Summary of cryogenic performance

Johan Bremer, Michel Chalifour,Shuoxing Wu
Laura Manenti & Laura Molina Bueno

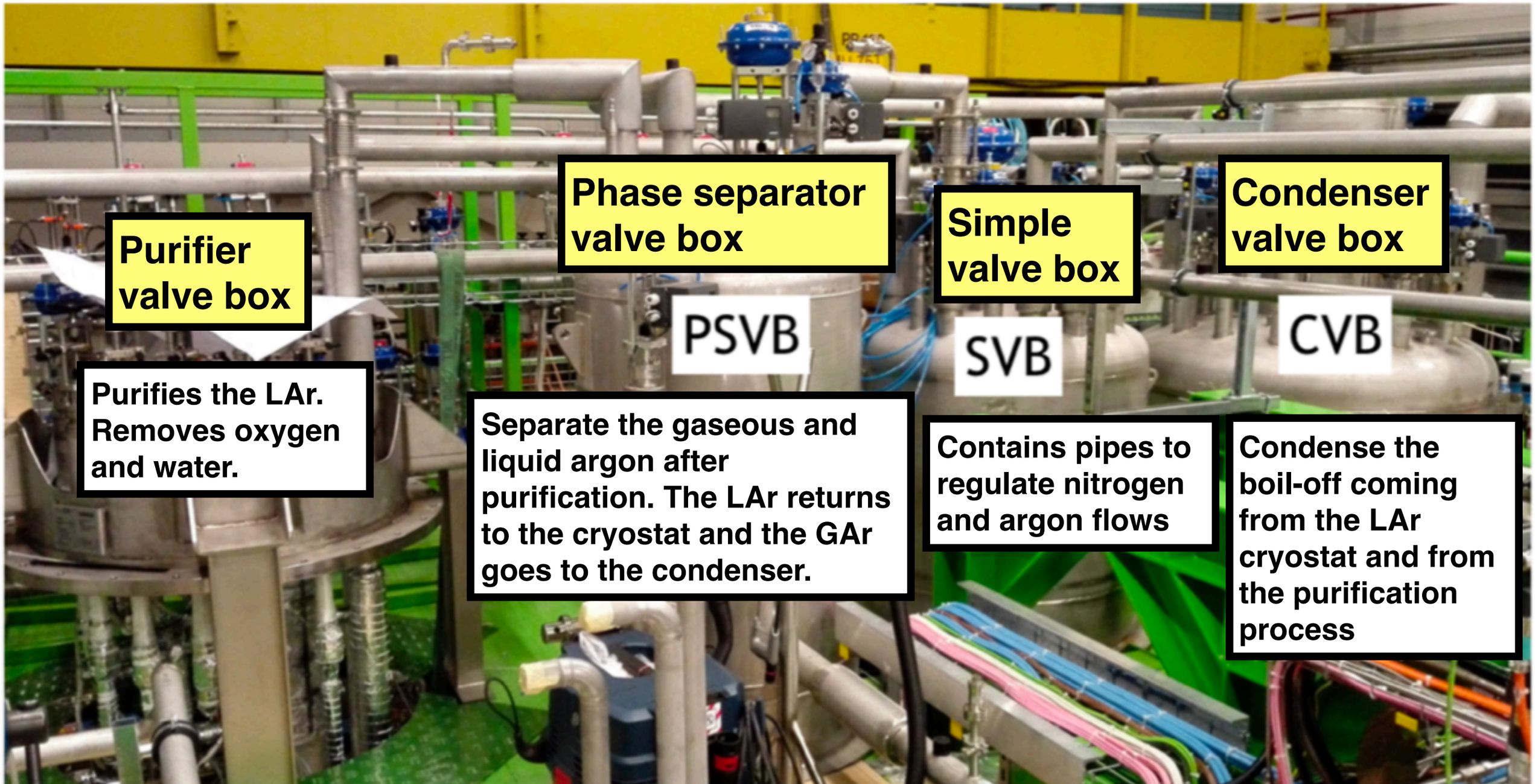
Outline

1. The cryogenic system
2. The cryogenic tasks
3. Cryogenic stages:
    1. Purge in open loop
    2. Purge in closed loop
    3. Cool down
4. Summary

The cryogenic system

Groups multiple valves and pipes into cold boxes with common vacuum insulation

“Valve box”



The cryogenic tasks

Aims to safely condense the boiling-off gas and provide purification to both the gas and liquid argon

LAr purity better than 0.1 ppb oxygen equivalent

Purge and gas purification system

Remove the air from the tank and fill with pure argon gas.

Boiling-Off gas compensation and purification system

Through the CVB the system re-condense the boil-off argon gas.

LAr recirculation and purification system

The LAr is recirculated with the help of a submersed cryogenic liquid pump and gets purified inside the PVB

Cryogenic stages

1.Purge in open loop

Oxygen, nitrogen and moisture below 50 ppm

2.Purge in closed loop

Oxygen 0.2 ppm, nitrogen 3.5 ppm and moisture 25 ppm

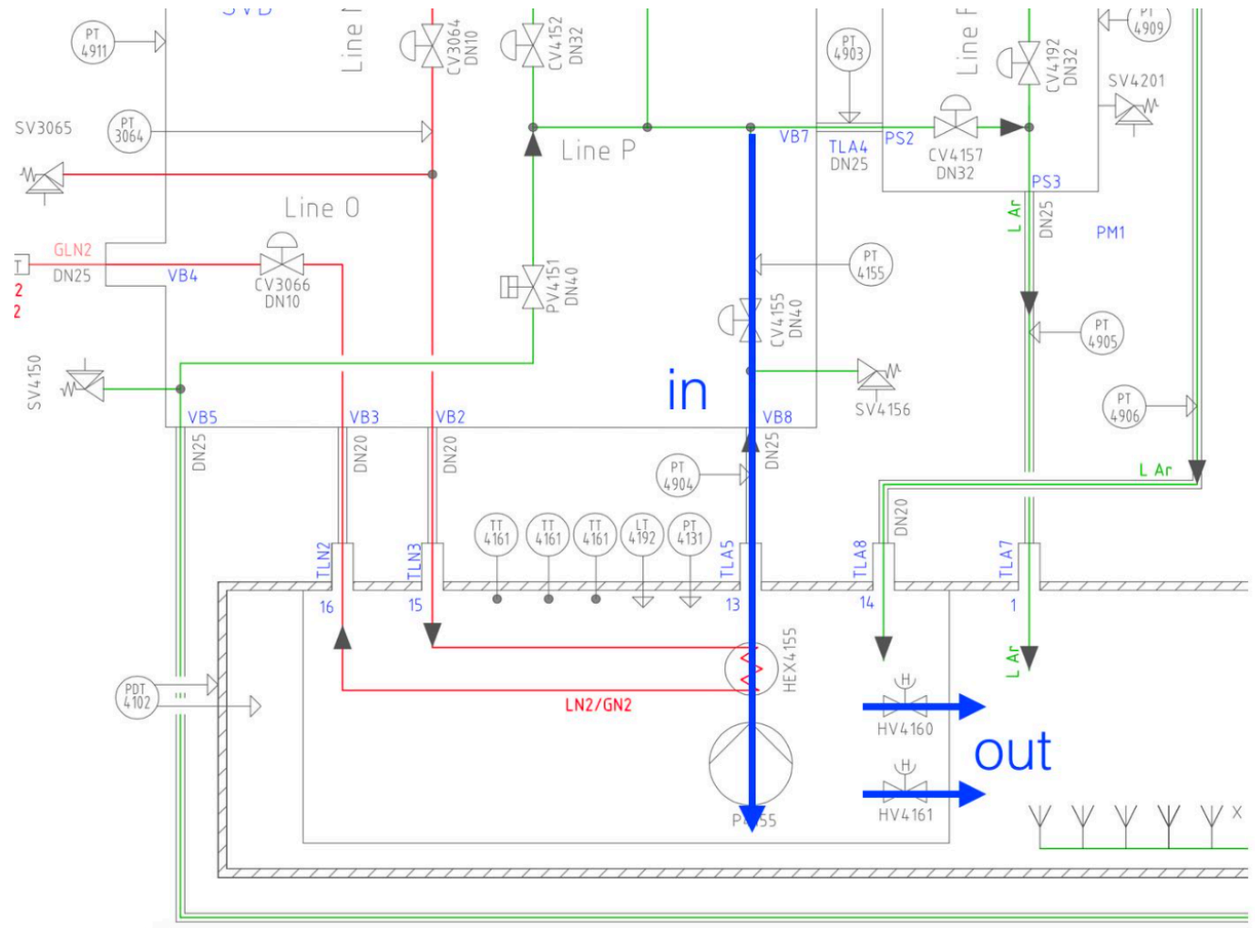
3.Cool down

Average temperature in the tank~87 K

4.Filling

Purging in open/closed loop

1. **Purging** of the **main pipes**
2. Then**, flush GAr through the pump line into the vessel**, in this way we remove air and impurities trapped inside. Then the gas exits the main cryostat through the 2 cryogenics valves welded onto the pump tower (HV4160 and HV4161)(10 volumes of the pump tower needed to be flushed).



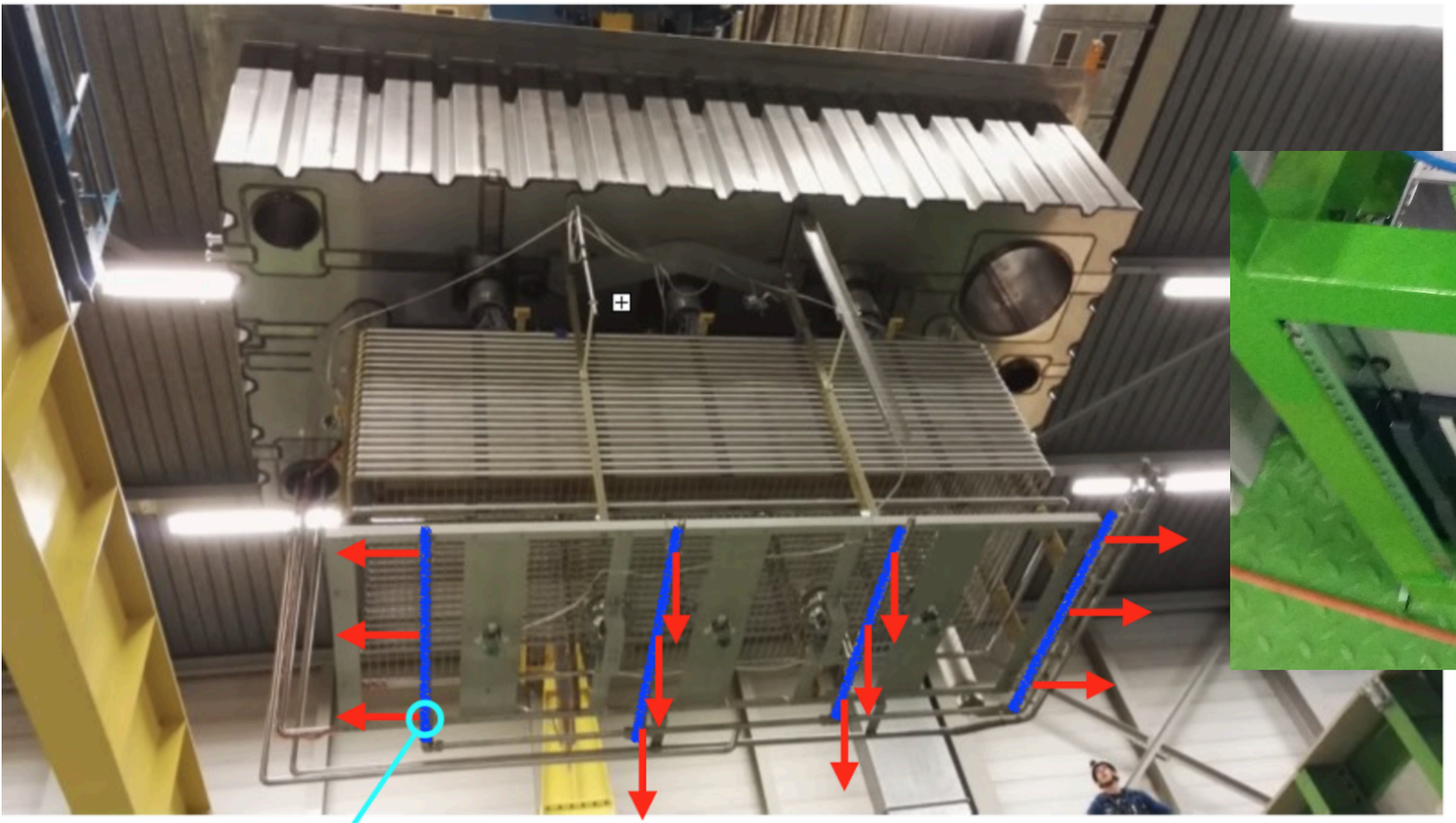
ISSUES:

