MELISSA

Contract Number: ESTEC/CONTRACT: 15671/01/NL/ND

Technical Note: 72.4

Control System Demonstrator
Data Package

Version: 1

Issue: 1

NTE SA

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Document Change Log

Version	Issue	Date	Observations
1	0	23/04/04	New document
1	1	28/07/04	Editorial changes

TABLE OF CONTENTS

1 SCOPE

This document contains the Control System Demonstrator data package as defined in the WP 3300 of the MELISSA, Adaptation for Space, Phase 1 Statement of Work [A1].

The Control System Demonstrator implements the new Control System Architecture defined in the earlier phases of this contract for the specific cases of MELISSA's compartments III and IVa.

This document corresponds to the Technical Note # 72.4 defined in [A1]

2 APPLICABLE DOCUMENTS

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**.TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.

[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.

3 DATA PACKAGE ORGANIZATION AND CONTENTS

The Control System Demonstrator data package is organised following the work package structure defined in [A1]. It is divided in the following four volumes:

- VOLUME I: Test Plan and Procedure, as per WP 3310
- VOLUME II: Hardware Set-up and Documentation, as per WP 3320
- VOLUME III: Test Performance, as per WP 3330
- VOLUME IV: Test Results Evaluation, as per WP 3340

The data package contents is summarised in **Figure 1**.

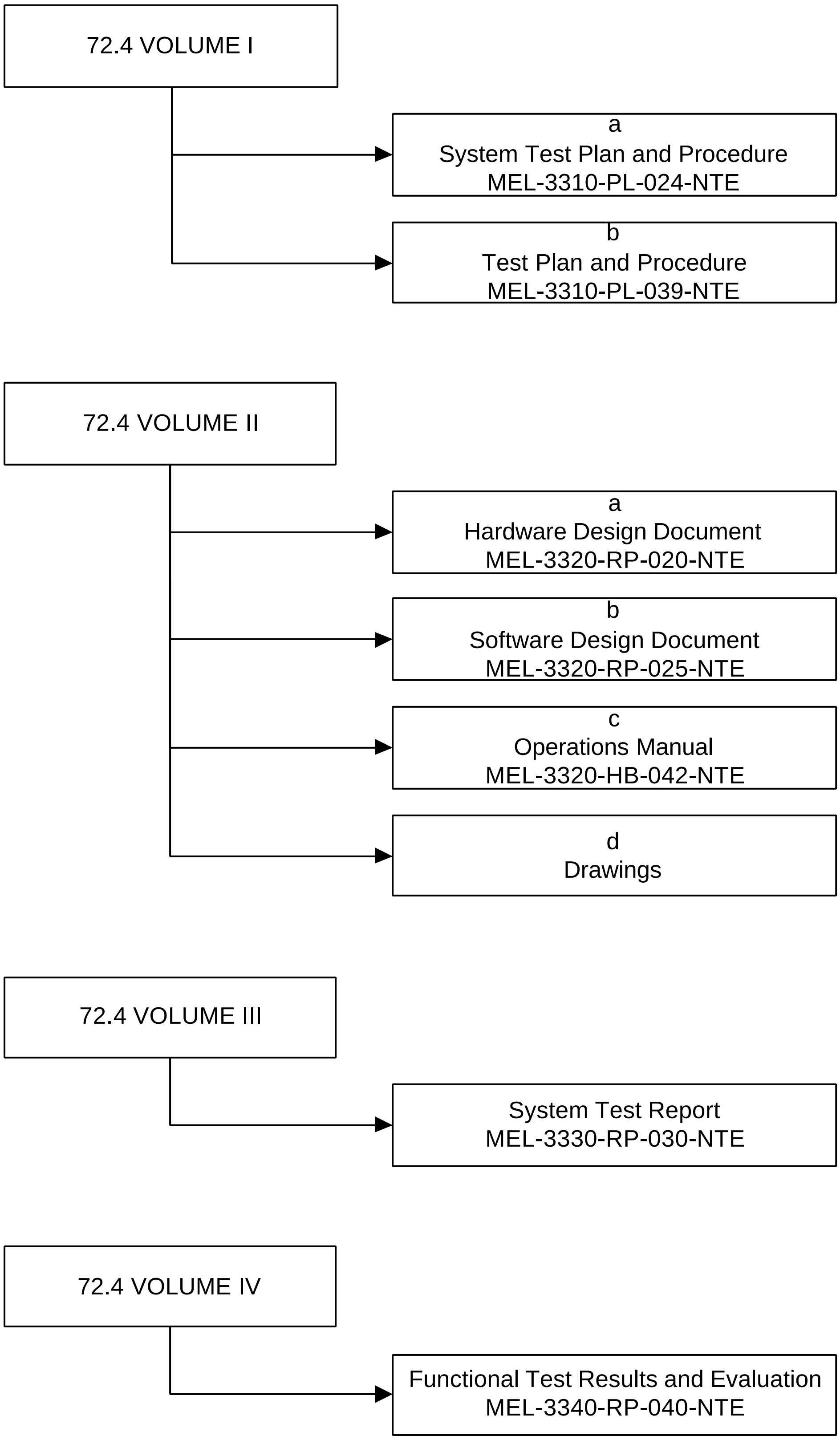

Figure 1: Data Package Organisation

4 VOLUME I

This volume contains the Test Plan and Procedures used to verify and validate the Control System Demonstrator implementation.

4.1 Volume Ia

Tests are carried out in two stages. First, System tests performed at NTE's premises over the Control System Demonstrator using ancillary hardware to simulate the interfaces with the plant's sensors and actuators. The purpose of this test is to validate the HW and SW implementation before releasing the Demonstrator for its installation and connection to the Plant. Plan and Procedure are documented in the:

Control System Demonstrator System Test Plan and Procedure, ref. MEL-3310-PL-024-NTE.

4.2 Volume Ib

Following the System Tests whose results are evaluated in the corresponding Test Review sessions the Demonstrator is brought to the MELISSA Plant in the UAB's premises and connected with the bioreactors for compartments III and IVa. The demonstrator is subject to some functional tests for its operational validation in the Plant. These tests are compiled in the:

Control System Demonstrator Test Plan and Procedure, ref. MEL-3310-PL-039-NTE.

5 VOLUME II

This volume contains all the documentation related to the design of the Demonstrator.

5.1 Volume IIa

The HW design, providing details on the mechanical design and configuration of the Demonstrator's racks as well a complete description of the electrical design is compiled in the:

Control System Demonstrator Hardware Design Document, ref. MEL-3320-RP-020-NTE.

5.2 Volume IIb

The SW design, consisting of the Supervision SW, the local control SW implemented in the PLCs and the specific SW of the local touchscreen is described in

Control System Demonstrator Software Design Document, ref. MEL-3320-RP-025-NTE.

5.3 Volume IIc

Operation guidelines for the Demonstrator´s users, addressing also some troubleshooting and maintenance issues are provided in

Control System Demonstrator Operations Manual, ref. MEL-3320-HB-042-NTE.

5.4 Volume IId

Finally the following drawings are also included:

Electrical Schematics, Rack III, ref. MEL-3320-DR-034-NTE
Electrical Connections, Rack III, ref. MEL-3320-DR-037-NTE
Mechanical Design, Rack III, ref. MEL-3320-DR-035-NTE

Electrical Schematics, Rack IV, ref. MEL-3320-DR-027-NTE
Electrical Connections, Rack IV, ref. MEL-3320-DR-038-NTE
Mechanical Design, Rack IV, ref. MEL-3320-DR-036-NTE

6 VOLUME III

This volume contains the reporting corresponding to the System tests performed at NTE. It basically consists of the electronic transcription of the “as run noted procedures”. The report is compiled in:

Control System Demonstrator System Test Report, ref. MEL-3330-RP-030-NTE.

7 VOLUME IV

This volume contains the reporting of the test results obtained after the tests performed on the Control System Demonstrator once connected to the MELISSA Plant. These results, have been validated by Sherpa Engineering (former ADERSA), for what concerns the system outputs in relation to the compartments III and IVa control laws. Test incidences are explained and finally conclusions on the Demonstrator performance are also stated. This is compiled in:

Control System DemonstratorFunctional Test Results and Evaluation, ref. MEL-3340-RP-040-NTE.

MELISSA

Contract Number: ESTEC/CONTRACT: 15671/01/NL/ND

Technical Note: 72.4
VOLUME I-a

Control System Demonstrator
System Test Plan and Procedure

Version: 1

Issue: 1

NTE SA

NTE Document Number:	MEL-3310-PL-024-NTE
Written by:	Jordi Duatis
Revised by:	Joan Mas
Quality Assurance:	Sònia Ferrer
Approved by:	Joan Mas

Document Change Log

Version	Issue	Date	Observations
Draft	0	26 Feb'03	Created
		24 Sept'03	Fixed value ranges and typos after procedures execution. Added TP to check initial values and sensor / actuator link errors. Added MEL-CIV-TC-0404 to check over temperature alarm action. Added MEL-CIV-TP-07 to check initial values Added MEL-CIV-TP-08 to check errors on current analogue signal inputs
	1	01 Oct'03	Added MEL-CIV-TP-09 to check operational modes.
	2	11 Nov'03	Added CIII Test Procedures.
	3	03 Feb'04	Updated after TIR CIII_7 resolution.
	4	05 March'04	Reviewed
1	0	19 April '04	First release (for ESA review)
1	1	28 July '04	Includes ESA comments dated 21/07/04

TABLE OF CONTENTS

1 SCOPE

This document contains the System Test Plan and Procedure for the MELISSA Control System Demonstrator developed by NTE. The System Tests procedures herein defined are to be conducted over the Demonstrator hardware at NTE's facilities. In this case the Control System Demonstrator interfaces with the MELISSA plant's sensors and actuators are simulated with auxiliary test equipment.

This Test Plan and Procedure is part of Technical Note 72.4.

The MELISSA Control System Demonstrator object of the tests comprises the software and hardware necessary to perform the control of the Compartment III and Compartment IVa. The Demonstrator implements the same functionality as the previously existing Control System but following the requirements and guidelines specified in [R1] and [R2]. The Demonstrator's architecture is shown in Figure 1.

The MELISSA Control System can be broken down into the following subsystems:

- Local control: implementing the low-level control loops.
- Master Control: implementing the global loop Control Laws.
- Supervision: allowing the configuration and monitoring of system status, and alarm reporting
- Human Machine Interface (HMI): allowing the supervision of system status from the same plant.

Functional tests to be conducted at the UAB's premises, once the Demonstrator is connected to the MELISSA plant, are compiled in the Control System Demonstrator Test Plan and Procedures [R7].

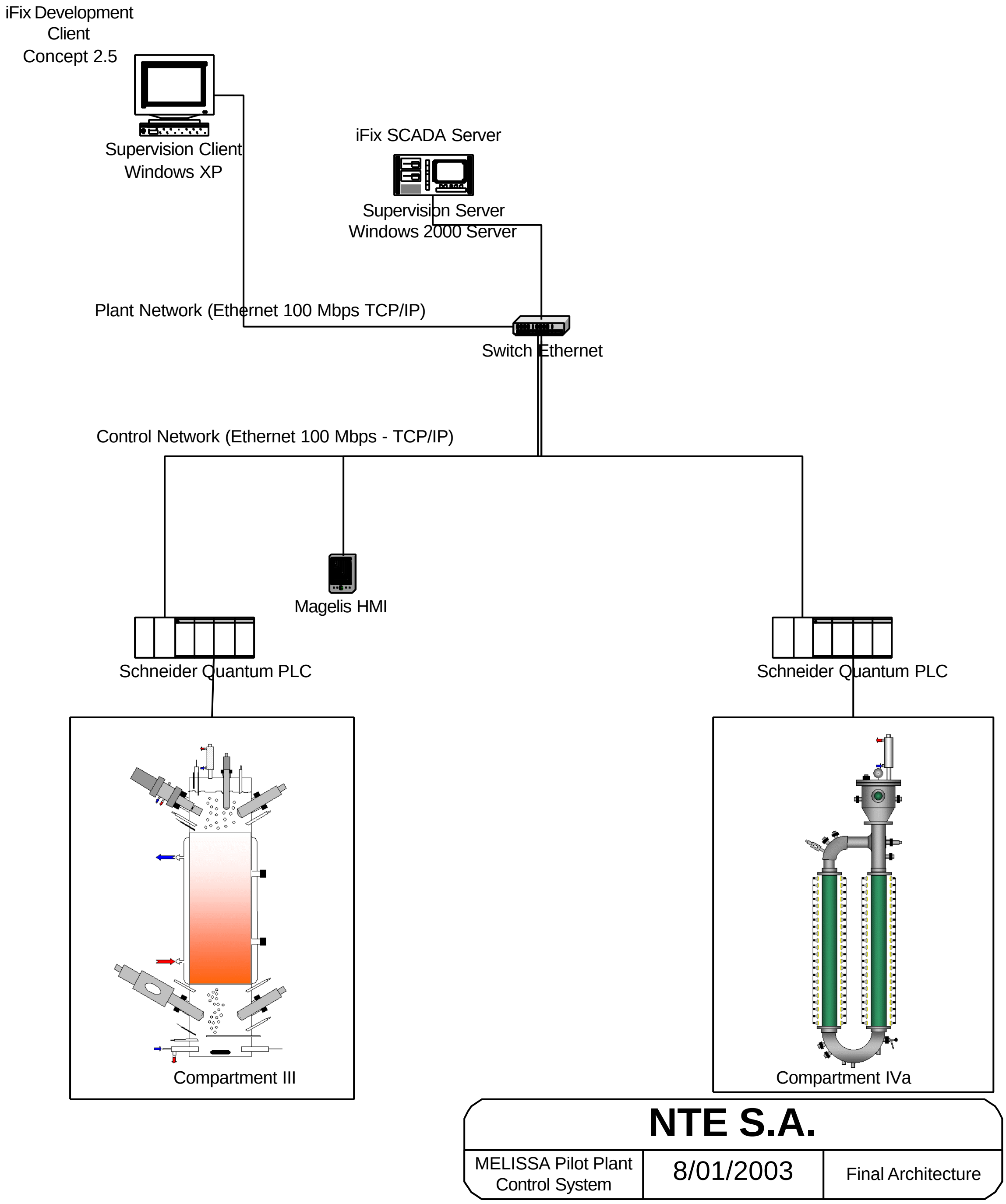

Figure 1: Control System Demonstrator architecture

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**. TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.

[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.

2.2 Reference Documents

[R1] **MEL-3100-SP-010-NTE, Definition of the control requirements for the MELISSA Loop**. TN 72.2, v.1.2, November 2002.

[R2] **MEL-3200-RP-014-NTE, MELISSA Control System Architecture and Trade-off**. TN 72.3, v. 1.0, February 2003.

[R3] **Nitrifying Compartment Studies.** TN 25.310. UAB, September 1996.

[R4] **Set-up of the Photosynthetic Pilot Reactor.** TN. 37.2. UAB, April 1998.

[R5] **MEL-3320-RP-020-NTE, Control System Demonstrator Hardware Design Document**, TN 72.4 Volume IIa, v. 1.1, July 2004

[R6] **MEL-3320-RP-025-NTE, Control System Demonstrator Software Design Document**, TN 72.4 Volume IIb, v. 1.1, July 2004

[R7] **MEL-3310-PL-039-NTE, Control System Demonstrator Test Plan and Procedure**, TN 72.4 Volume Ib, v.1.1 July 2004

[R8] **MEL-3330-RP-030-NTE, Control System Demonstrator System Test Report,** TN 72.4 Volume III, v. 1.1, July 2004

[R9] **MEL-3320-HB-042-NTE, Control System Demonstrator Operations Manual,** TN 72.4 Volume IIc, v. 1.1, July 2004

3 ACRONYMS LIST

AC	Alternate Current
APS	Adjustable Power Supply
DC	Direct Current
DW	Dry wheight
FG	Function Generator
GND	Ground
HDD	Hardware Design Document
HMI	Human Machine Interface
MM	MultiMeter
OSC	Oscilloscope
PLC	Programmable Logic Controller
SDD	Software Design Document
TC	Test Case
TP	Test Procedure
UAB	*Universitat Autònoma de Barcelona*
V&V	Validation and Verification

4 SYSTEM TEST PLAN

4.1 Introduction

The objective of this Test Plan is to validate and verify that the functionality described in the MELISSA Control System Demonstrator Hardware Design Document (HDD) and MELISSA Control System Demonstrator Software Design Document (SDD) is implemented as defined. That is, hardware elements exist, are placed and interconnected as specified in the HDD and control actions are performed as defined, and can be supervised from the Supervision as stated in the SDD.

The system is developed in two phases. First, the software and hardware corresponding to the Compartment IVa is developed, integrated and deployed, followed by Compartment III. Due to this sequence of events, System Tests are also planned two phases. First, tests for Compartment IV will be conducted followed by tests on Compartment III.

The baseline for defining the present test plan and procedure is:

- **HDD**: MELISSA Test Control System Hardware Design Document
- **SDD**: MELISSA Test Control System Software Design Document
- **CIII and CIV Rack**: Racks of Compartments III and IVa, which allocate PLC controllers and electronics to interface with sensors and actuators and for power distribution.
- **CIII and CIV Local Control**: PLC software for Local Control of Compartments III and IVa.
- **Master Control**: Control Laws software for the Master Control of Compartments III and IVa (Running in the Supervision Server).
- **Supervision Software** : Supervision Software for the Supervision of Compartments III and IVa (Supervision engine runs in the Supervision Server, Supervision displays run in the Supervision client).
- **HMI**: Human Machine Interface software running in the Magelis display for the compartments CIII and CIVa.

The System Test of the Compartments III and IVa will consist of:

1. Identification that all modules defined in the HDD are properly implemented for the CIII and CIV Racks.
2. Verification that all connections among electrical elements inside the Racks are performed according to the HDD.
3. Verification of the system functions following the process described in this plan.

All tests defined here in are to be conducted at NTE's premises.

4.2 Items under Test

- **CIV Rack:** verify integration, and mechanical and electrical interfaces
- **CIII Rack**: verify integration, and mechanical and electrical interfaces
- **Local Control**: verify control actions are performed as specified.
- **Master Control**: verify control actions are performed as specified.
- **Supervision Software** : verify control actions can be monitored from the Supervision Software as specified.

- **HMI**: Verify that control actions can be supervised for the HMI as specified.

4.3 Features to be tested

- Internal Electrical interfaces between the Rack elements.
- Electrical isolation.
- Hardware and software development, integration and deployment performed according to the HDD and SDD.
- Software Interfaces between:
  - CIV PLC and the Supervision Server.
  - CIV PLC and the HMI
  - CIII PLC and the Supervision Server
  - CIII PLC and the HMI

4.4 Features not to be tested

Control algorithms, algorithm parameters and alarms are taken directly from the current control system and therefore their effectiveness is not verified.

Performance, stress and non-nominal conditions (out of the alarm conditions specified in the SDD) are not verified.

4.5 Approach

The HDD defines the implementation of the electrical and mechanical interfaces internal to the CIII and CIV Racks. From this document, a set of procedures is developed to verify that all elements specified in the HDD are implemented in the corresponding racks. In addition, procedures are added to verify electrical interfaces between the different elements placed in the rack and electrical isolation with respect to ground (GND).

The SDD defines the functionality of the Local Control algorithms, the Master Control algorithms and the Supervision and HMI displays. A set of procedures is developed to verify that this functionality is implemented as defined from a functional test approach.

4.6 Item pass/fail criteria

Test items will pass the System Test if the test procedures expected outputs were achieved.

4.7 Suspension criteria and resumption requirements

System test verification campaign will be suspended either if no compliance to specifications or critical errors/problems that avoid to progress on the verification are found.
System test verification campaign will resume when an evidence of resolution of the non-compliance or errors found is available.

4.8 Testing Tasks

The following testing tasks will be performed separately for each Rack:

1. Electrical interface verification: Before powering the rack a point to point conductivity and isolation test must be performed according to procedures: MEL-CIV-TP-01 and MEL-CIV-TP-02 for compartment CIV and MEL-CIII-TP-01 and MEL-CIII-TP-02 for compartment CIII.
2. Power the rack
3. Connect in a local network the Supervision Server, the HMI, Supervision client and the rack.
4. Perform a *ping test* to each system to verify network connection is OK.
5. Update PLC software (if changed).
6. Update Master Control Software (if changed).
7. Update Supervision software (if changed).
8. Start Supervision Server software
9. Start Supervision Client software
10. Run the test procedures.
11. Generate the Test Report.

4.9 Test Deliverables

The following documents will be generated during the System Test:

- The V&V Plan (this document)
- Test Procedures (included in this document)
- Test Cases (included in this document)
- Test reports with the results of run tests ([R8])

4.10Environmental Needs

As the tests are performed with the Control System Demonstrator not connected to the plant it is necessary to simulate the plant's sensors and an acquisition system to read actuator responses are needed.
The generation of sensors signals will be performed using Adjustable Power Supplies (APS) and a Function Generator (FG).
The acquisition of signals will be performed using a multi-meter (MM) and an Oscilloscope (OSC) where necessary.

Figure 2 displays the hardware configuration to be used for conducting the tests.

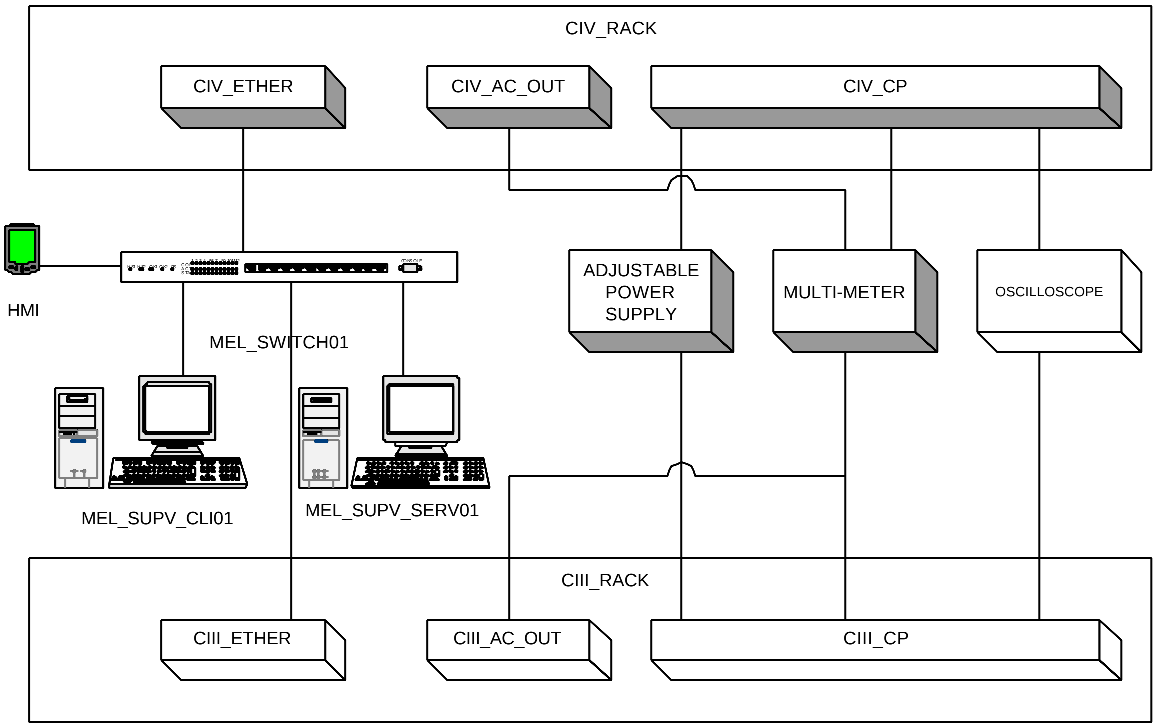

Figure 2: Test configuration

Device	Description
MEL_SWITCH01	Ethernet Switch placed in the Supervision Rack.
MEL_SUPV_CLI01	Supervision client Desktop PC.
MEL_SUPV_SERV01	Supervision Server placed in the Supervision Rack.
MEL_HMI	Human Machine Interface
CIV_ETHER CIII_ETHER	Ethernet connector placed in the corresponding Rack
CIV_AC_OUT CIII_AC_OUT	220 VAC switched power connector placed in the corresponding Rack.
CIV_CP CIII_CP	Connection panel of signals for sensor/actuators placed in the corresponding Rack.

5 COMPARTMENT VIa SYSTEM TEST PROCEDURES

Test Procedures are implemented to verify the system from a functional approach. Therefore, each Test Procedure (TP) verifies a high level function (as for example biomass regulation for a compartment). Test Procedures include one or more Test Cases (TC) that shall be executed as part of the procedure.

These Test Procedures are specified in the following sections:

Identifier	Name	Description
MEL-CIV-TP-01	Point to point connectivity test	Test point to point connectivity for the electrical interfaces.
MEL-CIV-TP-02	Electrical Isolation	Test electrical isolation
MEL-CIV-TP-03	Check Interfaces End to End	Test value ranges, communication with the supervision, supervision displays
MEL-CIV-TP-04	Biomass Production Regulation	Test biomass production control law
MEL-CIV-TP-05	Gas Flow Regulation	Test gas flow rate regulation
MEL-CIV-TP-06	pH Regulation	Test pH regulation
MEL-CIV-TP-07	Initial values	Test parameters initial values when PLC is restarted
MEL-CIV-TP-08	Sensor/Actuator Link Errors	Test errors on sensors / actuators links are handled as specified.
MEL-CIV-TP-09	Operational modes	Test changes in outputs caused by changing the operational mode (OFF, AUTO, MAN)

5.1 MEL-CIV-TP-01: Point to point connectivity test procedure

5.1.1 Purpose

- Identify all components are deployed as specified in the HDD.
- Verify electrical connections are implemented as defined in the HDD.

5.1.2 Description

CAUTION
This test procedure must be executed without powering the rack.

This test procedure is performed using a device that checks the electrical connectivity between two points (e.g. a multi-meter). Connections to check for Compartment IVa are specified in the ANNEX A. This ANNEX defines a template that shall be included as part of the Test Report.

5.1.3 Expected outcome

All connections specified in the template are checked OK.

5.1.4 Procedure steps

1. Check all connections specified in the template and mark if there is conductivity or not.

5.2 MEL-CIV-TP-02: Electrical isolation

5.2.1 Purpose

Check that electrical isolation between AC L and GND and AG N and GND is performed according to applicable regulations.

5.2.2 Description

CAUTION
This test procedure must be executed without powering the rack.

This test procedure is performed using a device that insulates 1500 V between AC L and GND and AC N and GND during a fixed period of time (60 seconds) to check that isolation in cabling, connectors and 220 VAC powered devices, is properly dimensioned.

5.2.3 Special requirements

A Dielectric Withstanding Voltage Tester device is needed to execute this test procedure. The device outputs 1500 V during a limited time and controls current is not over a defined value.

5.2.4 Expected outcome

Device response indicates test passed OK.

5.2.5 Procedure steps

1. Program device to output 1500 V during 60 seconds and limited current to 30 mA.
2. Connect device output to CIV_AC_IN pin 01 (AC L) and CIV_AC_IN pin 03 (GND).
3. Activate device to perform the verification.
4. Connect device output to CIV_AC_IN pin 02(AC N and CIV_AC_IN pin 03 (GND).
5. Activate device to perform the verification.
6. Annotate verification results.

5.3 MEL-CIV-TP-03 Check Interfaces end-to-end

5.3.1 Purpose

Check that signals applied to inputs are transmitted to Supervision and values fixed by the Supervision are transmitted to outputs adequately, with the correct ranges.

5.3.2 Features to be tested

Verify integration and functionality of the following items:

- PLC – Rack I/O Interface (CIV_CP)
- Supervision – PLC Interface (Software interface)

5.3.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIV-TC-0301	Check analogue inputs
MEL-CIV-TC-0302	Check analogue outputs
MEL-CIV-TC-0303	Check digital inputs

5.3.4 Special Requirements

To execute this procedure following devices will be necessary:

- Multimeter (to measure analogue outputs)
- Adjustable Power Supply (to generate known values)
- Resistances 1 Kohm (to allow measuring 4-20 mA outputs)

The values can be monitored from the Supervision Real Time Database display (iFix Database Manager application).

Table of inputs / outputs

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIV_MV_CxAbs	AI	01	Analogue input for biomass concentration measurement in light absorbance units	CIV_CP	001 005	+ -	4 – 20 mA
CIV_MV_M1	AI	02	Scale 1		009 013	+ -	4 – 20 mA
CIV_MV_M2	AI	03	Scale 2		017 021	+ -	4 – 20 mA
CIV_MV_P	AI	04	Pressure measurement		025 029	+ -	4 – 20 mA
CIV_MV_pH	AI	05	pH measurement		033 037	+ -	4 – 20 mA
CIV_MV_T	AI	06	Temperature measurement		041 045	+ -	4 – 20 mA

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIV_MGO_O2	AI	07	O2 measurement at gas output		049 053	+ -	4 – 20 mA
CIV_MGO_CO2	AI	08	CO2 measurement at gas output		057 061	+ -	4 – 20 mA
CIV_MV_DO	AI	09	Percent of DO saturation in the reactor		065 069	+ -	4 – 20 mA
CIV_MV_FrGas	AI	13	Gas flow at compartment input		097 101	+ -	0 – 5 V
CIV_MGO_FrGas	AI	14	Gas flow at output		105 109	+ -	0 – 5 V
CIV_MV_FrCO2	AI	15	CO2 flow measurement		113 117	+ -	0 – 5 V
CIV_MGI_FrGas	AI	16	Gas flow at external input		121 125	+ -	0 – 5 V
CIV_SP_FrCO2	AO	01	CO2 Flow rate set-point		129 133	+ -	0 – 5 V
CIV_SP_Fgi	AO	02	Gas input Flow rate set-point		137 141	+ -	0 – 5 V
CIV_SP_Fgo	AO	03	Gas output Flow rate set-point		145 149	+ -	0 – 5 V
CIV_SP_Fgex	AO	04	Gas external input Flow rate set-point		153 157	+ -	0 – 5 V
CIV_SP_Li1	AO	05	Liquid input tank 1 Flow rate set-point		161 165	+ -	0 – 5 V
CIV_SP_Li2	AO	06	Liquid input tank 2 Flow rate set-point		169 173	+ -	0 – 5 V
CIV_SP_LO	AO	07	Liquid output Flow rate Control set-point		177 181	+ -	0 – 5 V
CIV_SP_Bs	AO	09	Base Flow rate set-point		193 197	+ -	4 – 20 mA
CIV_SP_Ls	AO	10	Light supply Radiation set-point		201 205	+ -	4 – 20 mA
CIV_SP_Ac	AO	11	Acid Flow rate set-point		209 213	+ -	4 – 20 mA
CIV_CAL_CO2O2	DI	01	Calibration indicator		42 46	+ -	0 – 24 V
CIV_ERR_CO2O2	DI	02	Error indicator		50 54	+ -	0 – 24 V
CIV_SCL1_CO2O2	DI	03	Using scale 1 indicator		58 62	+ -	0 – 24 V
CIV_SCL2_CO2O2	DI	04	Using scale 2 indicator		66 70	+ -	0 – 24 V

5.3.5 Procedure Steps

Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

5.3.6 MEL-TC-CIV-0301: Check analogue inputs

TC Identifier	**MEL-TC-CIV-0301**	**Purpose:**	Verify that analogue inputs are connected, acquired, supervised and ranged as specified
Functions Tested	Interface between CIV_CP – CIV_PLC – Supervision		
Description	Known values applied to analogue inputs shall be displayed in the Supervision ranged as specified.		
Special Requisites:	Values to apply / check must be between the indicated range		
Tester:		**Date:**	

Course of Actions			
Step no	**Description**	**Expected value**	**OK/NOK**
1	Apply 4 – 5 mA current to AI 01 (CIV_MV_CxAbs) and check the displayed value (Biomass Concentration in DW units) in the Supervision screen MEL_CIV_Main and MEL_CIV_BP.	0 – 0.2	
2	Apply 19 – 20 mA current to AI 01 (CIV_MV_CxAbs) and check the displayed value (Biomass Concentration in DW units) in the Supervision screen MEL_CIV_Main and MEL_CIV_BP.	1.8 – 2	
3	Apply 4 – 5 mA current to AI 02 (CIV_MV_M1) and check the displayed value (Tank1 Level) in the Supervision screen MEL_CIV_BP.	0 – 15	
4	Apply 19 – 20 mA current to AI 02 (CIV_MV_M1) and check the displayed value (Tank1 Level) in the Supervision screen MEL_CIV_BP.	135 – 150	
5	Apply 4 – 5 mA current to AI 03 (CIV_MV_M2) and check the displayed value (Tank2 Level) in the Supervision screen MEL_CIV_BP.	0 – 15	
6	Apply 19 - 20 mA current to AI 03 (CIV_MV_M2) and check the displayed value (Tank2 Level) in the Supervision screen MEL_CIV_BP.	135 – 150	
7	Apply 4 – 5 mA current to AI 04 (CIV_MV_P) and check the displayed value (Pressure) in the Supervision screens MEL_CIV_Main and MEL_CIV_Gas.	0 – 0.15	
8	Apply 19 - 20 mA current to AI 04 (CIV_MV_P) and check the displayed value (Pressure) in the Supervision screens MEL_CIV_Main and MEL_CIV_Gas.	1.45 – 1.5	
9	Apply 4 – 5 mA current to AI 05 (CIV_MV_pH) and check the displayed value (pH) in the Supervision screens MEL_CIV_Main and MEL_CIV_pH.	0 – 1.4	
10	Apply 19 - 20 mA current to AI 05 (CIV_MV_pH) and check the displayed value (pH) in the Supervision screens MEL_CIV_Main and MEL_CIV_pH.	12.6 – 14	
11	Apply 4 – 5 mA current to AI 06 (CIV_MV_T) and check the displayed value (Temperature) in the Supervision screen MEL_CIV_Main, MEL_CIV_Temp	0 – 15	
12	Apply a 19 - 20 mA current to AI 06 (CIV_MV_T) and check the displayed value	145 – 150	

	(Temperature) in the Supervision screen MEL_CIV_Main, MEL_CIV_Temp		
13	Apply 4 – 5 mA current to AI 07 (CIV_MGO_O2) and check the displayed value (O2 output) in the Supervision screen MEL_CIV_Main, MEL_CIV_Gas.	0 – 2.5	
14	Apply 19 – 20 mA current to AI 07 (CIV_MGO_O2) and check the displayed value (O2 output) in the Supervision screens MEL_CIV_Main, MEL_CIV_Gas.	22.5 – 25	
15	Apply 4 – 5 mA current to AI 08 (CIV_MGO_CO2) and check the displayed value (CO2 output) in the Supervision screens MEL_CIV_Main, MEL_CIV_Gas.	0 – 50	
16	Apply 19 – 20 mA current to AI 08 (CIV_MGO_CO2) and check the displayed value (CO2 output) in the Supervision screens MEL_CIV_Main, MEL_CIV_Gas.	450 – 500	
17	Apply 4 – 5 mA current to AI 09 (CIV_MV_DO) and check the displayed value (DO) in the Supervision screen MEL_CIV_Gas.	0 – 10	
18	Apply 19 - 20 mA current to AI 09 (CIV_MV_DO) and check the displayed value (DO) in the Supervision screen MEL_CIV_Gas.	90 – 100	
19	Apply 0 – 0.2 V to AI 13 (CIV_MV_FrGas) and check the displayed value (FR-CI) in the Supervision screen MEL_CIV_Gas.	0 – 3	
20	Apply a 4.8 – 5 V to AI 13 (CIV_MV_FrGas) and check the displayed value (FR-CI) in the Supervision screen MEL_CIV_Gas.	27 – 30	
21	Apply 0 – 0.2 V to AI 14 (CIV_MGO_FrGas) and check the displayed value (FR-GO) in the Supervision screen MEL_CIV_Gas.	0 – 3	
22	Apply 4.8 – 5 V to AI 14 (CIV_MGO_FrGas) and check the displayed value (FR-GO) in the Supervision screen MEL_CIV_Gas.	27 – 30	
23	Apply 0 – 0.2 V to AI 15 (CIV_MV_FrCO2) and check the displayed value (FR-CO2) in the Supervision screen MEL_CIV_Gas.	0 – 0.5	
24	Apply 4.8 – 5 V to AI 15 (CIV_MV_FrCO2) and check the displayed value (FR-CO2) in the Supervision screen MEL_CIV_Gas.	4.5 – 5	
25	Apply 0 – 0.2 V to AI 16 (CIV_MGI_FrGas) and check the displayed value (FR-GI) in the Supervision screen MEL_CIV_Gas.	0 – 3	
26	Apply 4.8 – 5 V to AI 16 (CIV_MGI_FrGas) and check the displayed value (FR-GI) in the Supervision screen MEL_CIV_Gas.	27 – 30	

5.3.7 MEL-TC-CIV-0302: Check analogue outputs

TC Identifier	MEL-TC-CIV-0302	Purpose:	Verify that analogue inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIV_CP – CIV_PLC – Supervision		
Description	Known values applied to Supervision variables shall be translated to the analogue outputs within the ranges specified. Only outputs with direct set-points are checked, the rest will be checked by other TC.		
Special Requisites:			
Tester:		Date:	

Course of Actions			
Step no	Description	Expected value	OK/NOK
1	In the supervision screen MEL_CIV_pH set the value 0 to “Fixed CO2 Flow Rate” and measure AO 01 output volts.	0 V ±0.01	
2	In the supervision screen MEL_CIV_pH set the value 5 to “Fixed CO2 Flow Rate” and measure AO 01 output volts.	5 V ±0.01	
3	In the supervision screen MEL_CIV_Gas set the value 0 to “Gas Input Flow Rate” and measure AO 02 output volts.	0 V ±0.01	
4	In the supervision screen MEL_CIV_Gas set the value 30 to “Gas Input Flow Rate” and measure AO 02 output volts.	5 V ±0.01	
5	In the supervision screen MEL_CIV_Gas set the value 0 to “Gas Output Flow Rate” and measure AO 03 output volts.	0 V ±0.01	
6	In the supervision screen MEL_CIV_Gas set the value 30 to “Gas Output Flow Rate” and measure AO 03 output volts.	5 V ±0.01	
7	In the supervision screen MEL_CIV_Gas set the value 0 to “Air Flow Rate” and measure AO 04 output volts.	0 V ±0.01	
8	In the supervision screen MEL_CIV_Gas set the value 30 to “Air Flow Rate” and measure AO 04 output volts.	5 V ±0.01	
9	Apply a resistance 1Kohm between AO 10+ and AO 10-		
10	With the iFix Database Manager set the value 0 to CIV_SSP_LIGHT and measure AO 10 output volts	4 V ±0.1	
11	With the iFix Database Manager set the value 1 to CIV_SSP_ LIGHT and measure AO 10 output volts	20 V ±0.1	

5.3.8 MEL-TC-CIV-0303: Check digital inputs

TC Identifier	**MEL-TC-CIV-0303**	**Purpose:**	Verify that digital inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIV_CP – CIV_PLC – Supervision		
Description	Status set to digital inputs shall be translated to the supervision as specified.		
Special Requisites:			
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK
1	Set DI 01 in open circuit and check in supervision screen MEL_CIV_Gas, indicator “Calibrating”	Disabled	
2	Set DI 01 in closed circuit and check in supervision screen MEL_CIV_Gas, indicator “Calibrating”	Enabled	
3	Set DI 02 in open circuit and check in supervision screen MEL_CIV_Gas, indicator “Error”	Disabled	
4	Set DI 02 in closed circuit and check in supervision screen MEL_CIV_Gas, indicator “Error”	Enabled	
5	Set DI 03 in open circuit and check in supervision screen MEL_CIV_Gas, indicator “Scale1”	Disabled	
6	Set DI 03 in closed circuit and check in supervision screen MEL_CIV_Gas, indicator “Scale1”	Enabled	
7	Set DI 04 in open circuit and check in supervision screen MEL_CIV_Gas, indicator “Scale2”	Disabled	
8	Set DI 04 in closed circuit and check in supervision screen MEL_CIV_Gas, indicator “Scale2”	Enabled	

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5.4 MEL-CIV-TP-04 Biomass production regulation

5.4.1 Purpose

Biomass production regulation is performed by a software component running in the Supervision Server. This software component uses the Supervision software (iFix) to interface with the Local Control (PLC). The Local Control translates the setting points provided by he Supervision to the actuators and acquires sensor values sending proper values back to the Supervision.

5.4.2 Features to be tested

Verify integration and functionality of the following items:

- CIV Biomass Production Software Component: CIV_BP_CL
- Supervision displays:
  - MEL_CIV_Main: Display of the most important values of the CIV compartment.
  - MEL_CIV_BP: Biomass Production Loop display.
- Local Control (PLC) program sections:
  - CIV_PLCSW_Biomass: Biomass measurement.
  - CIV_PLCSW_Liquid: Liquid flow regulation.
  - CIV_PLCSW_Light: Light regulation.
- PLC – Rack I/O Interface
- Supervision – PLC Interface
- CIV BP Software Component – Supervision Interface

5.4.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIV-TC-0301	Biomass sensor cleaning
MEL-CIV-TC-0302	Liquid flow regulation
MEL-CIV-TC-0303	Verify light regulation
MEL-CIV-TC-0304	Over pressure alarm

5.4.4 Special Requirements

Table of I/O that participates in the Biomass Production loop:
Ty (Type) = RL: Relay, AI: Analogue Input, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIV_RL_Cx	RL	03	Relay output to activate aeration of biomass sensor for cleaning	CIV_AC_OUT	01	AC L	220 VAC
					03	AC N	
					05	GND	
CIV_MV_CxAbs	AI	01	Analogue input for biomass concentration measurement in light absorbance units	CIV_CP	001	+	4 – 20 mA
					005	-	

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIV_MV_T	AI	06	Temperature measurement	CIV_CP	041	+	4 – 20 mA
					045	-	
CIV_SP_Li1	AO	05	Analogue output to fix liquid input pump 1 set-point	CIV_CP	161	+	0 – 5 V
					165	-	
CIV_SP_Li2	AO	06	Analogue output to fix liquid input pump 2 set-point	CIV_CP	169	+	0 – 5 V
					173	-	
CIV_SP_LO	AO	07	Analogue output to fix liquid output pump set-point	CIV_CP	177	+	0 – 5 V
					181	-	
CIV_RL_Li1	RL	01	Relay to activate liquid input pump 1	CIV_CP	170	+	24V
					174	-	
CIV_RL_Li2	RL	02	Relay to activate liquid input pump 2	CIV_CP	178	+	24V
					182	-	
CIV_MV_M1	AI	02	Analogue input to acquire mass of liquid input tank 1	CIV_CP	009	+	4 – 20 mA
					013	-	
CIV_MV_M2	AI	03	Analogue input to acquire mass of liquid input tank 2	CIV_CP	017	+	4 – 20 mA
					021	-	
CIV_SP_Ls	AO	10	Analogue output to provide light regulation set-point	CIV_CP	201	+	4 – 20 mA
					205	-	

Devices needed in this test procedure:

- 2 Adjustable Power Supply (APS) to provide current / voltage to analogue inputs
- 1 Multimeter to measure analogue current / voltage outputs
- 1 Oscilloscope to measure output transitory

5.4.5 Procedure Steps

- Set Biomass loop operation mode to AUTO.
- Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

5.4.6 MEL-TC-CIV-0401: Verify biomass sensor cleaning

TC Identifier	**MEL-TC-CIV-0401**	**Purpose:**	Verify that output to activate valve to clean the biomass sensor is activated as specified and Biomass value is maintained.
Items Tested	CIV_PLCSW_Biomass, MEL_CIV_BP, MEL_CIV_MAIN		
Description	Every 5 minutes the digital output 03 shall be activated during 5 seconds. During this time, and 5 seconds after, the biomass sensor acquired value must be maintained.		
Special Requisites:	An APS is used to simulate the Biomass sensor. Check supervision values in MEL_CIV_BP and MEL_CIV_Main displays		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Set 2.9 - 3.1 V to AI 01 (CIV_MV_CxAbs) and check in MEL_CIV_BP Supervision display the value of Biomass concentration	1 gr/l ±0.1		
2	Check by inspection AIR valve is opened every 5 minutes during 5 seconds.			
3	During the time the valve is open modify AI 01 input and check value of Biomass concentration is not changed in the supervision.			
4	Immediately after AIR valve is closed modify AI 01 and check by inspection value is not changed during 5 seconds after the valve is closed.			
5	Check that if value is modified 5 seconds after AIR valve is closed Biomass Concentration value is changed as well.			

5.4.7 MEL-TC-CIV-0402: Liquid flow regulation

TP Identifier	**TP-TC-CIV-0402**	**Purpose:**	Verify that flow set points are transmitted to input output pumps according to specifications.		
Items Tested	CIV_PLCSW_Liquid, CIV_BP_CL, CIV_PLCSW_Light, MEL_CIV_BP, MEL_CIV_MAIN				
Description	Flow rate set point and light set point are provided from the Supervision, by the software module CIV_BP_CL. The PLC shall regulate the active input pump, flow rate of output pump and activate alarm in case input media tanks are empty, and transfer the light setting point to the light regulator device.				
Special Requisites:	Two APS (APS1, APS2) are needed to simulate scale sensors of liquid input tanks. Use MEL_CIV_MAIN and MEL_CIV_BP supervision displays Use a multimeter to measure analogue values				
Tester:		**Date:**			

Course of Actions				
Step no	**Description**	**Expected value**	**OK**	**Comments**
1	Apply with APS1 17 – 19 mA to AI 02 (CIV_MLI_M1) check in the supervision display MEL_CIV_BP the Tank 1 level.	130 liters ±15		
2	Apply with APS2 14 – 15 mA to AI 01 (CIV_MV_CxAbs) check in the supervision display MEL_CIV_BP the Biomass concentration	1.5 g/l ±0.2		
3	Apply a 1Kohm resistor to AO 10 (CIV_SP_Ls)			
4	In the MEL_CIV_MAIN display check Biomass concentration	1.5 g/l ±0.2		
5	In the MEL_CIV_BP display set Liquid input pump 1 calibration parameters to A=18.315, B=11.0989			
6	In the MEL_CIV_BP display set Liquid input pump 2 calibration parameters to A=16.103, B=0.8534			
7	In the MEL_CIV_BP display set Liquid output pump calibration parameters to A=20, B=10			
8	In the MEL_CIV_BP display set minimum volume to switch input tank to 10 liters			
9	In the MEL_CIV_BP display set: - Biomass production set-point to 1.2 gr/l - Liquid input flow rate set-point to 0.7 l/h Using the iFix Database Manager set CIV_SSP_LIGHTWM to 68.5844 and CIV_SSP_LIFR = 0.7			
10	Adjust APS2 to obtain a Biomass Concentration of 1.36±0.01 gr/l (check in MEL_CIV_BP)			

TP Identifier	**TP-TC-CIV-0402**	**Purpose:**	Verify that flow set points are transmitted to input output pumps according to specifications.		
Items Tested	CIV_PLCSW_Liquid, CIV_BP_CL, CIV_PLCSW_Light, MEL_CIV_BP, MEL_CIV_MAIN				
Description	Flow rate set point and light set point are provided from the Supervision, by the software module CIV_BP_CL. The PLC shall regulate the active input pump, flow rate of output pump and activate alarm in case input media tanks are empty, and transfer the light setting point to the light regulator device.				
Special Requisites:	Two APS (APS1, APS2) are needed to simulate scale sensors of liquid input tanks. Use MEL_CIV_MAIN and MEL_CIV_BP supervision displays Use a multimeter to measure analogue values				
11	From the Supervision iFix Scheduler configure as Foreground task and fire scheduled event CIV_CTRLLAW_BP				
12	Check in the MEL_CIV_BP display the Level 1 liquid input flow rate set point	0.77 l/h ±0.01			
13	Check in the MEL_CIV_BP display the % actuation of input pump 1	25.20% ±0.01			
14	Measure voltage output in CIV_SP_Li1 (AO 05)	1.26 V ±0.1			
15	Check in the MEL_CIV_BP display the output flow rate (must be +10% of the liquid input flow rate)	0.84 l/h ±0.01			
16	Check in the MEL_CIV_BP display the % actuation of output pump	26.8% ±0.2			
17	Measure voltage output in CIV_SP_LO (AO 07)	1.34 V ±0.1			
18	Check in the MEL_CIV_BP display the liquid input pump1 status	Enabled (green)			
19	Check in the MEL_CIV_BP display the liquid input pump2status	Disabled (red)			
20	Check in the MEL_CIV_BP display the output light set-point	217.61 w/m2 ±1			
21	In the MEL_CIV_MAIN display check light set-point (Light intensity)	217.61 w/m2 ±1			
22	In the MEL_CIV_BP display check light regulator actuation set point %	83.52% ±2			
23	Measure voltage output in CIV_SP_Ls (AO 10)	17.36 V ±0.2			
24	From the Supervision iFix Scheduler display fire scheduled event CIV_CTRLLAW_BP again				
25	Check in the MEL_CIV_BP display the output light set-point	223.00 w/m2 ±0.01			
26	Disconnect APS2 from AI 01 and set output to 17-18 mA				
27	Apply with APS2 17-18 mA to AI 03 (CIV_MLI_M2)				
28	Check in the MEL_CIV_BP display the tank 2 level	130 liters ±15			
29	Set APS1 output to 4 – 5 mA.				
30	Check in the MEL_CIV_BP display the tank 1 level	5 liters ±5			
31	Check in the MEL_CIV_BP display the input pump 1	Disabled			

TP Identifier	**TP-TC-CIV-0402**	**Purpose:**	Verify that flow set points are transmitted to input output pumps according to specifications.		
Items Tested	CIV_PLCSW_Liquid, CIV_BP_CL, CIV_PLCSW_Light, MEL_CIV_BP, MEL_CIV_MAIN				
Description	Flow rate set point and light set point are provided from the Supervision, by the software module CIV_BP_CL. The PLC shall regulate the active input pump, flow rate of output pump and activate alarm in case input media tanks are empty, and transfer the light setting point to the light regulator device.				
Special Requisites:	Two APS (APS1, APS2) are needed to simulate scale sensors of liquid input tanks. Use MEL_CIV_MAIN and MEL_CIV_BP supervision displays Use a multimeter to measure analogue values				
32	Check in the MEL_CIV_BP display the input pump 2	Enabled			
33	Set APS2 output to 4 - 5 mA				
34	Check in the MEL_CIV_BP display the tank 2 level	5 liters ±5			
35	Check in the MEL_CIV_BP display the input pump 1	Disabled			
36	Check in the MEL_CIV_BP display the input pump 2	Disabled			
37	Check in the MEL_CIV_BP display the output pump actuation	0%			
38	Measure voltage output in CIV_SP_LO (AO 07)	0 V ±0.01			

5.4.8 MEL-TC-CIV-0403: Light index

TP Identifier	**TP-TC-CIV-0403**	**Purpose:**	Verify that when the light index set point changes, a ramp is applied to set point output to smooth the variation.
Functions Tested	CIV_PLCSW_Light, MEL_CIV_BP		
Description	Light set point changes are applied using a ramp that changes from 0 to 1 in 15 seconds.		
Special Requisites:	Use an oscilloscope (OSC) to measure ramp.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Apply a 1 Kohm resistor to AO 10			
2	Connect the OSC channel 1 to TB_ACO pin 2 (-) and pin 5 (+) to monitor AO 10 (AO 4 mA => 0,4 V / AO 20 mA => 2V) . Time div 5 seconds. V div 0.5 V			
3	Set in the CIV_SSP_Light variable in the iFix Data Manager display the value 0. Wait until output voltage in AO 10 goes down to 4V.	0,4 V ±0.01		
4	Set in the CIV_SSP_Light variable in the MEL_CIV_TEST_01 display the value 1. Wait until output voltage in AO 10 goes up to 20V.	2 V ±0.1		
5	Check in the OSC the output voltage changed from 0,4V to 2V in 15±0.2 seconds.			

5.4.9 MEL-TC-CIV-0404: Over temperature alarm

TP Identifier	**TP-TC-CIV-0404**	**Purpose:**	Verify that when the over temperature alarm is on light supply is set to a safety value		
Functions Tested	CIV_PLCSW_Light, CIV_PLCSW_T, MEL_CIV_Temp				
Description	When an over temperature is detected, light supply is set to a low value to avoid over heating				
Special Requisites:	Use an APS to apply voltages				
Tester:			**Date:**		

Course of Actions				
Step no	**Description**	**Expected value**	**OK/NOK**	**Comments**
1	In the MEL_CIV_Temp supervision screen set Temperature set point to 27 ºC			
2	Apply with the APS 1.9 – 2.1 V to AI 06	37.5 ±4 ºC		
3	Check the over temperature alarm is displayed in the Alarm area of the Supervision screen			
4	Check in MEL_CIV_BP light supply actuation	10%		

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5.5 MEL-CIV-TP-05 Gas Flow Regulation

5.5.1 Purpose

Gas flow regulation controls pressure in the compartment and gas input/output set-points. Two modes of operation are defined:

- Control action enabled: if the pressure increases over a defined value, the controller commands the output gas valve to open 10% over the set point. If the pressure decreases below a defined value, the controller commands the input gas valve to open 10% over the set point.
- Control action disabled: Gas input / output flows are set directly from the supervision.

In addition the pressure valve is opened if pressure value goes over the max. allowed pressure.

5.5.2 Features to be tested

Verify integration and functionality of the following items:

- Supervision displays:
    - MEL_CIV_Main: Display of the most important values of the CIV compartment.
    - MEL_CIV_Gas: Biomass Production Loop display.
- Local Control (PLC) program sections:
    - CIV_PLCSW_Gas: Gas flow regulation.
- PLC – Rack I/O Interface
- Supervision – PLC Interface

5.5.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIV-TC-0501	Control action enabled
MEL-CIV-TC-0502	Pressure safety valve activation
MEL-CIV-TC-0503	Check over pressure alarm

5.5.4 Special Requirements

Table of I/O that participates in the Gas regulation loop:
Ty (Type) = RL: Relay, AI: Analogue Input, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIV_MGI_FrGas	AI	13	Gas flow at external input	CIV_CP	097	+	0 – 5 V
					101	-	
CIV_MGO_FrGas	AI	14	Gas flow at output	CIV_CP	105	+	0 – 5 V

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
					109	-	
CIV_MV_FrGas	AI	16	Gas flow at compartment input	CIV_CP	121	+	0 – 5 V
					125	-	
CIV_MV_P	AI	04	Pressure measurement	CIV_CP	025	+	4 – 20 mA
					029	-	
CIV_SP_Fgi	AO	02	Gas flow at input regulation	CIV_CP	137	+	0 – 5 V
					141	-	
CIV_SP_Fgo	AO	03	Gas flow at output regulation	CIV_CP	145	+	0 – 5 V
					149	-	
CIV_SP_Fgex	AO	04	Gas flow external input regulation	CIV_CP	153	+	0 – 5 V
					157	-	
CIV_RL_Fg	RL	04	Pressure safety valve activation	CIV_AC_OUT	07	AC L	220 VAC
					09	AC N	
					11	GND	

Devices needed in this test procedure:

- Adjustable Power Supply (APS)
- Multi-meter

5.5.5 Procedure Steps

- Set Gas loop operation mode to AUTO.
- Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

5.5.6 MEL-TC-CIV-0501: Control action enabled

TC Identifier	**MEL-TC-CIV-0501**	**Purpose:**	Verify that set points are modified by the PLC in case of over/under pressure	
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_GAS			
Description	In case of overpressure output flow increments a 10%, in case of under pressure input flow increments a 10%. Over pressure is when pressure is 0.01 over the nominal value, and under pressure is when pressure is 0.01 under the nominal value.			
Special Requisites:	An APS is used to simulate the pressure sensor. Use the multi-meter to measure currents and voltages. Check supervision values in MEL_CIV_Gas			
Tester:		**Date:**		

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_Gas set the max allowed pressure value to 1.1 bar			
2	In the MEL_CIV_Gas set the nominal pressure 1.0 bar			
3	In the MEL_CIV_Gas set the AIR input flow rate to 10 nLm			
4	Apply with the APS 3.66–3.68 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	1±0.005 bar		
5	Measure CIV_SP_Fgex (AO 04) voltage	1.66±0.01 V		
6	In the MEL_CIV_Gas set the gas input flow rate to 20 nLm			
7	Measure CIV_SP_Fgi (AO 02) voltage	3.33±0.01 V		
8	In the MEL_CIV_Gas set the gas output flow rate to 12 nLm			
9	Measure CIV_SP_Fgo (AO 03) voltage	2±0.01 V		
10	Check in MEL_CIV_Gas display the over pressure & under pressure indicators	Disabled		
11	Modify APS value to 3.69-3.72 V and check pressure value in MEL_CIV_Gas.	1.015±0.005 bar		
12	Check in MEL_CIV_Gas display the over pressure indicator	Enabled		
13	Measure CIV_SP_Fgo (AO 03) voltage (shall be 10% over set point measured in 9)	2.2±0.02 V		
14	Modify APS value to 3.59 -3.62 V and check pressure value in MEL_CIV_Gas.	0.98±0.005 bar		
15	Check in MEL_CIV_Gas display the under pressure indicator	Enabled		
16	Measure CIV_SP_Fgex (AO 04) voltage (shall be 10% over set point measured in 5)	1.82±0.02 V		
17	Measure CIV_SP_Fgi (AO 02) voltage (shall be 10% over set point measured in 7)	3.66±0.02 V		
18	Apply with the APS 3.67 –3.69 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	1.005 ±0.005 bar		

TC Identifier	**MEL-TC-CIV-0501**	**Purpose:**	Verify that set points are modified by the PLC in case of over/under pressure	
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_GAS			
Description	In case of overpressure output flow increments a 10%, in case of under pressure input flow increments a 10%. Over pressure is when pressure is 0.01 over the nominal value, and under pressure is when pressure is 0.01 under the nominal value.			
Special Requisites:	An APS is used to simulate the pressure sensor. Use the multi-meter to measure currents and voltages. Check supervision values in MEL_CIV_Gas			

19	Check in MEL_CIV_Gas display the under pressure indicator	Disabled		
20	Check in MEL_CIV_Gas display the over pressure indicator	Disabled		
21	Measure CIV_SP_Fgex (AO 04) voltage (initial value)	1.66±0.02 V		
22	Measure CIV_SP_Fgi (AO 02) voltage (initial value)	3.33±0.02 V		
23	Measure CIV_SP_Fgo (AO 03) voltage (initial value)	2.00±0.02 V		

5.5.7 MEL-TC-CIV-0502: Pressure safety valve activation

TC Identifier	**MEL-TC-CIV-0502**	**Purpose:**	Verify that pressure safety valve is activated in case of an high overpressure
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_GAS		
Description	In case pressure is over the max allowed pressure, the pressure safety valve shall be opened until pressure is nominal		
Special Requisites:	An APS is used to simulate the pressure sensor. Use the multi-meter to measure currents and voltages. Check supervision values in MEL_CIV_Gas		
Tester:		**Date:**	

Course of Actions

Step no	**Description**	**Expected value**	**OK/NOK**	**Comments**
1	In the MEL_CIV_Gas set the max allowed pressure value to 1.1 bar			
2	In the MEL_CIV_Gas set the nominal pressure 1.0 bar			
3	In the MEL_CIV_Gas set the external input flow rate to 10 nLm			
4	Apply with the APS 3.66–3.68 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	1±0.005 bar		
5	In the MEL_CIV_Gas check safety valve status	Closed		
6	Modify APS value to 4.2-4.5 V and check pressure value in MEL_CIV_Gas.	1.25±0.05 bar		
7	In the MEL_CIV_Gas check safety valve status	Open (green)		
8	Measure output Voltage AC CIV_RL_Fg (CIV_AC_OUT 08,10)	220 VEF ±10%		
9	Modify APS value to 3.70 -3.72 V and check pressure value in MEL_CIV_Gas.	1.015±0.005 bar		
10	In the MEL_CIV_Gas check safety valve status	Open		
11	Apply with the APS 3.64 3.66 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	0.995±0.005 bar		
12	In the MEL_CIV_Gas check safety valve status	Closed		

5.5.8 MEL-TC-CIV-0503: Check over pressure alarm

TC Identifier	MEL-TC-CIV-0503	Purpose:	Verify that over pressure alarm is activated
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_GAS		
Description	When an overpressure occurs during more than 5 seconds, the over pressure alarm shall be activated.		
Special Requisites:	An APS is used to simulate the pressure sensor. Check supervision values in MEL_CIV_Gas		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_Gas set the max allowed pressure value to 1.1 bar			
2	In the MEL_CIV_Gas set the nominal pressure 1.0 bar			
3	In the MEL_CIV_Gas set the AIR input flow rate to 10 nLm			
4	Apply with the APS 4.2-4.5 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	1.25±0.05 bar		
5	After 5 seconds check the MEL_CIV_Gas alarms. Verify that over pressure alarm has been indicated.			

5.6 MEL-CIV-TP-06 pH Regulation

5.6.1 Purpose

pH regulation controls the pH in the compartment. A pH probe measures pH and in case of deviation, several actions can be taken depending on the current operation mode:

- Only CO2: When the pH is over the set point, additional CO2 is added. A PID controls CO2 addition.
- CO2 and basic medium: When pH is over the set point, CO2 is added, when is under basic medium is added. A proportional controller controls basic medium addition.
- Acid and basic media. When pH is over the set point, acid media is added, when is under, basic media is added. A proportional controller controls both, basic and acid, media.

In addition a fixed quantity of CO2 can be added independently of the control action.

5.6.2 Features to be tested

Verify integration and functionality of the following items:

- Supervision displays:
    - MEL_CIV_Main: Display of the most important values of the CIV compartment.
    - MEL_CIV_pH: pH regulation display.
- Local Control (PLC) program sections:
    - CIV_PLCSW_pH: pH regulation.
- PLC – Rack I/O Interface
- Supervision – PLC Interface

5.6.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIV-TC-0601	Only CO2
MEL-CIV-TC-0602	CO2 and additional base medium
MEL-CIV-TC-0603	Base and Acid additional media
MEL-CIV-TC-0604	Check pH alarm

5.6.4 Special Requirements

Table of I/O that participates in the Gas regulation loop:
Ty (Type) = RL: Relay, AI: Analogue Input, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIV_MV_pH	AI	05	pH measurement	CIV_CP	033	+	4 – 20 mA
					037	-	
CIV_SP_FrCO2	AO	01	CO2 flow regulation	CIV_CP	129	+	0 – 5 V

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
					133	-	
CIV_SP_Bs	AO	09	Additional Base source for pH regulation	CIV_CP	193	+	4 – 20 mA
					197	-	
CIV_SP_Ac	AO	11	Additional Acid source for pH regulation	CIV_CP	209	+	4 – 20 mA
					213	-	

Devices needed in this test procedure:

- Adjustable Power Supply (APS)
- Multi-meter (MM)
- Oscilloscope (OSC)

5.6.5 Procedure Steps

- Set pH loop operation mode to AUTO.
- Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

5.6.6 MEL-TC-CIV-0601: Regulate pH with CO2 only

TC Identifier	**MEL-TC-CIV-0601**	**Purpose:**	Verify that CO2 flow meter regulates CO2 input to maintain pH set point
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	With the control action mode CO2 Only, the pH is regulated adding CO2. Control action is performed by means of a PID		
Special Requisites:	Use the multi-meter to measure currents and voltages. Use the FG to simulate variations in the pH. Use the OSC to display CIV_SP_CO2 (CO2 regulation PID output in AO 01) Check supervision values in MEL_CIV_pH Concept SW is used to modify enable/disable PID parameters		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_pH set the control action mode 1 (CO2 Only)			
2	In the MEL_CIV_pH set the pH set point to 6.5			
3	In the MEL_CIV_pH set the CO2 flow meter PID parameters to P=5, I=100, D=0.01			
4	With the Concept tool connect to the PLC and open CIV_PLCSW_pH section.			
5	In Concept set “FALSE” to EN_I, EN_D (only proportional part of the PID is enabled)			
6	With the FG apply a squared wave with duty cycle = 50%, Amp=0.1±0.05 V, Offset = 2.7±0.05 (2.7-2.9) and f=0.1 Hz to CIV_MV_pH (AI 05)			
7	Check in the MEL_CIV_pH display pH value is between the range	5.95 ±0.1 to 6.65 ±0.1 pH		
8	Measure CIV_SP_FrCO2 (AO 01) output MAX	0.75 ±0.3 V		
9	In Concept set “FALSE” to EN_P, EN_D and “TRUE” to EN_I (only Integrative part of the PID is enabled)			
10	In the FG increment Amp = 0.5 to increase integrative action			
11	Measure CIV_SP_FrCO2 (AO 01) output MAX	0.35±0.1 V		
12	In Concept set “FALSE” to EN_P, EN_I and “TRUE” to EN_D (only Derivative part of the PID is enabled)			
13	With the FG modify to a triangle wave with same parameters			
13	Measure CIV_SP_FrCO2 (AO 01) output MAX	0.035±0.05 V		

5.6.7 MEL-TC-CIV-0602: CO2 and additional base medium

TC Identifier	**MEL-TC-CIV-0602**	**Purpose:**	Verify that Base pump is activated when pH is under set-point and CO2 flowmeter is activated when pH is over set-point
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	With the control action mode 2 CO2 + Base media, the pH is regulated adding CO2 when pH is over the set point and Base media when pH is under the set-point. A PID controller regulates CO2 flow and a P (proportional) controller controls Base pump.		
Special Requisites:	Use the multi-meter to measure currents and voltages. Use the FG to simulate variations in the pH. Check supervision values in MEL_CIV_pH		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	
1	In the MEL_CIV_pH set the control action mode 2 (CO2 + Base)			
2	In the MEL_CIV_pH set the pH set point to 6.5			
3	In the MEL_CIV_pH set the CO2 flow meter PID parameters to P=5, I=100, D=0.01			
4	With the FG apply a squared wave with duty cycle = 50%, Amp=0.1±0.05 V, Offset = 2.7±0.05 (2.7-2.9) and f=0.1 Hz to CIV_MV_pH (AI 05)			
5	Check in the MEL_CIV_pH display pH value is between the range	5.95 ±0.1 to 6.65 ±0.1 pH		
6	Apply a 1 Kohm resistor to AO 09			
7	Measure CIV_SP_Bs (AO 09) output MAX	12.8 ±1 V		
8	Check in the MEL_CIV_pH display Base pump actuation	55±5 %		

5.6.8 MEL-TC-CIV-0603: Base and Acid additional media

TC Identifier	**MEL-TC-CIV-0603**	**Purpose:**	Verify that Base pump is activated when pH is under set-point and Acid pump is activated when pH is over set-point
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	With the control action mode 2 CO_2 + Base media, the pH is regulated adding CO_2 when pH is over the set point and Base media when pH is under the set-point. A PID controller regulates CO_2 flow and a P (proportional) controller controls Base pump.		
Special Requisites:	Use the multi-meter to measure currents and voltages. Use the FG to simulate variations in the pH. Check supervision values in MEL_CIV_pH		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_pH set the control action mode 3 (Base + Acid)			
2	In the MEL_CIV_pH set the pH set point to 6.5			
3	In the MEL_CIV_pH set the CO_2 flow meter PID parameters to P=5, I=100, D=0.01			
4	With the FG apply a squared wave with duty cycle = 50%, Amp=0.1±0.05 V, Offset = 2.8±0.05 (2.8-3.0) and f=0.1 Hz to CIV_MV_pH (AI 05)			
5	Check in the MEL_CIV_pH display pH value is between the range	6.30 ±0.1 to 7.00 ±0.1		
6	Apply a 1 Kohm resistor to AO 11			
8	Measure CIV_SP_Ac (AO 11) Output MAX	13±1 V		
9	Check in the MEL_CIV_pH display acid pump actuation	50 ±5 %		

5.6.9 MEL-TC-CIV-0604: Check pH alarm

TC Identifier	**MEL-TC-CIV-0604**	**Purpose:**	Verify that when pH is out of the nominal value during a period of time an alarm is generated
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	When pH is over or under the set point +/- dead band, during more than 15 minutes continuously, an alarm is generated and Supervision shall display the alarm condition.		
Special Requisites:	Use APS to generate the pH value		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_pH set the pH set point to 6			
2	With the APS set 2.9±0.5 V to CIV_MV_pH (AI 05)			
3	Check in the MEL_CIV_pH display pH value	6.65±0.1		
4	Wait 15 minutes			
5	Check after 15 minutes, the pH alarm has been notified to Supervision.			

5.7 MEL-CIV-TP-07: Initial Values

5.7.1 Purpose

When PLC is restarted, default initial values are loaded into program parameters. It shall be verified that these default values are properly defined, since the PLC will use this parameters immediately after is restarted.

5.7.2 Features to be tested

Verify default values loaded into the PLC used when it is restarted.

5.7.3 Procedure Steps

1. Stop the PLC
2. Load last program version into the PLC
3. Start the PLC
4. With the Concept tool Reference Data Editor, check that initial values are as in the following table:

TC Identifier	**MEL-CIV-TP-07**	**Purpose**	**Check that correct initial values are used at PLC restart**		
Tester:		**Date:**			
Variable name	**Type**	**Address**	**Init. Value**	**Description**	**OK**
CIV_CNS_AcKp	REAL	400544	100.0	Acid pump regulator proportional constant.	
CIV_CNS_BsKp	REAL	400546	100.0	Base pump regulator proportional constant.	
CIV_CNS_CO2_Kd	REAL	400552	0.01	CO2 flow regulator derivate constant for PID	
CIV_CNS_CO2_Ki	REAL	400550	100.0	CO2 flow regulator integration constant for PID	
CIV_CNS_CO2_Kp	REAL	400548	5.0	CO2 flow regulator proportional constant for PID	
CIV_CNS_ConvV	REAL	400518	1.0	Density factor to translate Kg. to liters	
CIV_CNS_DW	REAL	400542	1.0	Constant to calculate biomass dry weight	
CIV_CNS_Li1FrA	REAL	400512	18.315	Parameter A for liquid input pump 1 set point calc	
CIV_CNS_Li1FrB	REAL	400514	11.0989	Parameter B for liquid input pump 1 set point calc	
CIV_CNS_Li2FrA	REAL	400538	16.103	Parameter A for liquid input pump 2 set point calc	
CIV_CNS_Li2FrB	REAL	400540	0.8534	Parameter B for liquid input pump 2 set point calc	
CIV_CNS_LoFrA	REAL	400510	15.0	Parameter A for liquid output pump set point calc	
CIV_CNS_LoFrB	REAL	400516	1.0	Parameter B for liquid output pump set point calc	
CIV_CNS_MaxPress	REAL	400524	0.02	Maximum allowed pressure in the reactor	
CIV_CNS_MinV	REAL	400500	10.0	Minimum volume to switch liquid input tank	
CIV_CNS_OffsetCO2	REAL	400536	0.0	Offset to provided a constant flux of CO2 to the	
CIV_CNS_OpModeBP	Integer	400566	0	Biomass Production control mode (0=Off, 1=Auto, 2=Manual)	
CIV_CNS_OpModeGas	Integer	400568	0	Gas control mode (0=Off, 1=Auto, 2=Manual)	
CIV_CNS_OpModepH	Integer	400567	0	pH control mode ((0=Off, 1=Auto, 2=Manual)	
CIV_CNS_pHMode	Integer	400565	1	pH regulation mode parameter (1=CO2 only, 2=CO2+Base, 3=Base+Acid)	
CIV_SSP_L1BP	REAL	400554	0.0	Level 1 Biomass production set-point	
CIV_SSP_Fgex	REAL	400532	0.0	Gas flow external input supervision set point	
CIV_SSP_Fgi	REAL	400526	0.0	Gas flow at input regulation supervision set point	
CIV_SSP_Fgo	REAL	400528	0.0	Gas flow at output regulation supervision set point	
CIV_SSP_L1LiFr	REAL	400508	0.0	Level 1 Liquid input flow rate set-point	
CIV_SSP_Light	REAL	400520	0.0	Light Supervision set point.	
CIV_SSP_NomPress	REAL	400522	0.01	Nominal pressure in the reactor	

TC Identifier	MEL-CIV-TP-07	Purpose	Check that correct initial values are used at PLC restart		
Tester:		Date:			
Variable name	**Type**	**Address**	**Init. Value**	**Description**	**OK**
CIV_SSP_T	REAL	400562	36.0	Temperature set-point fixed by the supervision	
CIV_SSP_pH	REAL	400534	9.5	pH set-point fixed by the supervision	

5. If one or more initial values differ from those in the table then follow the procedure defined in the Operations Manual [R9], section 9.2 to update.

5.8 MEL-CIV-TP-08: Check Sensor / Actuator Link Errors

5.8.1 Purpose

When a current (4-20 mA) analogue input / output is disconnected (link error) the status shall be notified to the supervision.

5.8.2 Features to be tested

Verify link errors are notified to the supervision as specified.
Verify safety values are set to measured variables when a link error occurs.

5.8.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIV-TC-0801	Check link errors on analogue inputs
MEL-CIV-TC-0802	Check link errors on analogue outputs

5.8.4 Procedure Steps

Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

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5.8.5 MEL-TC-CIV-0801: Check Link Errors on Analogue Inputs

TC Identifier	**MEL-TC-CIV-0801**	**Purpose:**	Verify that when a current analogue input connection is broken is notified to supervision
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	Errors on sensor links are displayed in the supervision as alarms and safety values are displayed blinking in the supervision screens.		
Special Requisites:	All current inputs shall be disconnected		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_BP supervision display check Biomass Concentration value	1.0 (Blinking)		
2	In the MEL_CIV_BP supervision display check Tank 1 volume value	0.0 (Blinking)		
3	In the MEL_CIV_BP supervision display check Tank 2 volume value	0.0 (Blinking)		
4	In the MEL_CIV_Gas supervision display set pressure set point to 1.0			
5	In the MEL_CIV_Gas supervision display check Pressure (P) value	1.0 (Blinking)		
6	In the MEL_CIV_Gas supervision display check O2 value	0.0 (Blinking)		
8	In the MEL_CIV_Gas supervision display check CO2 value	0.0 (Blinking)		
9	In the MEL_CIV_Gas supervision display check DO value	0.0 (Blinking)		
10	In the MEL_CIV_Temp supervision display set Temperature set-point to 27 ºC			
11	In the MEL_CIV_Temp supervision display check Temperature value	27.0 (Blinking)		
13	In the MEL_CIV_pH supervision display set pH set-point to 6.5			
14	In the MEL_CIV_pH supervision display check pH value	6.5 (Blinking)		
15	In the MEL_CIV_Main supervision display check Biomass Concentration value	1.0 (Blinking)		
16	In the MEL_CIV_Main supervision display check Pressure value	1.0 (Blinking)		
17	In the MEL_CIV_Main supervision display check O2 value	0.0 (Blinking)		
18	In the MEL_CIV_Main supervision display check CO2 value	0.0 (Blinking)		
19	In the MEL_CIV_Main supervision display check DO value	0.0 (Blinking)		
20	In the MEL_CIV_Main supervision display Temperature value	27.0 (Blinking)		
21	In the MEL_CIV_Main supervision display pH value	6.5 (Blinking)		
22	Check following alarms are fired: - Alarm to notify O2 sensor link error - Alarm to notify biomass sensor link error - Alarm to notify DO sensor link error			

TC Identifier	MEL-TC-CIV-0801	Purpose:	Verify that when a current analogue input connection is broken is notified to supervision		
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH				
Description	Errors on sensor links are displayed in the supervision as alarms and safety values are displayed blinking in the supervision screens.				
Special Requisites:	All current inputs shall be disconnected				
	- Alarm to notify CO2 sensor link error - Alarm to notify pressure sensor link error - Alarm to notify pH sensor link error - Alarm to notify Temperature sensor link error - Alarm to notify scale1 sensor link error - Alarm to notify scale2 sensor link error				

5.8.6 MEL-TC-CIV-0802: Check Link Errors on Analogue Outputs

TC Identifier	MEL-TC-CIV-0802	Purpose:	Verify that when a current analogue output connection is broken is notified to supervision		
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH				
Description	Errors on actuator links are displayed in the supervision as alarms				
Special Requisites:	All current outputs shall be disconnected				
Tester:			Date:		
Course of Actions					
Step no	Description		Expected value	OK/NOK	Comments
1	Check following alarms are fired: - Alarm to notify acid pump link error - Alarm to notify base pump link error - Alarm to notify light supply link error				

5.9 MEL-CIV-TP-09: Check operational modes

5.9.1 Purpose

Each loop (Biomass, pH, Gas) allows the selection of the operational mode:
OFF: Outputs are set to 0
AUTO: Outputs are set with the value resulting of the control action.
MAN: Outputs are set to manual values (provided by the Supervision from each loop Supervision displays).

5.9.2 Features to be tested

Verify changing operational modes outputs are set as specified.

5.9.3 Test Cases

Following Test Cases are executed in this Test Procedure:

Identifier	Name
MEL-CIV-TC-0901	Check Biomass Production loop operational modes.
MEL-CIV-TC-0902	Check Gas loop operational modes
MEL-CIV-TC-0903	Check pH loop operational modes

5.9.4 Special Requirements

Table of Outputs that participates in the regulation loops:
Ty (Type) = RL: Relay, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIV_RL_Li1	RL	01	Relay to activate liquid input pump 1	CIV_CP	170	+	24V
					174	-	
CIV_RL_Li2	RL	02	Relay to activate liquid input pump 2	CIV_CP	178	+	24V
					182	-	
CIV_RL_Cx	RL	03	Relay output to activate aeration of biomass sensor for cleaning	CIV_AC_OUT	01	AC L	220 VAC
					03	AC N	
					05	GND	
CIV_RL_Fg	RL	04	Pressure safety valve activation	CIV_AC_OUT	07	AC L	220 VAC
					09	AC N	
					11	GND	
CIV_SP_FrCO2	AO	01	CO2 Flow rate set-point		129 133	+ -	0 – 5 V
CIV_SP_Fgi	AO	02	Gas input Flow rate set-point		137 141	+ -	0 – 5 V
CIV_SP_Fgo	AO	03	Gas output Flow rate set-point		145 149	+ -	0 – 5 V
CIV_SP_Fgex	AO	04	Gas external input Flow rate set-point		153 157	+ -	0 – 5 V

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIV_SP_Li1	AO	05	Liquid input tank 1 Flow rate set-point		161 165	+ -	0 – 5 V
CIV_SP_Li2	AO	06	Liquid input tank 2 Flow rate set-point		169 173	+ -	0 – 5 V
CIV_SP_LO	AO	07	Liquid output Flow rate Control set-point		177 181	+ -	0 – 5 V
CIV_SP_Bs	AO	09	Base Flow rate set-point		193 197	+ -	4 – 20 mA
CIV_SP_Ls	AO	10	Light supply Radiation set-point		201 205	+ -	4 – 20 mA
CIV_SP_Ac	AO	11	Acid Flow rate set-point		209 213	+ -	4 – 20 mA

Devices needed in this test procedure:

- 1 Multimeter to measure analogue current / voltage outputs
- 2 Pilot lights 220 VAC

5.9.5 Procedure Steps

Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

5.9.6 MEL-TC-CIV-0901: Check Biomass Production Loop Operational Modes

TC Identifier	**MEL-TC-CIV-0901**	**Purpose:**	Verify when operational mode is changed in the Biomass Production Loop, outputs are set as specified
Functions Tested	CIV_PLCSW_Biomass, CIV_PLCSW_Light, CIV_PLCSW_Liquid, MEL_CIV_BP		
Description	From the Biomass Production supervision screen it is possible to change the operational mode and set the manual values.		
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_BP supervision screen to change operational modes and manual values.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_BP supervision screen set operational mode to OFF			
2	Apply a 1 KOhm resistor to CIV_SP_Ls output (AO 10) Connect a pilot light to CIV_RL_Cx			
3	Check Pilot light	OFF		
4	Check CIV_SP_Li1 voltage output	0±0.1 V		
5	Check CIV_SP_Li2 voltage output	0±0.1 V		
6	Check CIV_SP_LO voltage output	0±0.1 V		
8	Check CIV_RL_Li1 voltage output	OPEN		
9	Check CIV_RL_Li2 voltage output	OPEN		
10	Check CIV_SP_Ls voltage output	4±0.1 V		
11	In the MEL_CIV_BP edit the manual values and set: Activate valve to clean biomass sensor: checked Enable liquid input pump 1: checked Liquid input pump 1 set-point (0-100%): 10 Enable liquid input pump 2: checked Liquid input pump 2 set-point (0-100%): 20 Liquid output pump set-point (0-100%): 30 Light supply set-point (0-100%): 50			
13	In the MEL_CIV_BP supervision screen set operational mode to MAN			
14	Check Pilot light	ON		
15	Check CIV_SP_Li1 voltage output	0.5±0.1 V		
16	Check CIV_SP_Li2 voltage output	1.0±0.1 V		

TC Identifier	MEL-TC-CIV-0901	Purpose:	Verify when operational mode is changed in the Biomass Production Loop, outputs are set as specified	
Functions Tested	CIV_PLCSW_Biomass, CIV_PLCSW_Light, CIV_PLCSW_Liquid, MEL_CIV_BP			
Description	From the Biomass Production supervision screen it is possible to change the operational mode and set the manual values.			
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_BP supervision screen to change operational modes and manual values.			

17	Check CIV_SP_LO voltage output	1.5±0.1 V		
18	Check CIV_RL_Li1 voltage output	CLOSED		
19	Check CIV_RL_Li2 voltage output	CLOSED		
20	Check CIV_SP_Ls voltage output	12±0.1 V		

5.9.7 MEL-TC-CIV-0902: Check Gas Loop Operational Modes

TC Identifier	**MEL-TC-CIV-0902**	**Purpose:**	Verify when operational mode is changed in the Gas Loop, outputs are set as specified	
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_Gas			
Description	From the Gas regulation supervision screen it is possible to change the operational mode and set the manual values.			
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_Gas supervision screen to change operational modes and manual values.			
Tester:		**Date:**		

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_BP supervision screen set operational mode to OFF Connect a Pilot light to CIV_RL_Fg			
2	Check Pilot light	OFF		
3	Check CIV_SP_Fgi voltage output	0±0.1 V		
4	Check CIV_SP_Fgo voltage output	0±0.1 V		
5	Check CIV_SP_Fgex voltage output	0±0.1 V		
6	In the MEL_CIV_Gas edit the manual values and set: Enable Pressure safety valve: checked			
8	In the MEL_CIV_Gas supervision screen set operational mode to MAN			
9	Check Pilot light	ON		

5.9.8 MEL-TC-CIV-0903: Check pH Loop Operational Modes

TC Identifier	**MEL-TC-CIV-0903**	**Purpose:**	Verify when operational mode is changed in the pH Loop, outputs are set as specified
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	From the pH regulation supervision screen it is possible to change the operational mode and set the manual values.		
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_pH supervision screen to change operational modes and manual values.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIV_pH supervision screen set operational mode to OFF			
2	Apply a 1 Kohm resistor to CIV_SP_Bs (AO 09) and CIV_SP_Ac (AO 11)			
3	Check CIV_SP_Bs voltage output	4±0.1 V		
4	Check CIV_SP_Ac voltage output	4±0.1 V		
5	Check CIV_SP_FrCO2 voltage output	0±0.1 V		
6	In the MEL_CIV_pH edit the manual values and set: Acid pump set-point (0-100%): 10 Base pump set-point (0-100%): 20 CO2 Flow Rate set-point (0-5 nLm): 2.5			
8	In the MEL_CIV_pH supervision screen set operational mode to MAN			
9	Check CIV_SP_Ac voltage output	5.6±0.1 V		
	Check CIV_SP_Bs voltage output	7.2±0.1 V		
	Check CIV_SP_FrCO2 voltage output	2.5±0.1 V		

6 COMPARTMENT III SYSTEM TEST PROCEDURES

These Test Procedures are implemented to verify the system from a functional approach. Therefore, each Test Procedure (TP) verifies a high level function (as for example biomass regulation for a compartment). Test Procedures include one or more Test Cases that shall be executed as part of the procedure.

The following Test Procedures are specified in the following sections:

Identifier	Name	Description
MEL-CIII-TP-01	Point to point connectivity test	Test point to point connectivity for the electrical interfaces.
MEL-CIII-TP-02	Electrical Isolation	Test electrical isolation
MEL-CIII-TP-03	Check Interfaces End to End	Test value ranges, communication with the supervision, supervision displays
MEL-CIII-TP-04	pH Regulation	Test pH regulation
MEL-CIII-TP-05	Liquid flows regulation	Test liquids flow rates regulation
MEL-CIII-TP-06	Gas flows regulation	Test gas flow rates regulation
MEL-CIII-TP-07	Temperature regulation	Test temperature regulation
MEL-CIII-TP-08	Initial values	Test parameters initial values when PLC is restarted
MEL-CIII-TP-09	Sensor/Actuator Link Errors	Test errors on sensors / actuators links are handled as specified.
MEL-CIII-TP-10	Operational modes	Test changes in outputs caused by changing the operational mode (OFF, AUTO, MAN)

6.1 MEL-CIII-TP-01: Point to point connectivity test procedure

6.1.1 Purpose

- Identify all components are deployed as specified in the HDD.
- Verify electrical connections are implemented as defined in the HDD.

6.1.2 Description

CAUTION **This test procedure must be executed without powering the rack.**

This test procedure is performed using a device that checks the electrical connectivity between two points (e.g. a multi-meter). Connections to check for Compartment III are specified in ANNEX B. This ANNEX define a template that shall be included as part of the Test Report.

6.1.3 Expected outcome

All connections specified in the template are checked OK.

6.1.4 Procedure steps

1. Check all connections specified in the template and mark if there is conductivity or not.

6.2 MEL-CIII-TP-02: Electrical isolation

6.2.1 Purpose

Check that electrical isolation between AC L and GND and AG N and GND is performed according to applicable regulations.

6.2.2 Description

CAUTION **This test procedure must be executed without powering the rack.**

This test procedure is performed using a device that insulates 1500 V between AC L and GND and AC N and GND during a fixed period of time (60 seconds) to check that isolation in cabling, connectors and 220 VAC powered devices, is properly dimensioned.

6.2.3 Special requirements

A Dielectric Withstanding Electrical Test device is needed to execute this test procedure. The device outputs 1500 V during a limited time and controls current is not over a defined value.

6.2.4 Expected outcome

Device response indicates test passed OK.

6.2.5 Procedure steps

1. Program device to output 1500 V during 60 seconds and limited current to 30 mA.
2. Connect device output to CIII_AC_IN pin 01 (AC L) and CIII_AC_IN pin 03 (GND).
3. Activate device to perform the verification.
4. Connect device output to CIII_AC_IN pin 02(AC N and CIII_AC_IN pin 03 (GND).
5. Activate device to perform the verification.
6. Annotate verification results.

6.3 MEL-CIII-TP-03 Check Interfaces end-to-end

6.3.1 Purpose

Check that signals applied on inputs are transmitted to Supervision and values fixed by the Supervision are transmitted to outputs adequately, with the correct ranges.

6.3.2 Features to be tested

Verify integration and functionality of the following items:

- PLC – Rack I/O Interface (CIV_CP)
- Supervision – PLC Interface (Software interface)

6.3.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIII-TC-0301	Check analogue inputs
MEL-CIII-TC-0302	Check analogue outputs
MEL-CIII-TC-0303	Check digital inputs
MEL-CIII-TC-0304	Check digital outputs

6.3.4 Special Requirements

To execute this procedure following devices will be necessary:

- Multimeter (to measure analogue outputs)
- Adjustable Power Supply (to generate known values)
- Resistances 500 ohm (to allow measuring 4-20 mA outputs)

The values can be monitored from the Supervision Real Time Database display (iFix Database Manager application).

Table of inputs / outputs

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIII_MV_Dob	AI	01	DO at bottom	CIII_CP	001 005	+ -	4 – 20 mA
CIII_MV_Dot	AI	02	DO at top		009 013	+ -	4 – 20 mA
CIII_MV_NH4	AI	03	Ammonium concentration		017 021	+ -	4 – 20 mA
CIII_MV_NO3	AI	04	Nitrate concentration		025 029	+ -	4 – 20 mA
CIII_MV_P	AI	05	Pressure at top of the gas phase		033 037	+ -	4 – 20 mA

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIII_MV_PHb	AI	06	pH at bottom		041 045	+ -	4 – 20 mA
CIII_MV_PHt	AI	07	pH at Top		049 053	+ -	4 – 20 mA
CIII_MV_Psl	AI	08	Pressure sensor for the sampling line		057 061	+ -	4 – 20 mA
CIII_MV_Tb	AI	09	Temperature at bottom		065 069	+ -	4 – 20 mA
CIII_MV_Tt	AI	10	Temperature at top		073 077	+ -	0 – 5 V
CIII_SP_CO2	AO	01	CO2 input flow regulation		129 133	+ -	0 – 5 V
CIII_SP_N2	AO	02	N2 flow regulation		137 141	+ -	0 – 5 V
CIII_SP_O2	AO	03	O2 flow regulation		145 149	+ -	0 – 5 V
CIII_SP_Ac	AO	05	Acid pump flow regulation		161 165	+ -	4 – 20 mA
CIII_SP_Bs	AO	06	Base pump flow regulation		169 173	+ -	4 – 20 mA
CIII_SP_Lin	AO	07	Liquid input pump flow regulation		177 181	+ -	4 – 20 mA
CIII_SP_LO	AO	08	Liquid output pump flow regulation		185 189	+ -	4 – 20 mA
CIII_IND_CalNH4	DI	01	NH4 Analyser calibration indicator		193 197	+ -	0 – 24 V
CIII_IND_CalNO3	DI	02	Nitrate analyser calibration indicator		002 006	+ -	0 – 24 V
CIII_MV_Llow	DI	03	Level measurement low		010 014	+ -	0 – 24 V
CIII_MV_Lhigh	DI	04	Level measurement high		018 022	+ -	0 – 24 V
CIII_MVO_Lbt	DI	05	Indicator of max level reached for a buffer tank		026 028	+ -	0 – 24 V
CIII_RL_Lbt	DO	01	Activation of the pump for the buffer tank		122 126	+ -	0 – 24 V
CIII_AC_AC	DO	02	Relay acid pump	CIII_AC_OUT	001 003 005	AC L AC N GND	220 VEF
CIII_AC_BS	DO	03	Relay base pump		007 009 011	AC L AC N GND	220 VEF
CIII_AC_Comp	DO	04	Compressor activation		013 015 017	AC L AC N GND	220 VEF
CIII_AC_CV	DO	05	Open/close the cooling valve		019 021 023	AC L AC N GND	220 VEF

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIII_AC_Heat	DO	06	Activate Heater		025 027 029	AC L AC N GND	220 VEF
CIII_RL_Lp	DO	07	Relay to have a pulse in the level sensor lecture	CIII_CP	11 19	+ +	24 V
CIII_AC_Safe	DO	08	Activation of Pressure Safety Valve	CIII_AC_OUT	31 33 35	AC L AC N GND	220 VEF

6.3.5 Procedure Steps

Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

6.3.6 MEL-TC-CIII-0301: Check analogue inputs

TC Identifier	MEL-TC-CIII-0301	Purpose:	Verify that analogue inputs are connected, acquired, supervised and ranged as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Known values applied to analogue inputs shall be displayed in the Supervision ranged as specified.		
Special Requisites:	Values to apply / check must be between the indicated range		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK
1	Apply 1 - 1.2 V to AI 01 (CIII_MV_Dob) and check the displayed value DObot % in the Supervision screen MEL_CIII_GAS.	0 – 5	
2	Apply 4.8 – 5 V to AI 01 (CIII_MV_Dob) and check the displayed value DObot % in the Supervision screen MEL_CIII_GAS.	95 – 100	
3	Apply 1 – 1.2 V to AI 02 (CIII_MV_Dot) and check the displayed value DOtop % in the Supervision screen MEL_CIII_GAS.	0 – 5	
4	Apply 4.8 – 5 V to AI 02 (CIII_MV_Dot) and check the displayed value DOtop % in the Supervision screen MEL_CIII_GAS.	95 – 100	
5	Apply 1 – 1.2 V to AI 03 (CIII_MV_NH4) and check the displayed value NH4 in the Supervision screen MEL_CIII_Liquid.	0 – 10	
6	Apply 4.8 - 5 V to AI 03 (CIII_MV_NH4) and check the displayed value NH4 in the Supervision screen MEL_CIII_BP.	190 – 200	
7	Apply 1 – 1.2 V to AI 04 (CIII_MV_NO3) and check the displayed value NO3 in the Supervision screen MEL_CIII_Liquid.	0 – 50	
8	Apply 4.8 - 5 V to AI 04 (CIII_MV_NO3) and check the displayed value NO3 in the Supervision screen MEL_CIII_Liquid.	950 – 1000	
9	Apply 1 – 1.2 V to AI 05 (CIII_MV_P) and check the displayed value P in the Supervision screen MEL_CIII_Gas.	0 – 50	
10	Apply 4.8 - 5 V to AI 05 (CIII_MV_P) and check the displayed value P in the Supervision screen MEL_CIII_Gas.	950 – 1000	
11	Apply 1 – 1.2 V to AI 06 (CIII_MV_PHb) and check the displayed value pHbot in the Supervision screen MEL_CIII_pH.	3 – 3.5	
12	Apply 4.8 - 5 V to AI 06 (CIII_MV_PHb) and check the displayed value pHbot in the	12.5 – 13	

TC Identifier	MEL-TC-CIII-0301	Purpose:	Verify that analogue inputs are connected, acquired, supervised and ranged as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Known values applied to analogue inputs shall be displayed in the Supervision ranged as specified.		
Special Requisites:	Values to apply / check must be between the indicated range		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK
	Supervision screen MEL_CIII_pH.		
13	Apply 1 – 1.2 V to AI 07 (CIII_MV_PHt) and check the displayed value pHtop in the Supervision screen MEL_CIII_pH.	1.5 – 2	
14	Apply 4.8 - 5 V to AI 07 (CIII_MV_PHt) and check the displayed value pHtop in the Supervision screen MEL_CIII_pH.	11 – 11.5	
15	Apply 1 – 1.2 V to AI 09 (CIII_MV_Tb) and check the displayed value Temperature in the Supervision screen MEL_CIII_Temp.	0.2 – 7.54	
16	Apply 4.8 - 5 V to AI 09 (CIII_MV_Tb) and check the displayed value Temperature in the Supervision screen MEL_CIII_Temp.	139.66 – 147	
17	Apply 1 – 1.2 V to AI 10 (CIII_MV_Tt) and check the displayed value Temperature in the Supervision screen MEL_CIII_Temp.	0.2 – 7.54	
18	Apply 4.8 - 5 V to AI 10 (CIII_MV_Tt) and check the displayed value Temperature in the Supervision screen MEL_CIII_Temp.	139.66 – 147	

6.3.7 MEL-TC-CIII-0302: Check analogue outputs

TC Identifier	**MEL-TC-CIII-0302**	**Purpose:**	Verify that analogue inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Known values applied to Supervision variables shall be translated to the analogue outputs within the ranges specified. Only outputs with direct set-points are checked, the rest will be checked by other TC.		
Special Requisites:	Use a Multimeter to measure voltage outputs		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK
1	Set regulation mode to MAN to all loops.		
2	In the supervision screen MEL_CIII_pH edit manual values and set the value 0 to “CO2 Flow set point” and measure AO 01 output volts.	0 V ±0.1	
3	In the supervision screen MEL_CIII_pH edit manual values and set the value 100 to “CO2 Flow set point” and measure AO 01 output volts.	5 V ±0.1	
4	In the supervision screen MEL_CIII_Gas edit manual values and set the value 0 to “N2 Flow set point” and measure AO 02 output volts.	0 V ±0.1	
5	In the supervision screen MEL_CIII_Gas edit manual values and set the value 150 to “N2 Flow set point” and measure AO 02 output volts.	5 V ±0.1	
6	In the supervision screen MEL_CIII_Gas edit manual values and set the value 0 to “O2 Flow set point” and measure AO 03 output volts.	0 V ±0.1	
7	In the supervision screen MEL_CIII_Gas edit manual values and set the value 100 to “O2 Flow set point” and measure AO 03 output volts.	5 V ±0.1	
8	Apply a 500 ohm resistor to AO 05		
9	In the supervision screen MEL_CIII_pH edit manual values and set the value 0 to “Acid pump set point” and check “Enable Acid pump”. Measure AO 05 output volts.	2 V ±0.2	
10	In the supervision screen MEL_CIII_pH edit manual values and set the value 100 to “Acid pump set point” and measure AO 05 output volts.	10 V ±0.2	
11	Apply a 500 ohm resistor to AO 06		
12	In the supervision screen MEL_CIII_pH edit manual values and set the value 0 to “Base pump set point” and check “Enable base pump”. Measure AO 06 output volts.	2 V ±0.2	
13	In the supervision screen MEL_CIII_pH edit manual values and set the value 100 to “Base pump	10 V ±0.2	

TC Identifier	MEL-TC-CIII-0302	Purpose:	Verify that analogue inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Known values applied to Supervision variables shall be translated to the analogue outputs within the ranges specified. Only outputs with direct set-points are checked, the rest will be checked by other TC.		
Special Requisites:	Use a Multimeter to measure voltage outputs		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK
	set point" and measure AO 06 output volts.		
14	Apply a 500 ohm resistor to AO 07		
15	In the supervision screen MEL_CIII_Liquid edit manual values and set the value 0 to "Liquid input pump set point" and measure AO 07 output volts.	2±0.2 V	
16	In the supervision screen MEL_CIII_Liquid edit manual values and set the value 100% to "Liquid input pump set point" and measure AO 07 output volts.	10±0.2 V	
17	Apply a 500 ohm resistor to AO 08		
18	In the supervision screen MEL_CIII_Liquid edit manual values and set the value 0 to "Liquid output pump set point" and measure AO 08 output volts.	2 ±0.2 V	
19	In the supervision screen MEL_CIII_Liquid edit manual values and set the value 100 to "Liquid output pump set point" and measure AO 08 output volts.	10±0.2 V	

6.3.8 MEL-TC-CIII-0303: Check digital inputs

TC Identifier	MEL-TC-CIV-0303	Purpose:	Verify that digital inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Status set to digital inputs shall be translated to the supervision as specified.		
Special Requisites:			
Tester:		Date:	

Course of Actions			
Step no	**Description**	**Expected value**	**OK/NOK**
1	Set DI 01 in open circuit and check in supervision screen MEL_CIII_Liquid, indicator “Calibrating” in NH4	Disabled	
2	Set DI 01 in closed circuit and check in supervision screen MEL_CIII_Liquid, indicator “Calibrating” in NH4	Enabled	
3	Set DI 02 in open circuit and check in supervision screen MEL_CIII_Liquid, indicator “Calibrating” in NO3	Disabled	
4	Set DI 02 in closed circuit and check in supervision screen MEL_CIII_Liquid, indicator “Calibrating” in NO3	Enabled	
5	Set DI 03 in open circuit and check in supervision screen MEL_CIII_Liquid, indicator “Level Low” in Level sensor	Enabled	
6	Set DI 03 in closed circuit and check in supervision screen MEL_CIII_Liquid, indicator “Level Low” in Level sensor	Disabled	
7	Set DI 04 in open circuit and check in supervision screen MEL_CIII_Liquid, indicator “Level High” in Level sensor	Disabled	
8	Set DI 04 in closed circuit and check in supervision screen MEL_CIII_Liquid, indicator “Level High” in Level sensor	Enabled	

6.3.9 MEL-TC-CIII-0304: Check digital outputs

TC Identifier	**MEL-TC-CIV-0304**	**Purpose:**	Verify that digital outputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Manual values applied to Supervision shall be translated to the digital outputs within the ranges specified. Only outputs with manual values are checked, functional TC will check the rest.		
Special Requisites:	Connect lights to 220 VEF relay outputs to check status		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK
1	Set regulation mode to MAN to all loops.		
2	In the supervision screen MEL_CIII_Liquid edit manual values and enable "Output buffer tank pump Activation" and check DO 01 connectivity.	Closed	
3	In the supervision screen MEL_CIII_Liquid edit manual values and disable "Output buffer tank pump Activation" and check DO 01 connectivity.	Open	
4	In the supervision screen MEL_CIII_pH edit manual values and enable "Acid pump activation" and check DO 02 light status.	On	
5	In the supervision screen MEL_CIII_pH edit manual values and disable "Acid pump activation" and measure DO 02 light status.	Off	
6	In the supervision screen MEL_CIII_pH edit manual values and enable "Base pump activation" and measure DO 03 light status.	On	
7	In the supervision screen MEL_CIII_pH edit manual values and disable "Base pump activation" and measure DO 03 light status.	Off	
8	In the supervision screen MEL_CIII_Temp edit manual values and enable "Cooling valve activation" and check DO 05 light status.	On	
9	In the supervision screen MEL_CIII_Temp edit manual values and disable "Cooling valve activation" and check DO 05 light status.	Off	
10	In the supervision screen MEL_CIII_Temp edit manual values and enable "Heater activation" and check DO 06 light status.	On	
11	In the supervision screen MEL_CIII_Temp edit manual values and disable "Heater activation" and check DO 06 light status.	Off	
12	In the supervision screen MEL_CIII_Gas edit manual values and enable "Enable Pressure safety	On	

TC Identifier	MEL-TC-CIV-0304	Purpose:	Verify that digital outputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Manual values applied to Supervision shall be translated to the digital outputs within the ranges specified. Only outputs with manual values are checked, functional TC will check the rest.		
Special Requisites:	Connect lights to 220 VEF relay outputs to check status		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK
	valve" and check DO 08 light status.		
13	In the supervision screen MEL_CIII_Gas edit manual values and disable "Enable Pressure safety valve" and check DO 08 light status.	Off	

6.4 MEL-CIII-TP-04 pH Regulation

6.4.1 Purpose

pH regulation controls the pH in the compartment. Two pH probes measure pH and in case of deviation, several actions can be taken depending on the current operation mode:

- Only CO2: When the pH is over the set point, additional CO2 is added. A PI controls CO2 addition.
- CO2 and basic medium: When pH is over the set point, CO2 is added, when is under basic medium is added. A PI controls basic medium/CO2 addition.
- Acid and basic media. When pH is over the set point, acid media is added, when is under, basic media is added. A PI controls both, basic and acid, media addition.

6.4.2 Features to be tested

Verify integration and functionality of the following items:

- Supervision displays:
  - MEL_CIII_Main: Display of the most important values of the CIII compartment.
  - MEL_CIII_pH: pH regulation display.
- Local Control (PLC) program sections:
  - CIII_PLCSW_pH: pH regulation.
- PLC – Rack I/O Interface
- Supervision – PLC Interface

6.4.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIII-TC-0601	pH Regulation with CO2
MEL-CIII-TC-0602	pH Regulation with CO2 and additional base medium
MEL-CIII-TC-0603	pH Regulation with Base and Acid additional media
MEL-CIII-TC-0604	pH alarms

6.4.4 Special Requirements

Table of I/O that participates in the pH loop:
Ty (Type) = DI: Digital Input, DO: Digital Output, AI: Analogue Input, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIII_MV_Dob	AI	01	DO at bottom	CIII_CP	001 005	+ -	4 – 20 mA
CIII_MV_Dot	AI	02	DO at top		009 013	+ -	4 – 20 mA

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIII_MV_PHb	AI	06	pH at bottom	CIII_CP	041 045	+ -	4 – 20 mA
CIII_MV_PHt	AI	07	pH at Top		049 053	+ -	4 – 20 mA
CIII_SP_Ac	AO	05	Acid pump flow regulation		161 165	+ -	4 – 20 mA
CIII_SP_Bs	AO	06	Base pump flow regulation		169 173	+ -	4 – 20 mA
CIII_SP_CO2	AO	01	CO2 input flow regulation		129 133	+ -	0 – 5 V
CIII_AC_AC	DO	02	Relay acid pump	CIII_AC_OUT	001 003 005	AC L AC N GND	220 VEF
CIII_AC_BS	DO	03	Relay base pump		007 009 011	AC L AC N GND	220 VEF

Devices needed in this test procedure:

- 2 Adjustable Power Supply (APS) to provide current / voltage to analogue inputs
- 1 Multimeter to measure analogue current / voltage outputs
- Lights to check 220 VEF relay outputs.
- 1 Function Generator

6.4.5 Procedure Steps

- Set pH loop operation mode to AUTO.
- Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

6.4.6 MEL-TC-CIII-0401: pH Regulation with CO2

TC Identifier	MEL-TC-CIII-0401	Purpose:	Verify that when in pH control mode 1, if pH goes over the set point, CO2 valve is opened according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH, MEL_CIII_Main		
Description	When in control mode 1, if pH goes over the set point, the PI shall open CO2 valve according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH and MEL_CIII_Main displays		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Set pH control mode to 1 – CO2 only			
2	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
3	In the MEL_CIII_pH Supervision screen check pH bottom value	8.0±0.1 pH		
4	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
5	In the MEL_CIII_pH Supervision screen check pH top value	8.0±0.1 pH		
6	In the MEL_CIII_MAIN Supervision screen check pH value	8.0±0.1 pH		
7	In the MEL_CIII_pH Supervision screen check pH value	8.0±0.1 pH		
8	In the MEL_CIII_pH check CO2 valve set point	0±0.1 %		
9	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 3, Integration = 0			
10	In the MEL_CIII_pH edit the proportional constant for CO2 valve (click over CO2 valve to open dialog). Set proportional = 5			
11	Using APS 1 set 4.10 – 4.20 V to AI 06 (CIII_MV_pHb)			
12	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
13	Check in MEL_CIII_pH Supervision display the value of pH	11±0.25 pH		
14	Check CO2 valve control action value	45±3.75 %		
15	Check AO 01 voltage output	2.3±0.2 V		
16	In the MEL_CIII_pH Supervision screen set pH Ramp parameter to 0.016			
17	In the MEL_CIII_pH Supervision screen set pH set point to 11.0.			
18	Check that in 3 minutes CO2 valve control action approaches to 0 (ramp effect)	0±5 %		
19	In the MEL_CIII_pH Supervision screen set pH set point to 8.0 and wait until CO2 valve control	45±3.75 %		

TC Identifier	MEL-TC-CIII-0401	Purpose:	Verify that when in pH control mode 1, if pH goes over the set point, CO2 valve is opened according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH, MEL_CIII_Main		
Description	When in control mode 1, if pH goes over the set point, the PI shall open CO2 valve according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH and MEL_CIII_Main displays		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
	action value is restored.			
20	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
21	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
22	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 1, Integration = 30			
23	Using APS 1 set 4.10 – 4.20 V to AI 06 (CIII_MV_pHb)			
24	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
24	In the MEL_CIII_pH annotate CO2 valve control action value at 10 seconds and at 40 seconds. Calculate the gradient (CO2 at 20 – CO2 at 10) / 30	0.5±0.05 %		

6.4.7 MEL-TC-CIII-0402: pH Regulation with CO2 and additional Base medium

TC Identifier	**MEL-TC-CIII-0402**	**Purpose:**	Verify that when in pH control mode 2, if pH goes under the set point, Base pump is activated according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH		
Description	When in pH control mode 2, if pH goes under the set point, the PI shall activate the base pump according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH display		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Set pH control mode to 2 – CO2 + Base			
2	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
3	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
4	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH		
5	Check DO 03 light	Off		
6	Check CO2 valve and Base pump control action values	0±0.1 %		
7	In the MEL_CIII_pH edit the PI parameters (click over base pump to open dialog). Set proportional = 3, Integration = 3000			
8	Using APS 1 set 1.70 – 1.90 V to AI 06 (CIII_MV_pHb)			
9	Using APS 2 set 2.30 – 2.50 V to AI 07 (CIII_MV_pHt)			
10	Check in MEL_CIII_pH Supervision display the value of pH	5 ±0.25 pH		
11	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 3, Integration = 0			
12	Check Base pump control action value during 10 seconds every 30 seconds	9±0.75 %		
13	Check DO 03 light during 10 seconds every 30 seconds	On		
14	Apply a 500 ohm resistor to AO 06			
15	Check AO 06 voltage output	2.72±0.1 V		
16	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 1, Integration = 30			
17	In the MEL_CIII_pH annotate max. Base pump control action value within the 10 seconds is active. Calculate gradient ($Base_{t=10}$ – $Base_{t=0}$) / 10	0.1±0.01 %		
18	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			

TC Identifier	MEL-TC-CIII-0402	Purpose:	Verify that when in pH control mode 2, if pH goes under the set point, Base pump is activated according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH		
Description	When in pH control mode 2, if pH goes under the set point, the PI shall activate the base pump according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH display		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
19	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
20	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH		
21	Check CO2 valve and Base pump control action values (wait 30 seconds)	0±0.1 %		
22	Check DO 03 light (wait 30 seconds)	Off		
23	Using APS 1 set 4.10 – 4.30 V to AI 06 (CIII_MV_pHb)			
24	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
25	Check in MEL_CIII_pH Supervision display the value of pH	11 ±0.25 pH		
26	Check CO2 valve control action value	> 0 %		
27	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
28	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
29	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH		
30	Check CO2 valve and Base pump control action values	0±0.1 %		

6.4.8 MEL-TC-CIII-0403: pH Regulation with Base and Acid additional media

TC Identifier	**MEL-TC-CIII-0403**	**Purpose:**	Verify that when in pH control mode 2, if pH goes under the set point, Base pump is activated according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH		
Description	When in pH control mode 3, if pH goes under/over the set point, the PI shall activate the base/acid pump respectively according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH display		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Set pH control mode to 3 – Acid + Base			
2	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
3	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
4	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH		
5	Check DO 02, DO 03 lights (wait 30 seconds)	Off		
6	Check Acid and Base pump control action values (wait 30 seconds)	0±0.1 %		
7	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 3, Integration = 0			
8	Using APS 1 set 4.10 – 4.20 V to AI 06 (CIII_MV_pHb)			
9	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
25	Check in MEL_CIII_pH Supervision display the value of pH	11 ±0.25 pH		
12	Check acid pump control action value during 10 seconds every 30 seconds	9±0.75 %		
13	Check DO 02 light during 10 seconds every 30 seconds	On		
16	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 1, Integration = 30			
17	In the MEL_CIII_pH annotate max. Acid pump control action value within the 10 seconds is active. Calculate gradient ($Acid_{t=10}$ – $Acid_{t=0}$) / 10	0.1±0.1 %		
18	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
19	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
20	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH		
21	Check Acid and Base pump control action values (wait 30 seconds)	0±0.1 %		
22	Check DO 02, DO 03 lights (wait 30 seconds)	Off		

TC Identifier	**MEL-TC-CIII-0403**	**Purpose:**	Verify that when in pH control mode 2, if pH goes under the set point, Base pump is activated according to provided parameters.		
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH				
Description	When in pH control mode 3, if pH goes under/over the set point, the PI shall activate the base/acid pump respectively according to parameters provided from the supervision.				
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH display				
Tester:		**Date:**			
Course of Actions					

Step no	Description	Expected value	OK/NOK	Comments
23	Using APS 1 set 1.70 – 1.90 V to AI 06 (CIII_MV_pHb)			
24	Using APS 2 set 2.30 – 2.50 V to AI 07 (CIII_MV_pHt)			
25	Check in MEL_CIII_pH Supervision display the value of pH	5 ±0.25 pH		
26	Check Base pump control action value during 10 seconds every 30 seconds	> 0 %		
27	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
28	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
29	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH		
30	Check Acid and Base pump control action values (wait 30 seconds)	0±0.1 %		

6.4.9 MEL-TC-CIII-0404: pH alarms

TC Identifier	**MEL-TC-CIII-0404**	**Purpose:**	Verify that when pH value is over the set point during 15 minutes an alarm is generated
Items Tested	CIII_PLCSW_pH, MEL_CIII		
Description	When pH is out of the set point for more than 15 minutes, a high priority alarm shall be generated.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH and MEL_CIII_Main displays		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Using APS 1 set 4.10 – 4.20 V to AI 06 (CIII_MV_pHb)			
2	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
3	Check in MEL_CIII_pH Supervision display the value of pH	11 ±0.25 pH		
27	Wait 15 minutes			
28	Check in alarm area pH deviation alarm status	Alarm		

6.5 MEL-CIII-TP-05 Liquid Flows Regulation

6.5.1 Purpose

Liquid flows regulation controls the liquid input/output flows of the compartment. Level is measured by to contact sensors (on/off) that indicate Low or High level. Output pump flow rate is decreased/increased depending on the level status. In addition, liquid input flow rate is controlled by the Nitrite estimator. This estimator is implemented as a algorithm running in the Supervision Server fired every 10 minutes.

