Karlsruhe Institute of Technology

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HELOKA-US Project: towards the verification of a DEMO-based conventional power plant technology

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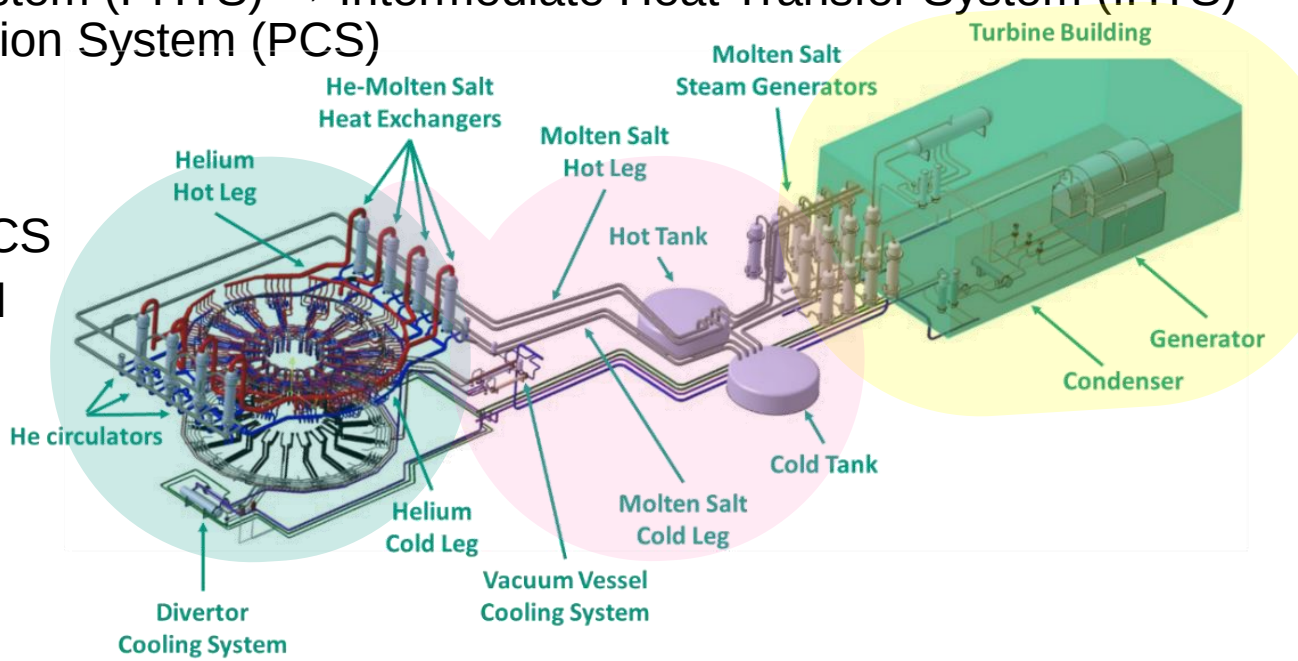
Introduction: He-cooled DEMO Balance of Plant

Indirect Coupling Design: Primary Heat Transfer System (PHTS) → Intermediate Heat Transfer System (IHTS) with Energy Storage System (ESS) → Power Conversion System (PCS)



Features:

- Decoupling plasma intermittent heat source from PCS
- Buffering energy during pulse and releasing in dwell
- Constant PCS steam load over complete operation

Coming steps:

- Consolidation of the **Conceptual Design**
- Assessment of the **Functional Feasibility**

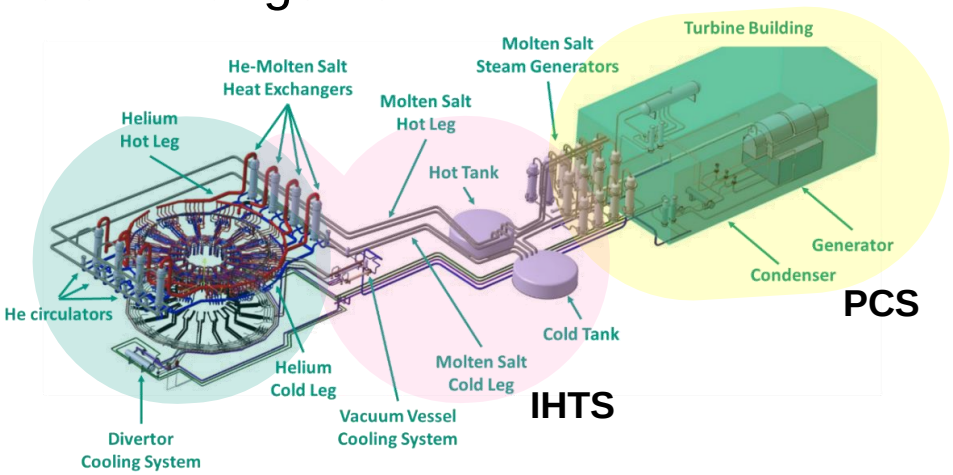
➡ **Experimental R&D platform** supporting He-cooled DEMO BOP Design

