Neutronics Assessment of Solid Breeder Blanket Concept

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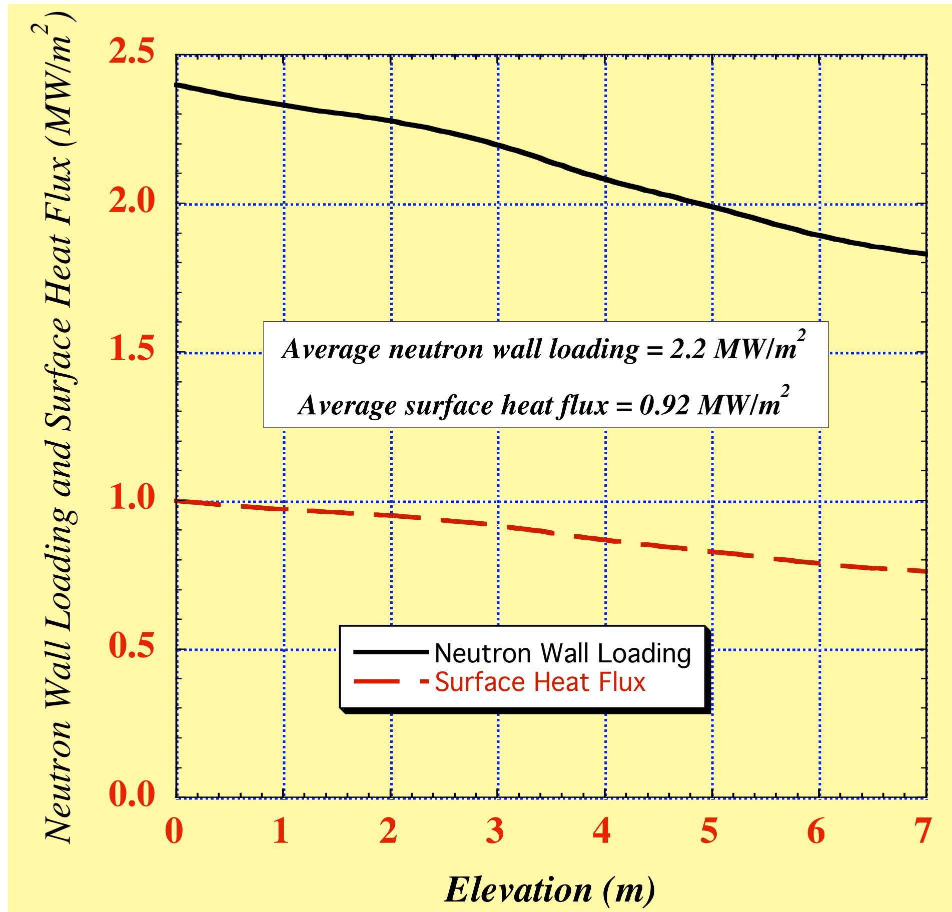
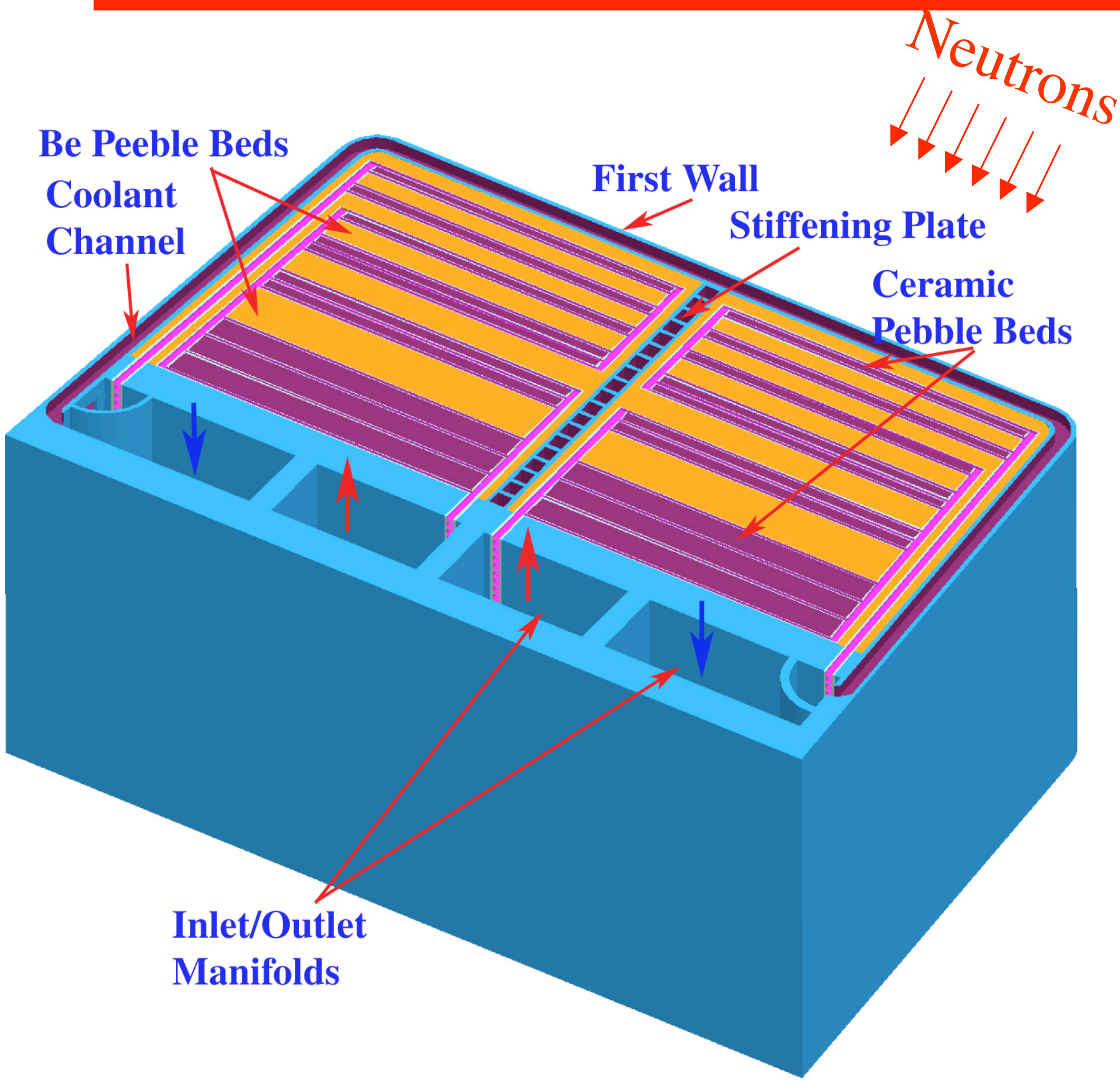
Basic Assumptions

