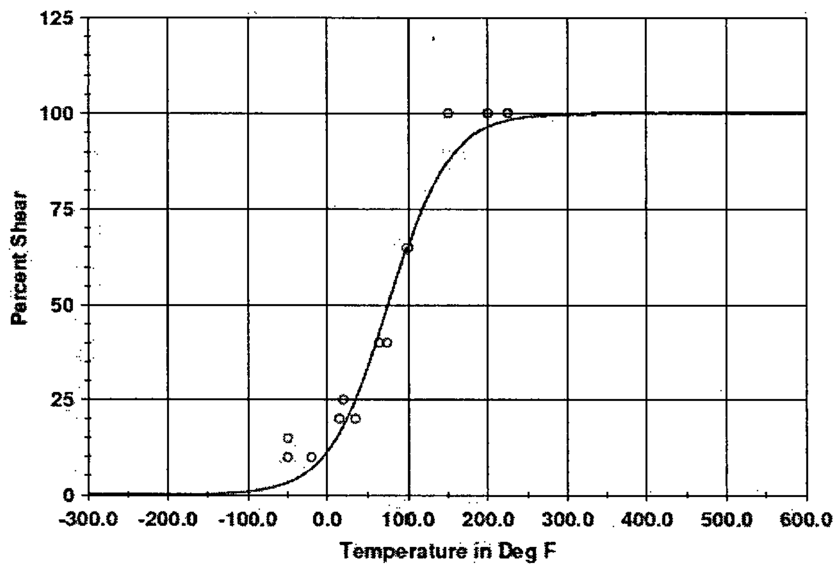
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
150.00	71.00	67.62	3.38
200.00	70.00	71.47	-1.47
200.00	70.00	71.47	-1.47
225.00	72.00	72.37	-.37
225.00	74.00	72.37	1.63

Correlation Coefficient = .987

Capsule U Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:16 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 74.71 T0 = 76.24 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 76.3
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	10.00	3.29	6.71
-50.00	15.00	3.29	11.71
-20.00	10.00	7.07	2.93
15.00	20.00	16.25	3.75
20.00	25.00	18.16	6.84
35.00	20.00	24.90	-4.90
65.00	40.00	42.53	-2.53
75.00	40.00	49.17	-9.17
100.00	65.00	65.39	-.39

Capsule U Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: U Fluence: n/cm^2

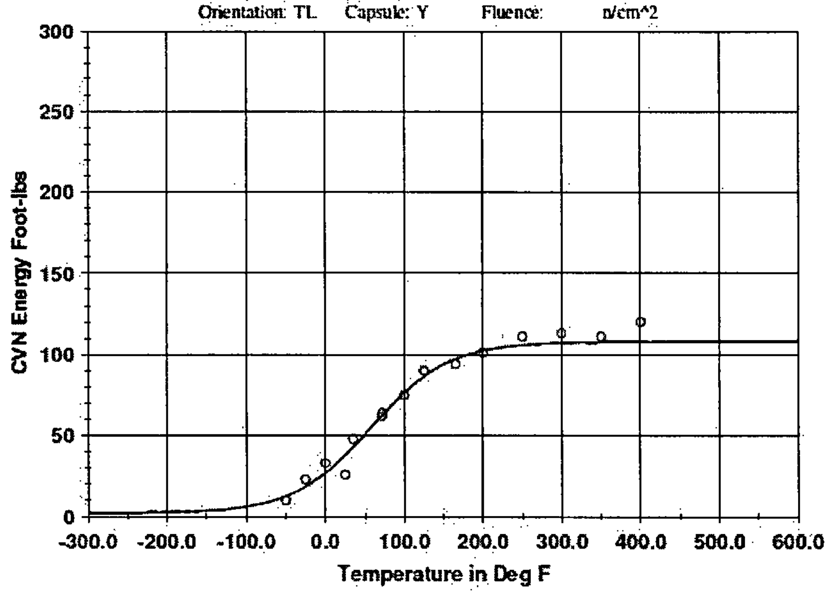
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
150.00	100.00	87.81	12.19
200.00	100.00	96.49	3.51
200.00	100.00	96.49	3.51
225.00	100.00	98.17	1.83
225.00	100.00	98.17	1.83

Correlation Coefficient = .989

Capsule Y Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/13/2011 09:06 AM
Page 1
Coefficients of Curve 1
A = 55.1 B = 52.9 C = 98.2 T0 = 57.78 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=108.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=7.2 Deg F Temp@50 ft-lbs=48.3 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	10.00	12.80	-2.80
-25.00	23.00	18.74	4.26
.00	33.00	27.13	5.87
25.00	26.00	38.07	-12.07
35.00	48.00	43.05	4.95
72.00	64.00	62.71	1.29
72.00	62.00	62.71	-.71
100.00	75.00	76.54	-1.54
125.00	90.00	86.55	3.45

Capsule Y Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: Y Fluence: n/cm^2

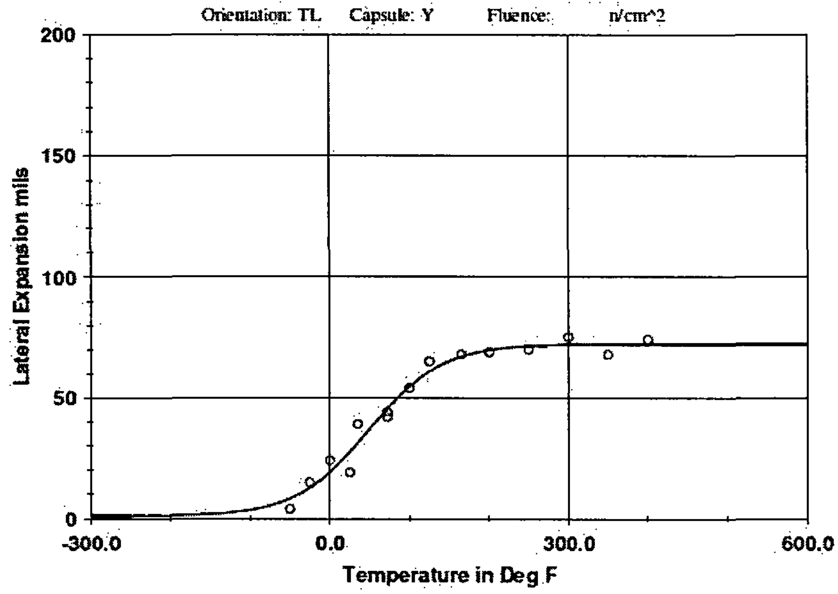
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
165.00	94.00	97.29	-3.29
200.00	101.00	102.46	-1.46
250.00	111.00	105.93	5.07
300.00	113.00	107.24	5.76
350.00	111.00	107.73	3.27
400.00	120.00	107.90	12.10

Correlation Coefficient = .990

Capsule Y Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:56 PM
Page 1
Coefficients of Curve 1
A = 36.67 B = 35.67 C = 91.24 T0 = 49. D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=72.3 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=44.8 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	4.00	8.31	-4.31
-25.00	15.00	12.76	2.24
.00	24.00	19.16	4.84
25.00	19.00	27.49	-8.49
35.00	39.00	31.23	7.77
72.00	42.00	45.47	-3.47
72.00	44.00	45.47	-1.47
100.00	54.00	54.76	-.76
125.00	65.00	60.99	4.01

Capsule Y Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: Y Fluence: n/cm^2

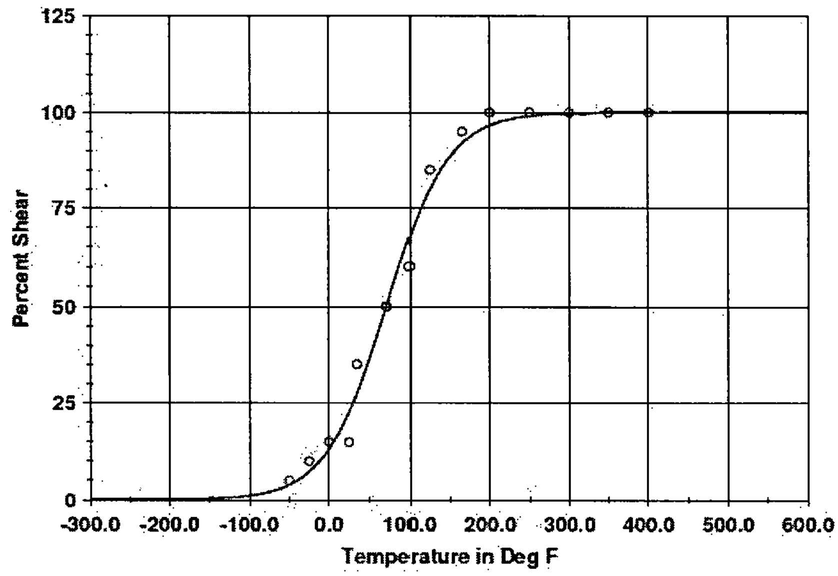
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
165.00	68.00	67.13	.87
200.00	69.00	69.82	-.82
250.00	70.00	71.47	-1.47
300.00	75.00	72.04	2.96
350.00	68.00	72.23	-4.23
400.00	74.00	72.30	1.70

Correlation Coefficient = .985

Capsule Y Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:15 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 76.22 T0 = 71.89 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 71.9
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	5.00	3.92	1.08
-25.00	10.00	7.29	2.71
.00	15.00	13.16	1.84
25.00	15.00	22.61	-7.61
35.00	35.00	27.53	7.47
72.00	50.00	50.07	-.07
72.00	50.00	50.07	-.07
100.00	60.00	67.65	-7.65
125.00	85.00	80.12	4.88

Capsule Y Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: Y Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
165.00	95.00	92.01	2.99
200.00	100.00	96.65	3.35
250.00	100.00	99.07	.93
300.00	100.00	99.75	.25
350.00	100.00	99.93	.07
400.00	100.00	99.98	.02

Correlation Coefficient = .994

Capsule V Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:50 PM

Page 1

Coefficients of Curve 1

A = 54.1 B = 51.9 C = 90.54 T0 = 63.29 D = 0.00E+00

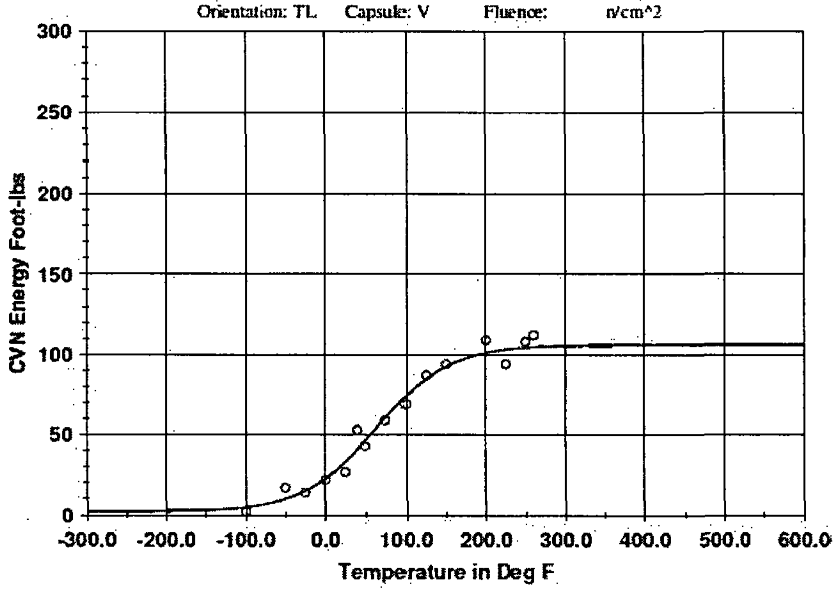
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=106.0(Fixed) Lower Shelf Energy=2.2(Fixed)

Temp@30 ft-lbs=17.8 Deg F Temp@50 ft-lbs=56.2 Deg F

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

Orientation: TL Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	2.00	4.94	-2.94
-50.00	17.00	10.05	6.95
-25.00	14.00	15.12	-1.12
.00	22.00	22.76	-.76
25.00	27.00	33.37	-6.37
40.00	53.00	41.04	11.96
50.00	43.00	46.54	-3.54
75.00	59.00	60.77	-1.77
100.00	69.00	74.06	-5.06

Capsule V Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: V Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
125.00	87.00	84.85	2.15
150.00	94.00	92.67	1.33
200.00	109.00	101.17	7.83
225.00	94.00	103.16	-9.16
250.00	108.00	104.35	3.65
260.00	112.00	104.67	7.33

Correlation Coefficient = .988

Capsule V Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:58 PM

Page 1

Coefficients of Curve 1

A = 35. B = 34. C = 81.8 T0 = 59.63 D = 0.00E+00

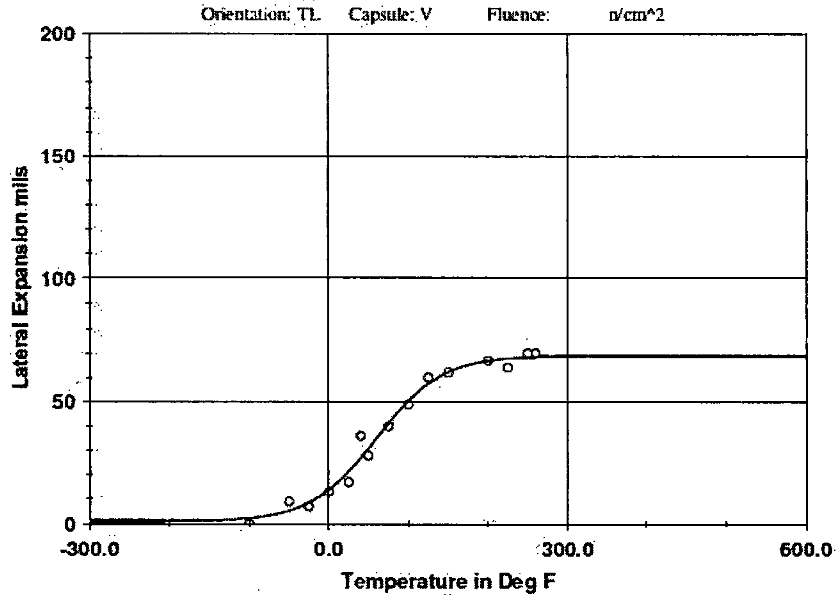
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf L.E.=69.0 Lower Shelf L.E.=1.0(Fixed)

Temp.@L.E. 35 mils=59.7 Deg F

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

Orientation: TL Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-100.00	.00	2.35	-2.35
-50.00	9.00	5.36	3.64
-25.00	7.00	8.62	-1.62
.00	13.00	13.84	-.84
25.00	17.00	21.41	-4.41
40.00	36.00	26.99	9.01
50.00	28.00	31.02	-3.02
75.00	40.00	41.31	-1.31
100.00	49.00	50.54	-1.54

