From: "DAVANT, GUY H" <GDAVANT@entergy.com>
To: "'twa@nrc.gov'" <twa@nrc.gov>
Date: 4/28/04 4:31PM
Subject: Revised Information Package Supporting Relief Request ANO1-R&R-006

Tom,

In addition to the revised Table 1 and Figure 6, our response to NRC Question 4 (discussed in yesterday's call) also changes. As I mentioned in my previous e-mail, the 94 ft-lb curve no longer meets SF = 3 for both primary and secondary stresses. We have revised our response to Question 4 to reflect this change, as reflected in the attached file. For convenience, I am providing a complete, revised package of information. This package replaces the package I sent to you yesterday. This information may be docketed.

Thanks!

Guy

<<SIA EPFM NRC CONF 4-27-04 Revsd 4-28.pdf>>

CC: "LEWIS, RAYMOND S" <RLEWIS1@entergy.com>

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Created By:	GDAVANT@entergy.com

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TWA (Thomas Alexion)

entergy.com
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Response to NRC Questions

1. Upper shelf Charpy V-notch energy (USE) estimates for the ANO-1 head material were developed as shown in Figure 4, This Figure indicates three Charpy energy data points derived from measurements on the ANO-1 head material at +10° F. The actual measurements were higher, but they were measured in the Longitudinal direction, so they were reduced for the Transverse direction in accordance with USNRC SRP/NUREG-75/087 MTEB 5-2 Position 1.1 B-3a. These are obviously not on the upper shelf, so they have been plotted on a complete Charpy Energy plot for a comparable material (GGNS beltline plate, comparable thickness, Transverse direction). The three ANO points fall well within the range of the GGNS data at +10°F, and therefore, the GGNS data, which exhibit USEs ranging from 94 to 120 ft-lbs, are considered representative of the ANO-1 head material USE. The lower bound value of 94 ft-lbs was used, in conjunction with J-T versus Charpy USE correlations in NUREG-0744 (Figures 2 and 3), to estimate a conservative J-T curve for the analysis.

2. The screening criteria of Appendix H were developed using the "Fracture Analysis Diagram" (FAD) approach. Although Appendix H itself is strictly applicable only to ferritic piping, the FAD approach upon which it is based is more generally applicable. A second criterion for the applicability of J-T stability analysis to ferritic materials is that the temperature be at least 50°F greater than the onset of upper shelf. From Figure 4, it is seen that onset of upper shelf occurs at about 210°F. Since the ANO-1 evaluation is at operating temperature of ~550°F, it clearly meets the latter criterion as well.

Response to NRC Questions (continued)

3. The Appendix K approximation for J-integral requires that the plastic zone size be small (i.e. contained plasticity). The plastic zone size with the recommended safety factors (SF=3 on primary loads, 1.5 on secondary) is 0.319", which is considered small in comparison to the original crack size of ~1.5" and the nominal head thickness of 6.6". The plastic zone sizes become significantly greater for the higher safety factor cases (0.5" to 2"), but these are just informational cases to demonstrate margin, and not the focal point of the analysis. Also, since the dominant loading in these analyses is residual stress (amplified by safety factors), which is strain controlled and highly localized, the approximation of using LEFM K-values to estimate EPFM J-values remains valid for much larger plastic zone sizes than might be interpreted from Appendix K.

4. The analysis demonstrates large margins between applied J-integral and the crack instability point (i.e. the point where the applied J-T line intersects the appropriate J-T material curve) in all cases. In Figure 6, it is seen that the applied J-T point for the recommended safety factors of 3 on primary loads and 1.5 on secondary (residual) loads is below even the 40 ft-lb J-T material curve, which was measured at +10 for the ANO-1 head material, and is an extreme lower bound of USE for this material. Considering a more reasonable estimate of J-T material for the ANO-head material on the upper shelf (the 94 ft-lb curve – still a lower bound) shows ample margin to instability.

