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TECHNICAL NOTE

TECHNICAL NOTE 85.73

Prototype Interface Specifications User Manual

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MELiSSA

TECHNICAL NOTE

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Appendix 3 to TN 85.7 – I/O Interface Panel Map	EXCEL Table	In Review – No ESA Reference Assigned

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1. Introduction

This document outlines the interface requirements of the CESRF and the MPP facilities to support operation of the prototype plant growth chamber – HPC1. The document describes the electrical, water, gas and labour requirements for functional testing and operation of the chamber and the consumable and tool requirements required for tests with crops.

The document also describes requirements for electrical supply from the Schneider PLC and Argus controllers in the form of an I/O Table.

2. High Power Electrical Requirements of the Prototype Sub-Systems

The following section details the electrical interface requirements for high powered devices of each sub-system.

2.1. Air-Lock Sub-System

The air-lock sub-systems (neither Air Lock A and C) do not require high power from either the CESRF or MPP facility.

2.2. Atmospheric Control (Temperature, Humidity and Pressure) Sub-System

The main power requirement for the Atmospheric Control System is that of the Variable Frequency Drive (VFD) and the motor driving the Main Centrifugal Blower. The power connection is to be made from the facility (CESRF or MPP) to a high powered disconnect specified by a certified electrician. The disconnect is then wired to the power input terminals of the VFD. Connection from facility power to the VFD and motor must be specified and performed by a certified electrician.

The power requirements for the VFD are as follows:

- 1 or 3 phase input, three phase output to motor, 220V at 50 or 60 Hz

The power requirements for the motor are as follows:

- 1 or 3 phase input, three phase output, 220V at 50 or 60 Hz, 2kW

Figure 2-1. Photograph of the VFD (blue device) and blower motor (below). Power supplies to the VFD are through conduits supplied by the electrical contractor.

2.3. Gas Analysis and Control (CO_2, O_2) Sub-System

The electrical requirements for the Gas Analysis and Control sub-system rest with the power supply requirements of the Infra-Red Gas Analyzer and Paramagnetic Oxygen Analyzer for O2. Connection may be through a wall outlet or supplied with bear leads Their requirements are as follows:

The power requirements for the LiCOR 7000 Infra-Red Gas Analyzer for CO_2 will be:

- 220/240 VAC, 50 Hz, 4 amp max. with a power requirement of 15-40Watts DC (dependent on temperature and pump usage).

The power requirements for the CA 100 Paramagnetic Analyzer for O_2 may be selected from the range of:

- 220/240 VAC, 50 Hz, 70 Watts per channel as specified by the desires of the MPP

2.4. Hydroponics Sub-System

The electrical requirements for the Hydroponics system rests with the power supply requirements of the main irrigation pump:

The power requirements for the irrigation pump are:

- 220 VAC, 50 Hz, 0.5 horse power (377 W)

The power connection is to be made from the facility (CESRF or MPP) to a high powered disconnect specified by a certified electrician. The disconnect is then wired to the power input terminals of the speed controller of the irrigation pump. Connection from facility power to the manual controller and irrigation pump must be specified and performed by a certified electrician.

Figure 2-2. Photograph of the irrigation pump and manual speed controller (above). Power supplies to the pump are through conduits supplied by the electrical contractor.

2.5. Lighting Sub-System

The power requirements for the lighting system rests with the lamp ballasts. The bulb socket and reflector assembly are mounted on the chamber separately from the ballasts. Therefore a certified electrician will be required to;

- Mount the external ballasts (9 in total) on a custom support frame
- Connect the ballasts to the lamp sockets (cable supplied by lighting supplier)
- Connect facility power supplies to the ballasts (through a properly specified contactor (consult electrician).

The requirements for each of the High Pressure Sodium lamps are as follows;

- 380 VAC, 50 Hz with a power load of 650 Watts

The requirements for each of the Metal Halide Lamps are as follows;

- 380 VAC, 50 Hz with a power load of 432 Watts

The total load requirement for all the lamps is expected to be: 5410 W

Note: The CESRF will use lamps operating at 60Hz and 220 V and will arrange for procurement and supply of lamps at the 50Hz and 380 V specification. Arrangement will be made to ship the lighting systems from the European supplier directly to the MPP so that the lighting systems arrive two weeks in advance the arrival of the prototype at the MPP.

