

The Potential for Graphite Oxidation in Dry Wall ICF Chambers

E.A. Mogahed, I. N. Sviatoslavsky, J. G. Murphy,
H. Y. Khater, M. H. Anderson, and
G. L. Kulcinski

Fusion Technology Institute
University of Wisconsin



May 31, 2001

Outline of Presentation

- Why are we concerned?
- Fundamental assumptions and model of worst accident
- Time dependent temperature of graphite first wall after accident (without oxidation)
- Time dependent availability of oxygen in the chamber
- Potential first wall carbon oxidation rates
- Time dependent temperature of graphite first wall after accident (with oxidation)
- Calculated erosion rates (with oxidation)
- Methods to mitigate carbon oxidation
- Conclusions and recommendations

Why are we concerned about possible oxidation of dry wall graphite structures?

- Woven graphite structures run at 800 to 1500 °C in a 0.5 torr Xe atmosphere in SOMBRERO.
- The introduction of air as a result of an accident could release radioactive tritium and result in structural degradation if oxidation were to take place.
- The fundamental question is “ Will the graphite first wall temperature be high enough, **when the oxygen reaches it**, to cause significant oxidation?”

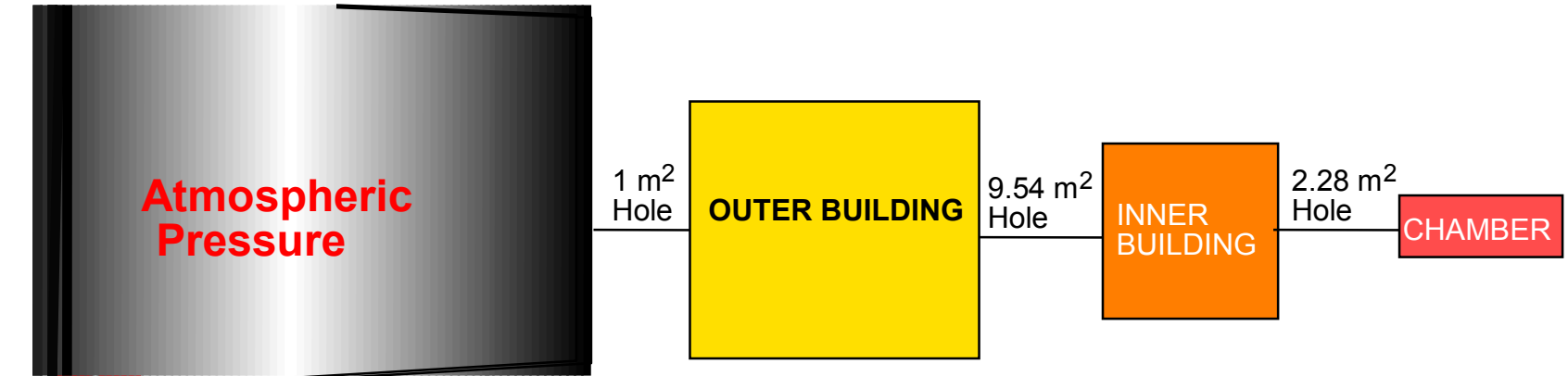
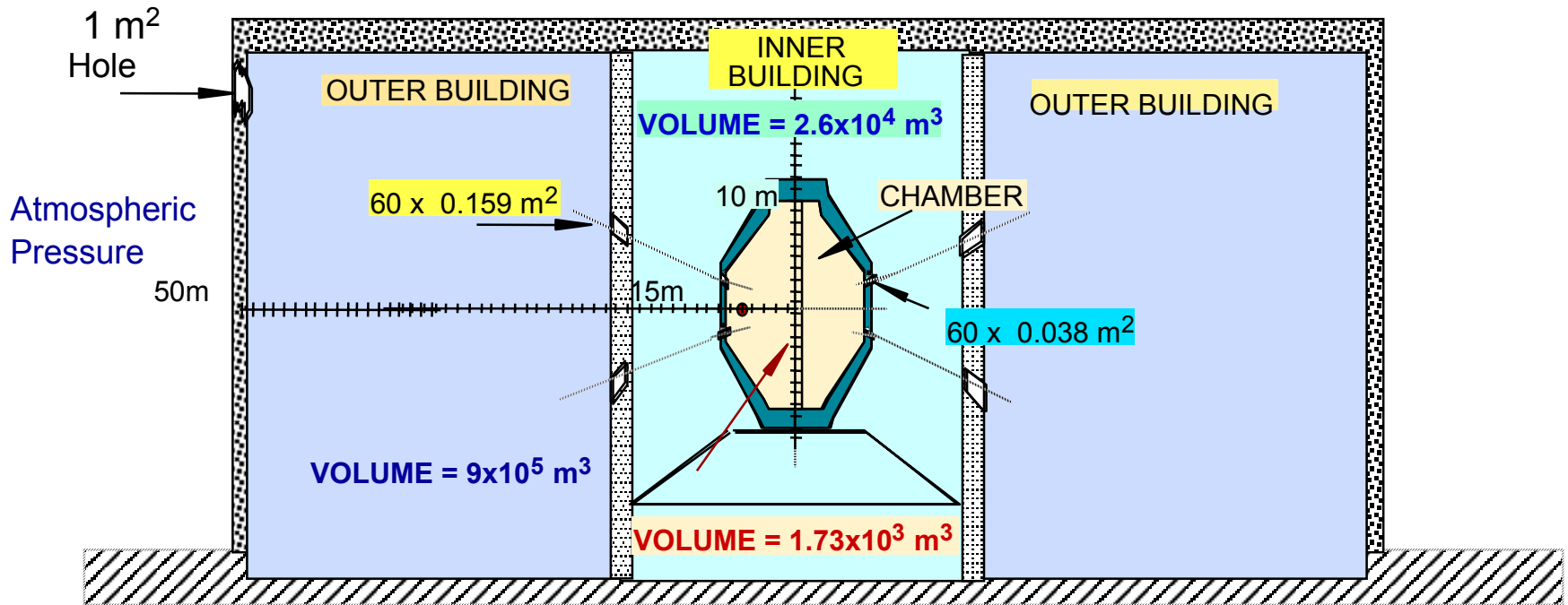


