MELiSSA

TECHNICAL NOTE

UNIVERSITY of GUELPH

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Prototype Control System Document

MELiSSA

TECHNICAL NOTE

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Appendix 1 to TN 85.7 – P&ID for HPC1	PDF	In Review – No ESA Reference Assigned
Appendix 2 to TN 85.7 – I/O Table	EXCEL Table	In Review – No ESA Reference Assigned
Appendix 3 to TN 85.7 – Intermediate I/O Panel Map	EXCEL Table	In Review – No ESA Reference Assigned

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1. Introduction

This document outlines the major control loops required for operation of the HPC prototype with emphasis on autonomous operation. It describes the logic for control using either the Argus or Schneider PLC systems. Suggested control logic as supplied to Argus is also provided.

2. Functional Overview of the HPC1 Sub-Systems

2.1. Air-Lock Sub-system

Access to the chamber growing area is gained through i) air-locks positioned at both chamber ends and ii) an access panel (exposed) on the middle chamber module. The air locks are designed to reduce atmospheric leakage or cross contamination between the chamber interior and exterior during seeding and harvesting procedures. On the interior side of the air-lock is Hypalon fabric door. The door is manually opened using magentics. A diagram of the air-locks is provided below.

During periodic cleaning of the HPC of to access the chamber interior in an emergency, the side panel may be opened. The access panel may be opened manually and is fitted with gaskets and bolts/acorn nuts to ensure a seal against the exterior chamber wall when not in use. If chamber side panel is opened, the chamber will not remain sealed.

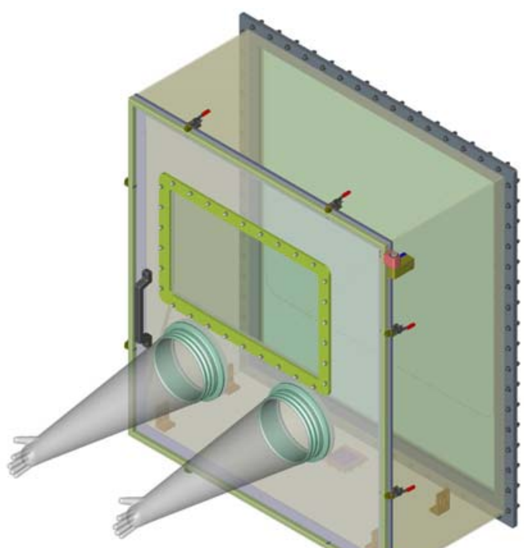


Figure 2-1. Exterior view of the prototype air lock. Shown are the gloves, window and latches.

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

Air is conditioned for temperature and humidity and re-circulated inside the chamber. Externally supplied chilled water and hot water are to be circulated through sealed and "heresite" coated (baked oxidation barrier) heat (cold and hot) exchange coils mounted in an internal plenum at the base of the chamber. Condensate from the chilled water coil is to collected on the condensate drip tray integrated into the chill water coil and is collected and measured in a condensate collection reservoir (4 L reservoir volume). The condensate water may then be pumped back into the hydroponics reservoir and/or (with the addition of a three way proportional valve) to the crew compartment of the MELiSSA loop depending on demand.

A heresite coated main centrifugal blower is mounted in the plenum and distributes the air through a duct running the length and height of the back chamber wall and into the chamber growing interior from outlets mounted an the upper interior wall. Modulated hot water and chilled water proportional valves effect temperature and dehumidification control of the aerial environment. The motor and variable frequency drive controller for the blower is positioned on the outside of the chamber and connected to the blower shaft using a rotary feed through shaft.

The chamber is fitted with three 200 litre double sealed Teflon positioned on the side of the chamber. The Teflon bags serve as a passive approach to atmospheric pressure management in the chamber since they will expand or contract with variable atmospheric volume within the chamber growing interior as associated with programmed diurnal temperature fluctuations. The bags are connected to the chamber growing volume custom designed fittings. The total temperature range influencing gas volume in the chamber represented by a single bag capacity of 200 L (nominally filled at 100L) is about ±6 degrees.

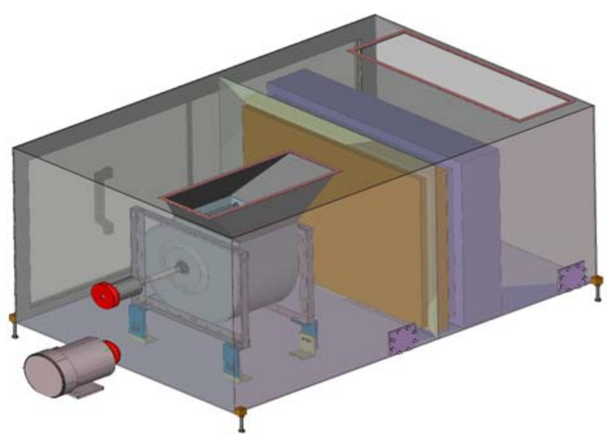


Figure 2-2. View of the air handling unit. Shown are the blower, hot and chilled water coils, the rotary fee-through shaft and the exterior mounted motor. The air intake is adjacent to the coils and the outlet is above the blower.

2.3. Gas Analysis Sub-System

The gas analysis sub-system primarily consists of an infra-red gas analyzer for CO_2 and a paramagnetic analyzer for O_2. Plumbing and fittings for gas sampling and return to the chamber interior also form part of this system.

The computer controller will maintain internal chamber CO_2 concentrations during the day-light hours so that any net carbon gain by the stand through photosynthetic activity is compensated for by injections from an external CO_2 tank. The tank may be commercially available bottled CO_2 or a reservoir of CO_2 collected from other MELiSSA compartments.

2.4. Hydroponics System Operation

The nutrient requirements for the plants are supplied in a hydroponics medium stored in a polypropylene nutrient solution reservoir mounted on the underside the chamber. The solution is pumped into the chamber to the head of sloped polypropylene growing trays (trays) using a water cascade system. The chamber has a total length of 5 m and can therefore accommodate up to 22 trays. The trays are designed to accommodate a variety of root media as a substrate for the hydroponics solution including Rockwool©, expanded clay (Lecca©) and newly developed biodegradable and inert media. The solution drains from each tray into a common collection trough via gravity. The collection trough (5m in length) then returns the solution back to the nutrient reservoir. The condition of the solution with respect to pH and electrical conductivity is monitored and adjusted continuously through measured injections of acid, base and/or various nutrient mixes.

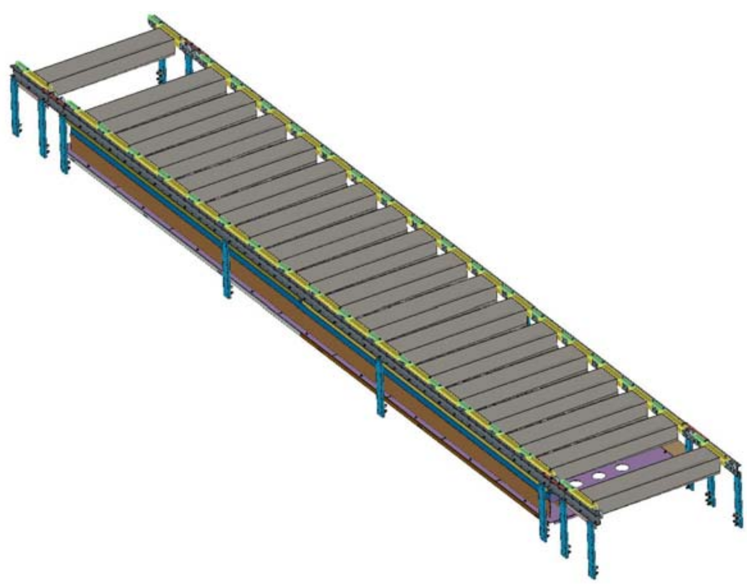


Figure 2-3. View of the plant growing tray conveyers.

2.5. Lighting System Operation

The plant growth chamber is equipped with 9 x 600W HPS and 3 x 400W MH lamps externally mounted overhead to provide illumination through a 10 mm tempered glass roof. Initially static ballasts will be used. This means that light intensity can not be attenuated through power supply regulation to the ballasts. Therefore, light intensity control will be discrete with binary (on/off) operation of the lamps to achieve desired illumination levels. The lighting system includes a lamp loft with fans for temperature control.

