Operating Windows in Tungsten-Coated Steel Walls

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HAPL

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Goal

- Determine Operating Windows of Tungsten-Coated Steel Walls in HAPL

Previous Work

- Establish operating windows for tungsten-clad steel walls using melting of tungsten and steel criteria as the limits
- This established feasibility of this concept
- Now we must address other design criteria

Design Criteria

- Vaporization
- Melting
- Roughening
- Fatigue
- Surface Cracks
- Crack Growth
- Cracks Propagating into Steel
- Blistering

Roughening

- Z and RHEPP experiments show roughening in Tungsten at 1-3 J/cm^2
- Roughening in tungsten is result of pitting and cracking
- Assumption is that this is stress-driven and thus controlled by peak temperature
- Hence, model Z and RHEPP and estimate temperatures that caused roughening
- Use these temperatures as roughening criteria

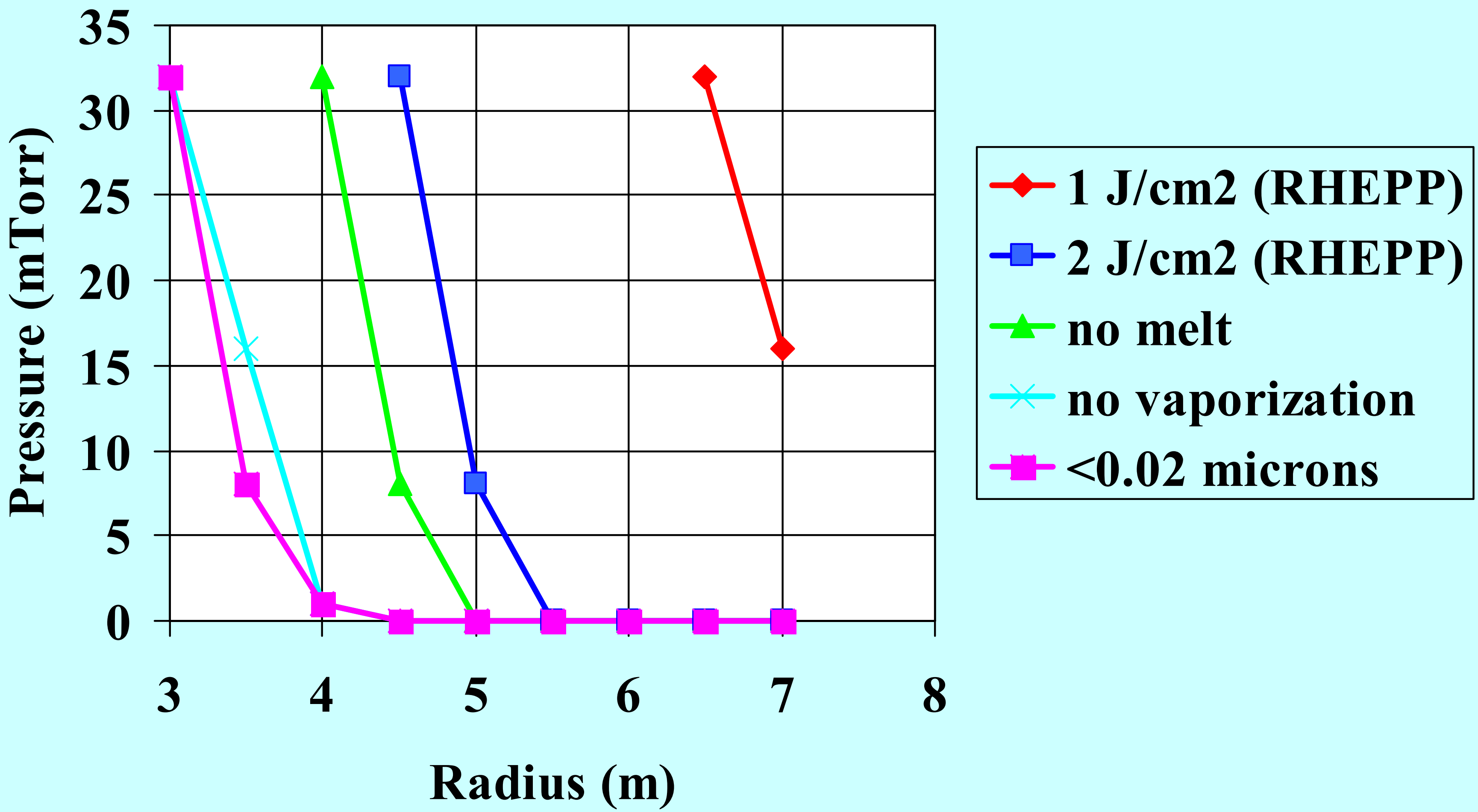
Roughening Temperatures

- RHEPP results modeled by Peterson

Fluence (J/cm^2)	Predicted Surface Temperature (C)
1	1400
2	2900
3	3600

Operating Windows Established from >50 BUCKY runs

40 MJ Target on Tungsten



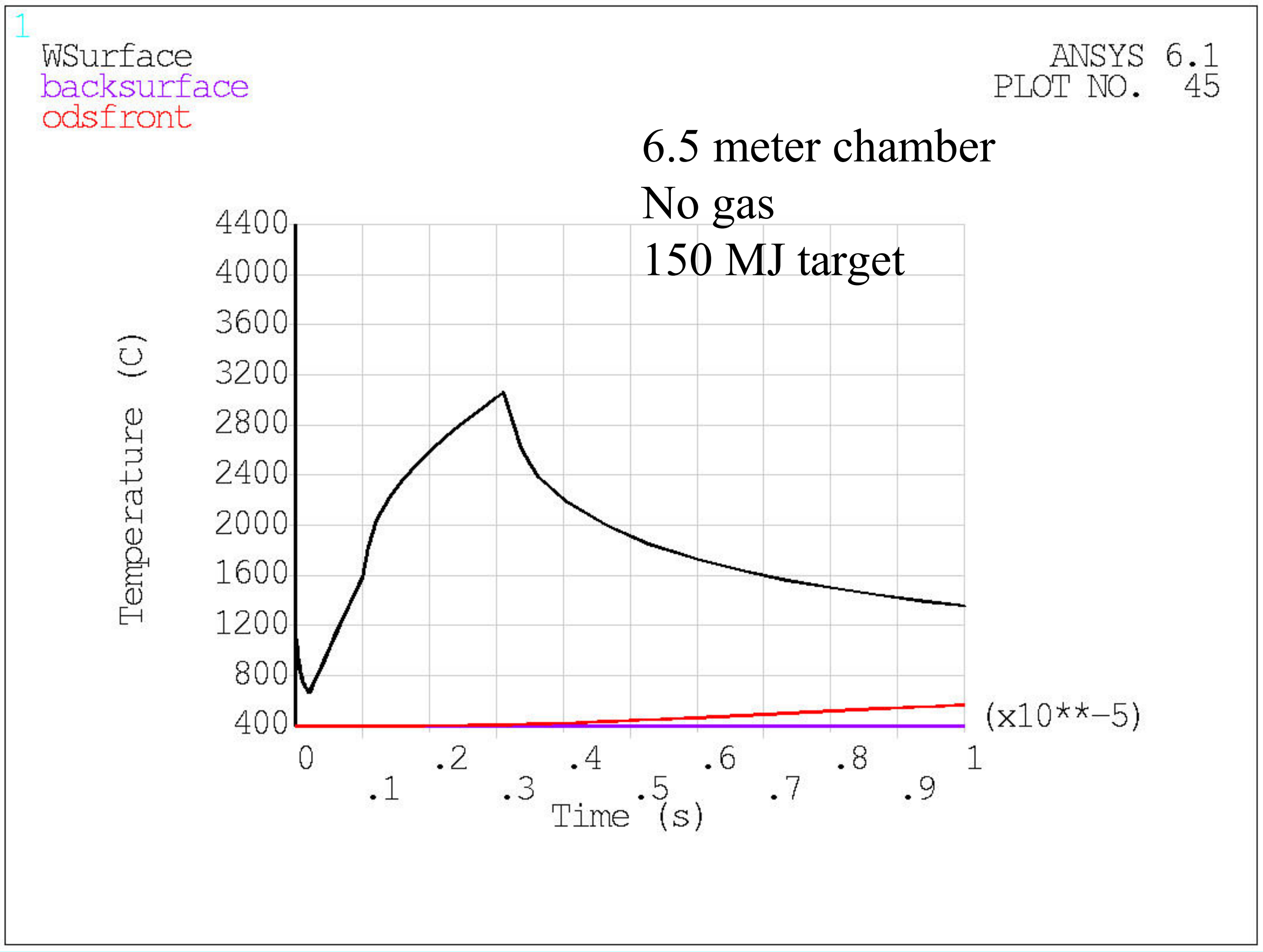
Working Designs by RHEPP Criteria Low (150 MJ) Yield Target

Temperature Limit (C)	Chamber Size (m) and Xe Pressure (mTorr)
3600 (3 J/cm^2 on RHEPP)	5.5, 10
2900 (2 J/cm^2)	6.5, 10
1400 (1 J/cm^2)	>7.5, 20

