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TECHNICAL NOTE 96.2

Functional Test Plan and Test Protocols with Argus Controller

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TECHNICAL NOTE 96.2

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1. Introduction

1.1. Purpose and Structure of Test Plan

The information contained in this technical note is presented 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 plan consists of three main phases. First, a series of Functional Tests will demonstrate the functionality of all chamber parts. Secondly, formal control tests are aimed to demonstrate chamber adherence to the environment control requirements listed in Annex to Appendix 1 of RFQ 3-11515. The final operational test will consist of a batch culture of lettuce conducted under static conditions. The batch culture of lettuce with an Argus Controller will not constitute a full crop cycle, as it is 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	0 – 10 µE PAR

levels	
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 dS/cm +/- 0.05dS/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)

1.5. Additional testing

Sherpa Engineering has requested a series of open and closed loop tests to characterize the chamber prior to the installation of the Schneider hardware. These tests have been gathered in paragraphs 15. and 16. of the present TN.

2. Functional, Control and Operational Tests Program for HPC1

Test	Procedure /Procedure number	Date	Duration (days)
Functional Tests			
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	02/06/09	0.05
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	02/06/09	0.05
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	02/04/09	0.1
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		

	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)		
6. Gas Analysis	**MPP-HPC1 – Gas_Analysis – FT** **Sequence:** 1. Demonstration of IRGA functioning 2. Demonstration of O2 analyzer functioning 3. Demonstration of the factory calibrated mass flow controller (with set-point) 4. Test of CO2 injection line solenoid **Parts Tested (P&ID Reference):** 1. AT_4113_01 (CO2 Analyzer/IRGA)		

	2. AT_4113_02 (O2 Sensor) 3. FC_4113_01 (Mass Flow Controller for CO2) 4. SV_4113_01 (CO2 injection line Solenoid)		
7. Integrity leakage Test	**MPP-HPC1 – Leakage – FT** Performance of passive CO2 decay test with running air circulation fan to determine operational leakage rate		
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)		
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 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)	02/04/09 and 02/06/09	0.2
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 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		
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		
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) 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 21C) 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		
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		
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		
Condensate Collection Control Loop 4110	**MPP-HPC1 – Condensate – CT** Activation of condensate drain procedure by the controller		
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		
CO2 compensation control	**MPP-HPC1 –CO2 – CT**		

Control Loop 4113	Profile tests of CO2 control by the controller		
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		

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

1. The two exterior air lock doors may be opened and securely closed by an operator without excessive force
2. 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 Procedure

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
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	
2	Confirm activation of LED (ZI_4100_01) indicator to indicate exterior door A is open	RED LED (ZI_4100_01) indicates door open			
3	Close exterior air lock door and secure latches along the door perimeter				
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			

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

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 Procedure

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
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				
2	Open the magnetic seals				
3	Using the polypropylene lift rod, set the door supports onto the upper support pegs				

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

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):

1. SV_4102_01, SV_4102_02, SV_4103_01, SV_4103_02
2. HV_4102_01 HV_4103_01
3. PS_4102_01, PS_4103_01
4. PT_4102_01, PT_4103_01
5. 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 Procedure

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
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		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	
2	Connect an air pump to the purge gas inlet line on the external solenoid panel and turn on the pump				
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	
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	
5	Connect on end of the tubing to the purge inlet (bottom) 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	
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	

7	Using the Argus control system, go to the input display for sensor PS_4102_01				
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	
9	Using the Argus control system, go to the input display for sensor PS_4103_0				
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	
11	Using the Argus system, observe and record the pressure sensor readings for air locks A and C		_____ A _____ C	Sensors should read between 95 and 105 kPa	
12	Disconnect the Overpressure Sensor Manifold from the chamber at the Swagelok fitting.				
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			
14	Turn on the air pump.				

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.		______ Initial detect # ______ 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.	
16	Turn off the pump, disconnect the Manometer manifold, and reconnect the Overpressure Sensor Manifold to the HPC				

5.12 Conclusions

Valves and pressure sensors 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

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):

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)

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 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 Procedure

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P)/ Fail (F)
1	Position and centre PAR Sensor A (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				
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				
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		
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			
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			
7	Using the Argus control system, activate lamp string HPSa	LHPS_4104_01, _03 and _05 are ON			
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			
9	Deactivate lamp string HPSa				

10	Confirm all air loft fans remain running				
11	Position and centre PAR sensor (RT_4104_01) under the HPS lamp reflector that is member of string HPSb in module A				
12	Position and centre PAR sensor (RT_4104_02) under the HPS lamp reflector that is member of string HPSb in module B				
13	Position and centre PAR sensor (RT_4104_03) under the HPS lamp reflector that is member of string HPSb in module C				
14	Activate lamp string HPSb				
15	Confirm continued operation of all lamp loft fans				
16	After a warm-up period of 10 minutes, confirm and record readings of PAR sensors corresponding to illumination of HPSb				
17	Deactivate lamp string HPSb				
18	Confirm all air loft fans remain running				
19	Position and centre PAR sensor (RT_4104_01) underneath the MH lamp reflector that is member of string MH in module A				
20	Position and centre PAR sensor (RT_4104_02) underneath the MH lamp reflector that is member of string MH in module B				
21	Position and centre PAR sensor (RT_4104_03) underneath the MH lamp reflector that is member of string MH in module C				
22	Activate lamp string MH				
23	Confirm continued operation of all lamp loft fans				
24	Confirm readings of PAR sensors corresponding to illumination of MH				
25	Activate lamp string HPSa				
26	Activate lamp string HPSb				
27	Activate lamp string MH				
28	Confirm continued operation of all lamp loft fans				

29	Confirm log of lamp loft temperature sensors Loft-T A-C, record initial values		A ______ B ______ C ______		
30	Allow lamps to run for 1 hour				
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.				
32	Confirm continued operation of lamp loft fans				
33	Turn off lamps and let cool for 15 minutes				
34	Reset lamp loft temperature limits and reactivate lamps				
35	Controller instructs lamp strings (HPSa, HPSb, and MH) to operate for an extended period.	14 hours (nominal)			
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.	

6.12 Conclusions

To be competed in the annotated procedures document

6.13 Deviations

Seq. Nb.	Description of the modification	Justification

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):

1. BLWR_4111_01 (Air Circulation Fan)
2. MVFD_4111_01 (Air Circulation Motor)
3. 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;

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

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 Procedure

Step by step description of the operations performance

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
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				
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				
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				
	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				
	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				
	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				
16	Return the VFD to 0 Hz, main centrifugal blower remains idle				

7.12 Conclusions

To be competed in the annotated procedures document

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 CO2, O2 analyzer, mass flow controller for CO2 injection, manual injection over-ride valve and the CO2 injection line solenoid.

