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TECHNICAL NOTE 95.1

MELISSA Pilot Plant Higher Plants Chamber: technical requirement of the control system and Control Software Design

Prepared by/Préparé par	Duatis, J. and Gerbi, O.
Reference/Réference	MELiSSA Pilot Plant Frame Contract 19445/05/NL/CP
Issue/Edition	0
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MELiSSA

TECHNICAL NOTE 95.1

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SECTION 1

MELISSA Pilot Plant Higher Plants Chamber: technical requirement of the control system

Prepared by/Préparé par	Olivier Gerbi
Reference/Référence	ESA/UAB Contract 19445/05/NL/CP
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Melissa Partners		

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1. Introduction

The first High Plant Compartment (HPC) is being constructed at the University of Guelph, one of the members of the MELISSA consortium.
Before its final transfer to the Melissa Pilot Plant (MPP) located at the premises of Universitat Autònoma de Barcelona (UAB), the HPC will be functionally tested with its own Control System, Argus, in Guelph.
According to a harmonization approach, same systems should be used in all the compartments. Black Box HPC control will be replaced with a White Box control system.
The main objective of the control is to pilot the light, CO2 concentration, temperature, humidity, conductivity and pH in the plant compartment.
The objective of the study is to develop the control laws in simulation, implement them in Schneider PLC Quantum with its electric hardware and do the validation at Guelph site.
Sherpa (France) with the partnership of NTE (Spain) will perform this work, in addition of UAB as Prime Contractor

Specific Objective of this Technical Note is to detailed the Technical Requirements of the control system.

Inputs for this document is mainly based on the

- TN85.5 : Detailed Design and Verification (G. Waters, UoG, A. Masot, UAB),
- Meetings betweens partners
- TN72.2 : Definition of the control requirements for the MELISSA Loop (NTE)
- TN72.4 : Control System Demonstrator Data Package (Jordi Duartis, NTE)
- Minutes of Meeting 02 July 2007 ESA/UoG/Sherpa
- P&ID Draft by Geoffrey Waters July 30 2007
- Technical Documentation : Coils B301 and B302. Main Centrifugal Fan.

Description of the HPC is not detailed in this document. Control point of view, software and hardware are developed.

2. System Description

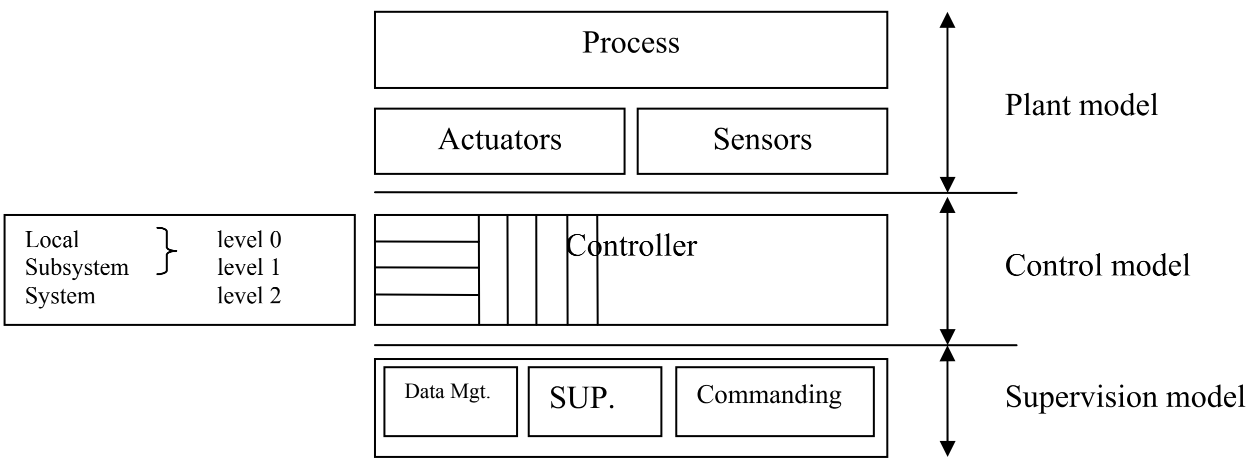
2.1. Control levels

4 levels for the control are commonly used:

Level 0 control: ancillaries, local regulations
Level 1 control: dynamic control
Level 2 control: static/dynamic optimisation
Level 3 control: planning, sequencing and scheduling.

Different Levels of Model are developed:

- Plant model including Process, Sensors and Actuators
- Control Model: for the Controller and including Local (level 0), subsystem and system (level 1 and 2) control laws.



According to the TN85.5 description, the system is discomposed into several subsystems :

- Chamber Access System
- Lighting System
- Liquid subsystem
- Atmospheric Control

For each of these 4 subsystems will be provided:

- a global requirement
- a process description
- list of sensors, actuators, MVs and DVs
- Control description
- Non Functional Requirements and Other Requirements

2.2. List of Inputs and Outputs

Reference: UoG HPC1 Prototype IO Tables Edited by GW Aug 30 2007 (version 1).xls.

CHAMBER ACCESS SYSTEM

Last Updated September 05, 2007 (G. Waters)

				Signal						
Control Loop	**Description**	**Instrument**	**IO**	**DI**	**DO**	**AI**	**AO**	**Elect. Int.**	**Instrument Type**	**Remarks**
	Exterior Air Lock Door Control									
XLC 04021A	Exterior air lock door contact sensors	Relay	O402A	4				Dry contact	Sensor	
	LED Indicators (indicating exterior doors are open)	Indicator	TBD		2			5 VDC	LED Indicator	
	Air Lock Purge Control									
XLC 04011	Injection of pressurized calibrated air into airlock A via solenoid	Relay	V4011		1			24 VAC DO	Normally closed solenoid	Normally closed solenoid connected to pressurized bottle air
XLC 04021	Injection of pressurized calibrated air into airlock C via solenoid	Relay	V4021		1			24 VAC DO	Normally closed solenoid	Normally closed solenoid connected to pressurized bottle air
XLC 04031	Airlock C ventilation solenoid valve	Relay	V4031		1			24 VAC DO	Normally closed solenoid	
XLC 04041	Airlock B ventilation solenoid valve	Relay	V4041		1			24 VAC DO	Normally closed solenoid	
	Airlock pressure sensor - Airlock A	Pressure sensor				1		4-20 mA	Sensor	1 pressure sensor for airlock, 1 pressure sensor immediately upstream of gas tank, before regulator, air lock sensor will indicate overpressure of the chamber in event exterior vent valve does not open
	Airlock pressure sensor - Airlock C	Pressure sensor				1		4-20 mA	Sensor	
	Airlock pressure switch – Airlock A	Switch		1				4-20 mA	Dry Contact	
	Airlock pressure switch - Airlock C	Switch		1				4-20 mA	Dry Contact	
	Growing Area Pressure Sensor	Pressure sensor				1		4-20 mA	Sensor	Strictly, this belongs in the Air Handling subsystem rows, but is left here, close to the other pressure sensors
	Subsystem Total			**6**	**6**	**3**	**0**			

LIGHTING SYSTEM

Last Updated September 05, 2007 (G. Waters)

				Signal						
Control Loop	**Description**	**Instrument**	**IO**	**DI**	**DO**	**AI**	**AO**	**Elect. Int.**	**Instrument Type**	**Remarks**
	Light Intensity Control									
ALC L1011	Turn on/off lamps positioned above chamber	Relay	XY L1011A		1			24 VAC to contactor	Relay to contactors	6 x 600 W HPS, 3 x 400 W MH total, 2 HPS and 1 x MH for each of the three strings
ALC L1011	Turn on/off lamps positioned above chamber	Relay	XY L1011B		1			24 VAC to contactor	Relay to contactors	contactors at 1600W per string x 3 strings
ALC L1011	Turn on/off lamps positioned above chamber	Relay	XY L1011C		1			24 VAC to contactor	Relay to contactors	
ALC L1011	Acquire light intensity and Signal conditioner	PAR Sensor	AT L1011A			1		0 - 10 V DC	Sensor	Need signal conditioners for each light sensor
ALC L1011	Acquire light intensity and Signal Conditioner	PAR Sensor	AT L1011B			1		0 - 10 V DC	Sensor	Need signal conditioners for each light sensor
ALC L1011	Acquire light intensity and Signal Conditioner	PAR Sensor	AT L1011C			1		0 - 10 V DC	Sensor	Need signal conditioners for each light sensor
	Lighting Loft Temperature Control									
TLC A1001	Operation of light loft fans	Relay	XY A1001		1			5 VDC		Through contactor at 1500W each x 3 fans
TLC A1001	Operation of light loft fans	Relay	XY A1002		1			5 VDC		
	Operation of light loft fans	Relay	XY A1002		1			5 VDC		
	Flow/ no flow	Switch		1				0 or 5 VDC		
	Flow/ no flow	Switch		1				0 or 5 VDC		
	Flow/ no flow	Switch		1				0 or 5 VDC		
TLC A1001	Light loft temperature sensor	Thermisters	TT A1001A			1		0-5 V DC	Thermister	
TLC A1001	Light loft temperature sensor	Thermisters	TT A1001B			1		0-5 V DC	Thermister	
TLC A1001	Light loft temperature sensor	Thermisters	TT A1001C			1		0-5 V DC	Thermister	
	Subsystem Total			**3**	**6**	**6**	**0**			

LIQUID SYSTEM

Last Updated September 05, 2007 (G. Waters)

				Signal						
Control Loop	Description	Instrument	IO	DI	DO	AI	AO	Elect. Int.	Instrument Type	Remarks
	Irrigation System									
XLC P2011	Main Irrigation Pump	Relay	XY P2001		1			24 VAC to relay	1/2 hp from motor through contactor	With contactor sized at 1500 W (1.5 hp)
XLC P2011	Outlet nutrient flow Sensor	Flow sensor	FT P2011B			1				
	Control of pH in the Solution									
ALC T2011	pH sensor	pH sensor	AT T2011			1		4-20 mA	Sensor	Loop powered device
ALC T2011	Acid tank valve	Solenoid valve	AV T2011A		1			24 VAC	Normally closed solenoid	
ALC T2011	Basic tank valve	Solenoid valve	AV T2011B		1			24 VAC	Normally closed solenoid	
	Acid tank level			1				Dry contact	Sensor	
	Base tank level			1				Dry contact	Sensor	
	Control of Electrical Conductivity in the solution									
CLC T2012	Electrical conductivity of nutrient sensor	EC sensor	CT T2012			1		4-20mA	Sensor	Loop powered device
CLC T2012	Stock solution A inject line	Solenoid valve	CV T2012A		1			24 VAC	Normally closed solenoid	
	Level Sensor for stock A			1				Dry contact	Float Sensors/Contact Sensor	
CLC T2012	Stock solution B inject line	Solenoid valve	CV T2012B		1			24 VAC	Normally closed solenoid	
	Level Sensor for Stock B			1				Dry contact	Float Sensors/Contact Sensor	
	Temperature Sensor for solution reservoir	Thermistors				1		0-5 V DC	Thermistor	
	Nutrient solution tank cooling line	Solenoid valve			1			24 VAC	Normally closed solenoid	
	Control of Nutrient Solution and Condensate Water Levels									
LLC T2013	Level sensor for reservoir tank (high and low)	Level sensor	LT T2013	2				Dry contact	Float Sensors/Contact Sensor	Dry contact, with low and high alarm
LLC T2013	Level sensor for condensation tank (high and low)	Level sensor	LT T2021	2				Dry contact	Float Sensors/Contact Sensor	Dry contract
LLC T2013	Condensate pump relay	Relay	XY P6011		1			24 VAC to relay	Normally closed solenoid	
	Subsystem Total			**8**	**7**	**4**	**0**			

ATMOSPHERIC SYSTEM

Last Updated September 05, 2007 (G. Waters)

				Signal						
Control Loop	**Description**	**Instrument**	**IO**	**DI**	**DO**	**AI**	**AO**	**Elect. Int.**	**Instrument Type**	**Remarks**
	Control of Air circulation fans									
XLC P3011	Air circulation fan with variable frequency drive controller	Motor	XY P3011				1	24 VAC	VFD (see comment)	Through contactor (3000 W each), variable speed
	1 air velocity sensor	flow sensor				1		0-5 V DC	Sensor	
	Temperature Control									
TLC A3001	Temperature sensor	Thermistors	TT A3001A			3		0-5 V DC	Thermistor	Vaisala
TLC A3001	Temperature sensor	Thermistors	TT A3001B			3		0-5 V DC	Thermistor	Vaisala
TLC A3001	Temperature sensor	Thermistors	TT A3001C			3		0-5 V DC	Thermistor	Vaisala
TLC A3001	Regulatory valve chilled water - proportional valve	Flow valve	V301				1	4-20 mA	Control Valve	
TLC A3001	Regulatory valve hot water - proportional valve	Flow valve	V302				1	4-20 mA	Control Valve	
	Temp sensor for facility chilled water line	Thermistors				1		4-20 mA	Thermistor	
	Temp sensor for facility hot water line	Thermistors				1		4-20 mA	Thermistor	
	Chilled coil surface temperature	Thermistors				1		4-20 mA	Thermistor	
	Heating coil surface temperature	Thermistors				1		4-20 mA	Thermistor	
	Hot Exit Temperature	Thermistors				1		4-20 mA	Thermistor	
	Coiled Exit Temperature	Thermistors				1		4-20 mA	Thermistor	
	Humidity Control									
ALC A3002	Humidity sensor (built in with temp sensor)	Humidity sensor	AT A3002A			1		4-20 mA	Sensor	Aspirated humidity sensors, Vaisala - comes with temp sensor
ALC A3002	Humidity sensor (built in with temp sensor)	Humidity sensor	AT A3002B			1		4-20 mA	Sensor	Aspirated humidity sensors, Vaisala
	Humidity sensor (built in with temp sensor)	Humidity sensor	AT A3002B			1		4-20 mA	Sensor	Aspirated humidity sensors, Vaisala
	RH associated temperature	Temperature				1		4-20 mA	Sensor	Aspirated temperature sensors, Vaisala
	RH associated temperature	Temperature				1		4-20 mA	Sensor	Aspirated temperature sensors, Vaisala
	RH associated temperature	Temperature				1		4-20 mA	Sensor	Aspirated temperature sensors, Vaisala
	Subsystem Total			**0**	**0**	**22**	**3**			

Last Updated	September 05, 2007 (G. Waters)									
				Signal						
Control Loop	Description	Instrument	IO	DI	DO	AI	AO	Elect. Int.	Instrument Type	Remarks
	CO2 Control									
ALC A3003	CO2 mass flow/sensor controller for feed to analyzer	Flow sen/cont	FTC A3003A			1	1	24V DC In, 4-20 mA OR 0-10V out	MFC	
ALC A3003	Infrared Gas Analyzer (IRGA) calib. for CO2	Analyzer	ATCO A3003			1		4-20 mA	Analyzer	
ALC A3003	Paramagnetic Analyzer calib. for O2	Analyzer	ATO2 A3003			1		4-20 mA	Analyzer	
ALC A3003	CO2 injection line - solenoid	Relay			1			24 VAC	Normally closed solenoid	
	CO2 injection line - mass flow/sensor controller					1	1	24V DC In, 4-20 mA OR 0-10V out	MFC	
	Subsystem Total			**0**	**1**	**4**	**2**			
Others :										
	Ambient Temp					**1**				
	Ambient Pressure					**1**				

				DI	DO	AI	AO			
Total				**17**	**20**	**41**	**5**			

Grand Total : **83 variables**

Inputs = DI + AI = 17 + 41 = **58 Inputs**, Analogical or Digital
Outputs = DO + AO = 20 + 5 = **25 Outputs**, Analogical or Digital

2.3. MPP names of the control loops and variables

Ref: TN 78.71 and TN78.72 documents.

Following the rules depicted in theses documents and also with reference to the norm ISA 5.2 (1992), the following control groups are defined.

These names will be used for the programming of the PLC and the next documentation about control.

As there is no possible mistake with the understanding, the P&ID names or Excel names (Waters) will be mainly use in this current Technical Note.

List of the Control Groups.
(450_1 is the first number for HPC 1, following TN 78.71 rule)

450_1	Exterior Air Lock Door Control - Side A
451_1	Exterior Air Lock Door Control - Side C
452_1	Air Lock Purge Control - Side A
453_1	Air Lock Purge Control - Side C
454_1	Light Intensity Control
455_1	Lighting Loft Temperature Control
456_1	Irrigation System
457_1	pH Control
458_1	EC Control
459_1	Nutrient Tank Temperature Control
460_1	Nutrient and Condensate Levels Control
461_1	Control of Air circulation fans
462_1	Chamber Temperature and Humidity Control
463_1	CO2 Control
464_1	Chamber Pressure
465_1	Ambient Parameters

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description	Signal
1	450_1	Exterior Air Lock Door Control - Side A	ZS_450_1_01	ZS_450_1_01	Y		Upper Exterior Air Lock Door Contact - Side A	DI
2	450_1	Exterior Air Lock Door Control - Side A	ZS_450_1_02	ZS_450_1_02	Y		Lower Exterior Air Lock Door Contact - Side A	DI
3	450_1	Exterior Air Lock Door Control - Side A	ZI_450_1_01	No Measurement		Y	Led Indicator when door is open - Side A	DO
4	451_1	Exterior Air Lock Door	ZS_451_1_01	ZS_451_1_01	Y		Upper Exterior Air Lock Door Contact -	DI

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description	Signal
		Control - Side C					Side C	
5	451_1	Exterior Air Lock Door Control - Side C	ZS_451_1_02	ZS_451_1_02	Y		Lower Exterior Air Lock Door Contact - Side C	DI
6	451_1	Exterior Air Lock Door Control - Side C	ZI_451_1_01	No Measurement		Y	Led Indicator when door is open - Side C	DO
7	452_1	Air Lock Purge Control - Side A	SV_452_1_01	SV_452_1_01_ MV		Y	Solenoid Valve for injection of pressurized air into airlock A	DO
8	452_1	Air Lock Purge Control - Side A	SV_452_1_02	SV_452_1_02_ MV		Y	Airlock A ventilation Solenoid Valve	DO
9	452_1	Air Lock Purge Control - Side A	PT_452_1_01	PT_452_1_01	Y		Pressure sensor for airlock A	AI
10	452_1	Air Lock Purge Control - Side A	PSH_452_1_01	PSH_452_1_01	Y		Airlock A pressure switch	DI
11	453_1	Air Lock Purge Control - Side C	SV_453_1_01	SV_453_1_01_ MV		Y	Solenoid Valve for injection of pressurized air into airlock C	DO
12	453_1	Air Lock Purge Control - Side C	SV_453_1_02	SV_453_1_02_ MV		Y	Airlock C ventilation Solenoid Valve	DO
13	453_1	Air Lock Purge Control - Side C	PT_453_1_01	PT_453_1_01	Y		Pressure sensor for airlock C	AI
14	453_1	Air Lock Purge Control - Side C	PSH_453_1_01	PSH_453_1_01	Y		Airlock A pressure switch	DI
15	454_1	Light Intensity Control	IRC_454_1_01	IRC_454_1_01_ MV		Y	Turn On/Off lamps - A	DO
16	454_1	Light Intensity Control	IRC_454_1_02	IRC_454_1_02_ MV		Y	Turn On/Off lamps - B	DO
17	454_1	Light Intensity Control	IRC_454_1_03	IRC_454_1_03_ MV		Y	Turn On/Off lamps - C	DO
18	454_1	Light Intensity Control	OT_454_1_01	OT_454_1_01	Y		PAR Sensor - A	AI
19	454_1	Light Intensity Control	OT_454_1_02	OT_454_1_02	Y		PAR Sensor - B	AI
20	454_1	Light Intensity Control	OT_454_1_03	OT_454_1_03	Y		PAR Sensor - C	AI
21	455_1	Lighting Loft Temperature Control	IS_455_1_01	IS_455_1_01	Y		Flow/Noflow of Light Loft Fan A	DI