3. Detailed Prototype Control System Requirements

3.1. Control Loop Definition Overview

Control Loop Identifier	Control Loop Name	Description
4100	Exterior Airlock Door A Alarm	Controller activates an alarm and purge-over ride condition when door sensors indicate door open. LEDs on the same sensor circuit indicate door open/closed status.
4101	Exterior Airlock Door C Alarm	Controller activates an alarm and purge-over ride condition when door sensors indicate door open. LEDs on the same sensor circuit indicate door open/closed status.
4102	Airlock A Purge	Controller acts upon user initiated purge sequence by opening gas outlet and inlet solenoids for an empirically determined mixing period. The purge operation is not allowed or is shut-down (closure of inlet vent) if door open alarm in loop 4100 exists, an over-pressure alarm is indicated or a vent solenoid fails.
4103	Airlock C Purge	Controller acts upon user initiated purge sequence by opening gas outlet and inlet solenoids for an empirically determined mixing period. The purge operation is not allowed or is shut-down (closure of inlet vent) if door open alarm in loop 4100 exists, an over-pressure alarm is indicated or a vent solenoid fails.
4104	Light Intensity Control	Independent activation of the three lamp strings in accordance with the user defined photoperiod. Alarms are indicated if PAR sensors do not respond to ignition or if air loft temperature (loop 4105) is high.
4105	Lamp Loft Control	Controller activates all lamp loft fans with the ignition of any lamp string or whenever lamp loft temperature is in excess. Alarms are indicated if loft temperature is high.
4106	Irrigation System	Controller activates the main irrigation pump according to the user defined irrigation period. If operation of the pump is indicated and flow sensor indicates low flow, an alarm is indicated.
4107	pH Control	The controller aims to keep pH levels in the hydroponics reservoir at demand with automated injections of either acid or base stocks. The injection run-time is determined from empirically determined equilibration times. Alarms are indicated if pH is out of bounds of if acid/base stock vessels are at low levels.
4108	EC Control	The controller aims to keep EC levels in the hydroponics reservoir at demand with automated injections of either A and B stocks. The injection run-time is determined from empirically determined equilibration times. Alarms are indicated if EC is out of bounds of if stock vessels are at low levels.

4109	Reservoir Temperature	Pulse width modulated control of an inlet solenoid feeding chilled water in a closed loop line to the reservoir from the facility
4110	Condensate Control	Controller activates the return pumping of collected condensate from the condensate vessel to the reservoir if volume levels are within limits.
4111	Air Circulation	The controller activates the VFD and confirms air flow. VFD set-point is determined from calibration profiles of air flow volume/speed at various VFD frequencies
4112	Humidity and Temperature Control	The controller modulates three-way proportional valves feeding chilled and hot water supplies from the facility to the heat exchange coils.
4113	CO2/O2Control	The controller maintains CO_2 concentrations at demand levels in the growing volume during the user specified photoperiod. Alarms are indicated for out of bound CO2 or high O2 levels.
4114	Passive Pressure	The controller activates an alarm, if passive pressure management fails.

3.2. P&ID for HPC1

The P&ID document for HPC1 is provided in a companion file: Appendix 1 to TN 85.7 – P&ID for HPC1

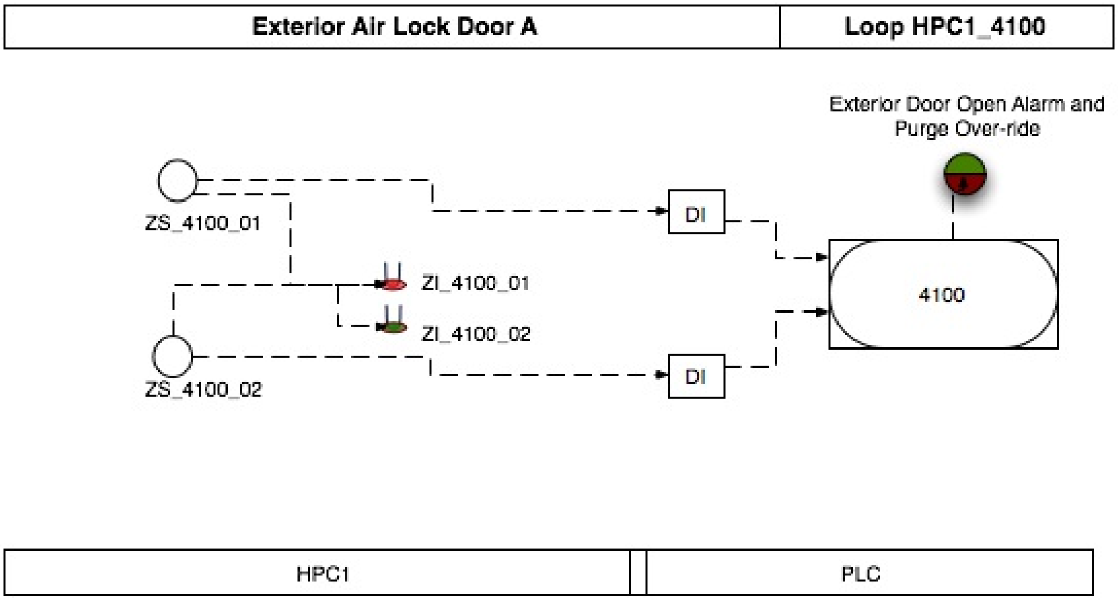
3.3. I/O Table for HPC1

The I/O Table HPC1 is provided in a companion file: Appendix 2 to TN 85.7 – I/O Table for HPC1

3.4. Detailed Control Requirements

3.4.1. *Exterior Air Lock Door Alarm – Loops 4100 and 4101*

The interior air lock doors are operated manually with the use of a magnetic closure. The external doors are also operated manually but are fitted with an upper and lower contact sensor to ensure closure. No formal control loop of the exterior or interior air lock doors is required other than an alarm indicating when the exterior door does not have proper seal (as indicated by contact sensors positioned on the door) against the outer gasket and a corresponding air lock purge over-ride condition.



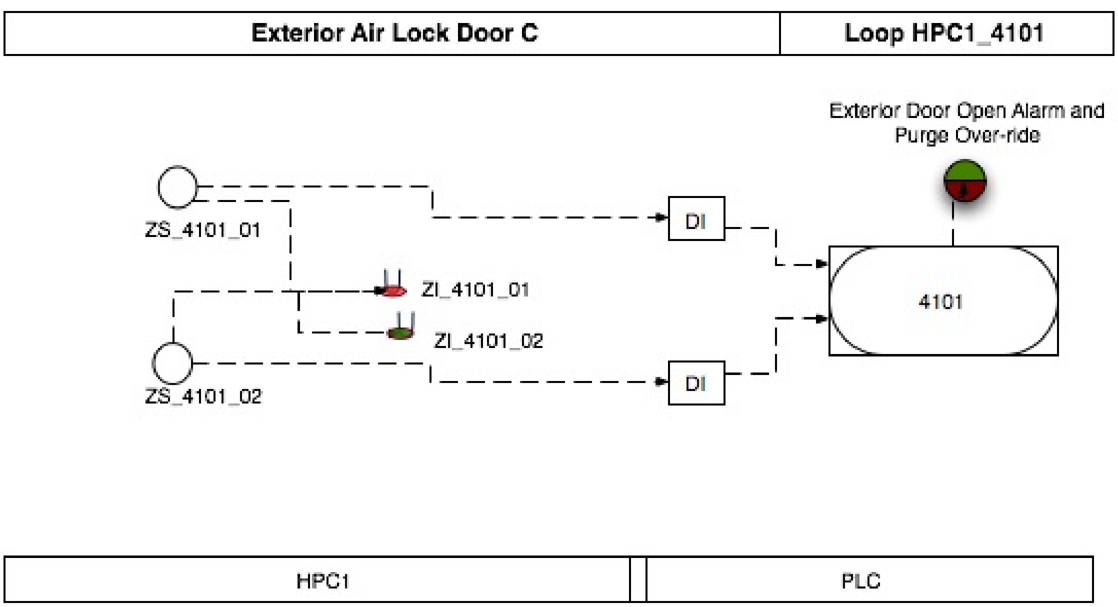


Figure 3-1. Control loop schematic for air lock exterior door alarm.

Equipment

Reference ID	Description
ZS_4100_01	Upper Exterior Air Lock Door Switch - Side A
ZS_4100_02	Lower Exterior Air Lock Door Switch - Side A
ZI_4100_01	LED Indicator when door is Open - Side A
ZI_4100_02	LED Indicator when door is fully Closed - Side A
ZS_4101_01	Upper Exterior Air Lock Door Switch - Side C
ZS_4101_02	Lower Exterior Air Lock Door Switch - Side C
ZI_4101_01	LED Indicator when door is Open - Side C
ZI_4101_02	LED Indicator when door is fully Closed - Side C

User Inputs:

Instrument	Description
N/A	N/A

Alarm Conditions:

Name	Description
4100_DOOR_OPEN_ALARM 4101_DOOR_OPEN_ALARM	Activated when ZS_4100_01, ZS_4100_02, ZS_4101_01 or ZS_4101_02 indicate opening (HIGH)
4100/4101_PURGE_OVERRIDE_ALARM	Occurs when Door Open Alarm is TRUE

