Summary of FS Lifetime Assessment and Activation Analysis

L. El-Guebaly
Fusion Technology Institute
University of Wisconsin - Madison

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(Full presentation posted @ http://fti.neep.wisc.edu/FTI/POSTERS/OCT2002/lae_lifetime.pdf)

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Objectives

- Assess nuclear performance of structure-free blanket concept using ARIES design rules
  - Lifetime of FS based on radiation damage:
    - dpa
    - Helium production
  - Breeding potential of candidate breeders:
    - Flibe
    - Flinabe.
  - Waste disposal rating of FS-based components (shield, nozzles, feeding tubes).
- Estimate reduction in waste for thick liquid wall concept.

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ARIES Requirements and Design Limits

dpa*:	
ODS-FS structure	**≤ 200 dpa**
304-SS structure	**≤ 25 dpa**
Overall TBR	**≥ 1.08**
Helium production for reweldability of FS	**≤ 1 He appm**
WDR for Class C low level waste	**≤ 1**

* Thermal creep strength @ EOL could be more restrictive than radiation damage, per M. Billone (ANL).

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Key Parameters

Target yield	458.7 MJ
Rep rate	4 Hz
Average source neutron energy	11.75 MeV
Penetrations coverage	3%
Plant lifetime	40 FPY
Availability	85%

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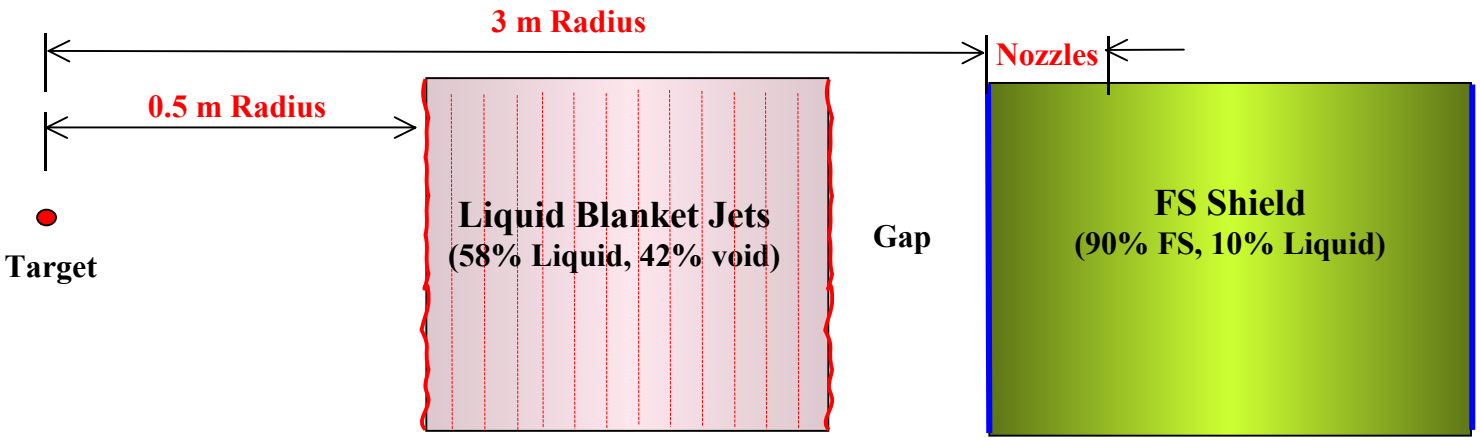
Schematic of Radial Build