Figure 2-3. Photograph of the lighting system ballasts, contactors (below) and Argus I/O panels. The mounting frame for the ballasts as installed at the CESRF is also shown.

3. Low Power Electrical Requirements of the Prototype Sub-Systems, Associated Control System I/O Table and I/O Interface Panel

The electrical interface requirements for lower powered devices (such as sensors and solenoids) are specified in a companion I/O Table (CESRF Appendix 2 to TN 85.7 – I/O Table.

- The prototype has resident conduits for connecting low powered devices to an intermediate panel. Connection of wires at the HPC1 interface is made through 8-pin quick connect wiring bulkheads mounted on shell interface plates. Wiring form the chamber to the intermediate panel is therefore made through 8 wire cables run through conduits which a provided with the shell.

- The CESRF will re-assemble wiring connections to the intermediate panel during the assembly sequence for the HPC1 at the MPP (as in TN 85.72). Connections from the intermediate wiring panel to the I/O terminals of the controller are also to be made during re-assembly to the Argus controller (by CESRF) and eventually to the Schneider PLC (MPP).

- All low power and signal connections are made through the intermediate wiring panel according to a map presented in a companion document designated CESRF Appendix 3 to TN 85.7 – Intermediate I/O Panel Map.

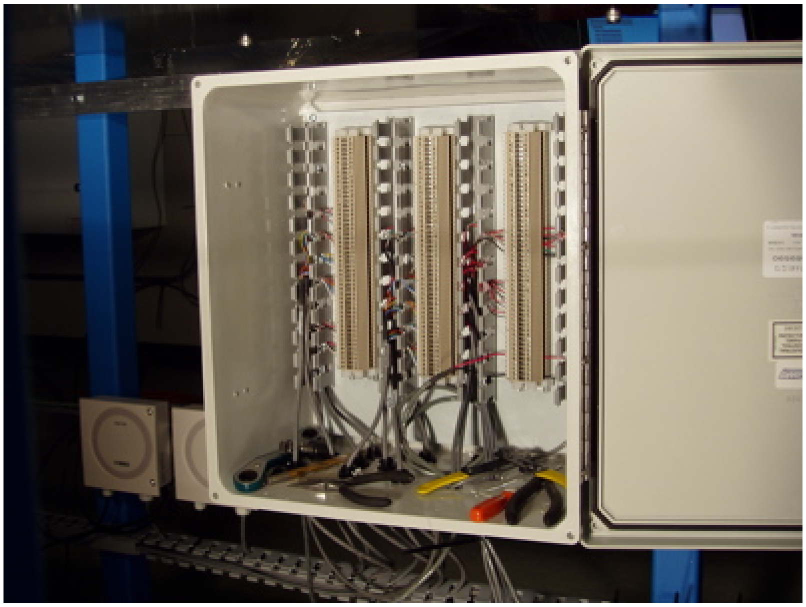

Figure 3-1. Photograph of one of two of the intermediate I/O interface wiring panels. Screw terminals and wiring conduit (below box) are shown. Eight wire cable is used for connections.

Figure 3-2. Photograph of mounting frames for ballasts in relation to the chamber. Shown are also the passive pressure compensation bladders.

