Blanket Design Issues for ARIES-AT

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Web address:
http://fti.neep.wisc.edu/FTI/ARIES/AUG99/blanket.pdf

ARIES Project Meeting
9 -10 August 1999
UCSD

Design Parameters

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Fusion power	2170 MW (ARIES-RS’)
FW location at midplane – OB , IB	6 , 3.5 m
at top/bottom– OB , IB	4.5 , 3.5 m
Γ : Peak OB , IB	6.6[#] , 5.1[#] MW/m^2
Average OB , IB	5.6 , 3.8 MW/m^2
FW poloidal length[*] – OB , IB	6 , 5 m
SiC burnup limit	3%
Machine lifetime	40 FPY

ARIES-RS’ vacuum vessel configuration (to be modified)

ARIES-RS’ LT magnet composition and dimensions (to be updated)

[#] For same fusion power, smaler radii result in higher wall loading
[*] Between X points

Preliminary 3-D Nuclear Parameters

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- Preliminary 3-D analysis needed at early stage of design to estimate key nuclear parameters:
  - Overall TBR
  - Overall Mn
  - Heat load to components
  - FW lifetime

- 3-D analysis:
  - MCNP code - pointwise FENDL-1 cross section data
  - 10,000 histories - < 1% statistical error in TBR and Mn
  - Neutron source distribution similar to ARIES-RS'
  - Homogenized zones: FW, blanket, HT shield, LT shield/V.V.
  - No radial gaps or RF penetrations (need info)
  - No metallic Kink stabilizing shell (need info)
  - No vertical stabilizing shell (need info)

- FW/Blanket main features:
  - Self-cooled LiPb/SiC system
  - IB and OB blankets only (no blanket behind divertor)
  - LiPb-cooled divertor and HT shields
  - 90% enriched LiPb
  - 10 cm thick seperate FW (17% SiC, 26% LiPb, 57% void)
  - 25 cm thick IB blanket (8% SiC, 92% LiPb)
  - 55 cm thick segmented OB blanket (8% SiC, 92% LiPb)

- 3-D results:

Overall TBR	1.1
Overall Mn	1.1
SiC Burnup fraction in OB FW	1.06% per FPY
FW EOL fluence	18.5 MWy/m^2
FW Lifetime	2.8 FPY

TBR Breakdown

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Components:	Inboard	Outboard	Divertor	Total
FW & DP	5%	11%	2%	**18%**
Blanket – Cell I	20%	38% (20 , 18)*	---	**58%**
Blanket – Cell II	---	21% (12 , 10)*	---	**21%**
HT Shield	1%	1.6%	0.4%	**3%**
Total	**26%**	**71.6%**	**2.4%**	**100%**

* middle and upper/lower sections

Nuclear Heat Load to In-vessel Components of Self-cooled Design

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(P_n= 1736 MW - ARIES-RS)

Nuclear Heating (MW)	Inboard	Outboard	Divertor	Total	
FW or DP	140	385	46	**571**	(30%)
Blanket	250	755	---	**1005**	(53%)
HT Shield	80	30	214	**324**	(17%)
Total	**470** (25%)	**1170** (62%)	**260** (13%)	**1900**	

Overall neutron energy multiplication is 1.1

Nuclear Heat Load to In-vessel Components of Dual-cooled Design

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(P_n= 1736 MW - ARIES-RS)

Nuclear Heating (MW)	Inboard	Outboard	Divertor	Total	
FW or DP	32	92	~10	134	(7%)
Blanket/ manifolds	334	1068	---	1402	(73%)
HT Shield	114	22	~250	386	(20%)
Total	480	1182	260	1922	
	(25%)	(62%)	(13%)		

