CHUPS staff
20.12.05, PSI

Brief summary of CHUPS operating experience during MuCAP run9

There is a preliminary report of MuCAP run9 from the point of view of CHUPS exploitation. It's based on some previous CHUPS notes, the ELOG materials and CHUPS database review. This note includes concise information about hardware and software alterations of CHUPS, overview of basic results, short description of new problems and prior explanation of these cases.

CHUPS design improvements as compared with the run 8

There are several considerable improvements in CHUPS design was made on the basis of run8 experience. Some of these improvements have been already presented in previous CHUPS notes.

During the June, 2005, CHUPS gas panel was completely disassembled and mounted anew with fixation of all "hanging" lines at panels (Fig. 1). During the assembling, second mass-flow controller (MFC5) and second reserve volume (RV2) with additional pressure sensor (PT4) were installed. These devices are intended to reach a smooth and stable hydrogen flow at the outlet of TPC. Pressure stabilization algorithm was rebuilt with respect of hardware update. Thus, actually CHUPS has a better system for pressure stabilization in TPC.

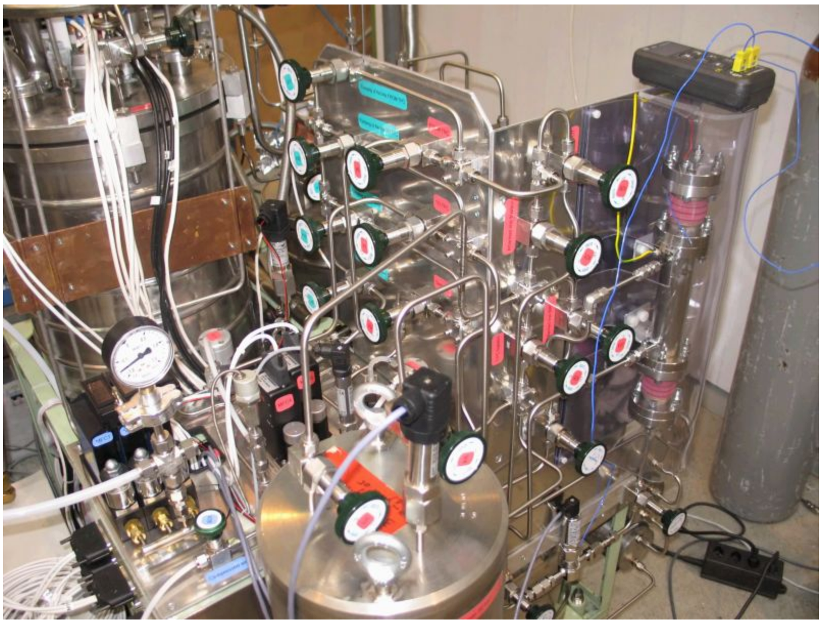

Fig. 1. New gas line bindings fixed on panels

Besides, before the start of the run an additional cleaning device (SAES MicroTorr [1] getter) was installed on CHUPS to provide final fine gas cleaning before TPC.

Another essential update is a system for online measurements of water vapor concentration. PURA PUR-TX-120 [2] humidity transmitter was installed and tested for the

[1] http://www.puregastechnologies.com/microt.htm.

first time in June 2005. First tests demonstrated an absence of good temperature stability of the sensor. To overcome this problem, temperature stabilization system on basis of Peltier elements was mounted in September (Fig. 2). Preliminary tests of temperature stabilized sensor were made at the same time.

The new principal scheme of CHUPS is presented on the Fig. 6. This renewal schematic diagram contains all improvements has been made since previous run.

Another considerable improvement is the system for distance liquid nitrogen filling. This system allowed saving up to 1 hour/day of beam time. It gave more than 1 day extra time for statistics accumulation.

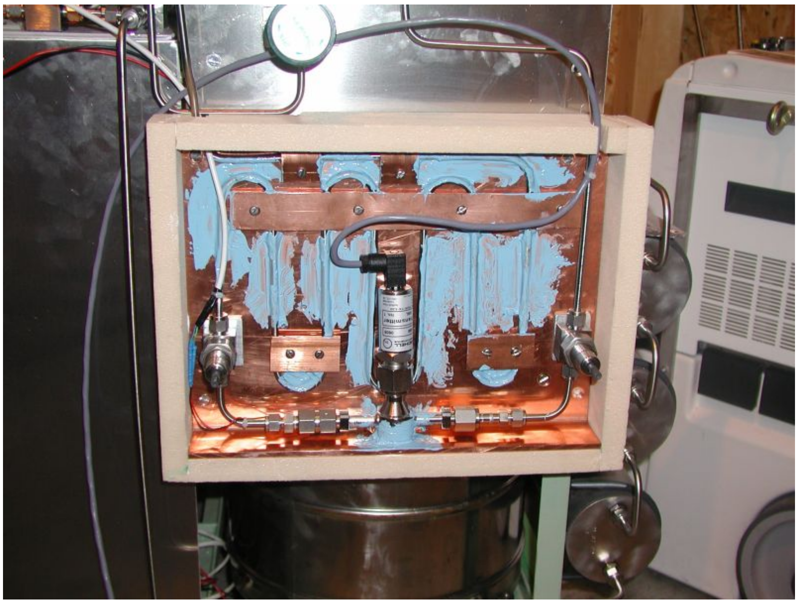

Fig. 2. Humidity sensor (HS) and its temperature stabilization system

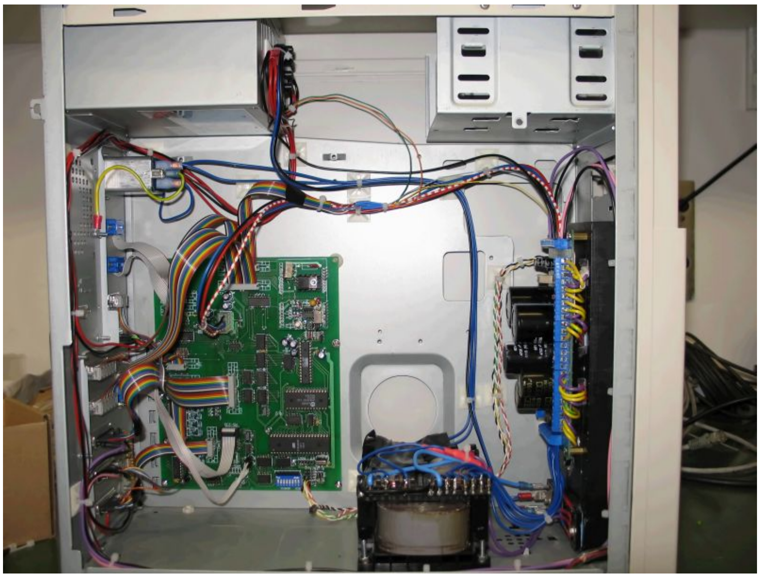

Fig. 3. Control block

[2] http://www.michell.co.uk/cat/view/pura.html.