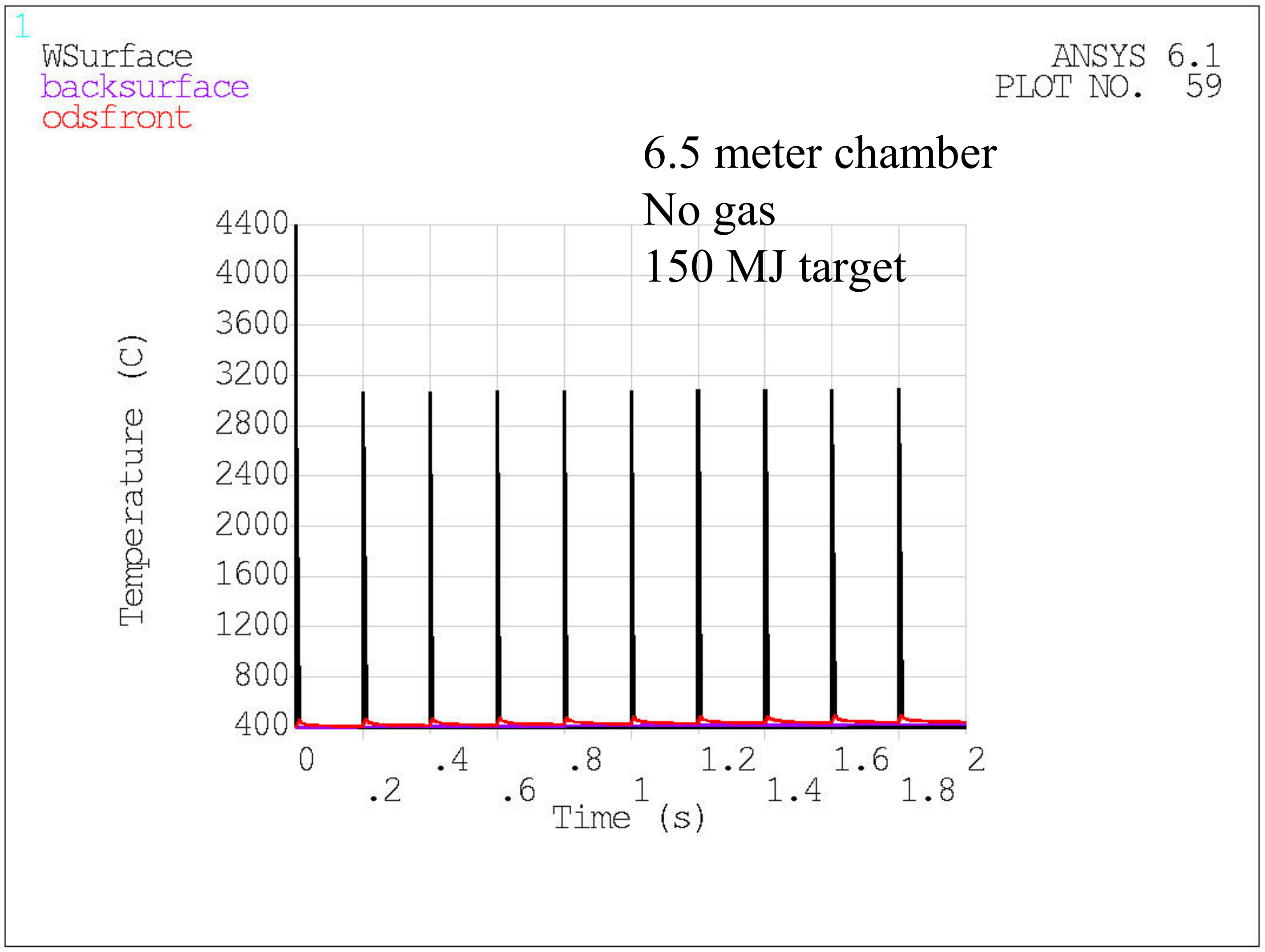
Fatigue Approach

- Begin with S/N type fatigue analysis (elastic plastic) to assess scope of problem
- Perform crack growth analysis to assess likelihood of cracks reaching steel
- Assess likelihood of interface crack to either cause debonding or cracks in steel
- Following results are for nominal case

