ARIES-CS Radial Builds and Compositions

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

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Contents

- Radial builds and compositions for preferred blanket/shield systems that have been selected for further analysis in FY05 during the second phase of the ARIES-CS study:
  - LiPb/SiC
  - LiPb/FS/He **with SiC inserts**.

- At present, the ARIES team is examining the internal vacuum vessel design option and will address the external vacuum vessel case later.

Breeding Blanket Concepts*

Breeder	Multiplier	Structure	FW/Blanket Coolant	Shield Coolant	VV Coolant
ARIES-CS:					
Internal VV:					
Flibe	Be	FS	Flibe	Flibe	H_2O
LiPb	**–**	**SiC**	**LiPb**	**LiPb**	**H_2O**
LiPb w/o SiC inserts	–	FS	He/LiPb	He	H_2O
LiPb w/ SiC inserts	**–**	**FS**	**He/LiPb**	**He**	**H_2O**
Li_4SiO_4	Be	FS	He	He	H_2O
External VV:					
LiPb*	–	FS	He/LiPb	He or H_2O	He
Li	–	FS	He/Li	He	He
SPPS:					
External VV:					
Li	–	V	Li	Li	He

* Refer to the 8/30/04 document for info on other blanket/shield systems.

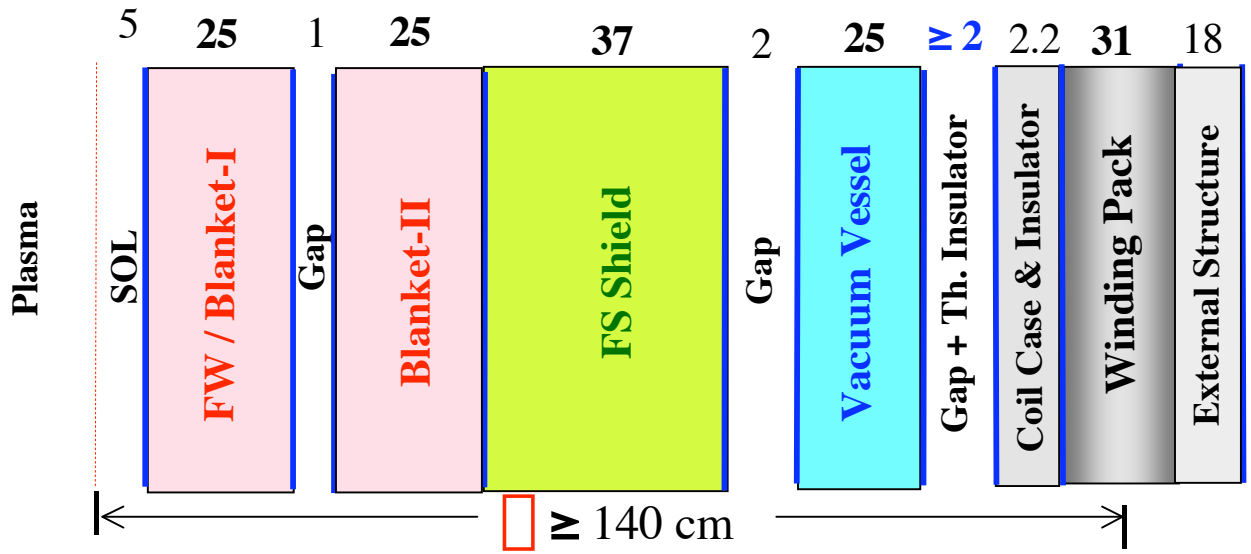
Radial Build has been Defined Using Same Design Basis

- 3 MW/m^2 peak neutron wall loading.
- 5 cm SOL and 2 cm minimum VV-magnet gap.
- 2 cm thick inner coil case.
- 31 cm thick winding packs-I/II.
- **1.1 overall TBR** for 3 FP configuration based on 92% uniform-blanket coverage fraction, 8% shield-only zones, 5 cm thick divertor plates/baffles covering 15% of FW area.
- ≤ 1% nuclear heating in LT shield and/or VV.
- Shield, VV, and magnet are lifetime components
- **Radiation limits** to structural components:
  - 3% burnup to SiC/SiC composites
  - 200 dpa to FS
  - 1 He appm @ VV.
- Radiation limits to MT S/C magnet (same fluence as for LT S/C):
  - 10^{19} n/cm^2 fast n fluence
  - 5 mW/cm^3 local nuclear heating*
  - 10^{11} rads dose to GFF polyimide
  - $6x10^{-3}$ dpa to Cu stabilizer
  - 50 kW total nuclear heating.