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description	Signal
22	455_1	Lighting Loft Temperature Control	IS_455_1_02	IS_455_1_02	Y		Flow/Noflow of Light Loft Fan B	DI
23	455_1	Lighting Loft Temperature Control	IS_455_1_03	IS_455_1_03	Y		Flow/Noflow of Light Loft Fan C	DI
24	455_1	Lighting Loft Temperature Control	GP_455_1_01	GP_455_1_01_ MV		Y	Operation of Light Loft Fan A	DO
25	455_1	Lighting Loft Temperature Control	GP_455_1_02	GP_455_1_02_ MV		Y	Operation of Light Loft Fan B	DO
26	455_1	Lighting Loft Temperature Control	GP_455_1_03	GP_455_1_03_ MV		Y	Operation of Light Loft Fan C	DO
27	455_1	Lighting Loft Temperature Control	TT_455_1_01	TT_455_1_01	Y		Light Loft Temperature sensor A	AI
28	455_1	Lighting Loft Temperature Control	TT_455_1_02	TT_455_1_02	Y		Light Loft Temperature sensor B	AI
29	455_1	Lighting Loft Temperature Control	TT_455_1_03	TT_455_1_03	Y		Light Loft Temperature sensor C	AI
30	456_1	Irrigation System	GP_456_1_01	GP_456_1_01_ MV		Y	Main irrigation Pump P2001	DO
31	456_1	Irrigation System	FT_456_1_01	FT_456_1_01	Y		Outlet nutrient flow sensor	AI
32	457_1	pH Control	AT_457_1_01	AT_457_1_01	Y		pH sensor	AI
33	457_1	pH Control	SV_457_1_01	SV_457_1_01_ MV		Y	Acid Tank Valve	DO
34	457_1	pH Control	SV_457_1_02	SV_457_1_02_ MV		Y	Base Tank Valve	DO
35	457_1	pH Control	LS_457_1_01	LS_457_1_01	Y		Acid Tank Level	DI
36	457_1	pH Control	LS_457_1_02	LS_457_1_02	Y		Base Tank Valve	DI
37	458_1	EC Control	CT_458_1_01	CT_458_1_01	Y		Electrical Conductivity of nutrient	AI
38	458_1	EC Control	SV_458_1_01	SV_458_1_01_ MV		Y	Stock A inject Valve	DO
39	458_1	EC Control	SV_458_1_02	SV_458_1_02_ MV		Y	Stock B inject Valve	DO
40	458_1	EC Control	LS_458_1_01	LS_458_1_01	Y		Level sensor Stock A	DI
41	458_1	EC Control	LS_458_1_02	LS_458_1_02	Y		Level sensor Stock B	DI
42	459_1	Nutrient Tank Temperature Control	TT_459_1_01	TT_459_1_01	Y		Temperature sensor for solution reservoir	AI

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description	Signal
43	459_1	Nutrient Tank Temperature Control	SV_459_1_01	SV_459_1_01_ MV		Y	Nutrient cooling line valve	DO
44	460_1	Nutrient and Condensate Levels Control	LSH_460_1_01	LSH_460_1_01	Y		High Level sensor for reservoir tank	DI
45	460_1	Nutrient and Condensate Levels Control	LSL_460_1_01	LSL_460_1_01	Y		Low Level sensor for reservoir tank	DI
46	460_1	Nutrient and Condensate Levels Control	LSH_460_1_02	LSH_460_1_02	Y		High Level sensor for condensate tank	DI
47	460_1	Nutrient and Condensate Levels Control	LSL_460_1_02	LSL_460_1_02	Y		Low Level sensor for condensate tank	DI
48	460_1	Nutrient and Condensate Levels Control	GP_460_1_01	GP_460_1_01_ MV		Y	Condensate pump relay	DO
49	461_1	Control of Air circulation fans	GP_461_1_01	GP_461_1_01_ MV		Y	Air circulation fan with VFD	AO
50	461_1	Control of Air circulation fans	FT_461_1_01	FT_461_1_01	Y		Air velocity sensor	AI
51	462_1	Chamber Temperature and Humidity Control	TT_462_1_01	TT_462_1_01	Y		Temperature A1 associated with humidity	AI
52	462_1	Chamber Temperature and Humidity Control	TT_462_1_02	TT_462_1_02	Y		Temperature A2	AI
53	462_1	Chamber Temperature and Humidity Control	TT_462_1_03	TT_462_1_03	Y		Temperature A3	AI
54	462_1	Chamber Temperature and Humidity Control	TT_462_1_04	TT_462_1_04	Y		Temperature A4	AI
55	462_1	Chamber Temperature and Humidity Control	TT_462_1_05	TT_462_1_05	Y		Temperature B1 associated with humidity	AI
56	462_1	Chamber Temperature and Humidity Control	TT_462_1_06	TT_462_1_06	Y		Temperature B2	AI
57	462_1	Chamber Temperature and Humidity	TT_462_1_07	TT_462_1_07	Y		Temperature B3	AI

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description	Signal
		Control						
58	462_1	Chamber Temperature and Humidity Control	TT_462_1_08	TT_462_1_08	Y		Temperature B4	AI
59	462_1	Chamber Temperature and Humidity Control	TT_462_1_09	TT_462_1_09	Y		Temperature C1 associated with humidity	AI
60	462_1	Chamber Temperature and Humidity Control	TT_462_1_10	TT_462_1_10	Y		Temperature C2	AI
61	462_1	Chamber Temperature and Humidity Control	TT_462_1_11	TT_462_1_11	Y		Temperature C3	AI
62	462_1	Chamber Temperature and Humidity Control	TT_462_1_12	TT_462_1_12	Y		Temperature C4	AI
63	462_1	Chamber Temperature and Humidity Control	TT_462_1_13	TT_462_1_13	Y		Temperature for facility chilled water	AI
64	462_1	Chamber Temperature and Humidity Control	TT_462_1_14	TT_462_1_14	Y		Temperature for facility hot water line	AI
65	462_1	Chamber Temperature and Humidity Control	TT_462_1_15	TT_462_1_15	Y		Chilled coil surface temperature	AI
66	462_1	Chamber Temperature and Humidity Control	TT_462_1_16	TT_462_1_16	Y		Heating coil surface temperature	AI
67	462_1	Chamber Temperature and Humidity Control	TT_462_1_17	TT_462_1_17	Y		Chilled Exit temperature	AI
68	462_1	Chamber Temperature and Humidity Control	TT_462_1_18	TT_462_1_18	Y		Hot Exit temperature	AI
69	462_1	Chamber Temperature and Humidity	AT_462_1_01	AT_462_1_01	Y		Humidity A1 associated with temp A1	AI

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description	Signal
		Control						
70	462_1	Chamber Temperature and Humidity Control	AT_462_1_02	AT_462_1_02	Y		Humidity B1 associated with temp B1	AI
71	462_1	Chamber Temperature and Humidity Control	AT_462_1_03	AT_462_1_03	Y		Humidity C1 associated with temp C1	AI
72	462_1	Chamber Temperature and Humidity Control	CV_462_1_01	CV_462_1_01_ MV		Y	Chilled Water Control Valve	AO
73	462_1	Chamber Temperature and Humidity Control	CV_462_1_02	CV_462_1_02_ MV		Y	Hot Water Control Valve	AO
74	463_1	CO2 Control	FC_463_1_01	FC_463_1_01	Y		CO2 Mass Flow	AI
75	463_1	CO2 Control		FC_463_1_01_ SP		Y	CO2 Mass Flow set point	AO
76	463_1	CO2 Control	AT_463_1_01	AT_463_1_01	Y		CO2 Analyser	AI
77	463_1	CO2 Control	AT_463_1_02	AT_463_1_02	Y		O2 Analyser	AI
78	463_1	CO2 Control	SV_463_1_01	SV_463_1_01_ MV		Y	CO2 injection line. Solenoid	DO
79	463_1	CO2 Control	FC_463_1_02	FC_463_1_02	Y		Injection Line - CO2 Mass Flow	AI
80	463_1	CO2 Control		FC_463_1_02_ SP		Y	Injection Line - CO2 Mass Flow set point	AO
81	464_1	Chamber Pressure	PT_464_1_01	PT_464_1_01	Y		Growing Area Pressure	AI
82	465_1	Ambient Parameters	TT_465_1_01	TT_465_1_01	Y		Ambient temperature	AI
83	465_1	Ambient Parameters	PT_465_1_01	PT_465_1_01	Y		Ambient pressure	AI
					58	**25**		**83**

Remark 1: 58 inputs and 25 outputs is to be compared to 58/25 in the previous table.
Remark 2 : the 2 LEDs (#3 and 6 are not connected to the PLC). So the number of output is 25.

Input	Output
56	25

Remark 3 : Instrument or Variable names underlined in yellow are not validated when writing this report. This table (HPC1VariableTagv4.xls) will be updated during the project. This file is annexed to the current TN.

3. CHAMBER ACCESS SYSTEM

Access to the chamber growing area.
2 control are designed:
- Interior Air-Lock Door Control
- Air-Lock Purge Control

Side A : Right, Harvesting
Side C : Left, Planting

3.1. Exterior Air-Lock Door control

No control loop, but LED indicating if doors are open. Alarm connected to the contacts.

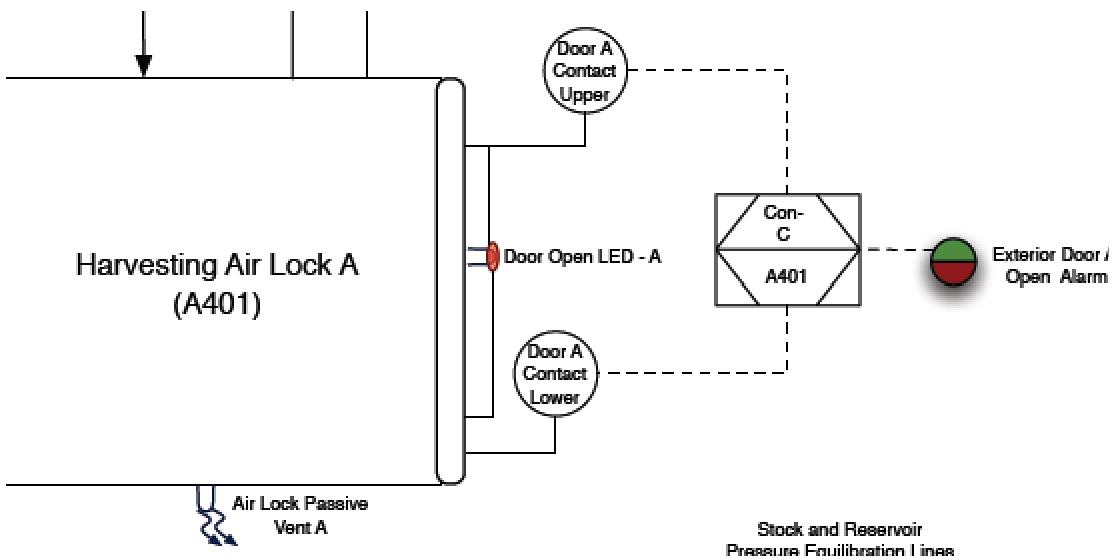


Figure 1 : P&ID Waters – Exterior Air Lock (side A)

3.1.1. Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
1	450_1	Exterior Air Lock Door Control - Side A	ZS_450_1_01	ZS_450_1_01	Y		Upper Exterior Air Lock Door Contact - Side A
2	450_1	Exterior Air Lock Door Control - Side A	ZS_450_1_02	ZS_450_1_02	Y		Lower Exterior Air Lock Door Contact - Side A
3	450_1	Exterior Air Lock Door Control - Side A	ZI_450_1_01	No Measurement		Y	Led Indicator when door is open - Side A

4	451_1	Exterior Air Lock Door Control - Side C	ZS_451_1_01	ZS_451_1_01	Y		Upper Exterior Air Lock Door Contact - Side C
5	451_1	Exterior Air Lock Door Control - Side C	ZS_451_1_02	ZS_451_1_02	Y		Lower Exterior Air Lock Door Contact - Side C
6	451_1	Exterior Air Lock Door Control - Side C	ZI_451_1_01	No Measurement		Y	Led Indicator when door is open - Side C

3.1.2.Sensors

- Door Contact Sensors DI : 4
  2 for Exterior Door A (up and down)
  2 for Exterior Door C (up and down)

3.1.3.Actuators and manipulated variables

- LED indicators DO : 2
  1 LED for Door A
  1 LED for Door C

- No strategy for interior air-lock door as they are manually operated

3.1.4.Disturbances

N/A

3.1.5.Control

3.1.5.1. *Specification*

N/A

3.1.5.2. *Control strategy*

If Exterior Door OPEN then
LED ON (direct connection)
Alarm (Screen)

If Exterior Door CLOSE then Alarm Off.

Door is considered OPEN if one of the two contactors indicates it
Door is considered CLOSE if both contactors are Ok.

Remark1:

Opening Interior Air-Lock Door should not be operated if Exterior Door is open.

Remark2 :

LED are directly connected to the contact sensors and are not operated with the PLC.

3.2. Air Lock Purge Control

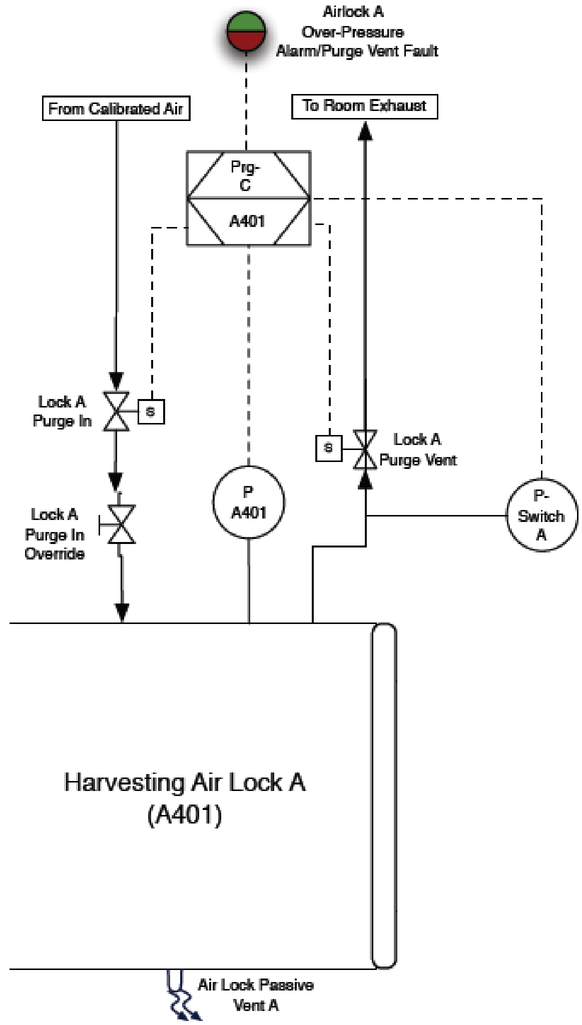


Figure 2 : P&ID Waters – Air Lock Purge (side A)

3.2.1. Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
7	452_1	Air Lock Purge Control - Side A	SV_452_1_01	SV_452_1_01_ MV		Y	Solenoid Valve for injection of pressurized air into airlock A
8	452_1	Air Lock Purge Control - Side A	SV_452_1_02	SV_452_1_02_ MV		Y	Airlock A ventilation Solenoid Valve
9	452_1	Air Lock Purge Control - Side A	PT_452_1_01	PT_452_1_01	Y		Pressure sensor for airlock A
10	452_1	Air Lock Purge Control - Side A	PSH_452_1_01	PSH_452_1_01	Y		Airlock A pressure switch
11	453_1	Air Lock Purge Control - Side C	SV_453_1_01	SV_453_1_01_ MV		Y	Solenoid Valve for injection of pressurized air into airlock C
12	453_1	Air Lock Purge Control - Side C	SV_453_1_02	SV_453_1_02_ MV		Y	Airlock C ventilation Solenoid Valve
13	453_1	Air Lock Purge Control - Side C	PT_453_1_01	PT_453_1_01	Y		Pressure sensor for airlock C
14	453_1	Air Lock Purge Control - Side C	PSH_453_1_01	PSH_453_1_01	Y		Airlock C pressure switch

3.2.2.Sensors

- A : pressure sensor for Air Lock and upstream of gas tank T401. AI
- C : pressure sensor for Air Lock and upstream of gas tank T401. AI
- A : Airlock A pressure switch DI
- C : Airlock C pressure switch DI

3.2.3.Actuators and manipulated variables

- Injection Valve into air-lock A DO
- Injection Valve into air-lock C DO
- air-lock A Ventilation valve DO
- air-lock C Ventilation valve DO

3.2.4. Disturbances

- No Disturbances

3.2.5. Control

3.2.5.1. *Specification*

N/A

3.2.5.2. *Procedure*

After seeding or harvesting

A or C strategy are identical.

- Interior Door should be closed (manual operation)
- Exterior Door is open
  → Harvesting or seeding
- Exterior Door is closed

→ **purge**

- When purge is over, interior door can be open

Purge :

- timer = 0
- open Purge Valve and open Air-Lock Vent valve
- increment timer
- when timer = timer_limit
- close Purge Valve and Air-Lock Vent valve

Pressure sensors :

- if overpressure : pressure > high_limit, then
  - close inlet_solenoid
  - alarm (screen)

4. LIGHTING SYSTEM

9 lamps ON/OFF.

6 x 600 W HPS (High Pressure Sodium)
3 x 400 W MH (Metal Halide)

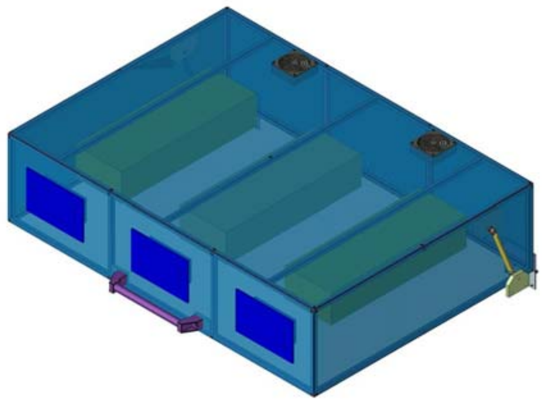


Figure 3 : one string : 3 lamps (HPS-MH-HPS)

3 strings of 3 lamps (HPS, MH HPS) are binary controlled

4.1. Light Intensity Control

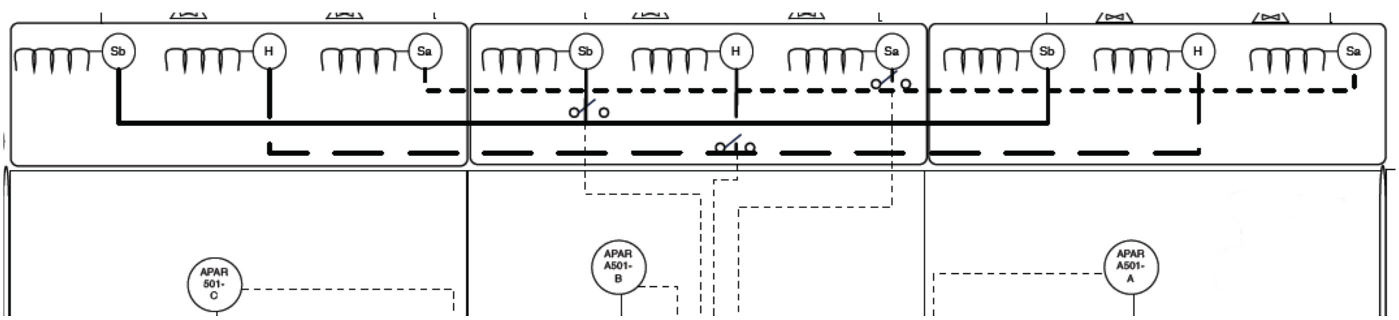


Figure 4 : P&ID Waters - Lighting System

4.1.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
15	454_1	Light Intensity Control	IRC_454_1_01	IRC_454_1_01_ MV		Y	Turn On/Off lamps - A
16	454_1	Light Intensity Control	IRC_454_1_02	IRC_454_1_02_ MV		Y	Turn On/Off lamps - B
17	454_1	Light Intensity Control	IRC_454_1_03	IRC_454_1_03_ MV		Y	Turn On/Off lamps - C
18	454_1	Light Intensity Control	OT_454_1_01	OT_454_1_01	Y		PAR Sensor - A
19	454_1	Light Intensity Control	OT_454_1_02	OT_454_1_02	Y		PAR Sensor - B
20	454_1	Light Intensity Control	OT_454_1_03	OT_454_1_03	Y		PAR Sensor - C

4.1.2.Sensors

3 PAR Sensors 3 * AI
Called hereafter PAR1, PAR2 and PAR3

4.1.3.Actuators and manipulated variables

3 On/Off Relays 3 * DO

Called hereafter LIGHT1, LIGHT2, LIGHT3

4.1.4.Disturbances

No neutral density screens introduced manually under the lamps to attenuate light intensity.