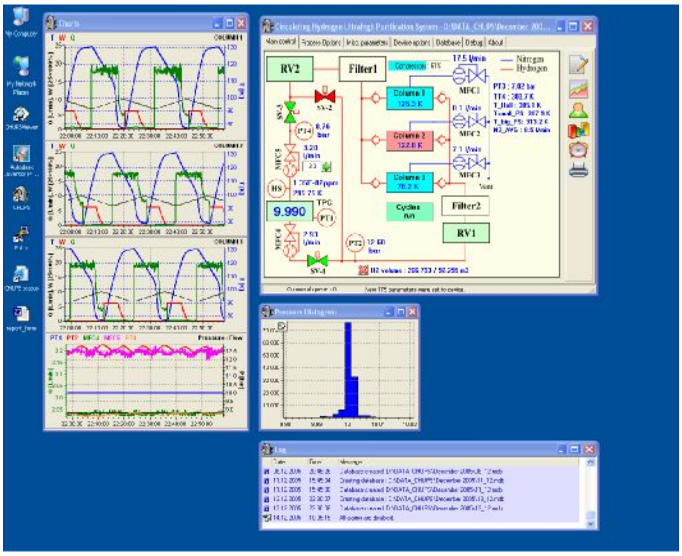

Fig. 4. New version of PC software

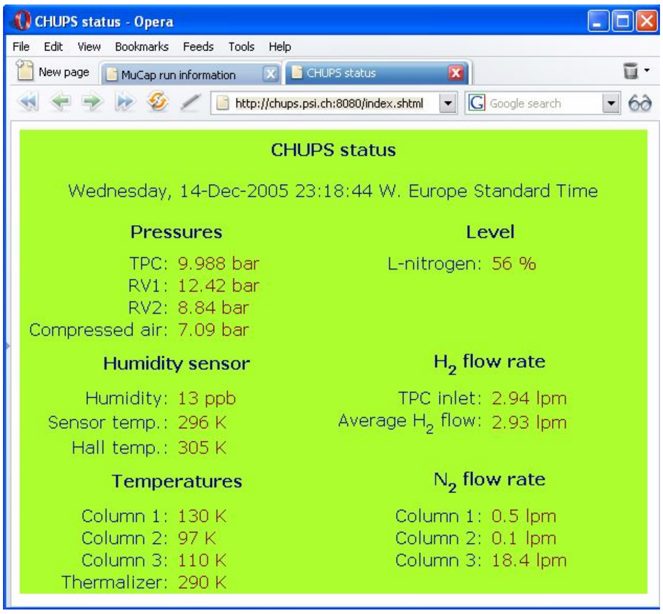

Fig. 5. CHUPS status monitor

The control system of CHUPS obtained a new completely revised Control Block (Fig. 3). This block contains new microprocessor controller and specially designed more powerful power supply. This supply (in contrast with previous standard PC power supply) is more suitable to provide team-work of numerous analogue and digital devices of CHUPS control system. Both Control block and PC now have new versions of software. Software updates concern to stability, usability and operating of additional devices. Thus, Control Block software now use elaborated PID regulation algorithm of pressure stabilization. PC software has a renewed interface (Fig. 4). Excess information and debug controls was removed from main CHUPS software desktop to accomplish to provide better convenience for an operator and exclude possible mistakes. Additional controls, such as a control for humidity sensor temperature stabilization system, were introduced. Alarm sound and light signalization operated by Control Block was mounted on MuCAP barrack wall. Web page with actual CHUPS status available from any computer inside of PSI was proposed (Fig. 5). This page simplified the supervision of CHUPS, especially for shift person.

CHUPS

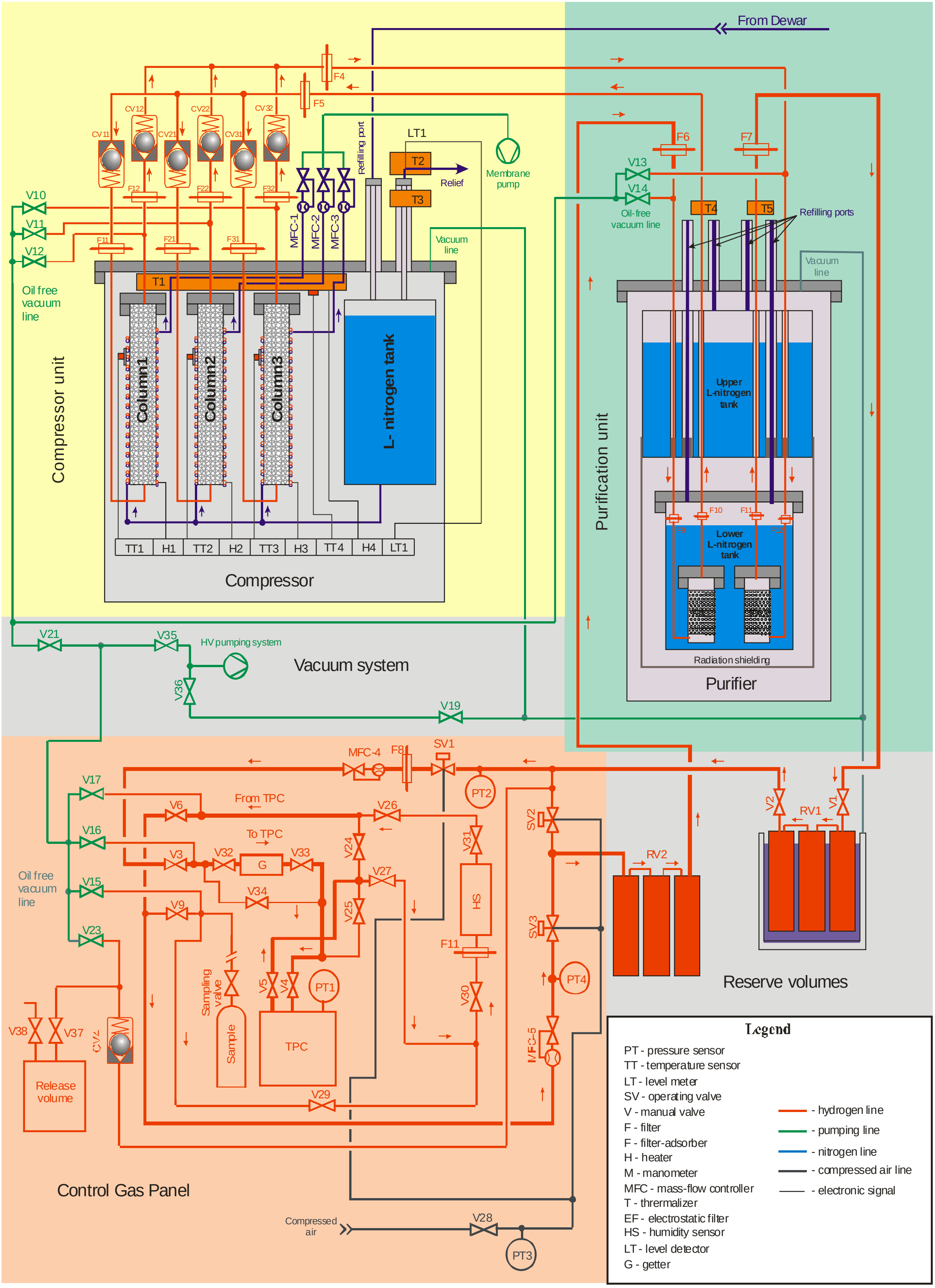

Fig. 6. CHUPS schematic diagram

Hydrogen flux and pressure stability

Improving of pressure stability was the essential aim of installing of MFC5 and RV2 on the TPC outlet.