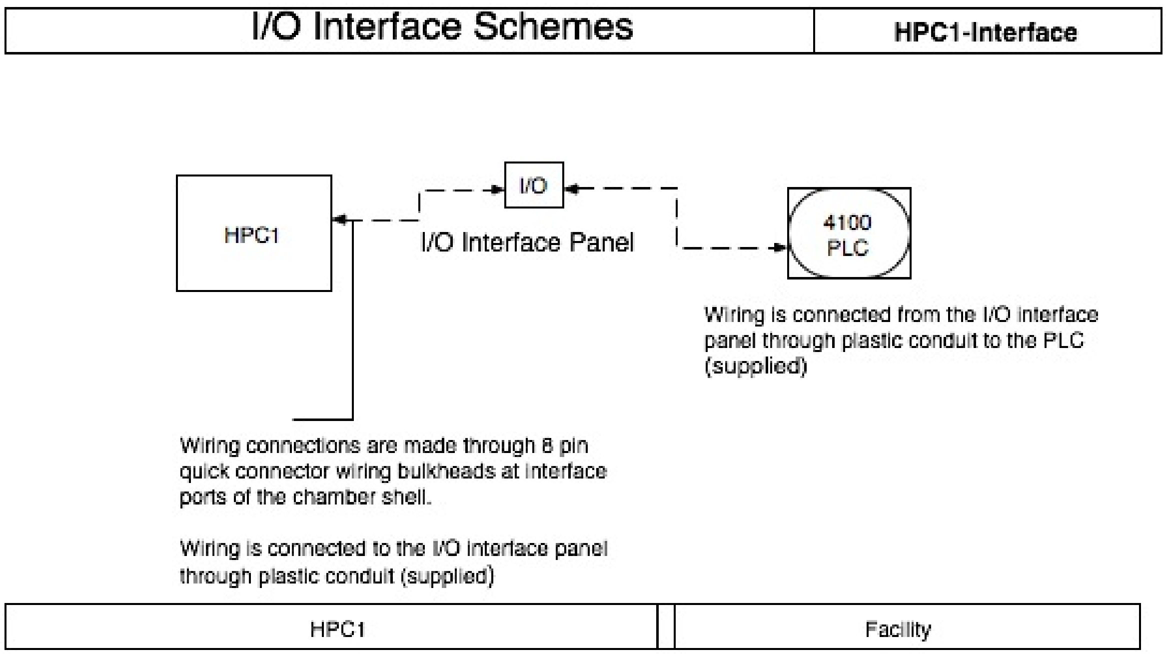

Figure 3-3. Scheme for connection of low powered devices between the PLC and prorotype..

4. Water Supply Requirements of the Prototype Sub-Systems

4.1. Air-Lock Sub-System

The air lock sub-system requires no water supply services.

4.2. Atmospheric Control Sub-System

The atmospheric control system will require chilled and hot water supplies to feed the hot and chilled water coils. The requirements for water supply to the coils is as follows;

- Nominal chilled water flow to the chill coil at a rate of 34 L / minute (9 U.S. Gallons/minute) with a coil entry temperature of 8 °C and a regulated supply pressure of 70 kPa (aprx. 10 psi). The chilled water supply must be capable of operating on a closed loop with return of water from the coil back to the facility supply.

- The chilled water service supply to the coil is connected to a ¾" female NPT fitting of the pressure regulator or to a fitting bridging the pressure regulator to the MPP service supply line. The CESRF will supply such a coupling if required.

- The water returning to the facility from the coil will connect through a ¾" female NPT fitting on the proportional valve. The CESRF will supply an appropriate coupling to match MPP facility.

- The CESRF will supply PVC plumbing and will construct the chilled-water by-pass system on site. The MPP will need to supply plumbing to feed the pressure regulator and for the return from the proportional valve to facility.

- Nominal hot water flow to the hot coil at a rate of 12 L / minute (aprx. 9 U.S. Gallons/minute) with a coil entry temperature of 49 °C and a regulated supply pressure of 70 kPa (aprx. 10 psi). The hot water supply must be capable of operating on a closed loop with return of water from the coil back to the facility supply tank. It is suggested that a gas or electric hot water boiler be supplied in the MPP to heat and store water supply.

- The hot water service supply to the coil is connected to a ½ " female NPT fitting of the pressure regulator or to a fitting bridging the pressure regulator to the MPP service supply line. The CESRF will supply such a coupling if required.

- The water returning to the facility supply from the hot coil will connect through a ¾" female NPT fitting on the proportional valve. The CESRF will supply an appropriate coupling to match MPP facility.

- The CESRF will supply PVC plumbing and will construct the hot water by-pass system on site. The MPP will need to supply plumbing to feed the pressure regulator and for the return line from the proportional valve to facility.

Figure 4-1 Photograph of the water supply service lines to the coils. The hot water coil (left) and chilled water coil (right) are connected to the proportional valve (orange device) and pressure regulator (brass device). Connection to and from facility supply is made to the pressure regulator and from the proportional valve, respectively.

4.3. Gas Analysis and Control (CO_2, O_2) Sub-System

The gas analysis and control subsystem requires no provision for water supply.

