

DESY Engineering and Innovation Day 2025

Design and automation of a High Pressure Water Cell

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Hamburg, 19.06.2025

HPWC - High Pressure Water Cell

Agenda

01 Motivation & Design Goals

02 Sealing of the HPWC

03 Hydraulics

04 Control Cabinet

05 Beckhoff DDC

06 VISU - User Interface

07 Functions of the DDC

08 Any problems?

HPWC - High Pressure Water Cell

Motivation & Design Goals

Motivation

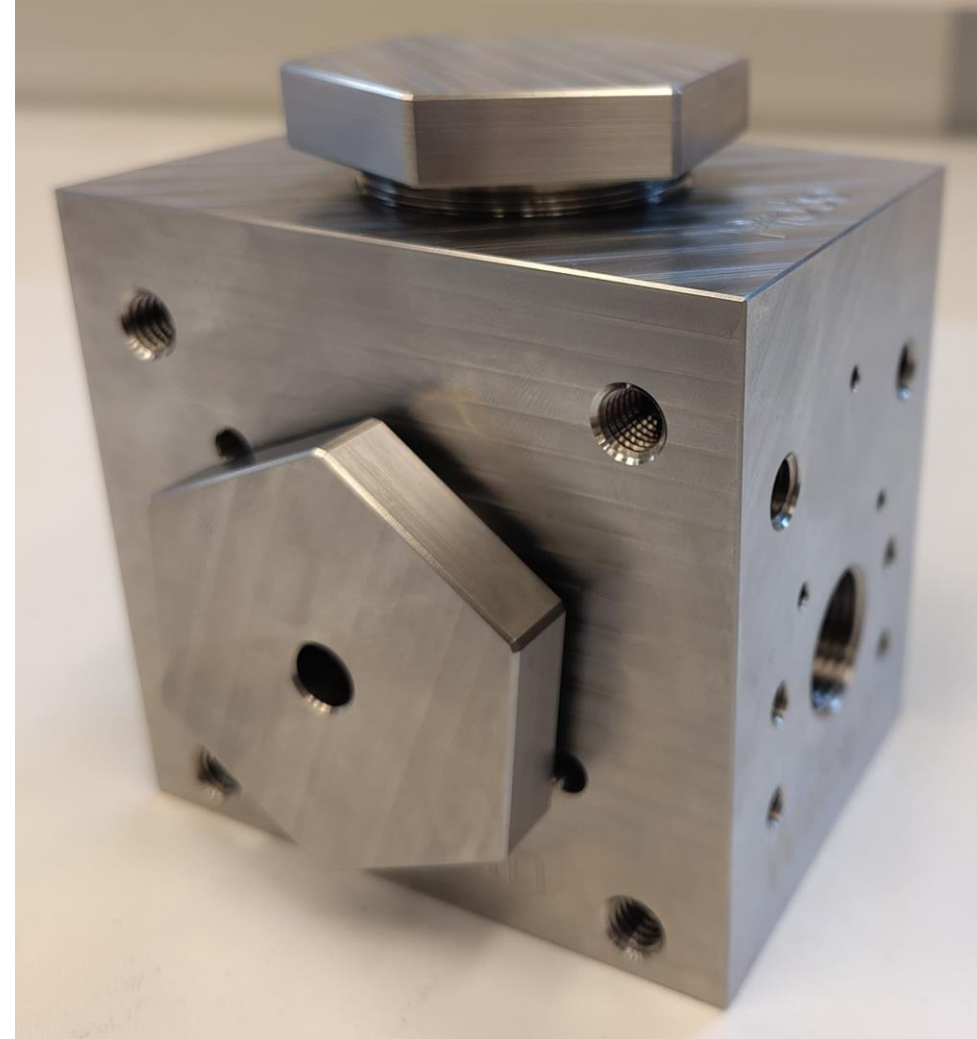
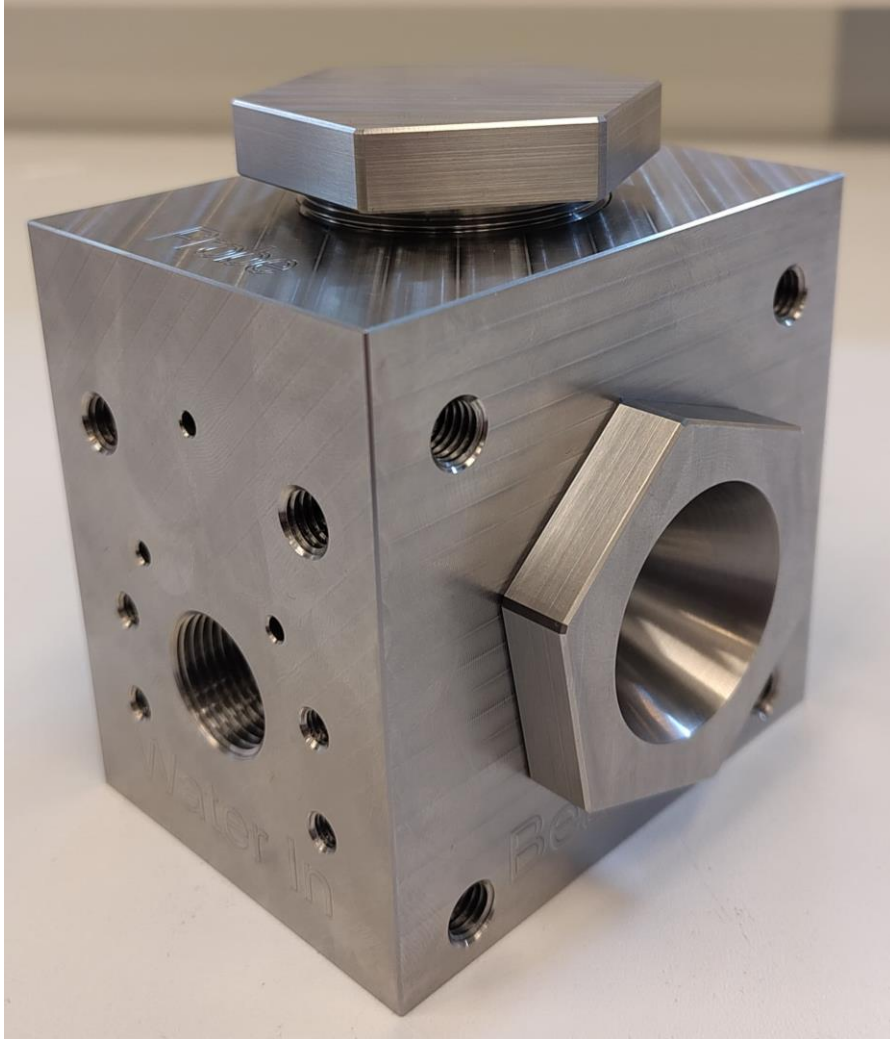
- Study of Metal-Organic Frameworks (MOFs) under pressure
- Increased pressure range from already existing hydrostatic pressure cells
- Integration of in-situ Raman spectroscopy and conductivity measurements

Design Goals

- Pressure range up to 1 GPa (10.000 bar)
- Controlled pressure increments of 1.5 MPa (15 bar)
- Sample change without removing cell from the beamline
- Largest possible exit angle
- Integration of in-situ Raman spectroscopy and conductivity measurements

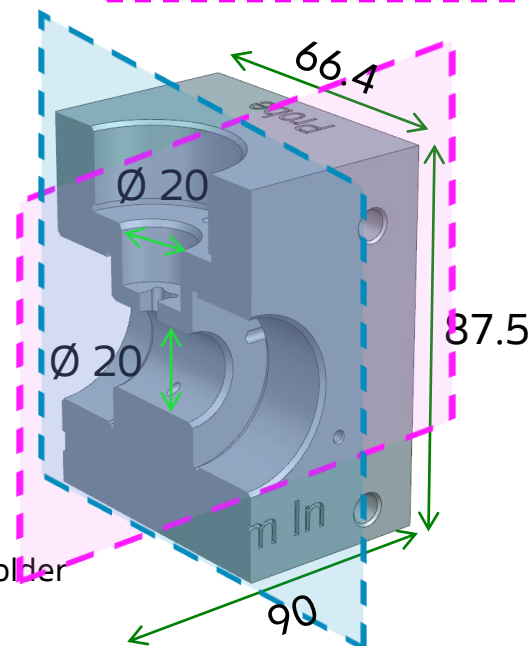
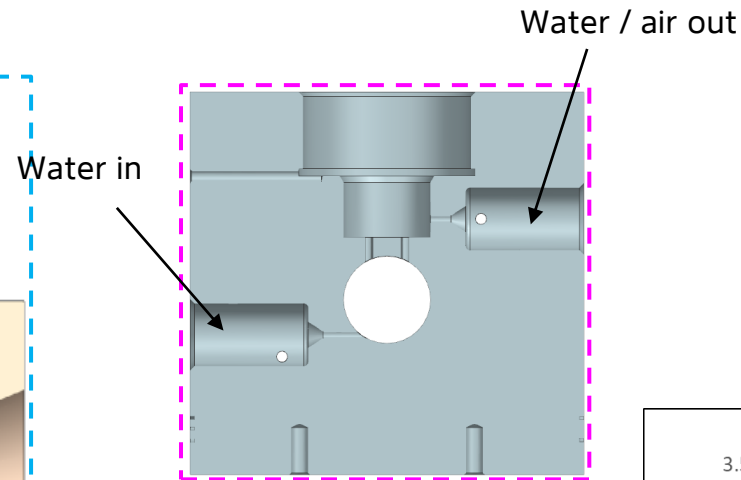
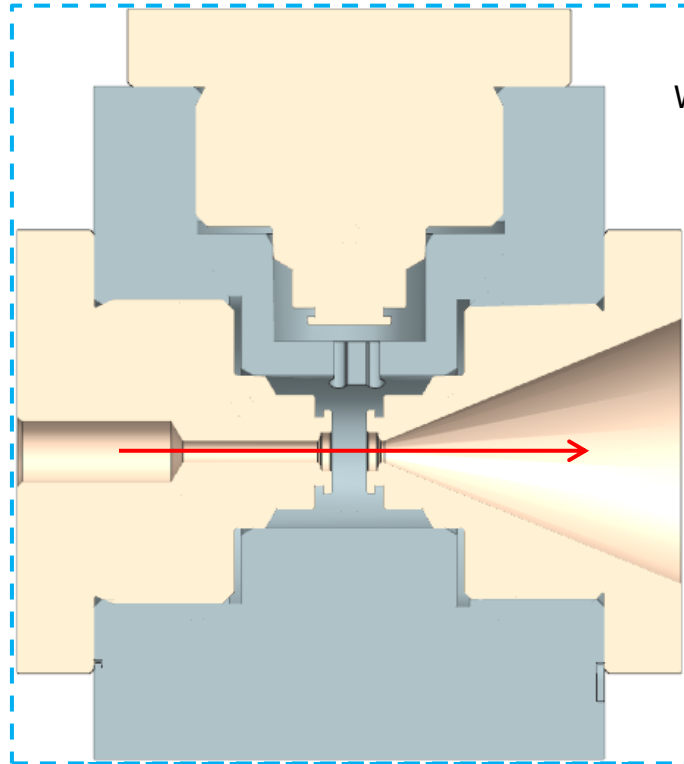
HPWC - High Pressure Water Cell