4.1.5.Control

4.1.5.1. *Specification*

Purpose of the control is not to compute the objectives.
We supposed the objectives known by an upper strategy.

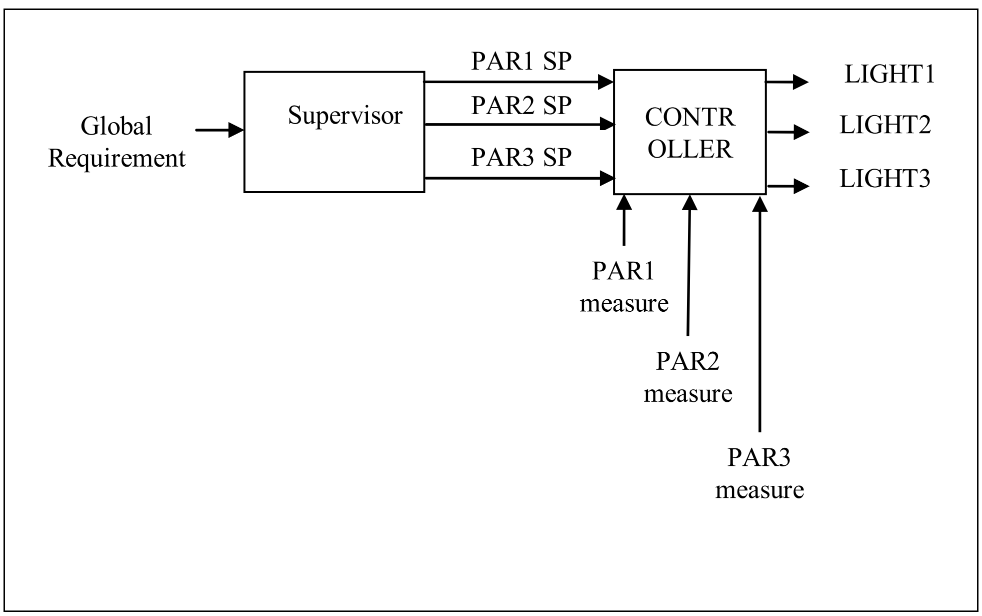
Control Light Level : PAR1 SP, PAR2 SP PAR3 SP.

Light Intensity could be modulated with the 3 strings from 0 W to 4800 W :

- 0 W
- 1200 W (MH string)
- 1800 W (HPS string)
- 3000 W (MH and HPS strings)
- 3600 W (2 HPS strings)
- 4800 W (All strings)

The supervisor could defined for each string the desired set point.
As strings are binary controlled, set point can be also described as ON/OFF for a string.

4.1.5.2. *Control Strategy*



Parameters :

- For each STRING (3 lights) :
  - DURATION_ON hours a day
  - DURATION_OFF hours a day (complementary to 24)

PARx_SP = f(time, DURATION_ON, DURATION_OFF)

```
If (PARx MEASURE) > PARx SP  then
        LIGHTx = OFF
else
        LIGHTx = ON
endif
```

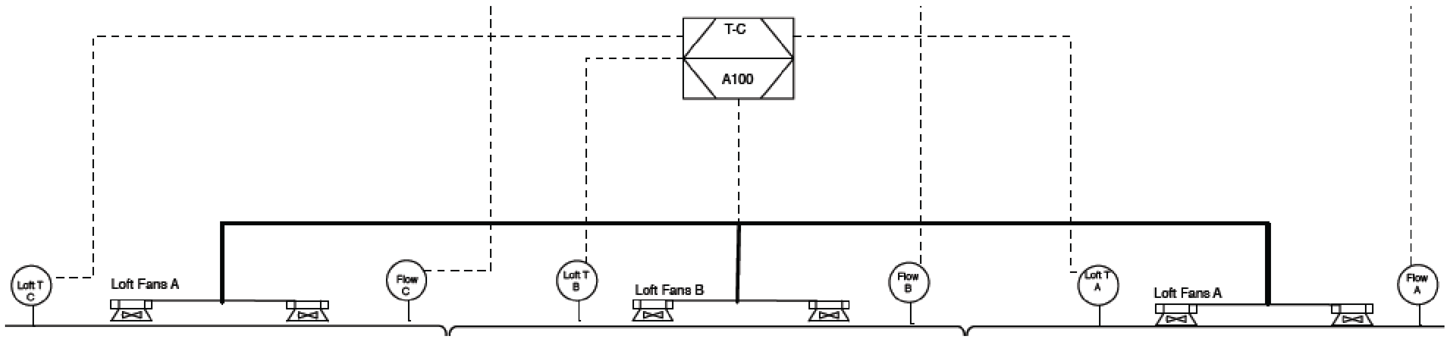
PARx MEASURE can also be used to check if the lamp status is coherent with the LIGHT status.

if (PAR MEASURE < lower_limit) and LIGHTx = ON then ALARM

if (PAR MEASURE > higher_limit) and LIGHTx = OFF then ALARM

4.2. Lighting Loft Temperature Control

No control loop. Checking if temperature if under a high limit.



4.2.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
21	455_1	Lighting Loft Temperature Control	IS_455_1_01	IS_455_1_01	Y		Flow/Noflow of Light Loft Fan A
22	455_1	Lighting Loft Temperature Control	IS_455_1_02	IS_455_1_02	Y		Flow/Noflow of Light Loft Fan B
23	455_1	Lighting Loft Temperature Control	IS_455_1_03	IS_455_1_03	Y		Flow/Noflow of Light Loft Fan C
24	455_1	Lighting Loft Temperature Control	GP_455_1_01	GP_455_1_01_ MV		Y	Operation of Light Loft Fan A
25	455_1	Lighting Loft Temperature Control	GP_455_1_02	GP_455_1_02_ MV		Y	Operation of Light Loft Fan B
26	455_1	Lighting Loft Temperature Control	GP_455_1_03	GP_455_1_03_ MV		Y	Operation of Light Loft Fan C
27	455_1	Lighting Loft Temperature Control	TT_455_1_01	TT_455_1_01	Y		Light Loft Temperature sensor A
28	455_1	Lighting Loft Temperature Control	TT_455_1_02	TT_455_1_02	Y		Light Loft Temperature sensor B
29	455_1	Lighting Loft Temperature	TT_455_1_03	TT_455_1_03	Y		Light Loft Temperature sensor

		Control					C

4.2.2.Sensors

3 Temperatures sensors in the loft, in each zone (A B and C) 3 * AI
3 Loft Fan Status (Flow/No Flow) 3 * DI

4.2.3.Actuators and manipulated variables

.3 Light Loft Fans 3 * DO

4.2.4.Disturbances

Lights is the main disturbance

4.2.5.Control

4.2.5.1. *Specification*

- Check if temperature in the 3 zones is under a Limit. (35 °C for instance)
- If not :
  - Alarm
  - Switch Off the lights
- Check if Fan Status is ON,
- If not :
  - Alarm

4.2.5.2. *Control Strategy*

1/ A soon as any string of light is ON → fans ON

2/ if temp. > limit then
- all lights OFF
- all fans remains ON, during 20 minutes after temp comes back under the limit.
- fan OFF if light OFF and temp. below limit for 20 minutes

(20 minutes is a parameter)

3/ Switching ON the light is only a manual operation (operator)

5. LIQUID SYSTEM

Global Diagram is the following (TN85.5).
Even if this diagram is obsolete it represents the main parts of the process

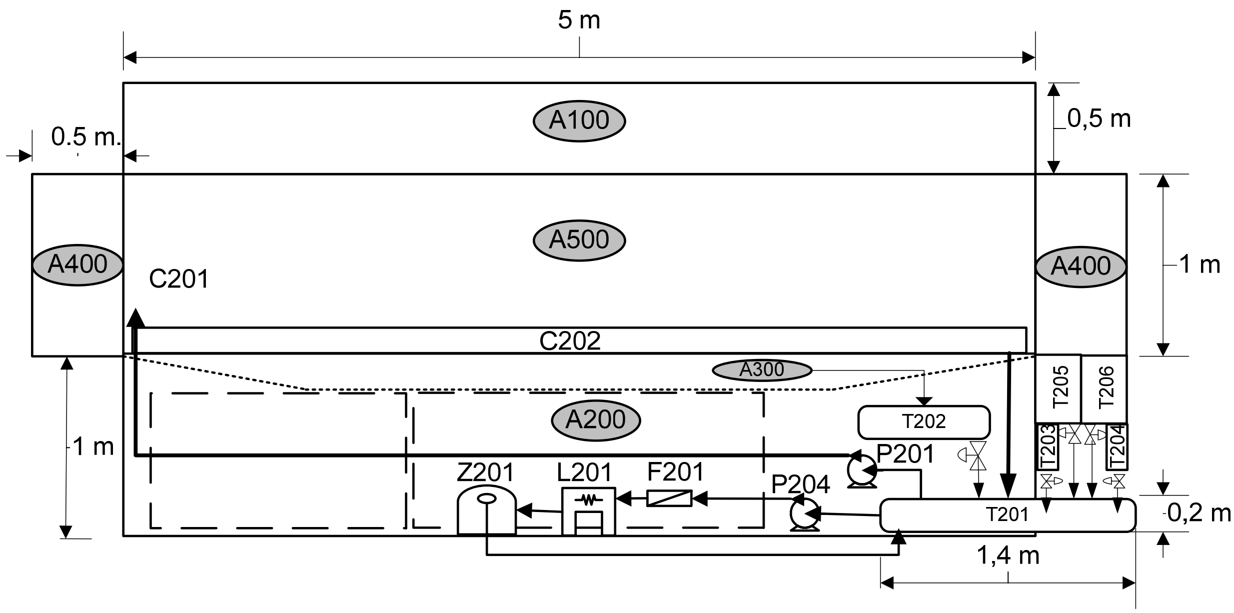


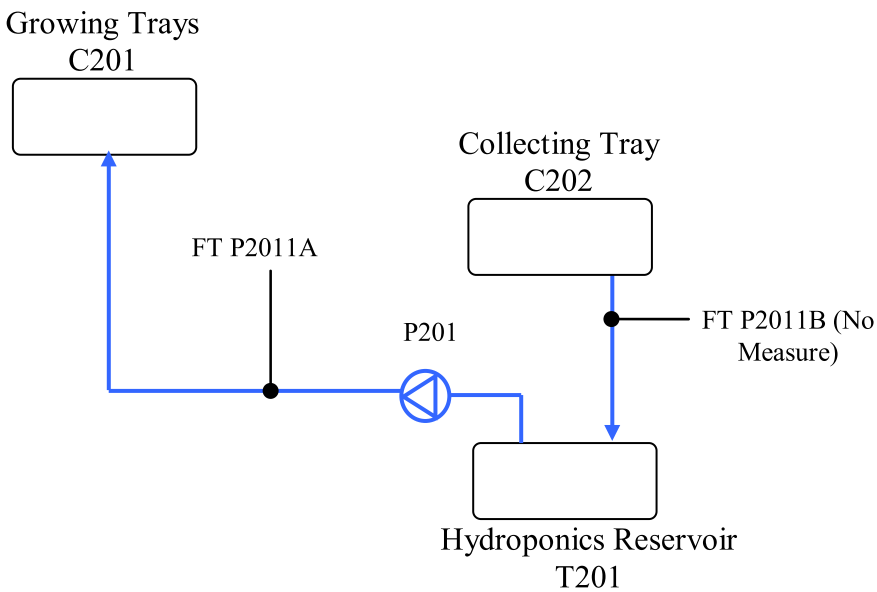
Figure 5 : Representation of the Liquid System

C201 : growing tray
C202 : collecting tray
T201 : nutrient tank
T202 : condensate tank
P201 : main irrigation pump
T203 : acid tank
T204 : base tank
T205 : stock A tank
T206 : stock B tank

But,

P204, FZ01, L201 and Z201 does not exist anymore in the final version of HPC.

5.1. Hydroponics Reservoir Pump



5.1.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
30	456_1	Irrigation System	GP_456_1_01	GP_456_1_01_ MV		Y	Main irrigation Pump P2001
31	456_1	Irrigation System	FT_456_1_01	FT_456_1_01	Y		Outlet nutrient flow sensor

5.1.2.Sensors

1 flow sensor 1 x AI
FT P2011 A : between the reservoir pump P201 and the growing trays C201

The second flow was suppressed in the final design of HPC

FT P2011 B : between the collecting tray C202 and the input of the reservoir tank

5.1.3.Actuators and manipulated variables

Pump Relay (Irrigation pump P201) 1 x DO

5.1.4.Disturbances

Trays Overflow.

5.1.5.Control

5.1.5.1. *Specification*

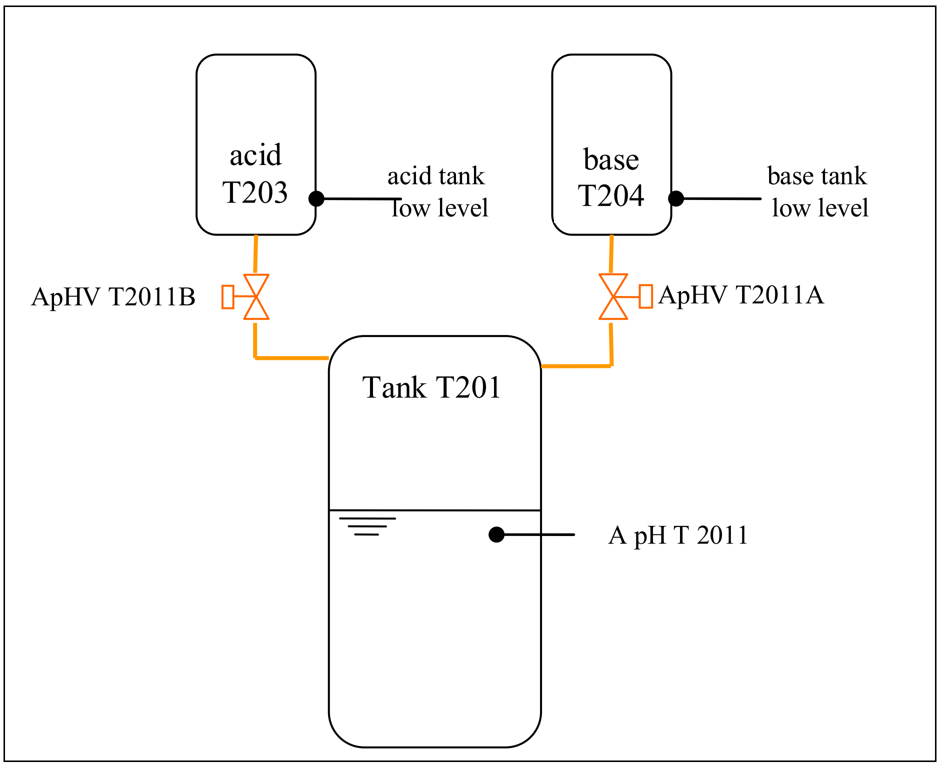
Prevent Tray Overflow by stopping the Nutrient pump.

5.1.5.2. *Control Strategy*

No control strategy.
Pump is always ON.

5.2. pH in the solution

The pH must be kept between two limits



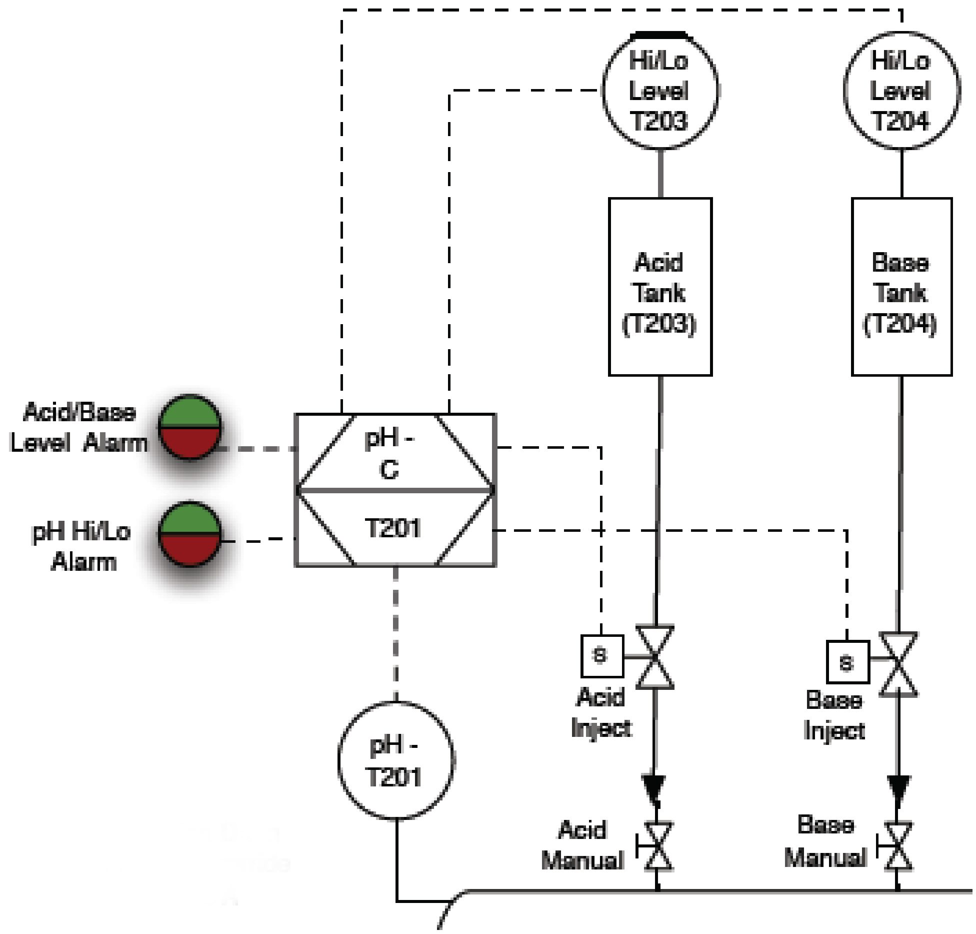


Figure 6 P&ID Waters. pH Control loop

5.2.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
32	457_1	pH Control	AT_457_1_01	AT_457_1_01	Y		pH sensor
33	457_1	pH Control	SV_457_1_01	SV_457_1_01_ MV		Y	Acid Tank Valve
34	457_1	pH Control	SV_457_1_02	SV_457_1_02_ MV		Y	Base Tank Valve
35	457_1	pH Control	LS_457_1_01	LS_457_1_01	Y		Acid Tank Level
36	457_1	pH Control	LS_457_1_02	LS_457_1_02	Y		Base Tank Valve

5.2.2.Sensors

pH Measurement in the tank T201	AI	1
Acid Tank (T203) low level sensor	DI	1
Base Tank (T204) low level sensor	DI	1

5.2.3.Actuators and manipulated variables

Valves	DO	2

Acid Valve ApHV T2011 A
Base Valve ApHV T2011 B

5.2.4.Disturbances

Plant uptake generally results in an acidification of the nutrient solution.