6.5.2 Features to be tested

Verify integration and functionality of the following items:

- Supervision displays:
  - MEL_CIII_Main: Display of the most important values of the CIII compartment.
  - MEL_CIII_Liquid: Liquid flows regulation display.
- Local Control (PLC) program sections:
  - CIII_PLCSW_Liquid: Liquid flows regulation.
  - CIII_PLCSW_N: Nitrates regulation
- PLC – Rack I/O Interface
- Supervision – PLC Interface

6.5.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIII-TC-0501	Liquid level control
MEL-CIII-TC-0502	Nitrite estimator
MEL-CIII-TC-0503	Output buffer tank pump activation
MEL-CIII-TC-0504	Liquid level alarms

6.5.4 Special Requirements

Table of I/O that participates in the Liquid flows loop:
Ty (Type) = DI: Digital Input, DO: Digital Output, AI: Analogue Input, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIII_MV_Dob	AI	01	DO at bottom	CIII_CP	001 005	+ -	4 – 20 mA
CIII_MV_Dot	AI	02	DO at top		009 013	+ -	4 – 20 mA
CIII_MV_NH4	AI	03	Ammonium concentration		017 021	+ -	4 – 20 mA
CIII_MV_NO3	AI	04	Nitrate concentration		025 029	+ -	4 – 20 mA

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIII_SP_Lin	AO	07	Liquid input pump flow regulation		177 181	+ -	4 – 20 mA
CIII_SP_LO	AO	08	Liquid output pump flow regulation		185 189	+ -	4 – 20 mA
CIII_MV_Llow	DI	03	Level measurement low		010 014	+ -	0 – 24 V
CIII_MV_Lhigh	DI	04	Level measurement high		018 022	+ -	0 – 24 V
CIII_MVO_Lbt	DI	05	Indicator of max level reached for a buffer tank		026 030	+ -	0 – 24 V
CIII_RL_Lbt	DO	01	Activation of the pump for the buffer tank		122 126	+ -	open/closed

Devices needed in this test procedure:

- 3 Adjustable Power Supply (APS) to provide current / voltage to analogue inputs
- 1 Multimeter to measure analogue current / voltage outputs

6.5.5 Procedure Steps

- Set Liquid loop operation mode to AUTO.
- Execute the Test Cases and record the successful or unsuccessful execution of tests in the Test Report.

6.5.6 MEL-TC-CIII-0501: Liquid level control

TC Identifier	**MEL-TC-CIII-0501**	**Purpose:**	Verify that when liquid level is high output pump flow rate is increased, when is low, output pump flow rate is decreased
Items Tested	CIII_PLCSW_Liquid, MEL_CIII_Liquid, MEL_CIII_Main		
Description	Initially output flow = input flow. When liquid level reaches high status, output pump flow is increased a 25%, when liquid level reaches low level, output pump flow is decreased a 25%.		
Special Requisites:	Check supervision values in MEL_CIII_Liquid display		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Liquid set control mode to AUTO			
2	In the MEL_CIII_Liquid set input pump calibration parameters to: Parameter A = 73.5294 Parameter B = 0.1765			
3	Using Concept tool modify liquid input safety set point to 0,4 (default)			
4	Check in MEL_CIII_Liquid supervision display “Liquid input flow rate”	0,4 (blinking)		
5	Check input pump actuation	29.59±0.1 %		
6	Check Level High indicator	Off		
7	Check Level Low indicator	On		
8	Check output pump actuation	22.19±0.1 %		
9	Set closed circuit to DI 03 (CIII_MV_Llow)			
10	Check Level High and Level Low indicators	Off		
11	Check output pump actuation	29.59±0.1 %		
12	Set open circuit to DI 03 (CIII_MV_Llow)			
13	Check Level Low indicator	On		
14	Check output pump actuation	22.19±0.1 %		
15	Set closed circuit to DI03 and DI 04 (CIII_MV_Llow, CIII_MV_Lhigh)			
16	Check Level High indicator	On		
17	Check output pump actuation	36.98±0.1 %		
18	Set open circuit to DI 04 (CIII_MV_Lhigh)			
19	Check Level High and Level Low indicators	Off		
20	Check output pump actuation	29.59±0.1 %		

6.5.7 MEL-TC-CIII-0502: Nitrite estimator

TC Identifier	MEL-TC-CIII-0502	Purpose:	Verify integration of the Nitrite estimator algorithm.	
Items Tested	CIII_PLCSW_Liquid, MEL_PLCSW_N, MEL_CIII_pH, MEL_CIII_pH			
Description	Firing manually the Nitrite Estimator control law, will set the Liquid input flow rate set point and NO2 estimation.			
Special Requisites:	Check supervision values in MEL_CIII_Liquid and MEL_CIII_Main displays			
Tester:			Date:	

Course of Actions				
Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Liquid Supervision display set control mode to AUTO			
2	In the MEL_CIII_Liquid Supervision display set input pump calibration parameters to: Parameter A = 73.5294 Parameter B = 0.1765			
3	In the MEL_CIII_Liquid Supervision display set Level 2 liquid level set point to 0.4			
4	Using Concept tool modify safety values for NO3, NH4, DO and the liquid input set point. Set: NO3 = 329 ppm NH4 = 4.2 ppm DO = 80% (default value) LIN = 0.4 l/h			
	Using iFix tool Database Manager, set CIII_SSP_L1IN to 0,4			
7	In the MEL_CIII_Liquid Supervision display, open Nitrite estimator parameters dialog.			
10	In the Nitrite estimator parameters dialog, check O2 at liquid output	0,0002 mol/l		
11	In the Nitrite estimator parameters dialog, check Required & Measured Liquid input flow rate	0.4 l/h		
	In the Nitrite estimator parameters dialog, update values using the table below (MEL-TC-CIII-0502.Table1)			
12	Using iFix Scheduler, set scheduler properties to “Run in Foreground”			
13	Fire CIII_CTRLLAW_NIT event			
14	In the MEL_CIII_Liquid Supervision display check Estimated NO2 concentration	1.59 ppm		
15	In the MEL_CIII_Liquid Supervision display check Level 1 Liquid Input Flow	0.4 l/h		
16	In the MEL_CIII_Liquid Supervision display check Liquid Input Flow	0.4 l/h		
17	In the MEL_CIII_Main Supervision display check Liquid Input Flow	0.4 l/h		
18	In the MEL_CIII_Main Supervision display check NO2 estimation	1.59 ppm		

Nitrite Estimator parameters table

Index	Description	Values	Unit
0	Measured liquid flow rate or setpoint of the FRC of the liquid pump	0.4000	l/h
1	O_2 concentration in the gas input stream	0.0066	mol/l
2	CO_2 concentration in the gas input stream	0.0019	mol/l
3	NH_3 concentration in the gas input stream	0.0000	mol/l
4	O_2 concentration in the liquid input stream	0.0004	mol/l
5	total CO_2 concentration in the liquid input stream	0.0159	mol/l
6	total NH_3 concentration in the liquid input stream	0.0250	mol/l
7	unused (room for NO_2 concentration if not null)	0.0000	mol/l
8	NO_3 concentration in the liquid input stream	0.0000	mol/l
9	PO_4 concentration in the liquid input stream	0.0016	mol/l
10	SO_4 concentration in the liquid input stream	0.0040	mol/l
11	O_2 concentration in the liquid output stream	0.0002	mol/l
12	total CO_2 concentration in the liquid output stream	0.0564	mol/l
13	total NH_3 concentration in the liquid output stream	0.0003	mol/l
14	NO_3 concentration in the liquid output stream	0.0235	mol/l
15	PO_4 concentration in the liquid output stream	0.0016	mol/l
16	SO_4 concentration in the liquid output stream	0.0039	mol/l
17	Measured gas flow rate or set point of the FRC of the gas pump	60.0000	l/h
18	‘Required’ liquid flow rate	0.4000	l/h
19	Maximum constraint of NO_2	0.0003	mol/l
20	Compensation term for estimator	0.0000	mol/l

MEL-TC-CIII-0502.Table1

6.5.8 MEL-TC-CIII-0503: Output buffer tank pump activation

TC Identifier	**MEL-TC-CIII-0503**	**Purpose:**	Verify buffer tank output pump is activated when level is high
Items Tested	CIII_PLCSW_Liquid, MEL_CIII_Liquid		
Description	When output buffer liquid reaches high level, the output pump is activated.		
Special Requisites:	Check supervision values in MEL_CIII_Liquid Use a Multimeter to check output voltage values.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Check in MEL_CIII_Liquid the Buffer tank Level High indicator	Off		
2	Check in MEL_CIII_Liquid the Buffer tank output pump status	Off		
3	Close circuit in DI 05			
4	Check in MEL_CIII_Liquid the Buffer tank Level High indicator	On		
5	Check in MEL_CIII_Liquid the Buffer tank output pump status	On		
6	Check DO 01 relay status	Closed		

6.5.9 MEL-TC-CIII-0504: Liquid level alarms

TC Identifier	**MEL-TC-CIII-0504**	**Purpose:**	Verify high liquid level alarm
Items Tested	CIII_PLCSW_Liquid, MEL_CIII_Liquid		
Description	High level alarm shall be activated when level is high during 15 minutes.		
Special Requisites:	Check supervision values in MEL_CIII_Liquid display		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Liquid set Liquid input set point to 0.4 l/h			
2	Close circuit in DI 04			
3	Check Level High indicator	On		
4	Wait 15 minutes	Alarm		
5	Check in Alarm area, the level high alarm has been indicated.	On		
6	Check Liquid input flow rate	0 l/h		

6.6 MEL-CIII-TP-06 Gas Flows Regulation

6.6.1 Purpose

Gas flows regulation controls gas input/output flows of the compartment. O2 and N2 are inserted to the compartment to regulate DO concentration. In addition CO2 is added to regulate pH (see MEL-CIII-TP-04 pH Regulation). A safety pressure valve controls overpressure status.

6.6.2 Features to be tested

Verify integration and functionality of the following items:

- Supervision displays:
  - MEL_CIII_Main: Display of the most important values of the CIII compartment.
  - MEL_CIII_Gas: Liquid flows regulation display.
- Local Control (PLC) program sections:
  - CIII_PLCSW_DO: DO Regulation.
  - CIII_PLCSW_P: Pressure Regulation.
- PLC – Rack I/O Interface
- Supervision – PLC Interface

6.6.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIII-TC-0601	DO regulation
MEL-CIII-TC-0602	Pressure valve activation
MEL-CIII-TC-0603	DO and Pressure alarms

6.6.4 Special Requirements

Table of I/O that participates in the Gas flow loop:
Ty (Type) = DI: Digital Input, DO: Digital Output, AI: Analogue Input, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIII_MV_Dob	AI	01	DO at bottom	CIII_CP	001 005	+ -	4 – 20 mA
CIII_MV_Dot	AI	02	DO at top		009 013	+ -	4 – 20 mA
CIII_MV_P	AI	05	Pressure at top of the gas phase		033 037	+ -	4 – 20 mA
CIII_AC_Safe	DO	08	Activation of Pressure Safety Valve	CIII_AC_OUT	31 33 35	AC L AC N GND	220 VEF
CIII_SP_N2	AO	02	N2 flow regulation		137 141	+ -	0 – 5 V
CIII_SP_O2	AO	03	O2 flow regulation		145 149	+ -	0 – 5 V

Devices needed in this test procedure:

- 2 Adjustable Power Supply (APS) to provide current / voltage to analogue inputs
- 1 Multimeter to measure analogue current / voltage outputs

6.6.5 Procedure Steps

- Set Gas loop operation mode to AUTO.
- Execute the Test Cases and record the successful or unsuccessful execution of tests in the Test Report.

6.6.6 MEL-TC-CIII-0601: DO regulation

TC Identifier	**MEL-TC-CIII-0601**	**Purpose:**	Verify DO regulation performed by a PID actuating over the N2 and O2 gas input flow regulators according to provided parameters.
Items Tested	CIII_PLCSW_DO, MEL_CIII_Gas, MEL_CIII_Main		
Description	When DO grows, O2 valve is closed. If O2 valve is completely closed and O2 is still over the set point, the N2 valve opens.		
Special Requisites:	1 APS and a FG are used to simulate DO sensor. Check supervision values in MEL_CIII_Gas and MEL_CIII_Main displays		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas set DO control action mode to AUTO			
2	In the MEL_CIII_Gas, set DO ramp parameter to 0.0167			
3	In the MEL_CIII_Gas, check DO set point (initial value)	80%		
4	In the MEL_CIII_Gas Supervision screen click over the O2 valve to edit PID parameters. Set: Proportional = 12 Integrative = 30 Derivative = 0.033 Bias = 0			
5	In the MEL_CIII_Gas Supervision screen click over the N2 valve to set Proportional constant to 0.5			
6	With Concept open CIII_PLCSW_DO and disable EN_I, EN_D (only proportional part is enabled).			
7	With APS set 4.15 – 4.25 to AI 01 (DO bottom)			
8	In the MEL_CIII_Gas check DO concentration bottom	80±1.25%		
9	With APS set 4.15 – 4.25 to AI 02 (DO top)			
10	In the MEL_CIII_Gas check DO concentration top	80±1.25%		
11	With APS set 4.15 – 4.25 V to AI 01 and AI 02 (DO bottom/top)			
12	In the MEL_CIII_Main check DO concentration	640±1.25 ppm		
13	In the MEL_CIII_Liquid check DO (ppm) concentration	640±1.25 ppm		
13	In the MEL_CIII_Gas check DO concentration	80±1.25%		
14	In the MEL_CIII_Gas, modify DO set point to 78%			
15	Check that in 2 minutes O2 Set Point moved to expected value (effect of ramp parameter applied	24±1.25%		

TC Identifier	MEL-TC-CIII-0601	Purpose:	Verify DO regulation performed by a PID actuating over the N2 and O2 gas input flow regulators according to provided parameters.
Items Tested	CIII_PLCSW_DO, MEL_CIII_Gas, MEL_CIII_Main		
Description	When DO grows, O2 valve is closed. If O2 valve is completely closed and O2 is still over the set point, the N2 valve opens.		
Special Requisites:	1 APS and a FG are used to simulate DO sensor. Check supervision values in MEL_CIII_Gas and MEL_CIII_Main displays		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
	to DO set point):			
16	In the MEL_CIII_Gas, modify DO set point to 80%			
17	Check that in 2 minutes O2 Set Point moved to expected value (effect of ramp parameter applied to DO set point):	0±1.5%		
18	With APS set 3.95 – 4.05 V to AI 01 and AI 02 (DO bottom/top)			
19	In the MEL_CIII_Gas check DO concentration	75±1.25%		
20	In the MEL_CIII_Gas check O2 flow controller set point (SP)	60%		
21	With APS set 4.35 – 4.45 V to AI 01 and AI 02 (DO bottom/top)			
22	In the MEL_CIII_Gas check DO concentration	85±1.25 %		
23	In the MEL_CIII_Gas check N2 flow controller set point (SP)	30±1.25 %		
24	With APS set 4.15 – 4.25 V to AI 01 and AI 02 (DO bottom/top)			
25	In the MEL_CIII_Gas check DO concentration	80±1.25%		
26	In the MEL_CIII_Gas check N2, O2 flow controllers set point	0±1.25%		
27	With Concept open CIII_PLCSW_DO and disable EN_P, EN_D and enable EN_I (only integrative part is enabled).			
28	With APS set 3.95 – 4.05 V to AI 01 and AI 02 (DO bottom/top)			
29	In the MEL_CIII_Gas annotate O2 valve control action value within the 10 seconds is active. Calculate gradient $(O2_{t=10} – O2_{t=0}) / 10$	2±0.15%		
30	With Concept open CIII_PLCSW_DO and disable EN_P, EN_I and enable EN_D (only derivative part is enabled).			
31	With a FG apply a triangular wave Freq=0.1 Hz, A=0.8 V, Offset=3.8 V (3.8 – 4.6 V / 70 – 80%)			
32	In the MEL_CIII_Gas check O2 flow controller set point (SP) MAX	4±0.5%		

6.6.7 MEL-TC-CIII-0602: Pressure valve activation

TC Identifier	MEL-TC-CIII-0602	Purpose:	Verify that safety valve is opened when pressure goes over the set point
Items Tested	CIII_PLCSW_P, MEL_CIII_Gas, MEL_CIII_Main		
Description	When pressure goes over the set point, the safety pressure valve shall be opened until the pressure returns under the set point.		
Special Requisites:	1 APS is used to simulate Pressure sensor. Check supervision values in MEL_CIII_Gas and MEL_CIII_Main displays		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas set control mode to AUTO			
2	In the MEL_CIII_Gas Supervision screen set Pressure Set point to 100 mb			
3	Apply 1.30 – 1.40 V to AI 05 (CIII_MV_P)			
4	In the MEL_CIII_Main Supervision screen check Pressure value	87.5±12.5 mb		
5	In the MEL_CIII_Gas Supervision screen check Pressure value	87.5±12.5 mb		
6	In the MEL_CIII_Gas Supervision screen check safety valve status	Closed		
7	Apply a light to DO 08 (CIII_AC_Safe in CIII_AC_OUT)			
8	Check light status	Off		
9	Apply 1.95 – 2.05 V to AI 05			
10	In the MEL_CIII_Gas Supervision screen check Pressure value	250±12.5 mb		
11	In the MEL_CIII_Gas Supervision screen check safety valve status	Open		
12	Check light status	On		
13	Apply 1.30 – 1.40 V to AI 05 (CIII_MV_P)			
14	In the MEL_CIII_Gas Supervision screen check Pressure value	87.5±12.5 mb		
15	In the MEL_CIII_Gas Supervision screen check safety valve status	Closed		
16	Check light status	Off		

6.6.8 MEL-TC-CIII-0603: DO and Pressure alarms

TC Identifier	**MEL-TC-CIII-0603**	**Purpose:**	Verify that DO and pressure alarms are notified
Items Tested	CIII_PLCSW_P, MEL_CIII_Gas, MEL_CIII_Main		
Description	When pressure goes over the set point, the safety pressure valve shall be opened until the pressure returns under the set point.		
Special Requisites:	1 APS is used to simulate Pressure sensor. Check supervision values in MEL_CIII_Gas and MEL_CIII_Main displays		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas Supervision screen set Pressure Set point to 100 mb			
2	Apply 1.95 – 2.05 V to AI 05 (CIII_MV_P)			
3	In the MEL_CIII_Gas Supervision screen check Pressure value	250±12.5 mb		
4	Wait 15 minutes.			
5	Check in the Alarm Area the pressure alarm status	Alarm		
6	In the MEL_CIII_Gas Supervision screen set DO set point to 80%			
7	Apply 4.65 – 4.75 V to AI 01 and AI 02 (CIII_MV_DO top/bottom)			
8	In the MEL_CIII_Gas Supervision screen check DO value	92.5±1.25 %		
9	Check in the Alarm Area the DO alarm status	Alarm		
10	Apply 4.15 – 4.25 V to AI 01 and AI 02 (CIII_MV_DO top/bottom)			
11	In the MEL_CIII_Gas Supervision screen check DO value	80±1.25 %		
12	Check in the Alarm Area the DO alarm status	OK		
13	Apply 3.65 – 3.75 V to AI 01 and AI 02 (CIII_MV_DO top/bottom)			
14	Check in the Alarm Area the DO alarm status	Alarm		

6.7 MEL-CIII-TP-07 Temperature regulation

6.7.1 Purpose

Temperature regulation maintains the temperature of the compartment in the set point. In case of over temperature the cooling valve is opened, and in case of under temperature the heater resistance is activated using a pulse action.

6.7.2 Features to be tested

Verify integration and functionality of the following items:

- Supervision displays:
  - MEL_CIII_Main: Display of the most important values of the CIII compartment.
  - MEL_CIII_Temp: Temperature regulation display.
- Local Control (PLC) program sections:
  - CIII_PLCSW_Temp: Temperature Regulation.
- PLC – Rack I/O Interface
- Supervision – PLC Interface

6.7.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIII-TC-0701	Temperature regulation
MEL-CIII-TC-0702	Temperature alarms

6.7.4 Special Requirements

Table of I/O that participates in the Gas flow loop:
Ty (Type) = DI: Digital Input, DO: Digital Output, AI: Analogue Input, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIII_MV_Tb	AI	09	Temperature at bottom	CIII_CP	065 069	+ -	4 – 20 mA
CIII_MV_Tt	AI	10	Temperature at top		073 077	+ -	0 – 5 V
CIII_AC_Heat	DO	06	Activate Heater	CIII_AC_OUT	025 027 029	AC L AC N GND	220 VEF
CIII_AC_CV	DO	05	Open/close the cooling valve		019 021 023	AC L AC N GND	220 VEF
CIII_SP_Lin	AO	07	Liquid input pump flow regulation		177 181	+ -	4 – 20 mA

Devices needed in this test procedure:

- 2 Adjustable Power Supply (APS) to provide current / voltage to analogue inputs
- 1 Multimeter to measure analogue current / voltage outputs

6.7.5 Procedure Steps

- Set Temperature loop operation mode to AUTO.
- Execute the Test Cases and record the successful or unsuccessful execution of tests in the Test Report.

6.7.6 MEL-TC-CIII-0701: Temperature regulation

TC Identifier	**MEL-TC-CIII-0701**	**Purpose:**	Verify that when temperature goes under the set point the heater is activated with a pulse action and when is over the set point the cooling valve is opened
Items Tested	CIII_PLCSW_Temp, MEL_CIII_Temp, MEL_CIII_Main		
Description	When temperature goes under the set point, the heater is activated with a pulse action and cooling valve is opened.		
Special Requisites:	1 APS is used to simulate Temperature sensors. Check supervision values in MEL_CIII_Temp and MEL_CIII_Main displays		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Temp set control mode to AUTO			
2	Apply a light to DO 06 and DO 05 (CIII_AC_Heat, CIII_AC_CV in the CIII_AC_CP)			
3	In the MEL_CIII_Temp, set Temp ramp parameter to 30 seconds.			
4	In the MEL_CIII_Temp, check Temp set point (initial value)	28º C		
5	Apply 1.70 – 1.80 V to AI 09 (Temperature bottom)			
6	In the MEL_CIII_Temp, check Temperature bottom value	27.725±1.8º C		
7	Apply 1.70 – 1.80 V to AI 10 (Temperature top)			
8	In the MEL_CIII_Temp, check Temperature top value	27.725±1.8º C		
9	Apply 1.70 – 1.80 V to AI 09, AI 10 (Temperature bottom/top)			
10	In the MEL_CIII_Temp, check Temperature value	27.725±1.8º C		
11	Apply 1.80 – 1.90 V to AI 09, AI 10 (Temperature bottom/top)			
12	In the MEL_CIII_Temp, check Temperature value	31.935±1.8º C		
13	Check DO 05 light (CIII_AC_CV)	On		
14	In the MEL_CIII_Temp check cooling valve status	Open		
15	Apply 1.60 – 1.70 V to AI 09, AI 10 (Temperature bottom/top)			
16	In the MEL_CIII_Temp, check Temperature value	24.04±1.8º C		
17	Check DO 05 light (CIII_AC_CV)	Off		
18	Check DO 06 light (CIII_AC_Heater) status every 5 seconds (shall be 5 seconds blinking, 5 seconds off)	On		
19	Apply 1.70 – 1.80 V to AI 09 (Temperature bottom)			
20	In the MEL_CIII_Temp, check Temperature bottom value	27.725±1.8º C		
21	Check DO 05, DO 06 lights (CIII_AC_CV, CIII_AC_Heater)	Off		

6.7.7 MEL-TC-CIII-0702: Temperature alarms

TC Identifier	MEL-TC-CIII-0702	Purpose:	Verify that when temperature goes under the set point the heater is activated with a pulse action and when is over the set point the cooling valve is opened
Items Tested	CIII_PLCSW_Temp, MEL_CIII_Temp, MEL_CIII_Main		
Description	When temperature goes under the set point, the heater is activated with a pulse action and cooling valve is opened.		
Special Requisites:	1 APS is used to simulate Temperature sensors. Check supervision values in MEL_CIII_Temp, CIII_MEL_Liquid and MEL_CIII_Main displays		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Temp set control mode to AUTO			
2	In the MEL_CIII_Temp, check Temp set point (initial value)	28º C		
	In the MEL_CIII_Liquid, set Liquid Input flow rate set point to 0.4 l/h			
3	Apply 1.45 – 1.55 V to AI 09 (Temperature bottom)			
4	In the MEL_CIII_Temp, check Temperature bottom value	18.55±1.8º C		
5	In the MEL_CIII_Temp, check Temperature value	20.44±1.8º C		
6	Check in the Alarm Area the Temperature deviation alarm status	Alarm		
7	Check in the MEL_CIII_Liquid, the Liquid input flow rate	0±0.1 l/h		
8	Apply 1.70 – 1.80 V to AI 09 (Temperature bottom)			
9	In the MEL_CIII_Temp, check Temperature value	27.725±1.8º C		
10	Check in the Alarm Area the Temperature deviation alarm status	OK		
11	Apply 2.45 – 2.55 V to AI 10 (Temperature top)			
12	In the MEL_CIII_Temp, check Temperature top value	55.25±1.8º C		
13	In the MEL_CIII_Temp, check Temperature value	33.45±1.8º C		
14	Check in the Alarm Area the Temperature deviation alarm status	Alarm		
15	Apply 1.70 – 1.80 V to AI 10 (Temperature top)			
16	In the MEL_CIII_Temp, check Temperature value	27.725±1.8º C		
17	Check in the Alarm Area the Temperature deviation alarm status	OK		

6.8 MEL-CIII-TP-08: Initial Values

6.8.1 Purpose

When PLC is restarted, default initial values are loaded into program parameters. It shall be verified that these default values are properly defined, since the PLC will use this parameters immediately after is restarted.

6.8.2 Features to be tested

Verify default values loaded into the PLC used when it is restarted.

6.8.3 Procedure Steps

1. Stop the PLC
2. Load last program version into the PLC
3. Start the PLC
4. With the Concept tool Reference Data Editor, check that initial values are as in the following table:

TC Identifier	MEL-CIII-TP-08	Purpose	Check that correct initial values are used at PLC restart		
Tester:		Date:			
Variable name	**Type**	**Address**	**Init. Value**	**Description**	**OK**
CIII_CNS_CO2Kp	real	400522	5	Additional proportional constant for CO2	
CIII_CNS_DOBias	real	400518	0	Disturbance variable (Feed_fw) for DO PID	
CIII_CNS_DOKd	real	400516	0.0033	Derivative constant for DO PID	
CIII_CNS_DOKi	real	400514	3000	Integrative constant for DO PID	
CIII_CNS_DOKp	real	400512	12	Proportional constant for DO PID	
CIII_CNS_Doramp	real	400588	0.016	DO supervision set point ramp coefficient	
CIII_CNS_LinA	real	400584	73.5294	Input pump calibration constant parameter A	
CIII_CNS_LinB	real	400586	0.1765	Input pump calibration constant parameter B	
CIII_CNS_LoA	real	400598	0	Output pump calibration constant parameter A	
CIII_CNS_LoB	real	400600	0	Output pump calibration constant parameter B	
CIII_CNS_N2Kp	real	400614	0.5	Proportional constant for N2 regulation	
CIII_CNS_OpModeDO	int	400568	0	DO control operational mode (0=Off, 1=Auto, 2=Manual)	
CIII_CNS_OpModeGas	int	400566	0	Gas control operational mode (0=Off, 1=Auto, 2=Manual)	
CIII_CNS_OpModeL	int	400565	0	Liquid control operational mode (0=Off, 1=Auto, 2=Manual)	
CIII_CNS_OpModepH	int	400612	0	pH control operational mode (0=Off, 1=Auto, 2=Manual)	
CIII_CNS_OpModeT	int	400567	0	Temperature control operational mode (0=Off, 1=Auto, 2=Manual)	
CIII_CNS_pHKi	real	400510	3000	Integration constant for Acid/Base PI	
CIII_CNS_pHKp	real	400508	3	Proportional constant for Acid/Base PI	
CIII_CNS_pHMode	int	400554	1	pH regulation mode variable (1=CO2 only, 2=CO2+Base, 3=Base+Acid)	
CIII_CNS_pHramp	real	400560	0.005	pH supervision set point ramp coefficient	
CIII_CNS_Tramp	real	400556	0.0083	Temperature supervision set point ramp coefficient	
CIII_MAN_Ac	real	400570	0	Manual acid pump set point	
CIII_MAN_Bs	real	400572	0	Manual base pump set point	

TC Identifier	MEL-CIII-TP-08	Purpose	Check that correct initial values are used at PLC restart		
Tester:		Date:			
Variable name	Type	Address	Init. Value	Description	OK
CIII_MAN_CO2	real	400574	0	Manual CO2 flow controller set point	
CIII_MAN_EnAc	Bool	000190	0	Manual enable of acid pump	
CIII_MAN_EnBs	Bool	000191	0	Manual enable of base pump	
CIII_MAN_EnCV	Bool	000192	0	Manual enable of the cooling valve	
CIII_MAN_EnHT	Bool	000193	0	Manual enable of the heater	
CIII_MAN_EnLOBT	Bool	000195	0	Manual enable of buffer output pump	
CIII_MAN_EnP	Bool	000194	0	Manual enable of pressure safety valve	
CIII_MAN_Lin	real	400576	0	Manual liquid input pump set point	
CIII_MAN_LO	real	400578	0	Manual liquid output pump set point	
CIII_MAN_N2	real	400580	0	Manual N2 flow controller set point	
CIII_MAN_O2	real	400582	0	Manual O2 flow controller set point	
CIII_SSP_DO	real	400520	80	DO Supervision set point	
CIII_SSP_L1Lin	real	400524	0	Level 1 liquid input supervision set point	
CIII_SSP_L2Lin	real	400542	0	Level 2 liquid Input supervision set point	
CIII_SSP_P	real	400526	80	Pressure supervision set point	
CIII_SSP_pH	real	400504	8	pH supervision set point	
CIII_SSP_T	real	400500	28	Temperature supervision set point	

5. If one or more initial values differ from those in the table then follow the procedure defined in the Operations Manual [R9], section 9.2 to update.

6.9 MEL-CIII-TP-09: Check Sensor / Actuator Link Errors

6.9.1 Purpose

When a current (4-20 mA) analogue input / output is disconnected (link error) the status shall be notified to the supervision.

6.9.2 Features to be tested

Verify link errors are notified to the supervision as specified.
Verify safety values are set to measured variables when a link error occurs.

6.9.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-CIII-TC-0901	Check link errors on analogue inputs
MEL-CIII-TC-0902	Check link errors on analogue outputs

6.9.4 Procedure Steps

Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

6.9.5 MEL-TC-CIII-0901: Check Link Errors on Analogue Inputs

TC Identifier	**MEL-TC-CIII-0901**	**Purpose:**	Verify that when a current analogue input connection is broken is notified to supervision
Functions Tested	CIII_PLCSW		
Description	Errors on sensor links are displayed in the supervision as alarms and safety values are displayed blinking in the supervision screens.		
Special Requisites:	All current inputs shall be disconnected		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
	In the MEL_CIII_Temp supervision display set Temperature set point to 28			
1	In the MEL_CIII_Temp supervision display check Temperature bottom value	28 (Blinking)		
2	In the MEL_CIII_Temp supervision display check Temperature top value	28 (Blinking)		
	In the MEL_CIII_Gas supervision display set DO(%) set point to 80			
3	In the MEL_CIII_Gas supervision display check DO(%) bottom value	80 (Blinking)		
4	In the MEL_CIII_Gas supervision display check DO(%) top value	80 (Blinking)		
8	In the MEL_CIII_Gas supervision display check Pressure value	80 (Blinking)		
5	In the MEL_CIII_Liquid supervision display check NH4 value	0.0 (Blinking)		
6	In the MEL_CIII_Liquid supervision display check NO3 value	0.0 (Blinking)		
9	In the MEL_CIII_pH supervision display check pH bottom value	8.0 (Blinking)		
10	In the MEL_CIII_pH supervision display check pH top value	8.0 (Blinking)		
11	In the MEL_CIII_Main supervision display check Pressure value	80 (Blinking)		
13	In the MEL_CIV_Main supervision display check DO value	640 (Blinking)		
14	In the MEL_CIV_Main supervision display check NH4 value	0.0 (Blinking)		
15	In the MEL_CIV_Main supervision display check NO3 value	0.0 (Blinking)		
16	In the MEL_CIV_Main supervision display Temperature value	28.0 (Blinking)		
17	In the MEL_CIV_Main supervision display pH value	8.0 (Blinking)		
22	Check following alarms are fired: - Alarm to notify Temperature sensor link error - Alarm to notify DO sensor link error - Alarm to notify NO3 sensor link error - Alarm to notify NH4 sensor link error - Alarm to notify pressure sensor link error			

TC Identifier	MEL-TC-CIII-0901	Purpose:	Verify that when a current analogue input connection is broken is notified to supervision		
Functions Tested	CIII_PLCSW				
Description	Errors on sensor links are displayed in the supervision as alarms and safety values are displayed blinking in the supervision screens.				
Special Requisites:	All current inputs shall be disconnected				
	- Alarm to notify pH sensor link error				

6.9.6 MEL-TC-CIII-0902: Check Link Errors on Analogue Outputs

TC Identifier	MEL-TC-CIII-0902	Purpose:	Verify that when a current analogue output connection is broken is notified to supervision		
Functions Tested	CIII_PLCSW				
Description	Errors on actuator links are displayed in the supervision as alarms				
Special Requisites:	All current outputs shall be disconnected				
Tester:		**Date:**			
Course of Actions					
Step no	**Description**		**Expected value**	**OK/NOK**	**Comments**
1	Check following alarms are fired: - Alarm to notify acid pump link error - Alarm to notify base pump link error - Alarm to notify liquid input link error - Alarm to notify liquid output link error				

6.10MEL-CIII-TP-10: Check operational modes

6.10.1Purpose

Each loop (Temperature, Liquid, pH, Gas) allows the selection of the operational mode:
OFF: Outputs are set to 0
AUTO: Outputs are set with the value resulting of the control action.
MAN: Outputs are set to manual values (provided by the Supervision from each loop Supervision displays).

6.10.2Features to be tested

Verify changing operational modes outputs are set as specified.

6.10.3Test Cases

Following Test Cases are executed in this Test Procedure:

Identifier	Name
MEL-CIII-TC-1001	Check Temperature loop operational modes.
MEL-CIII-TC-1002	Check Liquid loop operational modes.
MEL-CIII-TC-1003	Check pH loop operational modes Check
MEL-CIII-TC-1004	Check Gas loop operational modes

6.10.4Special Requirements

Table of Outputs that participates in the regulation loops:
Ty (Type) = RL: Relay, AO: Analogue Output

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIII_SP_CO2	AO	01	CO2 input flow regulation		129 133	+ -	0 – 5 V
CIII_SP_N2	AO	02	N2 flow regulation		137 141	+ -	0 – 5 V
CIII_SP_O2	AO	03	O2 flow regulation		145 149	+ -	0 – 5 V
CIII_SP_Ac	AO	05	Acid pump flow regulation		161 165	+ -	4 – 20 mA
CIII_SP_Bs	AO	06	Base pump flow regulation		169 173	+ -	4 – 20 mA
CIII_SP_Lin	AO	07	Liquid input pump flow regulation		177 181	+ -	4 – 20 mA
CIII_SP_LO	AO	08	Liquid output pump flow regulation		185 189	+ -	4 – 20 mA
CIII_RL_Lbt	DO	01	Activation of the pump for the buffer tank		122 126	+ -	0 – 24 V

Variable Name	Ty	N.	Description	Connector	Pin	Signal	Range
CIII_AC_AC	DO	02	Relay acid pump	CIII_AC_OUT	001 003 005	AC L AC N GND	220 VEF
CIII_AC_BS	DO	03	Relay base pump		007 009 011	AC L AC N GND	220 VEF
CIII_AC_Comp	DO	04	Compressor activation		013 015 017	AC L AC N GND	220 VEF
CIII_AC_CV	DO	05	Open/close the cooling valve		019 021 023	AC L AC N GND	220 VEF
CIII_AC_Heat	DO	06	Activate Heater		025 027 029	AC L AC N GND	220 VEF
CIII_RL_Lp	DO	07	Relay to have a pulse in the level sensor lecture	CIII_CP	11 19	+ +	24 V
CIII_AC_Safe	DO	08	Activation of Pressure Safety Valve	CIII_AC_OUT	31 33 35	AC L AC N GND	220 VEF

Devices needed in this test procedure:

- 1 Multimeter to measure analogue current / voltage outputs
- 6 Pilot lights 220 VAC

6.10.5 Procedure Steps

Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

6.10.6 MEL-TC-CIII-1001: Check Temperature Loop Operational Modes

TC Identifier	**MEL-TC-CIII-1001**	**Purpose:**	Verify when operational mode is changed in the Temperature Loop, outputs are set as specified		
Functions Tested	CIII_PLCSW_Temp, MEL_CIII_Temp				
Description	From the MEL_CIII_Temp supervision screen it is possible to change the operational mode and set the manual values.				
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_BP supervision screen to change operational modes and manual values.				
Tester:			**Date:**		

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Temp supervision screen set operational mode to OFF			
2	Connect a pilot light to AC outputs CIII_AC_CV, CIII_AC_Heat			
3	Check Pilot lights	OFF		
11	In the MEL_CIII_Temp edit the manual values and set: Cooling valve activation: checked Heater activation: checked			
13	In the MEL_CIII_Temp supervision screen set operational mode to MAN			
14	Check Pilot lights	ON		

6.10.7MEL-TC-CIII-1002: Check Liquid loop operational modes.

TC Identifier	**MEL-TC-CIII-1002**	**Purpose:**	Verify when operational mode is changed in the Liquid Loop, outputs are set as specified
Functions Tested	CIII_PLCSW_Liquid, MEL_CIII_Liquid		
Description	From the MEL_CIII_Liquid supervision screen it is possible to change the operational mode and set the manual values.		
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIII_Liquid supervision screen to change operational modes and manual values.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Liquid supervision screen set operational mode to OFF			
2	Apply a 500 ohm resistor to AO 07			
3	Check AO 07 (CIII_SP_Lin) voltage output	2.0±0.1 V		
4	Apply a 500 ohm resistor to AO 07			
5	Check AO 08 (CIII_SP_LO) voltage output	2.0±0.1 V		
6	In the MEL_CIII_Liquid edit the manual values and set: Liquid input set point: 30 Liquid output set point: 20			
7	In the MEL_CIII_Liquid supervision screen set operational mode to MAN			
8	Check AO 07 (CIII_SP_Lin) voltage output	4.4±0.1 V		
9	Check AO 08 (CIII_SP_LO) voltage output	3.6±0.1 V		

6.10.8 MEL-TC-CIII-1003: Check pH loop operational modes

TC Identifier	MEL-TC-CIII-1003	Purpose:	Verify when operational mode is changed in the pH Loop, outputs are set as specified
Functions Tested	CIII_PLCSW_pH, MEL_CIII_pH		
Description	From the MEL_CIII_pH supervision screen it is possible to change the operational mode and set the manual values.		
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIII_pH supervision screen to change operational modes and manual values.		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_pH supervision screen set operational mode to OFF			
2	Connect a pilot light to AC outputs CIII_AC_AC, CIII_AC_BS			
3	Place a 500 ohm resistor to AO 05, AO 06			
4	Check AO 05 (CIII_SP_AC)	2.0±0.1 V		
5	Check AO 06 (CIII_SP_BS)	2.0±0.1 V		
	Check AO 01 (CIII_SP_CO2)	0.0±0.1 V		
6	Check pilot lights	Off		
7	In the MEL_CIII_pH edit the manual values and set: Acid pump set point: 10 Acid pump activation: checked Base pump set point: 20 Base pump activation: checked CO2 flow rate set point: 30			
8	In the MEL_CIII_pH supervision screen set operational mode to MAN			
9	Check AO 05 (CIII_SP_AC)	2.8±0.1 V		
10	Check AO 06 (CIII_SP_BS)	3.6±0.1 V		
11	Check AO 01 (CIII_SP_CO2)	1.5±0.1 V		
12	Check pilot lights	On		

6.10.9 MEL-TC-CIII-1004: Check Gas loop operational modes

TC Identifier	MEL-TC-CIII-1004	Purpose:	Verify when operational mode is changed in the Gas Loop, outputs are set as specified
Functions Tested	CIII_PLCSW_Gas, MEL_CIII_Gas		
Description	From the MEL_CIII_Gas supervision screen it is possible to change the operational mode and set the manual values.		
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIII_Gas supervision screen to change operational modes and manual values.		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas supervision screen set operational mode to OFF			
2	Connect a pilot light to AC outputs CIII_AC_Safe			
3	Check AO 02 (CIII_SP_N2)	0.0±0.1 V		
4	Check AO 03 (CIII_SP_O2)	0.0±0.1 V		
5	Check pilot light	Off		
6	In the MEL_CIII_Gas edit the manual values and set: N2 Flow Set point: 10 O2 Flow set point: 20 Pressure safety valve activation: checked			
7	In the MEL_CIII_Gas supervision screen set operational mode to MAN			
8	Check AO 02 (CIII_SP_N2)	0.33±0.1 V		
9	Check AO 03 (CIII_SP_O2)	1.00±0.1 V		
10	Check pilot light	On		

7 HMI TEST PROCEDURES

The following Test Procedures are specified in the following sections:

Identifier	Name	Description
MEL- HMI -TP-01	Check CIII HMI Displays	Test values of Compartment CIII are displayed according to specifications.
MEL- HMI -TP-02	Check CIV HMI Displays	Test analogue output values of Compartment CIII are displayed according to specifications.

7.1 MEL-HMI-TP-01 Check CIII HMI Displays

7.1.1 Purpose

Check that CIII PLC values are displayed in the HMI displays according to specifications.

7.1.2 Features to be tested

Verify integration and functionality of the following items:

- HMI – CIII PLC Interface (Software interface)

7.1.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-HMI-TC-0101	Check CIII_HMI_Temp
MEL-HMI-TC-0102	Check CIII_HMI_pH
MEL-HMI-TC-0103	Check CIII_HMI_Liquid
MEL-HMI-TC-0104	Check CIII_HMI_Gas

7.1.4 Special Requirements

Values of displayed variables can be modified using following procedures:
Analogue input variables: Apply a voltage to rack connection panel using an APS.
Analogue output variables: Modify manual values in Supervision displays.
Supervision set points: Modify using Supervision screens.
Digital input variables: Close circuit using a resistance.
Digital output variables: Modify manual values in Supervision displays.

Table of inputs

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIII_MV_Dob	AI	01	DO at bottom	CIII_CP	001 005	+ -	4 – 20 mA
CIII_MV_Dot	AI	02	DO at top		009 013	+ -	4 – 20 mA
CIII_MV_NH4	AI	03	Ammonium concentration		017 021	+ -	4 – 20 mA
CIII_MV_NO3	AI	04	Nitrate concentration		025 029	+ -	4 – 20 mA
CIII_MV_P	AI	05	Pressure at top of the gas phase		033 037	+ -	4 – 20 mA
CIII_MV_PHb	AI	06	pH at bottom		041 045	+ -	4 – 20 mA
CIII_MV_PHt	AI	07	pH at Top		049 053	+ -	4 – 20 mA
CIII_MV_Psl	AI	08	Pressure sensor for the sampling line		057 061	+ -	4 – 20 mA

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIII_MV_Tb	AI	09	Temperature at bottom		065 069	+ -	4 – 20 mA
CIII_MV_Tt	AI	10	Temperature at top		073 077	+ -	0 – 5 V
CIII_IND_CalNH4	DI	01	NH4 Analyser calibration indicator		193 197	+ -	0 – 24 V
CIII_IND_CalNO3	DI	02	Nitrate analyser calibration indicator		002 006	+ -	0 – 24 V
CIII_MV_Llow	DI	03	Level measurement low		010 014	+ -	0 – 24 V
CIII_MV_Lhigh	DI	04	Level measurement high		018 022	+ -	0 – 24 V
CIII_MVO_Lbt	DI	05	Indicator of max level reached for a buffer tank		026 030	+ -	0 – 24 V

7.1.5 Procedure Steps

Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

7.1.6 MEL-TC-HMI-0101: Check CIII_HMI_Temp

TC Identifier	**MEL-TC-HMI-0101**	**Purpose:**	Verify that values in CIII_HMI_Te,mp are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Temp		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltages.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Apply 2.9 – 3.1 V to AI 09 (CIII_MV_Tb) and check the displayed value Temperature in the Supervision screen CIII_HMI_Temp.	73.6±4.3 mbar		
2	Apply 2.9 – 3.1 V to AI 10 (CIII_MV_Tt) and check the displayed value Temperature in the Supervision screen CIII_HMI_Temp.	73.6±4.3 mbar		
3	Apply 2.9 – 3.1 V to AI 09, AI 10 (CIII_MV_Tb, CIII_MV_Tt) and check the displayed value Temperature in the Supervision screen CIII_HMI_Temp.	73.6±4.3 mbar		
4	Check temperature value in the CIII_HMI_Main display.	73.6±4.3 mbar		
5	In the MEL_CIII_Temp Supervision display change the temperature set point to 27 º C			
6	Check the Temperature set point in the CIII_HMI_Temp display (note ramp action)	down to 27º C		
7	In the MEL_CIII_Temp Supervision display change the control mode to AUTO			
8	Check the operational mode changed accordingly in the CIII_HMI_Temp display	AUTO		
9	In the MEL_CIII_Temp Supervision display change the control mode to MAN			
10	Check the operational mode changed accordingly in the CIII_HMI_Temp display	MAN		
11	In the MEL_CIII_Temp Supervision display edit manual values and set: - Heater enabled. - Cooling valve enabled.			
12	Check in the CIII_HMI_Temp display status of Heater and the Cooling Valve.	Enabled		

7.1.7 MEL-TC-HMI-0102: Check CIII_HMI_pH display

TC Identifier	**MEL-TC-HMI-0102**	**Purpose:**	Verify that values in CIII_HMI_pH are displayed according to specifications.		
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_pH, CIII_HMI_Gas				
Description	Known values applied to PLC variables shall be displayed in the display as specified.				
Special Requisites:	Use an APS to generate voltage values.				
Tester:			**Date:**		
Course of Actions					

Step no	Description	Expected value	OK/NOK	Comments
1	Apply 2.9 – 3.1 V to AI 06 (CIII_MV_PHb) and check the displayed value pHbot in the Supervision screen CIII_HMI_pH.	8.0±0.25 pH		
2	Apply 2.9 – 3.1 V to AI 07 (CIII_MV_PHt) and check the displayed value pHtop in the Supervision screen CIII_HMI_pH.	6.5±0.25 pH		
3	Apply 2.9 – 3.1 V to AI 06 and AI 07 (CIII_MV_PHb, CIII_MV_PHt) and check the displayed value pH in the HMI screen CIII_HMI_pH.	7.85±0.25 pH		
4	Check pH value in the HMI screen CIII_HMI_Main	7.85±0.25 pH		
5	In the MEL_CIII_pH Supervision display change the pH set point to 9			
6	Check the pH set point in the CIII_HMI_pH display (note ramp action) in 3 minutes	up to 9 pH		
7	In the MEL_CIII_pH Supervision display change the control mode to AUTO			
8	Check the operational mode changed accordingly in the CIII_HMI_pH display	AUTO		
9	In the MEL_CIII_pH Supervision display change the pH operation mode to 2=CO2+Base			
10	Check the pH operation mode changed accordingly in the CIII_HMI_pH display	2		
11	In the MEL_CIII_pH Supervision display change the pH operation mode to 3=Acid+Base			
12	Check the pH operation mode changed accordingly in the CIII_HMI_pH display	3		
13	In the MEL_CIII_pH Supervision display change the control mode to MAN			
14	Check the operational mode changed accordingly in the CIII_HMI_pH display	MAN		
15	In the MEL_CIII_pH Supervision display edit manual values and set: - Acid pump enabled - Acid pump control action 10%. - Base pump enabled - Base pump control action 20%. - CO2 valve at 30%			

TC Identifier	MEL-TC-HMI-0102	Purpose:	Verify that values in CIII_HMI_pH are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_pH, CIII_HMI_Gas		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
16	Check in CIII_HMI_pH acid pump control action	10%		
17	Check in CIII_HMI_pH base pump control action	20%		
18	Check in CIII_HMI_pH CO2 valve control action	30%		
19	Check in CIII_HMI_Gas CO2 valve control action	30%		
20	Check acid and base pump status	Enabled		
21	In the MEL_CIII_pH Supervision display change the control mode to OFF			
22	Check the operational mode changed accordingly in the CIII_HMI_pH display	OFF		
23	Check acid, base, CO2 control actions	0.0		
24	Check acid, base pumps status	Disabled		

7.1.8 MEL-TC-HMI-0103: Check CIII_HMI_Liquid display

TC Identifier	**MEL-TC-HMI-0103**	**Purpose:**	Verify that values in CIII_HMI_Liquid are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Liquid, MEL_HMI_Main		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
	In the MEL_CIII_Liquid Supervision display change the Level 2 Liquid Input set point to 0,4			
1	Check Level 2 Liquid input set point value in the HMI screen CIII_HMI_Liquid	0,4		
2	Using iFix Database Manager change the Level 1 Liquid Input set point to 0,4			
3	Check Level 1 Liquid input set point value in the HMI screen CIII_HMI_Liquid	0,4		
4	Check in the CIII_HMI_Liquid display the Liquid Level Low indicator status	Enabled		
5	Apply a resistance to DI 04 (Level High)			
6	Check in the CIII_HMI_Liquid display the Liquid Level High indicator status	Enabled		
7	In the MEL_CIII_Liquid Supervision display change the control mode to AUTO			
8	Check in the CIII_HMI_Liquid display the control mode value	AUTO		
9	Check Liquid input flow rate value in the HMI screen CIII_HMI_Liquid	0,4		
10	Check Liquid input flow rate value in the HMI screen CIII_HMI_Main	0,4		
11	Check Liquid input flow rate value in the HMI screen MEL_HMI_Main	0,4		
12	Check Liquid input pump control action in the HMI screen CIII_HMI_Liquid	29.59%		
13	Check Liquid output pump control action in the HMI screen CIII_HMI_Liquid	36.99%		
14	Apply a resistance to DI 05 (CIII_MVO_Lbt)			
15	Check in the CIII_HMI_Liquid display the Buffer tank level high indicator	Enabled		
16	Check in the CIII_HMI_Liquid display the Buffer tank output pump status	ON		
17	In the MEL_CIII_Liquid Supervision display change the control mode to MAN			
18	Check in the CIII_HMI_Liquid display the control mode value	MAN		
19	In the MEL_CIII_Liquid Supervision display edit manual values and set: - Liquid input pump control action 10% - Liquid output pump control action 20%. - Buffer output pump enabled			

TC Identifier	MEL-TC-HMI-0103	Purpose:	Verify that values in CIII_HMI_Liquid are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Liquid, MEL_HMI_Main		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
20	Check in the CIII_HMI_Liquid display the Liquid input pump control action	10%		
21	Check in the CIII_HMI_Liquid display the Liquid output pump control action	20%		
22	Check in the CIII_HMI_Liquid display the Buffer tank pump status	ON		
23	Apply 2.9 – 3.1 V to AI 03 (CIII_MV_NH4) and check NH4 value in the HMI display CIII_HMI_Liquid	100±5 ppm		
24	Check NH4 value in the HMI screen CIII_HMI_Main	100±5 ppm		
25	Apply 2.9 – 3.1 V to AI 04 (CIII_MV_NO3) and check NO3 value in the HMI display CIII_HMI_Liquid	500±25 ppm		
26	Check NO3 value in the HMI screen CIII_HMI_Main	500±25 ppm		
27	Using iFix Data Manager set 5 to CIII_SMV_NO2	30%		
28	Check in the CIII_HMI_Liquid display the NO2 value	5		
29	Check in the MEL_HMI_Main display the NO2 value	5		
30	Check NO2 value in the HMI screen CIII_HMI_Main	5		
31	In the MEL_CIII_Liquid Supervision display change the control mode to OFF			
32	Check the operational mode changed accordingly in the CIII_HMI_Liquid display	OFF		
33	Check input and output pump control action values	0.0		
34	Check buffer pump status	Disabled		

7.1.9 MEL-TC-HMI-0104: Check CIII_HMI_Gas display

TC Identifier	**MEL-TC-HMI-0104**	**Purpose:**	Verify that values in CIII_HMI_Gas are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Gas		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas Supervision display change the DO set point to 85%			
2	Check in the CIII_HMI_Gas display the DO set point value (note ramp action) in 5 minutes	up to 85%		
3	Apply 2.9 – 3.1 V to AI 01 (CIII_MV_Dob) and check DO bottom value in CIII_HMI_Gas display.	50±2.5%		
4	Apply 2.9 – 3.1 V to AI 02 (CIII_MV_Dot) and check DO top value in CIII_HMI_Gas display.	50±2.5%		
5	Apply 2.9 – 3.1 V to AI 01 and AI 02 (CIII_MV_Dob, CIII_MV_Dot) and check DO value in CIII_HMI_Gas display.	50±2.5%		
6	Check in the CIII_HMI_Main display the DO value	50±2.5%		
7	Check in the MEL_HMI_Main display the DO value	50±2.5%		
9	In the MEL_CIII_Gas Supervision display change the DO control mode to AUTO			
10	Check in the CIII_HMI_Gas display the DO control mode value	AUTO		
11	In the MEL_CIII_Gas Supervision display change the DO control mode to MAN			
12	Check in the CIII_HMI_Gas display the DO control mode value	MAN		
13	In the MEL_CIII_Gas Supervision display edit manual values and set: - O2 control action to 10% - N2 Liquid output pump control action 20%.			
14	Check O2 valve control action in the HMI screen CIII_HMI_Gas	10%		
15	Check N2 valve control action in the HMI screen CIII_HMI_Gas	20%		
16	Apply 2.9 – 3.1 V to AI 05 (CIII_MV_P) and check P value in CIII_HMI_Gas display.	500±2.5 mbar		
17	Check in the CIII_HMI_Main display the P value			
18	In the MEL_CIII_Gas Supervision display change the Gas control mode to MAN			
19	Check in the CIII_HMI_Gas display the Gas control mode value	MAN		
20	In the MEL_CIII_Gas Supervision display change the Gas control mode to AUTO			

21	Check in the CIII_HMI_Gas display the Gas control mode value	AUTO		
22	In the MEL_CIII_Gas Supervision display change the P set point to 200 mbar			
23	Check in the CIII_HMI_Gas display the Pressure set point	200 mbar		
24	Check in the CIII_HMI_Gas display the Safety Pressure Valve status	OPEN (green)		
25	In the MEL_CIII_Gas Supervision display change the P set point to 500 mbar			
26	Check in the CIII_HMI_Gas display the Safety Pressure Valve status	CLOSED (red)		

7.2 MEL-HMI-TP-02 Check CIV_HMI_Displays

7.2.1 Purpose

Check that CIV PLC values are displayed in the HMI displays according to specifications.

7.2.2 Features to be tested

Verify integration and functionality of the following items:

- HMI – CIV PLC Interface (Software interface)

7.2.3 Test Cases

Following Test Cases are executed in this Test Procedure

Identifier	Name
MEL-HMI-TC-0201	Check CIV_HMI_pH
MEL-HMI-TC-0202	Check CIV_HMI_BP
MEL-HMI-TC-0203	Check CIII_HMI_Gas

7.2.4 Special Requirements

Values of displayed variables can be modified using following procedures:
Analogue input variables: Apply a voltage to rack connection panel using an APS.
Analogue output variables: Modify manual values in Supervision displays.
Supervision set points: Modify using Supervision screens.
Digital input variables: Close circuit using a resistance.
Digital output variables: Modify manual values in Supervision displays.

Table of inputs

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIV_MV_CxAbs	AI	01	Analogue input for biomass concentration measurement in light absorbance units	CIV_CP	001 005	+ -	4 – 20 mA
CIV_MV_M1	AI	02	Scale 1		009 013	+ -	4 – 20 mA
CIV_MV_M2	AI	03	Scale 2		017 021	+ -	4 – 20 mA
CIV_MV_P	AI	04	Pressure measurement		025 029	+ -	4 – 20 mA
CIV_MV_pH	AI	05	pH measurement		033 037	+ -	4 – 20 mA
CIV_MV_T	AI	06	Temperature measurement		041 045	+ -	4 – 20 mA
CIV_MGO_O2	AI	07	O2 measurement at gas output		049 053	+ -	4 – 20 mA
CIV_MGO_CO2	AI	08	CO2 measurement at gas output		057 061	+ -	4 – 20 mA

Variable Name	Tp.	N.	Description	Connector	Pin	Signal	Range
CIV_MV_DO	AI	09	Percent of DO saturation in the reactor		065 069	+ -	4 – 20 mA
CIV_MV_FrGas	AI	13	Gas flow at compartment input		097 101	+ -	0 – 5 V
CIV_MGO_FrGas	AI	14	Gas flow at output		105 109	+ -	0 – 5 V
CIV_MV_FrCO2	AI	15	CO2 flow measurement		113 117	+ -	0 – 5 V
CIV_MGI_FrGas	AI	16	Gas flow at external input		121 125	+ -	0 – 5 V
CIV_CAL_CO2O2	DI	01	Calibration indicator		42 46	+ -	0 – 24 V
CIV_ERR_CO2O2	DI	02	Error indicator		50 54	+ -	0 – 24 V
CIV_SCL1_CO2O2	DI	03	Using scale 1 indicator		58 62	+ -	0 – 24 V
CIV_SCL2_CO2O2	DI	04	Using scale 2 indicator		66 70	+ -	0 – 24 V

7.2.5 Procedure Steps

Execute the Test Cases and record the successful or unsuccessful execution of the test in the Test Report.

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7.2.6 MEL-TC-HMI-0201: Check CIV_HMI_pH display

TC Identifier	**MEL-TC-HMI-0201**	**Purpose:**	Verify that values in CIV_HMI_pH are displayed according to specifications.
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_pH, CIV_HMI_Gas		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Apply 2.9 – 3.1 V to AI 05 (CIV_MV_pH) and check the displayed value pH in the HMI screen CIV_HMI_pH.	7.0±0.35 pH		
2	Check pH value in the HMI screen CIV_HMI_Main	7.0±0.35 pH		
3	In the MEL_CIV_pH Supervision display change the pH set point to 9			
4	Check the pH set point in the CIV_HMI_pH display	9		
5	In the MEL_CIV_pH Supervision display change the control mode to AUTO			
6	Check the operational mode changed accordingly in the CIV_HMI_pH display	AUTO		
7	In the MEL_CIV_pH Supervision display change the control mode to MAN			
8	Check the operational mode changed accordingly in the CIV_HMI_pH display	MAN		
9	In the MEL_CIV_pH Supervision display edit manual values and set: - Acid pump control action 10% - Base pump control action 20%. - CO2 valve control action 2,5 nLm			
10	Check in CIV_HMI_pH acid pump control action	10 %		
11	Check in CIV_HMI_pH base pump control action	20 %		
12	Check in CIV_HMI_pH CO2 valve control action	2,5 nLm		
13	Check in CIV_HMI_Gas CO2 valve control action	2,5 nLm		
14	In the MEL_CIV_pH Supervision set CO2 offset to 1,5 nLm			
15	Check the CO2 offset changed accordingly in the CIV_HMI_pH display	1,5		
16	In the MEL_CIV_pH Supervision set pH control mode to 2=CO2 + Base			
17	Check the pH control mode changed accordingly in the CIV_HMI_pH display	2		
18	In the MEL_CIV_pH Supervision set pH control mode to 3=Acid + Base			
19	Check the pH control mode changed accordingly in the CIV_HMI_pH display	3		

TC Identifier	MEL-TC-HMI-0201	Purpose:	Verify that values in CIV_HMI_pH are displayed according to specifications.
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_pH, CIV_HMI_Gas		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
20	In the MEL_CIV_pH Supervision display change the operation mode to OFF			
21	Check the operational mode changed accordingly in the CIV_HMI_pH display	OFF		
22	Check acid, base and CO2 control actions	0.0		

7.2.7 MEL-TC-HMI-0202: Check CIV_HMI_BP display

TC Identifier	**MEL-TC-HMI-0202**	**Purpose:**	Verify that values in CIV_HMI_BP are displayed according to specifications.	
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_BP, MEL_HMI_Main			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:		**Date:**		

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Apply 2.9 – 3.1 V to AI 02 (CIV_MV_M1) and check the displayed level for input Tank 1 in the HMI screen CIV_HMI_BP.	75±3.75 l		
2	Apply 2.9 – 3.1 V to AI 03 (CIV_MV_M2) and check the displayed level for input Tank 2 in the HMI screen CIV_HMI_BP.	75±3.75 l		
3	Apply 2.9 – 3.1 V to AI 01 (CIV_MV_CxAbs) and check the displayed value for Biomass concentration in the HMI screen CIV_HMI_BP.	3.0±0.5 g/l		
4	In the MEL_CIV_BP Supervision display change the Level 2 Biomass Production Set point to 1,2			
5	Check the Level 2 Biomass production set point changed accordingly in the CIV_HMI_BP display	1,2		
6	Using iFix Data Manager change the (CIV_SSP_L1BP) Level 1 Biomass Production Set point to 1,1			
7	Check the Level 1 Biomass production set point changed accordingly in the CIV_HMI_BP display	1,1		
8	In the MEL_CIV_BP Supervision display change the Level 2 Liquid input flow rate Set point to 0,7			
9	Check the Level 2 Liquid input flow rate set point changed accordingly in the CIV_HMI_BP display	0,7		
10	Using iFix Data Manager change the (CIV_SSP_L1LiFr) Level 1 Liquid input flow rate Set point to 0,6			
11	Check the Level 1 Liquid input flow rate set point changed accordingly in the CIV_HMI_BP display	0,6		
12	Check the Biomass production rate in the CIV_HMI_BP display	0,66		

TC Identifier	MEL-TC-HMI-0202	Purpose:	Verify that values in CIV_HMI_BP are displayed according to specifications.
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_BP, MEL_HMI_Main		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
13	Check the Biomass production rate in the CIV_HMI_Main display	0,66		
14	Check the Biomass production rate in the MEL_HMI_Main display	0,66		
15	Check the Liquid input flow rate in the CIV_HMI_BP display	0,6		
16	Check the Liquid input flow rate in the CIV_HMI_Main display	0,6		
17	Check the Liquid input flow rate in the MEL_HMI_Main display	0,6		
18	Using iFix Data Manager change the (CIV_SSP_LightWm) Light intensity to 150			
19	Check the Light intensity set point in the CIV_HMI_BP display	150 W/m2		
20	Check the Light intensity set point in the CIV_HMI_Main display	150 W/m2		
21	In the MEL_CIV_BP Supervision display change the operational mode to AUTO			
22	Check the operational mode in the CIV_HMI_BP display	AUTO		
23	In the MEL_CIV_BP Supervision display change the operational mode to MAN			
24	In the MEL_CIV_BP Supervision display edit manual values and set: - Enable Biomass sensor aeration valve - Enable Liquid input pump 1 - Enable Liquid input pump 2 - Enable Liquid output pump - Set liquid input pump 1 set point to 10% - Set liquid input pump 2 set point to 20% - Set liquid output pump set point to 30% - Set light supply regulator set point to 40%			
25	Check in CIV_HMI_BP liquid input pump 1 control action	10 %		
26	Check in CIV_HMI_BP liquid input pump 2 control action	20 %		
27	Check in CIV_HMI_BP liquid output pump control action	30 %		
28	Check in CIV_HMI_BP light supply control action	40 %		
29	Check in CIV_HMI_BP liquid output flow rate	2,6 l/h		

TC Identifier	MEL-TC-HMI-0202	Purpose:	Verify that values in CIV_HMI_BP are displayed according to specifications.	
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_BP, MEL_HMI_Main			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:		Date:		

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
30	Check in CIV_HMI_Main liquid output flow rate	2,6 l/h		
31	Check in CIV_HMI_Main liquid input pump 1 status	Enabled (green)		
32	Check in CIV_HMI_Main liquid input pump 2 status	Enabled (green)		
33	Check in CIV_HMI_Main liquid output pump status	Enabled (green)		
34	Check in CIV_HMI_Main Biomass sensor aeration valve	Open (green)		
35	In the MEL_CIV_BP Supervision display change the operational mode to OFF			
36	Check the operational mode in the CIV_HMI_BP display	OFF		
37	Check liquid input/output, and light supply control actions	0,0		

7.2.8 MEL-TC-HMI-0203: Check CIV_HMI_Gas display

TC Identifier	**MEL-TC-HMI-0203**	**Purpose:**	Verify that values in CIV_HMI_Gas are displayed according to specifications.
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_Gas, MEL_HMI_Main		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Apply 2.9 – 3.1 V to AI 04 (CIV_MV_P) and check the displayed pressure value in the HMI screen CIV_HMI_Gas.	0.75±0.375 bar		
2	Check in CIV_HMI_Main the pressure value	0.75±0.375 bar		
3	Apply 2.9 – 3.1 V to AI 07 (CIV_MGO_O2) and check the displayed O2 flow rate value in the HMI screen CIV_HMI_Gas.	12.5±0.7 nLm		
4	Check in CIV_HMI_Main the O2 value	12.5±0.7 nLm		
5	Check in MEL_HMI_Main the O2 value	12.5±0.7 nLm		
6	Apply 2.9 – 3.1 V to AI 08 (CIV_MGO_CO2) and check the displayed CO2 at gas output value	250±15 ppm		
7	Check in CIV_HMI_Main the CO2 at output value	250±15 ppm		
8	Apply 2.9 – 3.1 V to AI 09 (CIV_MV_DO) and check the displayed DO concentration in the HMI screen CIV_HMI_Gas.	50±2.5 %		
9	Apply 2.9 – 3.1 V to AI 13 (CIV_MV_FrGas) and check the displayed gas flow at compartment input (FG-CI) in the HMI screen CIV_HMI_Gas.	18±0.6 nLm		
10	Check in CIV_HMI_Main the Gas at compartment input flow rate	18±0.6 nLm		
11	Apply 2.9 – 3.1 V to AI 14 (CIV_MGO_FrGas) and check the displayed gas flow at compartment output (FG-CO) in the HMI screen CIV_HMI_Gas.	18±0.6 nLm		
12	Apply 2.9 – 3.1 V to AI 15 (CIV_MV_FrCO2) and check the displayed CO2 flow at compartment input in the HMI screen CIV_HMI_Gas.	3±0.1 nLm		
13	Check in CIV_HMI_Main the CO2 input flow rate	3±0.1 nLm		
14	Apply 2.9 – 3.1 V to AI 16 (CIV_MGI_FrGas) and check the displayed Air flow at compartment input in the HMI screen CIV_HMI_Gas.	18±0.6 nLm		
15	Apply 2.9 – 3.1 V to AI 06 (CIV_MV_T) and check the Temperature value in the HMI screen	75±3.75 º C		

TC Identifier	MEL-TC-HMI-0203	Purpose:	Verify that values in CIV_HMI_Gas are displayed according to specifications.
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_Gas, MEL_HMI_Main		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
	CIV_HMI_Main.			
16	In the MEL_CIV_Gas Supervision display change the Pressure set point to 0,8			
17	Check in CIV_HMI_Gas the pressure set point	0,8 bar		
18	In the MEL_CIV_Gas Supervision display change the Air input set point to 10			
19	Check in CIV_HMI_Gas the Air input set point	10 nLm		
20	In the MEL_CIV_Gas Supervision display change the Gas at compartment input set point to 20			
21	Check in CIV_HMI_Gas the Gas at compartment input set point	20 nLm		
22	In the MEL_CIV_Gas Supervision display change the Gas at output set point to 15			
23	Check in CIV_HMI_Gas the Gas at compartment input set point	15 nLm		
24	In the MEL_CIV_Gas Supervision display change the operational mode to AUTO			
25	Check in CIV_HMI_Gas the operational mode	AUTO		
26	In the MEL_CIV_Gas Supervision display change the operational mode to MAN			
27	Check in CIV_HMI_Gas the operational mode	MAN		
28	In the MEL_CIV_Gas Supervision display edit manual values and set: - Enable Safety Pressure valve			
29	Check in CIV_HMI_Gas the Safety pressure valve status	Open (green)		
30	In the MEL_CIV_Gas Supervision display change the operational mode to OFF			
31	Check in CIV_HMI_Gas the operational mode	OFF		
32	Check in CIV_HMI_Gas the Air input, CO2 input, Gas at compartment input, Gas at output set points value	0,0		
33	Check in CIV_HMI_Gas the safety pressure valve status	Closed (red)		

8 APPENDIX A: Comp. CIV Connection Tables

CIV_TB_ACI							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_AI_01+	CIV_TB_ACI	1	CIV_CP	4	24	WH	
CIV_AI_01-		2		8		WH/YL	
CIV_AI_02+		5		12		BR/GN	
CIV_AI_02-		6		16		WH/GN	
CIV_AI_03+		11		20		PR	
CIV_AI_03-		12		24		RD	
CIV_AI_04+		15		28		BL	
CIV_AI_04-		16		32		PK	
CIV_AI_05+		21		36		YL	
CIV_AI_05-		22		40		YL/BR	
CIV_AI_06+		25		44		BR	
CIV_AI_06-		26		48		GN	
CIV_AI_07+		31		52		GY/PK	
CIV_AI_07-		32		56		GY	
CIV_AI_08+		35		60		RD/BL	
CIV_AI_08-		36		64		BK	
SENSE 1		3	CIV_TB_ACI	1			
SENSE 2		7		5			
SENSE 3		13		11			
SENSE 4		17		15			
SENSE 5		23		21			
SENSE 6		27		25			
SENSE 7		33		31			
SENSE 8		37		35			
N.C.		4					
		8					
		9					
		10					
		14					
		18					
		19					
		20					
		24					
		28					
		29					
		30					
		34					
		38					
		39					
		40					

CIV_TB_AVI							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_AI_09+	CIV_TB_AVI	3	CIV_CP	68	24	WH	
CIV_AI_09-		2		72		WH/YL	
CIV_AI_10+		5		76		BR/GN	
CIV_AI_10-		6		80		WH/GN	
CIV_AI_11+		11		84		PR	
CIV_AI_11-		12		88		RD	
CIV_AI_12+		15		92		BL	
CIV_AI_12-		16		96		PK	
CIV_AI_13+		21		100		YL	
CIV_AI_13-		22		104		YL/BR	
CIV_AI_14+		25		108		BR	
CIV_AI_14-		26		112		GN	
CIV_AI_15+		31		116		GY/PK	
CIV_AI_15-		32		120		GY	
CIV_AI_16+		35		124		RD/BL	
CIV_AI_16-		36		128		BK	
SENSE 1		3	CIV_TB_AVI	1			
N.C.		4					
		7					
		8					
		9					
		10					
		13					
		14					
		17					
		18					
		19					
		20					
		23					
		24					
		27					
		28					
		29					
		30					
		33					
		34					
		37					
		38					
		39					
		40					

CIV_TB_AVO1							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_AO_01+	CIV_TB_AVO1	1	CIV_CP	132	24	PK	
CIV_AO_01-		2		136		YL	
CIV_AO_02+		11		140		GY	
CIV_AO_02-		12		144		GN	
CIV_AO_03+		21		148		PR	
CIV_AO_03-		22		152		WH	
CIV_AO_04+		31		156		BK	
CIV_AO_04-		32		160		RD	
R1		3	CIV_TB_AVO1	1			
COMMON 1		4		8			
CONTROL 1		5		3			
MASTER OVER		8		4			
R2		13		11			
COMMON 2		14		18			
CONTROL 2		15		13			
MASTER OVER		18		14			
R3		23		21			
COMMON 3		24		28			
CONTROL 3		25		23			
MASTER OVER		28		24			
R4		33		31			
COMMON 4		34		38			
CONTROL 4		35		33			
MASTER OVER		38		34			
N.C.		6					
REFERENCE 1		7					
N.C.		9					
N.C.		10					
N.C.		16					
REFERENCE 1		17					
N.C.		19					
N.C.		20					
N.C.		26					
REFERENCE 1		27					
N.C.		29					
N.C.		30					
N.C.		36					
REFERENCE 1		37					
N.C.		39					
N.C.		40					

CIV_TB_AVO2							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_AO_05+	CIV_TB_AVO2	1	CIV_CP	164	24	YL	
CIV_AO_05-		2		168		PK	
CIV_AO_06+		11		172		GY	
CIV_AO_06-		12		176		GN	
CIV_AO_07+		21		180		PR	
CIV_AO_07-		22		184		WH	
CIV_AO_08+		31		188		BK	
CIV_AO_08-		32		192		RD	
R1		3	CIV_TB_AVO2	1			
COMMON 1		4		8			
CONTROL 1		5		3			
MASTER OVER		8		4			
R2		13		11			
COMMON 2		14		18			
CONTROL 2		15		13			
MASTER OVER		18		14			
R3		23		21			
COMMON 3		24		28			
CONTROL 3		25		23			
MASTER OVER		28		24			
R4		33		31			
COMMON 4		34		38			
CONTROL 4		35		33			
MASTER OVER		38		34			
N.C.		6					
REFERENCE 1		7					
N.C.		9					
N.C.		10					
N.C.		16					
REFERENCE 1		17					
N.C.		19					
N.C.		20					
N.C.		26					
REFERENCE 1		27					
N.C.		29					
N.C.		30					
N.C.		36					
REFERENCE 1		37					
N.C.		39					
N.C.		40					

CIV_TB_ACO							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_AO_09-	CIV_TB_ACO	4	CIV_CP	200	24	PK	
CIV_AO_10-		8		208		YL	
CIV_AO_11-		14		216		GY	
CIV_AO_12-		18		7		GN	
CIV_AO_13-		24		15		PR	
CIV_AO_14-		28		23		WH	
CIV_AO_15-		34		31		BK	
CIV_AO_16-		38		39		RD	
24V-		2	CIV_VC_24_CP	18	20	BK	
MONITOR 1		1					
N.C.		3					
MONITOR 2		5					
RETURN		6					
N.C.		7					
N.C.		9					
N.C.		10					
MONITOR 3		11					
RETURN		12					
N.C.		13					
N.C.		19					
N.C.		20					
MONITOR 4		15					
RETURN		16					
N.C.		17					
MONITOR 5		21					
RETURN		22					
N.C.		23					
MONITOR 6		25					
RETURN		26					
N.C.		27					
N.C.		29					
N.C.		30					
MONITOR 7		31					
RETURN		32					
N.C.		33					
MONITOR 8		35					
RETURN		36					
N.C.		37					
N.C.		39					
N.C.		40					

CIV_TB_DIO							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_DO_01	CIV_TB_DIO	1	CIV_RELAY_01	A1	24	PR	
CIV_DO_02		3	CIV_RELAY_02	A1		BK	
CIV_DO_03		5	CIV_RELAY_03	A1		RD	
CIV_DO_04		7	CIV_RELAY_04	A1		BR	
CIV_DO_05		11	CIV_RELAY_05	A1		WH	
CIV_DO_06		13	CIV_RELAY_06	A1		BL	
CIV_DO_07		15	CIV_CP	203		WH/BK	
CIV_DO_08		17		211		BR	
CIV_DI_01		21		47		RD/BL	
CIV_DI_02		22		55		BK	
CIV_DI_03		23		63		WH/RD	
CIV_DI_04		24		71		PR	
CIV_DI_05		25		79		BR	
CIV_DI_06		26		87		RD	
CIV_DI_07		27		95		GN	
CIV_DI_08		28		103		BL	
CIV_DI_09		31		111		WH/BL	
CIV_DI_10		32		119		PK/BR	
CIV_DI_11		33		127		BR/BL	
CIV_DI_12		34		135		PK/GY	
CIV_DI_13		35		143		WH	
CIV_DI_14		36		151		PK	
CIV_DI_15		37		159		WH/GN	
CIV_DI_16		38		167		BR/GN	
24V-		9	CIV_PS_CP	20	20	BK	
24V+		10		06		RD	
24V-		19		22		BK	
24V+		20		08		RD	
24V-		29		16		BK	
24V-		39		30		BK	
N.C.		2					
N.C.		2					
N.C.		4					
N.C.		6					
N.C.		8					
N.C.		12					
N.C.		14					
N.C.		16					
N.C.		18					
N.C.		30					
N.C.		40					

CIV_PS_SRC							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
GND	CIV_PS_SRC	1	CIV_AC_GND	3	20	YL/GN	
AC N		2	CIV_AC_CP	8		BL	
AC L		3		2		BR	
24V+		4	CIV_PS_CP	1		RD	
24V-		5		15		BK	
24V+		7		1		RD	
24V-		8		11		BK	

CIV_PS_CP							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
24V+	CIV_PS_CP	1	CIV_PS_SRC	4	20	RD	
24V+		13		7		RD	
24V-		15		5		BK	
24V-		29		8		BK	
24V+		3	CIV_PS_CP	1		RD	
24V+		5		3		RD	
24V+		7		5		RD	
24V+		9		7		RD	
24V+		11		9		RD	
24V+		13		11		RD	
24V-		17		15		BK	
24V-		19		17		BK	
24V-		21		19		BK	
24V-		23		21		BK	
24V-		25		23		BK	
24V-		27		25		BK	
24V-		16	CIV_TB_ACO	2		BK	
24V+		6	CIV_TB_DIO	10		RD	
24V+		8		20		RD	
24V-		18		9		BK	
24V-		20		19		BK	
24V-		22		29		BK	
24V-		24		39		BK	
24V+		10	CIV_CP	003		RD	
24V+				011		RD	
24V+				019		RD	
24V+				027		RD	
24V+				035		RD	
24V+				196		RD	
24V+				204		RD	
24V+				212		RD	
24V+		12		107		RD	
24V+				115		RD	
24V+				123		RD	
24V+				131		RD	
24V+				139		RD	
24V+				147		RD	
24V+				155		RD	
24V+				163		RD	
24V+		14		043		RD	
24V+				051		RD	
24V+				059		RD	
24V+				067		RD	
24V+				075		RD	
24V+				083		RD	
24V+				091		RD	
24V+				099		RD	
24V-		26		215		BK	
24V-		28		207		BK	
24V-		30	CIV_RELAY_01	A2		BK	
24V-			CIV_RELAY_02	A2		BK	
24V-			CIV_RELAY_03	A2		BK	
24V-			CIV_RELAY_04	A2		BK	
24V-			CIV_RELAY_05	A2		BK	
24V-			CIV_RELAY_06	A2		BK	
NC		2					
NC		4					

CIV_RELAY_01							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_DO_01	CIV_RELAY_01	A1	CIV_TB_DIO	1	24		
24V-		A2	CIV_PS_CP	28	20	BK	
CIV_RL_LI1_IN		11	CIV_CP	175		BK	
CIV_RL_LI1_OUT		14		171		WH	
N.C.		12					

CIV_RELAY_02							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_DO_02	CIV_RELAY_02	A1	CIV_TB_DIO	3	24		
24V-		A2	CIV_RELAY_01	A2	20	BK	
CIV_RL_LI2_IN		11	CIV_CP	183		PR	
CIV_RL_LI2_OUT		14		179		PK	
N.C.		12					

CIV_RELAY_03							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_DO_03	CIV_RELAY_03	A1	CIV_TB_DIO	5	24		
24V-		A2	CIV_RELAY_02	A2	20	BK	
AC L		11	CIV_AC_MGTH2	2		BR	
CIV_RL_Cx_L		14	CIV_AC_OUT	2		BR	
N.C.		12					

CIV_RELAY_04							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_DO_04	CIV_RELAY_04	A1	CIV_TB_DIO	7	24		
24V-		A2	CIV_RELAY_03	A2	20	BK	
AC L		11		11		BR	
CIV_RL_Fg_L		14	CIV_AC_OUT	8		BR	
N.C.		12					

CIV_RELAY_05							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_DO_05	CIV_RELAY_05	A1	CIV_TB_DIO	11	24		
24V-		A2	CIV_RELAY_04	A2	20	BK	
Not used		11	CIV_CP	191		RD	
Not used		14		185		RD/BL	
N.C.		12					

CIV_RELAY_06							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIV_DO_06	CIV_RELAY_06	A1	CIV_TB_DIO	13	24		
24V-		A2	CIV_RELAY_05	A2	20	BK	
Not used		11	CIV_CP	199		WH/GN	
Not used		14		195		GY/PK	
N.C.		12					

CIV_AC_IN

Tested by: | Date:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIV_AC_IN	2	CIV_AC_DIFF	1	20	BR	
AC N		4		3		BL	
AC GND		6	CIV_AC_GND	1		YL/GN	

CIV_AC_DIFF

Tested by: | Date:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIV_AC_DIFF	2	CIV_AC_MGTH6	1	20	BR	
AC N		4		3		BL	

CIV_AC_MGTH6

Tested by: | Date:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIV_AC_MGTH6	2	CIV_AC_FILT	1	20	BR	
AC N		4		3		BL	

CIV_AC_FILT

Tested by: | Date:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
GND	CIV_AC_FILT	2	CIV_AC_GND	2	20	YL/GN	
AC L		4	CIV_AC_CP	1		BR	
				5		BR	
				9		BR	
				13		BR	
AC N		5		3		BL	
				7		BL	
				11		BL	
				15		BL	

CIV_AC_CP

Tested by: | Date:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIV_AC_CP	2	CIV_AC_OUT	14		BR	
AC N		4		16		BL	
AC L		6	CIV_UPS	1		BR	
AC N		8		3		BL	
AC L		10	CIV_PS_SRC	3		BR	
AC N		12		2		BL	
AC L		14	CIV_MGTH2	1		BR	
AC N		16		3		BL	

CIV_AC_MGTH2

Tested by: | Date:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIV_AC_MGTH2	2	CIV_RELAY_03	11		BR	
			CIV_RELAY_04	11		BR	
AC N		4	CIV_AC_OUT	4		BL	
				10			

CIV_AC_OUT							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIV_AC_OUT	1	CIV_AC_Cx		20	BR	
AC N		3				BL	
AC GND		5				YL/GN	
AC L		7	CIV_AC_Fg			BR	
AC N		9				BL	
AC GND		11				YL/GN	
AC L		13	CIV_FAN			BR	
AC N		15				BL	
AC GND		17				YL/GN	
AC L		2	CIV_RELAY_03	14		BR	
AC L		8	CIV_RELAY_04	14		BR	
AC N		4	CIV_AC_MGTH2	6		BL	
AC N		10				BL	
GND		6	CIV_AC_GND	6		YL/GN	
		12		7		YL/GN	
GND		18		8		YL/GN	
AC L		14	CIV_AC_CP	2		BR	
AC N		16		4		BL	

CIV_AC_UPS							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIV_AC_UPS	4	CIV_PLC_CPS	5	20	BR	
GND		5		7		GN/YL	
AC N		6		6		BL	
AC N		1	CIV_AC_CP	4		BR	
AC L		3		2		BL	
GND		2	CIV_AC_GND	4		GN/YL	

CIV_AC_GND							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
GND	CIV_AC_GND	1	CIV_AC_IN	6	20	YL/GN	
		2	CIV_AC_FILT	2			
		3	CIV_PS_SRC	1			
		4	CIV_AC_UPS	2			
		5	CIV_PLC_CPS	7			
		6	CIV_AC_OUT	6			
		7		12			
		8		18			

9 APPENDIX B: Comp. III Connection Tables

CIII_TB_ACI							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_AI_01+	CIII_TB_ACI	1	CIII_CP	004	24	PR	
CIII_AI_01-		2		008		GY/PK	
CIII_AI_02+		3		012		RD	
CIII_AI_02-		4		016		BR	
CIII_AI_03+		5		020		BK	
CIII_AI_03-		6		024		GY	
CIII_AI_04+		7		028		GN	
CIII_AI_04-		8		032		YL	
CIII_AI_05+		11		036		RD/BL	
CIII_AI_05-		12		040		BR/GN	
CIII_AI_06+		13		044		WH	
CIII_AI_06-		14		048		WH/GN	
CIII_AI_07+		15		052		WH/YL	
CIII_AI_07-		16		056		BR/YL	
CIII_AI_08+		17		060		BL	
CIII_AI_08-		18		064		PK	
CIII_AI_09+		21		068		PR	
CIII_AI_09-		22		072		GY/PK	
CIII_AI_10+		23		076		RD	
CIII_AI_10-		24		080		BR	
CIII_AI_11+		25		084		BK	
CIII_AI_11-		26		088		GY	
CIII_AI_12+		27		092		GN	
CIII_AI_12-		28		096		YL	
CIII_AI_13+		31		100		RD/BL	
CIII_AI_13-		32		104		BR/GN	
CIII_AI_14+		33		108		WH	
CIII_AI_14-		34		112		WH/GN	
CIII_AI_15+		35		116		WH/YL	
CIII_AI_15-		36		120		BR/YL	
CIII_AI_16+		37		124		BL	
CIII_AI_16-		38		128		PK	
N.C.		9					
N.C.		10					
N.C.		19					
N.C.		20					
N.C.		29					
N.C.		30					
N.C.		39					
N.C.		40					

CIII_TB_AVO

Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_AO_01+	CIII_TB_AVO	1	CIII_CP	132	24	RD	
CIII_AO_01-		2		136		BK	
CIII_AO_02+		11		140		PK	
CIII_AO_02-		12		144		BR	
CIII_AO_03+		21		148		WH	
CIII_AO_03-		22		152		GN	
CIII_AO_04+		31		156		GY	
CIII_AO_04-		32		160		YL	
R1		3	CIII_TB_AVO	1		RD	
COMMON 1		4		8		BK	
CONTROL 1		5		3		RD	
MASTER OVERRIDE 4		8		4		BK	
R2		13		11		PK	
COMMON 2		14		18		BR/YL	
CONTROL 2		15		13		PK	
MASTER OVERRIDE 4		18		14		BR/YL	
R3		23		21		WH	
COMMON 3		24		28		WH/GN	
CONTROL 3		25		23		WH	
MASTER OVERRIDE 4		28		24		WH/GN	
R4		33		31		GY	
COMMON 4		34		38		WH/YL	
CONTROL 4		35		33		GY	
MASTER OVERRIDE 4		38		34		WH/YL	
N.C.		6					
Reference_1		7					
N.C.		9					
N.C.		10					
N.C.		16					
Reference_2		17					
N.C.		19					
N.C.		20					
N.C.		26					
Reference_3		27					
N.C.		29					
N.C.		30					
N.C.		36					
Reference_4		37					
N.C.		39					
N.C.		40					

CIII_TB_ACO							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK

CIII_AO_05+	CIII_TB_ACO	10	CIII_CP	164	24	YL	
CIII_AO_06+		20		172		GN	
CIII_AO_07+		30		180		RD	
CIII_AO_08+		40		188		WH	
24V+		9	CIII_PS_CP	12	20	RD	
		19				RD	
		29				RD	
		39				RD	
N.C.		10					
N.C.		20					
N.C.		30					
N.C.		40					
Monitor_1+		1					
N.C.		3					
N.C.		4					
N.C.		5					
N.C.		6					
N.C.		7					
N.C.		8					
Monitor_2+		11					
N.C.		13					
N.C.		14					
N.C.		15					
N.C.		16					
N.C.		17					
N.C.		18					
Monitor_3+		21					
N.C.		23					
N.C.		24					
N.C.		25					
N.C.		26					
N.C.		27					
N.C.		28					
Monitor_4+		31					
N.C.		33					
N.C.		34					
N.C.		35					
N.C.		36					
N.C.		37					
N.C.		38					

CIII_TB_DI							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO		AWG	COLOR	OK
CIII_DI_01	CIII_TB_DI	1	CIII_CP	200	24	PR	

CIII_DI_02		2		007		GY/PK	
CIII_DI_03		5		015		RD	
CIII_DI_04		6		023		BR	
CIII_DI_05		11		031		BK	
CIII_DI_06		12		039		GY	
CIII_DI_07		15		047		GN	
CIII_DI_08		16		055		YL	
CIII_DI_09		21		063		RD/BL	
CIII_DI_10		22		071		BR/GN	
CIII_DI_11		25		079		WH	
CIII_DI_12		26		087		WH/GN	
CIII_DI_13		31		095		WH/YL	
CIII_DI_14		32		103		BR/YL	
CIII_DI_15		35		111		BL	
CIII_DI_16		36		119		PK	
24V+		3	CIII_PS_CP	20	20	RD	
		7				RD	
		13				RD	
		17				RD	
		23				RD	
		27				RD	
		33				RD	
		37				RD	
24V-		4		02		BK	
		8				BK	
		14				BK	
		18				BK	
		24				BK	
		28				BK	
		34				BK	
		38				BK	
N.C.		9					
N.C.		10					
N.C.		19					
N.C.		20					
N.C.		29					
N.C.		30					
N.C.		39					
N.C.		40					

CIII_TB_DO							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_01	CIII_TB_DO	1	CIII_RELAY_01	A1	24	RD	
CIII_DO_02		3	CIII_RELAY_02	A1		BK	
CIII_DO_03		5	CIII_RELAY_03	A1		PK	
CIII_DO_04		7	CIII_RELAY_04	A1		BR	
CIII_DO_05		11	CIII_RELAY_05	A1		WH	
CIII_DO_06		13	CIII_RELAY_06	A1		GN	
CIII_DO_07		15	CIII_RELAY_07	A1		GY	
CIII_DO_08		17	CIII_RELAY_08	A1		YL	
CIII_DO_09		21	CIII_RELAY_09	A1		BL	
CIII_DO_10		23	CIII_RELAY_10	A1		PR	
CIII_DO_11		25	CIII_CP	147		RD	
CIII_DO_12		27		155		BK	
CIII_DO_13		31		163		PK	
CIII_DO_14		33		171		BR	
CIII_DO_15		35		179		WH	
CIII_DO_16		37		187		GN	
24V+		9	CIII_PS_CP	04		RD	
		29				RD	
24V-		19				BK	
		39				BK	
N.C.		2					
N.C.		4					
N.C.		6					
N.C.		8					
N.C.		10					
N.C.		12					
N.C.		14					
N.C.		16					
N.C.		18					
N.C.		20					
N.C.		22					
N.C.		24					
N.C.		26					
N.C.		28					
N.C.		30					
N.C.		32					
N.C.		34					
N.C.		36					
N.C.		38					
N.C.		40					

CIII_PS_SRC							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
GND	CIII_PS_SRC	1	CIII_AC_GND	03	20	YL/GN	
AC N		2	CIII_AC_CP	12		BL	
AC L		3		10		BR	
24V+		4	CIII_PS_CP	1		RD	
24V-		5		15		BK	
24V+		7		13		RD	
24V-		8		27		BK	

CIII_PS_CP							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
24V+	CIII_PS_CP	1	CIII_PS_SRC	4	20	RD	
24V+		13		7		RD	
24V-		15		5		BK	
24V-		27		8		BK	
24V+		1	CIII_PS_CP	3		RD	
24V+		3		5		RD	
24V+		5		7		RD	
24V+		7		9		RD	
24V+		9		11		RD	
24V+		11		13		RD	
24V-		15		17		BK	
24V-		17		19		BK	
24V-		19		21		BK	
24V-		21		23		BK	
24V-		23		25		BK	
24V-		25		27		BK	
24V+		6	CIII_CP	003		RD	
24V+				027		RD	
24V+				035		RD	
24V+				043		RD	
24V+				051		RD	
24V+				059		RD	
24V+				067		RD	
24V+				075		RD	
24V+				083		RD	
24V+				091		RD	
24V+				099		RD	
24V+				107		RD	
24V+				115		RD	
24V+				196		RD	
24V-		22		168		BK	
24V-				176		BK	
24V-				184		BK	
24V-				192		BK	
24V-				151		BK	
24V-				159		BK	
24V-				167		BK	
24V-				175		BK	
24V-				183		BK	
24V-				191		BK	
24V-		26	RELAY_01	A2		BK	
24V-			RELAY_02	A2		BK	
24V-			RELAY_03	A2		BK	
24V-			RELAY_04	A2		BK	
24V-			RELAY_05	A2		BK	
24V-			RELAY_06	A2		BK	
24V-			RELAY_07	A2		BK	
24V-			RELAY_08	A2		BK	
24V-			RELAY_09	A2		BK	
24V-			RELAY_10	A2		BK	
24V-		28	RELAY_10	A2		BK	
24V+		08	RELAY_07	11		RD	
24V-		12	CIII_TB_ACO	09		BK	
24V-				19		BK	
24V-				29		BK	
24V-				39		BK	
24V+		02	CIII_TB_DI	07		RD	
24V+				13		RD	
24V+				17		RD	
24V+				27		RD	
24V+				33		RD	
24V+				37		RD	
24V-		24		04		BK	
24V-				08		BK	
24V-				14		BK	
24V-				18		BK	

24V-				24		BK	
24V-				28		BK	
24V-				34		BK	
24V-				38		BK	
24V+		04	CIII_TB_DO	09		RD	
24V+				19		RD	
24V+				29		RD	
24V+				39		RD	

CIII_RELAY_01							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_01	CIII_RELAY_01	A1	CIII_TB_DO	01	24	RD	
24V-		A2	CIII_PS_CP	28	20	BK	
CIII_RL_BT_IN		11	CIII_CP	123	24	YL	
CIII_RL_BT_OUT		14		127		GN	
N.C.		12					

CIII_RELAY_02							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_02	CIII_RELAY_02	A1	CIII_TB_DO	03	24	BK	
24V-		A2	CIII_RELAY_01	A2	20	BK	
AC L		11	CIII_AC_MGTH2	02		BR	
CIII_AC_Ac_L		14	CIII_AC_OUT	02		BR	
N.C.		12					

CIII_RELAY_03							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_03	CIII_RELAY_03	A1	CIII_TB_DO	05	24	PK	
24V-		A2	CIII_RELAY_02	A2	20	BK	
AC L		11	CIII_RELAY_02	11B		BR	
CIII_AC_Bs_L		14	CIII_AC_OUT	08		BR	
N.C.		12					

CIII_RELAY_04							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_04	CIII_RELAY_04	A1	CIII_TB_DO	07	24	BR	
24V-		A2	CIII_RELAY_03	A2	20	BK	
AC L		11		11B		BR	
CIII_AC_Comp_L		14	CIII_AC_OUT	14		BR	
N.C.		12					

CIII_RELAY_05							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_05	CIII_RELAY_05	A1	CIII_TB_DO	11	24	WH	
24V-		A2	CIII_RELAY_04	A2	20	BK	
AC L		11	CIII_RELAY_04	11B		BR	
CIII_AC_CV_L		14	CIII_AC_OUT	20		BR	
N.C.		12					

CIII_RELAY_06							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_06	CIII_RELAY_06	A1	CIII_TB_DO	13	24	GN	
24V-		A2	CIII_RELAY_05	A2	20	BK	
AC L		11	CIII_RELAY_05	11B		BR	
CIII_AC_Heat_L		14	CIII_AC_OUT	26		BR	
N.C.		12					

CIII_RELAY_07							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_07	CIII_RELAY_07	A1	CIII_TB_DO	15	24	GY	
24V-		A2	CIII_RELAY_06	A2	20	BK	
24V+		11	CIII_PS_CP	08		RD	
CIII_MV_L1+		14	CIII_CP	11	24	RD	
CIII_MV_L1+				19		RD	
N.C.		12					

CIII_RELAY_08							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_08	CIII_RELAY_08	A1	CIII_TB_DO	17	24	YL	
24V-		A2	CIII_RELAY_07	A2	20	BK	
AC L		11	CIII_RELAY_06	11B		BR	
CIII_AC_Safe_L		14	CIII_AC_OUT	32		BR	
N.C.		12					

CIII_RELAY_09							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_09	CIII_RELAY_09	A1	CIII_TB_DO	21	24	BL	
24V-		A2	CIII_RELAY_08	A2	20	BK	
Not used		11	CIII_CP	131	24	YL	
		14		135	24	GN	
		12					

CIII_RELAY_10							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
CIII_DO_10	CIII_RELAY_10	A1	CIII_TB_IO_DO	23	24	PR	
24V-		A2	CIII_RELAY_09	A2	20	BK	
Not used		11	CIII_CP	139	24	YL	
		14		143	24	GN	
		12					

CIII_AC_IN							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIII_AC_IN	2	CIII_AC_MGTH6	1	20	BR	
AC N		4		3		BL	
AC GND		6	CIII_AC_GND	1		YL/GN	

CIII_AC_MGTH6							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIII_AC_MGTH6	2	CIII_AC_DIFF	1	20	BR	
AC N		4		3		BL	

CIII_AC_DIFF							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK

AC L	CIII_AC_DIFF	2	CIII_AC_FILT	1	20	BR	
AC N		4		3		BL	

CIII_AC_FILT							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
GND	CIII_AC_FILT	2	CIII_AC_GND	10	20	YL/GN	
AC L		4	CIII_AC_CP	1		BR	
				5		BR	
				9		BR	
				13		BR	
AC N		5		3		BL	
				7		BL	
				11		BL	
				15		BL	

CIII_AC_CP							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIII_AC_CP	2	CIII_AC_OUT	38		BR	
AC N		4		40		BL	
AC L		6	CIII_UPS	1		BR	
AC N		8		3		BL	
AC L		10	CIII_PS_SRC	3		BR	
AC N		12		2		BL	
AC L		14	CIII_MGTH2	1		BR	
AC N		16		3		BL	

CIII_AC_MGTH2							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIII_AC_MGTH2	2	CIII_RELAY_02	11		BR	
AC N		4	CIII_AC_OUT	04		BL	
AC N				10		BL	
AC N				16		BL	
AC N				22		BL	
AC N				28		BL	
AC N				34		BL	

CIII_AC_UPS							
Tested by:		Date:					
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	OK
AC L	CIII_AC_UPS	4	CIII_PLC_CPS	5	20	BR	
GND		5		7		GN/YL	
AC N		6		6		BL	
AC N		1	CIII_AC_CP	4		BR	
AC L		3		2		BL	
GND		2	CIII_AC_GND	4		GN/YL	

MELISSA

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Control System Demonstrator
Test Plan and Procedure

Version: 1

Issue: 1

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Written by:	Jordi Duatis
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Approved by:	Joan Mas

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Draft		05 March'04	Reviewed
1	0	19 April '04	Issued for ESA review
1	1	28 July '04	Implements ESA comments dated 21/07/04

TABLE OF CONTENTS

1 SCOPE

This document contains the Test Plan and Procedures designed to validate the implementation of the Control System Demonstrator designed and built following the system architecture proposed in [A4]. The test procedures will cover:

- Local regulation loops.
- In-plant verification of the Control law for the *Spirulina* compartment (variables, loops etc.) with the new control HW.
- In-plant verification of the Control law for the Nitrifying compartment (variables, loops etc.) with the new control HW.
- Non-nominal tests to verify alarm management

Tests will be conducted at the UAB premises after the Control System Demonstrator is installed and connected to the MELISSA plant.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**. TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.
[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.
[A3] **Memorandum of Understanding between the UAB and NTE S.A.** MEL-0000-SP-007-NTE. Version 1. Issue 0. 21 January 2002.
[A4] **MELISSA Control System Architecture and Trade-off**. TN 72.3. Version 1. Issue 0. December 2002.

2.2 Reference Documents

[R1] **Definition of the control requirements for the MELISSA Loop**. TN 72.2, v. 1.2, November 2002 (MEL-3100-SP-010-NTE).
[R2] **Photoheterotrophic Compartment Set-up.** TN 37.6. UAB, February 1998.
[R3] **Nitrifying Compartment Studies.** TN 25.310. UAB, September 1996.
[R4] **Set-up of the Photosynthetic Pilot Reactor**. TN. 37.2. UAB, April 1998.
[R5] **Spirulina Controller.** TN 72.3.1, v. 1.0, ADERSA, March 2003.
[R6] **Nitrite Controller Test Plan and Procedure.** TN 72.3.4, v. 1.1, SHERPA, February 2004.
[R7] **Test Plan and Procedure for the Spirulina Controller.** TN 72.3.3, v. 1.0, ADERSA, October 2003.
[R8] **Nitrite Controller.** TN 72.3.2, v. 1.1, ADERSA, October 2003.
[R9] **Control System Demonstrator System Test Plan and Procedure,** TN 72.4 VIa, v. 1.1, July 2004 (MEL-3310-PL-024-NTE).

3 TEM UNDER TEST

The Item under Test is the Melissa Control System Demonstrator consisting of:

- Control System Rack III for CIII
- Control System Rack IV for CIV
- Control SW running on Rack III and Rack IV
- Supervisory SW running on Client and Server PC.

4 TEST PLAN

Tests will be conducted at Compartment level and independently. For every Compartment a System Test and a Functional Test will be performed.

4.1 System Test Plan

The System Test will be carried out at NTE's facilities using external hardware to simulate the sensors and actuators that interact with every compartment. The System Test Plan's purpose is to check that the control hardware is properly built and connected and that every single function is implemented as specified in the design documents. The test procedures will be designed to cover end-to-end system functions. This Plan and Procedures is documented in the System Test Plan and Procedures Document [R9].

4.2 Functional Test Plan

The Functional Test will be conducted at UAB's facilities with the Control System Demonstrator connected to the Pilot Plant. To test the functionality of every compartment the following sequence will be followed:

1. Set-up:

- Objective: to carry out the transition from the old control system to the new one.
- Success criteria: the new control system is able to control and monitor all the compartment's input and output variables and control loops.

2. Alarm test:

- Objective: verify that the system properly detects an anomaly. Temperature difference, over-temperature and liquid level anomalies are checked for CIII. Temperature and no gas anomalies are checked for CIV.
- Success criteria: the system responds with an alarm notification upon detecting the anomaly

3. Compartment transition:

- Objective: defining a set point for a selected compartment's parameter and validate the compartment's transition to achieve this point.
- Success criteria: the system performs the required control actions so that the compartment is able to reach the new set point successfully in a stable manner.

Detailed test procedures are developed in chapter 5 for CIII and in chapter 6 for CIV.

5 CIII FUNCTIONAL TEST PROCEDURES

5.1 Compartment set-up

The compartment set-up with the new control system is considered as part of the test plan, since all local regulation loops, connections, measures and control actions will be validated and verified. Local regulation loops will be verified comparing measures and control actions with respect to the previous control system. Perturbations will be induced and results compared. Expected responses need to take place within the appropriate timing.

Five local control loops will be verified in Compartment III:
- pH Control loop
- Dissolved Oxygen (DO) control loop
- Temperature control loop
- Liquid Level control loop
- Pressure control loop

5.1.1 pH control

pH control is performed actuating over a valve to regulate input flow of CO_2 into the compartment, and actuating over a base medium pump and an acid medium pump. Two probes, one located on the base and one on the top of the compartment, measure pH. The global pH is measured as an average of the two probes.

It shall be checked that pH set point is reached after provoking perturbations. This shall be performed to check CO_2, base and acid addition.

Perform variations of the pH set point and verify that pH measure reaches the set point and is maintained inside the dead-band.

5.1.2 Dissolved Oxygen control

Dissolved Oxygen (DO) control is performed actuating over a valve that regulates O_2 and N_2 input flow. DO is measured by two probes, located on the top and on the bottom of the compartment. Again, global DO is measured as an average of two probes.

It shall be checked that DO set point is reached after provoking perturbations.

Perform variations of the DO set point and verify that the DO measure reaches the set point and is maintained inside the dead band.

5.1.3 Temperature control

Temperature regulation is performed by actuating over a heater (resistance inside the reactor) and a valve that regulates the flow of a cooling bath. Two probes located on the top and the bottom of the compartment measure the temperature. The compartment's temperature is the measured average values.

It shall be checked that temperature set point is reached after provoking perturbations.

Perform variations of the temperature set point and verify that the temperature measure reaches the set point and is maintained inside the dead band.

5.1.4 Liquid Level control

Liquid level is regulated actuating over the output liquid pump. Two sensors placed in the reactor's upper part measure the high and low liquid level status. When level is high, the output pump increases the output flow rate and it decreases the output flow rate when the level is low.

It shall be checked that the liquid output pump increases/decreases the flow rate when level high/low is reached.

Manually actuate over the input pump to provoke the level high and low status and check output flow rate is modified accordingly.

5.1.5 Pressure control

Pressure is regulated actuating over a valve placed on the top of the reactor that is opened when an overpressure is reached.

It shall be checked that the valve is opened in case of overpressure.

Set the pressure set point to a low value and provoke an overpressure and verify valve is opened and pressure restored.

5.2 Alarms

5.2.1 Temperature difference alarm

This alarm is activated when the temperatures measured by the top and the bottom probes have a difference greater that a given value. When this alarm is activated, the liquid input pump is stopped.

It shall be checked that alarm is notified and liquid input pump stopped.

Induce a temperature difference between top and bottom probes and verify that alarm is notified and input pump stopped.

5.2.2 Over temperature alarm

This alarm is activated when the temperature reaches a given value above the set point. When this alarm is activated, the temperature regulation loop is set to OFF.

It shall be checked that alarm is notified and loop is set to OFF.

Reduce the set point below the margin and verify that the over temperature alarm is notified and the loop is set to OFF.

5.2.3 Liquid level alarm

This alarm is notified when liquid level remains continuously high during a given time. When this alarm is activated, the liquid input pump is stopped.

It shall be checked that alarm is notified and liquid input pump is stopped.

Modify manually the liquid input pump causing a level high during the programmed period. Verify that alarm is notified and the liquid input pump stopped.

