CHUPS status report

All notations in the text refer to the updated CHUPS gas scheme.

1. Additional mass-flow controller and new reserve volume

New reserve volume (RV2) is installed in the TPC outlet manifold together with additional MFC5 mass-flow controller and pressure transmitter PT4. This greatly improved the pressure stability in the TPC. MFC5 controller restricts the TPC outlet flow and together with RV2 reduces the influence of the pressure drop caused by compressor columns.

Pressure behaviour is shown in Fig.1 together with compressor temperature cycles. The pressure stabilization algorithm was the following. TPC outlet mass-flow controller (MFC5) was set to a constant flow manually while inlet controller (MFC4) was regulated by a control system to stabilize the TPC pressure. Regulation algorithm for the MFC4 setpoint was also changed. Now it is PID-regulation in a special form which uses proportional, derivative and second derivative terms. MFC5 setpoint should be chosen in such a way that PT4 pressure will not exceed PT1 pressure. Otherwise MFC5 controller will be totally open and will not protect TPC from pressure drops.

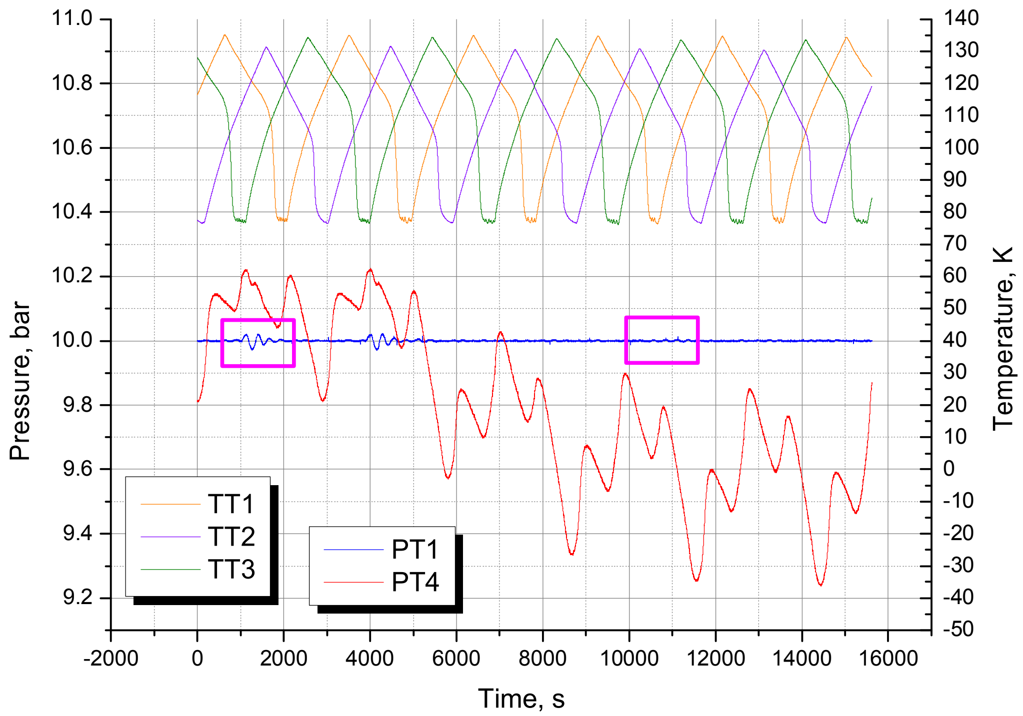

Fig. 1. Pressure and compressor temperatures behaviour.

Two magenta boxes in the chart show the PT1 pressure behaviour in case of too high MFC5 setpoint (left box) and normal MFC5 setpoint (right box). These boxes are zoomed in Fig.2.