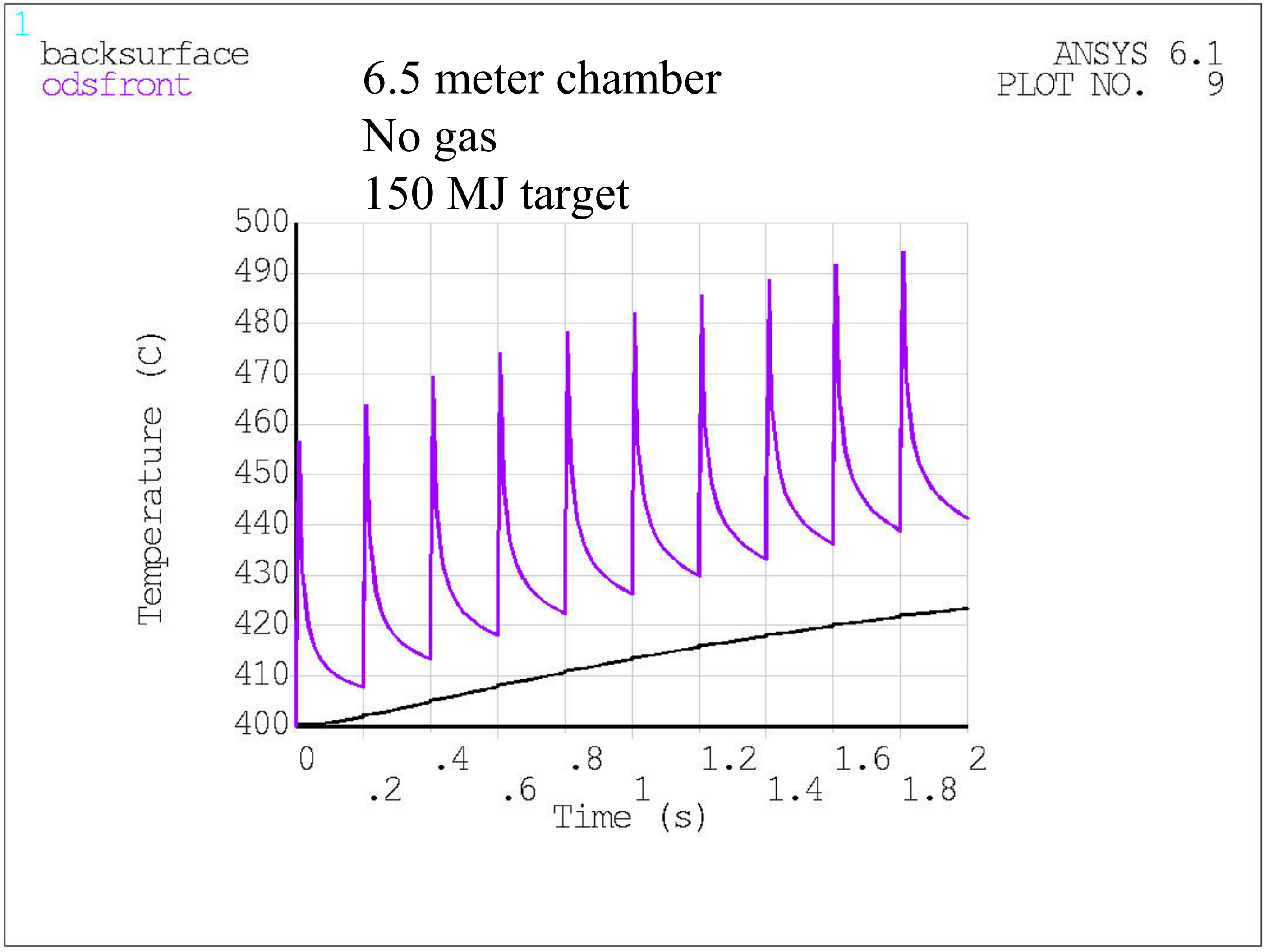
Temperature Histories - first cycle



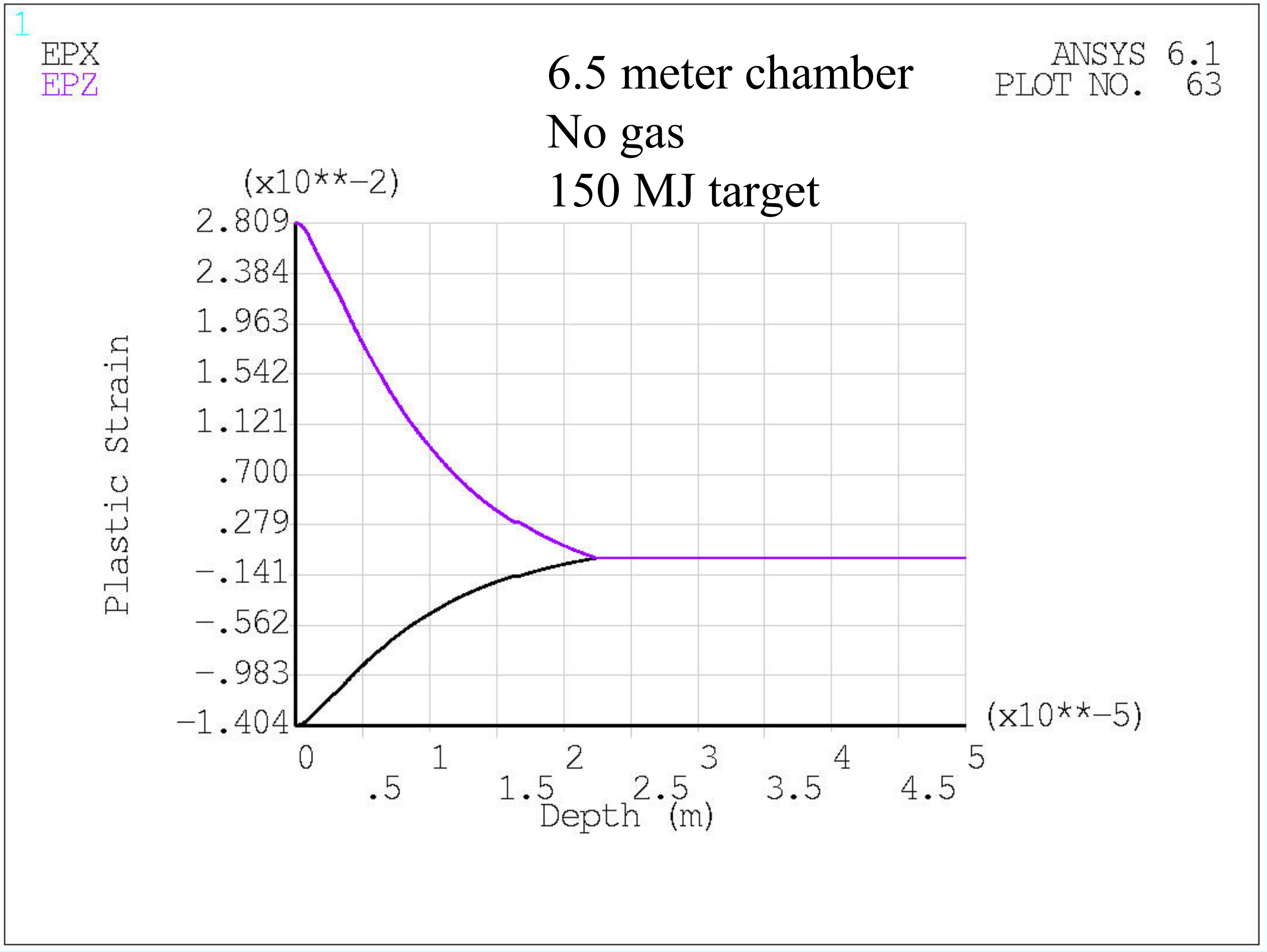