Design

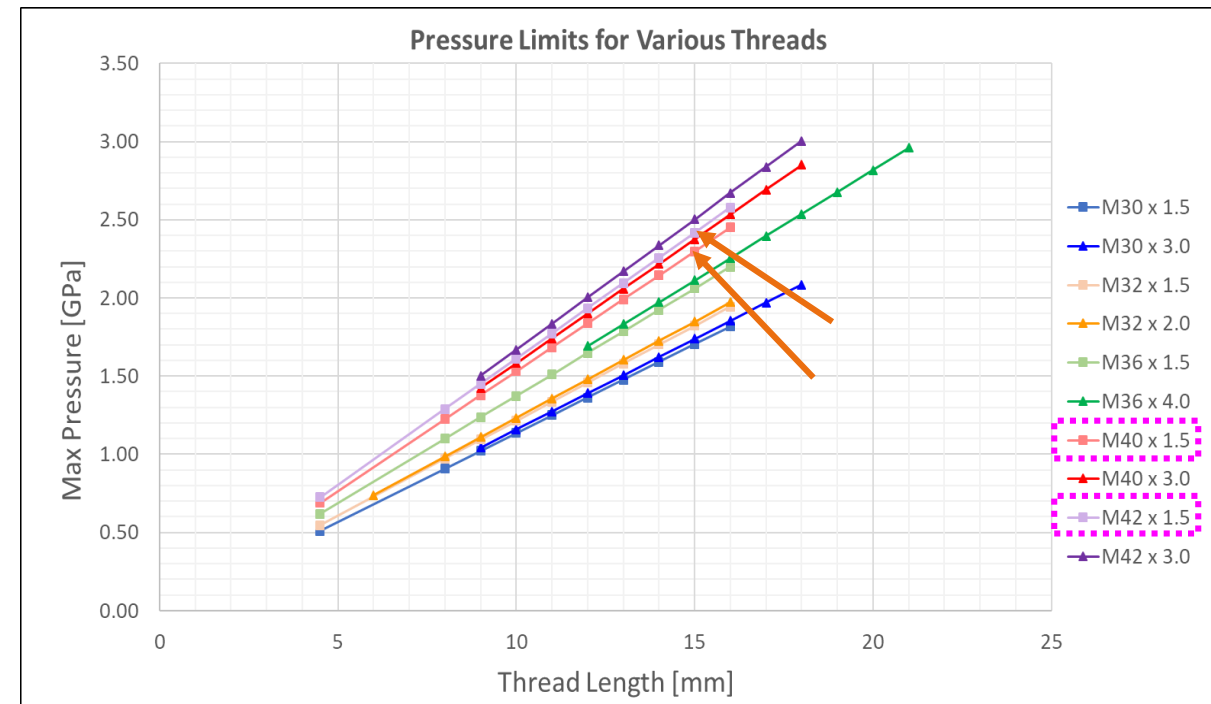
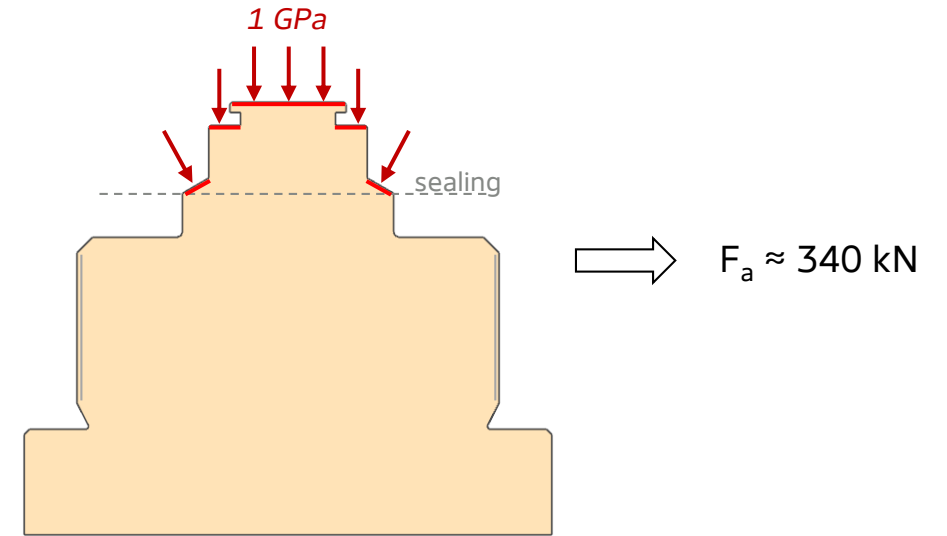


HPWC - High Pressure Water Cell

Design

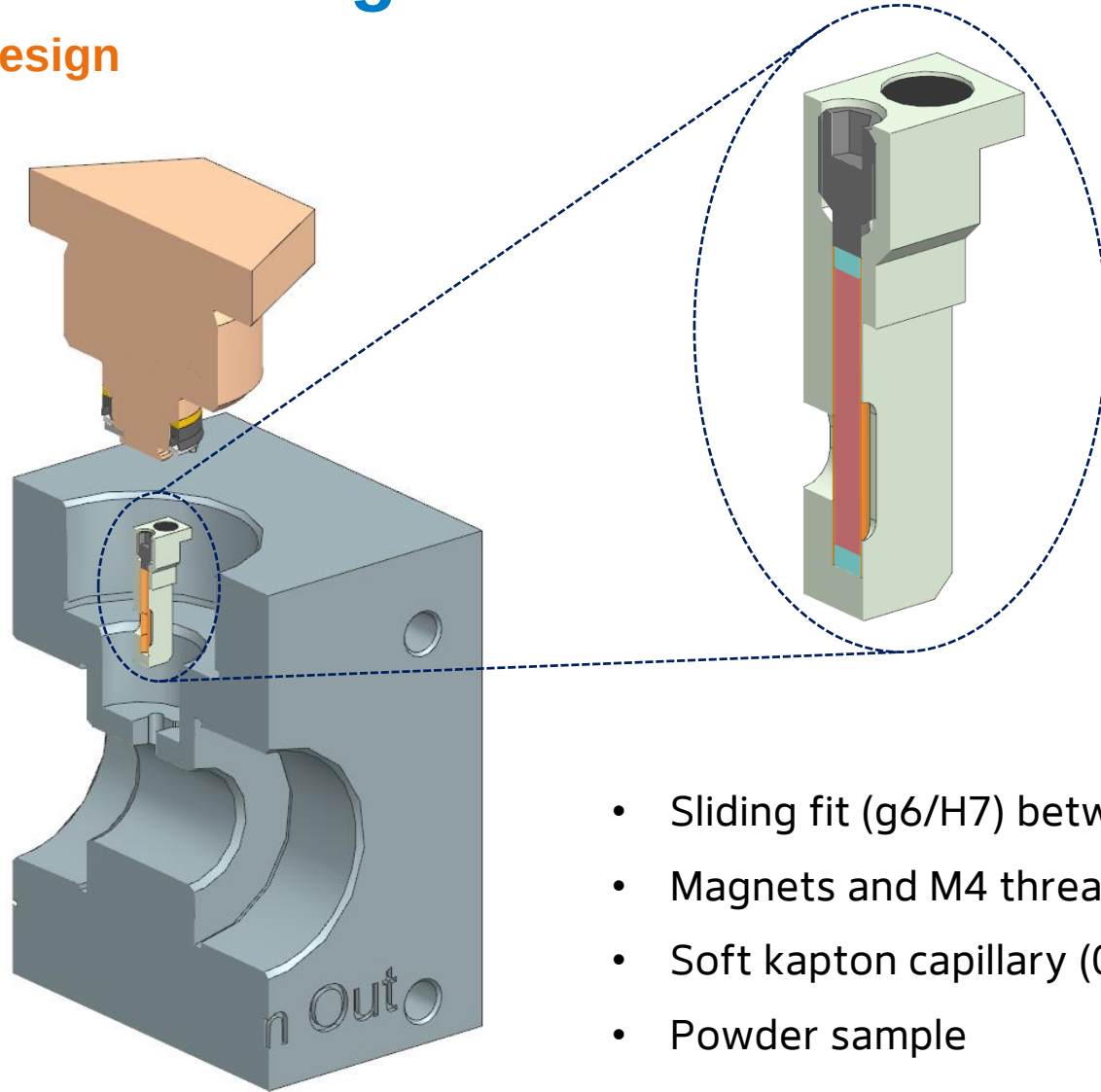


- 90 mm x 66.4 mm x 87.5 mm block
- Ø 20 mm bore holes
- 10 mm x 6 mm rectangular slot for sample holder

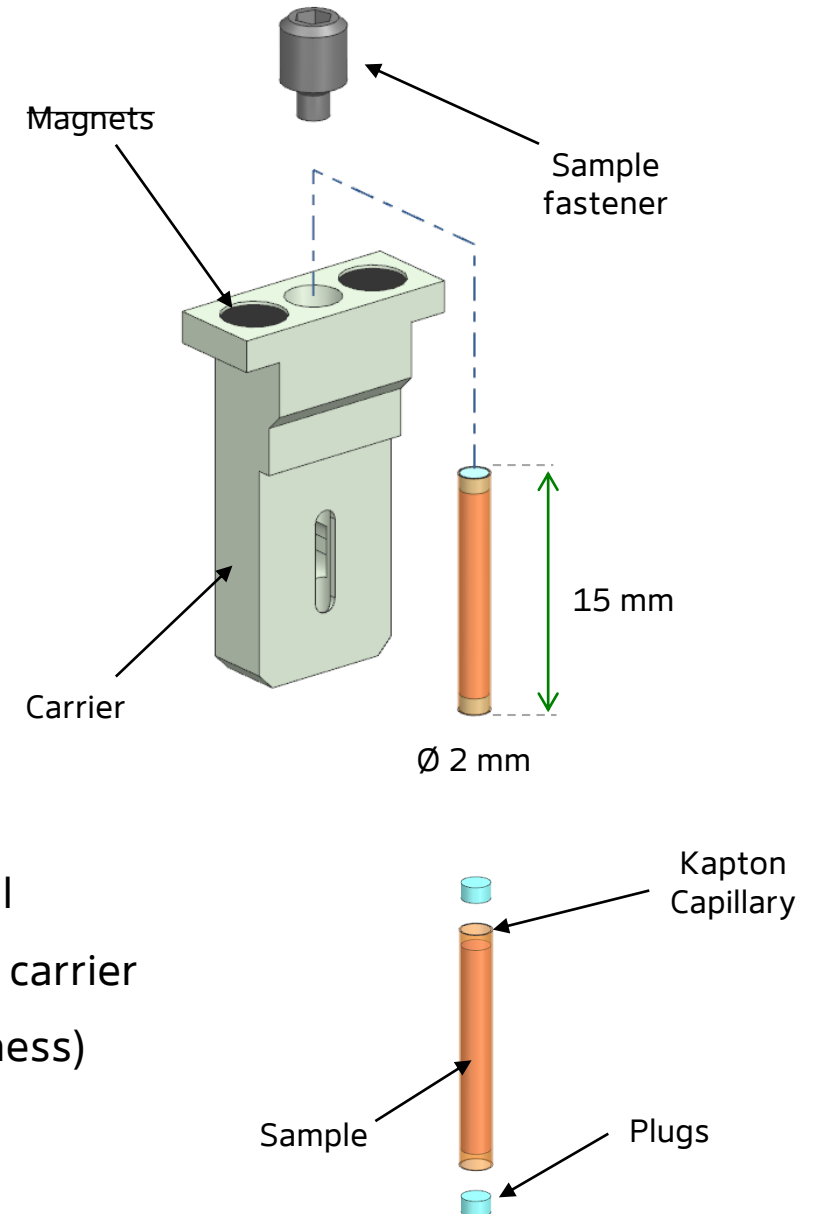


HPWC - High Pressure Water Cell

Design



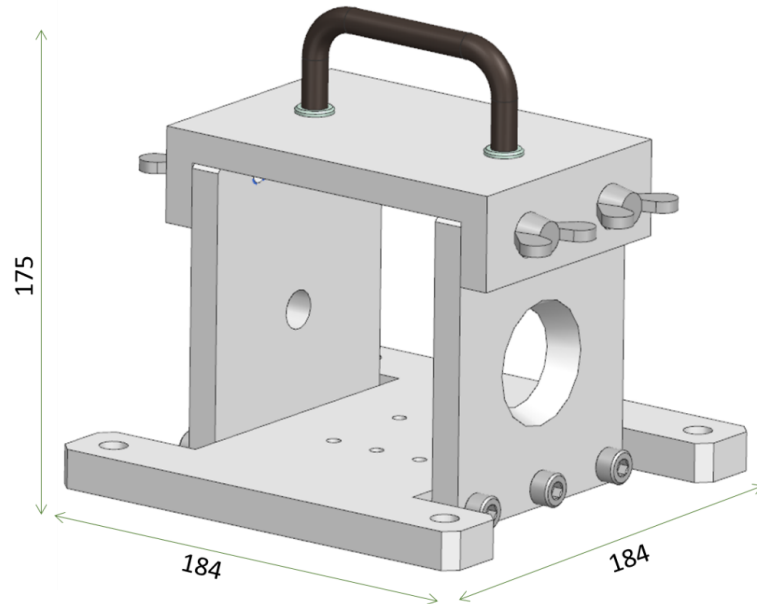
- Sliding fit (g6/H7) between carrier and cell
- Magnets and M4 thread for removing the carrier
- Soft kapton capillary (0.25 mm wall thickness)
- Powder sample



