APPENDIX J

TARGET CHAMBERS

BY

BOB PETERSON

Target Chamber Issues for Direct-Drive Targets

R.R. Peterson, G.L. Kulcinski, E.A. Mogahed,
and J.F. Santarius
University of Wisconsin-Madison

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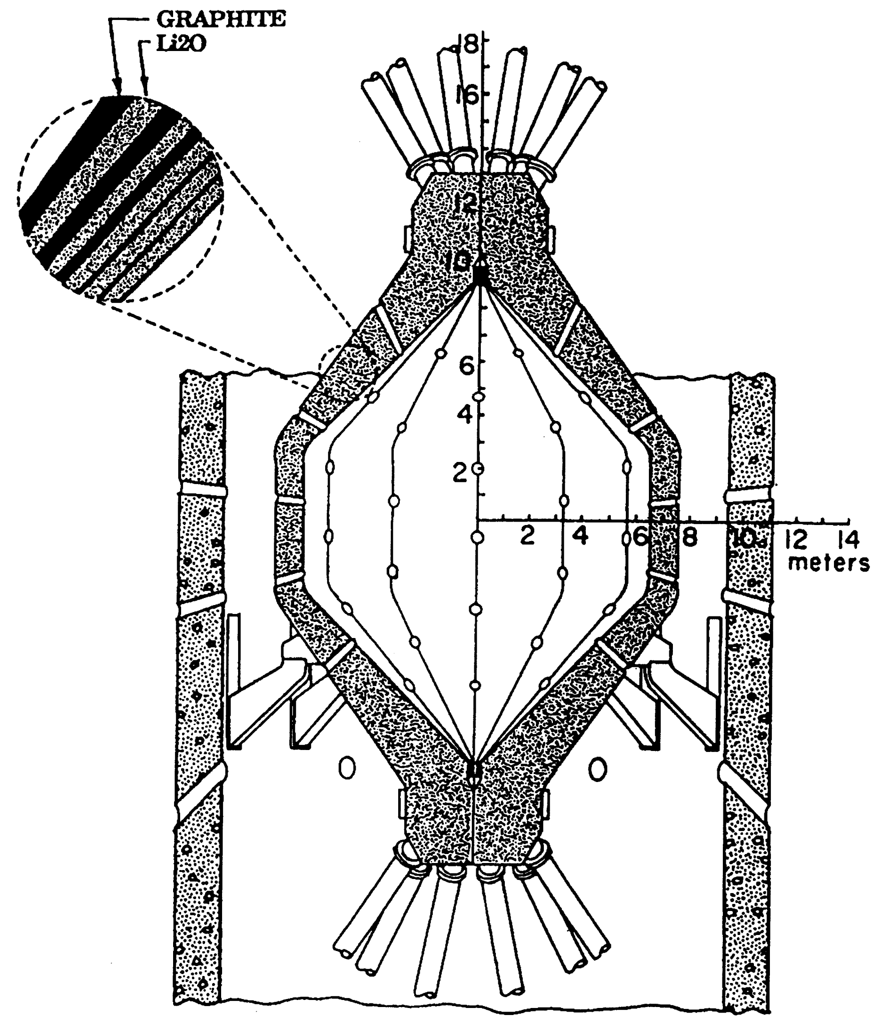
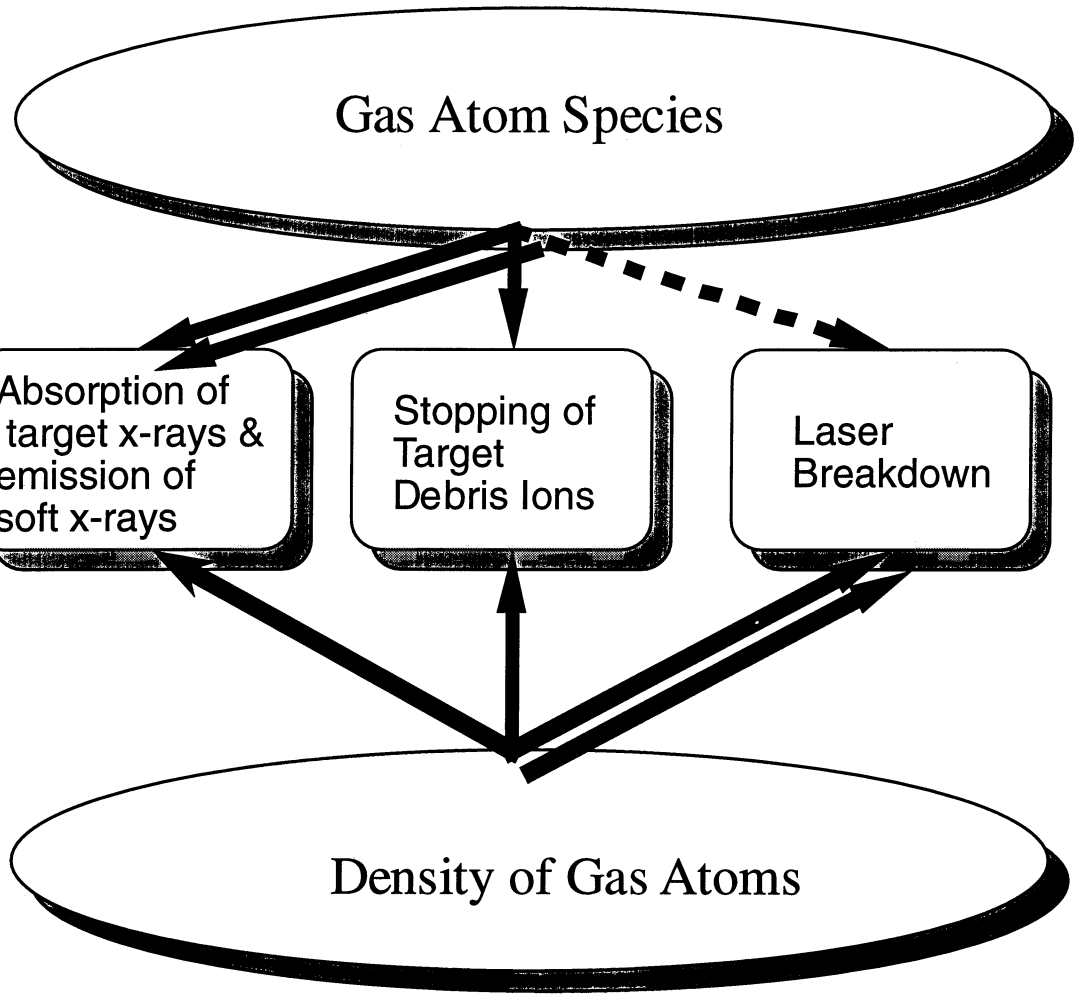
Xenon Gas in SOMBRERO Protects First Wall

- In SOMBRERO, 0.5 Torr of Xe stops 1.6 MeV carbon ions (containing most of the non-neutronic target output) before they reach the target chamber wall.
- The fireball radiation emission is slow enough that the graphite first wall stays below the sublimation limit. Bucky predicts a peak surface temperature 2,155 C.
- The shock applied to the wall applies and impulse of 2.21 Pa-s and a peak pressure of 0.013 MPa.
- BUCKY simulations show that wall survival is sensitive to Xe opacity.