5.3 Nitrite Estimator

5.3.1 Introduction

The Nitrite Estimator calculates the estimated value of Nitrite (NO_2) in the compartment, taking as inputs, among others, the concentrations of Nitrate (NO_3) and Ammonia (NH_4) present on the gas and liquid phases. Some values are provided on-line (Nitrate, Ammonia and current liquid input flow) and the rest are input from the console. In addition, regulates the liquid input flow according to the applied Nitrite constraint.

Before proceeding to the test procedure the proper integration of the Nitrite Estimator control law into the control system shall be checked following the procedure defined in [R8].

The test procedure will consist of two parts:

- A short test to check the data processing itself (refer to par. 5.3.2)
- A long test concerning more precisely the behaviour of the control (refer to par.5.3.3)

The detailed instructions provided in paragraphs 5.3.2 and 5.3.3 are extracted from [R6]

Test results of both tests are to be checked and validated by SHERPA.

5.3.2 Short Test

Duration: around 6h.

Before starting, the constraint on NO_2 is set to a high value ($1\ 10^{-3}$ mole/l, green curve of the upper graph on figure 1) and the requested flow rate is equal to the measured flow rate (0.4 l/h, green curve of the lower graph on figure 1). One sampling periods after the control has been turned on, the requested flow rate is moved to a high value (for example, 0.8 l/h or more). Then, 1.5 h later, the constraint on NO_2 is moved to a low value ($1\ 10^{-5}$ mole/l). The test can be stopped a short time after the 3 h of duration. The short test is plotted on the figure 1.

5.3.3 Long Test

Duration: around 20 h.

The conditions of the long test will depend on the results of the short one. The aim is to check that the control of the pilot plant is similar to the simulated one. Again, the requested flow rate is changed after one sampling period (0.1 h). An example of the long test is plotted on the figure 2.

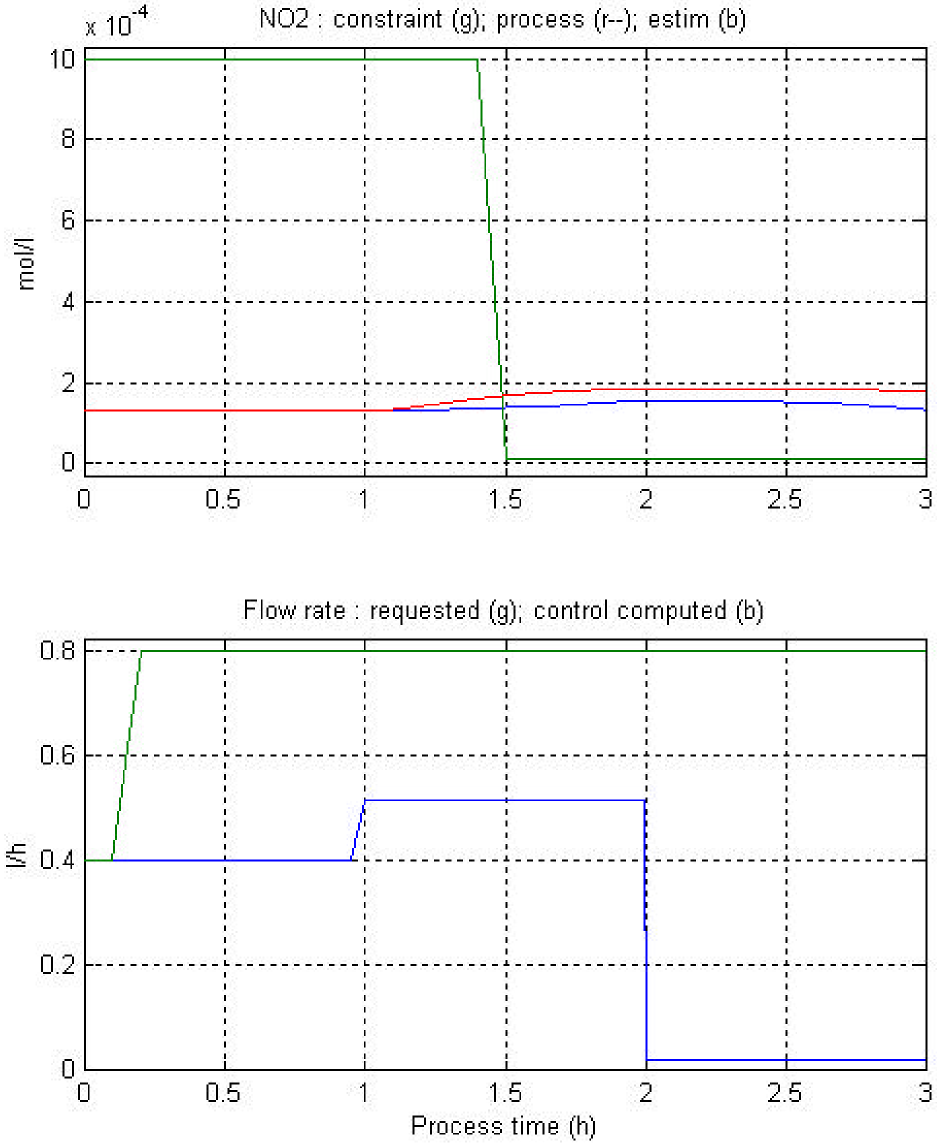

Figure 1 : Nitrite Estimator short test
Remark: the control computed flow rate (blue curve of the lower graph) is refreshed every hour.

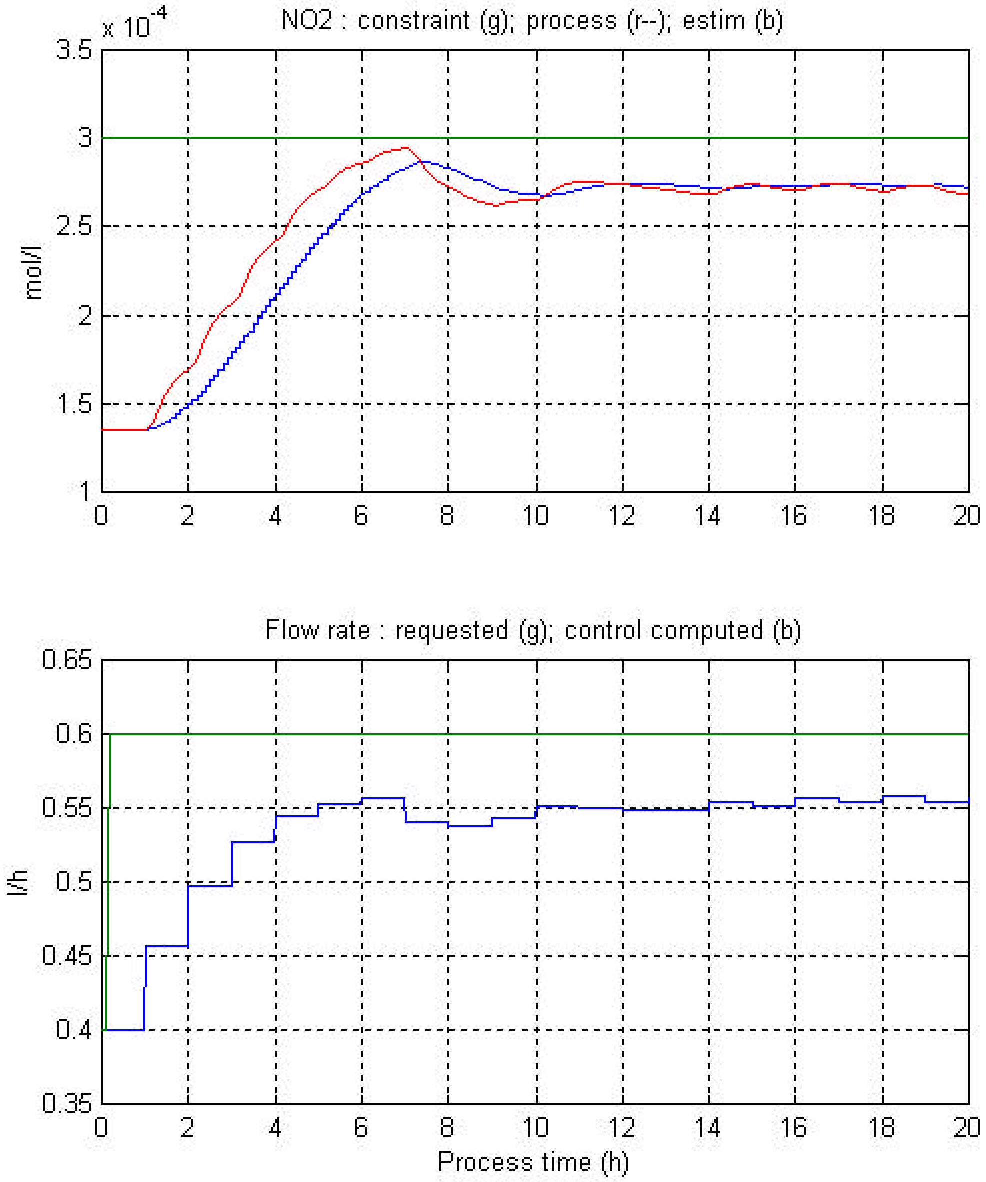

Figure 2: Nitrite estimator long test

6 CIV FUNCTIONAL TEST PROCEDURES

6.1 Compartment set-up

As in the Compartment III, the compartment set-up will be considered as part of the test plan, since all local regulation loops, connections, measures and control actions will be validated and verified.
Local regulation loops will be verified comparing measures and control actions with respect to the previous control system. Perturbations will be provoked and results compared.

6.1.1 Biomass sensor

Biomass sensor is cleaned periodically by blowing air into the conduction. The last measured value is held during the operation and measurement is restored after a given time is elapsed.

It shall be checked that sensor-cleaning action is performed periodically. In addition it shall be checked that the biomass measured value remains stable while the cleaning operation takes place plus a short time after.

Verify biomass sensor measure during a cleaning period.

6.1.2 Gas flow control

Gas flow set points are provided by the supervision actuating over a set of flow controllers that regulate gas input and output flow rates. Low variations of pressure are compensated actuating over the flow controllers. In addition, in case of overpressure a valve placed on the top of the reactor is opened.

It shall be checked that variation of flow rate set points are translated to the corresponding flow controllers, low variations of over pressure increase/decrease input/output flow rates and in case of an overpressure, the safety valve is opened.

Actuate over the flow controllers manually to provoke low over pressure and verify that set points are modified to compensate it. Modify the pressure set point and verify that safety pressure valve is opened.

6.1.3 pH control

pH control is performed actuating over a valve to regulate input flow of CO_2 into the compartment, and actuating over a base medium pump and an acid medium pump. One probe located on the base of the compartment measure the pH.

It shall be checked that pH set point is reached after provoking perturbations. This shall be performed to check CO_2, base and acid addition.

Perform variations of the pH set point and verify that pH measure reaches the set point and is maintained inside the dead-band.

6.2 Alarms

6.2.1 Temperature alarm

This alarm is activated when temperature is a given value over the set point. When this alarm is activated, the light is set to a safety value and liquid input and output pumps are stopped.

It shall be checked that alarm is notified, light is set to the safety value and liquid input and output pumps are stopped.

Reduce the set point below the margin and verify that over temperature alarm is notified, light is set to the safety value and liquid input/output pumps are stopped.

6.2.2 No Gas alarm

This alarm is activated when input gas flow is near to 0. This means that gas supply has been interrupted externally. When this alarm is activated, the light is set to a safety value and liquid input and output pumps are stopped.

It shall be checked that alarm is notified, light is set to the safety value and liquid input and output pumps are stopped.

Interrupt the gas supply and verify that No Gas alarm is notified, light is set to the safety value and liquid input/output pumps are stopped.

6.3 Biomass Production

6.3.1 Introduction

The Biomass Production control law regulates the production of biomass (Spirulina), taking as inputs the current biomass concentration, current and required liquid input flow rate and current light flux. These values are provided on-line, even the liquid input flow rate and the light flux are not measured but computed from the set points. The controlled variable is the light flux.

Before proceeding to the test procedure the proper integration of the Biomass Production control law into the control system shall be checked following the procedure defined in [R5].

To validate the control law of the Spirulina compartment two tests will be performed:

- A short one to test the data processing itself (refer to par. 6.3.2)

- A long one to test the internal variables of the control (refer to par. 6.3.3)

The detailed instructions provided in paragraphs 6.3.2 and 6.3.3 are excerpts from [R7].

Test results will be validated by SHERPA.

6.3.2 Short Test

Duration: around 6 h.

The proposed protocol is illustrated in the figure 3. At the beginning of the test, the level2 setpoint is set equal to the measured value of the Controlled Variable (i.e. the biomass production which is equal to the product of the biomass concentration and of the input flow rate). Two hours later, the level2 setpoint is set to a very high value (2 g/h in the upper graph of figure 3). Then 2 hours later, it is set to a very low value (0.1 g/h). The test is terminated 2 hours later.

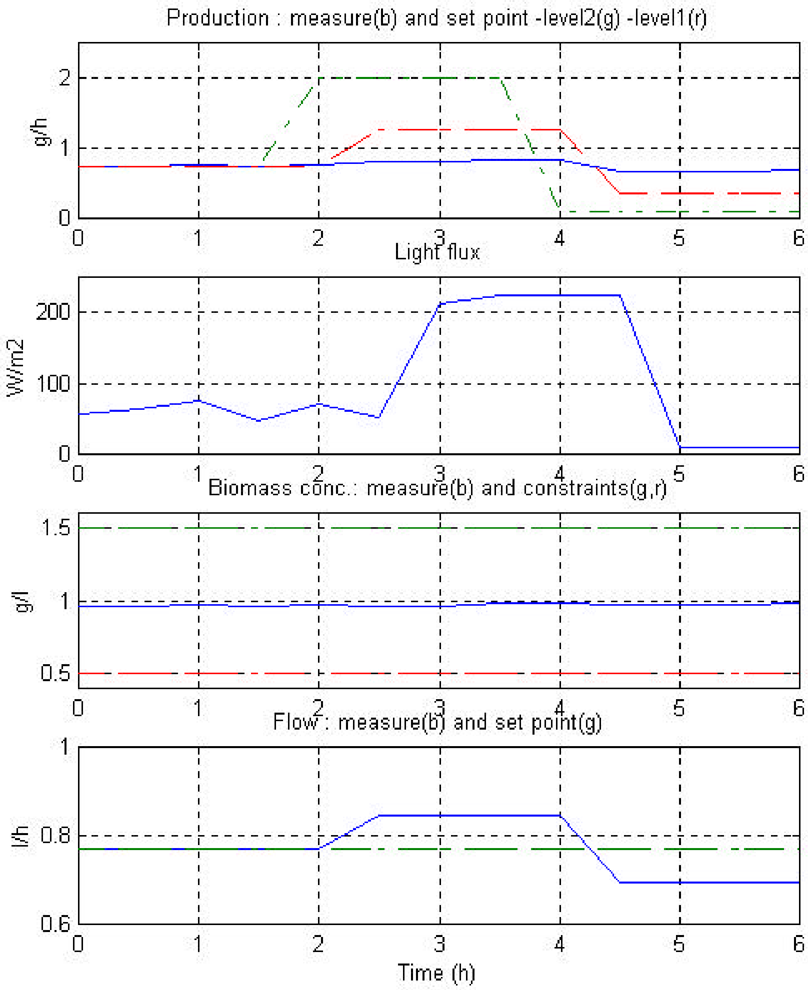

Figure 3: Spirulina control law short test

6.3.3 Long Test

Duration: around 200 h.

The objective is to test the behavior of the control. Therefore, it is proposed to move successively the set point and the disturbance (input flow rate).

An example of this protocol is shown in the figure 4. At the beginning of the test, when the closed loop system is at steady state, (t=5 h, on figure 4), a step of level2 production set point is applied (here, from 0.75 to 0.9 g/h, red curve of the top graph). The amplitude of the step is not too high so that the set point can be reached in a reasonable period of time. The interest is to check that the CV (Controlled Variable) converges towards its set point with no gap. When the CV is stable on its set point (at time t=100 h on figure 4), a step is applied on the disturbance (the input flow rate is moved from 0.77 to 0.5 l/h). The amplitude of the step is high enough so that the realizable production set point (red curve of the top graph) is lower than the level2 set point (green curve of the top graph). This allows to check that the biomass concentration does not overshoot its upper constraint (blue and green curves, respectively, of the third graph).

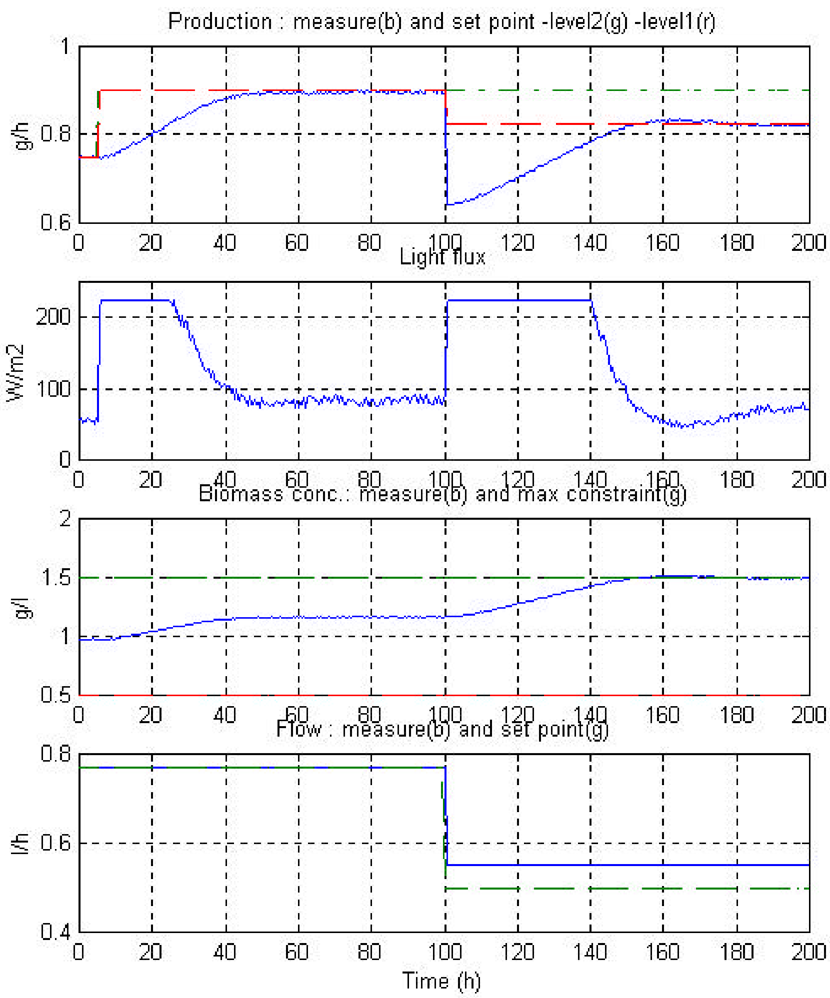

Figure 4: Spirulina control law long test

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Version	Issue	Date	Change description
1	0	23 April '04	First version
1	1	28 July '04	Updated after ESA comments dated 21/07/04

TABLE OF CONTENTS

1 SCOPE

This document presents the HW design of the Control System Demonstrator to be installed in the MELISSA Pilot Plant at UAB (E) premises for compartments III and IV.
Chapters 4 to 7 the mechanical and electrical design of the three racks that conform the Control System Demonstrator, (namely racks for CIII, CIVa and Supervisory HW).

Appendix A addresses the capabilities of the Demonstrator HW in order to implement redundancy.

Appendices B and C contain detailed tables showing the electrical interconnections of the different modules within racks III and IV. Appendix D contains the cable colour codes and Appendix E lists the complete HW part lists implemented in the Demonstrator.

Appendix F addresses the expansion capabilities of the racks III and IV in order to adapt to potential future modification or expansion of the associated bioreactors.

Finally Appendix G explains the electrical protection design measures implemented in the racks to guarantee their safe operation.

2 REFERENCE DOCUMENTS

2.1 Applicable documents

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**.TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.

[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.

[A3] **Memorandum of Understanding between the UAB and NTE S.A.** MEL-0000-SP-007-NTE. Version 1. Issue 0. 21 January 2002.

[A4] ***Reglamento de Baja Tensión* (RBT)**, July 2002.

[A5] **MELISSA Control System Architecture and Trade-off**. TN 72.3. Version 1. Issue 0. February 2003.

2.2 Reference Documents

[R1] **Definition of the control requirements for the MELISSA Loop**. TN 72.2, v. 1.2, November 2002 (MEL-3100-SP-010-NTE).

[R2] **Photoheterotrophic Compartment Set-up.** TN 37.6. UAB, February 1998.

[R3] **Nitrifying Compartment Studies.** TN 25.310. UAB, September 1996.

[R4] **Set-up of the Photosynthetic Pilot Reactor.** TN. 37.2. UAB, April 1998.

[R5] **Control System Demonstrator Test Plan and Procedure,** TN 72.4 Volume Ib, v.1.1, July 2004 (MEL-3310-PL-039-NTE.).

[R6] **Modicon Quantum Automation Series Hardware Reference Guide.** 840 USE 100 00 version 10.0, 2002.

3 ACRONYMS LIST

AWG	American Wire Gauge
HSBY	Hot StandBY
PLC	Programmable Logic Controller
RBT	*Reglamento de Baja Tensión* (Low Voltage Regulation)
STP	Shielded Twisted Pair
UAB	*Universitat Autònoma de Barcelona*

4 INTRODUCTION

This document describes the hardware design of the Control System demonstrator to be installed at the MELISSA Pilot Plant (UAB's premises).

This demonstrator has been designed as to permit the verification of some key aspects of the new MELISSA Control System Architecture described in [A5]. The aspects to be verified as previously agreed with ESA, are the following:

- In-plant verification of the Control law for the *Spirulina* compartment (variables, loops etc.) with the new control HW.
- In-plant verification of the Control law for the Nitrifying compartment. (Variables, loops etc.) with the new control HW.
- Non-nominal tests to verify alarm management

These verification objectives are developed in a specific Test Plan and Procedure produced by NTE in co-ordination with the UAB, [R5].

Based on these verification objectives NTE proposed for implementation the Control System demonstrator for compartments CIII and CIV shown in Figure 4-1. This diagram presents the demonstrator conceptual design and how it is implemented in terms of equipment and products. Redundant elements are displayed in grey and are not physically implemented within the demonstrator HW.

The demonstrator HW presents the following configuration:

- Client computer
- Supervisory rack, housing the supervision server and the Ethernet switch
- Compartment III (CIII) rack, housing the CIII PLC and auxiliary electronic equipment, implementing the local control for the MELISSA Nitrifying compartment and providing electrical interface to the Plant's sensors and actuators related to CIII.
- Compartment IV (CIV) rack, housing the CIV PLC and auxiliary electronic equipment implementing the local control for the MELISSA Spirulina compartment and providing electrical interface to the Plant's sensors and actuators related to CIV.
- HMI Touch screen

All these elements are to be interconnected through an Ethernet network.

The following chapters present the detailed design of the above-defined elements.

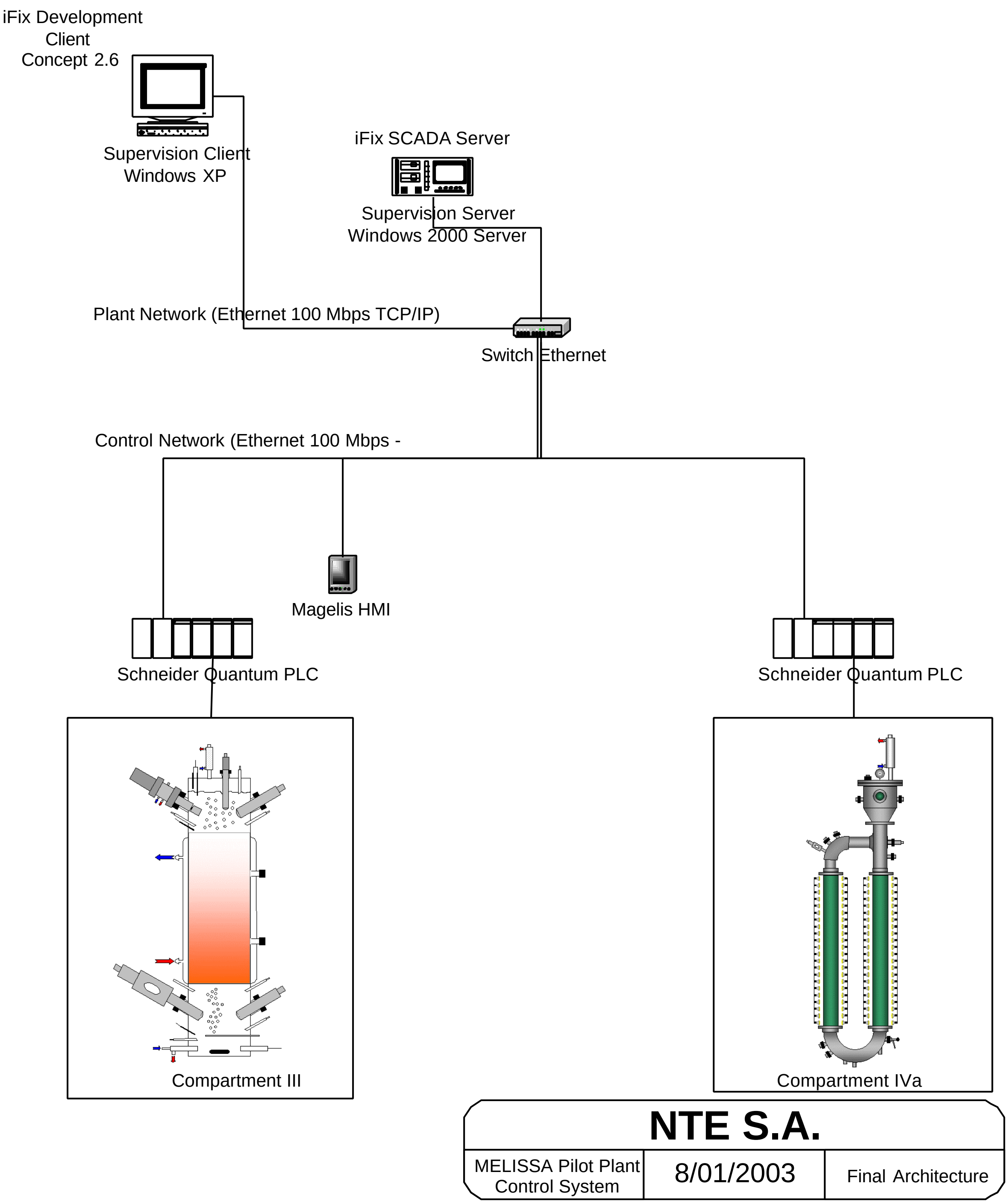


Figure 4-1: Control System demonstrator concept

5 Supervision Client computer

This computer is used to visualize supervision displays and to upload / download PLC programs.
No specific design is associated to this element, whose characteristics are standard. Some detailed information is presented hereafter:

MEL_SUPV_CLI01	
Model:	Dell OptiPlex GX260 P4 1.8 GHz
Power supply:	220 VAC 50 Hz
Main SW components:	MS Windows XP Professional Edition Concept V2.6 XL EN iFix Client
Physical location:	Plant’s control loop

6 Supervision Rack

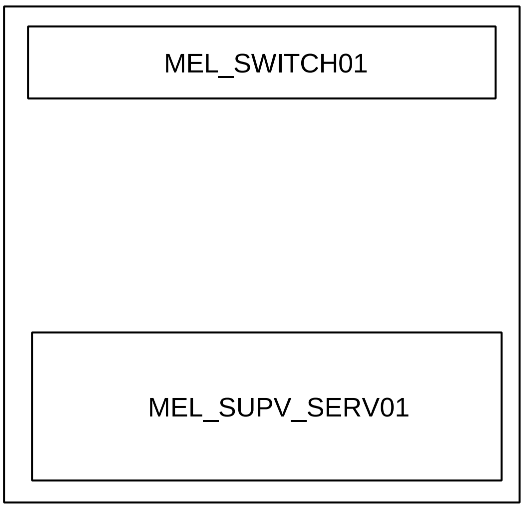
This rack has to be placed in a conditioned room (UAB Plant Control room). Allocates an Ethernet switch (MEL_SWITCH01) and the Supervision Server (MEL_SUPV_SERV01). No specific design is associated to this element, whose characteristics are standard. Some detailed information is presented hereafter:

MEL_SUPV_SERV01	
Model:	Dell Power Edge 2600
Power supply:	2x220 VAC 50 Hz redundant.
Storage:	2 SCSI disks 36 GB in Raid 3 configuration 1 Floppy 1 CDR 1 Tape (for backup purposes)
Main SW components:	MS Windows 2000 Server iFix Server Only
Physical location:	Plant's control room

MEL_SWITCH01	
Model:	3Com - Super Stack 3
Power supply:	220 VAC 50 Hz redundant.
Characteristics:	16 x 10/1000 Mbps Standard Ethernet ports

- Dimensions (h x w x l): 625 X 600 X 800 mm

The rack's elements are presented in the next diagram:



7 Compartment CIII rack (CIII_RACK)

Compartment CIII rack houses the hardware necessary to implement the control of the Compartment CIII bioreactor. This hardware covers (at least) the functionality of the current control system placed at the UAB for the CIII Compartment.

7.1 Introduction

MELISSA's CIII bioreactor is based on a Nitrifying reactor. The inputs are the liquid output of the compartment II and gas outputs from other compartments via a Buffer Tank. Its main function is to transform Ammonia to Nitrates producing Nitrate in the liquid phase and CO2 in the gas phase.

For information purposes, next table lists and describes the CIII control loops.

Loop	Description
CIII-CL-P	Maintain the pressure of the gas phase
CIII-CL-Ph	Maintain the pH in culture medium
CIII-CL-T	Maintain temperature of the culture
CIII-CL-Fl	Regulate input/output liquid flow
CIII-CL-NH4	Maintain Ammonium concentration
CIII-CL-O2	Oxygen concentration
CIII-CL-St	Stirring (Not implemented)

The following paragraphs present the control HW for this CIII (referred to as CIII_RACK) in terms of detailed mechanical and electrical design description

7.2 Mechanical design

The CIII control HW is implemented in the corresponding rack (referred to as CIII_RACK). It provides mechanical housing to the following elements:

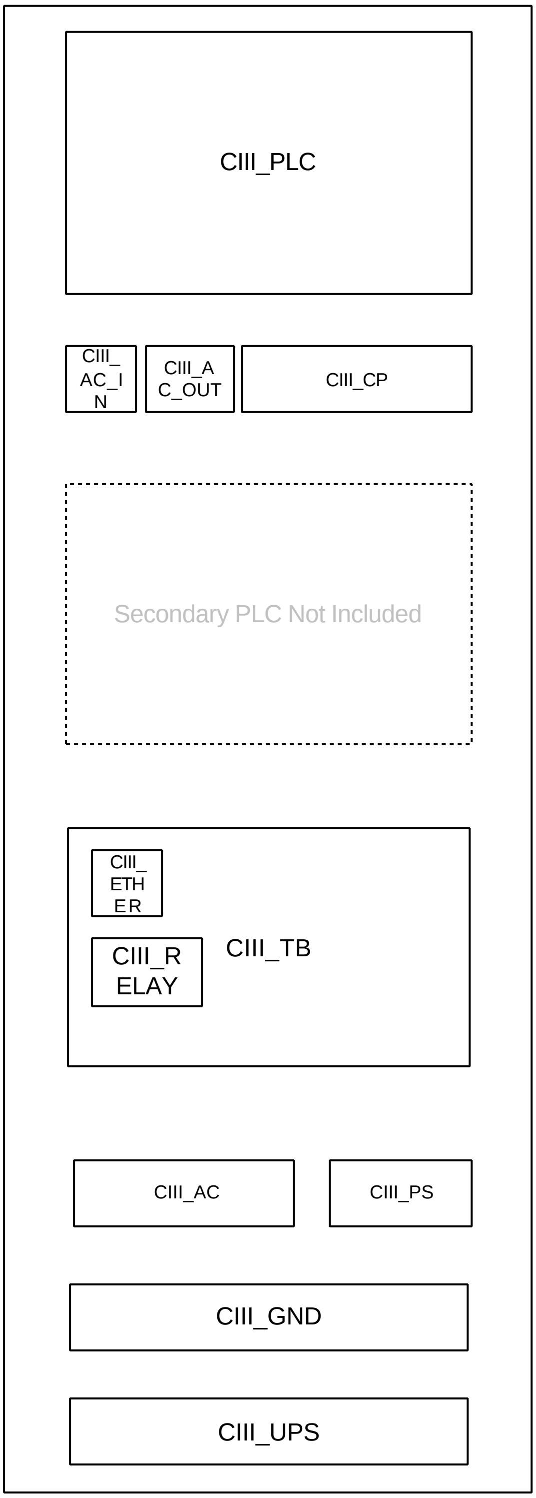
- A mounting board to place the electronics.
- PLC modules (CIII_PLC) attached to the rack's Backplane
- Connection elements (CIII_EXT_Eth, CIII_AC_OUT, CIII_AC_IN, CIII_CP)
- Power Supply for I/O (CIII_PLC_IO)
- Auxiliary electrical elements (CIII_PS, CIII_AC_GND and CIII_AC_UPS)
- Relay panel (CIII_Relay)
- It reserves free space for a secondary future redundant PLC.

The mechanical characteristics of the CIV rack are the following:

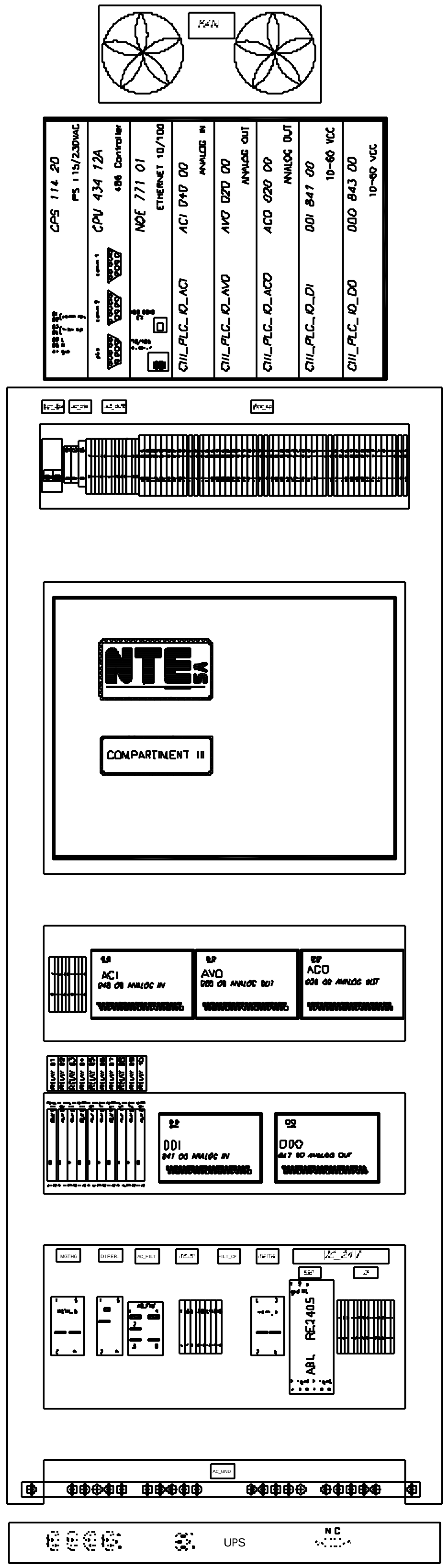
- Brand and model: RITTAL TS 8
- Ruggerised for laboratory environment
- Dimensions (h x w x l): 200 X 61 X 62 cm
- Includes a Fan system with 2 units for thermal dissipation
- Includes four wheels for mobility

Note: it must be ensured that all the rack's mechanical elements are properly interconnected in order to ensure a proper electrical grounding.

The following diagram depicts the distribution of the main blocks in the mounting board:



The following diagram presents the internal mechanical layout corresponding to the CIII_RACK:



7.3 Electrical design

CIII_RACK electrical design is described by defining the electrical interfaces, the rack's elements and their electrical interconnection.

The rack is externally powered from a line protected from power cuts by a generator that starts after 1 minute of power interruption (provided by UAB). Input power is limited by a magnetothermic at 6A. In addition to prevent possible hazards caused by current leaks a differential at 30 mA sensibility is also placed at the input.

Output signals (analogue and digital) and power lines have been dimensioned taking into account the current system at UAB.

7.3.1 CIII External Electrical Interfaces

The electrical interface description covers the I/O interface (i.e. interface with the Plant's sensors and actuators related to CIII), the network interface and the power interface.

7.3.1.1 CIII I/O Interface

The following table lists and describes all the I/O electrical signals interfacing between CIII_RACK and the rest of the Plant:

- Type: A (analogue signal) or D (digital signal)
- IO: I (Input signal) / O (Output signal)
- N: numerical identifier
- Name: mnemonic signal identifier
- Device: name of the Plant's device related to the signal
- Electric range: signal's electrical characteristics
- Measurement range: measurement range of the associated physical parameter
- Description: function of the signal
- Remarks: additional information

Type	IO	N	Name	Device	Electric Range	Measurement Range	Description	Remarks
A	I	01	CIII_MV_DObot	Oxygen analyzer	4-20 mA	0 – 100 %	DO at bottom	
A	I	02	CIII_MV_DOtop	Oxygen analyzer	4-20 mA	0 – 100 %	DO at top	
A	I	03	CIII_MV_NH4	Ammonium analyzer	4-20 mA	0 – 200 ppm N-NH4+	Ammonium concentration at top	
A	I	04	CIII_MV_NO3	NO3 analyzer	4-20 mA	0 – 1000 ppm N-NO3-	Nitrate concentration	
A	I	05	CIII_MV_P	Pressure sensor	4-20 mA	0 – 1000 mb	Pressure at top of the gas phase	
A	I	06	CIII_MV_PHb	pH meter	4-20 mA	3 – 13	pH at bottom	
A	I	07	CIII_MV_PHt	pH meter	4-20 mA	1.5 – 11.5	pH at Top	
A	I	08	CIII_MV_Psl	Sampling line pressure sensor	4-20 mA	-10 – 15 mb	Pressure sensor for the sampling line	

Type	IO	N	Name	Device	Electric Range	Measurement Range	Description	Remarks
A	I	09	CIII_MV_Tb	Thermometer	4-20 mA	0.2 – 147 ºC	Temperature at bottom	
A	I	10	CIII_MV_Tt	Thermometer	4-20 mA	0.2 – 147 ºC	Temperature at top	
A	O	01	CIII_FC_CO2	CO2 flow controller	0-5 V	0 – 100 %	CO2 mass flow meter	
A	O	02	CIII_FC_N2	N2 flow controller	0-5 V	0 – 150 %	N2 flow controller	
A	O	03	CIII_FC_O2	O2 flow controller	0-5 V	0 – 100 %	O2 flow controller	
A	O	05	CIII_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Acid pump	
A	O	06	CIII_PM_Bs	Base pump	4-20 mA	0 – 100 %	Base pump	
A	O	07	CIII_PM_Fl	Input media pump	4-20 mA	0 – 100 %	Input media pump	not used
A	O	08	CIII_PM_L	Output liquid pump	4-20 mA	0 – 100 %	Output liquid pump	
D	I	01	CIII_CAL_NH4	Ammonium analyzer	0-24 V	0-1 (=calibrating)	Analyzer calibration indicator	
D	I	02	CIII_CAL_NO3	NO3 analyzer	0-24 V	0-1 (=calibrating)	Nitrate calibration indicator	
D	I	03	CIII_MV_L1	Level sensor	0-24 V	0-1 (=level reached)	Level measurement top	Replace relay to switch between sensors
D	I	04	CIII_MV_L2	Level sensor	0-24 V	1-0 (=level reached)	Level measurement bottom	Inverse logic
D	I	05	CIII_MVI_Lbt	Level sensor	0-24 V	0-1 (=level reached)	Indicator of max level reached for a buffer tank	to be incorporated
D	O	01	CIII_PM_Lbt	Pump buffer tank	0-24 V	0-1 (=Active)	Activation of the pump for the buffer tank	Relay
D	O	04	CIII_RL_Comp	Compressor	0-24 V	0-1 (=Active)	Compressor activation	Relay
D	O	05	CIII_RL_CV	Cooling valve	0-24 V	0-1 (=Active)	Cooling valve	Relay
D	O	06	CIII_RL_HT	Heater resistance	0-24 V	0-1 (=Active)	Heater	Relay
D	O	07	CIII_RL_Lp	Level sensor	0-24 V	0-1 (=Active)	Relay to have a pulse in the level sensor lecture	Relay
D	O	08	CIII_RL_P	Pressure solenoid valve	0-24 V	0-1 (=Active)	Solenoid valve for pressure regulation	Relay. Valve activated via relay at 220 V / 6 W
D	O	09	CIII_RL_Ac	Acid pump	0-24 V	0-1 (=Active)	Relay acid pump	Relay
D	O	10	CIII_RL_Bs	Base pump	0-24 V	0-1 (=Active)	Relay base pump	Relay

7.3.1.2 CIII Control network interface

Standard STP-Cat5 Ethernet connection (RJ-45)

7.3.1.3 CIII AC Input power interface

220 VAC 50 Hz (AC L, AC N)
Proper conditioned ground shall be provided.

7.3.1.4 CIII AC Output interface

Output AC interface is implemented to provide 220VAC/50Hz (commuted by relays) to:

- Acid pump
- Base pump
- Compressor (not used)
- Cooling valve
- Heater
- Safety pressure valve

The output is protected by a magnetothermic at 2 A.

7.3.2 CIII Internal Electrical Interfaces

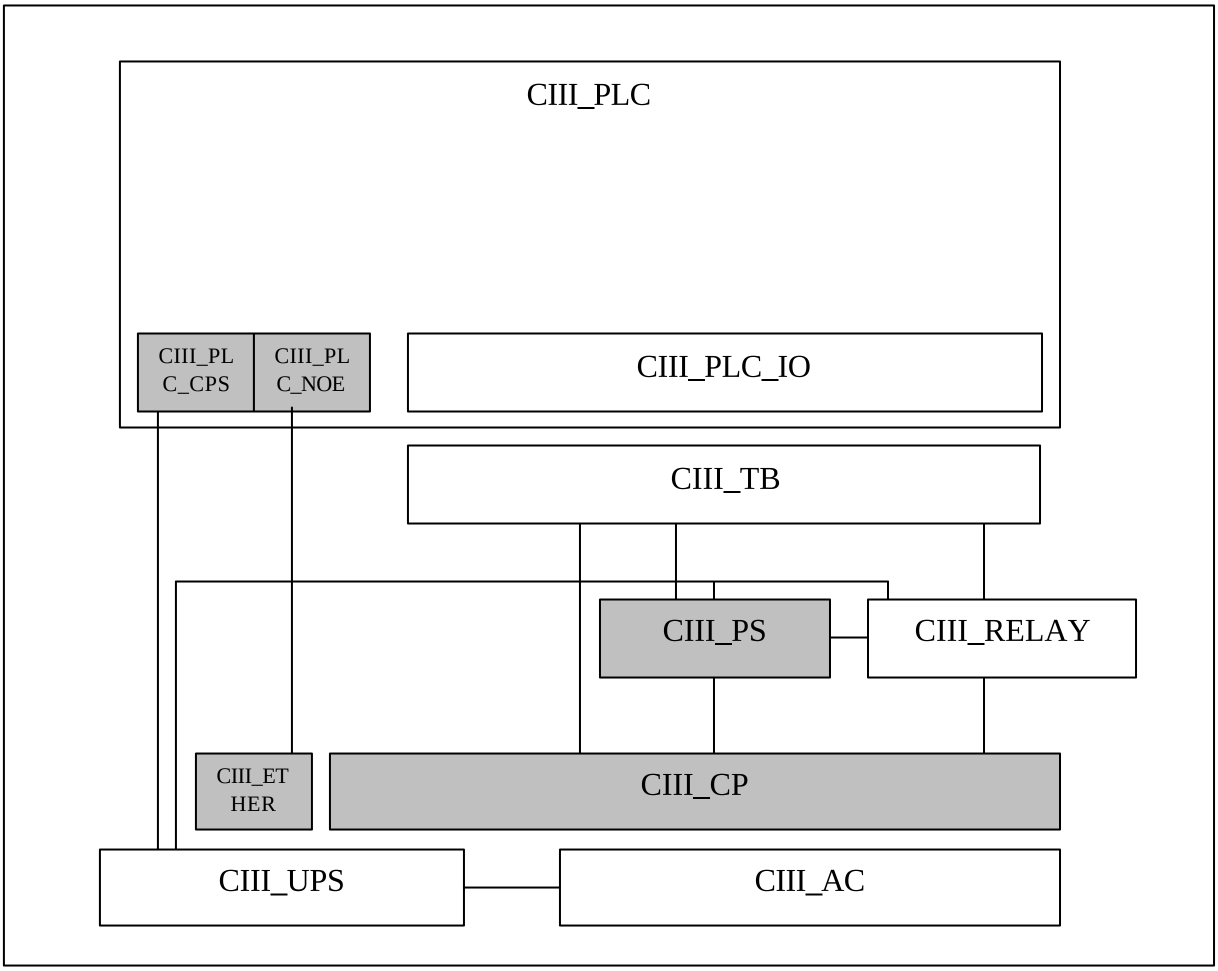
7.3.2.1 Wiring

There are three types of wires identified according to applicable regulations:

Net	Requirements	Wire characteristics
I/O Signals	Maximum power 24V/2 A (Digital outputs 140DDO88500) Colors specified in each connection table	24AWG
24V	Maximum power 24V 5A (max. power supply output) Red: 24V Black: Return	1mm section
220VAC	Limited at 6A at power input.	1 mm section Insulating cover nominal voltage 750 V

7.3.2.2 Connecting components overview.

Next schematic shows the various CIV_RACK components in a block diagram.



7.3.2.2.1 Naming convention

Each block is identified by a label formed as follows:

CIII_XXXX_YYYY, where

CIII: Element part of the Compartment III configuration.

XXXX:

PLC: Is part of the PLC placed in the CIIII_RACK
TB: Terminal Blocks
PS: Power supply
AC: Elements connected to the 220VAC net.
RELAY: Relay elements.
ETHER: Ethernet connection
CP: Connection Panel.

YYYY (only in sub-elements as part of previous XXXX)

IO: Input/Output signals.

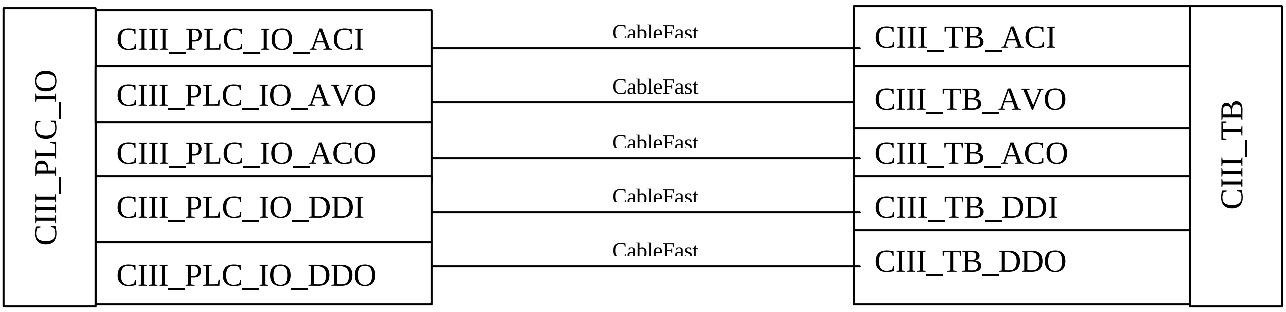
7.3.2.2.2 CIII_PLC

Compartment CIII Quantum (by Schneider) Programmable Logic Controller mounted on a backplane with 10 available slots. The PLC module distribution is displayed in the following table, showing the manufacturer reference identification (140XXXXXXXX), the description of the module and the mnemonic identification used in CIII_RACK. For description easiness, modules 4 to 8 are grouped into the CIV_PLC_IO element.

1	2	3	4	5	6	7	8	9	10
140CPS11420	140CPU43412A	140NOE77101	140ACI04000	140AVO02000	140ACO02000	140DDI84100	140DDO84300		
Backplane Power Supply module	CPU module	Ethernet module	16 Analog input 4-20 mA	4 Analog output 0-5V	4 Analog output 0-20/4-20 mA	16 Digital inputs 10-60 VCC	16 Digital outputs 10-60 VCC		
CIII_PLC_CPS		CIII_PLC_NOE	CIII_PLC_IO_ACI	CIII_PLC_IO_AVO	CIII_PLC_IO_ACO	CIII_PLC_IO_DDI	CIII_PLC_IO_DDO		

7.3.2.2.3 CIII_TB

Block defining the group of connectors corresponding to the CableFast Terminal Blocks.
The purpose of this block is to replicate the connections corresponding to the CIII_PLC_IO element (PLC´s I/O signal, either Analogue or Digital) so that connections and/or modifications cannot be done directly onto the PLC modules.

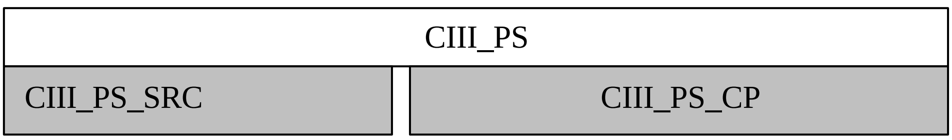


Connection between CIV_PLC_IO and CIV_TB are implemented by means of pre-manufactured CableFast cables. This system allows the connection of pre-wired cables to I/O cards, carrying the signals to a terminal block point to point by means of a standard 50 pin “D” connector.

7.3.2.2.4 CIII_PS and CIII_RELAY

CIII_PS supplies 24Vdc for distribution within the CIII_RACK. Two components are defined within this element:

- CIII_PS_SRC: Power Supply, model Telemecanique ABL7RE2405
- CIII_PS_CP: Connector panel for distribution of 24 Vdc where needed within the various rack’s elements. Connector type Phoenix UN 1,5 N (26-16 AWG 17,5 A 500 V).



CIII_RELAY encompasses the set of ten relays needed to activate certain external devices:

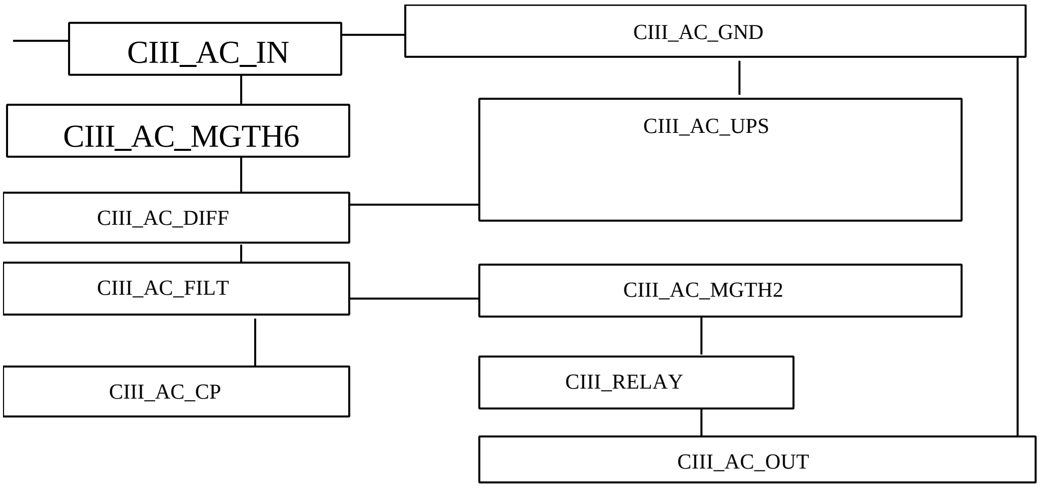
CIII_RELAY									
CIII_RELAY_01	CIII_RELAY_02	CIII_RELAY_03	CIII_RELAY_04	CIII_RELAY_05	CIII_RELAY_06	CIII_RELAY_07	CIII_RELAY_08	CIII_RELAY_09	CIII_RELAY_10

The generic connection table for the relays is as follows:

Rel.	Signal	Commuted (11-12/14)	Description
1	CIII_PM_Lbt	24 V	Activation of the pump for the buffer tank
2	CIII_RL_Ac	AC L (220V ?W)	Not used
3	CIII_RL_Bs	AC L (220V ?W)	Not used
4	CIII_RL_Comp	AC L (220V ?W)	Not used
5	CIII_RL_CV	AC L (220V 6W)	Cooling valve
6	CIII_RL_HT	AC L (220V 360O)	Heater resistance
7	CIII_RL_Lp	24 V	Liquid level pulse generation
8	CIII_VL_P	AC L (220V 6W)	Safety pressure valve
9	Not used	Contact	Acid pump
10	Not used	Contact	Base pump

7.3.2.2.5 CIII_AC

This element encapsulates the external AC power input, its conditioning and distribution to the rest of the rack's elements, where required. Next diagram shows the components within this element:



- CIII_AC_IN: external 220 V AC input power connector type UK 2,5 N (24-14 AWG 24 A 800 V).
- CIII_AC_DIFF: Current leaks protection at 30 mA.
- CIII_AC_MGTH6: Magnetothermic protection device to implement in-house over current protection at 6A (Merlin Gerin C60N/C6).
- CIII_AC_FILT: standard AC Input filter (YUNPEN YK06T1 230V 50Hz 6A).
- CIII_AC_CP: connection panel for distribution of filtered 220V AC internally to the rack. Connector type Phoenix UK 1,5 N (26-16 AWG 17,5 A 500 V).
- CIII_AC_OUT: connector to distribute the conditioned 220V AC to external devices. Connector type Phoenix ZFKK 1,5-MSTBV-5,08 (24-14 AWG 12 A 250 V).
- CIII_AC_UPS: Uninterrupted Power Supply (UPS), included to maintain under power the PLC in the event of a plant's power interruption during no less than 1 minute. Characteristics:
  - UPS 250 VA, 230V, 165 Watts, 230 Vin 50/60 Hz.
  - APC POWERSTACK 250VA
- CIII_AC_MGTH2: Magnetothermic device to implement an over current protection at 2A of the external powered devices. (Merlin Gerin C60N/C2).
- CIII_AC_GND: metallic strip for rack grounding purposes.

7.3.2.2.6 CIII_ETHER

RJ45 Ethernet connector to connect the system's Control Network to the PLC network module (CIII_PLC_NOE). Connector type RJ45 Cat 5 shielded.

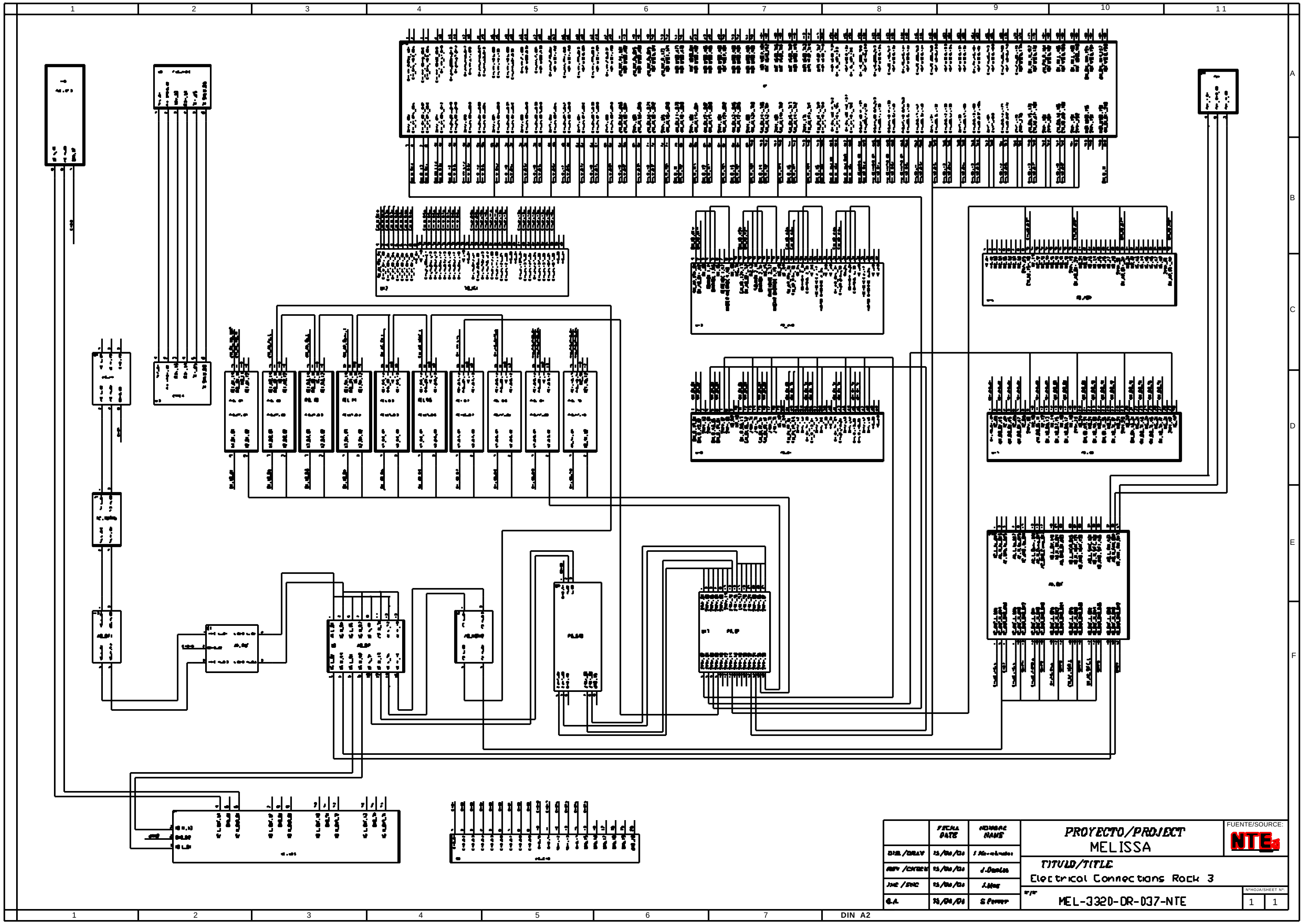
7.3.2.2.7 CIII_CP

Connection panel to perform signal connections from the CIII_RACK to the external plant's sensors and actuators related to CIII.
Connector type Phoenix ZFKK 1,5-MSTBV-5,08 (24-14 AWG 12 A 250 V).

7.3.2.3 Elements inter-connection diagram

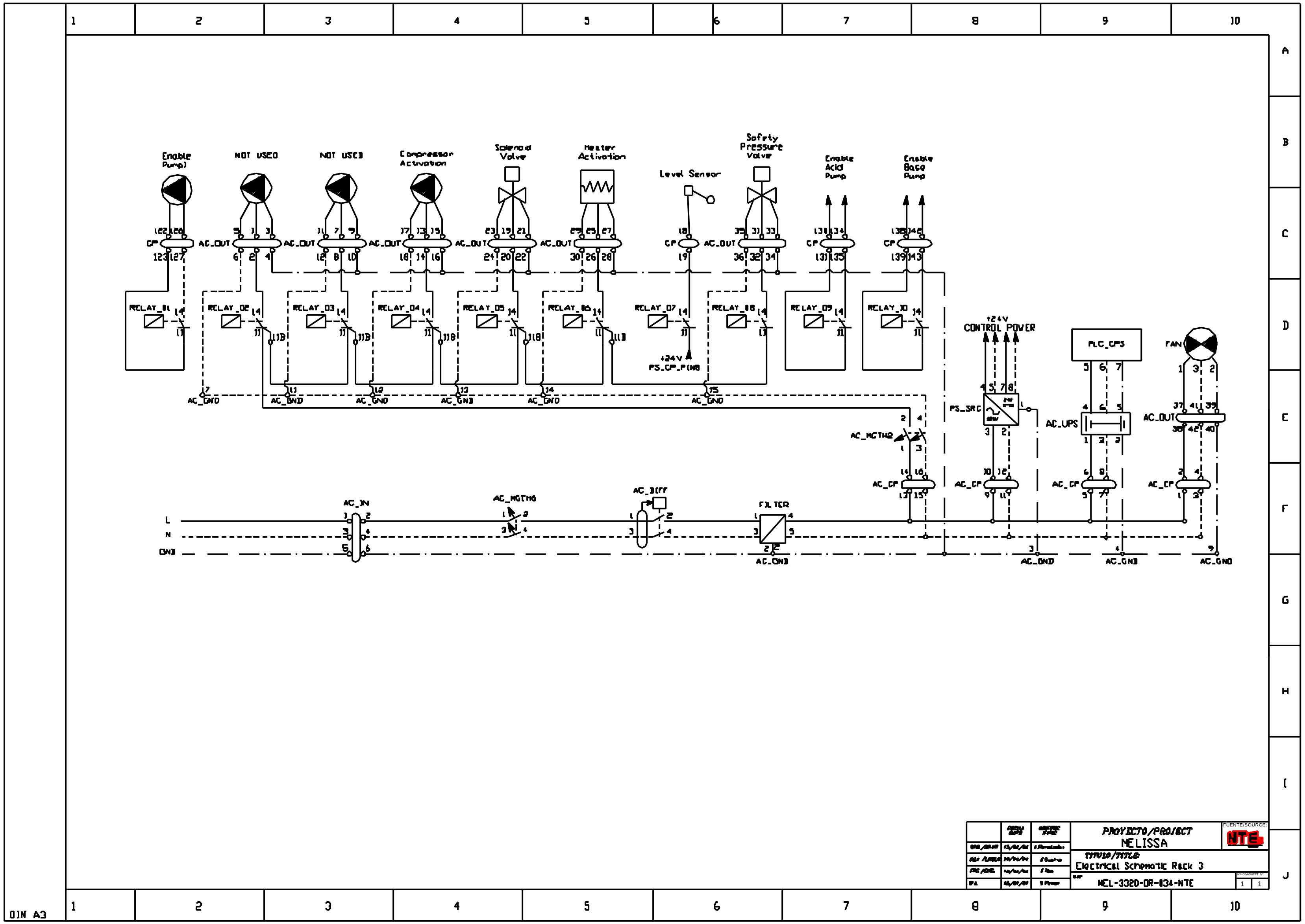
The following diagram shows the electrical connections for the CIII_RACK elements.

Detailed connection tables according to this diagram are provided in Appendix B.


PROYECTO/PROJECT
MELISSA
TITULO/TITLE
Electrical Connections Rack 3
MEL-3320-DR-037-NTE
FUENTE/SOURCE:
DIN A2

7.3.2.4 Electrical Schematic

The following diagram presents the electrical power distribution circuitry implemented in Rack CIII.


PROYECTO/PROJECT
MELISSA
TITULO/TITLE:
Electrical Schematic Rack 3
MEL-3320-DR-034-NTE

8 Compartment CIV rack (CIV_RACK)

Compartment CIV rack houses the hardware necessary to implement the control of the Compartment CIV bioreactor. This hardware covers (at least) the functionality of the current control system placed at the UAB for the CIV Compartment.

8.1 Introduction

MELISSA's compartment CIV bioreactor is based on a photosynthetic reactor. CIV inputs are the liquid phase from the compartment CIII and the gas outputs generated in other compartments through a buffer tank. The main function of CIV is to convert Nitrates into edible biomass and CO2 into O2. Therefore, the resulting output products are O2 in the gas phase and edible biomass in the solid phase.

For information purposes, next table lists and describes the CIV control loops.

Loop	Description
CIV-CL_Cx	Maintain biomass concentration
CIV_CL_Fr	Maintain light intensity inside the bioreactor
CIV_CL_G	Maintain gas concentrations
CIV_CL_P	Maintain the pressure of the gas phase (gas flow)
CIV_CL_pH	Maintain the pH set point in the culture
CIV_CL_T	Maintain temperature of the culture (not controlled by the PLC)

The following paragraphs present the control HW for this CIV (referred to as CIV_RACK) in terms of detailed mechanical and electrical design description

8.2 Mechanical design

The CIV control HW is implemented in the corresponding rack (referred to as CIV_RACK). It provides mechanical housing to the following elements:

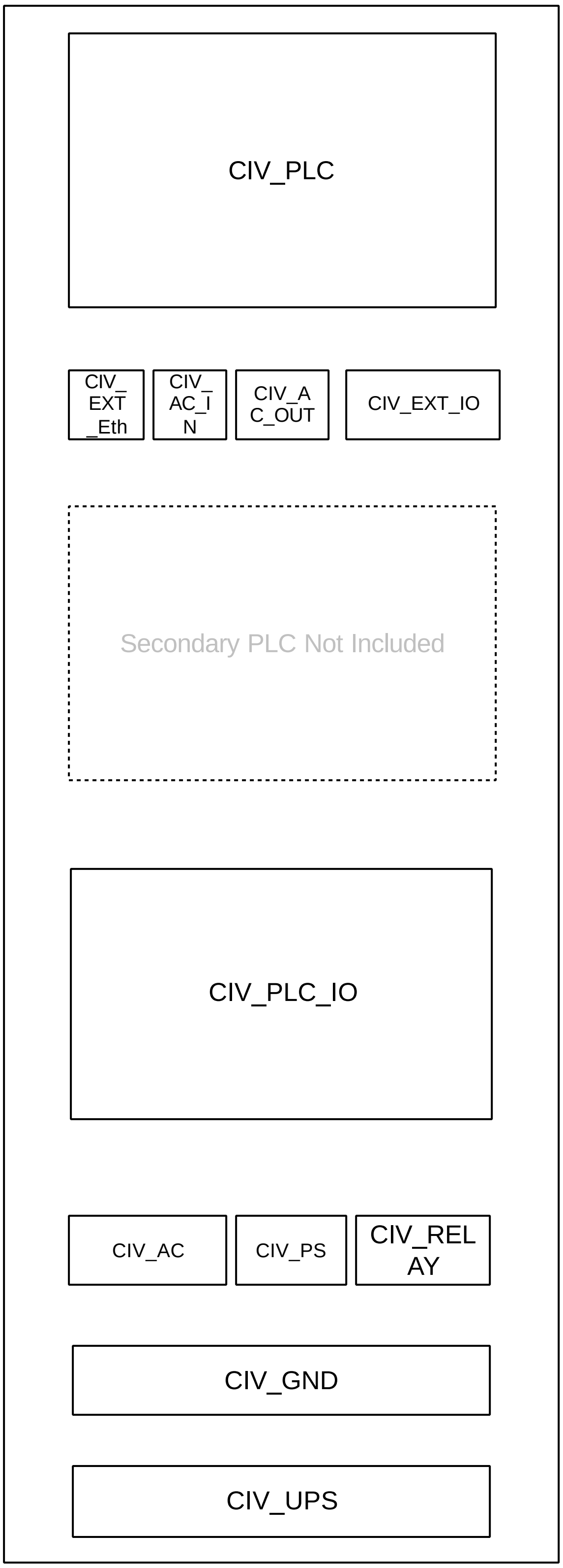
- PLC modules (CIV_PLC) attached to the rack's Backplane
- Connection elements (CIV_EXT_Eth, CIV_AC_OUT, CIVAC_IN, CIV_CP)
- Power Supply for I/O (CIV_PLC_IO)
- Auxiliary electrical elements (CIV_PS, CIV_AC_GND and CIV_AC_UPS)
- Relay panel (CIV_Relay)
- It reserves free space for future redundant CIV_PLC

The mechanical characteristics of the CIV rack are the following:

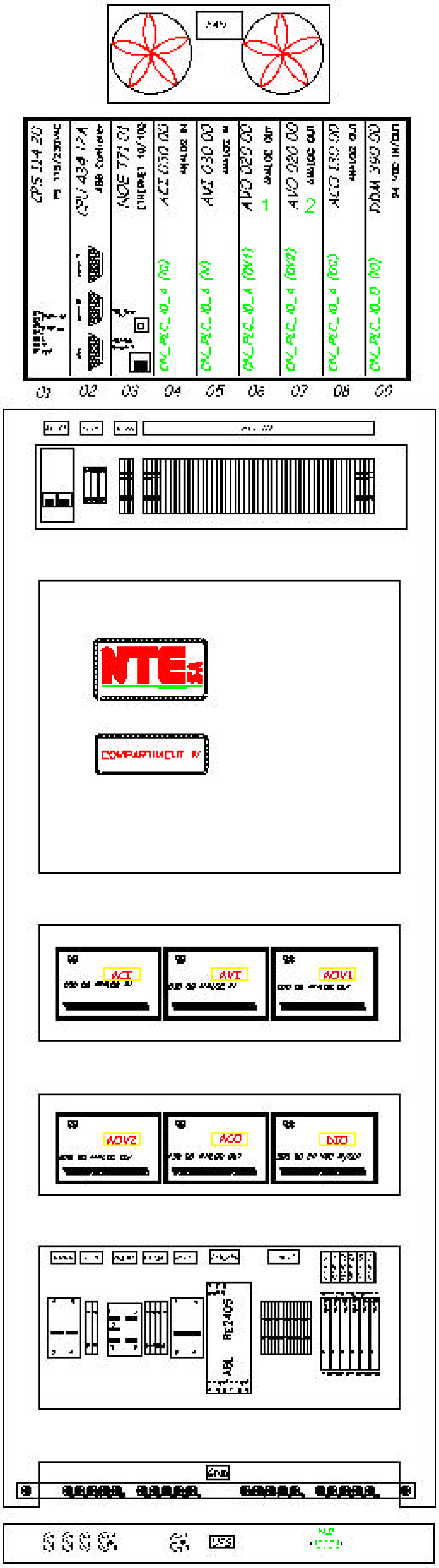
- Brand and model: RITTAL TS 8
- Ruggerised for laboratory environment
- Includes a Fan system with 2 units for thermal dissipation
- Includes four wheels for mobility
- Dimensions (h x w x l): 200 X 61 X 62 cm

Note: it must be ensured that all the rack's mechanical elements are properly interconnected in order to guarantee a proper electrical grounding.

The following diagram depicts the distribution of the main blocks in the mounting board:



The next diagram presents the internal mechanical layout corresponding to the CIV_RACK:



8.3 Electrical design

CIV_RACK electrical design is described by defining the electrical interfaces, the rack's elements and their electrical interconnection.

The rack will be externally powered from a line protected from power cuts by a generator that starts after 1 minute of power interruption (provided by UAB). Input power is limited by a magnetothermic at 6A. In addition to prevent possible hazards caused by current leaks a differential at 30 mA sensibility is also placed at the input.

Output signals (analogue and digital) and power lines have been dimensioned taking into account the current system at UAB.

8.3.1 CIV External Electrical Interfaces

The electrical interface description covers the I/O interface (i.e. interface with the Plant's sensors and actuators related to CIV), the network interface and the power interface.

8.3.1.1 CIV I/O Interface

The following table lists and describes all the I/O electrical signals interfacing between CIV_RACK and the rest of the Plant:

- Type: A (analogue signal) or D (digital signal)
- IO: I (Input signal) / O (Output signal)
- N: numerical identifier
- Name: mnemonic signal identifier
- Device: name of the Plant's device related to the signal
- Electric range: signal's electrical characteristics
- Measurement range: measurement range of the associated physical parameter
- Description: function of the signal
- Remarks: additional information

Type	IO	N	Name	Device	Electric Range	Measurement range	Description	Remarks
A	I	01	CIV_MV_Cx	Biomass sensor	4-20 mA	Configurable	Biomass measurement	Possibly non linear when converting to Kg/m^3.
A	I	02	CIV_MV_M1	Scale 1	4-20 mA	0 – 150 kg	Mass measurement to determine input flow	
A	I	03	CIV_MV_M2	Scale 2	4-20 mA	0 – 150 kg	Mass measurement to determine input flow	
A	I	04	CIV_MV_P	Pressure sensor	4-20 mA	0 – 1.5 bar	Pressure measurement	
A	I	05	CIV_MV_pH	pH sensor	4-20 mA	0 – 14	pH measurement	
A	I	06	CIV_MV_T	Temperature sensor	4-20mA	0 – 150 ºC	Temperature measurement	
A	I	07	CIV_MGO_O2	O2 gas sensor	4-20 mA	Configurable	Measure O2 at gas output	Two available scales
A	I	08	CIV_MGO_CO2	CO2 gas sensor	4-20 mA	Configurable	Measure CO2 at gas output	Two available scales

Type	IO	N	Name	Device	Electric Range	Measurement range	Description	Remarks
A	I	09	CIV_MV_DO	Dissolved Oxygen sensor	4-20 mA	Configurable	Percent of O2 saturation in the reactor	
A	I	13	CIV_MGI_Fg	Flowmeter	0-5 V	0 – 30 nLm*	Gas flow at input	
A	I	14	CIV_MGO_Fg	Flowmeter	0-5 V	0 – 30 nLm	Gas flow at output	
A	I	15	CIV_MV_CO2	CO_2 flowmeter	0-5 V	0 – 5 nLm	CO_2 flow measurement	
A	I	16	CIV_MV_Fg	Flowmeter	0-5 V	0 – 30 nLm	Gas flow re-circulation	
A	O	01	CIV_FR_CO2	CO_2 flow regulator	0-5 V	0 – 5 nLm	CO_2 flow regulation	
A	O	02	CIV_PM_Fgi	Flow regulator	0-5 V	0 – 30 nLm	Gas flow at input regulation	
A	O	03	CIV_PM_Fgo	Flow regulator	0-5 V	0 – 30 nLm	Gas flow at output regulation	
A	O	04	CIV_PM_Fgex	Flow regulator	0-5 V	0 – 30 nLm	Gas flow re-circulation regulation	
A	O	05	CIV_PM_Li1	Liquid input pump1	0-5 V	0 – 100 %	Liquid Pump input1 set point	Possibly non linear
A	O	06	CIV_PM_Li2	Liquid input pump2	0-5 V	0 – 100 %	Liquid Pump input1 set point	Possibly non linear
A	O	07	CIV_PM_LO	Liquid output pump	0-5 V	0 – 100 %	Liquid Pump output set point	Possibly non linear
A	O	09	CIV_PM_Bs	Base pump	4-20mA	0 – 100 %	Additional Base source for pH regulation	
A	O	10	CIV_RG_Ls	Light regulator	4-20 mA	0 – 100 %	Regulator of light supply	Set point is fixed by Supervision. Non linear (Wm^2=54,56x+289x ^{2}-24,19)
A	O	11	CIV_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Additional Acid source for pH regulation	Acid source can be CO2 or additional acid media
D	I	01	CIV_CAL_CO2O2	CO2/O2 sensor	0-24 V	0 – 1 (=Calibr.)	Calibration indicator of CO2/O2 sensor.	
D	I	02	CIV_ERR_CO2O2	CO2/O2 sensor	0-24 V	0 (=Error) – 1 (=OK)	Error Indicator of CO2/O2 sensor.	
D	I	03	CIV_SCL1_CO2O2	CO2/O2 sensor	0-24 V	0 (= scale 1) – 1 (= scale 2)	CO2/O2 sensor scale indicator	
D	I	04	CIV_SCL2_CO2O2	CO2/O2 sensor	0-24 V	0 (= scale 1) – 1 (= scale 2)	CO2/O2 sensor scale indicator	
D	O	01	CIV_RL_Li1	Enable liquid input pump1	0-24 V	0 – 1 (=active)	Liquid Pump input1 on	Relay. max 300 mA
D	O	02	CIV_RL_Li2	Enable liquid input pump2	0-24 V	0 – 1 (=active)	Liquid Pump input2 on	Relay. max 300 mA
D	O	03	CIV_RL_Cx	Electrovalve	0-24 V	0 – 1 (=cleaning)	Aeration of biomass sensor for cleaning	Relay. Pulse of 20sec each 10 min (220V AC)
D	O	04	CIV_RL_Fg	Pressure valve	0-24 V	0 – 1 (=close)	Pressure safety valve activation	Relay at 220V AC 6W

- nLm: Normal liters per minute.

8.3.1.2 CIV Control network interface

Standard STP-Cat5 Ethernet connection (RJ-45)

8.3.1.3 CIV AC Input power interface

220 VAC 50 Hz (AC L, AC N)
Proper conditioned ground shall be provided.

8.3.1.4 CIV AC Output interface

Output AC interface is implemented to provide commuted 220VAC/50Hz to:
- Aeration Biomass Sensor Electro Valve (6W)
- Safety Pressure Electro Valve (6W)

The output is protected by a magnetothermic at 2 A.

8.3.2 CIV Internal Electrical Interfaces

Due to the large number of connecting elements and the complexity of the wiring, first an overview of the various components within the rack is presented.

Detailed components interconnections are described afterwards by means of interface tables. These tables present the related connectors, connecting points, name of the signal and characteristics of the wiring.

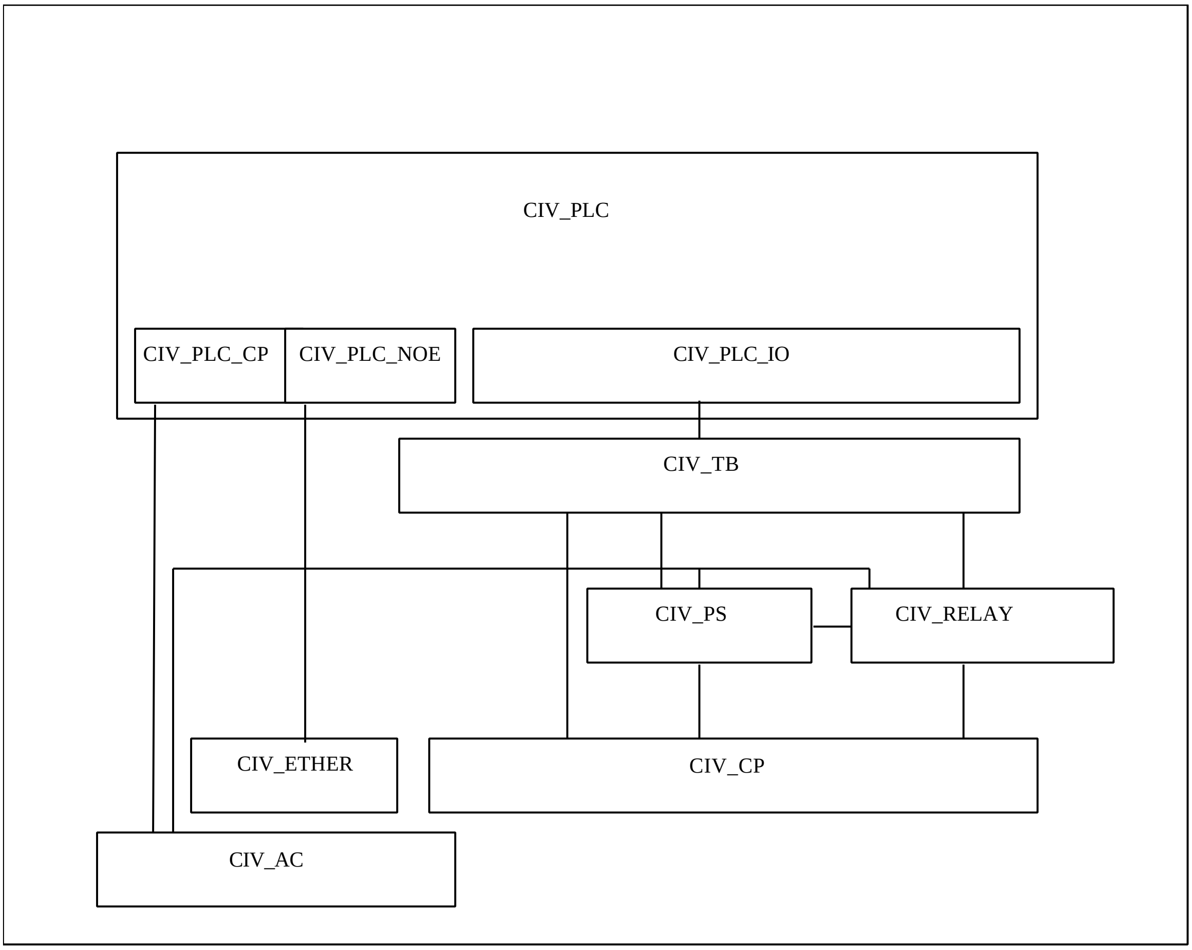
8.3.2.1 Wiring

Three types of wires are identified:

Net	Requirements	Wire characteristics
I/O Signals	Maximum power 24V/2 A (Digital outputs 140DDM39000) Colors specified in each connection table	24AWG
24V	Maximum power 24V 5A (max. power supply output) Red: 24V Black: Return	1 mm section
220VAC	Limited at 6A at power input.	1 mm section Insulating cover nominal voltage 750 V

8.3.2.2 Connecting components overview.

Next schematic shows the various CIV_RACK components.



8.3.2.2.1 Naming convention

Each block is identified by a label formed as follows:

CIV_XXXX_YYYY, where

CIV: Element part of the Compartment IV configuration.

XXXX:

PLC: Is part of the PLC placed in the CIV_RACK
TB: Terminal Blocks
PS: Power supply
AC: Elements connected to the 220VAC net.
RELAY: Relay elements.
ETHER: Ethernet connection
CP: Connection Panel.

YYYY: (only in sub-elements as part of previous XXXX)

IO: Input/Output signals.

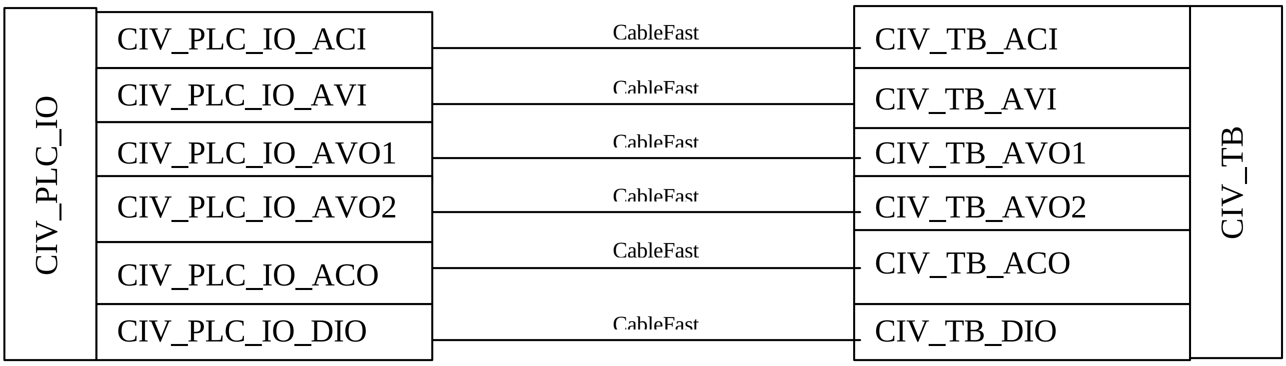
8.3.2.2.2 CIV_PLC

Compartment CIV Quantum (by Schneider) Programmable Logic Controller mounted on a backplane with 10 available slots. The PLC module distribution is displayed in the following table, showing the manufacturer reference identification (140XXXXXXXX), the description of the module and the mnemonic identification used in CIV_RACK. For description easiness, modules 4 to 9 are grouped into the CIV_PLC_IO element.

1	2	3	4	5	6	7	8	9	10
140CPS11420	140CPU43412 A	140NOE77101	140ACI03000	140AVI03000	140AVO01000	140AVO02000	140ACO13000	140DDM39000	NOT USED
Backplane Power Supply module	CPU module	Ethernet module	8 Analog input 4-20 mA	8 Analog input 0-5 V	4 Analog output 0-5 V	4 Analog output 0-5 V	8 Analog output 0-20/4-20 mA	16 Digital inputs / 8 Digital outputs 10-60 VCC	
CIV_PLC_CPS		CIV_PLC_NOE	CIV_PLC_IO_ACI	CIV_PLC_IO_AVI	CIV_PLC_IO_AVO1	CIV_PLC_IO_AVO2	CIV_PLC_IO_ACO	CIV_PLC_IO_DIO	

8.3.2.2.3 CIV_TB

Block defining the group of connectors corresponding to the CableFast Terminal Blocks.
The purpose of this block is to replicate the connections corresponding to the CIV_PLC_IO element (PLC´s I/O signal, either Analogue or Digital) so that connections and/or modifications cannot be done directly onto the PLC modules.



Connection between CIV_PLC_IO and CIV_TB are implemented by means of pre-manufactured CableFast cables. This system allows the connection of pre-wired cables to I/O cards, carrying the signals to a terminal block point to point by means of a standard 50 pin "D" connector.

Figure 8-1 and **Figure 8-2** depict the aspect of a Terminal Block and provide references on the connector's numbering.

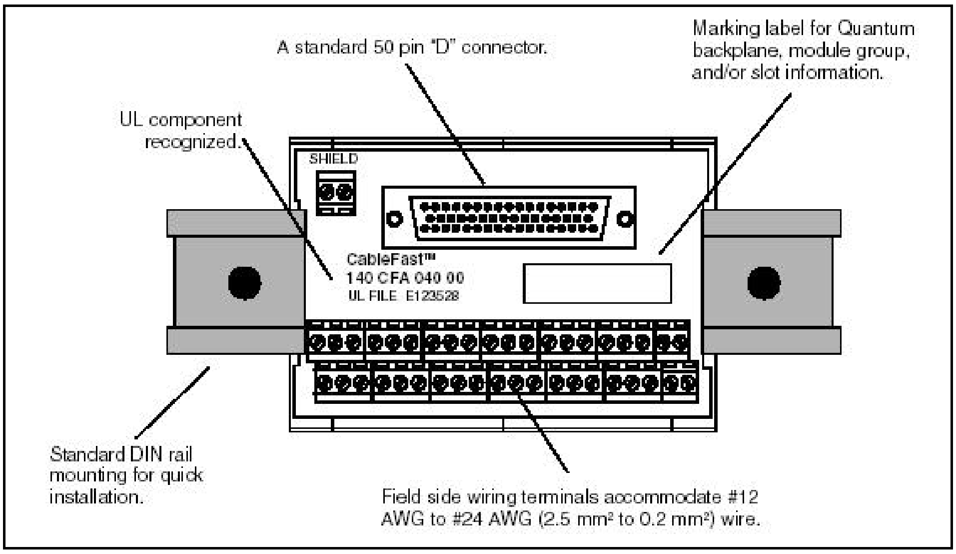


Figure 8-1. Terminal block

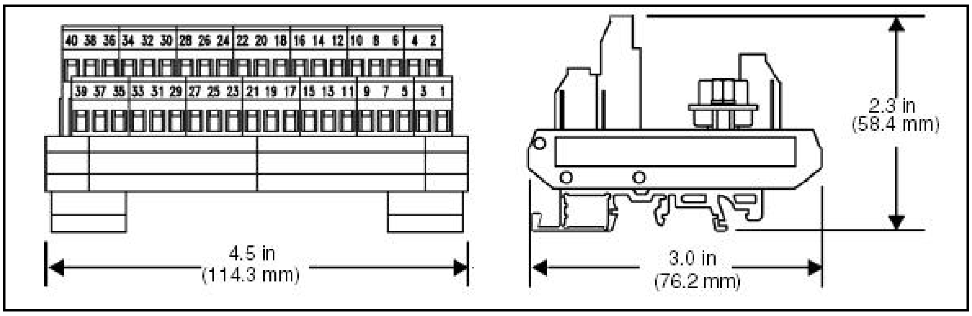


Figure 8-2. Terminal numbering equivalence and block sizes.

8.3.2.2.4 CIV_PS

This element supplies 24Vdc for distribution within the CIV_RACK. Two components are defined within this element:

- CIV_PS_SRC: Power Supply, model Telemecanique ABL7RE2405
- CIV_PS_CP: Connector panel for distribution of 24 Vdc where needed within the various rack's elements. Connector type Phoenix UN 1,5 N (26-16 AWG 17,5 A 500 V).

CIV_PS	
CIV_PS_SRC	CIV_PS_CP

8.3.2.2.5 CIV_RELAY

This element encompasses the set of 6 relays needed to activate certain external devices, as shown in the next diagram.

CIV_RELAY					
CIV_RELAY_01	CIV_RELAY_02	CIV_RELAY_03	CIV_RELAY_04	CIV_RELAY_05	CIV_RELAY_06

Relays reference is Phoenix EMG 10-REL/KSR-G 24/21-LC, the corresponding schematic is shown in Figure 7-3.

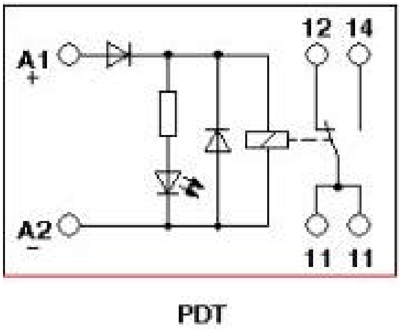


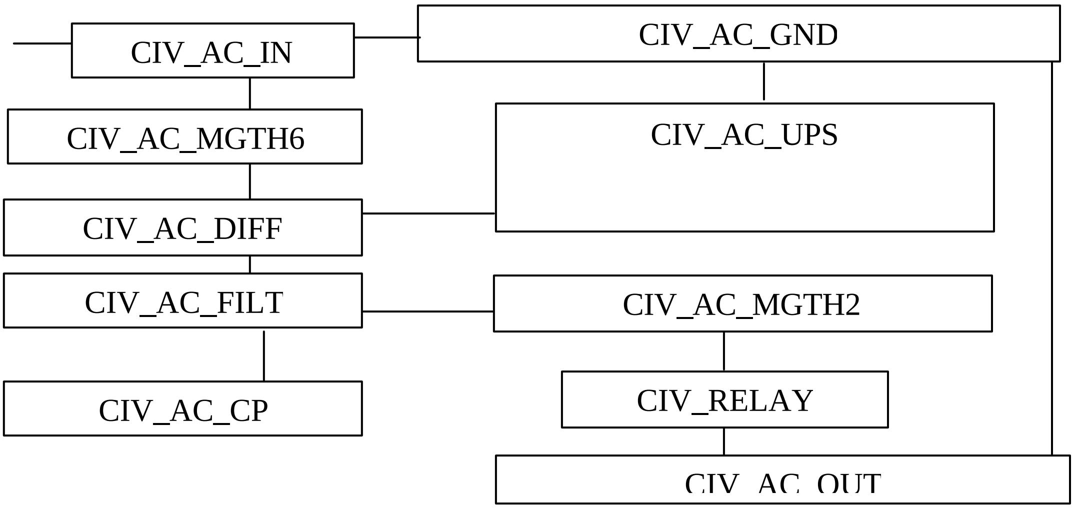
Figure 8-3. Relay schematic EMG 10-REL/KSR-G 24/21-LC

The generic connection table for the relays is as follows:

Relay	Signal	Commuted (11 – 12/14)	Description
1	CIV_RL_Li1	24 V	Liquid Input Pump 1
2	CIV_RL_Li2	24 V	Liquid Input Pump 2
3	CIV_RL_Cx	AC L (220V 6W)	Biomass sensor electro- valve
4	CIV_RL_Fg	AC L (220V 6W)	Safety pressure electro-valve
5	Not used		
6	Not used		

8.3.2.2.6 CIV_AC

This element encapsulates the external AC power input, its conditioning and distribution to the rest of the rack's elements, where required. Next diagram shows the components within this element:



- CIV_AC_IN: external 220 V AC input power connector type UK 2,5 N (24-14 AWG 24 A 800 V).
- CIV_AC_DIFF: Current leaks protection at 30 mA.
- CIV_AC_MGTH6: Magnetothermic protection device to implement in-house over current protection at 6A (Merlin Gerin C60N/C6).
- CIV_AC_FILT: standard AC Input filter (YUNPEN YK06T1 230V 50Hz 6A).
- CIV_AC_CP: connection panel for distribution of filtered 220V AC internally to the rack. Connector type Phoenix UN 1,5 N (26-16 AWG 17,5 A 500 V).
- CIV_AC_OUT: connector to distribute the conditioned 220V AC to external devices. Connector type Phoenix ZFKK 1,5-MSTBV-5,08 (24-14 AWG 12 A 250 V).
- CIV_AC_UPS: Uninterrupted Power Supply (UPS), included to maintain under power the PLC in the event of a plant's power interruption during no less than 1 minute. Characteristics:
  - UPS 250 VA, 230V, 165 Watts, 230 Vin 50/60 Hz.
  - APC POWERSTACK 250VA
- CIV_AC_MGTH2: Magnetothermic device to implement an over current protection at 2A of the external powered devices. (Merlin Gerin C60N/C2).
- CIV_AC_GND: metallic strip for rack grounding purposes.

8.3.2.2.7 CIV_ETHER

RJ45 Ethernet connector to connect the system's Control Network to the PLC network module (CIV_PLC_NOE). Connector type RJ45 Cat 5 shielded.

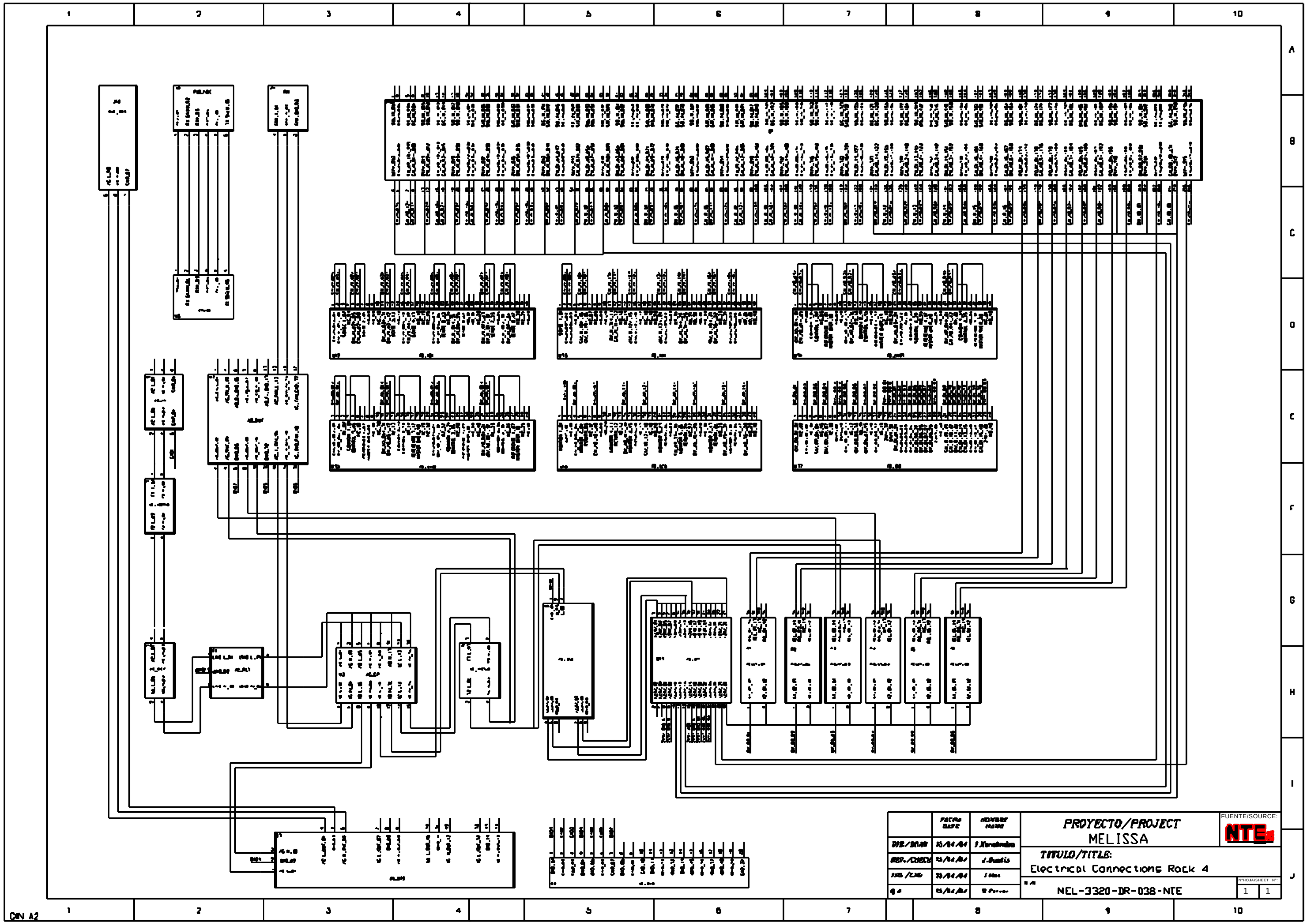
8.3.2.2.8 CIV_CP

Connection panel to perform signal connections from the CIV_RACK to the external plant's sensors and actuators related to CIV.
Connector type Phoenix ZFKK 1,5-MSTBV-5,08 (24-14 AWG 12 A 250 V).

8.3.2.3 Elements inter-connection diagram

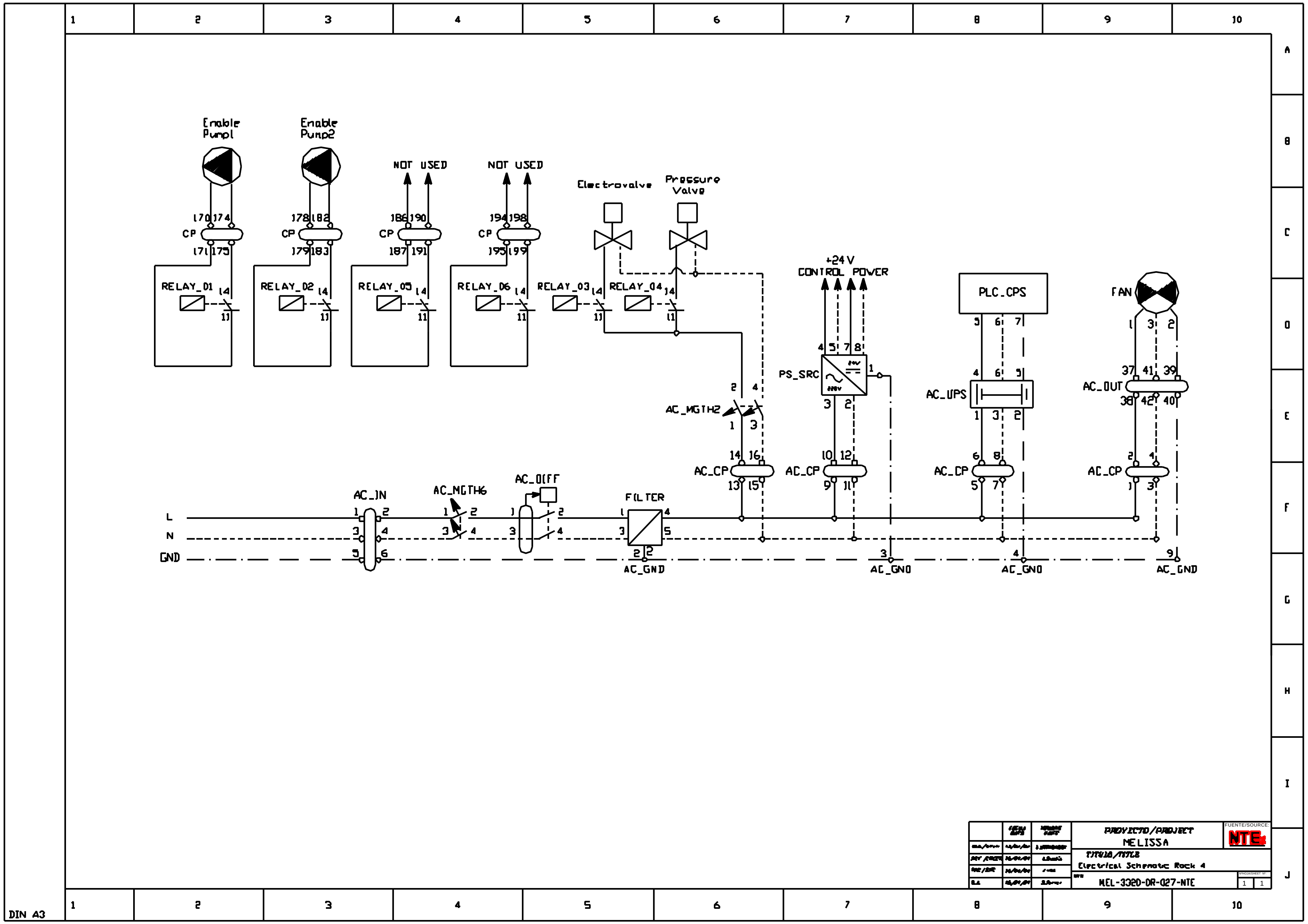
The following figure presents the connection diagram for the CIV_RACK elements.

Detailed connection tables according to this diagram are provided in Appendix C.


PROYECTO/PROJECT
MELISSA
TITULO/TITLE:
Electrical Connections Rack 4
MEL-3320-DR-038-NTE
DIN A2

8.3.2.4 Electrical Schematic

The following diagram presents the electrical power distribution implemented in Rack CIV.


Enable Pump1
Enable Pump2
NOT USED
NOT USED
Electrovalve
Pressure Valve
CP
RELAY_01
RELAY_02
RELAY_05
RELAY_06
RELAY_03
RELAY_04
+24 V
CONTROL POWER
PLC_CPS
FAN
PS_SRC
AC_UPS
AC_OUT
AC_MGTH2
AC_CP
AC_IN
AC_MGTH6
AC_OFF
FILTER
L
N
GND
AC_GND
PROYECTO/PROJECT
MELISSA
TITULO/TITLE
Electrical Schematic Rack 4
MEL-3320-DR-027-NTE
DIN A3

9 APPENDIX A: Hot-Standby Configuration

The racks have been designed to allocate a second back plane to support the hot-standby (HSBY) configuration following Schneider guidelines.

To transform current configuration into a redundant one, following considerations apply:

- Each HSBY CPU shall be installed in a different back plane.
- Each HSBY CPU back plane shall have the same configuration.
- A CHS-type module that permits fiber optic communications between nominal and redundant PLCs s shall be installed in each HSBY CPU back plane.
- Configurations do not allow local I/O modules.
- Only RIO bus is allowed to communicate with I/O modules.

Therefore, to transform the current configuration to a HSBY, the following tasks need to be performed:

- Install a second back plane (6 position) in the free space between the current (10 position) back plane and the (green) Cable-Fast Terminal Blocks.
- Move CPU from the first back plane to the second.
- Move NOE (Ethernet) module from the first back plane to the second.
- Install a CHS (HSBY module), a 2nd NOE (redundant network) and a CPS (Power supply) modules in the 2on back plane
- Install a RIO module in the 1^{st} back plane.

CPS	CPU	RIO	CHS	NOE(prim.)	NOE (red.)
1	2	3	4	5	6

Therefore the first back plane will be only an I/O back plane communicated via RIO bus to the (two) HSBY CPU back planes.

To configure the Secondary CPU back plane two options are available depending on the number of I/O that need to be redundant and the level of redundancy required:

A.- In case that only a low number of I/O need to be redundant, the second CPU back plane can be fixed in a panel placed in front of the current in the low part of the same rack.

B.- If a considerable number of I/O need to be redundant, a second rack will need to be deployed, with the secondary HSBY CPU back plane, an additional I/O black plane, additional powering electronics, connectors and so on. All I/O back planes will be connected to the same RIO bus, since it will be communicated through both HSBY CPU back planes.

10 APPENDIX B: CIII Rack Electrical Connection Tables

10.1CIII_TB_ACI: Current Analogue Inputs Terminal Block

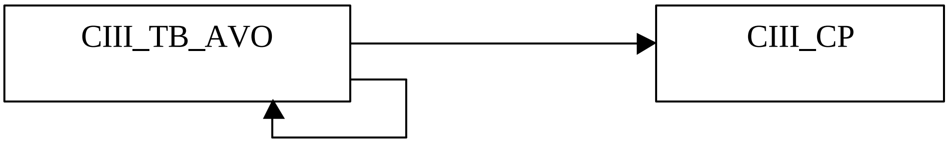
CableFast Terminal Block corresponding to the PLC's CIII_PLC_IO_ACI module (card 140ACI04000 featuring 16 Analog Inputs 4-20 mA).

The basic connection schematic is:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_AI_01+	CIII_TB_ACI	1	CIII_CP	004	24	PR	
CIII_AI_01-		2		008		GY/PK	
CIII_AI_02+		3		012		RD	
CIII_AI_02-		4		016		BR	
CIII_AI_03+		5		020		BK	
CIII_AI_03-		6		024		GY	
CIII_AI_04+		7		028		GN	
CIII_AI_04-		8		032		YL	
CIII_AI_05+		11		036		RD/BL	
CIII_AI_05-		12		040		BR/GN	
CIII_AI_06+		13		044		WH	
CIII_AI_06-		14		048		WH/GN	
CIII_AI_07+		15		052		WH/YL	
CIII_AI_07-		16		056		BR/YL	
CIII_AI_08+		17		060		BL	
CIII_AI_08-		18		064		PK	
CIII_AI_09+		21		068		PR	
CIII_AI_09-		22		072		GY/PK	
CIII_AI_10+		23		076		RD	
CIII_AI_10-		24		080		BR	
CIII_AI_11+		25		084		BK	
CIII_AI_11-		26		088		GY	
CIII_AI_12+		27		092		GN	
CIII_AI_12-		28		096		YL	
CIII_AI_13+		31		100		RD/BL	
CIII_AI_13-		32		104		BR/GN	
CIII_AI_14+		33		108		WH	
CIII_AI_14-		34		112		WH/GN	
CIII_AI_15+		35		116		WH/YL	
CIII_AI_15-		36		120		BR/YL	
CIII_AI_16+		37		124		BL	
CIII_AI_16-		38		128		PK	
N.C.		9					
N.C.		10					
N.C.		19					
N.C.		20					
N.C.		29					
N.C.		30					
N.C.		39					
N.C.		40					

10.2CIII_TB_AVO: Voltage Analogue Outputs Terminal Block

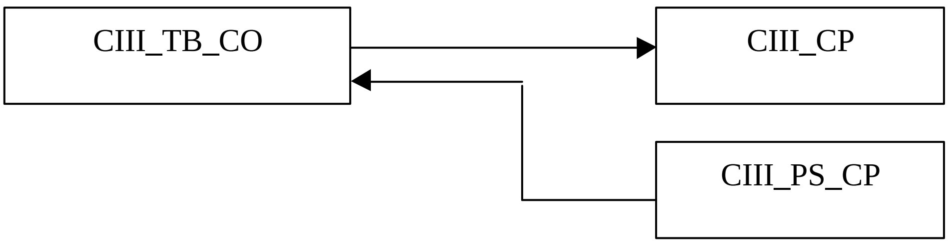
CableFast Terminal Block corresponding to the PLC's CIII_PLC_IO_AVO module (card 140AVO02000 featuring 4 Analog Outputs 0-5V).



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_AO_01+	CIII_TB_AVO	1	CIII_CP	132	24	RD	
CIII_AO_01-		2		136		BK	
CIII_AO_02+		11		140		PK	
CIII_AO_02-		12		144		BR	
CIII_AO_03+		21		148		WH	
CIII_AO_03-		22		152		GN	
CIII_AO_04+		31		156		GY	
CIII_AO_04-		32		160		YL	
R1		3	CIII_TB_AVO	1		RD	
COMMON 1		4		8		BK	
CONTROL 1		5		3		RD	
MASTER OVERRIDE 4		8		4		BK	
R2		13		11		PK	
COMMON 2		14		18		BR/YL	
CONTROL 2		15		13		PK	
MASTER OVERRIDE 4		18		14		BR/YL	
R3		23		21		WH	
COMMON 3		24		28		WH/GN	
CONTROL 3		25		23		WH	
MASTER OVERRIDE 4		28		24		WH/GN	
R4		33		31		GY	
COMMON 4		34		38		WH/YL	
CONTROL 4		35		33		GY	
MASTER OVERRIDE 4		38		34		WH/YL	
N.C.		6					
Reference_1		7					
N.C.		9					
N.C.		10					
N.C.		16					
Reference_2		17					
N.C.		19					
N.C.		20					
N.C.		26					
Reference_3		27					
N.C.		29					
N.C.		30					
N.C.		36					
Reference_4		37					
N.C.		39					
N.C.		40					

10.3 CIII_TB_ACO: Current Analogue Outputs Terminal Block

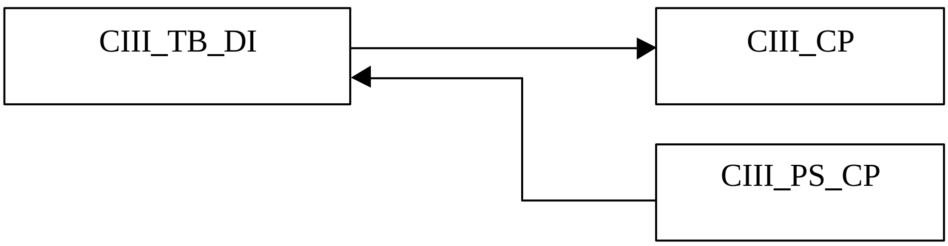
CableFast Terminal Block corresponding to the PLC's CIII_PLC_IO_ACO module (card 140ACO02000 featuring 4 Analog Outputs 4-20 mA).