5.2.5.Control

5.2.5.1. *Specification*

- Set point: 5 < pH < 6 (in steady state or transient conditions)
- or pH = 5.5 +/- 0.5

5.2.5.2. *Control Strategy*

- A split-range strategy based on a PI(Proportional Integral) or PCR(Predictive Controller) regulator

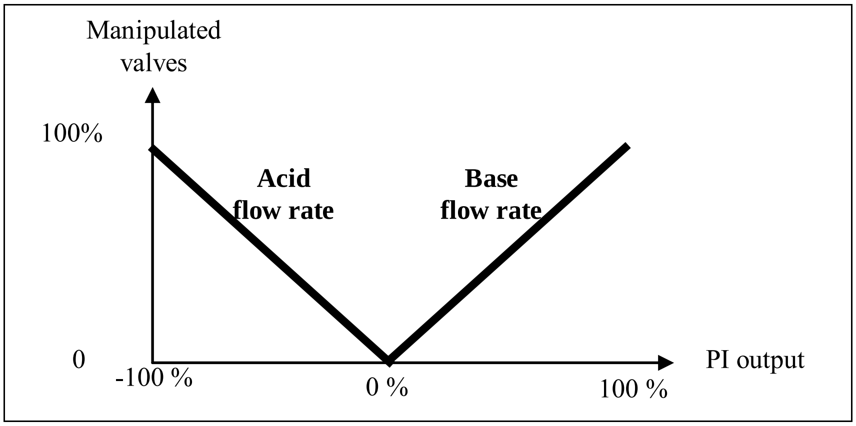
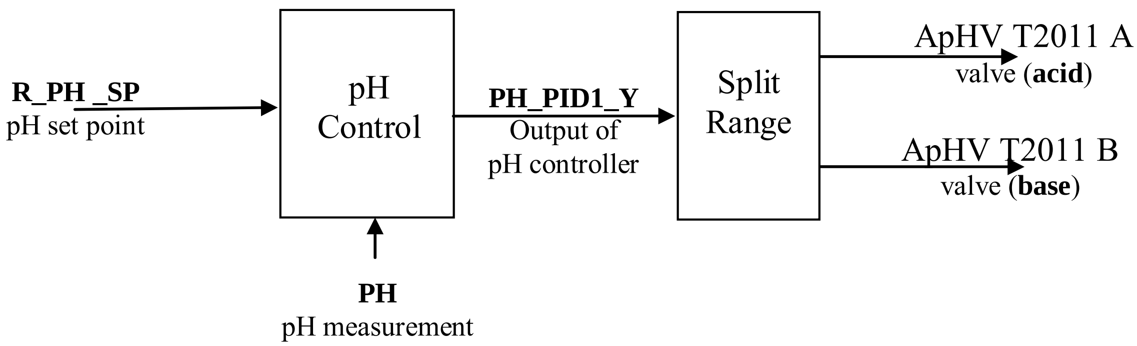


Figure 7: split-range between acid and base

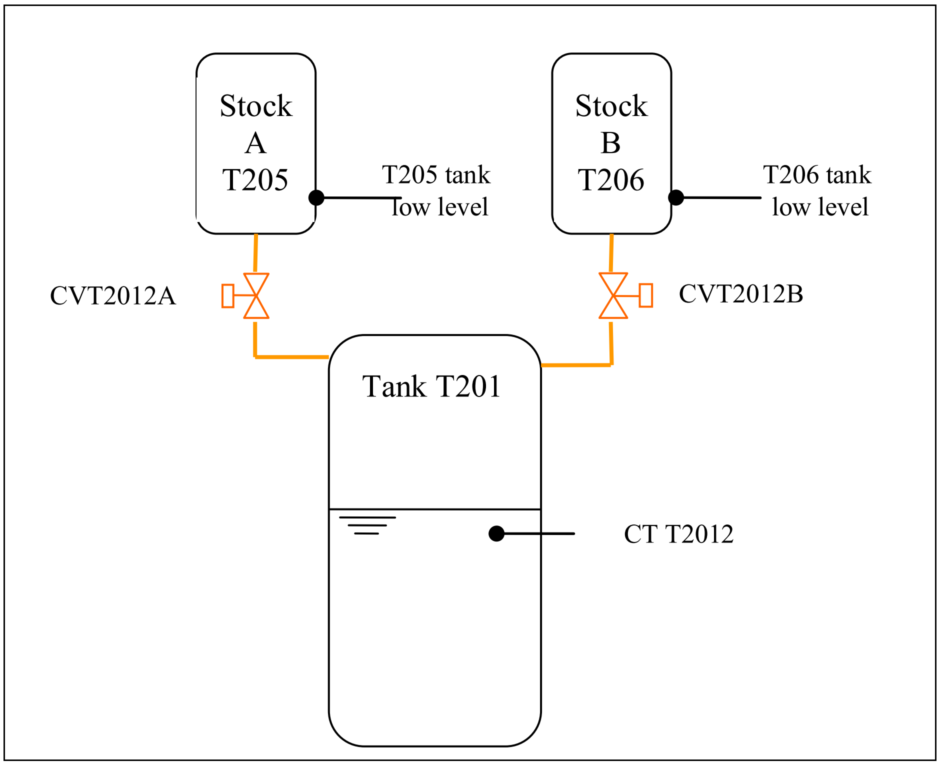


pH control is completed with a **Split-Range**.
Output of the control **PH_PID1_Y**. Range is -100/+100
-100/0 : **acid** action
0/100 : **base** action
pH control will include a **Dead Zone**

- Acid Tank Low Level → Alarm
- Base Tank Low Level → Alarm

5.3. Electrical Conductivity in the solution

Electrical Conductivity (EC) should be appropriate for the plant culture.
EC is usually around 1900 $\mu S.m^{-1}$



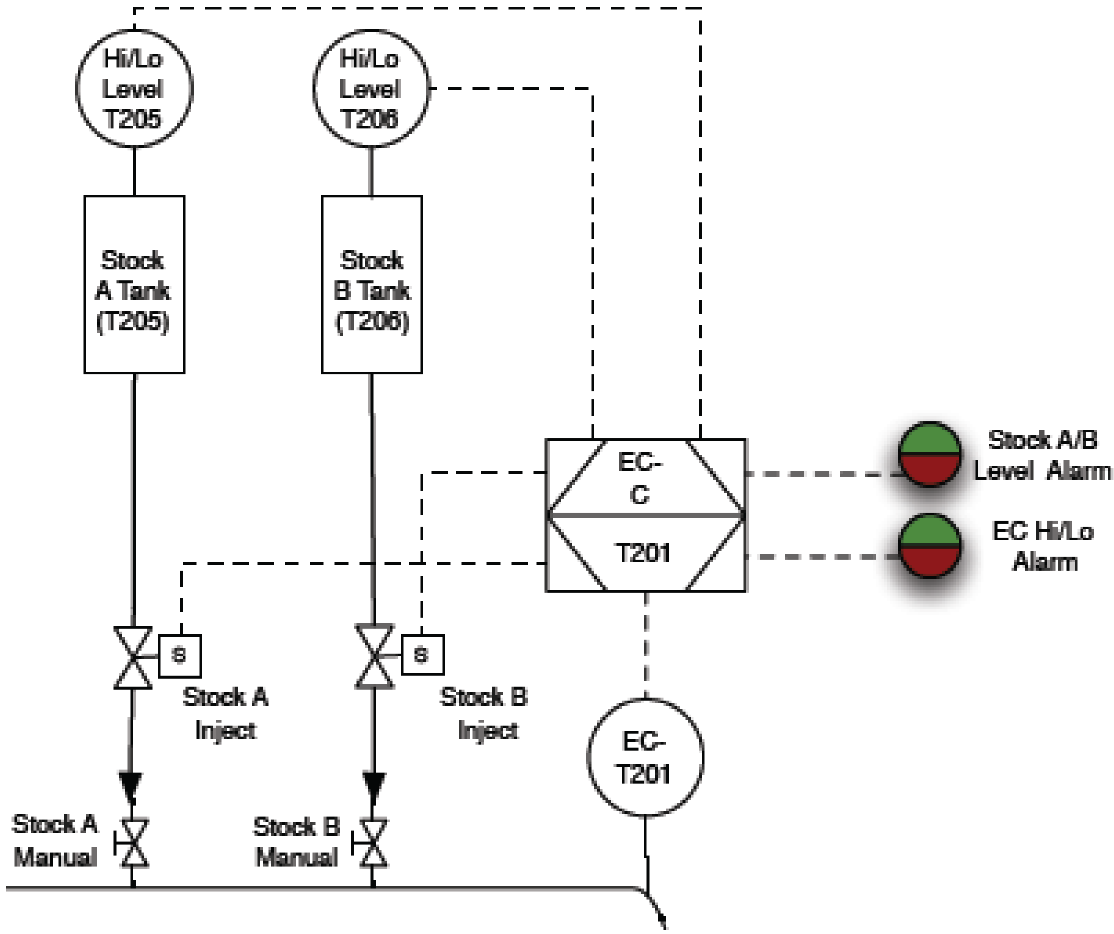


Figure 8 : P&ID Waters. EC control

5.3.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
37	458_1	EC Control	CT_458_1_01	CT_458_1_01	Y		Electrical Conductivity of nutrient
38	458_1	EC Control	SV_458_1_01	SV_458_1_01_MV		Y	Stock A inject Valve
39	458_1	EC Control	SV_458_1_02	SV_458_1_02_MV		Y	Stock B inject Valve
40	458_1	EC Control	LS_458_1_01	LS_458_1_01	Y		Level sensor Stock A
41	458_1	EC Control	LS_458_1_02	LS_458_1_02	Y		Level sensor Stock B

5.3.2.Sensors

EC sensor	AI	1
Tank (T205) low level sensor	DI	1
Tank (T206) low level sensor	DI	1

5.3.3.Actuators and manipulated variables

Valves	DO	2

Stock A Valve	CV T2012 A
Stock B Valve	CV T2012 B

5.3.4.Disturbances

Plant consumption of nutrient.

5.3.5.Control

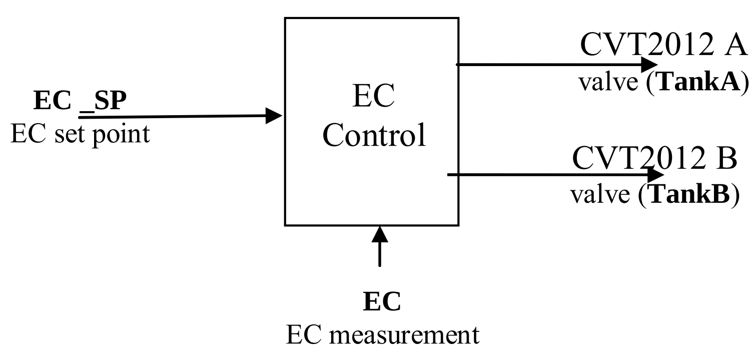
5.3.5.1. *Specification*

EC Set Point or EC Range

5.3.5.2. *Control Strategy*

Fixed Proportion between Stock A and Stock B : input parameters.

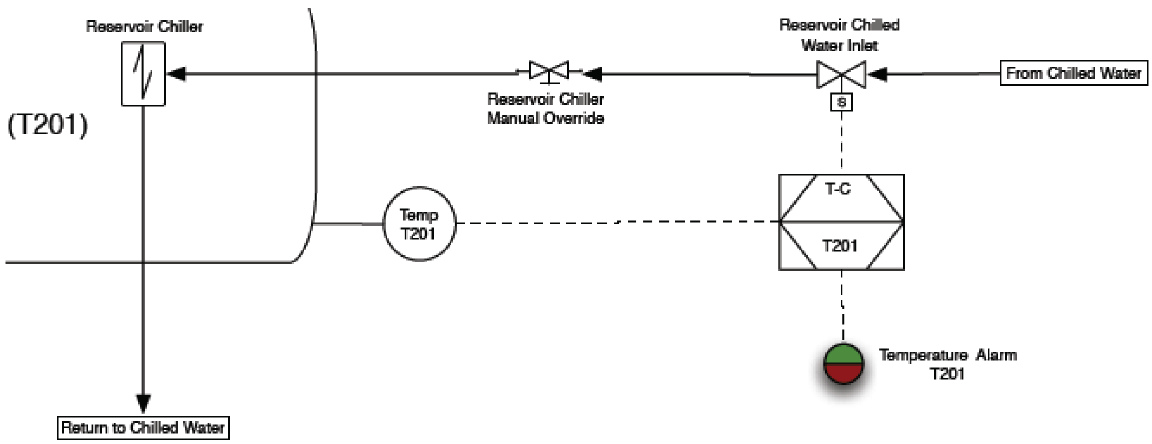
PI/PCR Controller.



- Tank A Low Level → Alarm
- Tank B Low Level → Alarm

- EC outside range → Alarm

5.4. Control of Nutrient Tank Temperature



Cooler Line Temperature is about 8 °C.
¼" stainless line carrying 8°C chilled water. The line will be snake.

5.4.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
42	459_1	Nutrient Tank Temperature Control	TT_459_1_01	TT_459_1_01	Y		Temperature sensor for solution reservoir
43	459_1	Nutrient Tank Temperature Control	SV_459_1_01	SV_459_1_01_ MV		Y	Nutrient cooling line valve

5.4.2.Sensors

Tank Temperature Sensor AI 1

5.4.3. Actuators and manipulated variables

Nutrient Tank Cooling Line Valve	DO	1

5.4.4. Disturbances

Temperature of the chamber

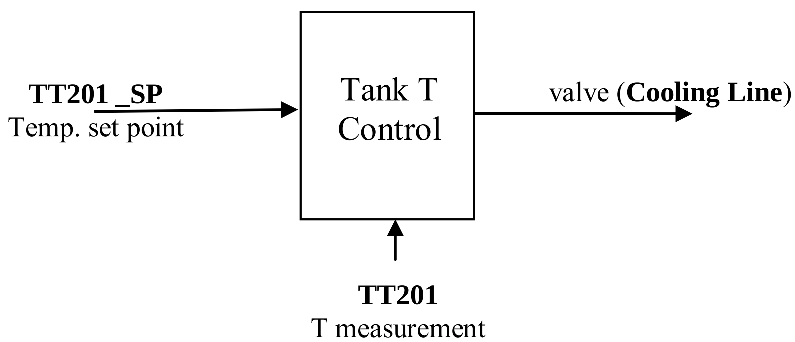
5.4.5. Control

5.4.5.1. *Specification*

Maintain the Tank Temperature at a specific Set Point = chamber set point.
For physiological reasons, the difference between chamber temperature and the nutrient solution temperature should not exceed 2 °C.

5.4.5.2. *Control Strategy*

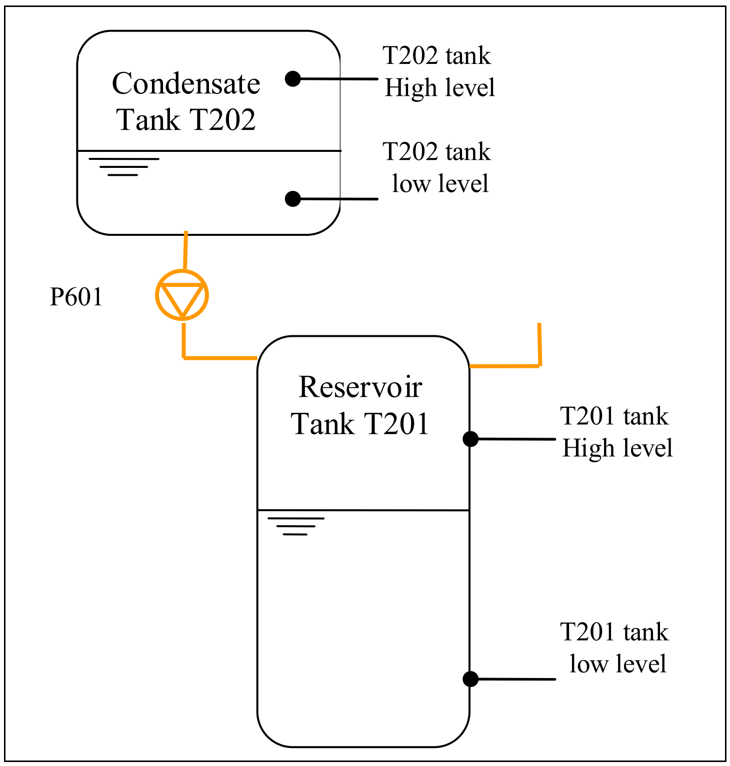
Controller (PI/PCR).

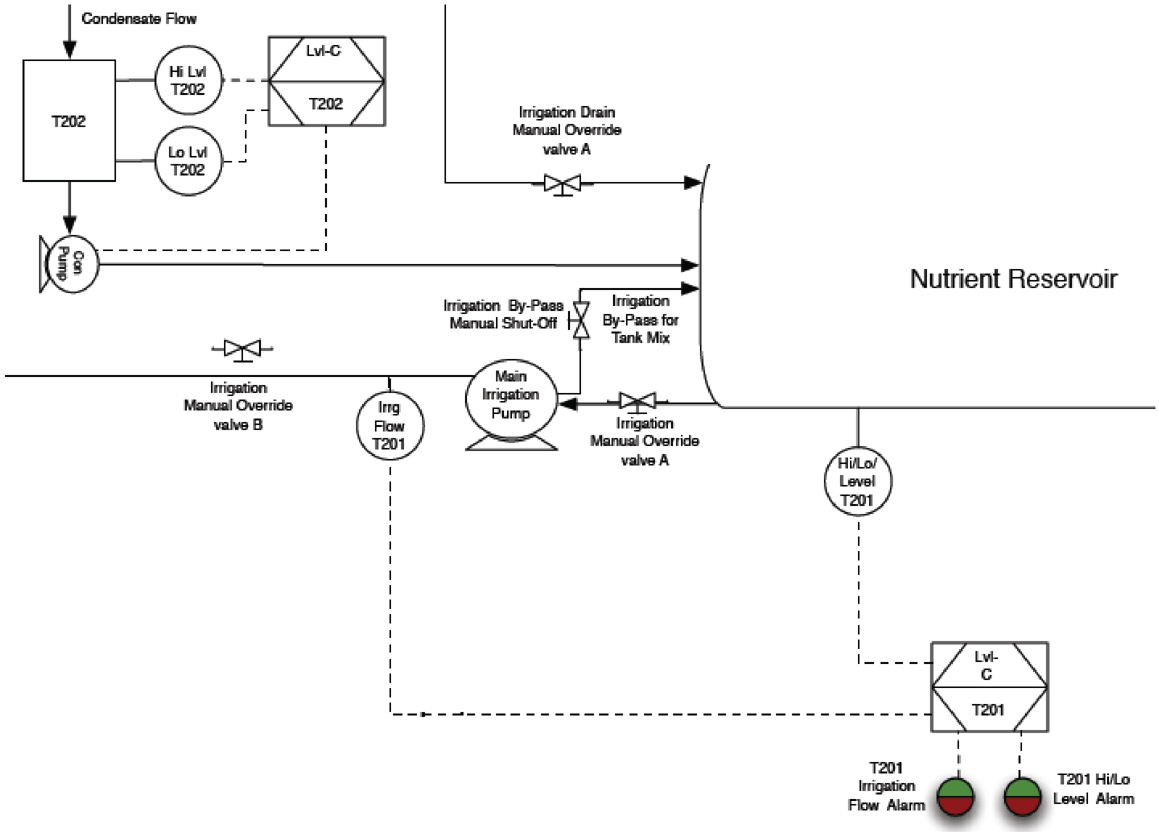


Important Remark : Only decreasing set point can be controlled with a cooler line.

