Final Radial Build and Composition for LiPb/FS/He System

Laila El-Guebaly

and the ARIES Team

Fusion Technology Institute

University of Wisconsin - Madison

http://fti.neep.wisc.edu/aries-cs/builds/build.html

May 24, 2006

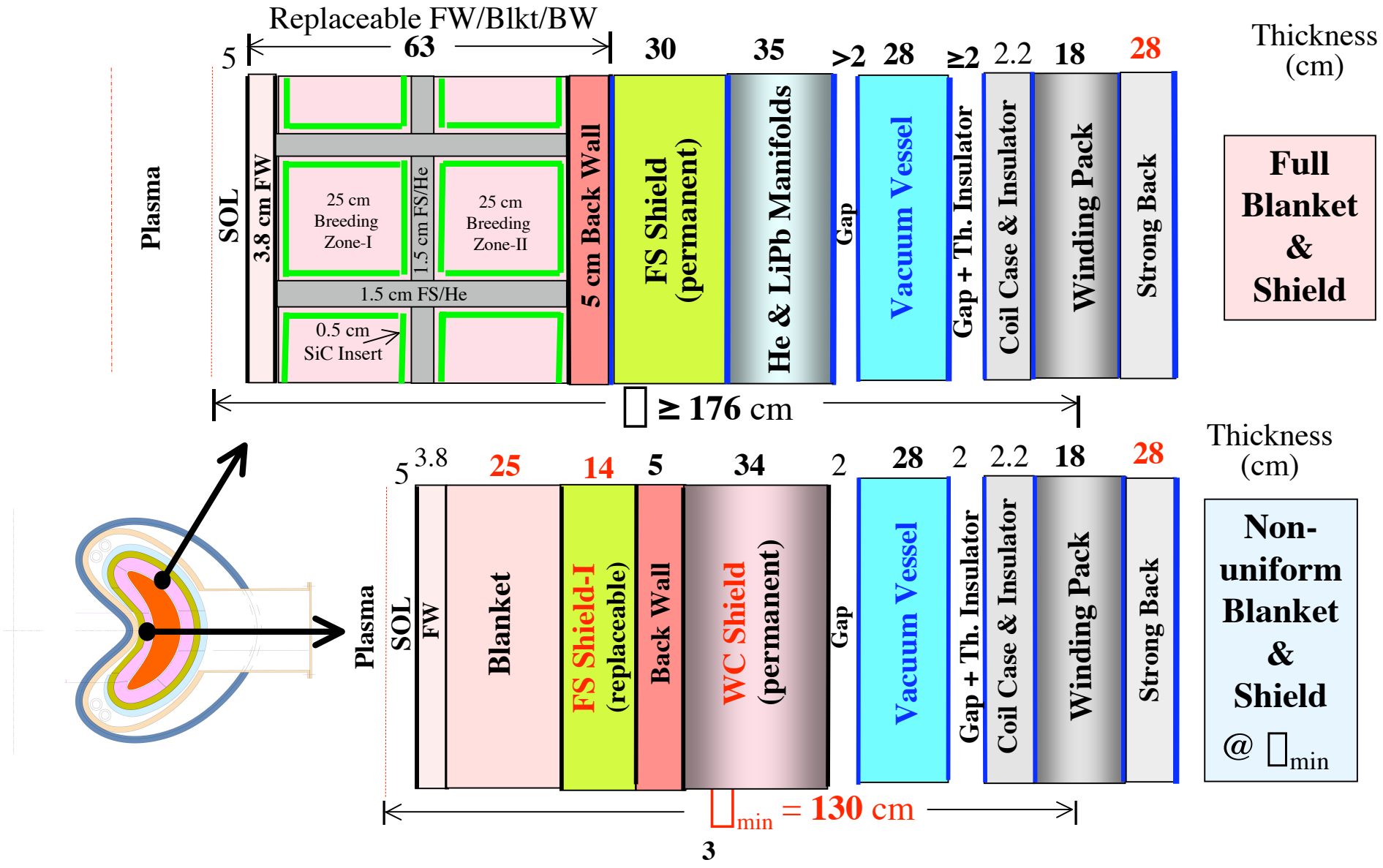
Blanket Concepts

Breeder	Structure	FW/Blanket Coolant	Shield Coolant	VV Coolant
LiPb (reference)	**FS**	**He/LiPb**	**He**	**H_2O**
LiPb (back-up)	**SiC**	**LiPb**	**LiPb**	**H_2O**