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_AO_05+	CIII_TB_ACO	10	CIII_CP	164	24	YL	
CIII_AO_06+		20		172		GN	
CIII_AO_07+		30		180		RD	
CIII_AO_08+		40		188		WH	
24V+		9	CIII_PS_CP	14	20	RD	
		19				RD	
		29				RD	
		39				RD	
N.C.		2					
N.C.		12					
N.C.		22					
N.C.		32					
Monitor_1+		1					
N.C.		3					
N.C.		4					
N.C.		5					
N.C.		6					
N.C.		7					
N.C.		8					
Monitor_2+		11					
N.C.		13					
N.C.		14					
N.C.		15					
N.C.		16					
N.C.		17					
N.C.		18					
Monitor_3+		21					
N.C.		23					
N.C.		24					
N.C.		25					
N.C.		26					
N.C.		27					
N.C.		28					
Monitor_4+		31					
N.C.		33					
N.C.		34					
N.C.		35					
N.C.		36					
N.C.		37					
N.C.		38					

10.4 CIII_TB_IO_DI: Digital Inputs Terminal Block

CableFast Terminal Block corresponding to the PLC's CIII_PLC_IO_DI module (card 140DDI84100 featuring 16 Digital Inputs 0-24 V).

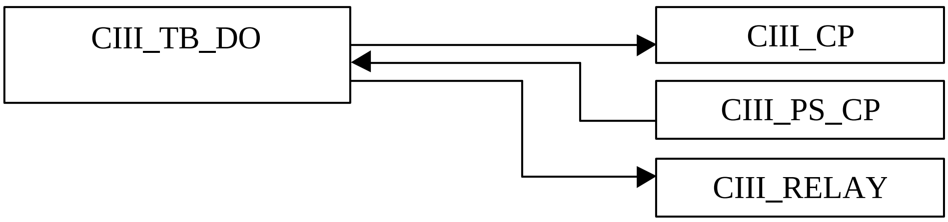


SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DI_01	CIII_TB_DI	1	CIII_CP	200	24	PR	
CIII_DI_02		2		007		GY/PK	
CIII_DI_03		5		015		RD	
CIII_DI_04		6		023		BR	
CIII_DI_05		11		031		BK	

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DI_06		12		039		GY	
CIII_DI_07		15		047		GN	
CIII_DI_08		16		055		YL	
CIII_DI_09		21		063		RD/BL	
CIII_DI_10		22		071		BR/GN	
CIII_DI_11		25		079		WH	
CIII_DI_12		26		087		WH/GN	
CIII_DI_13		31		095		WH/YL	
CIII_DI_14		32		103		BR/YL	
CIII_DI_15		35		111		BL	
CIII_DI_16		36		119		PK	
24V+		3	CIII_PS_CP	20	20	BK	
		7				BK	
		13				BK	
		17				BK	
		23				BK	
		27				BK	
		33				BK	
		37				BK	
24V-		4		02		RD	
		8				RD	
		14				RD	
		18				RD	
		24				RD	
		28				RD	
		34				RD	
		38				RD	
N.C.		9					
N.C.		10					
N.C.		19					
N.C.		20					
N.C.		29					
N.C.		30					
N.C.		39					
N.C.		40					

10.5 CIII_TB_IO_DO: Digital Outputs Terminal Block

CableFast Terminal Block corresponding to the PLC's CIII_PLC_IO_DO module (card 140DDO84300 featuring 16 Digital Outputs 0-24 V).

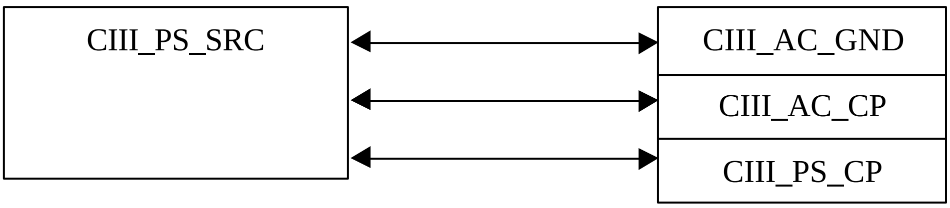


SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_01	CIII_TB_DO	1	CIII_RELAY_01	A1	24	RD	
CIII_DO_02		3	CIII_RELAY_02	A1		BK	
CIII_DO_03		5	CIII_RELAY_03	A1		PK	
CIII_DO_04		7	CIII_RELAY_04	A1		BR	
CIII_DO_05		11	CIII_RELAY_05	A1		WH	
CIII_DO_06		13	CIII_RELAY_06	A1		GN	
CIII_DO_07		15	CIII_RELAY_07	A1		GY	
CIII_DO_08		17	CIII_RELAY_08	A1		YL	
CIII_DO_09		21	CIII_RELAY_09	A1		BL	

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_10		23	CIII_RELAY_10	A1		PR	
CIII_DO_11		25	CIII_CP	147		RD	
CIII_DO_12		27		155		BK	
CIII_DO_13		31		163		PK	
CIII_DO_14		33		171		BR	
CIII_DO_15		35		179		WH	
CIII_DO_16		37		187		GN	
24V+		9	CIII_PS_CP	04		RD	
		19				RD	
		29				RD	
		39				RD	
N.C.		2					
N.C.		4					
N.C.		6					
N.C.		8					
N.C.		10					
N.C.		12					
N.C.		14					
N.C.		16					
N.C.		18					
N.C.		20					
N.C.		22					
N.C.		24					
N.C.		26					
N.C.		28					
N.C.		30					
N.C.		32					
N.C.		34					
N.C.		36					
N.C.		38					
N.C.		40					

10.6 CIII_PS_SRC: Power Supply

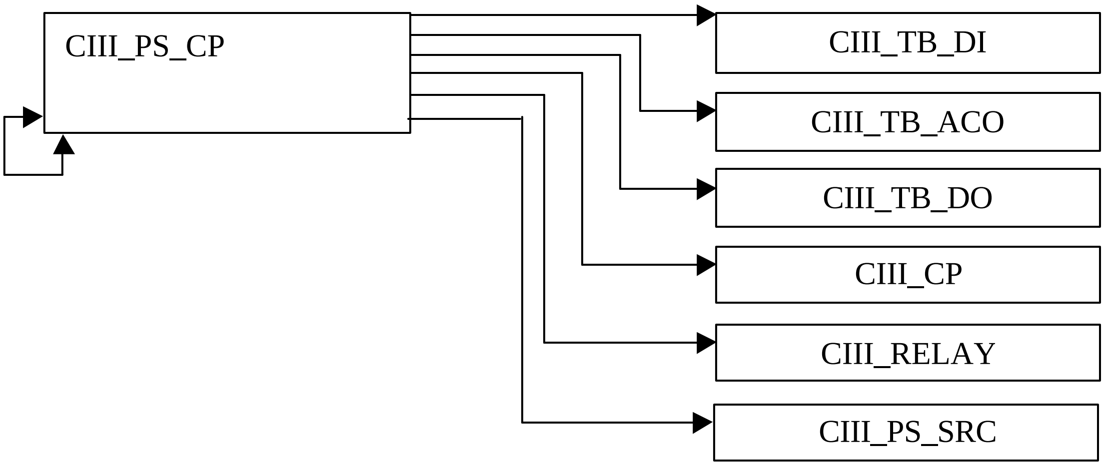
Basic connection schematic:



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
GND	CIII_PS_SRC	1	CIII_AC_GND	03	20	YL/GN	
AC N		2	CIII_AC_CP	12		BL	
AC L		3		10		BR	
24V+		4	CIII_PS_CP	1		RD	
24V-		5		15		BK	
24V+		7		13		RD	
24V-		8		27		BK	

10.7 CIII_PS_CP: Power Supply Connection Panel

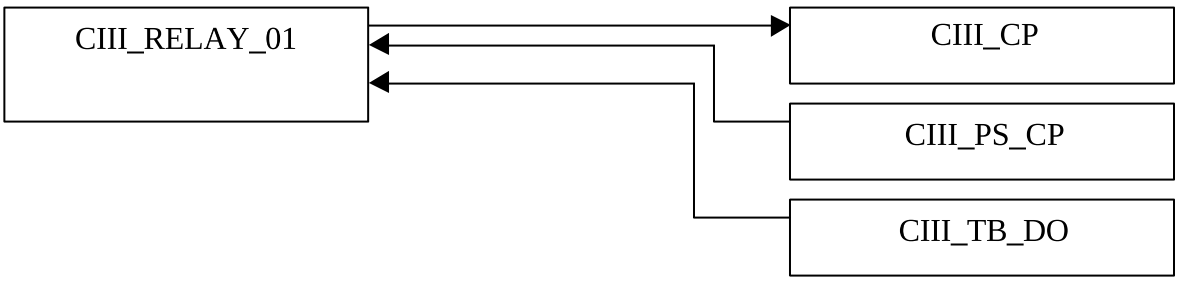
Connection panel to distribute 24Vdc:



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
24V+	CIII_PS_CP	1	CIII_PS_SRC	4	20	RD	
24V+		13		7		RD	
24V-		15		5		BK	
24V-		27		8		BK	
24V+		1	CIII_PS_CP	3		RD	
24V+		3		5		RD	
24V+		5		7		RD	
24V+		7		9		RD	
24V+		9		11		RD	
24V+		11		13		RD	
24V-		15		17		RD	
24V-		17		19		BK	
24V-		19		21		BK	
24V-		21		23		BK	
24V-		23		25		BK	
24V-		25		27		BK	
24V+		6	CIII_CP	003		RD	
24V+				027		RD	
24V+				035		RD	
24V+				043		RD	
24V+				051		RD	
24V+				059		RD	
24V+				067		RD	
24V+				075		RD	
24V+				083		RD	
24V+				091		RD	
24V+				099		RD	
24V+				107		RD	
24V+				115		RD	
24V+				196		RD	
24V-	CIII_PS_CP	22		168		BK	
24V-				176		BK	
24V-				184		BK	
24V-				192		BK	
24V-				151		BK	
24V-				159		BK	
24V-				167		BK	
24V-				175		BK	
24V-				183		BK	
24V-				191		BK	
24V-		26	RELAY_01	A2		BK	
24V-			RELAY_02	A2		BK	

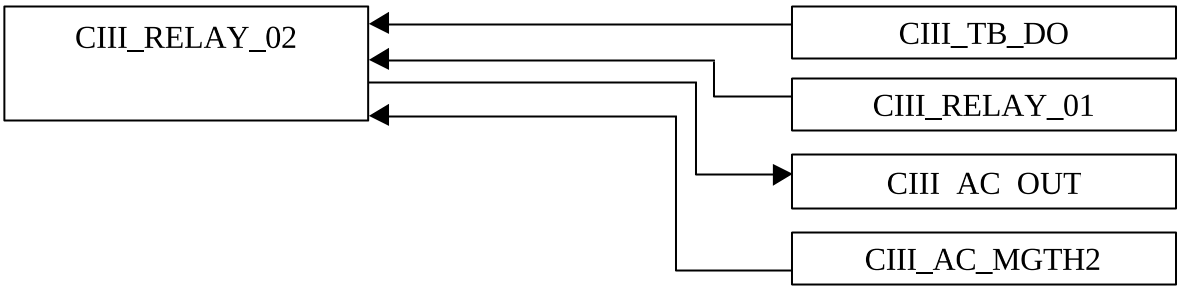
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
24V-			RELAY_03	A2		BK	
24V-			RELAY_04	A2		BK	
24V-			RELAY_05	A2		BK	
24V-			RELAY_06	A2		BK	
24V-			RELAY_07	A2		BK	
24V-			RELAY_08	A2		BK	
24V-			RELAY_09	A2		BK	
24V-			RELAY_10	A2		BK	
24V-		28	RELAY_10	A2		BK	
24V+		08	RELAY_07	11		RD	
24V+		14	CIII_TB_ACO	09		RD	
24V+				19		RD	
24V+				29		RD	
24V+				39		RD	
24V+		02	CIII_TB_DI	07		RD	
24V+				13		RD	
24V+				17		RD	
24V+				27		RD	
24V+				33		RD	
24V+				37		RD	
24V-		24		04		BK	
24V-				08		BK	
24V-				14		BK	
24V-				18		BK	
24V-				24		BK	
24V-				28		BK	
24V-				34		BK	
24V-				38		BK	
24V+		04	CIII_TB_DO	09		RD	
24V+				19		RD	
24V+				29		RD	
24V+				39		RD	

10.8 CIII_RELAY_01: Buffer Tank Pump



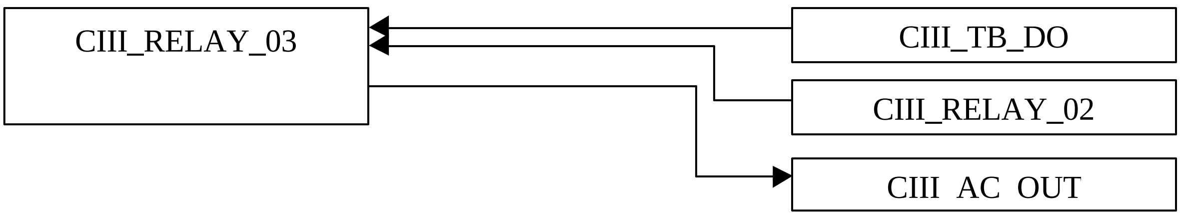
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_01	CIII_RELAY_01	A1	CIII_TB_DO	01	24	RD	Activation of the pump for the buffer tank
24V-		A2	CIII_PS_CP	28	20	BK	
CIII_RL_BT_IN		11	CIII_CP	123	24	YL	
CIII_RL_BT_OUT		14		127		GN	
N.C.		12					

10.9 CIII_RELAY_02: Not Used



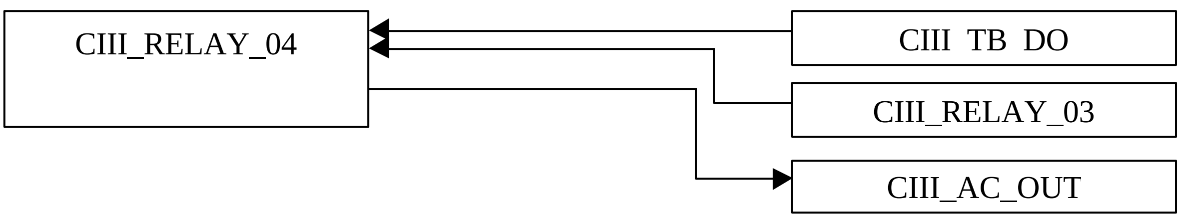
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_02	CIII_RELAY_02	A1	CIII_TB_DO	03		BK	Not used
24V-		A2	CIII_RELAY_01	A2	20	BK	
AC L		11	CIII_AC_MGTH2	02		BR	
CIII_AC_Ac_L		14	CIII_AC_OUT	02		BR	
N.C.		12					

10.10 CIII_RELAY_03: Not Used



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_03	CIII_RELAY_03	A1	CIII_TB_DO	05		PK	Not used
24V-		A2	CIII_RELAY_02	A2	20	BK	
AC L		11	CIII_RELAY_02	11B		BR	
CIII_AC_Bs_L		14	CIII_AC_OUT	08		BR	
N.C.		12					

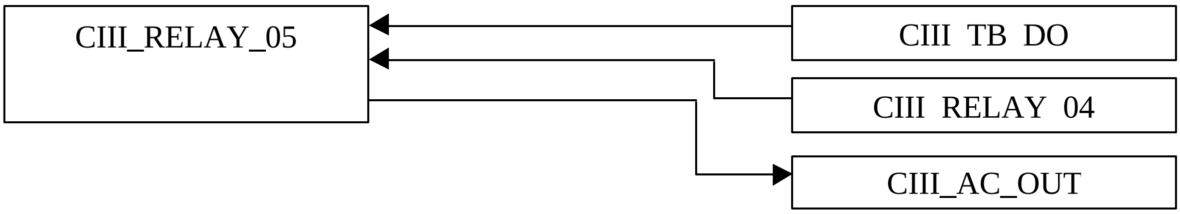
10.11 CIII_RELAY_04: Air compressor



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_04	CIII_RELAY_04	A1	CIII_TB_DO	07		BR	Air compressor activation
24V-		A2	CIII_RELAY_03	A2	20	BK	
AC L		11		11B		BR	

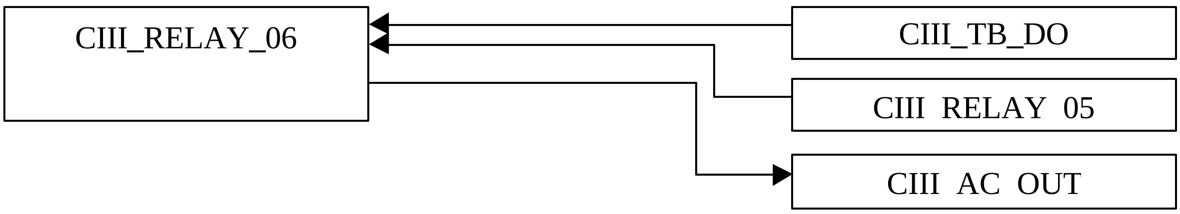
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_AC_Comp_L		14	CIII_AC_OUT	14		BR	
N.C.		12					

10.12 CIII_RELAY_05: Cooling Valve



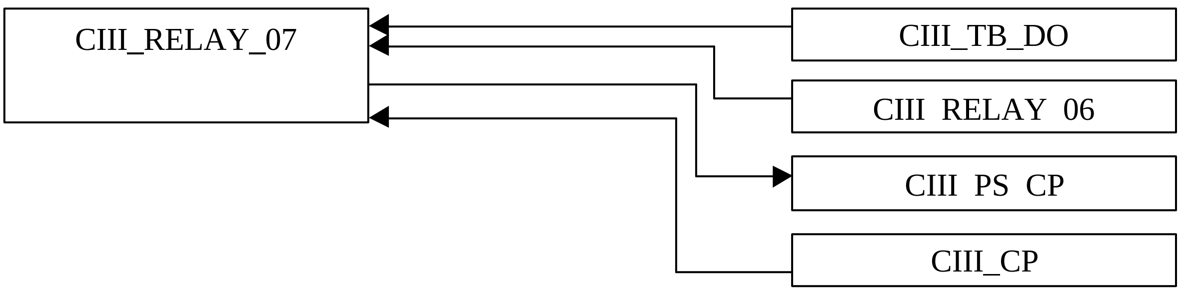
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_05	CIII_RELAY_05	A1	CIII_TB_DO	11		WH	Cooling valve activation
24V-		A2	CIII_RELAY_04	A2	20	BK	
AC L		11	CIII_RELAY_04	11B		BR	
CIII_AC_CV_L		14	CIII_AC_OUT	20		BR	
N.C.		12					

10.13 CIII_RELAY_06: Heater



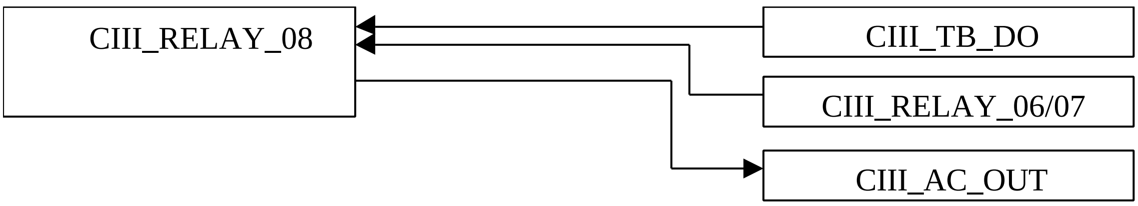
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_06	CIII_RELAY_06	A1	CIII_TB_DO	13		GN	Heater activation
24V-		A2	CIII_RELAY_05	A2	20	BK	
AC L		11	CIII_RELAY_05	11B		BR	
CIII_AC_Heat_L		14	CIII_AC_OUT	26		BR	
N.C.		12					

10.14 CIII_RELAY_07: Liquid Level Pulse



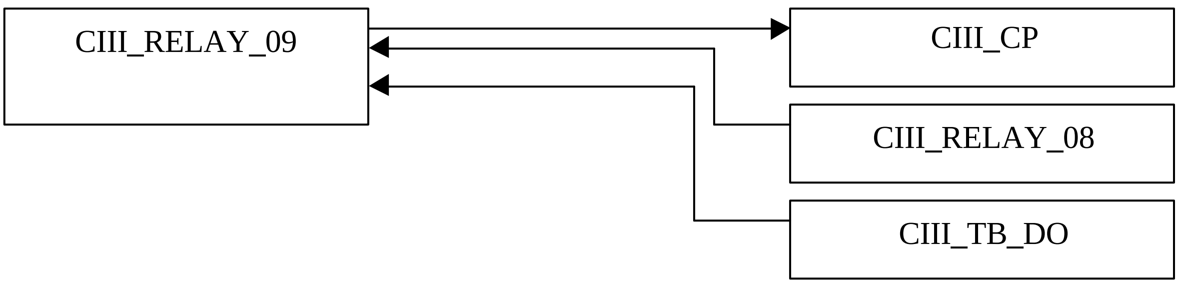
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_07	CIII_RELAY_07	A1	CIII_TB_DO	15		GY	Pulse to measure liquid level
24V-		A2	CIII_RELAY_06	A2	20	BK	
24V+		11	CIII_PS_CP	08		RD	
CIII_MV_L1+		14	CIII_CP	11	24	RD	
CIII_MV_L1+				19		RD	
N.C.		12					

10.15 CIII_RELAY_08: Safety Pressure Valve



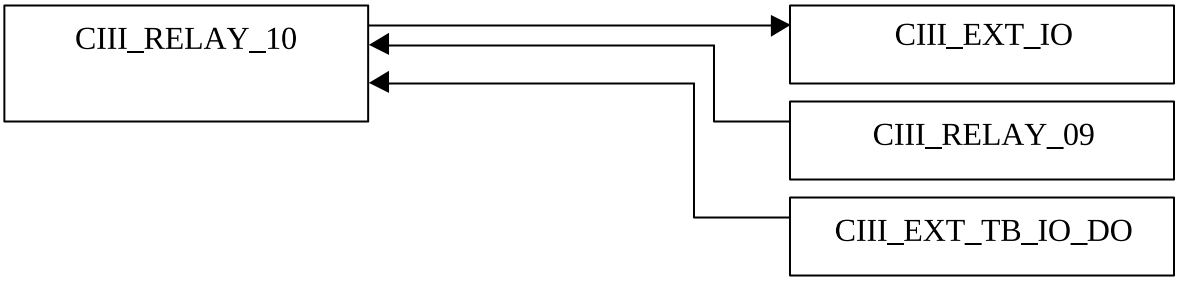
SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_08	CIII_RELAY_08	A1	CIII_TB_DO	17		YL	Safety pressure regulation valve activation
24V-		A2	CIII_RELAY_07	A2	20	BK	
AC L		11	CIII_RELAY_06	11B		BR	
CIII_AC_Safe_L		14	CIII_AC_OUT	32		BR	
N.C.		12					

10.16 CIII_RELAY_09: Acid pump



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_09	CIII_RELAY_09	A1	CIII_TB_DO	21		BL	pH Acid pump activation
24V-		A2	CIII_RELAY_08	A2	20	BK	
CIII_RL_Ac+		11	CIII_CP	131	24	YL	
CIII_RL_Ac-		14		135	24	GN	
		12					

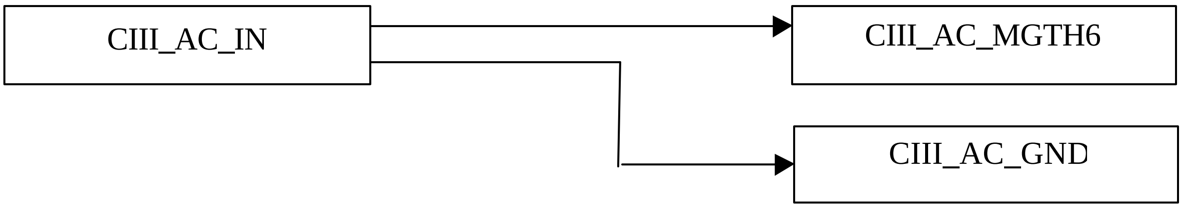
10.17 CIII_RELAY_10: Base pump



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_DO_10	CIII_RELAY_10	A1	CIII_TB_IO_DO	23		PR	pH Base pump activation
24V-		A2	CIII_RELAY_09	A2	20	BK	
CIII_RL_Bs+		11	CIII_CP	139	24	YL	
CIII_RL_Bs-		14		143	24	GN	
		12					

10.18 CIII_AC_IN: Input 220 VAC power

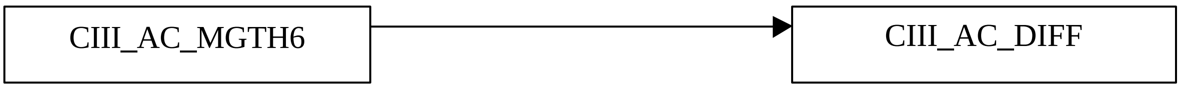
External AC Power input connector.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIII_AC_IN	2	CIII_AC_MGTH6	1	20	BR	
AC N		4		3		BL	
AC GND		6	CIII_AC_GND	1		YL/GN	

10.19 CIII_AC_MGTH6: Over current protection at 6 A

Magnetothermic, over current protection at 6 A.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIII_AC_MGTH6	2	CIII_AC_DIFF	1	20	BR	
AC N		4		3		BL	

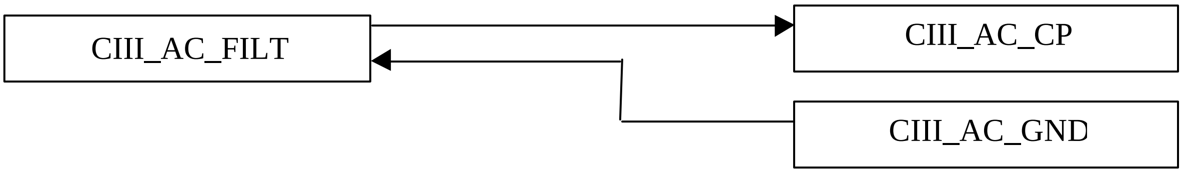
10.20 CIII_AC_DIFF: Current leaks protector

Current leaks protector.

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIII_AC_DIFF	2	CIII_AC_FILT	1	20	BR	
AC N		4		3		BL	

10.21 CIII_AC_FILT: AC Filter

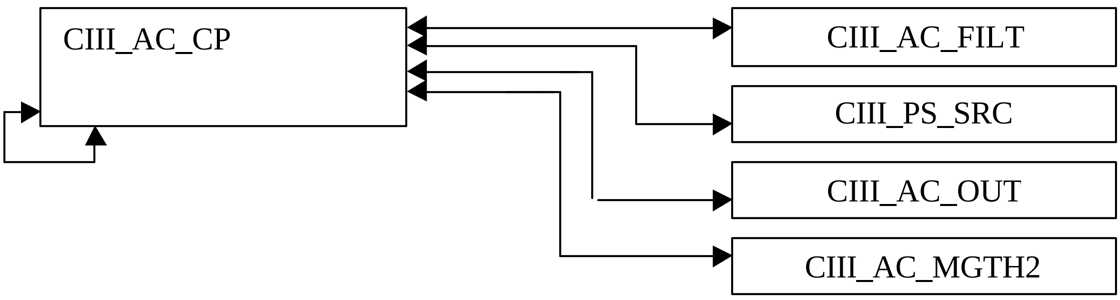
AC filter.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
GND	CIII_AC_FILT	2	CIII_AC_GND	10	20	YL/GN	
AC L		4	CIII_AC_CP	1		BR	
				5		BR	
				9		BR	
				13		BR	
AC N		5		3		BL	
				7		BL	
				11		BL	
				15		BL	

10.22 CIII_AC_CP: AC Connection Panel

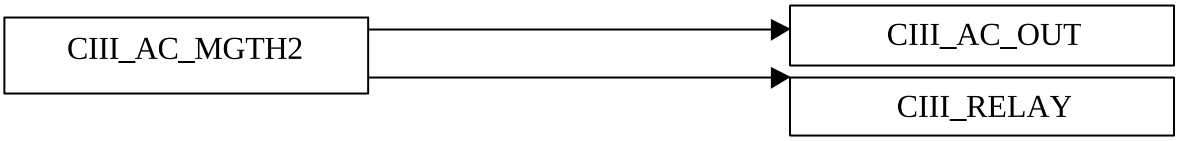
AC connection panel to distribute AC into the rack.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIII_AC_CP	2	CIII_AC_OUT	38		BR	
AC N		4		40		BL	
AC L		6	CIII_UPS	1		BR	
AC N		8		3		BL	
AC L		10	CIII_PS_SRC	3		BR	
AC N		12		2		BL	
AC L		14	CIII_MGTH2	1		BR	
AC N		16		3		BL	

10.23 CIII_AC_MGTH2: Over current protection at 2 A

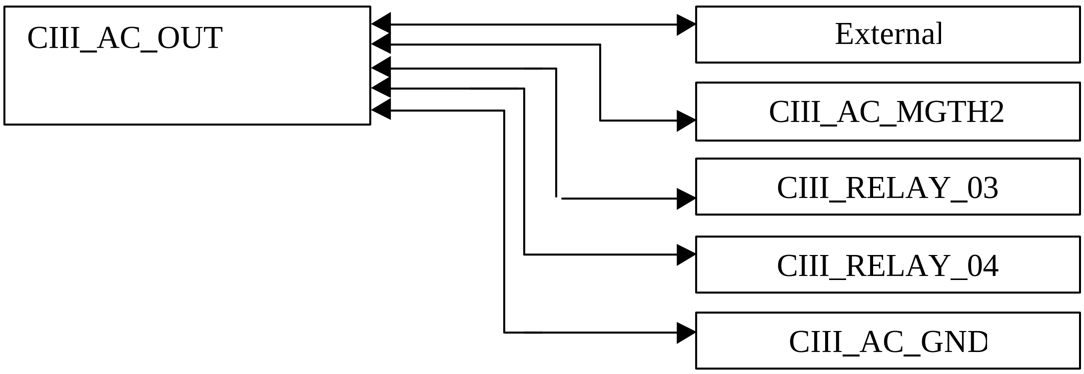
Magnetothermic, over current protection at 2 A.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIII_AC_MGTH2	2	CIII_RELAY_02	11		BR	
AC N		4	CIII_AC_OUT	04		BL	
AC N				10		BL	
AC N				16		BL	
AC N				22		BL	
AC N				28		BL	
AC N				34		BL	

10.24 CIII_AC_OUT: 220 VAC Out Connection Panel

AC connector to provide relay commuted power to external devices.

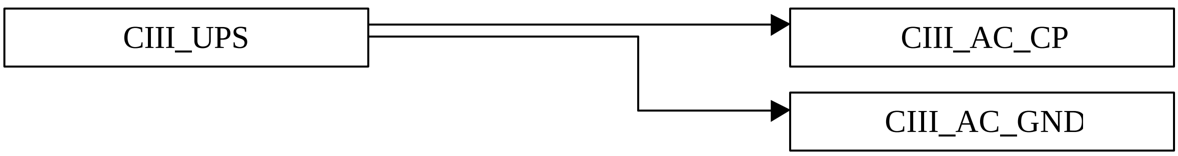


SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIII_AC_OUT	01	Not used		20	BR	Not used
AC N		03				BL	
AC GND		05				YL/GN	
AC L		07	Not used			BR	Not used
AC N		09				BL	
AC GND		11				YL/GN	
AC L		13	CIII_AC_Comp			BR	Compressor activation
AC N		15				BL	

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC GND		17				YL/GN	
AC L		19	CIII_AC_CV			BR	Cooling valve
AC N		21				BL	
AC GND		23				YL/GN	
AC L		25	CIII_AC_Heat			BR	Heater activation
AC N		27				BL	
AC GND		29				YL/GN	
AC L		31	CIII_AC_Safe			BR	Safety pressure valve activation
AC N		33				BL	
AC GND		35				YL/GN	
AC L		37	CIII_AC_FAN	01		BR	Rack Fans
AC N		39		02		BL	
AC GND		41		03		YL/GN	
AC L		02	CIII_RELAY_02	14		BR	
AC L		08	CIII_RELAY_03	14		BR	
AC L		14	CIII_RELAY_04	14		BR	
AC L		20	CIII_RELAY_05	14		BR	
AC L		26	CIII_RELAY_06	14		BR	
AC L		32	CIII_RELAY_08	14		BR	
AC N		04	CIII_AC_MGTH2	04		BL	
AC N		10				BL	
AC N		16				BL	
AC N		22				BL	
AC N		28				BL	
AC N		34				BL	
GND		06	CIII_AC_GND	07		YL/GN	
		12		11		YL/GN	
		18		12		YL/GN	
		24		13		YL/GN	
		30		14		YL/GN	
		36		15		YL/GN	
		42		09		YL/GN	
AC L		38	CIII_AC_CP	02		BR	
AC N		40		04		BL	

10.25 CIII_AC_UPS: Uninterrupted Power Supply

Uninterrupted Power Supply to provide continuous power to the PLC.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIII_AC_UPS	4	CIII_PLC_CPS	5	20	BR	
GND		5		7		GN/YL	
AC N		6		6		BL	
AC N		1	CIII_AC_CP	4		BR	
AC L		3		2		BL	
GND		2	CIII_AC_GND	4		GN/YL	

10.26 CIII_AC_GND: Metallic Strip to Distribute Ground

GND strip bar to distribute ground into the rack.

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
GND	CIII_AC_GND	01	CIII_AC_IN	06	20	YL/GN	
		02	CIII_AC_UPS	02			
		03	CIII_PS_SRC	01			
		07	CIII_AC_OUT	04			
		09		40			
		11		10			
		12		16			
		13		22			
		14		28			
		15		34			
		08	CIII_PLC_CPS	07			
		10	CIII_AC_FILT	02			

10.27 CIII_ETHER: Ethernet Connector

Ethernet connector to provide network connection to the PLC.

CIII_ETHER → CIII_PLC_NOE

Connector name:	Type:	Features:			
CIII_ETHER	RJ45				
Connectors pin out					
Pin Num	Signal	Signal type	Circuit Class	Remarks	Description
1	Ethernet TX+	Ethernet	RF	IEEE 802.3 I 10-BASE-T Ethernet/ IEEE 802.3 u 100-BASE-Tx Ethernet. Automatic sensing	Ethernet channel TX
2	Ethernet RX Shield				
3	Ethernet RX+	Ethernet	RF		Ethernet channel RX
4	Ethernet RX-	Ethernet	RF		Ethernet channel RX
5	Ethernet TX-	Ethernet	RF		Ethernet channel TX
6	Ethernet TX Shield				

10.28 CIII_CP: External Signals Connection Panel

The following table provides the connection from the CIII_RACK output connector CIII_CP to the external sensors / actuators related to CII.

It is assumed that the plant (under UAB's responsibility) shall provide cables/connectors properly labeled with the mnemonics identified in the TO column of this table. For clarity sake, these mnemonics coincide with the I/O signal denominations defined in **8.3.1.1**.

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_AI_01+	CIII_CP	1	CIII_MV_DObot		24		DO sensor bottom
CIII_AI_01-		5					
CIII_AI_02+		9	CIII_MV_DOtop				DO sensor top
CIII_AI_02-		13					
CIII_AI_03+		17	CIII_MV_NH4				NH4 Analyzer
CIII_AI_03-		21					
CIII_AI_04+		25	CIII_MV_NO3				NO3 Analyzer
CIII_AI_04-		29					
CIII_AI_05+		33	CIII_MV_P				Pressure sensor
CIII_AI_05-		37					
CIII_AI_06+		41	CIII_MV_PHb				pH sensor bottom
CIII_AI_06-		45					
CIII_AI_07+		49	CIII_MV_PHt				pH sensor top
CIII_AI_07-		53					

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_AI_08+		57	Not used				
CIII_AI_08-		61					
CIII_AI_09+		65	CIII_MV_Tb				Temperature sensor bottom
CIII_AI_09-		69					
CIII_AI_10+		73	CIII_MV_Tt				Temperature sensor top
CIII_AI_10-		77					
CIII_AI_11+		81	Not used				
CIII_AI_11-		85					
CIII_AI_12+		89	Not used				
CIII_AI_12-		93					
CIII_AI_13+		97	Not used				
CIII_AI_13-		101					
CIII_AI_14+		105	Not used				
CIII_AI_14-		109					
CIII_AI_15+		113	Not used				
CIII_AI_15-		117					
CIII_AI_16+		121	Not used				
CIII_AI_16-		125					
CIII_AO_01+		129	CIII_FC_CO2				CO2 Flow controller
CIII_AO_01-		133					
CIII_AO_02+		137	CIII_FC_N2				N2 Flow controller
CIII_AO_02-		141					
CIII_AO_03+		145	CIII_FC_O2				O2 Flow controller
CIII_AO_03-		149					
CIII_AO_04+		153	Not used				
CIII_AO_04-		157					
CIII_AO_05+		161	CIII_PM_Ac				Acid pump
24V-		165					
CIII_AO_06+		169	CIII_PM_Bs				Base pump
24V-		173					
CIII_AO_07+		177	CIII_PM_Fl				Liquid input pump
24V-		181					
CIII_AO_08+		185	CIII_PM_L				Liquid output pump
24V-		189					
24V+		193	CIII_CAL_NH4				NH4 Analyzer calibration indicator
CIII_DI_01-		197					
24V+		002	CIII_CAL_NO3				NO3 Analyzer calibration indicator
CIII_DI_02-		006					
24V+ (*)		010	CIII_MV_L1 (Low)				Level sensor low
CIII_DI_03-		014					
24V+ (*)		018	CIII_MV_L2 (High)				Level sensor high
CIII_DI_04-		022					
24V+		026	CIII_MVI_Lbt				Level of output buffer tank
CIII_DI_05-		030					
24V+		034	Not used				
CIII_DI_06-		038					
24V+		042	Not used				
CIII_DI_07-		046					
24V+		050	Not used				
CIII_DI_08-		054					
24V+		058	Not used				
CIII_DI_09-		062					
24V+		066	Not used				
CIII_DI_10-		070					
24V+		074	Not used				
CIII_DI_11-		078					
24V+		082	Not used				
CIII_DI_12-		086					
24V+		090	Not used				
CIII_DI_13-		094					
24V+		098	Not used				
CIII_DI_14-		102					
24V+		106	Not used				
CIII_DI_15-		110					
24V+		114	Not used				
CIII_DI_16-		118					
CIII_RL_Lbt in		122	CIII_RL_Lbt				

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIII_RL_Lbt out		126					
RELAY_09 in		130	CIII_PM_Ac				Activation of Acid pump
RELAY_09 out		134					
RELAY_10 in		138	CIII_PM_Bs				Activation of Base pump
RELAY_10 out		142					
CIII_DO_11		146	Not used				
24V-		150					
CIII_DO_12		154	Not used				
24V-		158					
CIII_DO_13		162	Not used				
24V-		166					
CIII_DO_14		170	Not used				
24V-		174					
CIII_DO_15		178	Not used				
24V-		182					
CIII_DO_16		186	Not used				
24V-		190					
24V+		003	CIII_CP	027			
24V+		027		035			
24V+		035		043			
24V+		043		051			
24V+		051		059			
24V+		059		067			
24V+		067		075			
24V+		075		083			
24V+		083		091			
24V+		091		099			
24V+		099		107			
24V+		107		115			
24V+		115		164			
24V+		164		172			
24V+		172		180			
24V+		180		188			
24V-		151		159			
24V-		159		167			
24V-		167		175			
24V-		175		183			
24V-		183		191			
CIII_MV_L1+		011		019			

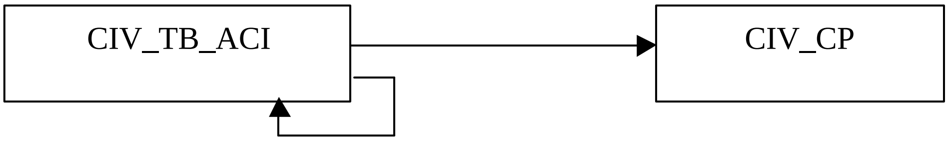
(*) Relay to generate a pulse of 100 ms to avoid electrolysis in the media when reading tank level.

11 APPENDIX C: CIV Rack Electrical Connection Tables

11.1 CIV_TB_ACI: Current Analogue Inputs Terminal Block

CableFast Terminal Block corresponding to the PLC's CIV-PLC_IO_ACI module (card 140ACI03000 featuring 8 Analog Inputs 4-20 mA).

The basic connection schematic is:



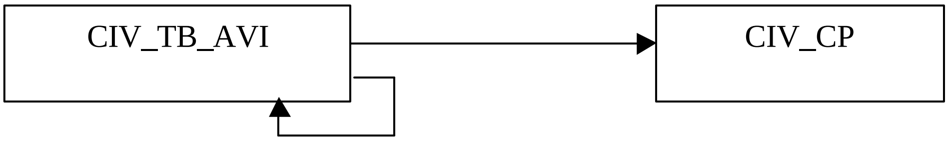
Detailed connection table:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_AI_01+	CIV_TB_ACI	1	CIV_CP	4	24	WH	
CIV_AI_01-		2		8		WH/YL	
CIV_AI_02+		5		12		BR/GN	
CIV_AI_02-		6		16		WH/GN	
CIV_AI_03+		11		20		PR	
CIV_AI_03-		12		24		RD	
CIV_AI_04+		15		28		BL	
CIV_AI_04-		16		32		PK	
CIV_AI_05+		21		36		YL	
CIV_AI_05-		22		40		YL/BR	
CIV_AI_06+		25		44		BR	
CIV_AI_06-		26		48		GN	
CIV_AI_07+		31		52		GY/PK	
CIV_AI_07-		32		56		GY	
CIV_AI_08+		35		60		RD/BL	
CIV_AI_08-		36		64		BK	
SENSE 1		3	CIV_TB_ACI	1			
SENSE 2		7		5			
SENSE 3		13		11			
SENSE 4		17		15			
SENSE 5		23		21			
SENSE 6		27		25			
SENSE 7		33		31			
SENSE 8		37		35			
N.C.		4					
		8					
		9					
		10					
		14					
		18					
		19					
		20					
		24					
		28					
		29					
		30					
		34					
		38					
		39					
		40					

11.2CIV_TB_AVI: Voltage Analogue Inputs Terminal Block

CableFast Terminal Block corresponding to the PLC's CIV_PLC_IO_AVI module (card 140AVI03000 featuring 8 Analog Inputs 0-5V / 4-20 mA).

The basic connection schematic is:



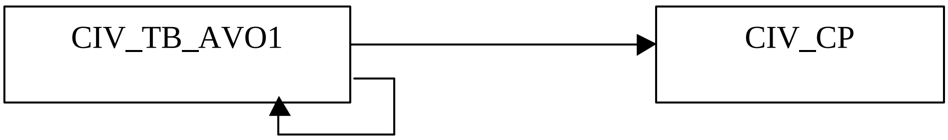
The detailed connection table is:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_AI_09+	CIV_TB_AVI	3	CIV_CP	68	24	WH	Current source
CIV_AI_09-		2		72		WH/YL	
CIV_AI_10+		5		76		BR/GN	Voltage source
CIV_AI_10-		6		80		WH/GN	
CIV_AI_11+		11		84		PR	Voltage source
CIV_AI_11-		12		88		RD	
CIV_AI_12+		15		92		BL	Voltage source
CIV_AI_12-		16		96		PK	
CIV_AI_13+		21		100		YL	Voltage source
CIV_AI_13-		22		104		YL/BR	
CIV_AI_14+		25		108		BR	Voltage source
CIV_AI_14-		26		112		GN	
CIV_AI_15+		31		116		GY/PK	Voltage source
CIV_AI_15-		32		120		GY	
CIV_AI_16+		35		124		RD/BL	Voltage source
CIV_AI_16-		36		128		BK	
SENSE 1		3	CIV_TB_AVI	1			Current jumper
N.C.		4					
		7					
		8					
		9					
		10					
		13					
		14					
		17					
		18					
		19					
		20					
		23					
		24					
		27					
		28					
		29					
		30					
		33					
		34					
		37					
		38					
		39					
		40					

11.3CIV_TB_AVO1: Voltage Analogue o/p Terminal Block 1

CableFast Terminal Block corresponding to the PLC's CIV_PLC_IO_AVO1 module (card 140AVO02000 featuring 4 Analog Outputs 0-5V).

The basic connection schematic is:



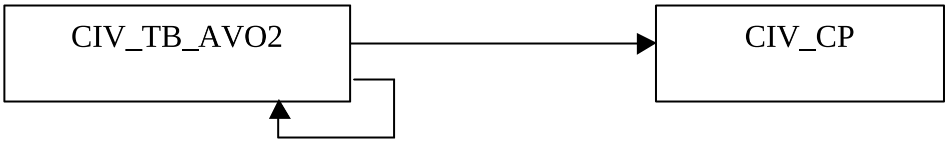
The detailed connection table is:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_AO_01+	CIV_TB_AVO1	1	CIV_CP	132	24	PK	
CIV_AO_01-		2		136		YL	
CIV_AO_02+		11		140		GY	
CIV_AO_02-		12		144		GN	
CIV_AO_03+		21		148		PR	
CIV_AO_03-		22		152		WH	
CIV_AO_04+		31		156		BK	
CIV_AO_04-		32		160		RD	
R1		3	CIV_TB_AVO1	1			
COMMON 1		4		8			
CONTROL 1		5		3			
MASTER OVER		8		4			
R2		13		11			
COMMON 2		14		18			
CONTROL 2		15		13			
MASTER OVER		18		14			
R3		23		21			
COMMON 3		24		28			
CONTROL 3		25		23			
MASTER OVER		28		24			
R4		33		31			
COMMON 4		34		38			
CONTROL 4		35		33			
MASTER OVER		38		34			
N.C.		6					
REFERENCE 1		7					
N.C.		9					
N.C.		10					
N.C.		16					
REFERENCE 1		17					
N.C.		19					
N.C.		20					
N.C.		26					
REFERENCE 1		27					
N.C.		29					
N.C.		30					
N.C.		36					
REFERENCE 1		37					
N.C.		39					
N.C.		40					

11.4CIV_TB_AVO2: Voltage Analogue o/p Terminal Block 2

CableFast Terminal Block corresponding to the PLC’s CIV_PLC_IO_AVO2 module (card 140AVO02000 featuring 4 Analog Outputs 0-5V).

The basic connection schematic is:



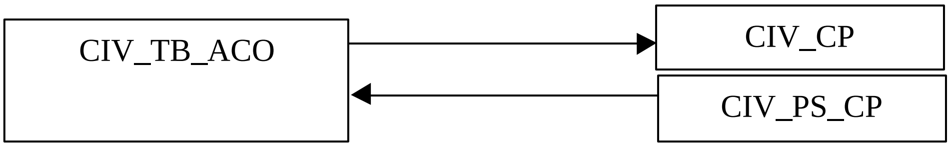
The detailed connection table is:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_AO_05+	CIV_TB_AVO2	1	CIV_CP	164	24	YL	
CIV_AO_05-		2		168		PK	
CIV_AO_06+		11		172		GY	
CIV_AO_06-		12		176		GN	
CIV_AO_07+		21		180		PR	
CIV_AO_07-		22		184		WH	
CIV_AO_08+		31		188		BK	
CIV_AO_08-		32		192		RD	
R1		3	CIV_TB_AVO2	1			
COMMON 1		4		8			
CONTROL 1		5		3			
MASTER OVER		8		4			
R2		13		11			
COMMON 2		14		18			
CONTROL 2		15		13			
MASTER OVER		18		14			
R3		23		21			
COMMON 3		24		28			
CONTROL 3		25		23			
MASTER OVER		28		24			
R4		33		31			
COMMON 4		34		38			
CONTROL 4		35		33			
MASTER OVER		38		34			
N.C.		6					
REFERENCE 1		7					
N.C.		9					
N.C.		10					
N.C.		16					
REFERENCE 1		17					
N.C.		19					
N.C.		20					
N.C.		26					
REFERENCE 1		27					
N.C.		29					
N.C.		30					
N.C.		36					
REFERENCE 1		37					
N.C.		39					
N.C.		40					

11.5CIV_TB_ACO: Current Analogue Outputs Terminal Block

CableFast Terminal Block corresponding to the PLC's CIV_PLC_IO_ACO module (card 140ACO13000 featuring 8 Analog Outputs 4-20 mA).

The basic connection schematic is:



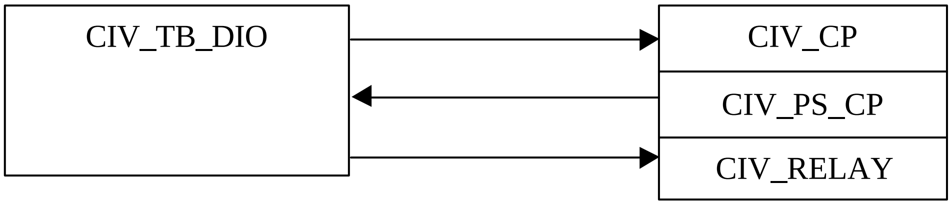
The detailed connection table is:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_AO_09-	CIV_TB_ACO	4	CIV_CP	200	24	PK	
CIV_AO_10-		8		208		YL	
CIV_AO_11-		14		216		GY	
CIV_AO_12-		18		7		GN	
CIV_AO_13-		24		15		PR	
CIV_AO_14-		28		23		WH	
CIV_AO_15-		34		31		BK	
CIV_AO_16-		38		39		RD	
24V-		2	CIV_VC_24_CP	18	20	BK	
MONITOR 1		1					
N.C.		3					
MONITOR 2		5					
RETURN		6					
N.C.		7					
N.C.		9					
N.C.		10					
MONITOR 3		11					
RETURN		12					
N.C.		13					
N.C.		19					
N.C.		20					
MONITOR 4		15					
RETURN		16					
N.C.		17					
MONITOR 5		21					
RETURN		22					
N.C.		23					
MONITOR 6		25					
RETURN		26					
N.C.		27					
N.C.		29					
N.C.		30					
MONITOR 7		31					
RETURN		32					
N.C.		33					
MONITOR 8		35					
RETURN		36					
N.C.		37					
N.C.		39					
N.C.		40					

11.6 CIV_TB_DIO: Digital Input/Outputs Terminal Block

CableFast Terminal Block corresponding to the PLC's CIV_PLC_IO_DIO module (card 140DDM39000 featuring 16 Digital Input / Digital Output 0-24V).

The basic connection schematic is:

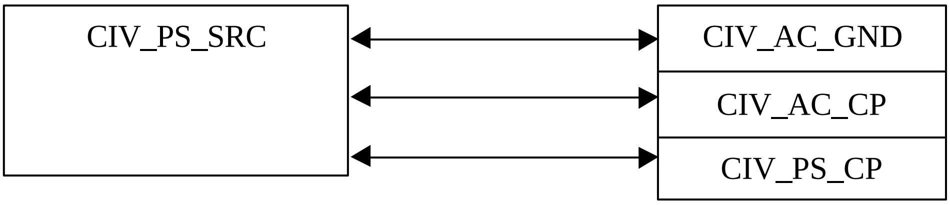


The detailed connection table is:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_DO_01	CIV_TB_DIO	1	CIV_RELAY_01	A1	24	PR	
CIV_DO_02		3	CIV_RELAY_02	A1		BK	
CIV_DO_03		5	CIV_RELAY_03	A1		RD	
CIV_DO_04		7	CIV_RELAY_04	A1		BR	
CIV_DO_05		11	CIV_RELAY_05	A1		WH	
CIV_DO_06		13	CIV_RELAY_06	A1		BL	
CIV_DO_07		15	CIV_CP	203		WH/BK	
CIV_DO_08		17		211		BR	
CIV_DI_01		21		47		RD/BL	
CIV_DI_02		22		55		BK	
CIV_DI_03		23		63		WH/RD	
CIV_DI_04		24		71		PR	
CIV_DI_05		25		79		BR	
CIV_DI_06		26		87		RD	
CIV_DI_07		27		95		GN	
CIV_DI_08		28		103		BL	
CIV_DI_09		31		111		WH/BL	
CIV_DI_10		32		119		PK/BR	
CIV_DI_11		33		127		BR/BL	
CIV_DI_12		34		135		PK/GY	
CIV_DI_13		35		143		WH	
CIV_DI_14		36		151		PK	
CIV_DI_15		37		159		WH/GN	
CIV_DI_16		38		167		BR/GN	
24V-		9	CIV_PS_CP	20	20	BK	Group A supply
24V+		10		06		RD	
24V-		19		22		BK	Group B supply
24V+		20		08		RD	
24V-		29		16		BK	
24V-		39		30		BK	
N.C.		2					
N.C.		2					
N.C.		4					
N.C.		6					
N.C.		8					
N.C.		12					
N.C.		14					
N.C.		16					
N.C.		18					
N.C.		30					
N.C.		40					

11.7CIV_PS_SRC: Power Supply

Basic connection schematic:

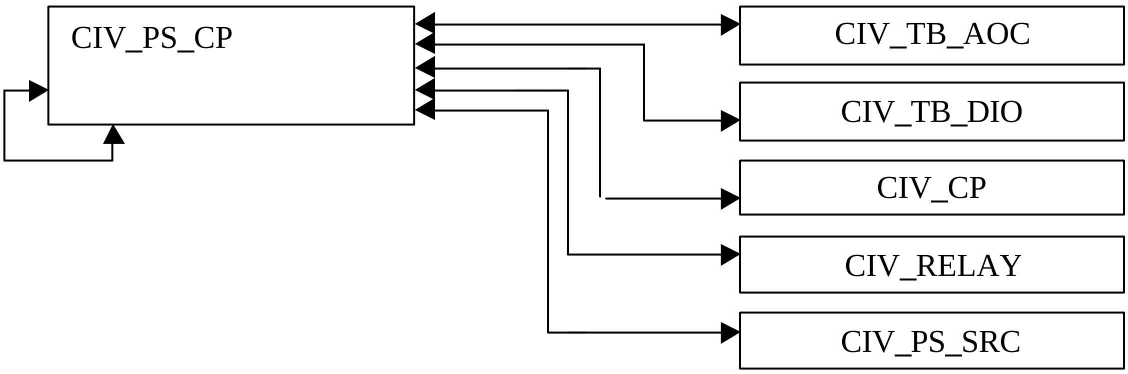


Detailed connection table:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
GND	CIV_PS_SRC	1	CIV_AC_GND	3	20	YL/GN	
AC N		2	CIV_AC_CP	8		BL	
AC L		3		2		BR	
24V+		4	CIV_PS_CP	1		RD	
24V-		5		15		BK	
24V+		7		13		RD	
24V-		8		29		BK	

11.8CIV_PS_CP: Power Supply Connection Panel

Basic connection schematic



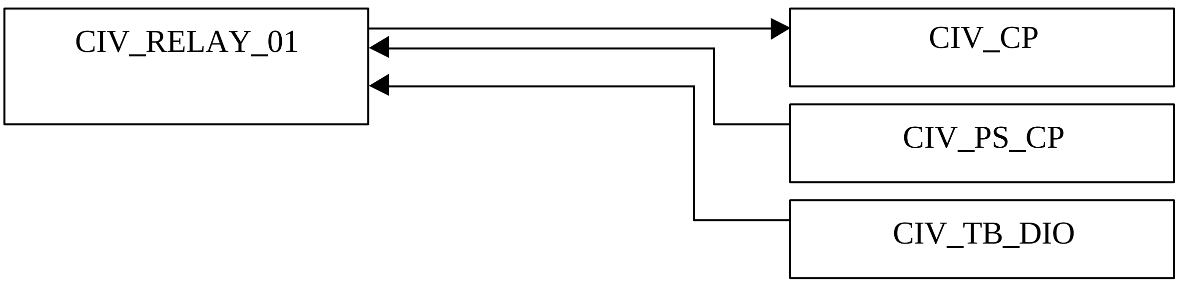
Detailed connection table:

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
24V+	CIV_PS_CP	1	CIV_PS_SRC	4	20	RD	
24V+		13		7		RD	
24V-		15		5		BK	
24V-		29		8		BK	
24V+		3	CIV_PS_CP	1		RD	
24V+		5		3		RD	
24V+		7		5		RD	
24V+		9		7		RD	
24V+		11		9		RD	
24V+		13		11		RD	
24V-		17		15		BK	

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
24V-		19		17		BK	
24V-		21		19		BK	
24V-		23		21		BK	
24V-		25		23		BK	
24V-		27		25		BK	
24V-		16	CIV_TB_ACO	2		BK	
24V+		6	CIV_TB_DIO	10		RD	
24V+		8		20		RD	
24V-		18		9		BK	
24V-		20		19		BK	
24V-		22		29		BK	
24V-		24		39		BK	
24V+		10	CIV_CP	003		RD	
24V+				011		RD	
24V+				019		RD	
24V+				027		RD	
24V+				035		RD	
24V+				043		RD	
24V+				051		RD	
24V+				059		RD	
24V+		12		067		RD	
24V+				075		RD	
24V+				083		RD	
24V+				091		RD	
24V+				099		RD	
24V+				107		RD	
24V+				115		RD	
24V+				123		RD	
24V+		14		131		RD	
24V+				139		RD	
24V+				147		RD	
24V+				155		RD	
24V+				163		RD	
24V+				196		RD	
24V+				204		RD	
24V+				212		RD	
24V-		26		215		BK	DO_07
24V-		28		207		BK	DO_08
24V-		30	CIV_RELAY_01	A2		BK	
24V-			CIV_RELAY_02	A2		BK	
24V-			CIV_RELAY_03	A2		BK	
24V-			CIV_RELAY_04	A2		BK	
24V-			CIV_RELAY_05	A2		BK	
24V-			CIV_RELAY_06	A2		BK	
NC		2					
NC		4					

11.9CIV_RELAY_01: Liquid input pump 1

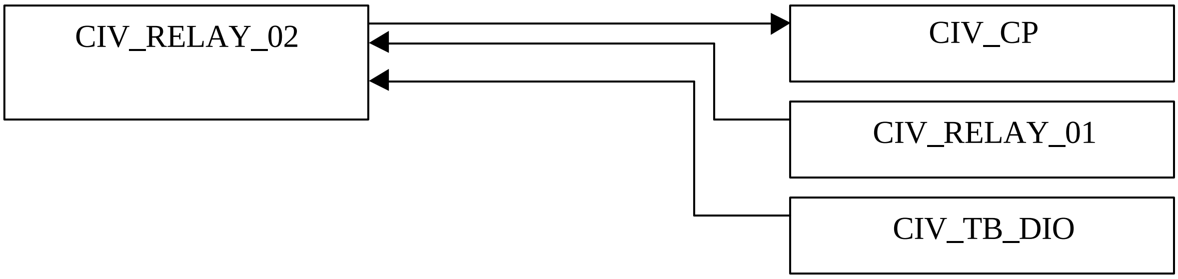
Relay to switch 24VC to activate liquid input pump1.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_DO_01	CIV_RELAY_01	A1	CIV_TB_DIO	1	24		
24V-		A2	CIV_PS_CP	28	20	BK	
CIV_RL_LI1_IN		11	CIV_CP	175		BK	
CIV_RL_LI1_OUT		14		171		WH	
N.C.		12					

11.10 CIV_RELAY_02: Liquid input pump 2

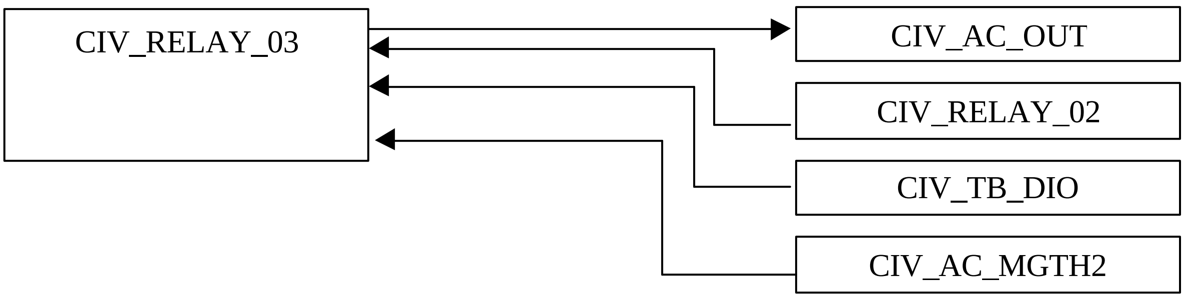
Relay to switch 24Vdc to activate liquid input pump2.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_DO_02	CIV_RELAY_02	A1	CIV_TB_DIO	3	24		
24V-		A2	CIV_RELAY_01	A2	20	BK	Activation of the liquid input pump 2
CIV_RL_LI2_IN		11	CIV_CP	183		PR	
CIV_RL_LI2_OUT		14		179		PK	
N.C.		12					

11.11 CIV_RELAY_03: Biomass aeration valve

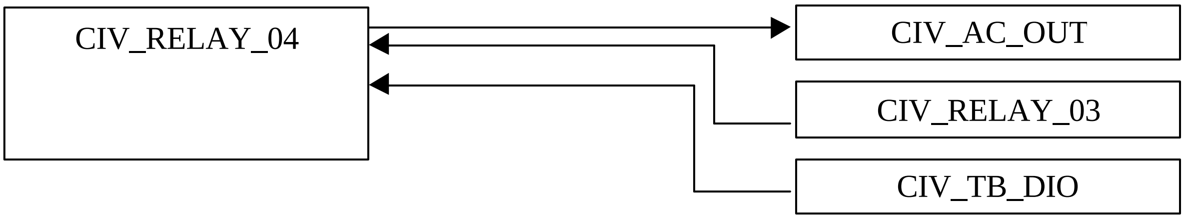
Relay to switch 220 VAC to activate biomass sensor cleaning valve.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_DO_03	CIV_RELAY_03	A1	CIV_TB_DIO	5	24		
24V-		A2	CIV_RELAY_02	A2	20	BK	Activation of electro-valve for cleaning the biomass sensor
AC L		11	CIV_AC_MGTH2	2		BR	
CIV_RL_Cx_L		14	CIV_AC_OUT	2		BR	
N.C.		12					

11.12 CIV_RELAY_04: Safety pressure valve

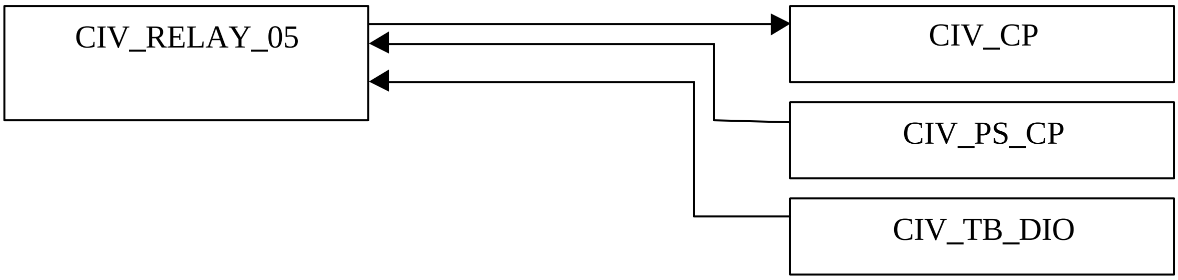
Relay to switch 220 VAC to activate pressure safety valve.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_DO_04	CIV_RELAY_04	A1	CIV_TB_DIO	7	24		
24V-		A2	CIV_RELAY_03	A2	20	BK	Activation of the pressure safety valve
AC L		11		11		BR	
CIV_RL_Fg_L		14	CIV_AC_OUT	8		BR	
N.C.		12					

11.13 CIV_RELAY_05: Not used

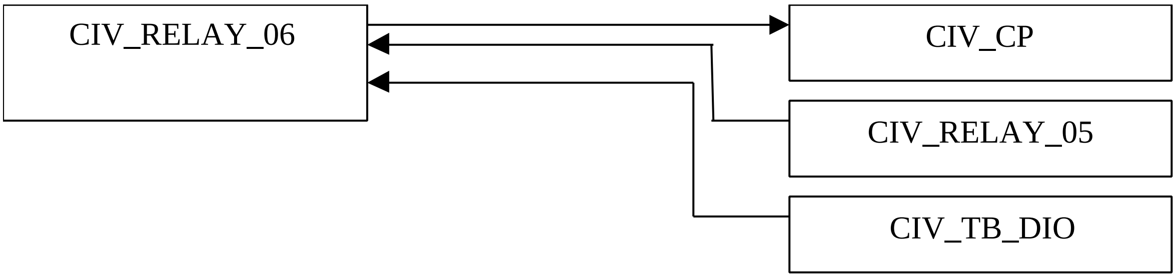
Relay not used.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_DO_05	CIV_RELAY_05	A1	CIV_TB_DIO	11	24		
24V-		A2	CIV_RELAY_04	A2	20	BK	
Not used		11	CIV_CP	191		RD	
Not used		14		187		RD/BL	
N.C.		12					

11.14 CIV_RELAY_06: Not used

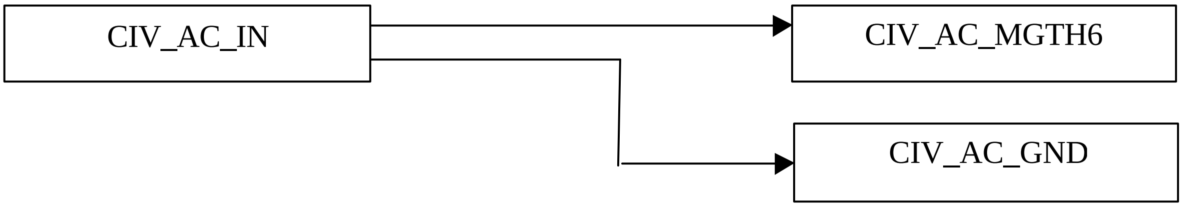
Relay not used.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_DO_06	CIV_RELAY_06	A1	CIV_TB_DIO	13	24		
24V-		A2	CIV_RELAY_05	A2	20	BK	Activation of the liquid input pump 2
Not used		11	CIV_CP	199		WH/GN	
Not used		14		195		GY/PK	
N.C.		12					

11.15 CIV_AC_IN: Input 220 VAC power

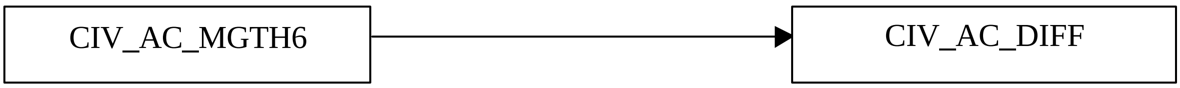
External AC Power input connector.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIV_AC_IN	2	CIV_AC_MGTH6	1	20	BR	
AC N		4		3		BL	
AC GND		6	CIV_AC_GND	1		YL/GN	

11.16 CIV_AC_MGTH6: Over current protection at 6 A

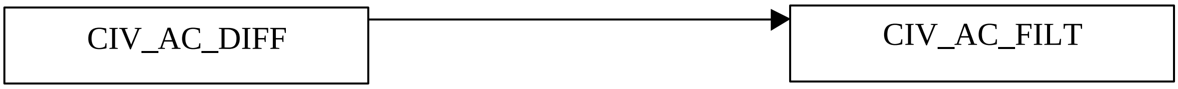
Magnetothermic, over current protection at 6 A.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIV_AC_MGTH6	2	CIV_AC_DIFF	1	20	BR	
AC N		4		3		BL	

11.17 CIV_AC_DIFF: Current leaks protector

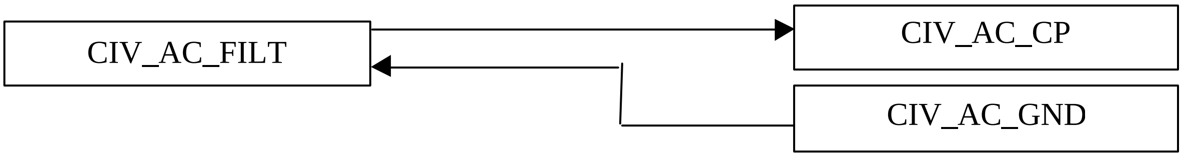
Current leaks protector.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIV_AC_DIFF	2	CIV_AC_FILT	1	20	BR	
AC N		4		3		BL	

11.18 CIV_AC_FILT: AC Filter

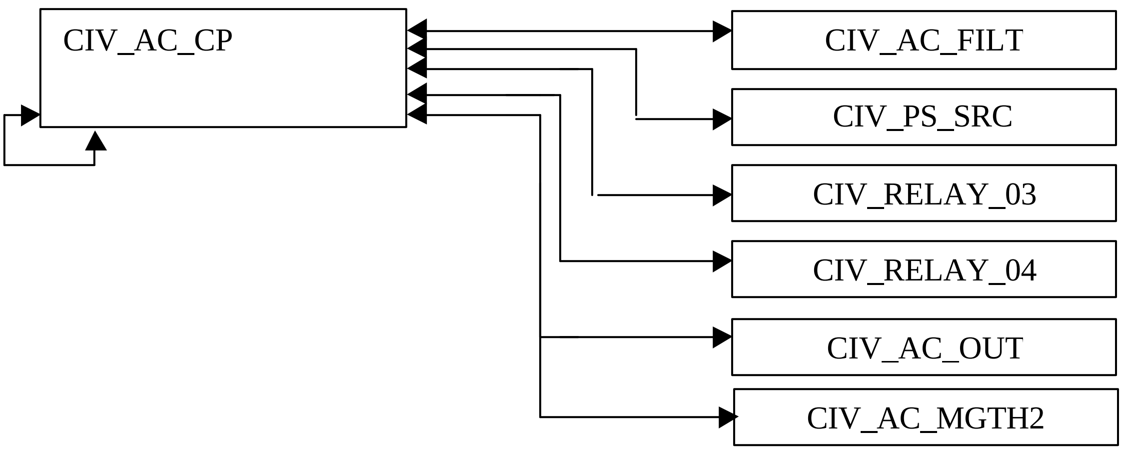
AC filter.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
GND	CIV_AC_FILT	2	CIV_AC_GND	2	20	YL/GN	
AC L		4	CIV_AC_CP	1		BR	
				5		BR	
				9		BR	
				13		BR	
AC N		5		3		BL	
				7		BL	
				11		BL	
				15		BL	

11.19 CIV_AC_CP: AC Connection Panel

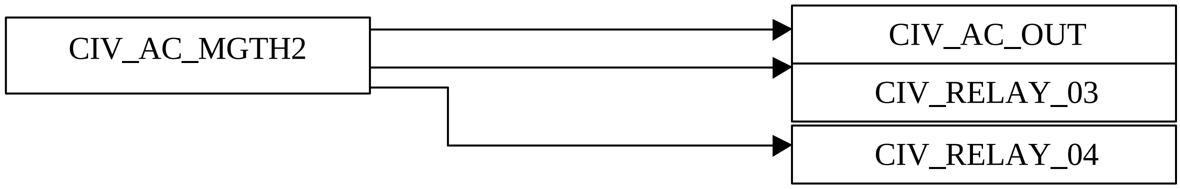
AC connection panel to distribute AC into the rack.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIV_AC_CP	2	CIV_AC_OUT	14		BR	
AC N		4		16		BL	
AC L		6	CIV_UPS	1		BR	
AC N		8		3		BL	
AC L		10	CIV_PS_SRC	3		BR	
AC N		12		2		BL	
AC L		14	CIV_MGTH2	1		BR	
AC N		16		3		BL	

11.20 CIV_AC_MGTH2: Over current protection at 2 A

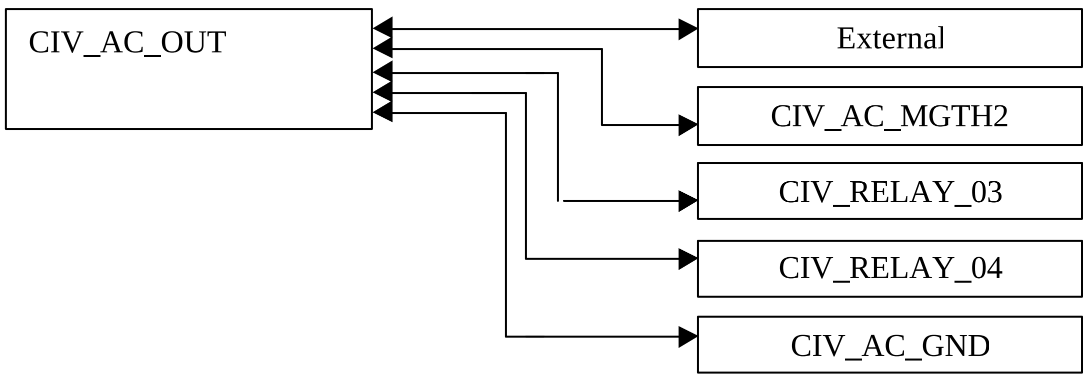
Magnetothermic, over current protection at 2 A.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIV_AC_MGTH2	2	CIV_RELAY_03	11		BR	
			CIV_RELAY_04	11		BR	
AC N		4	CIV_AC_OUT	4		BL	
				10		BL	

11.21 CIV_AC_OUT: 220 VAC Out Connection Panel

AC connector to provide relay commuted power to external devices.

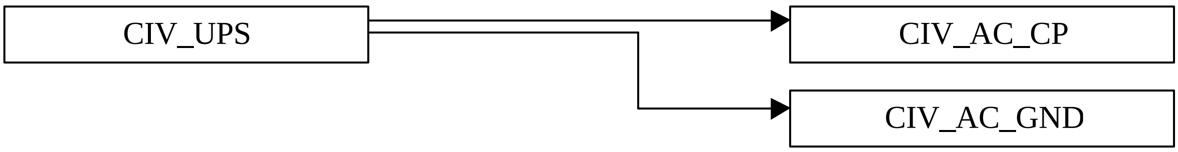


SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIV_AC_OUT	1	CIV_AC_Cx		20	BR	Cleaning biomass sensor
AC N		3				BL	
AC GND		5				YL/GN	
AC L		7	CIV_AC_Fg			BR	Pressure valve activation
AC N		9				BL	
AC GND		11				YL/GN	
AC L		13	CIV_FAN			BR	Rack Fans
AC N		15				BL	
AC GND		17				YL/GN	

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L		2	CIV_RELAY_03	14		BR	
AC L		8	CIV_RELAY_04	14		BR	
AC N		4	CIV_AC_MGTH2	6		BL	
AC N		10				BL	
GND		6	CIV_AC_GND	6		YL/GN	
		12		7		YL/GN	
		18		8		YL/GN	
AC L		14	CIV_AC_CP	2		BR	
AC N		16		4		BL	

11.22 CIV_AC_UPS: Uninterrupted Power Supply

Uninterrupted Power Supply to provide continuous power to the PLC.



SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
AC L	CIV_AC_UPS	4	CIV_PLC_CPS	5	20	BR	
GND		5		7		GN/YL	
AC N		6		6		BL	
AC N		1	CIV_AC_CP	4		BR	
AC L		3		2		BL	
GND		2	CIV_AC_GND	4		GN/YL	

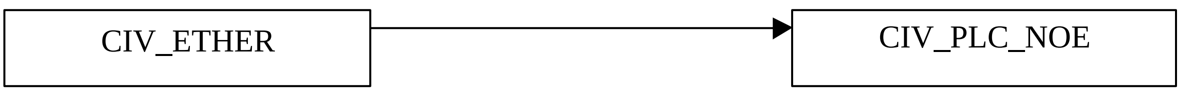
11.23 CIV_AC_GND: Metallic Strip to Distribute Ground

GND strip bar to distribute ground into the rack.

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
GND	CIV_AC_GND	1	CIV_AC_IN	6	20	YL/GN	
		2	CIV_AC_FILT	2			
		3	CIV_PS_SRC	1			
		4	CIV_AC_UPS	2			
		5	CIV_PLC_CPS	7			
		6	CIV_AC_OUT	6			
		7		12			
		8		18			

11.24 CIV_ETHER: Ethernet Connector

Ethernet connector to provide network connection to the PLC.



Connector name:		Type:		Features:	
CIV_ETHER_1		RJ45			
Connectors pin out					
Pin Num	Signal	Signal type	Circuit Class	Remarks	Description
1	Ethernet TX+	Ethernet	RF	IEEE 802.3 I 10-BASE-T Ethernet/ IEEE 802.3 u 100-BASE-Tx Ethernet. Automatic sensing	Ethernet channel TX
2	Ethernet RX Shield				
3	Ethernet RX+	Ethernet	RF		Ethernet channel RX
4	Ethernet RX-	Ethernet	RF		Ethernet channel RX
5	Ethernet TX-	Ethernet	RF		Ethernet channel TX
6	Ethernet TX Shield				

11.25 CIV_CP: External Signals Connection Panel

The following table provides the connection from the CIV_RACK output connector CIV_CP to the external sensors / actuators related to CIV.

It is assumed that the plant (under UAB's responsibility) shall provide cables/connectors properly labeled with the mnemonics identified in the TO column of this table. For clarity sake, these mnemonics coincide with the I/O signal denominations defined in **8.3.1.1**.

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_AI_01+	CIV_CP	001	CIV_MV_CxAbs		24		Biomass sensor
CIV_AI_01-		005					
CIV_AI_02+		009	CIV_MV_M1				Scale 1
CIV_AI_02-		013					
CIV_AI_03+		017	CIV_MV_M2				Scale 2
CIV_AI_03-		021					
CIV_AI_04+		025	CIV_MV_P				Pressure sensor
CIV_AI_04-		029					
CIV_AI_05+		033	CIV_MV_pH				pH sensor
CIV_AI_05-		037					
CIV_AI_06+		041	CIV_MV_T				Temperature sensor
CIV_AI_06-		045					
CIV_AI_07+		049	CIV_MGO_O2				O2 gas sensor
CIV_AI_07-		053					
CIV_AI_08+		057	CIV_MGO_CO2				CO2 gas sensor
CIV_AI_08-		061					
CIV_AI_09+		065	CIV_MV_DO				Dissolved Oxygen sensor
CIV_AI_09-		069					
CIV_AI_10		073	Not used				
CIV_AI_10-		077					
CIV_AI_11		081	Not used				
CIV_AI_11-		085					
CIV_AI_12		089	Not used				
CIV_AI_12-		093					
CIV_AI_13		097	CIV_MGI_FrGas				Flowmeter air input
CIV_AI_13-		101					
CIV_AI_14		105	CIV_MGO_FrGas				Flowmeter gas output
CIV_AI_14-		109					
CIV_AI_15		113	CIV_MV_FrCO2				CO_2 flowmeter
CIV_AI_15-		117					
CIV_AI_16		121	CIV_MV_FrGas				Flowmeter compartment input
CIV_AI_16-		125					
CIV_AO_01+		129	CIV_SP_CO2				CO_2 flow regulator
CIV_AO_01-		133					
CIV_AO_02+		137	CIV_SP_Fgi				Compartment input flow regulator
CIV_AO_02-		141					
CIV_AO_03+		145	CIV_SP_Fgo				Gas output flow regulator
CIV_AO_03-		149					

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
CIV_AO_04+		153	CIV_SP_Fgex				Air input flow regulator
CIV_AO_04-		157					
CIV_AO_05+		161	CIV_SP_Li1				Liquid input pump1
CIV_AO_05-		165					
CIV_AO_06+		169	CIV_SP_Li2				Liquid input pump2
CIV_AO_06-		173					
CIV_AO_07+		177	CIV_SP_LO				Liquid output pump
CIV_AO_07-		181					
CIV_AO_08+		185	Not used				
CIV_AO_08-		189					
24V+		193	CIV_SP_Bs				Base pump
CIV_AO_09-		197					
24V+		201	CIV_SP_Ls				Light regulator
CIV_AO_10-		205					
24V+		209	CIV_SP_Ac				Acid pump
CIV_AO_11-		213					
24V+		2	Not used				
CIV_AO_12-		6					
24V+		10	Not used				
CIV_AO_13-		14					
24V+		18	Not used				
CIV_AO_14-		22					
24V+		26	Not used				
CIV_AO_15-		30					
24V+		34	Not used				
CIV_AO_16-		38					
24V+		42	CIV_CAL_CO2O2				CO2/O2 sensor calibration indicator
CIV_DI_01		46					
24V+		50	CIV_ERR_CO2O2				CO2/O2 sensor error indicator
CIV_DI_02		54					
24V+		58	CIV_SCL1_CO2O2				CO2/O2 sensor scale1 indicator
CIV_DI_03		62					
24V+		66	CIV_SCL2_CO2O2				CO2/O2 sensor scale2 indicator
CIV_DI_04		70					
24V+		74	Not used				
CIV_DI_05		78					
24V+		82	Not used				
CIV_DI_06		86					
24V+		90	Not used				
CIV_DI_07		94					
24V+		98	Not used				
CIV_DI_08		102					
24V+		106	Not used				
CIV_DI_09		110					
24V+		114	Not used				
CIV_DI_10		118					
24V+		122	Not used				
CIV_DI_11		126					
24V+		130	Not used				
CIV_DI_12		134					
24V+		138	Not used				
CIV_DI_13		142					
24V+		146	Not used				
CIV_DI_14		150					
24V+		154	Not used				
CIV_DI_15		158					
24V+		162	Not used				
CIV_DI_16		166					
RELAY_01		170	CIV_RL_LI1				Enable liquid input pump1
RELAY_01		174					
RELAY_02		178	CIV_RL_LI2				Enable liquid input pump2
RELAY_02		182					
RELAY_05		186	Not used				
RELAY_05		190					
RELAY_06		194	Not used				
RELAY_06		198					
CIV_DO_07		202	Not used				

SIGNAL	FROM	PIN	TO	PIN	AWG	COLOR	NOTES
24V-		206					
CIV_DO_08		210	Not used				
24V-		214					
24V+		003	CIV_CP	011			
24V+		011		019			
24V+		019		027			
24V+		027		035			
24V+		035		043			
24V+		043		051			
24V+		051		059			
24V+		067		075			
24V+		075		083			
24V+		083		091			
24V+		091		099			
24V+		099		107			
24V+		107		115			
24V+		115		123			
24V+		131		139			
24V+		129		147			
24V+		147		155			
24V+		155		163			
24V+		163		196			
24V+		196		204			
24V+		204		212			

12 APPENDIX D: Wire Color Codes

BL	Blue
BK	Black
BR	Brown
GN	Green
GY	Grey
PK	Pink
PR	Purple
RD	Red
WH	White
YL	Yellow

13 APPENDIX E: Parts List

Item	N.	Reference	Manufacturer	Description
MEL_SUPV_CLI01	1	Dell OptiPlex GX260 P4 1.8 GHz	Dell	P4 1.8 GHz, 1 IDE disk 40 GB, 512 MB RAM, 1Floppy, 1 CD-ROM Monitor 17'', keyboard, mouse, Windows XP Professional
MEL_SUPV_RACK	1	7801000	Rittal	Server enclosure based on Rittal flexRack 625x600x800 mm
MEL_SUPV_SERV01	1	Dell PowerEdge 2600	Dell	PC Server Rack mounted, Xeon 2.0 GHz. 1GB RAM, 2 SCSI disks 36GB raid 3, 1 Floppy, 1 CD-ROM, 1 Tape, MS Windows 2000 Server, Monitor 17'', keyboard, mouse.
MEL_SWITCH_01	2	3Com Super Stack 3	3Com	16 x 10/100 Mbps Standard RJ45 Ethernet ports
CIII_RACK	1	7820600	Rittal	Top Enclosure System TS 8 with glass frontal door 600x1800x600 mm + mounting board
CIV_RACK	1	7820600	Rittal	Top Enclosure System TS 8 with glass frontal door 600x1800x600 mm + mounting board
CIII_PLC	1	140XTS01000	Schneider	10 slots back plane
	1	140CPS11420	Schneider	Summable Power supply 11 A
	1	140NOE77101	Schneider	Ethernet processor 10/100 TCP/IP
	1	140CPU43412A	Schneider	CPU 2 MB RAM/896 K CONCEPT
	1	140DDI84100	Schneider	ISOLATED 16 DIGITAL INPUTS 10-60VCC MODULE
	1	140DDO84300	Schneider	ISOLATED 16 DIGITAL OUTPUTS 1- 60VCC MODULE
	1	140ACO0200	Schneider	4 ANALOG CURRENT OUTPUTS MODULE
	1	140AVO0200	Schneider	4 ANALOG VOLTAGE OUTPUT MODULE
	1	140ACI04000	Schneider	16 CURRENT ANALOG INPUTS MODULE
CIV_PLC	1	140XTS01000	Schneider	10 slots back plane
	1	140CPS11420	Schneider	Summable Power supply 11 A
	1	140NOE77101	Schneider	Ethernet processor 10/100 TCP/IP
	1	140CPU43412A	Schneider	CPU 2 MB RAM/896 K CONCEPT
	1	140ACI03000	Schneider	8 ANALOG CURRENT INPUTS MODULE
	1	140AVI03000	Schneider	8 ANALOG VOLTAGE INPUTS MODULE
	1	140AVO02000	Schneider	4 ANALOG VOLTAGE OUTPUTS MODULE
	1	140ACO13000	Schneider	8 ANALOG CURRENT OUTPUTS MODULE
	1	140DDM39000	Schneider	16 DIGITAL INPUTS 8 OUTPUTS MODULE
CIII_TB	6	140XTS00206	Schneider	CableFast cable with Quantum connector
	6	140CFA04000	Schneider	CableFast connection blocks
CIV_TB	5	140XTS00206	Schneider	CableFast cable with Quantum connector
	5	140CFA04000	Schneider	CableFast connection blocks
CIII_CP	96	ZFKK 1,5-MSTBV-5,08	Phoenix-Contact	Double density terminal block (24-14 AWG, 12 A, 250 V)
	48	MVSTBR 2,5/2 ST / 17 92 01 6	Phoenix-Contact	Two pin pluggable connectors
CIV_CP	108	ZFKK 1,5-MSTBV-5,08	Phoenix-Contact	Double density terminal block (24-14 AWG, 12 A, 250 V)
	54	MVSTBR 2,5/2 ST / 17 92 01 6	Phoenix-Contact	Two pin pluggable connectors
CIII_PS_SRC	1	ABL7RE2405	Schneider	Commuted Power Supply 5 A
CIV_PS_SRC	1	ABL7RE2405	Schneider	Commuted Power Supply 5 A
CIII_PS_CP	14	UK 1,5N	Phoenix-Contact	Universal terminal block with screw connection, cross section: 0.14 - 1.5 mm², width: 4.2 mm, color: gray
CIV_PS_CP	15	UK 1,5N	Phoenix-Contact	Universal terminal block with screw connection, cross section: 0.14 - 1.5 mm², width: 4.2 mm, color: gray
CIII_AC_CP	8	UK 3N	Phoenix-Contact	Universal terminal block with screw connection, cross section: 0.2 - 2.5 mm², AWG: 28 - 12, width: 5.2 mm, color: gray
CIV_AC_CP	8	UK 3N	Phoenix-Contact	Universal terminal block with screw connection, cross section: 0.2 - 2.5 mm², AWG: 28 - 12, width: 5.2 mm, color: gray
CIII_AC_OUT	21	UK 3N	Phoenix-Contact	Universal terminal block with screw connection, cross section: 0.2 - 2.5 mm², AWG: 28 - 12, width: 5.2 mm, color: gray
CIV_AC_OUT	9	UK 3N	Phoenix-Contact	Universal terminal block with screw connection, cross section: 0.2 - 2.5 mm², AWG: 28 - 12, width: 5.2 mm, color: gray
CIII_AC_IN	3	UK 3N	Phoenix-Contact	Universal terminal block with screw connection, cross section: 0.2 - 2.5 mm², AWG: 28 - 12, width: 5.2 mm, color: gray
CIV_AC_IN	3	UK 3N	Phoenix-Contact	Universal terminal block with screw connection, cross section: 0.2 - 2.5 mm², AWG: 28 - 12, width: 5.2 mm, color: gray
CIII_AC_DIFF	1	CD748M	Hager	Differential current break at 30 mA
CIV_AC_DIFF	1	CD748M	Hager	Differential current break at 30 mA
CIII_AC_MGTH6	1	C60N/C6	Merlin Gerin	Magnetothermic 6 Amp
CIV_AC_MGTH6	1	C60N/C6	Merlin Gerin	Magnetothermic 6 Amp
CIII_AC_FILT	1	YK06T1	Yunpen	Standard AC input filter
CIV_AC_FILT	1	YK06T1	Yunpen	Standard AC input filter
CIII_AC_UPS	1	POWERSTACK 250 VA	APC	Uninterrupted Power Supply, 250 VA, 165 Watts, 230 Vin/Vout 50/60 Hz
CIV_AC_UPS	1	POWERSTACK 250 VA	APC	Uninterrupted Power Supply, 250 VA, 165 Watts, 230 Vin/Vout 50/60 Hz

Item	N.	Reference	Manufacturer	Description
CIII_AC_MGTH2	1	C60N/C2	Merlin Gerin	Magnetothermic 2 Amp
CIV_AC_MGTH2	1	C60N/C2	Merlin Gerin	Magnetothermic 2 Amp
CIII_AC_GND	1	7113.000	Rittal	Ground metal strip
CIV_AC_GND	1	7113.000	Rittal	Ground metal strip
CIII_RELAY	10	EMG 10-REL/KSR-G 24	Phoenix-Contact	Relay module, with soldered-in miniature switching relay, contact (AgCdO): medium to large loads, 1 PDT, input voltage 24 V DC
CIV_RELAY	6	EMG 10-REL/KSR-G 24	Phoenix-Contact	Relay module, with soldered-in miniature switching relay, contact (AgCdO): medium to large loads, 1 PDT, input voltage 24 V DC
CIII_ETHER	1	27898-31	Simon	DIN guide adapter
	1	75542	Simon	Lucent & ATT modular RJ-45 Cat-5 connector.
CIV_ETHER	1	27898-31	Simon	DIN guide adapter
	1	75542	Simon	Lucent & ATT modular RJ-45 Cat-5 connector.
HMI	1	XBTF034610	Schneider	TER. TFT C 10 Touch-screen PENTIUM ETHERNET
Supervision SW	1	iFix 3.0 / Blind server	Intellution	SCADA blind server
	1	iFix 3.0 / Development client	Intellution	SCADA development client
PLC programming	1	372SPU47101V25	Schneider	Concept 2.6
HMI programming	1	XBTL1003S	Schneider	KIT SOFT CD PROT -S- CABLES ESP

(*) Marked elements are parts of CIII and CIV racks.

14 APPENDIX F: Expansion capabilites

14.1 CIII Rack expansion capabilities

The Compartment III rack allows the following expansion capabilities:

- Available signals (initially not used):

Number	Type	Electrical Range	Location
6	Analog Inputs	4-20 mA	AI 11 – AI 16
1	Analog Output	0 – 5 V	AO 04
11	Digital Inputs	N/A	DI 05 – DI 16
6	Digital Outputs	0 – 24 V	DO 11 – DO 16

- 2 Available relays: RELAY_01 and RELAY_02
- 2 free slot in the PLC back plane
- Space in the mounting board to allocate a second back plane of 6 slots.
- Space in the rack to mount a secondary mounting board placed in front of the current.

14.2 CIV Rack expansion capabilities

The Compartment IV rack allows the following expansion capabilities:

- Available signals (initially not used):

Number	Type	Electrical Range	Location
3	Analog Inputs	4-20 mA	AI 10 – AI 12
1	Analog Output	0 – 5 V	AO 08
12	Digital Inputs	N/A	DI 05 – DI 16
5	Digital Outputs	0 – 24 V	DO 05 – DO 08

- 2 Available relays: RELAY_05 and RELAY_06
- 1 free slot in the PLC back plane
- Space in the mounting board to allocate a second back plane of 6 slots.
- Space in the rack to mount a secondary mounting board placed in front of the current.

15 APPENDIX G: RBT Compliance

Following considerations have been taken into account to be compliant with the Spanish *Reglamento Electrotécnico de Baja Tensión, RBT* (Low Voltage Equipments Regulation).

The Melissa Control System Demonstrator racks can be classified as Receivers. Therefore RBT's instruction MI BT 031 for Receiver General Prescriptions is applicable. This instruction has references to instructions MI BT 017, MI BT 020 and MI BT 021.

MI BT 031

- The system has been designed according to the location and environmental conditions in the UAB's Pilot Plant, according to the norm.
- The classification of the racks is Class I: System is provided with a ground connection to the installation and metallic parts are connected to the ground.
- Isolation has been successfully tested to 1500 V during 1 minute.
- Utilization conditions are referenced into MI BT 017 (indicated above).
- System has been labeled and detailed design documentation is provided.

MI BT 017

- Sections of conductors are dimensioned according to the regulations.
- AC line has been divided into two separated sections, the AC input section and the AC output section. A bipolar switch separates them. Power to the PLC is provided through an UPS connected to the AC input line.
- System can be switched off by an unipolar switch at the input.
- Measures to protect direct or indirect contacts are Class B: Ground elements are connected to installation ground. System is switched off by default intensity (MI BT 021).

MI BT 020

- Installation is protected over current by a magnetothermic of 6 Amp at AC input (before Differential) and a magnetothermic of 2 Amp at AC output (before AC output connectors).
- Differential at 50 mA is located at system AC input (unipolar switch) to interrupt power in case of current leak.

MI BT 021

- Measures to protect direct or indirect contacts are Class B: Ground elements are connected to installation ground. System is switched off by default intensity.

MELISSA

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Control System Demonstrator
Software Design Document

Version: 1

Issue: 1

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Version	Issue	Date	Observations
1	0	23 Feb ‘04	First version for ESA review
1	1	28 Jul ‘04	ESA comments dated 21/07/04 implemented

TABLE OF CONTENTS

1 SCOPE

This document describes de design of the software that will be implemented to test the Control System Demonstrator hardware, designed based on the architecture proposed in [A4] and built as described in [R7], for the MELISSA Pilot Plant placed at UAB premises, and in particular, to upgrade current compartment III and IV control system.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**.TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.
[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.
[A3] **Memorandum of Understanding between the UAB and NTE S.A.** MEL-0000-SP-007-NTE. Version 1. Issue 0. 21 January 2002.
[A4] **MELISSA Control System Architecture and Trade-off**. TN 72.3. Version 1. Issue 0. December 2002.

2.2 Reference Documents

[R1] **Definition of the control requirements for the MELISSA Loop**. TN 72.2, v.1.2, November 2002 (MEL-3100-SP-010-NTE).
[R2] **Photoheterotrophic Compartment Set-up.** TN 37.6. UAB, February 1998.
[R3] **Nitrifying Compartment Studies.** TN 25.310. UAB, September 1996.
[R4] **Set-up of the Photosynthetic Pilot Reactor.** TN. 37.2. UAB, April 1998.
[R5] **Spirulina Controller.** TN 72.3.1, v. 1.0, ADERSA, March 2003.
[R6] **Nitrite Controller.** TN 72.3.2, v. 1.1, ADERSA, October 2003.
[R7] **Control System Demonstrator Hardware Design Document.** TN 72.4 Volume IIa, v.1.1, July 2004 (MEL-3320-RP-020-NTE).

3 ACRONYMS LIST

DO	Dissolved Oxygen
FGB	Function Block Diagram
HDD	Hardware Design Document
HMI	Human Machine Interface
PID	Proportional, Integration, Derivative
PLC	Programmable Logic Controller
SCADA	Supervisory Control And Data Acquisition
SDD	Software Design Document
TC	Test Case
TP	Test Procedure
UAB	Universitat Autònoma de Barcelona

4 INTRODUCTION

This document describes the software design of the Control System demonstrator to be installed at the MELISSA Pilot Plant (UAB's premises).

This demonstrator has been designed as to permit the verification of some key aspects of the new MELISSA Control System Architecture described in [A4]. The aspects to be verified as previously agreed with ESA, are the following:

- In-plant verification of the Control law for the *Spirulina* compartment (variables, loops etc.) with the new control HW.
- In-plant verification of the Control law for the Nitrifying compartment. (Variables, loops etc.) with the new control HW.
- Non-nominal tests to verify alarm management

These verification objectives are to be developed in a specific Test Plan and Procedure that NTE will produce in co-ordination with the UAB (E) and SHERPA (F).

Based on these verification objectives NTE proposed for implementation the Control System demonstrator for compartments CIII and CIV shown in Figure 1.

4.1 SW Configuration

The Control System Demonstrator presents the following SW configuration:

- Local Control SW, consisting of PLC programs implemented using Concept 2.6 SW (by Schneider), running over Schneider's Modicon Quantum PLCs.
- Master Control SW, implemented using the iFix 3.0 Supervision SW (by Intellution) and running in the Supervision Server platform (Dell's PowerEdge).
- Dedicated Supervision (SCADA) SW, implemented using iFix 3.0 Supervision SW (by Intellution) and running in both, the Supervision Server platform and the Supervision Client platform (Dell's OptiPlex).
- Human Machine Interface (HMI), implemented using the Magelis XBT-L1000 design SW (by Schneider) and running over the HMI touch-screen (Schneider Magelis XBT-F034610).
- Supervision Server running Microsoft® Windows 2000 SP4
- Supervision Client running Microsoft® Windows XP SP1

The purchased SW and corresponding suppliers used in the Control System Demonstrator is summarised in the following list follows:

- Concept 2.6 by Schneider
- IFix 3.0 by Intellution
- XBT-L1000 by Schneider
- Windows 2000 SP4 by Microsoft®
- Windows XP SP1 Microsoft ®

4.2 Document organisation

Chapter 5 defines the Local Control SW implemented on the Quantum PLCs for CIII and CIV, respectively. Sections headed with a label (ex. CIII_PLCSW_pH) describe the SW design item that can be traced to the implementation. Each SW item is explained with the following subsections:

- A textual description of the SW item’s function
- The list and description of the variables involved
- A logical block diagram showing the interrelation and processes between i/p and o/p for that SW item as defined in the SW item’s function description
- Description of the associated alarms, triggering conditions and actions
- Description of the operational modes

Chapter 6 contains the description of the HMI SW running on the HMI touch-screen device and the various displays which build up this software element.

Chapter 7 covers the design of the Master Control SW running on the Supervision Server, which mainly consists on the adaptation of the control laws provided by SHERPA for CIII and CIV, respectively, to the iFix programming environment.

Chapter 8 shows the design of the supervision (SCADA) screens running on the supervision platforms. It first explain the screen layout and then details the Main Display and the various displays associated to CIII and CIV respectively. The Supervision Database is also described.

Finally, chapter 9 describes the network configuration providing the set of IP addresses.

Appendix A contains specific naming conventions for the internal variables used in calculations or to exchange data between PLCs and Supervision.

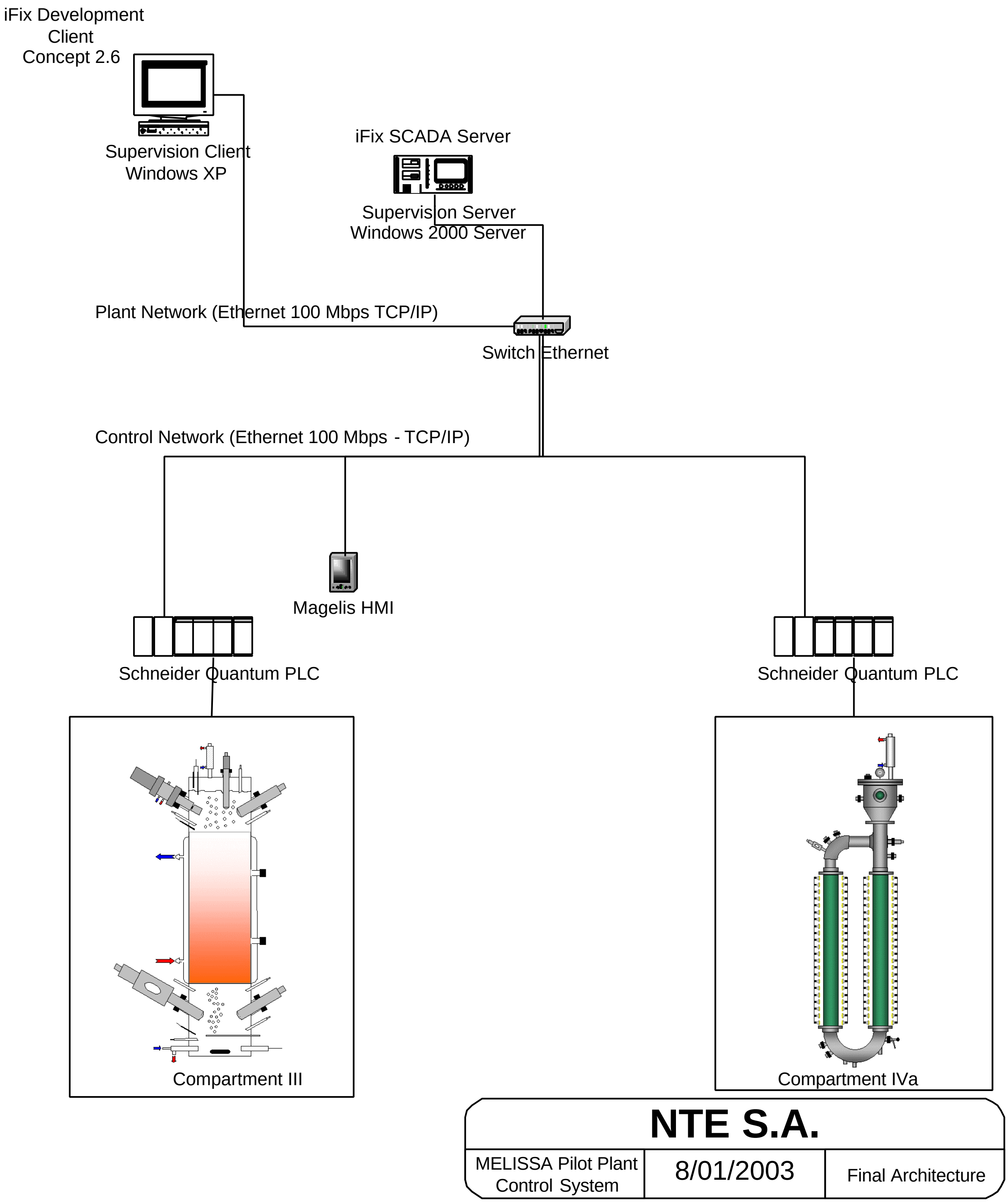


Figure 1. Control System Demonstrator

5 LOCAL CONTROL

Low level control is implemented as a set of loops running in a Quantum PLC.
Each compartment has its own PLC. Therefore a PLC program is developed for each PLC/Compartment. Each program is divided into sections. Each section is dedicated to perform a specific control and/or measurement function.
The design of the PLC programs enforces the flexibility of modification of calibration, PID and scaling parameters from the supervision.

5.1 Target Platform

PLC programs will be developed for the Schneider Quantum PLC using the Concept 2.6 software.
Sections are coded using the IEC standard language FBD (Function Block Diagram).

5.1.1 Memory Allocation

Each system will allocate memory to store system data and control data. System data is the data that allows system status monitoring, and control data is the information regarding each input / output module in the PLC to be shared with the Supervision.

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

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

5.2 CIII_PLC_SW: PLC Software for the Compartment III

This compartment is based on a Nitrifying reactor. The inputs are the liquid output of the compartment II and gas outputs from other compartments via a Buffer Tank. Its main function is to transform Ammonia to Nitrates producing Nitrate in the liquid phase and CO2 in the gas phase.

Following control actions are implemented:
- Regulation of Temperature
- Regulation of pH
- Regulation of DO
- Regulation of Level
- Regulation of Pressure
- Regulation of Nitrates

5.2.1 CIII PLC Configuration

Back plane modules distribution

140CPS11 420	140CPU4 3412A	140NOE7 7101	140ACI04 000	140AVO0 2000	140ACO0 2000	140DDI8 4100	140DDO8 4300	(Free)	(Free)
Backplane Power Supply module	CPU module	Ethernet module	16 Analogue input 4-20 mA	4 Analogue input 0-5 V	4 Analogue output 4-20 mA	16 Digital Inputs 10-60 V	16 Digital Outputs 10-60 V		
1	2	3	4	5	6	7	8	9	10

CPU: Quantum 140CPU43412A

Communications Module: 140NOE77101

PLC I/O Memory map is configured as follows:

Module	**Start Address**	**End Address**
140ACI04000	300100	300116
140AVO02000	400100	400103
140ACO02000	400104	400107
140DDI84100	100065	100080
140DDO84300	000065	000080

- First addresses of each group are reserved for system purposes.
- Variable addresses are specified in following sections.
- 140AVO02000 outputs are disabled in case of failure
- 140ACO02000 outputs are set to the minimum value in case of failure.

5.2.2 CIII PLC Program sections

The PLC program is divided into sections, where each section corresponds to a defined function that manages an independent group of input / outputs.

Section	Description
CIII_PLCSW_Temp	Temperature regulation
CIII_PLCSW_pH	pH regulation
CIII_PLCSW_DO	DO regulation
CIII_PLCSW_Liquid	Liquid flow regulation
CIII_PLCSW_P	Pressure regulation
CIII_PLCSW_N	Nitrates regulation

A brief description of the functionality of each section:

- Temperature is measured from two probes (top and bottom of the reactor). Regulation is performed by activating a Heater or a Cooling valve.
- pH is measured from two probes (top and bottom). Regulation is performed adding CO2/Acid media or base media.
- DO is measured by two probes (top and bottom). Regulation is performed actuating over the O2 input flow. In addition, N2 can be added if DO does not decrease when no O2 is added.
- Liquid level is measured by two contacts positioned in the top of the reactor to indicate low and high level status. In case of low level output pump flow is decreased and in case of high level output pump flow is increased. Initially input and output liquid flows are equal and constant.
- Pressure is measured at top of the reactor. It is regulated actuating over a valve; in case of overpressure this valve is opened to release this excessive overpressure.
- Ammonia/Nitrates control is regulated by actuating over the input liquid flow rate.

