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Cultivation as-run procedures, test results, and final test report

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MELiSSA

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Acronyms and Abbreviations

EC: Electrical conductivity
HPC1: Higher Plant Chamber Prototype
UAB: University "Autonoma" of Barcelona
UoG: University of Guelph
CS: Control System

1. Introduction

This document outlines the operational test results in HPC1 with a batch culture of lettuce (*Lactuca sativa* L . cv. Grand Rapids) performed at the UAB using the Schneider PLC controller .
In the previous work (TN 96.5) UoG had tested the HPC1 chamber in the MPP (MELiSSA Pilot Plant) to demonstrate the performance and compliance with the environmental control specifications. The controller tested in a first phase was the Argus Controller and the crop test was performed with a batch culture of lettuce (*Lactuca sativa* L . cv. Grand Rapids) for an 11 day period.
In the next step (TN 96.11) the Control System (CS) was replaced by Schneider Hardware with control subroutines implemented by SHERPA Engineering, and new control loop tests were performed to demonstrate that the new system fits to the requirements. The crop test was repeated with a batch culture of lettuce (*Lactuca sativa* L . cv. Grand Rapids) also for 11 days.

In this document results of a full crop cycle of a batch culture of lettuce (*Lactuca sativa* L . cv. Grand Rapids) are presented. The test was performed during 46 days with the Schneider Controller in order to characterise the chamber under full operational conditions over a full crop cycle.

2. Methods and Materials

Lettuce seeds (*Lactuca sativa* L . cv. Grand Rapids) were sown in small rockwool cubes (TN 96.3) on September 10, 2009. The chronology of the events for the following 8 days of seedling establishment and initial development can be found in Appendix 1.
At 8 days of age, seedlings were transplanted into large presoaked rockwool cubes (75x75x65cm) and then placed in the HPC1 growing troughs. Five seedlings were placed in each trough, with a total of 20 troughs placed into HPC1. The total number of plants in the chamber was 100.
The HPC1 medium reservoir was filled with nutrient solution prepared as shown in Table 1. The solution was changed every 5 days of growth period. pH was maintained at 5.9 +/- 0.1 and EC was set to 1.9 mS/cm. Samples of nutrient solution were taken every 5 days for later macro- and micronutrients analysis. Hydroponic flow was continuous and was started when all troughs were placed in the chamber.
The configuration of the hardware regarding HVAC, including the lower panels for air flow distribution, and position of the upper louvers, was the same as during the functional tests (performed both with Argus and Schneider controllers), so the original configuration fixed by UoG.
Plants were grown with a 16 hour photoperiod, with day/night temperatures of 26º C/20º C, with day/night relative humidity of 50%/70 %. Carbon dioxide was set to 1000 $\mu mol \cdot mol^{-1}$. The total HPC1 residence time for this crop was 38 days with a total plant growth period of 46 days.

Table 1: Nutrient solution recipe

Component	Mol. Wt. (g)	Feed Strength	
		mM	g/L
$Ca(NO_3)_2 \cdot 4H_2O$	236.16	3.62	0.85
$FeCl_3 \cdot 6H_2O$	270.30	0.08	0.02
Na- EDTA	372.24	0.10	0.04
$MgSO_4 \cdot 7H_2O$	246.48	1.00	0.25
KNO_3	101.10	5.00	0.51
$NH_4H_2PO_4$	115.08	1.50	0.17
$(NH_4)_2SO_4$	132.00	1.00	0.13
H_3BO_3	61.83	0.02	0.0012
$MnSO_4 \cdot H_2O$	169.01	0.0050	0.0008
$ZnSO_4 \cdot 7H_2O$	287.54	0.0035	0.0010
$CuSO_4 \cdot 5H_2O$	249.68	0.0008	0.0002
H_2MoO_4 (85% MoO_3)	161.97	0.0005	0.0001

3.Results

3.1. Plant growth

Figure 1. Lettuce crop after 38 days of growth in HPC1 of the MELiSSA Pilot Plant, view from module A to module C

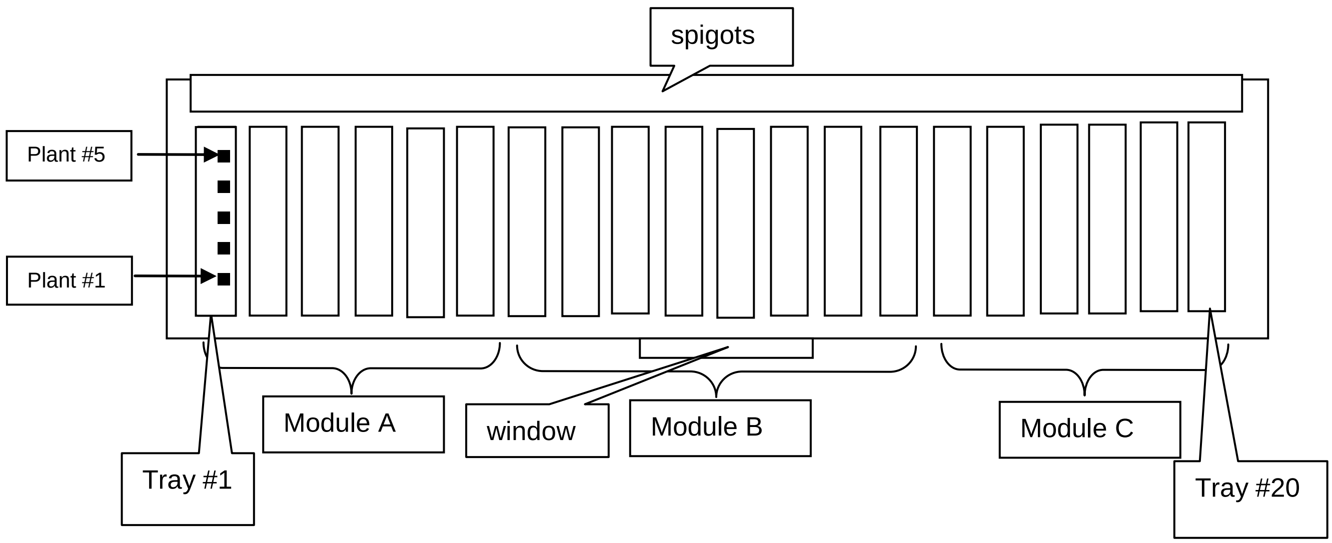


Figure 2. . **Schematic top view of HPC1 with plants and trays numbering**

Table 2: Lettuce fresh and dry leaf biomass after 38-days growth in HPC1

	Total (g)	per plant (g)	standard error
Leaf fresh mass	34100	344.4	6.8
Leaf dry mass	1698	17.3	0.5

As the result of crop test it could be observed that plants had rather high mass and size (figure 1). Total fresh leaf biomass of lettuce totaled 34 kg and total dry leaf biomass was 1.7 kg (table 2). However due to large size of the plants, crop density was high and air circulation between the plants was reduced, favoring the conditions for plant rot. Plant rot made a number of plants inedible. This is one of the reasons suggesting that future tests on lettuce in HPC1 should be shorter in duration.

Analysis of plants along the chamber showed a similar biomass distribution (figures 3-7) as observed in the previous 11-day tests (TN 96.5 and TN 96.11). Lowest shoot dry biomass for plant #1 was observed in the trays #7,8 (figure 3), for plant #2 - in the trays#8,10,12 (figure 4), for plant #3 – in the trays #2,5,7,11 (figure 5), for plant #4 – in the trays #3,6,12,18,19 (figure 6), and for plant #5 – in the trays #1,5,9,14,17. The lowest biomass variability in this lettuce crop was observed in the plant#4 position. Probably this area has the most uniform environmental conditions in comparison with the other growing areas.

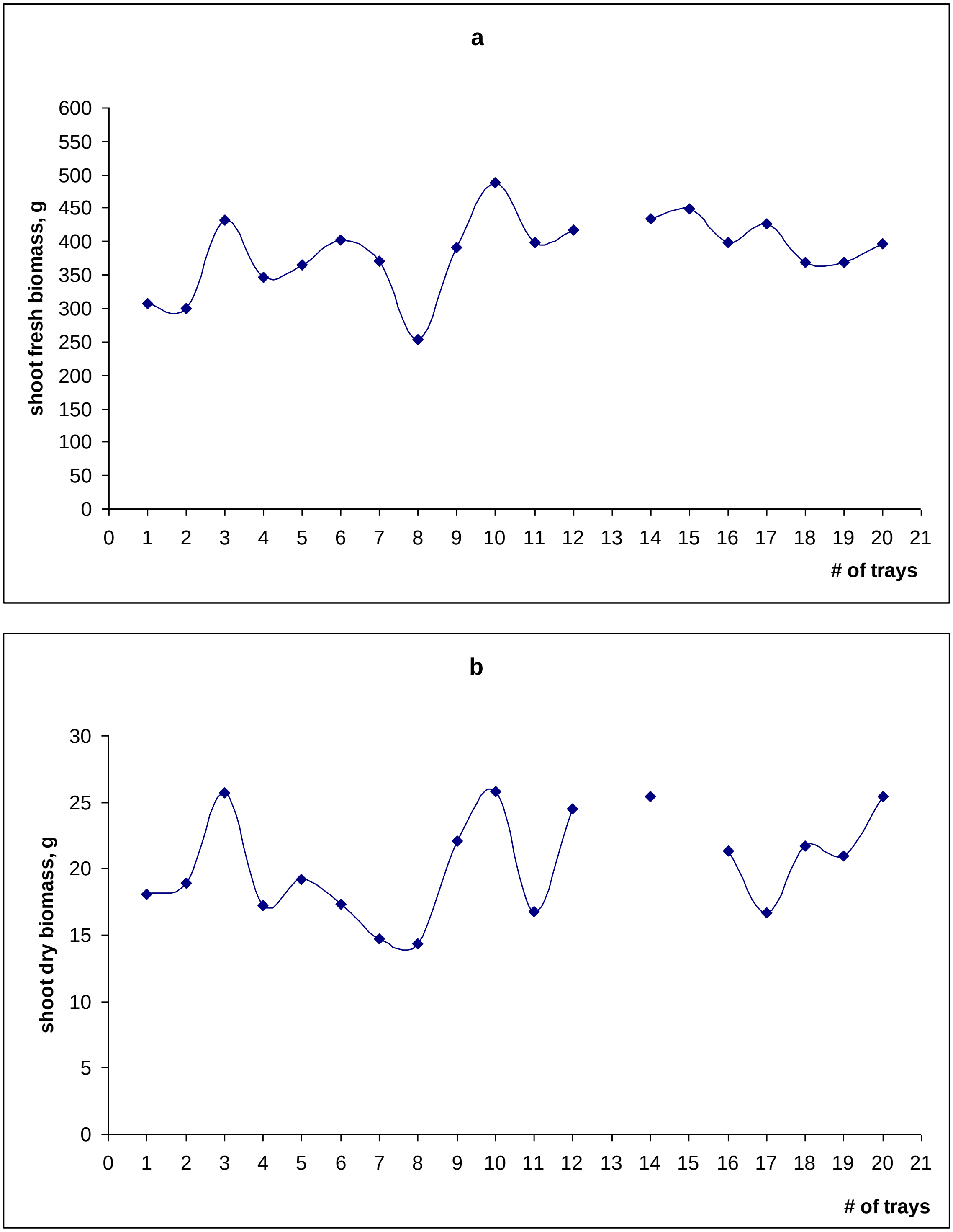


Figure 3. Lettuce shoot biomass (g) of plant # 1 along the chamber: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

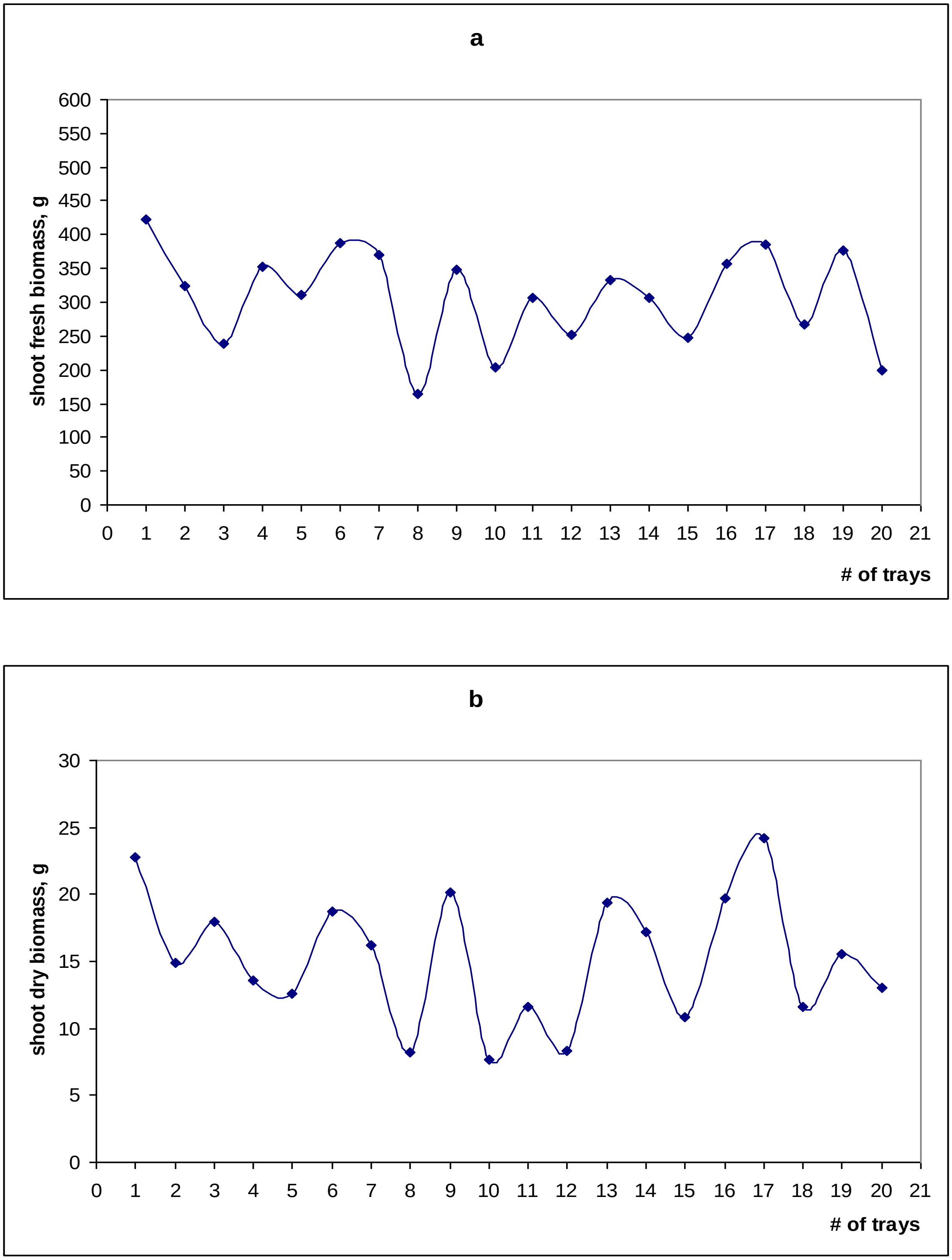
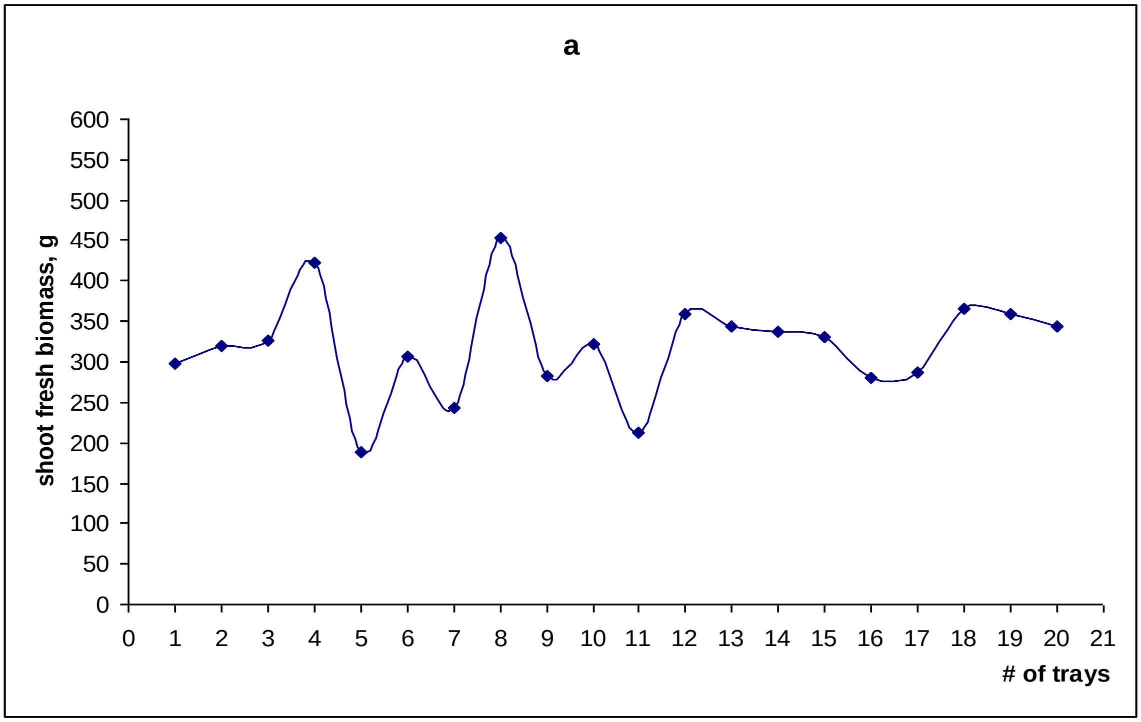


Figure 4. Lettuce shoot biomass (g) of plant # 2 along the chamber: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)



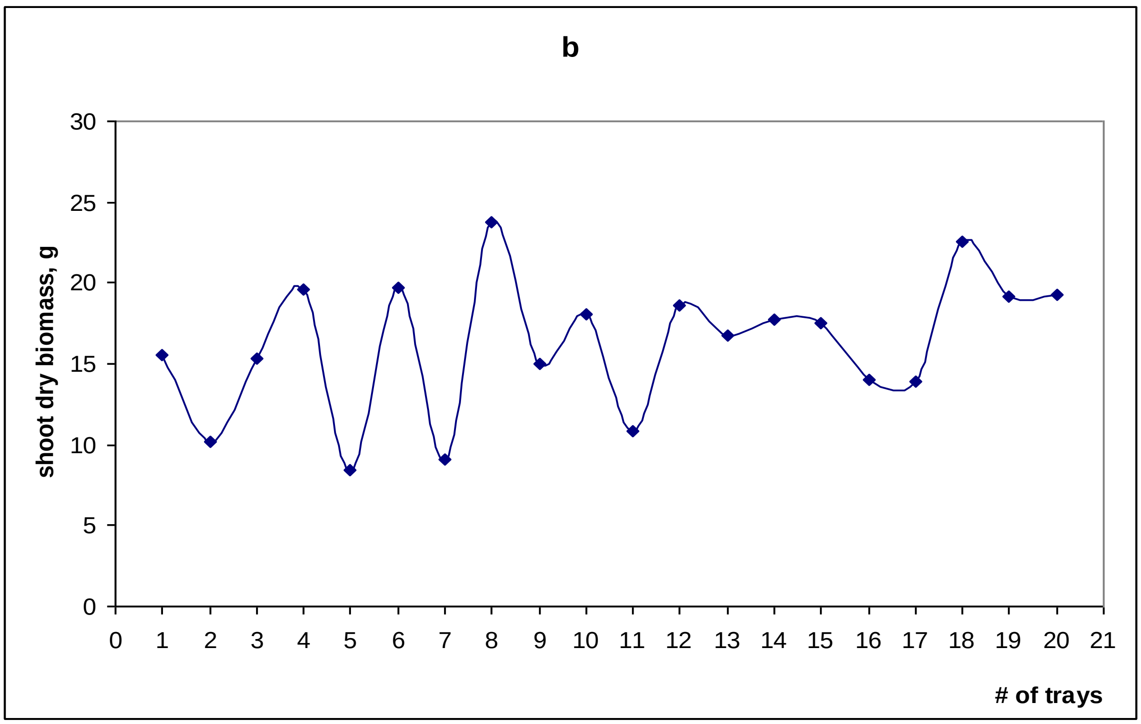


Figure 5. Lettuce shoot biomass (g) of plant # 3 along the chamber: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

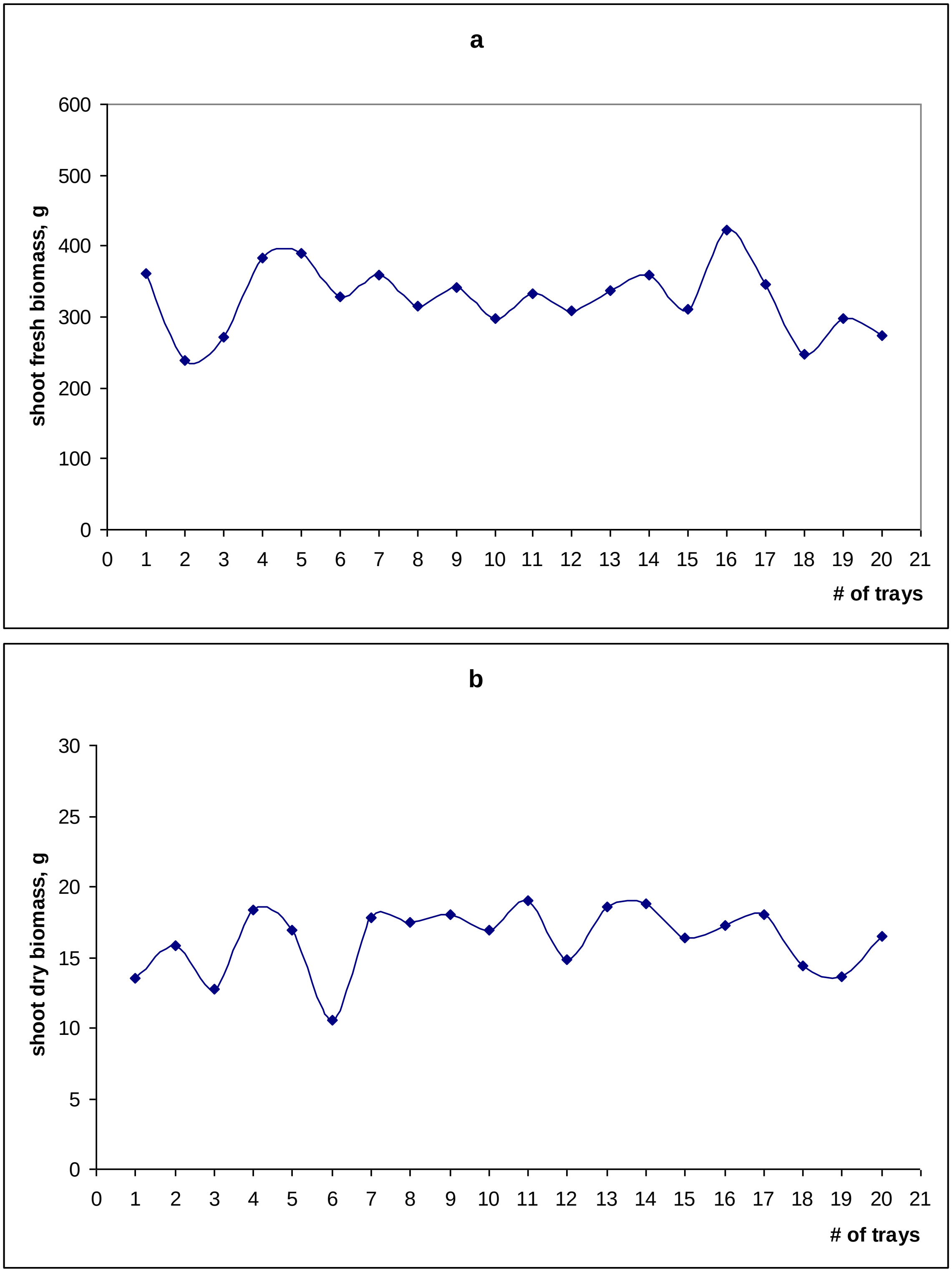
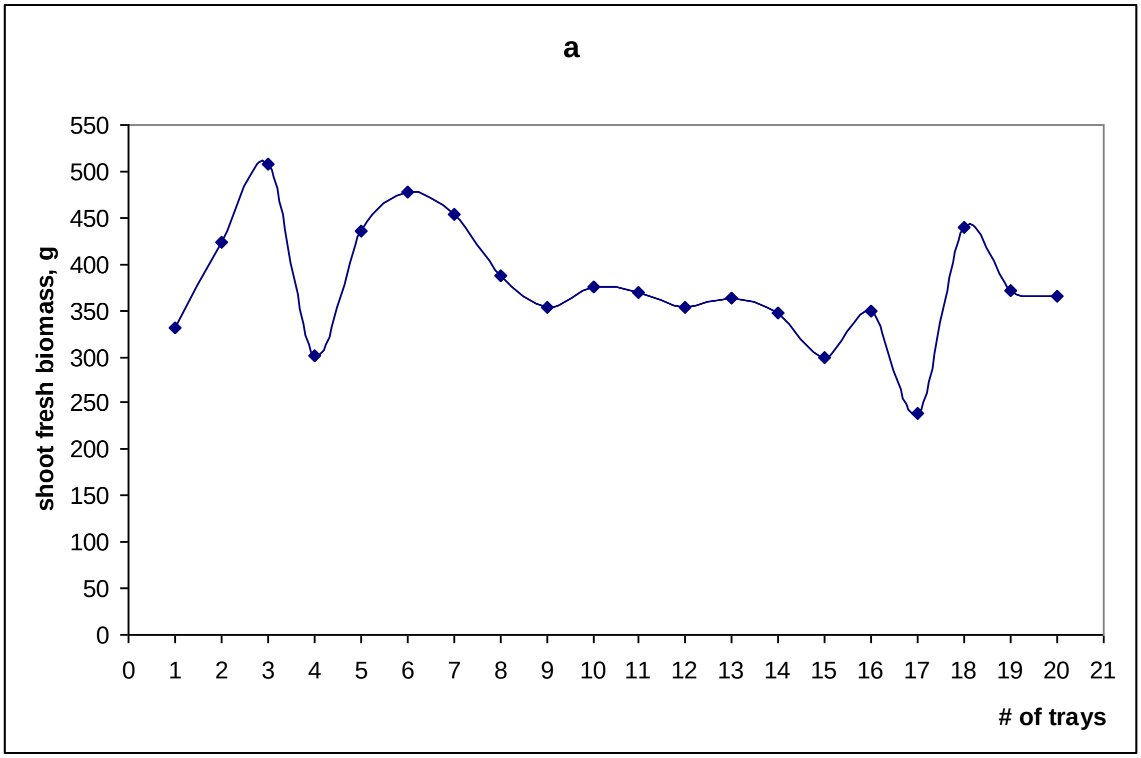


Figure 6. Lettuce shoot biomass (g) of plant # 4 along the chamber: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)



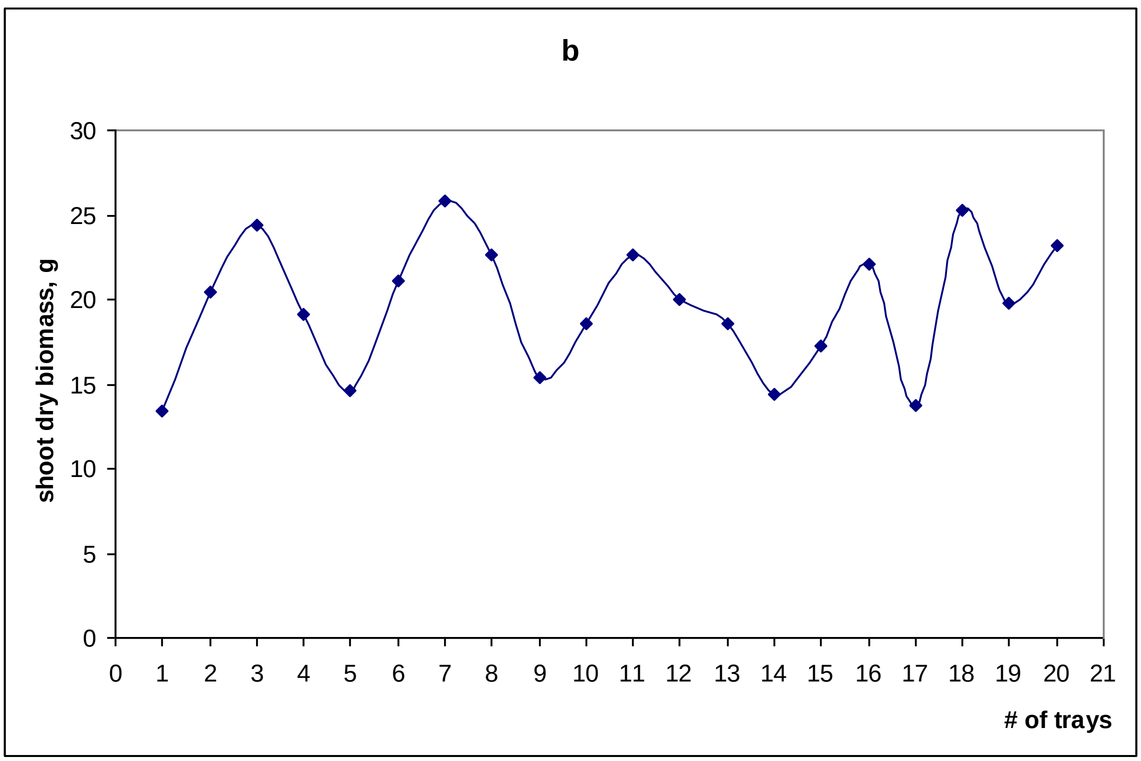
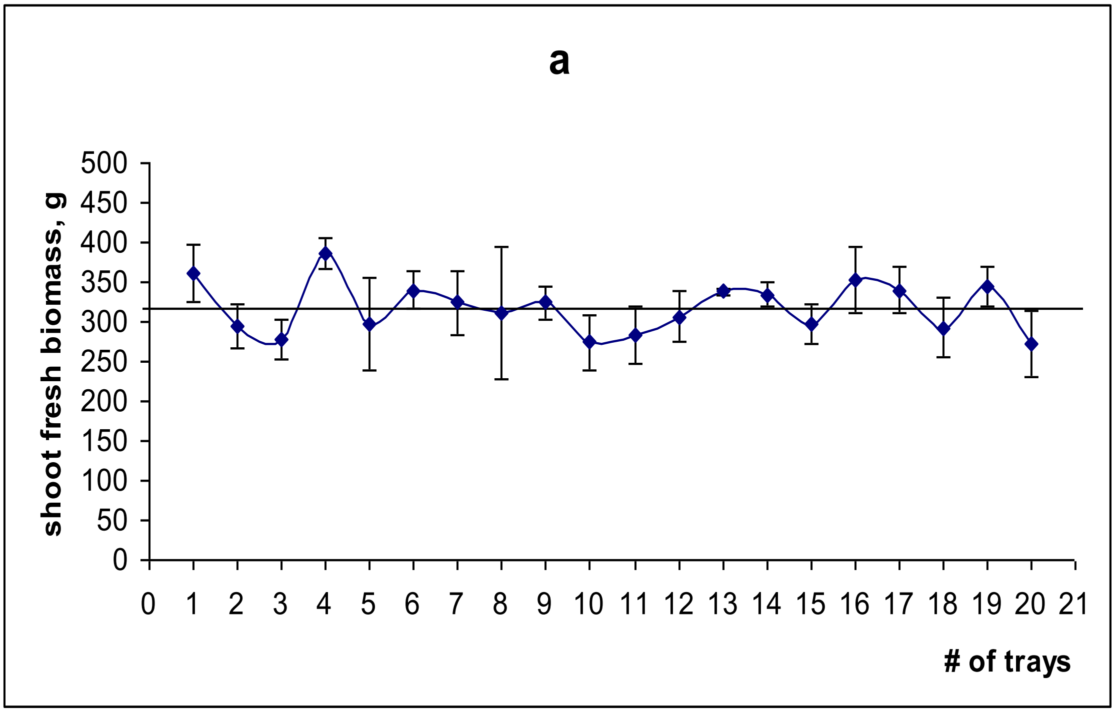


Figure 7. Lettuce shoot biomass (g) of plant # 5 along the chamber: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)



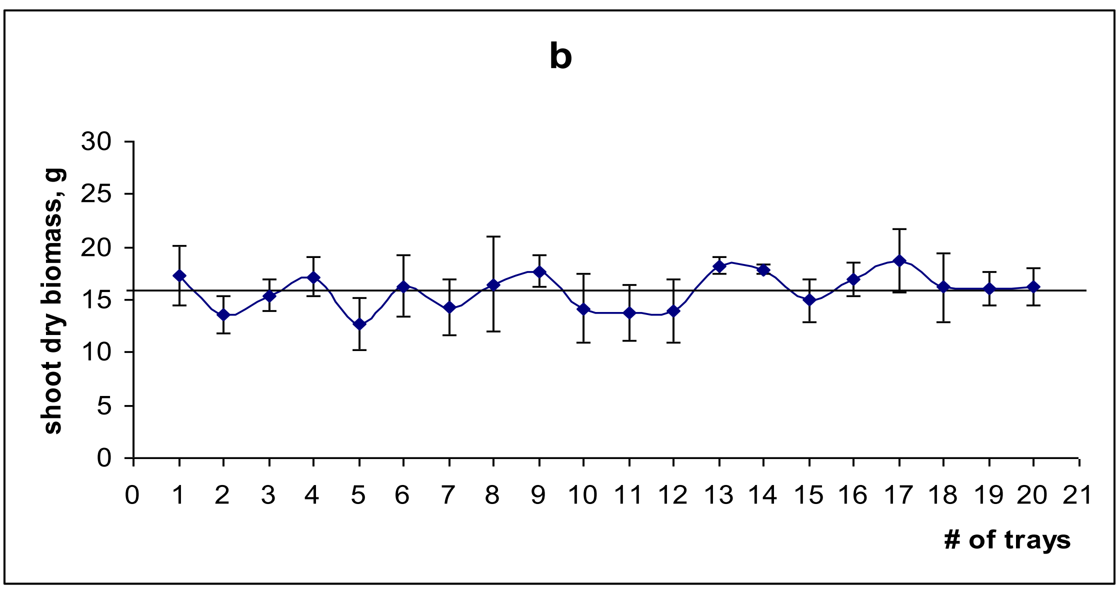


Figure 8. Lettuce shoot biomass (g) of plants #2,3,4 average per tray: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C). Black line along the graphs is showing average shoot biomass for plants #2,3,4 per all trays

Averaging of central plants (#2,3,4) shoot dry biomass per tray showed that dispersion of more than 15% error was observed for the trays #1,5,6,8,10-12, 17,18 (figure 8). Significant deviation from average per all trays was observed only for the trays #2, 5, 9, 13, 14. As for the average biomass of plants#1 and #5, dispersion of these values along the chamber were higher than for the central plants, especially in module B (figure 9). Error of more than 15% was observed for the trays #7-10 and trays # 13-15. Probably, as in previous crop tests (TN 96.5 and TN 96.11) it is indicating that environmental conditions in HPC1 growing area next to the walls are less uniform in comparison with the central area.