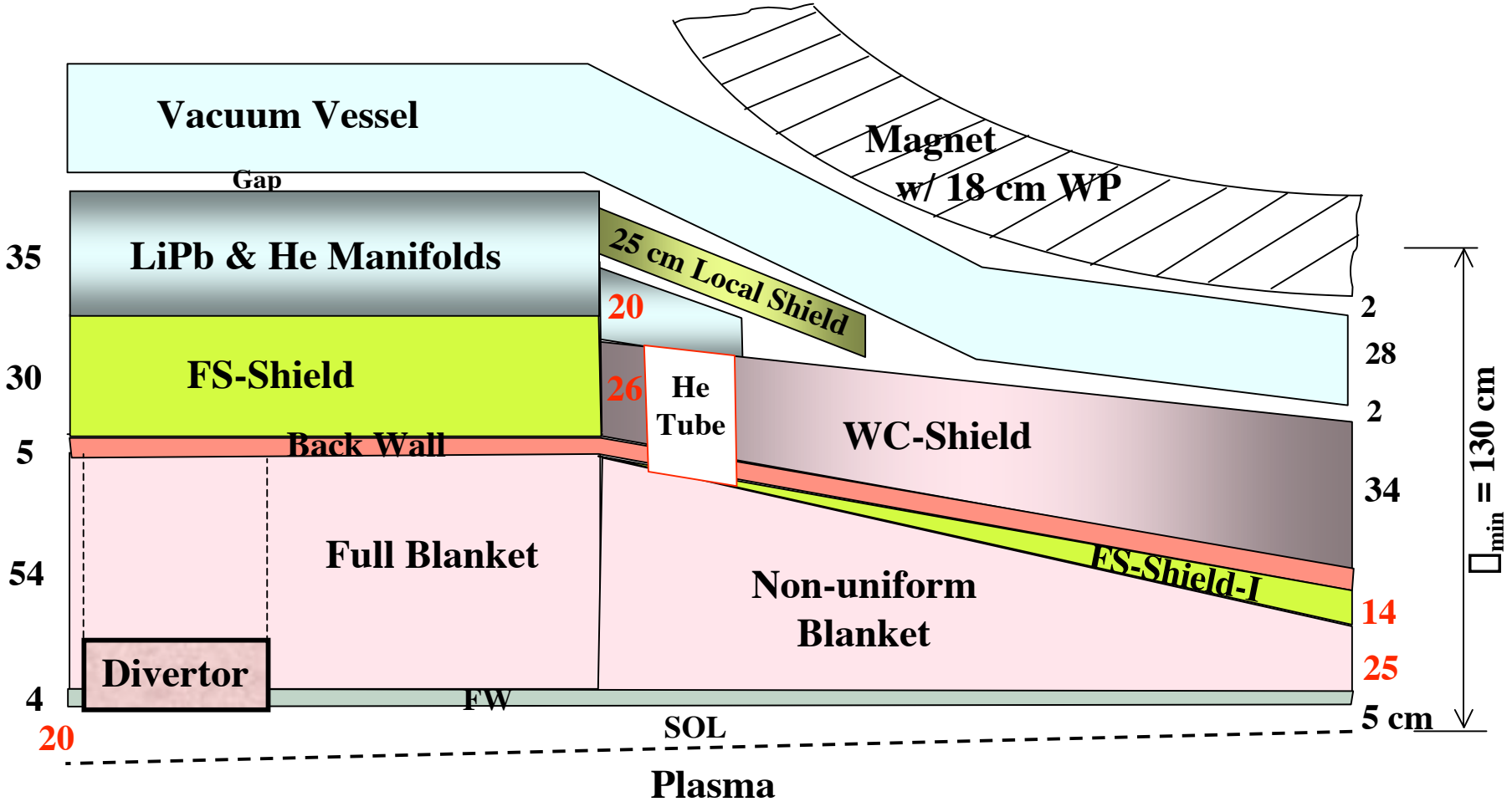
- 3 FP configuration
- Major Radius = 7.75 m
- Minor Radius = 1.7 m
- Peak $\square \approx 4$ MW/m^2
- Average $\square \approx 2.6$ MW/m^2
- 15% of FW for divertor system
- Internal VV (located inside magnets)
- Port maintenance approach.