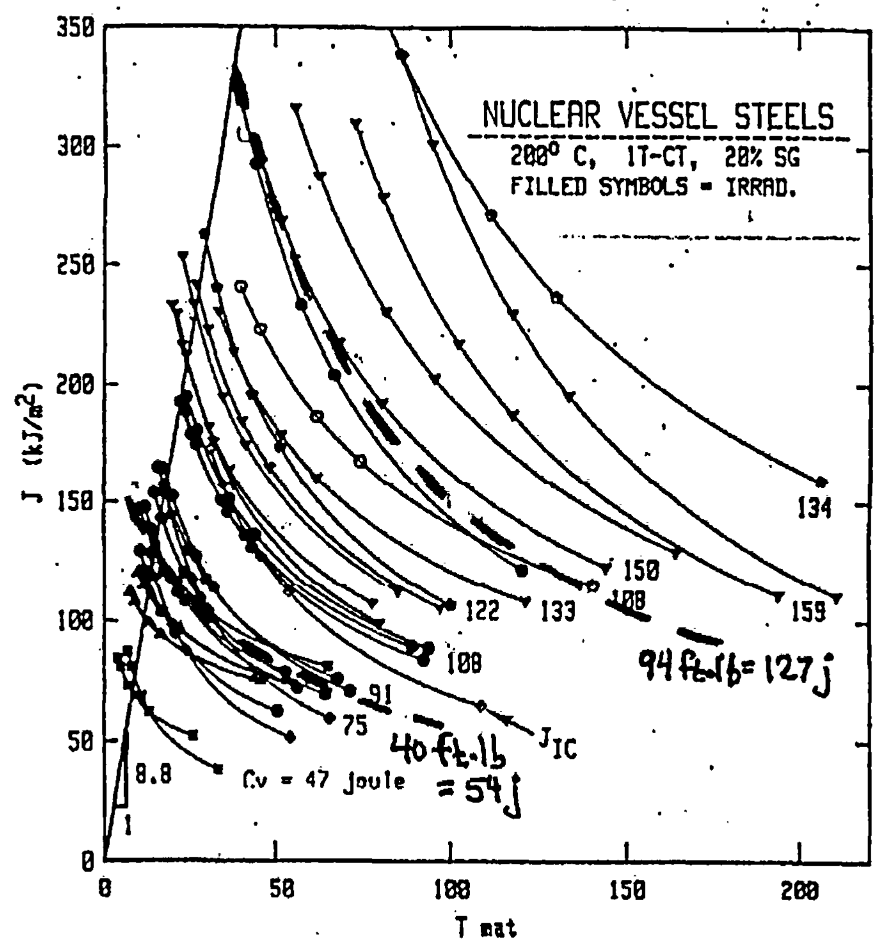

Figure 1: J-T Diagram for Several Reactor Vessel Steels and Welds Showing Rough Correlation with Charpy V-notch Upper Shelf Energy [5]. Power Law Correlations used for ANO-1 Head (40 and 94 ft-lbs) also Shown

