中国科学院大学
University of Chinese Academy of Sciences

Dynamic simulation of DALS test facility cryoplant

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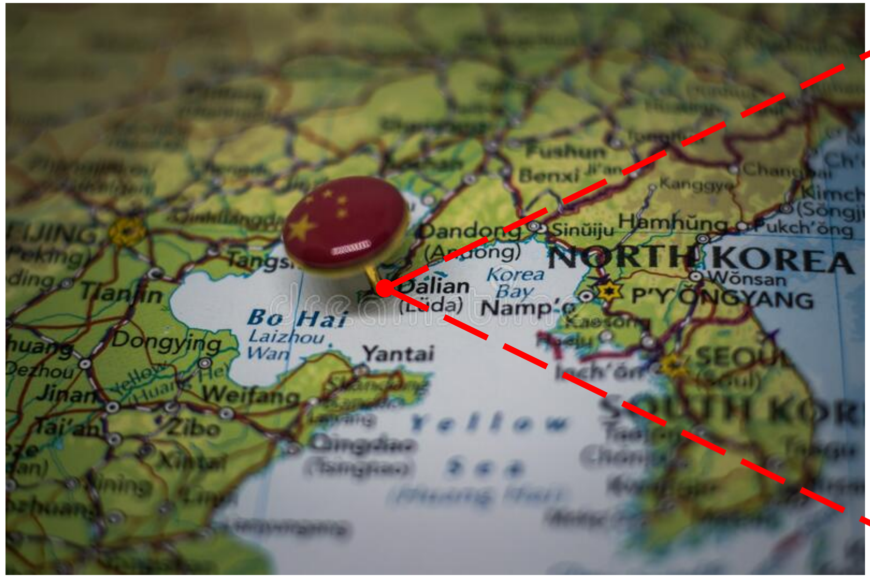
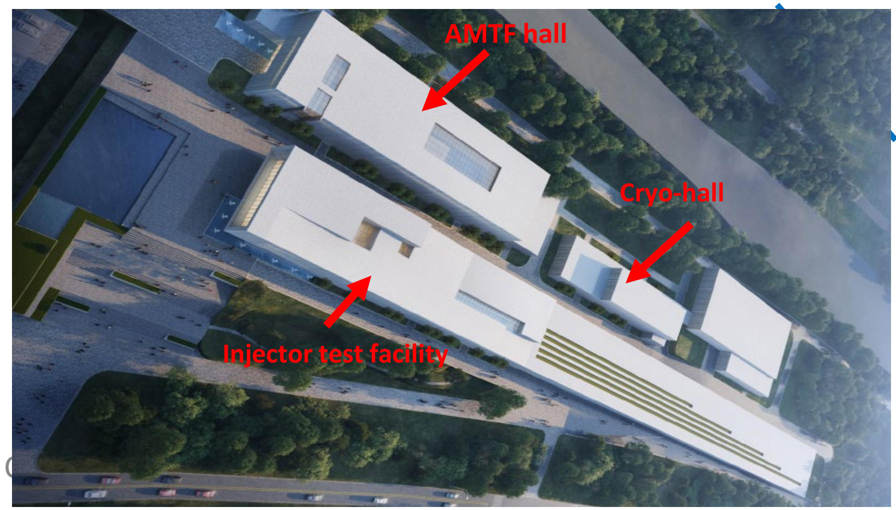
Contents

Dalian Institute of Chemical Physics (DICP)

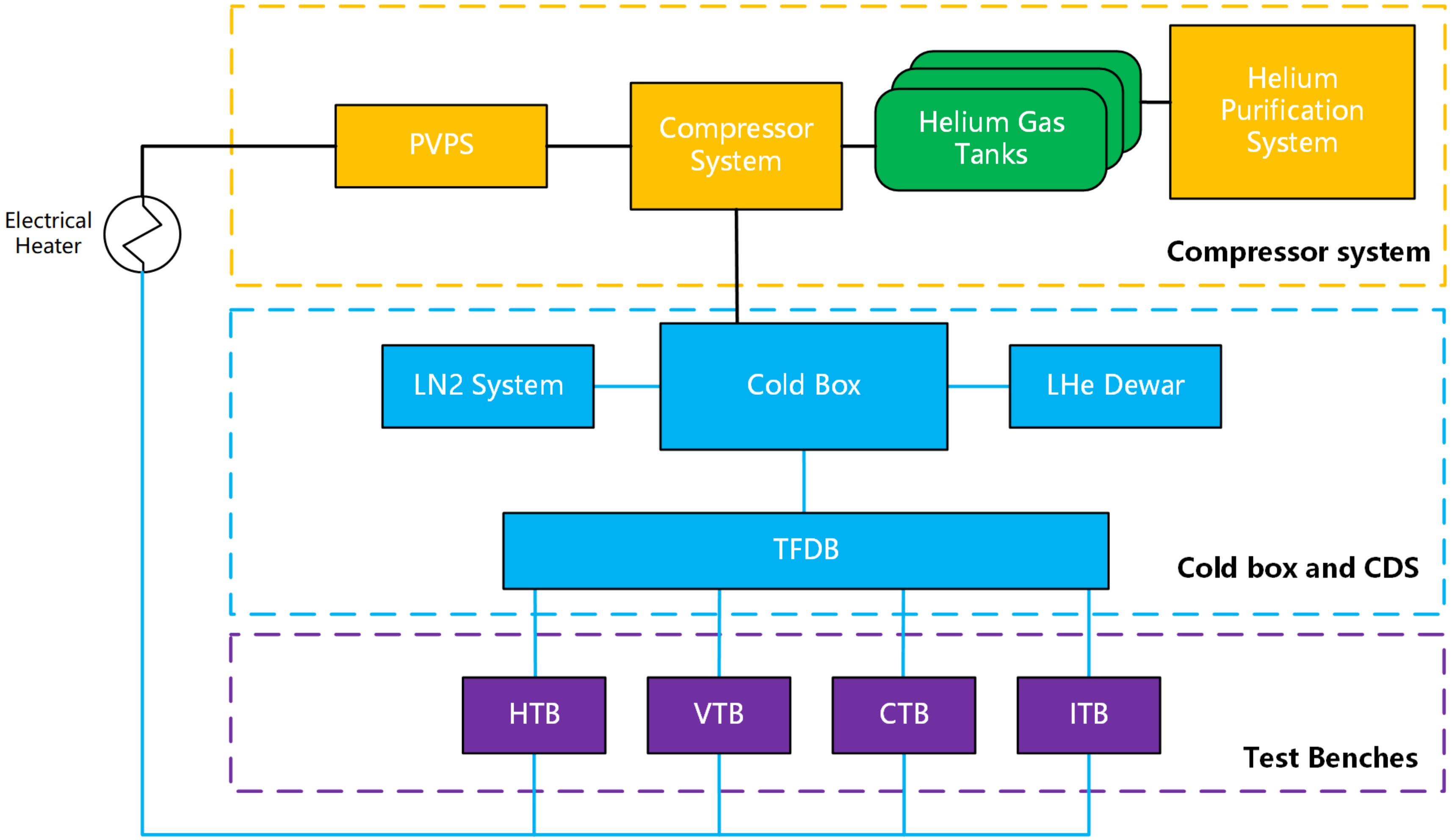


- **Located in Dalian, Liaoning, China**
  - **Dalian Coherent Light Source User Facility (Room Temperature)**
  - **Dalian Advanced Light Source Test Facility**

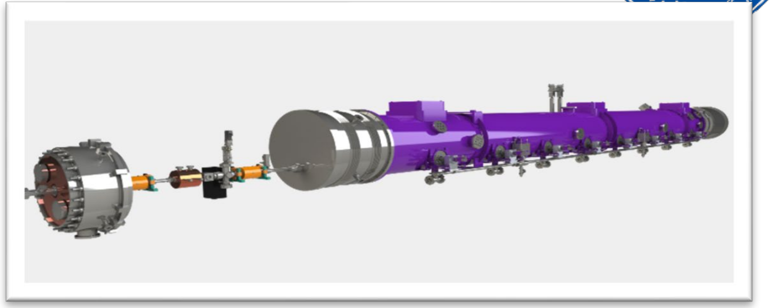
- **1 HTB, 1 VTB, 1 ITB, 1 CTB**
- **Cryogenic system(370 W@2 K), commissioning expected in 2023.12**