Final Radial Build

(4 MW/m^2 peak □)



Radial / Toroidal Xn

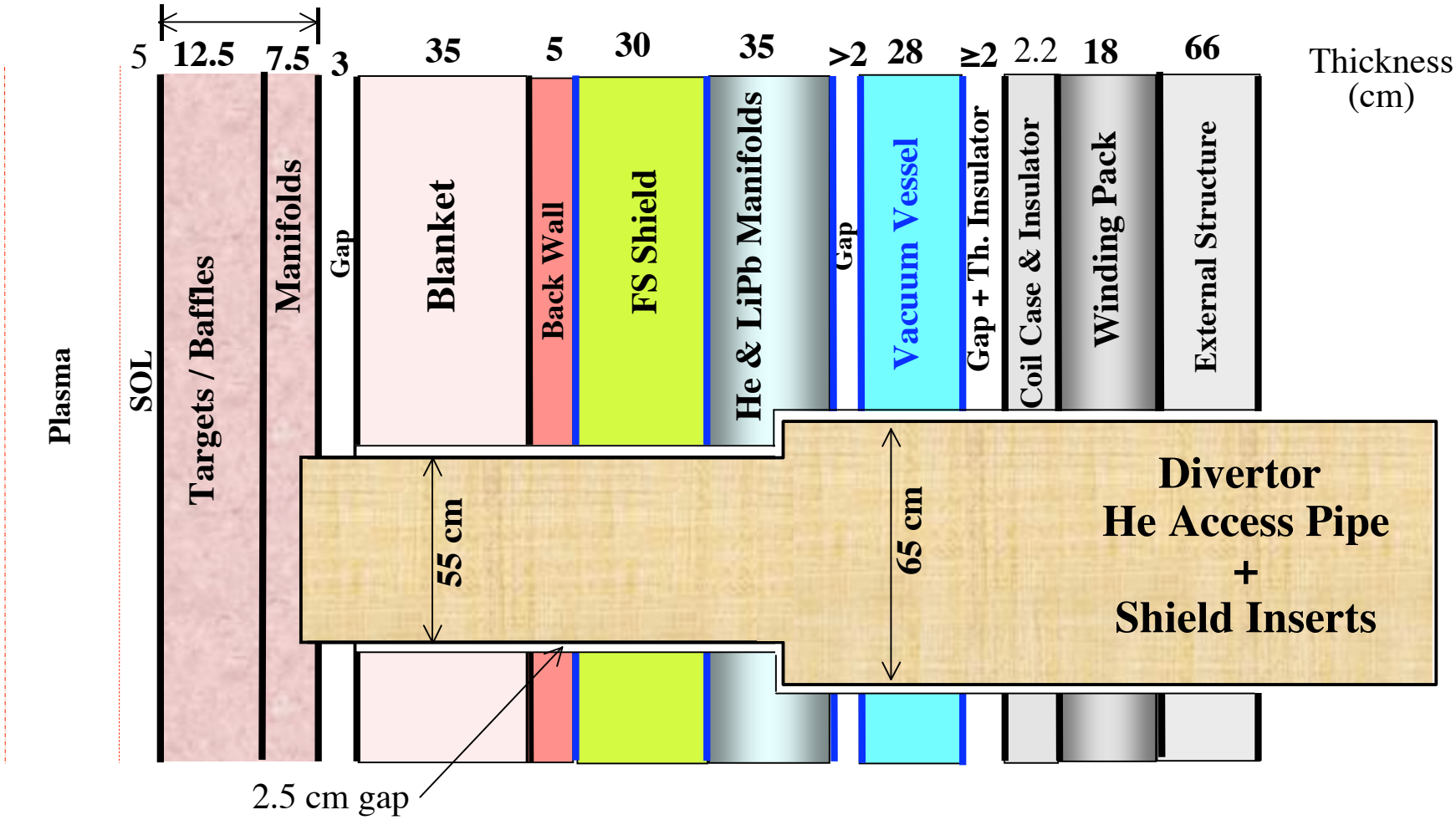


Full Blanket/shield **and** Divertor
(61%+15%= 76% of FW area)

Non-uniform, Tapered Blanket/Shield
(24% of FW area)

Xn through Divertor System

20 cm Divertor System



Damage at shield/manifolds TBD. It depends on at divertor and streaming through pipe

Compositions and Coverage Fractions
(R= 7.75 m)

Component	Thickness	Coverage Fraction		Composition
FW*	3.8 cm	85%	100%	34% FS Structure 66% He Coolant
Divertor System*	20 cm	15%		32.6% FS Structure 4.0% W 63.4% He Coolant
Blanket Behind Divertor*	35 cm	15%		75% LiPb (< 90% enriched Li) 9% SiC Inserts 8% FS Structure 8% He Coolant
Non-uniform Blanket*	25 - 54.3 cm	24%	100%	76% LiPb (< 90% enriched Li) 8% SiC Inserts 8% FS Structure 8% He Coolant
Full Blanket*	54.3 cm	61%		79% LiPb (< 90% enriched Li) 7% SiC Inserts 6% FS Structure 8% He Coolant
Back Wall*	5 cm	100%		80% FS Structure 20% He Coolant
FS Shield	30 cm	76%		15% FS Structure 10% He Coolant 75% Borated Steel Filler
Manifolds	35 cm	80%		52.0% FS Structure 22.7% LiPb (< 90% enriched Li) 24.0% He Coolant 1.3% SiC Inserts

* Replaceable component.

