Safety and Environmental Assessment of ARIES-AT

David Petti
Fusion Safety Program

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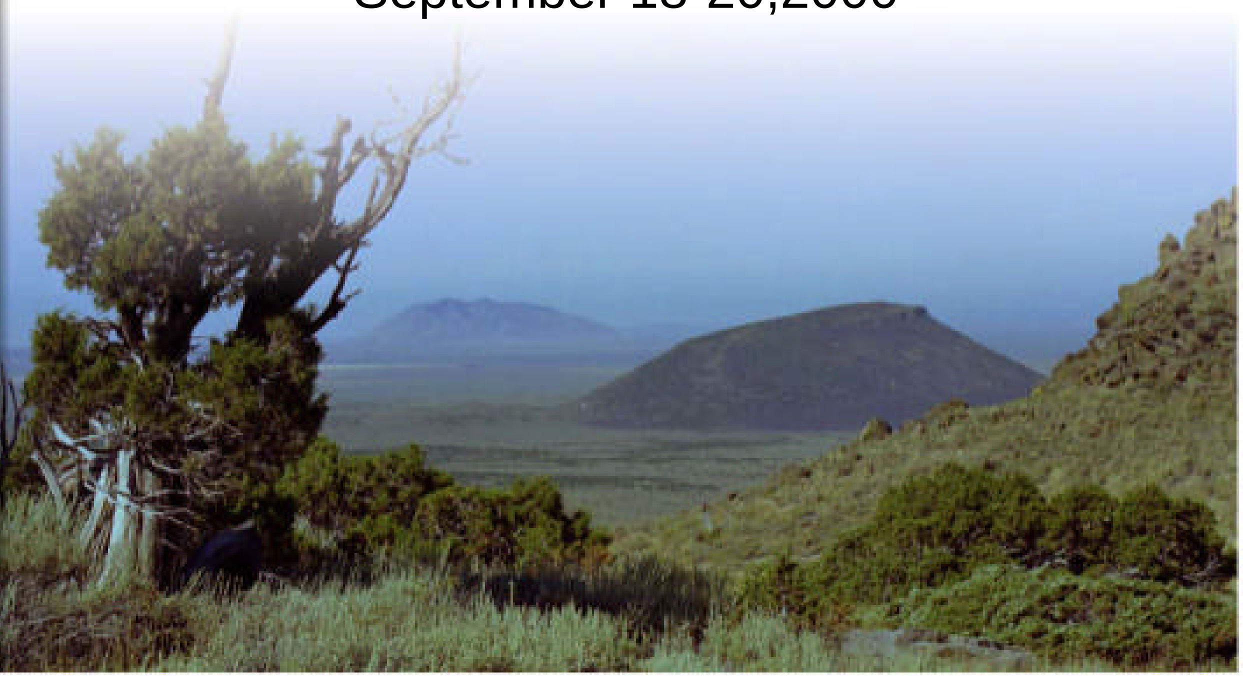


Outline

- Integrated Outline for the Report
- Inventories and Release Limits
- Results of Accident Analysis to Date
- Summary/Status

Integrated Safety and Environmental Chapter for ARIES-AT

- Objectives (INEEL)
  - No evacuation
  - Waste minimization
- Radiological Inventories and Release Limits
  - Inventories
  - Tritium
    - In SiC, in LiPb, in W divertor
  - Activation (Wisconsin)
    - In SiC, in LiPb, in FS, in W divertor
  - Allowable releases to meet no evacuation

Green sections are complete. Black sections are not yet.

- 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
    - 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-210 and Hg-203 in LiPb
  - Tritium in LiPb - very small
  - Tritium in SiC (implantation and co-deposition)
  - Activated W dust in divertor

Release Limits and Inventories for ARIES-AT

Material	Release Limit	Inventory
Tritium as HTO	150 grams -T	540 in SiC
		< 1 in LiPb
		30 g in W
		150 g in co-deposited layer
		(only 180 g is mobilizable in an accident)
Po-210	25 Curies	4 ~ 70 Ci/m^3
	(no Bi removal)	~40000 Ci
	(with Bi removal)	~ 2500 Ci
	(with Bi and Po removal)	????
Hg-203	25,000 Ci	2000 Ci/m^3
	(no cleanup)	1,200,000 Ci
	(with cleanup)	?????
Activated W dust	6 kg	10 - 100 kg

