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TECHNICAL NOTE

UNIVERSITY of GUELPH

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Prototype Tests Plan and Procedures Document

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TECHNICAL NOTE

Prepared by/Préparé par	Dr. Geoffrey Waters
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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. An additional outcome of the test plan is demonstration that the chamber prototype has sufficient flexibility in design to meet the evolving needs of the MPP research facility in Spain.

This test plan consists of three main phases. First, a series of Functional Tests is envisioned to demonstrate the functionality of all chamber parts before integration of a controller. For these tests, data log capability (on the part of the controller) is required, as outlined in the general procedures for test results data acquisition, below. Formal control tests are aimed to demonstrate chamber adherence to the environment control requirements listed in Annex to Appendix 1 of RFQ 3-11515. Controller tests are performed using system demand profiles. The final operational test with a batch culture of lettuce is conducted under static conditions.

1.2. General Procedures for Test Results Data Acquisition

Functional tests outlined in Section 2 below generally rely on video log, visual inspection or confirmation of signal transfer to/from the controller. Operational tests generally rely on data log by the controller over the period of the test. Electronic data or video log file names are defined in the relevant test procedure sections and summarized in the table below.

In general video logs will include English audio commentary and data logs are provided in coma or tab delimited test files easily importable into EXCEL for data analysis and plotting.

Test	**Data/Video/List file Name**
1.Chamber Completeness	Check list of in column of TN 85.7 EXCEL Sheet (i.e. HPC prototype Data Package)
2. Check of Outward Appearance	**Visual Inspection with Photos** CESRF_HPC1_Outward_Appearance.jpeg (digital photo album provided on CD-ROM)
3. Check of Dimensions	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book)
4. Exterior Airlock Doors	**Video Log** CESRF_HPC1_Exterior_Door_A_Operation_and_Tray_Mounting.mpeg CESRF_HPC1_Exterior_Door_C_Operation_and_Tray_Mounting.mpeg
5. Interior Airlock Doors	**CESRF-HPC1 – Interior_Airlock_Door – FT** CESRF_HPC1_Interior_Door_A_and_C_Operation_and_Tray_Mounting.mpeg
6. Airlock Purge	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book)
7. Lighting	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC_-LIGHTING_FT.txt • Includes confirmation of signal reading at controller

8. Main Centrifugal Blower and VFD Motor	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC1__AIR_CIRCULATION_FT.txt
9. Gas Analysis	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC1_GAS ANALYSIS_FT.txt
10. Integrity leakage Test	**Data File** CESRF_HPC1__LEAKAGE_FT.txt
11. EC System	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC1_EC_FT.txt
12. pH	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC1_pH_FT.txt
13. Hydroponics Cooling	The necessity of this system is not yet confirmed and therefore its design has not been finalized. Empirical assessment of the solution temperature during crop culture will be performed. In some cases, the solution temperature does not rise above ambient if the reservoir remains outside. CESRF needs to verify this during the operational tests of the irrigation system
14. Irrigation System	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC1_IRRIGATION_FT.txt
15. Temperature and Humidity	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC1_TEMP_HUMID_FT.txt
16. Control Loop Tests	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC1_PROFILE_OT.txt
17. Lettuce Batch Culture	**Written Measurement** CESRF_HPC1_Log_Book (writing in hardcover log-book) **Data File** CESRF_HPC1_LETTUCE_BATCH_OT.txt

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 of ESA. As part of their sub-contract, Argus calibrates or “tweaks” control, particularly in the case of thermal and humidity control, standard procedures defined in-house. Procedures for controller calibration are therefore not provided, and the Argus system is considered a “black-box” controller with specific training on the control hardware and proprietary software provided by Argus, if requested and budgeted, at the time of install at the MPP.

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 re-produced 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 daylight levels	0 – 800 μE PAR selectable in four discrete levels
Illumination night levels	0 – 10 μE PAR
Day/night cycle	Any combination of 1 day and 1 night period within a 24 hour span
Air Temperature	Selectable within 15 – 30 °C
Temperature Accuracy	Demand +/- 0.5 °C
Internal Air (refreshment) circulation rate	Not less than 1 crop volume per minute
Air Velocity	From 0.1-0.8 m/s
Water Supply in the Roots	200 mL / min
Nutrient Supply	Hydroponics (NFT) cultivation with EC demands of 0 – 3 mS/cm pH: 5.5 +/- 0.5 EC: 1.9 dS/cm +/- 0.05dS/cm Dissolved O_2: 80 – 100% of saturation
Pressure	Ambient
Atmospheric Composition	Humidity: 50 – 85% (no accuracy specified) O_2 - 20% +/- 1% (although not controlled) CO_2 - 300 – 2000 ppm (no accuracy for control specified) N_2 - Balance to 100%

2. Functional, Control and Operational Tests Program for HPC1

Test	Procedure /Procedure number	Date	Duration (days)
Functional Tests			
1.Chamber Completeness	Verification of the completeness of the delivered chamber shell and equipment in comparison to the TN 85.7 (i.e. HPC prototype Data Package - -EXCEL Database)		0.25
2. Check of Outward Appearance	**Visual Inspection** The visual inspection consists of verification of the outer equipment envelope. In detail the equipment shall be inspected with respect to the following aspects 1. Outer surface – cleanliness, damages, corrosion, coating, sharp edges 2. Mechanical assembly – tightness of fittings, material compliance 3. Electrical assembly (connectors, interconnecting cables marked, etc.) 4. Availability of protective caps		0.25
3. Check of Dimensions	**Measurement** The check of dimensions refers to confirming; 1. Shell dimensions 2. Clearance around chamber		0.25
4. Exterior Airlock Doors	**CESRF-HPC1–Exterior_Airlock_Door- FT** 1. Video demonstration of procedures/test for opening/closing the exterior air lock doors and tray mounting/dismount. Elasticity of the exterior door sealing gaskets is also demonstrated. 2. Functional demonstration of the door open/closed switch/LED indicator circuit (See part list below) **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		0.25
5. Interior Airlock Doors	**CESRF-HPC1 – Interior_Airlock_Door – FT** 1. Video demonstration of procedures/test for opening/closing the interior air lock door and tray movement in harvest and planting		0.25

	using glove access		
6. Airlock Purge	**CESRF-HPC1 – Airlock_Purge – FT** **Sequence:** 1. Testing of air lock injection and vent solenoids 2. Testing of air lock pressure sensors and switches 3. Testing of passive pressure relief valves **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		0.25
7. Lighting	**CESRF-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 luminaries **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)		0.25
8. Main Centrifugal Blower and VFD Motor	**CESRF-HPC1 – Blower_Assembly – FT** **Sequence:** 1. Visual inspection of the pulley assembly, support and rotary		0.25

	feed-through shaft 2. Demonstration of air flow through ducting 3. Testing and calibration of the air circulation VFD motor 4. Testing of the air circulation fan 5. 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)		
9. Gas Analysis	**CESRF-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. Demonstration of manual over-ride of CO2 injection line 5. 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) 5. HV_4113_01 (Manual CO2 injection over-ride valve)		0.25
10. Integrity leakage Test	**CESRF-HPC1 – Leakage – FT** 1. Performance of passive CO2 decay test with running air circulation fan to determine operational leakage rate		2
11. EC System	**CESRF-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. Calibration of stock delivery system 6. Testing of factory calibrated EC sensor **Parts Tested (P&ID Reference):**		0.25

	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)		
12. pH	**CESRF-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. Calibration of Acid and Base delivery system **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)		0.25
13. Hydroponics Cooling	The necessity of this system is not yet confirmed and therefore its design has not been finalized. Empirical assessment of the solution temperature during crop culture will be performed. In our early tests of solution temperature, the solution remained at ambient conditions since the 120L reservoir remains outside and has significant thermal capacitance. We have therefore not yet made provisions for solution temperature control given the limited availability of cooling water in the MPP.		
14. Irrigation System	**CESRF-HPC1 – Irrigation – FT** **Sequence:** 1. Integrity of nutrient reservoir and plumbing (leakage)		0.25

	2. Demonstration of main irrigation pump 3. Calibration of main irrigation pump delivery 4. Testing of irrigation flow sensor 5. Demonstration of manual valves positioned on the by-pass and main irrigation lines 6. Equilization of irrigation flow along the internal distribution manifold 7. 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)		
15. Temperature, Humidity and condensate collection	**CESRF-HPC1 – Temp_Humidity – FT** **Sequence:** 1. Testing of growing volume temperature sensors 2. Testing of growing volume humidity/temperature sensors 3. Integrity and functionality of hot water coil 4. Integrity and functionality of chilled water coil/condensate pan 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 take hi and low level switches 10. Testing of condensate metering pump **Parts Tested (P&ID Reference):** 1. TT 4112_04 - _012 (Growing volume temperature		0.25

	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	**CESRF-HPC1-Exterior_Airlock_Door - CT** 1. Confirmation of controller reading of ZS_4100_01, ZS_4100_02, ZS_4101_01 and ZS_4101_02 2. Induction of door open alarm tests at the controller in conjunction with purge sequence override in event of door open alarm		3 days
Airlock Purge Control Loop 4102 and 4103	**CESRF-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 3. Performance of the air lock purge sequence with the user initiation at the controller 4. Induction of air lock over pressure alarm states at the controller and deactivation of SV_4102_01 and SV_4103_01 in alarm state		
Lighting Intensity and Loft Temperature Control Loop 4104 and 4105	**CESRF-HPC1 – Lighting – CT** 1. Sequential activation of lamp strings at the controller in accordance with user defined Photoperiod in the profile test (LPHS_4104_01 through LHPS_4104_06 and LMH_4104_01 through LMH_4104_03 and serial 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 7. Induction of high air loft temperature alarm states		
Irrigation Control Loop 4106	**CESRF-HPC1 – Irrigation – CT** 1. Activation of main irrigation pump by the controller (GP_4106_01) 2. Confirmation of controller log of nutrient flow sensor (FT_4106_01) 3. Confirmation of nutrient flow rates greater than 0.2 L per minute		
pH Control Loop 4107	**CESRF-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. Calibration of solenoid opening time for pH control 5. Profile tests of pH control in maintenance of modified Hoagland's solution (pH Demand +/- 0.5 units) 6. Induction of hi/low pH alarms		
EC Control loop 4108	**CESRF-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. Calibration of solenoid opening time for EC control		