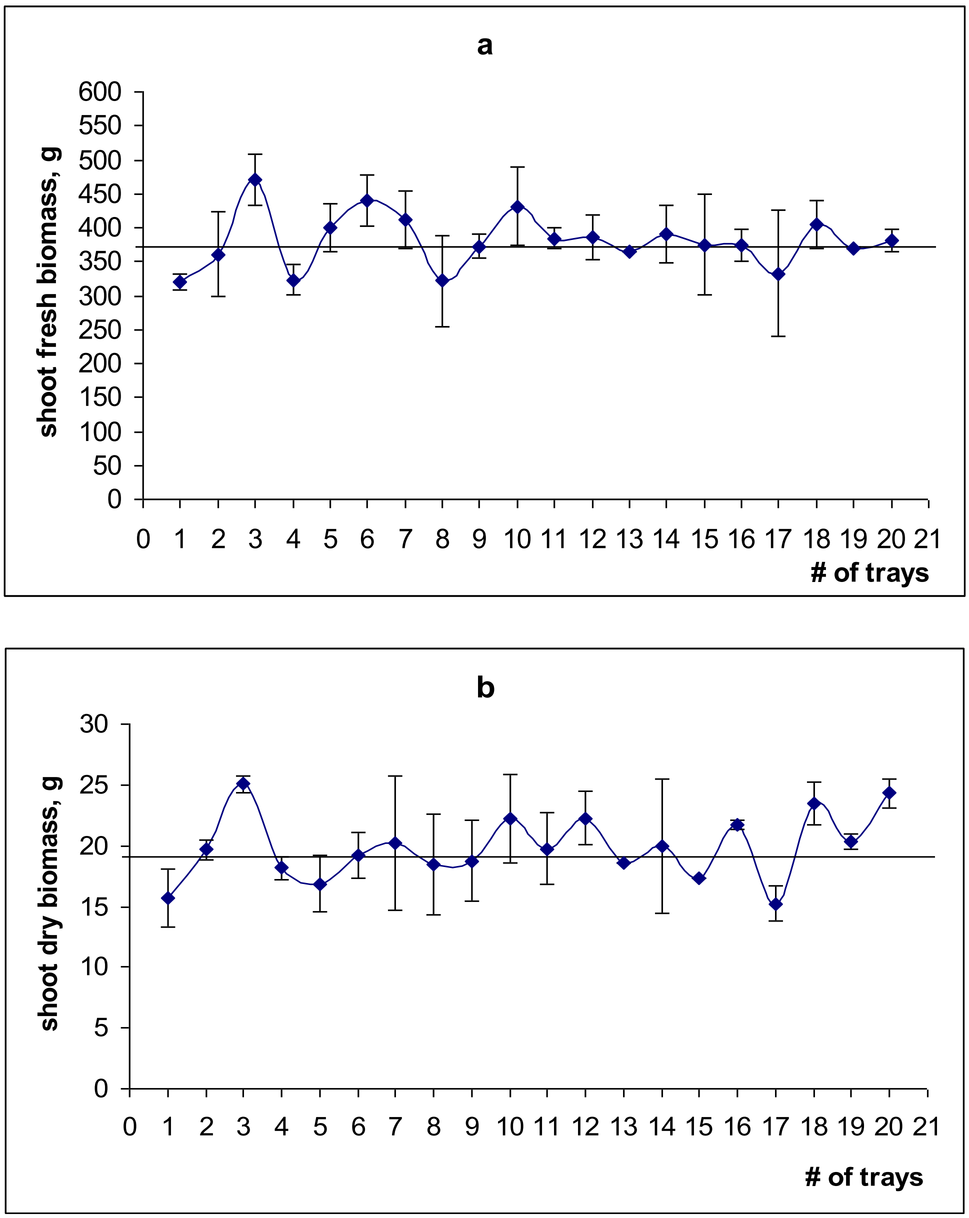
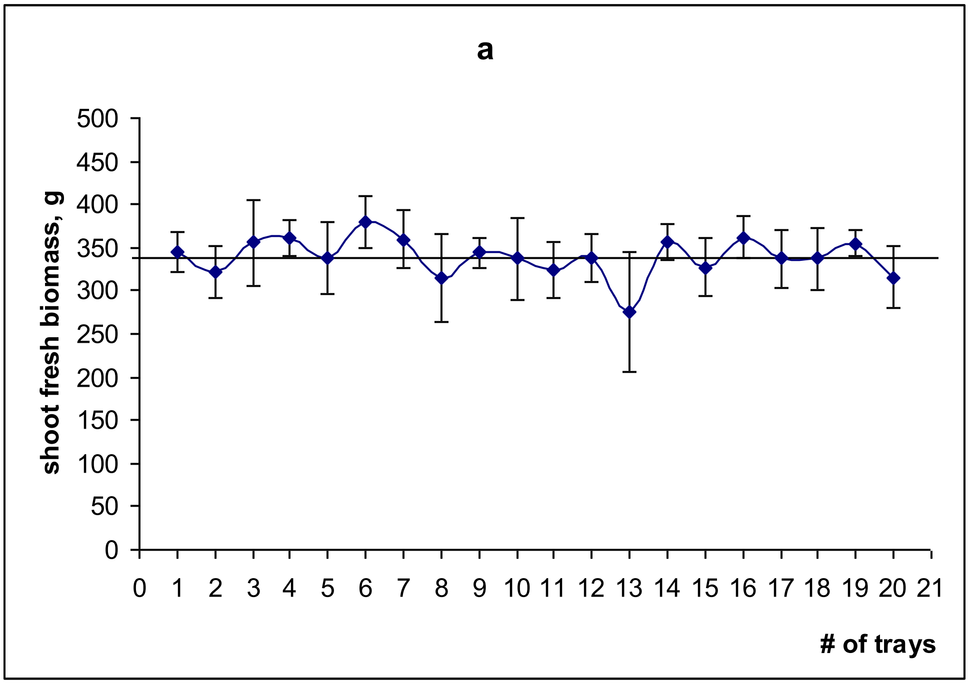


Figure 9. Lettuce shoot biomass (g) of plants #1,5 average per tray: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C). Black line along the graphs is showing average shoot biomass for plants #1,5 per all trays



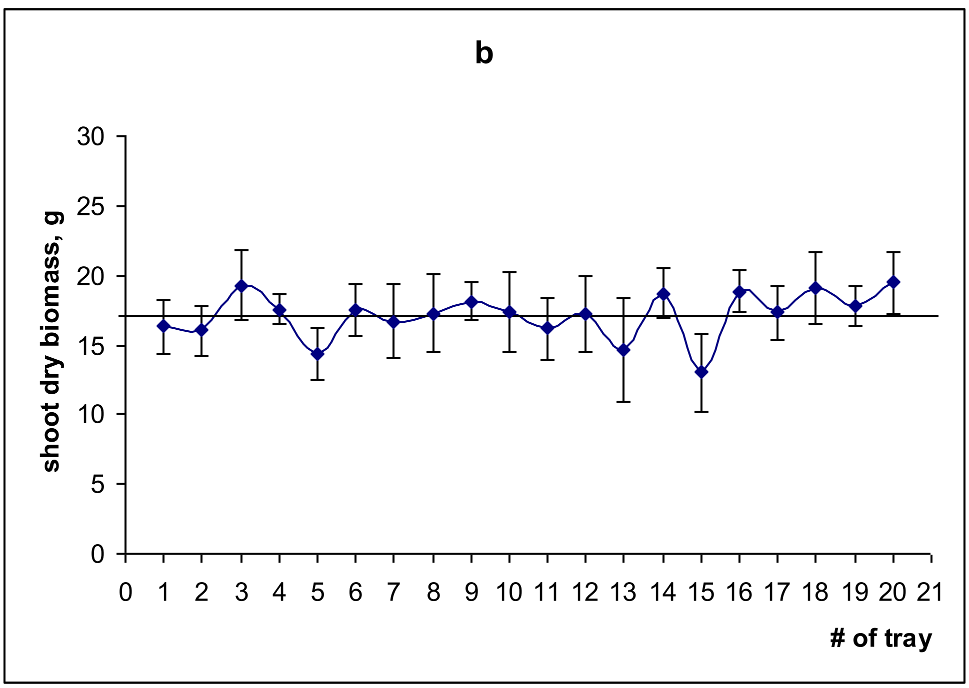


Figure 10. Lettuce shoot biomass (g) of plants #1-5 average per tray: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C). Black line along the graphs is showing average shoot biomass for plants #1-5 per all trays

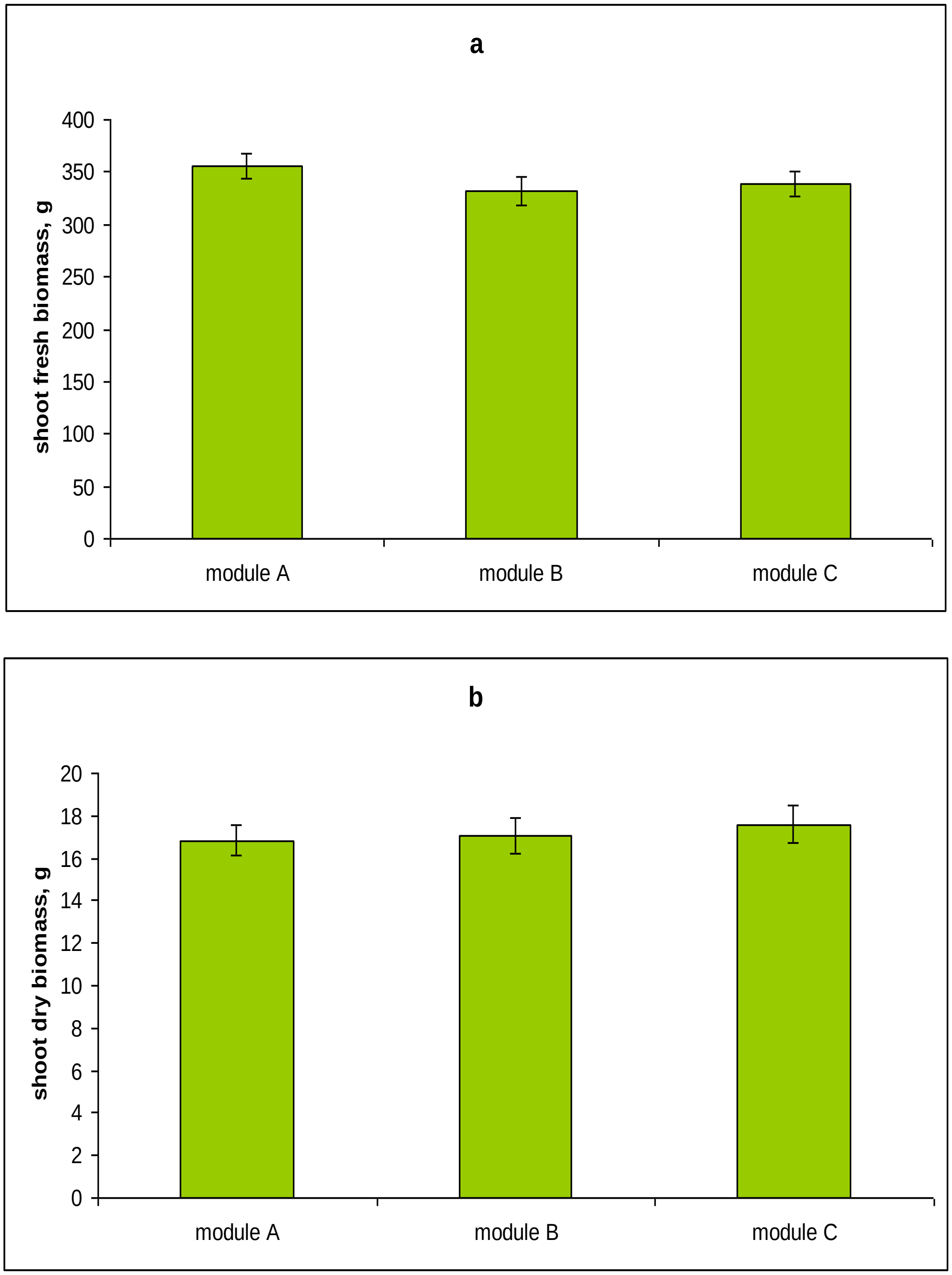


Figure 11. Lettuce shoot biomass (g) of plants #1,2,3,4,5, average per module: a – fresh biomass; b – dry biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

It should be noted that after 38 days of plant growth, distribution along the chamber of shoot average biomass of all plants per tray was significantly less variable in comparison with the biomass of the plants after 11days growth (TN 96.5 and 96.11) (figure 10). Also, no significant difference was observed between average shoot biomass of lettuce per module (figure 11), while

after 11 days growth shoot average biomass in module B was lower than in modules A and C (TN 96.5, TN 96.11). Probably this result was connected with plants adaptation to specific environmental conditions during growth period.
The measurement of water flow of each spigot showed that there was also dispersion along the chamber, but no evident correlation with dispersion of plants shoot biomass was observed.

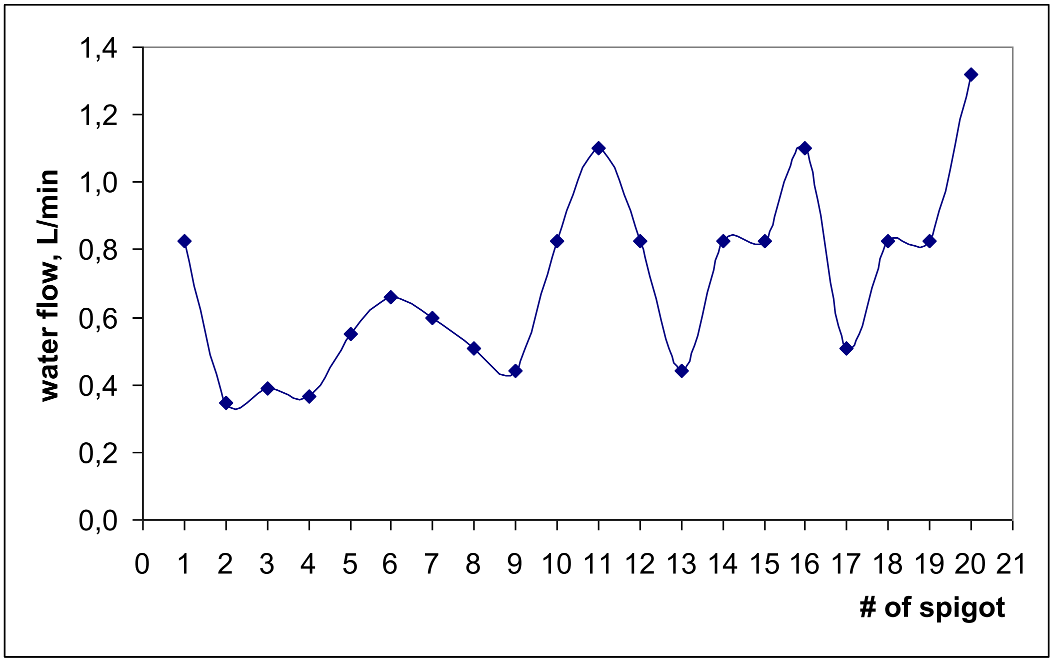


Figure 12. Water flow per spigot, from module A to module C

3.2. HPC Operation

During 38 days of closure the HPC1 performed well in general but some internal failures or external events caused deviations from normal operation that are reported in Table 3.

Table 3. Deviations from nominal conditions during HPC1 operation

Day N° of the test	Deviation	Probable reason	Taken action
3	The level of nutrient solution in stock A was significantly lower than in tank B	Injection of stock A during the previous days (weekend)	Nutrient tank was emptied and nutrient solution was changed to a new one
5	Approximately 2 L of acid and 2 L of base were introduced into HPC nutrient tank by gravity	Leaks of acid and base electro valves were detected	At the same day electro valves were changed as well as nutrient solution.
13	Continuous injection of CO_2 into the chamber during almost 1.5 hours. After gas analyzer	Error of gas analyzer	The chamber was opened in order to decrease CO_2 concentration, and then when it was 1240

	calibration, it was detected that concentration of CO_2 in the chamber was higher than 5000 ppm		ppm HPC1 was closed and CO_2 control was disabled until the morning (during 13 hours). Then next day after checking gas analyser one more time, CO_2 control was enabled.
18	Temperature of chilled water was increasing during almost 2 hours reaching a maximum of 28ºC. During those 2 hours temperature and relative humidity in the chamber also increased up to maximum 30ºC and 94% respectively	Error of general cooling machine	The machine was reset, temperature decreased to 10ºC
18-19	Values of O_2 and CO_2 concentration in HPC1 decreased without any reason and later returned to the correct ones without any manipulation with gas analyser	Failure of gas analyser	No action was taken
21	The chamber was depressurized by operator	Oxygen concentration in HPC1 had reached 23.33%	After 5 minutes of ventilation oxygen concentration decreased up to 21%, the chamber was closed and the test was continued.
21	Cut off of irrigation during almost 19 hours	Irrigation pump was broken	Since it happened in the evening it was not possible to change the pump with another one at the same day. After 19 hours a new pump was installed. Visually no any signs of plants fading were observed.
28	The chamber was depressurized by operator	Oxygen concentration in HPC1 had reached 23.69%	After 5 minutes of ventilation oxygen concentration decreased up to 21%, the chamber was closed and the test was

			continued
35	Decrease of air temperature in the chamber up to 17.1ºC and very fast increase of humidity up to 97% as it was night for the plants (RH set point=70%) during 1 hour	Attempt to change the resistance in hot water buffer tank in MELiSSA Pilot Plant that caused decrease of hot water temperature until 18º C	After observing the consequences hot water source was connected again

3.3. Environment control

After previous 11-days crop test with Schneider controller (TN 96.11) it was decided to have a set point for relative humidity at 50% during day time (period of lighting in HPC1) in order to make possible to maintain day temperature at 26º C. However, during first 3 days of crop test set point for day relative humidity was 60% by error of operator and it entailed increase of day temperature (figure 13, table 4). This result supports previous conclusion (TN 96.11) that in the beginning of crop test when the plants are small and transpiration is low, it is impossible to maintain day relative humidity (RH) at 60% with the given temperature set point (26º C). After changing the set point of day RH to 50%, the humidity and temperature during the test were controlled quite well, with the exception of periods when the above mentioned external events (table 3) caused some deviations (figure 13, table 4).

However, even though during the day time average temperature was controlled at 26°C, in module A temperature was about 27°C and in module C - about 25 °C. The same tendency was observed for humidity: during the day time average humidity was controlled at 50%, but in module A it was about 54% and in module C - about 46%. As for the module B, it was not possible to use readings of temperature and humidity sensor for any comparison as it was installed not in the plants growing area.

During the first 3 days set point for night temperature was 21º C and set point for night humidity was 55% also by mistake. It could be seen that at night was quite difficult to reach that humidity (figure 13, table 4). However, after changing set points for night humidity to 70%, control was performed well. Also no difference in night temperature and night humidity was observed between modules A and C during the test (Appendix 3).

Deviations in temperature and humidity, observed in figure 13, were caused by events, described in the previous subparagraph 3.2 HPC operation.
During transition from day to night stabilization of relative humidity took about 10 minutes, and from night to day was 2 times longer – 20 minutes (figure 14). The same time took for this process in the previous crop test with Schneider controller (TN 96.11).
During transition from day to night, stabilization of temperature took about 100 minutes, and from night to day about 40 minutes (figure 14), which was longer than during 11-days crop test with Schneider controller (TN 96.11).
Fluctuation of hot water temperature could be observed during the test, expressed in the form of peaks during transition from day to night and vice versa (figure 13). The reason of that problem was breakdown of main heating element of hot water buffer tank and inability to control the temperature of hot water with the second less powerful heating element. In other words, during transition from night to day the HPC hot water demand was larger than heating element could deliver, and temperature of the water decreased. During the transition from day to night, HPC hot water demand decreased, but the

heating element continued to work in former conditions, and the temperature of hot water increased. However, these fluctuations did not influence air temperature control of HPC1. Since it was not possible to change the heater element during the test and the problem was not critical, it was changed after the crop test was finished.

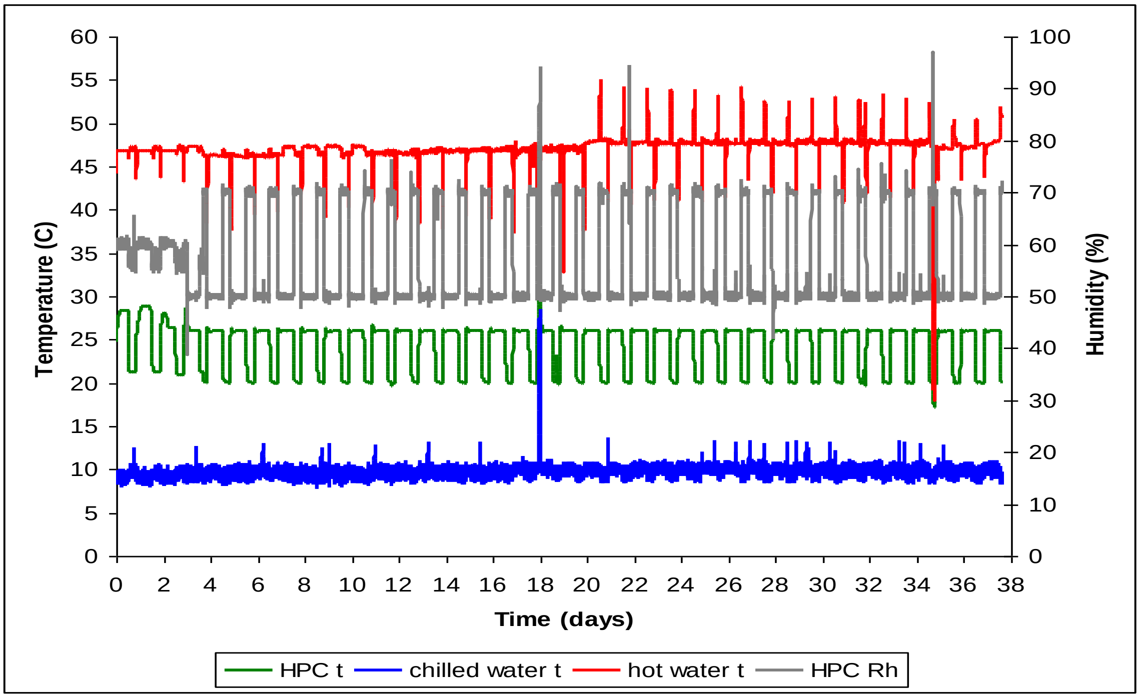


Figure 13. Temperature and humidity control in the HPC over the 38 day period of closure

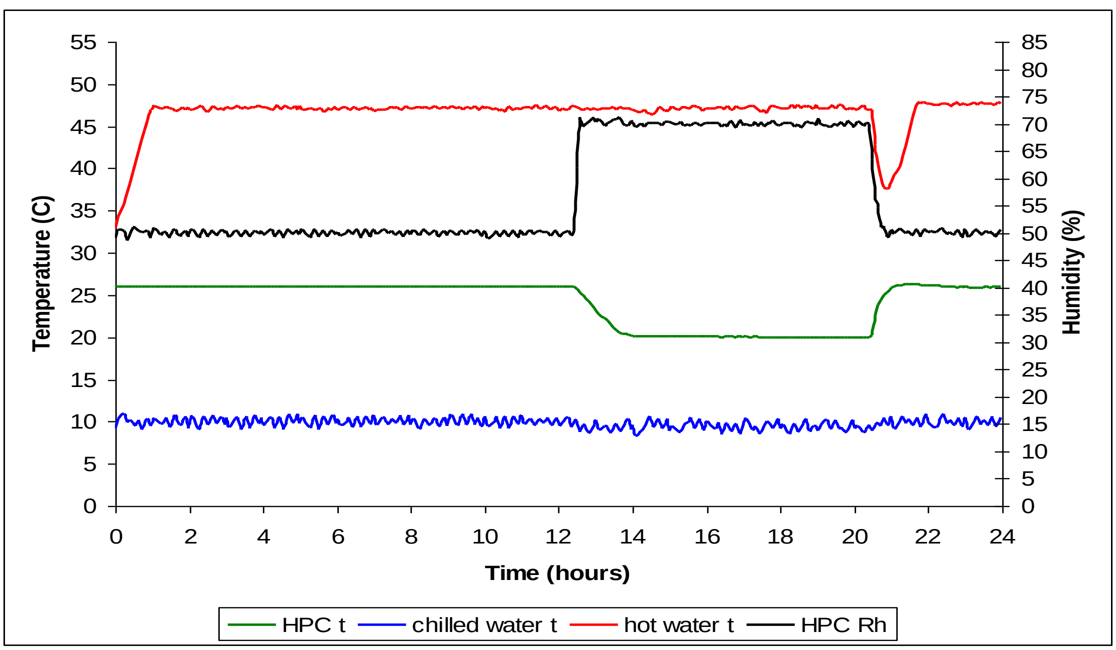


Figure 14. Temperature and humidity control in the HPC at 19th day of closure

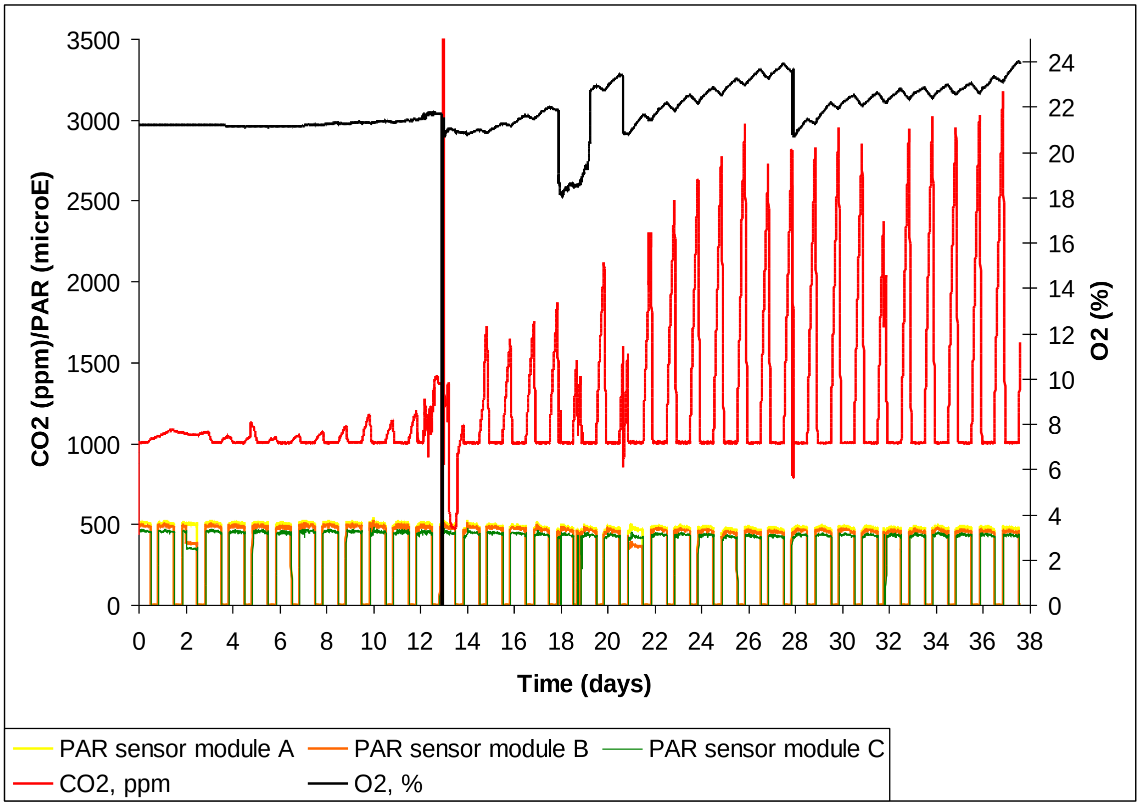


Figure 15. CO_2, O_2 concentration in HPC1 and PAR intensity over the 38 day period of closure

During the crop test, several gas analyser failures were observed. The most notable was on the 13th day of closure which was described in Table 3. Deviation from expected measurements of CO_2 concentration on the 9th and 27th days of closure was also likely due to incorrect measurements of gas analyser. On the 5th, 9th, 15th CO_2 concentration after night respiration was higher than expected as during that time liquid loop was isolated in order to change nutrient solution. On the 21st and 28th days of closure the chamber was opened in order to decrease O_2 concentration in the chamber that also caused a decrease in CO_2 concentration. On the 32d day of closure CO_2 release at night time was lower than expected as lights were on for 1 hour due to broadcasting activities in the MPP.

Deviations in PAR sensors measurements were caused by several factors. On the 3d day of the test there was probably failure of measurements of PAR sensors in module B and C that was automatically fixed on the next day (figure 15). On the18th day of closure lights were turned off for a couple of hours due to the problem with chilled water temperature (Table 3). On the 19th day of closure lights were switched on for one hour during night time due to broadcasting activities in the Plant. On the 21st day of closure an error in PAR sensor measurement in module B was observed (figure 15).

In most of the time of operation, out of the reported event, the HPC was working at nominal condition and CO_2 concentration in the chamber was controlled well on the level of 1002.8±9.2 µmol mol^{-1} (table 4).

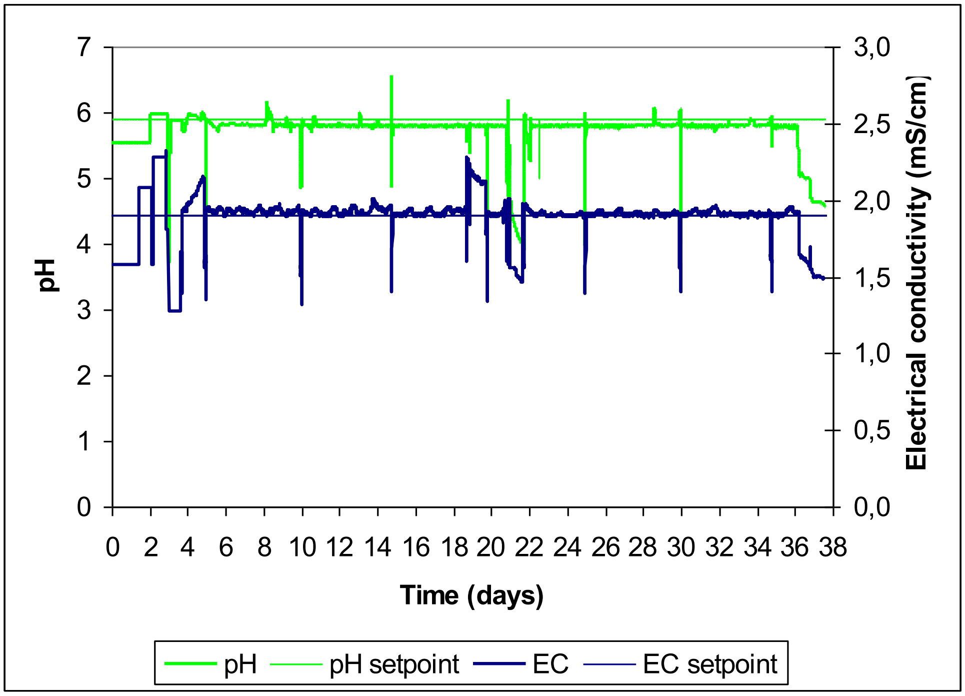


Figure 16. EC and pH control over a 38 day period in HPC1

During the first 4 days of crop testing there was an error in recordings of pH and EC values that was later fixed by NTE (figure 16. On the 4th day pH and EC were increasing due to base and acid leak. After changing the nutrient solution on the 5th day of crop test, values of pH and EC were close to set point. Deviations of pH and EC observed in figure 16 on the 10th, 15th, 20th, 25th, 30th, 35th days of crop test were caused by changes of nutrient solution. On the 19th day of closure irrigation was stopped for 1 hour due to broadcasting activities in HPC room that entailed apparent deviation in values of EC and pH (figure 16) that in fact were not real. However after irrigation was enabled, value of EC increased and probably it was an error of measurement but this could not be confirmed. On the 21-22 days after closure there was no irrigation in HPC1 due to failure of nutrient pump. From 37th day of the test and until the end of the test values of pH and EC decreased; that was again related with a failure in the irrigation loop However, in nominal conditions EC and pH were controlled well (figure 16, table 4).

Detailed 24 hour EC/pH control at the 25th day of the crop test is shown in figure 17 (further details in Appendix 3, pages 47-48). It could be observed that during the change of nutrient solution EC and pH values decreased as irrigation mode was disabled. After re-enabling, it took some time for pH and EC stabilisation, after which EC and pH were maintained almost on the same level like before the solution change.

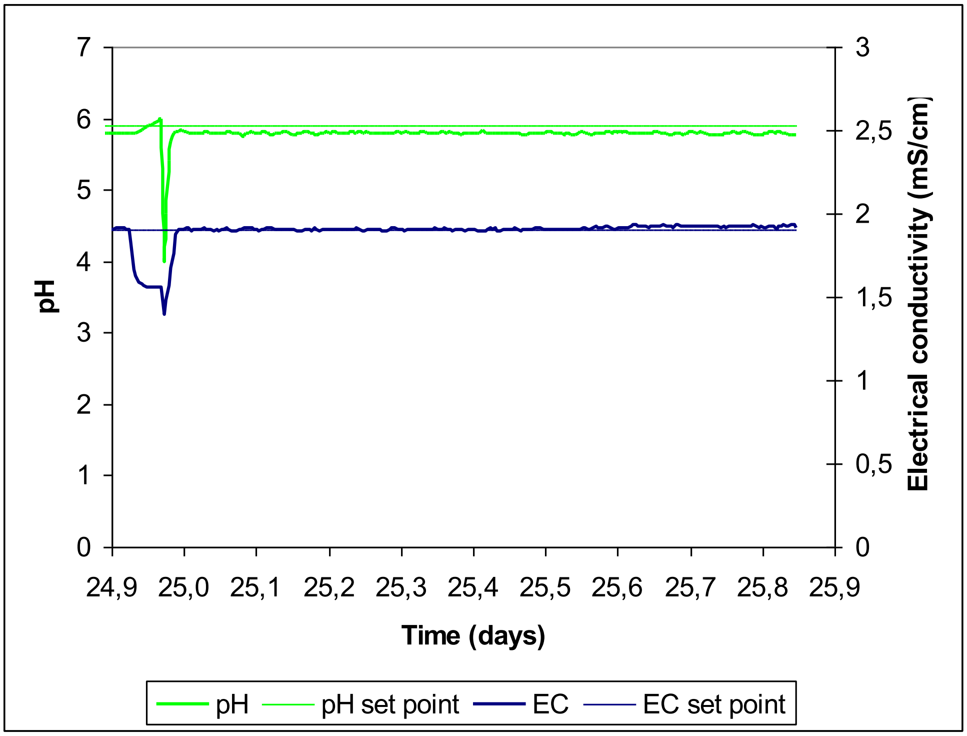


Figure 17. EC and pH control in HPC1at 25th day of closure

Table 4: Environmental control setpoint parameters and actual average readings

Parameter	Setpoint	Average values, calculated with allowance of deviation, caused by external events		Average values at nominal conditions	
		Actual	Standard deviation	Actual	Standard deviation
Temperature Day	26º C	26.1º C	0.6º C	26.00º C	0.07º C
Night	First 3 days of test 21º C	21.2º C	0.2º C		
	Rest of the test 20º C	20.0º C	0.5º C	20.04º C	0.06º C
Humidity Day	First 3 days of test 60% Rest of the test 50%	59.9% 50.3%	0.6% 2.4%	50.1%	0.6%
Night	First 3 days of test 55% Rest of the test 70%	56.6% 68.6%	1.6% 4.6%	70.0%	1.2%
Carbon Dioxide	1000 $\mu mol\ mol^{-1}$	1009.4 $\mu mol\ mol^{-1}$	204.5 $\mu mol\ mol^{-1}$	1002.8 $\mu mol\ mol^{-1}$	9.2 $\mu mol\ mol^{-1}$
pH	5.9	5.80	0.07	5.80	0.05
EC	1.9 mS cm^{-1}	1.94 mS cm^{-1}	0.08 mS cm^{-1}	1.93 mS cm^{-1}	0.05 mS cm^{-1}

3.4. Carbon and nitrogen balance

Since CO_2 injection into HPC1 was recorded with quite long interval (every 5 minutes) it was not possible to calculate quantity of CO_2 injected into the chamber. For that reason carbon balance was not calculated.

According to the nutrient solution analyses, total nitrogen input into the system with nutrients was 411 g. However the real value was higher but it was not possible to estimate as the timing of opening stocks A and B valves was not recorded. Nitrogen accumulated in lettuce leaves was 89 g and nitrogen taken out from the system with nutrient solution was 420 g (total accumulation during the test, including the canges in nutrient solution) . Thus nitrogen output totalled 509 g according to the data available. It should be taken into account that part of nitrogen contained in lettuce roots and Rockwool cubes, besides part of nitrogen that was in the nutrient solution in NH_4^+ form could volatilize to HPC atmosphere. But those outputs were not estimated. Hereby in line with available data, nitrogen mass balance was 0.8.

3.5. Nutrient analysis

During the first 3 days of the crop test there was significant increase of Ca, Fe, B and Na in the nutrient solution in comparison with the initial concentration (table 5). Dispersion in content of other minerals from day0 to day3 was in the frames of error. However as observation on nutrient injection showed, during the first days of the test only base was added into the solution but not the nutrients. Increase of quantity of above mentioned elements could be connected with error of analysis or leak of stock tanks. On the 5th day of the test increase of K concentration in the nutrient solution in comparison with the initial one was observed probably due to leak of base tank electro valve. Analysis of nutrients concentration in the solution starting from the 5th day, showed that in the end of every five days concentration of almost all nutrients in the solution increased in comparison with the initial one and in very similar proportion. One of the exceptions was molybdenum on the 15th, 20th and 38th days of the test, when on the 15th day concentration of this microelement was equal to the one in the initial solution 5 days ago, and on the 20th and 38th days of the test it was even less than in the initial solution. Also, concentration of P on the 20th day of the test was the same like in the new prepared solution 5 days previous. The same tendency for molybdenum and phosphorus was observed in the previous crop test with the Schneider controller under nutrient solution analysis at 7 and 11 days (TN 96.11). Concentration of Zn in the nutrient solution on the 30th and 35th days of crop test was less than in the initial solutions.

Probably those results meant that speed of consumption of the minerals was higher than the frequency of their addition into the media. However it did not mean that the plants necessarily had deficiency of those nutrients as they could be up taken passively. Also, those results could be connected with error of measurements as dispersion between values was not high. In order to make definite conclusion it would be necessary to perform more tests with a longer duration. It should be mentioned that values of minerals in the samples of nutrient solution, taken on the 10th day of the test from the top and the bottom of nutrient tank were very similar, so probably it meant that nutrient solution was mixed well and was homogeneous in the nutrient tank.

