Comparison of Chamber Response With and Without Ions

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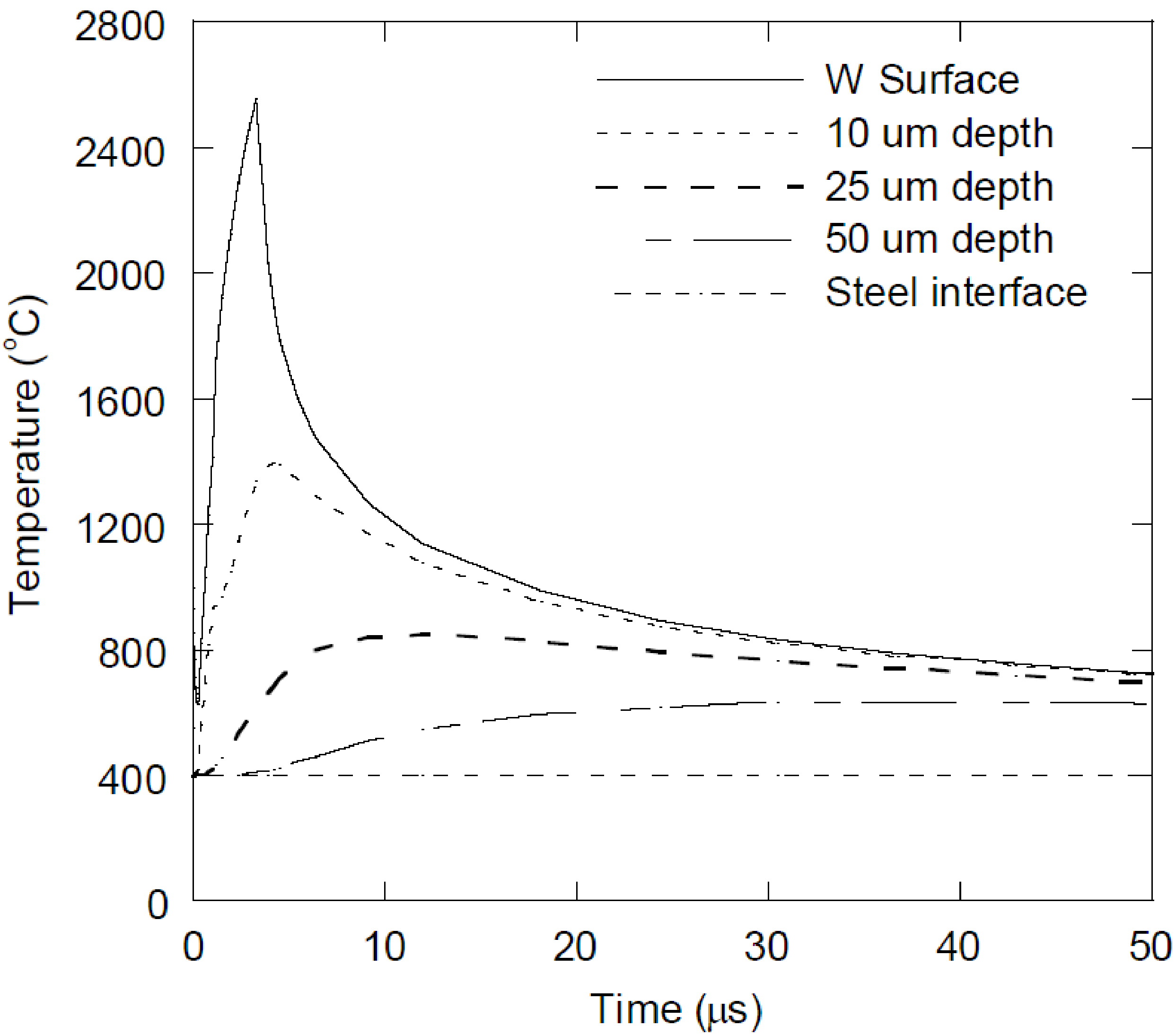
Summary of Previous Analysis

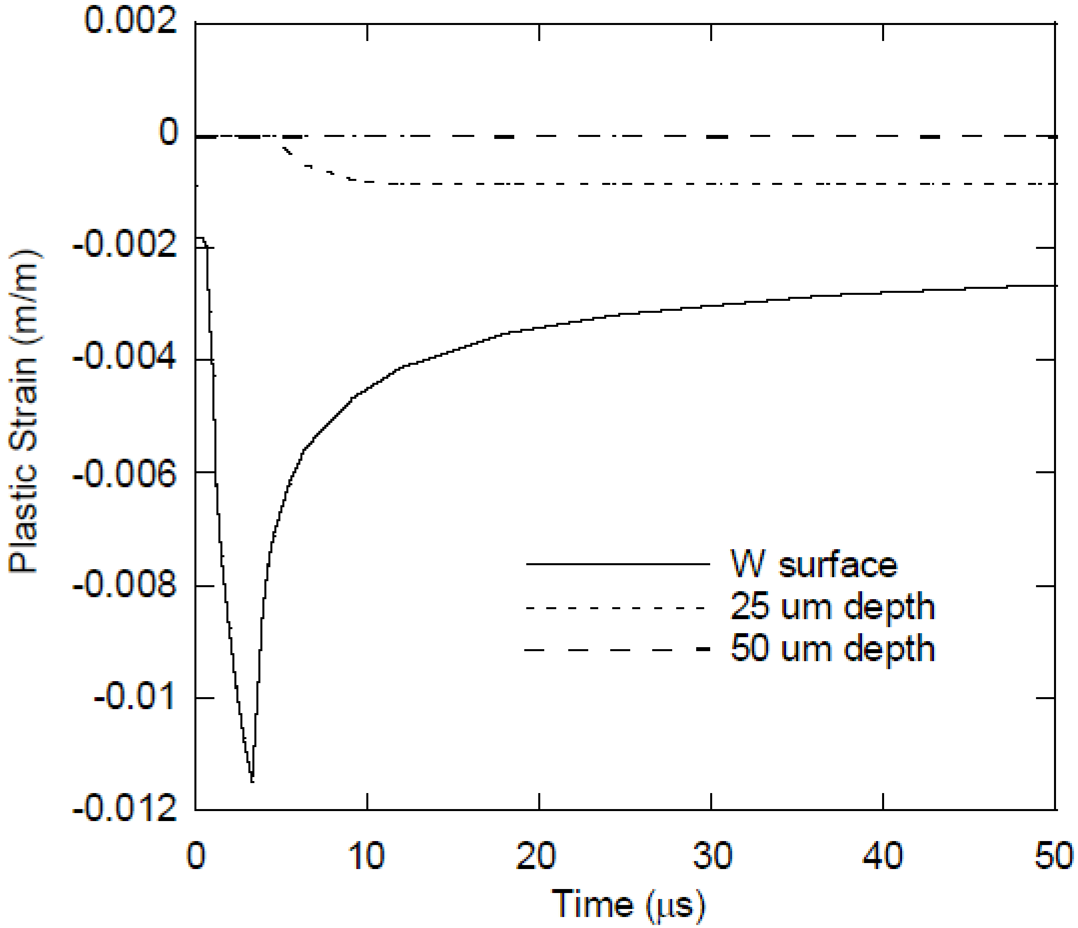
- Assume no magnetic deflection
- Perkins spectra
- Chamber wall is dry; tungsten coated ferritic steel
- Look at temperatures, stresses, strains, fatigue, and fracture

