MELCOR model development for ARIES Safety Analysis

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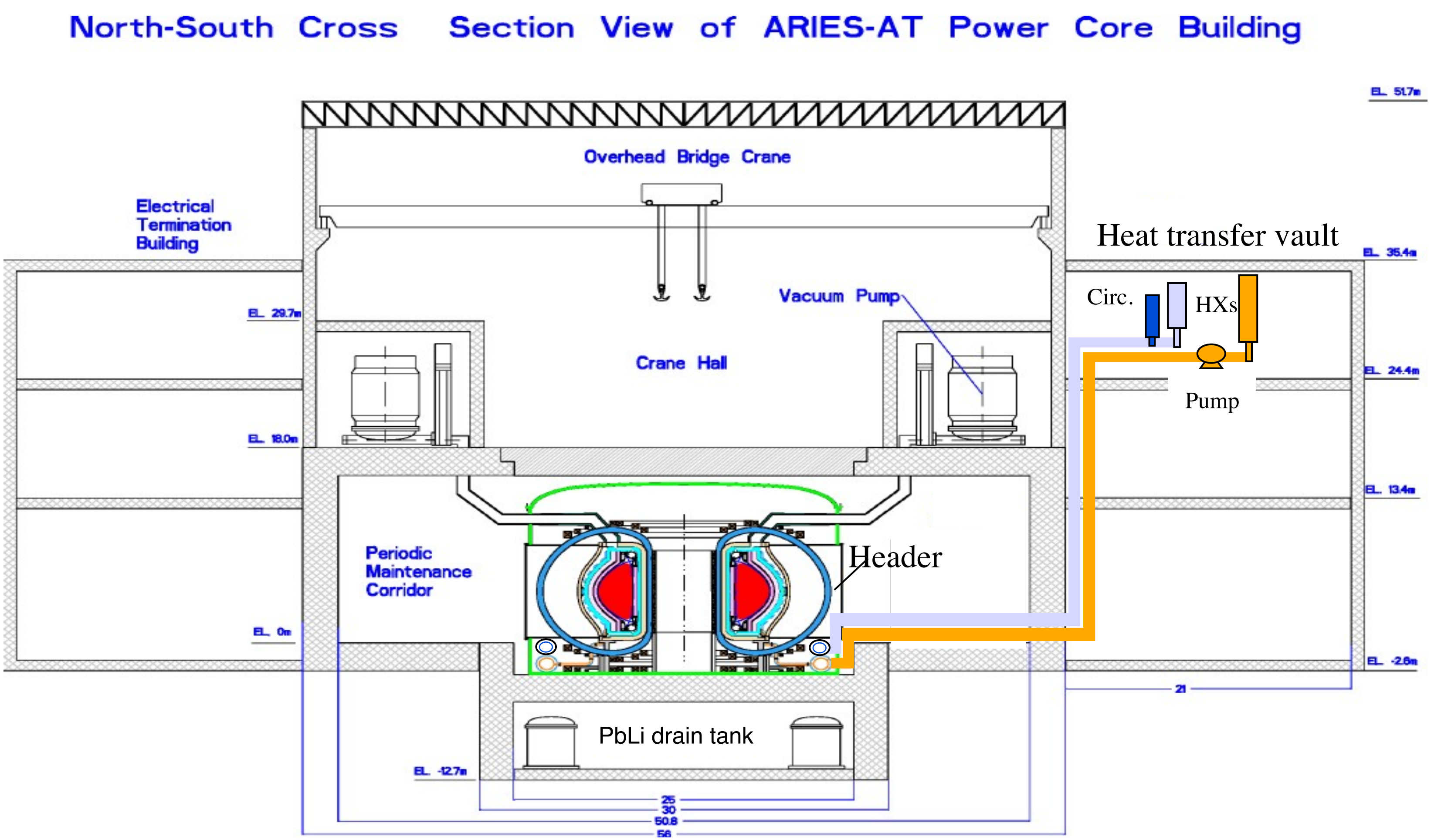
Presentation Outline

- Status of MELCOR modeling for ARIES-ACT
  - SiC
  - DCLL
- Follow up on VV permeation result from last meeting
- Plans and action items for next meeting

