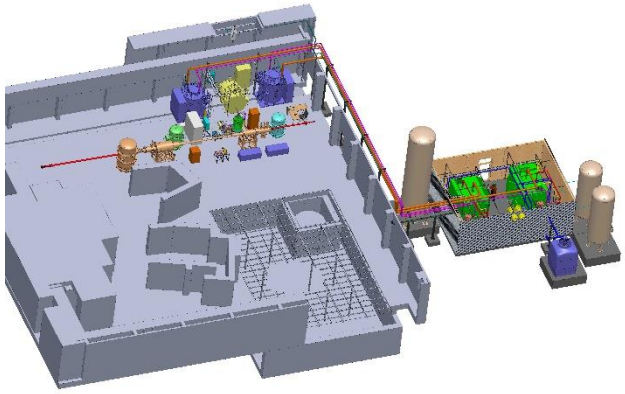
Cryogenic System for the Ultra Cold Neutron Source (UCN Source) at the FRM II

Part 2:
Main features, commissioning, operating, simulation and experience

Dr. Christian Bocquet

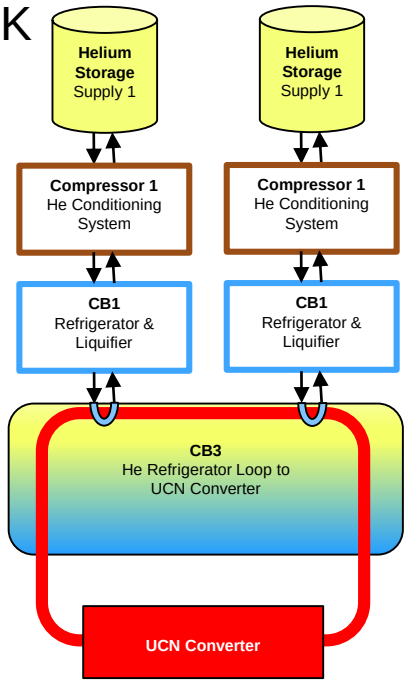
Outline of the presentation

- Main features
- Commissioning
- Operating
- Simulation
- Experience



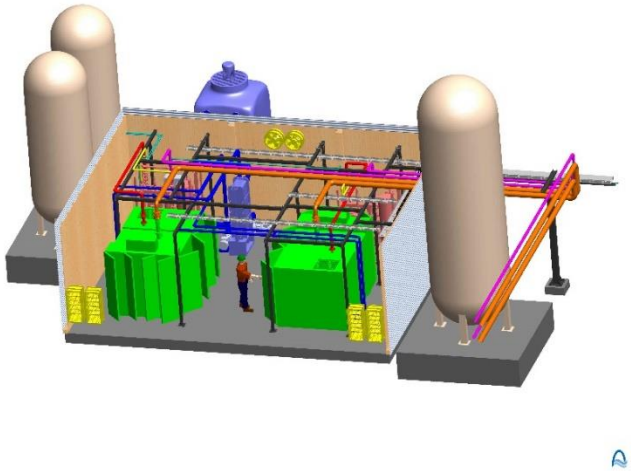
Main features / Framework of the project

- High flux reactor FRM II of TU Munchen, production of ultra cold neutrons
  - Superthermal converter filled with deuterium and hydrogen in solid state
    - under construction
  - Cryogenic system to maintain converter temperature of 5K
    - UCN converter with a heat load of ~500W in steady state
    - Overall cooling system made of 3 separate cooling loops:
      - Two independent primary refrigeration circuits (compressors, ORS, CB1 and CB2) with a refrigeration capacity of 500W each
      - One CB3 cold box to feed the converter with 120g/s of supercritical Helium
    - CB1 and CB2 may operate simultaneously to boost the cooling power to CB3 from 500W to 1000W



Pre-requisite

- New Building starting from a green field



- Utilities
  - Cooling Water: Max flow rate for ΔT_{max} (15K) 15,2 m³/h
  - Power: Compressor 2 x 250 kW
  - Compressed air system
  - Fire alarm system
  - Ventilation plant (control of the temperatur)
  - Oxygen detection system