Temperatures



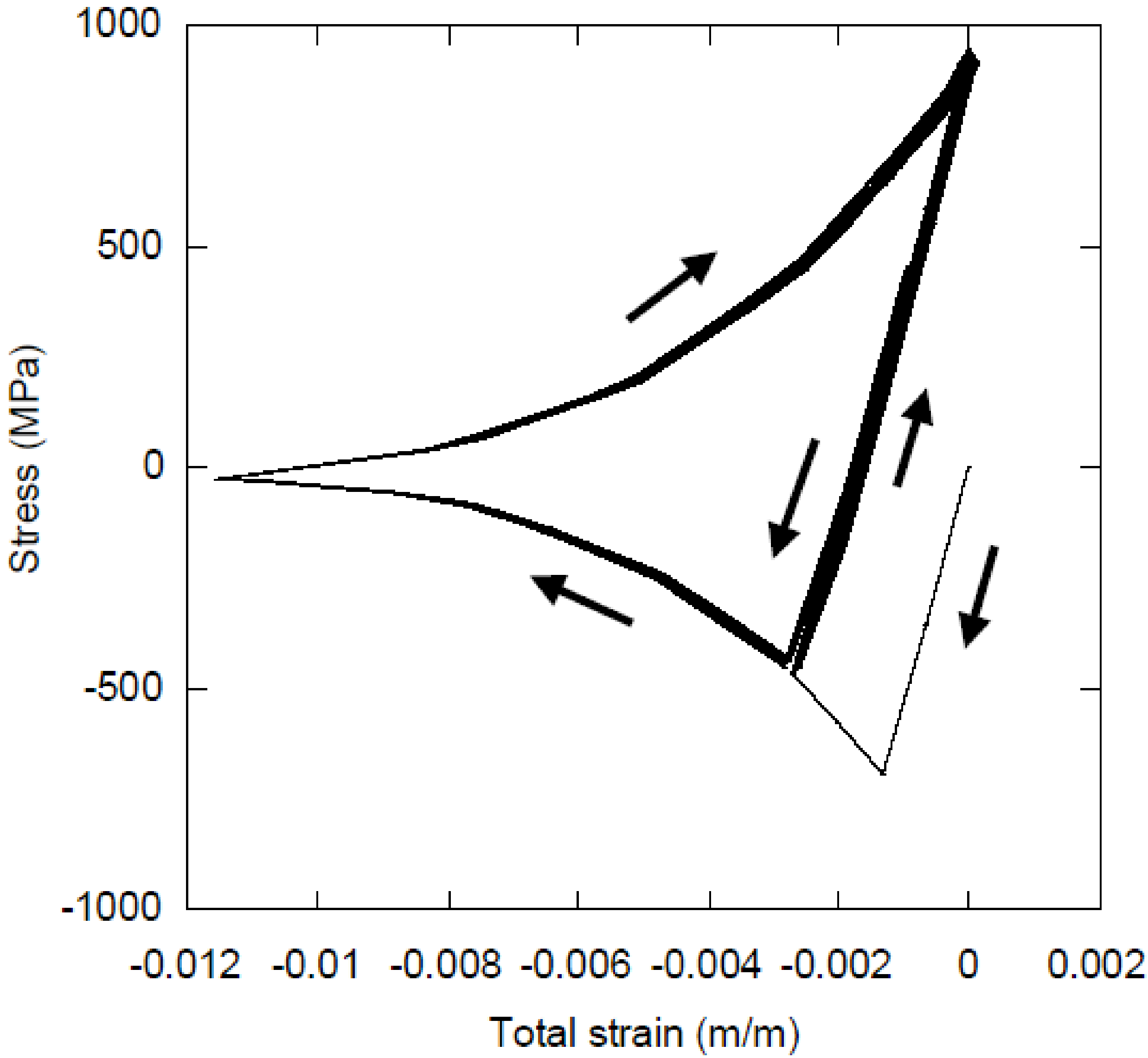
- 154 MJ
- 7 m
- 250 microns tungsten
- 3 mm steel