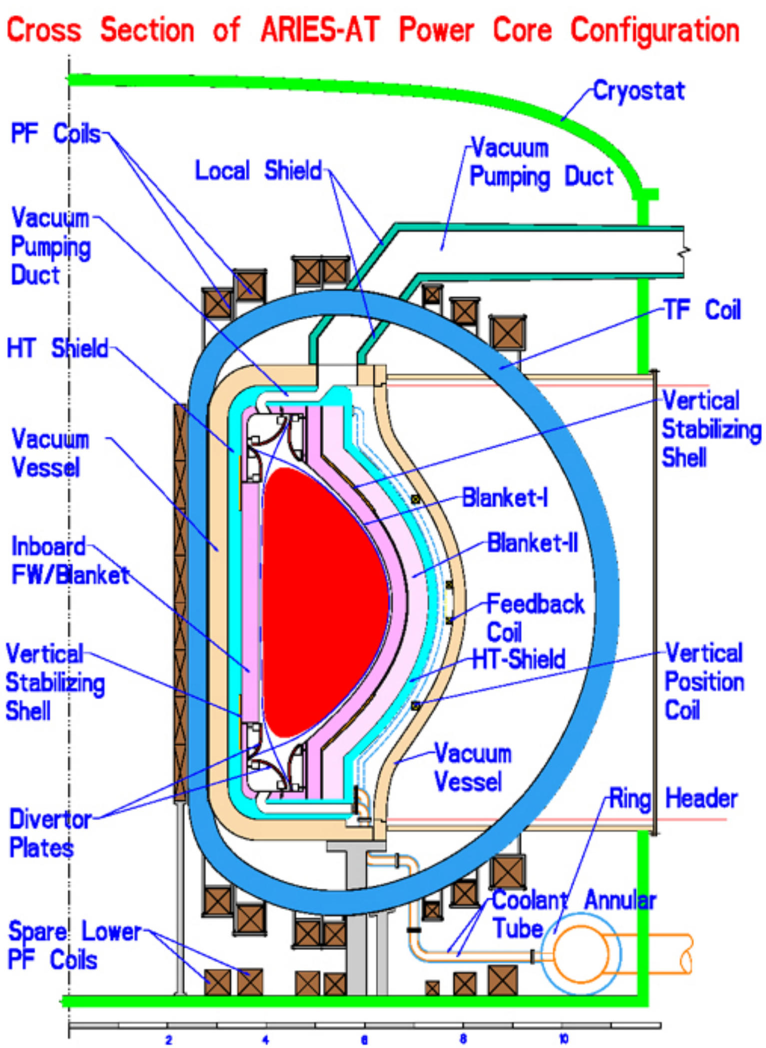
Status of ARIES-ACT MELCOR Models

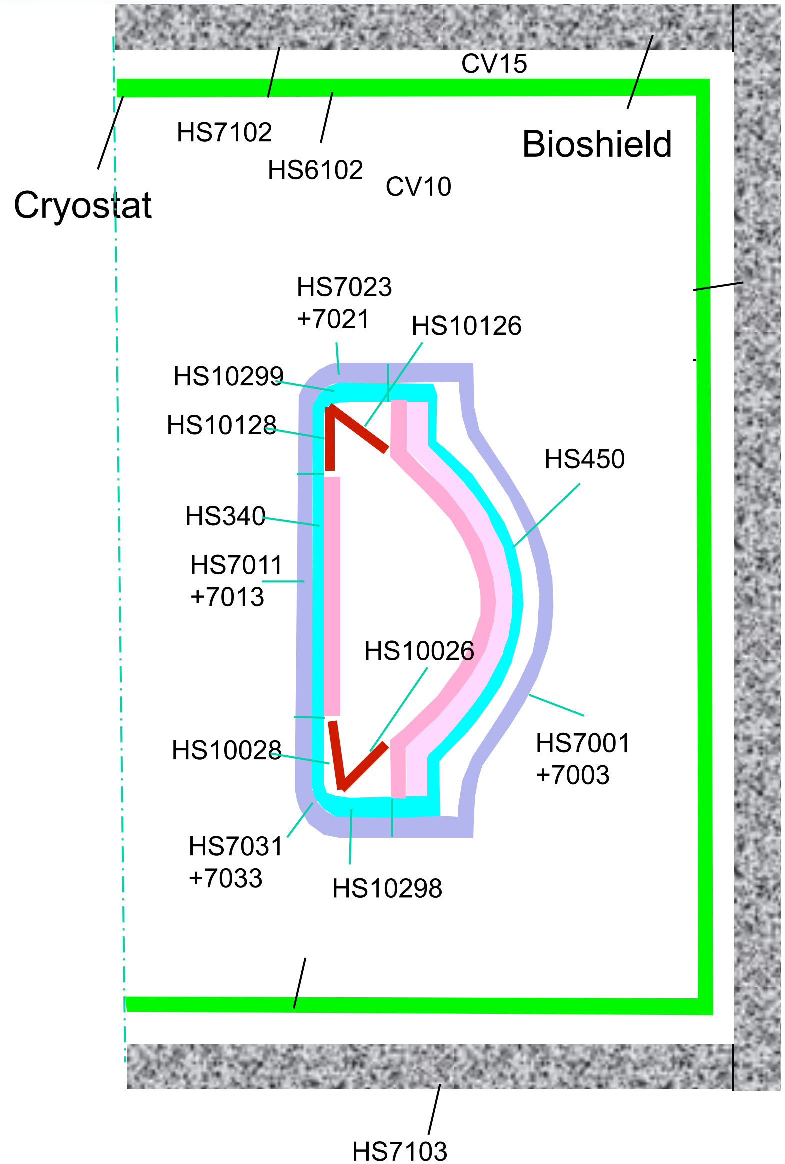
- An item from the last meeting was to start the update of existing MELCOR ARIES-AT models to perform accident analyses, primarily loss-of-coolant-accidents (LOCAs)
- Two models exist, one with the advanced SiC/SiC blanket and one with the DCLL blanket
- Both models lacked vacuum vessel, cryostat, and bioshield thermal models, need for decay heat removal and/or VV pressure relief accidents, and to answer the question of whether or not the VV can be cooled by helium
- Since the last meeting, we have modified and added the ARIES-CS VV to the ARIES-AT models, plus a cryostat based on ARIES-AT drawings. This required switching the VV cooling system to helium from water
- We are testing these models on a long-term-station-blackout (LTSBO) accident, with decay heat removal by gas injection into the cryostat volume

