Radiological Issues for Thin Liquid Walls of ARIES-IFE Study

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Objectives

- Develop activation approach and identify radiological issues for candidate liquid wall (LW) materials:

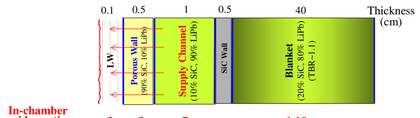
Liquid Metals*	Molten Salts
LiPb	Flibe# $_{(LiF)_2, BeF_2)}$
Pb	Flinabe# $_{(NaF, LiF, BeF_2)}$
Sn	

* No major activation problems identified for Li
\# Flibe and Flinabe exhibits similar activation behavior

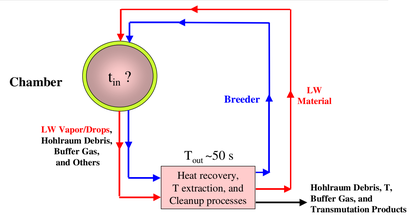
Representative Radial Build

- SiC/SiC composite structure and LiPb LW/coolant/breeder.
- Design parameters:

SiC T_{max}	1000 °C
Surface heat flux	≤ 1 MW/m²
⇒ Chamber radius	≥ 6 m
LiPb ΔT	200-300 °C
LiPb velocity	4-6 m/s
LiPb T_{max}	1100 °C
LW Thickness	1 mm



LW Cycle



In-chamber residence time for LW is unknown ⇒ parameterize it

LW and Breeder Options

Blanket:	Candidate LW Materials	
Liquid breeders:	Preferred	Backup
LiPb*	LiPb*	Pb
Flibe+	Flibe+	
Flinabe	Flinabe	
Li#	Li#	Ga
LiSn	LiSn	Sn

Recommendation: Use same breeder for LW to minimize waste stream

Solid breeders:		
Li_2O**, Li_2ZrO_3, Li_4SiO_4, Li_2TiO_3, $LiAlO_2$	Pb**	Sn, Ga

* HIBALL (UW-1981), HIBALL-II (UW-1984), LIBRA (UW-1990), LIBRA-SP (UW-1995)
* OSIRIUS (LLNL-1992)
\# LIBRA-LITE (UW-1991)
** Prometheus (MDC-1992)

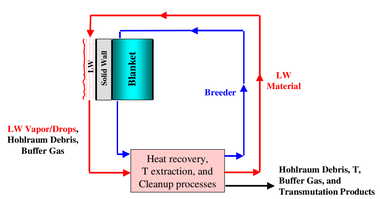
Computational Tools and Model for Pulsed Activation Analysis

- **Spherical model**
- **Neutron and gamma transport analysis:**
  - **DANTSYS discrete ordinate code**
  - **175 neutron and 42 gamma group structure**
  - **P_3-S_8 approximation**
- **Activation analysis:**
  - **ALARA code**
  - **Exact modeling of pulse sequence**
  - **175 neutron group structure**
- **Nuclear Data:**
  - **FENDL-2 IAEA cross section library**

Activation Assessment

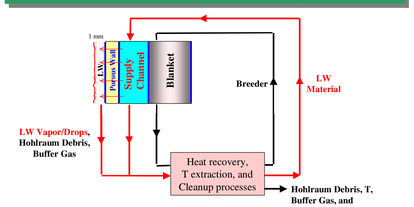
- **Develop activation approach for two liquid wall supply methods:**
  - **Tangential injection**
  - **Porous wall injection.**
- **Consider two extreme activation cases:**
  - **No mixing of LW material with breeder** (worst activation case)
  - **Mixing of LW material with breeder inside and outside chamber.**
- **Identify:**
  - **Waste disposal rating (WDR) for liquids and breeders**
  - **Means for waste minimization.**

Tangential Injection Option



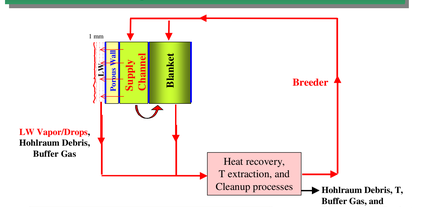
No outside mixing of LW with breeder

Porous Wall Injection - Option I (Solid Breeder Blanket)



No mixing with solid breeder outside chamber

Porous Wall Injection - Option II (Liquid Breeder Blanket)



Use same breeder for LW to minimize waste

Route breeder exiting supply channel through blanket to increase ΔT and enhance thermal conversion efficiency

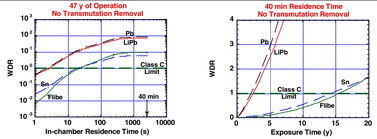
Conclusions

- **In most cases, candidate liquids generate multi-thousand tonnes of high-level waste.**
- **Tangential injection scheme results in highest WDR.**
- **Pb and LiPb are more radioactive than Sn and Flibe.**
- **Online removal of transmutation products could allow tonnes of liquid materials to be disposed as low-level waste or preferably, released for use in similar applications.**
- **Recommendation: Employ same breeding material for liquid film to minimize inventory and waste stream.**

ARIES-IFE Operating Conditions

HIB Fusion Yield	**460 MJ**
Rep Rate	**4 Hz**
# of Shots	**190 million/y**
Chamber Radius	**6 m**
Neutron Wall Loading	**~3 MW/m²**
Plant Lifetime	**40 FPY**
Availability	**85%**

WDR - Tangential Injection (No Outside Mixing with Breeder)



- WDR increases with LW residence time and saturates at ~ 40 min.
- **To dispose as LLW or reuse in other devices:**
  - Limit LW service life to ≤ 16 y
  - Control in-chamber residence time to ≤ 25 s
  - Or, filter out transmutation products online.

WDR - Porous Wall Injection (No Outside Mixing with Breeder - Prometheus-type)

- Example: Solid breeder blanket with Pb (or Sn) seeping from supply channel through porous wall.
- 1 mm thick LW controls volumetric average WDR#.
- Results for ~ 40 min residence time and 47 y of operation:

	WDR*
Pb	14
Sn	0.94

- Filter out Bi to reuse Pb in other devices or dispose as LLW.

* No transmutation products removal
\# 86% from LW and 14% from supply channel

WDR - Porous Wall Injection (Outside Mixing with same Breeder)

- Blanket controls volumetric average WDR.
- WDR is not sensitive to in-chamber residence time of LW.
- Results for 47 y of operation:

	WDR*
LiPb	10
Flibe	0.8

- Filter out Bi to reuse LiPb in other devices or dispose as LLW.

* No transmutation products removal.