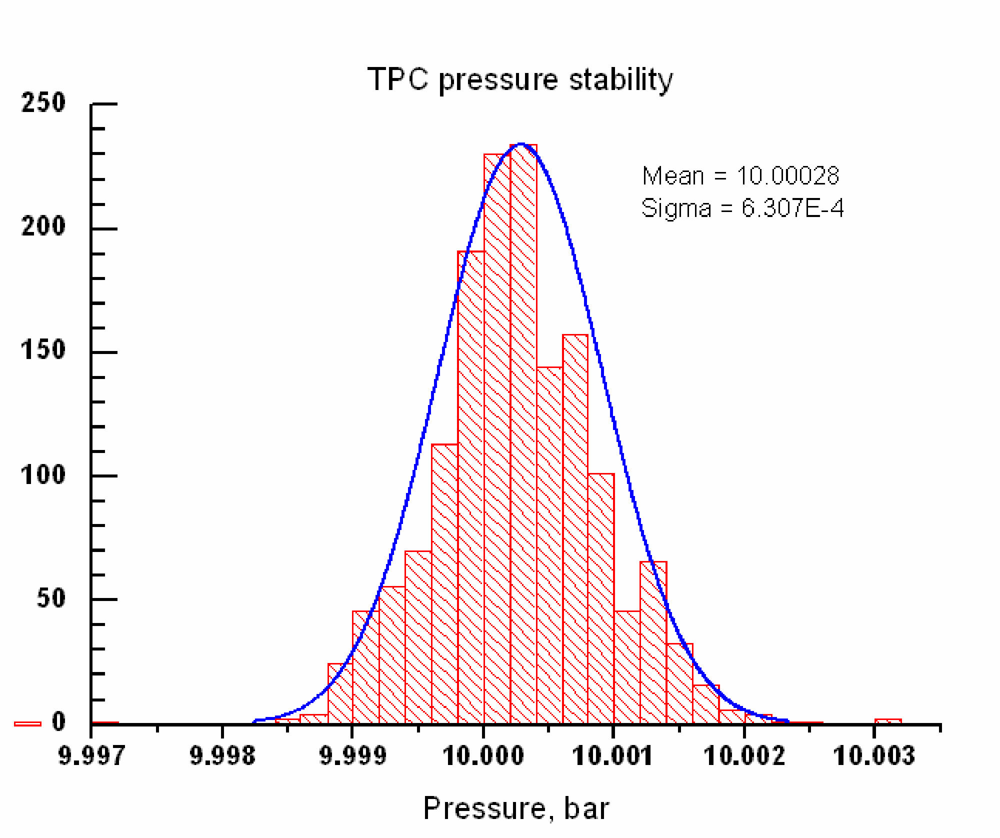

Fig. 7. TPC pressure stability at average hydrogen flux 1.3 l/min

Additional devices and new PID regulation algorithm allowed reaching good pressure stability, especially at moderate hydrogen flow. Thus, at the flux 1.3 l/min standard deviation of the pressure was $6.3*10^{-4}$ that means 0.006% stability (Fig. 7). The situation at larger fluxes was somewhat worse. Hence, at average fluxes 2.9 and 3.2 l/min (Fig. 8 and Fig. 9) we have 0.02 and 0.03%, respectively. It's still very good value that proves the efficiency of the new stabilization algorithm. Besides, further increasing of the flow gives rise to problems. The cooling power of CHUPS even at maximal supply rate of liquid nitrogen became deficient and pressure inside reserve volume RV2 increases. When RV2 pressure became more that TPC pressure, hydrogen flux through TPC loss its stability. This situation is dangerous from the point of view of pressure stability also. Moreover, the unstable flux results in bad conditions for humidity sensor measurements. An example of flux and pressure instability caused by RV2 pressure increasing is shown on Fig. 10.