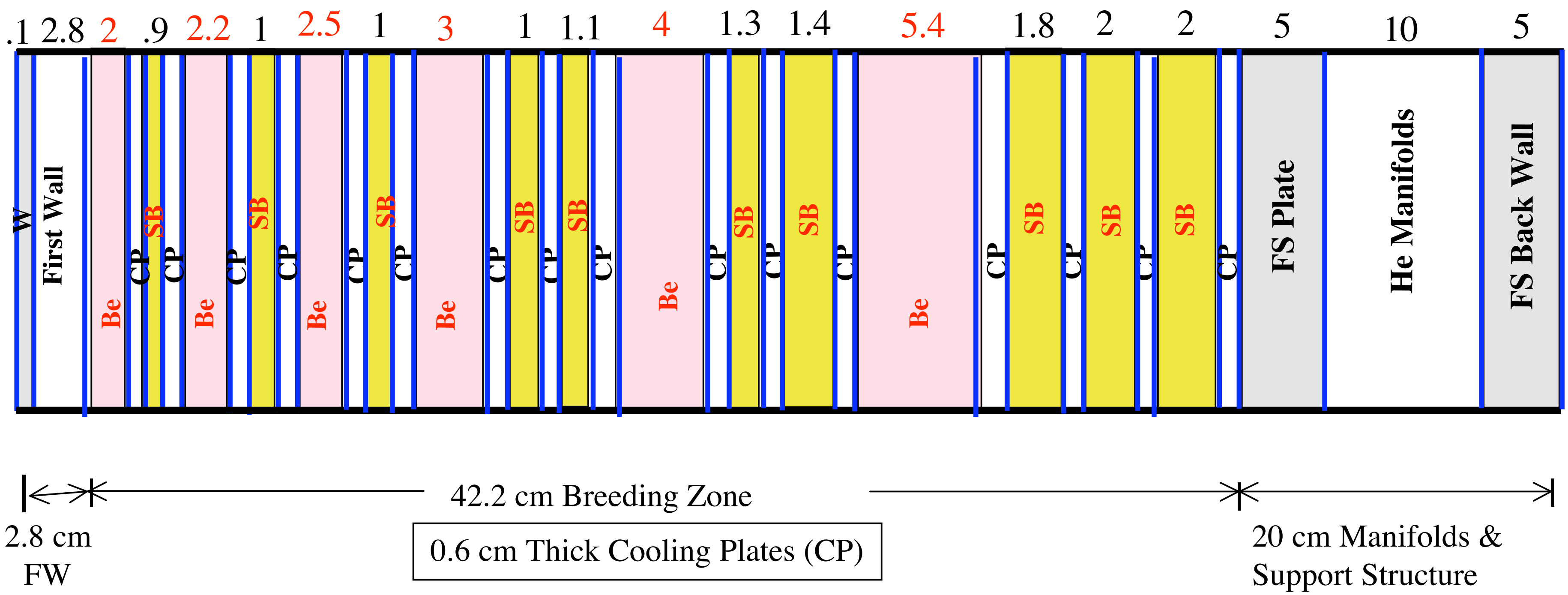
- 1 mm W armor on ferritic steel (F82H) FW
- Used target spectrum from LASNEX results (Perkins) for NRL direct-drive target
- 70.5% of target yield carried by neutrons with 12.4 MeV average energy
- 1.8 GW fusion power
- Chamber radius 6.5 m at mid-plane