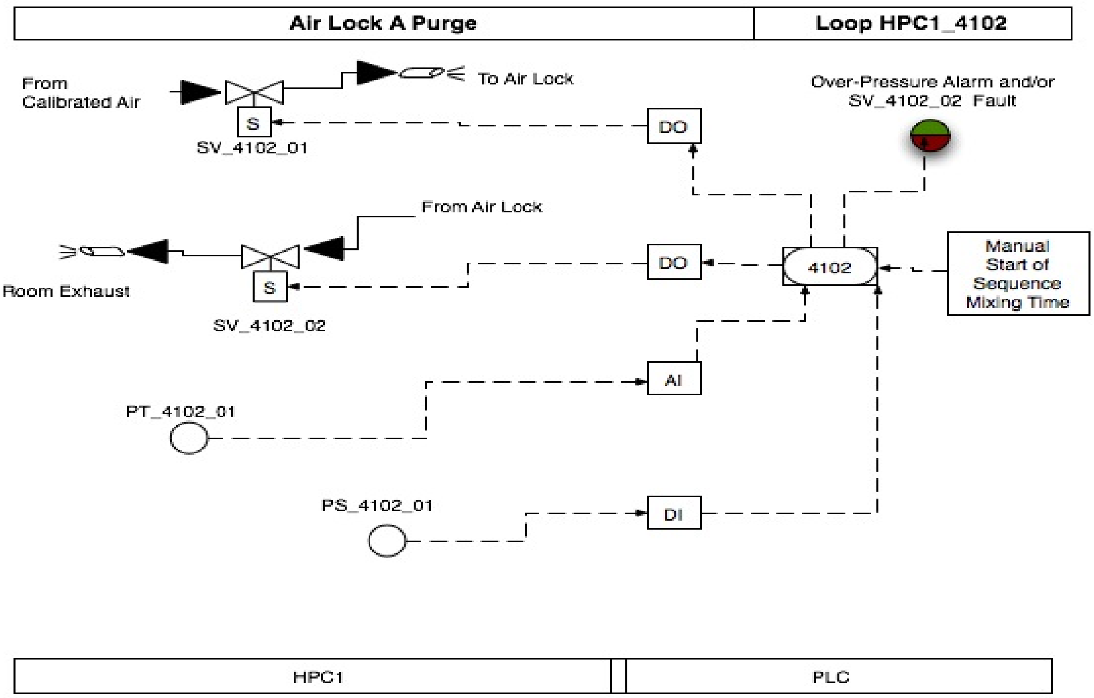
Control Logic:

For Airlock Door A:
Line 1: IF ZS_4100_01 is HIGH (OPEN) THEN DOOR_ OPEN_ALARM=TRUE AND PURGE OVER_RIDE
Line 2: IF ZS_4100_02 is HIGH (OPEN) THEN DOOR_OPEN_ALARM AND PURGE OVER_RIDE
Line 3: IF LINE 1 OR LINE 2 IS TRUE THEN ALARM AND PURGE OVER_RIDE

For Airlock Door C:
Line 1: IF ZS_4101_01 is HIGH (OPEN) THEN DOOR_OPEN_ALARM AND PURGE OVER_RIDE
Line 2: IF ZS_4101_02 is HIGH (OPEN) THEN DOOR_OPEN_ALARM AND PURGE OVER_RIDE
Line 3: IF LINE 1 OR LINE 2 IS TRUE THEN ALARM AND PURGE OVER_RIDE

IF PURGE OVER_RIDE =TRUE THEN

3.4.2. *Air Lock Purge Control – Loops 4102 and 4103*



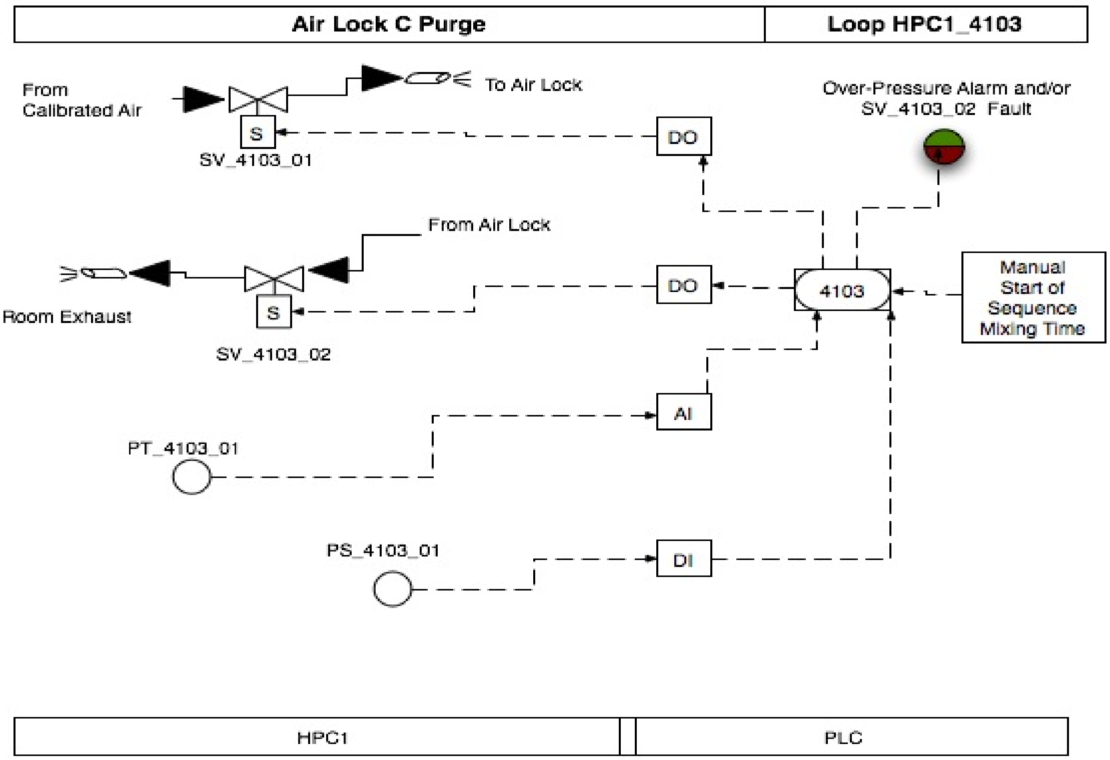


Figure 3-2. Control loop schematic for gas purge of the air locks after planting or harvesting.

Equipment

Reference ID	Description
SV_4102_01	Solenoid Valve for injection of pressurized air into airlock A
SV_4102_02	Airlock A ventilation Solenoid Valve
PT_4102_01	Pressure sensor for airlock A
PS_4102_01	Airlock A pressure switch
SV_4103_01	Solenoid Valve for injection of pressurized air into airlock C
SV_4103_02	Airlock C ventilation Solenoid Valve
PT_4103_01	Pressure sensor for airlock C
PS_4103_01	Airlock C pressure switch

User Inputs:

Name	Description
4102/4103_MANUAL_START	User initiated purge sequence at the controller
4102/4103_MIXING_TIME	The time (in minutes) to fully purge the air locks , as determined during the functional test, and correspondingly, the run time for the

	purge procedure

Alarm Conditions:

Name	Description
4100_DOOR_OPEN_ALARM 4101_DOOR_OPEN_ALARM	The manual start operation of the purge operation is in over-ride condition if the door open alarm is indicated
4102_PURGE_OVERRIDE_ALARM 4103_PURGE_OVERRIDE_ALARM	Occurs when Door Open Alarm is TRUE
4102_VENT_FAULT_ALARM 4103_VENT_FAULT_ALARM	Occurs when the purge solenoids do not open as indicated no flow signal from the pressure switches

Control Logic:

For 4102 Loop:

```
IF 4102_Manual_Start=TRUE THEN FOR Mixing_Time:
        IF 4100_DOOR_OPEN_ALARM=FALSE THEN
                SV_4102_02 =HIGH (opened)
                SV_4102_01=HIGH (opened)
                IF PS_4102_01=FALSE (indicates no flow) AND PT_4102_01>=TOLERANCE
                THEN SV_4102_01=LOW (off)
                ELSE 4102_VENT_FAULT_ALARM=TRUE
        ELSE 4102_PURGE_OVERRIDE_ALARM=TRUE
ELSE NOTHING
```

For 4103 Loop

```
IF 4103_Manual_Start=TRUE THEN FOR Mixing_Time:
        IF 4100_DOOR_OPEN_ALARM=FALSE THEN
                SV_4103_02 =HIGH (opened)
                SV_4103_01=HIGH (opened)
                IF PS_4103_01=FALSE (indicates no flow) AND PT_4103_01>=TOLERANCE
                THEN SV_4103_01=LOW (off)
                ELSE 4103_VENT_FAULT_ALARM=TRUE
        ELSE 4103_PURGE_OVERRIDE_ALARM=TRUE
ELSE NOTHING
```

3.4.3. *Light Intensity Control – Loop 4104*

In the case of fixed ballasts which are not dimmable, control of the lighting system intensity is limited. A relay switches each of three lamp strings on or off, depending on the photoperiod set for the given string. Each lamp string consists of a single HPS lamp from each module (2 strings) or the 3 MH lamps from each module.

