Commissioning of the Cryogenic Safety Test Facility PICARD

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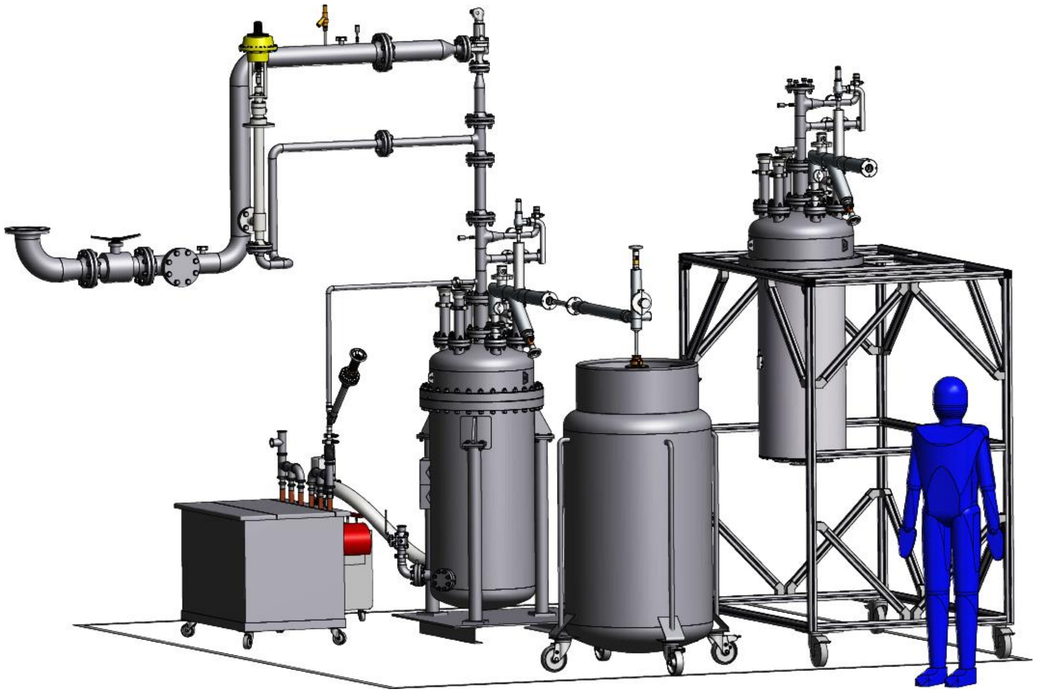
Motivation

- **Dimensioning** of cryogenic safety relief devices
  - Hazardous incidents e.g. venting of insulating vacuum with atmospheric air
- Existing models and standards (e.g. DIN EN 13648) do not consider **process dynamics** → $\dot{q} = \mathbf{const.}$ [1]
  - **Oversizing** of safety valves
  - Implications on spending, space and helium leakage
- **Dynamic model** links all time-dependent sub-processes [2]
  - ODE system based on thermodynamic and fluid mechanic principles
  - Contains some simplifications
  - Experiments for validation and extension of model → **fit parameters**

[1] Lehmann, W., Zahn, G., Safety aspects for LHe cryostats and LHe transport containers, 1987 *Proc. Int. Cryog. Eng. Conf.* **7** 569-579
[2] Heidt, C., Grohmann, S., Süßer, M., Modeling the Pressure Increase in Liquid Helium Cryostats after Failure of the Insulating Vacuum, 2014 *AIP Conf. Proc.* **1573** 1574-1580

Outline

- Purpose & Operating Range of PICARD
- Design & Construction
  - Test Setup
  - Instrumentation
- Status & Outlook