Strains



- Peak strains are >1%
- Effective strains are >2%

Stress/Strain Behavior



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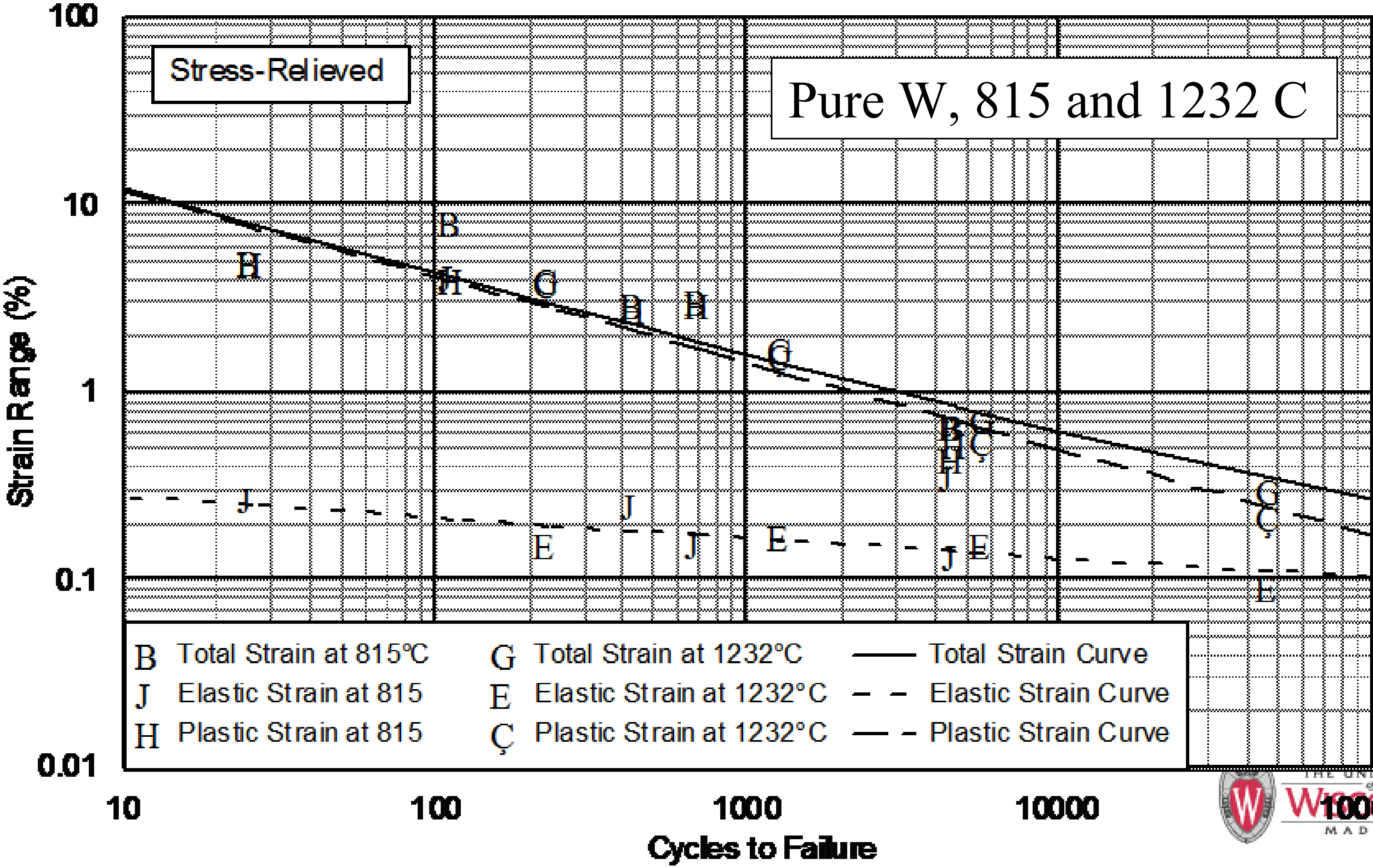
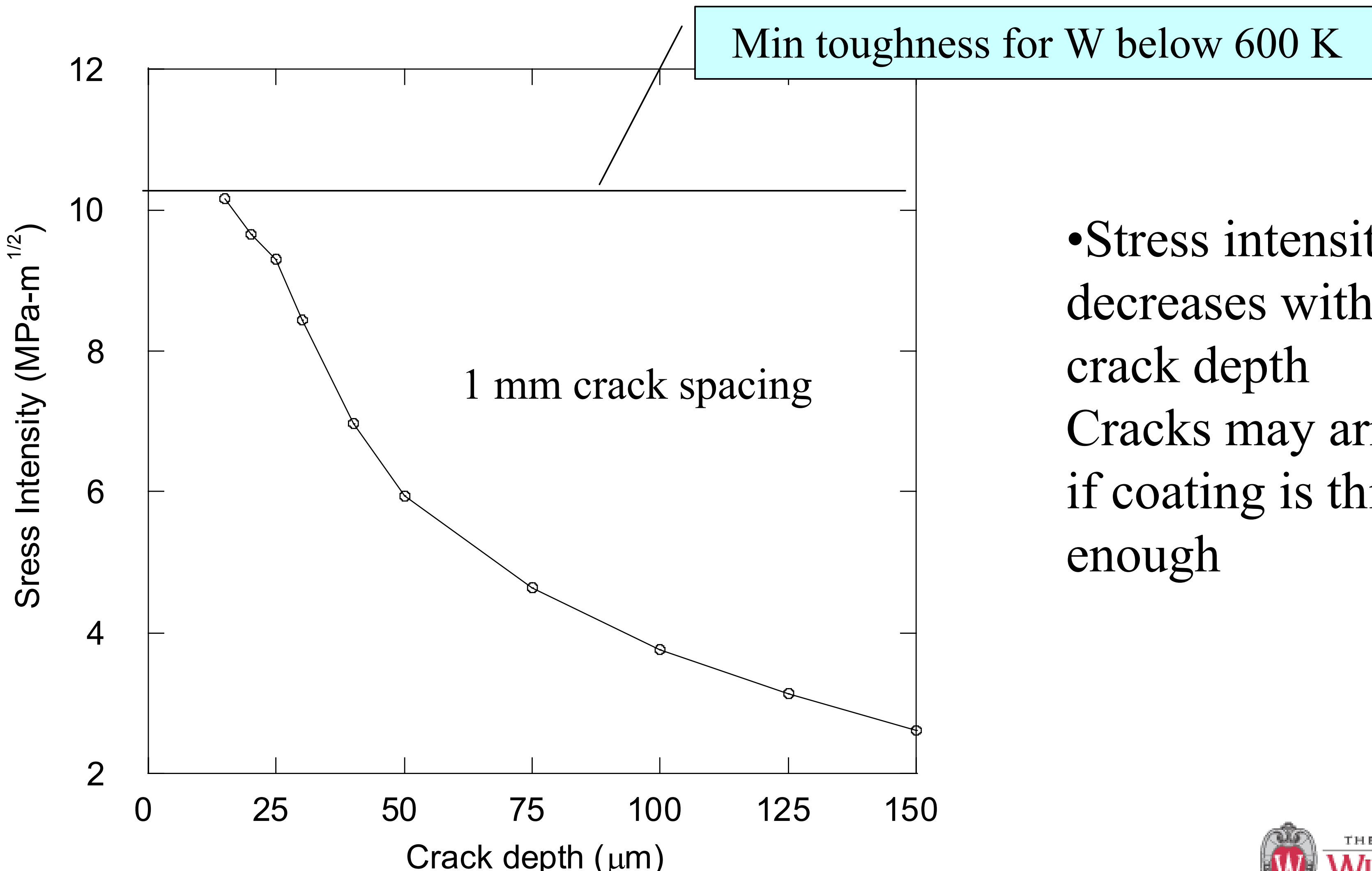
Fatigue Data for Stress-Relieved Tungsten

Cracking is expected in hundreds to thousands of cycles



Fracture Mechanics Analysis Results

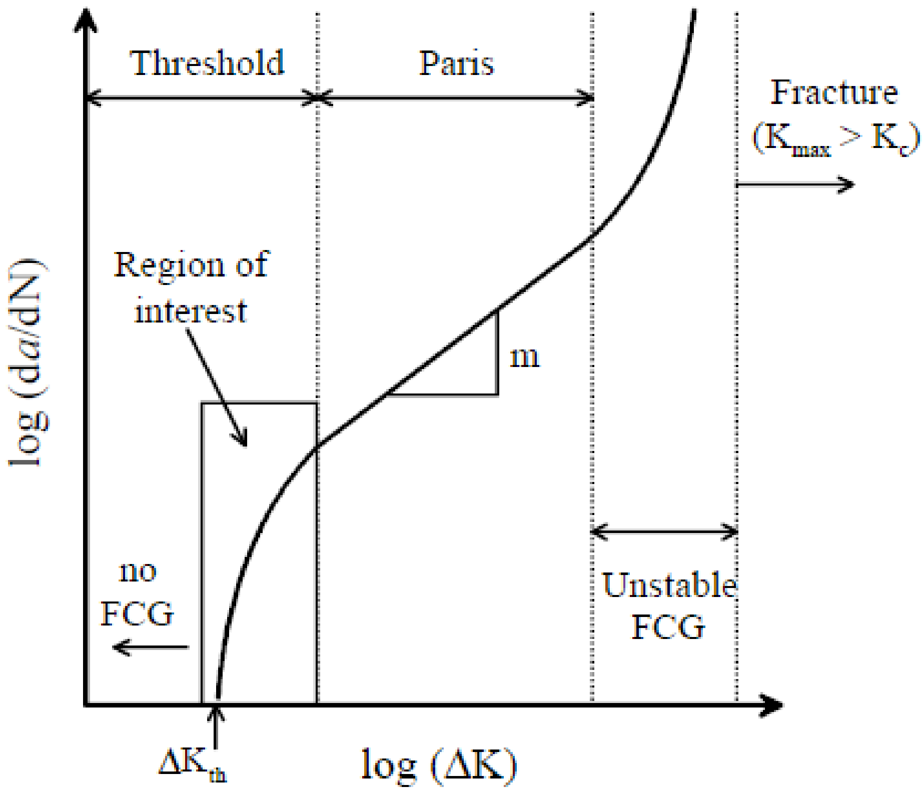
250 microns W; 7 m Chamber; 154 MJ Target