Temperature Histories – 10 cycles



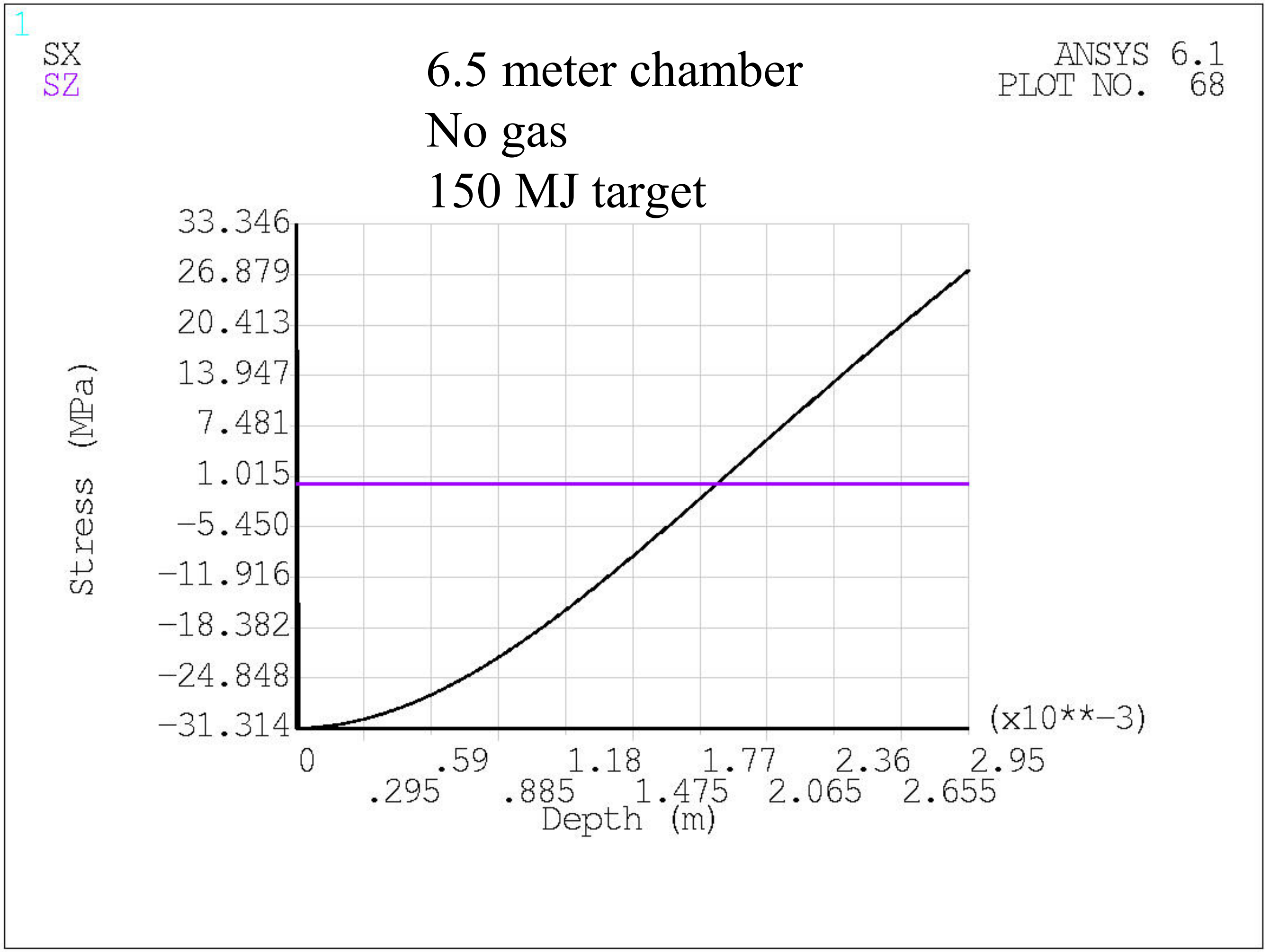
Temperature History at