

Some Considerations in Preparation for Starting Study On the Design of a Dry Wall Blanket for HAPL

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Contents of Presentation

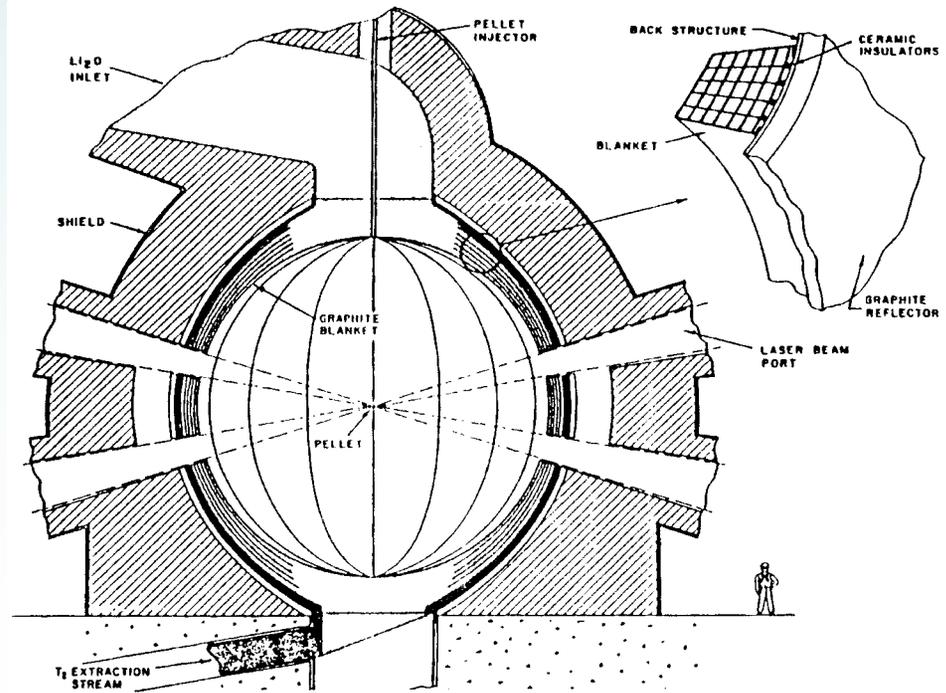
- Short review of previous solid wall laser IFE designs
- Brief comparison of liquid breeders, not used as liquid walls
- Some IFE specific important considerations:
 - Geometrical considerations such as chamber end closures and beam ports
 - Physical considerations, such as isochoric heating in confined tubes of liquid metal
 - Some considerations on maintenance of IFE blankets
- Planned activities in mechanical design and nuclear analysis at UW for FY04 and beyond



Review of Dry Wall Laser IFE Designs

UW Design SOLASE 1977

FW Material	Graphite
Breed/Cool. Material	Li_2O
Gravity flowing solid breeder granules 50-100 μm radius.	
Cavity 0.5 torr Neon gas.	
Cavity radius	6 m
Laser energy on target	1.0 MJ
Laser efficiency	6.7%
Pellet yield/gain	150 MJ
Pulse Rate	20 Hz
Net plant therm. Eff.	30%
Net plant elect. Output	1000 MW