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

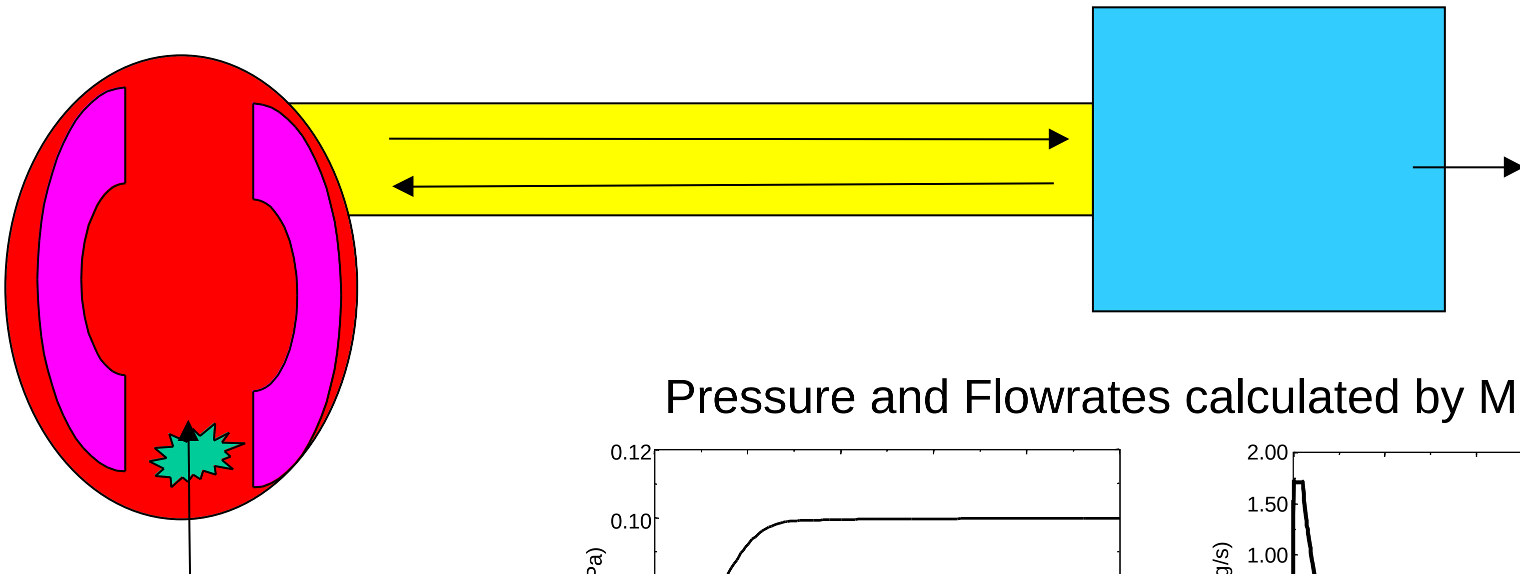
Accident Identification for ARIES-AT

- Failure of double confinement boundary leads to loss of vacuum event (LOVA)
- In-vessel LOCA of shield leading to bypass of confinement
- Total loss of all coolant (U-W reported earlier)
- Loss of Flow (U-W reported earlier)
- Ex-vessel loss of LiPb coolant to lower functional area

ARIES-AT LOVA

- Similar to ARIES-RS.
- Failure of double confinement in a penetration (perhaps heating and current drive system line)
- Air enters the plasma chamber
- Air extinguishes the plasma with a disruption that would mobilize dust and any "easily mobilizable" tritium
- Air exchanges between the plasma chamber and the upper functional area that is communicating with the chamber because of density gradient between hot air inside and cooler air outside (stratified flow in the duct)
- Releases depend on duct size, orientation of duct, and nature of ventilation and filtration in the upper functional area