HPWC - High Pressure Water Cell

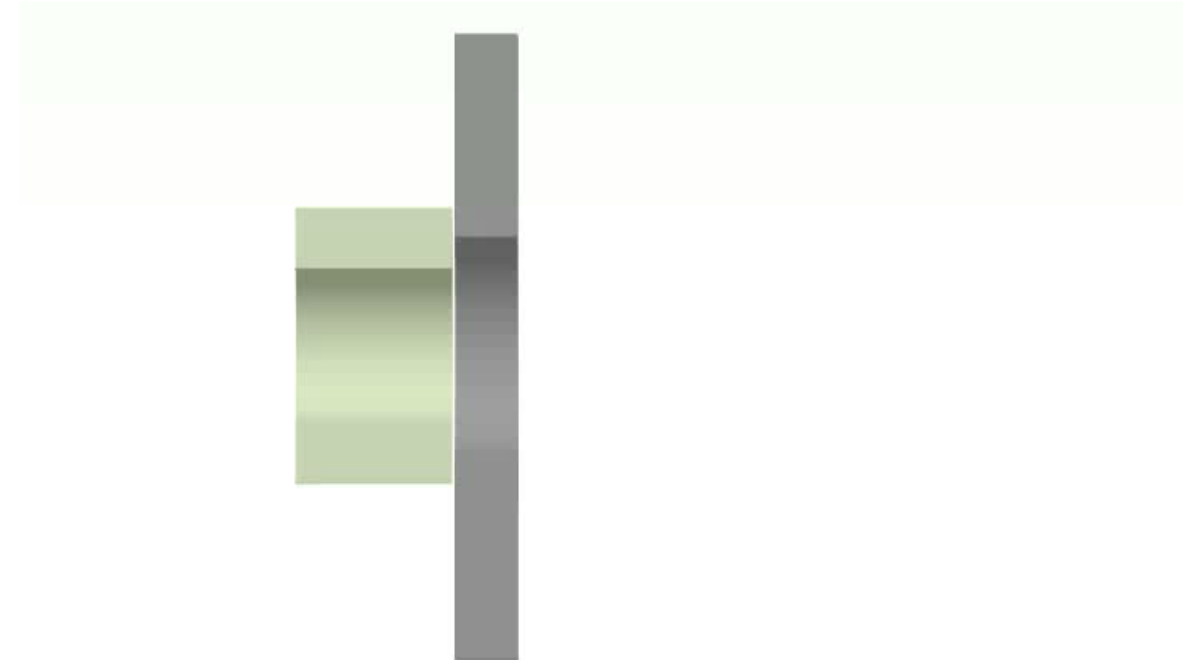
Design

- Failure could occur due to fatigue of extended use / loading cycles
- Worst case scenario → plugs being ejected like a bullet
- Safety enclosure must be included



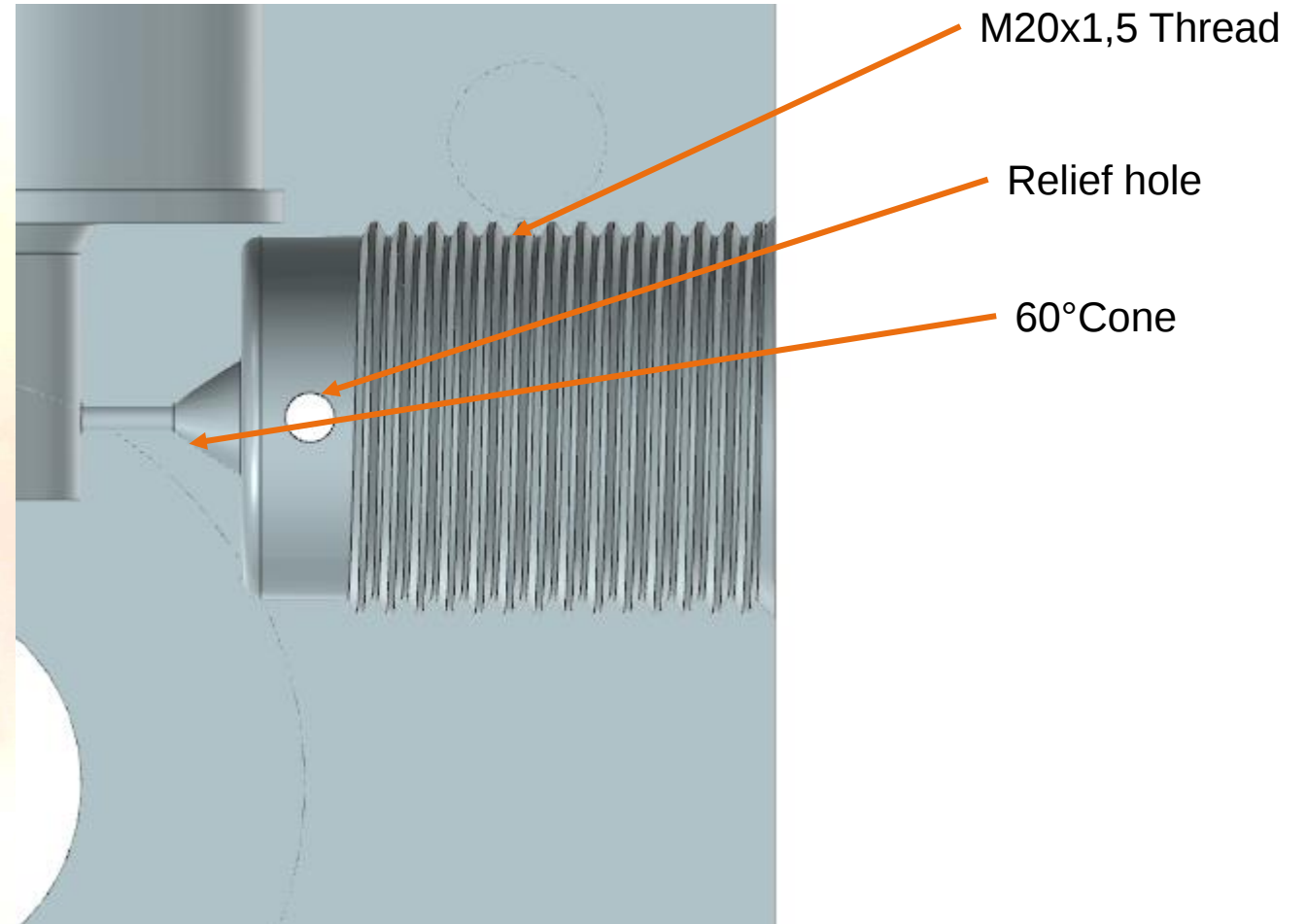
- Explicit Dynamics simulation (impact analysis)

- Plug (1.4534)
- Plate (Al 6061-T6): max. total strain = 11%
- Plug velocity $\leftrightarrow E_{pot} = \frac{\gamma}{2} V_0 p^2$
 - 72 m/s



