Karlsruhe Institute of Technology
Institute for Neutron Physics and Reactor Technology (INR)
76344, Eggenstein-Leopoldshafen, Germany
salvatore.d-amico@kit.edu

31st SYMPOSIUM ON FUSION TECHNOLOGY

Preliminary safety analysis of LOCA scenarios for the EU-DEMO Helium Cooled Pebble Bed blanket concept by using the RELAP5-3D system code

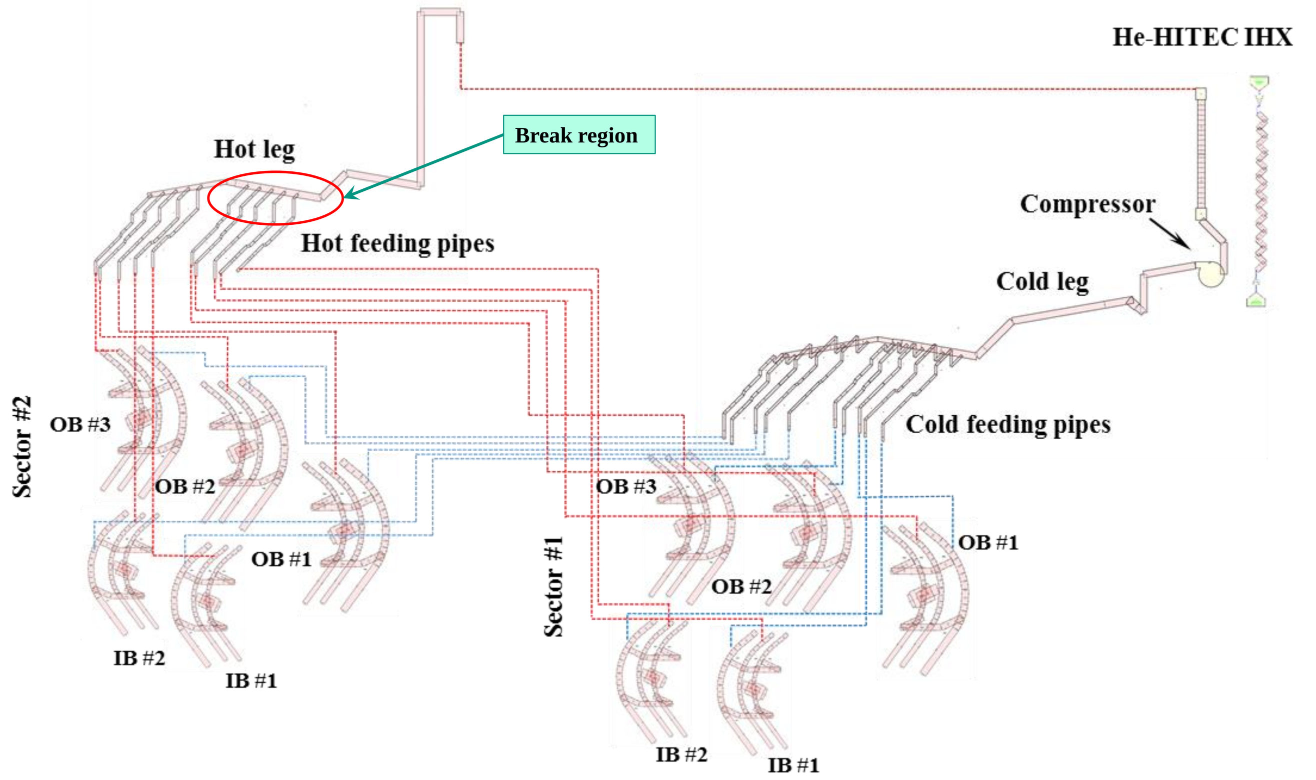
S. D'Amico[a], P. A. Di Maio[b], X. Z. Jin[a], F. A. Hernández[a], I. Moscato[b], G. Zhou[a]
[a]*Karlsruhe Institute of Technology (KIT), Eggenstein-Leopoldshafen, Germany*
[b]*Department of Engineering, University of Palermo, Palermo, Italy*

