MELiSSA

TECHNICAL NOTE 96.5

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TECHNICAL NOTE 96.5

Functional Testing with Argus Controller – As-run procedures, Test results and final Test report

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1 Introduction

1.1 Purpose and Structure of Test Report

The information contained in this technical note is presenting the results of the tests carried out to ensure that the HPC1 prototype designed and constructed by the University of Guelph and Angstrom Engineering adheres to the specifications of ESA, as defined in Annex to Appendix 1 of RFQ 3-11515.

This test report consists of three main sections. First, a series of Functional Tests that will demonstrate the functionality of all chamber parts. Secondly, formal control tests aimed at demonstrating chamber adherence to the environment control requirements listed in Annex to Appendix 1 of RFQ 3-11515. The final operational test consisting of a batch culture of lettuce conducted under static conditions. The batch culture of lettuce with an Argus Controller was not a full crop cycle, as it was intended to test subsystem performance under full operational conditions.

1.2 General Procedures for Test Results Data Acquisition

The functional tests outlined in Section 2 will rely on either a visual inspection or confirmation of signal transfer to/from the Argus controller. Operational tests will rely on data logs recorded by the Argus controller over the period of the test.

1.3 General Control System Test Procedures

The purpose of the control system tests outlined in Section 2 below is to demonstrate chamber performance and adherence to the environmental control specifications. As part of their sub-contract, Argus calibrates control procedures, particularly in the case of thermal and VPD control in-house. Procedures for controller calibration are proprietary and therefore not provided, and the Argus system is considered a “black-box” controller.

1.4 Conditions of Acceptance

In the case of functional tests, the requirements for acceptance of hardware are defined in the acceptance criteria of the individual test procedure, unless otherwise defined below. Acceptance of control tests is based on the technical specifications for environmental control as defined by ESA. The relevant section from the contract RFQ is reproduced below. The control test plan (sometimes referred to as the profile tests) are designed to demonstrate the functioning of the various control loops in maintaining the environmental/biological requirements defined in the table below.

Also, during the functional, operational (profile) and crop tests, the chamber shall be demonstrated to adhere to all sections of Annex to Appendix 1 of RFQ 3-11515. The requirements defined in the Annex to Appendix 1 of the RFQ are qualitative and no numerical bounds were defined.

Item	Requirement
Illumination light levels	0 – 800 µE PAR selectable in four discrete levels (no lamps, 3 lamps, 6 lamps, 9 lamps)
Illumination night levels	0 – 10 µE PAR
Day/night cycle	Any combination of 1 day and 1 night period within a 24 hour span
Air Temperature	Selectable within 15 – 30 °C
Temperature Accuracy	Demand +/- 0.5 °C
Internal Air (refreshment) circulation rate	Not less than 1 crop volume per minute
Air Velocity	From 0.1-0.8 m/s
Water Supply in the Roots	3 to 5 litres per minute average over all trays – equivalent to approximately 200mL/min/tray
Nutrient Supply	Hydroponics (NFT) cultivation with EC demands of 0 – 3 mS/cm pH: 5.8 +/- 0.5 EC: 1.9 mS/cm +/- 0.05 mS/cm Dissolved O_2: 80 – 100% of saturation (not analyzed ,not controllable)
Pressure	Ambient (typically 101 kPa +/- 2 kPa per hour)
Atmospheric Composition	Humidity: 50 – 85% (no accuracy specified) O_2 - 20% +/- 1% (ambient levels - not controlled) CO_2 - 300 – 2000 ppm (no accuracy for control specified) N_2 - Balance to 100% (not measured)

Table 1. list of HPC requirements

1.5 Additional testing to prepare the switch to Schneider control system

Sherpa Engineering had requested a series of open and closed loop tests to characterize chamber operation with the Argus Control System prior to installation and software customization of the Schneider hardware. The purpose of this testing was to gain better understanding of system control algorithms and control response criteria that are difficult to determine without direct response testing. The main results of these tests have been included in Section 17, and the extensive data in Appendix 3 of this technical note, but they are not directly related to the original HPC functional testing criteria.

2 Functional, Control and Operational Tests Program as conducted for HPC1

Test	Procedure /Procedure number	Date (dd/mm/yy)	Duration (days)	Status (P/F)
1. Exterior Airlock Doors	**MPP-HPC1–Exterior_Airlock_Door- FT** 1. Demonstration of procedures/test for opening/closing the exterior air lock doors and tray mounting/dismount. 2. Functional demonstration of the door open/closed switch/LED indicator circuit **Parts Tested (P&ID Reference):** 1. ZS_4100_01, ZS_4100_02, ZI_4100_01 2. ZS_4101_01, ZS_4101_02, ZI_4101_01	06/02/09	0.05	Passed
2. Interior Airlock Doors	**MPP-HPC1 – Interior_Airlock_Door – FT** Demonstration of procedures/test for opening/closing the interior air lock door and tray movement in harvest and planting using glove access	06/02/09	0.05	Passed
3. Airlock Purge	**MPP-HPC1 – Airlock_Purge – FT** **Sequence:** 1. Testing of air lock injection and vent solenoids 2. Testing of air lock pressure sensors **Parts Tested (P&ID Reference):** 1. RV_4100_01, SV_4102_01, SV_4102_02, PT_4102_01, PS_4102_01, HV_4102_01 2. RV_4101_01, SV_4103_01, SV_4103_02, PT_4103_01, PS_4103_01, HV_4103_01	04/02/09	0.1	Passed
4. Lighting	**MPP-HPC1 – Lighting – FT** **Sequence:** 1. Testing of the lamp loft cooling fans 2. Testing of the lamp loft temperature sensors 3. Testing of the lamp loft air flow indicator	09/03/09	0.05	Passed

	4. Testing of the lamp string relays and high-powered contactors to activate the lamps **Parts Tested (P&ID Reference):** 1. TT_4105_01, TT_4105_02, TT_4105_03 (lamp loft temperature transducers) 2. FAN_4105_01, FAN_4105_02, FAN_4105_03 (lamp loft cooling fans) 3. FSL_4105_01, FSL_4105_02, FSL_4105_03 (lamp loft air flow sensors) 4. RT_4104_01, RT_4104_02, RT_4104_03 (PAR sensors) 5. IY_4104_01, IY_4104_02, IY_4104_03 (lamp string relays and contactors) 6. LHPS_4104_01 through _06 (HPS Lamps) 7. LMH_4104_01 through _03 (MH Lamps)			
5. Main Centrifugal Blower and VFD Motor	**MPP-HPC1 – Blower_Assembly – FT** **Sequence:** 1. Visual inspection of the pulley assembly, support and rotary feed-through shaft 2. Testing of the air circulation fan 3. Testing of the air velocity sensor **Parts Tested (P&ID Reference):** 1. BLWR_4111_01 (Air Circulation Fan) 2. MVFD_4111_01 (Air Circulation Motor) 3. FT_4111_01 (Air Velocity Sensor)	11/03/09	0.05	Passed
6. Gas Analysis	**MPP-HPC1 – Gas_Analysis – FT** **Sequence:** 1. Demonstration of IRGA functioning 2. Demonstration of O_2 analyzer functioning 3. Demonstration of the factory calibrated mass flow controller (with set-point) 4. Test of CO_2 injection line solenoid **Parts Tested (P&ID Reference):** 1. AT_4113_01 (CO_2 Analyzer/IRGA)	11/03/09	0.05	Passed

	2. AT_4113_02 (O_2 Sensor) 3. FC_4113_01 (Mass Flow Controller for CO_2) 4. SV_4113_01 (CO_2 injection line Solenoid)			
7. Integrity leakage Test	**MPP-HPC1 – Leakage – FT** Performance of passive CO_2 decay test with running air circulation fan to determine operational leakage rate	11/03/09	2	Passed
8. EC System	**MPP-HPC1 –EC – FT** **Sequence:** 1. Integrity of Stock A and B tanks 2. Stock tank A and B injection solenoids 3. Stock tank A and B low level switches 4. Stock A and B manual valves 5. Testing of EC sensor **Parts Tested (P&ID Reference):** 1. VSSL_4108_01, VSSL_4108_02 (Stock Tanks A and B) 2. SV_4108_01, SV_4108_02 (Stock A and B injection valves) 3. LSL_4108_01, LSL_4108_02 (Stock A and B tank low level switches) 4. HV_4108_01, HV_4108_01 (Stock A and B Injection Manual Override Valves 5. AT_4108_01 (EC Sensor)	10/03/09	0.05	Passed
9. pH	**MPP-HPC1 – pH – FT** **Sequence:** 1. Integrity of Acid and Base tanks 2. Testing of Acid and Base Tank injection solenoids 3. Testing of Acid and Base Tank low level switches 4. Demonstration of Acid and Base Tank manual valves 5. Testing of pH sensor **Parts Tested (P&ID Reference):** 1. VSSL_4107_01, VSSL_4107_02 (Acid and Base Tanks) 2. SV_4107_01, SV_4107_02 (Acid and Base injection valves) 3. LSL_4107_01, LSL_4107_02 (Acid and Base tank low level	10/03/09	0.05	Passed

	switches) 4. HV_4107_01, HV_4107_01 (Acid and Base Injection Manual Override Valves) 5. AT_4107_01 (pH Sensor)			
10. Irrigation System	**MPP-HPC1 – Irrigation – FT** **Sequence:** 1. Integrity of nutrient reservoir and plumbing (leakage) 2. Demonstration of main irrigation pump 3. Testing of irrigation flow sensor 4. Demonstration of manual valves positioned on the by-pass and main irrigation lines 5. Demonstration of irrigation flow balancing along the internal distribution manifold 6. Testing of nutrient tank Hi/Low switches **Parts Tested (P&ID Reference):** 1. GP_4106_01 (Main Irrigation Pump) 2. FT_4106_01 (Irrigation Flow Sensor) 3. HV_4106_01 (Manual shutoff to chamber 4. Irrigation manifold in chamber 5. HV_4106_02 (Irrigation Pump Inlet Manual Override) 6. HV_4106_03 (Irrigation Drain Manual Override) 7. HV_4106_04 and HV_4106_05 (Irrigation By-pass Isolation Valves) 8. HV_4106_05, HV_4106_06, HV_4106_7, HV_4106_8 (Manifold Balancing Ball Valves) 9. VSSL_4106 (Nutrient Reservoir)	04/02/09 and 06/02/09	0.2	Passed
11. Temperature, Humidity and condensate collection	**MPP-HPC1 – Temp_Humidity – FT** **Sequence:** 1. Testing of growing volume temperature sensors 2. Testing of growing volume integrated humidity/temperature sensors 3. Integrity and functionality of hot water coil 4. Integrity and functionality of chilled water coil	05/02/09	0.05	Passed

	5. Functionality of chilled and hot water valve 6. Functionality of temperature sensors of water service lines and coil surface temperature 7. Integrity of condensate tank and fittings 8. Testing of passive condensate drain from coil drip tray 9. Testing of condensate tank high and low level switches 10. Testing of condensate pump **Parts Tested (P&ID Reference):** 1. TT 4112_04 - _012 (Growing volume temperature sensors) 2. AT 4112_01 - *03 and TT 4112*_01 - _03 (growing volume humidity and temperature sensors) 3. S3CV_4112_01 and S3CV_4112_02 (water service line control valves) 4. TT_4112_13 - _18 (water service line entry and exit temperature sensors, coil surface temperature sensors) 5. VSSL_4110_01 (Condensate Tank) 6. LSL_4110_01, LSH_4110_02 (Condensate tank hi and low level switches) 7. GP_4110_01 (Condensate pump and relay)			
Control/Profile Tests				
Exterior Air Lock Door Control Loop 4100 and 4101	**MPP-HPC1-Exterior_Airlock_Door - CT** 1. Confirmation of controller reading of ZS_4100_01, ZS_4100_02, ZS_4101_01 and ZS_4101_02	06/02/09	0.05	Passed
Airlock Purge Control Loop 4102 and 4103	**MPP-HPC1 –Airlock_Purge – CT** 1. Confirmation of pressure sensor log PT_4102_01, PT_4103_01 2. Confirmation of reading pressure switch PS_4102_01 and PS_4103_01	04/02/09	0.05	Passed
Lighting Intensity and Loft Temperature Control Loop 4104 and 4105	**MPP-HPC1 – Lighting – CT** 1. Sequential activation of lamp strings (LPHS_4104_01 through LHPS_4104_06 and LMH_4104_01 through LMH_4104_03 and activation of contactors IY_4104_01 through IY_4104_03)	09/03/09	1.5	Passed

	2. Confirmation of controller log of PAR sensors (RT_4104_01 through RT_4104_03) 3. Confirmation of air loft fan operation (FAN_4105_01, through FAN_4105_03) by controller 4. Confirmation of FAN operation indicator (FSL_4105_01 through FSL_4104_03) 5. Confirmation of controller log of lamp loft temperatures (T_4105_01 through TT_4105_03) 6. Confirmation lamp loft temperature remains below 35 ºC during operation of one photoperiod (assuming ambient temperatures are maintained at or below 21ºC) 7. Induction of high air loft temperature alarm states			
Irrigation Control Loop 4106	MPP-HPC1 – Irrigation – CT 1. Confirmation of controller log of nutrient flow sensor (FT_4106_01) 2. Confirmation of nutrient flow rates greater than 0.2 L per minute	05/02/09	0.05	Passed
pH Control Loop 4107	**MPP-HPC1 –pH – CT** 1. Confirmation of pH sensor log AT_4107_01 at the controller 2. Confirmation of controller read of acid and base tank low level sensors (LSL_4107_01 and LSL_4107_02) 3. Confirmation of controller activation of acid and base injection solenoids by the controller (SV_4107_01 and SV_4107_02) 4. Induction of hi/low pH alarms	10/03/09	0.05	Passed
EC Control loop 4108	**MPP-HPC1 –EC – CT** 1. Confirmation of EC sensor log AT_4108_01 at the controller 2. Confirmation of controller read of stock A and stock B tank low level sensors (LSL_4108_01 and LSL_4108_02) 3. Confirmation of controller activation of stock injection solenoids by the controller (SV_4108_01 and SV_4108_02) 4. Induction of hi/low EC alarms	10/03/09	0.05	Passed
Condensate Collection Control Loop 4110	**MPP-HPC1 – Condensate – CT** Activation of condensate drain procedure by the controller	23/04/09 to 29/04/09	7	Passed

Growing Volume Temperature and Humidity Control Control Loop 4112	**MPP-HPC1 –Temperature – CT** Diurnal profile tests in temperature/humidity control (demand vs. actual). To be performed during crop test	23/04/09 to 29/04/09	7	Failed
CO_2 compensation control Control Loop 4113	**MPP-HPC1 –CO2 – CT** Profile tests of CO_2 control by the controller	23/04/09 to 29/04/09	7	Passed
Crop Test	**MPP-HPC1 – Crop– OT** 1. Crop trial with lettuce in batch culture under nominal conditions – approximately 7 days in duration 2. Collection of NCER data 3. Collection of evapo-transpiration data 4. Collection of T/RH data	23/04/09 to 29/04/09	7	Passed

3 Exterior Air Lock Door Functional Testing

3.1 Procedure ID: MPP-HPC1-EXTERIOR_AIRLOCK_DOOR – FT

3.2 Introduction

The aim of this test is to demonstrate the operation of the exterior air-lock doors and confirm activation of the door open LED indicator when the door is open. The test is also used to inspect the gasket seal of the exterior air lock door for deformation.

3.3 Acronyms used in this test plan procedure

LED – Light Emitting Diode

3.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

3.5 Acceptance/rejection criteria

General

The test is considered successful when the following criteria are met

Acceptance criteria

- The two exterior air lock doors may be opened and securely closed by an operator without excessive force
- The two door ajar contact sensors (upper and lower) positioned on each of the two air locks are each, independently activated, when the door latches are not properly secured.

Rejection criteria

The test shall be repeated if the data looks doubtful or failed completely or if any of the conditions outlined above are not met.

3.6 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior air lock doors shall be opened in this test so no special environment control of the interior of the chamber is required.

3.7 Safety aspects

No special safety risks have been identified for this test.

3.8 Test set-up

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Air Lock	Interior Air Lock Doors (A&C)	N/A	Closed	
Air Lock	Exterior Air Lock Doors (A&C)	N/A	Closed	

3.9 Test As-Run Procedure

Date: 06/02/2009 Time: 16:00			Test Engineer/operator: Michael Stasiak MPP Supervision: Arnaud Fossen		
Seq. Nb.	Description	Required/Nominal	Measured/ calculated	Remarks/Calculation	Pass (P)/ Fail (F)
1	Exterior Air Lock Door A is unlatched around the perimeter and opened fully			AF not present for Door A demonstration but checked a posteriori	P
2	Confirm activation of LED (ZI_4100_01) indicator to indicate exterior door A is open	RED LED (ZI_4100_01) indicates door open	RED LED on		P
3	Close exterior air lock door and secure latches along the door perimeter				P
4	Ensure de-activation of the LED (ZI_4100_01) indicator on the exterior air lock door A to show door is closed	GREEN LED (ZI_4100_01) indicates door Closed	GREEN LED on		P

5	Unlatch exterior air lock door A and open fully. Confirm LED indicates door open.	RED LED (ZI_4100_01) indicates door Open	RED LED on		P
6	Demonstration of door C opening			AF present for this check	P
7	Exterior Air Lock Door C is unlatched around the perimeter and opened fully				P
8	Confirm activation of LED (ZI_4101_01) indicator showing exterior door C is open	RED LED (ZI_4101_01) indicates door open	RED LED on		P
9	Close exterior air lock door C and secure latches along the door perimeter				P
10	Ensure de-activation of the LED (ZI_4101_01) indicator	GREEN LED (ZI_4101_01) indicates door Closed	GREEN LED on		P
11	Unlatch exterior air lock door C and open fully. Confirm LED (ZI_4101_01) indicates door open.	RED LED (ZI_4100_01) indicates door Open	RED LED on		P

3.10 Conclusions

Doors function as required

3.11 Deviations

Seq. Nb.	Description of the modification	Justification

4 Interior Air Lock Door Functional Testing

4.1 Procedure ID: MPP-HPC1-INTERIOR_AIRLOCK_DOOR - FT

4.2 Introduction

The aim of this test is to demonstrate the operation of the interior air-lock doors and the movement of growing troughs through the glove boxes.

4.3 Acronyms used in this test plan procedure

None

4.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

4.5 Acceptance/rejection criteria

General

The test is considered successful when the following conditions are met

Acceptance criteria

1. The two interior air lock doors may be opened and securely closed by an operator without excessive force or physical exertion by the operator
2. The connection/removal of growing trays on the main conveyer system can be demonstrated and that connection can be made without excessive physical exertion by the operator.

Rejection criteria

The test shall be repeated if the any of the conditions outlined above are not met.

4.6 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior air lock doors shall be closed in this test but no special environment control of the interior of the chamber is required.

4.7 Safety aspects

No special safety risks have been identified for this test.

4.8 Test set-up

Ancillary Equipment Required for Test

1. Latex or Vinyl gloves to fit operator's hand
2. Conveyer system bridges placed on floor of air locks (supplied)
3. Tray connector and spacer bars (supplied)
4. One growing tray placed on upper support of Airlock A, one growing tray placed in Chamber A, and one growing tray placed in Chamber C (supplied)

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Air Lock	Interior Air Lock Doors (A&C)	N/A	Closed	
Air Lock	Exterior Air Lock Doors (A&C)	N/A	Closed	Air lock C should have two trays in position to demonstrate their proper removal
Irrigation	Irrigation pump	GP_4106_01	OFF	During this procedure water must not be flowing into the growing trays

4.9 Test As-Run Procedure

Date: 06/02/2009 Time: 16:10			Test Engineer/operator: Michael Stasiak MPP Supervision: Arnaud Fossen		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	While wearing vinyl or latex gloves, place hands inside the two Neoprene gloves of air lock A			AF not present for door A demonstration	P
2	Open the magnetic seals				P
3	Using the polypropylene lift rod, set the door supports onto the upper support pegs				P

4	Move the tray located on the upper tray close to the tray already positioned within the main chamber and connect with two spacer bars				P
5	Push the tray forward until the tray is centred on the irrigation spout inside the chamber				P
6	Lower the interior door back into position				P
7	Carefully secure the magnetic seals				P
8	Remove hands from airlock gloves				P
9	Move to Airlock C				P
10	While wearing vinyl or latex gloves, place hands inside the two Neoprene gloves of air lock C				P
11	Open the magnetic seals				P
12	Using the polypropylene lift rod, set the door supports onto the upper support pegs				P
13	Pull the tray located inside the chamber forward and onto the upper tray support and remove the two spacer bars				P
14	Push the remaining tray inside the chamber forward until the tray is centred on the irrigation spout inside the chamber				P
15	Lower the interior door back into position				P
16	Carefully secure the magnetic seals				P
17	Remove hands from airlock gloves				P

4.10 Conclusions

Inner doors function as required

4.11 Deviations

Seq. Nb.	Description of the modification	Justification

5 Air Lock Purge System Functional Testing

5.1 Procedure ID: MPP-HPC1-AIRLOCK_PURGE - FT

5.2 Introduction

The aim of this test is to demonstrate and test the operation of the air lock purge system, including the over-pressure passive relief valves, pressure transducers, pressure switches and purge in/vent solenoids of both air locks A and C.

5.3 Acronyms used in this test plan procedure

None

5.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

5.5 Data Log File Names:

Not Applicable

5.6 Parts Tested (P&ID Reference):

- SV_4102_01, SV_4102_02, SV_4103_01, SV_4103_02
- HV_4102_01 HV_4103_01
- PS_4102_01, PS_4103_01
- PT_4102_01, PT_4103_01
- RV_4114_01, FS_4114_01

5.7 Acceptance/rejection criteria

General

The test is considered successful when the following conditions are met

Acceptance criteria

Proper functioning of the following parts is demonstrated, according to the conditions noted;

1. Air lock inlet and purge solenoids SV_4102_01, SV_4102_02, SV_4103_01, SV_4103_02 open when charged and re-main closed when no current is applied
2. Air lock pressure switches PS_4102_01, PS_4103_01 are activated when an over pressure air stream is applied to the inlet port of each sensor

Rejection criteria

The test shall be repeated if any of the conditions outlined above are not met.

5.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior and interior air lock doors shall be closed in this test but no special environment control of the interior of the chamber is required.

5.9 Safety aspects

No special safety risks have been identified for this test.

5.10 Test set-up

Ancillary Equipment Required for Test:

1. Air source (eg. air pump or compressor)
2. 1 metre of teflon or polypropylene tubing
3. 500 mL Erlenmeyer Flask containing water
4. Manometer manifold (supplied by UoG for the test)

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Air Lock	Interior Air Lock Doors (A&C)	N/A	Closed	
Air Lock	Exterior Air Lock Doors (A&C)	N/A	Open	Airlock doors are open to allow connection of tubing to inlet and outlet ports of the purge system
Air Lock	Purge Inlet Solenoids (Airlock A and C)	SV_4102_01 SV_4103_01	Closed	

Air Lock	Purge Vent Solenoids (Airlock A and C)	SV_4102_02 SV_4103_02	Closed	
Air Lock	Pressure Switches (Airlock A and C)	PS_4102_0 PS_4103_01	Not Activated	
Air Lock	Pressure Transducers (Airlock A and C)	PT_4102_01 PT_4103_01	Reading ambient	Nominal sensor functioning is all that is required for this test

5.11 Test As-Run Procedure

Date: 04/02/09 Time: 14:00			Test Engineer/operator: Michael Stasiak MPP Supervision: Raul Moyano		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P)/ Fail (F)
1	Set the Purge Solenoids positioned in air locks A and C to 'manual on' using the Argus Control System. (SV_4102_01, SV_4102_02, SV_4103_01, SV_4103_02).	SV_4102_01 SV_4102_02 SV_4103_01 SV_4103_02 all OPEN	All valves open in control system	Set air lock A and C purge valves to manual open in the Argus control system. Purge valves may need to be operated individually if air pump supply volume is low	P
2	Connect an air pump to the purge gas inlet line on the external solenoid panel and turn on the pump				P
3	Connect one end of the tubing to the purge inlet (bottom) on the interior of airlock A, and place the other end in the flask of water			Air bubbles should form at the end of the tubing, indicating positive flow through the solenoid valve	P
4	Connect on end of the tubing to the purge vent (top) on the interior of airlock A, and place the other end in the flask of water			Air bubbles should form at the end of the tubing, indicating positive flow through the solenoid valve	P
5	Connect on end of the tubing to the purge inlet (bottom) on the interior of airlock B,			Air bubbles should form at the end of the tubing, indicating	P

	and place the other end in the flask of water			positive flow through the solenoid valve	
6	Connect on end of the tubing to the purge vent (top) on the interior of airlock B, and place the other end in the flask of water			Air bubbles should form at the end of the tubing, indicating positive flow through the solenoid valve	P
7	Using the Argus control system, go to the input display for sensor PS_4102_01				P
8	Connect the tubing to the inlet of the Air Lock Pressure Switch in air lock A and gently blow air into the tube using the air pump			The signal to the Argus system should change from 0V to + 5V when the switch is activated. The Argus alarm will sound. See deviations table 5.13	P
9	Using the Argus control system, go to the input display for sensor PS_4103_0				P
10	Connect the tubing to the inlet of the Air Lock Pressure Switch in air lock C and gently blow air into the tube using the air pump			The signal to the Argus system should change from 0V to + 5V when the switch is activated. The Argus alarm will sound. See deviations table 5.13	P
11	Using the Argus system, observe and record the pressure sensor readings for air locks A and C		98.29 A 98.12 C	Sensors should read between 95 and 105 kPa	P

12	Disconnect the Overpressure Sensor Manifold from the chamber at the Swagelok fitting.				P
13	Connect the air pump and Overpressure Sensor Manifold (including RV_4114_01 and FS_4114_01) to the Manometer manifold and open the needle valve fully	RV_4114_01 FS_4114_01	Pump connected needle open		P
14	Turn on the air pump.			*MELiSSA facility nitrogen supply was used as the air pump pressure was inconsistent*	N/A
15	Slowly close the needle valve to increase pressure to the Overpressure Sensor Manifold until a venting has occured. Monitor the Argus Control System 'Vent Detect' Parameter on the HPC System Overview Screen.		64 Initial detect # 66 final detect #	The pressure on the manometer will increase until a vent has occurred. Vent Detect counter will increase by one for each simulated venting that has occurred. *Venting occurred at a pressure of 1.3 kPa (13 mb)*	P
16	Turn off the pump, disconnect the Manometer manifold, and reconnect the Overpressure Sensor Manifold to the HPC				P

5.12 Conclusions

Valves, pressure sensors and Overpressure Sensor Manifold all function as required

5.13 Deviations

Seq. Nb.	Description of the modification	Justification

8 & 10	Signal changes from +5 to 0V when activated rather than 0 to +5 as indicated in the method	No changes were needed as the specification in the original test procedure was incorrect in stating 0 to +5V rather than +5V to 0 (it makes no difference).

6 Lighting Sub-System Functional Testing

6.1 Procedure ID: MPP-HPC1-LIGHTING-FT

6.2 Introduction

The aim of this test is to demonstrate the proper functioning of the chamber lighting system. This includes demonstration of proper functioning of the lamp loft fans, temperature sensors, air flow indicators and the relays and contactors for illumination of the 2 HPS lamp strings and the MH lamp string. Testing of the functioning of factory calibrated PAR sensors is also performed.

6.3 Acronyms used in this test plan procedure

LHPS – High Pressure Sodium lamp
LMH – Metal Halide lamp
PAR – Photosynthetically Active Radiation

6.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

6.5 Data Log File Name:

MPP_HPC_-LIGHTING_FT.txt

6.6 Parts Tested (P&ID Reference):

- TT_4105_01, TT_4105_02, TT_4105_03 (lamp loft temperature transducers)
- FAN_4105_01, FAN_4105_02, FAN_4105_03 (lamp loft cooling fans)
- FSL_4105_01, FSL_4105_02, FSL_4105_03 (lamp loft air flow sensors)
- RT_4104_01, RT_4104_02, RT_4104_03 (PAR sensors)
- IY_4104_01, IY_4104_02, IY_4104_03 (lamp string relays and contactors)
- LHPS_4104_01 through _06 (HPS Lamps)
- LMH_4104_01 through _03 (MH Lamps)

6.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely

The test is considered successful when the following conditions are met

Acceptance criteria

1. The lamps in string HPSa illuminate when activated by the controller and yield an average PAR level of not less than 300 µE at crop height (30 cm above bench) when the sensor is placed in the horizontal centre of the reflector for each lamp in string HPSa
2. The lamps in string HPSb illuminate when activated by the controller and yield an average PAR level of not less than 300 µE at crop height (30 cm above bench) when the sensor is placed in the horizontal centre of the reflector for each lamp in string HPSb
3. The lamps in string MH illuminate when activated by the controller and yield an average PAR level of not less than 300 µE at crop height (30 cm above bench) when the sensor is placed in the horizontal centre of the reflector for each lamp in string MH
4. The lamp loft fans all remain functional during periods of illumination
5. All alarms, listed in the Test As-Run Procedure, are activated
6. The temperature in any of the lamp loft does not exceed 40 C at any time during lamp operation under normal external temperature conditions

Rejection criteria

The test is considered to have failed under the following conditions;

1. When any of the conditions stated above are not met
2. When any of the data acquisition looks doubtful or failed completely

6.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber air lock doors shall remain open during this test (i.e. chamber not sealed) so as to allow the test engineer/operator the ability to move PAR sensors to the required positions. Air temperature with the MPP must be maintained between 19C and 21C during the entire test period.

6.9 Safety aspects

The operator shall take care when entering the chamber to take PAR measurements. The operator taking measurements should weigh less than 100 Kg.

All growing trays but three should be removed from the chamber to avoid a trip hazard when moving about the chamber interior.

The lower air flow baffles should not be in position as they will not support any operator's weight.

Care should be taken to avoid stepping on the hydroponic feed lines.

The operator entering the chamber shall be aware of the air flow return duct (hole) in the chamber floor. Care must be taken not to trip or fall in.

Because the operator will be inside the chamber, the air lock doors must remain open during this test.

6.10 Test set-up

Ancillary Equipment Required for Test:

- PAR sensors installed in chamber (RT_4104_01, RT_4104_02, RT_4104_3)
- step ladder to gain entry into the HPC
- anemometer

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Lighting System	Lamp String HPSa , including lamps: LHPS_4104_01 (HPS Lamp Aa) LHPS_4104_02 (HPS Lamp Ba) LHPS_4104_03 (HPS Lamp Ca)	IY_4104_01	Off	
	Lamp String HPSb, including lamps: LHPS_4104_04 (HPS Lamp Ab) LHPS_4104_05 (HPS Lamp Bb) LHPS_4104_06 (HPS Lamp Cb)	IY_4104_02	Off	
	Lamp String MH, including lamps: LMH_4104_01 (MH Lamp A) LMH_4104_02 (MH Lamp B) LMH_4104_03 (MH Lamp C)	IY_4104_03	Off	

	PAR Sensor A	RT_4104_01	Logging	Should initially read 0 uE
	PAR Sensor B	RT_4104_02	Logging	Should initially read 0 uE
	PAR Sensor C	RT_4104_03	Logging	Should initially read 0 uE
	Loft Fans A	FAN_4105_01 and FAN_4105_02	Off	Both fans in loft A should be off
	Loft Fans B	FAN_4105_03 and FAN_4105_04	Off	Both fans in loft B should be off
	Loft Fans C	FAN_4105_05 and FAN_4105_06	Off	Both fans in loft C should be off
	Loft Temperature Sensor (Loft T – A)	TT_4105_01	Logging	Should read ambient temperature
	Loft Temperature Sensor (Loft T – B)	TT_4105_02	Logging	Should read ambient temperature
	Loft Temperature Sensor (Loft T – C)	TT_4105_03	Logging	Should read ambient temperature
	Loft Air Flow Sensor (Flow – A)	FSL_4105_01	Logging	Should indicate no air flow in loft
	Loft Air Flow Sensor (Flow – B)	FSL_4105_02	Logging	Should indicate no air flow in loft
	Loft Air Flow Sensor (Flow – C)	FSL_4105_03	Logging	Should indicate no air flow in loft

6.11 Test As-Run Procedure

Date: 09/03/09 Time: 5:15 pm			Test Engineer/operator: M. Stasiak MPP Supervision: R. Moyano		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P)/ Fail (F)
1	Position and centre PAR Sensor A	300	397		P

	(RT_4104_01) underneath the HPS lamp reflector that is member of string HPSa in module A and fix it at a height of approximately 30 cm above growing tray height				
2	Position and centre PAR sensor A (RT_4104_02) underneath the HPS lamp reflector that is member of string HPSa in module B and fix it at a height of approximately 30 cm above growing tray height	300	396		P
3	Position and centre PAR sensor (RT_4104_03) underneath the HPS lamp reflector that is member of string HPSa in module C and fix it at a height of approximately 30 cm above growing tray height	300	369		P
4	Operator confirms operation of the fans by taking readings at the outlet (back) side of the fans with a hand-held anomemeter. All fans should yield a reading of greater than 0.10 m/s	Anemometer readings from each fan > 0.10 m/s	_____ A _____ B _____ C	*Anemometer was unavailable at UAB. Raul Moyano confirmed the functioning and significant air flow velocity of each fan.*	P
5	In the Argus control system, confirm air flow indicators in each lamp loft (FSL_4105_01, _02 and _03)	FSL_4105_01, _02 and _03 indicate air flow	Sensor reading positive		P
6	Confirm that temperature sensors in each lamp loft read ambient temperatures (TT_4105_01, _02 and _03)	TT_4105_01, _02 and _03 read AMBIENT	Loft sesnsors ambient T		P
7	Using the Argus control system, activate lamp	LHPS_4104_	Strings		P

	string HPSa	01, _03 and _05 are ON	activated in Argus		
8	After a period of 10 minutes, confirm readings of PAR sensors A-C (RT_4104_01, _02 and _03) each read above 300 uE corresponding to illumination of lamp string HPSa	RT_4104_01, _02 and _03 read > 300 uE	See below		P
9	Deactivate lamp string HPSa				P
10	Confirm all air loft fans remain running				P
11	Position and centre PAR sensor (RT_4104_01) under the HPS lamp reflector that is member of string HPSb in module A	300	389		P
12	Position and centre PAR sensor (RT_4104_02) under the HPS lamp reflector that is member of string HPSb in module B	300	396		P
13	Position and centre PAR sensor (RT_4104_03) under the HPS lamp reflector that is member of string HPSb in module C	300	367		P
14	Activate lamp string HPSb				P
15	Confirm continued operation of all lamp loft fans				P
16	After a warm-up period of 10 minutes, confirm and record readings of PAR sensors corresponding to illumination of HPSb				P
17	Deactivate lamp string HPSb				P
18	Confirm all air loft fans remain running				P
19	Position and centre PAR sensor (RT_4104_01) underneath the MH lamp reflector that is member of string MH in module A	140	152	See deviations table 6.13	P
20	Position and centre PAR sensor (RT_4104_02) underneath the MH lamp reflector that is member of string MH in module B	140	175	See deviations table 6.13	P
21	Position and centre PAR sensor (RT_4104_03) underneath the MH lamp reflector that is member of string MH in module C	140	170	See deviations table 6.13	P

22	Activate lamp string MH				P
23	Confirm continued operation of all lamp loft fans				P
24	Confirm readings of PAR sensors corresponding to illumination of MH				P
25	Activate lamp string HPSa				P
26	Activate lamp string HPSb				P
27	Activate lamp string MH				P
28	Confirm continued operation of all lamp loft fans				P
29	Confirm log of lamp loft temperature sensors Loft-T A-C, record initial values		25.5 A 26.0 B 25.1 C		P
30	Allow lamps to run for 1 hour				P
31	To test the temperature override control; lower the temperature limits on the control system to invoke a lamp loft high temperature alarm condition. Ensure the lamps shut off.				P
32	Confirm continued operation of lamp loft fans				P
33	Turn off lamps and let cool for 15 minutes				P
34	Reset lamp loft temperature limits and reactivate lamps				P
35	Controller instructs lamp strings (HPSa, HPSb, and MH) to operate for an extended period.	14 hours (nominal)	> 14 h	Started March 10, 2009 at 6:00 AM	P
36	After this period confirm shut-off of all lamp strings.			Fans may continue to run if the lamp loft temperature is above the set point.	P

6.12 Conclusions

Lamps, fans, alarms and PAR sensors function as required.

6.13 Deviations

Seq. Nb.	Description of the modification	Justification
19, 20, 21	Lamps in these tests differed from the other two lamp tests and acceptance criteria is thus changed to: The lamps in string MH illuminate when activated by the controller and yield an average PAR level of not less than 140 µE at crop height (30 cm above bench) when the sensor is placed in the horizontal centre of the reflector for each lamp in string MH	The differences in wattage and spectra of the MH compared to the HPS were not taken into account in the initial criteria. MH = 400 watts and ~24% conversion efficiency HPS = 600 watts and ~ 30% conversion efficiency

7 Air Circulation Fan Functional Testing

7.1 Procedure ID: MPP-HPC1 – Blower_Assembly – FT

7.2 Introduction

The aim of this test is to demonstrate the proper functioning of the centrifugal blower, VFD motor, pulley and belt drive for the motor, rotary feed through shaft and by consequence, the chamber shell ducting and louvers.

The test begins with the VFD motor set to 50 Hz which will enable the main centrifugal blower to run at full speed. After equilibration and air speed measurements have been recorded by the Argus Control system, the speed controller is reduced incrementally to show function at a range of speeds. The test concludes with a demonstration of the ramp-up and ramp-down capability in starting or shutting off of the motor of the main centrifugal blower.

7.3 Acronyms used in the test

VFD – Variable Frequency Drive (of the motor driving the main centrifugal blower)

7.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID
VFD Operation Manual
Motor Operation Manual

7.5 Data Log File Name:

MPP_HPC1__AIR_CIRCULATION_FT.txt

7.6 Parts Tested (P&ID Reference):

- BLWR_4111_01 (Air Circulation Fan)
- MVFD_4111_01 (Air Circulation Motor)
- FT_4111_01 (Air Velocity Sensor)

7.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the following conditions are met

Acceptance criteria

The functional tests of the air handling sub-system components are deemed acceptable when;

1. When the VFD successfully ramps from 0 Hz to 50 Hz without damage
2. When the VFD successfully ramps down from 50 Hz to 0 Hz without damage
3. When sufficient air flow is measured by FT_4111_01

Rejection criteria

The test is considered to have failed under the following conditions;

1. When any of the conditions stated above are not met
2. When any of the data acquisition looks doubtful or failed completely

7.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber air lock doors shall remain open during this test (i.e. chamber not sealed).

7.9 Safety aspects

When the motor and pulley are in operation under the chamber belly, the operator shall take care to get items caught in the fan belt and pulley assembly. Yellow caution tape should surround the perimeter of module C.

7.10 Test set-up

All growing trays and bottom air louvres must be in place for this test.

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Air handling unit	Main centrifugal blower		Idle	
	VFD Motor		Off	

7.11 Test As-Run Procedure

Step by step description of the operations performance

Date: 11/03/09 Time: 13:46			Test Engineer/operator: M. Stasiak MPP Supervision: A. Fossen		
Seq. Nb.	Description	Required / Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Visually inspect the rotary feed-through shaft and pulley system to confirm that there is no deflection in the assembly at system rest				P
2	Activate the VFD and set to 50 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Argus control system overview screen		26.12 m/s		P
3	Activate the VFD and set to 40 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Argus control system overview screen		20.70 m/s		P
	Activate the VFD and set to 30 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Argus control system overview screen		15.04 m/s		P
	Activate the VFD and set to 20 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Argus control system overview screen		9.33 m/s		P
	Activate the VFD and set to 10 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Argus control system overview screen		4.10 m/s		P
16	Return the VFD to 0 Hz, main centrifugal blower remains idle		0 m/s		P

7.12 Conclusions

Air circulation fan functions at the frequency setpoints indicated.

7.13 Deviations

Seq. Nb.	Description of the modification	Justification

8 Gas Analysis System Functional Testing

8.1 Procedure ID: MPP-HPC1-GAS_ANALYSIS – FT

8.2 Introduction

The aim of this test is to demonstrate and test the operation of the gas analysis system components including functioning of the IRGA for CO_2, O_2 analyzer, mass flow controller for CO_2 injection, manual injection over-ride valve and the CO_2 injection line solenoid.

8.3 Acronyms used in this test plan procedure

IRGA – InfraRed Gas Analyzer for CO_2
PO2 – Paramagnetic Analyzer for O_2

8.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

8.5 Data Log File Names:

MPP_HPC1__GAS ANALYSIS_FT.txt

8.6 Parts Tested (P&ID Reference):

1. AT_4113_01 (CO_2 Analyzer/IRGA)
2. AT_4113_02 (O_2 Sensor)
3. FC_4113_01 (Mass Flow Controller for CO_2)
4. SV_4113_01 (CO_2 injection line solenoid)
5. HV_4113_01 (CO_2 injection line manual over-ride valve)

8.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely

The test is considered successful when the following conditions are met:

Acceptance criteria

Proper functioning of the following parts is demonstrated, according to the conditions noted;

1. The IRGA (AT_4113_01) reads ambient CO2 (300 – 500 ppm) concentrations prior to test
2. The IRGA (AT_4113_01) responds to automated CO2 injection by the Argus control system at a setpoint of 1500 ppm
3. The PO2 (AT_4113_02) reads ambient conditions prior to and during the test
4. The Mass Flow Controller for CO2 is automatically controllable to a set point of 200 mL/min and flow of CO2 through the MFC is confirmed
5. Proper functioning of the CO2 injection line solenoid (SV_4113_01) is demonstrated

Rejection criteria

The test shall be repeated if the data acquisition looks doubtful or failed completely or if any of the conditions outlined in Section 2.2 are not met.

8.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior and interior air lock doors shall be closed in this test but no special environment control of the interior of the chamber is required.

8.9 Safety aspects

Carbon dioxide and nitrogen are asphyxiants. Care must be used when employing this gas in its pure form.

8.10 Test set-up

Ancillary Equipment Required for Test:

1. Pressure regulated and adjustable (0 – 120 kPa) 99.99% (or better) CO_2 gas source with to be connected to the CO_2 injection line inlet solenoid (SV_4113_01)
2. Calibrated air source (certified with levels according to anayzer manufacturer instructions) and regulator (0 – 120 kPa delivery) to be connected to the CO_2 analyzer when required for span calibration
3. Calibrated air source of 99.99 or better purity Nitrogen with a regulated supply to be connected to the CO_2 analyzer when required for zero calibration

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Gas Analysis	IRGA	AT_4113_01	Connected to HPC1 through dedicated inlet and outlet lines. Analyzer is turned on and operational	Confirm air flow through analyzer and operation of analyzer sampling pump. Analyzer sample return is back to the chamber growing volume to create a closed sampling system
Gas Analysis	PO_2	AT_4113_02	Integrated with CO_2 analyzer	*An O_2 analyzer was not available for this test. An O_2 analyzer was needed in order to verify the measurement of the PO_2*
Gas Analysis	Mass Flow Controller for CO_2	FC_4113_01	Closed (0 L/min flow)	
Gas Analysis	CO_2 injection line solenoid	SV_4113_01	Closed	
Gas Analysis	CO_2 injection line manual over-Ride ball valve	HV_4113_01	Closed	No CO_2 gas supplied to inlet solenoid at start of test
Air Lock	Exterior Air Lock Doors	N/A	Closed	
Air Lock	Interior Air Lock Doors	N/A	Open	
Air Circulation	Main Blower and VFD	BLWR_4111_01, MVFD_4111_01	Running at optimal speed (TBD)	

8.11 Test As-Run Procedure

Date: 11/03/09 Time: 13:55	Test Engineer/operator: M. Stasiak MPP Supervision: A. Fossen

Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Calibrate the IRGA/PO_2 analyzer			See anayzer operating manual for calibration instructions *Sensor was factory calibrated – no local calibration was performed as calibration standards were unavailable*	N/A
2	The mass flow controller is set to delivery CO_2 at a rate of 200 mL/min using the Argus Control System	FC_4113_01 is set to deliver CO_2 at ~200 mL/min	MFC set to 200	See MFC operating manual for manual setting of MFC	P
3	Set the Argus control system CO_2 demand to 1500 ppm	SV_4113_01 is OPEN	1500 setpoint on Argus	*Initial CO_2 concentration: 497 ppm*	P
4	Open the CO_2 line delivery pressure of 110 kPa	CO_2 tank regulator delivery at 110 kPa	*CO_2 regulator: 1.9 bar* *CO_2 flow: 193 ml/min*		P
5	Open the CO_2 injection (SV_4113_01) override valve	SV_4113_01	Valve opened		P
6	Monitor CO_2 concentrations on the Argus control system AND the IRGA and ensure that both are reading approximately the same value. CO_2 levels should rise within the HPC The PO_2 (AT_4113_02) should continue to read ambient concentrations	AT_4113_01 indicating rising CO_2 AT_4113_02 reading ambient O_2 (~21%)	CO2 increasing O2 sensor unavailable	The Argus controller will record CO_2 concentration *An initial setpoint of 800 ppm was used and allowed to plateau, followed by setpoint change to 1500. This change to the method was requested and approved by A. Fossen*	P
7	[CO_2] should reach 1500 and automated injection discontinues			[CO_2] levels may somewhat surpass the 1500 limit as internal mixing and analyzer lag times limit response. Without active CO_2 consumption and in	P

				the absence of major leaks, [CO_2] will remain high	
8	On the Argus control system, return the CO_2 control to 'Manual off', close the CO_2 injection override valve (SV_4113_01)				P

8.12 Conclusions

The gas analysis system functioned as required.

8.13 Deviations

Seq. Nb.	Description of the modification	Justification

9 Chamber Shell Integrity Leakage Test

9.1 MPP-HPC1-LEAKAGE-FT

9.2 Introduction

The aim of this test is to demonstrate the integrity of the chamber shell after assembly. CO_2 is injected into the chamber in a closed and idle configuration (all sub-systems off, main centrifugal blower excepted) to a set-point of 1500 ppm. CO_2 is allowed to passively decay through the chamber shell over a 48 hour period. The rate of leakage is calculated as the slope of a tangent to a 24 hour CO_2 curve, expressed as % Leakage of CO_2 (relative to initial value) per day.

9.3 Acronyms used in this test plan procedure

MFC – Mass Flow Controller
IRGA – Infra-Red Gas Analyzer for CO_2 (0-6000 ppm)

9.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

9.5 Data Log File Name:

MPP_HPC1__LEAKAGE_FT.txt

9.6 Parts Tested (P&ID Reference)

Chamber closure integrity

9.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the conditions outlined below are met.

Acceptance Criteria

The diffusive CO_2 leakage rate from inside the chamber against ambient total pressure and partial pressures of CO_2, calculated as the slope of a tangent to a 48 hour CO_2 concentration decay curve at the operational condition of 1000 ppm, expressed as % Leakage of CO_2 (relative to initial value) per day is less than 7% per day

Rejection Criteria

The diffusive CO_2 leakage rate from inside the chamber against ambient total pressure and partial pressures of CO_2, calculated as the slope of a tangent to a 48 hour CO_2 concentration decay curve at the operational condition of 1000 ppm,, expressed as % Leakage of CO_2 (relative to initial value) per day is greater than 7% per day

9.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior air lock doors shall remain closed during this test but the interior air lock doors shall remain open.

During the test the CO_2 concentration will be increased to 1500 ppm with the main centrifugal blower running.

9.9 Safety aspects

1. The operator must not enter the chamber during the test due to high CO_2 levels
2. The exterior doors and all interface ports must remain sealed

9.10 Test set-up

Ancillary Equipment Required for Test:

1. Pressure regulated and adjustable (0 – 120 kPa) 99.99% (or better) CO_2 gas source with to be connected to the CO_2 injection line inlet solenoid (SV_4113_01)
2. Calibrated air source (certified with concentrations according to manufacturer's instructions) and regulator (0 – 120 kPa delivery) to be connected to the CO_2 analyzer when required for calibration
3. Calibrated air source of 99.99 or better purity Nitrogen with a regulated supply to be connected to the CO_2 analyzer when required for calibration

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Gas Analysis	IRGA	AT_4113_01	Connected to HPC1 through dedicated inlet	Confirm air flow through analyzer and operation of

			and outlet lines. Analyzer is turned on and operational	analyzer sampling pump. Analyzer sample return is back to the chamber growing volume to create a closed sampling system
Gas Analysis	Mass Flow Controller for CO_2	FC_4113_01	Closed (0 L/min flow)	
Gas Analysis	CO_2 injection line solenoid	SV_4113_01	Closed	
Gas Analysis	CO_2 injection line manual over-Ride ball valves	HV_4113_01	Closed	No CO_2 gas supplied to inlet solenoid at start of test
Air Lock	Exterior Air Lock Doors	N/A	Closed	
Air Lock	Interior Air Lock Doors	N/A	Open	
Air Lock	Purge Inlet and Vent Solenoid Valves	RV_4100_01, SV_4102_01, SV_4102_02, RV_4101_01, SV_4103_01, SV_4103_02	Closed	
Air Circulation	Main Blower and VFD	BLWR_4111_01, MVFD_4111_01	Running at normal operational speed for mixing (TBD)	
EC/pH	Pressure equilibration valves manually closed		Closed	
Irrigation	Irrigation Pump Inlet Manual Override	HV_4106_02	Closed	
Irrigation	Irrigation Drain Manual Override	HV_4106_03	Closed	
Interface	All interface ports sealed		Sealed	

9.11 Test As-Run Procedure

Date: 11/03/09 Time: 15:15			Test Engineer/operator: M. Stasiak MPP Supervision: R. Moyano		
Seq. Nb.	Description	Required/Nominal	Measured/ calculated	Remarks/Calculation (raw data are expected as well as their treatment)	Pass (P) Fail (F)
1	Activate main centrifugal blower VFD to operate at the normal operating speed for mixing (TBD)				P
2	Confirm fan operation through Argus control system and air velocity sensor (FT_4111_01) output	Flow > 0	4.12 m/s		P
3	With the IRGA sampling (and stabilized) from the interior growing volume, record the initial reading	AT_4113_01 reading ambient CO_2 (350 – 400 ppm)	> ambient	*Test started after test 8 so CO_2 level was already elevated and not permitted to return to ambient level to save time in the testing procedures*	P
4	Set the Argus control system CO_2 demand to 1500 ppm	SV_4113_01 is OPEN	Demand set to 1500		P
5	Open the CO_2 line delivery pressure to 110 kPa	CO_2 tank regulator delivery at 110 kPa	Pressure at 1.9 bar		P
6	Open the CO_2 injection (SV_4113_01) override valve	SV_4113_01	Valve activated		P
7	Allow the system to equilibrate at 1500 ppm for 2 hours to allow time for equilibration with the passive air pressure compensation bags			The Argus control system will inject CO_2 until the setpoint is reached	P
8	In the Argus control system, set CO_2 control to 'manual off' so that no more CO_2 is added to the system			*Manual valve was also closed (SV_4113-01)*	P
9	Allow data collection by the Argus control system for a minimum of 48 hours				P

10	Calculate the leak rate given the concentration at the beginning of the test and after 24 hours ($[CO_2]$ start – $[CO_2]$ final) / $[CO_2]$ start * 100% = % leakage per day			*Initial: 1495* *Final : 1484* *Leakage rate = 0.74%*	P

9.12 Conclusions

Leakage rate was less than the maximum allowable rate of 7 percent. Leakage and chamber integrity criteria are met.

