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STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Development of experimental setup for hydraulic resistance measurements

HOT LAB

Development of experimental setup for hydraulic resistance measurements

G. Cornelis, J. Pakarinen, W. Faber, M. Verwerft

guy.cornelis@sckcen.be

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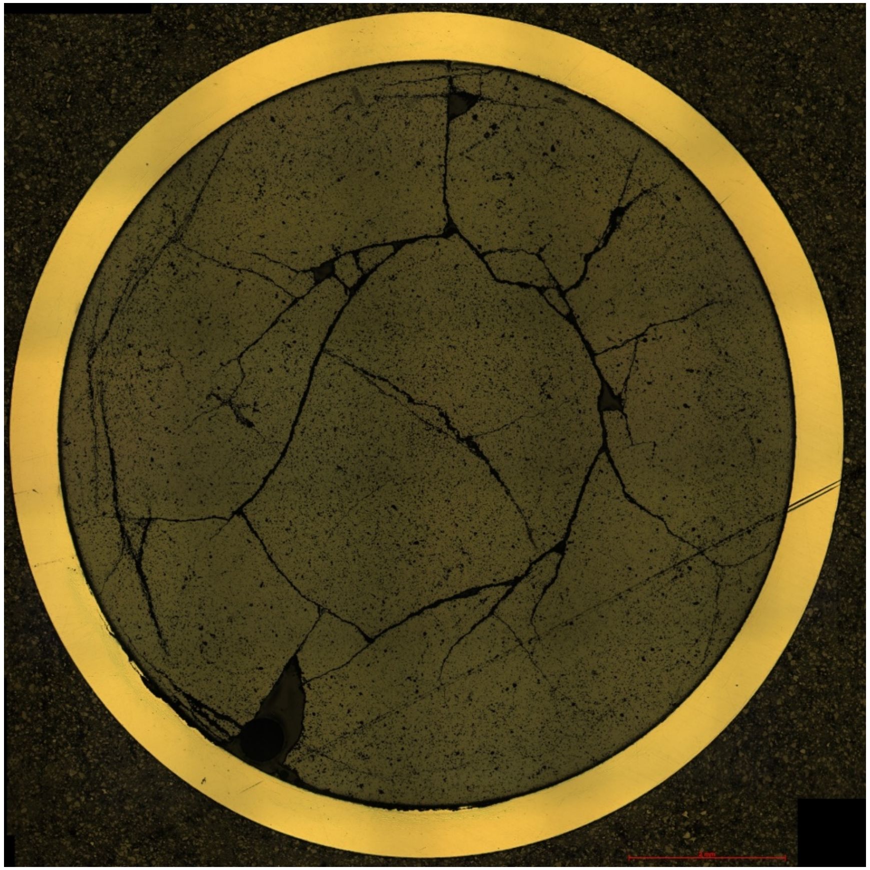
Outline

- Motivation
- Equipment
  - Development: first and final design
  - Selected components
  - Pictures of the experimental setup
- Achievements and example of operation

Motivation

Gas flow through fuel is an important parameter for various safety aspects, such as LOCA, spent fuel management, etc.

An experimental setup was developed to measure the hydraulic resistance in spent fuel



The pictures shows the problem:

Fuel is fragmented and porous

- leak path is not well defined

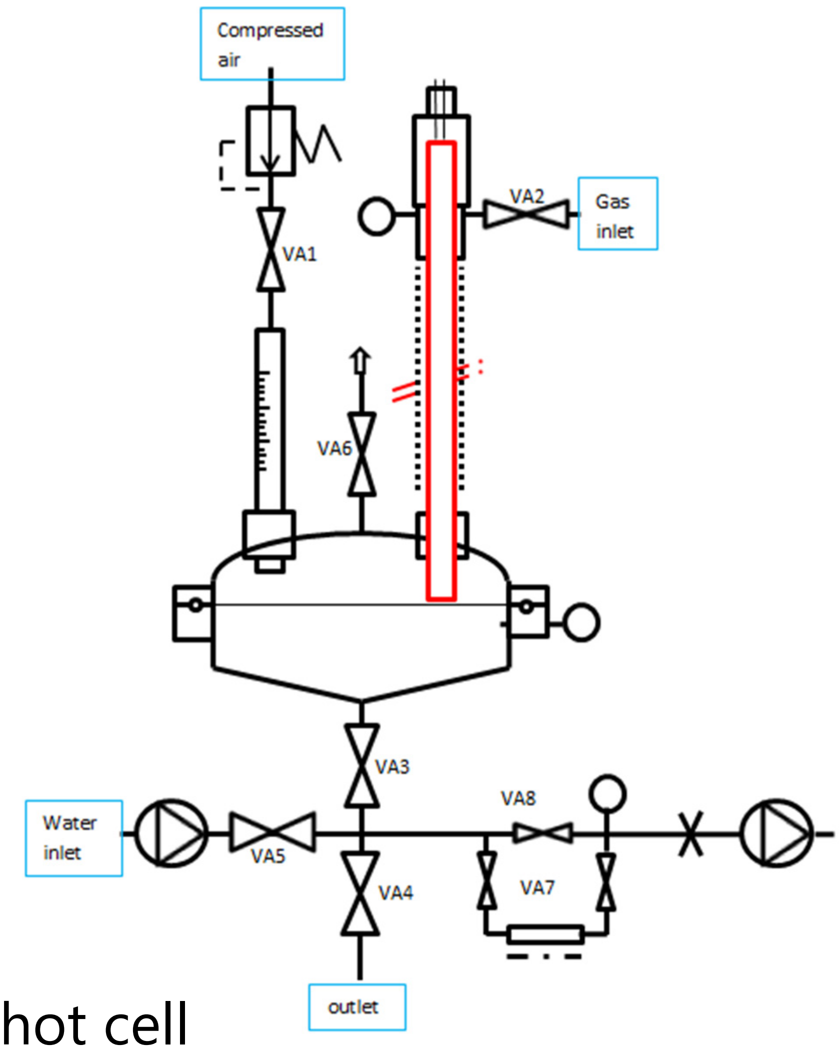
Equipment development

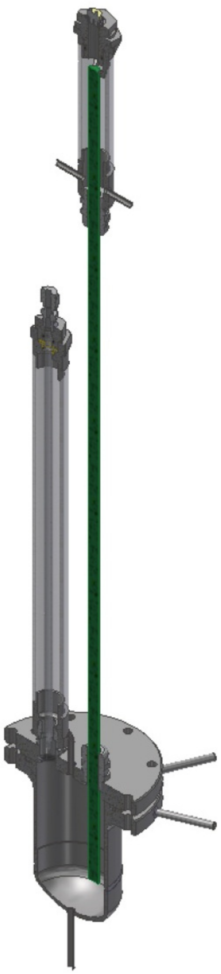
Fixed criteria for our device

- Maximum fuel length: 500 mm
  - Cut segments will be used => open fuel on both ends. Take measures against small particles dropping out!
- Gasses used: Argon, Helium and water vapor
  - System needed to fill the reservoir with water
  - Maybe cold trap needed to protect pump from moisture
  - Dew point meter to monitor that tubing is dry again
  - Vacuum pump needs a gas ballast, a condense separator and activated carbon filter
- Test will be performed with maximum 2 bar overpressure
  - Monitoring of vacuum and overpressure of different gasses is needed

