EUROfusion website: https://www.euro-fusion.org/
KIT-INR website: https://www.inr.kit.edu/english/index.php

P-2.94

32nd SOFT 2022 — 32nd SYMPOSIUM ON FUSION TECHNOLOGY
SEPTEMBER 18-23, 2022 • Dubrovnik, Croatia

European DEMO HCPB Breeding Blanket breeder zone mockup: engineering design and manufacturing

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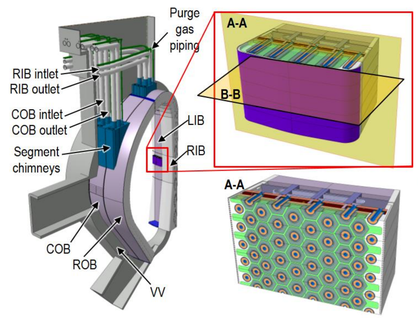
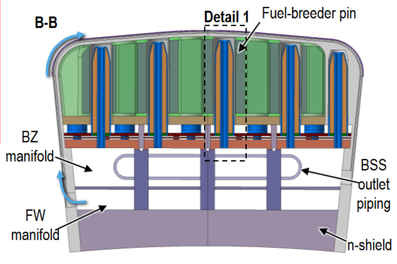
Design of HCPB BB at end of Pre-Concept Design (PCD) Phase

- **Fuel-breeder pin concept in Breeder Zone of HCPB BB [1]**

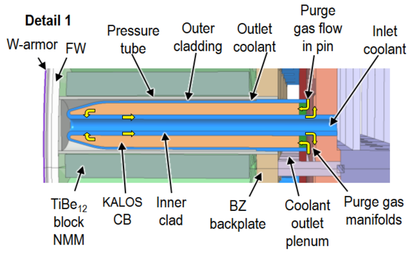
F.A. Hernández et al., talk IT-4C.1



HCPB Design for EU-DEMO BL2017



Radial-toroidal slice



Fuel-breeder pin

Motivation

Roughness is needed to enhance heat transfer in the fuel-breeder pin concept

Flow regime in rough channels is classified [2] following roughness Reynoulds number e+

$0 \le e^+ < 5$	Hydraulically smooth regime
$5 \le e^+ < 70$	Transition regime
$e^+ \ge 70$	Fully rough regime

$$e^+ = \frac{e \cdot u^*}{\nu} = \mathrm{Re}\frac{e}{D_{hyd}}\sqrt{\frac{f}{8}}$$

- **Investigate heat transfer enhancement of different surface roughness techniques**
- **Benchmark heat transfer correlation in breeder zone (pin)**
- **Validate CFD tools and system codes**

Facility and Up-scaling

The Helium Loop Karlsruhe (HELOKA) [3] is dedicated for testing fusion reactor components under relevant high heat flux while using high-pressure and high-temperature helium as a coolant.

HELOKA facility

Comparison of operating conditions

	HELOKA	Pin of HCPB
Operating Pressure	4 ~ 9.2 MPa	8 MPa
Operating Temp.	100 ~ 550°C	300 ~ 520°C
Mass flow rate	up to 1300 g/s	15 ~ 23 g/s

Up-scaling is needed

Up-scaling based on **Re** number, **Pe** number and dimensionless heating rate **q+**

$$\mathrm{Re} = \frac{\rho \cdot v \cdot D_h}{\eta} = \frac{\dot{m} \cdot D_h}{\eta \cdot A_{cross}}$$

$$\mathrm{Pe} = \mathrm{Pr} \cdot \mathrm{Re}$$

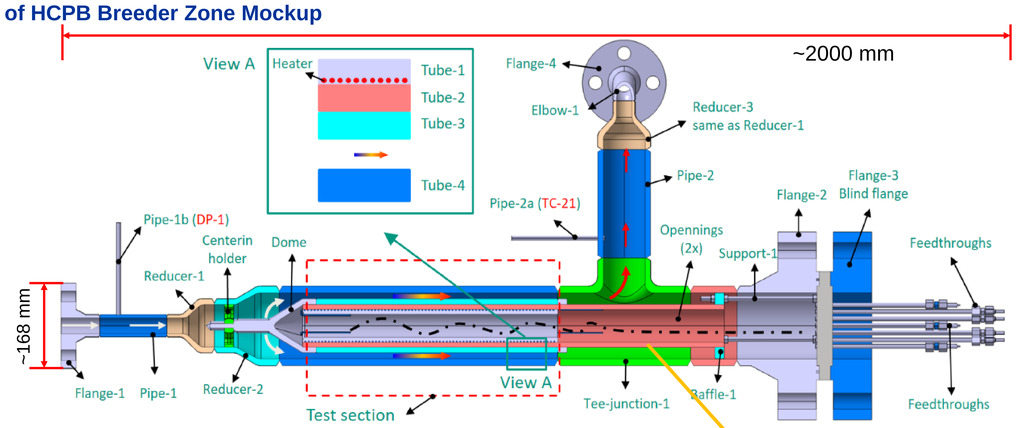
$$q^+ = \frac{q_w}{\frac{\dot{m}}{A_{cross}} \cdot c_p \cdot T_{in}}$$

Operation pressure: 8 MPa
Inlet temperature: 300 °C

Test matrix
Re = 4000, 6000, 8000, 10000
q^+ = 2e-4, 3e-4, 4e-4, 5e-4, 6e-4
Seven different surface roughness

B.-E. Ghidersa et al., talk IT-3C.2

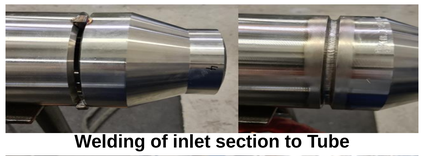
Design of HCPB Breeder Zone Mockup



Replaceable inserts, with different surface roughness

- **In test section, the mockup heated by embedded heating wire to simulate heating from breeder materials.**
- **7 different replaceable inserts are planned to investigate heat transfer enhancement of different surface roughness.**
- **Design passed the examination of Notified Body (TÜV Süd), justified by CFD analyses and pressure calculations.**

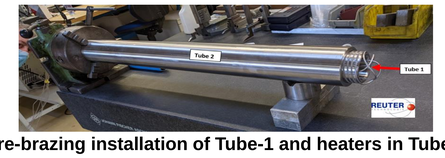
Manufacturing of HCPB Breeder Zone Mockup



Welding of inlet section to Tube

Secondary welding seam inert gas protection

Brazing paste on heater wires and mounting Tube



Pre-brazing installation of Tube-1 and heaters in Tube-2

Assembly

Integration into HELOKA facility

Thick layers of isolation will cover all parts to minimize heat loss.

★ **First experimental results are now available.**

A. Abou-Sena, poster P-2.71

[1] L.V. Boccaccini et al. Fusion Eng. Des. 179 (2022) 113116. DOI: 10.1016/j.fusengdes.2022.113116

[2] R. K. Shah, M. S. Bhatti. Proceedings of the NATO Advanced Study Institute on Thermal-Hydraulic Fundamentals and Design of Two-Phase Flow Heat Exchangers, Povoa de Varzim, Portugal, July 6-17, 1987.

[3] B.E. Ghidersa et al., Fusion Eng. Des. 81 (2006) 1471-1476. DOI: 10.1016/j.fusengdes.2005.06.370

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This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.