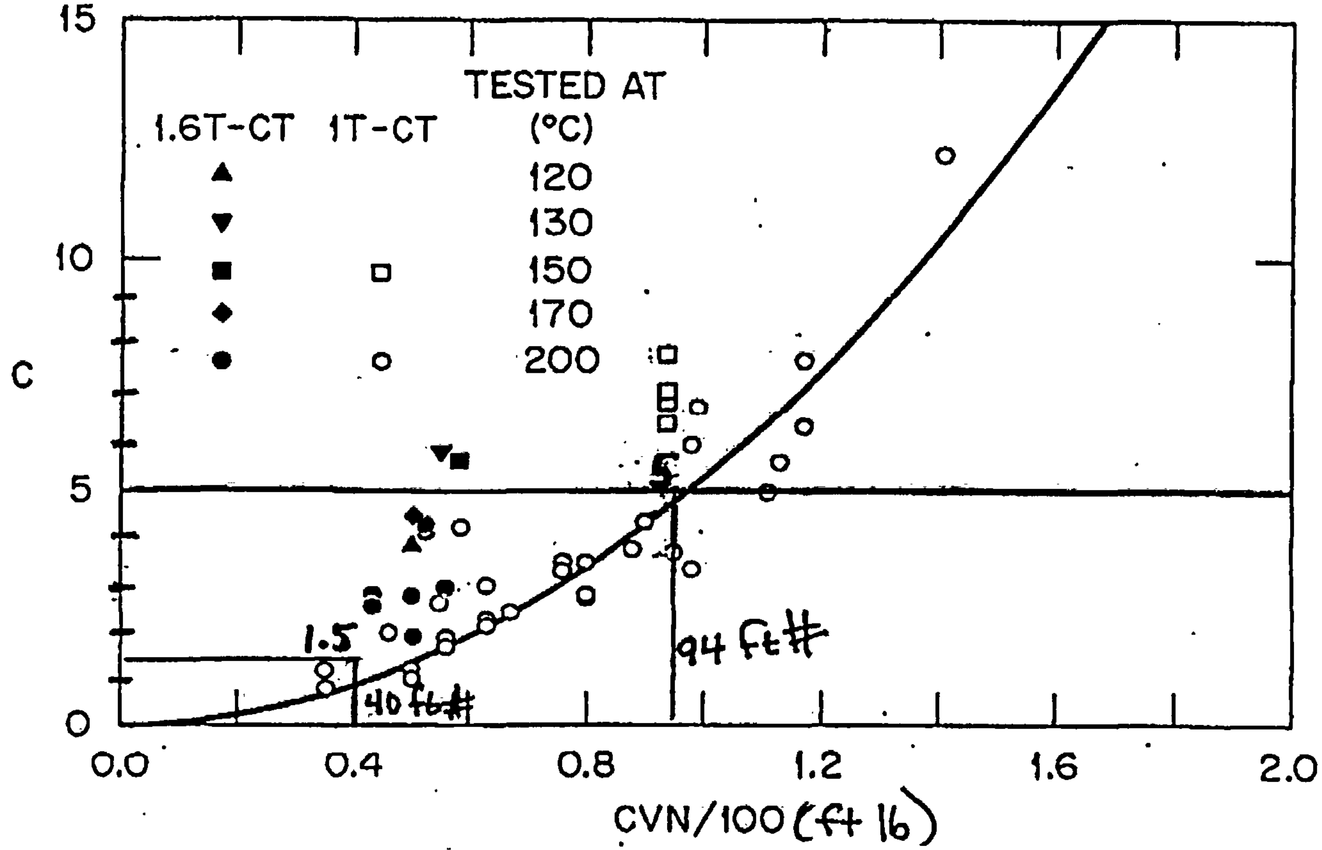

Figure 2: Correlation of Coefficient C of Power Law J R-curve Representation with Charpy V-notch Upper Shelf Energy [5]