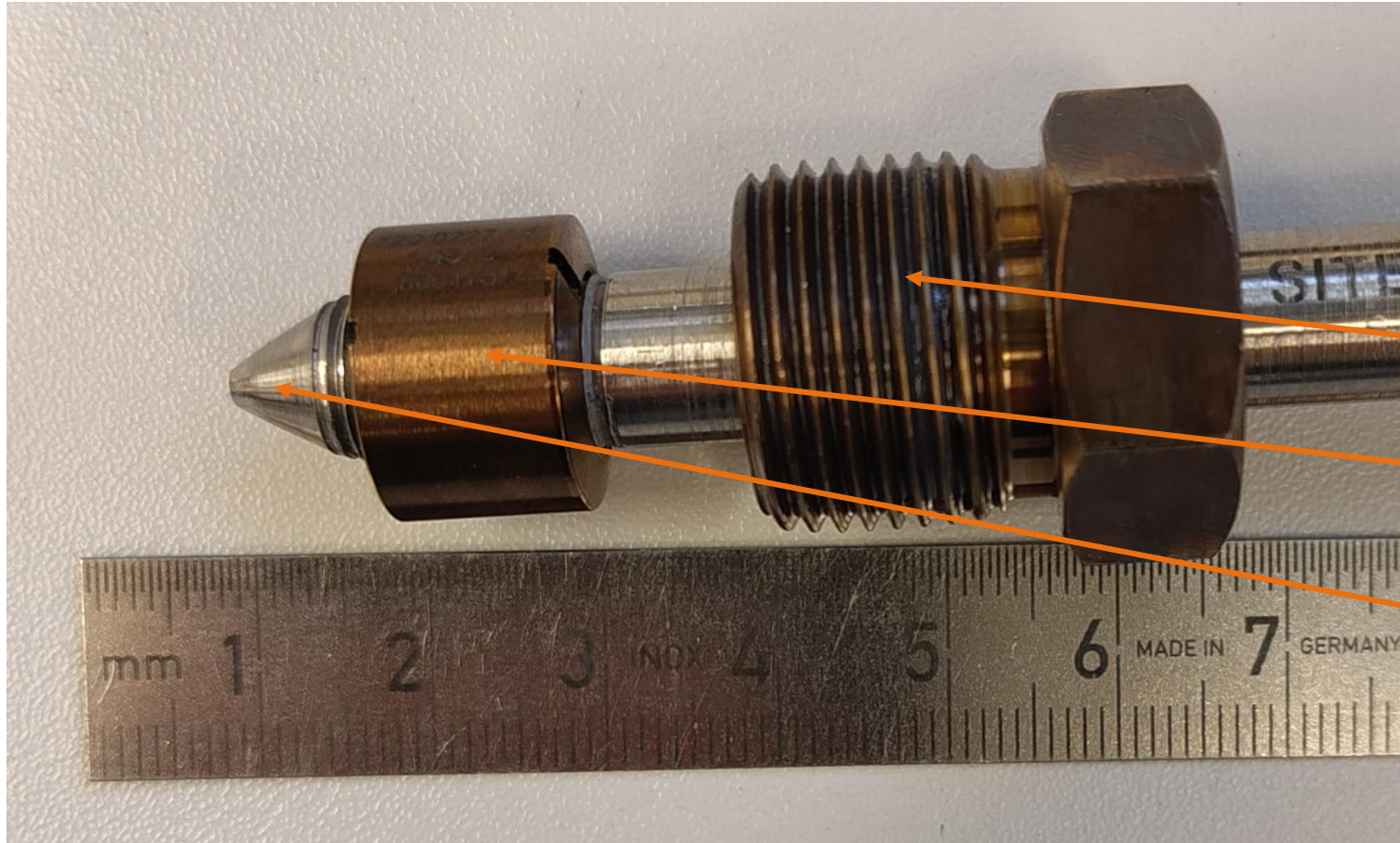
HPWC - High Pressure Water Cell

Sealing of the HPWC – Water Tubing



HPWC - High Pressure Water Cell

Sealing of the HPWC– Water Tubing



Pressure screw
M20x1,5 Thread

Collar
3/8"-24 UNF LH Thread

58°Cone

HPWC - High Pressure Water Cell

Sealing of the HPWC– Water Tubing

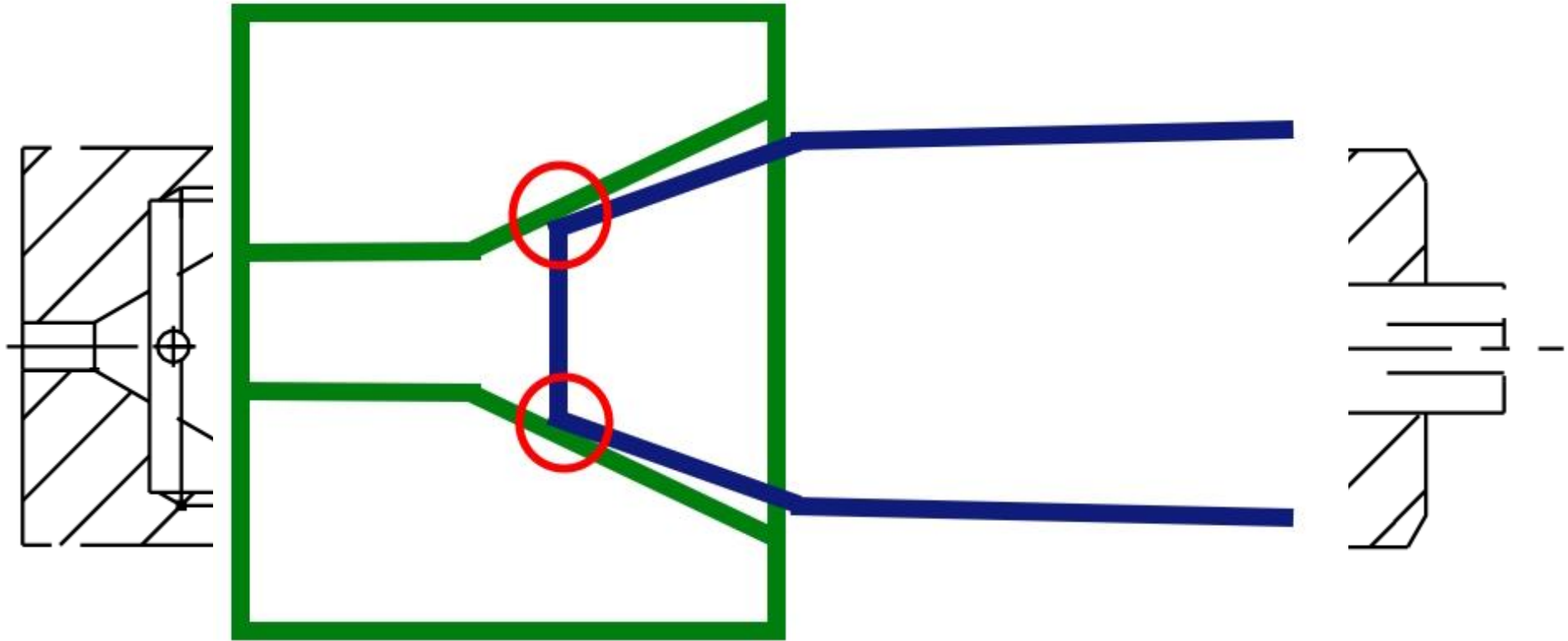


Stainless-steel High-pressure Tubing

- Max. pressure 11.000 bar
- Outer diameter: 9,52 mm (3/8 Inch)
- Inner diameter: 1,6 mm
- Bending radius: 50 mm

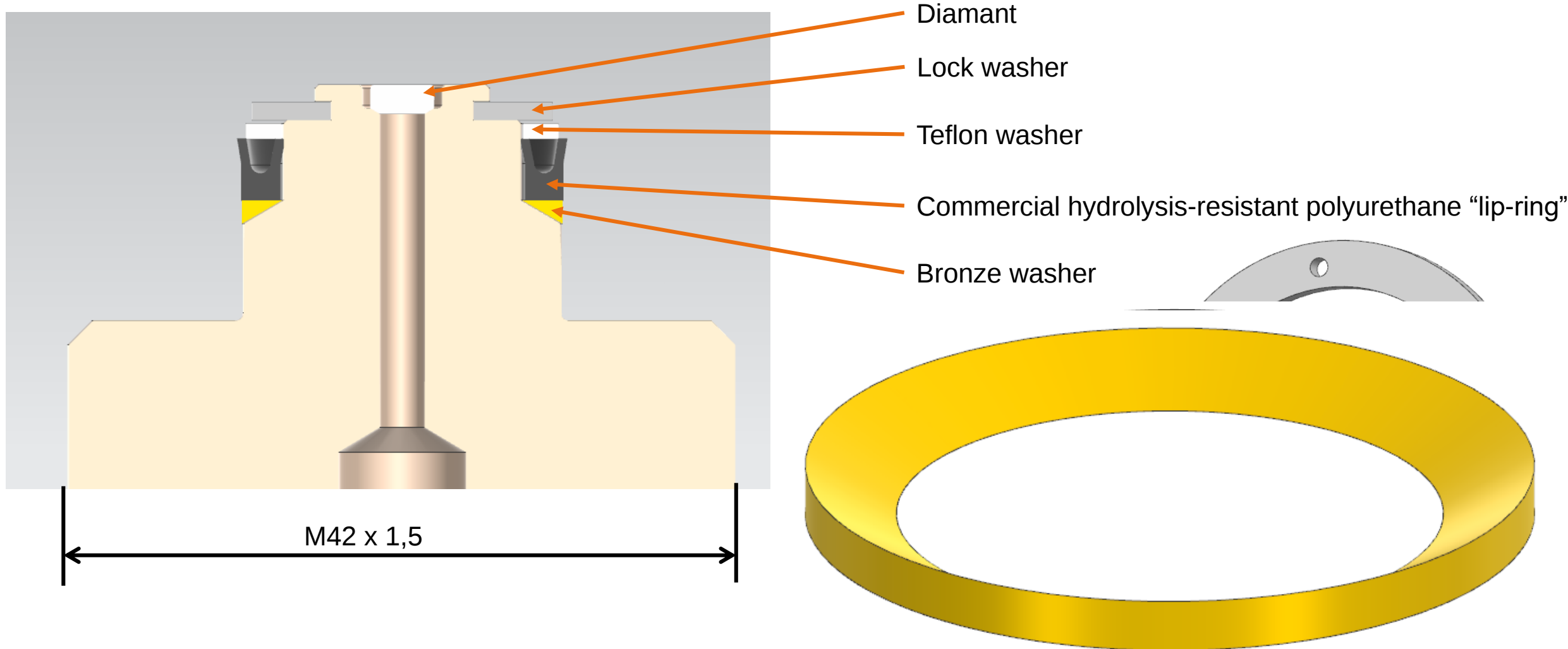
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Sealing of the HPWC– Water Tubing



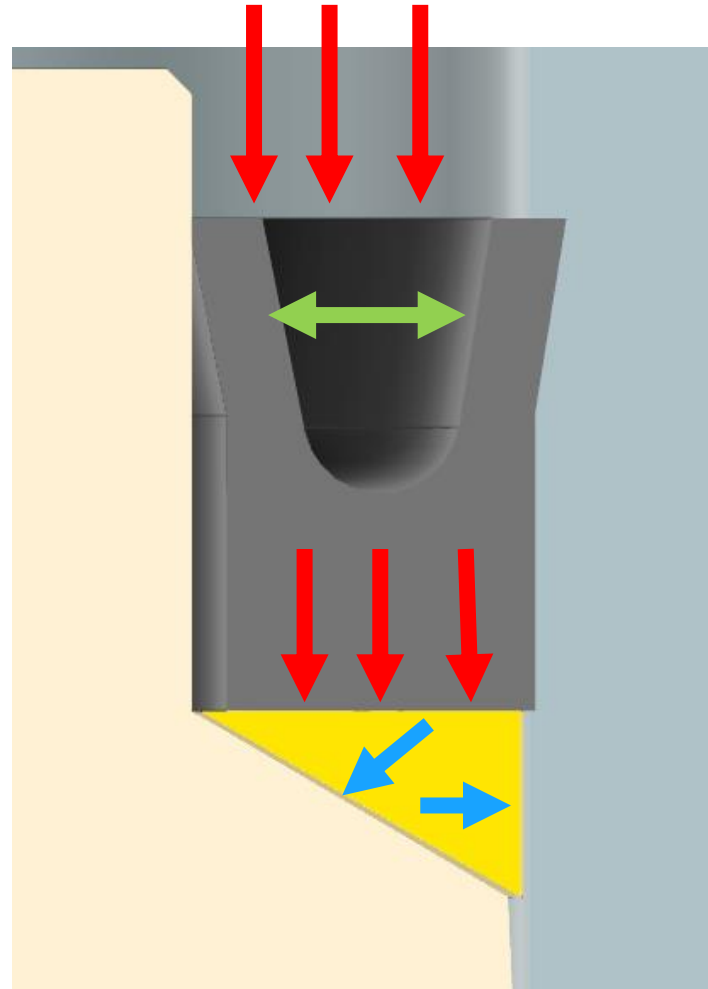
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Sealing of the HPWC– Plugs



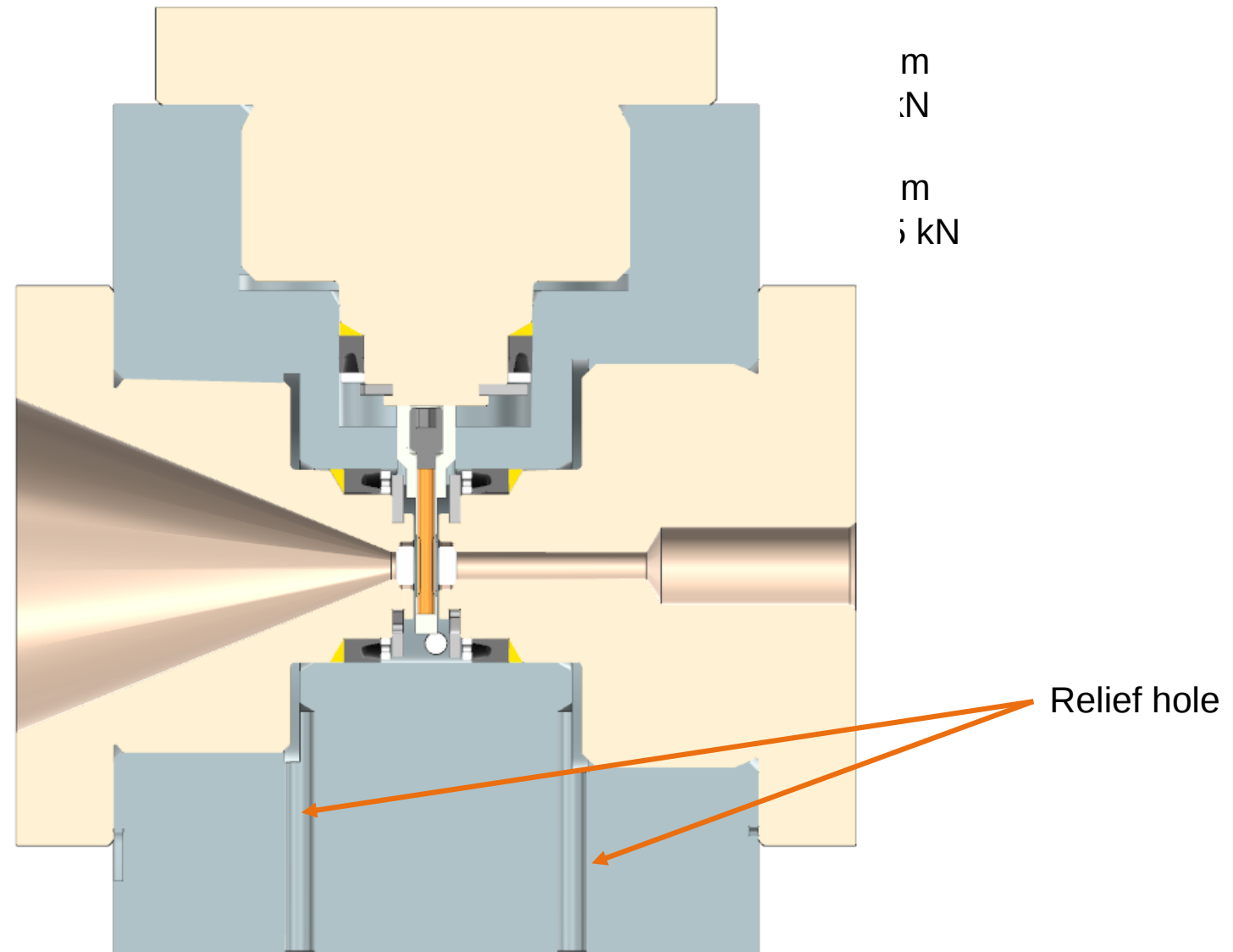
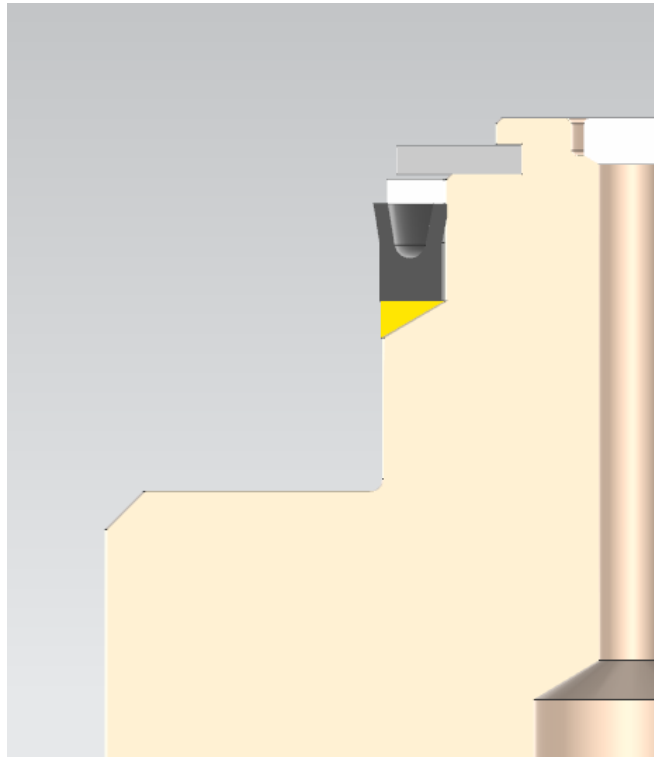
HPWC - High Pressure Water Cell