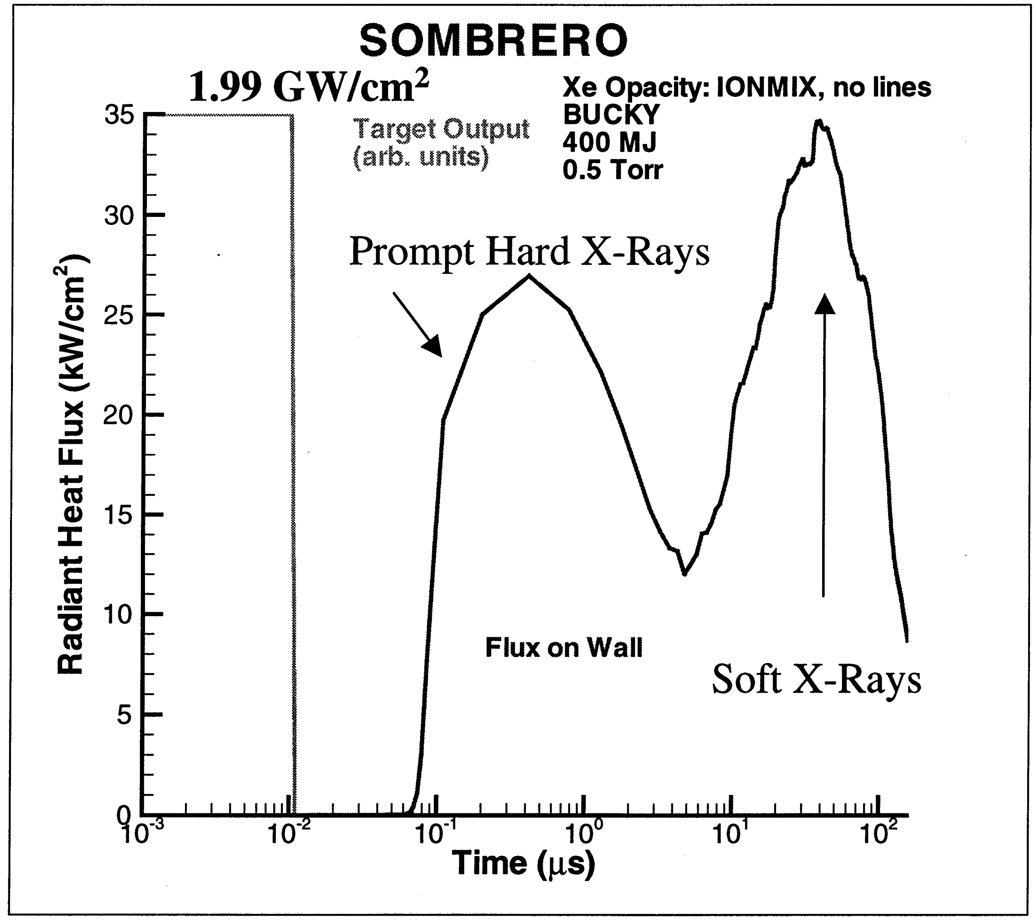


Variables Considered For Choosing the Cavity Gas Environment in SOMBRERO



Xenon Gas in SOMBRERO Spreads Out the heat Transfer to the Wall of the Target Chamber

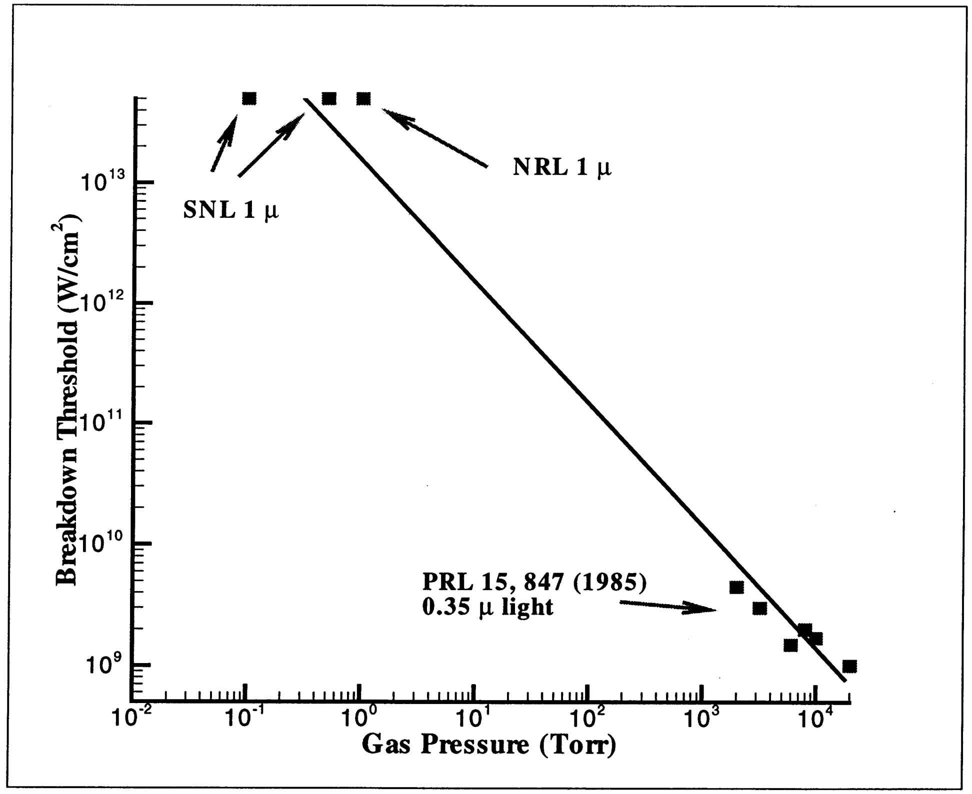
- 100 MJ of X-rays and Debris Ions are Released by the target over about 10 ns.
- Xenon Gas absorbs target x-rays and ions.
- Gas radiates energy to the wall over about 100 μs.



Laser Propagation in Target Chamber Gases Limits Fill Gas Density

- Laser beams need to avoid laser breakdown of the fill gas and plasma instabilities that can lead to unsmooth beams or poor laser-target coupling.
- SOMBRERO calls for 33 TW/cm^2 0.25 μ laser light on the surface of the target.
- The breakdown threshold is one way of measuring how well the laser traverses the gas.
- The breakdown threshold depends on laser wavelength, pulse shape, coherence, uniformity, focal length and gas conditions.
- Old data show that it is possible that KrF diver beams may traverse 1 Torr of Xenon; more experiments must confirm this.

Data compiled from work in the 1980's



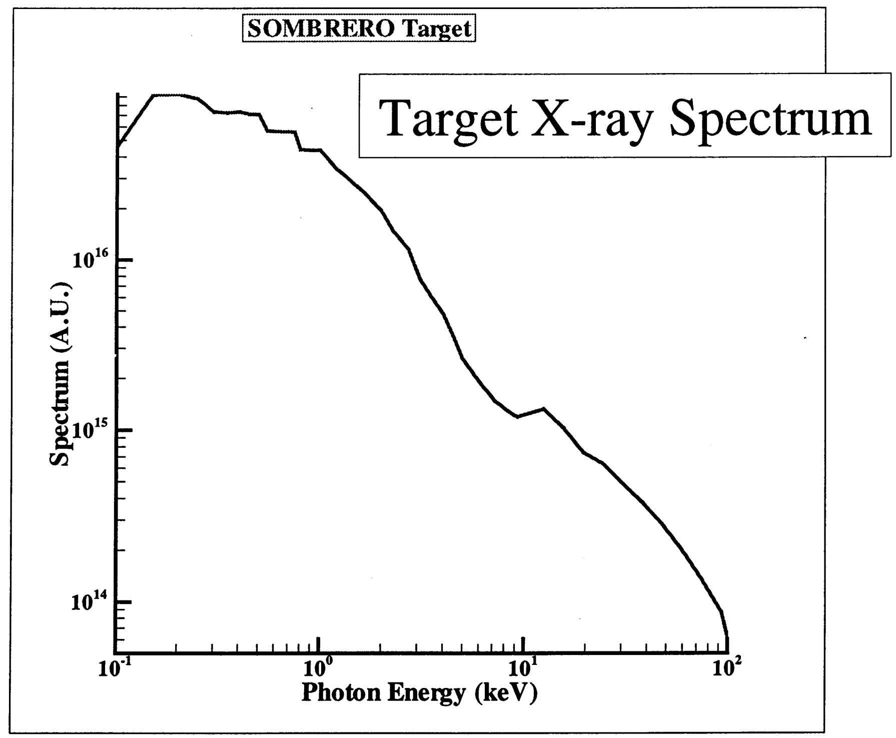
Direct-Drive Target Output is Dominated by Neutrons and Energetic Ablator Ions

Debris Ions

94 keV D -	5.81 MJ
141 keV T -	8.72 MJ
138 keV H -	9.24 MJ
188 keV He -	4.49 MJ
1600 keV C -	55.24 MJ
Total -	83.24 MJ