Compositions and Coverage Fractions (Cont.)

Component	Thickness	Coverage Fraction	Composition
FS Shield-I*	0 -14 cm	24%	15% FS Structure 10% He Coolant 75% Borated Steel Filler
WC Shield	26 - 34 cm	24%	15% FS Structure 10% He Coolant 75% WC Filler
Vacuum Vessel	28 cm	100%	28% FS Structure 49% Water 23% Borated Steel Filler
Inner Coil Case (in front of WPs only)	2 cm	28%	95% JK2LB Structure 5% LHe Coolant
Winding Pack @ 4K	18 cm	28%	18.5% JK2LB Structure 48.2% Cu 12.8% Nb_3Sn 10.0% GFF Polyimide 10.5% LHe Coolant
Strong Back (behind WPs only)	28 cm	28%	95% JK2LB Structure 5% LHe Coolant
Intercoil Structure (between WPs)	20 cm#	72%	95% JK2LB Structure 5% LHe Coolant
Cryostat	5 cm	100%	100% 304-SS Structure

100%

* Replaceable component.

~16 cm for outboard and ~28 cm for inboard, per Xueren.

Key Parameters

$\square_{min}$	**1.3 m**
Overall TBR	**~ 1.1#**
Li-6 Enrichment	**< 90%#**
Overall Energy Multiplication	**~ 1.155***
He : LiPb Power Ratio	**~ 48 : 52***
FW EOL Fluence	**15.7 MWy/m²** (for FS)
FW/Blanket/Divertor Lifetime	**3.9 FPY** (for 4 MW/m² peak □)
Plant Lifetime	**40 FPY**
System Availability	**~ 85%**

To be confirmed with 3-D analysis.