9.13 Deviations

Seq. Nb.	Description of the modification	Justification

10 EC System Functional Testing

10.1 Procedure ID: MPP-HPC1-EC – FT

10.2 Introduction

The aim of this test is to demonstrate and test the operation of the stock injection solenoids, the stock tank injection over-ride manual ball valves, the integrity of stock tanks, the EC sensor and the pressure equilibration manual ball valves.

10.3 Acronyms used in this test plan procedure

EC – Electrical Conductivity

10.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

10.5 Data Log File Names:

MPP_HPC1_EC_FT.txt

10.6 Parts Tested (P&ID Reference):

- VSSL_4108_01, VSSL_4108_02 (Stock Tanks A and B)
- SV_4108_01, SV_4108_02 (Stock A and B injection valves)
- LSL_4108_01, LSL_4108_02 (Stock A and B tank low level switches)
- HV_4108_01, HV_4108_02 (Stock A and B Injection Manual Over-ride Valves
- AT_4108_01 (EC Sensor)

10.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the acceptance criteria that follow are met

Acceptance criteria

Proper functioning of the following parts is demonstrated, according to the conditions noted;

1. Stock Tanks A and B do not show evidence of leakage (VSSL_4108_01, VSSL_4108_02)
2. The functionality of the injection solenoid valves is demonstrated (SV_4108_01, SV_4108_02)
3. The low level switches for the stock tanks are demonstrated (LSL_4108_01, LSL_4108_02)
4. The manual stock injection override valves are demonstrated (HV_4108_01, HV_4108_02)
5. The EC sensor is demonstrated operational

Rejection criteria

The test shall be repeated if the data acquisition looks doubtful or failed completely or if any of the conditions outlined above are not met.

10.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior and interior air lock doors shall be closed in this test (leakage test running concurrently) but no special environment control of the interior of the chamber is required.

10.9 Safety aspects

No special safety considerations have been identified for this test.

10.10 Test set-up

Ancillary Equipment Required for Test:

1. Prepared Stock A and B Solutions (see TN96.3 'Test protocols and procedures for lettuce cultivation')
2. Control system set to record signals from the EC sensor

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Irrigation	Main Irrigation Pump	GP_4106_01	Off	
Irrigation	Manual shut-off valve to chamber	HV_4106_01	Closed	
Irrigation	Irrigation drain manual valve	HV_4106_03	Closed	
Irrigation	Irrigation by-pass isolation valves	HV_4106_04 and HV_4106_05	Open	
Irrigation	Irrigation Pump Inlet Manual Over-Ride Valve	HV_4106_02	Open	

Irrigation	Stock Tanks A and B	VSSL_4108_01, VSSL_4108_02	Filled to capacity with deionized water 24 hours prior to this functional test.	
Irrigation	Hydroponics reservoir	VSSL_4106	Empty	
EC	EC Sensor	AT_4108_01	Logging with Argus	
EC	Stock Injection Solenoids	SV_4108_01, SV_4108_02	Closed	
EC	Stock Injection Manual Over-Ride valves	HV_4108_01, HV_4108_02	Closed	

10.11 Test As-Run Procedure

Date: 10/03/09 Time: 15:15			Test Engineer/operator: M. Stasiak MPP Supervision: R. Moyano		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Calibrate EC sensor as per manufacturers requirements.				P
2	Check Stock A and B tanks for leakage.			No leakage should be seen in acid/base tanks or allied plumbing lines. Tanks have been filled for 24 hours. Leaks will appear as drops or puddles in and around the tanks and/or feed lines	P
3	Open the Stock A manual injection valve (HV_4108_01)				P
4	Record the state of the Solution A float level sensor as shown in the Argus control system (LSL_4108_01)		100	The sensor should read 100%	P
5	Using the Argus control system, set the Stock Solution A valve to 'manual on' (VSSL_4108_01)				P

6	Observe Stock Tank A for 5 minutes or until the tank is empty			If water has drained from the tank, the test is successful	P
7	Record the state of the Solution A float level sensor as shown in the Argus control system (LSL_4108_01)		28	The sensor should read < 50%	P
8	Close Stock A manual injection valve (HV_4108_01) and set the control to 'manual off' (VSSL_4108_01) with Argus				P
9	Open the Stock B manual injection valve (HV_4108_02)				P
10	Record the state of the Solution B float level sensor as shown in the Argus control system (LSL_4108_02)		100	The sensor should read 100%	P
11	Using the Argus control system, set the Stock Solution B valve to manual on (VSSL_4108_02)				P
12	Observe Stock Tank B for 5 minutes or until the tank is empty			If water has drained from the tank, the test is successful	P
13	Record the state of the Solution B float level sensor as shown in the Argus control system (LSL_4108_02)		16	The sensor should read < 50%	P
14	Close Stock B manual injection valve (HV_4108_02) and set the control to 'manual off' (VSSL_4108_02) with Argus				P
EC System Test					
15	The hydroponics reservoir is filled, manually, with approximately 150 L of distilled water from facility source	VSSL_4106 filled to 150 L with dH2O	Tank filled	May be done through open top of the reservoir	P
16	Fill Stock Tanks with prepared Stock A and B Solutions.			see TN96.2 'Test protocols and procedures for lettuce cultivation'	P

17	The main irrigation pump is started and set to provide a mixing flow	GP_4106_01 is ON	Pump on	As the main valve to the hydroponics trays is closed, only use as much power as needed to allow a moderate flow through the bypass line	P
18	Adjust valves HV_4106_04'a' and 'b' to provide adequate flow through the irrigation bypass pipe and past the EC sensor.	HV_4106_04 valves are opened	Valves opened	25% is typical	P
19	Confirm that the EC sensor is reading less than 100 uS, although this depends on the water source available	AT_4108_01 reading less than 100 uS	0.06		P
20	Open the manual Stock A Tank injection valve	HV_4108_01 OPEN	Valve open		P
21	Activate the Stock A injection solenoid using the Argus control system for 20 seconds	SV_4108_01 is OPEN	Solenoid activated		P
22	Confirm that the EC rises – wait until the reading is stable before continuing to the next step		0.11		P
23	Open the manual Stock B Tank injection valve	HV_4108_02 OPEN	Valve opened		P
24	Activate the Stock B injection solenoid using the Argus control system for 20 seconds	SV_4108_02 is OPEN	Solenoid activated		P
25	Confirm that the EC rises		0.20		P

10.12 Conclusions

The EC control system functions as required.

10.13 Deviations

Seq. Nb.	Description of the modification	Justification

11 pH System Functional Testing

11.1 Procedure ID: MPP-HPC1-pH – FT

11.2 Introduction

The aim of this test is to demonstrate and test the operation of the acid and base injection solenoids, the acid/base tank injection over-ride manual ball valves, the integrity of acid/base tanks, and the pH sensor.

11.3 Acronyms used in this test plan procedure

None

11.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

11.5 Data Log File Names:

MPP_HPC1_pH_FT.txt

11.6 Parts Tested (P&ID Reference):

1. VSSL_4107_01, VSSL_4107_02 (Acid and Base Tanks)
2. SV_4107_01, SV_4107_02 (Acid and Base injection valves)
3. LSL_4107_01, LSL_4107_02 (Acid and Base tank low level switches)
4. HV_4107_01, HV_4107_02 (Acid and Base Injection Manual Override Valves)
5. AT_4107_01 (pH Sensor)

11.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the following conditions are met

Acceptance criteria

Proper functioning of the following parts is demonstrated, according to the conditions noted;

1. The acid and base tanks do not show evidence of leakage (VSSL_4107_01, VSSL_4107_02)
2. The functionality of the injection solenoid valves is demonstrated (SV_4107_01, SV_4107_02)
3. The low level switches for the stock tanks are demonstrated (LSL_4107_01, LSL_4107_02)
4. The manual stock injection override valves are demonstrated (HV_4107_01, HV_4107_01)
5. The pH sensor is demonstrated operational

Rejection criteria

The test shall be repeated if the data acquisition looks doubtful or failed completely or if any of the conditions outlined above are not met.

11.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior and interior air lock doors shall be closed in this test (leakage test running concurrently) but no special environment control of the interior of the chamber is required.

11.9 Safety aspects

Concentrated acid and base solutions will be used in this test. Caution and adherence to laboratory safety protocol must enforced at all times.

11.10 Test set-up

Ancillary Equipment Required for Test:

1. Prepared Acid and Base Solutions as per TN96.3
2. Control system set to record signals from the pH sensor

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Irrigation	Main Irrigation Pump	GP_4106_01	Off	
Irrigation	Manual shut-off valve to chamber	HV_4106_01	Closed	
Irrigation	Irrigation drain manual valve	HV_4106_03	Closed	
Irrigation	Irrigation by-pass isolation valves	HV_4106_04 and HV_4106_05	Open	
Irrigation	Irrigation Pump Inlet Manual Over-	HV_4106_02	Open	

	Ride Valve			
Irrigation	Hydroponics reservoir	VSSL_4106	Empty	
pH	Acid and Base Tanks	VSSL_4107_01, VSSL_4107_02	Each filled to capacity with deionized water 24 hours prior to this test.	No leakage should be seen in acid/base tanks or allied plumbing lines
pH	pH Sensor	AT_4107_01	Logging	
pH	Acid and Base Injection Solenoids	SV_4107_01, SV_4107_02	Closed	
pH	Acid and Base Manual Over-Ride valves	HV_4107_01, HV_4107_02	Closed	

11.11 Test As-Run Procedure

Date: 10/03/09 Time: 15:30			Test Engineer/operator: M. Stasiak MPP Supervision: R. Moyano		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Calibrate pH probe as per manufacturer requirements				P
2	Check Acid and Base reservoirs for signs of leakage			No leakage should be seen in acid/base tanks or allied plumbing lines. Tanks have been filled for 24 hours. Leaks will appear as drops or puddles in and around the tanks and/or feed lines	P
3	Open the Acid manual injection valve (HV_4107_01)				P
4	Record the state of the Acid float level sensor as shown in the Argus control system (LSL_4107_01)		100	The sensor should read 100%	P
5	Using the Argus control system, set the Acid valve to 'manual on'				P

	(VSSL_4107_01)				
6	Observe the acid tank for 5 minutes or until the tank is empty			If water has drained from the tank, the test is successful	P
7	Record the state of the Acid tank float level sensor as shown in the Argus control system (LSL_4107_01)		0	The sensor should read < 50%	P
8	Close acid manual injection valve (HV_4107_01) and set the control to 'manual off' (VSSL_4107_01) with Argus				P
9	Open the Base manual injection valve (HV_4107_02)				P
10	Record the state of the Base tank float level sensor as shown in the Argus control system (LSL_4107_02)		100	The sensor should read 100%	P
11	Using the Argus control system, set the Base valve to 'manual on' (VSSL_4107_02)				P
12	Observe the Base tank for 5 minutes or until the tank is empty			If water has drained from the tank, the test is successful	P
13	Record the state of the Base tank float level sensor as shown in the Argus control system (LSL_4107_02)		0	The sensor should read < 50%	P
14	Close Stock B manual injection valve (HV_4107_02) and set the control to 'manual off' (VSSL_4107_02) with Argus				P
pH System Test					
15	Fill the hydroponic reservoir with approximately 150 L of distilled water from facility source	VSSL_4106 filled to 150 L with dH2O	Tank filled	May be done through open top of the reservoir	P
16	Fill Acid and Base Tanks with prepared Solutions.			see appendix MPP-HPC1-Solution-App1	P

17	The main irrigation pump is started and set to provide a mixing flow	GP_4106_01 is ON	Pump on	As the main valve to the hydroponics trays is closed, only use as much power as needed to allow a moderate flow through the bypass line.	P
18	Adjust valves HV_4106_04'a' and 'b' to provide adequate flow through the irrigation bypass pipe and past the pH sensor.	HV_4106_04 valves are opened	Valves adjusted	25% is typical	P
19	Confirm that the pH sensor positioned on the by-pass line is logging	AT_4107_01	Sensor functional	Baseline pH level is dependent upon the water source	P
20	Open the manual Acid Tank injection valve	HV_4107_01 OPEN	Valve opened		P
21	Using the Argus control system, activate the Acid injection solenoid for 10 seconds	SV_4107_01 is OPEN	Solenoid activated		P
22	Confirm that the pH sensor readings decrease after injection	AT_4107_01 reading decreasing	pH decreasing		P
23	Close the manual Acid Tank injection valve	HV_4107_01 Closed	Valve closed		P
24	Allow pH to stabilize before proceeding to the next step				P
25	Open the manual Base Tank injection valve	AT_4107_02	Valve opened		P
26	Using the Argus control system, activate the Base injection solenoid for approximately 10 seconds	HV_4107_02 OPEN	Solenoid activated		P
27	Confirm that the pH sensor readings increase after injection	SV_4107_02 is OPEN	pH increased		P
28		AT_4107_01 reading			P

		increasing			
29	Close the manual Base injection valve	HV_4107_02 Closed	Valve closed		P

11.12 Conclusions

The pH control system functions as required.

11.13 Deviations

Seq. Nb.	Description of the modification	Justification

12 Irrigation Sub-System Functional Testing

12.1 Procedure ID: MPP-HPC1-IRRIGATION-FT

12.2 Introduction

The purpose of this test is to demonstrate the integrity of the nutrient reservoir and plumbing, to confirm flow among water cascade spigots, and to ensure operation of the main irrigation pump and outlet flow sensor.

12.3 Acronyms used in this test plan procedure

None

12.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

12.5 Data Log File Name:

MPP_HPC1_IRRIGATION_FT.txt

12.6 Parts Tested (P&ID Reference):

1. GP_4106_01 (Main Irrigation Pump)
2. FT_4106_01 (Irrigation Flow Sensor)
3. HV_4106_01 (Manual shutoff to chamber)
4. Irrigation manifold in chamber
5. HV_4106_02 (Irrigation Pump Inlet Manual Override)
6. HV_4106_03 (Irrigation Drain Manual Override)
7. HV_4106_04 and HV_4106_05 (Irrigation By-pass Isolation Valves)
8. HV_4106_05, HV_4106_06, HV_4106_7, HV_4106_8 (Manifold Balancing Ball Valves)
9. VSSL_4106 (Nutrient Reservoir)

12.7 Acceptance/rejection criteria

General

The test is considered successful when the following conditions are met

Acceptance criteria

1. There are no fluid leaks along the irrigation lines of in the reservoir
2. The total flow rate delivered to the trays is 3 L/min or greater as shown by the flow sensor

Rejection criteria

The test fails if any of the conditions for test success noted above are not met.

12.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient.

12.9 Safety aspects

No specific safety aspects are noted

12.10 Test set-up

Ancillary Equipment Required for Test: None

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Irrigation	Nutrient reservoir	VSSL_4106_01	Filled with 160L of deionized water	
Irrigation	All manual valves	All HV_ series valves in 4106 are open	All valves open	
Irrigation	Flow Sensor	FT_4106_01	Factory calibrated	

12.11 Test As-Run Procedure

Date: 05/02/09 Time: 14:30			Test Engineer/operator: M. Stasiak MPP Supervision: R. Moyano		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Install growing trays in chamber.				P
	Activate irrigation pump	GP_4106_01	Pump on		P

		is ON			
2	Set irrigation pump speed controller stepwise until a minimum of 3 L/min of flow is observed in the Argus control system overview screen			Speed can be adjusted to provide a visually adequate flow	P
4	Adjust balancing valves to provide a reasonably balanced flow across the four irrigation spout manifolds				P
5	Confirm reading of irrigation flow sensor	FT_4106_01 reading	5.18 L/min 4.63 L/min	5.19 L/min with sensor bypass closed 4.63 L/min with sensor bypass open	P
6	Confirm that flow is at or above 3 L/min and that there is water coming out of each of the spouts along the irrigation manifolds				P
	Deactivate irrigation pump	GP_4106_01 is OFF	0.26 L/min	Due to factory calibration requirements of the sensor, zero flow shows 0.265 L/min. Can be corrected with software modification.	P

12.12 Conclusions

Nutrient system functions as required. No leaks were present. System was demonstrated on 02/06/2009 to UAB staff.

12.13 Deviations

Seq. Nb.	Description of the modification	Justification

13 Thermal Control Sub-System Functional Testing

13.1 Procedure ID: MPP-HPC1-TEMPERATURE/HUMIDITY-FT

13.2 Introduction

The purpose of this test is to confirm operation of the growing volume temperature and humidity sensors, the fluid integrity of both the hot and chilled water coils and service lines, confirmation of operation of the 3 way proportional valves and the functionality of temperature sensors positioned on the coils and water service inlet and exit lines.

13.3 Acronyms used in this test plan procedure

None

13.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

13.5 Data Log File Name:

MPP_HPC1_TEMPERATURE_HUMIDITY_FT.txt

13.6 Parts Tested (P&ID Reference):

1. TT 4112_04 - _012 (Growing volume temperature sensors)
2. AT 4112_01 - _03 and TT 4112_01 - _03 (growing volume humidity and temperature sensors)
3. S3CV_4112_01 and S3CV_4112_02 (water service line control valves)
4. TT_4112_13 - _18 (water service line entry and exit temperature sensors, coil surface temperature sensors)

13.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the following conditions are met:

Acceptance criteria

The functional test is deemed successful if:

- all temperature sensors (TT_4112_Series) are shown to be functional
- all humidity sensors are shown to be functional
- The proportional valves may be opened with induction from external signal

Rejection criteria

The test has failed if any of the conditions above are not met

13.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient.

13.9 Safety aspects

No special safety issues have been identified for this test.

13.10 Test set-up

Ancillary Equipment Required for Test: None

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Air-Flow	Blower/VFD	BLWR_4111_01 MVFD_4111_01	ON	Operation under normal chamber conditions and Argus system control
Air handling	Chilled recirculated water must be available and below 6C +/- 0.5 Hot recirculated water must be available and set to 45C +/- 0.5			*Chilled water source temperature was above 6C and varied by greater than +/- 0.5C* *Hot water source temperature was above 45C*

13.11 Test As-Run Procedure

Date: 27/03/09 Time: 16:50	Test Engineer/operator: M. Stasiak MPP Supervision: R. Moyano

Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Record sensor readings from the Argus 'HPC System Overview' screen.			Sensors that are not functional will show a reading of 'Failed' instead of the actual sensor value. Sensor function passes if 'Failed' is not present.	P
2	Module A		T __27.67___ RH __31.8___		P
3	Module B		T __21.57___ RH __43.5___		P
4	Module C		T __25.83___ RH __30.7___		P
5	Heat exchanger		T_{src}_46.71_ T_{loop}_30.97_ _		P

			T_{exit} 33.25		
6	Condensing coil		T_{src} 9.44 T_{loop} 9.44 T_{exit} 19.45		P
7	Cold rad		T 19.79		P
8	Hot rad		T 20.86		P
9	Hydroponic Solution Temperature		T 23.41		P
10	Cold valve (S3CV_4112_01) function. In the Argus control system, set the cold valve to manual 100% open		T_{loop} 9.51 T_{exit} 9.50 $T_{cold\ rad}$ 10.05	Temperatures in these sensors should decrease over time	P
11	Set cold valve (S3CV_4112_01) to manual 0% open				P
12	Hot valve (S3CV_4112_02) function. In the Argus control system, set the hot valve to manual 100% open		T_{loop} 44.09 T_{exit} 36.82	Temperatures in these sensors should increase over time *Test was interrupted by UAB shutdown of hot water supply – completed March*	P

			$T_{hot\ rad}$ 31.36__	*30, 2009 @ 19:27*	
13	Set hot valve (S3CV_4112_02) to manual 0% open				P

13.12 Conclusions

Sensors and valves operate as required.

13.13 Deviations

Seq. Nb.	Description of the modification	Justification

14 Crop Testing

14.1 Introduction

The purpose of this test is to characterize system functioning with a growing crop. The primary criteria to be tested are temperature, humidity control and CO_2 control. Depending on crop development, pH and EC control may be utilized as well.

14.2 Consumables required for Operational Testing with Crops

Consumables:

1. Rockwool - small cubes - Grodan AO 36/40 6/15W (2940 in carton)
2. Rockwool - large cubes – Grodan Delta 4G 42/40(383 in carton)
3. Seed germination trays and covers
4. Lettuce seeds – cv. Grand Rapids

Equipment:

1. Balance for micro-nutrient and salt measurement (500 g ± 0.01g)
2. Solution stock storage tanks (2 x 20 L tanks with spigot, PP)
3. Seedling nutrient storage tank (1 x 10 L with spigot, PP)
4. Solution transfer tank (1 x 200 L tank, PP)
5. Submersible pump (5 L min^{-1} or greater) and connection tubing
6. Growth cabinet for seedling establishment (300 µmol s^{-1} m^{-2} PAR minimum). HPC can be substituted, if available, with all lamps on and appropriate temperature/RH setpoints
7. Higher plant chamber (1 or more)
8. Magnetic stirring plate, stirring bars
9. Tweezers

14.3 Solution Preparation

The chamber design allows for the use of a common nutrient solution (single reservoir) feeding all age classes of the crop in staged culture and all trays in batch culture. Studies using the nutrient solution formulation tabled below have been successfully used in staged and batch culture of beet and lettuce with periodic solution dumping. For the crop test, solution dumping will not be performed. For more detailed instruction on solution preparation, please refer to TN96.3.

Table 1. Typical hydroponics nutrient solution used in HPC studies

Component	Mol. Wt. (g)	Feed Strength (mM)
Stock A		
$Ca(NO_3)_2 \cdot 4H_2O$	236.16	3.62
$FeCl_3 \cdot 6H_2O$	270.30	0.08
Na- EDTA	372.24	0.10
Stock B		
$MgSO_4 \cdot 7H_2O$	246.48	1.00
KNO_3	101.10	5.00
$NH_4H_2PO_4$	115.08	1.50
$(NH_4)_2SO_4$	132.00	1.00
Micronutrients		
H_3BO_3	61.83	0.02
$MnSO_4 \cdot H_2O$	169.01	0.0050
$ZnSO_4 \cdot 7H_2O$	287.54	0.0035
$CuSO_4 \cdot 5H_2O$	249.68	0.0008
H_2MoO_4 (85% MoO_3)	161.97	0.0005

The nutrient solution is made using concentrated stocks solutions. Once made, the nutrient solution is pumped into the main NDS tank and the irrigation system is started once the seedlings have been added to the growing trays.

14.4 Germination, Emergence, Thinning, Planting

Plant individual seeds in Rockwool cubes (approximately 200 seeds for 2 flats of Rockwool cubes) rinsed with deionized water and place under a clear cover beneath a suitable lighting source. The seeds are watered regularly (daily) with a diluted feed stock solution. After emergence the clear cover is removed. Rockwool and trays for germination may be readily obtained from local greenhouse suppliers. Fourteen days after planting, the seedlings can be transferred to larger Rockwool blocks to be placed in the HPC1 growing trays and moved into the chamber.

As this is a batch culture test, all troughs will be loaded into the chamber at one time. Once in position, the irrigation system is activated. For more detailed instruction on plants cultivation, please refer to TN96.3. Samples of hydroponic solution should be tested for EC and pH daily to verify HPC1 sensors.

14.5 Crop growth

Once the chamber is loaded, the controller is programmed to provide the following environment conditions for the entire period of crop grow-out (7 days).

CO_2 Demand – 1000 ppm
Temperature – 26/20 º C (day/night)
VPD – 9.0 day, 6.0 night
EC – 2 mS/cm
pH - 5.8
O_2 – not controlled
Light Intensity – All lights operational

14.6 Analysis of Net Carbon Exchange Rate and Assessment of Model Performance

The computer controller maintains CO_2 concentrations at demand levels during day-light hours through the automated injection of pure CO_2 through a mass flow controller. The amount of time the mass flow controller is on, recorded by the Schneider control system as seconds of injection time, is used to estimate net carbon gain of the developing crop stand. If a suitable amount of time for crop growth permits, NCER can be calculated.

14.7 Harvest

As this is a shortened and basic functional test of the HPC with plants, harvest parameters are not required. Should time and equipment allow, the following can be performed for the purpose of training and practice:

1. At the end of the growing period (variable depending on time requirements for other HPC activities), each individual plant is harvested and separated into edible and inedible fractions. Fresh weight and leaf area for leaf material is recorded. Since it is not possible to separate completely roots from Rockwool cubes, only approximate estimation of roots weight can be done.
2. Leaf material and roots, removed from Rockwool cubes, are placed in paper bags in a drying oven for 3-7 days at 70º C, depending on the drying oven and plant material.
3. Dry weights of all plant parts is recorded.
4. Tissue samples are to be collected for % C, H, O, N, S, P determination.
5. A carbon balance is determined from the NCER estimates obtained above, the dried biomass and measured carbon content.

For more detailed instruction on plants sampling and analysis, please refer to TN 96.4.

14.8 Data log file names

HPC_CROPTEST_24h_1min.txt

HPC_CROPTEST_April23-May4_5min.txt

15 Crop test results and conclusions

The following outlines the short-term operational test results in HPC1 with a batch culture of lettuce (*Lactuca sativa* L . cv. Grand Rapids) performed at the UAB MELiSSA pilot plant in Barcelona, Spain. Lettuce seeds were planted in rockwool on April 8, 2009. One hundred seedlings were transplanted into larger rockwool cubes and placed in the HPC on April 23, 2009. The closed chamber test was performed over an eleven day period between April 23, 2009 and May 4, 2009. The chronology of the events for seedling establishment and initial development can be found in Appendix 1.

15.1 HPC operation

During eleven days of closure the HPC1 performed well with only a single external event which caused a loss of data and temperature control. On April 25, 2009 at approximately 06:10 there was a loss of power in the UAB MELiSSA facility. Although the HPC and its control systems regained power, the air circulation fan and Argus data computer remained without power. Power to the Argus computer was restored at approximately 07:50 on April 27, 2009, two days after the initial power loss. As the lettuce crop was visually unaffected, the test was allowed to continue until its scheduled partial harvest date of April 30, 2009 (Figure 1).

Figure 1. Lettuce crop resulting from 7 days of growth in HPC1 at UAB

On April 30, 2009, 20 lettuce plants were harvested (for detailed information on plants harvesting please refer to TN 96.4) and the crop test was continued past the scheduled final harvest date with the remaining 80 plants as requested by ESA. It was decided to have 2 dates of plant harvesting in order to obtain more data on chamber characteristics and plant production. The crop test was then subsequently completed on May 4, 2009, and resulted in an excellent crop of lettuce.

15.2 Environment Control

Time constraints prevented final tuning of the Argus Control System to UAB hot and chilled source temperatures and flow rates, however system performance was acceptable (Table 2). Day and night temperatures were 26.1C +/- 0.13 and 20.1 C +/- 0.16 respectively, averaging only 0.1 C above the desired setpoints when averaged over the 11 day growing period (Figure 2).

Relative humidity control did not perform as well as desired, with day and night values of 60.3 and 74.5 percent. The lack of control during the lighted period can be attributed to a combination of inadequate tuning and a fluctuating chilled water supply temperature. The fluctuations in RH closely matched the oscillations in the chilled water supply temperature (Figure 3,4,5). Improved control algorithms and improved control of the chilled water supply will greatly improve the control of relative humidity.

Parameter	Setpoint	Actual	Standard deviation
Temperature			
Day	26 C	26.1 C	0.13
Night	20 C	20.1 C	0.16
VPD			
Day	8.5	13.4	2.68
Night	6.0	6.0	0.28
Humidity			
Day	75 %	60.3 %	7.94
Night	75 %	74.5 %	1.14
Carbon Dioxide	1000 µmol mol^{-1}	1002 µmol mol^{-1}	1.35
pH	5.8	5.8	0.26
EC	1.97 mS cm^{-1}	2.0 mS cm^{-1}	0.07
MELiSSA Facility Environment Control			
Temperature			
Day	N/A	25.1	1.40
Night	N/A	20.6	0.78
Chilled water source	6 C	9.3	0.52
Hot water source	45 C	47.3	0.90

Table 2: Environmental control setpoints and parameter readings averaged over an 11 day period of closure of HPC1 growing 100 lettuce plants (for location of the sensors, refer to the PID of the HPC, MPP-PID-10-4101)

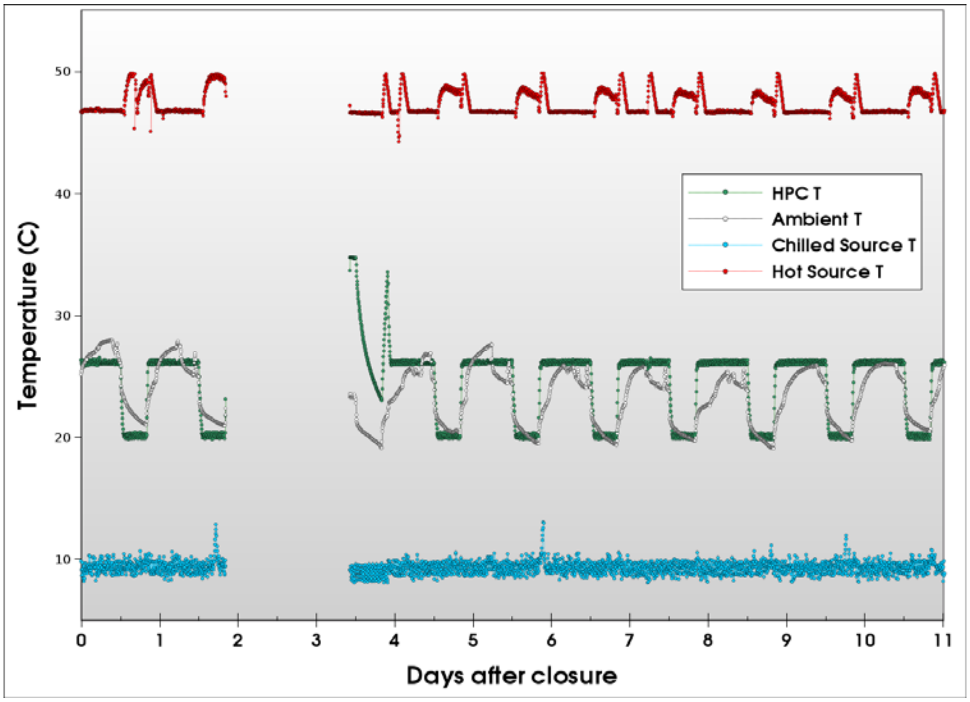


Figure 2. Temperature control in the HPC and UAB MELiSSA pilot plant over the 11 day period of closure

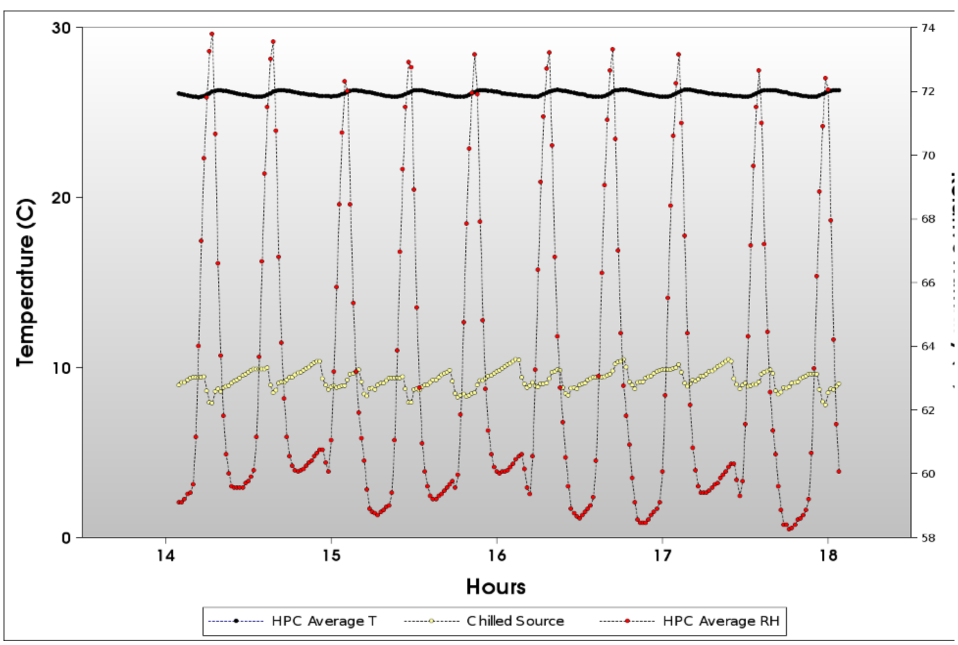


Figure 3. Relative humidity control in HPC1 and temperature control of UAB chilled water

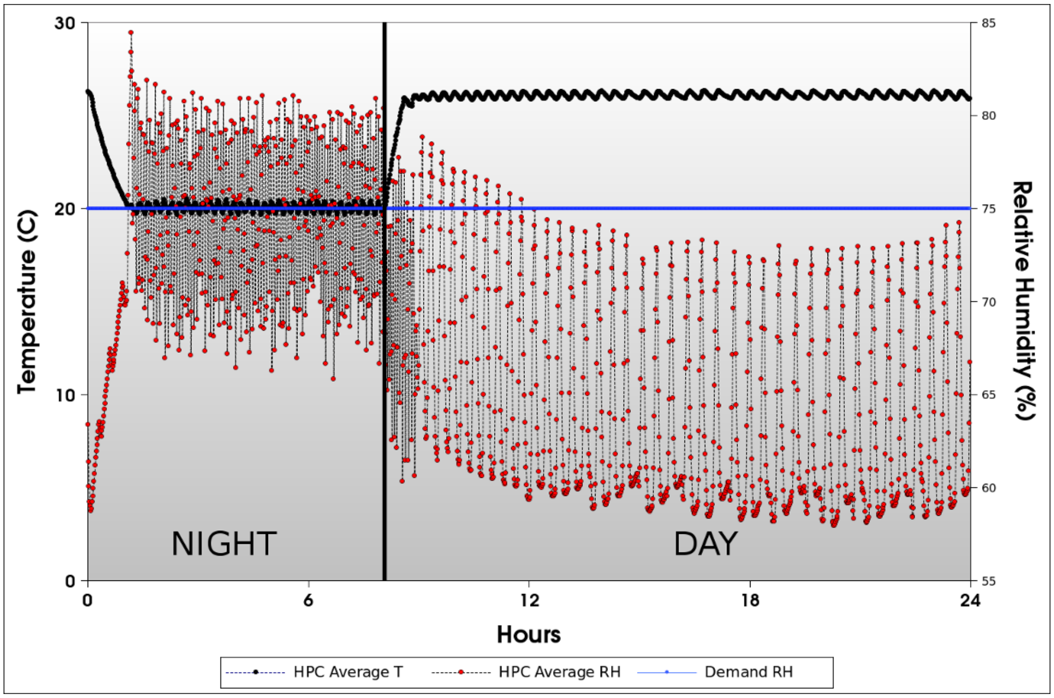


Figure 4. Control of temperature and humidity over a 24 hour period

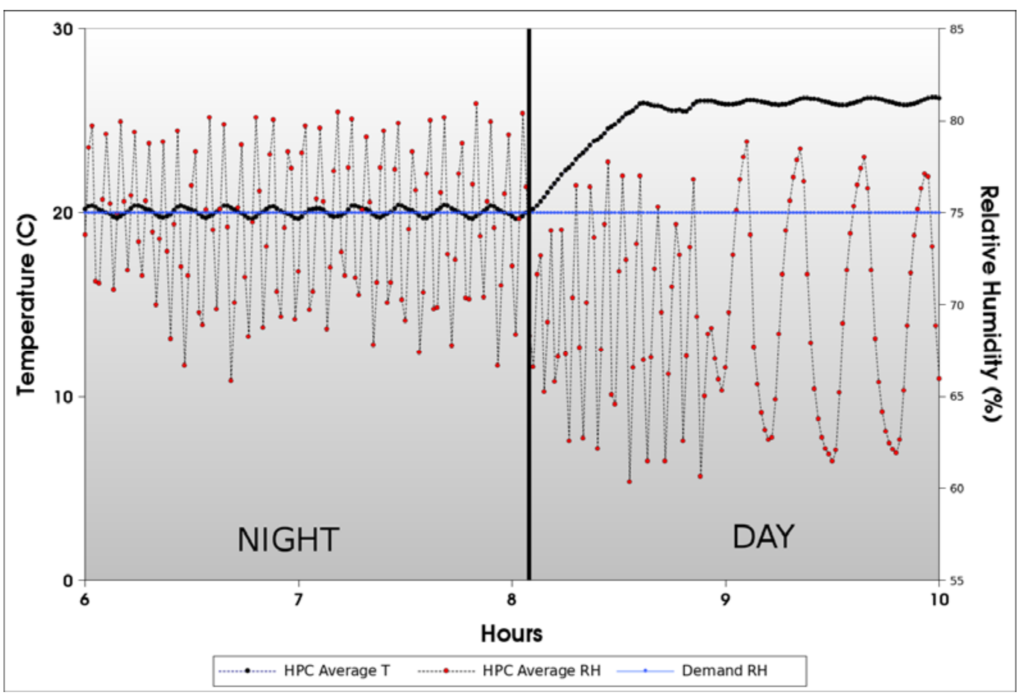


Figure 5. Control of temperature and humidity during the transition from day to night

Control of carbon dioxide was excellent with daytime control of 1000 ppm +/- 1.35 (Table 2, Figure 6,7). Night time respiration was not controlled so CO_2 levels increased during the dark phase. Over the 11 day test period, night time CO_2 increases showed a steady increase from night to night (Figure 7).

The gap in data observed in figure 7 was due to data loss during a general UAB power failure at the start of the testing period. The drop in CO_2 between day 7 and 8 was from stopping CO_2

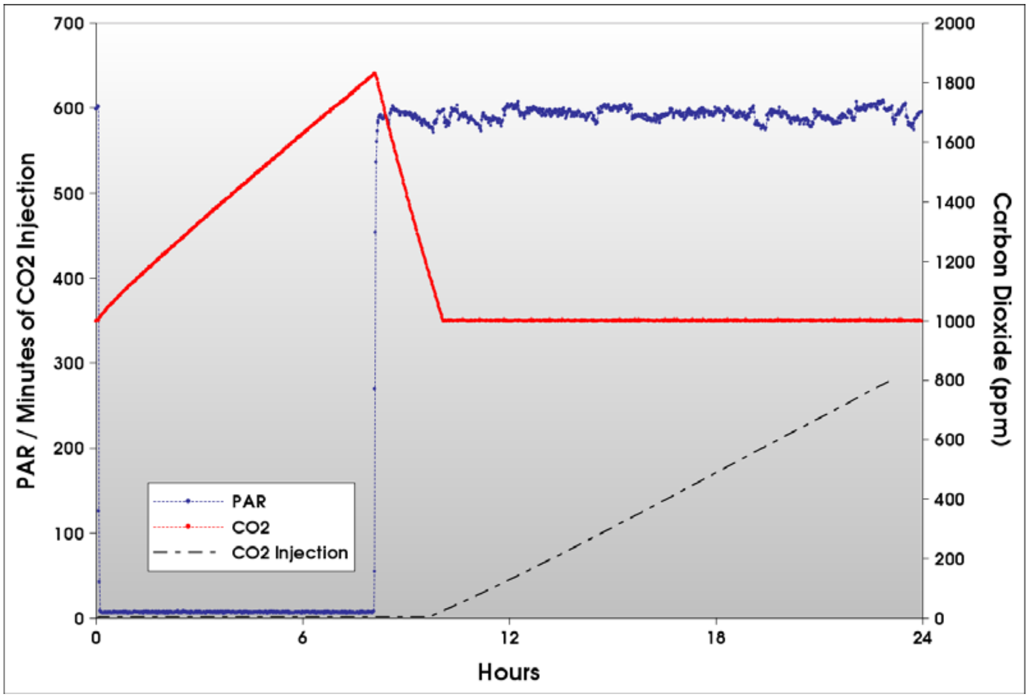


Figure 6. Carbon dioxide control over a 24 hour period on day 10 of the short term crop test. Light levels (PAR) are also indicated

control and opening the chamber doors to allow for the first harvest of 20 plants. In this case, the CO_2 dropped to ambient concentrations for a short period, and control was resumed when the doors were closed again. Over the period of closure, over 125 grams of carbon were accumulated, as calculated from injection from the UAB carbon dioxide gas source (Figure 7).

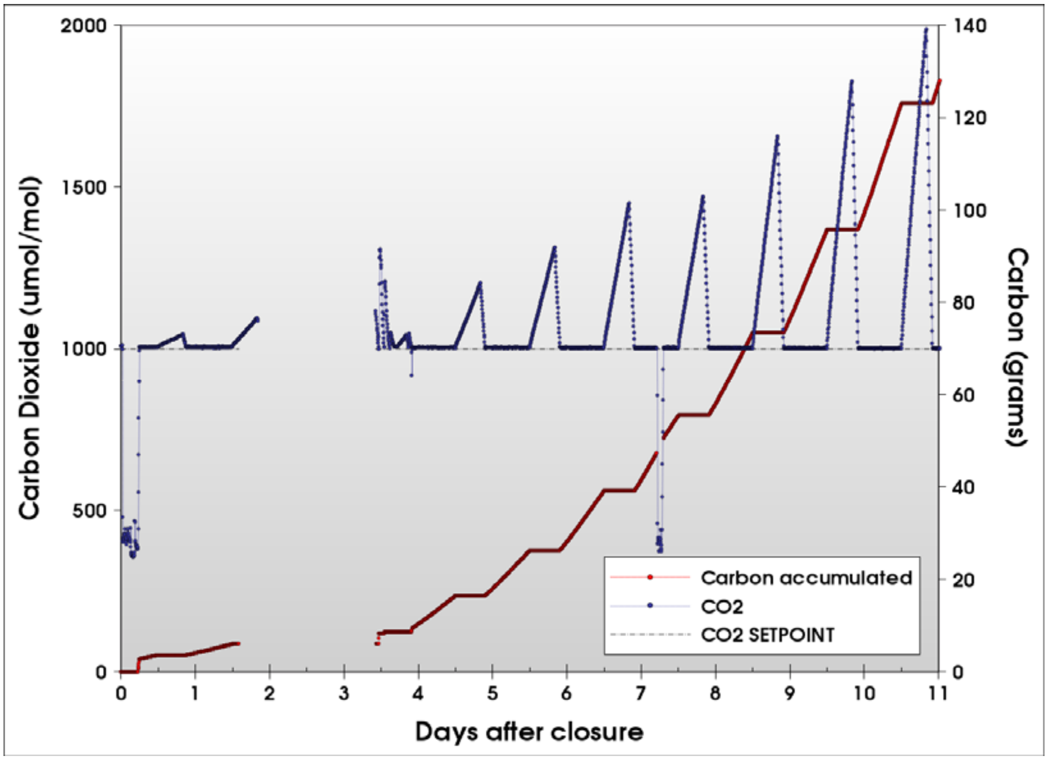


Figure 7. Carbon dioxide control over the full 11 day closed crop growth test in HPC1

Control of EC and pH was also within operational specifications. EC was maintained at or above the setpoint of 1.97 mS cm^{-1} by system injection of concentrated nutrient stock solutions (Figure 8) and averaged 2.04 mS cm^{-1} +/- 0.07 (Table 2). Similarly, pH was maintained between 5.6 and 6.0 by controlled injections of either acid or base, with an average pH of 5.8 +/- 0.26 (Figure 8, Table 2). Increase of pH value on the 6th day of closure was connected with the lack of HNO_3 in the acid tank. When the problem was detected, the acid tank was refilled and pH decreased.Collection of water from evapotranspiration was also recorded by the Argus system (Figure 9). Condensate collected as a result of HPC1 humidity control resulted in a net production of approximately 90 litres of water. The measurement of the volume of condensed water is made by a counter summing up the number of times the high level switch of the condensate tanks is reached, before the content of condensates tank is reinjected into the

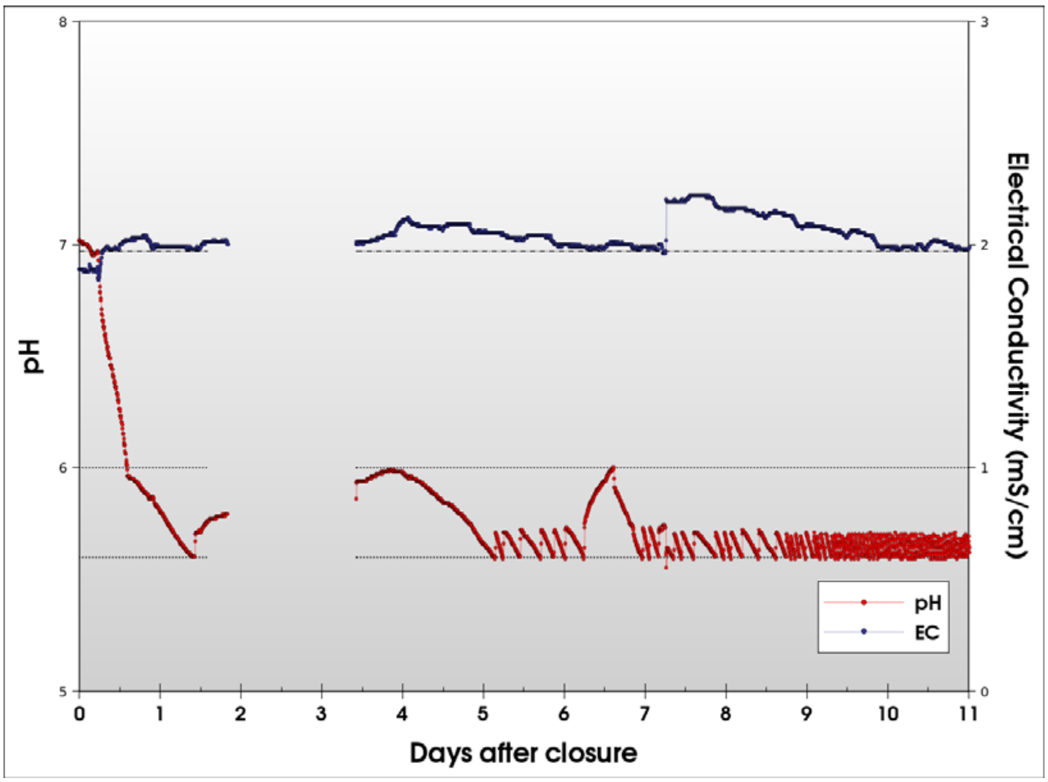


Figure 8. EC and pH control over an 11 day period in HPC1

nutrients tank by the pump CP_4110_01. The volume between the high level and low level switches in the condensate tank corresponding to one cycle of filling/emptying was measured to be 1L.

There was no way to separate evaporation from plants transpiration in this experiment, however future experiments could characterize evaporation from a fully operating system without plants.

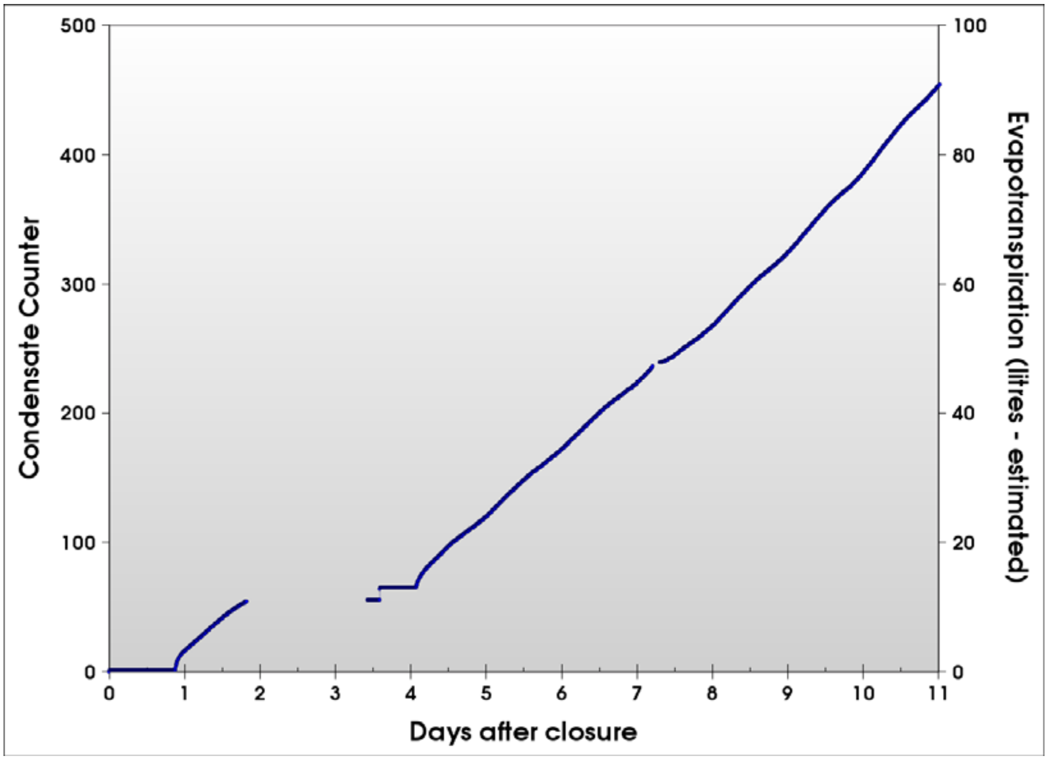


Figure 9. Condensate collection over a period of 11 days in the UAB HPC1

Even if the temperature management performed well within the specified limits during the present test, the control of MELiSSA pilot plant chilled and hot water did not meet operational requirements for the HPC (Table 2, Figure 2). Also on several occasions the measured ambient temperature in the plant exceeded the control temperature within the chamber. As heat removal is critical to internal environment control, an external heat load would make operation increasingly difficult. Therefore, the measurement of plant operating temperature should be improved during future plant growth experiments with the HPC (indeed the thermal sensor was placed in a zone where the lights loft air was exhausted).