Solid Breeder Blanket Configuration



Radial Build of SB Blanket



- Radial build of ARIES-CS SB blanket used
- 65 cm total blanket thickness
- Li_4SiO_4 breeder and RAFS F82H structure
- 1 mm W armor used in front of FW
- Uniform Li enrichment used

Material composition in radial layers includes module sides

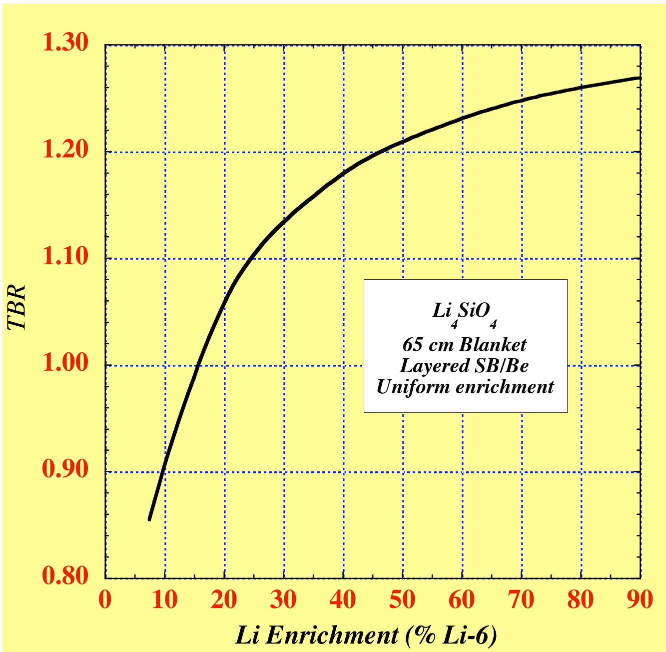
FW: 40.7% FS, 59.3% He

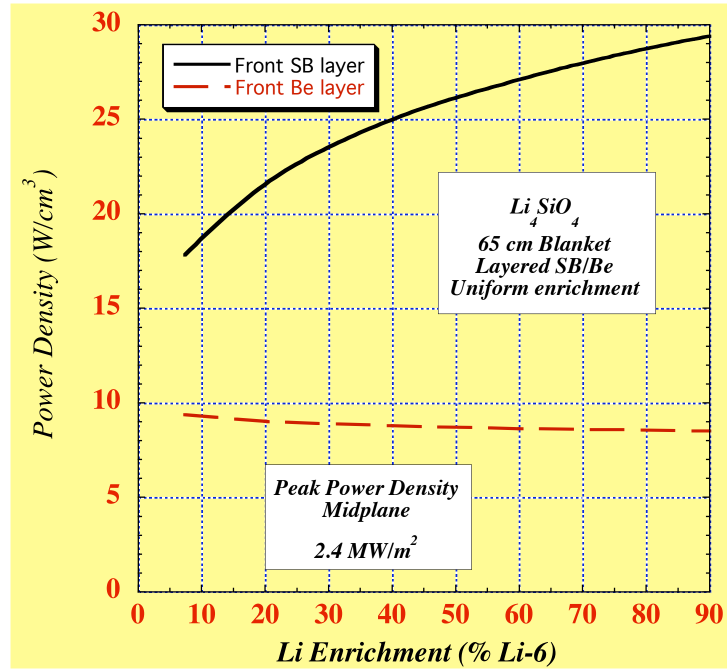
Be zone: 53% Be, 6% FS, 41% He

SB zone: 51% SB, 2.5% Be, 6% FS, 40.5% He