Sealing of the HPWC – Plugs



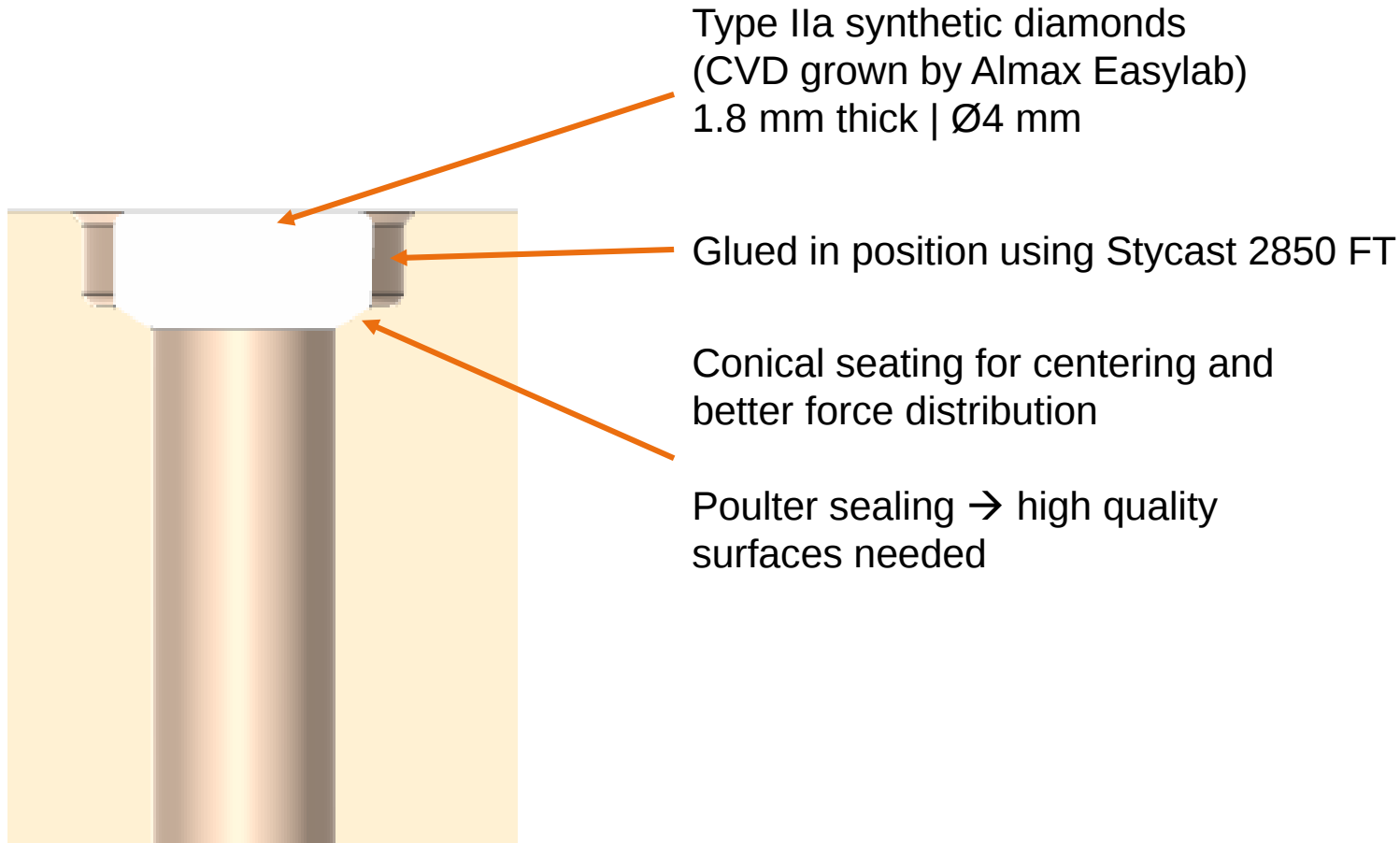
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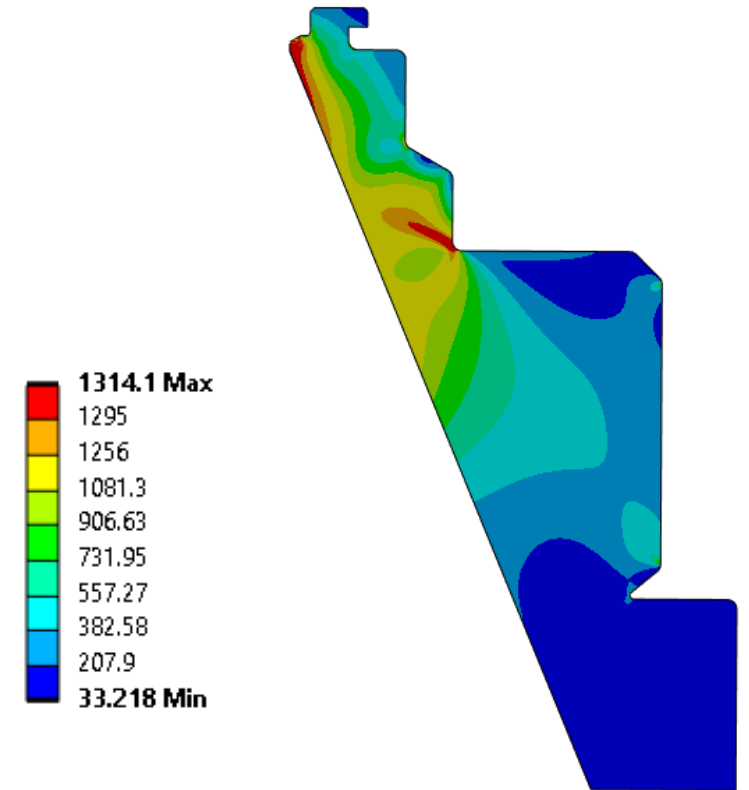


HPWC - High Pressure Water Cell

Sealing of the HPWC – Diamonds

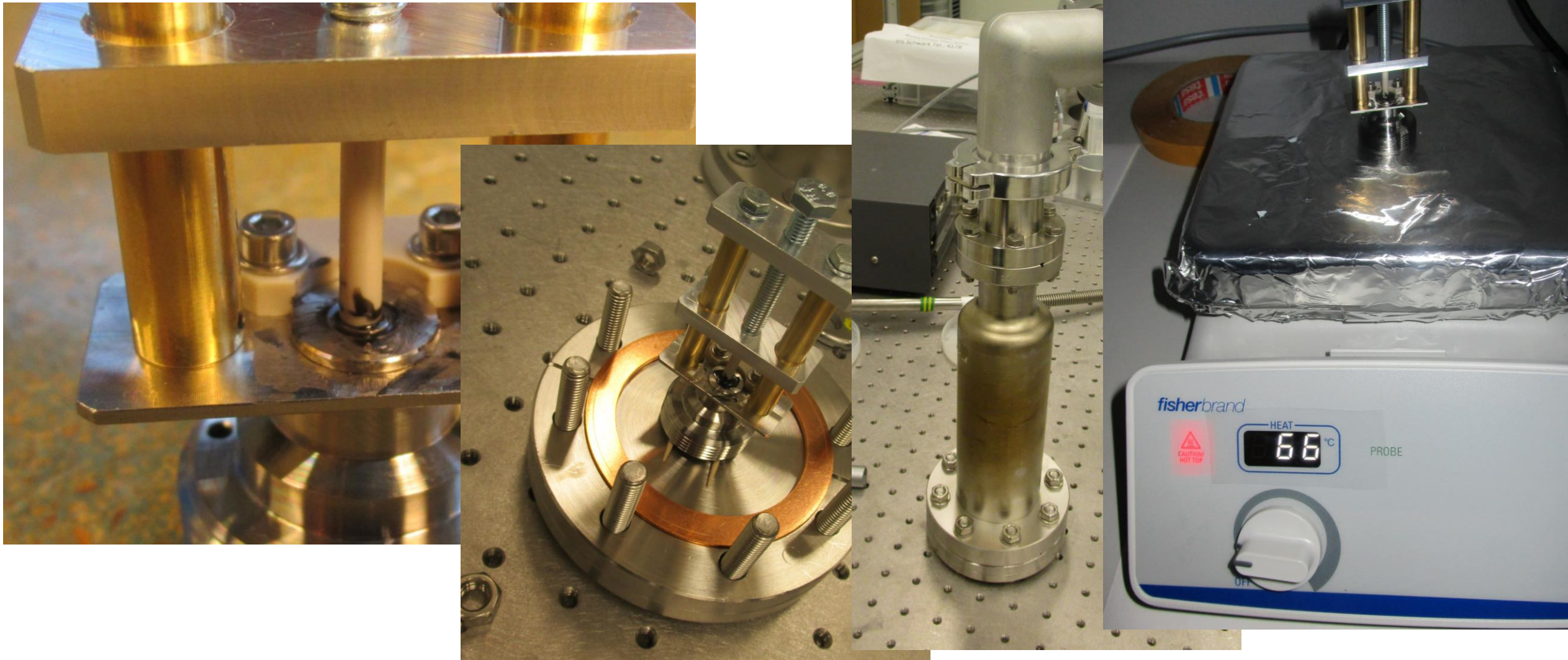


Equivalent Stress [MPa]



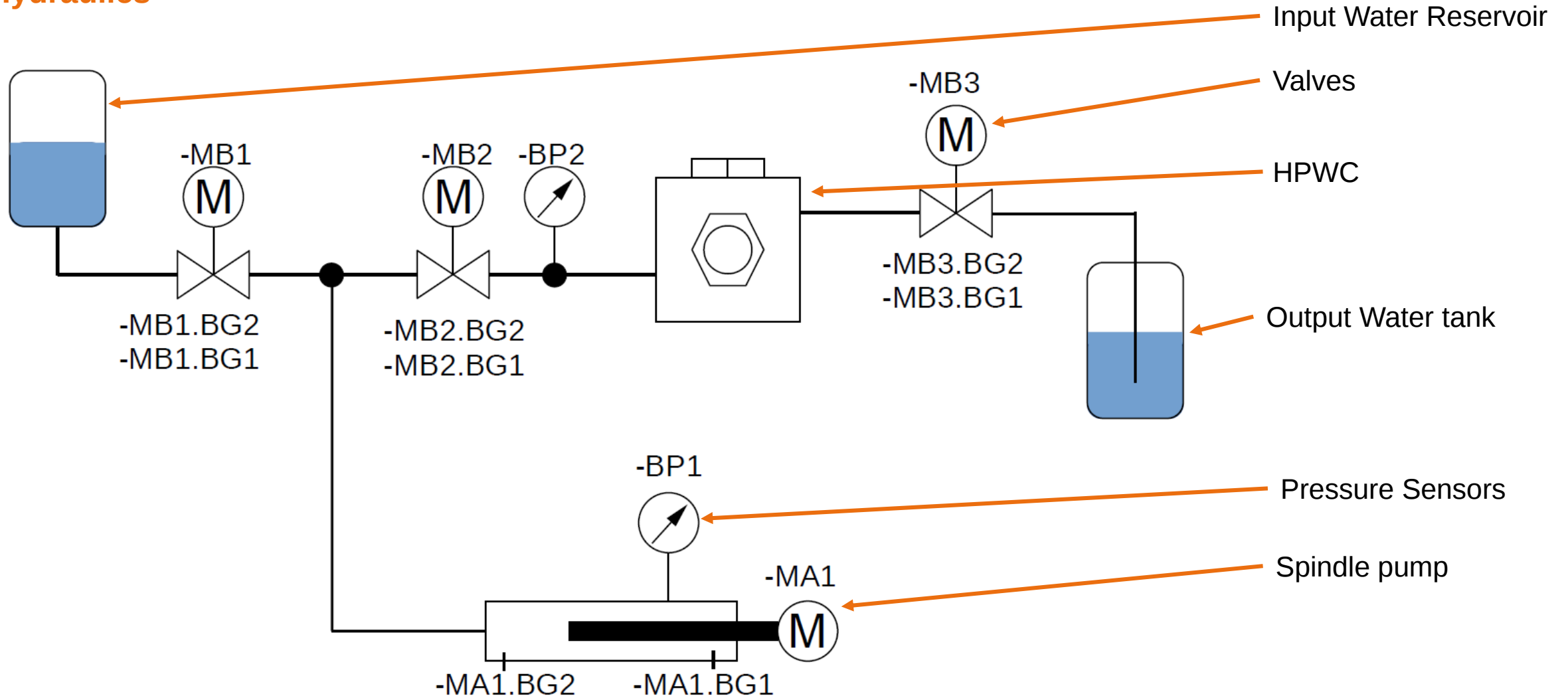
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Sealing of the HPWC – Diamonds