Worst Accident Scenario

- A 1 m² hole is introduced in the 1.3 m thick outer building wall while the reactor is operating.
- The air rushes through the 1 m² opening and through the laser ports in the outer chamber, and finally through the beam ports in the inner chamber.
- The reactor and all mechanical equipment shuts down and the Li₂O coolant drains from the chamber and upper manifold by gravity.
- The first wall radiates heat to the rest of the chamber and it also loses heat out the back of the blanket and shield.
- The ultimate heat sink is the wall of the outer building



SOMBRERO BUILDING



Model of SOMBRETO Building as it is used in the MELCOR code

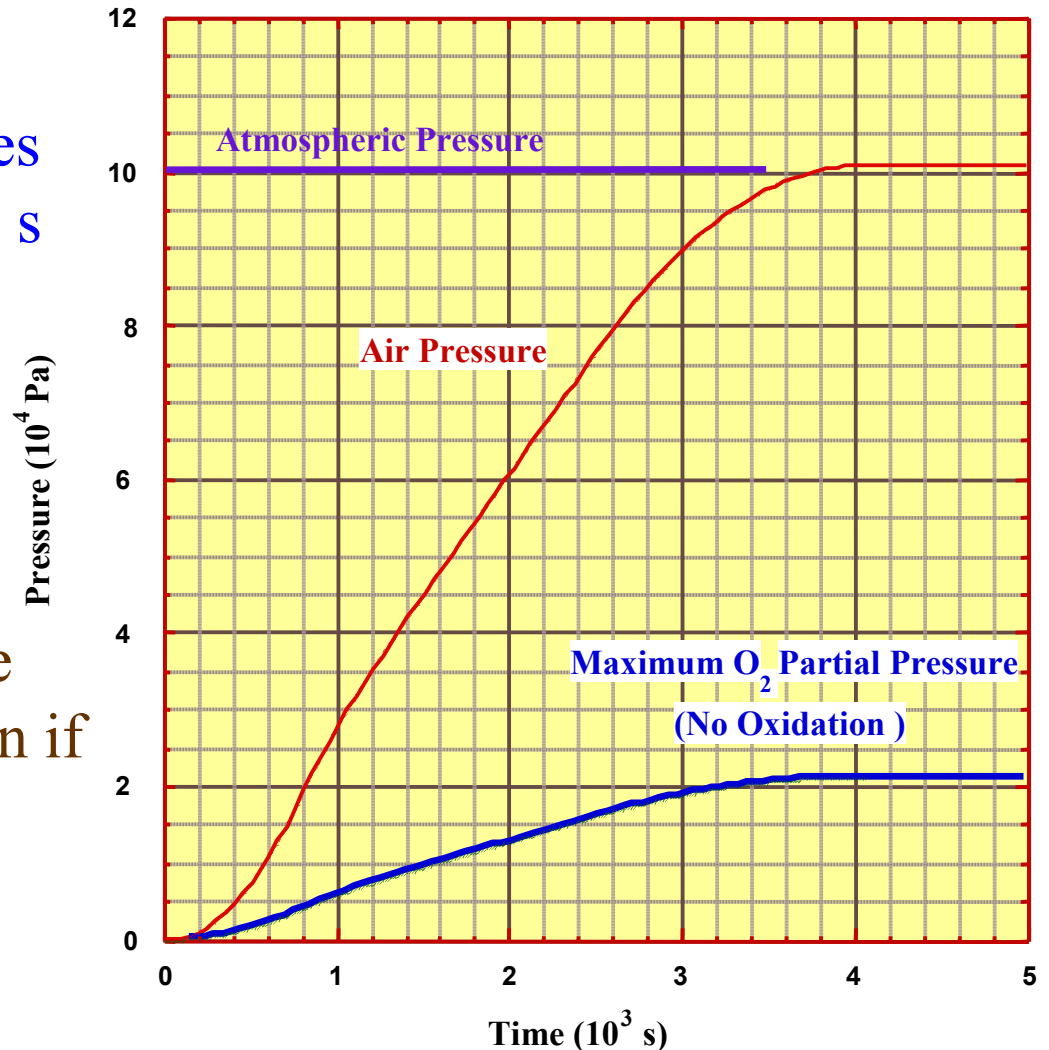