X-Rays

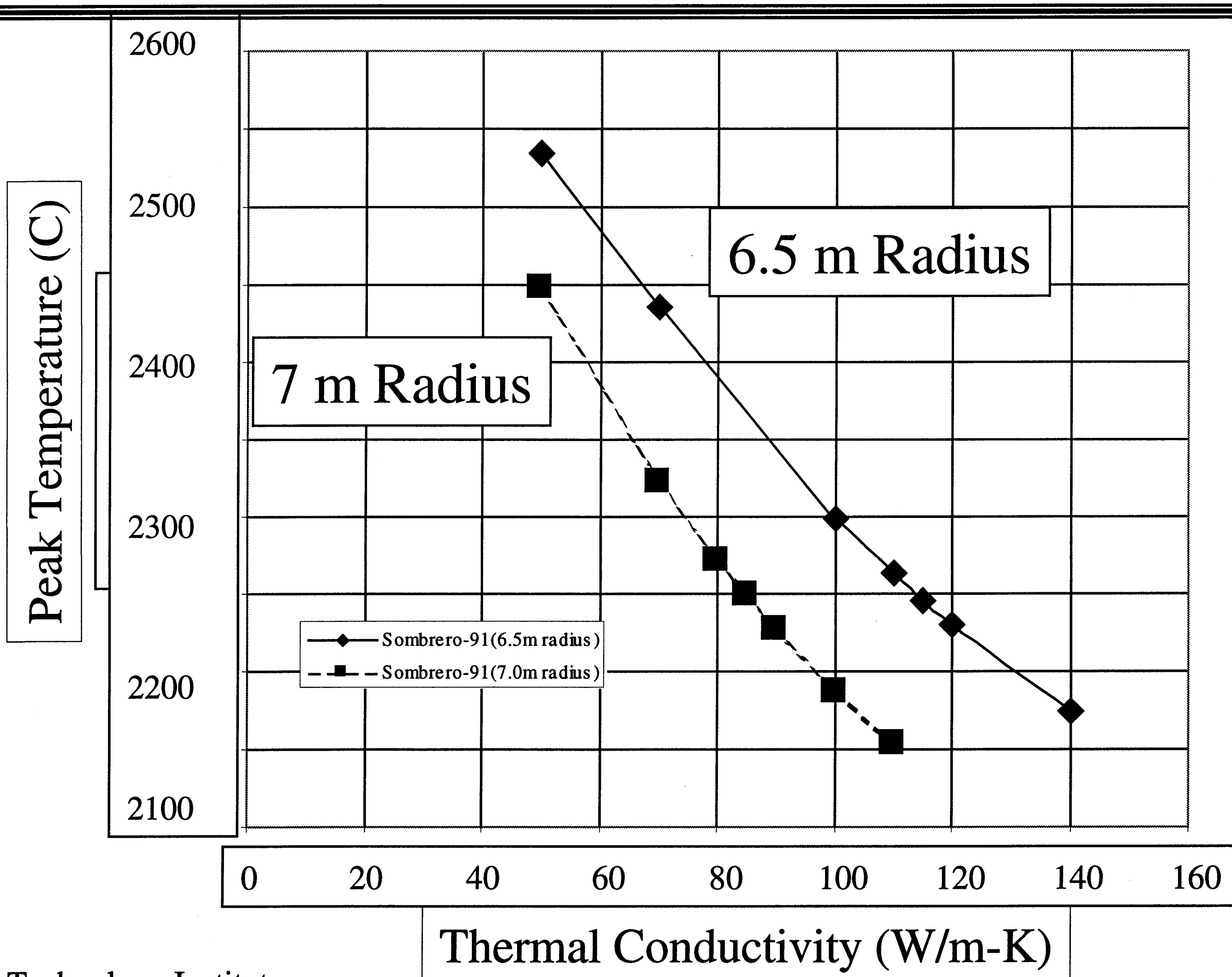
22.41 MJ



Neutrons

317 MJ

The Peak First Wall Temperatures in SOMBRERO Depend on the Thermal Conductivity of the First Few Microns



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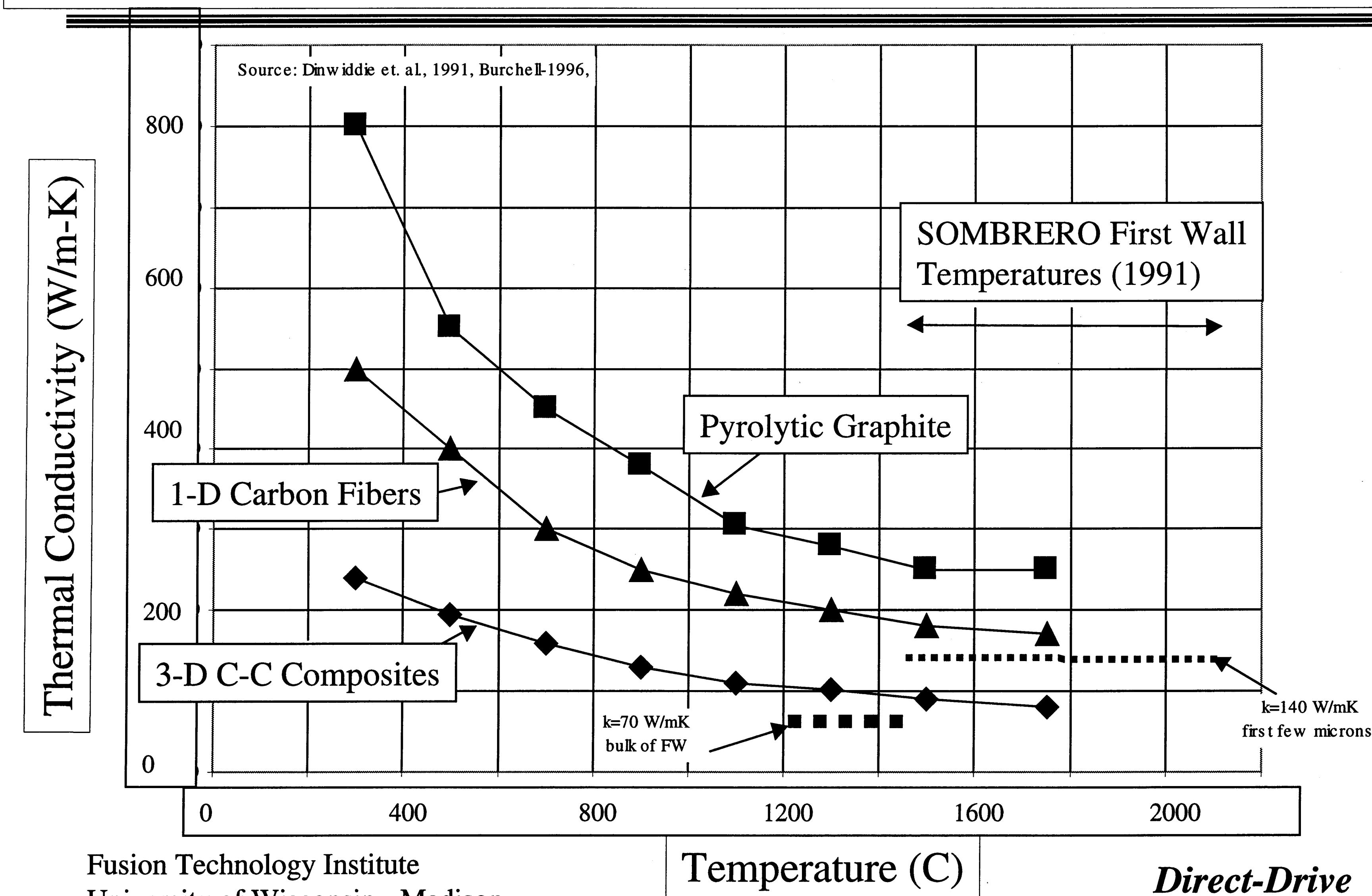
The Thermal Conductivity of Pyrolytic Graphite, Carbon Fibers and C-C Composites Drops with Increasing Temperature