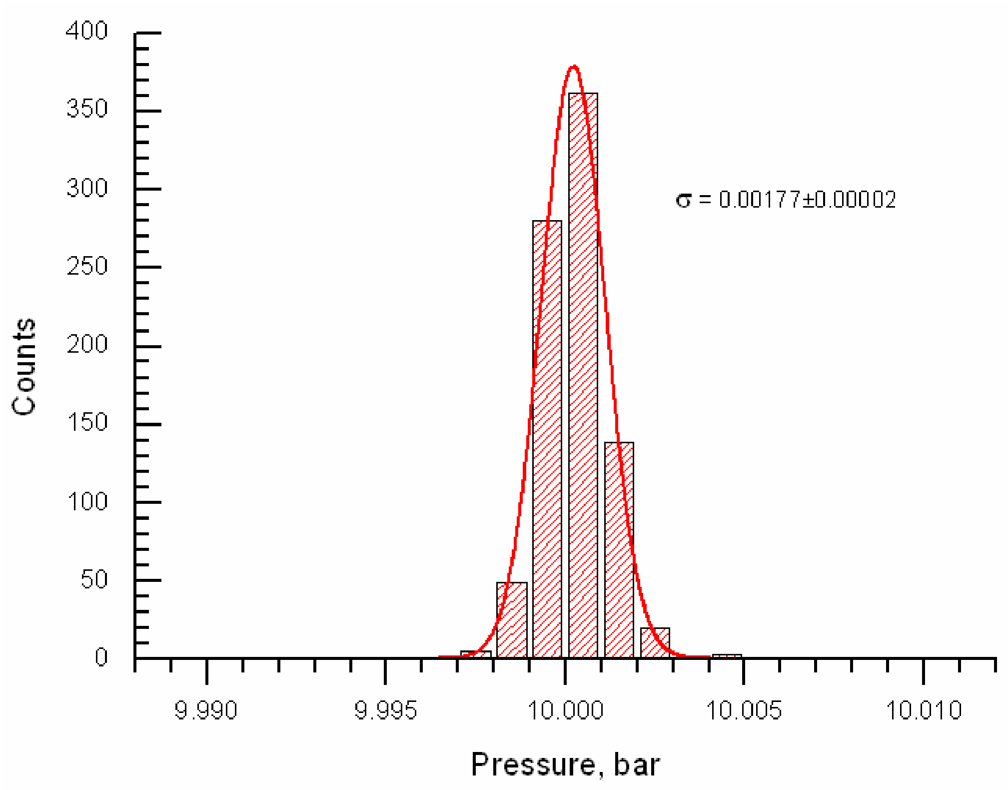

Fig. 8. Pressure stability at the flux 2.9 l/min

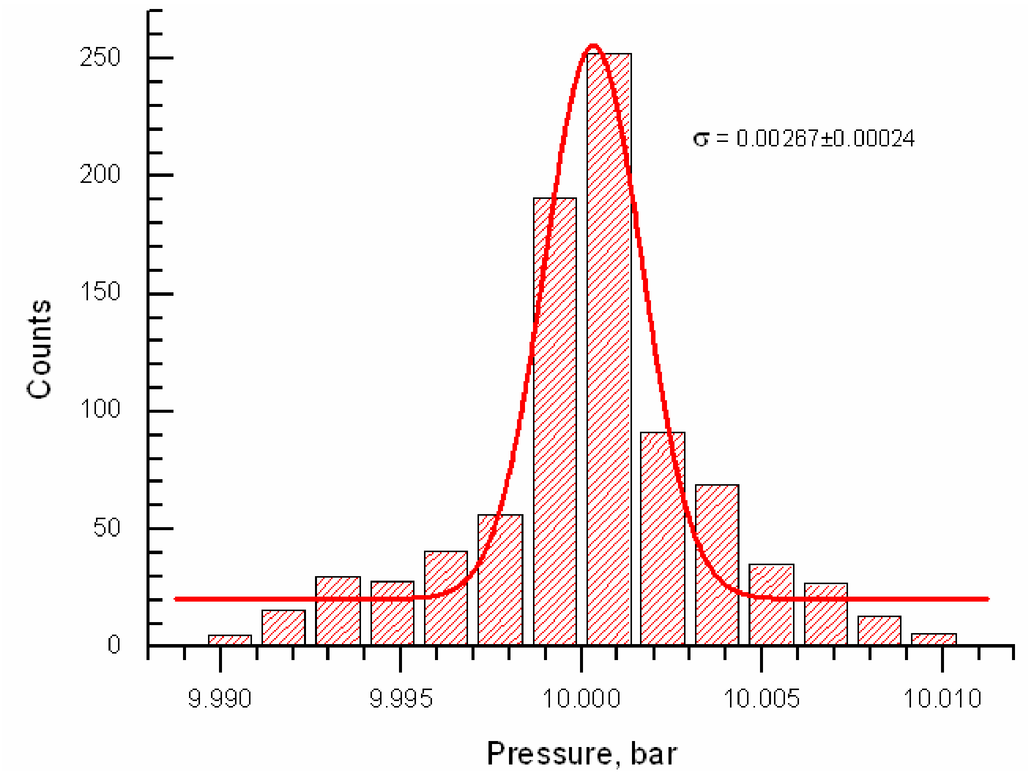

Fig. 9. Pressure stability at the flux 3.2 l/min

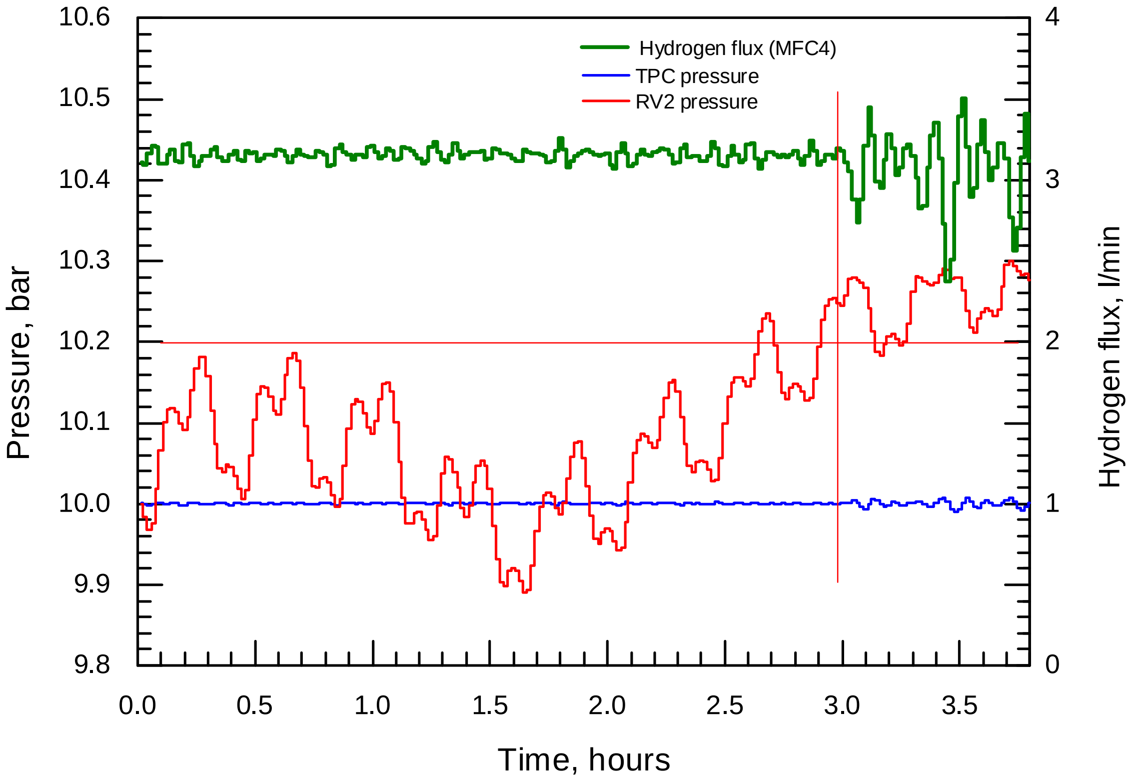

Fig. 10. Instability of TPC pressure and hydrogen flux caused by RV2 overpressure. Explanations are in the text

A horizontal red line shows the TPC pressure setpoint which is recalculated taking into account a “pedestal” between two pressure gages: PT1 (TPC) and PT4 (RV2). The instability of TPC pressure (blue line) and hydrogen flux (green line) appeared when PT4 pressure become more than TPC pressure. That means impossibility to support stable flux on the outlet of TPC.

Considering these circumstances, it’s not desirable to set flux more than sufficiently to keep positive difference in pressures of TPC and RV2. Practically, the largest average hydrogen flux that we can reach without the risk was 3.2 l/min.

Leaks

After the moving of CHUPS to the area, connecting to TPC and several days of circulation, symptom of leak on the system appeared. That showed in the behavior of pressure inside of RV1 (PT2 pressure). After that, several attempts to find