Equipment development

First idea (11/2012)



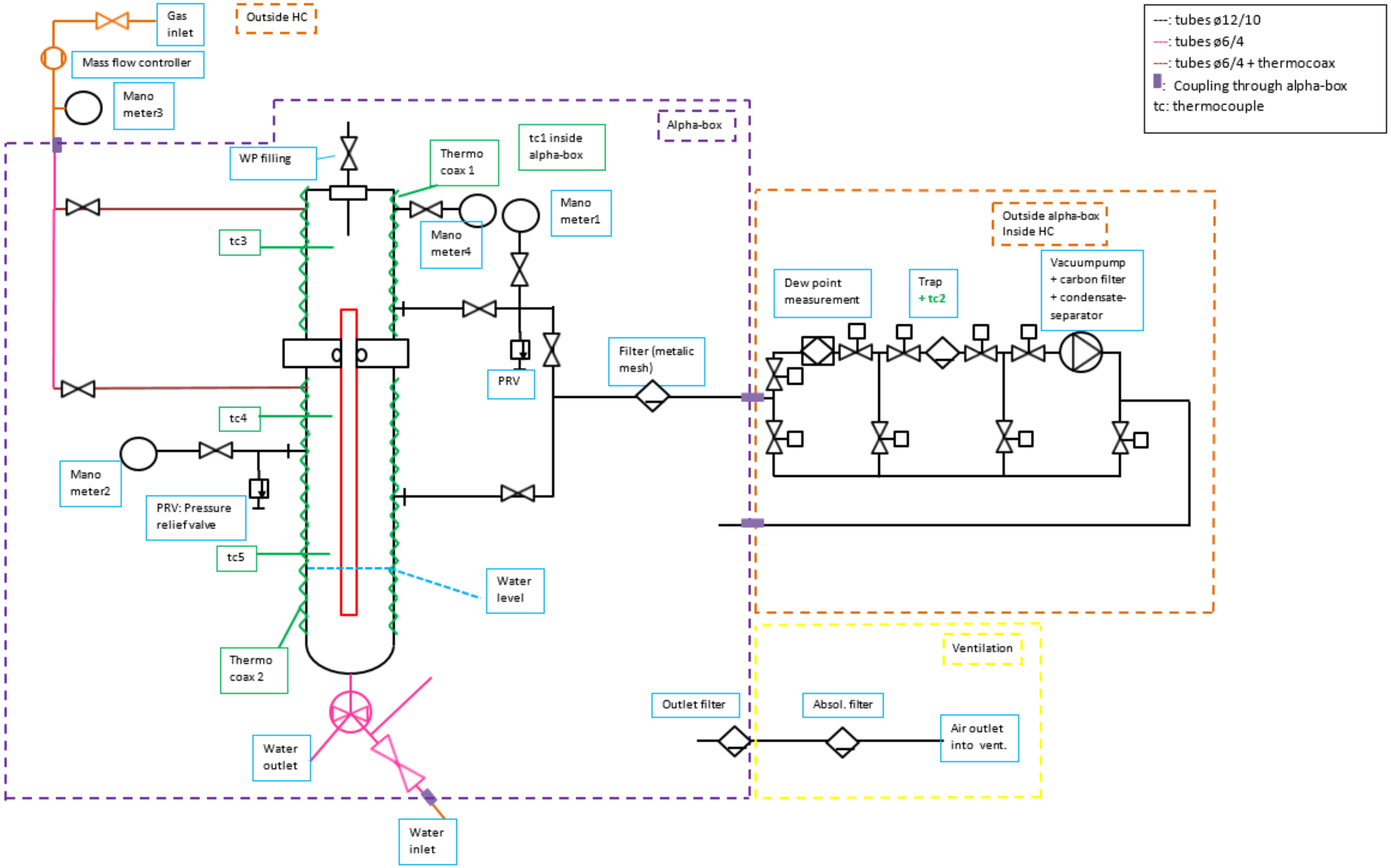


Big disadvantages:

- Not easy to handle in hot cell

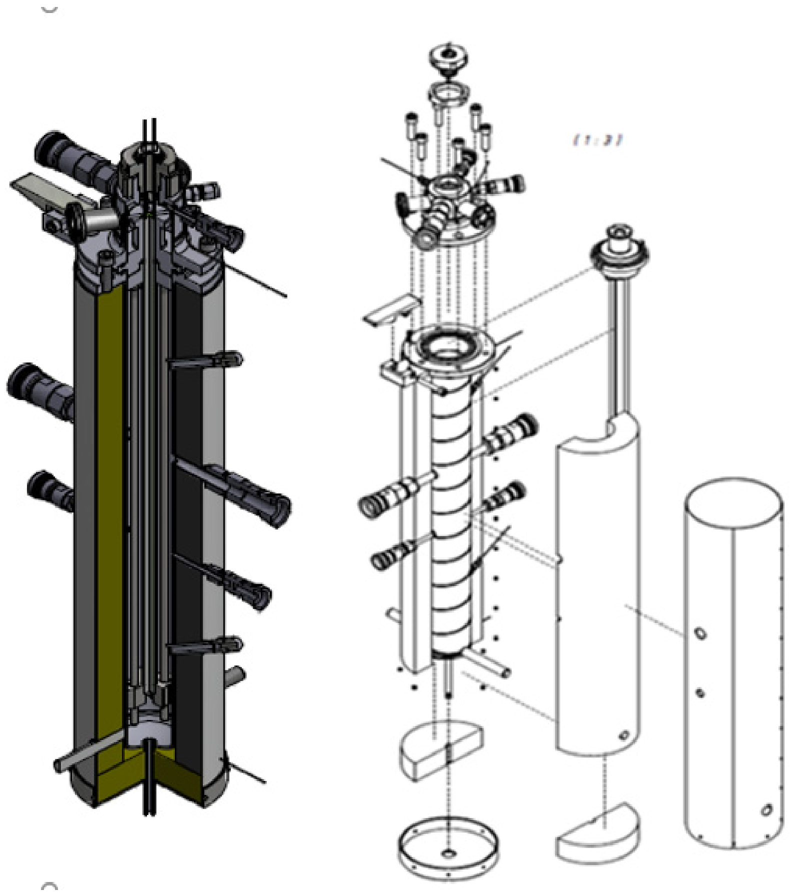
Equipment development

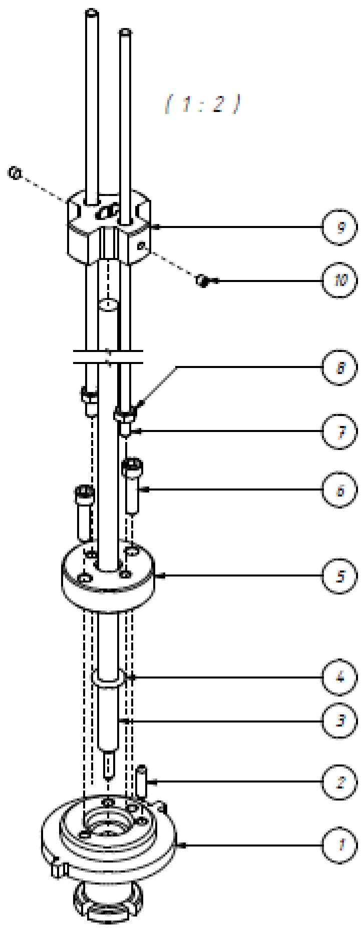
The actual device: schematically (02/2013)

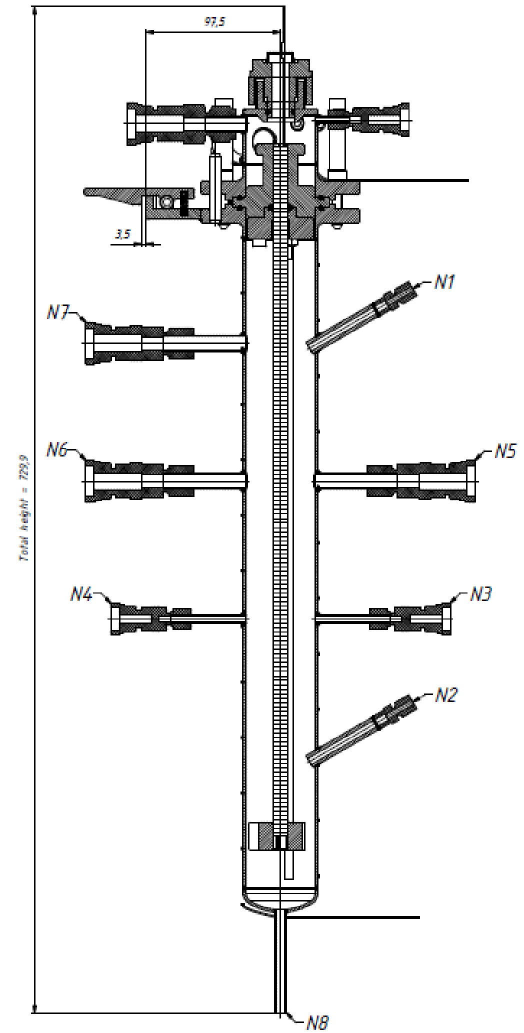


Equipment development

The actual device in 3D:







Used components

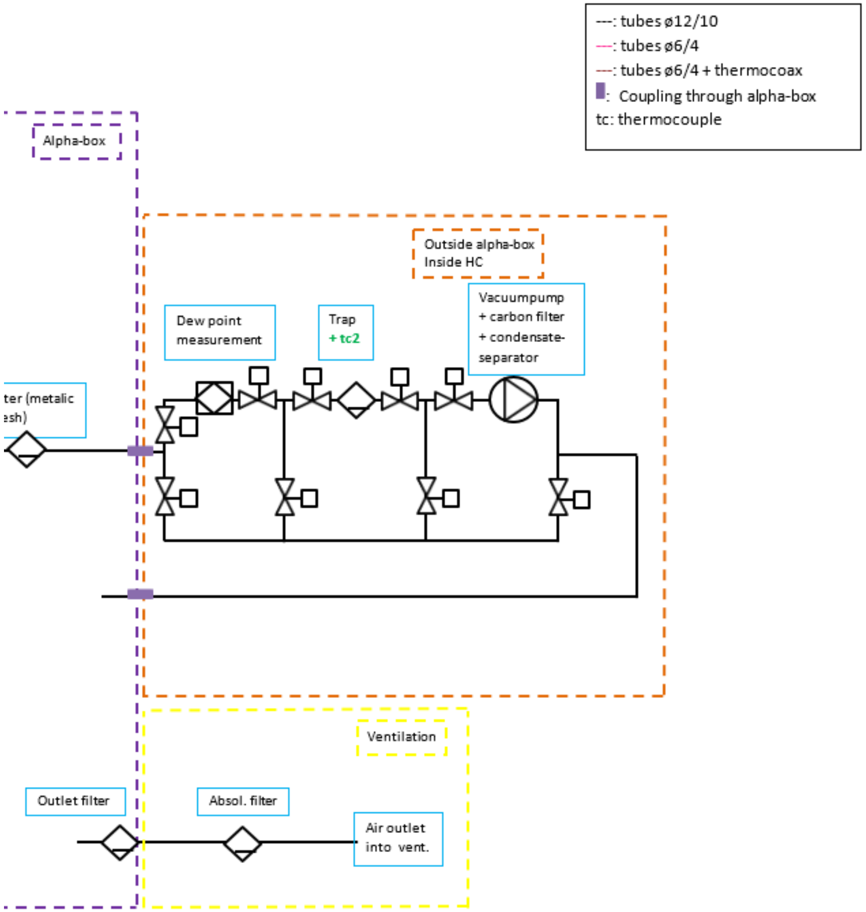
<u>Outer phericals</u>

Vacuum pump
- mesh filter
- exhaust back into HC

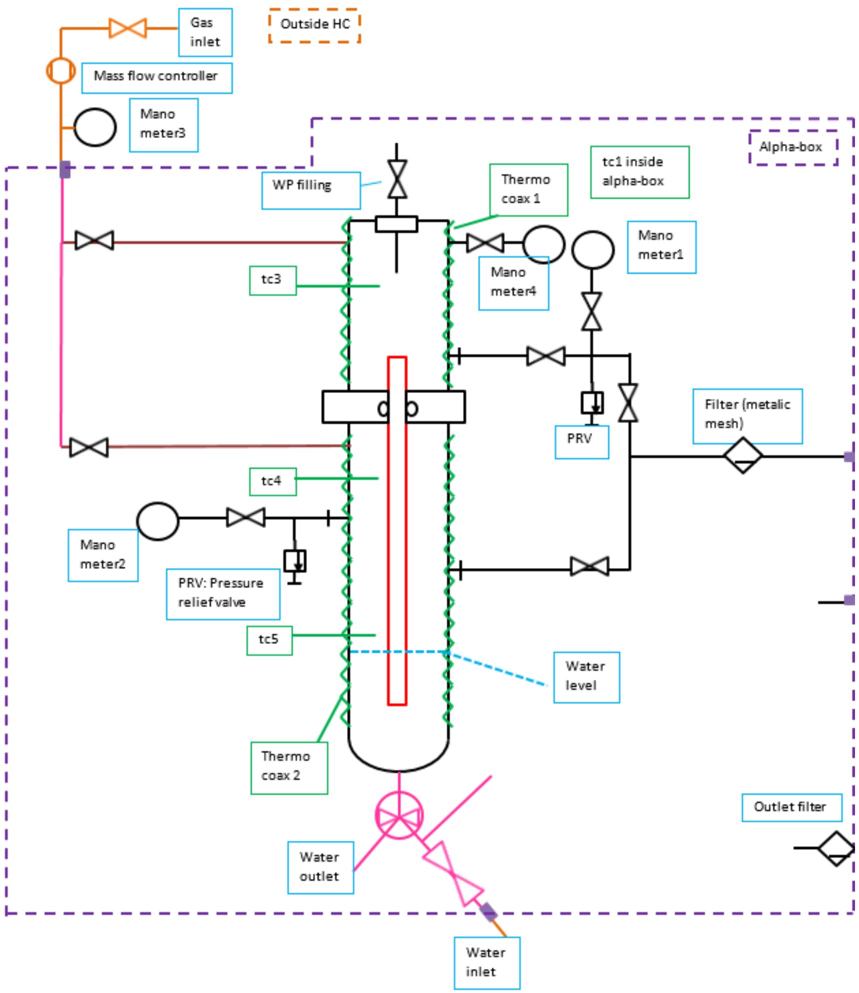
Cold trap

Dew point measurement

Gamma probe near the cold trap to monitor contamination



Used components



<u>Inside Alpha-box</u>

Reservoir

- Vacuum and overpressure up to 4 bar
- Pressure relief valve set at 3,5 bar
- Tests performed at 2 bar
