Gas System Status

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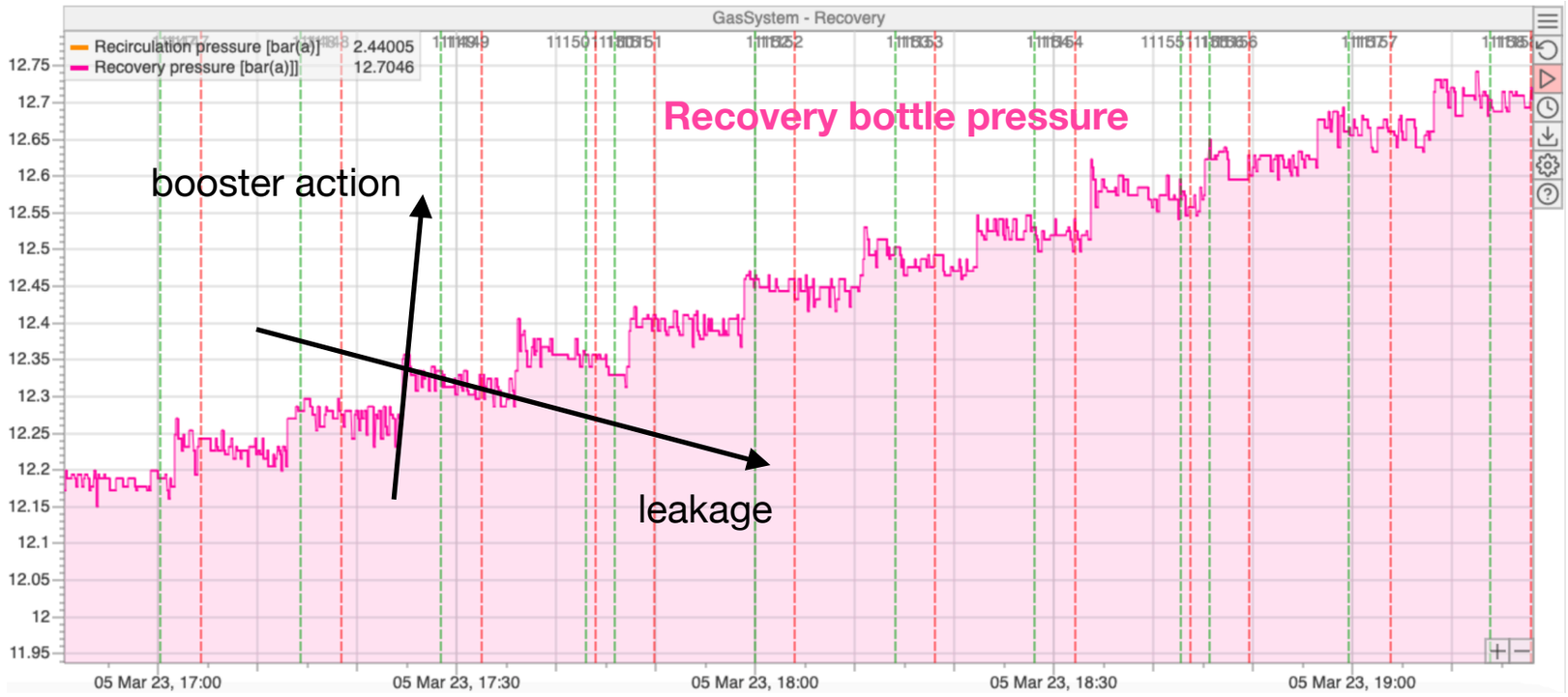
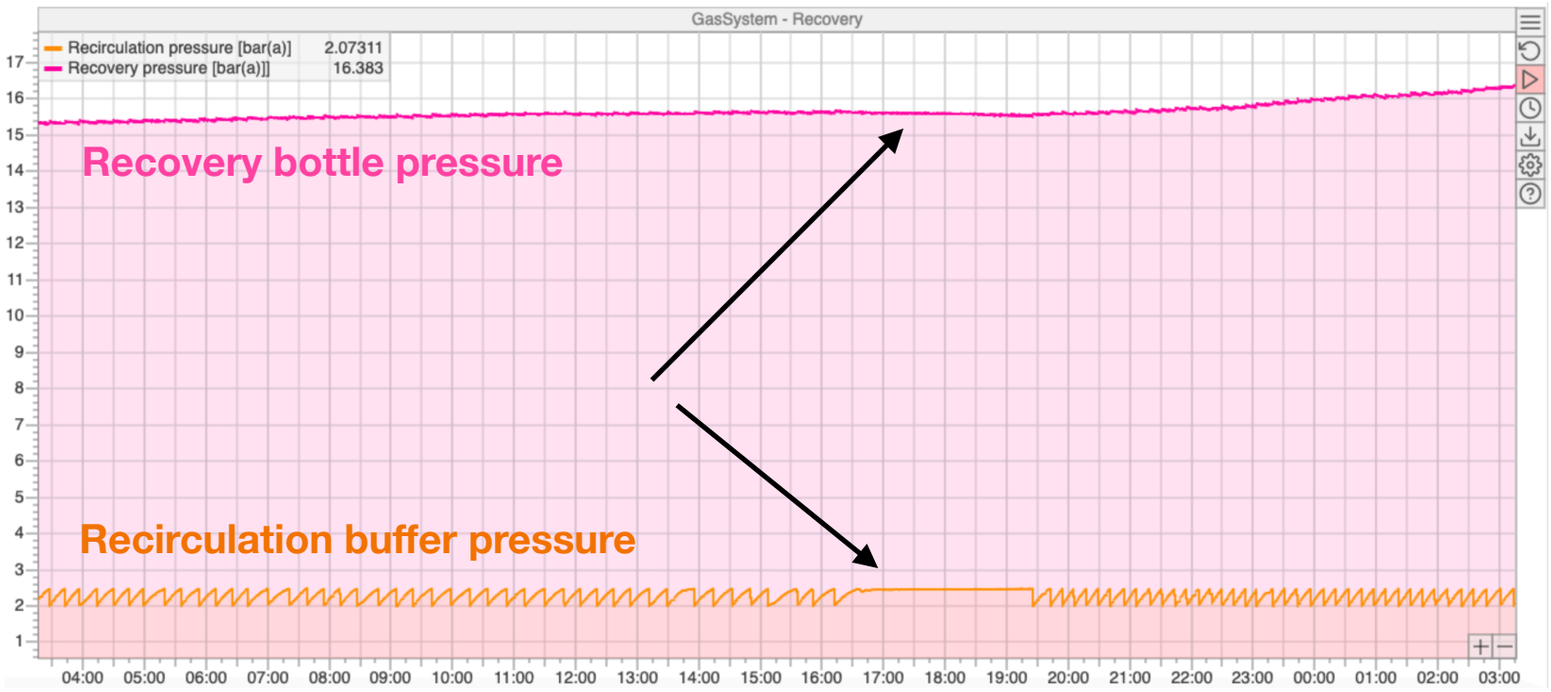
Current situation

