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Update of Pressurization Accidents in ARIES-CS

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ARIES Meeting
University of Wisconsin, April 27th, 2006

Presentation Outline

- Describe the details of a MELCOR model under development for the ARIES-CS dual coolant blanket concept
- Present MELCOR results for reactor startup
- Present the results for a in-vessel first wall (FW) helium loss-of-coolant accident (LOCA)
- Discuss possible accident scenarios that could be considered in assessing the safety of ARIES-CS
- Conclude by discussing future modeling activities and analyses

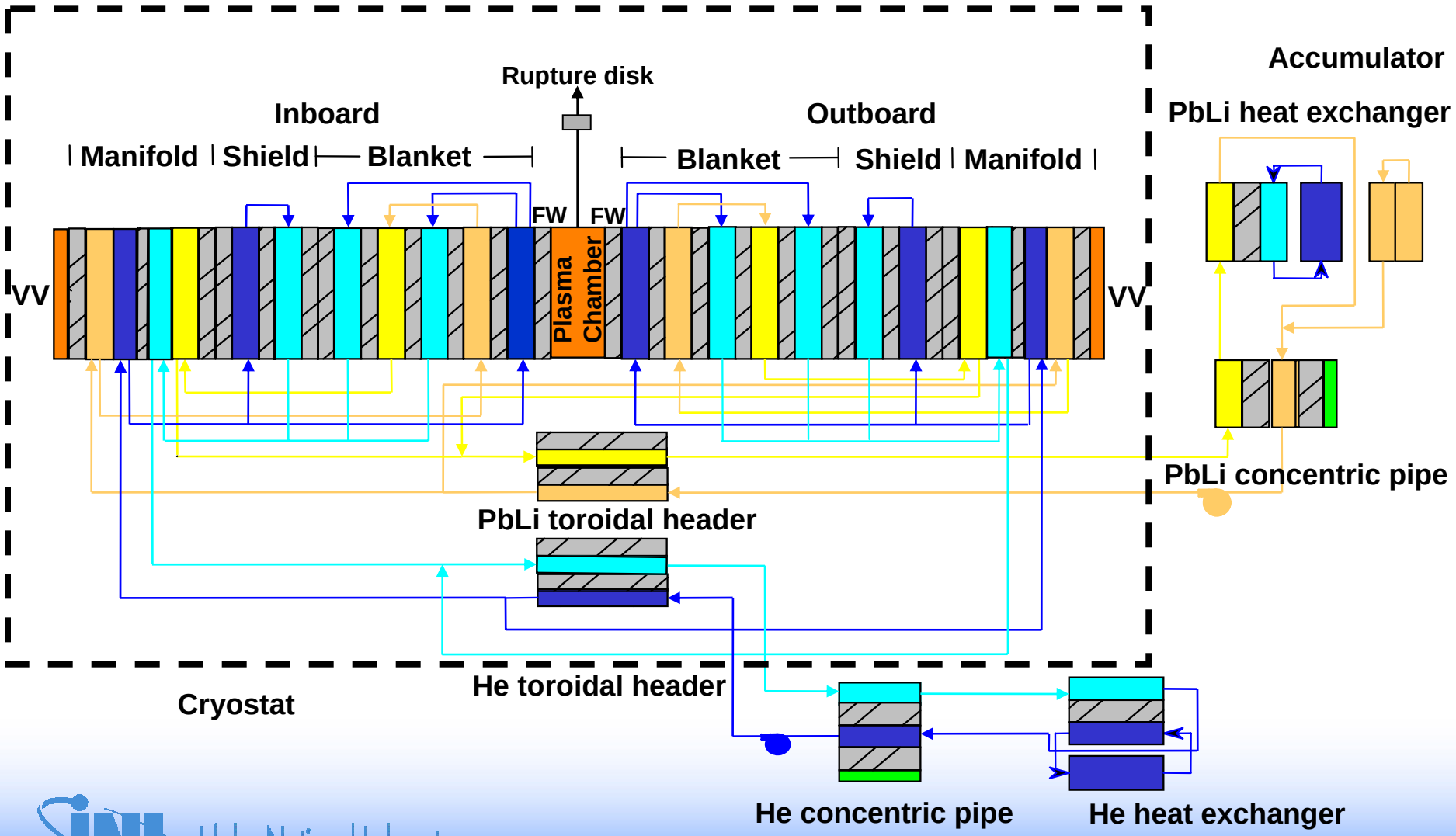
Modeling Assumptions and Parameters

- Modeled one-half a field period segment (1/6th of three field period reactor)
  - First wall surface area 1/6 of plasma surface area ~ 110 m^2
  - Applied first wall heat flux of 0.5 MW/m^2
  - Radial power profile based on Laila's Nov. 11th results (needs updating)
  - Total operating thermal power for model ~ 450 MW
  - Decay heat (obtained from "Initial Activation Assessment for ARIES Compact Stellarator Power Plant" paper ~ 10 MW at shutdown and 3 MW at 60 s)
  - Radial build and compositions based on Laila's March 8th ARIES-CS blanket
  - In-vessel volumes scaled from systems code output (R=7 m) to the new strawman (R=7.5 m), plus information obtained from Xueren
- Helium
  - Pressure 8 MPa and inlet /outlet temperature 300/480 °C
  - Mass flow rate 230 kg/s
- PbLi Loop
  - Pressure 4 MPa and inlet /outlet temperature 460/700 °C
  - Mass flow rate 7260 kg/s

Model Volumes (1/6th of reactor)

Component	Material Volumes (m^3)				
	Struc.	He	PbLi	Water	Void (full reactor)
Vacuum vessel	24.0	-	-	23.2	485
Blanket	10.6	8.7	46.6	-	-
Shields	26.7	3.0	-	-	-
Manifolds	27.9	12.6	11.9	-	-
Concentric headers	1.5	6.1	5.9	-	-
Cryostat	-	-	-	-	7000
Out of reactor	-	46.4	97.9	-	-
Total	90.7	76.8	162.3	23.2	7485