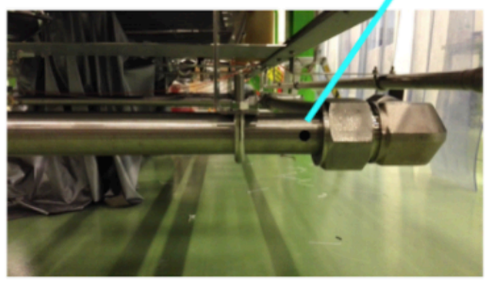
✦A large leak at the level of the **CF250 flange** gasket. When we opened we found there was no incision on the copper gasket. We found the gasket was at the same height of the rotatable flange. We solved the issue by putting a spacer underneath.

✦The gasket in the **CF-400 flange** was not properly fixed because the flange was deformed (not perfectly flat and round). This was solved by carefully screwing and positioning the gas.

✦ **Major leak from pump tower to main volume**: there are two manual valves which connect the pump tower to the cryostat. We realized that even when both were closed, there was gas going from the pump tower to the cryostat. By inspecting with an endoscope, we found that **one of the bellows was broken**. It might have been damaged during transport. The pump tower was dismantled and **sent it to the CERN workshop for repairing and reinforcing**.

Purging in open/closed loop

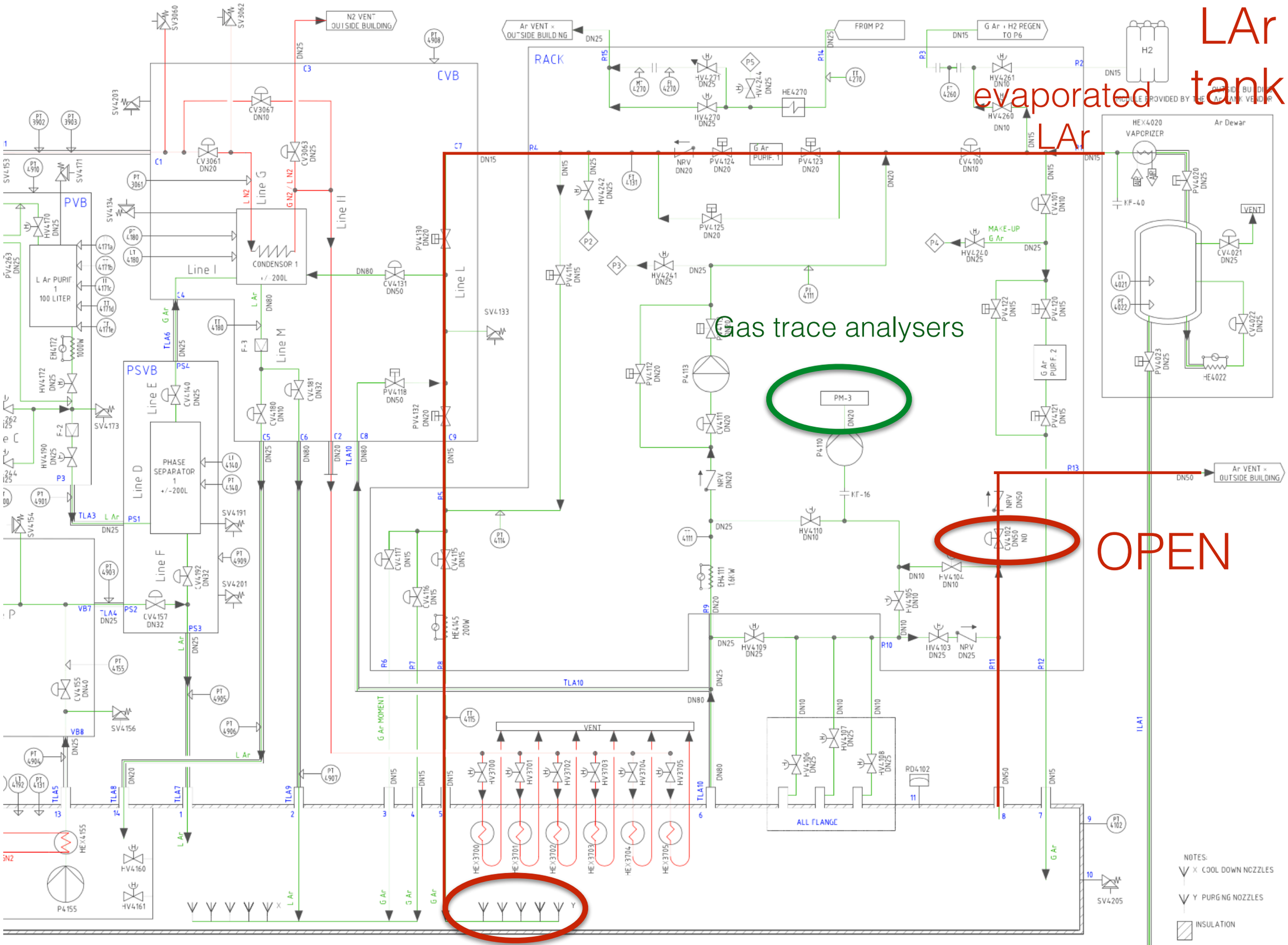




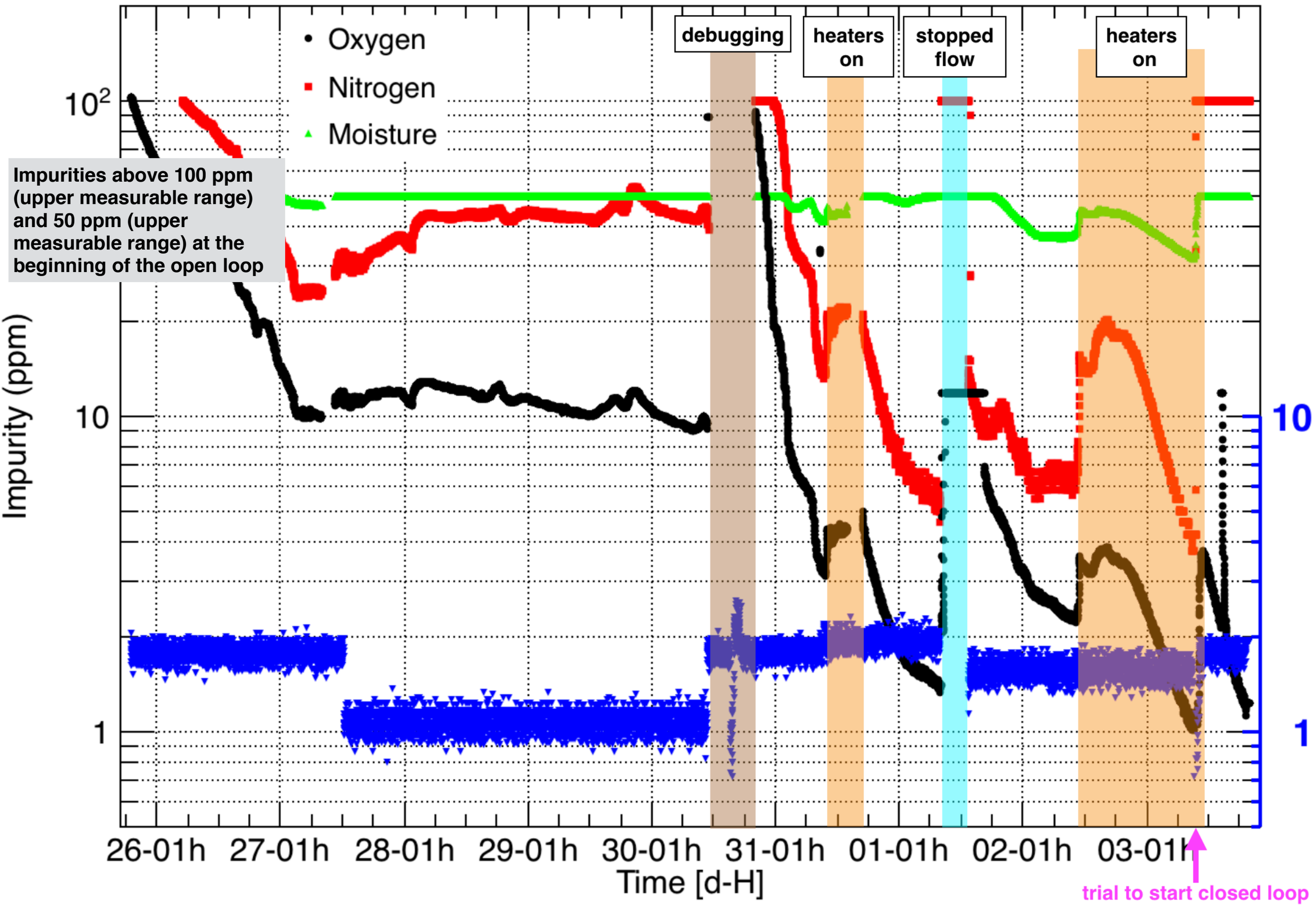
3. Instead of using the pump tower line, **we used the lines drawn in blue in the picture.** There are a total of **4 lines each with 3 openings of 12 mm diameter to perform the purge of the cryostat.** In the meantime, the gas was vented directly to outside through the control valve.

During the purge process, the gas impurities are continuously monitored and recorded with 3 trace analysers for nitrogen, oxygen and moisture. The sample gas to the trace analysers is taken with the help of a double diaphragm pump with a maximal capacity of 4.5 l/min.

