MELiSSA

TECHNICAL NOTE 96.8

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TECHNICAL NOTE 96.8

HPC1 mapping requirements

Prepared by/Préparé par	EnginSoft/UAB
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ACRONYMS

CESRF	Controlled Environment Systems Research Facility
CFD	Computational Fluid Dynamics
HPC	Higher Plant Chamber
HVAC	Humidity Ventilation Air Conditioning
MSDS	Material Safety Data Sheet
PAR	Photosynthetically Active Radiation
PP	Polypropylene
PPF	Photosynthetic Photon Flux
RH	Relative Humidity
UAB	Universitat Autònoma de Barcelona
UoG	University of Guelph

1.Introduction

1.1.General

In the frame of the Food Characterization Activity, EnginSoft is in charge of developing a digital 3D computational fluidic dynamics model of the HPC1, taking into account the temperature, light, humidity, CO2 and air velocity distributions. This model will be used in order to simulate various conditions in which the plants grow inside the chamber. For this, it has to be previously validated by comparing and correlating its computed results with real, experimental data of the existing hardware used in the MPP, the HPC1.

The scope of this document is to define the requirements for the measurements to be made in the MPP in the frame of Call Off Order 6 on the HPC1 in order to feed the theoretical 3D model of the chamber with experimental data of temperature, humidity, light and air velocities distribution.
These requirements include the additional instrumentation needed for the specific purpose of the mapping.

1.2.Validation

This mapping activity can in a first approach validate the operating scenario of the “dry model” (without plants) developed by EnginSoft, as shown in appendix 1 and in full detail in TN3.22.
As a matter of fact the CFD calculation described in the appendix, gives hints and clues to where experimental probes should be placed, in order to gain the maximum information with the minimum cost of hardware.
Hence it is assumed that the boundary conditions of the blower, trays spacing, air grilles etc. when the model validation is made are the ones described in TN3.22.

1.3.Future

The mapping requirements are nevertheless intended to be used also for future scenarios, where plants evapotranspiration processes will alter for example T and RH, and where different type of canopies will require different trays spacing.

2.Scope

The present document specifies the requirements for the mapping of HPC1 compartment to be done in the MPP for the following parameters : temperature, humidity, light and air velocity.

3.Reference and applicable documents

3.1.Applicable documents

AD1	19071/05/NL/CP	Frame Contract between ESA and UAB AD2
AD2	MPP-OFR-08-0001(3)	Proposal for Call Off Order 6 – HPC1 installation and start-up in the MPP
AD3	MPP-QA-07-0001	MPP Quality Manual
AD4	MPP-QA-07-0003	MPP rules for good lab practices

3.2.Reference documents

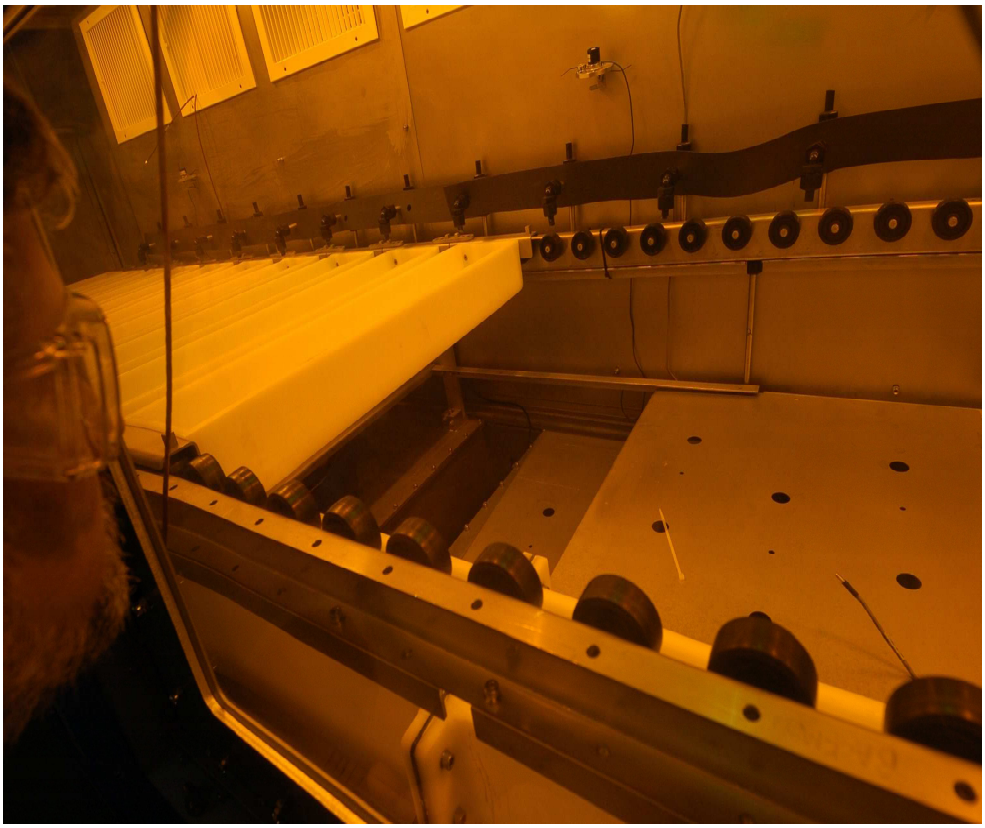
RD1	TN85.71	HPC1 User Manual
RD2	TN95.1	HPC1 control requirements and software description