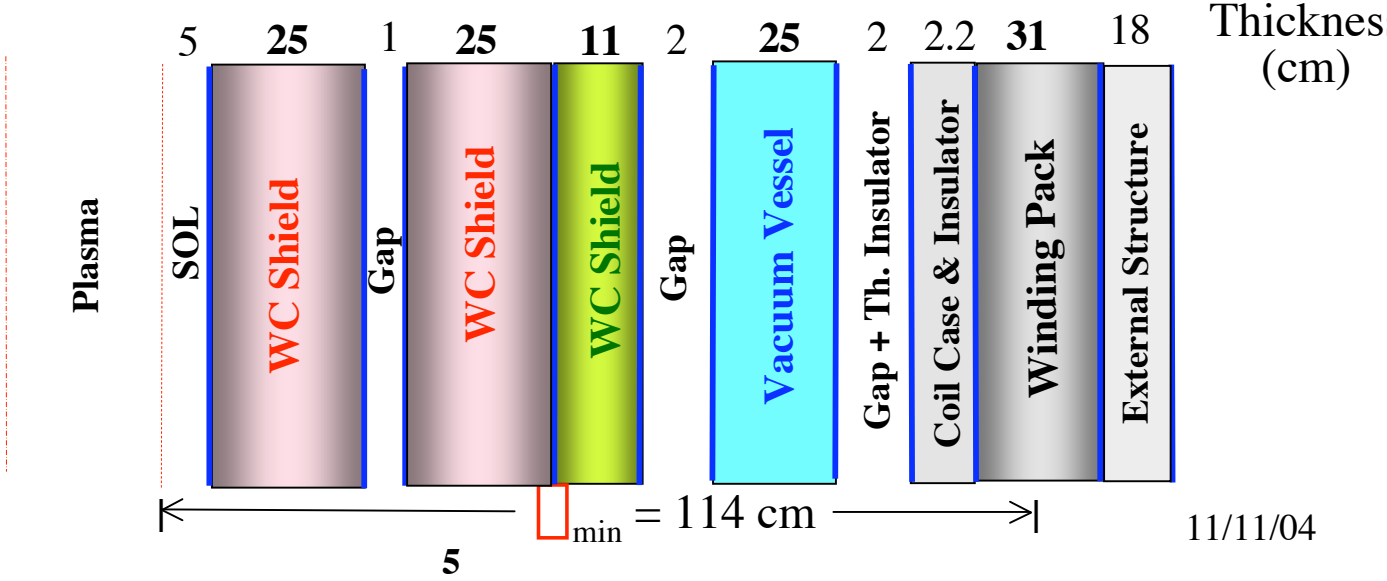
* Dec 03 ARIES meeting, Bromberg's presentation, Page 20.