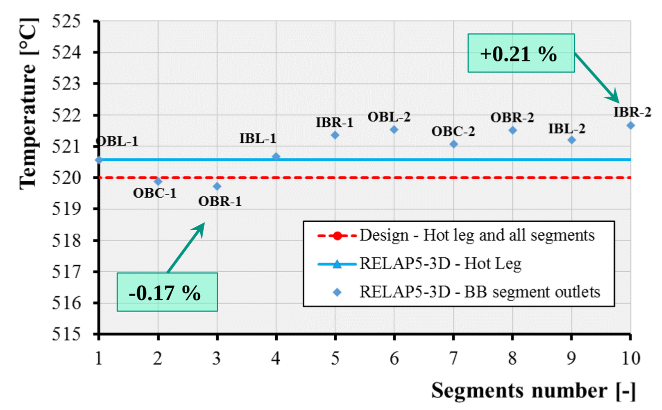
ABSTRACT

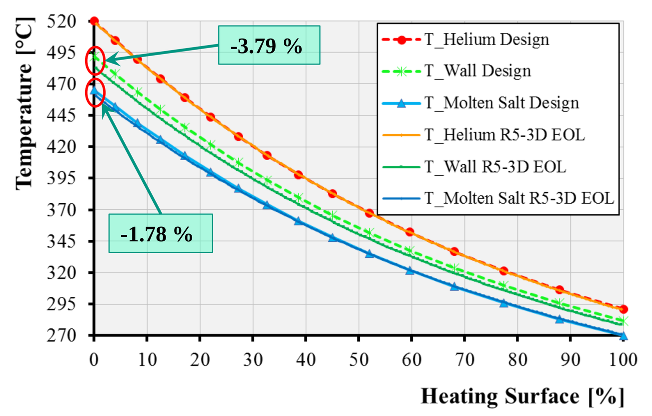
In consideration of the current EU-DEMO pre-conceptual design phase, significant efforts have been made within the framework of EUROfusion Safety and Environment actions, to incorporate the needed provisions to improve the overall plant safety and reliability performances as well as to analyse possible mitigation action for selected accidental scenarios which could jeopardise them. Consequently, an intense research campaign has been launched in order to develop a model, at thermal-hydraulic system code level, for the EU-DEMO HCPB-BB concept, aimed at characterizing its response under the most representative accidental scenarios. For the ex-vessel scenario, a DEG break occurring in a OB segment hot feeding pipe has been postulated. The main purpose has been to assess the dynamic pressure loads on the civil structures of the tokamak building checking whether the imposed design limit have been exceeded considering the current expansion volume available in the TCR. Thereafter, the consequences of an in-vessel LOCA due to a vacuum side DEG rupture in the largest feeding pipe have been investigated. In particular, two variants have been envisaged for such a scenario. Firstly, it has been assumed to have the safety-relevant VVPSS equipped with a dry expansion volume and then a possible design modification based on the adoption of an immersed heat exchanger to cool down the helium coming from the VV has been preliminarily explored to better cope with the VV design limit. Models, assumptions and outcomes of this preliminary study are herein presented.

