National Synchrotron Light Source II

Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Operation of the Cryogenic Plant at NSLS-II Problems and Solutions

A. Sitnikov, W. Gash, B. Bozeat, J. Oliva, J. Rose, R. Sikora,

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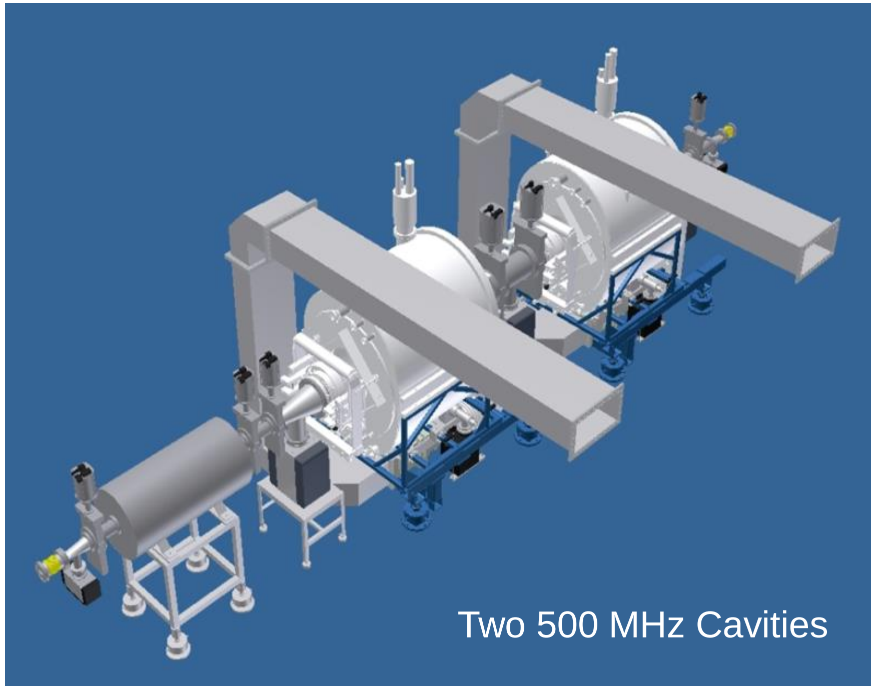
Outline

1. Introduction
2. Summary of cryoplant outages
3. Mitigations
4. Process Controls Issues
5. Future Plans
6. Summary

Introduction

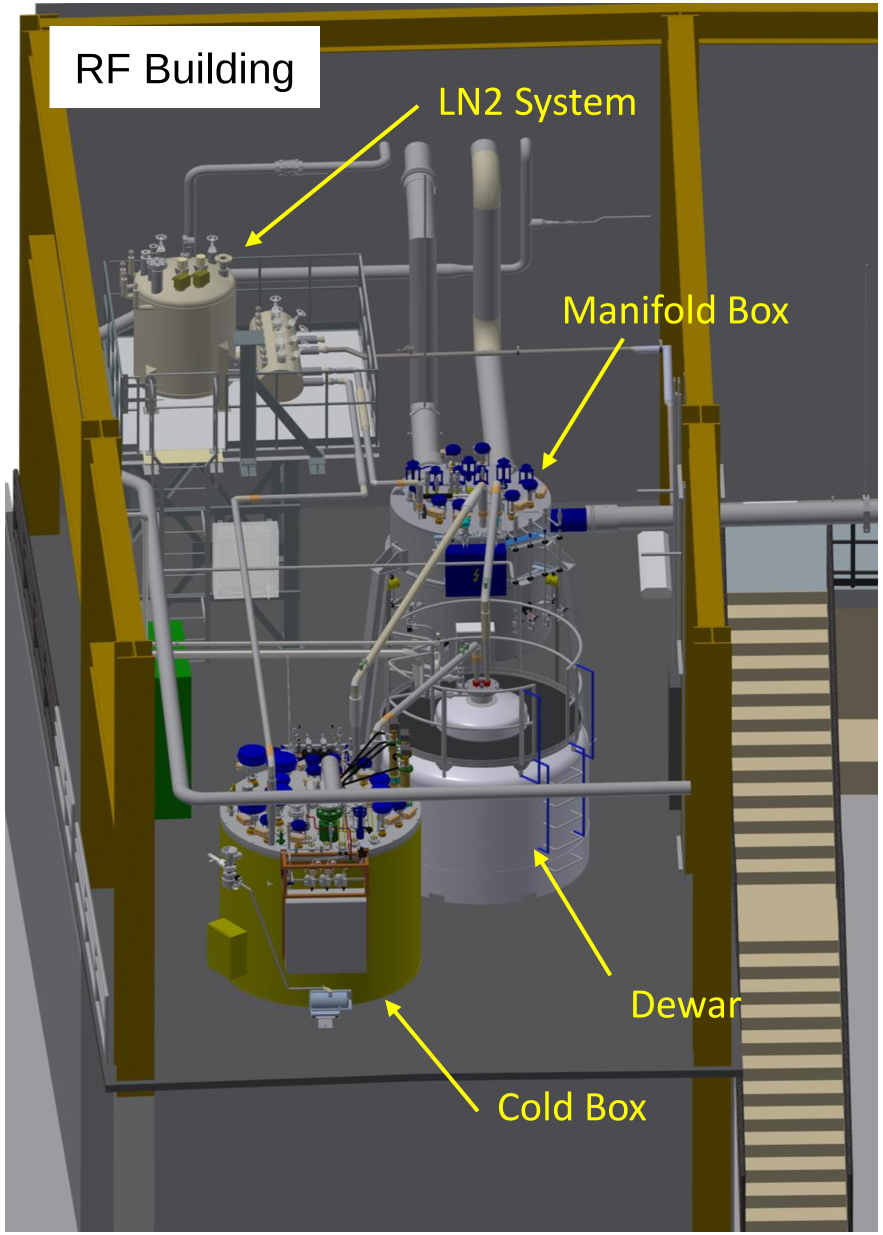
The National Synchrotron Light Source II (NSLS-II) is an optimized 3GeV electron Storage Ring with 792 m circumference at Brookhaven National Laboratory (BNL) in Upton, New York State.



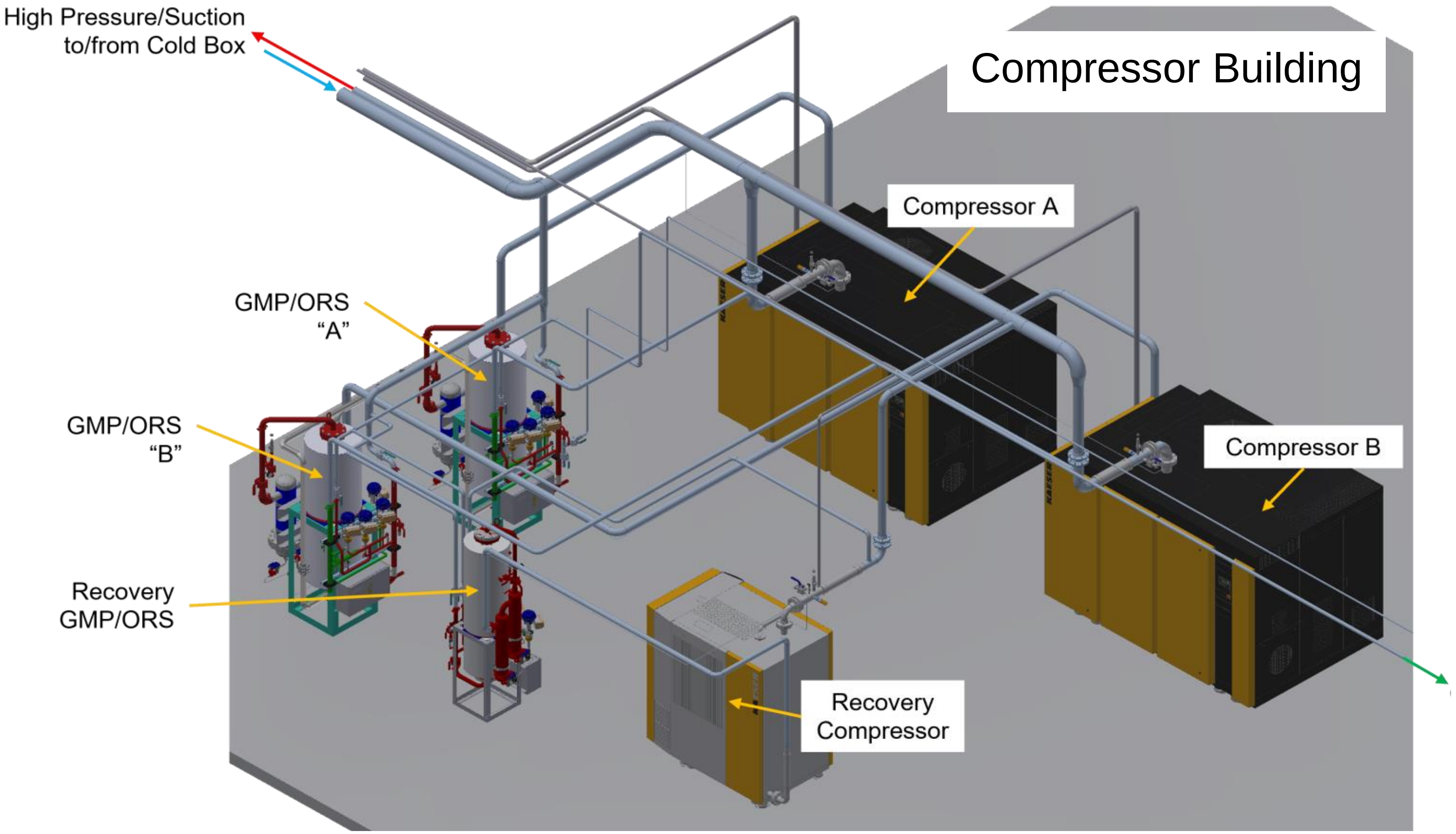
Two 500 MHz Cavities

The cryogenic system at NSLS-II is operating 8,700 - 8,760 hrs per year (10 years) and feeding three 500 MHz superconducting Radio Frequency cavities with liquid Helium.