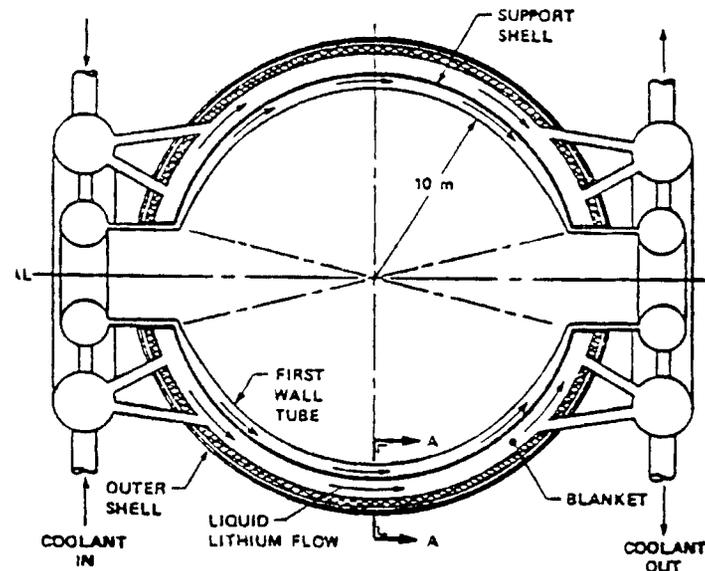
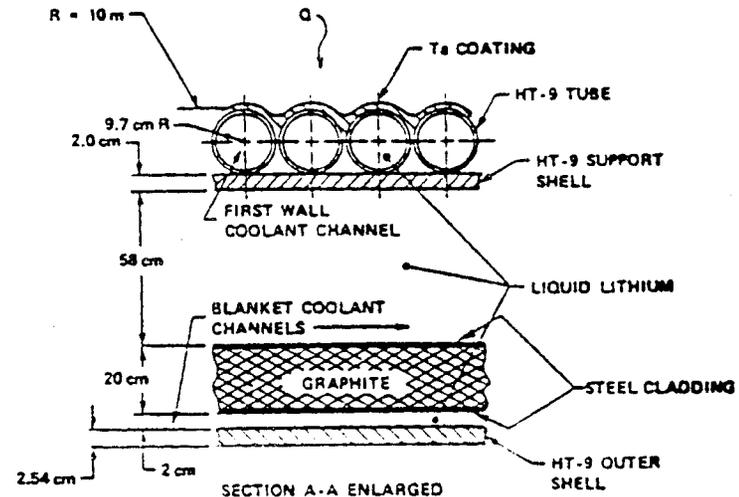


Review of Dry Wall Laser IFE Designs

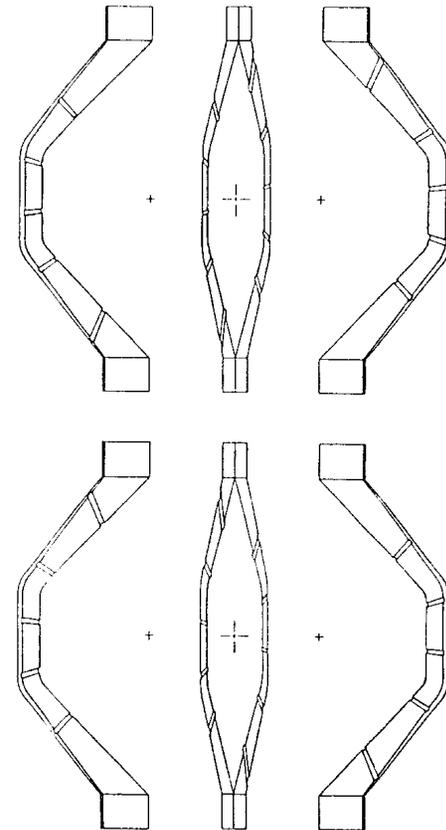
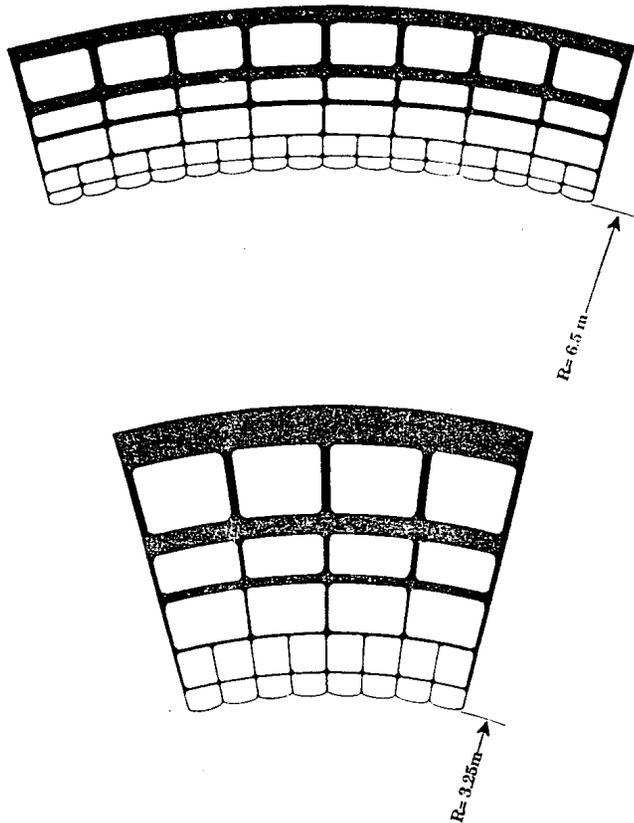
Westinghouse Design 1981

