Safety and Environmental Update for ARIES-AT

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Outline

- Integrated Outline for the Report
- Inventories and Release Limits
- Assessment of Safety Implementation in ARIES-AT
  - Confinement Challenges
  - Po-210 Release from LiPb
  - Ex-vessel Issues
- Waste Management
- Summary/Status

Integrated Safety and Environmental Chapter for ARIES-AT

- Objectives (INEEL)
  - No evacuation
  - Waste minimization
- Radiological Inventories and Release Limits
  - Inventories
  - Tritium(INEEL/ANL/Wisconsin)
    - In SiC, in LiPb, in W divertor
  - Activation (Wisconsin)
    - In SiC, in LiPb, in FS, in W divertor
  - Allowable releases to meet no evacuation
- Normal releases (?) - show that we can control tritium permeation from this system ANL/INEEL
- Assessment of Safety Implementation in Design
  - Introduction
  - Confinement (INEEL)
    - Implementation: VV and Cryostat as two major barriers
    - Assessment: What challenges confinement?
      - LOVA, Shield LOCA (?) LiPb/water interaction leading to LOVA
  - Decay Heat Removal (Wisconsin)
    - Show magnitude of decay heat versus time
    - Results from full LOCA in BKT and sensitivity studies DV LOCA
    - Results from BKT and DV LOFA
  - Chemical reactivity issues (INEEL)
    - Ex-vessel LOCA in LiPb loop
- Waste Management (Wisconsin)

Radiological Release Limits and Key In-Vessel Inventories

- Release limits to meet 1 Rem no-evacuation dose for 1 km site boundary, average weather (D & 4 m/s), ground level release
- Major Inventories
  - Po in LiPb
  - Tritium in LiPb
  - Tritium in SiC (implantation and uptake)
  - Activated W dust in divertor

Release Limits and Inventories for ARIES-AT

Material	Release Limit	Inventory
Tritium as HTO	150 grams -T	tbd in SiC
		tbd in LiPb
Po-210	25 Curies	4 ~ 70 Ci/m^3
	(no Bi removal)	~40000 Ci
	(with Bi removal)	~ 2500 Ci
Activated W dust	6000 grams	10 - 100 kg(?)

Use sum of fractions rule if more than one source is involved in an accidental release

Assessment of Safety Implementation
Confinement Challenges

- Failure of double confinement boundary leads to loss of vacuum event (LOVA) - calculations done for ARIES-RS in December; similar results expected here
- In-vessel LOCA of shield
  - Depends on temperature and pressure of water
  - How will the overpressure in the plasma chamber be accommodated?
  - Can penetrations survive the overpressure?
  - Is the shield loop segmented to minimize spill volume?

Assessment of Safety Implementation
Confinement Challenges (continued)

- In-vessel LiPb/water interaction
  - Shield LOCA at weld sprays water onto SiC and fails it
  - Water and LiPb spray out and interact
  - Modest pressure pulses expected (~ tens of atmospheres) based on data on Pb/water interaction.
  - Resulting overpressure leads to a LOVA in a penetration
  - Key issues are dust mobilization, and tritium and Po-210 release from LiPb
  - Will analyze with MELCOR
  - (Recommend keeping VV and LT shield separate to allow more physical separation from the hot LiPb and the primary confinement boundary)

Assessment of Safety Implementation
Ex-vessel Issues

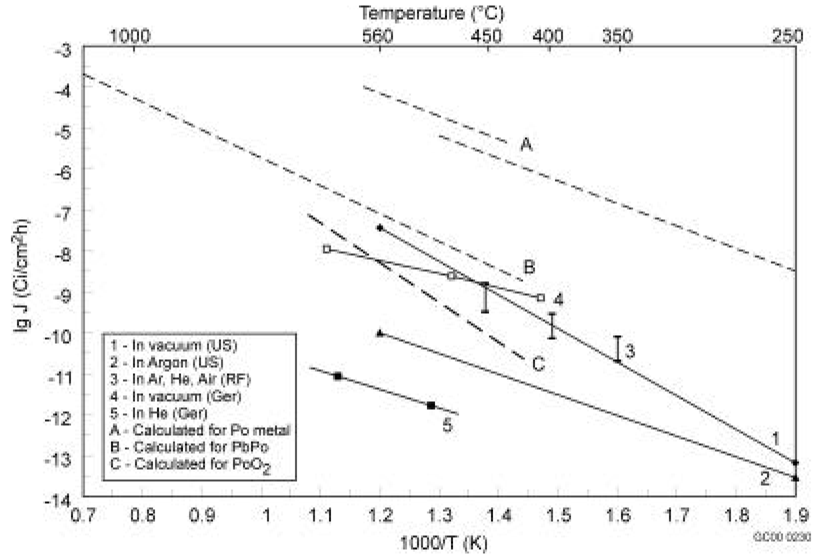
- Ex-vessel LOCA in LiPb Loop
  - Key issue is Po-210 and tritium release
  - Will analyze with MELCOR
  - Release is strongly dependent on surface area of spill, Po–210 content of LiPb, and time for spill to cool and resolidify
  - Nuclear grade ventilation would mitigate this event but would increase the size of the nuclear island
  - Loop segmentation would help mitigate this event
  - Drain tank, which is probably needed for maintenance, would help mitigate this event