MELCOR Model Elevations Based on ARIES-AT

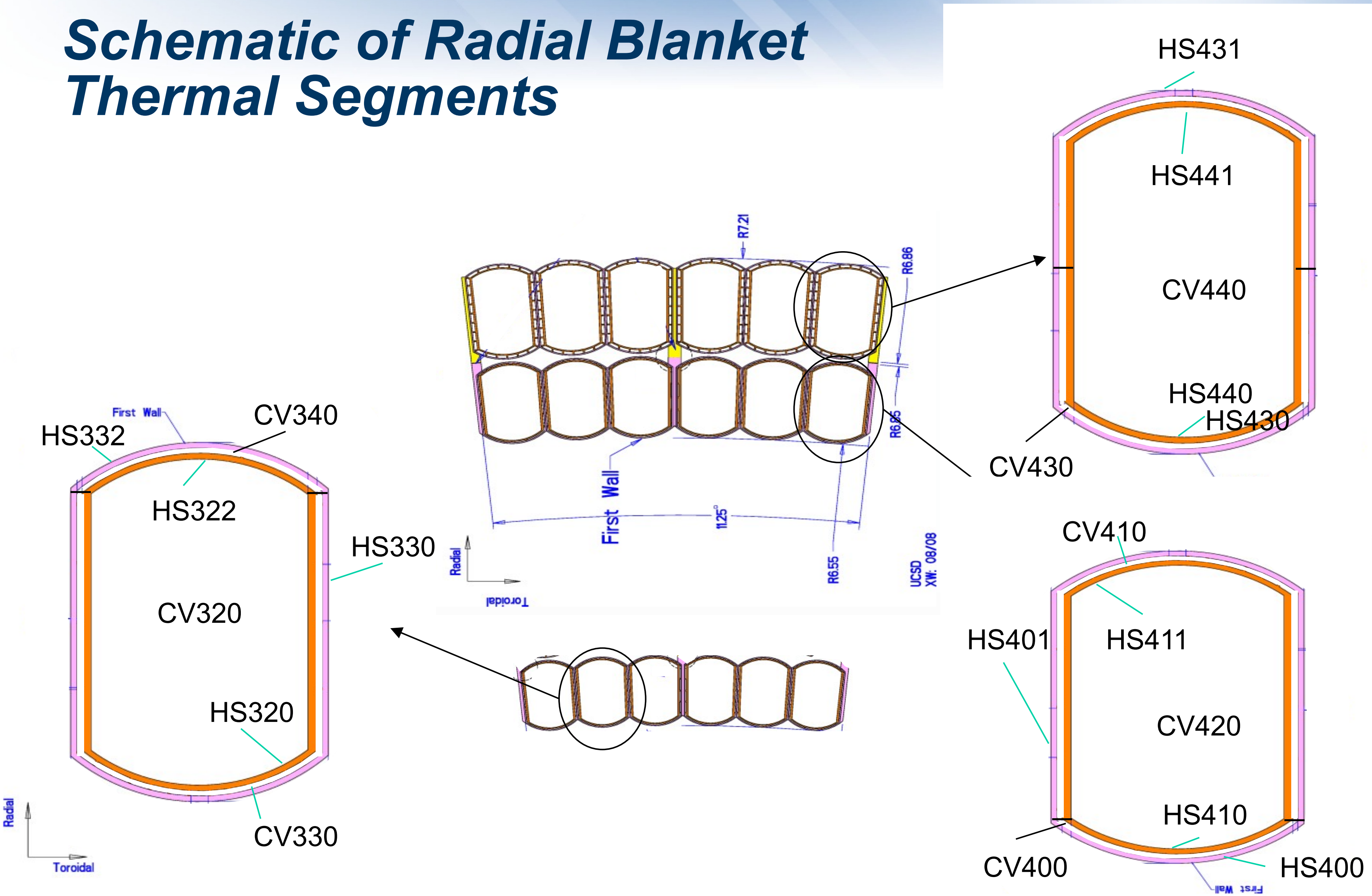


Vacuum Vessel/Cryostat/Divertor Model



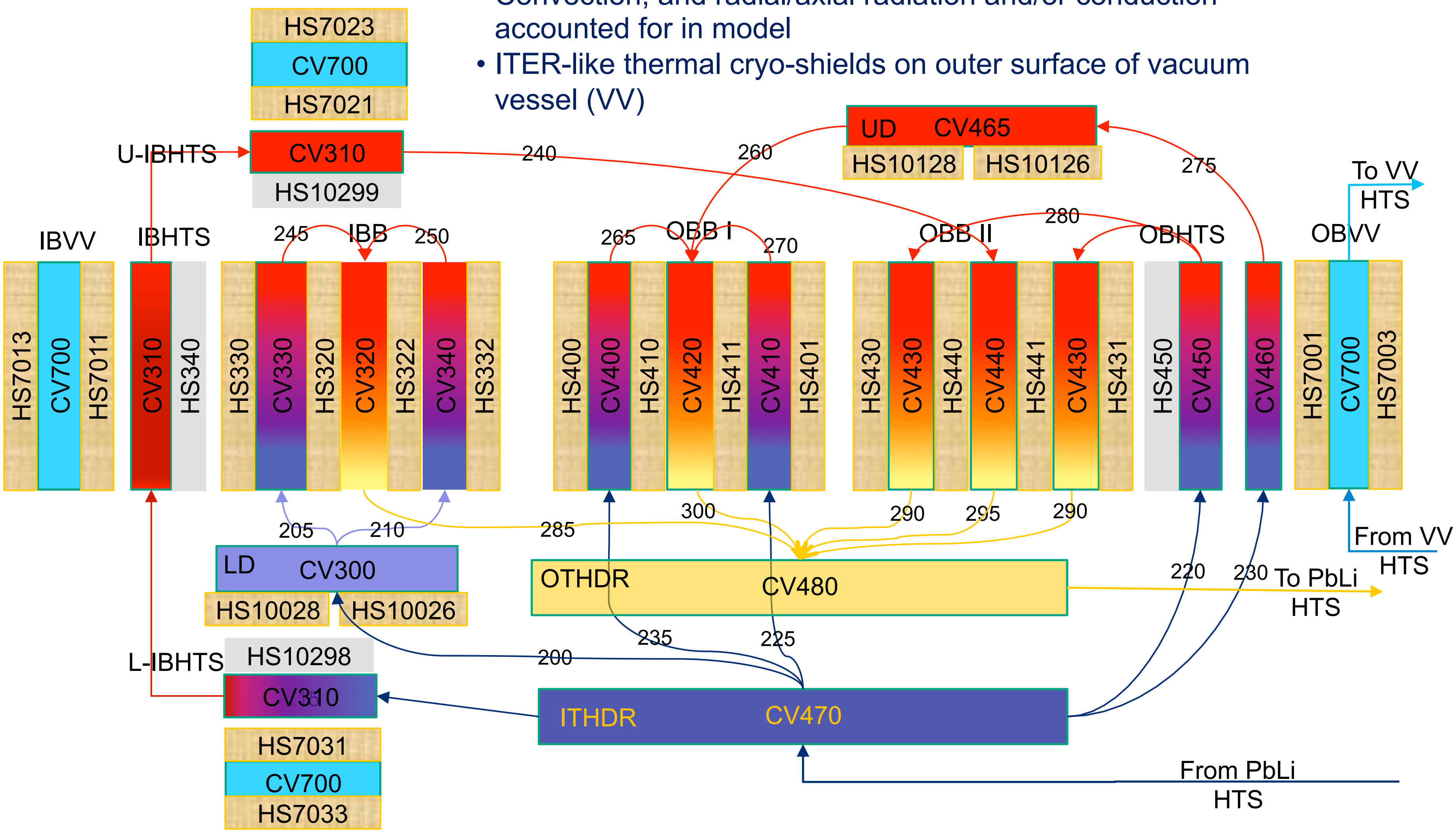


Schematic of Radial Blanket Thermal Segments



Advanced SiC Blanket Model