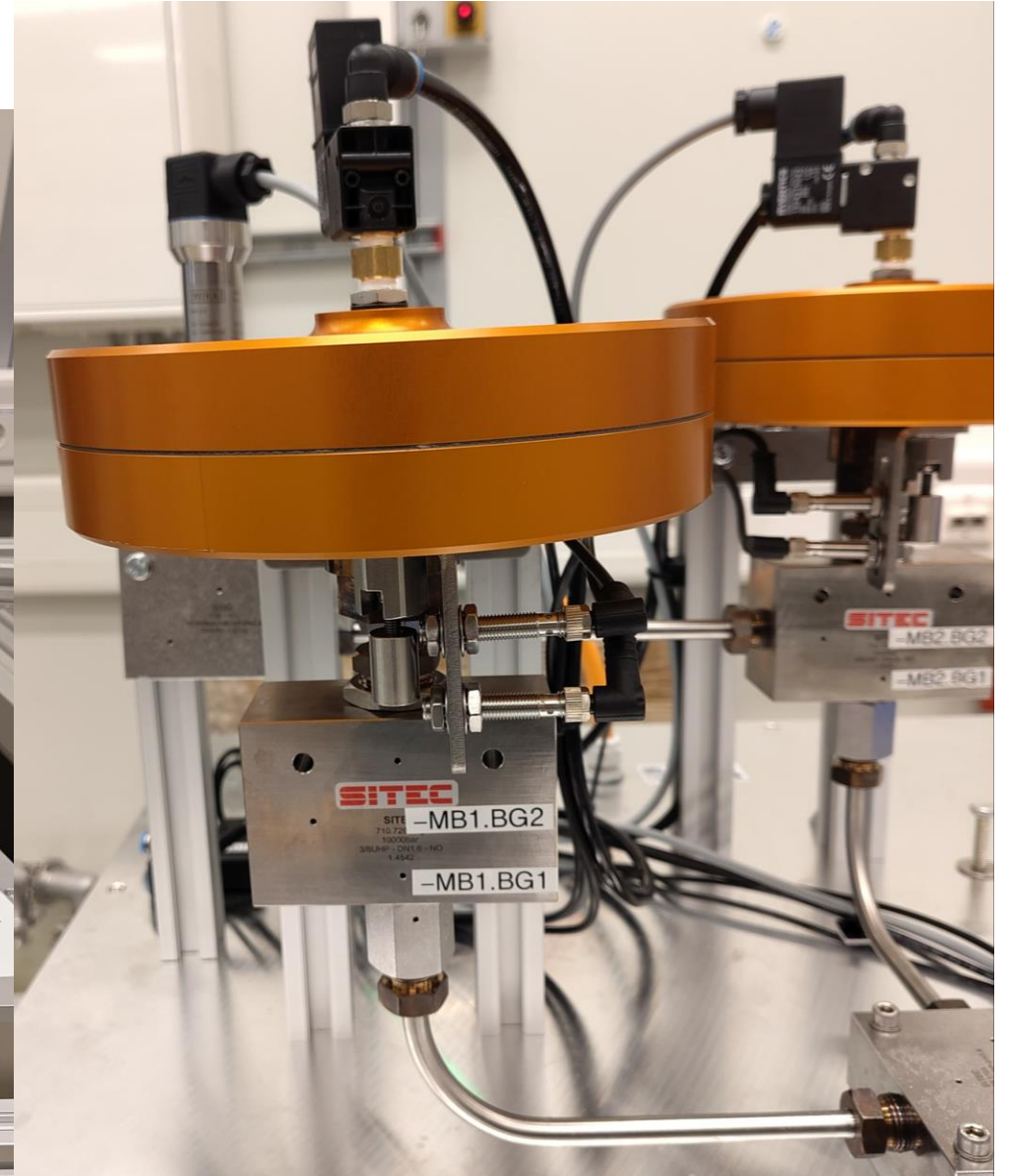
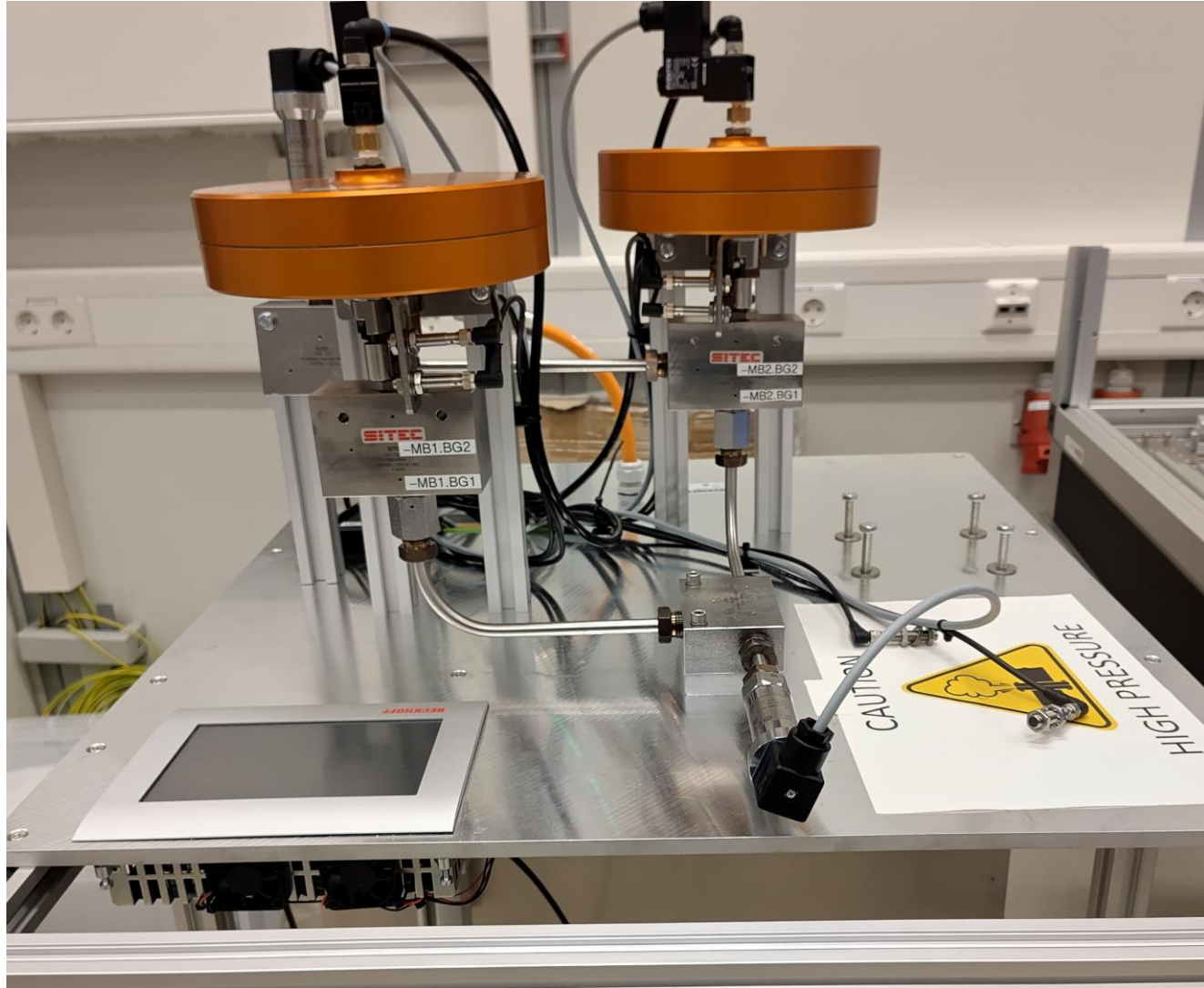
HPWC - High Pressure Water Cell