Table 5. Mineral composition of nutrient solution at different periods of crop test (mg/L) (error of measurements does not exceed 15 %)

Date	Sample	K	Ca	Mg	P	S	N-NO_3	N-NH_4	Fe	Mn	B	Zn	Cl	Na	Cu	Mo
17.09.2009	Start	260	198	31	58	82	213	81	7.20	0.38	0.28	0.34	14	8.20	0.07	0.06
21.09.2009	Day3 (1)*	285	321	31	57	83	325	82	12.09	0.43	0.46	0.35	28	14.63	0.07	0.06
23.09.2009	Day5(1)*	402	187	26	46	67	286	70	6.34	0.29	< 0.25	0.33		9.89	0.06	0.05
	Day5(2)**	175	140	23	43	60	n.a.	n.a.	5.80	0.29	< 0.25	0.31		5.21	0.05	0.04
28.09.2009	Day10(1)*	339	205	33	58	85	225	68	7.91	0.48	0.37	0.40	14	8.98	0.07	0.05
	Day10(2)**	173	129	22	41	58	146	57	4.24	0.34	0.29	0.30	8	12.22	0.05	0.04
	Day10(3)***	171	127	22	40	57	n.a.	58	4.17	0.33	< 0.25	0.25	8	12.17	0.05	0.04
03.10.2009	Day15(1) *	368	225	36	57	89	264	46	8.69	0.56	0.35	0.37	8	16.39	0.08	0.04
	Day15(2) **	192	141	24	44	63	167	58	4.60	0.35	0.26	0.27	10	29.65	0.05	0.05
08.10.2009	Day 20 (1)*	424	233	40	43	91	287	0	8.04	0.56	0.44	0.34	3	38.16	0.08	0.03
	Day 20(2)**	182	138	23	43	60	162	58	4.49	0.29	< 0.25	0.27	8	5.75	0.05	0.04
13.10.2009	Day 25 (1)*	346	240	40	36	99	234	0	8.49	0.41	0.32	0.33	3	15.17	0.09	0.06
	Day 25 (2)**	183	140	24	43	61	161	60	4.59	0.27	< 0.25	0.27	8	5.50	0.05	0.04
18.10.2009	Day 30(1)*	357	236	40	43	102	231	59	7.72	0.31	0.31	0.24	2	13.56	0.08	0.07
	Day 30(2)**	188	138	25	45	64	159	52	4.36	0.28	< 0.25	0.28	8	5.39	0.05	0.06
22.10.2009	Day 34(1)*	381	218	38	45	101	199	0	6.63	0.31	0.30	0.22	2	12.79	0.07	0.08
	Day 34(2)**	183	129	23	42	60	148	69	4.12	0.27	< 0.25	0.27	8	11.34	0.05	0.06
26.10.2009	End	351	175	31	45	79	205	2	5.67	0.49	0.49	0.23		13.33	0.06	0.02

***- samples were taken before changing nutrient solution, values are available on the third sample taken in a row from the drain valve of nutrient tank**

**** - samples were taken after changing nutrient solution from drain valve of nutrient tank, values are available on the third sample taken in a row**

***** - samples were taken after changing nutrient solution from the top of nutrient solution, values are available on the third sample taken in a row**

It could be concluded that average content of minerals in lettuce leaves did not significantly vary from module A to module C (table 6). Minerals concentration in the lettuce leaves were in the frames of maximum allowable content and no excessive accumulation was observed.

Table 6. Mineral composition of lettuce shoot (% dw), harvested at the end of vegetation (error of measurements does not exceed 15%)

Tray #	Na	K	Ca	Mg	P	S	N	Fe	Mn	B	Zn	Cu	Mo
1	0.05	5.96	0.83	0.22	0.69	0.32	5.46	0.02	0.007	0.003	0.006	0.001	0.0002
2	0.05	5.52	0.80	0.20	0.58	0.27	4.97	0.02	0.006	0.003	0.005	0.002	0.0002
3	0.05	6.36	0.95	0.22	0.70	0.33	4.79	0.02	0.008	0.003	0.006	0.001	0.0002
4	0.05	6.02	0.97	0.24	0.70	0.33	4.73	0.02	0.008	0.004	0.006	0.001	0.0002
5	0.05	6.14	1.07	0.26	0.71	0.35	4.84	0.02	0.009	0.003	0.007	0.001	0.0002
6	0.05	6.18	1.21	0.25	0.74	0.33	4.82	0.02	0.009	0.004	0.006	0.001	0.0003
Average	**0.05**	**6.03**	**0.97**	**0.23**	**0.69**	**0.32**	**4.94**	**0.02**	**0.008**	**0.003**	**0.006**	**0.001**	**0.0002**
7	0.06	6.01	1.10	0.24	0.72	0.34	5.01	0.04	0.009	0.003	0.007	0.001	0.0002
8	0.04	5.66	0.92	0.22	0.66	0.30	5.50	0.02	0.008	0.003	0.006	0.001	0.0002
9	0.05	6.40	1.19	0.23	0.73	0.36	5.06	0.03	0.010	0.004	0.009	0.001	0.0003
10	0.05	6.40	0.91	0.21	0.73	0.35	5.17	0.04	0.007	0.003	0.006	0.001	0.0002
11	0.05	6.52	1.32	0.25	0.76	0.38	5.16	0.02	0.011	0.004	0.006	0.001	0.0003
12	0.04	5.86	0.96	0.21	0.78	0.33	5.42	0.02	0.008	0.003	0.006	0.001	0.0002
13	0.05	6.42	0.99	0.23	0.79	0.36	5.78	0.03	0.008	0.003	0.008	0.001	0.0003
14	0.05	6.64	1.07	0.25	0.81	0.36	5.43	0.02	0.009	0.003	0.007	0.001	0.0002
Average	**0.05**	**6.24**	**1.06**	**0.23**	**0.75**	**0.35**	**5.34**	**0.03**	**0.009**	**0.003**	**0.007**	**0.001**	**0.0002**
15	0.04	5.89	1.04	0.21	0.68	0.33	5.49	0.02	0.008	0.004	0.006	0.001	0.0002
16	0.06	6.67	1.09	0.25	0.81	0.34	5.66	0.03	0.009	0.003	0.007	0.001	0.0002
17	0.04	5.36	1.01	0.21	0.66	0.30	5.01	0.02	0.009	0.003	0.006	0.001	0.0002
18	0.05	5.78	1.04	0.21	0.70	0.32	5.52	0.02	0.008	0.004	0.006	0.001	0.0003
19	0.06	6.62	0.92	0.22	0.84	0.33	4.83	0.02	0.006	0.003	0.005	0.001	0.0002
20	0.05	6.17	0.92	0.23	0.72	0.31	5.23	0.04	0.007	0.003	0.007	0.329	0.0002
Average	**0.05**	**6.08**	**1.00**	**0.22**	**0.73**	**0.32**	**5.29**	**0.02**	**0.008**	**0.003**	**0.006**	**0.056**	**0.0002**

Content of carbon in average sample of lettuce leaves per module did not show significant dispersion of those values between plants of different modules (table 7). Although average content of hydrogen in module B was lower than in modules A and C, it could be connected with error of determination. Results of the future tests will help to make definite conclusion on this issue.

Table 7. Content of elements, obtained from CO_2 and water, in lettuce shoots (% dw), harvested at the end of vegetation (error of measurements does not exceed 2%)

Tray #	C	H
1	39.36	5.34
2	40.21	5.45
3	39.42	5.34
4	39.85	5.45
5	39.83	5.31
6	39.16	5.26
Average	**39.64**	**5.36**
7	40.70	5.42
8	39.62	5.20
9	39.28	5.03
10	39.56	5.25
11	39.95	5.28
12	39.40	5.27
13	40.12	5.37
14	39.42	5.10
Average	**39.62**	**5.22**
15	40.04	5.39
16	38.28	5.08
17	39.69	5.44
18	38.89	5.34
19	40.65	5.52
20	38.93	5.32
Average	**39.41**	**5.35**

4.Ethylene analysis

Ethylene concentration in the air of HPC1 was analysed with gas chromatograph in the department of Chemical Engineering, but it was very difficult to detect ethylene with this equipment since its concentration during the crop test was below the level of detection (1 ppm).

However by the end of the test it was detected that ethylene concentration in HPC1 was 0.07 ppm. It should be taken into account that during the crop test the chamber was opened several times, that also influenced on ethylene concentration in the chamber.

5.Conclusions

It could be concluded that even though several external events entailed deviation from nominal conditions of HPC1 operation for some specific episodes in its operation, it did not affect the plants growth and productivity. Visually plants also looked well in the meaning of colour although some yellowing of the plants in module B was observed in the middle of the test, but the returned to a green colour later. The main problem was test duration as plants were too big and started to show signs of rot. Also, due to O_2 accumulation it was necessary to open the chamber several times that could influence on the test results.

Environmental control at nominal conditions performed well. Even though average values per chamber were maintained close to set point, the values of temperature in different modules at day time had a difference of 2°C, and the values of humidity during day time also varied. Air velocity in module B was visually higher than in the other modules. Probably, in order to improve control in HPC1, it is necessary to have several temperature and humidity sensors per module, especially at plant level. The problem with gas analyser should be better investigated and solved in order not to have these deviations in the future tests.

Conclusions drawn after 11-days crop test with Argus and Schneider controller (TN 96.5 and TN 96.11) can be applied here with the exception that due to longer test duration plants recovered from deviations from nominal conditions and were not affected as much as during the shorter tests.

6.Comments

Cultivation as-run procedures, test results, and final test report

Comments

General comments

The TNs are rather comprehensive however we miss basically some evaluation of the results and overall conclusions eg comparison with results of functional tests performed in Guelph, comparison between results obtained with Argus and with Schneider, overall conclusion on the functional testing of the chamber
Overall conclusion is added in Section 14 of TN96.11, including the comparison with results obtained with ARGUS system.

Some TNs and especially TN 96.5 are looking like compilation of inputs from several partners however without any link in between; some curves are even duplicated from one chapter to the other. The added-value of confronting different "views" (i.e control point of view, growing plant point of view...) of the chamber is missing. As a result the TNs look fuzzy and are very difficult to read and to use.
Confronting views foreseen more in last TNs (96.12 and 13).

Sometimes we do not understand the logic followed to fill in the as-run procedures, see detailed comments on each TN
OK, amended in each case.

There is a general mistake on EC unit, to be expressed in mS/cm or dS/m (these two units are equivalent)
OK, amended in each case.

Date and time in the as-run procedures are missing; in TN 96.5, the term ESA/UoG representative should be updated as discussed previously
OK, amended in each case.

The wording of the introduction, e.g. considered by ESA and SHERPA as a black box…. Should be rephrased.
OK, rephrased

Detailed comments

Page/paragraph	Comment
4/Section 1	Do you plan to send in a separate file the SCADA raw data? In fact we have them in csv format, compatible with excel, so we could eventually supply them if needed; we see more difficult to annex all of them to the TN in pdf. We understand however our concern is the issue of archiving over time. Hard drives can crash. This is something that we could address more generally for all of the MPP activities. OK, indeed to be discussed in the context of general MPP activities.
4/Section 2	Could you please recall briefly the status of the HPC itself, i.e. initial panels for air flow distribution The configuration of the panels was the initially fixed by UoG, so the same used in the 7 and 11 days tests; explained in the text.
6/Section 3.1	How long could we feed the CI with this quantity of biomass? According to the dry matter, it would be 1,15 weeks in case only leafs are used.
6/Section 3.1	Here shorter duration tests are suggested, in page 24 longer duration tests are suggested. The comment in page 24 (now rephrased) refers to a potential better understanding of the minerals consumption; it cannot contradict the general conclusion about the status of the crops.
6/Section 3.1	Remark only, not to generate any change in this TN: generally speaking, we have to decide when it is appropriate to remove some data, and when, on the contrary, they should be maintained. OK, agreed.
16/Section 3.1	This remark should be a bit more specific. No evident correlation is observed with dispersion of plants which have been cultivated for 38 days in the chamber, but was a potential correlation observed for the 11-days test? In TN96.11 it was only a guess that the spigots flow was related with the crops growth in the different modules, and in fact the measurement was performed only after the test; a real correlation

	cannot be demonstrated, as the cubes take the solution needed by capillarity, so a direct relationship cannot be made
16/Section 3.1	With the exception of item 18, 21, 28, 35 which can be considered as “external events”, the other events are HPC1-system related (i.e. internal events). This should be clarified. Agree; text amended
18/Section 3.3	Fig 12 reports the water flow in the spigots. Could you be so kind to clarify the link between Fig 12 and day temperature increase. It's a mistake of the figures and tables numbering in the text probably because the text was not updated when last table/figure was incorporated in the document; it should refer to Figure 13 and Table 4; text amended
18/Section 3.3, first paragraph	…*“Figure 12, Table 3”*… I guess figure 13 and table 4 Correct
18/Section 3.3, fourth paragraph	…*“Fig 12”*… Do you mean fig 13? Correct; text amended
21/Section 3.3, first paragraph in the page	… *“Figure 15”*… Fig 16? Correct; text amended
21/Section 3.3, first paragraph in the page	… *“Figure 15”*… Fig 16? Correct; text amended
21/Section 3.3	Why do we need to stop irrigation when broadcasting? It was needed to reduce the noise due to the irrigation pump operation and moving the trays; this was not considered to be critical for the process; in fact, the deviations in pH and EC measurements during the stopping were not real, and they appear because the pipe where the electrodes are located is emptied when the irrigation stops, so their values are not correct meanwhile. Explained in the text.
21/Section 3.3, first paragraph in the page	*“However after irrigation was enabled, value of EC increased and probably it was an error of measurement*”. It is not completely clear on the curve but it seems that there is a pH decrease at the same time. If this observation is correct, how do you explain this? In addition, to verify that it was an actual measurement error did you cross-check the EC value with an external measuring

	device (not the HPC sensor)? The drop in pH is only punctual (due to the mixing after the stopping of the pump), whereas the EC keeps high some hours. Regarding the check off-line, it was not done as the measurements were considered not real, only due to the empty pipe.
21/Section 3.3, first paragraph in the page	*"On the 21-22 days after closure there was no irrigation in HPC1 due to failure of nutrient pump".* It seems that during those 2 days pH and EC decreased largely. How do you explain this? As there was not any mixing, the values of pH and EC are not representative (empty pipe), but the pH and EC control were stopped so there could be a change in the EC and pH values of the solution, recovered only when the irrigation loop was again activated.
21/Section 3.3, first paragraph in the page	*"From 37th day of the test and until the end of the test values of pH and EC decreased;…"* Were those EC and pH values cross-checked with other measuring device (not the HPC sensor)? Again, these values are not real, so they were not taken into account; the hardware/procedures should be updated to avoid emptying of the pipe where the electrodes are located when the loop is not active, in order to have good measurements; beside this, we agree that an external check maybe anyway desirable after restarting the loop recirculation, and before starting the EC and pH control, but at that time they were not performed.
21/Section 3.3, second paragraph in the page	*"It could be observed that during the change of nutrient solution EC and pH values decreased as irrigation mode was disabled."* Not fully clear what is meant here. The EC and pH drop is due to the irrigation pump stop or to the emptying of the tank? The reason of the drop is again probably the emptying of the pipe where the electrodes are located (the electrodes are nor located in the tank) so related to the stopping of the loop in itself.
21/Section 3.3, second paragraph in the page	*"After re-enabling, it took some to some for pH and EC stabilization"* Some time? About 1,5 hours, as the prepared solution was in fact needed to be adjusted Previous comment was referring as well to the wording 'some to some' please update. OK, understood. Text amended: *"some time"*
23/Section 3.4, second	*"Total nitrogen input into the system with nutrients was 411 g"*

paragraph	Total nitrogen: sum of nitrogen provided by hydroponic solution exchanges? Yes, but taking into account both the inputs in new solution and the output in the old one.
23/Section 3.4, second paragraph	*"…as the timing of opening stocks A and B valves was not recorded."* Why? The PLC was not recording these data; it was implemented after this test
23/Section 3.4, second paragraph	*"Part of nitrogen that was in the nutrient solution in NH_4^+ form could volatilize to HPC atmosphere."* Not fully clear. Could you be so kind to clarify what is meant here. Depending of the pH, part of the ammonia can be transferred to the atmosphere as NH3; at the pH of the hydroponic solution this should not be very relevant anyway
24/Section 3.5, second paragraph	*"In order to make definite conclusion it is necessary to perform more tests with a longer duration."* Could you detail a bit this statement, it is not very clear what is gained by doing longer experiment. It seems in addition that few minerals were "over-added" (e.g. K, Ca, No3,..). Although there is no demonstration that the levels reached were disturbing the growth, an optimization in order to match the plants needs would be appropriate. What would be proposed to optimize the nutrient addition? In fact, the statement is rephrased, as to perform a longer experiment would be contradictory with the rest of the conclusions: *"In order to make definite conclusion it would be necessary to perform more tests with a longer duration."*
26/Section 3.5, Table 6	Although there is no specific standard describing the maximum mineral content of lettuce acceptable for human consumption, the values reported in this table are far above the maximum reported in food composition databases. To give an idea, with 100g of those lettuces 50% of the daily recommendations for Ca,Fe, Mg are covered, 100% for Mn, 200% for K. Future parallel activities on food will need to address this issue (same observation was done on wheat), but for the MPP, it means that the currently obtained lettuces are not a representative input for the CI. As it was reported in COSPAR (2010), the results are in the range of other hydroponic cultivation experiments and below for ex. the ones obtained by Masot (2007); could you please provide us some references of food composition databases to have a more precise view?
26/Section 3.5, Table 7	What would be the CHNP formula of the lettuces produced in this test?

	The CHNP formula of the lettuce produced in the test would be, accordingly, the following: $C\,H_{1,6}\,N_{0,113}\,P_{0,007}\,S_{0,003}$

Appendix 1 – chronology of events for seedlings establishment

1) **09.09 (Wednesday)**

Sterilization of 2 flats of rockwool small cubes - Grodan AO 36/40 6/15W with autoclave and 1 L of distilled water. Preparation of stock A (10 L) and stock B (10 L) solutions (TN 96.3).

2) **10.09 Day 0 (Thursday)**

Preparation of seedlings solution (10 L). Sterilization of lettuce seeds with 5% bleach with subsequent rinse with distilled sterile water (TN 96.3). Sowing of 196 seeds into 2 Rockwool sheets. Irrigation of each tray with 1000 mL of seedlings solution. Temperature and humidity:auto, Lighting mode:manual as it was not possible to activate in auto mode, 2 lamps per each module were on (1HPS and 1 MH). Temperature set point for the day time was 20° C, but actual temperature was 25.8° C. In order to decrease temperature set point was changed to 23° C, actual temperature 24°C, after temperature set point was changed to 20° C, actual temperature 22.7° C Night temperature set point was 20° C. Humidity set point was 70%. Placement of the trays with Rockwool sheets into the HPC1, module C.

3) **11.09 Day 1 (Friday)**

T=20.7° C, %Rh=59.5%. After SHERPA modified the program and fixed the problem, it's possible to have 1HPS and 1 MH lamps per module in auto mode. Photographing. No germination was observed. Measurement of irrigation solution (½ strength nutrient solution) pH, it´s 6.26. Watering of each tray with 800 mL of seedlings solution. T set point=20° C, %Rh=70%. Since t was growing (t=23.6° C, %Rh=69.4%), set point for %Rh was changed to 55%. After t decreased to 21° C.

4) **12.09 Day 2 (Saturday)**

No operations.

5) **13.09 Day 3 (Sunday)**

No operations.

6) **14.09 Day 4 (Monday)**

Emergence of more than 60% of seedlings, lids were taken out of the trays. Emergence of 69 (of 97 rockwool cubes) and 64 (of 98 rockwool) seedlings. Photographing.

7) **15.09 Day 5 (Tuesday)**

Both trays were humid, no watering. Photographing. Germination was 76 (of 97 rockwool cubes) and 65 (of 98 rockwool) seedlings.

8) **16.09 Day 6 (Wednesday)**

At 10:00 Germination was 78 (of 97 rockwool cubes) and 67 (of 98 rockwool) seedlings.

pH of irrigation solution for seedlings was 5.95. Irrigation of trays, 1000 mL for tray1 and 900 mL for tray2. At 16:15 temperature and himidity mode was off. T=30.1º C, Rh=82.6%. The trays were taken out of the chamber, set point for Rh was changed to 75% and for temperature – to 28º C. After that it was possible to activate temperature and himidity mode in auto. At 19:01 Rh set point=55%, actual=54.5%, temperature set point=21º C, actual t=25.7 º C (impossible to change set point to 20º C as temperature and himidity mode goes off). Trays were introduced into the chamber.

9) **17.09 Day 7 (Thursday)**

Photographing. At 12:30 the trays were taken out of the chamber, all lamps were on in order to check PAR intensity. Module A: PAR=469.38 µE, module B: PAR=480.06 µE, module C: PAR=450.0 µE. After 2 lamps per module were activated and trays were introduced into the chamber.

10) **18.09 Day 8 (Friday)**

Measurement of spigots flow, 5 spigots next to the door of module A and 5 spigots next to the door of module C.

Crop test start up.

Appendix 2: Plant Growth Raw data

# of tray	# of plant	Fresh weight of shoots, g 26.10.2009	Dry weight of shoots, g 3.11.2009
1	1	308.16	18.06
	2	423	22.74
	3	297.41	15.53
	4	362.22	13.55
	5	331.61	13.36
	Total	**1722.4**	**65.18**
2	1	299.37	18.89
	2	324.06	14.85
	3	320.55	10.16
	4	237.75	15.85
	5	422.89	20.46
	Total	**1604.62**	**80.21**
3	1	432.77	25.73
	2	239.39	18
	3	325.23	15.33
	4	271.91	12.79
	5	508.77	24.39
	Total	**1778.07**	**96.24**
4	1	346.51	17.24
	2	352.45	13.55
	3	422.91	19.59
	4	382.19	18.37
	5	300.16	19.07

	Total	**1804.22**	**87.82**
5	1	364.6	19.16
	2	310.21	12.61
	3	378.15	16.91
	4	390.47	16.96
	5	434.83	14.58
	Total	**1878.26**	**80.22**
6	1	402.61	17.37
	2	387.19	18.68
	3	305.48	19.7
	4	327.51	10.54
	5	477.78	21.08
	Total	**1900.57**	**87.37**
7	1	370.08	14.73
	2	369.67	16.17
	3	242.71	9.1
	4	359.49	17.8
	5	454.25	25.79
	Total	**1796.2**	**83.59**
8	1	254.17	14.34
	2	164.37	8.23
	3	453.01	23.73
	4	315.22	17.49
	5	388.36	22.65
	Total	**1575.13**	**86.44**
9	1	390.93	22.09
	2	349.24	20.19
	3	283.17	14.97
	4	341.35	17.98
	5	354.16	15.43
	Total	**1718.85**	**90.66**

10	1	488.38	25.83
	2	203.53	7.63
	3	321.04	18.03
	4	297.02	16.92
	5	374.65	18.6
	Total	**1684.62**	**87.01**
11	1	399.28	16.8
	2	306.39	11.56
	3	213.33	10.8
	4	332.67	19.02
	5	370.12	22.66
	Total	**1621.79**	**80.84**
12	1	417.68	24.51
	2	250.83	8.29
	3	359.72	18.58
	4	308.73	14.82
	5	353.49	20.03
	Total	**1690.45**	**86.23**
13	1	no plant	no plant
	2	332.58	19.39
	3	343.57	16.77
	4	336.96	18.52
	5	364.25	18.57
	Total	**1377.36**	**73.25**
14	1	433.94	25.46
	2	307.01	17.17
	3	336.2	17.7
	4	359.52	18.81
	5	347.37	14.43
	Total	**1784.04**	**93.57**
15	1	448.32	2.93

	2	247.35	10.84
	3	329.58	17.55
	4	310.95	16.42
	5	300.08	17.3
	Total	**1636.28**	**65.04**
16	1	397.84	21.3
	2	357.68	19.66
	3	279.48	14.06
	4	421.97	17.26
	5	349.56	22.06
	Total	**1806.53**	**94.34**
17	1	426.33	16.71
	2	385.9	24.25
	3	286.62	13.88
	4	346.44	17.99
	5	238.87	13.76
	Total	**1684.16**	**86.59**
18	1	368.27	21.71
	2	266.19	11.57
	3	364.94	22.53
	4	246.87	14.39
	5	439.55	25.23
	Total	**1685.82**	**95.43**
19	1	369.5	20.97
	2	375.92	15.56
	3	359.83	19.13
	4	296.73	13.63
	5	371.28	19.75
	Total	**1773.26**	**89.04**
20	1	397.34	25.48
	2	198.91	13.06

	3	344.02	19.25
	4	272.95	19.49
	5	364.55	23.14
	Total	**1577.77**	**100.42**

Appendix 3: Control loops graphs (Sherpa Engineering)

1. Introduction and Analysis

The following graphs are issued from data recorded during the 45 days crop test performed at the MPP in September/October 2009 with the HPC1 chamber and the Schneider PLC.
These data are non exhaustive as it was recorded from a Sherpa computer when needed.
It represents few days but is relevant for control validation
- September 24th during 22 hours
- And from October 13th to October 26th (Harvest) in several data files.

Control specifications:

Temperature Set Point
- 26 °C during the DAY
- 20 °C during the NIGHT

Humidity (RH) Set Point
- 50 % during the DAY
- 70 % during the NIGHT

PH Set Point
- between 5.8 and 6.0

As the process is acidifying, pH is maintained at the lower limit 5.8 by base injection.

EC Set Point
- 1.90 mS

CO2 Set Point
- 1000 ppm (only possible during the consumption of the plant, during the day)

Main Conclusions
- Temperature is controlled at the set point with a maximum standard deviation of **0.03°C**
- RH is controlled at the set point with a maximum standard deviation of **0.8 %**
- pH is controlled at its lower limit 5.8 with a maximum standard deviation of **0.01**
- EC is controlled at 1.9 mS with a maximum standard deviation of **0.01 mS** but if EC increases, there is no control action for decreasing it
- CO2 is controlled, when possible, at 1000 ppm with a maximum deviation of **4.4 ppm**

From the data recorded,
- CO2 max (ppm) was measured at **3186 ppm** during the NIGHT
- O2 max (%) was measured at **24 %** during the DAY

Some disturbances appeared during the tests when :
- changing the Nutrient tank
- Opening the chamber for relaxing O2 (safety reason)

Considering Temperature and Humidity, the average measurements between zone A and B are controlled. But, we can see that :
- during the DAY, Average Temperature is controlled at 26°C, but TT_4112_01 (zone A) is about 27°C and TT_4112_03 (zone C) is about 25 °C
- during the NIGHT, the 2 temperatures are at the same values (20°C)

- during the DAY Average Humidity is controlled at 50% but AT_4112_01 (zone A) is about 54% and AT_4112_03 (zone C) is about 46%
- during the NIGHT, the 2 humidity are at the same values (70%)

2. September 24th (22 hours records)

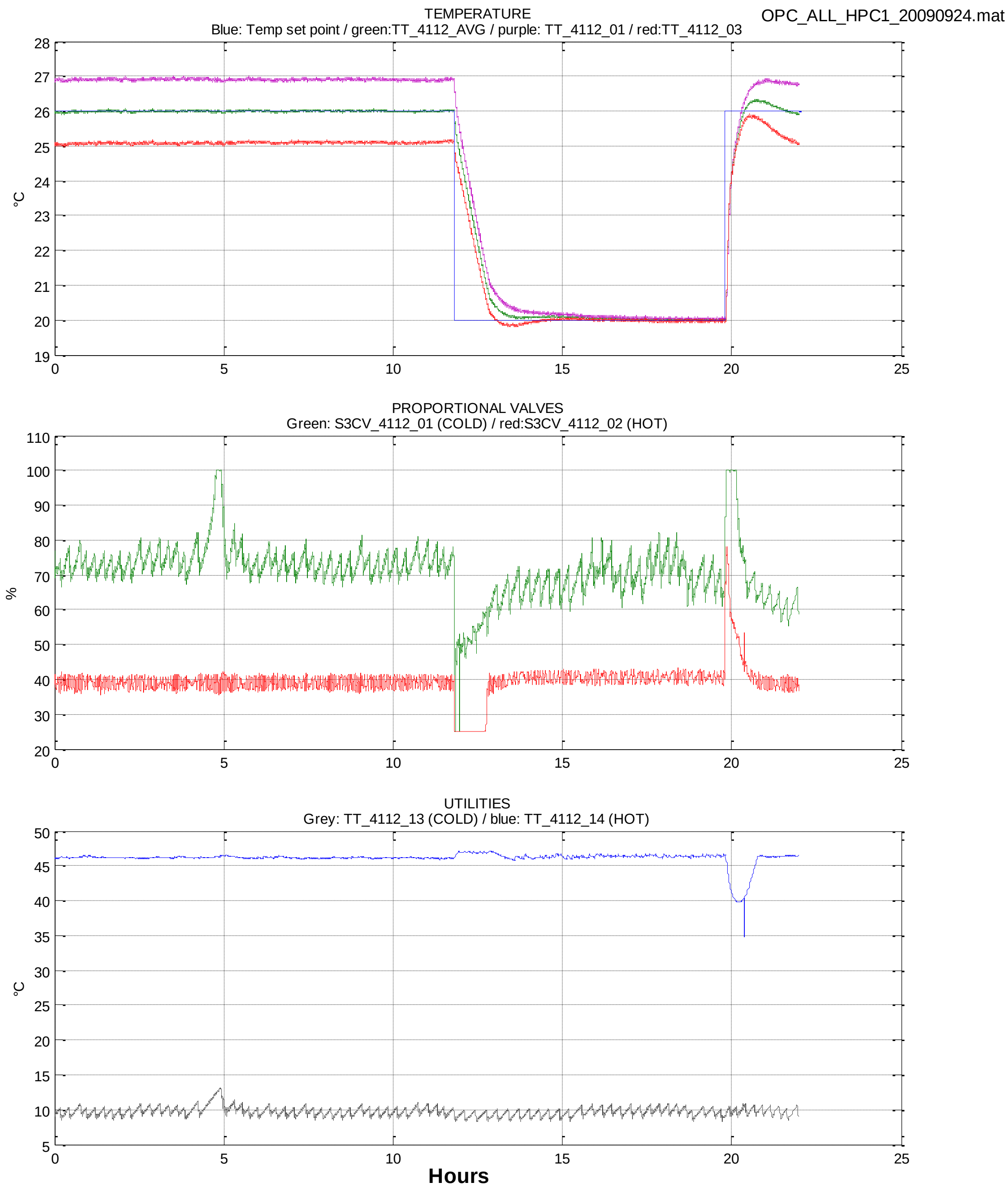
Remarks :
- during this test, O2 was not recorded by Sherpa.

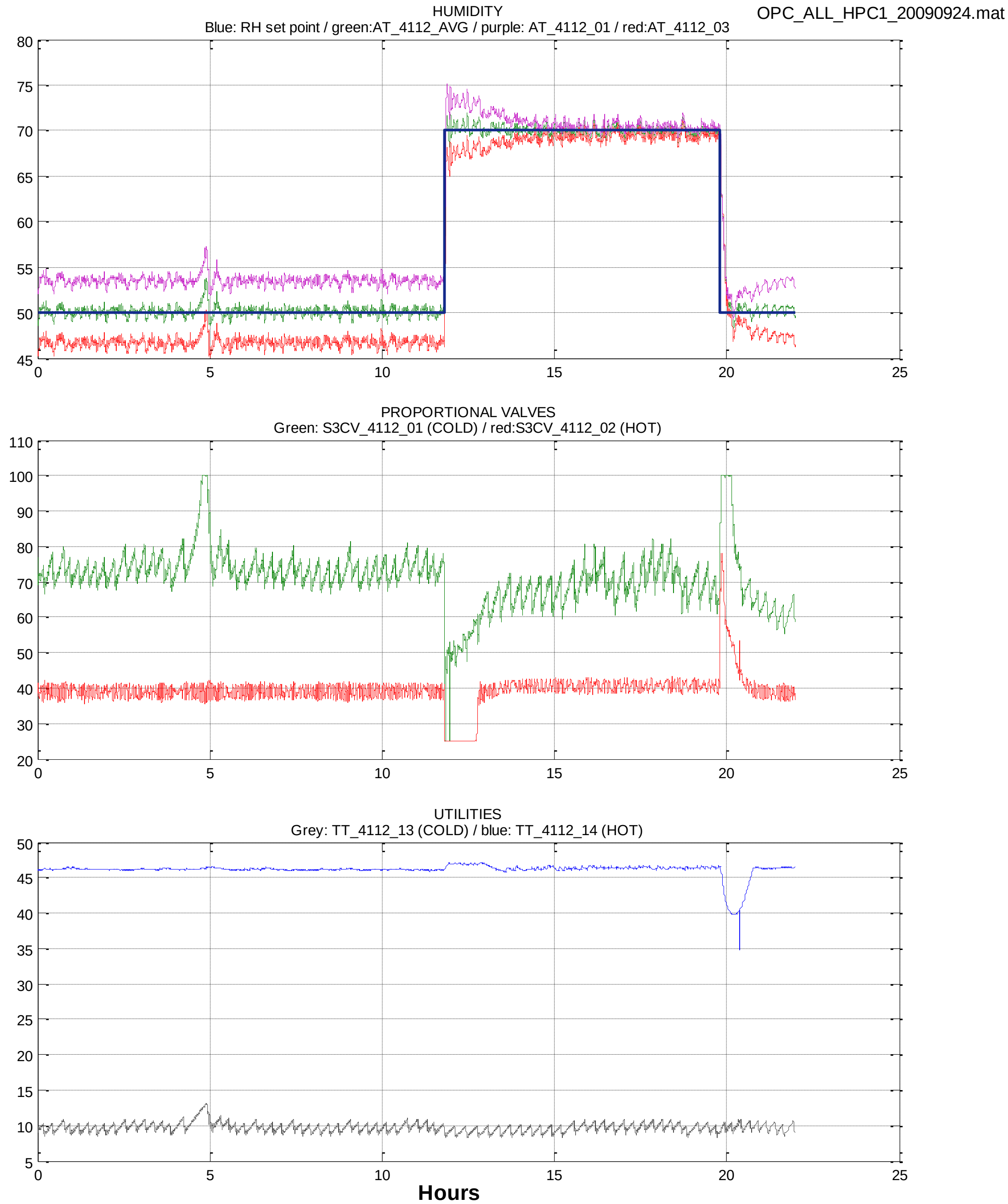
From 0.0 to 10.0 (hour) → **DAY**

pH	mean	5.82	std	0.01	min	5.79	max	5.99
EC	mean	1.93	std	0.01	min	1.90	max	1.95
CO2	mean	1001.5	std	0.9	min	999.4	max	1004.8
T	**mean**	**25.99**	**std**	**0.02**	**min**	**25.90**	**max**	**26.07**
RH	**mean**	**50.10**	**std**	**0.55**	**min**	**48.50**	**max**	**53.81**
Tcold Water	mean	9.84	std	0.70	min	8.40	max	13.20
Thot Water	mean	46.18	std	0.11	min	45.90	max	46.60

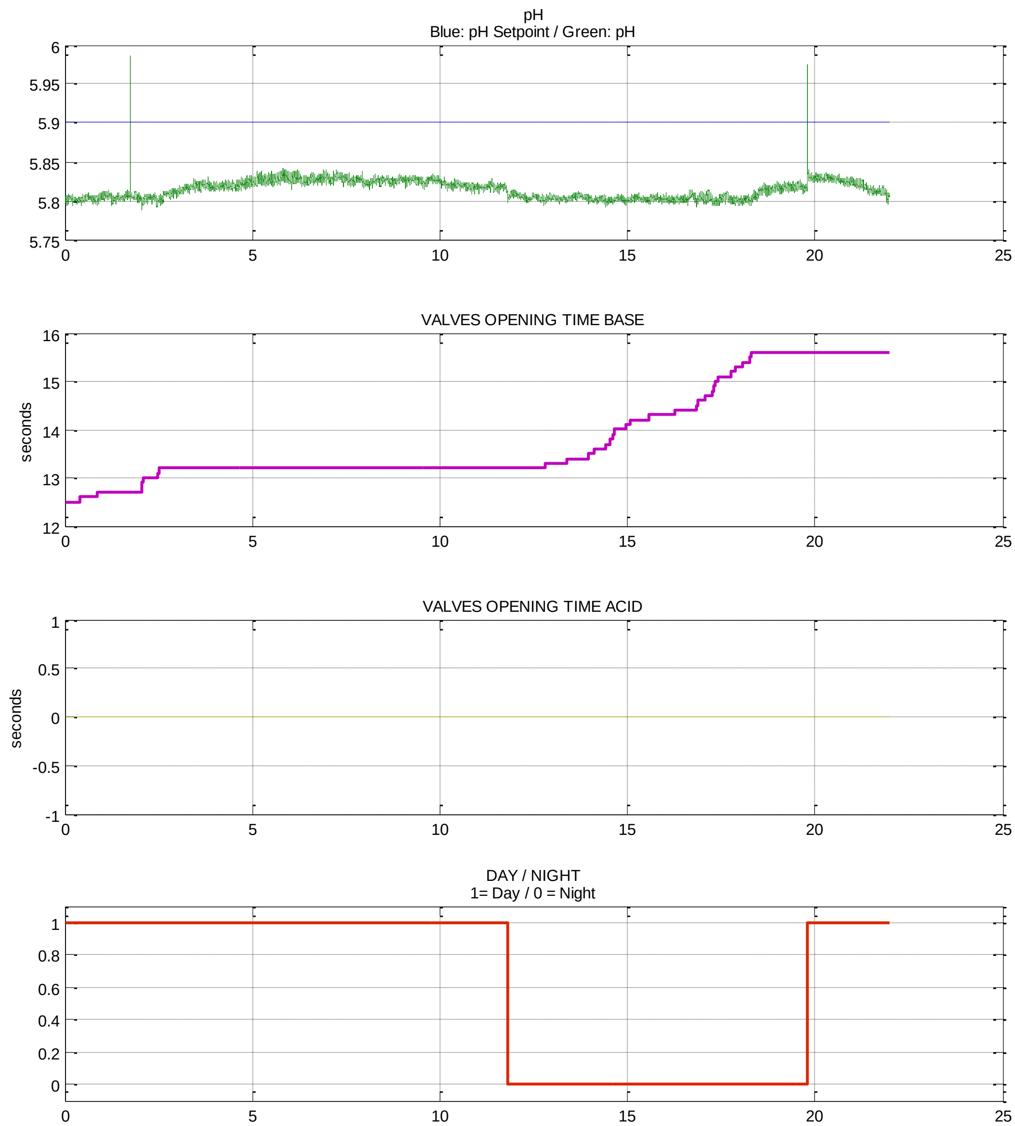
From 16.0 to 19.0 (hour) → **NIGHT**

pH	mean	5.80	std	0.01	min	5.79	max	5.83
EC	mean	1.95	std	0.00	min	1.93	max	1.96
CO2	mean	1041.5	std	4.3	min	1031.6	max	1049.1
T	**mean**	**20.02**	**std**	**0.02**	**min**	**19.97**	**max**	**20.09**
RH	**mean**	**69.94**	**std**	**0.45**	**min**	**68.62**	**max**	**71.47**
Tcold Water	mean	9.85	std	0.49	min	8.35	max	10.91
Thot Water	mean	46.40	std	0.14	min	46.06	max	46.81