the leak had been made. Handheld leak detector, liquid “Snoop” leak detector and mass-spectrometer in leak-testing mode (for some places) were used. In result, several suspicious places had been found and treated. The full story of leak search is shown on Fig. 1. Finally, obvious signs of leaks, such as decreasing of PT2 average pressure and weak bubbling of “Snoop” in suspicious places, disappeared.

There are several possible reasons for leaks appearing. First is a turning of Swagelok connections during the moving of CHUPS to the area. Second are vibrations of the platform inside the area caused by a membrane pump of the TPC vacuum system. Third is might be a overtightening of some Swagelok connections in a result of multiple connection and disconnection. Fourth is a possible broken bypass valve V25 (this place was found by handheld leak detector but was not approved by pressure test of the valve itself).

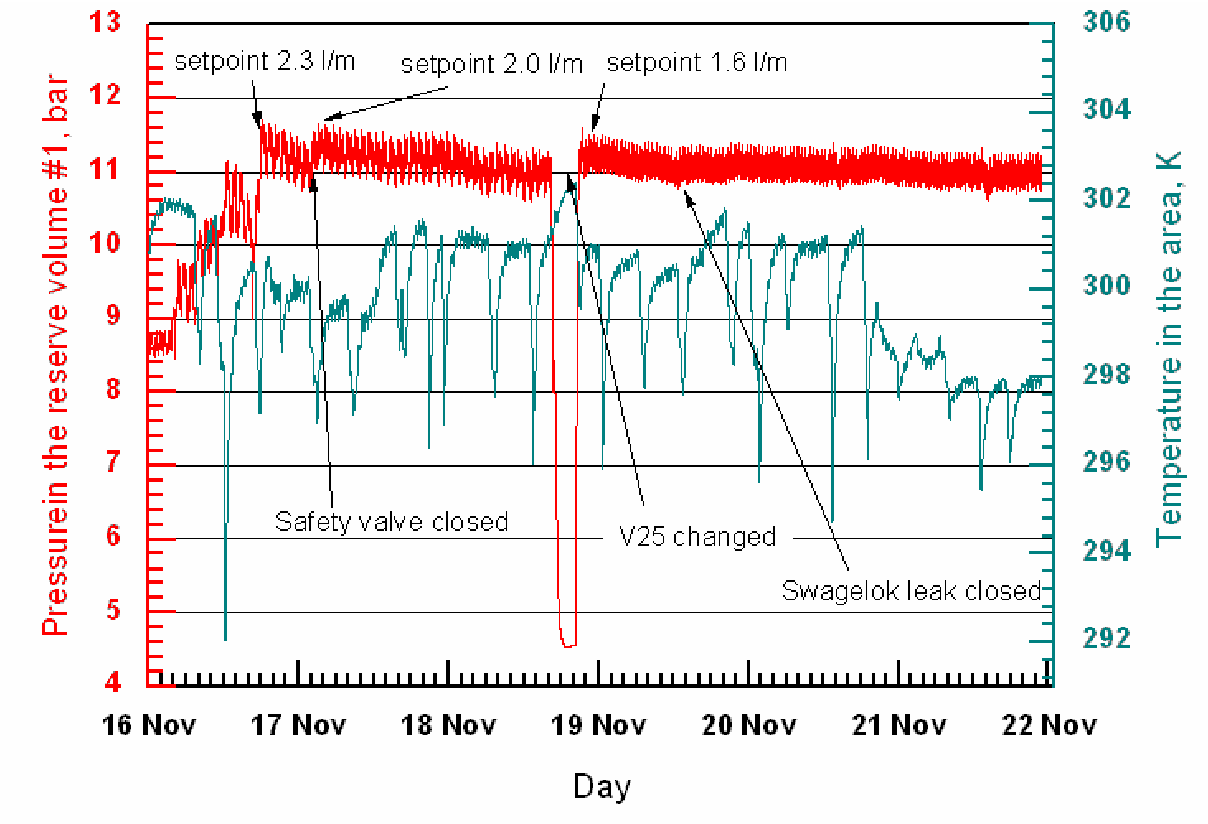

Fig. 11. History of leak search

Humidity

Purity conditions of TPC before run9 were likely worse than before run8. TPC has a less profitable history of cleaning before the run. This could affect to results of CHUPS operation.