	5. Profile tests of EC control in maintenance of modified Hoagland's solution (EC Demand +/- 0.05 dS/m) 6. Induction of hi/low EC alarms		
Condensate Collection Control Loop 4110	**CESRF-HPC1 – Condensate – CT** 1. Activation of condensate drain procedure by the controller		
Air Circulation Control Control Loop 4111	**CESRF-HPC1 – Air Circulation – CT** 1. Activation of the main centrifugal blower by the controller (static VFD setting)		
Growing Volume Temperature and Humidity Control Control Loop 4112	**CESRF-HPC1 –Temperature – CT** 1. Diurnal profile tests in temperature control (demand vs. actual) 2. Induction and test of hi/low temperature alarm states 3. Diurnal profile tests in humidity control (demand vs. actual) 4. Induction and test of hi/low humidity alarm states 5. Tests of condensate collection tank hi/low alarms, activation of condensate pump		
CO_2 compensation control Control Loop 4113	**CESRF-HPC1 –CO_2 – CT** 1. Profile tests of CO_2 control by the controller 2. Induction of CO_2 alarm states		
Crop Test	**CESRF-HPC1 – Crop– OT** 1. 30 day crop trial with lettuce in batch under nominal culture conditions 2. Collection of NCER data and comparison to lettuce gas exchange model predictions 3. Collection of nutrient uptake data (off-line HPLC) 4. Collection of evapo-transpiration data from condensate drainage profiles 5. Yield data at harvest 6. Nutritional composition of harvested tissue (mineral, proximate)		

3. Exterior Air Lock Door Functional Testing

3.1. ProcedureID: CESRF-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 and when an object of 2 mm thickness is used to obstruct the door from closing. 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. Video Log File Names:

CESRF_HPC1_Exterior_Door_A_Operation_and_Tray_Mounting.mpeg
CESRF_HPC1_Exterior_Door_C_Operation_and_Tray_Mounting.mpeg

3.6. Acceptance/rejection criteria

3.6.1. General

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

The test is considered successful when the conditions in Section 2.2 are me

3.6.2. 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 an object of 2 mm thickness is used to obstruct the door from closing
3. No visual deformation of the exterior air lock door gasket is observed when a 2mm thickness object obstructs door closure
4. The procedures for operation of the exterior air lock door, mounting of trays, positioning of the contact sensors and alarms, and their functionality are clearly documented in video log.

3.6.3. Rejection criteria

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

3.7. 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.

3.8. Safety aspects

No special safety risks have been identified for this test.

3.9. Test set-up

Ancillary Equipment Required for Test

1. Digital video recorder
2. Tray connector and spacer bars (supplied)
3. Growing trays (supplied)
4. Prior to the demonstration video log, two trays shall also be positioned in Air lock C in preparation for demonstration of their removal

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

3.10. Test Procedure

Video logs of the following steps are taken. The camera should be focused and recording before their execution

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
Seq. Nb.	Description	Required/Nominal	Measured/ calculated	Remarks/Calculation	Pass (P)/ Fail (F)
1	Start video log of door A opening and tray mounting			CESRF_HPC1_Exterior_Door_A_Operation_and_Tray_Mounting.mpeg	
2	Exterior Air Lock Door A is unlatched around the perimeter and opened fully				
3	Confirm activation of LED (ZI_4100_01) indicator to indicate exterior door A is open	LED (ZI_4100_01) indicates door open			
4	Place a single plant growing tray on the conveyer rails of the air lock				
5	Place an additional plant growing tray on the conveyer rails of the air lock				
6	Connect the two growing trays to each other using the inner most hole on two spacer bars. Position the bars on the connection posts of each growing tray.			Ensure trays are level on the rails	
7	Close exterior air lock door and secure latches along the door perimeter				
8	Ensure de-activation of the LED (ZI_4100_01) indicator on the exterior air lock door A to show door is closed	LED (ZI_4100_01) indicates door Closed			

9	Unlatch exterior air lock door A and open fully. Confirm LED indicates door open.	LED (ZI_4100_01) indicates door Open			
10	Exterior air lock door A is closed with a paper obstruction of 2mm thickness in place within 5 cm of the upper contact switch (ZS_4100_01)				
11	Confirm that the Exterior Air Lock Door A LED (ZI_4100_01) indicates the door is still open or obstructed.	LED (ZI_4100_01) indicates door Open			
12	Exterior Air Lock Door A is opened and the paper obstruction removed. Visual inspection for deformation in the sealing gasket is made				
13	Exterior air lock door A is closed again with the paper obstruction of 2mm thickness in place within 5 cm of the lower contact switch (ZS_4100_02)	LED (ZI_4100_01) indicates door Open			
14	Exterior Air Lock Door A is opened and the paper obstruction removed. Visual inspection for deformation in the sealing gasket is made				
15	End video log of door A opening and tray mounting				
16	Start video log of door C opening and tray mounting			CESRF_HPC1_Exterior_Door_C_Operation_and_Tray_Mounting.mpeg	
17	Exterior Air Lock Door C is unlatched around the perimeter and opened fully				
18	Confirm activation of LED (ZI_4101_01) indicator showing exterior door C is open	LED (ZI_4101_01) indicates door open			
19	Dis-connect the two growing trays (present in the air lock C at the test start) from each other by removing the spacer bars				

20	Remove both trays from the air lock in sequence				
21	Close exterior air lock door C and secure latches along the door perimeter				
22	Ensure de-activation of the LED (ZI_4101_01) indicator	LED (ZI_4101_01) indicates door Closed			
23	Unlatch exterior air lock door C and open fully. Confirm LED (ZI_4101_01) indicates door open.	LED (ZI_4100_01) indicates door Open			
24	Exterior air lock door C is closed with a paper obstruction of 2mm thickness in place within 5 cm of the upper contact switch (ZS_4101_01)				
25	Confirm that the Exterior Air Lock Door C LED (ZI_4101_01) indicates the door is still open or obstructed.	LED (ZI_4101_01) indicates door Open			
26	Exterior Air Lock Door C is opened and the paper obstruction removed. Visual inspection for deformation in the sealing gasket is made				
27	Exterior air lock door C is closed again with the paper obstruction of 2mm thickness in place within 5 cm of the lower contact switch (ZS_4101_02)	LED (ZI_4101_01) indicates door Open			
28	Exterior Air Lock Door C is opened and the paper obstruction removed. Visual inspection for deformation in the sealing gasket is made				
29	End video log of door C opening and tray mounting				

3.11. Conclusions

To be competed in the annotated procedures document

3.12. Deviations

Seq. Nb.	Description of the modification	Justification

4. Interior Air Lock Door Functional Testing

4.1. Procedure ID: CESRF-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 conveyer through the glove boxes. The test also demonstrates the procedures for tray mounting/removal into the main growing volume.

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. Video Log File Names:

CESRF_HPC1_Interior_Door_A_and_C_Operation_and_Tray_Mounting.mpeg

4.6. Acceptance/rejection criteria

4.6.1. General

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

The test is considered successful when the conditions in Section 2.2 are met

4.6.2. 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
3. The procedures for operation of the interior air lock door and the connection/removal of growing trays are clearly documented in video log.

4.6.3. Rejection criteria

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

4.7. 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.

4.8. Safety aspects

No special safety risks have been identified for this test.

4.9. Test set-up

Ancillary Equipment Required for Test
1. Digital video recorder
2. Latex or Vinyl gloves to fit operator's hand
3. Conveyer system bridges placed on floor of air locks (supplied)
3. Tray connector and spacer bars (supplied)
4. Growing trays (supplied)
5. Conveyer immobilization rods (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 Shut-Off Valve	HV_4106_02	Closed	During this procedure water must not be flowing into the growing trays

4.10. Test Procedure

Video logs of the following steps are taken. The camera should be focused and recording before their execution

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
Seq. Nb.	Description	Required/Nominal	Measured/ calculated	Remarks/Calculation	Pass (P)/ Fail (F)
1	Start video log of interior air lock door A opening and tray mounting			CESRF_HPC1_Interior_Door_A_and_C_Operation_and_Tray_Mounting.mpeg	
2	The operator places vinyl or latex gloves on his/her hands				
3	The operator then places his/her gloved hands inside the two Neoprene gloves of air lock A				
4	The operator takes the polypropylene lift rod in his/her left/right hand (through the glove box) and uses it to grasp the upper steel support of the interior air lock door				
5	Balance of procedures to be defined with replacement air lock door design				

4.11. Conclusions

To be competed in the annotated procedures document

4.12. Deviations

Seq. Nb.	Description of the modification	Justification

5. Air Lock Purge System Functional Testing

5.1. Procedure ID: CESRF-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. Video/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_4100_01, RV_4101_01

5.7. Acceptance/rejection criteria

5.7.1. General

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

The test is considered successful when the conditions in Section 2.2 are met

5.7.2. 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 transducers PT_4102_01 and PT_4103_01 detect ambient pressure under no air-flow in the air lock and detect a slight pressure increase in the air lock volume when nitrogen gas flows through the air lock at entry regulation to 115 kPa
3. Air lock pressure switches PS_4102_01, PS_4103_01 are activated when nitrogen gas flows into the air lock at entry regulation of 115 kPa and passes through the purge vent solenoids

4. Proper functioning of the manual purge override ball valves, HV_4102_01, HV_4103_01, is demonstrated
5. The passive pressure relief valves RV_4101_01, RV_4103_01 are immediately activated when slight overpressure of the air lock volume to a level of 115 kPa (as confirmed by the pressure transducers PT_4102_01 and PT_4103_01) when a nitrogen gas stream is applied at 115 kPa and the purge vent solenoids, SV_4102_02 and SV_4103_02 are temporarily obstructed with the use of a temporarily installed ball valve on the purge vent line

5.7.3. Rejection criteria

The test shall be repeated if the video data acquisition looks doubtful or failed completely or if any of the conditions outlined in Section 2.2 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

The operator must ensure that slight over-pressure of the air locks is accomplished through by slowly obstructing the vent solenoid so as to to cause over-pressure damage to the interior air lock doors of the glass of the exterior door. A manual ball valve temporarily mounted to the purge vent solenoid will assist in control the over-pressurization rate of the air locks.