Introduction

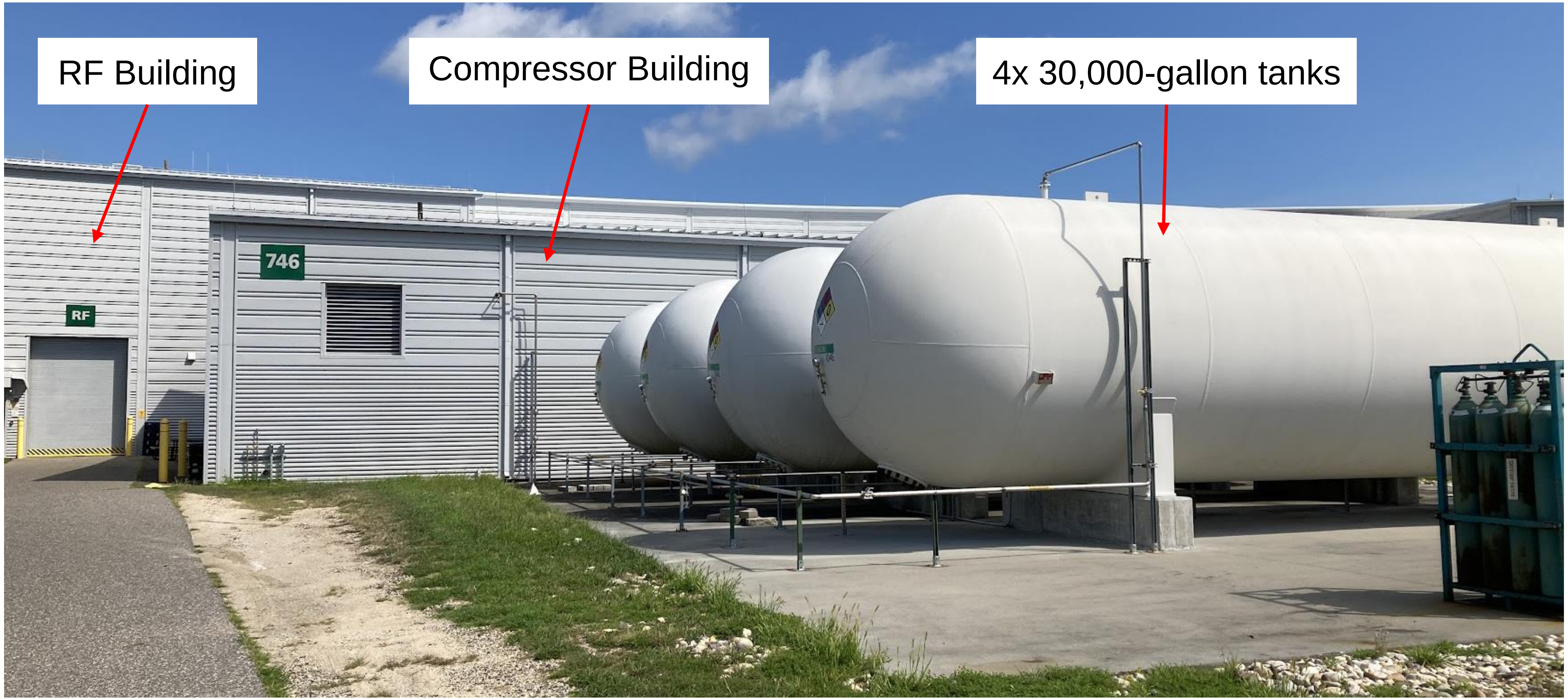


The cryogenic plant at NSLS-II is a 4 K closed loop Helium system that consists of two 250 kW redundant compressors, 900 W cooling capacity liquefier/refrigerator (Cold Box), Manifold Box, and two Valve Boxes.



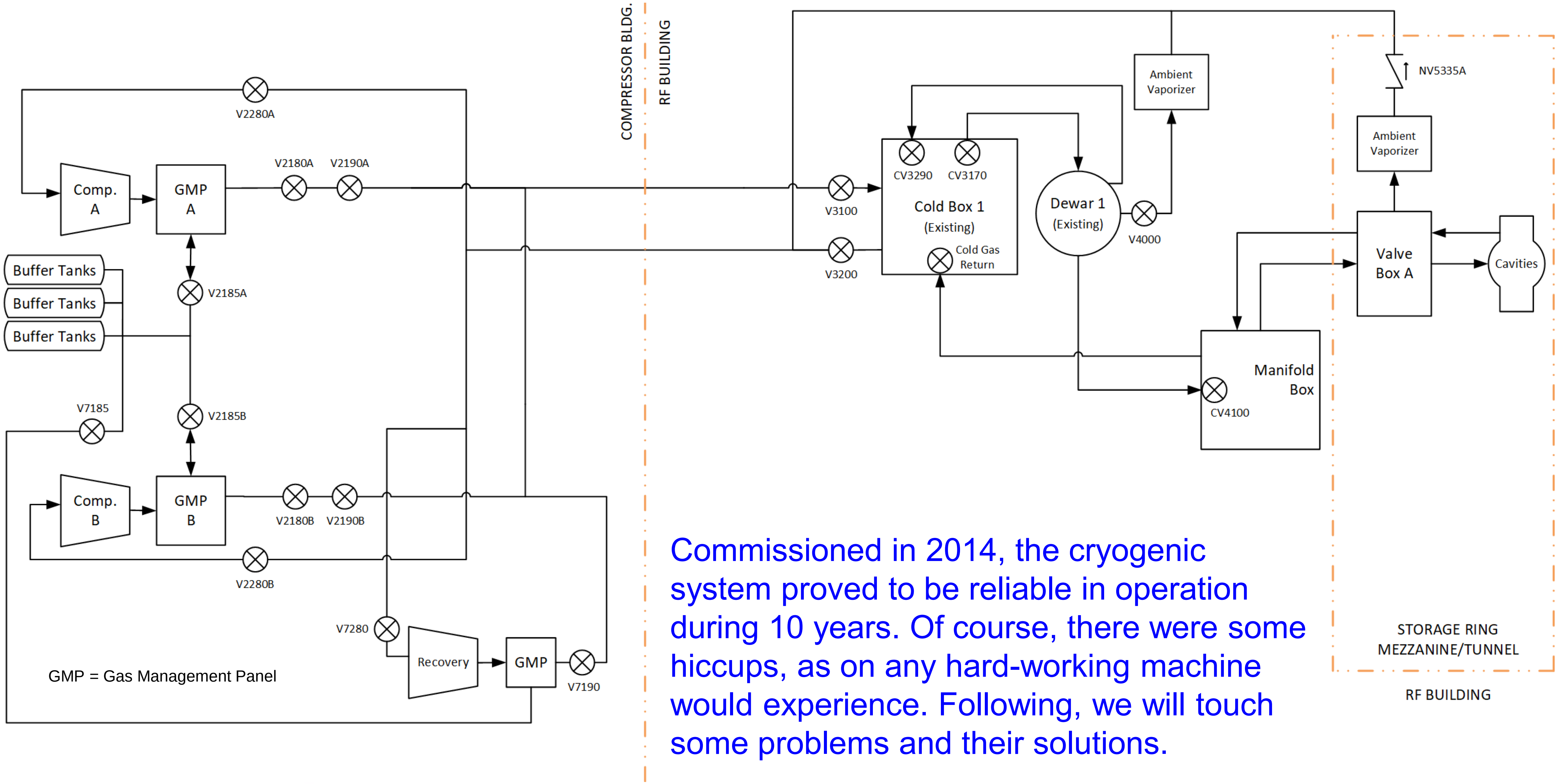
Introduction

Gaseous Helium Buffer Tanks, Compressor bldg. and RF bldg.



Introduction

Original cryoplant configuration



Commissioned in 2014, the cryogenic system proved to be reliable in operation during 10 years. Of course, there were some hiccups, as on any hard-working machine would experience. Following, we will touch some problems and their solutions.

Summary of cryoplant outages.

Series of Unfortunate Events

2014-07-06	Trip due to a power dip
2014-08-02	Trip when returning from back-up generator power
2015-02-01	Trip due to power dip
2017-06-21	Trip due to over temp and then communications (human error)
2017-11-07	Trip due to ground fault of the Adsorber's heater that initiated the controller fault
2017-11-08	Trip when returning from back-up generator power
2018-04-09	Trip the scroll pump XDS5 due to high current.
2019-09-10	Trip due to Power dip.
2019-12-14	Trip due to ice blockage in 80K HEX & ΔP jumped up to 1 Bar across HEX
2019-12-26	Trip due to back-up generator issue.
2020-04-14	Trip due to
2020-05-18	Trip due to ice blockage.
2020-07-25	Trip due to Power dip.
2021-05-04	Trip due to Air supply outage.
2021-07-13	Trip due to Power dip.
2021-08-14	Trip due to Power dip.
2022-04-03	Trip due to ice blockage.
2022-08-18	Trip due to Air supply outage (human error)
2022-10-04	Trip due to Power outage.
2023-06-13	Trip due to ice blockage.