MELCOR ARIES-CS Model Schematic



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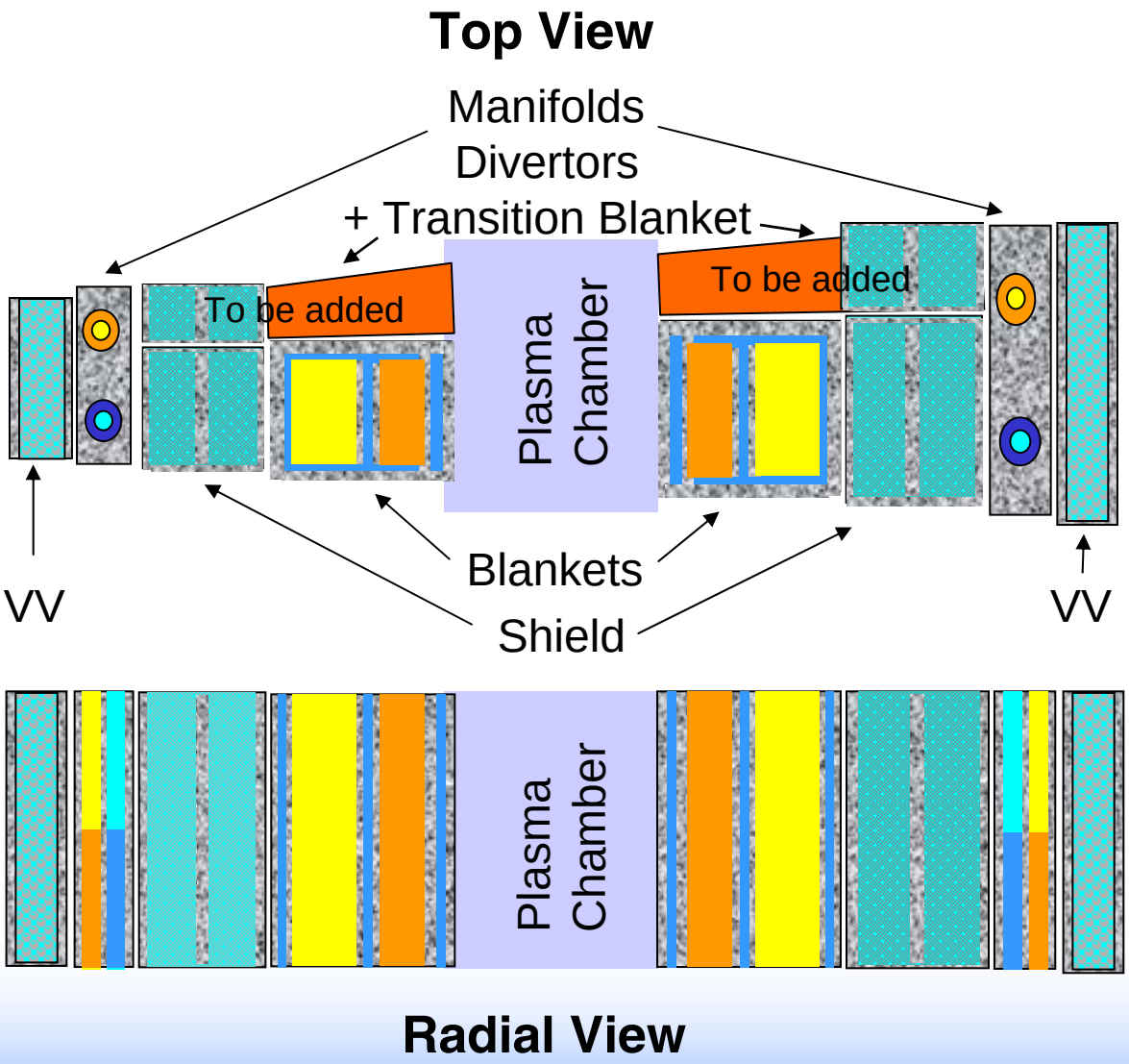
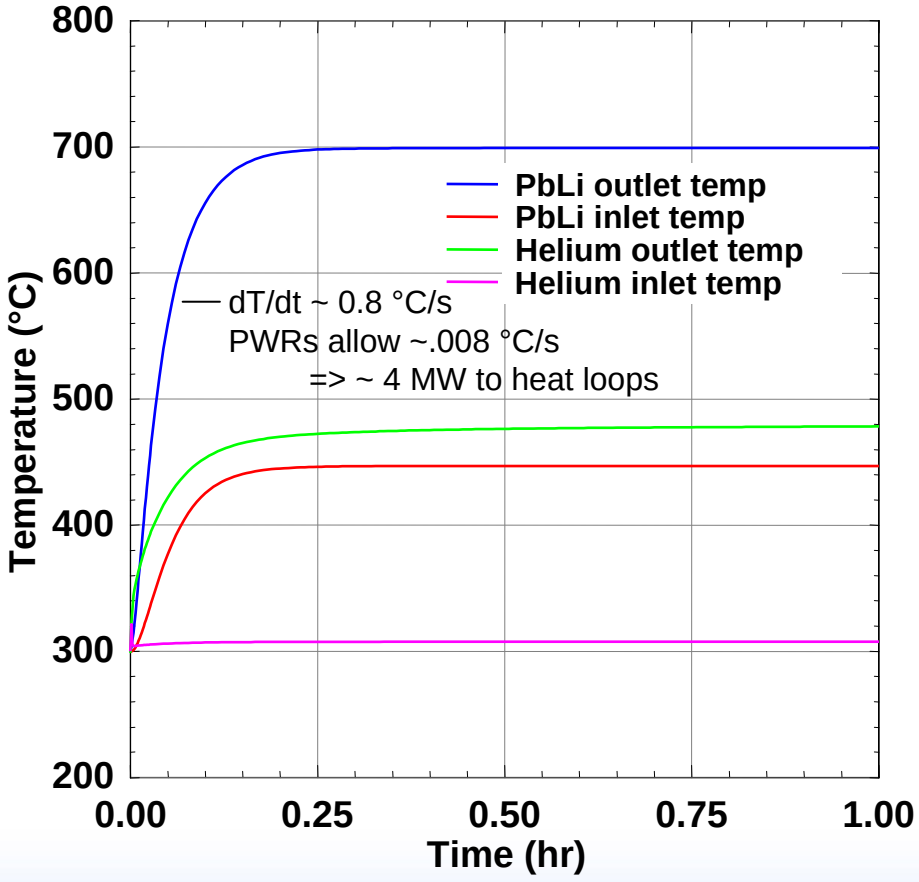
MELCOR ARIES-CS Model Schematic (cont.)

