Docket File

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

October 13, 1992

Docket No. 50-220

LICENSEE: Niagara Mohawk Power Corporation

UTILITY: Nine Mile Point Nuclear Station Unit 1

SUBJECT: SUMMARY OF SEPTEMBER 30, 1992, MEETING TO DISCUSS LICENSEE'S RESPONSE TO GENERIC LETTER 92-01, "REACTOR VESSEL STRUCTURAL INTEGRITY," FOR NINE MILE POINT NUCLEAR STATION UNIT NO. 1

A meeting was held in the NRC One White Flint North Office in Rockville, Maryland, with Niagara Mohawk Power Corporation (NMPC) and NRC staff representatives to discuss NMPC's response to Generic Letter (GL) 92-01 for Nine Mile Point Unit 1 (NMP-1). NMPC's July 2, 1992, response to GL 92-01 stated that the Charpy upper shelf energy (USE) of two beltline plates (G-8-1 and G-307-4) in the Nine Mile Point Unit 1 reactor vessel is predicted to be below the 50 ft lb screening criteria in Appendix G, 10 CFR Part 50, at the present time when the Charpy USE is calculated using the guidance of Branch Technical Position - MTEB 5-2, "Fracture Toughness Requirements," in Standard Review Plan 5.3.2 and Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials." NMPC's submittal contended that the NRC staff's guidance was overly conservative; therefore, the July 2, 1992, submittal also included an alternative calculational method which predicts that the USE of the critical plate will not fall below the 50 ft lb screening criteria prior to end-of-life.

The NRC staff has concerns regarding NMPC's alternative calculational method and, therefore, by letter dated August 12, 1992, recommended that NMPC perform an elastic-plastic fracture mechanics analysis to demonstrate that these two beltline plates have margins of safety against fracture equivalent to those required by Appendix G of the ASME Code. The NRC staff requested this meeting to discuss the recommended analysis. Enclosure 1 is a list of meeting attendees. Enclosure 2 is a copy of the handout material provided by NMPC and discussed at the meeting.

During the meeting, the licensee stated that it is performing the recommended fracture mechanics analysis. The licensee also stated that based on preliminary results of its analysis, NMPC expects to demonstrate that the NMP-1 reactor vessel will remain acceptable for use through the end-of-life. The licensee plans to submit the results of this analysis to the NRC by October 16, 1992, for Service Levels A and B, and by January 29, 1993, for Service Levels C and D. The NRC staff stated that the licensee's analysis appears to be a rationale approach which is consistent with Appendix X of Section XI of the ASME Code. The NRC staff also stated that the proposed schedule for submitting the results of this analysis is acceptable.

DF01

Memo Elk

The NRC staff made the following recommendations regarding the licensee's analysis:

1. The model for the J-R curves should be revised to more accurately fit the data in the area of greatest interest in the analysis.

2. The October 16, 1992, submittal should address prior compliance with the requirements of 10 CFR 50.60 and 10 CFR Part 50, Appendix G.

3. The proprietary evaluation of USE for welds (discussed during a closed session of the meeting) should be included in the October 16, 1992, submittal. The uncertainty analysis for this evaluation may be included in the January 29, 1993, submittal and should include benchmarking against data in the Embrittlement Data Base. The NRC staff provided a current copy of the Embrittlement Data Base to NMPC on October 2, 1992.

Donald S. Brinkman

Donald S. Brinkman, Senior Project Manager
Project Directorate I-1
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Enclosures:
1. List of Meeting Attendees
2. Licensee Handout

cc w/enclosures:
See next page

[illegible]

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Enclosure 1

Attendance List

SUMMARY OF SEPTEMBER 30, 1992, MEETING TO DISCUSS LICENSEE'S RESPONSE TO GENERIC LETTER 92-01, "REACTOR VESSEL STRUCTURAL INTEGRITY" FOR NINE MILE POINT UNIT 1

Name	Position	Organization
Donald S. Brinkman	Senior Project Manager (SPM)	NRR/PDI-1
Daniel G. McDonald	SPM, Lead PM-GL 92-01	NRR/PDI-1
Robert A. Capra	Director, PDI-1	NRR/PDI-1
John E. Menning	Project Manager	NRR/PDI-1
Steven A. Varga	Division Director	NRR/DRPE
Ed Hackett	Materials Engineer	RES/MEB
Shah Malik	Materials Engineer	RES/MEB/DE
Alfred Taboada	Sr. Materials Engineer	RES/MEB/DE
L. Zerr	Director, Business Development	STS/EPRI
Simon Sheng	Materials Engineer	NRR/EMCB
Dave Airozo	Mg. Editor	Nucleonics Week
Art J. Peterson Jr.	Assoc. Sr. Research Specialist	NMPC (R&D)
Yang Soong	Sr. Material Engineer	NMPC
George Inch	Assoc. Sr. Engineer	NMPC
Nick Spagnoletti	UI Project Director	NMPC
Bill Yaeger	Mgr., NMP1 Engineering	NMPC
Carl Terry	VP Nuclear Engineering	NMPC
Mike Manahan	President	MPM Consulting
E. Harold Gray	Materials Section Chief Reg. I	NRC/Region I
K. R. Wichman	Section Chief	NRR/EMCB
Barry J. Elliot	Sr. Materials Engineer	NRR/EMCB
Jack Strosnider	Chief Materials & Chem Eng. Br.	NRR/EMCB
Jose A. Calvo	A/D for DRPE	NRR
Jack Guttmann	Section Chief, Reactor Sys. Br.	NRR

Enclosure 2

Presentation

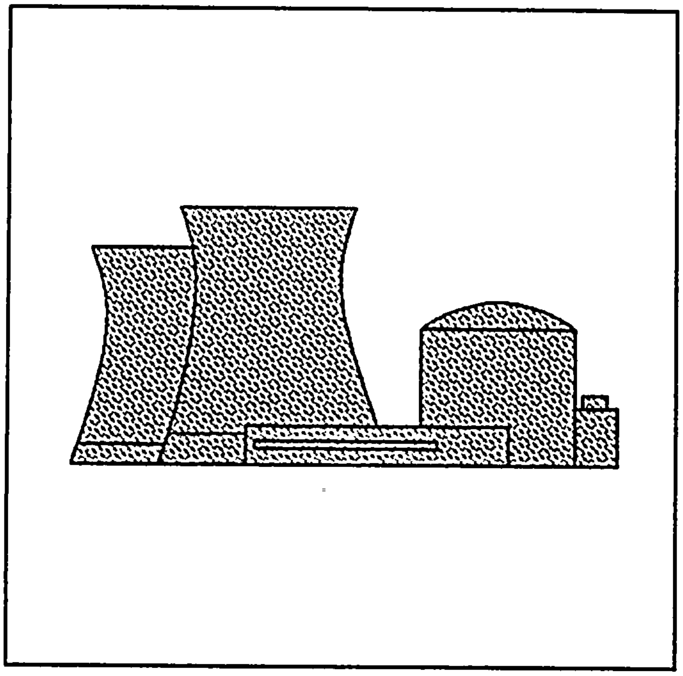
to the

Nuclear Regulatory Commission

concerning

Low Upper Shelf Energy (USE) Issue Resolution

for Nine Mile Point Unit 1



September 30, 1992

PRESENTATION OUTLINE

OPENING REMARKS *(C. Terry)*

1.0 NMP-1 LOW USE ISSUE *(M. P. Manahan)*

1.1 CHRONOLOGY OF RPV ISSUES/RESOLUTIONS

2.0 APPROACH TO RESOLUTION

3.0 ASME APPENDIX X ANALYSIS FOR SERVICE LEVELS A AND B

3.1 ANALYTICAL MODEL

3.2 A302B MATERIAL MODEL

3.3 A533B MATERIAL MODEL

3.4 ELASTIC-PLASTIC FRACTURE MECHANICS ASSESSMENT

4.0 TECHNICAL APPROACH FOR LEVEL C AND D ANALYSES

4.1 FRACTURE MECHANICS ASSESSMENT

4.2 LEVEL C AND D SERVICE LOADINGS

5.0 SUMMARY AND CONCLUSIONS

6.0 REFERENCES

1.0 NMP-1 LOW USE ISSUE

- Using the Regulatory Guide 1.99 (Revision 2) (RG1.99(2)) model and conservative unirradiated USE estimates, none of the NMP-1 beltline welds are expected to fall below the 10 CFR 50, Appendix G 50 ft-lb screening criterion.

- With the exception of plate G-8-3, only L-T Charpy data are available for the beltline plates.

- Using an L-T to T-L conversion factor of 0.65 [MTEB81] and the RG1.99(2) model, plates G-8-1 and G-307-4 are predicted to fall below 50 ft-lb.

- Using plant-specific data, plates G-8-1 and G-307-4 are predicted to remain above 50 ft-lb through 25 EFPY. It is NMPC's position that the plant-specific approach is appropriate and the USE will remain above 50 ft-lbs. through EOL.

- Since plates G-8-1 and G-307-4 are near the screening criterion, NMPC is performing an elastic-plastic fracture mechanics assessment.

Estimated Upper Shelf Energy for NMP-1 Beltline Materials [MA92]

Material	Wt. % Cu	Minimum Unirrad. USE (ft-lb) L-T [1]	Minimum Unirrad. USE (ft-lb) T-L[1]	Irradiation Decrement ΔUSE (%) 12/16/91[5]	Irradiation Decrement ΔUSE (%) EOL(25 efpy)[6]	Predicted USE (T-L)[1] 12/16/91 [5] (ft-lb)	Predicted USE(T-L)[1] at EOL(25 efpy)[6] (ft-lb)
Plates							
G-8-3/G-8-4	0.18	78	64[2] / 50.7[9]	15	17	54.4	53.1
G-8-1	0.23	82	53.3[9]	17	20	44.2	42.6
G-307-3	0.20	100	65.0[9]	16	19	54.6	52.7
G-307-4	0.27	80	52.0[9]	20	23	41.6	40.0
G-307-10	0.22	97	63.1[9]	17	20	52.4	50.5
Welds							
W5214/5G13F[8]	0.18	--	100[3]	17	20	83.0	80.0
86054B/4E5F	0.22[7]	--	90[4]	20	23	72.0	69.3
1248/4K13F	0.22[7]	--	90[4]	20	23	72.0	69.3
1248/4M2F	0.22[7]	--	90[4]	20	23	72.0	69.3

1 The L-T and T-L designations apply to plate material only
2 Measured using archive plate in the T-L orientation
3 Irradiated value measured at a fluence of 4.78×10^{17} n/cm^2
4 Conservatively estimated using data in [MA90] and [MA91]
5 Fast fluence of 7.26×10^{17} n/cm^2 at the peak 1/4T position
6 Fast fluence of 1.44×10^{18} n/cm^2 at the peak 1/4T position
7 Data from Reference [CE90]
8 Surveillance Weld
9 Calculated by multiplying L-T data by 0.65

Best Estimate Upper Shelf Energy for Plates G-8-1 and G-307-4

	Minimum Unirrad. USE (ft-lb) L-T	Minimum Unirrad. USE (ft-lb) T-L[1]	Irrad. Decre-ment[3] ΔUSE(%) 12/16/91[2]	Irrad. Decre-ment[3] ΔUSE(%) EOL (25efpy)[4]	Predicted USE (T-L) 12/16/91 (ft-lb)[2]	Predicted USE (T-L) at EOL (25 efpy)[4] (ft-lb)
G-8-1	82	65.6	11	13	58.4	57.1
G-307-4	80	64.0	11	13	56.9	55.7

[1] Plate G-8-3 measured L-T to T-L conversion of 0.8 applied
[2] Fast fluence of 7.26×10^{17} n/cm^2 at the peak 1/4T position
[3] Paragraph 2.2 of RG1.99 (Rev. 2) used. ΔUSE conservatively calculated using average unirradiated data and lowest irradiated datum
[4] Fast fluence of 1.44×10^{18} n/cm^2 at the peak 1/4T position

1.1 CHRONOLOGY OF RPV ISSUES/RESOLUTIONS

1984 - surveillance capsule data showed large Charpy shift and no shelf drop

1985 - second surveillance capsule confirmed 1985 data

1988 - two surveillance capsules reinserted to generate additional data

1988 - material mixup resolution study began

1/91 - material mixup resolved

2/91 - technical approach to resolve low USE developed

5/91 - application for P-T curve Technical Specification amendment

8/91 - NMP-1 RPV data and report which re-established surveillance capsule program sent to NRC

9/91 - technical approach for addressing low USE issue provided to NRC

3/92 - began work to resolve low USE issue

7/92 - response to NRC GL 92-01 submitted

8/92 - NRC letter requesting meeting and 60-day response on low USE issue

2.0 APPROACH TO RESOLUTION

NMPC is currently performing an ASME draft Appendix X analysis to resolve the low USE issue.

In addition to the elastic-plastic fracture mechanics assessment, several elements of the NMPC Pressure Vessel Materials Integrity Research Program are expected to provide useful data for confirming margins of safety:

- L-T to T-L conversion modelling
- Upper Shelf Energy (USE) drop trend curve modelling
- Miniature specimen technology development
- Surveillance capsule reinsertion

3.0 ASME APPENDIX X ANALYSES FOR SERVICE LEVELS A AND B

Revision 11 to the Draft ASME Appendix X [ASME92], which is currently formulated as a Code Case, was applied to the NMP-1 G-8-1 and G-307-4 plates.

3.1 ANALYTICAL MODEL
BASE MATERIAL - SERVICE LEVELS A AND B

- Interior axial and circumferential flaws, with depths of 1/4T and lengths equal to 6 times the depth, have been postulated.
- Toughness properties, which correspond to the postulated flaw orientation, were used in the analysis:

  -- T-L orientation properties for circumferential flaws

  -- L-T orientation properties for axial flaws
- The J-integral/tearing modulus approach was used in the evaluation
- The following evaluation criteria were applied:

  (1) Criterion for flaw growth of 0.1 inch

  $$J_1 < J_{0.1}$$

  (2) Criterion for flaw stability

  $$P^* > 1.25\ P_a$$

  where,

  J_1 = applied J-integral for a safety factor on pressure of 1.15, and a 1.0 factor on thermal loading

  $J_{0.1}$ = J-integral resistance at a ductile flaw growth of 0.1 inch

  P^* = internal pressure at flaw instability

  P_a = accumulation pressure, but not exceeding 1.1 times design pressure
- Since J-R curve data are not available for A302M, analyses were performed using an A302B and an A533B material model
- The material properties used in the analysis are a conservative representation of the toughness and tensile properties of plates G-8-1 and G-307-4 at plant operating temperature

3.2 A302B MATERIAL MODEL

Elastic Modulus

Table I-6.0 of [ASME80] was used to determine the elastic modulus at 500°F.

$E = 26.4 \times 10^6$ psi

Yield Stress (σ_y)

Table I-2.1 of [ASME80] shows that from RT to 500°F, there is an 8 ksi drop in σ_y. Therefore, the RT plate data were adjusted to yield operating temperature data.

NMP-1 Plate	σ_y at RT (ksi)	σ_y at 500°F (ksi)
G-307-4	69.4	61
G-8-1	66.6	58

J-R Curve

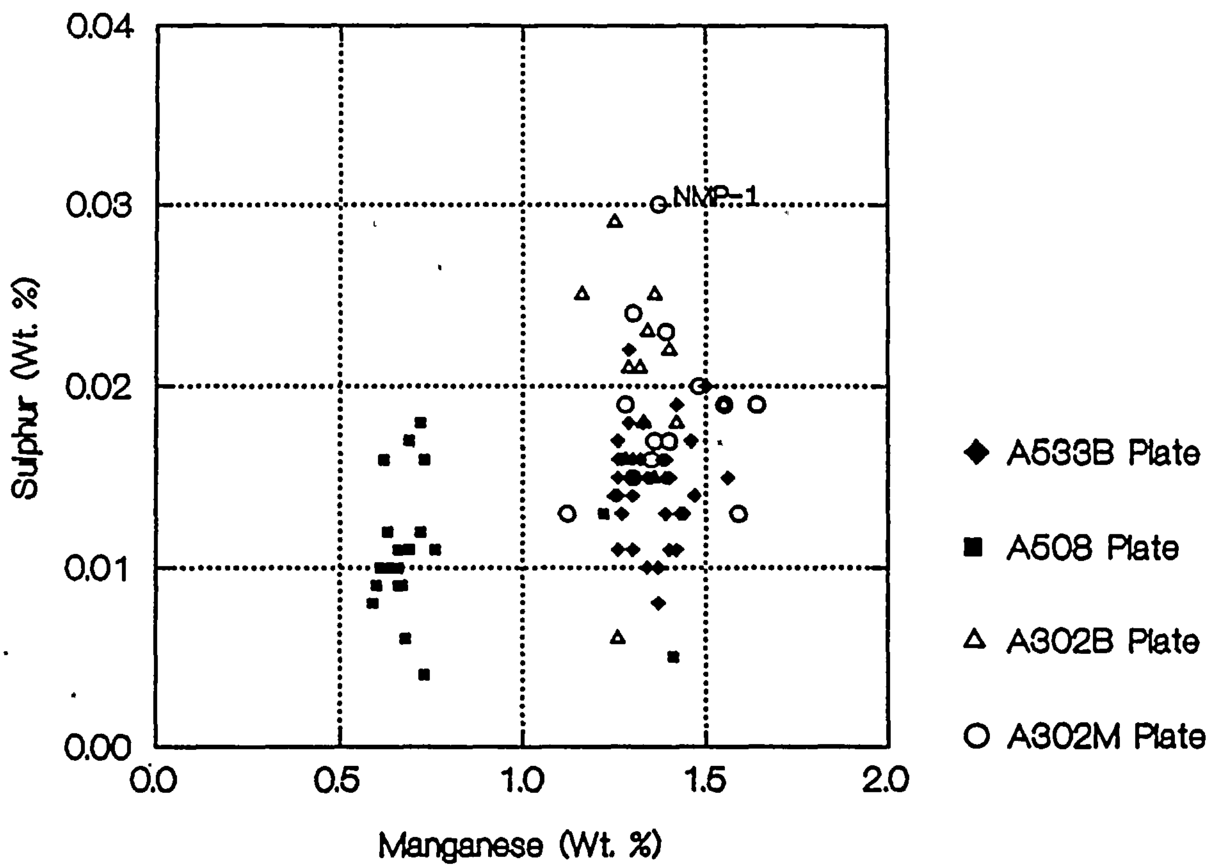
Based on analysis of Charpy USE data dependence on chemical composition, the NMP-1 plates are expected to exhibit upper shelf fracture behavior which is representative of A302B steel.