Capsule V Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: V Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
125.00	60.00	57.56	2.44
150.00	62.00	62.27	-.27
200.00	67.00	66.87	.13
225.00	64.00	67.83	-3.83
250.00	70.00	68.36	1.64
260.00	70.00	68.50	1.50

Correlation Coefficient = .991

Capsule V Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 03:06 PM

Page 1

Coefficients of Curve 1

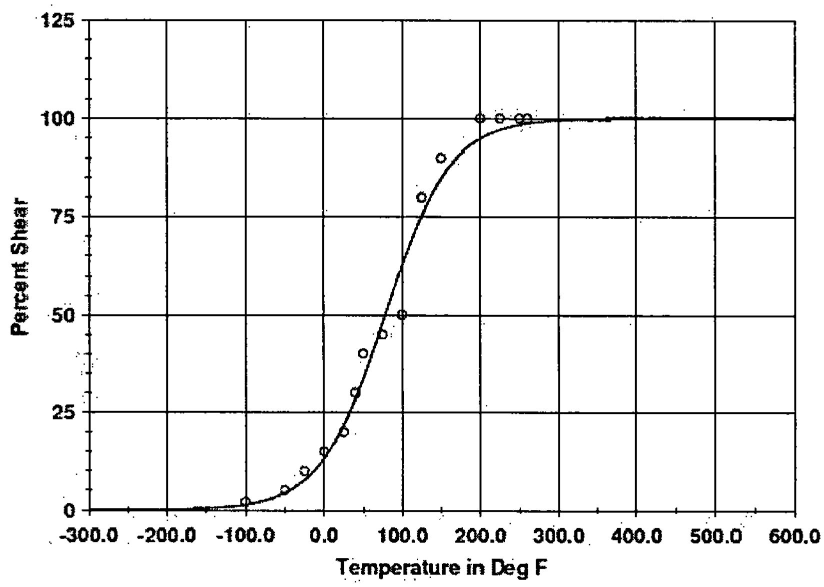
A = 50. B = 50. C = 83.26 T0 = 78.33 D = 0.00E+00

Equation is A + B * [Tanh((T-To)/(C+DT))]

Temperature at 50% Shear = 78.4

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

Orientation: TL Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100.00	2.00	1.36	.64
-50.00	5.00	4.38	.62
-25.00	10.00	7.71	2.29
.00	15.00	13.22	1.78
25.00	20.00	21.73	-1.73
40.00	30.00	28.48	1.52
50.00	40.00	33.61	6.39
75.00	45.00	48.00	-3.00
100.00	50.00	62.72	-12.72

Capsule V Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: V Fluence: n/cm^2

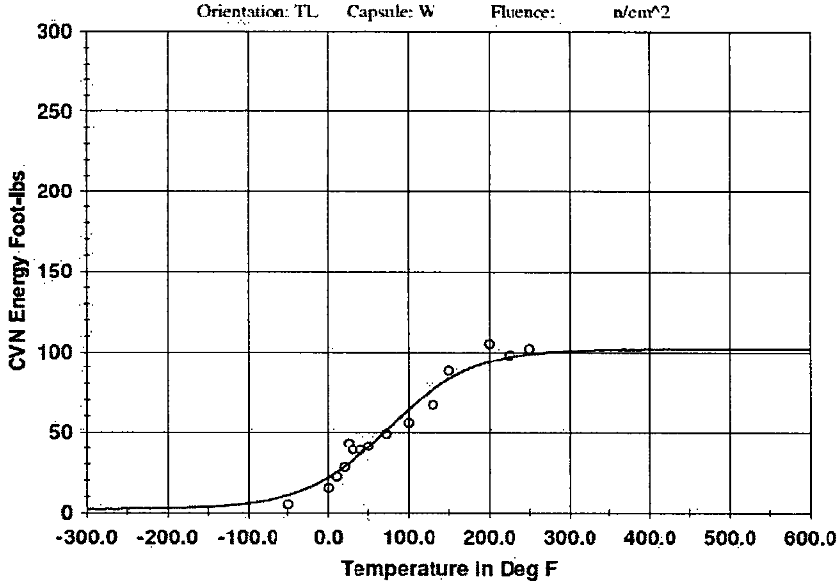
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
125.00	80.00	75.42	4.58
150.00	90.00	84.83	5.17
200.00	100.00	94.90	5.10
225.00	100.00	97.13	2.87
250.00	100.00	98.41	1.59
260.00	100.00	98.74	1.26

Correlation Coefficient = .993

Capsule W Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 08:26 AM
Page 1
Coefficients of Curve 1
A = 52.1 B = 49.9 C = 104.46 T0 = 73.98 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=102.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=24.3 Deg F Temp@50 ft-lbs=69.6 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	5.00	10.70	-5.70
.00	15.00	21.68	-6.68
10.00	22.00	24.86	-2.86
20.00	28.00	28.39	-.39
25.00	43.00	30.28	12.72
30.00	39.00	32.25	6.75
40.00	39.00	36.42	2.58
50.00	41.00	40.84	.16
72.00	49.00	51.16	-2.16

Capsule W Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: W Fluence: n/cm^2

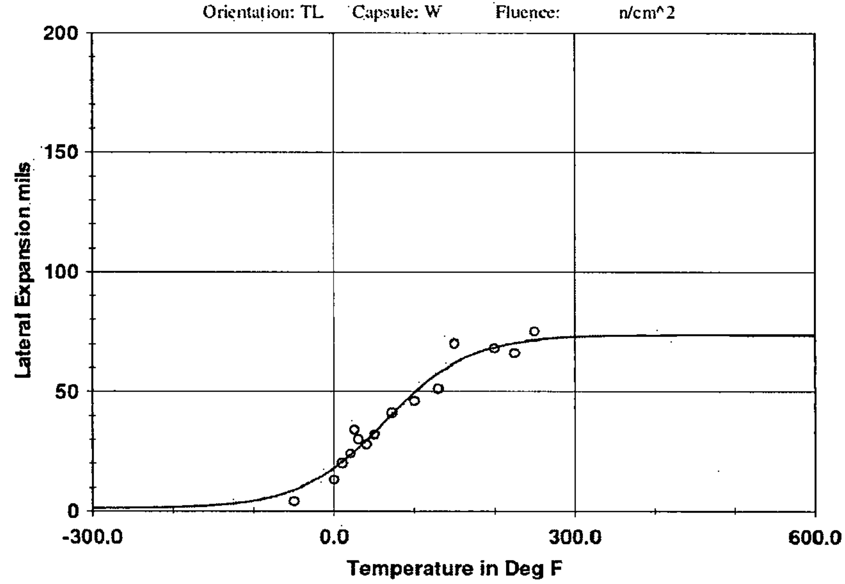
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
100.00	56.00	64.28	-8.28
130.00	67.00	76.56	-9.56
150.00	88.00	83.12	4.88
200.00	105.00	93.80	11.20
225.00	98.00	96.75	1.25
250.00	102.00	98.68	3.32

Correlation Coefficient = .979

Capsule W Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 03:41 PM
Page 1
Coefficients of Curve 1
A = 37.29 B = 36.29 C = 106.52 T0 = 62.72 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=73.6 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=56.0 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-50.00	4.00	8.80	-4.80
.00	13.00	18.09	-5.09
10.00	20.00	20.67	-.67
20.00	24.00	23.47	.53
25.00	34.00	24.95	9.05
30.00	30.00	26.48	3.52
40.00	28.00	29.67	-1.67
50.00	32.00	32.98	-.98
72.00	41.00	40.45	.55

Capsule W Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: W Fluence: n/cm^2

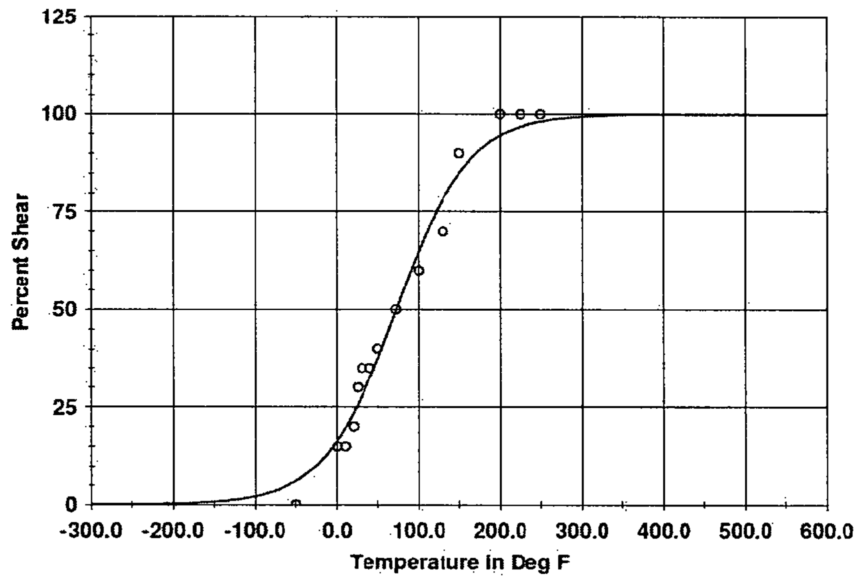
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
100.00	46.00	49.50	-3.50
130.00	51.00	57.58	-6.58
150.00	70.00	61.78	8.22
200.00	68.00	68.46	-.46
225.00	66.00	70.29	-4.29
250.00	75.00	71.49	3.51

Correlation Coefficient = .978

Capsule W Intermediate Shell Plate R1606-2 (Transverse)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/25/2012 04:34 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 89.27 T0 = 72.52 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 72.6
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-50.00	.00	6.04	-6.04
.00	15.00	16.45	-1.45
10.00	15.00	19.77	-4.77
20.00	20.00	23.56	-3.56
25.00	30.00	25.64	4.36
30.00	35.00	27.83	7.17
40.00	35.00	32.55	2.45
50.00	40.00	37.65	2.35
72.00	50.00	49.71	.29

Capsule W Intermediate Shell Plate R1606-2 (Transverse)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: TL Capsule: W Fluence: n/cm^2

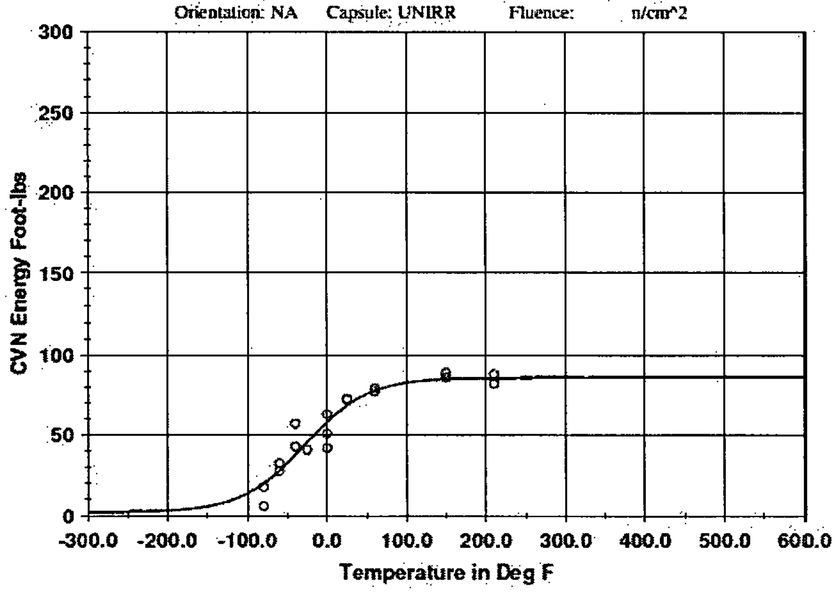
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
100.00	60.00	64.92	-4.92
130.00	70.00	78.38	-8.38
150.00	90.00	85.02	4.98
200.00	100.00	94.56	5.44
225.00	100.00	96.82	3.18
250.00	100.00	98.16	1.84

Correlation Coefficient = .991

Unirradiated (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:54 PM
Page 1
Coefficients of Curve 1
A = 44.1 B = 41.9 C = 79.68 T0 = -28.16 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=86.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-56.0 Deg F Temp@50 ft-lbs=-16.8 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	6.00	20.13	-14.13
-80.00	18.00	20.13	-2.13
-60.00	32.50	28.19	4.31
-60.00	28.00	28.19	-.19
-40.00	43.00	37.92	5.08
-40.00	57.00	37.92	19.08
-25.00	41.00	45.76	-4.76
.00	51.00	58.32	-7.32
.00	63.00	58.32	4.68

Unirradiated (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

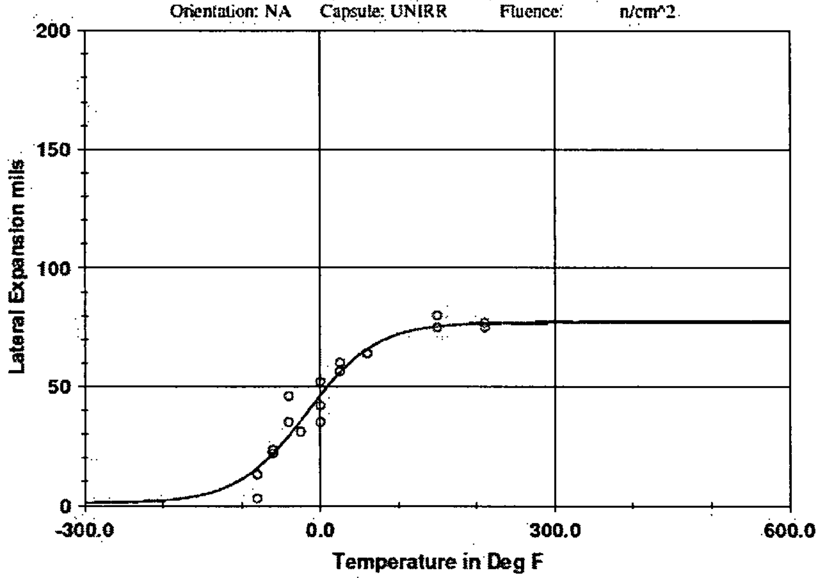
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	42.00	58.32	-16.32
25.00	72.00	68.53	3.47
25.00	72.50	68.53	3.97
60.00	79.00	77.74	1.26
60.00	77.00	77.74	-.74
150.00	86.00	85.05	.95
150.00	89.00	85.05	3.95
210.00	82.00	85.79	-3.79
210.00	88.00	85.79	2.21

Correlation Coefficient = .952

Unirradiated (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 03:03 PM
Page 1
Coefficients of Curve 1
A = 39.09 B = 38.09 C = 88.21 T0 = -17.08 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=77.2 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-26.6 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	3.00	15.75	-12.75
-80.00	13.00	15.75	-2.75
-60.00	22.00	21.90	.10
-60.00	23.50	21.90	1.60
-40.00	35.00	29.41	5.59
-40.00	46.00	29.41	16.59
-25.00	31.00	35.69	-4.69
.00	42.00	46.38	-4.38
.00	52.00	46.38	5.62