- Convection, and radial/axial radiation and/or conduction accounted for in model
- ITER-like thermal cryo-shields on outer surface of vacuum vessel (VV)



Super-insulation or Thermal-Shield?

- Super-insulations relies on thermal radiation heat transfer across gaps between multi-layered metal foils of high emissivity. For a vacuum in the gaps, the heat flux, q (W/m^2-K), across N foils of emissivity "ε" is:

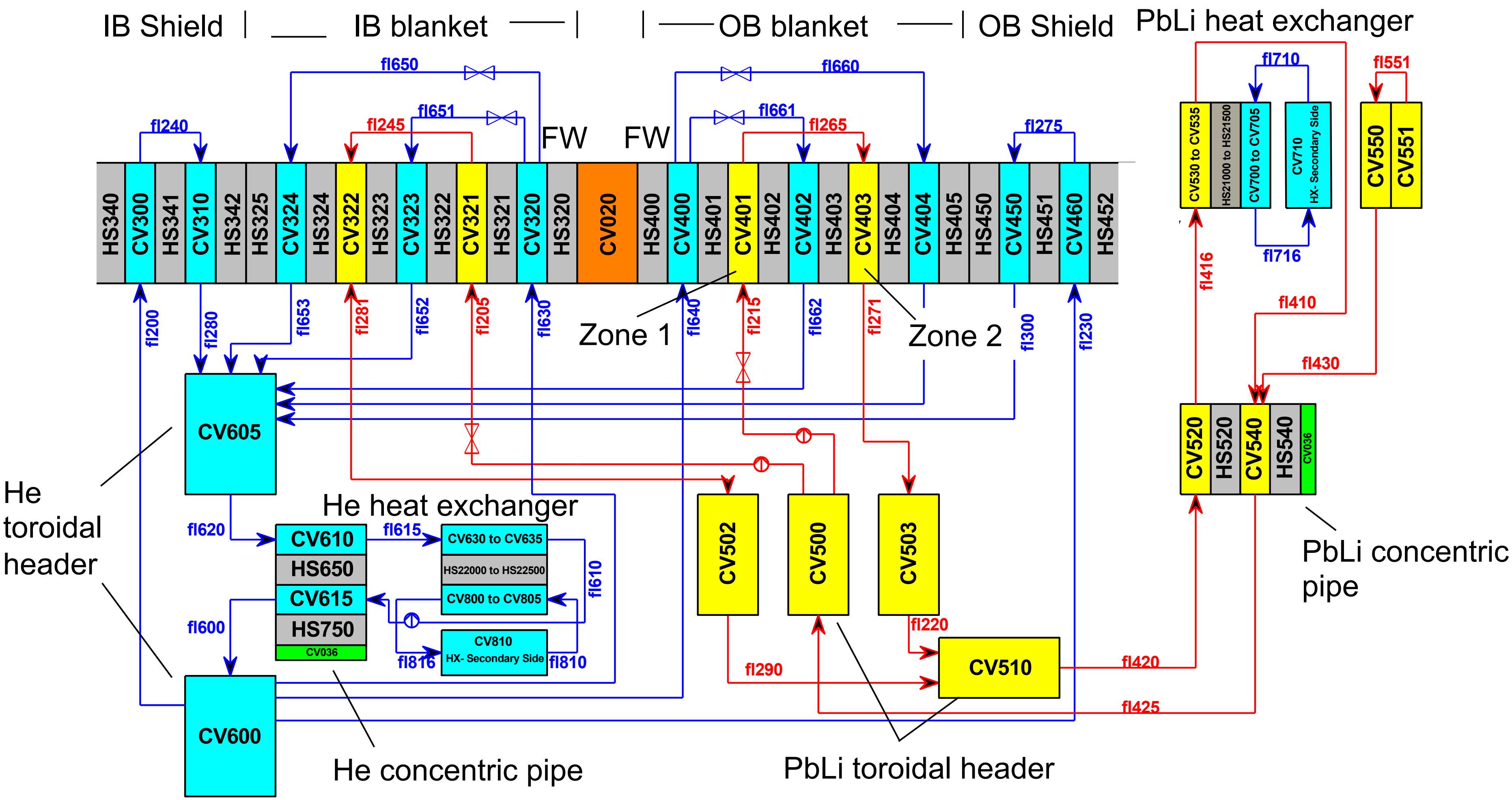
$$q = \frac{\varepsilon}{(N+1)}\sigma\left(T_H^4 - T_L^4\right)$$