Plate Chemistry (Weight %)

Element	ASTM A302B & 302M	ASTM A533B	NMP-1 Plates[1]
Carbon, max	0.25	0.25	0.18-0.20
Manganese	1.07-1.62	1.07-1.62	1.16-1.45
Phosphorous, max	0.035	0.035	0.012-0.021
Sulfur, max	0.040	0.040	0.026-0.034
Silicon	0.13-0.45	0.13-0.45	0.17-0.26
Molybdenum	0.41-0.64	0.41-0.64	0.45-0.52
Nickel	---	0.37-0.73	0.48-0.56

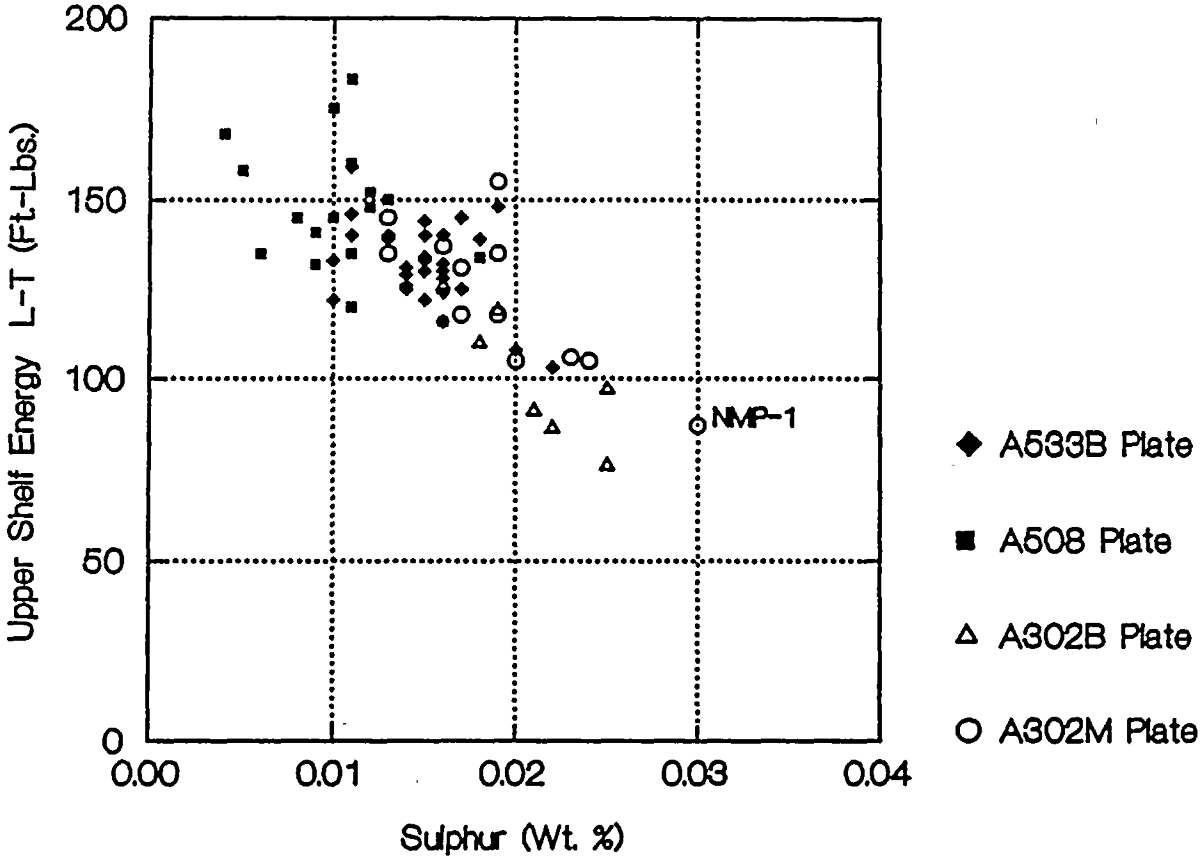
[1] Lukens ladel analysis by atomic absorption

Mn vs. S for LWR VESSEL MATERIALS



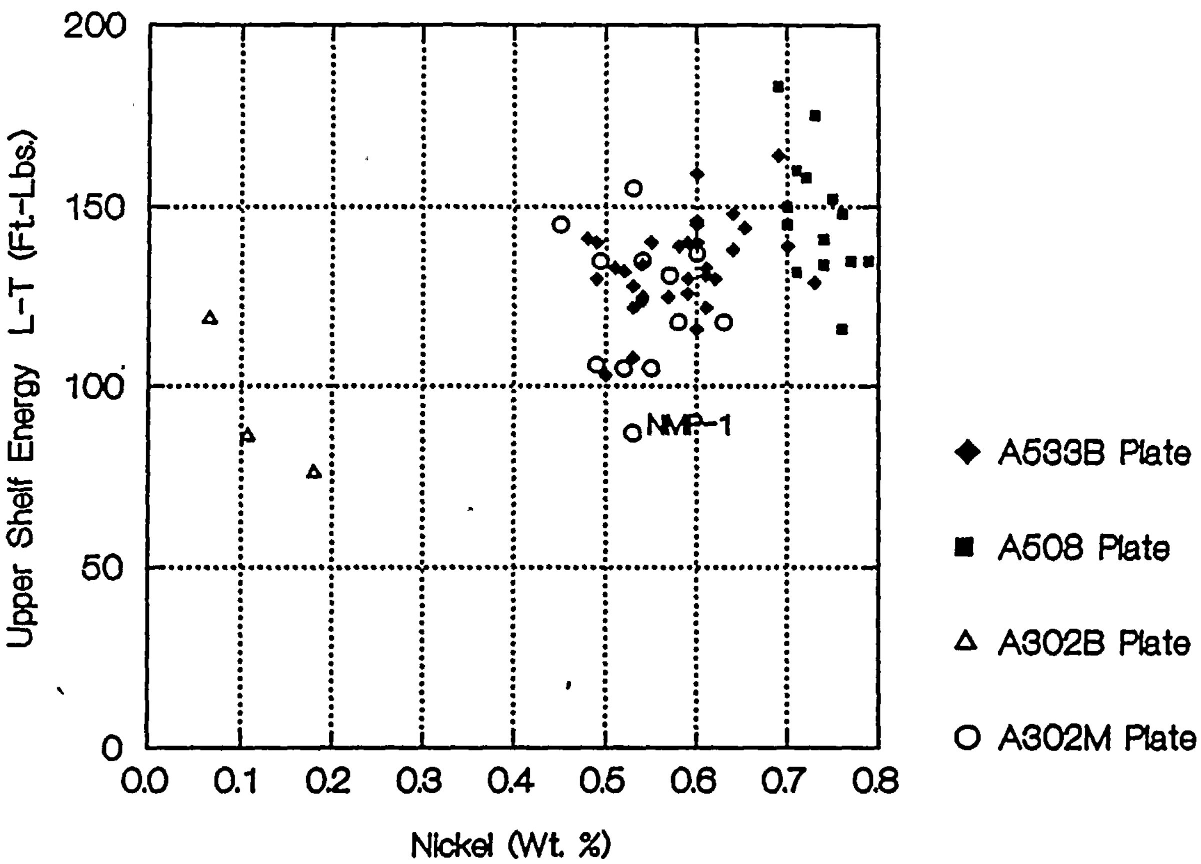
Plot of S and Mn Levels for LWR Pressure Vessel Materials

USE vs. S for LWR VESSEL MATERIALS



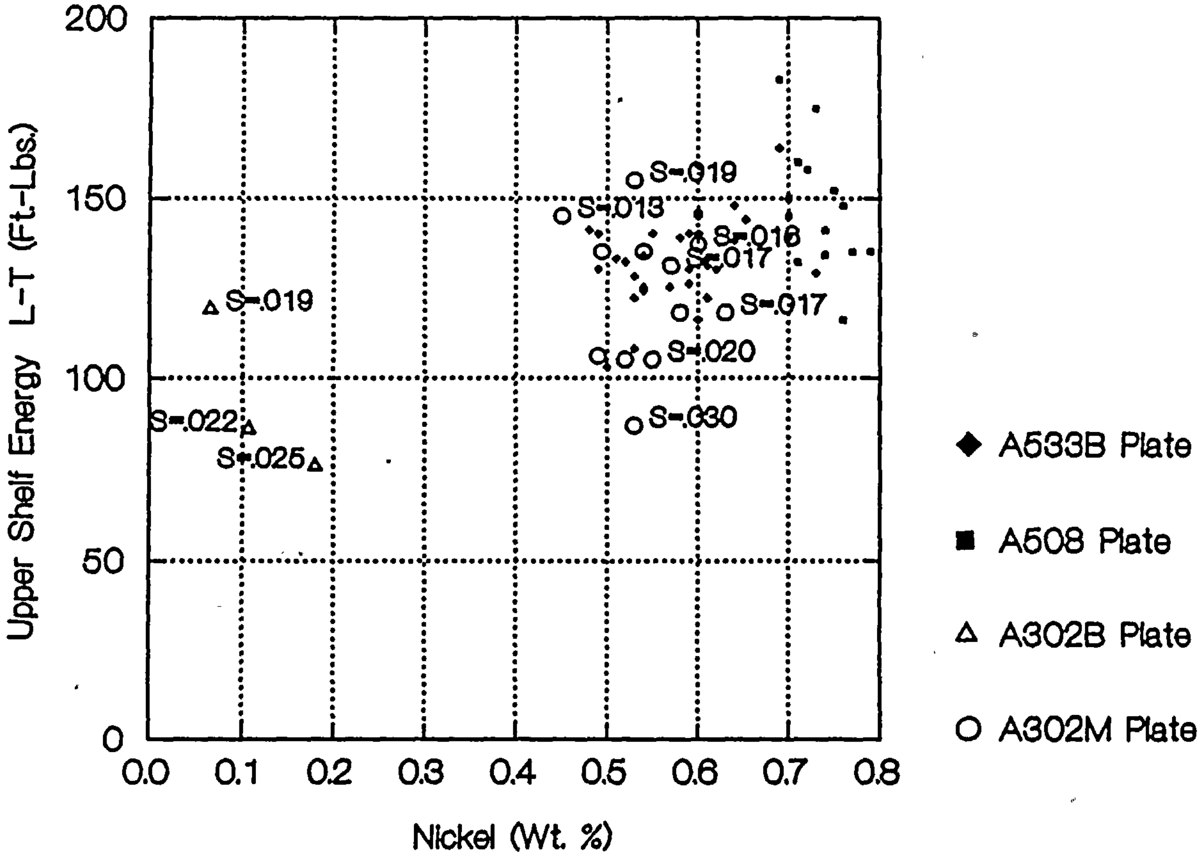
Plot of USE vs. S Content Showing the
Detrimental Effect of S on the USE Level

USE vs. Ni for LWR VESSEL MATERIALS



Plot of USE vs. Ni Content Showing the Generally Beneficial Effects of Ni on the USE Level

USE vs. Ni for LWR VESSEL MATERIALS



Plot of USE vs. Ni Content Showing the Impact of S Content in Counteracting the Beneficial Ni Effect

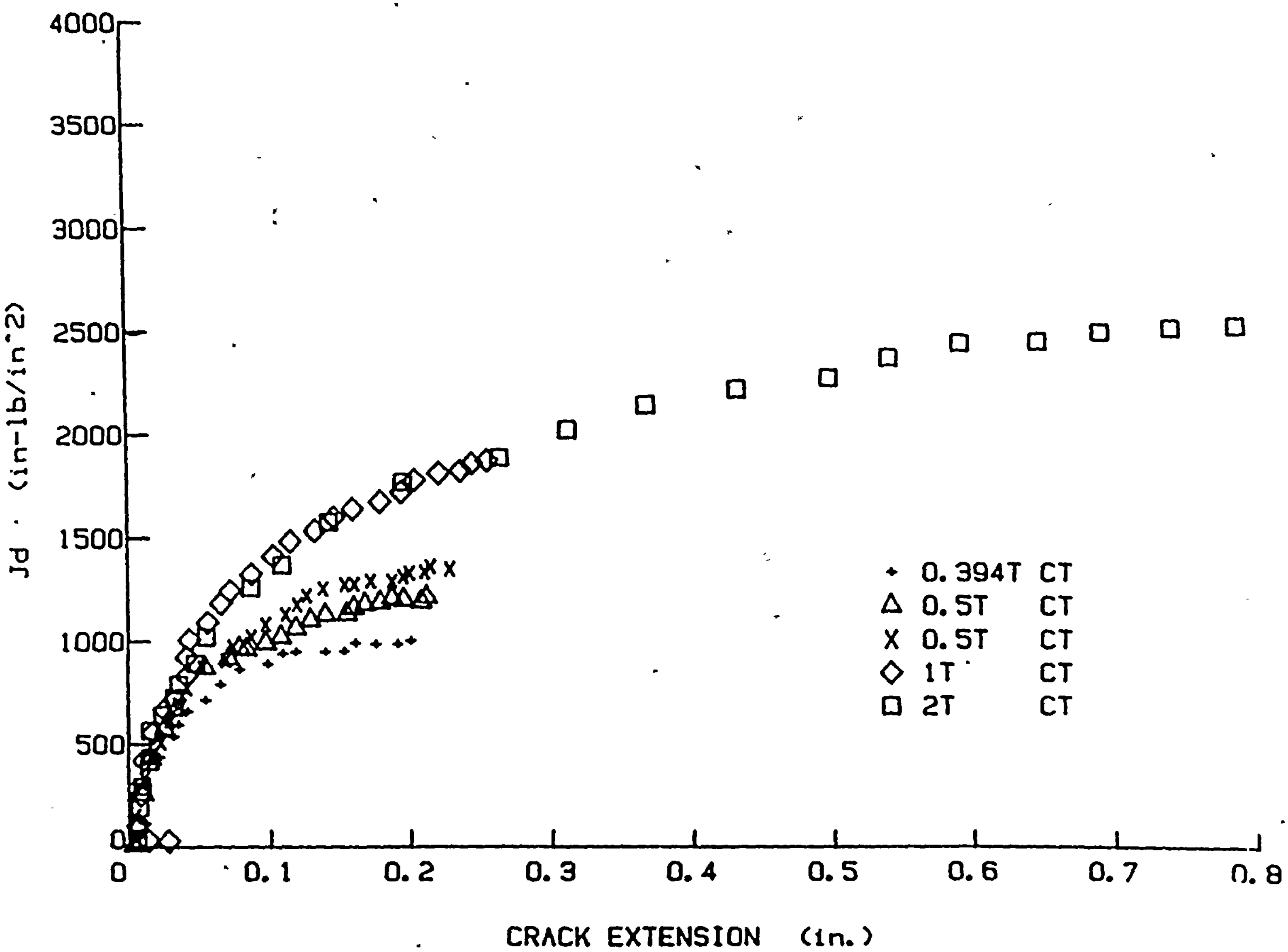
A302B J-R CURVE MODEL

A conservative model was developed which:

- is valid at reactor operating temperature
- accounts for the specimen size effect observed for A302B steel
- yields 95% C.I. lower bound J-R curves as a function of USE level

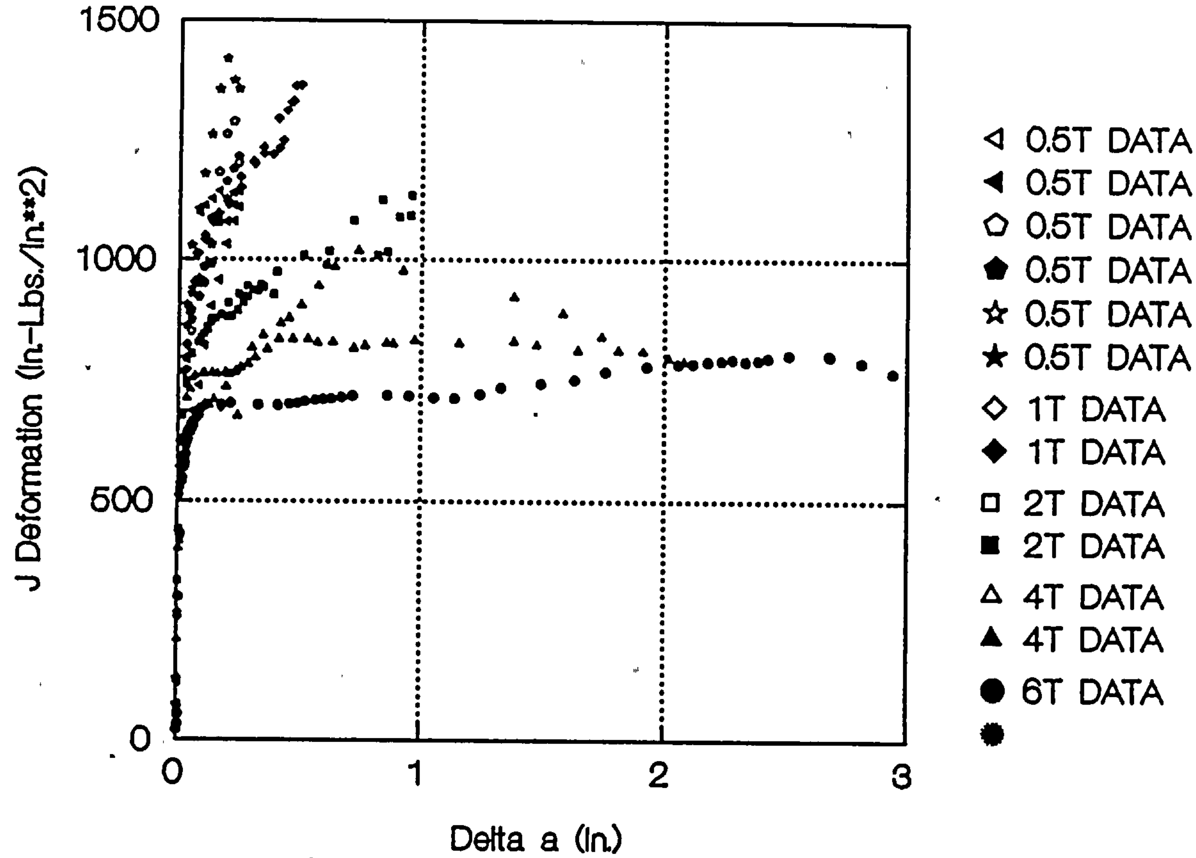
Key Assumptions

- The heat treatment and composition of the NMP-1 plates and the materials used in the [HI86] study are similar.
- J_{IC} correlates with USE level.
- The USE is approximately constant from the temperature of onset of 100% shear to 550°F.
- J_{IC} is approximately constant between 392°F and 550°F.
- The 6T data reported in [HI89] is representative of A302B full size vessel behavior.