5.5. Control of Nutrient Solution and Condensate Water Levels

Process Description





5.5.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
44	460_1	Nutrient and Condensate Levels Control	LSH_460_1_01	LSH_460_1_01	Y		High Level sensor for reservoir tank
45	460_1	Nutrient and Condensate Levels Control	LSL_460_1_01	LSL_460_1_01	Y		Low Level sensor for reservoir tank
46	460_1	Nutrient and Condensate Levels Control	LSH_460_1_02	LSH_460_1_02	Y		High Level sensor for condensate tank
47	460_1	Nutrient and Condensate Levels Control	LSL_460_1_02	LSL_460_1_02	Y		Low Level sensor for condensate tank
48	460_1	Nutrient and Condensate Levels Control	GP_460_1_01	GP_460_1_01_ MV		Y	Condensate pump relay

5.5.2.Sensors

T202 (Condensate) Tank, Low and High Level	DI	2
T201 (Reservoir) Tank, Low and High Level	DI	2

5.5.3.Actuators and manipulated variables

Pump Relay P601	DO	1

5.5.4.Disturbances

5.5.5.Control

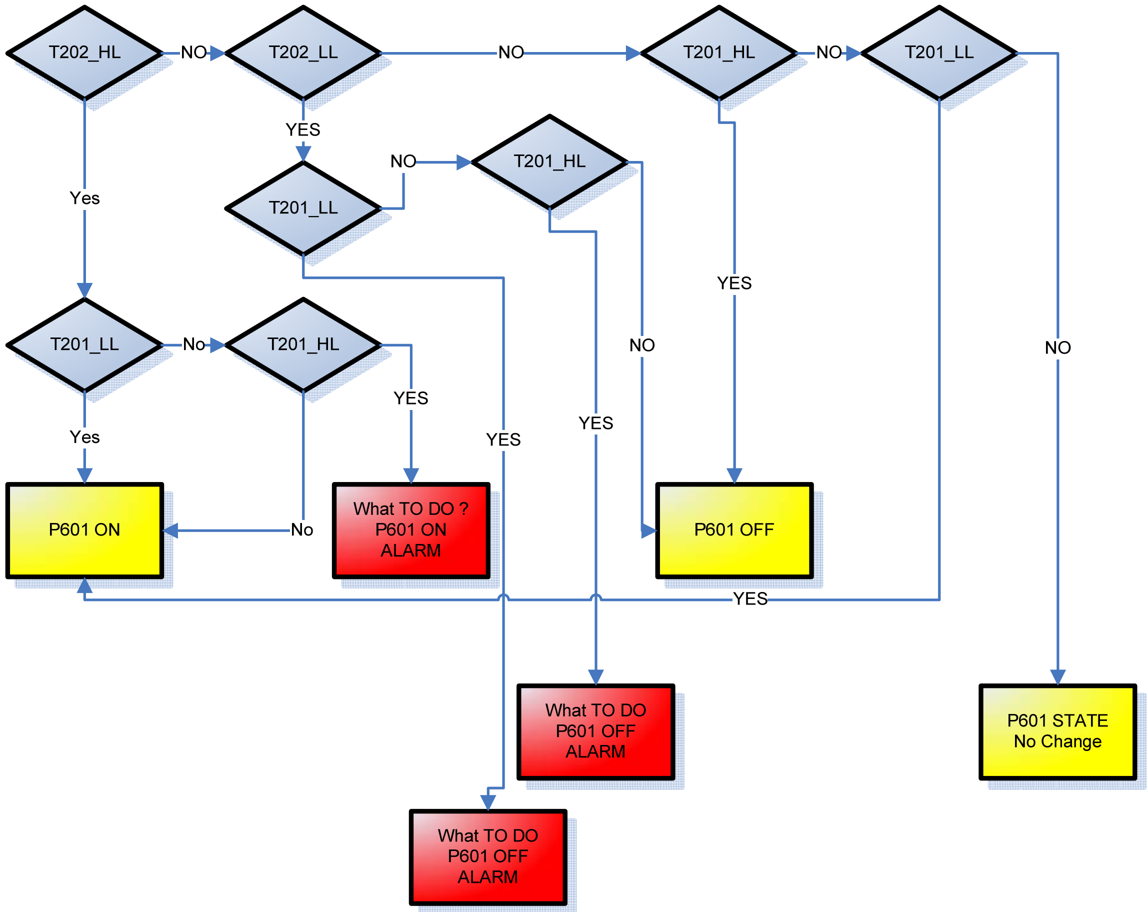
5.5.5.1. *Specification*

Maintain Level in the reservoir, between Level MIN and Level MAX

5.5.5.2. *Control Strategy*

LL = Low Level
HL = High Level

If T202 HL, PUMP ON until T202 LL


T202_HL
NO
T202_LL
NO
T201_HL
NO
T201_LL
YES
Yes
NO
T201_HL
T201_LL
YES
NO
NO
T201_LL
No
T201_HL
YES
YES
YES
Yes
P601 ON
No
What TO DO ?
P601 ON
ALARM
P601 OFF
YES
What TO DO
P601 OFF
ALARM
P601 STATE
No Change
What TO DO
P601 OFF
ALARM

6. ATMOSPHERIC SYSTEM

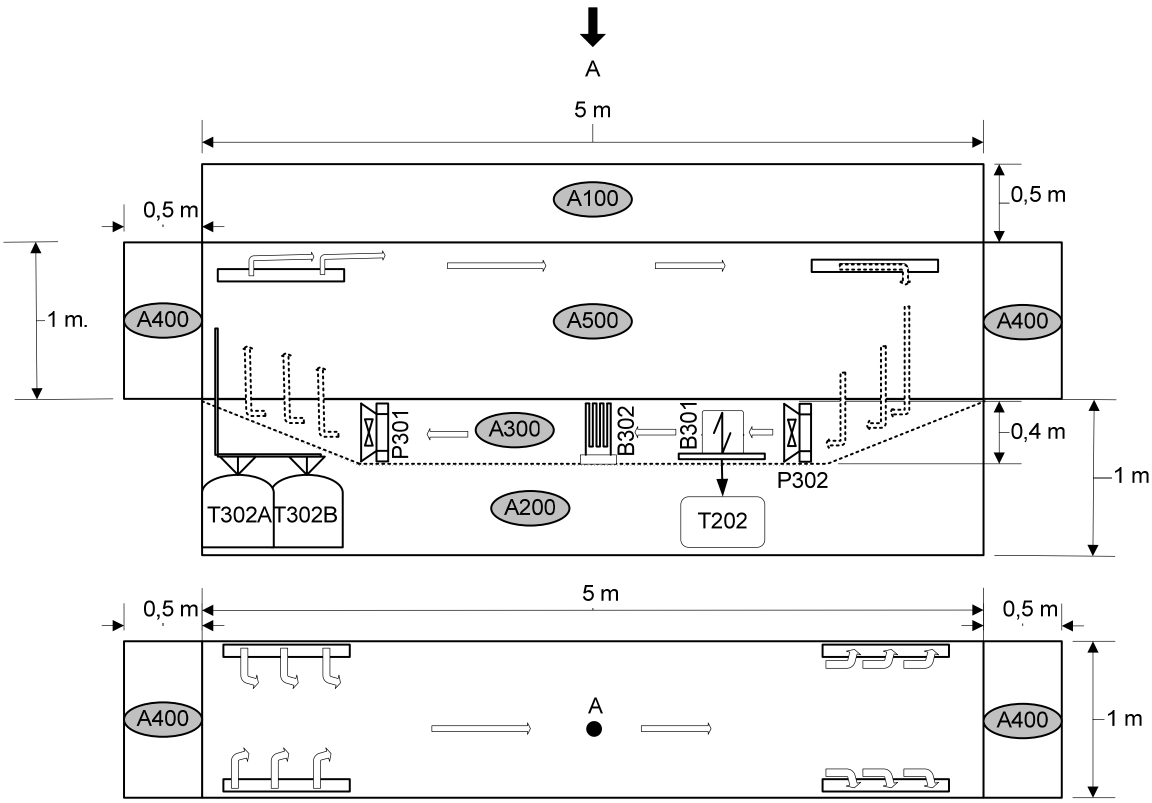


Figure 9:Air circulation patterns and handling system for the prototype chamber (Masot, 2004).

Remark :
T302A and T302B are the two Teflon Expansion bags.

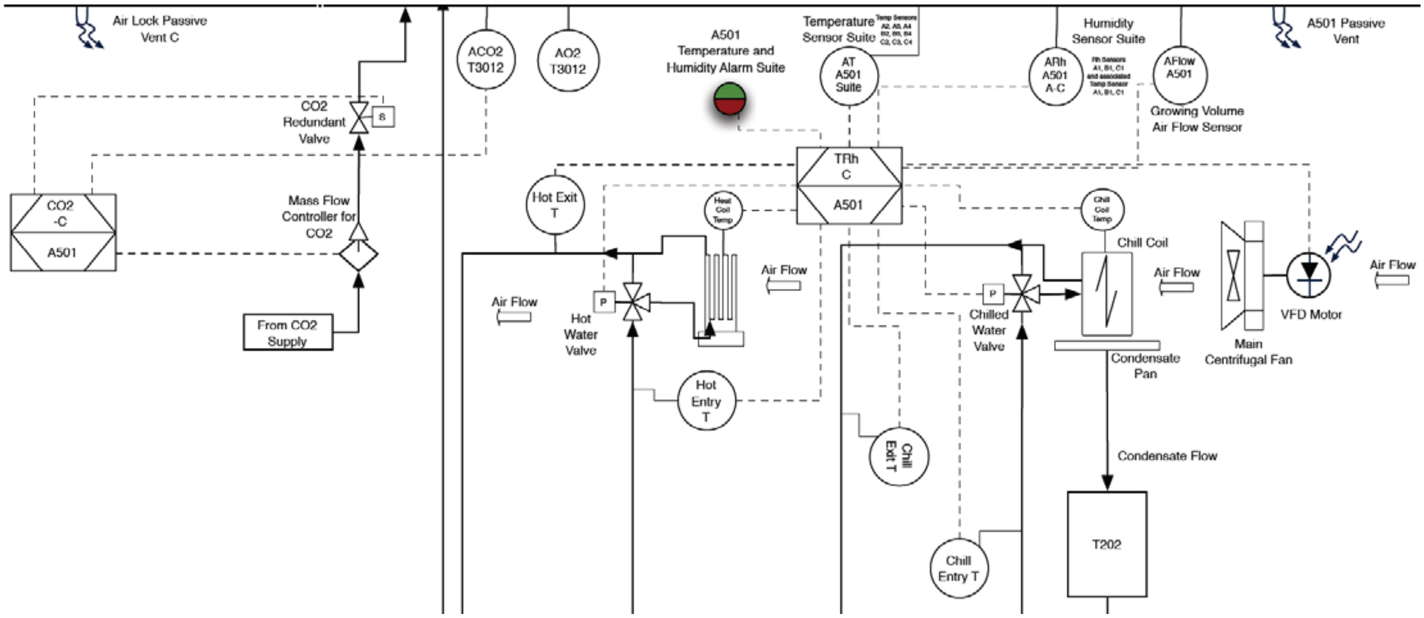


Figure 10 : P&ID Waters. Air Circulation

6.1. Control of Air Circulation fans

6.1.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
49	461_1	Control of Air circulation fans	GP_461_1_01	GP_461_1_01_ MV		Y	Air circulation fan with VFD
50	461_1	Control of Air circulation fans	FT_461_1_01	FT_461_1_01	Y		Air velocity sensor

6.1.2.Sensors

Air Velocity sensor (flow) AI 1

6.1.3.Actuators and manipulated variables

Air circulation Fan with variable frequency drive controller AO 1

Only one fan.

In the final design it is located at the left.

6.1.4. Disturbances

N/A

6.1.5. Control

6.1.5.1. *Specification*

Continuous circulation of AIR inside the chamber.

6.1.5.2. *Control Strategy*

No control.

In case of failure, ALARM

6.2. Temperature & Humidity Control

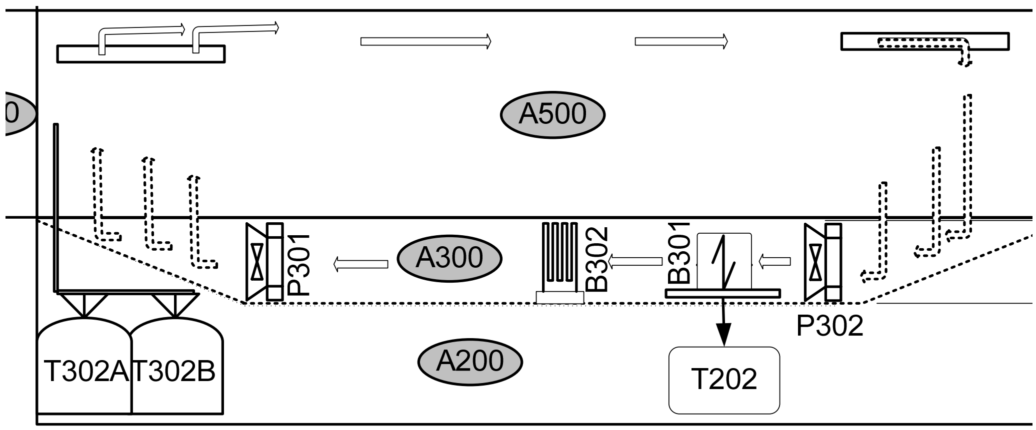


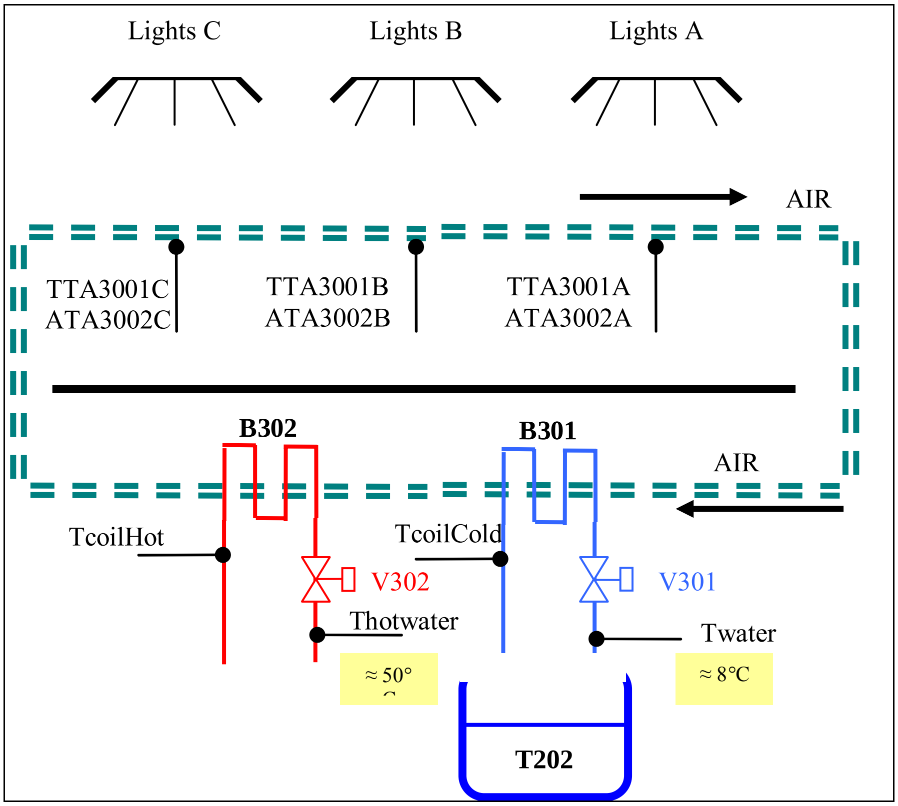
Figure 11: Temperature & Humidity

Temperature and Humidity are described in the same paragraph because they are linked
2 exchangers :

B301 : cold one

B302 : hot one

Condensation of water in the first exchanger. Condensate is collected in T202 tank (see Liquid Line control).



6.2.1. Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
51	462_1	Chamber Temperature and Humidity Control	TT_462_1_01	TT_462_1_01	Y		Temperature A1 associated with humidity
52	462_1	Chamber Temperature and Humidity Control	TT_462_1_02	TT_462_1_02	Y		Temperature A2
53	462_1	Chamber Temperature and Humidity Control	TT_462_1_03	TT_462_1_03	Y		Temperature A3
54	462_1	Chamber Temperature and Humidity Control	TT_462_1_04	TT_462_1_04	Y		Temperature A4

55	462_1	Chamber Temperature and Humidity Control	TT_462_1_05	TT_462_1_05	Y		Temperature B1 associated with humidity
56	462_1	Chamber Temperature and Humidity Control	TT_462_1_06	TT_462_1_06	Y		Temperature B2
57	462_1	Chamber Temperature and Humidity Control	TT_462_1_07	TT_462_1_07	Y		Temperature B3
58	462_1	Chamber Temperature and Humidity Control	TT_462_1_08	TT_462_1_08	Y		Temperature B4
59	462_1	Chamber Temperature and Humidity Control	TT_462_1_09	TT_462_1_09	Y		Temperature C1 associated with humidity
60	462_1	Chamber Temperature and Humidity Control	TT_462_1_10	TT_462_1_10	Y		Temperature C2
61	462_1	Chamber Temperature and Humidity Control	TT_462_1_11	TT_462_1_11	Y		Temperature C3
62	462_1	Chamber Temperature and Humidity Control	TT_462_1_12	TT_462_1_12	Y		Temperature C4
63	462_1	Chamber Temperature and Humidity Control	TT_462_1_13	TT_462_1_13	Y		Temperature for facility chilled water
64	462_1	Chamber Temperature and Humidity Control	TT_462_1_14	TT_462_1_14	Y		Temperature for facility hot water line
65	462_1	Chamber Temperature and Humidity Control	TT_462_1_15	TT_462_1_15	Y		Chilled coil surface temperature
66	462_1	Chamber Temperature and Humidity Control	TT_462_1_16	TT_462_1_16	Y		Heating coil surface temperature
67	462_1	Chamber Temperature and Humidity Control	TT_462_1_17	TT_462_1_17	Y		Chilled Exit temperature

68	462_1	Chamber Temperature and Humidity Control	TT_462_1_18	TT_462_1_18	Y		Hot Exit temperature
69	462_1	Chamber Temperature and Humidity Control	AT_462_1_01	AT_462_1_01	Y		Humidity A1 associated with temp A1
70	462_1	Chamber Temperature and Humidity Control	AT_462_1_02	AT_462_1_02	Y		Humidity B1 associated with temp B1
71	462_1	Chamber Temperature and Humidity Control	AT_462_1_03	AT_462_1_03	Y		Humidity C1 associated with temp C1
72	462_1	Chamber Temperature and Humidity Control	CV_462_1_01	CV_462_1_01_MV		Y	Chilled Water Control Valve
73	462_1	Chamber Temperature and Humidity Control	CV_462_1_02	CV_462_1_02_MV		Y	Hot Water Control Valve

6.2.2.Sensors

Temperature Sensors in each zone (3)	AI	3*3
TTA3001A A2 A3 A4		
TTA3001B B2 B3 B4		
TTA3001C C2 C3 C4		
And Temperature with Humidity Sensors	AI	2*3
TT A1 B1 C1		
MT A1 B1 C1		
ATA3002C1		
Temperature Sensor for Chilled water Line	AI	1
Temperature Sensor for Hot water Line	AI	1
Temperature Sensor for Exit Chilled water Line	AI	1
Temperature Sensor for Exit Hot water Line	AI	1
Chilled Coil Surface Temperature	AI	1
Hot Coil Surface temperature	AI	1

6.2.3.Actuators and manipulated variables

Chilled water control valve and Hot water control valve	AO	2

6.2.4.Disturbances

Disturbances for Temperature control and humidity are :

- Lights
- H20 production by the plant.