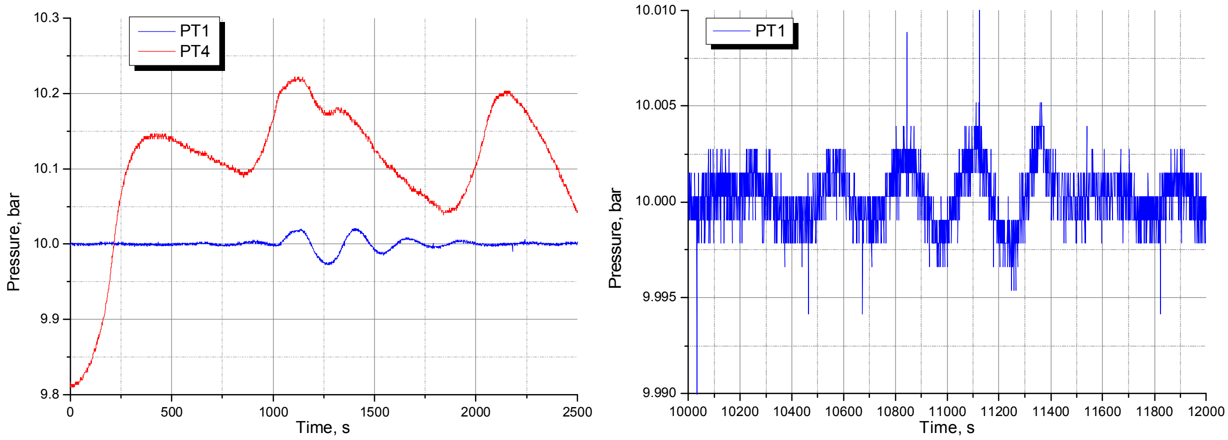

Fig. 2. PT-1 pressure oscillations for high MFC5 setpoint (left chart, MFC5 = 2L/min) and normal MFC5 setpoint (right chart, MFC5 = 1.8L/min).

Pressure histogram is also improved (Fig.3). Due to additional mass-flow controller and new PID regulation algorithm, width of the Gaussian fit of the pressure histogram reduces from 12 mbar to 1.7 mbar which is nearly equal to ADC resolution (ADC discretization is clearly shown in the right chart of Fig.2). Both histograms shown in Fig. 3 are measured with the dummy TPC. With real TPC histogram width slightly increases.

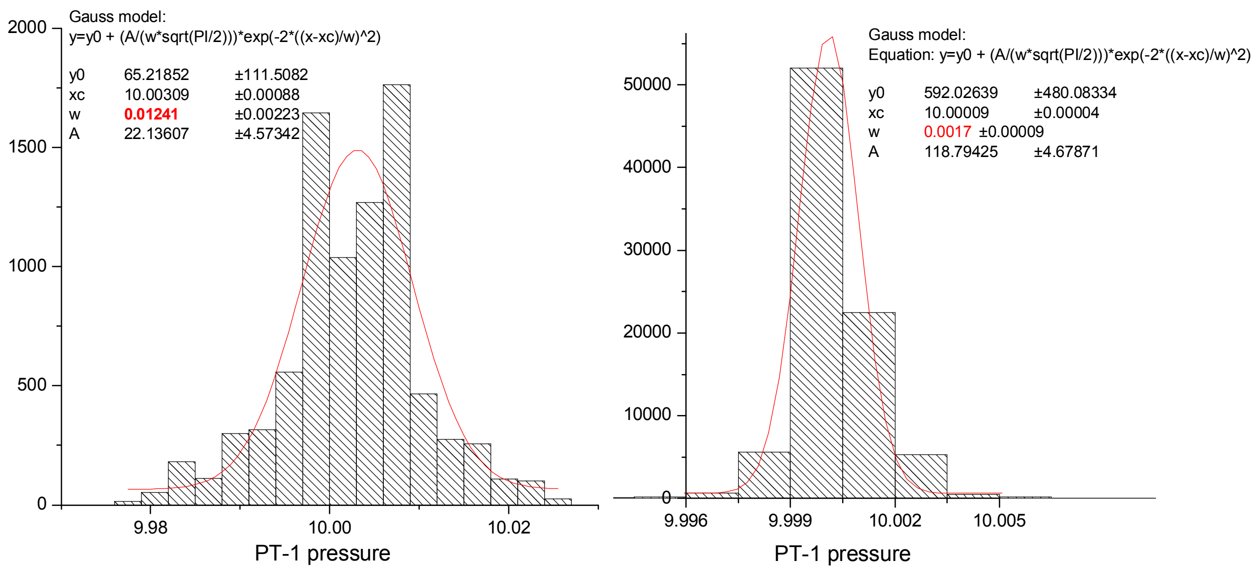

Fig. 3. Pressure histograms for old (left) and new (right) CHUPS.