Unirradiated (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

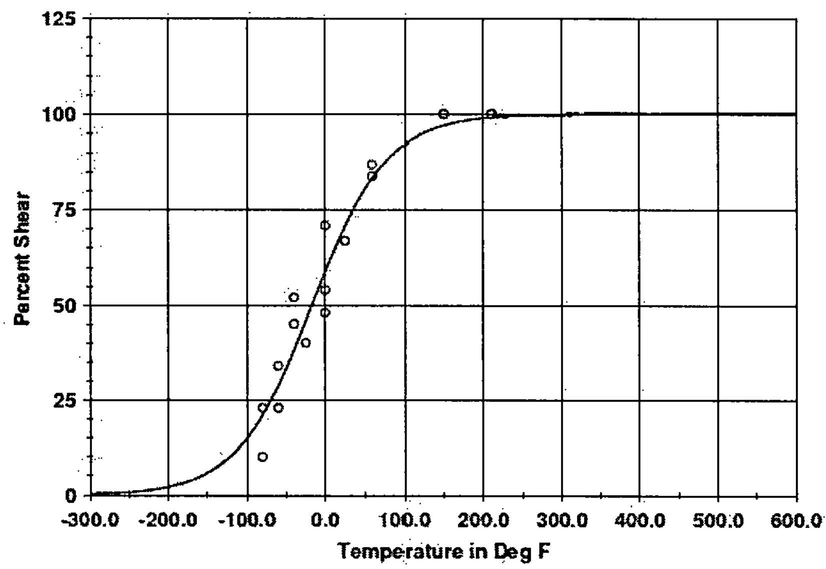
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	35.00	46.38	-11.38
25.00	60.00	56.01	3.99
25.00	56.50	56.01	.49
60.00	64.00	65.89	-1.89
60.00	64.00	65.89	-1.89
150.00	75.00	75.50	-.50
150.00	80.00	75.50	4.50
210.00	75.00	76.75	-1.75
210.00	77.00	76.75	.25

Correlation Coefficient = .960

Unirradiated (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:20 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 95.44 T0 = -17.12 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -17.1
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	10.00	21.12	-11.12
-80.00	23.00	21.12	1.88
-60.00	34.00	28.93	5.07
-60.00	23.00	28.93	-5.93
-40.00	45.00	38.24	6.76
-40.00	52.00	38.24	13.76
-25.00	40.00	45.88	-5.88
.00	48.00	58.87	-10.87
.00	71.00	58.87	12.13

Unirradiated (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

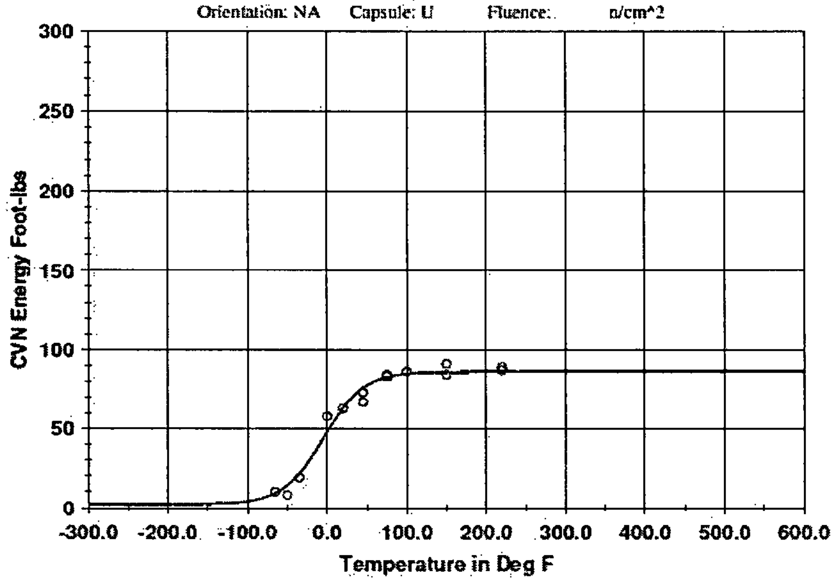
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	54.00	58.87	-4.87
25.00	67.00	70.74	-3.74
25.00	67.00	70.74	-3.74
60.00	84.00	83.43	.57
60.00	87.00	83.43	3.57
150.00	100.00	97.07	2.93
150.00	100.00	97.07	2.93
210.00	100.00	99.15	.85
210.00	100.00	99.15	.85

Correlation Coefficient = .972

Capsule U (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:52 PM
Page 1
Coefficients of Curve 1
A = 44.1 B = 41.9 C = 50.19 T0 = -4.99 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=86.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-22.5 Deg F Temp@50 ft-lbs=2.2 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-65.00	10.00	9.23	.77
-50.00	8.00	14.15	-6.15
-35.00	19.00	21.66	-2.66
.00	58.00	48.25	9.75
20.00	63.00	63.40	-.40
45.00	73.00	75.94	-2.94
45.00	67.00	75.94	-8.94
75.00	84.00	82.68	1.32
75.00	83.00	82.68	.32

Capsule U (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: U Fluence: n/cm^2

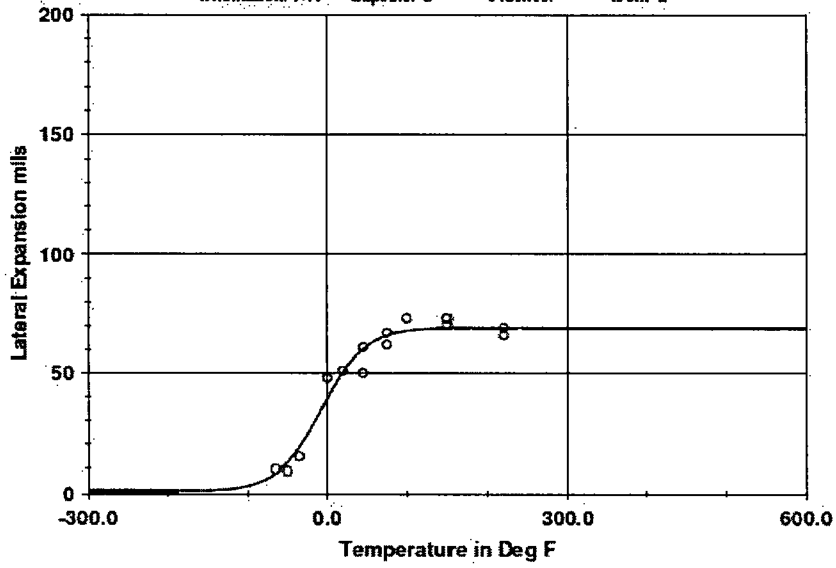
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
100.00	86.00	84.74	-1.26
150.00	84.00	85.83	-1.83
150.00	91.00	85.83	5.17
220.00	87.00	85.99	1.01
220.00	89.00	85.99	3.01

Correlation Coefficient = .989

Capsule U (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 03:00 PM
Page 1
Coefficients of Curve 1
A = 35.06 B = 34.06 C = 54.86 T0 = -6.9 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=69.1 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-7.0 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-65.00	10.00	8.31	1.69
-50.00	9.00	12.72	-3.72
-35.00	15.00	19.00	-4.00
.00	48.00	39.33	8.67
20.00	51.00	50.55	.45
45.00	61.00	60.21	.79
45.00	50.00	60.21	-10.21
75.00	62.00	65.86	-3.86
75.00	67.00	65.86	1.14

Capsule U (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: U Fluence: n/cm^2

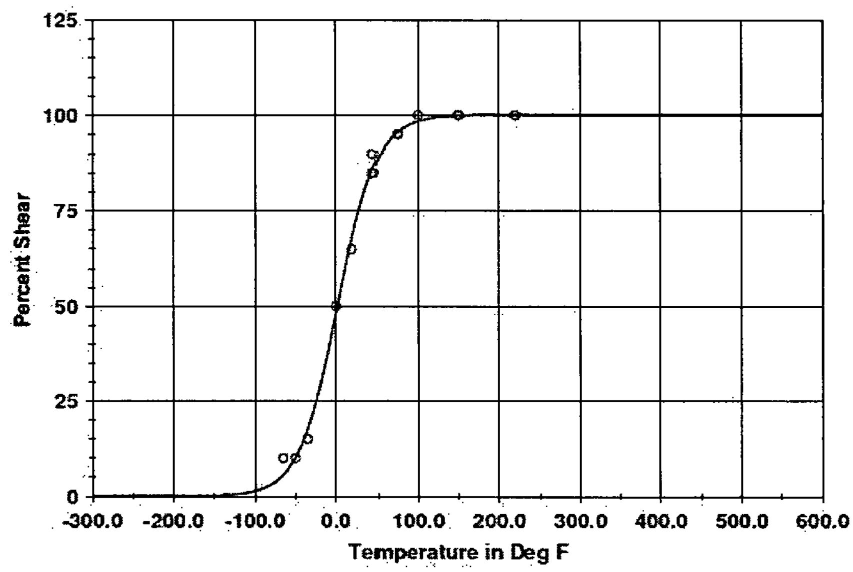
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
100.00	73.00	67.77	5.23
150.00	73.00	68.91	4.09
150.00	70.00	68.91	1.09
220.00	66.00	69.11	-3.11
220.00	69.00	69.11	-.11

Correlation Coefficient = .980

Capsule U (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:17 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 47.58 T0 = 1.87 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = 1.9
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-65.00	10.00	5.67	4.33
-50.00	10.00	10.15	-.15
-35.00	15.00	17.51	-2.51
.00	50.00	48.04	1.96
20.00	65.00	68.18	-3.18
45.00	90.00	85.97	4.03
45.00	85.00	85.97	-.97
75.00	95.00	95.58	-.58
75.00	95.00	95.58	-.58

Capsule U (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: U Fluence: n/cm^2

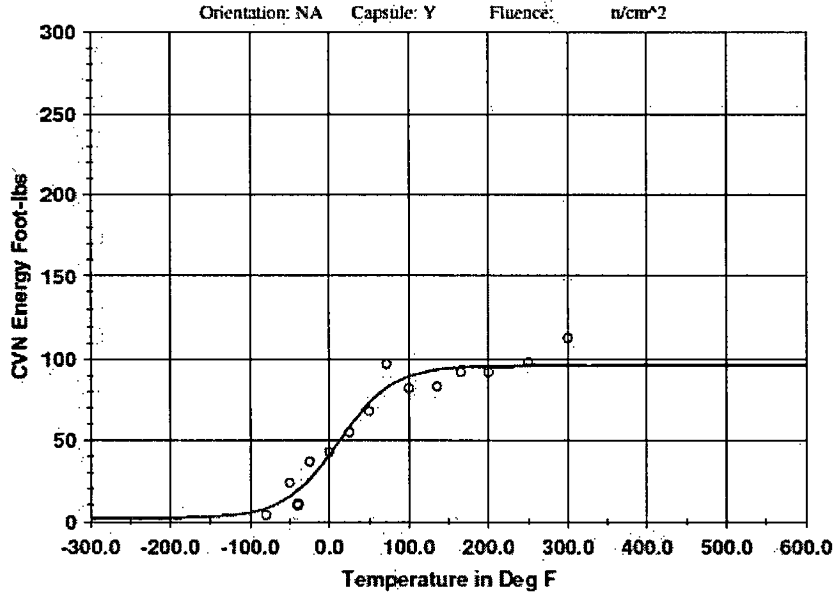
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
100.00	100.00	98.41	1.59
150.00	100.00	99.80	.20
150.00	100.00	99.80	.20
220.00	100.00	99.99	.01
220.00	100.00	99.99	.01

Correlation Coefficient = .998

Capsule Y (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:56 PM
Page 1
Coefficients of Curve 1
A = 49.1 B = 46.9 C = 68.71 T0 = 11.57 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=96.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-18.1 Deg F Temp@50 ft-lbs=12.9 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	4.00	8.30	-4.30
-50.00	24.00	15.59	8.41
-40.00	11.00	19.29	-8.29
-40.00	10.00	19.29	-9.29
-25.00	37.00	26.25	10.75
.00	43.00	41.27	1.73
25.00	55.00	58.15	-3.15
50.00	68.00	72.90	-4.90
72.00	97.00	82.22	14.78

Capsule Y (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: Y Fluence: n/cm^2

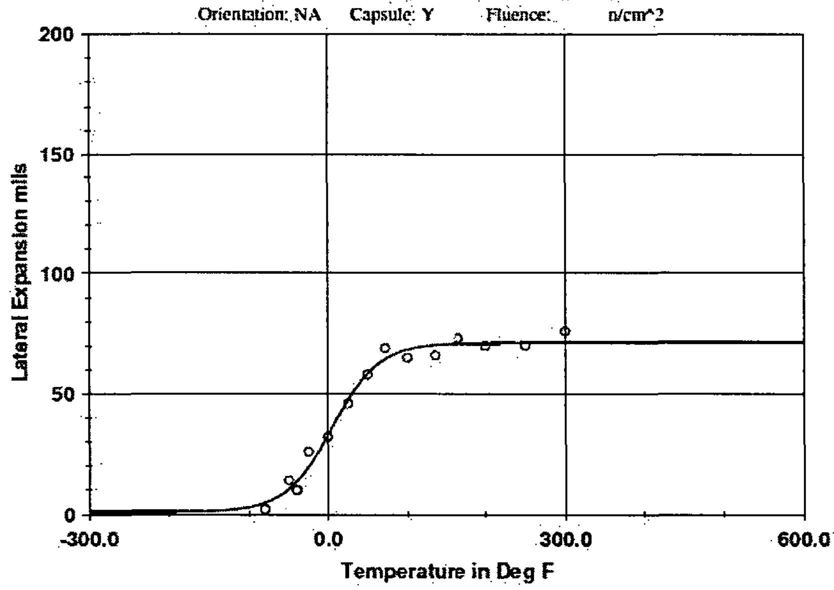
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
100.00	82.00	89.36	-7.36
135.00	83.00	93.49	-10.49
165.00	92.00	94.93	-2.93
200.00	92.00	95.61	-3.61
250.00	98.00	95.91	2.09
300.00	113.00	95.98	17.02

Correlation Coefficient = .971

Capsule Y (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 03:04 PM
Page 1
Coefficients of Curve 1
A = 36.1 B = 35.1 C = 59.45 T0 = 5.16 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=71.2 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=3.3 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-80.00	2.00	4.79	-2.79
-50.00	14.00	10.49	3.51
-40.00	10.00	13.61	-3.61
-40.00	10.00	13.61	-3.61
-25.00	26.00	19.68	6.32
.00	32.00	33.07	-1.07
25.00	46.00	47.40	-1.40
50.00	58.00	58.49	-.49
72.00	69.00	64.51	4.49