Purpose & Operating Range

Karlsruhe Institute of Technology

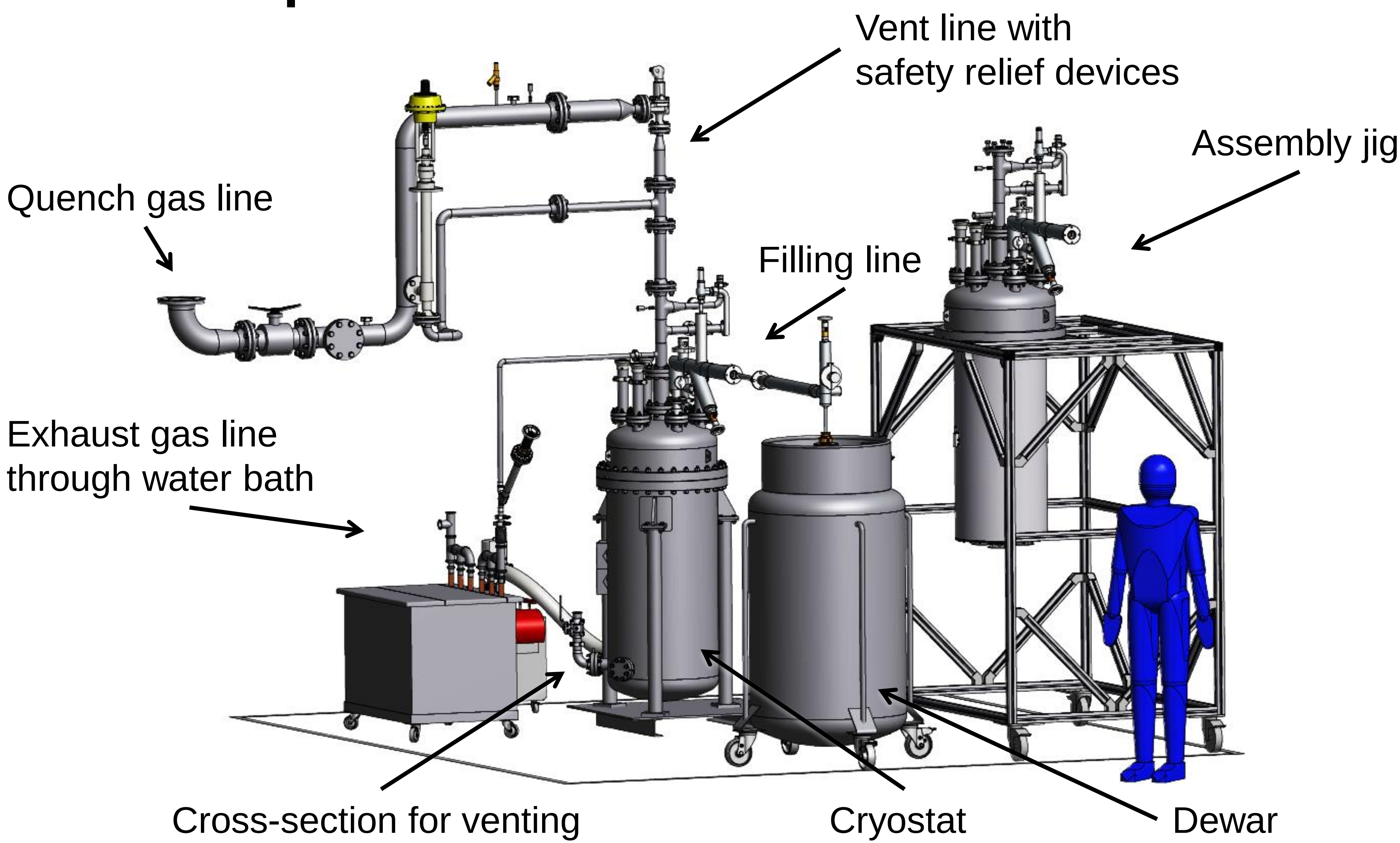
- Test facility PICARD: **P**ressure **I**ncrease in **C**ryostats and **A**nalysis of **R**elief **D**evices
  - Cryogenic liquid volume: **100 liters**
  - Nominal design pressure: **16 bar(g)**
  - Helium discharge mass flow rates: up to about **4 kg/s**
- **Broad range** of experiments with cryogenic fluids
  - **Heat flux** and **flow rate** measurements under various conditions
  - Studies on the impact of **two-phase flow**
  - Measurement of **flow coefficients** of safety devices at 4…300 K