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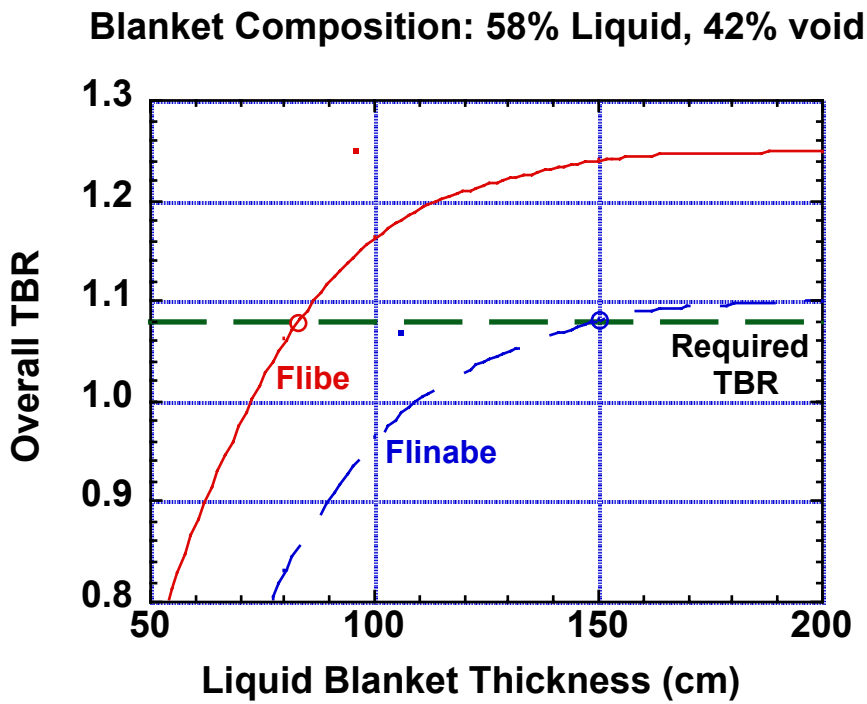
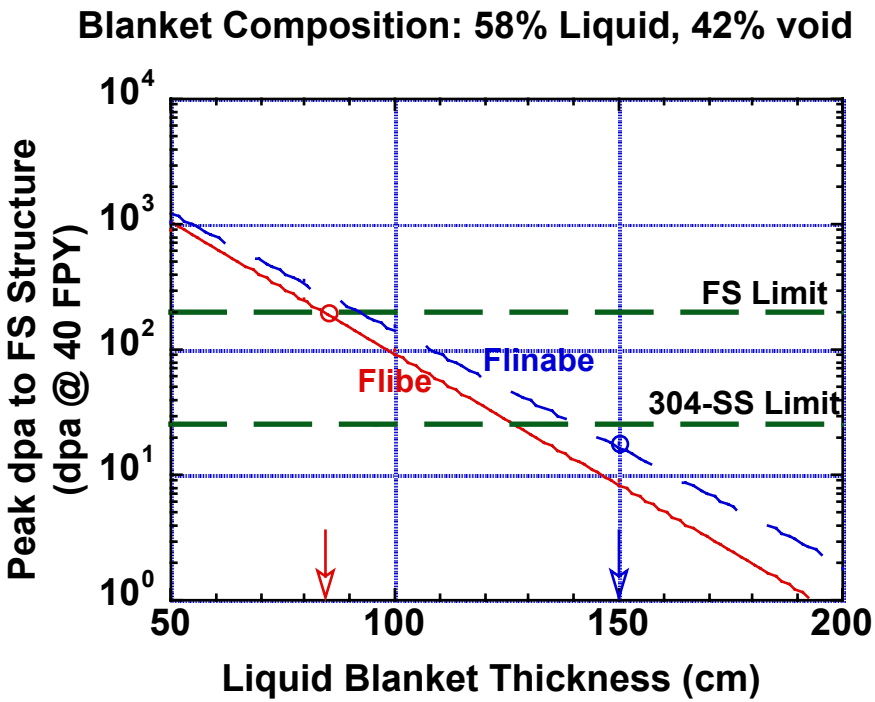
83 cm Thick Flibe and 150 cm Thick Flinabe Blankets Meet ARIES Breeding Requirement



dpa Limit Can be Met with 85-130 cm Flibe Blanket and 150 cm Flinabe Blanket



- 85 cm Flibe blanket meets FS 200 dpa limit.
- 130 cm Flibe *overbreeding* blanket meets 304-SS 25 dpa limit.
- 1.5 m Flinabe blanket meets both limits.

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Lifetime of Steel Structure Based on Radiation Damage

Breeder	**Flibe**		**Flinabe**
Blanket Thickness (meets both breeding requirement and dpa limit)	**85 cm**	**130 cm***	**150 cm**
Overall TBR	1.08	1.23	1.08
ODS-FS	40 FPY	–	>> 40 FPY
304-SS	–	40 FPY	55 FPY

* Overbreeding blanket.