Air Pressure History in SOMBRERO Chamber After the Accident

-The pressure in the chamber increases with time and reaches one atmosphere in about 4000 s (1.1 Hr) (MELCOR Calculations).

- The oxygen partial pressure follows same build-up pattern if there is no oxidation.

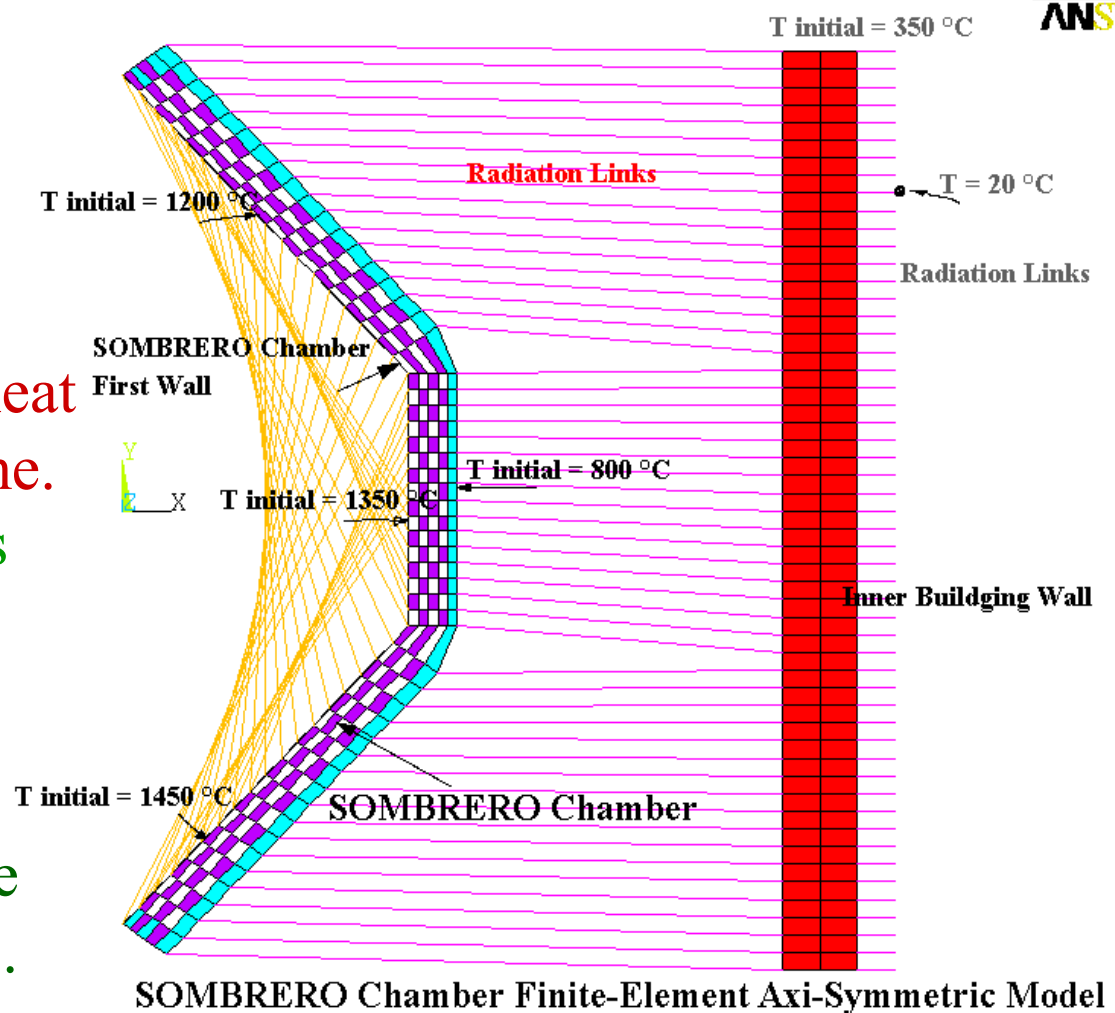
Pressure In the Chamber Time History



SOMBRERO Finite Element Thermal Model


Assumptions:


- Axi-symmetric model.
- Transient solution, that allows conduction, convection, and radiation heat transfer that varies with time.
- Back of chamber radiates to the inner building wall that is initially at 350°C .
- The back of the inner building wall radiates to the outer building wall at 20°C .