J-R Curves for Linde 80 Welds [JOY91]

A302B J-R DATA FOR VARIOUS SPECIMEN THICKNESSES



Comparison of J_D-R Curves for A302B Plate
(Data Taken From [HI89])

Comparison of the NMP-1 Plate Chemistry
with the [HI89] Study Material Chemistry

Element	NMP-1 Plates	[HI89] Material
Carbon	0.18 - 0.20	0.21
Manganese	1.16 - 1.45	1.46
Phosphorous	0.018 - 0.021	0.010
Sulfur	0.026 - 0.034	0.021
Silicon	0.17 - 0.26	0.24
Molybdenum	0.45 - 0.52	0.54
Nickel	0.48 - 0.56	0.23

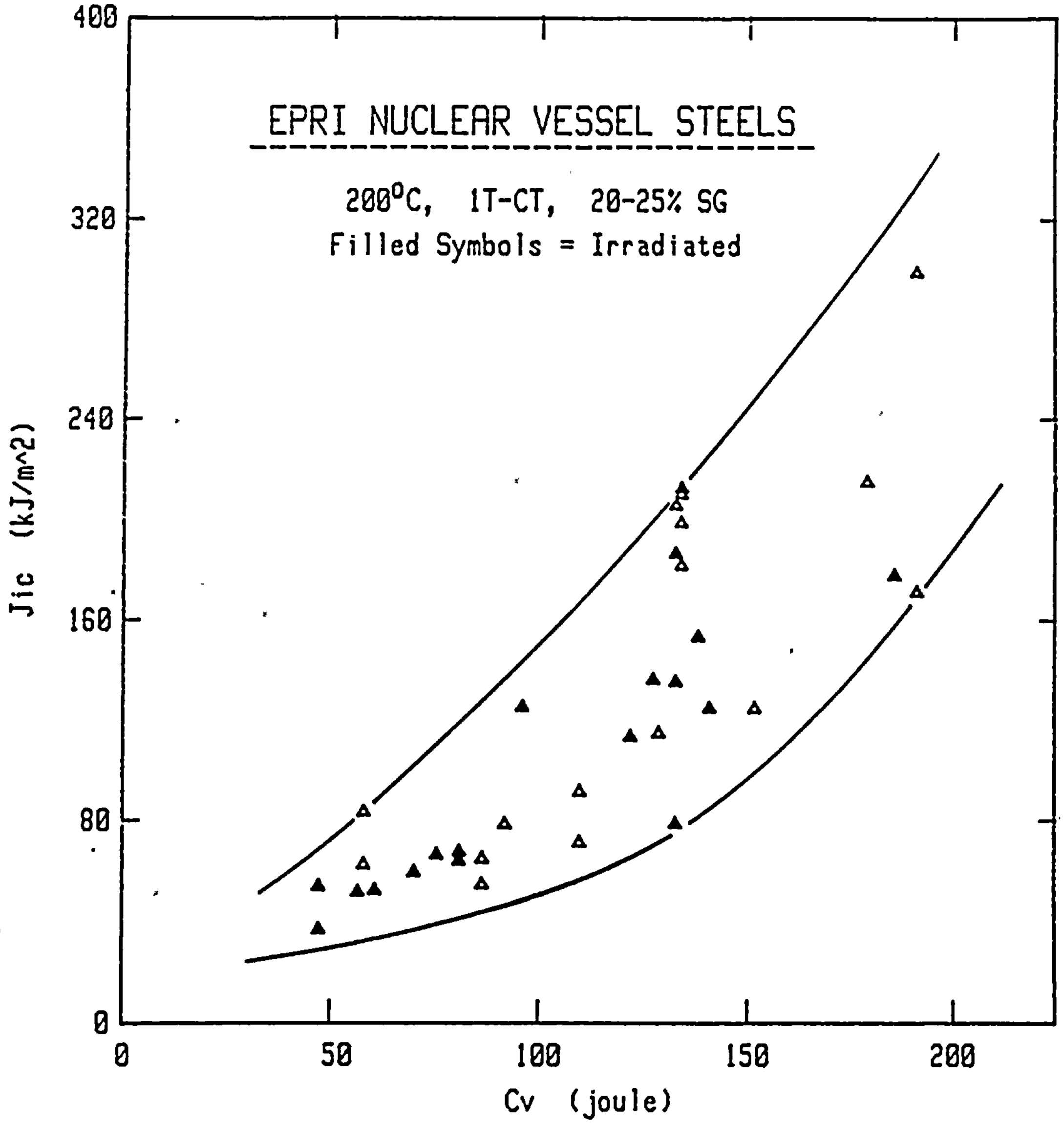
Comparison of NMP-1 Plate Heat Treatments and Charpy Data
with the [HI89] Study Material Heat Treatments and Charpy Data

Item	NMP-1 Plates/Specimens	[HI89] Material
Heat Treatment	1550-1600°F, 4 hr; water quench, 4 hr	1650 ±25°F, 6 hr; water quench
	1150 ±25°F, 10.5 hr., air cool	1200 ±25°F, 6 hr; air cool
	test specimens stress relieved at 1150 ±25°F, 30 hrs	stress relieve test specimens only
	1150 ±25°F, 40 hrs	1150 ±25°F, 24 hr, furnace cool to 600°F, air cool
USE (T-L)	68.5 (G-8-3)	53.6
T_{30}	0	26

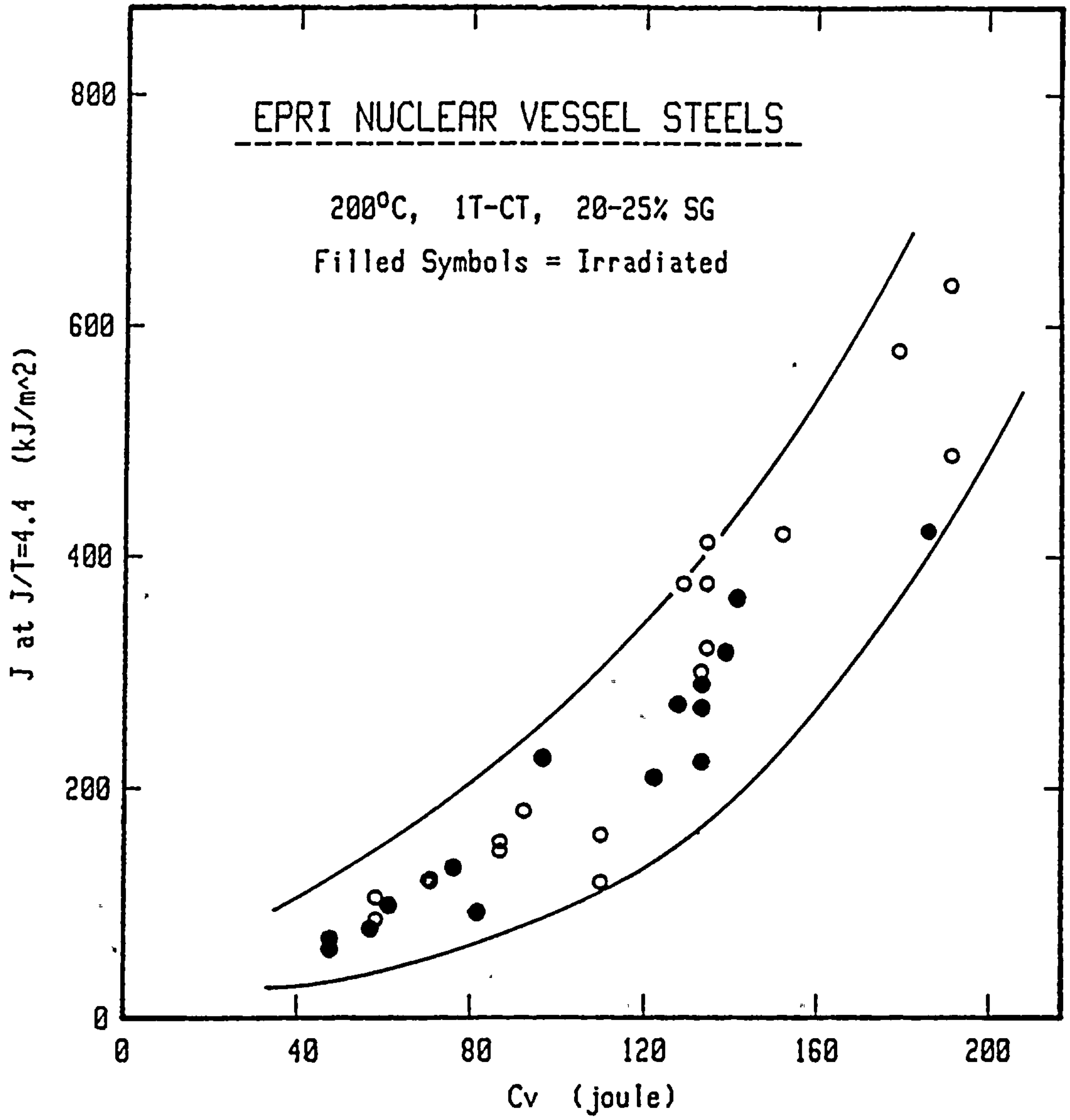
Summary of J_{IC} Data as a Function of
Specimen Size for A302B[1] Material [HI89] Tested at 180°F

Specimen ID	Specimen Thickness	J Deformation (J_D) (in-lb/in^2)
V50-113	0.5T	662
V50-116	0.5T	560
V50-114	0.5T	662
V50-117	0.5T	405
V50-115	0.5T	628
V50-118	0.5T	525
V50-119	0.5T	611
V50-120	0.5T	657
V50-121	0.5T	622
Average	0.5T	592
V50-109	1T	674
V50-112	1T	634
Average	1T	654
V50-105	2T	594
V50-108	2T	651
Average	2T	623
V50-102	4T	600
V50-103	4T	588
Average	4T	594
V50-101	6T	525

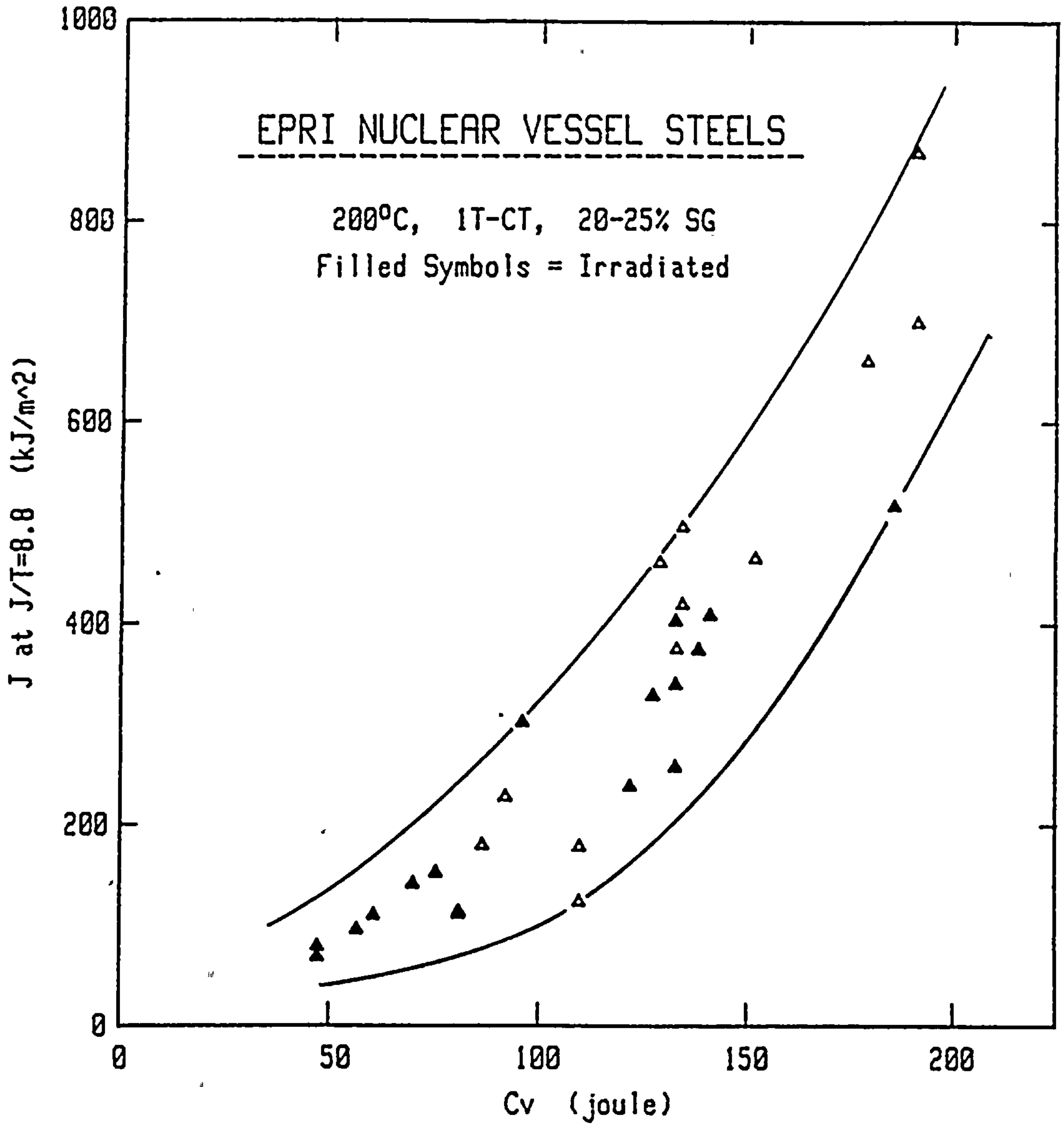
[1] T-L orientation, USE = 52 ft-lb upper shelf behavior at T>150°F



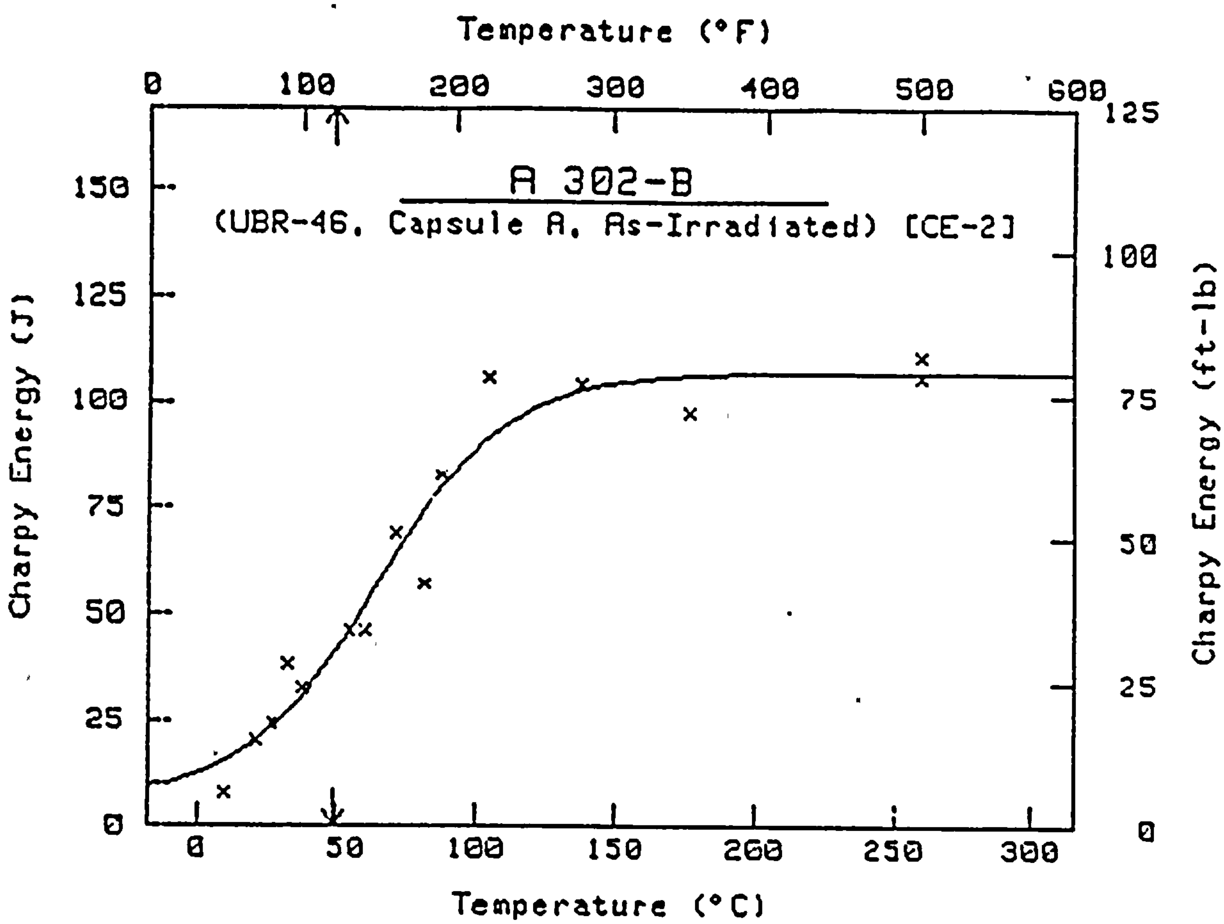
Comparison of J_{IC} and the C_V Upper Shelf Level for All Steels Investigated [HA82]



Comparison of C_V Upper Shelf Level with the J Level at a Point on the R Curve Where J/T = 4.4. Here, the Correlation with C_V shelf is Better than that between J_{IC} and the C_V Shelf [HA82]