RELAP5-3D Finite Volume Model

It has been developed a realistic finite volume model for the safety relevant loop of the new BB-PHTS consisting of all the required sub-models: the **flow domain sub-model**, the **constitutive sub-models**, the **hydraulic sub-model** the **thermal sub-model**. Here, the nodalization scheme adopted for the cold, hot legs and that adopted to simulate each of the 10 segments together with its assessment:

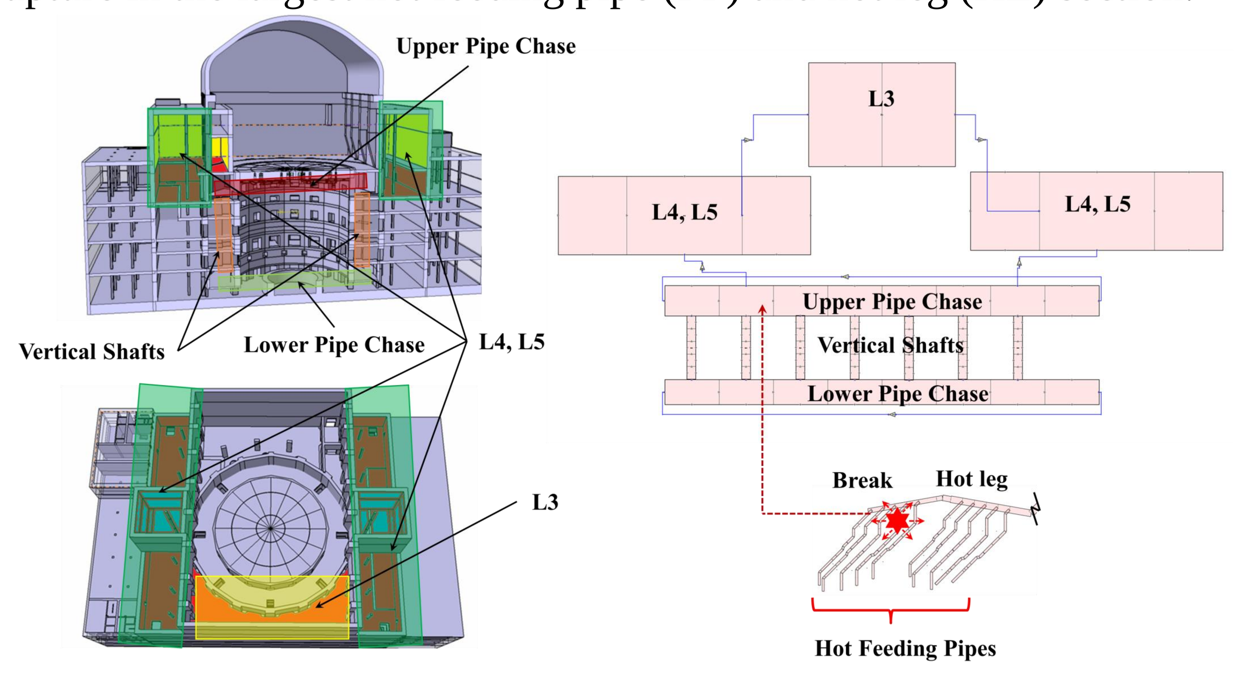


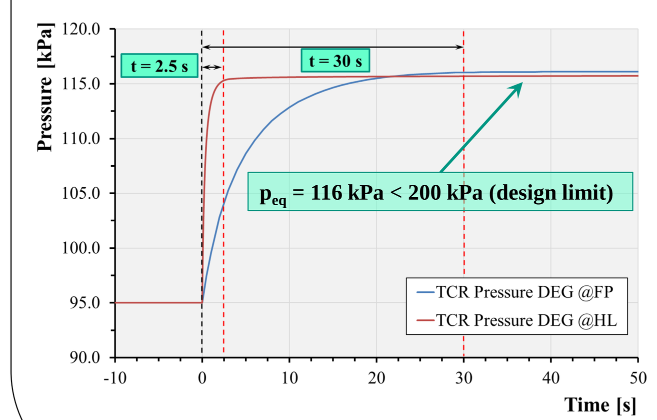


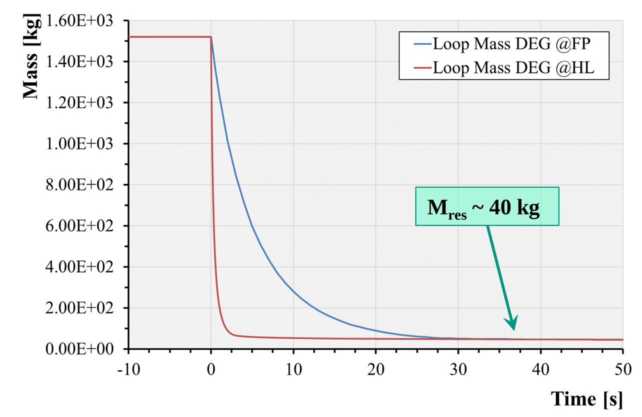


Ex-Vessel Loss of Coolant Accident Analysis

In order to simulate the selected scenario, the computational model has been extended to include the TCRs modelled as expansion volumes. The total ex-vessel volume available for the helium expansion is **~1.36·10^5** m³. The ex-vessel LOCA begins at t=0 s (@ end of pulse), it is