Summary of Downtime

- Power dips - 7 events
- Air supply outages - 2 events
- Impurities → ice blockage - 4 events

NOTE: add 24 preventive warm-ups because of the Cold Box periodic performance degradation due to hidden leak

- Back-up generator switching - 3 events

Summary of cryoplant outages.

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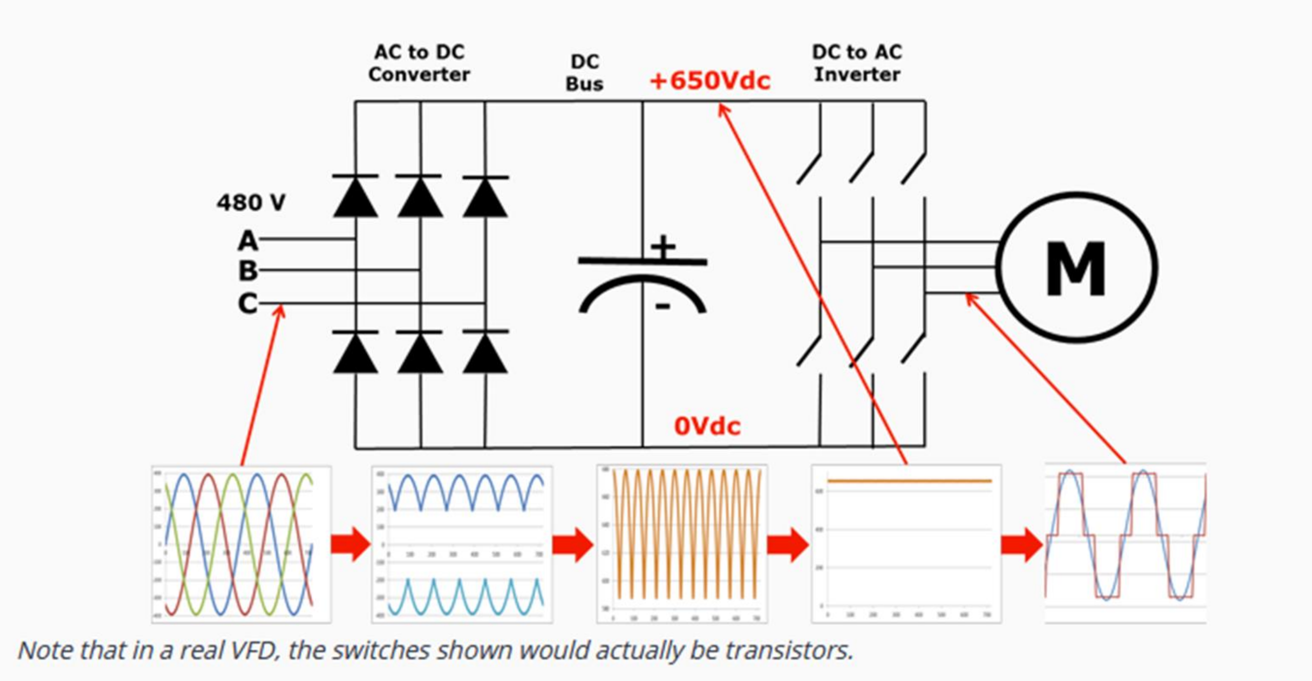
- Back-up generator switching - 3 events

Mitigations

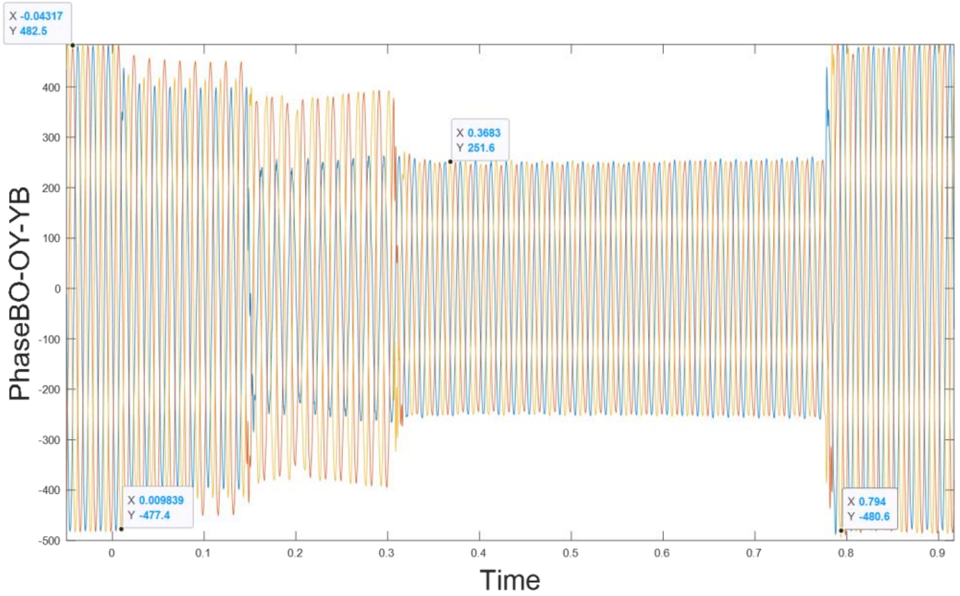
- Power dip ride-thru system and Quench detection system/pneumatic relief valves
- Redundant air supply
- Leaks elimination and Helium Purifier as backup
- Added the inhibit switch to the back-up generator

Mitigations <u>Power dip ride-thru system</u>

Added during April 2021 shutdown Ultracapacitor UPD (Uninterruptable Power for Drives) “Ride-Thru System” and it paid off at least 2 times during 2022 so far. Ultracapacitor can help the compressor (250 kW) ride through 100% power dip not exceeding 2 seconds.



Note that in a real VFD, the switches shown would actually be transistors.



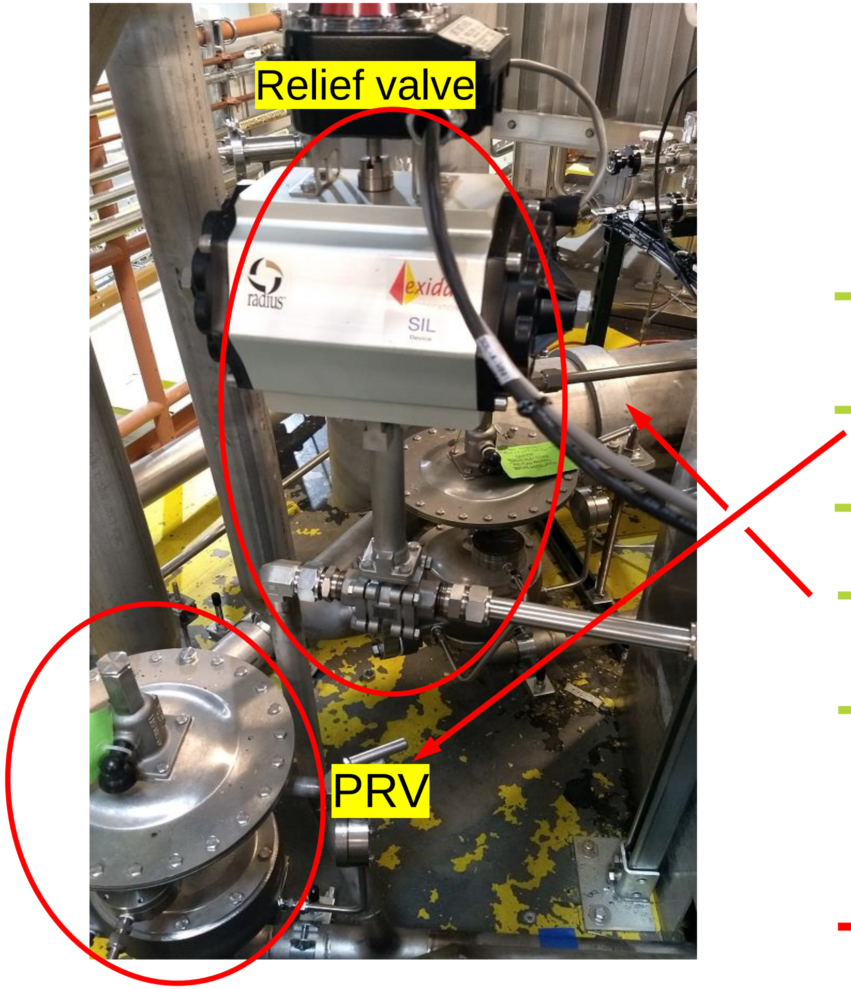
Compressor/cold box trip July 25th, 2020
50% power dip on 3 phases for 0.8 sec.

Ultracapacitor UPD →

Mitigations

Quench detection system/pneumatic relief valves

Cavity pressure protection



Quench detector chassis

1.56 bara, burst disc ruptures.

1.41 bara, PRV opens.

1.33 bara, sensor #1 triggers Transmitter to BEAM state (as backup).

1.32 bara, Pneumatic relief valve opens to atmosphere.

1.30 bara, sensor #2 triggers faster interlock and trips Transmitter to BEAM state
1.30 bara, Interlock Set Point, opens warm return.