Outline

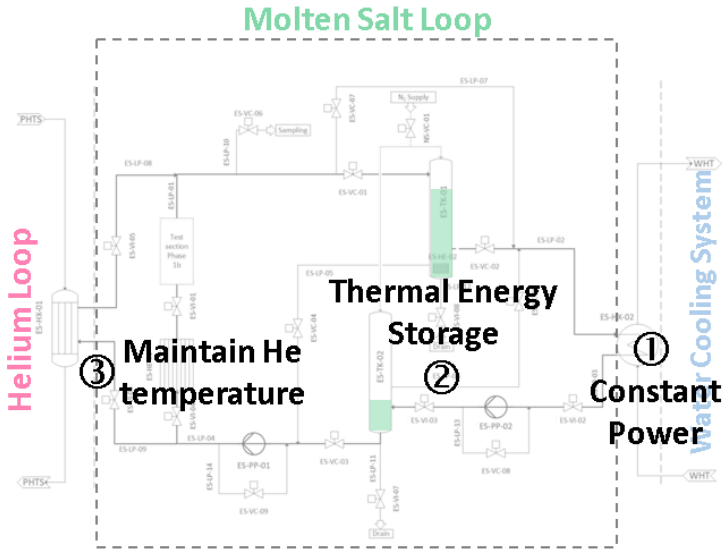
- **HELOKA - Upgrade Storage**: Functional & Operational requirements. Facility Description.
- Numerical results of pre-studies for the thermal-hydraulic behavior.
- Current project status and the experimental scope. Outlook.

HELOKA-US functional and operational requirements

Heat Transfer Arrangement



He-cooled DEMO BOP



HELOKA-US

	He supply	He-MS interface	MS heat source	MS Storage	MS heat sink
He-DEMO BOP	**BB-PHTS**	**IHX**	**IHX**	**ESS (two tanks)**	**PCS**
Phase 1a-1	-	-	elect. Heater	ESS (two tanks)	HELOKA-HP WCS
Phase 1a-2	-	-	elect. Heater + elect. heated MS side Test Section	ESS (two tanks)	HELOKA-HP WCS
Phase 1a-3	HELOKA-HP	He-MS Test Section	elect. Heater + He-MS Test Section	ESS (two tanks)	HELOKA-HP WCS
Phase 1b	HELOKA-HP	He-MS HX	He-MS HX (OTSTHX)	ESS (two tanks)	HELOKA-HP WCS

MS: Molten Salt (HITEC); HX: Heat Exchanger; OTSTHX: Once Through; Shell and Tube HX; WCS: Water Cooling System

HELOKA- US functional and operational requirements

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Thermal-Hydraulic Conditions

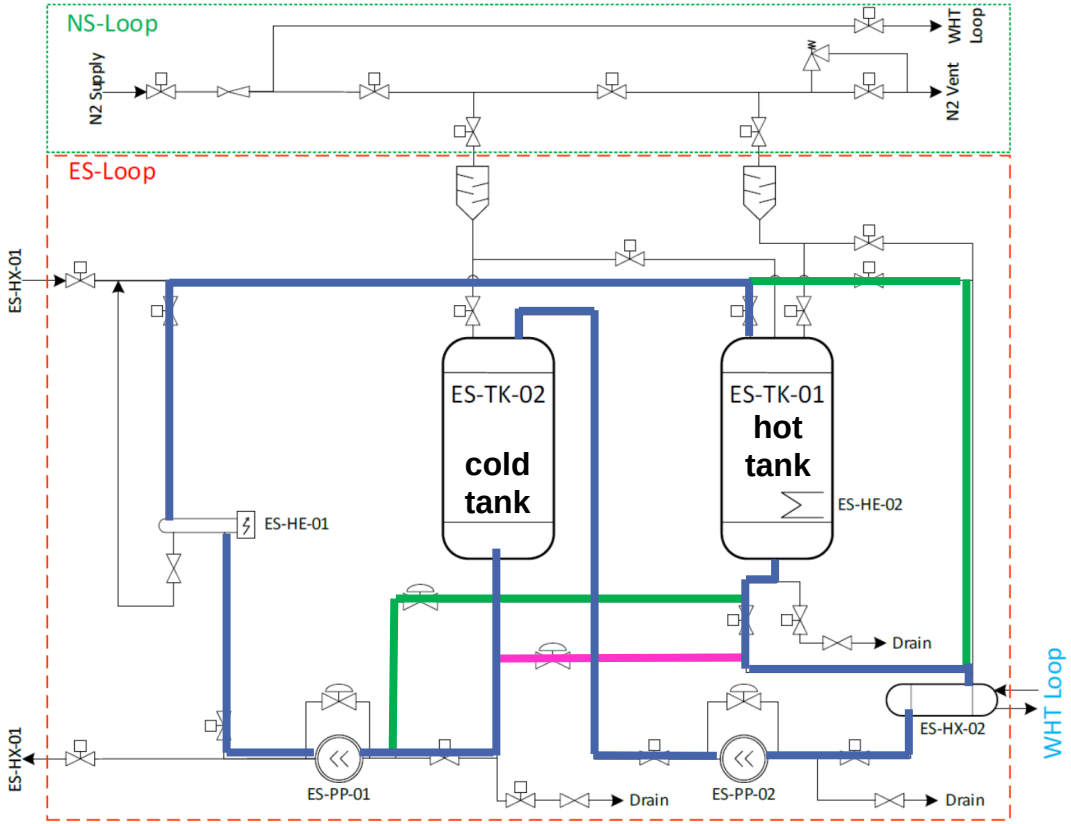
	He-DEMO BOP *		HELOKA-US	
	Pulse	Dwell	Pulse	Dwell
Thermal power of one PHTS loop (kW)	254,000	2,540	260	2.60
Duration (s)	7,200	600	7,200	600
MS IHX in / out temperature (°C)	270/465	270/299	270/465	270/299
MS SG in/out temperature (°C)	465/270	453/270	465/270	453/270
MS hot tank temperature (°C)	465	465	465	465
MS cold tank temperature (°C)	270	270	270	270
MS flow rate in charging line (kg/s)	898.7	58.4	0.854	0.0581
MS velocity in charging line (m/s)	0.66	0.04	0.452	0.031
MS flow rate in discharging line (kg/s)	810.2	927.0	0.789	0.727
MS velocity in discharging line (m/s)	0.60	0.68	0.417	0.385