8.3 Acronyms used in this test plan procedure

IRGA – InfraRed Gas Analyzer for CO2
PO2 – Paramagnetic Analyzer for O2

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 (CO2 Analyzer/IRGA)
2. AT_4113_02 (O2 Sensor)
3. FC_4113_01 (Mass Flow Controller for CO2)
4. SV_4113_01 (CO2 injection line solenoid)
5. HV_4113_01 (CO2 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) CO2 gas source with to be connected to the CO2 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 CO2 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 CO2 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	PO2	AT_4113_02	Integrated with CO2 analyzer	
Gas Analysis	Mass Flow Controller for CO2	FC_4113_01	Closed (0 L/min flow)	
Gas Analysis	CO2 injection line solenoid	SV_4113_01	Closed	
Gas Analysis	CO2 injection line manual over-Ride ball valve	HV_4113_01	Closed	No CO2 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 Procedure

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Calibrate the IRGA/PO2 analyzer			See anayzer operating manual for	

				calibration instructions	
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		See MFC operating manual for manual setting of MFC	
3	Set the Argus control system CO_2 demand to 1500 ppm	SV_4113_01 is OPEN			
4	Open the CO_2 line delivery pressure of 110 kPa	CO_2 tank regulator delivery at 110 kPa			
5	Open the CO_2 injection (SV_4113_01) override valve	SV_4113_01			
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 PO2 (AT_4113_02) should continue to read ambient concentrations	AT_4113_01 indicating rising CO_2 AT_4113_02 reading ambient O_2 (~21%)		The Argus controller will record CO_2 concentration	
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 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)				

8.12 Conclusions

To be competed in the annotated procedures document

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. CO2 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. CO2 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 CO2 curve, expressed as % Leakage of CO2 (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 CO2 (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 1200 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 and outlet lines. Analyzer	Confirm air flow through analyzer and operation of analyzer sampling pump.

			is turned on and operational	Analyzer sample return is back to the chamber growing volume to create a closed sampling system
Gas Analysis	Mass Flow Controller for CO2	FC_4113_01	Closed (0 L/min flow)	
Gas Analysis	CO2 injection line solenoid	SV_4113_01	Closed	
Gas Analysis	CO2 injection line manual over-Ride ball valves	HV_4113_01	Closed	No CO2 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 Procedure

Date: Time:	Test Engineer/operator: ESA/UoG Representative:

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)				
2	Confirm fan operation through Argus control system and air velocity sensor (FT_4111_01) output				
3	With the IRGA sampling (and stabilized) from the interior growing volume, record the initial reading	AT_4113_01 reading ambient CO2 (350 – 400 ppm)			
4	Set the Argus control system CO2 demand to 1500 ppm	SV_4113_01 is OPEN			
5	Open the CO2 line delivery pressure fo 110 kPa	CO2 tank regulator delivery at 110 kPa			
6	Open the CO2 injection (SV_4113_01) override valve	SV_4113_01			
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 CO2 until the setpoint is reached	
8	In the Argus control system, set CO2 control to 'manual off' so that no more CO2 is added to the system				
9	Allow data collection by the Argus control system for a minimum of 48 hours				
10	Calculate the leak rate given the concentration at the beginning of the test and after 24 hours ([CO2] start – [CO2] final) / [CO2] start * 100% = % leakage per day				

9.12 Conclusions

To be competed in the annotated procedures document

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):

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_02 (Stock A and B Injection Manual Over-ride Valves
5. 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 Procedure

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Calibrate EC sensor as per manufacturers requirements.				
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	
3	Open the Stock A manual injection valve (HV_4108_01)				
4	Record the state of the Solution A float level sensor as shown in the Argus control system (LSL_4108_01)			The sensor should read 100%	
5	Using the Argus control system, set the Stock Solution A valve to 'manual on' (VSSL_4108_01)				
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	

7	Record the state of the Solution A float level sensor as shown in the Argus control system (LSL_4108_01)			The sensor should read < 50%	
8	Close Stock A manual injection valve (HV_4108_01) and set the control to 'manual off' (VSSL_4108_01) with Argus				
9	Open the Stock B manual injection valve (HV_4108_02)				
10	Record the state of the Solution B float level sensor as shown in the Argus control system (LSL_4108_02)			The sensor should read 100%	
11	Using the Argus control system, set the Stock Solution B valve to manual on (VSSL_4108_02)				
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	
13	Record the state of the Solution B float level sensor as shown in the Argus control system (LSL_4108_02)			The sensor should read < 50%	
14	Close Stock B manual injection valve (HV_4108_02) and set the control to 'manual off' (VSSL_4108_02) with Argus				
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		May be done through open top of the reservoir	
16	Fill Stock Tanks with prepared Stock A and B Solutions.			see TN96.2 'Test protocols and procedures for lettuce cultivation'	
17	The main irrigation pump is started and set to provide a mixing flow	GP_4106_01 is 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	
18	Adjust valves HV_4106_04'a' and 'b' to	HV_4106_		25% is typical	

	provide adequate flow through the irrigation bypass pipe and past the EC sensor.	04 valves are opened				
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				
20	Open the manual Stock A Tank injection valve	HV_4108_ 01 OPEN				
21	Activate the Stock A injection solenoid using the Argus control system for 20 seconds	SV_4108_ 01 is OPEN				
22	Confirm that the EC rises – wait until the reading is stable before continuing to the next step					
23	Open the manual Stock B Tank injection valve	HV_4108_ 02 OPEN				
24	Activate the Stock B injection solenoid using the Argus control system for 20 seconds	SV_4108_ 02 is OPEN				
25	Confirm that the EC rises					

10.12 Conclusions

To be competed in the annotated procedures document

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-Ride Valve	HV_4106_02	Open	

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 Procedure

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Calibrate pH probe as per manufacturer requirements				
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	
3	Open the Acid manual injection valve (HV_4107_01)				
4	Record the state of the Acid float level sensor as shown in the Argus control system (LSL_4107_01)			The sensor should read 100%	
5	Using the Argus control system, set the Acid valve to 'manual on' (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	

7	Record the state of the Acid tank float level sensor as shown in the Argus control system (LSL_4107_01)			The sensor should read < 50%	
8	Close acid manual injection valve (HV_4107_01) and set the control to 'manual off' (VSSL_4107_01) with Argus				
9	Open the Base manual injection valve (HV_4107_02)				
10	Record the state of the Base tank float level sensor as shown in the Argus control system (LSL_4107_02)			The sensor should read 100%	
11	Using the Argus control system, set the Base valve to 'manual on' (VSSL_4107_02)				
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	
13	Record the state of the Base tank float level sensor as shown in the Argus control system (LSL_4107_02)			The sensor should read < 50%	
14	Close Stock B manual injection valve (HV_4107_02) and set the control to 'manual off' (VSSL_4107_02) with Argus				
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		May be done through open top of the reservoir	
16	Fill Acid and Base Tanks with prepared Solutions.			see appendix MPP-HPC1-Solution-App1	
17	The main irrigation pump is started and set to provide a mixing flow	GP_4106_01 is 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.	