5.2.3 CIII PLC Initial values

Following are the values that are loaded into PLC when it is restarted

Name	Description	Initial Value
CIII_CNS_CO2Kp	Additional proportional constant for CO2	5
CIII_CNS_DOBias	Disturbance variable (Feed_fw) for DO PID	0
CIII_CNS_DOKd	Derivative constant for DO PID	0.00083
CIII_CNS_DOKi	Integrative constant for DO PID	0
CIII_CNS_DOKp	Proportional constant for DO PID	1
CIII_CNS_DOramp	DO supervision set point ramp coefficient	0.016
CIII_CNS_LinA	Calibration constant parameter A	73.5294
CIII_CNS_LinB	Calibration constant parameter B	0.1765
CIII_CNS_N2Kp	Proportional constant for N2 regulation	0.5
CIII_CNS_OpModeGas	Gas control operational mode (0=Off, 1=Auto, 2=Manual)	0
CIII_CNS_OpModeL	Liquid control operational mode (0=Off, 1=Auto, 2=Manual)	0
CIII_CNS_OpModepH	pH control operational mode (0=Off, 1=Auto, 2=Manual)	0
CIII_CNS_OpModeT	Temperature control operational mode (0=Off, 1=Auto, 2=Manual)	0
CIII_CNS_pHKi	Integration constant for Acid/Base PI	0

CIII_CNS_pHKp	Proportional constant for Acid/Base PI	8
CIII_CNS_pHMode	PH regulation mode variable (1=CO2 only, 2=CO2+Base, 3=Base+Acid)	2
CIII_CNS_pHramp	pH supervision set point ramp coefficient	0.005
CIII_CNS_Tramp	Temperature supervision set point ramp coefficient	0.0083
CIII_MAN_Ac	Manual acid pump set point	0
CIII_MAN_Bs	Manual base pump set point	0
CIII_MAN_CO2	Manual CO2 flow controller set point	0
CIII_MAN_EnAc	Manual enable of acid pump	0
CIII_MAN_EnBs	Manual enable of base pump	0
CIII_MAN_EnCV	Manual enable of the cooling valve	0
CIII_MAN_EnHT	Manual enable of the heater	0
CIII_MAN_EnP	Manual enable of pressure safety valve	0
CIII_MAN_Lin	Manual liquid input pump set point	0
CIII_MAN_LO	Manual liquid output pump set point	0
CIII_MAN_N2	Manual N2 flow controller set point	0
CIII_MAN_O2	Manual O2 flow controller set point	0
CIII_SSP_DO	DO Supervision set point	80
CIII_SSP_L1in	Level 1 liquid input supervision set point	0
CIII_SSP_P	Pressure supervision set point	80
CIII_SSP_pH	pH supervision set point	8.0
CIII_SSP_T	Temperature supervision set point	28

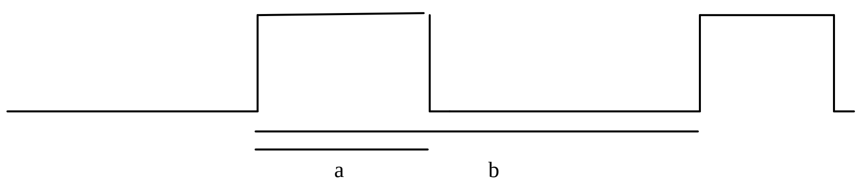
5.2.4 CIII_PLCSW_Temp: Temperature regulation

5.2.4.1 Function

This section regulates the temperature of the reactor. The functions of this section are:

1. Acquire the temperature from top and bottom sensors and calculate the average as 80% bottom and 20% top (0.2top + 0.8bot). Weights can be modified from the supervision.
2. On controller reset or loop mode change, the set point starts on the measured value and reaches the fixed value with a ramp of 0.5/min, this value can be modified from the supervision.
3. Consider a dead band of 0.1 over / 0.5 under the temperature set point.
4. In case of over temperature activate the Cooling valve.
5. In case of under temperature activate Heater with a pulse action with a duration regulated by a proportional (Kp=0.7, max=1, min=0) which output (Prop) sets the pulse period and duration as follows:

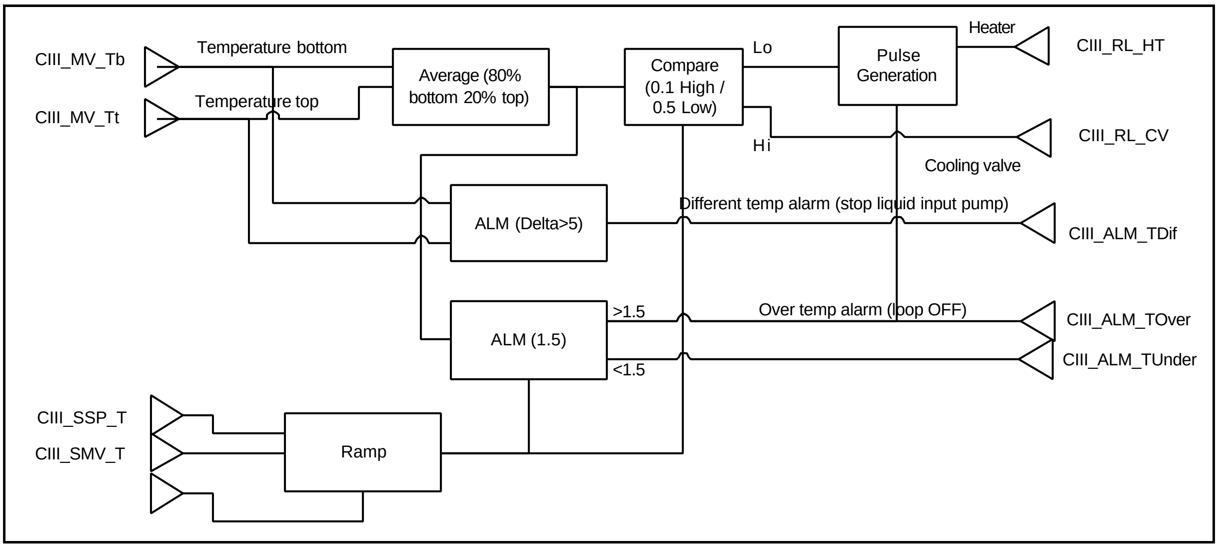
   a = 5 * Prop
   b = 16 * (Prop + 1)   (both values in seconds)



5.2.4.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIII_ALM_Tdif	Alarm of temperature difference between top and bottom	000165		bool	
CIII_ALM_Tover	Over temperature alarm	000166		bool	
CIII_ALM_Tunder	Under temperature alarm	000175		bool	
CIII_ALM_Tbot	Alarm to notify Temperature bottom sensor link error	000177		bool	
CIII_ALM_Ttop	Alarm to notify Temperature top sensor link error	000176		bool	
CIII_CNS_Tramp	Temperature supervision set point ramp coefficient	400556		real	0-100
CIII_CNS_OpModeT	Temperature control operational mode (0=Off, 1=Auto, 2=Manual)	400567		int	1,2,3
CIII_MAN_EnCV	Manual enable of the cooling valve	000192		Bool	0-1
CIII_MAN_EnHT	Manual enable of the heater	000193		Bool	0-1
CIII_MV_Tb	Temperature at bottom	300108	Thermometer	4-20 mA	0.2-147 Cº
CIII_MV_Tt	Temperature at top	300109	Thermometer	4-20 mA	0.2-147 Cº
CIII_RL_CV	Open/close the cooling valve	000084	Cooling valve	0-24 V	0-1
CIII_RL_HT	Activate Heater	000085	Hot finger	0-24 V	0-1
CIII_SMV_T	Temperature scaled measure	400532		real	0.2-147 Cº
CIII_SMV_Tb	Temperature at bottom scaled measure	400608		real	0-150 Cº
CIII_SMV_Tt	Temperature at top scaled measure	400606		real	0-150 Cº
CIII_SSP_T	Temperature supervision set point	400500		real	0-150 Cº

5.2.4.3 Block Diagram



5.2.4.4 Alarms

Alarm condition	Action
Temperature delta between top and bottom > 5	Activate alarm CIII_ALM_TDif and stop liquid input pump.
Temperature 1.5º C over the set point	Activate alarm CIII_ALM_TOver and set Temperature Loop operation mode to OFF.
Temperature 1.5 Cº under the set point	Activate alarm CIII_ALM_TUnder.
Temperature top sensor failure	Set safety value (set point) and notify failure
Temperature bottom sensor failure	Set safety value (set point) and notify failure

5.2.4.5 Operational Modes

Mode	Description	Action
0	Off	Set Heater and Cooling valve outputs to 0
1	Auto	Set outputs from control action
2	Manual	Manual enable/disable Heater and cooling valve

5.2.5 CIII_PLCSW_pH: pH regulation

5.2.5.1 Function

This section controls de pH in the reactor. The regulation can be done in 3 modes:

Mode	Description	CO_2 flow	Base pump	Acid pump
1	Only CO_2 is used to regulate pH	Enabled	Disabled	Disabled
2	CO_2 and Base medium is used to regulate pH.	Enabled	Enabled	Disabled
3	Base and additional Acid media is used to regulate pH.	Disabled	Enabled	Enabled

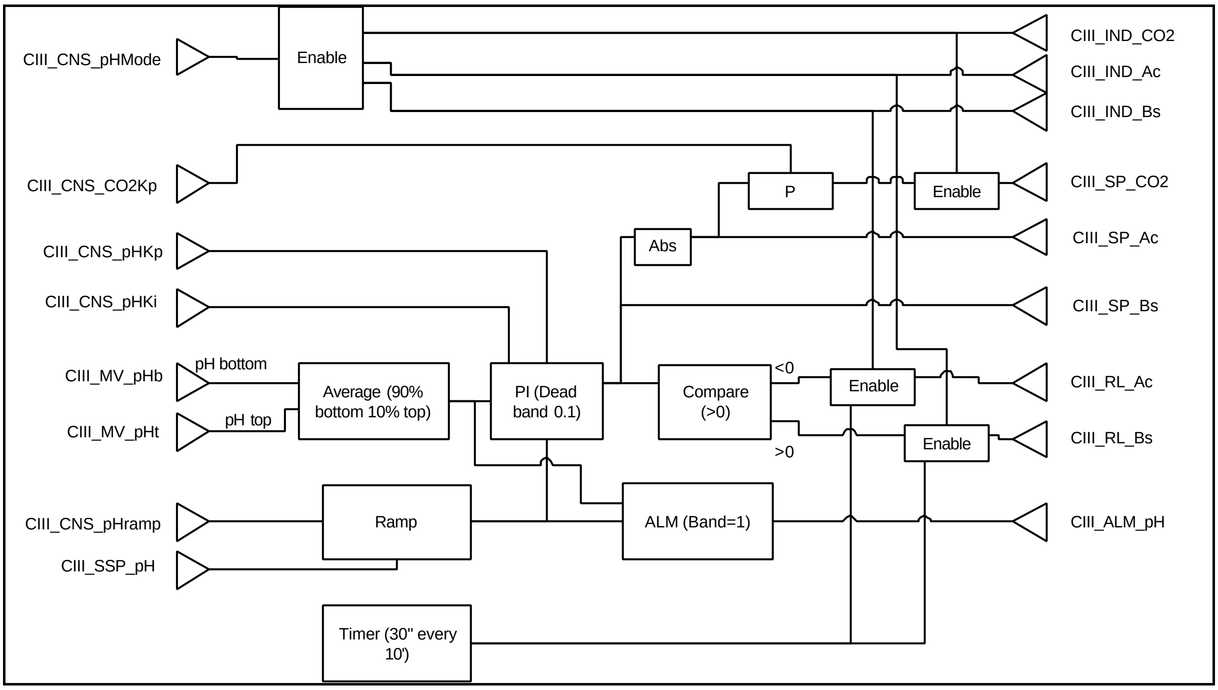
1. Acquire the pH from top and bottom sensors and calculate the average as 90% bottom and 10% top (0.1top + 0.9bot). Weights are provided by the supervision.
2. On controller reset or loop mode change, the set point starts on the measured value and reaches the fixed value with a ramp of 0.3/min, this value can be modified from the supervision.
3. Control action is regulated by a PI with parameters Kp=8, Ki=0. Values can be modified from the Supervision. Control action is only enabled during 30 seconds every 10 minutes.
4. CO_2 is regulated by previous PI, with an additional Kp = 5.0. Value can be modified from the Supervision.
5. In case of pH over the set point actuate with acid pump if enabled or CO_2 if enabled.
6. In case of pH under the set point actuate with base pump if enabled.
7. Consider a dead band of 0.1 (set point=8.0, dead band=7.9-8.1)

5.2.5.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIII_ALM_AcErr	Alarm to notify acid pump link error	000186		bool	
CIII_ALM_BsErr	Alarm to notify base pump link error	000185		bool	
CIII_ALM_pH	Alarm of pH deviation	000167		bool	
CIII_ALM_pHbot	Alarm to notify pH bottom sensor link error	000179		bool	
CIII_ALM_pHtop	Alarm to notify pH top sensor link error	000178		bool	
CIII_CNS_CO2Kp	Additional proportional constant for CO_2	400522		real	0-100
CIII_CNS_OpModepH	pH control operational mode (0=Off, 1=Auto, 2=Manual)	400564		int	0,1,2
CIII_CNS_pHMode	pH regulation mode variable (1= CO_2 only, 2=CO2+Base, 3=Base+Acid)	400569		int	1,2,3
CIII_CNS_pHKi	Integration constant for Acid/Base PI	400510		real	0-100
CIII_CNS_pHKp	Proportional constant for Acid/Base PI	400508		real	0-100
CIII_CNS_pHramp	pH supervision set point ramp coefficient	400560		real	0-100

Name	Description	PLC_Address	Device	Type	Range
CIII_IND_Ac	Enable Acid pump output to regulate pH	000169		bool	
CIII_IND_Bs	Enable Base pump output to regulate pH	000170		bool	
CIII_IND_CO2	Enable CO_2 output to regulate pH	000168		bool	
CIII_MAN_Ac	Manual acid pump set point	400570		real	0-100%
CIII_MAN_Bs	Manual base pump set point	400572		real	0-100%
CIII_MAN_CO2	Manual CO_2 flow controller set point	400574		real	0-100%
CIII_MAN_EnAc	Manual enable of acid pump	000190		Bool	0-1
CIII_MAN_EnBs	Manual enable of base pump	000191		Bool	0-1
CIII_MV_pHb	pH at bottom	300105	pH meter	4-20 mA	3-13
CIII_MV_pHt	pH at Top	300106	pH meter	4-20 mA	1.5-11.5
CIII_RL_Ac	Relay acid pump	000066	Acid pump	0-24 V	0-1
CIII_RL_Bs	Relay base pump	000067	Base pump	0-24 V	0-1
CIII_SMV_pH	pH scaled measure	400534		real	0 - 14
CIII_SMV_Ac	Acid pump control action	400536		real	0-100%
CIII_SMV_Bs	Base pump control action	400538		real	0-100%
CIII_SMV_pHb	Scaled pH value at bottom	400610		Real	3-13
CIII_SMV_pHt	Scaled pH value at top	400592		Real	3-13
CIII_SMV_CO2	CO_2 input flow control action	400540		real	0-100%
CIII_SP_Ac	Acid pump flow regulation	400104	Acid pump	4-20 mA	0-100%
CIII_SP_Bs	Base pump flow regulation	400105	Base pump	4-20 mA	0-100%
CIII_SP_CO2	CO_2 input flow regulation	400100	CO_2 flow controller	0-5 V	0-100%
CIII_SSP_pH	pH supervision set point	400504		real	0-14

5.2.5.3 Block Diagram



5.2.5.4 Alarms

Alarm condition	Action
1 unit of pH over/under set-point during 15'	Activate alarm CIII_ALM_pH.
pH bottom sensor failure	Set safety value measure (nominal set point) and notify failure
pH top sensor failure	Set safety value measure (nominal set point) and notify failure
pH bottom and pH top sensor failure	In case both sensors failed, stop PID action (PID output=0)
Acid pump link failure	Notify failure to Supervision (CIII_ALM_AcErr)
Base pump link failure	Notify failure to Supervision (CIII_ALM_BsErr)

5.2.5.5 Operational Modes

Mode	Description	Action
0	Off	Set acid/base pumps and CO_2 flow controller outputs to 0
1	Auto	Set outputs from control action
2	Manual	Set manual set points to acid/base pumps and flow controller

5.2.6 CIII_PLCSW_DO: DO regulation

5.2.6.1 Function

This section controls the DO (Dissolved Oxygen) in the reactor. The functions of this section are:

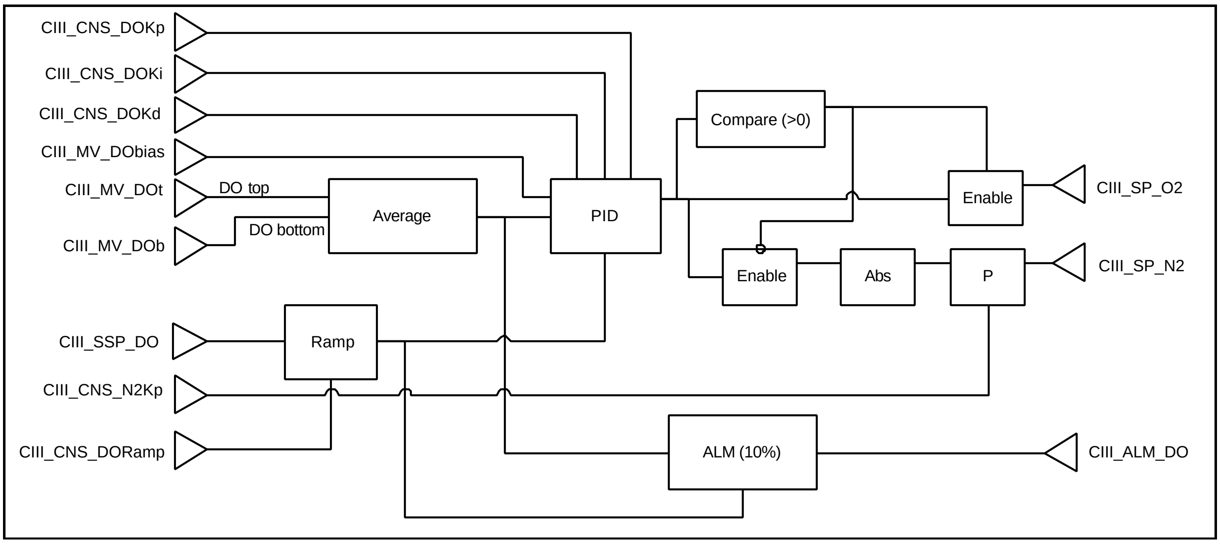
1. Acquire the DO from top and bottom sensors and calculate the average as 50% bottom and 50% top (arithmetical mean).
2. Control action is regulated by a PID with constants Kp=1, Ki=0, Kd=0.00083. Values can be modified from the Supervision.
3. When O_2 valve is completely closed and DO value is over the set point, a control action is performed opening the N_2 valve, action is regulated adding a Kp=0.5 to the output of the O_2 PID.
4. In case of DO over the set point close O_2 valve.
5. In case of DO under the set point open O_2 valve.
6. On controller reset or loop mode change, the set point starts on the measured value and reaches the fixed value with a ramp of 1.0/min, this value can be modified from the supervision.

5.2.6.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIII_ALM_DOTop	Alarm to notify DO top sensor link error	000180		bool	
CIII_ALM_DOBot	Alarm to notify DO bottom sensor link error	000181		bool	
CIII_ALM_DO	Alarm to notify DO is over the set point	000189		bool	
CIII_CNS_DOKp	Proportional constant for DO PID	400512		real	0-100
CIII_CNS_DOKi	Integrative constant for DO PID	400514		real	0-100
CIII_CNS_DOKd	Derivative constant for DO PID	400516		real	0-100
CIII_CNS_DOBias	Disturbance variable (Feed_fw) for DO PID	400518		real	0-100
CIII_CNS_N2Kp	Proportional constant for N_2 regulation	400614		real	0-100
CIII_CNS_OpModeGas	Gas control operational mode (0=Off, 1=Auto, 2=Manual)	400566		int	0,1,2
CIII_CNS_DOramp	DO supervision set point ramp coefficient	400588		real	0-100
CIII_MAN_N2	Manual N_2 flow controller set point	400580		real	0-150%
CIII_MAN_O2	Manual O_2 flow controller set point	400582		real	0-100%
CIII_MV_DOb	DO at bottom	300100	Oxygen analyser	4-20 mA	0-100%
CIII_MV_DOt	DO at top	300101	Oxygen analyser	4-20 mA	0-100%
CIII_SMV_DO	DO scaled measure value	400544		real	0-100%

Name	Description	PLC_Address	Device	Type	Range
CIII_SMV_DObot	DO at bottom scaled measure value	400604		real	0-100%
CIII_SMV_DOtop	DO at top scaled measure value	400602		real	0-100%
CIII_SMV_O2	O_2 input flow control action	400546		real	0-100%
CIII_SMV_N2	N_2 input flow control action	400548		real	0-150%
CIII_SP_O2	O_2 flow regulation	400102	O_2 flow controller	0-5 V	0-100%
CIII_SP_N2	N_2 flow regulation	400101	N_2 flow controller	0-5 V	0-150%
CIII_SSP_DO	DO Supervision set point	400520		real	0-200%

5.2.6.3 Block Diagram



5.2.6.4 Alarms

Alarm condition	Action
In case of DO is a 10% over/under the set-point	Activate alarm CIII_ALM_DO.
DO top sensor failure	Set safety value (nominal set point) and notify failure
DO bottom sensor failure	Set safety value (nominal set point) and notify failure
DO top and DO bottom sensors failure	In case both sensors failed, stop PID action (PID output = BIAS)

5.2.6.5 Operational Modes

Mode	Description	Action
0	Off	Set N_2 and O_2 flow controller outputs to 0 (closed)
1	Auto	Set outputs from control action
2	Manual	Set manual set points to N_2 and O_2 flow controller outputs

5.2.7 CIII_PLCSW_Liquid: Liquid flow regulation

5.2.7.1 Function

This section controls the liquid input/output and liquid level of the reactor. The functions of this section are:

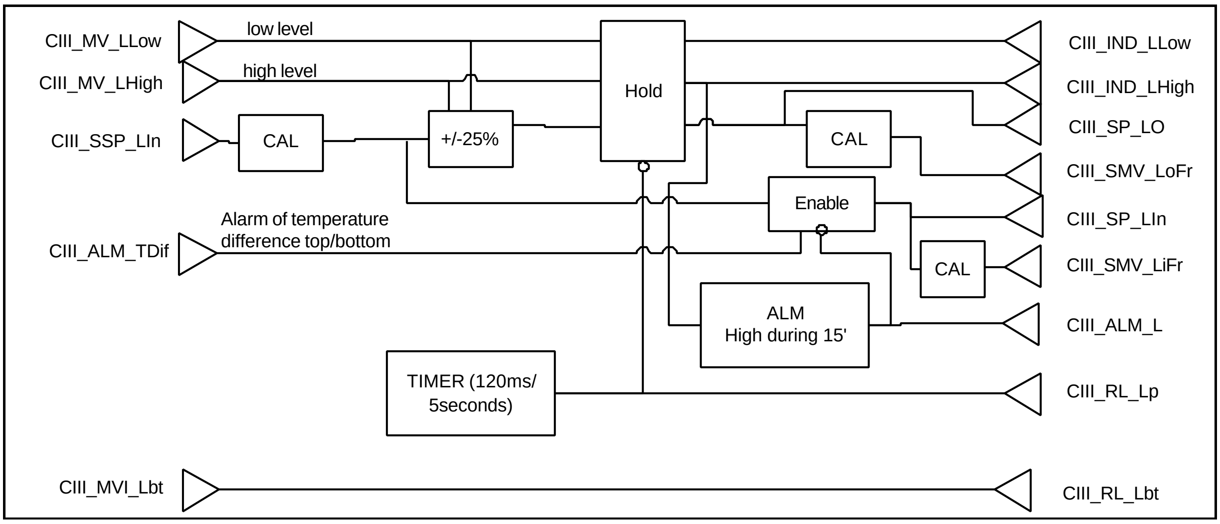
1. Generate a pulse every 5 seconds of 120 ms to enable level sensors
2. Increase output pump a 25% of the input pump set point if level is high.
3. Decrease output pump a 25% of the input pump set point if level is low.
4. Hold output pump set point and low level and high level indicators while pulse is 0.
5. Disable liquid input pump in case Temperature difference alarm is active.
6. When buffer tank at output reaches high level, activate buffer tank output pump.
7. Calculate liquid input pump set point as Ax + B where A, B values are initially A= 73.5294 and B= 0.1765 and x is the Level 1 liquid input supervision set point. These values can be modified from the supervision.

5.2.7.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIII_ALM_L	Alarm of high level	000171		bool	
CIII_ALM_LIErr	Alarm to notify liquid input pump link error	000187		bool	
CIII_ALM_LOErr	Alarm to notify liquid output pump link error	000188		bool	
CIII_CNS_OpModeL	Liquid flow control operational mode (0=Off, 1=Auto, 2=Manual)	400565		int	0,1,2
CIII_CNS_LinA	Input pump calibration constant parameter A	400584		real	0-100
CIII_CNS_LinB	Input pump calibration constant parameter B	400586		real	0-100
CIII_CNS_LoA	Output pump calibration constant parameter A	400598		real	0-100
CIII_CNS_LoB	Output pump calibration constant parameter B	400600		real	0-100
CIII_IND_Llow	Liquid level low indicator	000173		bool	
CIII_IND_Lhigh	Liquid level high indicator	000174		bool	
CIII_MAN_Lin	Manual liquid input pump set point	400576		real	0-100%
CIII_MAN_LO	Manual liquid output pump set point	400578		real	0-100%
CIII_MV_LHigh	Level measurement high	100083	Level sensor 2	0-24 V	0-1
CIII_MV_LLow	Level measurement low	100082	Level sensor 1	0-24 V	0-1
CIII_MVO_Lbt	Indicator of max level reached for a buffer tank	100084	Level sensor	0-24 V	0-1
CIII_RL_Lbt	Activation of the pump for the buffer tank	000065	Pump buffer tank	0-24 V	0-1

Name	Description	PLC_Address	Device	Type	Range
CIII_RL_Lp	Relay to have a pulse in the level sensor lecture	000071	Level sensor	0-24 V	0-1
CIII_SMV_LiFr	Liquid input flow rate	400596		real	0-10 l/h
CIII_SMV_LO	Liquid output flow control action	400550		real	0-100%
CIII_SMV_LoFr	Liquid output flow rate	400594		real	0-10 l/h
CIII_SP_Lin	Liquid input pump flow regulation	400106	Input liquid pump	4-20 mA	0-100%
CIII_SP_LO	Liquid output pump flow regulation	400107	Output liquid pump	4-20 mA	0-100%
CIII_SSP_L1Lin	Level 1 liquid input supervision set point	400524		real	0-10 l/h
CIII_SSP_L2Lin	Level 2 liquid Input supervision set point	400542		real	0-10 l/h

5.2.7.3 Block Diagram



5.2.7.4 Alarms

Alarm condition	Action
In case of level is high during 15'	Activate alarm CIII_ALM_L and disable input pump
Liquid input pump link error	Notify to Supervision (CIII_ALM_LIErr)
Liquid output pump link error	Notify to Supervision (CIII_ALM_LOErr)

5.2.7.5 Operational Modes

Mode	Description	Action
0	Off	Set liquid input/output pump outputs to 0
1	Auto	Set outputs from control action
2	Manual	Set manual set points to liquid input/output pump outputs

5.2.8 CIII_PLCSW_P: Pressure regulation

5.2.8.1 Function

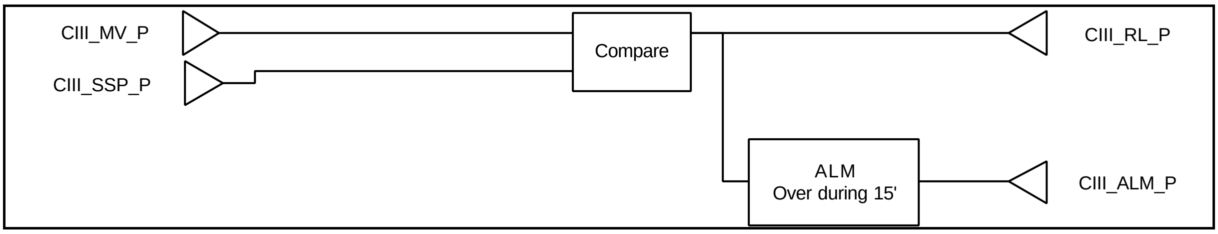
This section controls the pressure of the reactor. The functions of this section are:

1. Acquire pressure value
2. If pressure if over the set point open Pressure Safety Valve.

5.2.8.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIII_ALM_Perr	Alarm to notify Pressure sensor link error	000182		bool	
CIII_ALM_P	Over pressure alarm	000172		bool	
CIII_CNS_OpModeGas	Gas control operational mode (0=Off, 1=Auto, 2=Manual)	400566		int	0,1,2
CIII_MAN_EnP	Manual enable of pressure safety valve	000194		Bool	0-1
CIII_MV_P	Pressure at top of the gas phase	300104	Pressure sensor	0-20 mA	0-1000 mbar
CIII_RL_P	Activation of Pressure Safety Valve	000072	Pressure solenoid valve	0-24 V	0-1
CIII_SMV_P	Pressure scaled measure value	400552		real	0-1000 mbar
CIII_SSP_P	Pressure supervision set point	400526		real	0-1000 mbar

5.2.8.3 Block Diagram



5.2.8.4 Alarms

Alarm condition	Action
In case of over pressure during 15’	Activate alarm CIII_ALM_P
Pressure sensor failure	Set safety value (nominal set point)

5.2.8.5 Operational Modes

Mode	Description	Action
0	Off	Set status of safety pressure valve to open
1	Auto	Set outputs from control action
2	Manual	Set manual enable status to the safety pressure valve

5.2.9 CIII_PLCSW_N: Nitrates acquisition

5.2.9.1 Function

This section acquires the nitrate concentration in the reactor. The functions of this section are:

1. Acquire and scale NO3 value
2. Acquire and scale NH4 value

5.2.9.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIII_ALM_NO3	Alarm to notify NO_3 sensor link error	000183		bool	
CIII_ALM_NH4	Alarm to notify NH_4 sensor link error	000184		bool	
CIII_IND_CalNH4	Analyser calibration indicator	100080	Ammonium analyser	0-24 V	0-1
CIII_IND_CalNO3	Nitrate calibration indicator	100081	NO_3 analyser	0-24 V	0-1
CIII_MV_NH4	Ammonium concentration	300102	Ammonium analyser	4-20 mA	0-155.6 ppm N-NH_4+
CIII_MV_NO3	Nitrate concentration	300103	NO_3 analyser	4-20 Ma	0-1000 ppm N-NO_3 -
CIII_SMV_NH4	Ammonium concentration scaled measure	400528		real	0-200 ppm N-NH_4+
CIII_SMV_NO3	Nitrate concentration scaled measure	400530		real	0-1000 ppm N-NO_3 -
CIII_SMV_NO2	Estimation of NO_2 concentration (calculated by control law)	400612		real	mol/l

5.2.9.3 Alarms

Alarm condition	Action
NO_3 sensor failure	Set safety value 4.2 and notify failure
NH_4 sensor failure	Set safety value 329.0 and notify failure

5.3 CIV_PLCSW: PLC Software for the Compartment IVa

This compartment is based on a Photosynthetic reactor. Its inputs are the liquid phase of the compartment II and the gas outputs of other compartments via a Buffer Tank. The main function of this compartment is to convert Nitrates into edible biomass and CO_2 into O_2. Therefore the outputs are O_2 in the gas phase and edible biomass in the solid phase.

Following control actions are implemented:
- Cleaning of biomass sensor
- Regulation of liquid flow
- Regulation of gas flow
- Regulation of light intensity
- Regulation of pH

5.3.1 CIV PLC Configuration

Back plane modules distribution

140CPS11420	140CPU43412A	140NOE77101	140ACI03000	140AVI03000	140AVO02000	140AVO02000	140ACO02000	140DDM39000	(Free)
Backplane Power Supply module	CPU module	Ethernet module	8 Analogue input 4-20 mA	8 Analogue input 0-5 V	4 Analogue output 0-5 V	4 Analogue output 0-5 V	4 Analogue output 0-20/4-20 mA	16 Digital inputs / 8 Digital outputs 10-60 VCC	
1	2	3	4	5	6	7	8	9	10

CPU: Quantum 140CPU43412A

Communications Module: 140NOE77101

PLC I/O Memory map is configured as following:

Module	Start Address	End Address
140ACI03000	300100	300108
140AVI03000	300109	300117
140AVO02000	400100	400103
140AVO02000	400104	400107
140ACO02000	400108	400115
140DDM39000 / DI	100065	100080
140DDM39000 / DO	000065	000072

- First addresses of each group are reserved for system purposes.
- Variable addresses are specified in following sections.
- 140AVO02000 outputs are disabled in case of failure
- 140ACO02000 outputs are set to the minimum value in case of failure.

5.3.2 CIV PLC Program sections

The PLC program is divided into sections, where each section corresponds to a defined function that manages an independent group of input / outputs.

Section	Description
CIV_PLCSW_Biomass	Acquisition and conditioning of biomass concentration
CIV_PLCSW_Light	Light regulation
CIV_PLCSW_Liquid	Liquid flow regulation
CIV_PLCSW_Gas	Gas flow and pressure regulation
CIV_PLCSW_pH	pH regulation
CIV_PLCSW_T	Temperature acquisition

A brief description of the functionality of each section:

- Biomass concentration acquisition is performed in light attenuation units, to provide biomass concentration in dry weight units (g/l) a conditioning of the value has to be performed. In addition the section includes biomass sensor cleaning logic.
- Light regulation is done in open loop. Control action is adjusted using a mathematical expression deduced from previous experiments.
- Liquid flow is regulated in open loop since no flow meters are available. Liquid input set point is provided from the supervision and output set point is calculated adding a 10%.
- Gas flow is fixed from the supervision. Pressure is maintained adjusting gas input/output into a predefined range. In addition a pressure safety valve opens in case of an overpressure.
- pH regulation is performed using CO_2 and additional base and acid media. Operational mode can be determined from the supervision.
- Temperature regulation is performed externally using a specialised controller. The CIV PLC only acquires the temperature value and sends it to the Supervision.
- Nitrates measurement is not implemented since it is not used at this time.

5.3.3 CIV PLC Initial values

Following are the values that are loaded into PLC when it is restarted

Name	Description	Initial Value
CIV_CNS_AcKp	Acid pump regulator proportional constant for PID	100
CIV_CNS_BsKp	Base pump regulator proportional constant for PID	100
CIV_CNS_CO2Kd	CO2 flow regulator derivative constant for PID	0.01
CIV_CNS_CO2Ki	CO2 flow regulator integration constant for PID	100
CIV_CNS_CO2Kp	CO2 flow regulator proportional constant for PID	5
CIV_CNS_ConvV	Density factor to translate Kg to liters	1
CIV_CNS_DW	Dry Weight conversion factor	1
CIV_CNS_Li1FrA	Parameter A for liquid input pump 1 set-point calculation	18.315
CIV_CNS_Li1FrB	Parameter B for liquid input pump 1 set-point calculation	11.0989
CIV_CNS_Li2FrA	Parameter A for liquid input pump 2 set-point calculation	16.103
CIV_CNS_Li2FrB	Parameter B for liquid input pump 2 set-point calculation	0.8534
CIV_CNS_LoFrA	Parameter A for liquid output pump set-point calculation	15
CIV_CNS_LoFrB	Parameter B for liquid output pump set-point calculation	1
CIV_CNS_MaxPress	Maximum allowed pressure in the reactor	1.1

Name	Description	Initial Value
CIV_CNS_MinV	Minimum volume to switch liquid input tank	10
CIV_CNS_OffsetCO2	Offset to provided a constant flux of CO2 to the reactor	0
CIV_CNS_OpModeBP	Biomass Production control mode (0=Off, 1=Auto, 2=Manual)	0
CIV_CNS_OpModeGas	Gas control mode (0=Off, 1=Auto, 2=Manual)	0
CIV_CNS_OpModepH	pH control mode ((0=Off, 1=Auto, 2=Manual)	0
CIV_CNS_PHMODE	PH regulation mode parameter (1=CO2 only, 2=CO2+Base, 3=Base+Acid)	1
CIV_MAN_Ac	Manual Acid Pump set point	0
CIV_MAN_Bs	Manual Base Pump set point	0
CIV_MAN_EnCx	Manual enable of biomass sensor aeration valve	0
CIV_MAN_EnLi1	Manual enable of Liquid input Pump 1	0
CIV_MAN_EnLi2	Manual enable of Liquid input Pump 2	0
CIV_MAN_EnLO	Manual enable of Liquid output Pump	0
CIV_MAN_EnSafety	Manual enable of pressure safety valve	1
CIV_MAN_FrCO2	Manual CO2 flow regulation set point	0
CIV_MAN_Li1	Manual Liquid Pump input1 set point	0
CIV_MAN_Li2	Manual Liquid Pump input2 set point	0
CIV_MAN_LO	Manual Liquid Pump output set point	0
CIV_MAN_Ls	Manual regulator of light supply set point	0
CIV_SSP_Fgex	Gas flow external input supervision set point	0
CIV_SSP_Fgi	Gas flow at input regulation supervision set point	0
CIV_SSP_Fgo	Gas flow at output regulation supervision set point	0
CIV_SSP_L1BP	Level 1 Biomass production set point	0
CIV_SSP_L1LiFr	Level 1 Liquid input flow rate set-point	0
CIV_SSP_Light	Light supervision set-point	0
CIV_SSP_NomPress	Nominal pressure in the reactor set-point	0.01
CIV_SSP_pH	pH set-point fixed by the supervision	9.5
CIV_SSP_T	Temperature set-point fixed by the supervision	36

5.3.4 CIV_PLCSW_Biomass: Biomass measurement

5.3.4.1 Function

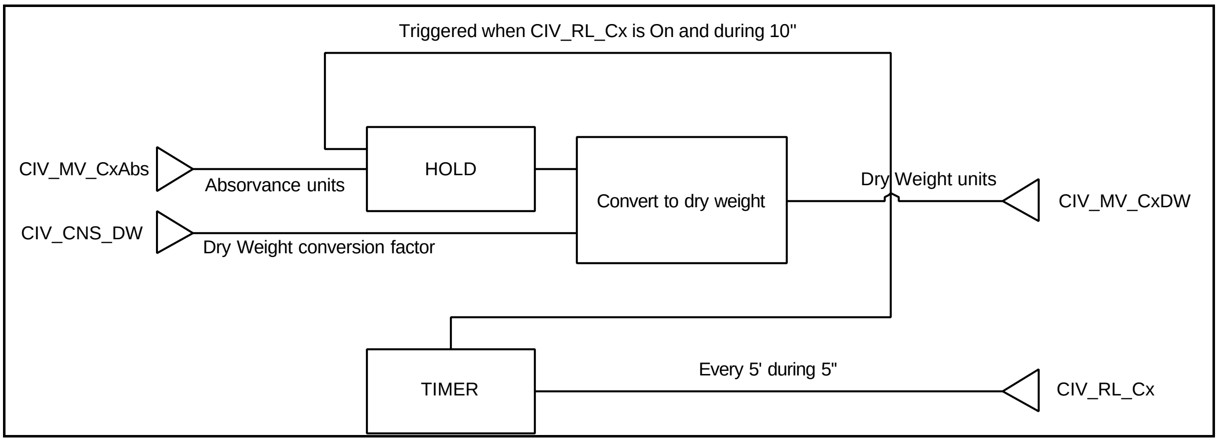
The functions of this section are:

3. Acquire the Biomass concentration and translate the input value in light attenuation units to dry weight units.
4. Clean the Biomass sensor generating a pulse every 5 minutes during 5 seconds to open the compressor valve.
5. Maintain the Biomass input value held since the valve is opened to 5 seconds after the valve is closed to avoid disturbances while the sensor is being cleaned.
6. Calculate actual Biomass Production = liquid input flow * biomass concentration(dw)
7. Biomass sensor range provided by Supervision (configurable).

5.3.4.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIV_ALM_CxErr	Alarm to notify biomass sensor link error	000171		Bool	
CIV_CNS_DW	Dry weight conversion factor	400542		Real	
CIV_CNS_OpModeBP	Biomass Production control mode (0=Off, 1=Auto,	400566		int	0,1,2
CIV_MAN_EnCx	Manual activation value of biomass sensor aeration valve	100165		Bool	
CIV_MV_CxAbs	Biomass measurement in absorvance units	300100	Biomass sensor	4-20 mA	Configurable (Abs.U)
CIV_RL_Cx	Aeration of biomass sensor for cleaning	000067	Electrovalve	0-24 V	0 – 1 (=cleaning)
CIV_SMV_BP	Biomass production	400584		Real	0 – 5 g/h
CIV_SMV_CxDW	Biomass concentration in dry weight units (gr/l)	400200		Real	Configurable (gr/l)
CIV_SSP_L1BP	Level 1 Biomass production set point	400554		Real	0 – 10 g/h
CIV_SSP_L2BP	Level 2 Biomass production set-point	400564		Real	0 – 10 g/h
CIV_CNS_CxAbsMin	Configurable max range of biomass sensor	400588		Real	0 Abs. u.
CIV_CNS_CxAbsMax	Configurable min range of biomass sensor	400590		Real	2 Abs. u.

5.3.4.3 Block Diagram



5.3.4.4 Alarms

Alarm condition	Action
Biomass sensor failure	Set safety value (1.0) and notify failure.

5.3.4.5 Operational modes

Mode	Description	Action
0	Off	Close aeration valve
1	Auto	Perform control action
2	Manual	Set manual value to aeration valve status.

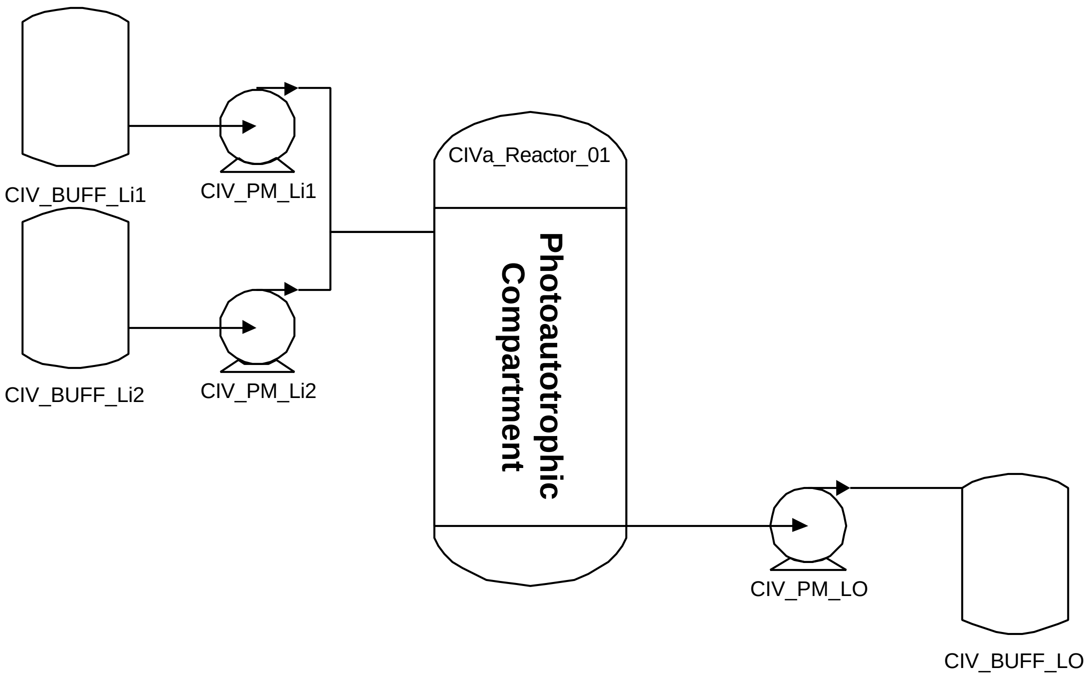
5.3.5 CIV_PLCSW_Liquid: Liquid flow regulation

5.3.5.1 Function

This section regulates the input/output liquid flow. Flow rate set-point is provided by the supervision. Liquid input media is provided from two buffer tanks with a pump for each one being only one active at a time. A balance measures the weight of each tank and this allows the system to detect when a tank is empty. Output flow rate is regulated maintaining the output pump a 10% over the input flow rate. When active buffer is under a defined volume (tank is empty), the alternative pump is activated (if its corresponding tank is not empty). This volume value is fixed from the supervision. If both tanks are under the minimum volume input and output pumps are stopped.

The functions of this section are:

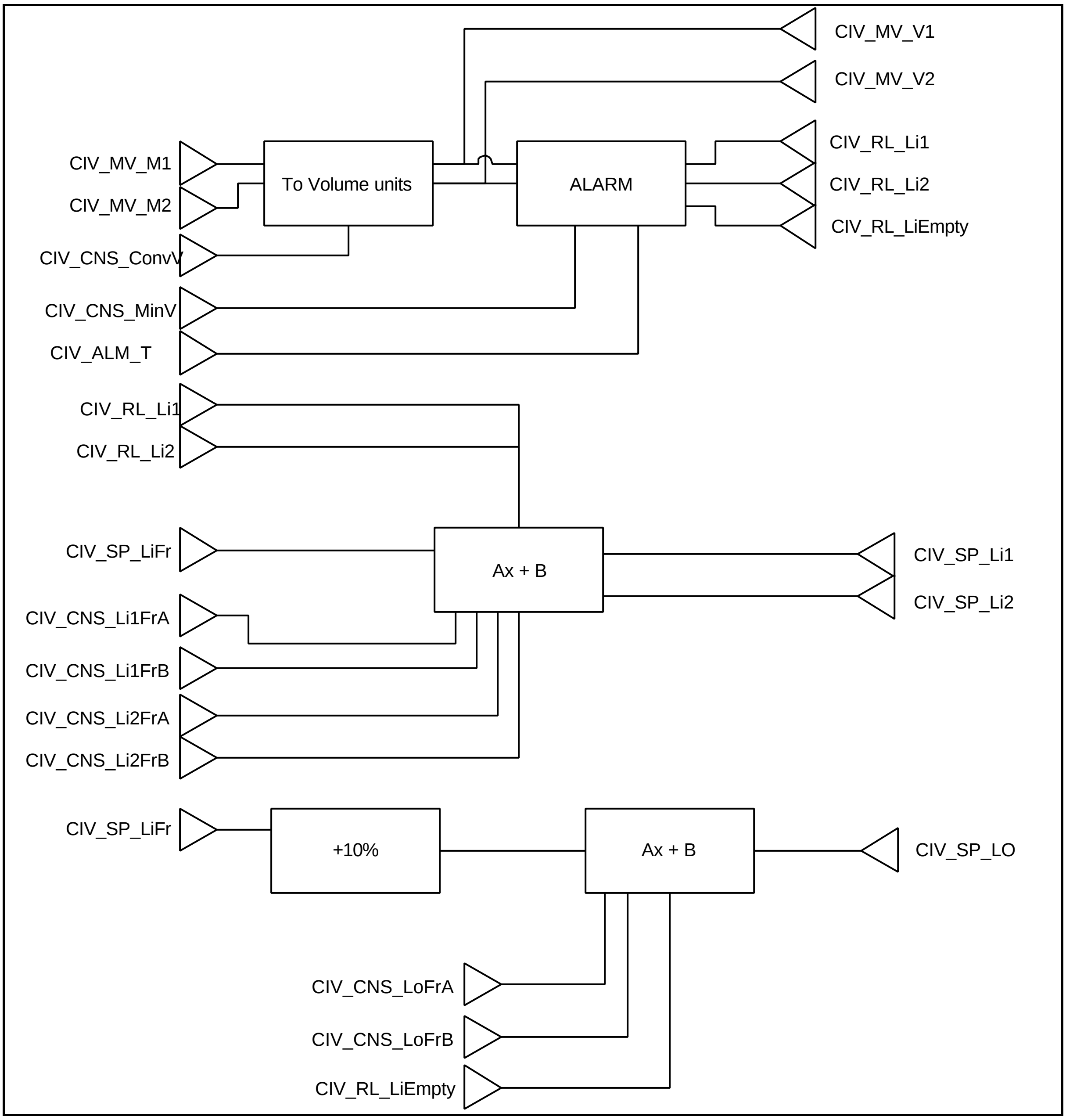
1. Acquisition and conditioning of the inlet media tanks weight translating weight units into volume units. The Supervision fixes the conversion factor.
2. Control the active inlet pump according to the medium tank remaining volume. The value for switching is fixed by the Supervision.
3. Calculate output pump flow rate as the 10% over the input flow rate. Output pump set-point is calculated using the expression Ax + B with the parameters (LoFrA, LoFrB) provided by the Supervision.
4. When the two input tanks are empty, an alarm is generated and output pump is stopped.
5. Calculate set-point of input pumps using the expression y=Ax + B (x = flow, y = %actuation) with the parameters fixed by the supervision (Li1FrA, Li1FrB, Li2FrA, Li2FrB).



5.3.5.2 Variables

Name	Description	PLC_Addres	Device	Type	Range
CIV_ALM_LiEmpty	Alarm liquid input tanks empty	000165		Bool	0 – 1 (=active)
CIV_ALM_V1Err	Alarm to notify scale1 sensor link error	000172		Bool	
CIV_ALM_V2Err	Alarm to notify scale2 sensor link error	000173		Bool	
CIV_CNS_ConvV	Density factor to translate Kg to litres	400518		Real	
CIV_CNS_Li1FrA	Parameter A for liquid input pump 1 set-point calculation	400512		Real	
CIV_CNS_Li1FrB	Parameter B for liquid input pump 1 set-point calculation	400514		Real	
CIV_CNS_Li2FrA	Parameter A for liquid input pump 2 set-point calculation	400538		Real	
CIV_CNS_Li2FrB	Parameter B for liquid input pump 2 set-point calculation	400540		Real	
CIV_CNS_LoFrA	Parameter A for liquid output pump set-point calculation	400510		Real	
CIV_CNS_LoFrB	Parameter B for liquid output pump set-point calculation	400512		Real	
CIV_CNS_MinV	Minimum volume to switch liquid input tank	400500		Real	
CIV_CNS_OpModeBP	Biomass Production control mode (0=Off, 1=Auto, 2=Manual)	400566		int	0,1,2
CIV_MAN_Li1	Manual Liquid Pump input1 set point	400570		Real	0 – 100 %
CIV_MAN_Li2	Manual Liquid Pump input2 set point	400572		Real	0 – 100 %
CIV_MAN_LO	Manual Liquid Pump output set point	400574		Real	0 – 100 %
CIV_MAN_EnLi1	Manual enable of Liquid input Pump 1	100166		Bool	0 – 1 (=active)
CIV_MAN_EnLi2	Manual enable of Liquid input Pump 2	100167		Bool	0 – 1 (=active)
CIV_MAN_EnLO	Manual enable of Liquid output Pump	100168		Bool	0 – 1 (=active)
CIV_MLI_M1	Mass measurement to determine input flow	300101	Scale1	4-20 mA	0 – 150 kg
CIV_MLI_M2	Mass measurement to determine input flow	300102	Scale2	4-20 mA	0 – 150 kg
CIV_RL_Li1	Liquid Pump input1 on	000065	Liquid input pump1	0-24 V	0 – 1 (=active)
CIV_RL_Li2	Liquid Pump input2 on	000066	Liquid input pump2	0-24 V	0 – 1 (=active)
CIV_SMLI_V1	Volume liquid input buffer tank1	400202		Real	0 – 150 l
CIV_SMLI_V2	Volume liquid input buffer tank2	400204		Real	0 – 150 l
CIV_SMV_Li1	Liquid Pump input1 set point in %	400222		real	0 – 100 %
CIV_SMV_Li2	Liquid Pump input2 set point in %	400224		real	0 – 100 %
CIV_SMV_LiFr	Liquid input flow rate	400586		real	0 – 100 %
CIV_SMV_LO	Liquid Pump output set point in %	400226		real	0 – 100 %
CIV_SMV_LoFr	Computed liquid output flow rate	400238		Real	
CIV_SP_Li1	Liquid Pump input1 set point	400104	Liquid input pump1	0-5 V	0 – 100 %
CIV_SP_Li2	Liquid Pump input1 set point	400105	Liquid input pump2	0-5 V	0 – 100 %
CIV_SP_LO	Liquid Pump output set point	400106	Liquid output pump	0-5 V	0 – 100 %
CIV_SSP_L1LiFr	Level 1 Liquid input flow rate set-point	400508		Real	0 – 10 l/h
CIV_SSP_L2LiFr	Level 2 Liquid input flow rate set point	400556		Real	0 – 10 l/h

5.3.5.3 Block Diagram



5.3.5.4 Alarms

Alarm condition	Action
Tank1 and Tank2 empty	Notify alarm to Supervision (CIV_RL_Li1, CIV_RL_Li2) and stop output pump.
Scale1 sensor failure	Set safety value and notify failure.
Scale2 sensor failure	Set safety value and notify failure.
Temperature alarm on	Stop input pumps.

5.3.5.5 Operational modes

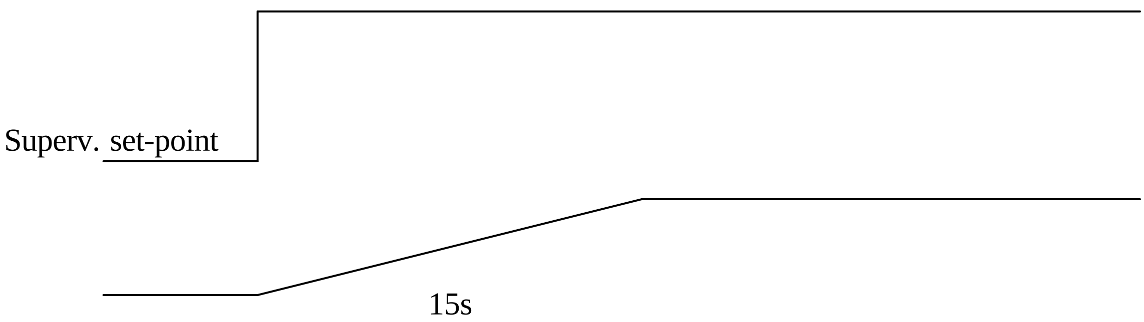
Mode	Description	Action
0	Off	Disable input/output pumps
1	Auto	Perform control action
2	Manual	Set manual enable/disable and set points to input/output pumps

5.3.6 CIV_PLCSW_Light: Light regulation

5.3.6.1 Function

This section performs conditioning of light regulation set point received from the Supervision. The functions of this section are:

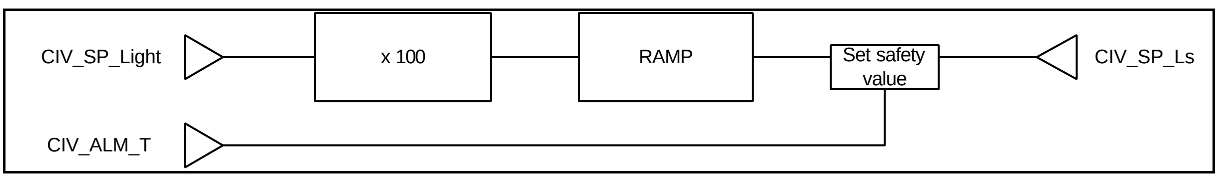
1. Amplify input set point from 0-1 to 0-100
2. Smooth a set point change step into a ramp in 15 seconds. The ramp is calculated to perform full change in 15''.
3. In case of temperature alarm set a safety value (10%) to light regulator.



5.3.6.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIV_ALM_LsErr	Alarm to notify light supply link error	000182		Bool	
CIV_MAN_Ls	Manual regulator of light supply set point	400576		Real	0 – 100 %
CIV_SMV_Ls	Regulator of light supply actuation in %	400236		Real	0 – 100 %
CIV_SP_Ls	Regulator of light supply	400109	Light regulator	4-20 mA	0 – 100 %
CIV_SSP_Light	Light Supervision set-point	400520		Real	0 – 1
CIV_SSP_LightWm	Light set-point (w/m2)	400558		Real	0-500 w/m2
CIV_CNS_OpModeBP	Biomass Production control mode (0=Off, 1=Auto, 2=Manual)	400566		int	0,1,2

5.3.6.3 Block Diagram



5.3.6.4 Alarms

Alarm condition	Action
Temperature alarm on	Set safety value to light regulator (10%).
Light supply link error	Notify error to supervision

5.3.6.5 Operational modes

Mode	Description	Action
0	Off	Set light supply output to 0
1	Auto	Perform control action
2	Manual	Set manual set point to light supply output

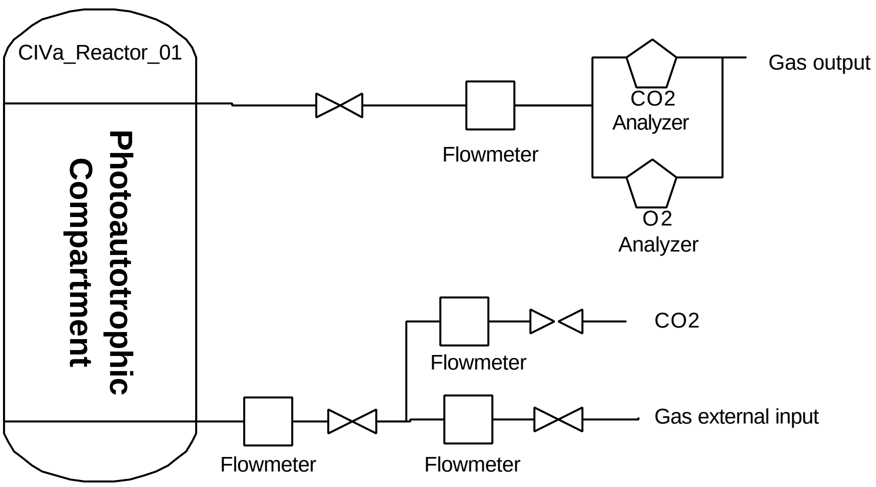
5.3.7 CIV_PLCSW_Gas: Gas flow regulation

5.3.7.1 Function

This section controls the gas loop.
The functions of this section are:

1. Acquire the current pressure value.
2. If pressure < NomPress increment a 10% input gas flow and activates the under pressure indicator. When pressure is again in a nominal value (inside dead band), stop incrementing supervision value. If pressure > NomPress, increment a 10% output gas flow and activates the over pressure indicator. Again, when pressure return to a nominal value (inside dead band), stop the incrementing the supervision value. NomPress is the nominal pressure specified by the Supervision. A dead band of +/-1% is considered.
3. Open pressure safety valve in case pressure reaches MaxPress. MaxPress is specified by the Supervision. Close it when pressure reaches the set point.
4. Allow manual setting of gas flow input and gas flow output (stop controlling action).
5. Acquire gas flow rate at compartment input.
6. Acquire gas flow rate at output
7. Acquire gas flow rate at external input.
8. Acquire CO_2 flow rate.
9. Acquire % DO saturation
10. Acquire CO_2 at output
11. Acquire O_2 at output
12. Allow to edit CO_2/O_2 sensor scales (scale1 and scale2)

NOTE: CO_2 flow regulation is performed in the CIV_PLCSW_pH section since is used to regulate pH.

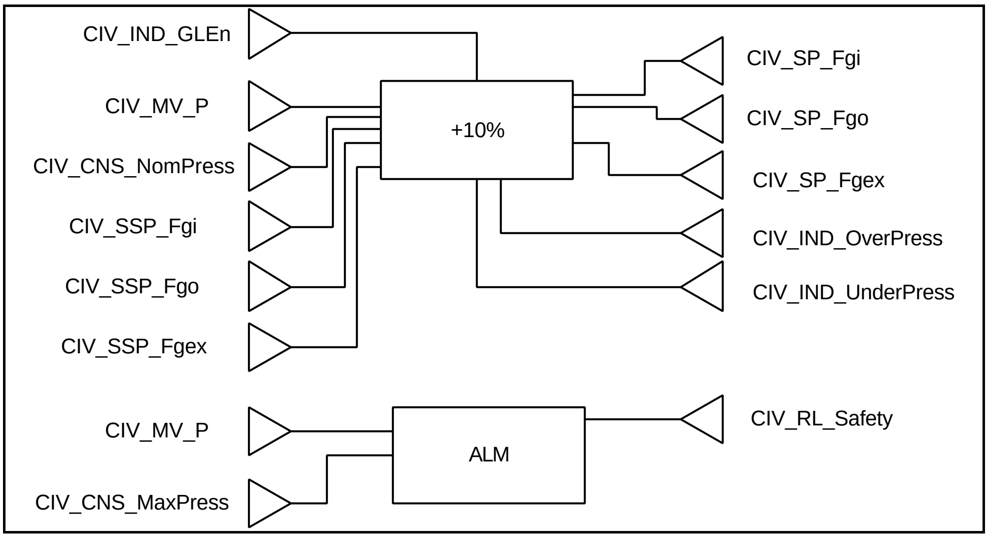


5.3.7.2 Variables

Name	Description	Address	Device	Type	Range
CIV_ALM_CO2Err	Alarm to notify O_2 sensor link error	000177		Bool	
CIV_ALM_Gas	Alarm notification for overpressure	000167		Bool	
CIV_ALM_Perr	Alarm to notify pressure sensor link error	000174		Bool	
CIV_ALM_O2Err	Alarm to notify O_2 sensor link error	000176		Bool	
CIV_ALM_DOErr	Alarm to notify DO sensor link error	000178		Bool	
CIV_CNS_MaxPress	Maximum allowed pressure in the reactor	400524		Real	
CIV_CNS_OpModeGas	Gas control mode (0=Off, 1=Auto, 2=Manual)	400568		int	0,1,2
CIV_IND_CalCO2O2	Calibration indicator of CO_2/O_2 sensor.	100065	CO_2/O_2 sensor	0-24 V	0 – 1 (=Calibr.)
CIV_IND_ErrCO2O2	Error Indicator of CO_2/O_2 sensor.	100066	CO_2/O_2 sensor	0-24 V	0 (=Error) 1 (=OK)
CIV_IND_Scale1CO2O2	CO_2/O_2 sensor scale	100067	CO_2/O_2 sensor	0-24 V	0 (= scale 1) 1 (= scale 2)
CIV_IND_Scale2CO2O2	CO_2/O_2 sensor scale	100068	CO_2/O_2 sensor	0-24 V	0 (= scale 1) 1 (= scale 2)
CIV_IND_OverPress	Over pressure indicator	000168		Bool	
CIV_IND_UnderPress	Under pressure indicator	000169		Bool	
CIV_MAN_EnSafety	Manual enable of pressure safety valve	100169		Bool	0 – 1 (=active)
CIV_MGI_FrGas	Gas flow at external input	300113	Flowmeter	0-5 V	0 – 30 nLm
CIV_MGO_CO2	CO_2 measurement at gas output	300107	CO_2 sensor	4-20 mA	Configurable %
CIV_MGO_FrGas	Gas flow at output	300114	Flowmeter	0-5 V	0 – 30 nLm
CIV_MGO_O2	O_2 measurement sensor input	300106	O_2 sensor	4-20 mA	Configurable %
CIV_MV_DO	Percent of DO saturation in the reactor	300109	DO sensor	4-20 mA	Configurable %
CIV_MV_FrCO2	CO_2 flow measurement	300115	Flowmeter	0-5 V	0 – 5 nLm
CIV_MV_FrGas	Gas flow at compartment input	300116	Flowmeter	0-5 V	0 – 30 nLm*
CIV_MV_P	Pressure measurement	300103	Pressure sensor	4-20 mA	0 – 1.5 bar
CIV_RL_Safety	Pressure safety valve activation	000068	Pressure valve	0-24 V	0 – 1 (=close)
CIV_SMGI_FrGas	Gas flow at external input scaled value	400208		real	0 – 30 nLm
CIV_SMGO_CO2	CO_2 at output measurement scaled value	400218		real	Configurable %
CIV_SMGO_FrGas	Gas flow at output scaled value	400214		real	0 – 30 nLm

Name	Description	Address	Device	Type	Range
CIV_SMGO_O2	O_2 measure scaled value	400216		real	Configurable %
CIV_SMV_DO	Percent of DO saturation in the reactor scaled value	400206		real	Configurable %
CIV_SMV_FrCO2	CO_2 at input measure scaled value	400210		Real	
CIV_SMV_FrGas	Gas flow at compartment input scaled value	400212		real	0 – 30 nLm*
CIV_SMV_P	Pressure measurement scaled value	400220		real	0 – 1.5 bar
CIV_SP_Fgex	Gas flow external input regulation	400103	Flow regulator	0-5 V	0 – 30 nLm
CIV_SP_Fgi	Gas flow at input regulation	400101	Flow regulator	0-5 V	0 – 30 nLm
CIV_SP_Fgo	Gas flow at output regulation	400102	Flow regulator	0-5 V	0 – 30 nLm
CIV_SSP_Fgex	Gas flow external input supervision set point	400532		Real	0 – 30 nLm
CIV_SSP_Fgi	Gas flow at input regulation supervision set point	400526		Real	0 – 30 nLm
CIV_SSP_Fgo	Gas flow at output regulation supervision set point	400528		Real	0 – 30 nLm
CIV_SSP_NomPress	Nominal pressure in the reactor	400522		Real	
CIV_CNS_DOMax	Configurable DO range max	400592		Real	400.0 %
CIV_CNS_DOMin	Configurable DO range min	400594		Real	0.0 %
CIV_CNS_CO2Max	Configurable CO2 range max	400596		Real	10 ppm
CIV_CNS_CO2Min	Configurable CO_2 range min	400598		Real	0 ppm
CIV_CNS_O2Max	Configurable O_2 range max	400600		Real	10 ppm
CIV_CNS_O2Min	Configurable O_2 range min	400602		Real	0 ppm
CIV_CNS_CO2E2Max	Configurable Scale2 CO_2 range max	400604		Real	20 ppm
CV_CNS_CO2E2Min	Configurable Scale2 CO_2 range min	400606		Real	0 ppm
CIV_CNS_O2E2Max	Configurable Scale2 O_2 range max	400608		Real	25 ppm
CV_CNS_O2E2Min	Configurable Scale2 O_2 range min	400610		Real	0 ppm

5.3.7.3 Block Diagram



5.3.7.4 Alarms

Alarm condition	Action
Over pressure during 5 seconds	Notify alarm to supervision (CIV_ALM_Gas)
Pressure sensor failure	Set safety value (nominal set point) and notify failure
CO_2 sensor failure	Set safety value (0.0) and notify failure
O_2 sensor failure	Set safety value (0.0) and notify failure
DO sensor failure	Set safety value (0.0) and notify failure
No Gas alarm	Stop liquid input pump, set light to 10% and notify failure (CIV_ALM_NoGas)

5.3.7.5 Operational modes

Mode	Description	Action
0	Off	Set gas input/output to 0
1	Auto	Perform control action
2	Manual	Set supervision set points directly to gas input/outputs and manual enable/disable of the pressure safety valve.

5.3.8 CIV_PLCSW_pH: pH regulation

5.3.8.1 Function

This section controls de pH in the reactor. The regulation can be done in 3 modes:

Mode	Description	CO2 flow rate	Base pump	Acid pump
1	Only CO2 is used to regulate pH	Enabled	Disabled	Disabled
2	CO2 is fixed and a base medium is used to regulate pH.	Enabled	Enabled	Disabled
3	CO2 is fixed and a base and additional acid medium is used to regulate pH.	Disabled	Enabled	Enabled

Disabled : Control Action = 0%
Enabled: Control action regulated.

The functions of this section are:

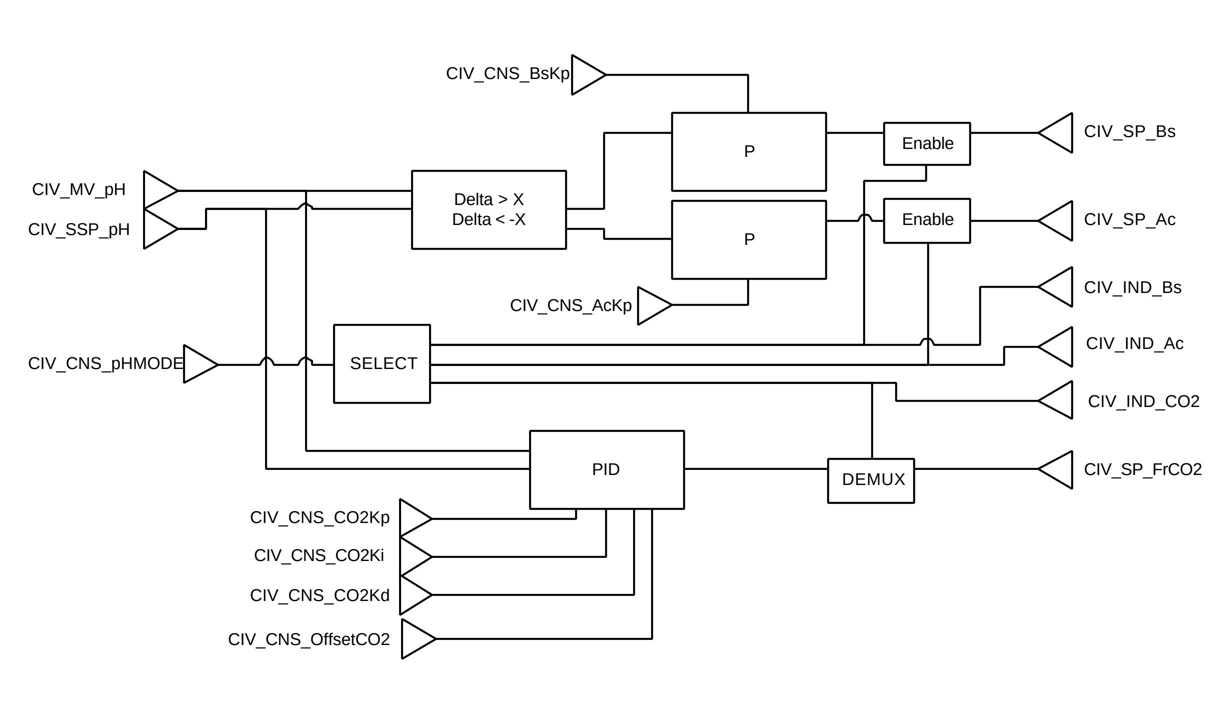
1. Acquire the pH value.
2. If Base Pump is enabled, in case deviation to the set point is <- 0.15 units activate Base Pump and Base On indicator.
3. If Acid Pump is enabled, in case deviation to the set point is > 0.15 units activate Acid Pump and Acid On indicator.
4. Acid and Base pumps control
5. If CO2 regulation is enabled, regulate CO2 input flow to control the pH using a PID (Mode 1) (Kp=5, Ki=1000, D=0, with PID output ranged 0-100%). Values can be modified from the Supervision.
6. Maintain a fix CO2 input flow rate (BIAS) value provided by the Supervision.

5.3.8.2 Variables

Name	Description	PLC_Add	Device	Type	Range
CIV_ALM_AcErr	Alarm to notify acid pump link error	000180		Bool	
CIV_ALM_BsErr	Alarm to notify base pump link error	000181		Bool	
CIV_ALM_pH	Alarm to notify problems in pH regulation	000166		Bool	
CIV_ALM_pHErr	Alarm to notify pH sensor link error	000175		Bool	
CIV_CNS_AcKp	Acid pump regulator proportional constant	400544		Real	
CIV_CNS_BsKp	Base pump regulator proportional constant	400546		Real	
CIV_CNS_CO2Kd	CO2 flow regulator derivative constant for PID	400552		Real	
CIV_CNS_CO2Kp	CO2 flow regulator proportional constant for PID	400548		Real	
CIV_CNS_CO2Ki	CO2 flow regulator integration constant for PID	400550		Real	

Name	Description	PLC_Add	Device	Type	Range
CIV_CNS_OffsetCO2	Offset to provided a constant flux of CO2 to the reactor	400536		Real	
CIV_CNS_OpModepH	pH control mode ((0=Off, 1=Auto, 2=Manual)	400567		int	0,1,2
CIV_CNS_pHMODE	pH regulation mode parameter (1=CO2 only, 2=CO2+Base, 3=Base+Acid)	400560		Real	1,2,3
CIV_IND_Ac	Enable addition of Acid for pH regulation	000203		Bool	
CIV_IND_Bs	Enable addition of Base for pH regulation	000204		Bool	
CIV_IND_CO2	Enable addition of CO2 for pH regulation	000202		Bool	
CIV_MAN_Ac	Manual Acid Pump set point	400580		Real	0 – 100 %
CIV_MAN_Bs	Manual Base Pump set point	400578		Real	0 – 100 %
CIV_MAN_FrCO2	Manual CO2 flow regulation set point	400582		Real	0 – 5 nLm
CIV_MV_pH	pH measurement	300104	pH sensor	4-20 mA	0 – 14
CIV_SMV_Ac	Additional Acid source actuation in %	400234		Real	0 – 100 %
CIV_SMV_Bs	Additional Base source actuation in %	400232		Real	0 – 100 %
CIV_SMV_CacCO2	Control action to regulate CO2 input	400240		Real	0 – 5 nLm
CIV_SMV_pH	Scaled pH measurement	400230		Real	
CIV_SP_Ac	Additional Acid source for pH regulation	400110	Acid pump	4-20 mA	0-100%
CIV_SP_Bs	Additional Base source for pH regulation	400108	Base pump	4-20 mA	0 – 100 %
CIV_SP_FrCO2	CO2 flow regulation	400100	CO2 flow regulator	0-5 V	0 – 5 nLm
CIV_SSP_pH	pH set-point fixed by the supervision	400534		Real	

5.3.8.3 Block Diagram



NOTE: PID output calculation is performed as follows (from Concept documentation):

dt: Time differential between the current cycle and the previous cycle
TI: Reset time
TD: Retaining time

YP = GAIN * ERR
YI(new) = YI(old) + GAIN * (dt/TI) * (ERR(new) + ERR(old))/2
YD(new) = YD(old) + TD*GAIN * (ERR(new)-ERR(old))/dt

Y = YP + YI + YD

5.3.8.4 Alarms

Alarm condition	Action
pH out of the set point during 15’	Notify alarm to supervision (CIV_ALM_pH)
pH sensor failure	Set safety value (nominal set point) and notify failure. Disable PID action (PID output = 0).
Base pump link error	Notify error to supervision
Acid pump link error	Notify error to supervision

5.3.8.5 Operational modes

Mode	Description	Action
0	Off	Set acid/base pumps and CO2 flow controller outputs to 0
1	Auto	Perform control action
2	Manual	Set manual set points to acid/base pumps and CO2 flow controller.

5.3.9 CIV_PLCSW_T: Temperature acquisition

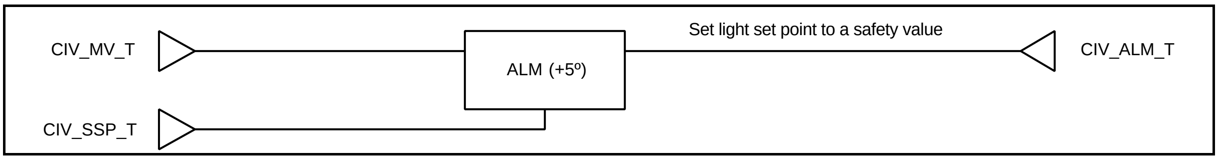
5.3.9.1 Function

Acquire and scale temperature sensor value.

5.3.9.2 Variables

Name	Description	PLC_Address	Device	Type	Range
CIV_ALM_T	Alarm to notify over temperature	000170		Bool	
CIV_ALM_TErr	Alarm to notify Temperature sensor link error	000179		Bool	
CIV_MV_T	Temperature measurement	300105	Temperature sensor	4-20 Ma	0 – 150 º C
CIV_SMV_T	Scaled Temperature value	400228		Real	0 – 150 º C
CIV_SSP_T	Temperature set-point fixed by the supervision	400562		Real	0-100 º C

5.3.9.3 Block Diagram



5.3.9.4 Alarms

Alarm condition	Action
Temperature 5º over the set point	Notify alarm and Set light set point to a safety value (10%)
Temperature sensor failure	Set a safety value (temperature set point) and notify error.

6 HMI

6.1 Target Platform

HMI is implemented by means of a Magelis display (Schneider Electric, model XBT-F34X). From this graphical touch-screen basic supervision functions can be performed over the local controllers.

6.2 Main HMI Display

6.2.1 MEL_HMI_Main: Main Display

In this display principal values of all compartments can be monitored. The display shall visualise following values:

Name	Description	PLC_Address
CIII_SMV_NO2	Estimation of NO2 concentration (calculated by control law)	400562
CIII_SMV_DO	DO scaled measure value	400544
CIII_SMV_LiFr	Liquid input flow rate	400596
CIII_SMV_LoFr	Liquid output flow rate	400594
CIV_SMGO_O2	O2 at output measure scaled value	400216
CIV_SMV_LiFr	Liquid input flow rate	400586
CIV_SMV_LoFr	Liquid output flow rate	400238
CIV_SMV_BP	Biomass production	400584

6.2.1.1 Navigation

- CIII_HMI_Main
- CIV_HMI_Main

6.3 CIII HMI Displays

6.3.1 CIII_HMI_Main: CIII Main display

Main display for the Compartment III which shall visualize following values:

Name	Description	PLC_Address
CIII_SMV_NO2	Estimation of NO2 concentration (calculated by control law)	400562
CIII_SMV_NO3	Nitrate concentration scaled measure	400530
CIII_SMV_NH4	Ammonium concentration scaled measure	400528
CIII_SMV_pH	pH scaled measure	400534
CIII_SMV_T	Temperature scaled measure	400532
CIII_SMV_DO	DO scaled measure value	400544
CIII_SMV_P	Pressure scaled measure value	400552
CIII_SSP_L2LiFr	Level 2 liquid Input supervision set point	400542
CIII_SMV_LiFr	Liquid input flow rate	400596
CIII_SMV_LoFr	Liquid output flow rate	400594

6.3.1.1 Navigation

- CIII_HMI_Temp
- CIII_HMI_pH
- CIII_HMI_Liquid
- CIII_HMI_Gas
- CIII_HMI_Main

6.3.2 CIII_HMI_Temp: Temperature regulation display

Display to visualize Temperature measure, and fix Temperature set point. Following values shall be visualized:

Name	Description	PLC_Address
CIII_SMV_T	Temperature scaled measure	400532
CIII_SMV_Tb	Temperature at bottom scaled measure	400608
CIII_SMV_Tt	Temperature at top scaled measure	400606
CIII_SSP_T	Temperature supervision set point	400500

Name	Description	PLC_Address
CIII_RL_CV	Open/close the cooling valve	000084
CIII_RL_HT	Activate Heater	000085
CIII_CNS_OpModeT	Temperature control operational mode (0=Off, 1=Auto, 2=Manual)	400567

6.3.2.1 Navigation

- CIII_HMI_Temp
- CIII_HMI_pH
- CIII_HMI_Liquid
- CIII_HMI_Gas
- CIII_HMI_Main

6.3.3 CIII_HMI_pH: pH regulation display

Display to visualize pH measure, change pH control mode, and fix pH set point. Following values shall be visualized:

Name	Description	PLC_Address
CIII_SSP_pH	pH supervision set point	400504
CIII_SMV_pH	pH scaled measure	400534
CIII_SMV_PHb	Scaled pH value at bottom	400590
CIII_SMV_PHt	Scaled pH value at top	400592
CIII_SMV_Ac	Acid pump control action	400536
CIII_SMV_Bs	Base pump control action	400538
CIII_SMV_CO2	CO2 input flow control action	400540
CIII_RL_Ac	Relay acid pump	000081
CIII_RL_Bs	Relay base pump	000082
CIII_CNS_pHMode	PH regulation mode variable (1=CO2 only, 2=CO2+Base, 3=Base+Acid)	400554
CIII_CNS_OpModepH	pH control operational mode (0=Off, 1=Auto, 2=Manual)	400564

6.3.3.1 Navigation

- CIII_HMI_Temp
- CIII_HMI_pH
- CIII_HMI_Liquid
- CIII_HMI_Gas

6.3.4 CIII_HMI_Liquid: Liquid flow regulation display

Display to visualize level, and input/output liquid flow rates and change input flow set-point. Following values shall be visualized:

Name	Description	PLC_Address
CIII_SSP_L1Lin	Level 1 liquid input supervision set point	400524
CIII_SSP_L2Lin	Level 2 Liquid input supervision set point	400542
CIII_SMV_LO	Liquid output flow control action	400550
CIII_SMV_LiFr	Liquid input flow rate	400596
CIII_SMV_NO3	Nitrate concentration scaled measure	400530
CIII_SMV_NH4	Amonium concentration scaled measure	400528
CIII_SMV_NO2	Estimation of NO2 concentration (calculated by control law)	400562
CIII_IND_Llow	Liquid level low indicator	000173
CIII_IND_Lhigh	Liquid level high indicator	000174
CIII_CNS_OpModeL	Liquid control operational mode (0=Off, 1=Auto, 2=Manual)	400565
CIII_SMV_LI	Liquid Input pump control action	400616

6.3.4.1 Navigation

- CIII_HMI_Temp
- CIII_HMI_pH
- CIII_HMI_Liquid
- CIII_HMI_Gas
- CIII_HMI_Main

6.3.5 CIII_HMI_Gas: Gas flows regulation display

Display to visualize DO, pressure measures, O2, N2 input flow rates and change DO set point. Following values shall be visualized:

Name	Description	PLC_Address
CIII_SSP_DO	DO Supervision set point	400520
CIII_SSP_P	Pressure supervision set point	400526
CIII_SMV_DO	DO scaled measure value	400544
CIII_SMV_DObot	DO at bottom scaled measure value	400604

Name	Description	PLC_Address
CIII_SMV_DOtop	DO at top scaled measure value	400602
CIII_SMV_O2	O2 input flow control action	400546
CIII_SMV_N2	N2 input flow control action	400548
CIII_SMV_CO2	CO2 input flow control action	400540
CIII_SMV_P	Pressure scaled measure value	400552
CIII_RL_P	Activation of Pressure Safety Valve	000087
CIII_CNS_OpModeGas	Gas control operational mode (0=Off, 1=Auto, 2=Manual)	400566
CIII_CNS_OpModeDO	DO regulation operational mode (0=Off, 1=Auto, 2=Manual)	400568

6.3.5.1 Navigation

- CIII_HMI_Temp
- CIII_HMI_pH
- CIII_HMI_Liquid
- CIII_HMI_Gas
- CIII_HMI_Main

6.4 CIV HMI Displays

6.4.1 CIV_HMI_Main: CIV main display

Main display which shall visualize following values:

Name	Description	PLC_Address
CIV_SMV_BP	Biomass production	400584
CIV_SMV_CxDW	Conditioned biomass concentration in dw units	400200
CIV_SMV_FrCO2	CO2 at input measure scaled value	400210
CIV_SMV_LiFr	Liquid input flow rate	400586
CIV_SMV_LoFr	Liquid output pump flow rate	400238
CIV_SMV_FrGas	Gas flow at compartment input	400212
CIV_SMGO_O2	O2 at output measure scaled value	400216
CIV_SMGO_CO2	CO2 at output measurement scaled value	400218
CIV_SMV_P	Pressure measurement scaled value	400220
CIV_SMV_T	Scaled Temperature value	400228
CIV_SMV_pH	Scaled pH measurement	400230
CIV_SSP_LightWm	Light supervision set-point in w/m2	400558

6.4.1.1 Navigation

- CIV_HMI_pH
- CIV_HMI_BP
- CIV_HMI_Gas
- CIV_HMI_Main

6.4.2 CIV_HMI_pH: pH regulation display

Display to visualise pH measure, pH actuators and modify pH set point. It shall visualize following values:

Name	Description	PLC_Address
CIV_SSP_pH	pH set-point fixed by the supervision	300234
CIV_SMV_FrCO2	CO2 at input measure scaled value	400210

Name	Description	PLC_Address
CIV_SMV_pH	pH measurement	400230
CIV_SMV_Bs	Additional Base source actuation in %	400232
CIV_SMV_Ac	Additional Acid source actuation in %	400234
CIV_CNS_OffsetCO2	Offset to provided a constant flux of CO2 to the reactor	400536
CIV_CNS_OpModepH	pH control mode ((0=Off, 1=Auto, 2=Manual)	400567
CIV_SMV_FrGas	Gas flow at compartment input	400212

6.4.2.1 Navigation

- CIV_HMI_pH
- CIV_HMI_BP
- CIV_HMI_Gas
- CIV_HMI_Main

6.4.3 CIV_HMI_BP: Biomass production regulation display

Display to visualise Biomass concentration measure, liquid input/output flow actuators and biomass production and liquid input set points. It shall visualize following values:

Name	Description	PLC_Address
CIV_RL_Li1	Liquid Pump input1 on	000065
CIV_RL_Li2	Liquid Pump input2 on	000066
CIV_RL_Cx	Aeration of biomass sensor for cleaning	000067
CIV_SMV_Li1	Liquid Pump input1 set point in %	400222
CIV_SMV_Li2	Liquid Pump input2 set point in %	400224
CIV_SMV_LO	Liquid Pump output set point in %	400226
CIV_SMV_CxDW	Conditioned biomass concentration in dw units	400200
CIV_SMLI_V1	Volume liquid input buffer tank1	400202
CIV_SMLI_V2	Volume liquid input buffer tank2	400204
CIV_SSP_LightWm	Global variable to store light intensity in w/m2	400558
CIV_SSP_L1BP	Level 1 Biomass production set-point	400554
CIV_SSP_L2BP	Level 2 Biomass production set-point	400564

Name	Description	PLC_Address
CIV_SSP_L1LiFr	Level 1 Liquid input flow rate set point	400508
CIV_SSP_L2LiFr	Level 2 Liquid input flow rate set point	400556
CIV_SMV_BP	Biomass production	400584
CIV_SMV_LiFr	Liquid input flow rate	400586
CIV_SMV_LOFR	Liquid output pump flow rate	400238
CIV_CNS_OpModeBP	Biomass Production control mode (0=Off, 1=Auto, 2=Manual)	400566

6.4.3.1 Navigation

- CIV_HMI_pH
- CIV_HMI_BP
- CIV_HMI_Gas
- CIV_HMI_Main

6.4.4 CIV_HMI_Gas: Gas flows regulation display

Display to visualise Gas input / output flows and CO2, air, pressure set points. It shall visualize following values:

Name	Description	PLC_Address
CIV_RL_Safety	Pressure safety valve activation	000068
CIV_IND_OverPress	Over pressure indicator	000168
CIV_IND_UnderPress	Under pressure indicator	000169
CIV_SMV_P	Pressure measurement scaled value	400220
CIV_SMGO_O2	O2 at output measure scaled value	400216
CIV_SMGO_CO2	CO2 at output measurement scaled value	400218
CIV_SMV_DO	Percent DO saturation scaled value	400206
CIV_SMGI_FrGas	Gas flow at external input	400208
CIV_SMV_FrGas	Gas flow at compartment input	400212
CIV_SMGO_FrGas	Gas flow at compartment output scaled value	400214
CIV_SMV_FrCO2	CO2 at input measure scaled value	400210
CIV_SSP_NomPress	Nominal pressure in the reactor set-point	400522

Name	Description	PLC_Address
CIV_SSP_Fgi	Gas flow at input regulation supervision set point	400526
CIV_SSP_Fgo	Gas flow at output regulation supervision set point	400528
CIV_SSP_Fgex	Gas flow external input supervision set point	400532
CIV_CNS_OpModeGas	Gas control mode (0=Off, 1=Auto, 2=Manual)	400568

6.4.4.1 Navigation

- CIV_HMI_pH
- CIV_HMI_BP
- CIV_HMI_Gas
- CIV_HMI_Main

7 MASTER CONTROL

7.1 Target Platform

Master control will run in the Supervision Server using the iFix platform.

7.2 CIV_CL_BP: Biomass production control law

The software that implements the Biomass regulation for Compartment IV is composed as follows:

- Control software package: C software modules funcalc.c, lightcalc.c and lspc.c provided by SHERPA that implement the control algorithm. This is described in 7.2.1, which is an excerpt of [R5].

- CIV_BPCtrlLaw: a Dynamic Link Library (DLL) that composes a binary module that can be called externally to calculate the control law outputs.

- CIV_BPCtrl: an ActiveX control to be attached to the Supervision to communicate with the PLC. Implements the control algorithm calling the CIV_BPCtrlLaw DLL.

7.2.1 SHERPA's control software package

The control software package for CIV consists of 3 files:

- lspc.c: main control program;
- funcalc.c: mathematical functions necessary to lspc.c;
- lightcal.c: bijective conversion between the light flux (W/m^2) and the index of the potentiometer of the lamps.

The source file 'lightcal.c' is not included in the main 'lspc.c' so that it can be changed when the lighting system is modified. When modification occurs on the lighting system, the relation between the light flux and the index of the potentiometer of the lamps has to be identified again. The program 'lightcal.c' has to be called :

- before the call to 'lsps.c' with the conversion option potentiometer index → light flux;
- after the call to 'lsps.c' with the conversion option light flux → potentiometer index;

Two main programs 'tst_lspc.c' and 'tst_lightcal.c' show an example of how to call the functions 'lspc' and 'lightcal'.

7.2.1.1 Arguments of the main control program

The arguments of the main program are listed hereafter :

```
LSPC(PROD_SP2,CX,QE_SP2,FR,QE_MES,SM_SUP,CONS_SUP,
     VOL,FI,DT,LAMBDA,INIT,VAR_OUT,TRACE)
```

and can be parted into different groups :

- set-points that are fixed by the operator : `PROD_SP2, QE_SP2;`

- measurements : `CX`, `FR`(computed by 'lightcal'), `QE_MES`; It is very important to note that `FR` is also an output argument. It has to be converted by 'lightcal' into 'potentiometer index' which has to be sent to the lighting system.
- internal variables that must be kept into the supervision program (but not initialized) from one call to the next one : `SM_SUP,CONS_SUP`;
- physical values : `VOL, FI`;
- parameters of the control : `DT, LAMBDA`;
- initialization flag : `INIT ;` It is very important to note that this flag has to be set to zero by supervision program at the first call of 'lspc' in order to initialize 'lspc' and must not be managed by the supervision program after this first call. It is set to 1 by 'lspc' itself.
- output arrays : `VAR_OUT,TRACE`; Only the coefficient 1 of the array `VAR_OUT` is useful now and contain the flow rate set-point that has to be sent to the FRC (Flow Rate Controller) of the pump. The array contains internal variables of the control and has to be saved on a disk file at each call of 'lspc' in order to check internal computations of the control.

```
Arguments description:
      (v) : numerical value
      (p) : pointer
      PROD_SP2 (v):level2 production set point (g/h)
      CX       (v):biomass concentration (g/l)
      QE_SP2   (v):level2 flow rate set point (l/h)
      FR       (p):light intensity : measured or computed by the control (W/m2)
                    . input argument : measured value of FR
                    . output argument : computed by the control
      QE_MES   (v):measure of flow rate (l/h)
      SM_SUP   (p):production model output computed by the supervisor (g/h)
                    . input argument : value at previous moment
                    . output argument : value at present moment
      CONS_SUP (p):production set point computed by the supervisor (g/h)
                    . input argument : value at previous moment
                    . output argument : value at present moment
      VOL      (v):volume of the reactor (l)
      FI       (v):illuminated surface fraction (no dimension)
      DT       (v):control period (h)
      LAMBDA   (v):dynamic of the reference trajectory (dimension less)
      INIT     (p):initialisation flag (when equal to 0)
                    put to 1 by this programme
      VAR_OUT[0]  :level 1 production set point (g/h)
      VAR_OUT[1]  :level 1 flow rate set point (l/h)
      VAR_OUT[2]  :derivative of the model biomass concentration (g/l/h)
                    (to be compared to the derivative of the process conc.)
      TRACE[50]   :array of internal variables to check the control
```

7.2.1.2 Conversion program between light flux and potentiometer index

A bijective function binding the light flux 'F_R' and the 'potentiometer index of the lamps' has been built (in TN 44.1) from the UAB data (TN 37.2 , p.22 , April 1998) and is plotted in Figure **2**.

Given :
x : potentiometer index of the lamps (between 0 and 1)
y : light flux F_R .

The expression of y function of x is :

$$y = a*x^2 + b*x + c$$

The inverse function x versus y is :

$$x = (-b + (b2 - 4*a *(c-y))^{1/2} / (2*a)$$

with : $a = 289.0$
$b = 54.56$
$c = -24.19$

The parameters a, b and c are identified by means of a least square method on the range :

$$5 \leq y \leq 223$$
$$0.2371 \leq x \leq 0.8352$$

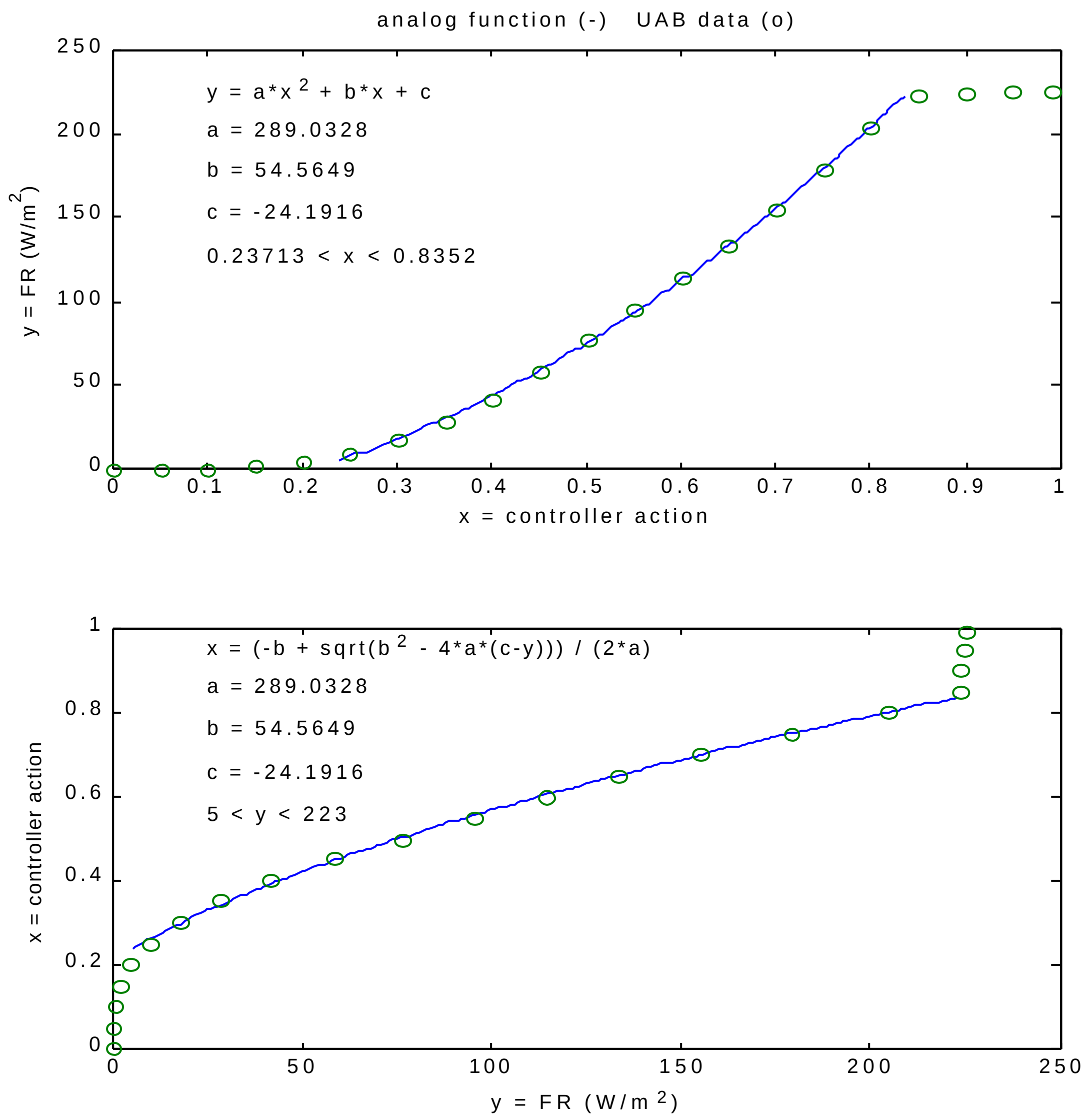


Figure 2: : Bijective function binding 'F_R' and 'potentiometer index'
Note : 'potentiometer index' is named 'controller action' in the figure

7.2.2 CIV_BPCtrlLaw Dynamic Link Library

This Dynamic Link Library encapsulates the SHERPA's software control package and allows external programs to use the control function. It implements the following interface:

7.2.2.1 CIV_FR_LigthCal

Calculate FR from setting point value and the setting point value from FR

7.2.2.1.1 Input parameters

Parameter	Type	Description
pdLightIndex	double*	Lamps Actuator Setting Point Value (between 0 and 1)
pdFR	double*	light intensity (W/m2)
iMode	int	Can be: CAL_FR = 0 - Calculate Light Intensity CAL_PO = 1 - Calculate Setting Point Value

7.2.2.1.2 Output parameters

Parameter	Type	Description
return	int	=1 : OK =0 : Error in parameter iMode

7.2.2.2 CIV_FR_ControlLaw

Non linear PFC control of Spirulina production by light

7.2.2.2.1 Input parameters

Parameter	Type	Description
prod_sp2	double	level2 production set point (g/h)
cx	double	biomass concentration (g/l)
qe_sp2	double	level2 flow rate set point (l/h)
Fr	double*	light intensity measured or computed by the control (W/m2) • input argument : measured value of FR • output argument : computed by the control
qe_mes	double	measure of flow rate (l/h)
sm_sup	double*	production model output computed by the supervisor (g/h) • input argument : value at previous moment • output argument : value at present moment
cons_sup	double	production set point computed by the supervisor (g/h) • input argument : value at previous moment • output argument : value at present moment
Vol	double	volume of the reactor (l)
FI	double	illuminated surface fraction (no dimension)
dt	double	control period (h)
Lambda	double	dynamic of the reference trajectory (dimension less)
Init	double*	initialisation flag (when equal to 0) put to 1 by this program
var_out	double[3]	var_out[0] :level 1 production set point (g/h) var_out[1] :level 1 flow rate set point (l/h) var_out[2] :derivative of the model biomass concentration (g/l/h) (to be compared to the derivative of the process conc.)
Trace	double[50]	array of internal variables to check the control

7.2.3 CIV_BPCtrl Activex Control

This Activex component eases the integration with the supervision software. Implements the following interface:

7.2.3.1 CIV_FR_LigthCal

Calculate FR from setting point value and the setting point value from FR

7.2.3.1.1 Input parameters

Parameter	Type	Description
p_light_index	double FAR*	Lamps Actuator Setting Point Value (between 0 and 1)
p_fr	double FAR*	light intensity (W/m2)
Mode	short	Can be: CAL_FR = 0 - Calculate Light Intensity CAL_PO = 1 - Calculate Setting Point Value

7.2.3.1.2 Output parameters

Parameter	Type	Description
Return	short	=1 : OK =0 : Error in parameter iMode

7.2.3.2 CIV_FR_ControlLaw

Non linear PFC control of Spirulina production by light

7.2.3.2.1 Input parameters

Parameter	Type	Description
prod_sp2	double	level2 production set point (g/h)
cx	double	biomass concentration (g/l)
qe_sp2	double	level2 flow rate set point (l/h)
p_fr	double FAR*	light intensity measured or computed by the control (W/m2) • input argument : measured value of FR • output argument : computed by the control
qe_mes	double	measure of flow rate (l/h)
p_sm_sup	double FAR*	production model output computed by the supervisor (g/h) • input argument : value at previous moment • output argument : value at present moment
cons_sup	double	production set point computed by the supervisor (g/h) • input argument : value at previous moment • output argument : value at present moment
Vol	double	volume of the reactor (l)
FI	double	illuminated surface fraction (no dimension)
dt	double	control period (h)
Lambda	double	dynamic of the reference trajectory (dimension less)
p_init	double FAR*	initialisation flag (when equal to 0) put to 1 by this program
var_out	VARIANT FAR& size=3 type=double	var_out[0] :level 1 production set point (g/h) var_out[1] :level 1 flow rate set point (l/h) var_out[2] :derivative of the model biomass concentration (g/l/h) (to be compared to the derivative of the process conc.)

Parameter	Type	Description
Trace	VARIANT FAR& size = 50 type = double	array of 50 internal variables to check the control

7.2.4 Deployment

To use the ActiveX control in the supervision:
1. Copy CIV_BPCtrlLaw.dll into the System32 folder of the Supervision Server.
2. Copy CIV_BPCtrl.ocx control into the System32 folder of the Supervision Server.
3. Register CIV_BPCtrl.ocx using the tool regsvr32:
   ex.:
   regsvr32 CIV_BPCtrl.ocx

After these steps, the control CIV_BPCtrl is available to be used in the iFix platform.
The control must be used from a scheduled task in background running as a Windows service (see Scheduler in iFix documentation).

7.2.5 PLC variables

Name	Description	PLC_Address	Device	Type	Range
CIV_SMV_CxDW	Biomass concentration in dw units	400200		real	0-2 gr/l
CIV_SSP_LightWm	Light set-point (w/m2)	400558		real	0-300 w/m2
CIV_SSP_Light	Light supervision set-point	400520		real	0-1
CIV_SSP_L1BP	Level 1 Biomass production set-point	400554		real	0-2 g/h
CIV_SSP_L1LiFr	Level 1 Liquid input flow rate set point	400508		real	0-10 l/h
CIV_SSP_L2BP	Level 2 Biomass production set point	400564		real	0-2 g/h
CIV_SSP_L2LiFr	Level 2 Liquid input flow rate set point	400556		real	0-10 l/h

7.3 CIII CL_NO: Nitrite Control Law

The software that implements the Biomass regulation for Compartment IV is composed as follows:

- Control software package: C software modules provided by SHERPA that implement the control algorithm. This is described in 7.3.1, which is an excerpt of [R6].
-
- CIII_NitCtrlLaw: a Dynamic Link Library (DLL) that composes a binary module that can be called externally to calculate the control law outputs.
- CIII_NitCtrl: an ActiveX control to be attached to the Supervision to communicate with the PLC. Implements the control algorithm calling the CIII_NitCtrlLaw DLL.

7.3.1 SHERPA's control software package

The control software package is composed of following files:

Name	Function of the sub-routine
nctrl.c	: Gateway from computer system
acq_par.c	: Break down of the parameters array by vectors of parameters table
estim_3.c	: Main function of estimation of state of internal model
estim_NX.c	: Estimation of nitrite and biomass concentrations
order.c	: Second and third order filter
con_3.c	: Main function of control itself
extremum.c	: Computation of the extreme of NO2 on horizon H of the scenario
integ_im.c	: Integration of state for scenario method
linterp.c	: Linear interpolation
im_nitr2.c	: State derivative of the internal model
stasysim.c	: Computation of matrices of the internal model
transbi.c	: Transfer parameters of the biphase compounds
irate.c	: Limiting coefficients for growth and maintenance rate of biomass

7.3.1.1 Functions of the control program

The program is conceived as a module with only one gateway connected to the computer system for exchanging data at a given period of time.

The 2 main functions of the program are :

- estimation of the state of the internal model;
- control itself based on a scenario method.

These 2 main functions run at different sampling periods of time : 0.1 and 1 h for the estimator and the control, respectively. The shorter value (0.1 h) is the period for exchanging data with the computer system.

7.3.1.2 Arguments of the gateway routine

This section describes the arguments of the main C routine (named *nctrl*) that are exchanged with the external environment. This routine *nctrl* has to be called by the machine (PC or PLC) system at given period of time. This period is the sampling period of the estimator that is set to 0.1 hour. The routine *nctrl* has 6 arguments:

Name	Definition
X	Outputs vector of control
Errors	Number and code of errors occurred in a run of the program
U	Inputs vector of control
flag_sav	Flag for saving spy files 'f_x.txt' and 'f_xef.txt' when set to 1 by the external environment
flag_ini	Initialization flag when set to 0 by the external environment
Param	Array of parameters of the control

The first two arguments are output arrays; the 2 following ones are inputs (1 array and 1 scalar).

The last argument 'flag_ini' is an input/output argument. Its function is very important as it implies the initialization of all the arrays of the program when its value is 0. Its returned value that is set by *nctrl* routine is 1. It has to be set to 0 by the supervisor system when and only when an initialization is needed, particularly to start the control or to make it to re-start.

The initial values of the arrays and internal variables depend on the values of the inputs of the process that is assumed to be at steady state at the moment of the initialization.

Description of the inputs vector 'u' :

The vector 'u' is composed of the following 21 components:

Index	Unit	Description
0	l/h	Measured liquid flow rate or setpoint of the FRC of the liquid pump
1	mol/l	O_2 concentration in the gas input stream
2	mol/l	CO_2 concentration in the gas input stream
3	mol/l	NH_3 concentration in the gas input stream
4	mol/l	O_2 concentration in the liquid input stream
5	mol/l	total CO_2 concentration in the liquid input stream
6	mol/l	total NH_3 concentration in the liquid input stream
7	mol/l	unused (room for NO_2 concentration if not null)
8	mol/l	NO_3 concentration in the liquid input stream
9	mol/l	PO_4 concentration in the liquid input stream
10	mol/l	SO_4 concentration in the liquid input stream
11	mol/l	O_2 concentration in the liquid output stream
12	mol/l	total CO_2 concentration in the liquid output stream
13	mol/l	total NH_3 concentration in the liquid output stream
14	mol/l	NO_3 concentration in the liquid output stream
15	mol/l	PO_4 concentration in the liquid output stream
16	mol/l	SO_4 concentration in the liquid output stream
17	l/h	Measured gas flow rate or setpoint of the FRC of the gas pump
18	l/h	'Required' liquid flow rate
19	mol/l	Maximum constraint of NO_2
20	mol/l	Compensation term for estimator

When a component of ‘u’ can not be measured, it should be replaced by a constant value set from the keyboard by the operator.

Description of the outputs vector ‘x’ :
The vector ‘x’ contains a lot of internal variables of the estimator and of the controller itself and has to be saved by the supervisor from one call to the next one. It is described as follows:

Limits of indices in x (C convention)	Description
0 to 20	Raw estimated state (concentrations of compounds in liquid phase of the parts A, B and C of the column)
21 to 37	Estimated NO_2 and biomass and internal variables of the estimator
38 to 80	Array for delayed inputs
81 to 87	MV and internal variables of the controller itself
88 to 129	Temporal evolution of NO_2 on the horizon H
130 to 150	Saving of ‘u’ for next call of the program by the supervisor

It is composed of 3 groups of components :
- x1 contains 81 components : the nitrite, biomass and state estimations and also internal variables of the estimator ;
- x2 contains 49 components : the MV, the behaviour of NO_2 on the scenario horizon H ;
- x3 is a saving of the inputs vector ‘u’ from a call to the next one and has the same size as ‘u’.

With the C convention for index (where the index of the first component is 0), the MV is the component of index 81 and the estimation of NO2 is the component of index 25.

Description of the vector ‘errors’ :
The vector ‘errors’ has got 5 components :
- the first one is the number of detected errors in a run;
- the 4 following ones are the codes of the four first errors (errors are arranged in sequence of occurrence if any). The message attached to a code is detailed in a next section.

7.3.1.3 Parameters of the control

The parameters of the control are saved in an ASCII file ‘f_ctrl_3.txt’ that is read by the system ‘iFix’ at initialization (each time flag_ini is equal to 0) and loaded in the array param that will be transferred to the main control program. The parameters file is attached to the software package.

Name	Definition
dt_c	Sampling period of controller
dt_e	Sampling period of estimator
H	Horizon of simulation of the scenario
T_s	Vector of periods of time on H
stepmax	Maximum step of the iterative algorithm in routine ‘con_3’
zone_c	Vector of parameters of the zone defined around the nitrite constraint
coefil	Coefficient of the low pass filter of the inputs
Par_im0	Vector of parameters of the internal model of the control
Vv_e	Vector of volumes for the estimator time constants
beta_e	Vector of coefficients of the linear system binding rates of NH3 NO3 and NO2

Name	Definition
delta_e	Vector of coefficients of the linear system binding rates of NH3 NO3 and the biomass
ind_3e	Vector of indices for the estimator
i_ctrl	Flag for running estimator and controller (if 1) or estimator alone (if 0)
boundin	Bounds of the validity domain of the components of the vector of inputs 'u'

7.3.1.4 Code of message

Message or error detection coming from the program are returned to the supervisor by means of a code number (in the output argument 'errors') at end of each run.
The table 6 gives the message corresponding to a code number and the subroutine where the message comes from.

Code	Content of Message	Origin
10,11,12	Identity of volumes will imply division by 0 in routine 'order'. The volumes have to corrected before restarting the program.	acq_par
20	Input liquid flow rate is null. Estimation is frozen	estim_NX
21	Input liquid flow rate is null at initialization. Restart the program when liquid flow is no more null.	estim_NX
22	Negative value of time constant 'tauB'	estim_NX
23	Negative value of time constant 'teta'	estim_NX
24	Negative value of time constant 'teta1'	estim_NX
25	Negative value of time constant 'teta2'	estim_NX
26	Negative value of time constant 'teta3'	estim_NX
27	Ammonia consumption rate cannot be positive (non reversible reaction)	estim_NX
28	Nitrate production rate cannot be negative (non reversible reaction)	estim_NX
29	Nitrosomonas concentration cannot be negative	estim_NX
30	No interval found for dichotomy method	con_3
31	No interval found for dichotomy method : max number of iterations has been trespassed	con_3
32	No convergence for dichotomy method	con_3
33	Sizing problem with Euler integration step and array dimension	con_3
400+j	The concentration of the component 'j' of the state vector is negative	integ_im
500+j	The value of the component 'j' of the inputs vector 'u' is outside its validity domain.	nctrl
70	Complex square root	transbi
71, 74	The first order approximation is not justified in part A of the column	transbi
72, 75	The first order approximation is not justified in part B of the column	transbi
73, 76	The first order approximation is not justified in part C of the column	transbi
90,91,92	Identity of time constants implies division by 0. The volumes have to corrected before restarting the program.	order
95,96	The components of the vector x are not monotonic ascending	linterp

7.3.1.5 Method of integration on the scenario horizon

The computation of the outputs of the state system during the horizon H of the scenario is done by integration of the derivative of the state system. The Euler method has been chosen because of the simplicity of the algorithm and despite its big computational time (big computational time is acceptable because the period of the control is long : 1 hour).
When the concentration of a compound reaches its limit, the system becomes non linear and the Euler method, which has no variable step, may have difficulty to deal with and the solution may be a negative concentration. So, at each integration step, each solution that is negative or zero is forced to be equal to the tenth of the limiting concentration. In fact this

value is assumed to be the lowest value that is physically possible. This rule is applied in the routine ‘integ_im’.

