Summary of ARIES Power Core Unit Costs

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Background

- This past year we have investigated and analyzed several concepts for:
  - Blanket and shielding configurations and material compositions
  - External and internal vacuum vessel location
  - Coil configurations (field periods and number of coils/period)
  - Maintenance approaches
- Next year, we will begin to assess integrated solutions
- The initial starting point will be the LiPb/FS/He with internal vacuum vessel
- The following unit costs are applicable to this set

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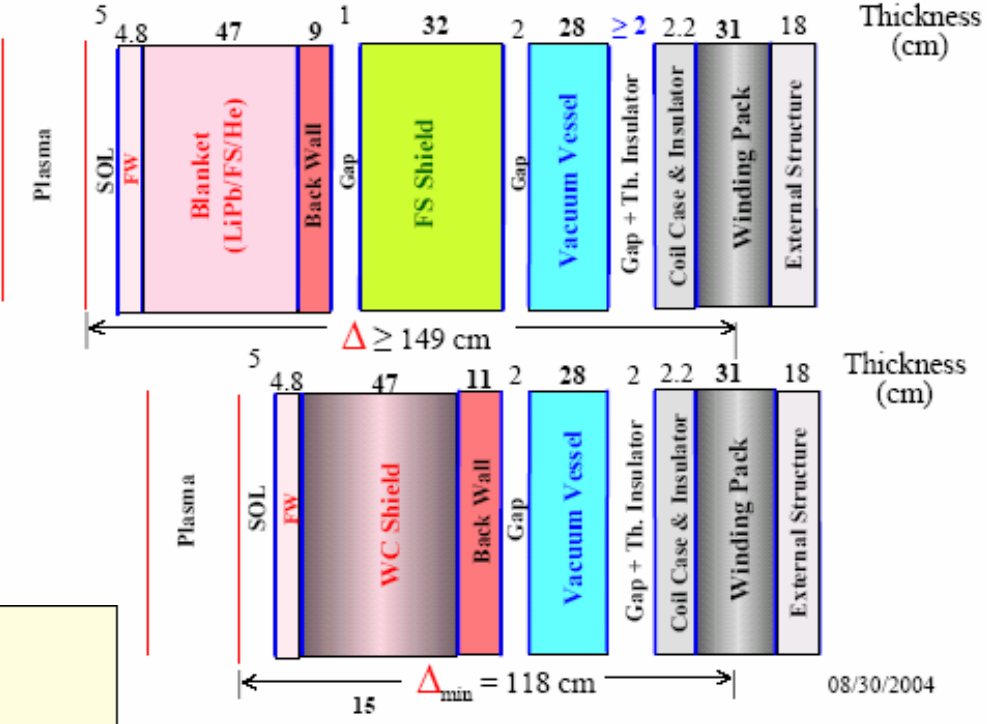
First Power Core Assessment

LiPb/FS/He/Intl VV



Component	Composition
FW	31% FS Structure 69% He Coolant
Blanket#	90% LiPb with 90% enriched Li 3% FS Structure 7% He Coolant
Back Wall	80% FS Structure 20% He Coolant
WC Shield*	90% WC Filler 3% FS Structure 7% He Coolant
FS Shield	15% FS Structure 10% He Coolant 75% Borated Steel Filler
VV	28% FS Structure 49% Water 23% Borated Steel Filler

Use this configuration and composition as a starting point

Costing Basis Background

Ferritic Steel (FS)

- Historical data from prior studies
- Data from variety of sources:
  - Blanket designs, conceptual (higher costs)
  - Vacuum vessels, detailed (moderate costs)
  - Structures, detailed (lower costs)
  - Shielding spheres or slabs (just above raw material cost)
- Reduced Activation Ferritic Steel is limited usage (higher costs than common steels)

Borated FS Filler	$31/kg
External VV, Stellarator	$48/kg
Internal VV , Stellarator	$56/kg
HT Shield, Stellarator	$78/kg
FWB, Stellarator	$103/kg

Silicon Carbide Insulator (SiC)

- Cost at $101/kg is somewhat higher than bulk SiC costs

Tungsten Carbide (WC)

- Current material quotes for high purity spheres
  - Raw material quotes range from $18-20/kg to $87/kg, with powder producers lower and resellers higher
  - Assume $20/kg for powder cost
  - Fabrication into spheres at $6/kg plus $4/kg for fee and handling, hence unit cost = $30/kg

Lead (Pb)

- Current material quotes for high purity (99.97%) ingots is $3/kg
  - Cost including shipping and handling = $3.50/kg

Costing Basis Background

Lithium, Natural (Li) (approx. 92.6% Li_7, 7.4% Li_6)