Capsule Y (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: Y Fluence: n/cm^2

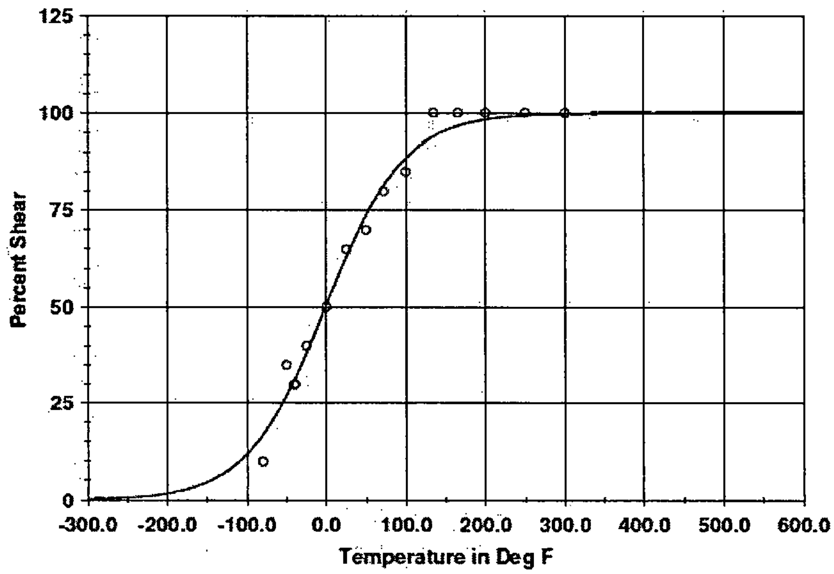
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
100.00	65.00	68.43	-3.43
135.00	66.00	70.33	-4.33
165.00	73.00	70.88	2.12
200.00	70.00	71.11	-1.11
250.00	70.00	71.19	-1.19
300.00	76.00	71.20	4.80

Correlation Coefficient = .992

Capsule Y (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:19 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 98.64 T0 = -1.12 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -1.1
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-80.00	10.00	16.81	-6.81
-50.00	35.00	27.07	7.93
-40.00	30.00	31.25	-1.25
-40.00	30.00	31.25	-1.25
-25.00	40.00	38.13	1.87
.00	50.00	50.57	-.57
25.00	65.00	62.94	2.06
50.00	70.00	73.82	-3.82
72.00	80.00	81.50	-1.50

Capsule Y (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: Y Fluence: n/cm^2

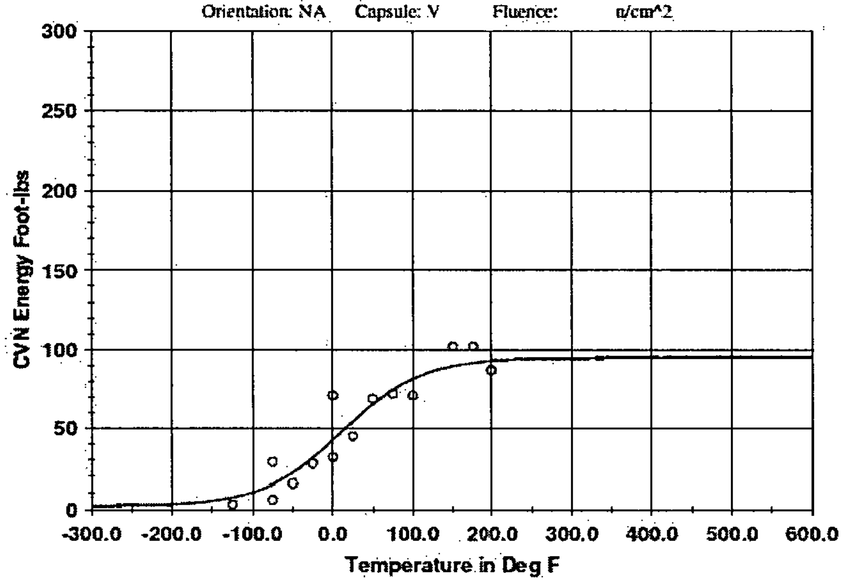
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
100.00	85.00	88.60	-3.60
135.00	100.00	94.05	5.95
165.00	100.00	96.67	3.33
200.00	100.00	98.33	1.67
250.00	100.00	99.39	.61
300.00	100.00	99.78	.22

Correlation Coefficient = .993

Capsule V (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:55 PM
Page 1
Coefficients of Curve 1
A = 48.6 B = 46.4 C = 98.5 T0 = 12.44 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=95.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-29.3 Deg F Temp@50 ft-lbs=15.5 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-125.00	3.00	7.57	-4.57
-75.00	29.00	15.64	13.36
-75.00	6.00	15.64	-9.64
-50.00	16.00	22.58	-6.58
-25.00	28.00	31.77	-3.77
.00	32.00	42.77	-10.77
.00	71.00	42.77	28.23
25.00	45.00	54.48	-9.48
50.00	69.00	65.48	3.52

Capsule V (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: V Fluence: n/cm^2

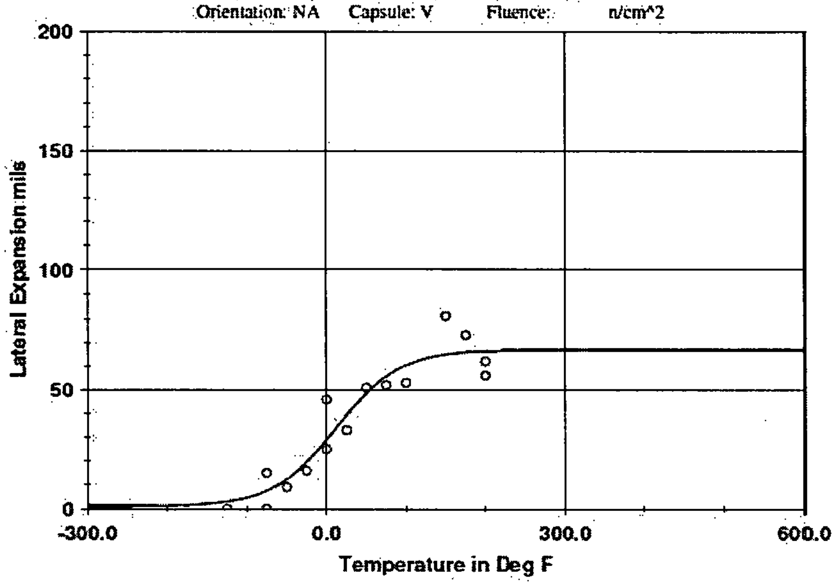
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
75.00	72.00	74.66	-2.66
100.00	71.00	81.58	-10.58
150.00	102.00	89.64	12.36
175.00	102.00	91.70	10.30
200.00	87.00	92.99	-5.99
200.00	87.00	92.99	-5.99

Correlation Coefficient = .942

Capsule V (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 03:02 PM
Page 1
Coefficients of Curve 1
A = 33.95 B = 32.95 C = 79.32 T0 = 11.89 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=66.9 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=14.5 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-125.00	.00	3.02	-3.02
-75.00	15.00	7.63	7.37
-75.00	.00	7.63	-7.63
-50.00	9.00	12.44	-3.44
-25.00	16.00	19.64	-3.64
.00	25.00	29.05	-4.05
.00	46.00	29.05	16.95
25.00	33.00	39.35	-6.35
50.00	51.00	48.67	2.33

Capsule V (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: V Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
75.00	52.00	55.75	-3.75
100.00	53.00	60.45	-7.45
150.00	81.00	64.93	16.07
175.00	73.00	65.84	7.16
200.00	62.00	66.33	-4.33
200.00	56.00	66.33	-10.33

Correlation Coefficient = .946

Capsule V (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:18 PM

Page 1

Coefficients of Curve 1

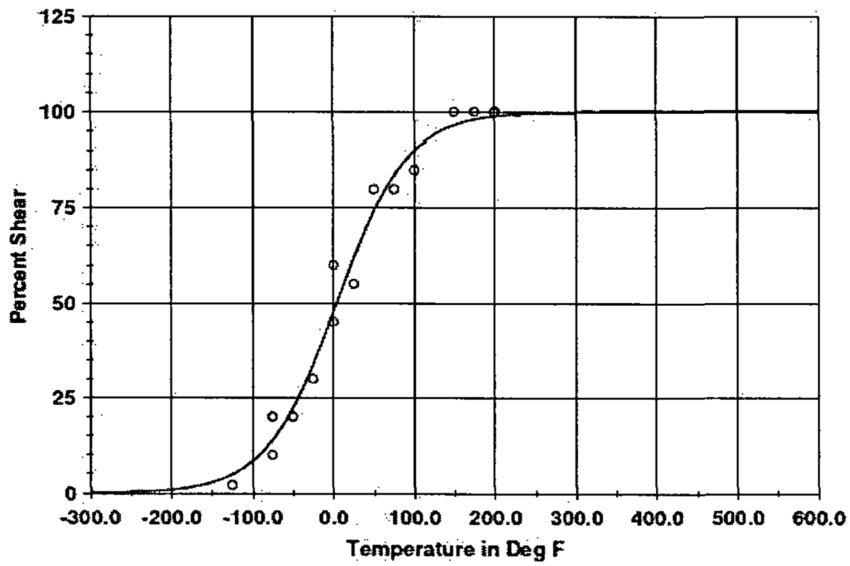
A = 50. B = 50. C = 86.92 T0 = 4.11 D = 0.00E+00

Equation is A + B * [Tanh((T-To)/(C+DT))]

Temperature at 50% Shear = 4.2

Plant: South Texas 1 Material: SAW Heat: 89476

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



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-125.00	2.00	4.88	-2.88
-75.00	10.00	13.94	-3.94
-75.00	20.00	13.94	6.06
-50.00	20.00	22.36	-2.36
-25.00	30.00	33.86	-3.86
.00	45.00	47.64	-2.64
.00	60.00	47.64	12.36
25.00	55.00	61.79	-6.79
50.00	80.00	74.19	5.81

Capsule V (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: V Fluence: n/cm^2

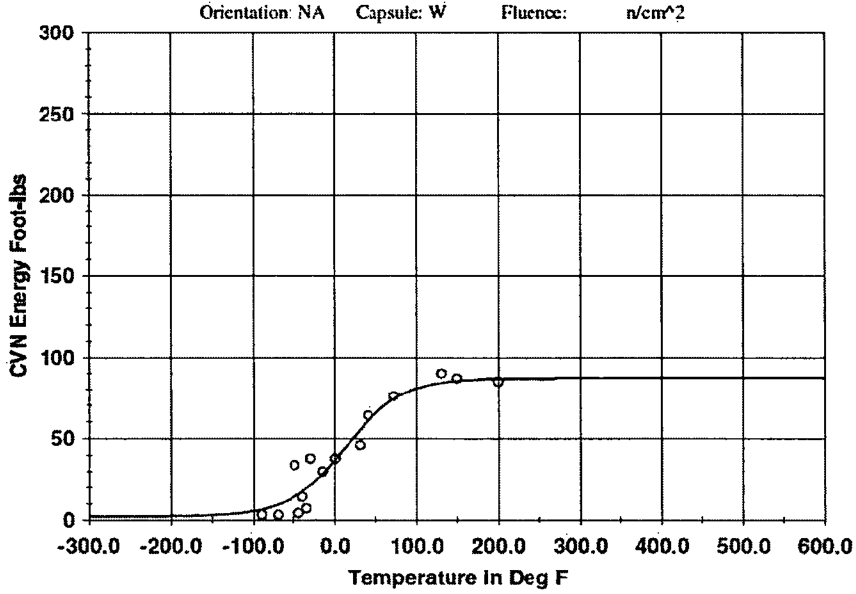
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
75.00	80.00	83.63	-3.63
100.00	85.00	90.08	-5.08
150.00	100.00	96.63	3.37
175.00	100.00	98.08	1.92
200.00	100.00	98.91	1.09
200.00	100.00	98.91	1.09

Correlation Coefficient = .990

Capsule W (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 08:27 AM
Page 1
Coefficients of Curve 1
A = 44.6 B = 42.4 C = 68.86 T0 = 12.23 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=87.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-12.4 Deg F Temp@50 ft-lbs=21.1 Deg F
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-90.00	3.00	6.34	-3.34
-70.00	3.00	9.33	-6.33
-50.00	34.00	14.15	19.85
-45.00	4.00	15.72	-11.72
-40.00	14.00	17.45	-3.45
-35.00	7.00	19.36	-12.36
-30.00	38.00	21.43	16.57
-15.00	30.00	28.65	1.35
.00	38.00	37.14	.86

Capsule W (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: W Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
30.00	46.00	55.30	-9.30
40.00	64.00	60.83	3.17
72.00	76.00	74.29	1.71
130.00	90.00	84.31	5.69
150.00	87.00	85.48	1.52
200.00	85.00	86.64	-1.64

Correlation Coefficient = .960

Capsule W (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 03:53 PM

Page 1

Coefficients of Curve 1

A = 38.48 B = 37.48 C = 82.43 T0 = 17.6 D = 0.00E+00

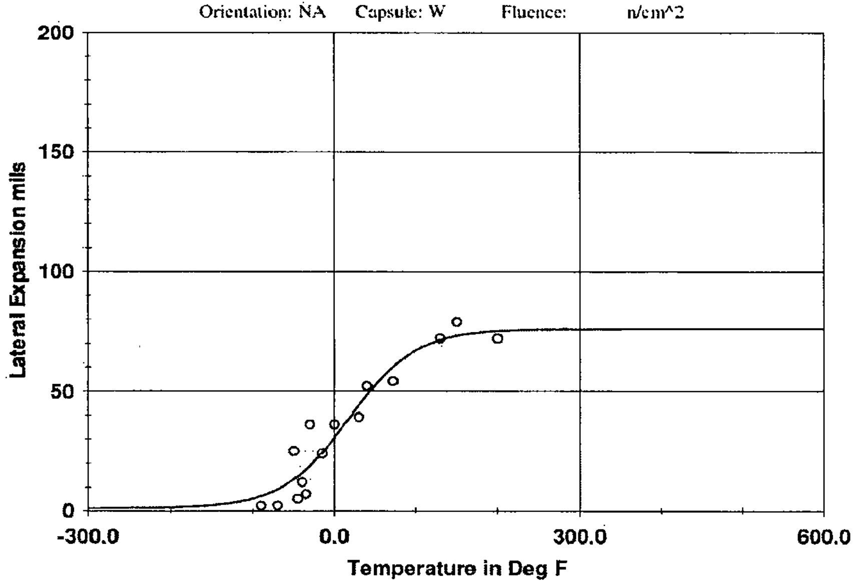
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf L.E.=76.0 Lower Shelf L.E.=1.0(Fixed)