CP zone: 52% FS, 2.5 Be, 45.5% He

Lithium Enrichment





- With near full coverage in HAPL chamber a uniform enrichment of 40% Li-6 is adequate with TBR of 1.18
- Solid angle fraction subtended by beam ports is ~0.4% with minimal impact on overall TBR

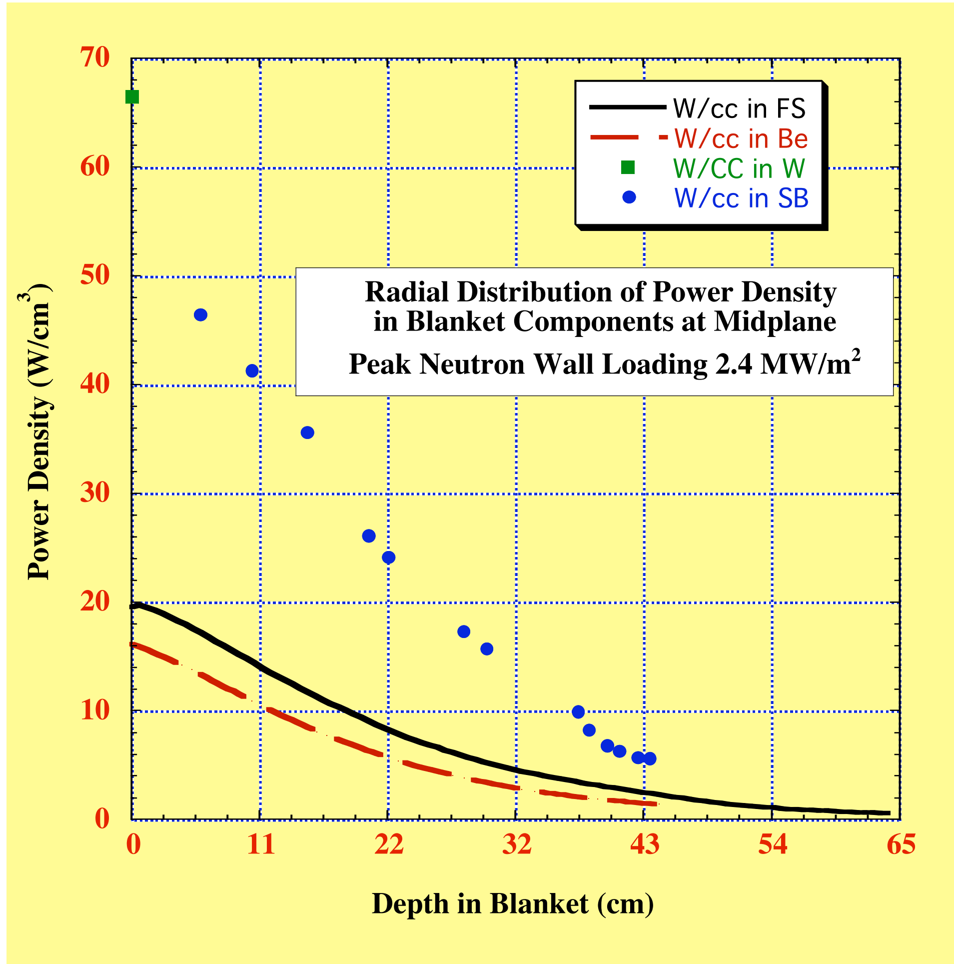
- Moderate power densities in front Be and SB layers ensure maximum temperature limits (750°C Be, 950°C SB) will not be exceeded with the current radial build even if a uniform enrichment of 90% is used

