Dry Wall Chamber Issues for the SOMBRERO Laser Fusion Power Plant

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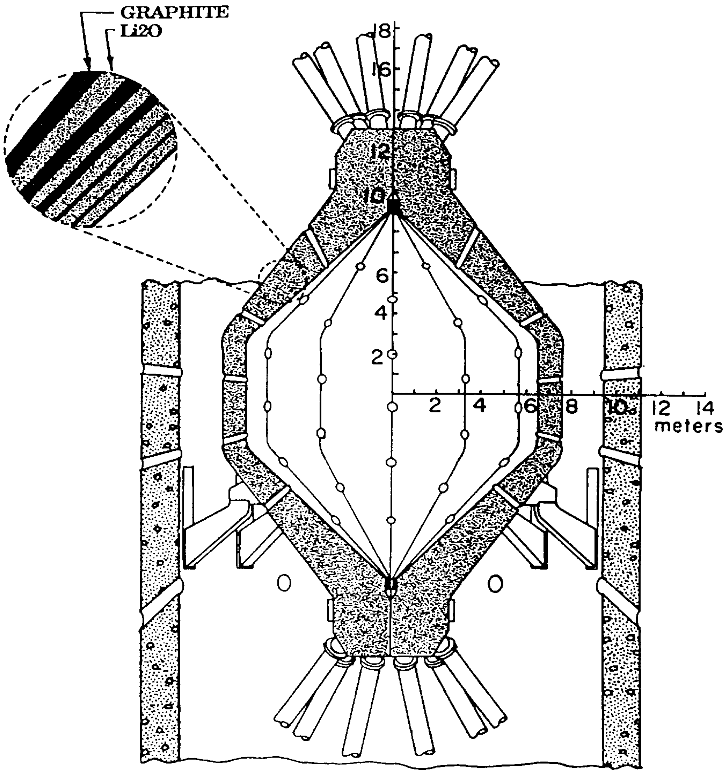
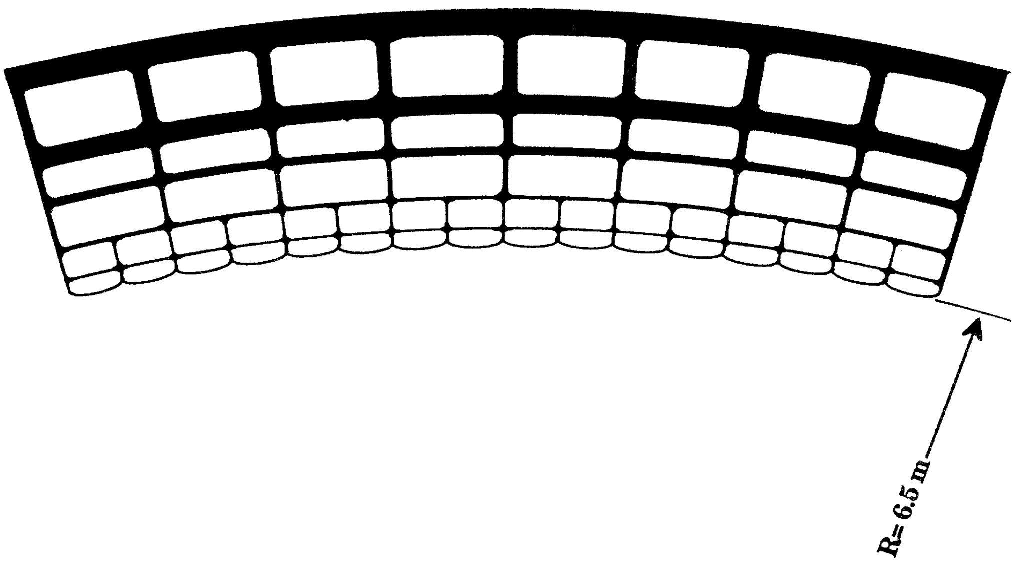
Fusion Technology Institute
University of Wisconsin

Schematic of the SOMBRERO Chamber and Cross Section of the Blanket at the Mid-plane



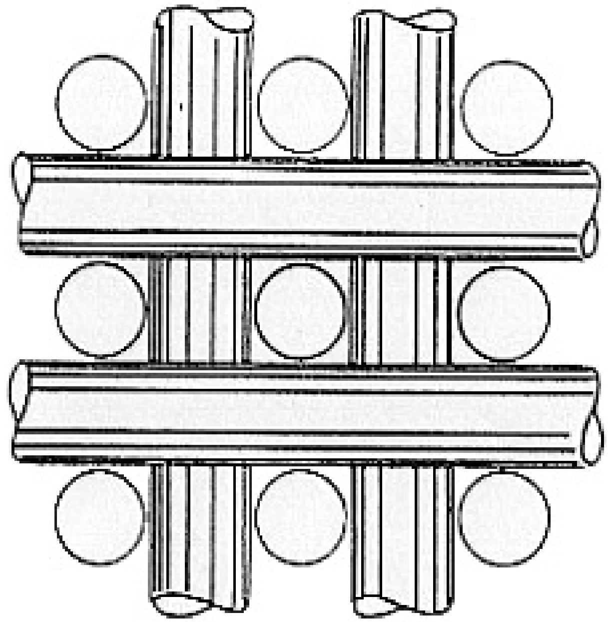


Key Operating Parameters for the SOMBRERO Chamber First Wall

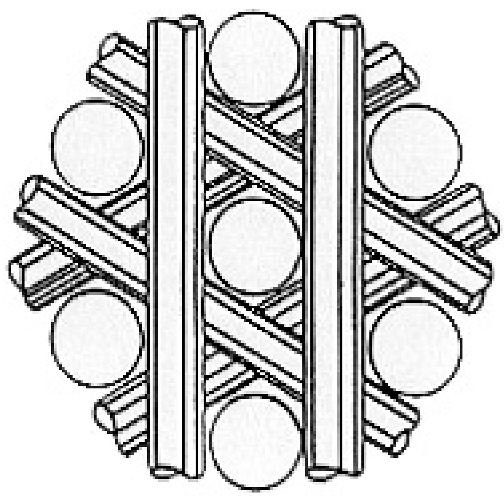
Target Yield/Rep Rate	400 MJ/6.7 Hz
Dry First Wall Protection Scheme	0.5 Torr Xe gas
First Wall Material	4D Woven Rigidized Graphite
Peak Neutron Wall Loading	3.4 MW/m^2
Peak Displacement Damage Rate	15.3 dpa/FPY
Peak Carbon Atom Destruction Rate	0.19 %/FPY
Steady State First Wall Temp. (ave)	1,485 °C
Peak First Wall Temperature	2,155 °C
Time of Peak Temperature	134 microseconds
Impulse on the First Wall	2.21 Pa-s
Peak Pressure on First Wall	0.0127 MPa
Time of Peak Pressure	89 microseconds