Hydraulics



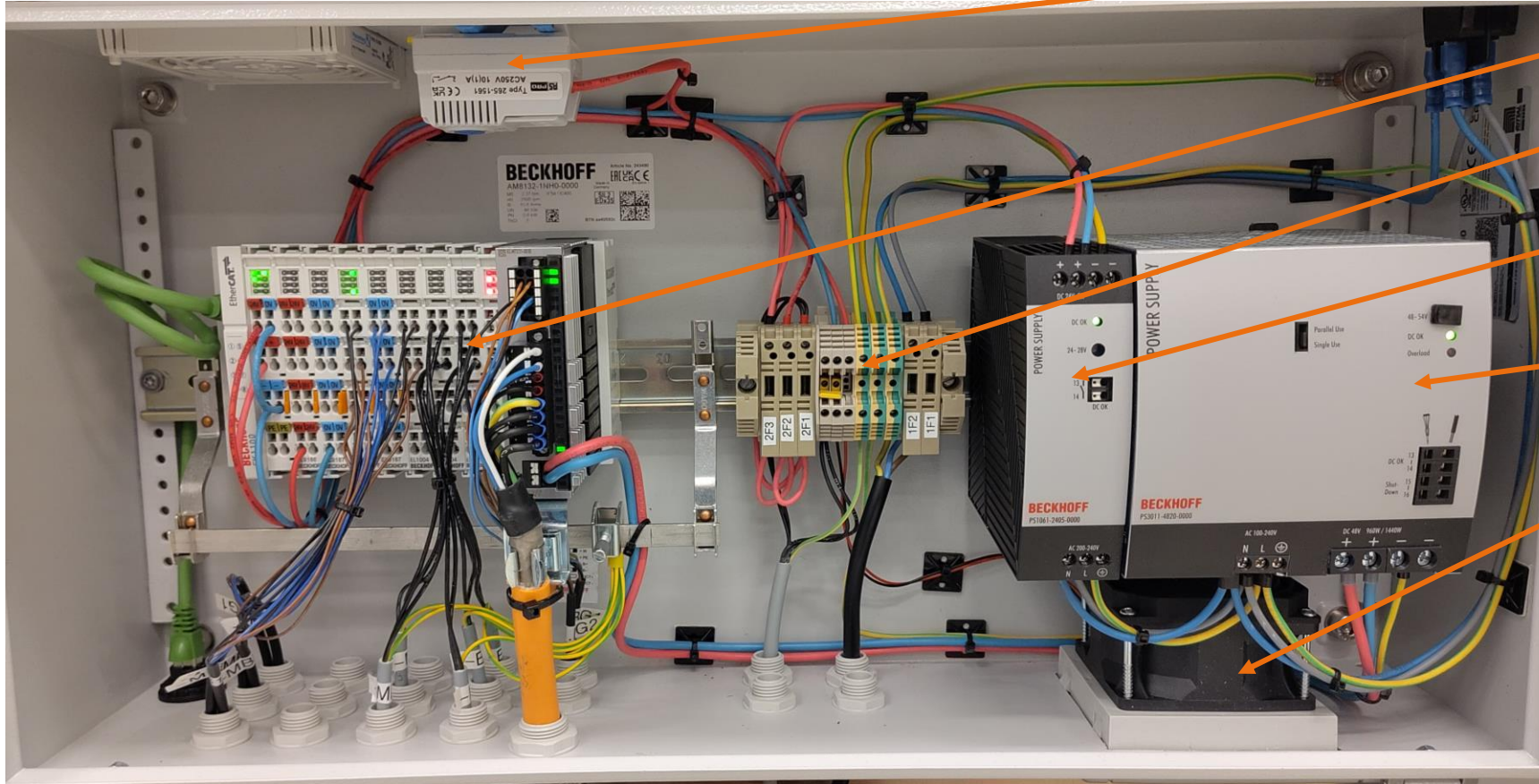
HPWC - High Pressure Water Cell

Hydraulics



HPWC - High Pressure Water Cell

Control Cabinet



Cooling thermostat

Beckhoff DDC

Terminal blocks

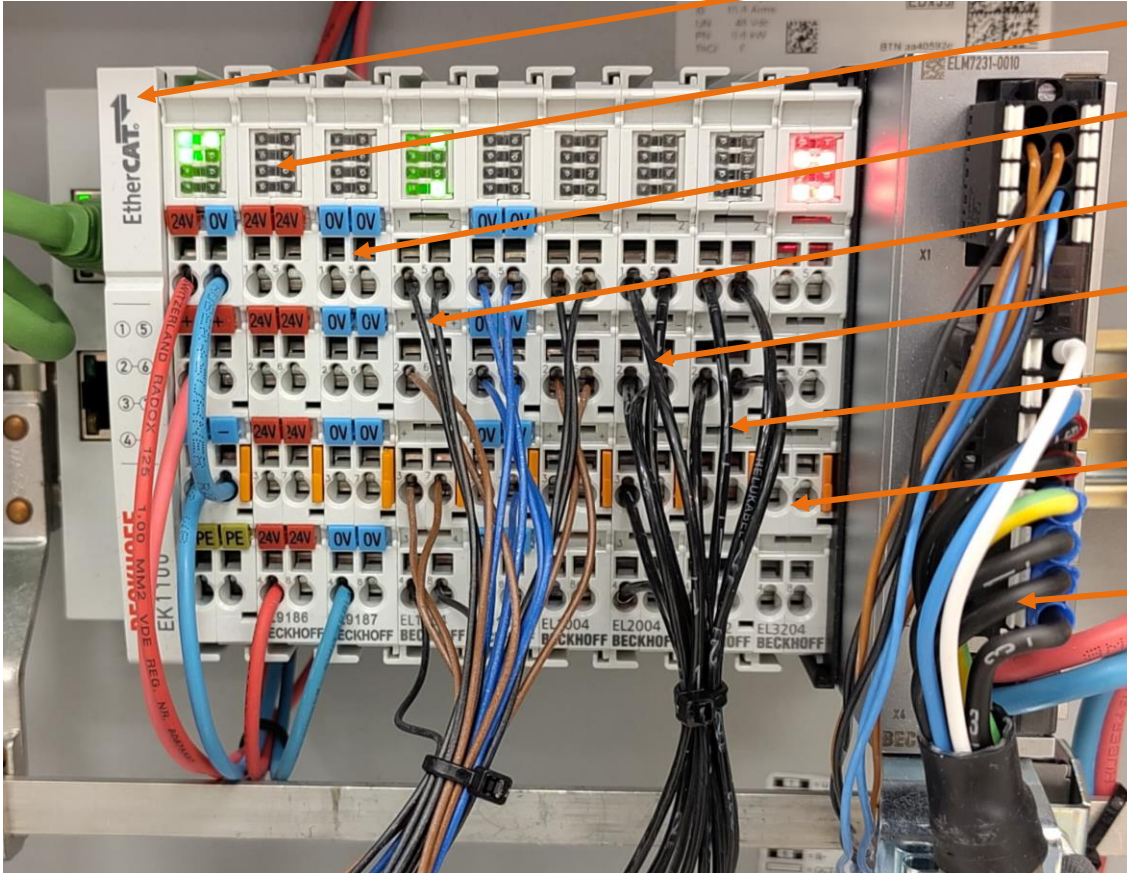
24 V power supply
DDC, Sensors, Valves

48 V power supply
Pump motor

Cooling fan

HPWC - High Pressure Water Cell

Beckhoff DDC



EK1100 | EtherCAT Coupler

EL9186 | Potential distribution terminal, 8 x 24 V DC

2x EL9187 | Potential distribution terminal, 8 x 0 V DC

2x EL1004 | EtherCAT Terminal, 4 x DI, 24 V DC, 3 ms

EL2004 | EtherCAT Terminal, 4 x DO, 24 V DC, 0.5 A

EL3152 | EtherCAT Terminal, 2 x AI, 4...20 mA, 16 bit

EL3204 | EtherCAT Terminal, 4 x AI, Pt100, 16 bit

ELM7231-0010 | EtherCAT Terminal,
1-channel motion interface, servomotor,
48 V DC, 16 A, OC

HPWC - High Pressure Water Cell

Beckhoff DDC



CP6706-0001-0060

7-inch Economy Panel PC

TwinCAT 3

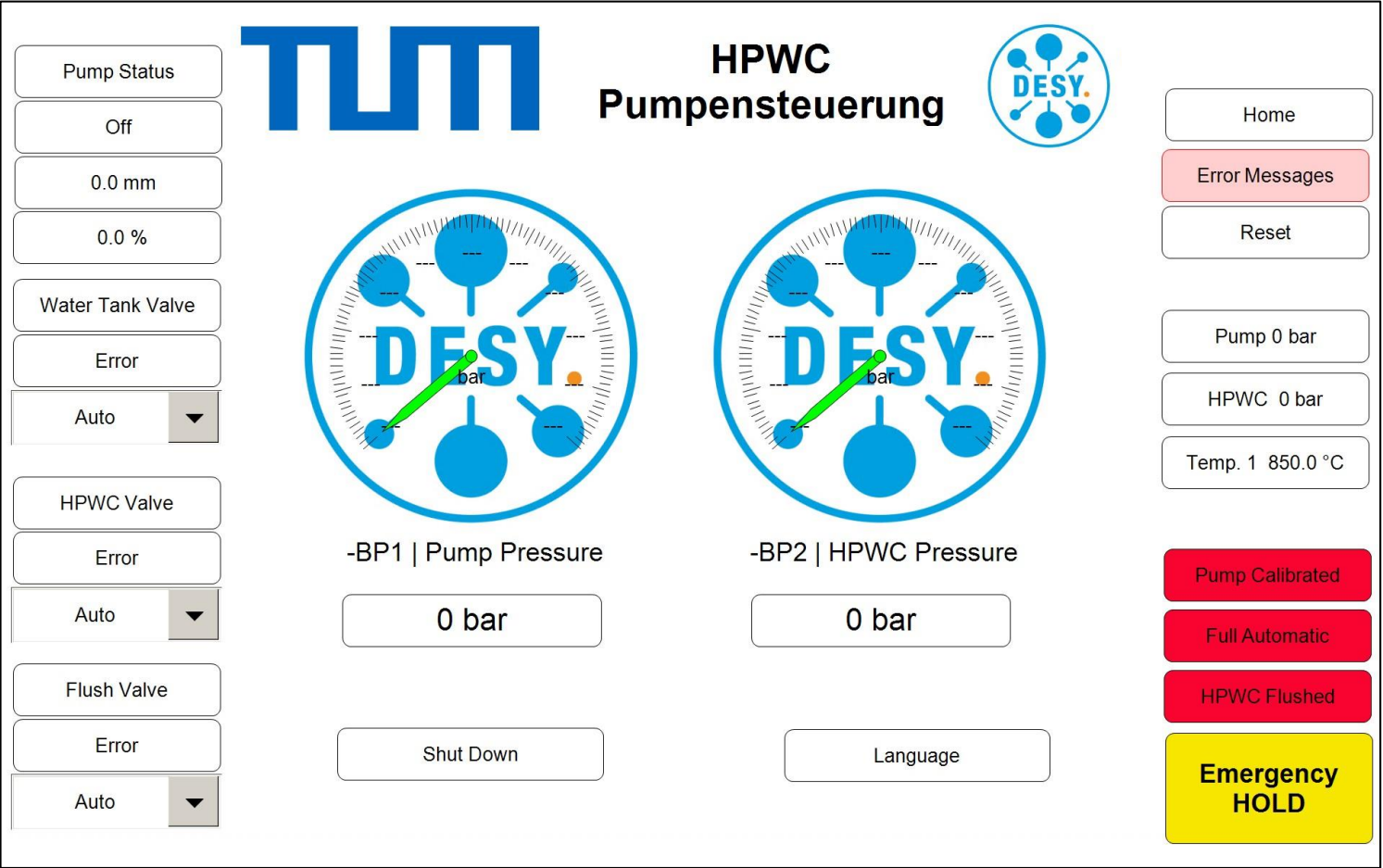
Control and data logging via Tango Server

Local control

Control via remote desktop

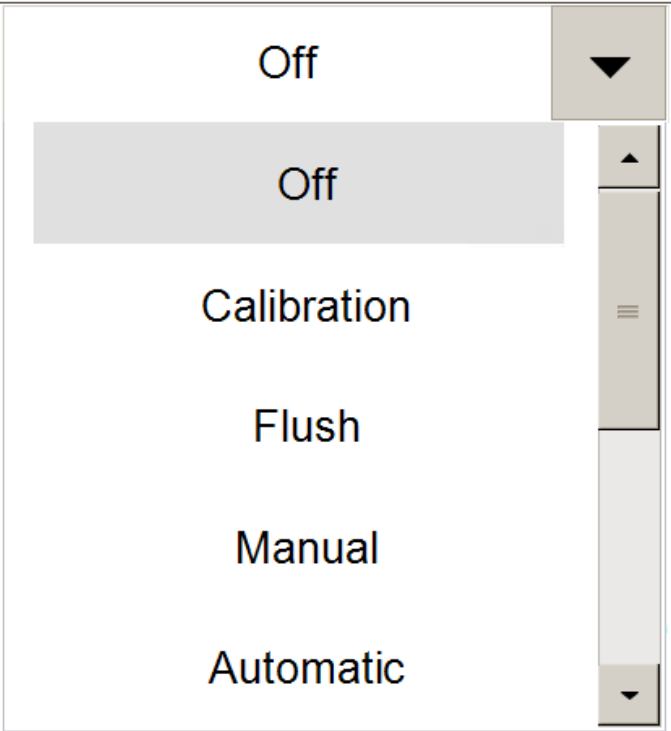
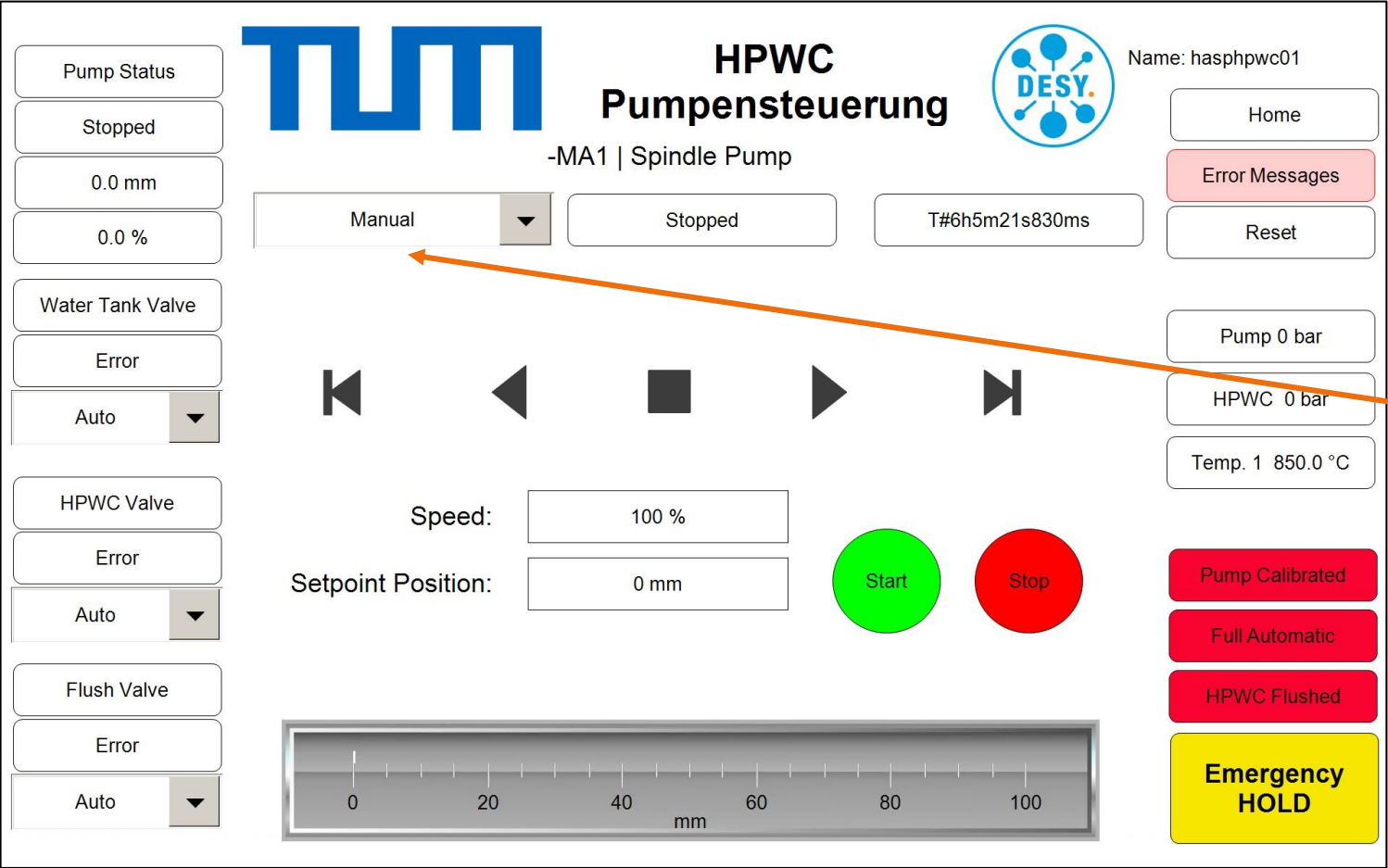
HPWC - High Pressure Water Cell