- Volume is limited

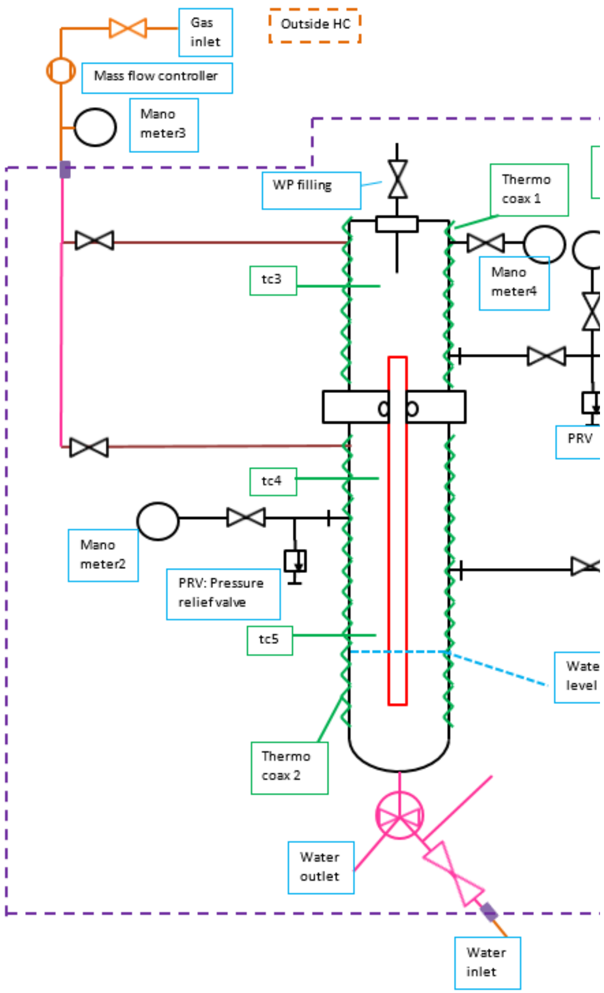
Heating wire (thermocoax)

- Power isn’t sufficient to heat HC above 50 °C
- Nevertheless HC monitored and temp limiter

Thermocouples

- In reservoir, cold trap and HC

Used components



Vacuum => TPR017 (Pfeiffer)

+ Good radiation resistant

- Not gas independent

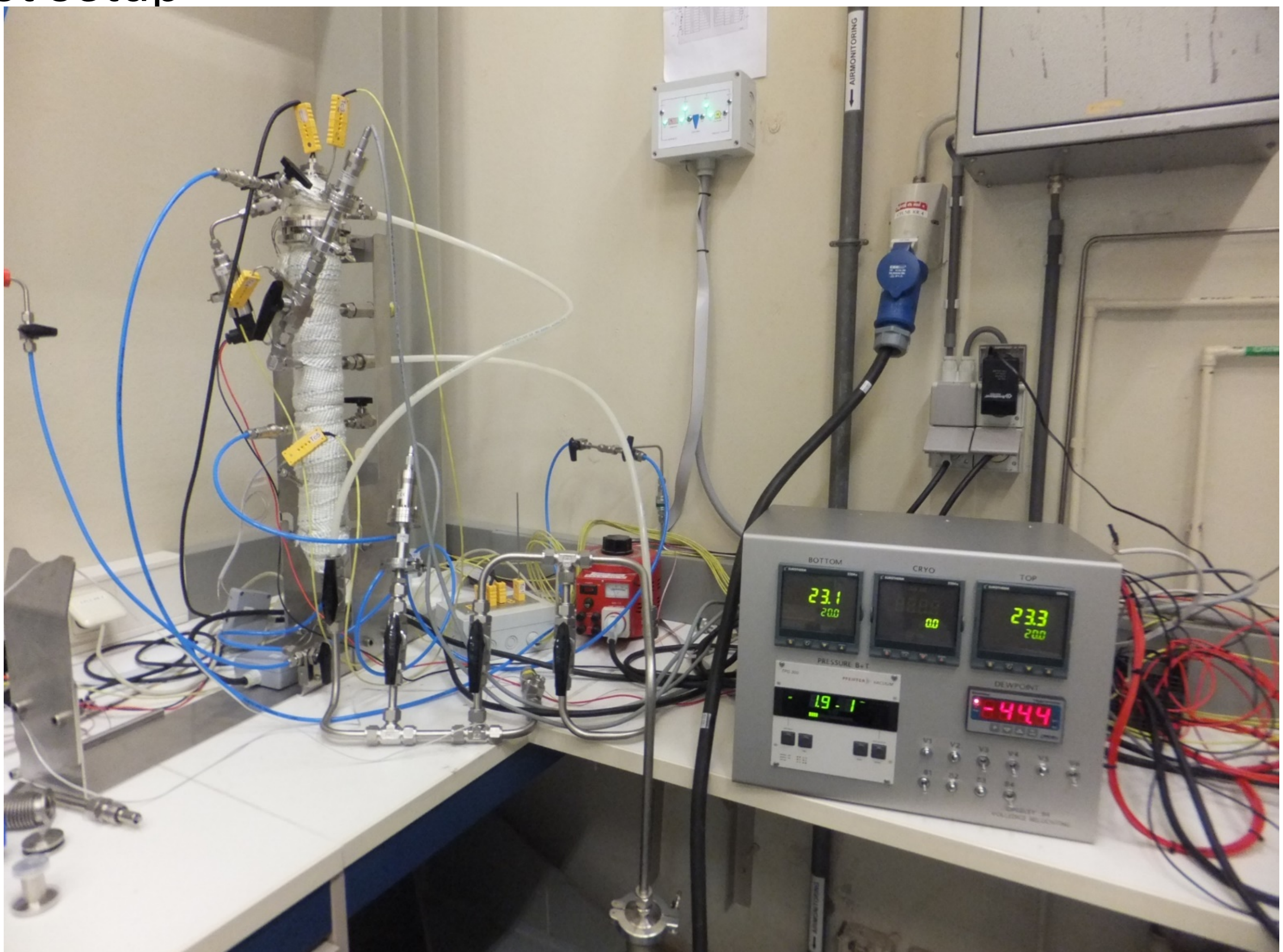
Overpressure => PXM (Omega):