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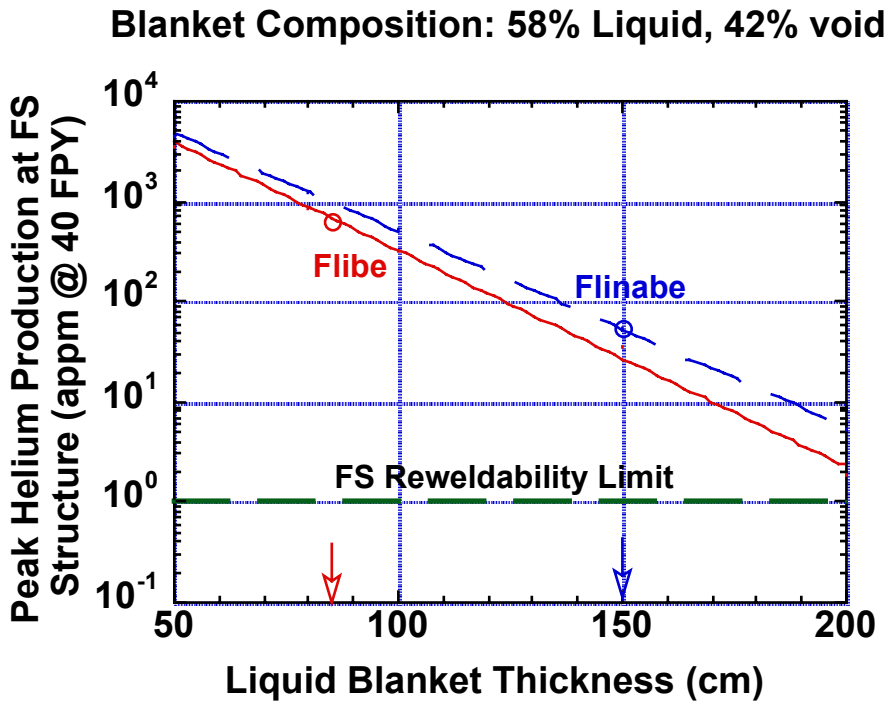
Helium Production is Excessive



Innermost shield layer/nozzles/feeding tubes cannot be re-welded at any time during operation.

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Steel Composition (in wt%)

	ODS-12YWT-FS* (Experimental Alloy)	ODS M-F82H-FS**	304-SS#
Fe	83.818	87.891	70.578
C	0.052	0.04	0.046
N	0.014	0.005	0.038
O	0.16	0.13	–
Si	0.1	0.24	0.47
P	–	0.005	0.026
S	0.001	0.002	0.012
Ti	0.35	0.09	0.03
V	0.01	0.29	–
Cr	12.58	8.7	17.7
Mn	0.05	0.45	1.17
Co	–	0.0028	0.1
Ni	0.27	0.0474	9.3
Cu	0.02	0.01	0.2
Nb	0.01	0.00033	–
Mo	0.02	0.0021	0.33
Ta	–	0.08	–
W	2.44	2	–
Y	0.16	0.7	–

* R. Klueh et al., "Microstructure and Mechanical Properties of Oxide Dispersion-Strengthened Steels" fusion materials semiannual progress report for the period ending June 30, 2000 (DOE/ER-0313/28), pp. 123-130. Fe-12Cr-3W-0.4Ti-0.25Y_2O_3 (12YWT) experimental alloy.

** IEA Modified F82H FS + 0.25wt% Y_2O_3, per M. Billone (ANL). Other elements include: B, Al, As, Pd, Ag, Cd, Sn, Sb, Os, Ir, Bi, Eu, Tb, Dy, Ho, Er, U.

\# Starfire report: C. Baker et. al, "Starfire-A Commercial Tokamak Fusion Power Plant Study," Argonne National Laboratory Report, ANL/FPP-80-1 (1980).