- The system is performing well from the mechatronic point of view:
  - all electromechanical instruments (flow controllers, valves, sensors,…) are working properly
  - a couple of bugs in the control system were identified and fixed immediately after the delivery, no other bug emerged later
  - feedback regulations (i.e. PID controls for absolute pressure and recirculation) work very well without any sort of dedicated tuning
  - occasional (2-3 times/year) issues related to an unexpected triggering of one thermal-magnetic switch —> replacement under consideration
- The single mechanical components, despite some design weakness, are well dimensioned and, strictly speaking, not broken:
  - the recirculation pump cannot be smoothly restarted after a stop if pressures at the inlet and outlet are not balanced. It is expected for a diaphragm pump and we probably found a procedure for a smoother restart.
  - the recovery booster can reach > 60 bar of outlet pressure if no large volume (i.e. bottle) has to be filled
- Nonetheless, we have three evident problems:
  - permanent **leakage** in the high pressure side of the booster and evidences of occasional leakages immediately upstream —> **no evidence of other reasons preventing the booster to fill 50-liter bottles at 40 bars**
  - **humidity source in the flow return line** (after the detector and before the gas system) prevents using the recirculation and hence the gas analysis sensors
  - **we are operating the system in a modality it is not designed for** (absolute pressure control with variable set point depending on the atmospheric pressure) —> we have to rely on an external system (SCS3000 + external sensor + MIDAS frontend) to control this modality —> it makes practically ineffective some of the internal controls and the most critical internal alarms

More about the booster

Permanent leakage





Occasional leakage

More about the booster

- According to the manufacturer, the booster is not designed to work with He/CF4:
  - the leakage in the high pressure side is not surprising
  - this was a mistake by Air Liquide in the choice of the booster, although they are reluctant to admit it
  - Air Liquide also overlooked the ineffectiveness of a check valve in mitigating the consequences of such a leakage
- Air Liquide engineers are reluctant to replace the booster with another model (because suitable boosters are too big to fit in the skid)
  - they are working to find an alternative solution
- In the meanwhile, the physics of our detector is unaffected, but we have to acknowledge a large release of CF4 in the atmosphere

