Preliminary analyses for ITER WCLL Test Blanket System with MELCOR

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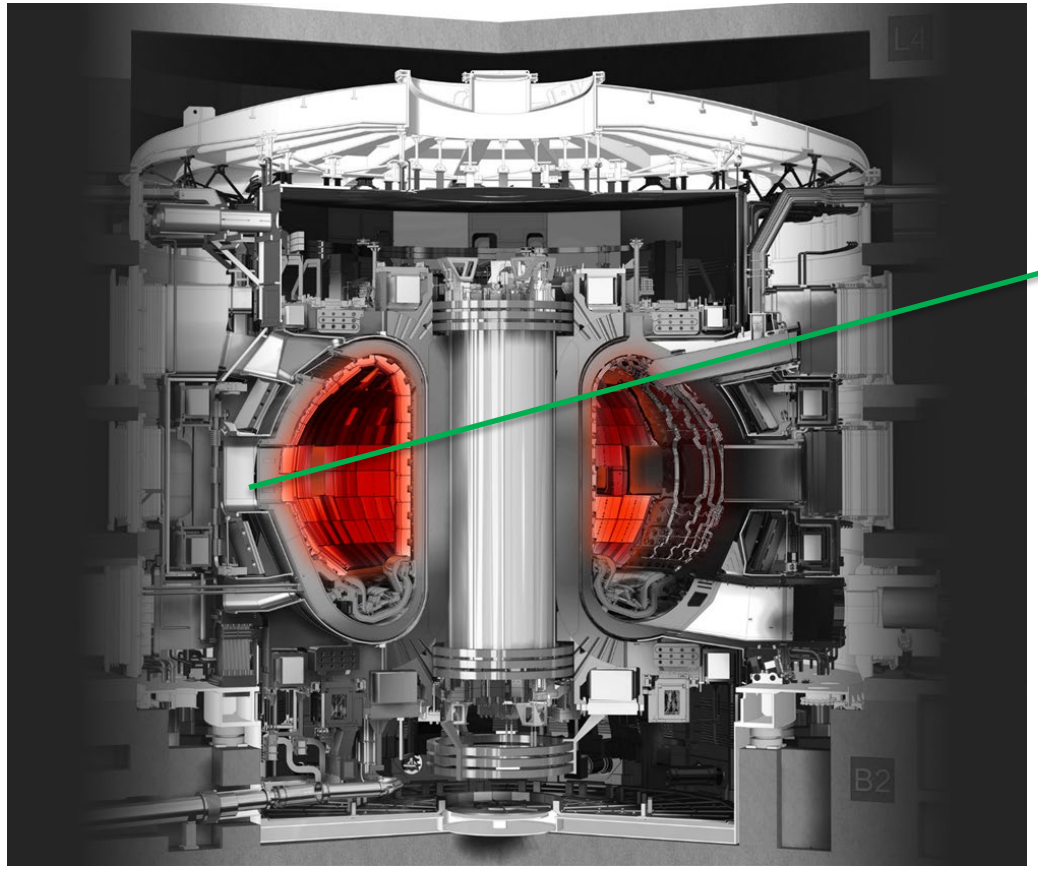
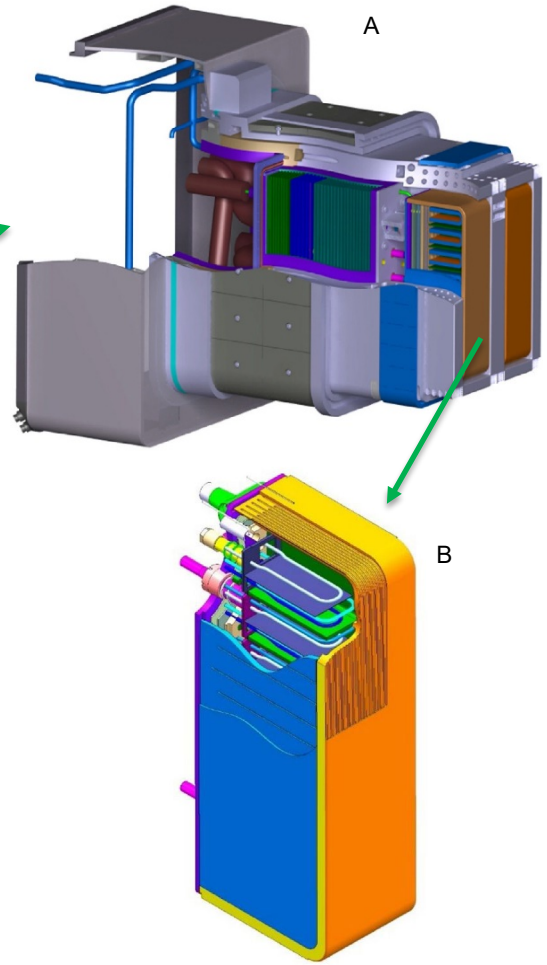
Outline

- Background
- WCLL Test Blanket System
- MELCOR model of WCS
- MELCOR model of TBM
- Preliminary parametric studies
- Summary

Background

- Test and validation of different design concepts of tritium breeding blankets during ITER operation
- TBMs are inserted in pairs, within a water-cooled stainless-steel frame called TBM Port Plug
- One of the two TBMs should be the Water-Cooled Lithium Lead Breeding Blanket (WCLL)
- Safety performance of TBS is an essential element for the integration of these TBSs into ITER