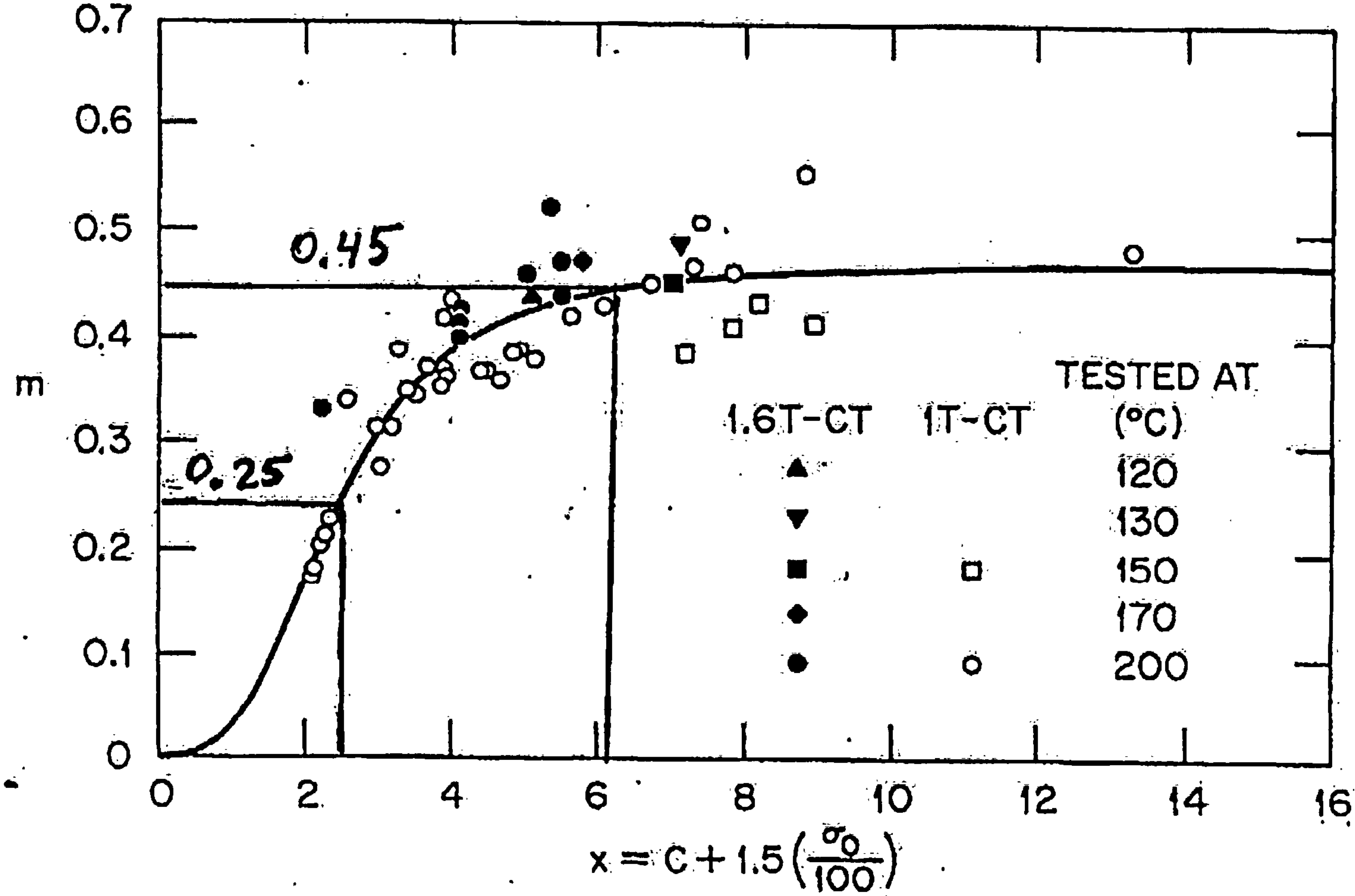

Figure 3: Correlation of Exponent m of Power Law J R-curve Representation with Coefficient C and Flow Stress σ_o [5]