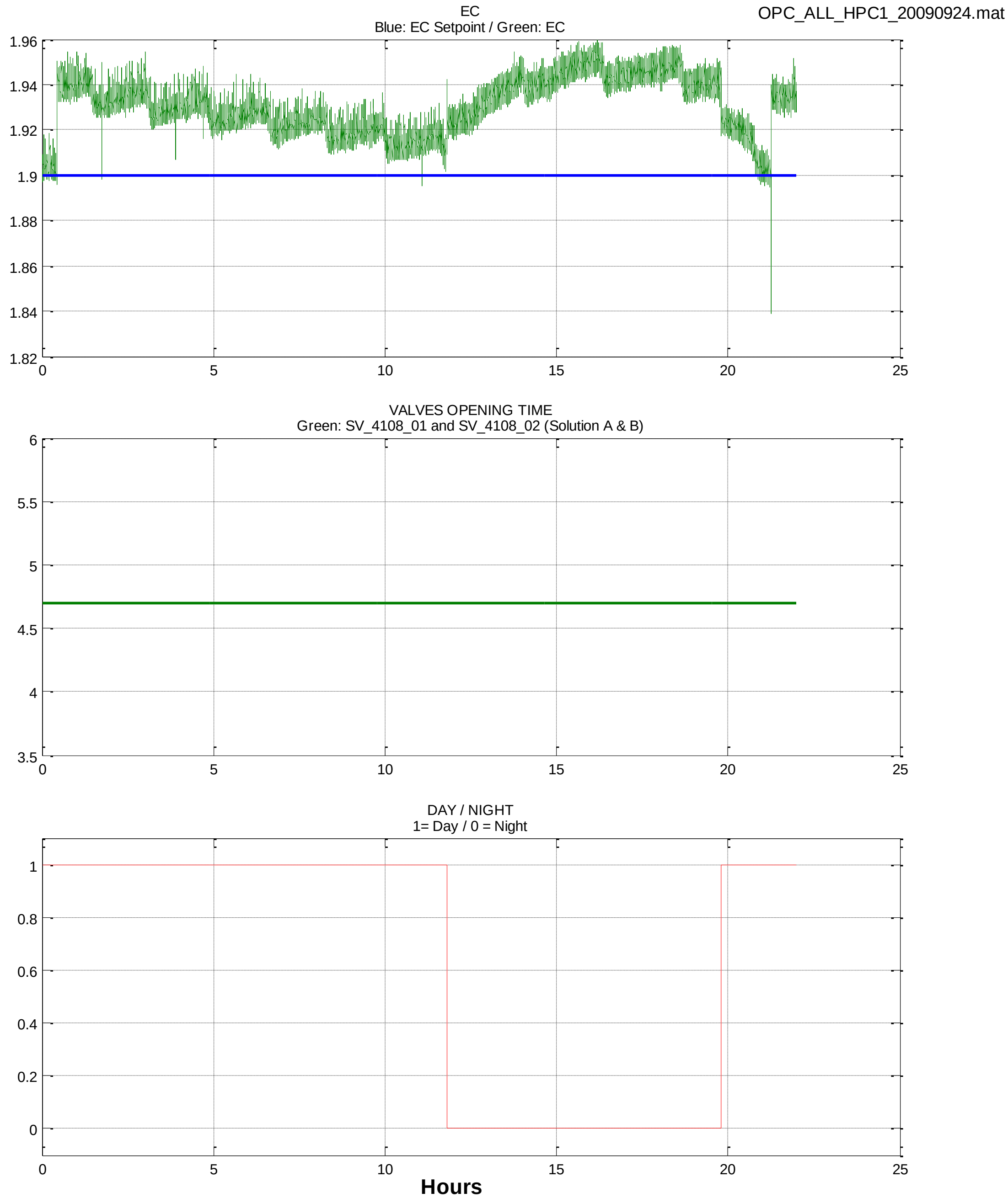

TEMPERATURE
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
OPC_ALL_HPC1_20090924.mat
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours

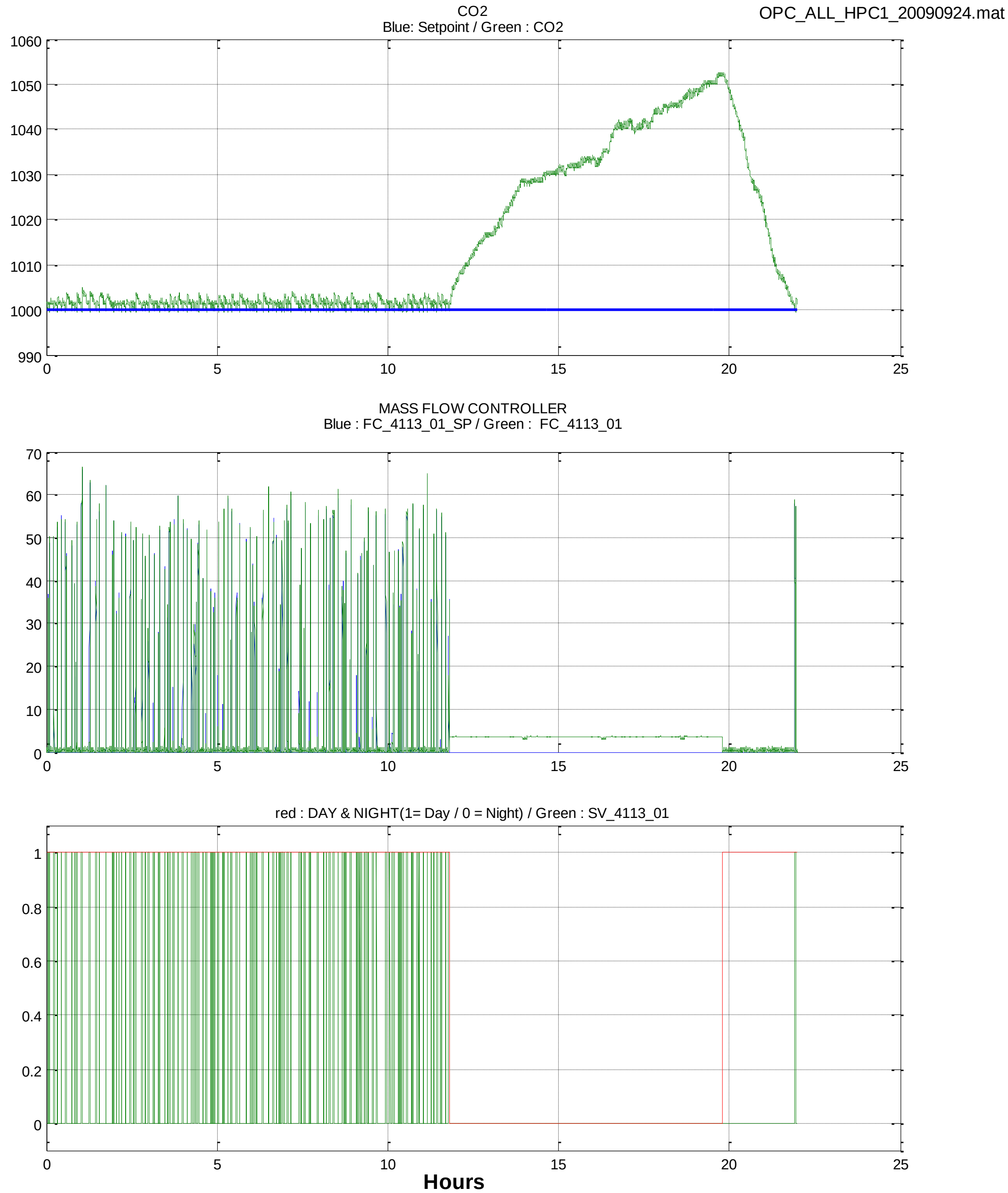

HUMIDITY
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
OPC_ALL_HPC1_20090924.mat
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

OPC_ALL_HPC1_20090924.mat



Hours


OPC_ALL_HPC1_20090924.mat
EC
Blue: EC Setpoint / Green: EC
1.96
1.94
1.92
1.9
1.88
1.86
1.84
1.82
0
5
10
15
20
25
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
6
5.5
5
4.5
4
3.5
DAY / NIGHT
1= Day / 0 = Night
1
0.8
0.6
0.4
0.2
0
Hours


OPC_ALL_HPC1_20090924.mat
CO2
Blue: Setpoint / Green : CO2
MASS FLOW CONTROLLER
Blue : FC_4113_01_SP / Green : FC_4113_01
red : DAY & NIGHT(1= Day / 0 = Night) / Green : SV_4113_01
Hours

3. October 13th (26.6 hours records)

Remark : when increasing or decreasing the temperature in the chamber, the hot water (utilities) temperature is affected. It is due to the position of the sensor, and is not real.

From 8.0 to 18.0 (hour) → **DAY**

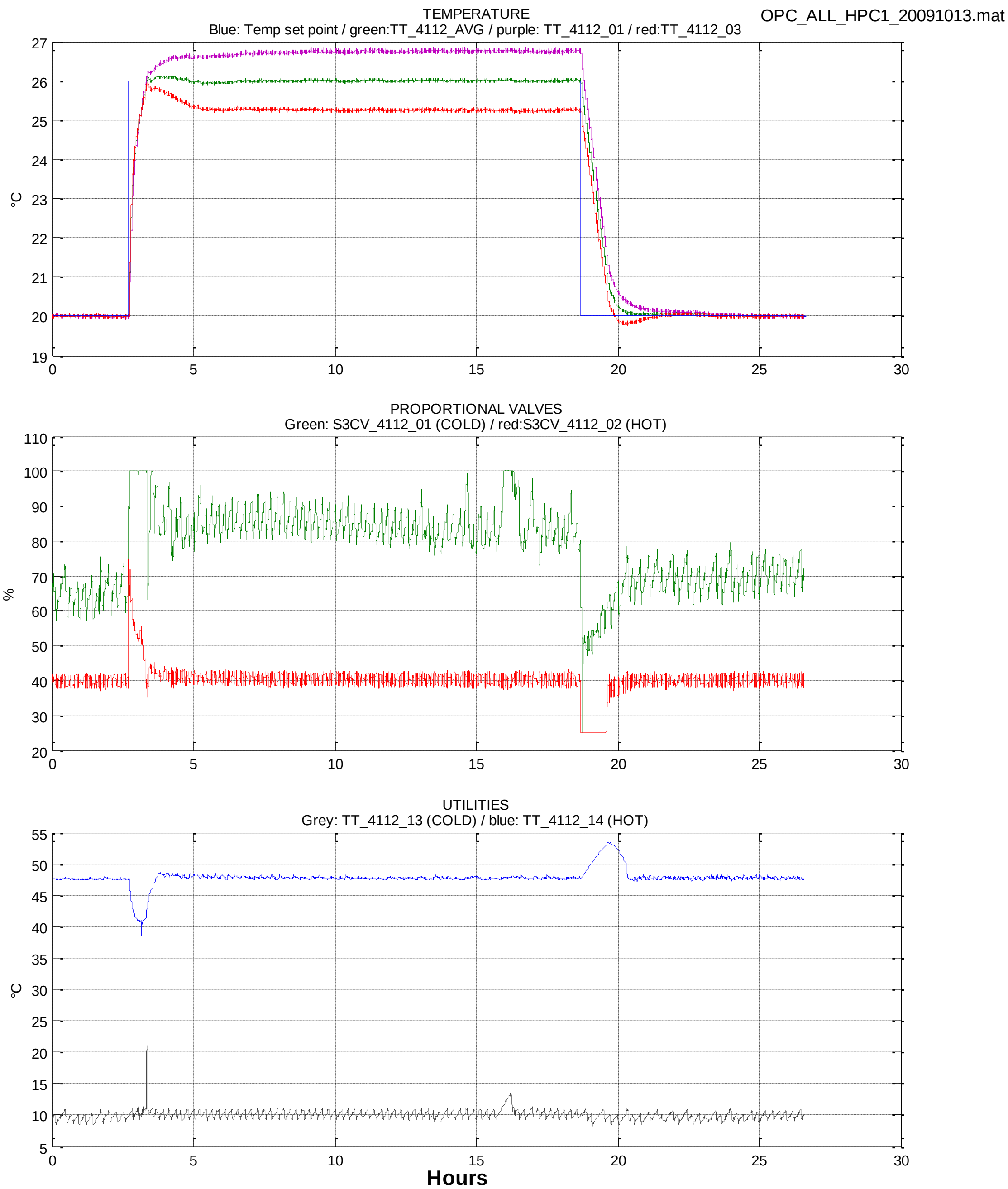
pH	mean	5.79	std	0.01	min	5.74	max	5.87
EC	mean	1.90	std	0.00	min	1.86	max	1.92
CO2	mean	1003.7	std	4.4	min	996.5	max	1011.0
T	**mean**	**26.00**	**std**	**0.02**	**min**	**25.94**	**max**	**26.07**
RH	**mean**	**50.21**	**std**	**0.86**	**min**	**47.61**	**max**	**55.35**
Tcold Water	mean	10.22	std	0.62	min	8.88	max	13.34
Thot Water	mean	47.73	std	0.15	min	47.36	max	48.22

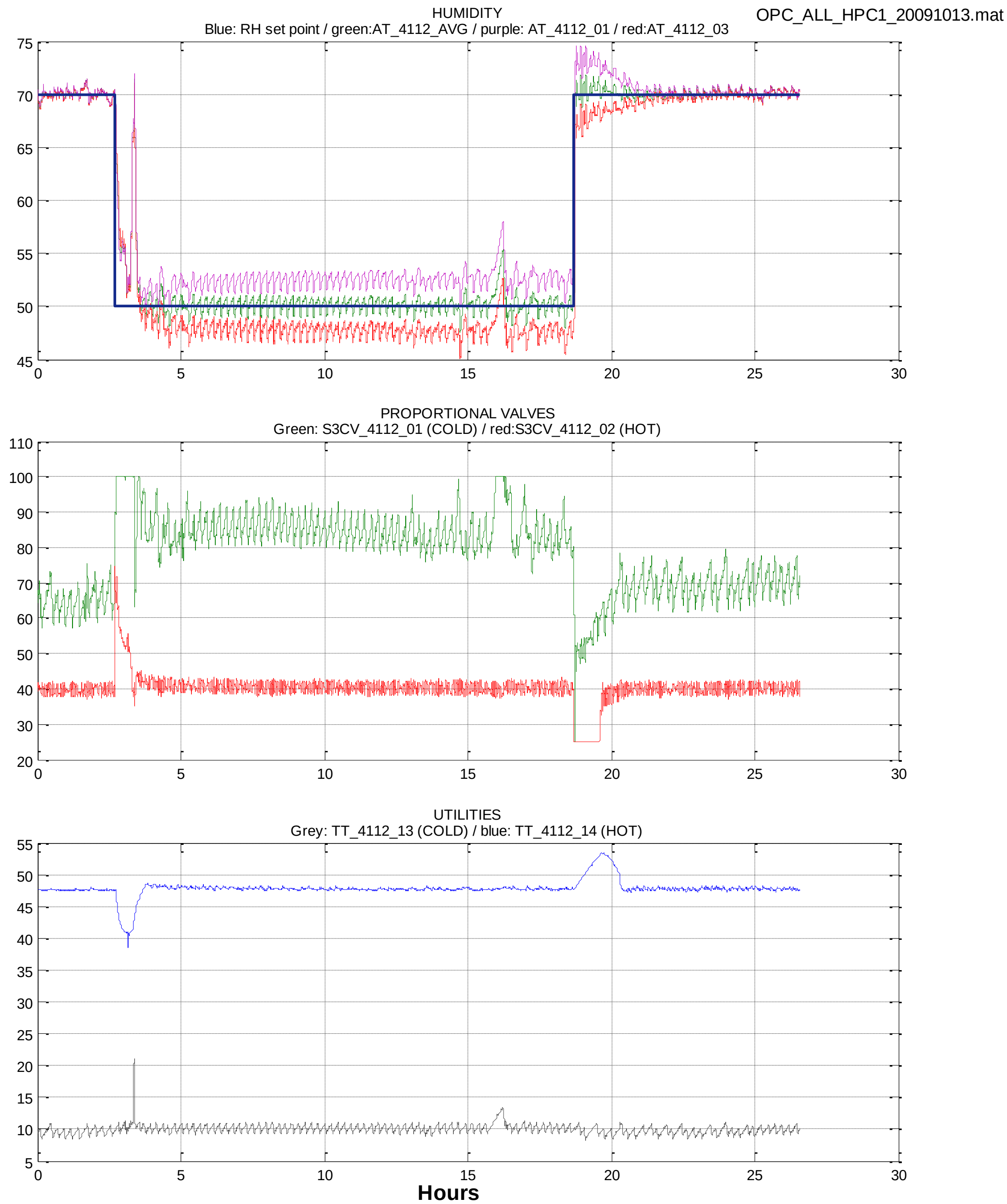
From 24.0 to 26.0 (hour) → **NIGHT**

pH	mean	5.79	std	0.01	min	5.75	max	5.84
EC	mean	1.92	std	0.00	min	1.89	max	1.94
CO2	mean	2652.1	std	113.4	min	2455.3	max	2840.5
T	**mean**	**20.01**	**std**	**0.01**	**min**	**19.96**	**max**	**20.05**
RH	**mean**	**70.09**	**std**	**0.33**	**min**	**69.11**	**max**	**70.89**
Tcold Water	mean	9.77	std	0.48	min	8.60	max	11.20
Thot Water	mean	47.76	std	0.19	min	47.32	max	48.30

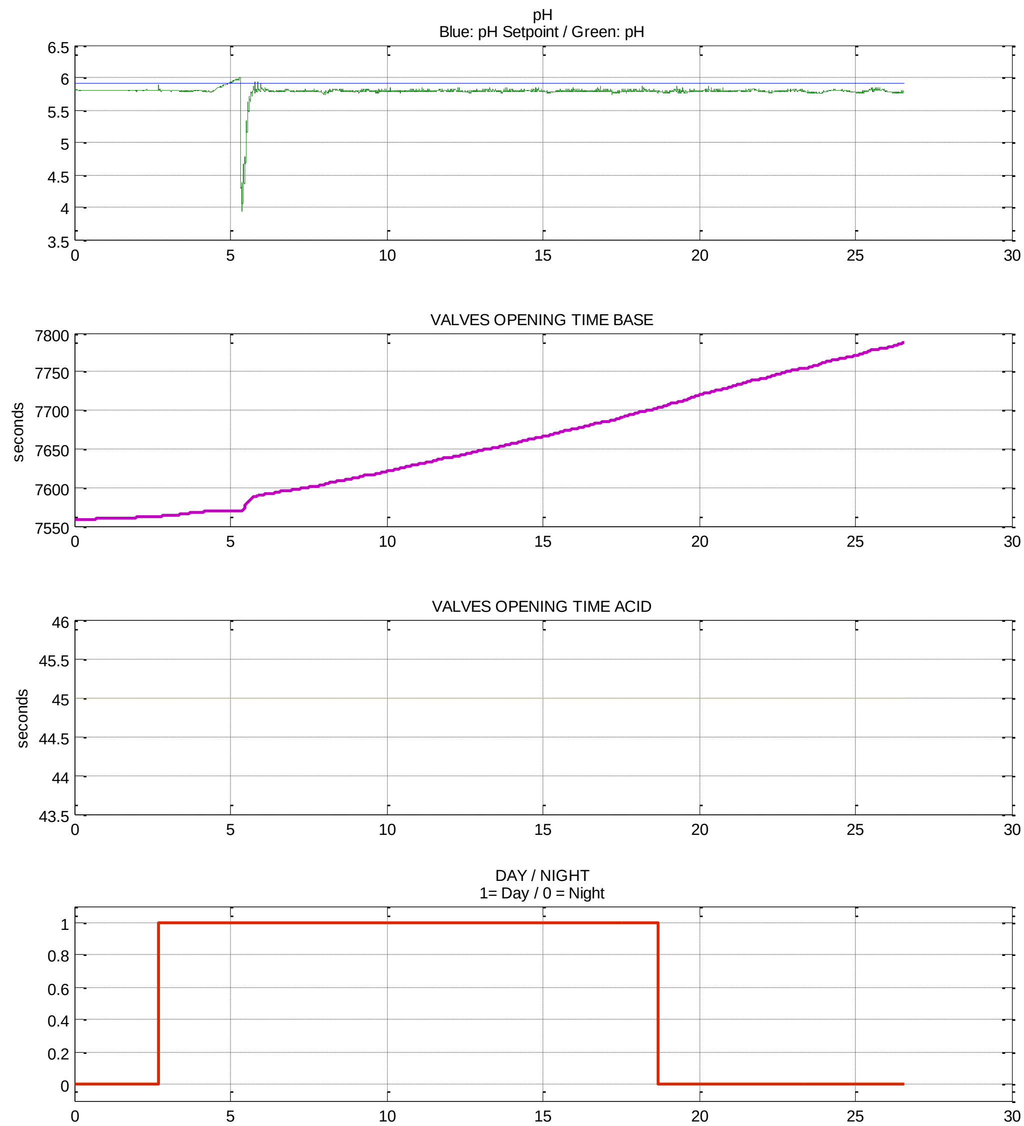
Complete file

CO2	mean	1539.5	std	670.9	min	848.1	max	2952.1
O2	mean	22.93	std	0.24	min	20.57	max	23.28

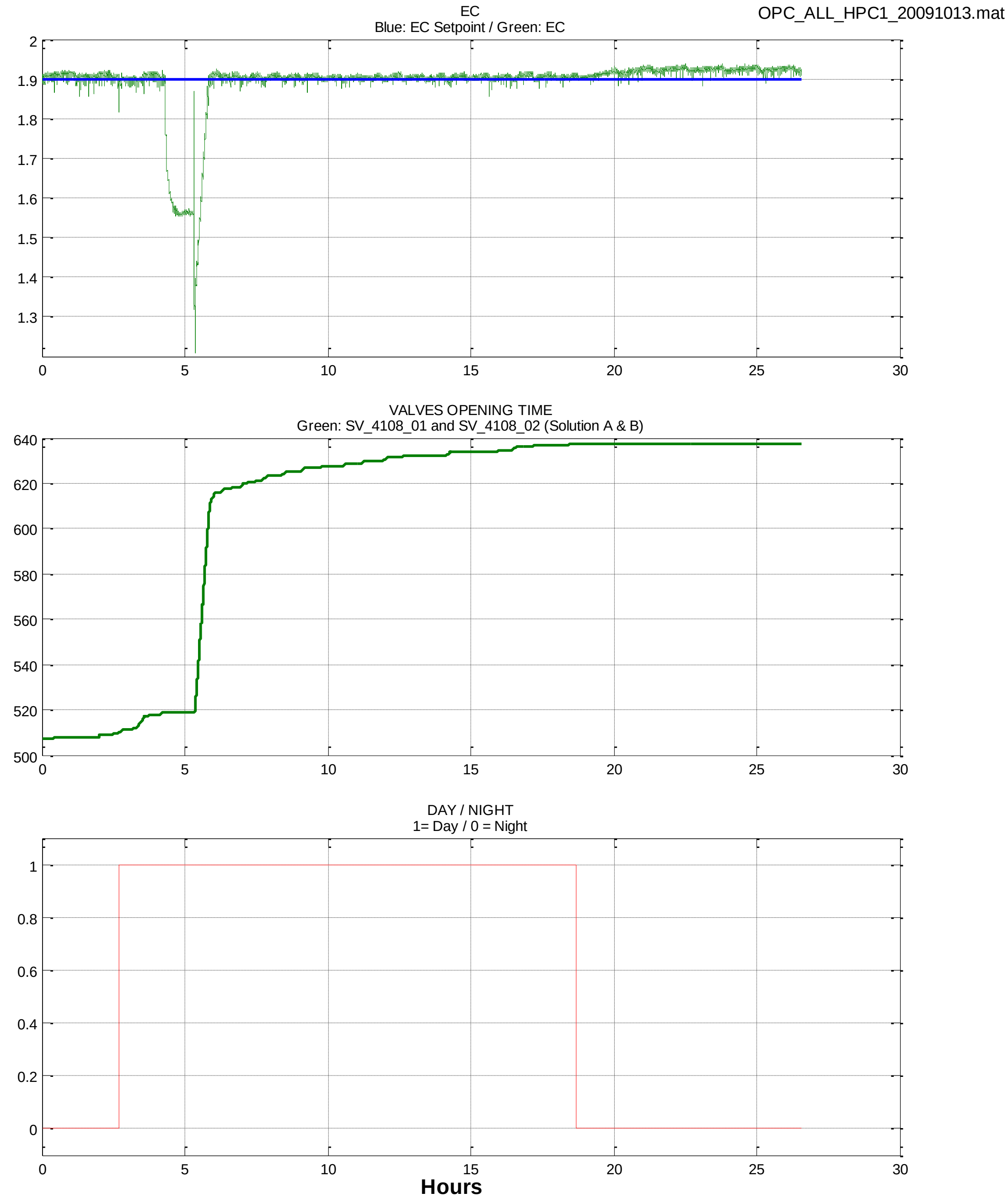

OPC_ALL_HPC1_20091013.mat
TEMPERATURE
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours


OPC_ALL_HPC1_20091013.mat
HUMIDITY
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

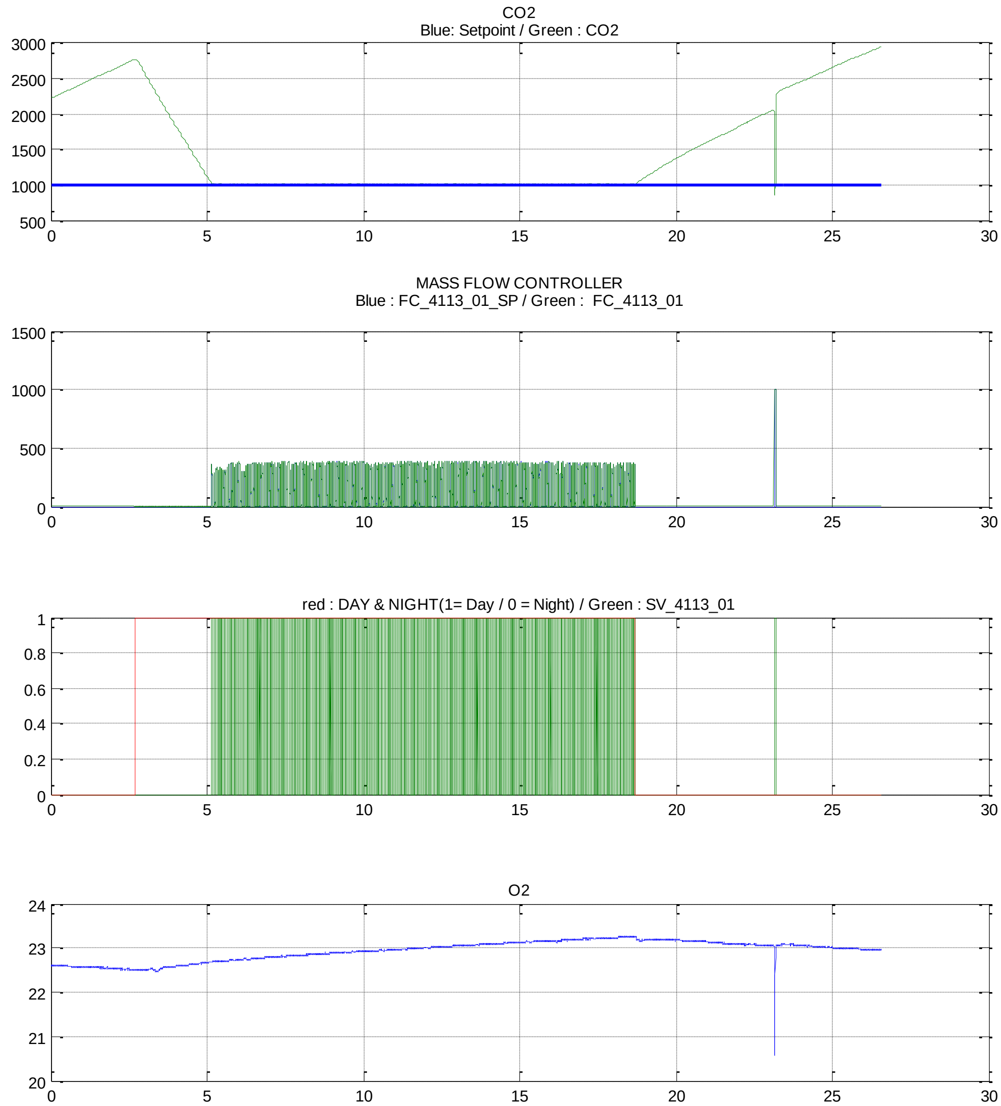
OPC_ALL_HPC1_20091013.mat



Hours


OPC_ALL_HPC1_20091013.mat
EC
Blue: EC Setpoint / Green: EC
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
DAY / NIGHT
1= Day / 0 = Night
Hours

OPC_ALL_HPC1_20091013.mat



Hours

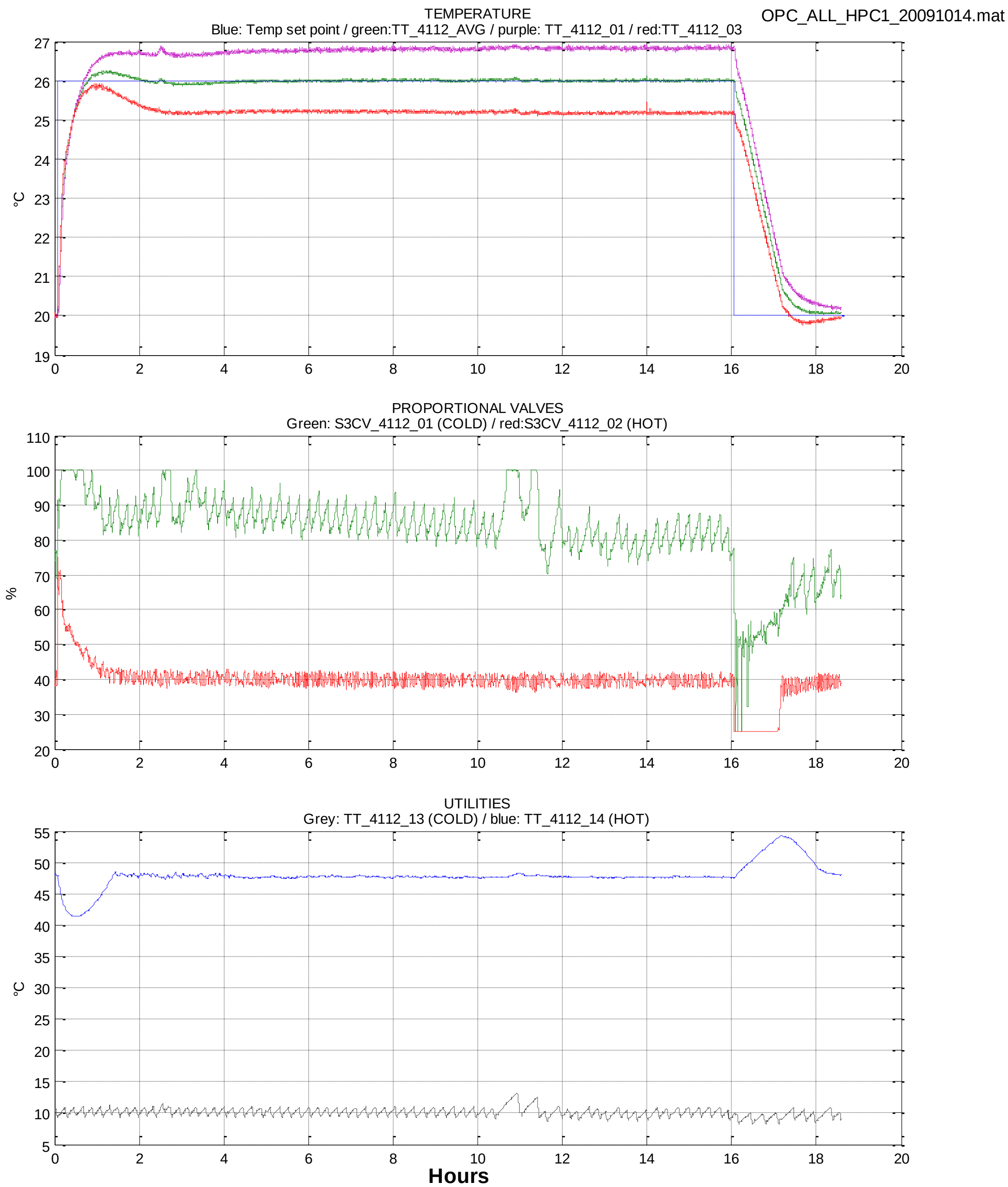
4. October 14th (18.6 hours records)

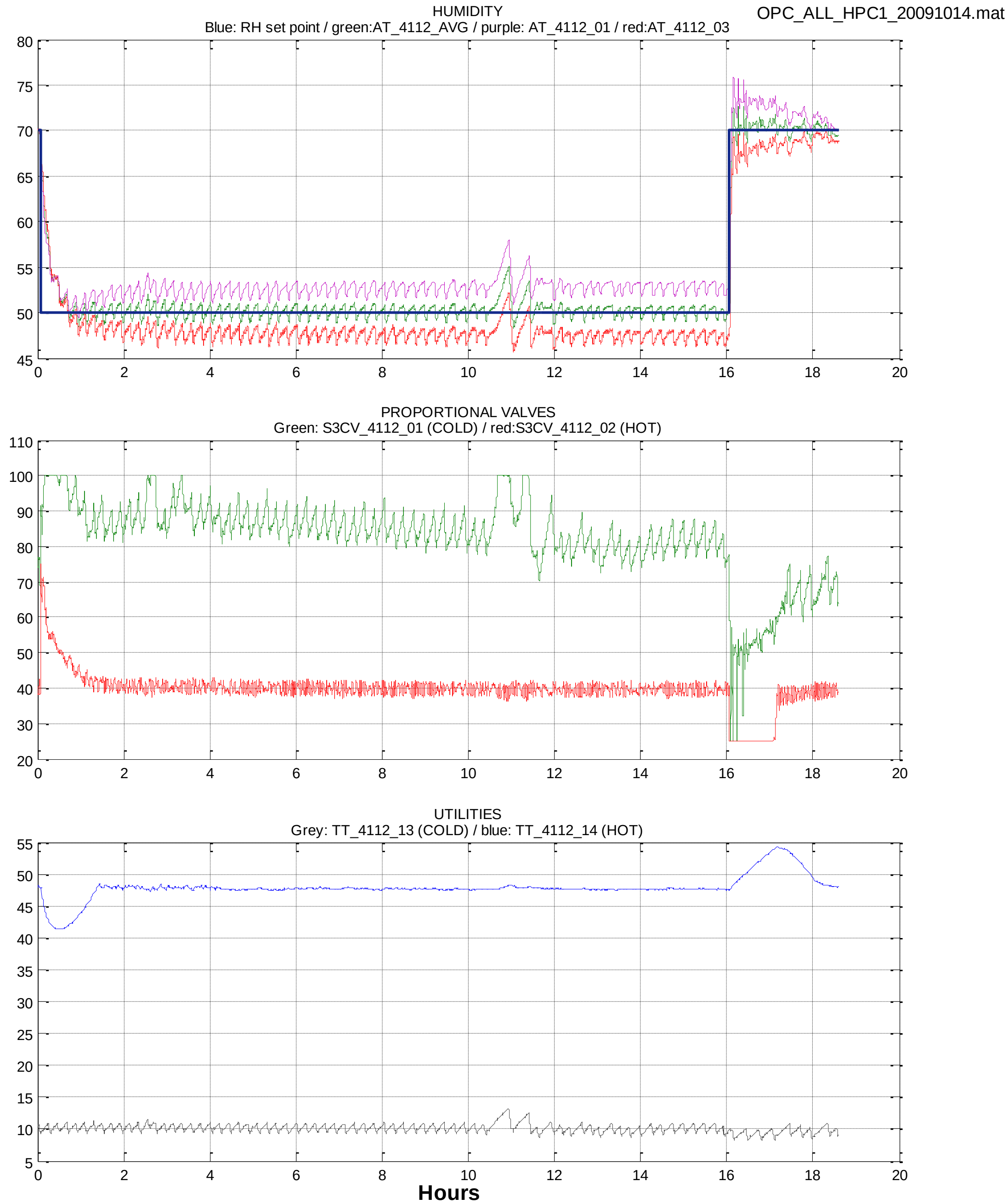
From 4.0 to 16.0 (hour) → **DAY**

pH	mean	5.79	std	0.01	min	5.75	max	5.89
EC	mean	1.91	std	0.00	min	1.85	max	1.93
CO2	mean	1002.0	std	3.1	min	996.7	max	1007.7
T	**mean**	**26.00**	**std**	**0.02**	**min**	**25.91**	**max**	**26.13**
RH	**mean**	**50.23**	**std**	**0.81**	**min**	**48.23**	**max**	**55.11**
Tcold Water	mean	10.16	std	0.64	min	8.60	max	13.21
Thot Water	mean	47.68	std	0.13	min	47.33	max	48.33