Temp.@L.E. 35 mils=10.0 Deg F

Plant: South Texas 1 Material: SAW Heat: 89476

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



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-90.00	2.00	6.13	-4.13
-70.00	2.00	8.99	-6.99
-50.00	25.00	13.18	11.82
-45.00	5.00	14.47	-9.47
-40.00	12.00	15.86	-3.86
-35.00	7.00	17.36	-10.36
-30.00	36.00	18.96	17.04
-15.00	24.00	24.39	-.39
.00	36.00	30.60	5.40

Capsule W (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: W Fluence: n/cm^2

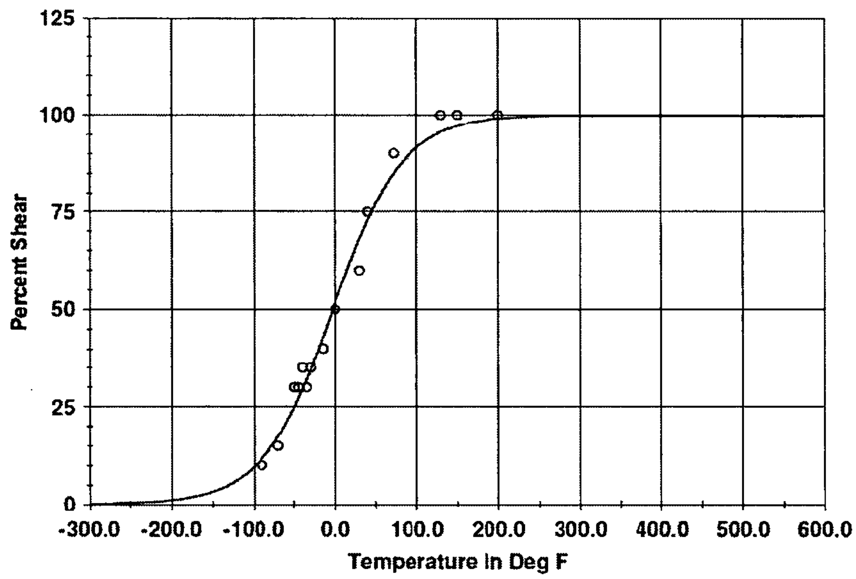
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
30.00	39.00	44.08	-5.08
40.00	52.00	48.43	3.57
72.00	54.00	60.16	-6.16
130.00	72.00	71.36	.64
150.00	79.00	73.06	5.94
200.00	72.00	75.08	-3.08

Correlation Coefficient = .956

Capsule W (Weld)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/25/2012 04:39 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 86.38 T0 = -2.83 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -2.8
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-90.00	10.00	11.73	-1.73
-70.00	15.00	17.43	-2.43
50.00	30.00	25.12	4.88
-45.00	30.00	27.36	2.64
-40.00	35.00	29.72	5.28
-35.00	30.00	32.19	-2.19
30.00	35.00	34.77	.23
-15.00	40.00	43.00	-3.00
.00	50.00	51.64	-1.64

Capsule W (Weld)

Page 2
Plant: South Texas 1 Material: SAW Heat: 89476
Orientation: NA Capsule: W Fluence: n/cm^2

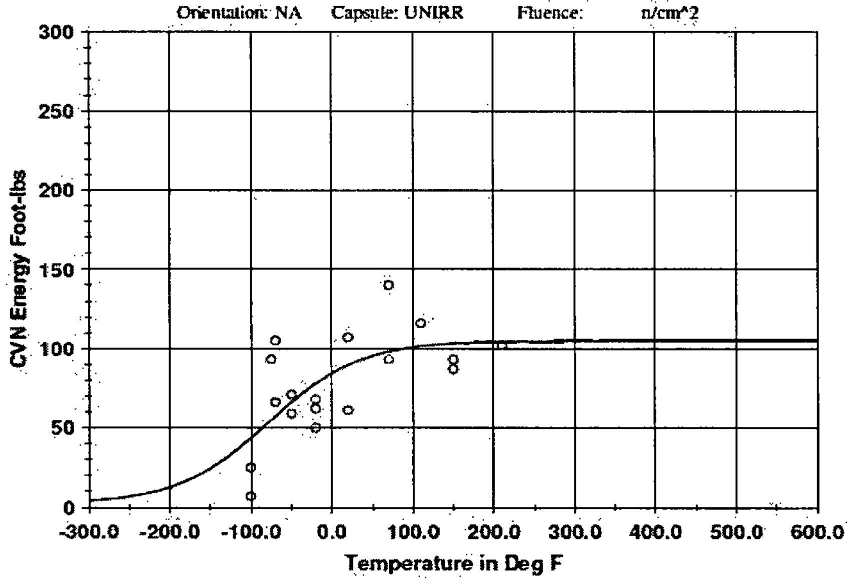
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
30.00	60.00	68.14	-8.14
40.00	75.00	72.94	2.06
72.00	90.00	84.97	5.03
130.00	100.00	95.59	4.41
150.00	100.00	97.18	2.82
200.00	100.00	99.10	.90

Correlation Coefficient = .993

Unirradiated (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:37 PM
Page 1
Coefficients of Curve 1
A = 53.6 B = 51.4 C = 112.83 T0 = -78.19 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=105.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-134.1 Deg F Temp@50 ft-lbs=-86.1 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	25.00	43.79	-18.79
-100.00	7.00	43.79	-36.79
-75.00	93.00	55.05	37.95
-70.00	105.00	57.32	47.68
-70.00	66.00	57.32	8.68
-50.00	59.00	66.18	-7.18
-50.00	71.00	66.18	4.82
-20.00	50.00	77.98	-27.98
-20.00	68.00	77.98	-9.98

Unirradiated (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-20.00	62.00	77.98	-15.98
20.00	107.00	89.66	17.34
20.00	61.00	89.66	-28.66
70.00	140.00	98.07	41.93
70.00	93.00	98.07	-5.07
110.00	116.00	101.47	14.53
150.00	93.00	103.23	-10.23
150.00	87.00	103.23	-16.23
210.00	102.00	104.38	-2.38

Correlation Coefficient = .659

Unirradiated (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:28 PM

Page 1

Coefficients of Curve 1

A = 37.55 B = 36.55 C= 109.93 T0 = -50.9 D = 0.00E+00

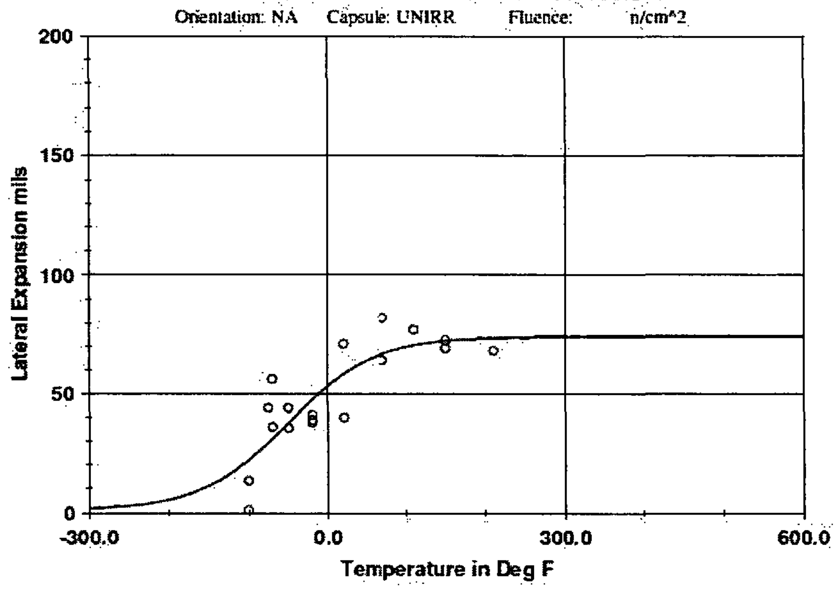
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf L.E.=74.1 Lower Shelf L.E.=1.0(Fixed)

Temp.@L.E. 35 mils=-58.5 Deg F

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

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



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-100.00	13.50	22.23	-8.73
-100.00	1.00	22.23	-21.23
-75.00	44.00	29.66	14.34
-70.00	56.00	31.26	24.74
-70.00	36.00	31.26	4.74
-50.00	35.50	37.85	-2.35
-50.00	44.00	37.85	6.15
-20.00	38.00	47.56	-9.56
-20.00	41.00	47.56	-6.56

Unirradiated (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

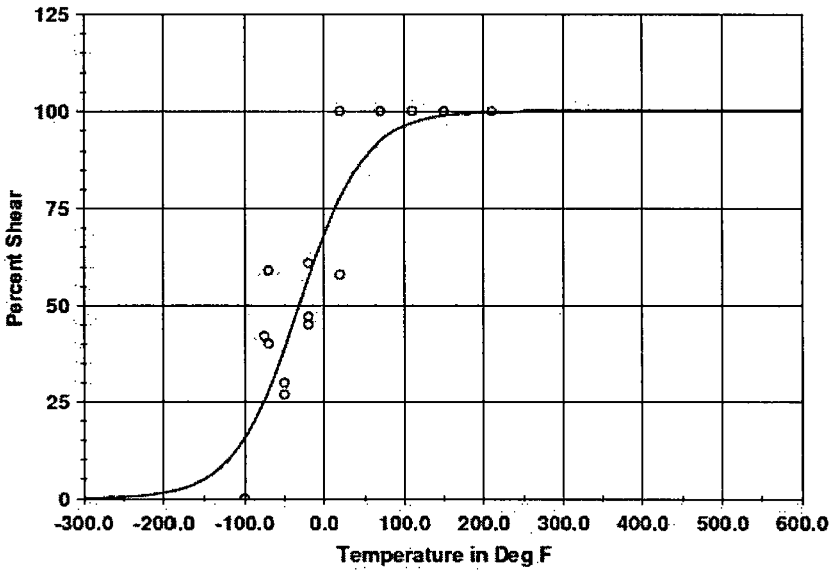
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-20.00	39.00	47.56	-8.56
20.00	71.00	58.32	12.68
20.00	40.00	58.32	-18.32
70.00	82.00	66.80	15.20
70.00	64.00	66.80	-2.80
110.00	77.00	70.38	6.62
150.00	72.50	72.25	.25
150.00	69.00	72.25	-3.25
210.00	68.00	73.47	-5.47

Correlation Coefficient = .840

Unirradiated (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:07 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 81.51 T0 = -31.39 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -31.3
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: UNIRR Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100.00	.00	15.66	-15.66
-100.00	.00	15.66	-15.66
-75.00	42.00	25.54	16.46
-70.00	59.00	27.94	31.06
-70.00	40.00	27.94	12.06
-50.00	27.00	38.78	-11.78
-50.00	30.00	38.78	-8.78
-20.00	61.00	56.94	4.06
-20.00	45.00	56.94	-11.94

Unirradiated (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: UNIRR Fluence: n/cm^2

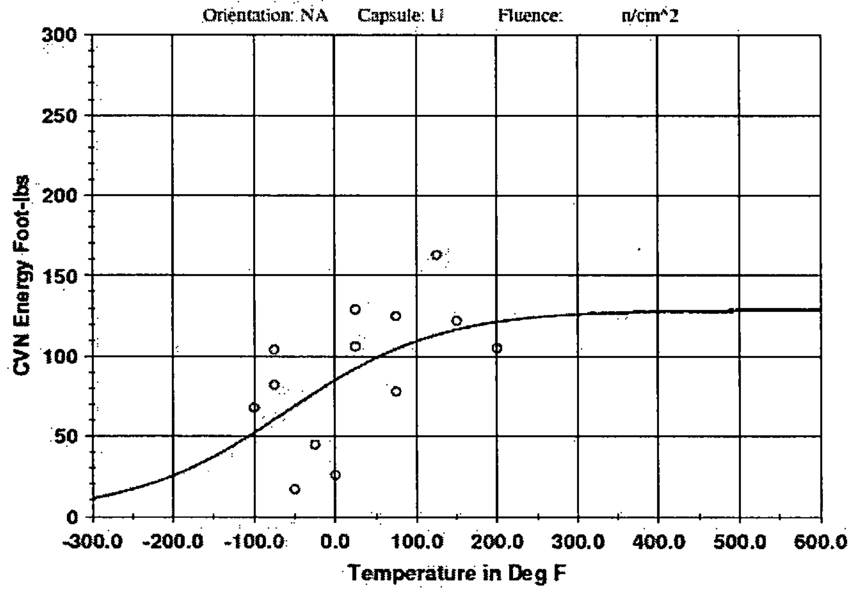
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-20.00	47.00	56.94	-9.94
20.00	100.00	77.92	22.08
20.00	58.00	77.92	-19.92
70.00	100.00	92.33	7.67
70.00	100.00	92.33	7.67
110.00	100.00	96.98	3.02
150.00	100.00	98.85	1.15
150.00	100.00	98.85	1.15
210.00	100.00	99.73	.27

Correlation Coefficient = .919

Capsule U (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:39 PM
Page 1
Coefficients of Curve 1
A = 65.6 B = 63.4 C = 188.42 T0 = -59.97 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=129.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-179.6 Deg F Temp@50 ft-lbs=-107.3 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	68.00	52.33	15.67
-75.00	82.00	60.55	21.45
-75.00	104.00	60.55	43.45
-50.00	17.00	68.95	-51.95
-25.00	45.00	77.24	-32.24
.00	26.00	85.13	-59.13
25.00	129.00	92.40	36.60
25.00	106.00	92.40	13.60
75.00	78.00	104.57	-26.57

Capsule U (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: U Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
75.00	125.00	104.57	20.43
125.00	163.00	113.39	49.61
150.00	122.00	116.68	5.32
200.00	105.00	121.45	-16.45

Correlation Coefficient = .554

Capsule U (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:30 PM

Page 1

Coefficients of Curve 1

A = 53.97 B = 52.97 C = 287.95 T0 = 32.7 D = 0.00E+00

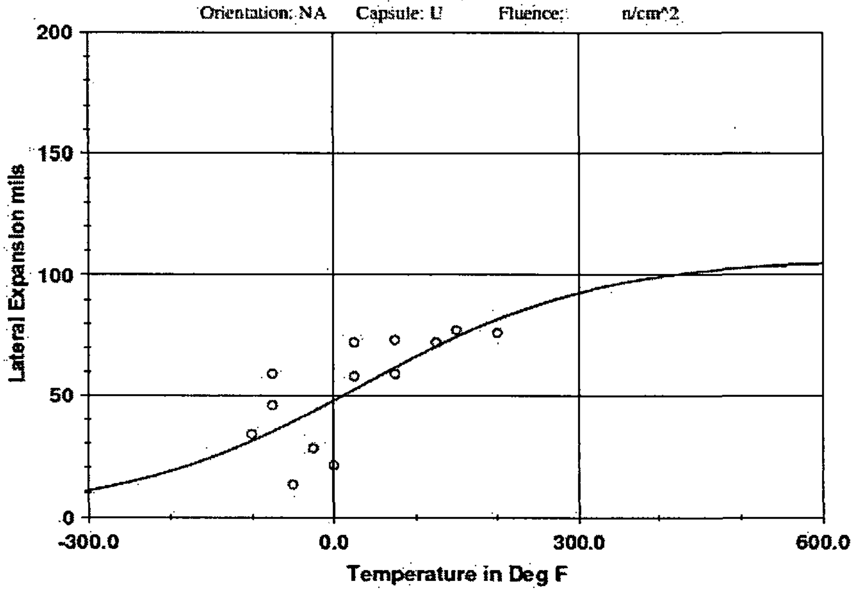
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf L.E.=106.9 Lower Shelf L.E.=1.0(Fixed)