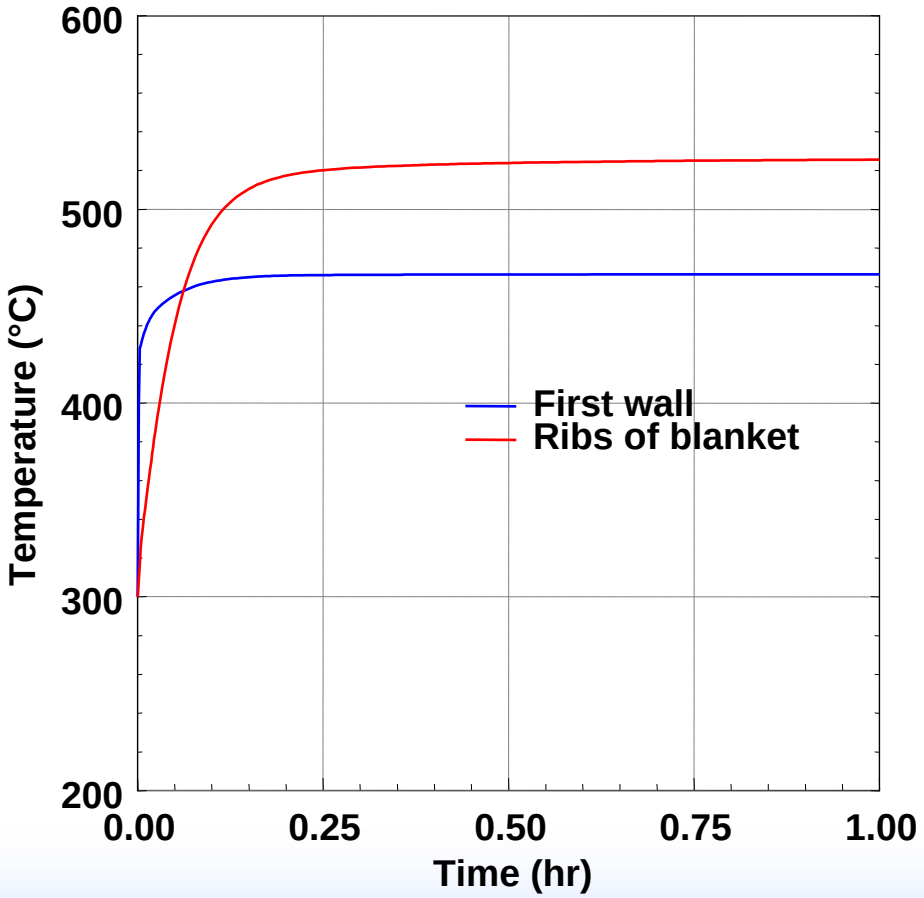


Startup Transient Predictions

Fluid temperatures



Structure temperatures



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