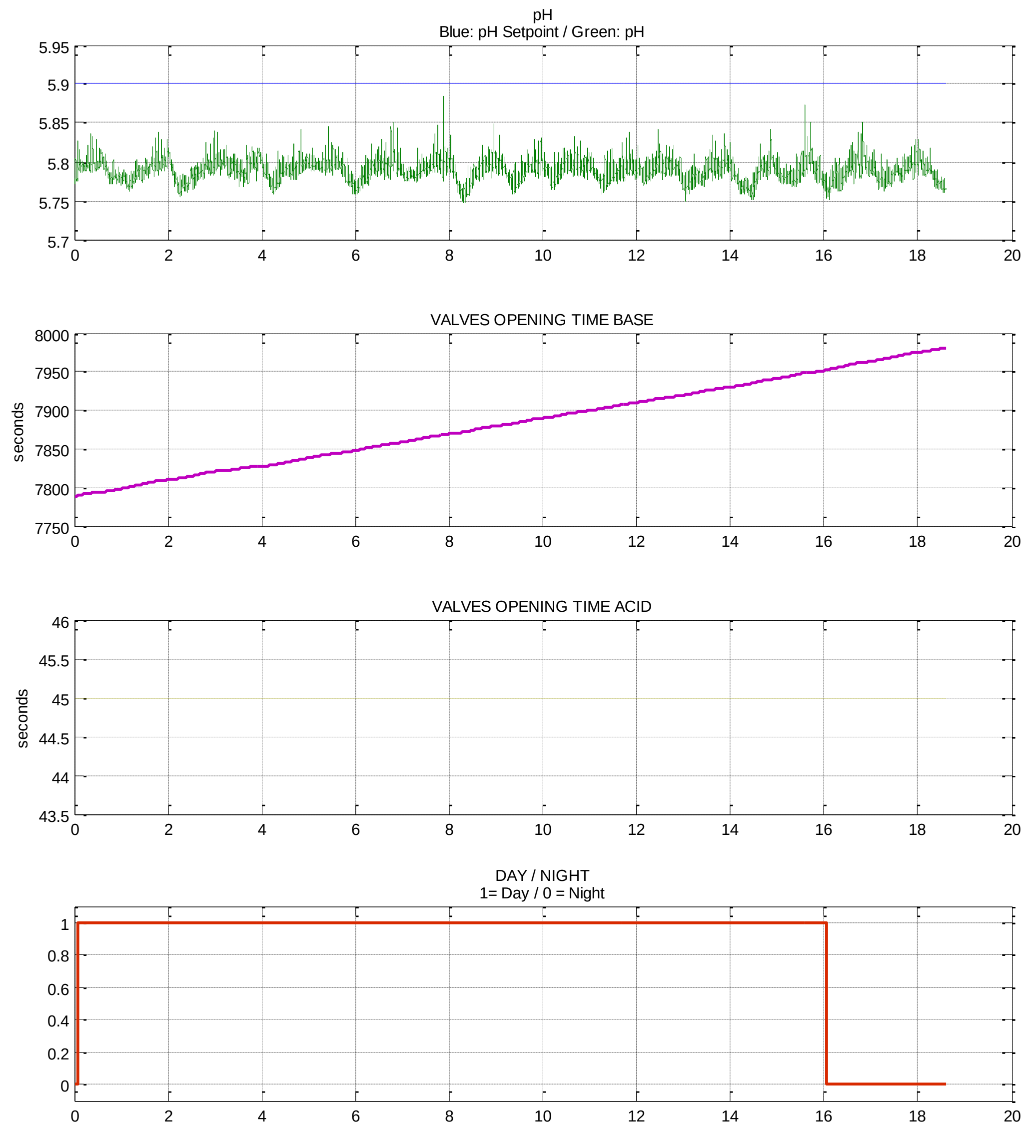
Complete file

CO2	mean	1186.5	std	414.9	min	996.7	max	**2977.8**
O2	mean	23.36	std	0.21	min	22.92	max	**23.69**

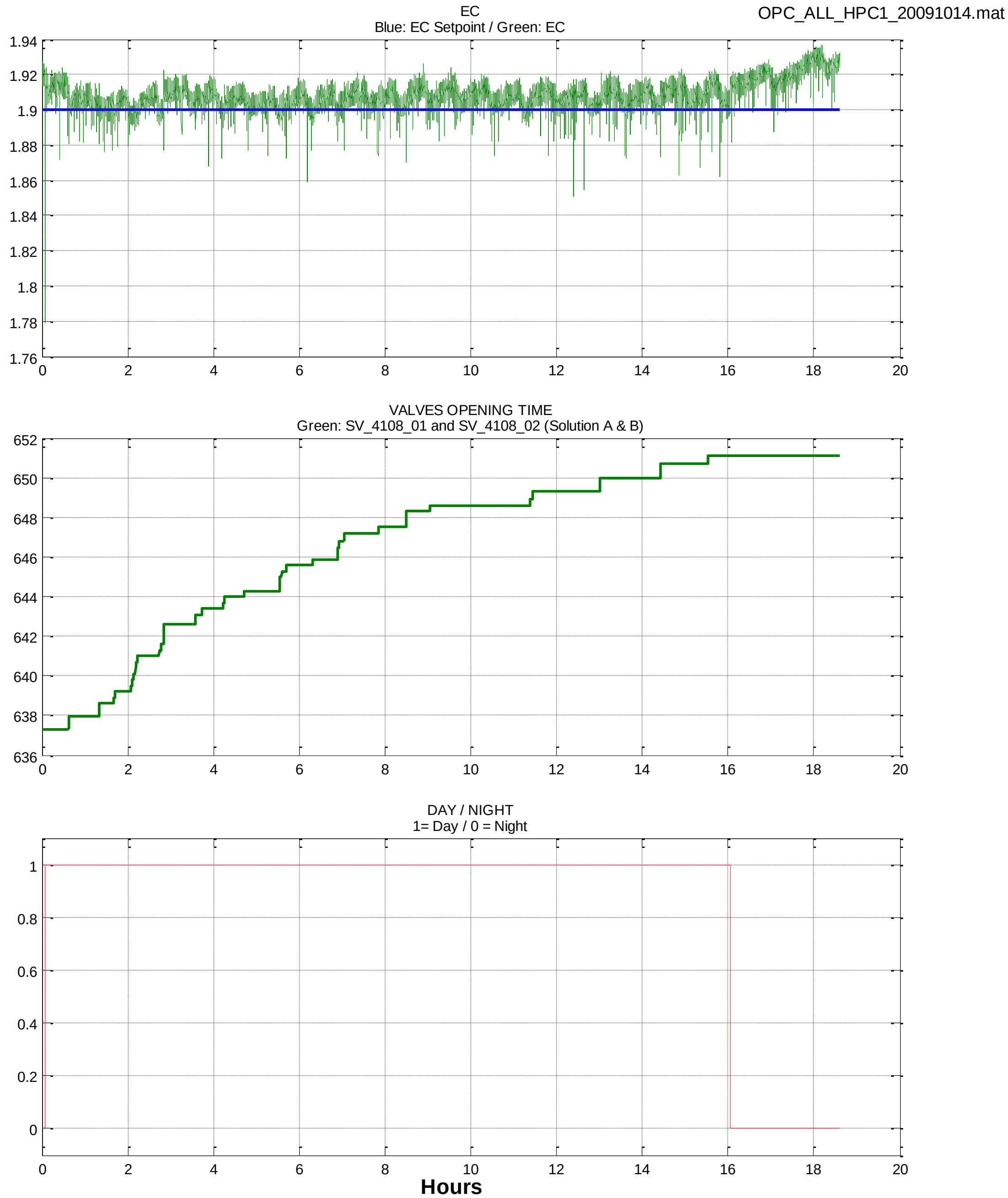

TEMPERATURE
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
OPC_ALL_HPC1_20091014.mat
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours


HUMIDITY
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
OPC_ALL_HPC1_20091014.mat
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

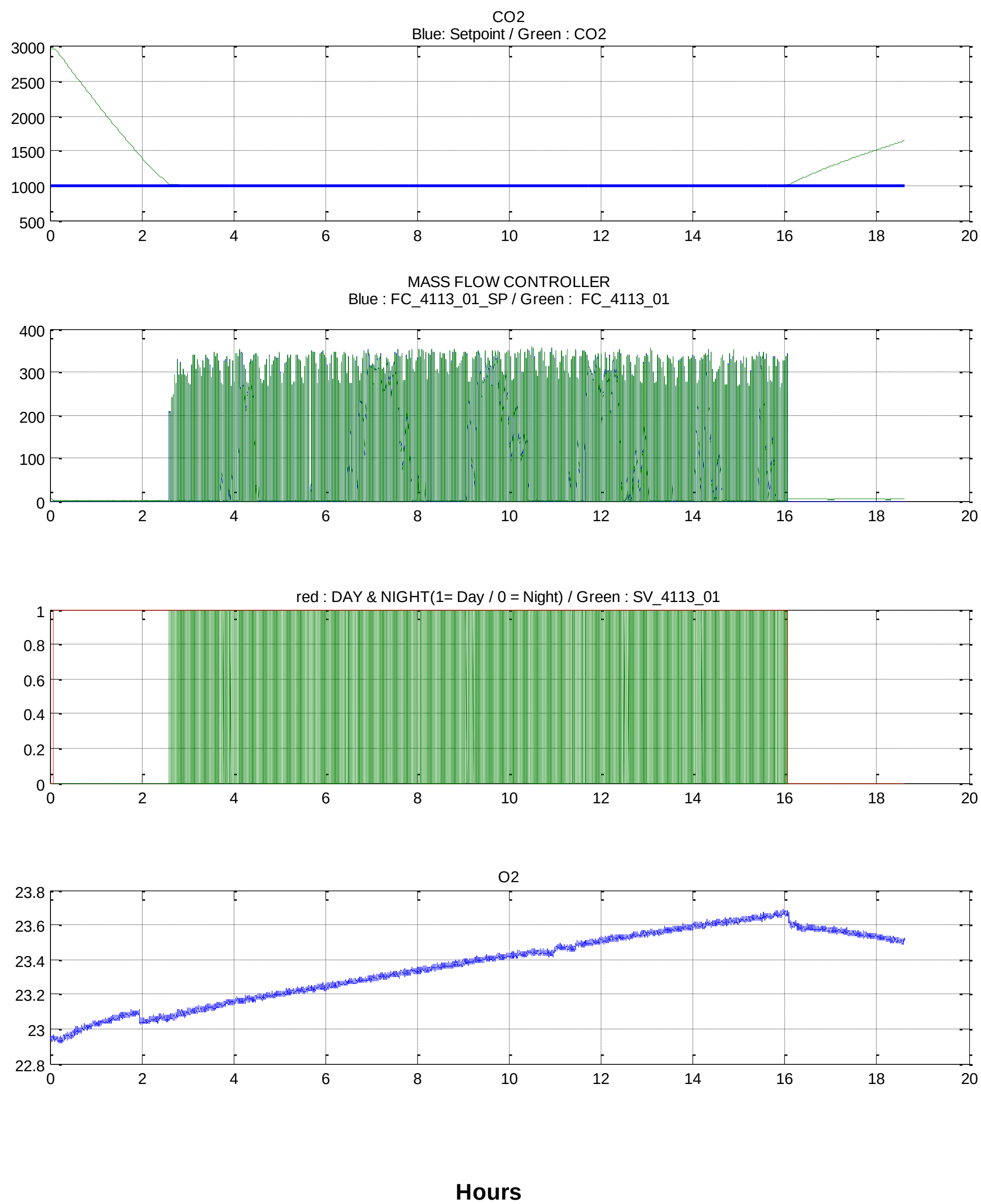
OPC_ALL_HPC1_20091014.mat



Hours


EC
Blue: EC Setpoint / Green: EC
OPC_ALL_HPC1_20091014.mat
1.94
1.92
1.9
1.88
1.86
1.84
1.82
1.8
1.78
1.76
0
2
4
6
8
10
12
14
16
18
20
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
652
650
648
646
644
642
640
638
636
DAY / NIGHT
1= Day / 0 = Night
1
0.8
0.6
0.4
0.2
0
Hours

OPC_ALL_HPC1_20091014.mat



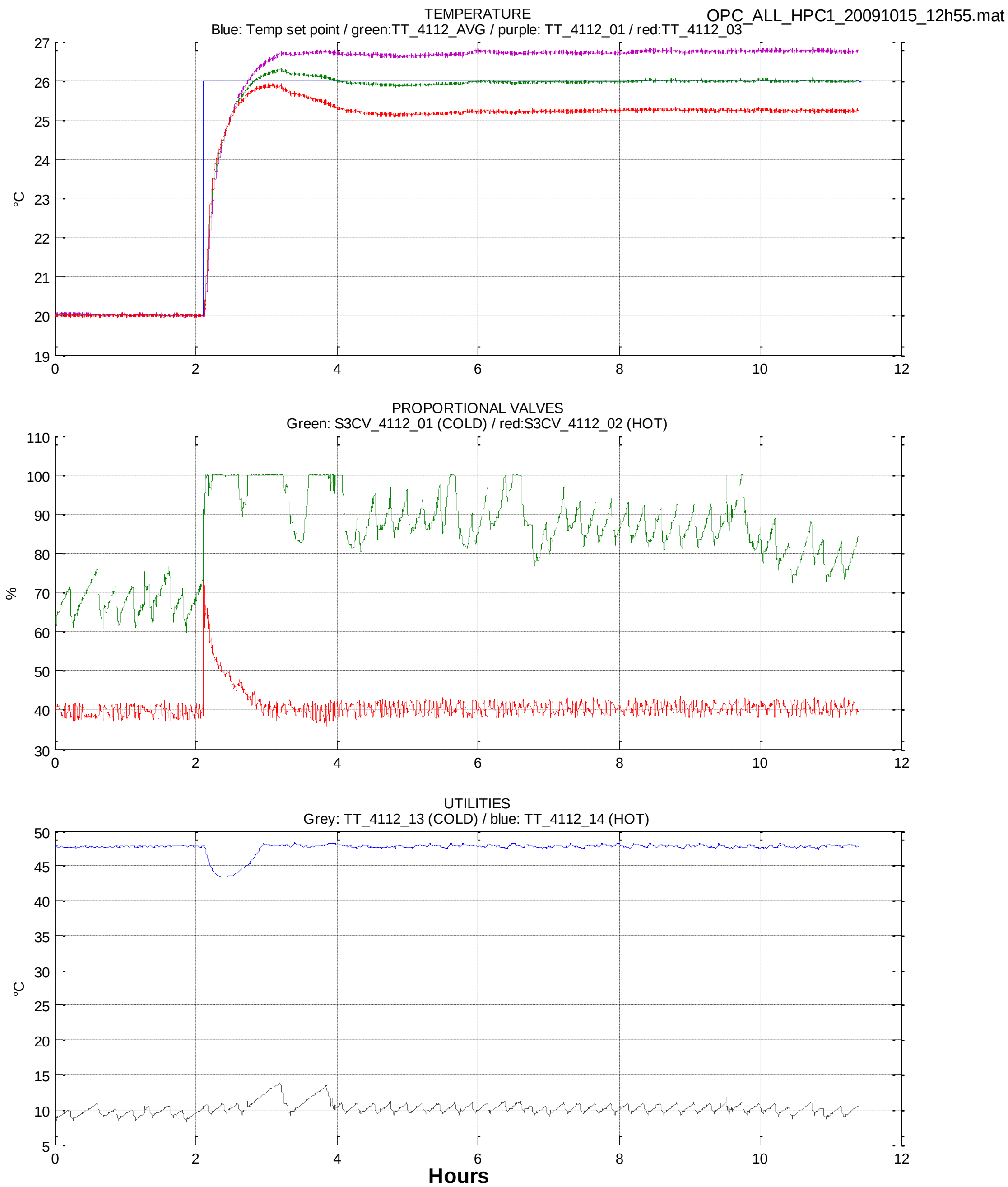
5. October 15th (11.4 hours records)

From 6.0 to 11.4 (hour) → **DAY**

pH	mean	5.79	std	0.01	min	5.76	max	5.84
EC	mean	1.90	std	0.00	min	1.86	max	1.92
CO2	mean	1002.2	std	3.3	min	996.7	max	1008.3
T	**mean**	**25.98**	**std**	**0.02**	**min**	**25.89**	**max**	**26.08**
RH	**mean**	**50.12**	**std**	**0.61**	**min**	**48.19**	**max**	**51.96**
Tcold Water	mean	10.08	std	0.49	min	8.59	max	11.82
Thot Water	mean	47.81	std	0.16	min	47.39	max	48.29

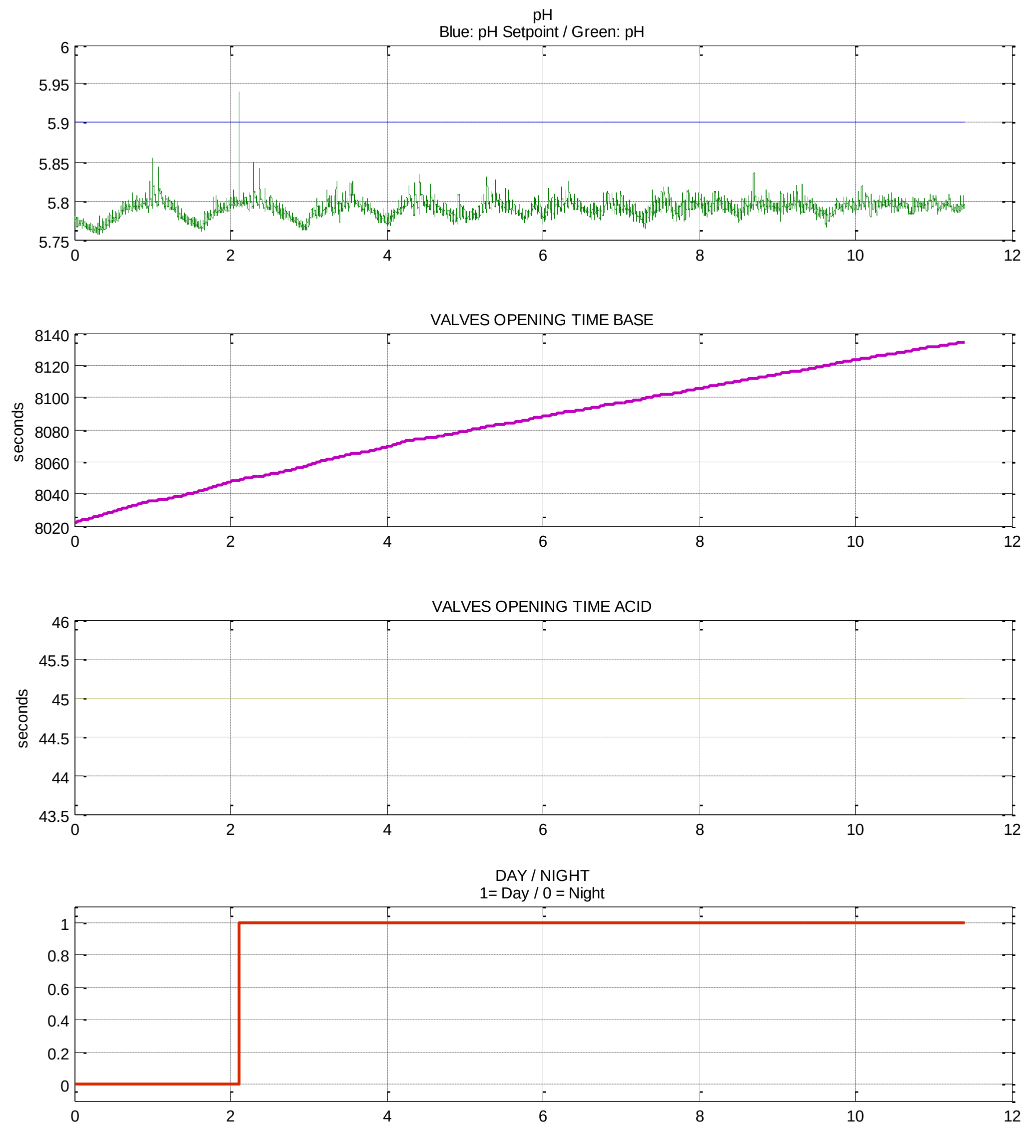
Complete file

CO2	mean	1443.6	std	647.4	min	996.7	max	**2726.8**
O2	mean	23.44	std	0.13	min	23.22	max	**23.69**

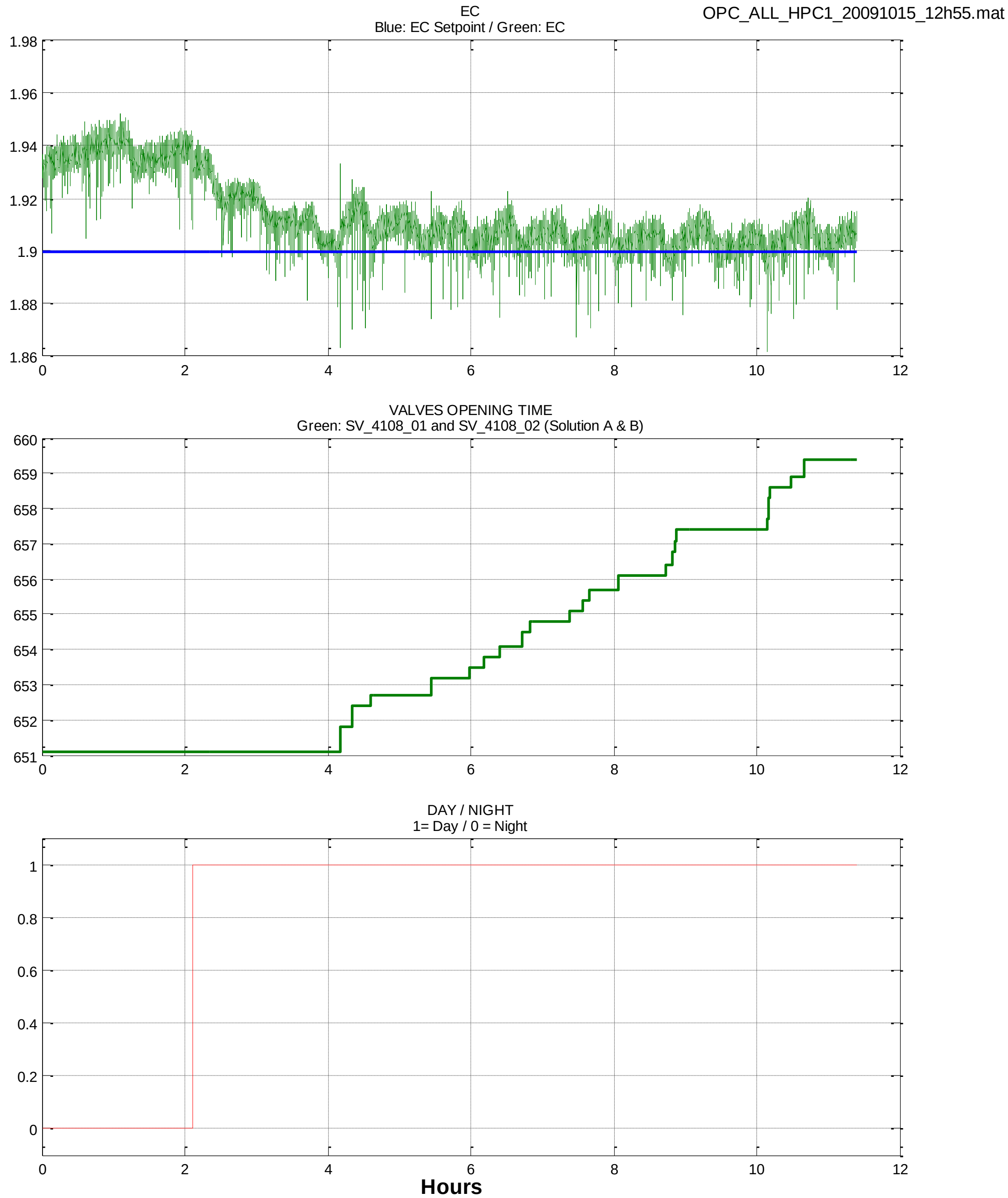

TEMPERATURE
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
OPC_ALL_HPC1_20091015_12h55.mat
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours


HUMIDITY
OPC_ALL_HPC1_20091015_12h55.mat
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

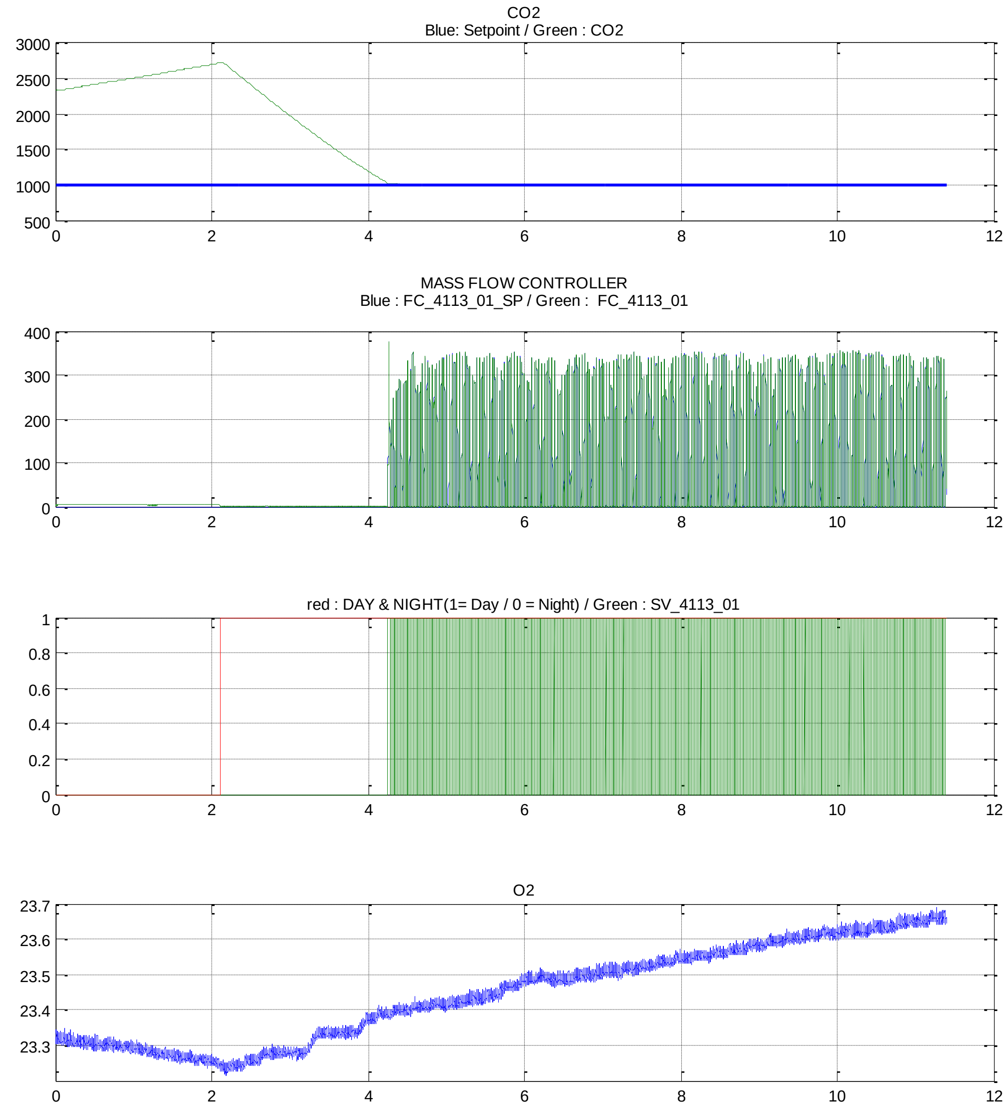
OPC_ALL_HPC1_20091015_12h55.mat



Hours


OPC_ALL_HPC1_20091015_12h55.mat
EC
Blue: EC Setpoint / Green: EC
1.98
1.96
1.94
1.92
1.9
1.88
1.86
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
660
659
658
657
656
655
654
653
652
651
DAY / NIGHT
1= Day / 0 = Night
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
Hours

OPC_ALL_HPC1_20091015_12h55.mat



Hours

6.October 16th (30.4 hours records)

From 10.0 to 20.0 (hour) → **DAY**

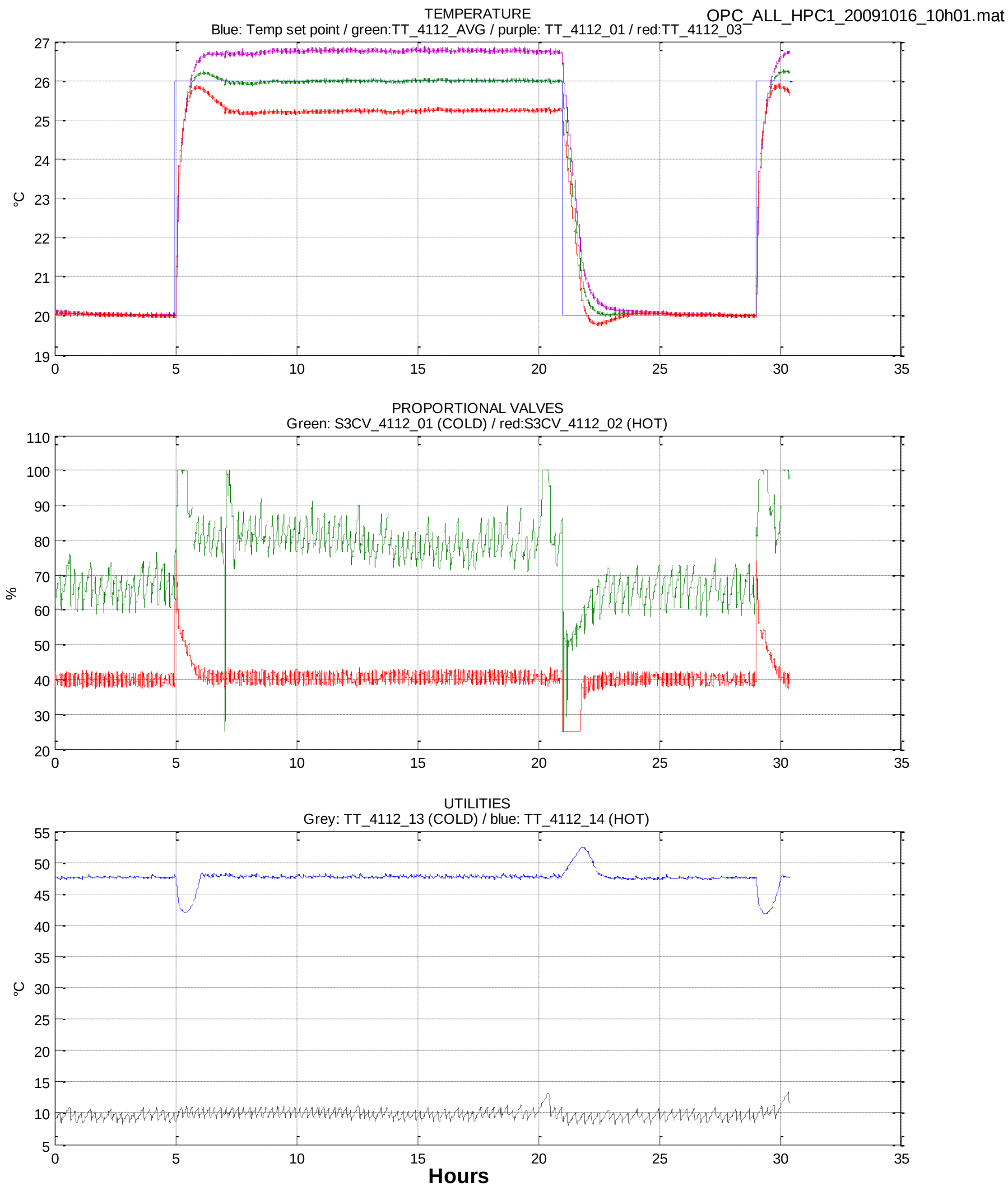
pH	mean	5.80	std	0.00	min	5.78	max	5.81
EC	mean	1.90	std	0.00	min	1.85	max	1.92
CO2	mean	1002.3	std	3.5	min	996.8	max	1008.5
T	**mean**	**25.99**	**std**	**0.02**	**min**	**25.92**	**max**	**26.07**
RH	**mean**	**50.16**	**std**	**0.52**	**min**	**48.47**	**max**	**51.04**
Tcold Water	mean	9.91	std	0.53	min	8.56	max	11.30
Thot Water	mean	47.72	std	0.16	min	47.31	max	48.18

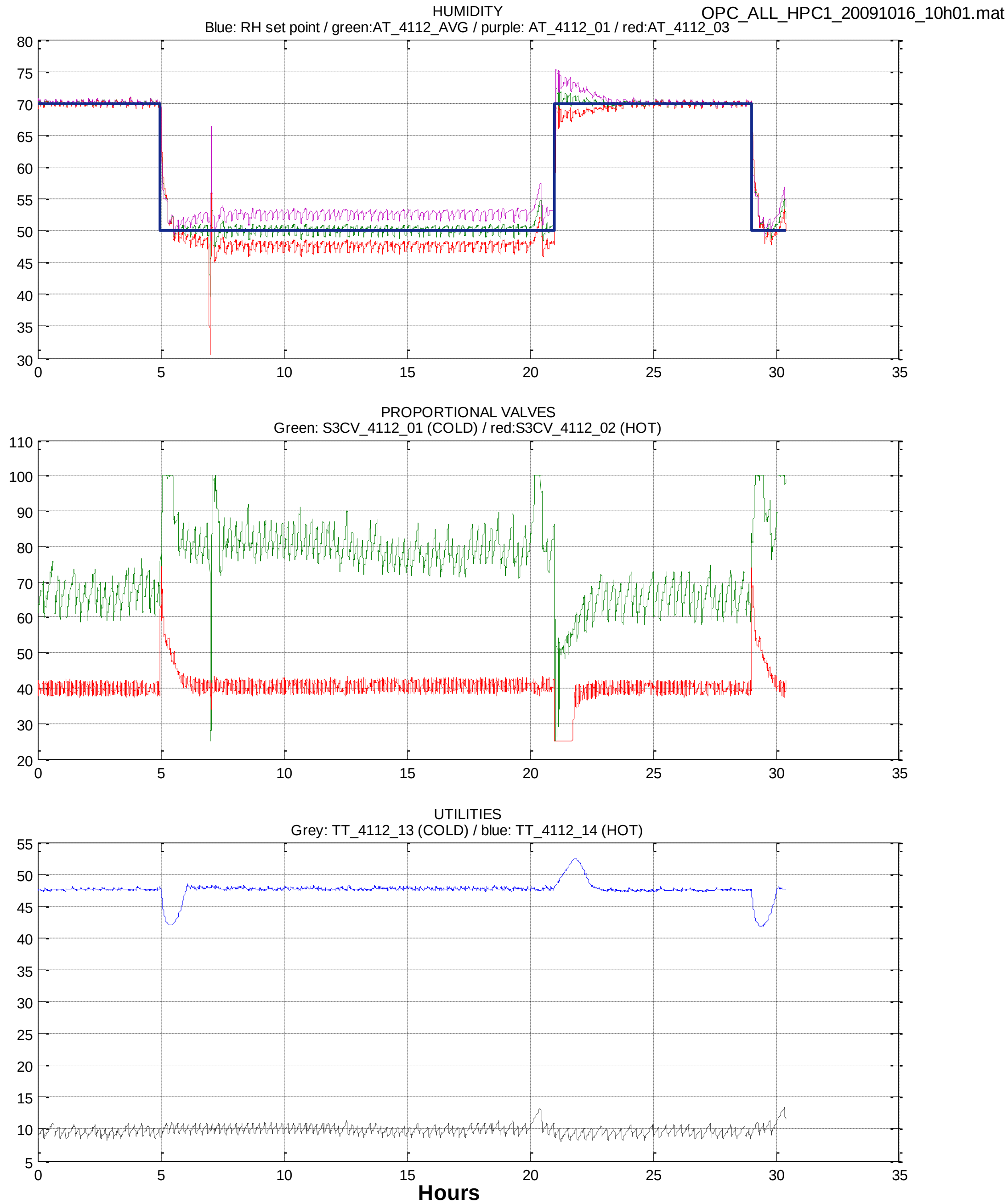
From 24.0 to 29.0 (hour) → NIGHT

pH	mean	5.83	std	0.02	min	5.80	max	5.93
EC	mean	1.92	std	0.01	min	1.85	max	1.94
CO2	mean	2306.5	std	300.6	min	1780.8	**max**	**2827.3**
T	**mean**	**20.03**	**std**	**0.03**	**min**	**19.96**	**max**	**20.12**
RH	**mean**	**69.99**	**std**	**0.28**	**min**	**68.61**	**max**	**70.70**
Tcold Water	mean	9.57	std	0.55	min	8.30	max	10.89
Thot Water	mean	47.51	std	0.12	min	47.21	max	47.99