Comparison of C_V Upper Shelf Level with the J Level at a Point on the R Curve where J/T = 8.8 for All Materials Investigated
Here, the Correlation with C_V Shelf is Better than that Between Both J_{Ic} and J at J/T = 4.4 and the C_V Shelf [HA82]



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Cv = A + B tanh[(T - To)/C]

		English	Metric
A	=	41.92 ft-lb	56.84 J
B	=	37.21 ft-lb	50.45 J
C	=	85.81 °F	47.67 °C
To	=	148.24 °F	64.58 °C
Cv = 30 ft-lb (41 J) at T	=	119.7 °F	48.7 °C
Upper Shelf Energy	=	79.1 ft-lb	107.3 J

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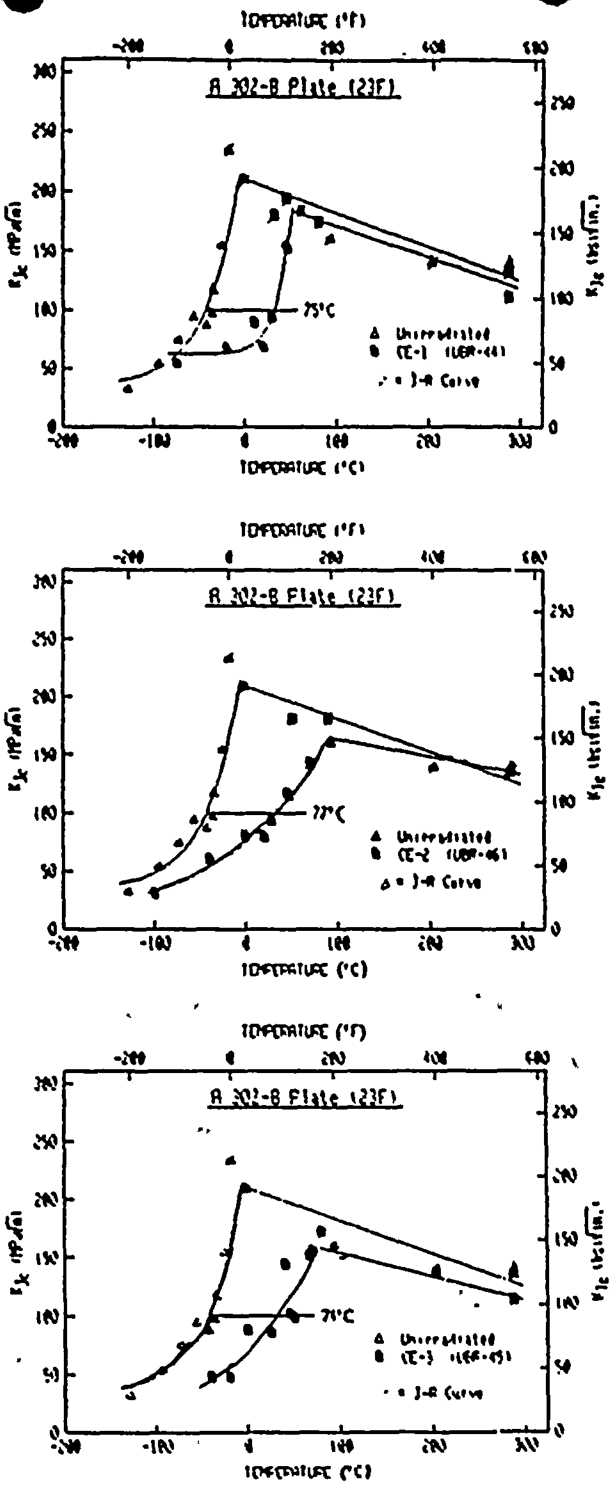
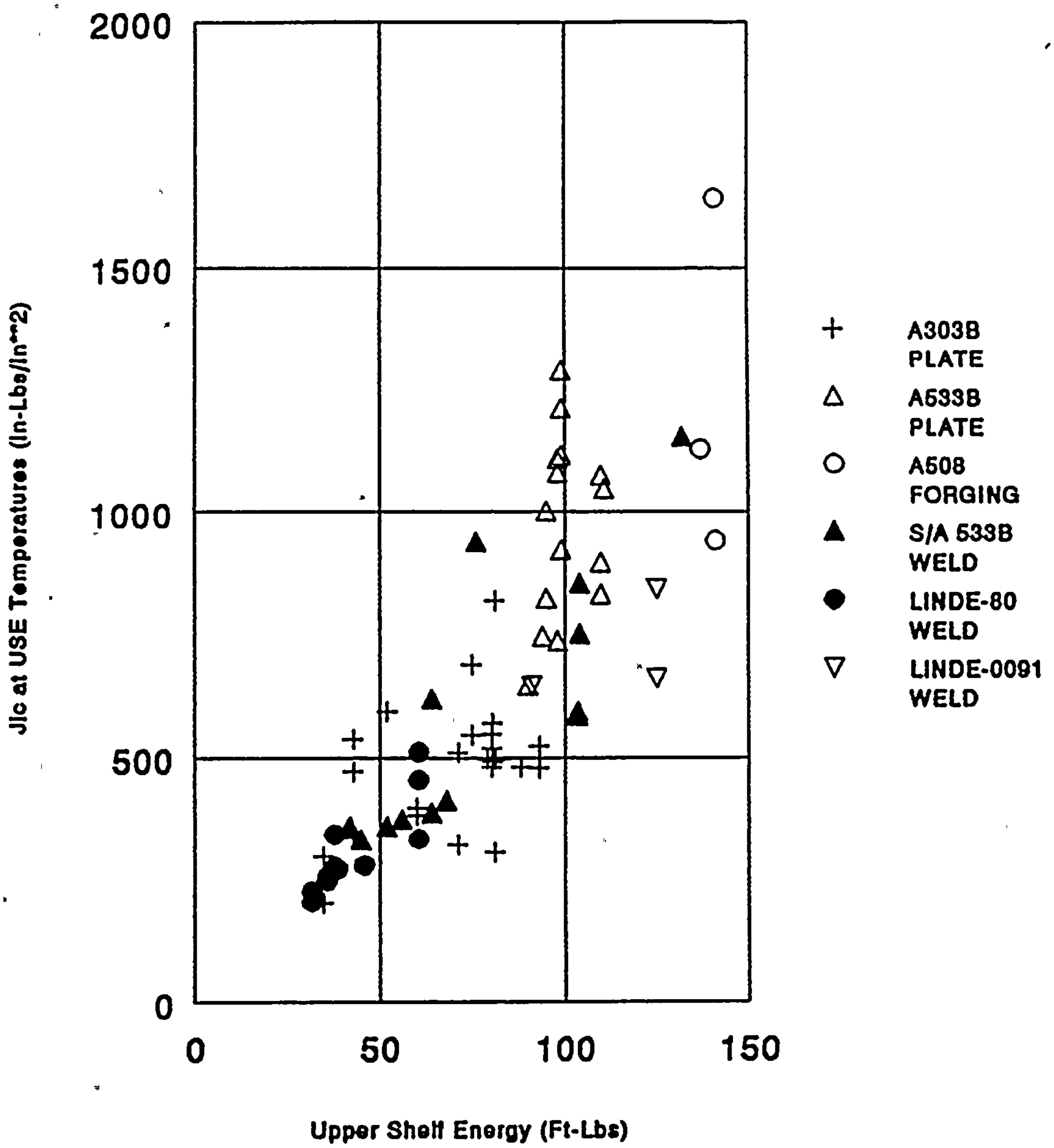
A302B Charpy Data Illustrating the Weak Temperature Dependence of the USE on Temperature [HA90]



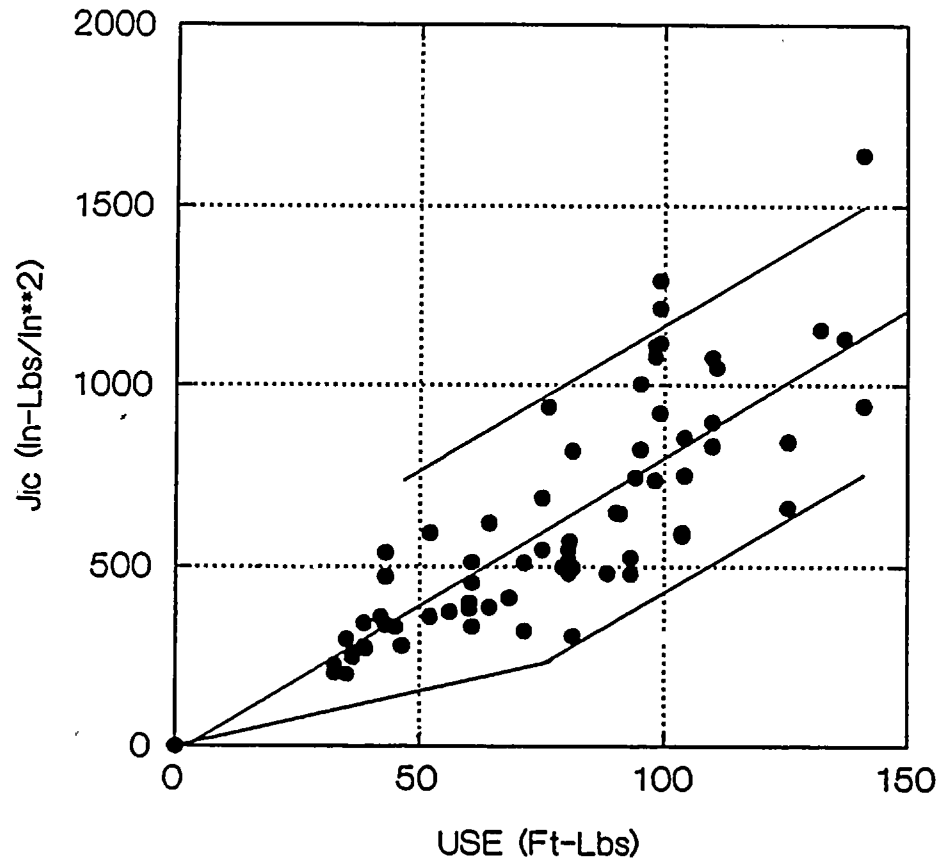
Plot of K_{Jc} vs. Test Temperature Showing the Strong Temperature Dependence on the Upper Shelf [HA90]

Jic/USE Correlation Data



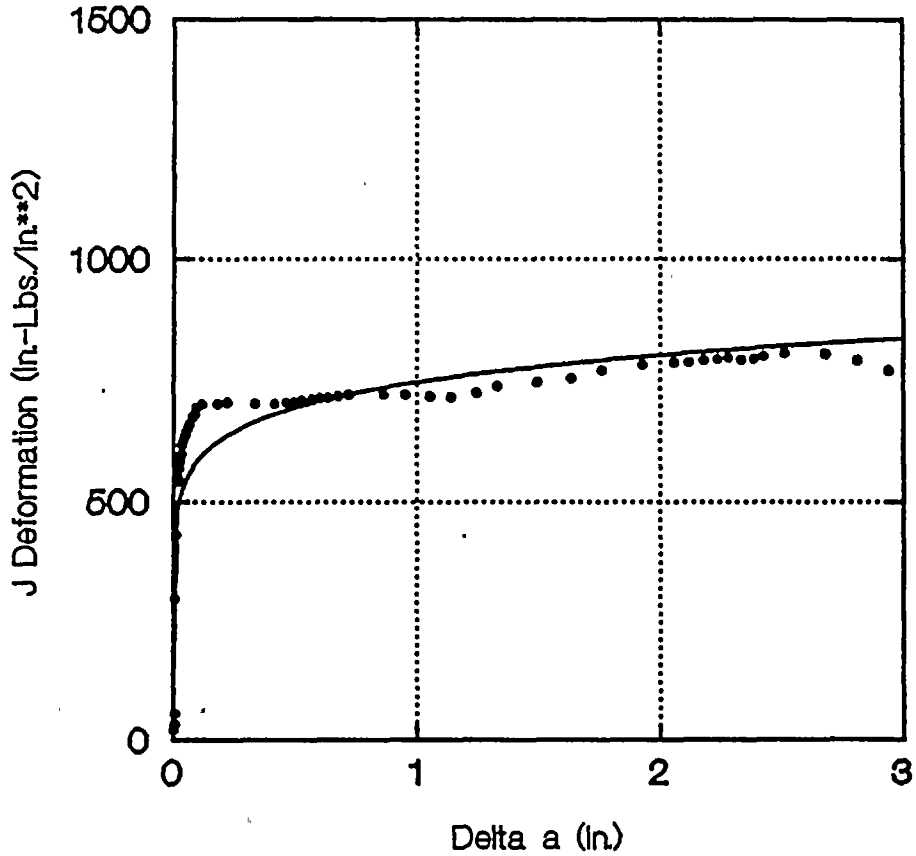
Data Set Used to Develop J_{IC}-USE Correlation

JIC-USE 95% C.I. LOWER BOUND LIMIT



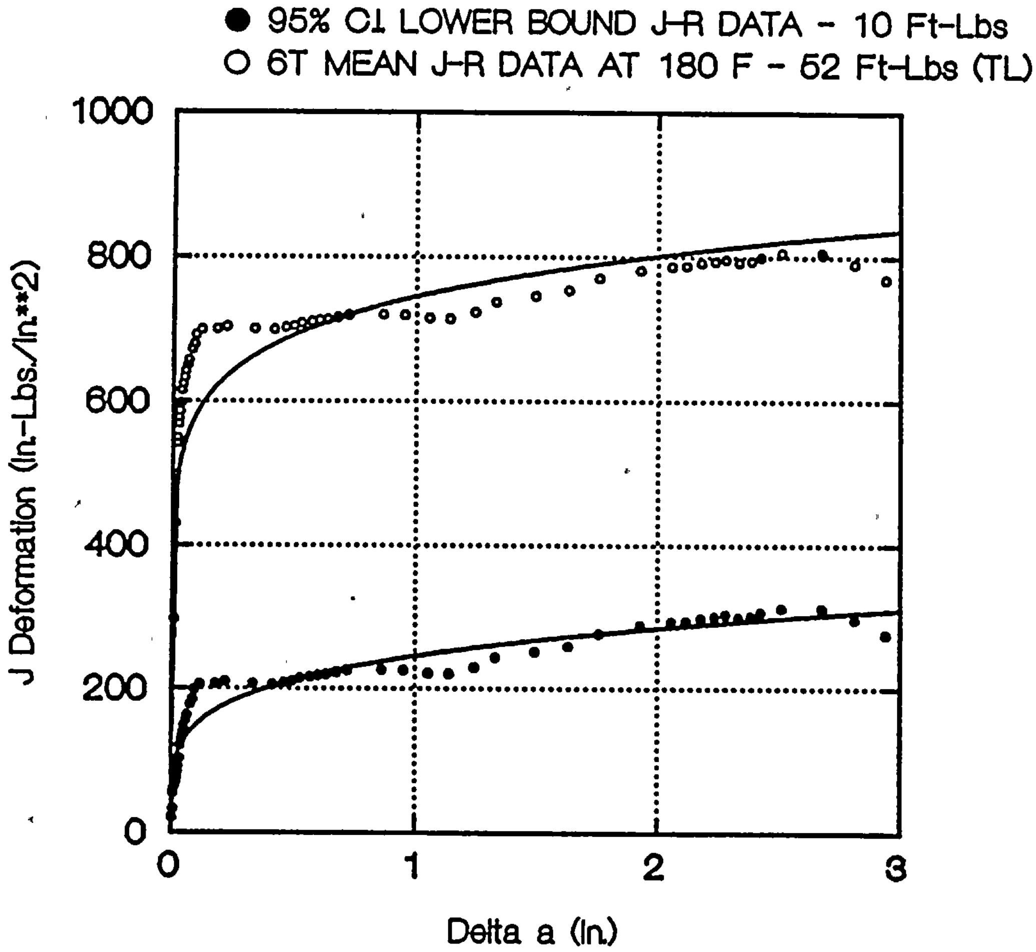
J_{IC}-USE Correlation and 95% Lower Bound Confidence Limit

A302B 6T DATA AND FIT FOR TEST AT 180 F

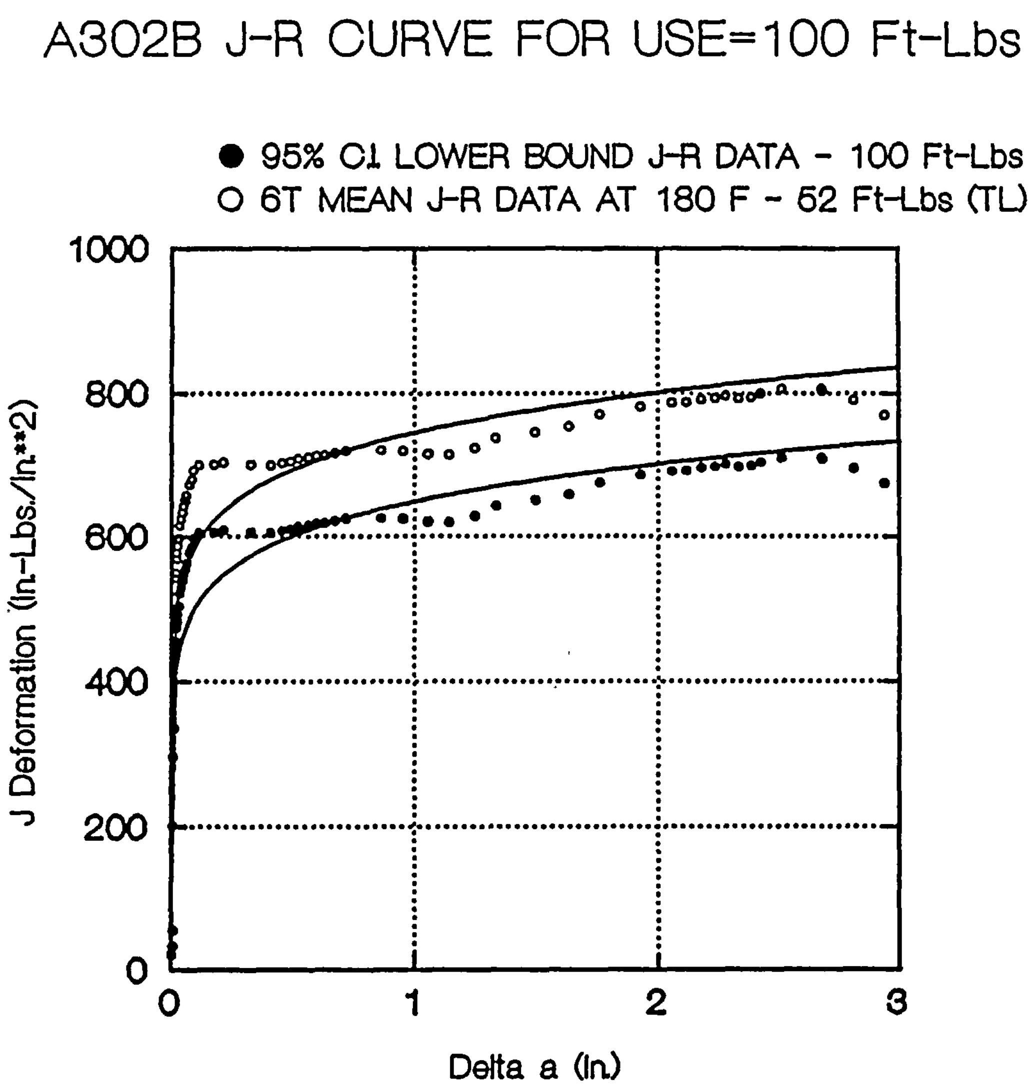


Power Law Fit for A302B 6T Data Tested at 180°F
(Data Taken From [HI89])