E. W. Sufov, ICF Central Station
Electric Power Generation Plant.
WFPS-TME-81-001, Feb. 1981

FW material	HT-9
FW coating	Tantalum
Breed./Cool. Material	Li
Major Radius	10 m
FW cooled by Li at 20 m/s in 20cm diameter toroidal tubes	
T ₂ removal from Li by yttrium bed	
Tantalum was used because of its high melting point and because it was a constituent of the target.	



Several Views of SOMBRERO Blanket



Cross section through a module at midplane ($R=6.5\text{m}$) and at $R=3.25\text{m}$

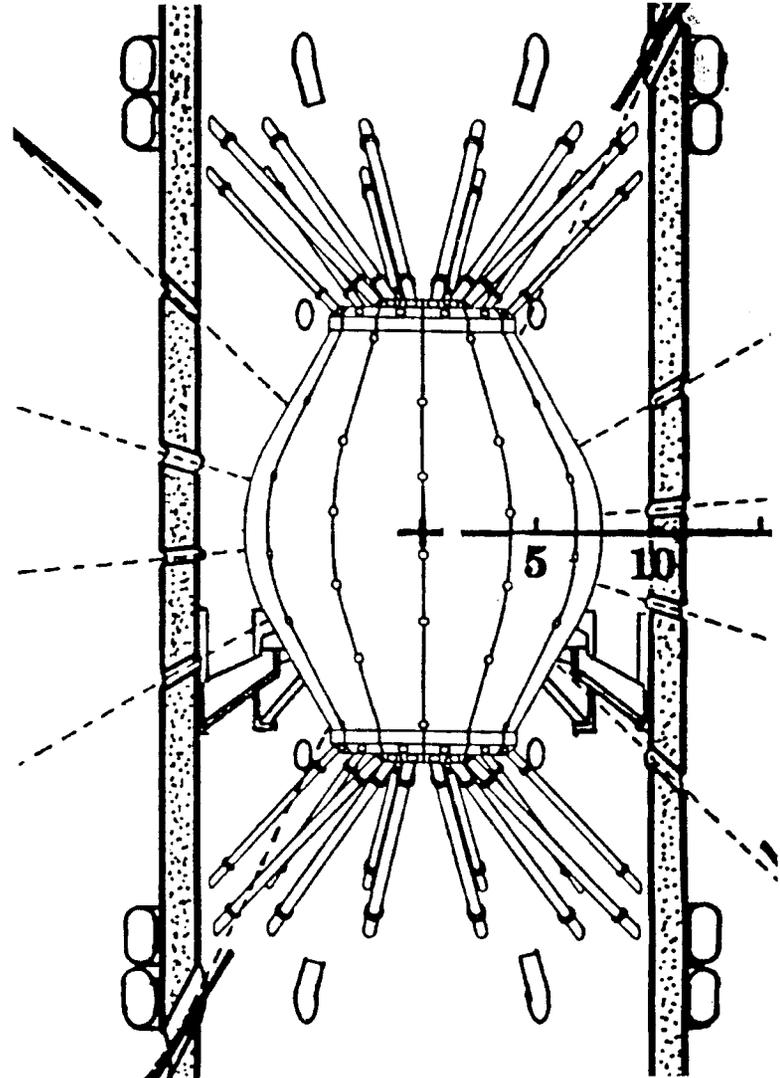
Several views of the two types of modules