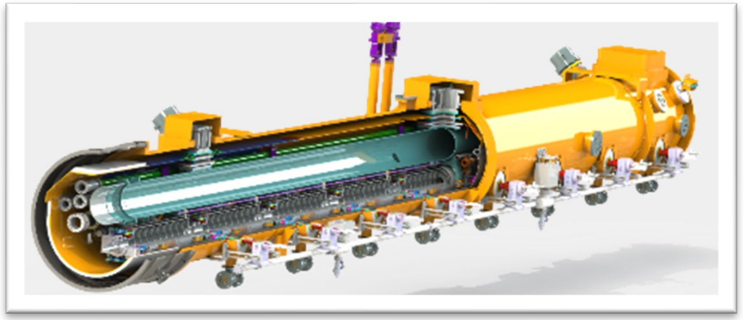
Cryogenic system block diagram



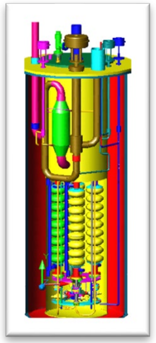
TFCP block diagram



1 Injector test bench



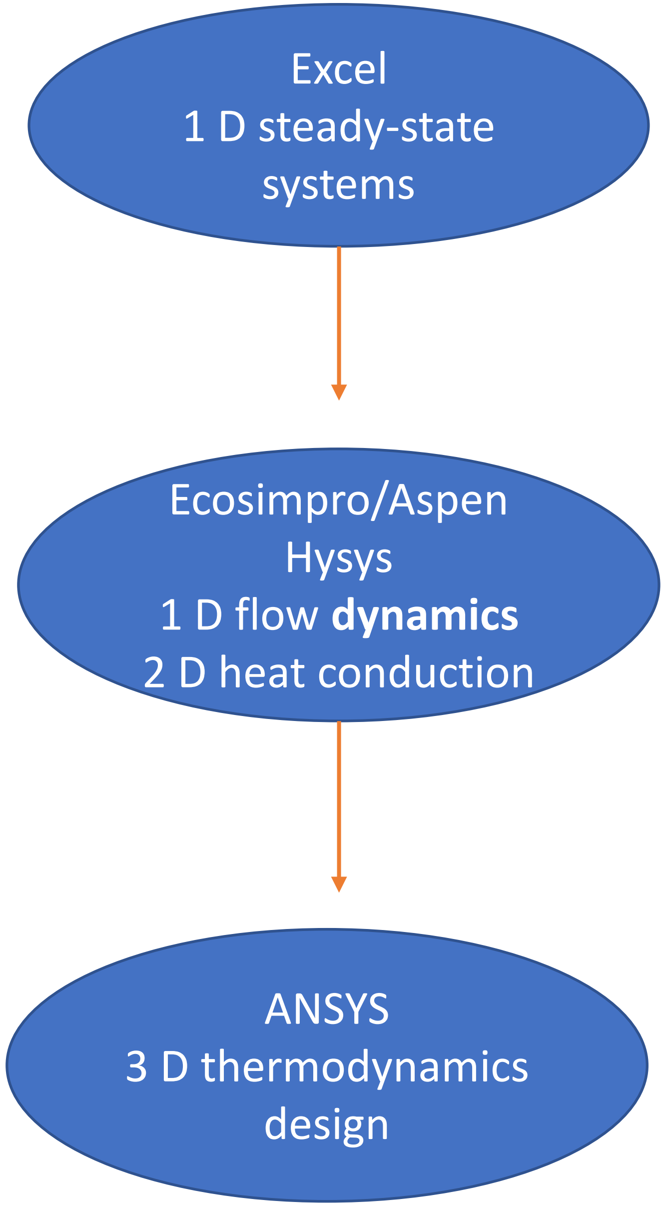
1 Horizontal test bench



1 Vertical test bench

1 Cryogenic test bench

What dynamic simulation can do?



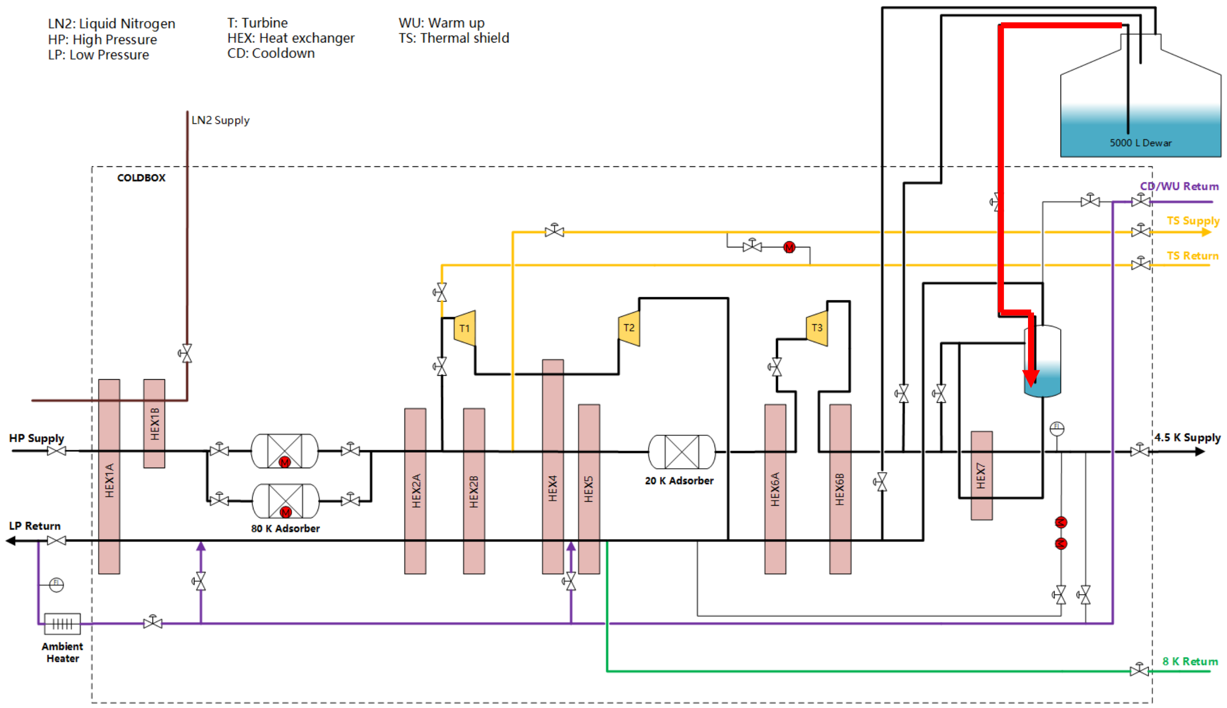
Steady state calculation

Flow dynamics
More complex system

Refined heat transfer
Need more time

- **Simple process calculations, reduce calculation time:** pressure drop calculation, valve selection, safety valve selection, etc.
- **Simulation of complex dynamic processes, virtual commissioning:** Cooldown, liquefaction, load variation, fast cooldown
- **Validate new process design:** add new components, new configuration
- **Validate new control strategies:** Model based prediction, Fuzzy control, Feed forward control, etc.
- **Failure simulation and failure prediction**
- **Operation training systems**

DALS test facility cryoplant



- **Fast Cool Down Mode: 57.7 g/s, 4.8 K @ 3.5 bar**
- **Large thermal gradient through Tc in SRF cavity help magnetic flux expulsion**

TFCP Expected Performance Data

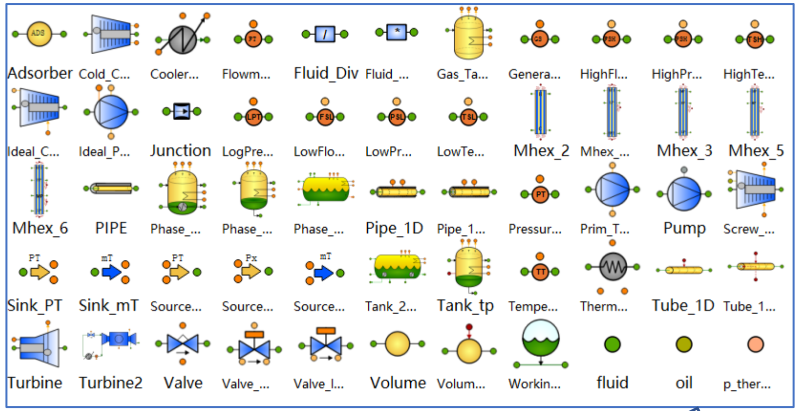
Section	LN2 Pre-cooling	Refrigeration Power @2 K	Thermal Shield @ 4.5-8 K	Thermal Shield @ 40-50 K	Liquefaction Rate g/s@ 1.3 bar
Refrigeration Mode	with	**370**	**420**	**2600**	-
P Supply	bar	3.5	3.5	13.5	-
P Return		-	1.3	12.9	-
T Supply	K	4.6	4.6	40	-
T Return		300	8	51.7	-
Mass flow	g/s	**19.9**	10.5	42	-
Fast cooldown Mode	with	-	420	2600	-
P Supply	bar	3.5	3.5	13.5	-
P Return		-	1.3	12.9	-
T Supply	K	4.8	4.8	40	-
T Return		-	7.9	50.9	-
Mass flow	g/s	**57.7**	10.5	45	-
Liquefaction Mode	with	-	-	-	**30.4**
	without	-	-	-	**12.8**