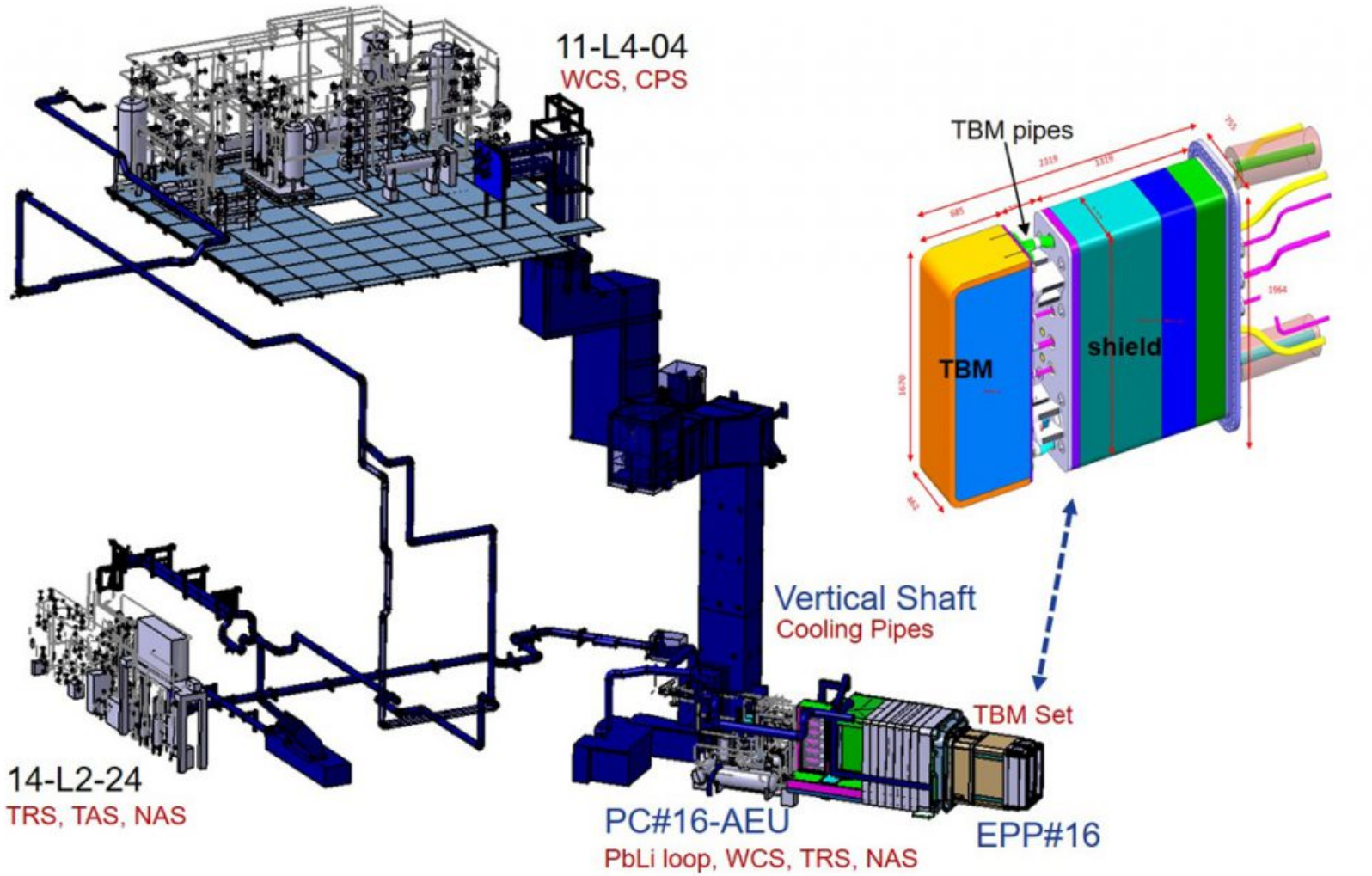




https://www.iter.org/

A) J. VALLORY, et al., “Design activities toward the achievement of the conceptual phase of the EU-TBM sets”, Fusion Engineering and Design, 109-111 (2016), pp. 1053-1057
B) J. Aubert, et al., “Design and preliminary analyses of the new Water Cooled Lithium Lead TBM for ITER”, Fusion Engineering and Design, 160 (2020), 111921,