4.Acronyms/Definitions

HPC1	Higher Plant Compartment 1
MPP	MELiSSA Pilot Plant
UAB	Universitat Autònoma de Barcelona
MELiSSA	Micro Ecological Life Support System Alternative
CFD	Computational fluid dynamics
PLC	Programmable logical computer
RH	Relative humidity
HPS	High Pressure Sodium
MH	Metal Halide
HVAC	Heating Ventilation Air Conditioning
SES	Sensor for Electromagnetic Spectrum

5.General Description of the HPC1 hardware

The HPC1 is a culture chamber composed of three subunits, where hydroponics culture can be achieved inside 20 trays that can be moved along the chamber axis. 9 lamps located at the top of the cultivation chamber enlights the plants through a glass top roof. In the cultivation volume, the air is conditioned for temperature and humidity control and re-circulated inside the chamber. It moves through a plenum positioned on one of the side walls of the chamber and through 9 air grilles positioned on the upper side of the growing volume.



As shown in the picture above, an opening placed at the bottom of the chamber directs the air back into the HVAC system.
See RD1 for more details.

6.Measurement specifications

6.1.Light Intensity

6.1.1.Types of measurements

Two different types of light measurements will take place:

1. At tray level ;
2. Below the upper glass under the two different light lamps (in the chamber)

6.1.2.Measurement at the tray level

The light intensity should be measured in proximity of the trays with a sensor able to detect the electromagnetic spectrum (SES). The required measurement points are shown in the following figures. As the measurements do not need to be performed all at the same time, the SES sensor could be moved from one measurement point to another in order to cover all the specified positions.

A = 20 cm
Distance between
- Probe
- Wall

B = 20 cm
Distance between
- Probe
- Top of the tray

SES = Sensor able to detect the Electromagnetic Spectrum

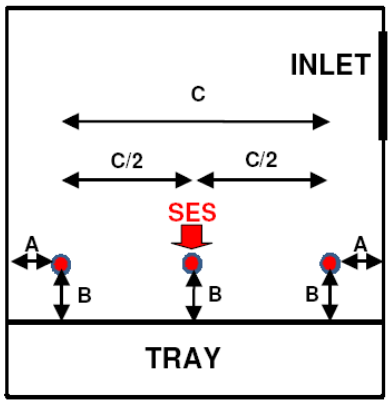


Figure 1 Measurement points in the cross section

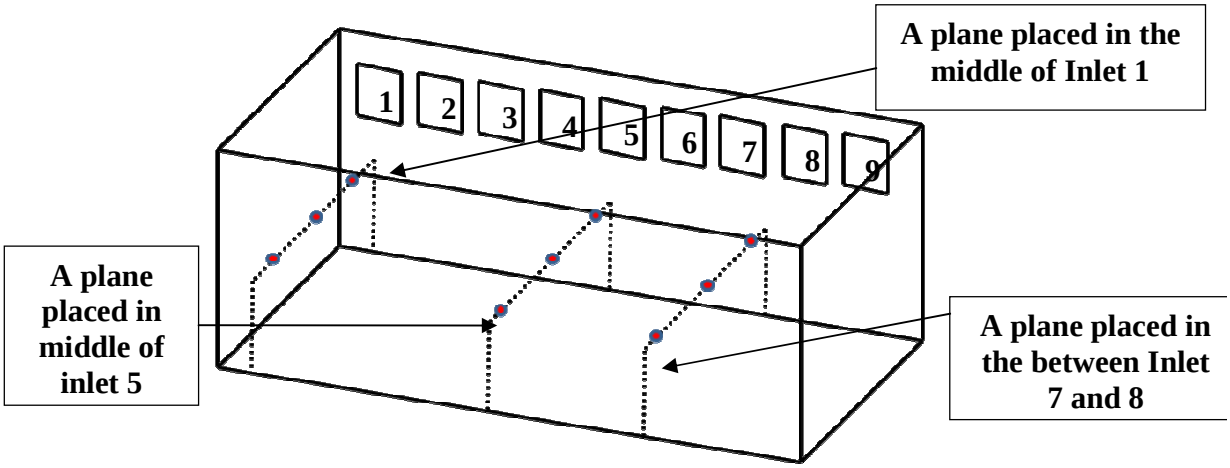


Figure 2 Measurement points along the axis

The SES sensor type (TRISTAN 5) proposed by NTE in agreement with UAB is regarded as adequate for the spectral characterization.