More about gas purity

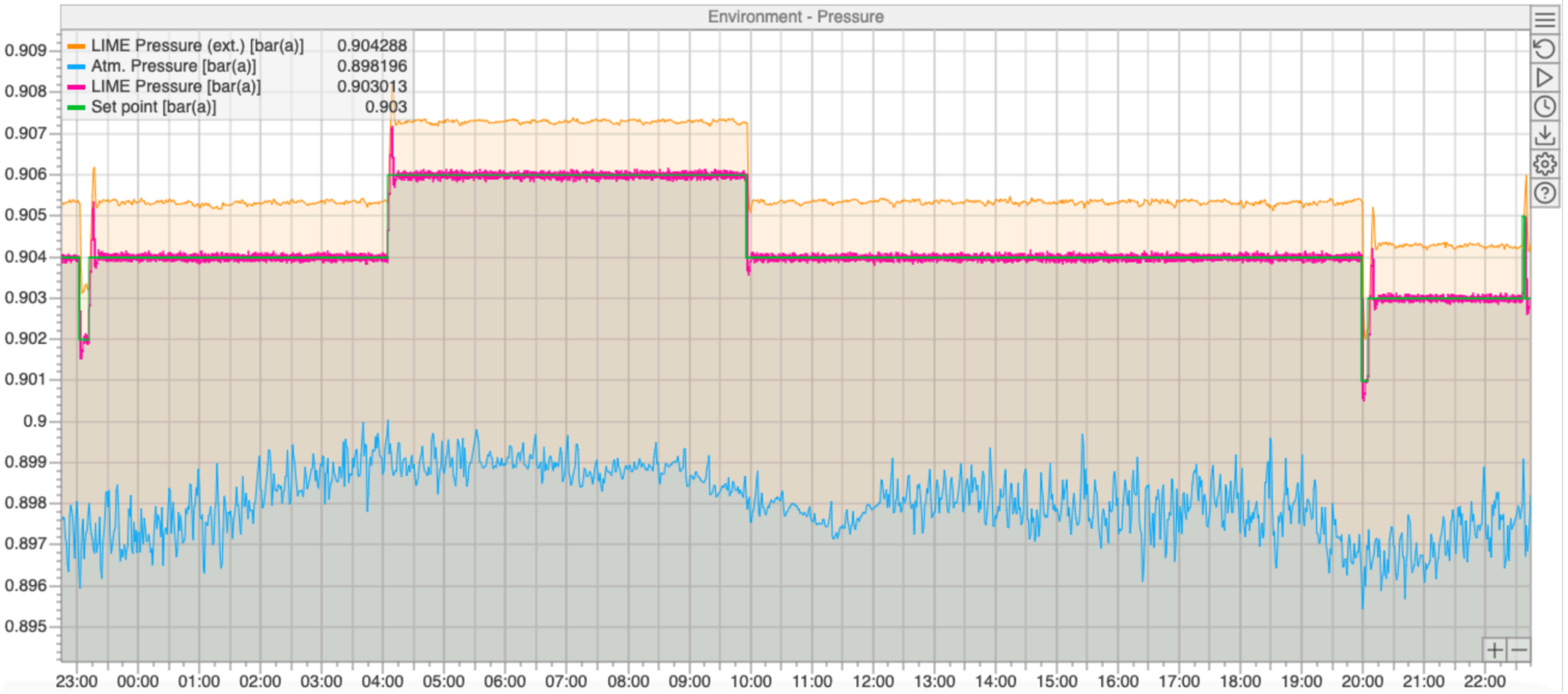
- Until we remove the source of humidity downstream of the detector (water bubbler??), any test with recirculation/purification is unreliable, and hence useless

- As soon as the source of humidity is removed, we can start the recirculation and use the sensors already installed in the system and the available filters (commercial + filters from the Sheffield group) to make all the necessary tests:
  - gas purity and composition without filters
  - gas purity and composition with commercial molecular sieves
  - radon removal by custom radiopure molecular sieves (need radon detector, e.g. RAD7 or RAD8 model)

More about the pressure control

- The “hybrid” pressure control works but is unsafe:
  - we already had an accident last week, with a failure of the SCS3000 that probably overstressed a pressure control valve, producing an excessive underpressure in LIME, and the gas system could not do anything to mitigate the consequences
- A safer system has to be developed:
  - implementation within the gas system by AirLiquide would be ideal, but it could be long and expensive (new sensors, electrical and firmware upgrade)
  - a dedicated hardware (PLC, single-board computer) with an OPC UA client, to replace the SCS + MIDAS combination, is probably a good compromise, along with a satisfactory mechanical device for over/underpressure release

More about the pressure control



To do list (in priority order)

1. Solicit a solution by Air Liquide for the booster leakage issue
2. Install a reliable under/overpressure relief system
    - temporary solution: bi-directional bubbler with light liquid paraffin
    - definitive solution: pressure relief valves with 10 mbar set point (order to be processed soon, ~ 1-2 months including bureaucracy and delivery time)
3. Start developing an hardware solution (PLC, single-board computer) for the pressure setpoint control
4. Long-term check for further leakages not connected to the booster
    - requires dedicated operations
    - delayed to not disturb the current run
5. Determination of the maximum outlet pressure that can be reached under current conditions (i.e. 20 l/h fresh flow and current leakages)
    - could not be completed due to the mentioned accident last week
6. Remove the source of humidity in the gas return line
    - solved at point 2 if the source is the water in the bubbler
7. Start recirculation to test gas composition and purification