Purging in open loop



Impurities during purge in open loop



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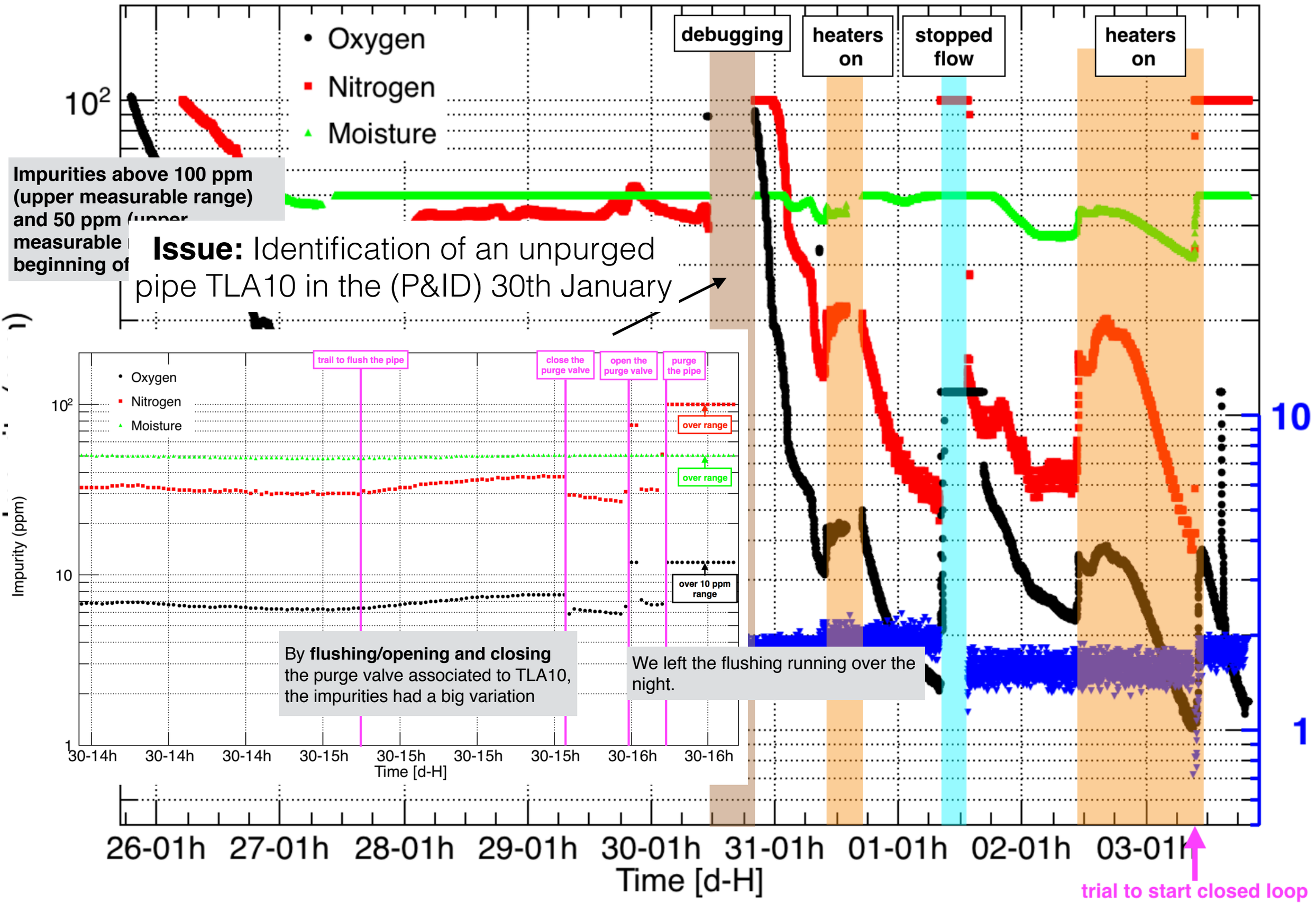

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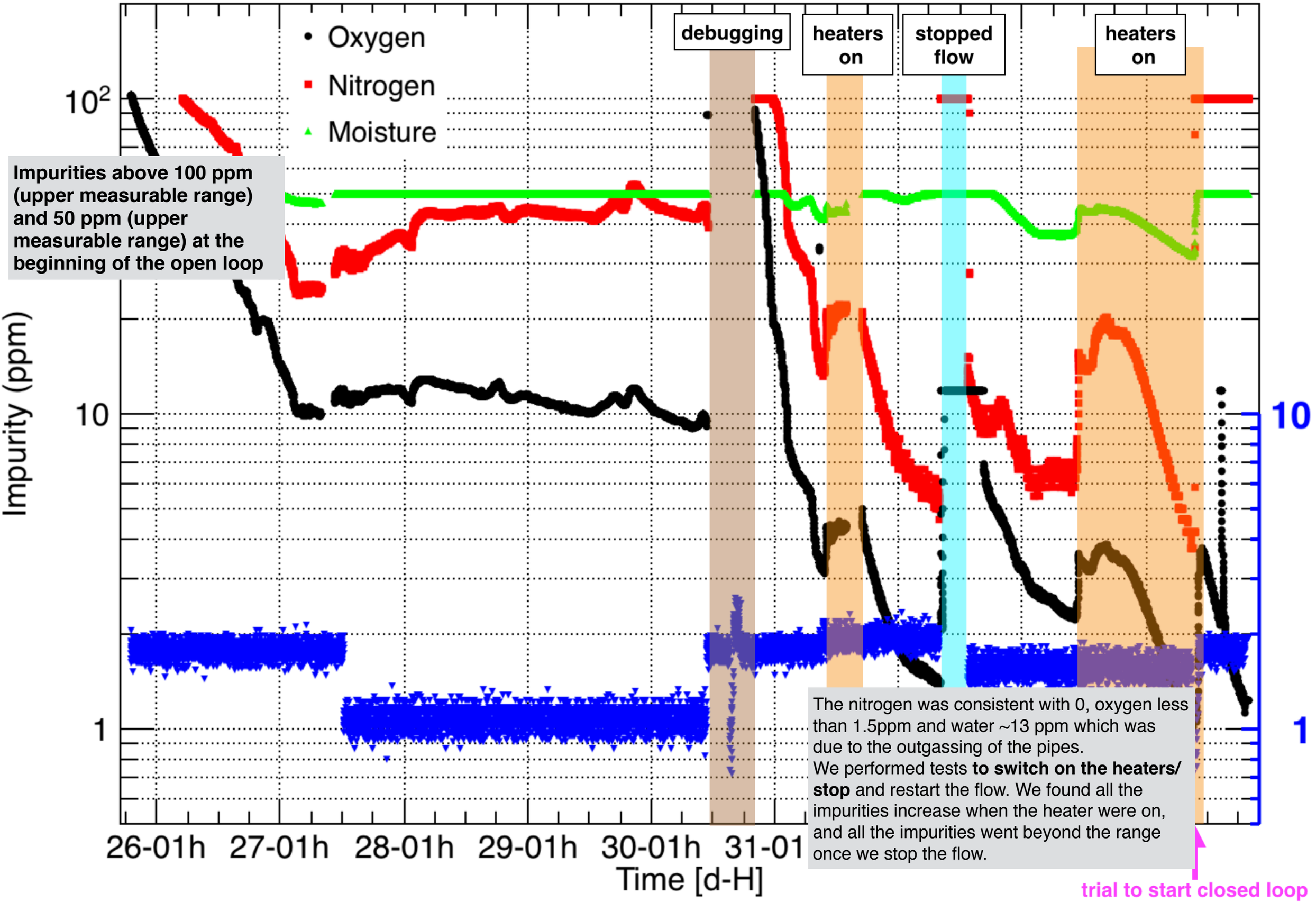

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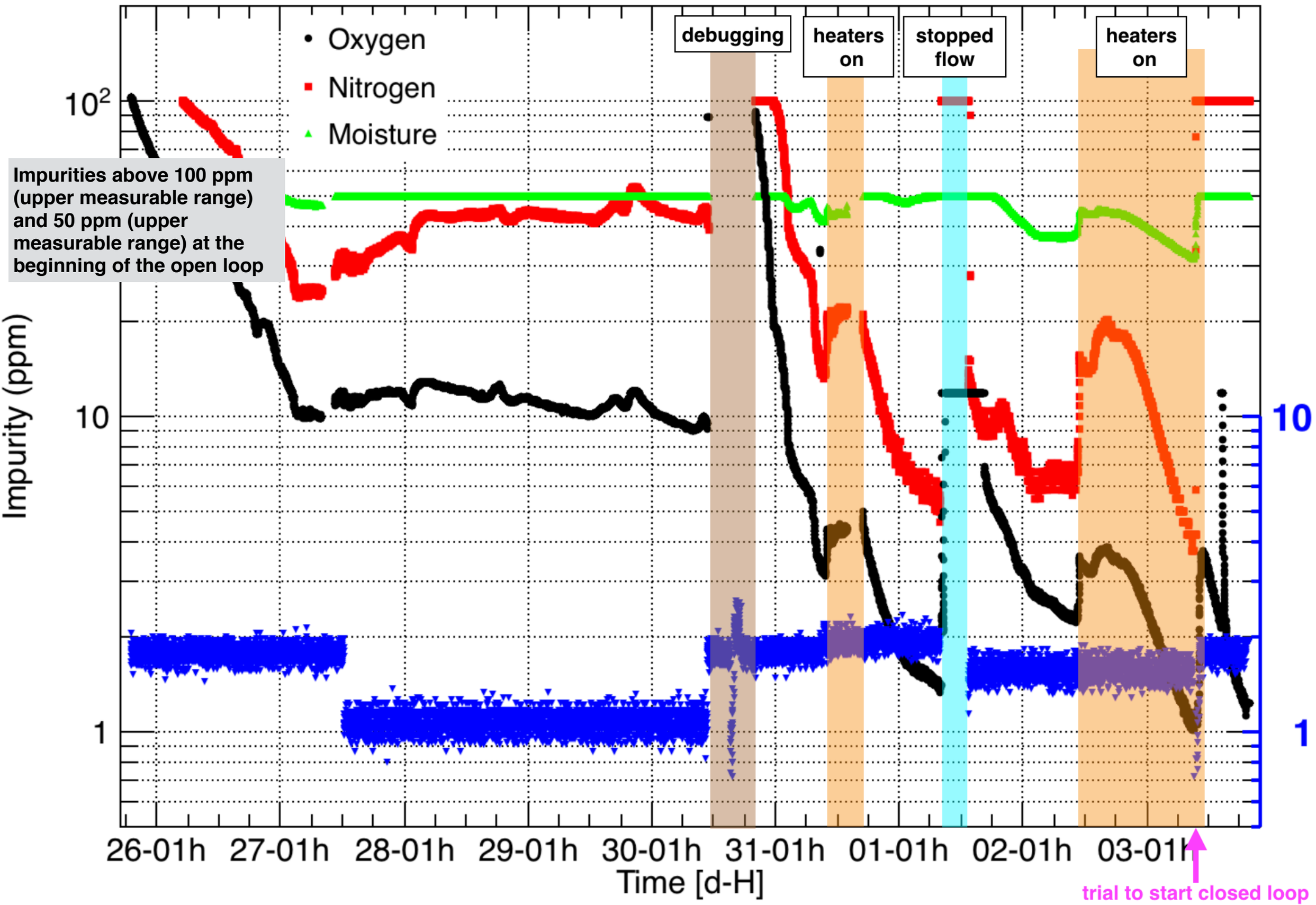
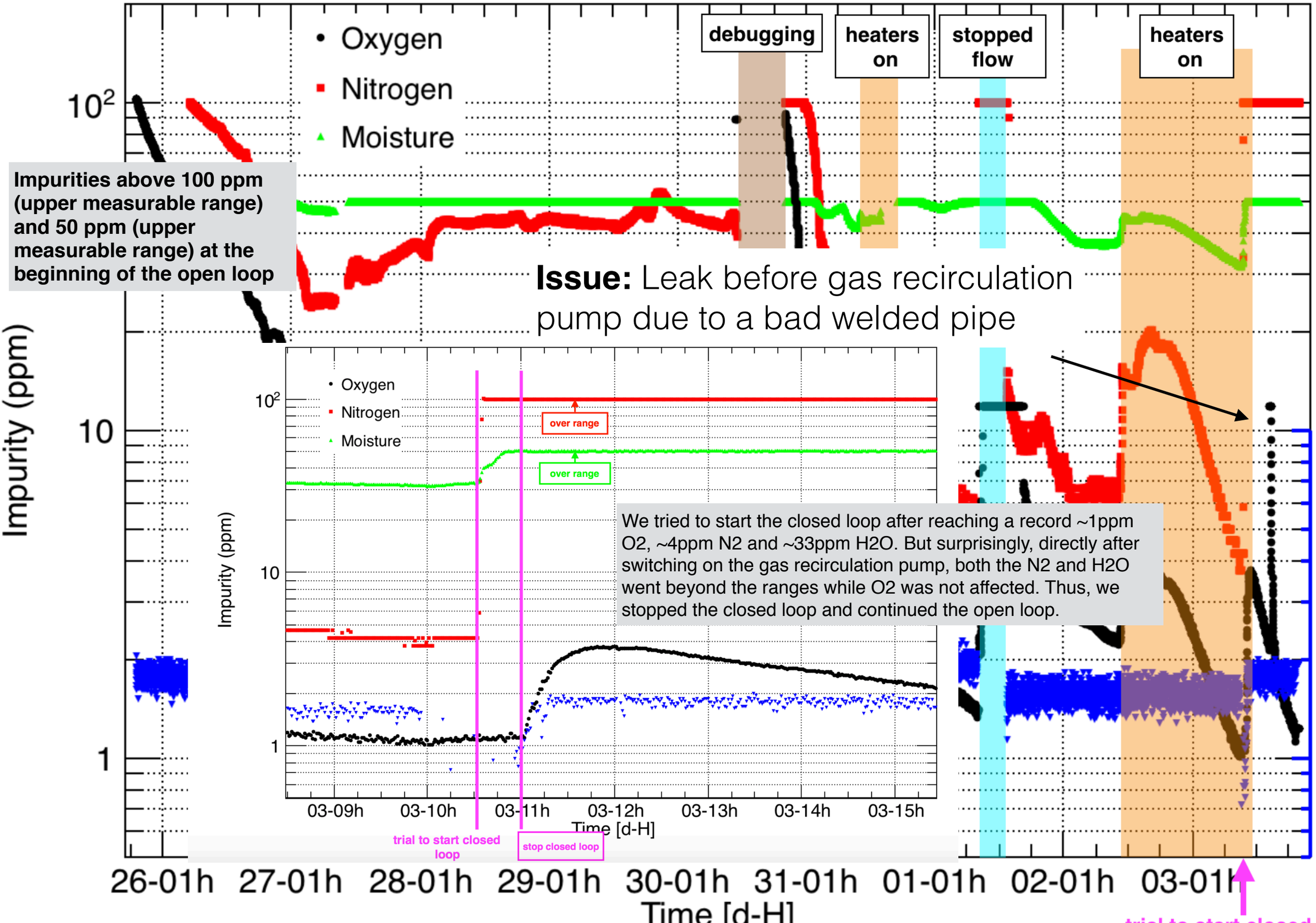