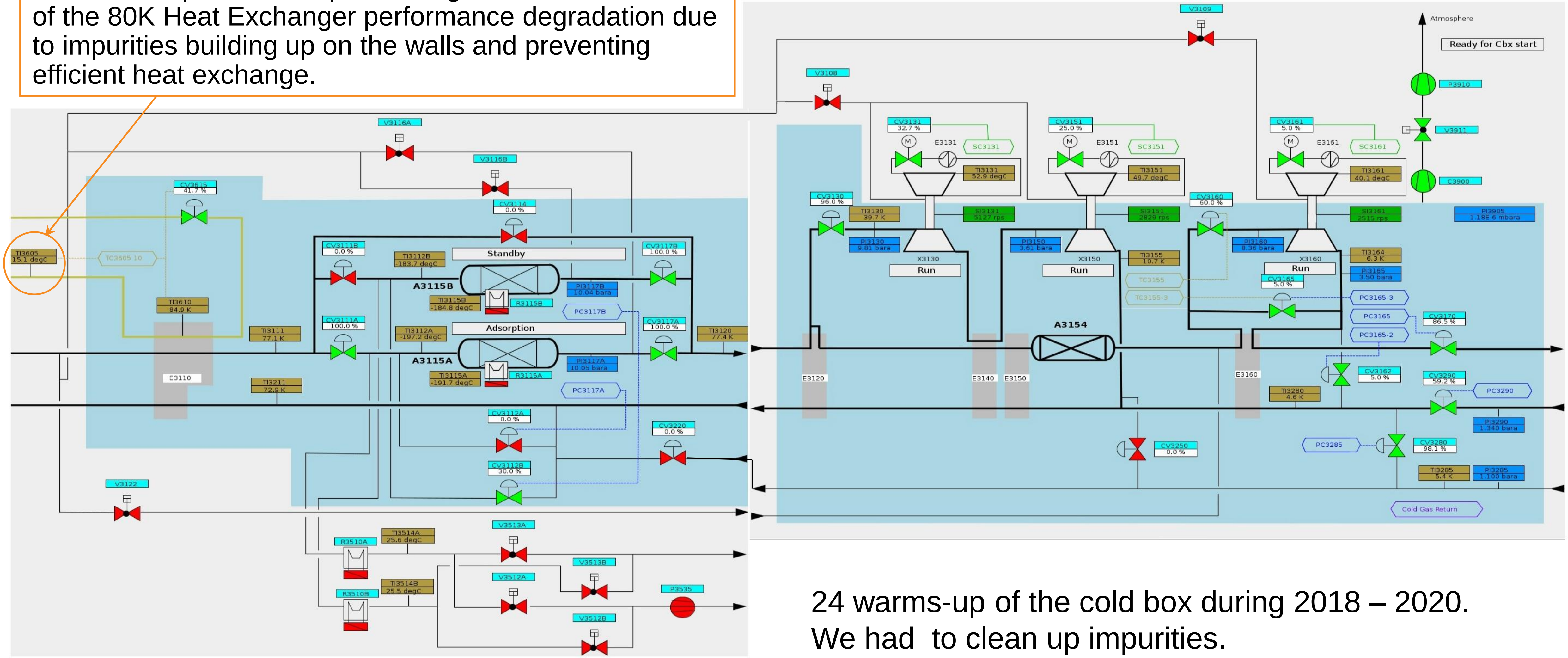
1.26 bara, Pneumatic relief valve closes.
1.26 bara, Cavity operating pressure set point.

Mitigations

Impurities troubleshooting

Signature of impurities

Exhaust temperature drop on Nitrogen side is an indicator of the 80K Heat Exchanger performance degradation due to impurities building up on the walls and preventing efficient heat exchange.



24 warms-up of the cold box during 2018 – 2020.
We had to clean up impurities.

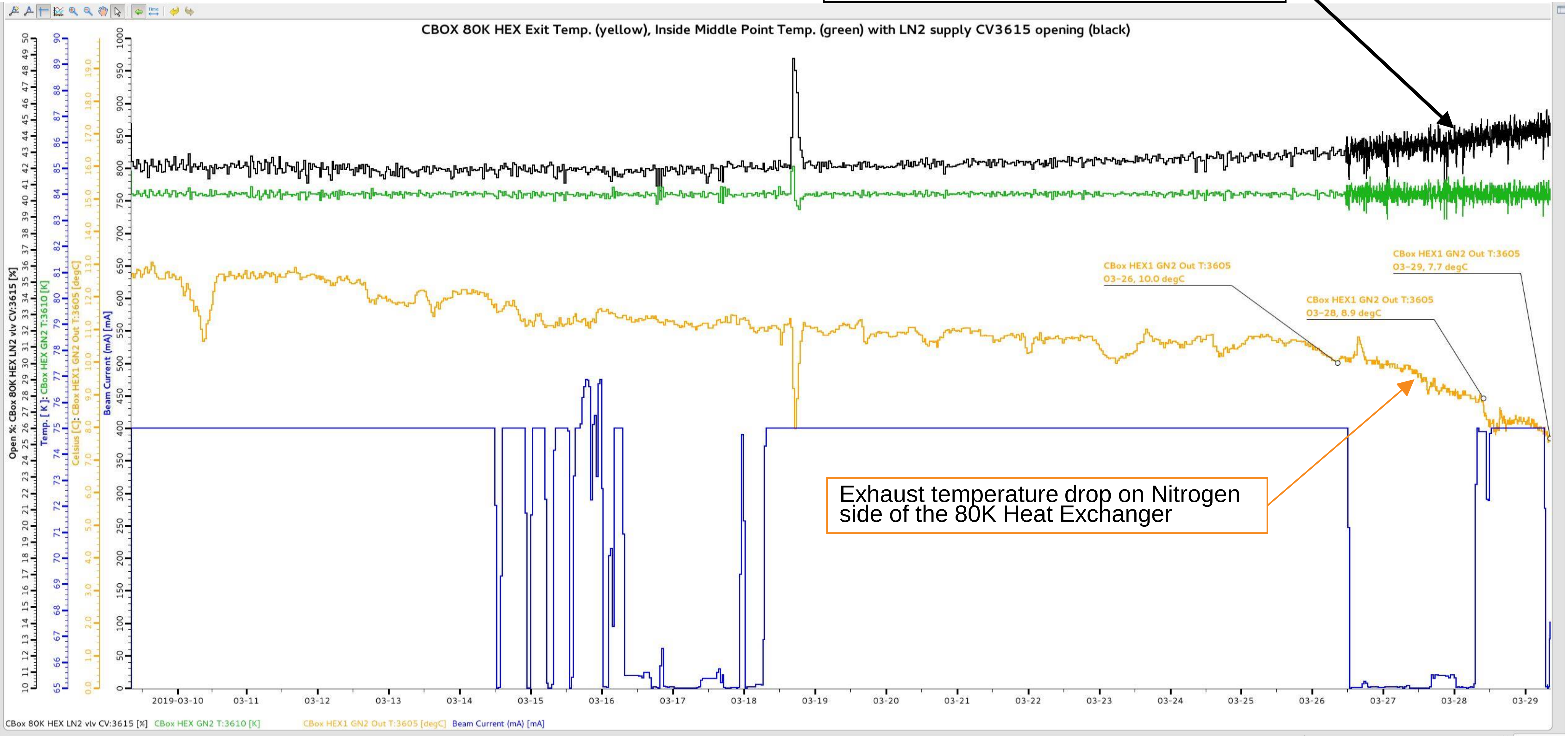
Mitigations

Impurities troubleshooting

Signature of impurities

20 days plot example

LN2 supply valve is opening gradually to compensate the loss of the heat exchange



Exhaust temperature drop on Nitrogen side of the 80K Heat Exchanger

Mitigations

Leaks in PRV and Check valves

One solution to fight the leaking seats of PRVs and check valves can be a U-turn pipe section installed upside down at the exit of the vent line. In this case a portion of the Helium gas will be locked in this section preventing air from going back and sitting near the valve's seat. We applied this on all Cavities relief valves which open quite often during the quenches.