Purpose & Operating Range

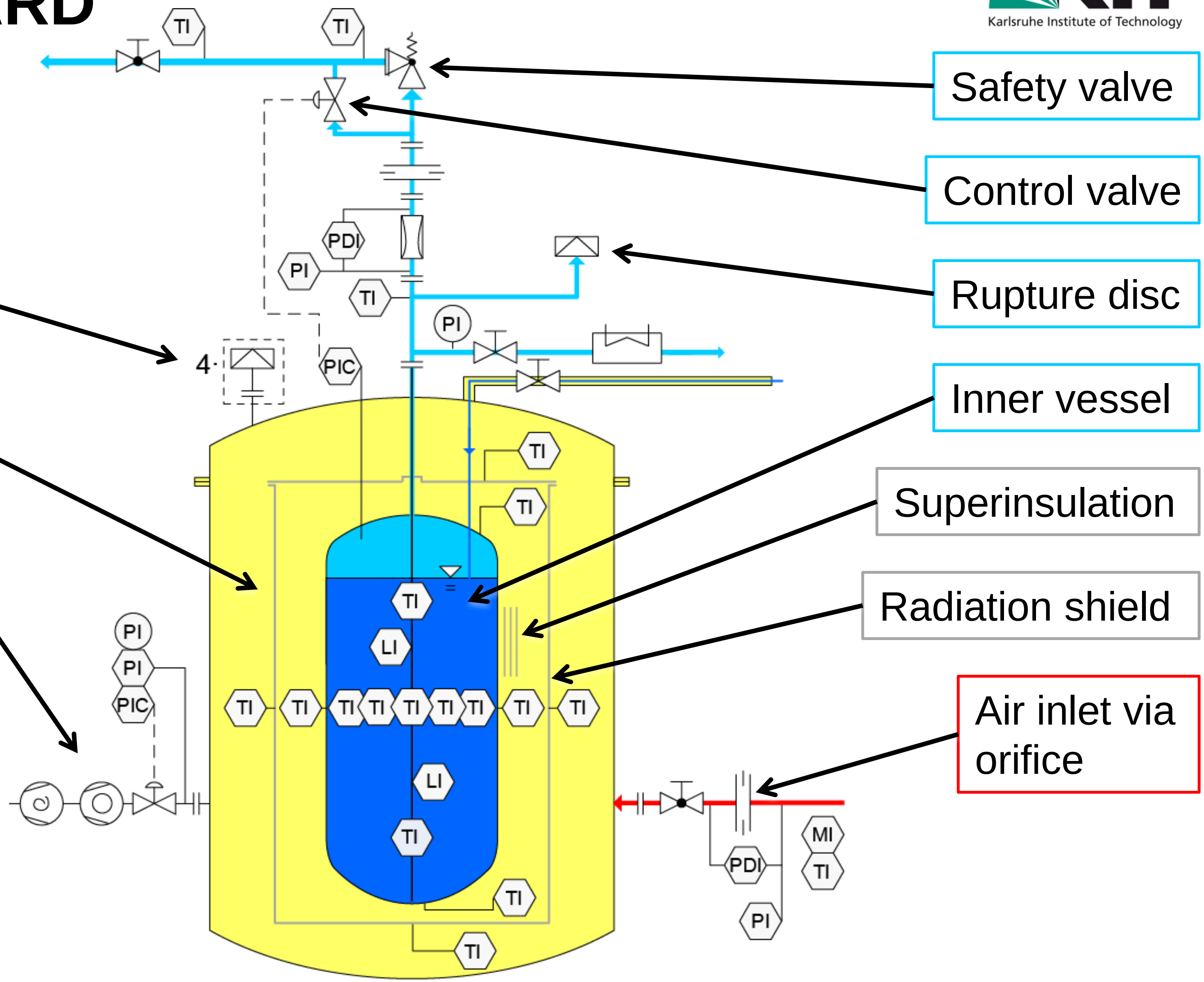
Karlsruhe Institute of Technology

Variation of	Range
Venting diameter	1…40 mm
Insulation	0…30 layers of superinsulation, with/without radiation shield
Liquid level	20…80 %
Set relief pressure	2…12 bar(g)
Cryogenic fluid	Helium, nitrogen, neon, argon
Venting fluid	Air, nitrogen
Safety relief device	Safety valve, rupture disc, control valve
Heating	With/without simulating the quench of a sc magnet
Relief mass flow	Single-phase, two-phase
Discharge coefficient	At 4…300 K