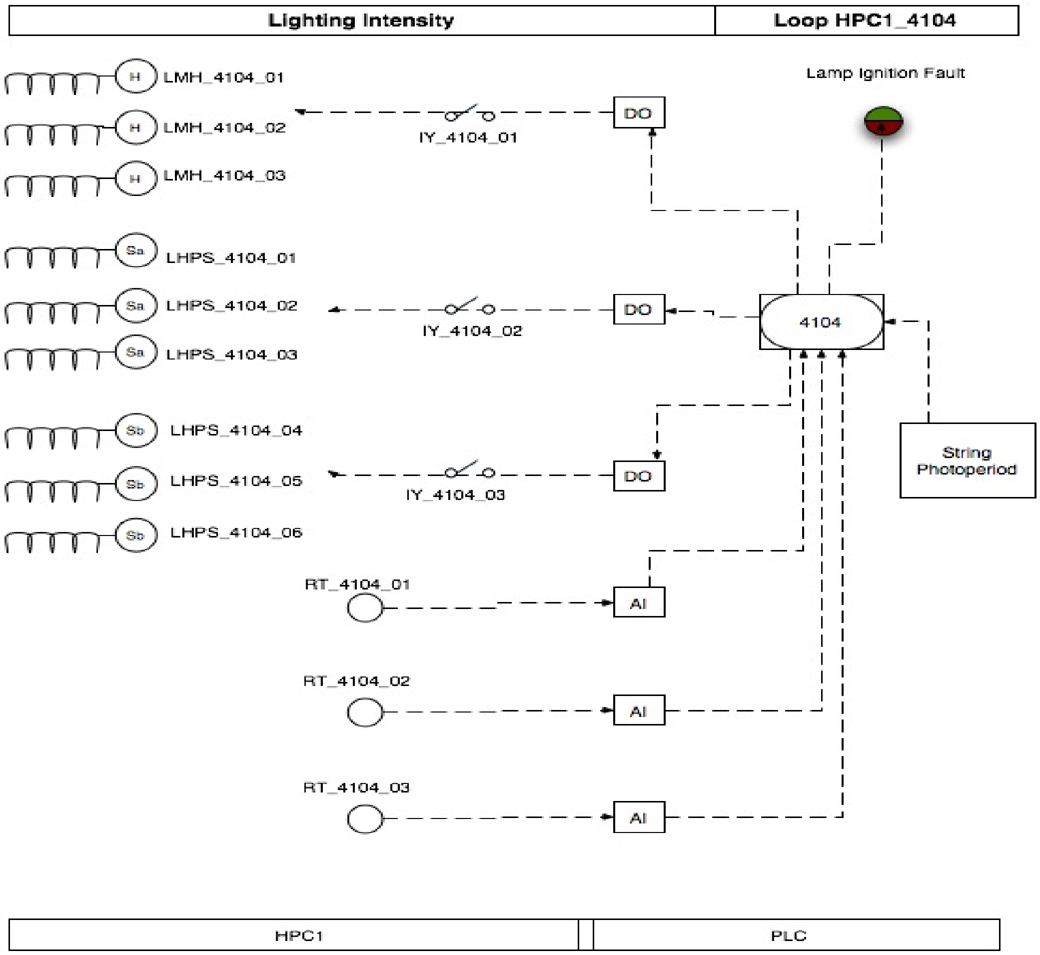


Figure 3-3. Light intensity control schematic

Equipment

Reference ID	Description
IY_4104_01	Turn On/Off lamps - A
IY_4104_02	Turn On/Off lamps - B
IY_4104_03	Turn On/Off lamps - C
RT_4104_01	PAR Sensor - A
RT_4104_02	PAR Sensor - B
RT_4104_03	PAR Sensor - C
LHPS_4104_01	HPS Lamp in String Aa
LHPS_4104_02	HPS Lamp in String Ab
LHPS_4104_03	HPS Lamp in String Ba
LHPS_4104_04	HPS Lamp in String Bb
LHPS_4104_05	HPS Lamp in String Ca
LHPS_4104_06	HPS Lamp in String Cb

LMH_4104_01	Metal Halide Lamp A
LMH_4104_02	Metal Halide Lamp B
LMH_4104_03	Metal Halide Lamp C

User Inputs:

Name	Description
4104_PHOTOPERIOD_STRING_A 4104_PHOTOPEIORD_STRING_B 4104_PHOTOPERIOD_STRNG_MH	The start and end hours for illumination of a given lamp string

Alarm Conditions:

Instrument	Description
4104_PAR_A_ALARM 4104_PAR_B_ALARM 4104_PAR_C_ALARM	Occurs when a PAR sensor is reading less than expected (200 µE), thereby indicating a lamp ignition fault or leaf covering the sensor.
4105_HIGH_TEMP_ALARM	Overrides Lamp ignition of loft temperature is high

Control Logic:

For Sting A:

IF TIME>=PHOTOPERIOD_STRING_A_START AND TIME<= PHOTOPERIOD_STRING_A_END THEN IY_4104_01=HIGH
IF IY_4104_01=HIGH AND (RT_4104_01 OR RT_4104_02 OR RT_4104_03)<=EXPECTED THEN 4100_PAR_A_ALARM=TRUE

For Sting B:

IF TIME>=PHOTOPERIOD_STRING_B_START AND TIME<= PHOTOPERIOD_STRING_B_END THEN IY_4104_02=HIGH
IF IY_4104_02=HIGH AND (RT_4104_01 OR RT_4104_02 OR RT_4104_03)<=EXPECTED THEN 4100_PAR_B_ALARM=TRUE

For Sting B:

IF TIME>=PHOTOPERIOD_STRING_MH_START AND TIME<= PHOTOPERIOD_STRING_MH_END THEN IY_4104_03=HIGH
IF IY_4104_03=HIGH AND (RT_4104_01 OR RT_4104_02 OR RT_4104_03)<=EXPECTED THEN 4100_PAR_MH_ALARM=TRUE

Override:

IF 4105_HIGH_TEMP_ALARM=TRUE THEN
IY_4104_01 AND IY_4104_02 AND IY_4104_03 = LOW (off) AND FAN_4105_01 AND FAN_4105_02 AND FAN_4105_03 = HIGH (On)

3.4.4. *Lighting Loft Temperature Control – Loop 4105*

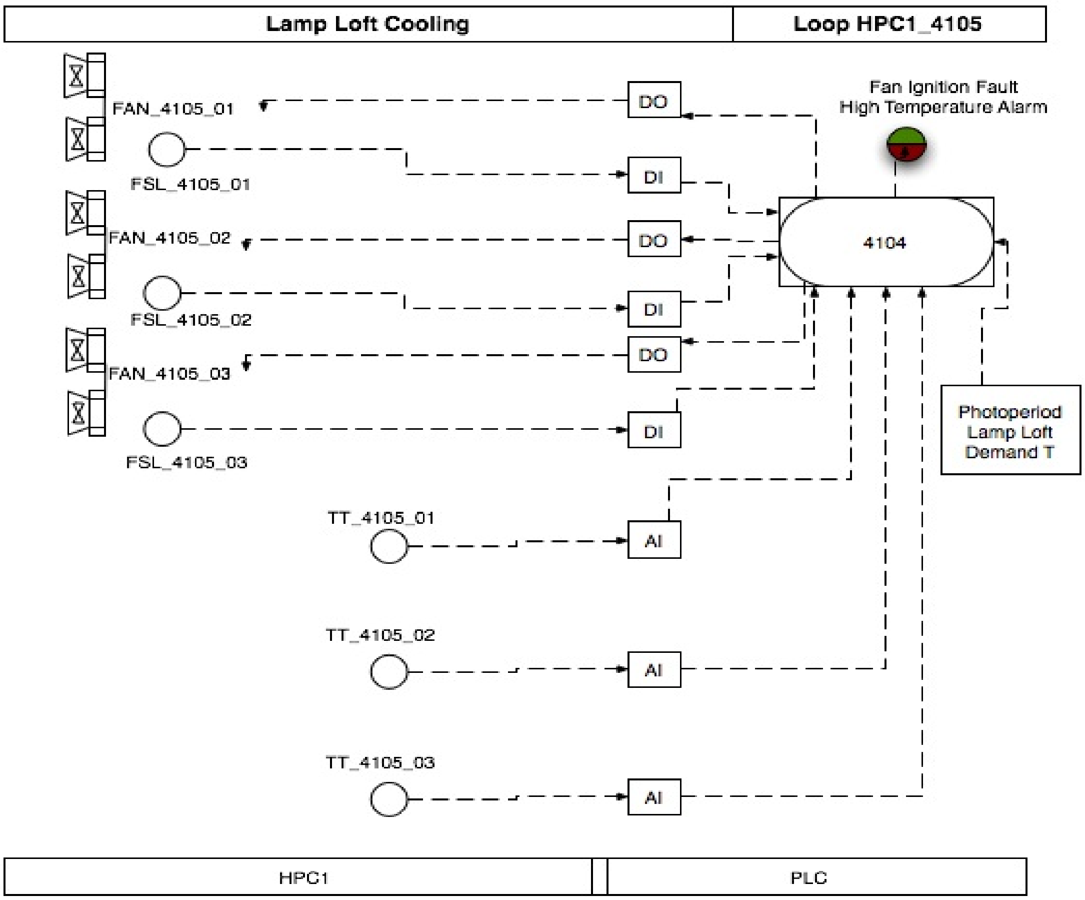


Figure 3-4. Control loop schematic for lighting loft temperature

Equipment

Reference ID	Description
FSL_4105_01	Flow/No flow of Light Loft Fan A
FSL_4105_02	Flow/No flow of Light Loft Fan B
FSL_4105_03	Flow/No flow of Light Loft Fan C
FAN_4105_01	Operation of Light Loft Fan A
FAN_4105_02	Operation of Light Loft Fan B
FAN_4105_03	Operation of Light Loft Fan C
TT_4105_01	Light Loft Temperature sensor A
TT_4105_02	Light Loft Temperature sensor B
TT_4105_03	Light Loft Temperature sensor C

User Inputs:

Instrument	Description
4104_PHOTOPERIOD_STRING_A 4104_PHOTOPEIORD_STRING_B 4104_PHOTOPERIOD_STRNG_MH	The start and end hours for illumination of a given lamp string
IY_4104_01	Turn On/Off lamps - A
IY_4104_02	Turn On/Off lamps - B
IY_4104_03	Turn On/Off lamps - C
4105_DEMAND_T	Maximum allowable temperature of lamp loft

Alarm Conditions:

Instrument	Description
4105_HIGH_TEMP_ALARM	Occurs when lamp loft temperature is in excess of demand temperatures
4105_FAN_IGNITION_FAULT	Occurs if there is a demand for lamp loft fans and fan indicates no operation/no air flow

Control Logic:

IF TT_4105_01 OR TT_4105_02 OR TT_4105_03 >= 4105_DEMAND_T THEN FAN_4105_01 AND FAN_4105_02 AND FAN_4105_03 = HIGH AND 4105_HIGH_TEMP_ALARM=TRUE

IF IY_4104_01 OR IY_4104_02 OR IY_4104_03 = HIGH THEN FAN_4105_01 AND FAN_4105_02 AND FAN_4105_03 = HIGH (On)

IF FSL_4105_01 OR FSL_4105_02 OR FSL_4105_03 = NO FLOW THEN 4105_FAN_IGNITION_FAULT=TRUE

3.4.5. *Hydroponics Reservoir Pump – Loop 4106*

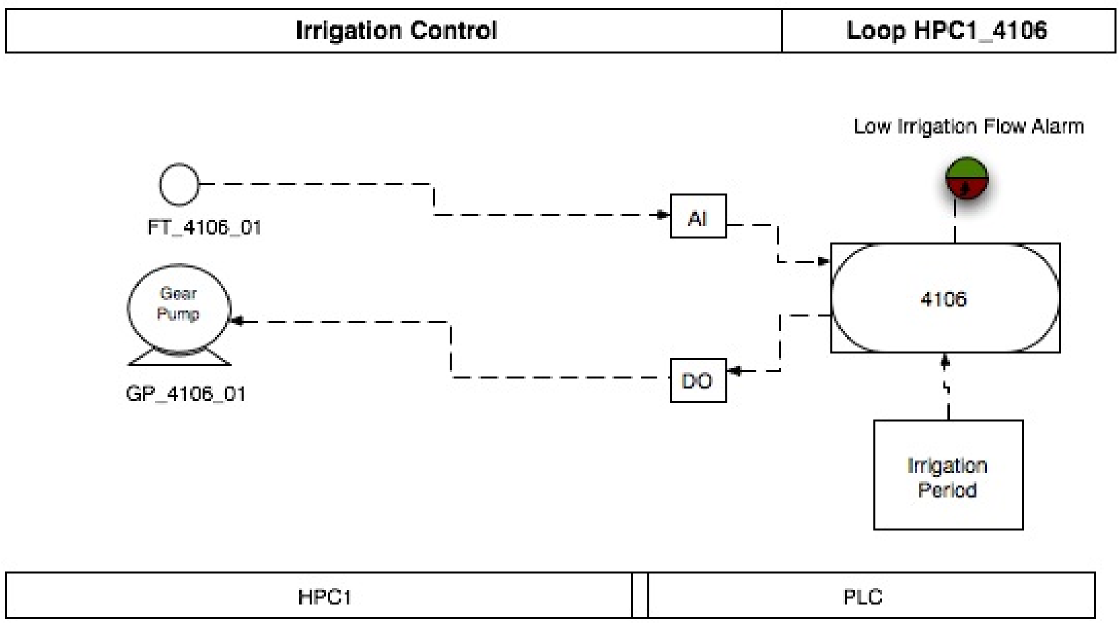


Figure 3-5. Control loop schematic for irrigation pump

Equipment

Hardware (P&ID Naming)	Control Diagram Reference ID
GP_4106_01	Main irrigation Pump P2001
FT_4106_01	Outlet nutrient flow sensor

User Inputs:

Name	Description
4106_IRRIGATION_PERIOD	Defines the start and end times for chamber irrigation
4106_DEMAND_FLOW	Defines the critical flow below which a low flow alarm is activated

Alarm Conditions:

Instrument	Description
4106_LOW_FLOW_	Activated when the flow sensor indicates a flow rate below the demand flow

Control Logic:

IF TIME>=4106_IRRIGATION_PERIOD_START AND TIME<= 4106_IRRIGATION_PERIOD_END THEN GP_4106_01=HIGH (on)

Sub:
IF FT_4106 <4106_ DEMAND_FLOW - TOLERANCE THEN 4106_LOW_FLOW=TRUE

IF FT_4106 >4106_ DEMAND_FLOW + TOLERANCE THEN 4106_LOW_FLOW=TRUE

3.4.6. *Control of pH in the Solution – Loop 4107*

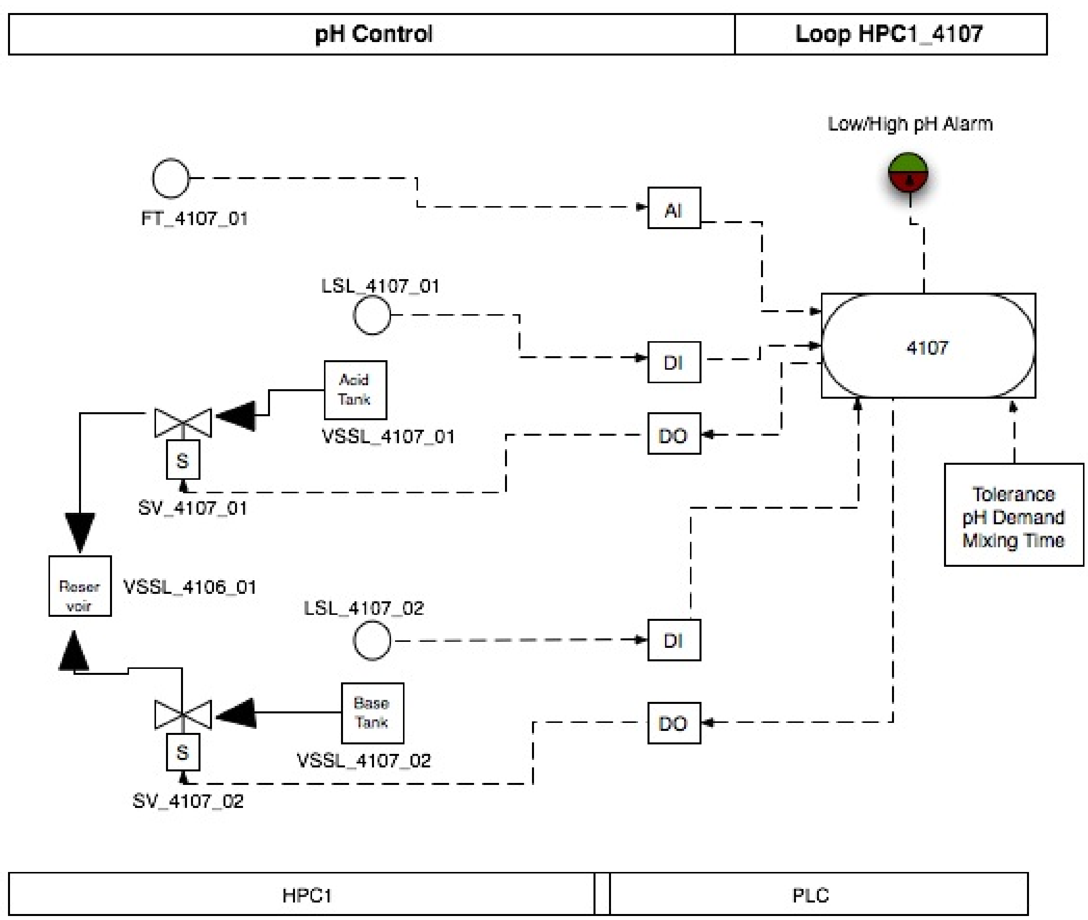


Figure 3-6. Control loop schematic for control of pH in the hydroponics solution

Equipment

Hardware (P&ID Naming)	Control Diagram Reference ID
AT_4107_01	pH sensor
SV_4107_01	Acid Tank Valve
SV_4107_02	Base Tank Valve
LSL_4107_01	Acid Tank Level low
LSL_4107_02	base tank low level
HV_4107_01	Acid Manual Valve
HV_4107_02	Base Manual Valve
VSSL_4107_01	Acid Tank
VSSL_4107_02	Base Tank

User Inputs:

Instrument	Description
4107_DEMAND_pH	User defined pH demand
4107_TOLERANCE	Acceptable number of pH units deviation from demand
4107_MIXING_TIME	Empirically determined time of acid or base mixing in the hydroponics solution, dependent on by-pass valve aperture (from calibration curves)
4107_INJECTION_RUN_TIME	Empirically determined run time for injections of acid or base stock of a given molarity

Alarm Conditions:

Instrument	Description
4107_LOW_pH_ALARM	Occurs if pH is less or equal to (DEMAND_pH – TOLERANCE)
4107_HIGH_pH_ALARM	Occurs if pH is more than (DEMAND_pH – TOLERANCE)
4107_LOW_ACID_VOLUME_ALARM	Occurs when the low level sensor of the acid tanks indicates low volume
4107_LOW_BASE_VOLUME_ALARM	Occurs when the low level sensor of the base tank indicates low volume

Control Logic:

IF AT_4107_01 > DEMAND+pH_TOLERANCE THEN SV_4107_01 = HIGH DURING INJECTION_RUN_TIME

IF AT_4107_01 < DEMAND – pH_TOLERANCE THEN SV_4107_02 = HIGH DURING INJECTION_RUN_TIME

WAIT for MIXING_TIME before AT_4107_01 SCAN

IF LSL_4107_01 = FALSE (low level indicated) THEN SV_4107_01 =LOW (off) AND LOW_ACID_VOLUME_ALARM=TRUE