5.10. Test set-up

Ancillary Equipment Required for Test:

1. Nitrogen gas source and regulator (0 – 120 kPa delivery) to be connected to the air lock purge inlet solenoid (SV_4102_01, SV_4103_01) through a Teflon or polypropylene line
2. Ball valves for temporary mounting on the air lock purge vent solenoids (SV_4102_02 and SV_4103_02) to control over-pressurization tests

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
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	Manual Purge Over-Ride Ball Valves (Airlock A and C)	HV_4102_01 HV_4103_01	Closed	No gas supplied to inlet solenoid at start of test
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	
Air Lock	Passive Pressure Relief Valves (Airlock A and C)	RV_4100_01, RV_4101_01	Closed	

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	The operator manually sends a charge signal to the Purge Vent Solenoid positioned in air lock A (SV_4102_02). Opening of the valve is confirmed	SV_4102_02 is OPEN		Set manual override switches for the valves on the control panel to on.	
2	The Purge Vent Solenoid positioned on air lock A (SV_4102_02) is discharged manually. Closing of the valve is confirmed.	SV_4102_02 is Closed		Set manual override switches for the valves on the control panel to off.	
3	The operator manually sends a charge signal to the Purge Inlet Solenoid positioned in air lock A (SV_4102_01). Opening of the valve is confirmed	SV_4102_01 is OPEN		Set manual override switches for the valves on the control panel to on.	
4	The Purge Inlet Solenoid positioned on air lock A (SV_4102_01) is discharged manually. Closing of the valve is confirmed.	SV_4102_01 is CLOSED		Set manual override switches for the valves on the control panel to off.	
5	The operator manually sends a charge signal to the Purge Vent Solenoid positioned in air lock C (SV_4103_02). Opening of the valve is confirmed	SV_4103_02 is OPEN		Set manual override switches for the valves on the control panel to on.	
6	The Purge Vent Solenoid positioned on air lock C (SV_4103_02) is discharged manually. Closing of the valve is confirmed.	SV_4103_02 is Closed		Set manual override switches for the valves on the control panel to off.	
7	The operator manually sends a charge signal to the Purge Inlet Solenoid positioned in air lock C (SV_4103_01). Opening of the valve is confirmed	SV_4103_01 is OPEN		Set manual override switches for the valves on the control panel to on.	

8	The Purge Inlet Solenoid positioned on air lock C (SV_4103_01) is discharged manually. Closing of the valve is confirmed.	SV_4103_01 is CLOSED		Set manual override switches for the valves on the control panel to off.	
9	The manual purge over-ride ball valve of air lock A (HV_4102_01) is opened and closed to demonstrate functioning	HV_4102_01 is OPEN and CLOSED			
10	The manual purge over-ride ball valve of air lock C (HV_4103_01) is opened and closed to demonstrate functioning.	HV_4103_01 is OPENED and left CLOSED			
11	The nitrogen gas line is connected to the CLOSED manual purge over-ride ball valve of air lock A (HV_4102_01) with the regulator of the supply tank CLOSED	HV_4102_01 remains closed Regulator on N2 tank is CLOSED			
12	The operator manually sends a charge signal to the Purge Vent Solenoid positioned in air lock A (SV_4102_02). Opening of the valve is confirmed	SV_4102_02 IS OPEN			
13	The operator manually sends a charge signal to the Purge Inlet Solenoid positioned in air lock A (SV_4102_01). Opening of the valve is confirmed	SV_4102_02 IS OPEN			
14	A second operator slowly opens the regulator on the nitrogen gas supply to delivery pressure of 110 kPa				
15	The main operator slowly opens the manual purge over-ride ball valve of airlock A (HV_4102_01) to start nitrogen flow into the air lock A	HV_4102_01 OPENED SLOWLY			

16	The main operator confirms that the Air Lock Pressure Switch A (PS_4102_01) is activated and indicates vent flow. The operator shall also confirm that air flow is felt at the exit of the Purge Vent Solenoid of Airlock A (SC_4102_02)	PS_4102_01 indicates FLOW Air Flow felt at PS_4102_01 exit		If air flow is not confirmed, raise the entry pressure of nitrogen gas at the regulator until PS_4102_01 is activated. Record and maintain that delivery pressure at the regulator.	
17	The manual purge over-ride ball valve of airlock A (HV_4102_01) is closed	HV_4102_01 CLOSED			
18	The operator installs a temporary ball valve on the Airlock A Purge Vent Solenoid	TEMPORARY BALL VALVE IS OPEN			
19	The manual purge over-ride ball valve of airlock A (HV_4102_01) is opened slowly	HV_4102_01 OPENED SLOWLY			
20	The temporary ball valve on the Airlock A Purge Vent Solenoid is closed slightly until a slight over-pressure in the air lock is achieved and the Air Lock A Passive Vent (RV_4100-01) is activated. The operator confirms that the Air Lock A Pressure Transducer (PT_4102_01) responds to the slight over pressure. The pressure at which the Air Lock A Passive Vent (RV_4100_01) is activated is recorded	TEMPRORAY BALL VALVE IS CLOSDE SLOWLY RV_4100-01 IS ACTIVATED PT_4102_01 IS RESPONDING TO OVERPRESSURE		Record Pressure at which RV_4100_01 is activated	
21	The manual purge over-ride valve on air lock A (HV_4102_01) is closed and the nitrogen gas line is disconnected and the regulator of the N2 tanks is closed. C (HV_4103_01)	HV_4102_01 is CLOSED N2 tank			

		regulator is CLOSED			
22	The nitrogen line is then connected to the CLOSED manual purge over-ride ball valve of air lock	HV_4103_01 remains closed			
23	The operator manually sends a charge signal to the Purge Vent Solenoid positioned in air lock C (SV_4103_02). Opening of the valve is confirmed	SV_4103_02 IS OPEN			
24	The operator manually sends a charge signal to the Purge Inlet Solenoid positioned in air lock C (SV_4103_01). Opening of the valve is confirmed	SV_4103_01 IS OPEN			
25	A second operator slowly opens the regulator on the nitrogen gas supply to delivery pressure of 110 kPa				
26	The main operator slowly opens the manual purge over-ride ball valve of airlock C (HV_4103_01) to start nitrogen flow into the air lock C	HV_4103_01 OPENED SLOWLY			
27	The main operator confirms that the Air Lock Pressure Switch C (PS_4103_01) is activated and indicates vent flow. The operator shall also confirm that air flow is felt at the exit of the Purge Vent Solenoid of Airlock C (SV_4103_02)	PS_4103_01 indicates FLOW Air Flow felt at SV_4103_02 exit			
28	The manual purge over-ride ball valve of airlock C (HV_4103_01) is closed	HV_4103_01 CLOSED			

29	The operator removes the temporary ball valve from Air Lock A and mounts it on the Airlock C Purge Vent Solenoid (SV_4103_02)	TEMPORARY BALL VALVE IS OPEN			
30	The manual purge over-ride ball valve of airlock C (HV_4103_01) is opened slowly. Air flow is confirmed at the outlet of the Air Lock C Purge Vent Solenoid (SV_4103_02)	HV_4102_01 OPENED SLOWLY Air Flow felt at SV_4103_02 exit			
31	The temporary ball valve on the Airlock C Purge Vent Solenoid (SV_4103_02) is closed slightly until a slight over-pressure in the air lock is achieved and the Air Lock C Passive Vent (RV_4101_01) is activated. The operator confirms that the Air Lock C Pressure Transducer (PT_4103_01) responds to the slight over pressure. The pressure at which the Air Lock C Passive Vent (RV_4101_01) is activated is recorded	TEMPRORAY BALL VALVE IS CLOSDE SLOWLY RV_4101_01 IS ACTIVATED PT_4103_01 IS RESPONDING TO OVERPRESSURE		Record Pressure at which RV_4101_01 is activated	

5.12. Conclusions

To be completed in the annotated procedures document

5.13. Deviations

Seq. Nb.	Description of the modification	Justification

6. Lighting Sub-System Functional Testing

6.1. Procedure ID: CESRF-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 completed.

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:

CESRF_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

6.7.1. General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the conditions in Section 2.2 are met

6.7.2. 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 of the lamp loft does not exceed 40 C at any time during lamp operation

6.7.3. Rejection criteria

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

- When any of the conditions stated above are not met
- 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 take PAR readings.