A302B J-R CURVE FOR USE=10 Ft-Lbs



Lower Bound 95% CI J-R Curve for A302B Thick Section Material Exhibiting a 10 Ft-lb Charpy USE Level (Data Taken From [HI89])



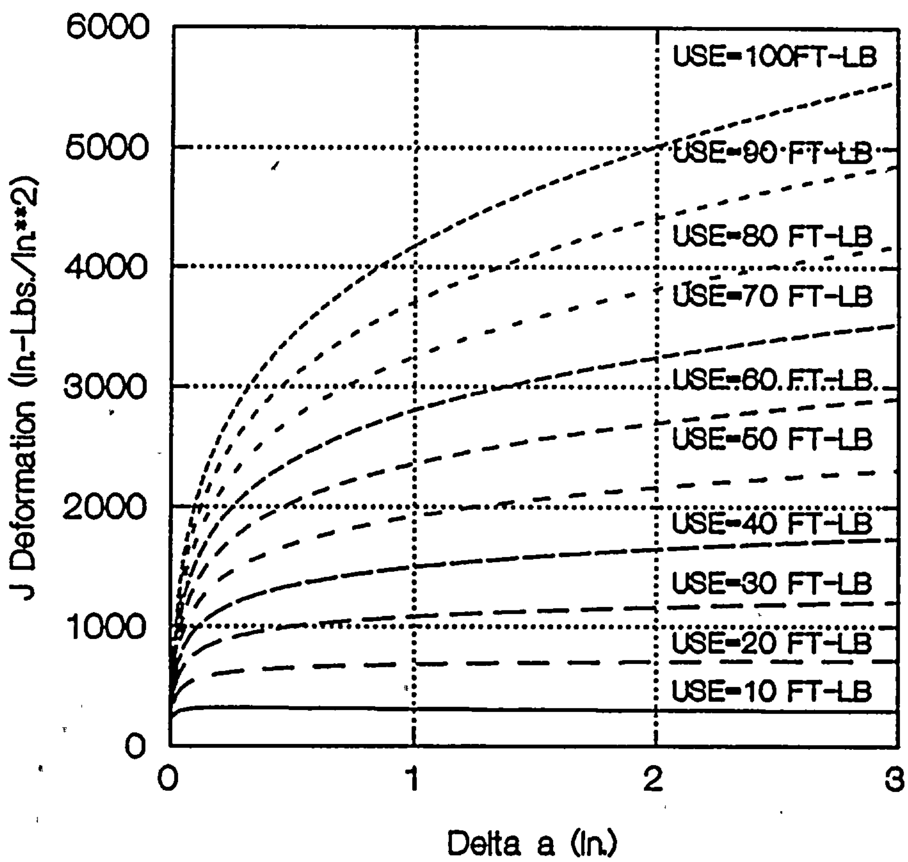
Lower Bound 95% CI J-R Curve for A302B Thick Section Material
Exhibiting a 100 Ft-lb Charpy USE Level
(Data Taken From [HI89])

3.3 A533B MATERIAL MODEL

J-R Curve

The Reference [EA91] "Charpy Model" was used to develop J-R curves which vary with USE level. As in the A302B model, lower bound 95% C.I. curves, which are applicable at reactor operating temperature, were used in the analysis.

A533B J-R CURVES FOR VARIOUS USE LEVELS



Lower Bound 95% CI J-R Curves
for A533B Thick Section Material

3.4 ELASTIC-PLASTIC FRACTURE MECHANICS ASSESSMENT

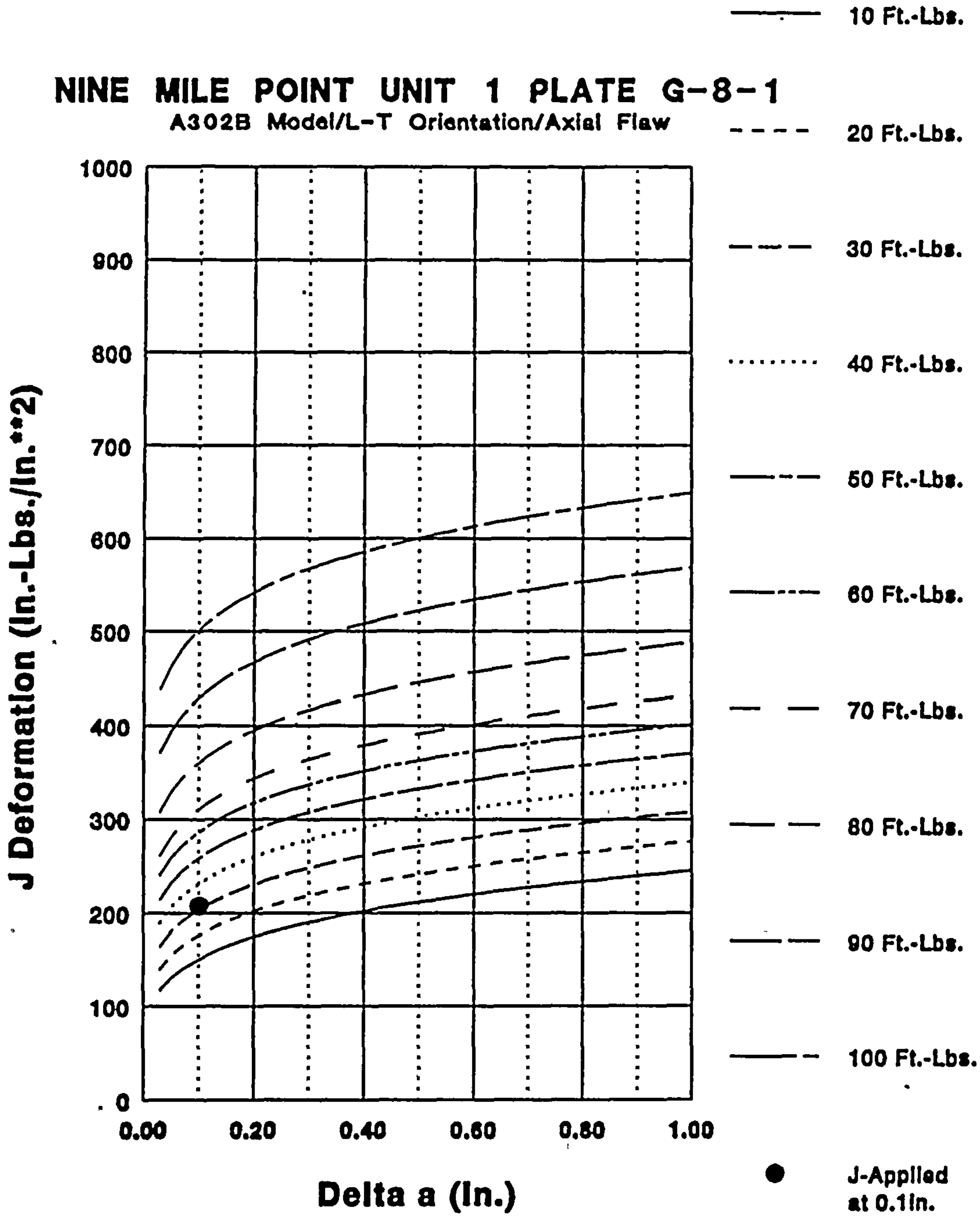
The results obtained for the NMP-1 G-8-1 and G-307-4 beltline plates indicate:

- the flaw stability criterion is more limiting than the flaw growth of 0.1 inch criterion

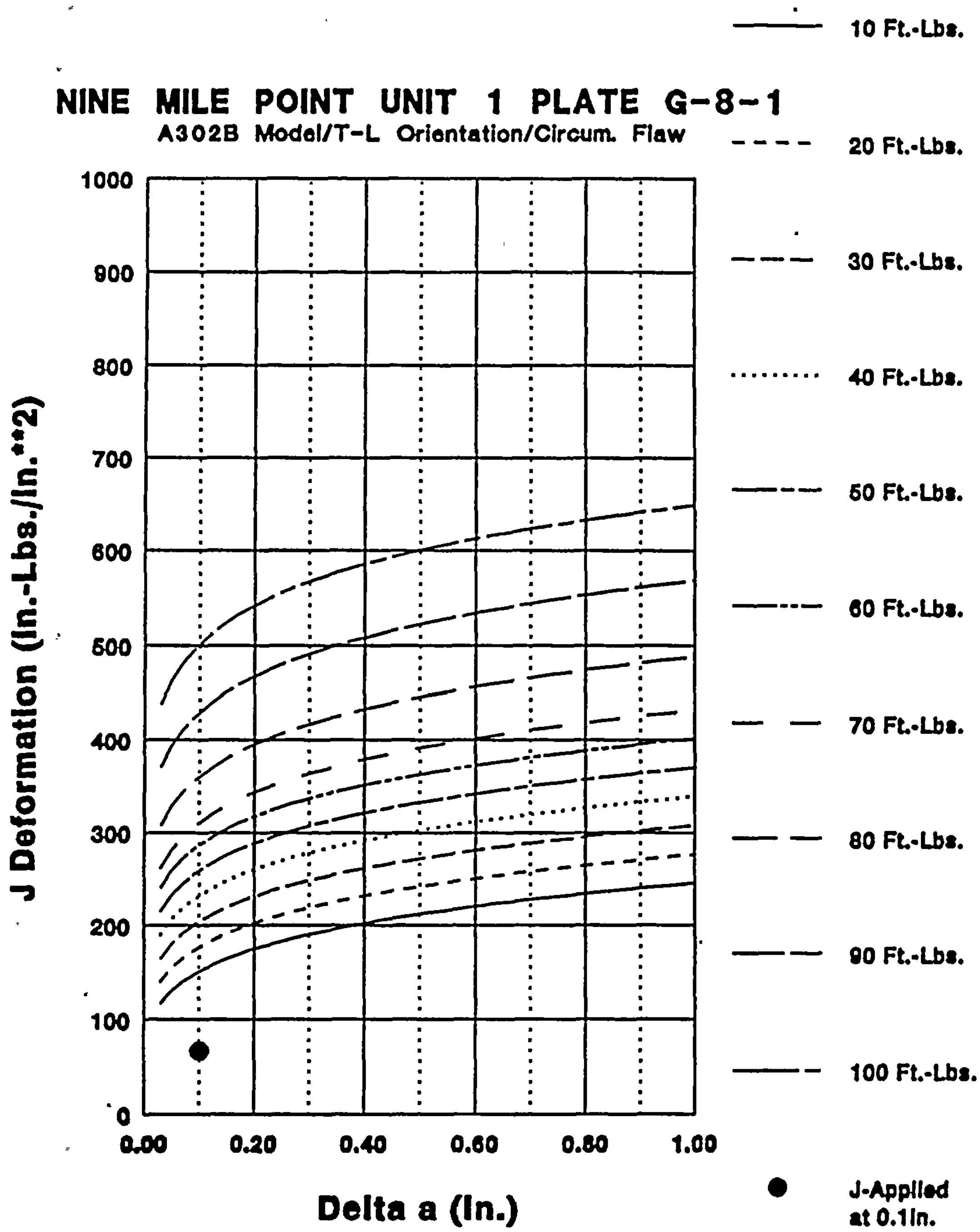
- as expected, the A302B material model yields significantly more conservative results

- the small difference (3 ksi) in the yield strengths of the two materials does not have a significant effect on the minimum allowable USE

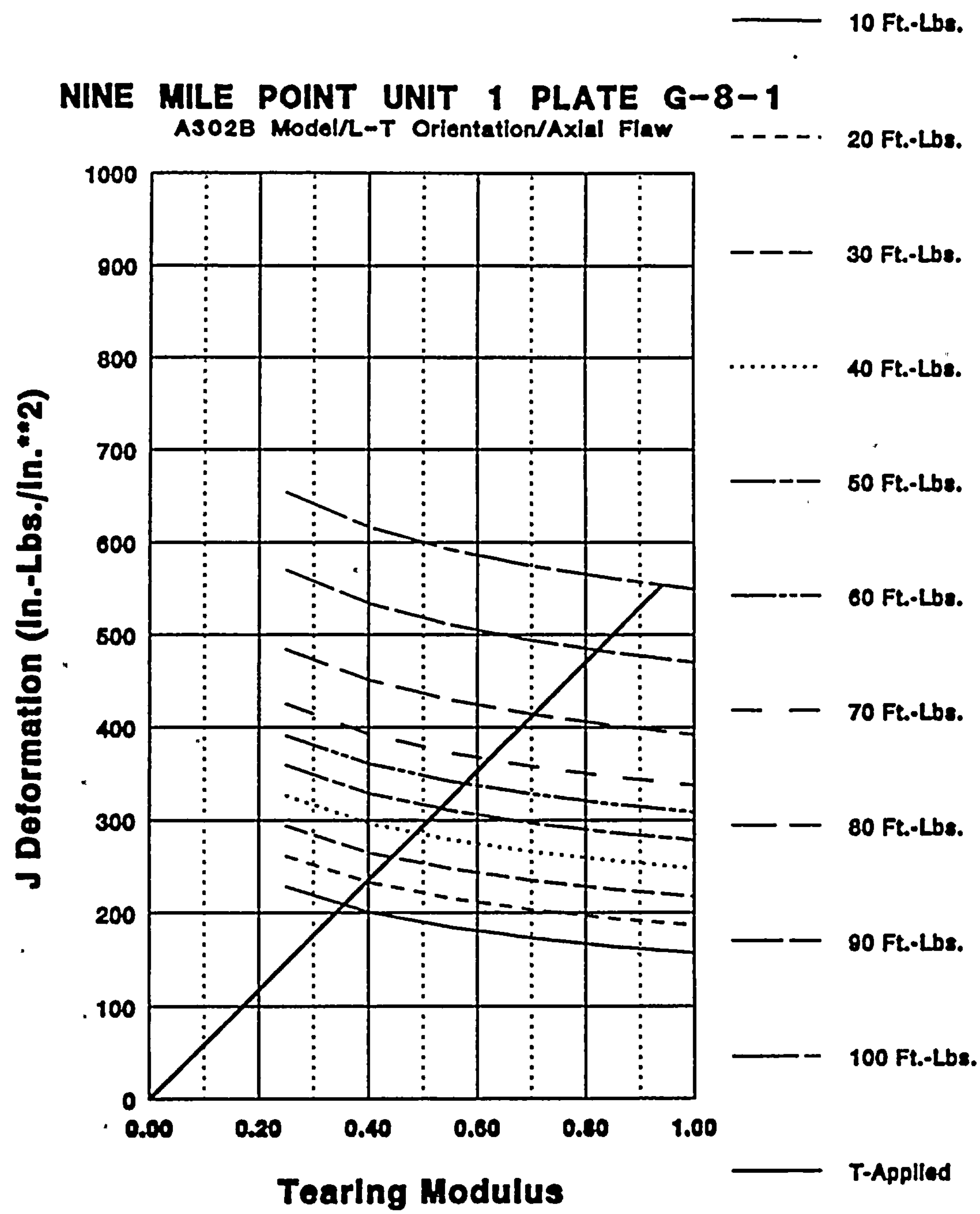
- plates G-8-1 and G-307-4 are expected to maintain sufficient resistance to ductile tearing provided the USE remains above 38 ft-lbs and 37 ft-lbs, respectively.