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		25% is typical	
19	Confirm that the pH sensor positioned on the by-pass line is logging	AT_4107_01		Baseline pH level is dependent upon the water source	
20	Open the manual Acid Tank injection valve	HV_4107_01 OPEN			
21	Using the Argus control system, activate the Acid injection solenoid for 10 seconds	SV_4107_01 is OPEN			
22	Confirm that the pH sensor readings decrease after injection	AT_4107_01 reading decreasing			
23	Close the manual Acid Tank injection valve	HV_4107_01 Closed			
24	Allow pH to stabilize before proceeding to the next step				
25	Open the manual Base Tank injection valve	AT_4107_02			
26	Using the Argus control system, activate the Base injection solenoid for approximately 10 seconds	HV_4107_02 OPEN			
27	Confirm that the pH sensor readings increase after injection	SV_4107_02 is OPEN			
28		AT_4107_01 reading increasing			
29	Close the manual Base injection valve	HV_4107_02 Closed			

11.12 Conclusions

To be competed in the annotated procedures document

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 Procedure

Date: 02/05/2009 Time: 14:30			Test Engineer/operator: Michael Stasiak ESA/UoG Representative: Michael Stasiak		
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 is ON			P

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):

TT 4112_04 - _012 (Growing volume temperature sensors)
AT 4112_01 - _03 and TT 4112_01 - _03 (growing volume humidity and temperature sensors)
S3CV_4112_01 and S3CV_4112_02 (water service line control valves)
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			

13.11 Test Procedure

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
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.	
2	Module A		T ________ RH _______		
3	Module B		T ________ RH _______		
4	Module C		T ________ RH _______		
5	Heat exchanger		T_{src}________ T_{loop}________ T_{exit} ________		
6	Condensing coil		T_{src}________ T_{loop}________ T_{exit} ________		
7	Cold rad		T ________		
8	Hot rad		T ________		

9	Hydroponic Solution Temperature		T ________		
10	Cold valve (S3CV_4112_01) function. In the Argus control system, set the cold valve to manual 100% open		T_{loop}________ T_{exit} ________ $T_{cold\ rad}$ ______	Temperatures in these sensors should decrease over time	
11	Set cold valve (S3CV_4112_01) to manual 0% open				
12	Hot valve (S3CV_4112_02) function. In the Argus control system, set the hot valve to manual 100% open		T_{loop} ________ T_{exit} ________ $T_{hot\ rad}$ ______	Temperatures in these sensors should increase over time	
13	Set hot valve (S3CV_4112_02) to manual 0% open				

13.12 Conclusions

To be competed in the annotated procedures document

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 CO2 control. Depending on crop development, pH and EC control may be utilized as well.

14.2 Consumables required for Operational Testing with Crops

Preparation Tools:

- Balance for dry and fresh weight masses and micro-nutrient/hydroponics salt measurement (500 g ± 0.01g)
- Rockwool cubes (2 x 1 m^3 boxes)
- Seed germination trays (consumable)
- Solution stock storage tanks (2 x 50 L tanks with spigot, PP)
- Solution transfer tank (1 x 200 L tank, PP)
- Submersible pump (5 L min^{-1} or greater) and connection tubing

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. The EC/pH control system will be enabled. For more detailed instruction on solution preparation, please refer to TN96.3.

Table 14-1. 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
	Stock B	
$MgSO_4 \cdot 7H_2O$	246.48	1
KNO_3	101.1	5

$NH_4H_2PO_4$	115.08	1.5
$(NH_4)_2SO_4$	132	1
Micronutrients		
$FeCl_3$ (DTPA)	162.20	0.025
H_3BO_4	61.83	0.02
$MnSO_4 \cdot H_2O$	169.01	0.005
$ZnSO_4 \cdot 7H_2O$	289.54	0.0035
$CuSO_4 \cdot 5H_2O$	249.68	0.0008
H_2MoO_4 (85%MoO3)	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 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. Three to 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. 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 to 20 days dedpending upon UAB testing requirements)

CO_2 Demand – 1000 ppm
Temperature – 26/20 º C (day/night)
VPD – 9.0 day, 6.0 night
EC – 2 mS
pH high/low 6.3/5.7

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 Argus 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 equiment 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.
2. Leaf material and roots in preweighted Rockwool cubes are placed in paper bags in a drying oven for approximately 4 - 14 days at 60º 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 determination.
5. A carbon balance is determined from the NCER estimates obtained above, the dried biomass and measured carbon content.

15. Complementary tests : open loop tests with ARGUS controller

15.1. Introduction

UoG will test 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, considered by ESA and Sherpa as a black box.
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 sytem 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, CO2 concentration, temperature, humidity, conductivity and pH in the plant compartment.

Specific Objective of this Technical Note is to complement the TN96.2 (Functional Test Plan and Test Protocols with Argus Controller, February 2009, UoG) with the proposed Open and Closed loop tests.

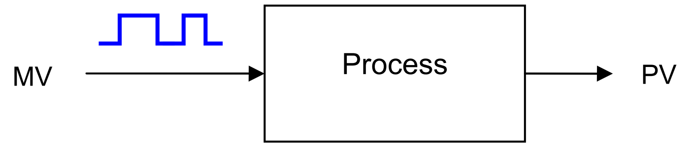
15.2. Open Loop Tests description

Objectives: identification of the process in order to tune the control model and the controllers.

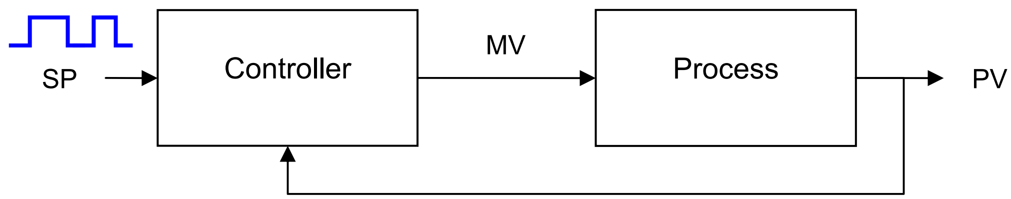
15.2.1) General points

Two possible ways of tests are possible:

1. Open loop test if no control is implemented
   In this case the test signal is applied on manipulated variables (MV) of the process



2. Closed loop test for the existing controllers.
   In this case the test signal is applied on the set point(s) of the controller.



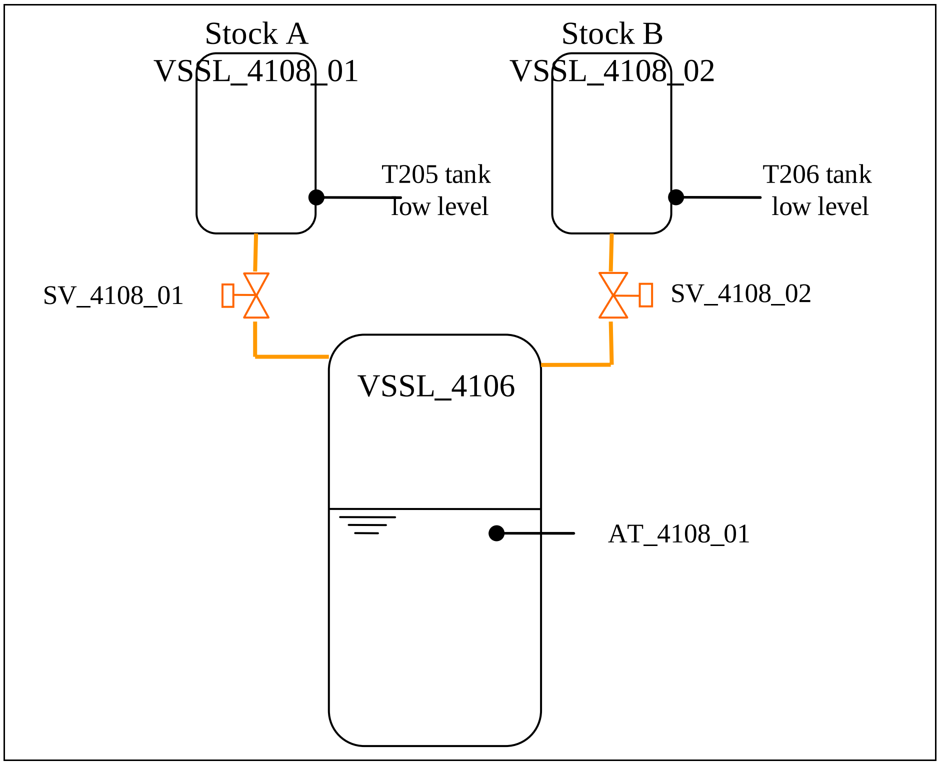
In the Test Plan, the magnitude of the variations of manipulated variables or set points and their durations are only rough estimations. Those values will be adjusted when applying the tests to the HPC :