6.1.3.Measurement below the upper glass

The W/m^2 distribution should be also monitored right below the tempered glass (approximately 5cm distance) which divides the chamber from the lighting system for the two different lamps. The objective is to evaluate the spatial distribution of the light intensity and to characterize the spectrum of the lamps. Therefore the light measurement points should be placed as shown in Figure 3.

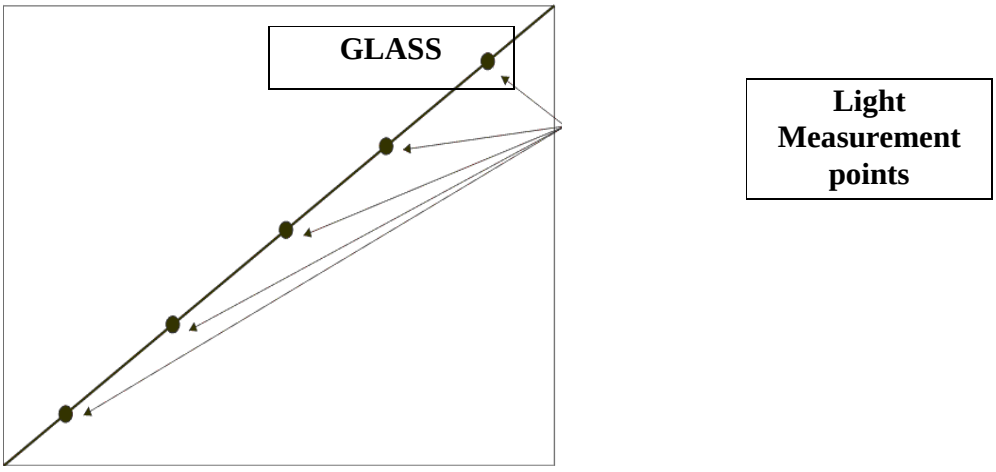


Figure 3 Light measurement points

Again, the SES sensor could be moved from one measurement point to another in order to cover all the specified positions.
As the plant growth chamber is equipped with two different types of lamp (600W HPS and 400W MH), the measurements should be done at 100% power for each type (could be any one but must be the same for the 5 measurement). During the measurements the electrical power of the lamp under consideration should be monitored with at least an amperometric clamp (one shot value for each point).
The accuracy of the probe should be at least 10% of the measurement.

In order to stabilize the glass temperatures and the lighting system ventilation, the measurements should be taken after approximately 15 minutes to allow for the thermal inertia of the system to stabilize. In order to allow repositioning of the sensor, the chamber will be opened, the sensor moved and the chamber closed again: during this operational time lights should not be switched off and 15 minutes must be awaited to stabilize again the chamber internal conditions.

The assumptions made for the light measurement specifications are:

1) The sequence of the lamps from 1 to 9 is:
   600W, 400W, 600W, 600 W, 400W, 600W, 600 W, 400W, 600W
   (3 MH and 6 HPS lamps)

2) The plant evapotranspiration process does not affect light intensity. Indeed this process does not yield excessive water volume fractions and air opacity changes are negligible. Hence the light measurement could be taken once, with the objective to characterize the light intensity.

6.1.4.Light Measurement conclusions

In conclusion, tables 1 and 2 summarize the light intensity experimental mapping points needed inside the chamber for a single scenario. A total amount of 19 measurements is required.
During the measurements, the temperature and RH inside the chamber should be acquired on the 3 internal chamber probes. The T and RH conditions will not affect the measurement, provided that they are in agreement with the testing condition “B” in paragraph 3.7.
The sensor should be able to measure light in the Visible spectrum (250-750 nm), any kind of support can be chosen provided that it does not affect the measurement itself (no reflective surfaces).

	number
Probes	5
Lamps	2
TOT	10

Table 1 Measurements below the tempered glass

	number
Probes per cross section	3
Cross sections	3
TOT	9

Table 2 Measurements in proximity of the trays

6.2.Temperature, Relative Humidity and Air Flow

The cross section of the chamber with the trays in place measures about 75*90 cm^2 (b*h). On this section the measurement points should be placed as shown in