4.4. Hydroponics Sub-System

The hydroponics system will require the following water supplies (assuming solution replacement in the hydroponics/nutrient reservoir every 5 days);

- 200 L of distilled or de-ionized water peak volume requirement every 5 days
- nominal requirements of up to 50 L per day (peak) for washing, stock preparation etc.,
- Chilled water supply for cooling of the nutrient reservoir of the same specifications as that for the chamber's chill coil (entry temperature of 8 °C and a regulated supply pressure of 70 kPa (aprx. 10 psi)

Additionally, at times when solution dump and re-fill of fresh solution is required, a submersible pump (10 L / min) will be required to pump nutrient solution out of the hydroponics/nutrient reservoir to the facility drain. The pump may be connected directly to an electrical outlet in the facility and should be stored nearby the chamber (under the laboratory bench).

For mixing of fresh nutrient solutions a graduate 200 L tank will be required. The tank is required to mix distilled or de-ionized water with concentrated stocks stored in two separate 50 L tanks (with spigot) (one each for Stock A and B). These tanks are in addition to those mounted as part of the chamber hardware. The submersible pump may be used (or a second identical pump) to transfer the fresh solution from the 260 - 300 L mixing tank to the nutrient/hydroponics reservoir.

Distilled or de-ionized water supply for filling of the reservoir may be delivered through a conventional garden hose from facility supply.

The requirements for stock solutions and acid/bases are described in the consumable section.

4.5. Lighting Sub-System

The lighting system requires no special water supply services from the facility (MPP or CESRF).

5. Gas Supply Requirements of the Prototype Sub-Systems

5.1. Air-Lock Sub-System

The purge operation of the air locks will require calibrated gas with a regulated supply (~120 kPa). The volume of the calibrated air supply will be dependent upon availability from suppliers but a conventional 50L (@ 20 kPa) tank is appropriate. The tank should have the following composition (assuming nominal chamber operation at 1000 ppm CO_2);

- 1000 ppm CO2, 21 % O2, balance nitrogen

The calibrated air will be required during the purge of both air locks. Therefore it is desirable to have one of the two configurations;

- two calibrated air tanks each with its own regulator to supply each of the two air locks independently, or;
- a single calibrated air tank with a three way manual valve (or electronically actuated valve) to switch the feed flow to either air lock (not supplied by CESRF).

Given the volume of each air lock of 1.2 m x 1 m x 0.5 m = 0.6 m^3, it is estimated that at least total of 1.2 L of calibrated air will be consumed (at 101.3 kPa) for each air lock purge operation (both planting and harvest ends).

5.2. Atmospheric Control Sub-System

The gas requirements for the atmospheric control system are described as part of the gas analysis and control sub-system below.

5.3. Gas Analysis and Control (CO_2, O_2) Sub-System

The gas and analysis sub-system will require three gas supply types as follows;

- A calibrated air tank (with regulator) for span calibration of the infrared gas analyzer and the paramagnetic oxygen analyzer, having the following composition; 3000 ppm CO_2, 20% oxygen the balance nitrogen. Calibration of the analyzers occurs weekly and a single 50L (@ 20 kPa) tank should last several months. Design of the plumbing/tubing to the analyzers from the calibration gas tanks should be done on-site.
- An air tank (with regulator) for zero calibration of the infrared gas analyzer and the paramagnetic oxygen analyzer, having the following composition; 100% pure nitrogen. Again, calibration of the analyzers occurs weekly and a single 50L (@ 20 kPa) tank should last several months. Design of the plumbing/tubing to the analyzers from the calibration gas tanks should be done on-site.
- A tank of pure CO_2 for compensatory and regulated injections (through the mass flow controller for CO_2) into the chamber atmosphere (off-setting photosynthesis and for calculating NCER). A 50L (@ 20 kPa) size tank should last for the duration of a 100 day crop grow-out period, depending on the type of crop and the planting density. It is possible supply from facility CO_2 sources is acceptable if concentrations are in excess of 90%.

5.4. Hydroponics Sub-System

No special gas supply requirements are envisioned for the hydroponics sub-system.