simulated a time delay, t_{res}, in detecting the break equal to 3 s, after which both the practically immediate plasma shutdown and the decay heat are simulated. The model has been applied in analysing two scenarios due to a DEG rupture in the largest hot feeding pipe (FP) and hot leg (HL) section.

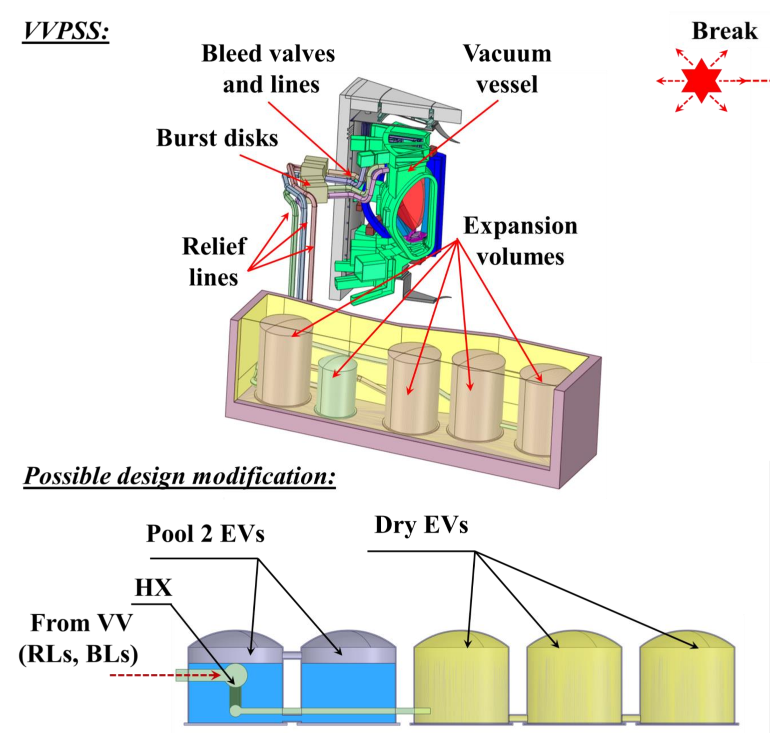


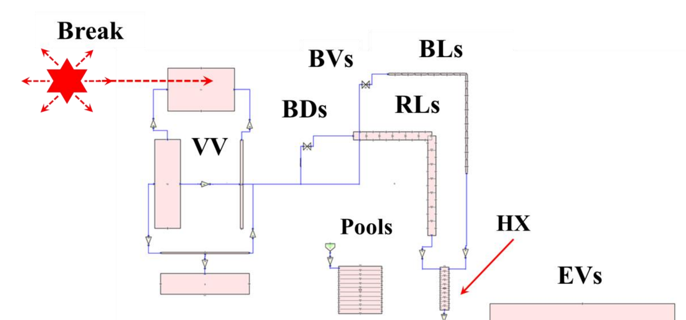




In-Vessel Loss of Coolant Accident Analysis

The consequences of a DEG rupture of one OB segment hot feeding pipe on the vacuum side will be investigated. In particular, two scenarios have been envisaged: the first foresees a dry expansion volume while for the second one the VVPSS is equipped with an in-pool heat exchanger emulating the Isolation Condenser (IC) installed in some advanced BWR designs. The main goal is to assess the pressure behaviour in the VV considering the design limit value of 200 kPa.