LiPb/SiC Radial Build

Blanket Zones



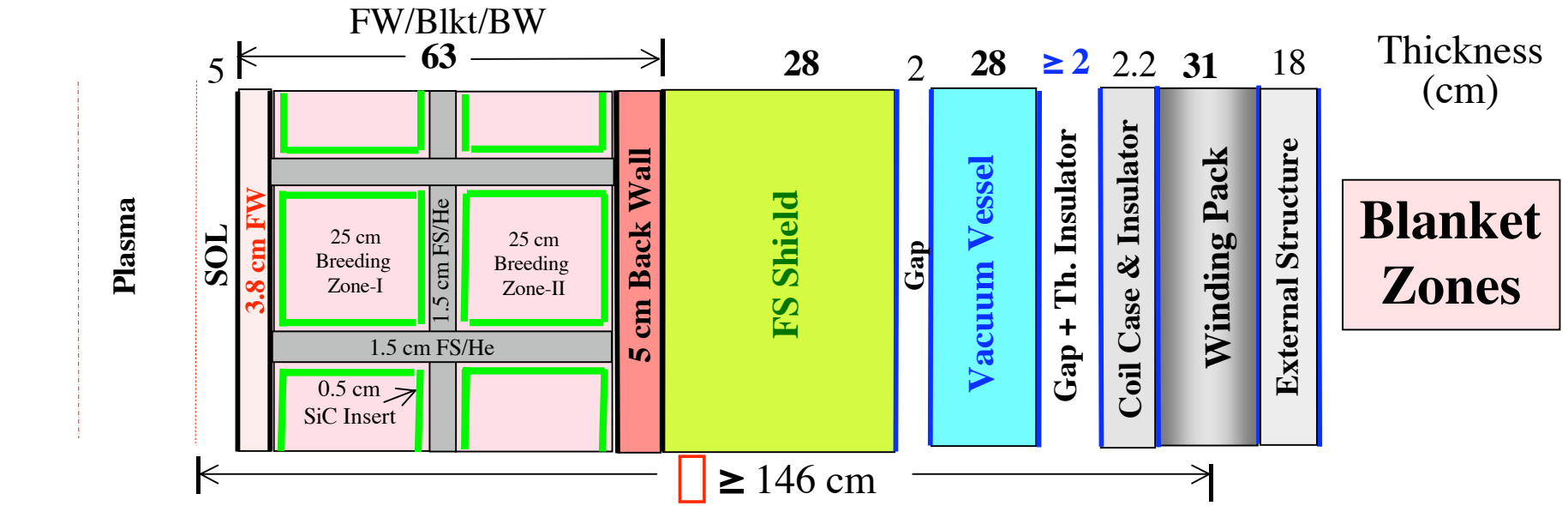
Shield Only Zones

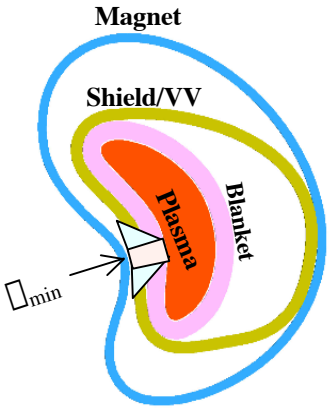


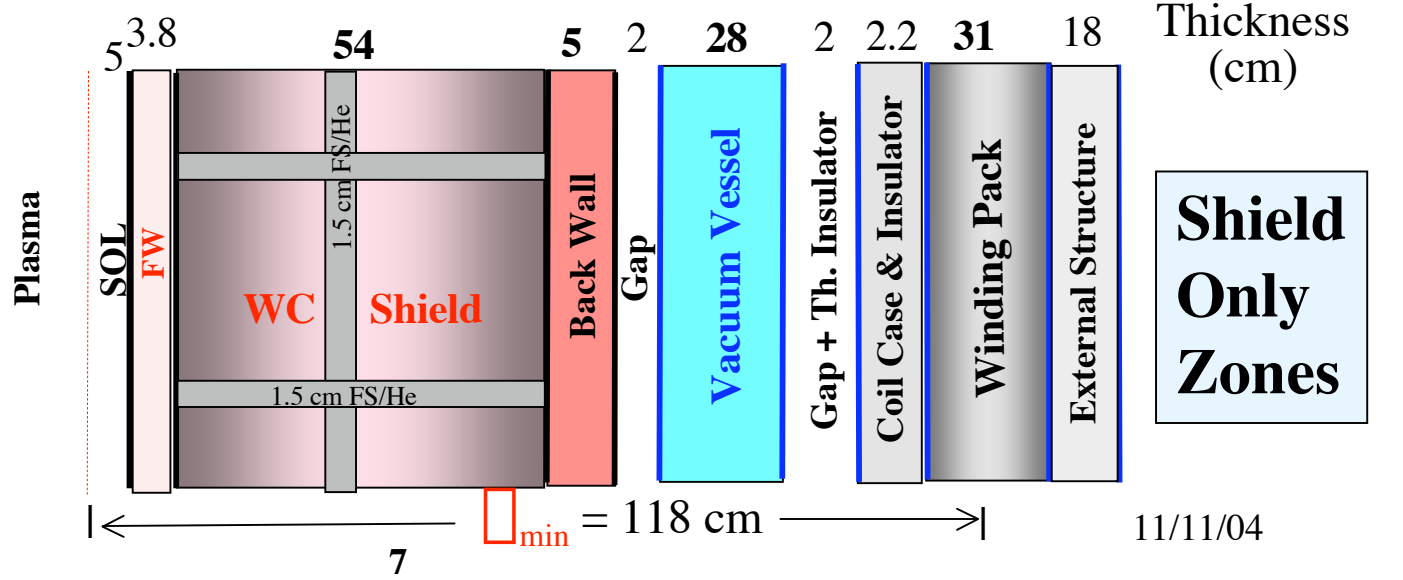
LiPb/SiC Composition

Component	Composition
Replaceable FW/Blanket-I	79% LiPb with 90% enriched Li 21% SiC/SiC Composite Structure
Permanent Blanket-II	79% LiPb with 90% enriched Li 21% SiC/SiC Composite Structure
FS Shield	15% SiC/SiC Composite Structure 10% LiPb with 90% enriched Li 75% Borated Steel Filler
WC Shield	20% SiC/SiC Composite Structure 10-15% LiPb 65-70% WC Filler
VV	28% FS Structure 49% Water 23% Borated Steel Filler