5.5. Lighting Sub-System

The lighting system requires no special gas supply services of the facility (MPP or CESRF). However, it should be noted that special ventilation of the air lofts may be required if room temperatures are extreme (> 30 °C) or if the room's air handling system does not sufficiently reject heat exhausted by the lamp loft fans.

6. Logistical and Labour Requirements of the Prototype Sub-System

6.1. Air-Lock Sub-System

Operation of the air-lock system (harvest and planting) will require an operator who is capable of lifting up to 20 Kg (growing trays with wet Rockwool and mature crops). Operation of the air lock will require an individual with sufficient dexterity to open and close the interior air-lock doors (magnetic) through the glove boxes.

Peak labour loads for harvesting and planting can be inferred from the chamber operational manual, but at a minimum, the facility should plan for 1-2 hrs of labour for each tray planted. This includes preparation and planting/harvest time.

6.2. Atmospheric Control Sub-System

The atmospheric control sub-system will require periodic inspection to ensure equipment is operational (blower, water supply lines and valves). It is estimated that 1 person-hour per week will be required for inspection.

6.3. Gas Analysis and Control (CO_2, O_2) Sub-System

The gas analysis and control sub-system will require an individual trained in the operation of the gas analyzers. The individual will be required to calibrate the analyzers at weekly intervals (approximately ½ person-hour labour per week). The individual should also be capable of moving gas tanks using an appropriate gas trolley (assumed to be on site at the facility).

6.4. Hydroponics Sub-System

In addition to the distilled water supply hose, the solution mixing tanks and the submersible pumps for solution drainage some consumables are required in the operation of the hydroponics sub-system. These consumables are detailed in the consumable section below.

Labour requirement for solution preparation and maintenance (i.e. re-filling of stock tanks, E.C./pH sensor calibration, inspection) should require about 1 -2 hrs of labour per week.

It is critical that the hydroponics sub-system have provisions for solution dump (submersible pump described above) and a facility water drain.

6.5. Lighting Sub-System

The lighting system requires so special logistical requirements. Labour requirements include the cleaning of the glass roof of dust and change-out of lamps amounting to no more than 1 hr per month.

The facility should maintain supplies of light bulbs (400 W BULB 400W K P HPI/T MH for Metal Halide) and Phillips HPS Bulb 600 W (both supplied by P.L. Lighting Systems/Hortilux, The Netherlands). Each bulb should last approximately 3000 hours.

6.6. Other Supplies for Logistical Operations

In addition to the provisions described above, it is useful to have the following items on hand to support logistical activity:

- A hand pumpable lift cart to support transfer of heavy items (filled water tanks) if required
- A cart for transport of tissue samples and equipment
- A wheeled step-ladder to allow for access to the chamber roof, lamps etc.
- Depending on the height of the chamber operator, a stool may be required for air-lock operations (height of glove boxes based on a 1.80 m tall individual)

7. Storage, Space and Special Hardware Mounting Requirements

Inspection of the MPP facility indicated that the laboratory bench space and under-bench storage cabinets would be sufficient for storage of most consumables. Provision should be made however for special storage of acid and bases and large containers of nutrient salts (calcium nitrate). Storage requirements for these materials is dependent upon the container/bottle sizes selected by MPP staff and the availability from supplier. For calculation, 50 L of stock will last 25 nutrient solution change-overs. Quantities required for formulation for 50L of stock is as follows:

		Final Solution		Target Stock Solution		Actual Stock Solution		
Concentration Factor		**1**		**100**		**123**		
	mol wt.	mM	g/L	mM	g/L	mM	g/L	g/50 L
Macronutrients								
A								
Ca(NO3)2•4H2O	236.16	3.62	0.85	362.00	85.49	445.26	105.15	**5257.63**
B								
MgSO4.7H2O	246.48	1.00	0.25	100.00	24.65	123.00	30.32	**1515.85**
KNO3	101.10	5.00	0.51	500.00	50.55	615.00	62.18	**3108.83**
NH4H2PO4	115.08	1.50	0.17	150.00	17.26	184.50	21.23	**1061.61**
FeCl3	162.20	0.025	0.0041	2.50	0.41	3.08	0.50	**24.94**
Micronutrients								
H3BO3	61.83	0.0200	0.0012	2.00	0.12	2.46	0.15	**7.61**
MnSO4.H2O	169.01	0.0050	0.0008	0.50	0.08	0.62	0.10	**5.20**
ZnSO4.7H2O	289.54	0.0035	0.0010	0.35	0.10	0.43	0.12	**6.23**
CuSO4.5H2O	249.68	0.0008	0.0002	0.08	0.02	0.10	0.02	**1.23**
H2MoO4 (85% MoO3)	161.97	0.0005	0.0001	0.05	0.01	0.06	0.01	**0.50**
Base								
NaOH	40.00	0.6000	0.0240	60.00	2.40	73.80	2.95	**147.60**