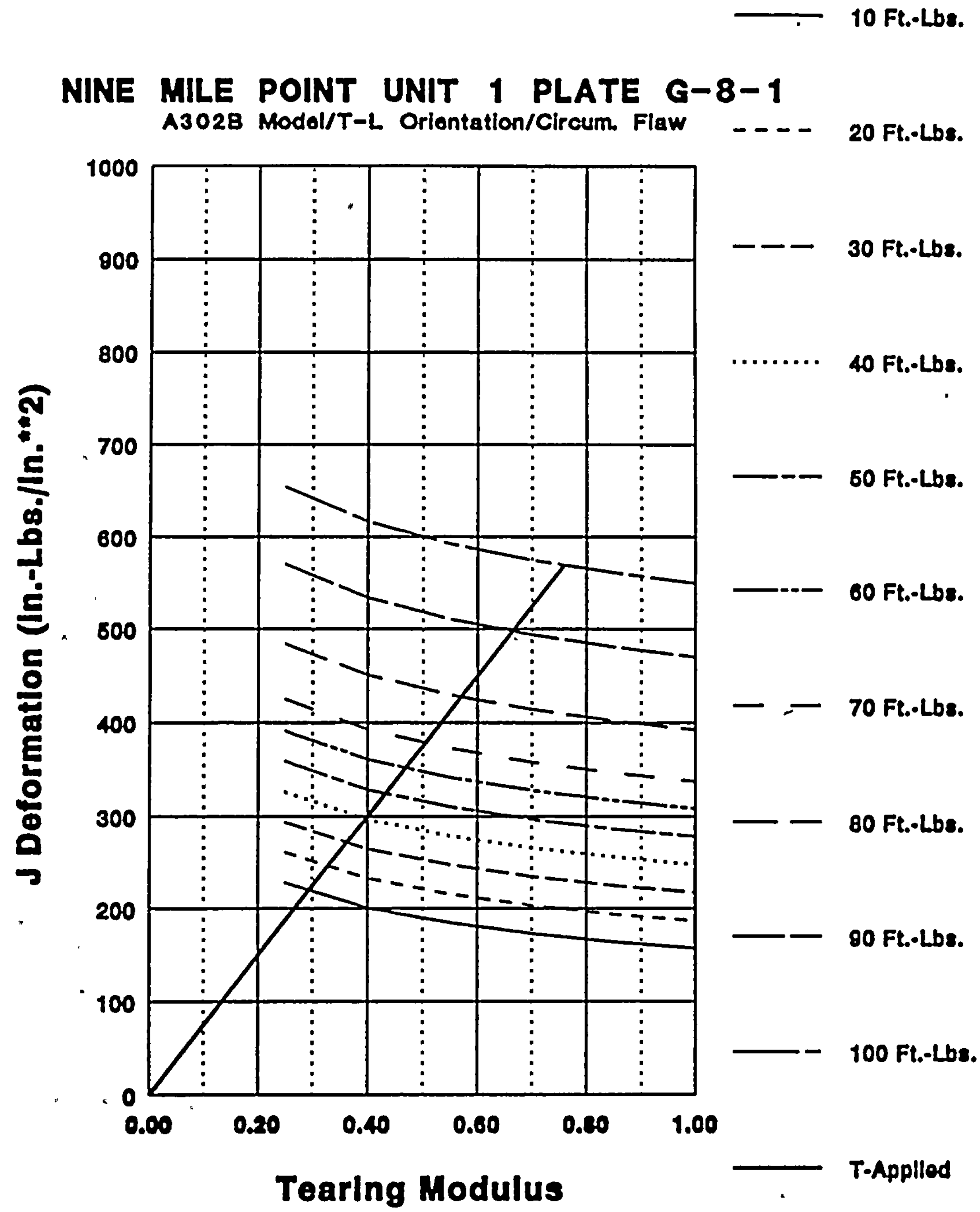
Evaluation Using Criterion for Flaw Growth of 0.1 in. for
Plate G-8-1 Modelled Using A302B Material Model (Axial Flaw)



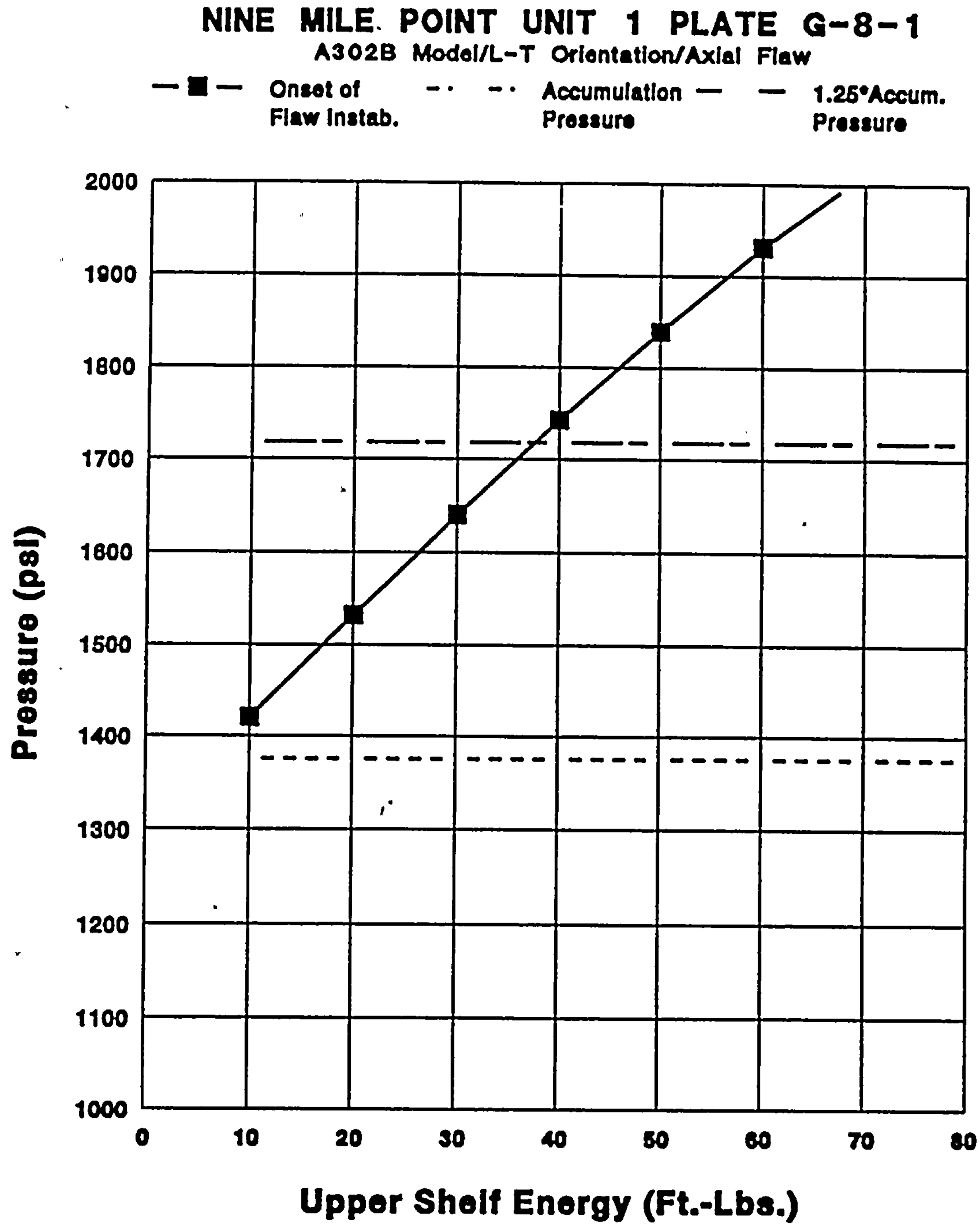
Evaluation Using Criterion for Flaw Growth of 0.1 in. for
Plate G-8-1 Modelled Using A302B Material Model (Circumferential Flaw)



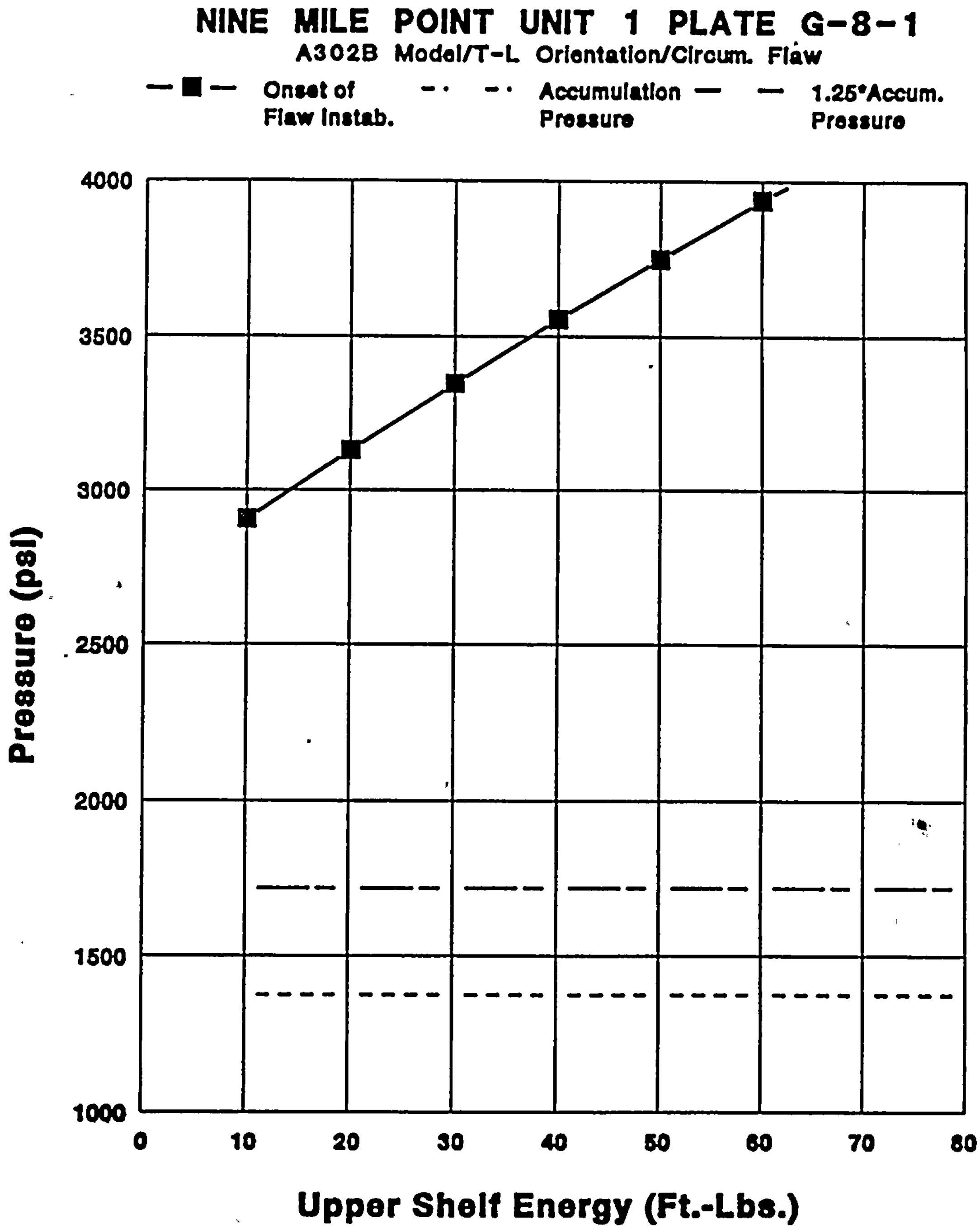
J-T Material and J-T Applied Curves for Plate G-8-1 Modelled Using A302B Material Model (Axial Flaw).



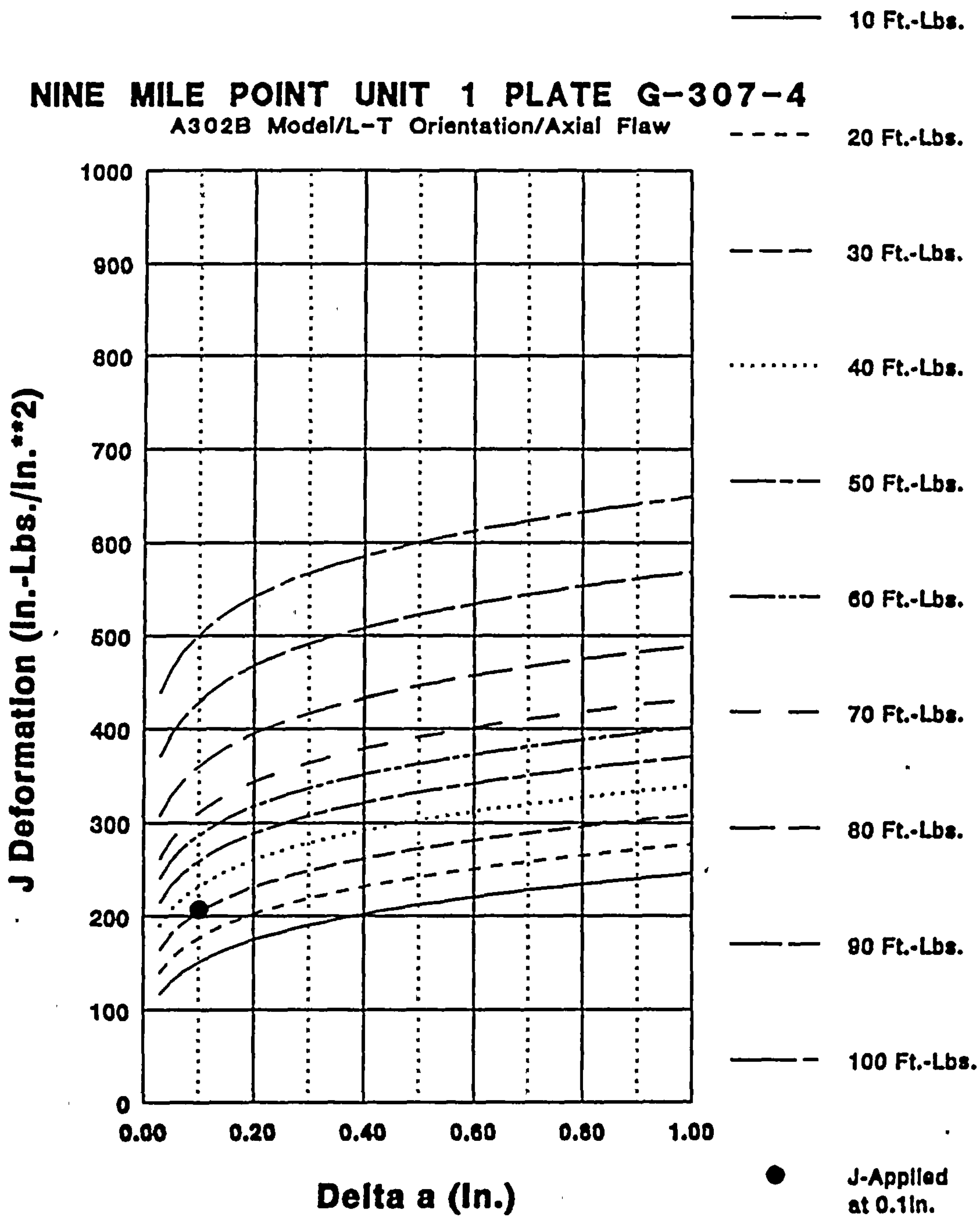
J-T Material and J-T Applied Curves for Plate G-8-1 Modelled Using A302B Material Model (Circumferential Flaw)



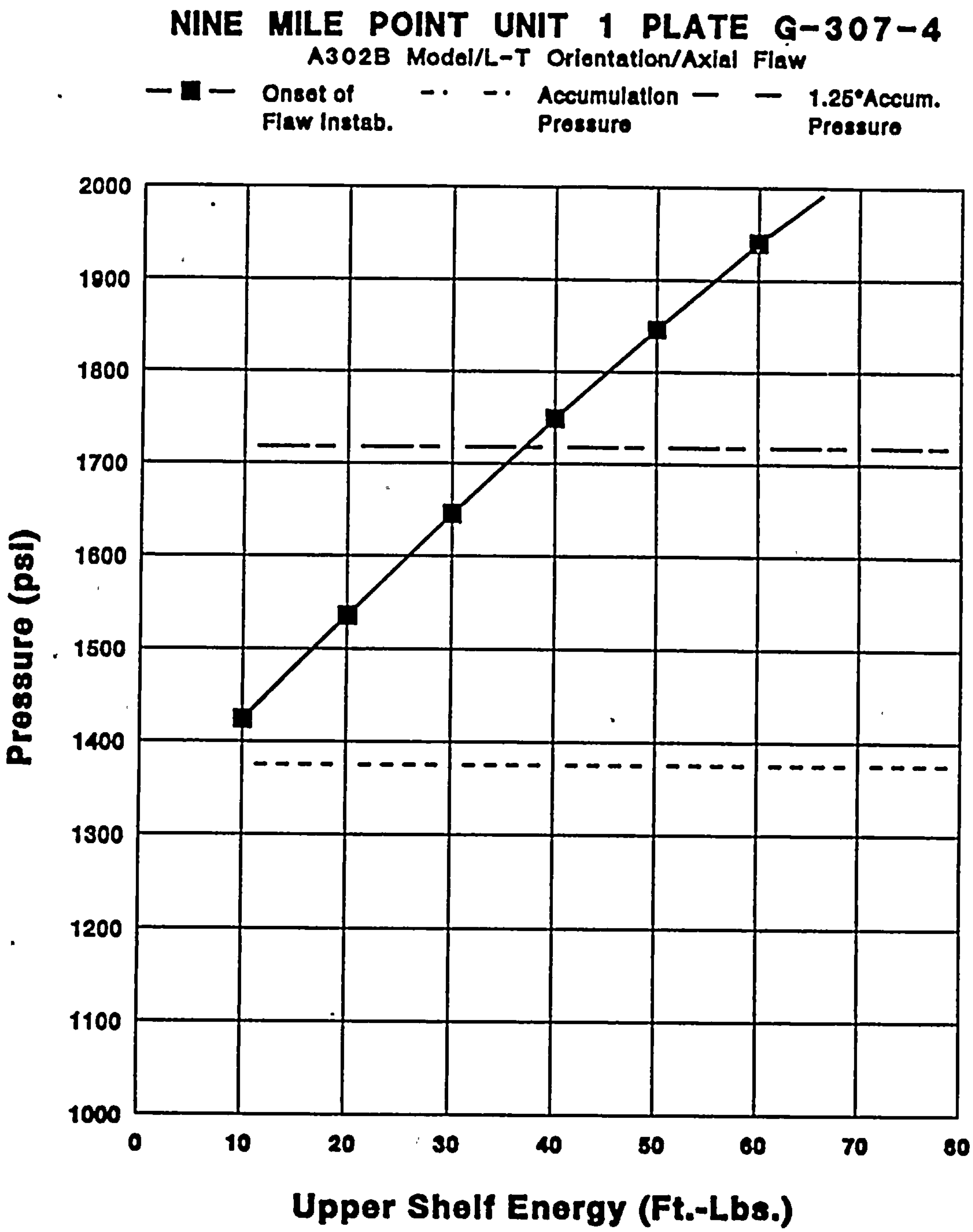
Evaluation Using Criterion for Flaw Stability for Plate G-8-1 Modelled Using A302B Material Model (Axial Flaw)