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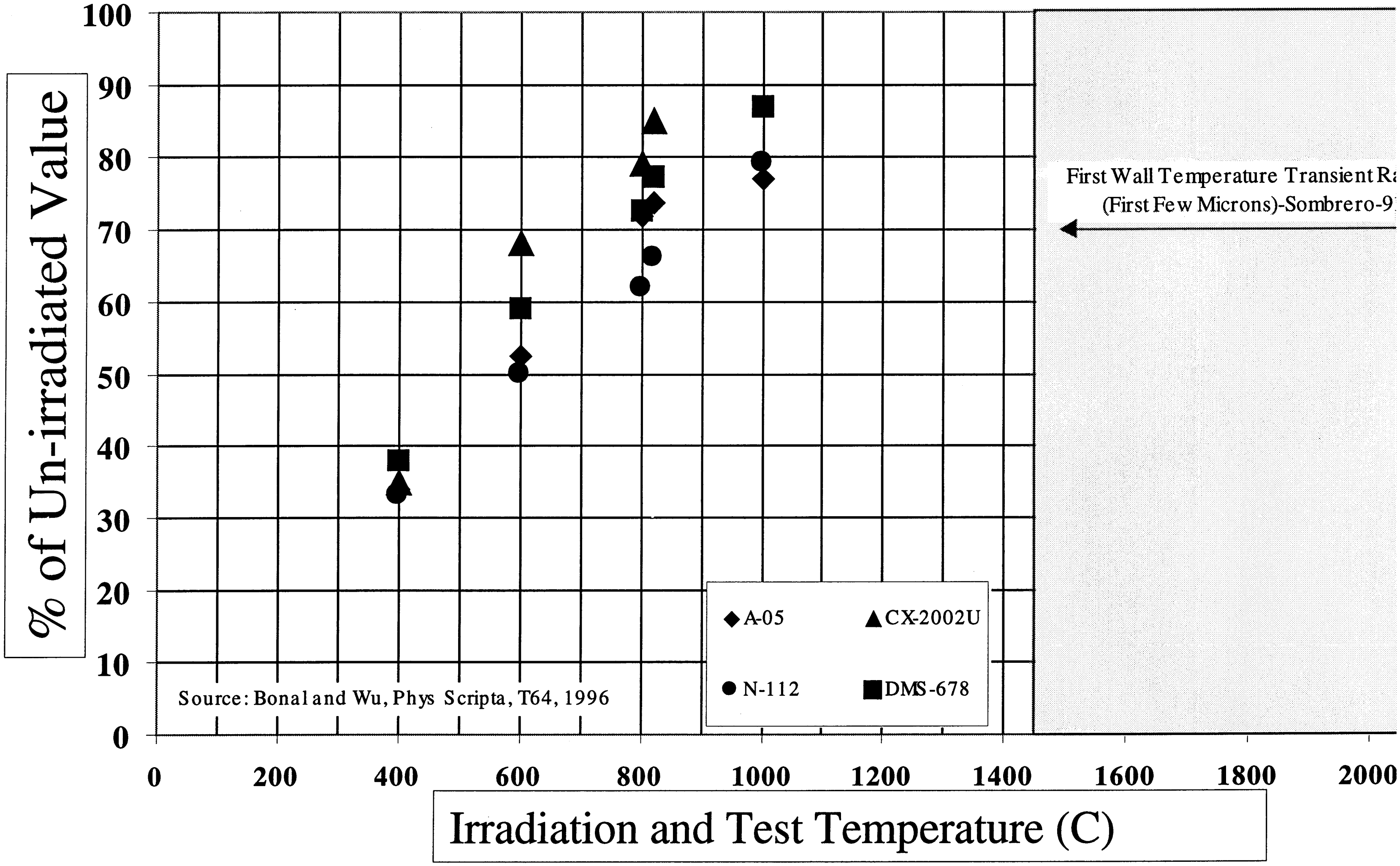
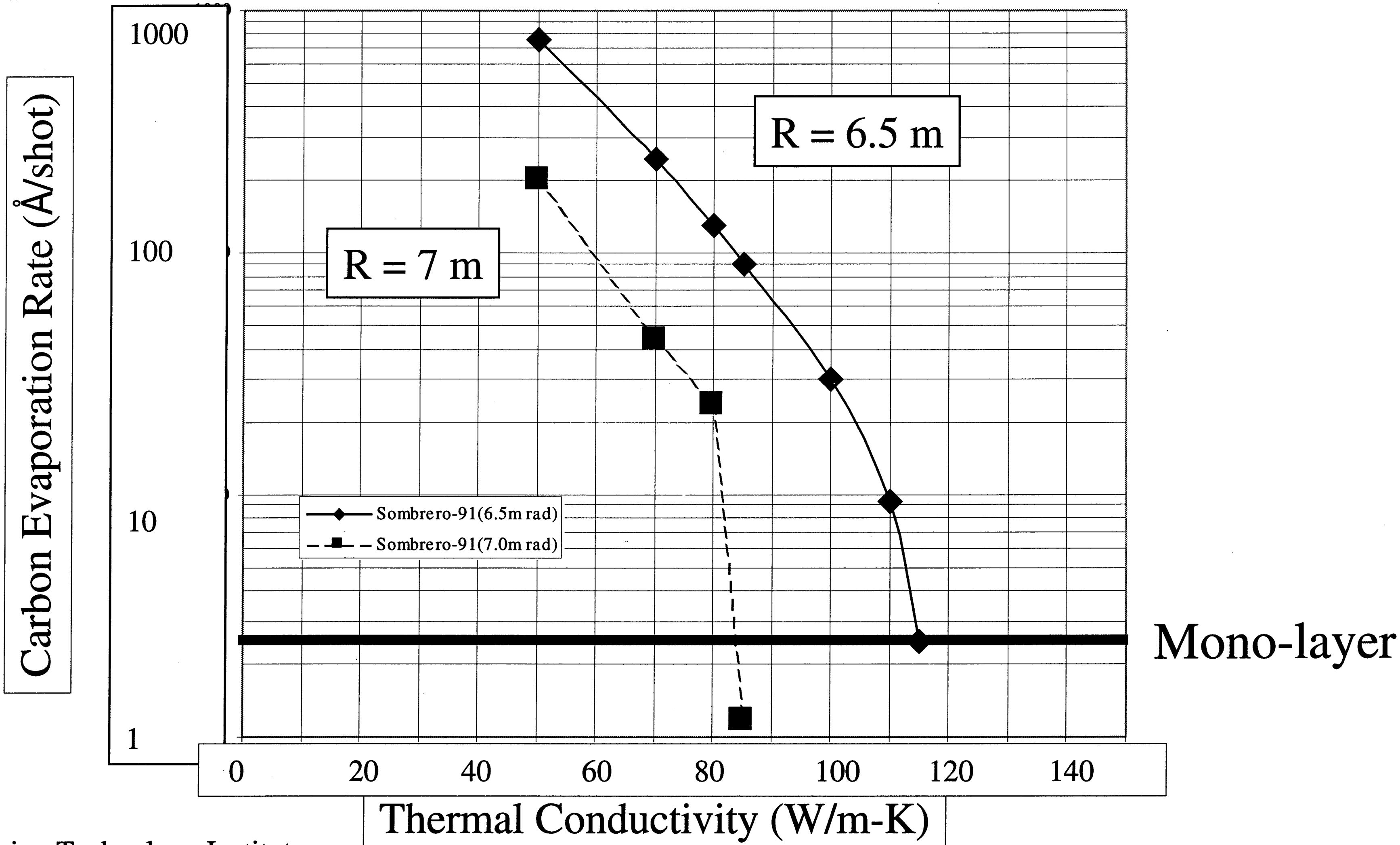
Neutron Irradiated Thermal Conductivity of Graphite at ≈ 1-2 dpa Approaches Un-irradiated Thermal Values at High Temperatures



Once the Evaporation is Below a Few Å Per Shot There is Essentially No Erosion of the C-C First Wall



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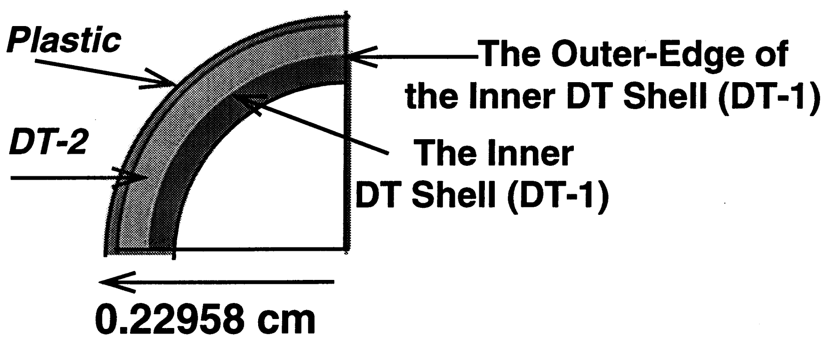
Target Heating During Injection has been Calculated

Transient Finite Element Model:

- Spherical Finite Element Model (ANSYS 5.4).
- Layers of the Model:

Inner radius of the DT-1 = 0.18 cm
Outer radius of the DT-1 = 0.2077 cm
Outer radius of the DT-2 = 0.2295 cm
Outer radius of the DT-1 = 0.22958 cm
Density of DT (ice) = 0.2125 g/cm^3



Assumptions:

* The Target is rotating/spinning during flight (homogeneous surface heating, due to aerodynamic friction).