- PXM219: (accuracy 0,25%)
  General purpose transmitter
  Silicon diaphragm
- PXM359 (accuracy 0,25%)
  Strain gages on stainless steel diaphragm
- PXM459 (accuracy 0,08%)
  Silicon type: not radiation hardened
  Replaced: directly on top

=> Need to replace it regularly

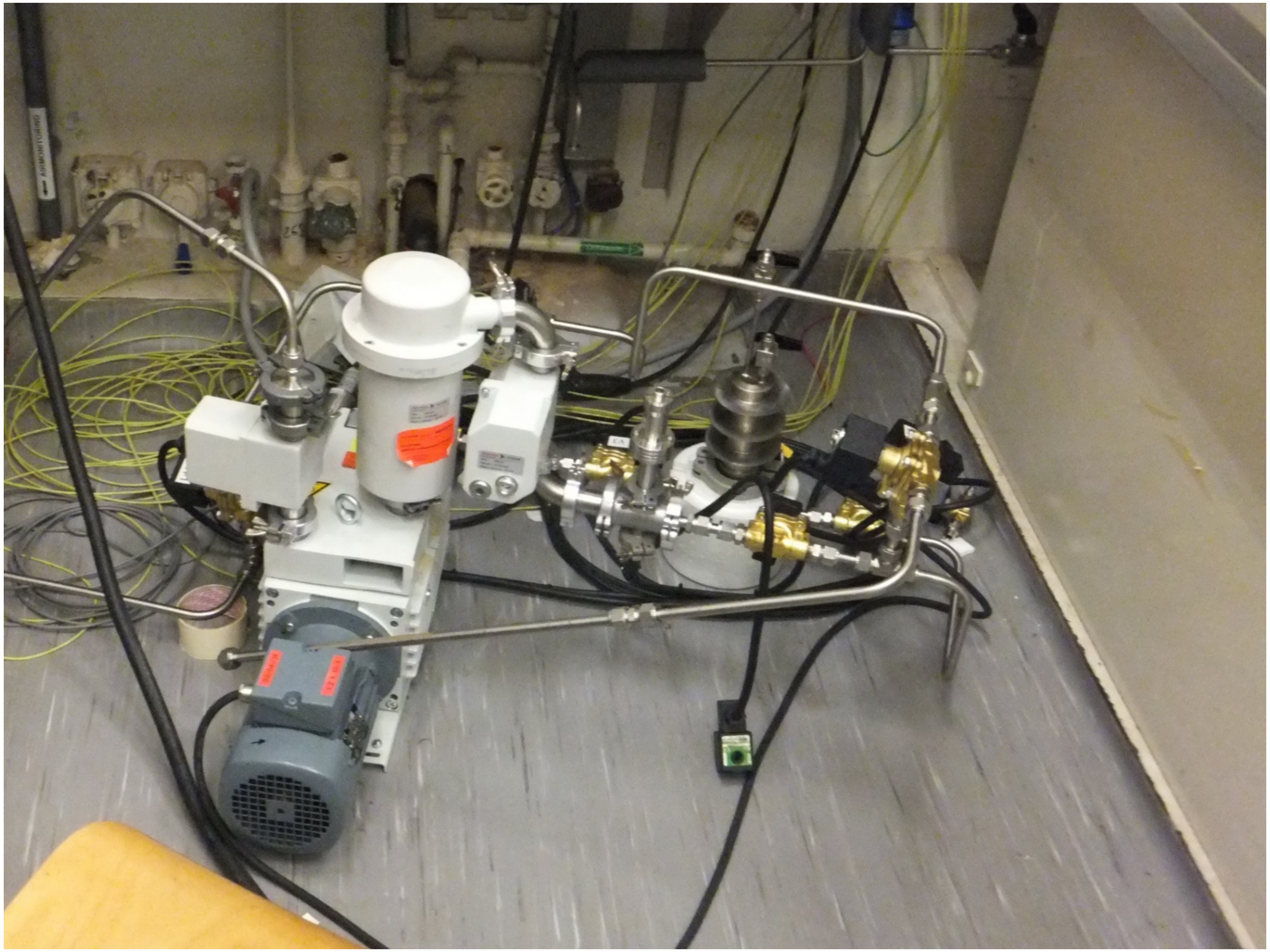
Pictures of the experimental setup

Cold test setup



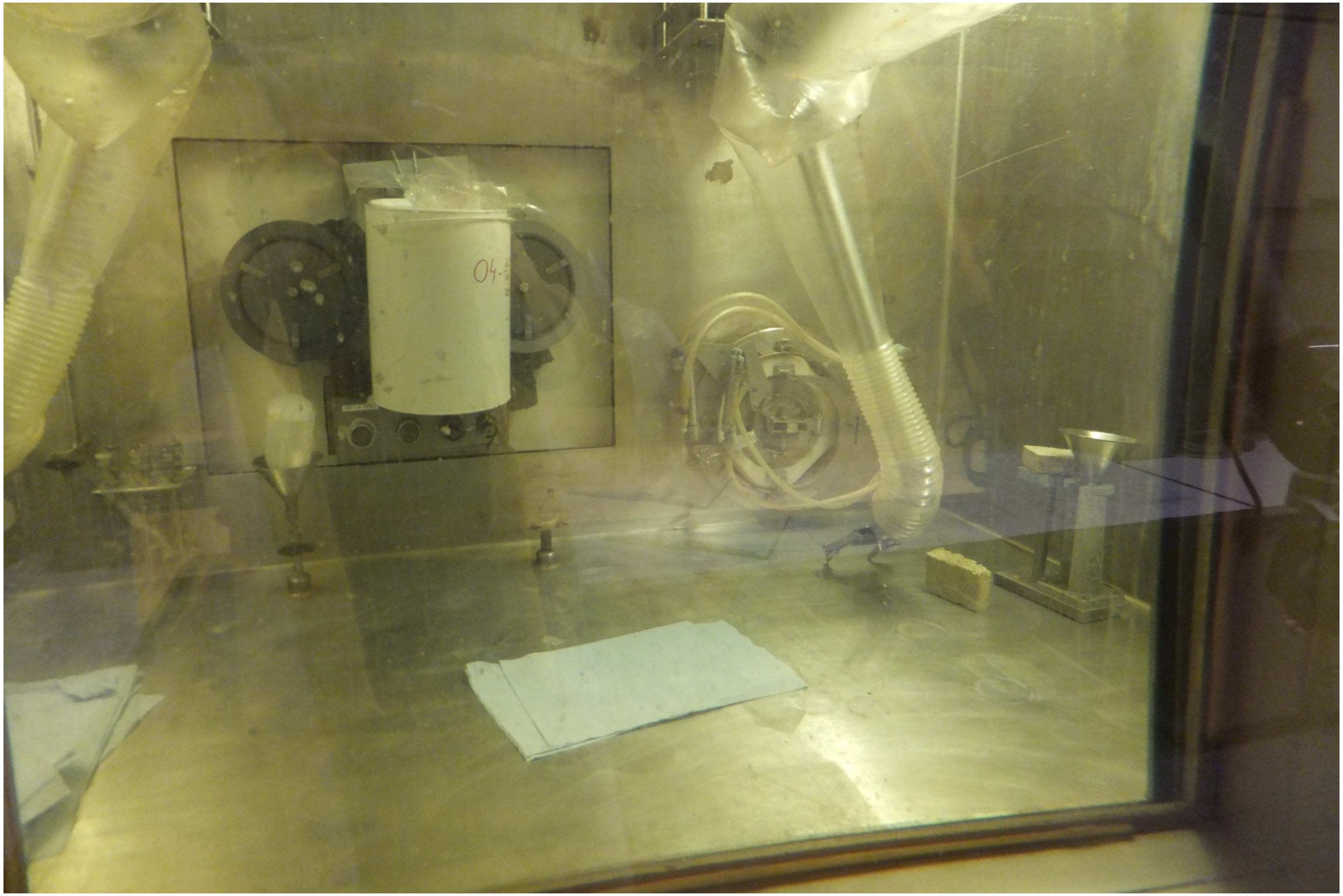
Pictures of the experimental setup

Cold test setup



Pictures of the experimental setup

Hot cell before installation

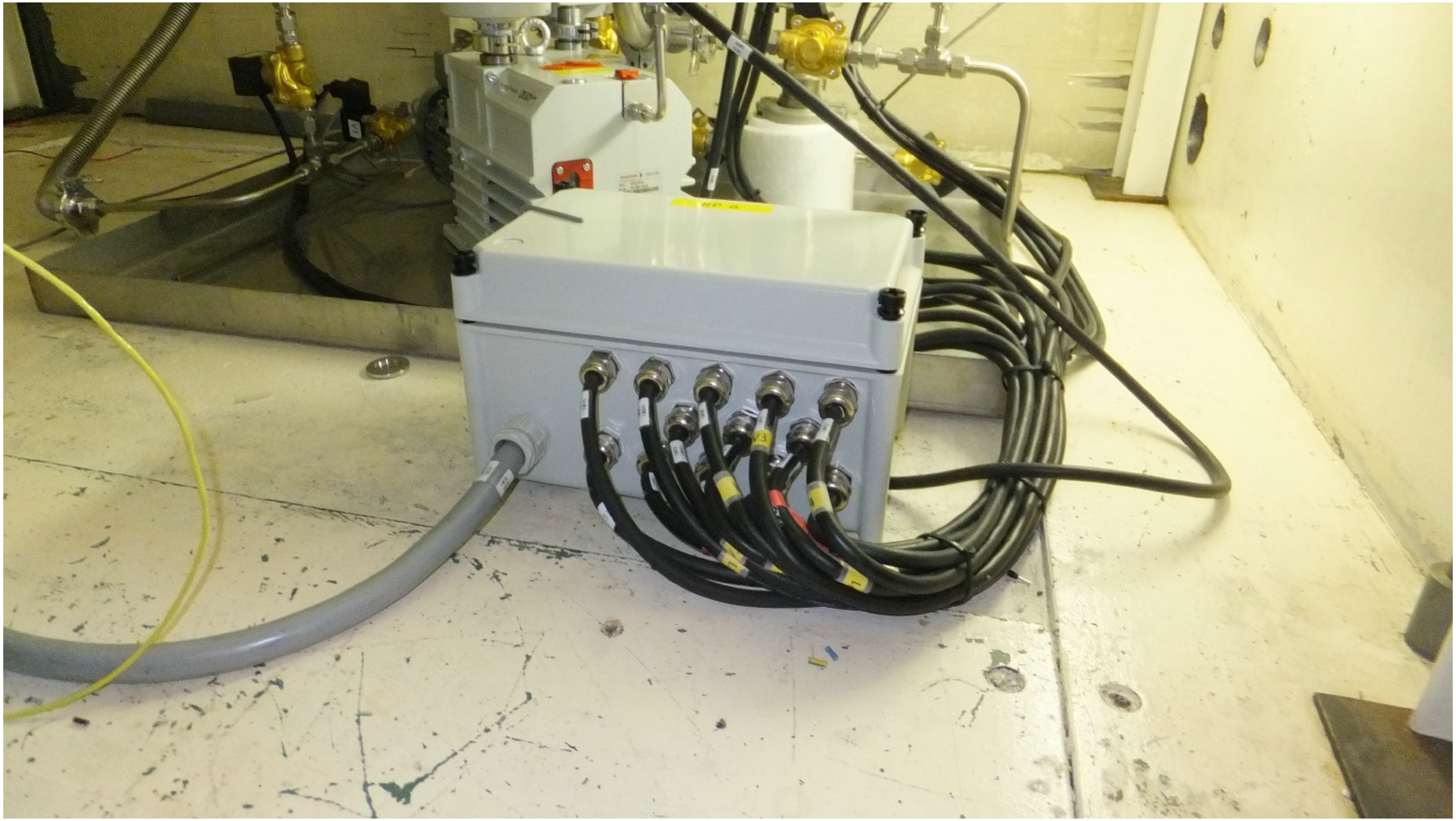