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.

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

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

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

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:

3 factory calibrated PAR sensors installed in chamber (RT_4104_01, RT_4104_02, RT_4104_3),

- standard flash light (torch)
- hand-held anemometer (0 – 8 m/s air velocity sensing required)
- step ladder

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 and respond to a flash light test*
	PAR Sensor B	RT_4104_02	Logging	Should initially read 0 uE and respond to a flash light test*
	PAR Sensor C	RT_4104_03	Logging	Should initially read 0 uE and respond to a flash light test*
	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	Off	Both fans in loft B

		and FAN_4105_04		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 (raw data are expected as well as their treatment)	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 30 cm above growing tray height using the supplied support rack				
2	Position and centre PAR sensor APAR-501B underneath the HPS lamp reflector that is member of string HPSa in module B and fix it at a height of 30 cm above growing tray height using the supplied support rack				
3	Position and centre PAR sensor APAR-501C underneath the HPS lamp reflector that is member of string HPSa in module C and fix it at a height of 30 cm above growing tray height using the supplied support rack				
4	Operator manually activates the lamp loft fans for loft A, B and C (FAN 4105_01, _02 and _03).	Fans ON			
5	Operator confirms operation of the fans by taking readings at the outlet (back) side of the fans with a hand-held anometer. All fans should yield a reading of greater than 0.10 m/s	Anemometer readings from each fan > 0.10 m/s			
6	Operator confirms air flow indicators in each lamp loft indicate air flow (FSL_4105_01, _02 and _03)	FSL_4105_01, _02 and _03 indicate air flow			
7	Operator confirms that temperature sensors in each lamp loft read ambient temperatures (TT_4105_01, _02 and _03)	TT_4105_01, _02 and _03 read AMBIENT			
8	Controller activates relay to lamp string HPSa to turn	LHPS_4104_0			

	string HPSa ON	1, _03 and _05 are ON			
9	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			
10	Operator manually shuts off shuts off relay to lamp string HPSa				
11	Confirm all air loft fans remain running				
12	Position and centre PAR sensor APAR-501A underneath the HPS lamp reflector that is member of string HPSb in module A				
13	Position and centre PAR sensor APAR-501B underneath the HPS lamp reflector that is member of string HPSb in module B				
14	Position and centre PAR sensor APAR-501C underneath the HPS lamp reflector that is member of string HPSb in module C				
15	Controller activates relay to lamp string HPSb				
16	Confirm continued operation of all lamp loft fans with indication from loft air flow sensors (record)				
17	Confirm and record readings of PAR sensors APAR-501 A – C each read above 300 uE corresponding to illumination of HPSb				
18	Controller shuts off relay to lamp string HPSb				
19	Confirm all air loft fans remain running				
20	Position and centre PAR sensor APAR-501A underneath the MH lamp reflector that is member of string MH in module A				
21	Position and centre PAR sensor APAR-501B underneath the MH lamp reflector that is member of string MH in module B				
22	Position and centre PAR sensor APAR-501C underneath the MH lamp reflector that is member of string MH in module C				
23	Controller activates relay to lamp string MH				

24	Confirm continued operation of all lamp loft fans with indication from loft air flow sensors (record)				
25	Confirm and record readings of PAR sensors APAR-501 A – C each read above 300 uE corresponding to illumination of MH				
26	Controller activates relay to lamp string HPSa				
27	Controller activates relay to lamp string HPSb				
28	Controller activates relay to lamp string MH				
29	Confirm continued operation of all lamp loft fans with indication from loft air flow sensors (record)				
30	Confirm log of air loft temperature sensors Loft-T A-C, record initial values				
31	Controller instructs lamp strings (HPSa, HPSb, and MH) to operate for 14 hrs				
32	Confirm continued operation of lamp loft fans				
33	Confirm temperature readings in all air lofts (Loft T A-C) are less than 40 0 C every ten minutes for the first two hours of all lamp operation	< 40			
34	After 14 hrs confirm shut-off of all lamp strings				
35	Confirm temperature of air loft (Loft-T A-C read) each read < 40	< 40			

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: CESRF-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 60 Hz which will enable the main centrifugal blower to run at full speed. After equilibration and air speed measurements taken in the centre front of the louvers at 10 minute intervals the readings are averaged and reported. The controller then instructs the VFD to reduce the VFD set point in 10 Hz increments and repeated measures of air flow are taken. 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:

CESRF_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

7.7.1. General

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

The test is considered successful when the conditions in Section 2.2 are met:

7.7.2. Acceptance criteria

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

- when the timed average of air flow readings measured with a hand-held anemometer positioned over each of the 6 louvers and in the air flow return plenum each yield a value of not less than XXX when the motor is running at full speed as set by the VFD of the motor to 60 Hz.
- When the VFD successfully ramps from 0 Hz to 60 Hz without damage
- When the VFD successfully ramps down from 60 Hz to 0 Hz without damage

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 the belly.

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

The growing trays should be removed from the chamber to avoid a trip hazard when moving about the chamber interior. The air flow baffles should not be in position as they will not support any operator's weight.

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

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

7.10. Test set-up

Equipment required for test performance (ancillary equipment and its specifications): Hand held 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
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 (raw data are expected as well as their treatment)	Pass (P)/ Fail (F)
1	Visual inspection of the rotary feed-through shaft and pulley system to confirm that there is no deflection in the assembly at system rest				
2	The operator activates the VFD to ramp from 0 Hz to 60 Hz over a period of 30 seconds			Refer to VFD manual for operation and set-up of the VFD	
3	Visual confirmation of air-flow at full speed of the VFD motor is made by looking for deflection of flag tape tied to the louvers of the internal growing volume				
4	The operator enters chamber with handheld anemometer or positions the anemometer in the air return outlet duct from the blower				
5	With fan running at full speed (VFD set to 60 Hz), operator takes measurement of air flow (m/s) in front of each of the louvers and in the return plenum				
6	After 2 minutes of operation, another set of readings with the handheld anemometer is taken in the centre front of each of the louvers and in the plenum				
7	After 2 additional minutes of operation, another set of readings with the handheld anemometer is taken in the centre front of each of the louvers.				
8	The average of these readings is recorded. Readings must exceed air flow prescriptions of > 0.8 m/S	>= 0.8 m/S			
6	The operator manually reduces the VFD set point to 50 Hz	>= 0.1 m/S			
7	Three additional sets of air velocity readings are taken as prescribed in steps 5-7 with the VFD running at 50Hz	>= 0.1 m/S			
8	The operator manually reduces the VFD set point to 40 Hz	>= 0.1 m/S			

9	Three additional sets of air velocity readings are taken as prescribed in steps 5-7 with the VFD running at 40Hz	>= 0.1 m/S			
10	The operator manually reduces the VFD set point to 30 Hz	>= 0.1 m/S			
11	Three additional sets of air velocity readings are taken as prescribed in steps 5-7 with the VFD running at 30Hz	>= 0.1 m/S			
12	The operator manually reduces the VFD set point to 20 Hz	> 0 m/s			
13	Three additional sets of air velocity readings are taken as prescribed in steps 5-7 with the VFD running at 20Hz	> 0 m/s			
14	The operator manually reduces the VFD set point to 10 Hz	> 0 m/S			
15	Three additional sets of air velocity readings are taken as prescribed in steps 5-7 with the VFD running at 10Hz	> 0 m/S			
16	The operator shuts off VFD and 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: CESRF-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. Video/Data Log File Names:

CESRF_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

8.7.1. General

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

The test is considered successful when the conditions in Section 2.2 are met

8.7.2. 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 – 450 ppm) concentrations prior to test
2. The IRGA (AT_4113_01) responds to increases to 1500 ppm in the chamber growing volume with manual CO2 injection
3. The PO2 (AT_4113_02) reads ambient conditions prior to and during the test
4. The Mass Flow Controller for CO2 is manually controllable to a set point of 1 L/min and flow of CO2 through the MFC is confirmed

5. Proper functioning of the CO2 injection line solenoid (SV_4113_01) and manual override valve (HV_4113_01) is demonstrated

8.7.3. 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

The operator must ensure that slight over-pressure of the air locks is accomplished through by slowly obstructing the vent solenoid so as to to cause over-pressure damage to the interior air lock doors of the glass of the exterior door. A manual ball valve temporarily mounted to the purge vent solenoid will assist in control the over-pressurization rate of the air locks.

8.10. Test set-up

Ancillary Equipment Required for Test:

1. CO2 gas source (pure CO2) and regulator (0 – 120 kPa delivery) to be connected to the CO2 injection line inlet solenoid (SV_4113_01) through a Teflon or polypropylene line
2. Calibrated air source (2000 ppm CO2, 30% O2, balance Nitrogen, certified)) and regulator (0 – 120 kPa delivery) to be connected to the CO2 injection line inlet solenoid (SV_4113_01) through a Teflon or polypropylene line
3. Portable data logger set to record signals from PO2 and IRGA at 5 second intervals to calculate mixing time.