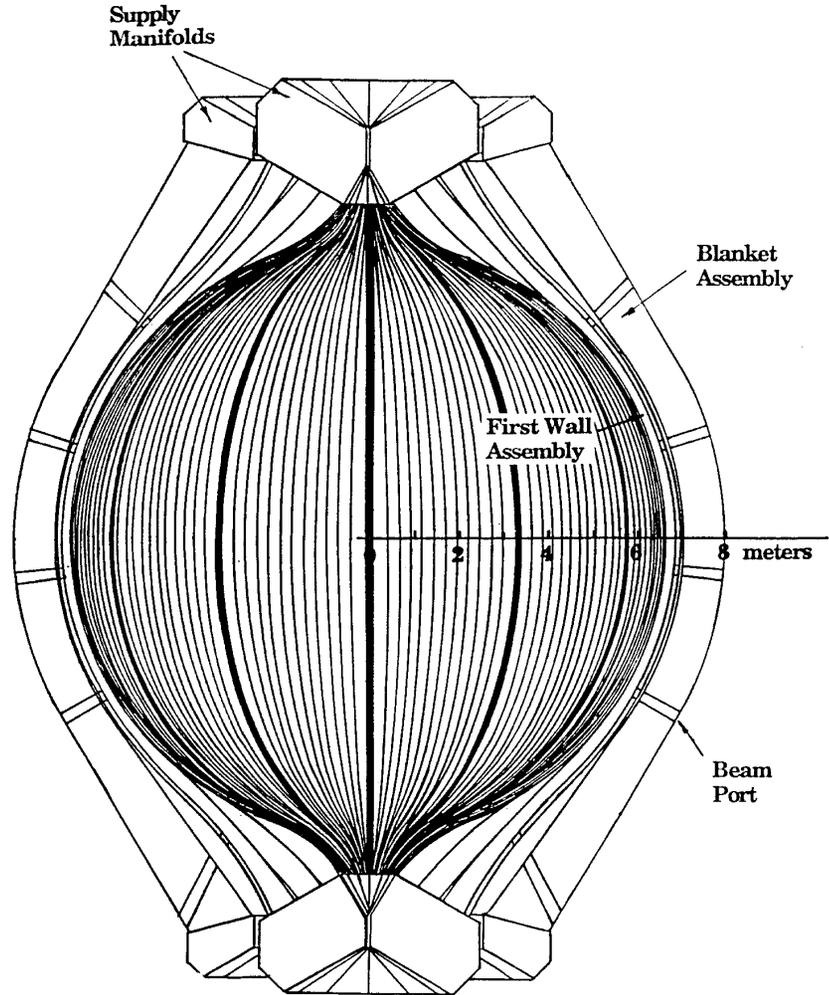
Review of Dry Wall Laser IFE Designs

UW Design SIRIUS-P 1993

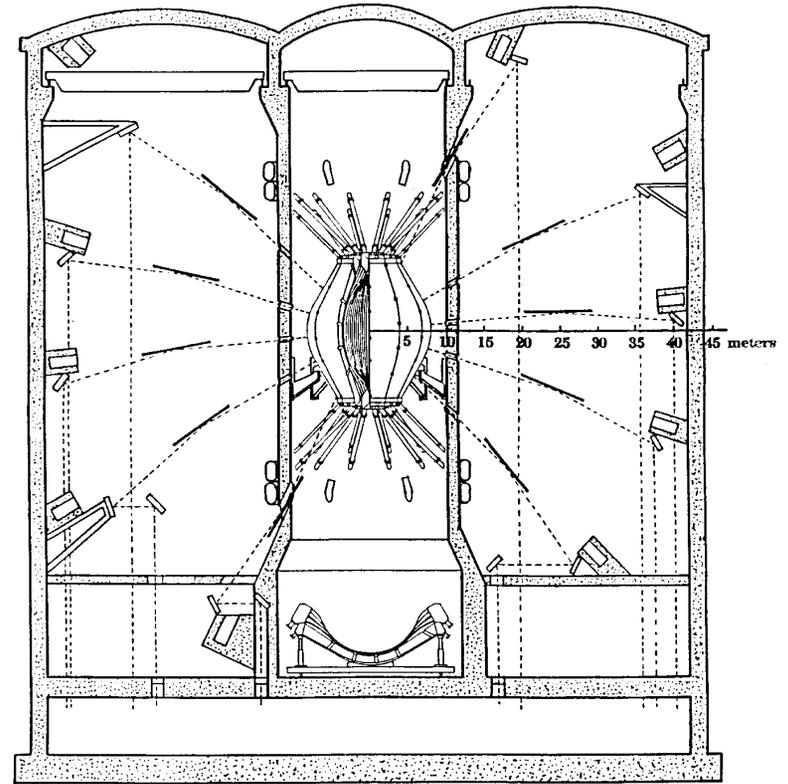
FW Material-	C/C composite
FW cooling mater.-	TiO ₂ particles
Chamber material	SiC
Coolant/breeder Mat.	Li ₂ O
Gravity flow particles in both cases	
Chamber radius	6.5 m
KrF laser energy	3.4 MJ
Laser efficiency	7.5%
Direct drive target gain	118
Target yield	400 MJ
Pulse rate	6.7 Hz
Power cycle efficiency	47.5%
Net plant elect. Output	1000 MW



Several Views of SIRIUS-P



View of SIRIUS-P chamber



Overall layout of reactor



Why Moving Bed Solid Breeder Blankets were Chosen

- Solid breeder blankets have many advantages, among them high temperature capability, safety, low activation and no corrosion or corrosion transport
- The main disadvantage is the need to lift large quantities of solid breeder during a cycle
- However, there are some disadvantages that are eliminated by moving beds. Those are:
 - The need for a separate coolant eliminated
 - The need for high pressure eliminated
 - Breeder material swelling eliminated
 - Temperature control
 - Hot spot/sintering eliminated
 - Temperature window for T_2 recovery eliminated
 - Li burn up eliminated
 - T_2 recovery/inventory alleviated



Comparison of Liquid Breeding/Cooling Materials

	<u>Li</u>	<u>LiPb</u>	<u>Molten Salt</u>