Pictures of the experimental setup

Inside alpha-box

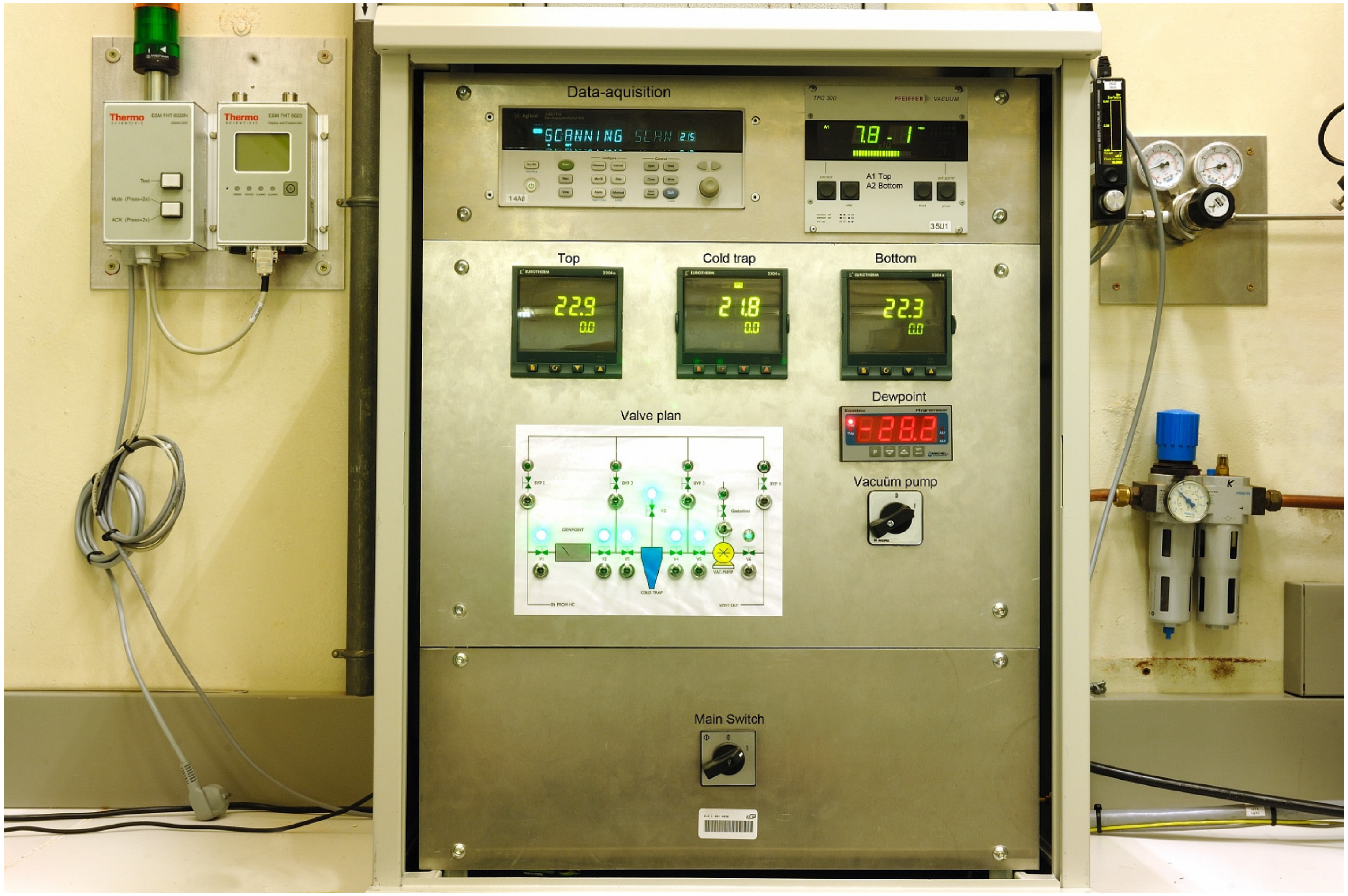
Pictures of the experimental setup

underneath alpha-box



Pictures of the experimental setup

Electrical cabinet

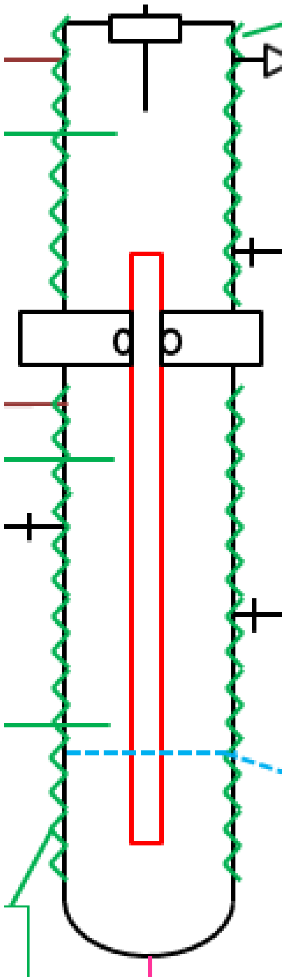


Achievements of the base program

Altogether 38 experiment campaigns for 8 spent fuel segments:

- September 2014 – March 2017 (>> 1 campaign per month)
- Proof of principle for drying protocols
- Development of axial gas flow measurements
- Water removal rates through the fuel column