15.3 Growth results (7 days)

After 7 days of closure, lettuce growth was visually excellent (Figure 10). Growth beyond the planned 7 day test procedure was requested by ESA (Christel Paille, email communication, April 27, 2009) so at this stage only plants from position 3 were harvested in all 20 trays. The extension was required due to extended power losses at the MELiSSA pilot plant facility during the initial phases of plant growth. Plant numbering for harvest is shown in figures 10 and 11.

Detailed information on plant harvest methodology is found in TN 96.4. Shoot fresh biomass distribution along the chamber length is shown in Figure 12. Average shoot fresh and dry biomass per each module was also estimated in order to compare lettuce production between modules A, B and C (Figure 13).

Figure 10 Lettuce crop resulting from 7 days of growth in HPC1 at MPP viewed from module C to module A

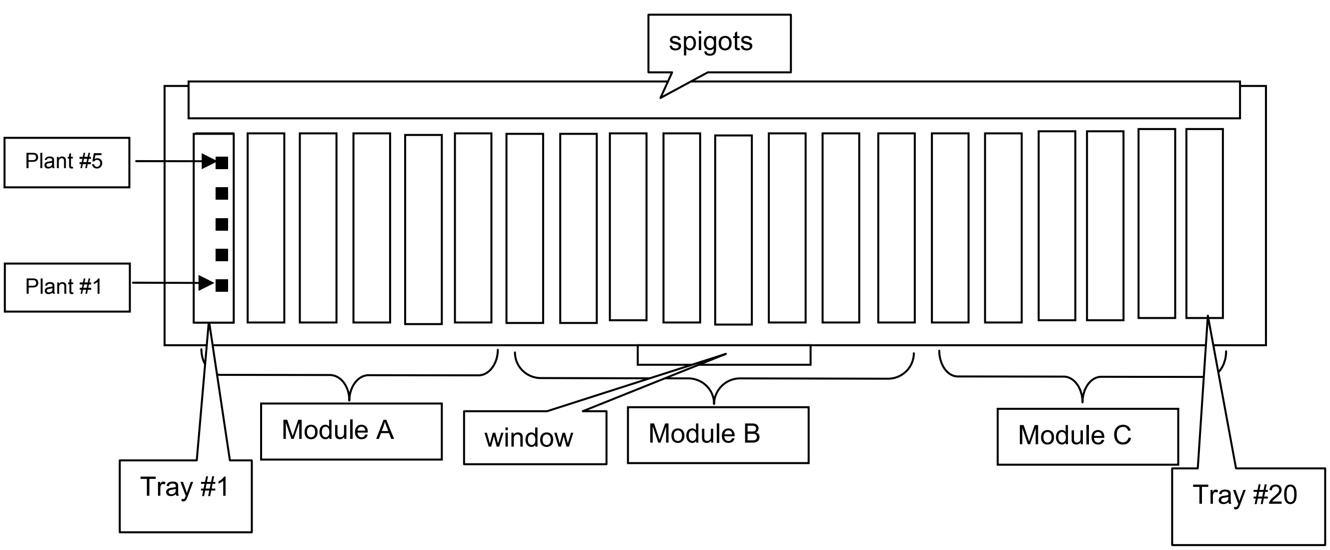


Figure 11 Schematic top view of HPC1 with plants and trays numbering

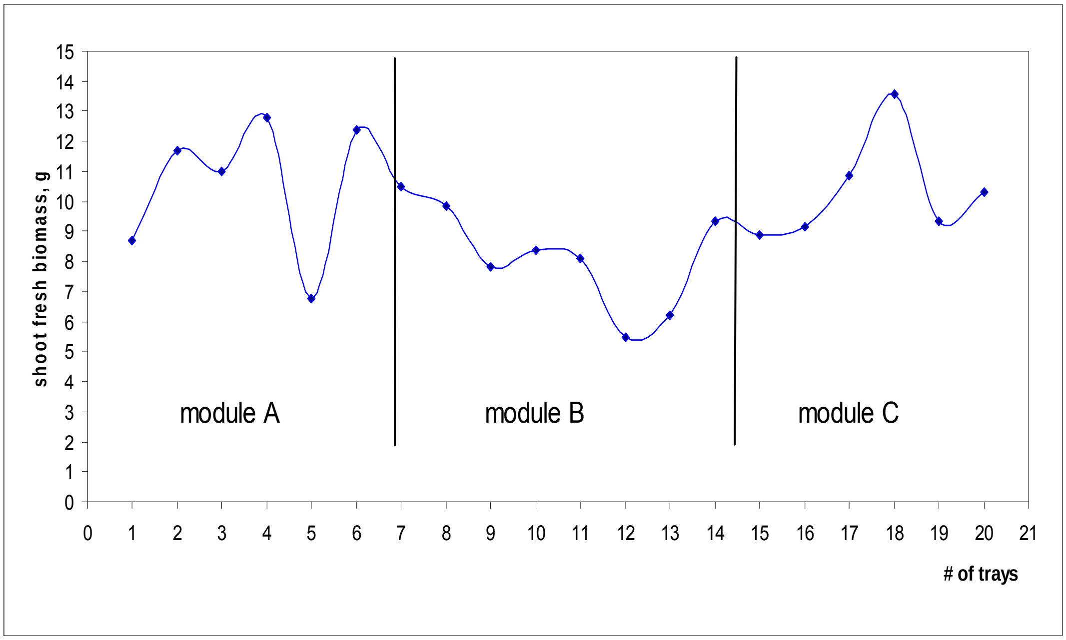


Figure 12. Lettuce shoot fresh biomass (g) of plant # 3 along the chamber after 7 days of closure

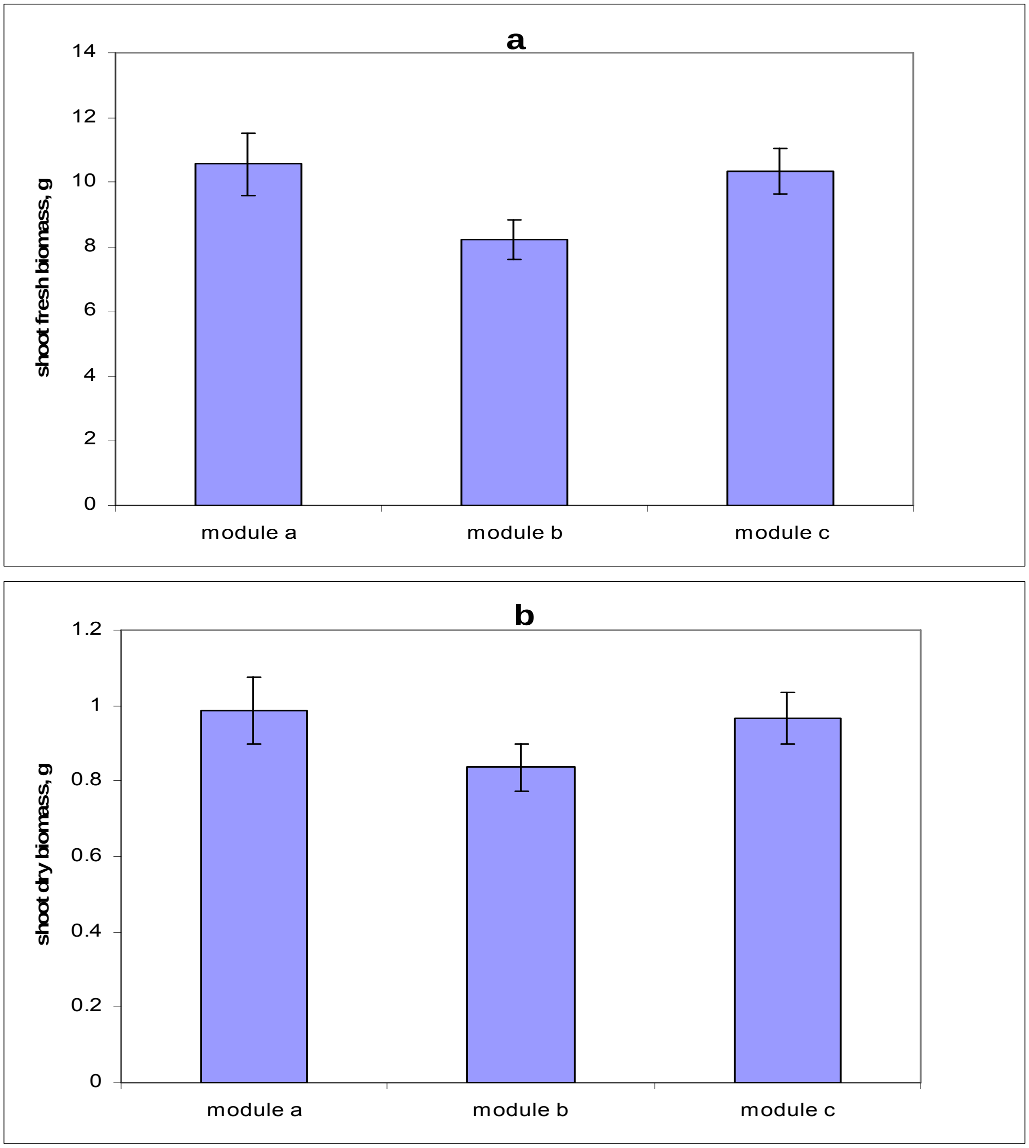


Figure 13. Lettuce shoot biomass (g) of plant # 3, average per module after 7 days of closure: a - fresh biomass, b - dry biomass

After 7 days of lettuce cultivation in HPC1, differences in plant mass were observed along the chamber from module A to module C (Figure12). The lowest values were seen with individual plants in trays 12 and 13. These results could be connected with inequality of environmental conditions; however additional study replication is required to differentiate between environmental effects and naturally occurring genetic variability. No statistically significant difference could be seen in average lettuce shoot dry biomass per module (Fig.13, b). Lower average shoot fresh biomass of plants grown in Module B in comparison with the ones grown in module A and C (Fig.13, a) was correlated with lower water content in the shoots of plants from module B. In order to make valid conclusions, it is necessary to perform experiments with a longer test duration under the same environmental conditions with a minimum of 3 replications.

15.4 Growth results (11 days)

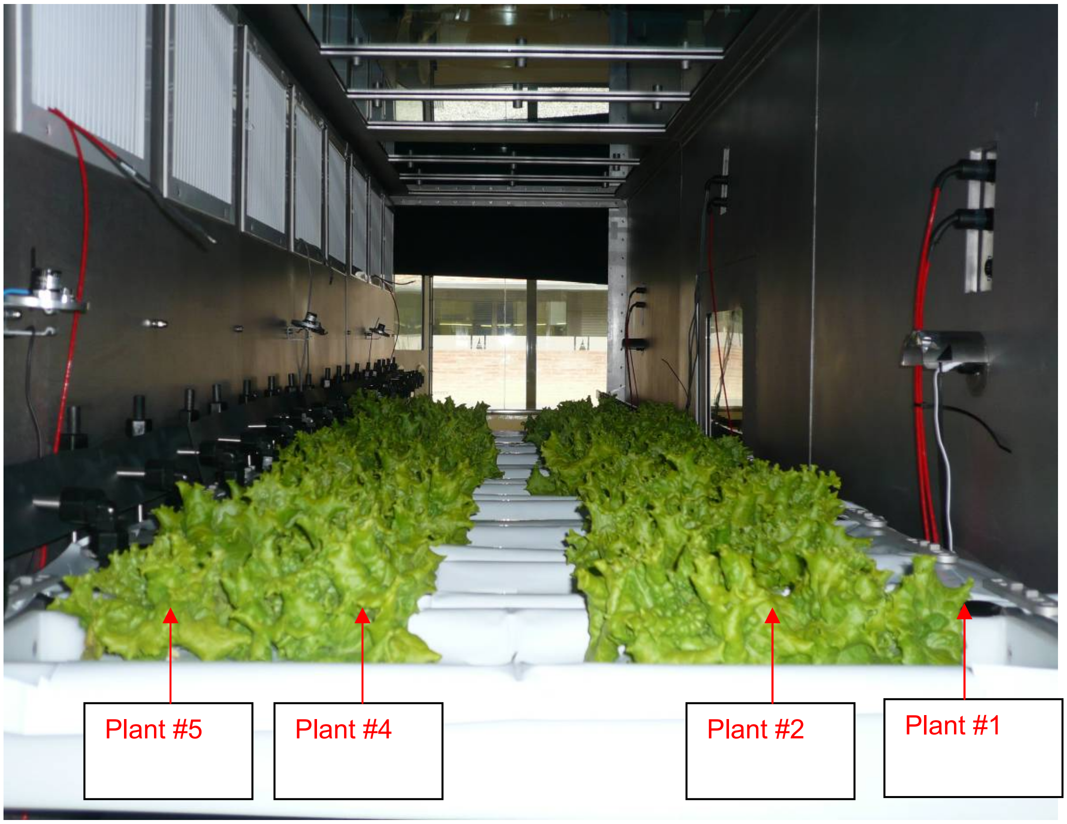
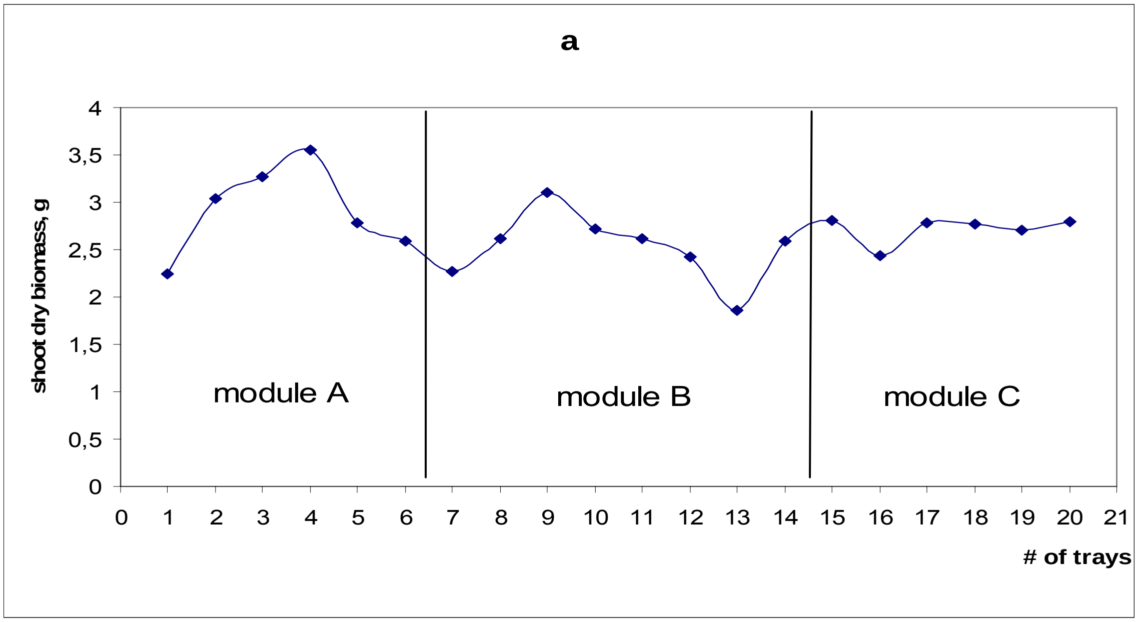


Figure 14. Lettuce crop resulting from 11 days of growth in HPC1 at UAB, from module A to module C

After 11 days of closure the plants were harvested in the same order as after 7 days of closure, from module A to module C (Figure 11). Since plant 3 was harvested previously, only 4 plants per tray were weighed: plants 1,2,4 and 5 (figure 14).

On order to analyze plant mass distribution along the chamber, it was decided to present data of lettuce shoot dry and fresh biomass for each plant number (plant 1, 2, 4 and 5, see Figure 14) separately. Distribution of plant 1 shoot dry and fresh biomass is given in Figure 15. As it can be noted in Figure 16, shoot dry biomass of plant 2 is shown only for certain trays, as random plants from other trays were mixed with plant 4, and 7 samples were prepared for further analysis (TN 96.4). Absence of shoot dry biomass data of plant 4 for some trays (Figure 17) was also connected with samples preparation for the same analysis. Distribution of plant 5 along the chamber is shown in Figure 18.



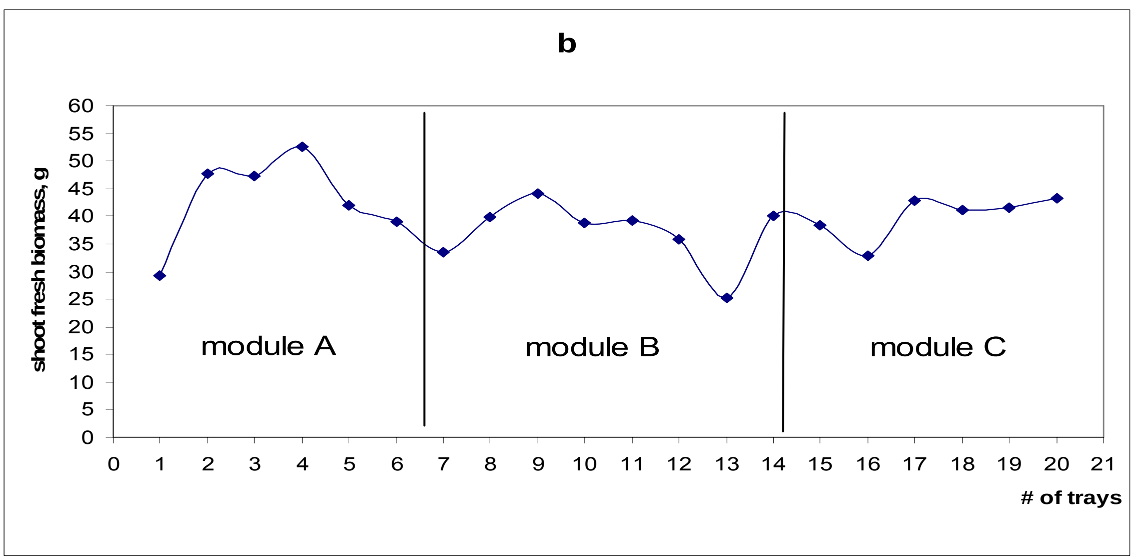
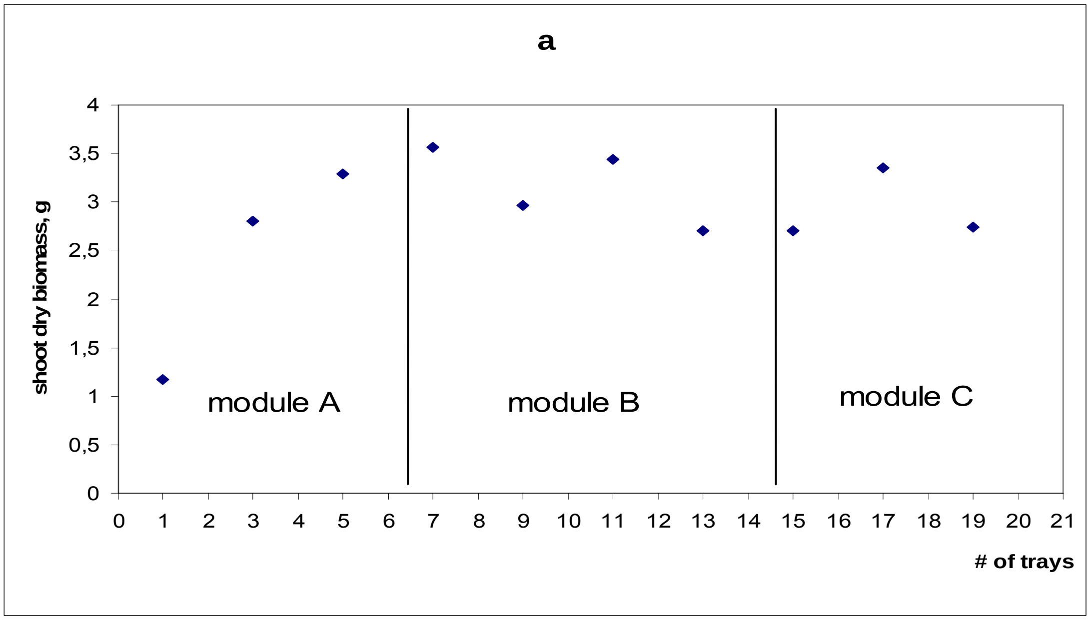


Figure 15. Lettuce shoot biomass (g) of plant 1 along the chamber after 11 days of closure: a - dry biomass; b - fresh biomass



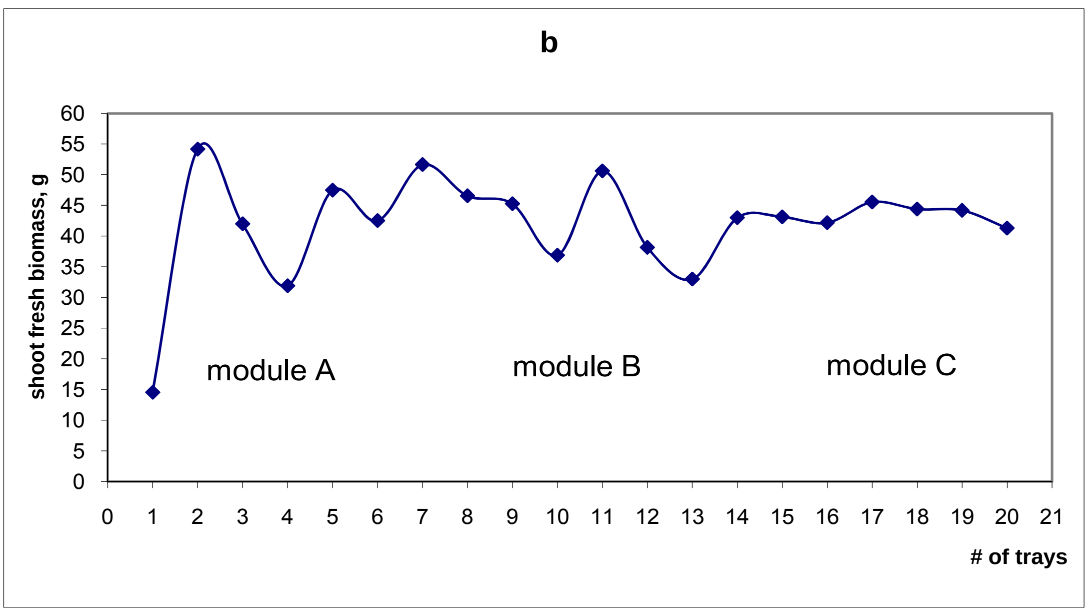
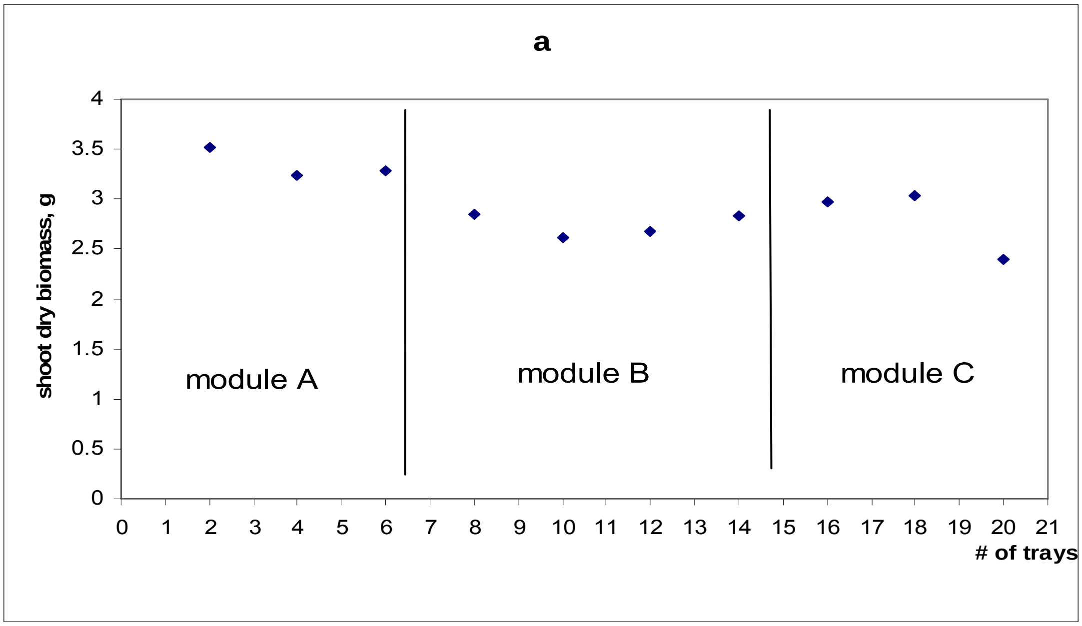


Figure 16. Lettuce shoot biomass (g) of plant 2 along the chamber after 11 days of closure: a - dry biomass (data available for trays 1, 3, 5, 7, 9,11,13,15,17,19); b - fresh biomass



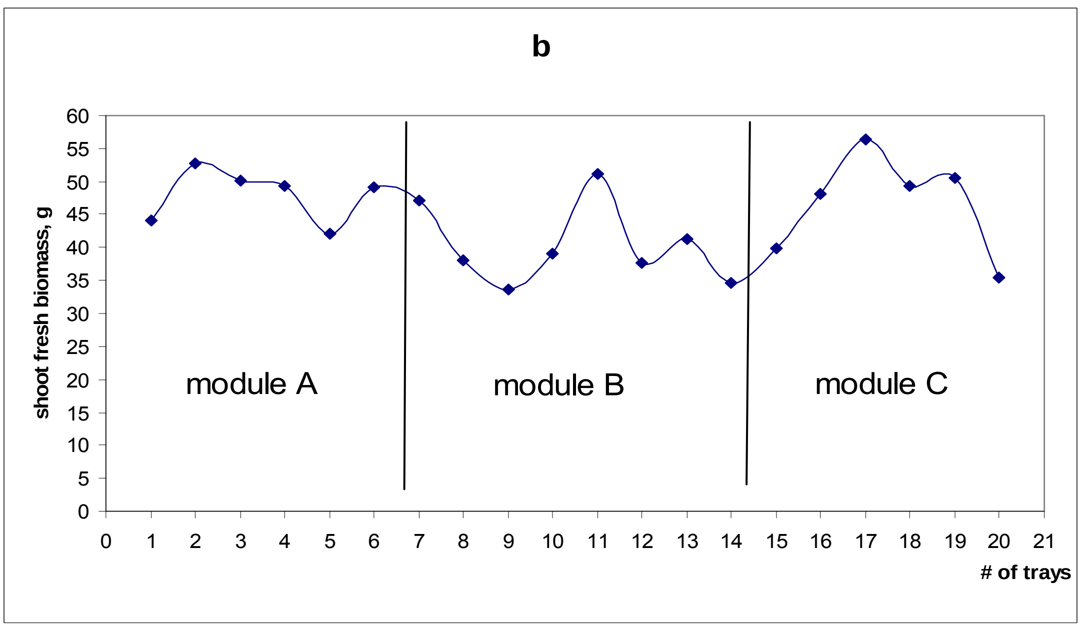


Figure 17. Lettuce shoot biomass (g) of plant 4 along the chamber after 11 days of closure: a - dry biomass (data available for trays 2, 4, 6, 8,10,12,14,16,18, 20); b - fresh biomass

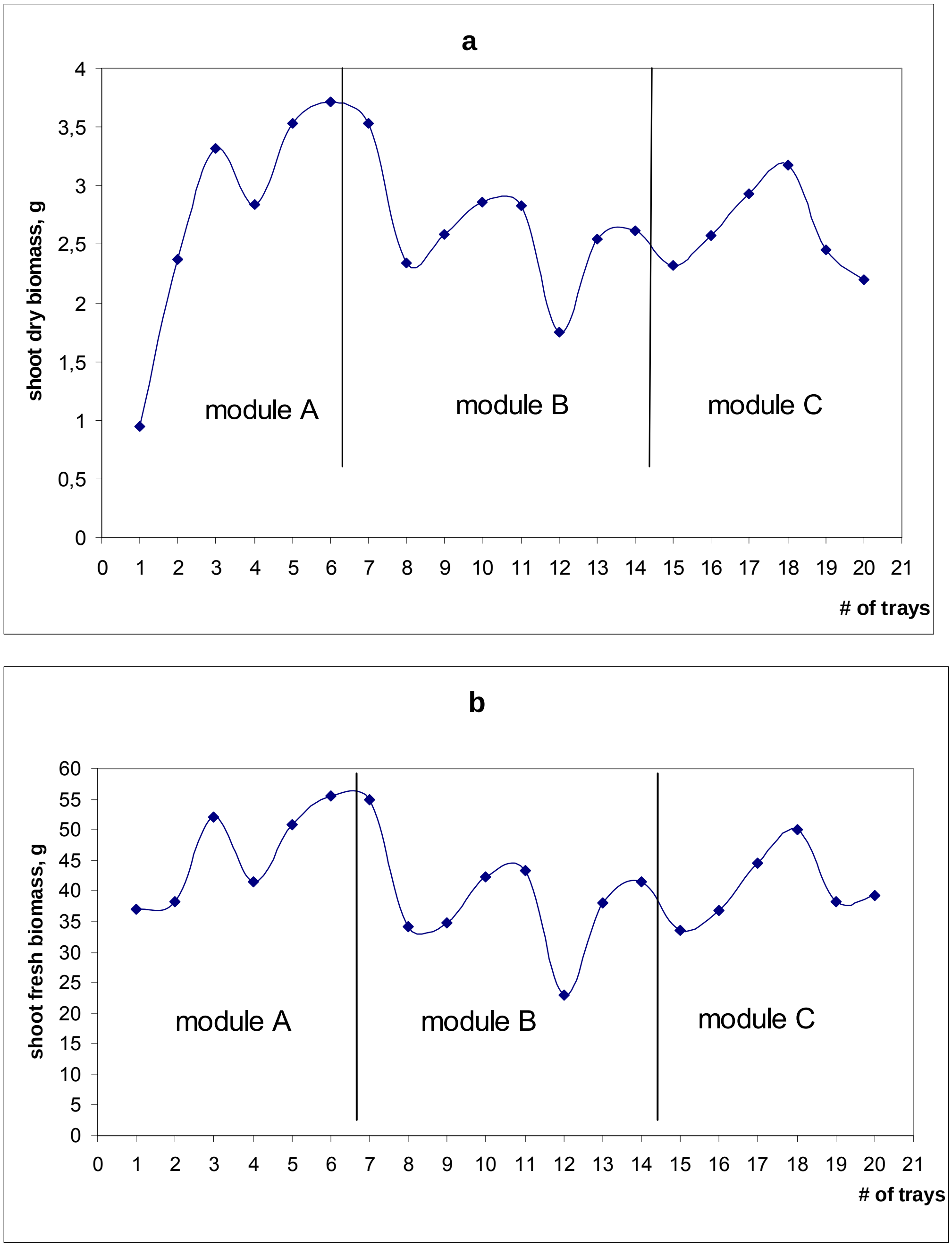


Figure 18. Lettuce shoot biomass (g) of plant 5 along the chamber after 11 days of closure: a - dry biomass; b - fresh biomass

As it can be seen from figures 15-18, after 3 additional days of plant cultivation in HPC1 variation in plant biomass along the chamber could be also observed. The same tendency for all plants took place: decrease of shoots biomass in module B, namely trays 12-14 depending on plant position in tray. For plants 1 and 2, biomass decrease was in tray 13 (Figure15, 16), for plant 4 – in tray 14 (Figure 17) and for plant 5 - in tray 12 (Figure 18). This biomass decrease may be correlated with differences in environmental conditions in this particular area in comparison with the rest of the areas of the chamber. Also decrease in plants 1, 2 and 5 biomasses was observed in tray 1. But since it was not the case for all plants of tray 1, more replications should be carried out for assertion that there is a problem in this area. As this is a single experiment, specific cause/effect relationships cannot be easily ascertained without detailed replication of data. More work is required to determine plant/chamber interactions and to determine natural genetic variability within this cultivar when grown under controlled conditions.

In order to analyze distribution of plants that were grown along the walls of HPC1 (plants 1 and 5), where environmental conditions usually are not optimal, and in the central part of HPC1 (plants 2 and 4), average shoot dry and fresh biomass of central and extreme plants per tray was calculated and data is shown in figures 19 and 20. The average shoot biomass of plants 1 and 5 is shown in Figure 19. For plants 2 and 4 only shoot fresh biomass values were used as dry mass values were unavailable due to extended analytical procedures., thus data shown in Figure 20a is data taken from Figure 16a and 17a.

Averaging of lettuce biomass for the plants located next to the walls of the chamber (plant 1 and 5) showed high variability (more than 11%) in eight of a twenty trays (Figure19b). This observation is typical for the plants that grow along the edges of a plant growth chamber.

For the plants 2 and 4, differences in biomass could be observed only in 2 cases: for the plants grown in tray 1 and tray 4, in general, difference between plants was not high (1 - 8%) (Figure 20b). These results may indicate more equalized environmental conditions in the central (along the length) part of the HPC1, however without replication this is difficult to ascertain definitively.

Average plant biomass per tray is shown in Figure 21. Lower average shoot dry biomass could be observed in trays 1 and 13 (Figure 21a). For better visualization of plant distribution in HPC1, the data is shown in 3D format (Fig. 22). Data spread can be also seen in Figure 22, however shoot fresh biomass of majority of the plants was in range of 40-50 g per plant.

Average lettuce shoot dry and fresh biomass per each module of HPC1 is given in Figure 23, and no significant difference in lettuce average biomass per module could be observed. This indicates that although some variability in environmental conditions may be present in different areas of HPC1, it is not enough to cause significant differences in overall plants growth and development. Further replication of these results is required to further evaluate chamber variability and plant growth capabilities.

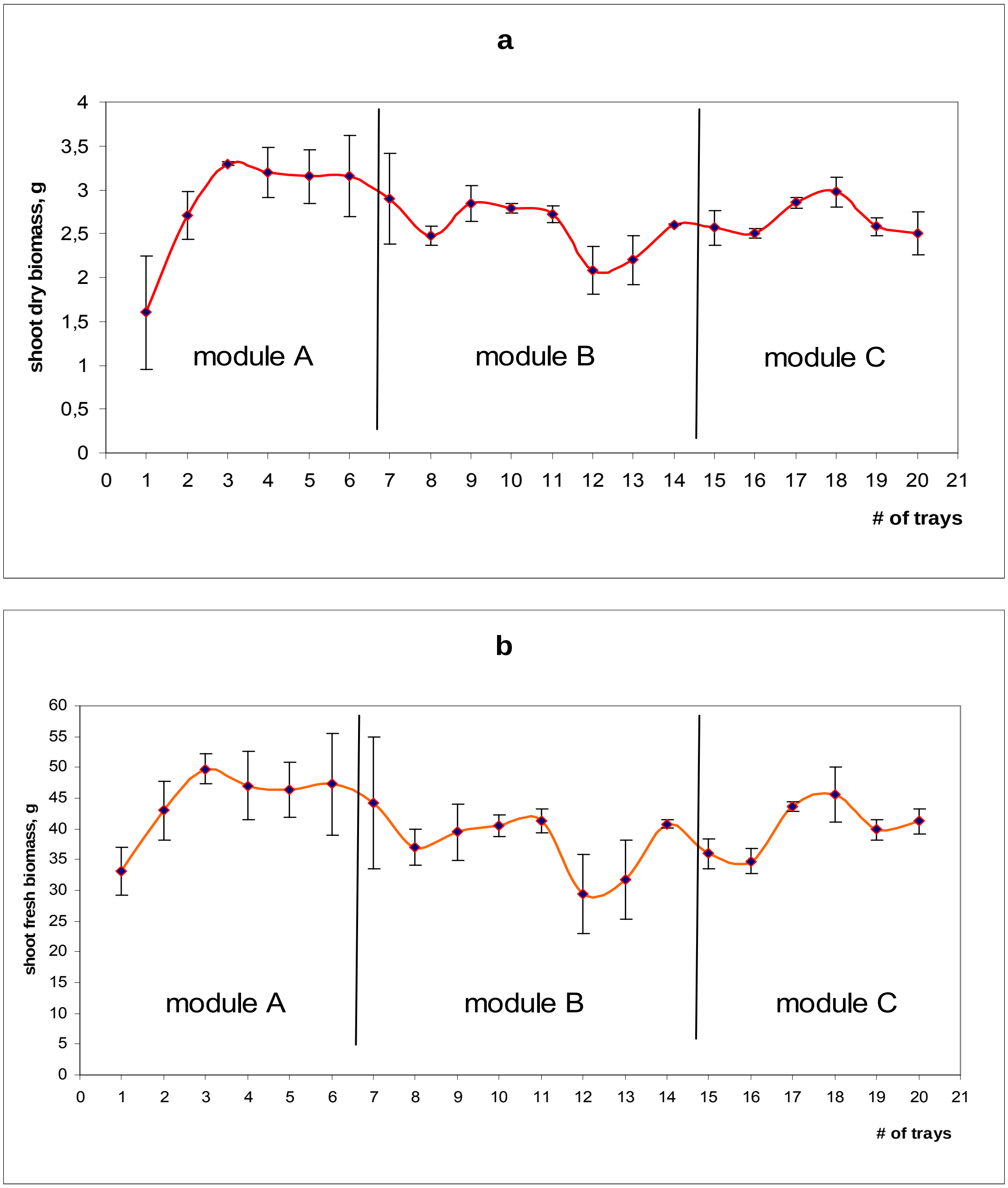


Figure 19. Lettuce shoot average biomass (g) of plant # 1 and #5 along the chamber after 11 days of closure: a - dry biomass; b - fresh biomass

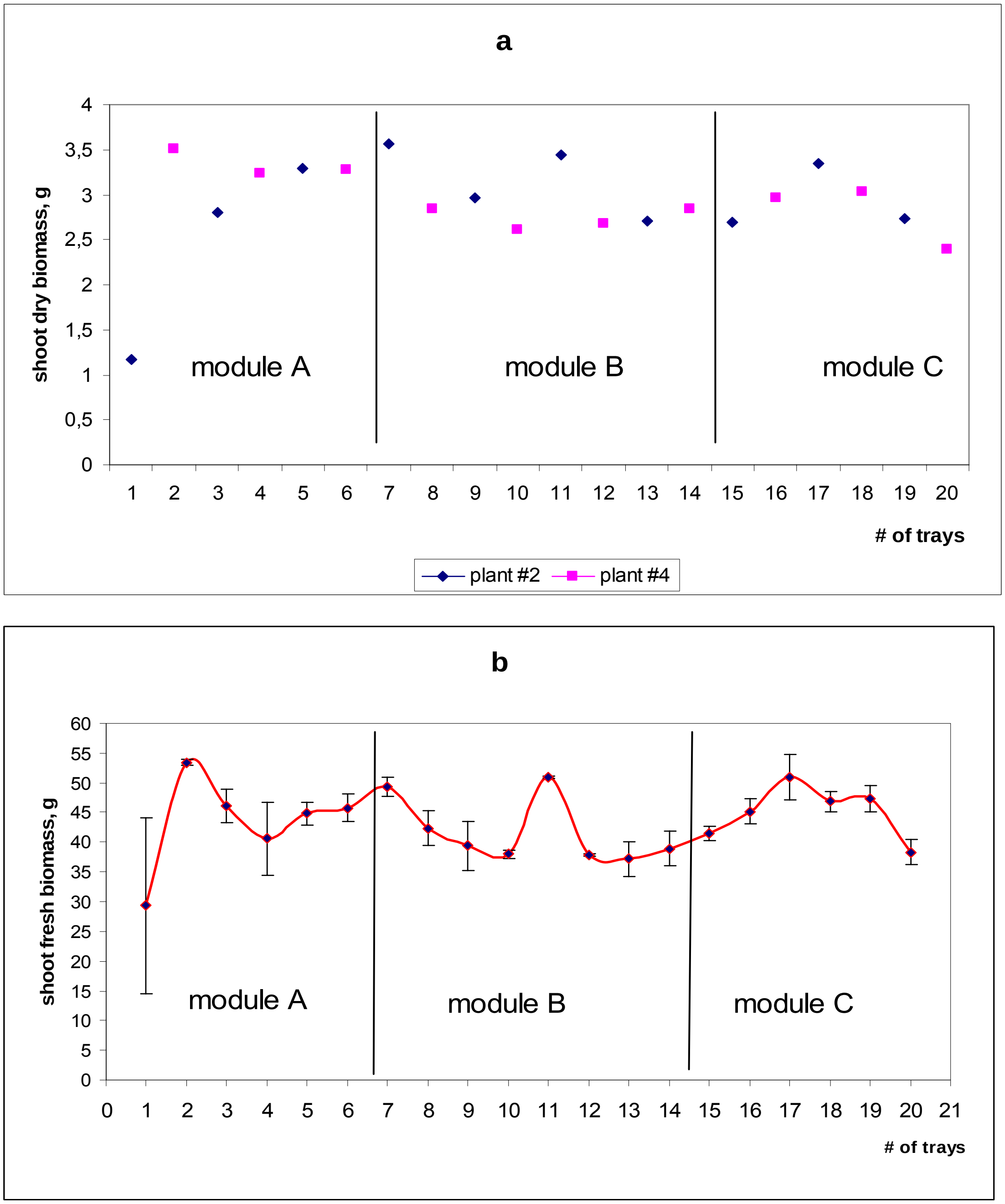
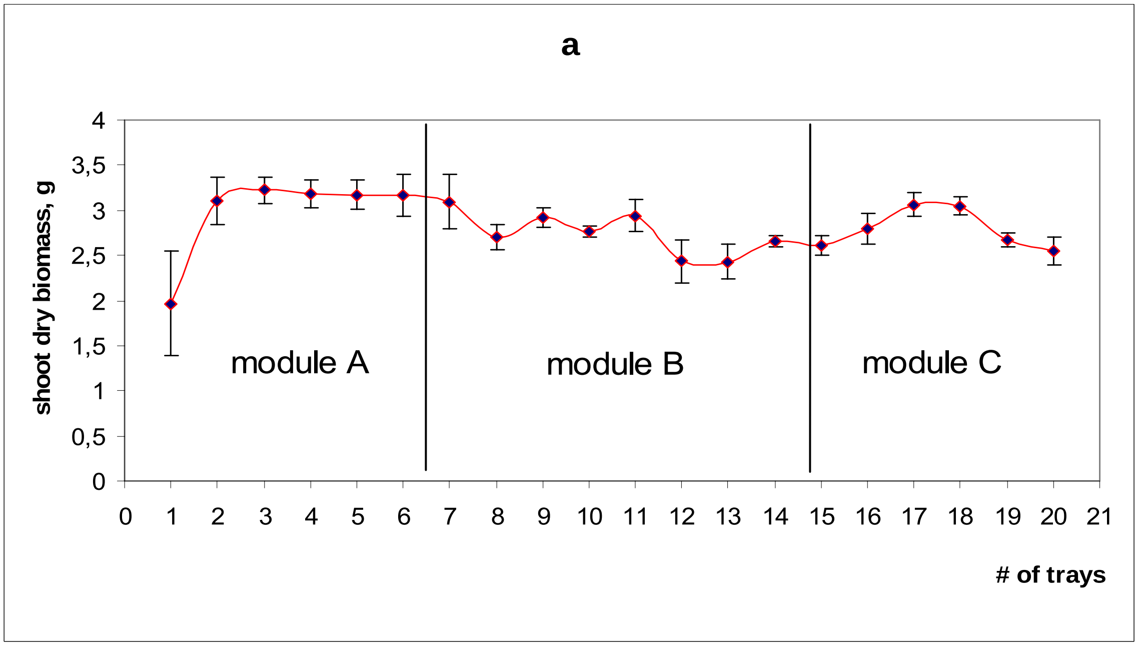


Figure 20. Lettuce shoot biomass (g) of plant # 2 and #4 along the chamber after 11 days of closure: a - dry biomass of each plant along the chamber; b - average fresh biomass



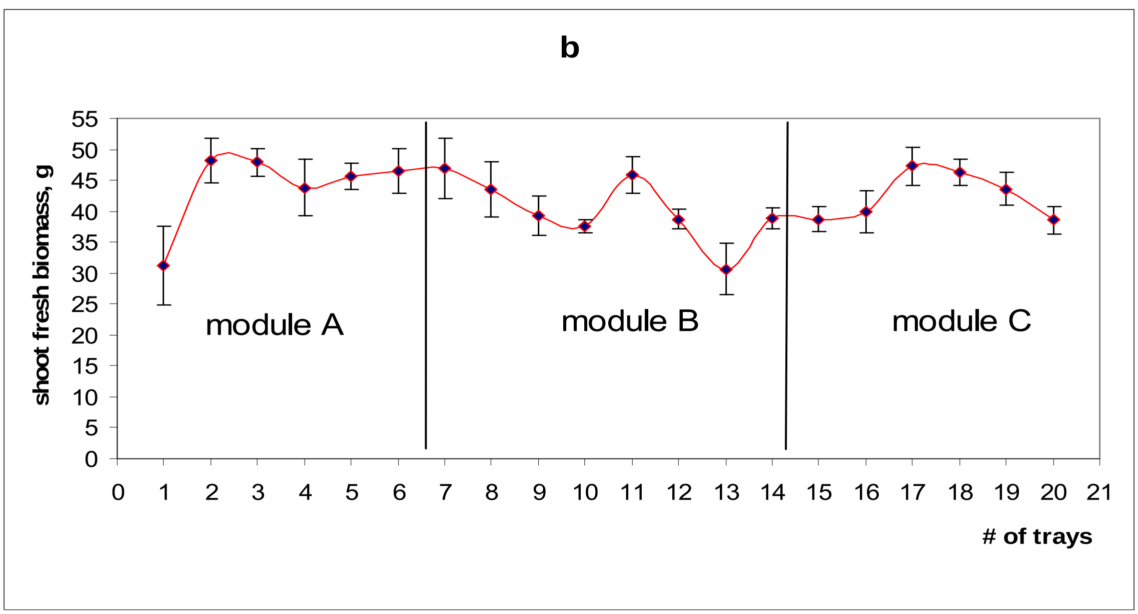


Figure 21. Lettuce shoot biomass (g) of plants 1, 2, 4, 5, averaged per tray after 11 days of closure: a - dry biomass; b - fresh biomass

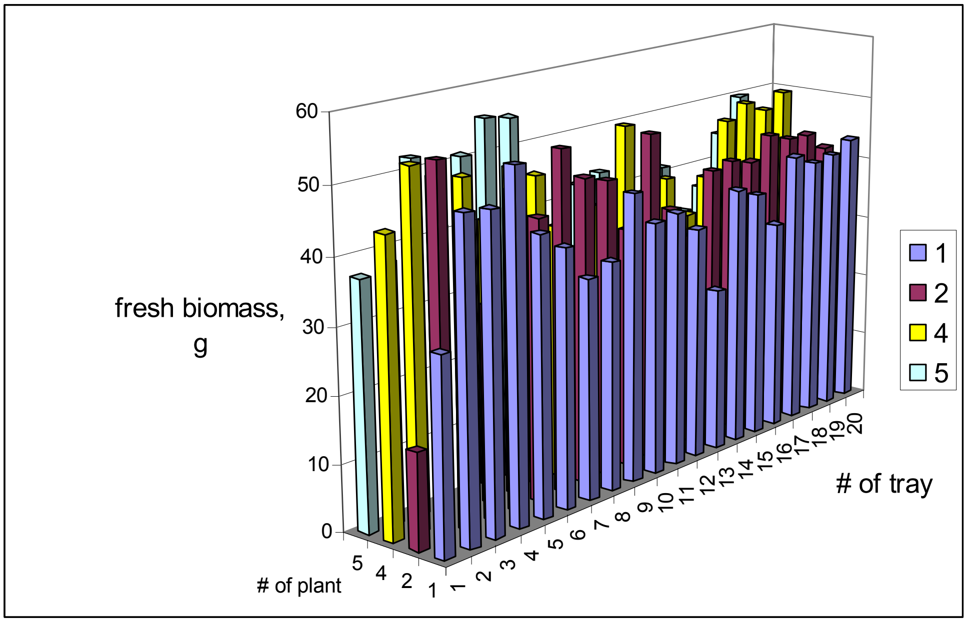


Fig.22. Lettuce shoot fresh biomass (g) of plants #1,2,4,5, after 11 days of closure

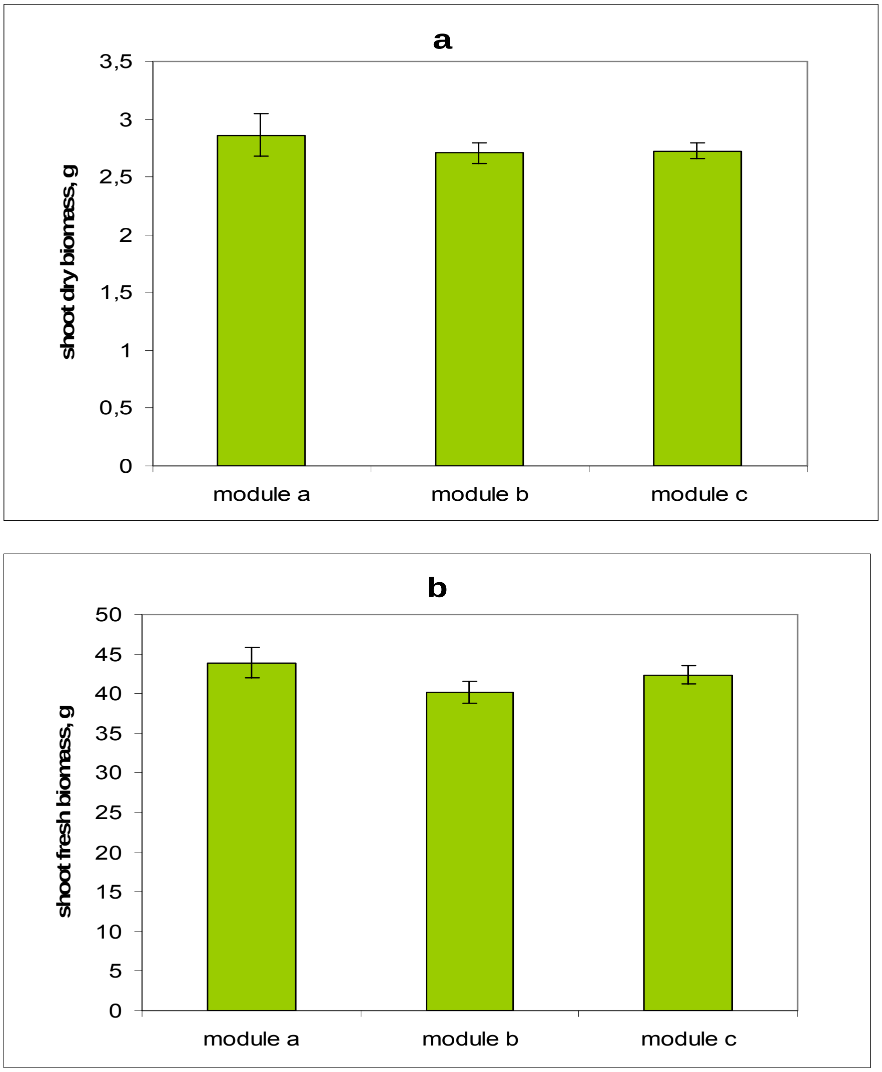


Figure 23. Lettuce shoot biomass (g) of plants #1,2,4,5, average per module after 11 days of closure: a - dry biomass; b - fresh biomass

15.5 Analytical results

During seedling development, 9.4 L of seedling solution was used for irrigation. During the crop test, 8.06 L of stock solution (together stock A and stock B) was injected into the main nutrient tank, as well as 1.6 L of 0.5 M HNO_3 and 2.1 L of 0.5 M KOH. It should be noted that chemical analysis of nutrient solution and plant material was not required in the test protocol, but was a special request by ESA (Brigitte Lamaze-Lefebvre, email communication, April 24, 2009).