Surface of Steel



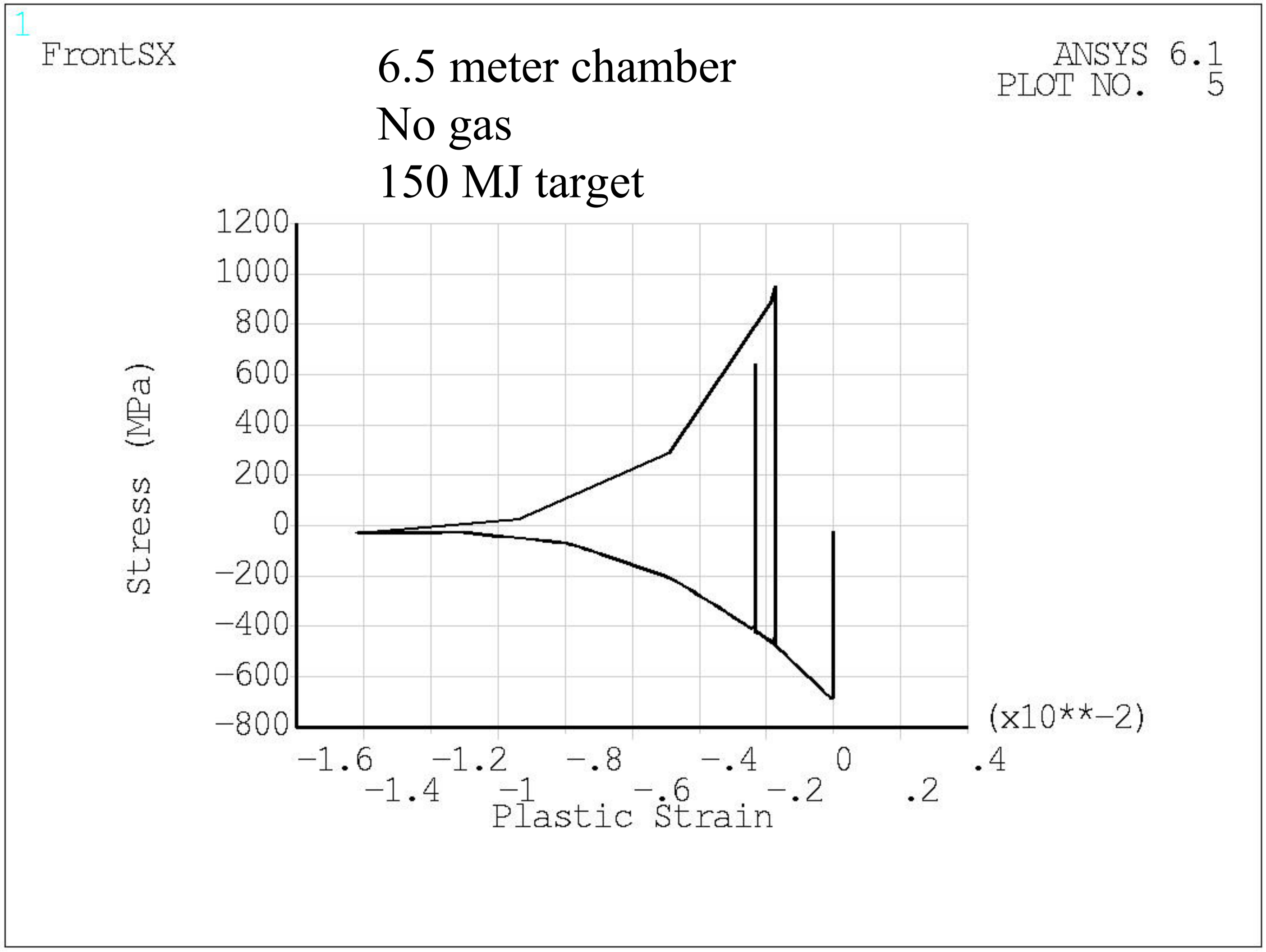
Strain Distributions – Tungsten after last pulse



