

Summary of FS Lifetime Assessment and Activation Analysis

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



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.



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

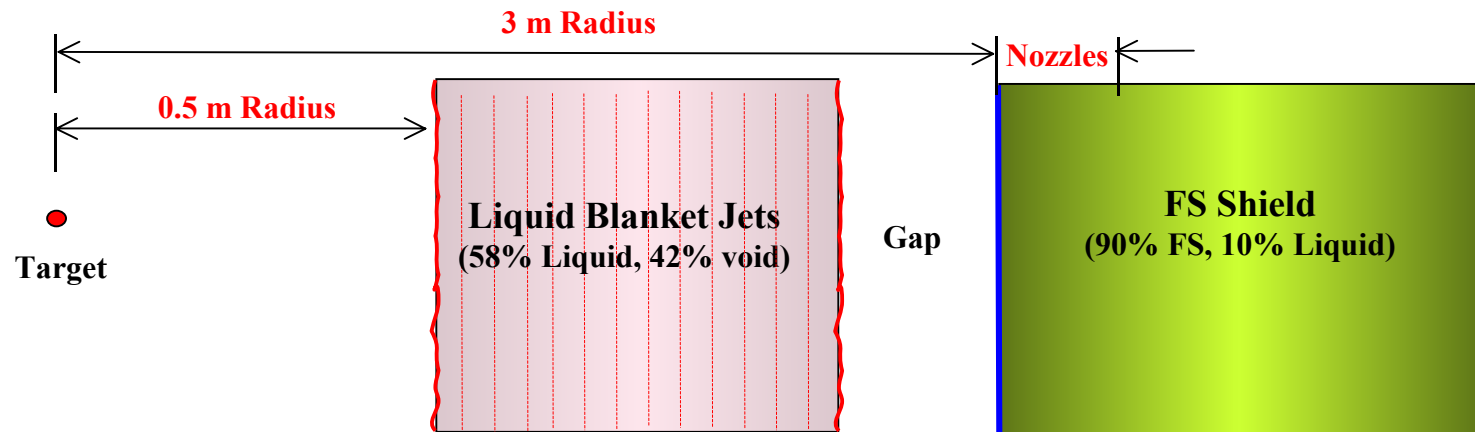
* Thermal creep strength @ EOL could be more restrictive than radiation damage, per M. Billone (ANL).