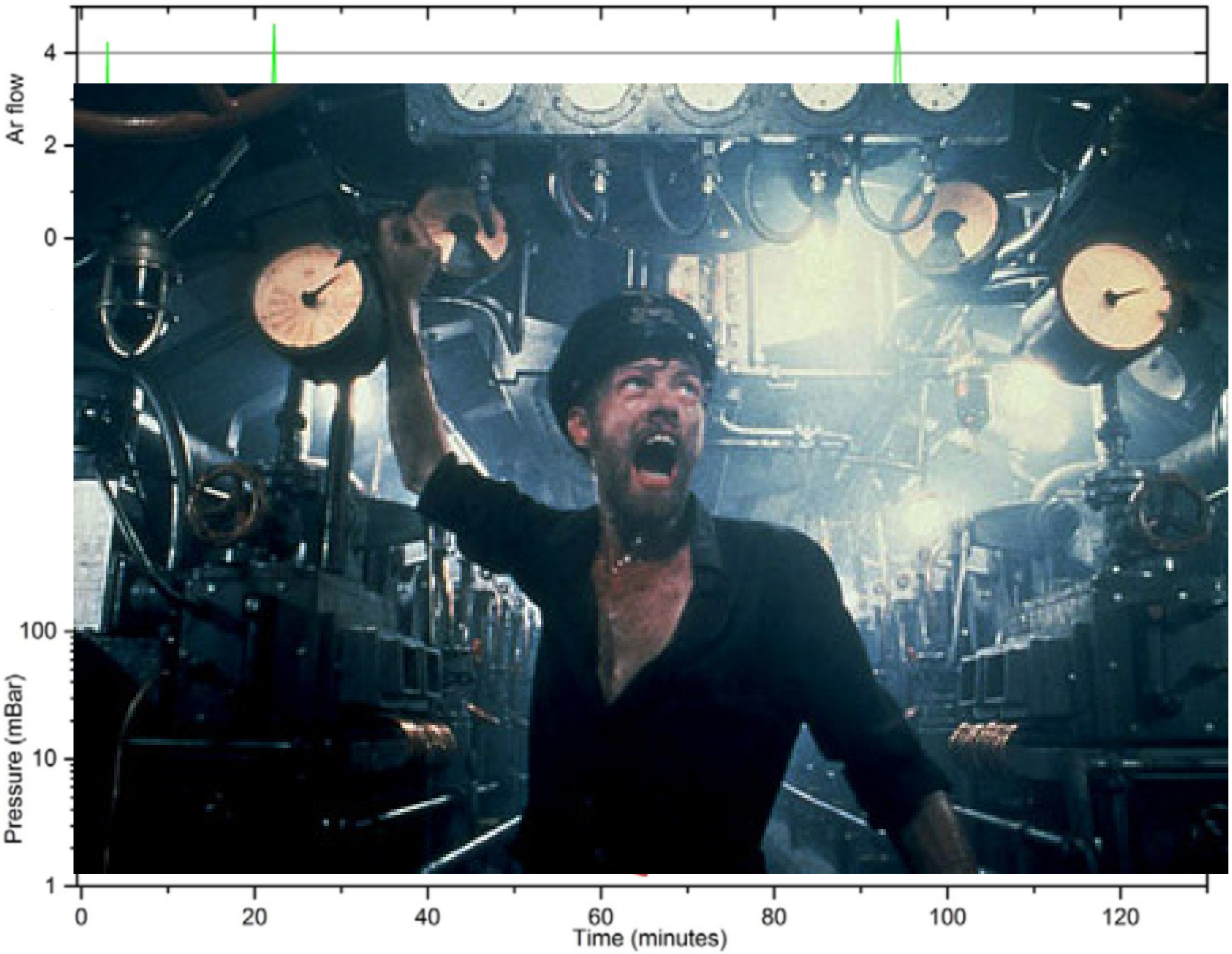
Axial gas flow measurements - Principle



Simple measurement principle:

- P1 ≠ P2 → gas flows through the rod
- Open top and bottom ends are isolated with leak tight seal – flow through the fuel column
- Determination:
  - Directly by flow meter (mock-ups)
  - Pressure increase/decrease rates in known volume

Axial gas flow measurements

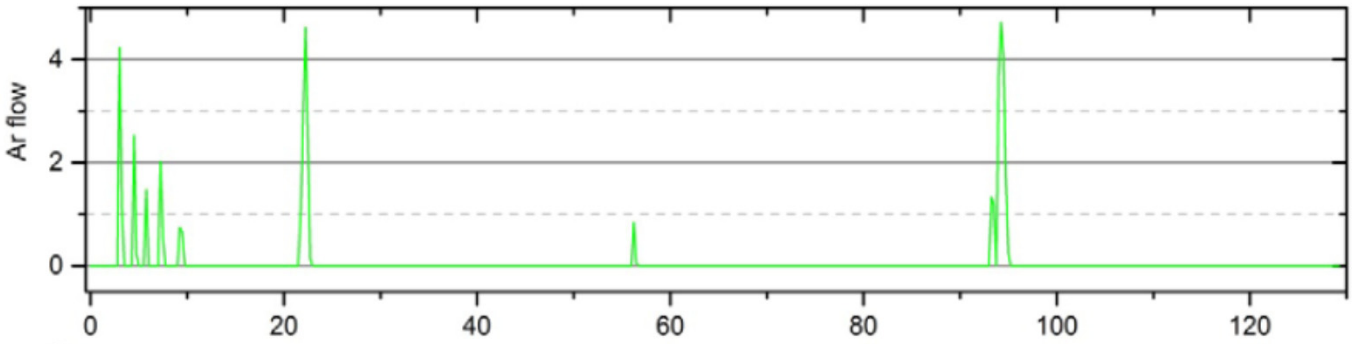


NO FLOW!!

WAIT….

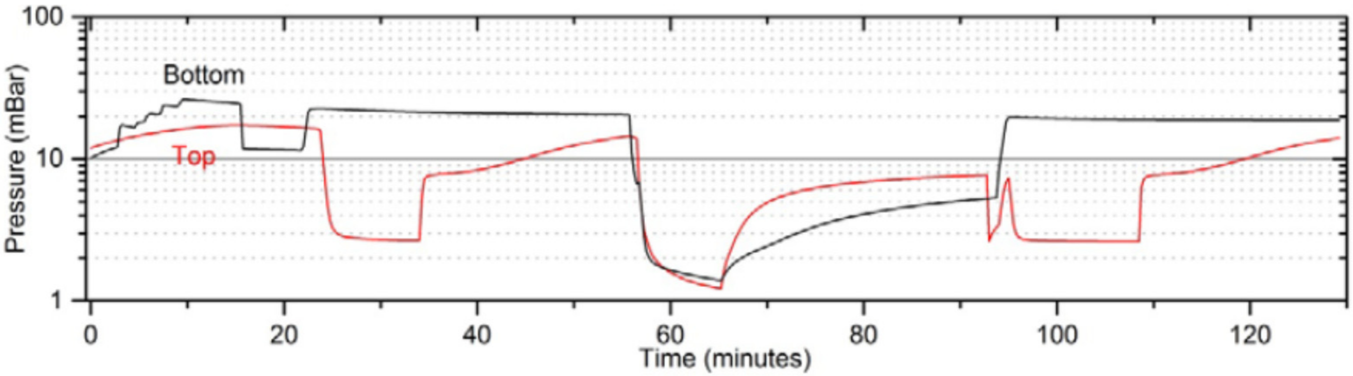
HARDLY ANY FLOW!!

Axial gas flow measurements



Correct: Smaller flow than flowmeter can detect

Correct transducer – there is connection after all



Calibration of pirani gauge: air vs argon…

Project management

Timing

Mid 2012: Information of new possible project

Nov 2012: First design

Feb 2013: Actual design (3D draft) / start including safety officer

Jul 2013: Fabrication of parts

Jan 2014: Start testing device: leak tests / cold tests / handling in HC

Mar 2014: Start cleaning HC / fabrication new back plate / ALARA

Mar 2014: Start of electrical work: new cabinet / work at HC

Jun/Jul 2014: Intervention: device in HC

Aug 2014: Electrical work / safety report: installation + as-built drawings / Hot cell approval: leak test + biological shielding

Sept 2014: First measurements

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Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire
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Stichting van Openbaar Nut
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Foundation of Public Utility

Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSELS
Operational Office: Boeretang 200 – BE-2400 MOL

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