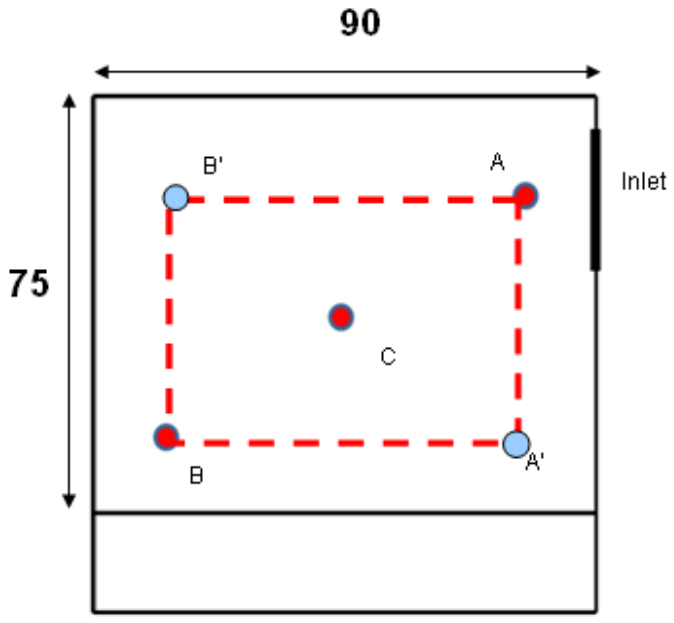


Figure 4:

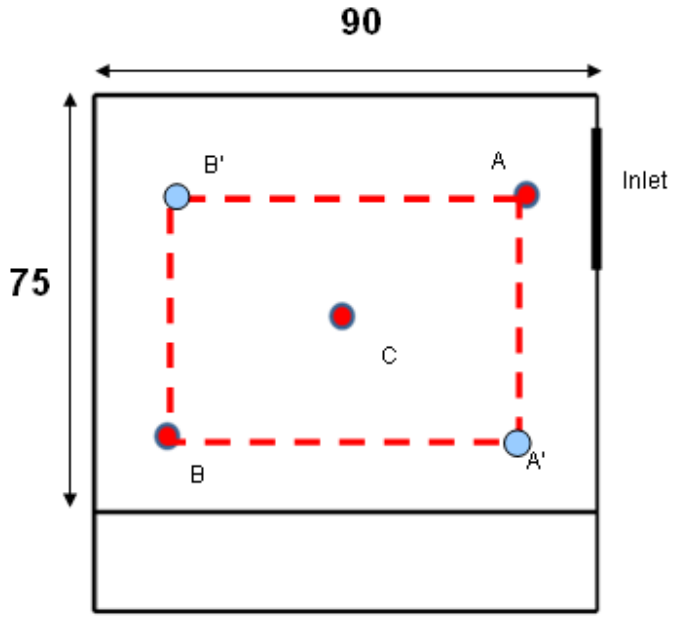


Figure 4 Cross section

- Point A centered on the air inlet at 7-8 cm from it.
- Point B positioned 7-8 cm from the wall, 7-8 cm from the top of the tray
- Point C placed in the middle of the diagonal between point A and B
- Points A' and B' are specular and measurements could be taken during the way back of the movement of the trays, changing the connecting poles.

The temperature and Relative Humidity probes are requested to have the following accuracies:

- 0,1deg C for T
- 3% for RH

As the air velocity field changes a lot with the height, the measurement ranges differ on the basis of the measurement point:

1. Point A: range 0.5 – 10 [m/s]
2. Point B and C (B' A'): range 0.1 – 2 [m/s]

The accuracy of the air velocity probes should be 0.08 [m/s] measured at 0.5 [m/s]
The probes could be different in order to accommodate the different velocity ranges.
Regarding velocity, only magnitude (hot wire anemometer) probes are requested, there is no need to investigate direction, since it can be derived from CFD simulation.
On the longitudinal direction the measurements should be scanned as shown in Figure 5