Contents

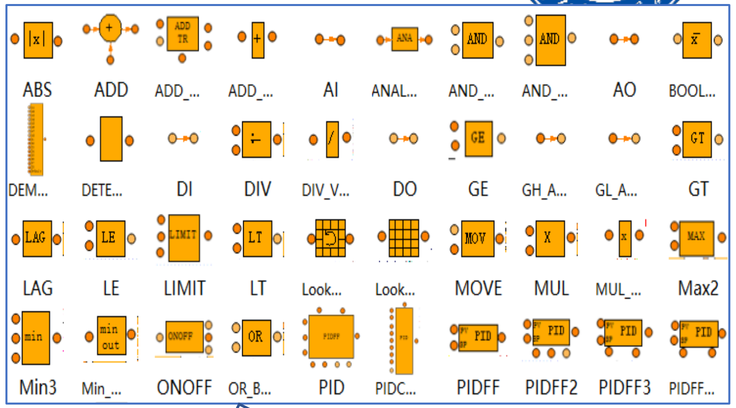
Ecosimpro introduction

EcosimPro
Modelling and Simulation Software

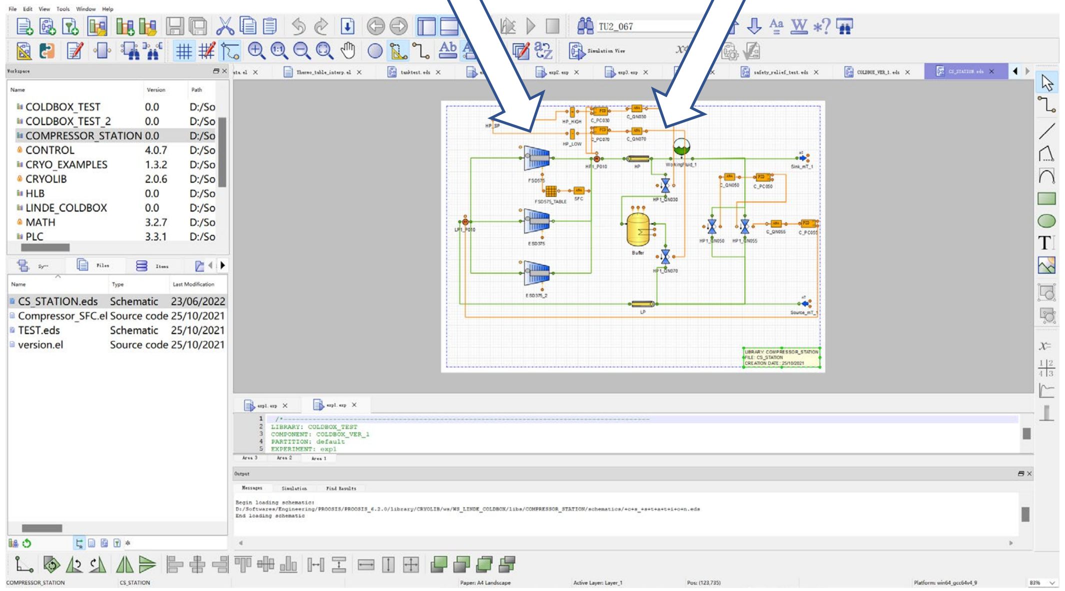
- Developed by EI company from Spain
- Models all systems that can be described as ODE, PDE and discrete event
- **EL language** modeling and graphical programming
- **Cryogenic library CRYOLIB** developed by CERN
- Easy modeling of complex cryogenic systems