3. the applied magnitude is tuned in order to minimize the disturbance on the process, but should be big enough to see a clear result (sufficient ratio signal/noise);
4. the duration is tuned in order to have the HPC in a new steady-state condition.

The first way of testing, which is the simplest for the identification of the process is described hereafter.

The main control loops are :
pH, EC, CO2, Nutrient Tank Temperature (in fact this control loop disappeared in the new design) and Temperature and Humidity Chamber.

15.3. EC control loop



15.3.1) Operating Conditions

- Main Irrigation Pump GP_4106_01 ON
- Tank Level in the range (between LOW and HIGH)
- Tanks A and B not at Low Level.

15.3.2) Variables to be recorded

Sampling Period : 5 or 10 s

Main Irrigation Pump	GP_4106_01
EC	AT_4108_01
TankA Valve	SV_4108_01
TankB Valve	SV_4108_02

15.3.3) Protocol Test

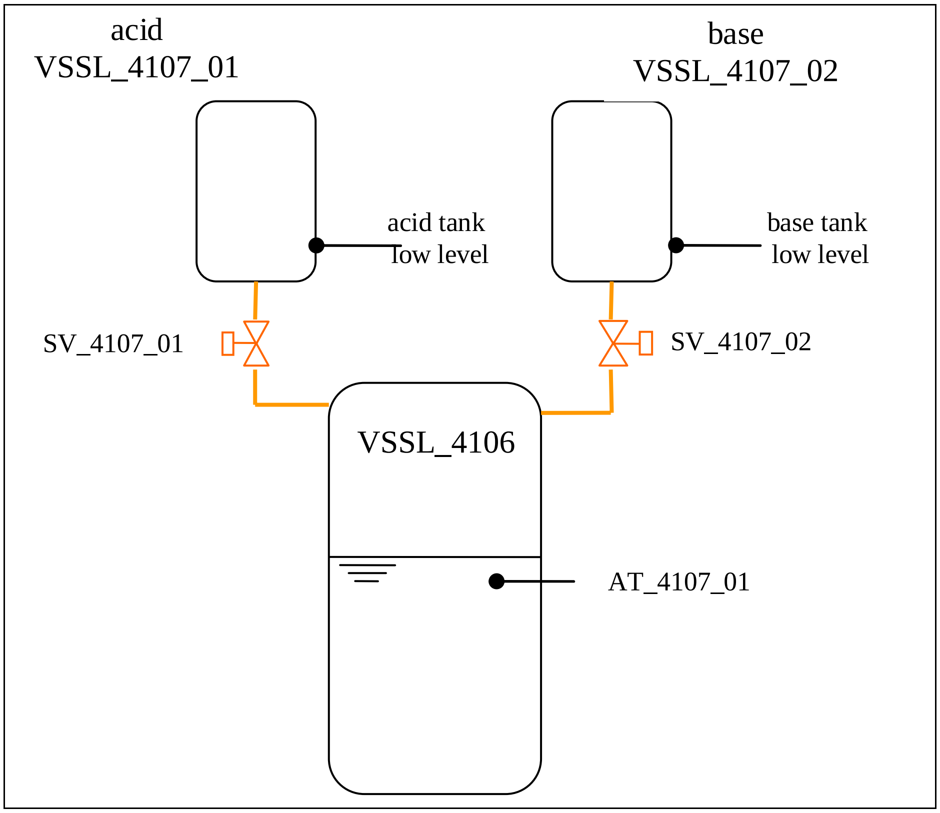
EC should be steady before the test.

If there is a ratio between both tanks, it should be activated

Open Valves during Time Duration D (To be determined), with Ratio respect
Close Valves

The duration D will be determined in order to significantly increase the EC in the tank (+ 100 $\mu S.m^{-1}$ for instance)

15.4. pH control loop



15.4.1) Operating Conditions

- Main Irrigation Pump GP_4106_01 ON
- Tank Level in the range (between LOW and HIGH)
- Acid and Base tanks not at Low Level.

15.4.2) Variables to be recorded

Sampling Period : 5 or 10 s

Main Irrigation Pump	GP_4106_01
pH	AT_4107_01
Acid Valve	SV_4107_01
Base Valve	SV_4107_02

15.4.3) Protocol Test

pH should be steady before the test.

Open Acid Valve during Time Duration D (To be determined)
Close Acid Valve.
The duration D will be determined in order to significantly decrease the pH in the tank (-0.1 for instance)

Open Base Valve during Time Duration D (To be determined)
Close Base Valve.
The duration D will be determined in order to significantly increase the pH in the tank (+0.1 for instance)