Impurities during purge in open loop

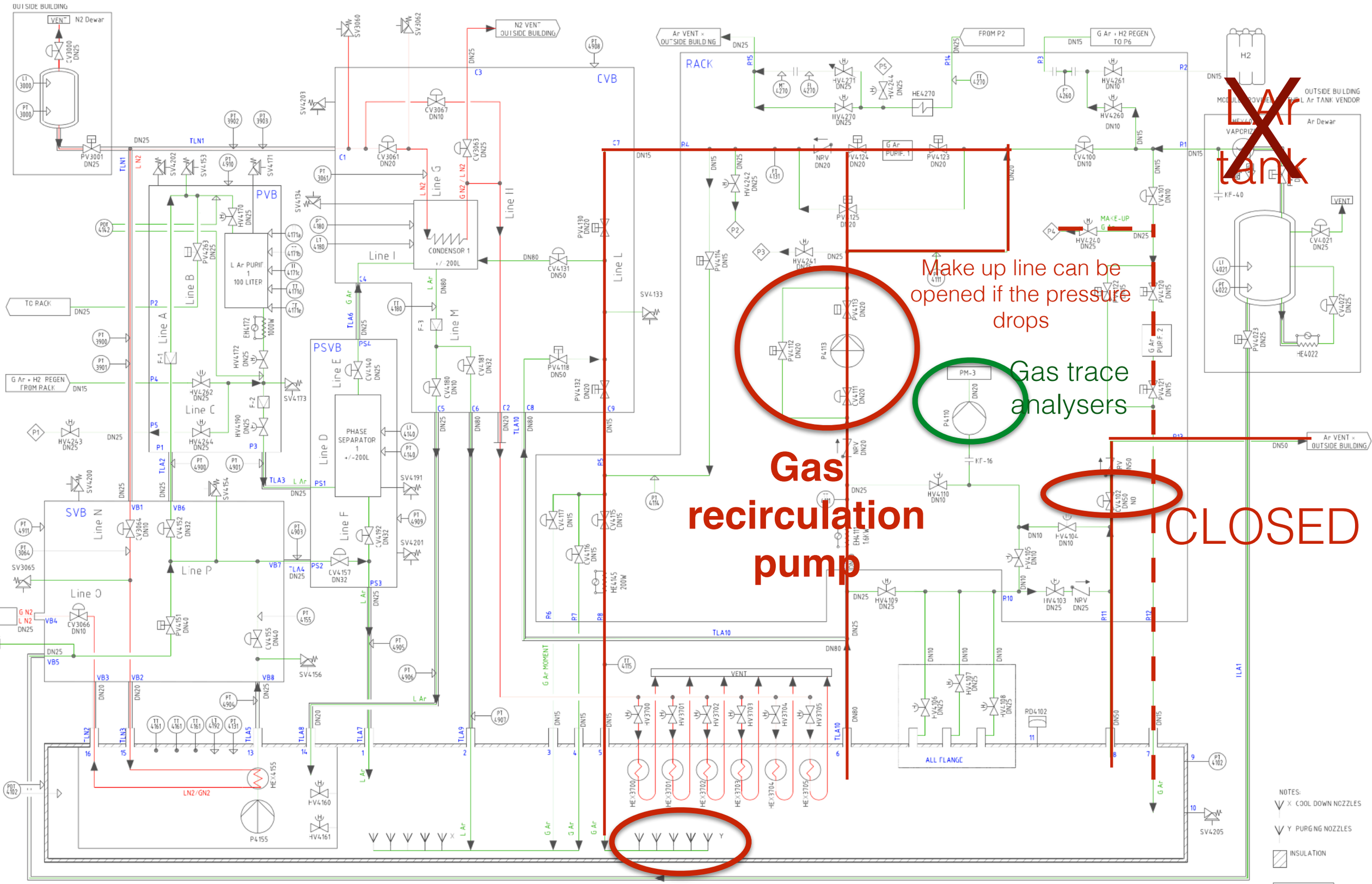
Impurities above 100 ppm (upper measurable range) and 50 ppm (upper measurable range) at the beginning of the open loop

Issue: Leak before gas recirculation pump due to a bad welded pipe

We tried to start the closed loop after reaching a record ~1ppm O2, ~4ppm N2 and ~33ppm H2O. But surprisingly, directly after switching on the gas recirculation pump, both the N2 and H2O went beyond the ranges while O2 was not affected. Thus, we stopped the closed loop and continued the open loop.



Purging in closed loop



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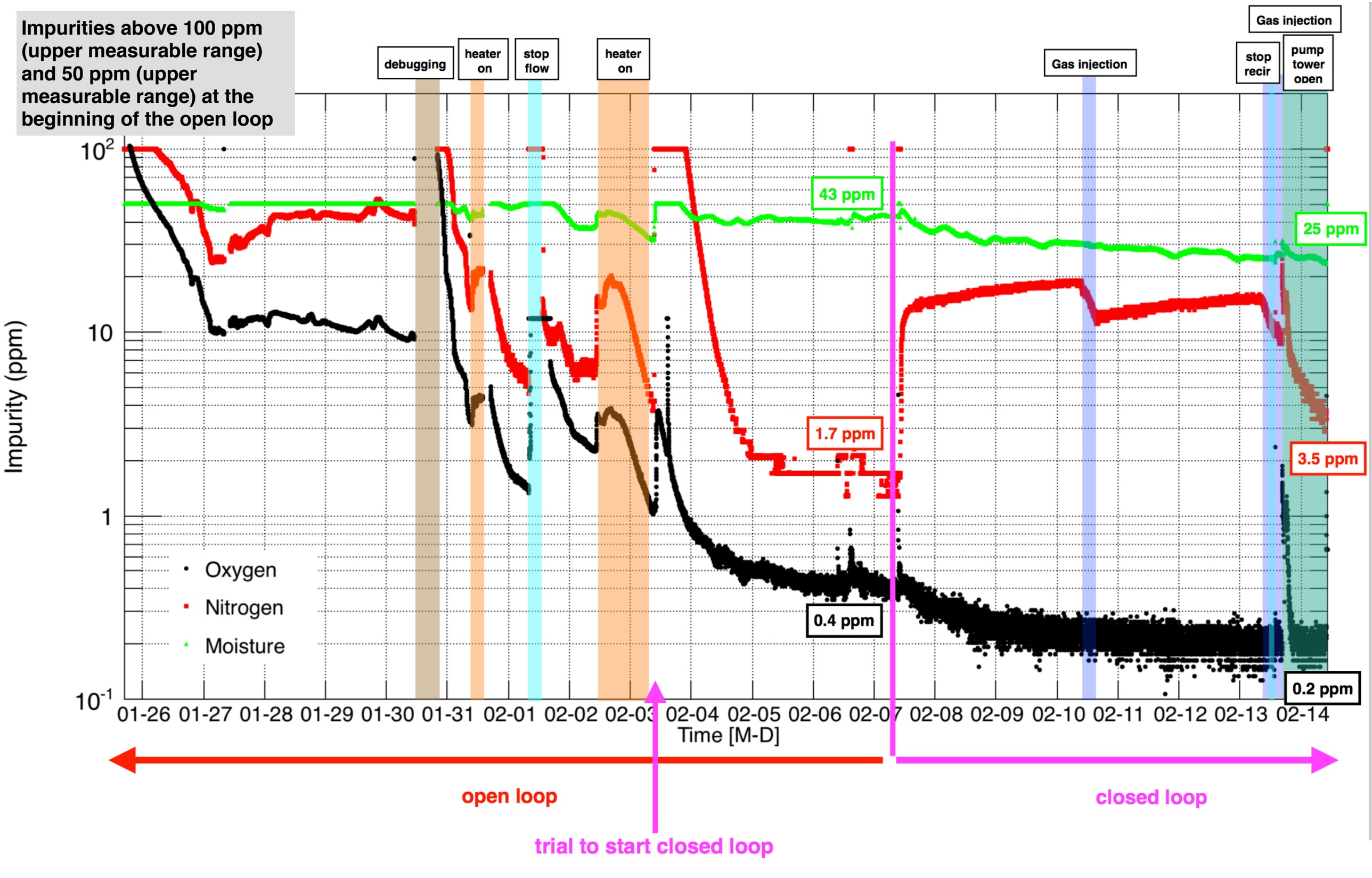