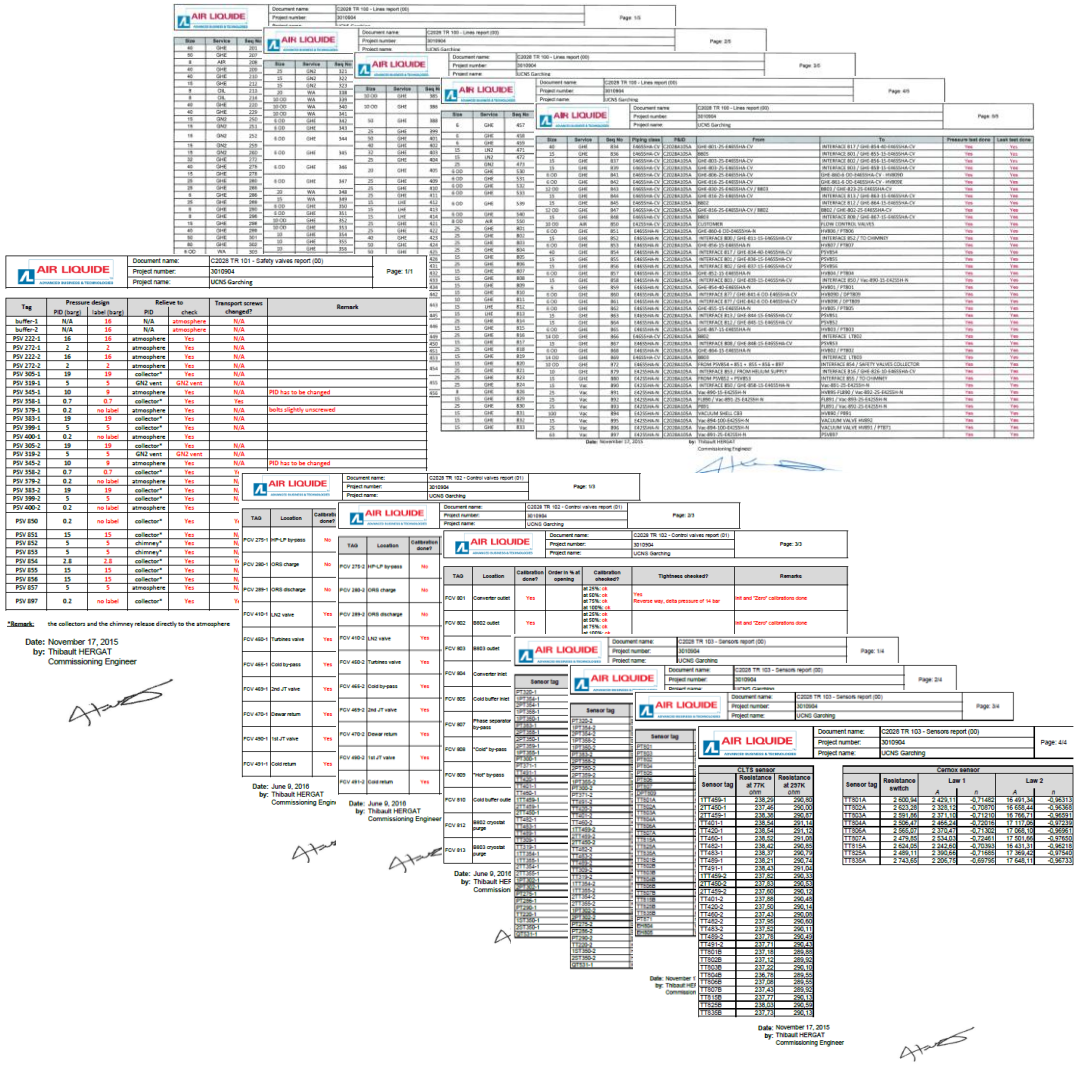
- Installation of the equipment and all the pipes

Pre-commissioning

Equipment test

Operational test, electrical test, PID check, Leak test, conditioning

- 215 Lines tested
- 31 Safety Valves tested
- 31 Control Valves tested
- 141 Sensors tested



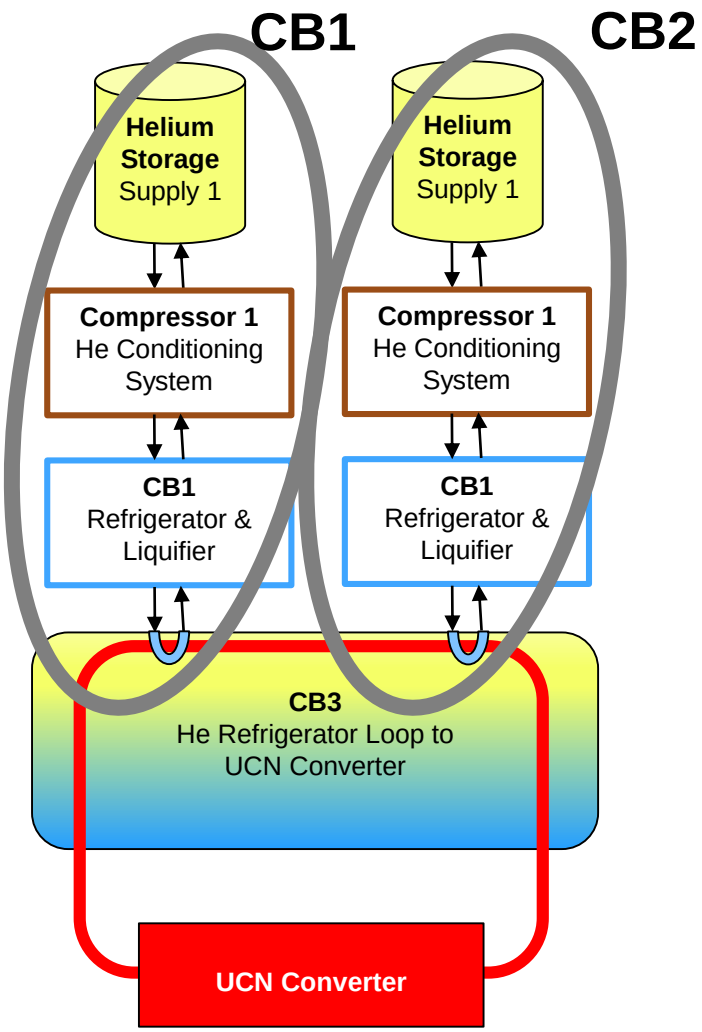
Machine Commissioning

Sub-system test

Basic automatic sequences test

Process and control optimization

- For Cold box 1 and Cold box 2:
  - Compressor start
  - Turbines installation and start
  - Vacuum start
  - Cool-down
- For Cold box 3:
  - Helium pump start
  - Cool-down