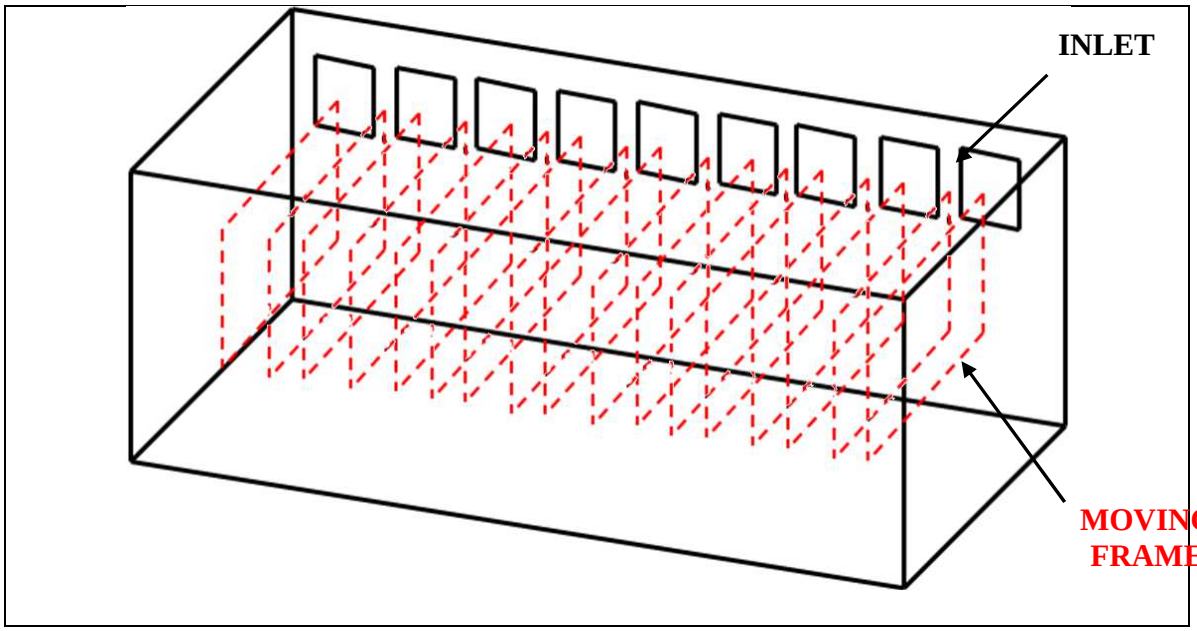


Figure 5 Measurements on the longitudinal direction

Therefore the sensors positioned on a moving frame are meant to scan the whole 5 meters length. The structure of the moving frame was proposed by NTE (see the attached pdf) and it is designed to not disturb the air flow inside the chamber.
A total amount of 17 cross sections are investigated. The position of the sections should be monitored and cross-checked with the centre of each air grill.
The frame should be moved from one end of the chamber to the other and back. On the way back, the positions of probes B and A should be swapped (upside B and downside A) to monitor in the backward movement the two other positions B' and A'.
Therefore there will be 5 different positions monitored with 3 sensors during a round trip, position C being measured twice.

In conclusion,

	Number
Probes per cross section	3
Physical variables per probe (T, RH, V)	3
Cross sections	9
TOT	81

Table 3 summarizes the experimental mapping of Temperature, Relative Humidity and Air Flow Velocity inside the chamber, for each scenario.

	Number
Probes per cross section	3
Physical variables per probe (T, RH, V)	3
Cross sections	9
TOT	81

Table 3 Measurement summary

6.3.Pressure

Five pressure probes are required. Two probes should be placed in the plenum of the chamber (see Figure 6), one probe in proximity of the HVAC return entrance below the air balancing panels and above the chamber floor (see figure 7), one probe in between the cooler and heater (see Figure 8) and the last probe in the lower right of the HVAC system (see Figure 9).
The objective of P1 and P2 is to check the balanced pressurization of the air plenum distribution system.
P3 is intended to evaluate the pressure drop before the HVAC system thermally processes the air.
P4 will validate with P3 the pressure drop of the cooler.
P5 will validate with P4 the pressure drop of the heater and with P1 and P2 the pressure rise of the blower.