TPC inlet hydrogen flow became more stable in comparison with old CHUPS setup. Flow oscillations required for TPC pressure stabilization decreased from 3.5 L/min to 0.15 L/min (Fig. 4 and 5). This obviously provides more stable conditions for TPC.

Difference in MFC4 and MFC5 readings in Fig. 4 is not clear – we have to calibrate these controllers as well as all pressure sensors.

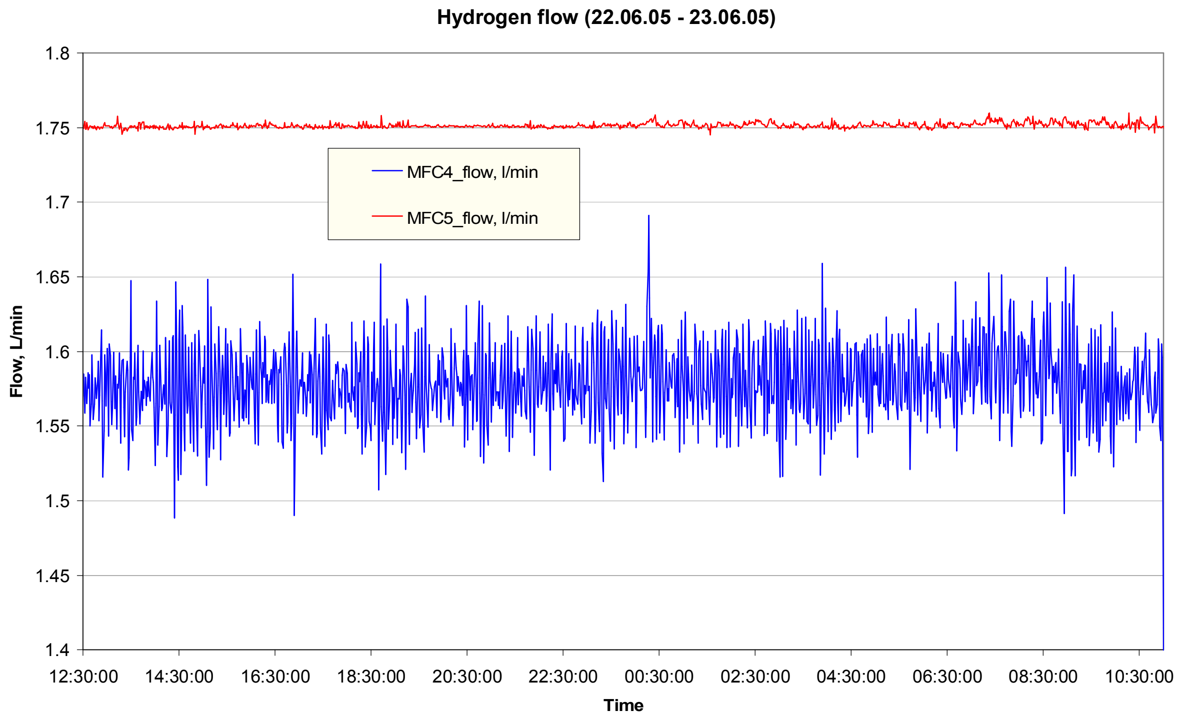

Fig. 4. TPC inlet (MFC4) and outlet (MFC5) flows.

