

Blanket Design Issues for ARIES-AT

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Web address:

<http://fti.neep.wisc.edu/FTI/ARIES/AUG99/blanket.pdf>

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Design Parameters



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
: 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, smaller radii result in higher wall loading

^{*} Between X points

Preliminary 3-D Nuclear Parameters



- 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 separate 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

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



($P_n = 1736$ MW - ARIES-RS)

Nuclear Heating (MW)	<u>Inboard</u>	<u>Outboard</u>	<u>Divertor</u>	<u>Total</u>
FW or DP	140	385	46	571 (30%)
Blanket	250	755	---	1005 (53%)
HT Shield	<u>80</u>	<u>30</u>	<u>214</u>	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



($P_n = 1736$ MW - ARIES-RS)

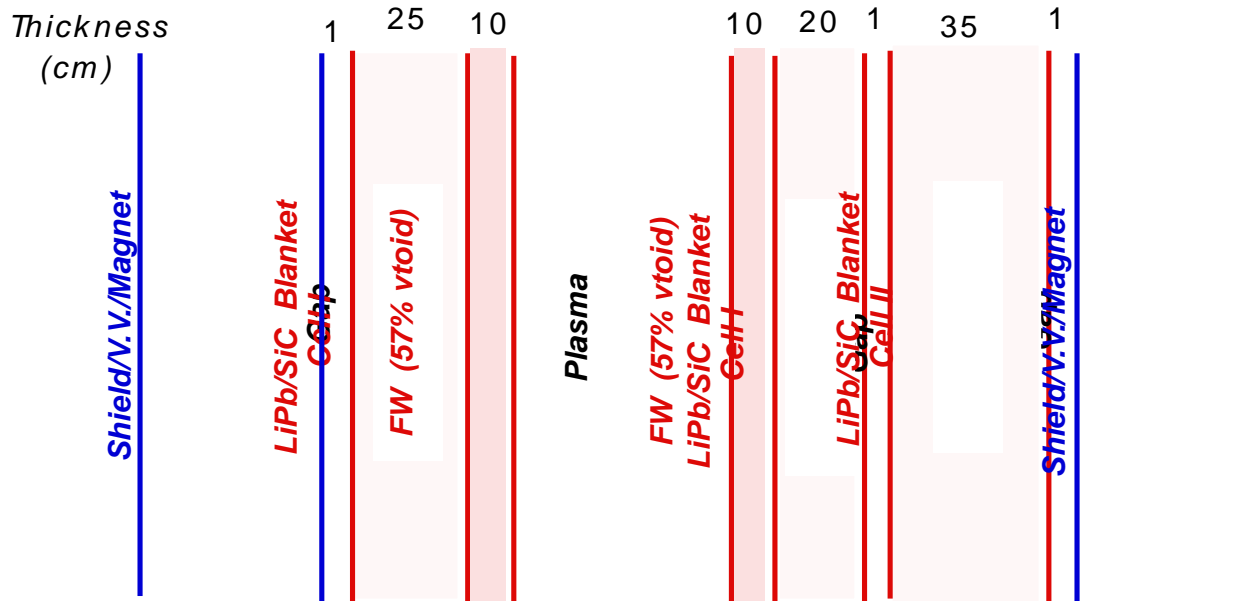
Nuclear Heating (MW)	<u>Inboard</u>	<u>Outboard</u>	<u>Divertor</u>	<u>Total</u>
FW or DP	32	92	~10	134 (7%)
Blanket/ manifolds	334	1068	---	1402 (73%)
HT Shield	<u>114</u>	<u>22</u>	~ <u>250</u>	<u>386</u> (20%)
Total	480 (25%)	1182 (62%)	260 (13%)	1922

Overall neutron energy multiplication is 1.1

Blanket Segmentation

- 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

	Single Unit FW/B 2.8 FPY 14 Replacements during 40 FPY			Segmented Blanket			
SiC Vol. (m ³)	Integral SiC Vol. (m ³)	Direct Cost* (M\$)	Lifetime (FPY)	# of Replace. in 40 FPY	Integral SiC Vol. (m ³)	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

- 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)?