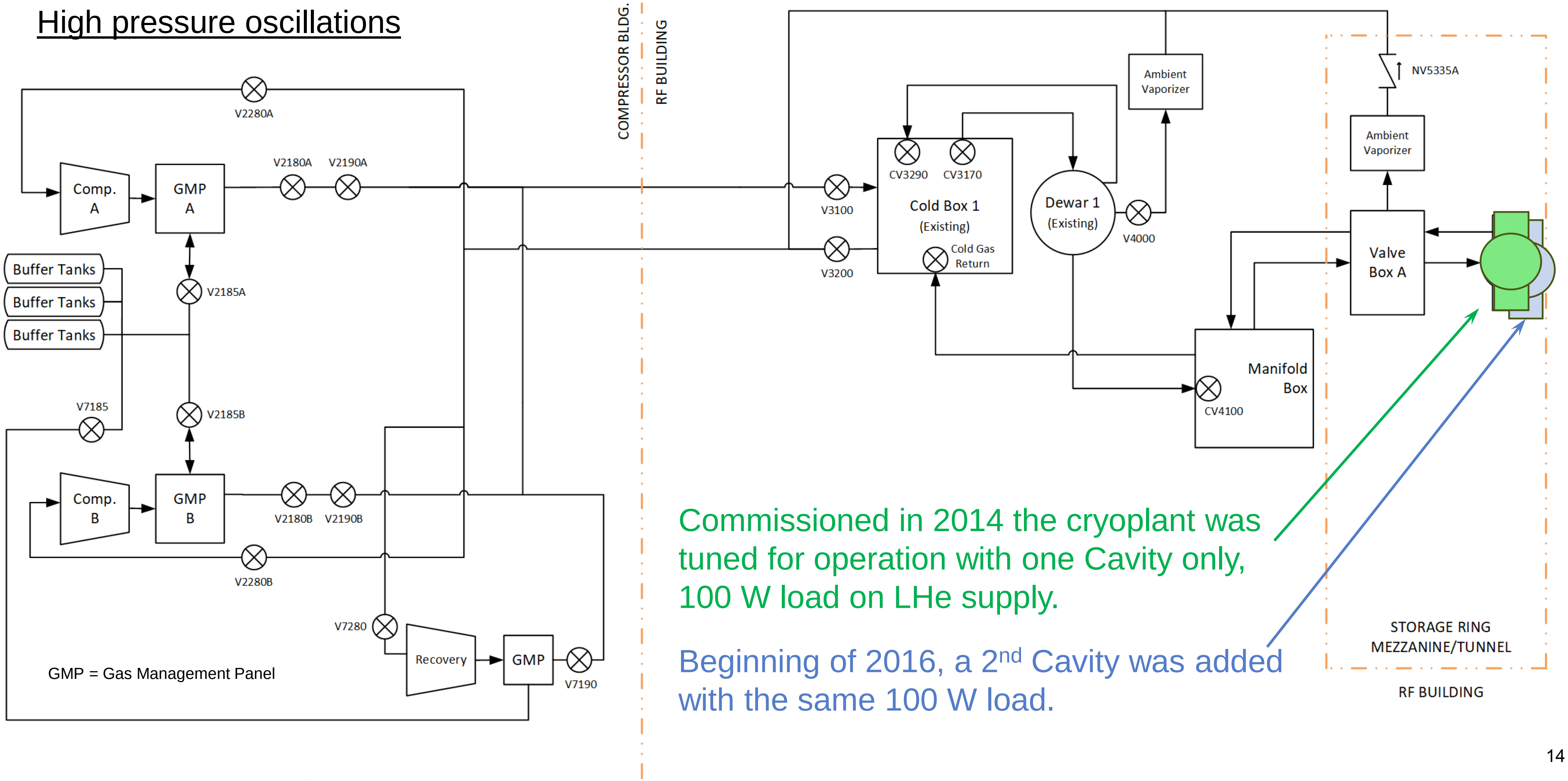
Purifier – mitigation of impurities.

When the cold box trips due to ice blockage there is a spike of impurities during the cold box warming up cycle up to 10 … 30 ppm when the temperature achieve about 80 … 90 K in the first heat exchanger (80K HEX) of the cold box. Having a portable purifier connected in parallel allows to dump impurities down to 2 … 6 ppm, and with in-line purifier down to 0 … 1 ppm.

Process control issues

High pressure oscillations

Original cryoplant configuration



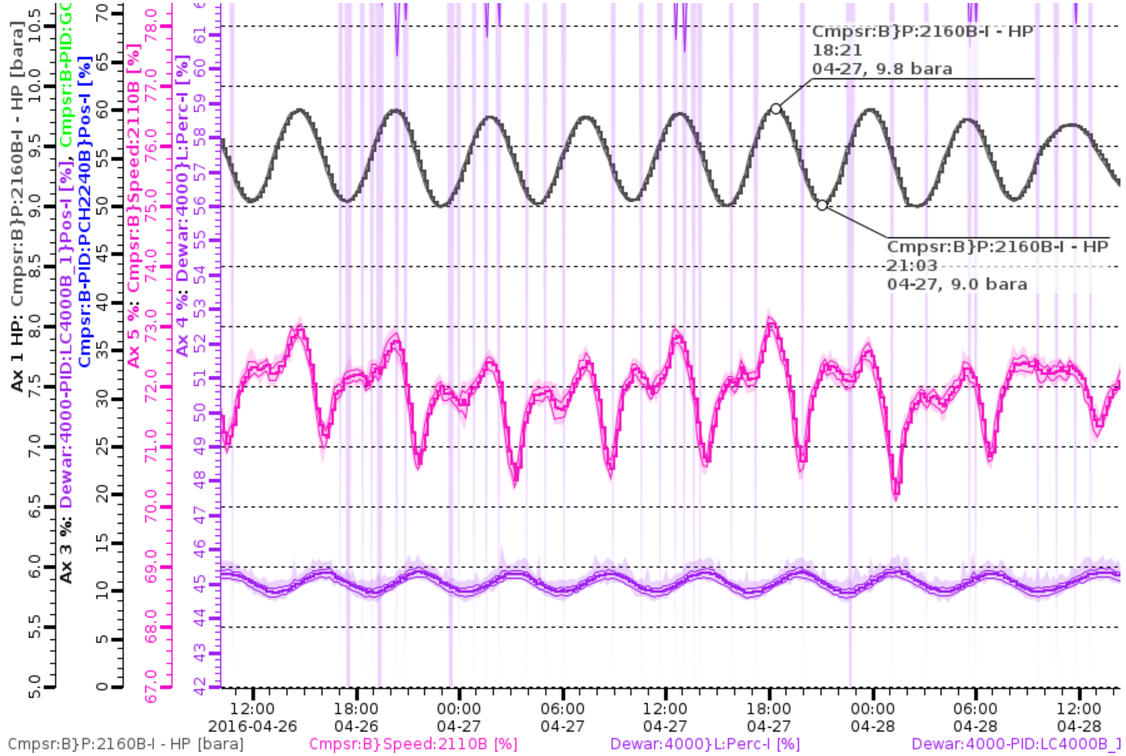
Commissioned in 2014 the cryoplant was tuned for operation with one Cavity only, 100 W load on LHe supply.

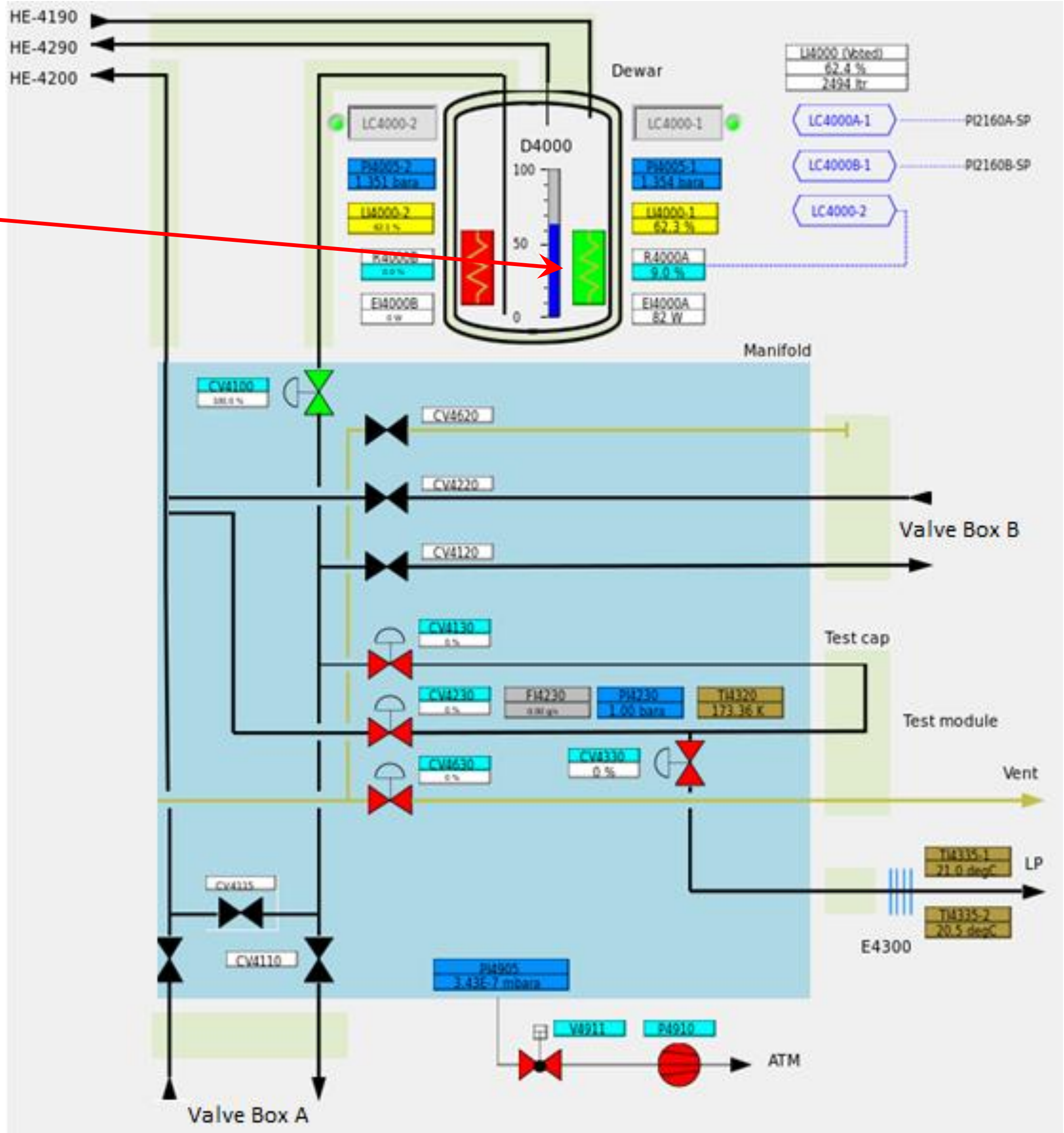
Beginning of 2016, a 2nd Cavity was added with the same 100 W load.