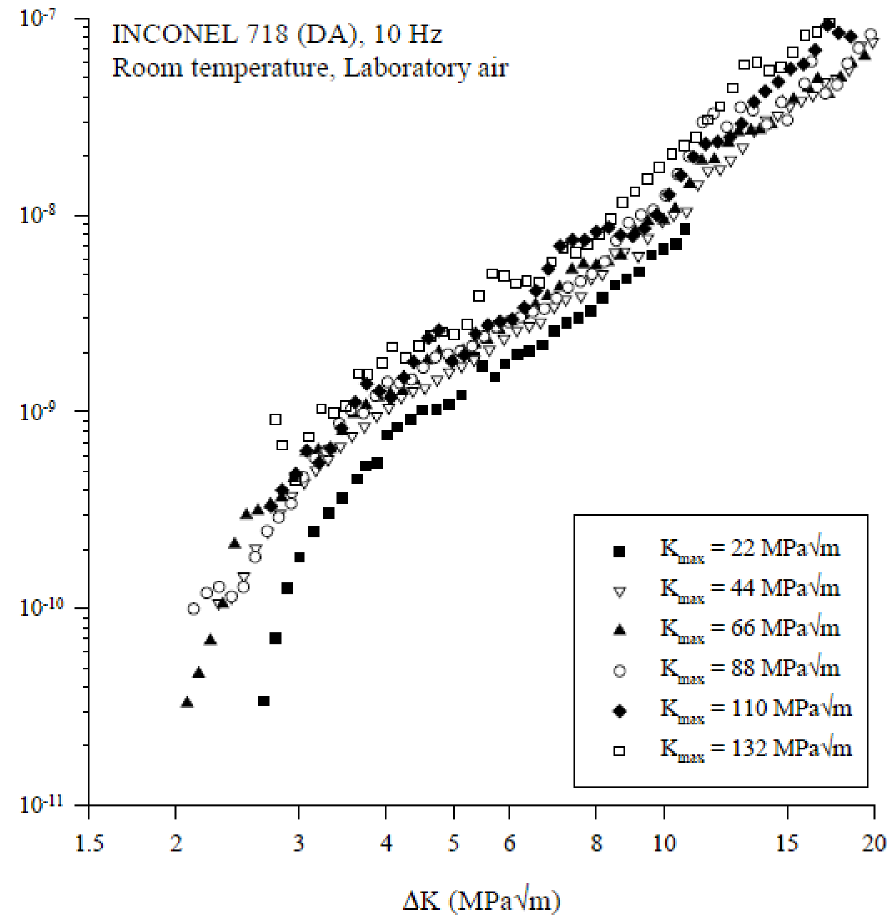


- Stress intensity decreases with crack depth

Cracks may arrest, if coating is thick enough

Crack Growth





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More Crack Growth Data

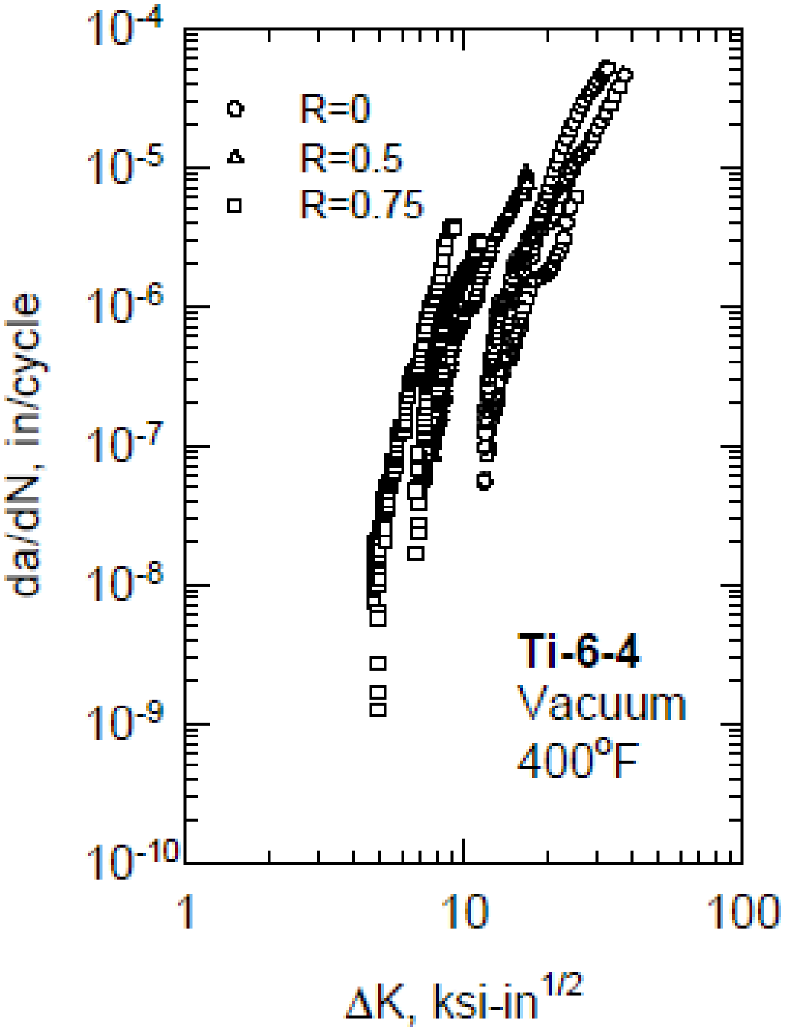
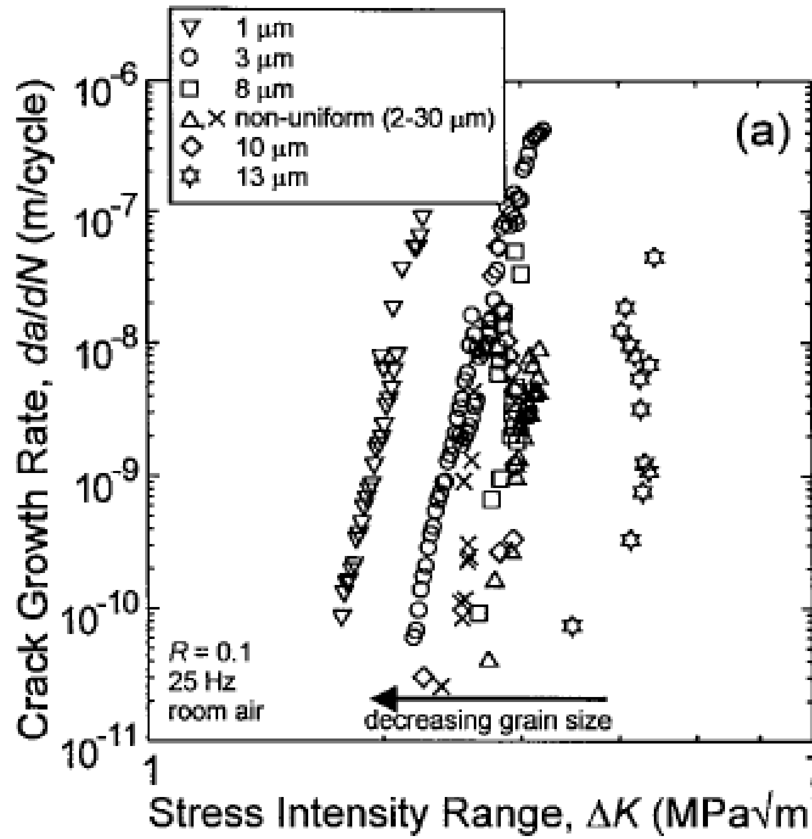