CRYOLIB library

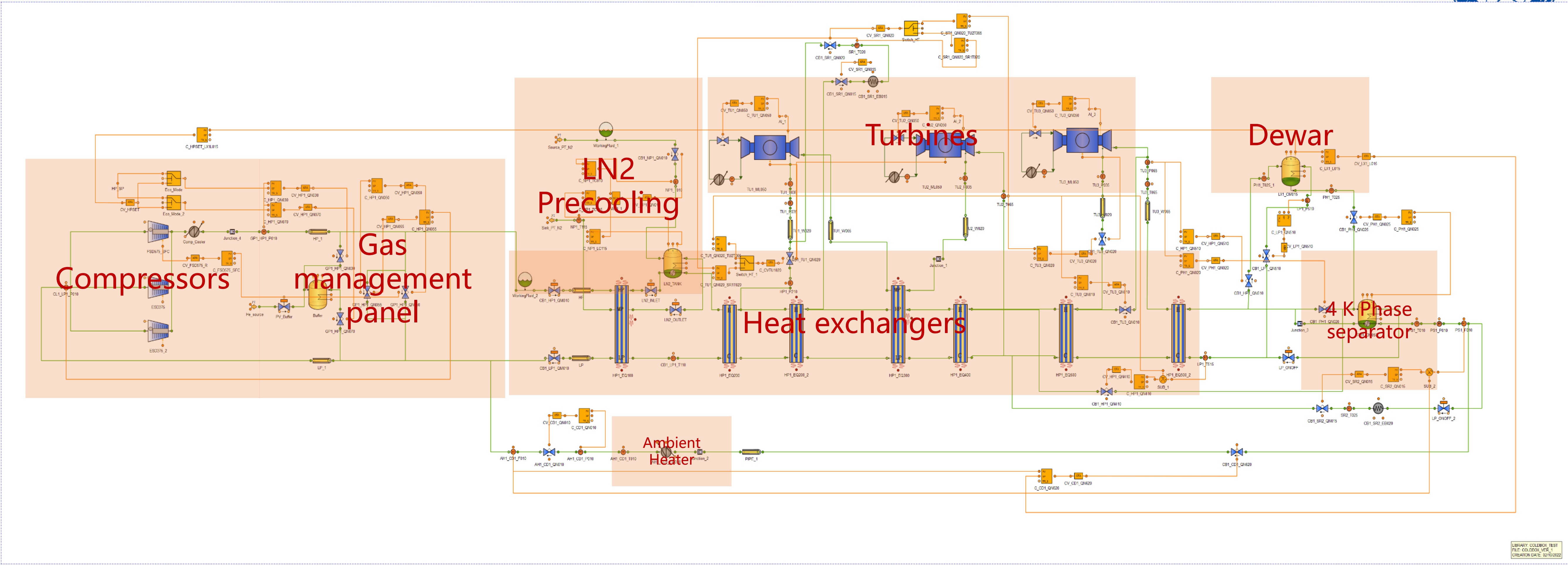


PLC library



Software Interface

370 W @ 2 K Refrigerator model

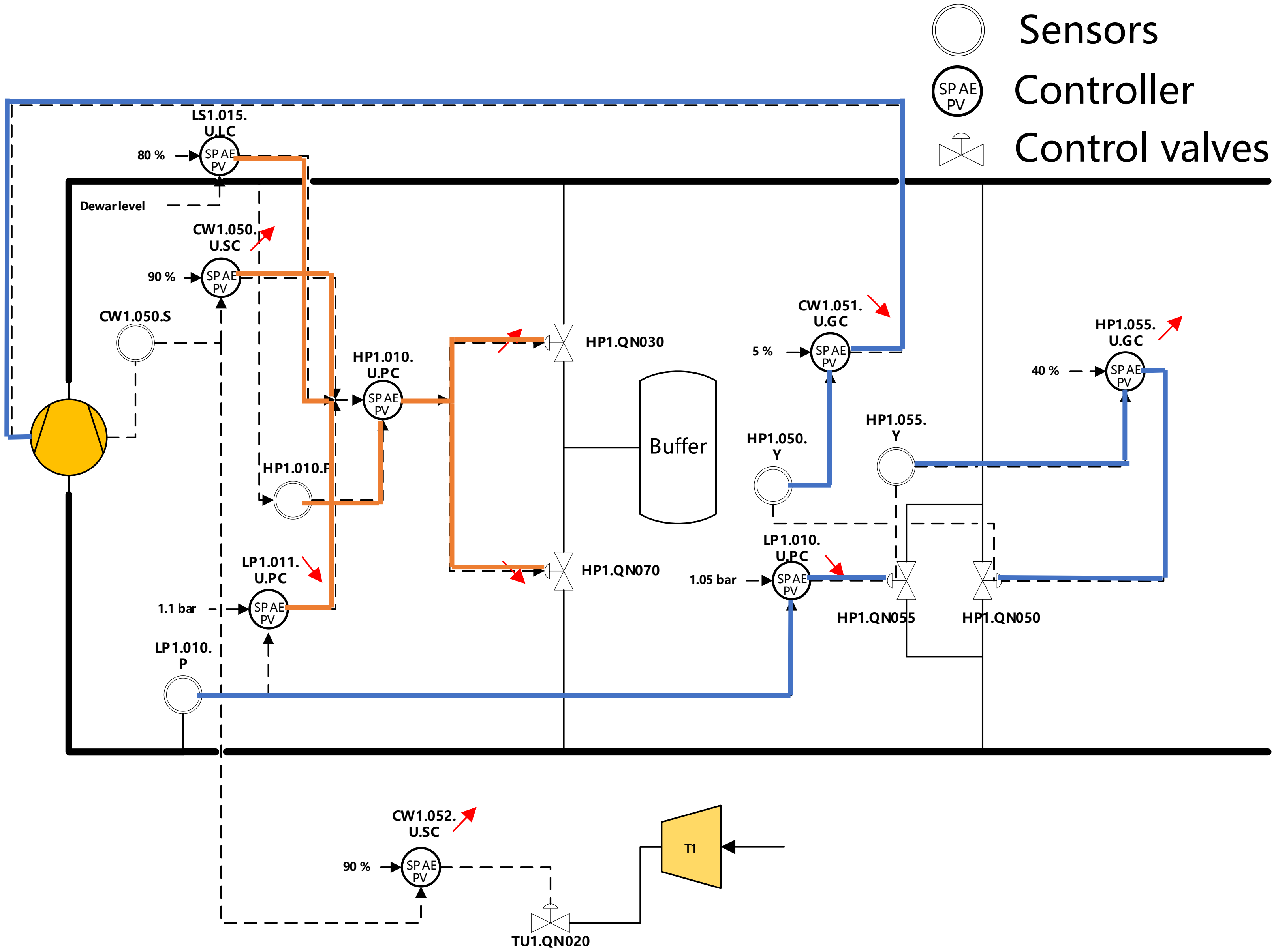


Compressor station：
FSD575 with VFD
ESD375 * 2
Gas management panel

Cold Box：
LN2 Pre-cooling, Turbines, Heat exchangers, Dewar

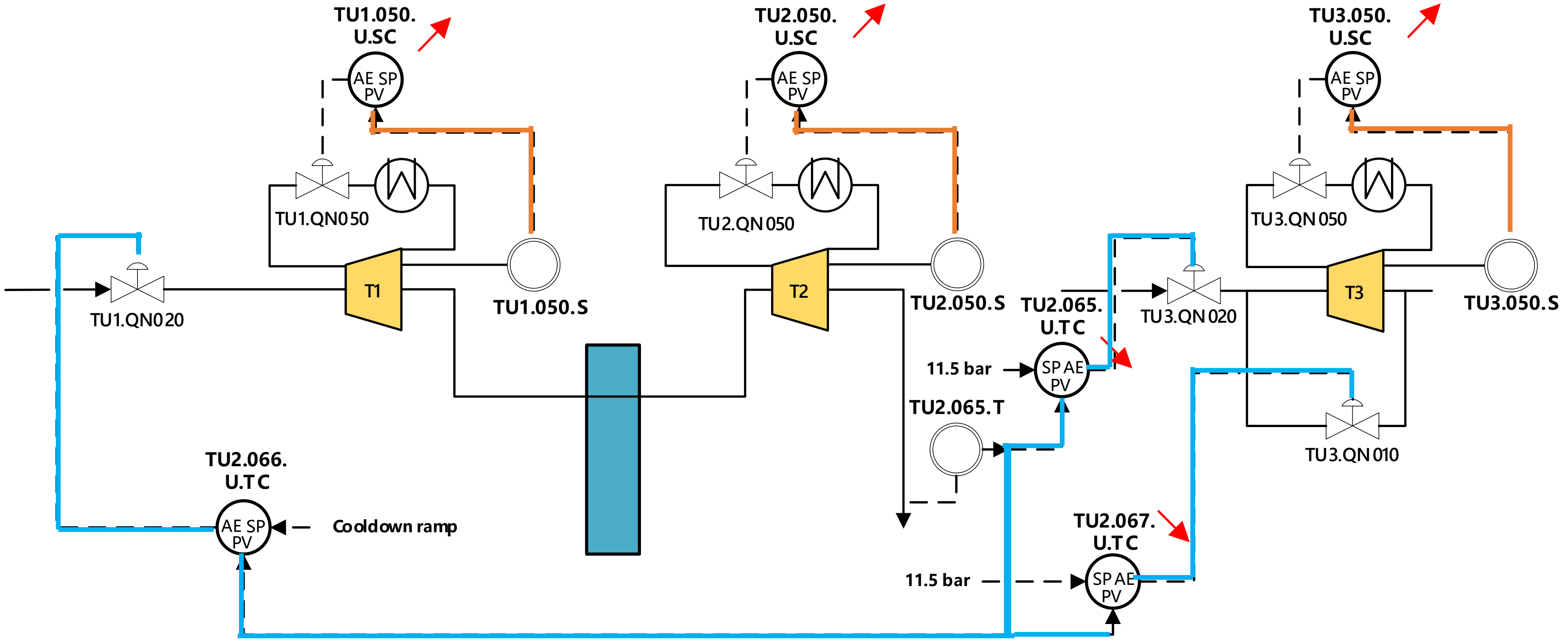
Operation modes:
- **Refrigeration mode**
- **Liquefaction mode**
- **Fast cooldown mode**

Control loops of Compressors



- HP control: HP1.010.U.PC
  - HP > 13.8 bar, HP1.QN030 OPEN
  - HP < 13.8 bar, HP1.QN070 OPEN
- The set value of HP Setpoint is determined by three control loops:
  - LS1.015.U.PC: Dewar liquid level control
  - CW1.050.U.SC: Compressor revolution speed
  - LP1.011.U.PC: LP overpressure control
- LP Control: PID + Cascade
  - LP1.010.U.PC： Little valve
  - →HP1.055.U.GC： Large valve
  - →CW1.051.U.GC： Revolution control

Control loops of Turbines



Turbine revolution control:
TU1.050.U.SC,
TU2.050.U.SC,
TU3.050.U.SC

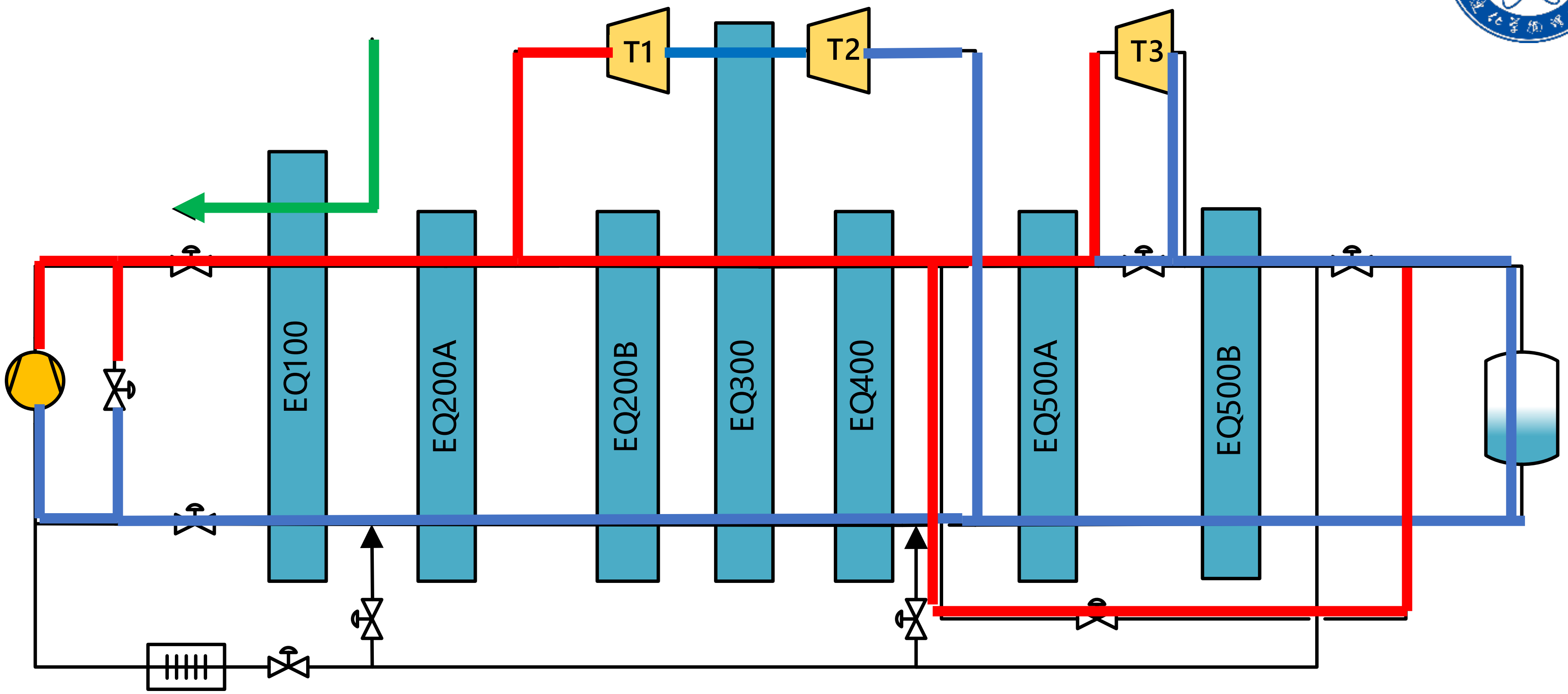
TU2.065.U.TC: TU2 Temperature control through TU3 inlet valve