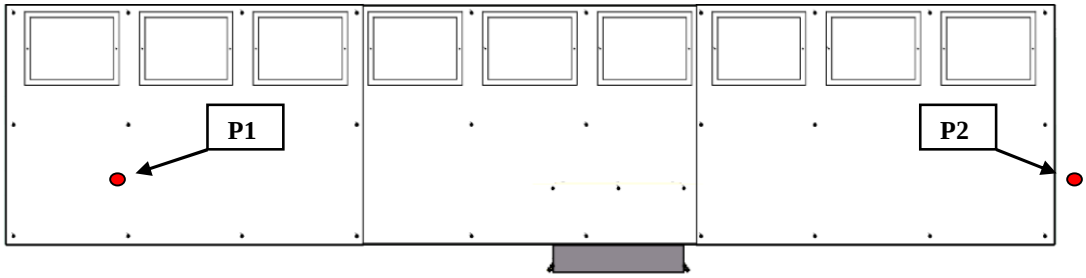


Figure 6 Pressure probes in the plenum of the chamber

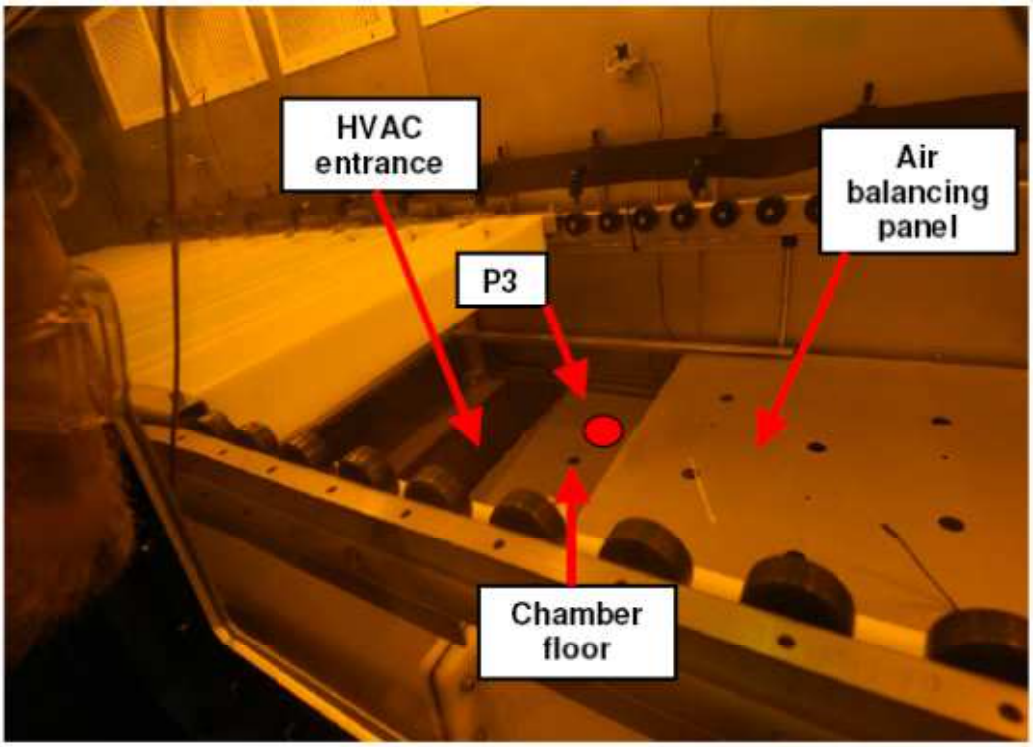


Figure 7 Pressure probe in proximity of the HVAC entrance

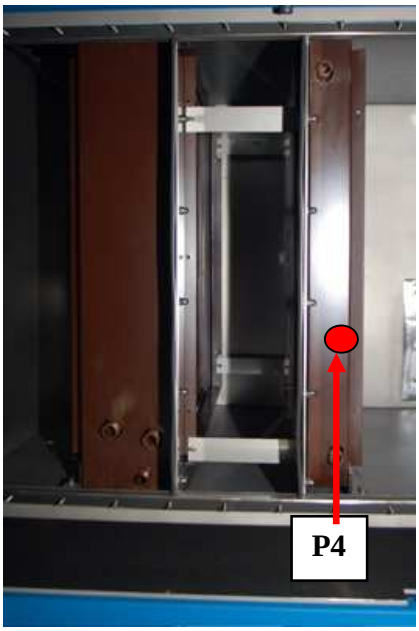


Figure 8 Pressure probe between the heater and the cooler

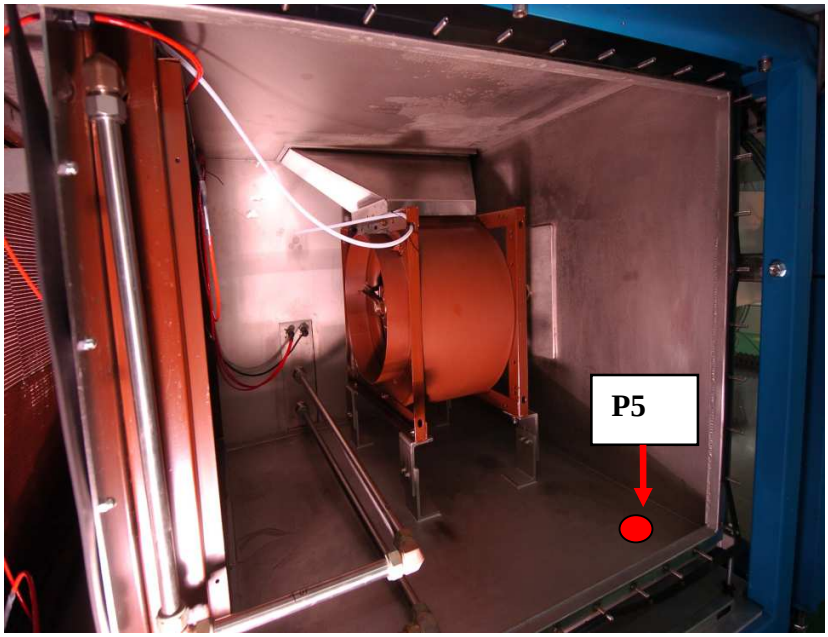


Figure 9 Pressure probe in the HVAC

6.4.Data acquisition conditions

During the mapping tests, the PLC (control system) should perform the mapping measurements of T, RH and Air-flow on all available points at the same time.