Figure 4. Vacuum FCG data for Ti-6Al-4V at 400°F (204°C)



Polycrystalline alumina

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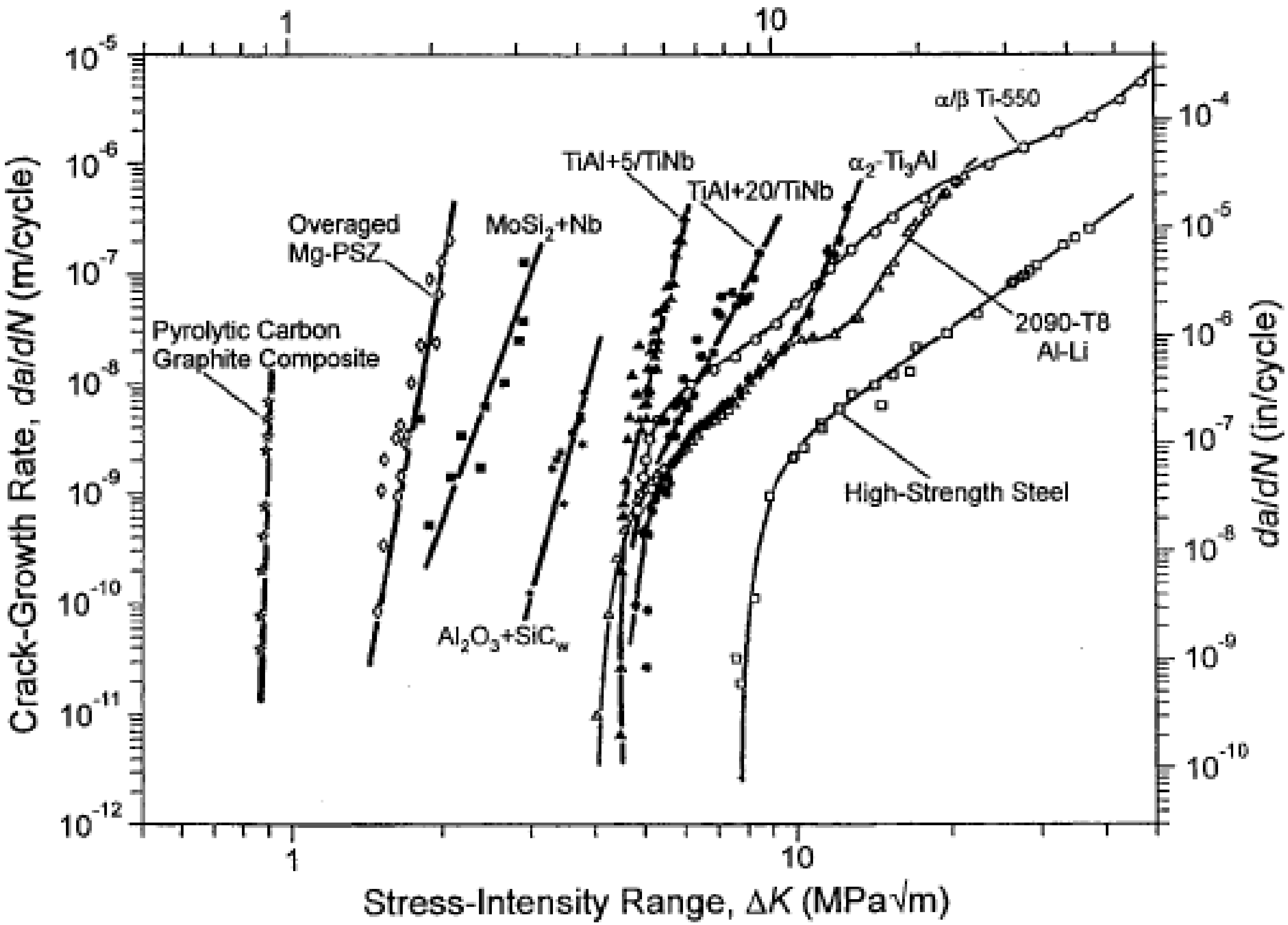
More Crack Growth Data



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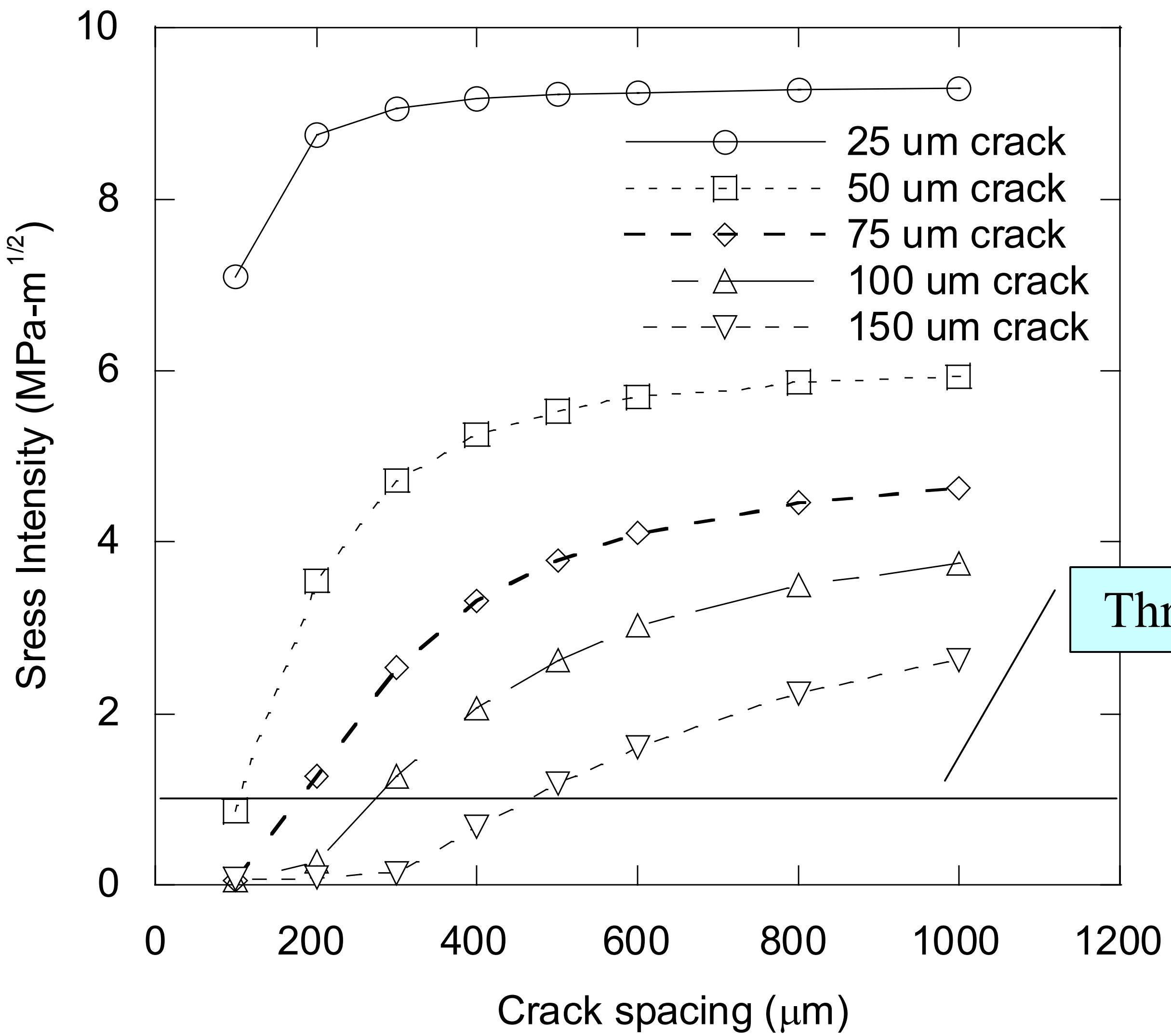
Fracture Mechanics Analysis Results