- Super-insulation used for LHC VV and cryostat*

- ITER's Thermal-Shield is constructed is a shell around the VV coated with silver for low surface emissivity. The low temperature shell is cooled by helium at 80 K. Air injected into the cryostat during a long term station blackout (LTSBO) will add air heat convection in the gap between the shell and the VV.
- LHC employs both a super-insulation blankets and Thermal-shields. Which option will be used for ARIES-AT?

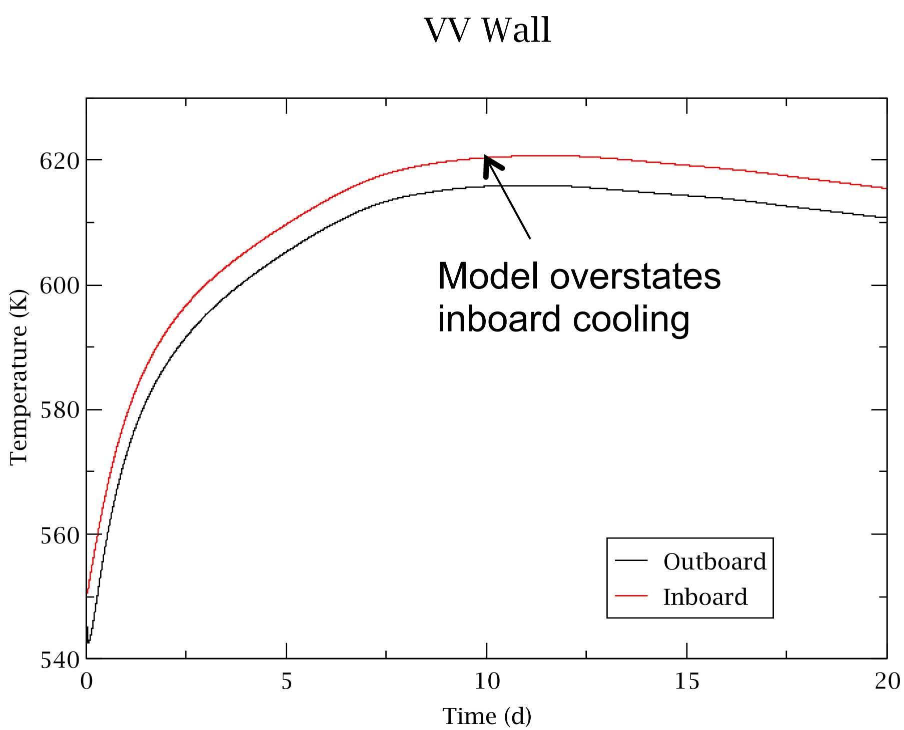
*A. Poncet, "Series-Produced Helium II Cryostats for the LHC Magnets: Technical Choices, Industrialization, Costs," Adv. Cryo. Engr., Vol. 53