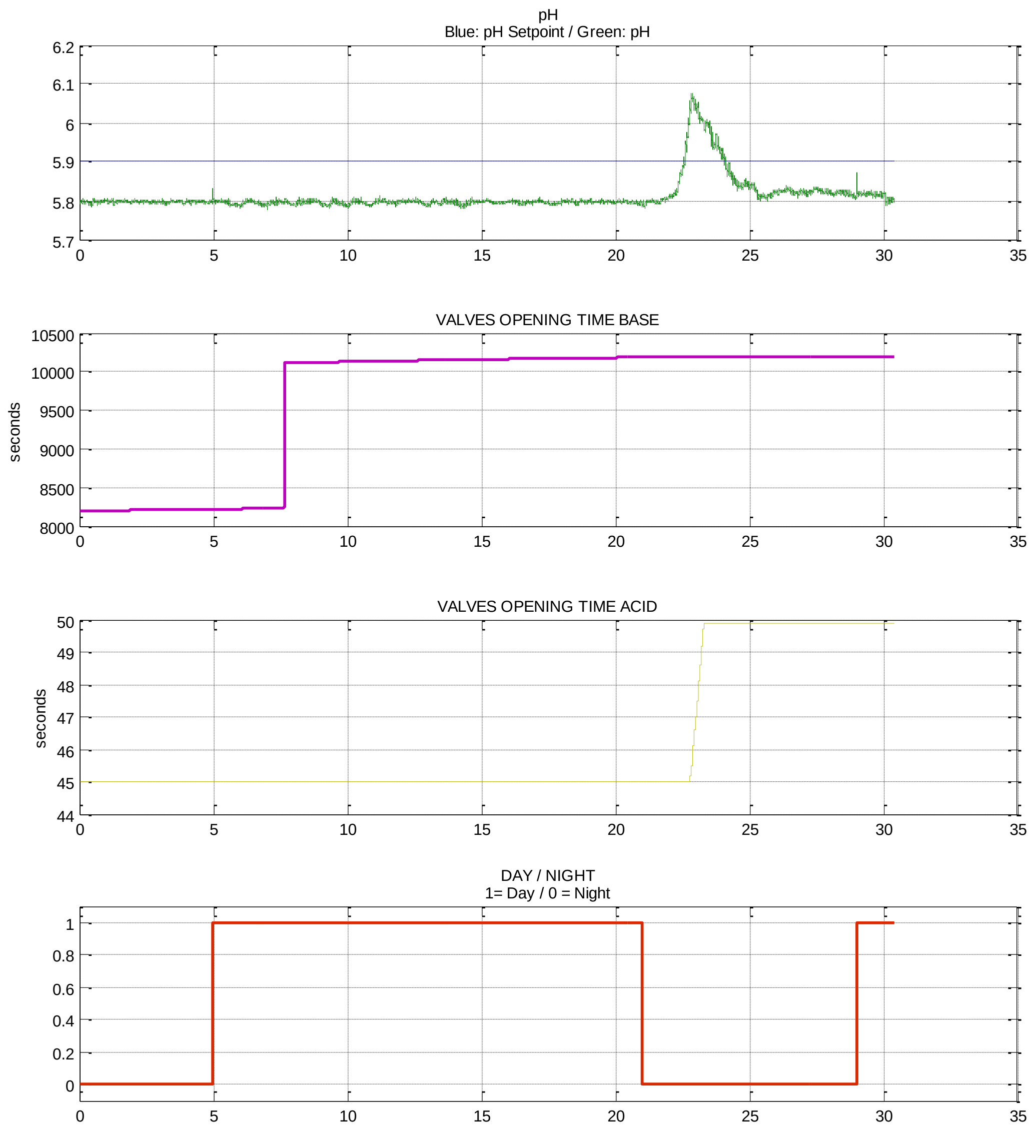
Complete file

CO2	mean	1592.3	std	644.6	min	778.1	max	**2829.2**
O2	mean	21.73	std	1.04	min	20.61	max	**23.75**


OPC_ALL_HPC1_20091016_10h01.mat
TEMPERATURE
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours

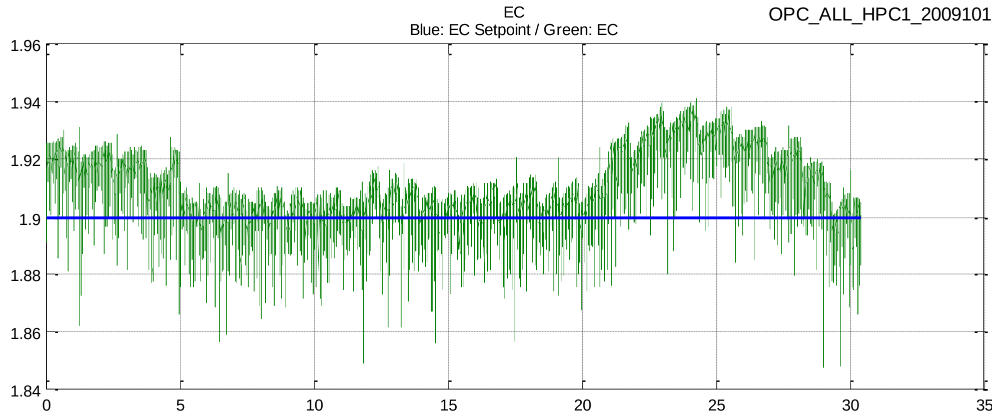

HUMIDITY
OPC_ALL_HPC1_20091016_10h01.mat
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

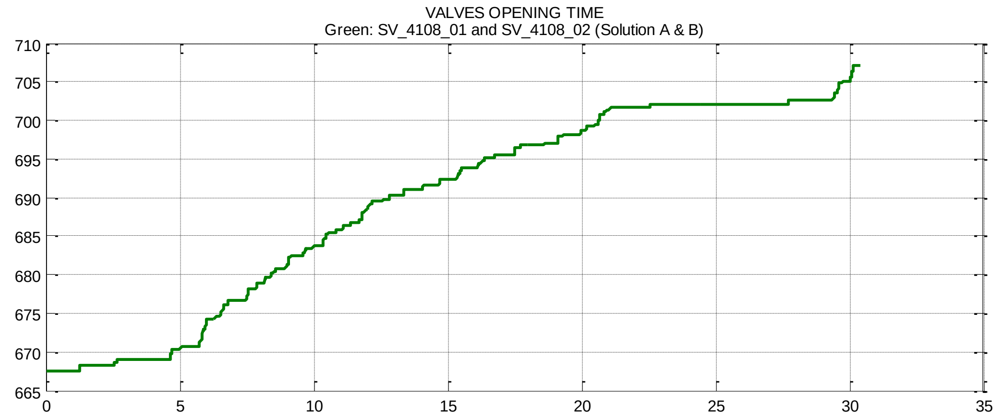
OPC_ALL_HPC1_20091016_10h01.mat

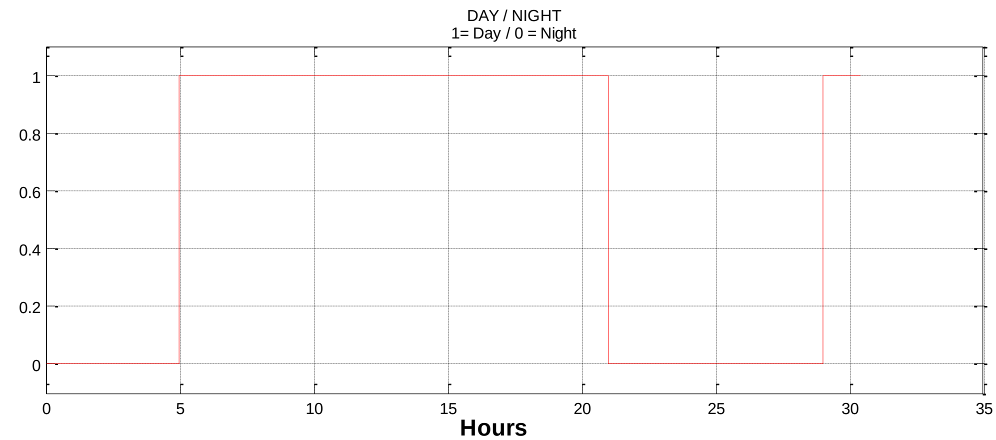


Hours

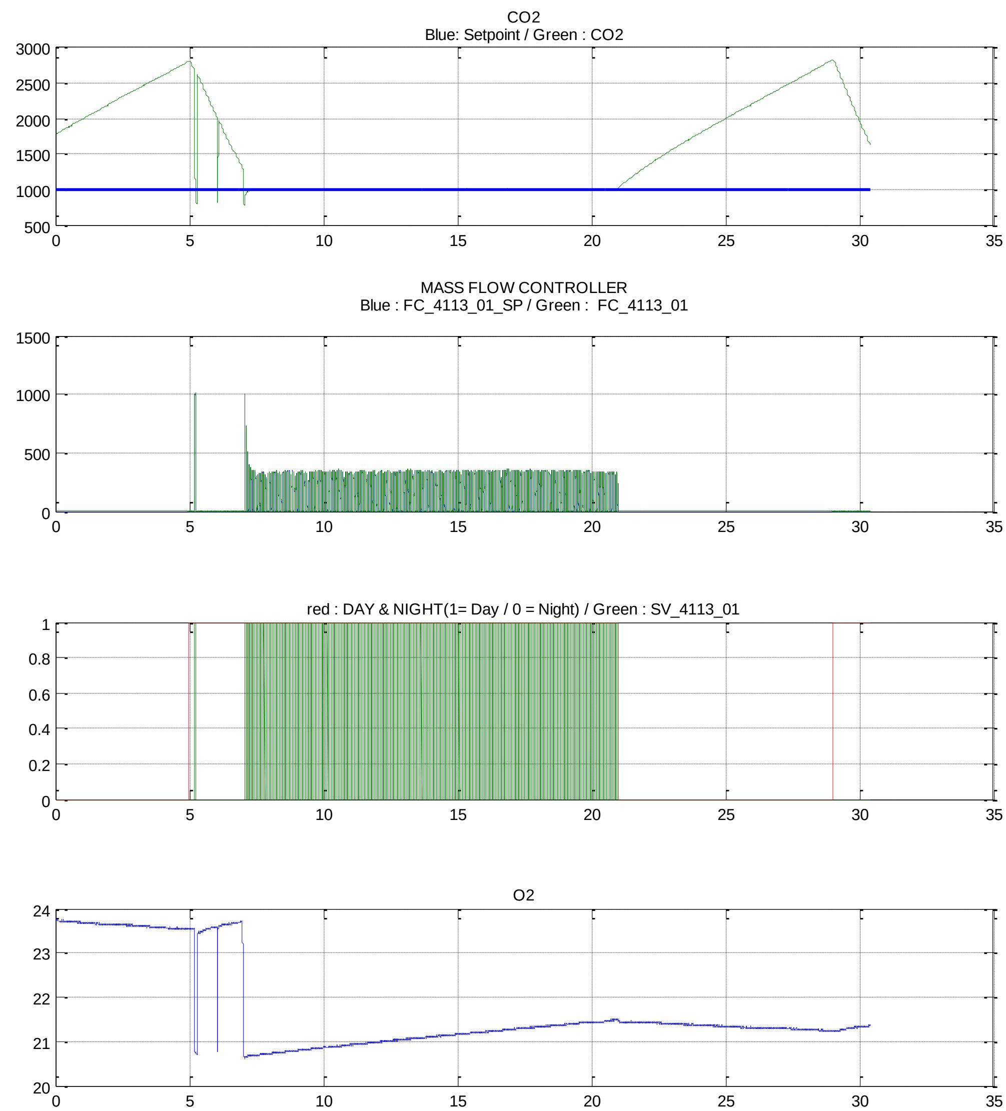
OPC_ALL_HPC1_20091016_10h01.mat







OPC_ALL_HPC1_20091016_10h01.mat



Hours

7. October 17th (63.3 hours records)

From 4.0 to 14.0 (hour) → **DAY**

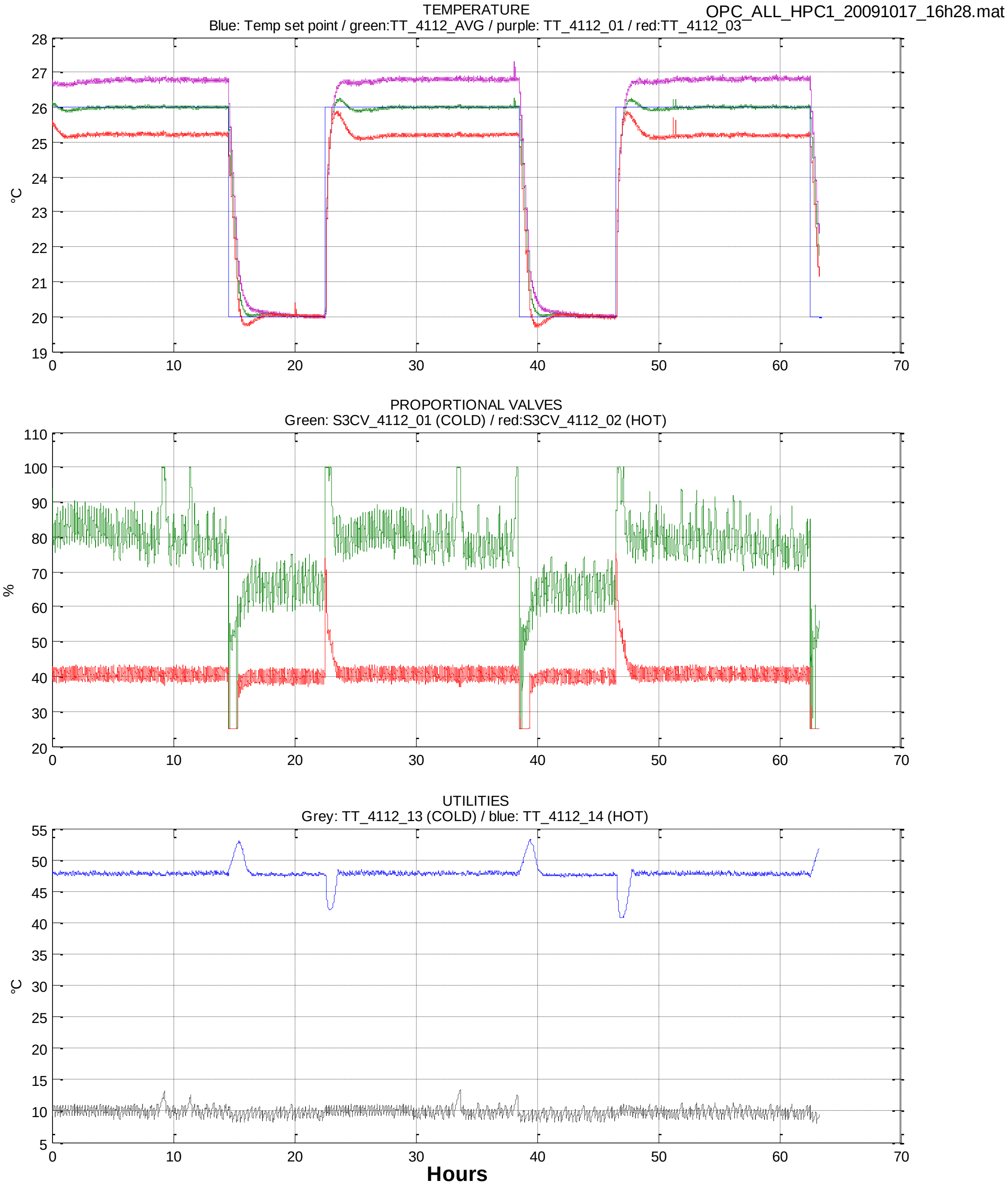
pH	mean	5.80	std	0.01	min	5.77	max	6.03
EC	mean	1.91	std	0.00	min	1.86	max	1.93
CO2	mean	1002.6	std	3.7	min	996.6	max	1008.8
T	**mean**	**26.00**	**std**	**0.02**	**min**	**25.92**	**max**	**26.08**
RH	**mean**	**50.29**	**std**	**0.79**	**min**	**48.41**	**max**	**54.86**
Tcold Water	mean	10.10	std	0.73	min	8.64	max	13.26
Thot Water	mean	47.80	std	0.17	min	47.37	max	48.30

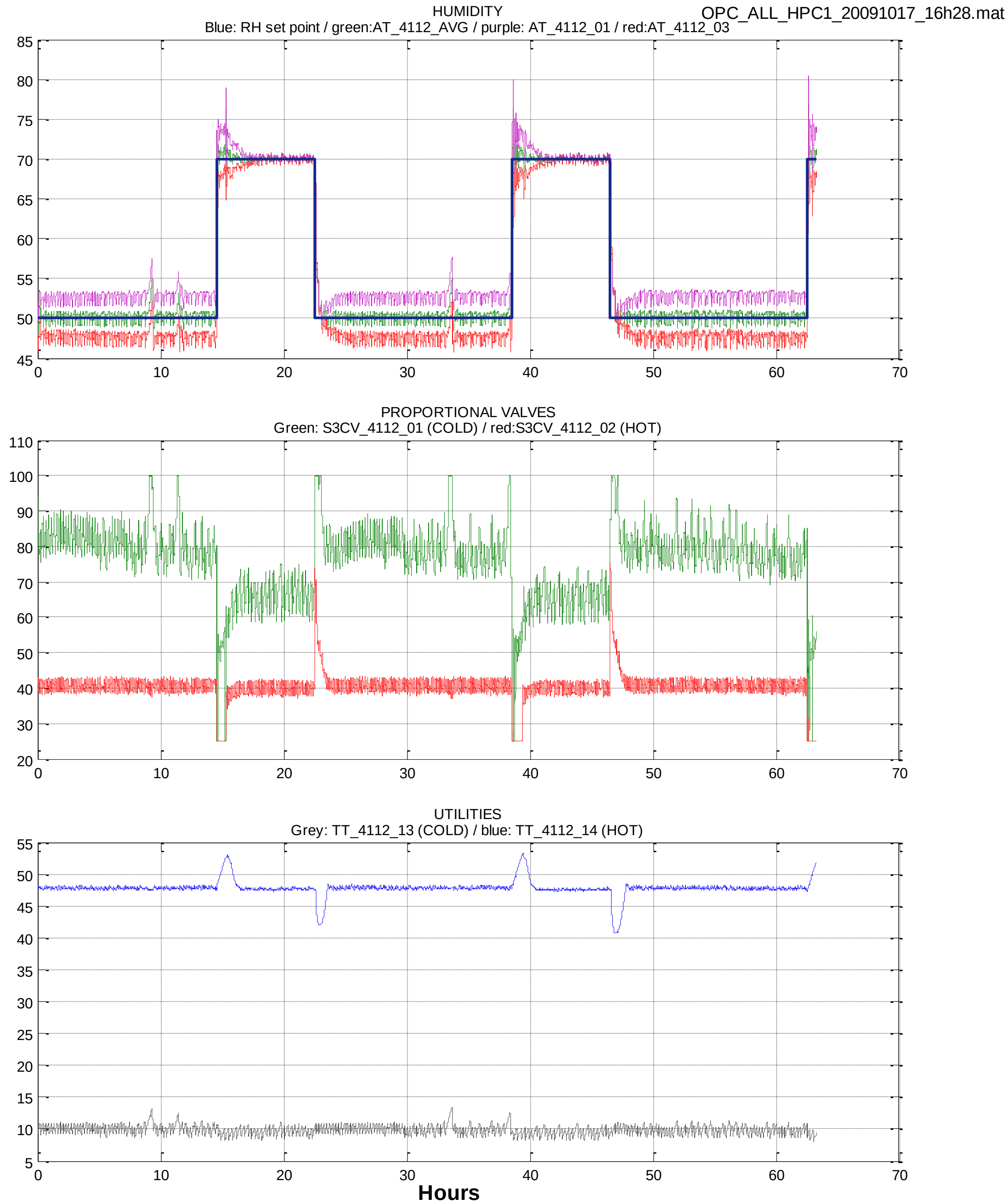
From 18.0 to 22.0 (hour) → **NIGHT**

pH	mean	5.81	std	0.01	min	5.78	max	5.83
EC	mean	1.92	std	0.01	min	1.86	max	1.93
CO2	mean	2384.0	std	255.9	min	1936.4	max	2829.2
T	**mean**	**20.03**	**std**	**0.02**	**min**	**19.96**	**max**	**20.22**
RH	**mean**	**70.07**	**std**	**0.27**	**min**	**69.29**	**max**	**70.71**
Tcold Water	mean	9.69	std	0.54	min	8.30	max	11.05
Thot Water	mean	47.65	std	0.13	min	47.29	max	48.12

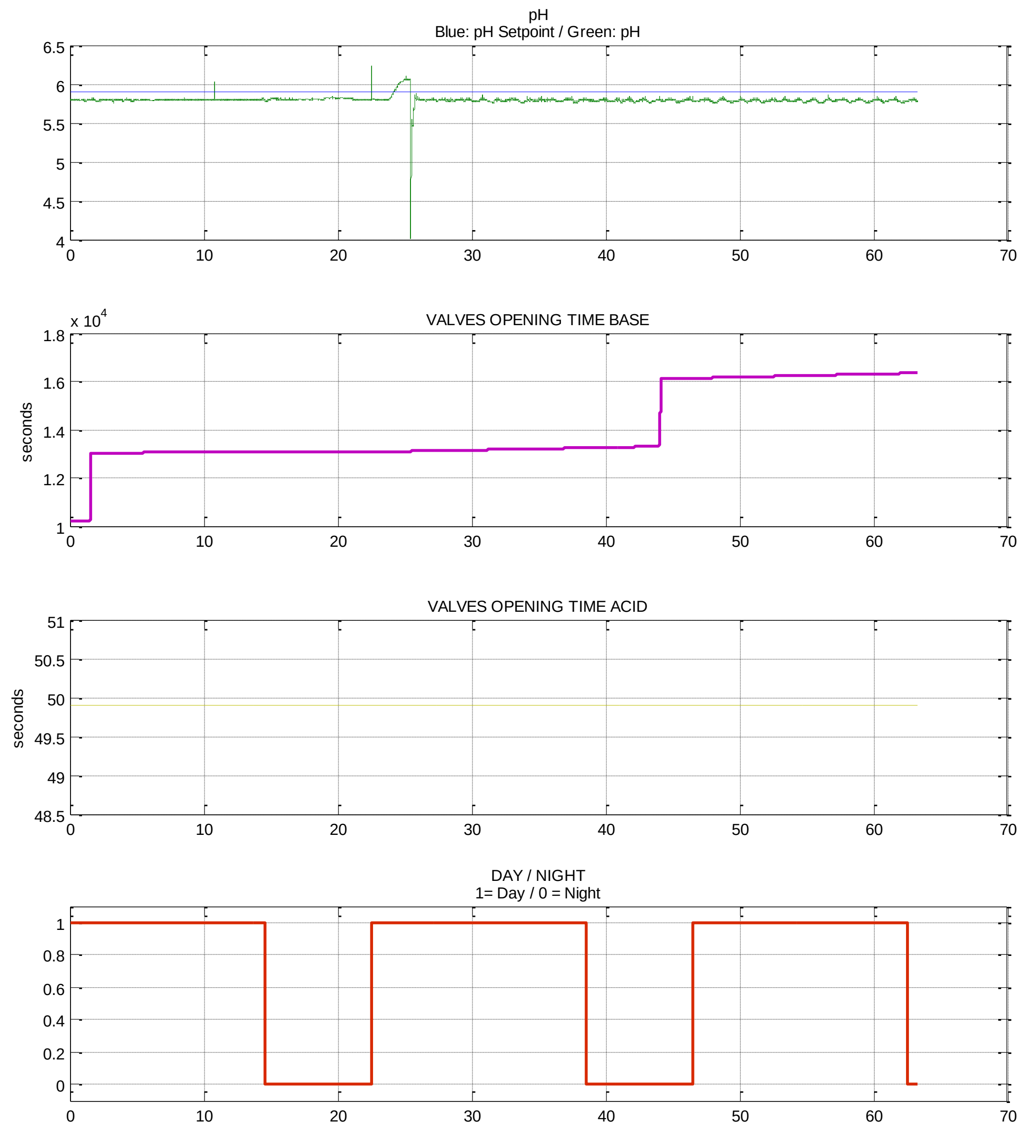
Complete file

CO2	mean	1334.2	std	560.9	min	996.5	max	**2957.2**
O2	mean	22.17	std	0.27	min	21.36	max	**22.65**

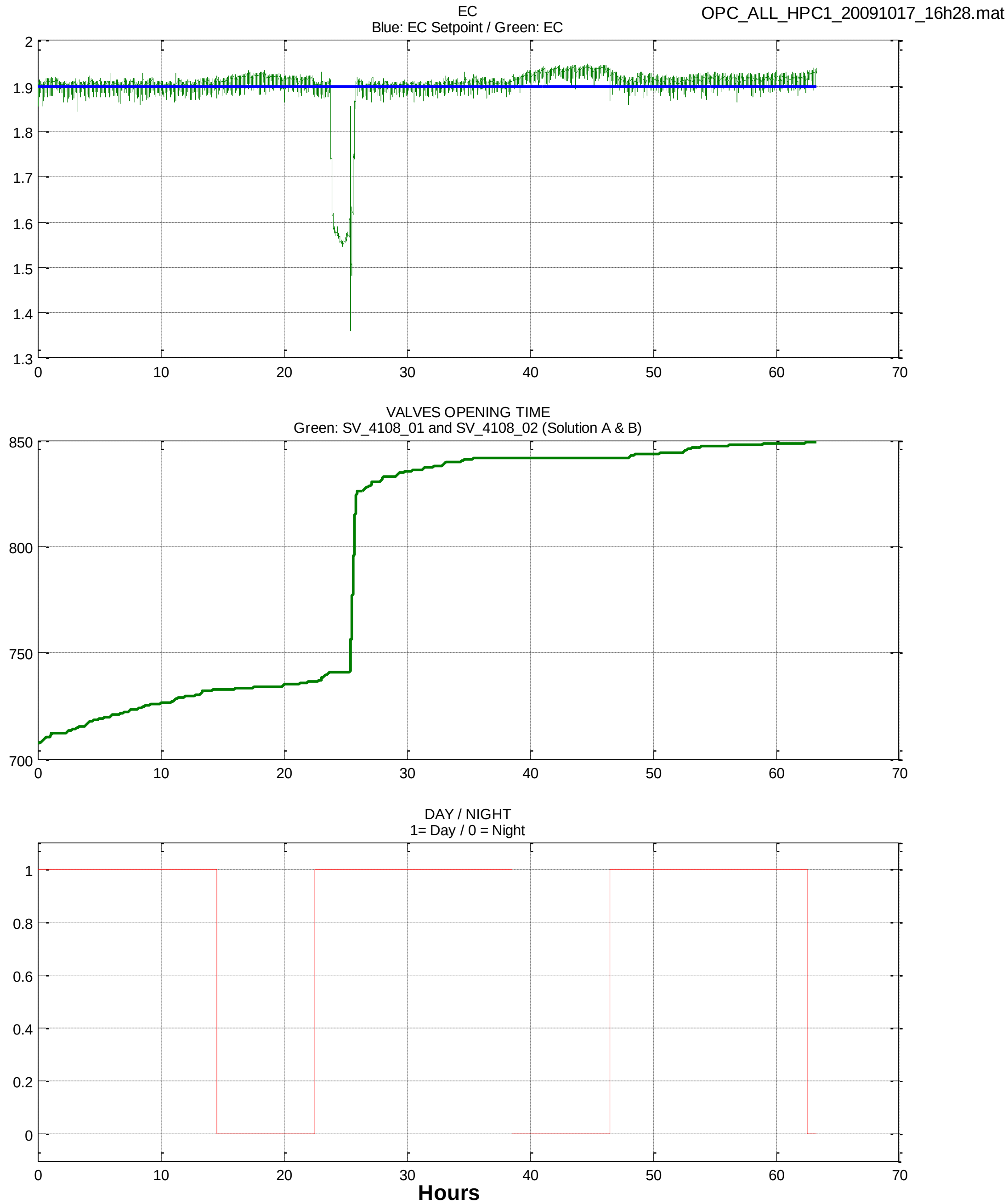

TEMPERATURE
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
OPC_ALL_HPC1_20091017_16h28.mat
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours


HUMIDITY
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
OPC_ALL_HPC1_20091017_16h28.mat
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

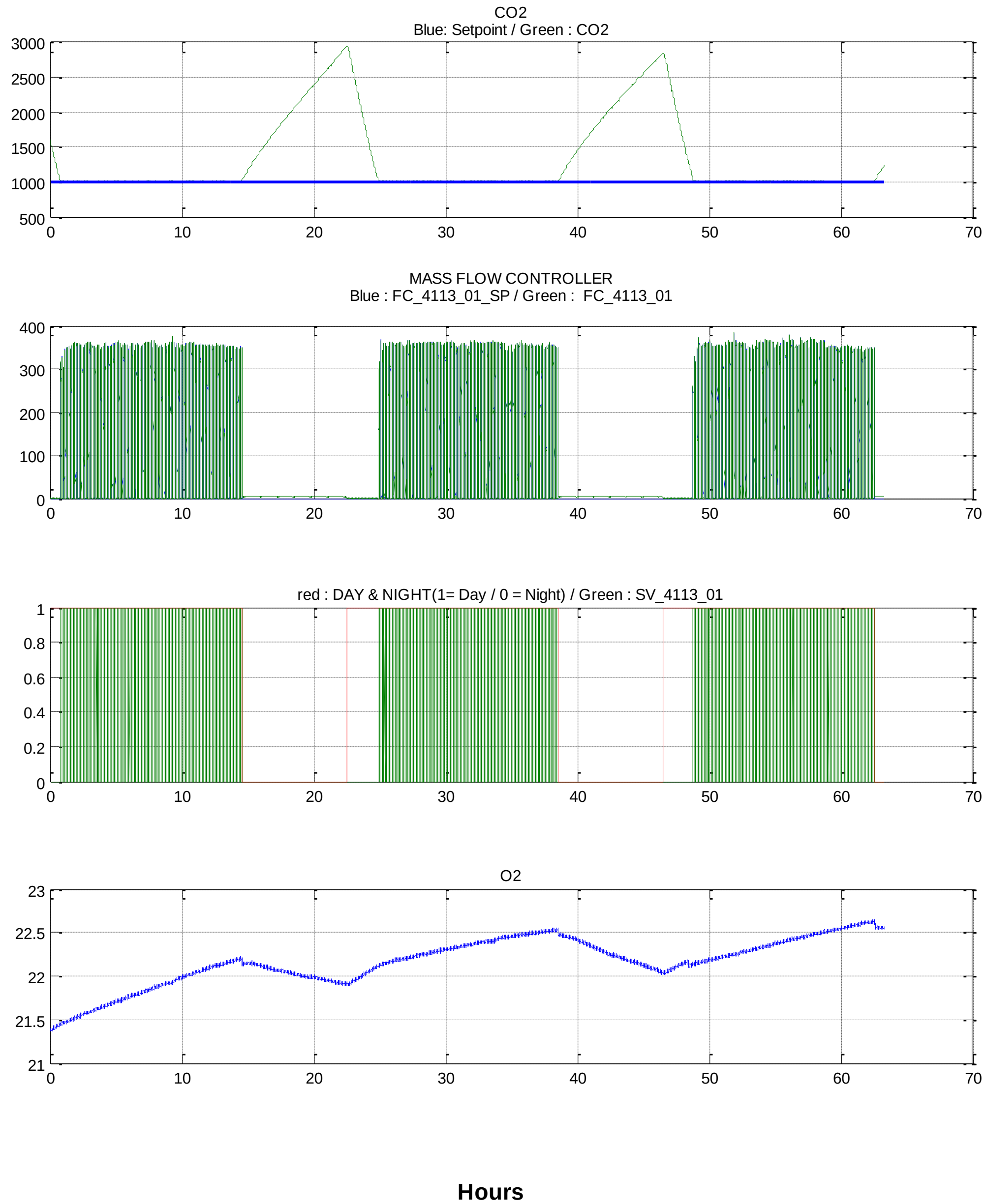
OPC_ALL_HPC1_20091017_16h28.mat



Hours


OPC_ALL_HPC1_20091017_16h28.mat
EC
Blue: EC Setpoint / Green: EC
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
0
10
20
30
40
50
60
70
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
850
800
750
700
DAY / NIGHT
1= Day / 0 = Night
1
0.8
0.6
0.4
0.2
0
Hours

OPC_ALL_HPC1_20091017_16h28.mat



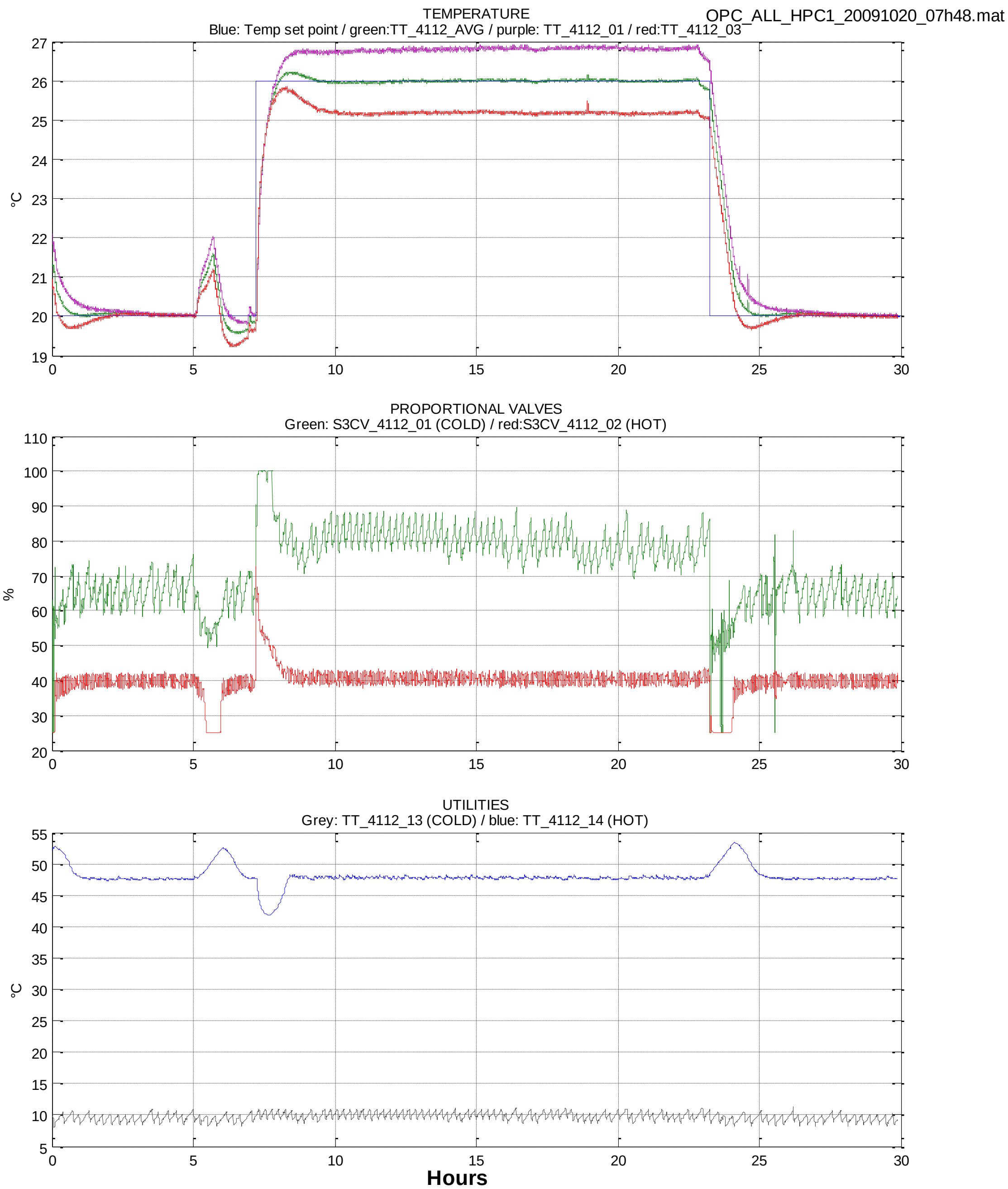
8. October 20th (29.9 hours records)