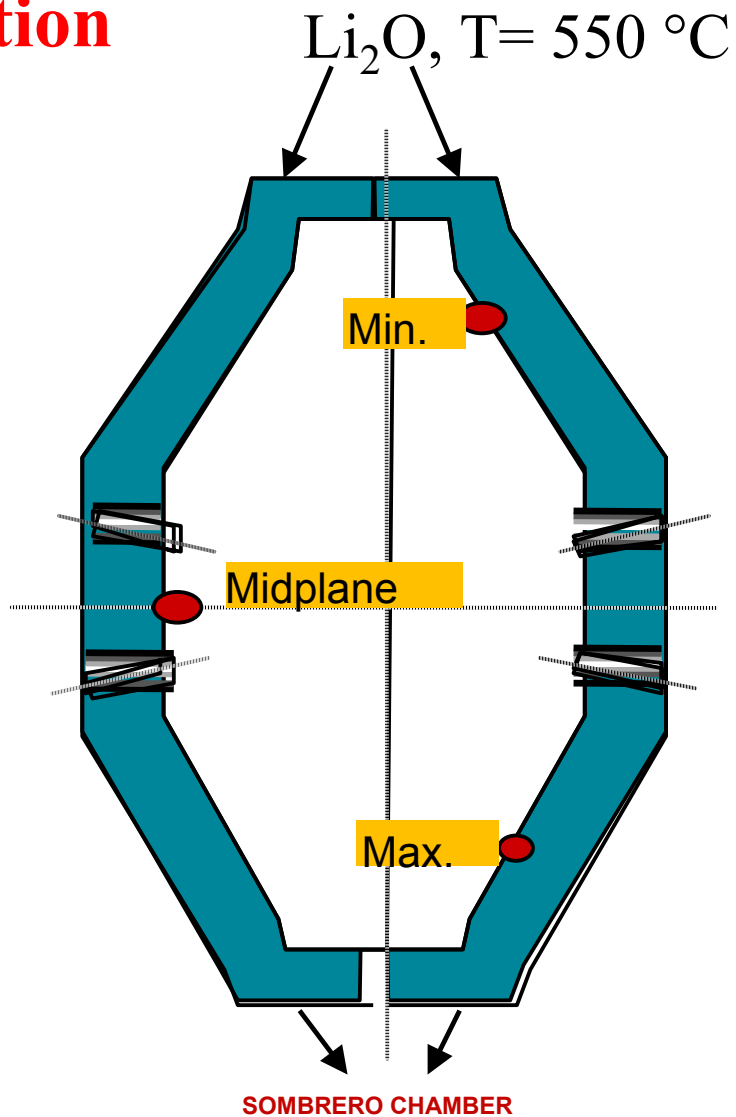


Transient Thermal Analysis of SOMBRERO First Wall With No Oxidation

- Assumptions:


 Cooling due to Li_2O drainage during the first 130 s after the accident


 Only conduction and radiation heat transfer are in force after 130 s.