Melting point (C)	181	234	469 Flibe ~ 340 Flinabe
Density (g/cm ³)	0.48	9.06	2.0
Specific heat (J/Kg K)	4022	187	2400
Thermal conduc. (w/m K)	56	20	5
Viscosity (Pa.s)	0.0003	0.001	0.01
Max.T interf.w/Fer.St. (C)	500-550	450	550-600
Chemistry control	Moderate	Moderate	Difficult
T ₂ Breeding	Good	Good	Need Multiplier
T ₂ Diffusion	No problem	Problem	Problem
T ₂ Extraction	Mod./Hard	Moderate	Moderate
Activation	Very low	Po. (remove Bi)	Moderate
Chemical reactivity	Very high	Low	Low
Spill cleanup	Moderate	Difficult	Difficult
Isochoric heating pressure	Can be high	Very high	Do not know
Power conversion	He/Brayton	He/Brayton Steam/Carnot+Rht.	He/Brayton Steam/Carnot+ Rht.



Geometric Considerations

There are several important aspects to be considered in the design of the HAPL blanket:

- Whether the chamber is spherical or cylindrical, the blanket should be capable of extending to close the upper and lower ends. This implies cross-sectional variation of the blanket in the poloidal direction
- Not all the chamber surface need to be of breeding capability, but the whole surface must be capable of capturing and thermalizing the neutrons and handling the surface heat
- HAPL will have at least 60 beam ports. The location and the accommodation of the beam ports by the blanket and shield is of prime importance