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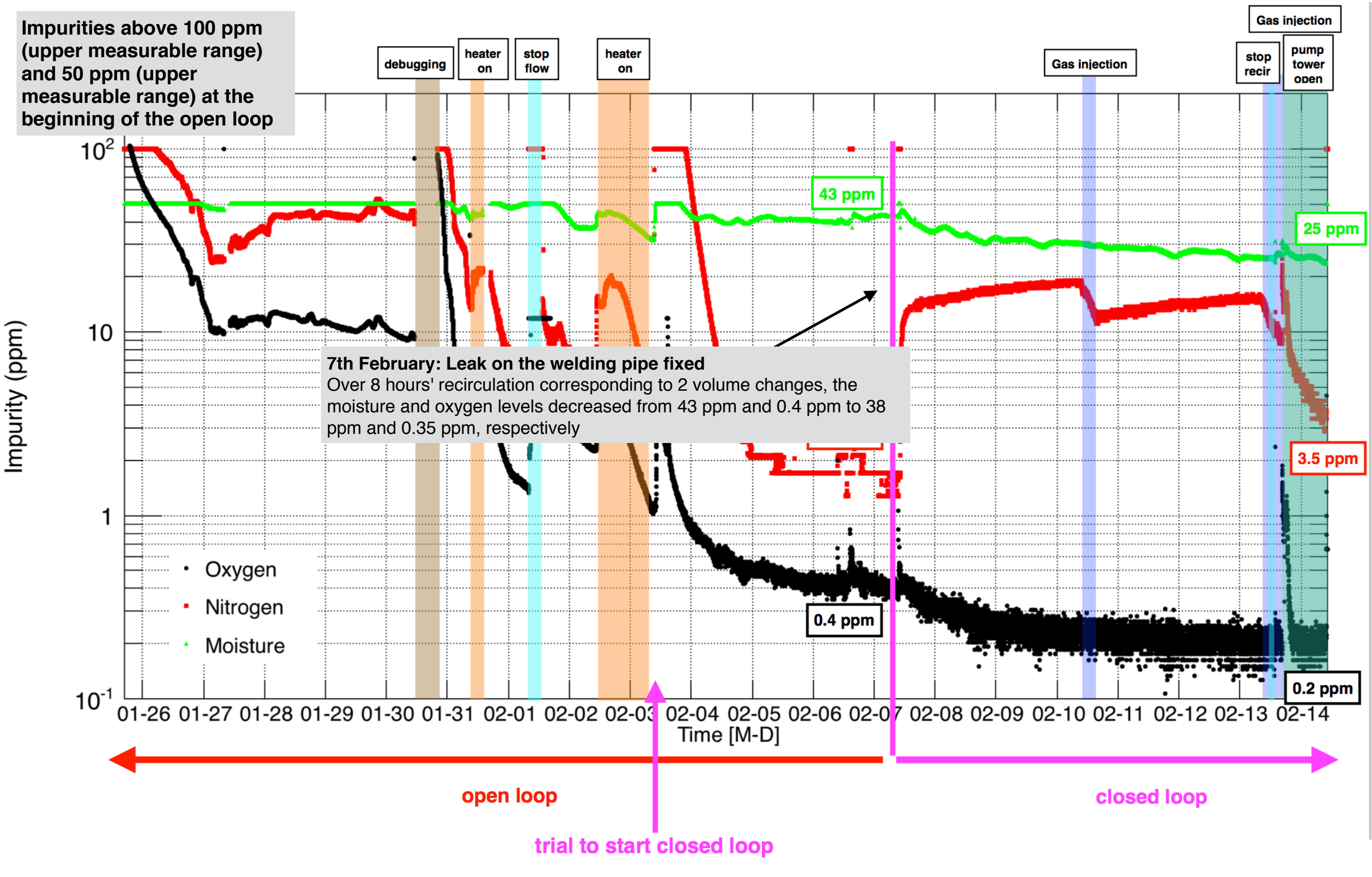

7th February: Leak on the welding pipe fixed
Over 8 hours' recirculation corresponding to 2 volume changes, the moisture and oxygen levels decreased from 43 ppm and 0.4 ppm to 38 ppm and 0.35 ppm, respectively

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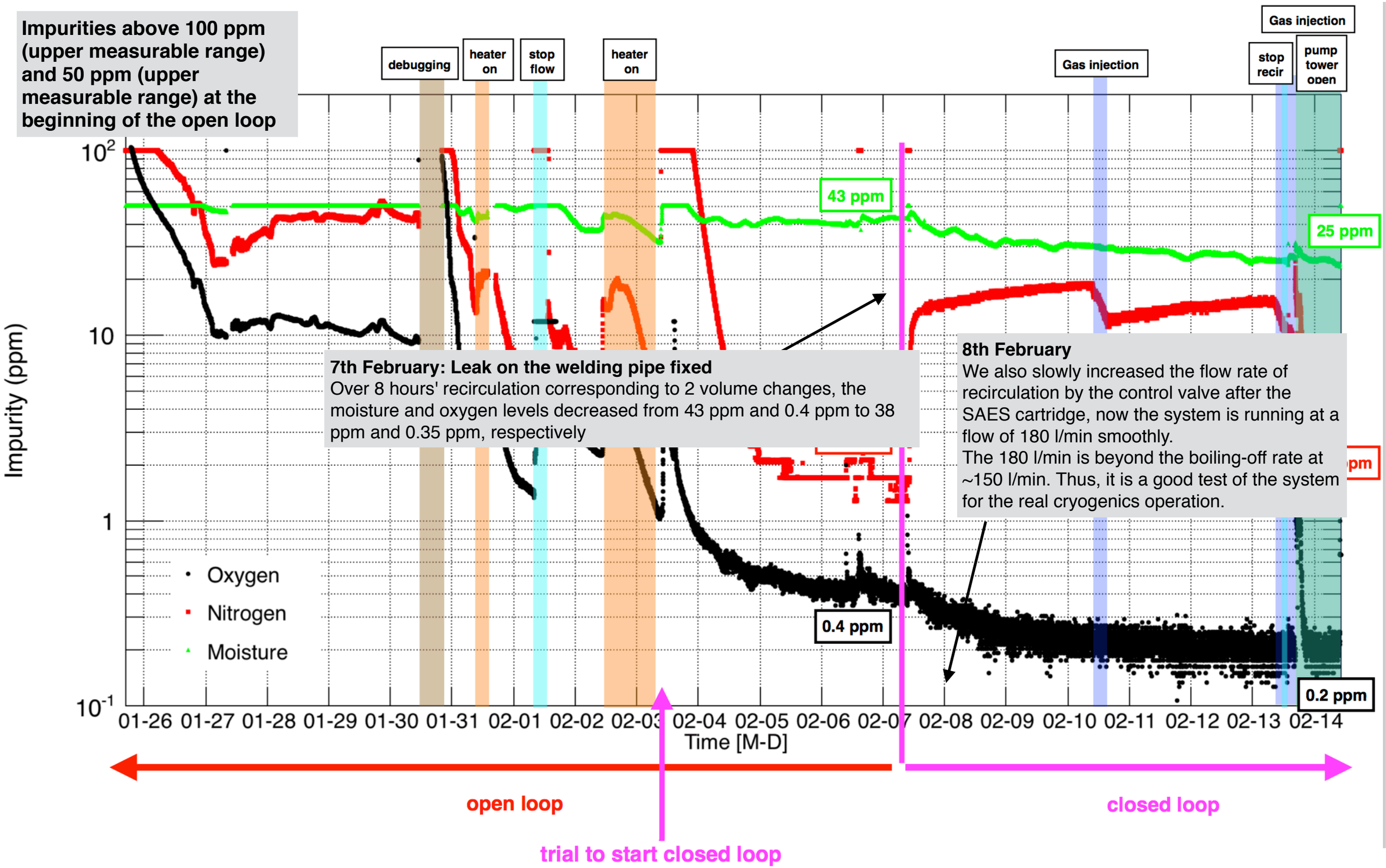

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8th February
We also slowly increased the flow rate of recirculation by the control valve after the SAES cartridge, now the system is running at a flow of 180 l/min smoothly.
The 180 l/min is beyond the boiling-off rate at ~150 l/min. Thus, it is a good test of the system for the real cryogenics operation.

Impurities after purging

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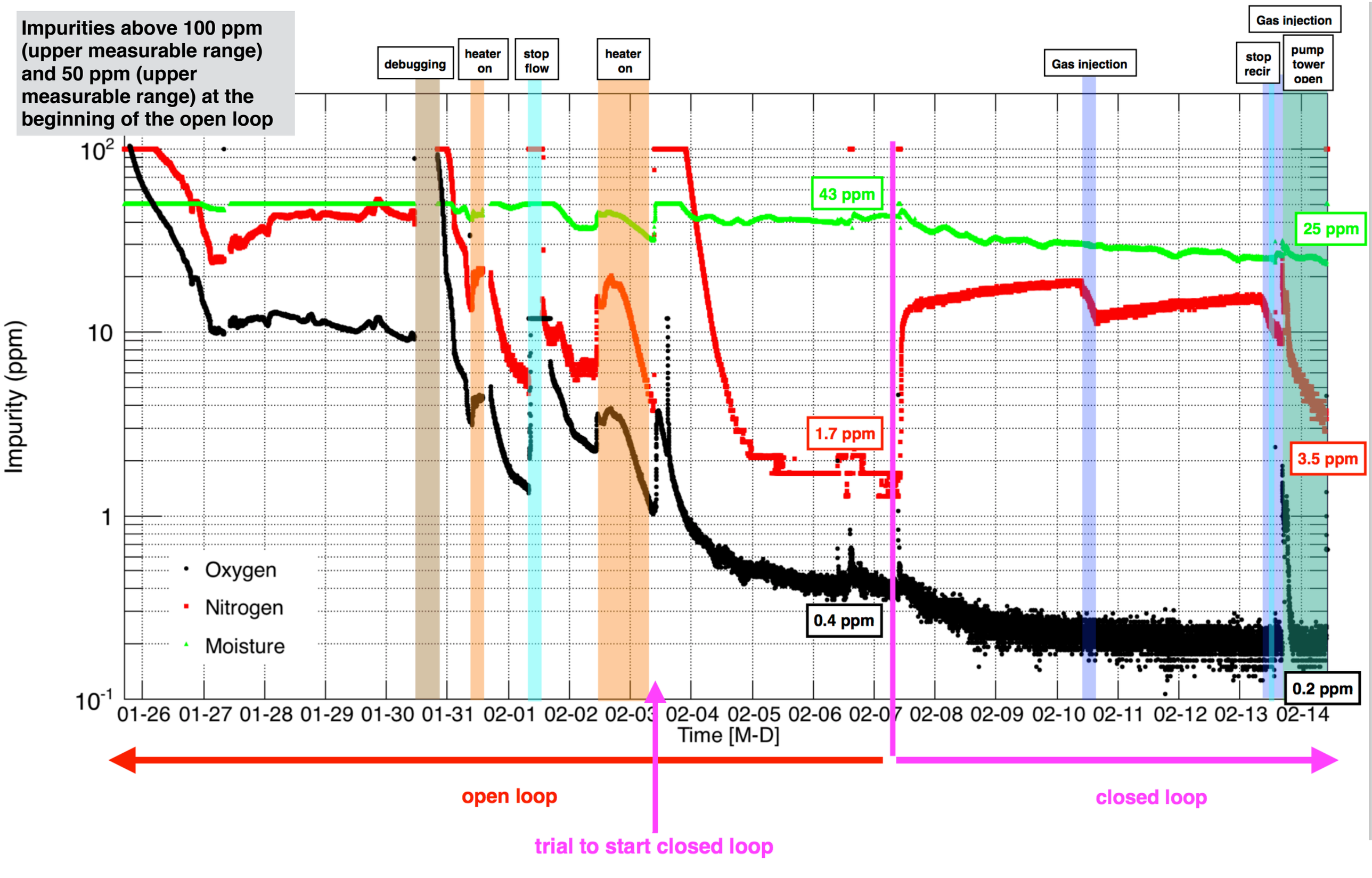