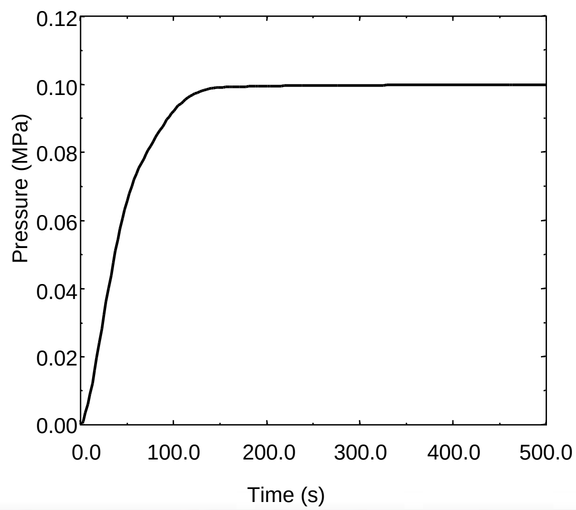
ARIES-AT LOVA Results

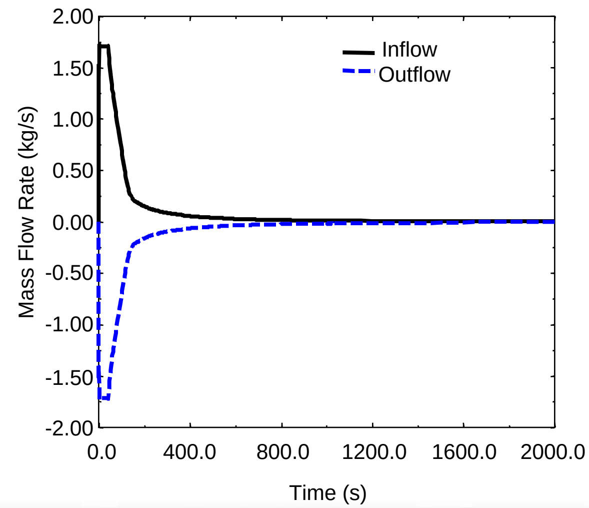


0.08 g of tritium and 0.04 g of dust is released

180 g of tritium and 10 kg of dust is mobilized

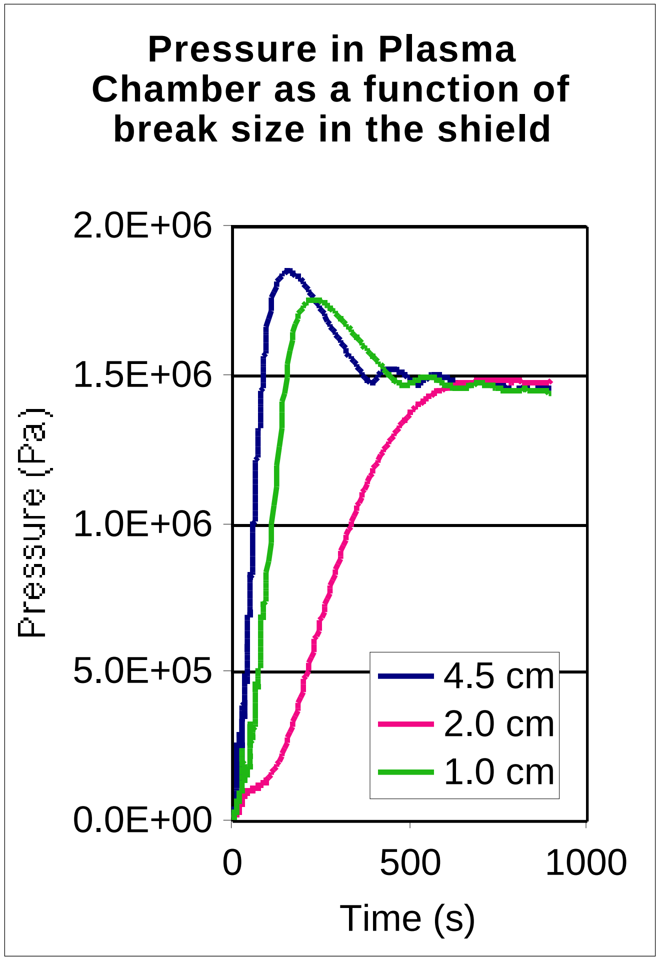
Pressure and Flowrates calculated by MELCOR