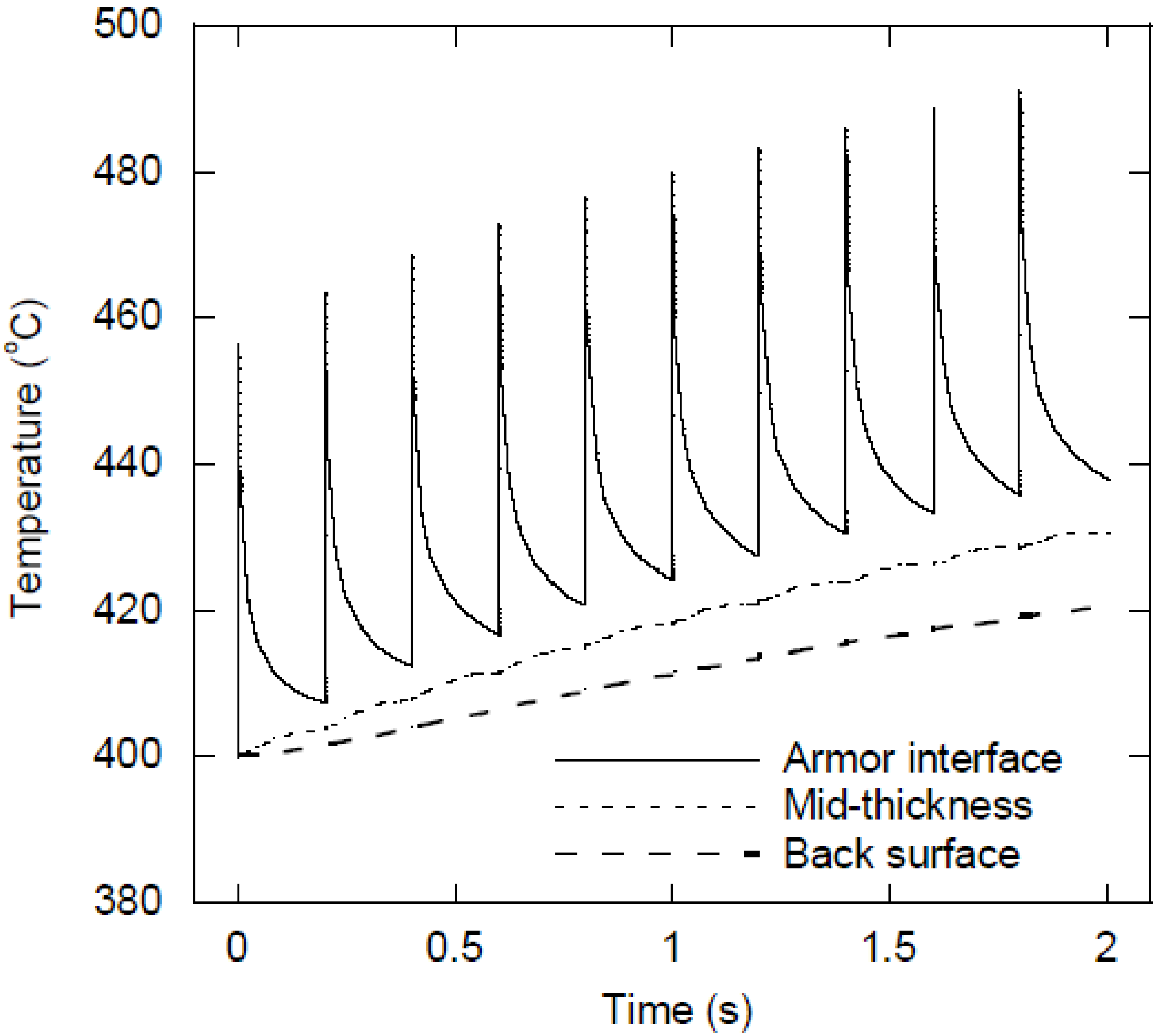
250 microns W; 7 m Chamber; 154 MJ Target



•Stress intensity decreases with crack depth
Cracks may arrest, if coating is thick enough

Threshold (assume toughness/10)

Temperatures in Steel



- 7 m, 154 MJ, 250 microns W
- Swing can be small with sufficiently thick coating
- Stresses are under ASME and fatigue limits

Intermediate Conclusions

- Cracking is inevitable
- Cracks may well arrest before reaching steel
- Uncertainties:
  - Roughening issues
  - Other ion effects (blistering, etc.)
  - Radiation damage
  - Tungsten properties
  - X-ray propagation down cracks
  - Is threat well characterized?
  - Do we have enough margin?

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Impact of Diverting Ions

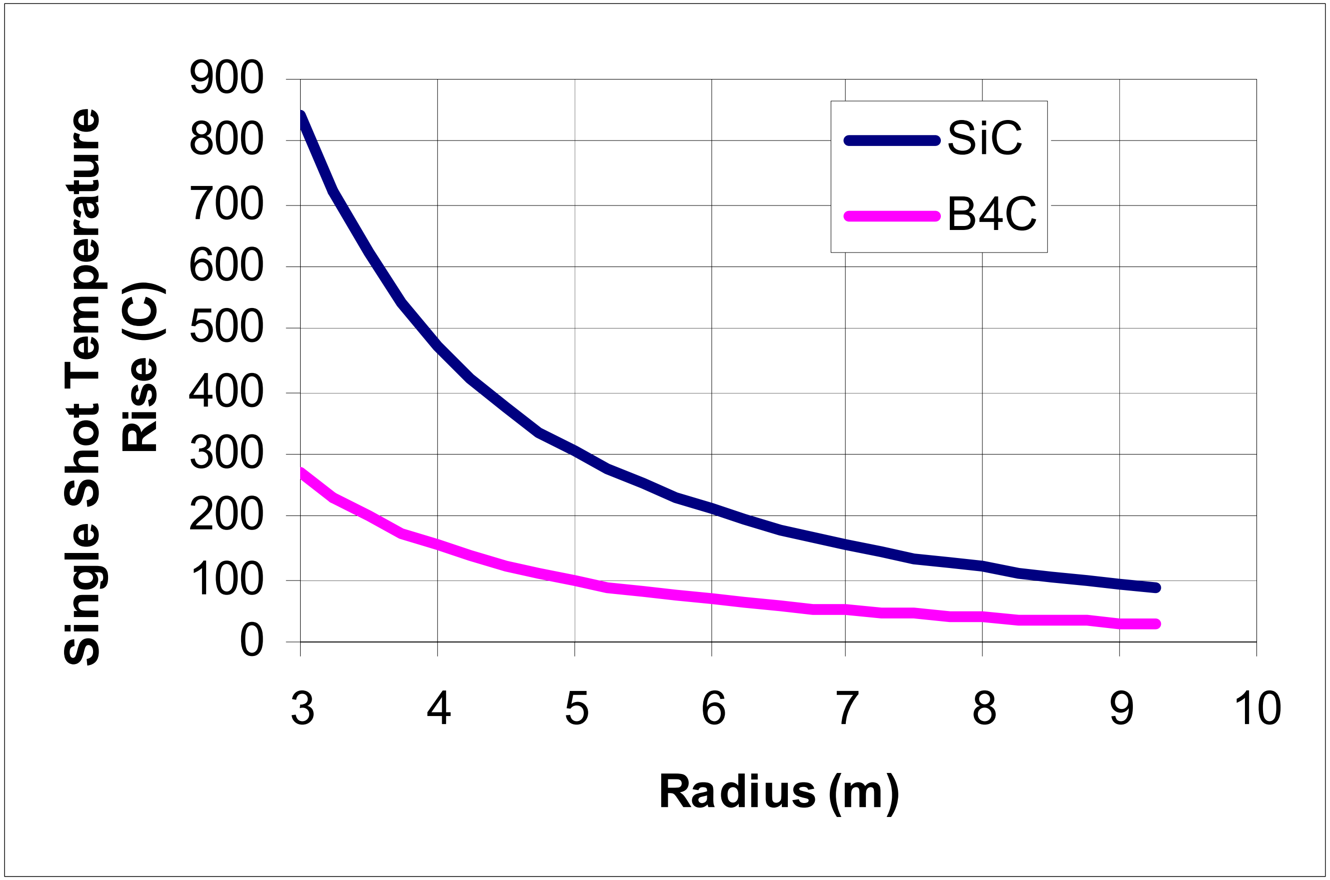
- Diversion of the ions will reduce the impact on the first wall
- Just having x-rays opens up the possibility of using different materials to spread heat over larger volume
- Consider silicon carbide and boron carbide
- Assume 1 ns deposition time (uniform heating)
- Low energy ions might not be diverted