7.3.2 CIII_NitCtrlLaw Dynamic Link Library

This Dynamic Link Library encapsulates the SHERPA’s software control package and allows external programs to use the control function. It implements the following interface:

7.3.2.1 CIII_nctrl

Main function of nitrite control

7.3.2.1.1 Input parameters

Parameter	Type	Description
x	double FAR*	see section 6.3.1.2
errors	double FAR*	see section 6.3.1.2
u	double FAR*	see section 6.3.1.2
flag_sav	double	Flag to save data on ASCII files (for checking internal variables)
flag_ini	double FAR*	Initialisation flag (when set to 0 by the calling program) 'flag_ini' is set to 1 by this program and must not be changed by the calling system
param	double FAR*	see section 6.3.1.2

7.3.2.1.2 Output parameters

(none)

7.3.3 CIII_NitCtrl Activex Control

This Activex component eases the integration with the supervision software. Implements the following interface:

7.3.3.1 CIII_nctrl

Main function of nitrite control

7.3.3.1.1 Input parameters

Parameter	Type	Description
x	VARIANT FAR& array of double size = 151	see section 6.3.1.2
errors	VARIANT FAR& array of double size = 5	see section 6.3.1.2
u	VARIANT FAR& array of double size = 21	see section 6.3.1.2
flag_sav	double	Flag to save data on ASCII files (for checking internal variables)

Parameter	Type	Description
flag_ini	double FAR&	Initialisation flag (when set to 0 by the calling program) 'flag_ini' is set to 1 by this program and must not be changed by the calling system
param	VARIANT FAR& array of double size = 21	

7.3.3.1.2 Output parameters
(none)

7.3.4 Deployment
To use the ActiveX control in the supervision:

1. Copy CIII_NitCtrlLaw.dll into the System32 folder of the Supervision Server.
2. Copy CIII_NitCtrl.ocx control into the System32 folder of the Supervision Server.
3. Register CIII_NitCtrl.ocx using the tool regsvr32:
   ex.:
   regsvr32 CIII_NitCtrl.ocx

After these steps, the control CIII_NitCtrl is available to be used in the iFix platform.

The control must be used from a scheduled task in background running as a Windows service (see Scheduler in iFix documentation).

7.3.5 PLC variables

Name	Description	PLC_Address	Device	Type	Range
CIII_SMV_NH4	Ammonium concentration scaled measure	400528		real	0-200 ppm
CIII_SMV_NO3	Nitrate concentration scaled measure	400530		real	0-1000 ppm
CIII_SSP_L1Lin	Level 1 liquid input supervision set point	400524		real	0-5 l/h
CIII_SSP_L2Lin	Level 2 liquid Input supervision set point	400542		real	0-5 l/h
CIII_SMV_NO2	Estimation of NO2 concentration (calculated by control law)	400562		real	mol/l

8 SUPERVISION

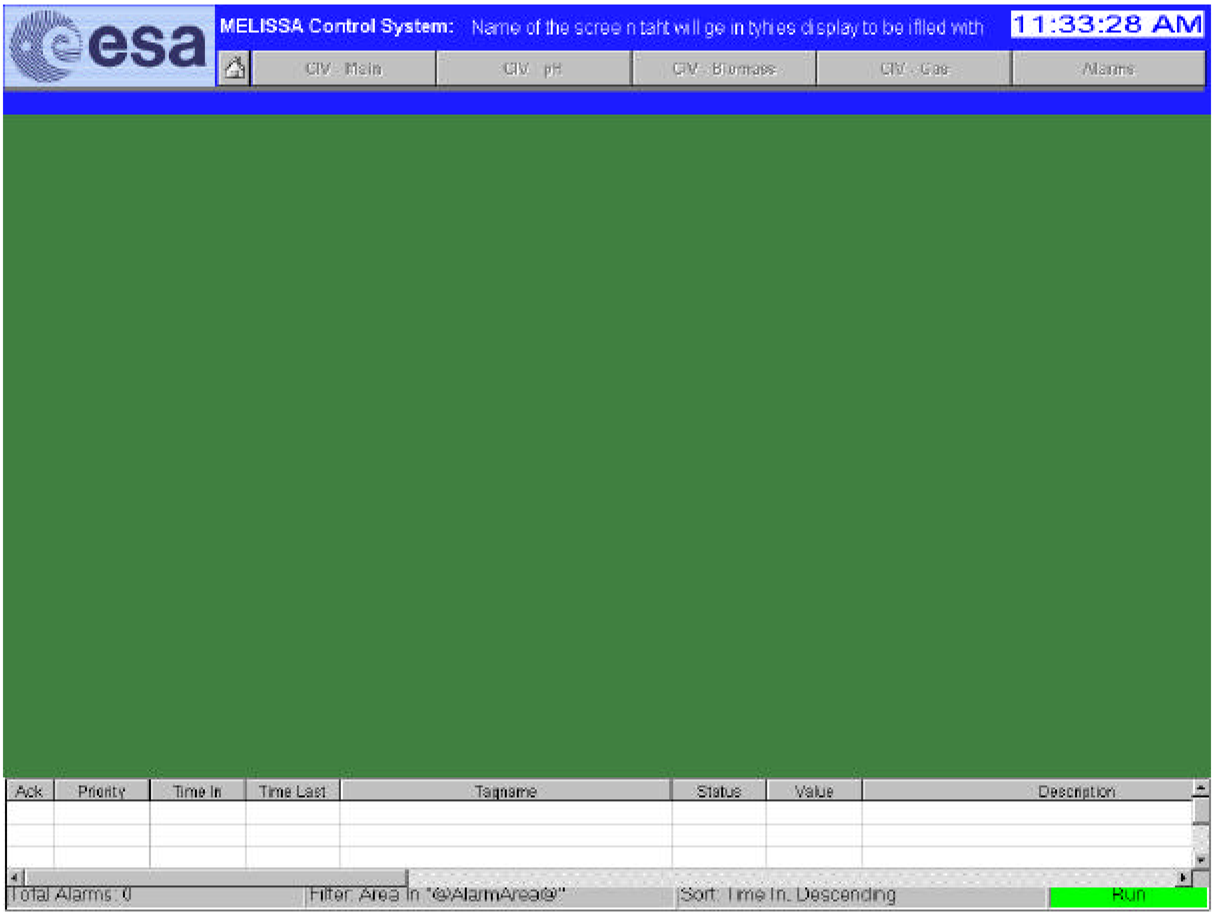
Supervision is used to display the control system status and to modify control system parameters.

8.1 Target Platform

Supervision software runs in the iFix platform over the Supervision Server and the Supervision Client. The Supervision Server runs the supervision algorithms while the Supervision client is used as the user interface.

8.2 Display layout

Following layout is used in the supervision displays:



Title bar: Placed on the top of the window shows information about the current display and the clock.

Navigation toolbar: Placed on the top of the window allows the user to navigate to other displays.

Working area: The green area is where the process variables and parameters will be displayed using schematics.

Alarm area: Placed on the bottom of the window will show the last alarms, allowing the user to acknowledge the alarm.

8.3 Main Supervision Display

8.3.1 MEL_Main: Main Display

8.3.1.1 Function

Form this display principal loop measures and set points will be visualised.

8.3.1.2 Values displayed

Name	Description
CIII_SMV_DO	DO scaled measure value
CIII_SMV_NO2	Estimation of NO2 concentration (calculated by control law)
CIII_SMV_LiFr	Liquid input flow rate
CIII_SMV_LoFr	Liquid output flow rate
CIV_SMV_BP	Biomass production
CIV_SMV_LiFr	Liquid input flow rate
CIV_SMV_LoFr	Computed liquid output flow rate
CIV_SMGO_O2	O2 at output measure scaled value

8.3.1.3 Navigation

From this display it is possible to navigate using the buttons next to compartment images to the following displays:

- CIII_SUP_Main
- CIV_SUP_Main

8.4 Compartment III displays

8.4.1 MEL_CIII_MAIN: CIII Main Display

8.4.1.1 Function

Displays a general view of the compartment with the most relevant measure values of each loop.

8.4.1.2 Values displayed

Name	Description
CIII_SMV_NO3	Nitrate concentration scaled measure
CIII_SMV_NH4	Ammonium concentration scaled measure
CIII_SMV_pH	pH scaled measure
CIII_SMV_T	Temperature scaled measure
CIII_SMV_DO	DO scaled measure value
CIII_SMV_P	Pressure scaled measure value
CIII_SMV_NO2	Estimation of NO2 concentration (calculated by control law)
CIII_SMV_LiFr	Liquid input flow rate
CIII_SMV_LoFr	Liquid output flow rate
CIII_CNS_OpModeO2	DO control operational mode (0=Off, 1=Auto, 2=Manual)
CIII_CNS_OpModeP	Pressure control operational mode (0=Off, 1=Auto, 2=Manual)
CIII_CNS_OpModepH	pH control operational mode (0=Off, 1=Auto, 2=Manual)
CIII_CNS_OpModeT	Temperature control operational mode (0=Off, 1=Auto, 2=Manual)

8.4.1.3 Parameters

- Set all control loops Operational Mode to Off
  (CIII_CNS_OpModeO2, CIII_CNS_OpModeP, CIII_CNS_OpModepH, CIII_CNS_OpModeT = 0)

8.4.1.4 Navigation

From this display it is possible to navigate using the common navigation bar and additionally to the following displays:
- CIII_SUP_pH
- CIII_SUP_Liquid
- CIII_SUP_Gas
- CIII_SUP_Temp

8.4.2 MEL_CIII_pH: pH Loop Display

8.4.2.1 Function

Displays variables and values that participate in the pH regulation loop.

8.4.2.2 Values displayed

Name	Description
CIII_CNS_pHramp	pH supervision set point ramp coefficient
CIII_CNS_CO2Kp	Additional proportional constant for CO2
CIII_CNS_pHKp	Proportional constant for Acid/Base PI
CIII_CNS_pHKi	Integration constant for Acid/Base PI
CIII_CNS_pHMode	PH regulation mode variable (1=CO2 only, 2=CO2+Base, 3=Base+Acid)
CIII_CNS_OpModepH	pH control operational mode (0=Off, 1=Auto, 2=Manual)
CIII_IND_CO2	Enable CO2 output to regulate pH
CIII_IND_Ac	Enable Acid pump output to regulate pH
CIII_IND_Bs	Enable Base pump output to regulate pH
CIII_RL_Ac	Relay acid pump
CIII_RL_Bs	Relay base pump
CIII_SMV_Ac	Acid pump control action
CIII_SMV_Bs	Base pump control action
CIII_SMV_CO2	CO2 input flow control action
CIII_SMV_pH	pH scaled measure
CIII_SMV_PHt	Scaled pH value at top
CIII_SMV_PHb	Scaled pH value at bottom
CIII_SSP_pH	pH supervision set point

8.4.2.3 Parameters

From this display the following parameters can be modified:

Name	Description
CIII_SSP_pH	pH supervision set point
CIII_CNS_pHramp	pH supervision set point ramp coefficient
CIII_CNS_CO2Kp	Additional proportional constant for CO2
CIII_CNS_pHKp	Proportional constant for Acid/Base PI
CIII_CNS_pHKi	Integration constant for Acid/Base PI
CIII_CNS_pHMode	PH regulation mode variable (1=CO2 only, 2=CO2+Base, 3=Base+Acid)
CIII_CNS_OpModepH	pH control operational mode (0=Off, 1=Auto, 2=Manual)

pH regulation modes:

1- CO2 used to regulate pH.
2- CO2 fixed and a base source to regulate pH.
3- CO2 fixed and a base and acid sources are used to regulate pH.

8.4.2.4 Navigation

Common navigation bar.

8.4.2.5 Alarms

Alarm	Description
CIII_ALM_AcErr	Alarm to notify acid pump link error
CIII_ALM_BsErr	Alarm to notify base pump link error
CIII_ALM_pH	Alarm of pH deviation
CIII_ALM_pHbot	Alarm to notify pH bottom sensor link error
CIII_ALM_pHtop	Alarm to notify pH top sensor link error

8.4.2.6 Manual values

Allow the edition of following manual values:

Name	Description	Type	Range
CIII_MAN_Ac	Manual acid pump set point	real	0-100%
CIII_MAN_Bs	Manual base pump set point	real	0-100%
CIII_MAN_CO2	Manual CO2 flow controller set point	real	0-100%
CIII_MAN_EnAc	Manual enable of acid pump	Bool	0-1
CIII_MAN_EnBs	Manual enable of base pump	Bool	0-1

8.4.3 MEL_CIII_Liquid: Liquid Loop Display

8.4.3.1 Function

Displays variables and values that participate in the Liquid input / output flow regulation.

8.4.3.2 Values displayed

Name	Description
CIII_CNS_LinA	Input pump calibration constant parameter A
CIII_CNS_LinB	Input pump calibration constant parameter B
CIII_CNS_LoA	Output pump calibration constant parameter A
CIII_CNS_LoB	Output pump calibration constant parameter B
CIII_CNS_OpModeL	Liquid control operational mode (0=Off, 1=Auto, 2=Manual)
CIII_IND_Llow	Liquid level low indicator
CIII_IND_Lhigh	Liquid level high indicator
CIII_IND_CalNH4	Analyzer calibration indicator
CIII_IND_CalNO3	Nitrate calibration indicator
CIII_RL_Lbt	Activation of the pump for the buffer tank
CIII_SMV_LiFr	Liquid input flow rate
CIII_SMV_LO	Liquid output flow control action
CIII_SMV_LoFr	Liquid output flow rate
CIII_SMV_NH4	Amonium concentration scaled measure
CIII_SMV_NO2	Estimation of NO2 concentration (calculated by control law)
CIII_SMV_NO3	Nitrate concentration scaled measure
CIII_SSP_L1LI	Level 1 liquid input supervision set point
CIII_SSP_L2LI	Level 2 liquid input supervision set point

8.4.3.3 Parameters

From this display the following parameters can be modified:

Name	Description
CIII_SSP_LI	Liquid input supervision set point

8.4.3.4 Navigation

Common navigation bar.

8.4.3.5 Alarms

Alarm	Description
CIII_ALM_L	Alarm of high level
CIII_ALM_LIErr	Alarm to notify liquid input pump link error
CIII_ALM_LOErr	Alarm to notify liquid output pump link error
CIII_ALM_NH4	Alarm to notify NH4 sensor link error

Alarm	Description
CIII_ALM_NO3	Alarm to notify NO3 sensor link error

8.4.3.6 Manual values

Allow the edition of following manual values:

Name	Description	Type	Range
CIII_MAN_Lin	Liquid input pump manual value	real	0-100%
CIII_MAN_LO	Liquid output pump manual value	real	0-100%

8.4.4 MEL_CIII_Gas: Gas Loop Display

8.4.4.1 Function

Displays variables and values that participate in the gas phase.

8.4.4.2 Values displayed

Name	Description
CIII_CNS_DOBias	Disturbance variable (Feed_fw) for DO PID
CIII_CNS_DOKd	Derivative constant for DO PID
CIII_CNS_DOKi	Integrative constant for DO PID
CIII_CNS_DOKp	Proportional constant for DO PID
CIII_CNS_DOramp	DO supervision set point ramp coefficient
CIII_CNS_N2Kp	Proportional constant for N2 regulation
CIII_CNS_OpModeGas	Gas control operational mode (0=Off, 1=Auto, 2=Manual)
CIII_RL_P	Activation of Pressure Safety Valve
CIII_SMV_DO	DO scaled measure value
CIII_SMV_DObot	DO at bottom scaled measure value
CIII_SMV_DOtop	DO at top scaled measure value
CIII_SMV_N2	N2 input flow control action
CIII_SMV_O2	O2 input flow control action
CIII_SMV_CO2	CO2 input flow control action
CIII_SMV_P	Pressure scaled measure value
CIII_SSP_DO	DO Supervision set point
CIII_SSP_P	Pressure supervision set point

8.4.4.3 Parameters

From this display the following parameters can be modified:

Name	Description
CIII_CNS_DOBias	Disturbance variable (Feed_fw) for DO PID
CIII_CNS_DOKd	Derivative constant for DO PID
CIII_CNS_DOKi	Integrative constant for DO PID
CIII_CNS_DOKp	Proportional constant for DO PID
CIII_CNS_OpModeGas	Gas control operational mode (0=Off, 1=Auto, 2=Manual)
CIII_CNS_DOramp	DO supervision set point ramp coefficient
CIII_CNS_N2Kp	Proportional constant for N2 regulation
CIII_SSP_DO	DO Supervision set point
CIII_SSP_P	Pressure supervision set point

8.4.4.4 Navigation

Common navigation bar.

8.4.4.5 Alarms

Alarm	Description
CIII_ALM_DO	Alarm to notify DO is over the set point
CIII_ALM_DOBot	Alarm to notify DO bottom sensor link error
CIII_ALM_DOTop	Alarm to notify DO top sensor link error
CIII_ALM_P	Over pressure alarm
CIII_ALM_Perr	Alarm to notify Pressure sensor link error

8.4.4.6 Manual values

Allow the edition of following manual values:

Name	Description	Type	Range
CIII_MAN_N2	Manual N2 flow controller set point	real	0-150%
CIII_MAN_O2	Manual O2 flow controller set point	real	0-100%
CIII_MAN_EnP	Manual enable of pressure safety valve	Bool	

8.4.5 MEL_CIII_Temp: Temperature Loop Display

8.4.5.1 Function

Displays variables and values that participate in the temperature regulation.

8.4.5.2 Values displayed

Name	Description
CIII_CNS_Tramp	Temperature supervision set point ramp coefficient
CIII_CNS_OpModeT	Temperature control operational mode (0=Off, 1=Auto, 2=Manual)
CIII_RL_CV	Open/close the cooling valve
CIII_RL_HT	Activate Heater
CIII_SMV_T	Temperature scaled measure
CIII_SMV_Tb	Temperature at bottom scaled measure
CIII_SMV_Tt	Temperature at top scaled measure
CIII_SSP_T	Temperature supervision set point

8.4.5.3 Parameters

From this display the following parameters can be modified:

Name	Description
CIII_SSP_T	Temperature supervision set point
CIII_CNS_Tramp	Temperature supervision set point ramp coefficient
CIII_CNS_OpModeT	Temperature control operational mode (0=Off, 1=Auto, 2=Manual)

8.4.5.4 Alarms

Alarm	Description
CIII_ALM_Tbot	Alarm to notify Temperature bottom sensor link error
CIII_ALM_Tdif	Alarm of temperature difference between top and bottom
CIII_ALM_Tover	Over temperature alarm
CIII_ALM_Ttop	Alarm to notify Temperature top sensor link error
CIII_ALM_Tunder	Under temperature alarm

8.4.5.5 Manual values

Allow the edition of following manual values:

Name	Description	Type	Range
CIII_MAN_EnCV	Manual enable of the cooling valve	Bool	0-1
CIII_MAN_EnHT	Manual enable of the heater	Bool	0-1

8.5 Compartment IV displays

8.5.1 MEL_CIV_MAIN: CIV Main Display

8.5.1.1 Function

Displays a general view of the compartment with the most relevant measure values of each loop.

8.5.1.2 Values displayed

Name	Description
CIV_SMGO_O2	O2 at output measure scaled value
CIV_SMGO_CO2	CO2 at output measurement scaled value
CIV_SMV_BP	Biomass production
CIV_SMV_CxDW	Conditioned biomass concentration in dw units
CIV_SMV_FrCO2	CO2 at input measure scaled value
CIV_SMV_FrGas	Gas flow at compartment input
CIV_SMV_LiFr	Liquid input flow rate
CIV_SMV_LoFr	Liquid output flow rate
CIV_SMV_P	Pressure measurement scaled value
CIV_SMV_pH	Scaled pH measurement
CIV_SMV_T	Scaled Temperature value
CIV_SSP_LightWm	Light supervision set-point in w/m2
CIV_CNS_OpModeBP	Biomass Production control mode (0=Off, 1=Auto, 2=Manual)
CIV_CNS_OpModeGas	Gas control mode (0=Off, 1=Auto, 2=Manual)
CIV_CNS_OpModepH	pH control mode ((0=Off, 1=Auto, 2=Manual)

8.5.1.3 Parameters

- Set all control loops Operational Mode to Off (CIV_CNS_OpModeBP, CIV_CNS_OpModeGas, CIV_CNS_OpModepH = 0)

8.5.1.4 Navigation

From this display it is possible to navigate using the common navigation bar and additionally to the following displays:
- CIV pH Loop display
- CIV Biomass Production display
- CIV Gas Loop display

8.5.2 MEL_CIV_pH: pH Loop Display

CIV_pH_Display

8.5.2.1 Function

Displays variables and values that participate in the pH regulation loop.

8.5.2.2 Values displayed

Name	Description
CIV_CNS_AcKp	Acid pump regulator proportional constant for PID
CIV_CNS_BsKp	Base pump regulator proportional constant for PID
CIV_CNS_CO2Kd	CO2 flow regulator derivative constant for PID
CIV_CNS_CO2Ki	CO2 flow regulator integration constant for PID
CIV_CNS_CO2Kp	CO2 flow regulator proportional constant for PID
CIV_CNS_OffsetCO2	Offset to provided a constant flux of CO2 to the reactor
CIV_CNS_OpModepH	pH control mode ((0=Off, 1=Auto, 2=Manual)
CIV_CNS_PHMODE	PH regulation mode parameter (1=CO2 only, 2=CO2+Base, 3=Base+Acid)
CIV_IND_CO2	Enable addition of CO2 for pH regulation
CIV_IND_Ac	Enable addition of Acid for pH regulation
CIV_IND_Bs	Enable addition of Base for pH regulation
CIV_SMV_FrCO2	CO2 at input measure scaled value
CIV_SMV_Ac	Additional Acid source actuation in %
CIV_SMV_Bs	Additional Base source actuation in %
CIV_SMV_CacCO2	Control action to regulate CO2 input
CIV_SMV_pH	pH measurement
CIV_SMV_FrGas	Gas flow at compartment input
CIV_SSP_pH	pH set-point fixed by the supervision

8.5.2.3 Parameters

From this display the following parameters can be modified:

Name	Description
CIV_SSP_pH	pH set-point fixed by the supervision
CIV_CNS_AcKp	Acid pump regulator proportional constant for PID
CIV_CNS_BsKp	Base pump regulator proportional constant for PID
CIV_CNS_CO2Kd	CO2 flow regulator derivative constant for PID
CIV_CNS_CO2Ki	CO2 flow regulator integration constant for PID
CIV_CNS_CO2Kp	CO2 flow regulator proportional constant for PID
CIV_CNS_OffsetCO2	Offset to provided a constant flux of CO2 to the reactor
CIV_CNS_OpModepH	pH control mode ((0=Off, 1=Auto, 2=Manual)

Name	Description
CIV_CNS_PHMODE	PH regulation mode parameter (1=CO2 only, 2=CO2+Base, 3=Base+Acid)

pH regulation modes:
1. CO2 used to regulate pH.
2. CO2 fixed and a base source to regulate pH.
3. CO2 fixed and a base and acid sources are used to regulate pH.

8.5.2.4 Navigation

Common navigation bar.

8.5.2.5 Alarms

Register a high-priority alarm when:

Alarm	Description
CIV_ALM_AcErr	Alarm to notify pH sensor link error
CIV_ALM_BsErr	Alarm to notify base pump link error
CIV_ALM_Ph	Alarm to notify problems in pH regulation
CIV_ALM_PhErr	Alarm to notify pH sensor link error

8.5.2.6 Manual values

Allow the edition of following manual values:

Name	Description	Type	Range
CIV_MAN_Ac	Manual Acid Pump set point	Real	0 – 100 %
CIV_MAN_Bs	Manual Base Pump set point	Real	0 – 100 %
CIV_MAN_FrCO2	Manual CO2 flow regulation set point	Real	0 – 5 nLm

8.5.3 MEL_CIV_BP: Biomass Production Display

8.5.3.1 Function

Displays variables and values that participate in the biomass production regulation loop.

8.5.3.2 Values displayed

Name	Description
CIV_CNS_Li1FrA	Parameter A for liquid input pump 1 set-point calculation
CIV_CNS_Li1FrB	Parameter B for liquid input pump 1 set-point calculation
CIV_CNS_Li2FrA	Parameter A for liquid input pump 2 set-point calculation
CIV_CNS_Li2FrB	Parameter B for liquid input pump 2 set-point calculation
CIV_CNS_LoFrA	Parameter A for liquid output pump set-point calculation
CIV_CNS_LoFrB	Parameter B for liquid output pump set-point calculation
CIV_CNS_MinV	Minimum volume to switch liquid input tank
CIV_CNS_ConvV	Density factor to translate Kg to liters
CIV_CNS_OpModeBP	Biomass Production control mode (0=Off, 1=Auto, 2=Manual)
CIV_RL_Li2	Liquid Pump input2 on
CIV_RL_Li1	Liquid Pump input1 on
CIV_RL_Cx	Aeration of biomass sensor for cleaning
CIV_SMV_Li1	Liquid Pump input1 set point in %
CIV_SMV_Li2	Liquid Pump input2 set point in %
CIV_SMV_LO	Liquid Pump output set point in %
CIV_SMV_Ls	Regulator of light supply actuation in %
CIV_SMV_CxDW	Conditioned biomass concentration in dw units
CIV_SMLI_V1	Volume liquid input buffer tank1
CIV_SMLI_V2	Volume liquid input buffer tank2
CIV_SMV_LiFr	Liquid input flow rate
CIV_SMV_BP	Biomass production
CIV_SMV_LoFr	Liquid output pump flow rate
CIV_SSP_LightWm	Light supervision set-point in w/m2
CIV_SSP_L1BP	Level 1 Biomass production set point
CIV_SSP_L2BP	Level 2 Biomass production set point
CIV_SSP_L1LiFr	Level 1 Liquid input flow rate set-point
CIV_SSP_L2LiFr	Level 2 Liquid input flow rate set-point
CIV_CNS_CxAbsMin	Configurable max range of biomass sensor
CIV_CNS_CxAbsMax	Configurable min range of biomass sensor
CIV_CNS_DW	Dry weight conversion factor

8.5.3.3 Parameters

From this display the following parameters can be modified:

Name	Description
CIV_CNS_MinV	Minimum volume to switch liquid input tank
CIV_CNS_ConvV	Density factor to translate Kg to liters
CIV_CNS_Li1FrA	Parameter A for liquid input pump 1 set-point calculation
CIV_CNS_Li1FrB	Parameter B for liquid input pump 1 set-point calculation
CIV_CNS_Li2FrA	Parameter A for liquid input pump 2 set-point calculation
CIV_CNS_Li2FrB	Parameter B for liquid input pump 2 set-point calculation
CIV_CNS_LoFrA	Parameter A for liquid output pump set-point calculation
CIV_CNS_LoFrB	Parameter B for liquid output pump set-point calculation
CIV_SSP_L2BP	Level 2 biomass production set-point
CIV_SSP_L2LiFr	Level 2 liquid input flow rate set-point
CIV_CNS_CxAbsMin	Configurable max range of biomass sensor
CIV_CNS_CxAbsMax	Configurable min range of biomass sensor
CIV_CNS_DW	Dry weight conversion factor

8.5.3.4 Chart

The following variables are displayed in chart format:

Name	Description
CIV_SSP_L2BP	Global variable to store biomass production set-point
CIV_SMV_BP	Biomass production
CIV_SSP_L2LiFr	Level 2 liquid input flow rate set-point
CIV_SMV_LiFr	Liquid input flow rate
CIV_SSP_Light	Light supervision set-point
CIV_SMV_CxDW	Conditioned biomass concentration in dw units

8.5.3.5 Navigation

Common navigation bar.

8.5.3.6 Alarms

Alarm	Description
CIV_ALM_LiEmpty	Alarm liquid input tanks empty
CIV_ALM_V1Err	Alarm to notify scale1 sensor link error
CIV_ALM_V2Err	Alarm to notify scale2 sensor link error
CIV_ALM_CxErr	Alarm to notify biomass sensor link error
CIV_ALM_LsErr	Alarm to notify light supply link error

8.5.3.7 Manual values

Allow the edition of following manual values:

Name	Description	Type	Range
CIV_MAN_EnCx	Manual enable of biomass sensor aeration valve	Bool	0 – 1 (=cleaning)
CIV_MAN_EnLi1	Manual enable of Liquid input Pump 1	Bool	0 – 1 (=active)
CIV_MAN_EnLi2	Manual enable of Liquid input Pump 2	Bool	0 – 1 (=active)
CIV_MAN_EnLO	Manual enable of Liquid output Pump	Bool	0 – 1 (=active)
CIV_MAN_Li1	Manual Liquid Pump input1 set point	Real	0 – 100 %
CIV_MAN_Li2	Manual Liquid Pump input2 set point	Real	0 – 100 %
CIV_MAN_LO	Manual Liquid Pump output set point	Real	0 – 100 %
CIV_MAN_Ls	Manual regulator of light supply set point	Real	0 – 100 %

8.5.4 MEL_CIV_Gas: Gas Loop Display

8.5.4.1 Function

Displays variables and values that participate in the gas flow and pressure regulation loop.

8.5.4.2 Values displayed

Name	Description
CIV_CNS_MaxPress	Maximum allowed pressure in the reactor
CIV_CNS_OpModeGas	Gas control mode (0=Off, 1=Auto, 2=Manual)
CIV_IND_CalCO2O2	Calibration indicator of CO2/O2 sensor.
CIV_IND_ErrCO2O2	Error Indicator of CO2/O2 sensor.
CIV_IND_Scale1CO2O2	CO2/O2 sensor scale
CIV_IND_Scale2CO2O2	CO2/O2 sensor scale
CIV_IND_OverPress	Over pressure indicator
CIV_IND_UnderPress	Under pressure indicator
CIV_RL_Safety	Pressure safety valve activation
CIV_SMGI_FrGas	Gas flow at external input
CIV_SMGO_FrGas	Gas flow at compartment output scaled value
CIV_SMGO_CO2	CO2 at output measurement scaled value
CIV_SMGO_O2	O2 at output measure scaled value
CIV_SMV_DO	Percent DO saturation scaled value
CIV_SMV_FrCO2	CO2 at input measure scaled value
CIV_SMV_FrGas	Gas flow at compartment input
CIV_SMV_P	Pressure measurement scaled value
CIV_SSP_Fgex	Gas flow external input supervision set point
CIV_SSP_Fgi	Gas flow at input regulation supervision set point
CIV_SSP_Fgo	Gas flow at output regulation supervision set point
CIV_SSP_NomPress	Nominal pressure in the reactor set-point
CIV_CNS_DOMax	Configurable DO range max
CIV_CNS_DOMin	Configurable DO range min
CIV_CNS_CO2Max	Configurable CO2 range max
CIV_CNS_CO2Min	Configurable CO2 range min
CIV_CNS_O2Max	Configurable O2 range max
CIV_CNS_O2Min	Configurable O2 range min
CIV_CNS_CO2E2Max	Configurable Scale2 CO2 range max
CV_CNS_CO2E2Min	Configurable Scale2 CO2 range min
CIV_CNS_O2E2Max	Configurable Scale2 O2 range max
CV_CNS_O2E2Min	Configurable Scale2 O2 range min

8.5.4.3 Parameters

From this display the following parameters can be modified:

Name	Description
CIV_CNS_MaxPress	Maximum allowed pressure in the reactor
CIV_CNS_OpModeGas	Gas control mode (0=Off, 1=Auto, 2=Manual)
CIV_SSP_Fgex	Gas flow external input supervision set point
CIV_SSP_Fgi	Gas flow at input regulation supervision set point
CIV_SSP_Fgo	Gas flow at output regulation supervision set point
CIV_SSP_NomPress	Nominal pressure in the reactor set-point
CIV_CNS_DOMax	Configurable DO range max
CIV_CNS_DOMin	Configurable DO range min
CIV_CNS_CO2Max	Configurable CO2 range max
CIV_CNS_CO2Min	Configurable CO2 range min
CIV_CNS_O2Max	Configurable O2 range max
CIV_CNS_O2Min	Configurable O2 range min
CIV_CNS_CO2E2Max	Configurable Scale2 CO2 range max
CV_CNS_CO2E2Min	Configurable Scale2 CO2 range min
CIV_CNS_O2E2Max	Configurable Scale2 O2 range max
CV_CNS_O2E2Min	Configurable Scale2 O2 range min

8.5.4.4 Chart

The following variables are displayed in chart format:

Name	Description
CIV_SMV_P	Pressure measurement scaled value
CIV_SSP_NomPress	Nominal pressure in the reactor set-point

8.5.4.5 Navigation

Common navigation bar.

8.5.4.6 Alarms

Alarm	Description
CIV_ALM_CO2Err	Alarm to notify CO2 sensor link error
CIV_ALM_DOErr	Alarm to notify DO sensor link error
CIV_ALM_Gas	Alarm notification for overpressure
CIV_ALM_O2Err	Alarm to notify O2 sensor link error
CIV_ALM_Perr	Alarm to notify pressure sensor link error

8.5.4.7 Manual values

Allow the edition of following manual values:

Name	Description	Type	Range
CIV_MAN_EnSafety	Manual enable of pressure safety valve	Bool	0 – 1 (=active)

8.5.5 MEL_CIV_Temp: Temperature Display

8.5.5.1 Function

Displays variables and values that participate in the temperature regulation loop.

8.5.5.2 Values displayed

Name	Description
CIV_SMV_T	Scaled Temperature value
CIV_SSP_T	Temperature set-point fixed by the supervision

8.5.5.3 Parameters

From this display the following parameters can be modified:

Name	Description
CIV_SSP_T	Temperature set-point fixed by the supervision

8.5.5.4 Chart

The following variables are displayed in chart format:

Name	Description
CIV_SMV_T	Scaled Temperature value
CIV_SSP_T	Temperature set-point fixed by the supervision

8.5.5.5 Navigation

Common navigation bar.

8.5.5.6 Alarms

Alarm	Description
CIV_ALM_T	Alarm to notify over temperature
CIV_ALM_Terr	Alarm to notify Temperature sensor link error

8.6 Supervision Database

Supervision Database is implemented as a set of Microsoft® Access MDB files with a file for each compartment. Each file contains only one table to store measured values. Files are located in the same folder as the iFix pictures ("\DYNAMICS\PIC"). Tables are separated into different MDB files in order to allow the manipulation of individual files without perturbation on the other compartments.

***NOTE**: To enable Database Access in iFix, DAO library has to be added into VB script object library references. See iFix documentation.*

8.6.1 Update method

Supervision database is updated from iFix. A task has to be configured in the Scheduler for every compartment that updates regularly the database (initially every 1h).

8.6.2 Compartment III

Scheduler Task: MEL_CIII_SAVEVALUES

File	CIII_DB.mdb	
Table	CIII_MeasuredValues	
Column	**Description**	**Type**
DateTime (PK)	Time stamp	Date/Time
CIII_SSP_L2Lin	Level 2 Liquid input flow rate set point	Double
CIII_SSP_L1Lin	Level 1 Liquid input flow rate set point	Double
CIII_SMV_NO3	Nitrate concentration scaled measure	Double
CIII_SMV_NO2	Estimated nitrite concentration	Double
CIII_SMV_N2	N_2 to regulate DO concentration	Double
CIII_SMV_NH4	Amonium concentration scaled measure	Double
CIII_SMV_O2	O_2 to regulate DO concentration	Double
CIII_SSP_pH	pH set point	Double
CIII_SMV_pH	pH scaled measure	Double
CIII_SMV_CO2	CO_2 to regulate pH	Double
CIII_SMV_AC	Acid medium to regulate pH	Double
CIII_SMV_BS	Base medium to regulate pH	Double
CIII_SSP_T	Temperature set point	Double
CIII_SMV_T	Temperature scaled measure	Double
CIII_SSP_DO	DO set point	Double
CIII_SMV_DO	DO scaled measure value	Double
CIII_SSP_P	Pressure set point	Double
CIII_SMV_P	Pressure scaled measure value	Double
CIII_SMV_LiFr	Liquid input flow rate	Double

8.6.3 Compartment IVa

Scheduler Task: MEL_CIV_SAVEVALUES

File	CIV_DB.mdb	
Table	CIV_MeasuredValues	
Column	**Description**	**Type**
DateTime (PK)	Time stamp	Date/Time
CIV_SMV_CxDW	Biomass concentration in dw units	Double
CIV_SSP_L1LiFr	Level 1 Liquid input flow rate set-point	Double
CIV_SSP_L2LiFr	Level 2 Liquid input flow rate set-point	Double
CIV_SMV_LiFr	Liquid input flow rate	Double
CIV_SMV_LoFr	Liquid output flow rate supervision set-point	Double
CIV_SMV_BP	Biomass production	Double
CIV_SSP_L2BP	Level 2 Biomass production set point	Double
CIV_SSP_L1BP	Level 1 Biomass production set point	Double
CIV_SSP_Light	Light supervision set-point	Double
CIV_SSP_pH	pH supervision set point	Double
CIV_SMV_pH	Scaled pH measurement	Double
CIV_SMGO_CO2	CO_2 at output measurement scaled value	Double
CIV_SSP_P	Pressure supervision set point	Double
CIV_SMV_P	Pressure measurement scaled value	Double
CIV_SMGO_O2	O_2 at output measure scaled value	Double
CIV_SMV_FrCO2	CO_2 at input measure scaled value	Double
CIV_SSP_T	Temperature set point	Double
CIV_SMV_T	Temperature measurement	Double
CIV_SMV_DO	DO measurement	Double
CIV_SMLI_V1	Tank 1 volume	Double
CIV_SMLI_V2	Tank 2 volume	Double

9 NETWORK CONFIGURATION

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
CIV_PLC	172.16.0.141	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.

10 APPENDIX A. VARIABLE MNEMONICS

Process variables mnemonics have been selected following MELISSA's common used naming conventions stated in [A3], section 11.2.

In addition to the process variables there are internal variables that need to be used for calculations or to exchange data between the PLC and the Supervision (tags). Internal variables are not considered here but the tags follow the following rules:

All tag names can be divided into three parts:

- Compartment identification (CIV, CIII)
- Purpose of the tag:
  - CNS: Constant parameter
  - RL: Digital output (relay)
  - ALM: Alarm
  - IND: Indicator
  - MV: Measured variable (of the process)
  - SP: Set point
  - SMV: Scaled value to be monitored from the Supervision.
  - SSP: Supervision provided set point.
  - MAN: Manual set points.
- Name

MELISSA

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Control System Demonstrator
Operations Manual

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Document Change Log

Version	Issue	Date	Observations
1	0	15 Apr 2004	New document
1	1	28 Jul 2004	Acronyms list added ESA comments dated 21/07/04 implemented.

TABLE OF CONTENTS

ACRONYMS LIST

AC	Alternate Current
CIII	Compartment III
CIV	Compartment IV
CPU	Central Process Unit
DC	Direct Current
DW	Dry weight
ESA	European Space Agency
FBD	Function Block Diagram .
FG	Function Generator
GND	Ground
HDD	Hardware Design Document
HMI	Human Machine Interface
LED	Light Emitting Diode
PID	Proportional, Derivative, Integration
PLC	Programmable Logic Controller
SCADA	Supervisory Control And Data Acquisition
SDD	Software Design Document
STP	Shielded Twisted Pair
UAB	*Universitat Autònoma de Barcelona*
VBA	Visual Basic for Applications

1 SCOPE

This Operations Manual is intended to help the operation and maintenance of the Control System Demonstrator for compartments III and IV in the MELISSA Plant installed at the UAB.

The detailed design description of this system is provided in the Hardware Design Document and Software Design Document, [R2] and [R3] respectively.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**.TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.

[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.

[A3] **Memorandum of Understanding between the UAB and NTE S.A.** MEL-0000-SP-007-NTE. Version 1. Issue 0. 21 January 2002.

[A4] ***Reglamento de Baja Tensión* (RBT)**, July 2002.

[A5] **MELISSA Control System Architecture and Trade-off**. TN 72.3. Version 1. Issue 0. February 2003.

2.2 Reference Documents

[R1] **Definition of the control requirements for the MELISSA Loop**. TN 72.2, v.1.2, November 2002.

[R2] **Melissa Control System Demonstrator Hardware Design Document,** TN 72.4 Volume IIa, v.1.1, July 2004 (MEL-3320-RP-020-NTE)

[R3] **Melissa Control System Demonstrator Software Design Document,** TN 72.4 Volume IIb, v.1.1, July 2004 (MEL-3320-RP-025-NTE)

[R4] **iFix Electronic Books. iFIX Version 3.0 - 06.02 software distribution, 2002**

[R5] **Modicon Quantum Automation Series Hardware Reference Guide.** 840 USE 100 00 version 10.0, 2002

[R6] **Concept User Manual.** Volume 1, 840 USE 493 00 eng., Version 2.5 – SR2. September 2001

3 INTRODUCTION

3.1 Intended Readership

This manual is intended for personnel in charge of the operation of the MELISSA Control System for both maintenance and scientific purposes.

- Investigators responsible of performing in-plant experiments.
- Maintenance and troubleshooting personnel in charge of the installation and maintenance of the MELISSA Pilot Plant Software.

It is expected that users have some basic Microsoft® Windows knowledge and familiarity with the MELISSA Pilot Plant.

Note that no detailed explanation about the operation of third-party software(s) used to implement the Control System is given in this manual, but only reference to their corresponding user manuals when more detail is needed.

3.2 Applicability Statement

This manual applies to the Control System Demonstrator developed to assess the capability of the Control System Architecture [A5] to achieve Control System Requirements stated in [R1]. The Control System comprises the following parts:

- CIII Rack, including control hardware for compartment III and running CIII local regulation loops.
- CIV Rack, including control hardware for compartment IV and running CIV local regulation loops.
- Supervision Rack including the Supervision server and the network switch and running Supervision software iFIX 3.0 (server application).
- Client Computer, running the supervision software iFIX 3.0 (client application), Concept 2.6 (Quantum PLC programming tool) and XBT-L1000 V3 (MAGELIS programming tool).

3.3 Purpose

The purpose of this document is to provide the user with an understanding of the functions available in the MELISSA Control System Demonstrator and a description of the common operations to be performed during its utilisation and maintenance. Following the instructions described in this manual will lead to a better understanding and to obtain a full profit of the MELISSA Control System Demonstrator.

3.4 How to use this document

The Overview section is intended for all users. It summarises what this system is used for, into the process of using the MELISSA Pilot Plant.

The Table of Contents can be used to easily locate the detailed description of a specific function.

Maintenance and troubleshooting are addressed in par. 12 and 13 respectively.

3.5 Problem reporting instructions

Problems found must be reported to NTE following the form included in APPENDIX B.

NTE S.A.
Pol. Can Malé s/n
08186 Lliça d'Amunt
Barcelona
Spain
www.nte.es
info@nte.es
Tel.: 93 860 9001
Fax: 93 860 9019

4 OVERVIEW

The Melissa Control System Demonstrator has been designed as to permit the verification of some key aspects of the new MELISSA Control System Architecture described in [A5]. The aspects to be verified as previously agreed with ESA, are the following:

- In-plant verification of the Control law for the *Spirulina* compartment (variables, loops etc.) with the new control HW.
- In-plant verification of the Control law for the Nitrifying compartment. (Variables, loops etc.) with the new control HW.
- Verification of local regulation loops.
- Non-nominal tests to verify alarm management

Based on these verification objectives NTE proposed for implementation the Control System demonstrator for compartments CIII and CIV. HW and SW design details can be found in [R2] and [R3].
Figure 1 presents the demonstrator conceptual design and how it is implemented in terms of equipment and products. Redundant elements are not implemented within the demonstrator HW.

The demonstrator HW presents the following configuration:
- Client computer
- Supervisory rack, housing the supervision server and the Ethernet switch
- Compartment III (CIII) rack, housing the CIII PLC and auxiliary electronic equipment, implementing the local control for the MELISSA Nitrifying compartment and providing electrical interface to the Plant's sensors and actuators related to CIII.
- Compartment IV (CIV) rack, housing the CIV PLC and auxiliary electronic equipment implementing the local control for the MELISSA Spirulina compartment and providing electrical interface to the Plant's sensors and actuators related to CIV.
- HMI Touch screen

All these elements are to be interconnected through an Ethernet network.

Note: CIII and CIV racks are generically referred in this document as controller racks.

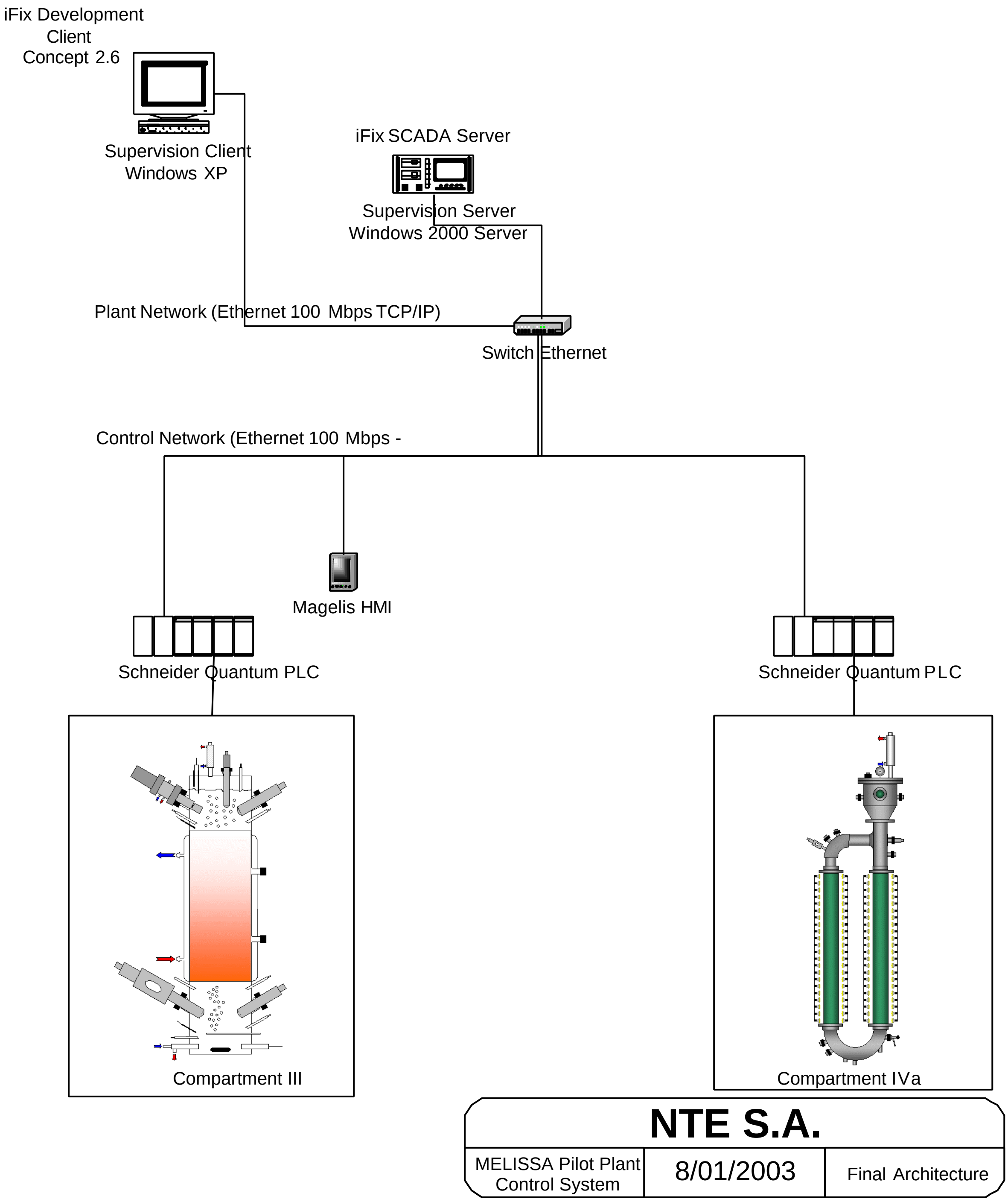


Figure 1: Control System demonstrator concept

5 HARDWARE DESCRIPTION

5.1 Controller racks common characteristics

Controller racks house the hardware necessary to implement the control of the Compartment III and IV. The mechanical characteristics of the controller racks are the following:

- Brand and model: RITTAL TS 8
- Ruggerised for laboratory environment
- Dimensions (h x w x l): 200 X 61 X 62 cm
- Includes a Fan system with 2 units for thermal dissipation
- Includes four wheels for mobility

5.2 Compartment III rack

This section contains the description of the specific characteristics of the rack for the Compartment III.

5.2.1 Compartment III rack description

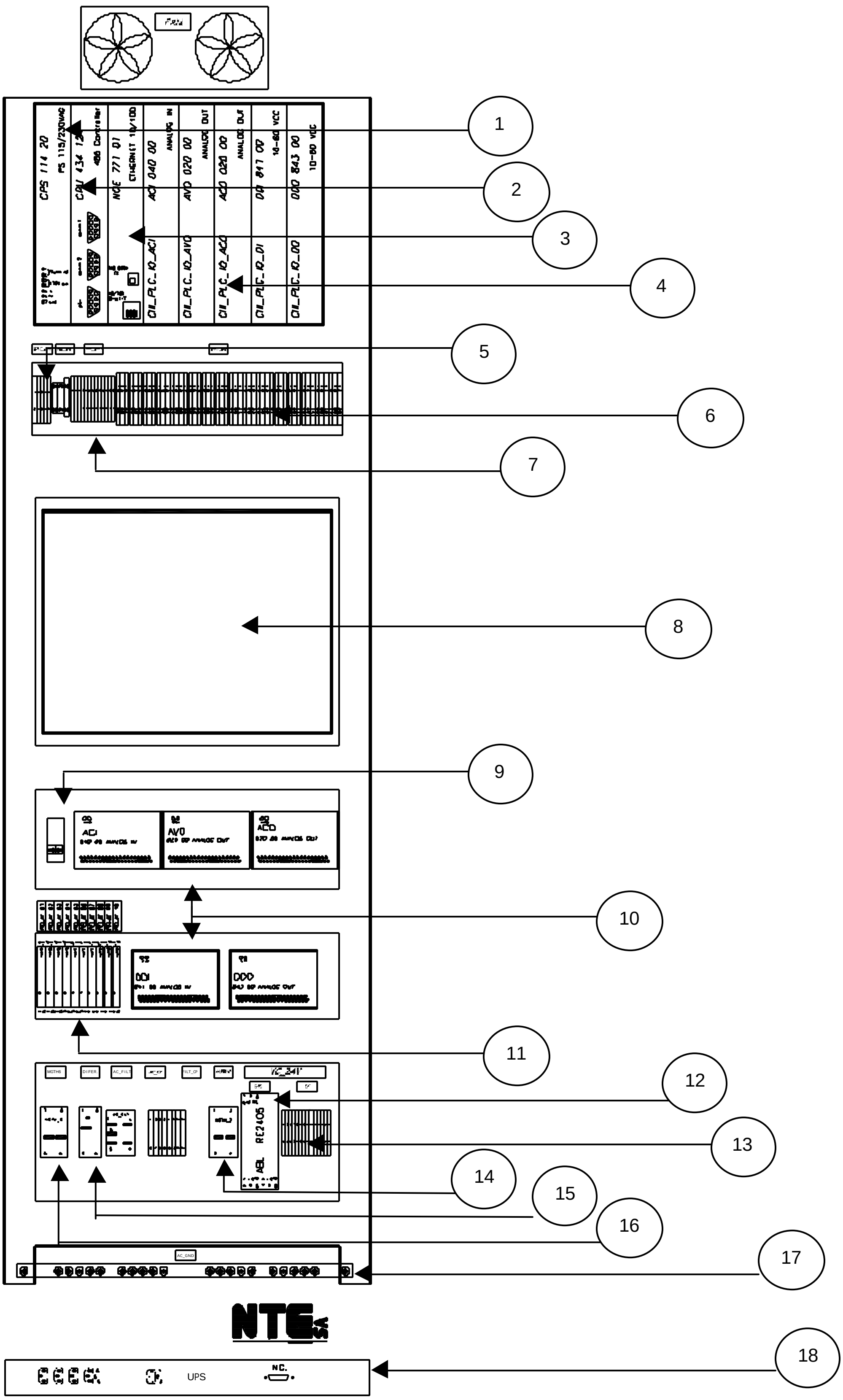


Figure 2. Rack III elements localisation.

Rack III elements (as in Figure 2):

1. PLC Power supply module
2. PLC CPU module
3. PLC Ethernet communications module
4. I/O modules (16 AI, 8 AO, 16 DI, 16 DO)
5. AC input (6 Amp max.)
6. I/O signals (CIII_CP)
7. AC output (direct or via relay, 2 Amp max.) (CIII_AC_OUT)
8. Free space reserved for future use
9. Ethernet connector
10. I/O connectors
11. Relays
12. Power supply 12 V DC
13. 12 V connector panel
14. AC output magnetothermic switch (bipolar circuit breaker at 2 Amp).
15. Differential switch (current leak circuit breaker at AC input, 30 mA sensibility).
16. AC input magnetothermic switch (bipolar circuit breaker at 6 Amp).
17. Ground strip bar
18. Uninterrupted Power Supply

5.2.2 Compartment III I/O signals table (CIII_CP)

Type	IO	N	CIII_CP pin out	Name	Device	Electric Range	Measurement Range	Description
A	I	01	001 005	CIII_MV_DObot	Oxygen analyser	4-20 mA	0 – 100 %	DO at bottom
A	I	02	009 013	CIII_MV_DOtop	Oxygen analyser	4-20 mA	0 – 100 %	DO at top
A	I	03	017 021	CIII_MV_NH4	Ammonium analyser	4-20 mA	0 – 200 ppm N-NH4+	Ammonium concentration at top
A	I	04	025 029	CIII_MV_NO3	NO3 analyser	4-20 mA	0 – 1000 ppm N-NO3-	Nitrate concentration
A	I	05	033 037	CIII_MV_P	Pressure sensor	4-20 mA	0 – 1000 mb	Pressure at top of the gas phase
A	I	06	041 045	CIII_MV_PHb	pH meter	4-20 mA	3 – 13	pH at bottom
A	I	07	049 053	CIII_MV_PHt	pH meter	4-20 mA	1.5 – 11.5	pH at Top
A	I	08	057 061	CIII_MV_Psl	Sampling line pressure sensor	4-20 mA	-10 – 15 mb	Pressure sensor for the sampling lineq
A	I	09	065 069	CIII_MV_Tb	Thermometer	4-20 mA	0.2 – 147 ºC	Temperature at bottom
A	I	10	073 077	CIII_MV_Tt	Thermometer	4-20 mA	0.2 – 147 ºC	Temperature at top
A	I	11	081 085	Not used	Not used	4-20 mA	Not used	Not used
A	I	12	089 093	Not used	Not used	4-20 mA	Not used	Not used
A	I	13	097 101	Not used	Not used	4-20 mA	Not used	Not used
A	I	14	105 109	Not used	Not used	4-20 mA	Not used	Not used

Type	IO	N	CIII_CP pin out	Name	Device	Electric Range	Measurement Range	Description
A	I	15	113 117	Not used	Not used	4-20 mA	Not used	Not used
A	I	16	121 125	Not used	Not used	4-20 mA	Not used	Not used
A	O	01	129 133	CIII_FC_CO2	CO2 flow controller	0-5 V	0 – 100 %	CO2 mass flow meter
A	O	02	137 141	CIII_FC_N2	N2 flow controller	0-5 V	0 – 150 %	N2 flow controller
A	O	03	145 149	CIII_FC_O2	O2 flow controller	0-5 V	0 – 100 %	O2 flow controller
A	O	04	153 157	Not used	Not used	0-5 V	Not used	Not used
A	O	05	161 165	CIII_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Acid pump
A	O	06	169 173	CIII_PM_Bs	Base pump	4-20 mA	0 – 100 %	Base pump
A	O	07	177 181	CIII_PM_Fl	Input media pump	4-20 mA	0 – 100 %	Input media pump
A	O	08	185 189	CIII_PM_L	Output liquid pump	4-20 mA	0 – 100 %	Output liquid pump
D	I	01	193 197	CIII_CAL_NH4	Ammonium analyser	N/A	0-1 (=calibrating)	Analyser calibration indicator
D	I	02	002 006	CIII_CAL_NO3	NO3 analyser	N/A	0-1 (=calibrating)	Nitrate calibration indicator
D	I	03	010 014	CIII_MV_L1	Level sensor	N/A	0-1 (=level reached)	Level measurement top
D	I	04	018 022	CIII_MV_L2	Level sensor	N/A	0-1 (=level reached)	Level measurement bottom
D	I	05	026 030	CIII_MVI_Lbt	Level sensor	N/A	0-1 (=level reached)	Indicator of max level reached for a buffer tank
D	I	06	034 038	Not used	Not used	N/A	Not used	Not used
D	I	07	042 046	Not used	Not used	N/A	Not used	Not used
D	I	08	050 054	Not used	Not used	N/A	Not used	Not used
D	I	09	058 062	Not used	Not used	N/A	Not used	Not used
D	I	10	066 070	Not used	Not used	N/A	Not used	Not used
D	I	11	074 078	Not used	Not used	N/A	Not used	Not used
D	I	12	082 086	Not used	Not used	N/A	Not used	Not used
D	I	13	090 094	Not used	Not used	N/A	Not used	Not used
D	I	14	098 102	Not used	Not used	N/A	Not used	Not used
D	I	15	106 110	Not used	Not used	N/A	Not used	Not used
D	I	16	114 118	Not used	Not used	N/A	Not used	Not used
D	O	01	122 126	CIII_PM_Lbt	Pump buffer tank	0-24 V	0-1 (=Active)	Activation of the pump for the buffer tank
D	O	09	130 134	CIII_RL_Ac	Acid pump	0-24 V	0-1 (=Active)	Activation of Acid pump
D	O	10	138 142	CIII_RL_Bs	Base pump	0-24 V	0-1 (=Active)	Activation of Base pump
D	O	11	146 150	Not used	Not used	0-24 V	Not used	Not used
D	O	12	154 158	Not used	Not used	0-24 V	Not used	Not used

Type	IO	N	CIII_CP pin out	Name	Device	Electric Range	Measurement Range	Description
D	O	13	162 166	Not used	Not used	0-24 V	Not used	Not used
D	O	14	170 174	Not used	Not used	0-24 V	Not used	Not used
D	O	15	178 182	Not used	Not used	0-24 V	Not used	Not used
D	O	16	186 190	Not used	Not used	0-24 V	Not used	Not used

5.2.3 Compartment III AC output table (CIII_AC_OUT)

Type	IO	N	CIII_AC_OUT pin out	Name	Device	Electric Range	Measurement Range	Description
D	O	04	146 150	CIII_RL_Comp	Compressor	220 VAC	0-1 (=Active)	Compressor activation
D	O	05	154 158	CIII_RL_CV	Cooling valve	220 VAC	0-1 (=Active)	Cooling valve
D	O	06	162 166	CIII_RL_HT	Heater resistance	220 VAC	0-1 (=Active)	Heater
D	O	08	178 182	CIII_RL_P	Pressure solenoid valve	220 VAC	0-1 (=Active)	Solenoid valve for pressure regulation

5.3 Compartment IV rack

This section contains the description of the specific characteristics of the rack for the compartment IV.

5.3.1 Compartment IV rack description

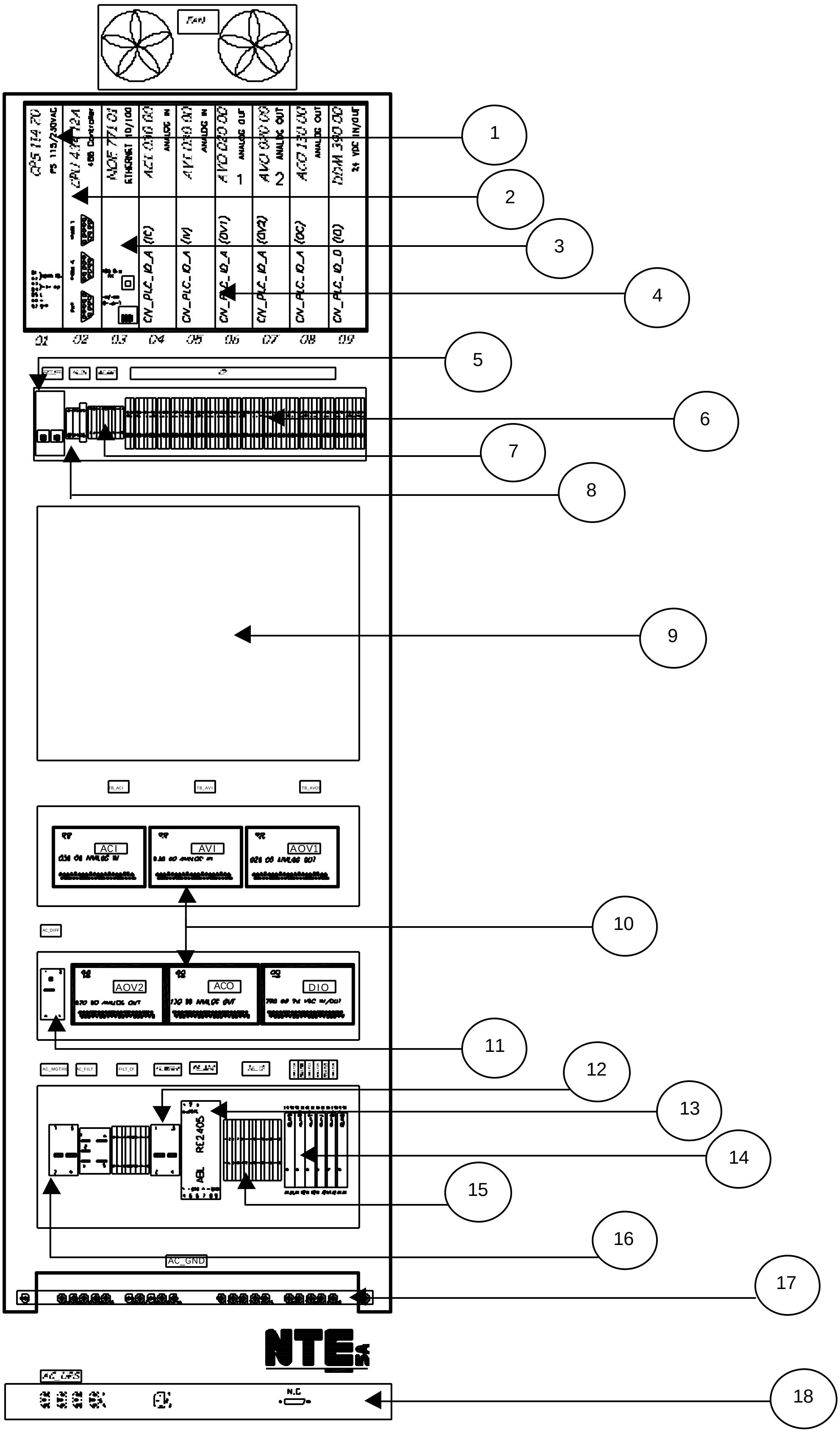


Figure 3. Rack IV elements localisation.

Rack IV elements (as in Figure 3):

1. PLC Power supply module
2. PLC CPU module
3. PLC Ethernet communications module
4. PLC I/O modules (16 AI, 8 AO, 16 DI, 16 DO)
5. Ethernet connector
6. I/O signals connection panel (CIV_CP)
7. AC output connector panel (direct or via relay, 2 Amp max.) (CIV_AC_OUT)
8. AC input connection (6 Amp max.)
9. Free space reserved for future use
10. I/O internal connectors
11. AC input magnetothermic switch (bipolar circuit breaker at 6 Amp).
12. AC output magnetothermic switch (bipolar circuit breaker at 2 Amp).
13. Relays
14. Power supply 12 VDC
15. 12 VDC connection panel
16. Differential switch (current leak circuit breaker at AC input, 30 mA sensibility)
17. Ground strip
18. Uninterrupted Power Supply

5.3.2 Compartment IV I/O signals table (CIV_CP)

Type	IO	N	CIV_CP pin out	Name	Device	Electric Range	Measurement range	Description
A	I	01	001 005	CIV_MV_Cx	Biomass sensor	4-20 mA	Configurable	Biomass measurement
A	I	02	009 013	CIV_MV_M1	Scale 1	4-20 mA	0 – 150 kg	Mass measurement to determine input flow
A	I	03	017 021	CIV_MV_M2	Scale 2	4-20 mA	0 – 150 kg	Mass measurement to determine input flow
A	I	04	025 029	CIV_MV_P	Pressure sensor	4-20 mA	0 – 1.5 bar	Pressure measurement
A	I	05	033 037	CIV_MV_pH	pH sensor	4-20 mA	0 – 14	pH measurement
A	I	06	041 045	CIV_MV_T	Temperature sensor	4-20mA	0 – 150 ºC	Temperature measurement
A	I	07	049 053	CIV_MGO_O2	O2 gas sensor	4-20 mA	Configurable	Measure O2 at gas output
A	I	08	057 061	CIV_MGO_CO2	CO2 gas sensor	4-20 mA	Configurable	Measure CO2 at gas output
A	I	09	065 069	CIV_MV_DO	Dissolved Oxygen sensor	4-20 mA	Configurable	Percent of O2 saturation in the reactor
A	I	10	073 077	Not used	Not used	4-20 mA	Not used	Not used
A	I	11	081 085	Not used	Not used	4-20 mA	Not used	Not used
A	I	12	089 093	Not used	Not used	4-20 mA	Not used	Not used
A	I	13	097 101	CIV_MGI_Fg	Flowmeter	0-5 V	0 – 30 nLm*	Gas flow at input
A	I	14	105 109	CIV_MGO_Fg	Flowmeter	0-5 V	0 – 30 nLm	Gas flow at output
A	I	15	113 117	CIV_MV_CO2	CO_2 flowmeter	0-5 V	0 – 5 nLm	CO_2 flow measurement
A	I	16	121 125	CIV_MV_Fg	Flowmeter	0-5 V	0 – 30 nLm	Gas flow re-circulation

Type	IO	N	CIV_CP pin out	Name	Device	Electric Range	Measurement range	Description
A	O	01	129 133	CIV_FR_CO2	CO_2 flow regulator	0-5 V	0 – 5 nLm	CO_2 flow regulation
A	O	02	137 141	CIV_PM_Fgi	Flow regulator	0-5 V	0 – 30 nLm	Gas flow at input regulation
A	O	03	145 149	CIV_PM_Fgo	Flow regulator	0-5 V	0 – 30 nLm	Gas flow at output regulation
A	O	04	153 157	CIV_PM_Fgex	Flow regulator	0-5 V	0 – 30 nLm	Gas flow re-circulation regulation
A	O	05	161 165	CIV_PM_Li1	Liquid input pump1	0-5 V	0 – 100 %	Liquid Pump input1 set point
A	O	06	169 173	CIV_PM_Li2	Liquid input pump2	0-5 V	0 – 100 %	Liquid Pump input1 set point
A	O	07	177 181	CIV_PM_LO	Liquid output pump	0-5 V	0 – 100 %	Liquid Pump output set point
A	O	08	185 189	Not used	Not used	0-5 V	Not used	Not used
A	O	09	193 197	CIV_PM_Bs	Base pump	4-20mA	0 – 100 %	Additional Base source for pH regulation
A	O	10	201 205	CIV_RG_Ls	Light regulator	4-20 mA	0 – 100 %	Regulator of light supply
A	O	11	209 213	CIV_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Additional Acid source for pH regulation
A	O	12	002 006	CIV_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Additional Acid source for pH regulation
A	O	13	010 014	CIV_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Additional Acid source for pH regulation
A	O	14	018 022	CIV_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Additional Acid source for pH regulation
A	O	15	026 030	CIV_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Additional Acid source for pH regulation
A	O	16	034 038	CIV_PM_Ac	Acid pump	4-20 mA	0 – 100 %	Additional Acid source for pH regulation
D	I	01	042 046	CIV_CAL_CO2O2	CO2/O2 sensor	N/A	0 – 1 (=Calibr.)	Calibration indicator of CO2/O2 sensor.
D	I	02	050 054	CIV_ERR_CO2O2	CO2/O2 sensor	N/A	0 (=Error) – 1 (=Ok)	Error Indicator of CO2/O2 sensor.
D	I	03	058 062	CIV_SCL1_CO2O2	CO2/O2 sensor	N/A	0 =using scale 1 1=using scale 2	CO2/O2 sensor is using scale 1
D	I	04	066 070	CIV_SCL2_CO2O2	CO2/O2 sensor	N/A	0 =using scale 1 1=using scale 2	CO2/O2 sensor is using scale 2
D	I	05	074 078	Not used	Not used	N/A	Not used	Not used
D	I	06	082 086	Not used	Not used	N/A	Not used	Not used
D	I	07	090 094	Not used	Not used	N/A	Not used	Not used
D	I	08	098 102	Not used	Not used	N/A	Not used	Not used
D	I	09	106 110	Not used	Not used	N/A	Not used	Not used
D	I	10	114 118	Not used	Not used	N/A	Not used	Not used
D	I	11	122 126	Not used	Not used	N/A	Not used	Not used
D	I	12	130 134	Not used	Not used	N/A	Not used	Not used
D	I	13	138 142	Not used	Not used	N/A	Not used	Not used
D	I	14	146 150	Not used	Not used	N/A	Not used	Not used
D	I	15	154 158	Not used	Not used	N/A	Not used	Not used
D	I	16	162 166	Not used	Not used	N/A	Not used	Not used

Type	IO	N	CIV_CP pin out	Name	Device	Electric Range	Measurement range	Description
D	O	01	170 174	CIV_RL_Li1	Enable liquid input pump1	0-24 V	0 – 1 (=active)	Relay liquid Pump input1
D	O	02	178 182	CIV_RL_Li2	Enable liquid input pump2	0-24 V	0 – 1 (=active)	Relay liquid Pump input2
D	O	05	186 190	Not used	Not used		Not used	Relay 05
D	O	06	194 198	Not used	Not used		Not used	Relay 06
D	O	07	202 206	Not used	Not used	0-24 V	Not used	Not used
D	O	08	210 214	Not used	Not used	0-24 V	Not used	Not used

5.3.3 Compartment IV AC output table (CIV_AC_OUT)

Type	IO	N	CIV_AC_OUT pin out	Name	Device	Electric Range	Measurement range	Description
D	O	03	001 003 005	CIV_RL_Cx	Electrovalve	220 VAC	0 – 1 (=cleaning)	Aeration of biomass sensor for cleaning
D	O	04	007 009 011	CIV_RL_Fg	Pressure valve	220 VAC	0 – 1 (=close)	Pressure safety valve activation

5.4 Supervision rack

This rack has to be placed in a conditioned room (UAB Plant Control room). Allocates an Ethernet switch (MEL_SWITCH01) and the Supervision Server (MEL_SUPV_SERV01). No specific design is associated to this element, whose characteristics are standard. Some detailed information is presented hereafter:

MEL_SUPV_SERV01	
Model:	Dell Power Edge 2600 17’’ monitor, mouse and keyboard.
Power supply:	2x220 VAC 50 Hz redundant.
Network:	2xEthernet 10/100/1000
Storage:	2 SCSI disks 36 GB in Raid 3 configuration 1 Floppy 1 CDR 1 Tape (for backup purposes)
Main SW components:	MS Windows 2000 Server iFix (Server Only license) MBE Driver (PLC communications driver)
Physical location:	Plant’s control room (in Supervision Rack)

MEL_SWITCH01	
Model:	3Com - Super Stack 3
Power supply:	220 VAC 50 Hz redundant.
Characteristics:	16 x 10/1000 Mbps Standard Ethernet ports
Physical location:	Plant’s control room (in Supervision Rack)

- Dimensions (h x w x l): 625 X 600 X 800 mm
- equipped with wheels to easy the mobility.

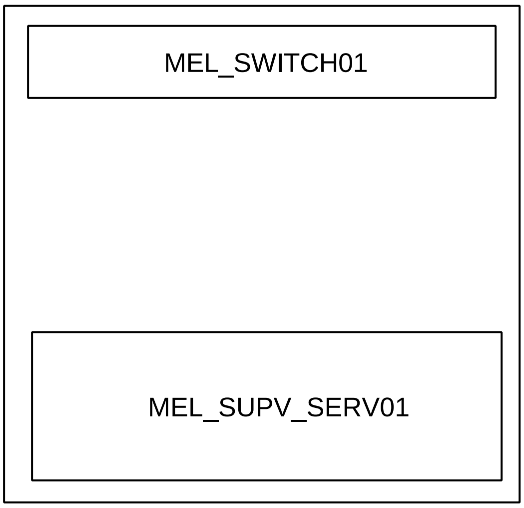


Figure 4. Supervision Rack components distribution.

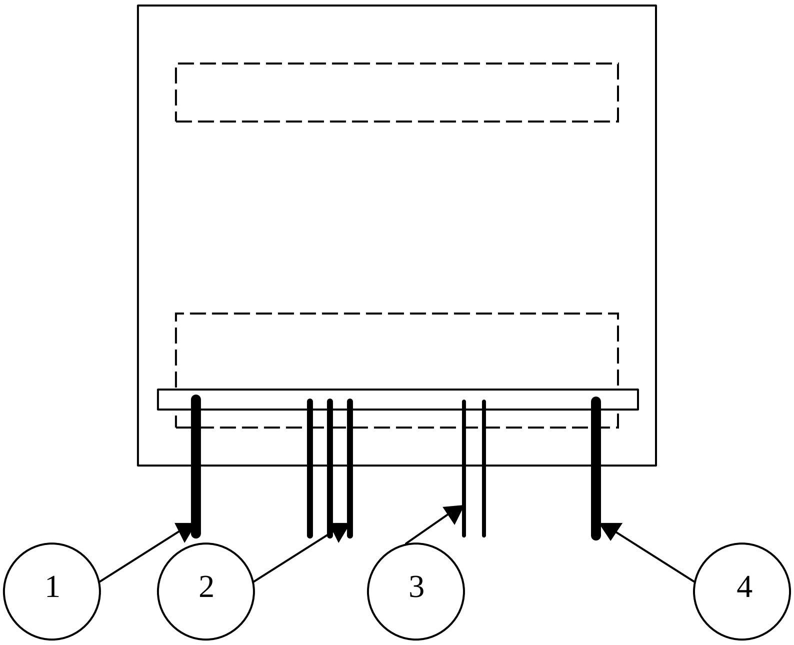


Figure 5. Supervision Rack rear side view.

Supervision Rack rear side view elements:

1. AC power cable, to be connected to main power line.
2. Network cables to be connected to racks, supervision clients and HMI.
3. Supervision Server mouse, keyboard and monitor cables.
4. Redundant AC power cable, to be connected to secondary power line.

5.5 Supervision client

This computer is used to visualise supervision displays and to upload / download PLC programs.
No specific design is associated to this element, whose characteristics are standard. Some detailed information is presented hereafter:

MEL_SUPV_CLI01	
Model:	Dell OptiPlex GX260 P4 1.8 GHz 1 DVD 1 Floppy 17’’ monitor, mouse and keyboard.
Power supply:	220 VAC 50 Hz
Network:	Ethernet 10/100
Main SW components:	MS Windows XP Professional Edition Concept V2.6 XL EN iFix (Developer Client license) XBT-L1000 V3 (HMI SW development tool)
Physical location:	Plant’s control room

5.6 HMI

The HMI will be placed near to the compartments to provide a way of monitor process data of any compartment from inside the lab. This device consists on a MAGELIS touch-screen XBT with the following characteristics:

MEL_HMI_01	
Model:	XBT-F34X touch-sensitive screen 10,4’’ 640x480 colour display.
Power supply:	24 VC
Main SW components:	XBT-L1000 V3
Network:	Ethernet 10/100
Physical location	Laboratory

The device has been mounted into a PVC box that includes:

- A 24VC power supply dimensioned to power the screen (including a 1m power cord to plug to the 220/50 Hz AC source)
- An Ethernet connector to provide connection to the control network.
- A parallel port for an optional printer
- A serial port for maintenance

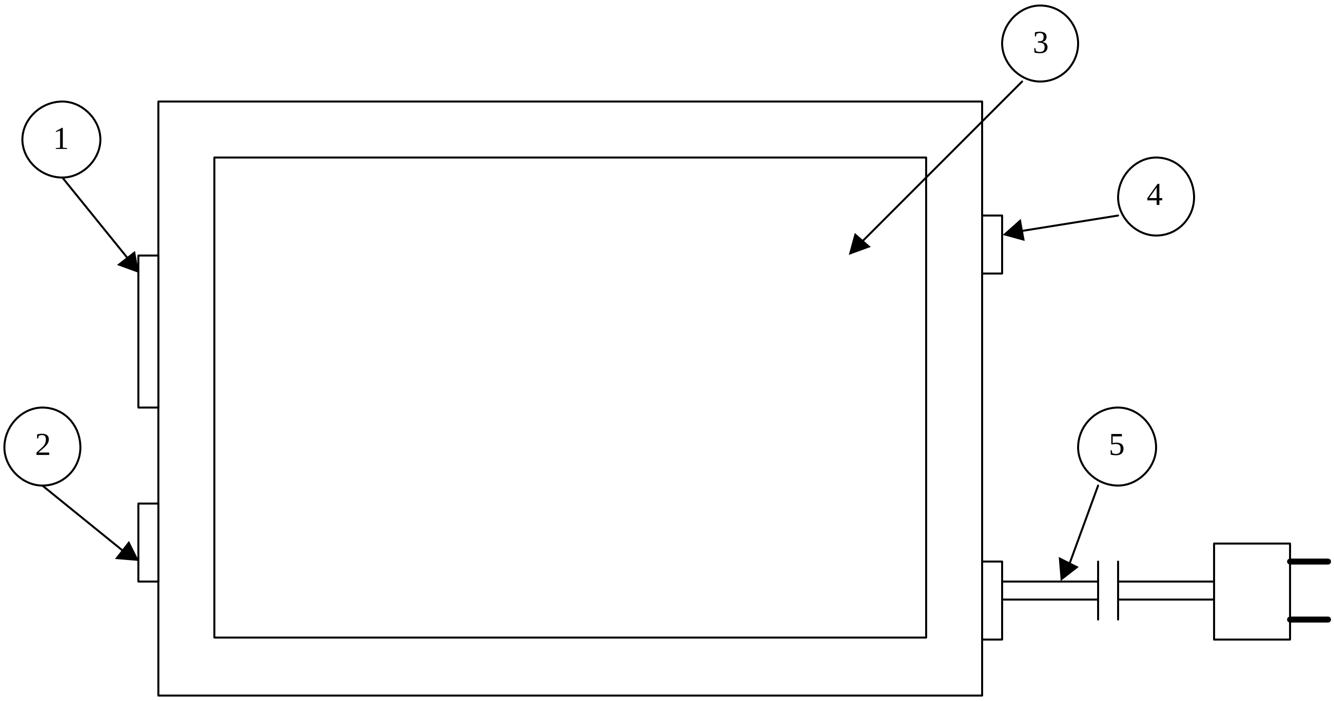


Figure 6. HMI touch-screen front view.

HMI touch-screen elements (as in Figure 6):

1. Parallel connector, to be connected to an optional printer for alarm management.
2. Serial connector, to download the software in case Ethernet is not available.
3. Display
4. Ethernet connector, to be connected to the control network.
5. AC power cable, to be connected to power line.

6 HARDWARE OPERATION

6.1 Supervision rack installation

This procedure will describe the steps to perform the installation of the Supervision rack. The Supervision Rack is described in section 5.4. To install the rack perform the following steps:

1. Remove the screws on the back part of the rack and dismount the back door.
2. Pass all cables through the slot in the back door and connect them to the respective connectors in the Supervision Server (Power, mouse, monitor and keyboard) and in the switch (network cables).
3. Mount the back door in the rack.
4. Plug the power cables to the main power line.

Important

The Supervision Server is equipped with a dual redundant power supply. In order to avoid power loss both power cables must be connected and preferably to two different power sources, that is, to an emergency power source and to the common power line.

6.2 Controller racks installation

This procedure will describe the steps to perform the installation of the controller racks. The installation will consist on:

- Connecting power pipe to the rack AC input.
- Connecting the rack to the control network.
- Connecting analogue and digital outputs.
- Connecting AC outputs via relay.
- Connecting the rack to the mains.

CAUTION

Plugging the power pipe to the mains must be the last step in installation procedure. In addition, to avoid personal injures and device damages during hardware operation a proper ground shall be provided to the power input.

To install the rack perform the following steps:

1. Connect a proper dimensioned power line 3-wire cable to AC in (see localisation in figure 2 and 3). Connect GND (yellow/green), AC L (brown), and AC N (blue) to the respective connectors.
2. Plug a Cat5 STP network cable to Ethernet input (see localisation in figure 2 and 3).
3. Connect analogue and digital signals as described in sections 5.2.2 and 5.3.2.
4. Plug the AC connector to the mains.
5. Power on the rack following the procedure described in section 6.4.

6.3 Controller racks power off

This section will describe the steps to power off the controller racks (CIII and CIV Racks) properly. This action will be usually taken before performing any maintenance operation in the rack since the rack must be powered off.

CAUTION
When the rack is powered off the controller outputs are disabled and all devices receiving power directly from the rack electronics will be powerless. Therefore the related reactor will be out of control.

Once the rack has been powered off, the PLC controller, power supplies and all electronic devices will be powerless. This can be verified checking activity LED in all those devices. The PLC controller has a battery that can maintain the status of the controller memory during some hours (depending on the status of the battery). Therefore, when the rack is powered again, the same status as when powered off will be recovered and used.

To power off the rack perform following steps:

1. Switch off the AC output magnetothermic. This action will interrupt power to the devices connected via relay to AC.
2. Turn off the uninterrupted power supply that powers the PLC. This action will switch off the PLC.
3. Switch off the AC input magnetothermic. This action will cut AC power input. The 24VC power supply will be switched off.
4. Switch off the differential switch. This action will interrupt AC power input.

Note: switches can be identified in Figure 2 for CIII rack and in Figure 3 for CIV rack.

6.4 Controller racks power on

This section will describe the steps to power on the controller racks (CIII and CIV Racks) properly. This action will be usually taken after performing any maintenance operation in the rack.

CAUTION
In case that during a maintenance operation any modification of the wiring has been performed a connectivity test must be passed before powering on the rack.

Once the rack has been powered on, the PLC controller, power supplies and all electronic devices will be switched on, this can be verified checking activity LED in all these devices. Because the PLC controller has a battery that can maintain the status of the controller memory during some hours (depending on the status of the battery), when the rack is powered again, the same status as when powered off will be recovered and used.

To power on the rack perform following steps:

1. Switch on the differential switch. This action will restore AC power input.
2. Switch on the AC input magnetothermic. This action will connect AC power input. The 24VC power supply will be switched on.
3. Turn on the uninterrupted power supply that powers the PLC. This action will switch on the PLC. Activity can be verified looking at the PLC module activity LED.
4. Switch on the AC output magnetothermic. This action will restore power to the devices connected via relay to AC.

Note: switches can be identified in Figure 2 for CIII rack and in Figure 3 for CIV rack.

7 CONTROL NETWORK

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
CIV_PLC	172.16.0.141	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.

8 SOFTWARE DESCRIPTION

8.1 PLC software description

PLC software is implemented using the Concept 2.6 programming tool provided by Schneider that is installed in the Supervision Client computer. To start this software, in the Supervision Client go to the Programs menu and select Concept V2.26 XL EN and then Concept.

This tool is used to:

- Configure the PLC (see Figure 7).
- Program local control loops using IEC languages
- Download / Upload the programs to/from the PLC
- Monitoring the execution of the programs in the PLC.
- 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) and the sections containing the control loops (as shown in Figure 8). The PLC configuration is defined using the PLC Configuration window. The sections of the PLC program can be accessed through the Project Browser.

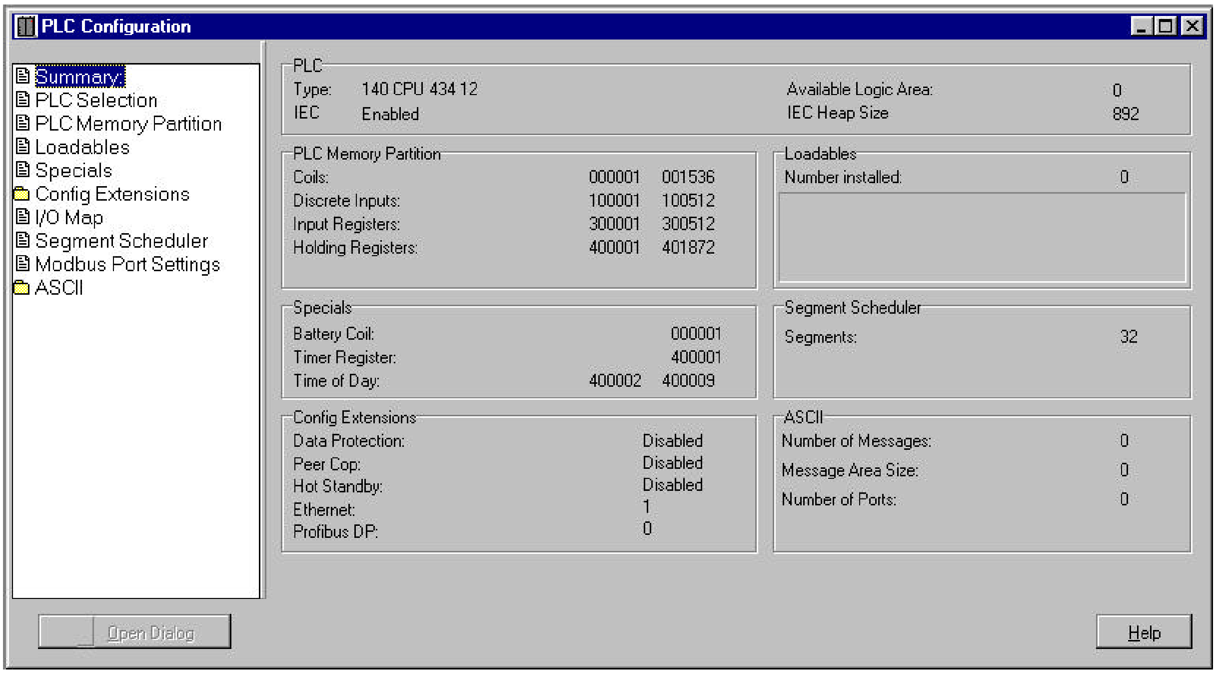


Figure 7. Concept configurator window

In the MELISSA control system, the programming language that has been selected for the implementation of the local control loops is the Function Blocks Diagram (FBD). The project is organised into sections. Each section implements a local regulation loop. For example, the CIV_PLCSW_pH section regulates pH for the compartment CIV controller.

In each section a group of digital and analogue inputs are related to a group of analogue and digital outputs. The variables in the controller are addressed as follows:

Address range	Variable type
0xXXXXXX	Digital inputs
1xXXXXXX	Digital outputs
3xXXXXXX	Analogue inputs
4xXXXXXX	Analogue outputs

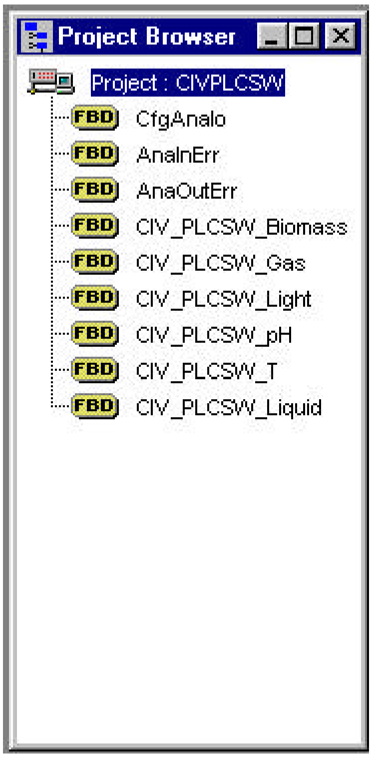
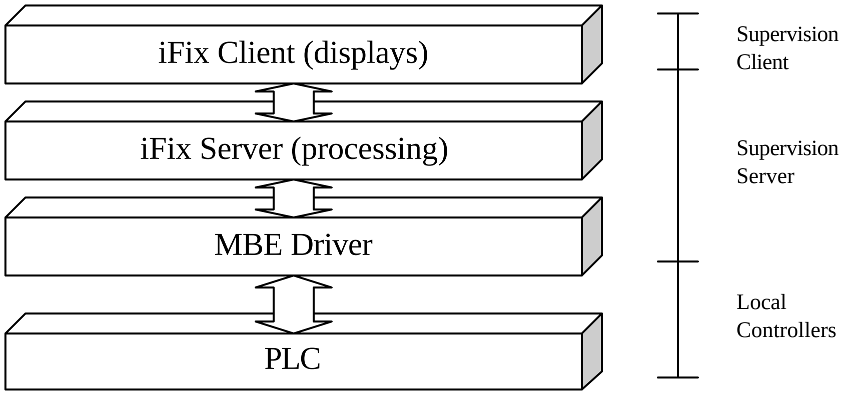


Figure 8. PLC Program sections of CIV

8.2 Supervision software description

Supervision software is implemented using the Intellution iFix platform. Intellution iFix is a SCADA software that allows the monitoring and modification of process variables. Variable values are acquired through an interface driver (the so-called Mod-Bus Ethernet driver) that communicates with the PLC. Values are acquired and processed by the iFix Server, according to the information stored in the iFix Database. Once processed, these values are displayed numerically, as object animations or in charts in the client displays. In addition, iFix handles automatically alarm events, displaying the alarm information in a predefined area (Alarm Area) and can execute pre-programmed tasks defined in scripts using Visual Basic for Applications (VBA).



The MBE driver runs in the Supervision Server. This application uses Modbus over TCP/IP to communicate with the PLC. The configuration of the driver is edited with the MBE Power Tool, this application can be accessed directly from the iFix Database Manager. The resulting file defines the configuration of the blocks of information transferred from/to the PLC.

Data sent and received from the MBE driver is processed according to the iFix Database configuration. The iFix Database Manager application is used to modify this information, allowing the addition, modification and deletion of tags. A tag is an element of information that can be displayed product of a calculation or directly a measured process variable (input) or process set point/parameter (output). The configuration of a tag includes alarm generation by allowing the definition of several predefined alarm conditions. The iFix Database Manager application can be accessed directly from a desktop icon or from the iFix Workspace application.

Calculations, process variables and alarms are visualised in displays. These displays group related data in a schematic representation of the process. From these displays it is possible to modify set points, fix regulation parameters, change the operational mode, etc. They define the user interaction with the control system. The displays are accessed from the iFix client, starting the Intellution iFix Workspace application.

Intellution iFIX development and operation is performed through the Intellution iFIX Workspace application (Figure 9). This application can be used as the development environment to define displays, scripting, etc. (Configuration mode) or as the run environment to visualise the displays and interact with the process (Run Mode). The two modes can be changed through the menu option Workspace and Switch to run/configuration according to the current mode.

The application is installed in the Supervision Client and the Supervision Server. The following tasks is mandatory to be performed using the Supervision Server installation:
- Changes in the process database using the Database Manager.
- Changes in the task configurations.

The rest of the configuration tasks can be performed either from the Client or the Server installation.

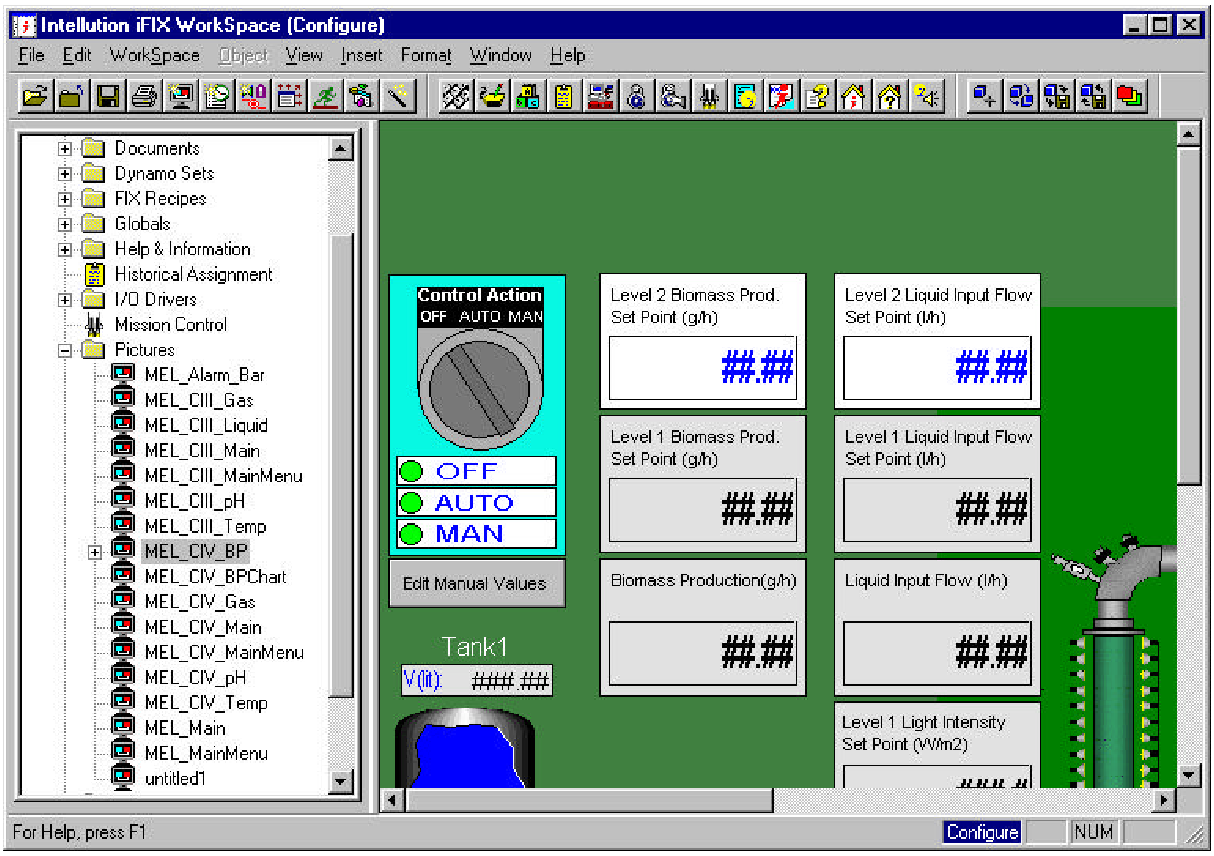


Figure 9. iFIX Workspace application.

To start this software for monitoring purposes, in the **Supervision Client** go to the Programs menu, select iFIX and Intellution iFIX Workspace. It is configured in such manner that the process displays are displayed automatically.

To start this program to change the configuration in the **Supervision Server** go to the Programs menu, select iFIX and Intellution iFIX Workspace.

8.3 Master Control software description

The Master Control is in charge of executing Level 2 control algorithms so-called the compartment control laws. For this demonstrator system the control laws will consist of regulating the biomass production in compartment IV and regulating the Nitrite in compartment III. For each compartment this SW consists of the compartment's Control Law algorithm supplied by former ADERSA in the form of C SW modules plus additional SW modules needed to integrate the algorithms into the Master Control environment.

The Master Control environment is implemented using the iFix capability to execute scheduled tasks (Figure 10), and therefore is part of the Supervision Software. The execution of these tasks is controlled by the iFIX Scheduler, which allows the execution of a task at defined time intervals. The tasks are implemented in scripts using Visual Basic for Applications, which is provided as part of the iFIX development environment.

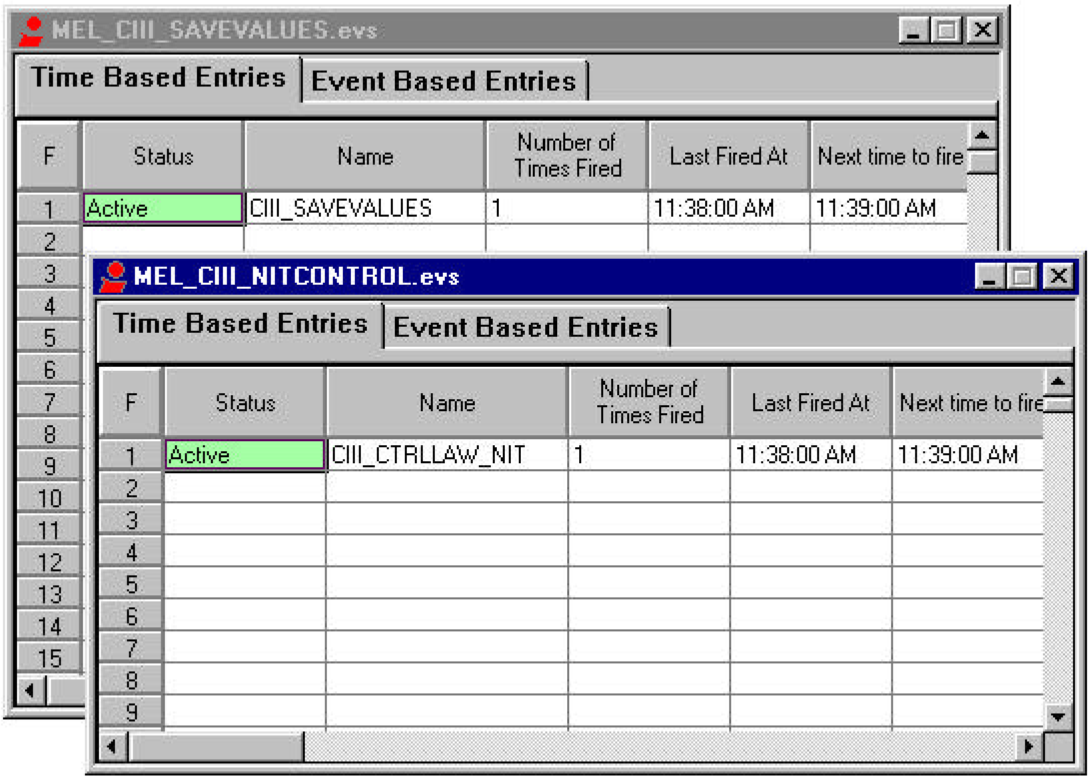


Figure 10. Scheduled tasks in the iFIX

8.4 HMI software description

The HMI display is programmed using the XBT-L1000 V3 software (Figure 11). This software is installed in the Supervision Client and is used to:

- Implement HMI displays and alarm management.
- Configure HMI displays
- Debug displays through simulation.

To start this software using the Programs menu select the XBT-L1000 V3 submenu and XBT-L1000 V3.80.

The HMI application can be modified using the Supervision Client. Any modification needs to be downloaded to the HMI device through the Ethernet network.

The HMI device connects transparently to the PLC to receive the required display values, the configuration of the PLC IP addresses and communication protocol is provided in the application.

This device is connected to the control network and can display variable values numerically and as object animations. No modification of process variables can be performed from the HMI.

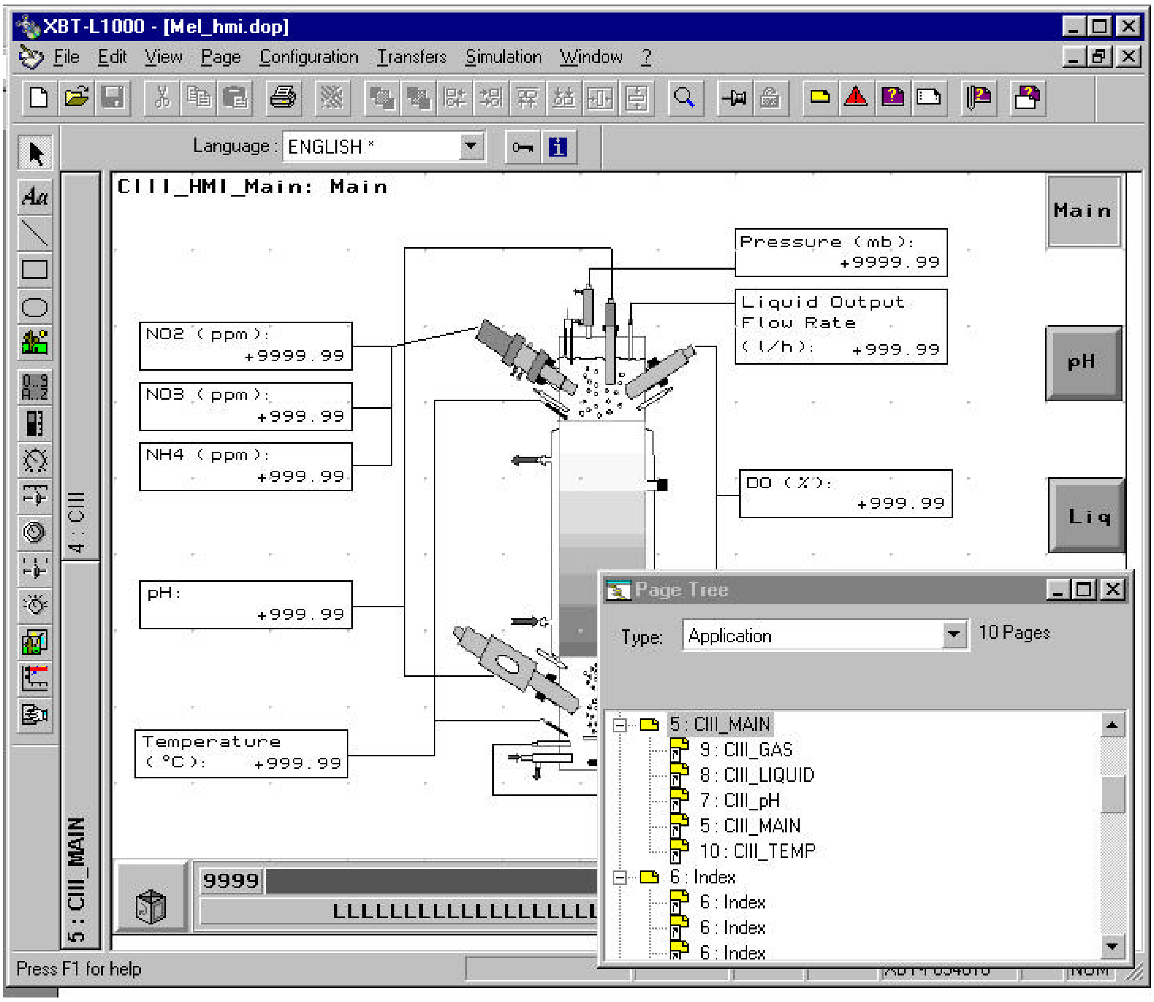


Figure 11. XBT-L1000 application.

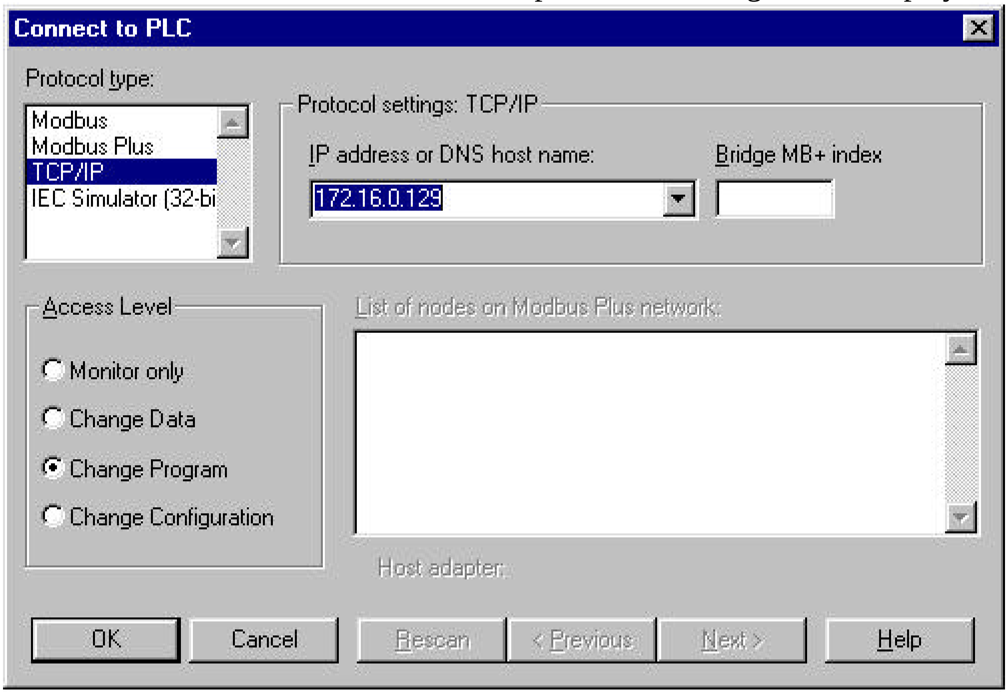
9 PLC SOFTWARE OPERATION

9.1 Connect to PLC

First step to perform changes in a PLC using Concept will be to connect to this PLC. The connection is performed through the TCP/IP protocol by using the PLC IP address, which has been configured at installation time.

To connect to the PLC perform the following steps:

1) Start Concept
2) Load the software project corresponding to the PLC where the change will be performed (for example CIVPLCSW or C3PLCSW).
3) Select Online and Connect… The connection parameters dialog will be displayed.



4) Select TCP/IP as the protocol type, the corresponding IP address and set Change Program in Access Level. Press OK to confirm and close this dialog. Once connected the caption of the main window will indicate the IP address of the PLC and the status bar will display the status of the PLC.

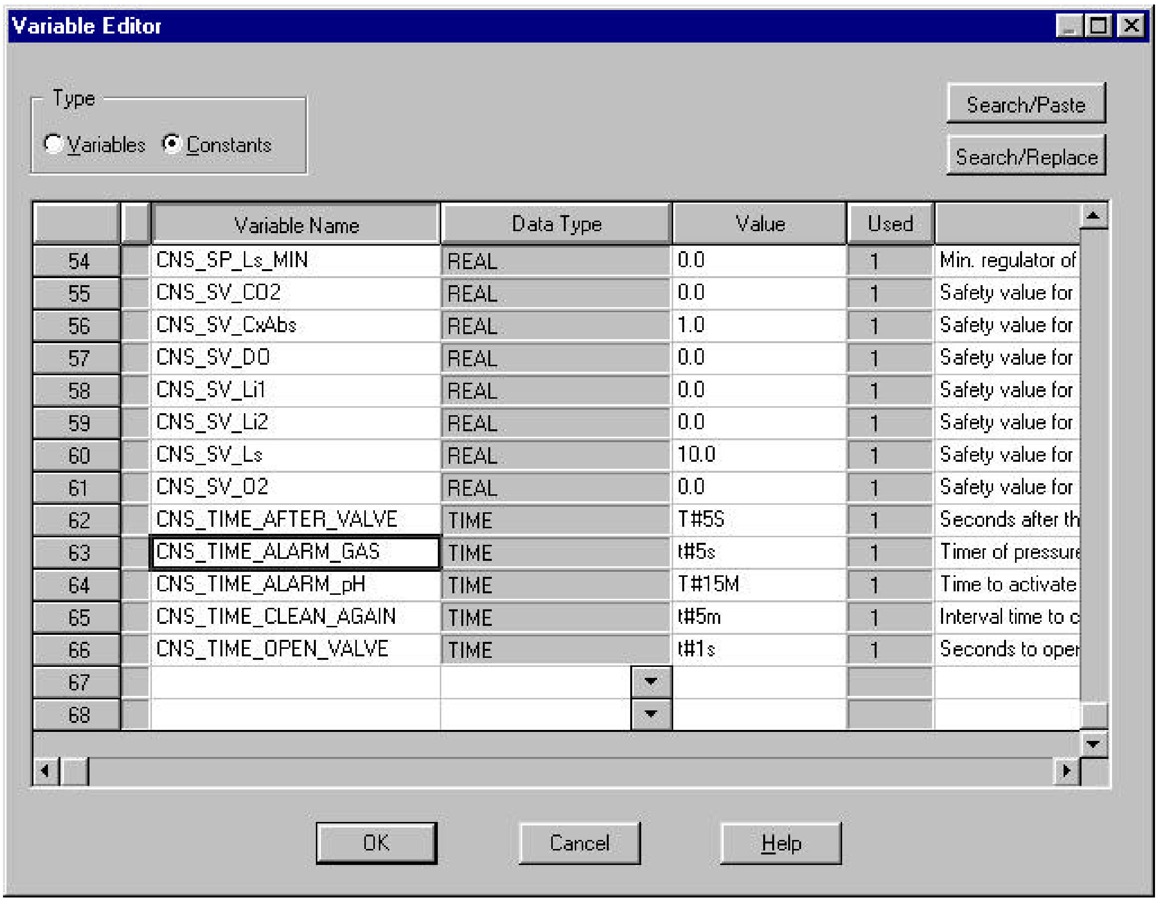
9.2 Modify constant values

This section will indicate how to modify constant values directly stored in the PLC. These values cannot be modified through the Supervision because there is not a variable tag associated to it. Therefore, it is necessary to access directly to the memory of the PLC to modify the values and update the PLC program accordingly. A common situation where a constant value will need to be modified is when a sensor is changed and the scale for this measure needs to be redefined.

The modification of values will be performed using the Concept software from the Supervision Client computer.