Process control issues

High pressure oscillations

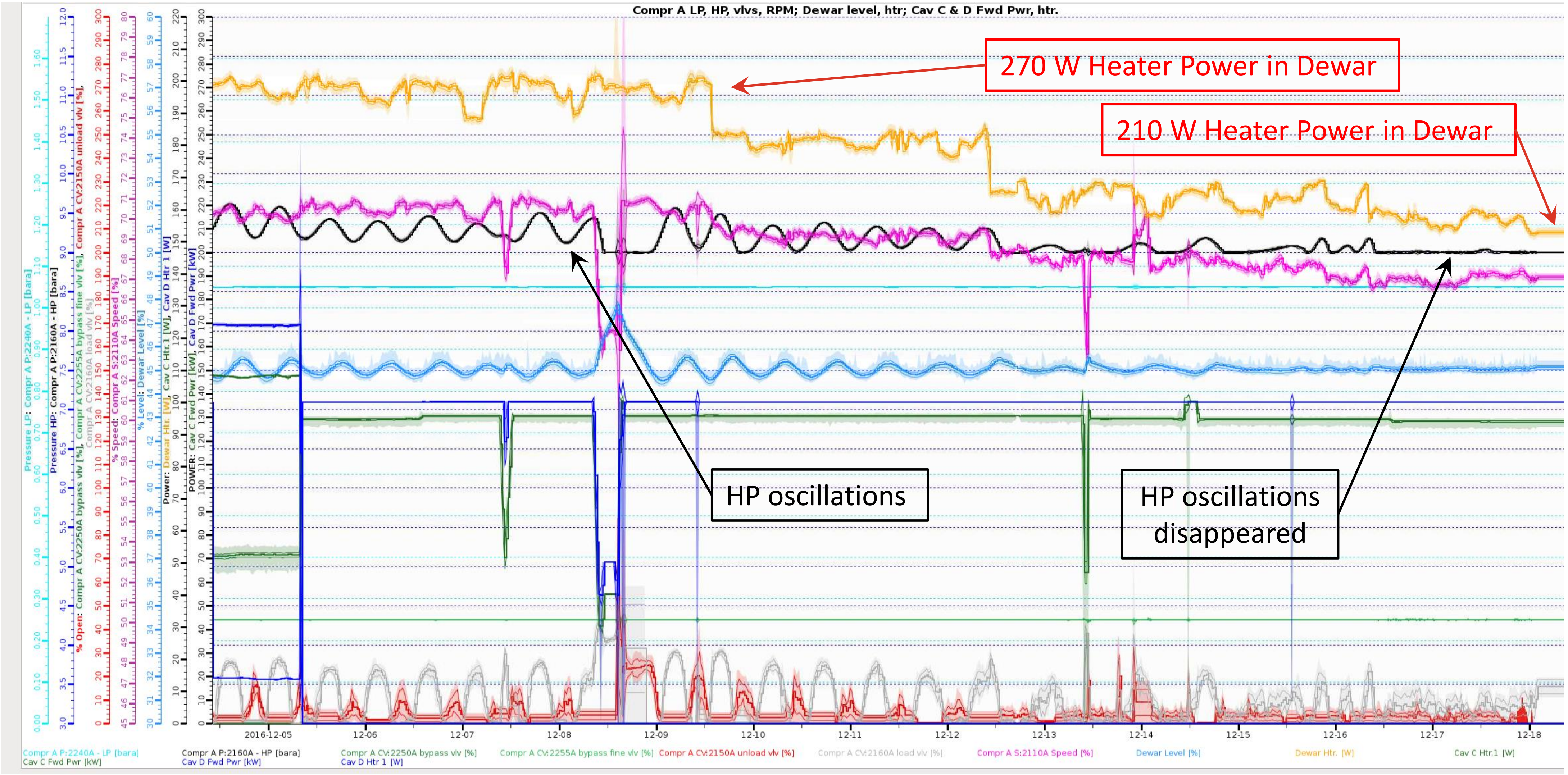
After Cavity D was added, the high-pressure oscillations appeared, up to 0.8 bar. The solution was to adjust the heater power in Dewar from 270 W down to 210 W to rebalance the load between Dewar and Cavity D.





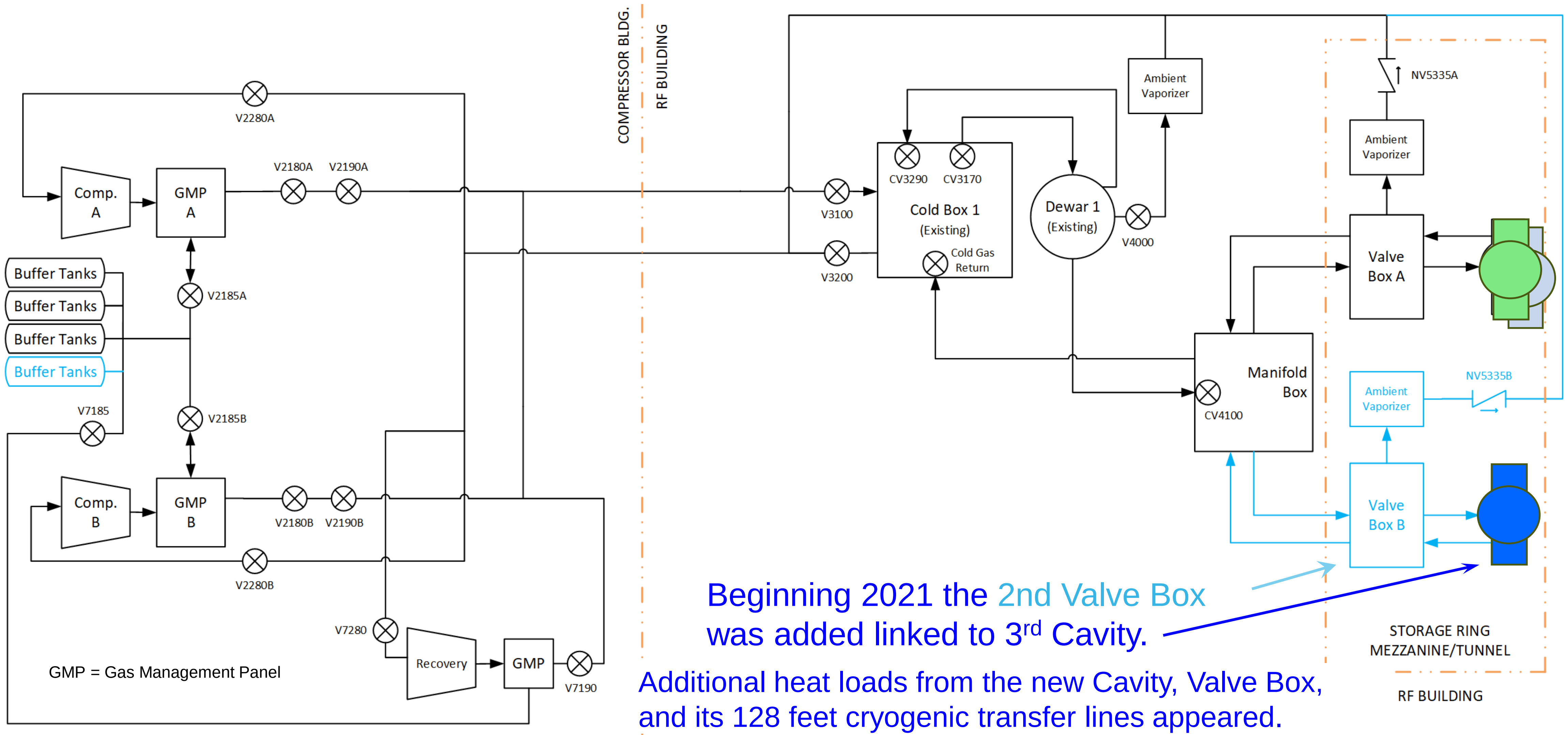
Process control issues

High pressure oscillations



Process control issues

High pressure oscillations



Beginning 2021 the 2nd Valve Box was added linked to 3rd Cavity.

Additional heat loads from the new Cavity, Valve Box, and its 128 feet cryogenic transfer lines appeared.