- 40% enrichment used in reference design
- Li enrichment can be used as a knob in design allowing for adjustment of TBR and shielding if needed

Nuclear Heating

Zone	Thickness (cm)	Power Density (W/cm^3)
W	0.1	66.52
FW	2.8	7.95
Be-1	2.0	8.77
CP	0.6	9.57
SB-1	0.9	25.06
CP	0.6	8.99
Be-2	2.2	7.37
CP	0.6	8.12
SB-2	1.0	22.21
CP	0.6	7.49
Be-3	2.5	5.89
CP	0.6	6.57
SB-3	1.0	19.07
CP	0.6	5.99
Be-4	3.0	4.49
CP	0.6	5.09
SB-4	1.0	14.03
CP	0.6	4.63
SB-5	1.1	12.93
CP	0.6	4.14
Be-5	4.0	2.89
CP	0.6	3.31
SB-6	1.3	9.26
CP	0.6	2.94
SB-7	1.4	8.40
CP	0.6	2.56
Be-6	5.4	1.63
CP	0.6	1.91
SB-8	1.8	4.88
CP	0.6	1.65
SB-9	2.0	3.55
CP	0.6	1.42
SB-10	2.0	3.08
CP	0.6	1.23
Manifold	20.0	0.64

- Nuclear heating calculated in radial zones of blanket and used in thermal hydraulics analysis



Plant Thermal Power

for 1800 MW Fusion Power

Total Thermal Power = 2302 MW

2254 MW removed from 65 cm blanket by He

(531 MW surface + 1723 MW volumetric)

48 MW removed from 30 cm VV by He

Peak Radiation Damage in Blanket

	dpa/FPY	He appm/FPY
W armor	6.4	4.6
FW	20.1	183

Blanket lifetime is ~10 FPY

Peak EOL (40 FPY) Radiation Damage in 30 cm VV

	dpa	He appm
Front of VV	19.3	33.6
Back of VV	2.5	0.4

- VV is lifetime component
- Rewelding is possible at back of VV

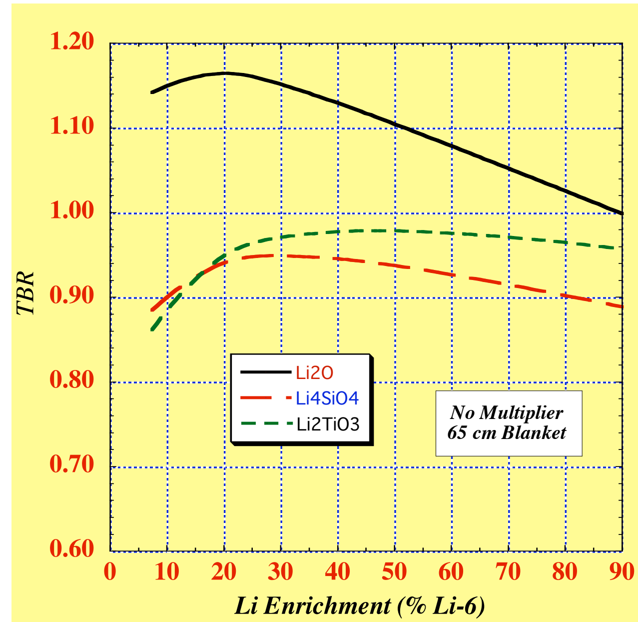
Comparison between Nuclear Performance of Li and SB Blankets in HAPL