Circulation through TPC was started for the first time 17.11.2005 at 10:00.

Preliminary cleaning of CHUPS itself by inner circulation had been done before.

Fast step up to 10 ppm (sensor's high bound) during several minutes after the start is good viewable on Fig. 12. The long exponential drying curve follows the step. The first "cycle" of TPC cleaning was anomalous successful. During 3 days roughly humidity went down to 28 ppb at moderate hydrogen flow (1.5 l/min).

After the first TPC disconnecting the situation was changed (Fig. 13). A relatively wide "peak" of humidity indication followed the first step. After subsequent provided TPC disconnections circulation started smoothly so first "jump" wasn't observed (Fig. 14) and the second "peak" become lower. This could suggest we improved humidity situation during the run. The main tendency of humidity was stabilization on the level of 30-35 ppb (at maximal reachable flux of 3-3.2 l/min).

The difference between the first start of CHUPS and further starts after breaks is not fully clarified by now. Possible the reason of this "strange" behavior is saturation of earlier very dry inner CHUPS lines during the first start.

Humidity decline on each step of "quiet cleaning" could be fitted by combination of two exponential decays.

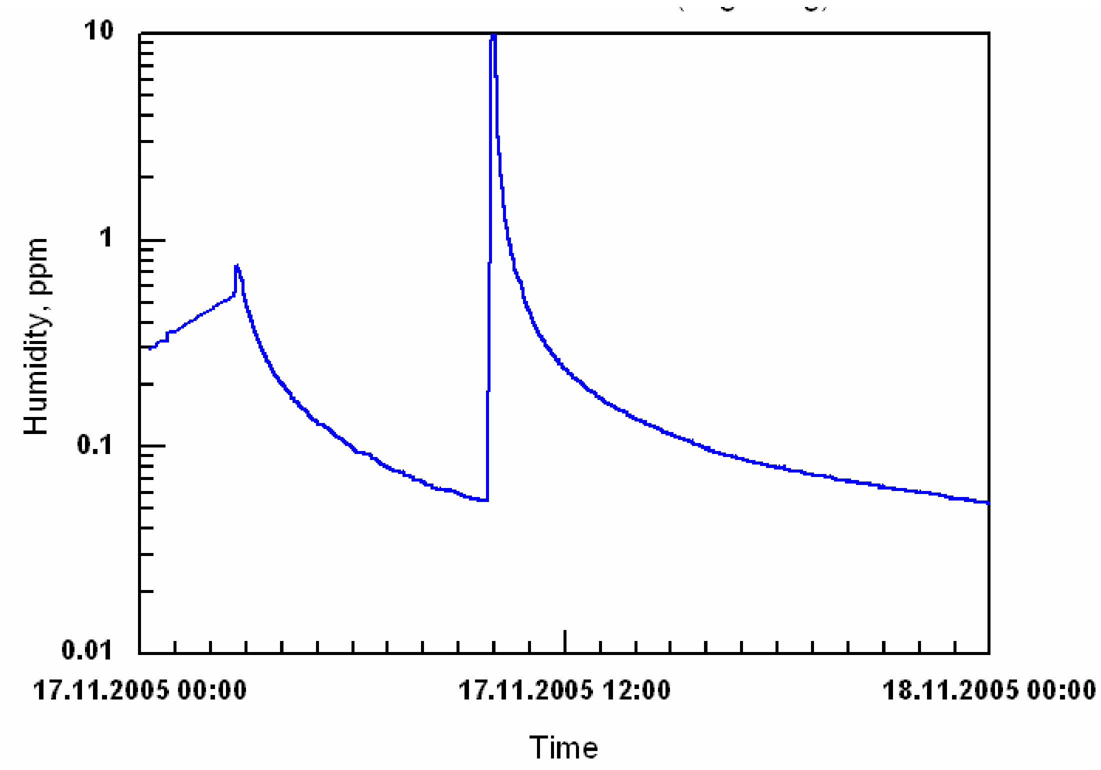

Fig. 12. Humidity during first TPC connection

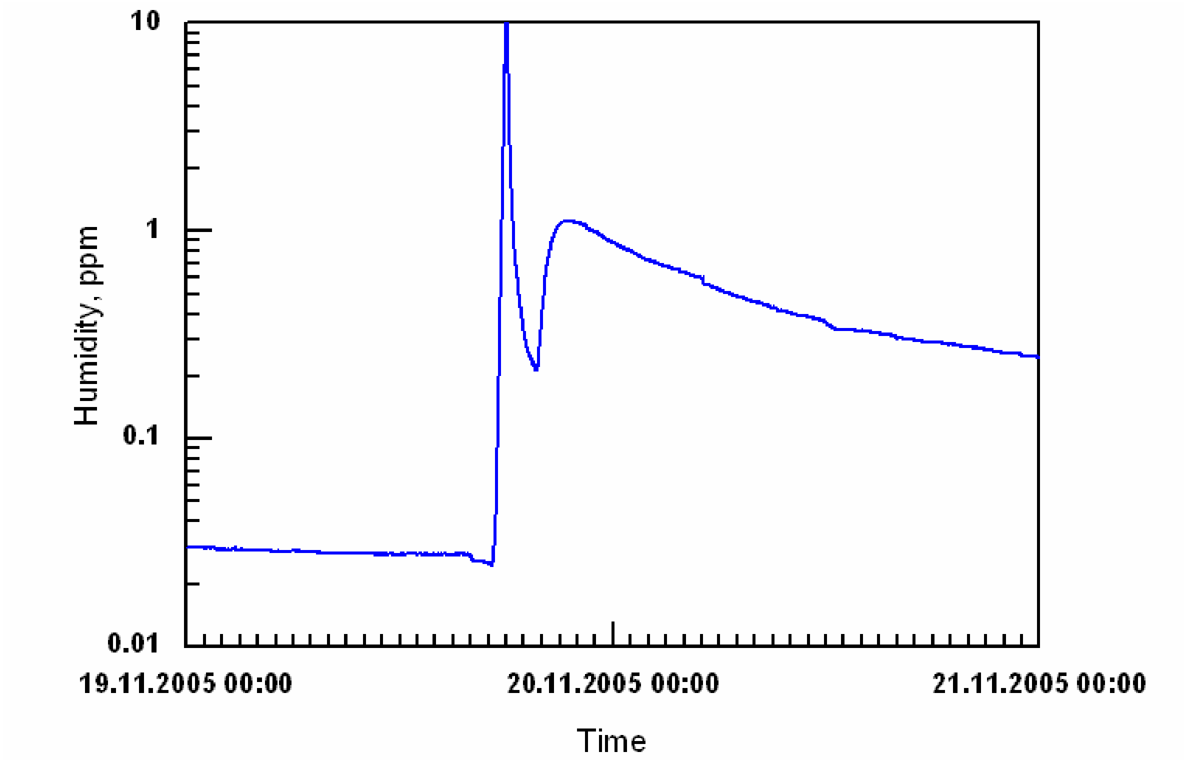

Fig. 13. Humidity after first TPC provided disconnection

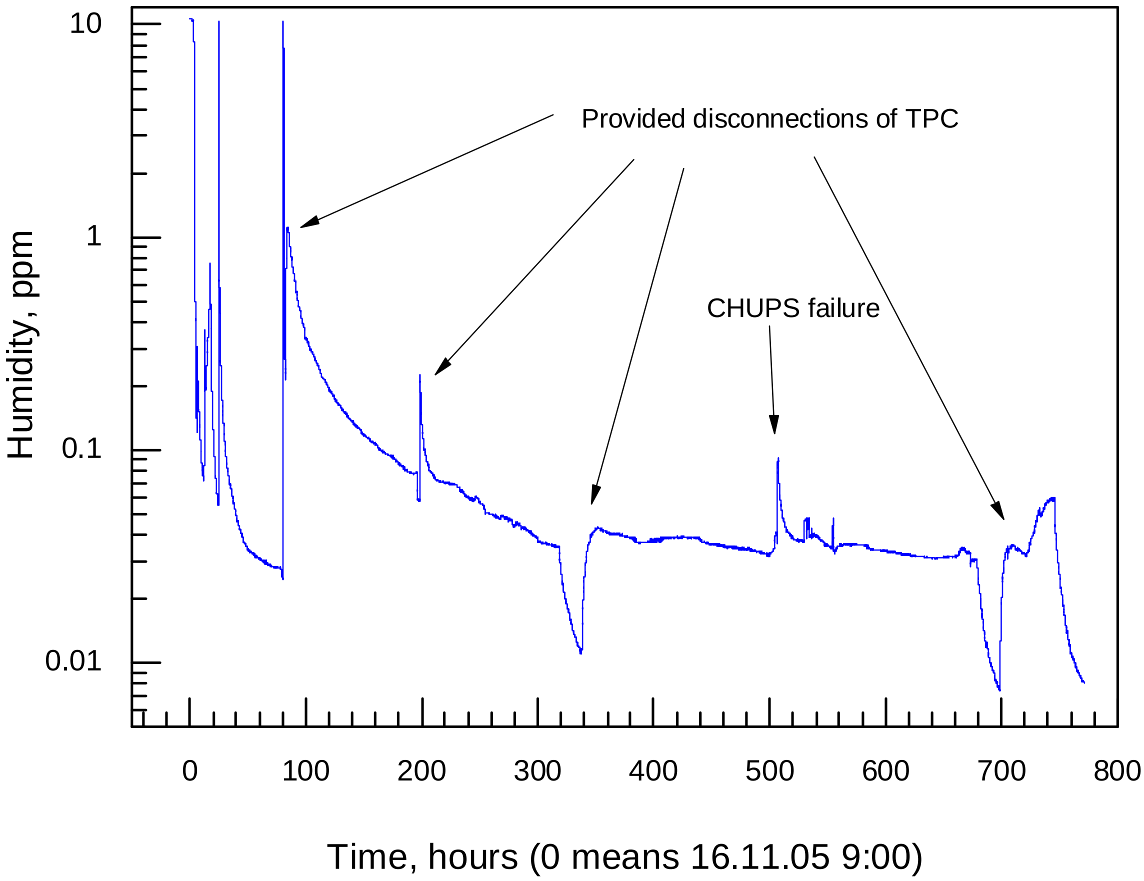

Fig. 14. Full history of TPC drying. Explanations in the text

The first term might be concerned to outgasing of TPC walls, pipes, and drying of the sensor itself. In turn, it could be divided to several "second order" terms.

The second exponent, as it was signed in previous notes, corresponds to exchange of hydrogen inside the TPC. The affect of tubes purity on the second term of the dependency could be shown on the instance of humidity behavior after the exchange of V25 valve and concomitant refilling the CHUPS (pouring of hydrogen).

Comparison between two situations: before and after hydrogen refilling is presented (Fig. 15 and Fig. 16). Both curves can be approximated by a combination of two exponents (A1*exp(-x/t1) + A2*exp(-x/t2) + y0). Parameters of exponents for both cases:

Situation	y_0	A_1	t_1	A_2	t_2
Before	0.063	0.036	34.919	0.489	5.992
After	0.069	0.042	1.038	0.055	5.203

We have very similar asymptotes and similar parameters of the second exponent. Time constant of this exponent is very close to the usual time constant for volume cleaning by the constant gas flow: $t=pV/Q$, for pV=400 and Q=1.35 l/min we have ~5 hours. The first exponent has very different time constants. It may be explained exactly the slow "bleeding" of humidity from "wet" V25 before exchange. During the refilling we flushed the valve and changed the situation. Asymptote is the same because it is connected with TPC outgasing speed.