IF LSL_4107_02 = FALSE (low level indicated) THEN SV_4107_02 =LOW (off) AND LOW_BASE_VOLUME_ALARM=TRUE

3.4.7. *Control of Electrical Conductivity – Loop 4108*

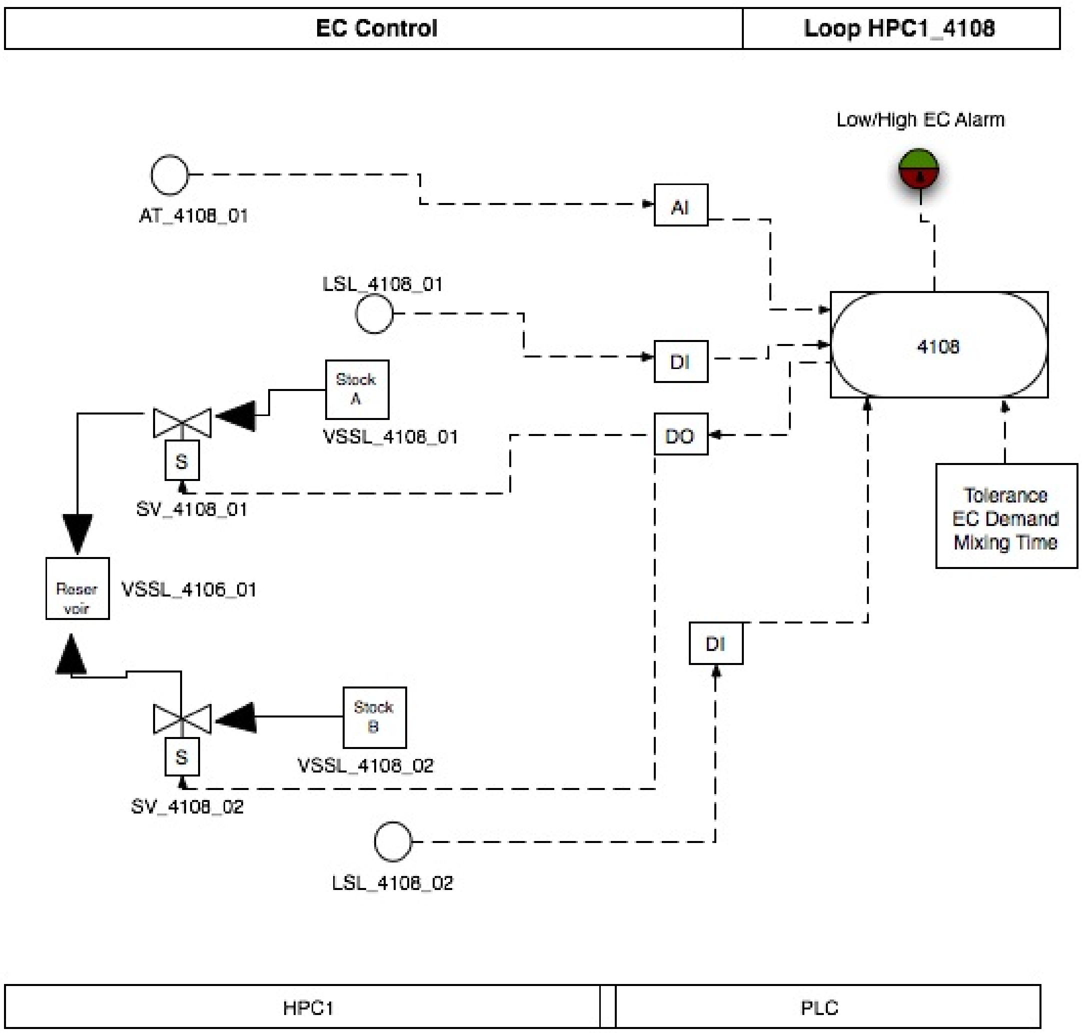


Figure 3-7. Control loop schematic for electrical conductivity control in the hydroponics reservoir

Equipment

Hardware (P&ID Naming)	Control Diagram Reference ID
AT_4108_01	Electrical Conductivity of

	nutrient
SV_4108_01	Stock A inject Valve
SV_4108_02	Stock B inject Valve
LSL_4108_01	stock A low level switch
LSL_4108_02	stock B low level switch
HV_4108_01	Stock A Manual Valve
HV_4108_02	Stock B Manual Valve
VSSL_4108_01	Stock A Tank
VSSL_4108_02	Stock B Tank

User Inputs:

Name	Description
4108_DEMAND_EC	User defined EC demand
4108_TOLERANCE	Acceptable number of EC units deviation from demand
4108_MIXING_TIME	Empirically determined time of Stock A and B mixing in the hydroponics solution, dependent on by-pass valve aperture (from calibration curves)
4108_INJECTION_RUN_TIME	Empirically determined run time for injections of Stock A and B of a given concentration

Alarm Conditions:

Instrument	Description
4108_LOW_EC_ALARM	Occurs if EC is less or equal to (DEMAND_EC – TOLERANCE)
4108_HIGH_EC_ALARM	Occurs if pH is more than (DEMAND_EC – TOLERANCE)
4108_LOW_A_VOLUME_ALARM	Occurs when the low level sensor of the Stock A tank indicates low volume
4108_LOW_B_VOLUME_ALARM	Occurs when the low level sensor of the Stock B tank indicates low volume

Control Logic:

IF AT_4108_01 > DEMAND+EC_TOLERANCE THEN SV_4108_01 = HIGH AND SV_4108_02=HIGH DURING INJECTION_RUM_TIME
ELSE NOTHING

WAIT for MIXING_TIME before AT_4108_01 SCAN

IF LSL_4108_01 = FALSE (low level indicated) THEN SV_4108_01 =LOW (off) AND LOW_A_VOLUME_ALARM=TRUE

IF LSL_4108_02 = FALSE (low level indicated) THEN SV_4108_02 =LOW (off) AND LOW_B_VOLUME_ALARM=TRUE

3.4.8. *Reservoir Temperature Control – Loop 4109*

The need and capability of the MPP to supply this systems is yet to be determined. If present, control may be pulse-width modulated control of a solenoid valve connected on a closed loop line to facility chilled water supply.

3.4.9. *Nutrient Solution and Condensate Water Levels – Loop 4110*

This section describes the control loops necessary to mediate injections from the condensate tank into the MELiSSA loop (crew) and the feed of MELiSSA loop liquid effluent into the HPC hydroponics reservoir.

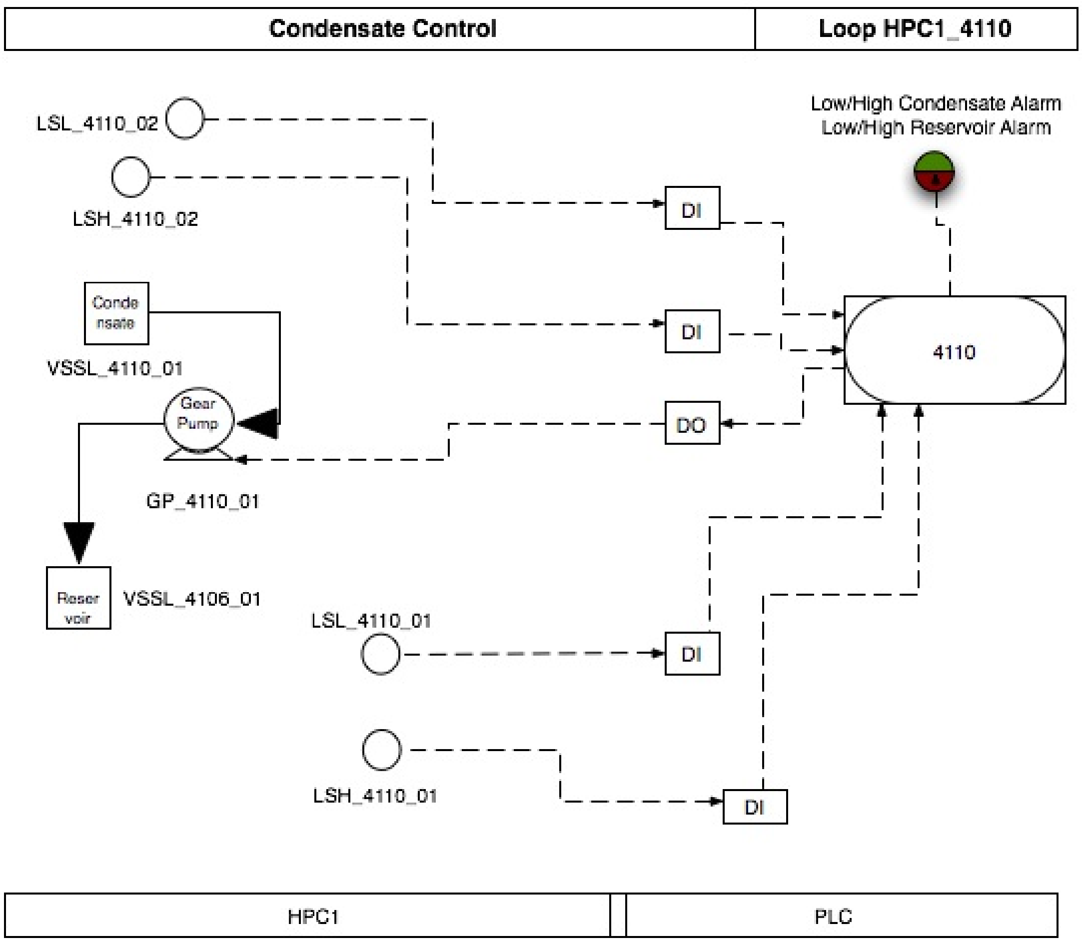


Figure 3-8. Control loop schematic for nutrient solution and condensate water levels