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%

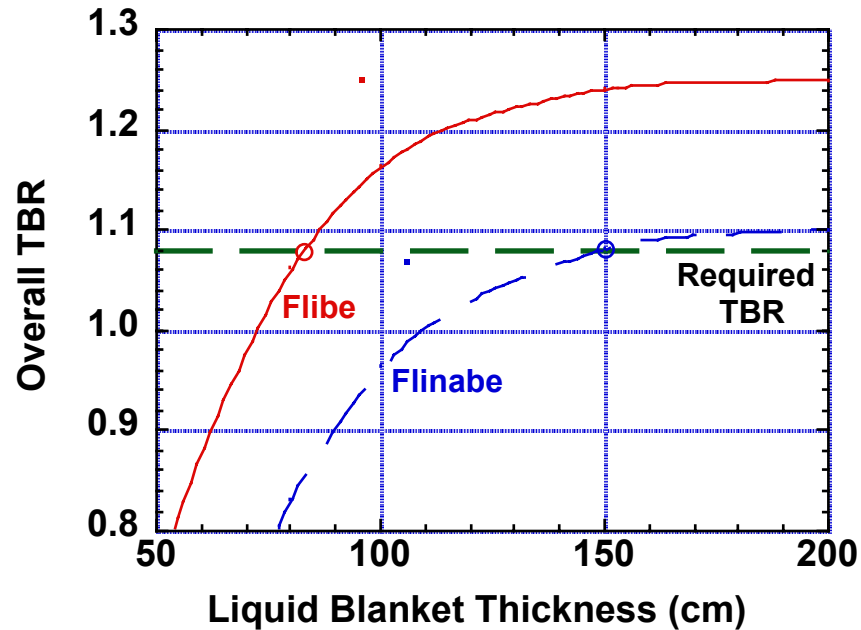


Schematic of Radial Build

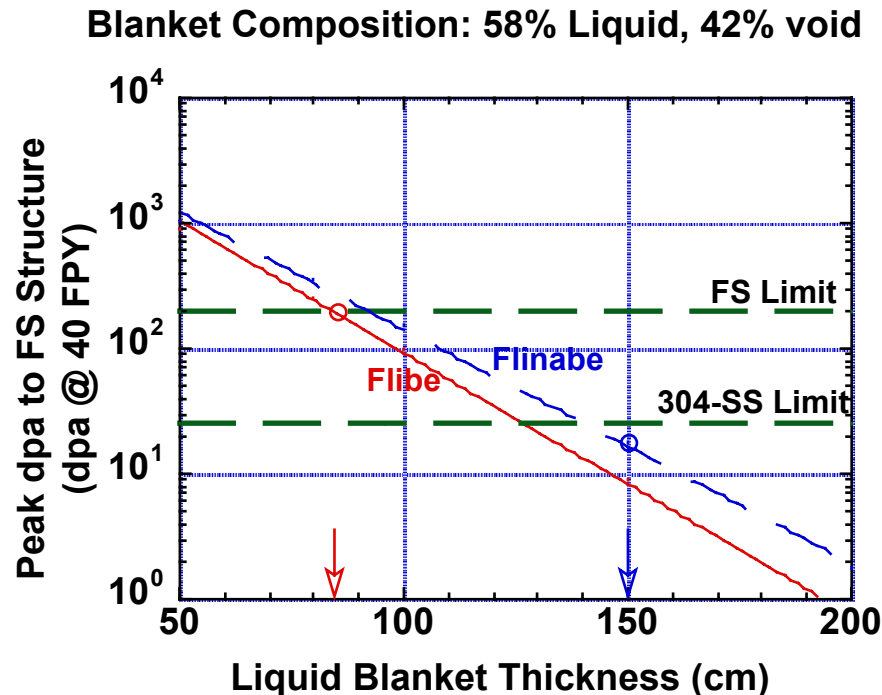


83 cm Thick Flibe and 150 cm Thick Flinabe Blankets Meet ARIES Breeding Requirement

Blanket Composition: 58% Liquid, 42% void



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.

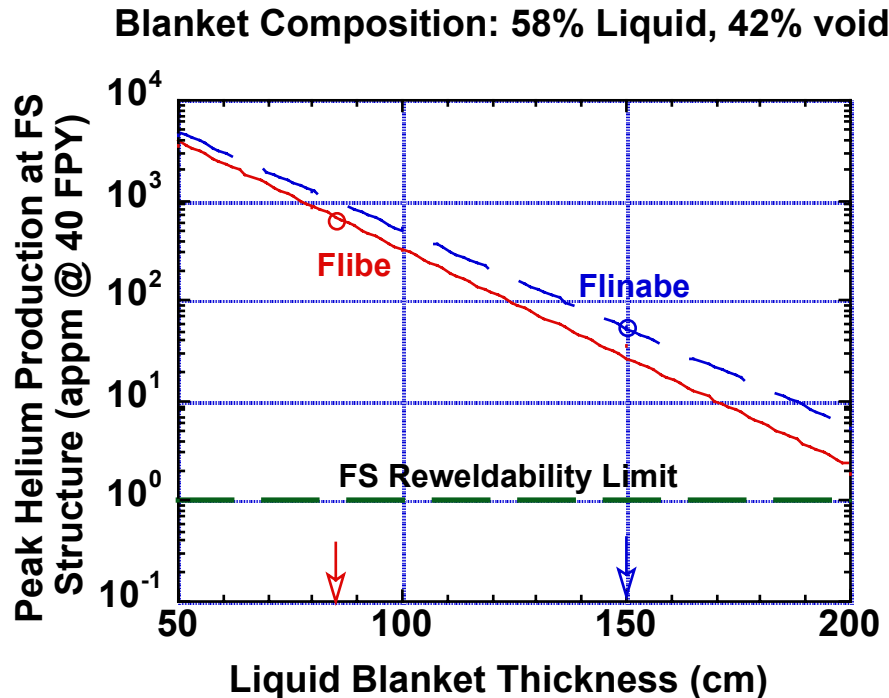


Lifetime of Steel Structure Based on Radiation Damage

Breeder	<u>Flibe</u>	<u>Flinabe</u>	
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.