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 growing volume sample line, actively sampling and reading ambient conditions	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	Connected to growing volume sample line, actively sampling and reading ambient conditions	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	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	Open	
Air Lock	Interior Air Lock Doors	N/A	Open	
Air Circulation	Main Blower and VFD	BLWR_4111_01, MVFD_4111_01	Running at full speed (60 Hz)	

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	With the IRGA sampling (and stabilized) from the interior growing volume, the operator records its reading	AT_4113_01 reading ambient CO2 (350 – 400 ppm)			
2	With the PO2 sampling (and stabilized) from the interior growing volume, the operator records its reading	AT_4113_02 reading ambient O2 (21%)			
3	The mass flow controller is manually set to delivery CO2 at a rate of 1 L/min	FC_4113_01 is set to deliver CO2 at 1 L/min		See MFC operating manual for manual setting of MFC	
4	The operator uses the manual switch at the control panel to open the injection solenoid (SV_4113_01)	SV_4113_01 is OPEN			
5	The CO2 tank regulator is opened to a delivery pressure of 110 kPa	CO2 tank regulator delivery at 110 kPa		Set manual override switches for the valve on the control panel to on.	
6	The manual CO2 injection (SV_4113_01) override valve is opened slowly to start the flow of CO2 into the chamber growing volume	SV_4113_01 is OPENED SLOWLY			
7	The operator watches the IRGA (AT_4113_01) display to confirm and monitor a rise in chamber growing volume CO2 concentrations.	AT_4113_01 indicating rising CO2		Record/log rising CO2 levels at 5 second intervals to calculate chamber mixing/equilibration time. May use a portable data logger (CR&) or the	

	The PO2 (AT_4113_02) should continue to read ambient concentrations.	AT_4113_02 reading ambient O2 (21%)		control system.	
8	The manual CO2 injection (SV_4113_01) override valve is closed to stop the air flow into the chamber	SV_4113_01 is CLOSED			
9	The CO2 supply line is disconnected from the injection solenoid (SV_4113_01) and replaced with a calibrated air stream to test function of PO2 (AT_4113_02). The regulator of the calibrated air supply tank should remain off	Calibrated Air injection line is connected to inlet solenoid (AT_4113_02) Calibrated air line regulator OFF			
10	The regulator on the calibrated air tank is opened to 110 kPa delivery pressure	Calibrated Air Supply tank regulator delivery at 110 kPa			
11	The manual CO2 injection (SV_4113_01) override valve is opened slowly to start the flow of calibrated air into the chamber growing volume	HV_4103_01 is OPENED			
12	The operator watches the IRGA (AT_4113_01) display to confirm and monitor a rise in chamber growing volume CO2 concentrations to 2000 ppm The PO2 (AT_4113_02) rise to 30% O2	AT_4113_01 indicating rising CO2 AT_4113_02 reading 30%		Record/log rising CO2 levels at 5 second intervals to calculate chamber mixing/equilibration time. May use a portable data logger (CR&) or the control system.	

13	The manual CO2 injection (SV_4113_01) override valve is closed to stop the air flow into the chamber when CO2 levels reach 2000 ppm AND O2 levels reach 30% through purging of the main chamber growing volume with calibrated air.	HV_4113_01 is CLOSED			
14	The operator uses the manual switch at the control panel to CLOSE the injection solenoid (SV_4113_01)	SV_4113_01 is CLOSED			

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. CESRF-HPC1-LEAKAGE-FT

9.2. Introduction

The aim of this test is to demonstrate the integrity of the chamber shell after assembly. CO_2 is injected into the chamber in a closed and idle configuration (all sub-systems off, main centrifugal blower excepted) to a set-point of 1500 ppm. CO_2 is allowed to passively decay through the chamber shell. The rate of leakage is calculated as the slope of a tangent to a 48 hour CO_2 curve at the operational condition of 1000 ppm and is expressed as % Leakage of CO_2 (relative to initial value) per day.

9.3. Acronyms used in this test plan procedure

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

9.4. Applicable documents

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

9.5. Data Log File Name:

CESRF_HPC1__LEAKAGE_FT.txt

9.6. Parts Tested (P&ID Reference)

Chamber integrity

9.7. Acceptance/rejection criteria

9.7.1. General

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

The test is considered successful when the conditions in Section 2.2 are met.

9.7.2. Acceptance Criteria

1. 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

9.7.3. Rejection Criteria

1. 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 CO2 (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 CO2 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 CO2 levels
2. The exterior doors and interface ports must remain sealed.

9.10. Test set-up

Ancillary Equipment Required for Test:

4. CO2 gas source (pure CO2) and regulator (0 – 120 kPa delivery) to be connected to the CO2 injection line inlet solenoid (SV_4113_01) through a Teflon or polypropylene line
5. Portable data logger set to record signals from PO2 and IRGA at 5 second intervals to calculate mixing time.

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 growing volume sample line, actively sampling and reading ambient conditions	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	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	N/A	Closed	

	Doors			
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 full speed (60 Hz)	
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 60Hz (full speed)				
2	Confirm fan operation by visual inspection of the fan belt assembly and that flag tape fixed to the air louvers show air movement				
3	With the IRGA sampling (and stabilized) from the interior growing volume, the operator records its reading	AT_4113_01 reading ambient CO2 (350 – 400 ppm)			
4	The mass flow controller is manually set to delivery CO2 at a rate of 1 L/min	FC_4113_01 is set to deliver CO2 at 1 L/min		See MFC operating manual for manual setting of MFC	
5	The operator uses the manual switch at the control panel to open the injection solenoid (SV_4113_01)	SV_4113_01 is OPEN			
6	The CO2 tank regulator is opened to a delivery pressure of 110 kPa	CO2 tank regulator delivery at 110 kPa		Set manual override switches for the valve on the control panel to on.	
7	The manual CO2 injection (SV_4113_01) override valve is opened slowly to start the flow of CO2 into the chamber growing volume	SV_4113_01 is OPENED SLOWLY			
10	The operator watches the IRGA (AT_4113_01) display to confirm and monitor a rise in chamber growing volume CO2 concentrations.	AT_4113_01 indicating rising CO2		Record/log rising CO2 levels at 5 second intervals to calculate chamber mixing/equilibration time. May use a portable data logger (CR&) or the control system.	
11	The manual CO2 injection (SV_4113_01) override	AT_4113_01			

	valve is closed to stop the air flow into the chamber when internal CO2 levels reach 1500 ppm	indicating CO2 levels of 1500 ppm SV_4113_01 is CLOSED			
12	The IRGA output is recorded by the data logger at 5 minute intervals			Data log interval set to 5 min	
13	The chamber is left in its current configuration for 48 hrs and CO2 is allowed to passively decay				
14	Data log is stopped after 48 hours and the reading from the IRGA is recorded and the end of test completion. If the reading from the IRGA is not less than 900 ppm after 48 hours, then the test is allowed to continue until passive decay results in levels less than 900 ppm	Final reading from AT_4113_01 is taken (must be < 900 ppm)		Concentrations of CO2 must pass through 1000 ppm in order to calculate leakage rates	

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: CESRF-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. Video/Data Log File Names:

CESRF_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

10.7.1. General

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

The test is considered successful when the conditions in Section 2.2 are met

10.7.2. 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

10.7.3. 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.

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. Hand-held EC Sensor (0 – 2500 uS)
2. Prepared Stock A and B Solutions (see appendix CESRF-HPC1-Solution-App1
3. Portable data logger set to record signals from the EC sensor at 5 second intervals

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 stocks A and B accordingly. During filling, the containers	No leakage should be seen in stock tanks or allied plumbing lines

			graduated at 100 mL intervals and the 1.3 delivered mark is hi-lighted	
EC	EC Sensor	AT_4108_01	Logging	Connected to data logger at 5 second intervals
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	The hydroponics reservoir is filled, manually, with 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	
2	The main irrigation pump is started and set to maximum flow	GP_4106_01 is ON			
3	The operator confirms that there is flow of water from the reservoir, through the irrigation bypass valve and back to the reservoir				
4	The operator confirms that the EC sensor positioned on the by-pass line is logging and reading less than 100 uS	AT_4108_01 reading less than 100 uS			
5	The operator activates the Stock A injection solenoid to open	SV_4108_01 is OPEN		Use manual switch at controller panel	
6	The operator opens the manual Stock A Tank injection valve to full aperture slowly so there is flow from the Stock A tank into the reservoir	HV_4108_01 OPEN		Set manual override switches for the valve on the control panel to on.	
7	The operator allows approximately 1.3 L of Stock A solution to flow into the reservoir. The time required to provide 1.3L from the Stock A tank is recorded. The Stock A Tank override valve is closed once 1.3L has been injected. Confirm that the EC sensor readings increase during injection	HV_4108_01 CLOSED alter 1.3L Stock A delivered to reservoir AT_4108_01 reading increasing		The operator records the time (in seconds) to reach the various 100mL delivered marks on the tank up to 1.3L delivered	

8	The operator activates the Stock B injection solenoid to open	SV_4108_02 is OPEN		Use manual switch at controller panel	
9	The operator opens the manual Stock B injection override valve to full aperture slowly so there is flow from the Stock A tank into the reservoir	HV_4108_02 OPEN		Set manual override switches for the valve on the control panel to on.	
10	The operator allows approximately 1.3 L of Stock B solution to flow into the reservoir. The time required to provide 1.3L from the Stock B tank is recorded. The Stock B Tank override valve is closed once 1.3L has been injected. Confirm that the EC sensor readings increase during injection .	HV_4108_02 CLOSED alter 1.3L Stock B delivered to resercoir AT_4108_01 reading increasing		The operator records the time (in seconds) to reach the various 100mL delivered marks on the tank up to 1.3L delivered	
11	If proper amounts of Stock A and B have been injected, the EC sensor, after at least 5 minutes of mixing of the reservoir through the by-pass valve near 2000 uS	AT_4108_01 reads near 2000 uS			
12	The remaining solution in Stock A and Stock B tanks is removed and replaced with water to the 1.3L capacity mark on the tanks			Use wet-dry vacuum to remove solution.	
13	The operator opens the manual Stock A Tank injection valve to full aperture slowly so there is flow water from the Stock A tank into the reservoir	HV_4108_01 OPEN			
14	The operator allows the remaining volume of water to flow into the reservoir. The time required to activate the Stock A low level tank switch during injection is recorded. The	AT_4108_01 reading decreasing		The operator records the time (in seconds) to reach the various 100mL delivered marks on the tank until the low level switch is activated.	

	operator allows the Stock A tank to drain to its lowest level (after activation of the low level switch) Confirm that the EC sensor readings decrease during injection				
15	The operator activates the Stock B injection solenoid to open	SV_4108_02 is OPEN			
16	The operator opens the manual Stock B injection override valve to full aperture slowly so there is flow of the remaining water from the Stock B tank into the reservoir	HV_4108_02 OPEN			
17	The operator allows the remaining volume of of water to flow into the reservoir. The time required to activate the Stock B low level tank switch during stock injection is recorded. The operator allows the Stock B tank to drain to its lowest level (after activation of the low level switch) Confirm that the EC sensor readings decrease during injection	LSL_4108_0 2 is activated AT_4108_01 reading decreasing		The operator records the time (in seconds) to reach the various 100mL delivered marks on the tank until the low level switch is activated.	
18	The reservoir solution composition after this test is close to operational EC concentrations (2000 uS) and volume (160L). It should not discarded until the crop tests.				