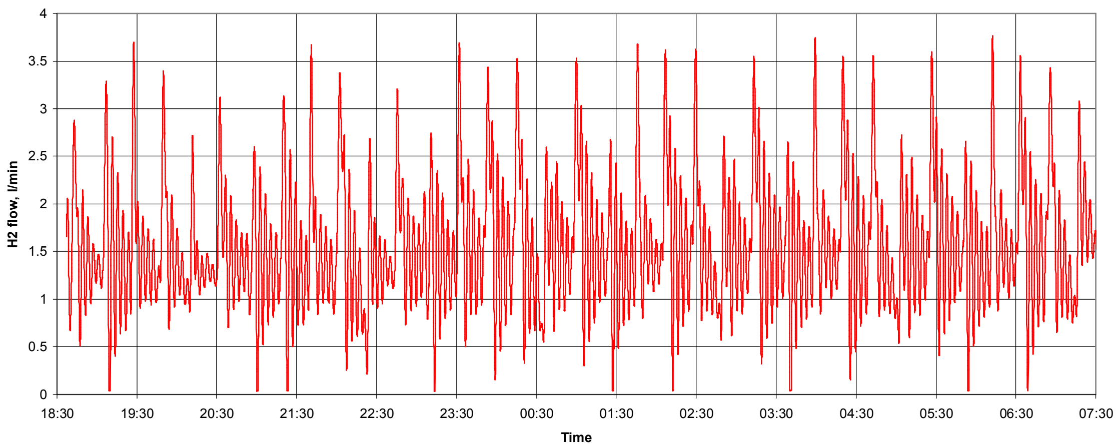

Fig. 5. TPC inlet flow for old CHUPS setup.

2. Membrane pump for nitrogen

We have installed the membrane pump at the nitrogen outlet manifold of compressor (outputs of the MFC1, MFC2 and MFC3 controllers). This allows us to keep liquid nitrogen tank of compressor at the atmospheric pressure. The advantages are:

1. Compressor columns could reach lower temperature during the cycles (see Fig. 1, 78K instead of 90K).
2. Atmospheric pressure in the liquid nitrogen tank simplifies the filling procedure. This also makes possible to join all three liquid nitrogen vessels by a single filling system and the automatic filling procedure in the future.

3. Humidity sensor

PURA gas dew-point transmitter (HS) was installed in the TPC outlet line together with electrostatic dust filter (EF). Vacuum and purity tests have been done. Continuous measurements of the moisture content shows that PURA sensor is temperature dependent. Using the temperature sensor and cooling by alcohol, rough temperature dependence was measured (Fig. 6). This was a reason to contact the company, because it is written in the datasheet that PURA sensor is temperature compensated.