Test Setup PICARD



P&ID PICARD



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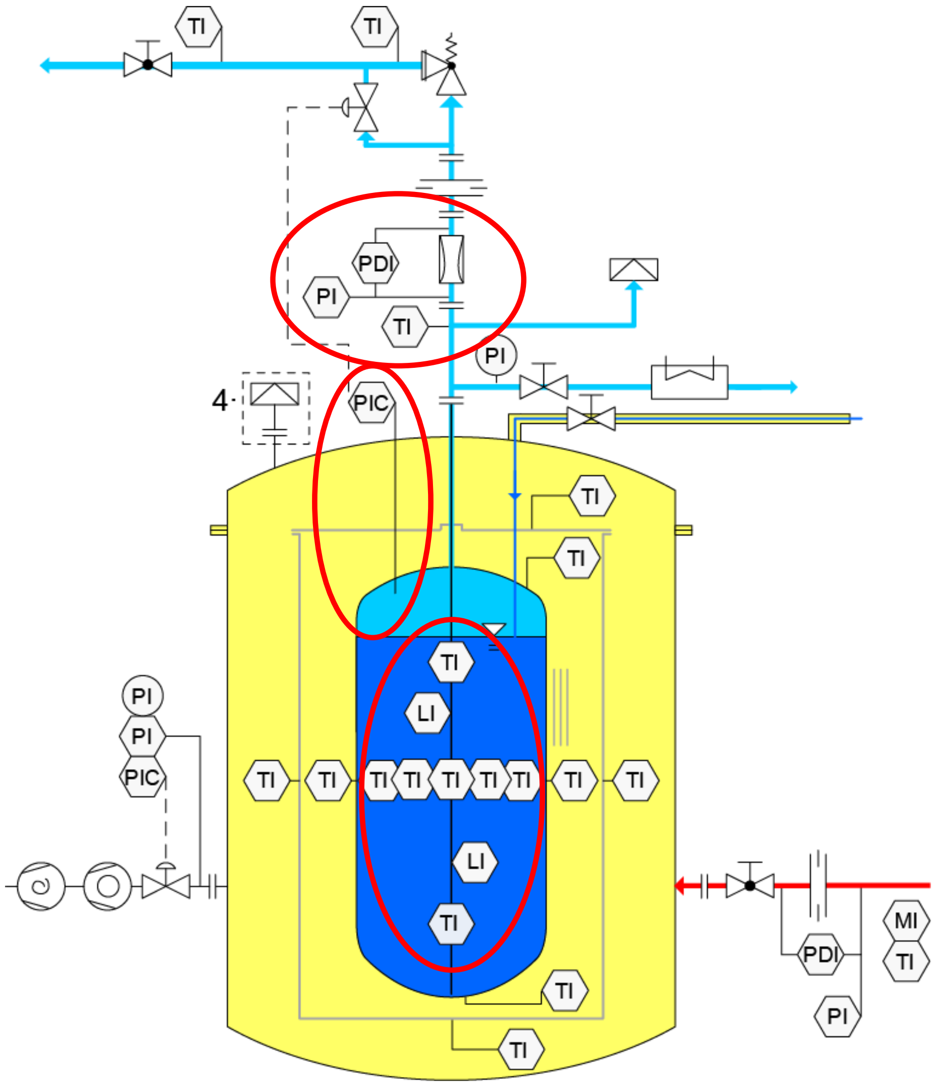
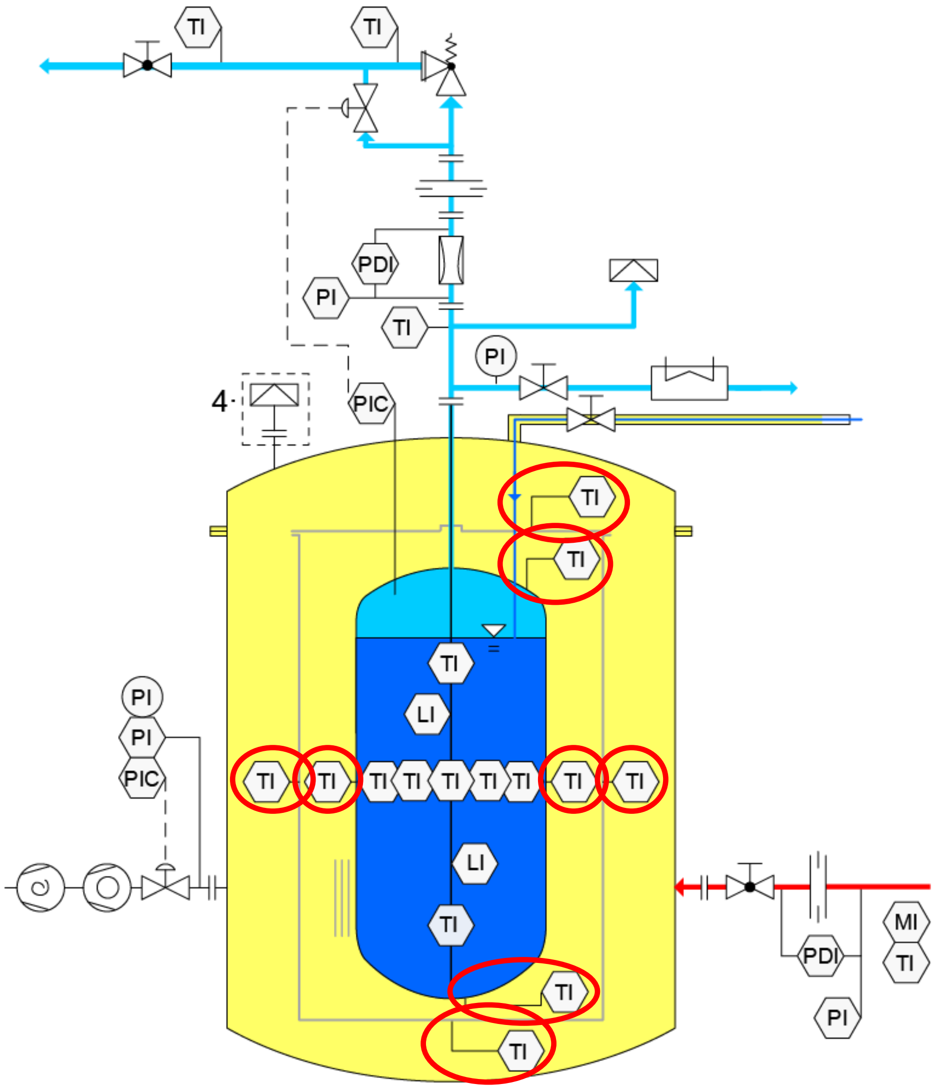
Discharge Mass Flow Measurement

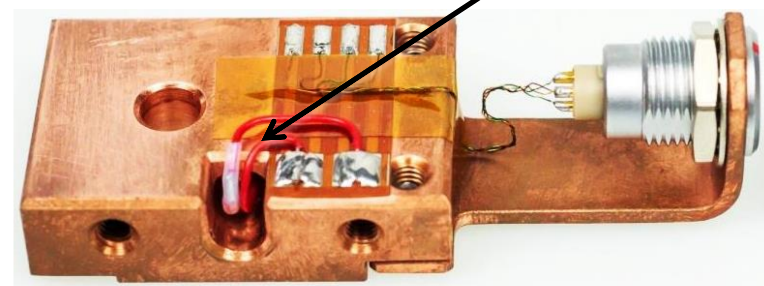


- Challenges:
  - Fast changes
  - Low inlet pressure losses
  - Possible two-phase flow (outlet)
- Two measurement principles:
  - Venturi tube measurement
    - DIN EN ISO 5167-4
  - Changes of mass
    - Measurement of $T(\tau), p(\tau)$
    - $\rightarrow \rho(\tau) \rightarrow m(\tau) \rightarrow \dot{m}(\tau)$
    - Measurement uncertainty ~ 20 %