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: CESRF-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. Video/Data Log File Names:

CESRF_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

11.7.1. General

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

The test is considered successful when the conditions in Section 2.2 are met

11.7.2. 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

11.7.3.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.

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

No special safety considerations have been identified for this test.

11.10. Test set-up

Ancillary Equipment Required for Test:

1. Hand-held pH Sensor
2. Prepared Acid and Base Solutions (see appendix CESRF-HPC1-Solution-App1)
3. Portable data logger set to record signals from the pH sensor at 5 second intervals

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	Filled with solution resident at end of EC test	
pH	Acid and Base Tanks	VSSL_4107_01, VSSL_4107_02	Each filled to capacity with	No leakage should be seen in

			water. During filling, the containers graduated at 100 mL intervals and the 1.3 delivered mark is hi-lighted	acid/base tanks or allied plumbing lines
pH	pH Sensor	AT_4107_01	Logging	Connected to data logger at 5 second intervals
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)
2	The main irrigation pump is started and set to maximum flow	GP_4106_01 is ON			
3	The operator confirms that there is flow of water from the reservoir, through the irrigation bypass valve and back to the reservoir				
4	The operator confirms that the pH sensor positioned on the by-pass line is logging and reading near 7	AT_4107_01 reading near 7			
5	The operator activates the Acid injection solenoid to open	SV_4107_01 is OPEN		Use manual switch at controller panel	
6	The operator opens the manual Acid Tank injection valve to full aperture slowly so there is flow from the acid tank into the reservoir	HV_4107_01 OPEN		Set manual override switches for the valve on the control panel to on.	
7	The operator allows approximately 1.3 L of Acid solution to flow into the reservoir. The time required to provide 1.3L from the Acid tank is recorded. The Acid Tank override valve is closed once 1.3L has been injected. Confirm that the pH sensor readings decrease during injection	HV_4107_01 CLOSED alter 1.3L Acid delivered to reservoir AT_4107_01 reading increasing		The operator records the time (in seconds) to reach the various 100mL delivered marks on the tank up to 1.3L delivered	

8	The operator activates the Base injection solenoid to open	SV_4107_02 is OPEN		Use manual switch at controller panel	
9	The operator opens the manual Base injection override valve to full aperture slowly so there is flow from the Base tank into the reservoir	HV_4107_02 OPEN		Set manual override switches for the valve on the control panel to on.	
10	The operator allows approximately 1.3 L of Base solution to flow into the reservoir. The time required to provide 1.3L from the Base tank is recorded. The Base Tank override valve is closed once 1.3L has been injected. Confirm that the pH sensor readings increase during injection .	HV_4107_02 CLOSED alter 1.3L Stock B delivered to resercoir AT_4107_01 reading increasing		The operator records the time (in seconds) to reach the various 100mL delivered marks on the tank up to 1.3L delivered	
12	The remaining solution in Base and Acid tanks is removed and replaced with water to the 1.3L capacity mark on the tanks			Use wet-dry vacuum to remove solution.	
13	The operator opens the manual Acid Tank injection valve to full aperture slowly so there is flow water from the Base tank into the reservoir	HV_4107_01 OPEN			
14	The operator allows the remaining volume of water to flow into the reservoir. The time required to activate the Acid low level tank switch during injection is recorded. The operator allows the Acid tank to drain to its lowest level (after activation of the low level switch)			The operator records the time (in seconds) to reach the various 100mL delivered marks on the tank until the low level switch is activated.	

15	The operator activates the Base injection solenoid to open	SV_4107_02 is OPEN			
16	The operator opens the manual Base injection override valve to full aperture slowly so there is flow of the remaining water from the Stock B tank into the reservoir	HV_4107_02 OPEN			
17	The operator allows the remaining volume of of water to flow into the reservoir. The time required to activate the Base low level tank switch during stock injection is recorded. The operator allows the Base tank to drain to its lowest level (after activation of the low level switch)	LSL_4107_02 is activated		The operator records the time (in seconds) to reach the various 100mL delivered marks on the tank until the low level switch is activated.	

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: CESRF-HPC1-IRRIGATION-FT

12.2. Introduction

The purpose of this test is to demonstrate the integrity of the nutrient reservoir and plumbing, to confirm equitable 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:

CESRF_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)

VSSL_4106 (Nutrient Reservoir)

12.7. Acceptance/rejection criteria

12.7.1. General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the conditions in Section 2.2 are met

12.7.2. Acceptance criteria

1. The test is not considered successful if there are any fluid leaks along the irrigation lines of in the reservoir
2. The test is not successful if the flow rate among spigots deviates for than 10%
3. The irrigation flow sensor is non-responsive
4. Any of the manual valves are not properly opened and closed

12.7.3. 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:

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 tap 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

<table>
<tr><td colspan="3">Date:
Time:</td><td colspan="3">Test Engineer/operator:
ESA/UoG Representative:</td></tr>
<tr><td>Seq. Nb.</td><td>Description</td><td>Required/Nominal</td><td>Measured/ calculated</td><td>Remarks/Calculation (raw data are expected as well as their treatment)</td><td>Pass (P)/ Fail (F)</td></tr>
</table>

1	Set irrrigation pump speed controller to 100%	Maximum speed			
2	Activate irrigation pump	GP_4106_01 is ON			
3	Confirm reading of irrigation flow sensor	FT_4106_01 reading			
4	Turn off irrigation pump	GP_4106_01 is OFF			
5	Open air lock doors	Air lock open			
6	Plug all growing trays with rubber stoppers (supplied)	Growing trays plugged			
7	Activate irrigation pump for 5 minutes, not allowing water from spigots to drain from growing trays (manual timing)	GP_4106_01 is ON for 5 minute			
8	Shut off irrigation pump	GP_4106_01 is OFF			
9	Measure height of water in growing trays			Height of water in each growing tray should not deviate more than 10% to indicate equitable lfow	
10	Turn on irrigation pump	GP_4106_01 is ON			
11	Adjust speed of irrigation pump to 80% by manually turning the speed adjustment on the pump controller box				
12	Record flow sensor reading	FT_4106_01			
13	Repeat steps 11 and 12 for 60%, 40% , 20% and 0% of full speed. Record corresponding flow.			Calibration curve for irrigation pump	
14	Create look-up table for irrigation pump (as % of full speed) speed against realized flow				
15	Open and close all manual valves. Ensure ball valves isolate or open flow along irrigation line as required				
16	By manually manipulating (rotating) the irrigation flow sensor, confirm signal is sent by sensor				

12.12. Conclusions

To be competed in the annotated procedures document

12.13. Deviations

Seq. Nb.	Description of the modification	Justification

13. Sub-System Functional Testing

13.1. Procedure ID: CESRF-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:

CESRF-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

13.7.1. General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the conditions in Section 2.2 are met

13.7.2. 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

- Condensate freely drains into from the collection pan into the condensate collection reservoir

13.7.3.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 tst.

13.10. 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-Flow	Blower/VFD	BLWR_4111_01 MVFD_4111_01	Running at 60Hz	

13.11. 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	Open facility supply to chilled water coil and slowly (manually) open chilled water proportional valve fully (S3CV_4112_01)				
2	Confirm TT_4112_13 indicates chilled water flow				
3	Confirm chilled water flow through coil by depressions of TT_4112_14 reading			Confirm by visual inspection that no leaks exist in the water supply lines of in the coil	
4	Confirm flow out of coil and into water return line to facility by depression of TT_4112_15 reading				
5	Open facility supply to hot water coil and slowly (manually) open hot water proportional valve fully (S3CV_4112_02)			Confirm by visual inspection that no leaks exist in the water supply lines of in the coil	
6	Confirm TT_4112_16 indicates hot water flow (raise in temperature)				
7	Confirm hot water flow through hot coil by increases in TT_4112_17 reading				

8	Confirm flow out of coil and into hot water return line to facility with rise in TT_4112_18 reading				
9	Fully close hot water proportional valve (S3CV_4112_02)				
10	Activate blower and VFD (full speed)				
11	Manually record temperature sensor readings in chamber growing volume (TT_4112_04 to _012)				
12	Allow for air circulation passed chilled water coil for five minutes				
13	Manually record temperature sensor readings in chamber growing volume and confirm reading of cooler temperatures (TT_4112_04 to _012)				
14	Using a misting bottle the operator humidifies the main growing volume			Open exterior door of chamber to gain access	
15	Confirm increased humidity readings by humidity sensors (AT_4112_01 to _03)				
16	In the humid environment, water should passively condense on the coil				
17	Confirm collection of water on the condensate tray and passive drain into to condensate reservoir			Confirm that no leakage occurs on condensate drainage line or tank by visual inspection	
18	To save time, the user manually fills the condensate collection reservoir to activate the condensate hi level switch (LSH_4110_02)			Confirm activation of hi level switch	
19	Manually activate the condensate pump (GP_4110_01) to drain the condensate reservoir until the low level switch is activated (LSL_4110_02)				

13.12. Conclusions

To be competed in the annotated procedures document

13.13. Deviations

Seq. Nb.	Description of the modification	Justification

14. Control and Operational Tests

14.1. Procedure ID: CESRF-HPC1-PROFILE - OT

14.2. Introduction

The aim of this test is to demonstrate the operation of the chamber under control. The test confirms sensor reading at the controller and confirms signals are properly sent to actuators. The test procedures follow general start-up of the chamber and uses a 48 hour profile test to span a range of operational environmental conditions. Acceptance criteria for the test is based on the environment control requirements defined in Section 2.0 above.