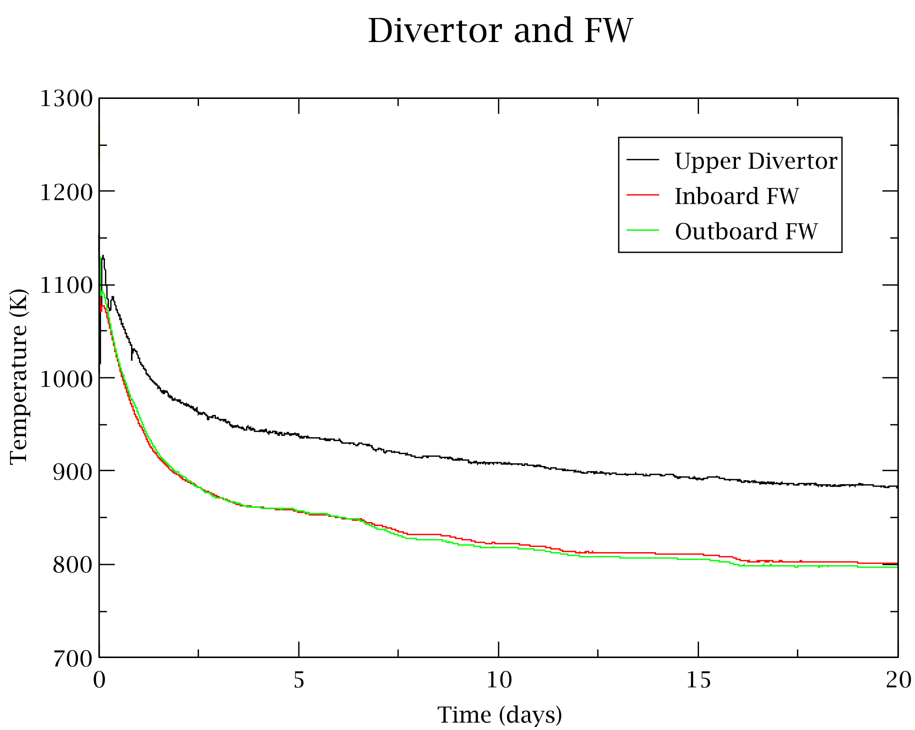
MELCOR DCLL Model Schematic



SiC Results for a LTSBO with Air Injection in the Cryostat

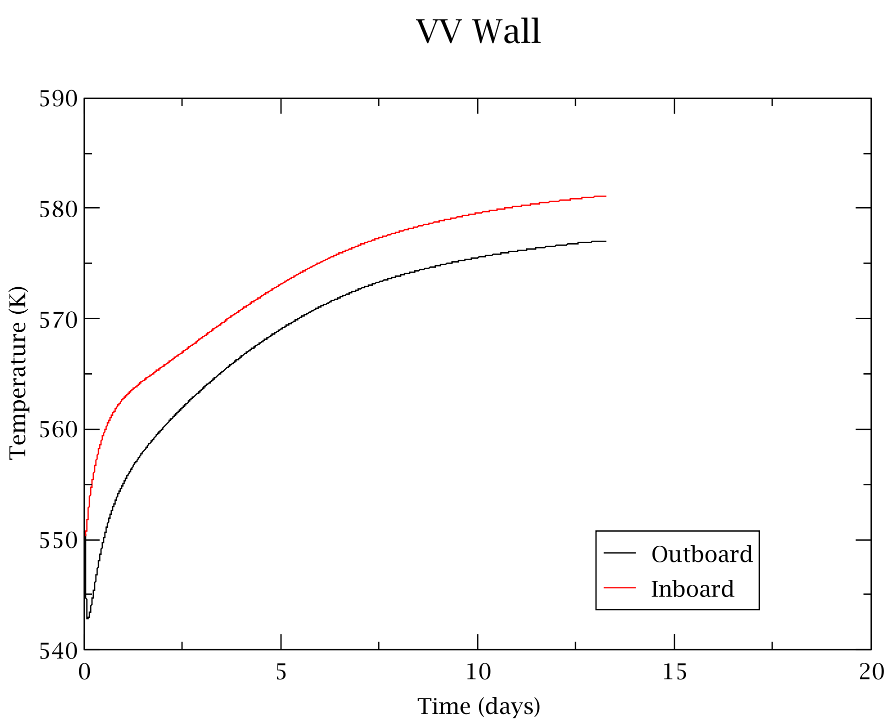
The inboard side of the VV is being cooled by the helium interior to VV, suggesting that internal natural convection from the inboard to the outboard of the VV may be important. However, because the VV model only has a single fluid volume, additional modeling will have to be performed to verify this possibility.