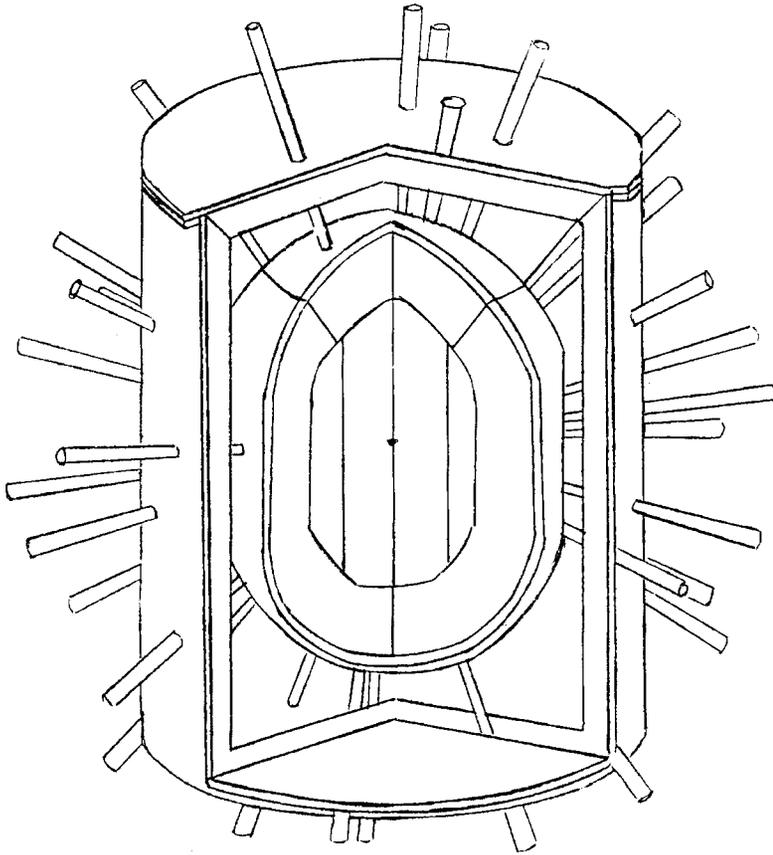


Some Considerations on Maintenance of HAPL Blanket Sectors

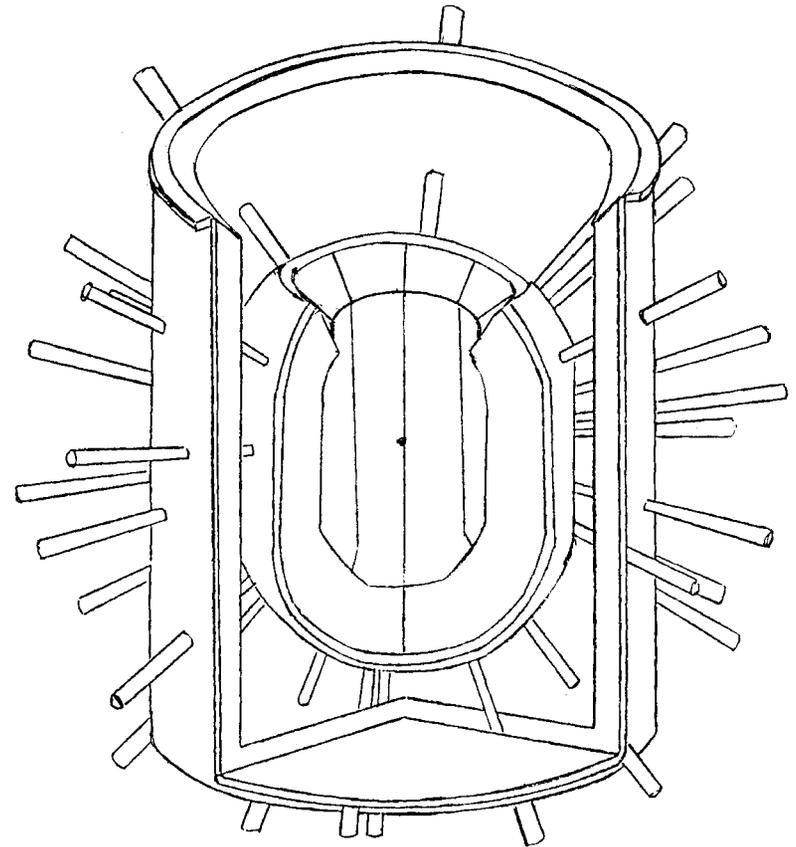
- IFE chambers using direct drive targets will be surrounded with up to sixty or more beam tubes on all sides, making radial maintenance of blanket sectors difficult if not impossible. Some other scheme must be provided
- One such scheme is vertical maintenance. This would entail:
 - Disconnecting and removing several beam tubes on the top
 - Unbolting and removing the upper shield cap
 - Disconnecting and lifting the upper blanket cap which would be of a different design from the rest of the blanket
 - The access port thus provided will allow vertical removal of blanket sectors without disturbing the remaining beam tubes