Surface Temperature Measurement



TVO sensor in copper sleeve



Surface Temperature Measurement

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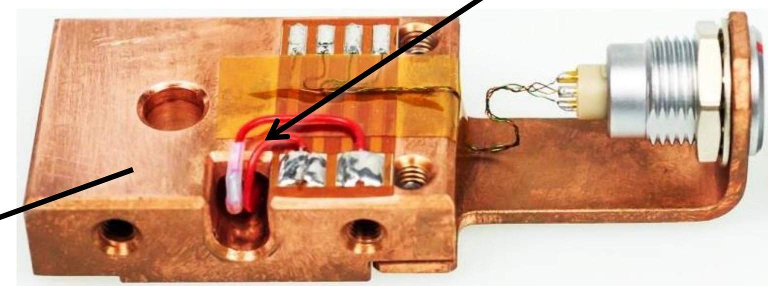
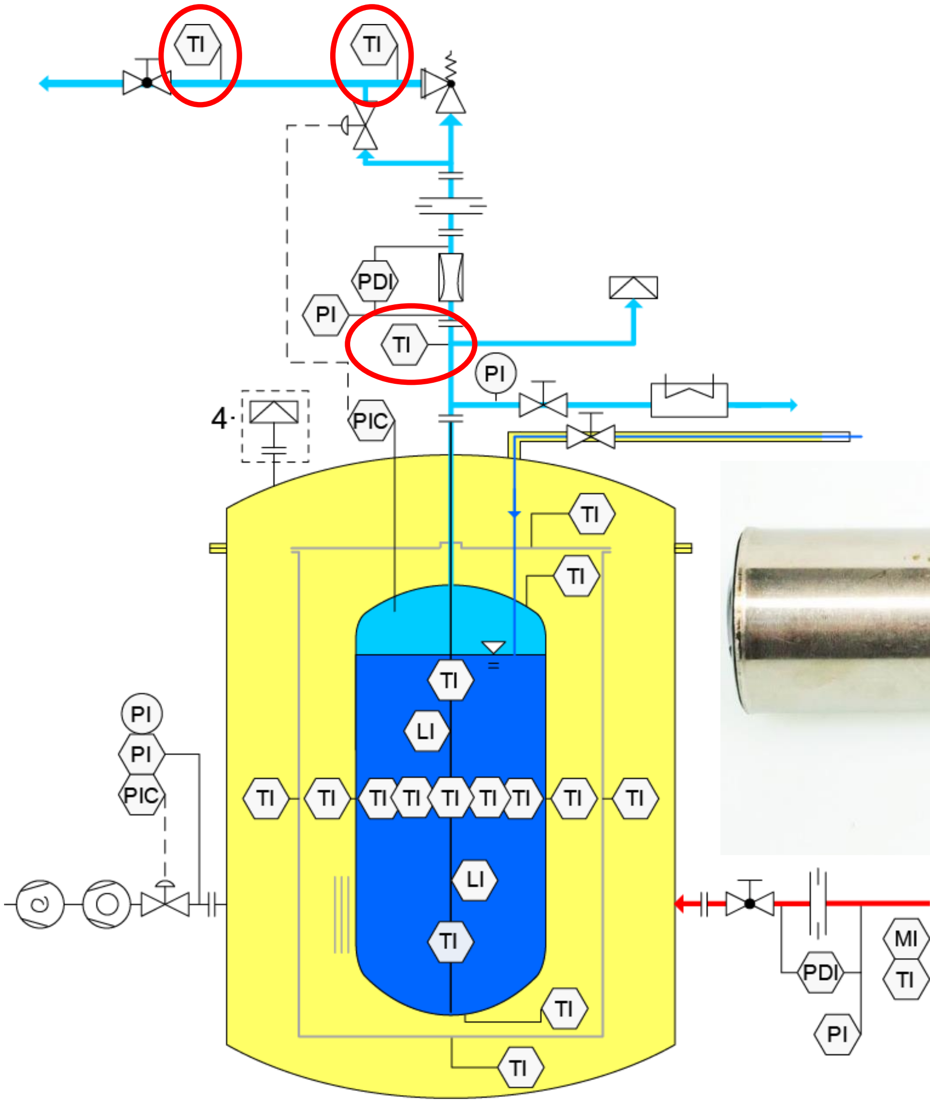
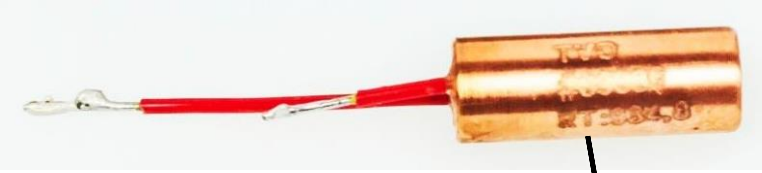