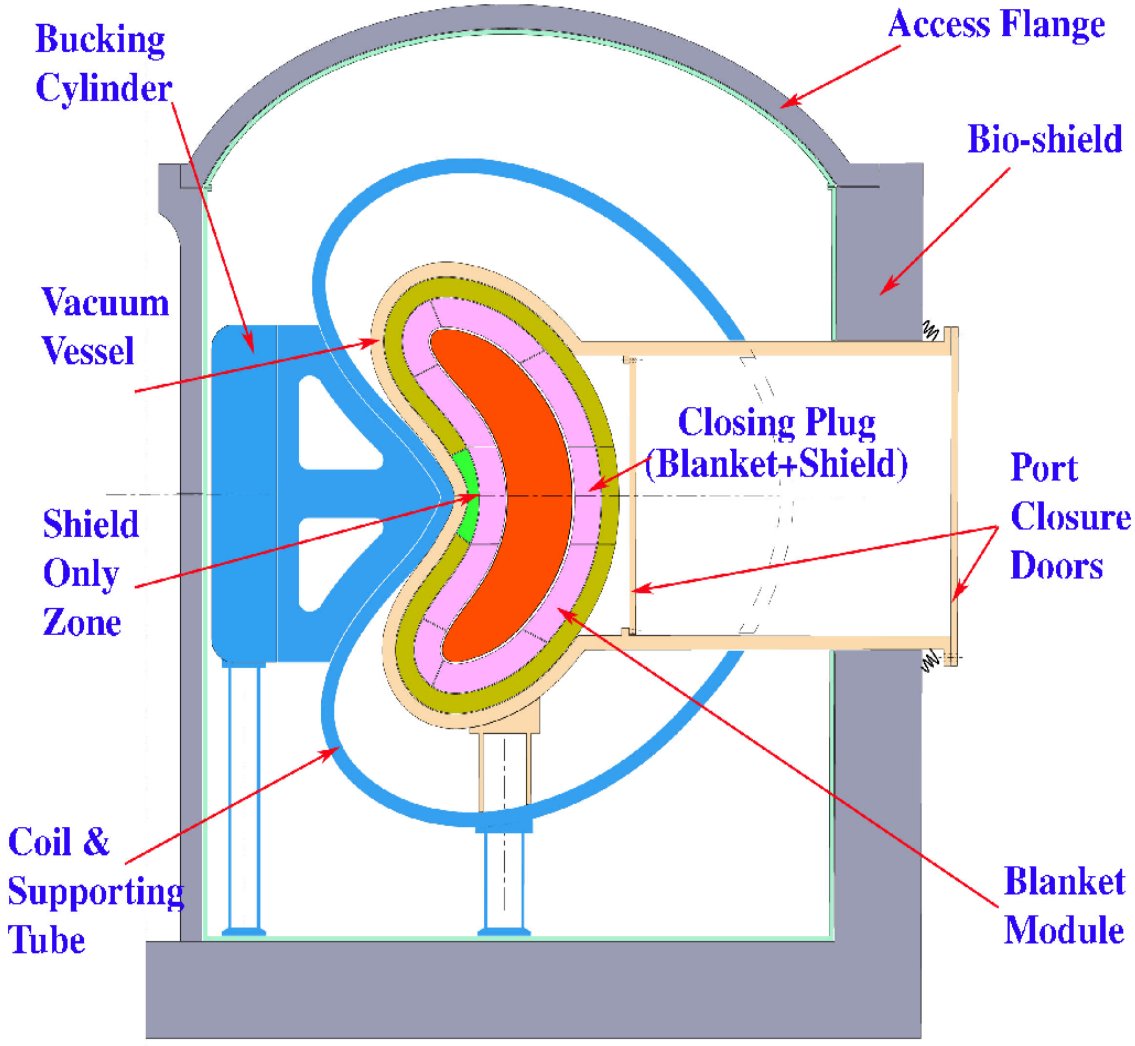
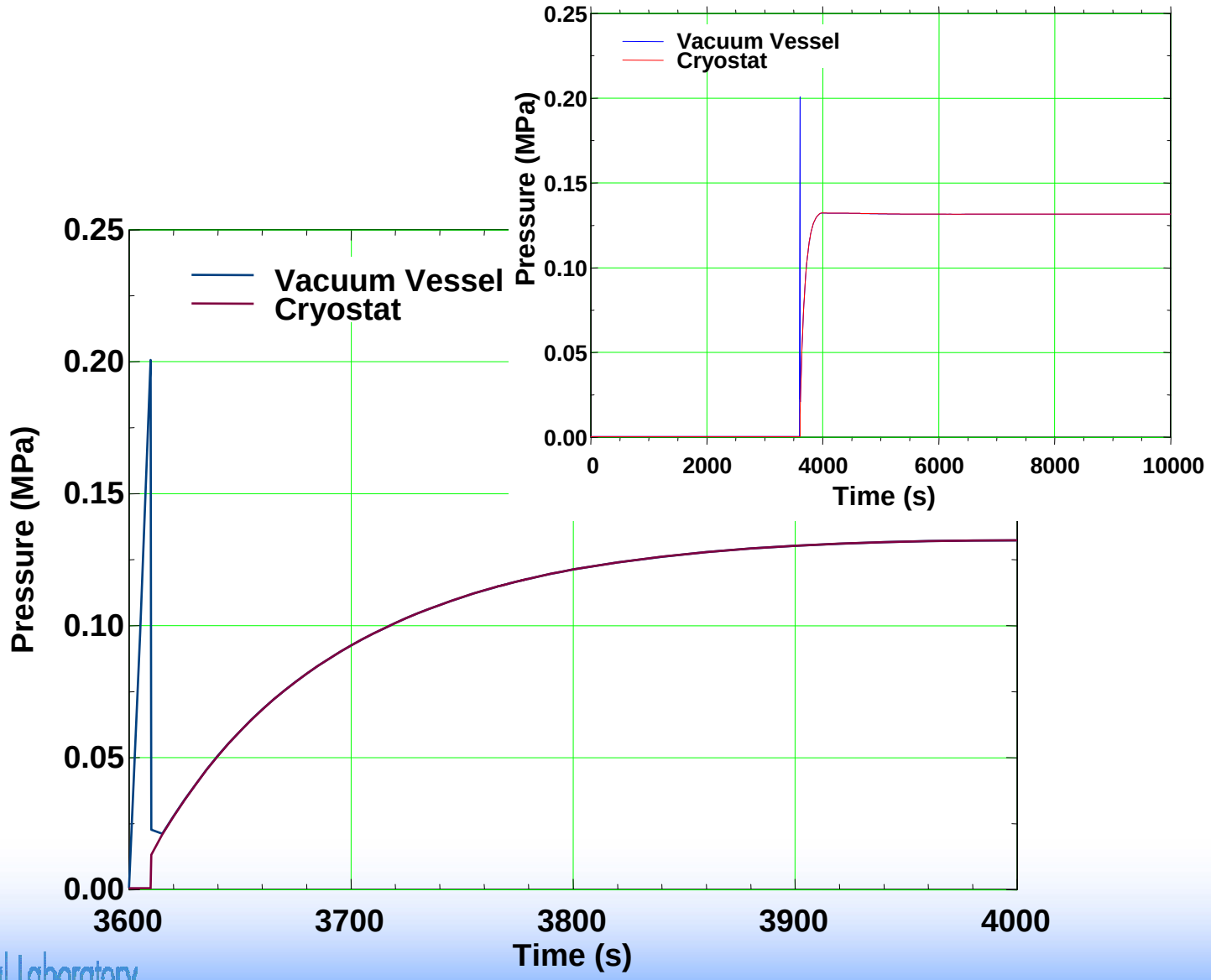
Pressurization of ARIES-CS Vacuum Vessel