Pictorial Representation of Vertical Maintenance



Cut away of a typical chamber



Chamber prepared for maintenance

One Physical Consideration not found in MFE

Isochoric heating and resulting issues

Definition: Isochoric (constant volume) heating occurs when energy is deposited in a liquid on a time scale which is less than the sound wave transit time of the liquid region. In cases where the liquids are confined, the sudden increase in temperature and energy content results in a high rise in pressure.

The heating is isochoric if $2R/c > 0.1\mu\text{s}$. where R is the tube radius and c the sound speed in the liquid, 4500 m/s for Li and 1800 m/s for LiPb.

The pressure rise: $\Delta P = \rho_m \Gamma e$ where ρ_m is mass density, Γ is the Gruneisen parameter (which is 1 for Li and 2 for LiPb) and e is the specific energy deposition.

In Hylife-I with Li the pressure rise was 400 MPa ($e=800$ kJ/kg)

In HIBAL with LiPb, the pressure rise was 9 MPa ($e=0.5$ kJ/kg)



Blanket Scoping and Selection

1) Blanket Engineering Design:

- Scoping design of three blanket concepts
- Blanket design integration with FW protection scheme
- Accommodation of beam tubes in the blanket sectors
- Coolant routing consistent with a selected maintenance scheme
- Support of blanket and shield components
- Scoping thermal hydraulics and structural analysis (with UCSD)



UW Blanket Design Tasks in FY04 (0.5 FTE)

2) Blanket Nuclear Analysis:

- Nuclear analysis performed for three blanket concepts
- 1-D spherical geometry calculation using homogenized composition in radial zones
- Optimize the FW/blanket design to insure tritium self-sufficiency while maximizing thermal power
- Determine nuclear heating profiles in different blanket components for thermal hydraulics assessment
- Determine radiation damage s for lifetime assessment
- Compare radioactive inventory, decay heat, and radwaste classification for the blanket concepts



UW Blanket Design Tasks in FY05 and Beyond

(Depends on Available Resources)

Detailed Design and Analysis of Selected Blanket Concept

1) Blanket Engineering Design:

- Detailed blanket design integration with respect to all required coolant connections, beam ports, supports and auxiliary systems
- Detailed thermal hydraulics and structural analysis (with UCSD)
- Analysis of fabrication of blanket segments
- Detailed plan for maintaining the blanket sectors based on information from neutronic lifetime analysis



UW Blanket Design Tasks in FY05 and Beyond

(Depends on Available Resources)

2) Blanket Nuclear Analysis:

- Detailed 3-D modeling of the FW/blanket design with accurate representation of heterogeneity
- Perform 3-D neutronics for the blanket to determine overall TBR and thermal power with contribution from roof and bottom blankets
- Determine 3-D distribution of nuclear heating and radiation damage in blanket components
- Provide radioactive inventory and decay heat for safety analysis and radwaste assessment
- Perform time-dependent neutronics to determine pulsed nuclear heating for isochoric heating assessment and pulsed radiation damage for lifetime assessment
- Determine shielding requirements and maintenance dose
- Assess impact of streaming through beam ports on laser optics