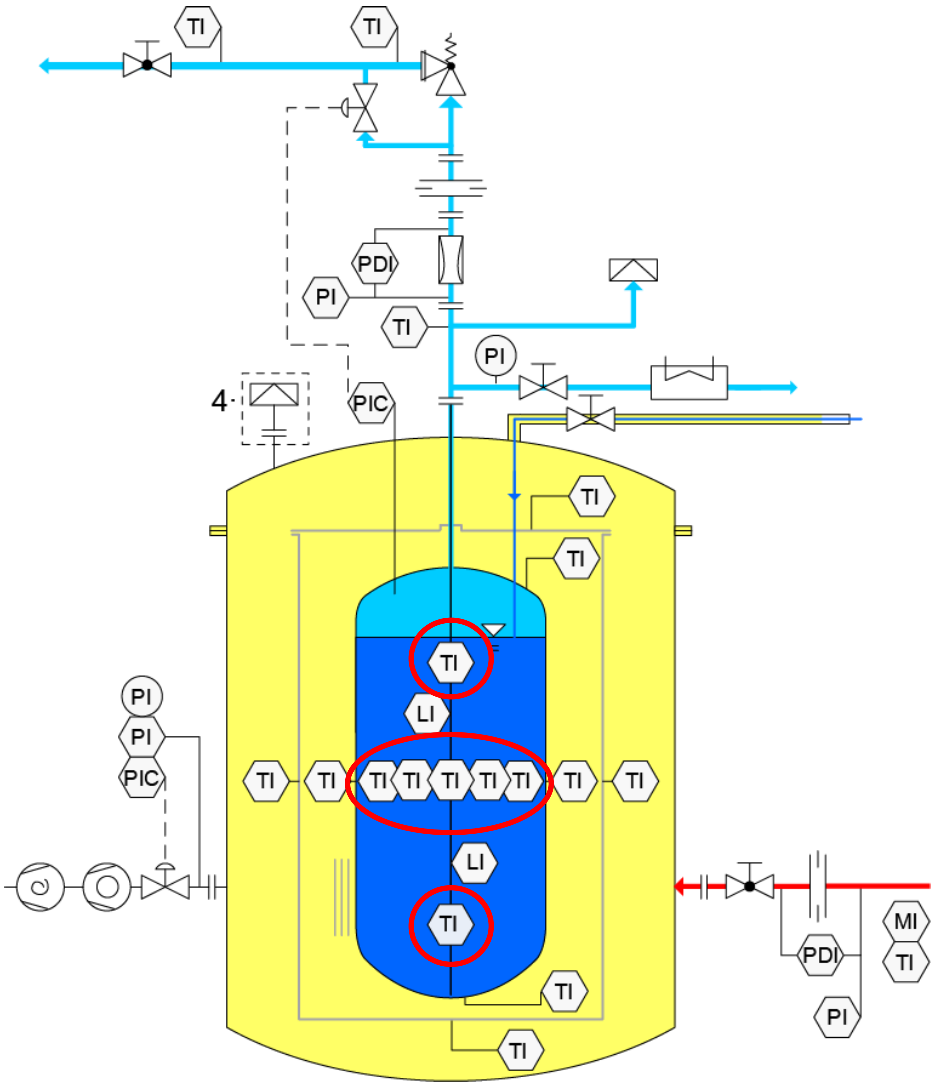
Flow Temperature Measurement

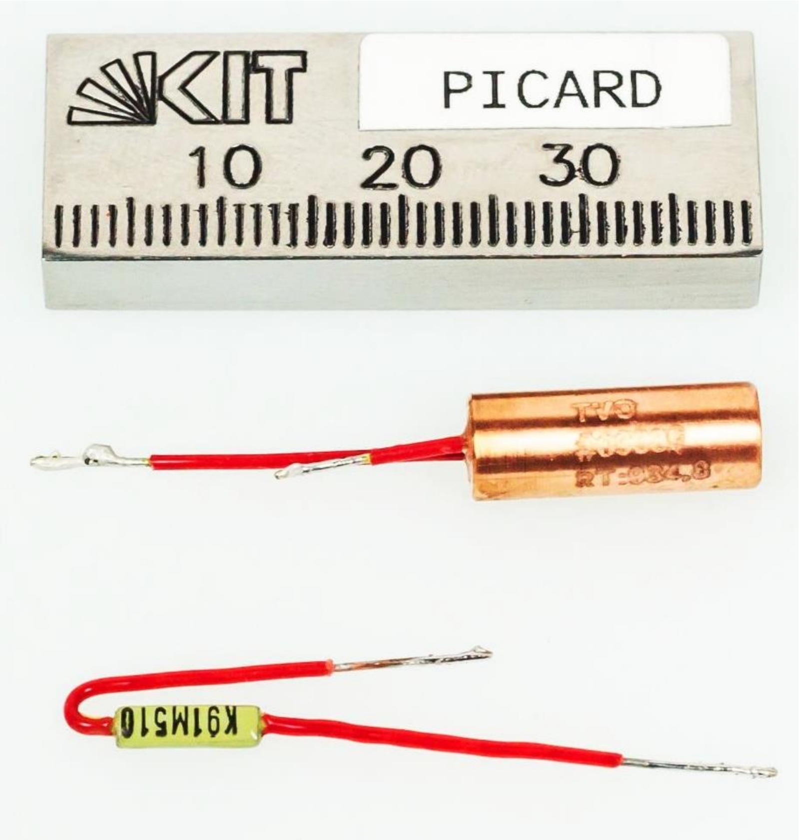




TVO sensor in copper sleeve

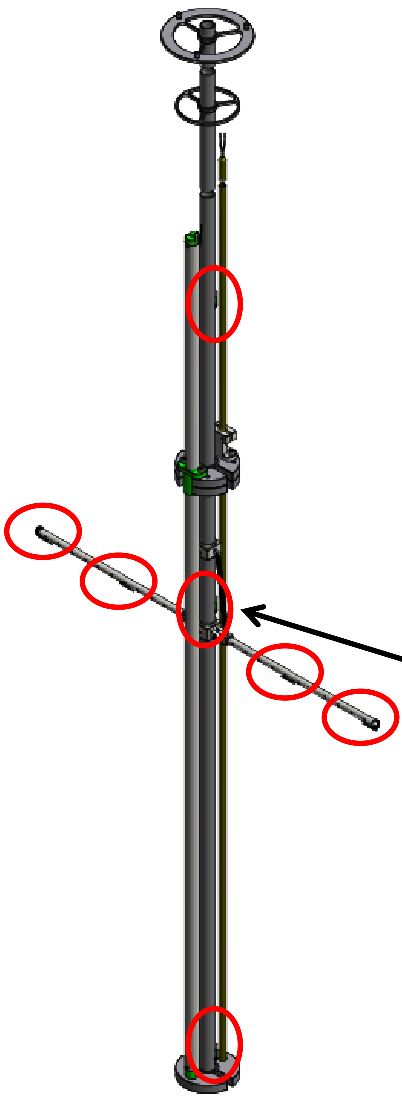
Fast Temperature Measurement

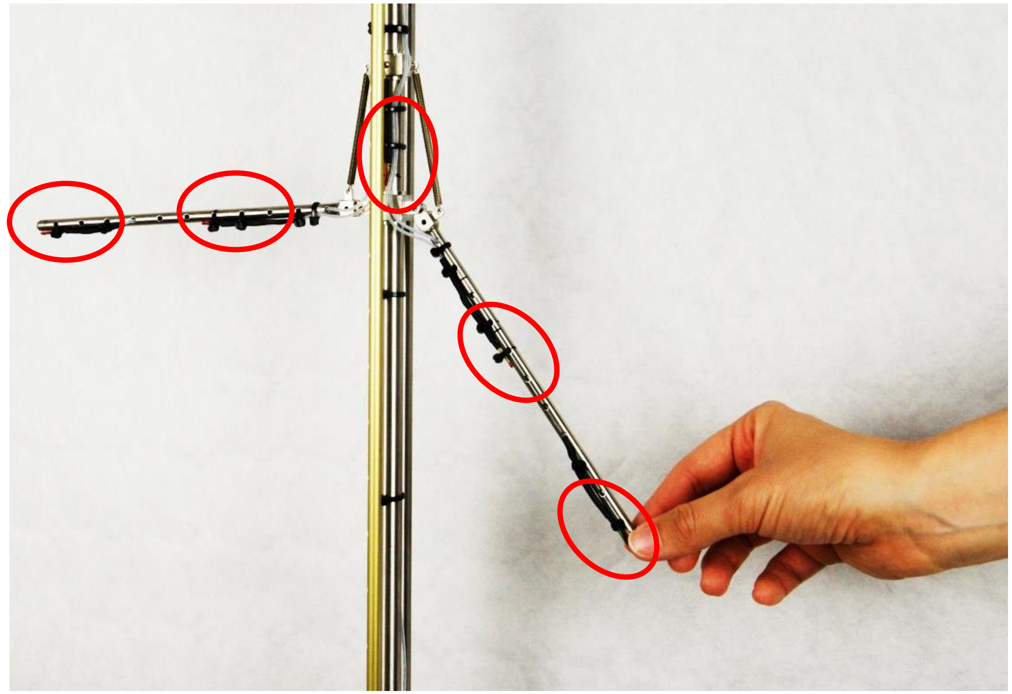




Plain TVO sensor

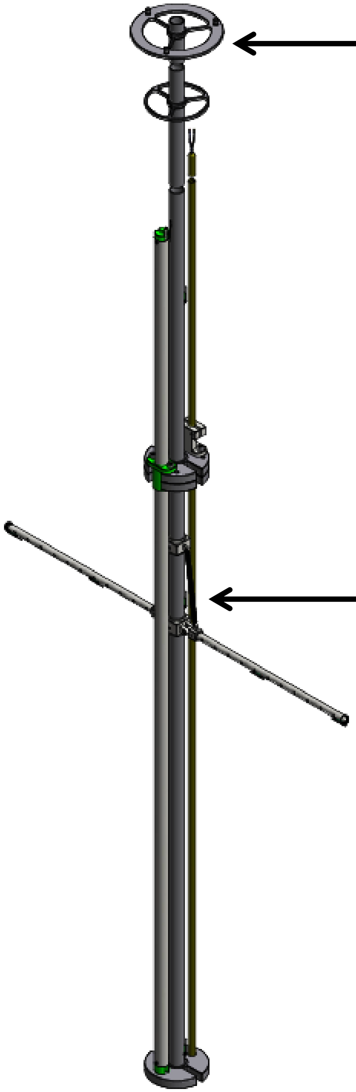
Fast Temperature Measurement

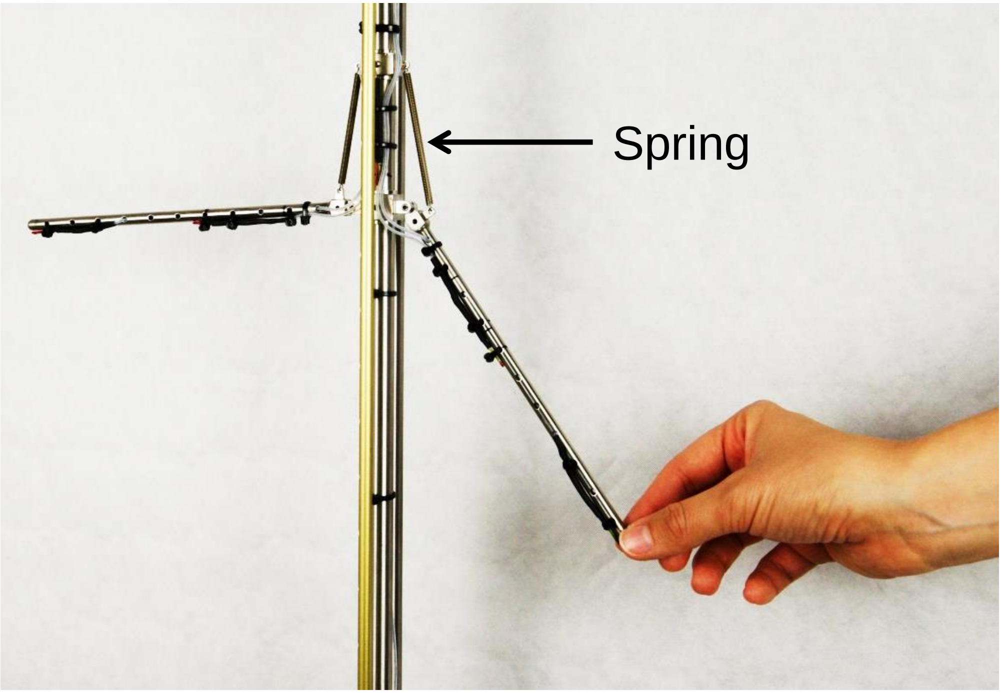




Plain TVO sensor

Measurement Insert