In HELOKA-US, the water cooling system acting as heat sink of the MS Loop has an inlet/outlet setpoint of 160/220 ° C.
The limit is confined by the HITEC melting point of 142 °C, as well as by the final WHT design temperature of 240 °C.

* In one of the 8 BB-PHTS loops.

Description of the HELOKA-US facility

Flexible and upgradable facility

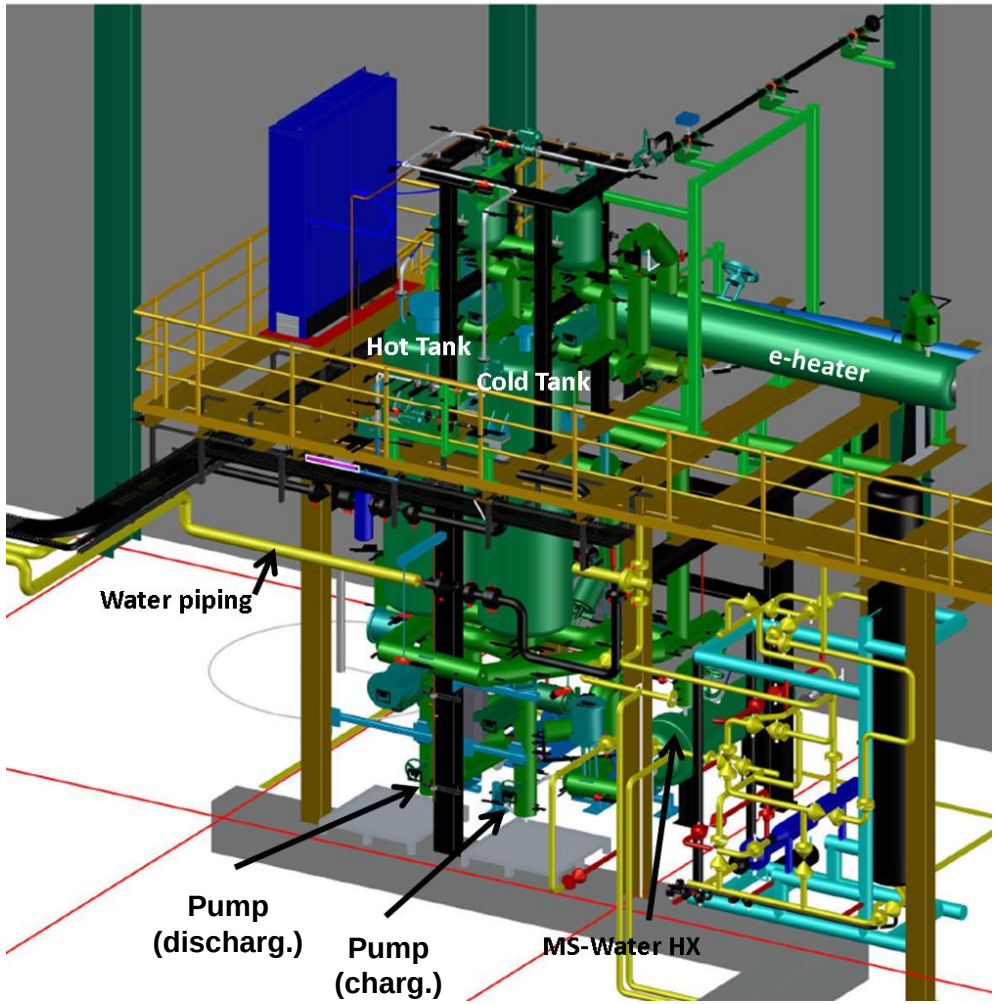


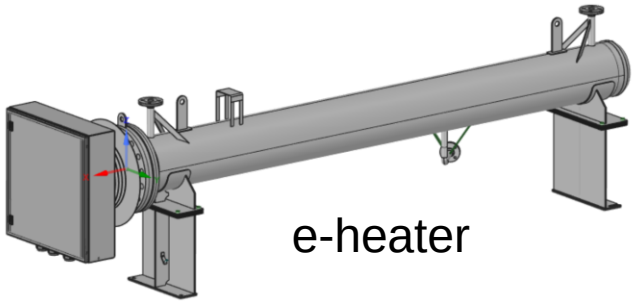
Phase 1a-1

Component ID	Type	Fluid	Pressure pulse/dwell (bar g)	Temperature pulse/dwell (ºC)	Piping connection
ES-TK-01	Tank	MS	<2 / <2	465 / 465	DN32
ES-TK-02	Tank	MS	<2 / <2	270 / 270	DN32
ES-HE-01	Electrical Heater	MS	7 / 7	465 / 299	DN32
ES-HE-02	Internal electrical heater in TK-01	MS	<2 / <2	465 / 465	-
ES-HX-02	U-Type HX	MS / Water	<2 / <2	465-270 / 453-270 (MS) 220-160 / 220-160 (Wa)	DN32
ES-PP-01	Pump (max.pres. 8.3 barg)	MS	≤2-~7 / ≤2-~7	270 / 270	DN32
ES-PP-02	Pump (max.pres. 8.3 barg)	MS	≤2-~7 / ≤2-~7	270 / 270	DN32
ES-SE-01	Separator (above ES-TK-01)	MS / Nitrogen	7 / 7	465 / 465	DN25
ES-SE-02	Separator (above ES-TK-02)	MS / Nitrogen	7 / 7	465 / 465	DN25