- Current principal usage are batteries, alloying element, and medical
- Requests for quotes were generally ineffective
  - Mostly firms that deal in very small quantities
  - Need to involve corporate purchasing resources
  - Historical cost rose to near $95/kg in 1998
  - FMC Lithium Corp budgetary quote of $55/kg for 100 MT lots

Isotopically Separated Li_6, Li_7

- Primary separation process is Column Exchange (COMEX)
- US Government was primary producer/user through 1963
- ORNL Y-12 site still stockpiles Li_6 and Li_7 materials
- Budgetary quote for small quantities unreasonably high (ICON Services, NJ)
  - Li_7 (98% atom) is $3000/kg, Li_6 (95% atom) is $9000/kg
  - Vendor volunteered to scope a large scale production estimate
- Placeholder cost estimate of isotopically pure Li_7 = $300/kg and Li_6 = $900/kg
- Price of enriching natural lithium to 90% Li_6 may be much cheaper than mixing high purity isotopic lithium concentrations @ $840/kg
- Cost of $Li_{17}Pb_{83}$ with 90% enriched Li_6 is $145.70/kg
- Solution may be to purchase raw materials and build COMEX facility

Preparation for Estimate

Put on your Rose-Colored Glasses for the next slide

CS Budgetary Estimate

Generic Volumes and Masses for Compact Stellarators
Calculation based on torus shell formula; $V=2*Pi^2*R*(r_2^2-r_1^2)$

Three Field Period Compact Stellartor
Maj Rad, R= 8.250

Blanket Radial Build, m — **Coverage =** 0.920

Element	Delta Radius	Inner Rad	Outer Rad	Volume	Material	Density	Vol Frct	Mass	Unit Cost	Cost
	m	m	m	m3		kg/m3		MT	$/kg	M$
Plasma	1.850	0.000	1.850	557.348						
SOL	0.050	1.850	1.900							
First Wall	0.048	1.900	1.948	27.672	FS	7800.000	0.31	67	$103	$6.89
Blanket	0.470	1.948	2.418	307.434	FS	7800.000	0.033	79	$103	$8.15
				307.434	$Li_{17}Pb_{83}$	9501.000	0.9	2,629	$146	$383.02
Back Wall	0.090	2.418	2.508	66.421	FS	7800.000	0.8	414	$103	$42.69
Gap	0.010	2.508	2.518							
HT Shield	0.320	2.518	2.838	256.780	FS	7800.000	0.15	300	$78	$23.43
				256.780	Borated FS	7800.000	0.75	1,502	$31	$46.57
Gap	0.020	2.838	2.858							
VV, Internal	0.280	2.858	3.138	251.530	FS	7800.000	0.28	549	$56	$30.76
				251.530	Borated FS	7800.000	0.23	451	$31	$13.99
									Subtotal	$555.51

Shield Zone Radial Build — **Coverage =** 0.080

Element	Delta Radius	Inner Rad	Outer Rad	Volume	Material	Density	Vol %	Mass	Unit Cost	Cost
	m	m	m	m3		kg/m3	%	kg	$/kg	M$
Plasma	1.850	0.000	1.850	557.348						
SOL	0.050	1.850	1.900							
First Wall	0.048	1.900	1.948	2.406	FS	7800.000	0.31	6	$103	$0.60
WC Shield	0.470	1.948	2.418	26.733	FS	7800.000	0.03	6	$103	$0.64
					WC	15500.000	0.9	0	$30	$0.00
Back Wall	0.110	2.418	2.528	7.088	FS	7800.000	0.8	44	$103	$4.56
Gap	0.020	2.528	2.548	1.323						
Vac Vessel	0.280	2.548	2.828	19.611	FS	7800.000	0.28	43	$56	$2.40
					Borated FS	7800.000	0.23	0	$31	$0.00
									Subtotal	$8.20
									Total	**$563.71**

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Comparison of -CS with -AT

	ARIES-AT	ARIES-CS*
Plasma Volume	328	557
First Wall Surface Area, m^2	425	618
First Wall Thickness, m	0.014	0.048
First Wall Volume, m^3	3.23	30
FWB Cost, M$	$67 (SiC)	$52.1 (w/o LiPb) $435(w/LiPb)
FWBS Cost, M$	$141.1 $174.3 (w/nat. LiPb)	$180.7 (w/o LiPb) $563.7 (w/LiPb)

* CS data calculated with simple torus formulas

Formulas are simplifications, but trends are reasonable. The cost of natural LiPb ($15.7/kg) was not included in ARIES-AT, which added $33.2M in power core and $83.1 M total. I am estimating the cost of 90% enriched LiPb $146/kg and $383M for blanket alone. The exo-blanket LiPb coolant would be approximately 150% higher.

Future Work

- **Refine existing material and fabrication unit costs**
- **Expand data base for additional configurations**
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