- Only pressurization accident considered to date is the rupture of a single FW channel (0.0012 m^2)
- Design basis events with probabilities in the 10^{-3}/year range
- Free volume within the vacuum vessel (VV) was set at plasma volume of ~485 m^3
- Immediate plasma shutdown occurs, but FW heating from a radiant collapse was not included



Pressurization of Vacuum Vessel

- Shutdown and loss-of-coolant occurs after 1 hour, and VV cooling enters natural convection mode
- VV Pressures reach 2 atm within 10 s after a small break
- Rupture disk pressure relief to cryostat results in final pressure less than 1.5 atm



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Possible Reference Accidents

- In-vessel helium (design basis accident- DBA) or water (beyond design basis accident BDBA) loss-of-coolant accident (LOCA) to assess VV pressurization and possible PbLi/water chemical reactions that could form hydrogen
- In-blanket (breeder zone) helium LOCA to assess blanket pressurization and possible blanket failure into the VV (DBA)
- Ex-vessel helium and PbLi LOCA analysis to determine heat transport system vault pressurization (DBA)
- Loss-of-vacuum accident (LOVA), a confinement bypass accident (BDBA)
- A heat exchanger tube breach introducing 14 MPa helium from the Brayton cycle into the FW/blanket cooling systems which over-pressurizes and fails these systems (BDBA)
- Complete-loss-of-site power (CLOPA) or station blackout to demonstrate passive decay heat removal

Would like to select three accidents to demonstrate ARIES-CS safety

Possible Reference Accidents (cont.)

- However before we can proceed with the analysis of these accidents, at least two important questions must be addressed by the ARIES-CS team
  1. Will the ingress of FW/blanket helium coolant into the plasma result in a rapid plasma boot-strap current that induces (displaces) currents to flow in the VV, resulting in significant electromagnetic forces on the VV and the possible failure of VV windows, isolation valves, etc)?
  2. Will the same ingress of coolant create significant plasma electric fields that generate runaway electrons that when lost from the plasma cause significant FW/blanket damage?
- The reasons why these questions must be answered are
  1. The severity of the accident will depend on which components fail, for example a LOVA requires the failure of VV windows plus isolation valves
  2. We have been assuming that ARIES-CS will have two independent cooling systems per period and that the failure of one system does not fail the other five, but if runaway electrons are produced the possibility of all six loops failing simultaneously exists.

     Let me try to estimate the rate of current decay based on LTE impurity radiation in balance with resistive plasma power. We are probably talking about a current decay rate that is much less than the 1 MA/ms seen in tokamak disruptions.

Future Work

- Update MELCOR nuclear heating rates and add divertor components
- Assess tritium inventory, permeation, and accident releases with TMAP
- Select accidents to analyze with input from ARIES-CS team regarding coolant ingress questions
- Perform safety analyses and document in a paper for TOFE
- Need component decay heating, activation inventories and estimate of mass of in-vessel PFC erosion dust
- ARIES-AT PFC dust and Po-210 inventories could be used for accident source terms if everyone agrees