6.2.5.Control

6.2.5.1. *Specification*

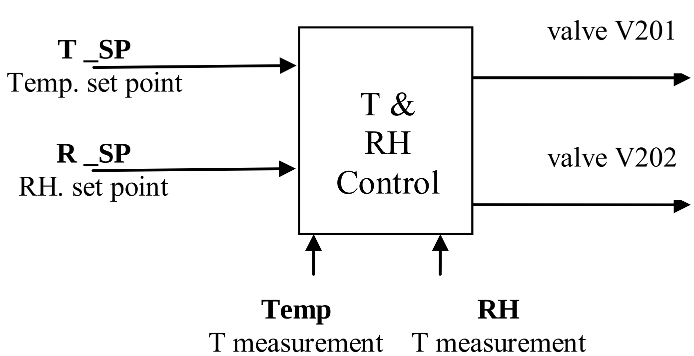
Temperature : Set Point.

Temperature to be controlled is a linear weighting of the 3 measured temperatures Temperature set point can be changed depending on the HPC strategy.

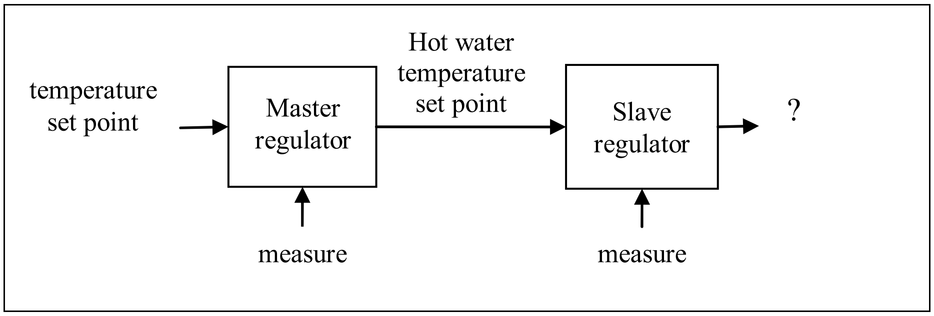
Humidity : Maintain humidity into a range [RHmin RHmax] : 50 – 85 %.
Accuracy : 2 %
Expected response time :

6.2.5.2. *Control Strategy*

2 variables to control with two Manipulated Variable.



The strategy for the control of both temperatures and humidity will be developed in TN95.2



6.3. CO2 Control

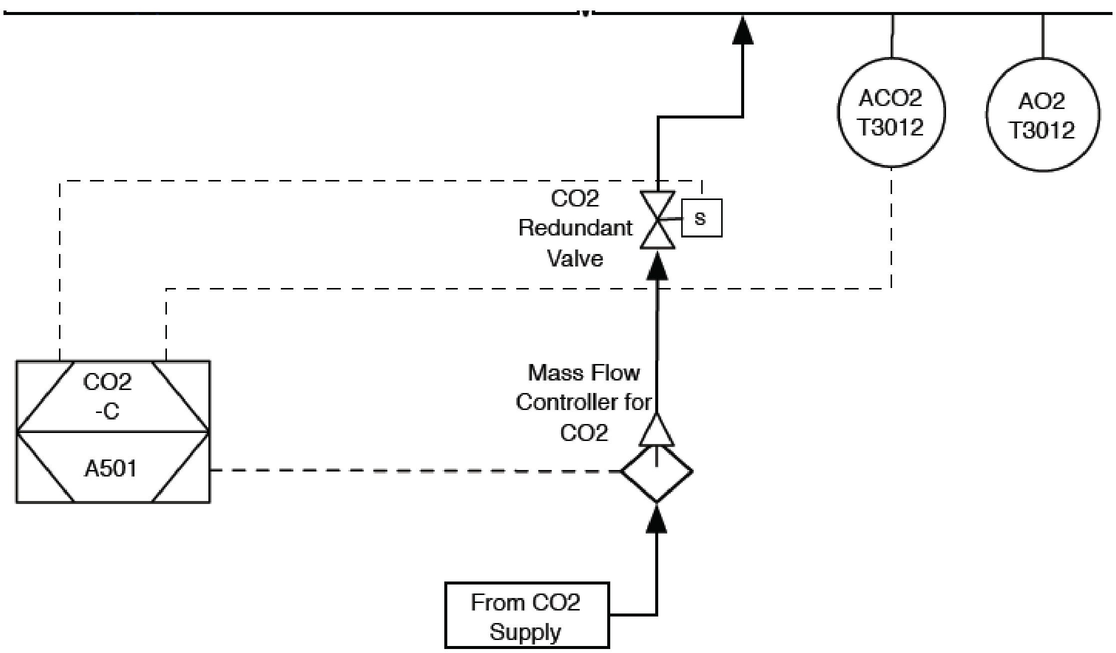


Figure 12 : P&ID Waters. CO2 control

6.3.1.Control Loop and Variables

FC_463_1_01 is a Mass Flow Controller for feed to analyser (if this technology is necessary for the last design)

#	Control Loop	Control_Loop_Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
74	463_1	CO2 Control	FC_463_1_01	FC_463_1_01	Y		CO2 Mass Flow
75	463_1	CO2 Control		FC_463_1_01_SP		Y	CO2 Mass Flow set point

76	463_1	CO2 Control	AT_463_1_01	AT_463_1_01	Y		CO2 Analyser
77	463_1	CO2 Control	AT_463_1_02	AT_463_1_02	Y		O2 Analyser
78	463_1	CO2 Control	SV_463_1_01	SV_463_1_01_MV		Y	CO2 injection line. Solenoid
79	463_1	CO2 Control	FC_463_1_02	FC_463_1_02	Y		Injection Line - CO2 Mass Flow
80	463_1	CO2 Control		FC_463_1_02_SP		Y	Injection Line - CO2 Mass Flow set point

6.3.2. Sensors

CO2 mass flow sensor and actuator AI : 1 (flow)
AO: 1 (flow set point)

CO2 sensor ATCOA3003 AI 1
O2 sensor ATO2A3003 AI 1

6.3.3. Actuators and manipulated variables

Redundant Valve DO 1

6.3.4. Disturbances

CO2 consumption or production by the crop depending on the LIGHT levels.

6.3.5. Control

6.3.5.1. *Specification*

CO2 set point. 1000 ppm +/- 5ppm.

6.3.5.2. *Control Strategy*

Will be developed in the TN95.2

6.1. Pressure Control

There is no active pressure control.
Pressure is passively controlled with two Teflon bags T302A and T302B.

6.1.1.Control Loop and Variables

#	Control Loop	Control_Loop_ Name	Instrument Tag Name	Tag Variable	Inputs	Outputs	Description
81	464_1	Chamber Pressure	PT_464_1_01	PT_464_1_01	Y		Growing Area Pressure

6.1.2.Sensors

Pressure Sensor AI

7. Non Functional Requirements. Other Requirements.

(Source : TN74.2)

Operational

Operation Modes

Reliability

Maintainability

CS-MAN-100
The Control System shall be designed taking into account that the system can evolve, change or expand, in order to minimise the impact.
CS-MAN-110
The selection of technologies for the Control System shall take into account the maintenance and support for the purchased elements for a long period (>5 years).
CS-MAN-120
The Control System shall allow the fixing or replacement of broken or damaged parts without affecting the MELISSA function.

Security

CS-SEC-100
The Control System shall provide security in the operations performed.

Safety

CS-SFY-100
For functions identified as potential safety hazards, specific backups shall be provided.
CS-SFY-110
All critical functions controlled by software and identified as potential safety hazards shall feature a hardware backup.

No Hazards identified

8. Document with all control Requirements

Hereafter are the control requirements.

Control Loop number	Description	Objective	Performances
450_1	Exterior Air Lock Door Control - Side A	Alarm and LED if door open (One of the contactor)	N/A
451_1	Exterior Air Lock Door Control - Side C	Alarm and LED if door open (One of the contactor)	N/A
452_1	Air Lock Purge Control - Side A	N/A	N/A
453_1	Air Lock Purge Control - Side C	N/A	N/A
454_1	Light Intensity Control	Switch ON or OFF Lights, following a defined strategy DAY/NIGHT per STRING	N/A
455_1	Lighting Loft Temperature Control	Switch Off Lights if temperature above limit	N/A
456_1	Irrigation System	N/A	N/A
457_1	pH Control	Control the pH between 5 and 6	pH = 5.5 +/- 0.5 Time Response : TBD
458_1	EC Control	Control EC	EC = 1900 µS/m +/- X Time Response : TBD
459_1	Nutrient Tank Temperature Control	Maintain Tank Temperature at the Chamber temperature set point	Deviation 2 °C max between Set Point and Measure Time Response (when decreasing set point) : TBD
460_1	Nutrient and Condensate Levels Control	Maintain level between MIN and MAX	N/A
461_1	Control of Air circulation fans	Continuous Air circulation in the chamber	N/A
462_1	Chamber Temperature and Humidity Control	Temperature Set Point control Humidity Range control	Temperature Response : TBD Humidity should be maintained between 50 and 85 % Response Time : TBD
463_1	CO2 Control	Set Point Control	Set Point 1000 ppm +/- 5 ppm
464_1	Chamber Pressure	No control	N/A
465_1	Ambient Parameters	N/A	N/A

SECTION 2

MELISSA Pilot Plant Higher Plants Chamber: Control Software Design

TN 95.1

MELISSA SOFTWARE DESIGN AND IMPLEMENTATION GUIDELINES DOCUMENT

APPROVAL LIST		
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DISTRIBUTION LIST		
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CHANGE RECORD			
AUTHOR	ISSUE	DATE	CHANGE
J. Duatis	1.0	28/03/2008	First version

CONTENTS

ACRONYMS LIST

CPU	Central Processor Unit
FBD	Functional Block Diagram
HMI	Human Machine Interface
IP	Internet Protocol
MELiSSA	Micro Ecological Life Support System Alternative
PC	Personal Computer
PID	Proportional Integrator Derivative controller
P&ID	Process and Instrumentation Diagram
PLC	Programmable Logic Controller
STP	Shielded Twisted Pair

0. SCOPE

This document will define guidelines for designing and implementing concept software for the MELiSSA Pilot Plant control system.

1. APPLICABLE AND REFERENCE DOCUMENTS

1.1 Applicable Documents

[A 1] SHERPA ENGINEERING, Purchase Order P1804_NTE, MELiSSA HPC Control System, dated 03/04/07

1.2 Reference Documents

[R 1] Concept User Manual. 840 USE 493 00 Version 2.5 SR2

[R 2] Magelis software user manual

[R 3] iFix Software User Manual

[R 4] TN 78.72. Technical Data Base of MELiSSA, issue 1.2 Draft, March 2008.

[R 5] MEL-3100-SP-010-NTE. TN 72.2, Definition of the Control Requirements for the Complete MELISSA Loop. Version 1.2. 25 November 2002.

[R 6] MEL-3200-RP-014-NTE. TN 72.3 Study of MELISSA Control System Architecture and Trade-off, Version 1.0, 5 Feb 2003

[R 7] TN 72.4 Control System Demonstrator. Hardware Design Document. Volume II-b, Version 1.1, 28 July 2004

[R 8] MEL-3320-RP-020-NTE. TN 72.4 Control System Demonstrator. Software Design Document. Volume II-a, Version 1.1, 28 Jul 2004.

[R 9] MEL-3320-HB-042-NTE. Control System Demonstrator. Operations Manual. Volume II-c. Version 1.1, 28 July 2004

[R 10] TN 78.71. Technical Data Base of MELiSSA, issue 1.0, 04/04/2006.

2. CONTROL SYSTEM ARCHITECTURE

According to the analysis performed in [R6], the architecture depicted in Figure 2-1 was proposed for the MELISSA's Control System.

Based on the conclusions drawn from the above mentioned studies two elements within the new architecture were already set forth:

- The distributed architecture
- The use of Ethernet in control networks.

2.1 Distributed Architecture

The distributed architecture provides the following characteristics:

- Reliability: failure in upper levels does not affect lower levels.
- Scalability: dividing the functions into different separated devices allows scaling precisely where necessary.
- Performance: again separating functions into different devices allows the use of specific hardware that will better satisfy performance requirements at each level.

2.2 Control Network

Control network is based on Switched Ethernet since it has become deterministic, fault tolerant and covers large distances.

Additionally, Ethernet offers the possibility of interconnecting heterogeneous devices using wide available interfaces, reducing costs and allowing the selection of products from a large number of vendors.

Redundancy is necessary to implement a reliable network, since a failure in a network device or a broken network segment, will prevent to communicate with some or even all controllers. Therefore, network devices, network interfaces and cabling need to be redundant.

Topology selected for the network is Shielded Twisted Pair (STP) in redundant star.

2.3 Conceptual Architecture

The MELISSA Control System Architecture is presented in the next figure. Each box in the diagram corresponds to a defined function in [R1]. Controller functionality is separated into Master Control and Local Control. A brief description follows:

- **Commanding**: Development, modification and debugging of control algorithms, Supervision displays and administration of the Control System.
- **Supervision Client**: Visualisation of Supervision displays, on-line modification of variables. Execution of Planning (Level 3) algorithms to modify lower level settings. It interacts with the Supervision Server.
- **Data Management**: Storage of historical data into the Historical Database by means of a Relational Database Management System (RDBMS). It allows access to extract data for analysis, reporting, diagnostics, etc.

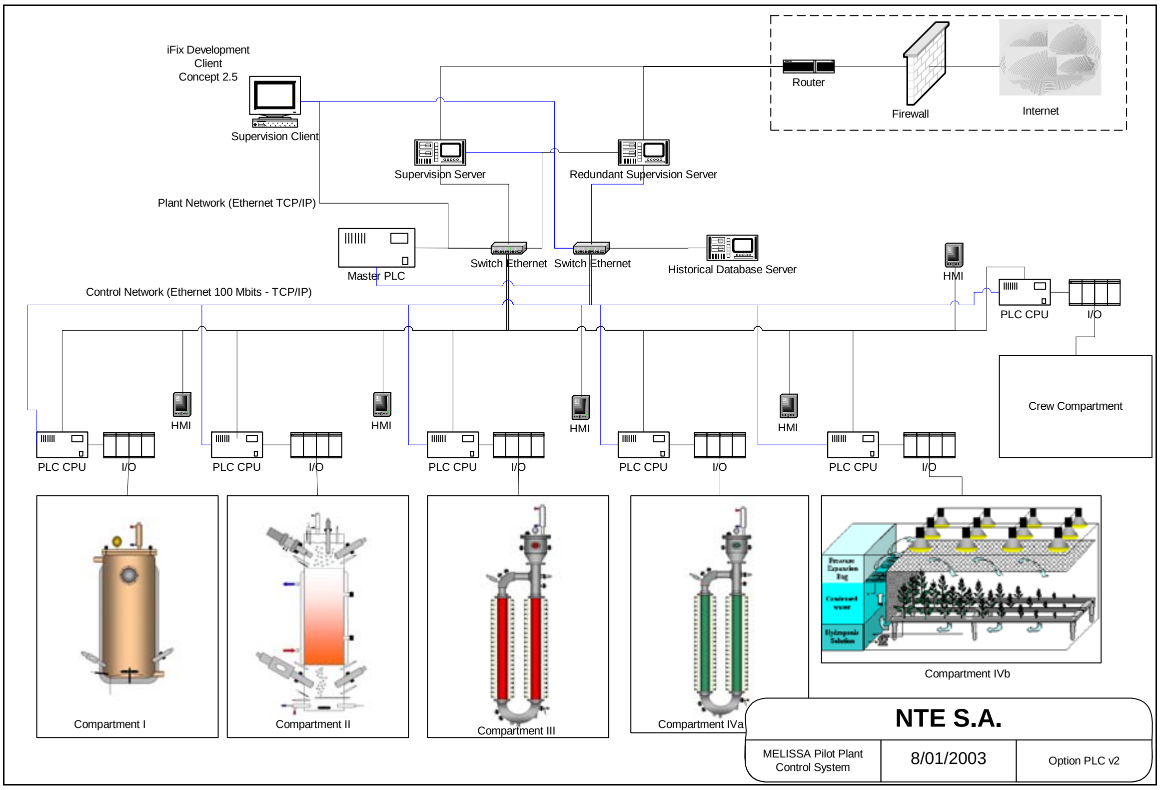


Figure 2-1: MELiSSA Control System proposed architecture

Level 0	Local controllers are implemented by means of a Programmable Logic Controllers (PLC) connected through Ethernet to the Control Network.
Level 1,2	Level 1 control can be implemented into the PLC. For instance, temperature control or pH control. Dynamic control & optimisation is implemented in a Server Computer. This Computer is communicating with the lowest levels PLC through the Control Network.
Level 3	Planning & scheduling is implemented in a Client Computer. This Client Computer is communicating with the Plant through the Plant Network.

Control of heterogeneous devices connected to the network is allowed by this configuration since several communication interfaces can be used in the Server. In addition, the control algorithms at Levels 1,2 can be implemented using general-purpose languages integrated to the Supervision Software.

Although the Server is based on a PC architecture, reliability is assured in several ways:

- Implementation of redundant parts in the Server (e.g. power supplies, fans, and hard-drives)
- Installation of two servers in “hot-standby”.

The Supervision software allows the connection of two servers to the same network. In case of failure of one of the servers, the second takes over the control in a transparent manner for the lower level controllers and the Supervision Clients.

2.4 Network Configuration

According to [R 8] the following network configuration was defined:

Network Address: 172.16.0.0 (reserved for private networks, not routed in Internet)

Group	Addresses
Supervision Servers	172.16.0.1 to 172.16.0.64
Supervision Clients	172.16.0.65 to 172.16.0.85
HMI	172.16.0.86 to 172.16.0.128
Local Control	172.16.0.129 to 172.16.0.256

Server Name	IP Address	Mask
MEL_SUPV_SERV01	172.16.0.1	255.255.255.0

Client Name	IP Address	Mask
MEL_SUPV_CLI01	172.16.0.65	255.255.255.0

HMI	IP Address	Mask
MEL_HMI_01	172.16.0.86	255.255.255.0

Local Control	IP Address	Mask
CI_PLC	172.16.0.129 (*)	255.255.255.0
CII_PLC	172.16.0.133	255.255.255.0
CIII_PLC	172.16.0.137	255.255.255.0
CIVa_PLC	172.16.0.141	255.255.255.0
CIVb_PLC	172.16.0.145	255.255.255.0

(*) Four addresses are reserved for each PLC to reserve addresses for a second CPU for redundant configuration and for a second Ethernet module to implement the redundant network.