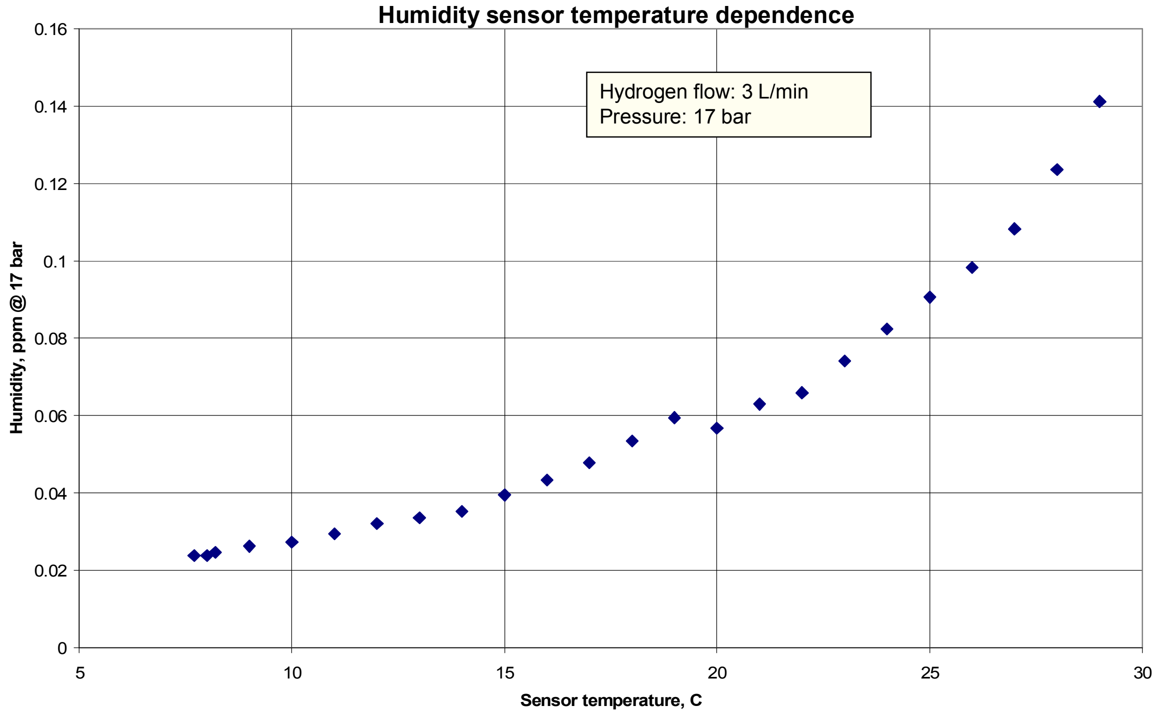

Fig. 6. Temperature dependence of the PURA moisture sensor.

Second question not clear from the datasheet is PURA response time. The only mention about response time is "response characteristics from dry to wet are orders of magnitude faster than from wet to dry". After Peter's negotiation with company they send some charts of the sensor response time (Fig. 7). This clarifies that dry-to-wet response time appears to be about one hour. But wet-to-dry response time is still unknown. "Orders of magnitude" could result to days and months.

Moisture decrease of the dummy TPC was measured during two days (Fig. 8). The result was fitted by exponential decay and gave us a time constant of 367 minutes. Assuming drying of the dummy TPC one could estimate the exponential decay as $e^{-\frac{Q}{pV}\cdot t}$, where p – pressure in the dummy TPC, V – it's volume and Q – flushing flux. During these two days average hydrogen flux was about 2 L/min. So the time constant is $\frac{pV}{Q} = 130$ minutes, which is almost 3 times less than experimental. This difference is defined either by unknown source of water or just by long drying of the sensor. May be one should use another model of water outgassing with partial pressure dependence (which is also unknown). Two dips in the experimental curve just before 1500 and 3000 minutes correspond to morning opening of the experimental hall doors that immediately cause ambient temperature drop.

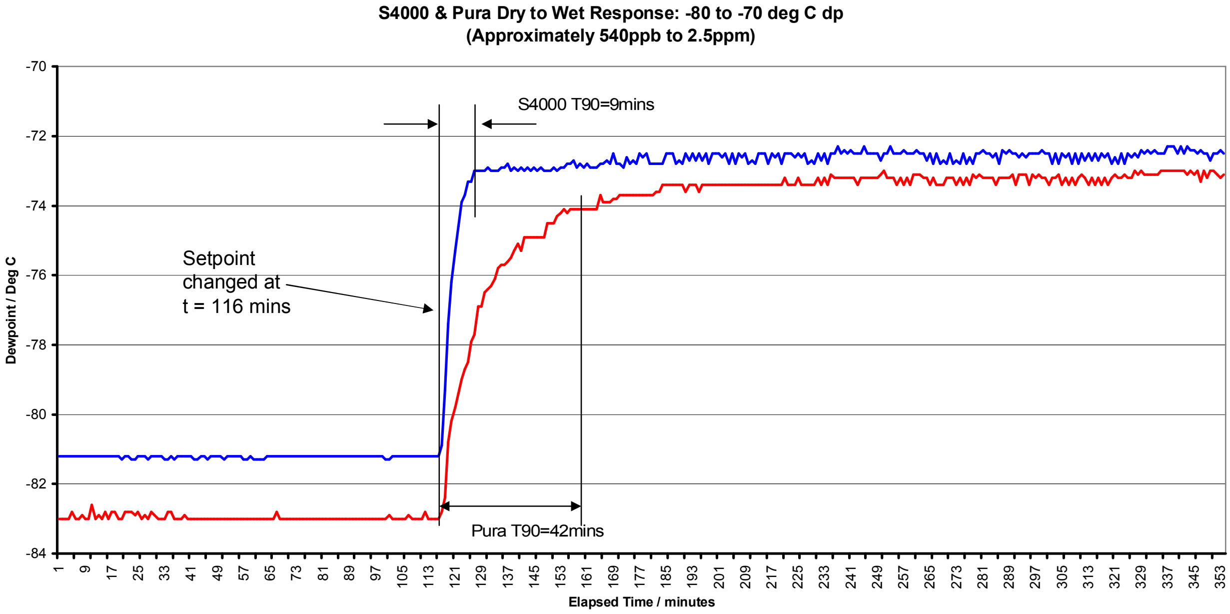

Fig. 7. Typical PURA dry to wet response.