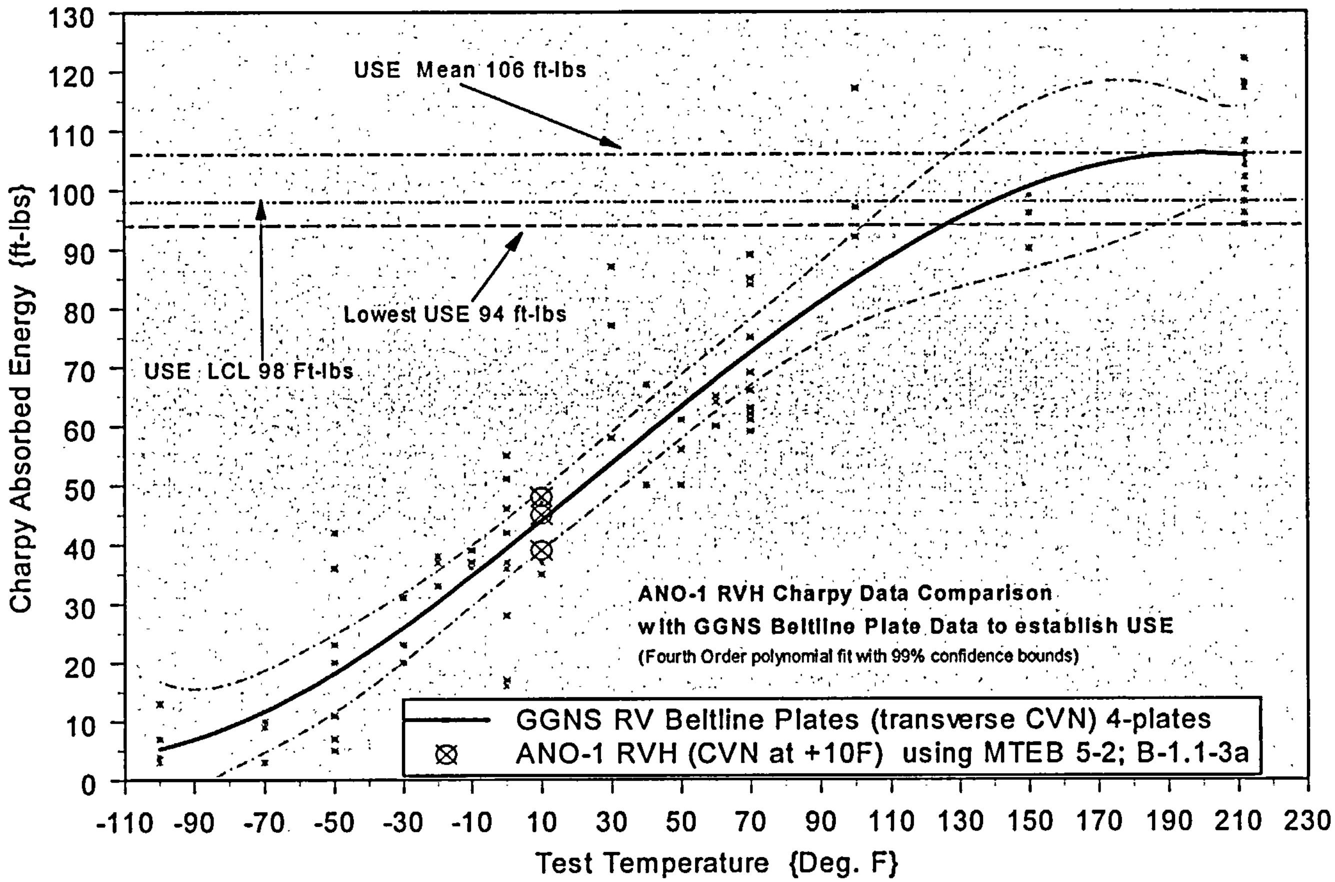

Figure 4. GGNS RV Plate (beltline) data (Lukens Steel A533 Gr. B Cl. 1) from transverse Charpy V-notch test. ANO-1 data from FSAR Table 4-16, @ +10 F Longitudinal. Converted to Transverse using USNRC SRP/NUREG-75/087 MTEB 5-2 Position 1.1 B-3a.