Examples of 3D and 4D C/C Composite Weaves

3-D Orthogonal Weave

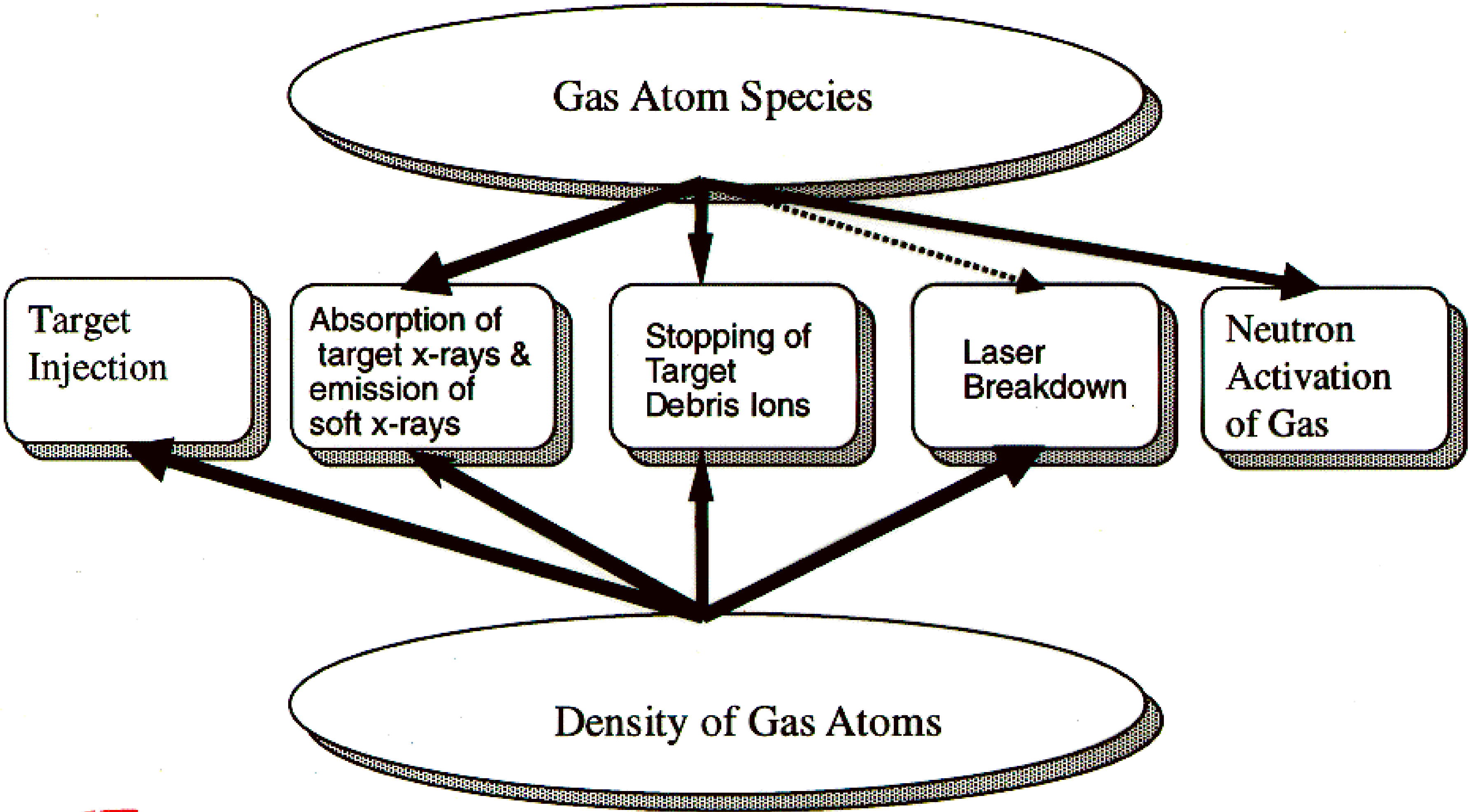


4-D Hexagonal Array



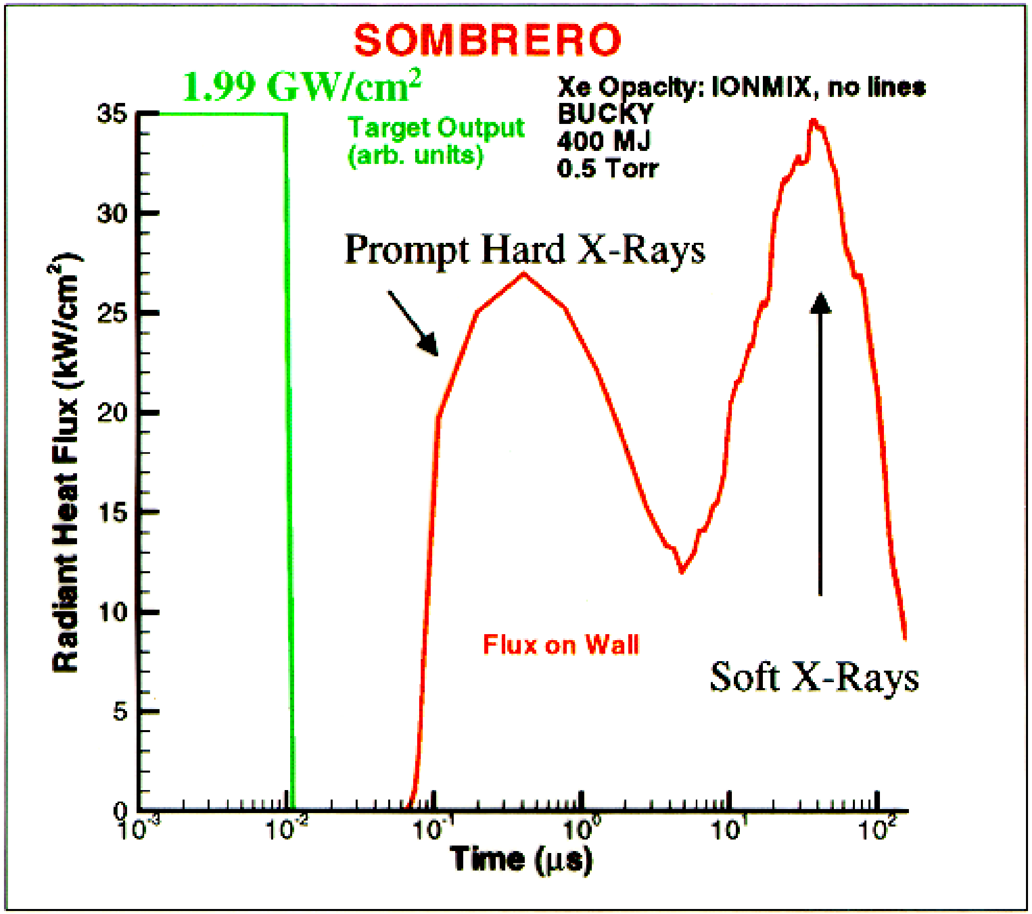
Courtesy of Mr. Leslie Cohen
Fiber Materials Inc.
Biddeford, Maine