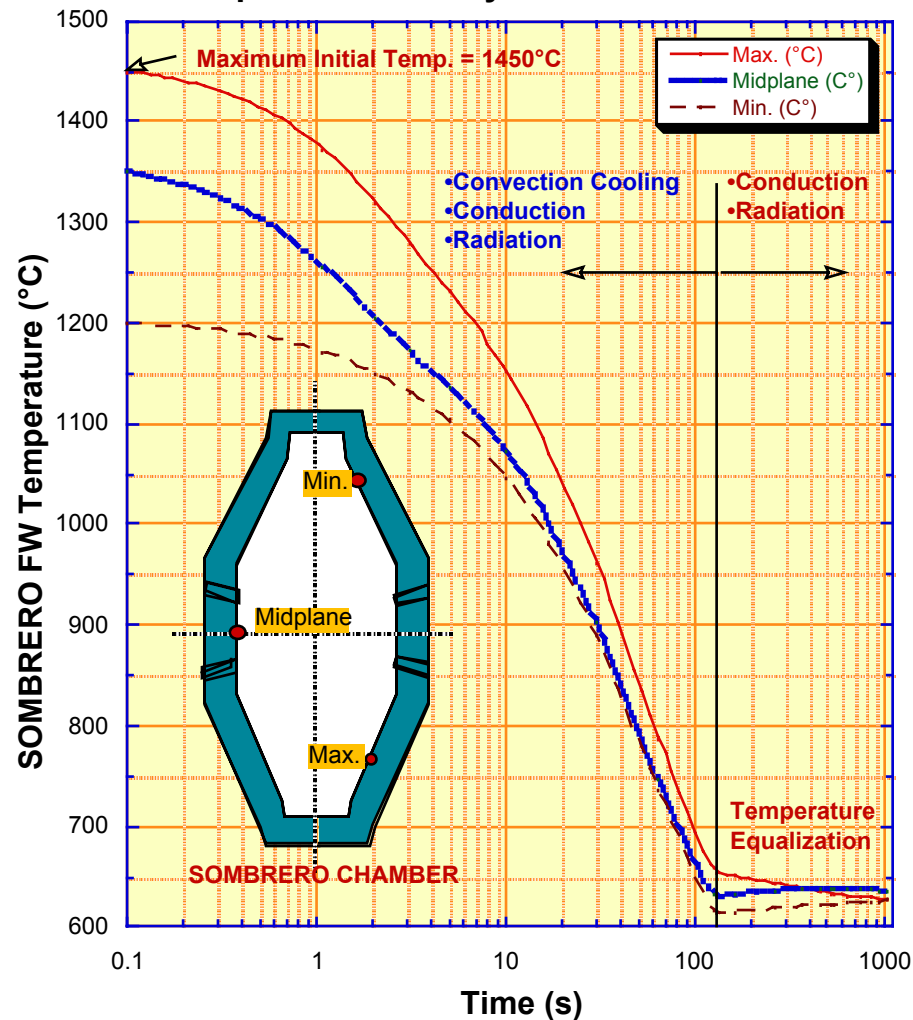
Transient Thermal Analysis of SOMBRERO First Wall With No Oxidation

- Assumptions:

 Cooling due to Li_2O drainage during the first 130 s after the accident

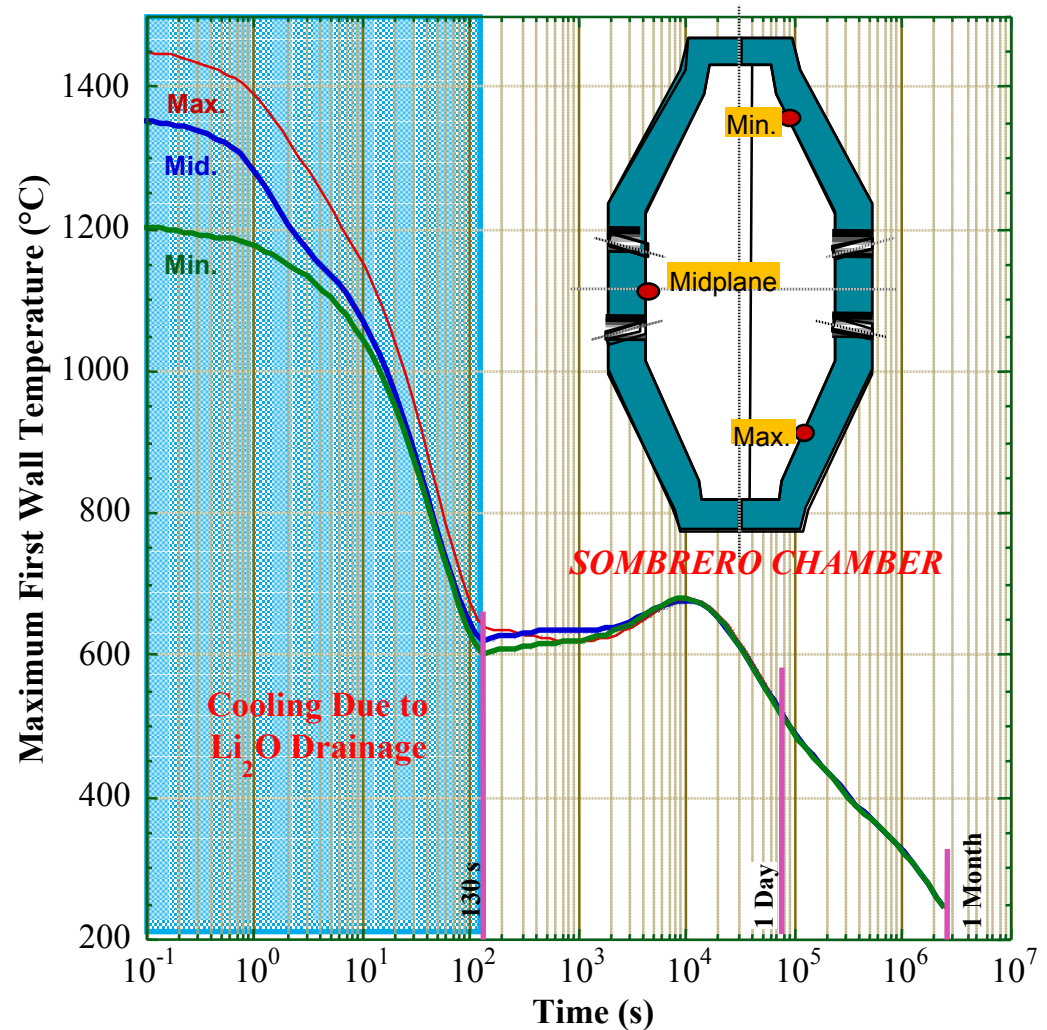
 Only conduction and radiation heat transfer are in force after 130 s.