Analysis of nutrient solution mineral composition at the end of the 11 day test (table 3) showed accumulation of almost all macro- and micronutrients in comparison with the calculated initial solution composition. Depending on the element, final concentration of macro- and micronutrients was 2-3 times higher than initial one, but for Zn that value reached 4 times, and for Na and Cl – 5 times. It should be taken into consideration that mineral composition was not analyzed but only estimated according to solution recipe, and without analyzed starting solution values, comparisons between the starting and ending solutions cannot be reliably made. Future experiments will require analysis of the starting solution to improve confidence in data analysis and interpretation. In general, accumulation will occur as the total complex of nutrient components are added into the nutrient solution even though not all nutrients are required by the plants. As crops are grown and tested, modifications to the stock solution recipe for replenishment can be made according to plant developmental requirements.

In order to know the mineral and elemental composition of the seedlings before starting the crop test (t_0), the seedlings that were not planted in the chamber were collected 15 days after sowing. (the day following the start of the crop test), weighed, lyophilized and analyzed. Sixty-nine seedlings were collected and had a fresh weight 60.38 g and dry weight of 2.48 g. This crop phase is called as **Treatment 1** (table 4 and following).

Treatment 2 is the lettuce shoots, located in the central raw along HPC1 (plant 3, Figure 10), harvested after 7 days. **Treatment 3** is the lettuce shoots of plant 2 (Figure 13, samples were taken from trays 2, 4, 6, 8, 10, 12, 14, 16, 18, 20) and plant 4 (Figure 13, samples were taken from trays 1, 3, 5, 7, 9, 11, 13, 15, 17, 19), harvested after 11 days of crop test.

Analysis of lettuce shoot mineral composition at different phases of vegetative growth (Table 4) showed that the concentration of Ca, K, N, Fe and Mn in lettuce seedlings was higher than in lettuce shoots after 7 and 11 days of growth. Also content of P in seedlings was higher than in lettuce leaves after 7 days of crop test. One of possible reasons of the results obtained could be availability of more representative sample of seedlings for mineral analyses in comparison with samples of older plants (sample of seedlings was taken from 69 plants and samples of treatment 2 and 3 – from 20 plants each, see description of treatments for Table 4). It was noticed that the concentration of minerals in lettuce shoots of treatment 3 was equal or higher (for most of the minerals) than in the shoots of treatment 2. However it should be taken into consideration that even though error of measurements given by laboratory that analyzed samples (University of Barcelona) is 1%, when the concentration is near the quantification limit the error can increase up to a maximum of 15%. In Table 4 error is calculated according to data repeatability, but if error will be increased, no significant difference will be observed for most of nutrients between treatment 2 and treatment 3 and for some nutrients of treatment 1 in comparison with treatments 2 and 3. As this is a single test without replication, data interpretation is difficult. For better statistical reliability, further testing and replication should be performed.

Content of carbon and hydrogen in lettuce leaves (Table 5) was in the frames of average content of these elements in plants. However in lettuce shoots of treatment 2 contained higher quantities of these elements in comparison with treatment 1 and treatment 3. This difference between treatment 2 and treatment 3 could be connected with better environmental conditions, in particular light intensity, for CO_2 fixation for the plants in the central row (plant 3, treatment 2) in comparison with plants situated in more extreme rows (plants 2 and 4, treatment 3). However this assumption is to be proved in the future experiments.

Estimation of total minerals introduction into the nutrient solution and nutrients accumulation in the plants (table 6 and table 7) showed, that plants contained very few quantity of nutrients relative to total injection, maximum 6% of total quantity of each element introduced during the test. Approximately 30-50% of elements are left in the nutrient solution by the end of the test and the rest are accumulated in lettuce roots, rockwool cubes and different parts of liquid loop including trays and pipes. If to take into account that roots dry weight compounds about 20-30 % of lettuce shoot dry weight and content of minerals in the roots is less or approximately equal to the one in the shoots, then most of the salts are probably accumulating in the rockwool cubes and trays.

Table 3. Mineral composition of nutrient solution in the beginning (estimated) and the end of the crop test (average of 3 samples) (mg/L)

Nutrients (mg/L)		Initial composition (estimated. TN 96.3)	After 11-days crop test	
			Average sample	Standard***** error
Macronutrients	Ca	140	325	65
	Mg	20	57	5
	K	200	538	38
	P	50	54	14
	S	60	138	14
	N-NO_3	170	431	75
	N-NH_4	50	49	19
Micronutrients	Fe	4.5	11	3
	B	0.2	0.45	0.03
	Zn	0.2	0.8	0.1
	Mo	0.06	< 0.04-0.07	N/A
	Mn	0.3	0.54	0.07
	Cu	0.05	0.12	0.01
	Na	4.9	24	1
	Cl	8.5	45	20

* uncertainty is dispersion observed on 3 samples of nutrient solution

Table 4. Mineral composition of lettuce shoot, harvested at different phases of vegetation

Nutrients		Treatment 1	Treatment 2	Treatment 3
Macronutrients (% dw)	Ca	1.09±0.03*	0.70±0.02**	0.76±0.02**
	Mg	0.241±0.004	0.235±0.005	0.252±0.004
	K	6.5±0.1	4.0±0.1	5.6±0.1
	P	0.67±0.02	0.50±0.01	0.65±0.02
	S	0.38±0.01	0.40±0.01	0.40±0.01
	N	5.63±0.05	4.94±0.05	5.34±0.02
Micronutrients (mg % dw)	Fe	19±2	12.9±0.8	12±1
	B	2.6±0.1	2.4±0.1	2.6±0.1
	Zn	3.7±0.1	4.3±0.1	4.8±0.2
	Mo	0.23±0.01	0.29±0.01	0.27±0.01
	Mn	8.4±0.3	3.6±0.1	4.6±0.2
	Cu	0.62±0.01	0.75±0.02	0.82±0.02
	Na	34±1	55±2	66±2

* - uncertainty for Treatment 1 was calculated by averaging of errors of Treatment 2 and Treatment 3 as only one sample was taken for analyses for Treatment 1

** - uncertainty for Treatment 2 and Treatment 3 is dispersion observed on 7 samples of lettuce for each treatment

Table 5. Content of elements, obtained from CO_2 and water, in lettuce shoots, harvested at different phases of vegetation (% dw)

Treatment	C	H
Treatment 1	40.5±0.2	5.45±0.05
Treatment 2	42.5±0.2	5.9±0.1
Treatment 3	40.7±0.2	5.63±0.02

Table 6. Mineral composition of lettuce shoot at different phases of vegetation, mg

Nutrients		*Treatment 1		*Treatment 2		*Treatment 3	
		Average per plant	Total for 169 plants	Average per plant	Total for 20 plants	Average per plant	Total for 80 plants
Macro-nutrients	Ca	0.39±0.01	67±2	6.5±0.2	129±4	23±1	1844±49
	Mg	0.087±0.001	14.8±0.2	2.17±0.05	43±1	7.6±0.1	611±10
	K	2.34±0.04	395±7	37±1	735±13	171±3	13658±243
	P	0.24±0.01	41±1	4.6±0.1	92±2	20±1	1577±49
	S	0.137±0.004	23±1	3.7±0.1	74±2	12.1±0.3	970±24
	N	2.04±0.02	345±3	45.5±0.5	910±9	162±1	12955±49
Micro-nutrients	Fe	0.007±0.001	1.2±0.1	0.12±0.01	2.4±0.1	0.37±0.03	30±2
	B	0.00096±0.00004	0.16±0.01	0.022±0.001	0.44±0.02	0.079±0.003	6.3±0.2
	Zn	0.00133±0.00004	0.22±0.01	0.040±0.001	0.79±0.02	0.15±0.01	11.6±0.5
	Mo	0.000084±0.000004	0.014±0.001	0.0027±0.0001	0.053±0.002	0.0082±0.0003	0.66±0.02
	Mn	0.0030±0.0001	0.51±0.02	0.033±0.001	0.66±0.02	0.14±0.01	11.2±0.5
	Cu	0.000225±0.000004	0.038±0.001	0.0069±0.0002	0.138±0.004	0.025±0.001	1.99±0.05
	Na	0.0121±0.0004	2.05±0.07	0.50±0.01	10.1±0.3	2.00±0.05	160±4

Table 7. Estimated accumulation of minerals in rockwool, roots and liquid loop at different phases of lettuce vegetation

Nutrients		*Treatment 1		*Treatment 2 and *Treatment 3		
		Applied with nutrient solution, mg	Estimated accumulation in rockwool, roots and trays, mg	Applied with nutrient solution, g	Left in nutrient solution, g	Estimated accumulation in rockwool, roots and liquid loop, g
Macro-nutrients	Ca	648	581	140	52	86
	Mg	93	78	20	9	10
	K	926	531	240	86	140
	P	231	190	50	9	40
	S	278	255	60	22	37
	N	1018	673	228	77	137
Micro-nutrients	Fe	21	20	4	2	3
	B	0.9	0.8	0.2	0.1	0.1
	Zn	0.9	0.7	0.2	0.1	0.05
	Mo	0.28	0.26	0.06	<0.006 - 0.01	N/A
	Mn	1.4	0.9	0.3	0.1	0.2
	Cu	0.23	0.19	0.05	0.02	0.03
	Na	23	21	5	4	1

15.6 Growth test conclusions

Even though this crop test was the first test after HPC1 installation in the MELiSSA Pilot Plant and lettuce was used as bioindicator of environmental conditions inside the chamber, several conclusions can be drawn from the crop test.

Overall HPC1 performance was good over an eleven day period of closure with a full lettuce crop. The main concern was with the control of humidity. Humidity control can be easily corrected through improvements in chilled water source temperature stability and control system tuning. As the Argus control system was temporary, humidity control will be retested and validated in the following tests with Schneider PLC (to be reported in TN96.11).

The decrease of plant biomass observed in module B, especially for lettuce grown in tray 12-14, while statistically insignificant in variation, show a need to further evaluate environmental conditions along the chamber to detect and to try to evaluate potential reasons for plants growth inhibition. In particular more detailed measurements are required along the chamber since temperature, humidity and PAR sensors are located only in a few points of the chamber.

Accumulation of minerals in the nutrient solution by the end of the test showed that more frequent change of the solution may be required in the further tests. However for life support system, where quantity of wastes should be minimized, this is not an optimal solution. Mineral composition of nutrient solution should be analyzed at least on weekly basis and addition of salts should be done according to analytical results and plants requirements. Also, a reusable alternative to the rockwool substrate should be tested and eventually utilized for future plant cultivation.

In order to avoid recurrences in data loss as seen in this test, checking of system operation on a regular basis will be required during crop campaigns, including weekends, either directly by attending the laboratory or remotely through networked data connections. In particular, the detection of power supply failure is considered one of the most critical points to be addressed.

16 General Conclusions

The results of Functional Testing of HPC1 showed satisfactory operation of all HCP1 subsystems although some deviations from nominal conditions took place. However those deviations were justified and the chamber was considered ready for further subsystem performance test under full operational conditions.

Crop testing in HPC1 resulted in an excellent crop of lettuce in terms of color, shape and average biomass. Some deviations in plant growth were observed, but these were statistically insignificant and will be monitored in future testing over longer growing periods. Specifically, module B of HPC1 showed a decrease of plants biomass that could be an indicator of heterogeneity of environmental conditions in the chamber

The control of humidity did not perform well due to instability of chilled water temperature and a lack of time to complete control system tuning. These assumptions should be validated in the following tests with Schneider PLC.

In general, the comparison of the obtained results during the crop test performed with the data obtained in UoG in the same chamber (although with a shorter duration of the test) shows an acceptable reproduction of the behaviour demonstrated before the shipment, with the exception of the humidity control (already discussed), and the deviation of the measured parameters respect to the setpoint was even improved respect to the results obtained in UoG (see TN85.83 "Prototype Test Results", section 3.3).

17 Complementary tests : open and closed loop tests with ARGUS controller

17.1 Introduction

UoG tested the HPC1 chamber in the MPP (MELiSSA Pilot Plant) to demonstrate the performance and adherence to the environmental control specifications.
The controller tested is the Argus Controller, a black box control system for the final user.
As the Control System (CS) will be replaced by Schneider Hardware with Sherpa's conrol subroutines. it was decided to take advantage of the testing of the HPC1 with the Argus system to perform simple Open and Closed Loop tests, in order that Sherpa can prepare the tuning of the controllers for the Argus replacement by Schneider controller.

The Black Box HPC control will be replaced with a White Box control system.

The main objective of the control is to pilot the lights. CO_2 concentration. temperature. humidity. conductivity and pH in the plant compartment.

The objective was to perform and analyse the proposed complementary tests (see TN96.2 "Functional test Plan and Test protocols with Argus controller", Section 15.6)

Planned tests		Implemented	Dates of test
Open Loop Tests	EC control	N	
	pH control	N	
	CO_2 control	N	
	T & RH control	Y	April 2nd –April 3rd
Closed loop tests without crops	EC without crops	Y	April 1st
	pH without crops	N	
	CO_2 without crops	Y	April 2nd
	T & RH without crops	N	
Closed loop tests with crops	CO_2 with crops	Y	April 23rd – April 29th
	T & RH with crops	Y	April 23rd – April 29th

Table 8. Summary of complementary tests with Argus controller

The complete set of graphs are annexed to this document in Appendix 2 (corresponding to the document "Sherpa CIVb ArgusTests April09")

Some tests were not performed (N in the Implemented column). EC/pH and CO2 tests were more relevant to be done in closed loop in order to evaluate the performance, as open loop tests will be performed with the Schneider Control System.

The main conclusions are pointed out within the description of each test.

17.2 Open Loop on Heat Exchangers valves

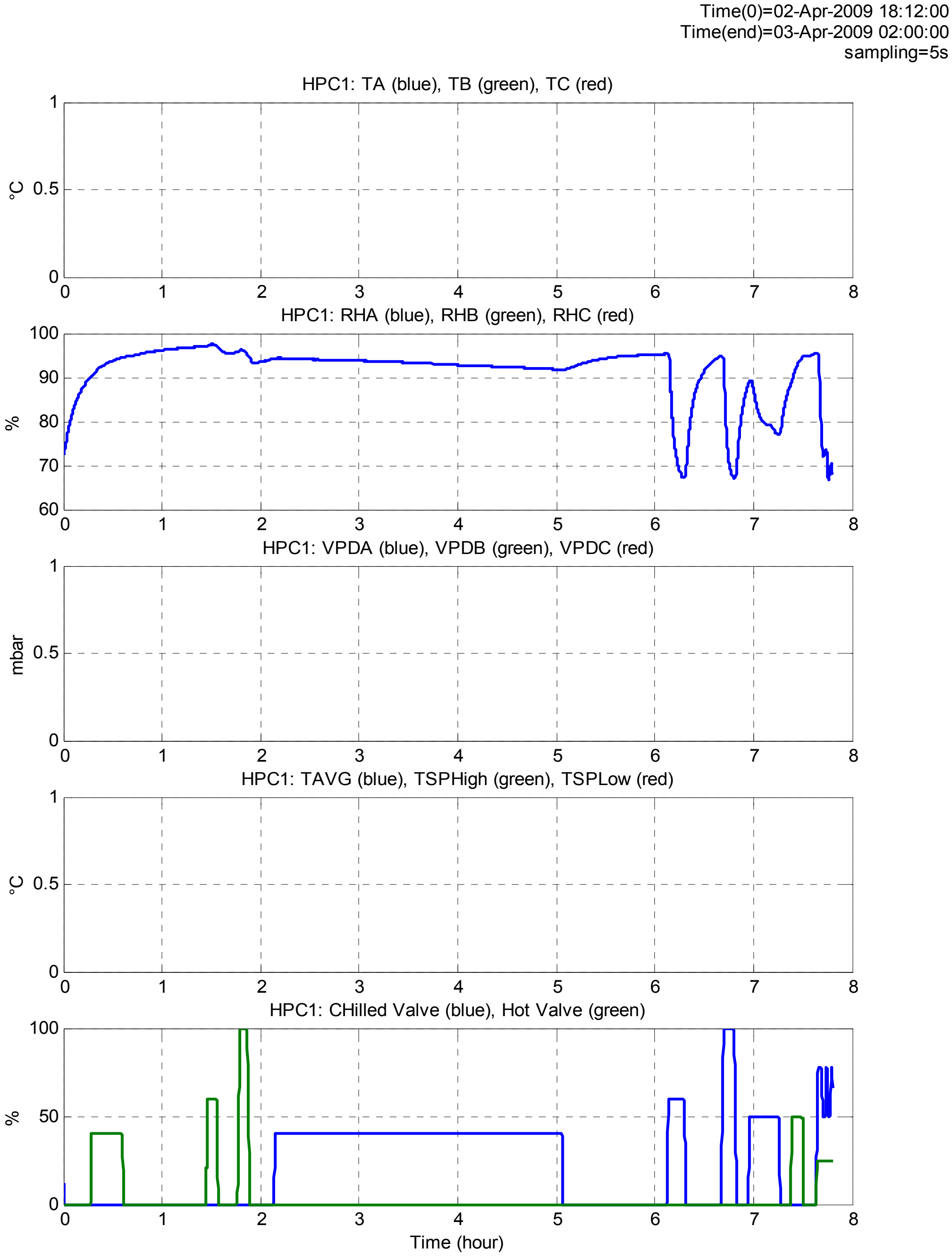
No Lights.
Qair = 20 m/s

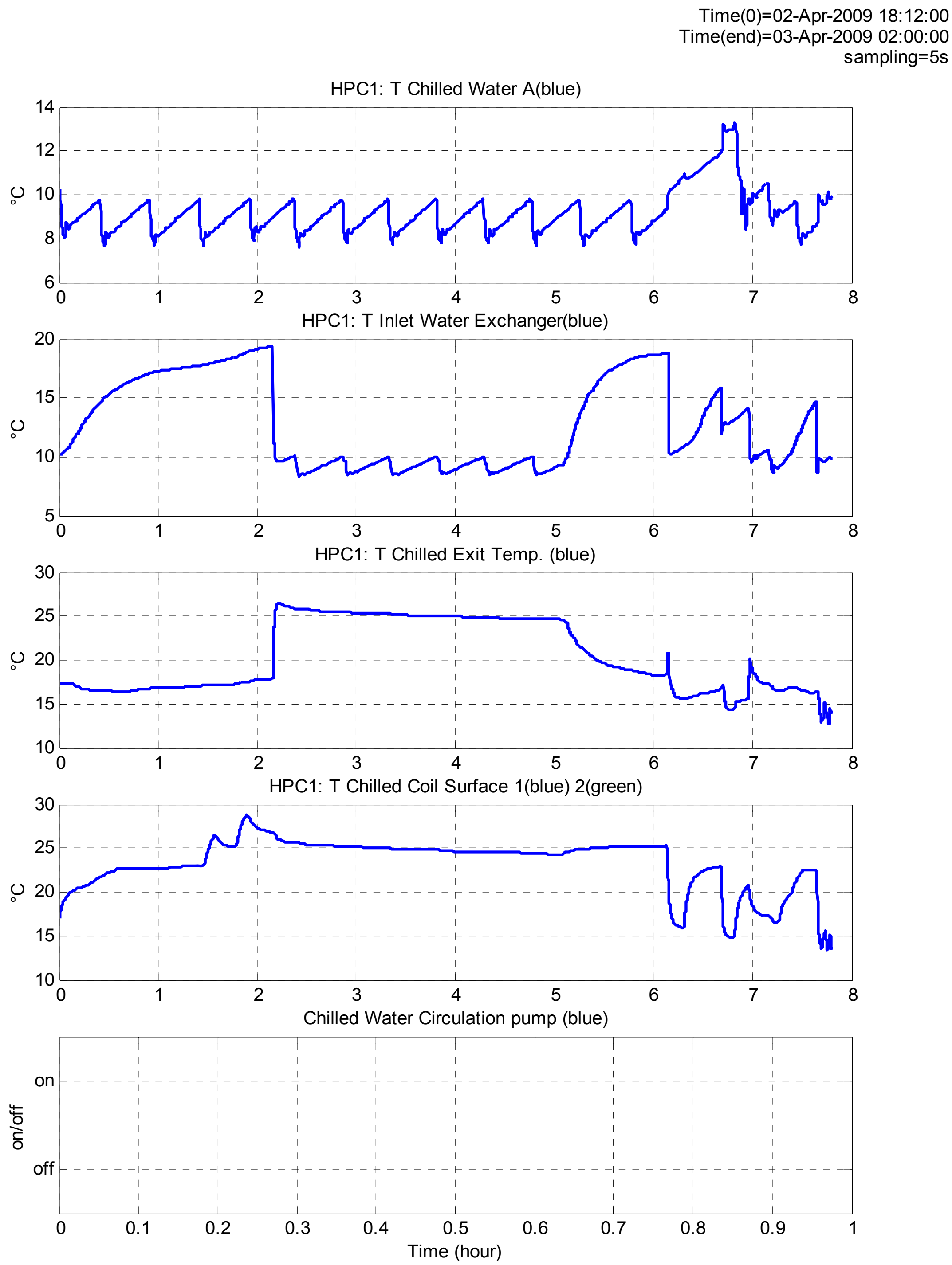
Important fluctuation of source chilled water (between 8 and 10 °C)
Average temperature in the chamber is missing

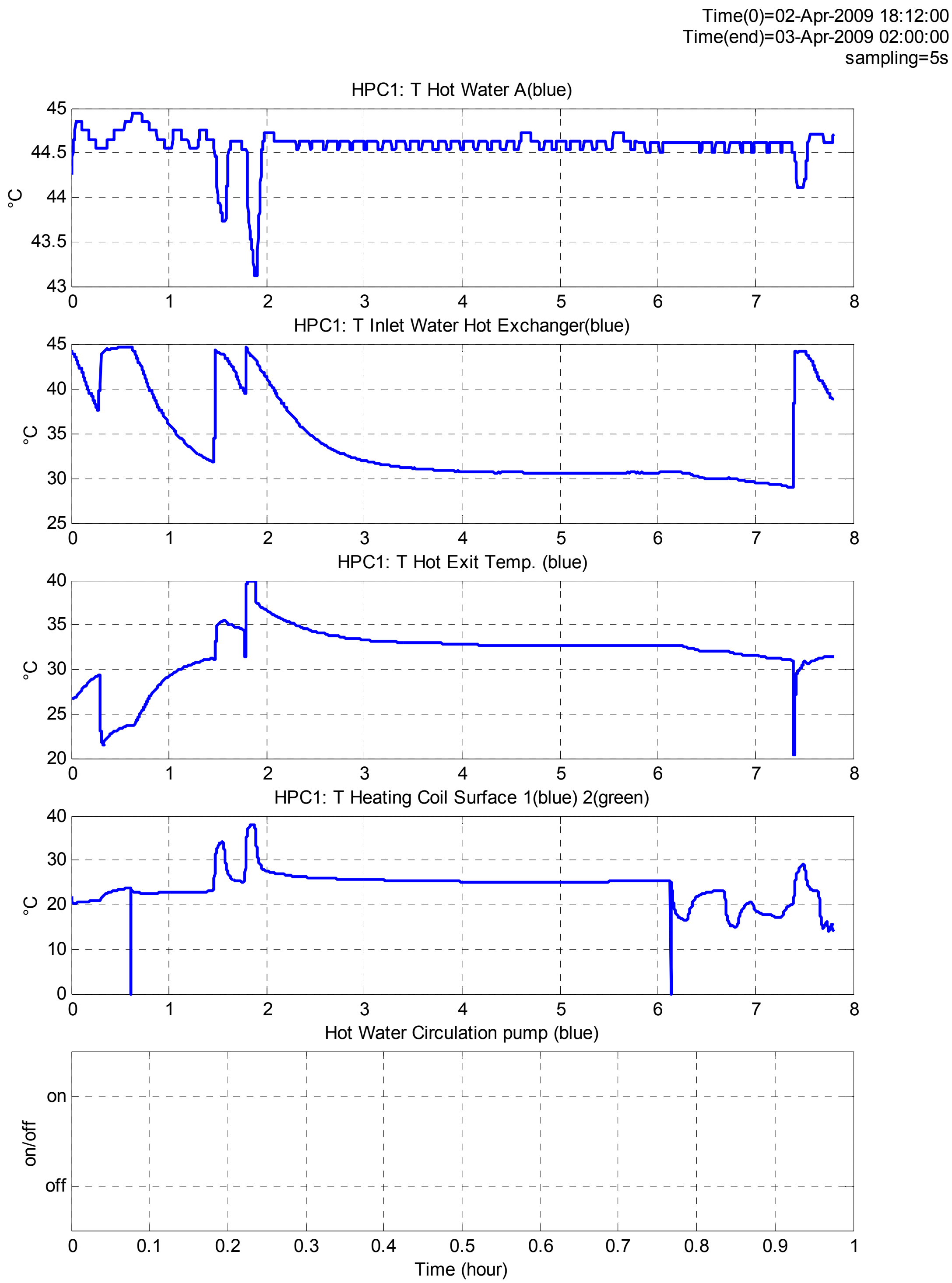
The test should be re performed with Schneider PLC.
The position of the sensor at the output of the exchangers can be changed for control improvement. It will be better to have Air outlet temperature for each exchanger.

The objective of the test was to evaluate the behaviour of T and RH with specific positions of hot and cold valves.

Some data are missing because not recorded or exported in the Argus system.


Time(0)=02-Apr-2009 18:12:00
Time(end)=03-Apr-2009 02:00:00
sampling=5s
HPC1: TA (blue), TB (green), TC (red)
°C
HPC1: RHA (blue), RHB (green), RHC (red)
%
HPC1: VPDA (blue), VPDB (green), VPDC (red)
mbar
HPC1: TAVG (blue), TSPHigh (green), TSPLow (red)
°C
HPC1: CHilled Valve (blue), Hot Valve (green)
%
Time (hour)

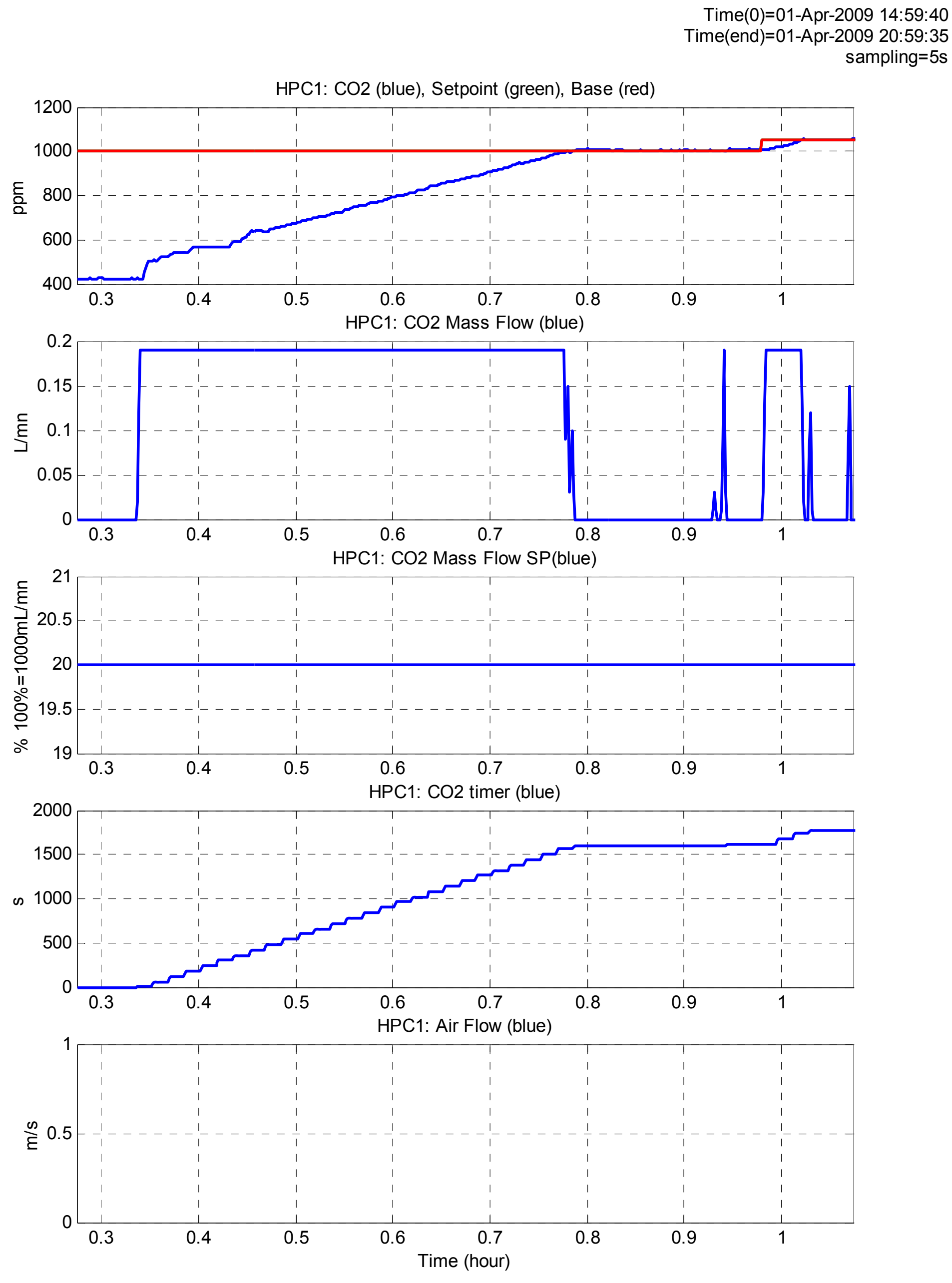

Time(0)=02-Apr-2009 18:12:00
Time(end)=03-Apr-2009 02:00:00
sampling=5s
HPC1: T Chilled Water A(blue)
°C
HPC1: T Inlet Water Exchanger(blue)
°C
HPC1: T Chilled Exit Temp. (blue)
°C
HPC1: T Chilled Coil Surface 1(blue) 2(green)
°C
Chilled Water Circulation pump (blue)
on/off
on
off
Time (hour)



Figures 24, 25 and 26. Trend of the open loop test on heat Exchangers valves and measurements related (T: temperature; RH: relative humidity)

17.3 Closed Loop CO2 April 1st

The test demonstrates clearly the link between CO_2 addition and CO_2 measurement.

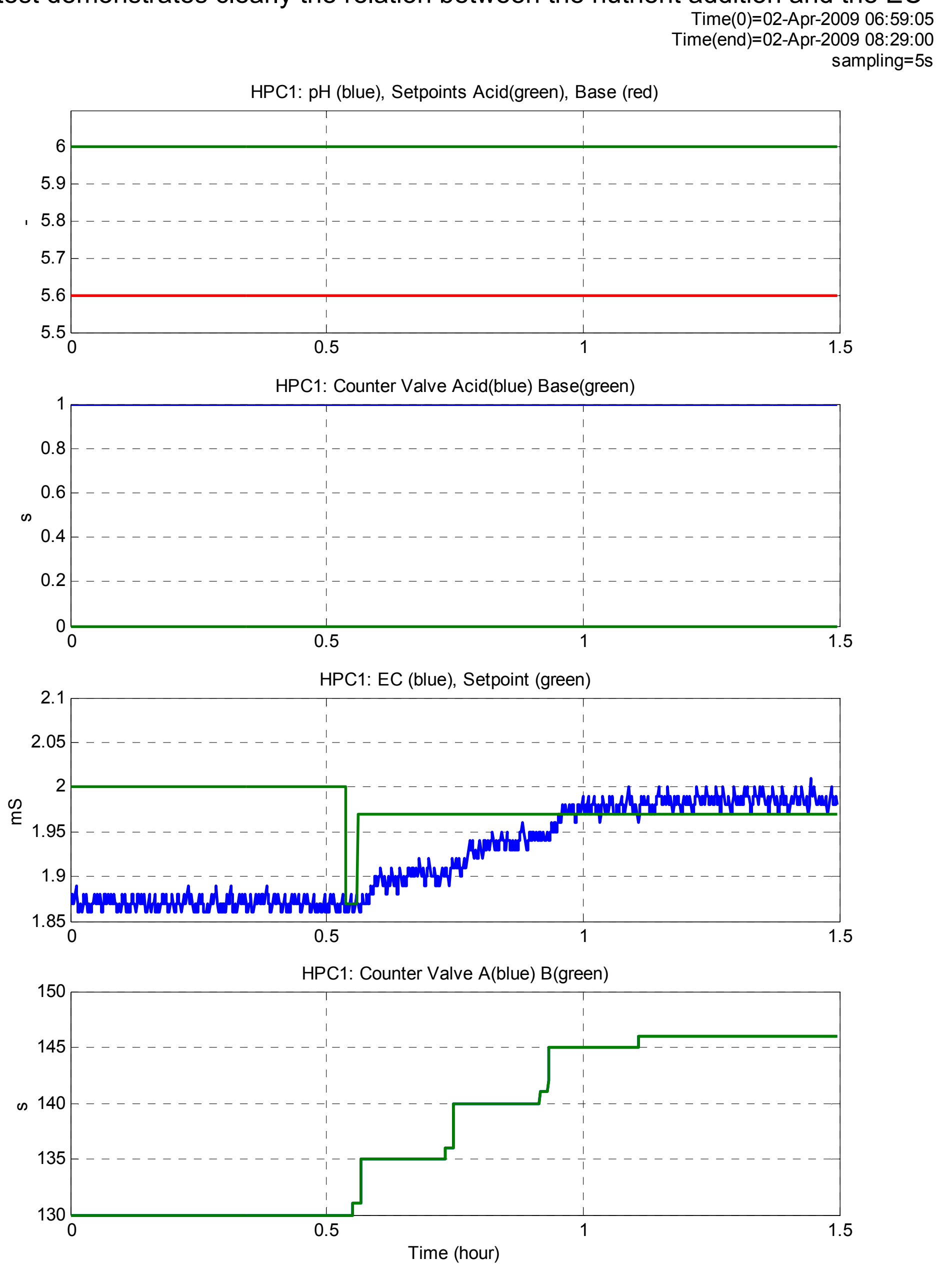


HPC1 : ClosedLoopCO2_April1.xls

Figure 27: Trend of the Close loop test on CO_2 (1st April 2009)

17.4 Closed Loop EC April 2nd

The test demonstrates clearly the relation between the nutrient addition and the EC



HPC1 : ClosedLoopECpH_April2.xls

Figure 28: Trend of the Closed loop test on Electroconductivity (2nd April 2009)

17.5 Closed Loop Tests with crops

All graphs are annexed to this document (Appendinx 2, corresponding to the document "Sherpa C4b ArgusTests April09"). This paragraph presents only general remarks and analysis.

From the tests with crops. we can obtain a “reference” for the next step of the project : tests with the Schneider system.

- Test was performed from April 23 16:00 to April 30 15:00
- Test was interrupted from Saturday 25th 6am to Sunday 26th 8pm. due a power micro cut
- Temperature was over 35 °C in the chamber on Sunday 26th. due to the micro cut power and no control. After inspection, the plants were not damaged.

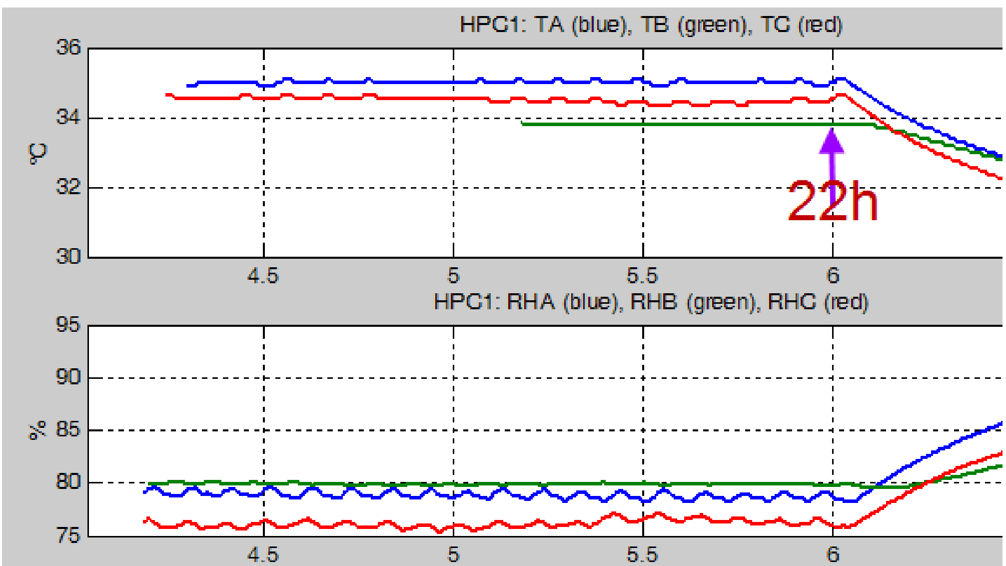


Figure 29. Change of the conditions of the HPC (temperature and humidity) at the day-night shift

<u>Conditions of the tests :</u>

- Air Flow : 20 m/s
- Nutrient Flow : 5.3 L/mn
- Day : between 6 am to 22 pm
  - 2 Temperature set points : range 25.6 26.0 °C
- Night : between 22 pm and 6 am
  - 2 Temperature set point : range 19.95 20.35 °C

(Remark : the “Zone B” sensor is installed inside the wall of the chamber and should not be taken into account for the control. Only “A” and “C” zone are controlled)

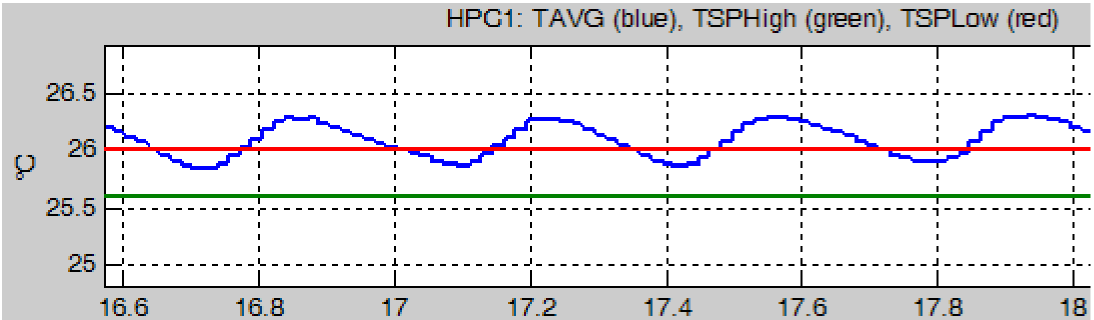


Figure 30: April 28th. 9 am (day). Controlled Temp (blue) at 26 °C

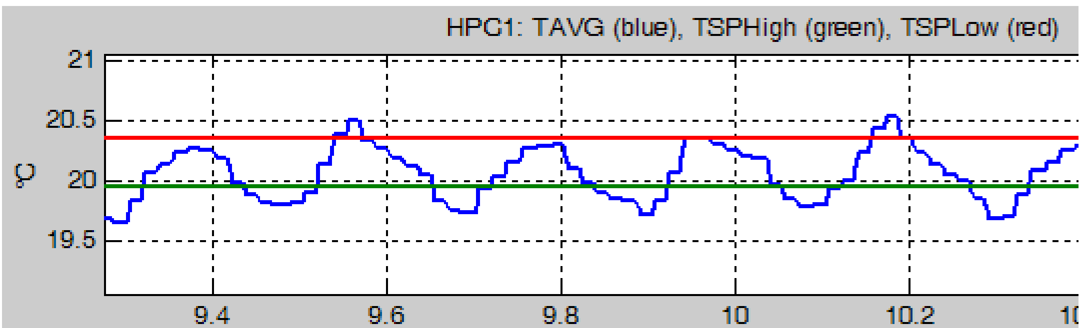


Figure 31 : April 28th 2am (night). Controlled temp (blue) at 20°C

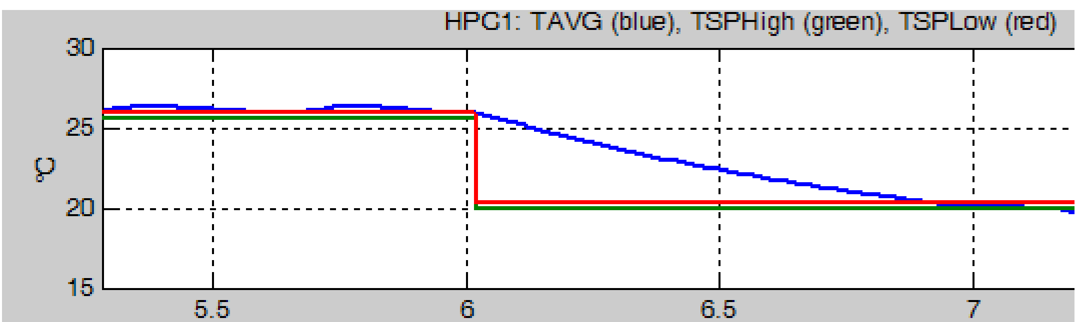


Figure 32 : Day-->Night 29th April. One hour to decrease temp.

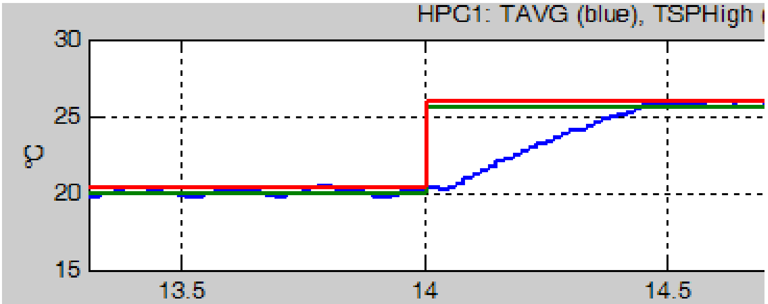


Figure 33: Night-->Day 29thApril. 1/2h to reach the set point

- Humidity is :
  - o day : between 50 and 60 %
  - o night : between 70 and 80 %

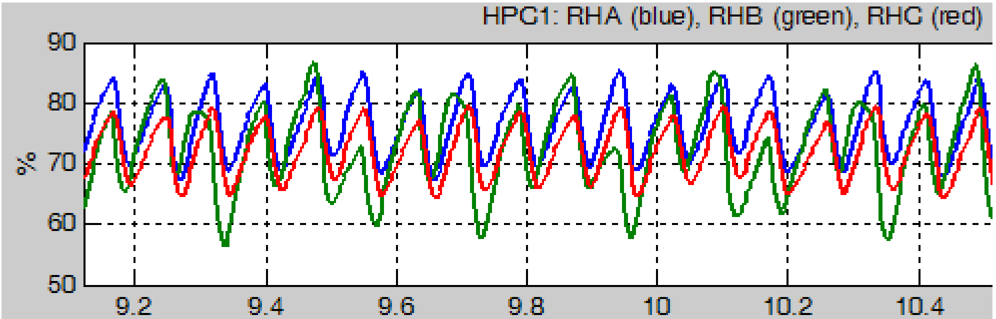


Figure 34: Humidity. during the night

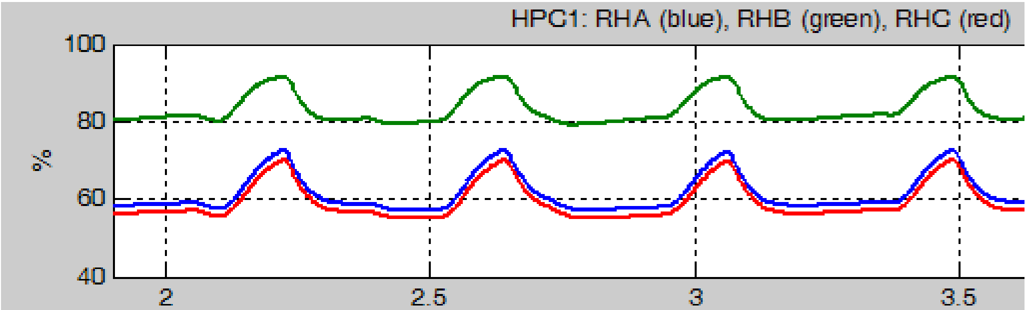


Figure 35: Humidity during the day

- CO_2 set point is 1000 ppm

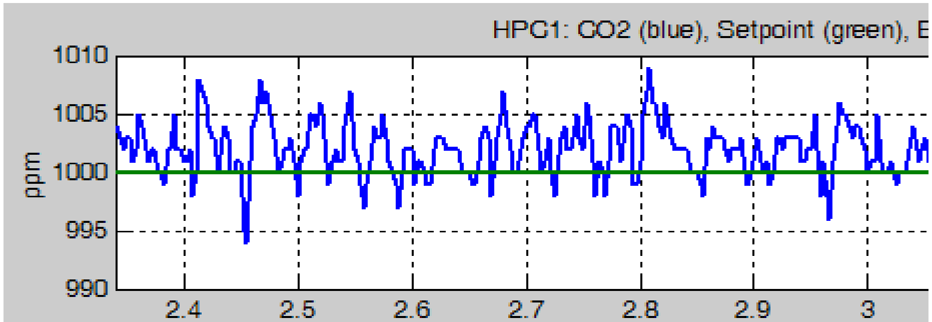


Figure 36: 28th April. day. CO_2 control

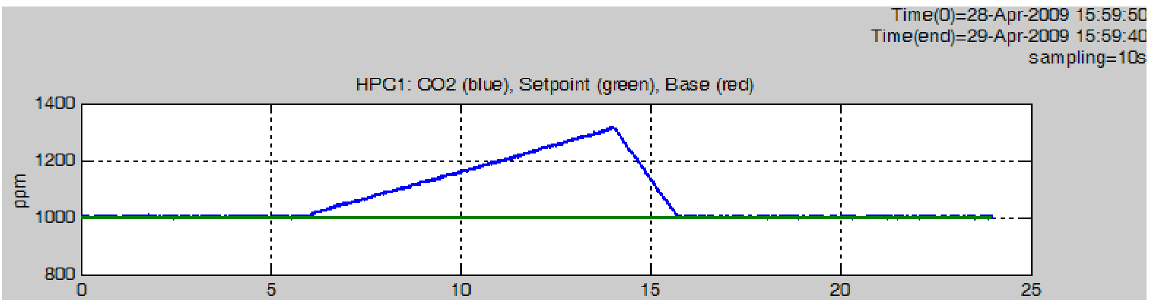
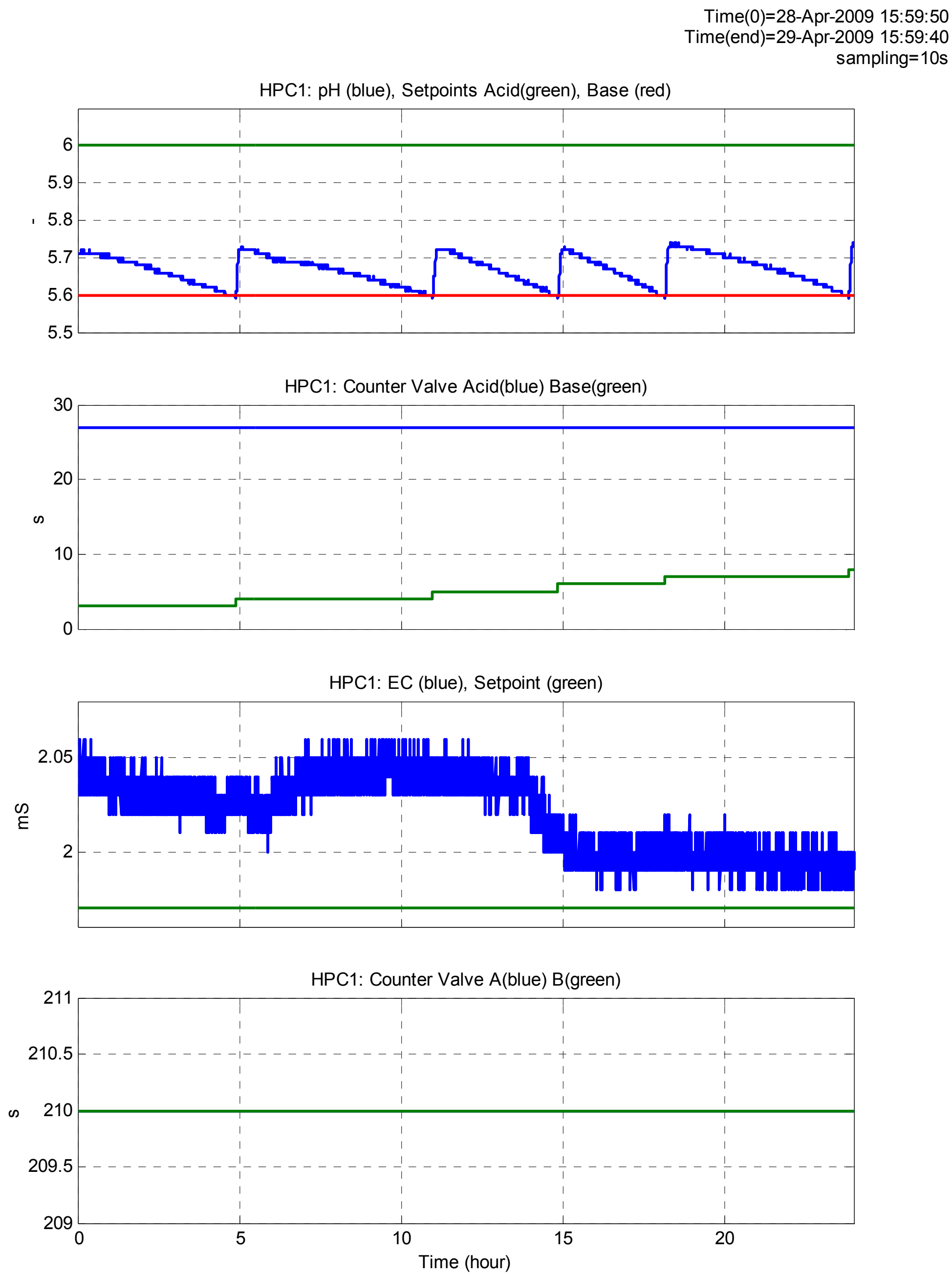


Figure 37: Night 28/29 April. CO_2 production

- EC set point : 1.97 ppm
- pH set point : between 5.6 and 6.0

There is an acidification of the nutrient with the crop : .0.1 in 5 hours.
The pH is maintained between 5.6 and 5.7



HPC1 : HPC_CROPTEST_April28_24h.xls

Figure 128: 28 April. pH and EC evolution

Other remark

Water Inlet Temperature is not stable.

