S&E considerations for IFE thick liquid wall concepts

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ARIES Meeting

April 22-23, 2002

U. Wisconsin, Madison

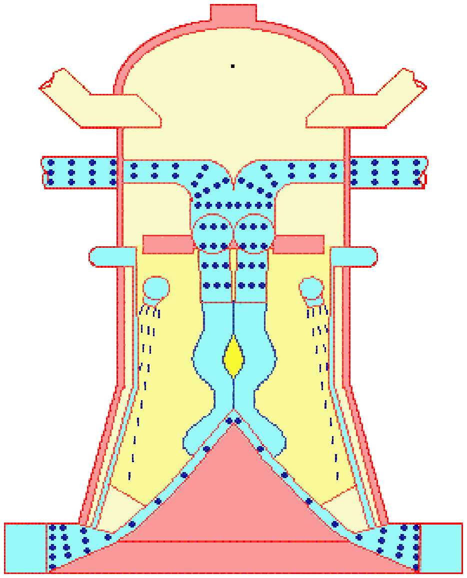
Work performed under the auspices of the U. S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48

Outline

- Overview of HYLIFE-II
- Overview of accident analyses
- Waste management options
- Alternative materials for thick liquid wall

HYLIFE-II IFE design has attractive S&E characteristics

- HYLIFE-II IFE concept is based on thick liquid wall chamber, heavy ion driver and double sided illumination (96 beams per side) of indirect drive targets

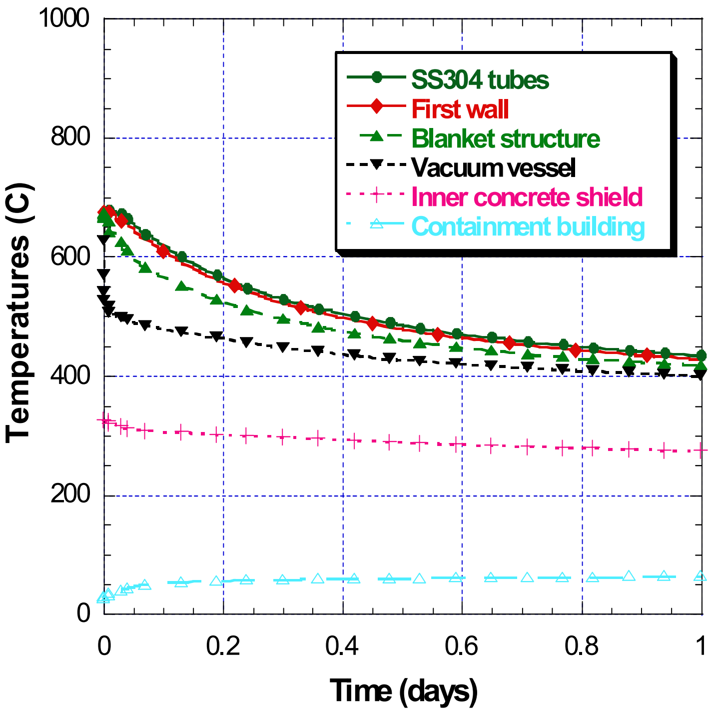


HYLIFE-II

- S&E characteristics have been given strong emphasis since the original design
- Flibe (Li_2BeF_4) oscillating and steady jets inside target chamber protect FSW and breed tritium fuel
- Two more flibe circuits contained in blanket for cooling and shielding

We have performed updated accident analysis for HYLIFE-II

- Updated computer codes and methodologies used to calculate heat transfer, thermal-hydraulics, and fusion product release and transport
- Simulated loss-of-coolant and loss-of-flow accidents (LOCA, LOFA) with simultaneous loss of confinement
- Radioactive afterheat low enough to allow cooling of structures during transient
- FSW temperature far below melting point ($T_{melt} \approx 1400$ ºC)



Temperature evolution of HYLIFE-II structures during LOCA accident

Tritium retained in structures dominates accident dose

- 3 radioactivity sources are available for mobilization in accident scenario
  - **FLIBE** inside chamber and in blanket structures
    - 10 kg of vaporized flibe form last reactor shot
    - 140 tonnes of liquid flibe present in the chamber at any given time
  - **SS304** corrosion and oxidation products
    - 8.3 kg of corrosion products in flibe inventory (1µm/y maintained at 1-y supply in a 1040m^2 area)
    - 0.5 kg mobilized by steam oxidation at accident temperatures (INEEL experimental data)
    - only 5% flibe in chamber at any time, gives a total 0.5 kg of SS304
  - **Tritium**: 140 g trapped in chamber, blanket and piping, giving ≈ 1 kg of HTO
- Results show that **tritium** dominates the off-site dose
- Accident dose ~ **5 rem** assuming conservative weather conditions

Alternatives for waste management in HYLIFE-II have been considered

- Previous IFE studies have traditionally used the **WDR** to evaluate if activated material qualifies for shallow land burial (WDR < 1)