3. CONCEPT PROGRAMMING GUIDELINES

3.1 PLC Configuration

PLC software is implemented using the Concept 2.6 programming tool provided by Schneider.

From Concept it is possible:

- To configure the PLC (see Figure 3-1).
- To program local control loops using IEC languages
- To download / upload the programs to/from the PLC
- To monitor the execution of the programs in the PLC.
- To simulate the programs.

The programs for each PLC are organised in projects. Each project has two main parts:

- The part storing the configuration of the PLC (modules, addresses and system configuration)
- The sections containing the control loops.

The PLC configuration is defined using the PLC Configuration window (*Figure 3-1*). The sections of the PLC program can be accessed through the Project Browser.

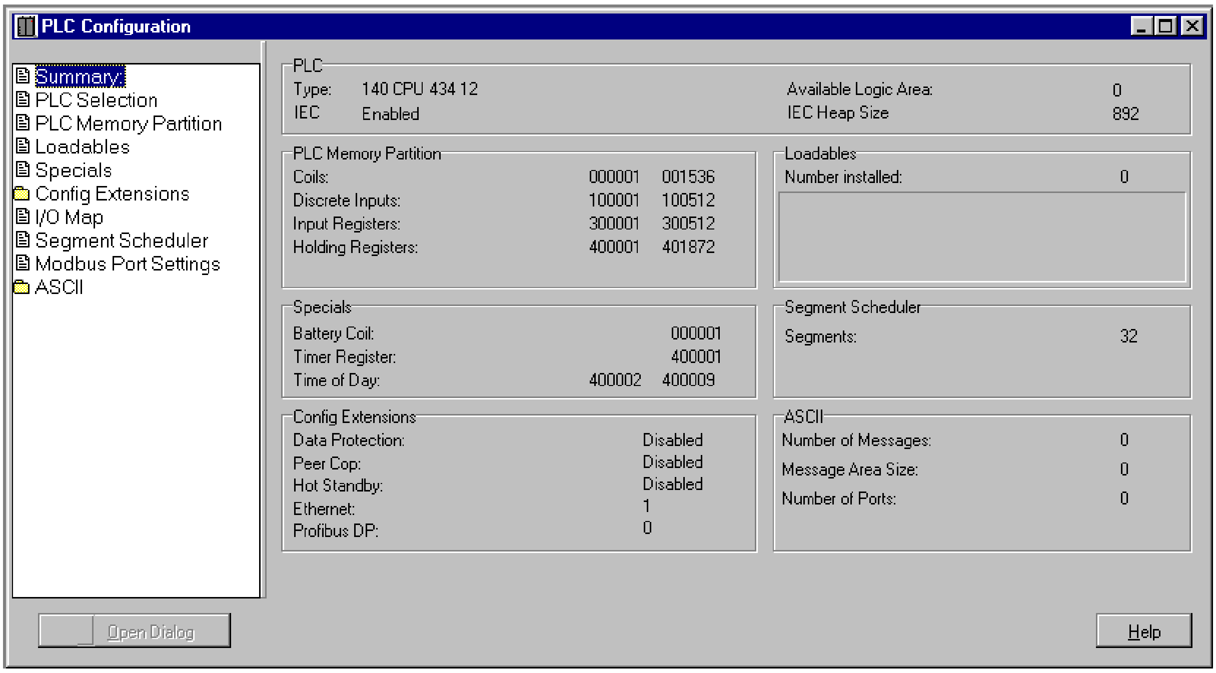


Figure 3-1. Concept PLC configuration window

3.2 Project structure

The PLC software project is organised into sections (Figure 3-3). Each section implements a local regulation loop. For example, the CIV_PLCSW_pH section regulates pH for the compartment CIV controller.

There are special sections to perform general functions which need to be located previously to the regulation loop sections since the order in the tree designates the order in execution.

It is recommended to create a section to configure analog input/outputs and check for sensor / actuator connections. This will ease the scaling and error handling in the loop sections. The sections could be named as follows:

CfgAnalo: To perform analog input/outputs configuration
AnalnError: To detect analog inputs connection status.
AnaOutError: To detect analog output connection status.

3.2.1 CfgAnalo:

General acquired signals conditioning.

In order to use scaling EFB function blocks, the signals must be of type ANL_IN, ANL_OUT, then automatic scaling can be performed in the rest of the sections.

3.2.2 AnaInError, AnaOutError:

Handling of errors in the analog input/output sensors.

Analog input/output cards can be provided with registers to indicate if a signal is connected and other status information of the signal. This information has to be gathered early to allow the rest of the segments use it, disabling loops or generating alarms.

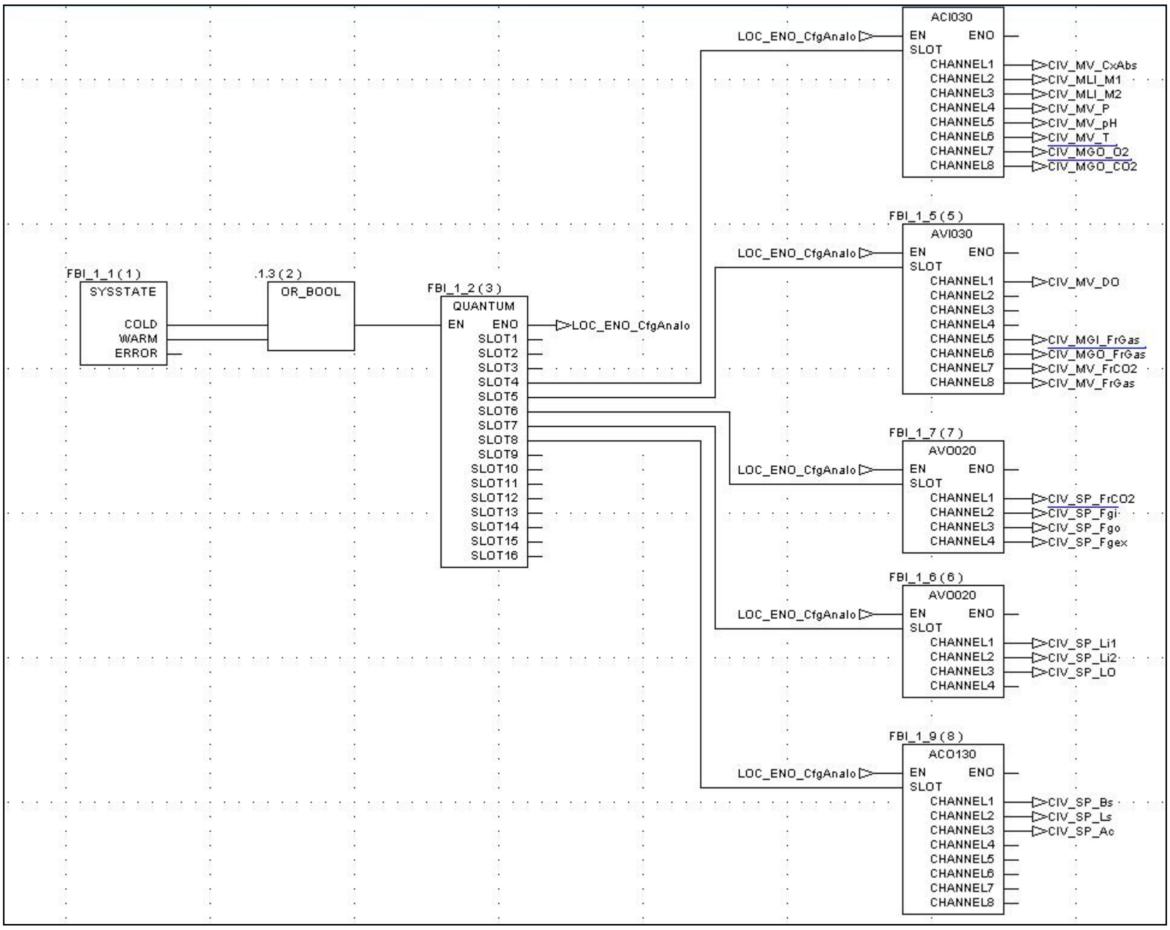


Figure 3-2: CfgAnalo section

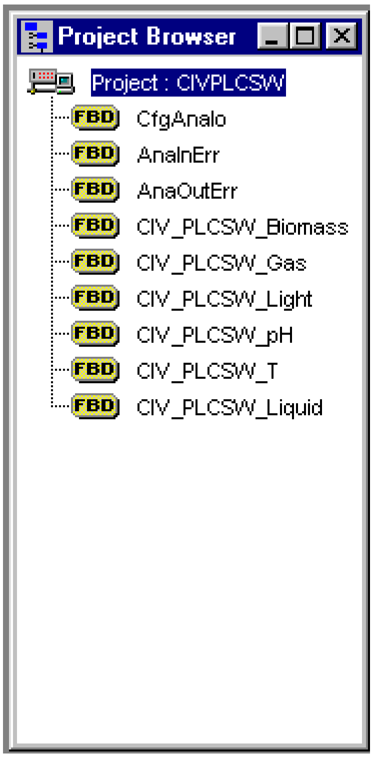


Figure 3-3: PLC Program sections of CIV

Following the numbering rules described in TN 78.72, [R 4], it was decided to use the structure displayed in Figure 3-4 for the HPC1 (compartment CIVb) application:

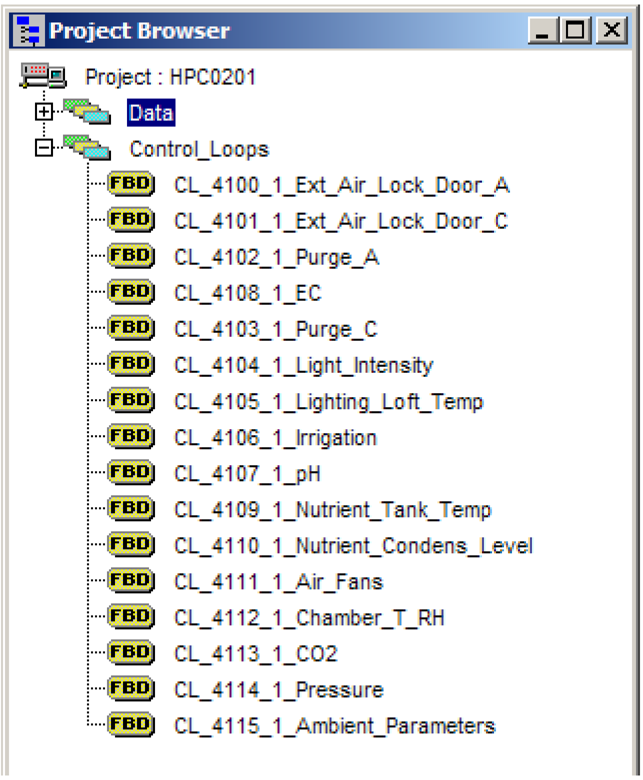


Figure 3-4: PLC Program sections for the HPC application.

The different control loops are identified as:

CL_AAAA_comment,

Where AAAA indicates the control loop number according to the rules extracted from [R 4] and reproduced in Figure 3-5:

3.4.2.2 Rule n°2 - the figure of the hundreds corresponds to the number of the compartment:

- Compartment I : loops from 1000 to 1999
- Compartment II :loops from 2000 to 2999
- Compartment III : loops from 3000 to 3999
- Compartments IV : loops from 4000 to 4999
- Compartment V : loops from 5000 to 5999
- Particular case of Compartment IV: Compartment IV is divided into two compartments, CIVa and CIVb[2]
- Compartment IVa : loops from 4000 to 4099
- Compartment IVb : CIVb is a particular case, also called HPC as Higher Plant Compartment. CIVb is divided into three compartments, HPC1, HPC2 and HPC3
- Compartment HPC1: loops from 4100 to 4199
- Compartment HPC2: loops from 4200 to 4299
- Compartment HPC3: loops from 4300 to 4399

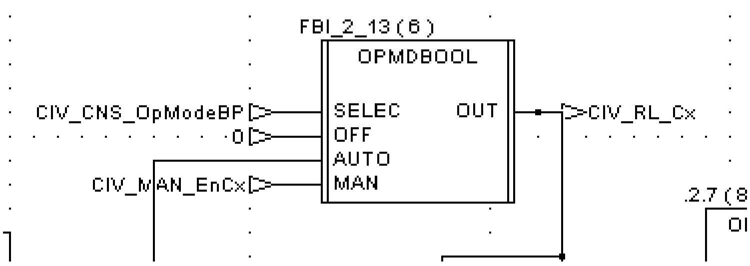
Figure 3-5: Control loop numbering convention

3.3 Programming Languages

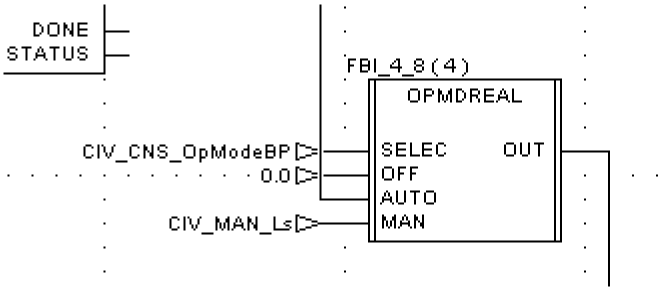
The PLC software can be programmed in any of the IEC languages supported by Concept. The language is determined when a project segment is created. However it is encouraged to use Functional Block Diagrams (FBD) programming since is the most standardised language and the easiest to understand.

In addition, custom function blocks for the development of CIII and CIV compartments have been already defined and are available for any future development. A library of custom function blocks for MELISSA could be created.

For compartment CIV and CIII following blocks were created:



OPMDBOOL: to switch a Boolean value depending on the operational mode.



OPMDREAL: to switch a real value depending on the operational mode.

3.4 PLC Variables

3.4.1 Memory map

In Quantum PLC the I/O memory addresses are formed as follows:

Group	Type
0x	Digital Outputs
1x	Digital Inputs
3x	Analogue Inputs
4x	Analogue Outputs

Located variable: variable with an address signal assigned.
Unlocated variable: variable without an address signal assigned.

A variable that maps a signal from a port of an acquisition board is located (normally of type ANL_IN). A variable that is used to store a value transmitted from the supervision software is named unlocated.

3.4.2 Variables shared with the supervision software

Variables shared with the iFix software are of type Analogue outputs (0x4XXXXX). Enough margin shall be maintained for the variables attached to an acquisition board. As example for CIII and CIV the range was 500 variables, i.e. first variable defined for interfacing with iFix was at address 0x400501.

All variables interfacing with iFix should be defined as analogue outputs, although other variable types such as "Binary" can be defined. The number of tags (variables interfacing with the supervision software) is a limited resource in iFix since are constrained by the purchased license. Using analogue variables allow the transmission of 32 Boolean values in one variable.

3.4.3 Variable behaviour at PLC start

Variables interfacing with the supervision software shall be initialised in the PLC software since if a reboot is performed in the PLC side the values will be lost and when the PLC starts the uncontrolled outputs can have undesired effects.

In start behaviour of PLCs there is a distinction between cold starts and warm starts:

Cold start

Following a cold start (loading the program with Online Load) all variables (irrespective of type) are set to ”0” or, if available, their initial value.

That means that to avoid undesired effects, all variables used for parameters need a default value. For instance, a Kp constant for a PID with address 400566 which value is set through the Supervision software, needs a default initial value since when PLC is cold restarted this value will be used.

Default values are set with the option Project\Variables declaration. Therefore in the variables table it is possible to define all the initial values for 4XXXXX unlocated variables.

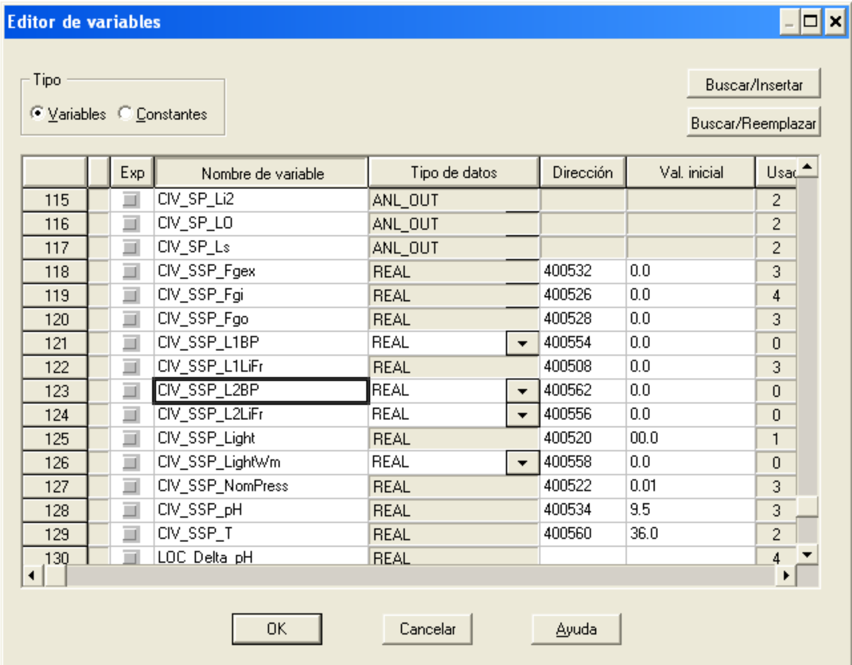


Figure 3-6: Variables editor

Warm start

In a warm start (stopping and starting the program or Online Load changes) different start behaviours are valid for located variables/direct addressees and unlocated variables:

- Located variables/direct addresses

  In a warm start all 0x, 1x and 3x registers are set to “0” or, if available, their initial value.

  4x registers retain their current value (storage behaviour)

- Unlocated variables

  In a warm start all unlocated variables retain their current value (storing behaviour)

3.4.4 IEC1131-3 Variable naming rules

3.4.4.1 Identifier length

Table 3-1 table shows the maximum length of identifiers according to IEC1131-3. Variables in Concept programs belong to the "All others" category, with a limited length of 32 characters.

Identifier	Maximum length
Program name	8
Formal parameter names	8
DFB type names	8
EFB type names	17
Data type names	24
All others	32

Table 3-1: Maximum identifiers length according to IEC1131-3

3.4.4.2 IEC1131-3 identifier naming conventions

An identifier is a sequence of letters, figures, and underscores, which must start with a letter or underscore. Letters from national stets of characters can be used.

Underscores are significant in identifiers; e.g. "A_BCD" and "AB_CD" are interpreted as different identifiers. Several leading and multiple underscores are not authorised consecutively.

Identifiers are not permitted to contain space characters. Upper an/or lower case is not significant; e.g. "ABDC" and "abcd" are interpreted as the same identifier.

Identifiers are not permitted to be (language) Key words.

3.4.4.3 Internal and external variables naming conventions

The naming conventions for the internal and external variables can follow the directions given in [R 4], and are based on the associated control loop number.

For clarity purposes these naming conventions are reproduced in Figure 3-7. The types of variables are reproduced in Figure 3-8.

3.3.4.1 Equipment Tag

The coding rules of the equipment tags are partially described within TN 78.71 and more precisely hereafter.

The label of each instrument is built in the following way "LLLL_1111_22" where:

1. "LLLL" corresponds to the mnemonic of the instrument such as described in the document TN 78.72 Shape Library. This mnemonic contains from 1 to 4 letters. The choice of letters is defined according to ISA S5 norm [See TN 78.71].
2. "1111" corresponds to the digital code of the control loop in which the instrument participates. The coding of the loops is described in the chapter 3.4.2
3. "22" corresponds to a counter which differentiates the instruments of the same type inside the same loop.