Temp.@L.E. 35 mils=-75.1 Deg F

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

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



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-100.00	34.00	31.15	2.85
-75.00	46.00	35.03	10.97
-75.00	59.00	35.03	23.97
-50.00	13.00	39.16	-26.16
-25.00	28.00	43.49	-15.49
.00	21.00	47.98	-26.98
25.00	72.00	52.55	19.45
25.00	58.00	52.55	5.45
75.00	59.00	61.69	-2.69

Capsule U (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: U Fluence: n/cm^2

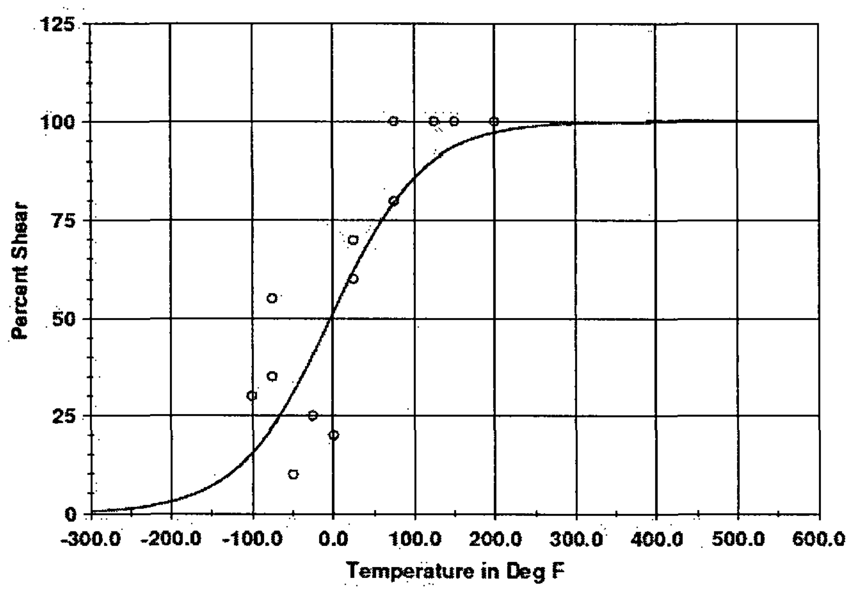
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
75.00	73.00	61.69	11.31
125.00	72.00	70.39	1.61
150.00	77.00	74.42	2.58
200.00	76.00	81.69	-5.69

Correlation Coefficient = .713

Capsule U (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:10 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 114.58 T0 = -2.95 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -2.9
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: U Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-100.00	30.00	15.53	14.47
-75.00	35.00	22.14	12.86
-75.00	55.00	22.14	32.86
-50.00	10.00	30.55	-20.55
-25.00	25.00	40.50	-15.50
.00	20.00	51.29	-31.29
25.00	70.00	61.96	8.04
25.00	60.00	61.96	-1.96
75.00	80.00	79.59	.41

Capsule U (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: U Fluence: n/cm^2

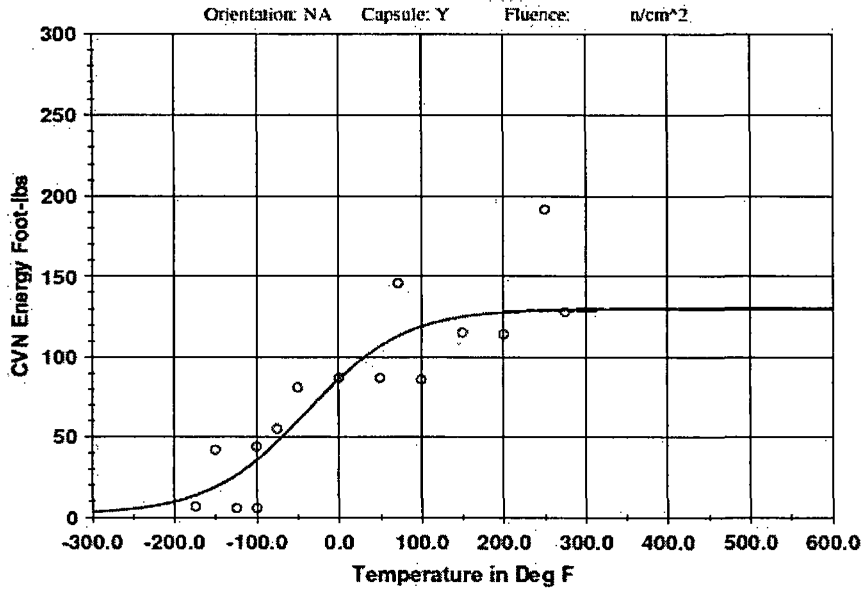
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
75.00	100.00	79.59	20.41
125.00	100.00	90.32	9.68
150.00	100.00	93.52	6.48
200.00	100.00	97.19	2.81

Correlation Coefficient = .859

Capsule Y (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:34 PM
Page 1
Coefficients of Curve 1
A = 66.1 B = 63.9 C = 118.53 T0 = -38.82 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=130.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-114.6 Deg F Temp@50 ft-lbs=-69.3 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-175.00	7.00	13.87	-6.87
-150.00	42.00	19.18	22.82
-125.00	6.00	26.40	-20.40
-100.00	6.00	35.76	-29.76
-100.00	44.00	35.76	8.24
-75.00	55.00	47.18	7.82
-50.00	81.00	60.09	20.91
.00	87.00	86.31	.69
50.00	87.00	106.66	-19.66

Capsule Y (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: Y Fluence: n/cm^2

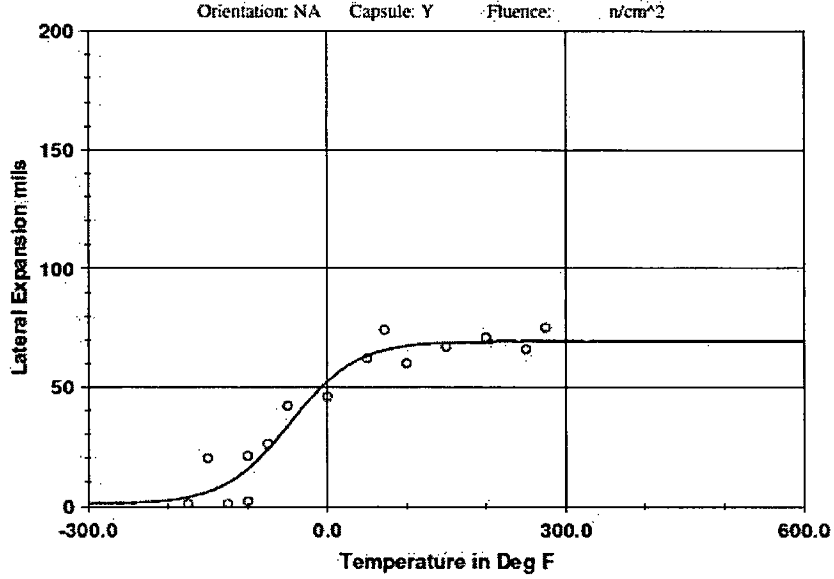
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
72.00	146.00	112.93	33.07
100.00	86.00	118.80	-32.80
150.00	115.00	124.93	-9.93
200.00	114.00	127.77	-13.77
250.00	192.00	129.03	62.97
275.00	128.00	129.36	-1.36

Correlation Coefficient = .883

Capsule Y (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:27 PM
Page 1
Coefficients of Curve 1
A = 35.18 B = 34.18 C = 82.88 T0 = -46.04 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=69.4 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-46.4 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: Y Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-175.00	1.00	3.91	-2.91
-150.00	20.00	6.14	13.86
-125.00	1.00	9.85	-8.85
-100.00	2.00	15.62	-13.62
-100.00	21.00	15.62	5.38
-75.00	26.00	23.70	2.30
-50.00	42.00	33.55	8.45
.00	46.00	52.43	-6.43
50.00	62.00	63.23	-1.23

Capsule Y (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: Y Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
72.00	74.00	65.62	8.38
100.00	60.00	67.40	-7.40
150.00	67.00	68.76	-1.76
200.00	71.00	69.18	1.82
250.00	66.00	69.31	-3.31
275.00	75.00	69.33	5.67

Correlation Coefficient = .964

Capsule Y (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:06 PM

Page 1

Coefficients of Curve 1

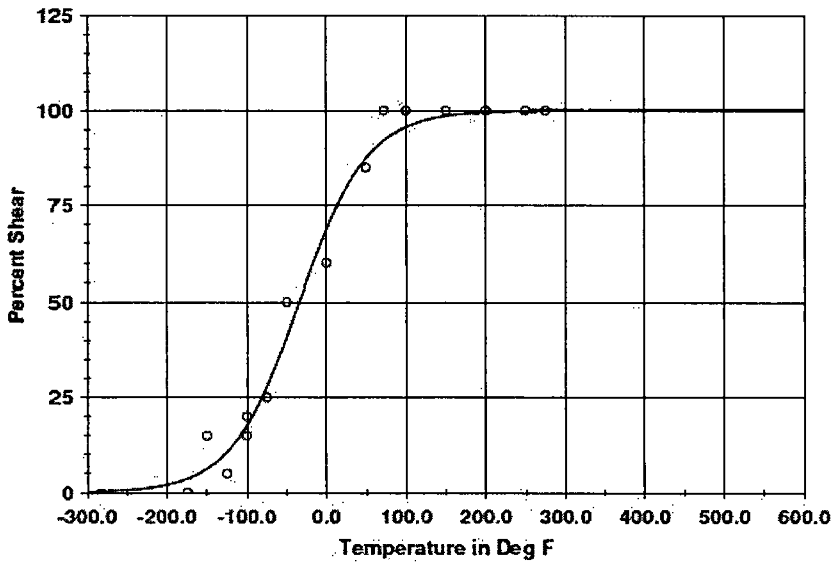
A = 50. B = 50. C = 86. T0 = -34.02 D = 0.00E+00

Equation is A + B * [Tanh((T-To)/(C+DT))]

Temperature at 50% Shear = -34.0

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

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



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-175.00	.00	3.63	-3.63
-150.00	15.00	6.32	8.68
-125.00	5.00	10.76	-5.76
-100.00	20.00	17.74	2.26
-100.00	15.00	17.74	-2.74
-75.00	25.00	27.83	-2.83
-50.00	50.00	40.82	9.18
.00	60.00	68.81	-8.81
50.00	85.00	87.59	-2.59

Capsule Y (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: Y Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
72.00	100.00	92.17	7.83
100.00	100.00	95.76	4.24
150.00	100.00	98.63	1.37
200.00	100.00	99.57	.43
250.00	100.00	99.86	.14
275.00	100.00	99.92	.08

Correlation Coefficient = .992

Capsule V (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 01:39 PM

Page 1

Coefficients of Curve 1

A = 54.6 B = 52.4 C = 86.31 T0 = -28.52 D = 0.00E+00

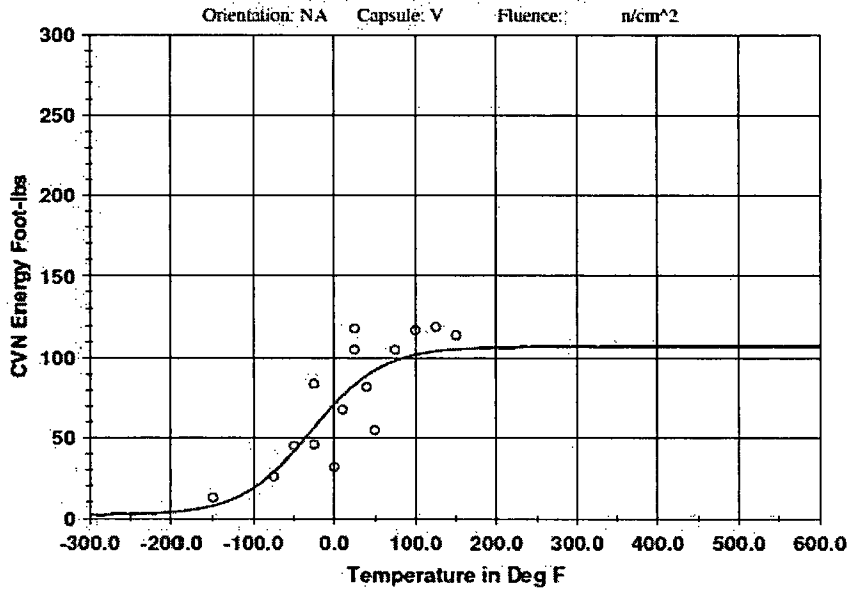
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=107.0(Fixed) Lower Shelf Energy=2.2(Fixed)

Temp@30 ft-lbs=-72.4 Deg F Temp@50 ft-lbs=-36.1 Deg F

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

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



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-150.00	13.00	8.12	4.88
-75.00	26.00	28.82	-2.82
-50.00	45.00	41.82	3.18
-25.00	46.00	56.74	-10.74
-25.00	84.00	56.74	27.26
.00	32.00	71.31	-39.31
10.00	68.00	76.55	-8.55
25.00	118.00	83.48	34.52
25.00	105.00	83.48	21.52

Capsule V (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: V Fluence: n/cm^2

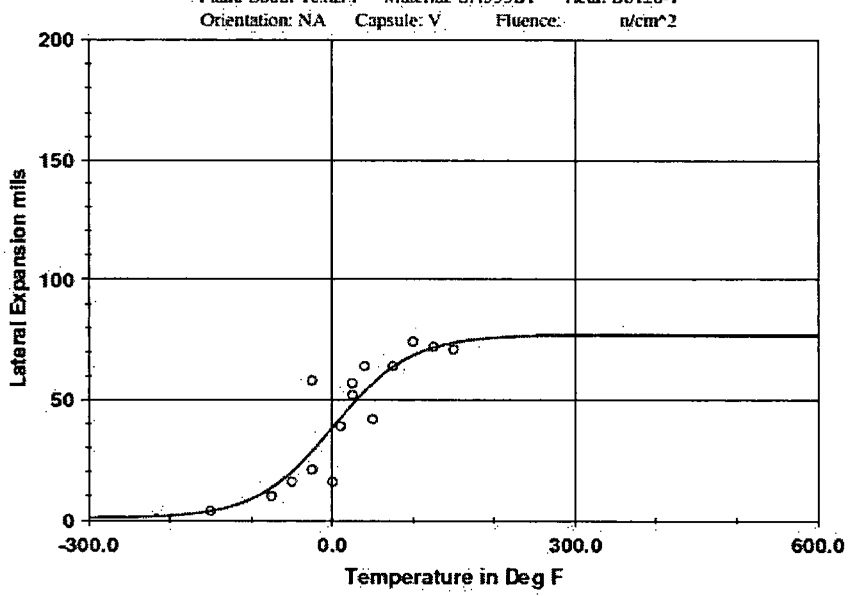
Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
40.00	82.00	89.22	-7.22
50.00	55.00	92.38	-37.38
75.00	105.00	98.27	6.73
100.00	117.00	101.93	15.07
125.00	119.00	104.10	14.90
150.00	114.00	105.35	8.65