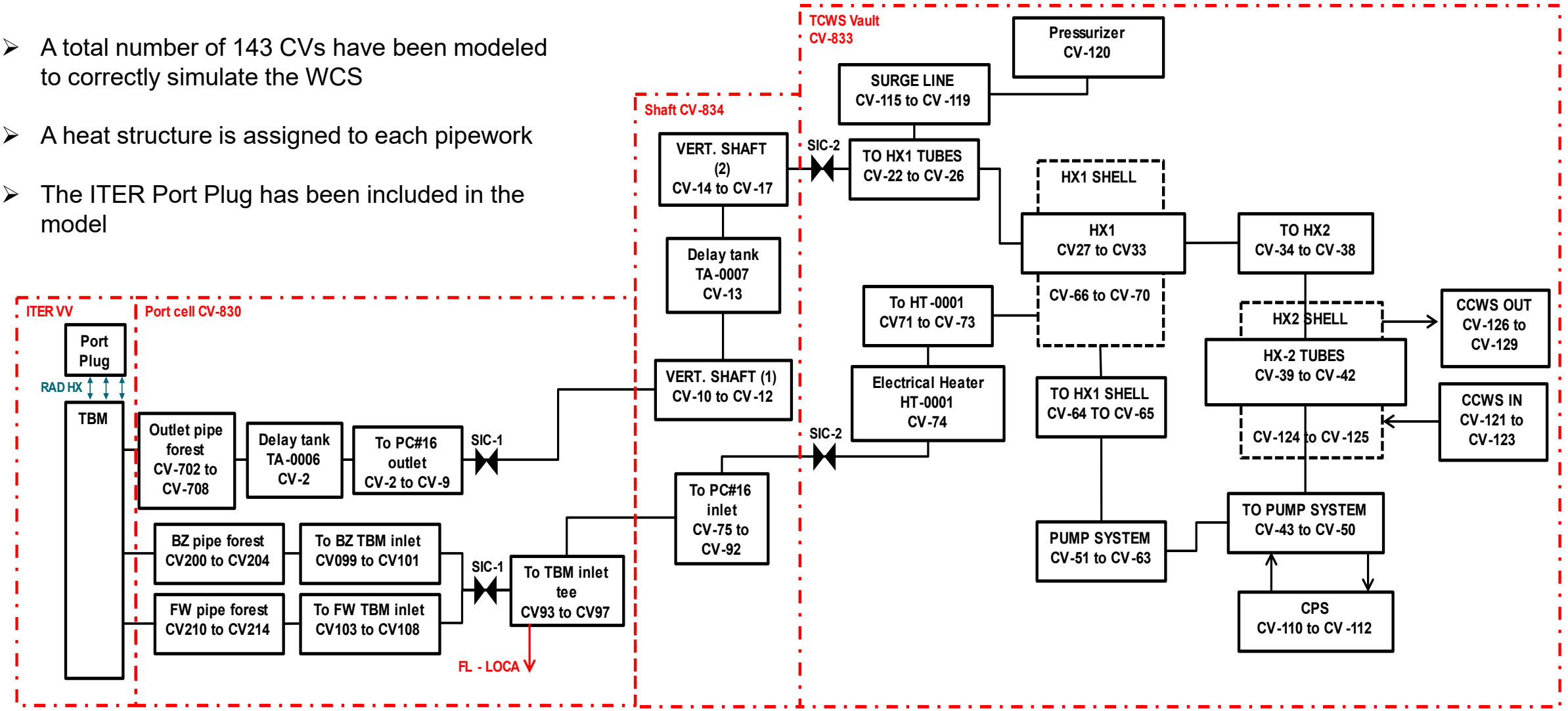
Background



https://fusionforenergy.europa.eu/news/iter-test-blanket-system-passes-conceptual-design-review/