Helium Production is Excessive



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



Steel Composition (in wt%)

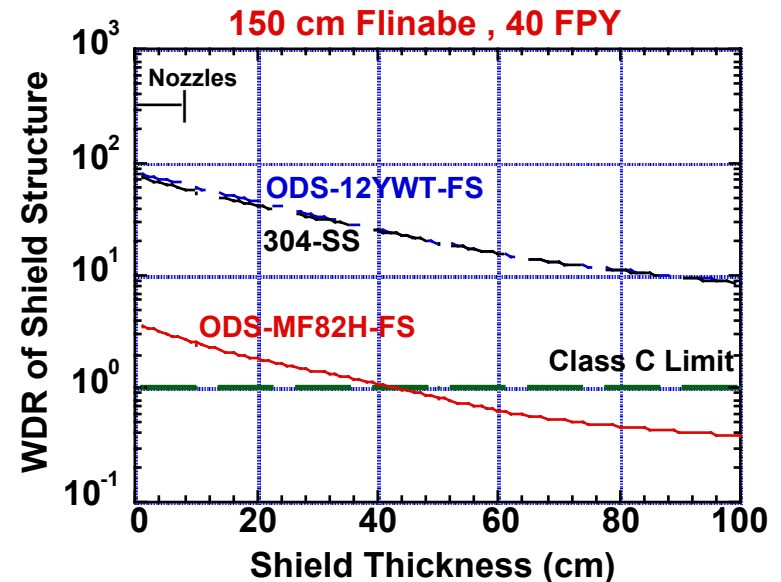
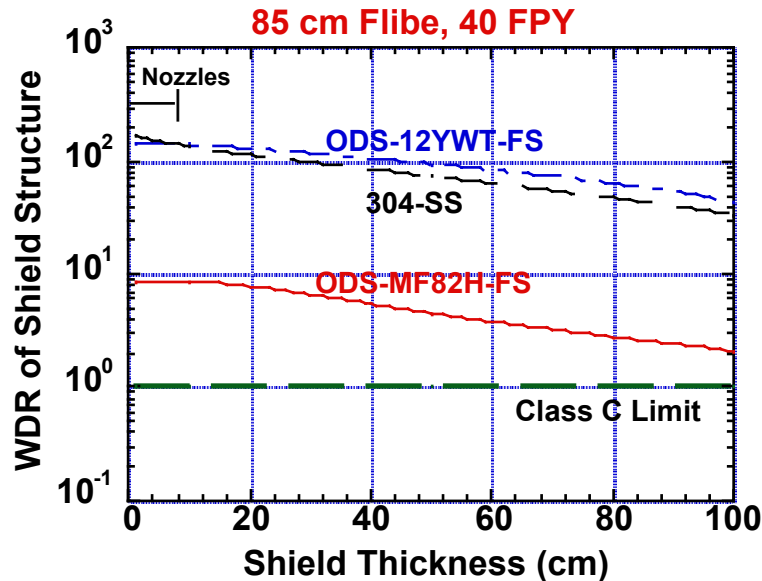
	<u>ODS-12YWT-FS*</u> (Experimental Alloy)	<u>ODS M-F82H-FS**</u>	<u>304-SS#</u>
Fe	83.818	87.891	70.578
C	0.052	0.04	0.046
N	0.014	0.005	0.038
O	0.16	0.13	—
Si	0.1	0.24	0.47
P	—	0.005	0.026
S	0.001	0.002	0.012
Ti	0.35	0.09	0.03
V	0.01	0.29	—
Cr	12.58	8.7	17.7
Mn	0.05	0.45	1.17
Co	—	0.0028	0.1
Ni	0.27	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-0.25Y₂O₃ (12YWT) experimental alloy.