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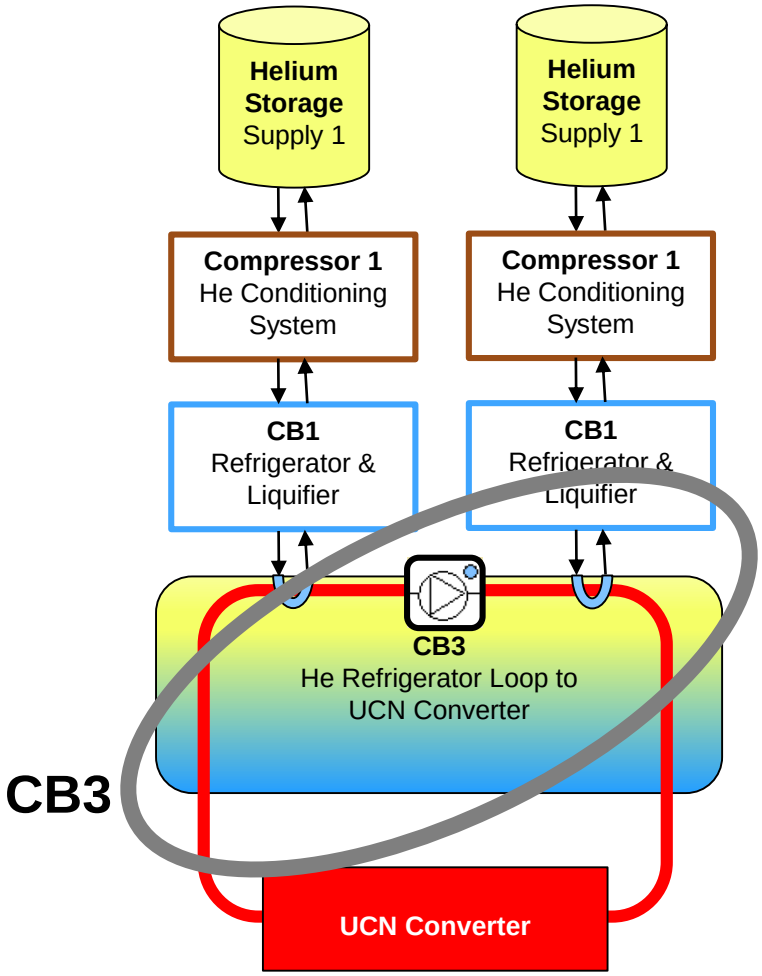
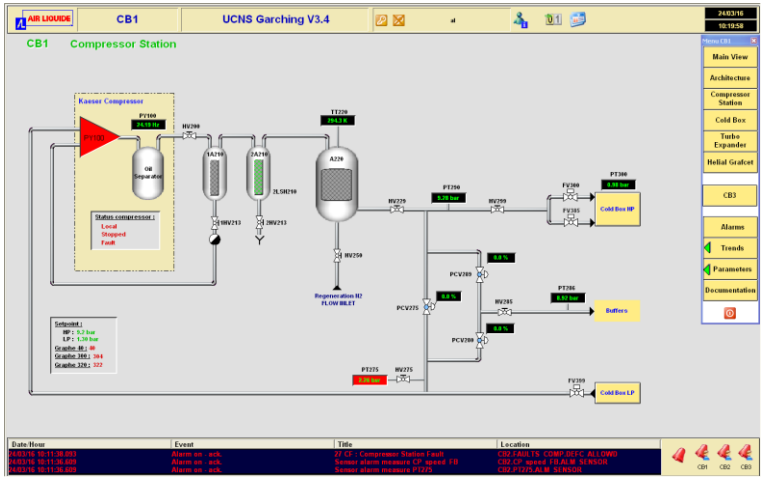
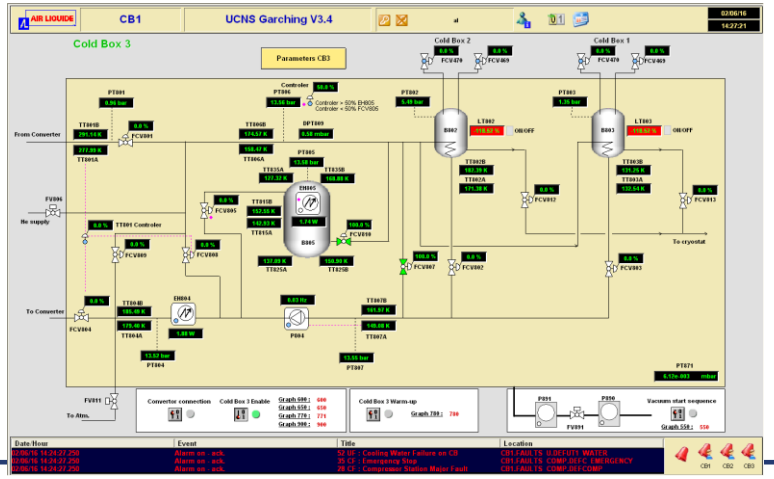