HX: Heat Exchanger
MS: Molten Salt
SE: Separator

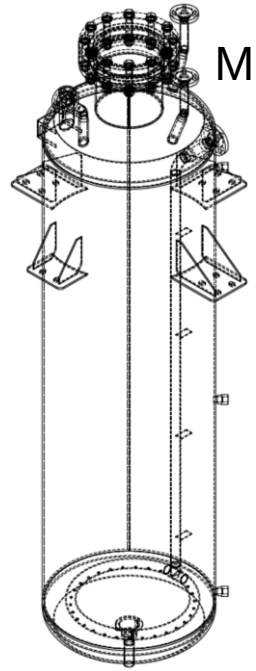
Description of the HELOKA-US facility

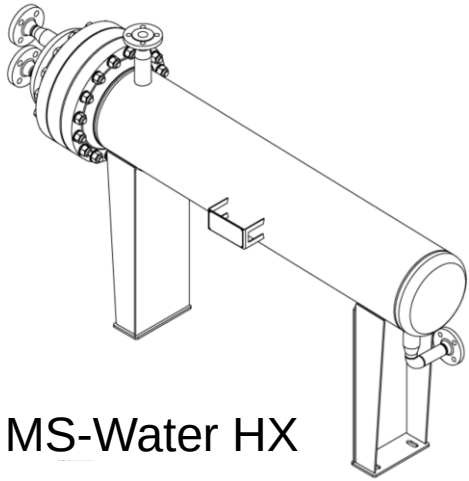




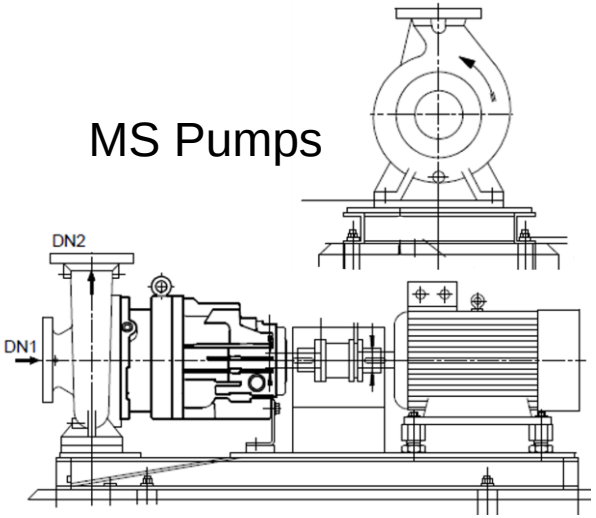