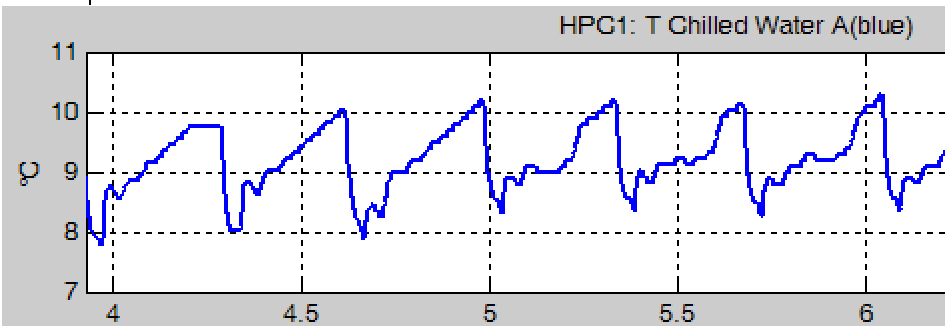


Figure 39: Chilled Water temperature evolution

18 APPENDIX 1 - Chronology of events for seedling establishment

1) **8.04 Day 0**

Preliminary safe treatment (moistening) of 2 Rockwool sheets. Sowing of 196 seeds into 2 Rockwool sheets. Photographing. Placement of the trays with Rockwool sheets into the HPC1. Lighting was enabled. 2 lamps per each module were on (1HPS and 1 MH). PAR intensity on the trays level was 380-420 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Temperature set point for the day time was 20°C. but actual temperature was 23°C. Night temperature set point was 20°C.

2) **9.04 Day 1**
Measurement of irrigation solution (½ strength nutrient solution) pH. it´s 5.87. Watering of each Rockwool sheet with 800 mL of the solution. Photographing.

3) **10.04 Day 2**
More than 60 percent emergence could be observed. the plastic cover of each tray was removed. t=21.6°C. Photographing.

4) **11.04 Day 3 (Saturday)**
From 6 a.m. the blower in the chamber did not work. Average temperature in the chamber was 34.6°C at day time.

5) **12.04 Day 4 (Sunday)**

Temperature in the chamber at day time was 34.6°C until 15:00. At 15:00 the lamps were switched off and the plants were taken out of the chamber. Watering of the plants with 500 mL of solution in total for both Rockwool sheets. Photographing. The trays were introduced into the incubator. PAR intensity in the incubator on the plants level was 25-50 $\mu mol \cdot m^{-2} \cdot s^{-1}$. temperature was 24°C.

6) **13.04 Day 5**
Plants were maintained in the incubator.

7) **14.04 Day 6**
At 10:00 a.m the trays with the plants were placed back into the chamber. t=21°C. 2 lamps per each module on. PAR intensity on the trays level was 380-420 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Photographing. Measurement of the solution pH. it´s 5.82. Watering of each Rockwool sheet with 800 mL of solution.

8) **15.04 Day 7**
Photographing.
9) **16.04 Day 8**
Photographing. Watering of each Rockwool sheet with 900 mL of nutrient solution.

10) **17.04 Day 9**

At 10:15 3d lamp in each module of the chamber was switched on. day temperature set points: heating was 25.8°C. cooling was 26.2°C. Night temperature control enabled.
At 11:28 day temperature set points were changed: heating was 25.6°C. cooling was 26.0°C as temperature in module A and module C was higher than 26.0°C.
At 12:15 the trays were dislocated from module A to module C since temperature in module C was lower than in module A (25.3°C and 26.8°C respectively) and PAR intensity was higher (630 $\mu mol \cdot m^{-2} \cdot s^{-1}$ in module C and 540 $\mu mol \cdot m^{-2} \cdot s^{-1}$ in module A).
At 12:25 interior and exterior doors were closed. Enabled CO_2 control. CO_2 setpoint 1000 ppm. MFC setpoint – 20%.
At 15:30 activated circulation of the nutrient solution in the chamber in order to increase relative humidity (it was below 60%) and to decrease VPD (it was higher than 14 mb). The doors were opened in order to move the trays for solution recirculation.
At 17:05 CO_2 control was enabled again.

11) **18.04 Day 10 (Saturday)**

Chamber was closed. control system was enabled.

12) **19.04 Day 11 (Sunday)**
Chamber was closed. control system was enabled.

13) **20.04 Day 12**

At 9:32 CO_2 control was disabled. The chamber was opened. photographing of the plants. In one of the trays half of Rockwool sheet was contaminated with algae. In the second tray beginning of contamination was observed. Measurement of the solution pH. it´s 5.83. Watering of the plants with the solution. approximately 1L per each tray.
At 16:36 the chamber was closed and CO_2 control was enabled.

14) **21.04 Day 13**
Chamber was closed. control system was enabled.

15) **22.04 Day 14**

At 14:40 CO_2 control was disabled. the chamber was opened. Watering of the plants with the solution. 900 mL per each tray. Photographing. The plants were taken out of the chamber.
At 15:00 the chamber was closed and CO_2 control was enabled in order to check CO_2 leakage in the chamber.
At 19:11 nutrient pump was deactivated.

16) **23.04 Day 15**

Beginning of 1-week crop test.

19 APPENDIX 2 – Lettuce raw data

Fresh and dry weight of lettuce leaves, harvested after 7 days of closure (30.04.2009)				
# of tray	# of plant	Fresh weight, g	# of sample for lyophilization	Dry weight, g
1	3	8.70	1	2.90
2	3	11.71		
3	3	10.99		
4	3	12.79	2	3.02
5	3	6.77		
6	3	12.39		
7	3	10.49	3	2.77
8	3	9.84		
9	3	7.80		
10	3	8.39	4	2.28
11	3	8.12		
12	3	5.48		
13	3	6.22	5	2.48
14	3	9.34		
15	3	8.89		
16	3	9.17	6	3.21
17	3	10.86		
18	3	13.56		
19	3	9.35	7	1.77
20	3	10.29		

Dry weight of lettuce leaves after lyophilization, harvested after 11 days of closure (4.05.2009)			
# of tray	# of plant	# of sample for lyophilization	Dry weight, g
1	4	1	10.52
2	2		
3	4		
4	2	2	9.27
5	4		
6	2		
7	4	3	9.04
8	2		
9	4		
10	2	4	8.64
11	4		
12	2		
13	4	5	7.81
14	2		
15	4		
16	2	6	9.68
17	4		
18	2		
19	4	7	5.69
20	2		

Fresh and dry weight of lettuce leaves after 11 days of closure (harvested on 4.05.2009)			
# of tray	**# of plant**	**Fresh weight, g**	**Dry weight, g**
1	1	29.3	2.25
	2	14.53	1.17
	4	44.19	
	5	37.07	0.95
2	1	47.77	3.04
	2	54.16	
	4	52.73	3.51
	5	38.23	2.37
3	1	47.26	3.27
	2	41.44	2.8
	4	50.21	
	5	52.16	3.32
4	1	52.54	3.55
	2	31.89	
	4	49.34	3.24
	5	41.47	2.84
5	1	41.9	2.78
	2	47.48	3.29
	4	42.18	
	5	50.82	3.53
6	1	39.01	2.59
	2	42.51	
	4	49.09	3.28
	5	55.56	3.72
7	1	33.42	2.27
	2	51.65	3.56
	4	47.05	
	5	54.84	3.53
8	1	34.89	2.61
	2	46.55	
	4	38.53	2.85
	5	34.16	2.34
9	1	44.09	3.1
	2	45.26	2.97
	4	33.57	
	5	34.83	2.59
10	1	38.71	2.72
	2	36.87	
	4	39.88	2.61
	5	42.29	2.86
11	1	39.31	2.61
	2	50.61	3.44
	4	51.18	
	5	43.33	2.83
12	1	35.85	2.42
	2	38.15	
	4	37.6	2.68
	5	22.96	1.75
13	1	25.23	1.86
	2	32.99	2.71

	4	41.31	
	5	38.1	2.54
14	1	40.06	2.59
	2	42.49	
	4	34.73	2.84
	5	41.56	2.62
15	1	38.47	2.81
	2	43.12	2.7
	4	39.81	
	5	33.49	2.32
16	1	32.77	2.44
	2	42.17	
	4	48.09	2.97
	5	36.72	2.57
17	1	42.83	2.78
	2	45.54	3.35
	4	50.28	
	5	44.51	2.93
18	1	41.09	2.77
	2	44.4	
	4	48.33	3.03
	5	50.03	3.18
19	1	41.52	2.71
	2	44.18	2.74
	4	50.52	
	5	38.22	2.45
20	1	43.29	2.8
	2	41.29	
	4	35.47	2.4
	5	34.21	2.2

Concentration of minerals and trace elements in the nutrient solution after 11 days of closure (mg/L)															
# of samples	**Ca**	**Mg**	**K**	**Na**	**Cu**	**Mn**	**B**	**Zn**	**Mo**	**Fe**	**P**	**S**	**Cl**	**N-NO_2**	**N-NO_3**	**N-NH_4**
1	267	52	498	23	0.11	0.48	0.42	0.73	<0.04	8	42	125	21	0.02	371	32
2	455	66	615	27	0.14	0.67	0.52	1.00	0.07	17	82	165	85	0.95	579	86
3	254	52	502	23	0.12	0.47	0.42	0.75	<0.04	8	39	123	27	0.02	342	29

Mineral composition of lettuce shoot, harvested at different phases of vegetation														
Treatment	# of samples[4]	Mineral content (% dw)												
		Ca	Mg	K	Na	P	S	N	Fe	B	Zn	Mo	Mn	Cu
[1]Treatment 1	1	1.09	0.24	6.45	0.03	0.67	0.38	5.63	0.02	0.003	0.004	0.0002	0.008	0.001
[2]Treatment 2	1	0.73	0.23	4.22	0.06	0.52	0.39	4.82	0.01	0.002	0.004	0.0003	0.004	0.001
	2	0.71	0.24	3.83	0.06	0.52	0.39	5.05	0.01	0.002	0.004	0.0003	0.004	0.001
	3	0.73	0.25	4.00	0.05	0.53	0.42	5.10	0.01	0.003	0.005	0.0003	0.003	0.001
	4	0.74	0.25	3.92	0.05	0.53	0.44	4.87	0.01	0.003	0.005	0.0003	0.004	0.001
	5	0.67	0.23	3.70	0.05	0.45	0.39	4.89	0.01	0.002	0.004	0.0003	0.003	0.001
	6	0.72	0.24	4.22	0.05	0.51	0.40	4.79	0.02	0.003	0.004	0.0003	0.004	0.001
	7	0.63	0.21	4.03	0.05	0.47	0.37	5.09	0.01	0.002	0.004	0.0003	0.003	0.001
[3]Treatment 3	1	0.68	0.23	5.44	0.06	0.63	0.38	5.35	0.01	0.002	0.004	0.0003	0.004	0.001
	2	0.71	0.25	5.32	0.06	0.61	0.38	5.39	0.01	0.002	0.004	0.0002	0.004	0.001
	3	0.75	0.25	5.46	0.07	0.60	0.39	5.28	0.01	0.003	0.005	0.0003	0.004	0.001
	4	0.79	0.26	5.76	0.07	0.66	0.41	5.33	0.01	0.003	0.005	0.0003	0.005	0.001
	5	0.76	0.26	5.62	0.06	0.62	0.39	5.33	0.01	0.003	0.004	0.0003	0.005	0.001
	6	0.81	0.25	6.10	0.07	0.70	0.42	5.23	0.01	0.003	0.005	0.0003	0.005	0.001
	7	0.82	0.27	5.74	0.07	0.72	0.44	5.45	0.02	0.003	0.006	0.0003	0.005	0.001

1. seedlings of lettuce (shoots) in age of 15 days after seeds sowing, the rest of the seedlings (totaled 69) after crop test start up
2. lettuce shoot, located in the central raw along HPC1 (plant 3), harvested after 7 days of crop test
3. lettuce shoot, plant 2 (samples were taken from trays 2,4,6,8,10,12,14,16,18, 20) and plant 4 (samples were taken from trays 1,3,5,7,9,11,13,15,17,19), harvested after 11 days of crop test
4. number of samples corresponds to the number of sample for lyophilization (see tables 1 and 2 of Appendix 8)

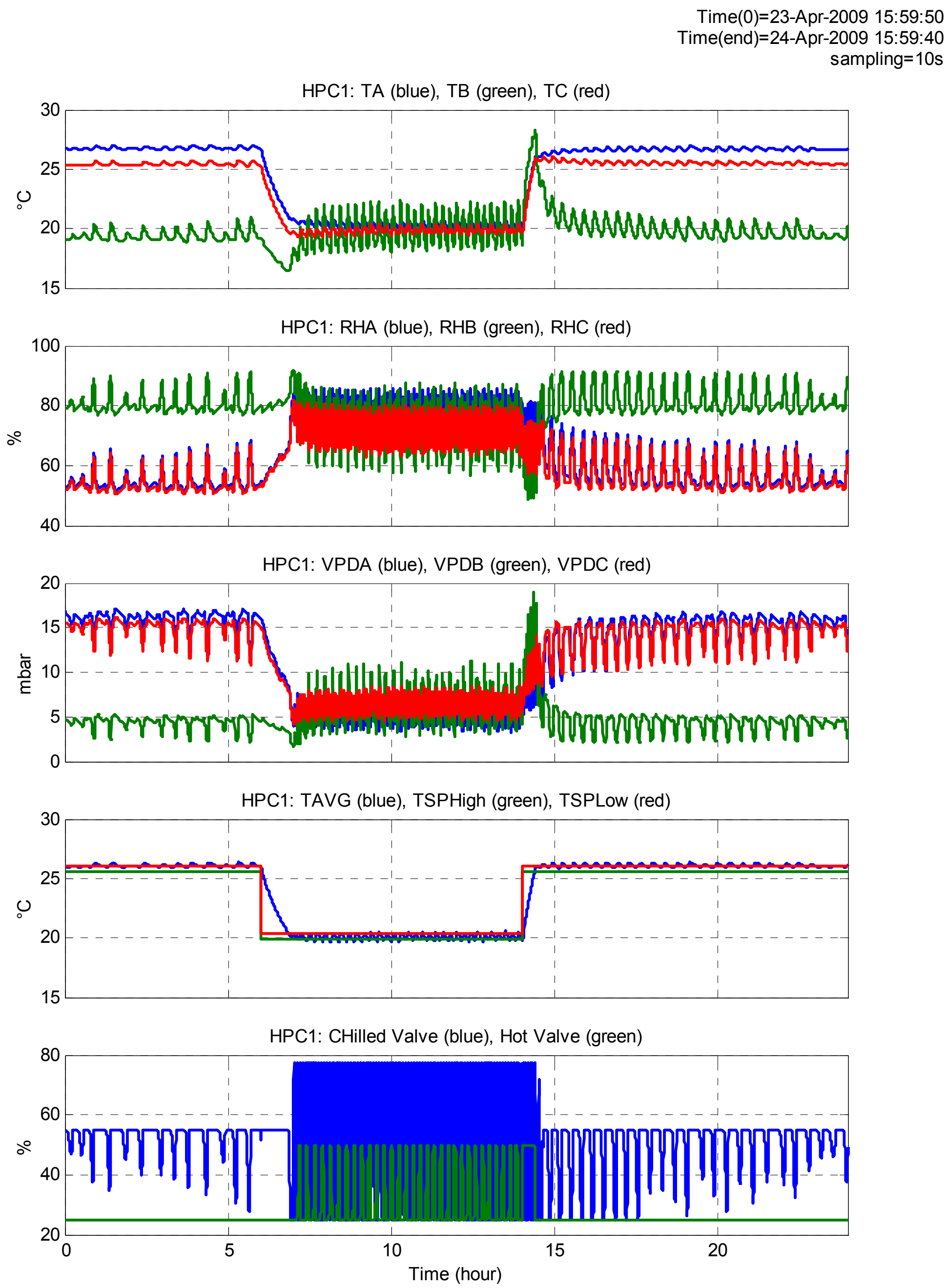
Content of elements, obtained from CO_2 and water, in lettuce shoots, harvested at different phases of vegetation (% dw)

Treatment	# of samples[4]	# of replications	C	H
[1]Treatment 1	1	1	40.32	5.38
		2	40.69	5.49
		3	40.53	5.48
[2]Treatment 2	1	1	42.60	5.85
		2	42.90	5.92
		3	42.76	5.91
	2	1	43.18	5.99
		2	42.99	5.95
		3	43.26	5.99
	3	1	43.12	6.05
		2	42.86	5.93
		3	42.87	5.95
	4	1	42.37	6.04
		2	42.48	6.05
		3	42.27	6.03
	5	1	42.77	6.03
		2	42.87	6.05
		3	42.60	6.01
	6	1	42.12	6.00
		2	42.11	6.04
		3	42.29	6.05
	7	1	42.04	4.97
		2	40.95	5.63
		3	42.15	5.79
[3]Treatment 3	1	1	41.06	5.67
		2	41.04	5.69
		3	40.92	5.73
	2	1	41.65	5.55
		2	41.50	5.69
		3	41.23	5.71
	3	1	40.56	5.53
		2	40.51	5.72
		3	39.79	5.60
	4	1	40.31	5.66
		2	40.55	5.69
		3	40.63	5.62
	5	1	40.99	5.44
		2	40.51	5.61

	3	40.48	5.64
6	1	40.62	5.55
	2	40.94	5.64
	3	40.78	5.62
7	1	40.02	5.63
	2	39.85	5.53
	3	40.26	5.67

20 APPENDIX 3 – Extensive data for 1 week crop test

(From the document "Sherpa C4b ArgusTests April09")



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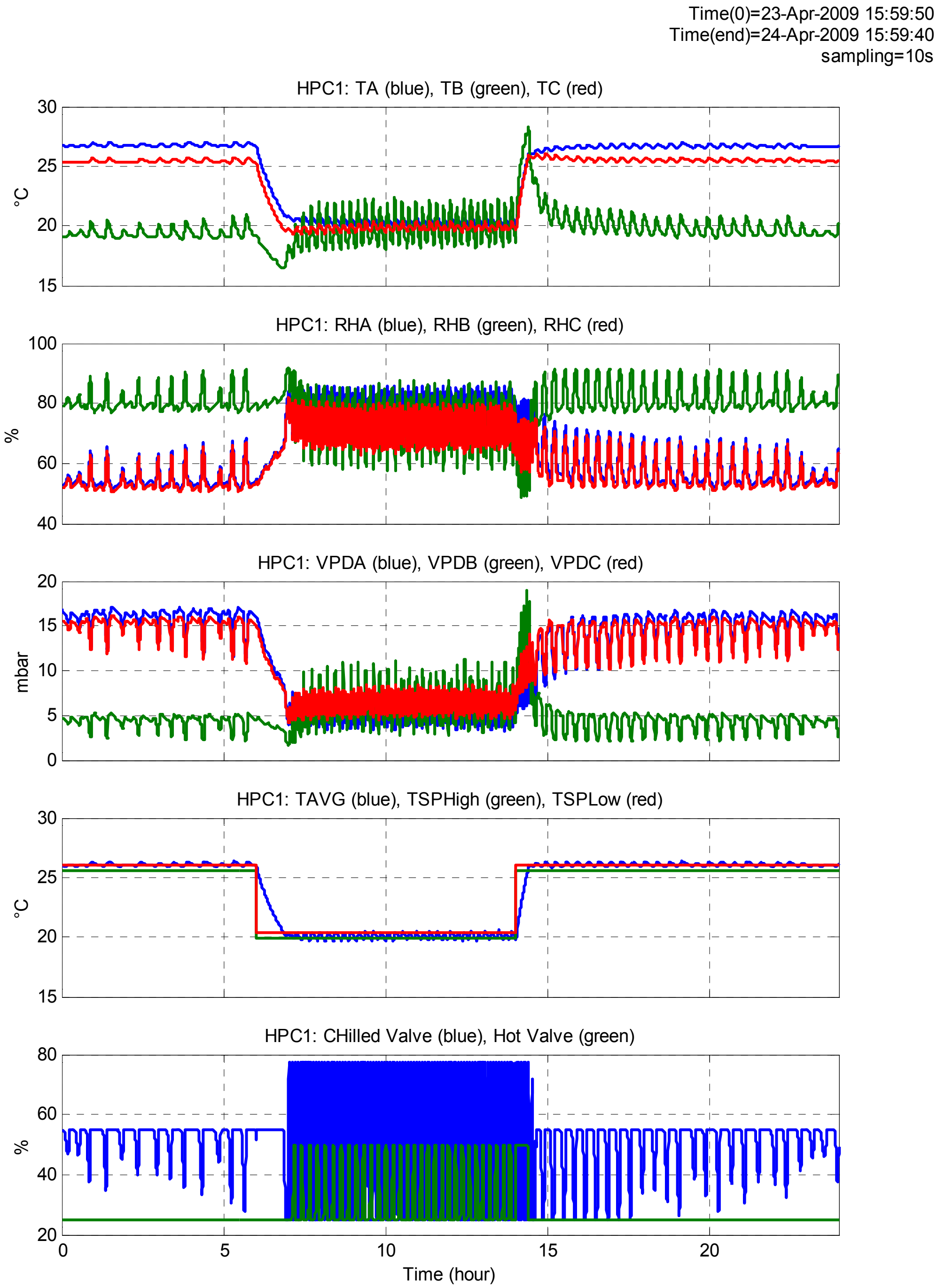

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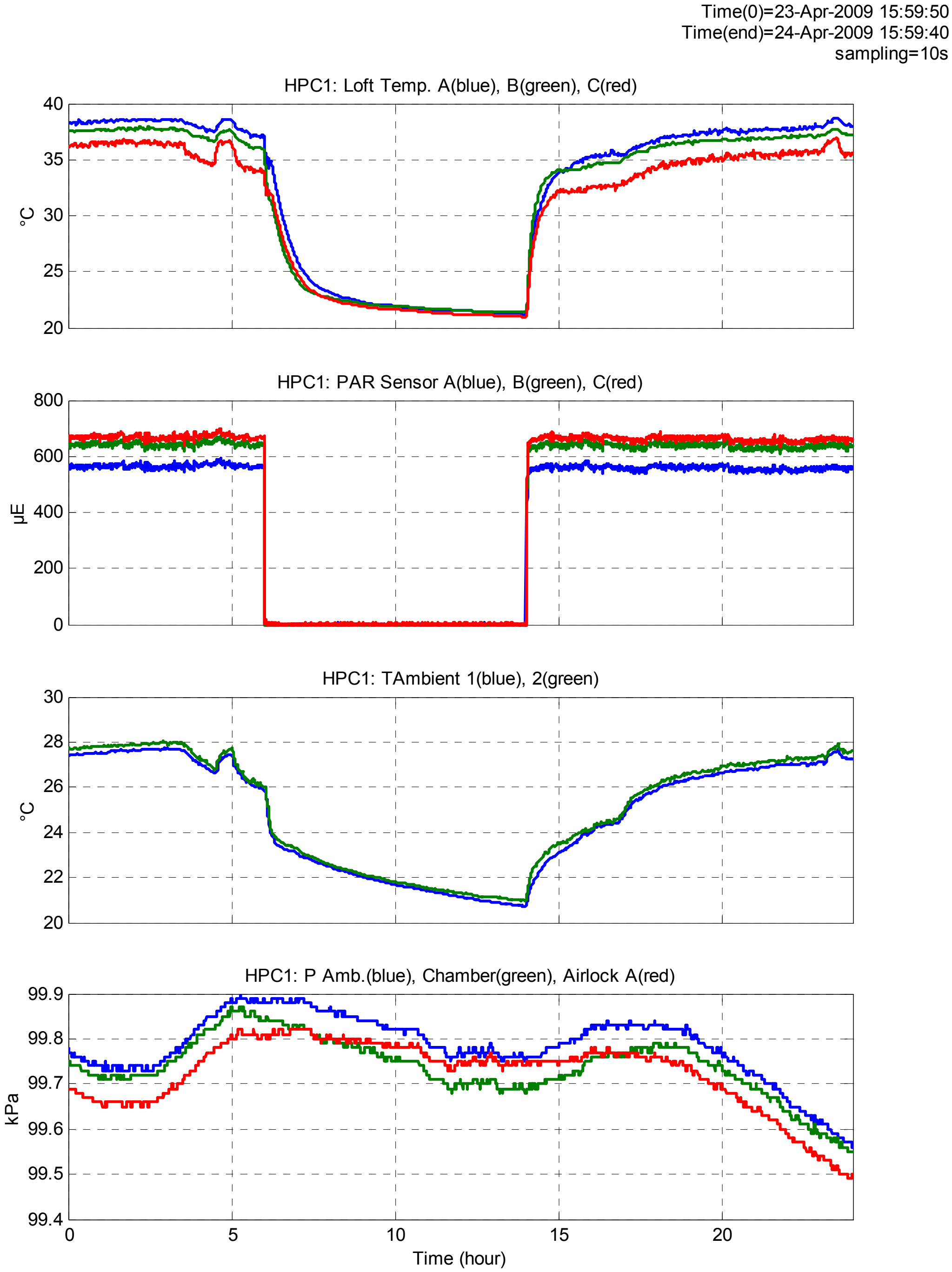

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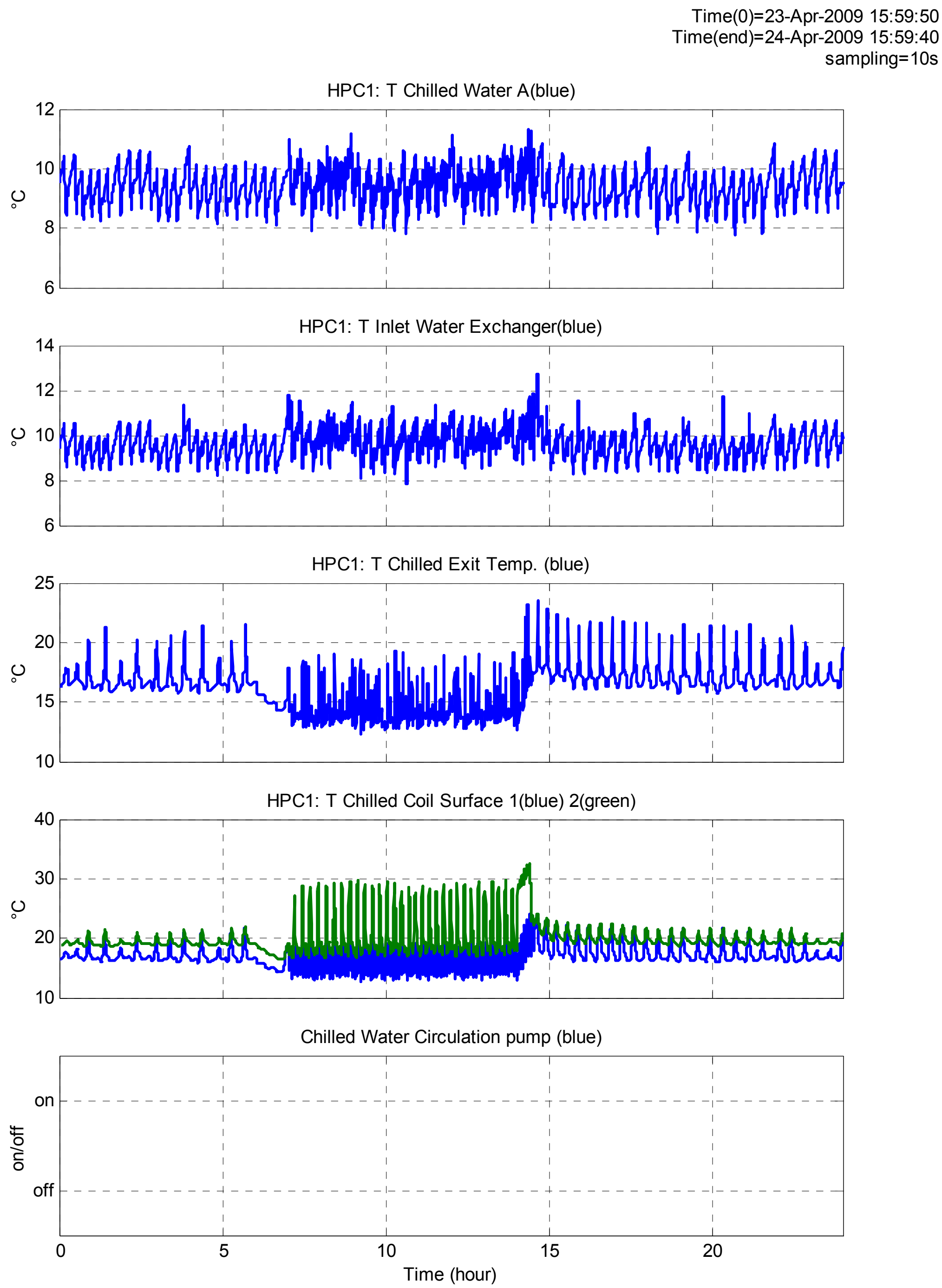

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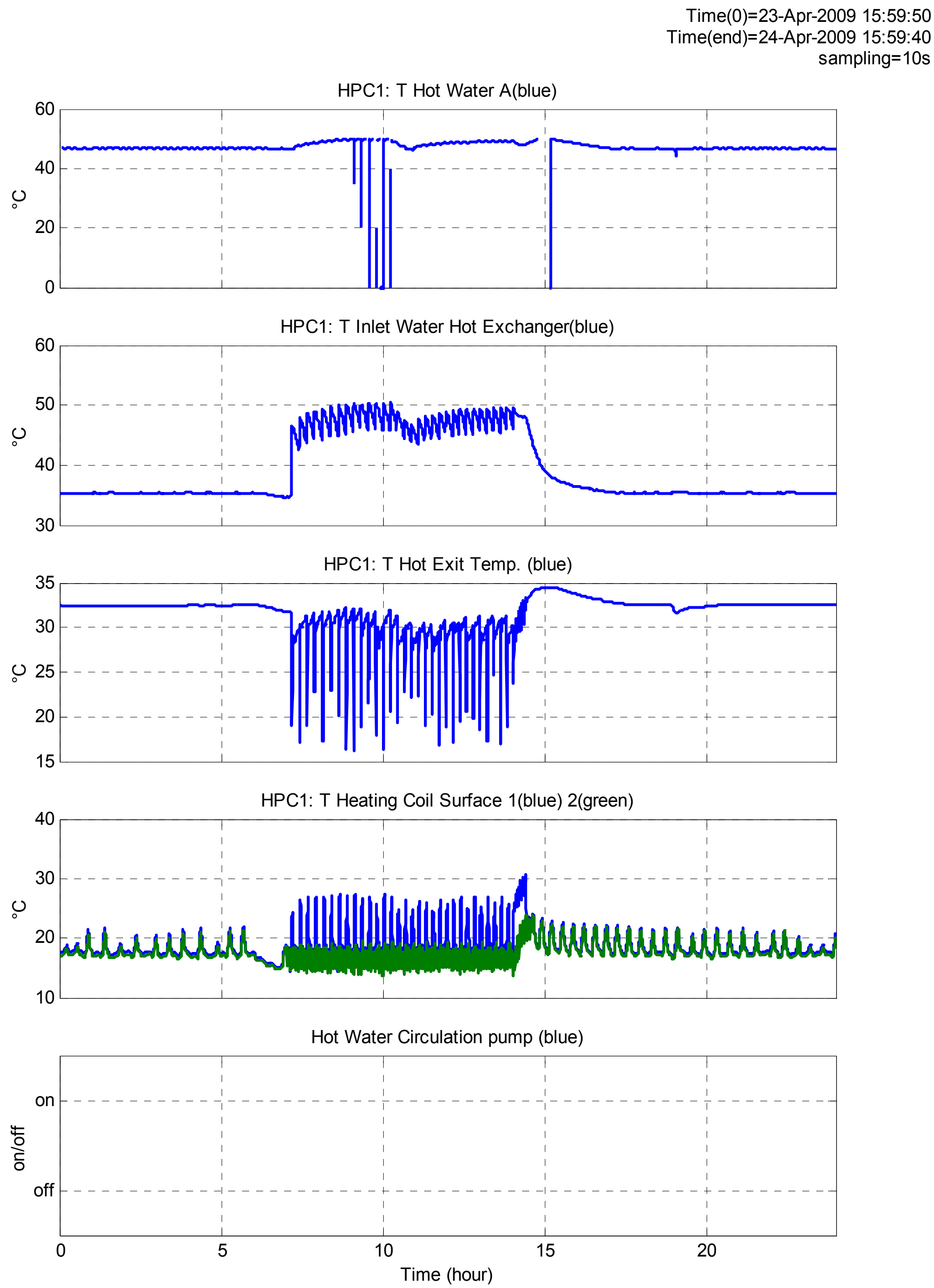

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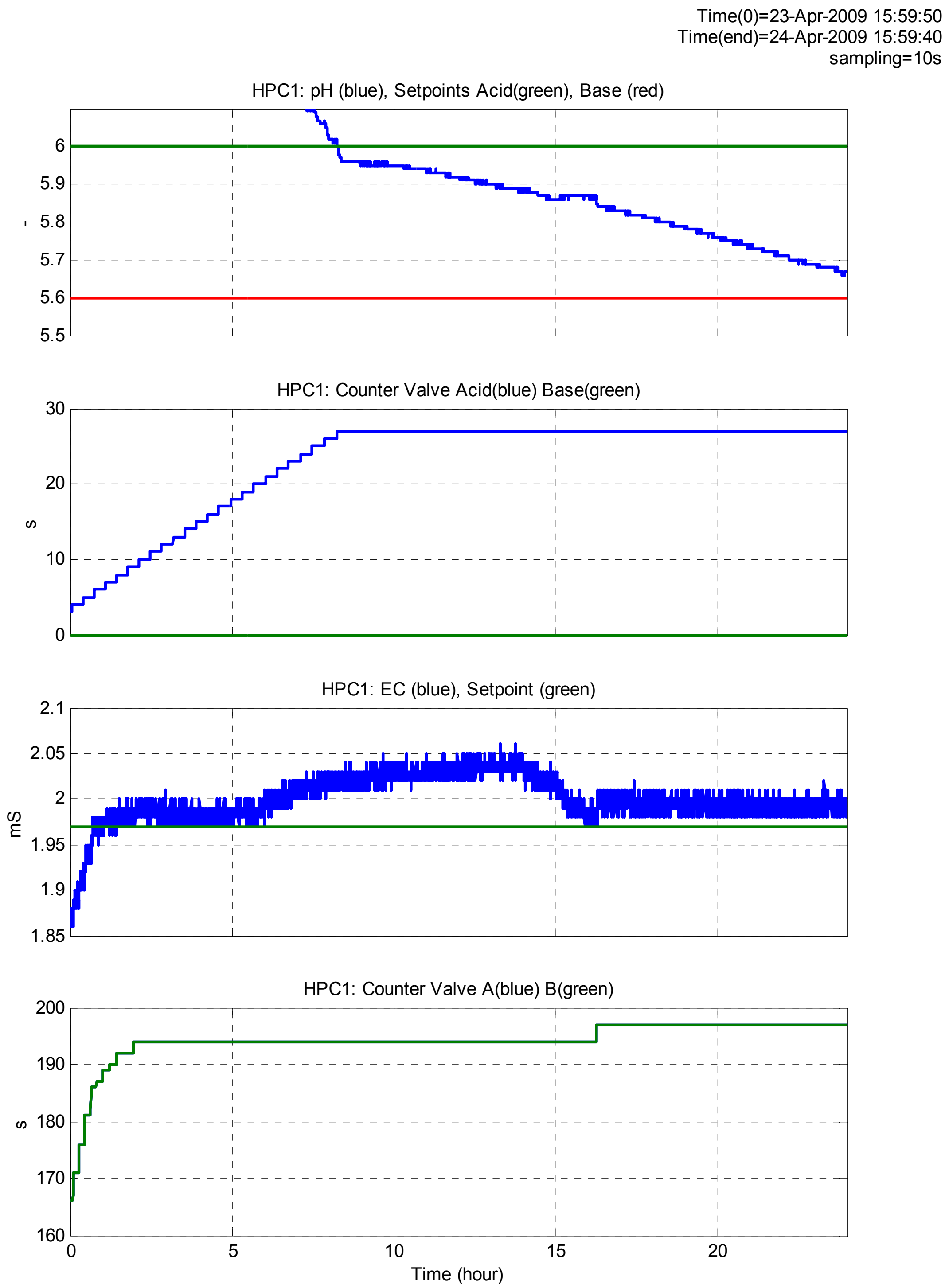

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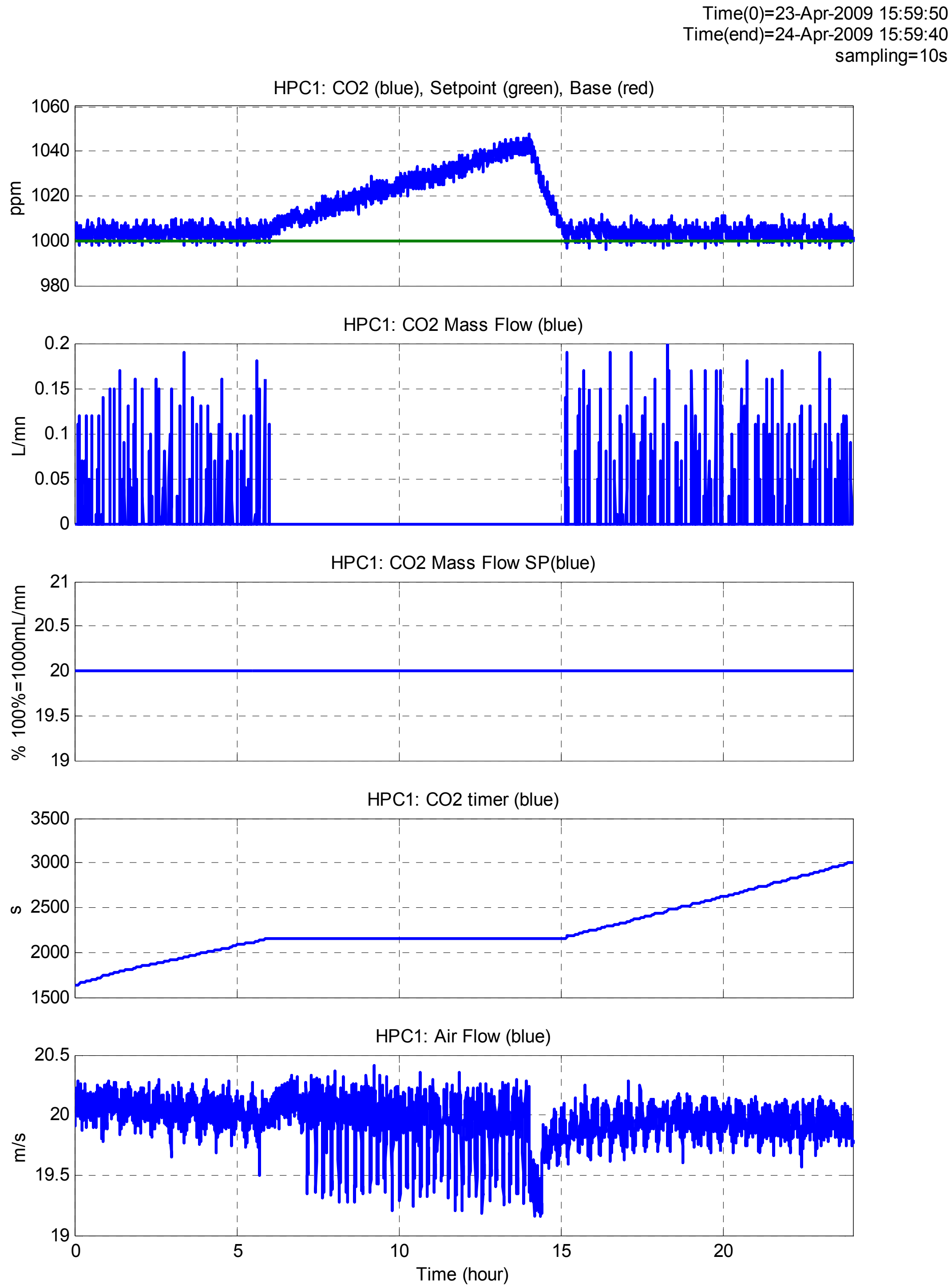

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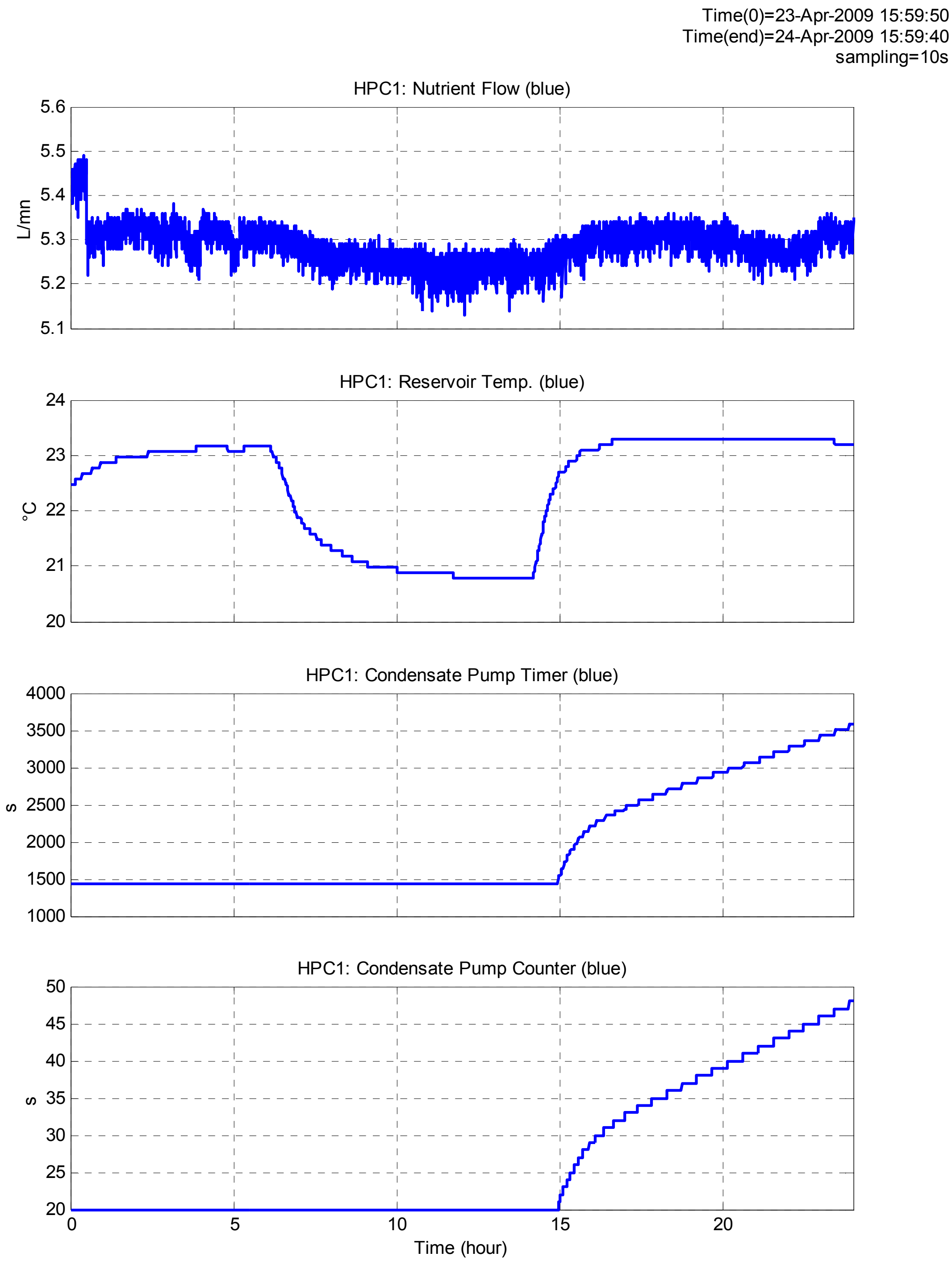

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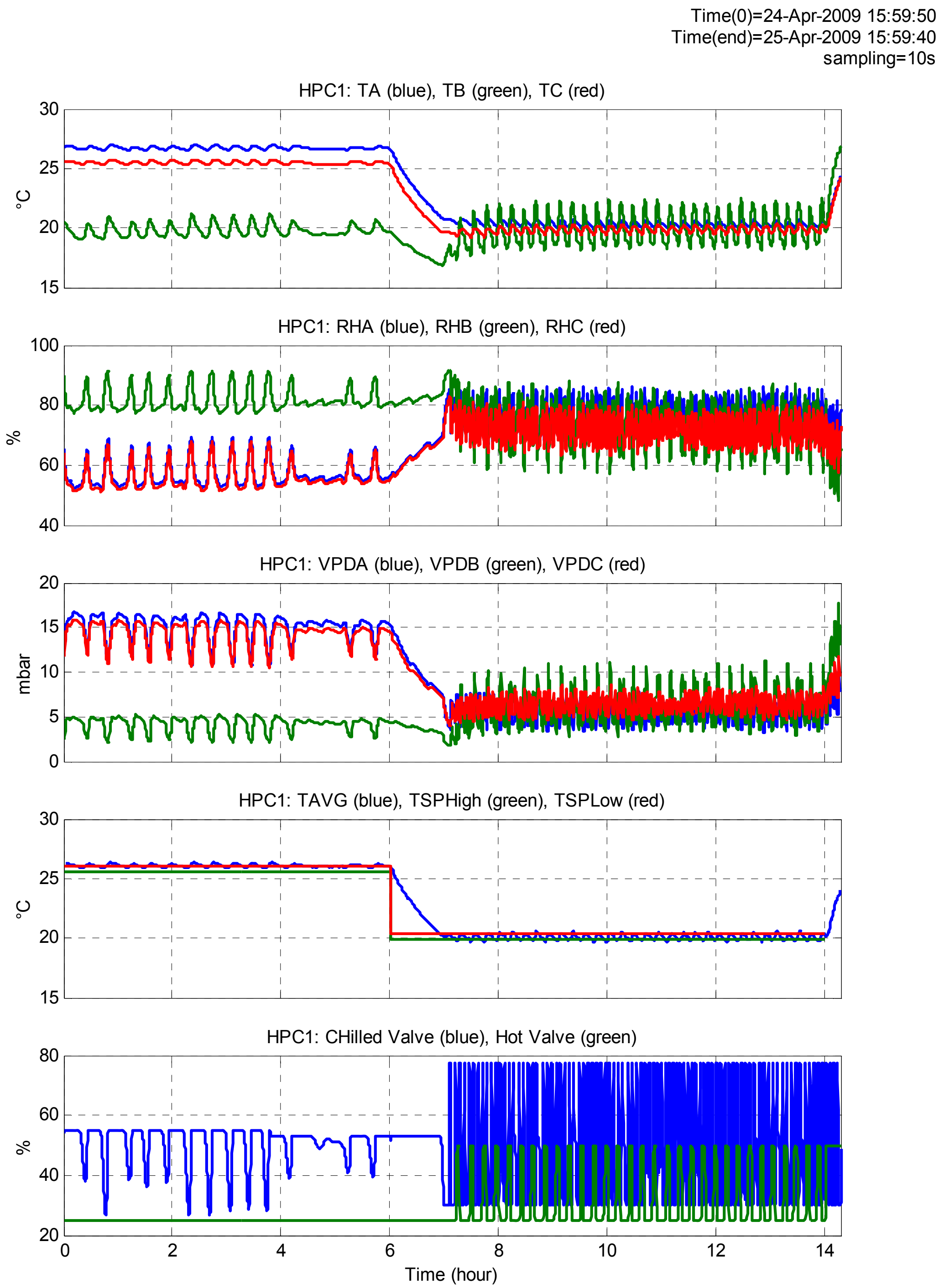