Commissioning / Operating

Tested automatic sequences:

- For Cold box 1 and Cold box 2:
  - Compressor start and stop
  - Compressor emergency stop
  - Vacuum group start, stop and line pumping
  - Turbines start and stop
  - Cold box leak search
  - Cold box conditioning
  - Cold box depressurization
  - Cold box pressurization
  - Cold box drying
  - Cold box helium analysis
  - Cold box cool-down
  - Cold box voluntary stop
  - Cold box emergency stop
  - Cold box warm-up
- For Coldbox 3:
  - Vacuum group start and stop
  - Cold box cool-down
  - Cold box pressure management
  - Converter connection management
  - Cold box 1 and cold box 2 connection management
  - Cold box warm-up





Process Flow

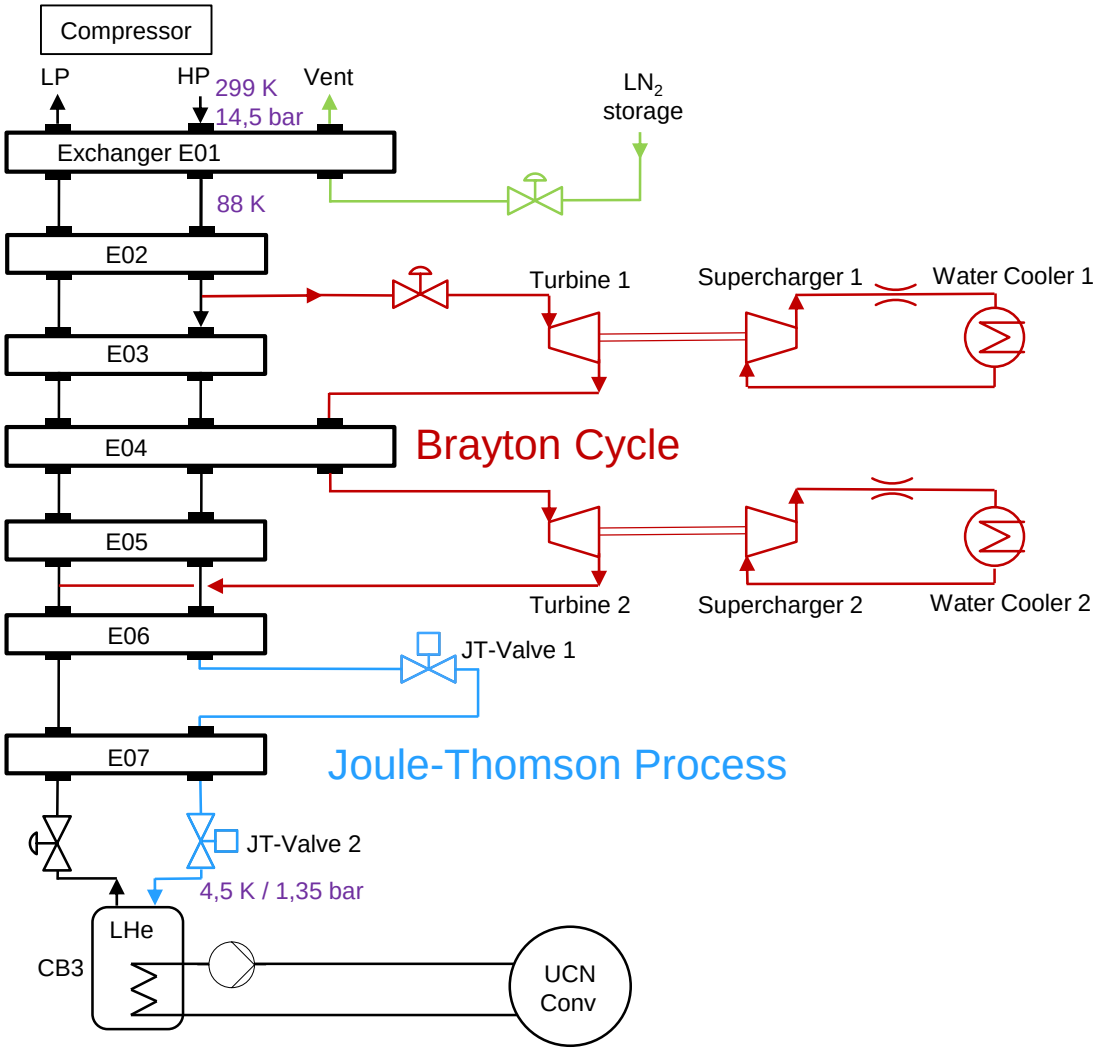
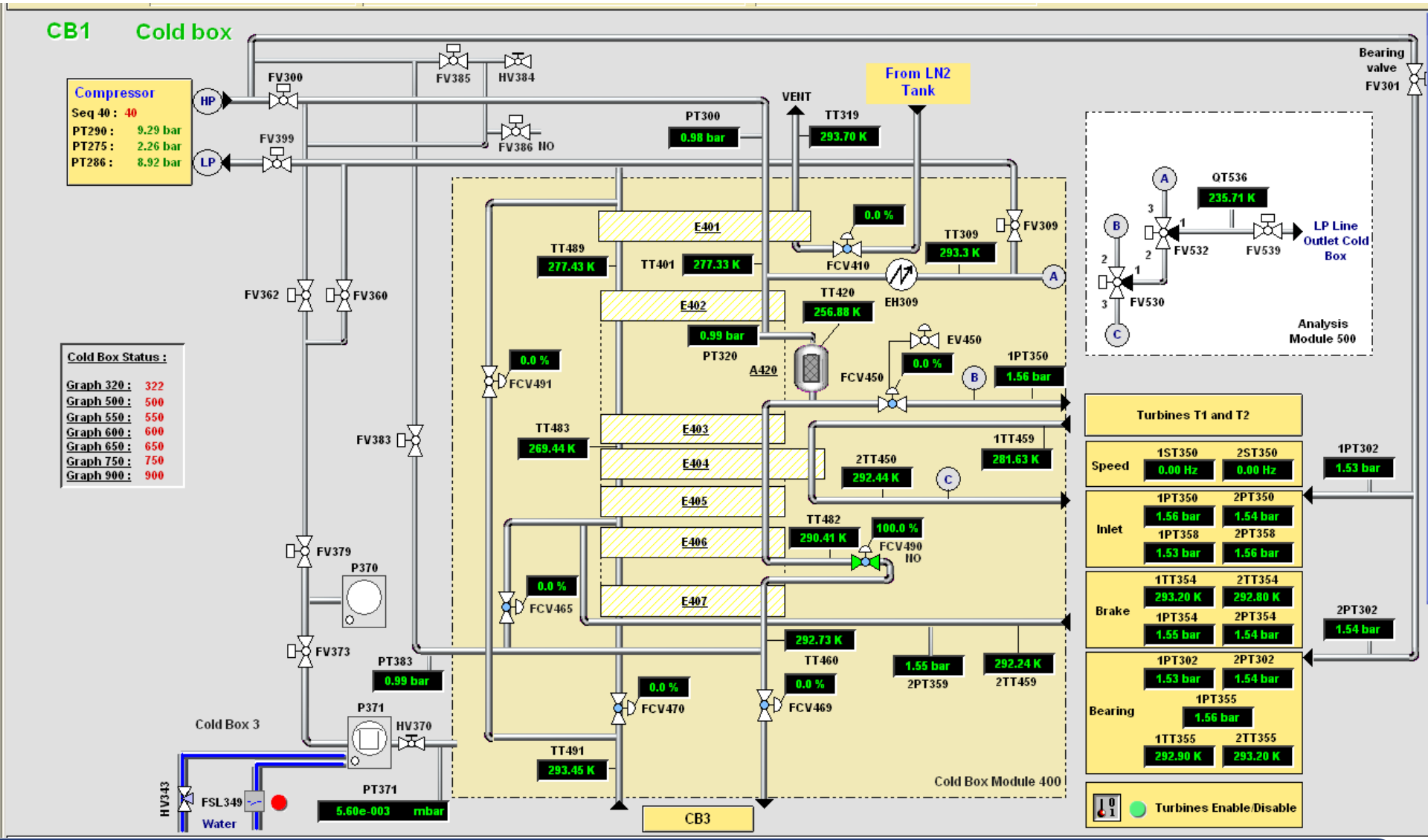