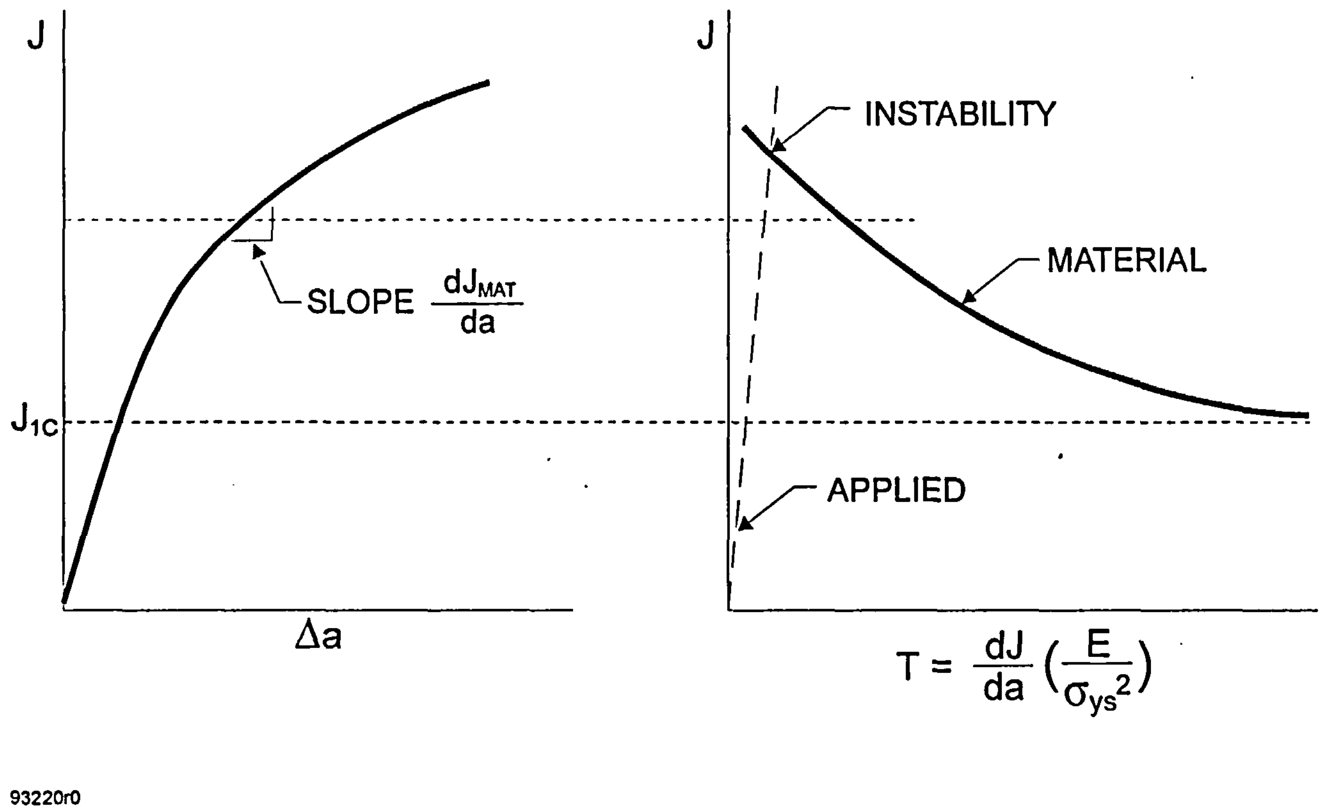

Figure 5– Schematic of EPFM Stability Analysis from ASME XI, Appendix K [4]