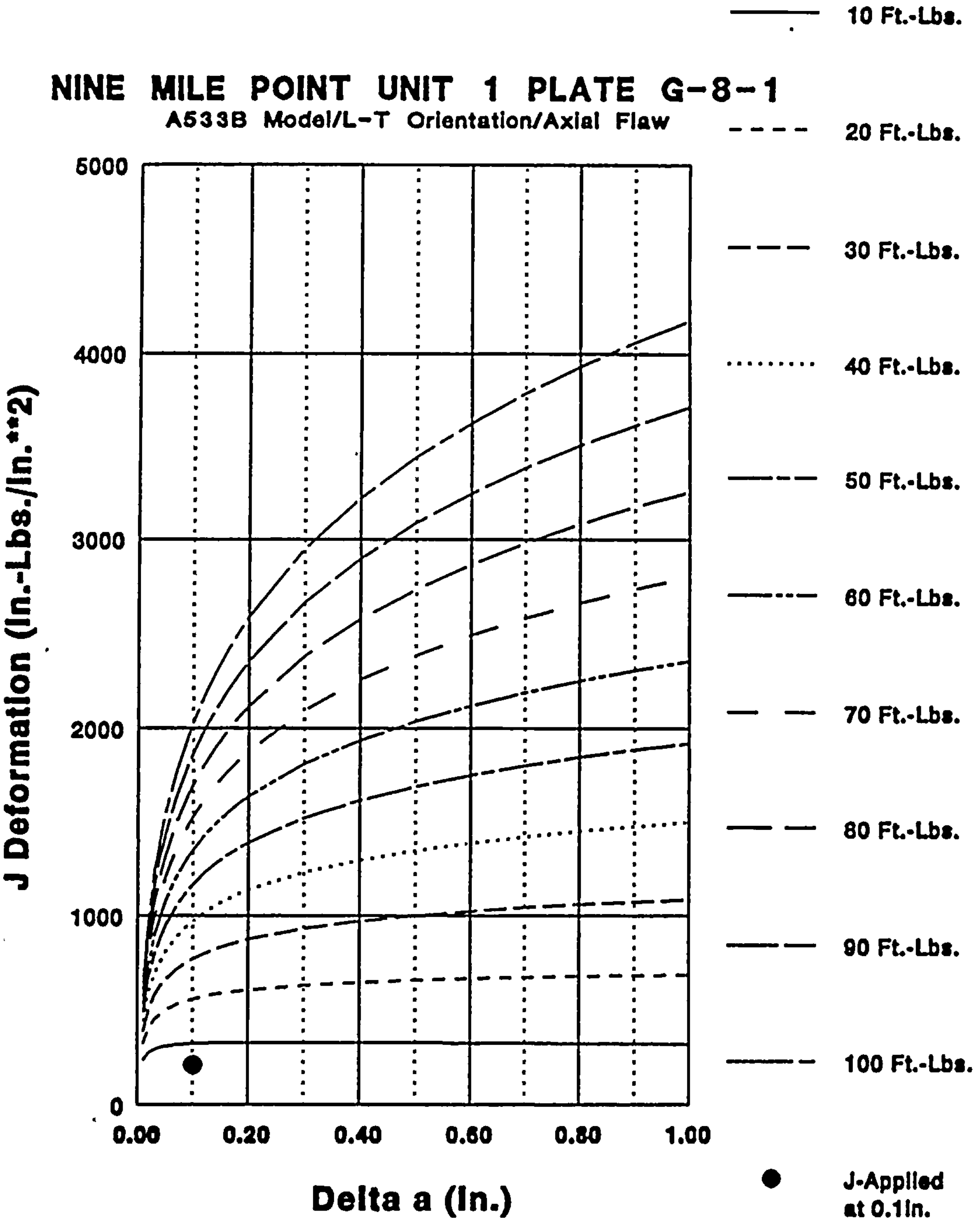
Evaluation Using Criterion for Flaw Stability for Plate G-8-1 Modelled Using A302B Material Model (Circumferential Flaw)



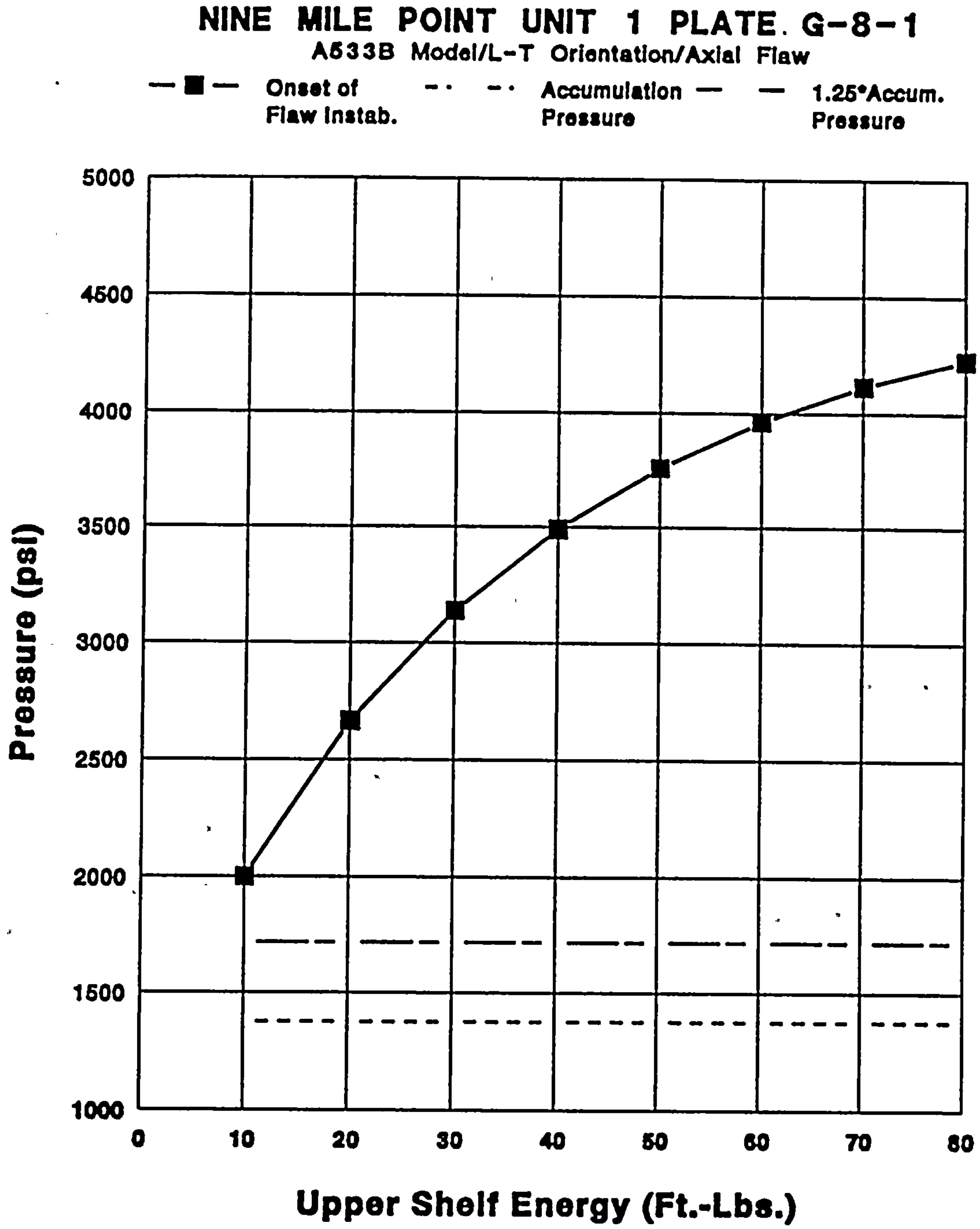
Evaluation Using Criterion for Flaw Growth of 0.1 in. for
Plate G-307-4 Modelled Using A302B Material Model (Axial Flaw)



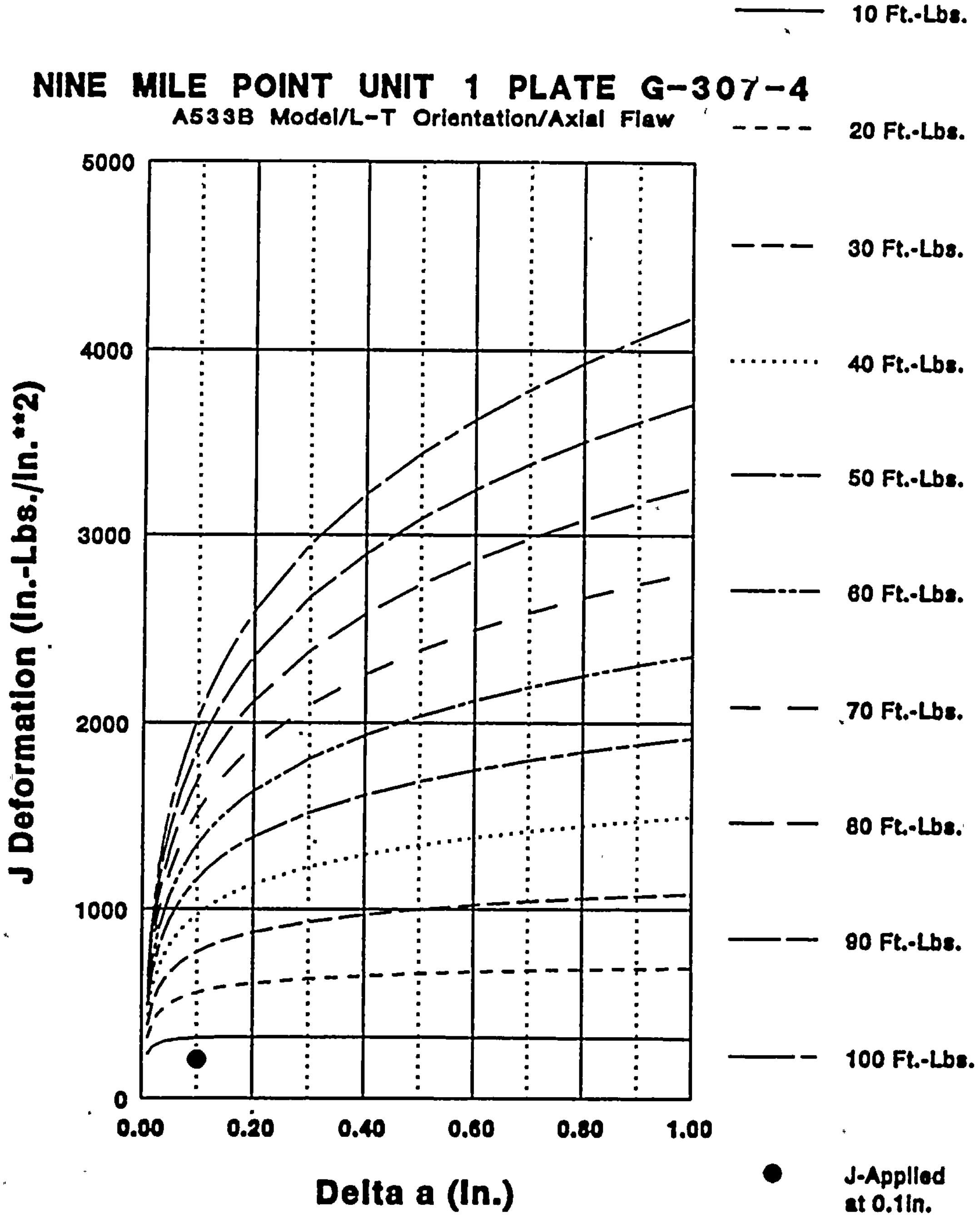
Evaluation Using Criterion for Flaw Stability for Plate G-307-4
Modelled Using A302B Material Model (Axial Flaw)



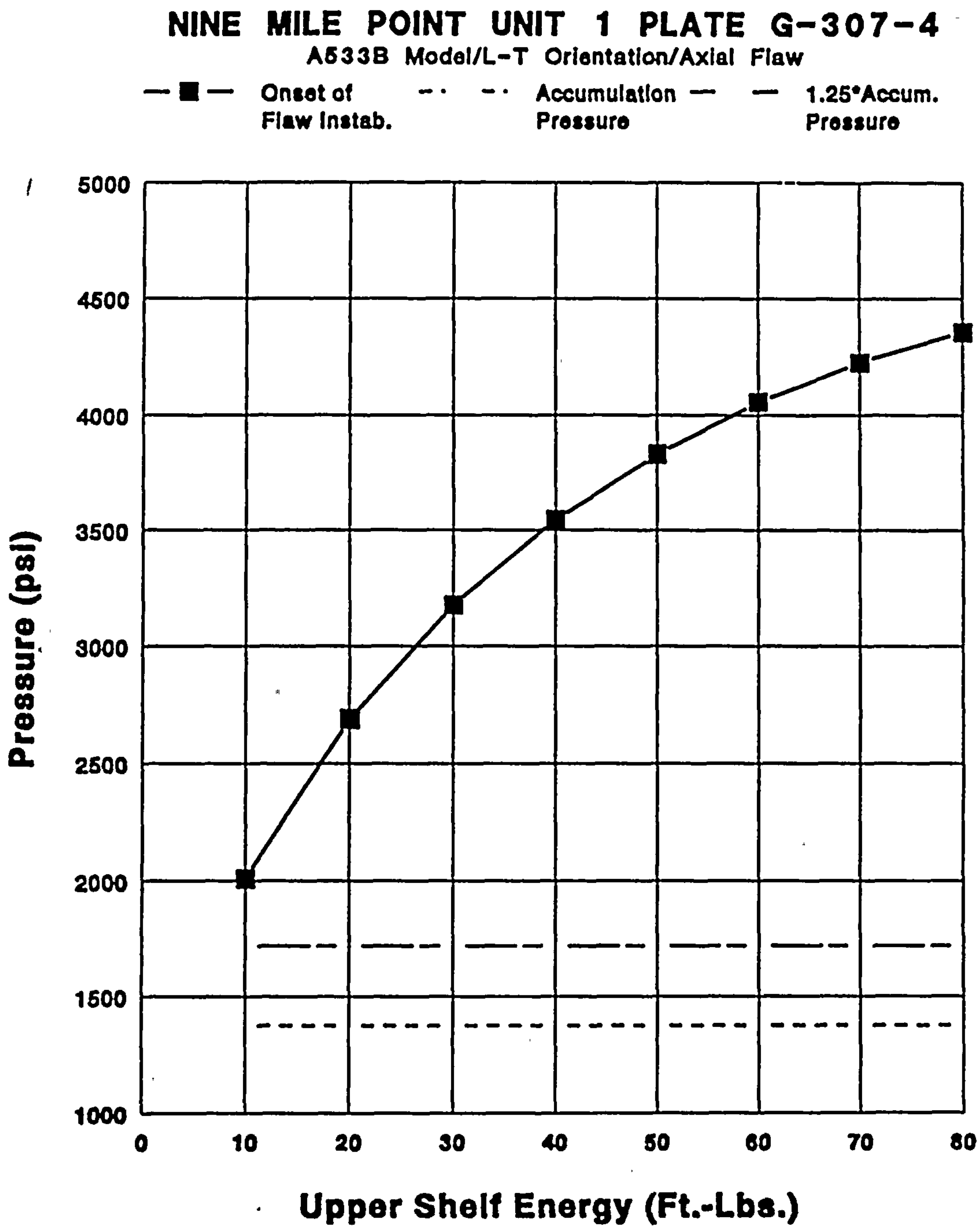
Evaluation Using Criterion for Flaw Growth of 0.1 in. for
Plate G-8-1 Modelled Using A533B Material Model (Axial Flaw)



Evaluation Using Criterion for Flaw Stability for Plate G-8-1 Modelled Using A533B Material Model (Axial Flaw)



Evaluation Using Criterion for Flaw Growth of 0.1 in. for
Plate G-307-4 Modelled Using A533B Material Model (Axial Flaw)



Evaluation Using Criterion for Flaw Stability for Plate G-307-4 Modelled Using A533B Material Model (Axial Flaw)

Minimum Upper Shelf Energy Level for NMP-1 Plates
Based on the ASME Draft Appendix X Evaluation Criteria
for Service Levels A and B

Plate	Material Model	Minimum USE (Ft-Lbs)	
		Flaw Growth of 0.1 in. Criterion $J_1 < J_{0.1}$	Flaw Stability Criterion $P^* > 1.25P_a$
G-8-1	A302B	32	38
G-8-1	A533B	<10	<10
G-307-4	A302B	31	37
G-307-4	A533B	<10	<10

SUMMARY

- The A302B material model best represents the NMP-1 plates.
- For Service Levels A and B, the low USE issue will be closed upon issuance of the final report to the NRC.
- The final report for Service Levels A and B will be issued by October 16, 1992.

4.0 TECHNICAL APPROACH FOR LEVEL C AND D ANALYSES

The acceptance criteria given in the Draft ASME Appendix X [ASME92] will be applied to the G-8-1 and G-307-4 plates using the A302B material model for a postulated axial flaw. The NMP-1 design basis transients for Service Levels C and D have been reviewed to define the limiting loads from a ductile fracture perspective.

4.1 FRACTURE MECHANICS ASSESSMENT
BASE MATERIAL - SERVICE LEVEL C

- An interior axial flaw, with depth up to 1/10 of the base metal wall thickness (plus cladding thickness), and a surface length 6 times the depth, shall be postulated.

- Toughness properties, which correspond to the postulated flaw orientation shall be used in the analysis.

- The J-integral/tearing modulus approach shall be used.

- The following criteria shall be satisfied:
  (1) criterion for flaw growth of 0.1 inch
  $J_1^C < J_{0.1}$
  (2) criterion for flaw stability
  $P^* >$ larger of 1.25 P_a or the peak pressure during the transient where,

J_1^C = applied J-integral for a safety factor of 1.0 on pressure and thermal loading

$J_{0.1}$ = J-integral resistance at a ductile flaw growth of 0.1 inch

P^* = internal pressure at flaw instability

P_a = accumulation pressure, but not exceeding 1.1 times design pressure

- Flaws of various depths, ranging up to the maximum postulated depth, shall be analyzed to determine the most limiting flaw depth

- The material properties used in the analysis shall be a conservative representation of the toughness and tensile properties of plates G-8-1 and G-307-4 at plant operating temperature

- The impact of residual stress associated with the stainless steel cladding will not be included in the analysis

BASE MATERIAL - SERVICE LEVEL D

- Flaws for Level D loadings shall be postulated as specified for Level C, and the toughness properties for the corresponding orientation shall be used.
- The J-integral/tearing modulus approach shall be used.
- The flaw shall be shown to be stable, with the possibility of ductile flaw growth, using a factor of safety of 1.0 on loading.
- The flaw depth shall not exceed 3/4T, and the remaining ligament shall be safe in terms of tensile instability.
- Flaws of various depths, ranging up to the maximum postulated depth, shall be analyzed to determine the most limiting flaw depth.
- The material properties used in the analysis shall be a best estimate representation of the toughness and tensile properties of plates G-8-1 and G-307-4 at plant operating temperature.
- The impact of residual stress associated with the stainless steel cladding will not be included in the analysis.