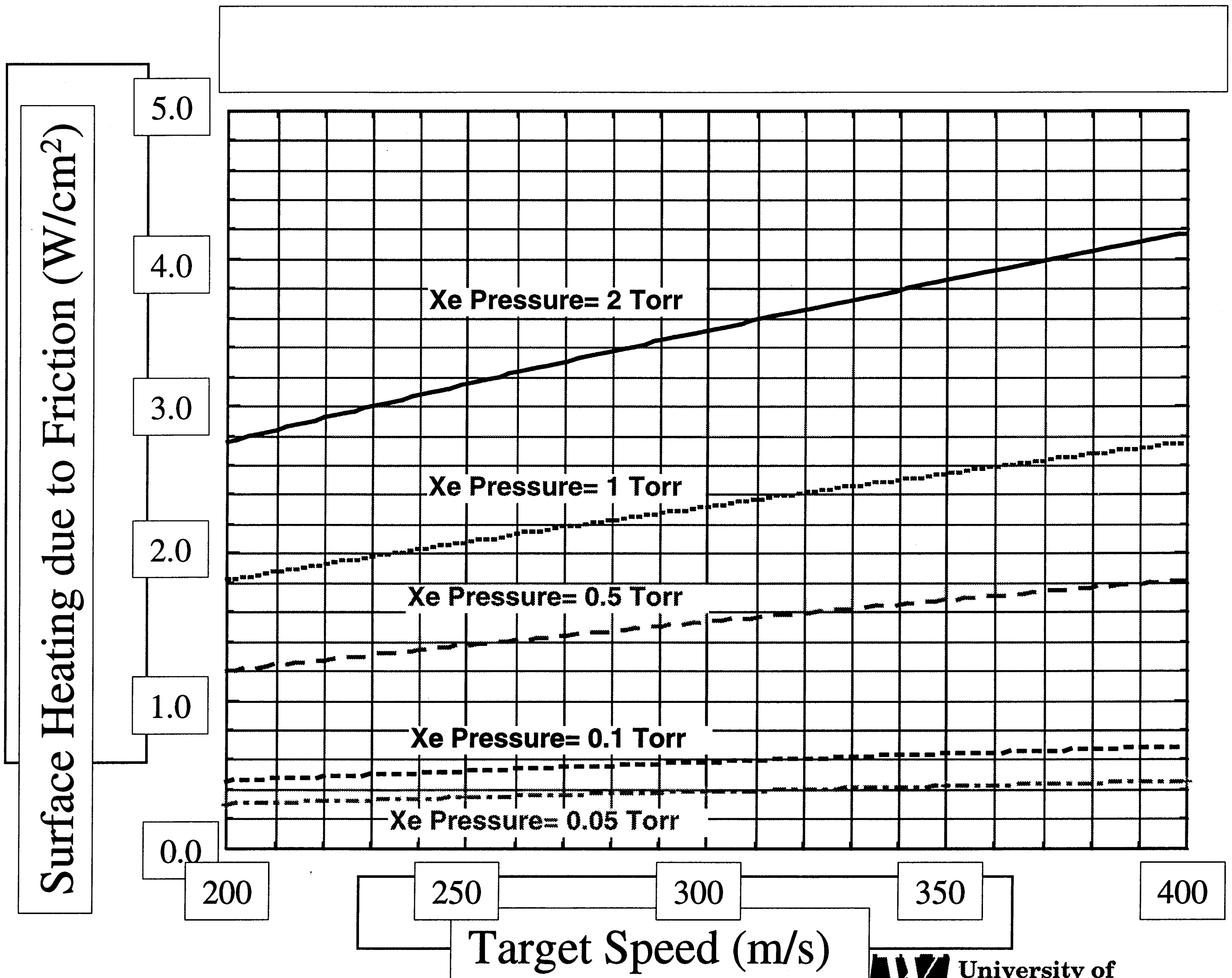
* Thermal conductivity of the outer shell, κ (CH) = 0.035 W/m K.

* Initial Temperature, T_o = 14 K .

* Most of the target surface heating is due to aerodynamic heating (Friction).

* The model is considering two phase changes of DT, (Solid to liquid and liquid to gas).

Surface Heating due to Friction Varies with Gas Density and Target Speed



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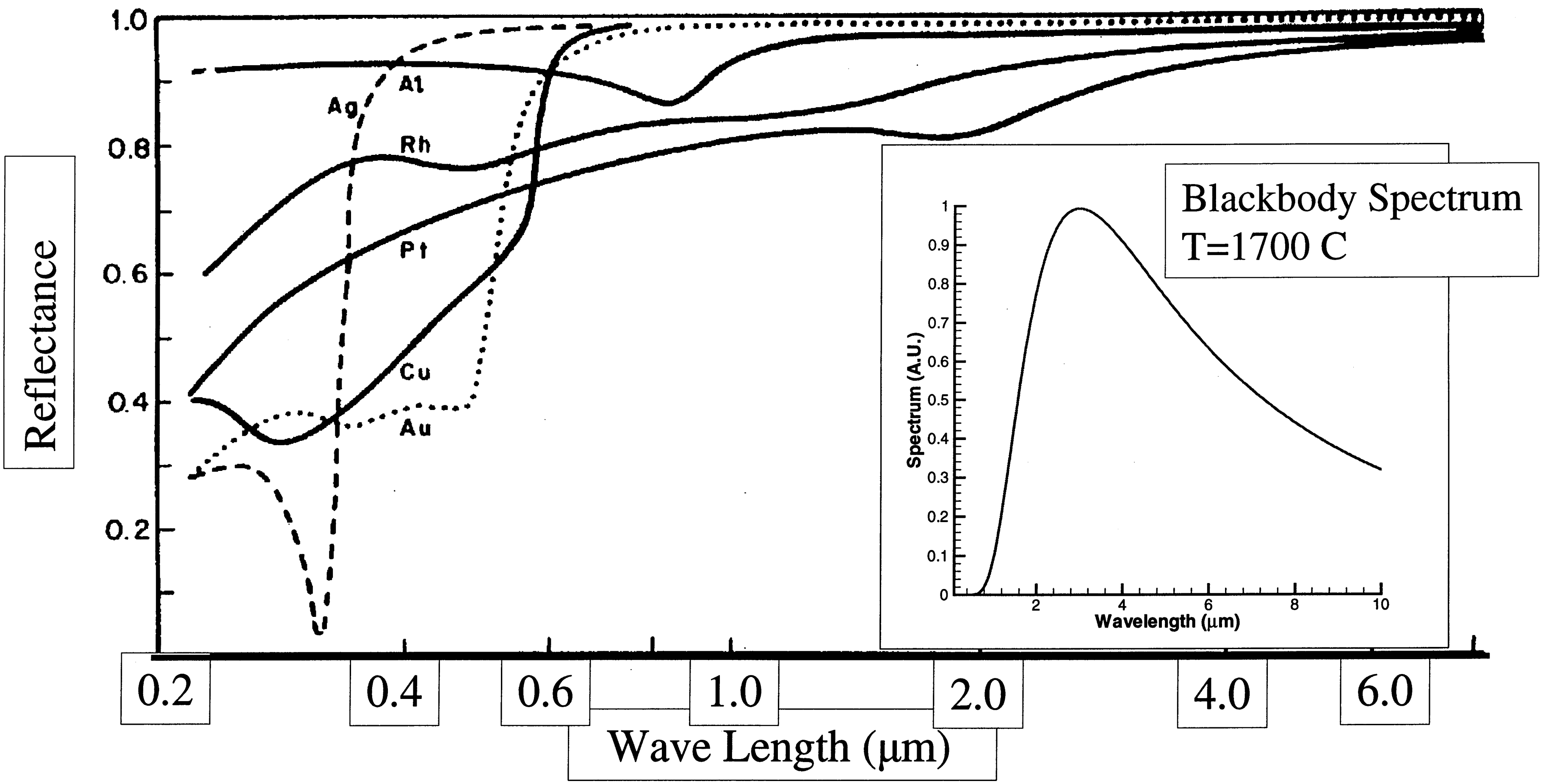
Target Heating by Thermal Radiation May be Minimized by Coating the Target with a High Reflectivity Metal

Ref: "A Physicist's Desk Reference", edited by H.L. Anderson (AIP Press, 1981)



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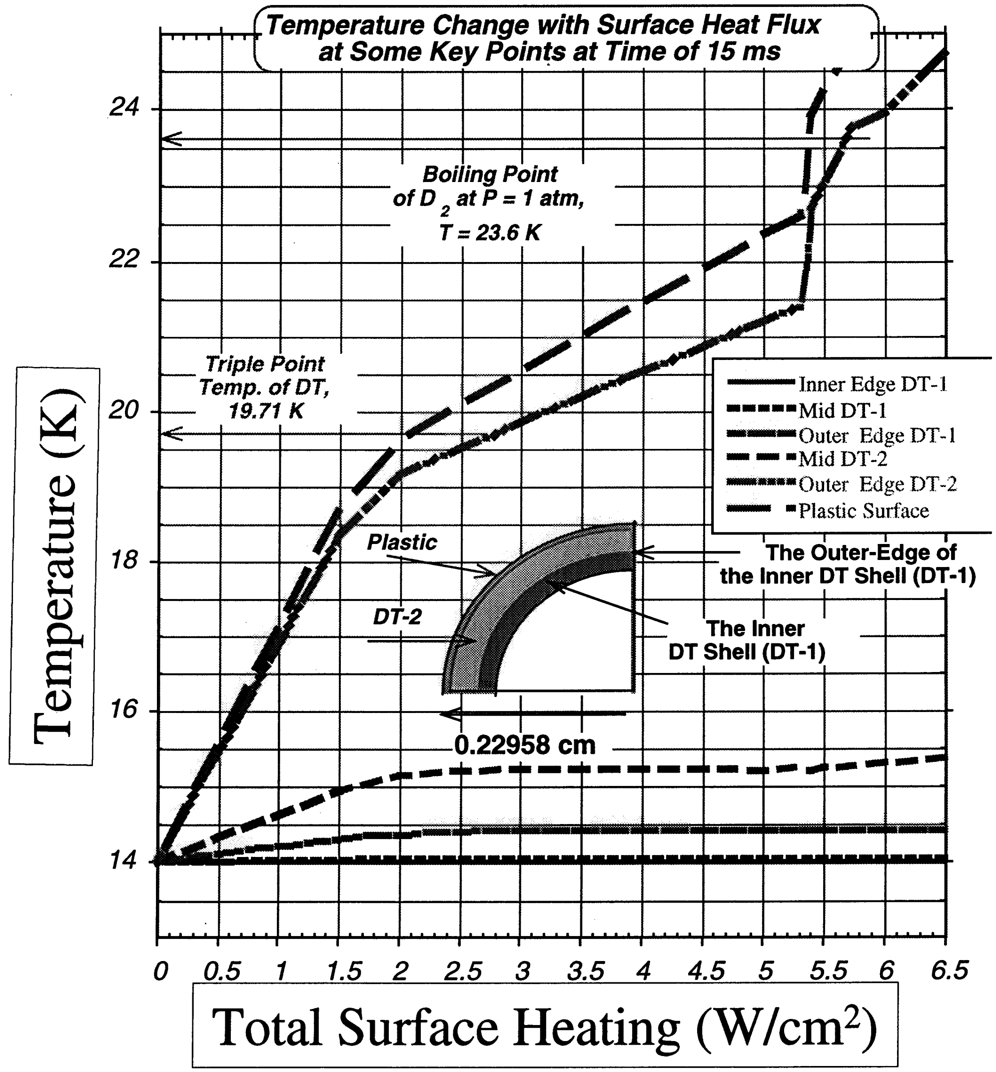
Target Heating Calculations Show that Very Low Heat Loads will Warm Outer DT by Several ° K

