Final 3-D Neutronics Results

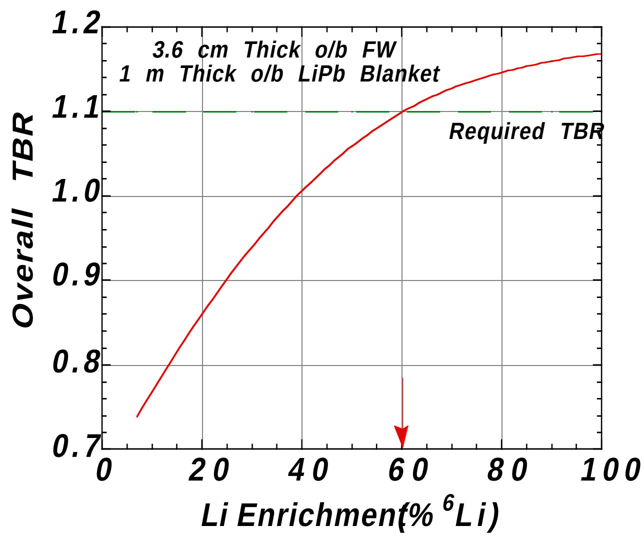
Laila El-Guebaly
Fusion Technology Institute
University of Wisconsin - Madison

ARIES E-Meeting
4 December 1998
PPPL

Nuclear Parameters

University of Wisconsin

- 20 cm thick helium cooled i/b shield is optimal for ARIES-ST
- Overall TBR= 1.1 (1 m thick LiPb/FS/SiC/He Blanket, 60% enriched Li)



- Overall M_n= 1.11 (excluding heating of TF coil and LT div. shield)
- FW/B End-of-Life Fluence= 18 MWy/m^2 for FS
- Lifetimes:

o/b FW/Blanket/Manifolds	3 FPY
i/b FW/Shield	3 FPY
Div. Plates and Manifolds	3 FPY
Center Post	6 FPY
TF-coil Shell	40 FPY
PF Magnets	40 FPY
Div. HT and LT shields	40 FPY

W Stabilizing Shells 3(?) FPY

Nuclear Heat Loads to All Components

University of Wisconsin

(P_f = 2859 MW , P_n= 2287 MW)

Nuclear Heating (MW)	Inboard	Outboard	Divertor	Total
Inboard W Shells	71	----	----	71
FW or Div. Plates	18	100	42	160
Blanket	----	1929	----	1929
Manifolds	----	15	64	79
Shield	199	-----	95	294
Total	288	2044	201	2533
				(⇒ M_n=1.11)
Surface Heating	117	198	345	660
Total Thermal Power	405	2242	546	~3200

Low Grade Heat (MW):

CP	164	
TF-coil Shell	39	(21 in collar + 18 in shell)
Total in TF coil	203	
Div. LT Shield	8	
Total	211	(9% of P_n or 6% of P_{th})