Temperature History of SOMBRERO FW

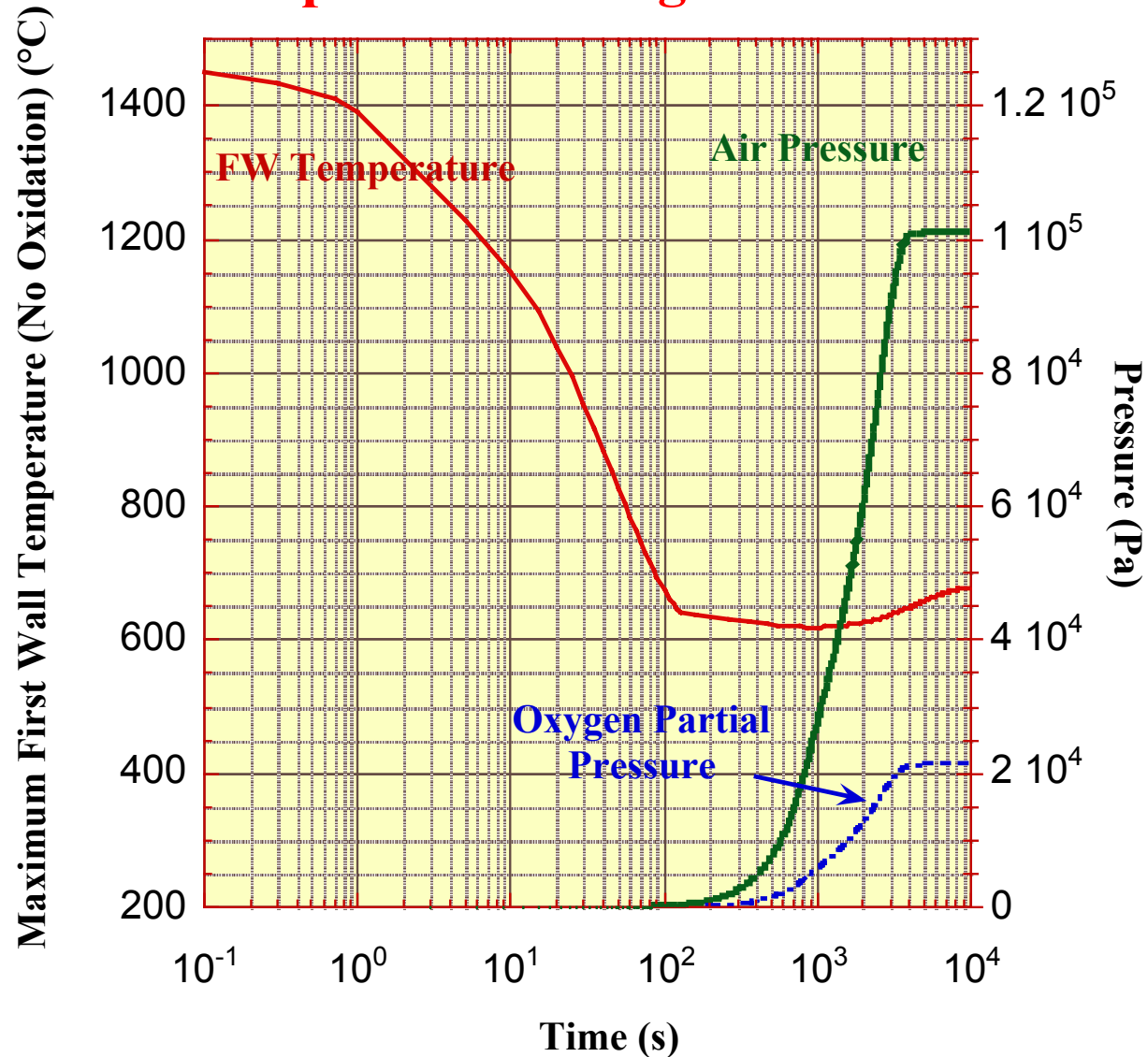


Transient Thermal Analysis of SOMBRERO FW/Chamber With No Oxidation

- Cooling due to Li_2O Drainage During the First 130 s After the Accident.
- Only Conduction and Radiation Heat Transfer is in effect after 130 s.
- The Back of the Chamber Remains Hot ($\approx 780^\circ\text{C}$) During the First 130 s.