Variables Considered For Choosing the Cavity Gas Environment in SOMBRERO



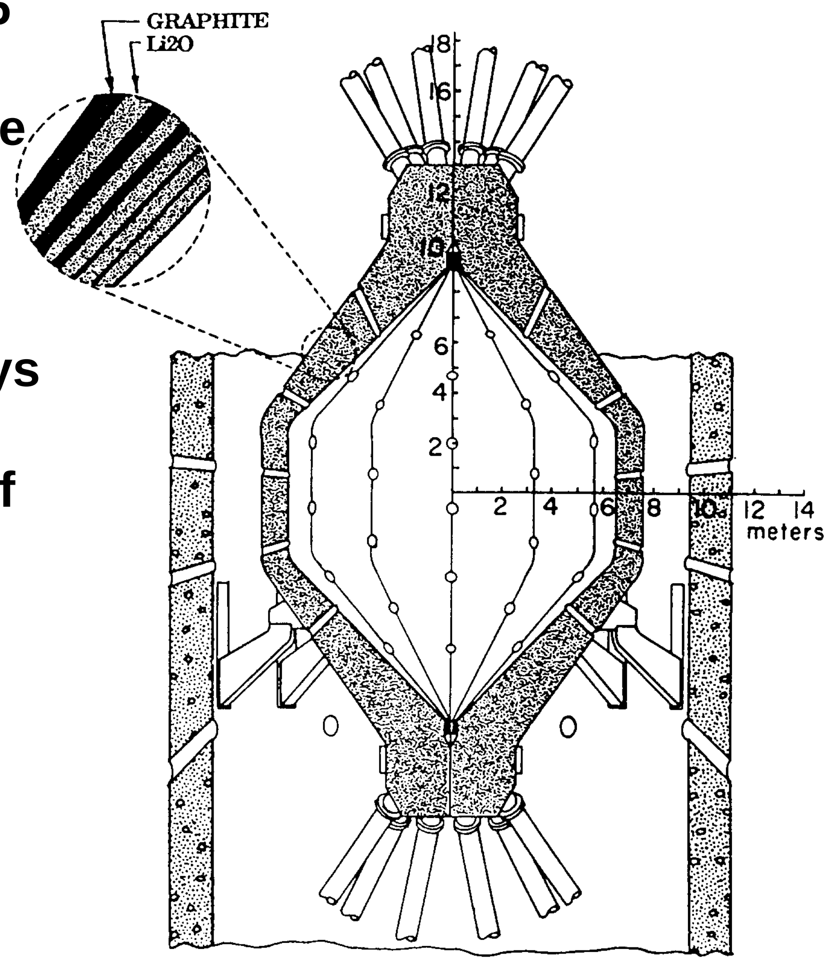
Xenon Gas in SOMBRERO Spreads Out the heat Transfer to the Wall of the Target Chamber

- 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.



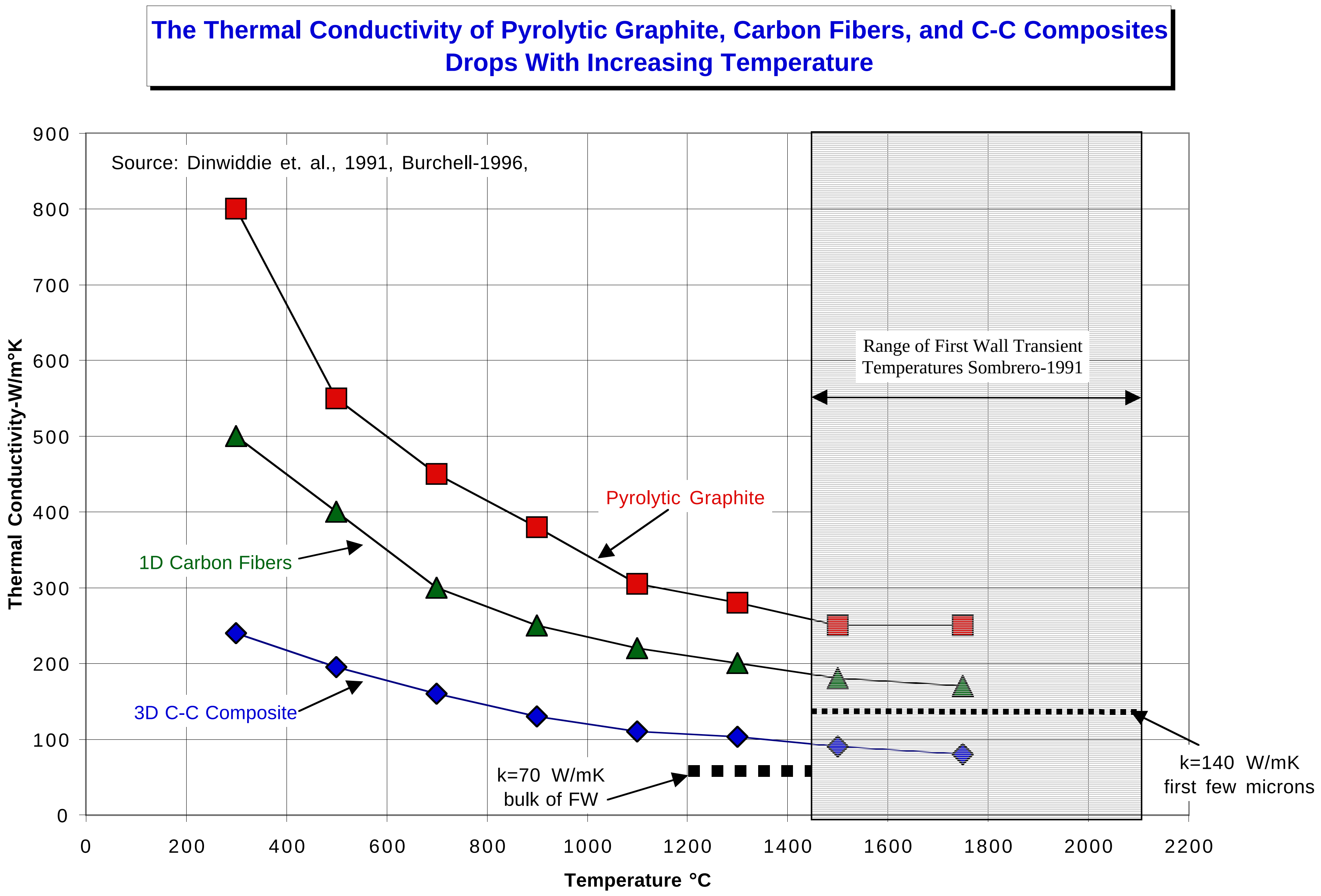
Xenon Gas in SOMBRERO Protects First Wall