- Shallow land burial may not be the best option for waste disposal:
  - space limitations
  - negative public perception of large volumes of waste

- The IAEA has proposed **clearance levels** of radionuclides below which traditional regulation may be relinquished on the grounds that the associated radiation hazards are trivial

- Here, we have updated the waste assessment for HYLIFE-II:
  - implemented calculation of Clearance Indexes (CIs) in the activation code
  - obtained WDRs and CIs for the different components to determine waste management options for the different power plant components

We have analyzed waste management options for HYLIFE-II

- First, using the results from neutron transport and activation calculations, we calculated the **WDRs** for the different components in HYLIFE-II

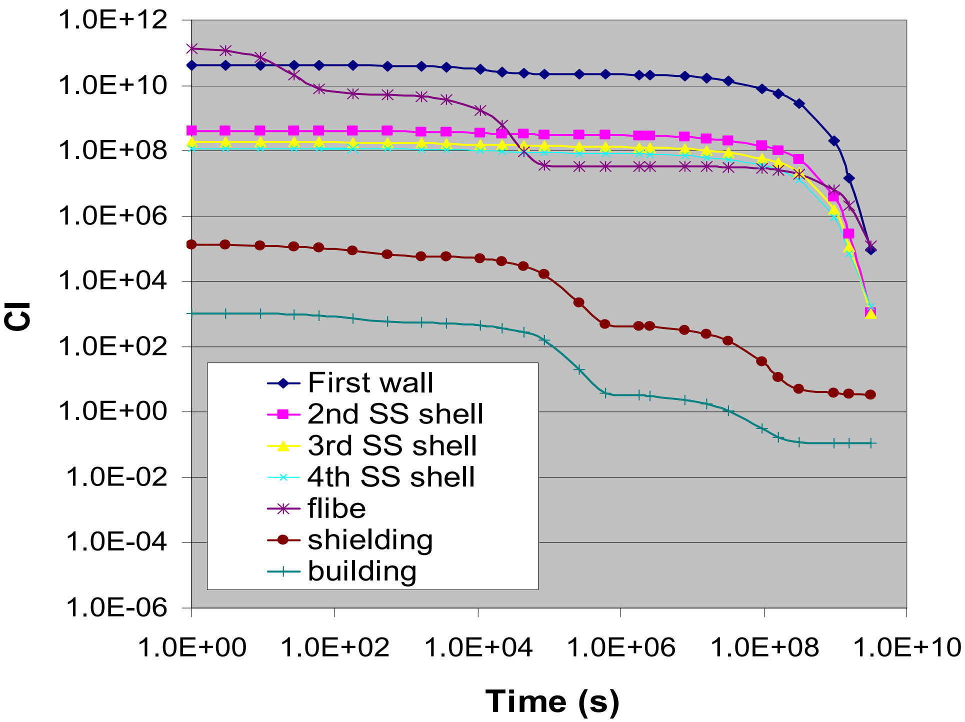
Component	WDR	LCWV (m^3)
SS304 blanket structures	8.7E-01	3.1E+01
Flibe coolant	2.3E-03	1.2E+03
Inner shielding	3.0E-05	9.1E+02
Confinement building	2.7E-05	5.3E+03

WDRs and life-cycle waste volumes (LCWVs) for the different components of the HYLIFE-II design

- It can be observed that all of the structures would qualify for shallow land burial (WDR < 1)

- The total life-cycle waste volume is dominated by the 5300 m^3 of concrete from the building.

Second, we calculated the CIs for the different structures in HYLIFE-II



Clearance indexes for the different power plant components as a function of the cooling time after shutdown

- In the cases of SS structures, flibe and inner shielding, best option would still be shallow land burial
- The confinement building, however, reaches clearance level after about one year of cooling
- Concrete building dominates the total life-cycle waste volume of the power plant
- Also, required cooling time for building to reach clearance level (~1 year) is quite short compared to the plant decommissioning time

Alternative materials have been considered for thick liquid wall concepts

- We have considered five potential materials for a thick liquid wall in a HYLIFE-II type chamber: flibe, flinabe, Li , LiPb and LiSn

- 3 assessments have been performed for each of the liquids:
  - Safety and environmental characteristics
  - Pumping power required
  - TBR