From 10.0 to 22.0 (hour) → **DAY**

pH	mean	5.79	std	0.01	min	5.77	max	5.82
EC	mean	1.91	std	0.01	min	1.86	max	1.93
CO2	mean	1002.4	std	3.6	min	996.7	max	1008.5
T	**mean**	**25.99**	**std**	**0.02**	**min**	**25.90**	**max**	**26.16**
RH	**mean**	**50.15**	**std**	**0.54**	**min**	**48.82**	**max**	**51.11**
Tcold Water	mean	9.98	std	0.51	min	8.58	max	11.22
Thot Water	mean	47.77	std	0.17	min	47.35	max	48.26

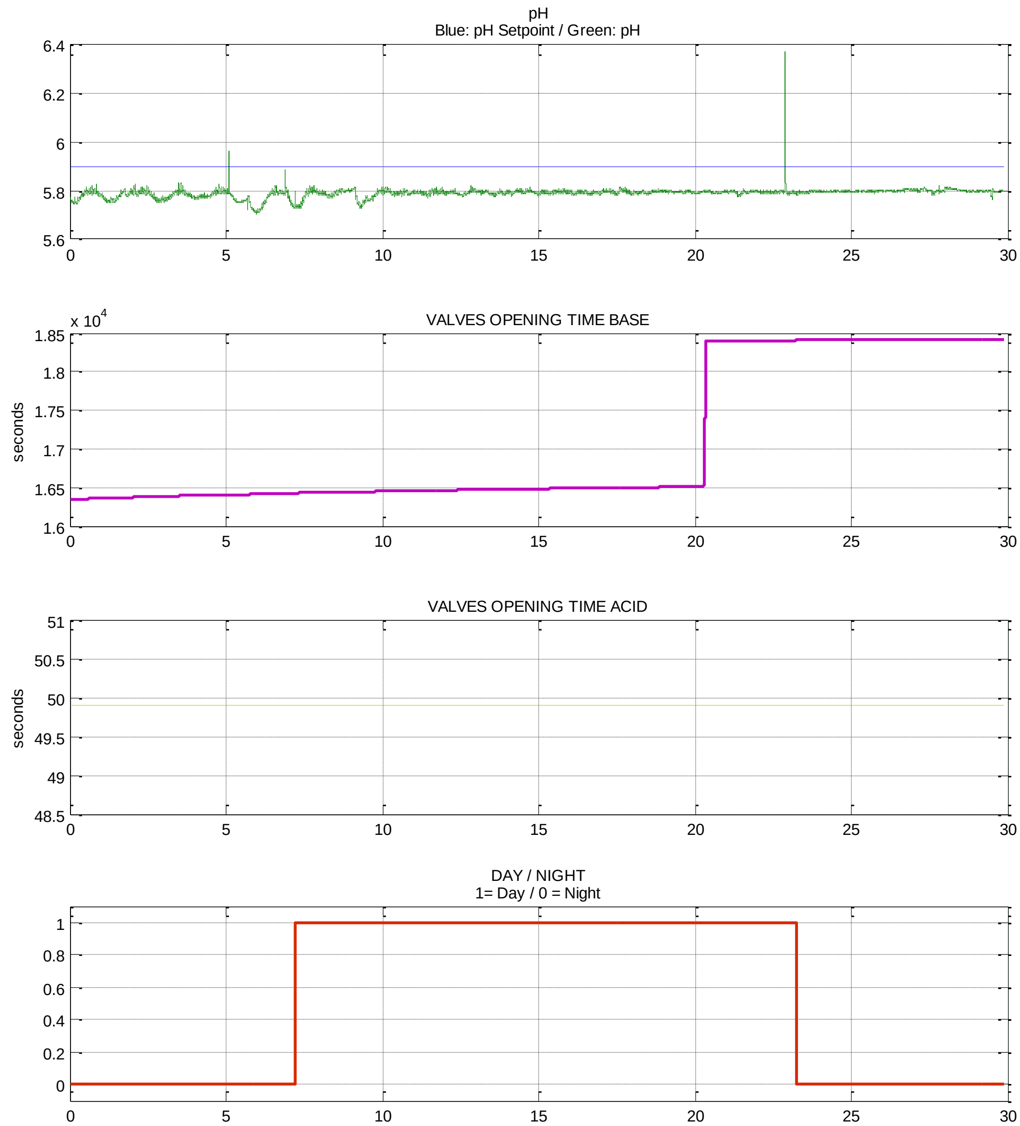
Complete file

CO2	mean	1435.7	std	510.5	min	996.7	max	**2671.9**
O2	mean	22.49	std	0.17	min	22.13	max	**22.82**

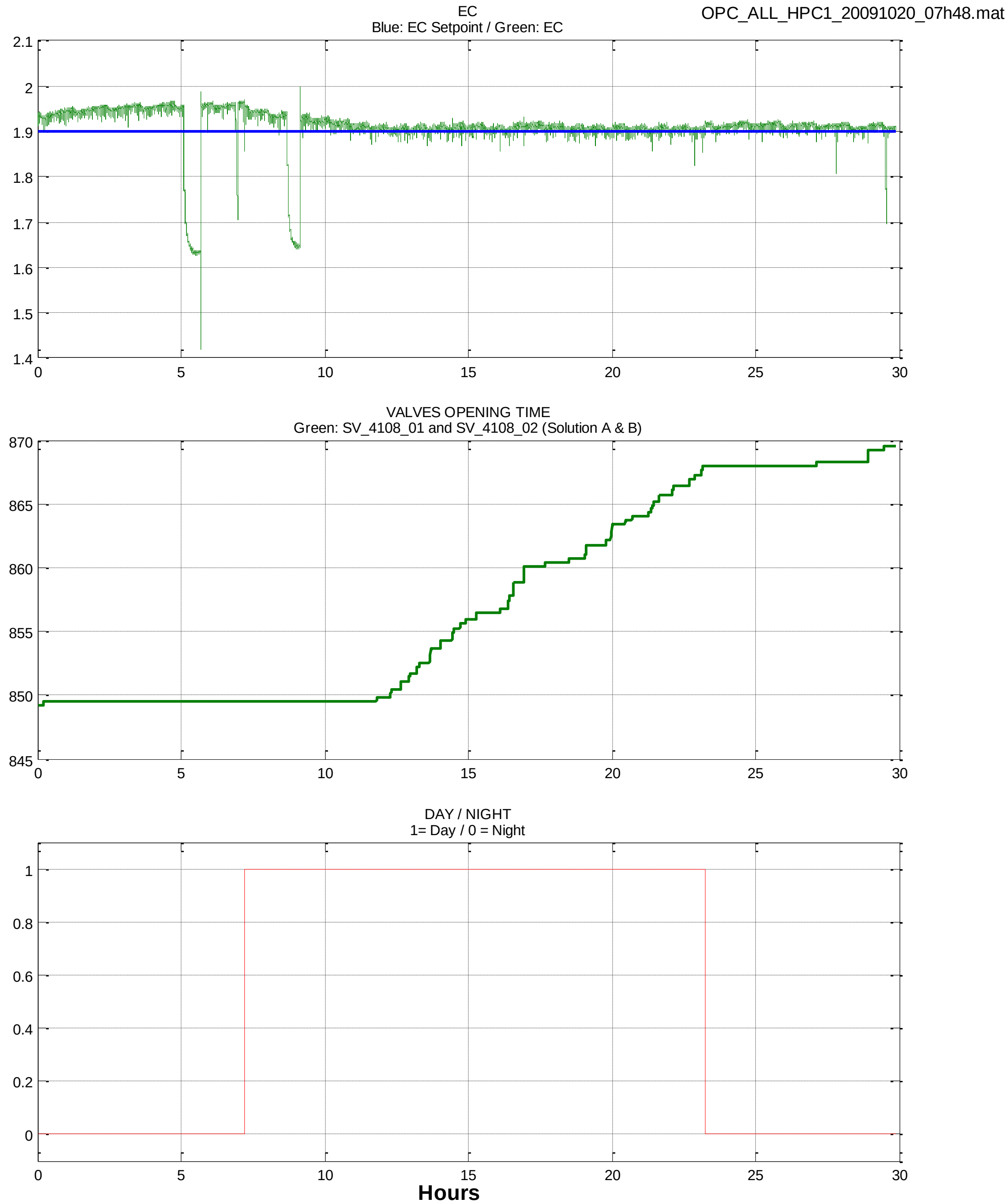

TEMPERATURE
OPC_ALL_HPC1_20091020_07h48.mat
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours


OPC_ALL_HPC1_20091020_07h48.mat
HUMIDITY
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

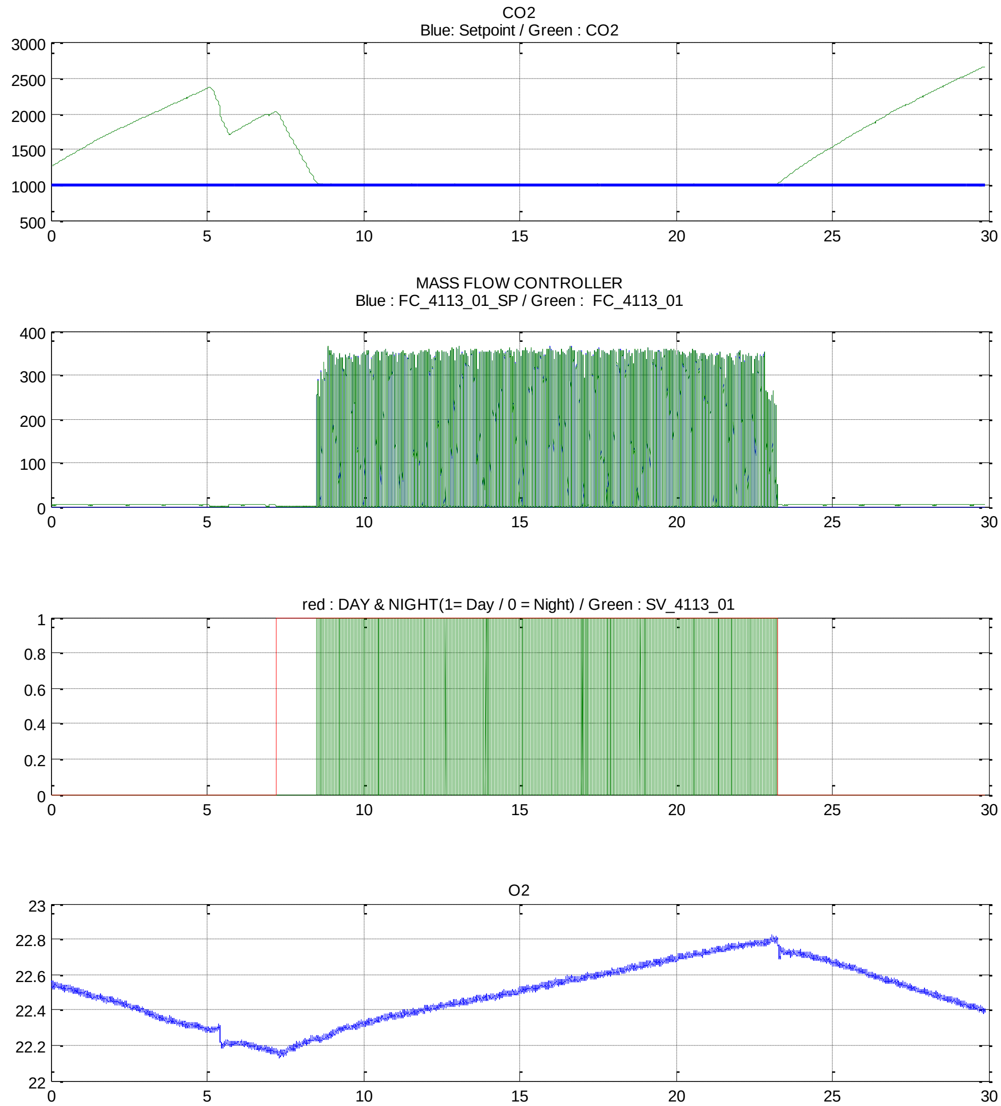
OPC_ALL_HPC1_20091020_07h48.mat



Hours


EC
Blue: EC Setpoint / Green: EC
OPC_ALL_HPC1_20091020_07h48.mat
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
0
5
10
15
20
25
30
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
870
865
860
855
850
845
DAY / NIGHT
1= Day / 0 = Night
1
0.8
0.6
0.4
0.2
0
Hours

OPC_ALL_HPC1_20091020_07h48.mat



Hours

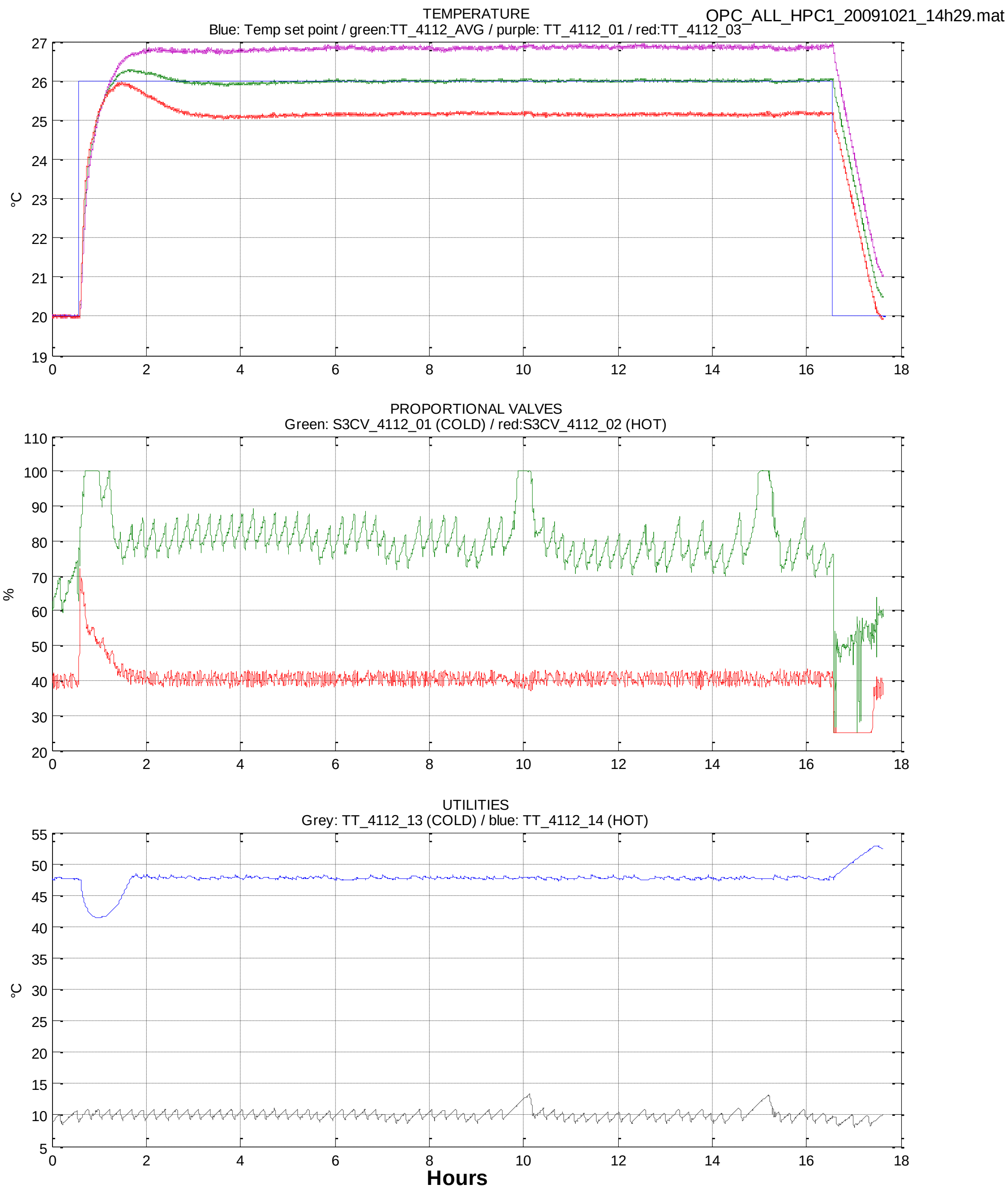
9. October 21st (17.6 hours records)

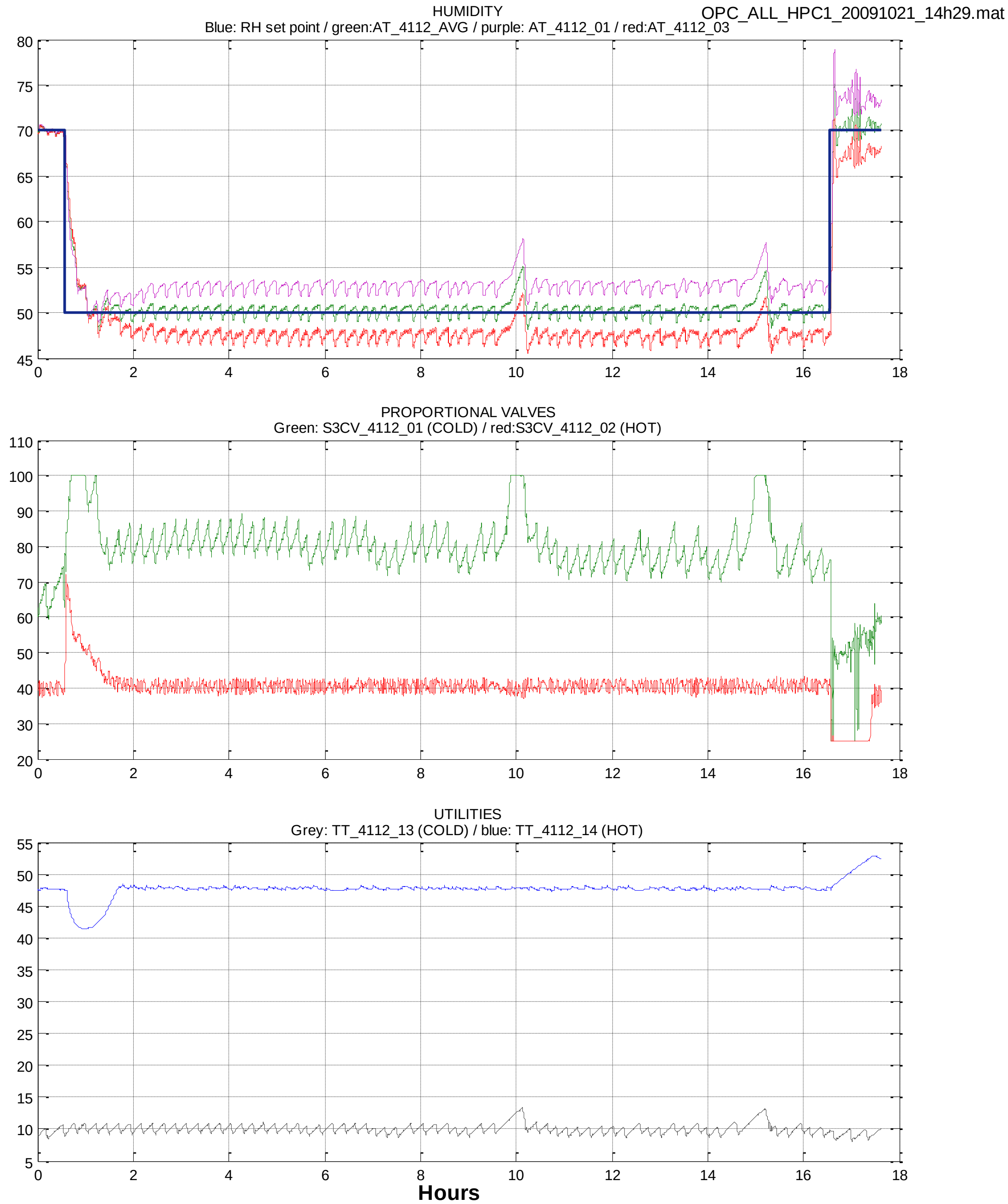
From 6.0 to 16.0 (hour) → **DAY**

pH	mean	5.80	std	0.00	min	5.78	max	5.87
EC	mean	1.90	std	0.00	min	1.86	max	1.92
CO_2	mean	1002.4	std	3.5	min	996.7	max	1008.7
T	**mean**	**25.99**	**std**	**0.02**	**min**	**25.92**	**max**	**26.07**
RH	**mean**	**50.35**	**std**	**0.90**	**min**	**48.17**	**max**	**55.12**
Tcold Water	mean	10.05	std	0.82	min	8.57	max	13.35
Thot Water	mean	47.73	std	0.17	min	47.29	max	48.24

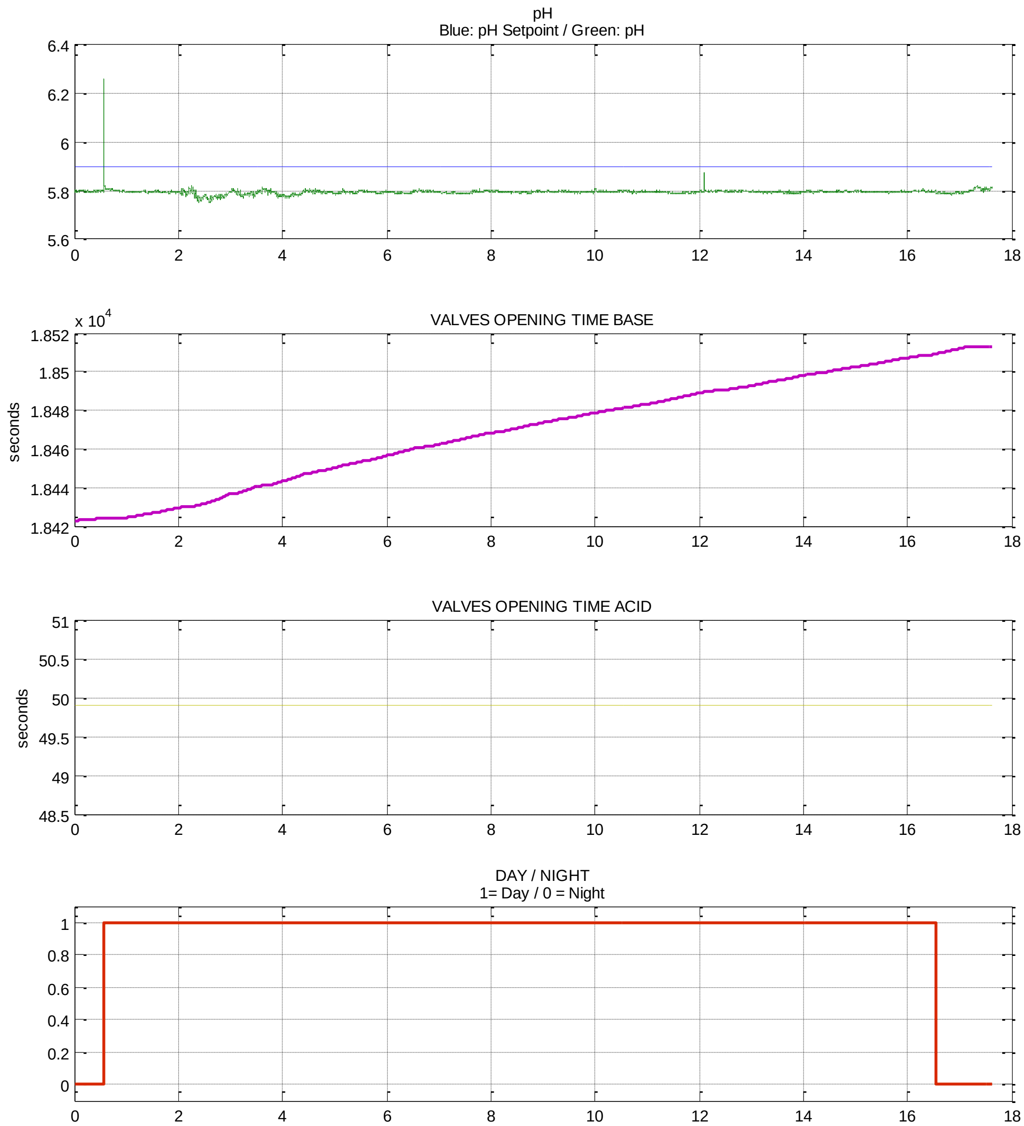
Complete file

CO_2	mean	1199.6	std	491.3	min	996.7	max	**2948.8**
O_2	mean	22.64	std	0.16	min	22.29	max	**22.90**

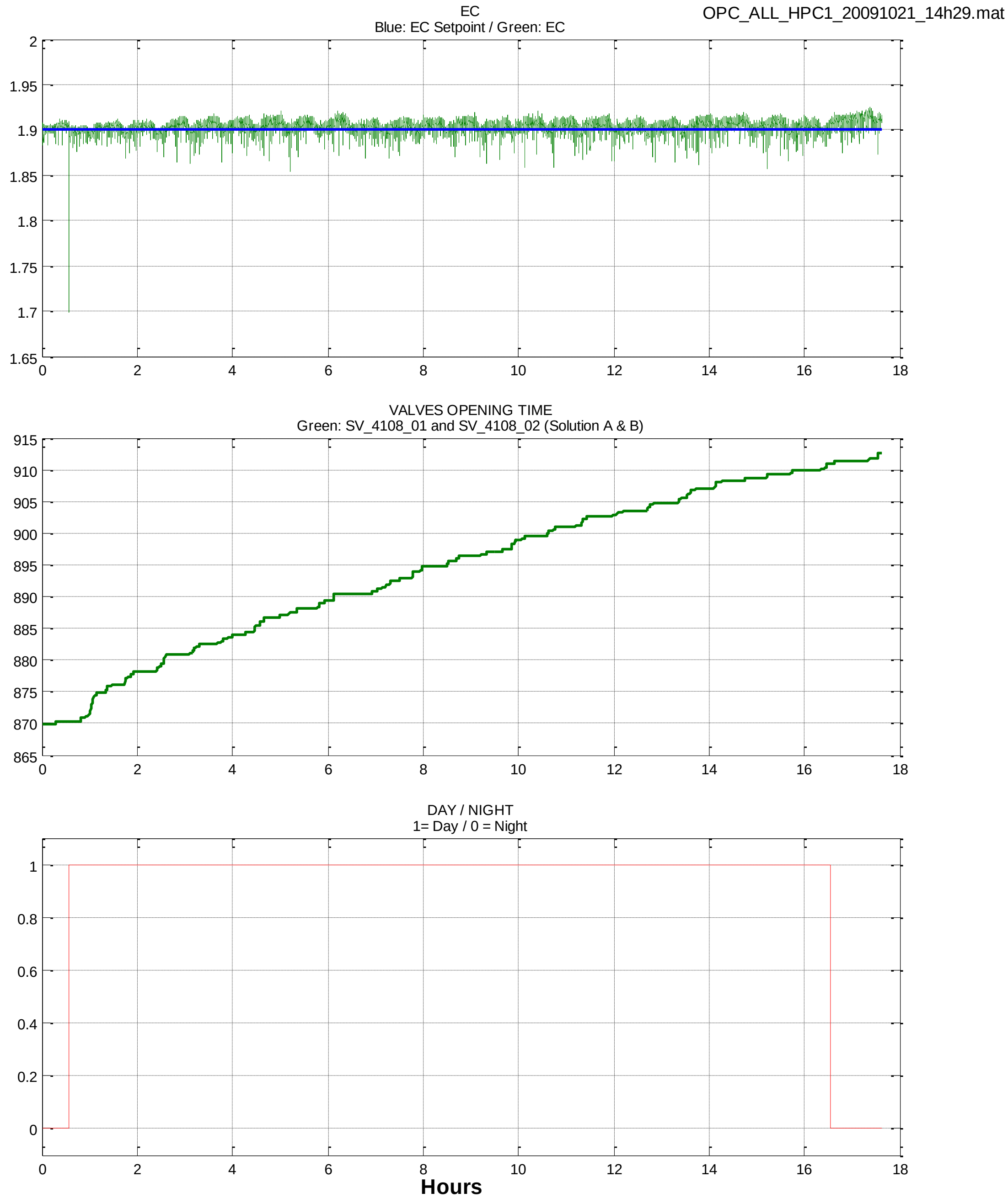

TEMPERATURE
OPC_ALL_HPC1_20091021_14h29.mat
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours


HUMIDITY
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
OPC_ALL_HPC1_20091021_14h29.mat
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

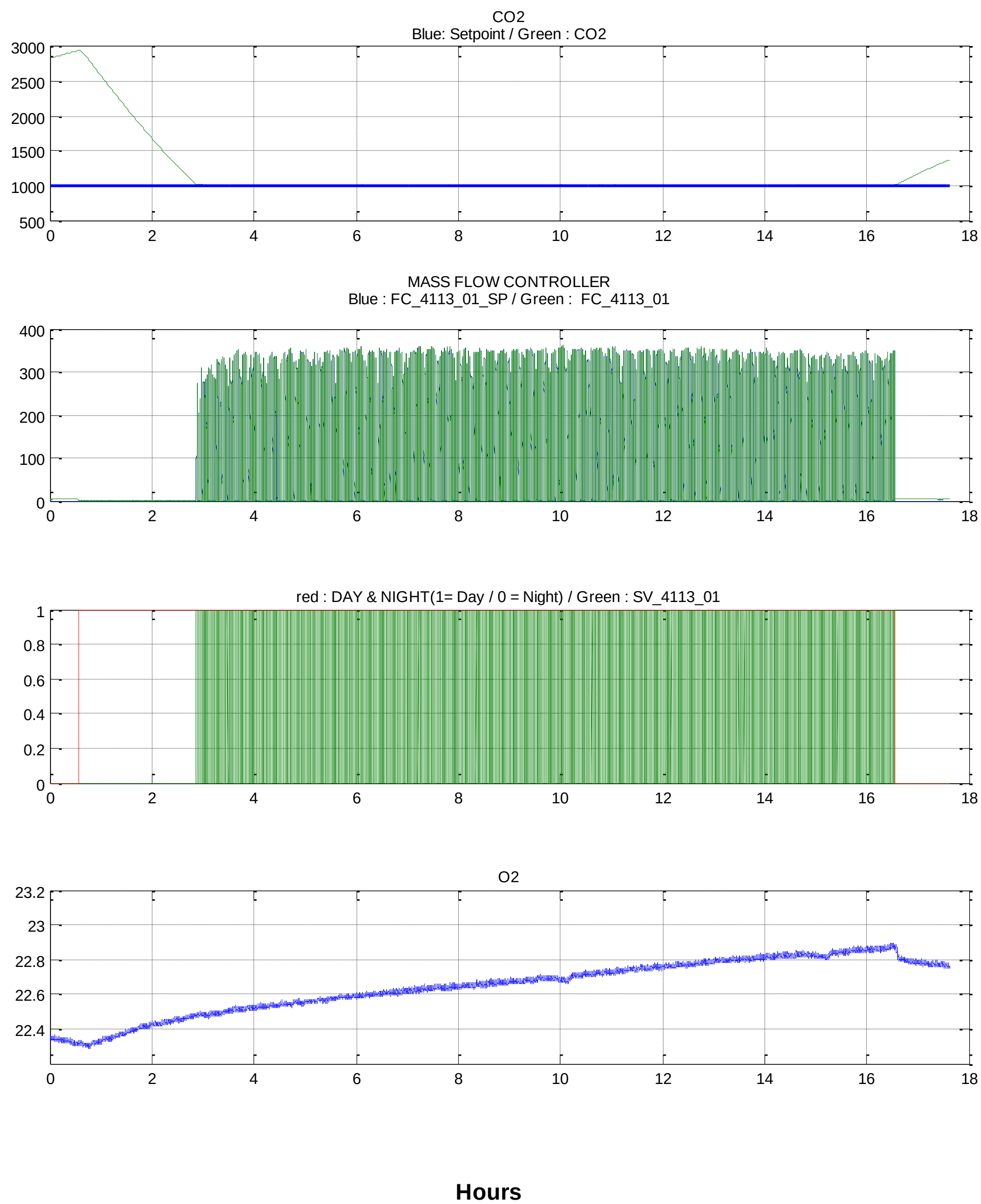
OPC_ALL_HPC1_20091021_14h29.mat



Hours


EC
Blue: EC Setpoint / Green: EC
OPC_ALL_HPC1_20091021_14h29.mat
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
0 2 4 6 8 10 12 14 16 18
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
915
910
905
900
895
890
885
880
875
870
865
0 2 4 6 8 10 12 14 16 18
DAY / NIGHT
1= Day / 0 = Night
1
0.8
0.6
0.4
0.2
0
0 2 4 6 8 10 12 14 16 18
Hours

OPC_ALL_HPC1_20091021_14h29.mat



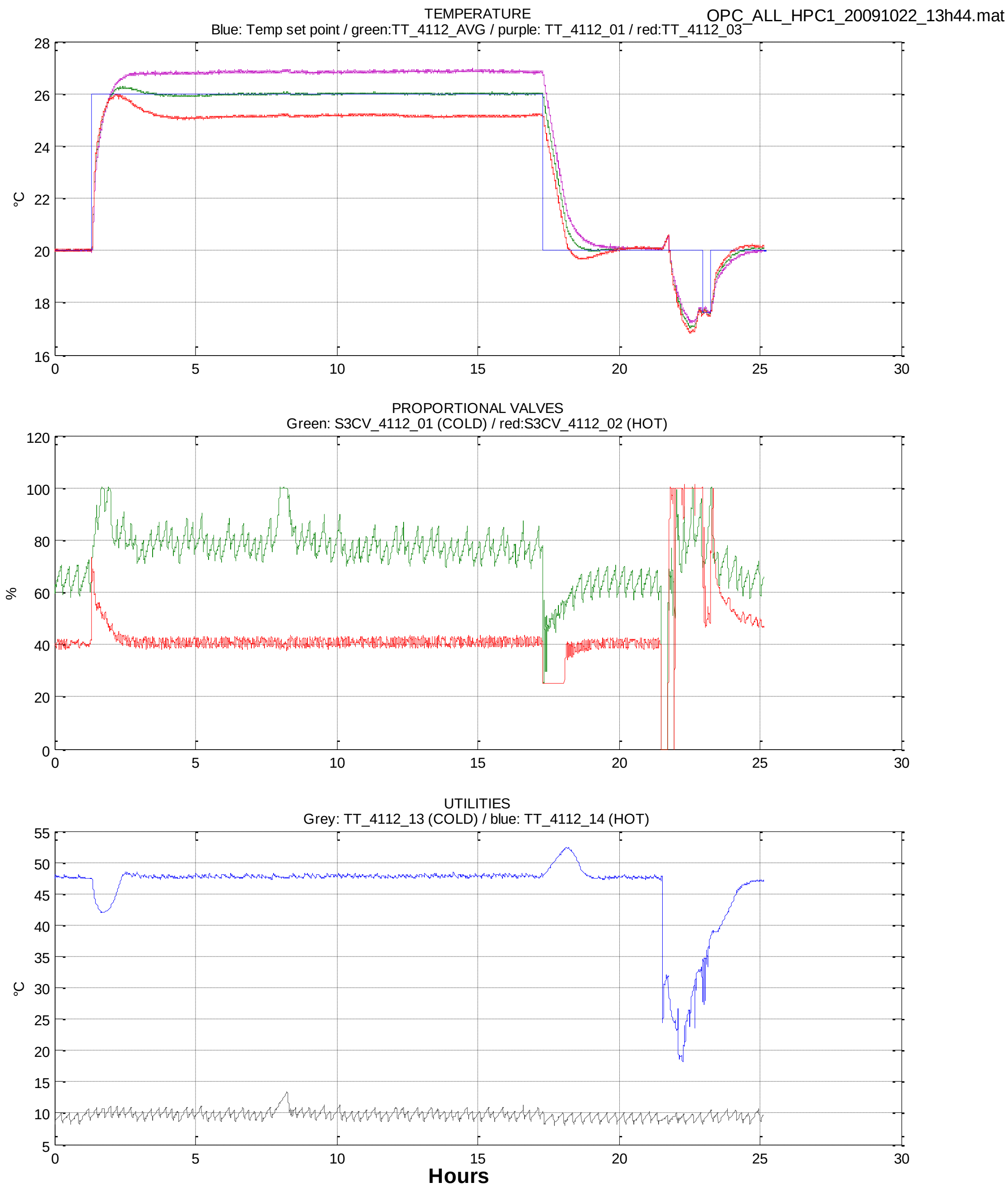
10. October 22nd (25.1 hours records)