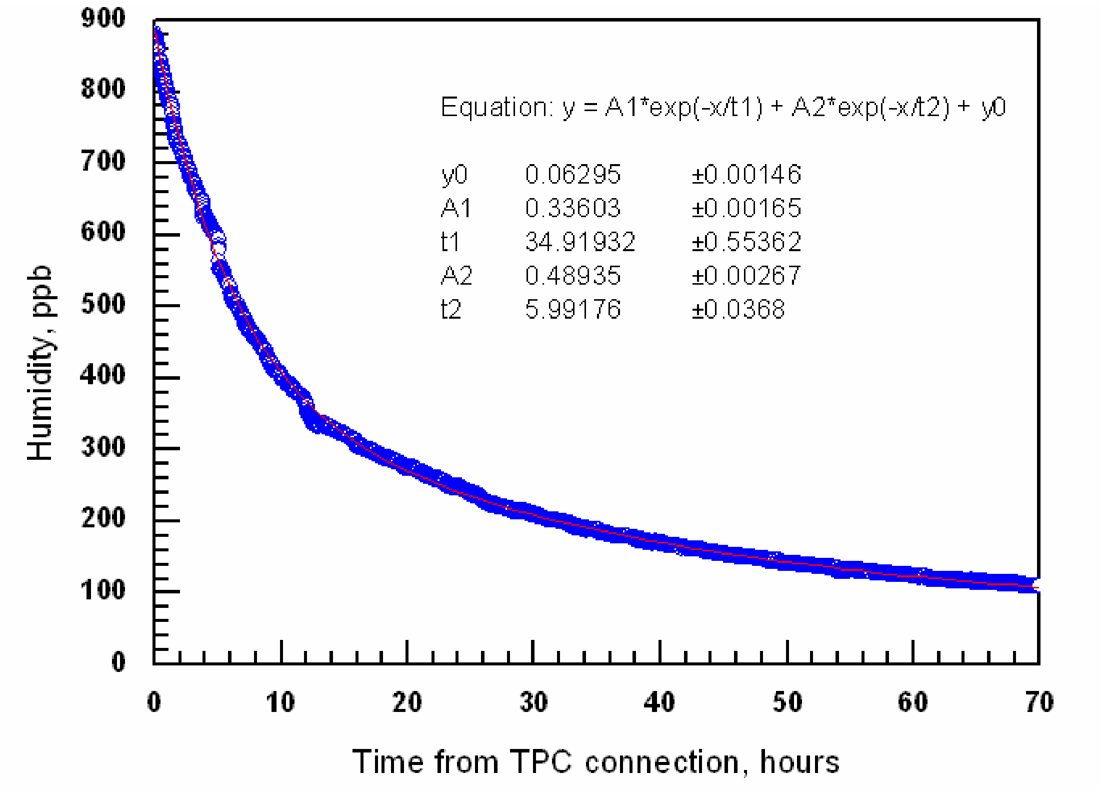

Fig. 15. Humidity curve before refilling

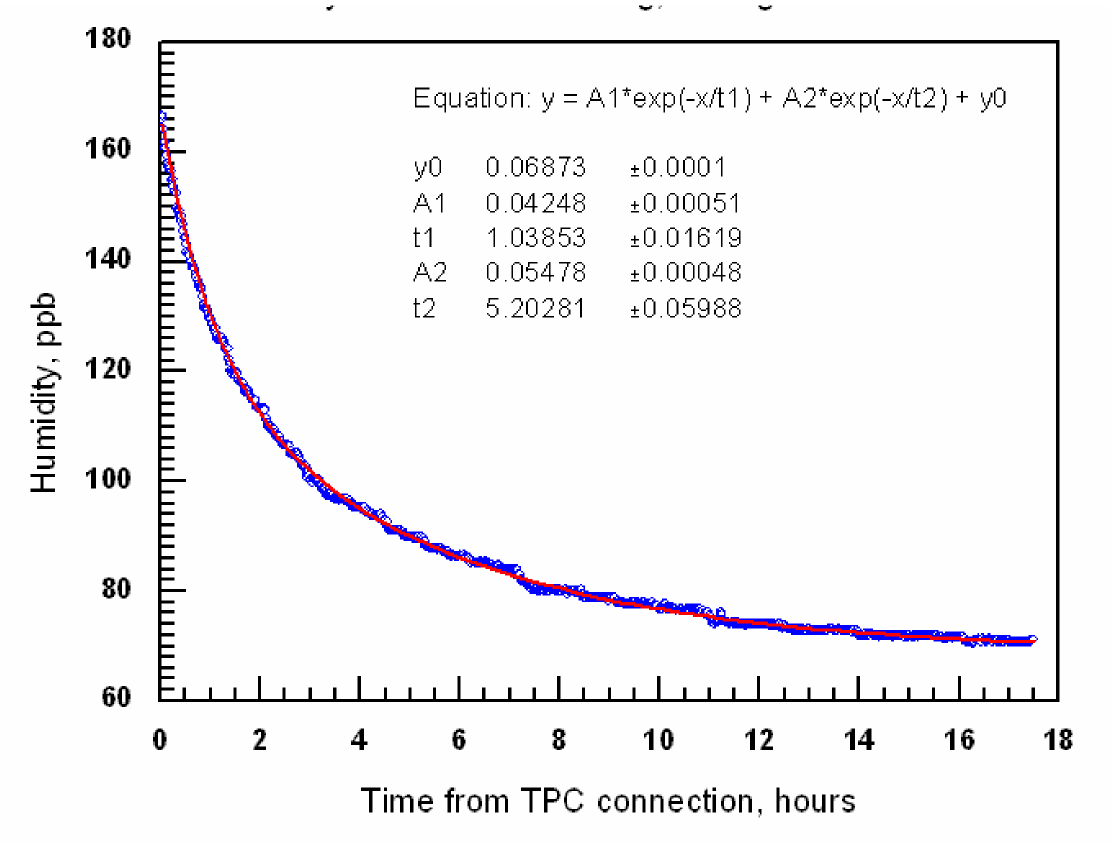

Fig. 16. Humidity curve after refilling

In the general case, one exponent is good enough to fit a drying curve. Particularly, this fit could be used to estimate a level of humidity inside the TPC after a circulation break. Direct measurements of this value are impossible because of long response time of the sensor, but some kind of rough estimation is available. Let's use a case of 320 hours after the circulation start (Fig. 17).

The derivative curve (brown line) gave the point of humidity curve's contraflexure. This point corresponds to humidity sensor (or entire system: sensor + tubes) response time. After the contraflexure point the sensor showed real (as close as possible) indication of humidity. Further, exponential fit of the humidity curve after the contraflexure point (red line) was extrapolated to zero point - time of circulation renewal. This extrapolation gave us a desired humidity point (68 ppb).

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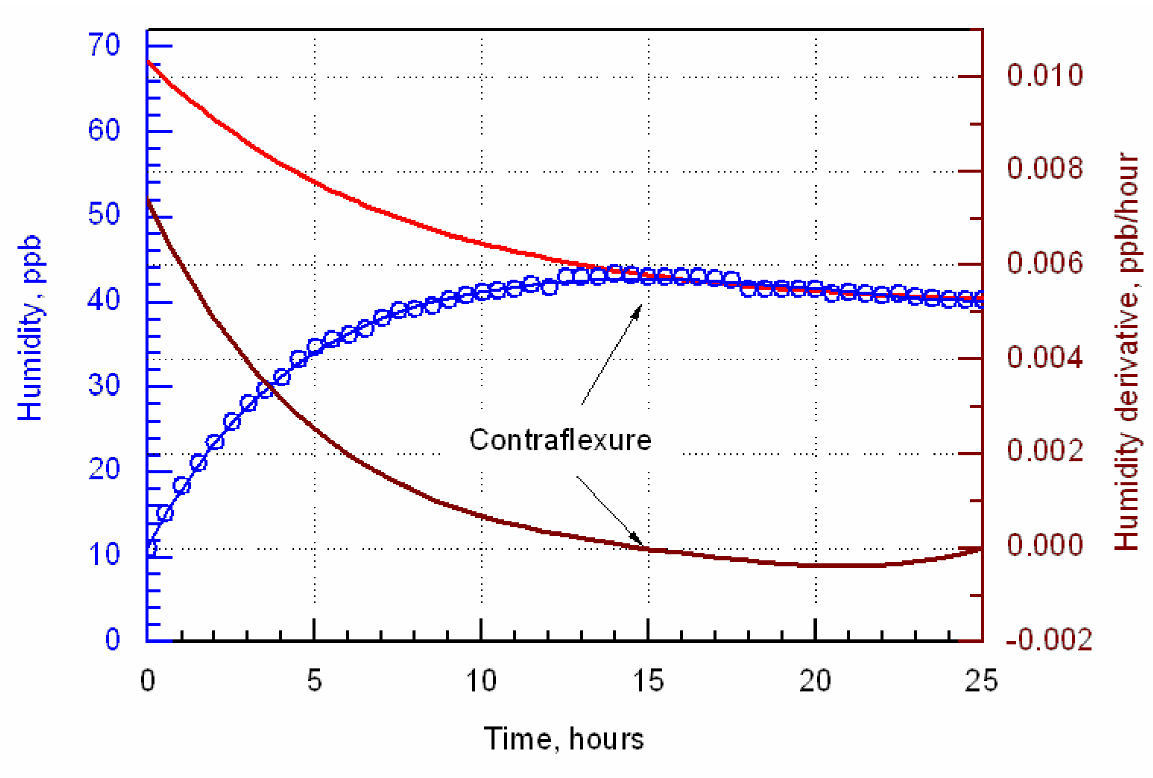

Fig. 17. TPC humidity curve estimation. Explanations in the text

Then circulating with bypassing the TPC, CHUPS achieved 8 ppb humidity inside.

Nitrogen purity

Unfortunately, during this run we couldn't plot a full curve of cleaning for nitrogen because of problems with sampling. The stable result (by chromatographic analysis) corresponded to stable humidity and capture yield measurements is 8-12 ppb.

Capture yields

Capture yields variation during the run showed viewable correlation with CHUPS regimes. When CHUPS is disconnected, yields grow. When CHUPS is cleaning the gas from TPC, yields tend to stable level which depends on the flux rate. This is an obvious illustration of CHUPS efficiency. The proportionality between humidity, nitrogen concentration and yields as well as other questions of impurity measurements should be a subject of special analysis (to be prepared).