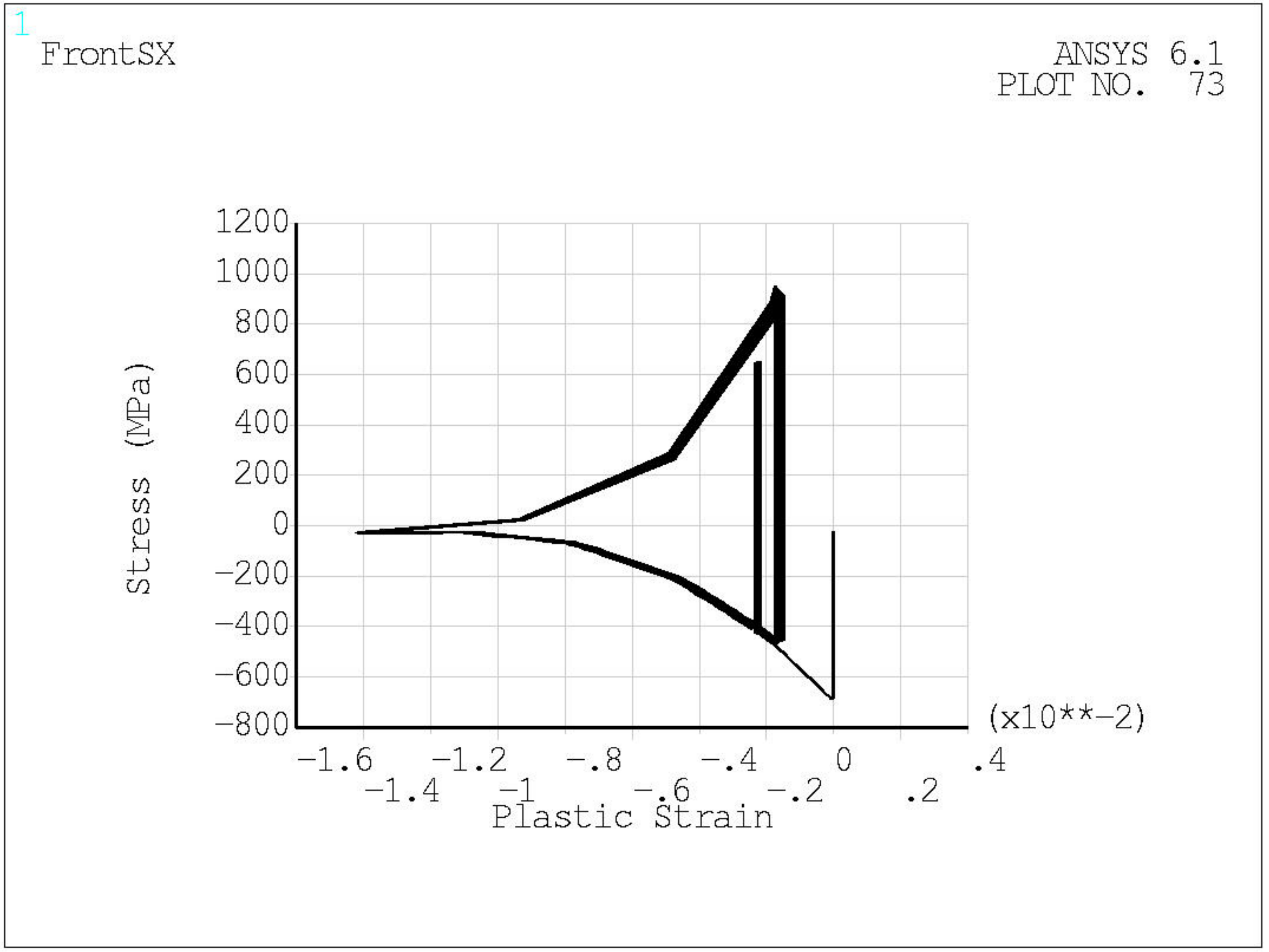
Stress Distributions – Steel after last pulse