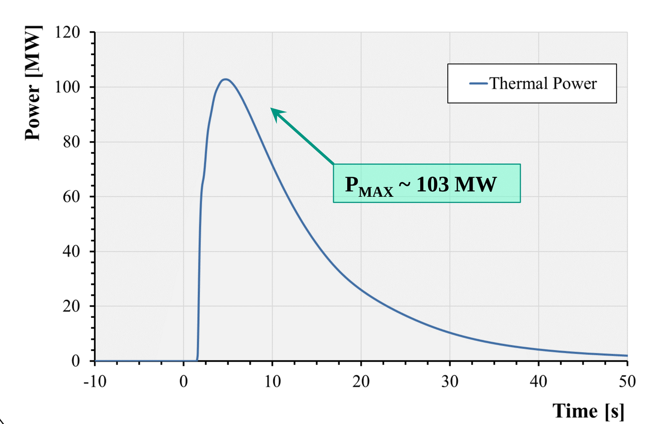


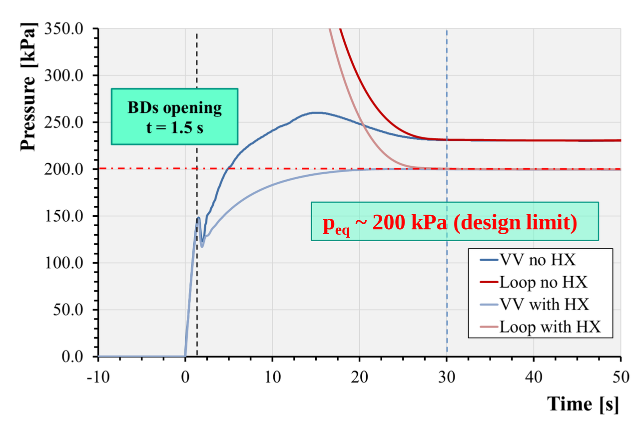


BVs setpoint := 90 kPa
BDs setpoint := 150 kPa

HX Design parameters:

Parameter	Value
Tube outer diameter [mm]	50.80
Tube inner diameter [mm]	48.80
Tube thickness [mm]	1.00
Design pressure [kPa]	250.00
Thermal conductivity [W/m·K]	20.34
Thermal power [MW]	150.00
Tubes length [m]	6.04
Number of tubes [-]	7821





CONCLUSION

For the Ex-Vessel LOCA, considering the available expansion volume in TCR, the evaluated maximum pressure is safely below the limit of 200 kPa. In order to further reduce the accidental scenario consequences, the feasibility to install isolation valves to limit the coolant inventory released to the TCR and therefore the release of radioactive materials can be addressed in future work.

As the in-vessel LOCA scenarios concerns, they differ according to whether the VVPSS is equipped with a dry EV (5 identical tanks of ~980 m³ each) or by resorting to an immersed HX (2 tanks as water reservoir where the HX is immersed while the remaining tanks serve as dry EV). This latter solution is promising, but since the obtained pressure peak is lying on the design limit (200 kPa), it requires thus the recourse to possible modifications. Some potential solutions might be the adoption of a greater expansion volume or a different HX configuration, which require additional feasibility studies.

Q&A Session

The session will be held on Skype on Monday 24th Sept. at 17:00. You can find the corresponding author on Skype under the name: "Salvatore D'Amico (KIT-INR)" or through the following link:
https://join.skype.com/invite/g9dVOXKdXQN8

EUROfusion

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.