	Li Blanket	*SB Blanket*
Overall TBR	1.12	1.17
Blanket thickness (cm)	47	65
Total Thermal power (MW)	2103	2302
Power density in FW structure (W/cm^3)	13	20
Blanket lifetime (FPY)	10	10
Required VV thickness (cm)	50	30

- Thicker SB blanket with significant amount of Be required for tritium breeding
- The large amount of Be in SB blanket yields ~10% more thermal power
- While FW radiation damage is similar about 50% higher nuclear heating is generated in FW of SB blanket
- Thicker VV required with Li blanket to allow rewelding at back of VV

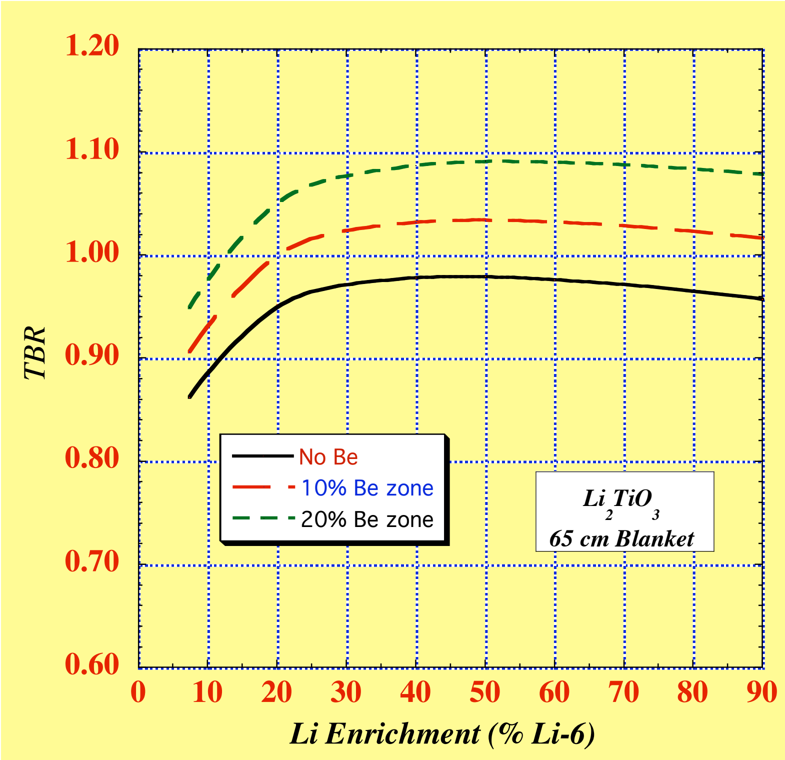
Neutronics assessment of SB Flowing Bed Blanket