The Oxygen Partial Pressure is Low While the First Wall Temperature is High

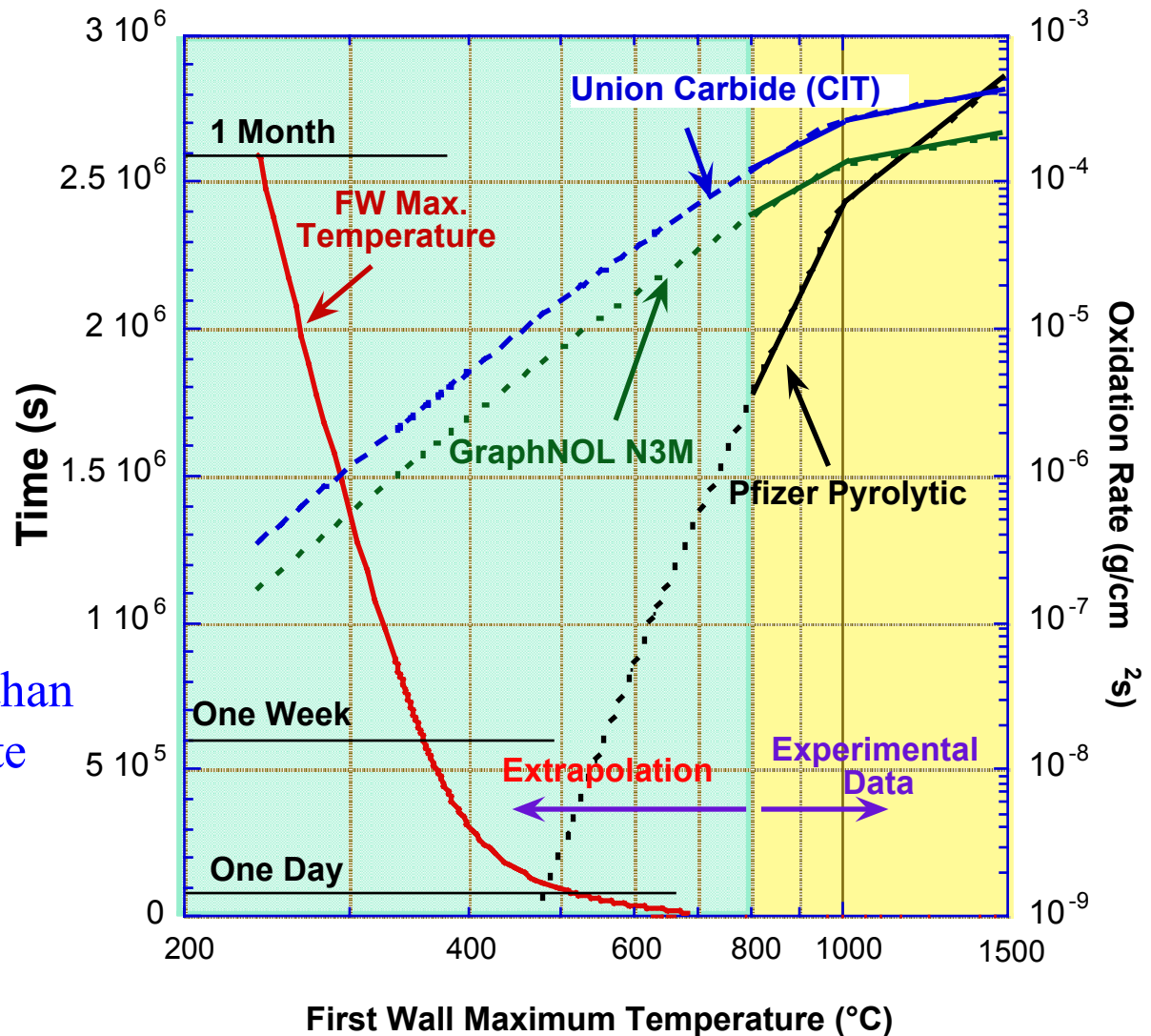


Different Graphites Have Very Different Oxidation Rates

Experimental data is available for temperatures over 800°C.