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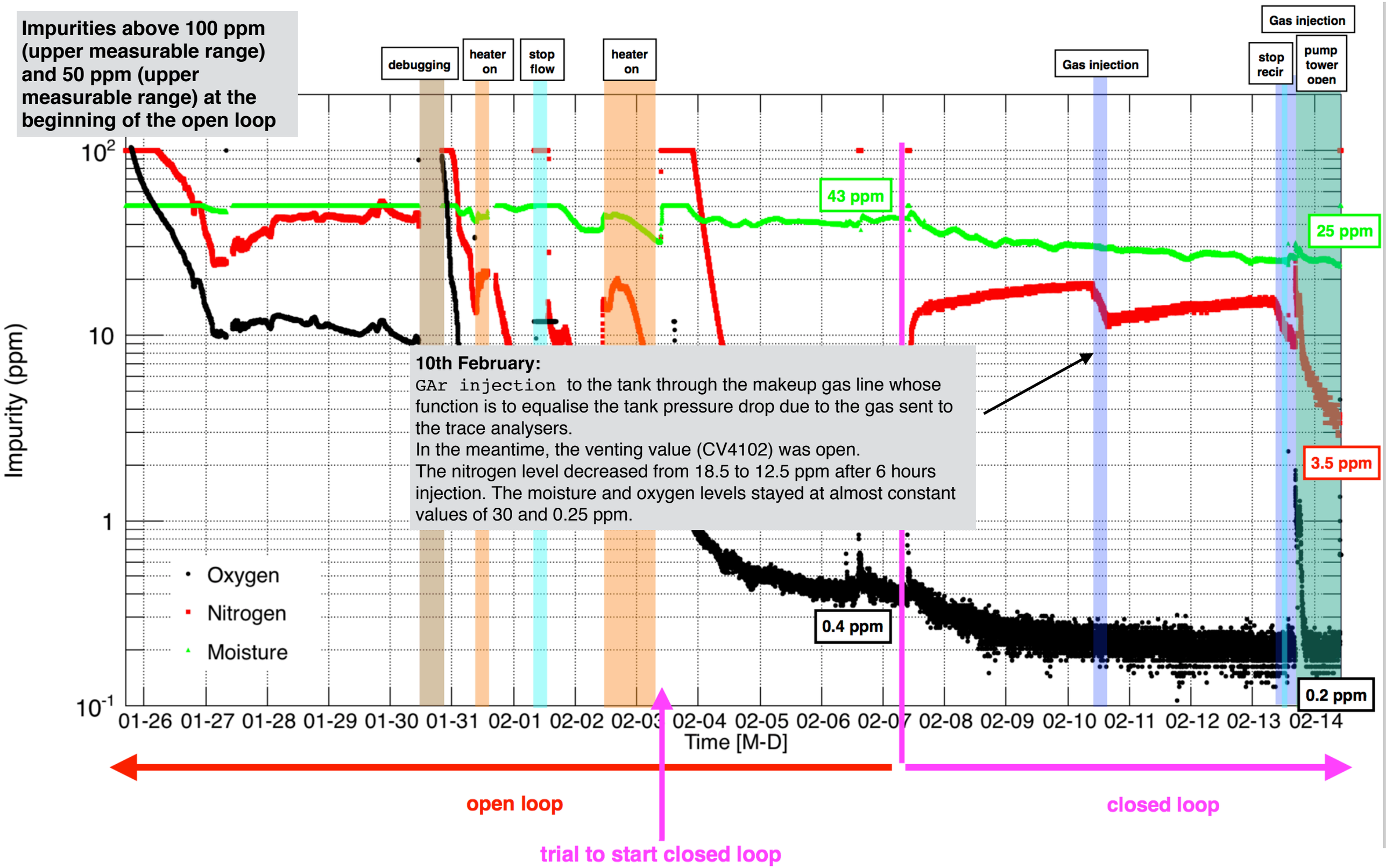
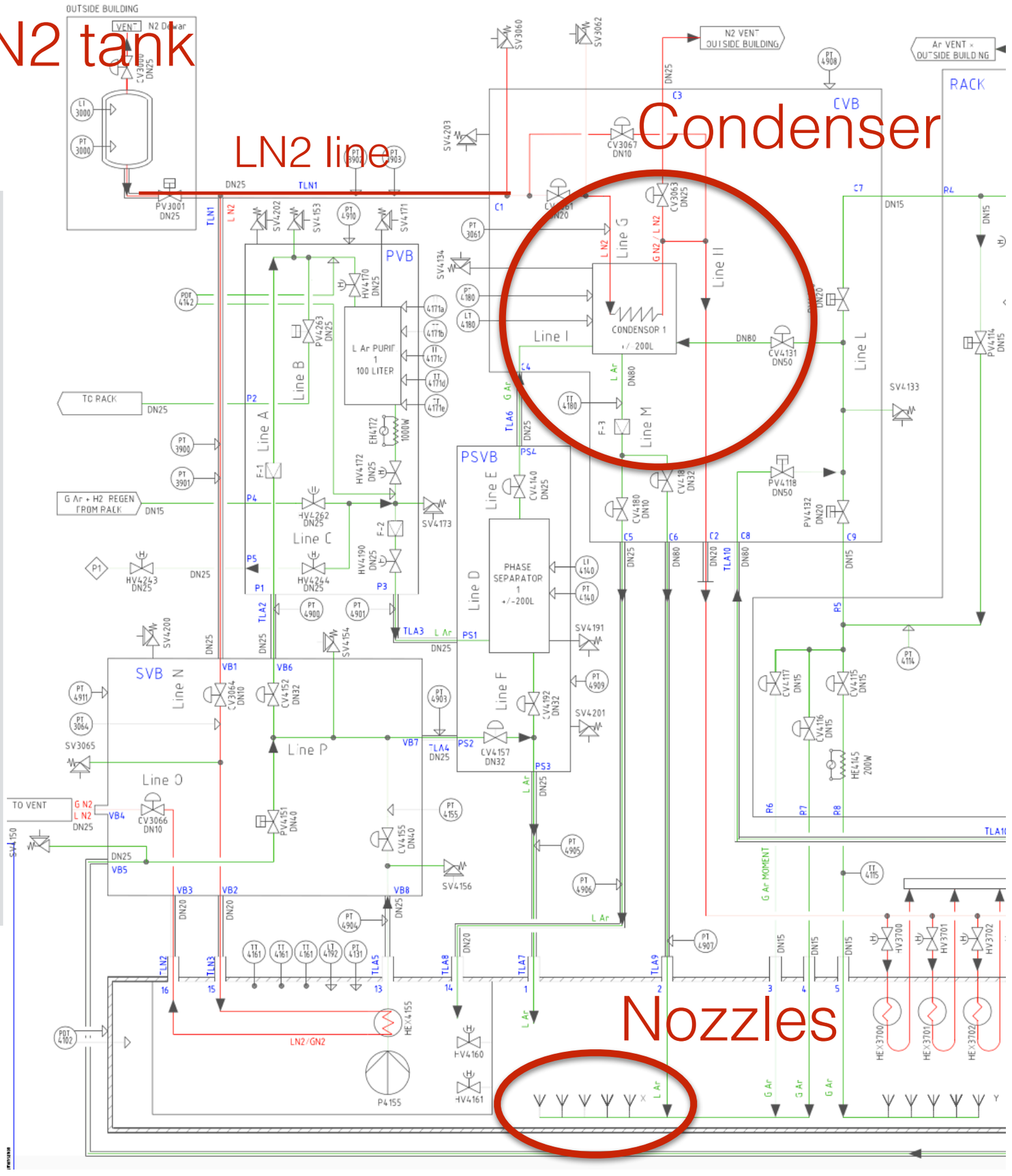


10th February:
`GAr injection` to the tank through the makeup gas line whose function is to equalise the tank pressure drop due to the gas sent to the trace analysers.
In the meantime, the venting value (CV4102) was open.
The nitrogen level decreased from 18.5 to 12.5 ppm after 6 hours injection. The moisture and oxygen levels stayed at almost constant values of 30 and 0.25 ppm.

Cool down

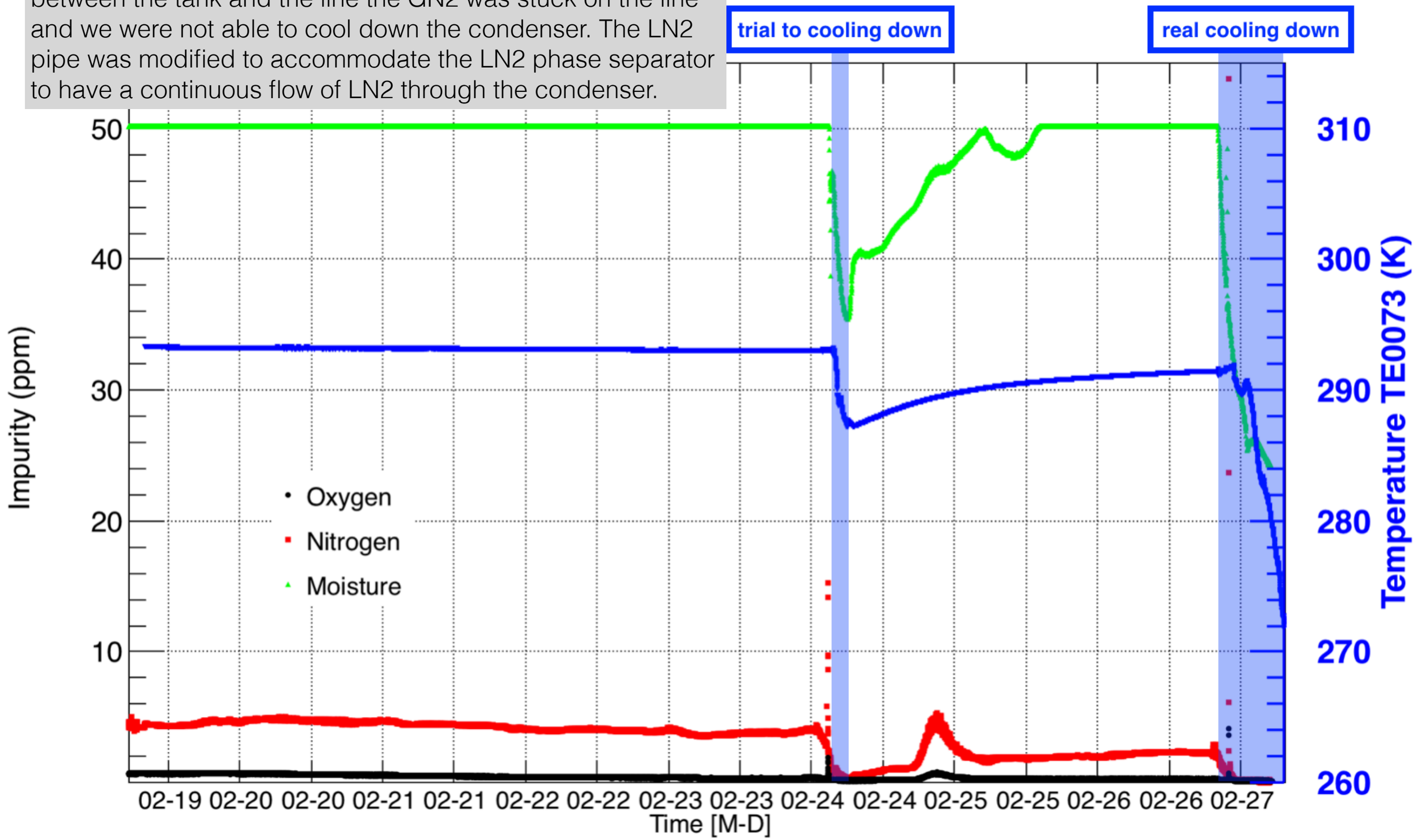
- We insert a mixture of LAr and GAr at 300 K through a system of nozzles which inject 4x5.3 l/h of LAr and 500 l/h of GAr, This system generates a spray which allows to cool down uniformly the tank.

- The cooling power should compensate the total heat input coming from the cables, chimneys, electronics, cryostat and the injection of warm gas and provide enough power to reach 87 K.