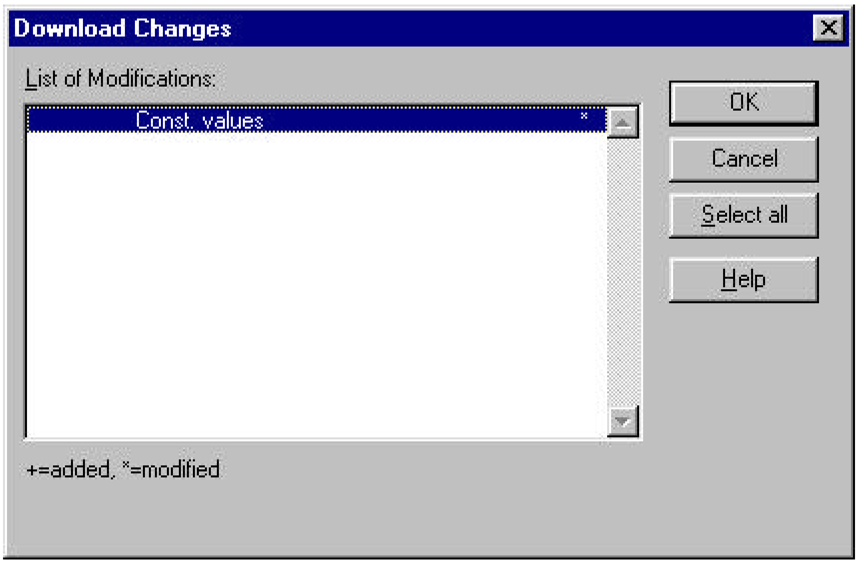
To modify the constant values stored in the PLC perform the following steps:

1) Connect to the PLC (follow procedure explained in section 8.1).
2) Select Project and Variable Declarations (or press F8). This action will display the Variable Editor dialog. Select Constants and modify the values needed. Press OK to confirm.



	Variable Name	Data Type	Value	Used	
54	CNS_SP_Ls_MIN	REAL	0.0	1	Min. regulator of
55	CNS_SV_CO2	REAL	0.0	1	Safety value for
56	CNS_SV_CxAbs	REAL	1.0	1	Safety value for
57	CNS_SV_DO	REAL	0.0	1	Safety value for
58	CNS_SV_Li1	REAL	0.0	1	Safety value for
59	CNS_SV_Li2	REAL	0.0	1	Safety value for
60	CNS_SV_Ls	REAL	10.0	1	Safety value for
61	CNS_SV_O2	REAL	0.0	1	Safety value for
62	CNS_TIME_AFTER_VALVE	TIME	T#5S	1	Seconds after th
63	CNS_TIME_ALARM_GAS	TIME	t#5s	1	Timer of pressure
64	CNS_TIME_ALARM_pH	TIME	T#15M	1	Time to activate
65	CNS_TIME_CLEAN_AGAIN	TIME	t#5m	1	Interval time to c
66	CNS_TIME_OPEN_VALVE	TIME	t#1s	1	Seconds to oper
67					
68					

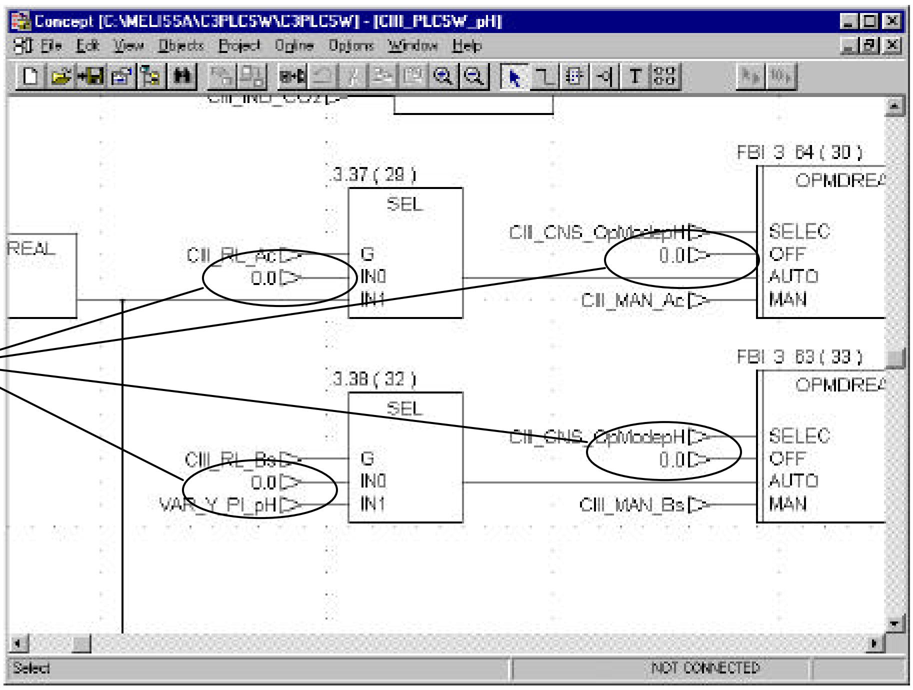
3) To update the values into the PLC select Online and Download changes. The list of changes will contain the item “Const. values” which indicates that constant values are pending to be updated. Press OK to update the values.



The last step should be to modify the values into the documentation since when these values will be reviewed it will be verified according to the specifications.

Although most constant values have a constant name associated, there are some trivial that are defined in the diagram. These values can be directly changed in the same diagram. Double-clicking the value will display a dialog where value can be changed. Once the change is confirmed follow step 6 defined above.

Constant values defined in the diagram



9.3 Monitor on-line values

All current variable values stored in the PLC memory can be displayed using Concept. This will allow, for example, the verification of the values currently used by the local regulation loops.

The following steps will describe how to display the value of a variable from the PLC memory by using the Reference Data Editor tool, which is invoked from Concept.

To display a variable value from the PLC perform the following steps:

1) Connect to the PLC.
2) From the Online menu select the Reference Data Editor command. This action will display the Reference Data Editor window (Figure 12).

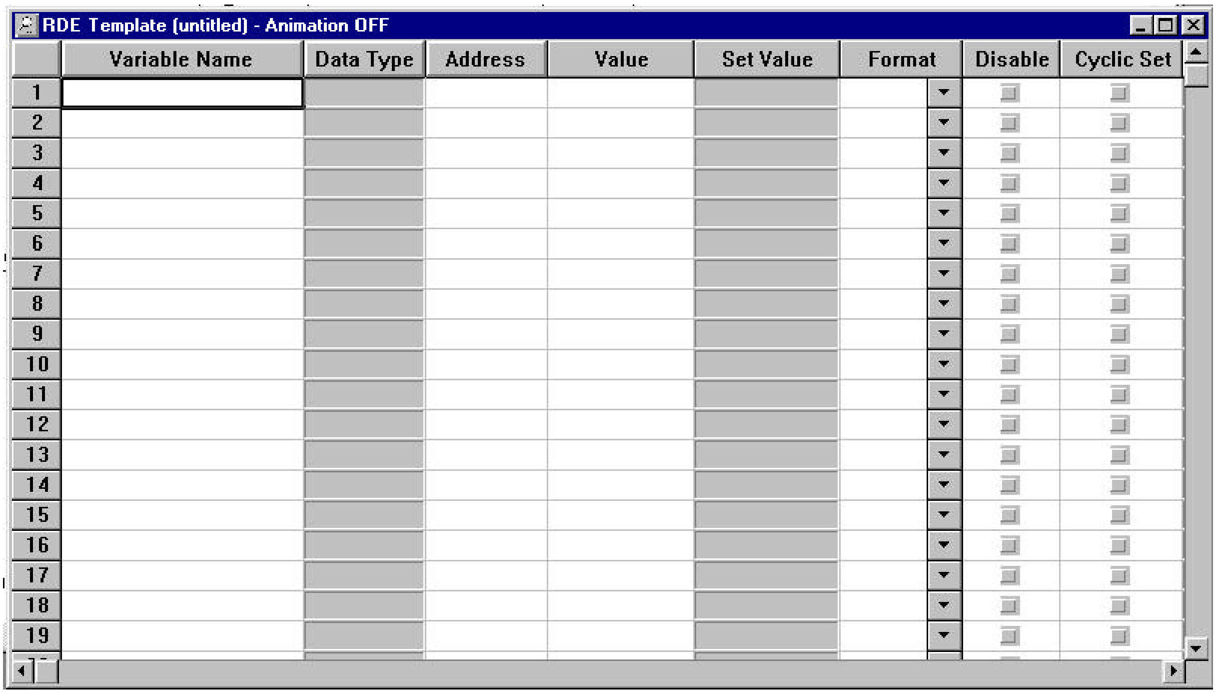


Figure 12. Reference Data Editor window.

3) Specify the name of the variable whose value needs to be displayed in the Variable Name column.
4) From the Online menu select Animate. This action will cause the value of the variable to be displayed in the Value column (Figure 13).

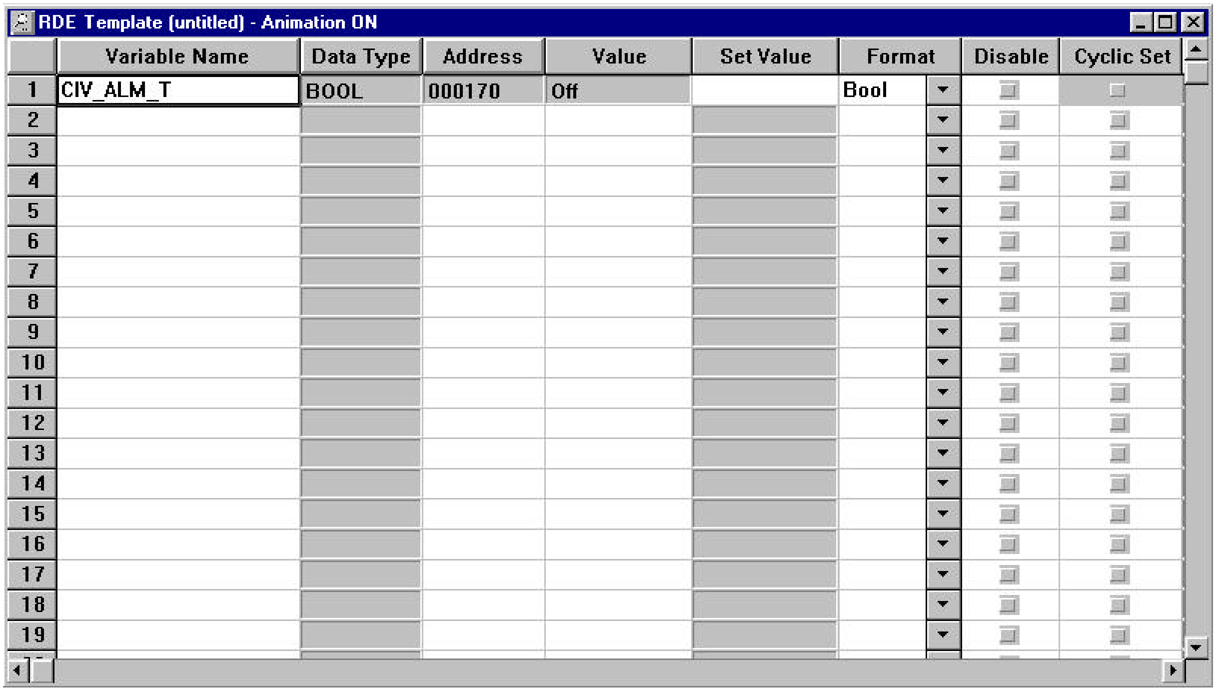


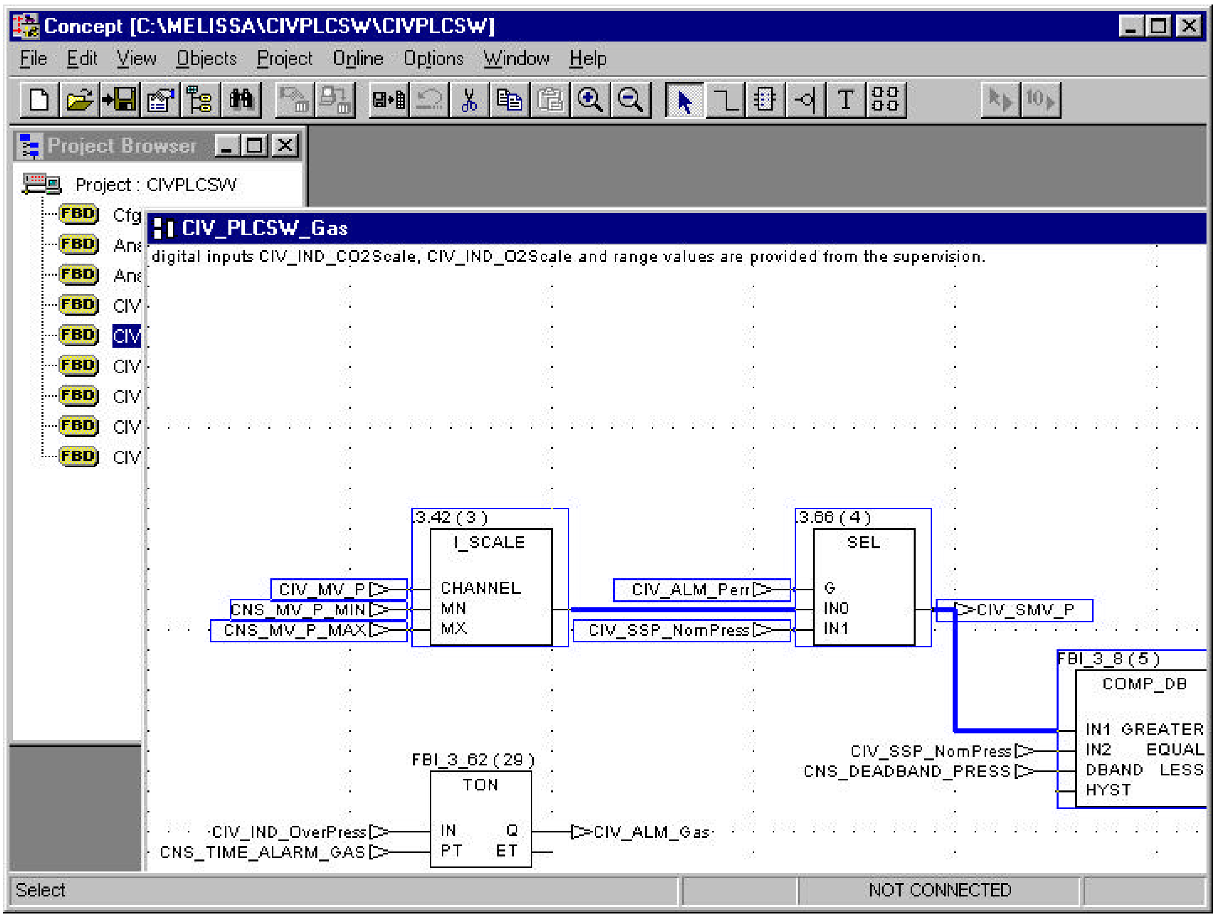
Figure 13. Reference Data Editor window with Animation ON

9.4 Monitor control loops

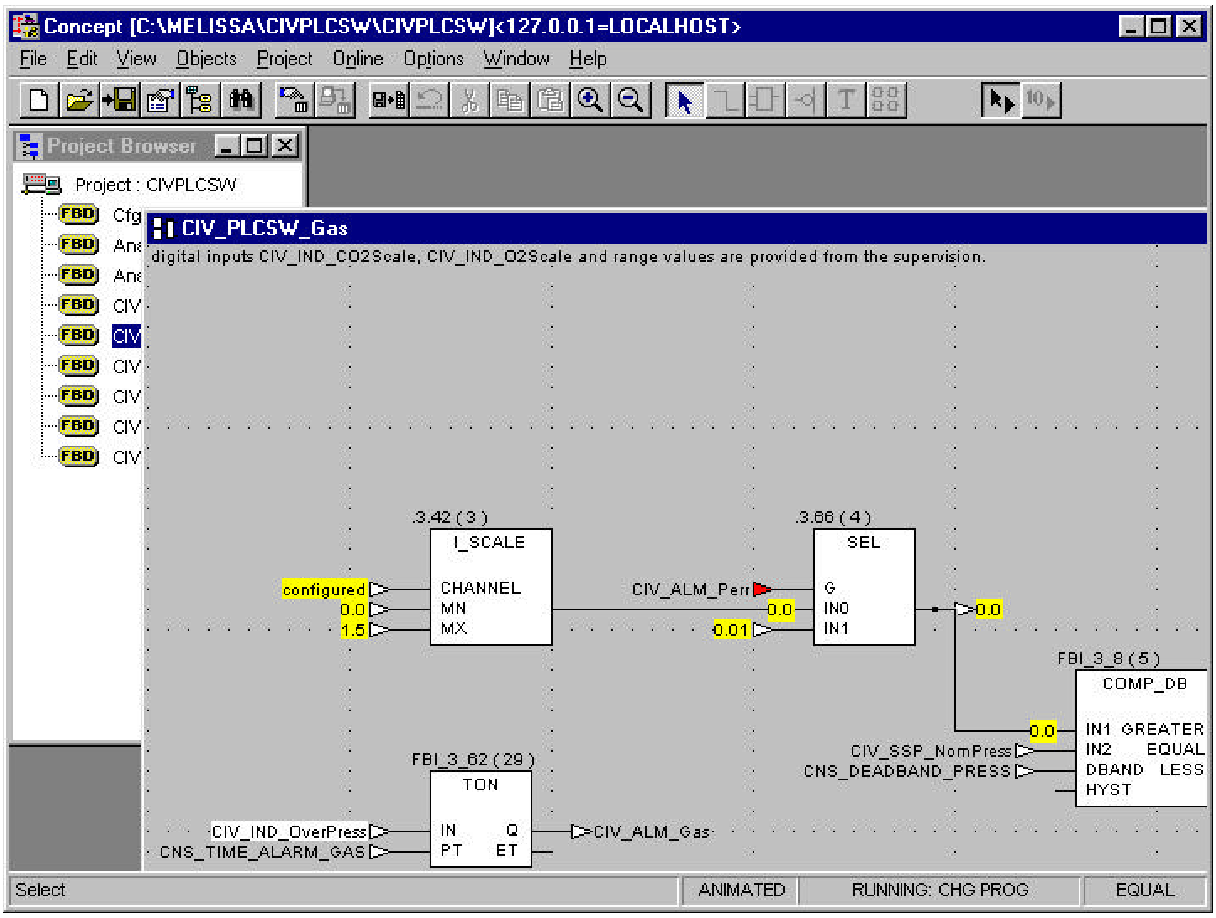
In case it is necessary to check the execution of a local regulation loop it is possible to enable the monitoring of a diagram. This action will cause to display the values calculated by the PLC in real-time.

To monitor the execution of a control loop perform the following steps:

1) Connect to the PLC.
2) Open the section that will be monitored. This can be achieved selecting the section from the Project Browser. To open the Project Browser select from the Project Menu the Project Browser command. From the Project Browser double-click over the desired section.
3) To monitor the execution of part of the diagram, using the mouse, select the modules that will be monitored.



4) To monitor the execution of part of the diagram, using the mouse, select the blocks that will be monitored. A blue line will surround the blocks selected.
5) From the Online menu, select the Animate Selected command. This action will cause the values currently used and calculated by the PLC to be displayed in the diagram.



When a selection of blocks is animated the analogue values are with a yellow background and the digital ones are red (0) and green (1).

10 SUPERVISION SOFTWARE OPERATION

10.1 Getting Started

Supervision is accessed by means of the Intellution iFIX Workspace application. The same application is used to create and modify Supervision displays, the Configure Mode, and to run the displays, the Run Mode.
The system is configured to start automatically in Run Mode.

To start Supervision Client application:
1) Switch on the Supervision Client.
2) From the Start Menu, run the Login application and input the User name and Password.
3) Once logged in correctly, select to run the iFix Workspace application.

Workspace Application will start and display the MELISSA Control System Main Window.

To close Supervision Client application:
1) Press F10, a main menu will appear on the top of the window.
2) Select File/Exit. Workspace application will close.
3) Run the Login application and press Logout.

10.1.1 General display layout

All implemented displays follow the same display layout as shown in Figure 14:

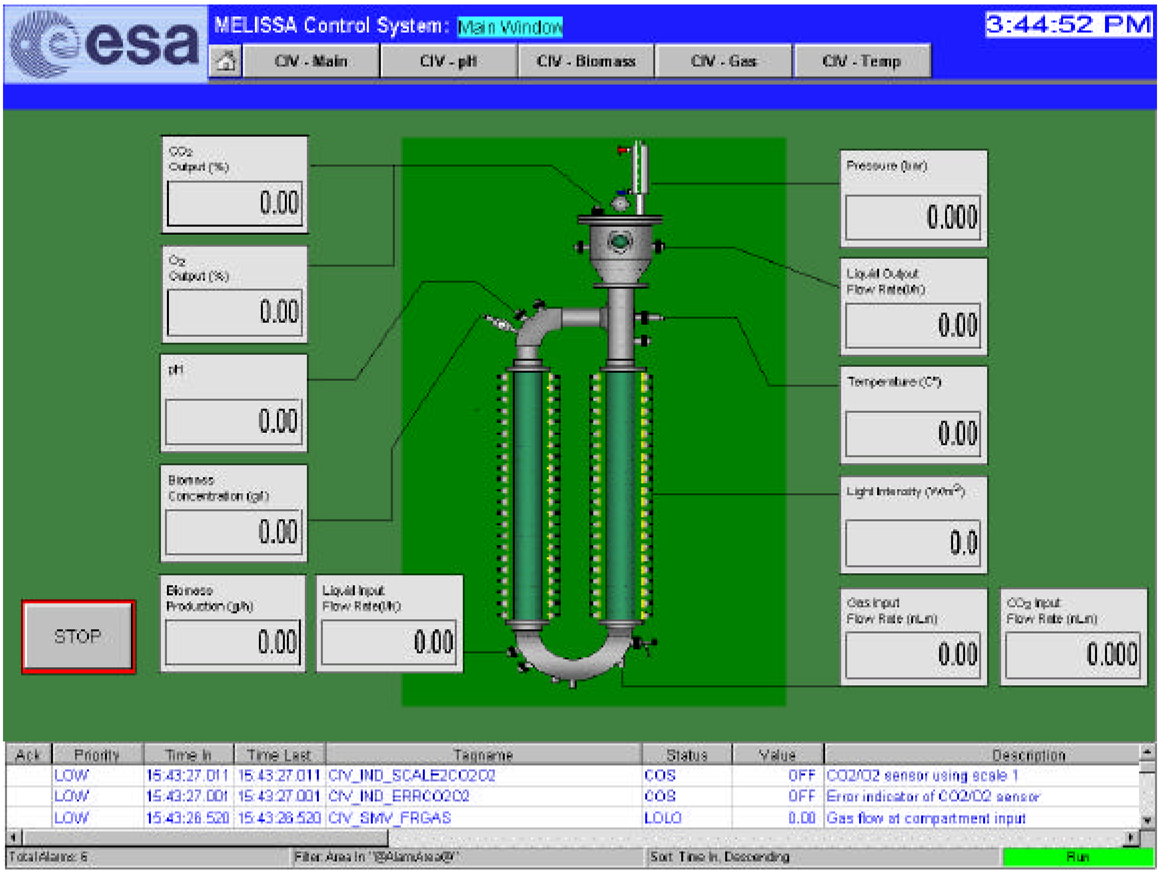


Figure 14. Supervision display general layout.

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 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 the alarm.
- **Description:** Description of the tag.

10.1.2 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 loop (Figure 15):

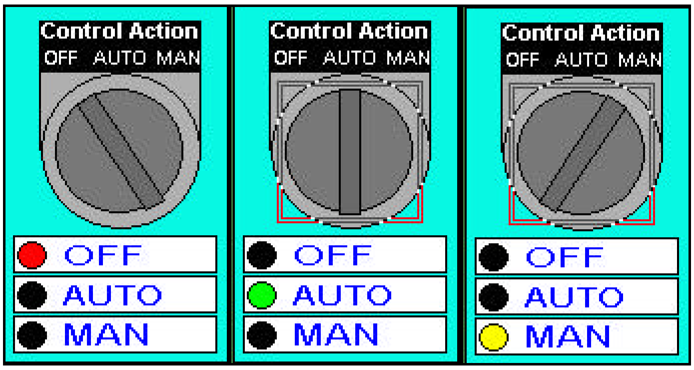


Figure 15. Colour of the operational mode indicators in Supervision displays.

- OFF is indicated in red, since loop is not regulated and outputs are set to 0.
- AUTO is the nominal situation, where outputs are regulated automatically by the control and is indicated in green.
- MAN is a situation that needs caution, then sets manual values to the outputs, and this action has to be used carefully since it can cause several malfunctions to the process. This indicator has the yellow colour.
- Options not active are displayed in black.

10.1.3 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 16) 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.

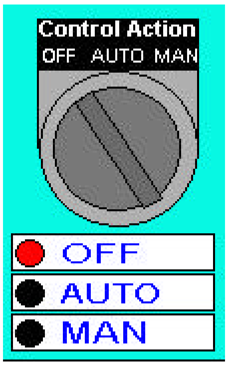


Figure 16. Operational Mode Control in Supervision displays.

CAUTION

Manual operational mode will set the outputs of the current loop to the manual values. This action can cause damage to the process and the system devices and therefore shall be used carefully. The user should edit and review the manual values before setting this operational mode.

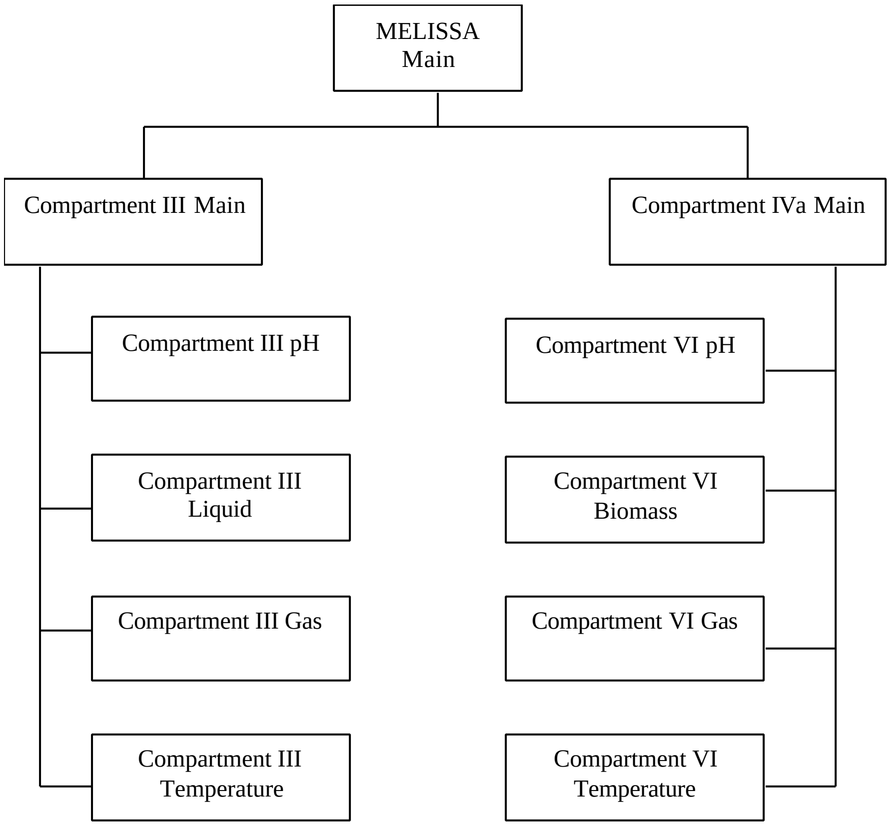
Edit Manual Values
Every loop display contains a button to allow the edition of the manual values. Click over the Edit Manual Values and a dialog will appear to allow the manual values modification.

Edit Set Points
Set points can be identified because are in blue foreground colour. To edit a value, 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.

10.1.4 Displays hierarchy

Supervision displays navigation is implemented as follows:



A process display has been implemented for every main loop, grouping process variables and control actions.

10.2 Compartment III Displays

10.2.1 Compartment III – Main window

The Compartment III Main window displays the principal values measured on the Compartment III. The lines indicate the approximated situation of the sensors in the reactor.

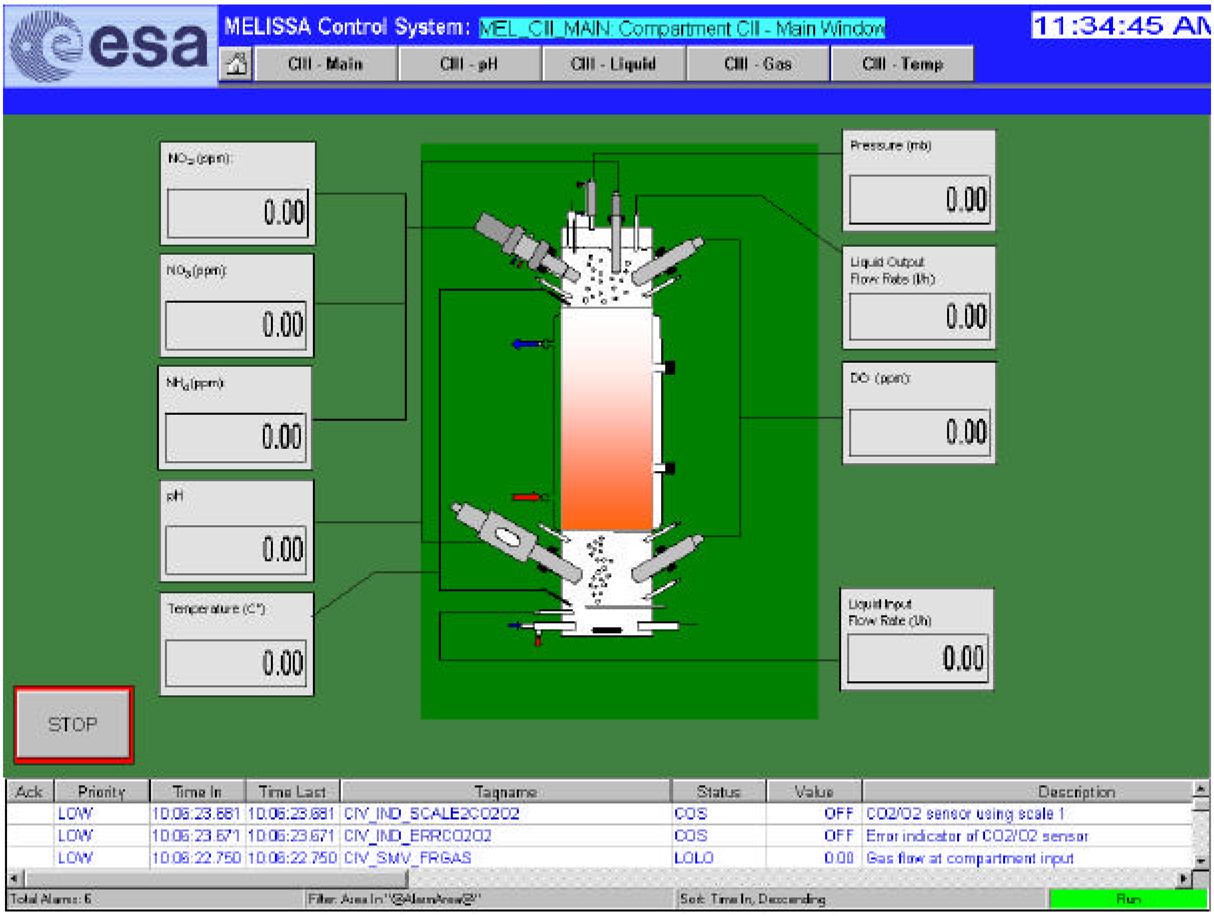


Figure 17. Compartment III Main Window

Specific Actions

- **STOP process regulation**

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

10.2.2 Compartment III – pH Regulation

The pH regulation display shows the relevant values of the process variables related to the pH regulation.

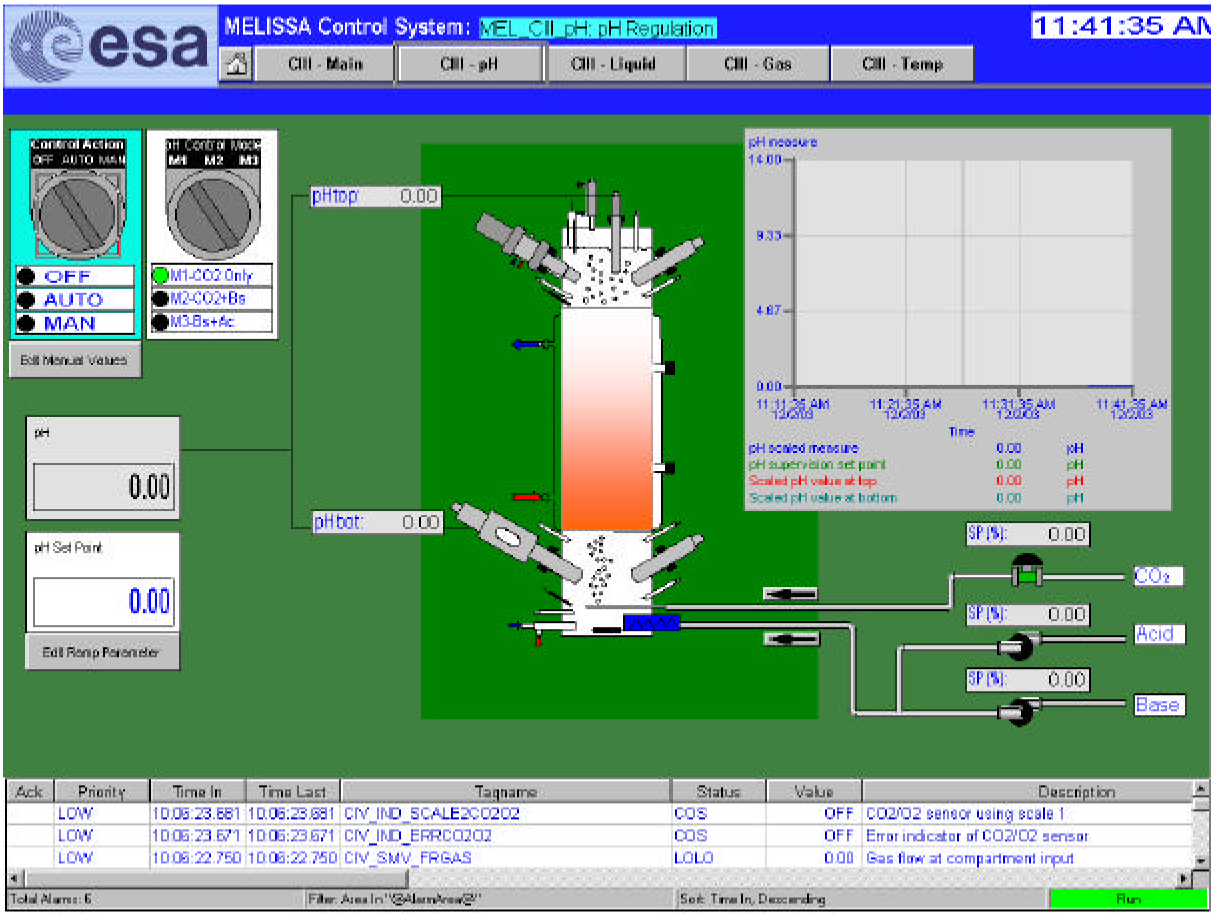


Figure 18 . Compartment III pH regulation display

<u>**Specific Actions**</u>

- **pH Control Mode**

Set the pH control mode as follows:

1) CO2 only: The system tries to regulate pH by controlling the CO2 input. Base and Acid pumps are displayed in black background colour and CO2 valve “hat” is displayed in blue.
2) CO2 + basic medium: The system tries to regulate pH controlling the CO2 input and the Base medium pump. Acid pump is displayed in black colour and Basic pump and CO2 vale are displayed in blue
3) Basic + Acid media: The system tries to regulate pH controlling the Base and Acid input media pumps. Acid and Basic pumps are displayed in blue.

To edit the pH control mode, double-click over the control. A dialog appears which allow the modification of the control mode.

- **Edit PI controller constants for Acid and Base pumps**

To edit the proportional and integrative constants, double-click over the Acid or Base pumps. A dialog will appear to allow the edition of the PI regulator parameters (common to both pumps).

- **Edit CO2 regulation constant**

To edit parameter for the CO2 regulation, double-click over the CO2 valve. A dialog will appear to allow the edition of the Proportional constant applied to acid/base PI regulator output, to adapt this output to the CO2 regulation.

- **Edit Ramp Parameter**

To edit parameter to smooth set point changes, click the Edit Ramp Parameter button. A dialog will appear, allowing the user to change the value. The value is applied in units per second.

10.2.3 Compartment III – Liquid

Figure 19 displays liquid flow regulation relevant values. Estimated NO2 concentration resulting of the Nitrite Estimator Control Algorithm is displayed in the Estimated NO2 concentration box. Estimation depends on the “Level 2 Liquid Input Flow Set Point”, providing as output the better possible value for the given conditions. This value is displayed in the “Level 1 Liquid Input Flow Set Point” box, which actually, is the value used to regulate the liquid input pump.
Liquid flows are regulated according to Level High/Low sensors (yellow light when active), actuating over the input and output pumps (output pump in green when active). In addition, the display shows the activation (green background) of the output pump for the liquid output buffer tank when maximum allowed level (level high indicator) is reached.

Specific Actions

- **Edit input / output pump calibration parameters**

To edit the calibration parameters for liquid input and output pumps, double-click over the pump. A dialog will appear allowing the user to modify the calibration parameters. Parameters are used as follows:

y(% of actuation) = Parameter A * (litres/h set point) + Parameter B

- **Edit Nitrite Estimator Parameters**

The Nitrite Estimator Algorithm needs a set of parameters. Current installed sensors provide some of them, the user can provide the other parameters through the Nitrite Estimator Parameters dialog (Figure 20). To open this dialog, click over the Nitrite Estim. Parameters button.

Parameters with grey background are acquired directly from the sensors and therefore are defined as read only.

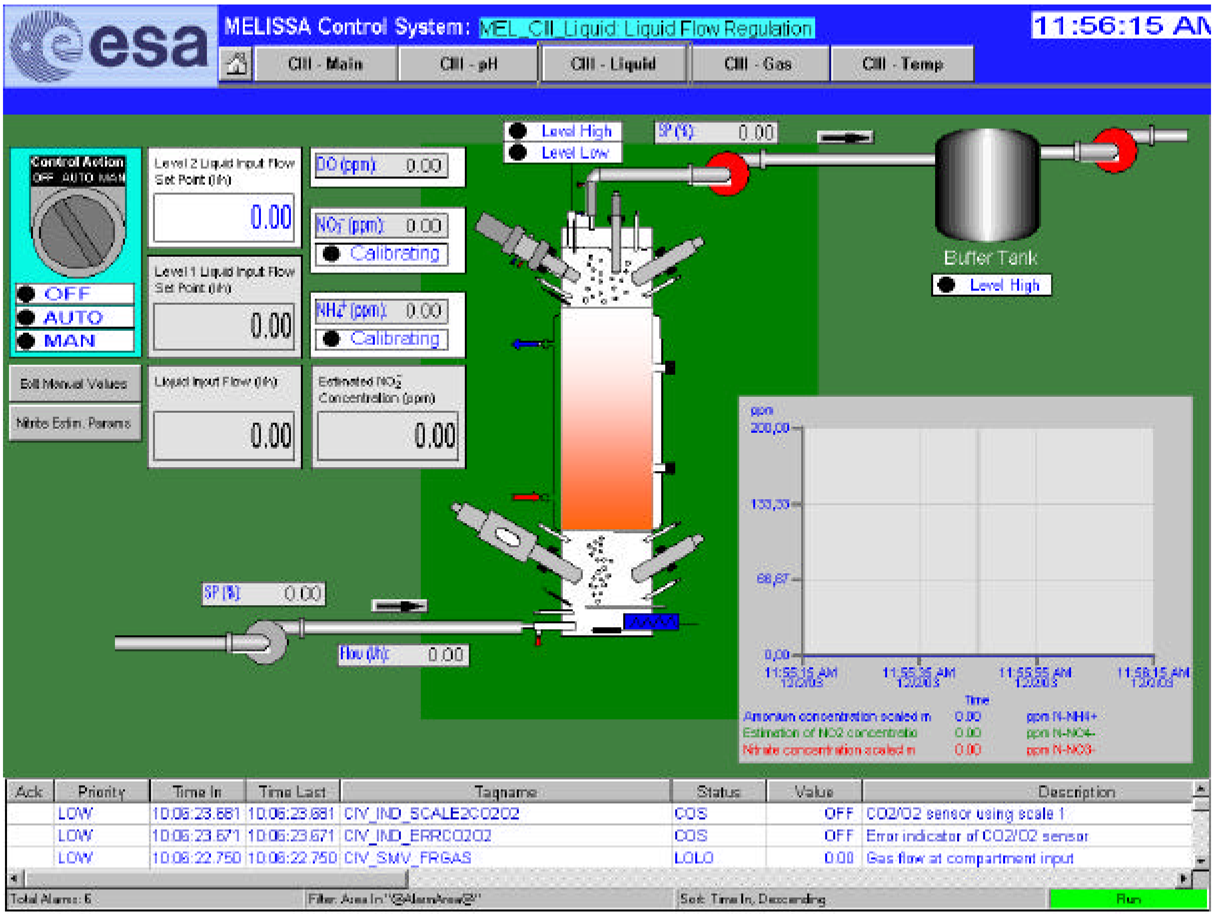


Figure 19. Compartment III Liquid regulation display

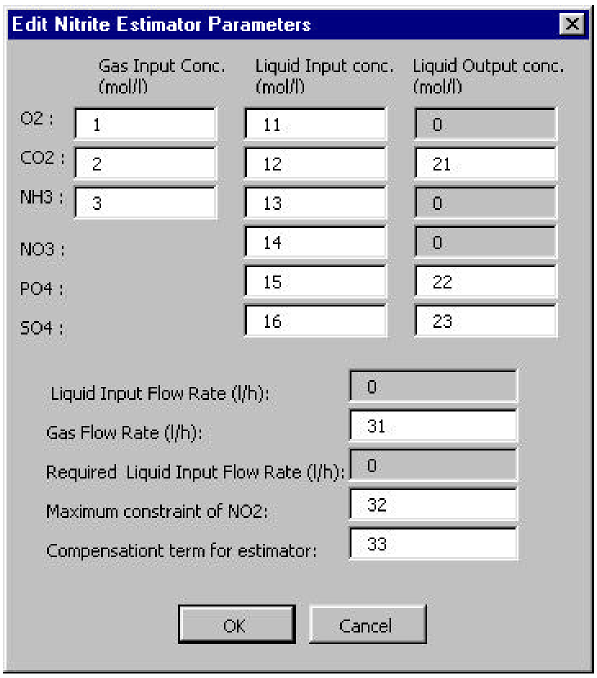


Figure 20 . Nitrite Estimator parameters dialog.

10.2.4 Compartment III – Gas

The Gas Loop Regulation display shows the relevant values related with the Gas regulation. The user can set the operational modes for Pressure and DO regulation separately through the Press. Loop and DO Loop controls. CO2 regulation is controlled from the pH Regulation display.

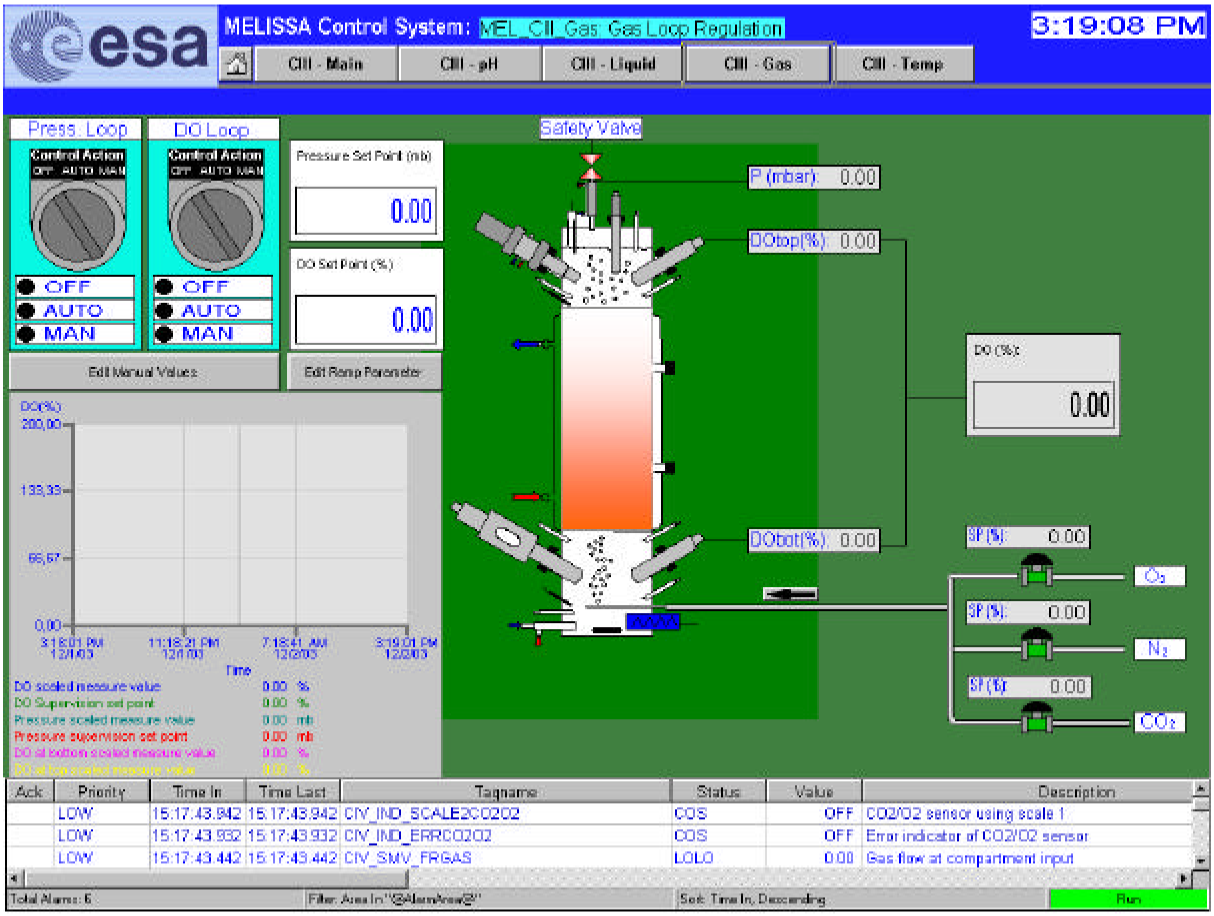


Figure 21. Compartment III Gas regulation display.

<u>**Specific Actions**</u>

- **Edit Ramp Parameter**

The Ramp Parameter is used to filter changes of the DO set point. To edit this parameter click on the Edit Ramp Parameter button. A dialog will appear, allowing the user to change the previous value. The value is applied in units per second.

- **Edit PID parameters for the O2 input regulation**

To edit the proportional, derivative and integrative constants of the O2 regulator double-click the O2 input valve. A dialog will appear to allow the edition of the PID regulator parameters.

- **Edit proportional constant for the N2 input regulation**

To edit the proportional constant of the N2 regulator double-click over the N2 input valve. A dialog will appear to allow the edition of the Proportional regulator parameter. Note that this proportional constant is applied to the output of the O2 PID regulator.

10.2.5 Compartment III – Temperature

The Temperature display shows the process variable values related to the Temperature regulation loop. When the heater is on, the heater object blinks in red/yellow and when the compartment needs refrigeration, the Cooling Valve switches to green colour indicating is open.

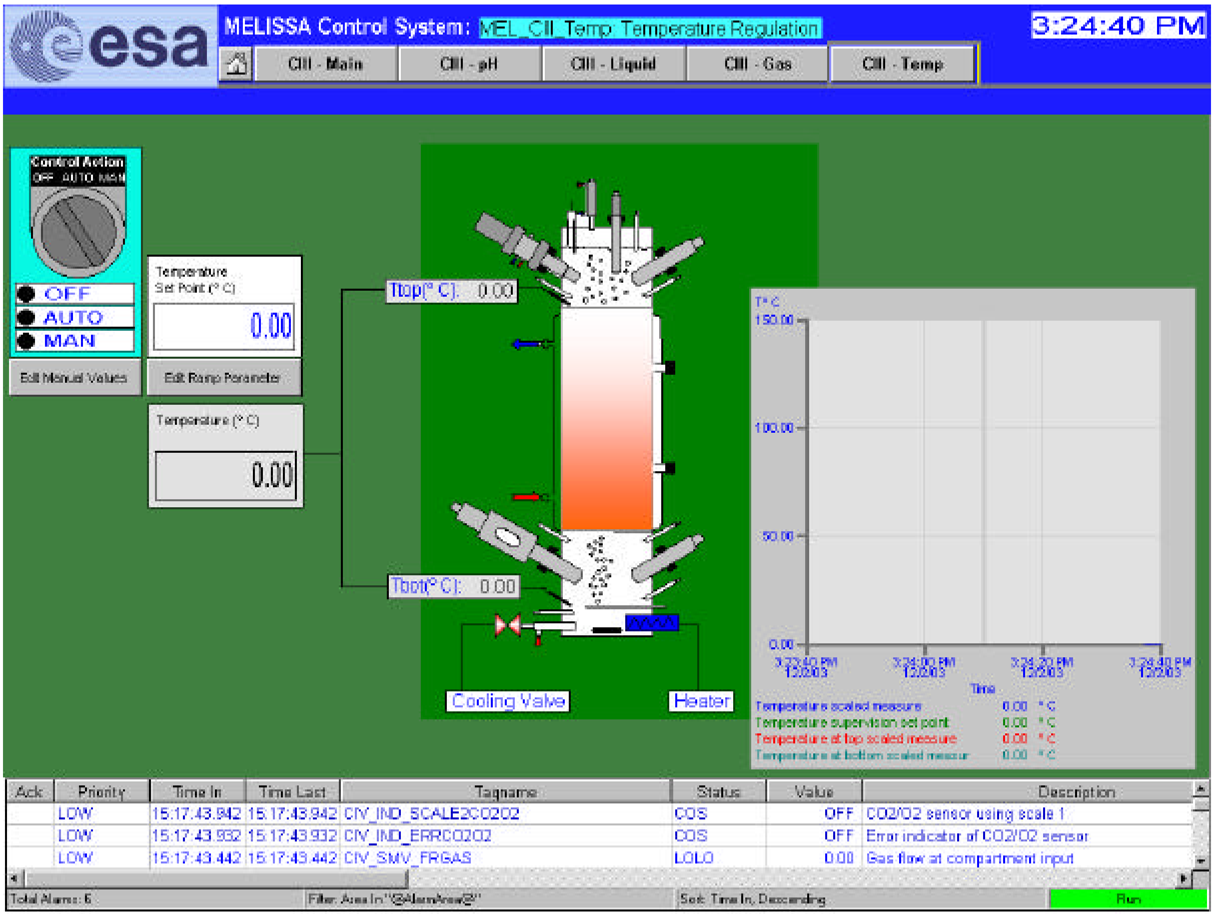


Figure 22 . Compartment III Temperature regulation display.

Specific Actions

- **Edit Ramp Parameter**

To edit parameter to smooth set point changes, click the Edit Ramp Parameter button. A dialog will appear, allowing the user to change the value. The value is applied in units per second.

10.3 Compartment IV Displays

10.3.1 Compartment IVa –Main Window

The Compartment IV Main window displays the principal values measured on the Compartment IV. The lines indicate the approximated situation of the sensors in the compartment.

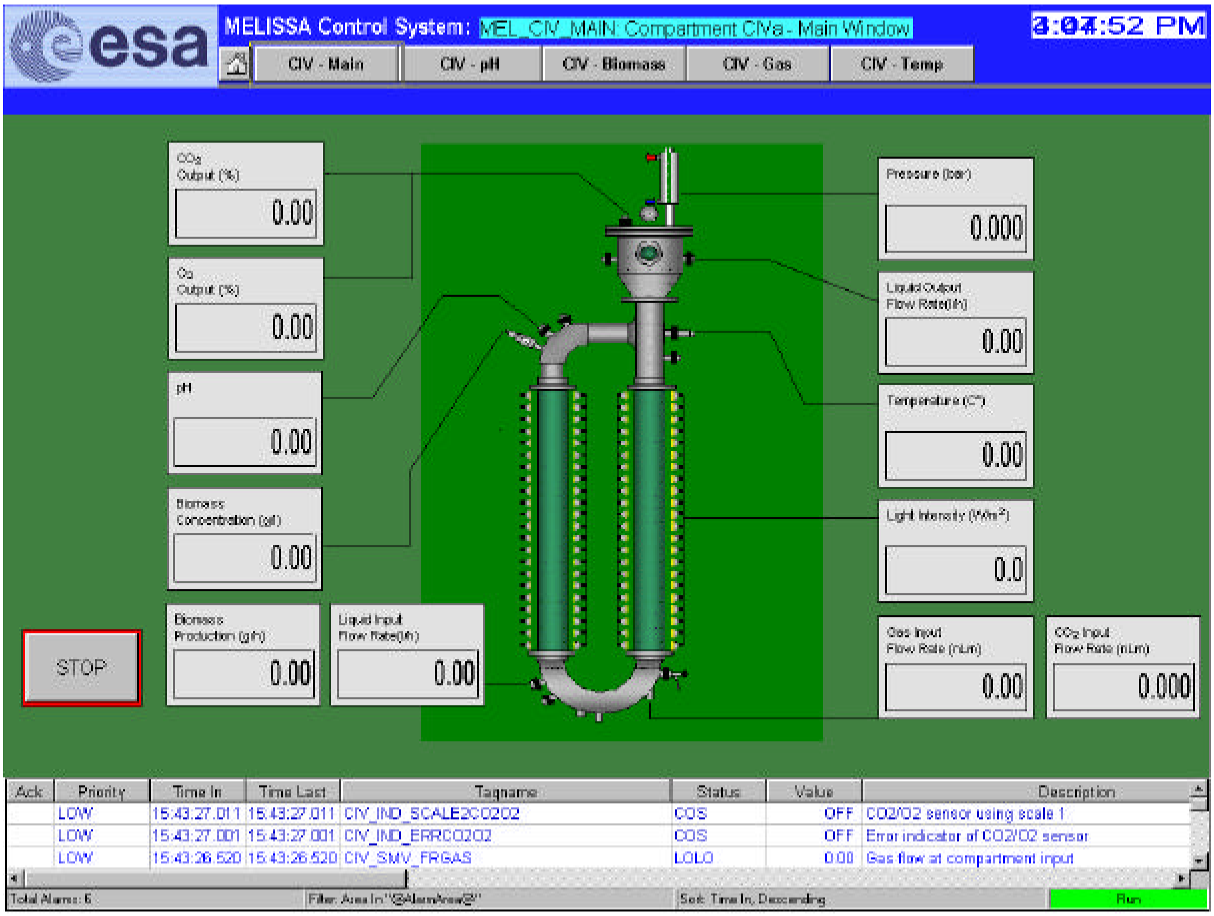


Figure 23. Compartment IV Main Window.

- **STOP process regulation**

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

10.3.2 Compartment IVa – pH

The pH regulation display shows the relevant values of the process variables related to the pH regulation.

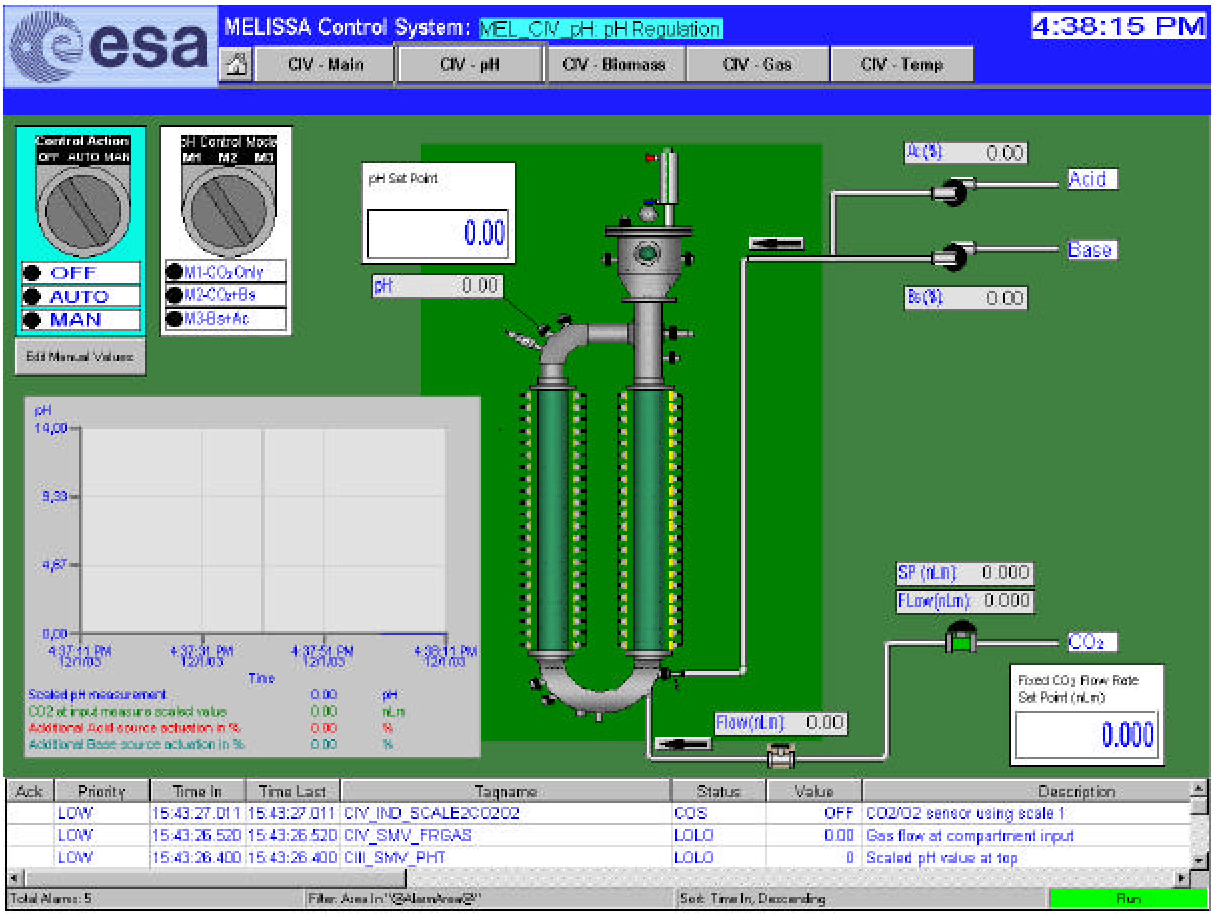


Figure 24. Compartment IV pH regulation display.

Specific Actions

- **pH Control Mode**

Set the pH control mode as follows:

1) CO2 only: The system tries to regulate pH by controlling the CO2 input. Base and Acid pumps are displayed in black background colour and CO2 valve "hat" is displayed in blue.
2) CO2 + basic medium: The system tries to regulate pH controlling the CO2 input and the Base medium pump. Acid pump is displayed in black colour and Basic pump and CO2 vale are displayed in blue
3) Basic + Acid media: The system tries to regulate pH controlling the Base and Acid input media pumps. Acid and Basic pumps are displayed in blue.

To edit the pH control mode, double-click over the control. A dialog appears which allow the modification of the control mode.

- **Edit proportional constant for Acid and Base pumps**

To edit the proportional constant, double-click over the Acid or Base pumps. A dialog will appear to allow the edition of the constant for the proportional regulator (common to both pumps).

- **Edit PID parameters of CO2 regulation**

To edit the PID parameters for the CO2 regulation, double-click over the CO2 valve. A dialog will appear to allow the edition of the Proportional, Derivative and Integrative constants of the regulator.

10.3.3 Compartment IVa – Biomass

Displays the relevant values of the biomass production regulation. Level 2 Biomass Production and Level 2 Liquid Input Flow set points, are the inputs for the Biomass Production Model Predictive Control algorithm. The algorithm calculates the best possible values the system can provide and these values are displayed in the “Level 1 Biomass Production set point” and “Level 1 Liquid Input Flow set point” boxes. Actually, the last one is the set point used to fix the pump that regulates the liquid input flow rate (Level 1 control). The real flow rate is displayed in the “Liquid Input Flow” box.

The tanks display graphically the current level, and the active liquid input pump is displayed in green. When the aeration valve is opened to clean the biomass sensor, colour of the valve (Air) switches from read to green.

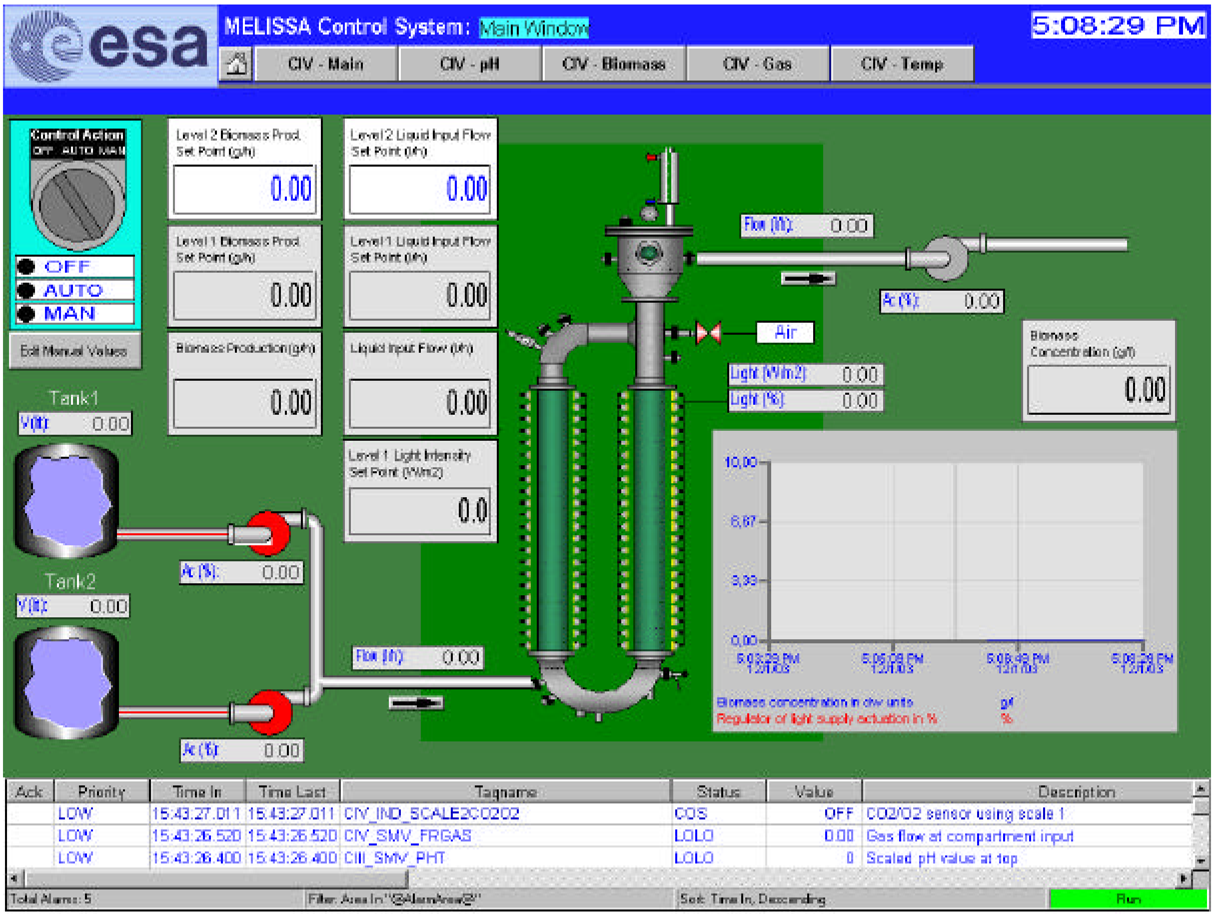


Figure 25. Compartment IV Biomass regulation display.

Specific Actions

- **Edit Tank minimum value and volume conversion parameters**

To edit the tank parameters, double-click over one tank. A dialog will appear to modify the minimum liquid level to switch to the alternative tank, and the density constant to convert Kg to litres. Parameters are common to both tanks.

- **Edit pump calibration parameters**

To edit the calibration parameters for liquid input and output pumps, double-click over the pump. A dialog will appear allowing the user to modify the calibration parameters. Parameters are used as follows:

y(% of actuation) = Parameter A * (litres/h set point) + Parameter B

- **Edit biomass sensor parameters**

To edit the biomass sensor parameters, double-click over the Biomass Concentration box. A dialog will appear which will allow the user to modify the sensor range and the Absorbance units (A.U.) to Dry weight units (gr./l) conversion parameter.

10.3.4 Compartment IVa – Gas

Displays the relevant values of the Gas regulation. From this display the user can change the gas input and output set points. When in Auto operational mode, if the pressure reaches the maximum allowed, the safety pressure valve is opened (changes from red to green), over pressure and under pressure is also regulated by actuating over the input and output gas valves.

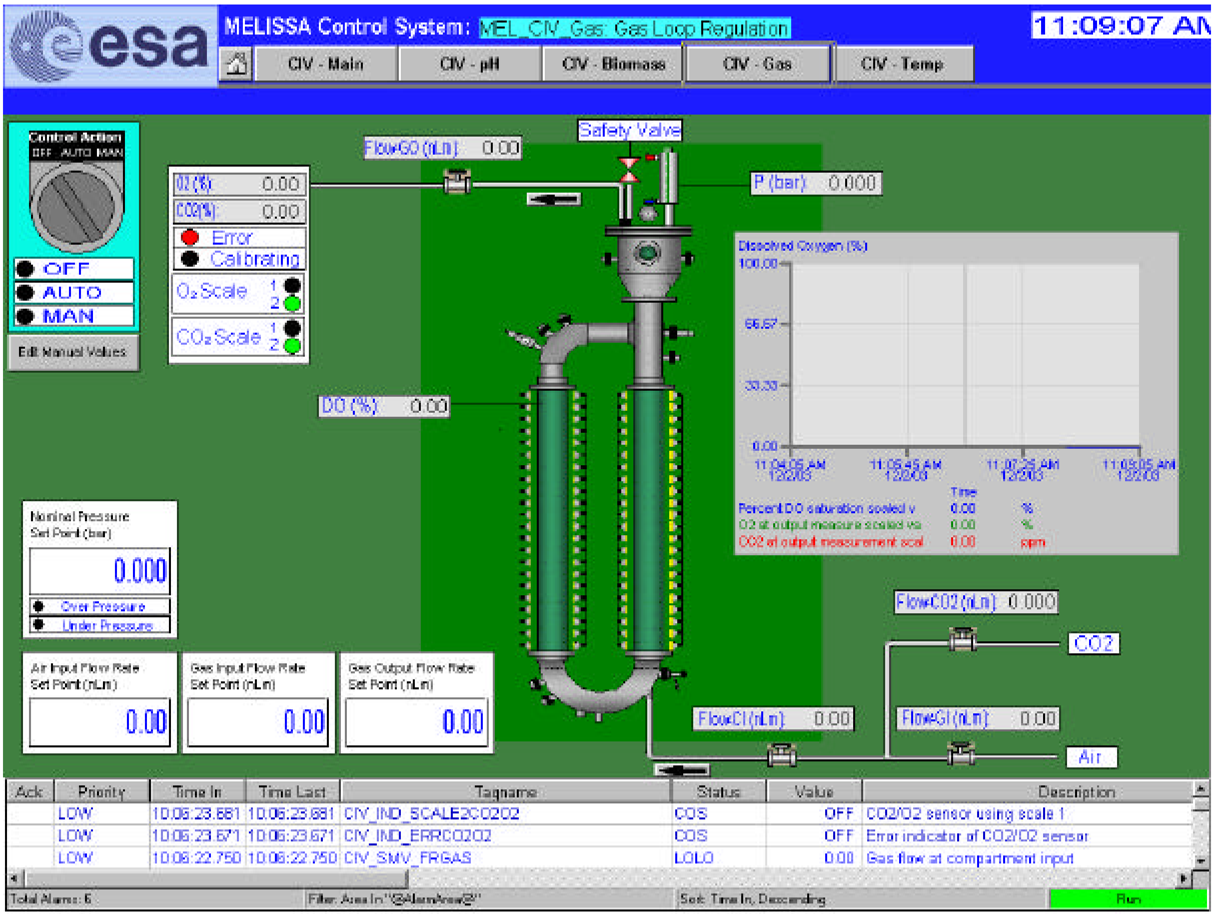


Figure 26. Compartment IV Gas regulation display.

Specific actions

- **Edit O2/CO2 sensor ranges**

To edit the O2/CO2 sensor ranges, double-click over the O2/CO2 values box. A dialog will appear allowing the user to edit the sensor ranges

- **Edit Maximum allowed pressure**

To edit the maximum allowed pressure, double-click over the Safety Valve. A dialog will appear allowing the user to edit the maximum pressure value.

10.3.5 Compartment IVa – Temperature

Display values relevant to the Temperature regulation. Actually, temperature regulation is not performed by PLC but apart with a specific controller.

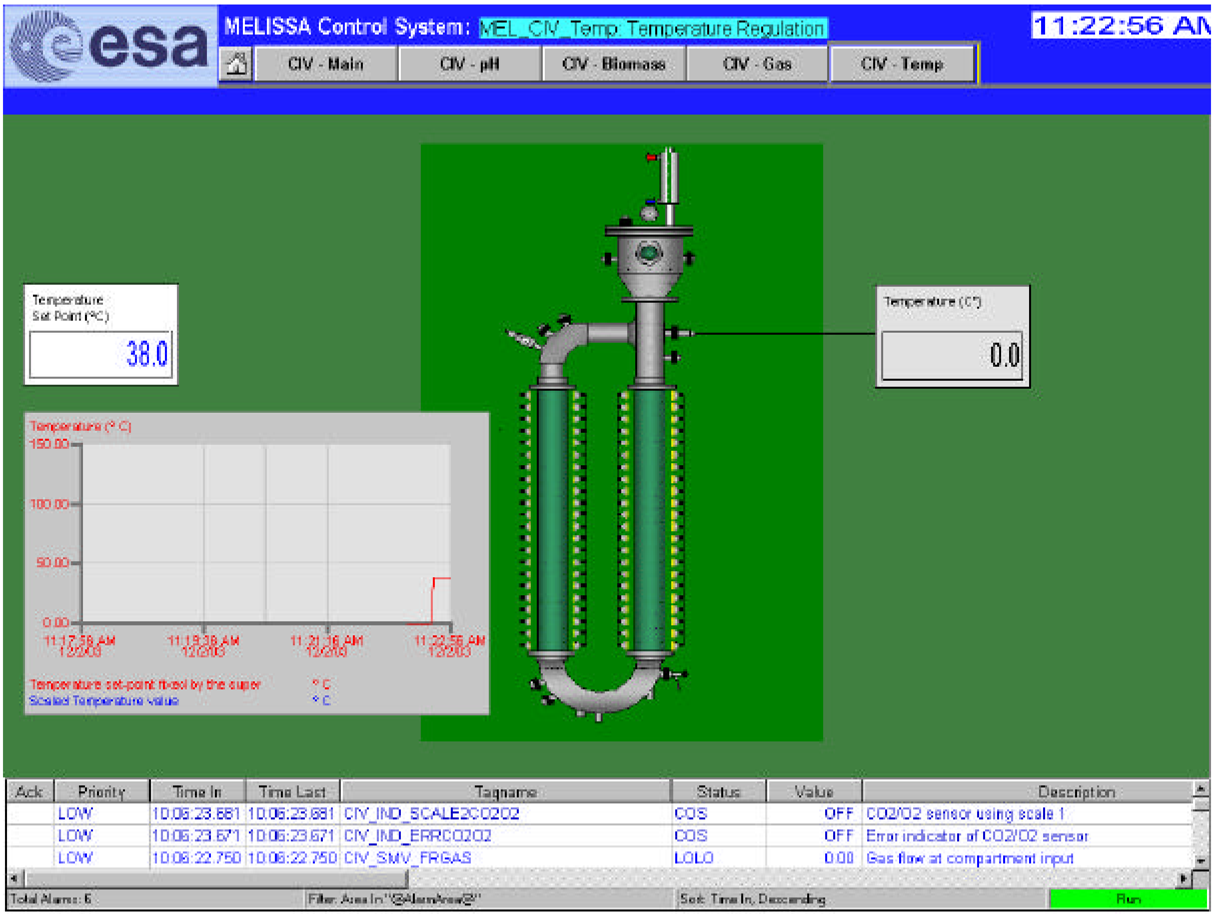


Figure 27 . Compartment IV Temperature regulation display.

<u>Specific Actions</u>

No specific actions are available in this display.

<u>10.4 Master Control</u>

The Master Control is executed by the iFix Scheduler module. This module allows the configuration of a task that needs to be executed periodically at fixed time intervals. The tasks can be configured to run in background, and therefore, is not necessary to start a Windows session in the Supervision Server. From this module, algorithms can access to process variables. By default, tasks will be running in background, to perform a change or to initialise a control algorithm, task configuration needs to be changed to run in foreground.

Task configuration is managed from the Supervision Server Workspace application.

In this MELISSA Control System, following tasks are configured:

- **MEL_CIV_BPCONTROL**

This task runs the Biomass Production control law algorithm, which regulates biomass production.

- **MEL_CIV_SAVEVALUES**

This task saves the principal process variable values of the Compartment IV in the Supervision Database.

- **MEL_CIII_NITCONTROL**

This task runs the Nitrite Estimator algorithm, which regulates Compartment III input flow and estimates dissolved Nitrite in the reactor.

- **MEL_CIII_SAVEVALUES**

This task saves the principal process variable values of the Compartment III in the Supervision Database.

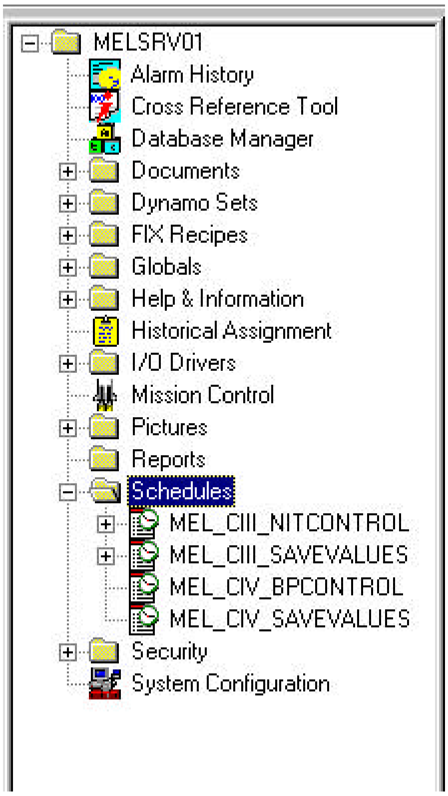


Figure 28. Tasks scheduled in the System Tree of the iFIX Workspace Application.

10.4.1 Open configured tasks

To access to configured tasks, from the Supervision Server follow these steps:

1) Open Intellution iFix Workspace application. Application will be started in configuration mode.
2) In the object tree, expand Schedules node. There, a list of scheduled tasks will be presented.
3) To modify one task, double-click it. In the right pane, a table will appear displaying all configuration parameters.

10.4.2 Change the task run mode (foreground/background)

Tasks can be configured to run in foreground or in background. Executing the tasks in foreground will allow the user to test the task by firing its execution manually and initialise algorithm status by changing the run mode. To execute a task in foreground perform following steps:

1) In the iFIX Workspace open the task.
2) Open the pop-up menu, pressing the right mouse button.
3) Select Scheduler Properties. A dialog with Run in Foreground and Run in Background options will appear.
4) In the dialog, select run in foreground.
5) Press OK.
6) Select the task and from the Workspace menu select Workspace and Switch to Run. Task Status is displayed in green showing “Active”. Switching again the Workspace to Configuration mode will stop the task.
7) To restore the run mode to background, open again the configuration dialog, select “Run in background” and confirm changes. Task status will be displayed in green showing “Active”.

In case Biomass production control law or Nitrite estimator tasks need to be initialised before starting a test, change the configuration to run it in foreground and restore the previous configuration to run the task again in background. Task status is displayed in green showing “Active” and if the user switches Workspace mode to Run, it can be verified that the “Number of Times Fired” is reset to 0.

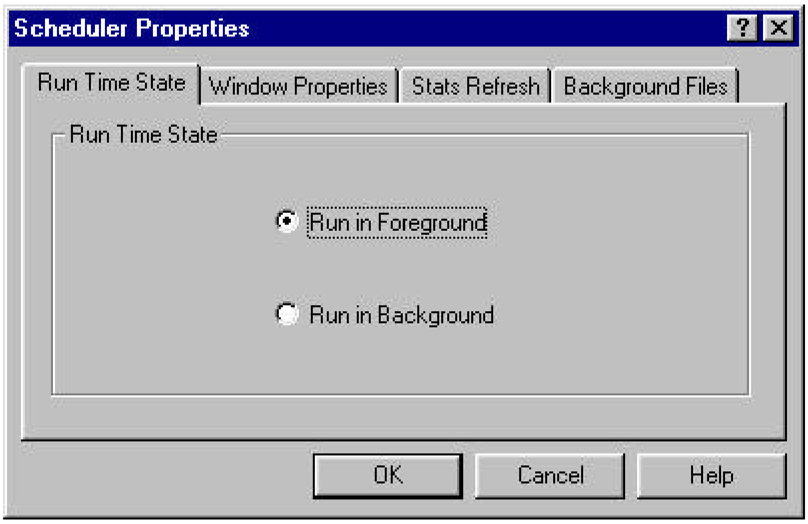


Figure 29. Task foreground/background run mode configuration.

Important

Control algorithms such as the Spirulina Biomass Production or the Nitrite Estimator must run in Background in order to allow the user to change other configuration parameters of the system without affecting the execution of these algorithms. Running in foreground a task blocks the Workspace Application in run mode since mode cannot be changed to configuration again without stopping the tasks that are running in foreground.

10.4.3 Enable/Disable logs

The Master Control tasks can generate logs to monitor its execution. These logs are stored in the folder SUPERVISION\Pic\Logs. The activation or deactivation of these logs is controlled by a global variable to change the value of this variable perform the following steps:

1) In the iFIX Workspace access to the elements tree.
2) Open the Globals\User branch.
3) Select the EnableLogs item and open the context menu by clicking the right mouse button.
4) Select the “Property Window…” command.
5) Modify the property CurrentValue to True to activate the logs and to False to deactivate it.

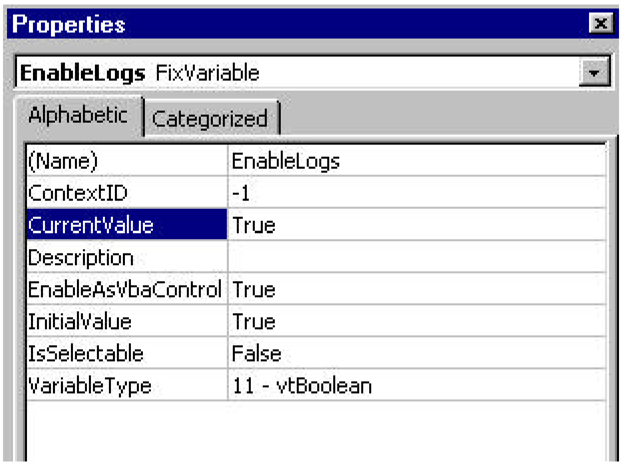


Figure 30. EnableLogs configuration dialog.

10.5 Supervision Database

Supervision Database is updated by means of the tasks MEL_CIII_SAVEVALUES and MEL_CIV_SAVEVALUES running under the iFIX Task Scheduler. These tasks are scripts that build the SQL sentence to update the corresponding Microsoft Access® database. Data can be retrieved using the Microsoft Access® application export features.

10.5.1 Change the update rate

It is possible to change the database update rate to adapt it to the characteristics of the current test.
To change the database update rate perform the following steps:
1) Open the corresponding schedule task.
2) Modify the Interval setting (1 in the figure 29).
3) Close the task and confirm save changes.

This action will reset the task, which will be fired at new time interval.

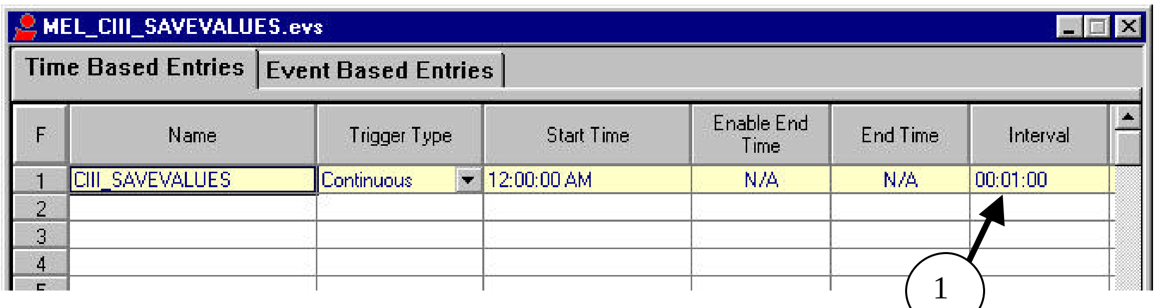


Figure 31. Supervision database task configuration.

10.5.2 Compartment III

The following values of the Compartment III are saved in the Supervision Database:

Scheduler Task: MEL_CIII_SAVEVALUES

File	CIII_DB.mdb	
Table	CIII_MeasuredValues	
Column	**Description**	**Type**
DateTime (PK)	Time stamp	Date/Time
CIII_SSP_L2LiFr	Level 2 Liquid input flow rate set point	Double
CIII_SSP_L1LiFr	Level 1 Liquid input flow rate set point	Double
CIII_SMV_NO3	Nitrate concentration scaled measure	Double
CIII_SMV_NO2	Estimated nitrite concentration	Double
CIII_SMV_NH4	Ammonium concentration scaled measure	Double
CIII_SSP_pH	pH set point	Double
CIII_SMV_pH	pH scaled measure	Double
CIII_SSP_T	Temperature set point	Double
CIII_SMV_T	Temperature scaled measure	Double
CIII_SMV_DO	DO scaled measure value	Double
CIII_SSP_P	Pressure set point	Double
CIII_SMV_P	Pressure scaled measure value	Double
CIII_SMV_LiFr	Liquid input flow rate	Double

10.5.3 Compartment IVa

The following values of the Compartment IV are saved in the Supervision Database:

Scheduler Task: MEL_CIV_SAVEVALUES

File	CIV_DB.mdb	
Table	CIV_MeasuredValues	
Column	**Description**	**Type**
DateTime (PK)	Time stamp	Date/Time
CIV_SMV_CxDW	Biomass concentration in dw units	Double
CIV_SSP_L1LiFr	Level 1 Liquid input flow rate set-point	Double
CIV_SSP_L2LiFr	Level 2 Liquid input flow rate set-point	Double
CIV_SMV_LiFr	Liquid input flow rate	Double
CIV_SMV_LoFr	Liquid output flow rate supervision set-point	Double
CIV_SMV_BP	Biomass production	Double
CIV_SSP_L2BP	Level 2 Biomass production set point	Double
CIV_SSP_L1BP	Level 1 Biomass production set point	Double
CIV_SSP_Light	Light supervision set-point	Double
CIV_SSP_pH	pH supervision set point	Double
CIV_SMV_pH	Scaled pH measurement	Double

File	CIV_DB.mdb	
Table	CIV_MeasuredValues	
Column	**Description**	**Type**
CIV_SMGO_CO2	CO2 at output measurement scaled value	Double
CIV_SSP_P	Pressure supervision set point	Double
CIV_SMV_P	Pressure measurement scaled value	Double
CIV_SMGO_O2	O2 at output measure scaled value	Double
CIV_SMV_FrCO2	CO2 at input measure scaled value	Double
CIV_SSP_T	Temperature set point	Double
CIV_SMV_T	Temperature measurement	Double
CIV_SMV_DO	DO measurement	Double
CIV_SMLI_V1	Tank 1 volume	Double
CIV_SMLI_V2	Tank 2 volume	Double

11 HMI SOFTWARE OPERATION

11.1 HMI General layout

HMI displays are composed by a working area, with a white background and an information area placed at the bottom of the window with grey background.

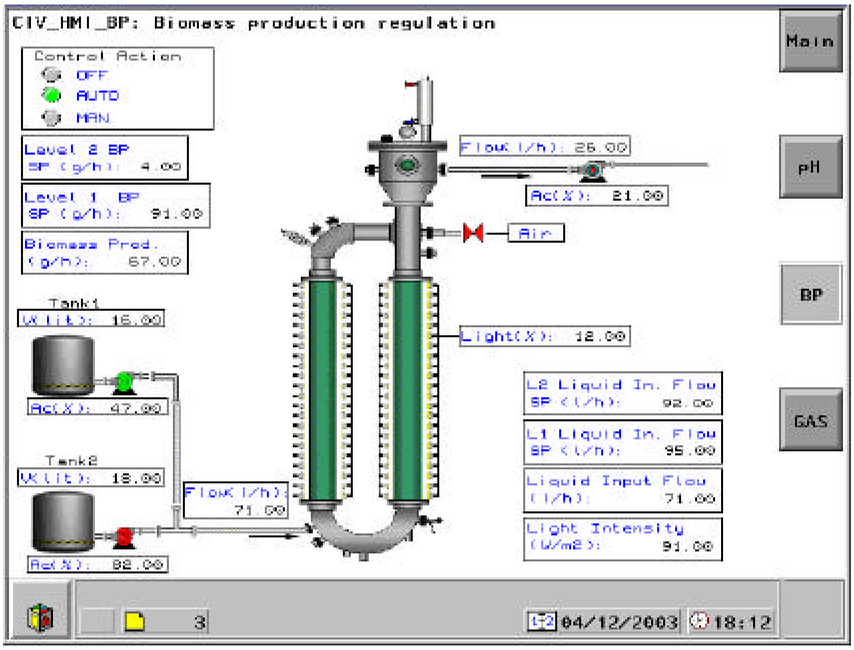


Figure 32. HMI Layout.

11.1.1 Working Area

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

11.1.1.1 Navigation Buttons

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

11.1.1.2 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.

11.1.2 Information Area

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

11.1.2.1 System Button

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

11.1.2.2 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).

11.2 HMI Main Display

It displays principal values of different compartments. Allows the navigation to compartment specific displays.

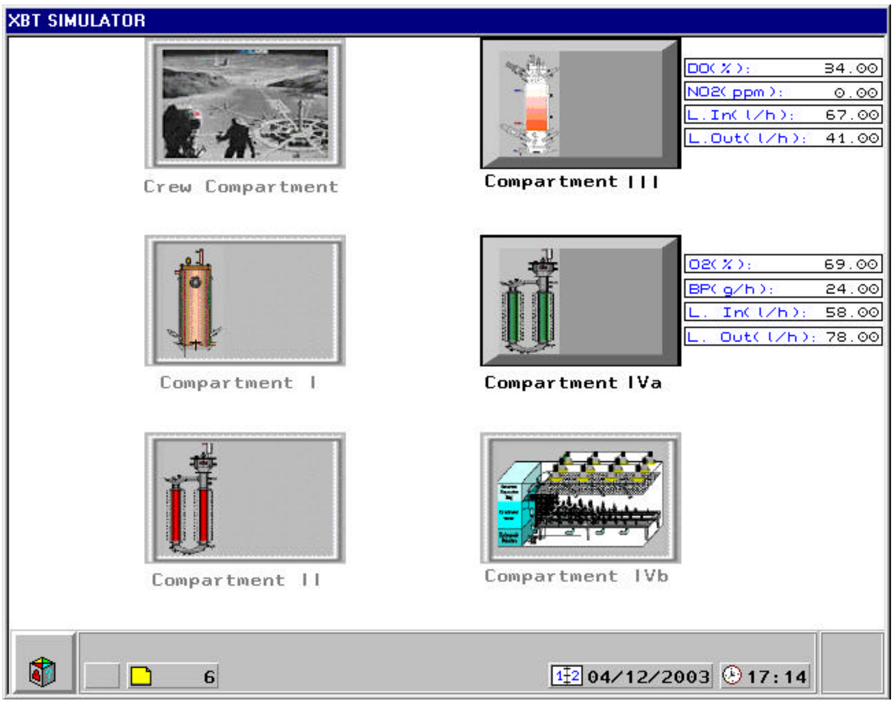


Figure 33. HMI Main Display.

11.3 Compartment III Displays

11.3.1 Compartment III – Main

It displays the principal values of the Compartment III.

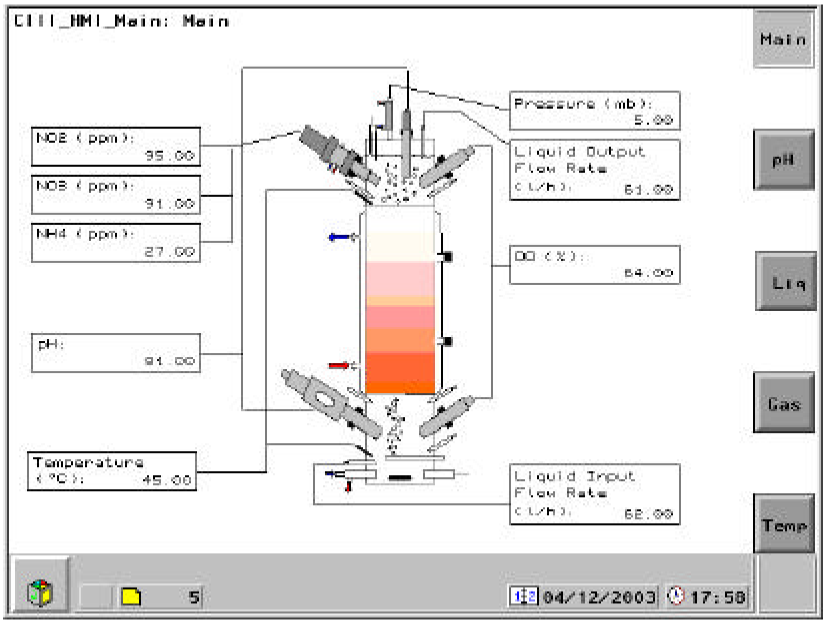


Figure 34. HMI Compartment III Main Display.

11.3.2 Compartment III - pH

It displays values related to the pH regulation.

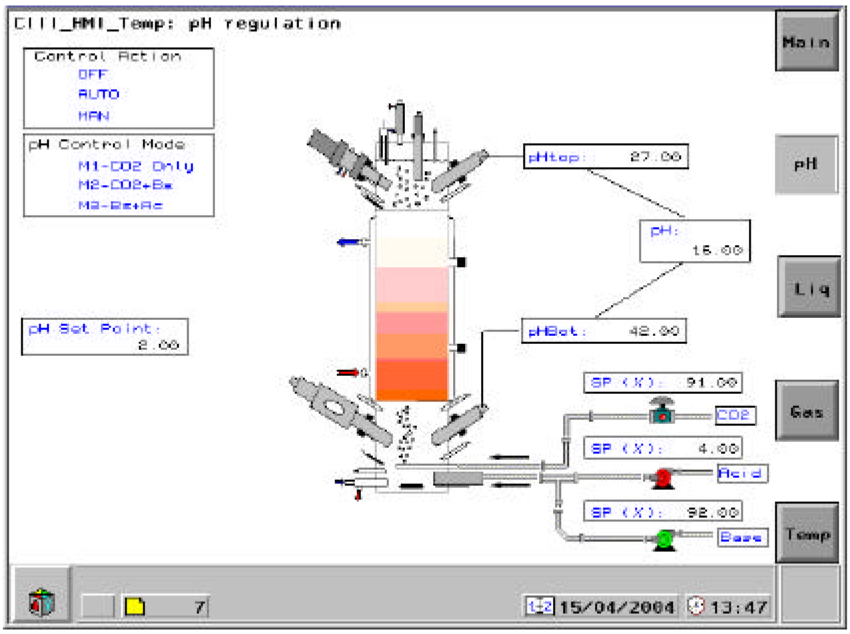


Figure 35. HMI Compartment III - pH Display

11.3.3 Compartment III – Liquid

It displays values participating in the liquid input / output regulation.

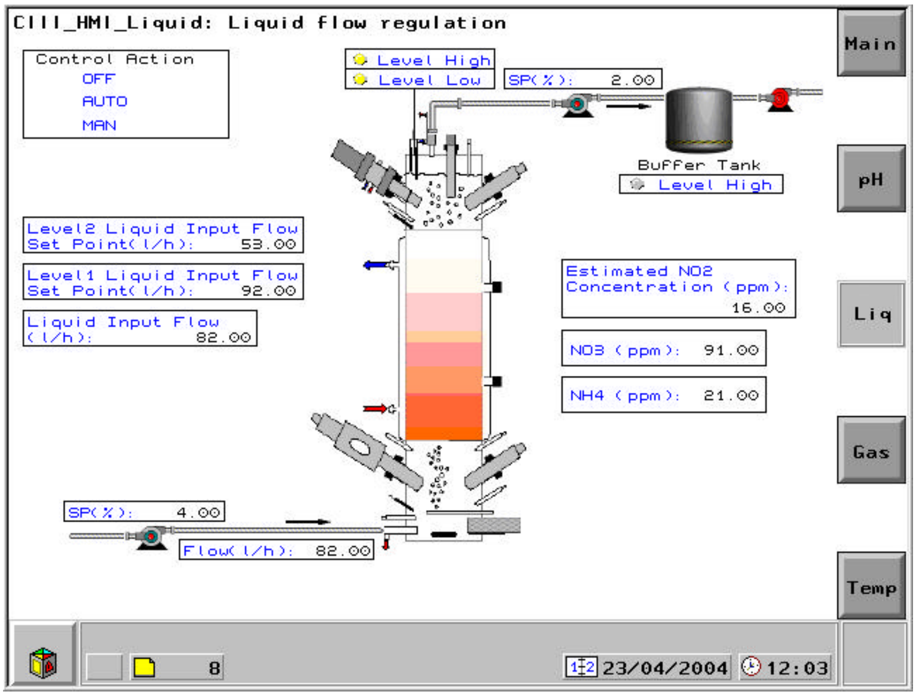


Figure 36. HMI Compartment III - Liquid

11.3.4 Compartment III – Gas

It displays values participating in the gas input / output regulation

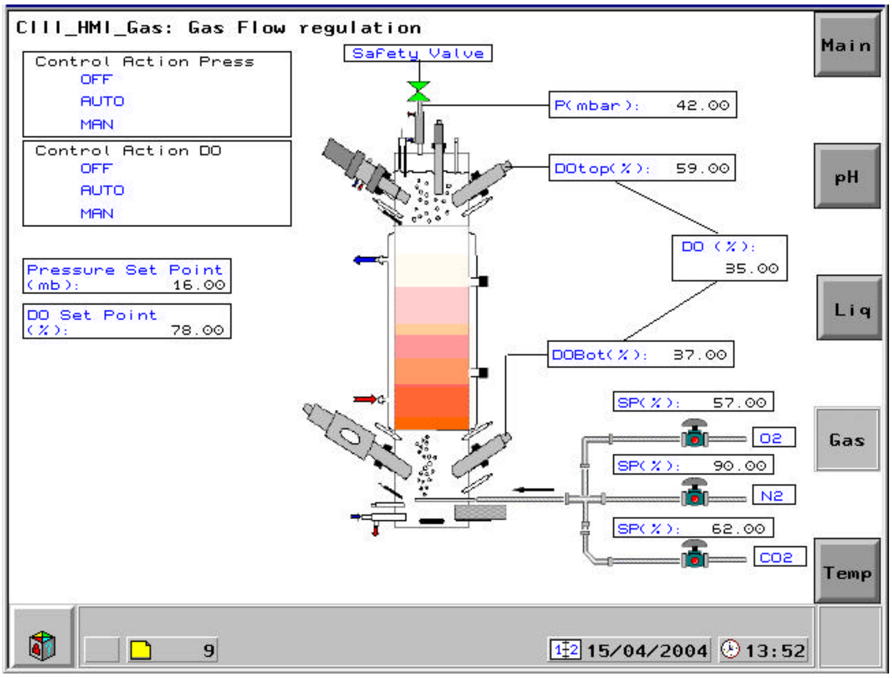


Figure 37. HMI Compartment III - Gas

11.3.5 Compartment III – Temperature

It displays values related to temperature regulation.

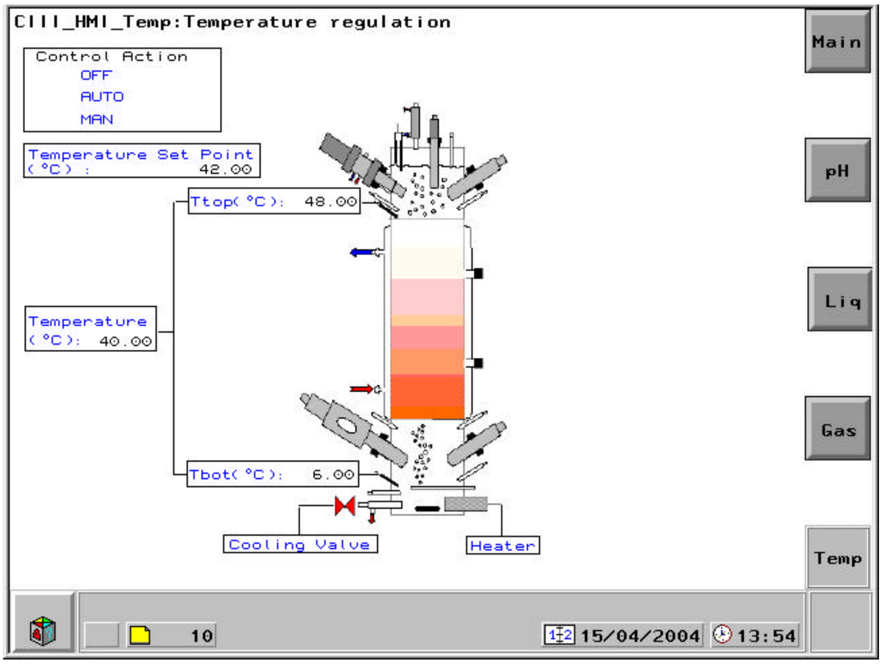


Figure 38. HMI Compartment III - Temperature

11.4 Compartment IV Displays

11.4.1 Compartment IV – Main

It displays values related to biomass production regulation.

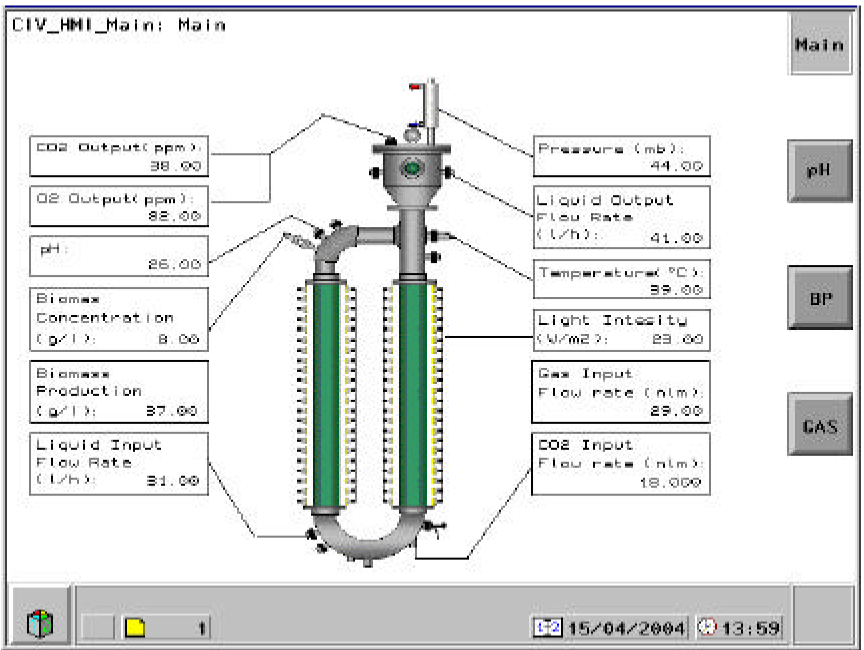


Figure 39. HMI Compartment IV - Main

11.4.2 Compartment IV – pH

It displays values related to pH regulation.

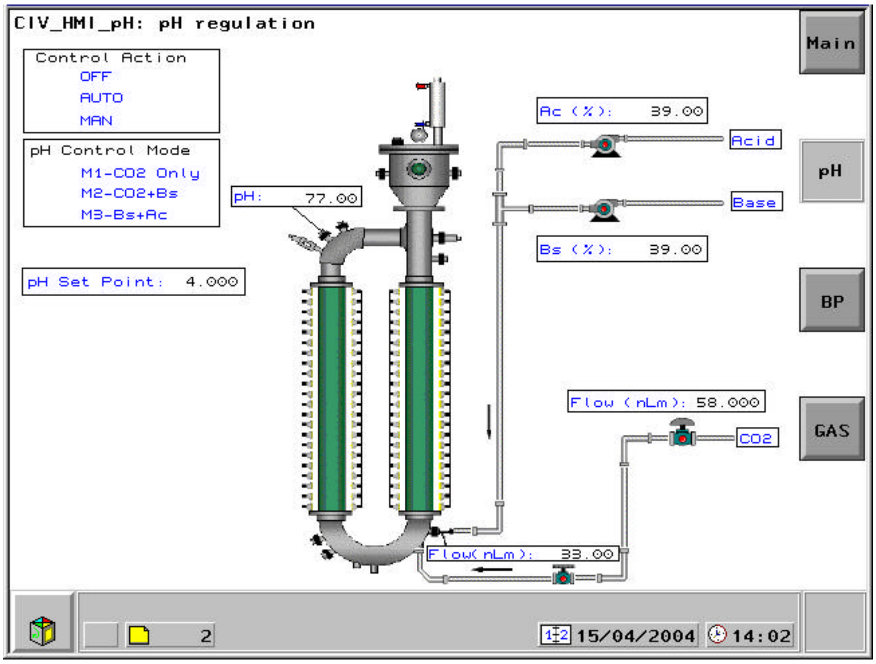


Figure 40. HMI Compartment IV - pH

11.4.3 Compartment IV – Biomass

It displays values related to biomass production regulation.

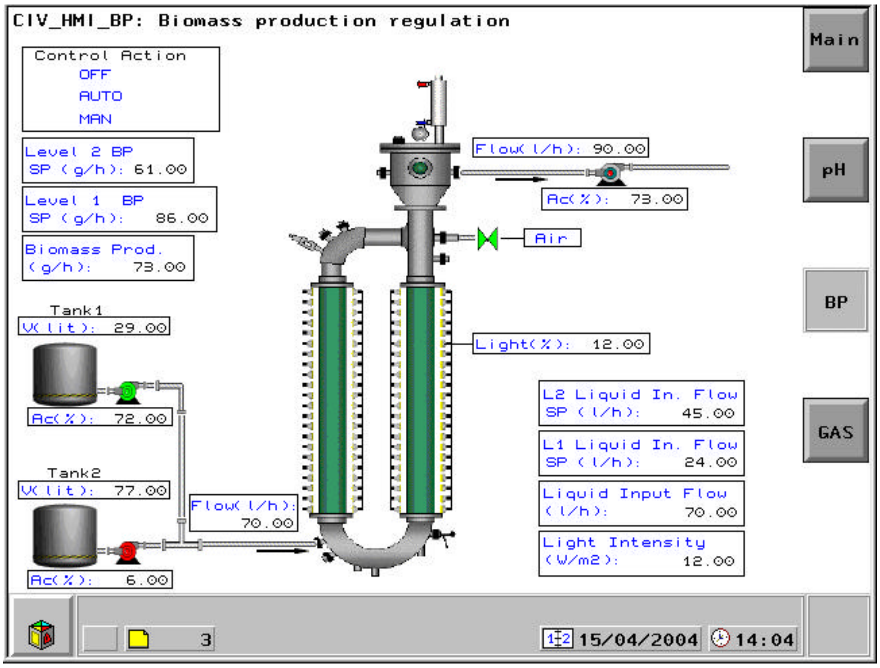


Figure 41. HMI Compartment IV - Biomass

11.4.4 Compartment IV – Gas

It displays values related to the gas input / output regulation.

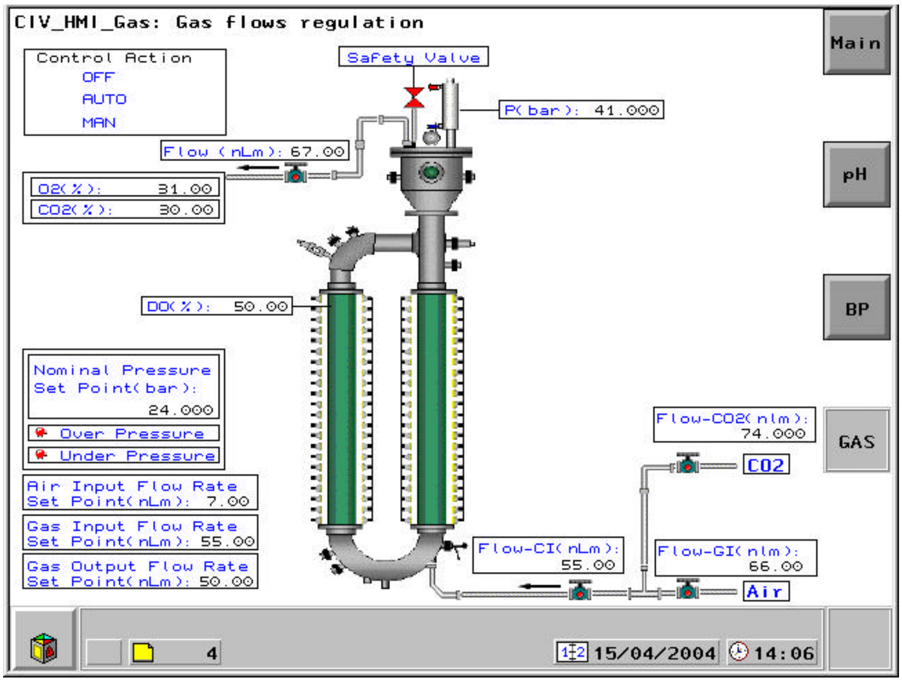


Figure 42. HMI Compartment IV - Gas

12 MAINTENANCE

12.1 Backup Procedure

To prevent the system to lose the data stored due to a hardware failure, backups of relevant data must be performed regularly. The periodicity will vary depending on the type of experiments currently performed in the Plant. The recommended approach is to perform a backup of data at the end of every experiment and empty the data files.

In addition, a backup of the entire system is recommended each time a change on the configuration is performed in order to avoid loosing these changes.

To perform a backup use the tape device included in the Supervision Server and the Backup software tool accessible from the Windows menu Programs and Accessories.

Important

To perform a full backup using the Windows 2000 Backup tool the files must not be locked or otherwise are skipped. In order to avoid files locked the iFIX service must be stopped. To stop the service, close all iFIX applications and from the Control Panel select Services and stop the iFIX service. This will cause the Master Control to be stopped and therefore this operation can only be performed when there are not experiments on course. Once the backup process is ended, restart the iFIX service.

12.2 Data Management

In a regular basis, data generated must be removed in order to prevent the system to run out of disk space. The time will vary depending on the acquisition data rates used. Therefore, when a long test is going to start it is highly recommended to check if data can be reset for the compartment since data are generated independently for each compartment. To reset the data for a compartment perform the following steps:

1. Perform a backup of the corresponding Microsoft Access Database file (mdb) located in the SUPERVISION\PIC\Database.
2. Empty the database file.

13 TROUBLESHOOTING

13.1 Rack power input is interrupted

When the rack power is interrupted the Uninterrupted Power Supply will start beeping. This is to alert that this device is powering the PLC. The power interruption can be caused for several reasons. To detect the cause of the power interruption perform the following steps:

1) Check that the rack receives external power. This can be checked by verifying that other devices have power. In case that the external power is not available the recovery procedure is out of the scope of this instructions.
2) Check the magnetothermic circuit breaker in the AC input (see figure 2 for rack III and figure 3 for rack IV). In case that the differential is open is because an over power consumption has occurred. The rack power consumption is limited to 6 Amp @ 220 V 50 Hz. An over power consumption most probably is caused by a short circuit. Review the connections and devices of the rack to identify and solve the short circuit problem and connect again the magnetothermic.
3) Check the differential circuit breaker status in the AC input. In case that the differential is open is because of a current leak. Review the connections and devices of the rack to identify and solve the current leak problem. After detecting and solving the current leak connect the differential circuit breaker.