Figure 7-1. Typical salt consumption rates for mixing of 50L of stock (which should last 25 solution change overs (125 days).

It should be noted again that special mounting of lamp ballasts will be required since, given the heat load of the ballasts they should not be mounted on the chamber itself. A certified electrician should be consulted to design and construct a mounting system (built to code) for the lighting ballasts.

For operations of the chamber, clearance around the air lock ends and the side of the chamber with access and sensor interface panels should be 2 m. (Clearance of at least 50 cm should be added on the back long side of the chamber to accommodate expansion of the Teflon bags (passive expansion bladders).

For seed germination, a cooler or refrigerator will be required to keep seeds in petri dishes for 48-72 hrs (3°C, three or four petri dishes, stacked). Additionally, a location for seed germination (kept at 20 ºC, is usually sufficient) with a household fluorescent grow lamp should suffice until an off-the-shelf growth chamber can be procured.

8. Consumable/Supporting Equipment Requirements

- **Harvesting and Preparation Tools, including:**
  - Balance for dry and fresh weight masses and micro-nutrient/hydroponics salt measurement (500 g ± 0.01 Kg)
  - Bleach or Virkon (consumable)
  - Rockwool cubes (2.5 cm^2 and 10 cm^2 blocks) (2 x 1 m^3 boxes) (consumable, requirements depending on planting density, but on average 150 of the large blocks and 1200 of the small blocks will be required for full stocking of beet/lettuce and wheat respectively)
  - Seed germination trays with covers (20) – (semi-consumable with a life-time of approximately three or four crop grow out periods depending on care)
  - Petri dishes for seed imbibitions
  - Solution stock storage tanks (2 x 50 L tanks with spigot, PP, as described above)
  - Solution transfer tank (1 x 200 L tank, PP, as described above)
  - Submersible pump (10 L min^{-1} or greater), for solution dump and transfer
  - Cutting board, serrated bread knife, scissors, paper towels, paper bags (for tissue sample storage and drying)
  - Plastic vials for solution sample storage, gas sampling tubes (for off-line VOC analysis)
  - Coffee grinder for tissue sample preparation (of sufficient size to hold 20 g of ground biomass)
  - Seeds (depends on variety and supplier)
  - Tweezers
  - Glass cleaner
  - Broom
  - Dust-Pan
  - Garbage pail
  - Sharps storage container
- **Hydroponics Salts (all reagent grade):**
  - $Ca(NO_3)_2 \cdot 4H_2O$, Calcium Nitrate, $MgSO_4 \cdot 7H_2O$, KNO_3, $NH_4H_2PO_4$, $(NH_4)_2SO_4$, $FeCl_3$ (DTPA), H_3BO_4, $MnSO_4 \cdot H_2O$, $ZnSO_4 \cdot 7H_2O$, $CuSO_4 \cdot 5H_2O$, H_2MoO_4 (85%MoO3)
  - Acid and Base (suggested sulphuric acid and sodium bi-carbonate)
- **Calibration buffers for pH** – for pH 3 and 7 (less than 100 mL per month)
- **Glass jars for storage of EC meter calibration solution**
- **Polypropylene film for tray covering** (initially supplied by CESRF)
- **Tools:**
  - An adjustable metric wrench (0 – 3 cm)
  - Screw-driver set
  - Set of metric Hex (Allan) keys
  - Wire cutters/stripper
- **Software (recommended)**
  - R or S-plus for data analysis using code already written by CESRF (may be supplied)
  - Microsoft Office Suite (EXCEL, Word)
  - ftp server / software
- **Television or computer monitor for visualization of camera images (PAL – web cam and monitor to be purchased in Europe)**