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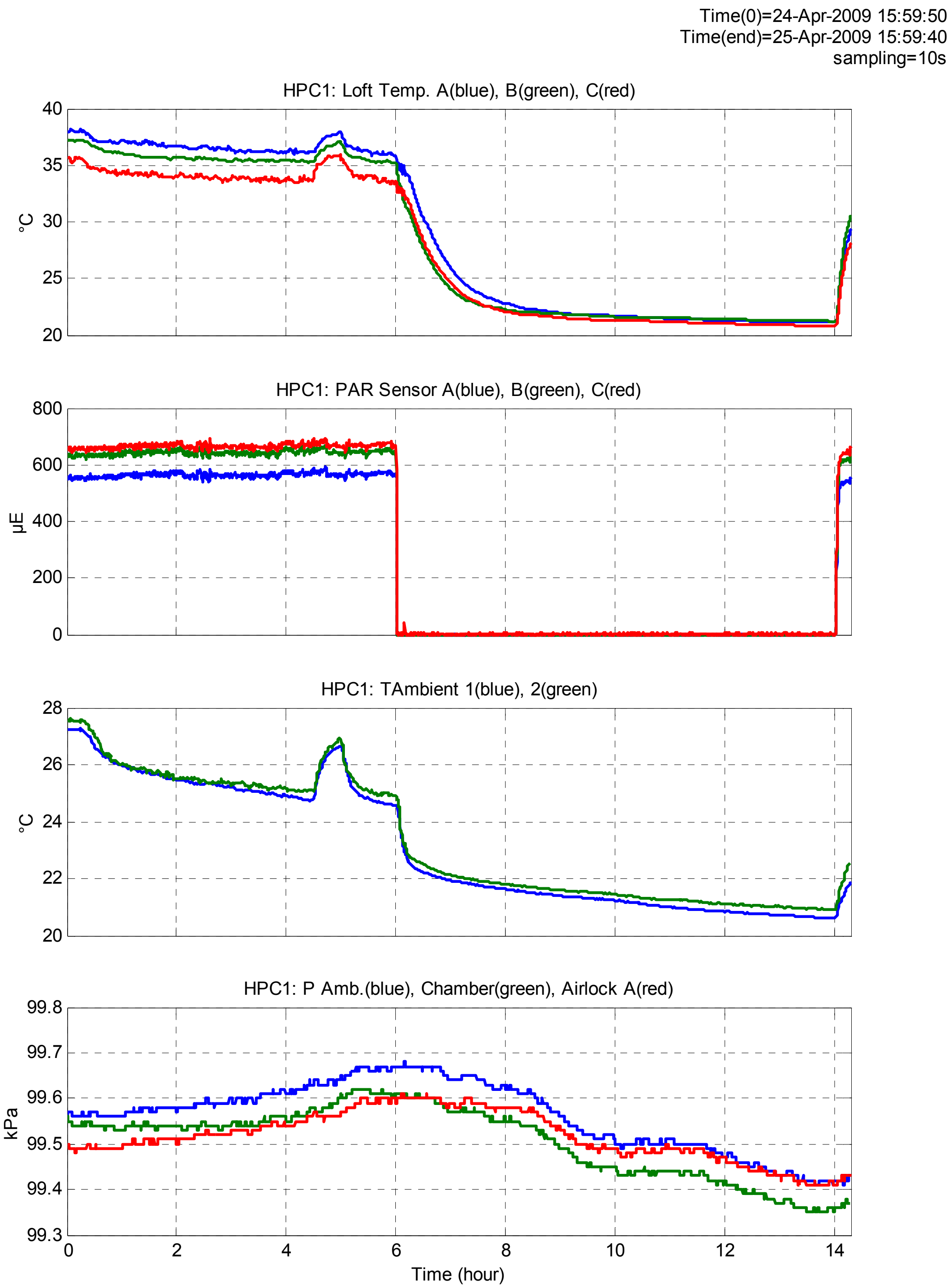

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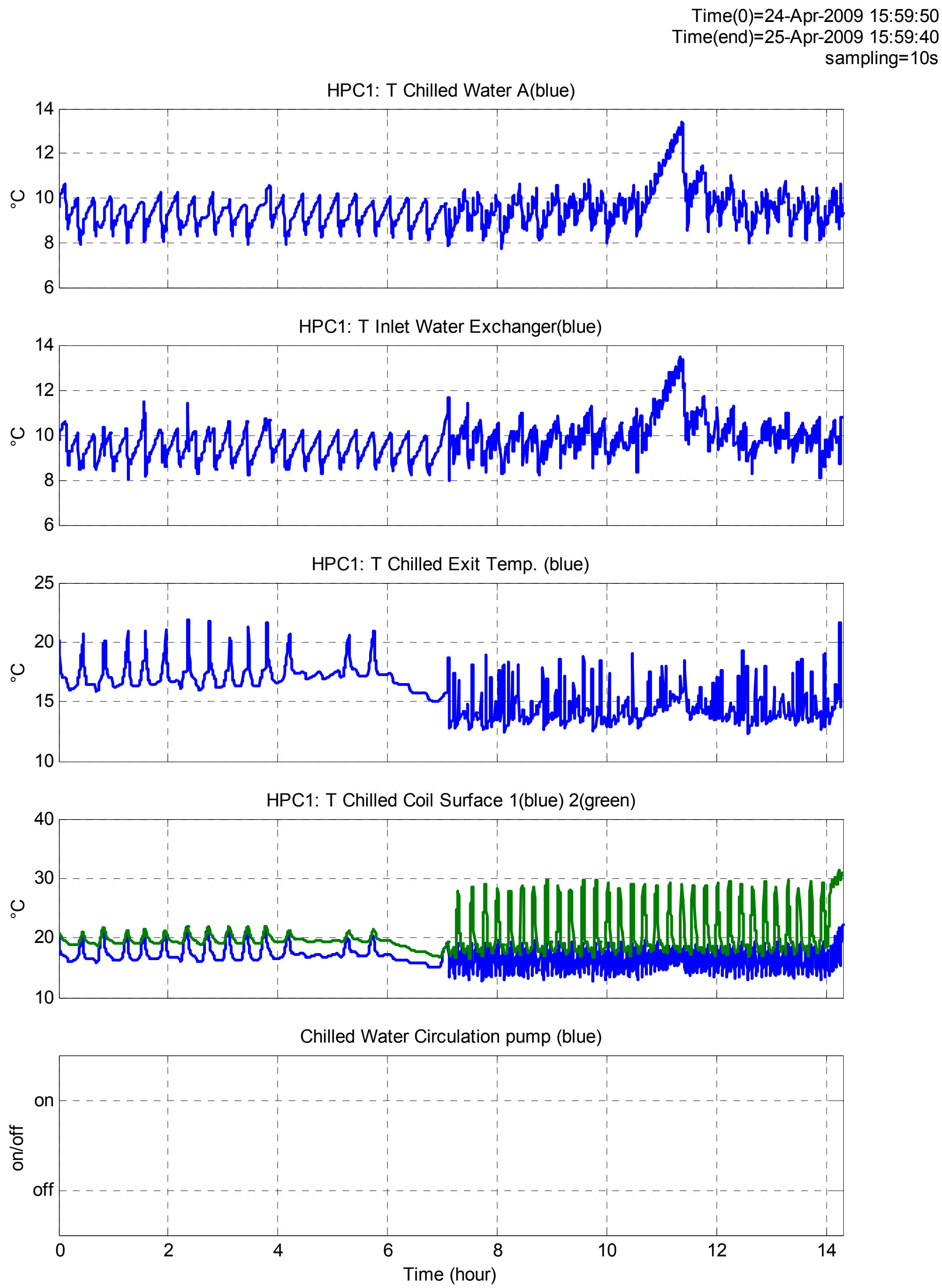

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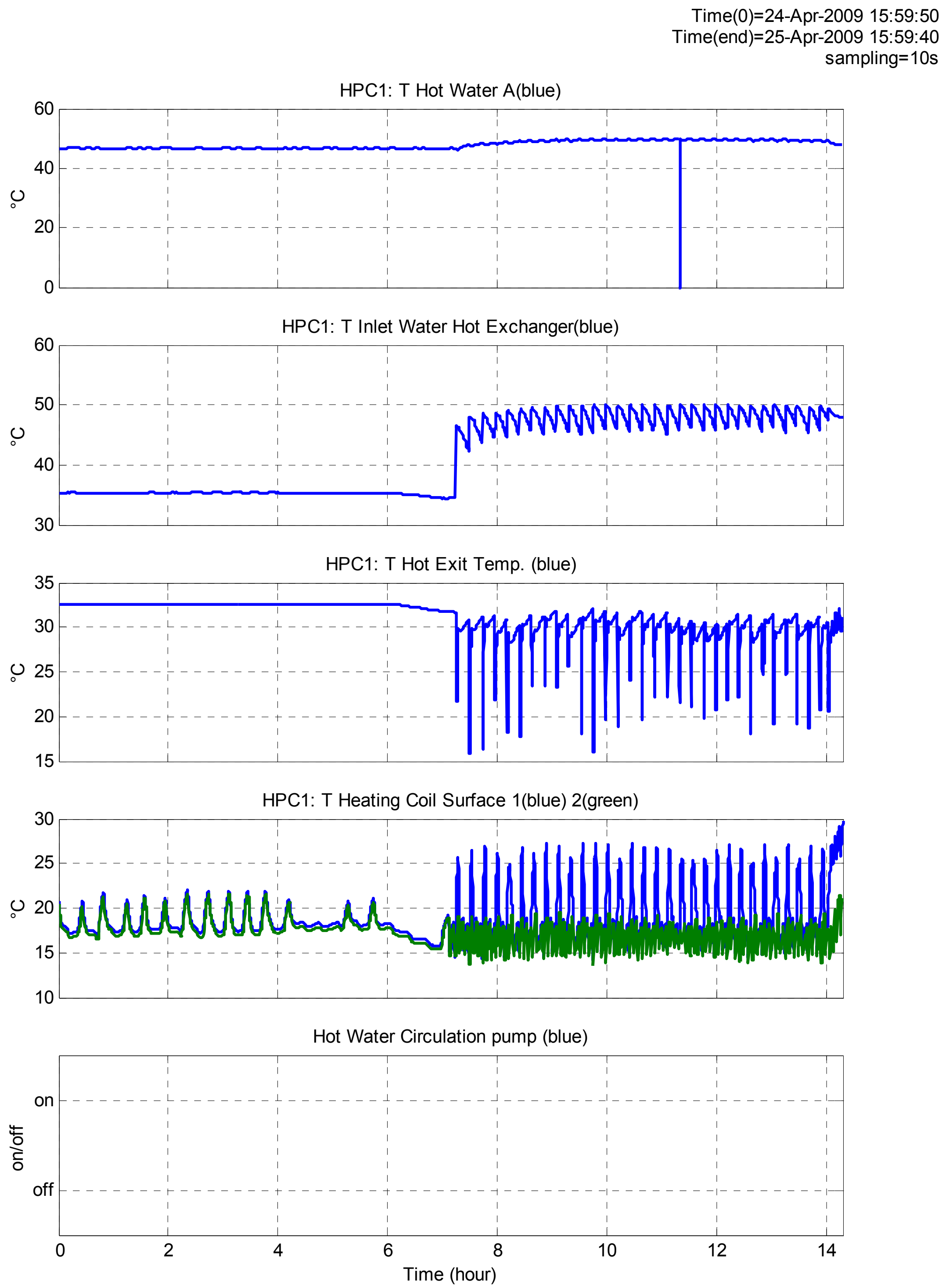

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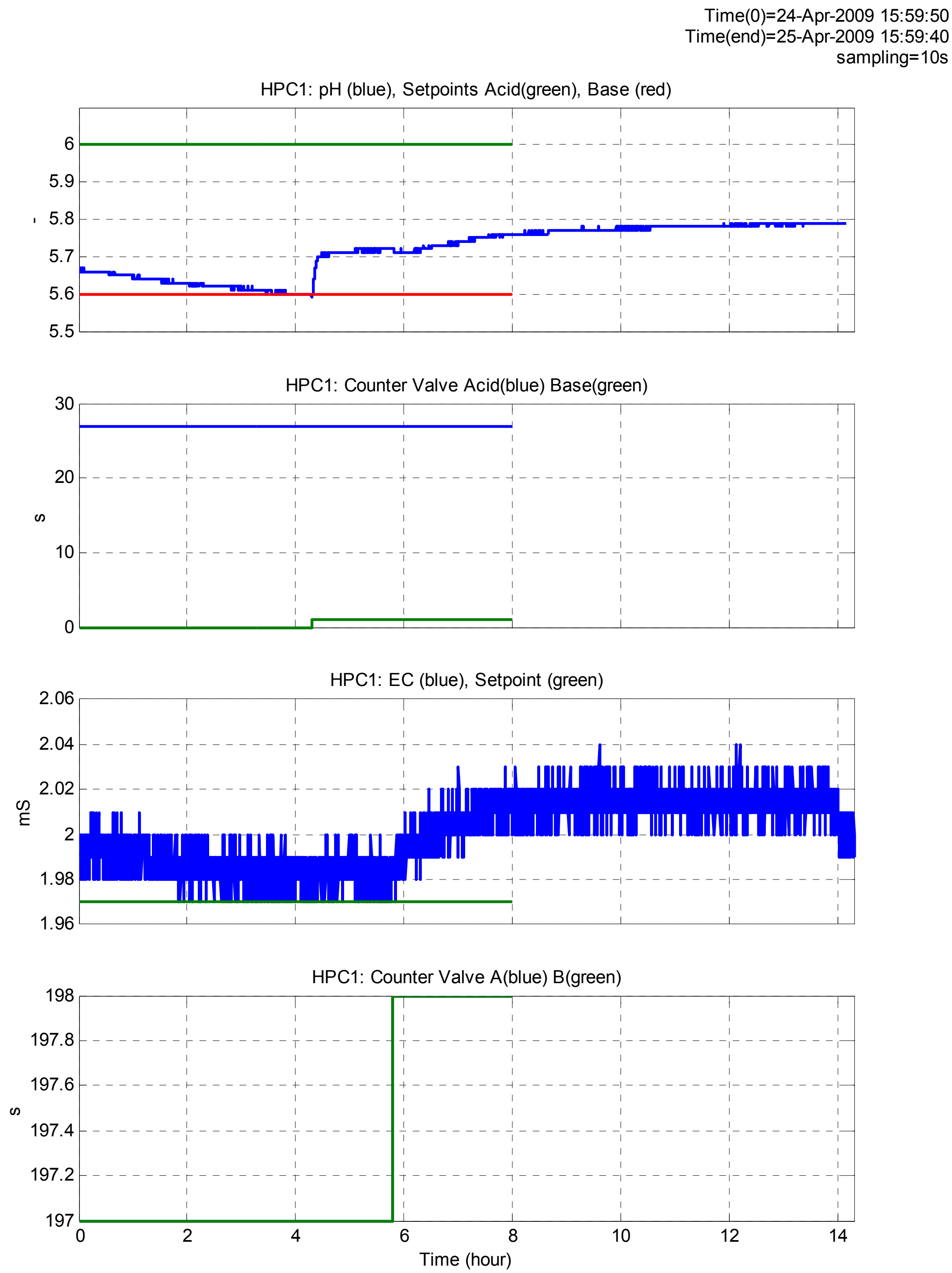

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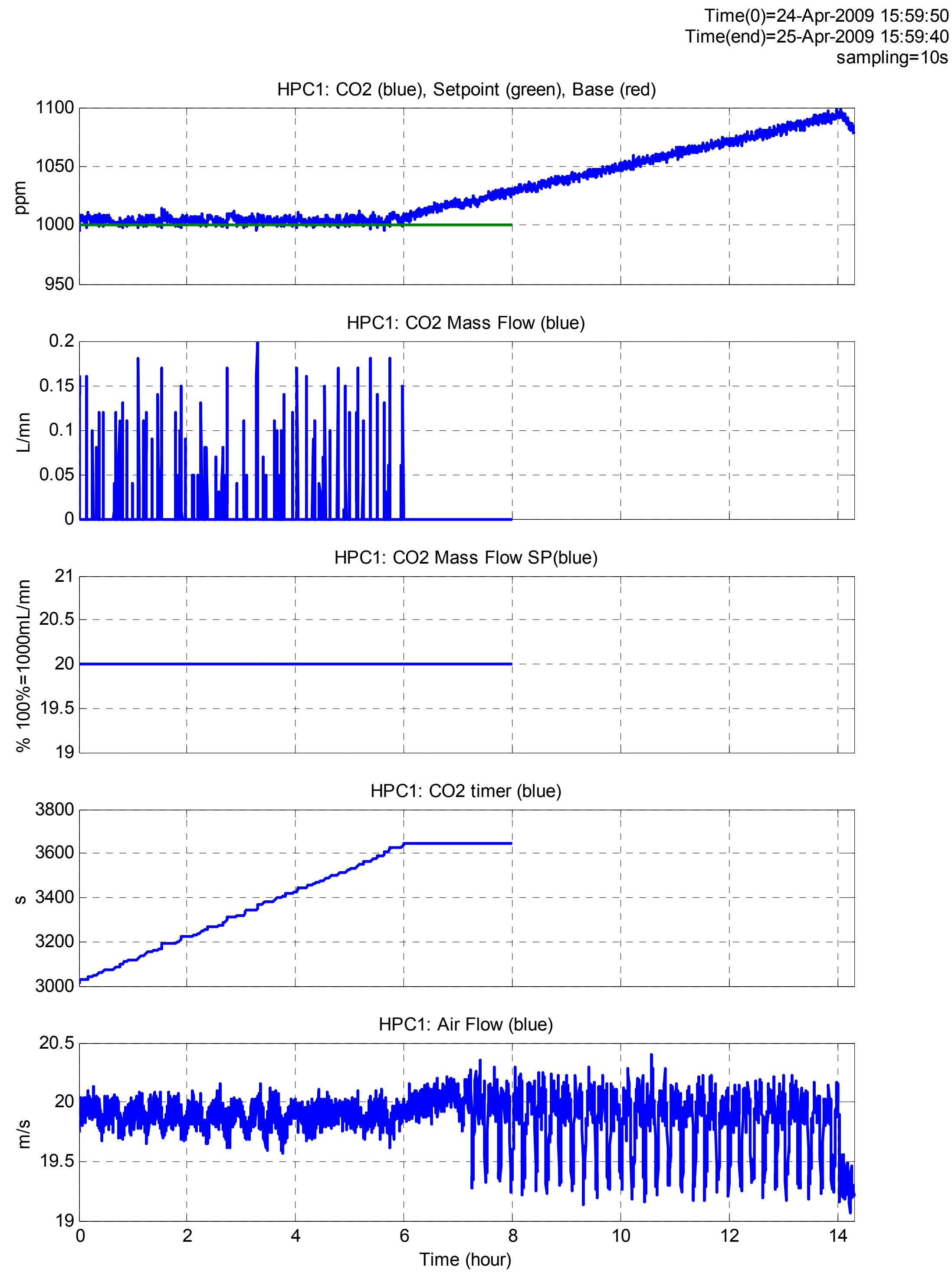

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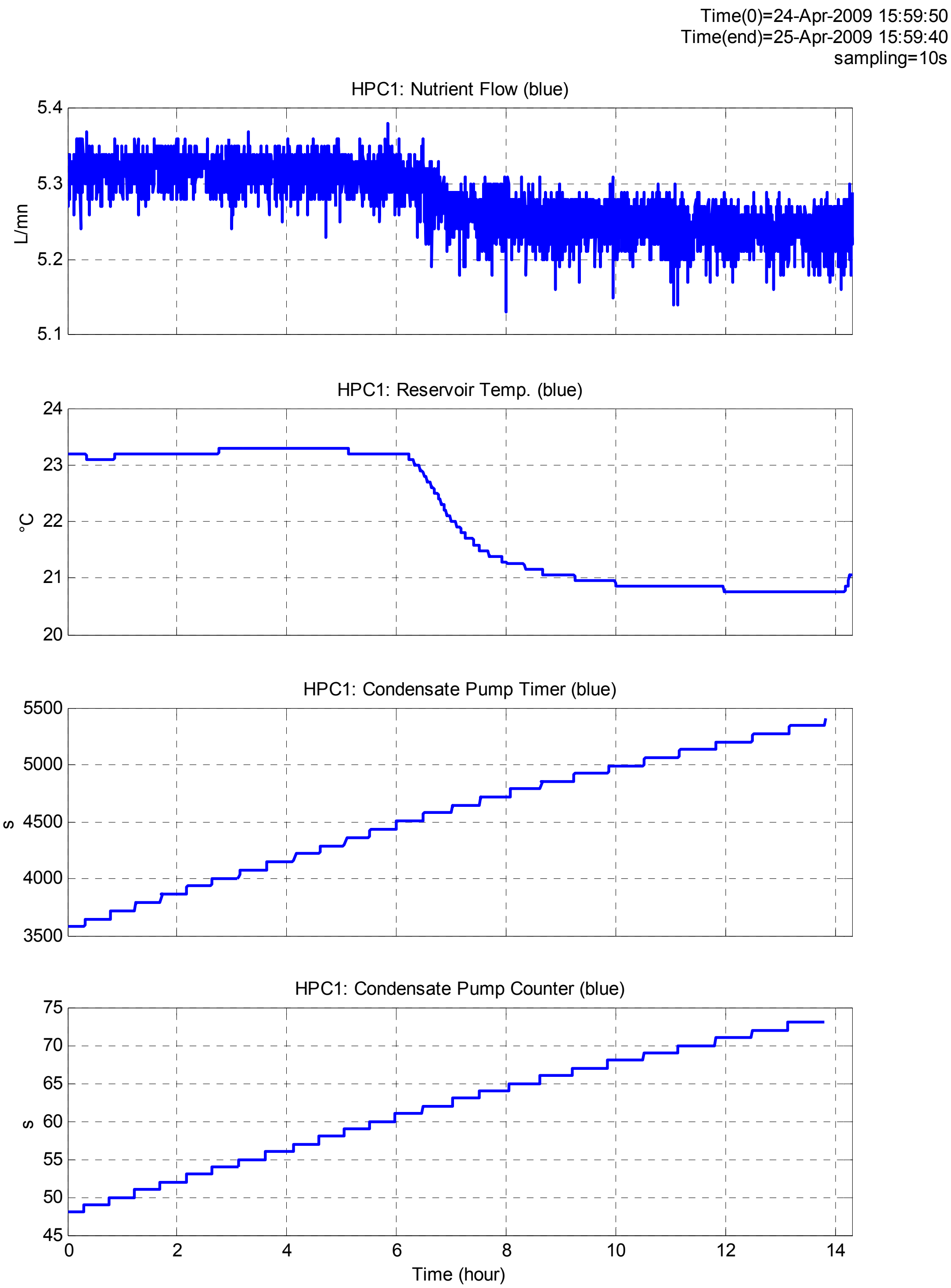

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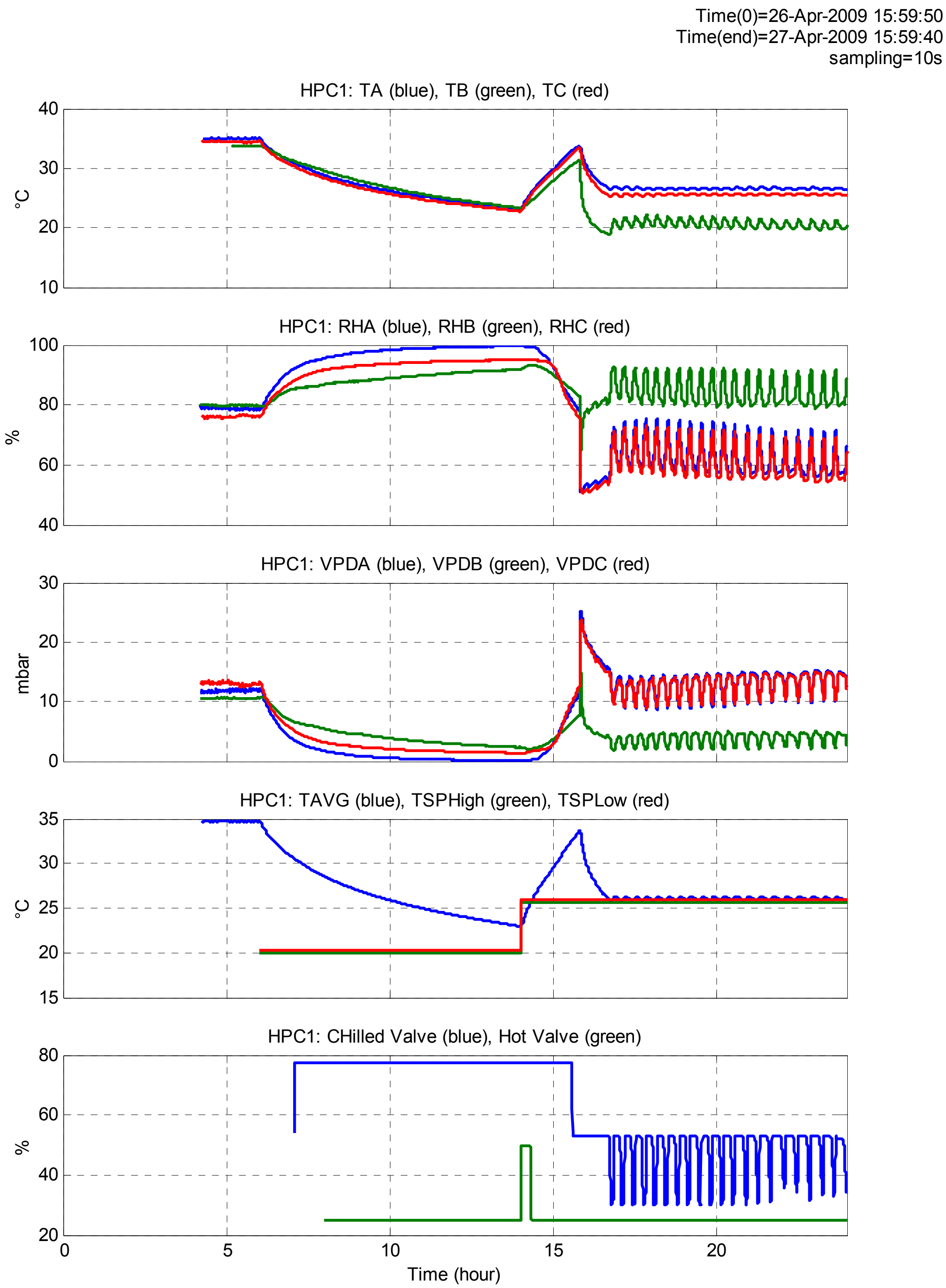

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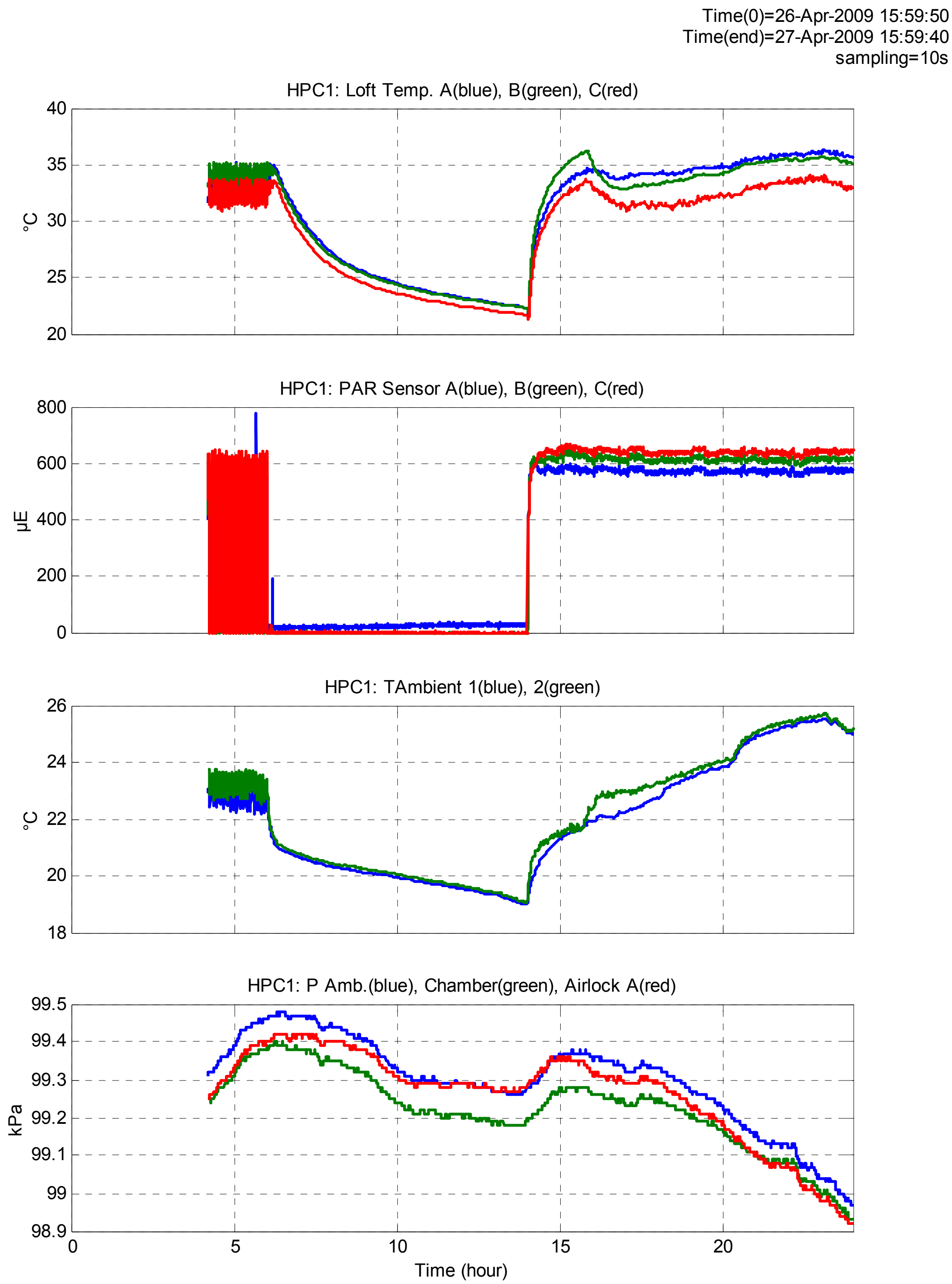

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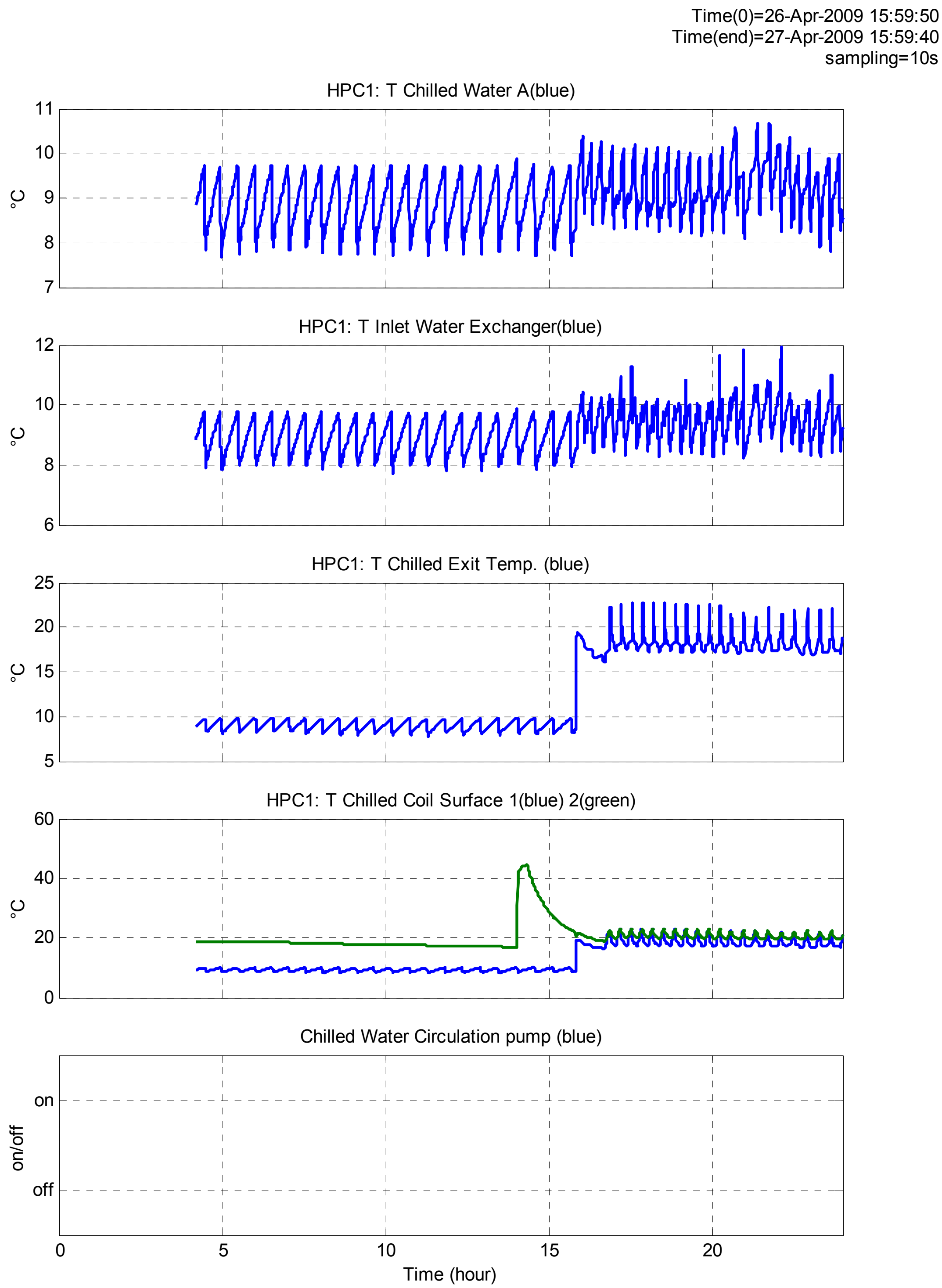

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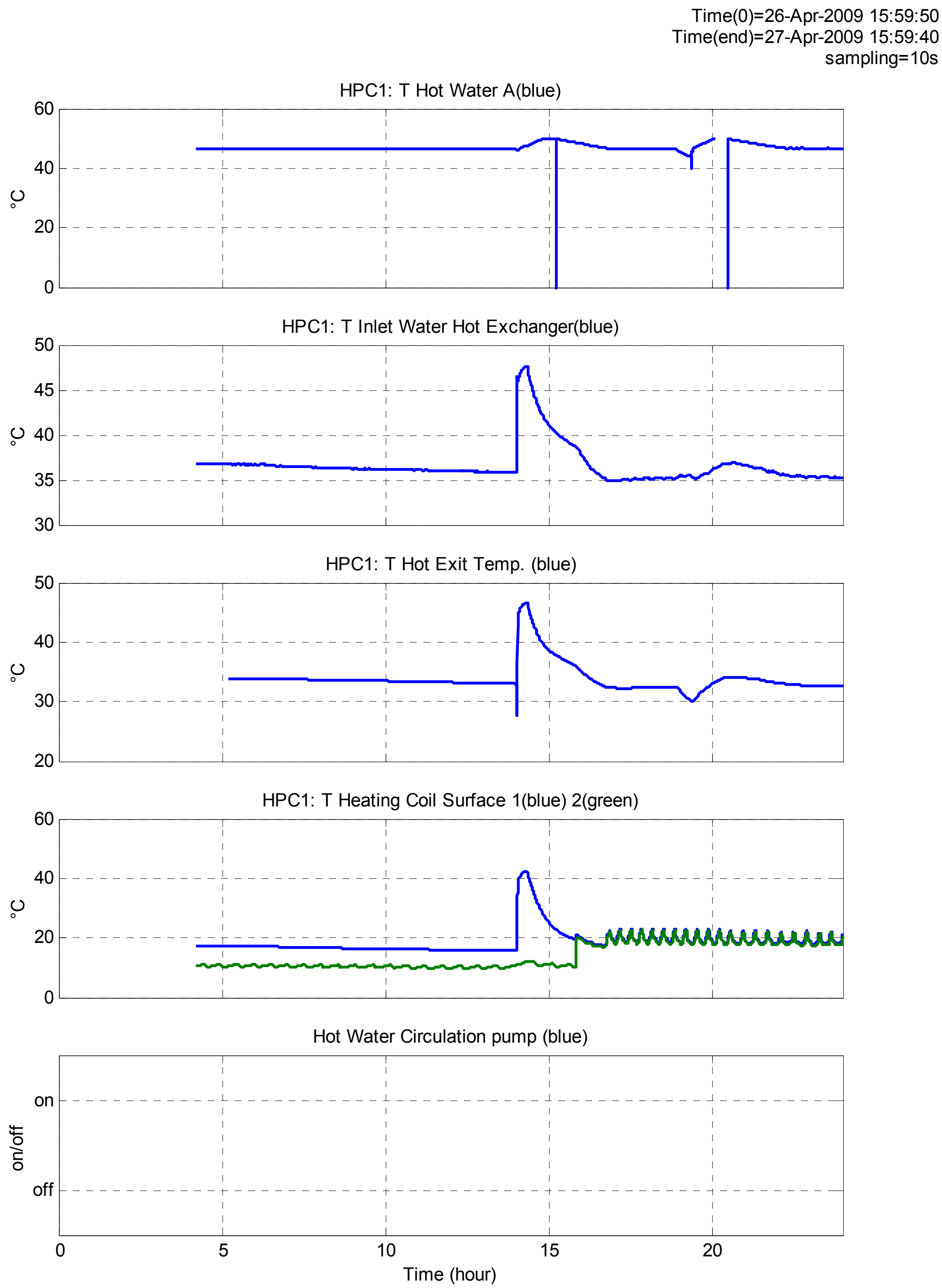

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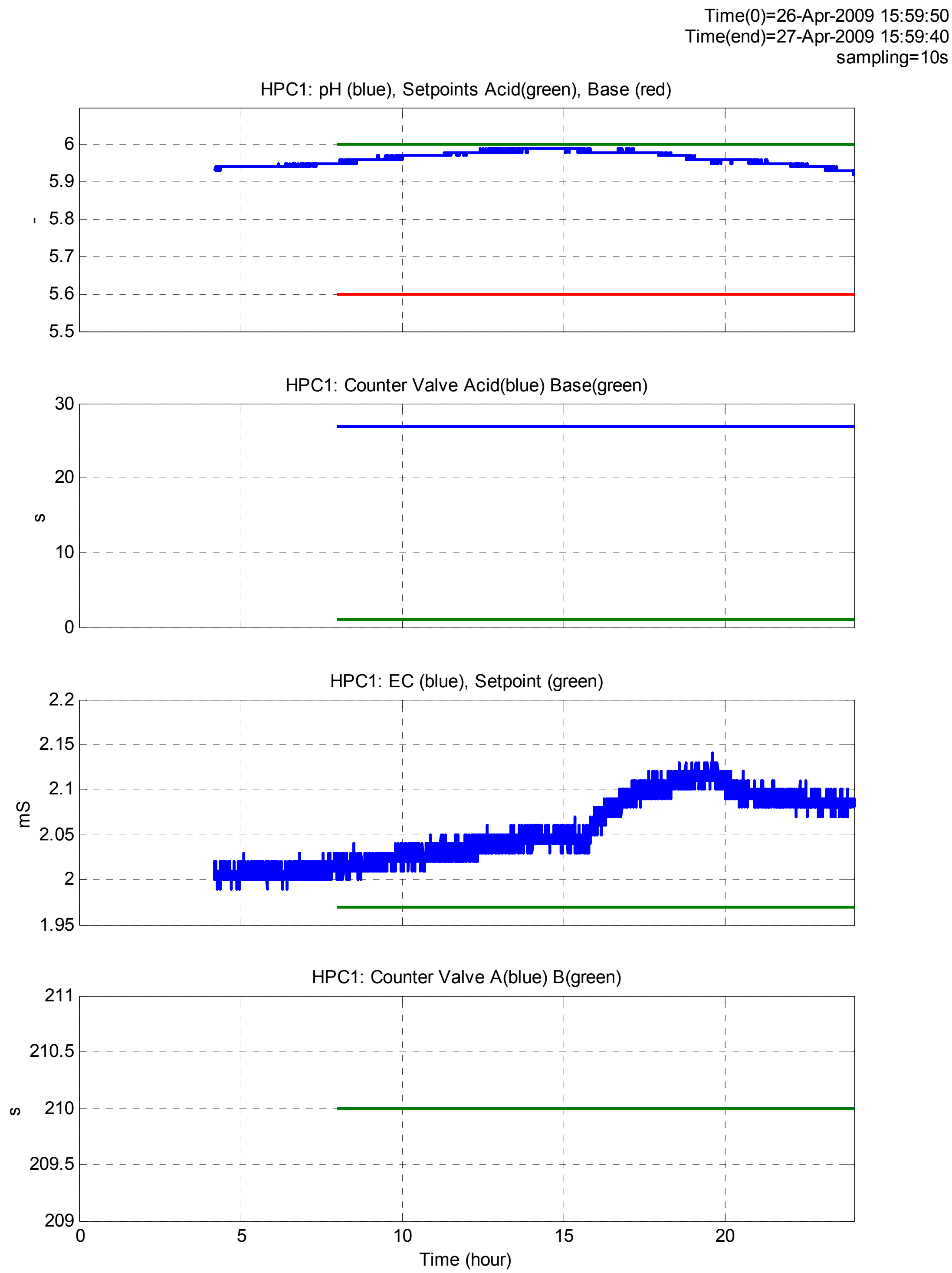

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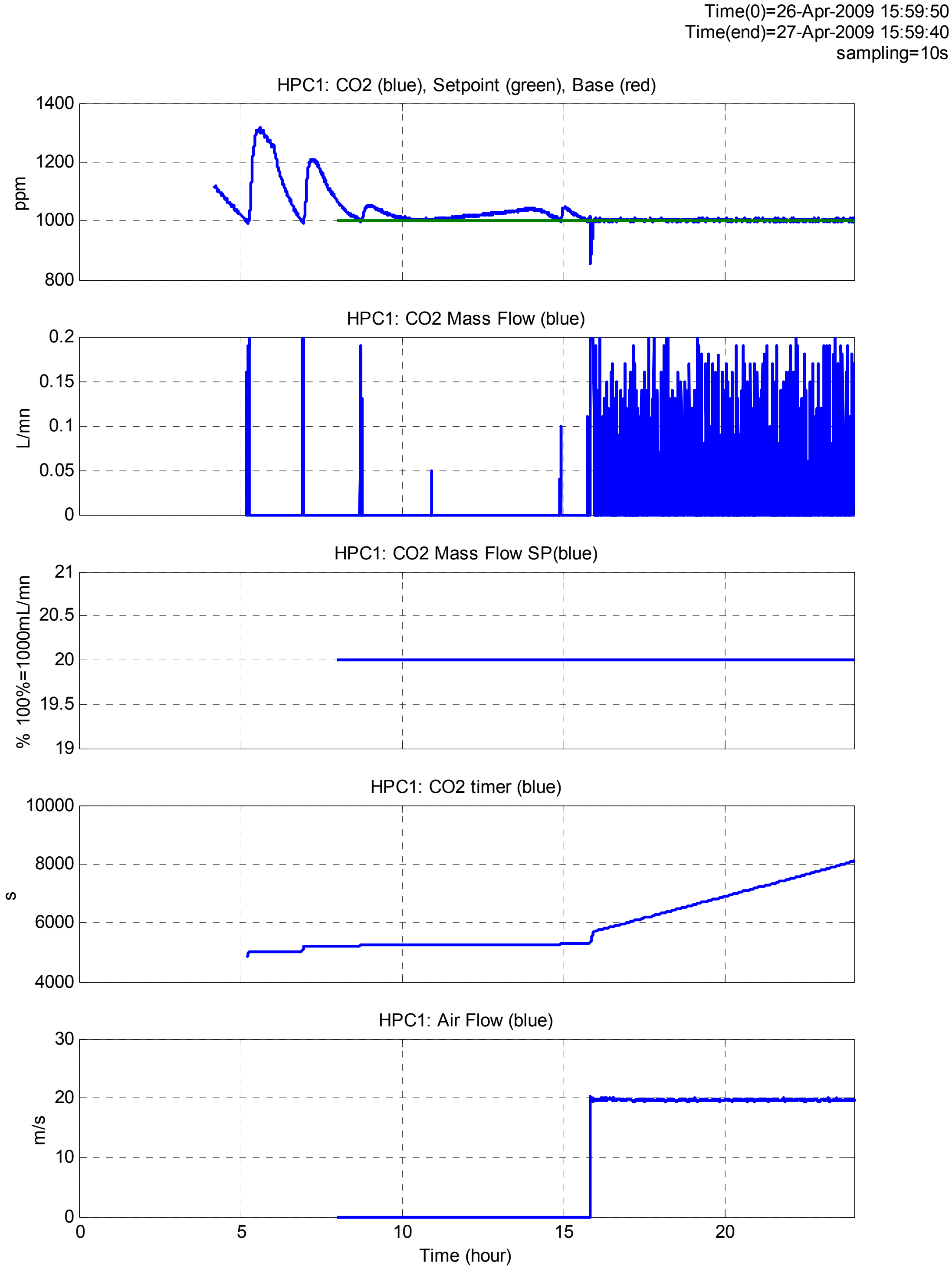

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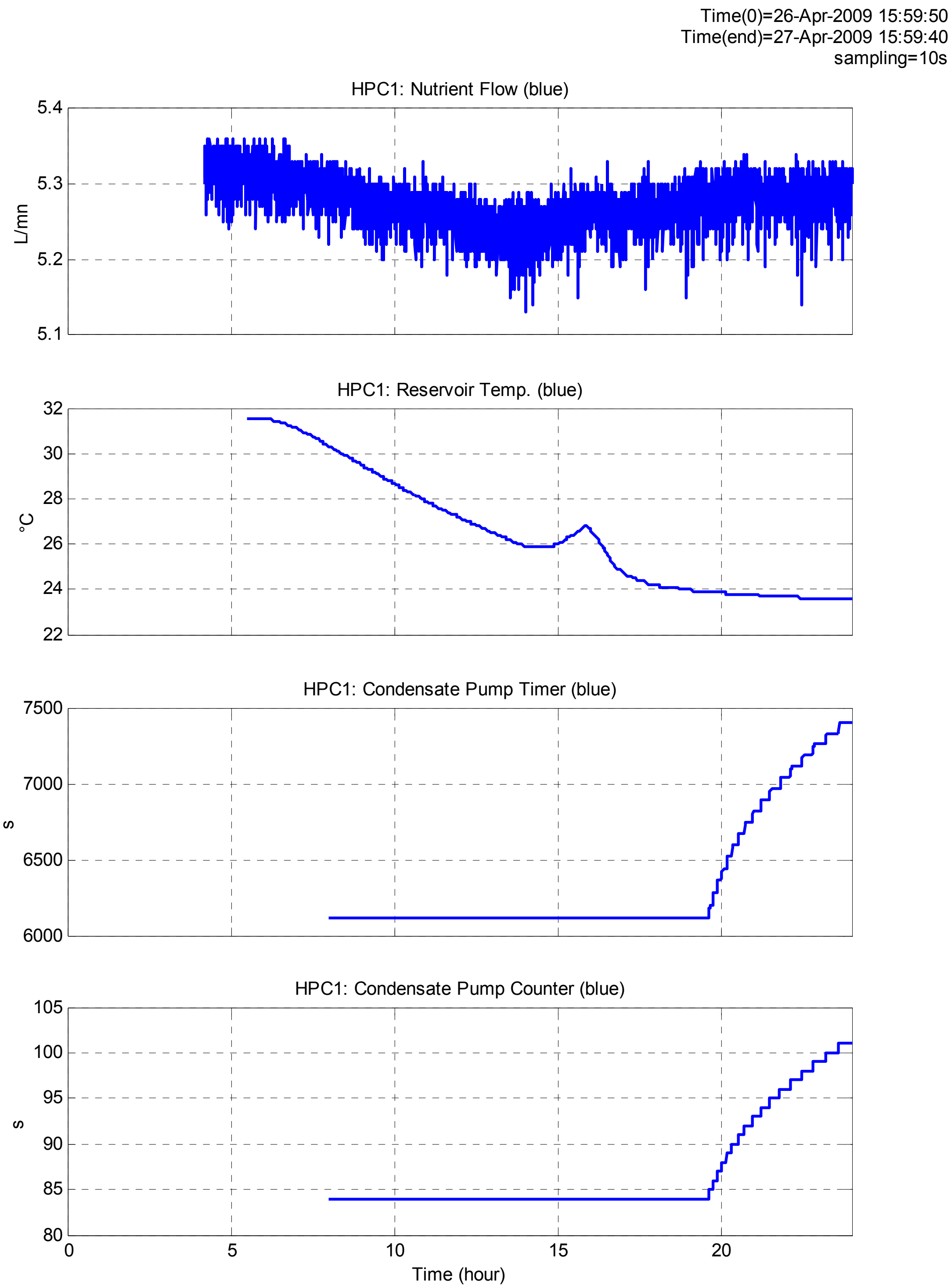

