Summary
The cryogenic test facility CuLTKa was built up and commissioned. The first CL-tests were conducted successfully.

The base of the process design are longtime experiences in designing and operating cryogenic facilities using forced-flow Helium at overcritical pressures. For the detailed design basic design calculations based on common engineering relations were applied. Comparisons with measured data attest the reliabilty of these tools. Paired with a flexible process design and reasonable safety margins such a test facility can be realized.

Objectives
- Sketching the design process of the facility: from demand to facility setup
- Presentation of empirical engineering tools used for the process engineering design and their characterization by comparison with measured data

Facility setup - major properties
- A 2-K refrigeration provides 2 He flows at different temperature levels (5 K and 300 K) to overcritical pressures (~5 bar) into existing infrastructure of ITER
- Cryostats installed on a platform: easy installation of test objects, flexible orientation of test boxes; cryostat access by lowering bottom
- LHe-bath (400 l) with cooling heat exchanger (HEX) for temperature control during experiments
- No sensitive measurement equipment in test boxes; simple, fast, save installation of CL He cooling shields in test boxes
- Heat exchanger provides 2 He flows at different temperature levels (5 K and 300 K) @ overcritical pressures (30 kA DC power supply with watercooled flexible copper cables)
- 0.6 g/s, < 3 W; 4.5 K, 0 A
- Heat load @ I
- design calculations based on common engineering relations in good agreement with the measured data
- Performance of HEX: Performs very good!
- During experiments liquefaction of return flow from the CL
- Additional heat input (heater) to reach stable process conditions (e.g. steady overshink)
- Theoretical holding time during experiments: 3 to 4 h (HEX heat load corresponds to additional inlet mass flow of 2-3 g/s @ 300 K)
- Pressure drop HEX is approached during experiments
- Limited length HEX: 50 m including 25% safety margin
- Performance of whole subcool: performs very good!

Design aspects - process engineering using empirical calculation methods

Pipe dimensioning and pressure losses
- Scaling of plant model concerning pipes diameter, lengths, bends, components (valves, venturi, filters) to determine pressure losses and flow velocities
- Case sensitive pressure loss calculation characterized by Re-number and inner pipe roughness

Valve design
- Calculation of valve flow coefficient for compressible and incompressible flow
- Standard equations without and incompressible flow
- Design calculations are in good agreement with measured data

Design calculations are in good agreement with the measured performance and control behaviour of the facility is very good during cool-down, warm-up as well as during operation.

Stabilization of 4.5 K-level flow by a heat exchanger through a cooling LHe-bath
- Function: balancing thermal losses due to long transfer distances from refrigeration (50°C) thermal buffer during faults and control fluctuations of refrigeration, well defined operation temperature of buffer (4.5-6 K level of CL, 40°C)
- Process & vessel design: strongly experience based, 2 options for liquefaction (inlet, return flow); heater in LHe-bath
- Evaporation due to HEX-cooling vs. liquefaction, determination of max. holding time
- Vessel volume ca. 400 l, max. pressure 10 bar g (overcritical blow-down pressure during fault)
- HEX design: calculation in sections; total amount of heat to be extracted divided by no. of sections
- Considered: heat transfer from He-Flow to piping (depending on flow conditions and pressure losses), through pipe and to LHe-bath
- Calculation input: conservative inlet flow conditions (6 K, 4 bar), ATmax<0.2 K
- Determined length HEX: 50 m including 25% safety margin

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Institute for Technical Physics
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen
www.iltk.de

Karlsruhe Institute of Technology
Richter T., Lietzow R.
Design details of the Current Lead Test Facility Karlsruhe (CuLTKa)

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Performance of HEX: good approximation achieved by design calculation

Parameter | Unit | Design | Measurement | Deviation
--- | --- | --- | --- | ---
Bath pressure | bar | 1.15 | 1.14 | -0.01
Bath temperature | K | 4.36 | 4.37 | 0.01
Inlet flow | m³/h | 6.51 | 6.52 | 0.01
Temperature HCK | K | 5.14 | 5.15 | 0.01
Pressure HCK | bar | 4 | 4.05 | 0.05
Temperature HCK out | K | 5.14 | 5.15 | 0.01
Pressure drop HCK | bar | 25 | 25.1 | 0.01

Pressure loss in line with one or more inclusion of pressure drop in experiment

Performance of whole subcool: performs very good!
- During experiments liquefaction of return flow from the CL
- Additional heat input (heater) to reach stable process conditions (e.g. steady overshink)
- Theoretical holding time during experiments: 3 to 4 h (HEX heat load corresponds to additional inlet mass flow of 2-3 g/s @ 300 K)
- Individual heat exchanger designs for essential baseline. This shows during process design phase as well as in setting reasonably conservative boundary conditions and safety margins for the design calculations.

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