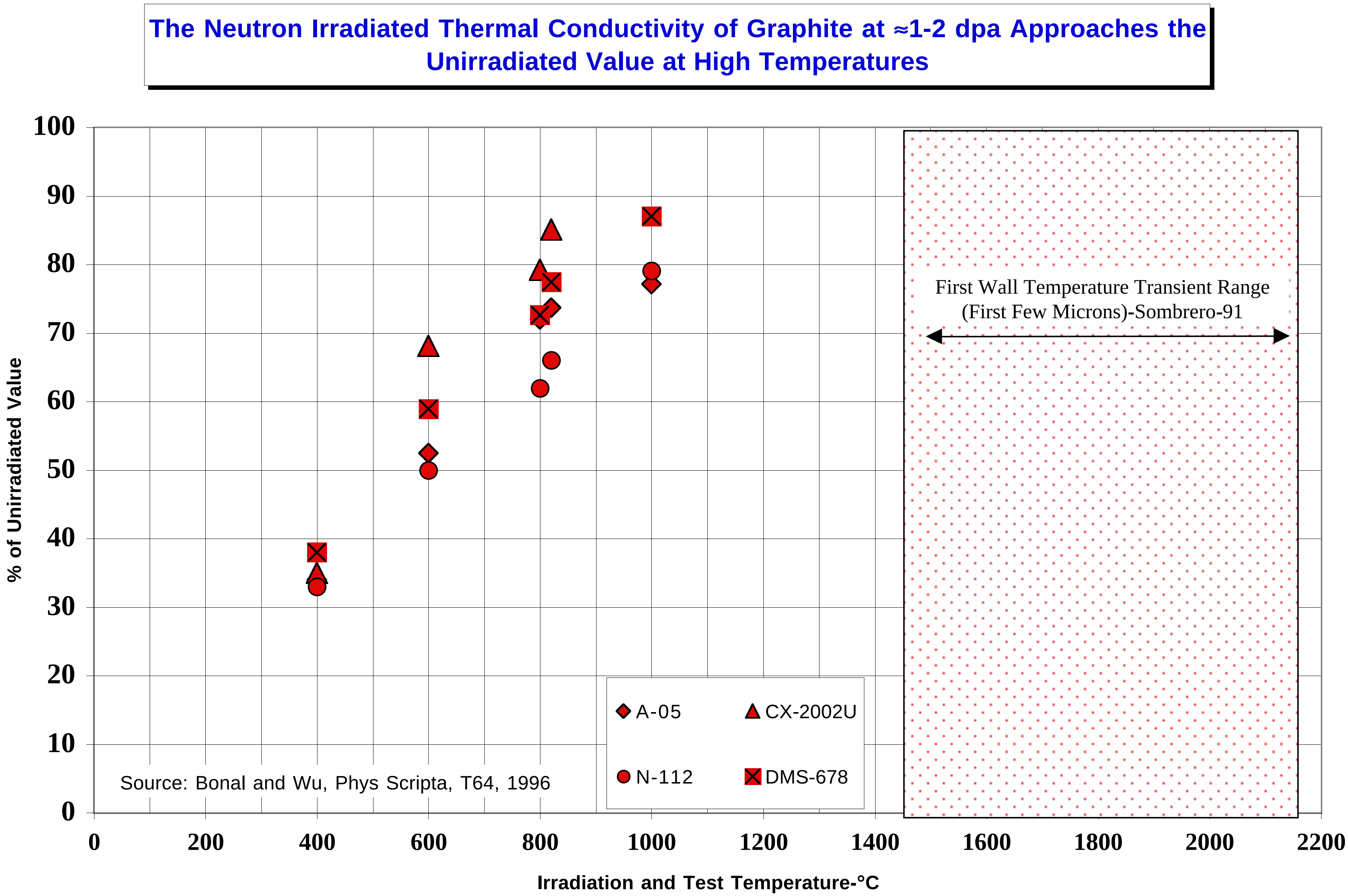
- In SOMBRERO, 0.5 torr of Xe stops 1.6 MeV carbon ions (containing most of the non-neutronic target output) before they reach the target chamber wall.
- The fireball radiation emission is slow enough that the graphite first wall stays below the sublimation limit. BUCKY predicts a peak surface temperature of 2155 C.
- The shock applied to the wall applies an 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.



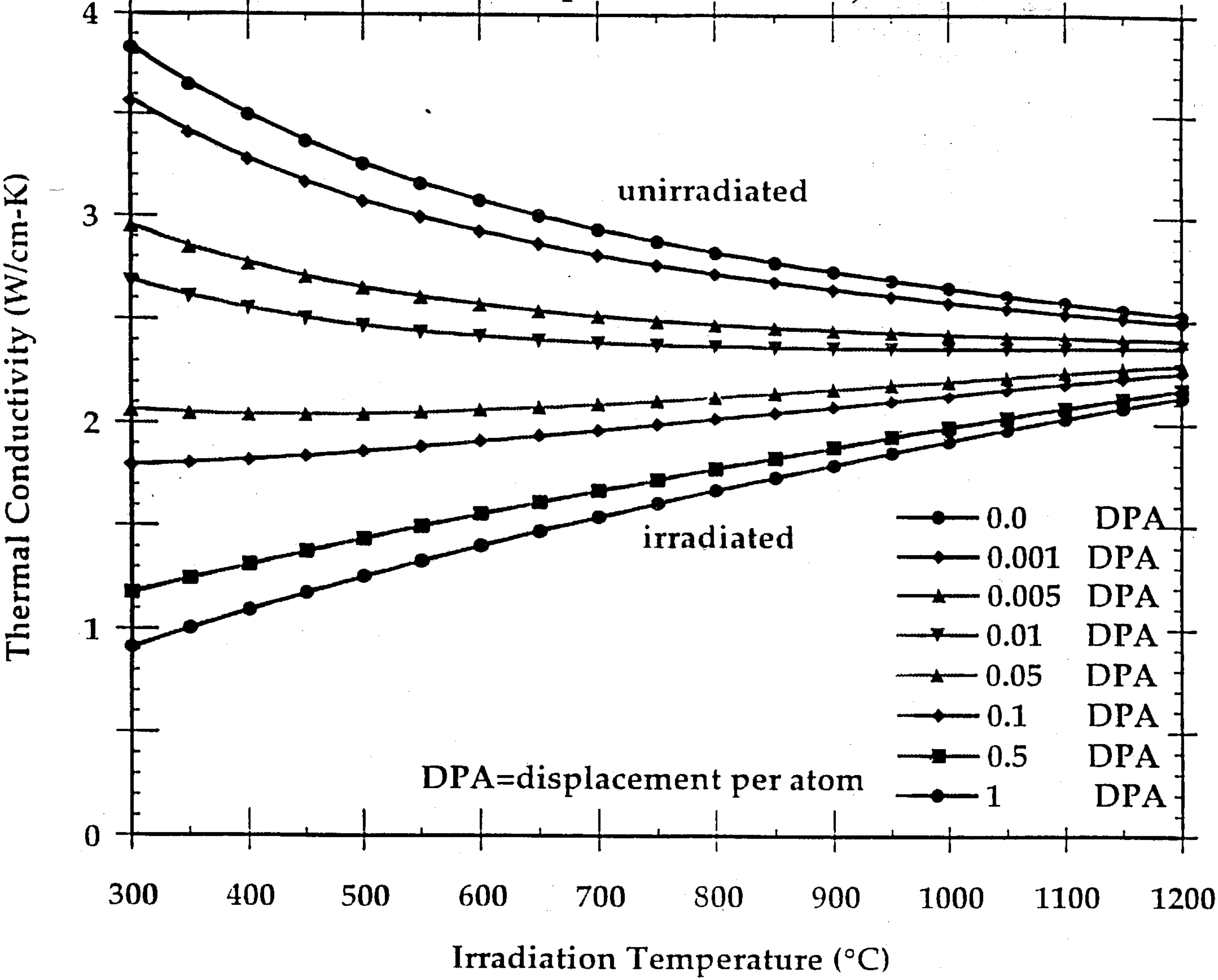
Key Chamber Technology Issues From the 1990-1991 Design of SOMBRERO

- **Erosion of First Wall Due to Vaporization**
- **Tritium Transport Through the Blanket Walls**
- **Tritium Inventory in C-C Composites**
- **Useful Lifetime of Neutron Irradiated C-C Composites**