Equipment

Hardware (P&ID Naming)	Control Diagram Reference ID
LSH_4110_01	High Level sensor for reservoir tank
LSL_4110_01	Low Level sensor for reservoir tank
LSH_4110_02	High Level sensor for condensate tank
LSL_4110_02	Low Level sensor for condensate tank
GP_4110_01	Condensate pump relay

VSSL_4110_01	Condensate Tank T 202

User Inputs:

Instrument	Description
N/A	N/A

Alarm Conditions:

Name	Description
4110_HIGH_RESERVOIR_VOLUME_ALARM	Activated when the volume of the reservoir triggers the high volume switch
4110_LOW_RESERVOIR_VOLUME_ALARM	Activated when the volume of the reservoir triggers the low volume switch
4110_HIGH_CONDENSATE_ALARM	Activated when the volume of the condensate triggers the high volume switch

Control Logic:

IF LSH_4110_02=TRUE (activated) AND LSL_4110_01=FALSE THEN GP_4110_01=HIGH (activated) UNTIL LSL_4110_02=TRUE AND COUNT<-COUNT+1 (one empty of VSSL_4110_01

IF LSH_4110_01=TRUE (activated) THEN HIGH_RESERVOIR_VOLUME_ALARM = TRUE

IF LSL_4110_01=TRUE (activated) THEN LOW_RESERVOIR_VOLUME_ALARM = TRUE

WAIT (5 seconds)

IF_LSH_4110_02=TRUE AND GP_4110_01=HIGH THEN HIGH_CONDENSATE_ALARM

3.4.10. *Control of Air circulation fans – Loop 4111*

The diagrams below represent the control loop required for turning on the air circulation fan.

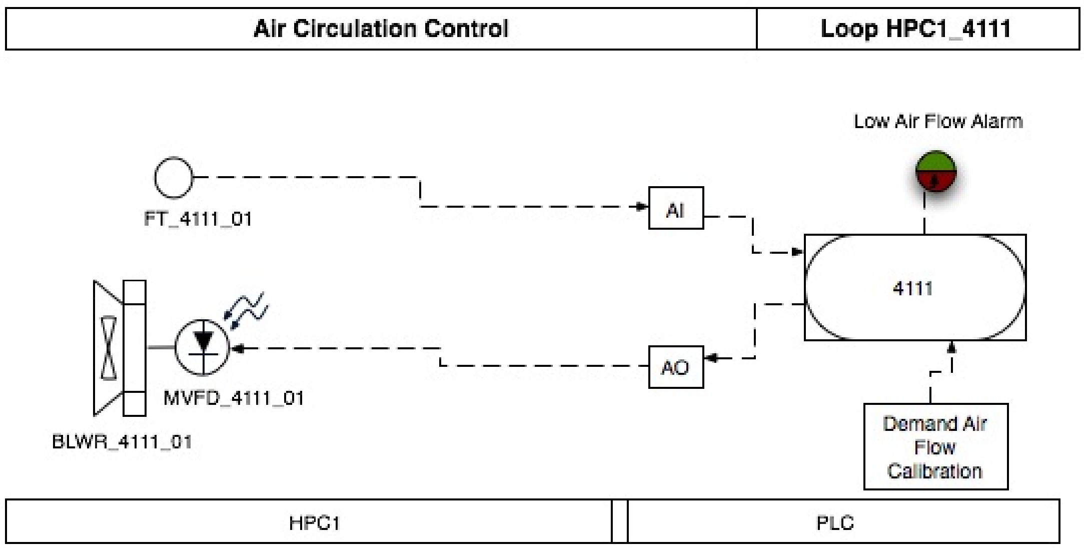


Figure 3-9. Control loop schematic for air circulation fans

Equipment

Reference ID	Description
BLWR_4111_01	Air circulation fan
FT_4111_01	Air velocity sensor
MVFD_4111_01	Air circulation motor VFD

User Inputs:

Instrument	Description
4111_VFD_CALBIRATION	Look-up table of calibration of the measured air flow or speed against VFD set-point (frequency)
4111_VFD_DEMAND_FLOW	Demand for chamber air flow volume or speed
4111_AIR_FLOW_ALARM_SETPOINT	The air flow or speed reading at which the low air flow alarm is activated

Alarm Conditions:

Instrument	Description
4111_LOW_AIR_FLOW_ALARM	The low air flow alarm is activated when the air flow sensor indicates an air flow volume or speed below the set-point

Control Logic:

IF VFD_DEMAND_FLOW > 0 THEN MVFD_4111_01=VFD CALIBRATION(VFD_DEMAND_FLOW)

IF FT_4111_01 < AIR_FLOW_ALARM_SETPOINT THEN LOW_AIR_FLOW_ALARM=TRUE

3.4.11. *Temperature and Humidity Control – Loop 4112*

The diagrams below represent the control loop required for temperature and humidity control in the chamber.

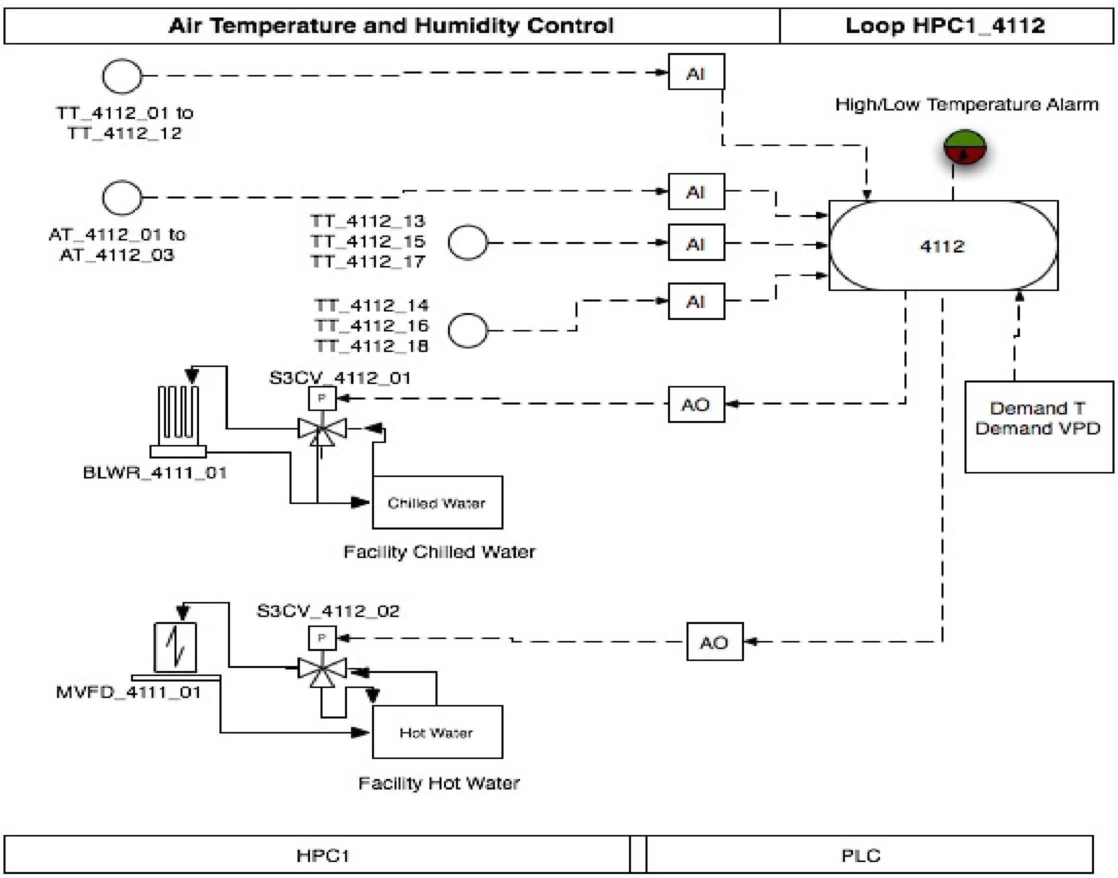


Figure 3-10. Control loop schematic for air temperature control

Equipment

Hardware	Control Diagram

(P&ID Naming)	Reference ID
TT_4112_01	Temperature A1 associated with humidity
AT_4112_01	Humidity associated with temperature A1
TT_4112_02	Temperature B1 associated with Humidity B1
AT_4112_02	Humidity associated with temperature B1
TT_4112_03	Temperature C1 associated with humidity
AT_4112_03	Humidity associated with temperature C1
TT_4112_04	Temperature A2
TT_4112_05	Temperature A3
TT_4112_06	Temperature A4
TT_4112_07	Temperature B2
TT_4112_08	Temperature B3
TT_4112_09	Temperature B4
TT_4112_10	Temperature C2
TT_4112_11	Temperature C3
TT_4112_12	Temperature C4
TT_4112_13	Temperature for facility chilled water
TT_4112_14	Temperature for facility hot water line
TT_4112_15	Chilled coil surface temperature
TT_4112_16	Heating coil surface temperature
TT_4112_17	Chilled Exit temperature
TT_4112_18	Hot Exit temperature
S3CV_4112_01	Chilled Water Control Valve
S3CV_4112_02	Hot Water Control Valve