Overall neutron energy multiplication is 1.1

Blanket Segmentation

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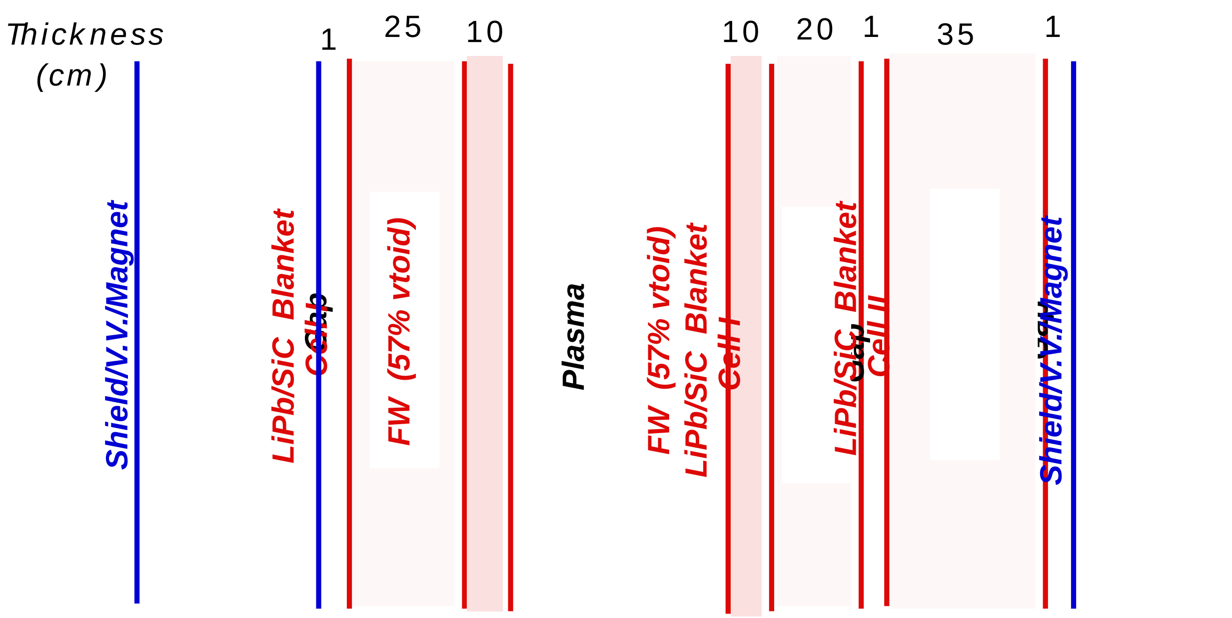
- To reduce radwaste stream and replacement cost, segment self-cooled FW/B into 3 components: FW, Cell-I, and Cell-II (on OB only)
- Replace each component at end of its service lifetime
- 3% burnup to SiC structure determines lifetime of each component
- Segmentation of dual-cooled blanket is not feasible

Component	Lifetime (FPY)	EOL Fluence* (MWy/m^2)
FW	2.8	18.5
Cell-I	5.6 – 8.4#	37 – 55
Cell-II	> 40	> 250
Shield/V.V./magnet	> 40	> 300



* = lifetime x peak OB n wall loading

\# To be determined by 3-D analysis

FW/B Radwaste Volume and Cost

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	SiC Vol. (m^3)	Single Unit FW/B, 2.8 FPY, 14 Replacements during 40 FPY: Integral SiC Vol. (m^3)	Single Unit FW/B: Direct Cost* (M$)	Segmented Blanket: Lifetime (FPY)	Segmented Blanket: # of Replace. in 40 FPY	Segmented Blanket: Integral SiC Vol. (m^3)	Segmented Blanket: Direct Cost (M$)
Components:							
IB FW	1.7	26	31	2.8	14	26	31
IB Blkt	2	30	37	8.4	4	10	12
OB FW	3.8	57	70	2.8	14	57	70
OB B Cell-I	3.6	55	66	8.4	4	18	22
OB B Cell-II	6	92	112	40	--	6	8
Total	17	260	316			117	143
FW/B : Shield Ratio		0.5				0.25	

Blanket segmentation reduces cumulative FW/B radwaste volume and replacement cost by factor of ~2

* based on 400 $/kg for SiC/SiC composites

Single vs. Dual Loop Cost

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- In ASC, Account 22.2 for "Main Heat Transfer and Transport Systems" is function of:
  - Thermal Power
  - Power split between coolants of dual cycle

- Dual loop increases Account 22.2 by 37%, per Miller.

- Example:

  2400 MW thermal power
  50/50 power split between He and LiPb coolants

  Account 22.2:

Single Loop	220 M$
Dual Loop	300 M$

He loop increases direct cost by ~80 M$ and COE by 2-3 mills/kWh

Question: Does incremental increase in η_{th} of added He loop outweigh drawbacks of high-pressure design, expensive heat transfer/transport system (Δ =2-3 mills/kWh), high replacement cost (Δ ~3 mills/kWh), and high pumping power (>10 MW)?