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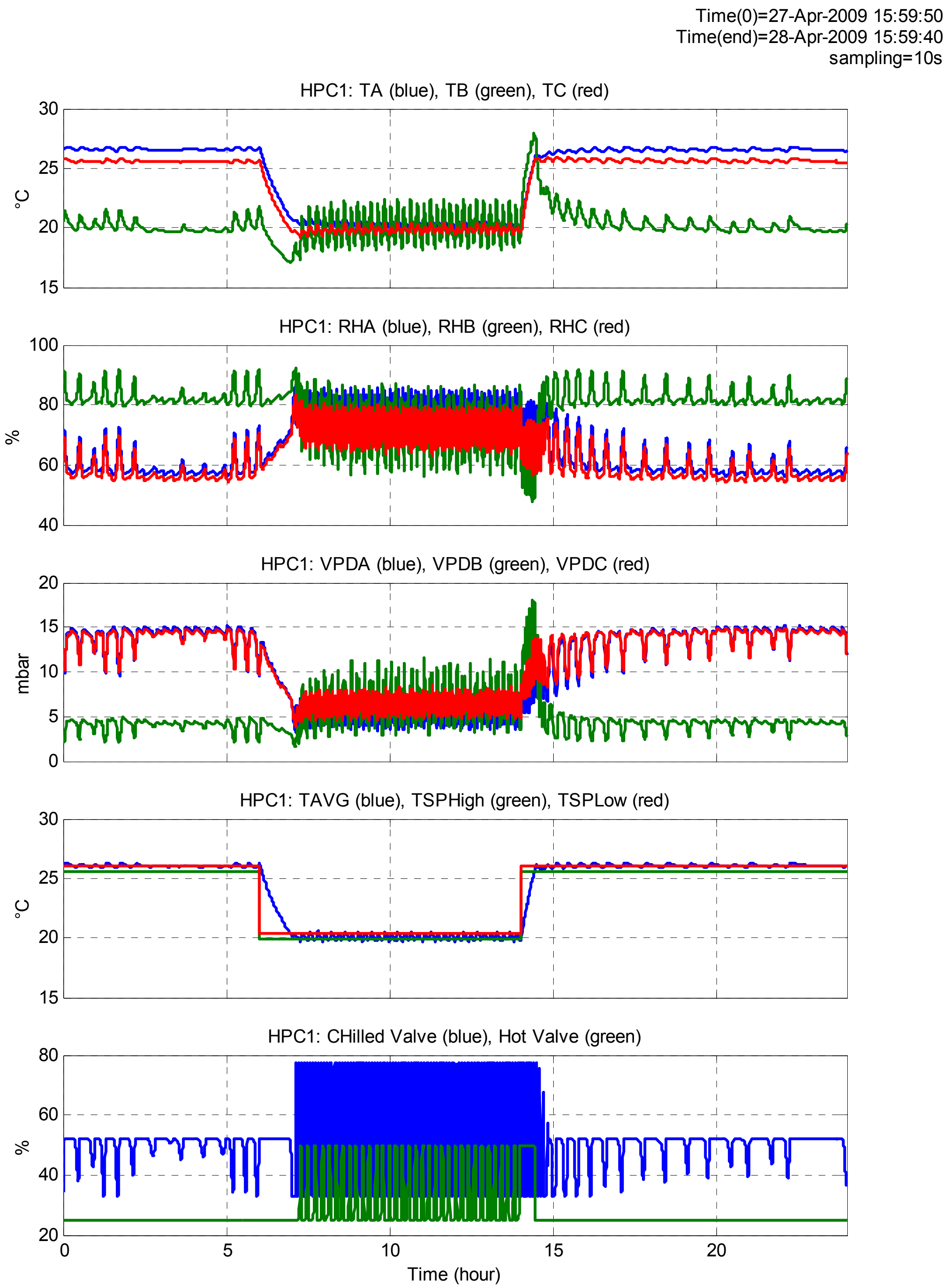

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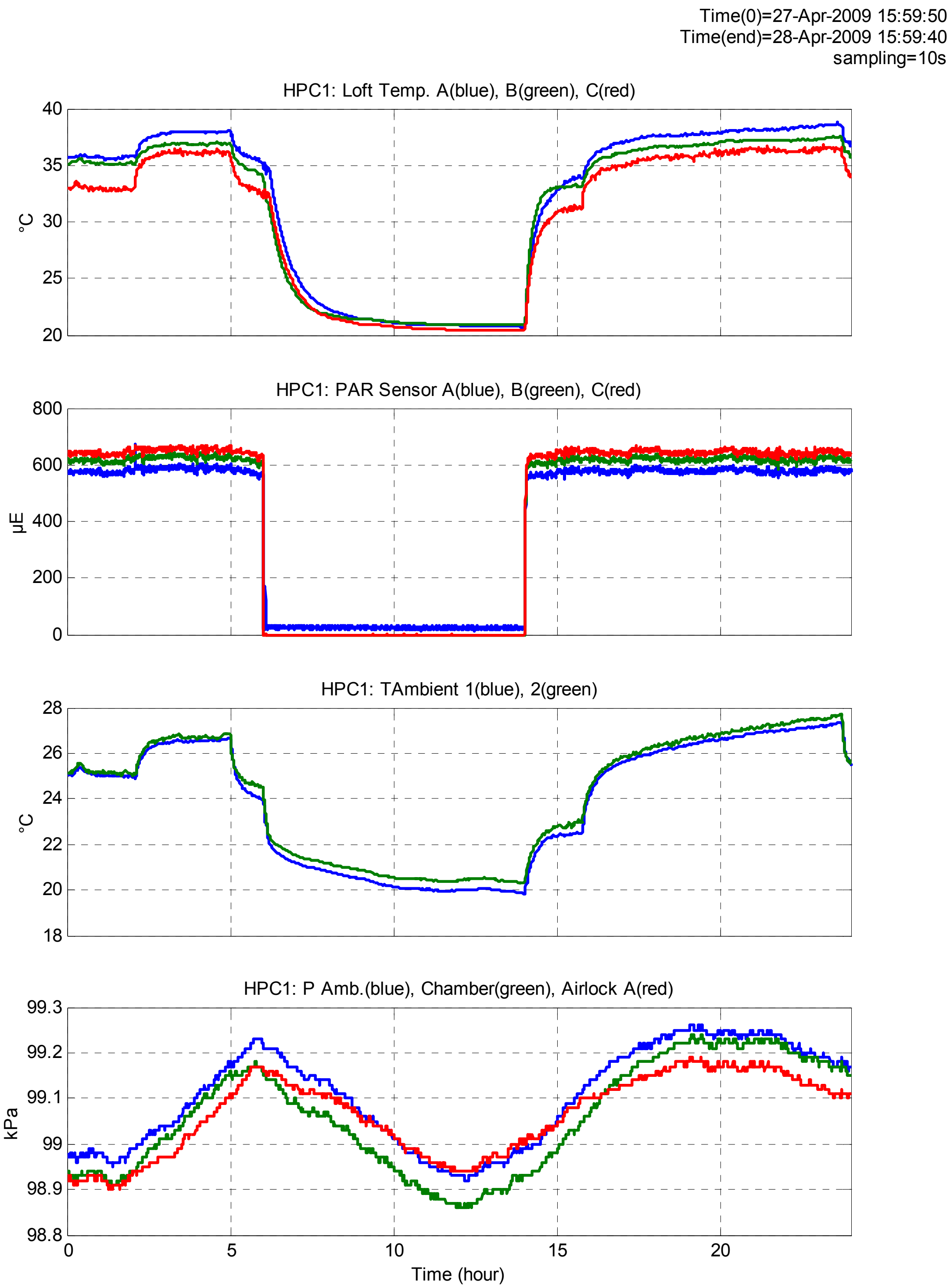

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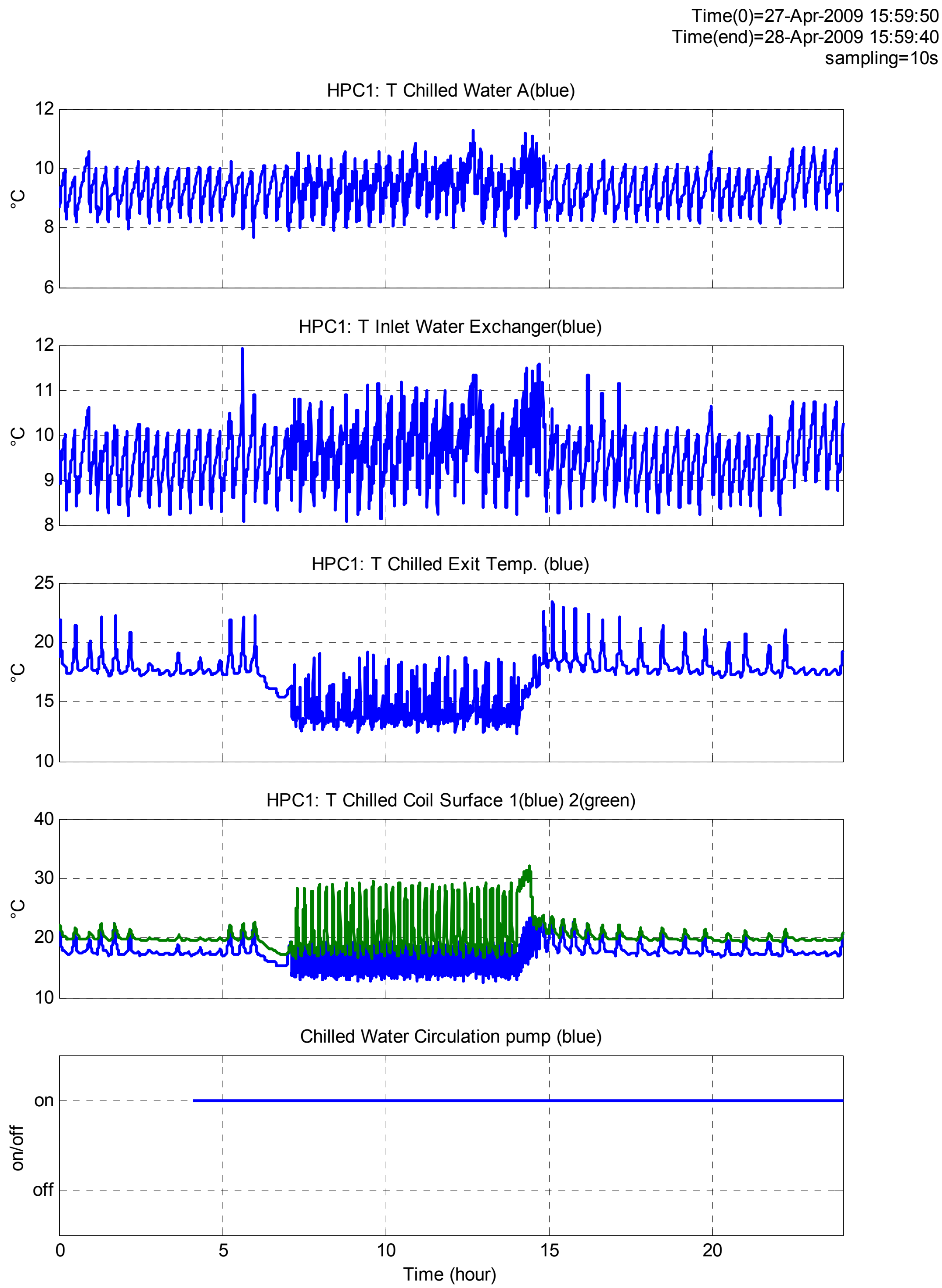

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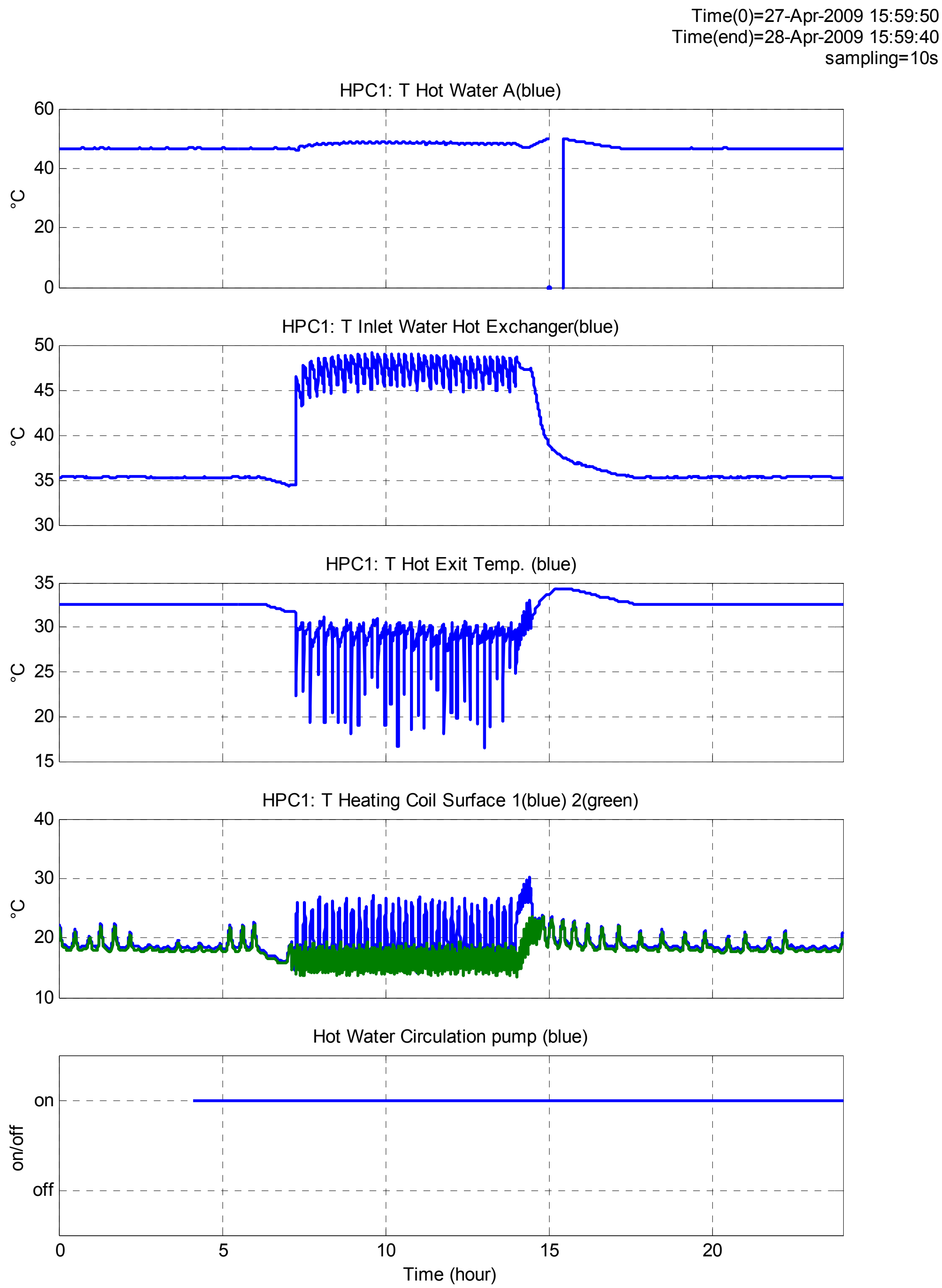

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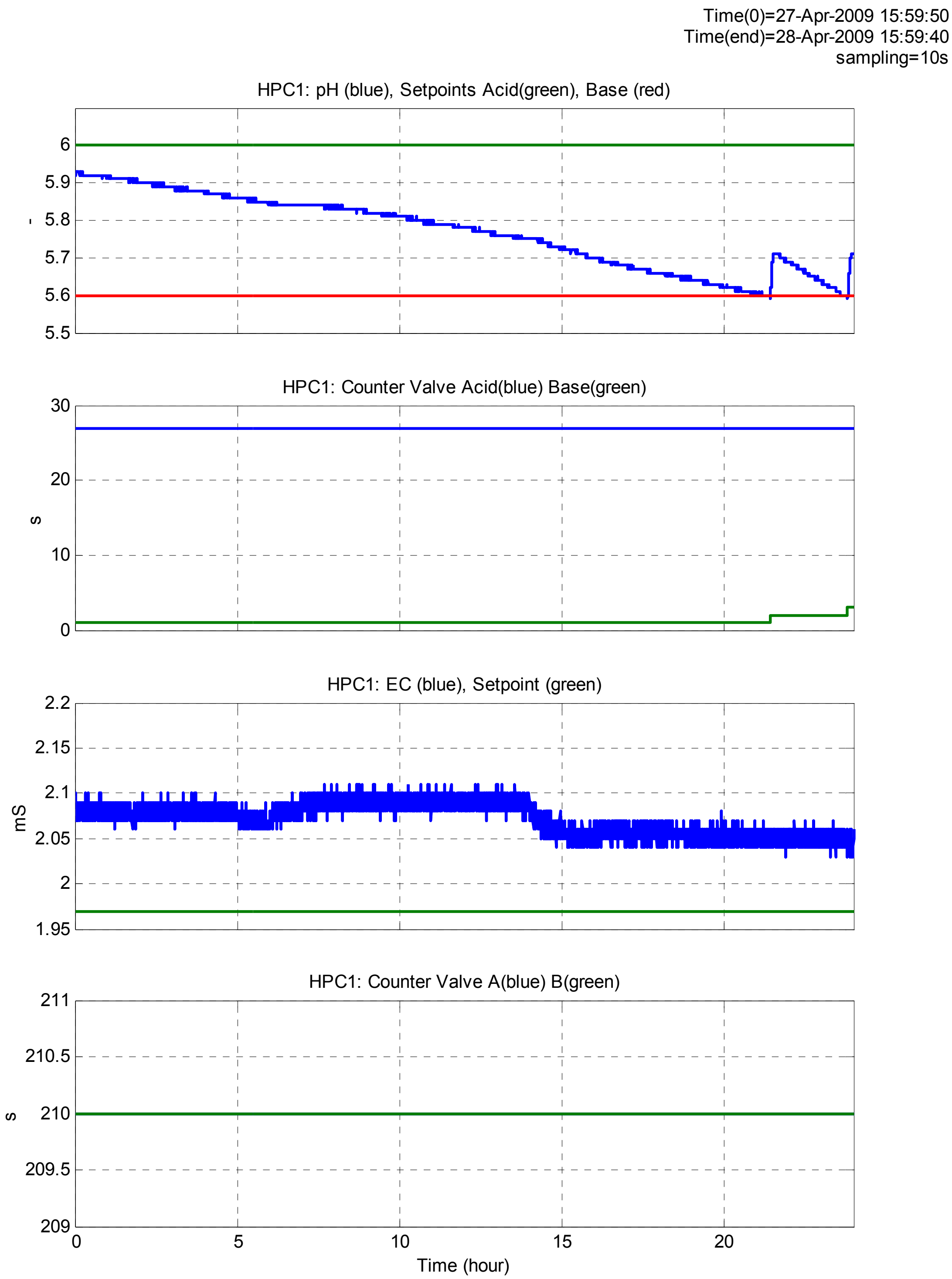

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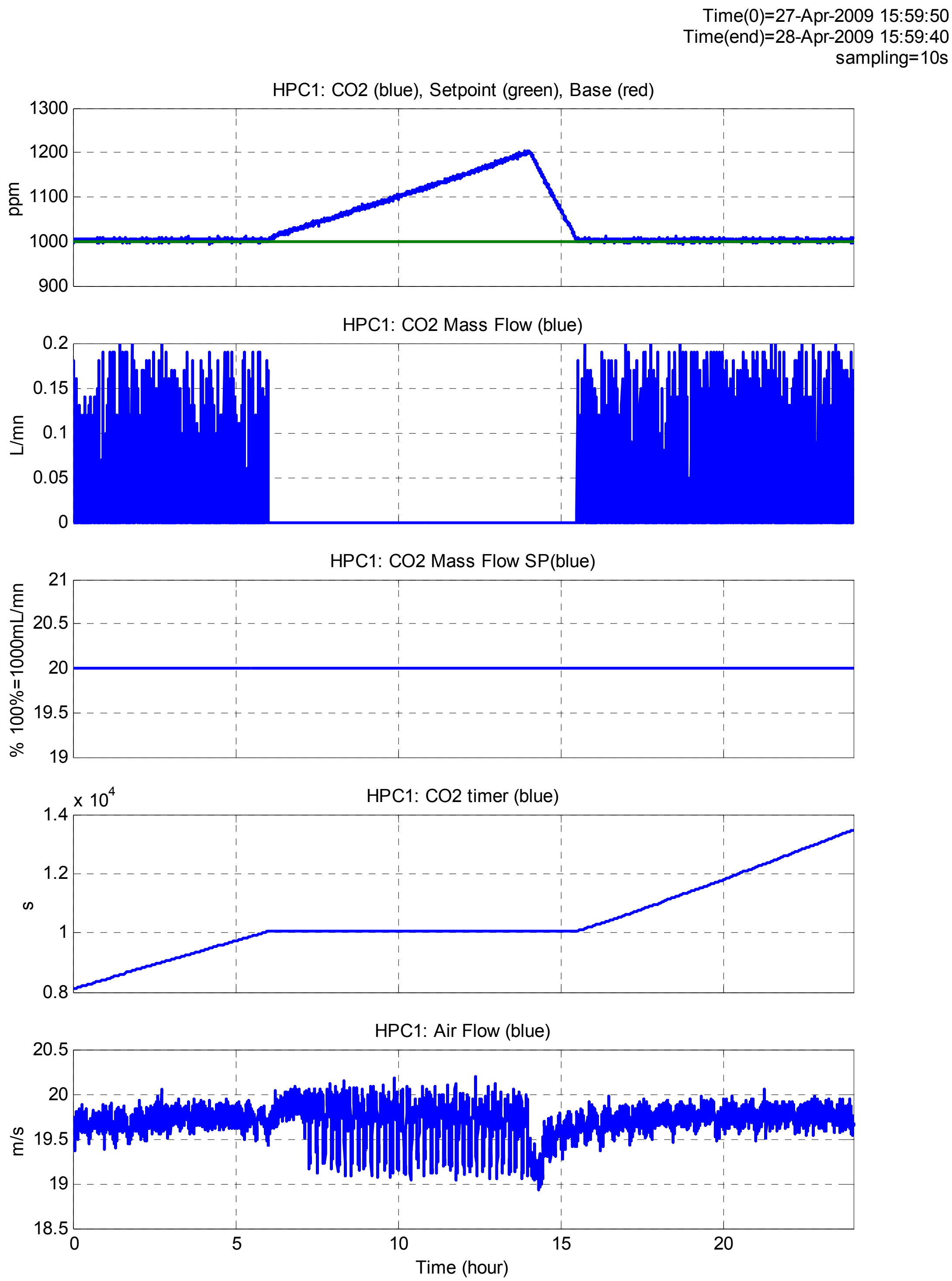

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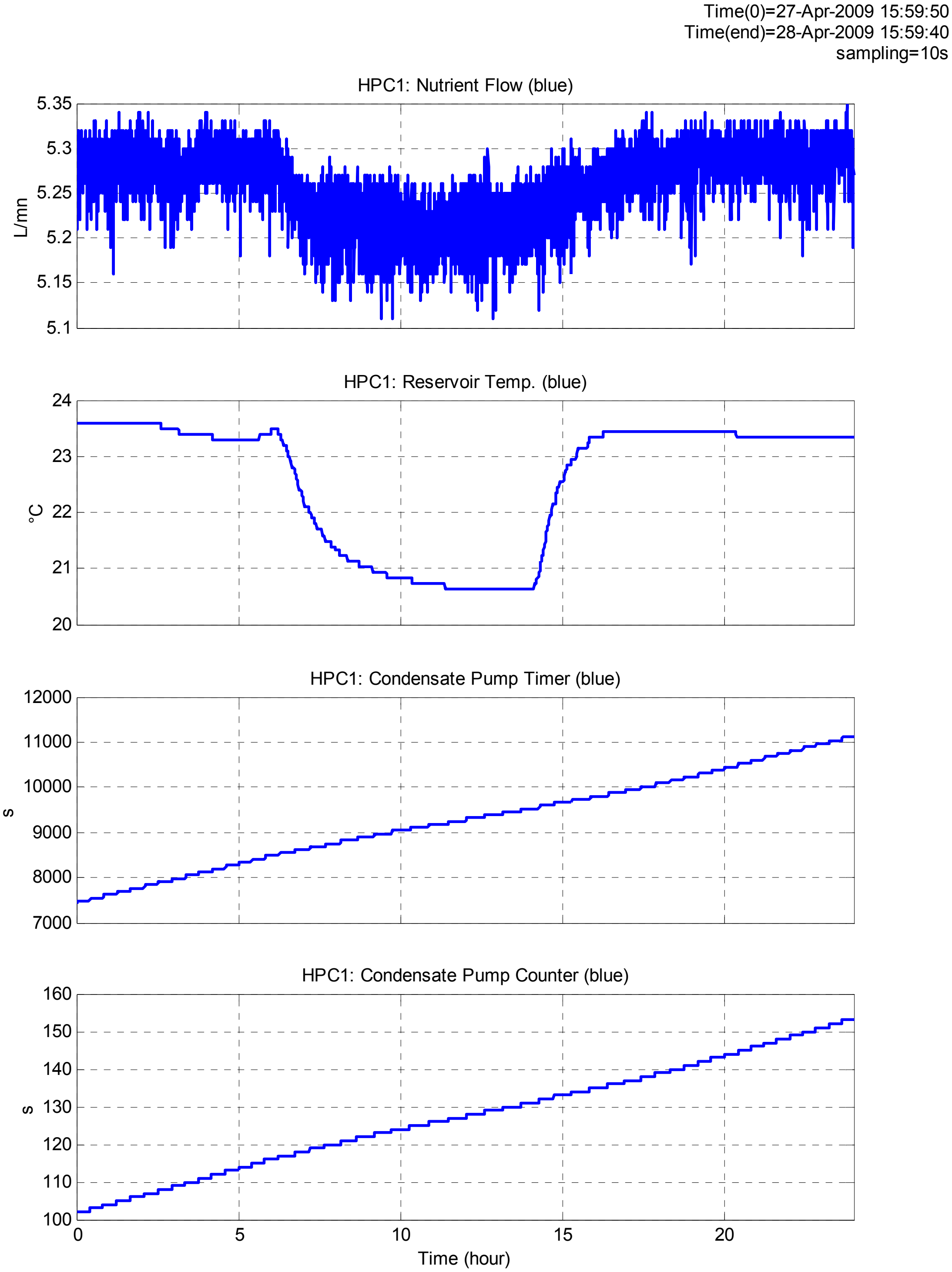

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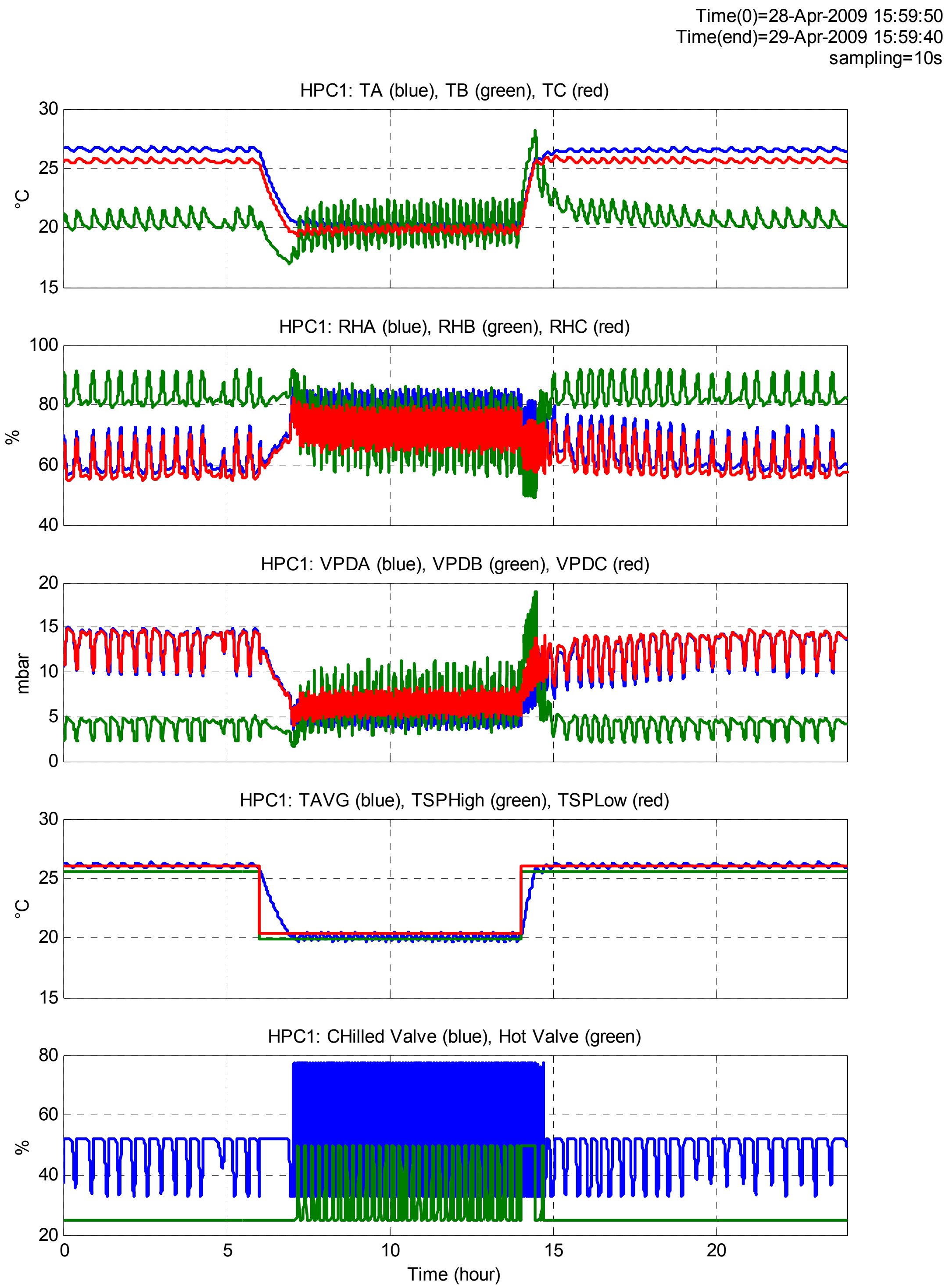

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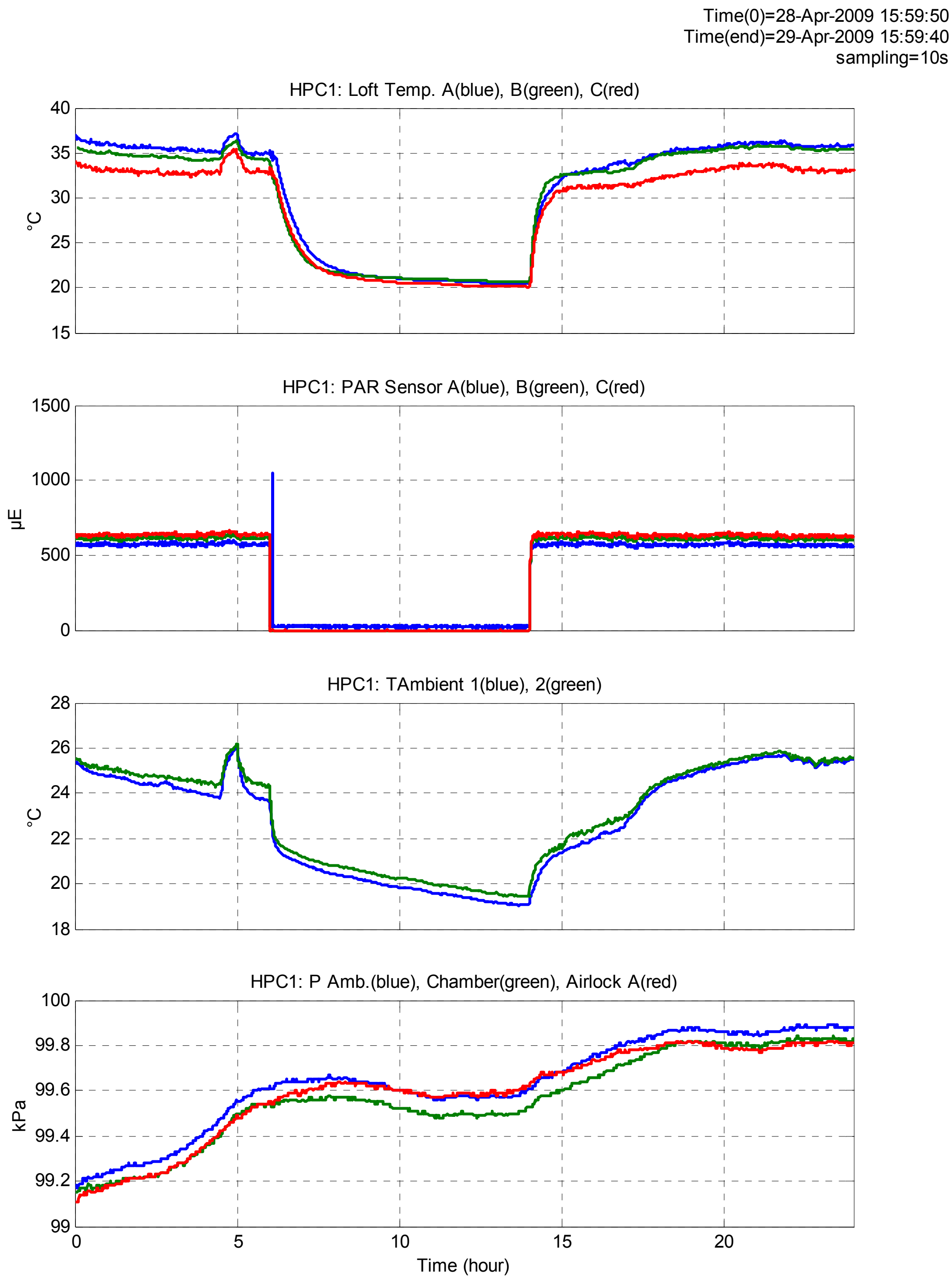

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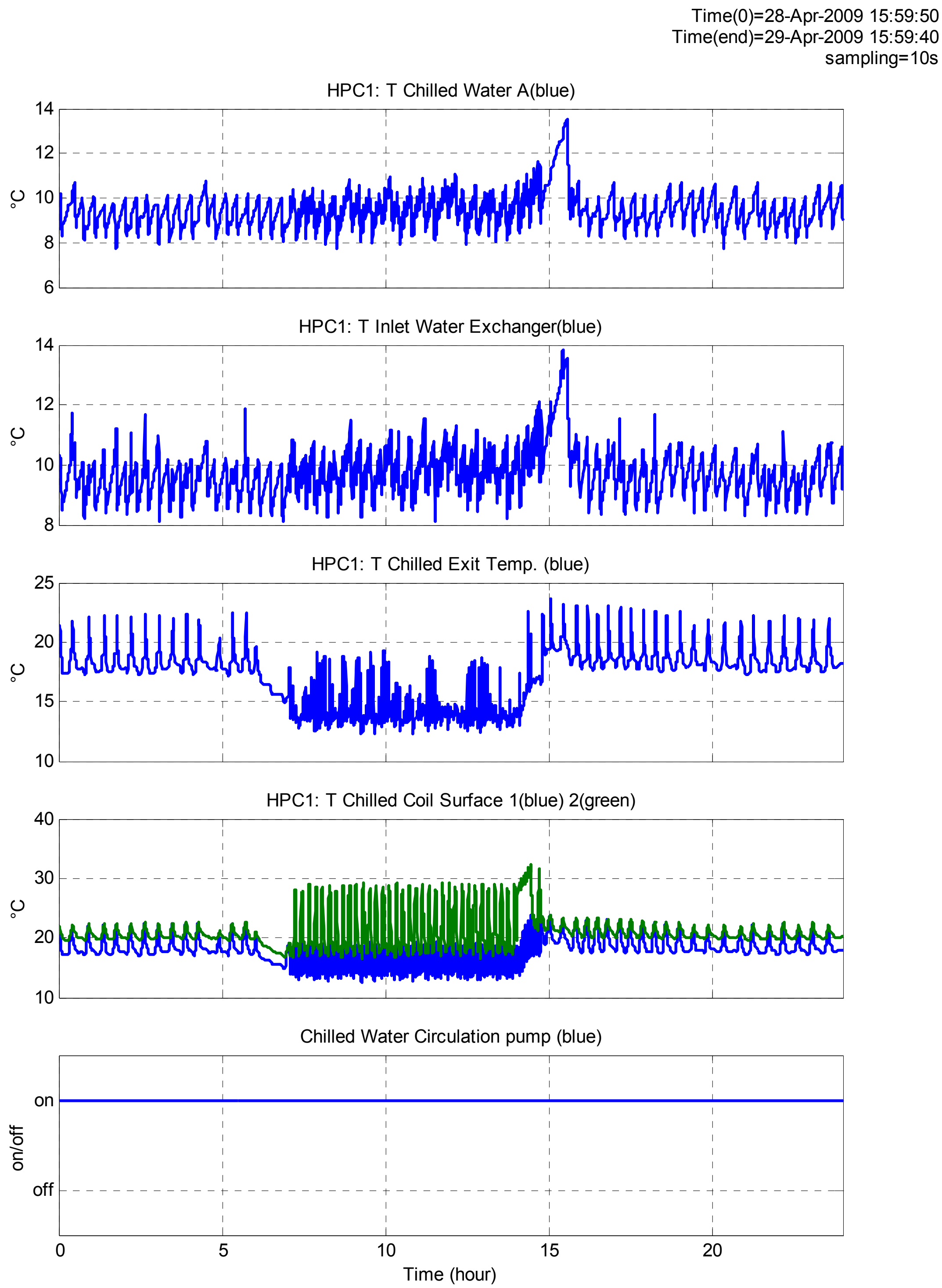

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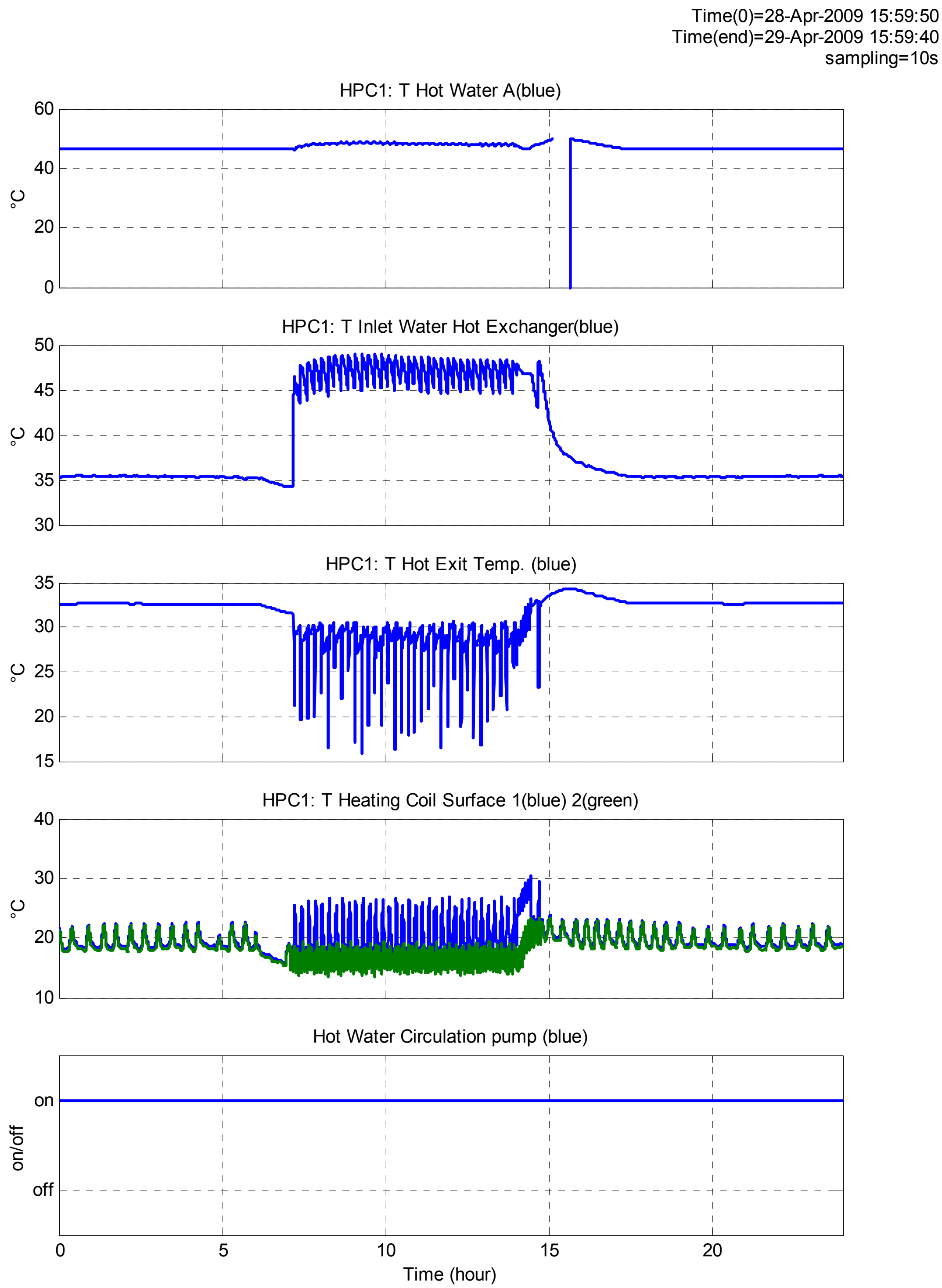

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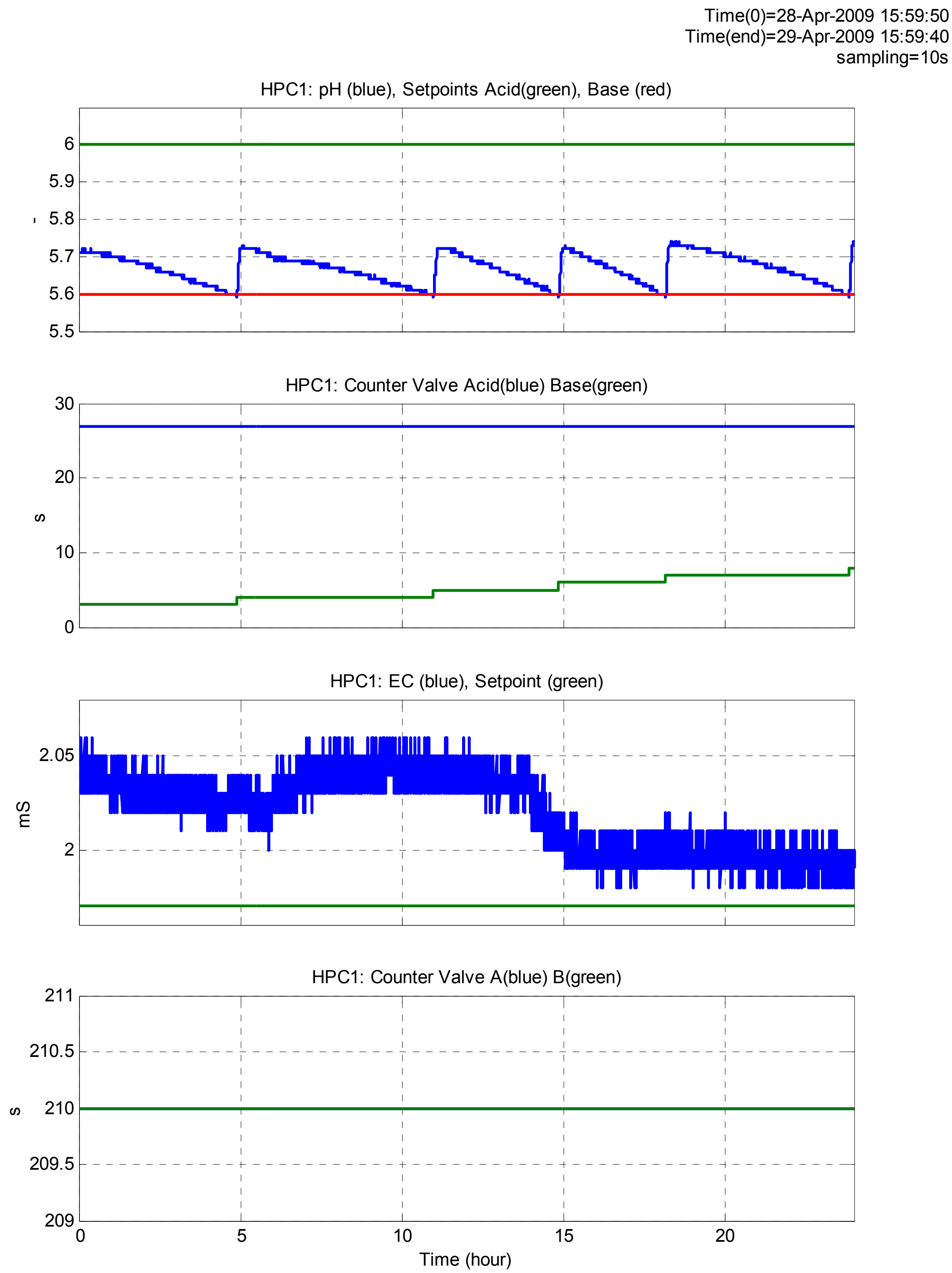

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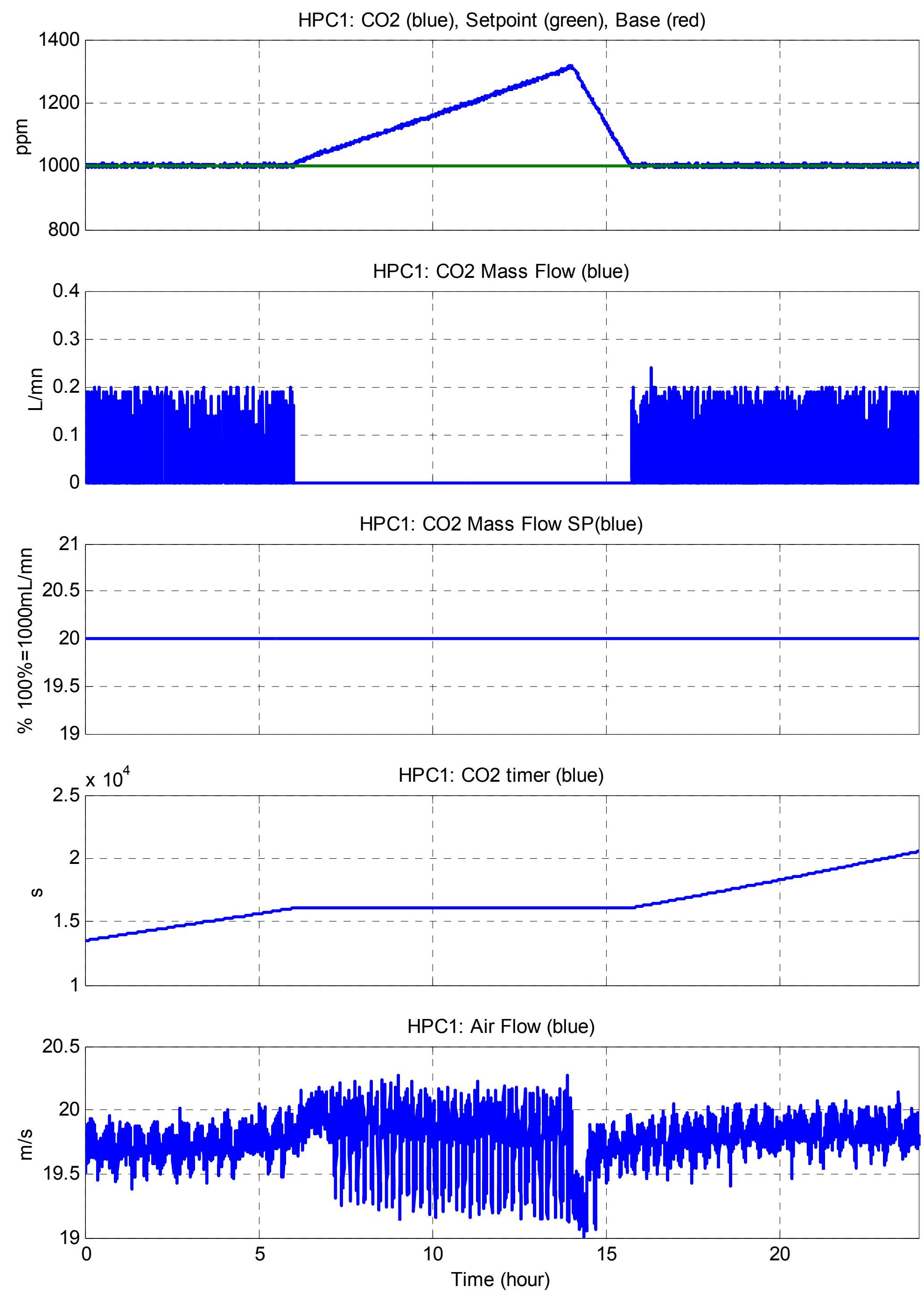