User Inputs:

Reference ID	Description
4112_DEMAND_T	Air temperature demand of the chamber growing volume as a function of time
4112_OBSERVED_T	A weighted average of all temperature sensors in the growing volume. Weights are programmer defined.
4112_OBSERVED_VPD	A weighted average of all humidity sensors in the growing volume. Weights are programmer defined.
4112_DEMAND_VPD	Demand Vapour Pressure Deficit (VPD) of the chamber growing volumes as a function of time
4112_DEMAND_T_TOLERANCE	Tolerance band for activation of high or low temperature alarms
4112_DEMAND_VPD_TOLERACE	Tolerance band for activation of high or low VPD alarms
4112_WATER_TEMP_ALARM_SET-POINTS	A vector of alarm set points for the chilled and hot water coil entry temperature, coil temperatures and chilled and hot water line exit temperature

Derived Inputs	Description
Psychometric curves relating Saturation VP to Temperature	Used in the determination of VPD at coil and air temperatures and for the conversion of RH to VPD
4112_OBSERVED_T	A weighted average of all temperature sensors in the growing volume. Weights are programmer defined.
4112_OBSERVED_VPD	A weighted average of all humidity sensors in

	the growing volume. Weights are programmer defined.

Alarm Conditions:

Reference	Description
4112_HIGH_T	Occurs when growing volume temperature is out of tolerated high limit
4112_LOW_T	Occurs when growing volume temperature is out of tolerated low limit
4112_HIGH_VPD	Occurs when growing volume VPD is out of tolerated high limit
4112_LOW_VPD	Occurs when growing volume VPD is out of tolerated low limit
4412_WATER_TEMP	Alarm is activated if any of the watery entry, coil or exit temperatures are out of bounds

Basic Control Sequence:

IF OBSERVED_VPD<DEMAND_VPD THEN
OPEN C3SV_4112_01 to APETURE where TT_4112_15=DEWPOINT(DEMAND_T, OBSERVED_VPD)
OPEN C3SV_4112_02 to APETURE until OBSERVED_T=DEMAND_T)

Corresponding PID control logic of Argus system is not available.

ALARMS activated if any temperature is out of its corresponding temperature bounds:

i.e. IF OBSERVED_T>DEMAND_T+TOLERANCE THEN HIGH_T ALARM=TRUE etc…)

3.4.12. *CO_2 Control – Loop 4113*

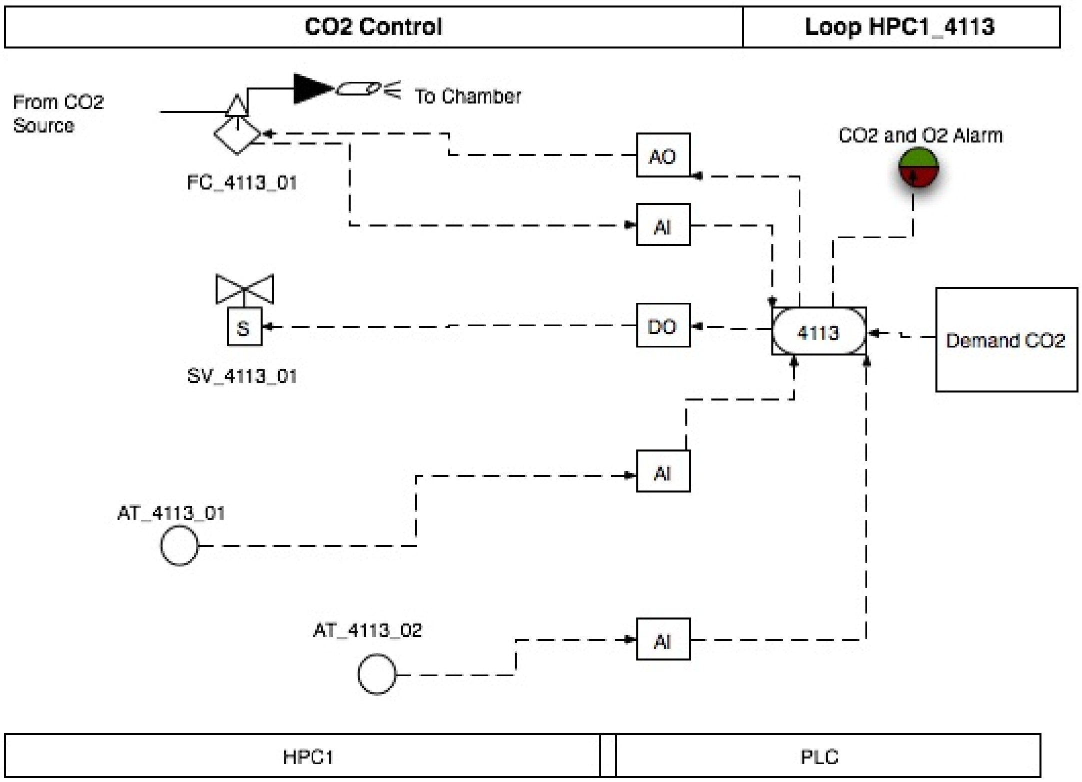


Figure 3-11. Control loop schematic for CO_2 levels

Equipment

Hardware (P&ID Naming)	Control Diagram Reference ID
FC_4113_01	CO2 Mass Flow
FC_4113_01	CO2 Mass Flow set point
AT_4113_01	CO2 Analyser
AT_4113_02	O2 Analyser
SV_4113_01	CO2 injection line. Solenoid
FC_4113_02	Injection Line - CO2 Mass Flow
FC_4113_02	Injection Line - CO2 Mass Flow set point
AT_4113_02	O2 Analyser

User Inputs:

Name	Description
4113_ DEMAND_CO2	Demand CO2 concentration in the chamber growing volume (ppm)
4113_ TOLERANCE_CO2	Tolerance for CO2 concentration in the chamber growing volume (usually 50 ppm) during daylight hours
4113_MAX_O2	Specifies the maximum allowable O2 concentration and the one at which an alarm is indicated
4113_MFC_SET_POINT	User defined (usually fixed at 1 L / min)
4113_MIXING_TIME	Time required for equilibration after CO2 injection at 1L/min

Alarm Conditions:

Instrument	Description
4113_CO2_HIGH_ALARM	Occurs when the observed CO2 concentration is excessively above demand (+50 ppm during photoperiod)
4113_CO2_LOW_ALARM	Occurs when the observed CO2 concentration is chronically (repeatedly) below demand
4413_MFC_FAULT	Occurs when the MCF flow signal indicates no flow when called for
4413_O2_HIGH_ALARM	

Control Logic:

IF AT_4113_01<DEMAND_CO2 THEN:
PULSE-WIDTH-MODULTED(MIXING_TIME) control of SV_4113_01 at a fixed MFC_SET_POINT UNTIL AT_4113_01 >=DEMAND CO2

IF AT_4113_01<DEMAND AND FC_4113_01 SIGNAL not=MFC_SET_POINT THEN MFC_FAULT=TRUE

IF AT_4113_01>DEMAND+TOLERANCE_CO2 AND TIME=PHOTOPERIOD THEN CO2_HIGH_ALARM=TRUE

IF AT_4113_01<DEMAND-TOLERANCE_CO2 AND TIME not= PHOTOPERIOD THEN CO2__LOW_ALARM=TRUE

IF AT_4113_02>MAX_O2 THEN O2_HIGH_ALARM=TRUE

3.4.13. *Pressure Control – Loop 4114*

Pressure control in the chamber is passive. Expansion bladders having a total volume capacity of 200L are required. These bladders will be positioned under the chamber and will expand and contract with changing chamber volumes precipitated by programmed diurnal temperature fluctuations. The expansion bags are connected to the interior chamber volume via a manifold.

Additionally, to prevent air accumulation in the headspace of the hydroponics reservoir, associated with growing tray drainage, a pressure equilibration line is connected to the chamber interior.

Equipment

Reference ID	Description
3x Teflon expansion bags (0.45m diameter, 1.25 m length) Total Volume = 200 L each	T302A-B
PT_4114_01	Growing Area Pressure
RV_4114_01	Passive Pressure Relief Valve
PT_4115_01	Ambient Pressure Sensor

User Inputs:

Name	Description
4114_ TOLERANCE_PRESSURE	Tolerance for atmospheric pressure of the growing volume deviation from ambient levels (usually very small, < 1 kPa, depending on sensor variability)

Alarm Conditions:

Instrument	Description
4414_PRESSURE_ALARM	Activated when the pressure sensor reading of the growing volume exceeds deviation limit from ambient pressure sensor

Control Logic:

IF PT_4114_01<PT_4115_01 - TOLERANCE_PRESSURE THEN PRESSURE_ALARM=TRUE

IF PT_4114_01>PT_4115_01 -+TOLERANCE_PRESSURE THEN PRESSURE_ALARM=TRUE

4. Acknowledgements

The HPC integration team would like to thank Michael Stasiak for his continued efforts related to the technical activities at the CESRF and his consultation in the design process.