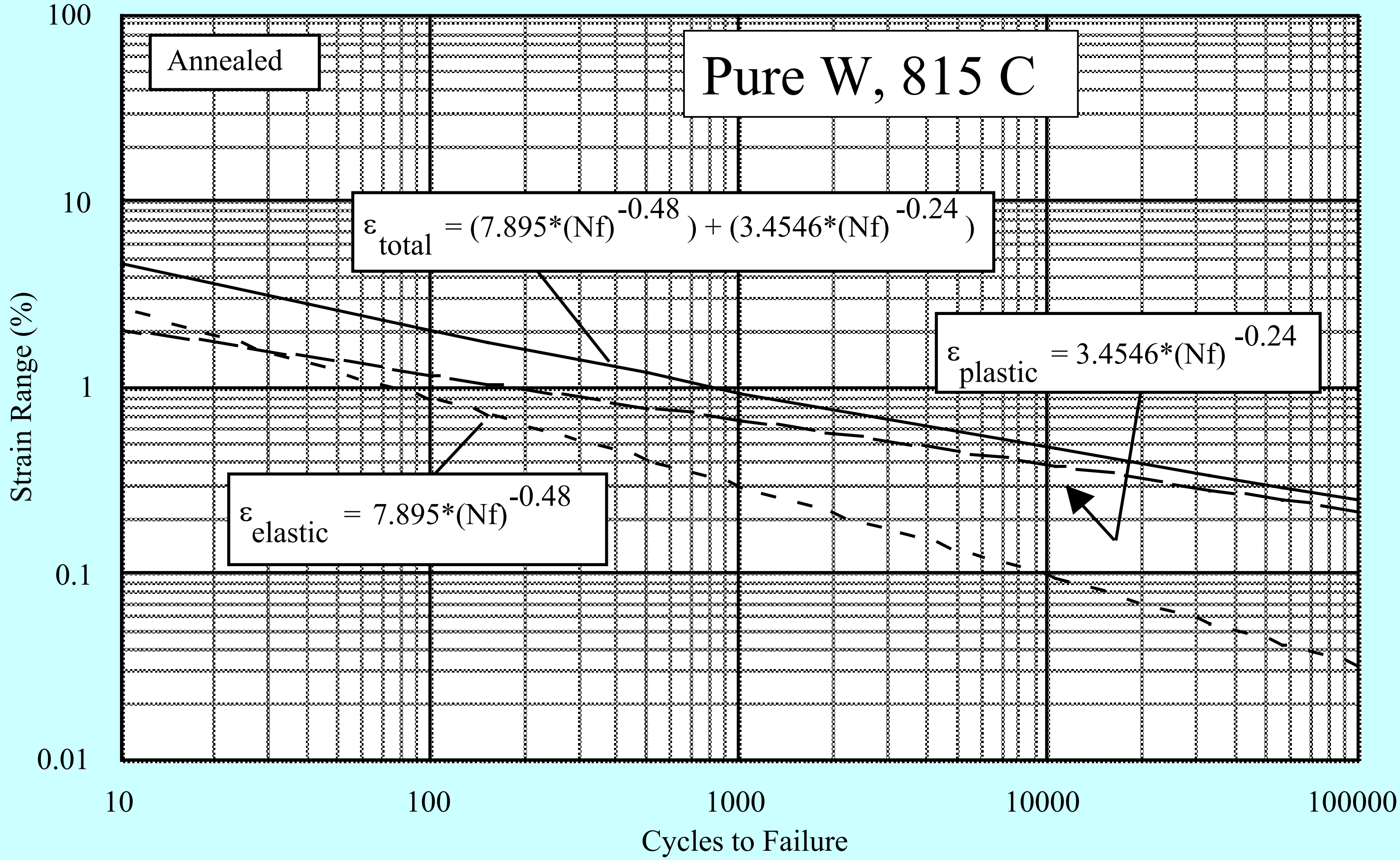
Stress-Strain Behavior at W Surface
1 Cycle



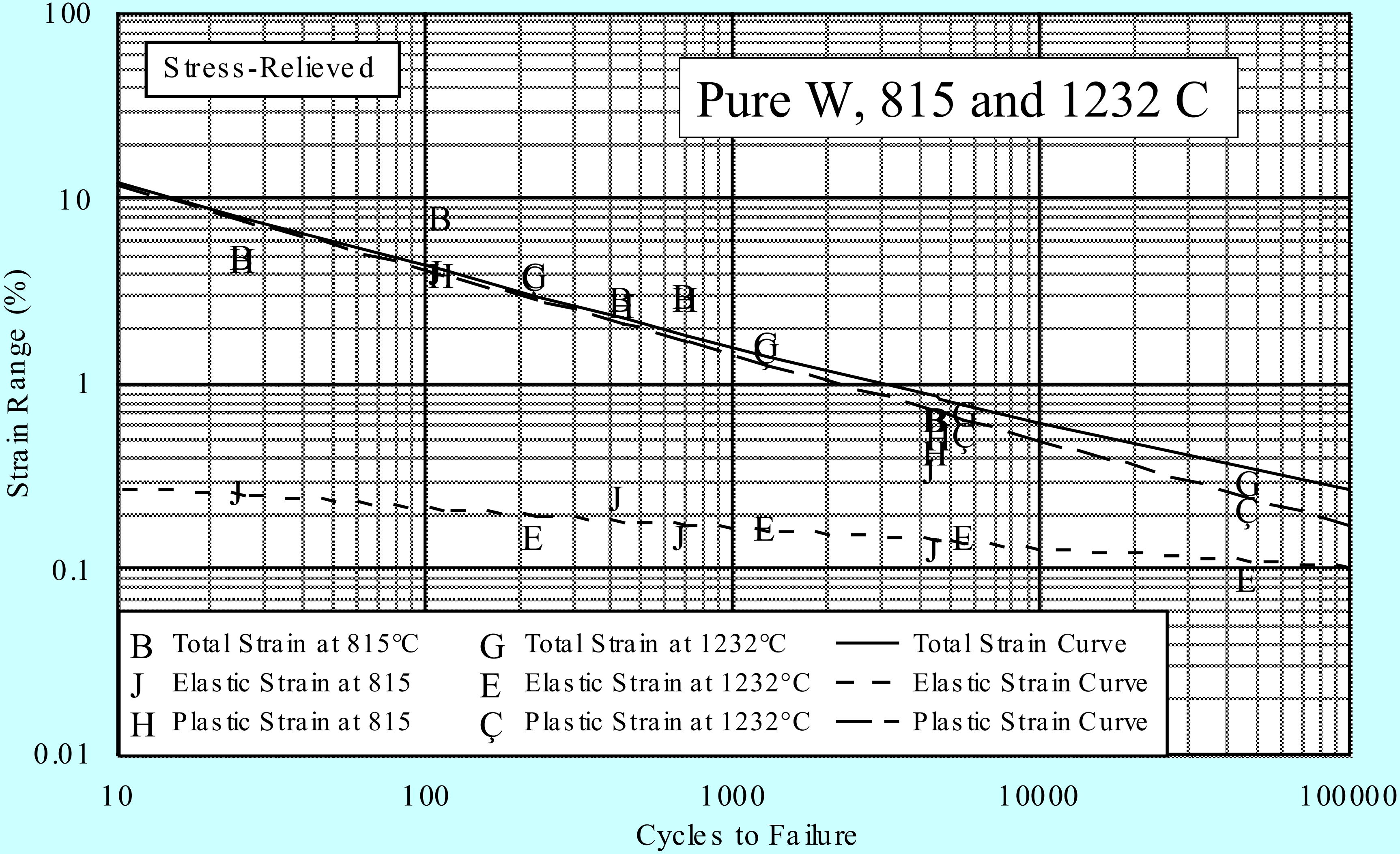
Stress-Strain History at W Surface
10 cycles Superimposed