4.1.1 Pressure Loading

Zahoor's [ZA91] stress intensity factor solution for a finite length axial part-throughwall flaw shall be used.

Applicability

$0.15 < a/t \leq 0.8$

$5 \leq R/t \leq 20$

$3 \leq 2c/a \leq 12$

where,

a = flaw depth

t = vessel thickness

R = vessel radius

2c = surface flaw length

The effective flaw depth for small scale yielding is given by:

$$a_e = a \left[1 + \frac{J_o E'}{(6\pi a \sigma_F^2)} \right]$$

4.1.2 THERMAL LOADING

The ASME Section III, Appendix G, Subsection G-2214.3(b) approach for calculation of K_{IT} shall be followed. In particular, the stress distribution in the vicinity of the flaw shall be calculated using a one dimensional finite element model. The Raju-Newman [RA82] stress-intensity factor influence coefficients shall be used to determine K_{IT}.

4.1.3 COMBINED LOADING FOR 0.1 FLAW GROWTH CRITERION

The applied J-integral shall be calculated for various initial flaw depths as follows:

$$J = \frac{(K_{IP} + K_{IT})^2}{E'}$$

4.1.4 J-INTEGRAL AT FLAW INSTABILITY

$$T = \frac{dJ}{da} \quad \frac{E}{\sigma_F^{\,2}}$$

$$K_{IP}^{*} = (J^{*}E')^{0.5} - K_{IT}^{*}$$

4.2 LEVEL C AND D SERVICE LOADINGS

General Approach:

- Thermal hydraulic transient analyses, design basis accident analyses, and the original thermal stress analysis data are available for NMP-1.

- The NMP-1 stress data are not sufficient for defining the transients as Level C and Level D Service Conditions.

- The NMP-2 transients can be used to define the NMP-1 Level C and D Service Levels by comparing the reactor vessel thermal cycle drawings and related data.

- Candidate Level C transients will be screened by performing a thermal transient analysis to identify the limiting transient from a ductile fracture perspective.

- The limiting Level C and D transients will be analyzed in accordance with the Draft ASME Appendix X.

Level C Service Events:

The NMP-2 reactor vessel thermal cycle definition of emergency conditions was defined consistent with paragraph NB-3113.3 of Section III of the ASME Code. The NMP-2 emergency conditions are defined as events 22 through 26:

Event 22) Reactor Overpressure with Delayed Scram (feedwater stays on, isolation valves stay open)

Event 23) Automatic Blowdown (550°F to 375°F in 3.3 minutes followed by 300°F/hr to 281°F)

Event 24) Improper Start of Cold Recirculation Loop

Event 25) Sudden Start of Pump in Cold Recirculation Loop

Event 26) Hot Standby Drain Shut-off Pump Restart

Review of the Unit 2 emergency condition events indicates that Event 23 (Automatic Blowdown) is the limiting NMP-2 Level C event from a ductile fracture perspective.

The original NMP-1 Thermal Stress Analysis included the following transients:

- Linear heatup and cooldown at 100°F/hr from 90°F to 546°F
- Steady state @ 546°F then:

  a) Decrease linearly to 90°F at
  100°F/hr Normal Cooldown
  300°F/hr Emergency Cooldown

  b) Decrease linearly to 400°F at 100°F/hr and increase to 546°F at 100°F/hr for the scram-loss of feedwater event

  c) Decreases linearly to 369°F at rate of 1056°F/hr (decrease to 369°F in 10 minutes), remains constant at 369°F for 1.6 hours, then decreases linearly to 90°F at 100°F/hr for the one relief valve blowdown

Level C Service Events (Continued)

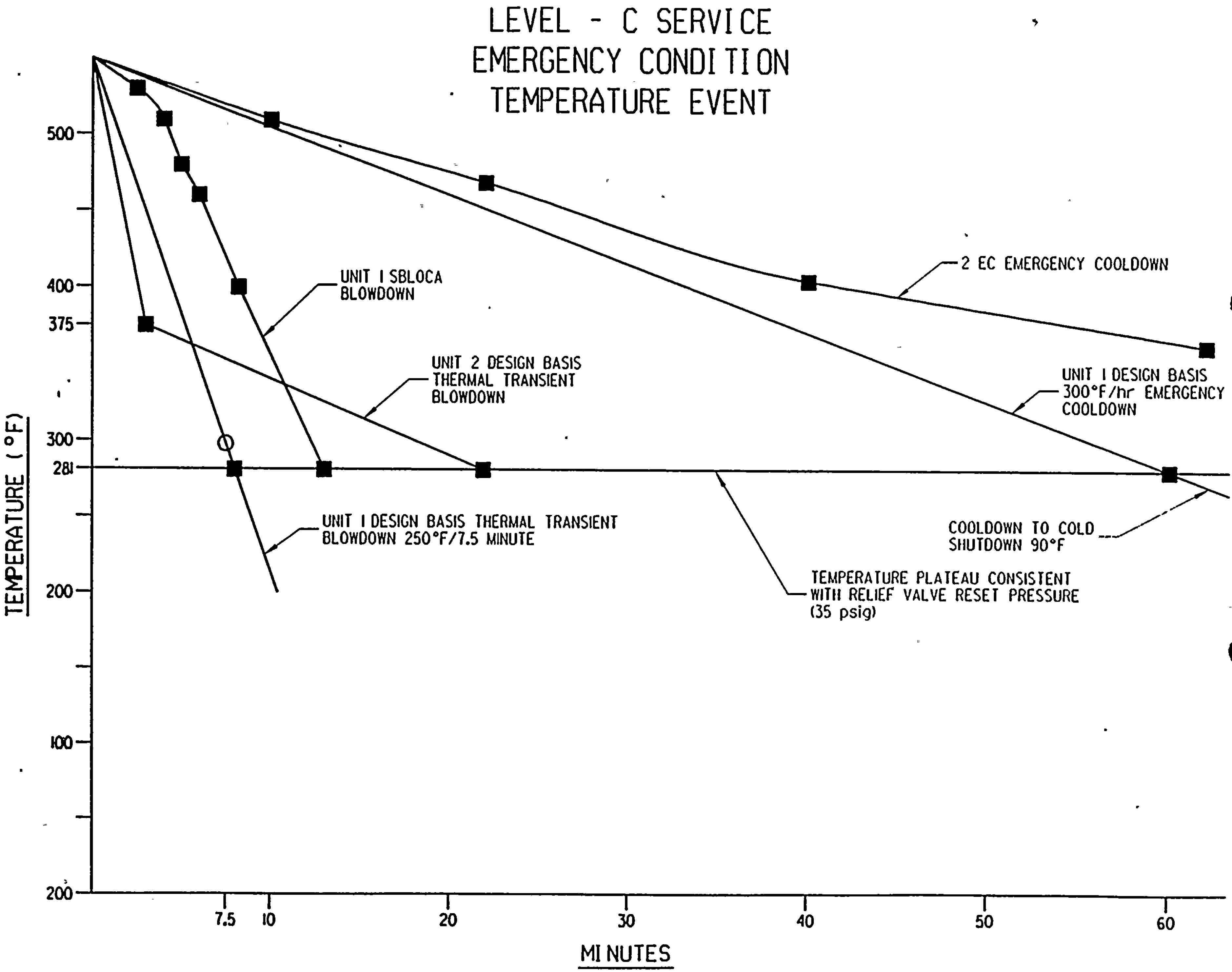
The NMP-1 FSAR also includes discussion of two additional blowdown transients which were analyzed:

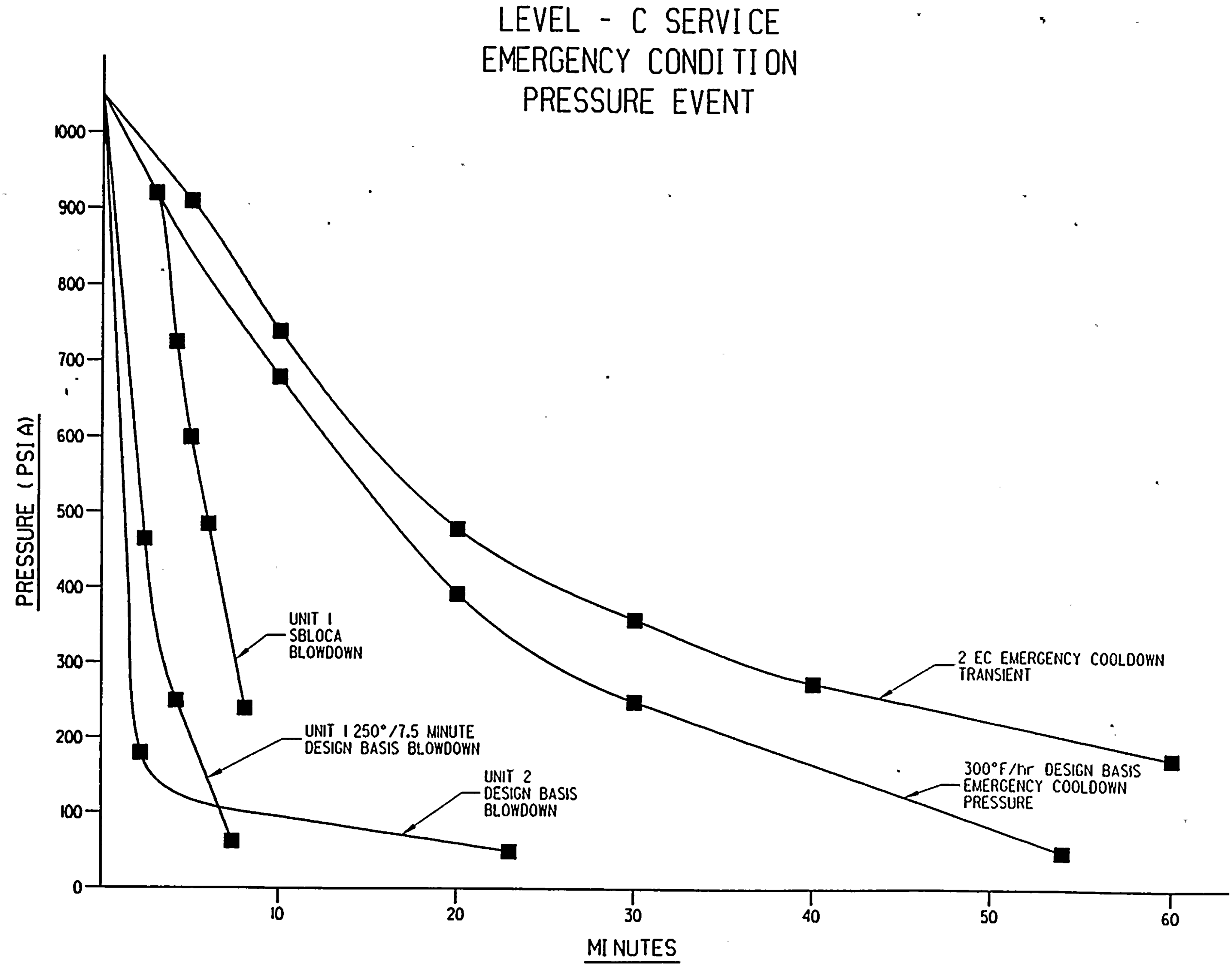
- Blowdown of six relief valves at a rate of 250°F in 7.5 minutes
- Blowdown of reactor by pressure regulator malfunction from hot standby, 215°F in 5.5 minutes

The NMP-1 blowdown event, the NMP-2 thermal transient blowdown, and the 300°F/hr emergency cooldown shall be analyzed to determine the limiting event.

Conclusions:

The proposed approach is to bound the original NMP-1 FSAR thermal transients and the NMP-2 automatic blowdown event. The limiting transient, from a ductile fracture perspective, shall be analyzed in accordance with the ASME Appendix X.


LEVEL - C SERVICE
EMERGENCY CONDITION
TEMPERATURE EVENT
500
400
375
300
281
200
100
200
TEMPERATURE (°F)
7.5
10
20
30
40
50
60
MINUTES
2 EC EMERGENCY COOLDOWN
UNIT I SBLOCA BLOWDOWN
UNIT 2 DESIGN BASIS THERMAL TRANSIENT BLOWDOWN
UNIT I DESIGN BASIS 300°F/hr EMERGENCY COOLDOWN
UNIT I DESIGN BASIS THERMAL TRANSIENT BLOWDOWN 250°F/7.5 MINUTE
COOLDOWN TO COLD SHUTDOWN 90°F
TEMPERATURE PLATEAU CONSISTENT WITH RELIEF VALVE RESET PRESSURE (35 psig)



LEVEL - C SERVICE
EMERGENCY CONDITION
PRESSURE EVENT
PRESSURE (PSIA)
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
MINUTES
UNIT 1 SBLOCA BLOWDOWN
UNIT 1 250°/7.5 MINUTE DESIGN BASIS BLOWDOWN
UNIT 2 DESIGN BASIS BLOWDOWN
2 EC EMERGENCY COOLDOWN TRANSIENT
300°F/hr DESIGN BASIS EMERGENCY COOLDOWN PRESSURE

Level D Service Conditions

The NMP-2 reactor vessel thermal cycle definition of the faulted condition is based on paragraph NB-3113.4 of Section III of ASME B&PV Code.

The NMP-2 faulted condition is the complete break of one recirculation outlet line. This event occurs immediately following the maximum earthquake event for which the faulted condition loadings are used. This is the design basis LOCA.

The Level D events for NMP-1 are defined as the LOCA events. Review of the NMP-1 accident analysis indicates that the recirculation discharge line break and the main steam line break result in the most severe depressurization. A thermal transient heat transfer analysis shall be performed to determine the limiting event.

Conclusions:

The Level D event is consistent with the NMP-1 design basis and the NMP-2 definition of faulted condition thermal cycle event. As with Level C, the limiting transient shall be analyzed in accordance with Appendix X.

5.0 SUMMARY AND CONCLUSIONS

- For service levels A and B, plates G-8-1 and G-307-4 will maintain sufficient resistance to ductile fracture provided the USE level remains above 38 ft-lbs and 37 ft-lbs, respectively.

- Using an L-T to T-L conversion of 0.65 and the RG1.99(2) model, the USE for plates G-8-1 and G-307-4 are not expected to drop below 40 ft-lbs prior to EOL.

SCHEDULE FOR COMPLETION OF USE ISSUE RESOLUTION FOR NMP-1

ITEM	COMPLETION DATE
Report on the Results of the Calculations for Service Levels A and B	October 16, 1992
Report on the Results of the Calculations for Service Levels C and D	January 29, 1993

6.0 REFERENCES

[ASME80] ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Power Plant Components", July 1, 1980

[ASME92] ASME, Draft Code Case N-XXX, "Assessment of Reactor Vessels with Low Upper Shelf Charpy Energy Levels", Revision 11, May 27, 1992.

[CE90] "Niagara Mohawk Power Corporation Nine Mile Point Unit 1 Reactor Vessel Weld Materials", Report No. 86390-MCC-001, ABB Combustion Engineering Nuclear Power Combustion Engineering, Inc., Windsor, Connecticut, June, 1990.

[EA91] Eason, E.D., Wright, J.E., Nelson, E.E., "Multivariable Modeling of Pressure Vessel and Piping J-R Data, NUREG/CR-5729, May, 1991.

[HA82] Hawthorne, J.R., Menke, B.H., Loss, F.J., Watson, H.E., Hiser, A.L., Gray, R.A., "Evaluation and Prediction of Neutron Embrittlement in Reactor Pressure Vessel Materials", prepared for EPRI, December, 1982.

[HA90] Hawthorne, J.R., Hiser, A.L., "Influence of Fluence Rate on Radiation-Induced Mechanical Property Changes in Reactor Pressure Vessel Steels", NUREG/CR-5493, March, 1990.

[HI89] Hiser, A.L., Terrell, J.B., "Size Effects on J-R Curves for A302B Plate", NUREG/CR-5265, January, 1989.

[JOY91] Joyce, J.A., Hackett, E.M., "Extension and Extrapolation of J-R Curves and Their Application to the Low Upper Shelf Toughness Issue", NUREG/CR-5577, March, 1991.

[MA90] Manahan, M.P., "Nine Mile Point Unit 1 RT_{NDT} Determination", Final Report from MPM Research & Consulting to NMPC, September 28, 1990.

[MA91] Manahan, M.P., "Nine Mile Point Unit 1 Surveillance Capsule Program", NMEL-90001, January 4, 1991.

[MA92] Manahan, M.P., Soong, Y., "Response to NRC Generic Letter 92-01 for Nine Mile Point Unit 1", June 12, 1992.

[MTEB81] NRC Branch Technical Position MTEB 5-2, "Fracture Toughness Requirements", Revision 1, July, 1981.

[ZA88] Zahoor, A., "Allowable Minimum Upper Shelf Toughness for Nuclear Reactor Pressure Vessels", Nuclear Engineering and Design, 1988

[ZA91] Zahoor, A., "Ductile Fracture Handbook", Volume 3, EPRI research project 1757-69, January, 1991.

The NRC staff made the following recommendations regarding the licensee's analysis:

1. The model for the J-R curves should be revised to more accurately fit the data in the area of greatest interest in the analysis.

2. The October 16, 1992, submittal should address prior compliance with the requirements of 10 CFR 50.60 and 10 CFR Part 50, Appendix G.

3. The proprietary evaluation of USE for welds (discussed during a closed session of the meeting) should be included in the October 16, 1992, submittal. The uncertainty analysis for this evaluation may be included in the January 29, 1993, submittal and should include benchmarking against data in the Embrittlement Data Base. The NRC staff provided a current copy of the Embrittlement Data Base to NMPC on October 2, 1992.

Original signed by:
Donald S. Brinkman, Senior Project Manager
Project Directorate I-1
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

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