Impurities during cool down

Issue with the LN2 line: Due to the difference in height between the tank and the line the GN2 was stuck on the line and we were not able to cool down the condenser. The LN2 pipe was modified to accommodate the LN2 phase separator to have a continuous flow of LN2 through the condenser.



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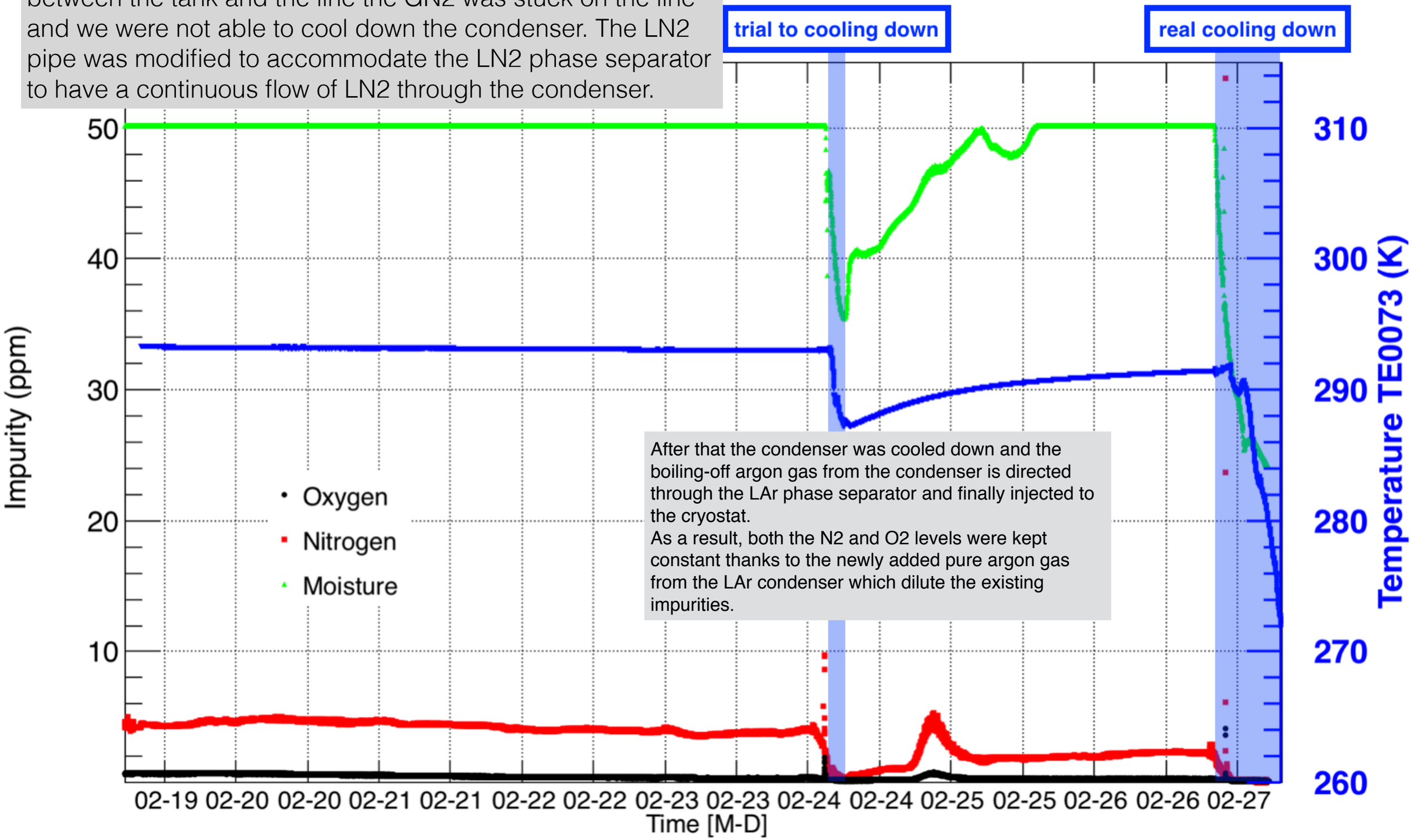

After that the condenser was cooled down and the boiling-off argon gas from the condenser is directed through the LAr phase separator and finally injected to the cryostat.
As a result, both the N2 and O2 levels were kept constant thanks to the newly added pure argon gas from the LAr condenser which dilute the existing impurities.

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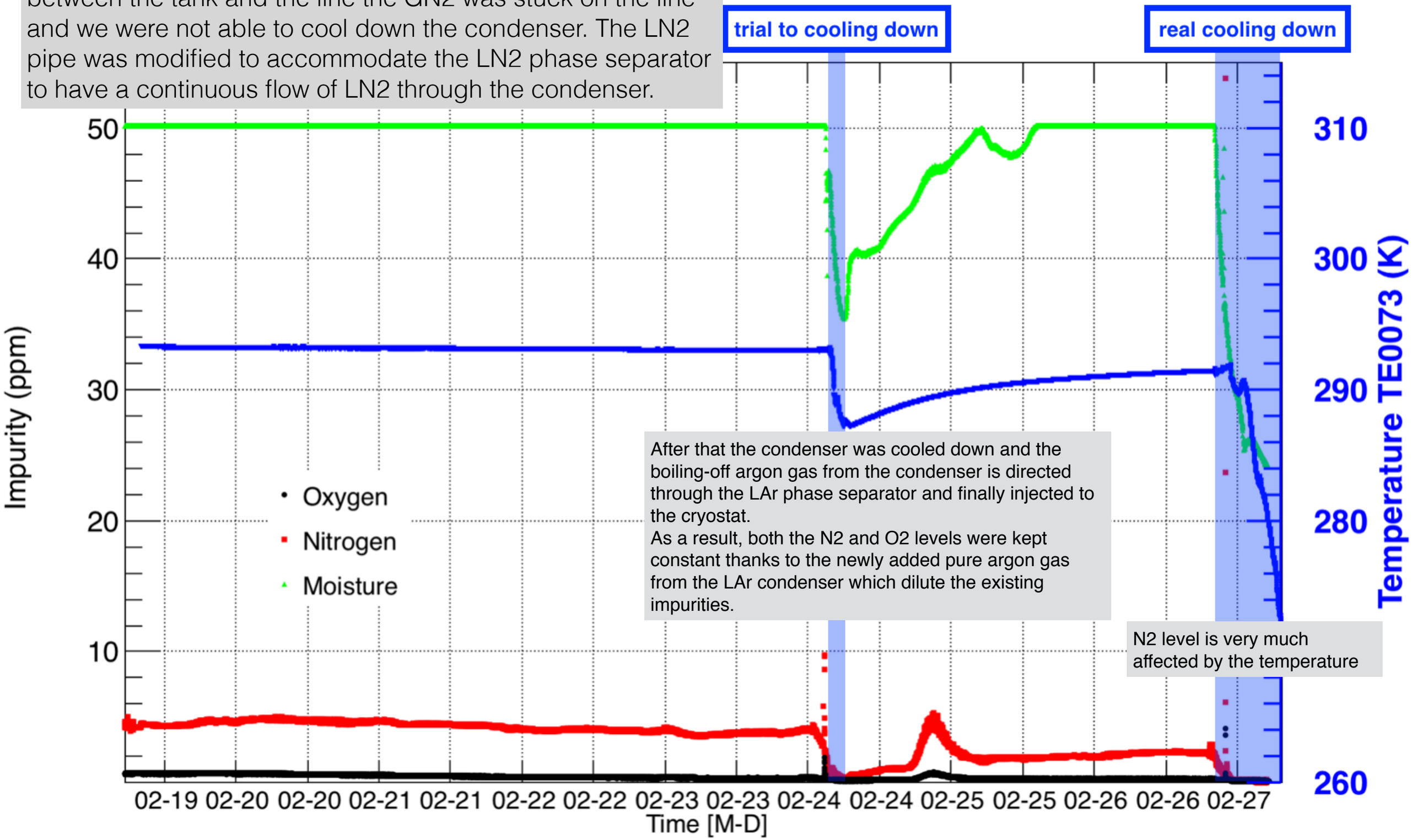

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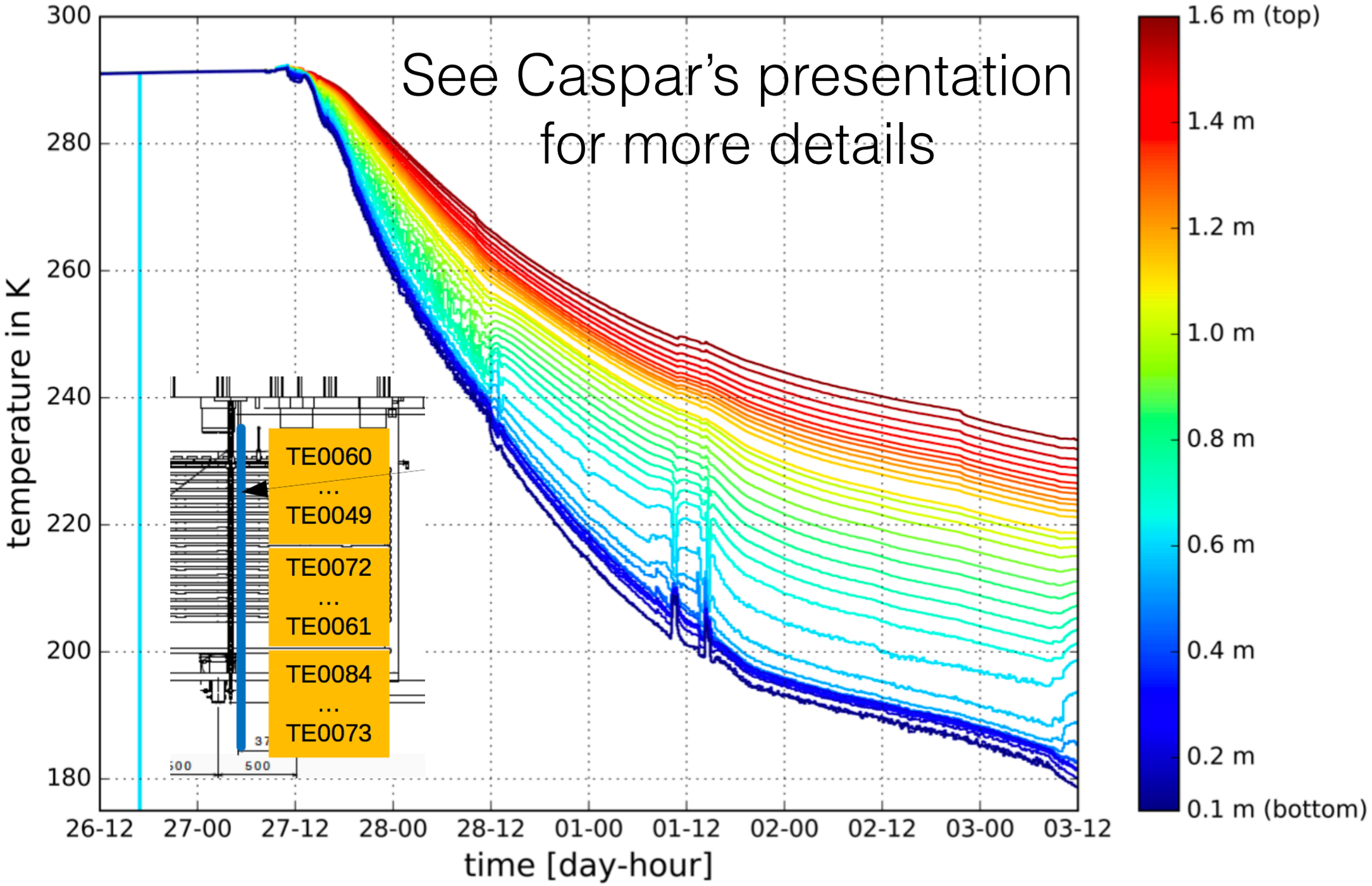
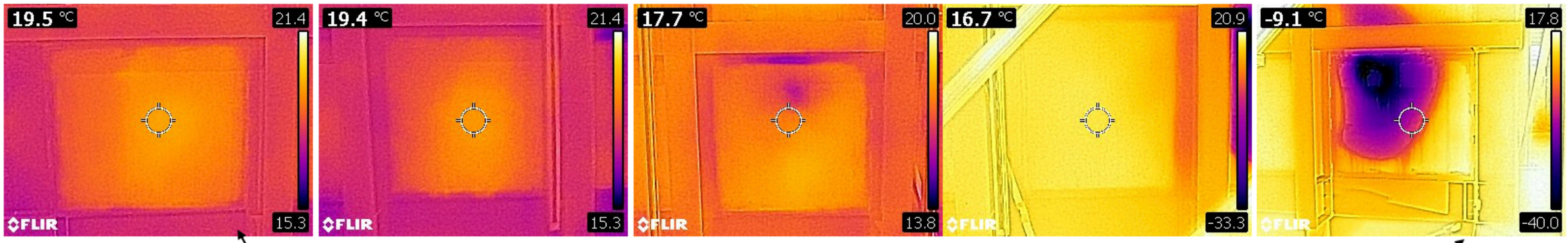
N2 level is very much affected by the temperature