Po-210 Concentration in LiPb

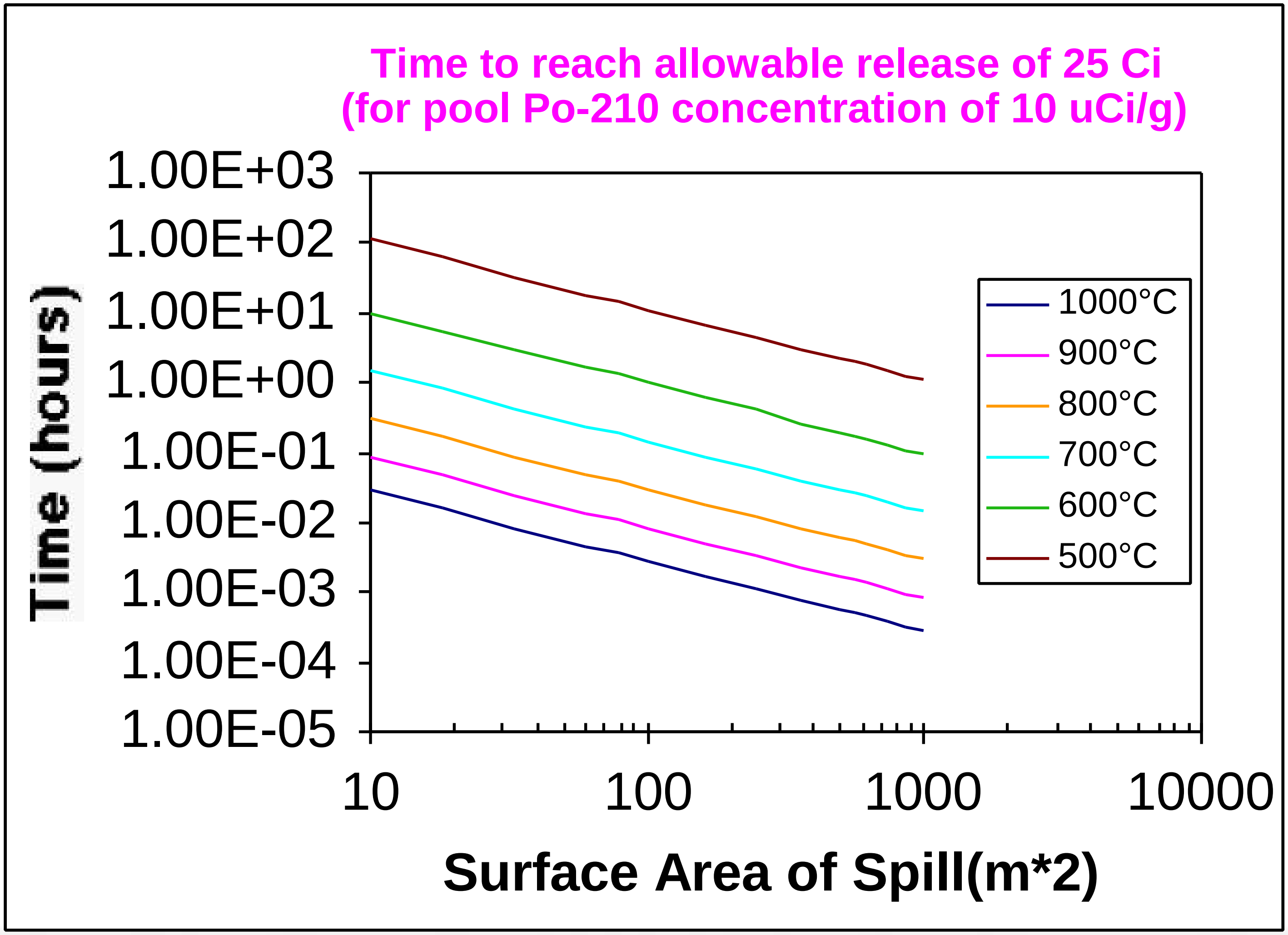
- 600 m^3 of LiPb, with a concentration of 70 Ci/m^3 is no Bi control system is employed. Total inventory is ~ 40,000 Ci
- Control of Bi to 1 ppm is possible based on Malang and Mattas, *Fusion Engineering and Design 27 (1995), p. 399-06.*
- This would result in Po-210 concentration of 0.1 ppb. This corresponds to about 4 Ci/m^3 or about 2500 Ci total inventory
- Thus, a factor of 100 reduction is needed in any accident involving spill of LiPb to meet the 25 Ci release limit. Options include: loop segmentation, drain tank and nuclear grade filtering of rooms where spills might be expected