6.5.CO_2 system

In the absence of plants inside the chamber the CO2 mapping is not relevant. Since the first modelling step does not deal with plants, the CO2 mapping is currently not in the scope of these requirements.
The CO2 mapping will be a relevant issue during the second step of the chamber characterization when canopies will evapotranspirate.
However, the CO2 distribution inside the plant growth chamber, as the distribution of all the other environmental factors, is directly related to the velocity flow field ; furthermore, there will be a lot of diffusion transport.
Hence we assume a rather uniform distribution of CO2 and the probe present for the control logic system sufficient, and CO2 mapping not strictly necessary.

6.6.Measurement stabilization

Each measurement position has to be evaluated 30 seconds after the probe placement in order to assure the stabilization of the physical variable under evaluation.

6.7.Operating conditions

Two relevant test conditions were identified and for each of them the measurements required are shown in the following table:

Condition	Presence of plant	T [°C]	RH% (as dictated by PLC)	Light %	Measurements
A	no	22	See below	0	P, V, T, RH
B	no	26	See below	100	P, V, T, RH, Light Intensity

Table 4 Test conditions

RH is governed by the control system of the chamber and could not be set a-priori. The test conditions are representative of what the PLC system can maintain inside the chamber. Therefore the RH would be reasonable between the range 60-70 % for dry conditions and expected in this range (no real feedback from functionality test available until now).
For reference temperature, the mean of two fixed sensors inside the chamber will be taken. The proposed temperatures (22 and 26 deg C) are those that the control system can reasonably maintain in the chamber. It should be noted that these are not absolute temperatures, but a reasonable value for the mapping and could be slightly shifted for real operating conditions. Once the reference temperature has been fixed for a single set of measurements (A or B) it should be maintained constant by the control system. If the chamber were opened during the measurements, it should be waited, before taking another measurement, for the system stabilization in the same conditions (the time estimated is about 15 min).

Pressure and velocity fields are not modified by the presence of the plants thus the mapping of these physical variables in the dry conditions is representative for all the conditions.

During measurements all PLC reference values on the HPC1 existing sensors should be available to be sure of the operating conditions inside the chamber.

7.Outputs

For each test condition and for each measurement point the following data should be stored:

1. Position (X,Y,Z) of the frame
2. Absolute time (if available)

Depending on the probe type:

3. Temperature
4. Relative Humidity
5. Air Flow velocity
6. Light intensity

At the same time the data acquired by the HPC1 nominal sensors (pressure, temperature etc..) in the control system should be stored for correlation.

8.Measurement guide-lines

Following are the guide lines recommended for the mapping:

- The chamber should be closed (air lock and curtains)
- The plants should not be placed inside the chamber
- The sensors should be placed in the specified positions
- Lights should be off for condition A
- Light should be on for condition B, all the lights should be at 100% power, a spot monitoring of the lamps current should be taken at the beginning and at the end of the measure condition for each lamp with an amperometric clamp
- The lamp sequence should not be changed during the measurement activity
- The blower should work in stable condition (no rpm or flow rate changes)
- The trays should be place inside the chamber
- The trays should be equally spaced (mid position of the tray spacer)
- The trays spacing should not be modified during the measurement activity
- If the chamber were to be opened for operating on probes, the following measurement should be taken in the same operating conditions as before (based on the chamber sensors T and RH) (10 to 15 min)
- It curtains only were to be opened, as before, the stabilization time should be a few minutes

9.Conclusions

The table below summarizes the equipment required for the proposed new measurements.

Sensor	Number	Position	Remarks and Reminders
Pressure	5	Fixed	Used to check the static pressure drops of the air flow across the locations pointed out in paragraph 6.3
Velocity	3	Moving on rail/frame	Only magnitude probes are requested in the range 0.1-5 m/s or larger with required accuracy
Temperature	3	Moving on rail/frame	Required range 0-40 deg C
Relative Humidity	3	Moving on rail/frame	
Light Intensity	1	Moving	The light intensity distribution is evaluated by moving the SES sensor in the specified position below the tempered glass and above the trays.