Cool down

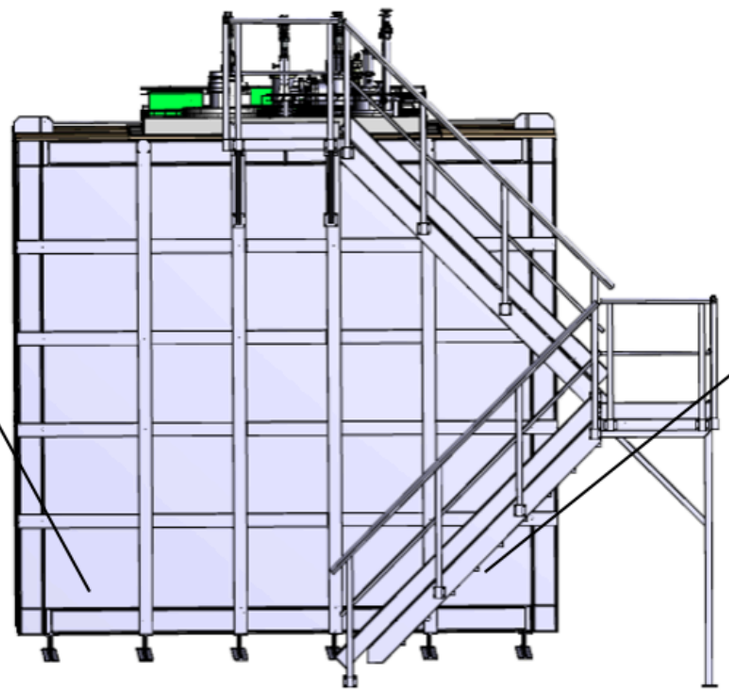
- **ISSUE:** We found that the cooling power provided by the nozzles was not enough to compensate the heat input and we were not able to go below 170 K. We realised that the ordered LAr nozzles were not the correct ones. The expected flow is 4x15l/h instead of 4x5.3l/h.



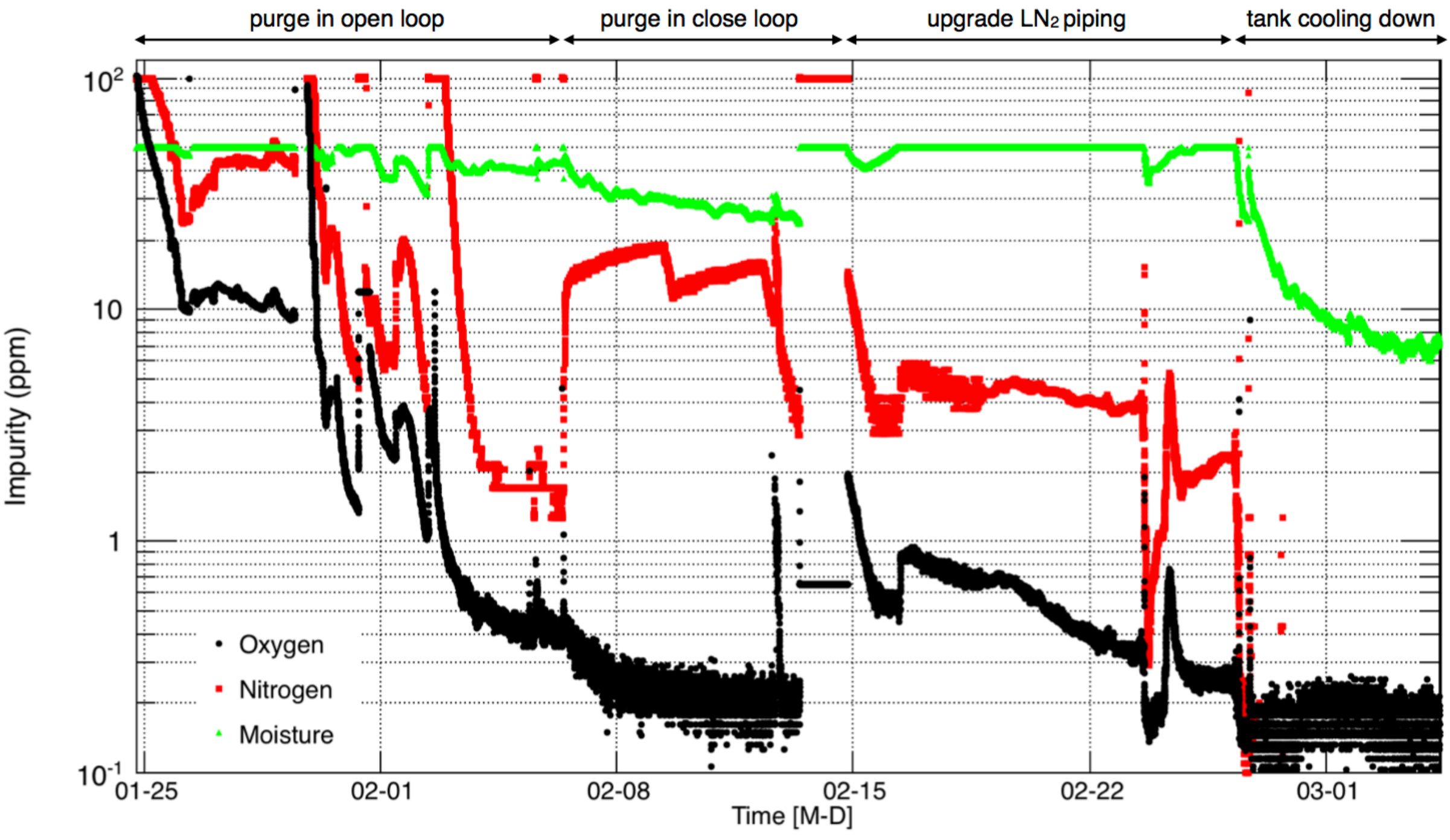
Cool down



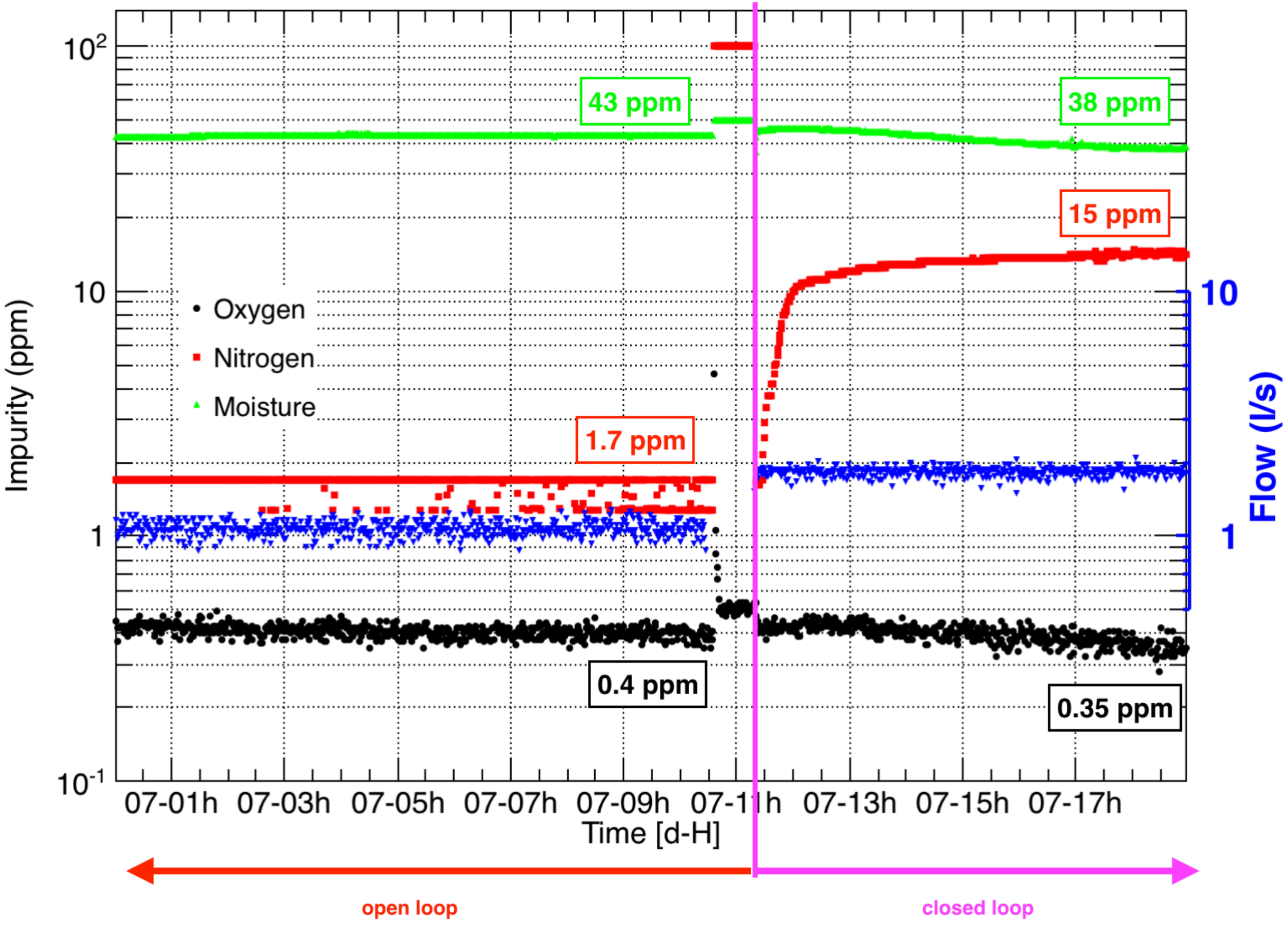
South face



Summary of impurities evolution with time



Back-up


43 ppm
38 ppm
15 ppm
1.7 ppm
0.4 ppm
0.35 ppm
Oxygen
Nitrogen
Moisture
Impurity (ppm)
Flow (l/s)
10
1
10^{2}
10^{-1}
07-01h
07-03h
07-05h
07-07h
07-09h
07-11h
07-13h
07-15h
07-17h
Time [d-H]
open loop
closed loop

Impurities during purge in closed loop