e-heater

MS Tanks

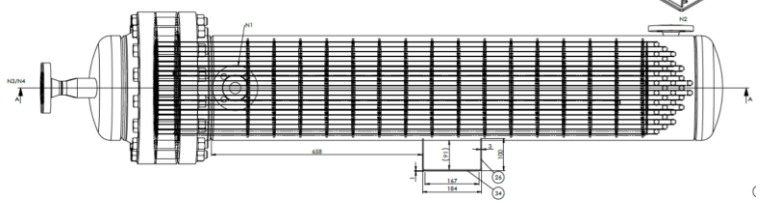




MS Pumps



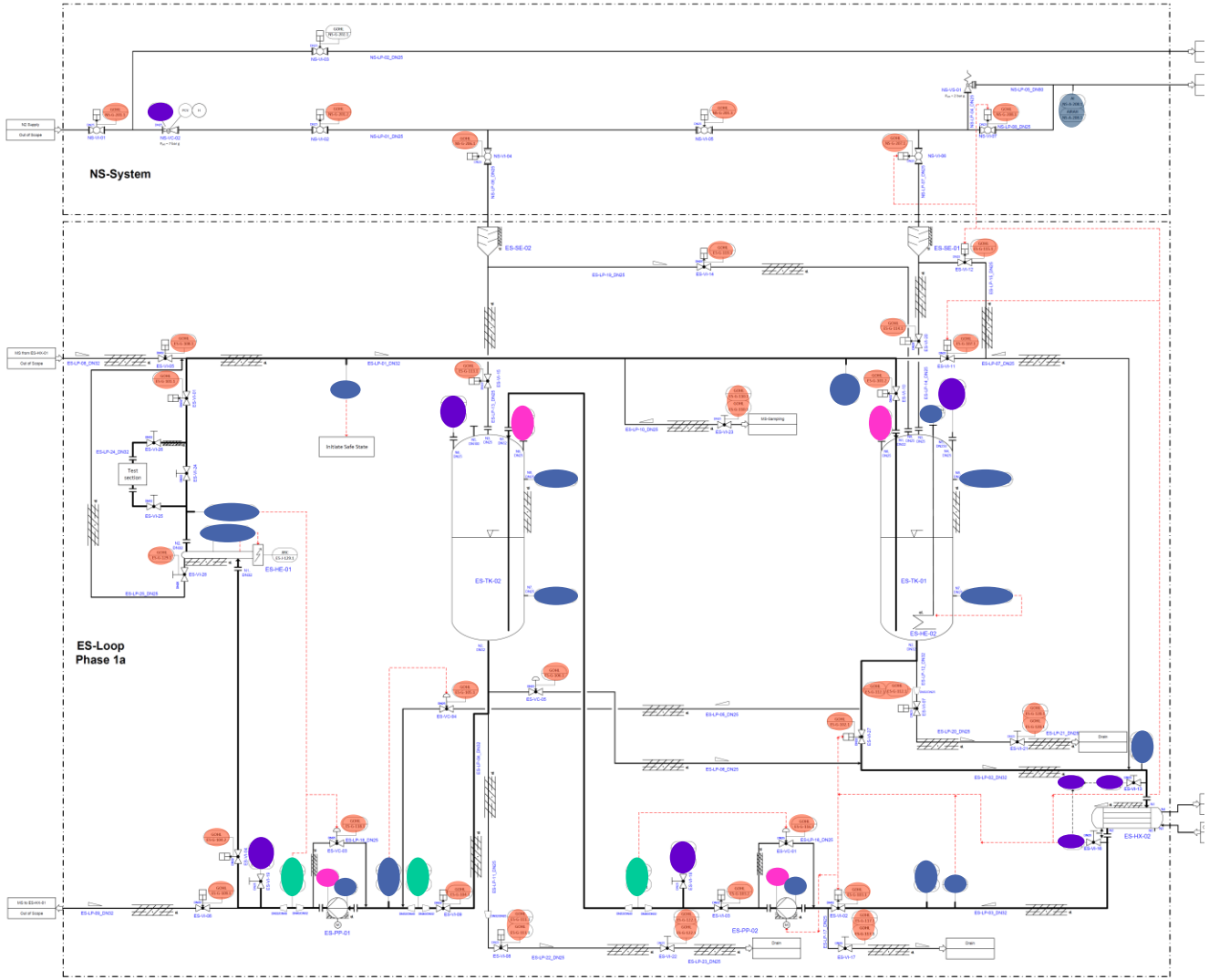
MS-Water HX



HELOKA-US PID

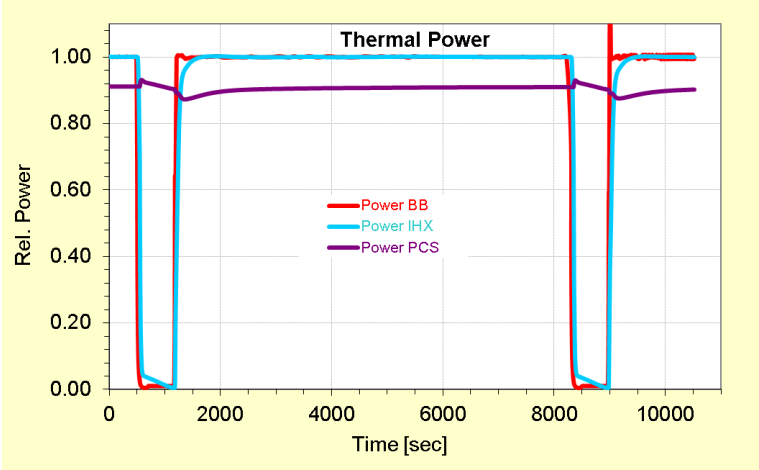
Highly instrumented:

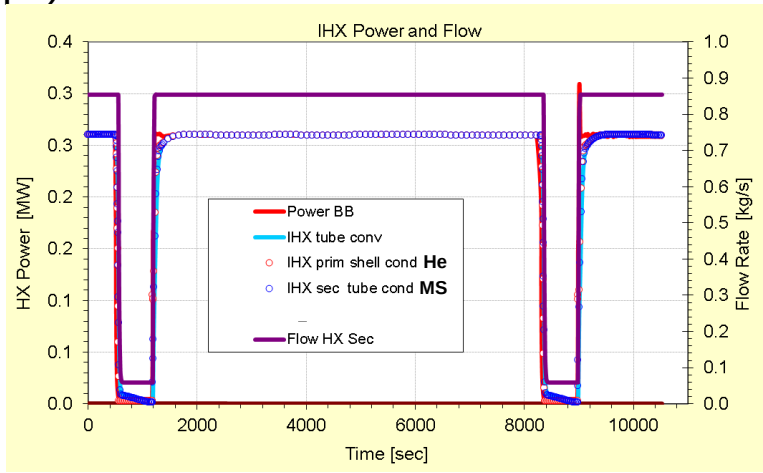
- 16 x Thermocouples
- 9 x Pressure Sensors
- 3 x Flowmeters
- 4 x Level Sensors
- 1 x NOx-Sensor
- 33 x Valve indicator

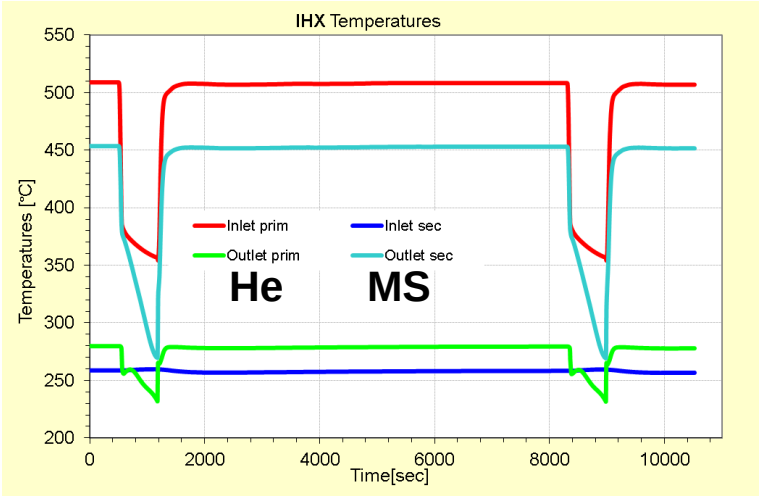


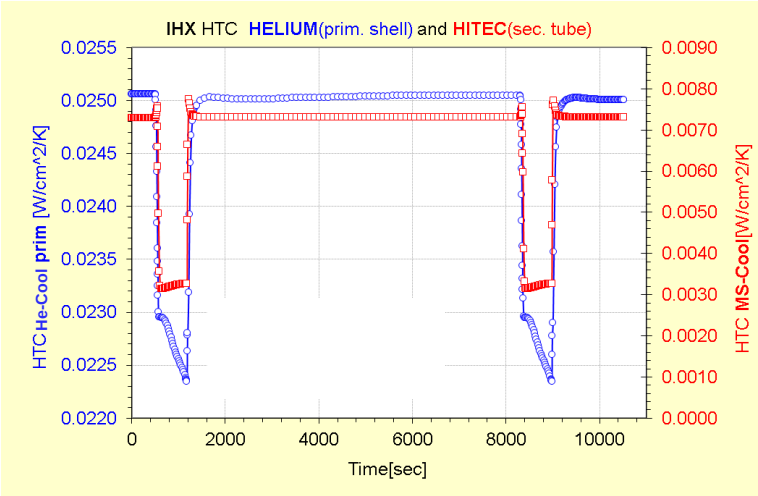
Numerical results of the thermal-hydraulic behavior

- Results of SIM-Code* for Phase 1b (He-MS-Water loops)