Fatigue Data for Annealed Tungsten



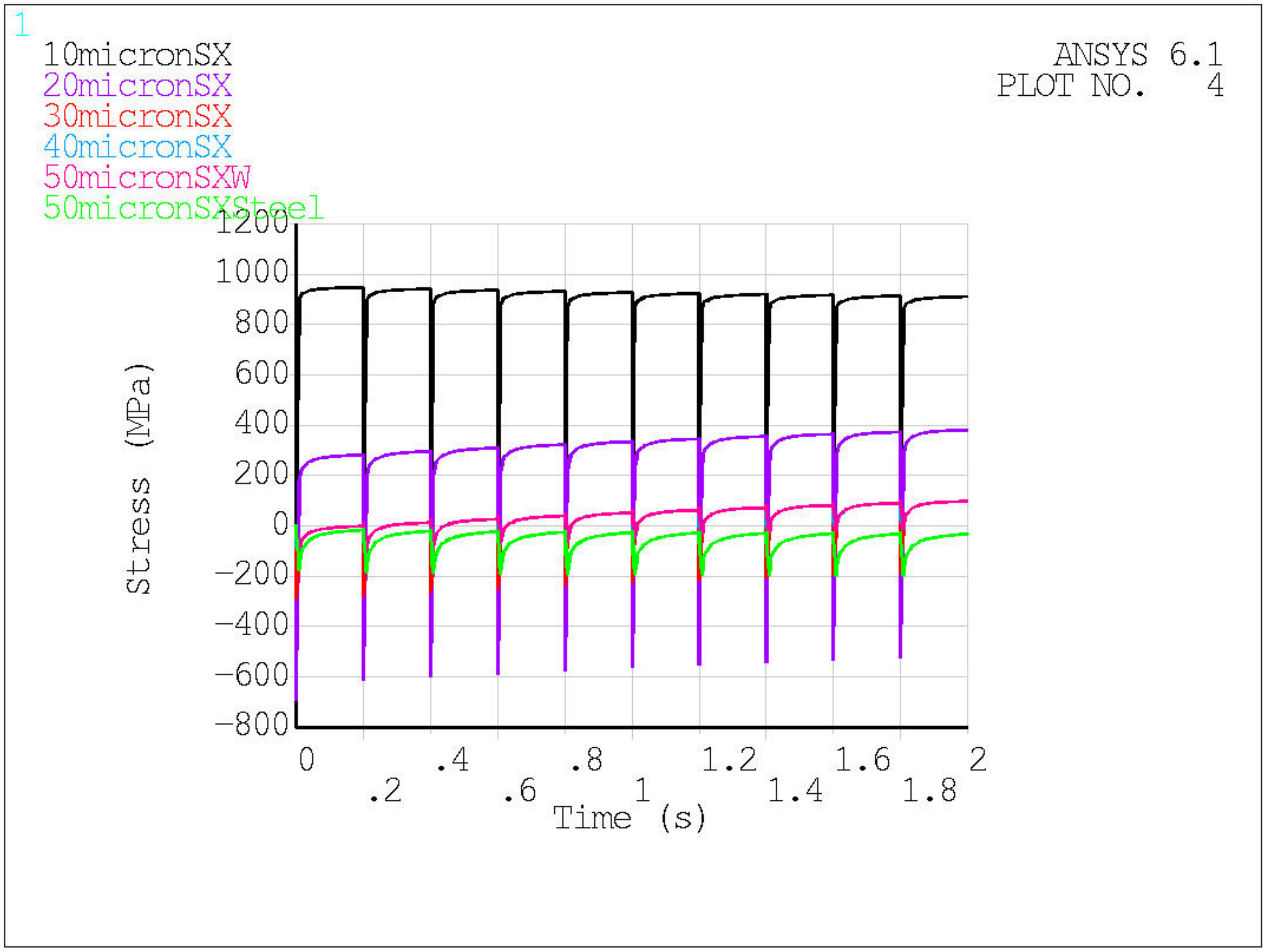
Fatigue Data for Stress-Relieved Tungsten



Fatigue Analysis

Chamber Radius (m)	Xe Pressure (mTorr)	Multiaxial Strain Range (%)	Cycles to Cracking
6.5	0	2.4	300
7.5	0	1.6	1000
5.5	10	3.0	200
6.5	10	2.0	500
7.5	10	0.8	3000
7.5	20	0.7	4000
6.5 (40 MJ target)	0	0.13	$>10^5$

Crack Growth Through Thickness is Governed by Stress Gradients



Conclusions

- Extensive BUCKY runs for 40 MJ target reveal that for Xe pressures of 32 mTorr, minimum chamber radii are:
  - 3 m for <0.02 microns vaporized
  - 3 m for no vaporization
  - 4 m for no melting
  - 4.5 m for the 2 J/cm2 RHEPP roughening limit
  - 6.5 m for the 1 J/cm2 RHEPP roughening limit

Conclusions

- Fatigue analysis predicts cracking in approximately 100s to 1000s of cycles for the low yield target and reasonable chamber sizes
- There appears to be little driving force for cracks to reach steel, unless heating directly heats crack tip
- Fracture analysis for crack reaching steel surface is pending