15.5. CO2 control loop

Requirement : CO2 controlled at 1000 ppm +/- 5 ppm

15.5.1) Operating Conditions

- Air Blower	BLWR_4111_01	ON
- No crop		

15.5.2) Variables to be recorded

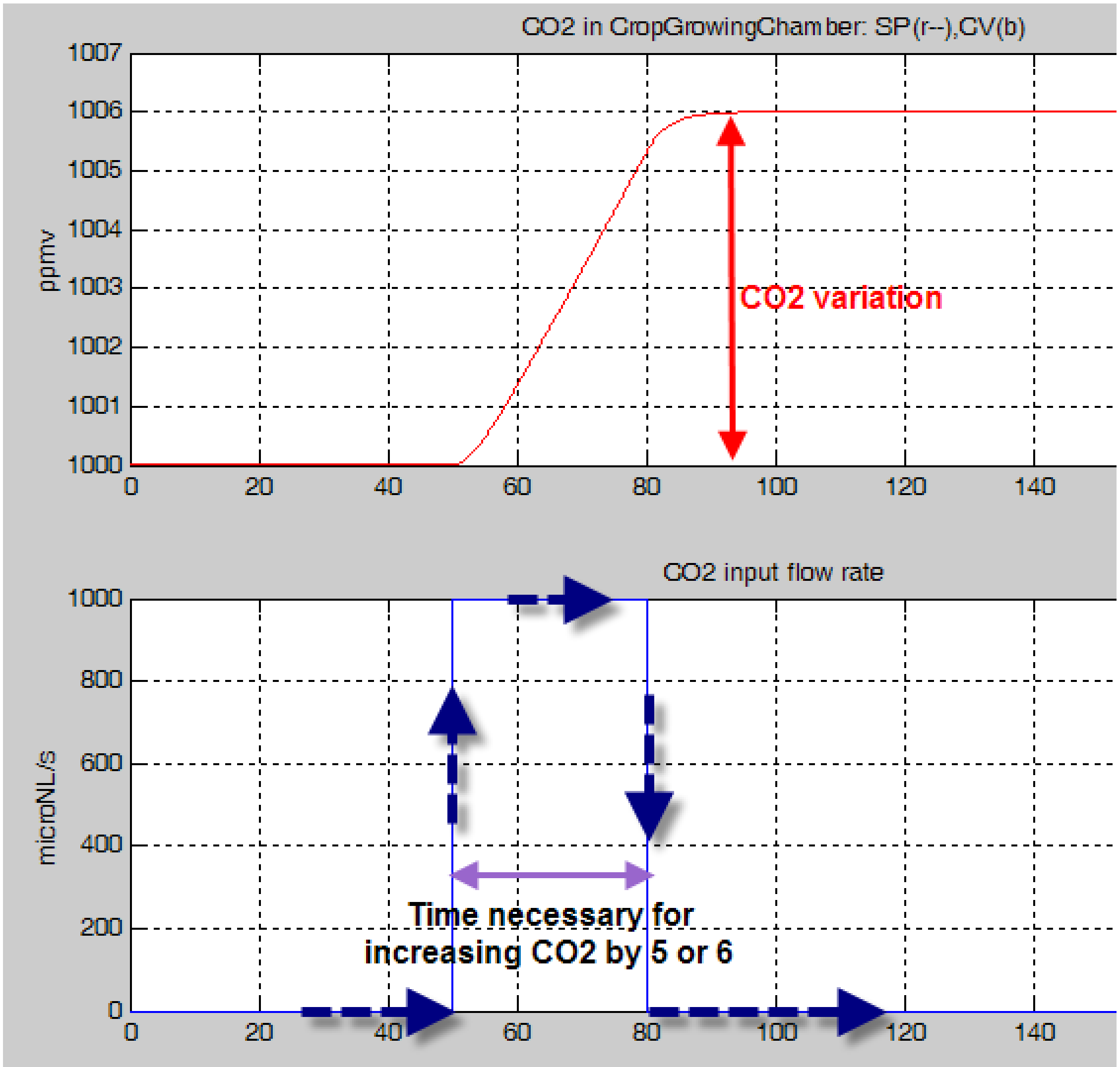
Sampling Period : 5 or 10 s

Air Blower	BLWR_4111_01
Air Flow	FT_4111_01
CO2	AT_4107_01
Valve	SV_4113_01_MV
Flow Set Point	FC_4113_01_SP
Flow	FC_4113_01

All necessary variables linked to Air circulation should be recorded.

15.5.3) Protocol Test

CO2 should be steady before the test.



Inject CO2 the necessary time for a variation of 5 (or 6) ppm
And close CO2 injection.

This test can be repeated for better results.

15.6. T & RH control loop

The Open Loop tests are necessary in order to tune the T and RH controllers

Heat Exchanger should be identified with open loop tests
Cold Exchanger should be identified with open loop tests
Temperature and Humidity behaviour will also be identified during these tests.
It will permit to adjust a simulator and tune properly the controllers.

15.6.1) Operating Conditions

No lights, no crop, no water addition.
Nominal Air circulation.
Temperature and humidity in nominal conditions (20°C, 75% for instance)

15.6.2) Variables to be recorded

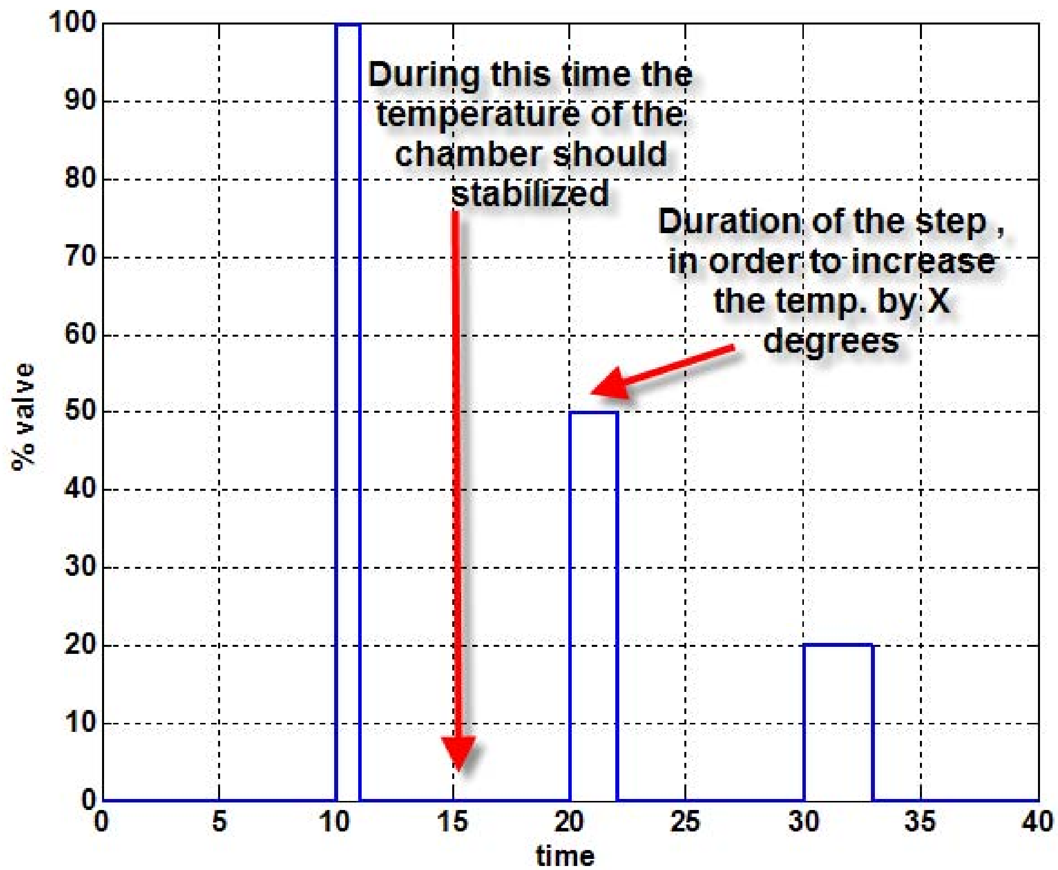
All temperatures, humidity, including utility temperatures
The 2 Controlled Valves,

15.6.3) Protocol Test

- Identification of the exchangers, temperature and humidity.