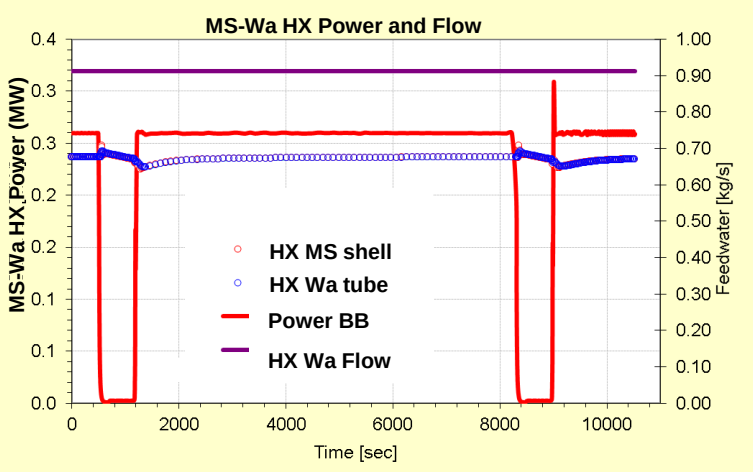


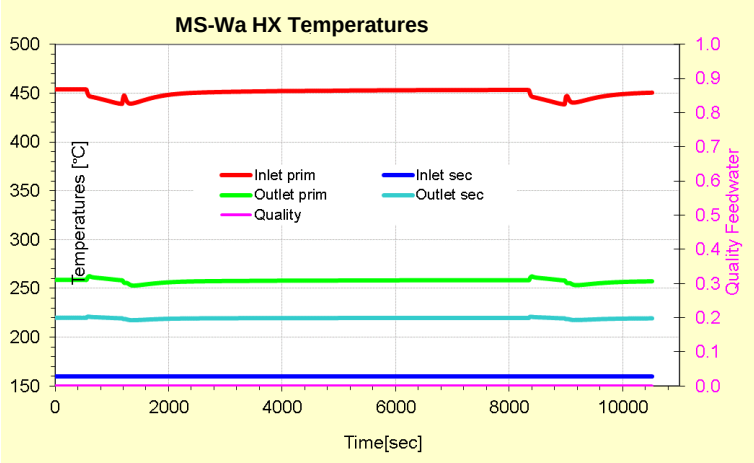


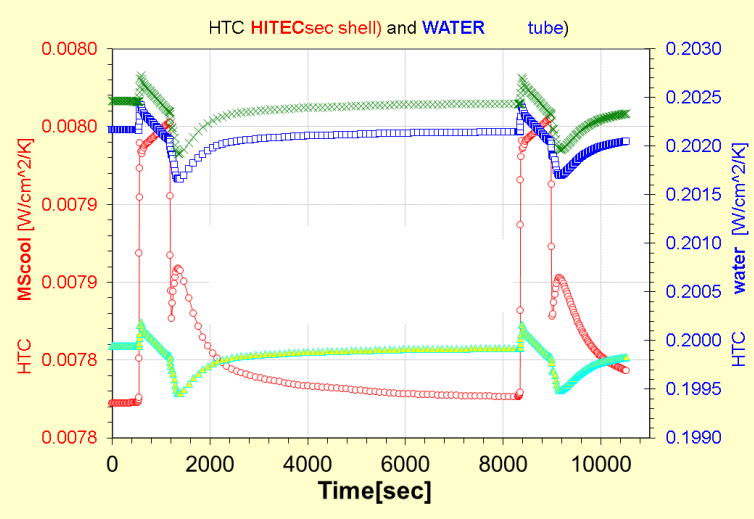


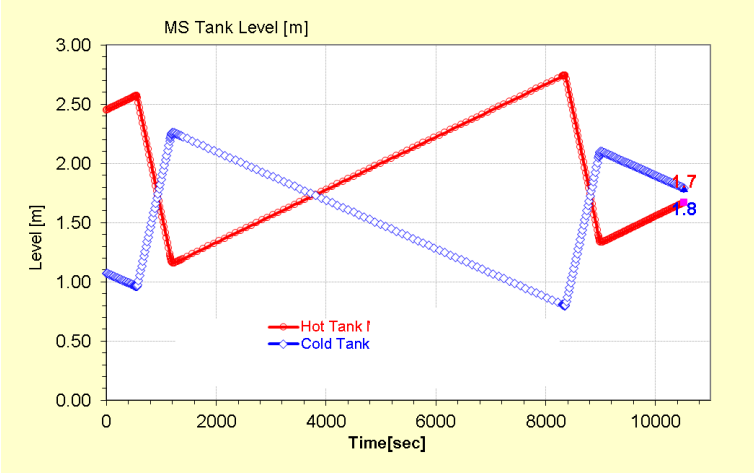
* Extension of the SIM-family system code able to assess the transient behaviour of reactors dealing with different coolants (helium, HITEC, water, heavy liquid metals, sodium, etc.)