* To be updated.

Design Requirements Satisfied Except at Divertor*

Overall TBR (for T self-sufficiency)	1.1	
Damage to FS Structure	200	dpa
Helium Production @ Manifolds and VV (for reweldability of FS)	1	appm
S/C Magnet (@ 4 K):		
Peak fast n **fluence** to Nb_3Sn ($E_n > 0.1$ MeV)	10^{19}	n/cm^2
Peak nuclear **heating**	2	mW/cm^3
Peak **dpa** to Cu stabilizer	$6x10^{-3}$	dpa
Peak **dose** to electric insulator	$> 10^{11}$	rads

* Due to unknown NWL at divertor location and streaming effect.

FS Structure

Composition: Modified F82H Ferritic Steel (8Cr-2WVTaC)
Reference: R. Klueh et al., Impurity effects on reduced-activation ferritic steels developed for fusion applications Journal of Nuclear Materials 280 (2000) 353-359.
Density: ~7.89 g/cm^3

	wt%
C	0.1
Al	14e-4
V	0.2
Cr	7.5
Fe	90.11586
Co	28e-4
Ni	474e-4
Cu	100e-4
Nb	3.3e-4
Mo	21e-4
Pd	0.05e-4
Ag	0.1e-4
Cd	0.4e-4
Ta	0.02
W	2.0
Os	0.05e-4
Ir	0.05e-4
Bi	0.2e-4
Eu	0.05e-4
Tb	0.02e-4
Dy	0.05e-4
Ho	0.05e-4
Er	0.05e-4
U	0.05e-4

SiC/SiC Composites

Based on: SUPERSiC (r)
Reference: S. Sharafat, IPFR/UCLA, ARIES Study: Materials, Sept. 1993, pg 3.
Density: 3.217 g/cm^3 (64th CRC Handbook of Chemistry and Physics B-135).

	wt %		**wt %**
C	29.95	Ag	0.002e-4
Na	0.050e-4	Cd	0.004e-4
Si	70.05	In	0.001e-4
K	0.180e-4	Sn	0.076e-4
Sc	0.013e-4	Sb	0.001e-4
Cr	0.017e-4	Cs	0.001e-4
Fe	0.440e-4	Ba	0.047e-4
Co	0.013e-4	La	0.018e-4
Ni	0.074e-4	Eu	0.001e-4
Cu	0.048e-4	Tb	0.001e-4
Zn	0.043e-4	Vb	0.001e-4
Ga	0.005e-4	Hf	0.001e-4
As	0.003e-4	Ta	0.001e-4
Se	0.001e-4	W	0.032e-4
Br	0.001e-4	Ir	0.001e-4
Rb	0.001e-4	Pt	0.542e-4
Sr	0.012e-4	Hg	0.001e-4
Zr	0.236e-4	Th	0.001e-4
Mo	0.041e-4	U	0.001e-4

LiPb Breeder

Reference: S. Malang & K. Schleisiek, "Dual Coolant Blanket Concept", KFK5424, Karlsruhe, Nov 1994.

Density: 9 g/cm^3 @ 580 ^{o}C

	wt %
Pb	99.29
Li*	0.7
Zn	10e-4
Fe	10e-4
Bi	43e-4
Cd	5e-4
Ag	5e-4
Sn	5e-4
Ni	2e-4

* < 90% Li-6 enrichment. TBD.

JK2LB Steel

Reference: ITER magnet structure.
P. Heizenroeder and R. Reed "Comments on Selection of U.S. ITER CS Coil Jacket Material" (9/12/2005)

Density: 8.0 g/cm^3

	wt%
B	0.002
C	0.02
N	0.2
Si	0.3
P	0.004
S	0.004
Cr	13
Mn	21
Fe	55.47
Ni	9
Mo	1