Fig. 7 – Schematic of refrigeration process flow

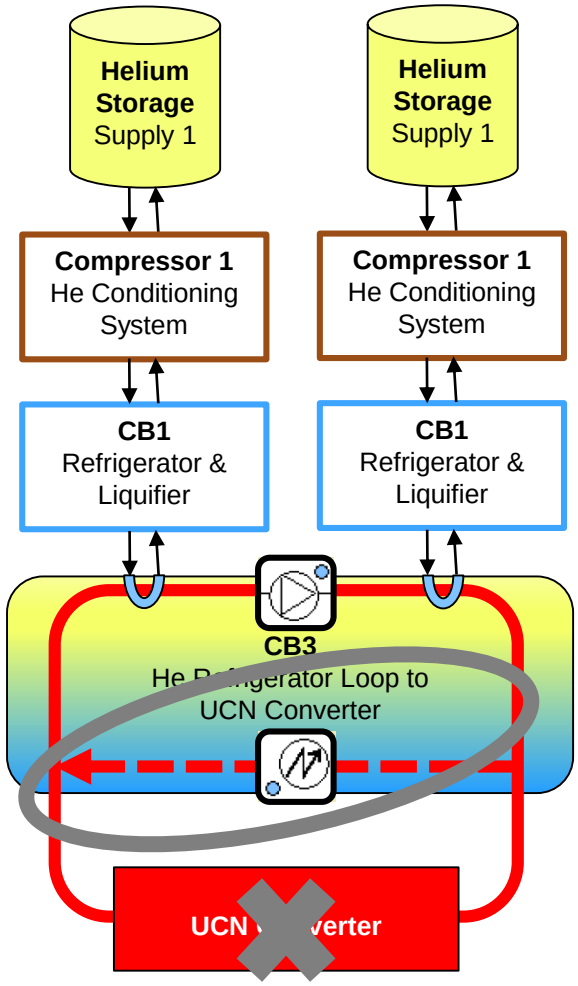
Process Cold box cool-down



Simulation 1 “dummy converter” in the CB3

To be able to test and to commission the CB3 without the converter, a „converter-simulation“ was included into the design of the CB3