Numerical results of the thermal-hydraulic behavior









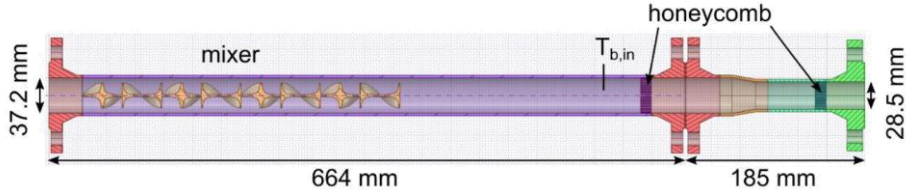
Current project status and the experimental scope

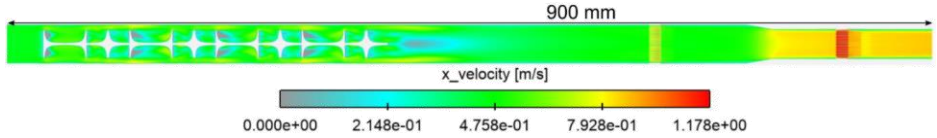
- Phase 1a: MS loop simulating the IHTS Phase 1a: commissioning of the MS loop simulating the HCPB IHTS
  - Ph 1a-1: basic MS loop setup to study IHTS behavior under DEMO conditions
  - Ph 1a-2/3: test sections with representative geometries of HX MS-side/He&MS-sides
- Phase 1b: integration of a scaled-down He-MS HX

	MS heat source	2023	2024	2025	2026	2027
Phase 1a-1	Electrical heater					
Phase 1a-2	Electrical heater + elect. heated MS side TS					
Phase 1a-3	Electrical heater + He-MS TS					
Phase 1b	He-MS HX					

Design | Construction and Commissioning | Experimental Campaign

- Test sections will be integrated for investigating the convective heat transfer configurations and the thermohydraulic validation of the IHX design for the HCPB DEMO.





Entry region of the test section HX (MS-side)

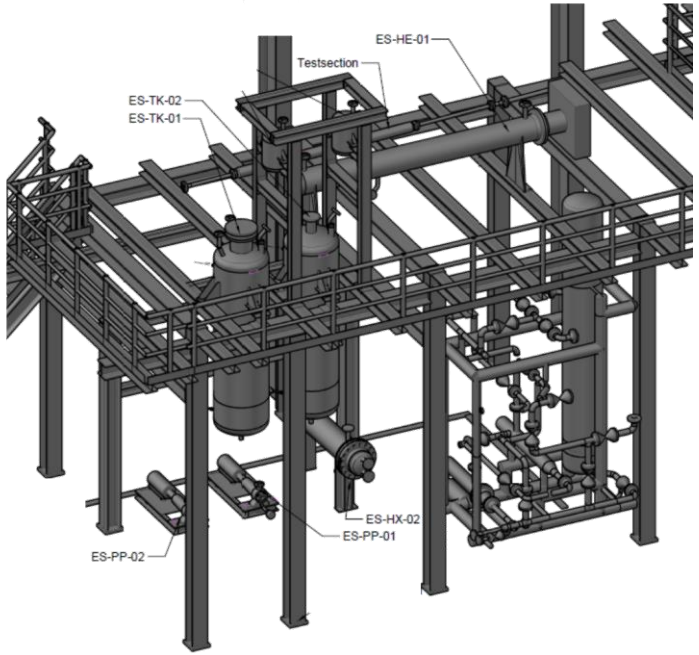
IHTS: Intermediate Heat Transfer System
IHX: Intermediate Heat Exchanger
HX: Heat Exchanger
MS: Molten Salt
e-heater: electrical heater

Conclusions and Outlook

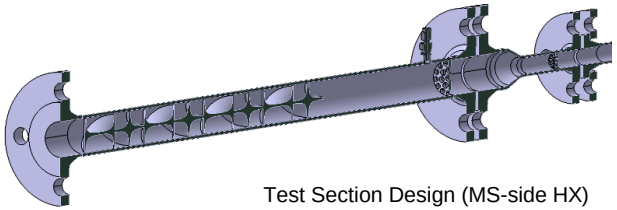
- HELOKA-Upgrade Storage Design completed and under construction ✓

- HELOKA-US experimental platform provides unique contributions to:
  - Test innovative geometries of interest for the He-MS HX
  - Experimental data to validate HCPB BOP thermal-hydraulic models
  - Optimize and verify HCPB BOP Control System
  - Operational experience also for IHTS states other than power operation

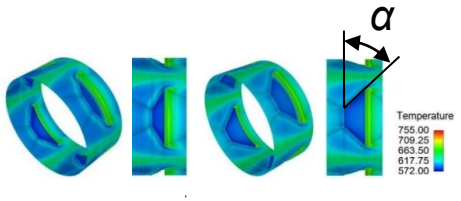
- Flexible and upgradable platform conceived to be able to support:
  - In getting higher-TRL for key components of the HCPB DEMO BOP
  - Thermal-hydraulic system codes, reduced order models and turbulent HT models in CFD
  - BOP conceptual design for innovative fusion power plants
  - Adaptation to HELIAS (Stellarator) BOP with power-to-X



ES-HE-01: e-heater
ES-TK-01: hot tank
ES-TK-02: cold tank
ES-PP-01: hot MS pump
ES-PP-02: cold MS pump
ES-HX-02: MS-Water HX



Test Section Design (MS-side HX)



Delta-wing ribs
HITEC Pr= 14.7
Re = 50.000, 0.3 MW/m2

www.inr.kit.edu/594.php