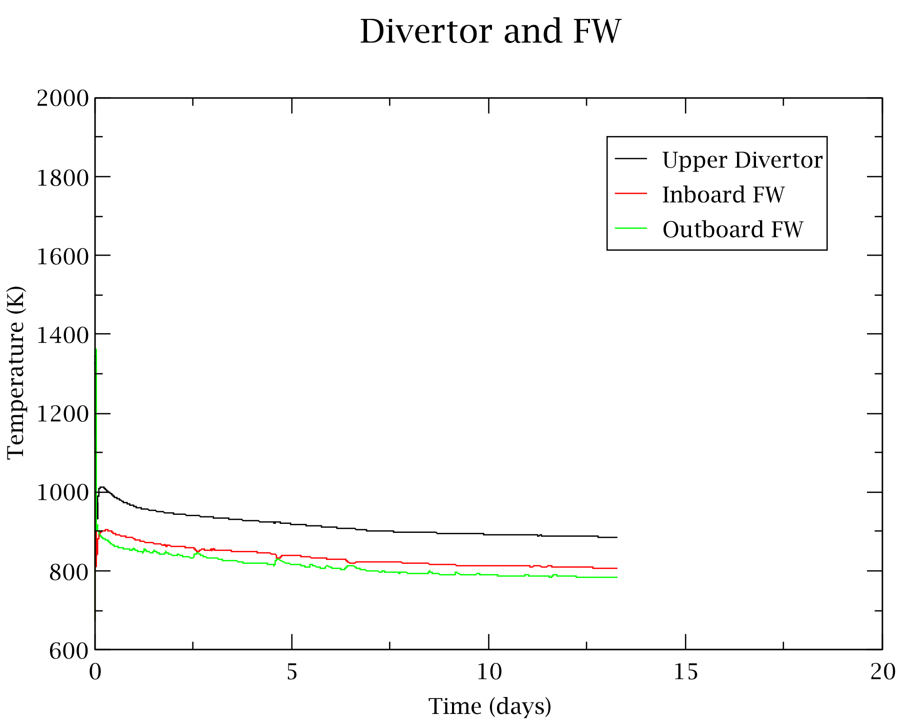




DCLL Results for a LTSBO with Air Injection in the Cryostat

Calculation has not progressed as far as SiC case. Steady state FW temperatures do not include enhancement for helium cooling. Need guidance on this.





Summary

- ARIES-AT MELCOR models have been modified and expanded to model ARIES-ACT, including both SiC and DCLL cases
- Preliminary LTSBO analysis verifies model is “wired” correctly
- Future work will focus on refinement of the model to reflect ARIES-ACT parameters
    - Many model details are still for ARIES-AT
    - Helium vs. Water cooled VV
    - Thermal Shield vs. Super-insulation
    - Divide VV into multiple control volumes
        - Natural convection may occur within the VV from the inboard to the outboard side of the VV; present model doesn’t capture this correctly

Follow up - Vacuum Vessel Permeation

Simple equilibrium permeation model used for scoping

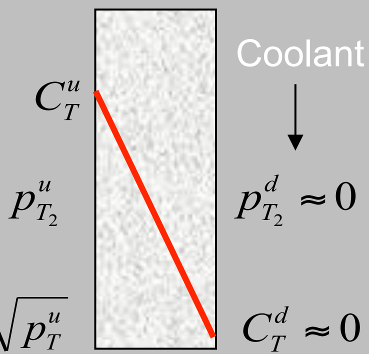
Surface concentrations

u – upstream d - downstream

$$C_T^u = K_s\sqrt{p_{T_2}^u} \qquad C_T^d = K_s\sqrt{p_{T_2}^d}$$

Fick’s law of diffusion

$$\Gamma_T = -D_T A_s \frac{\partial C_T}{\partial x} \approx -\frac{D_T K_s A_s}{\Delta t}\left(\sqrt{p_T^d} - \sqrt{p_T^u}\right) \approx \frac{PA_s}{\Delta t}\sqrt{p_T^u}$$



- Parameters used for the VV permeation analysis:
  - Upstream T_2 pressure 5 Pa and downstream pressure of zero
    - Question from last time on the validity of 5 Pa
- Detailed ITER divertor analysis* gives similar neutral pressures:

*A. S. Kukushkin et. al, “Effect of neutral transport on ITER divertor performance”, Nuclear Fusion **45** (2005) 608-616.