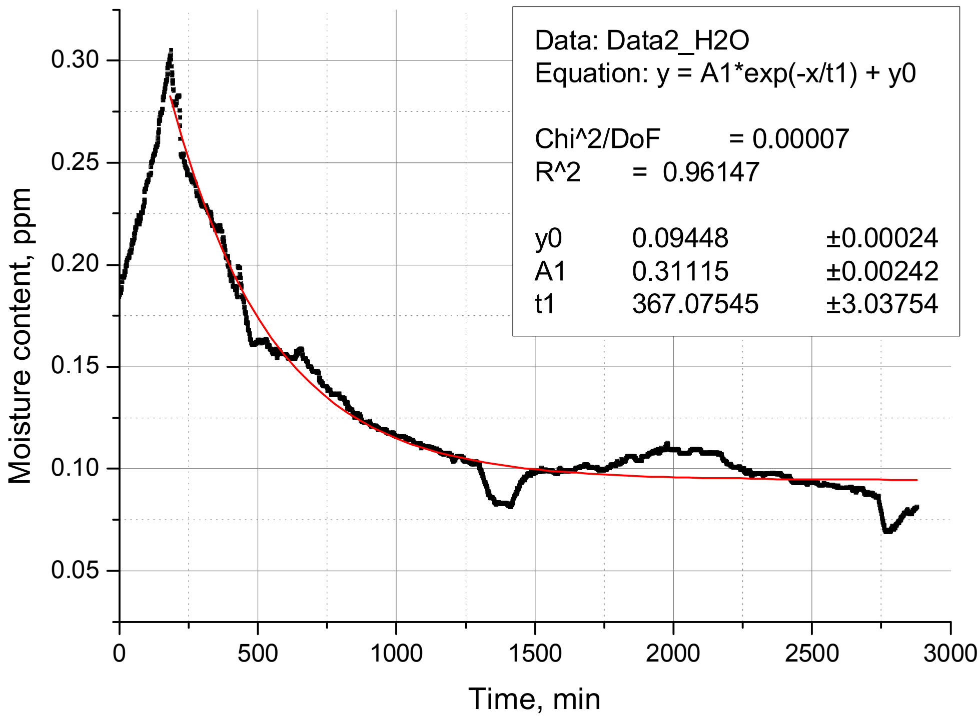

Fig. 8. Dummy TPC moisture decrease.

Two tests were done to localize the source of water in the system at the moisture level of 100 ppb. First, reserve volume (RV1) was heated by 100 degree to exclude it's influence to water content. The moisture level was stable. Second, additional membrane pump was used to pump out the liquid nitrogen vessel of Zeolite filters. At the pressure of 100 mbar that corresponds to about 10 degree temperature decrease no changes of the moisture content were observed. The conclusion is that RV1 volume is dry and does not affect the moisture content and that Zeolite filters adsorbs all the water in the hydrogen flow.

Electrostatic filter test was also carried out. At 5 kV discharge (current was about 200 μA) moisture content did not change. The voltage was applied to a 50 μm gold plated tungsten wire placed in the axis of the aluminum cylinder of 10 mm diameter and 50 mm length. This finalizes discussion about producing water from aluminum using ions.

The measurement of the moisture content at the Pd filter outlet was canceled because of indeterminate response time. With CHUPS volumes the maximum duration of the Pd filter experiment is about 2-3 hours. This is definitely not enough for PURA sensor to normalize.

PURA company send also a chart of sensor response to increasing of the ambient temperature by 20°C (Fig. 9). As it shown sensor really compensate the changing of the ambient temperature, but it takes more than 12 hours, which is absolutely unacceptable for changing of the experimental hall temperature.