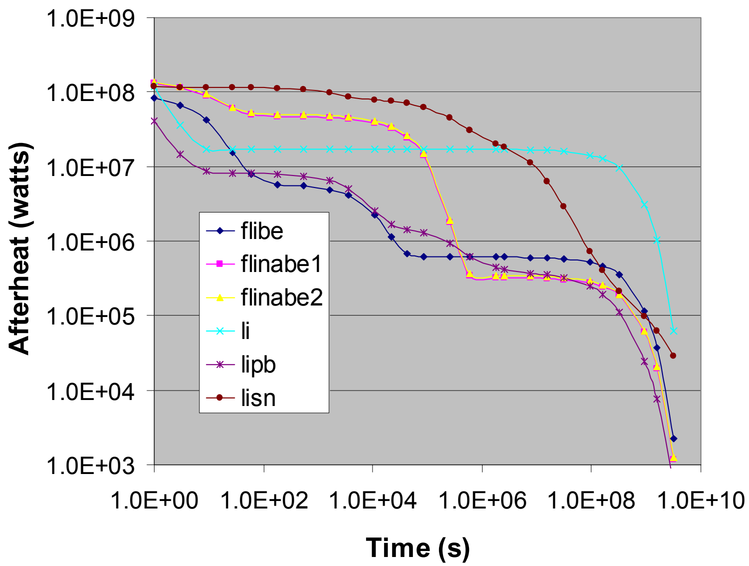
- For the S&E assessment we have estimated
  - radioactive afterheat
  - contact dose rate
  - WDR

- The pumping power calculation includes
  - head velocity
  - friction losses
  - required lift power

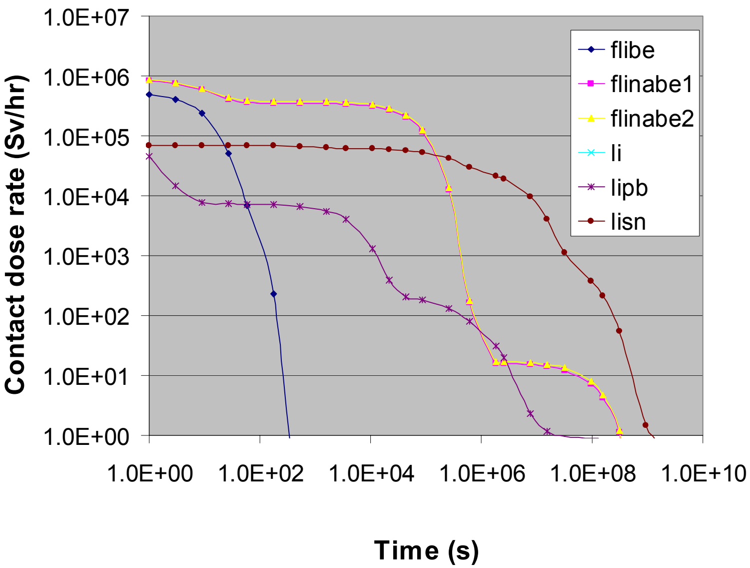
Safety assessment addresses activation after 30 FPY operation

- Flibe, flinabe and LiPb have similar afterheat at t = 1 week, values for Li and LiSn are almost two orders of magnitude higher
- From the contact dose rate point of view, LiPb and flibe present the lowest values, LiSn is the highest in the long term
- All liquids have WDR < 1 (qualify for shallow land burial)

Radioactive afterheat as a function of cooling time after shutdown



Contact dose rate as a function of cooling time after shutdown



Required pumping power has been addressed for the various candidates

Liquid	Composition	Pocket thickness (m)	Total pumping power (MW)	Pumping power 80% eff. (MW)	TBR
Flibe	BeF_2(34%) LiF(66%)	0.56	48.46	60.57	1.25
Flinabe[1]	BeF_2(33.4%) LiF(33.3%) NaF(33.3%)	0.62	55.26	69.07	1.07
Flinabe[2]	BeF_2(37.5%) LiF(31.5%) NaF(31%)	0.62	63.23	79.04	1.07
LiPb	Li (17%) Pb(83%)	1.03	681.76	852.21	1.61
Li	Li(100%)	1.25	65.01	81.27	1.80
LiSn	Li(50%) Sn(50%)	0.59	158.91	198.64	1.15

- The thickness of the liquid pocket is such that FW damage is limited to 100 dpa after 30 FPY operation
- LiPb and LiSn pumping power requirements may be excessive
- Li has a large tritium inventory and poses fire hazards
- ***From this we can conclude the flibe and flinabe stand as the best options***

Conclusions (I)

- Accident analyses for the HYLIFE-II design show that tritium trapped in structures dominates accident doses
- For waste disposal management, shallow land burial may not be the best option in case of large volumes of waste
- We have calculated CIs to determine if any of the components of HYLIFE-II could qualify for clearance
- Results show that in the case of the confinement building, which dominates the total waste volume, clearance would be possible in ~ 1 yr of cooling
- Required cooling time for building to reach clearance level is quite short compared to the plant decommissioning time

Conclusions (II)

- We have addressed safety characteristics, required pumping power and TBR of 6 different candidates for thick liquid wall material in a HYLIFE-II type design

- Regarding S&E characteristics, flibe, LiPb and flinabe stand as the most attractive options

- Required pumping power for LiPb and LiSn maybe too high

- From the assessments one can conclude that flibe and flinabe stand as the most attractive candidates for a HYLIFE-II type, thick liquid wall concept