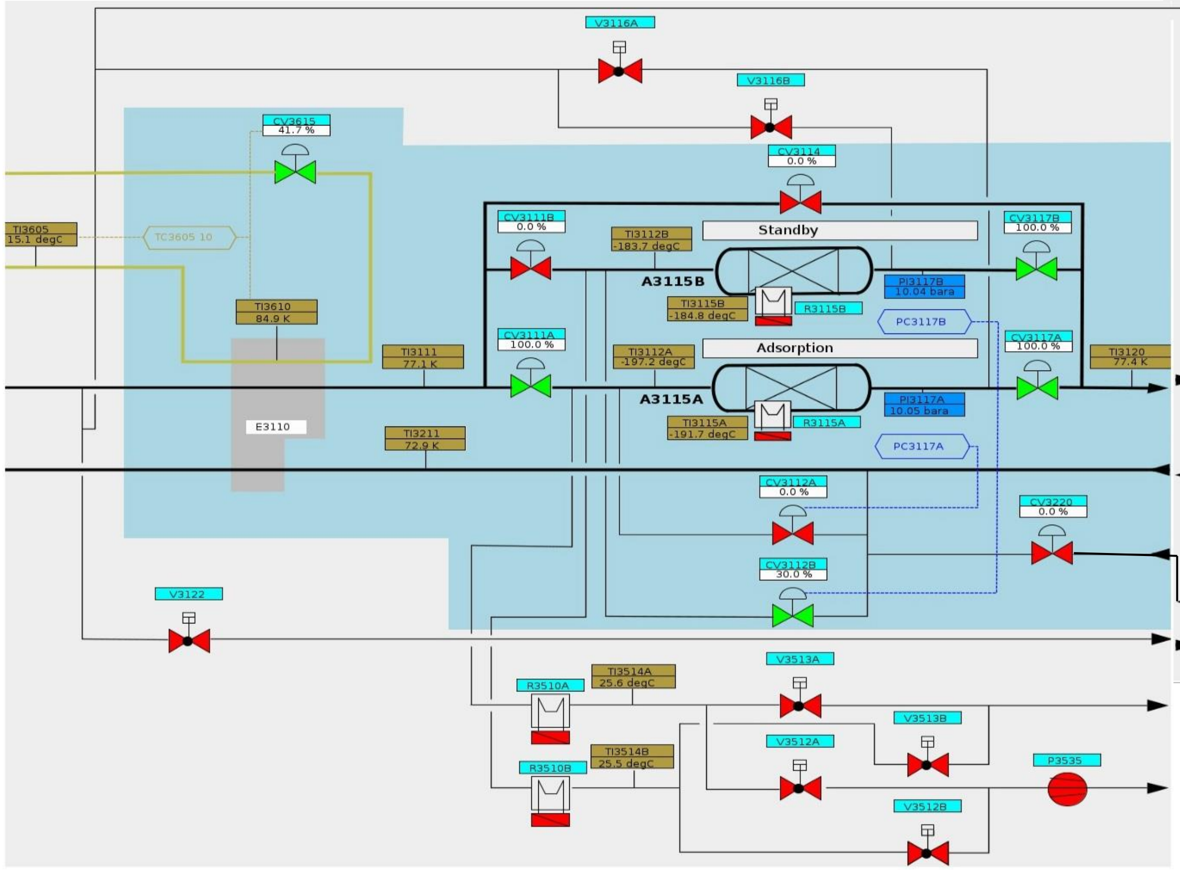
To avoid HP oscillation the heater power in Dewar was adjusted from 210 W down to 80 W, but this wasn't enough. The operating pressure set point increase from 9 bara up to 10 bara was required also.

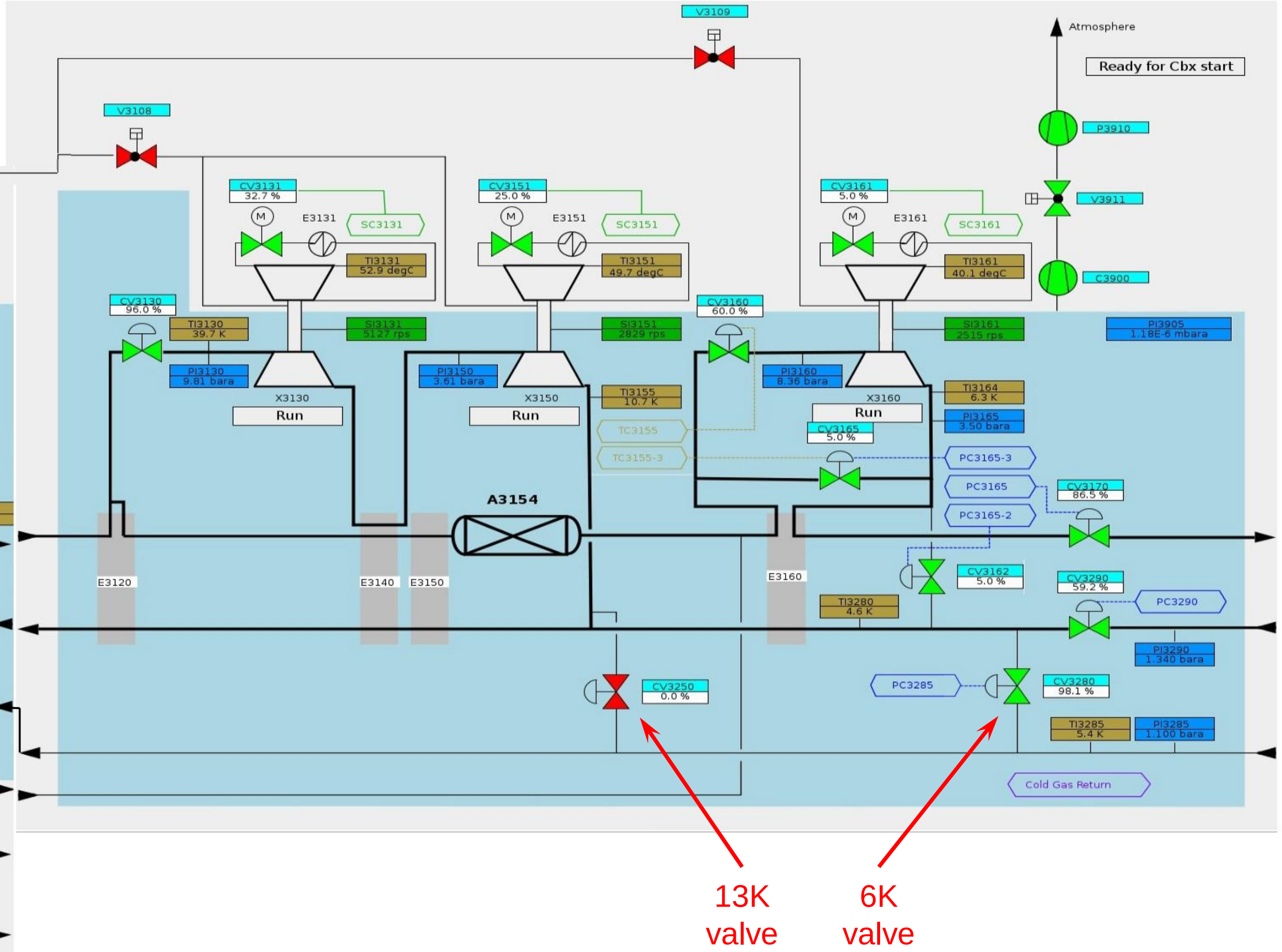
Process control issues

<u>transition from 13K valve to 6K valve during cooling down</u>

After cryoplant 2021 expansion there was another issue that was discovered. The increase of the LHe supply proportionally increased the gaseous Helium return to the cold box, almost doubling it.

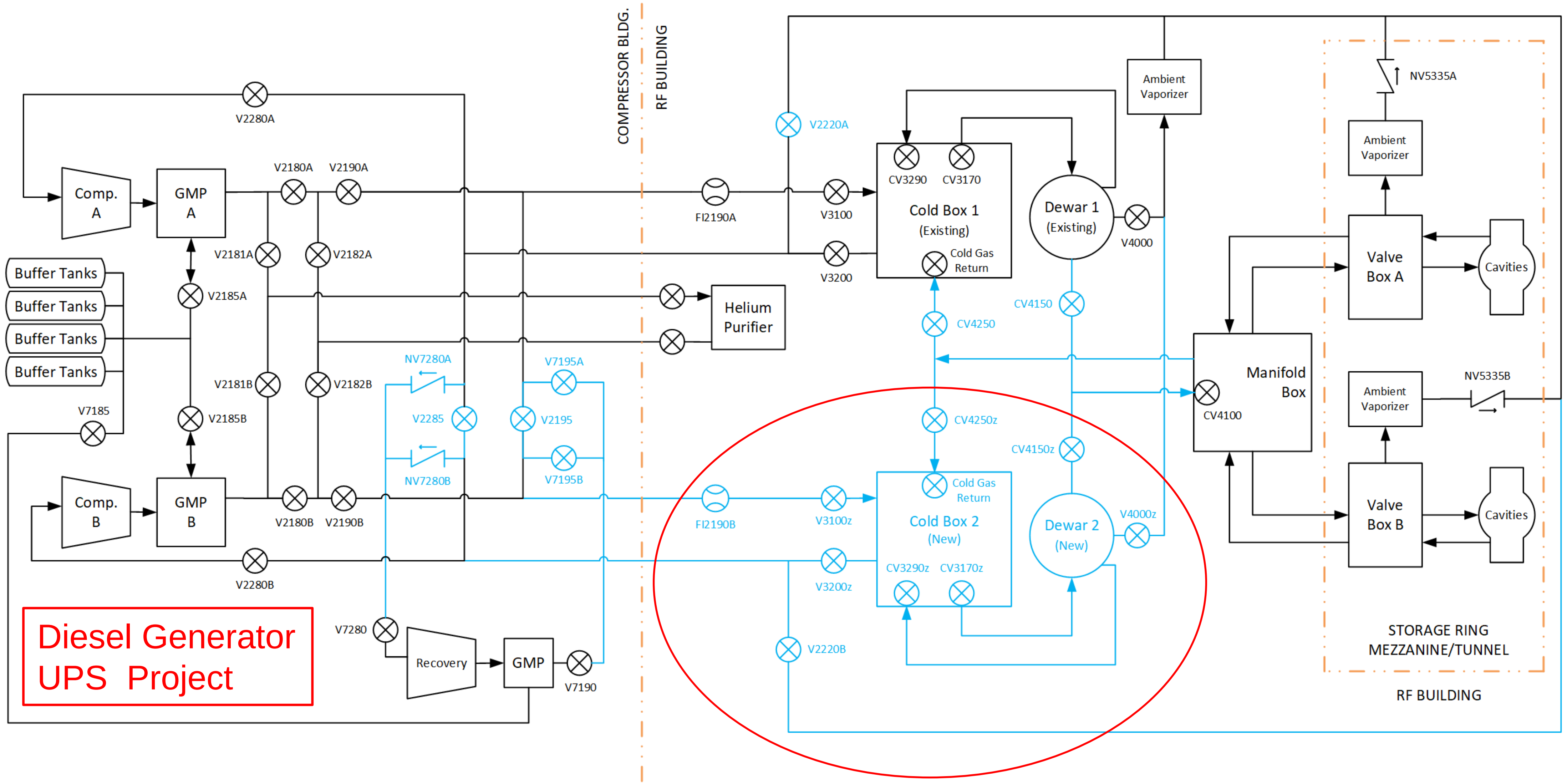
The automatic PLC algorithm that was working well during commissioning would no longer switch between 13K and 6K valves during the cooldown process without tripping.