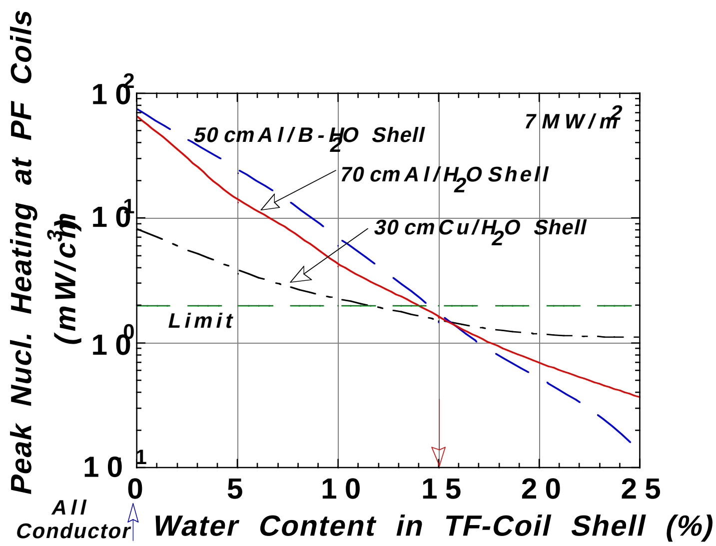
Radiation Damage to PF Coils

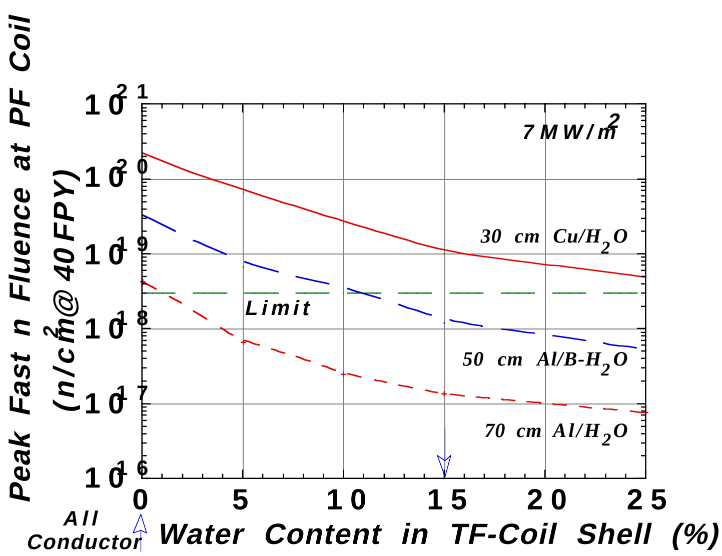
University of Wisconsin

- PF coils 1,2 are well protected by HT and LT divertor shields

- Outboard blanket and TF-coil shell protect PF coils 3,4,5. One of following options should be considered to satisfy PF magnets radiation limits:

  30 cm thick Cu/H_2O (85/15) TF-coil shell
  50 cm thick Al/B-H_2O (85/15) TF-coil shell
  70 cm thick Al/H_2O (85/15) TF-coil shell





Radiation Streaming Through NBI

University of Wisconsin

- 2 NBI's were included in 3-D model
- NBI sets on insulator between upper and middle TF-coil shells
- Neutrons streaming through NBI will induce swelling in insulators
- Swelling depends on insulator type and fluence level
- Spinel has high radiation resistance to swelling (compared to BeO, Al_2O_3, MgO)
- 10^{22} n/cm^2 fast n fluence (E_n > 0.1 MeV) results in 1% swelling in spinel
- 3-D calculations indicate that fast n flux (E_n > 0.1 MeV) at insulator is 5×10^{12} n/cm^{2}s, resulting in < 1% swelling at end of plant life (40 FPY). This means spinel will exhibit no significant change in volume and will not cause any stress problem to TF-coil shell.

20 cm Thick He-Cooled Inboard Shield is Optimal for ARIES-ST

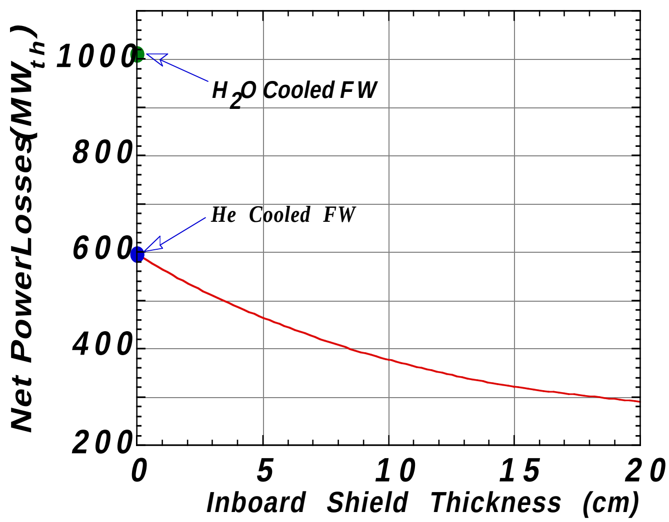
University of Wisconsin

- Inboard power losses (and thus COE) minimize near 20 cm thick shield

- Net i/b power losses (in MW_{th})=

$$P_{\Omega} / \eta \;+\; NH_{CP} \;+\; PP/\eta \;-\; [SH + NH_{FW/Shell} \;+\; NH_{shield} \;+\; 0.9\, PP\,]$$

where P_{Ω} is CP Joule losses,
η is thermal conversion efficiency,
SH is Surface Heating,
NH is Nuclear Heating,
PP is He Pumping Power (90% of PP is recovered as thermal heat)



- Designs with i/b shields thinner than 20 cm will have higher COE (and lower breeding, higher CP damage, shorter CP lifetime, higher Cu radwaste stream, and higher CP decay heat)