TU2.067.U.TC: TU2 Temperature control through TU3 bypass valve

TU2.066.U.TC: Cooldown ramp control through TU1 inlet valve

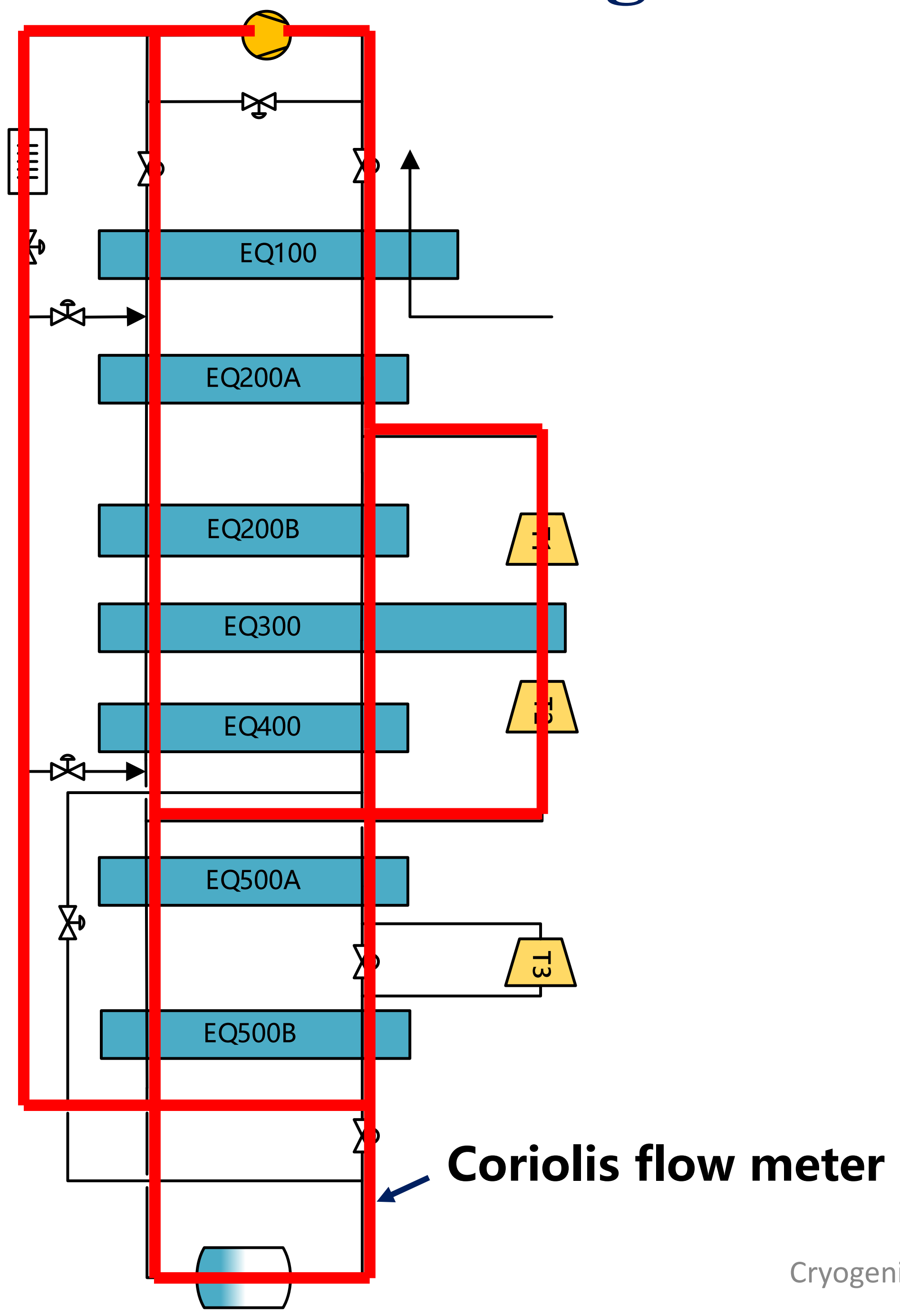
Sequence control

1	Compressor Mode
2	Cold box connection
3	Cold Mode
3-1	LN2 precooling
3-2	TU1,2 Start
4	HTTS Mode
5	JT Turbine Mode
6	sHe Supply
7	LTTS Mode



- Sequence control through Experiment code
- Loop switch through adjusting Model EL code

Simulation target

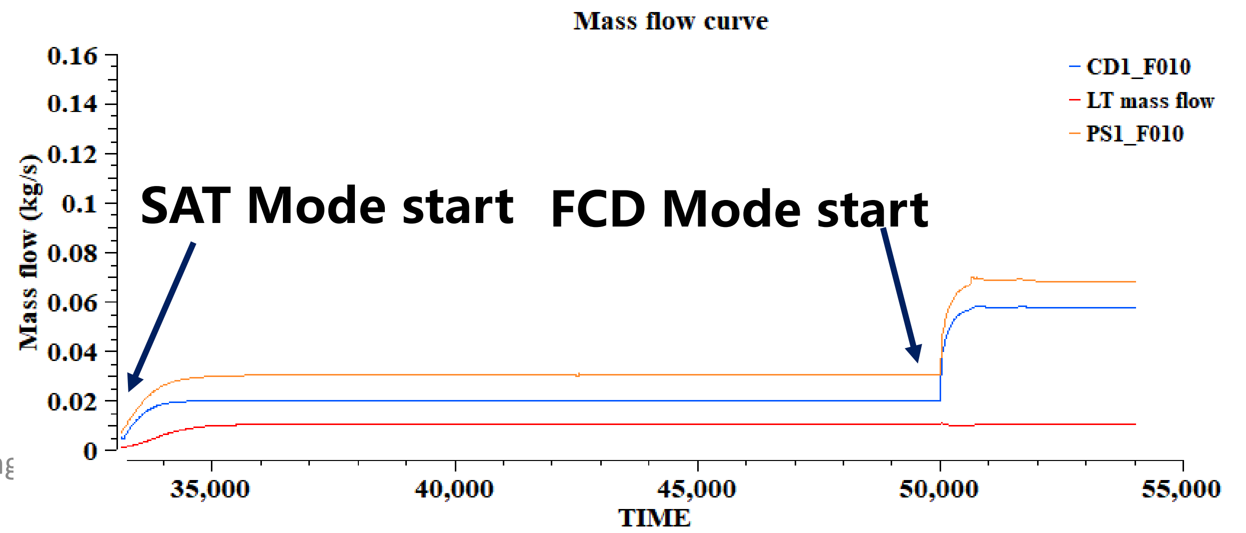


Current target:

- **Simulation of Site Acceptance (SAT)**
- **Verify the model accuracy with TS diagram from manufacturer**

Site acceptance sequence:

- **Compressor Mode → Cold Mode → JT Mode → SAT Mode**
- **Check Dewar level rising rate (Liquefaction Mode)**
- **All 4.5 K bypass through CD line, HT shield heater 2600 W, LT shield heater 400 W**
- **Adjust LT shield mass flow 10.5 g/s and Coriolis 30.4 g/s check Dewar level rise (Refrigeration Mode)**
- **Adjust LT shield mass flow 10.5 g/s and Coriolis 68.2 g/s (FCD Mode)**