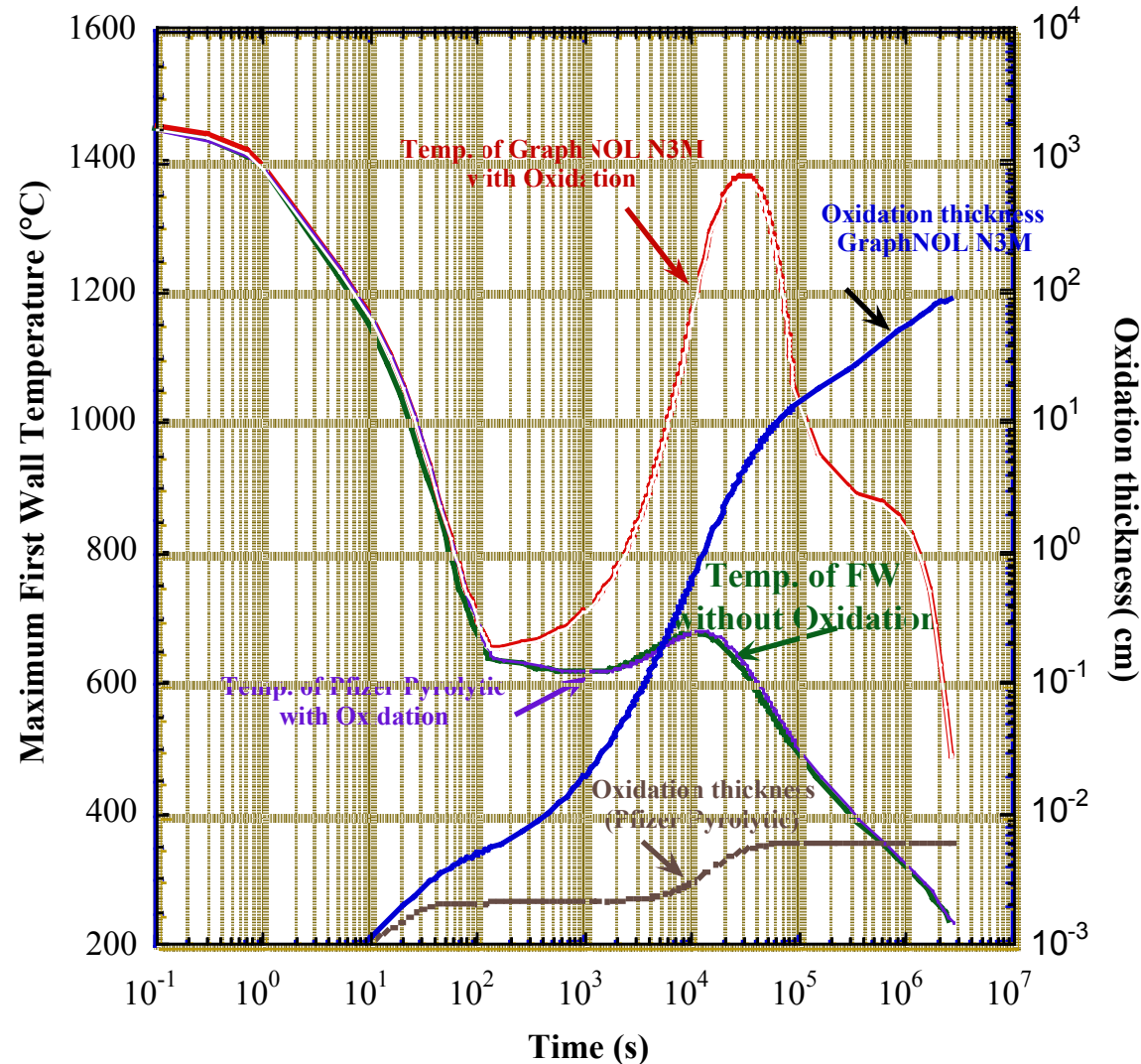
- Union Carbide graphite oxidation rate is two times higher than GraphNOL N3M.

- Pfizer pyrolytic graphite oxidation rate is much less than both Union Carbide Graphite and GraphNOL N3M.



The Choice of the Wrong Graphite for an IFE First Wall Could Cause Problems if The Building is Breached

- FW graphite temperature rises as a result of exothermic reaction with oxygen.
- Oxidation of GraphNOL graphite is very rapid, it will oxidize the 1 cm FW in about 3.5 Hr.
- Oxidation of pyrolytic graphite is very low and raises FW temperature about 10°C at most.



Methods of Mitigating Air Ingress Accident Effect

- Shutters on chamber beam-ports triggered by pressure imbalance
- Reduce inner building wall temperature
- SiC coating everywhere except first wall
- Thin ($\approx 30 \mu$) SiC undercoating on the first wall
- Flood chamber with CO₂
- Plug hole in building!



Conclusions

- The survival of the graphite first wall, in the event of an unlikely ingress of air, is critically dependent on the type of graphite used.
- If the wrong type of graphite is chosen, the first wall could be completely oxidized in a few hours
- If pyrolytic, or H-451 graphite is chosen, there should be little oxidation (even after a few months)
- An experiment is needed to measure oxidation rates at reduced oxygen levels and at $200 < T < 800$ °C.