- ANSYS calculations out to 15 ms.
- Perfect contact is assumed.
- Even at 1.0 W/cm², outer DT increases by 3 K to 17 K.
- Inner DT heats by less than 0.5 K, even at much higher heating.



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Experimental Validation of Chamber Dynamics in Gas-Protected Chambers

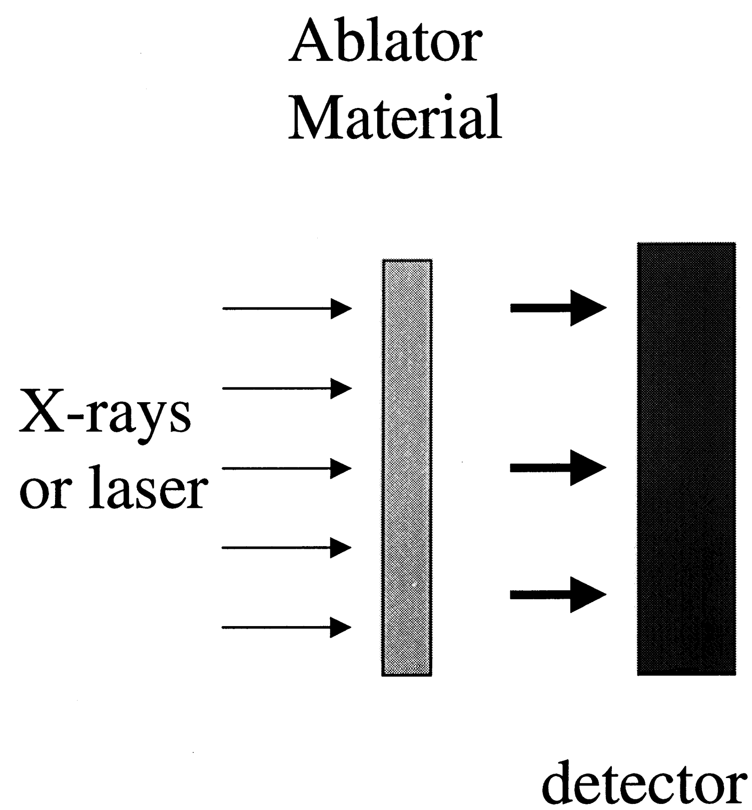
- Target Output
- Radiation Transport
- Gas Opacity
- Target Heating
- Thermal Properties of Wall Material
- Wall Evaporation

Target Output Predictions Need to be Validated by Experiments

•Chamber fill gas wall protection requirements set by ion spectrum.

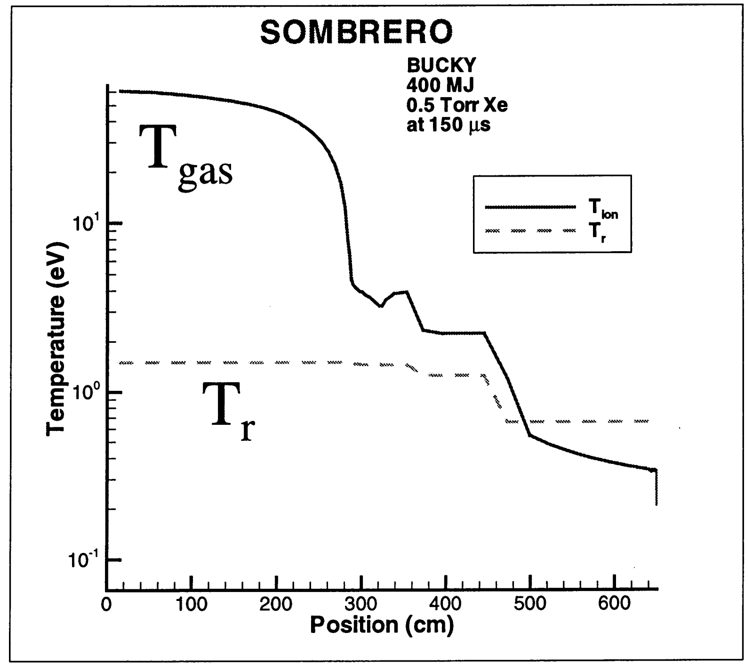
•High energy density experiments could validate code predictions is a system that mimics conditions in ablator of exploding target.

•Experiments could be done on Z, SATURN, or a laser.



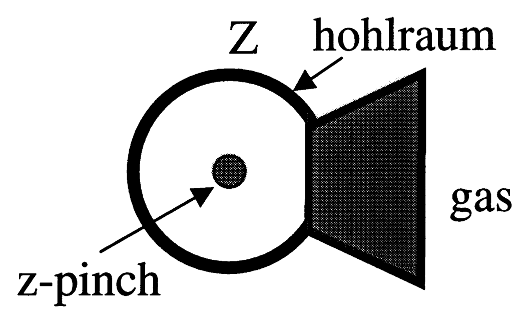
Radiation Transport in Gas Protected Target Chambers

Issue: Radiation Transport in SOMBRERO fireballs is far out of equilibrium and flux-limited radiation diffusion must be validated.



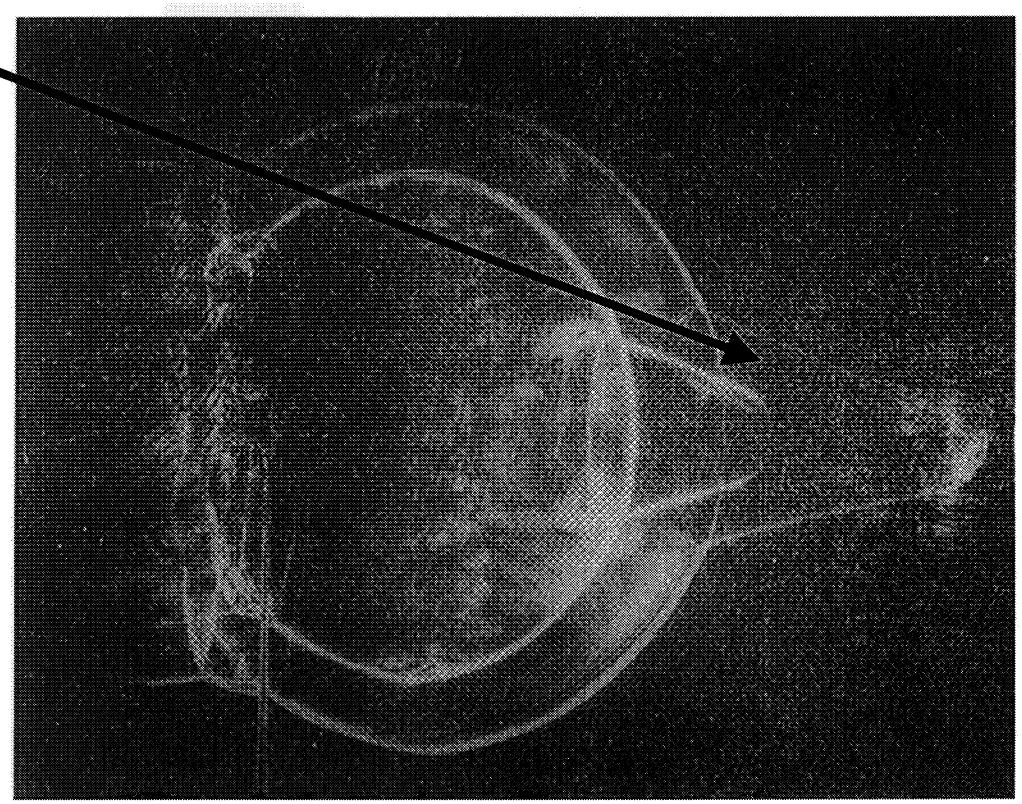
Status: Radiation-hydro codes (BUCKY, RAGE, Lasnex) can model radiation-dominated-blasts. NRL laser generated blasts in the 80's showed that radiation fronts can be unstable.