In order to clarify these rules of coding, here are some examples:

Example 1 (switch): "ZS_4100_01"

4. Z: FIRST letter which corresponds to a "position"
5. S: is a SUCCEEDED letter which corresponds to a "switch"
6. 4100 : corresponds to function "Exterior air lock door control"
7. 01: the number of this switch

Example 2 (sensor): "WDIT_3012_09"

8. W: first letter which corresponds to a "weight"
9. D: is a modified letter which defines a new variable "differential weight"
10. I: is a succeeded letter. The sensor can indicate the value of the variable.
11. T: is a succeeded letter. The sensor can transmit the value of the variable.
12. 3012: is an example of function.
13. 09: the number of this switch.

Example 3.1: instrument tag name of the actuator "SV_4162_02"

14. SV: this tag corresponds to a "solenoid valve". Binary control valve
15. 4162: chamber temperature and humidity control function
16. 02: the number of this actuator.

3.3.4.2 Variable Tag

The tag of the variable includes the tag of the equipment to which the variable associated is. An extension specifies the type of the variable.

The label of each variable is built in the following way "LLLL_1111_22_TT3" where:

1. "LLLL" corresponds to the mnemonic of the equipment associated to the variable [See §3.3.4.1].
2. "1111" corresponds to the digital code of the loop in which the variable participates;
3. "22" corresponds to a possible counter;
4. "TT" defines the type of the variable. The list of the types is defined in Table 3 of TN 78-72.
5. "3" corresponds to a counter if there are several variables of the same type

Example 3.2: tag variable associated to the actuator "CV_4162_02_MV"

1. CV: control valve
2. 4162: the function corresponds to the control of the temperature and humidity of the chamber
3. 02: the number of this variable
4. MV: the variable associated to this tag is a manipulated variable

Figure 3-7: Internal and external variables naming convention

Types of variables	
Label	***Definition of the variable***
SP	Setpoint
MSP	Manual setpoint
MV	Manipulated variable
DV	Disturbed variable
A	State alarm
AH	High alarm
AL	Low alarm
AO	Open state alarm
AC	Close state alarm

Figure 3-8: Types of variables

3.5 Operational modes

Generic description of the three possible operational modes of the MELiSSA compartments, auto, manual and off, is provided in this chapter. These three possible operational modes should be selected through a physical switch or software.

3.5.1 Auto

In this mode the Compartment should work with minimum human intervention.

This operational mode has to protect all the compartment's components in any situation.

In case of component failure the control system has to be intelligent enough to protect all the compartment's devices. In a worse case it should go to off operational mode.

Dangerous situations have to be indicated through some visual alarm indications, visible for humans. These visual alarms indications have to be according minimum with the standard European laws.

This operational mode should keep a database to record the historic of alarms and important compartment's variables.

3.5.2 Manual

This mode has to allow a soft start, a components test (in case of failure) and test some experiments.

This mode should permit modifying the the state of all the available actuators and to monitor all the available sensors.

This mode cannot permit any modification that would entail damage to any compartment's component or bring into a dangerous, unstable condition any compartment's subsystem.

3.5.3 Off

This operational mode has to be able to implement in any situation a soft stop from Auto and Manual modes. A generic stop button is defined in the supervision software to set all loops into this mode in case of emergency situations.

Soft stop means that the system can go from normal operation or failure situation to safe, stable situation, in a soft way and variables are kept within a safe range to avoid damage of HW components or bioreactors' microorganisms.

All variables have to be off value (initial value). This value has to be stable and safe in any situation.

4. IFIX PROGRAMMING GUIDELINES

4.1 Screen layout

The following screen layout (Figure 4-1) is proposed for implementation of the MELISSA supervision software displays:

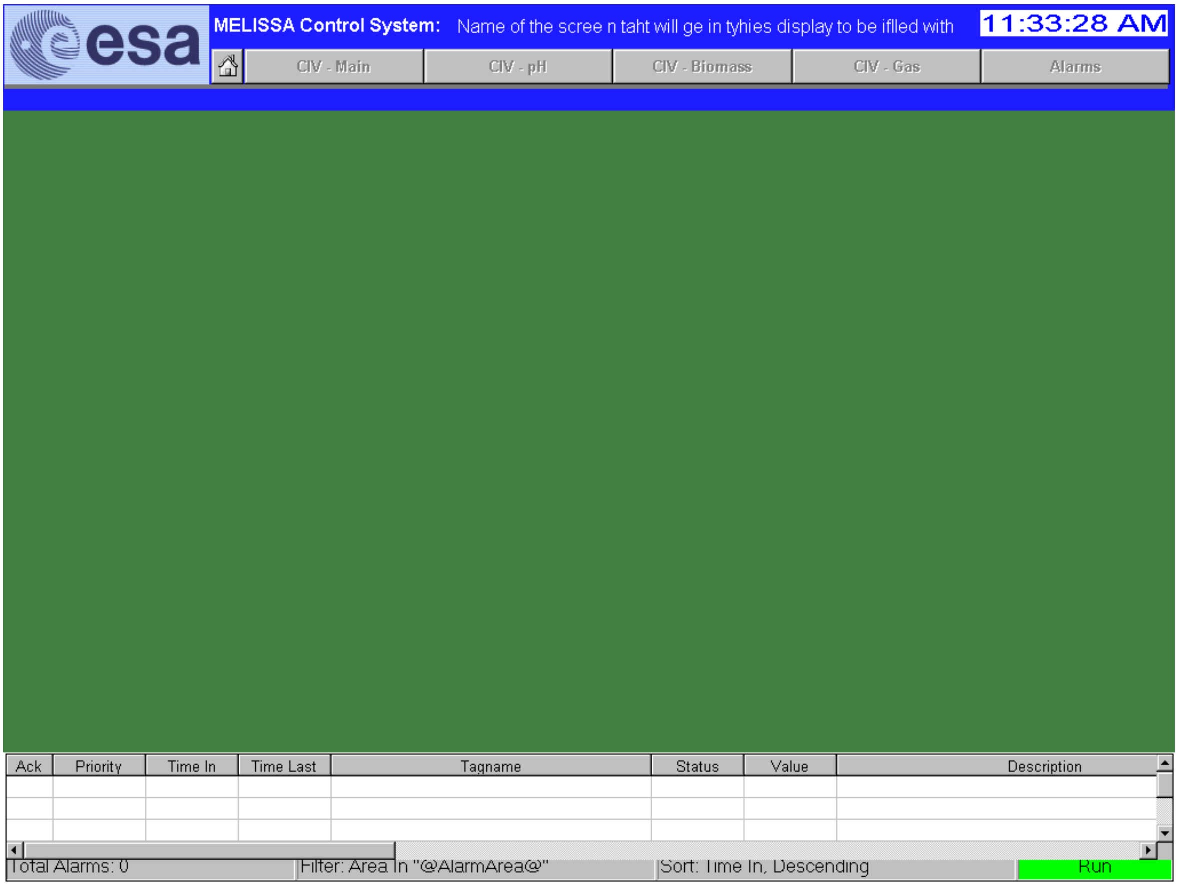


Figure 4-1: Screen layout

A specific example is illustrated in Figure 4-4. The various items in the display are as follows:

Display Title
The title of the current display can be located in the top of the window, in light blue background.

Navigation Bar
The Navigation bar is located below the display title. It allows, by pressing one of the buttons, the navigation to the indicated display. The button with a house allows returning to the main (home) screen.

Working Area
The working area is where variables are displayed using a schema of the process (pumps, valves, pipes, etc.). The working area is placed under the Navigation bar, with green background.

Alarm Area
The Alarm Area is placed in the lower part of the display. This area contains information about the alarms detected. Alarms can be acknowledged by performing a double-click with the mouse over the alarm.
Pressing the right mouse button over the Alarm Area displays a menu pop-up with allowed alarm actions.

The Alarm Area displays the following attributes:

- **Priority:** High (red background), Medium (gray background), Low (White background).
- **Date In:** Date in which first alarm event was fired.
- **Time In:** Time in which first alarm event was fired.
- **Time Last:** Time in which last alarm event was fired.
- **Tag name:** Name of the tag that fired the alarm.
- **Status:** Analogue tags display alarms such as High (HIHI), Low (LOLO), Rate of Change (ROF), or Deviation (DEV). Digital tags display alarms such as Change of State (COS) or Change from Normal (CFN)
- **Value:** Current value of the tag that produced

4.2 Screen definitions

4.2.1 Colour conventions

The next conventions are followed in objects with parts animated with different colours:

- Red: Stopped. The object is enabled but not running at his moment.
- Green: Nominal, OK, running. Object is enabled and running.
- Yellow: Caution. The object status indicates temporary malfunction, or the status can affect negatively to the process.
- Black: Disabled. Object is not active.

For example, the operational mode control in each control loop is colour coded as shown in Figure 4-2.

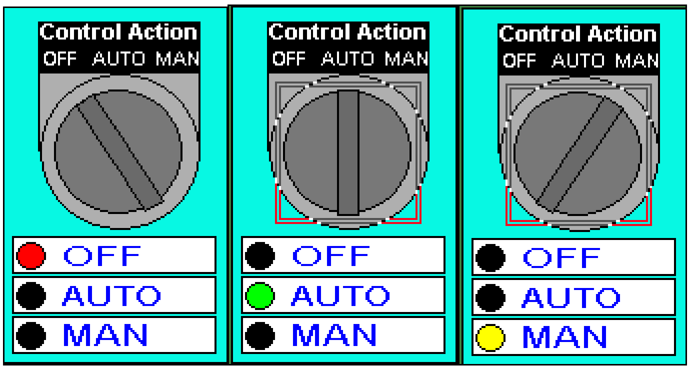


Figure 4-2: Colour of the operational mode indicators in Supervision displays.

- OFF is indicated in red, since loop is not regulated and outputs are set to safe values.
- AUTO corresponds to the nominal situation, where outputs are regulated automatically by the control. It is indicated in green colour.
- MAN is a situation that needs caution. Manual values can be set to the outputs. Therefore, this mode has to be used carefully since it could cause process malfunction or even components damage. This indicator has the yellow colour.
- Inactive options are displayed in black.

4.2.2 General display actions

From every display, a set of common actions can be performed:

Change Operational Mode

In each process loop there is a control to change the operational mode. The control is a switch (see Figure 4-3:) with three positions and can be set from their respective displays independently. The operational modes are:

- OFF: All outputs regulated in the loop are set to 0. Indicator is red light.
- AUTO: In this mode the control algorithms perform the regulation of the loops. Indicator is green light (normal operation mode).
- MAN: Values of outputs regulated by the loop are set manually. Indicator is yellow light.

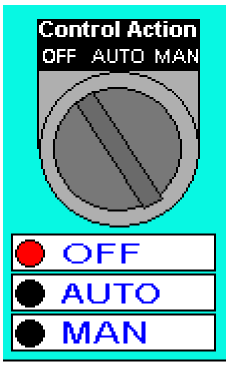


Figure 4-3: Operational Mode Control in Supervision displays.

Edit Manual Values
Every loop display shall contain a button to allow the edition of the manual values. Click over the Edit Manual Values and a dialog will appear to allow the manual values modification.

Edit Set Points
Set points can be identified because there shall be in blue foreground colour. To edit a value, user must double-click over the value and overwrite the selection. Non-editable values are in black foreground colour.

Chart configuration
Chart configuration can be changed double-clicking the chart. A system dialog will appear which allows the modification of the default values.

4.2.3 Main compartment display

Each compartment will have a main display were at least the STOP process regulation action will be implemented.

- **STOP process regulation**

To stop regulation for all loops user must press the STOP button. This action will set all control loop outputs to 0. To restore the automatic regulation (AUTO mode), user must navigate to every display and change it manually.

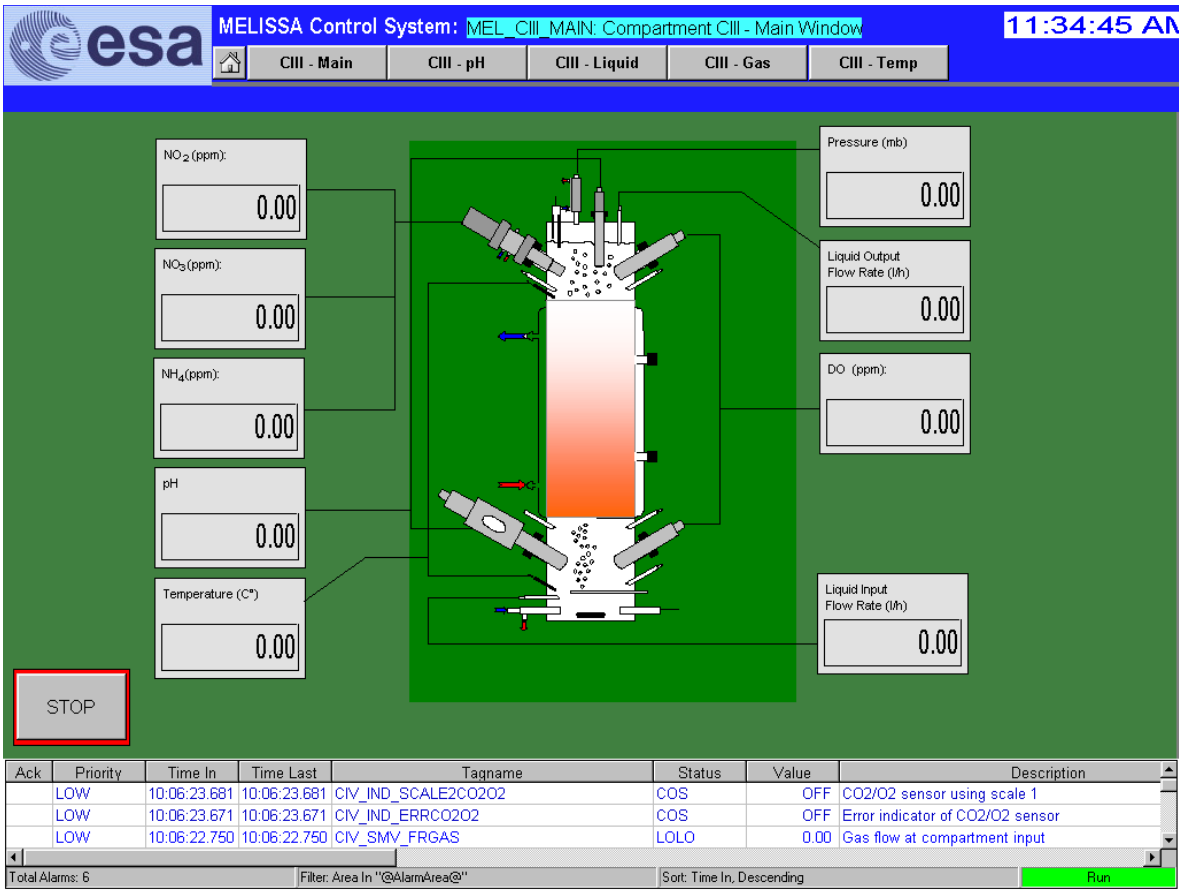


Figure 4-4: Compartment main display.

5. MAGELIS PROGRAMMING GUIDELINES

5.1 Screen layout

An example of the MAGELIS (local touch screen) information layout is shown in Figure 5-1 for the compartment CIVa.

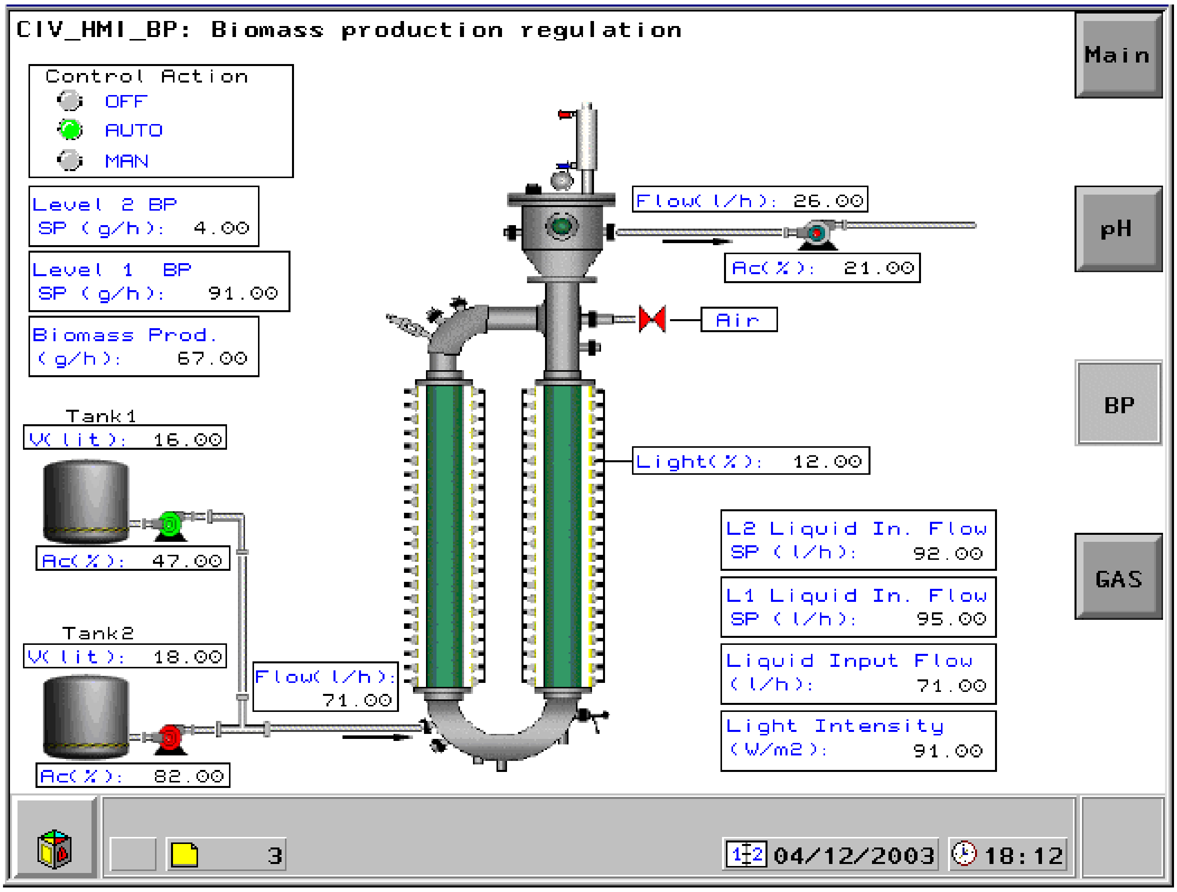


Figure 5-1: CIVa HMI display layout.

5.1.1 Working Area

The working area is where the values are displayed in form of object animations (pumps, valves, etc.) and numerical values.

5.1.1.1 Navigation Buttons

Navigation buttons are placed on the right side of the working area. Press these buttons to navigate to the indicated process display.

5.1.1.2 Control Action

All process displays show the Control Action mode (upper left box), which can be:

- OFF: All controller outputs are set to 0.
- AUTO: Regulation of output values is performed by the controller.
- MAN: Output values are set manually from the Supervision.

5.1.2 Information Area

This area shows the display number, the date and the time.

5.1.2.1 System Button

The System Button is placed on the left corner of this area. By pressing this button the System Toolbar is displayed.

5.1.2.2 System Toolbar

ESC	Return to previous screen.
HOME	Navigate to the Main Display.
MENU	Access to system menu with generic system options (List of pages, List of recipes, List of forms, Password, List of Alarms, Alarm history, Stop printing, Screen lock mode).
SYST	Access to system information menu (Terminal parameters, Protocol parameters, Printer parameters, Password, Product references, Adjust page, PLCs in online mode)
ALARM	Access to alarm screen (not implemented).
HELP	No action (not implemented).