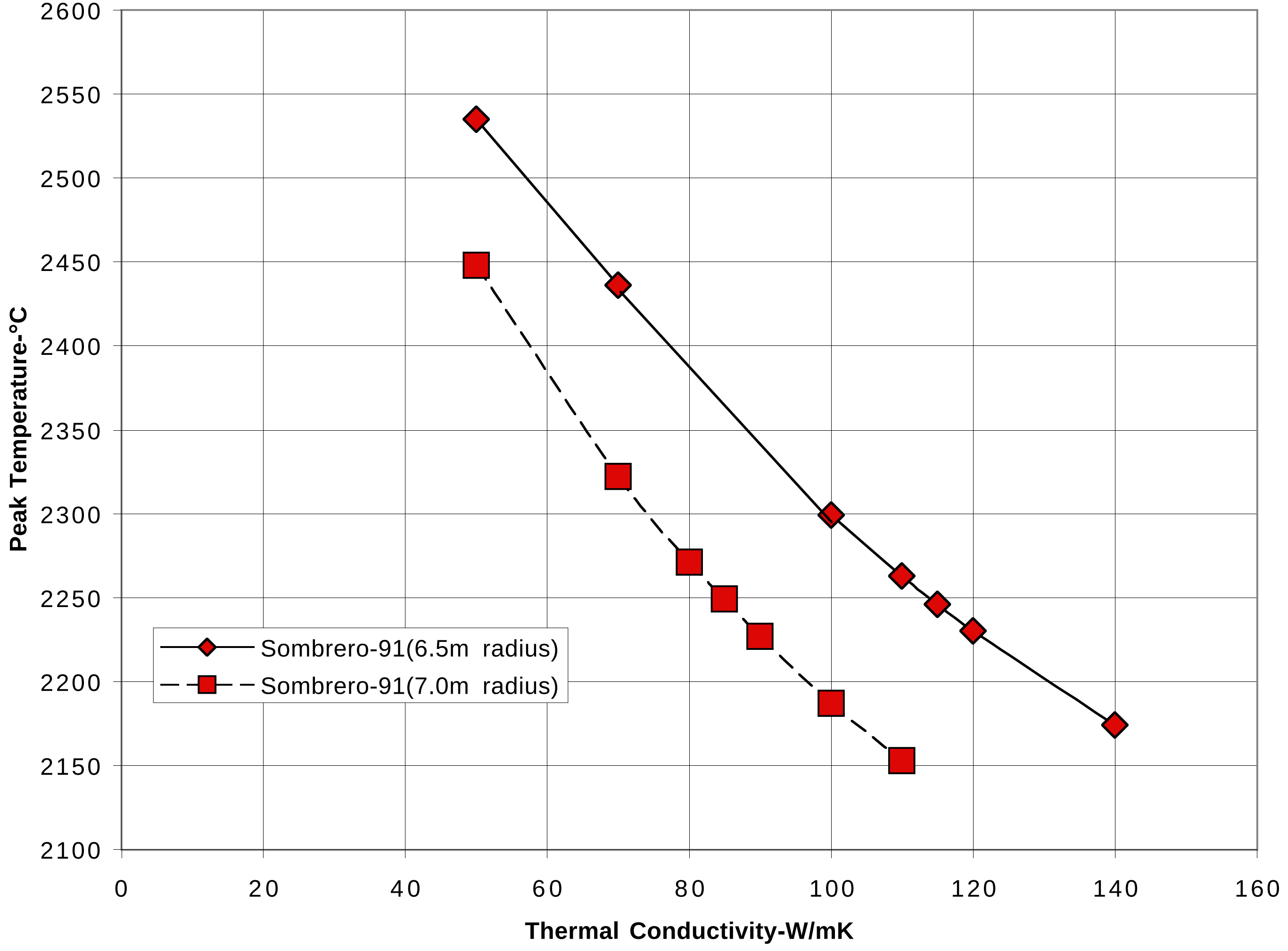

The Thermal Conductivity of Pyrolytic Graphite, Carbon Fibers, and C-C Composites
Drops With Increasing Temperature
Source: Dinwiddie et. al., 1991, Burchell-1996,
Range of First Wall Transient
Temperatures Sombrero-1991
Pyrolytic Graphite
1D Carbon Fibers
3D C-C Composite
k=70 W/mK
bulk of FW
k=140 W/mK
first few microns
Thermal Conductivity-W/m°K
Temperature °C
0
100
200
300
400
500
600
700
800
900
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200


The Neutron Irradiated Thermal Conductivity of Graphite at ≈1-2 dpa Approaches the Unirradiated Value at High Temperatures
% of Unirradiated Value
Irradiation and Test Temperature-°C
0
10
20
30
40
50
60
70
80
90
100
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
First Wall Temperature Transient Range
(First Few Microns)-Sombrero-91
A-05
CX-2002U
N-112
DMS-678
Source: Bonal and Wu, Phys Scripta, T64, 1996

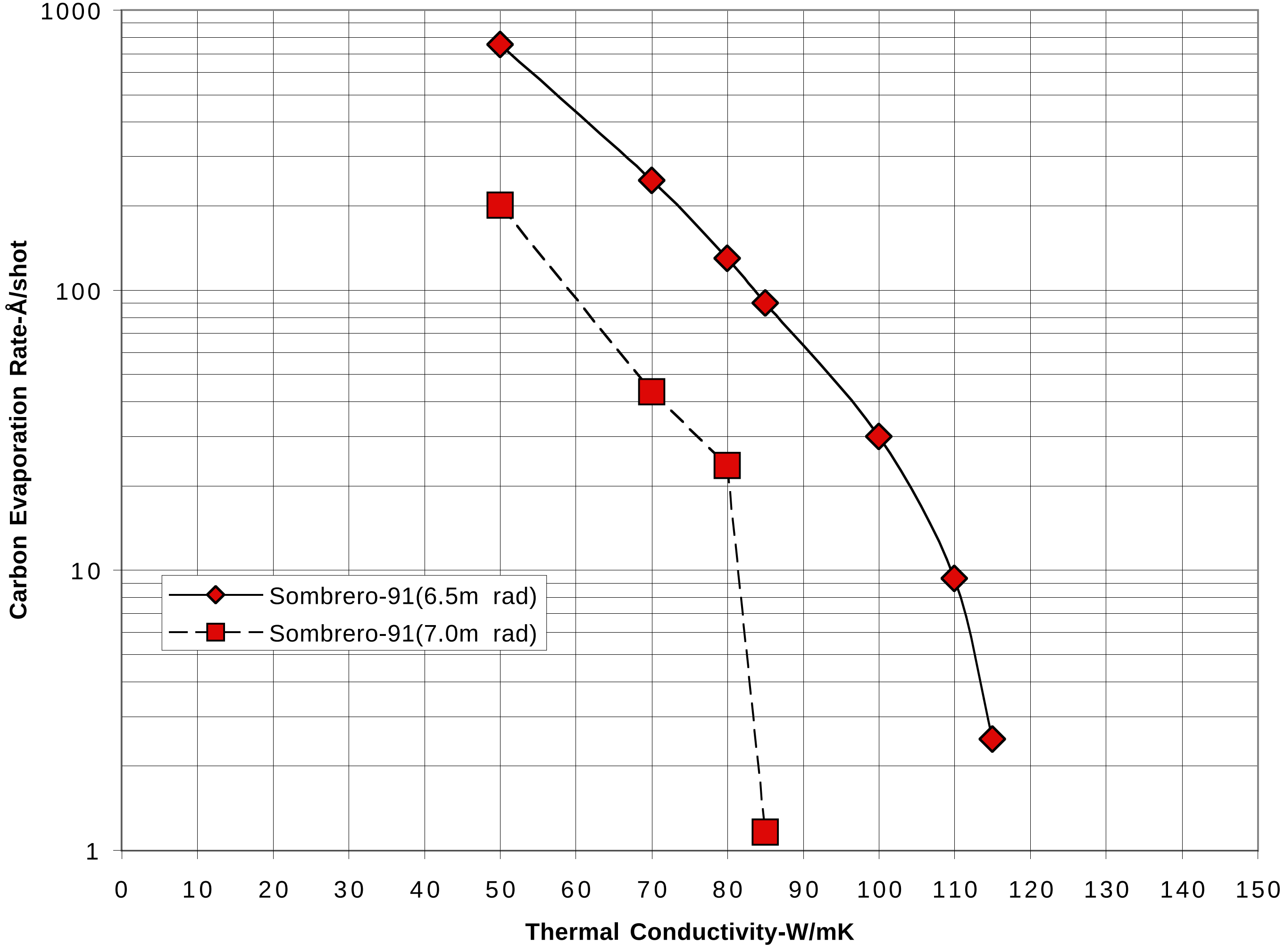
The Reduction of Thermal Conductivity in CFCs is Most Prominent at Low Irradiation Temperatures – Snead, ORNL