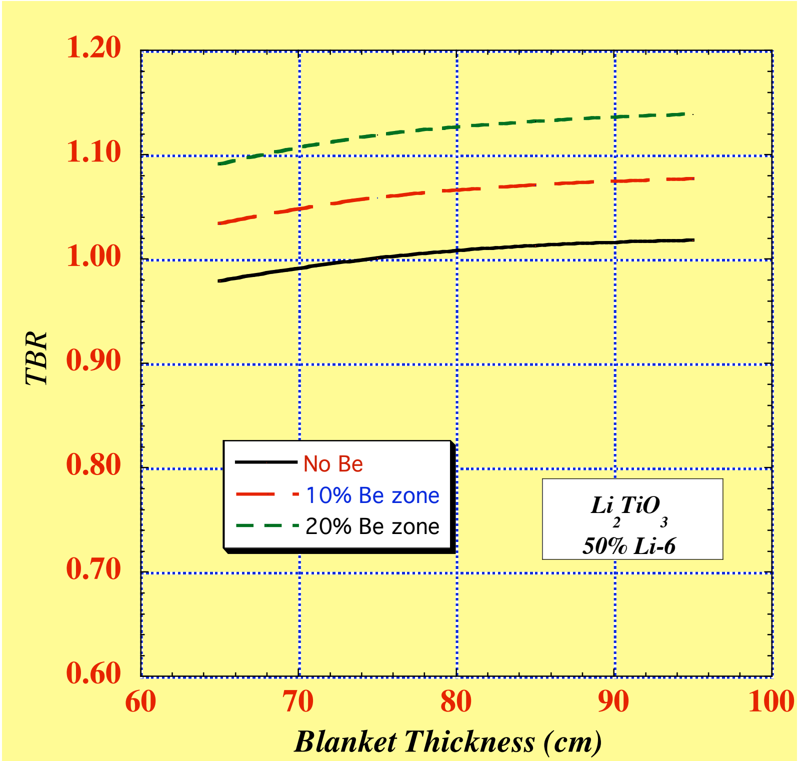
- The layered 42.2 cm breeding region is replaced by a homogenized composition of 3.67% FS, 62.61% SB, 33.72% He
- The 20 cm manifold zone at the back has 57.5% FS, 42.5% He
- Total blanket thickness 65 cm
- Blanket thickness allowed to change by changing thickness of breeding region
- Three breeders considered (Li_2O, Li_4SiO_4, Li_2TiO_3)
- Considered the option of adding Be zones (53% Be, 6% FS, 41% He) in the breeding region to enhance TBR
- Used uniform Li-6 enrichment in SB



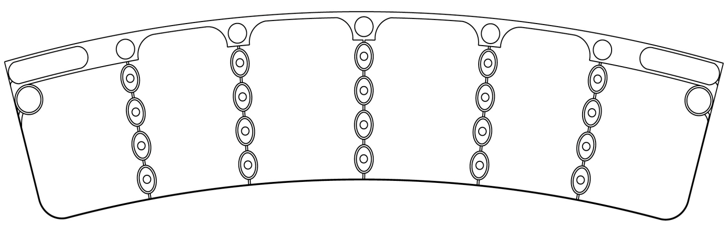
- We must add Be and/or increase blanket thickness if the Li_4SiO_4 or Li_2TiO_3 breeders are used
- With Li_2O we can keep blanket thickness at 65 cm and there is no need for enrichment

Adding Be and Increasing Thickness to Enhance TBR





- With Li_4SiO_4 or Li_2TiO_3 breeders blanket thickness should be increased to ~85 cm in addition to enriching and adding up to 20% Be zone in breeding region



Neutronics Parameters for SB Flowing Bed Blanket Options

Breeder	Enrich	Be zone	Blanket Thick (cm)	Local TBR	Blanket lifetime (FPY)	VV dpa @ 40 FPY	Required VV thick (cm)
Li_2O	Nat.	0%	65	1.142	10	17.3	30
Li_4SiO_4	40%	20%	85	1.139	10	4	15
Li_2TiO_3	50%	20%	85	1.132	10	2.5	10

- Using Li_2O flowing bed allows achieving adequate TBR in the 65 cm blanket without enrichment or adding Be
- Using Li_4SiO_4 or Li_2TiO_3 flowing bed a 20 cm thicker blanket should be used with smaller amount of Be compared to the static layered SB case. A much thinner VV can also be used

Summary

- Overall TBR >1.1 can be achieved with 65 cm thick SB blanket with significant amount of Be and Li-6 enrichment
- VV can be lifetime component and its back can be reweldable if its thickness is at least 30 cm
- Blanket lifetime expected to be ~10 FPY
- For 1800 MW_f, total thermal power is 2300 MW_{th} which is ~10% larger than that in Li blanket. About 50% higher nuclear heating is generated in FW and front part of blanket
- Using Li_4SiO_4 or Li_2TiO_3 flowing bed a 20 cm thicker blanket should be used with smaller amount of Be and much thinner VV compared to the static layered SB case