14.3. Acronyms used in this test plan procedure

None

14.4. Applicable documents

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

14.5. Video Log File Names:

CESRF_HPC1_Exterior_Door_A_Operation_and_Tray_Mounting.mpeg
CESRF_HPC1_Exterior_Door_C_Operation_and_Tray_Mounting.mpeg

14.6. Acceptance/rejection criteria

14.6.1. General

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

The test is considered successful when the conditions in the section below are met:

14.6.2. Acceptance criteria

1. The controller reads exterior air lock door switches ZS_4100_01, ZS_4100_02, ZS_4101_01 and ZS_4101_02 when the door is open
2. The controller properly executes the purge sequence override in the event of door open signal
3. The controller reads the air lock pressure sensor PT_4102_01 and reads pressure switch PS_4102_01 and PS_4103_01
4. The controller properly executes the purge sequence with user initiation at the controller (manual start)
5. The controller detects manual induction of air-lock overpressure and responds with deactivation of SV_4102_01 and SV_4013_01 purge-in solenoids
6. The controller properly executes the photoperiod defined by the user for the profile test, which includes serial activation of lamp strings
7. The controller logs readings from all PAR sensors (RT_4104_01 through RT_4104_03) at the specified interval
8. The controller activates all lamp loft fans when PAR sensors indicate any lamp string is on and confirmation of lamp loft fans is made by the controller

9. The controller properly logs lamp loft temperatures (TT_4105_01 through TT_4105_03)
10. The lamp loft temperature remains below 35 ºC when lamps are on
11. The controller signals a high lamp loft temperature alarm in response to readings from TT_4105_01 through TT_4105_03 and user defined alarm threshold
12. The controller activates the main irrigation pump in accordance with the defined irrigation period (which may be selected to be less than 24 hrs or to match the photoperiod)
13. The controller logs nutrient flow sensor FT_4106_01 and that flow is greater than 0.2L per minute
14. Confirmation of pH sensor log AT_4107_01 at the controller
15. The controller reads of acid and base tank low level sensors (LSL_4107_01 and LSL_4107_02) when fluid in acid and base tanks is at low levels
16. The controller activates acid and base injection solenoids in cases where actual solution pH is different from demand levels defined in the profile test
17. A calibration curve of acid/base solution delivery as a function of acid/base vessel volume is obtained
18. The controller activates hi and low pH alarms when actual pH is beyond demand and tolerance
19. Confirmation of EC sensor log AT_4108_01 at the controller
20. Confirmation of controller read of stock A and stock B tank low level sensors (LSL_4108_01 and LSL_4108_02)
21. Confirmation of controller activation of stock injection solenoids by the controller (SV_4108_01 and SV_4108_02)
22. Calibration of solenoid opening time for EC control
23. Profile tests of EC control in maintenance of modified Hoagland's solution (EC Demand +/- 0.05 dS/m)
24. Induction of hi/low EC alarms
25. Induction and test of hi/low stock tank volume alarms
26. Confirmed activation of condensate drain procedure by the controller
27. Hi/low temperature alarm states are activated at the controller
28. Hi/low humidity alarm states are activated at the controller
29. Activation of condensate collection tank hi/low alarms and activation of condensate pump by the controller
30. Observed chamber temperature does not deviate by more than 0.5 °C at any time during the period of the profile test, in the absence of a crop
31. Confirmation of controller induction of hi CO2 alarm states during the day period (i.e. when CO2 concentration exceeds demand by more than tolerance by a user defined specified period of time)
32. Observed chamber CO2 concentration does not deivate by more than 100 ppm during the day periods defined in the profile test period (i.e. when compensatory CO2 injections are active)
33. The controller successfully logs O2 concentration

14.6.3. Rejection criteria

The test, in its entirety, or relevant sections of the test shall be repeated if the data acquisition looks doubtful , the controller does not initiate alarms as expected or control is not within specified tolerance limits, as defined in the section above.

14.7. Environmental requirements

This test defines the interior operational conditions of the chamber as part of a profile test. Normal ambient conditions in the MPP or at CESRF are sufficient for the test.

14.8. Safety aspects

No special safety risks have been identified for this test.

14.9. 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) Exterior Air Lock Doors	N/A N/A	CLOSED CLOSED	
Lighting	Lamp Strings	LHPS_4104_01-_06 (HPS Lamps) LMH_4104_01 -_03 (MH Lamps)	All strings off	
Lamp Loft	Lamp Loft Fans	FAN_4105_01, FAN_4105_02, FAN_4105_03	All fans off	
Air handling	Main centrifugal blower	BLWR_4111_01	Off	VFD set to 0 Hz
Temperature and Humidity	Chilled and Hot water proportional valves	S3CV_4112_02 and S3CV_4112_02	Flow to coils off, flow through by-pass occurs	
Gas Analysis	CO2 analyzer MFC for CO2 CO2 Injection Solenoid CO2 Injection Override	AT_4113_01 FC_4113_01 SV_4113_01 HV_4113_01	Analyzer ON MFC Set to 1L/min CLOSED OPEN	regulator pressure set to 120 kPa
Gas Analysis	O2 analyzer	AT_4113_02	On and flow through analyzer confirmed	
EC System	Stock A Tank Stock B Tank Stock A Manual Override Stock B Manual Override Stock A Injection Solenoid Stock B Injection Solenoid EC Sensor	VSSL_4108_01, VSSL_4108_02 HV_4108_01 HV_4108_02 SV_4108_01 SV_4108_02 AT_4108_01	Filled with Stock A Filled with Stock B OPEN OPEN CLOSED CLOSED Logging at Controller	See TN 85.73 for Stock A and B recipe
pH	AcidTank Base Tank Acid Manual Override Base Manual Override Acid Injection Solenoid Base Injection	VSSL_4107_01, VSSL_4107_02 HV_4107_01 HV_4107_02 SV_4107_01 SV_4107_02 AT_4107_01	Filled with 1M Nitric Acid Filled with 1M Na(CO3)2 OPEN OPEN CLOSED CLOSED	

	Solenoid pH Sensor		Logging at Controller	
Irrigation System	Irrigation/growing trays Irrigation Flow Sensor Manual Shutoff to Chamber Irrigation Pump Inlet Override Irrigation Drain Override Irrigation By-Pass Valves Nutrient Reservoir	N/A FT_4106_01 HV_4106_01 HV_4106_02 HV_4106_03 HV_4106_04, HV_4106_05 VSSL_4106	22 trays In position Logging OPEN OPEN OPEN OPEN OPEN Filled with 120L H_2O	
Condensate	Condensate Reservoir Condensate Pump	VSSL_4110_01 GP_4110_01	EMPTY OFF	

14.10. Test Procedure

Video logs of the following steps are taken.

Date: Time:			Test Engineer/operator: ESA/UoG Representative:		
Seq. Nb.	Description	Required/Nominal	Measured/calculated	Remarks/Calculation	Pass (P)/ Fail (F)
1	Operator initiates purge sequence in both air locks A and C by manual start at the controller and allows sequence to complete fully			Confirm proper opening and reading of RV_4100_01, SV_4102_01, SV_4102_02, PT_4102_01, PS_4102_01, HV_4102_01, RV_4101_01, SV_4103_01, SV_4103_02, PT_4103_01, PS_4103_01, HV_4103_01 Confirm completion of purge	
2	Operator initiates a second purge sequence in air lock A . Within 5 seconds of purge start, operator opens exterior air lock door A			Confirm start of purge sequence When exterior door is opened, confirm activation of ZS_4100_01, ZS_4100_02 and ZI_4100_01 and Purge override event which shuts down purge sequence	
3	Operator closes exterior air lock door A				
4	Operator initiates a second purge sequence in air lock C. Within 5 seconds of purge start, operator opens exterior air lock door C			Confirm start of purge sequence When exterior door is opened, confirm activation of ZS_4101_01, ZS_4101_02 and ZI_4101_01 and Purge override event which shuts down purge sequence	
5	Operator Closes exterior air lock door C				
6	User programs environment conditions according to profile including; • Photoperiod for each light string • Temperature regime				