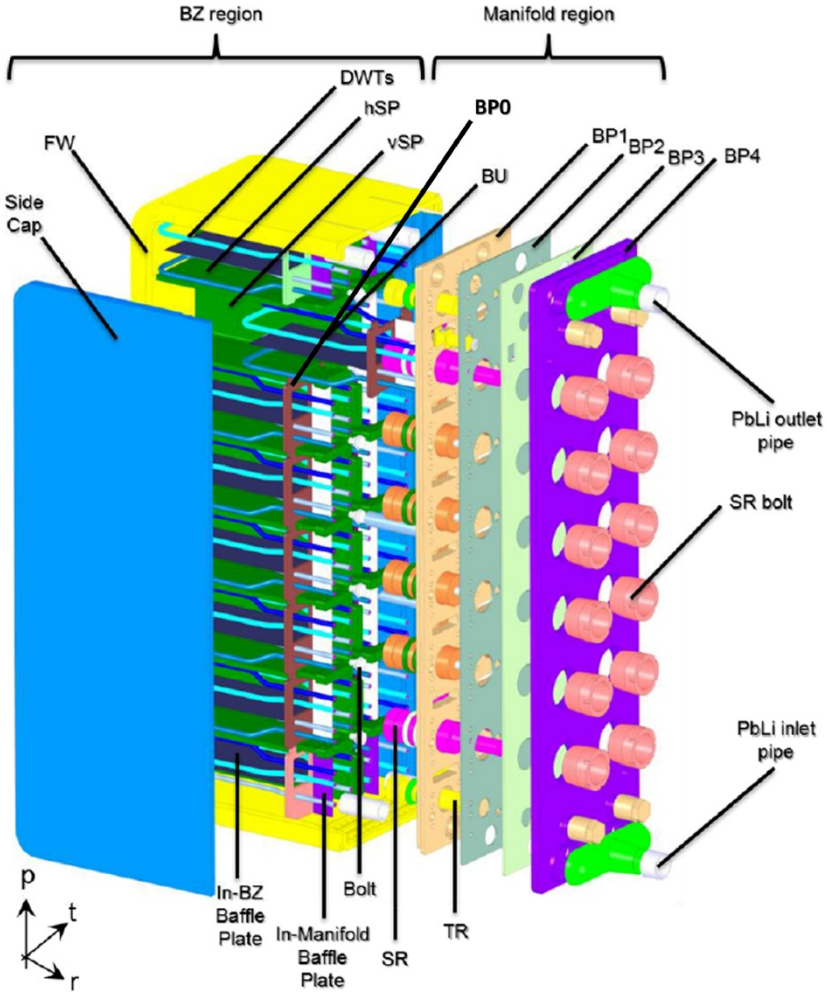
MELCOR model of WCS

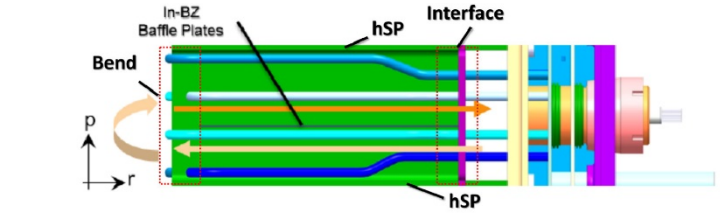
- A total number of 143 CVs have been modeled to correctly simulate the WCS
- A heat structure is assigned to each pipework
- The ITER Port Plug has been included in the model



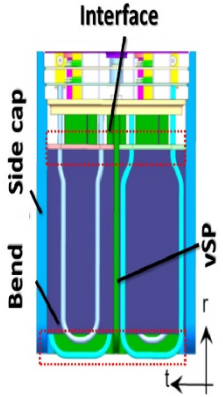
WCLL Test Blanket Module

- Reduced Activation Ferritic Martensitic (RAFM) steel EUROFER-97 as structural material
- Eutectic LiPb as tritium breeder and neutron multiplier
- Water @15.5 MPa as coolant
- 16 separate channels called Breeder Units (BUs) in which lithium-lead circulates