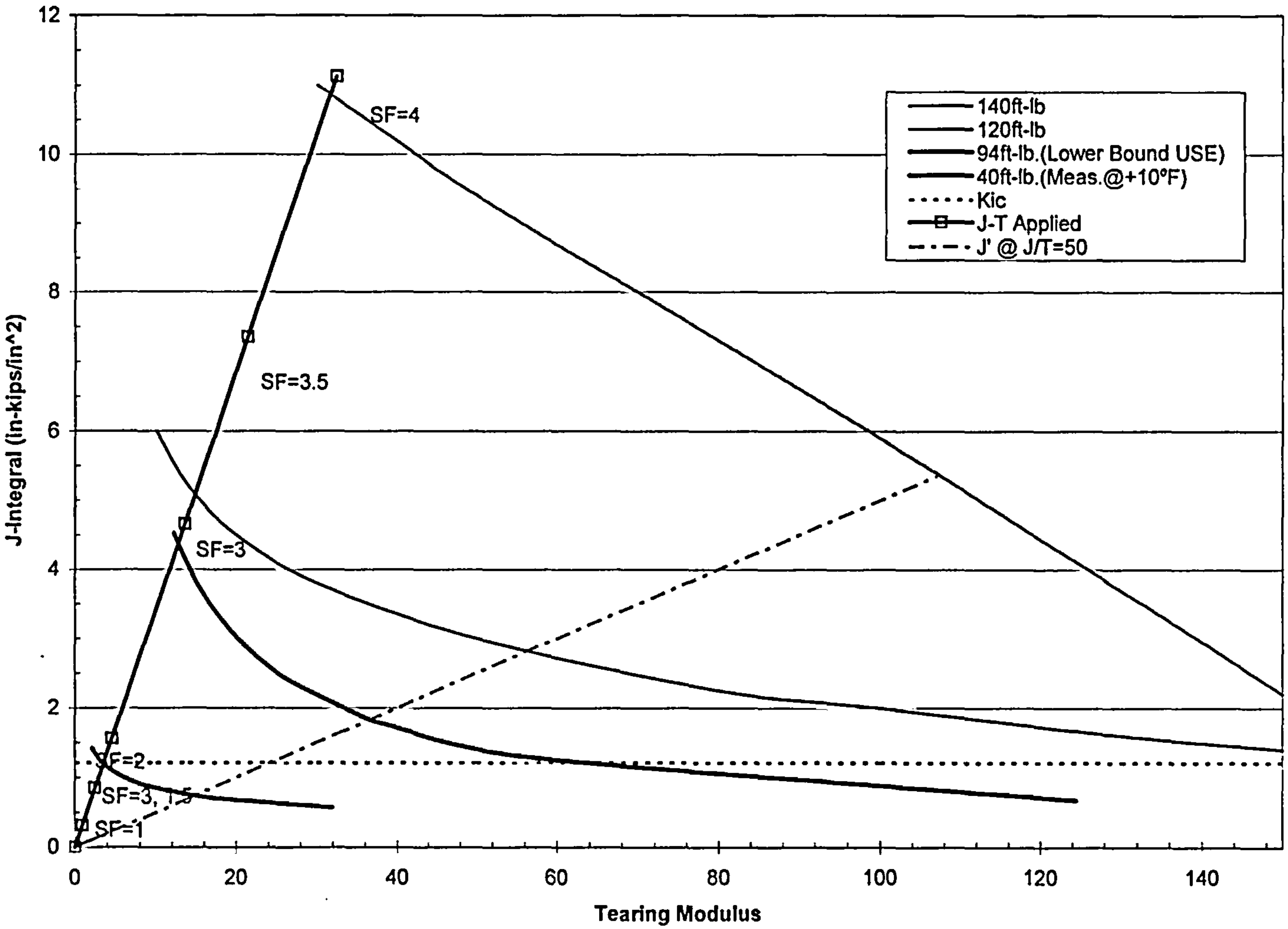

Figure 6– Results of EPFM Stability Analysis for ANO-1 Top Head Remnant Cracking Concern

Table 1: J-T Computations for ANO-1 Top Head Remnant Crack using ASME Section XI Appendix K Approximate Method

Safety Factor	K_{Ip}	K_{Ir}	K_{total}	r_p	a_e	$\sqrt{(a_e/a)}$	K'total
	ksi√in			inches			ksi√in
SF=1	3.7	90.7	94.4	0.131	1.631	1.043	98.4
***SF=3, 1.5**	**11.1**	**136.1**	**147.2**	**0.319**	**1.819**	**1.101**	**162.0**
SF=2	7.4	181.4	188.8	0.525	2.025	1.162	219.4
SF=3	11.1	272.1	283.2	1.182	2.682	1.337	378.7
SF=3.5	13.0	317.5	330.4	1.609	3.109	1.440	475.6
SF=4	14.8	362.8	377.6	2.101	3.601	1.549	585.1

Safety Factor	K_{Ip}	K_{Ir}	K_{total}	K'_{total}	J'_{total}	T'	J @ Instability
	ksi√in				in-kips/in^2		in-kips/in^2
SF=1	3.7	90.7	94.4	98.4	0.315	0.916	4.4
***SF=3, 1.5**	**11.1**	**136.1**	**147.2**	**162.0**	**0.853**	**2.483**	4.4
SF=2	7.4	181.4	188.8	219.4	1.564	4.551	4.4
SF=3	11.1	272.1	283.2	378.7	4.660	13.559	4.4
SF=3.5	13.0	317.5	330.4	475.6	7.353	21.392	4.4
SF=4	14.8	362.8	377.6	585.1	11.125	32.367	4.4

***** *Appropriate Safety Factor case for ductile material: SF=3 on primary, 1.5 on secondary***