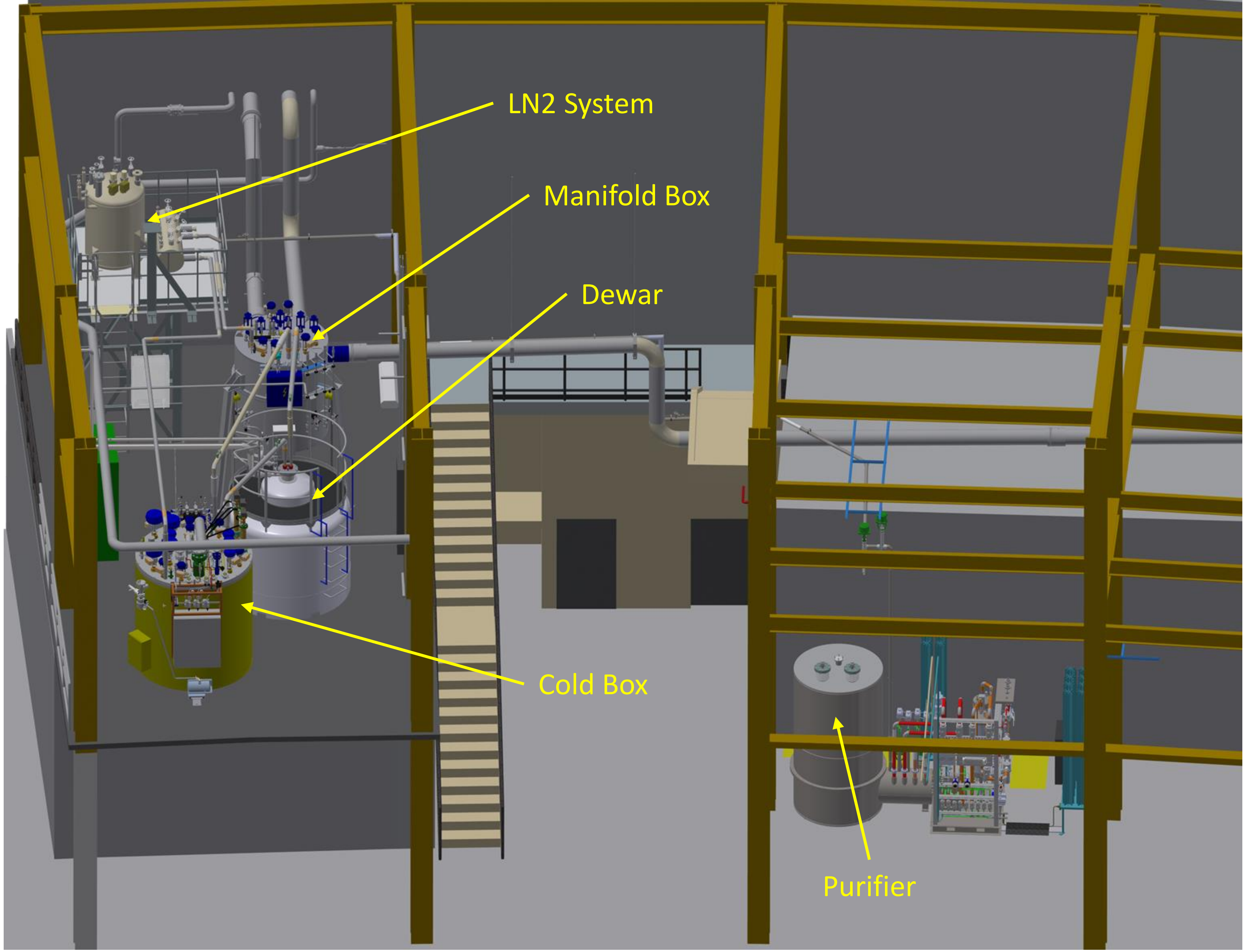
Future Plans

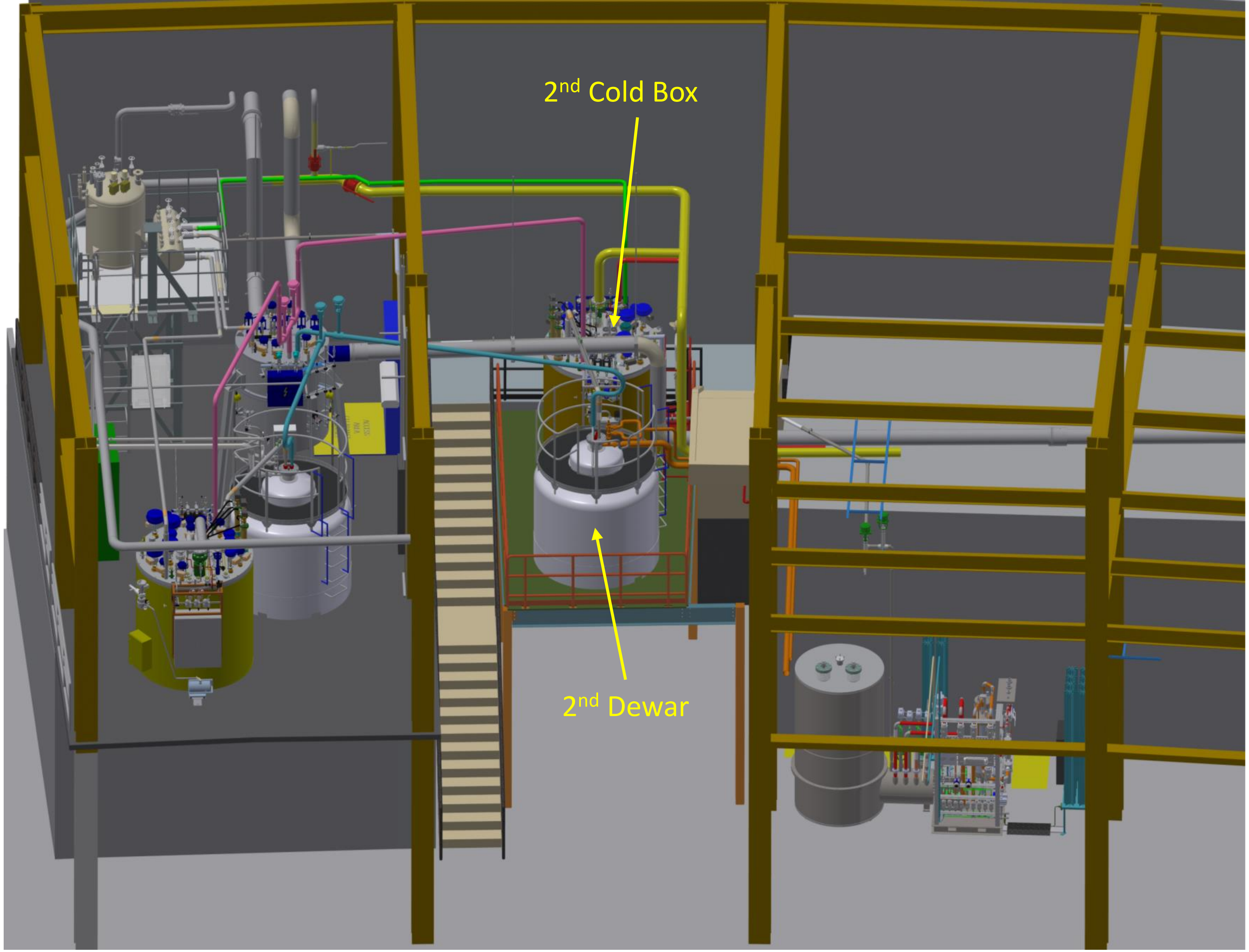
Cold Box-2 Project



Diesel Generator UPS Project

Cold Box-2 Project


LN2 System
Manifold Box
Dewar
Cold Box
Purifier


2nd Cold Box
2nd Dewar

Summary

- The Helium Cryogenic Plant has been running since 2014
- Overall, the plant has been running very reliable.
- Over the last 10 years, we have experienced a series of unfortune events resulting in contaminating the system.
- A number of improvements increased the reliability of the cryoplant.
- The redundant future cold box-2 will allow us to switch between systems and perform preventive maintenance on the standby system.
- The controls issues due to the cryoplant expansion during last 10 years have been addressed and will be incorporated in the future operation.

Thank you for your attention