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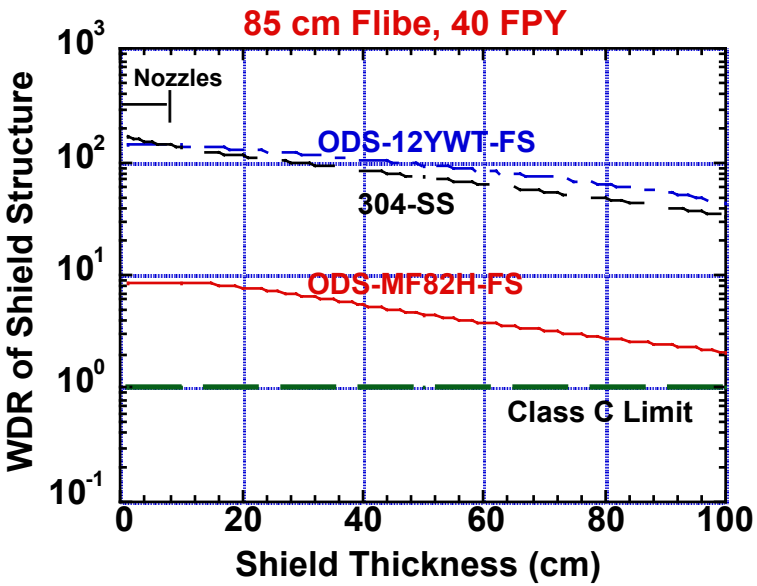
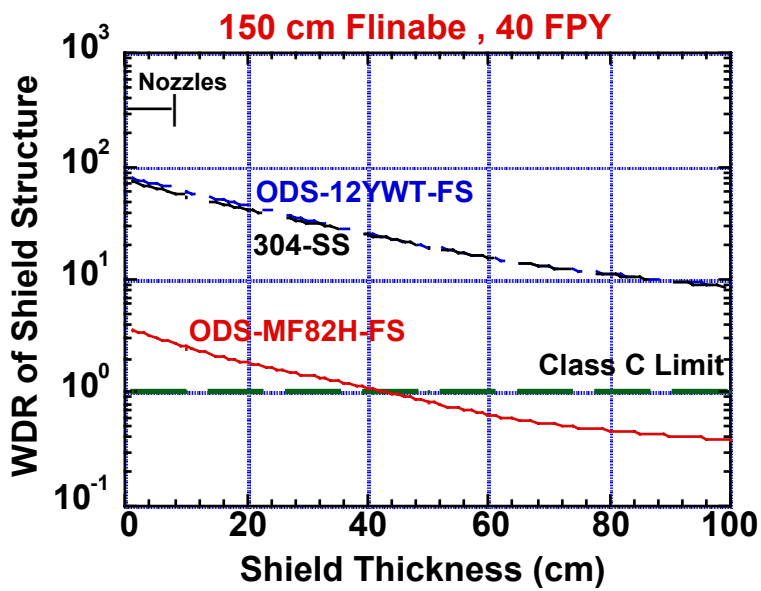
All Steel Alloys Generate High Level Waste





- ODS-MF82H-FS offers lowest WDR.
- Thicker Flinabe blanket results in lower WDR.
- Main contributors to WDR: ^{94}Nb (from Nb), ^{99}Tc (from Mo), and ^{192n}Ir (from W).
- Potential solutions to meet waste requirement (WDR < 1):
  - Control Mo and Nb,
  - Thicken blanket (and readjust TBR).

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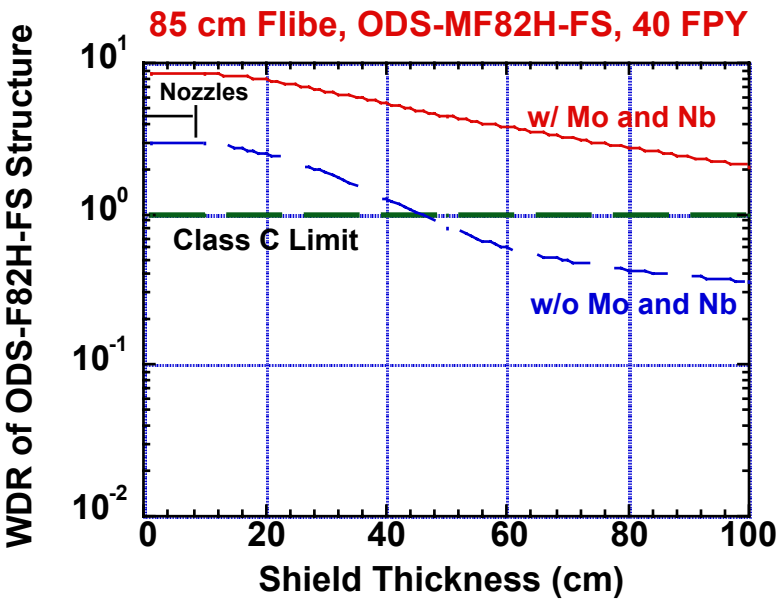
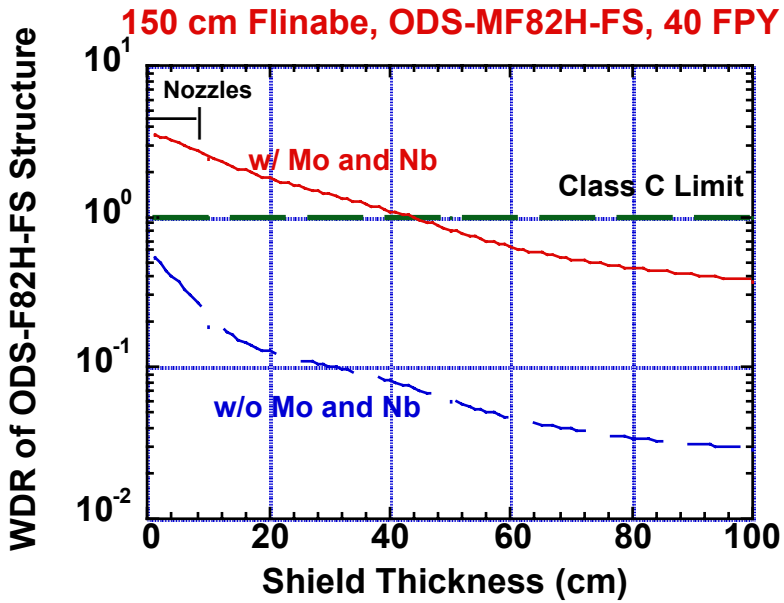
Effect of Mo and Nb on WDR