Needs: High energy density (enough to heat Xe to ~ 100 eV) experiments on Z would simulate radiation dominated blasts. Need a sample large enough to be optically thick.



Laser Generated Fireballs were Seen to Preferentially Propagate Along Laser Path

- 1988 NRL Laser Generated Fireball Experiments Show Propagation in Laser Path Ahead of Main Fireball.
- Dark-field Shadowgrams at 71 and 146 ns.
- Reduced Opacity in Laser Path due to Laser Heating.

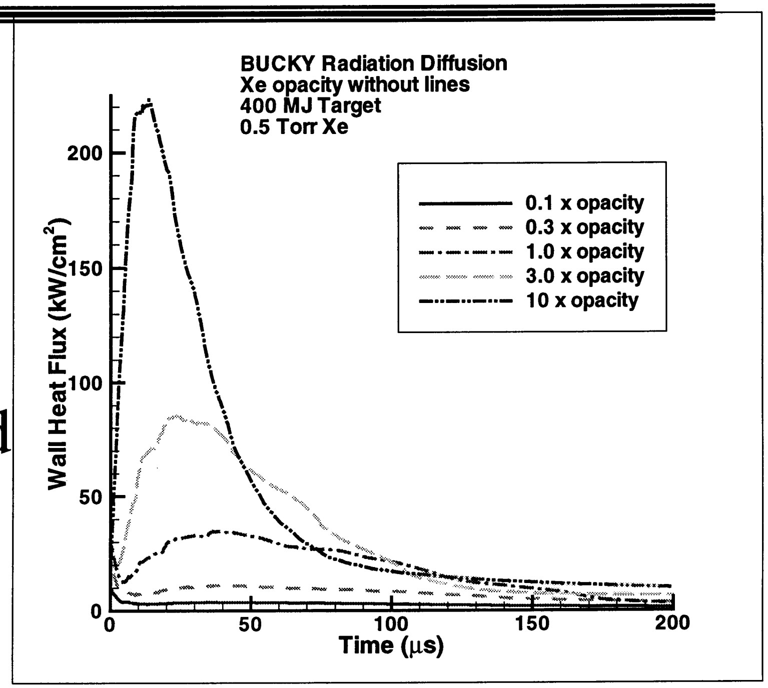


J.A. Stamper, et al., *Phys. Fluids* **31,** 3353 (1988).

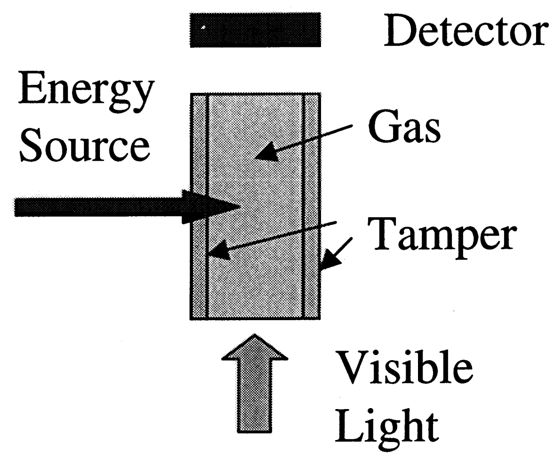
Atomic Physics and Opacity Effects Dictate Fireball Behavior: Experiments are Needed

ISSUE: Gas opacity dominates fireball dynamics. Fireball dynamics determines survival of first wall.

PROBLEM: For SOMBRERO Xenon (Z=54) has a very complicated atomic structure, leading to a great many lines that cannot be modeled with any reasonable group structure in a radiation hydrodynamics calculation.



Experimental Validation: The opacity needs to be measured at about 1 Torr and 100 eV.

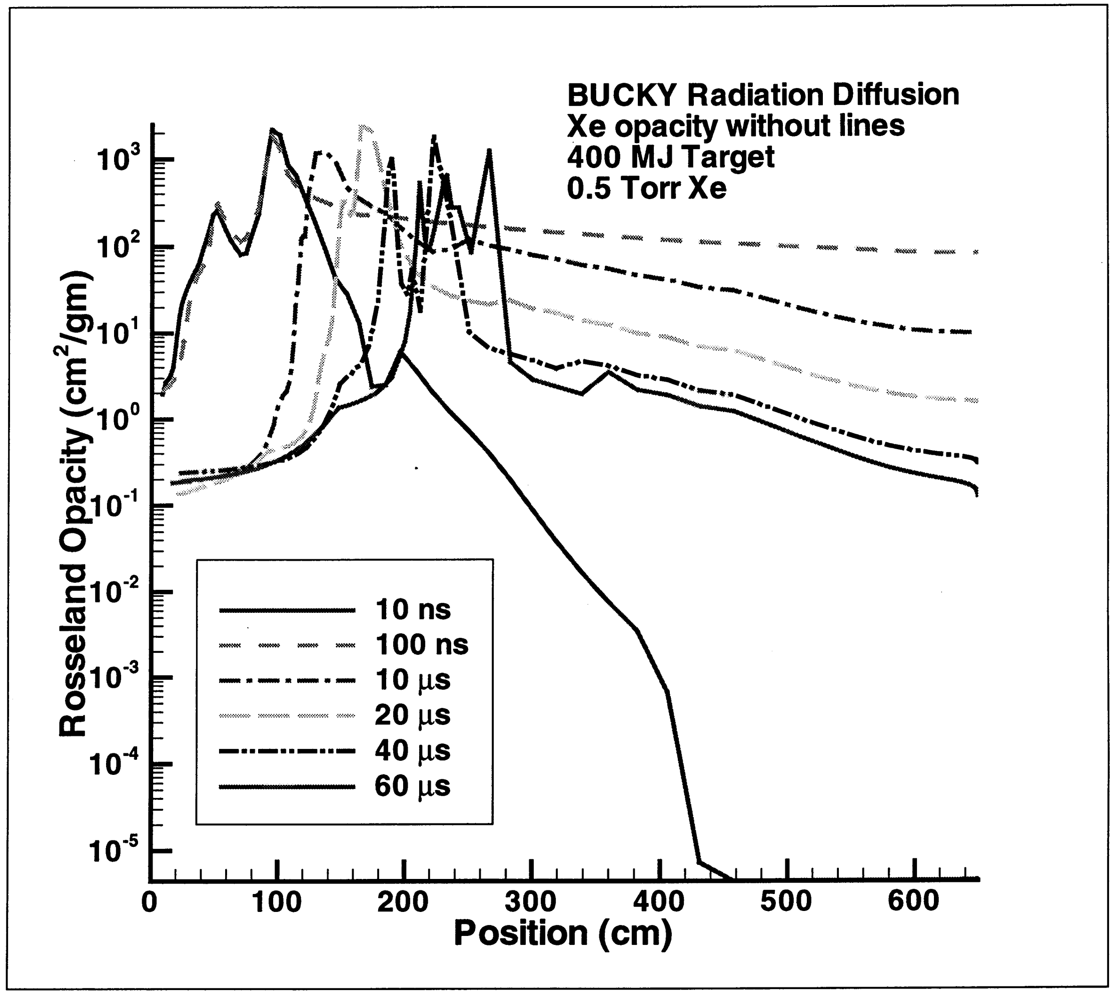


In SOMBRERO Radiation Flow is Governed by Emission, NOT Transport

•Highest opacity at the edge of the fireball is the barrier to radiation transport.

• In this barrier, $\sigma_{Ross}\rho \approx 10^{-3}$ 1/cm, or the radiation mean-free-path is 1000 cm.

•Therefore, radiation flow to the wall is limited by emission.