Table 5 Equipment summary

The proposed new measurements are necessary and sufficient for the characterization of the plant growth chamber.

The moving frame for T RH and V measurement could be equipped with at least 3 probes and swapped at the extremity to monitor a total of 5 points for each section.

To limit the number of probes and cut costs, just one light intensity probe could be used. As mentioned in paragraph 6.1.1, the light measurement are not supposed to be performed all at the same time thus the light intensity probe could be moved from one measurement point to another in order to cover all the specified positions (10 points below the glass and 9 points above the trays).

10.Appendix 1 – Modelling activities by EnginSoft

Excerpt of MELISSA TN 3.22 showing the 3D CFD model constructed by Enginsoft for the MPP Higher Plants Compartment :

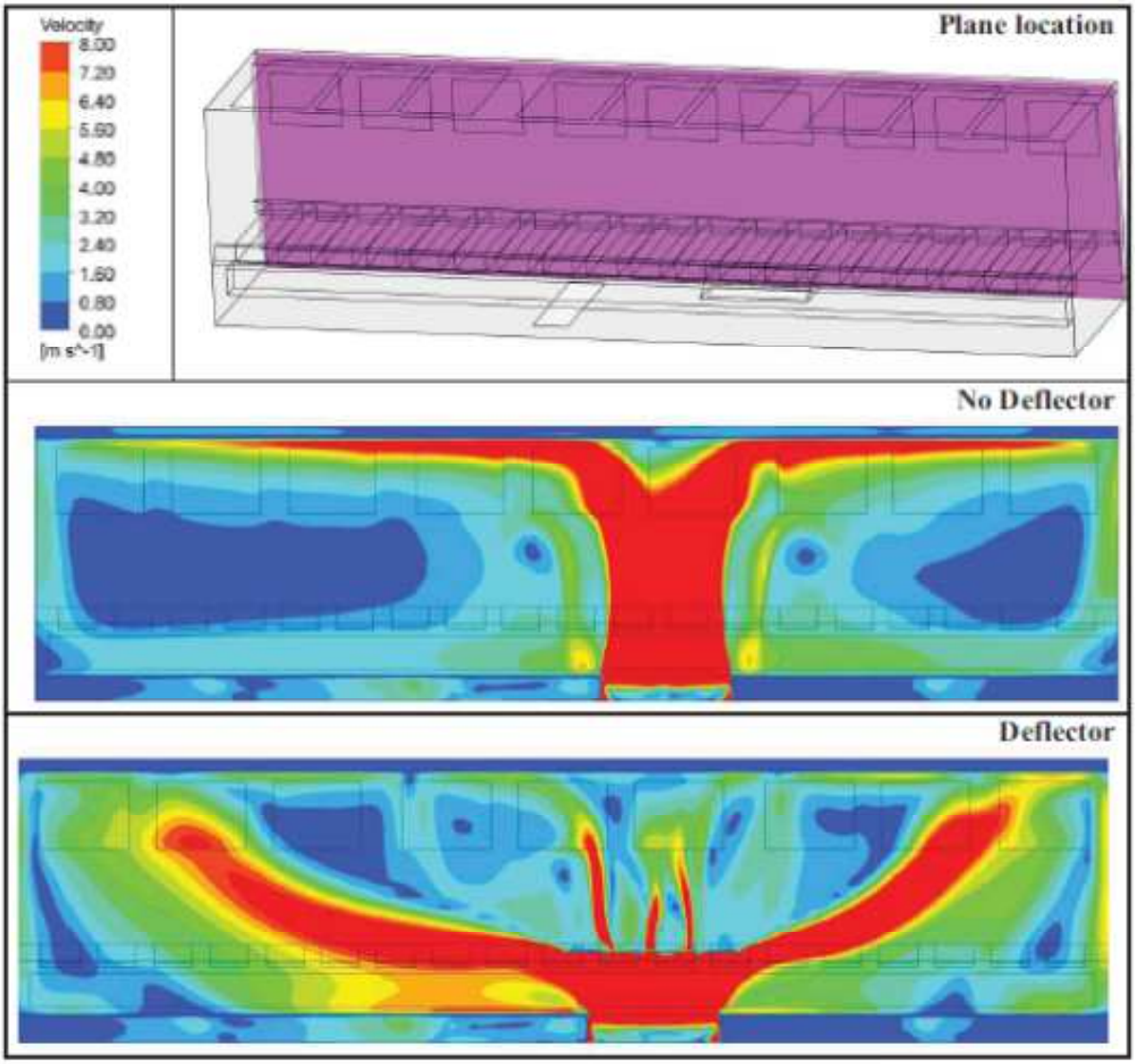


Figure 22 Chamber: velocity contours in the plenum region