** IEA Modified F82H FS + 0.25wt% Y₂O₃, 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).

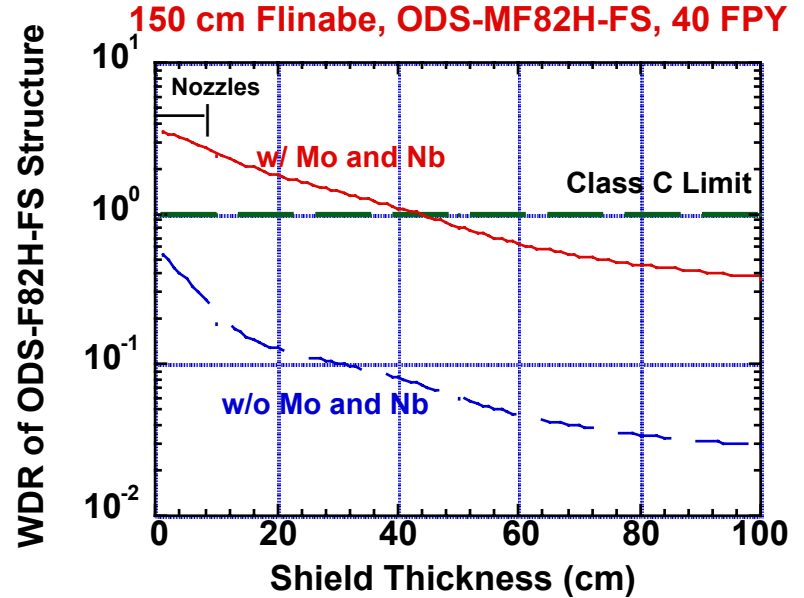
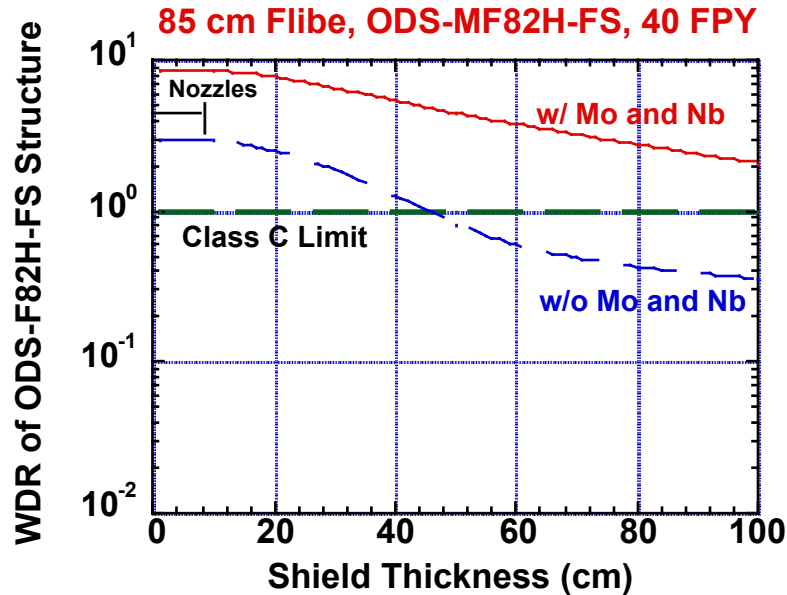
All Steel Alloys Generate High Level Waste



- 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 ^{192}nIr (from W).
- Potential solutions to meet waste requirement (WDR < 1):
 - Control Mo and Nb,
 - Thicken blanket (and readjust TBR).



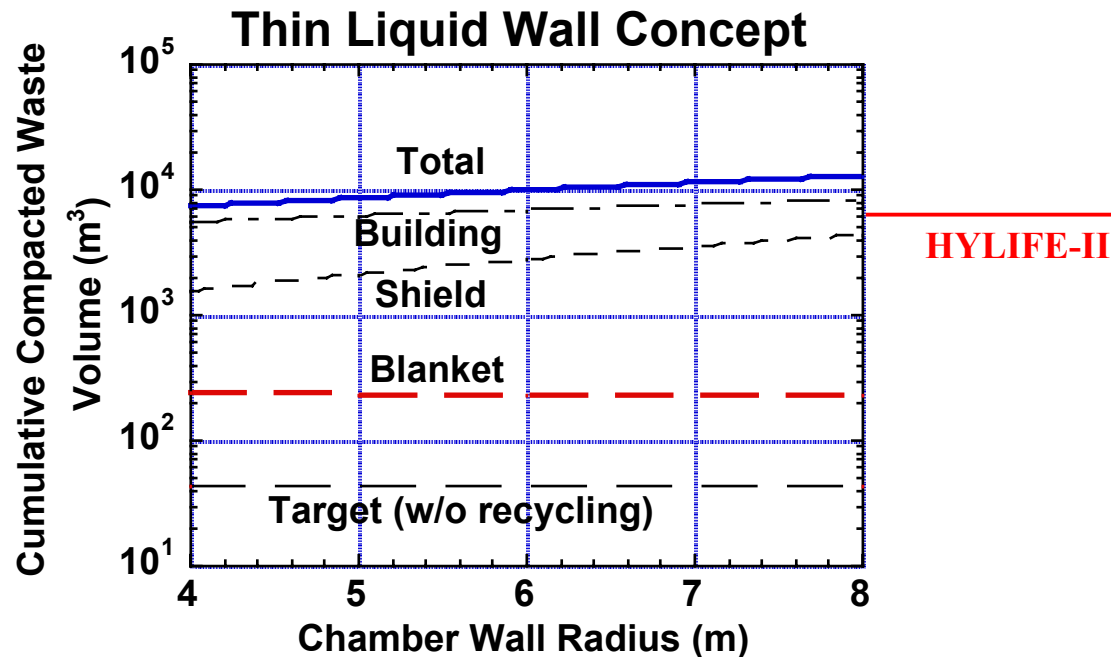
Effect of Mo and Nb on WDR



- 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.



Revisiting Logic Behind Thick Liquid Wall Concept



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



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 \gg 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.**