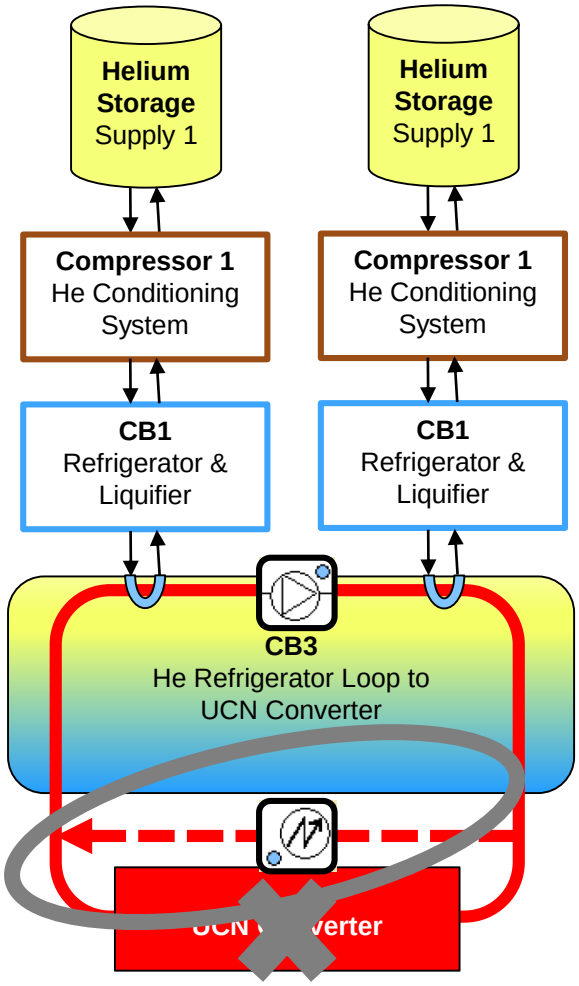
- The CB3 is build with a by-pass and a heater
- The heat load is simulated by the heater, regulating the temperature



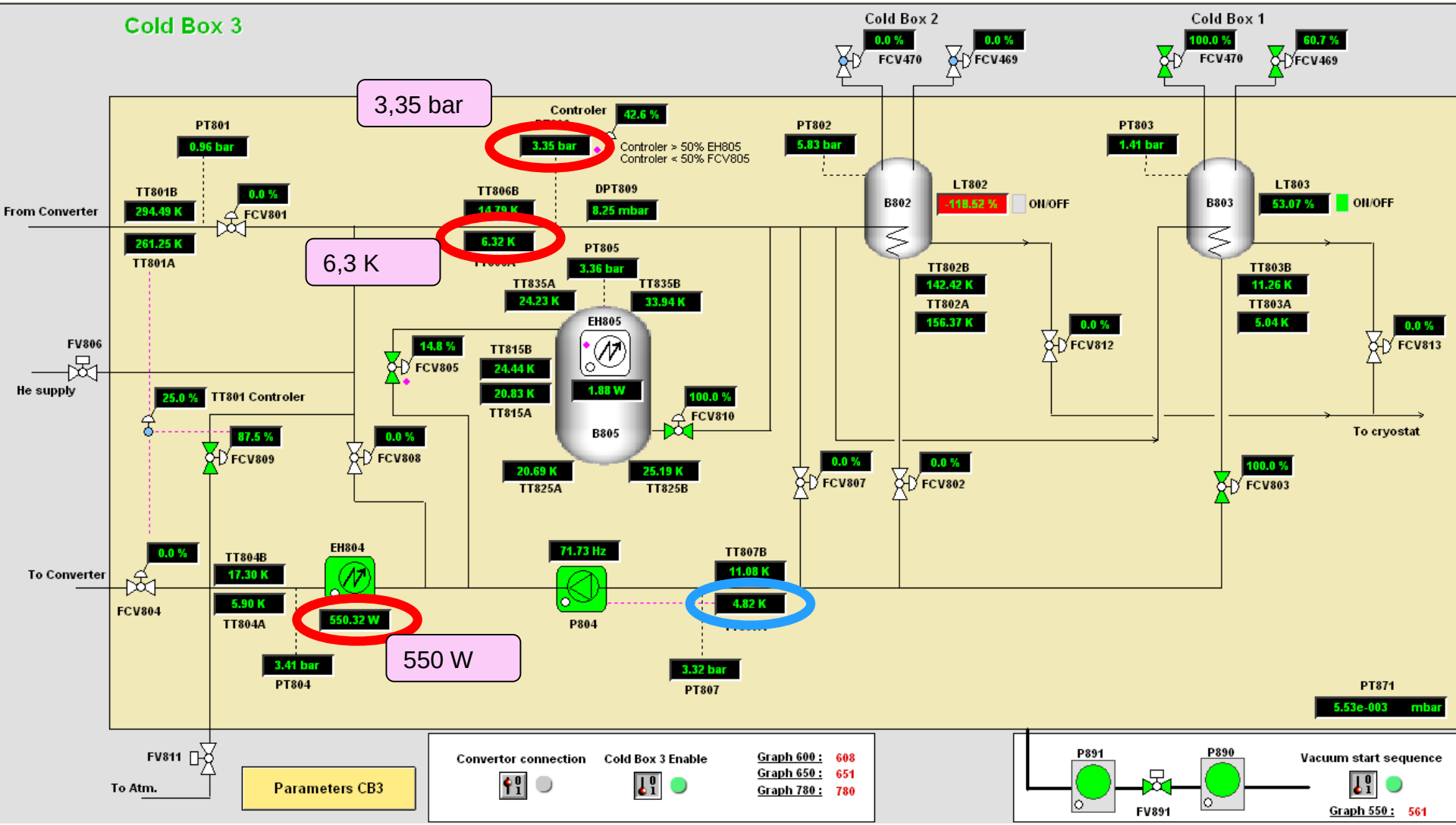
Simulation 2 “dummy converter” outside the CB3