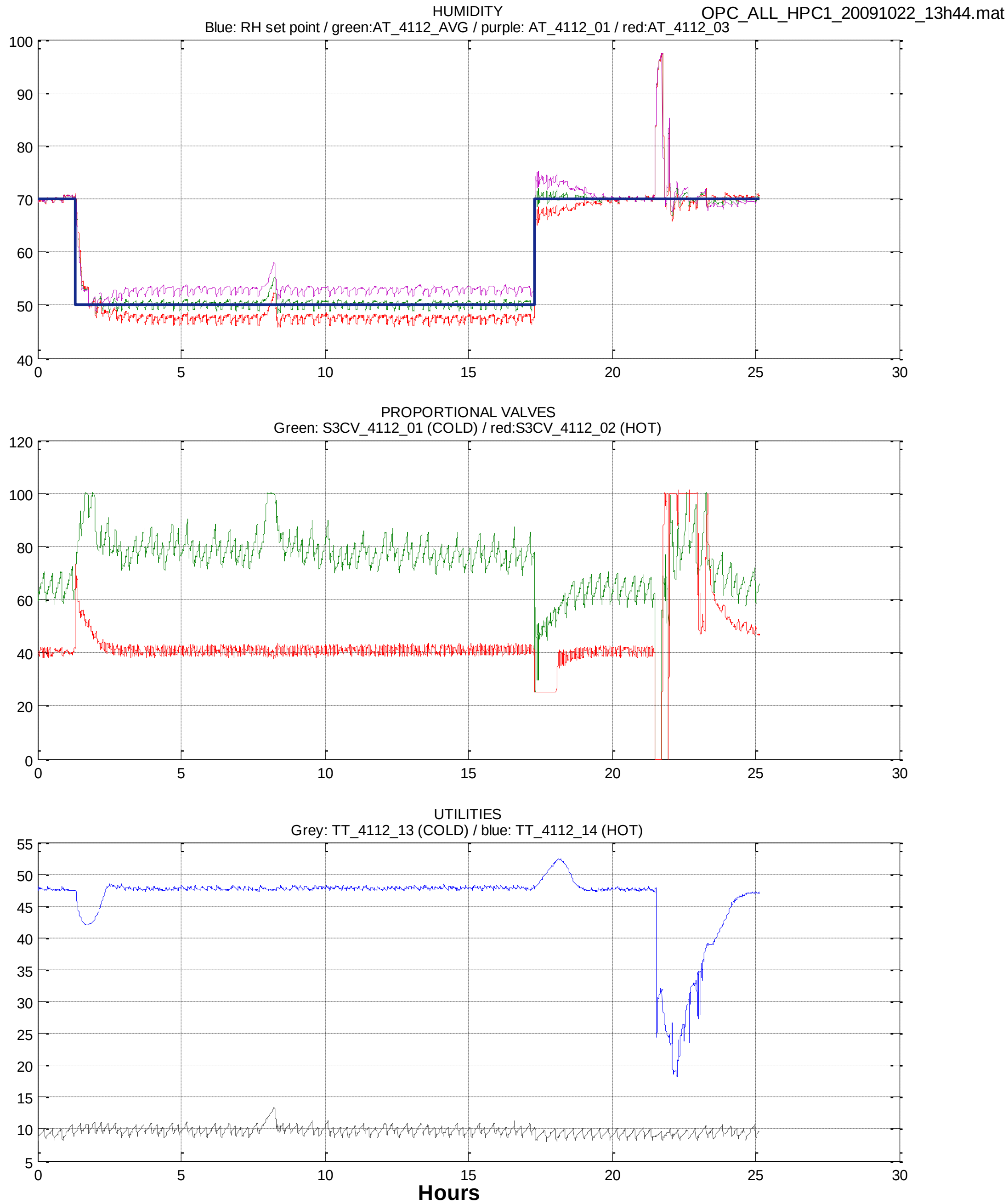
From 6.0 to 16.0 (hour) → **DAY**

pH	mean	5.80	std	0.00	min	5.78	max	5.81
EC	mean	1.91	std	0.01	min	1.85	max	1.93
CO2	mean	1002.5	std	3.6	min	996.7	max	1008.8
T	**mean**	**25.99**	**std**	**0.02**	**min**	**25.92**	**max**	**26.07**
RH	**mean**	**50.28**	**std**	**0.78**	**min**	**48.45**	**max**	**55.24**
Tcold Water	mean	9.94	std	0.72	min	8.55	max	13.39
Thot Water	mean	47.79	std	0.19	min	47.29	max	48.40

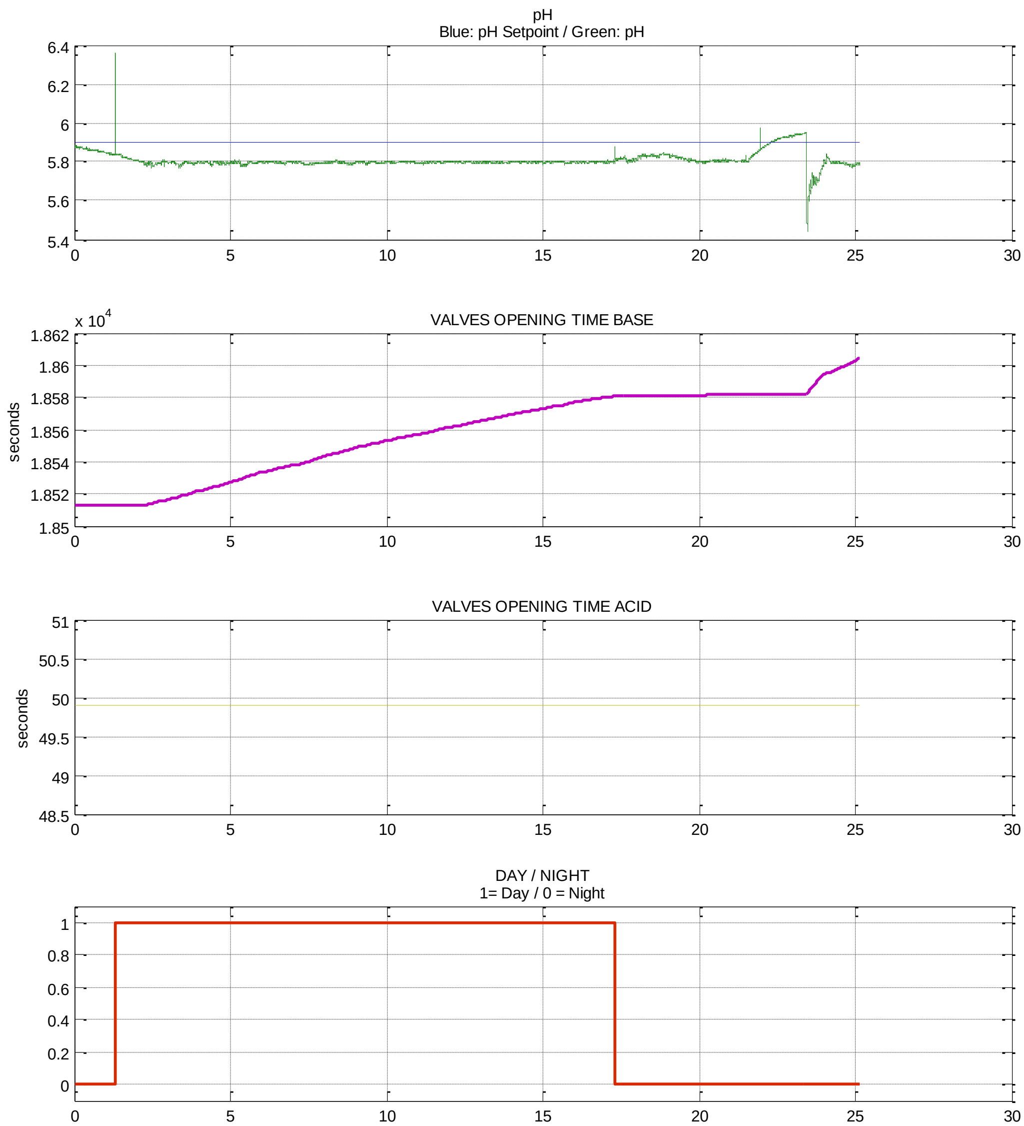
Complete file

CO2	mean	1522.1	std	690.7	min	996.7	max	**3027.8**
O2	mean	22.70	std	0.16	min	22.34	max	**22.99**

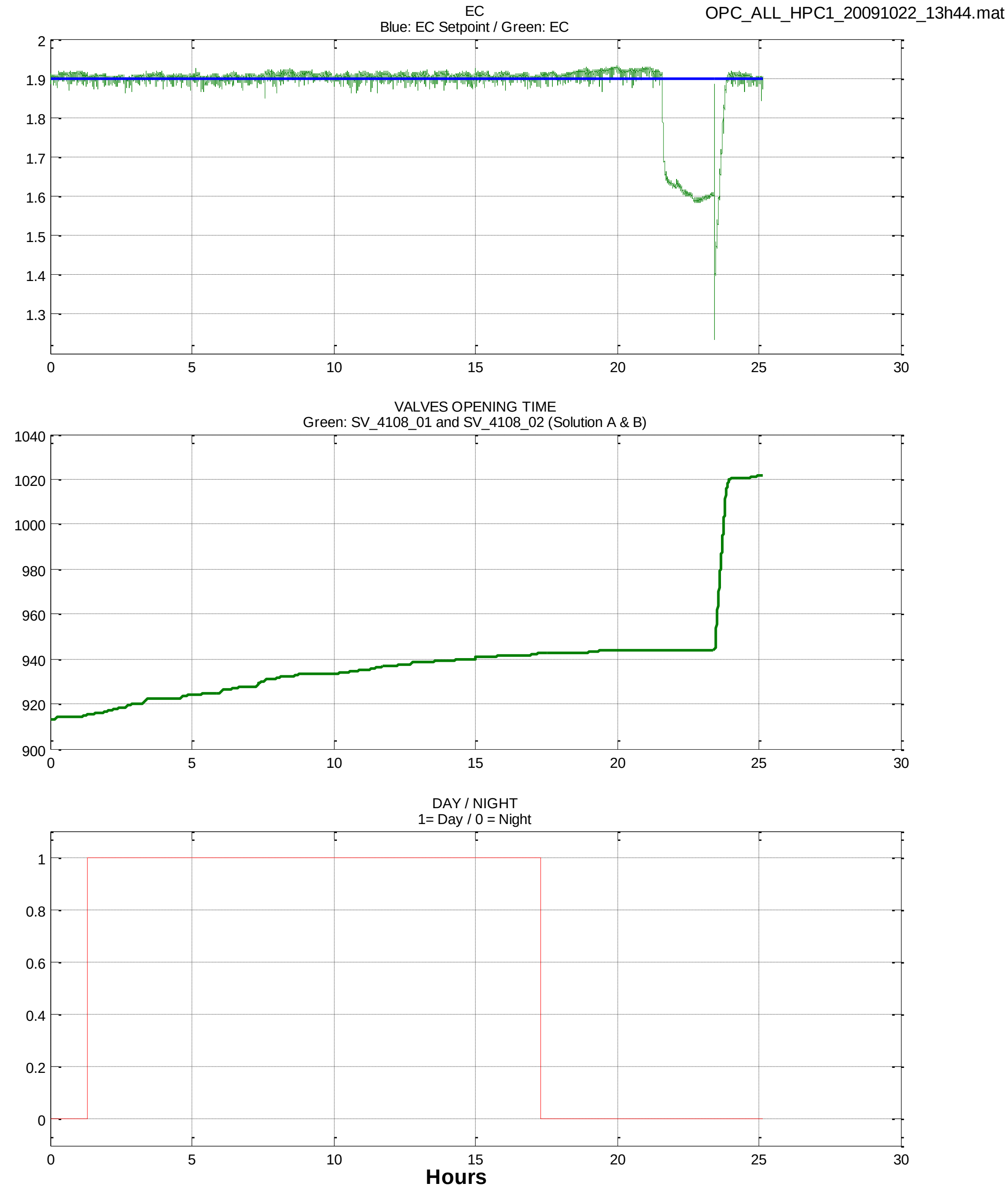

TEMPERATURE
OPC_ALL_HPC1_20091022_13h44.mat
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours


HUMIDITY
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
OPC_ALL_HPC1_20091022_13h44.mat
100
90
80
70
60
50
40
0
5
10
15
20
25
30
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
120
100
80
60
40
20
0
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
55
50
45
40
35
30
25
20
15
10
5
Hours

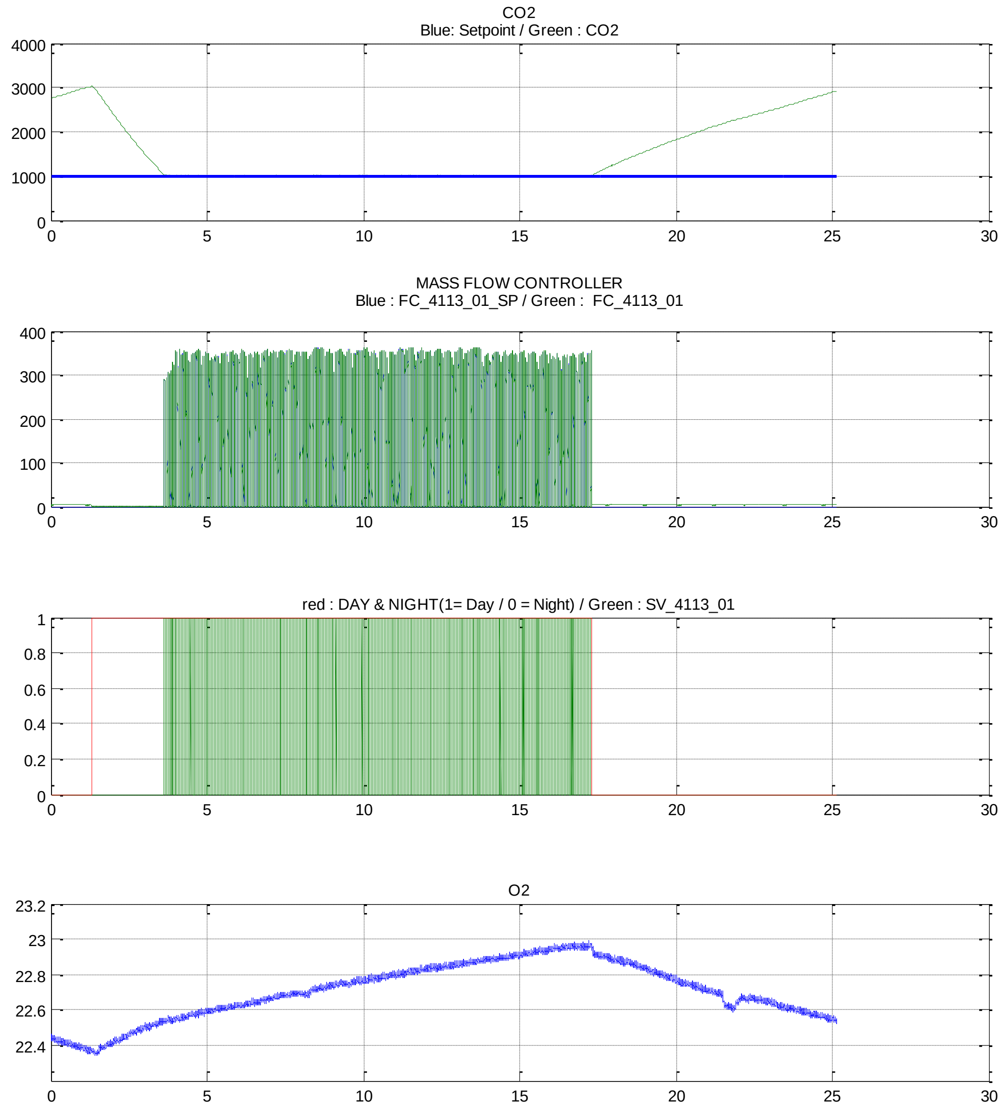
OPC_ALL_HPC1_20091022_13h44.mat



Hours


OPC_ALL_HPC1_20091022_13h44.mat
EC
Blue: EC Setpoint / Green: EC
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
DAY / NIGHT
1= Day / 0 = Night
Hours

OPC_ALL_HPC1_20091022_13h44.mat



Hours

11. October 23rd (67 hours records)

Remark :

Due to lack of Base solution, pH decreases and the Irrigation flow was automatically stopped when too low (time 31h). When no irrigation, pH and EC controllers are automatically switched off.

From 52.0 to 64.0 (hour) → **DAY**

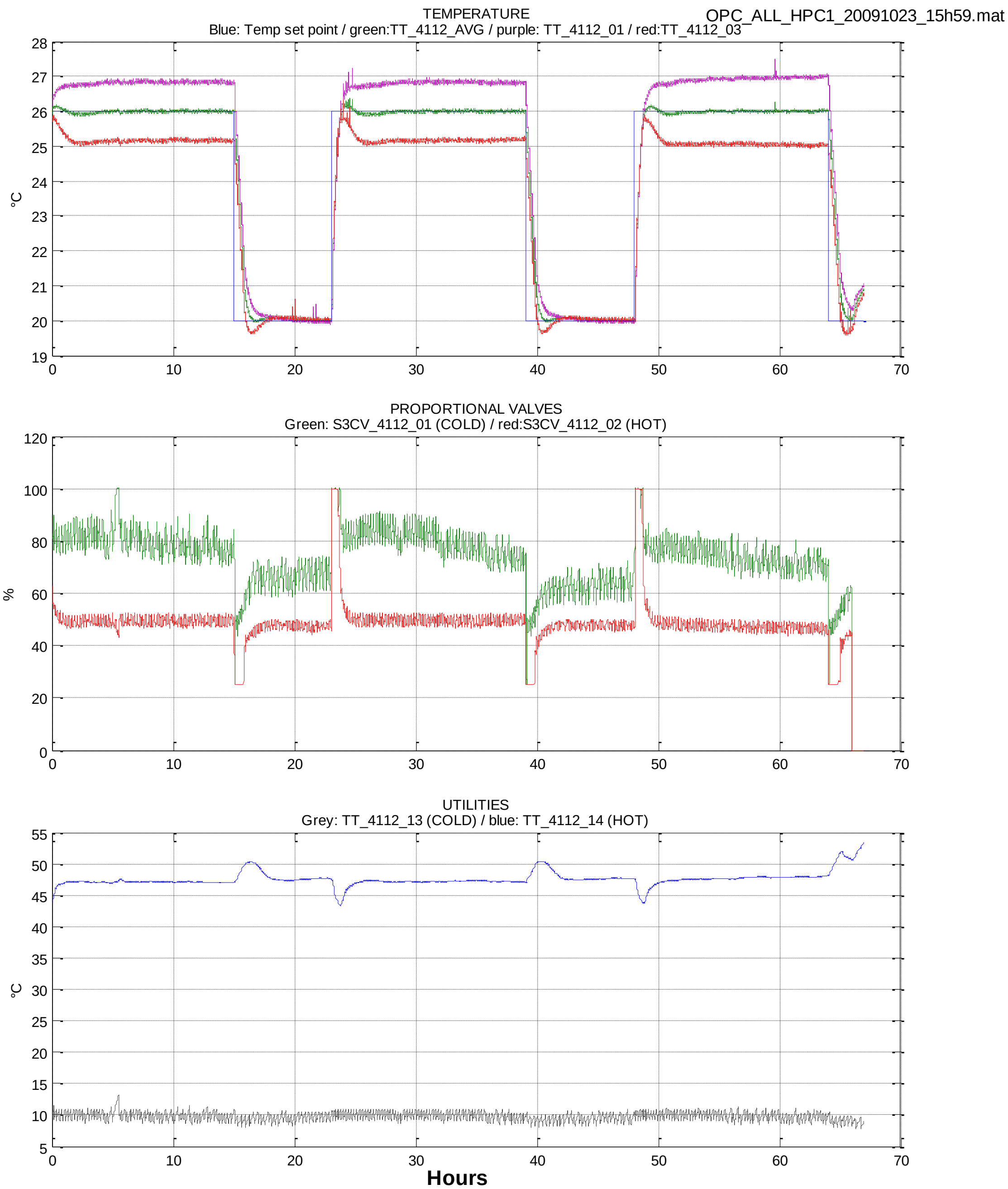
CO2	mean	1002.8	std	3.8	min	996.6	max	1009.0
T	**mean**	**25.99**	**std**	**0.02**	**min**	**25.91**	**max**	**26.27**
RH	**mean**	**50.12**	**std**	**0.43**	**min**	**48.99**	**max**	**50.83**
Tcold Water	mean	9.82	std	0.55	min	8.46	max	11.39
Thot Water	mean	47.77	std	0.16	min	47.44	max	48.18

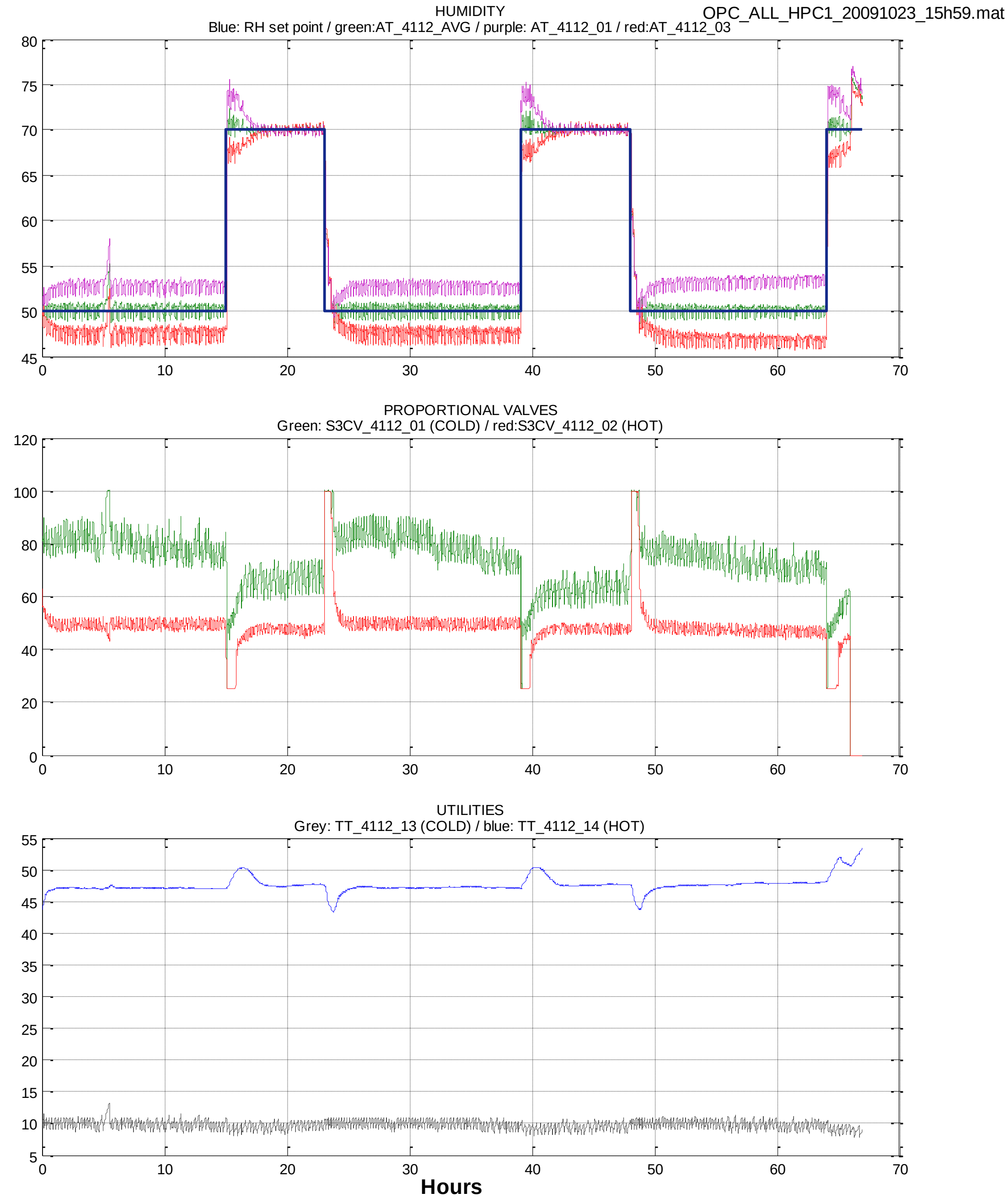
From 42.0 to 48.0 (hour) → **NIGHT**

CO2	mean	2510.2	std	382.8	min	1834.0	max	**3166.9**
T	**mean**	**20.03**	**std**	**0.03**	**min**	**19.95**	**max**	**20.13**
RH	**mean**	**69.99**	**std**	**0.28**	**min**	**69.33**	**max**	**70.83**
Tcold Water	mean	9.49	std	0.54	min	8.20	max	10.83
Thot Water	mean	47.59	std	0.10	min	47.34	max	47.86

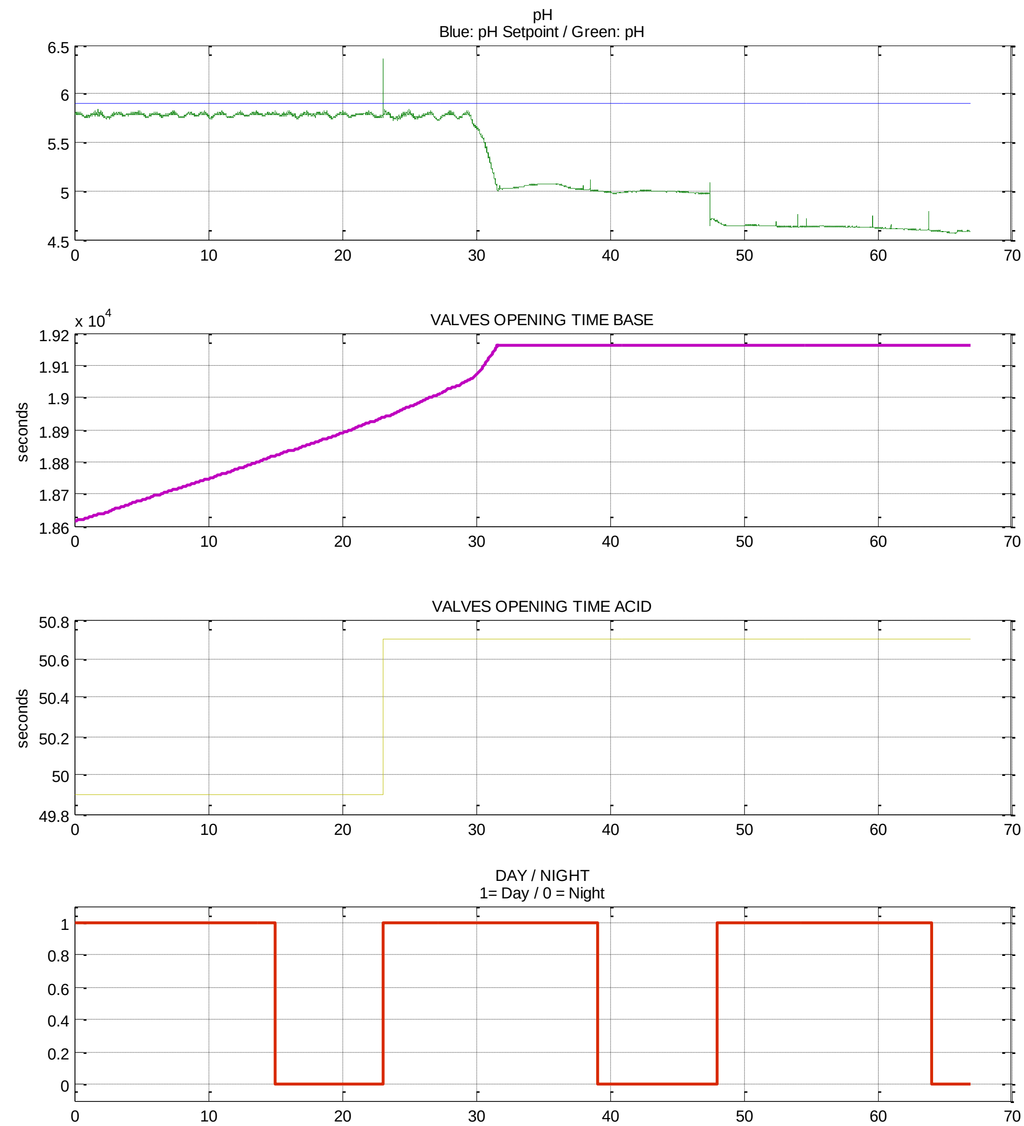
Complete file

CO2	mean	1387.9	std	619.6	min	772.5	max	**3185.9**
O2	mean	23.13	std	0.41	min	20.60	max	**24.06**

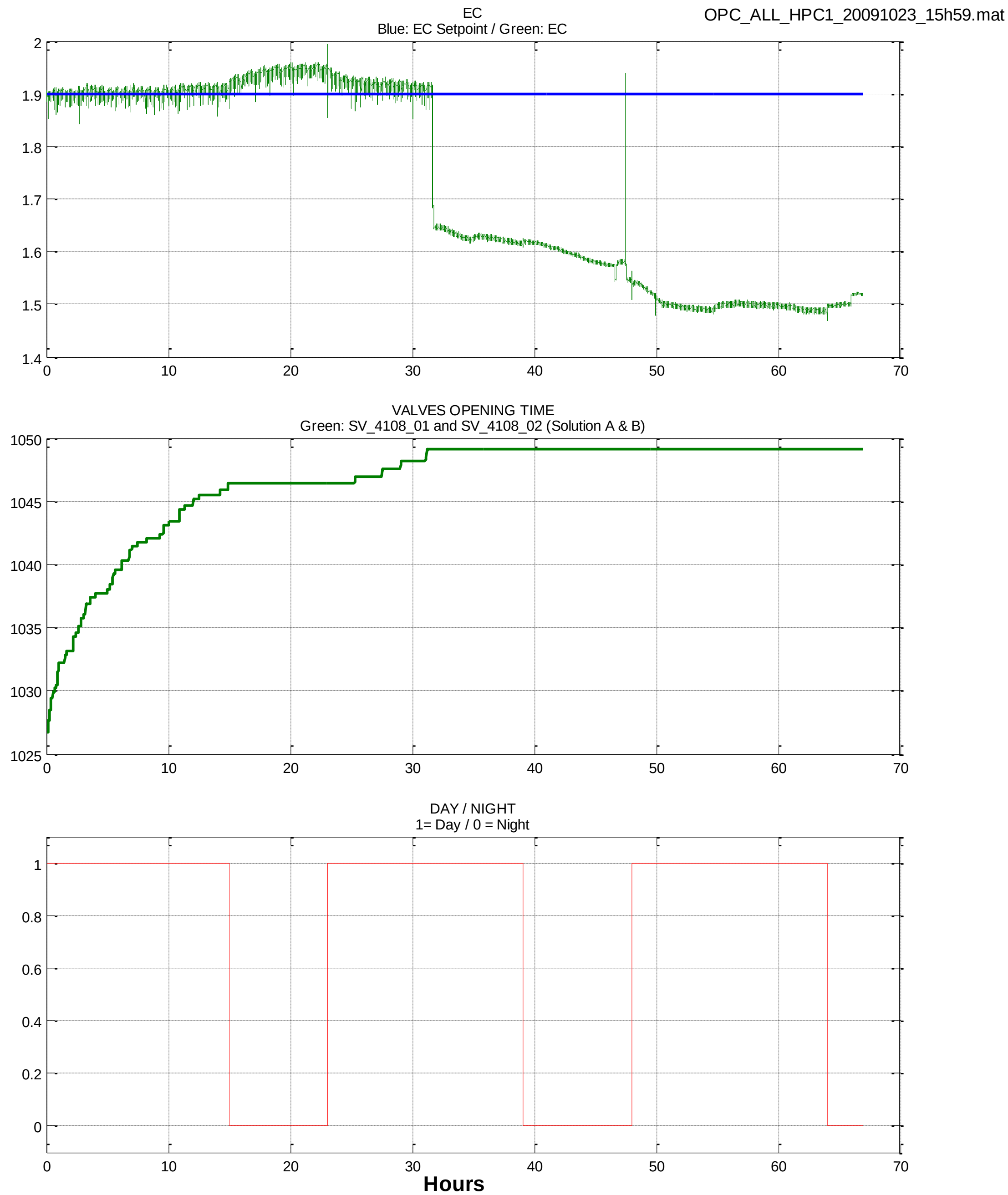

TEMPERATURE
Blue: Temp set point / green:TT_4112_AVG / purple: TT_4112_01 / red:TT_4112_03
OPC_ALL_HPC1_20091023_15h59.mat
°C
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
%
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
°C
Hours


OPC_ALL_HPC1_20091023_15h59.mat
HUMIDITY
Blue: RH set point / green:AT_4112_AVG / purple: AT_4112_01 / red:AT_4112_03
PROPORTIONAL VALVES
Green: S3CV_4112_01 (COLD) / red:S3CV_4112_02 (HOT)
UTILITIES
Grey: TT_4112_13 (COLD) / blue: TT_4112_14 (HOT)
Hours

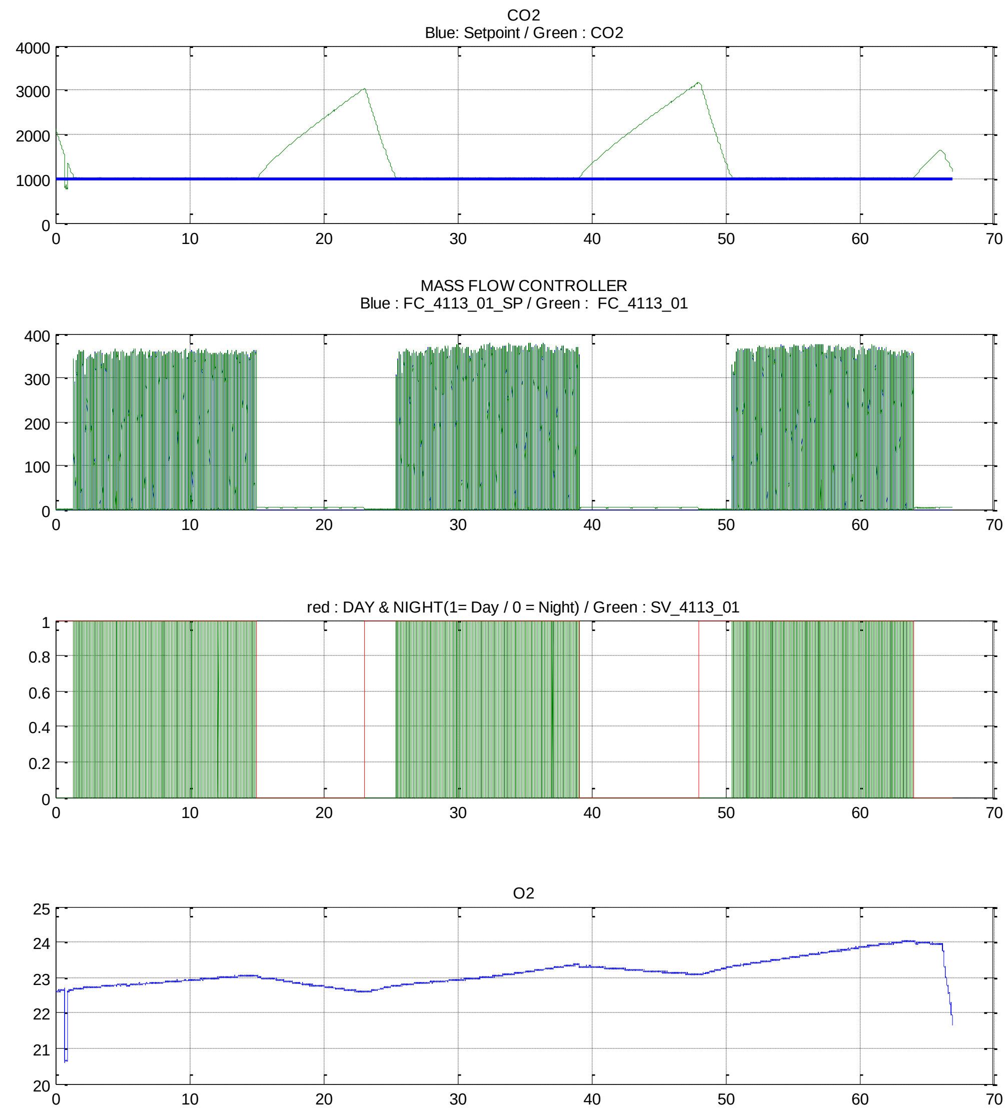
OPC_ALL_HPC1_20091023_15h59.mat



Hours


OPC_ALL_HPC1_20091023_15h59.mat
EC
Blue: EC Setpoint / Green: EC
2
1.9
1.8
1.7
1.6
1.5
1.4
0
10
20
30
40
50
60
70
VALVES OPENING TIME
Green: SV_4108_01 and SV_4108_02 (Solution A & B)
1050
1045
1040
1035
1030
1025
0
10
20
30
40
50
60
70
DAY / NIGHT
1= Day / 0 = Night
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
Hours

OPC_ALL_HPC1_20091023_15h59.mat



Hours