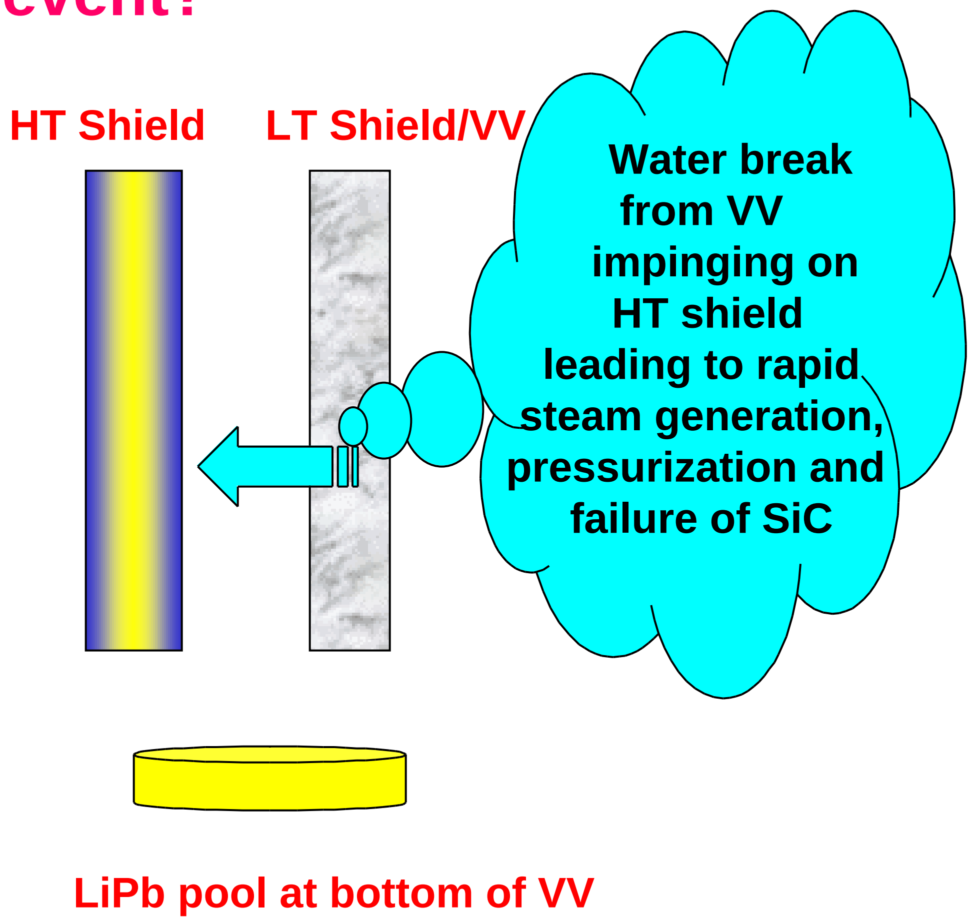


In-vessel Shield LOCA

- LOCA in the shield results in impingement of steam/water onto the SiC of the high temperature shield. Film boiling occurs leading to rapid pressurization (10-20 atm) if no pressure relief.
- This pressurization is much faster than in other systems we have analyzed because of the high temperature of the in-vessel components. Effect of suppression system on overall pressure response is currently being modeled.
- High pressure in the vacuum vessel can prevent break flow/blowdown from continuing
- Equilibrium pressure is ~ pressure in VV system (need help to define VV system more accurately. We used ITER design details)



Will the in-vessel shield LOCA lead to a more severe event?



Energetic interaction between LiPb and water is not expected to provide any additional pressure source inside the vacuum vessel because the water is already rapidly vaporizing via interaction with the walls of the high temperature shield.