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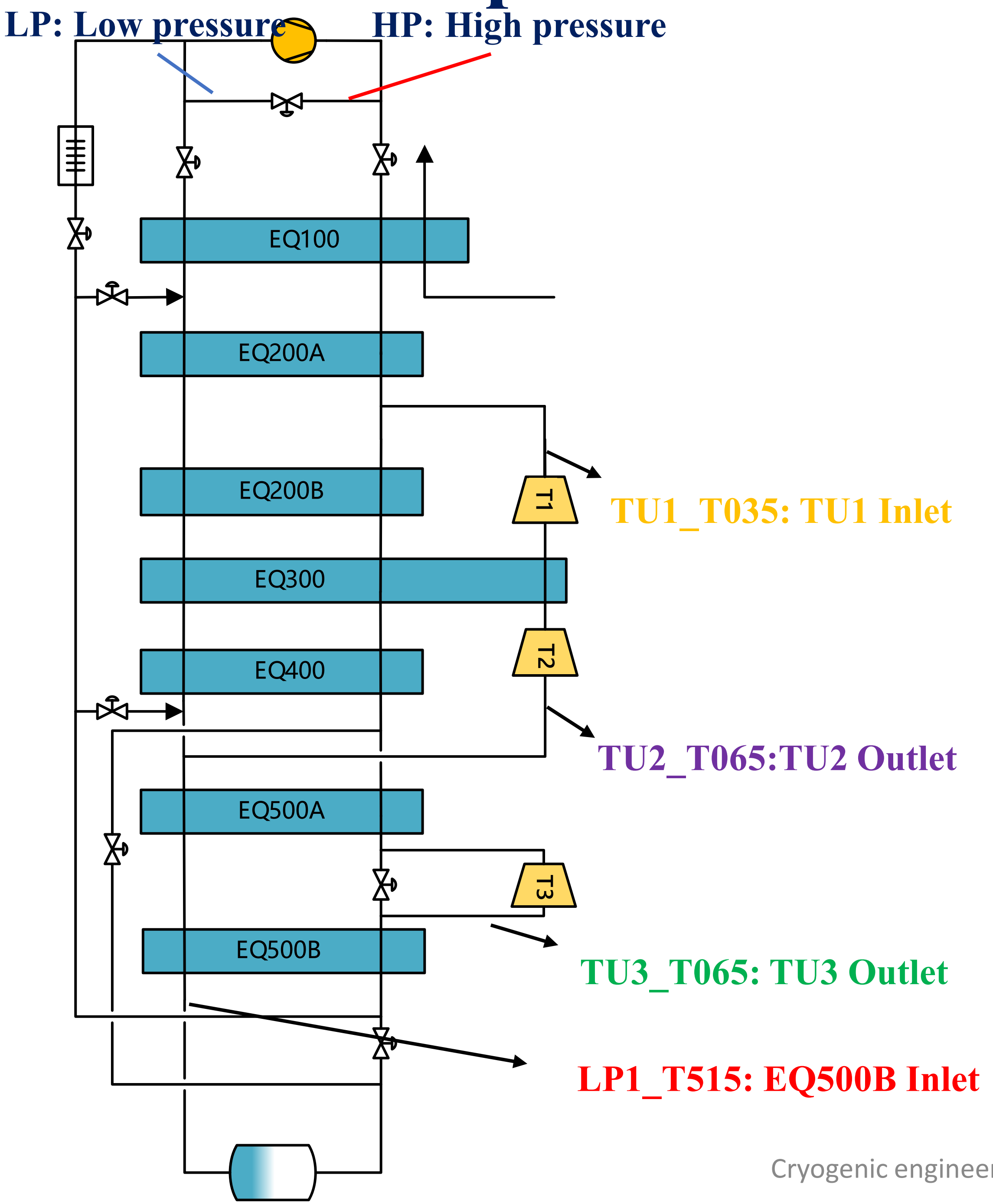
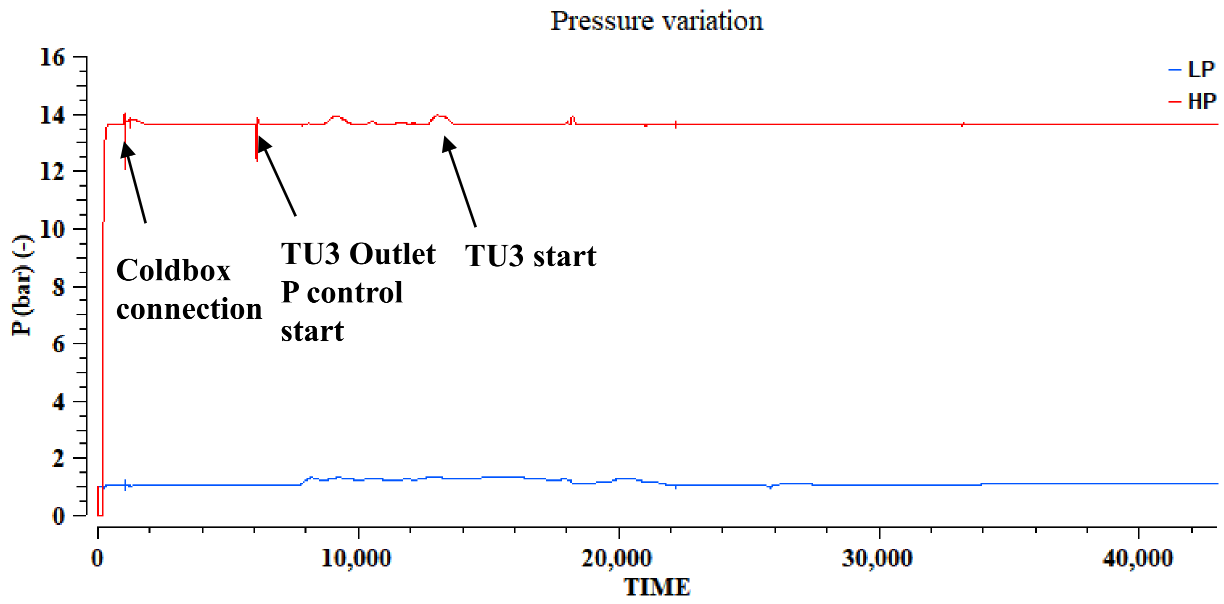
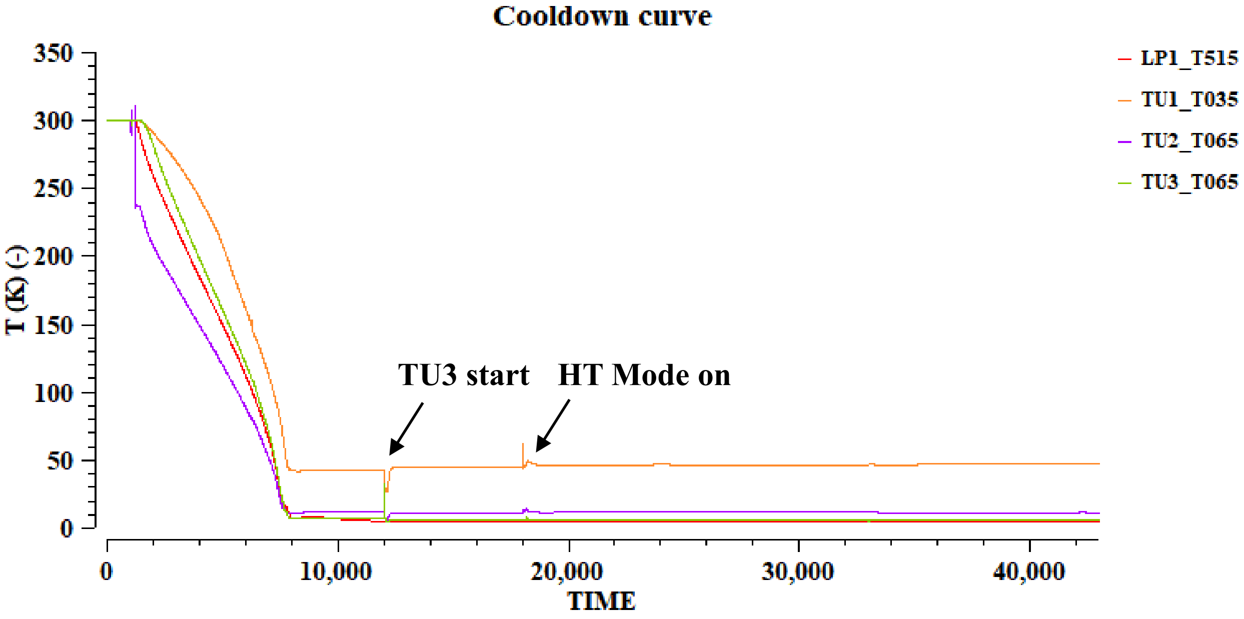
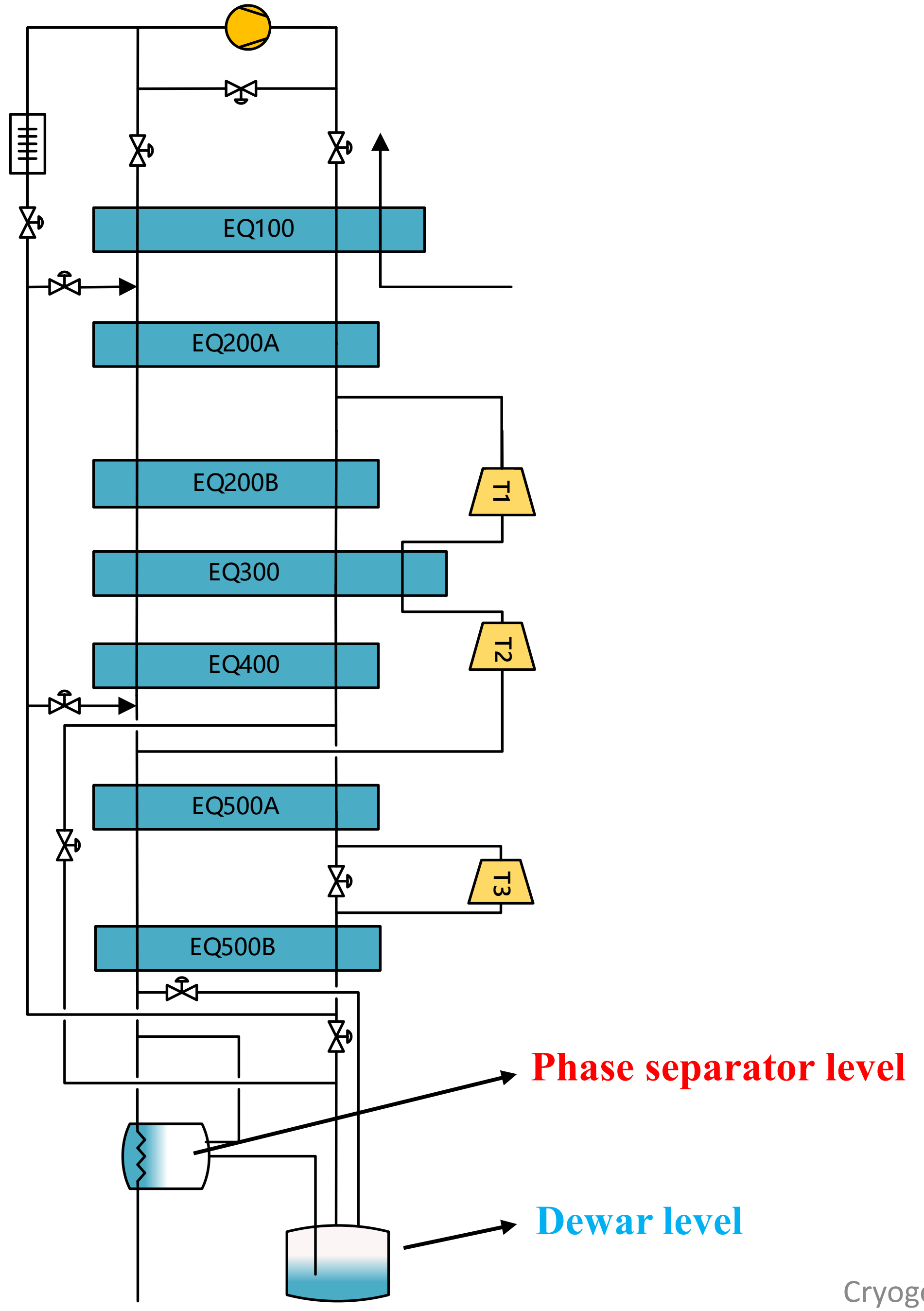
Cooldown process curve