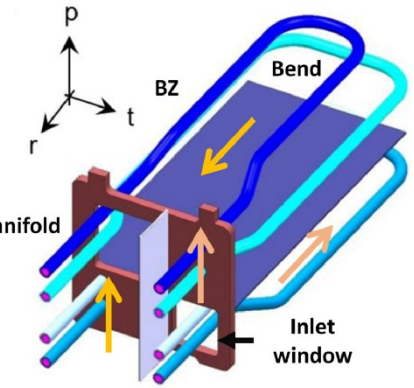




(a) Poloidal-radial view



(b) Radial-toroidal

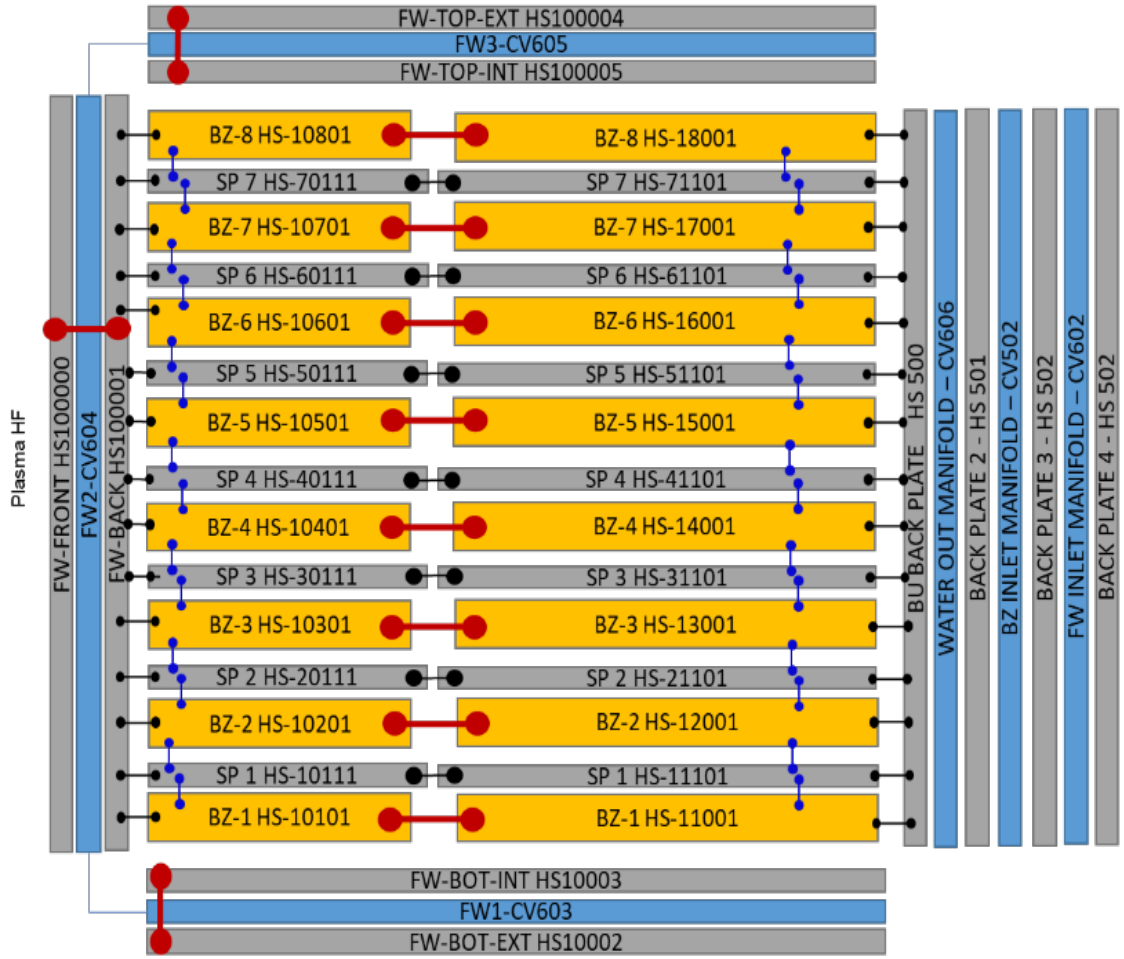


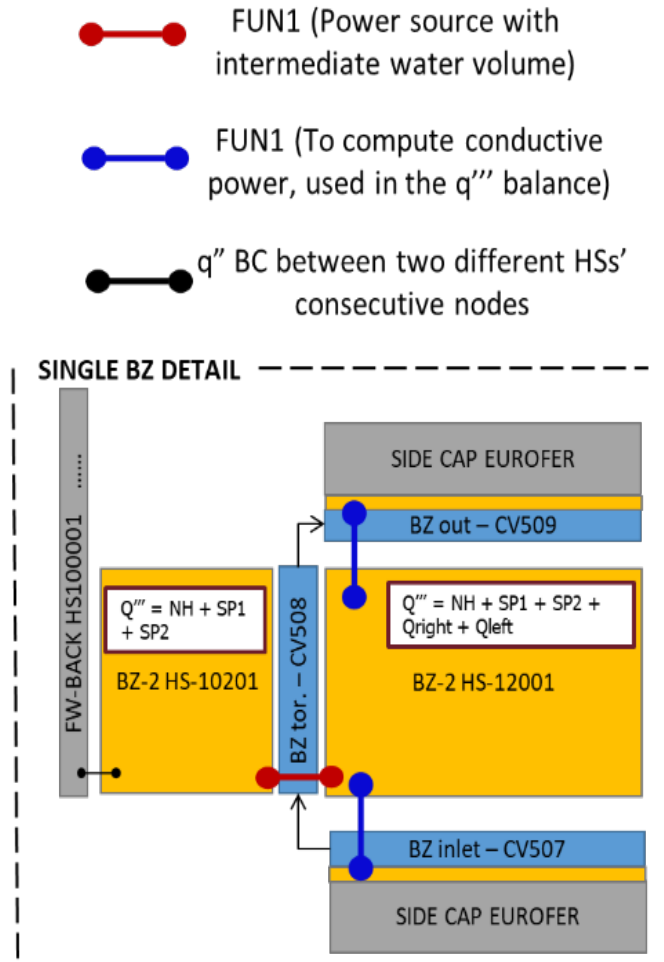
(c) Isometric view

R. Boullon, J. Aubert, A. Morin, **Definition of a WCLL reference TBM set design based on the WCLL BB design - First CAD model and scoping calculations** CEA (2019), https://idm.euro-fusion.org/?uid=2N7CDT

MELCOR model of TBM

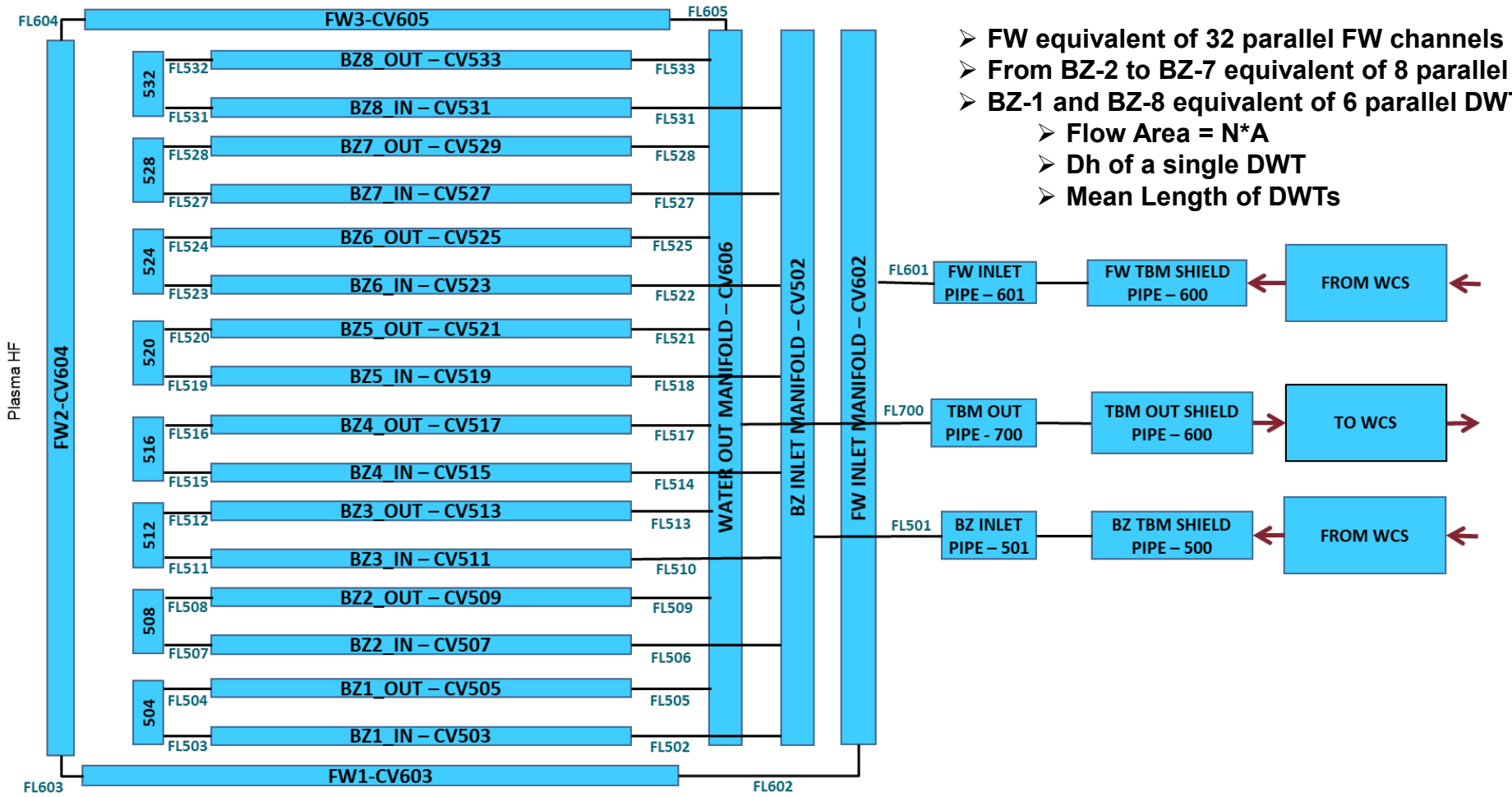
- The simultaneous presence of different working fluids cannot be achieved by the MELCOR code.
- LiPb has been simulated with HSs components thermally coupled by FUN1