Correlation Coefficient = .827

Capsule V (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:29 PM
Page 1
Coefficients of Curve 1
A = 38.91 B = 37.91 C = 94.27 T0 = 1.18 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf L.E.=76.8 Lower Shelf L.E.=1.0(Fixed)
Temp.@L.E. 35 mils=-8.5 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-150.00	4.00	3.95	.05
-75.00	10.00	13.56	-3.56
-50.00	16.00	20.13	-4.13
-25.00	21.00	28.64	-7.64
-25.00	58.00	28.64	29.36
.00	16.00	38.43	-22.43
10.00	39.00	42.44	-3.44
25.00	52.00	48.29	3.71
25.00	57.00	48.29	8.71

Capsule V (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: V Fluence: n/cm^2

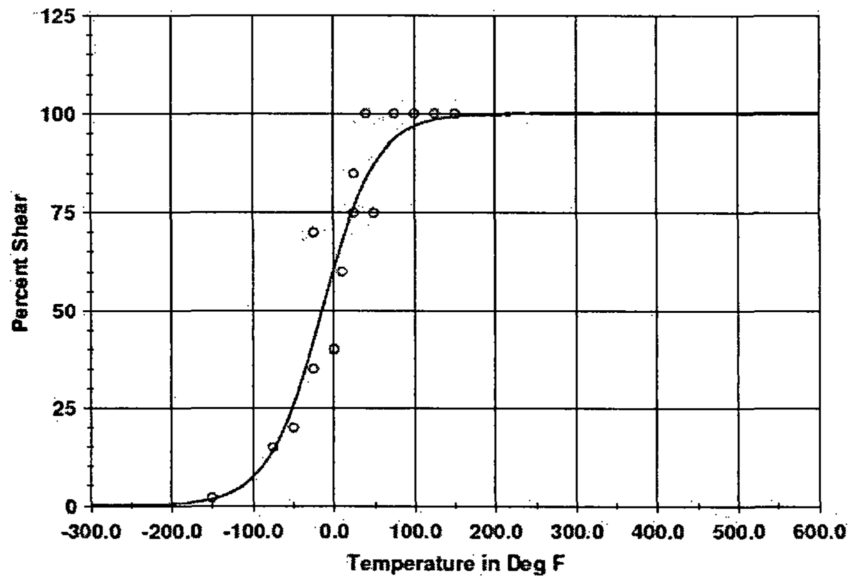
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
40.00	64.00	53.69	10.31
50.00	42.00	56.95	-14.95
75.00	64.00	63.72	.28
100.00	74.00	68.52	5.48
125.00	72.00	71.70	.30
150.00	71.00	73.72	-2.72

Correlation Coefficient = .880

Capsule V (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 09/01/2011 02:08 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 66.93 T0 = -14.6 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -14.6
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: V Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-150.00	2.00	1.72	.28
-75.00	15.00	14.13	.87
-50.00	20.00	25.78	-5.78
-25.00	35.00	42.30	-7.30
-25.00	70.00	42.30	27.70
.00	40.00	60.74	-20.74
10.00	60.00	67.59	-7.59
25.00	85.00	76.56	8.44
25.00	75.00	76.56	-1.56

Capsule V (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: V Fluence: n/cm^2

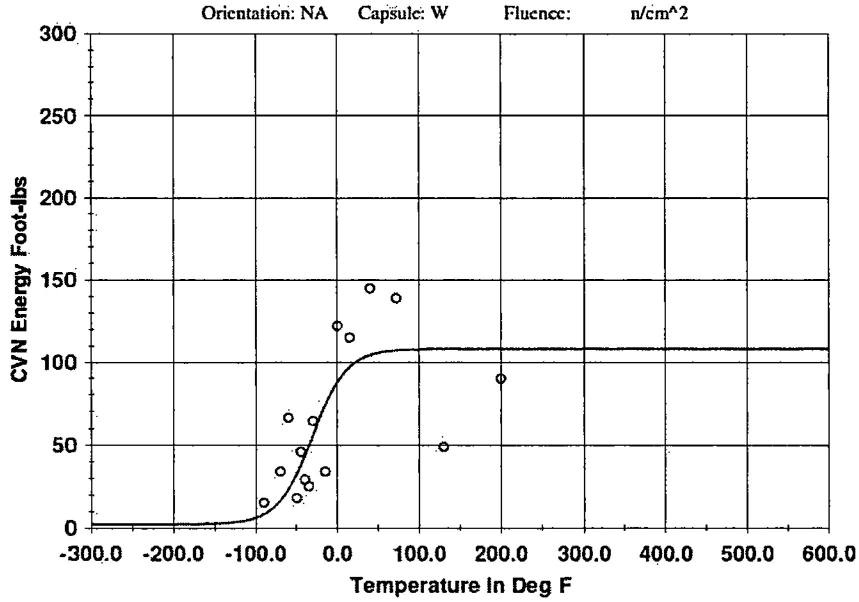
Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
40.00	100.00	83.64	16.36
50.00	75.00	87.33	-12.33
75.00	100.00	93.57	6.43
100.00	100.00	96.85	3.15
125.00	100.00	98.48	1.52
150.00	100.00	99.27	.73

Correlation Coefficient = .942

Capsule W (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/30/2012 09:07 AM
Page 1
Coefficients of Curve 1
A = 55.1 B = 52.9 C = 42.16 T0 = -30.8 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=108.0(Fixed) Lower Shelf Energy=2.2(Fixed)
Temp@30 ft-lbs=-52.5 Deg F Temp@50 ft-lbs=-34.8 Deg F
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-90.00	15.00	8.21	6.79
-70.00	34.00	16.45	17.55
-60.00	66.00	23.37	42.63
-50.00	18.00	32.54	-14.54
-45.00	46.00	37.92	8.08
-40.00	29.00	43.73	-14.73
-35.00	25.00	49.84	-24.84
-30.00	64.00	56.10	7.90
-15.00	34.00	74.04	-40.04

Capsule W (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: W Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	122.00	88.08	33.92
15.00	115.00	97.18	17.82
40.00	145.00	104.44	40.56
72.00	139.00	107.20	31.80
130.00	49.00	107.95	-58.95
200.00	90.00	108.00	-18.00

Correlation Coefficient = .744

Capsule W (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/26/2012 04:01 PM

Page 1

Coefficients of Curve 1

A = 34.85 B = 33.85 C = 42.45 T0 = -20.95 D = 0.00E+00

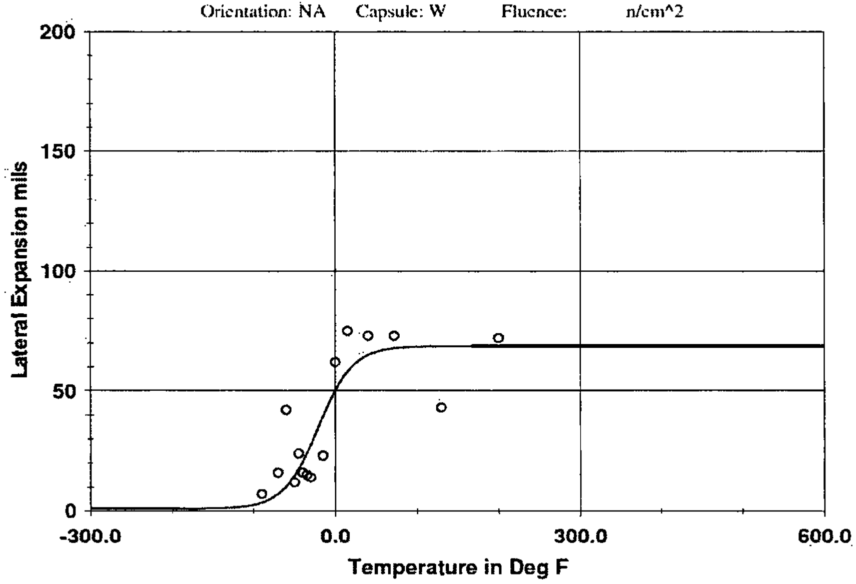
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf L.E.=68.7 Lower Shelf L.E.=1.0(Fixed)

Temp.@L.E. 35 mils=-20.7 Deg F

Plant: South Texas 1 Material: SA533B1 Heat: B8120-1

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



Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
-90.00	7.00	3.52	3.48
-70.00	16.00	7.11	8.89
-60.00	42.00	10.28	31.72
-50.00	12.00	14.73	-2.73
-45.00	24.00	17.49	6.51
-40.00	16.00	20.60	-4.60
-35.00	15.00	24.04	-9.04
-30.00	14.00	27.74	-13.74
-15.00	23.00	39.57	-16.57

Capsule W (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: W Fluence: n/cm^2

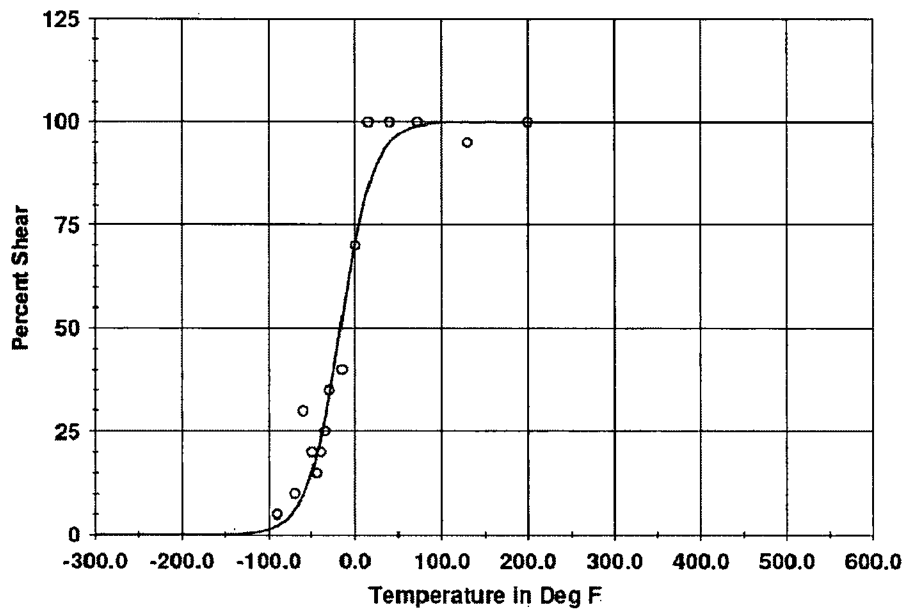
Charpy V-Notch Data

Temperature	Input L.E.	Computed L.E.	Differential
.00	62.00	50.32	11.68
15.00	75.00	58.19	16.81
40.00	73.00	65.07	7.93
72.00	73.00	67.86	5.14
130.00	43.00	68.64	-25.64
200.00	72.00	68.70	3.30

Correlation Coefficient = .845

Capsule W (Heat Affected Zone)

CVGRAPH 5.3 Hyperbolic Tangent Curve Printed on 01/25/2012 04:41 PM
Page 1
Coefficients of Curve 1
A = 50. B = 50. C = 38.56 T0 = -17.13 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Temperature at 50% Shear = -17.1
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: W Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
-90.00	5.00	2.23	2.77
-70.00	10.00	6.05	3.95
-60.00	30.00	9.77	20.23
-50.00	20.00	15.38	4.62
-45.00	15.00	19.07	-4.07
-40.00	20.00	23.39	-3.39
-35.00	25.00	28.36	-3.36
-30.00	35.00	33.90	1.10
-15.00	40.00	52.76	-12.76

Capsule W (Heat Affected Zone)

Page 2
Plant: South Texas 1 Material: SA533B1 Heat: B8120-1
Orientation: NA Capsule: W Fluence: n/cm^2

Charpy V-Notch Data

Temperature	Input Percent Shear	Computed Percent Shear	Differential
.00	70.00	70.86	-.86
15.00	100.00	84.11	15.89
40.00	100.00	95.09	4.91
72.00	100.00	99.03	.97
130.00	95.00	99.95	-4.95
200.00	100.00	100.00	.00

Correlation Coefficient = .978

APPENDIX D
SOUTH TEXAS UNIT 1 SURVEILLANCE PROGRAM CREDIBILITY EVALUATION

D.1 INTRODUCTION

Regulatory Guide 1.99, Revision 2 [Ref. D-1] describes general procedures acceptable to the NRC staff for calculating the effects of neutron radiation embrittlement of the low-alloy steels currently used for light-water-cooled reactor vessels. Positions 2.1 and 2.2 of Regulatory Guide 1.99, Revision 2, describe the method for calculating the adjusted reference temperature and Charpy upper-shelf energy of reactor vessel beltline materials using surveillance capsule data. The methods of Positions 2.1 and 2.2 can only be applied when two or more credible surveillance data sets become available from the reactor in question.

To date there have been four surveillance capsules removed from the South Texas Unit 1 reactor vessel and tested. To use these surveillance data sets, they must be shown to be credible. In accordance with Regulatory Guide 1.99, Revision 2, the credibility of the surveillance data will be judged based on five criteria.

The purpose of this evaluation is to apply the credibility requirements of Regulatory Guide 1.99, Revision 2, to the South Texas Unit 1 reactor vessel surveillance data and determine if that surveillance data is credible.

D.2 EVALUATION

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

The beltline region of the reactor vessel is defined in Appendix G to 10 CFR Part 50, "Fracture Toughness Requirements" [Ref. D-2], as follows:

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

The South Texas Unit 1 reactor vessel consists of the following beltline region materials:

- Intermediate Shell Plates R1606-1, R1606-2, and R1606-3 (Heat # B-8120-2, B-8120-1, and C-4326-2)
- Lower Shell Plates R1622-1, R1622-2, and R1622-3 (Heat # B-9566-2, B-9575-2, and B-9575-1)
- Intermediate Shell Longitudinal Weld Seams 101-124A, B, C & Lower Shell Longitudinal Weld Seams 101-142A, B, C (Heat # 89476, Linde 0091 flux type, lot # 0145)
- Intermediate to Lower Shell Circumferential Weld Seam 101-171 (Heat # 89476, Linde 124 flux type, lot # 1061)

The South Texas Unit 1 surveillance program utilizes longitudinal and transverse test specimens from Intermediate Shell Plate R1606-2. The surveillance weld metal was fabricated with weld wire Heat # 89476, Linde 124 flux, lot # 1061.