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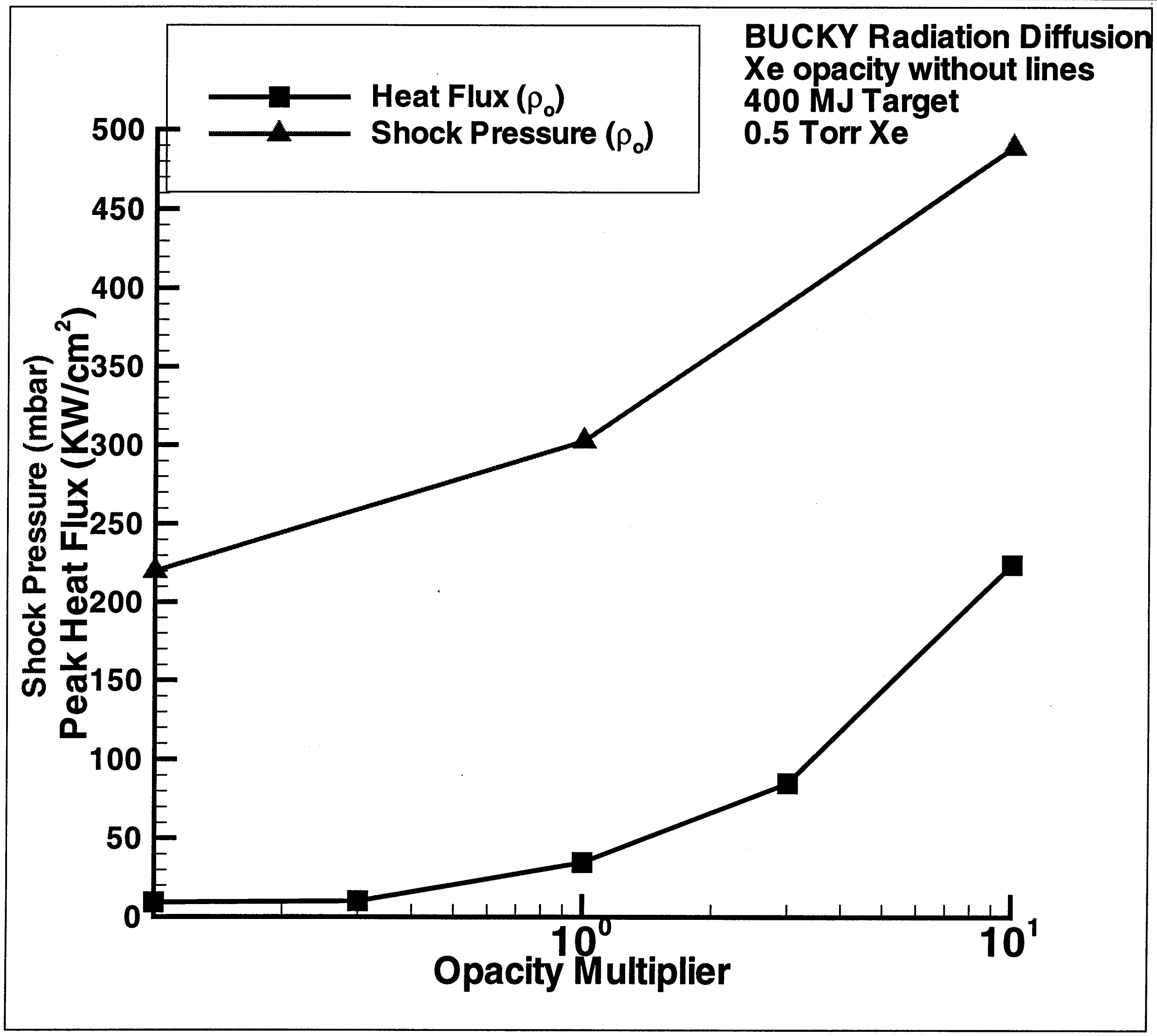
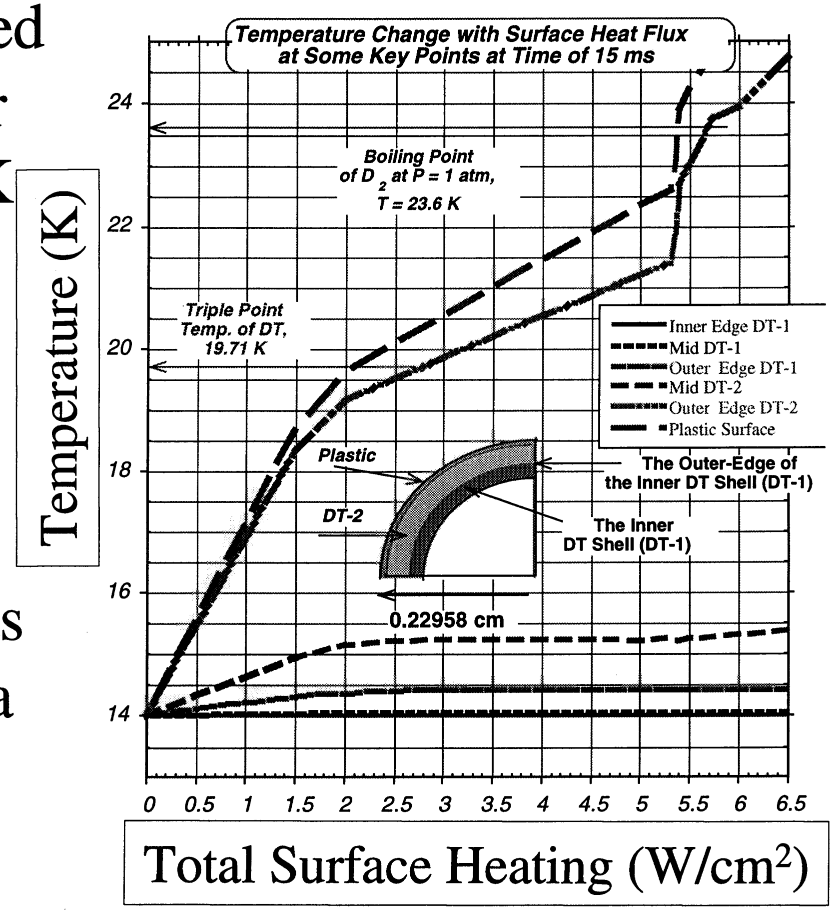
Wall Thermal and Mechanical Loading is Sensitive to Gas Opacity



Heating During Injection of Direct-Drive Targets Could Govern Chamber Design: Need Experiments

- ISSUE: Frictional heating of injected direct drive targets could warm outer parts of cryogenic fuel by several ° K
- STATUS: Calculations show that total heating of a few W/cm^2 warm outer fuel by a few ° K. Does this distort target unacceptably?
- EXPERIMENTS: Cryogenic targets need to be heated by a few ° K with a calibrated surface source and the condition of the fuel observed via radiography.



Materials Qualification Experiment for C/SiC

- **Purpose:**

  Measure the thermal conductivity of C/SiC at temperatures of 1,500 to 2,000 °C while being irradiated with neutrons to at least 1 dpa:

  ~ 2×10^{21} n/cm^2 fast neutron HFIR (or equivalent) spectra

  ~ 8×10^{20} n/cm^2 14 MeV RTNS (or equivalent) spectra

- **Objective:**

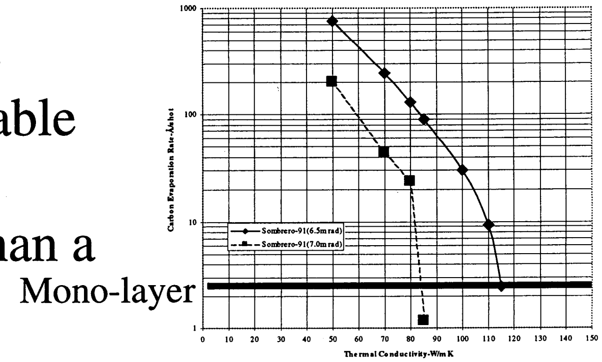
  To determine the amount of degradation in k from unirradiated values at high temperatures

- **Goal:**

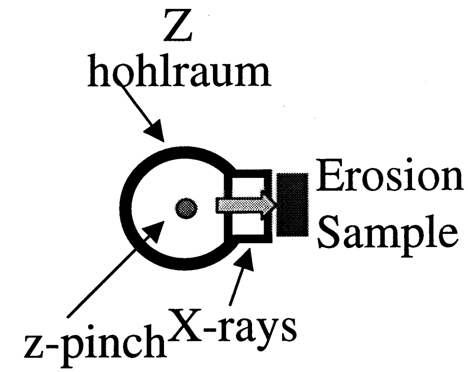
  Identify a C/SiC material that can maintain a k of ~ 100 W/m°K while it is under neutron irradiation

Wall Material Erosion Experiments are Possible on Existing Facilities (e.g. Z, Omega, GEKKO)

Issue: X-ray vaporization of wall materials in gas protected chambers may erode wall at an unacceptable rate. About 10^8 shots per year times 0.1 Å per shot would erode 1 mm per year. But 0.1 Å is far less than a mono-layer.



Status: BUCKY (continuum) calculations show that it is possible to get wall erosion per shot of less than 1 mono-layer of material loss per shot, but what does that mean?



Needs: Z, NIF, Omega, or GEKKO experiments could supply enough energy (in x-rays or from thermal radiation from a gas) to investigate evaporation near and below 1 mono-layer per shot.