LiPb/FS/He Radial Build







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LiPb/FS/He Composition

Component	Composition
FW (3.8 cm)	34% FS Structure 66% He Coolant
Blanket (54.3 cm)	79% LiPb with 90% enriched Li 7% SiC Inserts 6% FS Structure 8% He Coolant
Back Wall (5 cm)	80% FS Structure 20% He Coolant
WC Shield	86% WC Filler 6% FS Structure 8% He Coolant
FS Shield	15% FS Structure 10% He Coolant 75% Borated Steel Filler
VV	28% FS Structure 49% **Water** 23% Borated Steel Filler

Nominal Radial Distance Varies within 6 cm

(Blanket/Shield Dimensions for CAD Drawings)

ARIES-CS:

	Blanket/Shield/VV/Gaps	Plasma – Mid Coil
Internal VV:		
Flibe/FS/Be	1.07 (min)	1.32 (min)
LiPb/SiC	**1.15**	**1.40**
LiPb/FS/He w/o SiC inserts	1.24	1.49
LiPb/FS/He w/ SiC inserts	**1.21**	**1.46**
Li_4SiO_4/Be/FS/He	**1.30** (max)	**1.55** (max)
External VV:	**Blanket/Shield/Gaps**	
LiPb/FS/He/B-H_2O	1.28	1.53
LiPb/FS/He	1.60	1.85
Li/FS/He	1.79 (max)	2.04 (max)

SPPS*:

External VV:		
Li/V	1.20	1.96

* 15 cm SOL, 36 cm half winding pack, 15 cm thick cryostat, and 8 cm wide shield-magnet gap.

Minimum Radial Distance Varies within 4 cm

(ρ_{min} for Systems Code Analysis)

		ρ_{min} (m)	
ARIES-CS:			
Internal VV:	**WC-Shield/VV/Gaps**		**Plasma – Mid Coil**
Flibe/FS/Be	0.86 (min)		1.11 (min)
LiPb/SiC	**0.89**		**1.14**
LiPb/FS/He w/o SiC inserts	0.93		1.18
LiPb/FS/He w/ SiC inserts	**0.93**		**1.18**
Li_4SiO_4/Be/FS/He	1.04 (max)		1.29 (max)
External VV:	**WC-Shield/Gaps**		
LiPb/FS/He/B-H_2O	0.87		1.12
LiPb/FS/He	0.93		1.18
Li/FS/He	0.91		1.16
SPPS:			
External VV:			
Li/V	–		–

4 cm difference in ρ_{min} translates into ~25 cm change in R

Key Parameters for System Analysis (3 FP Configuration)

	Flibe/FS/Be	LiPb/SiC	SB/FS/Be*	LiPb/FS (w/o SiC inserts)	LiPb/FS (w/ SiC inserts)	Li/FS
η_{min}	1.11	1.14	1.29	1.18	1.18	1.16
TBR	1.1	1.1	1.1	1.1	1.1	1.1
Energy Multiplication (M_n)	1.2	1.1	1.3	1.15	1.14	1.13
Thermal Efficiency (η_{th})	45%	58%	45%	~ 45%	~ 45%	~ 45%
FW Lifetime (FPY)	6.5	6	4.4	5	5	7
FW EOL Fluence (MWy/m^2)	20	18	20	15	15	21
# of Blanket Replacements	6	6	9	7	7	5
System Availability	~ 85%	~ 85%	~ 85%	~ 85%	~ 85%	~ 85%