	• Humidity regime • CO2 regime • Irrigation period (always on) • pH and EC demand				
7	Set controller to fully automatic mode and allow chamber to run for the full 48 period. Set log sensor log interval to 5 minutes.			• Confirm log of ALL chamber sensors • Confirm operation of irrgation pump • Confirm operation of blower • Confirm operation of lamp loft fans	
8	Download all logged data				
9	Calculate deviation of environment parameter readings against demand • Plot deviation of average of temperature sensor readings from demand for full 48 hour period • Plot deviation in observed CO2 from demand for all readings collected during 48 hour period • Plot deviation in pH from demand for all readings taken during photoperiod • Plot deviation in EC from demand for all readings taken during 48 hour period • Plot deviation from humidity demand for all readings taken during 48 hour period • Plot light intensity for all readings taken during profile test period and confirm light levels correspond to user define photoperiods for each string for each PAR sensor			Deviation of any empirical reading should not differ from demand levels by more than ESA specified tolerance at any point during profile test	
10	At end of profile test, if low Stock A, Stock B, Acid or Base volume alarms have not been activated, confirm activation at the controller by manually draining the tanks to low level			A shop vac can be used. Low stock, acid, and base tank alarms should activate when tanks empty	

11	Confirm that volumes of stock A, Stock B, acid and base tanks have changed during profile test indicating proper functioning of injection solenoids				
12	At end of profile test shut off all lamp strings and confirm operation of lamp loft fans for user defined cool down period			Fans should stay on for 20 minutes after all lamps off	
13	Turn on all lamp strings. Confirm start of all lamp loft fans.				
14	Manually induce lamp loft high temperature alarms by heating loft temperature sensors with hair dryer			Confirm activation of high loft temperature alarms	
15	Calibrate Stock A tank delivery volume as a function of tank head space by filling Stock tank A, manually opening injection solenoid for 2 seconds, record head space volume, repeat until low Stock tank alarm is activated				
16	Repeat Step 15 for Stock B, Acid and Base Tanks. Plot volume delivered as a function of accumulated solenoid opening time to generate calibration curve and look-up table				
17	Map light intensity for all permutations of lamp string operation by moving PAR sensors through chamber at user defined distances at three distances away from glass (see below)				
18	Return chamber to idle mode				

14.11. Conclusions

To be competed in the annotated procedures document

14.12. Deviations

Seq. Nb.	Description of the modification	Justification

Table 14-1. Diurnal temperature demand profiles for the operational functional test.

Hour	Demand Temperature	Lamp Strings On	Demand Humidity %	Demand CO_2 (ppm)
0:00 – 1:00	10	None	75	1000
1:00 – 2:00	15	None	75	1000
2:00 – 3:00	20	None	75	1000
3:00 – 4:00	25	None	75	1000
4:00 – 5:00	30	None	75	1000
5:00 – 6:00	30	None	75	1000
6:00 – 7:00	10	Sa	75	1000
7:00 – 8:00	15	Sa	75	1000
8:00 – 9:00	20	Sa	75	1000
9:00 – 10:00	25	Sa	75	1000
10:00 – 11:00	30	Sa	75	1000
11:00 – 12:00	30	Sa	75	1000
12:00 – 13:00	10	Sa + Sb	75	1000
13:00 – 14:00	15	Sa + Sb	75	1000
14:00 – 15:00	20	Sa + Sb	75	1000
15:00 – 16:00	25	Sa + Sb	75	1000
16:00 – 17:00	30	Sa + Sb	75	1000
17:00 – 18:00	30	Sa + Sb	75	1000
18:00 – 19:00	10	Sa + Sb + H	75	1000
19:00 – 20:00	15	Sa + Sb + H	75	1000
20:00 – 21:00	20	Sa + Sb + H	75	1000
21:00 – 22:00	25	Sa + Sb + H	75	1000
22:00 – 23:00	30	Sa + Sb + H	75	1000
23:00 – 24:00	30	Sa + Sb + H	75	1000

The controller efficacy is evaluated from data collected over the 24 hr profile test. The accuracy of temperature, CO_2 and humidity control is compared to ESA specifications.

When complete, the chamber is ready for a full functional test with a batch crop of lettuce.

15. Crop Testing

15.1. Consumables required for Operational Testing with Crops

- **Harvesting and Preparation Tools, including:**
  - Balance for dry and fresh weight masses and micro-nutrient/hydroponics salt measurement (500 g ± 0.01 Kg)
  - Bleach
  - 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)
- Cutting board, knife, scissors, paper towels, paper bags
- Plastic vials
- Coffee grinder for tissue sample preparation

- **Additional Analytical Equipment, as required:**
  - Li-COR Leaf Area Analyzer
  - HPLC for hydroponics sample analysis (ions; F. Cl. NO_2, NO_3, PO_4, SO_4, Na, NH_4, K, Mg, Ca

15.2. 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 considered and the EC/pH control system is operational. Periodic analysis using off-line HPLC will indicate if solution dump is required.

Table 5.2-15-1. 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 (In Stock B)		
$FeCl_3$ (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 crafted using concentrated stocks (on hand) to the feed strength by dilution and adjusted to a pH of 6.0 with the addition of sodium bicarbonate. Once crafted the nutrient solution is pumped through the irrigation system once the seedlings have been added to the growing trays.

15.3. Germination, Emergence, Thinning, Planting

Lettuce seeds will be subjected to a period of vernalization at cool (4°C) temperatures and high humidity in a paper lined Petri dish for a period of 72 hrs. Seeds are transferred to Rockwool cubes rinsed with distilled water and placed under cover beneath a suitable lighting source. The seeds are watered regularly (daily) with water and diluted feed stock solution. After emergence, plants are thinned from the Rockwool to the desired planting number and the covers, used to promote high humidity, are removed. Rockwool and trays for germination may be readily obtained from local suppliers. Following true leaf emergence, the seedlings are moved into the chamber.

The transplantation of the seeds in the chamber may be done as follows:

- Ensure interior air lock door seal at the harvesting end of the chamber
- Open the exterior air lock door
- Place up to two growing troughs with seedlings placed at the proper density into the air lock, with the tray and chamber long dimensions perpendicular to each other
- Slide the troughs onto the air lock conveyer
- Close the exterior air lock door and ensure seal
- The above process is completed until all trays are in position
- Purge the air lock volume with the calibrated air stream
- Open the interior air lock door
- Using the air-lock glove box, fasten the newly introduced troughs to those already on the conveyer
- Open the harvest air lock interior door

Once in position, the irrigation system is activated with the irrigation by-pass line operational.

15.4. Crop growth

Once the crops are planted, the controller is programmed to provide the following environment conditions for the entire period of crop grow-out (approximately 20 days after germination)

CO_2 Demand – 1000 ppm constant
Temperature – 26/20 º C (day/night)
Humidity – 75%
EC – seat at initial solution EC (approximately 2 mS cm^{-1})
pH – 6.0
O_2 – not controlled
Light Intensity – All lights operational

15.5. Analysis of Net Carbon Exchange Rate and Assessment of Model Performance

The computer controller of the SEC-2 chambers maintains CO_2 concentrations at demand levels during day-light hours through the automated injection of CO_2 from a bottle store and a mass flow controller. Output from the mass flow controller/meter are used to estimate net carbon gain of the developing crop stands using a compensation technique. The computer controller maintained internal chamber CO_2 concentrations during the daylight hours so that any net carbon gain by the stand through photosynthetic activity was compensated for by injections from the gas external tank. The volume and duration of CO_2 injections were used to estimate day-time NCER. During the dark period it was not possible to remove CO_2 from the chamber to achieve static conditions, and as such, the difference in observed CO_2 and demand concentrations was used to calculate dark period respiration (negative NCER). The sum of these signed NCER estimates over a 24 hour period (in moles C), yielded daily carbon gain (DCG).

15.6. Harvest

1. At crop maturity (approximately 20 days after plant in chamber, 35 days total), all materials is harvested and separated into edible and inedible fractions by growing tray. Fresh weight by tray is determined. For the harvest of the first few trays, the air lock functionality is demonstrated. Subsequently, the remaining trays are removed in batch
2. Fresh weight of the edible and inedible fractions is determined and the plant parts are placed in paper bags in a drying oven for 7 days at 60º C.
3. Dry weights of all plant parts is recorded.
4. Tissue samples are sent for % C determination
5. A carbon balance is determined from the NCER estimates obtained above, the dried biomass and measured carbon content

16. Procedures for Temperature and Light Intensity Mapping in the Chamber Growing Volume

16.6.1. Spatial Characterization in Light Intensity

The spatial characterization in light testing is done to map the light intensity over the three dimensional space of the growing volume.

1. Three PAR sensors are mounted on the support rack (supplied) which is rested on the growing trays. Light intensity readings are taken with the three lamp strings on at the first position of the tray.
2. After equilibration, the PAR sensors are moved along the length of the chamber by pulley/line. The distance travelled is recorded.
3. Readings from each of the PAR sensors in their new position are recorded after equilibration.
4. The three sensors are moved further down the chamber in 25 cm increments
5. Readings from each of the sensors are taken again (for a total of 20 readings along the length of the chamber)
6. The height of the mounting rack for the sensors is adjusted to yield a two dimensional light map at the new distance from the glass roof. The process above is repeated.
7. The rack is adjusted again for a third and final map at a new height.
8. All of the above processes are repeated for all combinations of lamp string operations.
9. Plots of light intensity in two dimensional space for the three heights are made for all combinations of lamp string operation

16.6.2. Spatial Characterization in Temperature

1. The process above is completed concurrently for temperature with three temperature sensors (with radiation shielding) positioned on the rack adjacent to the PAR sensors.

17. Procedures for Calibration of the VFD and Blower Speed

1. With the air flow sensor in position and reading flow in m/s, the VFD is set sequentially to 0 Hz to 60Hz in 10Hz increments and air flow/speed mearuements are recorded for each

increment. A plot of air speed against VFD setting is then made to generate the calibration curve. This result may be useful in advanced thermal control of the chamber.