Comparison of Attenuation

Material	Attenuation Coefficient (/cm at 5 keV)	Coating Thickness (microns)
Tungsten	10,700	250
Silicon Carbide	637	800
Boron Carbide	29	1200

http://atom.kaeri.re.kr/cgi-bin/w3estar

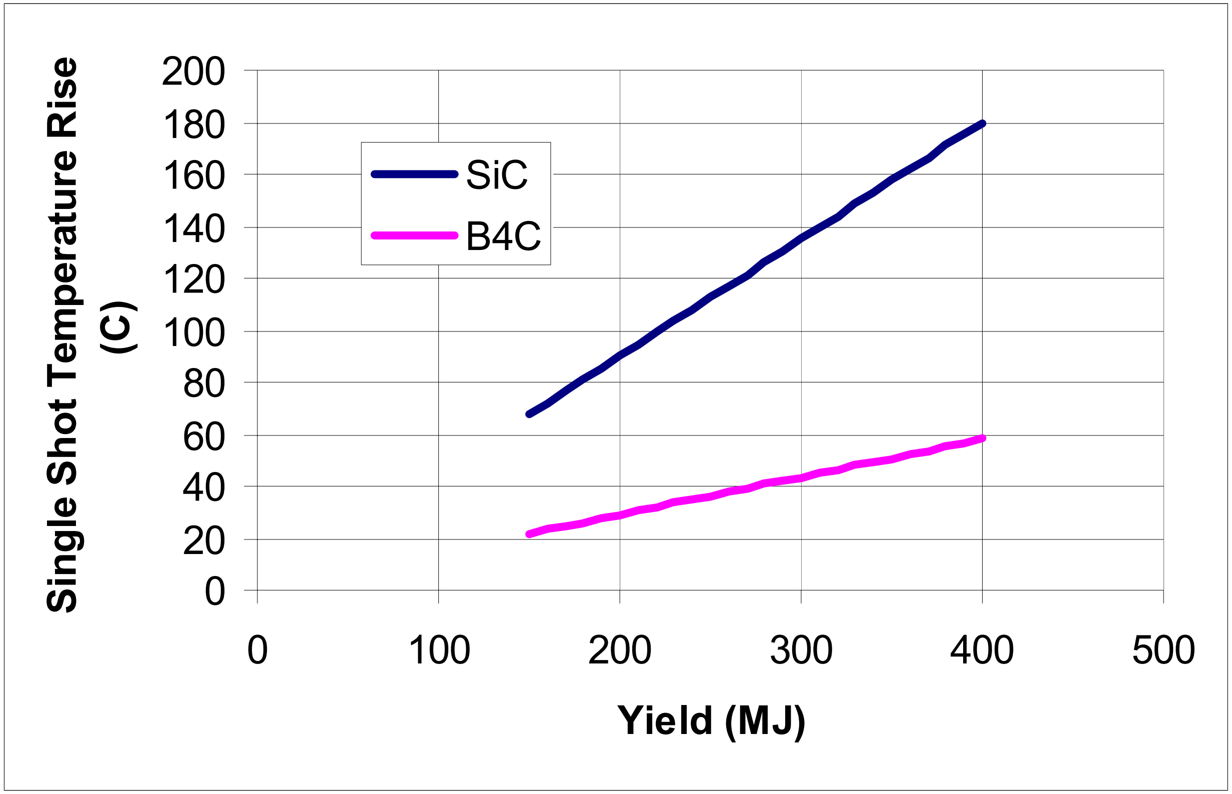
First Wall Temperature Rise from X-Ray Heating Only