TBM WATER COOLANT CVH & FL

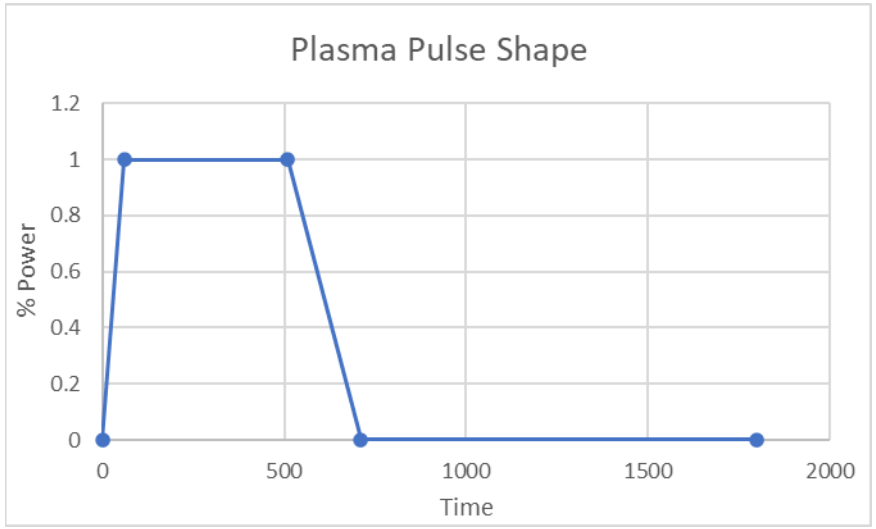
- In the developed CVH nodalisation, all FW channels are assumed to flow from the bottom to the top of the FW vertical structure.
- It is an approximation with respect to the real FW design in which channels are in counter-current one other two.



- **FW equivalent of 32 parallel FW channels**
- **From BZ-2 to BZ-7 equivalent of 8 parallel DWT**
- **BZ-1 and BZ-8 equivalent of 6 parallel DWT**
  - **Flow Area = N*A**
  - **Dh of a single DWT**
  - **Mean Length of DWTs**

Preliminary parametric studies

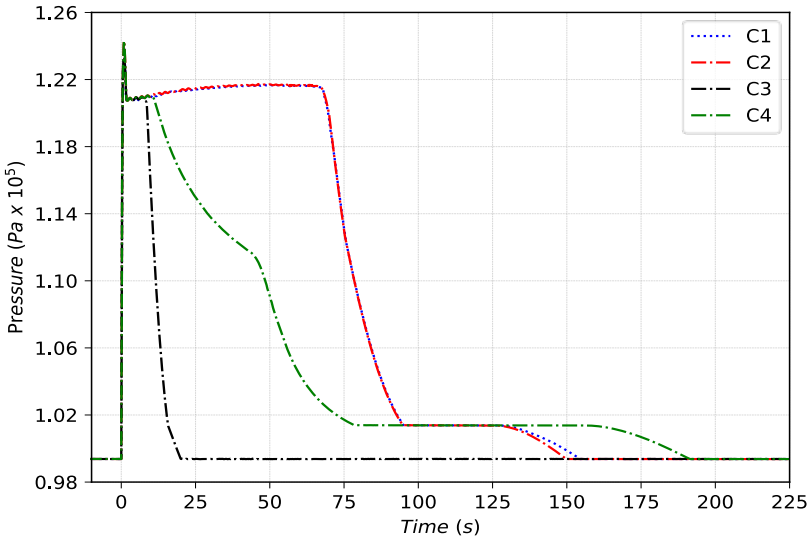
- **Ex-vessel loss of cooling accident**: Double-Ended Guillotine Break (DEGB) of the 3” TBM inlet WCS pipe during an ITER plasma burn phase
- **LOFA:** WCS pumps seizure during an ITER plasma burn phase