1/ Heat Exchanger
Cold exchanger Valve is closed
Heat Exchanger can be identified with the following protocol.
3 steps of Hot valve.
The duration should be long enough to see a significant temperature increase. For instance 1 °C

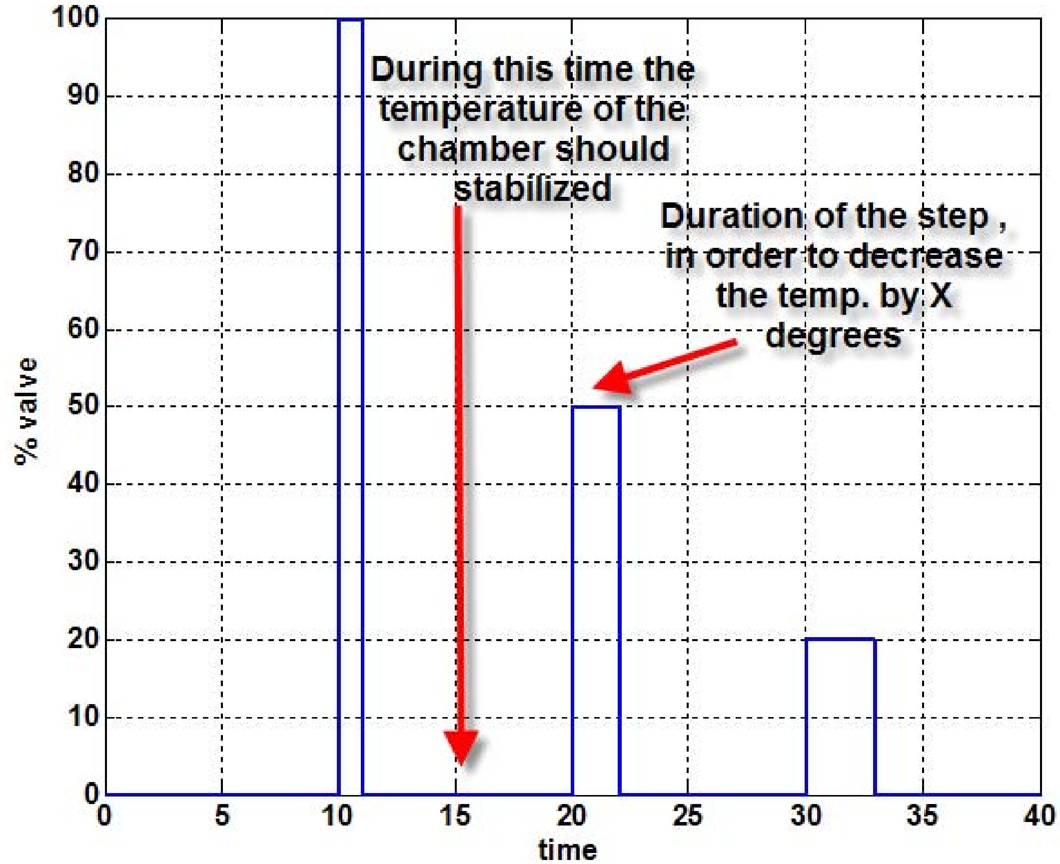
No other variable, excepted the HOT Valve should be manipulated during the test.



2/ Cold Exchanger
Initial Conditions: Nominal (20°C, Air Circulation, 75% Humidity)

Hot exchanger Valve is closed
Hot Exchanger can be identified with the following protocol.
3 steps of Cold valve.
The duration should be long enough to see a significant temperature decrease. For instance 1 °C

No other variable, excepted the COLD Valve should be manipulated during the test.


100
90
80
70
60
50
40
30
20
10
0
% valve
0
5
10
15
20
25
30
35
40
time
During this time the temperature of the chamber should stabilized
Duration of the step , in order to decrease the temp. by X degrees

16. Complementary tests : closed loop tests with ARGUS controller

These tests are normally performed by UoG when testing the Argus Controller.

Nevertheless, we propose some Reference test, which results can also be used later for the validation of the Sherpa's control.

16.1. EC Control Loop

This test can be performed without and with crop

16.1.1) Operating Conditions

- Main Irrigation Pump GP_4106_01 ON
- Tank Level in the range (between LOW and HIGH)
- Tanks A and B not at Low Level.

16.1.2) Variables to be recorded

Sampling Period : 5 or 10 s

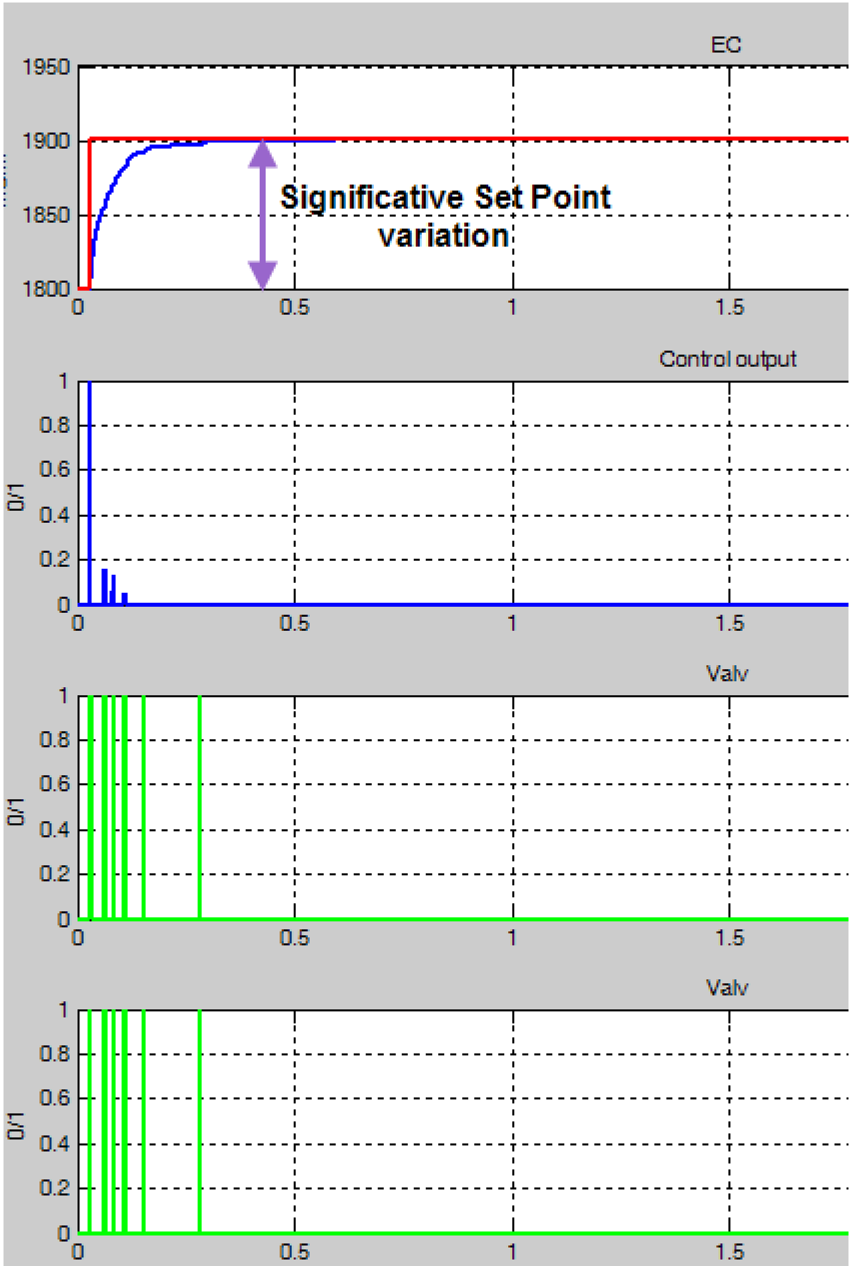
Main Irrigation Pump	GP_4106_01
EC	AT_4108_01
TankA Valve	SV_4108_01
TankB Valve	SV_4108_02
EC Set Point	AT_4108_01_SP

All variables linked to the nutrient control loop should be recorded

16.1.3) Protocol Test

EC should be steady and controlled before the test.