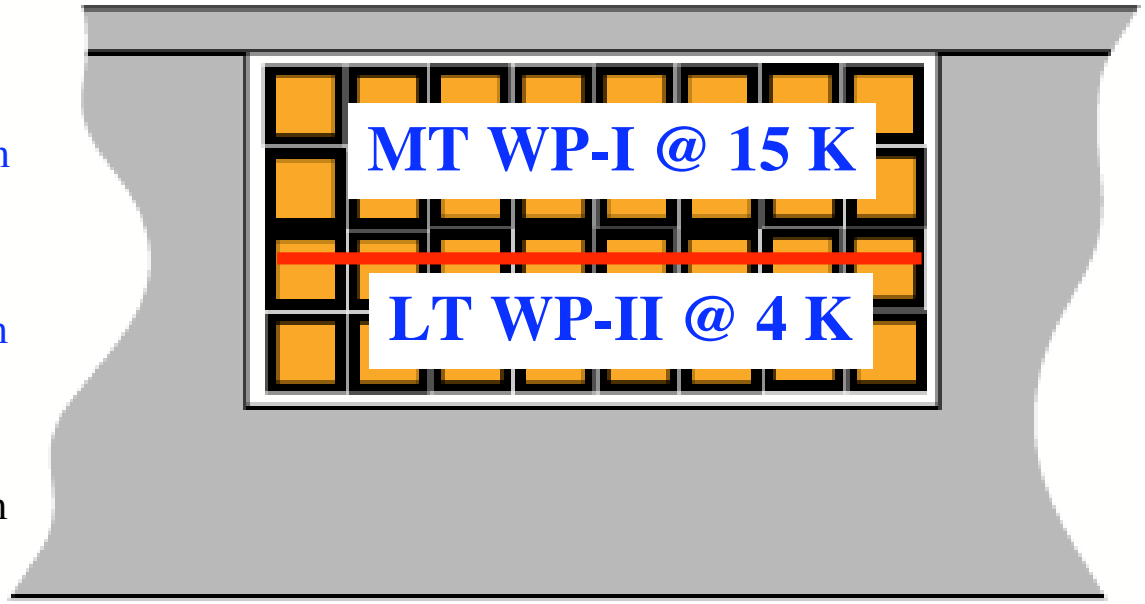
* Evaluated at 4.5 MW/m^2 peak n wall loading.

System analysis will assess impact of η_{min}, M_n and η_{th} on COE

Magnet Design
(L. Bromberg - 2/04)

Plasma/Blanket/Shield/VV

Coil Case - 2 cm
Insulator - 0.2 cm
Winding Pack-I - 17 cm
Winding Pack-II - 14 cm
Insulator - 0.2 cm
External Structure - 18 cm



Magnet Homogeneous Composition:
45% 316-SS (gray)
50% winding packs (orange/black)
5% GFF polyimide (white)

MT Winding Pack-I:
12.7% MgB_2
45.5% Cu
15.5% He @ 15 k
17.3% 316-SS
9.0% GFF poly.

LT Winding Pack-II:
9.6% NbTi
54.1% Cu
21.8% LHe @ 4 k
5.5% 316-SS
9.0% GFF poly.

ORNL FS Composition

Composition: 9Cr-2WVTa
Reference: R. Klueh, M.L. Grossbeck, and E.E. Bloom,
Impurity content of reduced-activation ferritic
steels and vanadium alloy, Fusion Materials
Semiannual Progress Report for Period Ending
December 31, 1996, U.S. Department of Energy Office of
Fusion Energy Sciences, DOE/ER-0313/21 (April 1997).
Density: 7.78 g/cm^3

ORNL-FS	**wt %**		**wt%**
c	0.1	cd	0.05e-4
si	0.25	ta	0.07e-4
v	0.025	w	2.0
cr	9.0	os	0.02e-4
mn	0.5	ir	0.05e-4
fe	88.055	bi	0.05e-4
co	34e-4	eu	0.05e-4
ni	402e-4	dy	0.05e-4
nb	4e-4	ho	0.05e-4
mo	70e-4	er	0.05e-4
pd	0.18e-4	u	0.6e-4
ag	0.16e-4		

ODS FS Composition

ODS IEA Modified F82H Ferritic Steel
Composition: 9Cr-2WVTa
Reference: M. Billone (ANL) - 9/20/02
Density: ~7.78 g/cm^3

ODS-MF82H	**wt %**		**wt %**
b	3e-4	cd	0.4e-4
c	0.04	sn	10e-4
n	50e-4	sb	5e-4
o	0.13	ta	0.08
al	0.01	w	2.0
si	0.24	os	0.05e-4
p	50e-4	ir	0.05e-4
s	20e-4	bi	0.2e-4
ti	0.09	eu	0.05e-4
v	0.29	tb	0.02e-4
nb	3.3e-4	dy	0.05e-4
mo	21e-4	ho	0.05e-4
pd	0.05e-4	er	0.05e-4
ag	0.1e-4	u	0.05e-4

SiC/SiC Composition

Based on: SUPERSiC (r)

References: 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).

SiC/SiC Composites	**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	yb	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 Composition

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

Density (@ 700 °C): 8.8 g/cm^3

LiPb	**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

Comparison Between Major and Minor Radii