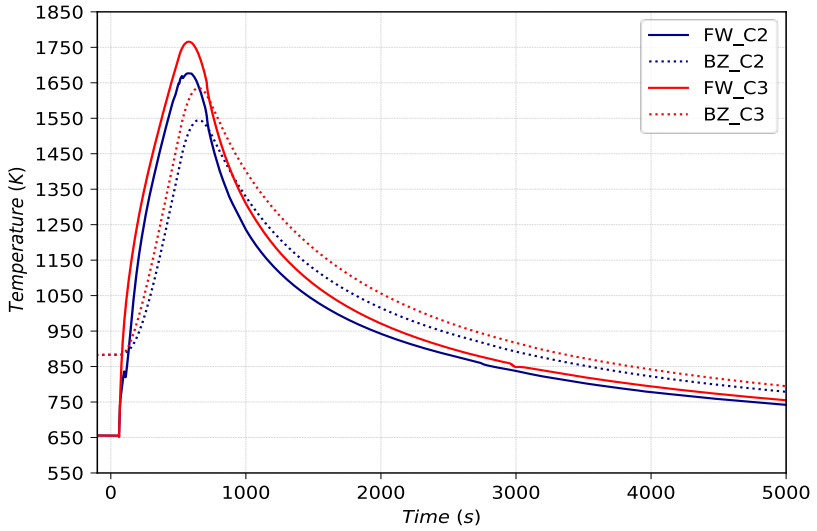
PIE	CASE ID	Time of PIE	FPTS	SIC1 Valve closure	SIC2 Valve closure
Ex-vessel LOCA	1	460 s	--	--	EPP (710 s)
	2	60 s	--	--	EPP (710 s)
	3		--	80% Pn	80% Pn
	4	460 s	80% Pn	--	80% Pn
LOFA	1	60 s	--	--	--
	2	60 s	Y (5s)	--	--
	3	510 s	--	Spurious closure at 510 s	--

Preliminary parametric studies (LOCA – Analyses)

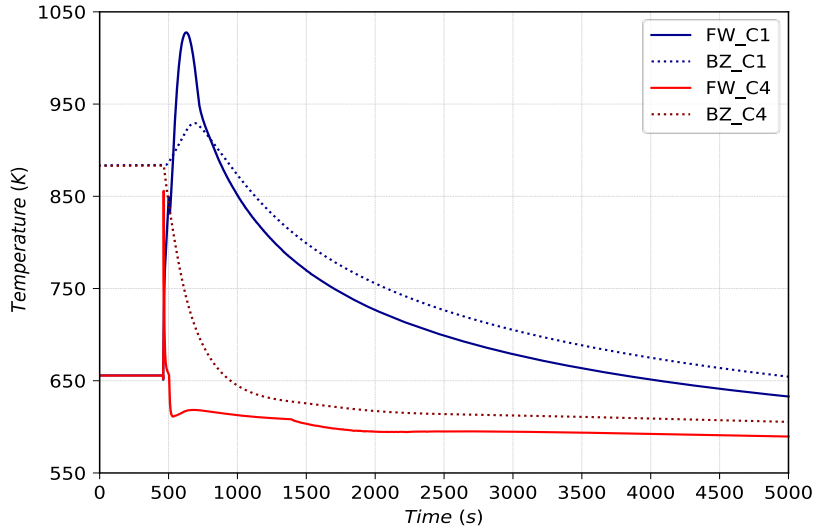
Pressure in Port Cell (PIE at 0 s)



FW and BZ temperature transient in C2 C3



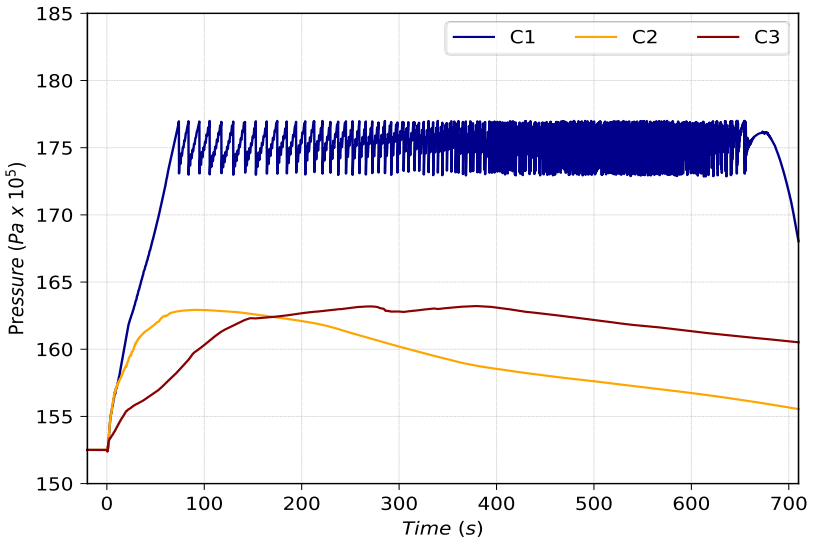
FW and BZ temperature transient in C1 C4