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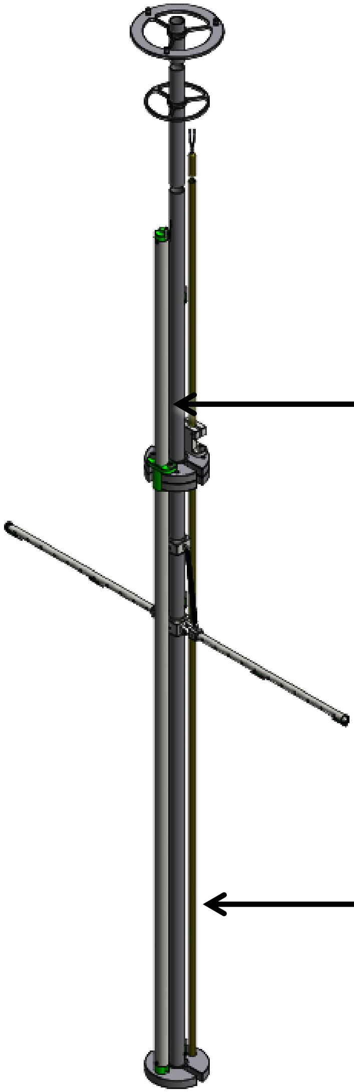
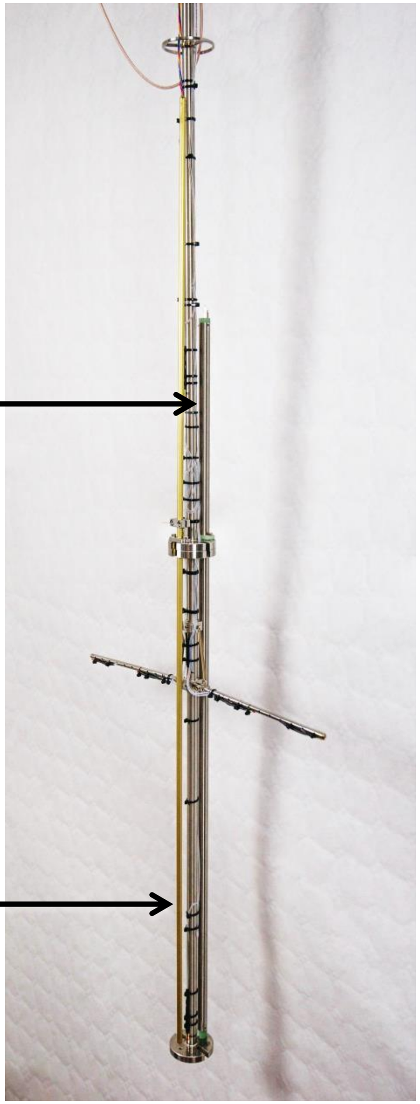
Level Measurement



Capacitive level sensor

Superconducting level sensor



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Status & Outlook

- Leak tests:
  - $\leq 10^{-6}\,\mathrm{mbar} \cdot l \cdot s^{-1}$ ✓
- Pressure tests:
  - $p \geq 16\,\mathrm{bar(g)}$ for inner vessel components ✓
  - $p \geq 10\,\mathrm{bar(g)}$ for vacuum vessel components ✓
  - $p \geq 1.5\,\mathrm{bar(g)}$ for vacuum pumping components ✓

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- Further commissioning:
  - 07/2015: Approval by notified body
  - 08/2015: First cooldown
  - 10/2015: First venting experiments
  - 11/2015: First two-phase flow experiments in collaboration with CERN
  - …

Thank you for your attention!