Change EC Set Point and wait until the stabilisation



The test can be repeated for better estimation

16.2. pH Control Loop

This test can be performed without and with crop

16.2.1) Operating Conditions

- Main Irrigation Pump GP_4106_01 ON
- Tank Level in the range (between LOW and HIGH)
- Acid and Base tanks not at Low Level.

16.2.2) Variables to be recorded

Sampling Period : 5 or 10 s

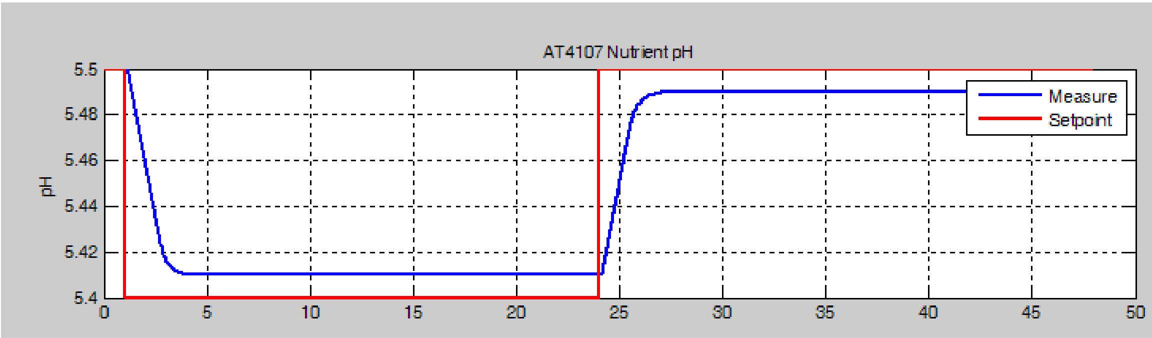
Main Irrigation Pump	GP_4106_01
pH	AT_4107_01
Acid Valve	SV_4107_01
Base Valve	SV_4107_02
pH Set Point	AT_4107_01_SP

All variables linked to the nutrient control loop should be recorded

16.2.3) Protocol Test

pH should be steady and controlled before the test.

Change pH Set Point and wait until the stabilisation.
Can be done in both sense.
pH set point variation from 5.5 to 5.4
pH set point variation from 5.4 to 5.5



16.3. CO2 Control Loop

This test can be performed without and with crop

16.3.1) Operating Conditions

- Air Blower	BLWR_4111_01	ON
- No crop		

16.3.2) Variables to be recorded

Sampling Period : 5 or 10 s

Air Blower	BLWR_4111_01
Air Flow	FT_4111_01
CO2	AT_4107_01
CO2 Set Point	AT_4107_01_SP
Valve	SV_4113_01_MV
Flow Set Point	FC_4113_01_SP
Flow	FC_4113_01

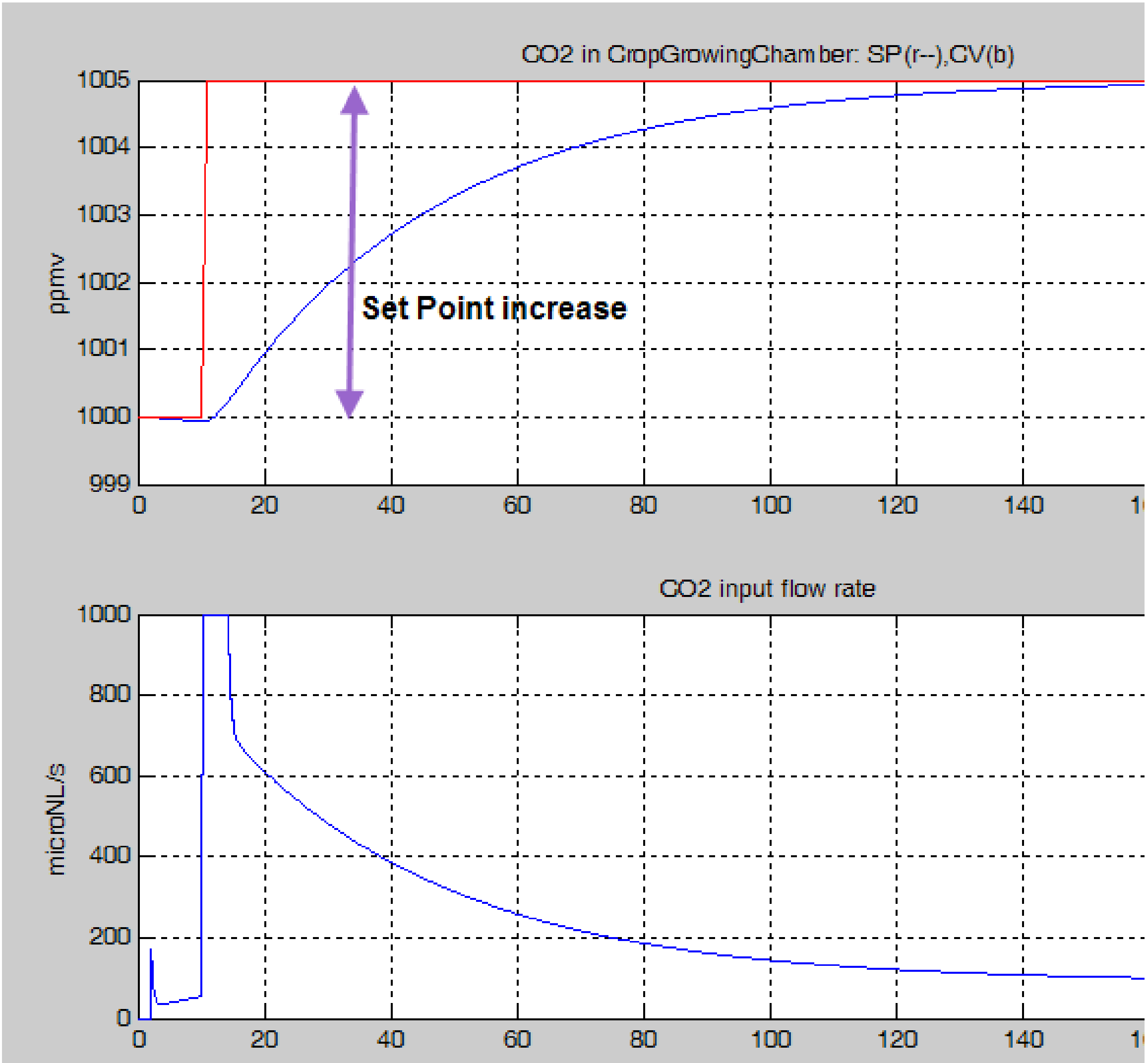
All necessary variables linked to Air circulation should be recorded.

16.3.3) Protocol Test

CO_2 should be steady and controlled before the test.

Without Crop :
Change CO_2 Set Point from 1000 to 1005 ppm and wait until the stabilisation.