At the time when the surveillance program material was selected, it was believed that copper and phosphorus were the elements most important to embrittlement of reactor vessel steels. The Intermediate Shell Plate R1606-2 had one of the highest initial RT_{NDT} and the lowest initial USE values of all plate materials in the beltline region. In addition, the Intermediate Shell Plate R1606-2 had approximately the same copper and phosphorus content of the other beltline plate materials. Based on the highest initial RT_{NDT} and the lowest initial USE values of all plate materials in the beltline region, Intermediate Shell Plate R1606-2 was chosen for the surveillance program.

The weld material in the South Texas Unit 1 surveillance program was made of the same wire as all the reactor vessel beltline welds, thus it was chosen as the surveillance weld material.

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

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

Based on engineering judgment, the scatter in the data presented in these plots is small enough to permit the determination of the 30 ft-lb temperature and the USE of the South Texas Unit 1 surveillance materials unambiguously. Hence, the South Texas Unit 1 surveillance program meets this criterion.

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

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

The South Texas Unit 1 Intermediate Shell Plate R1606-2 and surveillance weld material will be evaluated for credibility. The weld is made from weld wire Heat # 89476; South Texas Unit 1 does not have a sister plant that shares the same weld wire heat and thus does not utilize data from other surveillance programs. Therefore, the method of Regulatory Guide 1.99, Revision 2 will be followed for determining credibility of the weld as well as the plate material.

Credibility Assessment:

Since all surveillance data is from one vessel (South Texas Unit 1), the measured ΔRT_{NDT} and fluence factor (FF) should be used to calculate the chemistry factors to determine if the South Texas Unit 1 surveillance material test results are credible.

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

Table D-1 Calculation of Interim Chemistry Factors for the Credibility Evaluation using South Texas Unit 1 Surveillance Capsule Data

Material	Capsule	Capsule Fluence ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	ΔRT_{NDT} (°F)	FF*ΔRT_{NDT} (°F)	FF^2
Intermediate Shell Plate R1606-2 (Longitudinal)	U	0.2623	0.636	17.9	11.39	0.405
	Y	1.312	1.076	43.9	47.22	1.157
	V	2.680	1.263	39.7	50.16	1.596
	W	4.365	1.375	64.9	89.22	1.890
Intermediate Shell Plate R1606-2 (Transverse)	U	0.2623	0.636	23.3	14.82	0.405
	Y	1.312	1.076	13.3	14.30	1.157
	V	2.680	1.263	23.9	30.20	1.596
	W	4.365	1.375	30.4	41.79	1.890
				SUM:	299.10	10.095
	$CF_{R1606-2} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (299.10) \div (10.095) =$ **29.6°F**					
Surveillance Weld Material (Heat # 89476)	U	0.2623	0.636	33.5	21.31	0.405
	Y	1.312	1.076	37.9	40.76	1.157
	V	2.680	1.263	26.7	33.73	1.596
	W	4.365	1.375	43.6	59.94	1.890
				SUM:	155.74	5.048
	$CF_{Surv. Weld} = \Sigma(FF * \Delta RT_{NDT}) \div \Sigma(FF^2) = (155.74) \div (5.048) =$ **30.9°F**					

Table D-2 South Texas Unit 1 Surveillance Capsule Data Scatter about the Best-Fit Line

Material	Capsule	CF ($Slope_{best fit}$) (°F)	Capsule Fluence ($x10^{19}$ n/cm^2, E > 1.0 MeV)	FF	Measured ΔRT_{NDT} (°F)	Predicted ΔRT_{NDT} (°F)	Scatter ΔRT_{NDT} (°F)	<17°F (Base Metal) <28°F (Weld)
Intermediate Shell Plate R1606-2 (Longitudinal)	U	29.6	0.2623	0.636	17.9	18.8	0.9	Yes
	Y	29.6	1.312	1.076	43.9	31.8	12.1	Yes
	V	29.6	2.680	1.263	39.7	37.4	2.3	Yes
	W	29.6	4.365	1.375	64.9	40.7	24.2	No
Intermediate Shell Plate R1606-2 (Transverse)	U	29.6	0.2623	0.636	23.3	18.8	4.5	Yes
	Y	29.6	1.312	1.076	13.3	31.8	18.5	No
	V	29.6	2.680	1.263	23.9	37.4	13.5	Yes
	W	29.6	4.365	1.375	30.4	40.7	10.3	Yes
Surveillance Weld Material (Heat # 89476)	U	30.9	0.2623	0.636	33.5	19.7	13.8	Yes
	Y	30.9	1.312	1.076	37.9	33.2	4.7	Yes
	V	30.9	2.680	1.263	26.7	39.0	12.3	Yes
	W	30.9	4.365	1.375	43.6	42.5	1.1	Yes

From a statistical point of view, +/- 1σ would be expected to encompass 68% of the data. Table D-2 indicates that two of the eight surveillance data points fall outside the +/- 1σ of 17°F scatter band for surveillance base metals; therefore, the plate data is deemed "credible" per the third criterion.

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

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

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

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

The South Texas Unit 1 surveillance program does not contain correlation monitor material. Therefore, this criterion is not applicable to the South Texas Unit 1 surveillance program.

D.3 CONCLUSION

Based on the preceding responses to all five criteria of Regulatory Guide 1.99, Revision 2, Section B, the South Texas Unit 1 surveillance plate and weld data is deemed credible.

D.4 REFERENCES

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

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

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

APPENDIX E
SOUTH TEXAS UNIT 1 UPPER-SHELF ENERGY EVALUATION

Per Regulatory Guide 1.99, Revision 2 [Ref. E-1], the Charpy upper-shelf energy (USE) is assumed to decrease as a function of fluence and copper content as indicated in Figure 2 of the Guide (Figure E-1 of this appendix) when surveillance data is not used. Linear interpolation is permitted. In addition, if surveillance data is to be used, the decrease in upper-shelf energy may be obtained by plotting the reduced plant surveillance data on Figure 2 of the Guide (Figure E-1 of this appendix) and fitting the data with a line drawn parallel to the existing lines as the upper bound of all the data. This line should be used in preference to the existing graph.

The 34 EFPY (end-of-license) and 54 EFPY (end-of-license renewal) upper-shelf energy of the vessel materials can be predicted using the corresponding 1/4T fluence projection, the copper content of the beltline materials and/or the results of the capsules tested to date using Figure 2 in Regulatory Guide 1.99, Revision 2. The maximum vessel clad/base metal interface fluence value was used to determine the corresponding 1/4T fluence value at 34 and 54 EFPY.

The South Texas Unit 1 reactor vessel beltline region minimum thickness is 8.63 inches. Calculation of the 1/4T vessel surface fluence values at 34 and 54 EFPY for the beltline materials is shown as follows:

Maximum Vessel Fluence @ 34 EFPY = 2.51×10^{19} n/cm^2 (E > 1.0 MeV)

1/4T Fluence @ 34 EFPY = $(2.51 \times 10^{19}\ \text{n/cm}^2) * e^{(-0.24 * (8.63/4))}$

= 1.50×10^{19} n/cm^2 (E > 1.0 MeV)

Maximum Vessel Fluence @ 54 EFPY = 3.88×10^{19} n/cm^2 (E > 1.0 MeV)

1/4T Fluence @ 54 EFPY = $(3.88 \times 10^{19}\ \text{n/cm}^2) * e^{(-0.24 * (8.63/4))}$

= 2.31×10^{19} n/cm^2 (E > 1.0 MeV)

The following pages present the South Texas Unit 1 upper-shelf energy evaluation. Figure E-1, as indicated above, is used in making predictions in accordance with Regulatory Guide 1.99, Revision 2. Table E-1 provides the predicted upper-shelf energy values for 34 EFPY (end-of-license). Table E-2 provides the predicted upper-shelf energy values for 54 EFPY (end-of-license renewal).

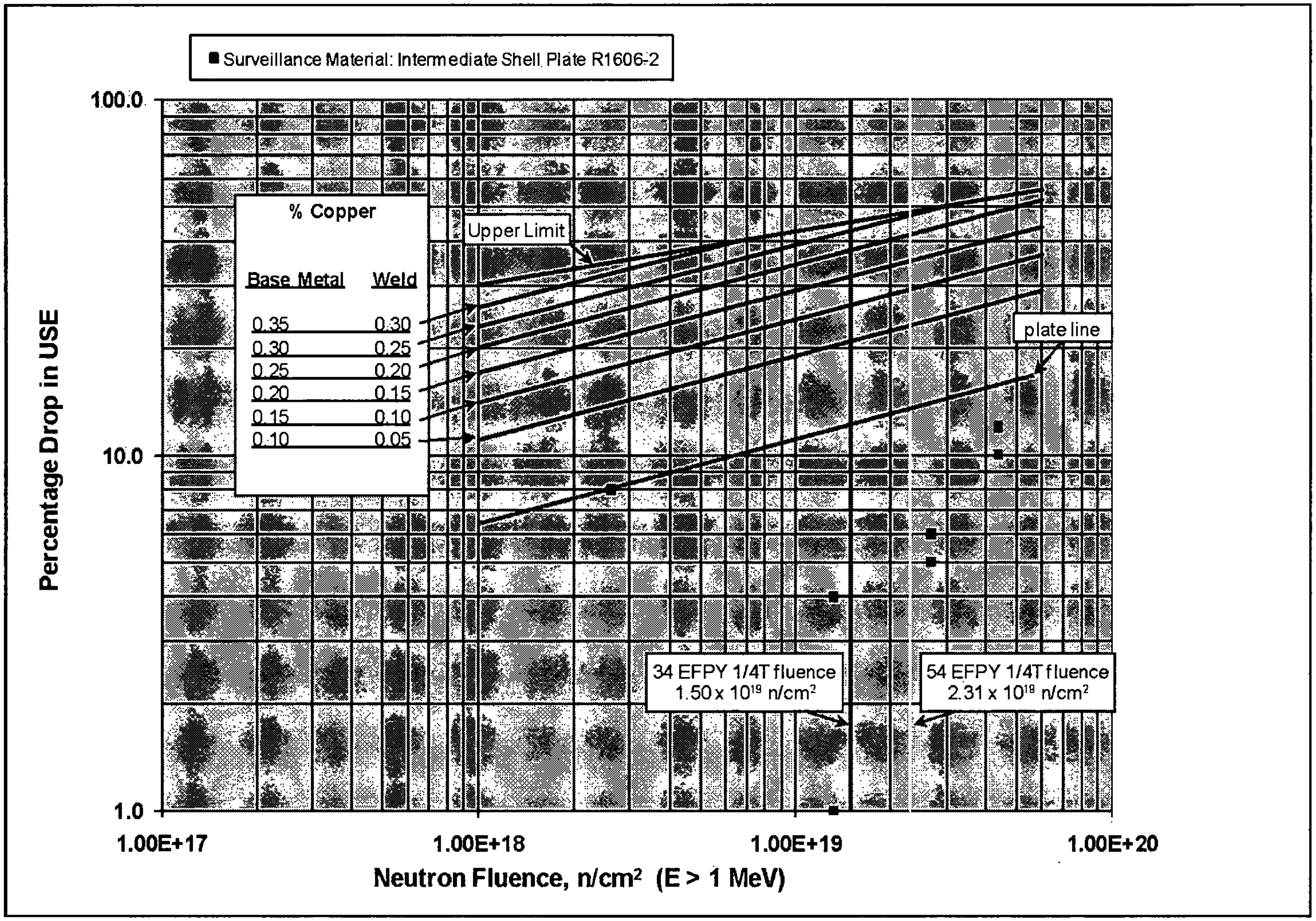


Figure E-1 **Regulatory Guide 1.99, Revision 2 Predicted Decrease in Upper-Shelf Energy as a Function of Copper and Fluence**

Table E-1 Predicted Positions 1.2 and 2.2 Upper-Shelf Energy Values at 34 EFPY

Material	Weight % of Cu	1/4T EOL Fluence ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Unirradiated USE (ft-lb)	Projected USE Decrease (%)	Projected EOL USE (ft-lb)
Position 1.2					
Intermediate Shell Plate R1606-1	0.04	1.50	110	21	87
Intermediate Shell Plate R1606-2	0.04	1.50	94	21	74
Intermediate Shell Plate R1606-3	0.05	1.50	106	21	84
Lower Shell Plate R1622-1	0.05	1.50	111	21	88
Lower Shell Plate R1622-2	0.07	1.50	122	21	96
Lower Shell Plate R1622-3	0.05	1.50	127	21	100
Intermediate Shell Longitudinal Weld Seams 101-124A, B, C	0.022	1.50[(a)]	158	21	125
Lower Shell Longitudinal Weld Seams 101-142A, B, C	0.022	1.50[(a)]	158	21	125
Intermediate to Lower Shell Circumferential Weld Seam 101-171	0.022	1.50	100	21	79
Position 2.2[(b)]					
Intermediate Shell Plate R1606-2	0.04	1.50	94	12	83

Notes:

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

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

Table E-2 Predicted Positions 1.2 and 2.2 Upper-Shelf Energy Values at 54 EFPY

Material	Weight % of Cu	1/4T EOLR Fluence ($x10^{19}$ n/cm^2, E > 1.0 MeV)	Unirradiated USE (ft-lb)	Projected USE Decrease (%)	Projected EOLR USE (ft-lb)
Position 1.2					
Intermediate Shell Plate R1606-1	0.04	2.31	110	23	85
Intermediate Shell Plate R1606-2	0.04	2.31	94	23	72
Intermediate Shell Plate R1606-3	0.05	2.31	106	23	82
Lower Shell Plate R1622-1	0.05	2.31	111	23	85
Lower Shell Plate R1622-2	0.07	2.31	122	23	94
Lower Shell Plate R1622-3	0.05	2.31	127	23	98
Intermediate Shell Longitudinal Weld Seams 101-124A, B, C	0.022	2.31[a]	158	23	122
Lower Shell Longitudinal Weld Seams 101-142A, B, C	0.022	2.31[a]	158	23	121
Intermediate to Lower Shell Circumferential Weld Seam 101-171	0.022	2.31	100	23	77
Position 2.2[b]					
Intermediate Shell Plate R1606-2	0.04	2.31	94	13.5	81

Notes:

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

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

USE Conclusion

All of the beltline materials in the South Texas Unit 1 reactor vessel are projected to remain above the USE screening criterion value of 50 ft-lb (per 10 CFR 50, Appendix G) at 34 and 54 EFPY.

E.1 REFERENCES

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