400 MJ target yield

Constant properties

First Wall Temperature Rise from X-Ray Heating Only

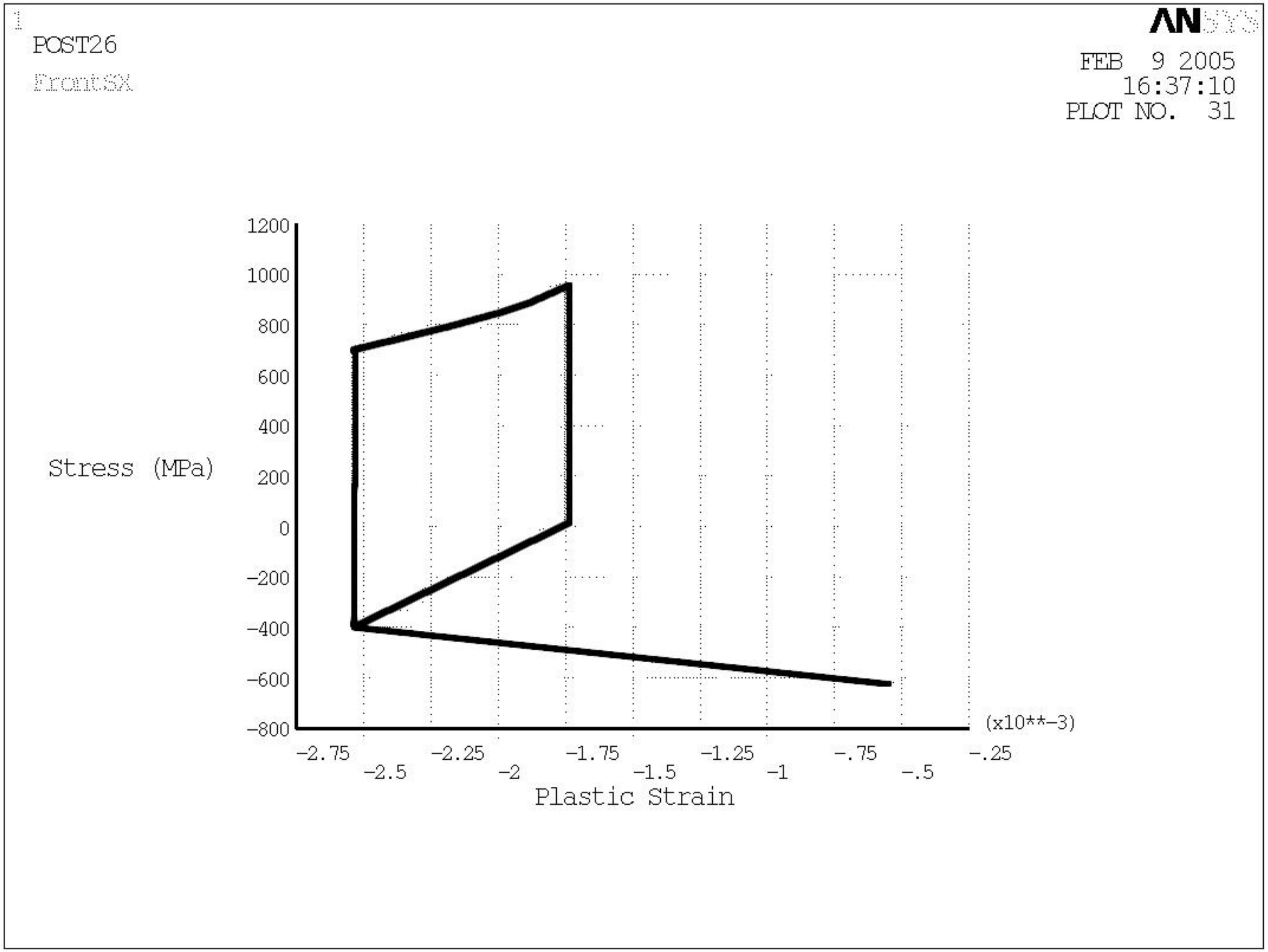


Radius=6.5 m

Peak Stresses in Coatings

- Peak stresses in coatings (400 MJ, 6.5 m)
  - Silicon Carbide: 25 MPa (bulk strength ~ 500 MPa)
  - Boron Carbide: 145 MPa (bulk strength ~ 150 MPa)
  - Residual stresses from fabrication are key
  - Fracture analyses are needed

Stress-Strain Behavior (W/154/6.5)



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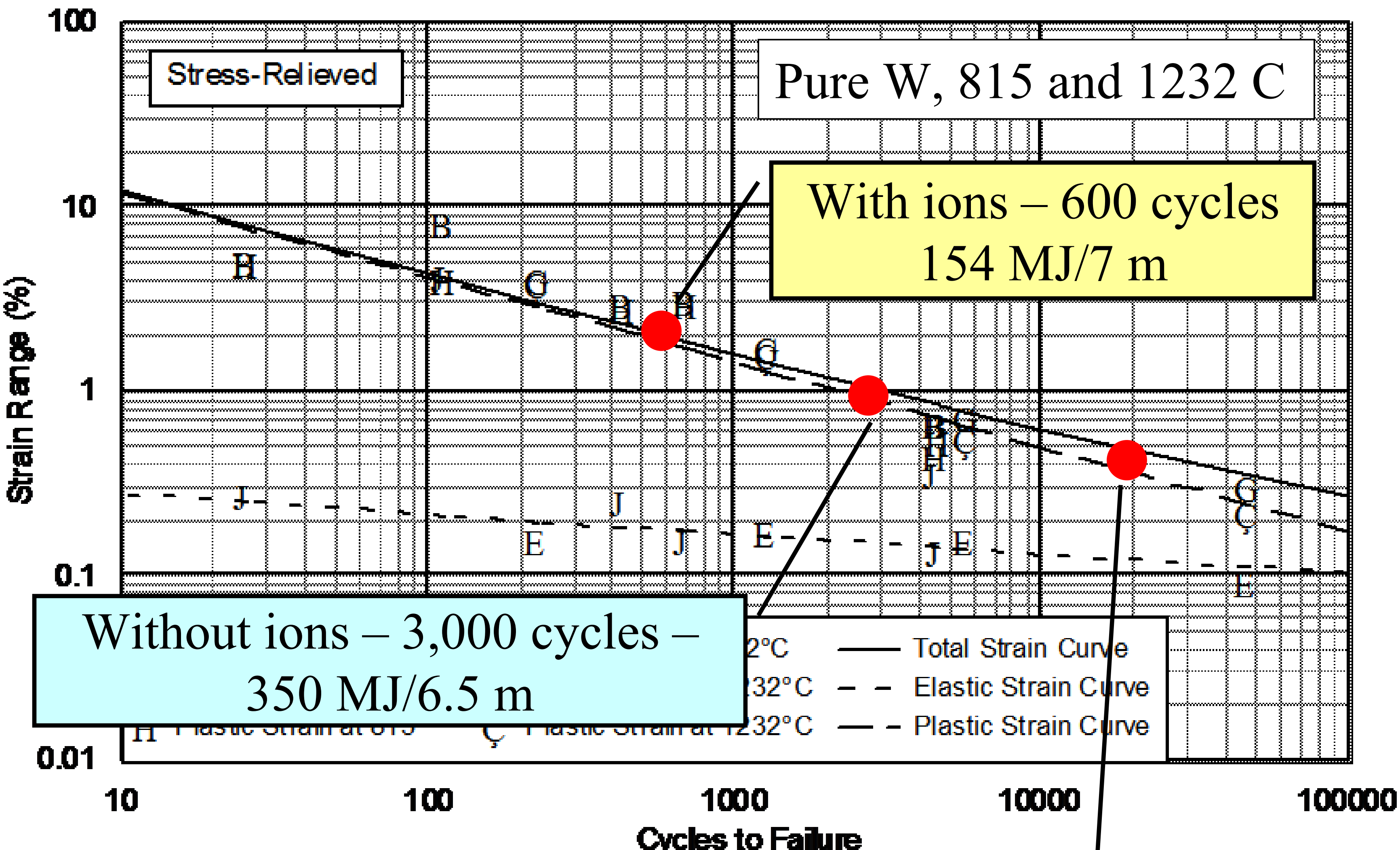
Fatigue Data for Stress-Relieved Tungsten



Without ions – 20,000 cycles – 154 MJ/6.5 m

Effect on Substrate

- Energy per pulse is less than 5% of total ion and x-ray energy
- Hence, substrate effects are minimal
- For 400 MJ yield and 6.5 m radius, temperature rises and stresses in the steel are less than 10 degrees and 15 MPa
- Steel fatigue strength is well over 100 MPa

Low Energy Ions

- What if ions below 20 keV are not diverted
- Less than 0.4% of debris ion energy is in ions below 20 keV
- For 400 MJ yield, assuming 13% of energy is in debris ions, even depositing 0.4% of that on surface in 2 microseconds would cause less than 20 degree rise in tungsten

Tests

- Start samples at 600 C
- Run for as many cycles as is reasonable
- Characterization as usual
- Achieve peak temperatures of:
  - Silicon Carbide: 750, 900 C
  - Boron Carbide: 650, 700 C

Conclusions

- The load on the chamber is substantially reduced if the ions end up elsewhere
- The question would be how much we wanted to push it by going to an even smaller chamber