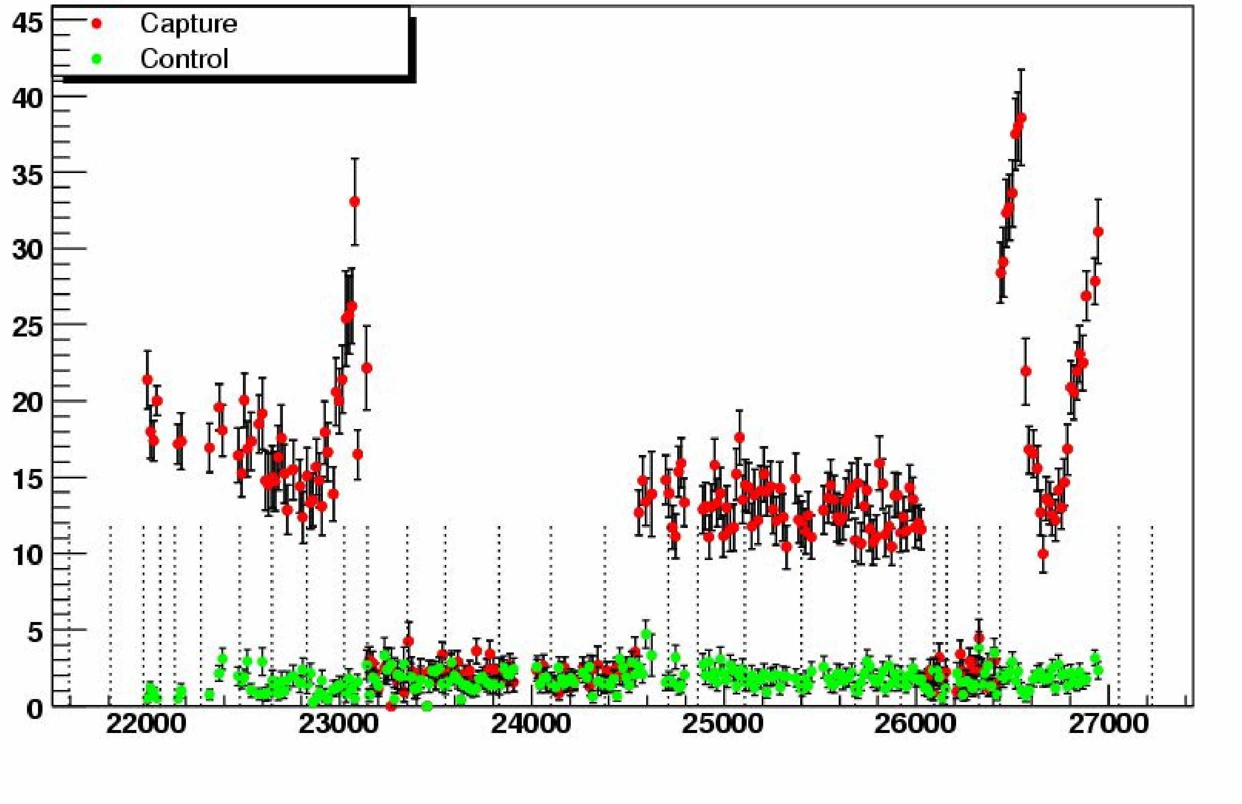

Fig. 18. Capture yields changing during the run

Some control problems

Basically, the CHUPS control system showed very good stability during. Nevertheless, several episodes of malfunctions not concerned with danger for TPC or other devices are happened.

First problem was concerned to "silent" alarm processing. December, 7 in the morning we had a special alarm in the control block for low pressure P2-P1 difference, which was set 0.01 bar. This situation was caused by an attempt to keep a large (more than 3.0 l/min) hydrogen flux without sufficient reserve of hydrogen. All alarm actions concerned to TPC safety was done (particularly, TPC was cut-off). Nevertheless, sound and light alarm didn't appear. This led to circulation interrupt corresponded to "CHUPS malfunction" humidity peak on Fig. 14. The reason for this is time period of computer data acquisition. Computer reads all parameters only once per 5 seconds (or 1 second during system adjustment). Control block is much faster. So block handled "dP low" alarm, and after some time of pressure rise, it reset the alarm flag, because pressure difference returned to normal condition. All this operations took place between computer readings, so computer did not see "dP Low" alarm flag. Besides, pressure in the reserve volume RV1 had grown almost up to critical value (16 bar) because "dP High" alarm threshold was set to 7 bar, which is more than release valve setpoint. This problem is very unlikely to be repeated but it will be excluded in the next run by software modification and correction of alarm threshold.

Second problem was concerned mainly with overheating of pressure sensor (Fig. 19).

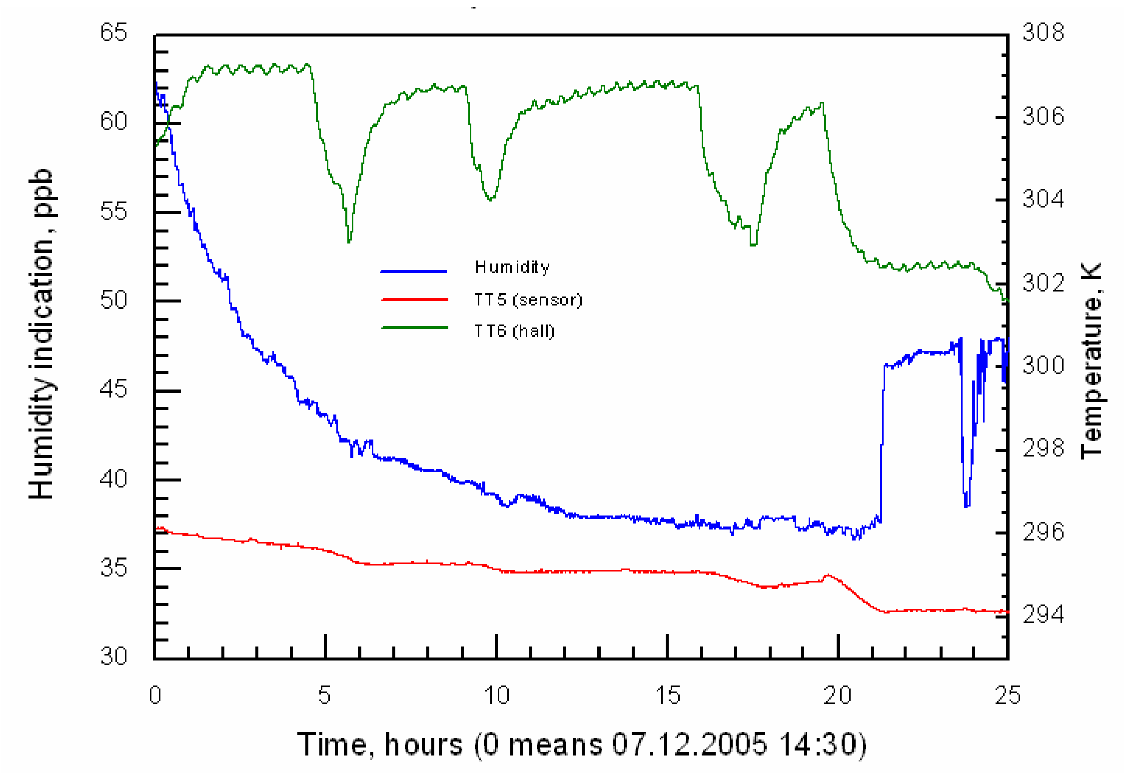

Fig. 19. Humidity sensor's indication trouble

Then air temperature nearby the CHUPS becomes more than 302 K (because of strong heat flow from TPC electronics and insufficient air conditioner action), Peltier elements of temperature stabilization system cease to manage one's task, temperature grows and humidity indication gets broken. Increasing of Peltier elements power range doesn't help because it leads to reduction of theirs efficiency and increasing of heat generation. In condition of bad ventilation, it results in even greater heating of the sensor.

An additional problem appeared simultaneously with overheating was bad contact in one of humidity sensor's connectors which resulted in the rough "jumps" of humidity indications up and down to 10 ppb roughly. This problem was removed by turning of the connectors.

The only one method to solve the problem of overheating was arrange the flow of air conditioner properly and to set its power to maximum. Quite possible it's necessary to install an additional fan nearby the Peltier elements heat exchanger.

Conclusion

As a whole, CHUPS performed good efficiency. Purification power of the system seems to be at least not less than for previous run. Usability of CHUPS and its reliability was sufficiently increased. The system needs the minor debugging (see above) but in general is ready to the next production run.