VISU - User Interface



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VISU - User Interface

Pump Status

Error

0.0 mm

0.0 %

Water Tank Valve

Error

Auto

HPWC Valve

Error

Auto

Flush Valve

Error

Auto



HPWC
Pumpensteuerung



-MB1 | Valve Water Tank

Auto

Error

✔ Limits interlock

✔ Pressure interlock

-MB2 | Valve HPWC

Auto

Error

✔ Limits interlock

✔ Pressure interlock

-MB3 | Valve Flush

Auto

Error

✔ Limits interlock

✔ Pressure interlock

Home

Error Messages

Reset

Pump 0 bar

HPWC 0 bar

Temp. 1 850.0 °C

Pump Calibrated

Full Automatic

HPWC Flushed

Emergency
HOLD

HPWC - High Pressure Water Cell

VISU - User Interface

Pump Status

Off

0.0 mm

0.0 %

Water Tank Valve

Error

Auto

HPWC Valve

Error

Auto

Flush Valve

Error

Auto



HPWC

Pumpensteuerung

Error Messages



Name: hasphpwc01

Home

Error Messages

Reset

Pump 0 bar

HPWC 0 bar

Temp. 1 850.0 °C

Pump Calibrated

Full Automatic

HPWC Flushed

Emergency HOLD

Main Alarm

Water Tank Valve

HPWC Valve

Flush Valve

Pump

Pump NC

Pump Limit-switch

Calibration

Calibration Limit 0 mm

Calibration Limit 100 mm

Flush

Pressure Control

Pressure Control - Diff. Pressu

Pressure Control - Partial Rele

Pressure Control - Refill

Release pressure (0 bar)

Filter Drucksensor Pumpe

Filter Drucksensor HPWC

HPWC - High Pressure Water Cell

Functions of the DDC

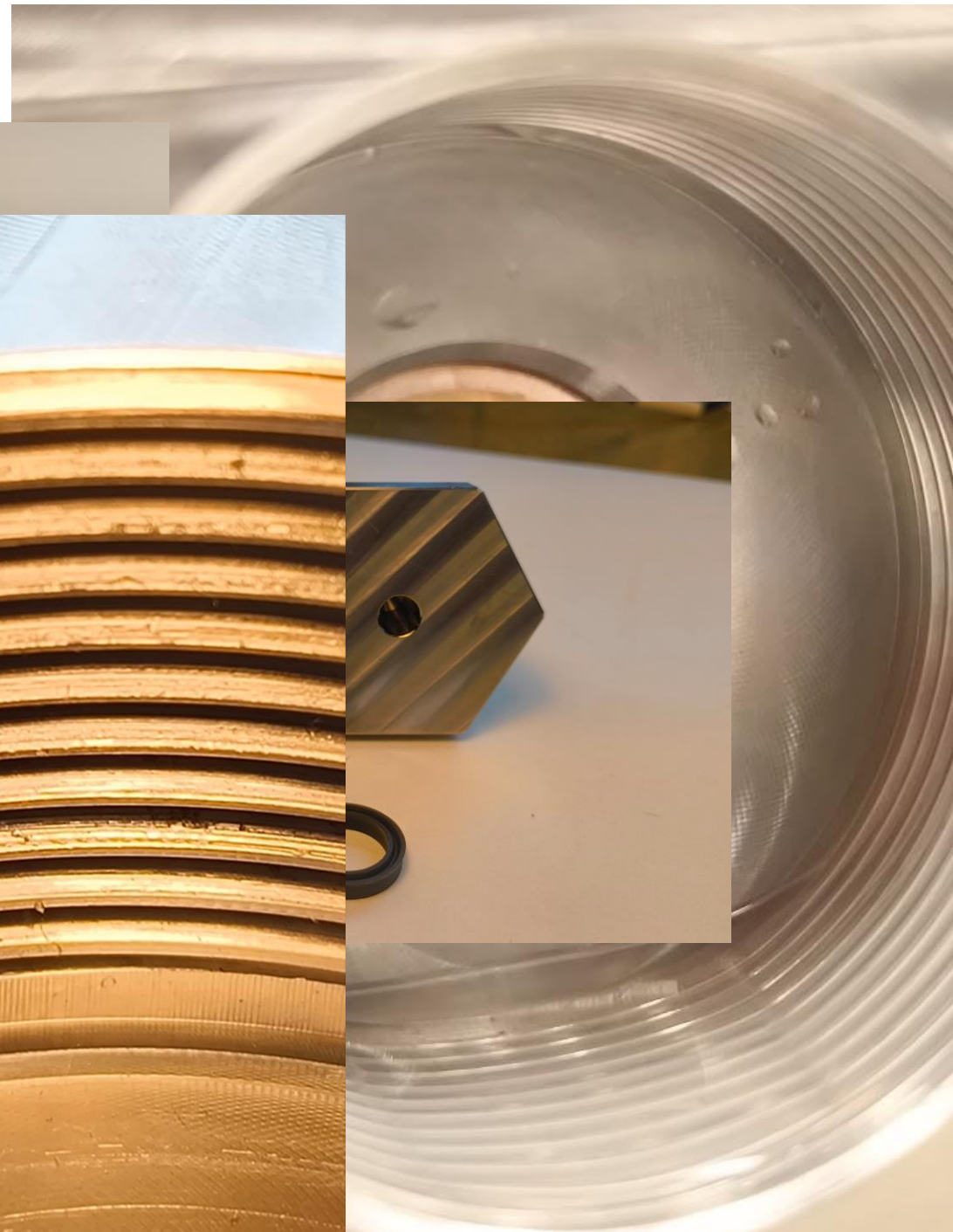
Functions of the DDC

- Pump operating hours counter.
- PID controller for pressure.
- Automatic flushing of the system.
- Automatic pressure reduction.
- Automatic water refilling
- Recording of operating conditions for pump, valves, temperatures and pressures.

Software safety features

- Stepwise, pressure-dependent reduction of the pumping speed.
- Smooth driving into the pump limits.
- Switching off the pump when the maximum pressure is reached.
- Open the valves only when the pressure is balanced.
- End position monitoring of valves and pump.
- Monitoring pump calibration and flushing cycles.

er Cell

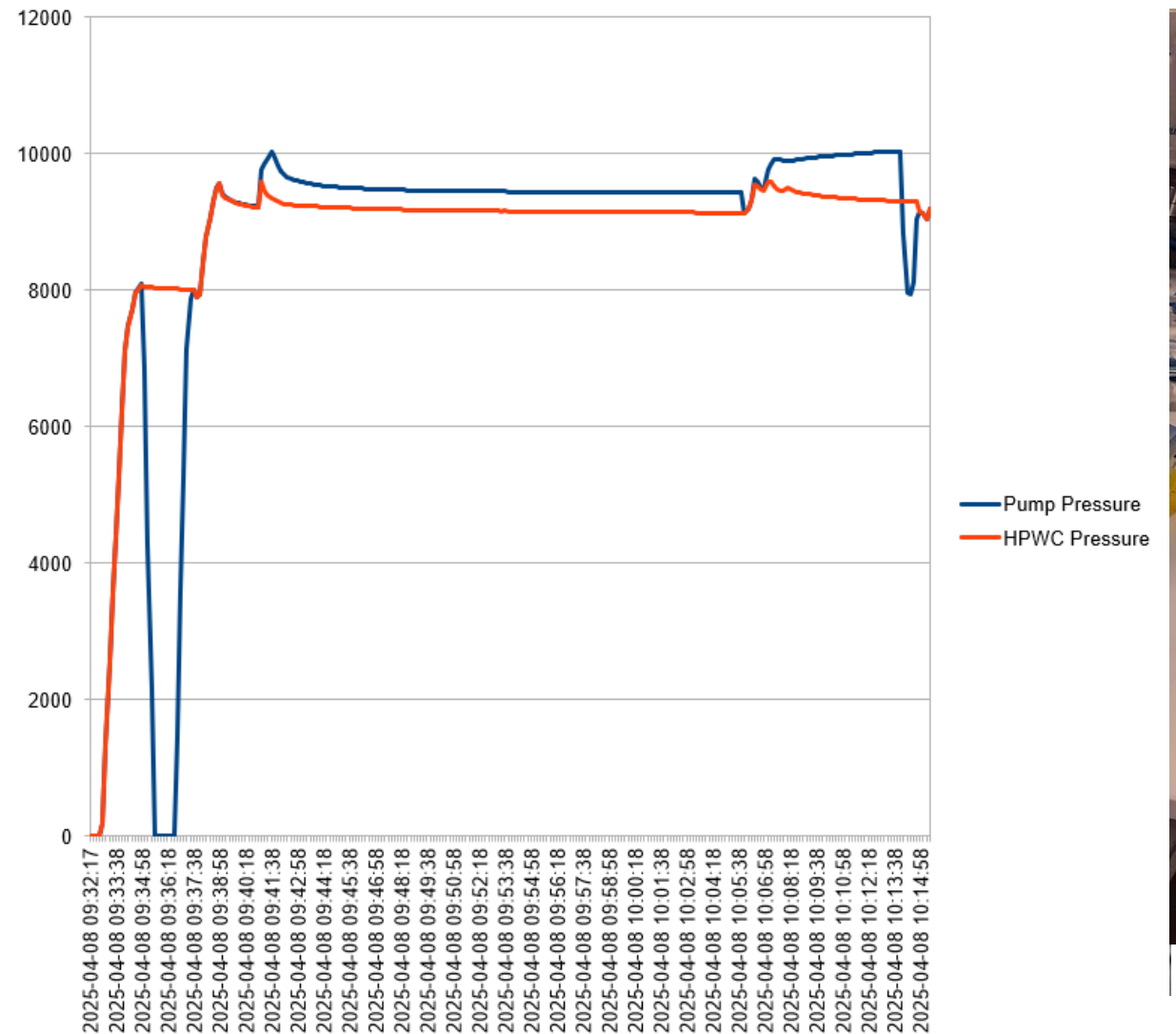


HPWC - High Pressure Water Cell

Good things

Successes

- Dummy test at over 11 kBar
- Long-term laboratory pressure test at 7 kBar
- Two successful beamtimes at 7 kBar
- Successful automatic test at 10 kBar



Thank you very much for your attention.

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