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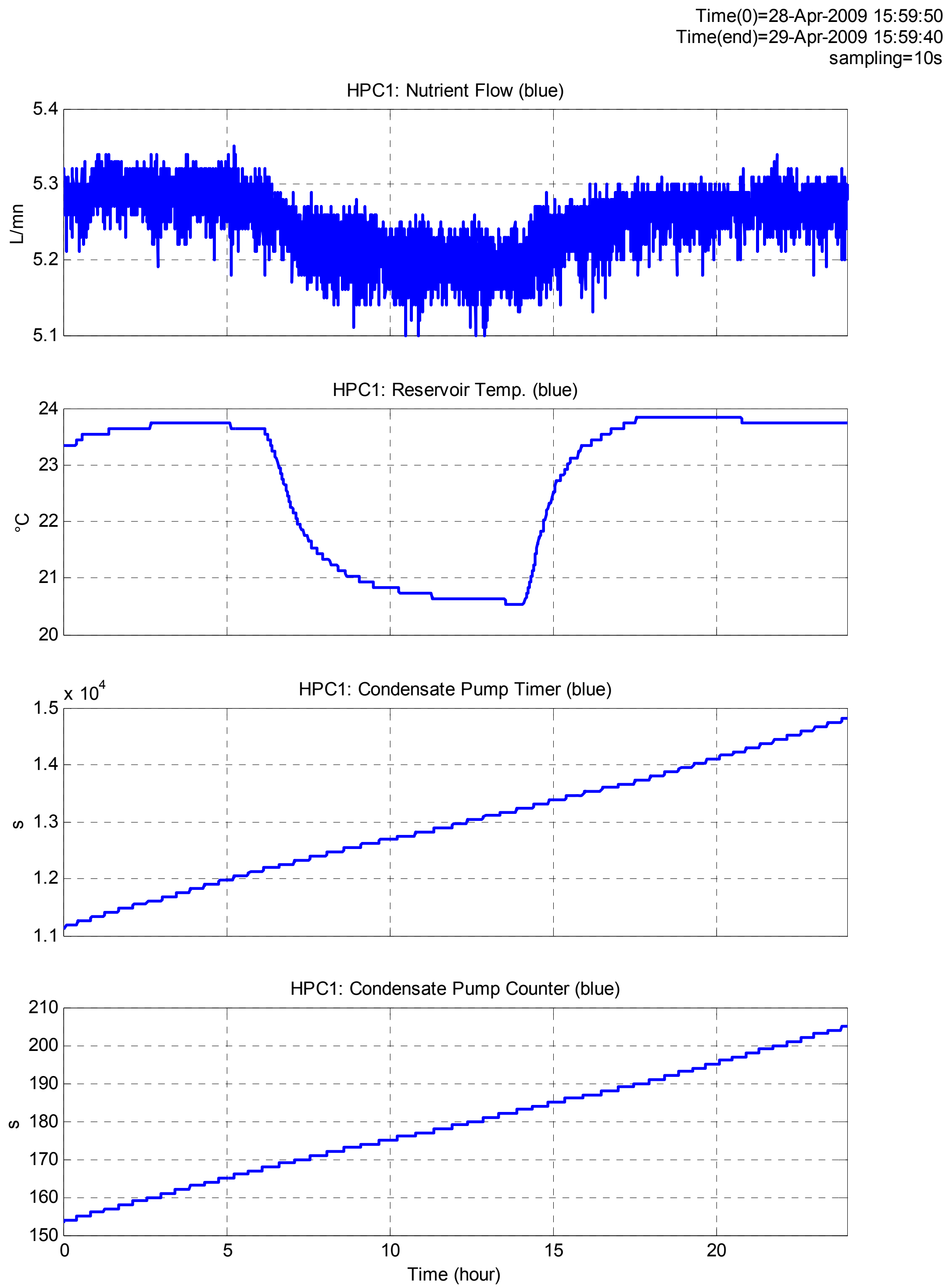

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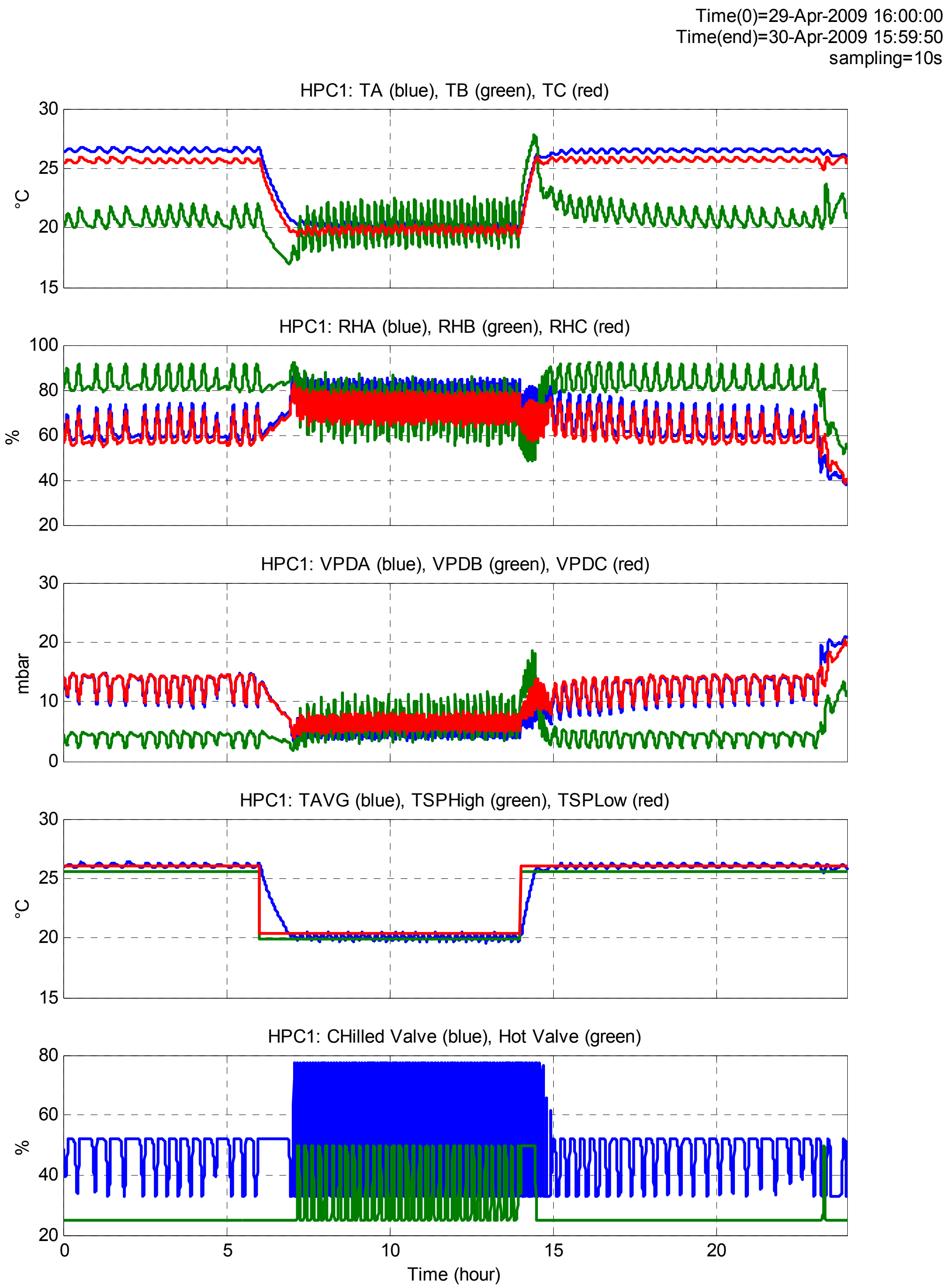

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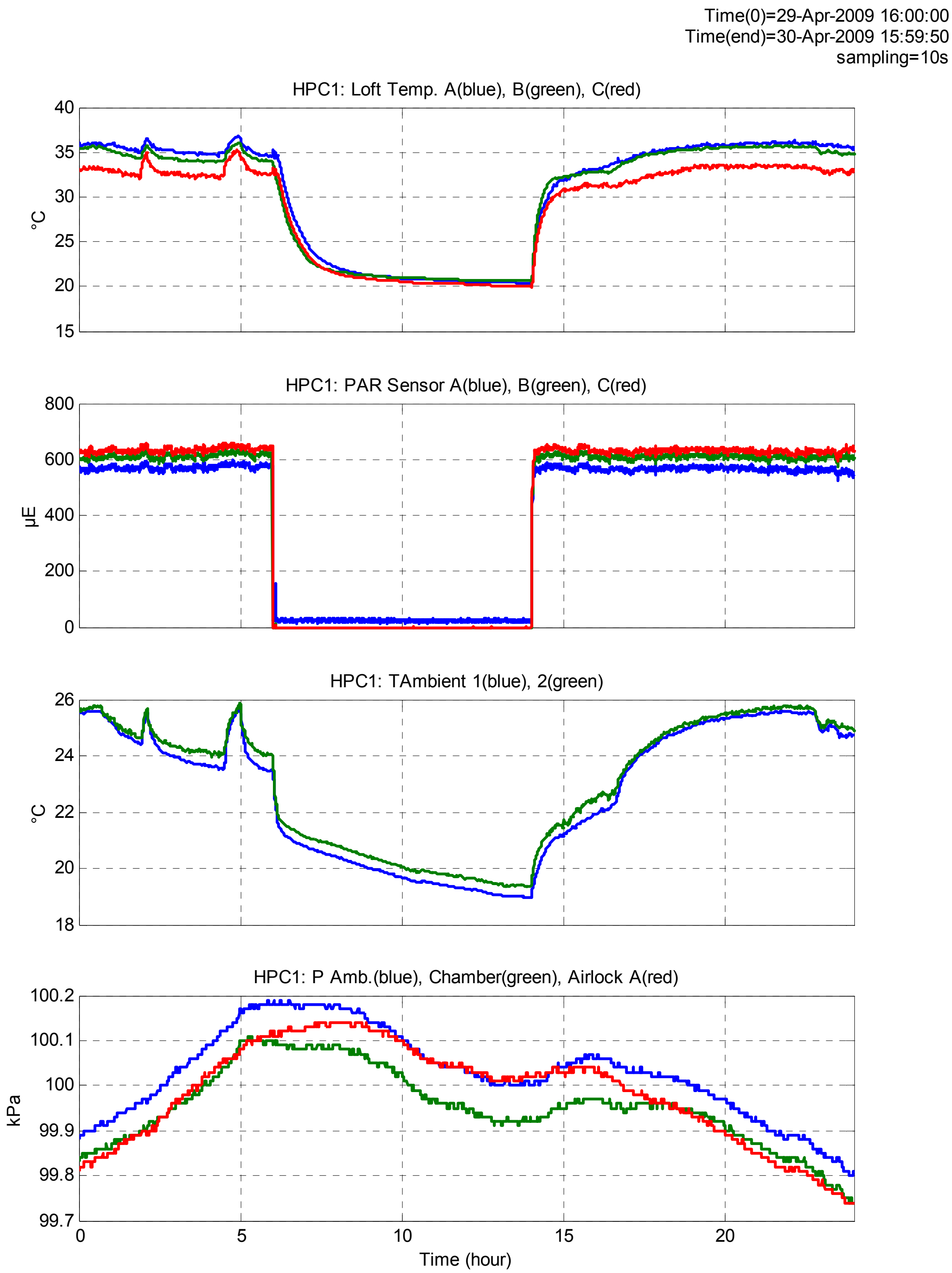

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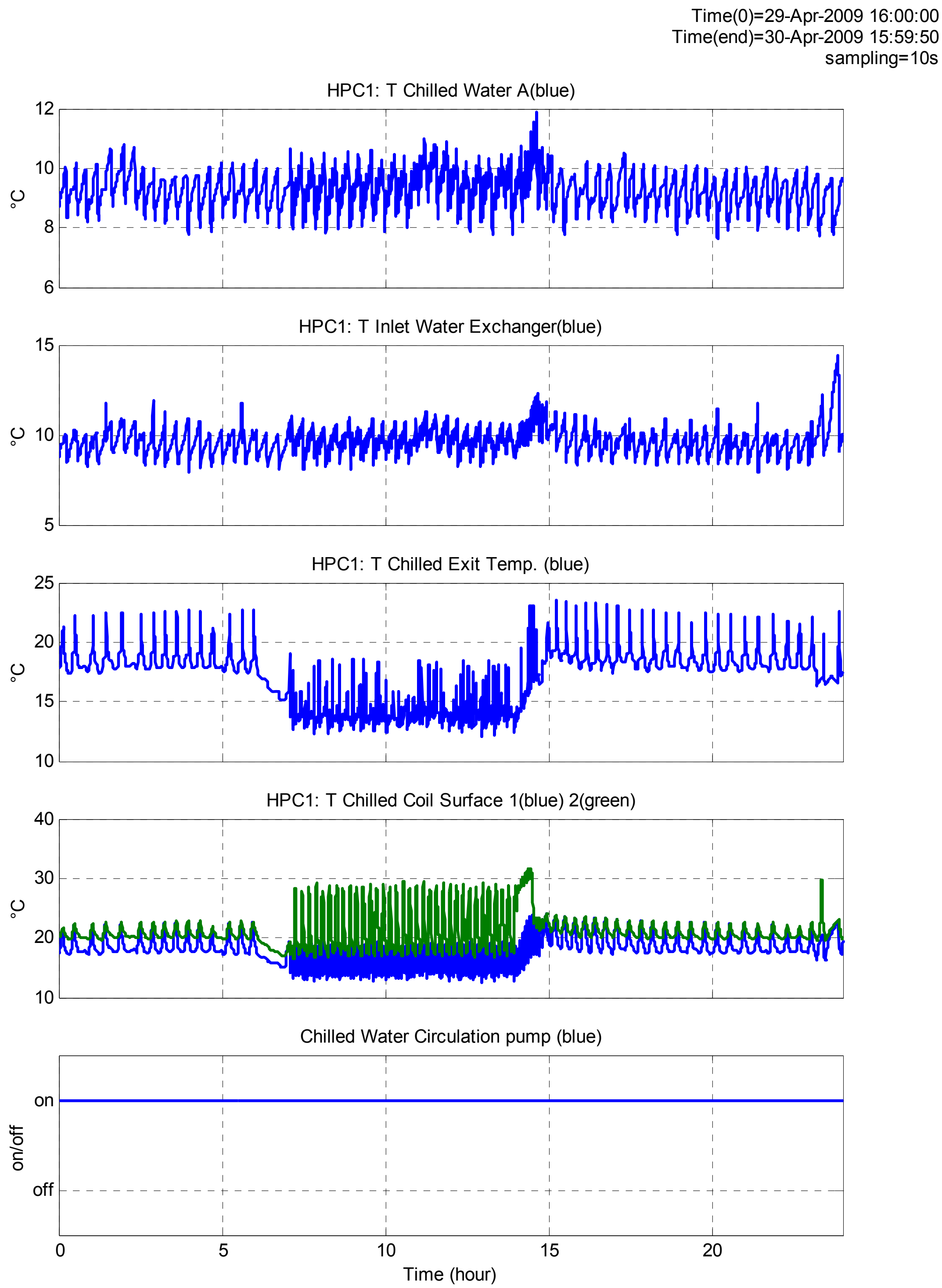

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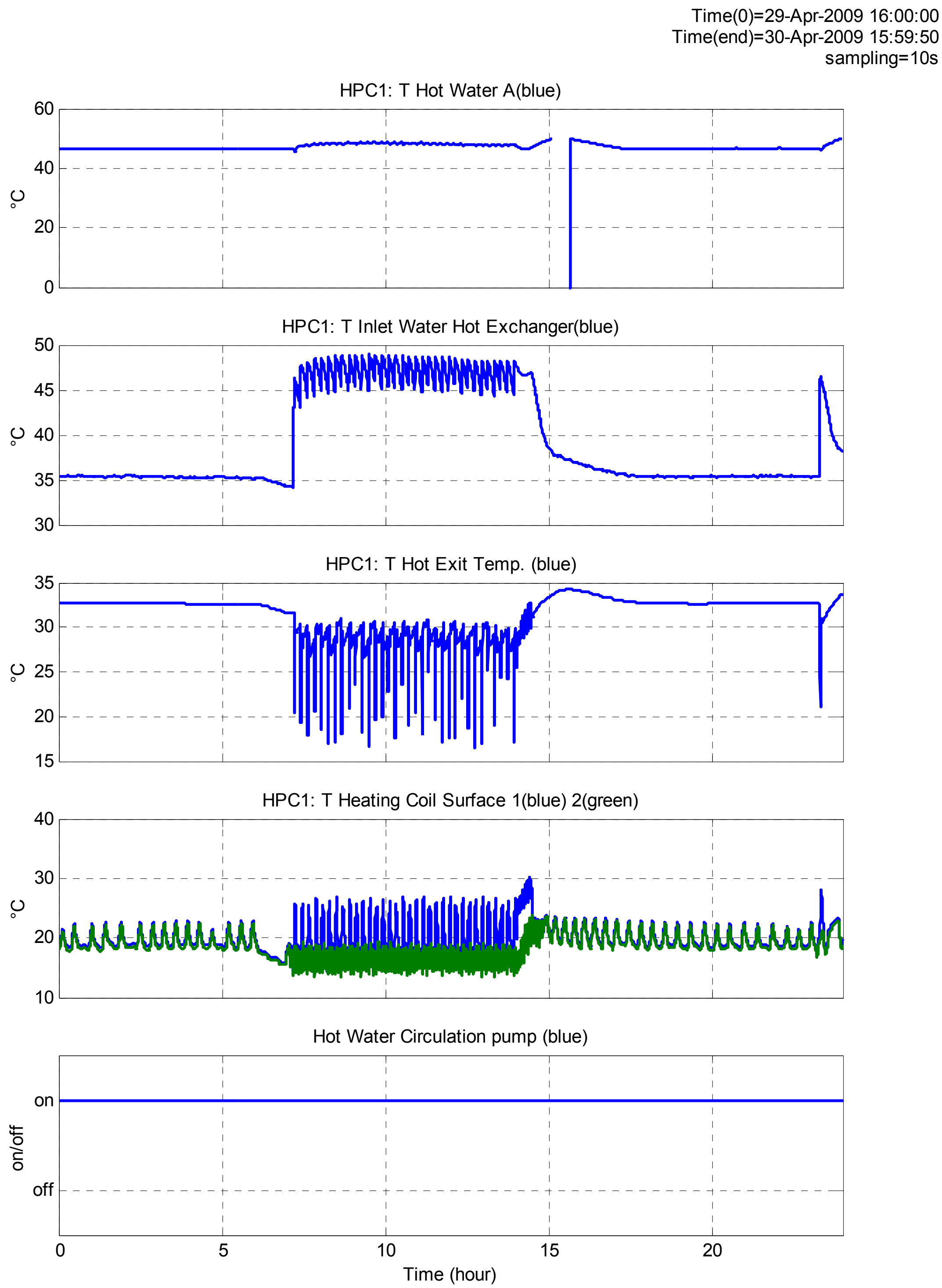

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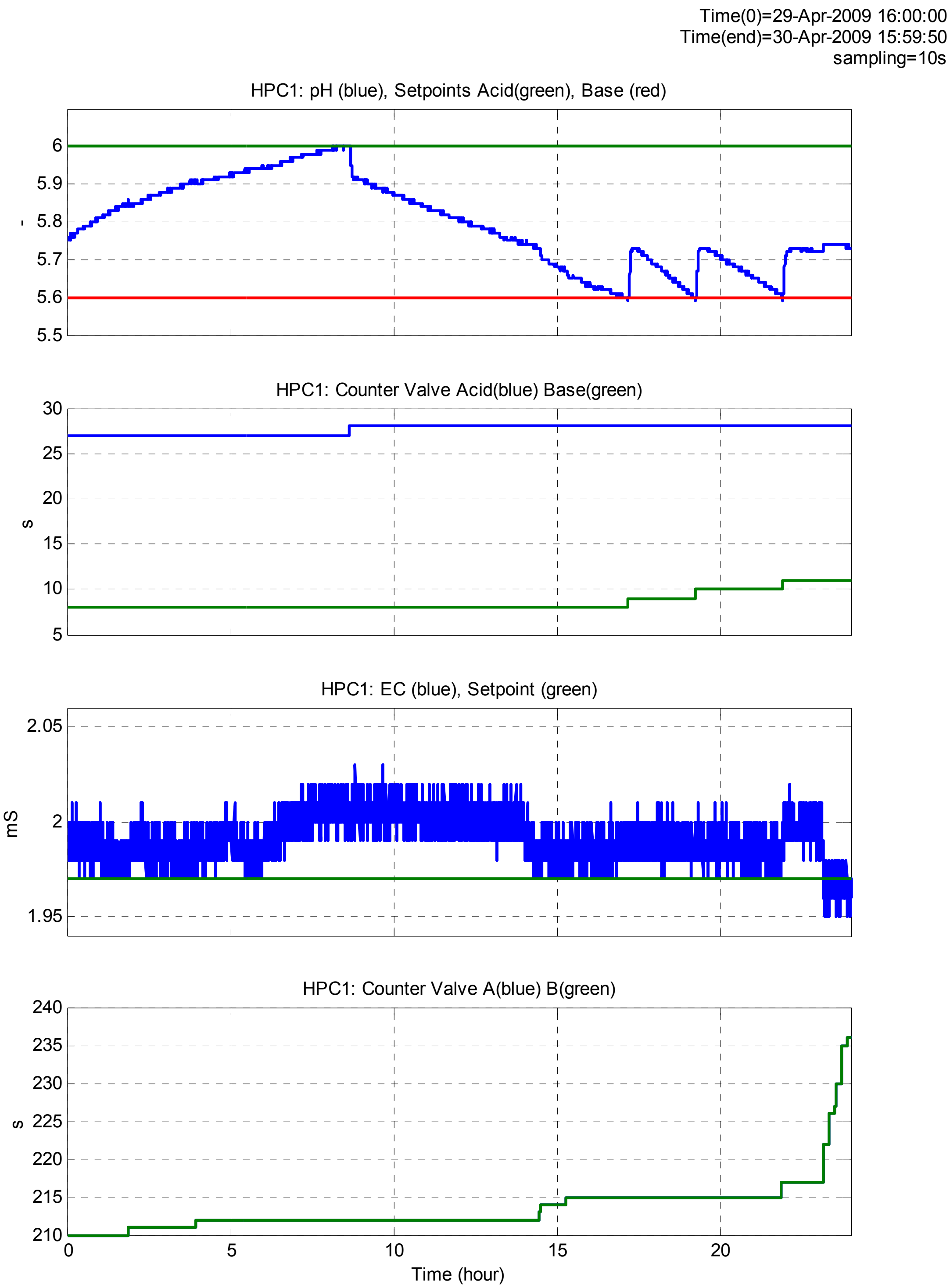

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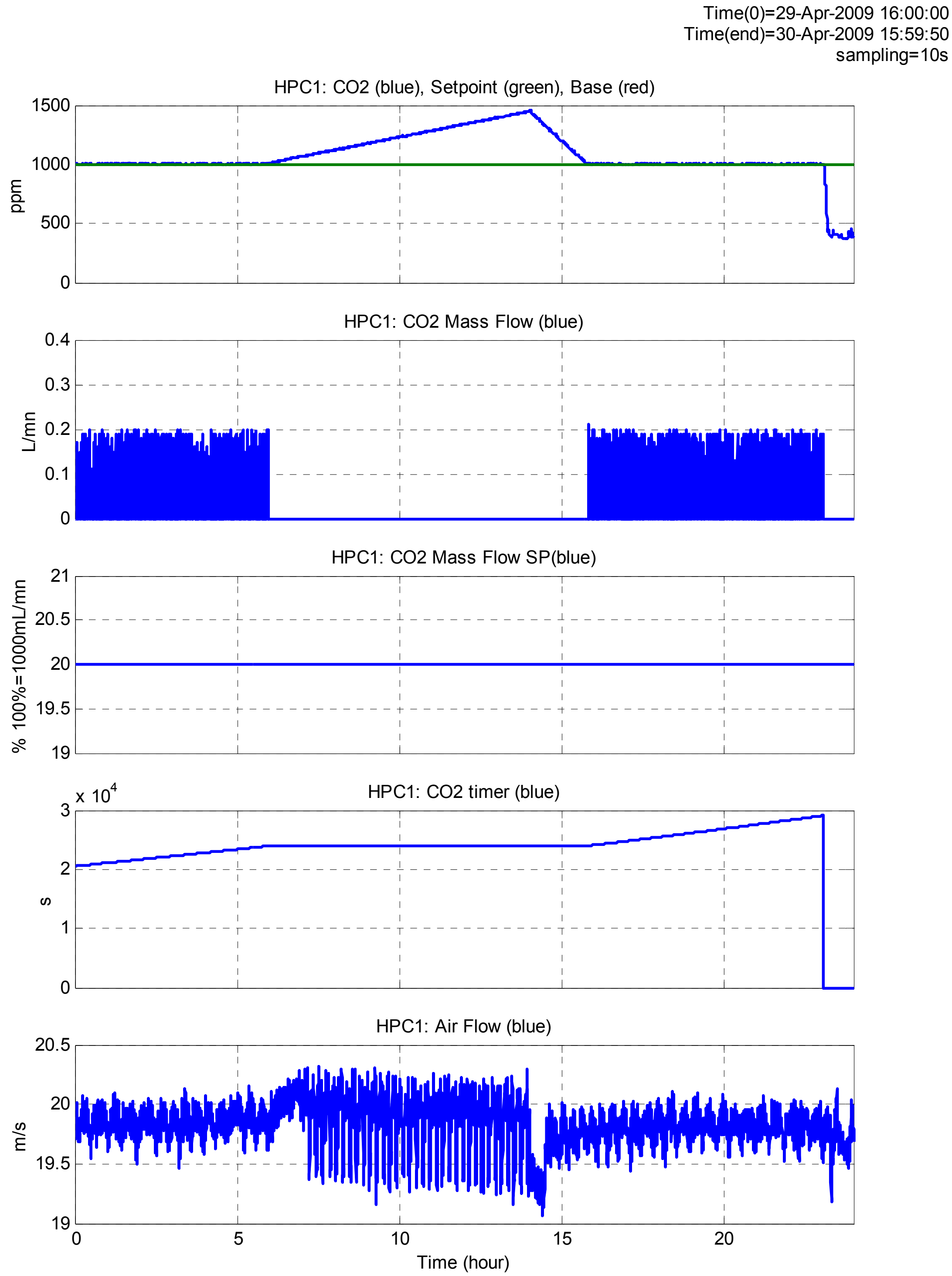

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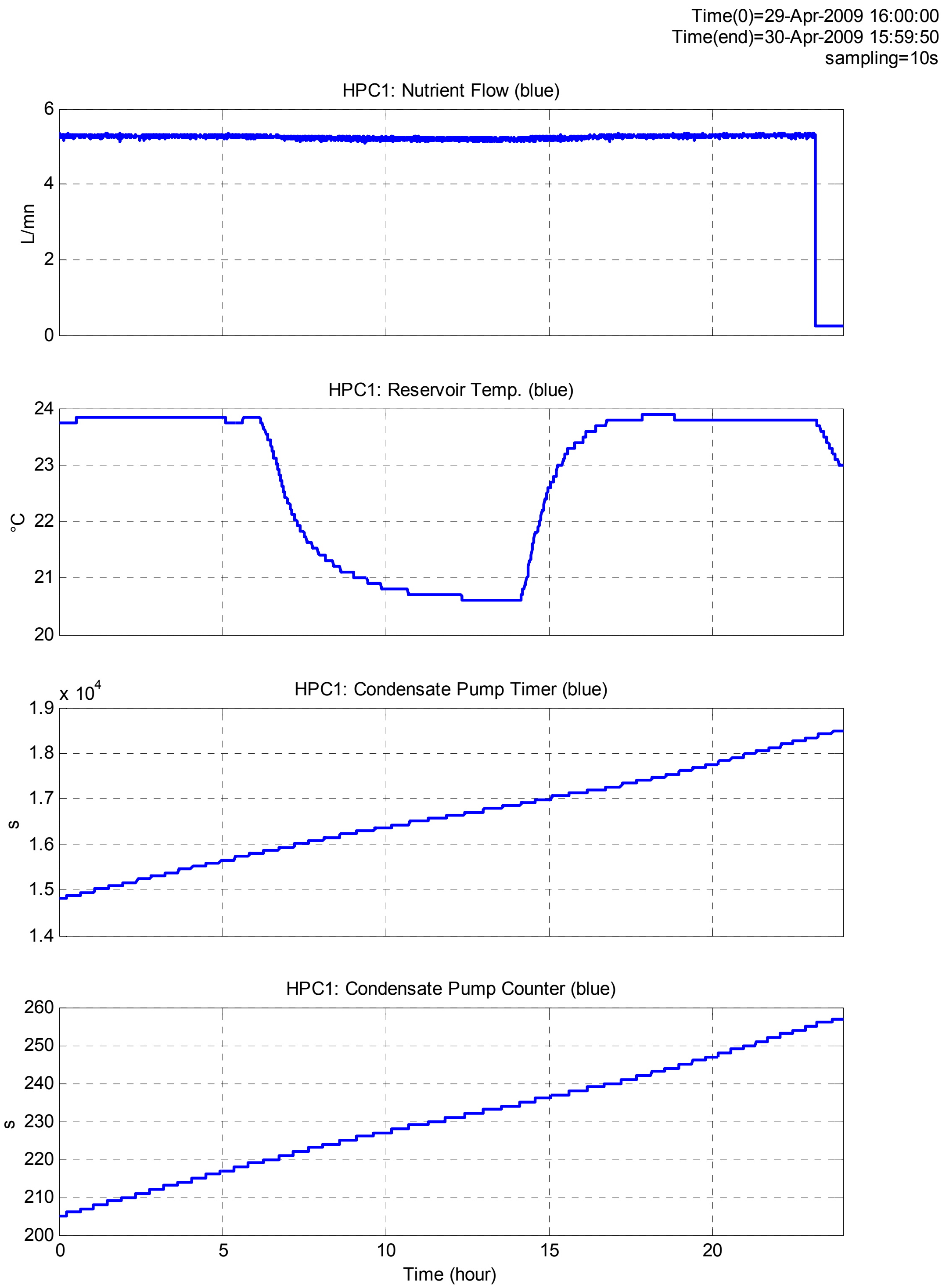

HPC1 : HPC_CROPTEST_April29_24h.xls

21 APPENDIX 4 – List of variables Argus/MPP/Simplified

This table is the correspondence between the Argus Names (in files). the MPP tag names and the "Simplified Names" used for the graphs.

#	Argus File Tags	MPP_Tag	MPP Tag Description	Simplified Name	Unit
1	DateTime	DateTime	DateTime	DateTime	
2	IO 1-8; A T1 Final Reading	TT_4112_01	Temperature A1 associated with humidity	TA	°C
3	IO 1-8; B T1 Final Reading	TT_4112_02	Temperature B1 associated with humidity	TB	°C
4	IO 1-8; C T1 Final Reading	TT_4112_03	Temperature C1 associated with humidity	TC	°C
5	IO 1-7; A RH Final Reading	AT_4112_01	Humidity A1 associated with temp A1	RHA	%
6	IO 1-7; B RH Final Reading	AT_4112_02	Humidity B1 associated with temp B1	RHB	%
7	IO 1-7; C RH Final Reading	AT_4112_03	Humidity C1 associated with temp C1	RHC	%
8	IO 1-2; A PAR Light Final Reading	RT_4104_01	PAR Sensor - A	PARA	µE
9	IO 1-2; B PAR Light Final Reading	RT_4104_02	PAR Sensor - B	PARB	µE
10	IO 1-2; C PAR Light Final Reading	RT_4104_03	PAR Sensor - C	PARC	µE
11	IO 1-3; Lamp Loft A Temperature Final Reading	TT_4105_01	Light Loft Temperature sensor A	TLoftA	°C
12	IO 1-3; Lamp Loft B Temperature Final Reading	TT_4105_02	Light Loft Temperature sensor B	TLoftB	°C
13	IO 1-3; Lamp Loft C Temperature Final Reading	TT_4105_03	Light Loft Temperature sensor C	TLoftC	°C
14	IO 1-1; Ambient T 2 Final Reading	TT_4112_12	Temperature C4 --> Reaffected to External T	TAmb2	°C
15	IO 1-9; Pressure C Ambient Final Reading (HiRes)	PT_4103_01	Pressure sensor for airlock C --> Reaffected to External Pressure	PAmb	kPa

16	IO 1-9; Pressure Air Lock A Final Reading (HiRes)	PT_4102_01	Pressure sensor for airlock A	PA	kPa
17	IO 1-9; Pressure Main Volume Final Reading (HiRes)	PT_4114_01	Growing Area Pressure	PChamber	kPa
18	AVG_T	TT_4112_AVG	T Average (A+C) in chamber	TAVG	°C
19	IO 1-6; Chilled Water Source T Final Reading	TT_4112_13	Temperature for facility chilled water	TCW	°C
20	IO 1-5; Chilled Water Loop T Final Reading	TT_4112_21	Inlet water Chilled Exchanger	TInletCW	°C
21	IO 1-3; Chilled Water Exit T Final Reading	TT_4112_17	Chilled Exit temperature	TOuletCW	°C
22	IO 1-7; Hot Water Source T Final Reading	TT_4112_14	Temperature for facility hot water line	THW	°C
23	IO 1-5; Hot Water Loop T Final Reading	TT_4112_22	Inlet water Hot Exchanger	TInletHW	°C
24	IO 1-3; Hot Water Exit T Final Reading	TT_4112_18	Hot Exit temperature	TOuletHW	°C
25	IO 1-7; Condensor Coil T 1 Final Reading	TT_4112_15	Chilled coil surface temperature	TChilCoil1	°C
26	IO 1-7; Heater Coil T 1 Final Reading	TT_4112_16	Heating coil surface temperature	THeatCoil1	°C
27	IO 1-4; Nutrient Solution T Final Reading	TT_4109_01	Temperature sensor for solution reservoir	TNutrient	°C
28	IO 1-4; pH Final Reading	AT_4107_01	pH sensor	PH	
29	IO 1-4; EC Final Reading	AT_4108_01	Electrical Conductivity of nutrient	EC	mS
30	IO 1-5; Nutrient Flow Final Reading	FT_4106_01	Outlet nutrient flow sensor	QNutrient	L/mn
31	IO 1-5; Air Flow Final Reading	FT_4111_01	Air velocity sensor	Qair	m/s
32	IO 1-8; CO2 Reading Final Reading	AT_4113_01	CO2 Analyser	CO2	ppm

33	Cold Valve	S3CV_4112_01_MV	Chilled Water Control Valve	CWValve	%
34	Hot Valve	S3CV_4112_02_MV	Hot Water Control Valve	HWValve	%
35	Heat S.P.	TT_4112_SP1	Temp. SP. High Value	TSPHigh	°C
36	Diurnal Setpoints; Cooling Setpoint Scheduled Setpoint	TT_4112_SP2	Temp. SP. Low Value	TSPLow	°C
37	IO 1-1; Ambient T 1 Final Reading	TT_4112_06	Temperature A4 --> Reaffected to External T	TAmb1	°C
38	LL; IO 1-4; Hot Loop Pump Final State	GP_4112_01_MV	Chilled water Circulation pump	PumpCW	
39	IO 1-4; Chilled Loop Pump Final State	GP_4112_02_MV	Hot water Circulation pump	PumpHW	
40	IO 1-8; CO2 MFC Flow Final Reading	FC_4113_01	CO2 Mass Flow	CO2MFlow	L/mn
41	IO 1-7; Heater Coil T 2 Final Reading	TT_4112_20	Outlet Air (TO BE CONFIRMED). hot exchanger	TChilCoil2	°C
42	IO 1-8; Condensor Coil T 2 Final Reading	TT_4112_19	Outlet Air (TO BE CONFIRMED). chilled exchanger	THeatCoil2	°C
43	CO2 setpoint	AT_4113_SP	CO2 Setpoint	CO2SP	ppm
44	CO2 Timer	AT_4113_Timer	CO2 Timer	CO2Tmr	s
45	MFC Setpoint	FC_4113_01_SP	CO2 Mass Flow set point	CO2MFCSP	%
46	NS EC setpoint	AT_4108_SP	EC SP	ECSP	mS
47	NS Acid setpoint	AT_4107_SP1	Acid SP	AcidSP	
48	NS Base setpoint	AT_4107_SP2	Base SP	BaseSP	
49	NS; Nutrient A+B Program; Counter/Accumulator Valve A Active	CL4108_CntA	Counter Valve A	ValveACnt	s
50	NS; Nutrient A+B Program; Counter/Accumulator Valve B Active	CL4108_CntB	Counter Valve B	ValveBCnt	s

51	NS; Nutrient ACID Program; Counter/Accumulator Acid Valve Active	CL4107_CntA	Counter Valve Acid	ValveAcidCnt	s
52	NS; Nutrient BASE Program; Counter/Accumulator BASE Valve Active	CL4107_CntB	Counter Valve Base	ValveBaseCnt	s
53	NS Condensate timer	CL4110_Timer	Condensate Pump timer	CondPumpTmr	s
54	NS Condensate counter	CL4110_Cnt	Condensate Pump counter	CondPumpCnt	s
55	A VPD	CL4112_VPDA	VPD A	VPDA	mbar
56	B VPD	CL4112_VPDB	VPD B	VPDB	mbar
57	C VPD	CL4112_VPDC	VPD C	VPDC	mbar

Not I/O variable. HMI or Control Parameters

22 Comments

Functional Testing with Argus Controller – As-run procedures, Test results and final Test report

Comments

General comments

1 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

OK. Conclusion added in Section 16; comparison with tests performed in UoG is briefly explained in the Conclusion chapter. Comparison with Schneider will be included in TN96.11.

2 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

The writing of TN96.5 has been improved for clarity; duplicated curves removed and confronting views foreseen more in last TNs (96.12 and 13)

3 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

4 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

5 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

6 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
8-9/index	Graphs to be removed from the index table Done
12/ table	There is s problem on the EC unit which should be in mS/cm or dS/m not in dS/cm; for you rinformation, the annex to appendix 1 of the RFQ 3-11515 is given in a separate doc. Done
12/ Section 1.5	Please clarify the title 'Additional testing' ; additional to functional testing as performed in UoG? UoG: As requested by SHERPA, it was decided to take advantage of the testing of the HPC1 with the Argus sytem to perform simple Open and Closed Loop tests to characterize the Argus contol system so that Sherpa could prepare the tuning of the controllers for the Argus replacement by Schneider controller - this detail has been added and the actual documents that outlined the procedures are now appended to the TN to improve clarity. MPP : the title of previously named part 15 was "complementary tests : open and closed loop tests with ARGUS controller" ; another possibility is :Additional testing to prepare the switch to Schneider control system
21	When there is mention to a required/nominal value, we understand the corresponding measured/calculated cell should contain a value. Please clarify or update when appropriate along the full TN Done
30/item 8 and 10	Please make a link to the deviation ; otherwise the test should be reported as Failed Done
31/Section 5.13	The justification of the deviation should be clarified; why are "no changes needed"? UoG: no changes were required because it does not matter if the signal goes from 0 to 5 or from 5 to 0. there is a distinct change in the signal and that is all that is required for the control system. MPP: Clarified in the text
36-38	In mosts cases the measured/calculated column shoulkd be filled in; please update Done
37/ item 19 to 21	Please include reference to the deviation Done
46/table	Can you clarify why you needed an O2 analyzer; to verify the measurement of the PO2?

	The clarification is given in the table (p.42)
76/Section 14.5	Please clarify that VPD is neither controlled nor even measured (This is what is understood from other TNs); please correct EC unit; please clarify for pH if there is a set-point or not, and explain why During the test with Argus controller VPD is the control point for atmospheric water content rather than RH. VPD is a calculation, RH was measured. EC unit is corrected; the set-point for pH was 5.8 and it is indicated in TN
74/Section 14	Please include reference to the TNs about cultivation protocols, sampling protocols…please clarify somewhere the phases (treatments?) of the test, i.e. how many seeds, renewal of the nutrient solution……as a general remark we miss precise data all along the reporting of this test, e.g. the raw data to produce the graphs, how many tissue samples, their weight, the analytical methods.... The reference to the TNs about cultivation protocols, sampling protocols is added; quantity of seeds is given in TN96.5, page 73; renewal of the nutrient solution is not required for this test, this information is given on page 73; raw data of plants weight, minerals content in the nutrient solution and mineral and elemental composition of plants is given in the end of TN 96.5, Appendix 4, as well as quantity of tissue samples; information about analytical methods is given in TN 96.4
77/1.	We understood the separation of roots from rockwool was rather impossible; please calrify and report Clarification is given on page 75 of TN 96.5
77/2.	Aproximately 1 to 14 days: indeed rather approximative, please clarify this range Done
78/1st par.	*"Was observed"* please precise if it was a visual observation only Done
78	The scheduled completion date is sometimes May 4, sometimes April 30; please clarify Done
78/2nd par	*"Was apparently unaffected"*; please precise if visual inspection only Done
79	Please precise which 20 plants have been harvested e.g. which trays…please explain why 20 plants were harevested and why we decided to continue with the other remaining 80. Done
79 and fol.	The complete paragraph 14.8 shoud be reorganized . There is mix of results, conclusions all along this paragraph, without any outline/numbering to discriminate Agreed. The TN has been updated to improve clarity.

80 and fol	There are discrepancies between the figures numbers in the legend and in the text; please verify and update Done
80	We don't have the figures with water temperature There are figures 2 and 3 with water temperature
80/table 2	Please refer somewhere or include a diagram with the positioning of the sensors; the full 11days was performed only with 80 plants, right? Please update the title . I see a set-point at 5.8 for pH (see my remark on page 76/14.5 We now refer in Table 2 description to the PID of the chamber, where the location of the different sensors is shown; and we can even include the PID as an annex to the TN The title is updated; set point was 5.8
81/fig.2	Please clarify what is meant by Average(I anticipate average of all sensors of the chamber); do we have discrepancies over the chamber, can we explain the amplitudes of the peaks?; can we have a view over many days as well? UoG: Average is not of all sensors, only the ones used for control. Amplitudes of which peaks - HPC T, Hot water, Chilled water, and ambient T are displayed in this graph. There were no peaks wrt the HPC control other than during periods of lost central control of chilled or hot water.
82/fig3	Can you confirm the profile is the same for other days? UoG: Yes (data not provided)
83/fig4	Can you provide as well a zoom of some parts? UoG: sure. Please specify what is required. Note that all the data is available in the accompanying data files. MPP: The zoom is provided in Figure 5, isn't it? Apart of the transition, is there any other relevant part?
84	Illustration: do you mean figure 5? corrected, it refers to Figure 7 in fact
85	In the text you mention 2.0+/- 0.7 mS/cm; it seems low when looking at the curve; can you please clarify? UoG: 2.0 +/- 0.07 mS It is correct - note that the control line indicated is at 1.97, not 2.0. We have added an additional decimal place which results in an EC of 2.04
85	Can you explain the pH profile at aournd 6-7 days of plant growth? Explained in the text

86 Can you please provide more information on how you obtain the profile of figure 7; is it the result of condensate volume measurement? Please note that the water you collect is not at potable water quality. The volume seems rather high; do we have any "blind test" to discriminate between evapotranspiration of plants and normal condensation?Did you record the residual volume of nutrient solution?

UoG: water is collected as condensate during dehumidification. Why is it not potable? The collected water is in contact with food grade wetted surfaces. If containment systems are cleaned prior to collection, the water is suitable for consumption.

MPP : We suppose you refer to Figure 9. Not blind test was performed to discriminate evapotranspiration/ condensation. Text rephrased to better explain it. Residual volume of nutrient solution was not recorded, but all the condensate collected in the condensate tank was transferred to the nutrient solution reservoir. The measurement of the volume of condensed water is made by a counter summing up the number of times the high level switch of the condensate tanks is reached, before the content of condensates tank is reinjected into the nutrients tank by the pump CP_4110_01. The volume between the high level and low level switches in the condensate tank corresponding to one cycle of filling/emptying was measured to be 1L.

86 It is stated that the room temperature was sometimes exceeding the control temperature inside the chamber. Although we understand that there are some physical limitations of the heat removal capacity, there should not be a direct influence of the room temperature if the chamber is tight and well insulated. Can you confirm/clarify?

UoG: The chamber was designed to operate within a propery controlled human habitable building environment. The chamber is tight but insulation was minimized due to building size limitations.

MPP: Text rephrased, stating that in fact the ambient conditions didn't jeopardise the temperature control inside the chamber within the current test.

87 You state 100 plants of 11 days however we have only 80, haven't we? You mention that no argus control tuning has been performed because of schedule constraints: can you please confirm?Can you please include where necessary the profile o fthe chilled water temperature?Last paragraph looks like UoG conclusion to UAB and should be rephrased/ amended by UAB

UoG: Tuning was not performed because we were running out of time to complete everything in a reasonable time after all the infrastructure delays

MPP: 100 plants were changed by 80 plants; last paragraph is rephrased (now in Section 15.6); profile of chilled water temp. is shown in Fig. 2 and 3

88 and fol. We miss somewhere the tables with the raw data (to be placed in annex?) I guess the 20 plants harvested after 7 days were all plant#3 along the chamber; please clarify. The titles of the figures should be self understandable, e.g. precising the duration of the growth period… to ease comparison with others

The tables with raw data are added to Appendix 2; the other comments are taken into account and corrections/additions are made

89 I do not understand the consistency between figure 12 and 13 b. It would be helpful to start fig 13 with fresh biomass instead of dry biomass as it is a direct continuation of figure 12.

Done

89 A link to TN about analysis protocol would eb appreciated; you suggest several replications; how many would you recommend?

requied information is added

91 Environmental conditions: do you something more specific in mind?

Information is added

92 and fol. It would be very useful to have 3D graphs to see the discrepancies on both axes of the chamber. Can you please clarify why you do not have fres and dry weights for all trays whereas in the sampling protocls it is mentioned that every single plant is harvested for at least fresh an dry weight determination? You produce a serie of figures however you do not explain why you choose to illustrate your results this way: can you clarify your logic and introduce your figures? To ease the reading of this TN, it would be usefull to raise your conclusions and illustrate them with your figures.Raw data are needed in annex to this TN. This will be very important to compare with future crop tests results.

All comments are taken into account and necessary changes are performed in the document

100 Sampling strategy of the nutrient solution is not given; how do you take your 3 samples, when? Which volume do you collect? Was the nutrient solution renewed during the test?

This information is given in TN 96.4

101 Do we know how much of the nutrient solution has been added? "treatment" is maybe most the best wording: crop growth Phase? Please precise the rationale of analysing the seedlings at 15 days,i.e at the time of transplanting to the chamber. What is the sampling strategy for each "treatment"? PLease refer to the relevant TNs. Maybe it is worth to give all the information provide as annotatoions to table 4 in the main text before the table itself.

Information about quantity of consumed nutrient solution is added into the document; "treatment" is an universal term used in Anglophone scientific journals for designation of version of experiment; all other comments are taken into account and the changes are done

102 Table 5: obtained--> do you mean uptaken from CO2 and water; it is not clear from the title of table 5 that you have analysed the leaves only. Do you compare the leaves analysis with the analysis o fthe correpsondong whole plants? Please clarify

There is set expression in plant physiology when it comes to those elements (C, H), "obtained from water", etc.; in the title of table 5 it is mentioned that content of those elements was given for lettuce shoots, which is in case of lettuce plants is equal to lettuce leaves

106	The title of pararaph refers to open loop tests whereas closed loop tests are included as well Amended
106	*"Specific objective.."*: this remark should be removed as the tests had been included in TN 96.2. The remark under the table should be rephrased/removed: there is no Sherpa document there is one MPP TN. Please clarify why some tests planned were not implemented (see table) UoG: There are separate Sherpa documents - these are included in the appendix. MPP : Agree to remove both sentences (text amended). Sherpa documents can be included in Appendix as proposed by UoG. Some tests were not performed (N in the Implemented column). EC/pH and CO2 tests were more relevant to be done in closed loop in order to evaluate the performance, as open loop tests will be performed with the Schneider Control System (explained in the text).
106	15.2 open loop valves is illustrated by closed loop valves, is it correct? UoG: The additional testing for Sherpa has been separated from this document and the original documents have been included to improve the clarity of this TN. MPP:"closed loop valves" was the name of the excel file provided by UoG for the test. Even if the name is not relevant it is really an open loop test. Text supressed in the figures.
107	15.2. Wording to be updated to include purpose of the test, clarifications on why some data are missing… Data are missing because they were not recorded by the Argus system (explained in the text). The purpose of the test was to evaluate the behaviour of T and RH with specific sollicitations of hot and cold valves (explained in the text).
108 and fol	Many colored lines are missing on the graphs, some are even empty, some units are wrong, some are missing. Please update . Conclusions of the tests are missing. Lines or data are missing because data were were not provided for these parameters The main conclusions are provided within the description of each test
116 and fol	Duplication with pages138 and fol. Please update the TN to be one document not a succession of various inputs.Legend is missing on axes on many graphs. Graphs seem cut at the end Duplication has been removed; document has been updated. Graphs amended and legend included.
116	Conditions of the test: I do not understand that we refer to 2 temp set points with such narrow temp range, can you clarify? In the Argus system, temperature is not controlled by a set point but in a

	range(Low/High)
119	please update the EC unit
	Done
122	Nutrient tank temperature: please clarify which new design you are referring to.
	Explained: it refers to the Final design of the HPC
138 and fol	Results of the complementary tests: see previous remark
	Duplication has been removed; document has been updated.
	An overall conclusion of this TN is missing
	Overall conclusion included