Po-210 Release from LiPb

- Based on experimental work from RF and FZK, we will use the evaporation rate of PbPo since it bounds the data
- Data only go to about 550°C. Extrapolation required at higher temperatures



- Release is part aerosol and part vapor. The aerosol is condensed PbPo and vapor is hydroxide of Po based on RF work. In air some PoO_2 is expected but it decomposes above 500°C.
- More aerosol at higher temperatures


Time to reach allowable release of 25 Ci
(for pool Po-210 concentration of 10 uCi/g)
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
Time (hours)
10
100
1000
10000
Surface Area of Spill(m*2)
1000°C
900°C
800°C
700°C
600°C
500°C

Safety Design Issues

- Loop Segmentation
  - Single cooling system is more susceptible to faults, since a small leak requires shutdown of the entire cooling system for repair
  - Segmentation of the cooling system allows easier removal of decay heat
  - Cooling system operation is needed to prevent freezing of coolant
  - Segmented system is more robust to anticipated operational transients
  - Segmented system can minimize the volume of LiPb spilled in a LOCA
  - Probably higher capital cost but maintenance should be less demanding which will help on plant availability

Safety Design Issues

- Drain Tank and Freezing of LiPb
  - How will the system be designed to ensure no freeze up of LiPb in the loop during maintenance and other unforeseen outages (for example - loss of off-site power)?
  - Drain tank is a solution that could also help mitigate LOCA events by taking the LiPb away from the break location
  - Multiple small drain tanks are probably preferable to one large tank because of ease of heating several small tanks versus one large tank
  - Multiple small drain tanks are more easily integrated into a segmented cooling system design
  - Multiple small drain tanks may result in faster drainage of LiPb

Safety Recommendations

- We need a factor of 100 reduction in overall Po-210 inventory that can be released in an accident
- Four loop segmentation would reduce coolant inventory at risk in any spill from 600^3 m to ~ 150 m^3
- Four drain tanks off of each loop (~ 38 m^3 each) that can actuate on low pressure and/or low flow, would minimize spill volume. Exact spill volume would depend on design of lines leading to the drain tanks and location of leak.
- If LiPb cools quickly complete release may not occur in the spill. Large surface area would increase cooling rate but also increase release rate. Expect to be able to transfer heat faster than mass because of thermal radiation
- Above approach would minimize need for nuclear grade ventilation around the tokamak. (The need for such ventilation will not be known until actual accident calculations are done).

Waste Management

- All key components meet class C (assuming magnet impurities are not excessive)
- Overall waste volume is minimized by having very compact design
- Cannot meet clearance for any components
- Would like to understand if the components could be considered for recycling
- Need to calculate contact dose rate of each component and compare to both remote recycling criteria (~ 1 rem/hr) and hands-on criteria (~ 1 mrem/hr)

Summary/Status

- INEEL will provide estimates of tritium in SiC
- Dai-Kai will provide estimates of tritium in LiPb circuit
- Need cooling loop segmentation configuration and drain tank issue resolved
- Ex-vessel LiPb LOCA will be done using MELCOR at INEEL
- In-vessel shield LOCA will be done using MELCOR at INEEL
- In-vessel LiPb/water vapor explosion leading to LOVA will be performed using MELCOR
- Divertor LOCA and LOFA will be performed by UW
- Contact dose assessment will be calculated by UW
- Documentation by September