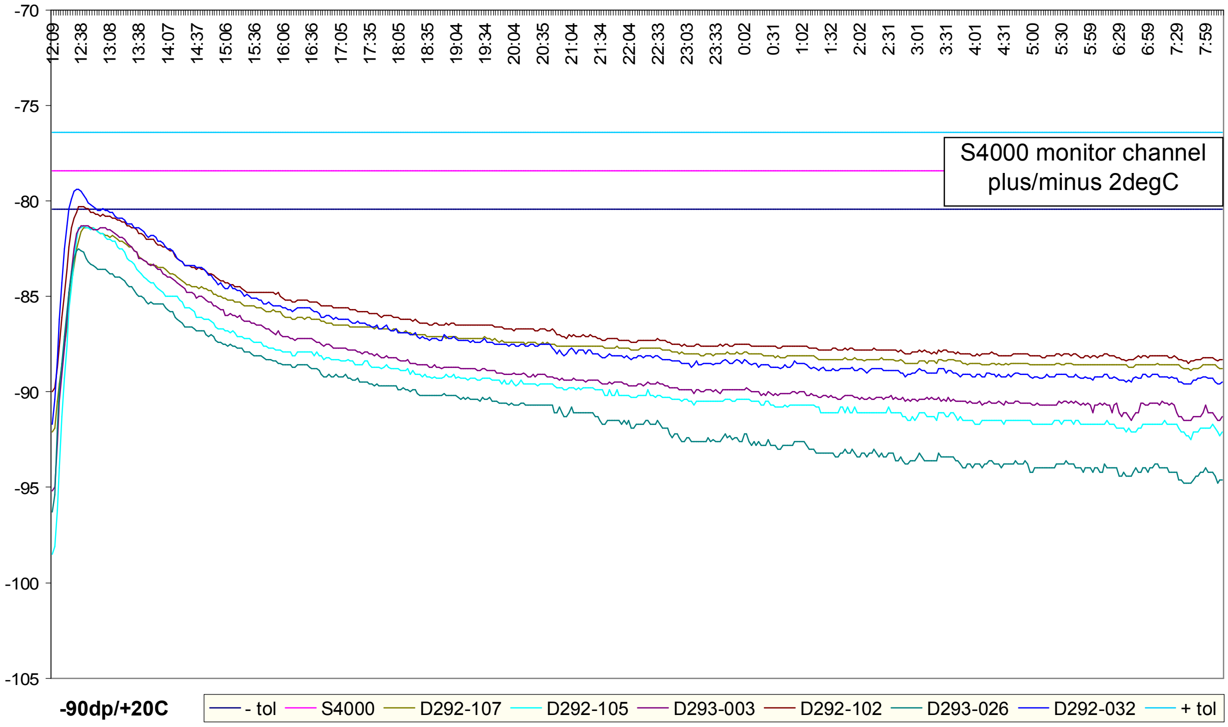

Fig. 9. Response time of the PURA sensor to increasing of the ambient temperature by 20°C.

4. Gas hardware

Most of the pipes were reassembled. All hanging components from the front panel were mounted in the new vertical panel (see Fig. 10). Some manual valves were added to enable flexible operation of CHUPS with electrostatic filter, moisture sensor and vacuum system. Due to new design of the hydrogen lines in the Zeolite filters block liquid nitrogen consumption was reduced significantly. New 10 micron filters were installed in the outlet lines of Zeolite filters to protect manual valves.

5. New control system

The new control electronic board was produced and installed. Now it supports up to 16 temperature (Pt-100) sensors. ADC and DAC channels were added to control and measure additional mass-flow controllers, pressure transmitters and moisture sensor.

New linear power supply was produced in exchange for switched computer power supply that was used in the control block last autumn. Hopefully this eliminates sensors readout problems happened in November 2004. Now there are two linear power supplies in the control block:

1. 12VDC 4A power supply for nitrogen mass-flow controllers,
2. Quad voltage (+5VDC, +15VDC, -15VDC and +24VDC) power supply for the rest of the system.

Everything except resistive thermalizers at the nitrogen filling ports is supplied from the control block power supplies.

New patch panel and all cables were produced and installed.

Fig. 10. CHUPS.