To be able to test and to commission the converter, a „dummy“ converter was created to awoid a damage on the original converter

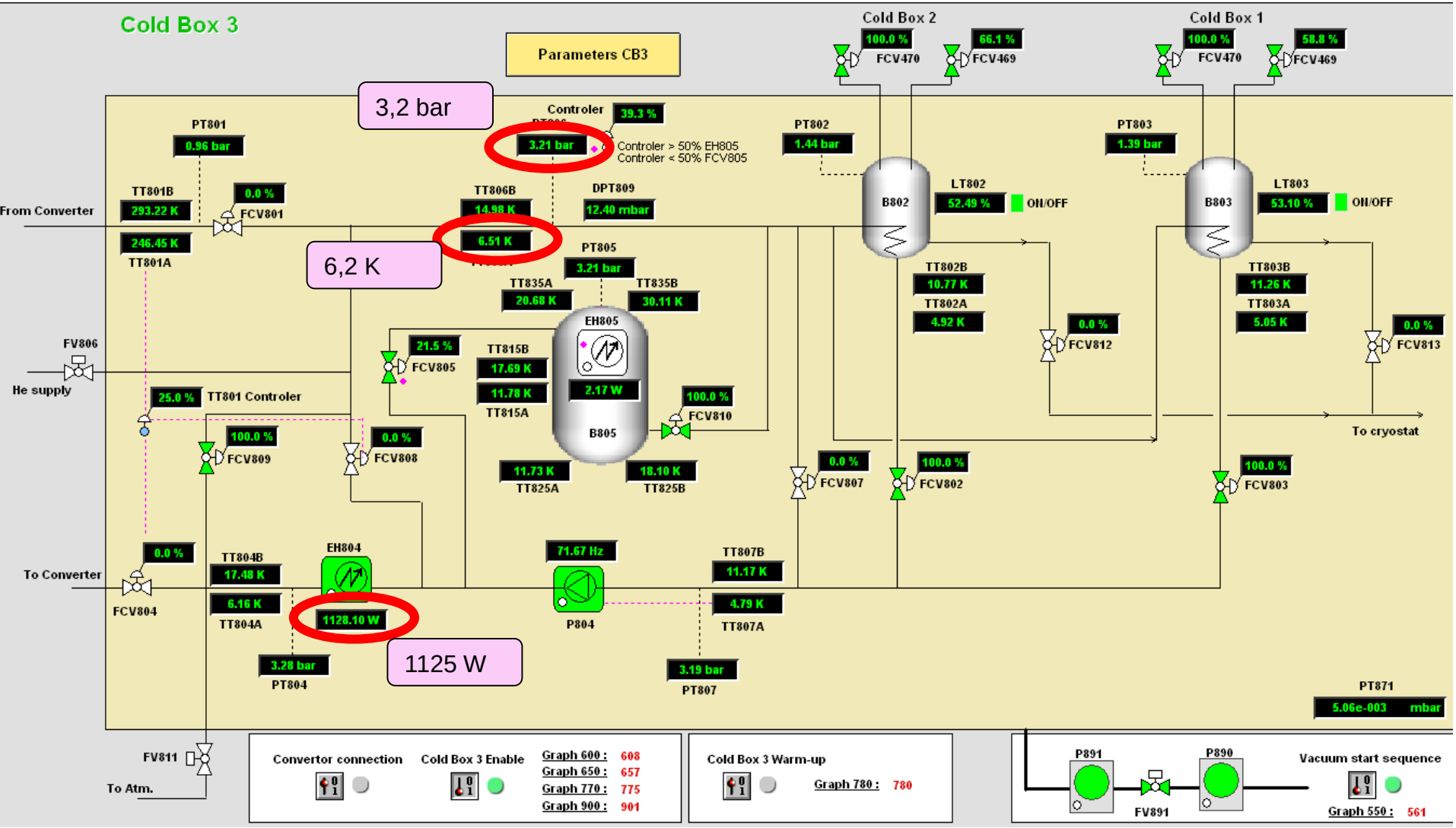
- The „dummy-converter“ is designed to support more than 16bar pressure
- The heat load is simulated by a heater in side the „dummy-converter“