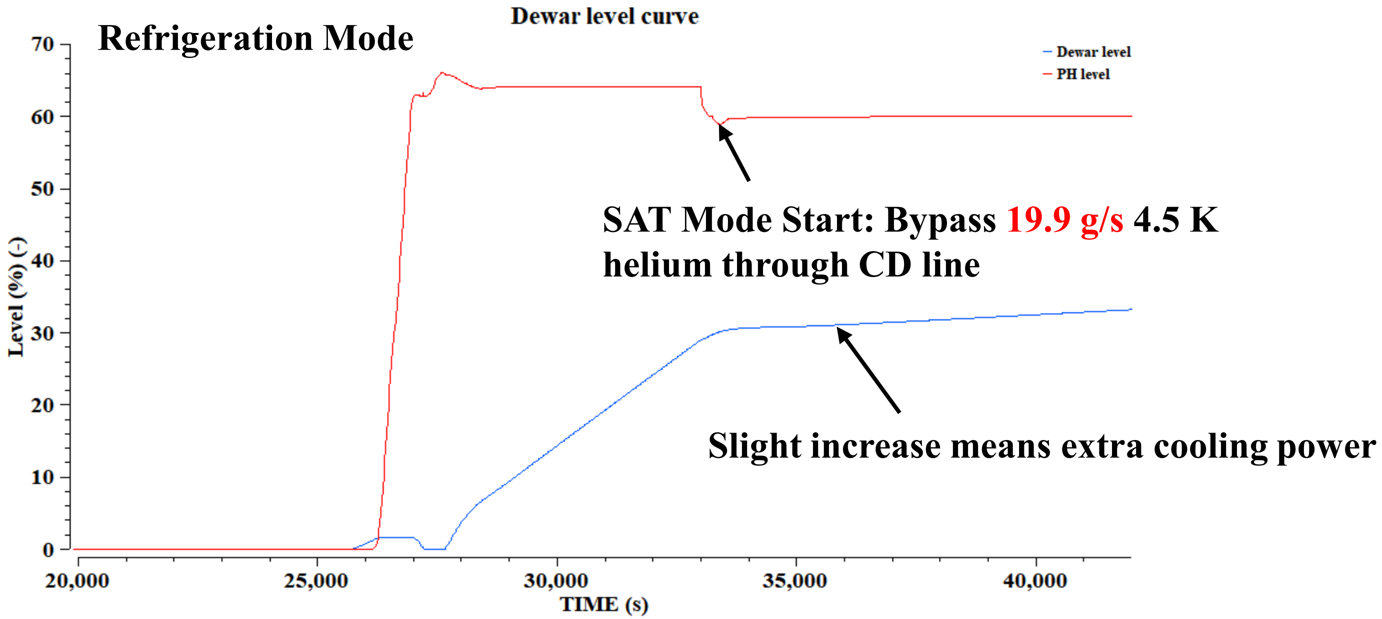


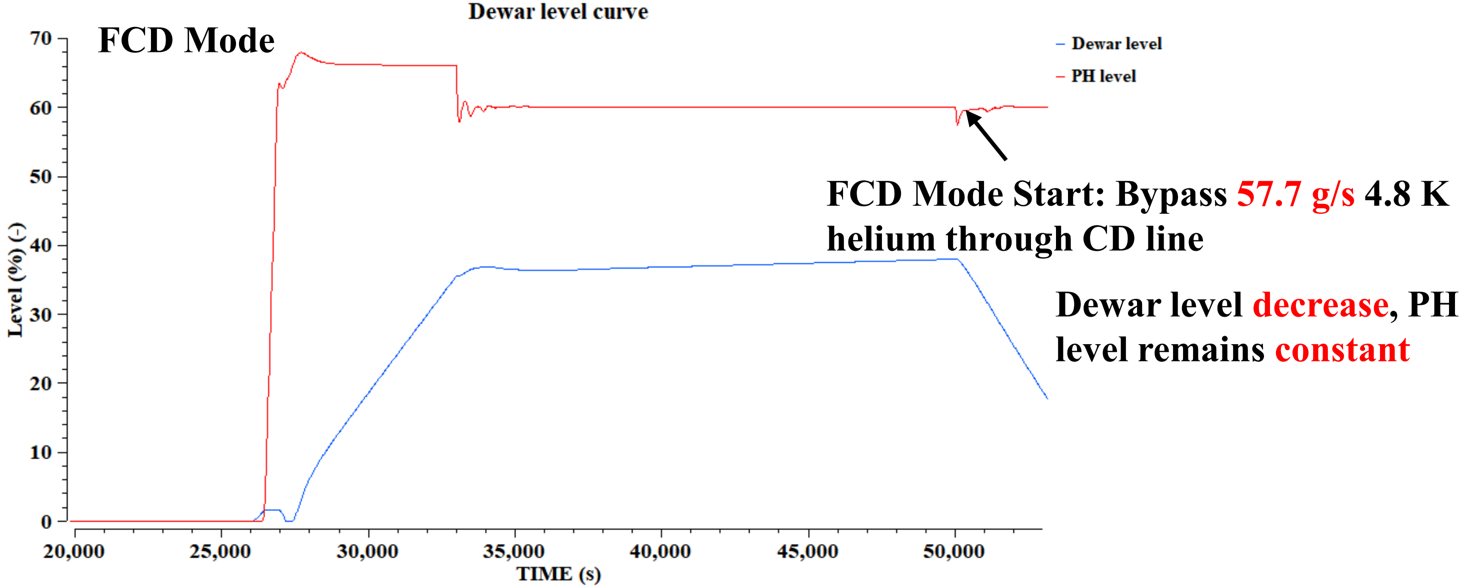




Dewar level curve







Steady state parameters comparison

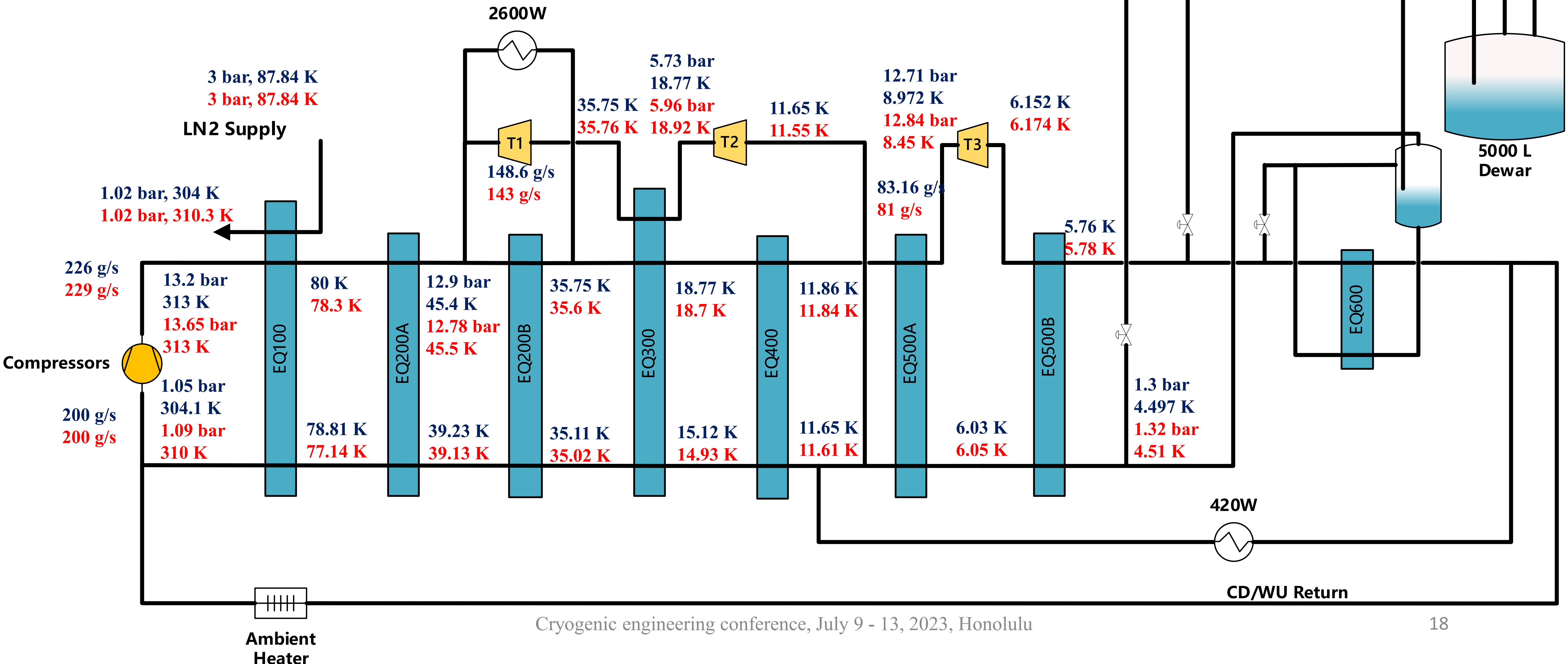
Liquefaction Mode

Parameters from Manufacturer TS diagram

Parameters calculated from Ecosimpro

Liquefaction rate: 32 g/s

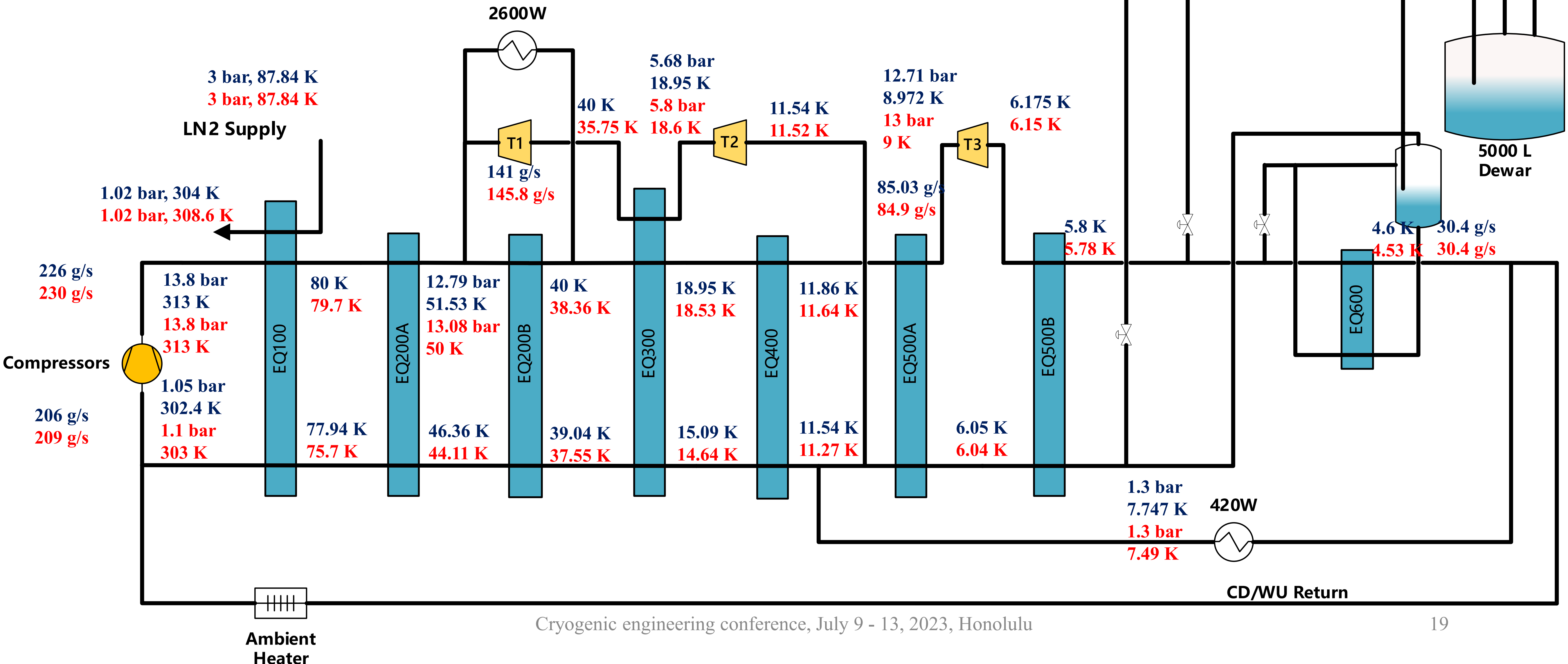
29.26 g/s



Steady state parameters comparison

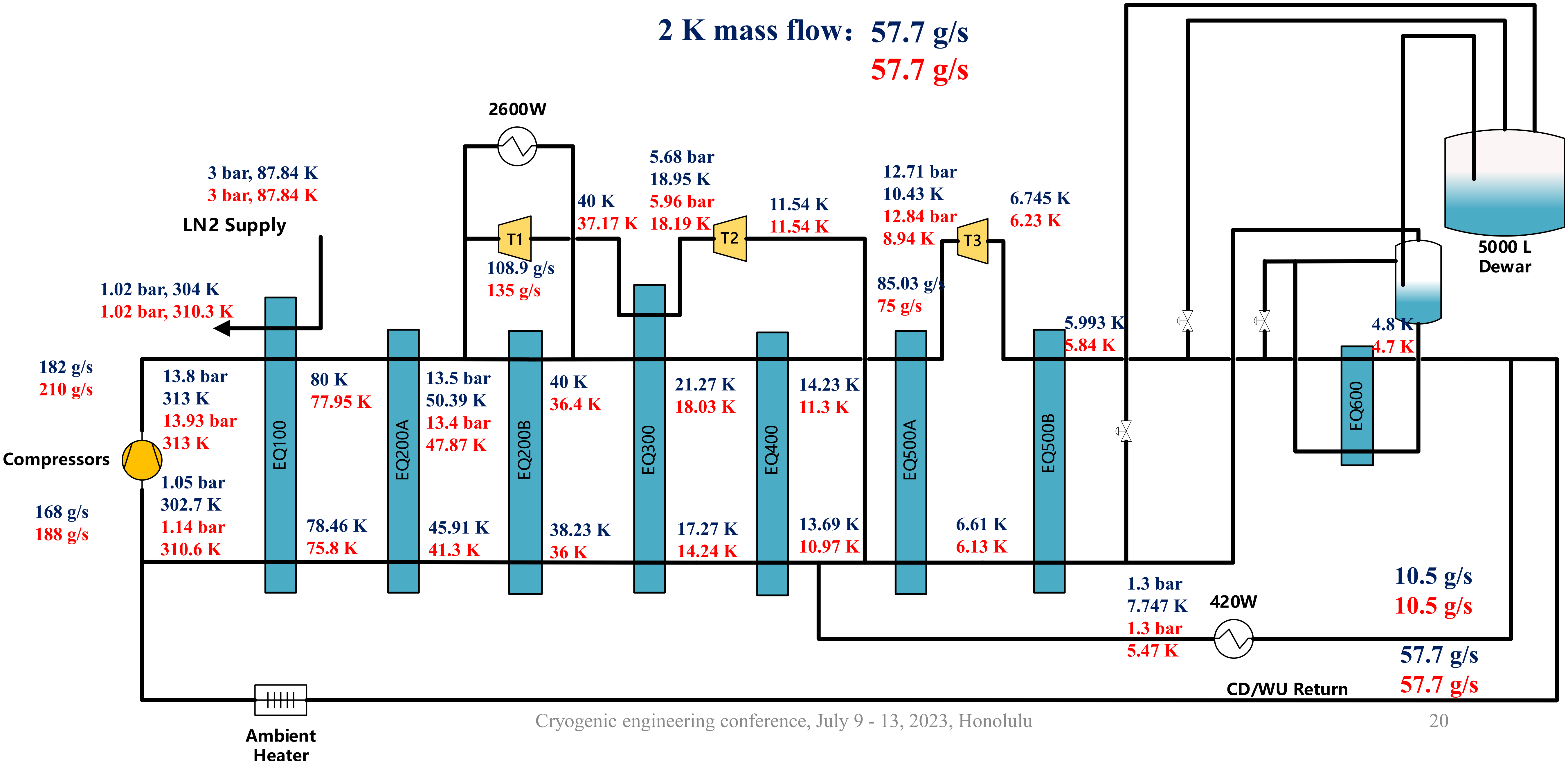
Refrigeration Mode

2 K mass flow: 19.9 g/s
19.9 g/s



Steady state parameters comparison

FCD Mode



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Conclusions

- A refrigerator model of the DALS test facility was built, including sequence control and control loop switch logic
- Three operation modes were simulated with Ecosimpro and the parameters correspond well with the TS diagram
- The next step is to improve the model accuracy based on the future commissioning data and use it to solve real problems

Thank you

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DESY

ESS