With Crop :
- With Lamp:
Change CO_2 Set Point from 1000 to 1005 ppm and wait until the stabilisation.
- Without Lamps:
Record CO_2. Due to the night, CO_2 will increase slightly, depending on the plant production. It could be recorded during a significant period of time (8 to 10 hours)


CO2 in CropGrowingChamber: SP(r--),CV(b)
ppmv
1005
1004
1003
1002
1001
1000
999
0
20
40
60
80
100
120
140
Set Point increase
CO2 input flow rate
microNL/s
1000
800
600
400
200
0

16.4. T&RH Control Loop

These tests can be performed without and with crop

All variables and Set Points should be recorded

Remark : "Stabilisation" means T & RH should be stable.

<u>Without Crop</u>

T is controlled
RH is not controlled,
- T is stable and controlled. Do not change the set point
- Switch ON the lamps and wait the Temperature stabilisation
- Switch OFF the lamps and wait for the Temperature stabilisation
- Change the Temperature Set Point (+ 2 °C for instance) and wait for stabilisation
- Change back the temperature Set Point (-2°C) and wait for stabilisation

Wait for complete stabilisation of Temperature and Humidity.
Fix the RH Set Point to the current value and switch ON the controller → RH is controlled
Fix the Temp. Set Point to the current controlled measurent
- Do not change the Temperature Set Point
- Decrease by 5 % the RH Set Point and wait for stabilisation
- If it is possible, decrease again by 5 % the RH Set Point and wait for stabilisation
- if possible, repeat until 50 %

<u>With Crop</u>

With T control,
Without RH control,
- Switch ON the lamps, wait for stabilisation
- Switch OFF the lamps, wait fro stabilisation

Switch ON the lamps
- Change T Set Point (+2 °C) and wait for stabilisation
- Change T Set Point (-2°C) and wait for stabilisation

T and RH controlled,
With Lamps :
- Change T Set Point (+2) and wait for Stabilisation (T & RH)
- Change T Set Point (-2) and wait for Stabilisation (T & RH)
- Change RH Set Point (from 75 to 60 for instance) and wait for stabilisation (T & RH)
- Change RH Set Point (from 60 to 75 for instance) and wait for stabilisation (T & RH)

Without Lamps :
- Change T Set Point (+2) and wait for Stabilisation (T & RH)
- Change T Set Point (-2) and wait for Stabilisation (T & RH)
- Change RH Set Point (from 75 to 60) and wait for stabilisation (T & RH)
- Change RH Set Point (from 60 to 75) and wait for stabilisation (T & RH) – Not sure this can be reached

17.Comments

Functional Test Plan and Test Protocols with Argus Controller

Comments

General comments

From Minutes of Meeting of Test Readiness Review for the HPC1 functional tests with ARGUS (MPP-MOM-09-4102(0)-AF-20090306), page 3, third paragraph:

- UAB took the action to include in this document the SHERPA complementary tests for open and closed loops tests.

Chapter 17 is empty and should be either removed or completed as appropriate
Chapter 17 removed

Detailed comments

Page/paragraph	Comment
8/ Section 1.2	"*Electronic data log file names are defined in the relevant test procedure sections and summarized in the table below*" Which one? Removed in the text (UoG)
9/ Section 1.4	*Nutrient supply: "pH: 5.8 +/0.5"* In TN 85.81, there was as well a requirement on dissolved oxygen content Added but this is neither monitored or controlled so the specification is of little use (UoG): *"Dissolved O2: 80 – 100% of saturation (not analyzed ,not controllable)"*
10/ Section 2 Functional tests	*Test 3: Airlock purge* Why don't we have the testing of passive pressure relief valves anymore, i.e. compared to TN 85.81? It has been added (UoG)
11/ Section 2 Functional tests	*Test 6: Gas analysis* You mention in the part tested that the manual CO2 injection over-ride valve is tested, whereas it does not appear in the test sequences Removed this reference to the manual override valve (UoG)
12/ Section 2 Functional tests	*Test 8: EC System* There is no verification of calibration of the stock delivery system? Calibration is not required for functional verification (UoG)

12/ Section 2 Functional tests	*Test 8: EC System* Testing of EC sensor: wrt calibration? or is it a simple measurement? Test verifies that the EC probe functions - calibration has been performed and is not required (UoG)
12/ Section 2 Functional tests	*Test 9: pH* Testing of pH sensor: wrt calibration? or is it a simple measurement? Test verifies that the pH probe functions - calibration has been performed and is not required (UoG)
13/ Section 2 Functional tests	*Test 10: Irrigation System* What about the calibration verification (for the irrigation pump)? The irrigation pump does not require calibration (UoG)
14/Section 2 Control/Profile Tests	*Exterior Air Lock Door Control Loop 4100 and 4101* Step 2, as mentioned in TN 85.81 is missing; why? Controller response tests are not required to show function (UoG)
14/Section 2 Control/Profile Tests	*Airlock Purge Control Loop 4102 and 4103* Steps 3 and 4, as mentioned in TN 85.81, are missing; why? Controller/software testing has been minimized. Controller response/alarm tests for purging are not required as this controller will not be employed at UAB and pressurization of any part of this system is not permitted (UoG)
15/Section 2 Control/Profile Tests	*Irrigation Control Loop 4106* Why did you remove for the test the activation of the main irrigation pump by the controller? Controller and software testing has been minimized in this functional test (UoG).
15/Section 2 Control/Profile Tests	*EC Control loop 4108* As a general remark, all calibration steps and all profile tests have been removed from the test plan; why? Calibrations have been performed and are not required to show function. Profile tests are not required for function but are included in the Sherpa Addendum (UoG)
15/Section 2 Control/Profile Tests	*Growing Volume Temperature and Humidity Control Control Loop 4112* The test of control loop 4111 is not considered anymore; why? There is no software control of the blower (UoG)
15/Section 2 Control/Profile Tests	*Growing Volume Temperature and Humidity Control Control Loop 4112* Test rather reduced when compared to TN 85.81, why? A number of the tests in 85.81 were never possible to perform and were removed as per previous discussions with ESA. Control during a crop test is the best way to demonstrate system function (UoG)
15/Section 2 Control/Profile Tests	*CO2 compensation control* No induction of CO2 alarm states?

	Controller and software testing has been minimized (UoG)
18/Section 3.9 Test procedure	Why did you remove all tests with obstruction of the doors? The doors should not be obstructed - the test was removed as it was deemed destructive to the sealing surfaces and closing mechanisms (UoG)
23/Section 5.7	Acceptance criteria seem over-simplified (see section 3.6.2 of TN 85.82) These tests confirm that all valves and sensors function. Tests requiring pressurization of the airlocks are not allowed with this chamber (UoG)
44/Section 9.2	*"CO2 is injected into the chamber in a closed and idle configuration (all subsystems off, main centrifugal blower excepted) to a setpoint of 1200 ppm. CO2 is allowed to passively decay through the chamber shell. The rate of leakage is calculated as the slope of a tangent to a 24 hour CO2 curve"* Set-point value, duration of the test differ from TN 85.82, why? Amended in the text: *"CO2 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. CO2 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 CO2 curve"*
45/Section 9.7	*Acceptance criteria* 24 h in the introduction, 48 hour here, please clarify 24 hours is used for the calculation, 48 hours is required for stabilization (UoG)