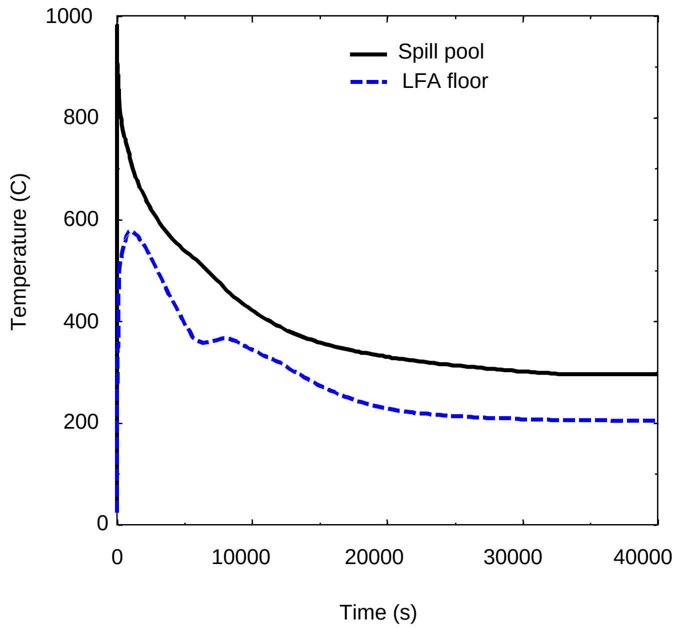
No need to consider LiPb/water interaction in the event sequence

Still need to consider failure of the VV with bypass to the upper functional area. But this time the driving pressure is the steam in the VV not outside air

Source term is 180 g tritium,
10 kg tungsten dust and
Po-210 and Hg-203 from LiPb

ARIES-AT Ex-Vessel LOCA

- An ex-vessel LOCA into the functional area below the maintenance corridor was analyzed.
- The MELCOR model included all of the in-vessel fluid components, plus the ring header and the primary cooling system. MHD pressure drop was included in the calculation.
- The total spill was about 150 m^3 from one of four loops. Pool surface area is 525 m^2 and pool depth is 0.24 m. Pool cools by transferring heat to floor. No drain tank in the analysis.
- The ventilation system provides one volume exchange per hour, which exhausts directly to the stack. The leak rate is 1 volume per day at an over pressure of 400 Pa.



- About 500 Ci of Po-210 and 250,000 Ci of Hg-203 are available for release

Mobilization of Po-210 and Hg-203 from LiPb pool

- Diffusional fractional release from the pool is given by:

$$FR = 1 - \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp[-\frac{D(2n+1)^2 \pi^2}{4L^2}]$$

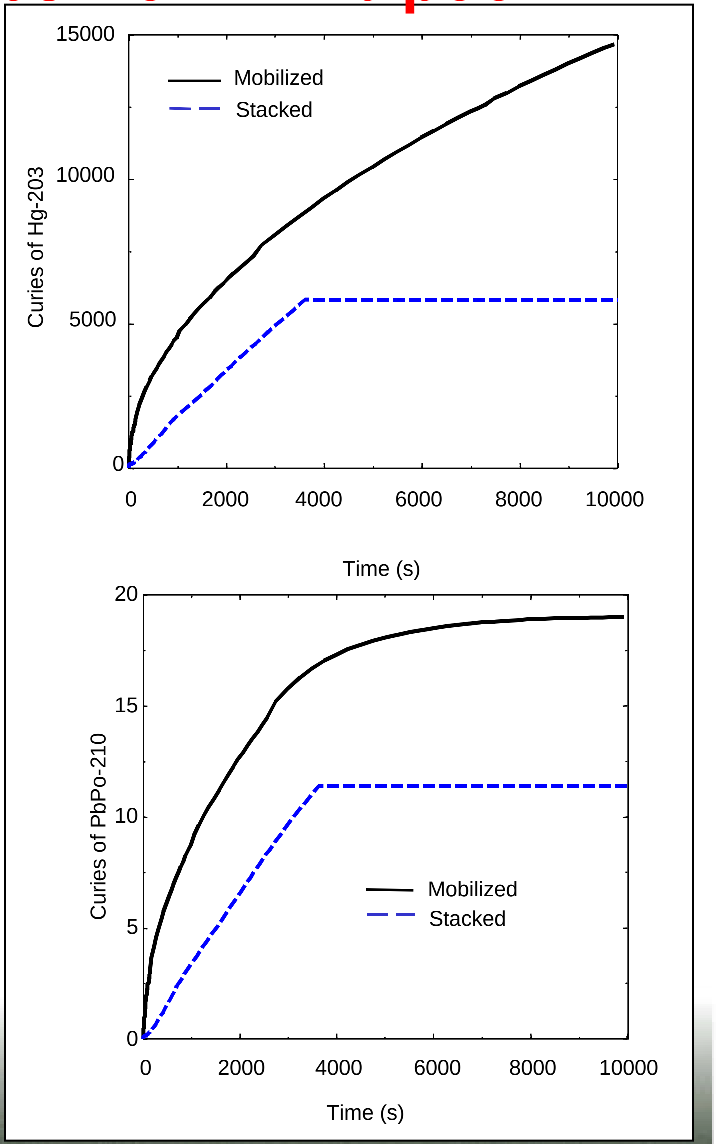
- Where L is the pool depth and D is given by:

  $D(cm^2/s) = 8.2E\text{-}10\ [1 + (3V_a/V_m)2/3]\ T/\ [\mu(V_m)^{1/3}]$

- Vaporization off of the surface for Po-210 is given by:

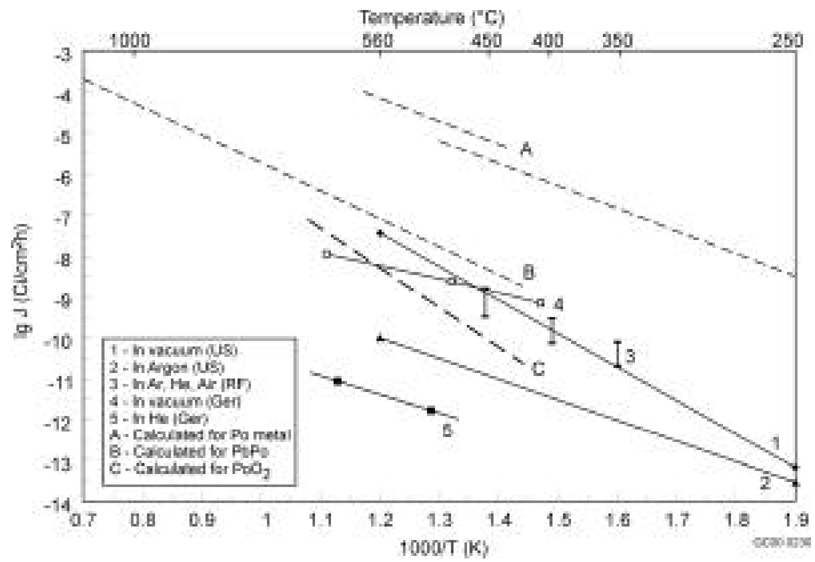
  $J\ (Ci/cm^2\text{-}hr) = 2.75 \times 10^{-5}\ P_{sat}(T)\ (1000/T)^{0.5}$

- Mobilization is given by the minimum of these two rates for Po-210. Complete vaporization of Hg is assumed since pool is above boiling point of Hg
- Releases are below no-evac limits



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

The need for on-line removal from a safety and environmental perspective

- On-line removal of Hg and Po to levels below the no-evacuation limits would greatly improve the safety case for ARIES-AT
- In such a case, all spills would have no public safety impact because inventories are inherently below no-evacuation threshold
- We have tried based on the design detail to select the the worst spill geometry and spill location to bound the release. If the inventories are very low, any disagreements about this topic become moot
- Hg is well above its boiling point (350°C) in the LiPb coolant. Thus, removal should be easy. The vapor pressure of PbPo is high enough at these coolant temperatures to allow efficient removal of Po-210
- On-line removal of Bi to prevent Bi-208 buildup will help the waste picture for LiPb

Summary/Status

- Key inventory and release targets are complete
- Ex-vessel LOCA and LOVA are complete
- In-vessel shield LOCA currently underway using MELCOR at INEEL.
- Divertor LOCA and LOFA complete by UW
- Waste management evaluation is complete by UW
- Current INEEL portion of the document is 85% complete. Will finish by end of the FY. Various papers at ANS Fusion Topical
- UW documentation needs to be integrated into the document. Expected in December 2000.
- Expect all work will be finished by the end of the FY. Start ARIES-IFE in October.