- In practice, Mo and Nb impurities cannot be zeroed out. Actual level depends on $/kg to keep Mo and Nb < 1 wppm.
- Flibe shield **with Mo/Nb control** should be > 50 cm thick to qualify as LLW.
- Flinabe shield **without Mo/Nb control** meets waste requirement if ≥ 45 cm thick.
- **Nozzles**/feeding tubes generate high level waste unless protected by thicker blanket **or** mixed with shield and disposed as single unit at EOL.

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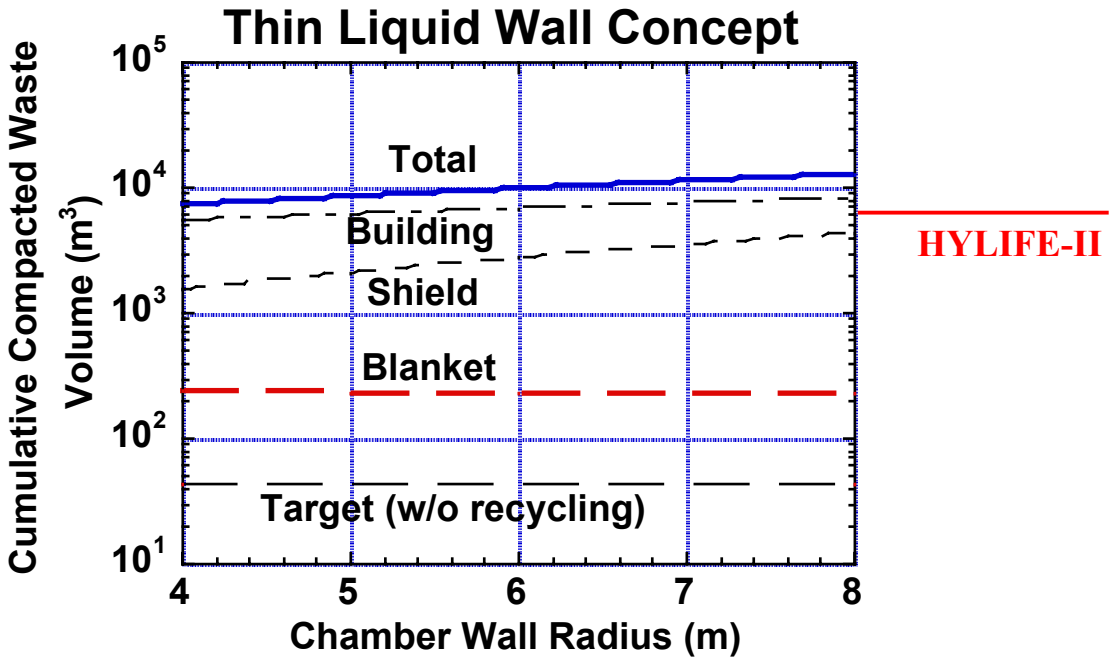
Revisiting Logic Behind Thick Liquid Wall Concept



- Thick liquid wall concept developed to eliminate blanket replacement, **reduce waste**, and increase availability by 10% ⇒ 20% lower COE, per R. Moir (UCRL-JC-115748, April 1994).
- In IFE solid wall designs, blanket generates only 2-4% of total waste
  - ⇒ **Thick liquid wall concept offers small waste reduction. (same conclusion made for MFE - APEX project)**
  - ⇒ **No significant difference in waste volume generated by thin and thick liquid wall concepts.**

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Conclusions

- Class C LLW requirement is more restrictive than breeding and dpa requirements.
- No breeding problem identified for Flibe and Flinabe.
- 85/150 cm thick Flibe/Flinabe blankets provide TBR of 1.08 **and** meet FS dpa limit.
- Helium production in FS is excessive and precludes FS reweldability during operation.
- All steel alloys produce **high** level waste (WDR >> 1). **Low** level waste can be achieved with combination of Mo/Nb control **and** blanket/shield adjustment.
- Nozzles/Feeding tubes need additional protection to qualify as LLW unless combined with shield.
- Both **thin** and **thick** liquid wall concepts generate ~ same volume of waste.

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