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



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



Tritium is Converted to Its Oxide to Reduce Diffusion Through the Chamber Walls

- T_2 and HT diffusion much faster (orders of magnitude) than T_2O or HTO

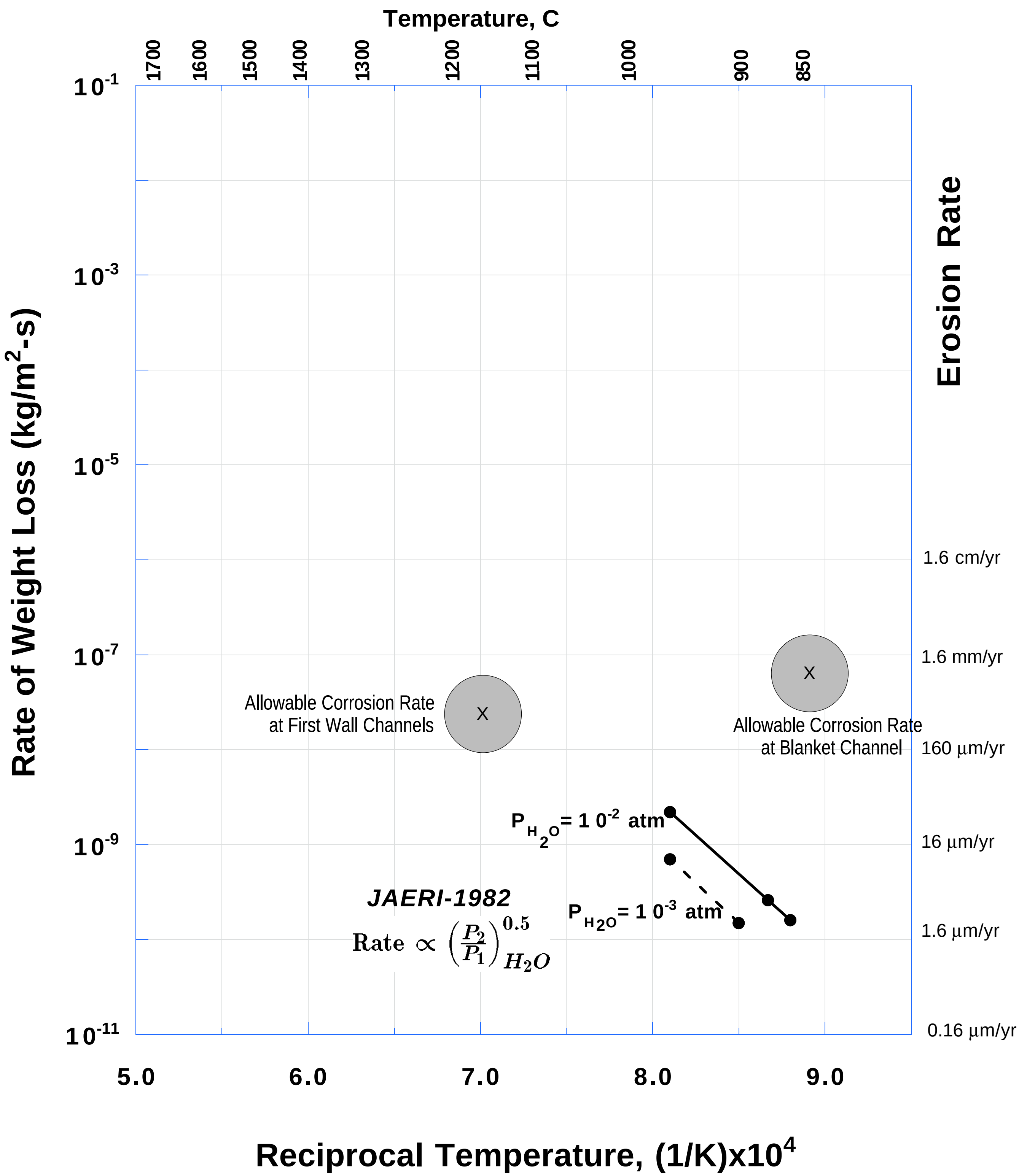
- A small amount of steam is added to the He sweep stream in the Li_2O breeder material

- The question is “How much erosion of the C-C composite takes place from the dilute steam environment?”

Basis for 1990 Sombrero Analysis on Carbon Weight Loss

Graphite Steam Interactions:

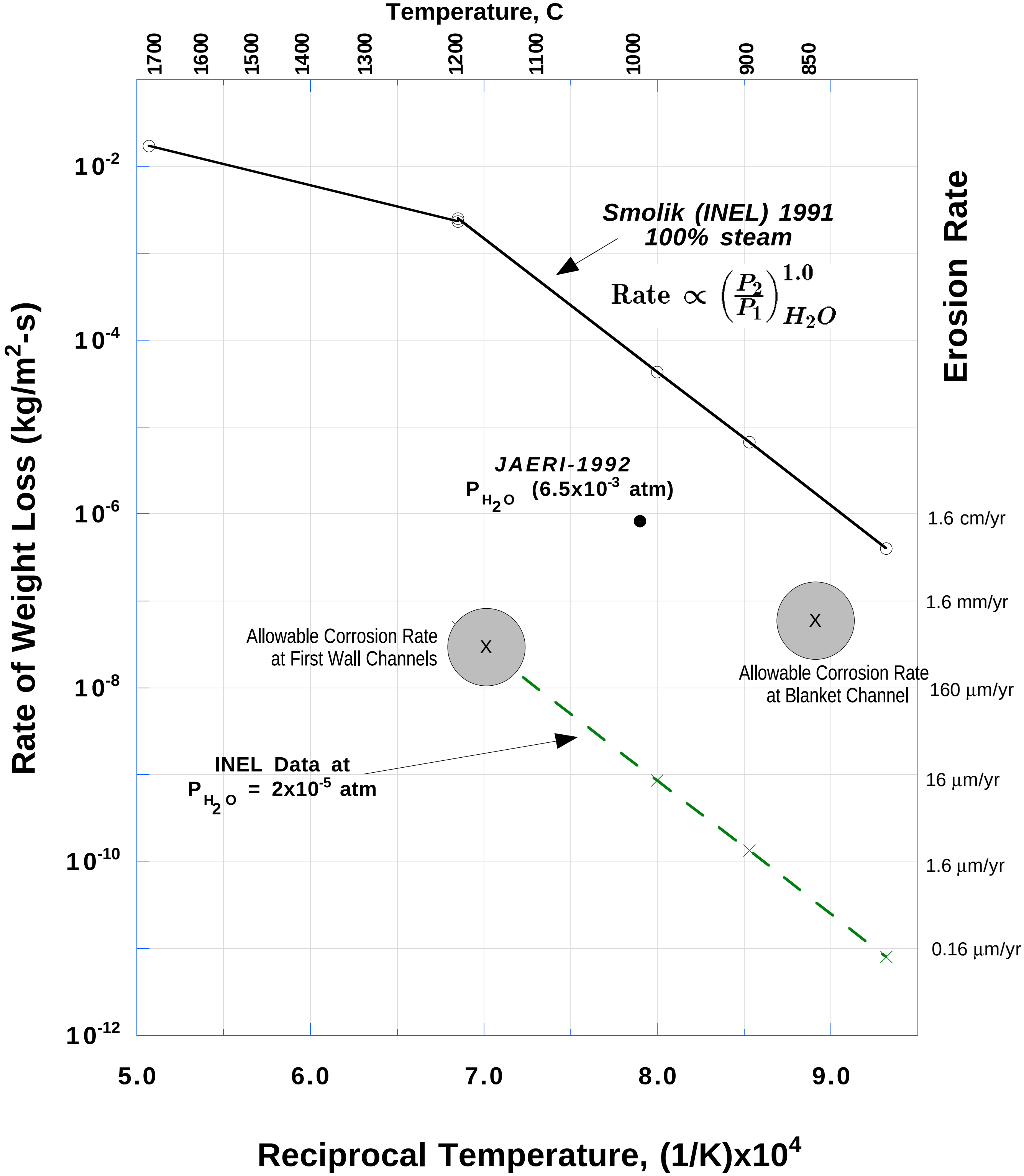
$$H_2O + C \rightarrow CO + H_2$$



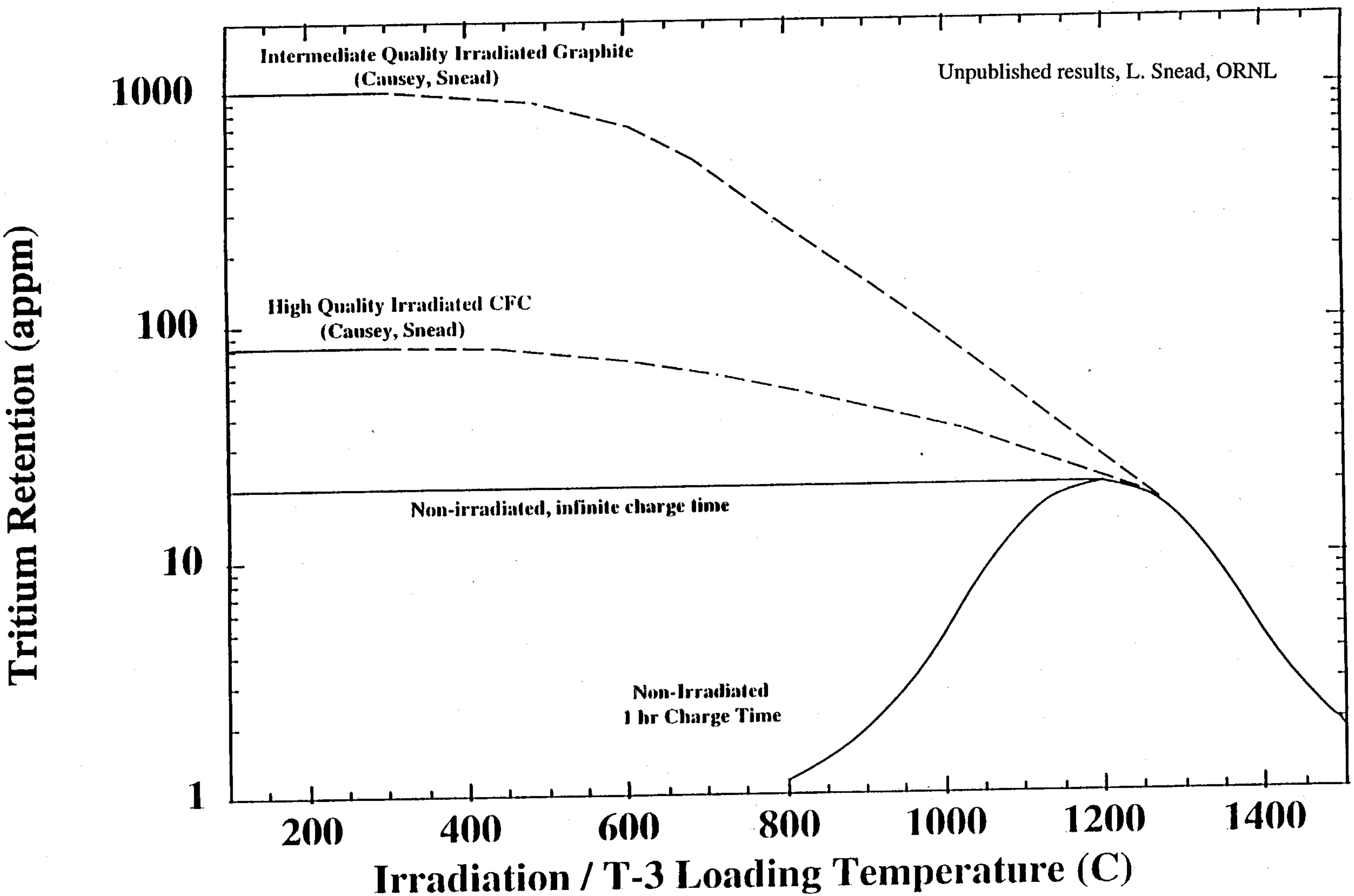
Effect of Post-Sombrero Information on Carbon Weight Loss

Graphite Steam Interactions:

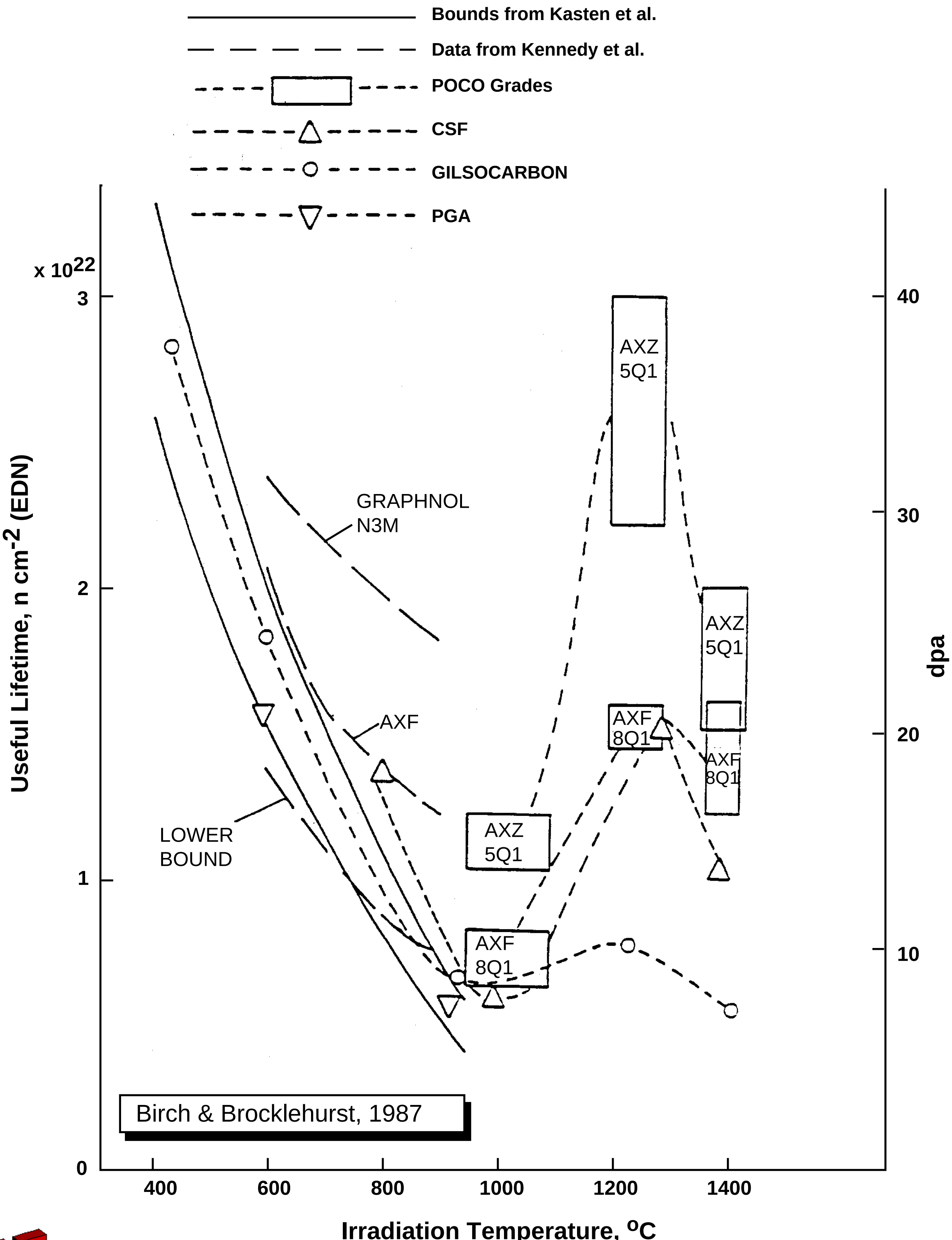
$$H_2O + C \rightarrow CO + H_2$$



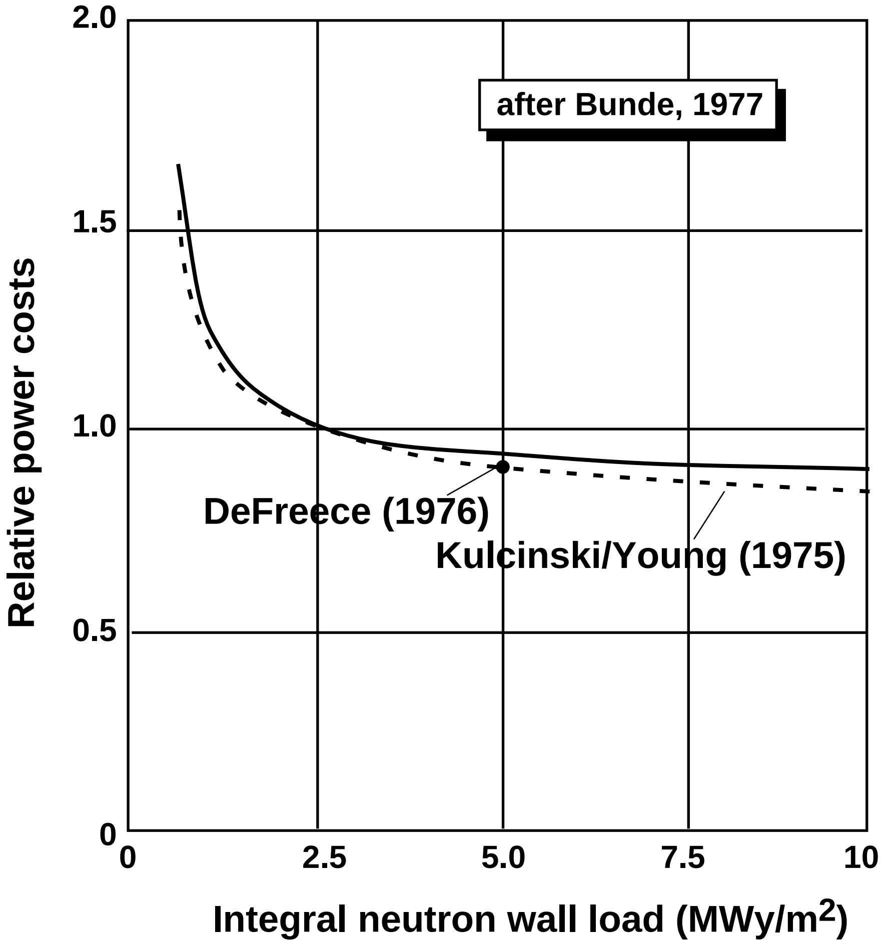
Tritium Retention is Reduced by Increasing Irradiation Temperatures



The Useful Lifetime of Graphite is a Function of the Neutron Irradiation Temperature



The Relative COE from Fusion Plants is a Weak Function of Damage Rate



Conclusions-I

- Under current designs conditions, there should be very little vaporization of the SOMBRERO first wall

- The tritium transport through the blanket walls will be minimized by adding small amounts of steam to the He sweep gas in the Li_2O

- The tritium inventory in C-C composites may be ≈ 1 kg

- The useful lifetime of neutron irradiated C-C composites may approach 2-3 FPY

Conclusions-II

There are four issues for the SOMBRERO chamber design that could be addressed by modest experiments in the near future.

- The effect of high temperature (1,500 to 2,000°C) neutron irradiation on the thermal conductivity of C-C composites.
- The effect of a very dilute steam environment on the erosion of C-C composites.
- The measurement of vaporization rates in C-C composites from typical IFE spectra.
- The rate of tritium trapping in high temperature (800 to 1200°C) neutron irradiated C-C composites from a dilute environment of HTO or T_2O.

The Useful Lifetime of Carbon Material is Determined by the Dpa Level at Which the Net Dimensional Change is Zero