Recorded Performance CB1

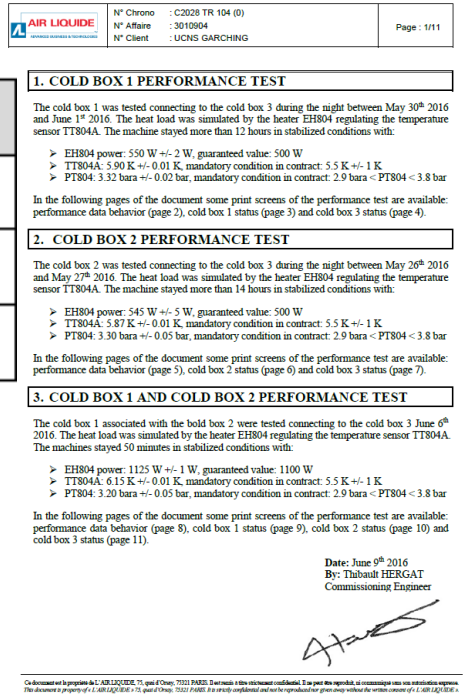


Recorded Performance CB1 & CB2



Recorded Performance

Test	Guaranteed cold power	Measured cold power	Test duration	Test conditions
CB1 connected to CB3	500 W	550 W (+10%)	> 12 h	TT804 = 5.5 K +/- 1 K: yes 2.9 bar < PT804 < 3.8 bar: yes
CB2 connected to CB3	500 W	545 W (+9%)	> 14 h	TT804 = 5.5 K +/- 1 K: yes 2.9 bar < PT804 < 3.8 bar: yes
CB1 and CB2 connected to CB3	1 100 W	1 125 W (+2.3%)	50 min	TT804 = 5.5 K +/- 1 K: yes 2.9 bar < PT804 < 3.8 bar: yes



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1. COLD BOX 1 PERFORMANCE TEST

The cold box 1 was tested connecting to the cold box 3 during the night between May 30th 2016 and June 1st 2016. The heat load was simulated by the heater EH804 regulating the temperature sensor TT804A. The machine stayed more than 12 hours in stabilized conditions with:

- EH804 power: 550 W +/- 2 W, guaranteed value: 500 W
- TT804A: 5.90 K +/- 0.01 K, mandatory condition in contract: 5.5 K +/- 1 K
- PT804: 3.32 bara +/- 0.02 bar, mandatory condition in contract: 2.9 bara < PT804 < 3.8 bar

In the following pages of the document some print screens of the performance test are available: performance data behavior (page 2), cold box 1 status (page 3) and cold box 3 status (page 4).

2. COLD BOX 2 PERFORMANCE TEST

The cold box 2 was tested connecting to the cold box 3 during the night between May 26th 2016 and May 27th 2016. The heat load was simulated by the heater EH804 regulating the temperature sensor TT804A. The machine stayed more than 14 hours in stabilized conditions with:

- EH804 power: 545 W +/- 5 W, guaranteed value: 500 W
- TT804A: 5.87 K +/- 0.01 K, mandatory condition in contract: 5.5 K +/- 1 K
- PT804: 3.30 bara +/- 0.05 bar, mandatory condition in contract: 2.9 bara < PT804 < 3.8 bar

In the following pages of the document some print screens of the performance test are available: performance data behavior (page 5), cold box 2 status (page 6) and cold box 3 status (page 7).

3. COLD BOX 1 AND COLD BOX 2 PERFORMANCE TEST

The cold box 1 associated with the bold box 2 were tested connecting to the cold box 3 June 6th 2016. The heat load was simulated by the heater EH804 regulating the temperature sensor TT804A. The machines stayed 50 minutes in stabilized conditions with:

- EH804 power: 1125 W +/- 1 W, guaranteed value: 1100 W
- TT804A: 6.15 K +/- 0.01 K, mandatory condition in contract: 5.5 K +/- 1 K
- PT804: 3.20 bara +/- 0.05 bar, mandatory condition in contract: 2.9 bara < PT804 < 3.8 bar

In the following pages of the document some print screens of the performance test are available: performance data behavior (page 8), cold box 1 status (page 9), cold box 2 status (page 10) and cold box 3 status (page 11).

Date: June 9th 2016
By: Thibault HERGAT
Commissioning Engineer

Test for Reactortrip (Reactor schnell Abschaltung, RESA)

Test: Heat load falling instantly from 500 W to 0 W

The reactortrip was tested with succes

Experience and next step

Yes, we got the cooling power to reach 5K with a cold power of 500W and
with a cold power of 1100W

The system was succesfully tested using the „dummy-converter“

Next steps:

- Work on automatic warming up procedures
- Work on a „dummy“ converter, filled with deuterium and hydrogen in solid state
- Work on divers operating models (simulating reactor-scenarios / behaviours)
- Test of malfunction procedures

- In parallel: authorisation procedures for implementation of the UCN source in the FRM II

Thank for your attention