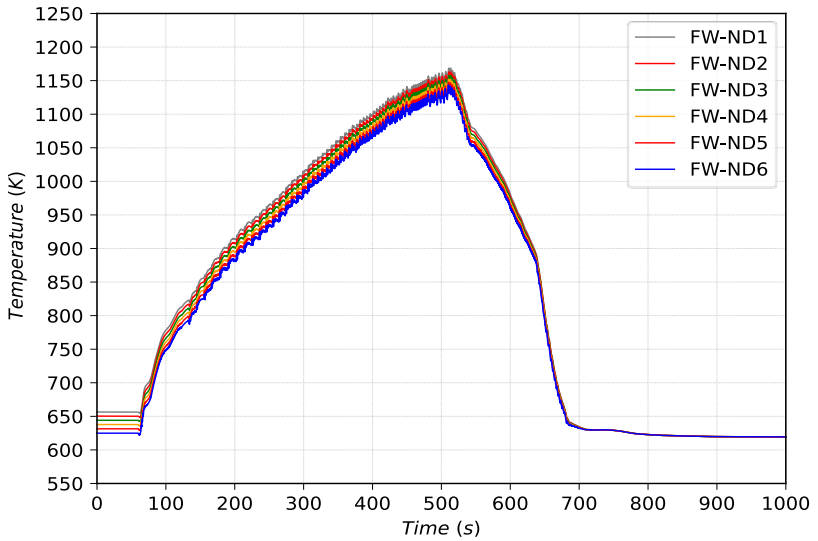
- The LOCA results in a release of water in the port cell environment and subsequent pressurization. The pressure peak of 124 kPa is reached in the PC immediately after the LOCA.
- The closure of SIC valves reduces the total inventory of water discharged in the PC, allowing also for a faster depressurization of PC volume, reducing HTO releases toward external environment.
- Preliminary results of LOCA analyses highlight that the TBM-FW can reach temperatures up to around 1700 K for PIE occurring at the beginning of the flat-top phase.

Preliminary parametric studies (LOFA – Analyses)

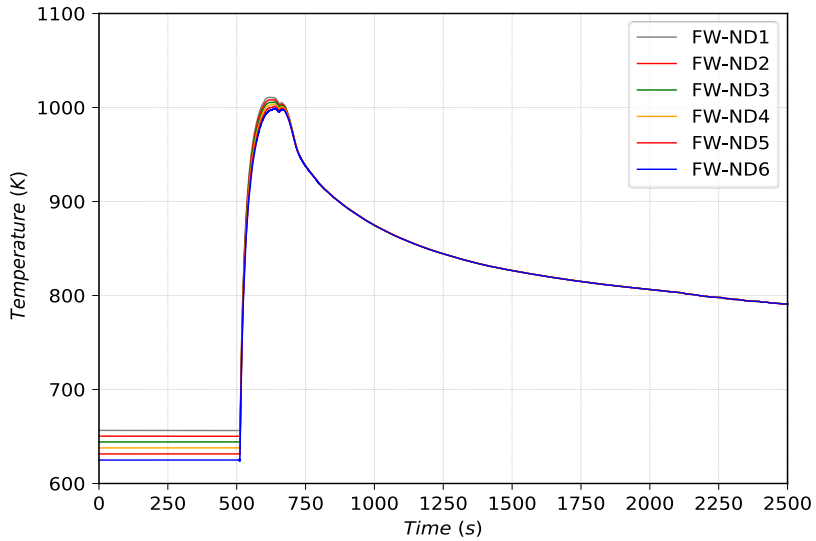
Pressure transient in WCS pressurizer (PIE at 0 s)



FW temperature in all HS nodes for LOFA C1



FW temperature in all HS nodes for LOFA C3



- The loss of coolant flow causes a rapid reduction in the rate of heat removal from the TBM, leading to temperature excursion of the TBM FW and pressurization of the WCS and TBM coolant.
- The FW temperature rises from 657 K at 60.0 s to reach the maximum temperature of 1175 K at t=540 s, 480 s after the PIE.
- It is still to be assessed which combined load conditions (structure temperature point combined with the related pressure load) would result into EUROFER structural integrity loss.

Summary

- A preliminary MELCOR model has been developed to perform safety studies on ITER WCLL TMB
- Simulation transients are quite stable. For the LOCA case around 6 days are needed to simulate a 32 h accident sequence. LOFA case is faster, but MFR oscillations are experienced in modelling natural circulation.
- Whilst waiting for the release of a new code version (MELCOR-TMAP) that simultaneously treats multiple fusion coolants the breeder material within the TBM has been simulated with equivalent heat structures.
- A set of parametric cases on time of occurrence of PIE and activation of safety provisions has been performed on two PIEs.
- Further modelling and accident analyses will be performed

Open issues

- Issues in using the structure-to-structure radiation model, spikes in heat exchange causes the calculation to crash. (Fixed using FUN1)

- The “multi-fluids” version of MELCOR 1.8.6 effectively replaces MELCOR’s steam/water property tables with data for other fluids, however the simultaneous presence of different working fluids cannot be achieved by the code. To simulate multi-fluids:
    - Coupling between two MELCOR runs using different working fluids has been done to work with multiple fluids.
        1) Using External data files (EDF). We experienced some issues in the MELCOR-FUS code v.1.8.6. in printing heat transfer coefficients. CF values are different than those in the plot file. It seems that HS wall temperature are printed instead of HTC.
        2) Using PLT file. Need to open PLOT files size of up to gigabytes at each time step

THANK YOU

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