13.2 Rack power output is interrupted

When the devices connected to the rack AC power output stop receiving power can be due to a short circuit in the wiring or devices connected.

1) Check the status of the magnetothermic at power output input (see figure 2 for rack III and figure 3 for rack IV). In case the status is open, check the devices and wiring to detect the short circuit and once detected and solved restore the magnetothermic status to closed. If the status is closed then the problem can be in the device that is not receiving power.
2) Check the status of the rest of the devices to isolate the problem. If the rest of the devices are not working check if the rack is receiving power at its input and follow procedure stated in section 13.1.

13.3 Communications with the PLC are broken

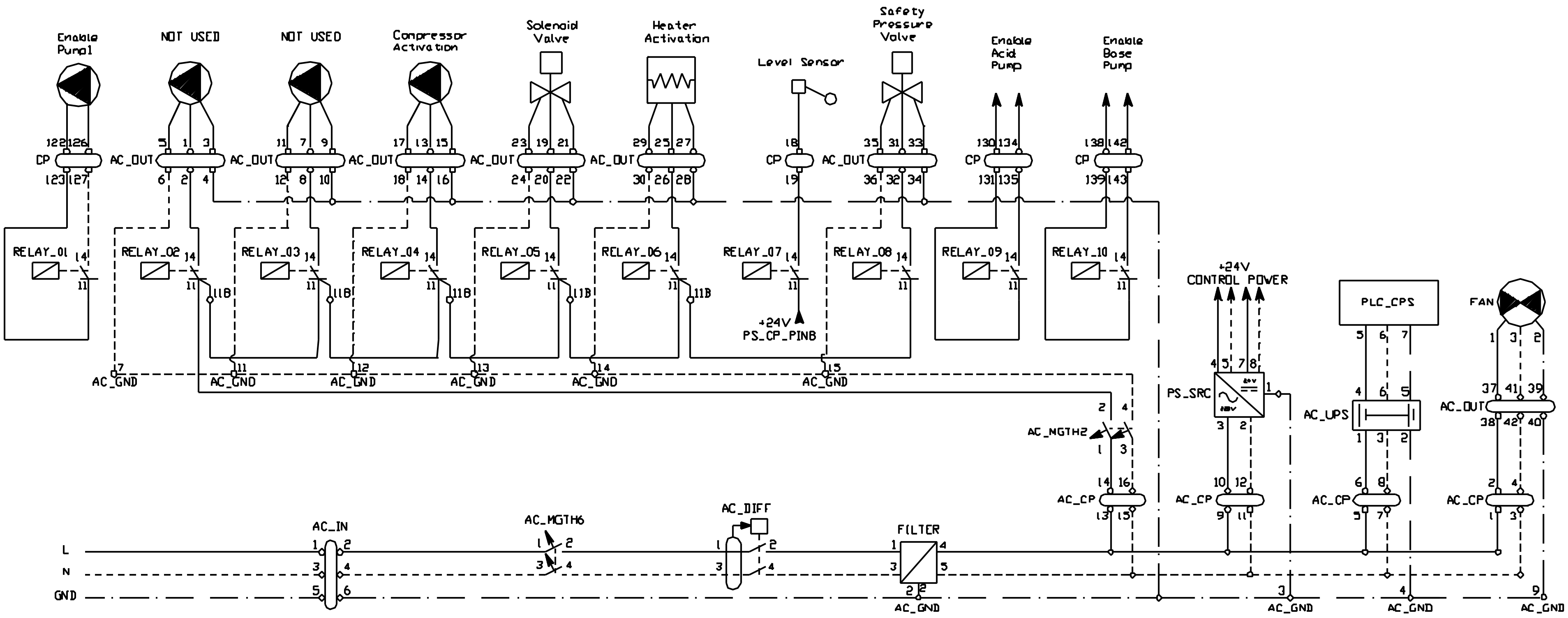
In case the supervision displays @@@@ symbols in the variable values can be due to the lost of communications with the PLC.

1) Check the rack receives power. In case that is not powered follow procedure stated in section 13.1.
2) Check the network connection. The network connection can be checked by looking at the led status of the switch (located in the Supervisory Rack) and the led status of the network module of the PLC (see figure 2 for rack III and figure 3 for rack IV). If the led are indicate malfunction check the network connectors to the switch and the PLC (plug and unplug the connectors), if still not working check the cable connectivity.

14 APPENDIX A. Table of figures

15 APPENDIX B. Problem Report Form

MELISSA Control System Demonstrator - Problem Report		
Reported by:	Identifier:	Date:
Title:		Reference:
Problem Found		
Suspected Cause		
Disposition Result		
Disposition option: *Reject*	*Repair, rework*	*Use as is*
Disposition Date:		
Actions		
Close Out		
Verification results:		
Verified by: Date:	Authorised by: Date:	



	FECHA DATE	NOMBRE NAME
DIB./DRAW	16/04/04	
REV./CHECK	16/04/04	
ING./ENG.	15/04/04	
	15/04/04	

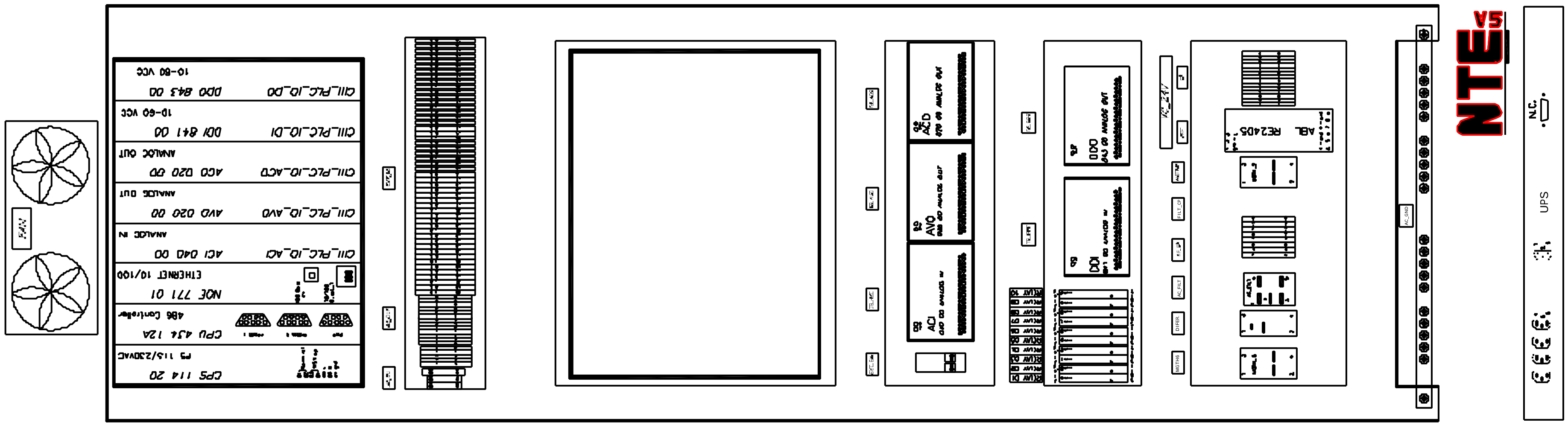
PROYECTO/PROJECT
MELISSA

FUENTE/SOURCE: NTE

TITULO/TITLE.
Electrical Schematic Rack 3

MEL-3320-DR-034-NTE

NºHOJA/SHEET Nº: 1 1



ISS.	CHANGES	Date	Draw.	Eng.	Q.A.

	FECHA DATE	NOMBRE NAME
DIB./DRAW	15/04/04	A. López
REV./CHECK	15/04/04	J. Duatis
Autorized	15/04/04	J. Mas
Q A	15/04/04	S. Ferrer

RUGOSIDAD/ROUGHNESS

TOLERANCIAS/TOLERANCES

x ±0.20
.xx ±0.10
.xxx ±0.03

MATERIAL/MATERIAL

--

ESPEC/SPEC

--

ACABADO/FINISH

--

--

PROYECTO/PROJECT

MELISSA

NTE S.A.

CAN MALE. LLIÇA D'AMUNT
08186-BARCELONA.SPAIN

MASA/MASS N.A.

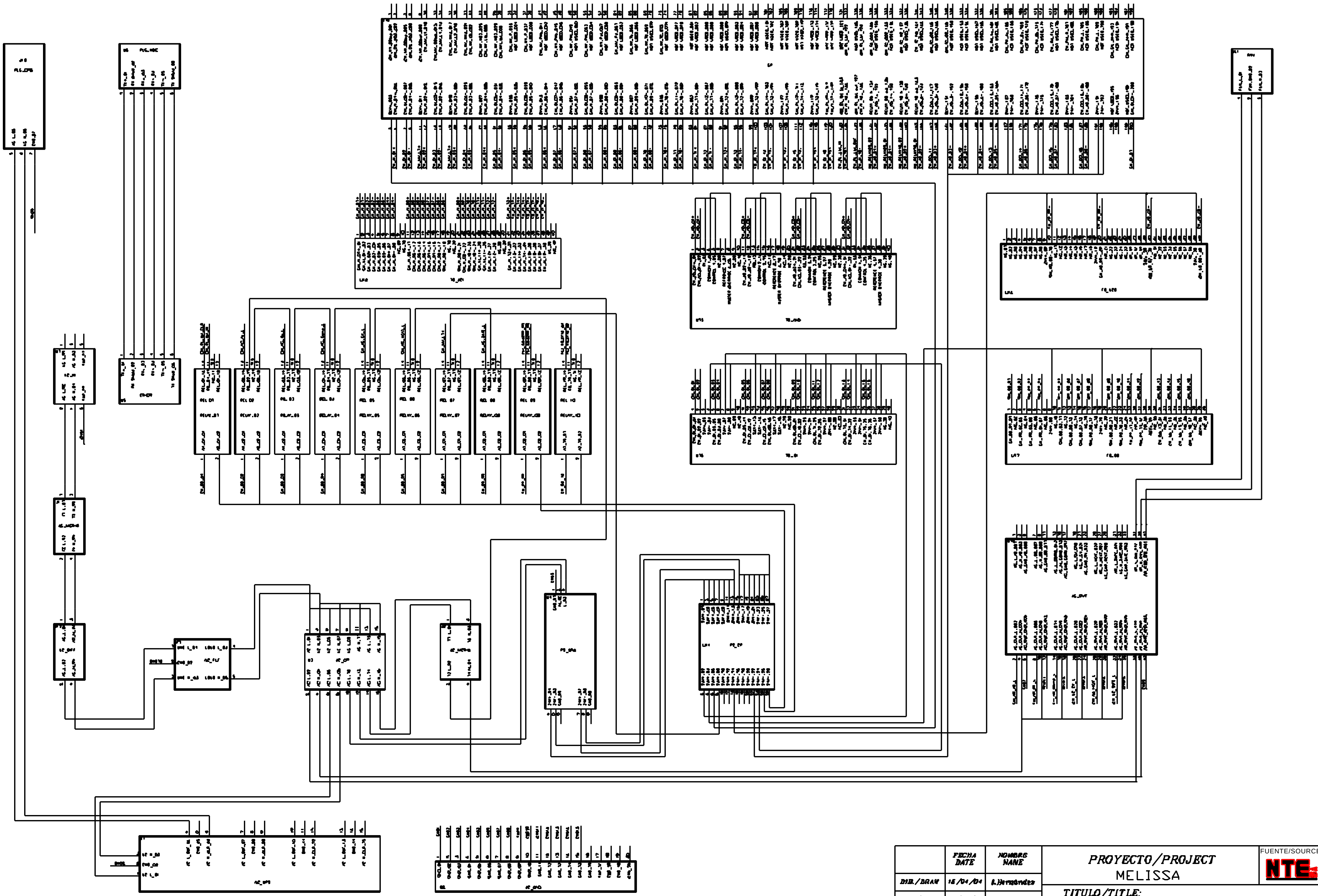
SHEET 1 OF 1

ESCALA/SCALE N.A. DIM mm

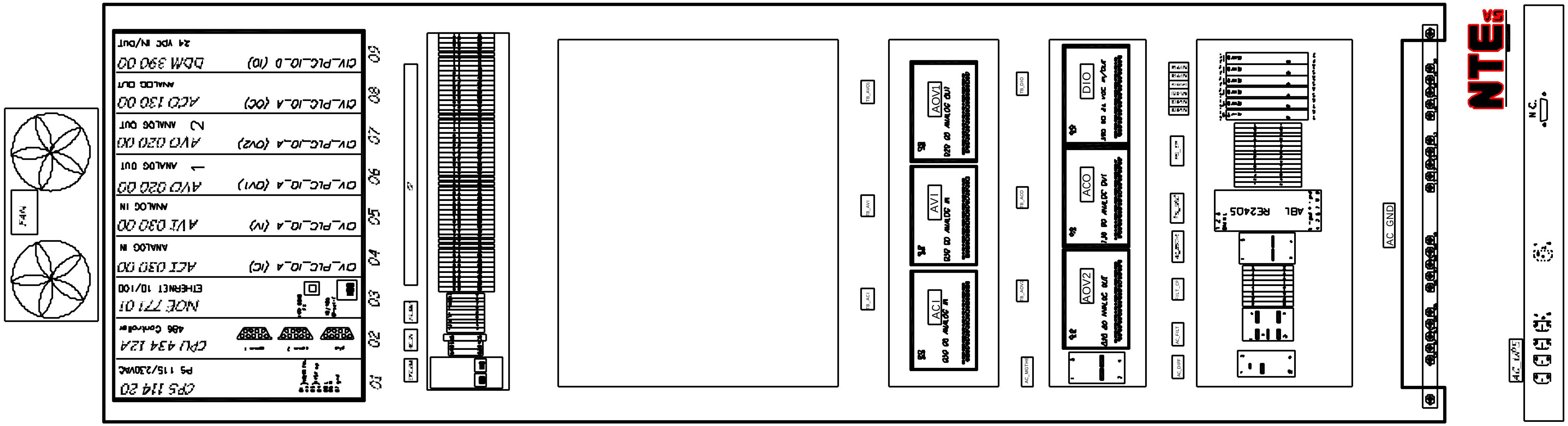
TITULO/TITLE:
Mechanical Design Rack 3

DIBUJO N.°/DRAWING N.°
MEL-3320-DR-035-NTE

ED/ISS
1 0



	FECHA DATE	NOMBRE NAME	PROYECTO/PROJECT MELISSA	FUENTE/SOURCE: NTE
DIB./DRAW	15/04/04	A.Hernández	TITULO/TITLE: Electrical Connections Rack 3	
REV./CHECK	15/04/04	J Duatis		
ING./ENG	15/04/04	J Mas		N°HOJA/SHEET N°: 1 / 1
Q A	15/04/04	S Ferrer	N° pr MEL-3320-DR-037-NTE	



ISS.	CHANGES	Date	Draw.	Eng.	Q A.

	FECHA DATE	NOMBRE NAME
DIB./DRAW	15/04/04	A.López
REV./CHECK	15/04/04	J Duatis
INC./ENG.	15/04/04	J.Mas
Q.A	15/04/04	S Ferrer

RUGOSIDAD/ROUGHNESS

TOLERANCIAS/TOLERANCES

.X ±0.20
.XX ±0.10
.XXX ±0.03

MATERIAL/MATERIAL

– –

ESPEC/SPEC

– –

ACABADO/FINISH

– –

– –

PROYECTO/PROJECT

MELISSA

NTE SA

CAN MALÉ. LLIÇA D'AMUNT
08186-BARCELONA.SPAIN

MASA/MASS N.A.

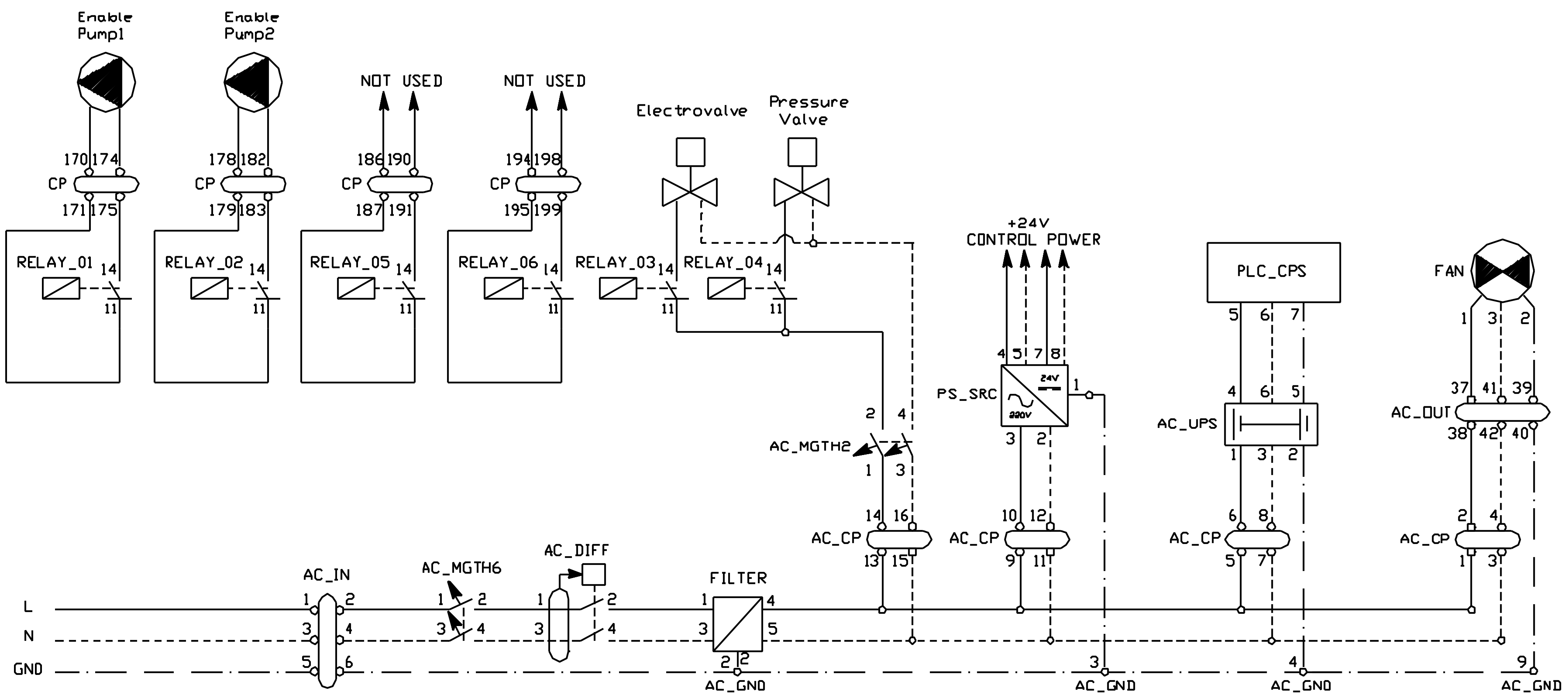
SHEET 1 OF 1

ESCALA/SCALE N.A. DIM mm

TITULO/TITLE:
Mechanical Design Rack 4

DIBUJO N.º/DRAWING N.º
MEL-3320-DR-036-NTE

ED/ISS
1.0



	FECHA DATE	NOMBRE NAME
DIB./DRAW	15/04/04	
REV./CHECK	15/04/04	
ING./ENG.	15/04/04	
Q.A.	15/04/04	S Ferrer

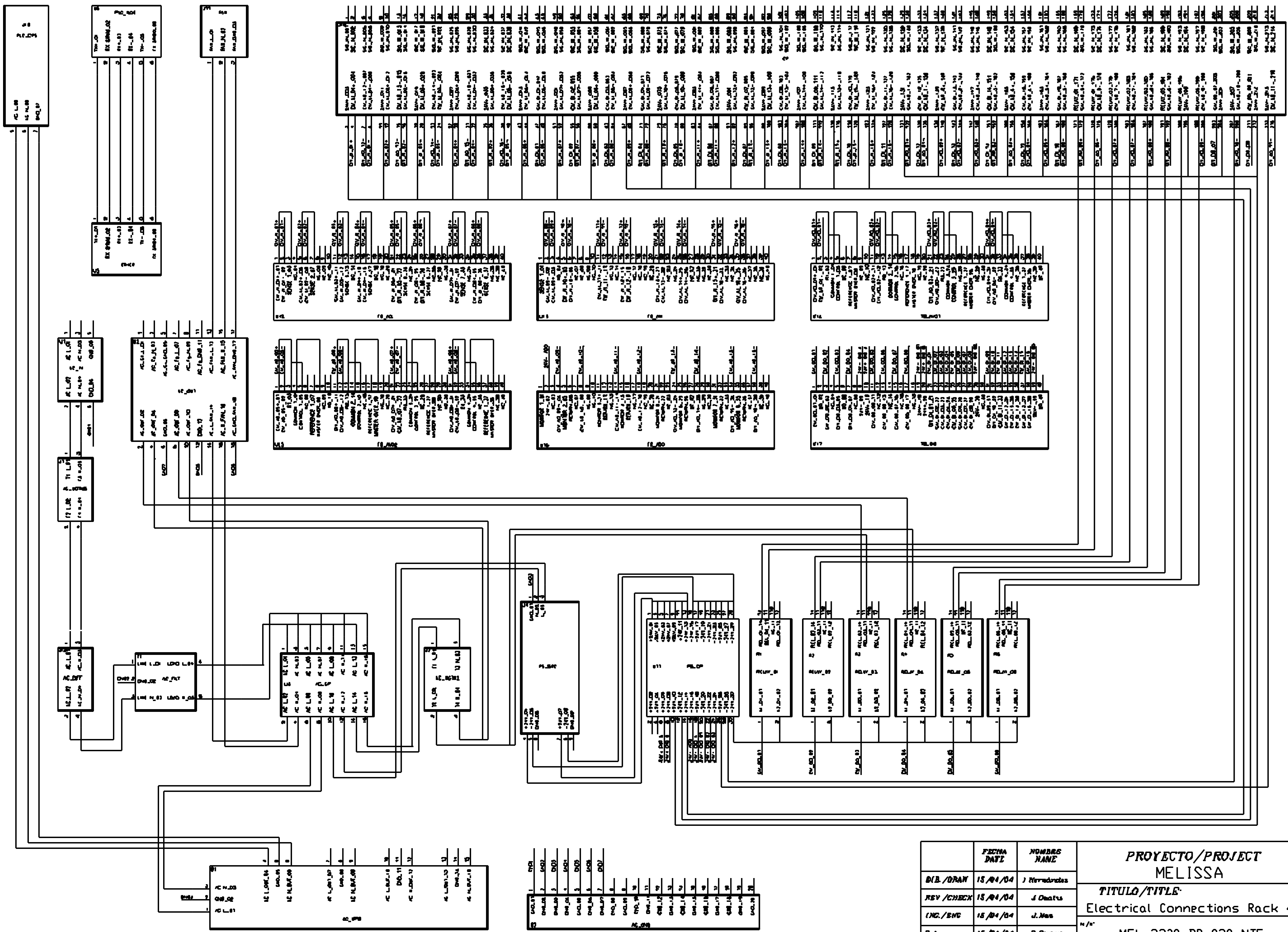
PROYECTO/PROJECT
MELISSA

FUENTE/SOURCE: NTE

TITULO/TITLE.
Electrical Schematic Rack 4

MEL-3320-DR-027-NTE

NºHOJA/SHEET Nº: 1 1



	FECHA DATE	NOMBRE NAME
DIB./DRAW	15/04/04	J Hernández
REV/CHECK	15/04/04	J Duatis
ING./ENG	15/04/04	J. Mas
Q.A	15/04/04	S.Ferrer

PROYECTO/PROJECT
MELISSA

FUENTE/SOURCE: NTE

TITULO/TITLE:
Electrical Connections Rack 4

N/º: MEL-3320-DR-038-NTE

NºHOJA/SHEET Nº: 1 1

MELISSA

Contract Number: ESTEC/CONTRACT: 15671/01/NL/ND

Technical Note: 72.4
VOLUME III

Control System Demonstrator
System Test Report

Version: 1

Issue: 1

NTE SA

NTE Document Number:	MEL-3330-RP-030-NTE
Written by:	Jordi Duatis
Revised by:	Joan Mas
Quality Assurance:	Sònia Ferrer
Approved by:	Joan Mas

Document Change Log

Version	Issue	Date	Observations
Draft	0	06 Oct ‘03	Created
	1	05 Mar ‘04	Reviewed. Included CVI HMI test results.
1	0	20 Apr’04	First Release
1	1	28 Jul’04	ESA comments dated 21/07/04 implemented

TABLE OF CONTENTS

1 SCOPE

This document contains the System Test Report resulting from the execution of the System Test procedures defined in the [R1] over the Control System Demonstrator implemented for the MELISSA loop compartments III and IVa.

Tests were carried out at NTE's premises in the time frame September – November 2003.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**.TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.

[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.

2.2 Reference Documents

[R1] **MEL-3310-PL-024-NTE, Control System Demonstrator System Test Plan and Procedure**. TN 72.4 Volume Ia, v.1.1, July 2004

[R2] **MEL-3300-MN-028-NTE, Control System Test Readiness Review Meeting** Minutes of Meeting, 17/09/03

[R3] **MEL-3300-MN-031-NTE, Control System (CIII) Test Readiness Review Meeting** Minutes of Meeting, 13/11/03

3 TEST SUMMARY

The test procedures executed correspond to the verification of the compartments CIII and CIV before being transferred to the UAB for its connection to the plant.

Following the conduction of all the required test procedures / test cases it was concluded that the Control System Demonstrator implemented by NTE met all the design features in terms of control functionality and that the hardware was fit for its connection to the MELISSA plant at UAB's premises.

These results and conclusions were confirmed in the corresponding Test Review sessions documented in [R2] and [R3].

4 COMPARTMENT VIa SYSTEM TEST REPORT

4.1 MEL-CIV-TP-01: Point to point connectivity test procedure

MEL-CIV-TP-01: Point to point connectivity test procedure					
Tester	JD	Date:	29-30 Jul 2003	Result:	OK
Comments:					

4.2 MEL-CIV-TP-02: Electrical isolation

MEL-CIV-TP-02: Electrical isolation					
Tester	XLL / JD	Date:	18 Sept 2003	Result:	OK
Comments:					

4.3 MEL-CIV-TP-03: Check Interfaces end-to-end

TC Identifier	**MEL-TC-CIV-0301**	**Purpose:**	Verify that analogue inputs are connected, acquired, supervised and ranged as specified
Functions Tested	Interface between CIV_CP – CIV_PLC – Supervision		
Description	Known values applied to analogue inputs shall be displayed in the Supervision ranged as specified.		
Special Requisites:	Values to apply / check must be between the indicated range		
Tester:	**JCM**	**Date:**	**28 August 2003**

Course of Actions

Step no	Description	Expected value	OK/NOK
1	Apply 4 – 5 mA current to AI 01 (CIV_MV_CxAbs) and check the displayed value (Biomass Concentration in DW units) in the Supervision screen MEL_CIV_Main and MEL_CIV_BP.	0 – 0.2	OK
2	Apply 19 – 20 mA current to AI 01 (CIV_MV_CxAbs) and check the displayed value (Biomass Concentration in DW units) in the Supervision screen MEL_CIV_Main and MEL_CIV_BP.	1.8 – 2	OK
3	Apply 4 – 5 mA current to AI 02 (CIV_MV_M1) and check the displayed value (Tank1 Level) in the Supervision screen MEL_CIV_BP.	0 – 15	OK
4	Apply 19 – 20 mA current to AI 02 (CIV_MV_M1) and check the displayed value (Tank1 Level) in the Supervision screen MEL_CIV_BP.	135 – 150	OK
5	Apply 4 – 5 mA current to AI 03 (CIV_MV_M2) and check the displayed value (Tank2 Level) in the Supervision screen MEL_CIV_BP.	0 – 15	OK
6	Apply 19 - 20 mA current to AI 03 (CIV_MV_M2) and check the displayed value (Tank2 Level) in the Supervision screen MEL_CIV_BP.	135 – 150	OK
7	Apply 4 – 5 mA current to AI 04 (CIV_MV_P) and check the displayed value (Pressure) in the Supervision screens MEL_CIV_Main and MEL_CIV_Gas.	0 – 0.15	OK
8	Apply 19 - 20 mA current to AI 04 (CIV_MV_P) and check the displayed value (Pressure) in the Supervision screens MEL_CIV_Main and MEL_CIV_Gas.	1.45 – 1.5	OK
9	Apply 4 – 5 mA current to AI 05 (CIV_MV_pH) and check the displayed value (pH) in the Supervision screens MEL_CIV_Main and MEL_CIV_pH.	0 – 1.4	OK
10	Apply 19 - 20 mA current to AI 05 (CIV_MV_pH) and check the displayed value (pH) in the Supervision screens MEL_CIV_Main and MEL_CIV_pH.	12.6 – 14	OK
11	Apply 4 – 5 mA current to AI 06 (CIV_MV_T) and check the displayed value (Temperature) in the Supervision screen MEL_CIV_Main.	0 – 15	OK

12	Apply a 19 - 20 mA current to AI 06 (CIV_MV_T) and check the displayed value (Temperature) in the Supervision screen MEL_CIV_Main.	145 – 150	OK
13	Apply 4 – 5 mA current to AI 07 (CIV_MGO_O2) and check the displayed value (O2 output) in the Supervision screen MEL_CIV_Main, MEL_CIV_Gas.	0 – 2.5	OK
14	Apply 19 – 20 mA current to AI 07 (CIV_MGO_O2) and check the displayed value (O2 output) in the Supervision screens MEL_CIV_Main, MEL_CIV_Gas.	22.5 – 25	OK
15	Apply 4 – 5 mA current to AI 08 (CIV_MGO_CO2) and check the displayed value (CO2 output) in the Supervision screens MEL_CIV_Main, MEL_CIV_Gas.	0 – 50	OK
16	Apply 19 – 20 mA current to AI 08 (CIV_MGO_CO2) and check the displayed value (CO2 output) in the Supervision screens MEL_CIV_Main, MEL_CIV_Gas.	450 – 500	OK
17	Apply 4 – 5 mA current to AI 09 (CIV_MV_DO) and check the displayed value (DO) in the Supervision screen MEL_CIV_Gas.	0 – 10	OK
18	Apply 19 - 20 mA current to AI 09 (CIV_MV_DO) and check the displayed value (DO) in the Supervision screen MEL_CIV_Gas.	90 – 100	OK
19	Apply 0 – 0.2 V to AI 13 (CIV_MV_FrGas) and check the displayed value (FR-CI) in the Supervision screen MEL_CIV_Gas.	0 – 3	OK
20	Apply a 4.8 – 5 V to AI 13 (CIV_MV_FrGas) and check the displayed value (FR-CI) in the Supervision screen MEL_CIV_Gas.	27 – 30	OK
21	Apply 0 – 0.2 V to AI 14 (CIV_MGO_FrGas) and check the displayed value (FR-GO) in the Supervision screen MEL_CIV_Gas.	0 – 3	OK
22	Apply 4.8 – 5 V to AI 14 (CIV_MGO_FrGas) and check the displayed value (FR-GO) in the Supervision screen MEL_CIV_Gas.	27 – 30	OK
23	Apply 0 – 0.2 V to AI 15 (CIV_MV_FrCO2) and check the displayed value (FR-CO2) in the Supervision screen MEL_CIV_Gas.	0 – 0.5	OK
24	Apply 4.8 – 5 V to AI 15 (CIV_MV_FrCO2) and check the displayed value (FR-CO2) in the Supervision screen MEL_CIV_Gas.	4.5 – 5	OK
25	Apply 0 – 0.2 V to AI 16 (CIV_MGI_FrGas) and check the displayed value (FR-GI) in the Supervision screen MEL_CIV_Gas.	0 – 3	OK
26	Apply 4.8 – 5 V to AI 16 (CIV_MGI_FrGas) and check the displayed value (FR-GI) in the Supervision screen MEL_CIV_Gas.	27 – 30	OK

4.3.1 MEL-TC-CIV-0302: Check analogue outputs

TC Identifier	**MEL-TC-CIV-0302**	**Purpose:**	Verify that analogue inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIV_CP – CIV_PLC – Supervision		
Description	Known values applied to Supervision variables shall be translated to the analogue outputs within the ranges specified. Only outputs with direct set-points are checked, the rest will be checked by other TC.		
Special Requisites:			
Tester:	**Josep Carles Mariño**	**Date:**	**28 August 2003**

Course of Actions

Step no	Description	Expected value	OK/NOK
1	In the supervision screen MEL_CIV_pH set the value 0 to “Fixed CO2 Flow Rate” and measure AO 01 output volts.	0 V ±0.01	OK
2	In the supervision screen MEL_CIV_pH set the value 5 to “Fixed CO2 Flow Rate” and measure AO 01 output volts.	5 V ±0.01	OK
3	In the supervision screen MEL_CIV_Gas set the value 0 to “Gas Input Flow Rate” and measure AO 02 output volts.	0 V ±0.01	OK
4	In the supervision screen MEL_CIV_Gas set the value 30 to “Gas Input Flow Rate” and measure AO 02 output volts.	5 V ±0.01	OK
5	In the supervision screen MEL_CIV_Gas set the value 0 to “Gas Output Flow Rate” and measure AO 03 output volts.	0 V ±0.01	OK
6	In the supervision screen MEL_CIV_Gas set the value 30 to “Gas Output Flow Rate” and measure AO 03 output volts.	5 V ±0.01	OK
7	In the supervision screen MEL_CIV_Gas set the value 0 to “Air Flow Rate” and measure AO 04 output volts.	0 V ±0.01	OK
8	In the supervision screen MEL_CIV_Gas set the value 30 to “Air Flow Rate” and measure AO 04 output volts.	5 V ±0.01	OK
9	Apply a resistance 1Kohm between AO 10+ and AO 10-		
10	With the iFix Database Manager set the value 0 to CIV_SSP_LIGHT and measure AO 10 output volts	4 V ±0.1	OK
11	With the iFix Database Manager set the value 1 to CIV_SSP_ LIGHT and measure AO 10 output volts	20 V ±0.1	OK

4.3.2 MEL-TC-CIV-0303: Check digital inputs

TC Identifier	**MEL-TC-CIV-0303**	**Purpose:**	Verify that digital inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIV_CP – CIV_PLC – Supervision		
Description	Status set to digital inputs shall be translated to the supervision as specified.		
Special Requisites:			
Tester:	**Josep Carles Mariño**	**Date:**	**28 August 2003**

Course of Actions

Step no	Description	Expected value	OK/NOK
1	Set DI 01 in open circuit and check in supervision screen MEL_CIV_Gas, indicator “Calibrating”	Disabled	OK
2	Set DI 01 in closed circuit and check in supervision screen MEL_CIV_Gas, indicator “Calibrating”	Enabled	OK
3	Set DI 02 in open circuit and check in supervision screen MEL_CIV_Gas, indicator “Error”	Disabled	OK
4	Set DI 02 in closed circuit and check in supervision screen MEL_CIV_Gas, indicator “Error”	Enabled	OK
5	Set DI 03 in open circuit and check in supervision screen MEL_CIV_Gas, indicator “Scale1”	Disabled	OK
6	Set DI 03 in closed circuit and check in supervision screen MEL_CIV_Gas, indicator “Scale1”	Enabled	OK
7	Set DI 04 in open circuit and check in supervision screen MEL_CIV_Gas, indicator “Scale2”	Disabled	OK
8	Set DI 04 in closed circuit and check in supervision screen MEL_CIV_Gas, indicator “Scale2”	Enabled	OK

4.4 MEL-CIV-TP-04: Biomass production regulation

4.4.1 EL-TC-CIV-0401: Verify biomass sensor cleaning

TC Identifier	**MEL-TC-CIV-0401**	**Purpose:**	Verify that output to activate valve to clean the biomass sensor is activated as specified and Biomass value is maintained.
Items Tested	CIV_PLCSW_Biomass, MEL_CIV_BP, MEL_CIV_MAIN		
Description	Every 5 minutes the digital output 03 shall be activated during 5 seconds. During this time, and 5 seconds after, the biomass sensor acquired value must be maintained.		
Special Requisites:	An APS is used to simulate the Biomass sensor. Check supervision values in MEL_CIV_BP and MEL_CIV_Main displays		
Tester:	**JD**	**Date:**	**01/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 01/10/2003	Comments
1	Set 2.9 - 3.1 V to AI 01 (CIV_MV_CxAbs) and check in MEL_CIV_BP Supervision display the value of Biomass concentration	1 gr/l ±0.1	OK	
2	Check by inspection AIR valve is opened every 5 minutes during 5 seconds.		OK	Constant value in PLC program LOC_TIME_OPEN_VALVE was empty, probably due to a bad modification when inserting initial values. Value restored.
3	During the time the valve is open modify AI 01 input and check value of Biomass concentration is not changed in the supervision.		OK	
4	Immediately after AIR valve is closed modify AI 01 and check by inspection value is not changed during 5 seconds after the valve is closed.		OK	
5	Check that if value is modified 5 seconds after AIR valve is closed, Biomass Concentration value is changed as well.		OK	

4.4.2 MEL-TC-CIV-0402: Liquid flow regulation

TP Identifier	**TP-TC-CIV-0402**	**Purpose:**	Verify that flow set points are transmitted to input output pumps according to specifications.
Items Tested	CIV_PLCSW_Liquid, CIV_BP_CL, CIV_PLCSW_Light, MEL_CIV_BP, MEL_CIV_MAIN		
Description	Flow rate set point and light set point are provided from the Supervision, by the software module CIV_BP_CL. The PLC shall regulate the active input pump, flow rate of output pump and activate alarm in case input media tanks are empty, and transfer the light setting point to the light regulator device.		
Special Requisites:	Two APS (APS1, APS2) are needed to simulate scale sensors of liquid input tanks. Use MEL_CIV_MAIN and MEL_CIV_BP supervision displays Use a multimeter to measure analogue values		
Tester:	**Jordi Duatis**	**Date:**	**2/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
1	Apply with APS1 17 – 19 mA to AI 02 (CIV_MLI_M1) check in the supervision display MEL_CIV_BP the Tank 1 level.	130 litres ±15	OK	
2	Apply with APS2 14 – 15 mA to AI 01 (CIV_MV_CxAbs) check in the supervision display MEL_CIV_BP the Biomass concentration	1.5 g/l ±0.2	OK	
3	Apply a 1Kohm resistor to AO 10 (CIV_SP_Ls)			
	In the MEL_CIV_MAIN display check Biomass concentration	1.5 g/l ±0.2	OK	
5	In the MEL_CIV_BP display set Liquid input pump 1 calibration parameters to A=18.315, B=11.0989			
6	In the MEL_CIV_BP display set Liquid input pump 2 calibration parameters to A=16.103, B=0.8534			
7	In the MEL_CIV_BP display set Liquid output pump calibration parameters to A=20, B=10			
8	In the MEL_CIV_BP display set minimum volume to switch input tank to 10 litres			
9	In the MEL_CIV_BP display set: - Biomass production set-point to 1.2 gr/l - Liquid input flow rate set-point to 0.7 l/h Using the iFix Database Manager set CIV_SSP_LISHTWM to 68.5844 and CIV_SSP_L1FR = 0.7			Normalised variable names. LiFR need to be fixed then now is calculated from pump actuation using the calibration parameters.
10	Adjust APS2 to obtain a Biomass Concentration of 1.36±0.01 gr/l (check in MEL_CIV_BP)			
11	From the Supervision iFix Scheduler configure as Foreground task and fire scheduled event CIV_CTRLLAW_BP			

TP Identifier	TP-TC-CIV-0402	Purpose:	Verify that flow set points are transmitted to input output pumps according to specifications.
Items Tested	CIV_PLCSW_Liquid, CIV_BP_CL, CIV_PLCSW_Light, MEL_CIV_BP, MEL_CIV_MAIN		
Description	Flow rate set point and light set point are provided from the Supervision, by the software module CIV_BP_CL. The PLC shall regulate the active input pump, flow rate of output pump and activate alarm in case input media tanks are empty, and transfer the light setting point to the light regulator device.		
Special Requisites:	Two APS (APS1, APS2) are needed to simulate scale sensors of liquid input tanks. Use MEL_CIV_MAIN and MEL_CIV_BP supervision displays Use a multimeter to measure analogue values		
Tester:	**Jordi Duatis**	**Date:**	**2/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
12	Check in the MEL_CIV_BP display the Level 1 liquid input flow rate set point.	0.77 l/h ±0.01	OK	Clarify variable identification.
13	Check in the MEL_CIV_BP display the % actuation of input pump 1	25.20% ±0.01	OK	
14	Measure voltage output in CIV_SP_Li1 (AO 05)	1.26 V ±0.1	OK	
15	Check in the MEL_CIV_BP display the output flow rate (must be +10% of the liquid input flow rate)	0.84 l/h ±0.01	OK	Clarification
16	Check in the MEL_CIV_BP display the % actuation of output pump	26.8% ±0.2	OK	
17	Measure voltage output in CIV_SP_LO (AO 07)	1.34 V ±0.1	OK	
18	Check in the MEL_CIV_BP display the liquid input pump1 status	Enabled (green)	OK	
19	Check in the MEL_CIV_BP display the liquid input pump2status	Disabled (red)	OK	
20	Check in the MEL_CIV_BP display the output light set-point	217.61 w/m2 ±1	OK	
21	In the MEL_CIV_MAIN display check light set-point (Light intensity)	217.61 w/m2 ±1	OK	Easy identification
22	In the MEL_CIV_BP display check light regulator actuation set point %	83.52% ±2	OK	Precision tolerance too low. Fixed editorial error.

TP Identifier	TP-TC-CIV-0402	Purpose:	Verify that flow set points are transmitted to input output pumps according to specifications.
Items Tested	CIV_PLCSW_Liquid, CIV_BP_CL, CIV_PLCSW_Light, MEL_CIV_BP, MEL_CIV_MAIN		
Description	Flow rate set point and light set point are provided from the Supervision, by the software module CIV_BP_CL. The PLC shall regulate the active input pump, flow rate of output pump and activate alarm in case input media tanks are empty, and transfer the light setting point to the light regulator device.		
Special Requisites:	Two APS (APS1, APS2) are needed to simulate scale sensors of liquid input tanks. Use MEL_CIV_MAIN and MEL_CIV_BP supervision displays Use a multimeter to measure analogue values		
Tester:	Jordi Duatis	Date:	2/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
23	Measure voltage output in CIV_SP_Ls (AO 10)	17.36 V ±0.2	OK	Precision tolerance too low
24	From the Supervision iFix Scheduler display fire scheduled event CIV_CTRLLAW_BP again			
25	Check in the MEL_CIV_BP display the output light set-point	223.00 w/m2 ±0.01	OK	
26	Disconnect APS2 from AI 01 and set output to 17-18 mA			
27	Apply with APS2 17-18 mA to AI 03 (CIV_MLI_M2)			
28	Check in the MEL_CIV_BP display the tank 2 level	130 litres ±15	OK	
29	Set APS1 output to 4 – 5 mA.			
30	Check in the MEL_CIV_BP display the tank 1 level	5 litres ±5	OK	
31	Check in the MEL_CIV_BP display the input pump 1	Disabled	OK	
32	Check in the MEL_CIV_BP display the input pump 2	Enabled	OK	
33	Set APS2 output to 4 - 5 mA			
34	Check in the MEL_CIV_BP display the tank 2 level	5 litres ±5	OK	
35	Check in the MEL_CIV_BP display the input pump 1	Disabled	OK	
36	Check in the MEL_CIV_BP display the input pump 2	Disabled	OK	
37	Check in the MEL_CIV_BP display the output pump actuation	0%	OK	
38	Measure voltage output in CIV_SP_LO (AO 07)	0 V ±0.01	OK	

4.4.3 MEL-TC-CIV-0403: Light index

TP Identifier	**TP-TC-CIV-0402**	**Purpose:**	Verify that when the light index set point changes, a ramp is applied to set point output to smooth the variation.		
Functions Tested	CIV_PLCSW_Light, MEL_CIV_BP				
Description	Light set point changes are applied using a ramp that changes from 0 to 1 in 15 seconds.				
Special Requisites:	Use an oscilloscope (OSC) to measure ramp. Use MEL_CIV_TEST_01 to apply a value to the light set point.				
Tester:	**Jordi Duatis / Joan Ariño**	**Date:**	**29/08/2003, 18/09/2003, 02/10/2003**		

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
1	Apply a 1 Kohm resistor to AO 10			
2	Connect the OSC channel 1 to monitor TB_ACO pin 2 (-) and pin 5 (+) to monitor AO 10 (AO 4 mA => 0.4 V / AO 20 mA => 2V) . Time div 5 seconds. V div 0.5 V			
3	Set in the CIV_SSP_Light variable in the iFix Data Manager display the value 0. Wait until output voltage in AO 10 goes down to. 0.4V.	0.4 V ±0.01	OK	
4	Set in the CIV_SSP_Light variable in the MEL_CIV_TEST_01 display the value 1. Wait until output voltage in AO 10 goes up to 2V.	2 V ±0.1	OK	
5	Check in the OSC the output voltage changed from 0,4V to 2 V in 15±0.2 seconds.		OK	

4.4.4 MEL-TC-CIV-0404: Over temperature alarm

TP Identifier	**TP-TC-CIV-0404**	**Purpose:**	Verify that when the over temperature alarm is on light supply is set to a safety value
Functions Tested	CIV_PLCSW_Light, CIV_PLCSW_T, MEL_CIV_Temp		
Description	When an over temperature is detected, light supply is set to a low value to avoid over heating		
Special Requisites:	Use an APS to apply voltages		
Tester:	**Jordi Duatis**	**Date:**	**02/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
1	In the MEL_CIV_Temp supervision screen set Temperature set point to 27 ºC			
2	Apply with the APS 1.9 – 2.1 V to AI 06	37.5 ±4 ºC	OK	
3	Check the over temperature alarm is displayed in the Alarm area of the Supervision screen		OK	
4	Check in MEL_CIV_BP light supply actuation	10%	OK	

4.5 MEL-CIV-TP-05: Gas Flow Regulation

4.5.1 MEL-TC-CIV-0501: Control action enabled

TC Identifier	**MEL-TC-CIV-0501**	**Purpose:**	Verify that set points are modified by the PLC in case of over/under pressure
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_GAS		
Description	In case of overpressure output flow increments a 10%, in case of under pressure input flow increments a 10%. Over pressure is when pressure is 0.01 over the nominal value, and under pressure is when pressure is 0.01 under the nominal value.		
Special Requisites:	An APS is used to simulate the pressure sensor. Use the multimeter to measure currents and voltages. Check supervision values in MEL_CIV_Gas		
Tester:	**JD**	**Date:**	**02/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
1	In the MEL_CIV_Gas set the max allowed pressure value to 1.1 bar			
2	In the MEL_CIV_Gas set the nominal pressure 1.0 bar			
3	In the MEL_CIV_Gas set the AIR input flow rate to 10 nLm			
4	Apply with the APS 3.66 – 3.68 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	1±0.005 bar	OK	Fixed ranges in doc. Recalculated ranges
5	Measure CIV_SP_Fgex (AO 04) voltage	1.66 ±0.01V	OK	
6	In the MEL_CIV_Gas set the gas input flow rate to 20 nLm			
7	Measure CIV_SP_Fgi (AO 02) voltage	3.33 ±0.01V	OK	
8	In the MEL_CIV_Gas set the gas output flow rate to 12 nLm			
9	Measure CIV_SP_Fgo (AO 03) voltage	2±0.01V	OK	
10	Check in MEL_CIV_Gas display the over pressure & under pressure indicators	Disabled	OK	
11	Modify APS value to 3.69-3.72 V and check pressure value in MEL_CIV_Gas.	1.015 ±0.005 bar	OK	
12	Check in MEL_CIV_Gas display the over pressure indicator	Enabled	OK	
13	Measure CIV_SP_Fgo (AO 03) voltage (shall be 10% over set point measured in 9)	2.2 ±0.02V	OK	
14	Apply with the APS 3.59 – 3.62 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	0.98±0.005 bar	OK	Fixed ranges in doc. Recalculated ranges, recalculated expec. value
15	Check in MEL_CIV_Gas display the under pressure indicator	Enabled	OK	

TC Identifier	**MEL-TC-CIV-0501**	**Purpose:**	Verify that set points are modified by the PLC in case of over/under pressure		
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_GAS				
Description	In case of overpressure output flow increments a 10%, in case of under pressure input flow increments a 10%. Over pressure is when pressure is 0.01 over the nominal value, and under pressure is when pressure is 0.01 under the nominal value.				
Special Requisites:	An APS is used to simulate the pressure sensor. Use the multimeter to measure currents and voltages. Check supervision values in MEL_CIV_Gas				
16	Measure CIV_SP_Fgex (AO 04) voltage (shall be 10% over set point measured in 5)	1.82 ±0.02V	OK		
17	Measure CIV_SP_Fgi (AO 02) voltage (shall be 10% over set point measured in 7)	3.66 ±0.02V	OK		
18	Modify APS value to 3.67 – 3.69 V and check pressure value in MEL_CIV_Gas.	1.005 ±0.005 bar	OK	Fixed ranges in doc	
19	Check in MEL_CIV_Gas display the under pressure indicator	Disabled	OK		
20	Check in MEL_CIV_Gas display the over pressure indicator	Disabled	OK		
21	Measure CIV_SP_Fgex (AO 04) voltage (initial value)	1.66 ±0.02V	OK		
22	Measure CIV_SP_Fgi (AO 02) voltage (initial value)	3.33 ±0.02V	OK		
23	Measure CIV_SP_Fgo (AO 03) voltage (initial value)	2.00 ±0.02V	OK		

4.5.2 MEL-TC-CIV-0502: Pressure safety valve activation

TC Identifier	**MEL-TC-CIV-0502**	**Purpose:**	Verify that pressure safety valve is activated in case of an high overpressure
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_GAS		
Description	In case pressure is over the max allowed pressure, the pressure safety valve shall be opened until pressure is nominal		
Special Requisites:	An APS is used to simulate the pressure sensor. Use the multimeter to measure currents and voltages. Check supervision values in MEL_CIV_Gas		
Tester:	**Jordi Duatis**	**Date:**	**02/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
1	In the MEL_CIV_Gas set the max allowed pressure value to 1.1 bar			
2	In the MEL_CIV_Gas set the nominal pressure 1.0 bar			
3	In the MEL_CIV_Gas set the external input flow rate to 10 nLm			
4	Apply with the APS 3.66 – 3.68 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	1±0.005 bar	OK	Fixed ranges in doc
5	In the MEL_CIV_Gas check safety valve status	Closed	OK	
6	Modify APS value to 4.2 – 4.5 V and check pressure value in MEL_CIV_Gas.	1.25 ±0.05 bar	OK	Fixed ranges in doc
7	In the MEL_CIV_Gas check safety valve status	Open (green)	OK	
8	Measure output Voltage AC CIV_RL_Fg (CIV_AC_OUT 08, 10)	220 VEF ±10%	OK	
9	Modify APS value to 3.70 -3.72 V and check pressure value in MEL_CIV_Gas.	1.015 ±0.005 bar	OK	
10	In the MEL_CIV_Gas check safety valve status	Open	OK	
11	Apply with the APS 3.64 – 3.66 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	0.995 ±0.005 bar	OK	Fixed ranges in doc. Modified CIV_PLCSW_Gas to close safety valve when P reaches set-point (no dead band)
12	In the MEL_CIV_Gas check safety valve status	Closed	OK	

4.5.3 MEL-TC-CIV-0503: Check over pressure alarm

TC Identifier	MEL-TC-CIV-0503	Purpose:	Verify that over pressure alarm is activated
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_GAS		
Description	When an overpressure occurs during more than 5 seconds, the over pressure alarm shall be activated.		
Special Requisites:	An APS is used to simulate the pressure sensor. Check supervision values in MEL_CIV_Gas		
Tester:	Jordi Duatis	Date:	29/08/2003, 18/09/2003, 02/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
1	In the MEL_CIV_Gas set the max allowed pressure value to 1.1 bar			
2	In the MEL_CIV_Gas set the nominal pressure 1.0 bar			
3	In the MEL_CIV_Gas set the AIR input flow rate to 10 nLm			
4	Apply with the APS 4.2 - 4.5 V to CIV_MV_P (AI 04) and check pressure value in MEL_CIV_Gas.	1.25 ±0.05 bar	OK	Fixed ranges in doc
5	After 5 seconds check the MEL_CIV_Gas alarms. Verify that over pressure alarm has been indicated.		OK	

4.6 MEL-CIV-TP-06: pH Regulation

4.6.1 MEL-TC-CIV-0601: Regulate pH with CO2 only

TC Identifier	**MEL-TC-CIV-0601**	**Purpose:**	Verify that CO2 flow meter regulates CO2 input to maintain pH set point
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	With the control action mode CO2 Only, the pH is regulated adding CO2. Control action is performed by means of a PID		
Special Requisites:	Use the multimeter to measure currents and voltages. Use the FAG to simulate variations in the pH. Use the OSC to display CIV_SP_CO2 (CO2 regulation PID output in AO 01) Check supervision values in MEL_CIV_pH Concept SW is used to modify enable/disable PID parameters		
Tester:	**Jordi Duatis, Joan Ariño**	**Date:**	**1/09/2003, 18/09/2003, 06/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 06/10/2003	Comments
1	In the MEL_CIV_pH set the control action mode 1 (CO2 Only)			When pH input is in link error PID output goes to saturation, modified program to set PID output = 0 when sensor link error.
2	In the MEL_CIV_pH set the pH set point to 6.5			
3	In the MEL_CIV_pH set the CO2 flow meter PID parameters to P=5, I=100, D=0.01			
4	With the Concept tool connect to the PLC and open CIV_PLCSW_pH section.			Changed due to review of declared constant values.
5	In Concept set “FALSE” to ENNUI, END(only Proportional part of the PID is enabled)			Changed due to review of declared constant values.
6	With the FAG apply a squared wave with duty cycle = 50%, Amp=0.1±0.05 V, Offset = 2.7±0.05 (2.7-2.9) and f=0.1 Hz to CIV_MV_pH (AI 05)			
7	Check in the MEL_CIV_pH display pH value is between the range	5.95±0.1 to 6.65±0.1	OK	
8	Measure CIV_SP_FrCO2 (AO 01) output MAX	0.75±0.3 V	OK	
9	In Concept set “FALSE” to EN_P, EN_D and “TRUE” to EN_I (only Integrative part of the PID is enabled)			Changed due to review of declared constant values.
	In the FG increment Amp = 0.5 to increase integrative action			

TC Identifier	MEL-TC-CIV-0601	Purpose:	Verify that CO2 flow meter regulates CO2 input to maintain pH set point	
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH			
Description	With the control action mode CO2 Only, the pH is regulated adding CO2. Control action is performed by means of a PID			
Special Requisites:	Use the multimeter to measure currents and voltages. Use the FAG to simulate variations in the pH. Use the OSC to display CIV_SP_CO2 (CO2 regulation PID output in AO 01) Check supervision values in MEL_CIV_pH Concept SW is used to modify enable/disable PID parameters			
10	Measure CIV_SP_FrCO2 (AO 01) output MAX	0.35±0.1 V	OK	Precision range too low
11	In the Reference Data Editor set “FALSE” to EN_P, EN_I and TRUE EN_D (only Derivative part of the PID is enabled)			Changed due to review of declared constant values.
12	With the FG modify to a triangle wave with same parameters			
13	Measure CIV_SP_FrCO2 (AO 01) output MAX	0.035 ±0.05 V	OK	Modified CIV_PLCSW_pH when PH input is in error status, PID goes to saturation, PID is now disabled when pH input is in error.

4.6.2 MEL-TC-CIV-0602: CO2 and additional base medium

TC Identifier	**MEL-TC-CIV-0602**	**Purpose:**	Verify that Base pump is activated when pH is under set-point and CO2 flowmeter is activated when pH is over set-point		
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH				
Description	With the control action mode 2 CO2 + Base media, the pH is regulated adding CO2 when pH is over the set point and Base media when pH is under the set-point. A PID controller regulates CO2 flow and a P (proportional) controller controls Base pump.				
Special Requisites:	Use the multimeter to measure currents and voltages. Use the FG to simulate variations in the pH. Use the OSC to display CIV_SP_CO2 (CO2 regulation PID output in AO TBD) Check supervision values in MEL_CIV_pH				
Tester:	**Jordi Duatis, Joan Ariño**	**Date:**	**06/10/2003**		

Course of Actions

Step no	**Description**	**Expected value**	**OK/NOK 06/10/2003**	
1	In the MEL_CIV_pH set the control action mode 2 (CO2 + Base)			
2	In the MEL_CIV_pH set the pH set point to 6.5			Fixed error in document
3	In the MEL_CIV_pH set the CO2 flow meter PID parameters to P=5, I=100, D=0.01			
4	With the FG apply a squared wave with duty cycle = 50%, Amp=0.1±0.05 V, Offset = 2.7±0.05 (2.7-2.9) and f=0.1 Hz to CIV_MV_pH (AI 05)			
5	Check in the MEL_CIV_pH display pH value is between the range	5.95±0.1 to 6.65±0.1	OK	
6	Apply a 1 Kohm resistor to AO 09			Added
7	Measure CIV_SP_Bs (AO 09) output MAX	12.8 ±1 V	OK	
8	Check in the MEL_CIV_pH display Base pump actuation	55±5 %	OK	

4.6.3 MEL-TC-CIV-0603: Base and Acid additional media

TC Identifier	**MEL-TC-CIV-0603**	**Purpose:**	Verify that Base pump is activated when pH is under set-point and Acid pump is activated when pH is over set-point
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	With the control action mode 2 CO2 + Base media, the pH is regulated adding CO2 when pH is over the set point and Base media when pH is under the set-point. A PID controller regulates CO2 flow and a P (proportional) controller controls Base pump.		
Special Requisites:	Use the multimeter to measure currents and voltages. Use the FG to simulate variations in the pH. Use the OSC to display CIV_SP_CO2 (CO2 regulation PID output in AO TBD) Check supervision values in MEL_CIV_pH		
Tester:	**Jordi Duatis**	**Date:**	**01/09/2003, 06/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 06/10/2003	Comments
1	In the MEL_CIV_pH set the control action mode 3 (Base + Acid)			
2	In the MEL_CIV_pH set the pH set point to 6.5			
3	In the MEL_CIV_pH set the CO2 flow meter PID parameters to P=5, I=100, D=0.01			
4	With the FG apply a squared wave with duty cycle = 50%, Amp=0.1±0.05 V, Offset = 2.8±0.05 (2.8-3.0) and f=0.1 Hz to CIV_MV_pH (AI 05)			Fixed document
5	Check in the MEL_CIV_pH display pH value is between the range	6.30 ±0.1 to 7.00 ±0.1	OK	
6	Apply a 1 Kohm resistor to AO 11			Added
8	Measure CIV_SP_Ac (AO 11) Output MAX	13±1 V		Fixed document
9	Check in the MEL_CIV_pH display acid pump actuation	50 ±5 %		Fixed document

4.6.4 MEL-TC-CIV-0604: Check pH alarm

TC Identifier	**MEL-TC-CIV-0604**	**Purpose:**	Verify that when pH is out of the nominal value during a period of time an alarm is generated
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	When pH is over or under the set point +/- dead band, during more than 15 minutes continuously, an alarm is generated and Supervision shall display the alarm condition.		
Special Requisites:	Use APS to generate the pH value		
Tester:	**Jordi Duatis**	**Date:**	**01/09/2003, 06/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 06/10/2003	Comments
1	In the MEL_CIV_pH set the pH set point to 6			
2	With the APS set 2.9±0.5 V to CIV_MV_pH (AI 05)			
3	Check in the MEL_CIV_pH display pH value	6.65±0.1	OK	
4	Wait 15 minutes			
5	Check after 15 minutes, the pH alarm has been notified to Supervision.		OK	

4.7 MEL-CIV-TP-07: Initial Values

TC Identifier	MEL-CIV-TP-07	Purpose	Check that correct initial values are used at PLC restart			
Tester:	**Jordi Duatis**	**Date:**	**03/10/2003**			
Variable name	**Type**	**Address**	**Value**	**Description**	**OK**	**Comments**
CIV_CNS_AcKp	REAL	400544	100.0	Acid pump regulator proportional constant.	OK	
CIV_CNS_BsKp	REAL	400546	100.0	Base pump regulator proportional constant.	OK	
CIV_CNS_CO2_Kd	REAL	400552	0.01	CO2 flow regulator derivate constant for PID	OK	
CIV_CNS_CO2_Ki	REAL	400550	100.0	CO2 flow regulator integration constant for PID	OK	
CIV_CNS_CO2_Kp	REAL	400548	5.0	CO2 flow regulator proportional constant for PID	OK	
CIV_CNS_ConvV	REAL	400518	1.0	Density factor to translate Kg. to litres.	OK	
CIV_CNS_DW	REAL	400542	1.0	Constant to calculate biomass dry weight	OK	
CIV_CNS_Li1FrA	REAL	400512	18.315	Parameter A for liquid input pump 1 set point calc	OK	
CIV_CNS_Li1FrB	REAL	400514	11.0989	Parameter B for liquid input pump 1 set point calc	OK	
CIV_CNS_Li2FrA	REAL	400538	16.103	Parameter A for liquid input pump 2 set point calc	OK	
CIV_CNS_Li2FrB	REAL	400540	0.8534	Parameter B for liquid input pump 2 set point calc	OK	
CIV_CNS_LoFrA	REAL	400510	15.0	Parameter A for liquid output pump set point calc	OK	
CIV_CNS_LoFrB	REAL	400516	1.0	Parameter B for liquid output pump set point calc	OK	
CIV_CNS_MaxPress	REAL	400524	0.02	Maximum allowed pressure in the reactor	OK	
CIV_CNS_MinV	REAL	400500	10.0	Minimum volume to switch liquid input tank.	OK	
CIV_CNS_OffsetCO2	REAL	400536	0.0	Offset to provided a constant flux of CO2 to the	OK	
CIV_CNS_OpModeBP	Integer	400566	0	Biomass Production control mode (0=Off, 1=Auto, 2=Manual)	OK	
CIV_CNS_OpModeGas	Integer	400568	0	Gas control mode (0=Off, 1=Auto, 2=Manual)	OK	
CIV_CNS_OpModepH	Integer	400567	0	pH control mode ((0=Off, 1=Auto, 2=Manual)	OK	
CIV_CNS_pHMode	Integer	400565	1	PH regulation mode parameter (1=CO2 only, 2=CO2+Base, 3=Base+Acid)	OK	Fixed address in document
CIV_SSP_L1BP	REAL	400554	0.0	Level 1 Biomass production set-point	OK	
CIV_SSP_Fgex	REAL	400532	0.0	Gas flow external input supervision set point	OK	
CIV_SSP_Fgi	REAL	400526	0.0	Gas flow at input regulation supervision set point	OK	
CIV_SSP_Fgo	REAL	400528	0.0	Gas flow at output regulation supervision set point	OK	
CIV_SSP_L1LiFr	REAL	400508	0.0	Level 1 Liquid input flow rate set-point	OK	
CIV_SSP_Light	REAL	400520	0.0	Light Supervision set point.	OK	
CIV_SSP_NomPress	REAL	400522	0.01	Nominal pressure in the reactor	OK	
CIV_SSP_T	REAL	400562	36.0	Temperature set-point fixed by the supervision	OK	Fixed value in doc.
CIV_SSP_pH	REAL	400534	9.5	pH set-point fixed by the supervision	OK	Fixed value in doc.

4.8 MEL-CIV-TP-08: Check Sensor / Actuator Link Errors

4.8.1 MEL-TC-CIV-0801: Check Link Errors on Analogue Inputs

TC Identifier	**MEL-TC-CIV-0801**	**Purpose:**	Verify that when a current analogue input connection is broken is notified to supervision
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	Errors on sensor links are displayed in the supervision as alarms and safety values are displayed blinking in the supervision screens.		
Special Requisites:	All current inputs shall be disconnected		
Tester:	**Jordi Duatis**	**Date:**	**02/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 02/10/2003	Comments
1	In the MEL_CIV_BP supervision display check Biomass Concentration value	1.0 (Blinking)	OK	
2	In the MEL_CIV_BP supervision display check Tank 1 volume value	0.0 (Blinking)	OK	
3	In the MEL_CIV_BP supervision display check Tank 2 volume value	0.0 (Blinking)	OK	
4	In the MEL_CIV_Gas supervision display set pressure set point to 1.0			
5	In the MEL_CIV_Gas supervision display check Pressure (P) value	1.0 (Blinking)	OK	
6	In the MEL_CIV_Gas supervision display check O2 value	0.0 (Blinking)	OK	
8	In the MEL_CIV_Gas supervision display check CO2 value	0.0 (Blinking)	OK	
9	In the MEL_CIV_Gas supervision display check DO value	0.0 (Blinking)	OK	
10	In the MEL_CIV_Temp supervision display set Temperature set-point to 27 ºC			
11	In the MEL_CIV_Temp supervision display check Temperature value	27.0 (Blinking)	OK	
13	In the MEL_CIV_pH supervision display set pH set-point to 6.5			
14	In the MEL_CIV_pH supervision display check pH value	6.5 (Blinking)	OK	
15	In the MEL_CIV_Main supervision display check Biomass Concentration value	1.0 (Blinking)	OK	
16	In the MEL_CIV_Main supervision display check Pressure value	1.0 (Blinking)	OK	
17	In the MEL_CIV_Main supervision display check O2 value	0.0 (Blinking)	OK	
18	In the MEL_CIV_Main supervision display check CO2 value	0.0 (Blinking)	OK	
19	In the MEL_CIV_Main supervision display check DO value	0.0 (Blinking)	OK	
20	In the MEL_CIV_Main supervision display Temperature value	27.0 (Blinking)	OK	
21	In the MEL_CIV_Main supervision display pH value	6.5 (Blinking)	OK	
22	Check following alarms are fired:		OK	

TC Identifier	**MEL-TC-CIV-0801**	**Purpose:**	Verify that when a current analogue input connection is broken is notified to supervision
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	Errors on sensor links are displayed in the supervision as alarms and safety values are displayed blinking in the supervision screens.		
Special Requisites:	All current inputs shall be disconnected		

	- Alarm to notify O2 sensor link error - Alarm to notify biomass sensor link error - Alarm to notify DO sensor link error - Alarm to notify CO2 sensor link error - Alarm to notify pressure sensor link error - Alarm to notify pH sensor link error - Alarm to notify Temperature sensor link error - Alarm to notify scale1 sensor link error - Alarm to notify scale2 sensor link error			

4.8.2 MEL-TC-CIV-0802: Check Link Errors on Analogue Outputs

TC Identifier	**MEL-TC-CIV-0802**	**Purpose:**	Verify that when a current analogue output connection is broken is notified to supervision
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	Errors on actuator links are displayed in the supervision as alarms		
Special Requisites:	All current outputs shall be disconnected		
Tester:	**Jordi Duatis**	**Date:**	**02/10/2003**

Course of Actions

Step no	**Description**	**Expected value**	**OK/NOK 02/10/2003**	**Comments**
1	Check following alarms are fired: - Alarm to notify acid pump link error - Alarm to notify base pump link error - Alarm to notify light supply link error		OK	
9				

4.9 MEL-CIV-TP-09: Check operational modes

4.9.1 MEL-TC-CIV-0901: Check Biomass Production Loop Operational Modes

TC Identifier	**MEL-TC-CIV-0901**	**Purpose:**	Verify when operational mode is changed in the Biomass Production Loop, outputs are set as specified
Functions Tested	CIV_PLCSW_Biomass, CIV_PLCSW_Light, CIV_PLCSW_Liquid, MEL_CIV_BP		
Description	From the Biomass Production supervision screen it is possible to change the operational mode and set the manual values.		
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_BP supervision screen to change operational modes and manual values.		
Tester:	**Jordi Duatis**	**Date:**	**03/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 03/10/2003	Comments
1	In the MEL_CIV_BP supervision screen set operational mode to OFF			
2	Apply a 1 KOhm resistor to CIV_SP_Ls output (AO 10) Connect a pilot light to CIV_RL_Cx			
3	Check Pilot light	OFF	OK	
4	Check CIV_SP_Li1 voltage output	0±0.1 V	OK	
5	Check CIV_SP_Li2 voltage output	0±0.1 V	OK	
6	Check CIV_SP_LO voltage output	0±0.1 V	OK	
8	Check CIV_RL_Li1 output status	OPEN	OK	Fixed expected output in doc.
9	Check CIV_RL_Li2 output status	OPEN	OK	Fixed expected output in doc.
10	Check CIV_SP_Ls voltage output	4±0.1 V	OK	Fixed value in doc.
11	In the MEL_CIV_BP edit the manual values and set: Activate valve to clean biomass sensor: checked Enable liquid input pump 1: checked Liquid input pump 1 set-point (0-100%): 10 Enable liquid input pump 2: checked Liquid input pump 2 set-point (0-100%): 20			

TC Identifier	MEL-TC-CIV-0901	Purpose:	Verify when operational mode is changed in the Biomass Production Loop, outputs are set as specified
Functions Tested	CIV_PLCSW_Biomass, CIV_PLCSW_Light, CIV_PLCSW_Liquid, MEL_CIV_BP		
Description	From the Biomass Production supervision screen it is possible to change the operational mode and set the manual values.		
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_BP supervision screen to change operational modes and manual values.		

	Liquid output pump set-point (0-100%): 30 Light supply set-point (0-100%): 50			
13	In the MEL_CIV_BP supervision screen set operational mode to MAN			
14	Check Pilot light	ON	OK	
15	Check CIV_SP_Li1 voltage output	0.5±0.1 V	OK	
16	Check CIV_SP_Li2 voltage output	1.0±0.1 V	OK	
17	Check CIV_SP_LO voltage output	1.5±0.1 V	OK	
18	Check CIV_RL_Li1 output status	CLOSED	OK	Fixed expected output in doc.
19	Check CIV_RL_Li2 output status	CLOSED	OK	Fixed expected output in doc.
20	Check CIV_SP_Ls voltage output	12±0.1 V		Fixed value in doc

4.9.2 MEL-TC-CIV-0902: Check Gas Loop Operational Modes

TC Identifier	**MEL-TC-CIV-0902**	**Purpose:**	Verify when operational mode is changed in the Gas Loop, outputs are set as specified		
Functions Tested	CIV_PLCSW_Gas, MEL_CIV_Gas				
Description	From the Gas regulation supervision screen it is possible to change the operational mode and set the manual values.				
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_Gas supervision screen to change operational modes and manual values.				
Tester:	**Jordi Duatis**	**Date:**	**03/10/2003**		
Course of Actions					
Step no	**Description**	**Expected value**	**OK/NOK 03/10/2003**	**Comments**	
1	In the MEL_CIV_BP supervision screen set operational mode to OFF Connect a Pilot light to CIV_RL_Fg				
2	Check Pilot light	OFF	OK		
3	Check CIV_SP_Fgi voltage output	0±0.1 V	OK		
4	Check CIV_SP_Fgo voltage output	0±0.1 V	OK		
5	Check CIV_SP_Fgex voltage output	0±0.1 V	OK		
6	In the MEL_CIV_Gas edit the manual values and set: Enable Pressure safety valve: checked				
8	In the MEL_CIV_Gas supervision screen set operational mode to MAN				
9	Check Pilot light	ON	OK		

4.9.3 MEL-TC-CIV-0903: Check pH Loop Operational Modes

TC Identifier	**MEL-TC-CIV-0903**	**Purpose:**	Verify when operational mode is changed in the pH Loop, outputs are set as specified
Functions Tested	CIV_PLCSW_pH, MEL_CIV_pH		
Description	From the pH regulation supervision screen it is possible to change the operational mode and set the manual values.		
Special Requisites:	Use a Multimeter to measure expected outputs Use MEL_CIV_pH supervision screen to change operational modes and manual values.		
Tester:	**Jordi Duatis**	**Date:**	**03/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK 03/10/2003	Comments
1	In the MEL_CIV_pH supervision screen set operational mode to OFF			
2	Apply a 1 Kohm resistor to CIV_SP_Bs (AO 09) and CIV_SP_Ac (AO 11)			
3	Check CIV_SP_Bs voltage output	4±0.1 V	OK	
4	Check CIV_SP_Ac voltage output	4±0.1 V	OK	
5	Check CIV_SP_FrCO2 voltage output	0±0.1 V	OK	
6	In the MEL_CIV_pH edit the manual values and set: Acid pump set-point (0-100%): 10 Base pump set-point (0-100%): 20 CO2 Flow Rate set-point (0-5 nLm): 2.5			
8	In the MEL_CIV_pH supervision screen set operational mode to MAN			
9	Check CIV_SP_Ac voltage output	5.6±0.2 V	OK	Fixed exp. precision in doc.
	Check CIV_SP_Bs voltage output	7.2±0.1 V	OK	
	Check CIV_SP_FrCO2 voltage output	2.5±0.1 V	OK	

5 COMPARTMENT III SYSTEM TEST REPORT

5.1 MEL-CIII-TP-01: Point to point connectivity test procedure

MEL-CIII-TP-01: Point to point connectivity test procedure					
Tester	JD	Date:	10 Oct 2003	Result:	OK
Comments:					

5.2 MEL-CIII-TP-02: Electrical isolation

MEL-CIII-TP-02: Electrical isolation					
Tester	XLL / JD	Date:		Result:	
Comments:					

5.3 MEL-CIII-TP-03 Check Interfaces end-to-end

5.3.1 MEL-TC-CIII-0301: Check analogue inputs

TC Identifier	**MEL-TC-CIII-0301**	**Purpose:**	Verify that analogue inputs are connected, acquired, supervised and ranged as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Known values applied to analogue inputs shall be displayed in the Supervision ranged as specified.		
Special Requisites:	Values to apply / check must be between the indicated range		
Tester:	**JD**	**Date:**	**29/10/2003**

Course of Actions			
Step no	**Description**	**Expected value**	**OK/NOK**
1	Apply 1 - 1.2 V to AI 01 (CIII_MV_Dob) and check the displayed value DObot % in the Supervision screen MEL_CIII_GAS.	0 – 5	OK
2	Apply 4.8 – 5 V to AI 01 (CIII_MV_Dob) and check the displayed value DObot % in the Supervision screen MEL_CIII_GAS.	95 – 100	OK
3	Apply 1 – 1.2 V to AI 02 (CIII_MV_Dot) and check the displayed value DOtop % in the Supervision screen MEL_CIII_GAS.	0 – 5	OK
4	Apply 4.8 – 5 V to AI 02 (CIII_MV_Dot) and check the displayed value DOtop % in the Supervision screen MEL_CIII_GAS.	95 – 100	OK
5	Apply 1 – 1.2 V to AI 03 (CIII_MV_NH4) and check the displayed value NH4 in the Supervision screen MEL_CIII_Liquid.	0 – 10	OK
6	Apply 4.8 - 5 V to AI 03 (CIII_MV_NH4) and check the displayed value NH4 in the Supervision screen MEL_CIII_BP.	190 – 200	OK
7	Apply 1 – 1.2 V to AI 04 (CIII_MV_NO3) and check the displayed value NO3 in the Supervision screen MEL_CIII_Liquid.	0 – 50	OK
8	Apply 4.8 - 5 V to AI 04 (CIII_MV_NO3) and check the displayed value NO3 in the Supervision screen MEL_CIII_Liquid.	950 – 1000	OK
9	Apply 1 – 1.2 V to AI 05 (CIII_MV_P) and check the displayed value P in the Supervision screen MEL_CIII_Gas.	0 – 50	OK
10	Apply 4.8 - 5 V to AI 05 (CIII_MV_P) and check the displayed value P in the Supervision screen MEL_CIII_Gas.	950 – 1000	OK
11	Apply 1 – 1.2 V to AI 06 (CIII_MV_PHb) and check the displayed value pHbot in the	3 – 3.5	OK

TC Identifier	MEL-TC-CIII-0301	Purpose:	Verify that analogue inputs are connected, acquired, supervised and ranged as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Known values applied to analogue inputs shall be displayed in the Supervision ranged as specified.		
Special Requisites:	Values to apply / check must be between the indicated range		
Tester:	**JD**	**Date:**	**29/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK
	Supervision screen MEL_CIII_pH.		
12	Apply 4.8 - 5 V to AI 06 (CIII_MV_PHb) and check the displayed value pHbot in the Supervision screen MEL_CIII_pH.	12.5 – 13	OK
13	Apply 1 – 1.2 V to AI 07 (CIII_MV_PHt) and check the displayed value pHtop in the Supervision screen MEL_CIII_pH.	1.5 – 2	OK
14	Apply 4.8 - 5 V to AI 07 (CIII_MV_PHt) and check the displayed value pHtop in the Supervision screen MEL_CIII_pH.	11 – 11.5	OK
15	Apply 1 – 1.2 V to AI 09 (CIII_MV_Tb) and check the displayed value Temperature in the Supervision screen MEL_CIII_Temp.	0.2 – 7.54	OK
16	Apply 4.8 - 5 V to AI 09 (CIII_MV_Tb) and check the displayed value Temperature in the Supervision screen MEL_CIII_Temp.	139.66 – 147	OK
17	Apply 1 – 1.2 V to AI 10 (CIII_MV_Tt) and check the displayed value Temperature in the Supervision screen MEL_CIII_Temp.	0.2 – 7.54	OK
18	Apply 4.8 - 5 V to AI 10 (CIII_MV_Tt) and check the displayed value Temperature in the Supervision screen MEL_CIII_Temp.	139.66 – 147	OK

5.3.2 MEL-TC-CIII-0302: Check analogue outputs

TC Identifier	**MEL-TC-CIII-0302**	**Purpose:**	Verify that analogue inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Known values applied to Supervision variables shall be translated to the analogue outputs within the ranges specified. Only outputs with direct set-points are checked, the rest will be checked by other TC.		
Special Requisites:	Use a Multimeter to measure voltage outputs		
Tester:	**JD**	**Date:**	**29/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK
1	Set regulation mode to MAN to all loops.		
2	In the supervision screen MEL_CIII_pH edit manual values and set the value 0 to “CO2 Flow set point” and measure AO 01 output volts.	0 V ±0.1	OK
3	In the supervision screen MEL_CIII_pH edit manual values and set the value 100 to “CO2 Flow set point” and measure AO 01 output volts.	5 V ±0.1	OK
4	In the supervision screen MEL_CIII_Gas edit manual values and set the value 0 to “N2 Flow set point” and measure AO 02 output volts.	0 V ±0.1	OK
5	In the supervision screen MEL_CIII_Gas edit manual values and set the value 150 to “N2 Flow set point” and measure AO 02 output volts.	5 V ±0.1	OK
6	In the supervision screen MEL_CIII_Gas edit manual values and set the value 0 to “O2 Flow set point” and measure AO 03 output volts.	0 V ±0.1	OK
7	In the supervision screen MEL_CIII_Gas edit manual values and set the value 100 to “O2 Flow set point” and measure AO 03 output volts.	5 V ±0.1	OK
8	Apply a 500 ohm resistor to AO 05		
9	In the supervision screen MEL_CIII_pH edit manual values and set the value 0 to “Acid pump set point” and check “Enable Acid pump”. Measure AO 05 output volts.	2 V ±0.2	OK
10	In the supervision screen MEL_CIII_pH edit manual values and set the value 100 to “Acid pump set point” and measure AO 05 output volts.	10 V ±0.2	OK
11	Apply a 500 ohm resistor to AO 06		
12	In the supervision screen MEL_CIII_pH edit manual values and set the value 0 to “Base pump set point” and check “Enable base pump”. Measure AO 06 output volts.	2 V ±0.2	OK
13	In the supervision screen MEL_CIII_pH edit manual values and set the value 100 to “Base pump set point” and measure AO 06 output volts.	10 V ±0.2	OK

TC Identifier	MEL-TC-CIII-0302	Purpose:	Verify that analogue inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Known values applied to Supervision variables shall be translated to the analogue outputs within the ranges specified. Only outputs with direct set-points are checked, the rest will be checked by other TC.		
Special Requisites:	Use a Multimeter to measure voltage outputs		
Tester:	JD	Date:	29/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK
14	Apply a 500 ohm resistor to AO 07		
15	In the supervision screen MEL_CIII_Liquid edit manual values and set the value 0 to “Liquid input pump set point” and measure AO 07 output volts.	2±0.2 V	OK
16	In the supervision screen MEL_CIII_Liquid edit manual values and set the value 100% to “Liquid input pump set point” and measure AO 07 output volts.	10±0.2 V	OK
17	Apply a 500 ohm resistor to AO 08		
18	In the supervision screen MEL_CIII_Liquid edit manual values and set the value 0 to “Liquid output pump set point” and measure AO 08 output volts.	2 ±0.2 V	OK
19	In the supervision screen MEL_CIII_Liquid edit manual values and set the value 100 to “Liquid output pump set point” and measure AO 08 output volts.	10±0.2 V	OK

5.3.3 MEL-TC-CIII-0303: Check digital inputs

TC Identifier	MEL-TC-CIV-0303	Purpose:	Verify that digital inputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Status set to digital inputs shall be translated to the supervision as specified.		
Special Requisites:			
Tester:	**JD**	**Date:**	**29/10/2003**

Course of Actions			
Step no	**Description**	**Expected value**	**OK/NOK**
1	Set DI 01 in open circuit and check in supervision screen MEL_CIII_Liquid, indicator “Calibrating” in NH4	Disabled	OK
2	Set DI 01 in closed circuit and check in supervision screen MEL_CIII_Liquid, indicator “Calibrating” in NH4	Enabled	OK
3	Set DI 02 in open circuit and check in supervision screen MEL_CIII_Liquid, indicator “Calibrating” in NO3	Disabled	OK
4	Set DI 02 in closed circuit and check in supervision screen MEL_CIII_Liquid, indicator “Calibrating” in NO3	Enabled	OK
5	Set DI 03 in open circuit and check in supervision screen MEL_CIII_Liquid, indicator “Level Low” in Level sensor	Enabled	OK
6	Set DI 03 in closed circuit and check in supervision screen MEL_CIII_Liquid, indicator “Level Low” in Level sensor	Disabled	OK
7	Set DI 04 in open circuit and check in supervision screen MEL_CIII_Liquid, indicator “Level High” in Level sensor	Disabled	OK
8	Set DI 04 in closed circuit and check in supervision screen MEL_CIII_Liquid, indicator “Level High” in Level sensor	Enabled	OK

5.3.4 MEL-TC-CIII-0304: Check digital outputs

TC Identifier	MEL-TC-CIV-0304	Purpose:	Verify that digital outputs are connected, acquired and supervised as specified	
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision			
Description	Manual values applied to Supervision shall be translated to the digital outputs within the ranges specified. Only outputs with manual values are checked, functional TC will check the rest.			
Special Requisites:	Connect lights to 220 VEF relay outputs to check status			
Tester:	**JD**		**Date:**	**29/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK
1	Set regulation mode to MAN to all loops.		
2	In the supervision screen MEL_CIII_Liquid edit manual values and enable “Output buffer tank pump Activation” and check DO 01 connectivity.	Closed	OK
3	In the supervision screen MEL_CIII_Liquid edit manual values and disable “Output buffer tank pump Activation” and check DO 01 connectivity.	Open	OK
4	In the supervision screen MEL_CIII_pH edit manual values and enable “Acid pump activation” and check DO 02 light status.	On	OK
5	In the supervision screen MEL_CIII_pH edit manual values and disable “Acid pump activation” and measure DO 02 light status.	Off	OK
6	In the supervision screen MEL_CIII_pH edit manual values and enable “Base pump activation” and measure DO 03 light status.	On	OK
7	In the supervision screen MEL_CIII_pH edit manual values and disable “Base pump activation” and measure DO 03 light status.	Off	OK
8	In the supervision screen MEL_CIII_Temp edit manual values and enable “Cooling valve activation” and check DO 05 light status.	On	OK
9	In the supervision screen MEL_CIII_Temp edit manual values and disable “Cooling valve activation” and check DO 05 light status.	Off	OK
10	In the supervision screen MEL_CIII_Temp edit manual values and enable “Heater activation” and check DO 06 light status.	On	OK
11	In the supervision screen MEL_CIII_Temp edit manual values and disable “Heater activation” and check DO 06 light status.	Off	OK

TC Identifier	MEL-TC-CIV-0304	Purpose:	Verify that digital outputs are connected, acquired and supervised as specified
Functions Tested	Interface between CIII_CP – CIII_PLC – Supervision		
Description	Manual values applied to Supervision shall be translated to the digital outputs within the ranges specified. Only outputs with manual values are checked, functional TC will check the rest.		
Special Requisites:	Connect lights to 220 VEF relay outputs to check status		
Tester:	JD	Date:	29/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK
12	In the supervision screen MEL_CIII_Gas edit manual values and enable "Enable Pressure safety valve" and check DO 08 light status.	On	OK
13	In the supervision screen MEL_CIII_Gas edit manual values and disable "Enable Pressure safety valve" and check DO 08 light status.	Off	OK

5.4 MEL-CIII-TP-04 pH Regulation

5.4.1 MEL-TC-CIII-0401: pH Regulation with CO2

TC Identifier	MEL-TC-CIII-0401	Purpose:	Verify that when in pH control mode 1, if pH goes over the set point, CO2 valve is opened according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH, MEL_CIII_Main		
Description	When in control mode 1, if pH goes over the set point, the PI shall open CO2 valve according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH and MEL_CIII_Main displays		
Tester:	JD	Date:	30/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Set pH control mode to 1 – CO2 only			
2	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
3	In the MEL_CIII_pH Supervision screen check pH bottom value	8.0±0.1 pH	OK	
4	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
5	In the MEL_CIII_pH Supervision screen check pH top value	8.0±0.1 pH	OK	
6	In the MEL_CIII_MAIN Supervision screen check pH value	8.0±0.1 pH	OK	
7	In the MEL_CIII_pH Supervision screen check pH value	8.0±0.1 pH	OK	
8	In the MEL_CIII_pH check CO2 valve set point	0±0.1 %	OK	
9	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 3, Integration = 0			
10	In the MEL_CIII_pH edit the proportional constant for CO2 valve (click over CO2 valve to open dialog). Set proportional = 5			
11	Using APS 1 set 4.10 – 4.20 V to AI 06 (CIII_MV_pHb)			
12	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
13	Check in MEL_CIII_pH Supervision display the value of pH	11±0.25 pH	OK	
14	Check CO2 valve control action value	45±3.75 %	OK	
15	Check AO 01 voltage output	2.3±0.2 V		
16	In the MEL_CIII_pH Supervision screen set pH Ramp parameter to 0.016			
17	In the MEL_CIII_pH Supervision screen set pH set point to 11.0.			

TC Identifier	MEL-TC-CIII-0401	Purpose:	Verify that when in pH control mode 1, if pH goes over the set point, CO2 valve is opened according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH, MEL_CIII_Main		
Description	When in control mode 1, if pH goes over the set point, the PI shall open CO2 valve according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH and MEL_CIII_Main displays		
Tester:	JD	Date:	30/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
18	Check that in 3 minutes CO2 valve control action approaches to 0 (ramp effect)	0±5 %	OK	
19	In the MEL_CIII_pH Supervision screen set pH set point to 8.0 and wait until CO2 valve control action value is restored.	45±3.75 %	OK	
20	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
21	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
22	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 1, Integration = 30			
23	Using APS 1 set 4.10 – 4.20 V to AI 06 (CIII_MV_pHb)			
24	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
24	In the MEL_CIII_pH annotate CO2 valve control action value at 10 seconds and at 40 seconds. Calculate the gradient (CO2 at 20 – CO2 at 10) / 30	0.5±0.05 %	OK	

5.4.2 MEL-TC-CIII-0402: pH Regulation with CO2 and additional Base medium

TC Identifier	**MEL-TC-CIII-0402**	**Purpose:**	Verify that when in pH control mode 2, if pH goes under the set point, Base pump is activated according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH		
Description	When in pH control mode 2, if pH goes under the set point, the PI shall activate the base pump according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH display		
Tester:	**JD**	**Date:**	**30/10/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Set pH control mode to 2 – CO2 + Base			
2	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
3	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
4	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH	OK	
5	Check DO 03 light	Off	OK	
6	Check CO2 valve and Base pump control action values	0±0.1 %	OK	
7	In the MEL_CIII_pH edit the PI parameters (click over base pump to open dialog). Set proportional = 3, Integration = 3000			
8	Using APS 1 set 1.70 – 1.90 V to AI 06 (CIII_MV_pHb)			
9	Using APS 2 set 2.30 – 2.50 V to AI 07 (CIII_MV_pHt)			
10	Check in MEL_CIII_pH Supervision display the value of pH	5 ±0.25 pH	OK	
11	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 3, Integration = 0			
12	Check Base pump control action value during 10 seconds every 30 seconds	9±0.75 %	OK	
13	Check DO 03 light during 10 seconds every 30 seconds	On		
14	Apply a 500 ohm resistor to AO 06			
15	Check AO 06 voltage output	2.72±0.1 V	OK	Fixed doc.
16	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 1, Integration = 30			
17	In the MEL_CIII_pH annotate max. Base pump control action value within the 10 seconds is active. Calculate gradient ($Base_{t=10} – Base_{t=0}$) / 10	0.1±0.01 %	OK	
18	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			

TC Identifier	MEL-TC-CIII-0402	Purpose:	Verify that when in pH control mode 2, if pH goes under the set point, Base pump is activated according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH		
Description	When in pH control mode 2, if pH goes under the set point, the PI shall activate the base pump according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH display		
Tester:	JD	Date:	30/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
19	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
20	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH	OK	
21	Check CO2 valve and Base pump control action values (wait 30 seconds)	0±0.1 %	OK	
22	Check DO 03 light (wait 30 seconds)	Off	OK	
23	Using APS 1 set 4.10 – 4.30 V to AI 06 (CIII_MV_pHb)			
24	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
25	Check in MEL_CIII_pH Supervision display the value of pH	11 ±0.25 pH	OK	
26	Check CO2 valve control action value	> 0 %	OK	
27	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
28	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
29	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH	OK	
30	Check CO2 valve and Base pump control action values	0±0.1 %	OK	

5.4.3 MEL-TC-CIII-0403: pH Regulation with Base and Acid additional media

TC Identifier	**MEL-TC-CIII-0403**	**Purpose:**	Verify that when in pH control mode 2, if pH goes under the set point, Base pump is activated according to provided parameters.		
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH				
Description	When in pH control mode 3, if pH goes under/over the set point, the PI shall activate the base/acid pump respectively according to parameters provided from the supervision.				
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH display				
Tester:	**JD**	**Date:**	**30/10/2003**		

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Set pH control mode to 3 – Acid + Base			
2	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
3	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
4	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH	OK	
5	Check DO 02, DO 03 lights (wait 30 seconds)	Off	OK	
6	Check Acid and Base pump control action values (wait 30 seconds)	0±0.1 %	OK	
7	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 3, Integration = 0			
8	Using APS 1 set 4.10 – 4.20 V to AI 06 (CIII_MV_pHb)			
9	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
25	Check in MEL_CIII_pH Supervision display the value of pH	11 ±0.25 pH	OK	
12	Check acid pump control action value during 10 seconds every 30 seconds	9±0.75 %	OK	
13	Check DO 02 light during 10 seconds every 30 seconds	On	OK	
16	In the MEL_CIII_pH edit the PI parameters (click over Acid pump to open dialog). Set proportional = 1, Integration = 30			
17	In the MEL_CIII_pH annotate max. Acid pump control action value within the 10 seconds is active. Calculate gradient ($Acid_{t=10}$ – $Acid_{t=0}$) / 10	0.1±0.1 %	OK	
18	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
19	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
20	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH	OK	
21	Check Acid and Base pump control action values (wait 30 seconds)	0±0.1 %	OK	
22	Check DO 02, DO 03 lights (wait 30 seconds)	Off	OK	

TC Identifier	MEL-TC-CIII-0403	Purpose:	Verify that when in pH control mode 2, if pH goes under the set point, Base pump is activated according to provided parameters.
Items Tested	CIII_PLCSW_pH, MEL_CIII_pH		
Description	When in pH control mode 3, if pH goes under/over the set point, the PI shall activate the base/acid pump respectively according to parameters provided from the supervision.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH display		
Tester:	JD	Date:	30/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
23	Using APS 1 set 1.70 – 1.90 V to AI 06 (CIII_MV_pHb)			
24	Using APS 2 set 2.30 – 2.50 V to AI 07 (CIII_MV_pHt)			
25	Check in MEL_CIII_pH Supervision display the value of pH	5 ±0.25 pH	OK	
26	Check Base pump control action value during 10 seconds every 30 seconds	> 0 %	OK	
27	Using APS 1 set 2.90 – 3.10 V to AI 06 (CIII_MV_pHb)			
28	Using APS 2 set 3.50 – 3.70 V to AI 07 (CIII_MV_pHt)			
29	Check in MEL_CIII_pH Supervision display the value of pH	8 ±0.25 pH	OK	
30	Check Acid and Base pump control action values (wait 30 seconds)	0±0.1 %	OK	

5.4.4 MEL-TC-CIII-0404: pH alarms

TC Identifier	MEL-TC-CIII-0404	Purpose:	Verify that when pH value is over the set point during 15 minutes an alarm is generated
Items Tested	CIII_PLCSW_pH, MEL_CIII		
Description	When pH is out of the set point for more than 15 minutes, a high priority alarm shall be generated.		
Special Requisites:	2 APS are used to simulate the pH sensors. Check supervision values in MEL_CIII_pH and MEL_CIII_Main displays		
Tester:	JD	Date:	30/10/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Using APS 1 set 4.10 – 4.20 V to AI 06 (CIII_MV_pHb)			
2	Using APS 2 set 4.70 – 4.90 V to AI 07 (CIII_MV_pHt)			
3	Check in MEL_CIII_pH Supervision display the value of pH	11 ±0.25 pH	OK	
4	Wait 15 minutes			
5	Check in alarm area pH deviation alarm status	Alarm	OK	

5.5 MEL-CIII-TP-05 Liquid Flows Regulation

5.5.1 MEL-TC-CIII-0501: Liquid level control

TC Identifier	**MEL-TC-CIII-0501**	**Purpose:**	Verify that when liquid level is high output pump flow rate is increased, when is low, output pump flow rate is decreased
Items Tested	CIII_PLCSW_Liquid, MEL_CIII_Liquid, MEL_CIII_Main		
Description	Initially output flow = input flow. When liquid level reaches high status, output pump flow is increased a 25%, when liquid level reaches low level, output pump flow is decreased a 25%.		
Special Requisites:	Check supervision values in MEL_CIII_Liquid display		
Tester:	**JD**	**Date:**	**3/11/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Liquid set control mode to AUTO			
2	In the MEL_CIII_Liquid set input pump calibration parameters to: Parameter A = 73.5294 Parameter B = 0.1765			
3	Using Concept tool modify liquid input safety set point to 0,4 (default)			
4	Check in MEL_CIII_Liquid supervision display “Liquid input flow rate”	0,4 (blinking)	OK	
5	Check input pump actuation	29.59±0.1 %	OK	
6	Check Level High indicator	Off	OK	
7	Check Level Low indicator	On	OK	
8	Check output pump actuation	22.19±0.1 %	OK	
9	Set closed circuit to DI 03 (CIII_MV_Llow)			
10	Check Level High and Level Low indicators	Off	OK	
11	Check output pump actuation	29.59±0.1 %	OK	
12	Set open circuit to DI 03 (CIII_MV_Llow)			
13	Check Level Low indicator	On	OK	
14	Check output pump actuation	22.19±0.1 %	OK	
15	Set closed circuit to DI03 and DI 04 (CIII_MV_Llow, CIII_MV_Lhigh)			
16	Check Level High indicator	On	OK	
17	Check output pump actuation	36.98±0.1 %	OK	

TC Identifier	MEL-TC-CIII-0501	Purpose:	Verify that when liquid level is high output pump flow rate is increased, when is low, output pump flow rate is decreased
Items Tested	CIII_PLCSW_Liquid, MEL_CIII_Liquid, MEL_CIII_Main		
Description	Initially output flow = input flow. When liquid level reaches high status, output pump flow is increased a 25%, when liquid level reaches low level, output pump flow is decreased a 25%.		
Special Requisites:	Check supervision values in MEL_CIII_Liquid display		
Tester:	JD	Date:	3/11/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
18	Set open circuit to DI 04 (CIII_MV_Lhigh)			
19	Check Level High and Level Low indicators	Off	OK	
20	Check output pump actuation	29.59±0.1 %	OK	

5.5.2 MEL-TC-CIII-0502: Nitrite estimator

TC Identifier	**MEL-TC-CIII-0502**	**Purpose:**	Verify integration of the Nitrite estimator algorithm.	
Items Tested	CIII_PLCSW_Liquid, MEL_PLCSW_N, MEL_CIII_pH, MEL_CIII_pH			
Description	Firing manually the Nitrite Estimator control law, will set the Liquid input flow rate set point and NO2 estimation.			
Special Requisites:	Check supervision values in MEL_CIII_Liquid and MEL_CIII_Main displays			
Tester:	**JD**	**Date:**	**31/10/2003**	
Course of Actions				
Step no	**Description**	**Expected value**	**OK/NOK**	**Comments**
1	In the MEL_CIII_Liquid Supervision display set control mode to AUTO			
2	In the MEL_CIII_Liquid Supervision display set input pump calibration parameters to: Parameter A = 73.5294 Parameter B = 0.1765			
3	In the MEL_CIII_Liquid Supervision display set Level 2 liquid level set point to 0.4			
4	Using Concept tool modify safety values for NO3, NH4, DO and the liquid input set point. Set: NO3 = 329 ppm NH4 = 4.2 ppm DO = 80% (default value) LIN = 0.4 l/h			
5	Using iFix tool Database Manager, set CIII_SSP_L1IN to 0,4			
6	In the MEL_CIII_Liquid Supervision display, open Nitrite estimator parameters dialog.			
7	In the Nitrite estimator parameters dialog, check O2 at liquid output	0,0002 mol/l	OK	Fixed document
8	In the Nitrite estimator parameters dialog, check Required & Measured Liquid input flow rate	0.4 l/h	OK	
9	In the Nitrite estimator parameters dialog, update values using the table below (MEL-TC-CIII-0502.Table1)			
10	Using iFix Scheduler, set scheduler properties to "Run in Foreground"			
11	Fire CIII_CTRLLAW_NIT event			
12	In the MEL_CIII_Liquid Supervision display check Estimated NO2 concentration	1.59 ppm	OK	
13	In the MEL_CIII_Liquid Supervision display check Level 1 Liquid Input Flow	0.4 l/h	OK	
14	In the MEL_CIII_Liquid Supervision display check Liquid Input Flow	0.4 l/h	OK	
15	In the MEL_CIII_Main Supervision display check Liquid Input Flow	0.4 l/h	OK	
16	In the MEL_CIII_Main Supervision display check NO2 estimation	1.59 ppm	OK	

Nitrite Estimator parameters table

Index	Description	Values	Unit
0	Measured liquid flow rate or set point of the FRC of the liquid pump	0.4000	l/h
1	O_2 concentration in the gas input stream	0.0066	mol/l
2	CO_2 concentration in the gas input stream	0.0019	mol/l
3	NH_3 concentration in the gas input stream	0.0000	mol/l
4	O_2 concentration in the liquid input stream	0.0004	mol/l
5	total CO_2 concentration in the liquid input stream	0.0159	mol/l
6	total NH_3 concentration in the liquid input stream	0.0250	mol/l
7	unused (room for NO_2 concentration if not null)	0.0000	mol/l
8	NO_3 concentration in the liquid input stream	0.0000	mol/l
9	PO_4 concentration in the liquid input stream	0.0016	mol/l
10	SO_4 concentration in the liquid input stream	0.0040	mol/l
11	O_2 concentration in the liquid output stream	0.0002	mol/l
12	total CO_2 concentration in the liquid output stream	0.0564	mol/l
13	total NH_3 concentration in the liquid output stream	0.0003	mol/l
14	NO_3 concentration in the liquid output stream	0.0235	mol/l
15	PO_4 concentration in the liquid output stream	0.0016	mol/l
16	SO_4 concentration in the liquid output stream	0.0039	mol/l
17	Measured gas flow rate or set point of the FRC of the gas pump	60.0000	l/h
18	‘Required’ liquid flow rate	0.4000	l/h
19	Maximum constraint of NO_2	0.0003	mol/l
20	Compensation term for estimator	0.0000	mol/l

MEL-TC-CIII-0502.Table1

5.5.3 MEL-TC-CIII-0503: Output buffer tank pump activation

TC Identifier	**MEL-TC-CIII-0503**	**Purpose:**	Verify buffer tank output pump is activated when level is high		
Items Tested	CIII_PLCSW_Liquid, MEL_CIII_Liquid				
Description	When output buffer liquid reaches high level, the output pump is activated.				
Special Requisites:	Check supervision values in MEL_CIII_Liquid Use a Multimeter to check output voltage values.				
Tester:	**JD**	**Date:**	**3/11/2003**		
Course of Actions					
Step no	**Description**		**Expected value**	**OK/NOK**	**Comments**
1	Check in MEL_CIII_Liquid the Buffer tank Level High indicator		Off	OK	
2	Check in MEL_CIII_Liquid the Buffer tank output pump status		Off	OK	
3	Close circuit in DI 05				
4	Check in MEL_CIII_Liquid the Buffer tank Level High indicator		On	OK	
5	Check in MEL_CIII_Liquid the Buffer tank output pump status		On	OK	
6	Check DO 01 relay status		Closed	OK	

5.5.4 MEL-TC-CIII-0504: Liquid level alarms

TC Identifier	**MEL-TC-CIII-0504**	**Purpose:**	Verify high liquid level alarm		
Items Tested	CIII_PLCSW_Liquid, MEL_CIII_Liquid				
Description	High level alarm shall be activated when level is high during 15 minutes.				
Special Requisites:	Check supervision values in MEL_CIII_Liquid display				
Tester:	**JD**	**Date:**	**3/11/2003**		
Course of Actions					
Step no	**Description**		**Expected value**	**OK/NOK**	**Comments**
1	In the MEL_CIII_Liquid set Liquid input set point to 0.4 l/h				
2	Close circuit in DI 04				
3	Check Level High indicator		On	OK	
4	Wait 15 minutes		Alarm	OK	
5	Check in Alarm area, the level high alarm has been indicated.		On	OK	
6	Check Liquid input flow rate		0 l/h	OK	

5.6 MEL-CIII-TP-06 Gas Flows Regulation

5.6.1 MEL-TC-CIII-0601: DO regulation

TC Identifier	**MEL-TC-CIII-0601**	**Purpose:**	Verify DO regulation performed by a PID actuating over the N2 and O2 gas input flow regulators according to provided parameters.
Items Tested	CIII_PLCSW_DO, MEL_CIII_Gas, MEL_CIII_Main		
Description	When DO grows, O2 valve is closed. If O2 valve is completely closed and O2 is still over the set point, the N2 valve opens.		
Special Requisites:	1 APS and a FG are used to simulate DO sensor. Check supervision values in MEL_CIII_Gas and MEL_CIII_Main displays		
Tester:	**JD**	**Date:**	**3/11/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas set DO control action mode to AUTO			
2	In the MEL_CIII_Gas, set DO ramp parameter to 0.0167			
3	In the MEL_CIII_Gas, check DO set point (initial value)	80%	OK	
4	In the MEL_CIII_Gas Supervision screen click over the O2 valve to edit PID parameters. Set: Proportional = 12 Integrative = 30 Derivative = 0.033 Bias = 0			
5	In the MEL_CIII_Gas Supervision screen click over the N2 valve to set Proportional constant to 0.5			
6	With Concept open CIII_PLCSW_DO and disable EN_I, EN_D (only proportional part is enabled).			
7	With APS set 4.15 – 4.25 to AI 01 (DO bottom)			
8	In the MEL_CIII_Gas check DO concentration bottom	80±1.25%	OK	
9	With APS set 4.15 – 4.25 to AI 02 (DO top)			
10	In the MEL_CIII_Gas check DO concentration top	80±1.25%	OK	
11	With APS set 4.15 – 4.25 V to AI 01 and AI 02 (DO bottom/top)			
12	In the MEL_CIII_Main check DO concentration	640±1.25 ppm	OK	
13	In the MEL_CIII_Liquid check DO (ppm) concentration	640±1.25 ppm	OK	
14	In the MEL_CIII_Gas check DO concentration	80±1.25%	OK	

TC Identifier	MEL-TC-CIII-0601	Purpose:	Verify DO regulation performed by a PID actuating over the N2 and O2 gas input flow regulators according to provided parameters.
Items Tested	CIII_PLCSW_DO, MEL_CIII_Gas, MEL_CIII_Main		
Description	When DO grows, O2 valve is closed. If O2 valve is completely closed and O2 is still over the set point, the N2 valve opens.		
Special Requisites:	1 APS and a FG are used to simulate DO sensor. Check supervision values in MEL_CIII_Gas and MEL_CIII_Main displays		
Tester:	JD	Date:	3/11/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
15	In the MEL_CIII_Gas, modify DO set point to 78%			
16	Check that in 2 minutes O2 Set Point moved to expected value (effect of ramp parameter applied to DO set point):	24±1.25%	OK	
17	In the MEL_CIII_Gas, modify DO set point to 80%			
18	Check that in 2 minutes O2 Set Point moved to expected value (effect of ramp parameter applied to DO set point):	0±1.5%	OK	Fixed document
19	With APS set 3.95 – 4.05 V to AI 01 and AI 02 (DO bottom/top)			
20	In the MEL_CIII_Gas check DO concentration	75±1.25%	OK	
21	In the MEL_CIII_Gas check O2 flow controller set point (SP)	60%	OK	
22	With APS set 4.35 – 4.45 V to AI 01 and AI 02 (DO bottom/top)			
23	In the MEL_CIII_Gas check DO concentration	85±1.25 %	OK	
24	In the MEL_CIII_Gas check N2 flow controller set point (SP)	30±1.25 %	OK	
25	With APS set 4.15 – 4.25 V to AI 01 and AI 02 (DO bottom/top)			
26	In the MEL_CIII_Gas check DO concentration	80±1.25%	OK	
27	In the MEL_CIII_Gas check N2, O2 flow controllers set point	0±1.25%	OK	
28	With Concept open CIII_PLCSW_DO and disable EN_P, EN_D and enable EN_I (only integrative part is enabled).			
29	With APS set 3.95 – 4.05 V to AI 01 and AI 02 (DO bottom/top)			
30	In the MEL_CIII_Gas annotate O2 valve control action value within the 10 seconds is active. Calculate gradient ($O2_{t=10} - O2_{t=0}$) / 10	2±0.15%	OK	
31	With Concept open CIII_PLCSW_DO and disable EN_P, EN_I and enable EN_D (only derivative part is enabled).			
32	With a FG apply a triangular wave Freq=0.1 Hz, A=0.8 V, Offset=3.8 V (3.8 – 4.6 V / 70 – 80%)			
33	In the MEL_CIII_Gas check O2 flow controller set point (SP) MAX	4±0.5%	OK	

5.6.2 MEL-TC-CIII-0602: Pressure valve activation

TC Identifier	**MEL-TC-CIII-0602**	**Purpose:**	Verify that safety valve is opened when pressure goes over the set point		
Items Tested	CIII_PLCSW_P, MEL_CIII_Gas, MEL_CIII_Main				
Description	When pressure goes over the set point, the safety pressure valve shall be opened until the pressure returns under the set point.				
Special Requisites:	1 APS is used to simulate Pressure sensor. Check supervision values in MEL_CIII_Gas and MEL_CIII_Main displays				
Tester:	**JD**	**Date:**	**4/11/2003**		
Course of Actions					

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas set control mode to AUTO			
2	In the MEL_CIII_Gas Supervision screen set Pressure Set point to 100 mb			
3	Apply 1.30 – 1.40 V to AI 05 (CIII_MV_P)			
4	In the MEL_CIII_Main Supervision screen check Pressure value	87.5±12.5 mb	OK	
5	In the MEL_CIII_Gas Supervision screen check Pressure value	87.5±12.5 mb	OK	Fixed document
6	In the MEL_CIII_Gas Supervision screen check safety valve status	Closed	OK	
7	Apply a light to DO 08 (CIII_AC_Safe in CIII_AC_OUT)			
8	Check light status	Off	OK	
9	Apply 1.95 – 2.05 V to AI 05			
10	In the MEL_CIII_Gas Supervision screen check Pressure value	250±12.5 mb	OK	
11	In the MEL_CIII_Gas Supervision screen check safety valve status	Open	OK	
12	Check light status	On	OK	
13	Apply 1.30 – 1.40 V to AI 05 (CIII_MV_P)			
14	In the MEL_CIII_Gas Supervision screen check Pressure value	87.5±12.5 mb	OK	
15	In the MEL_CIII_Gas Supervision screen check safety valve status	Closed	OK	
16	Check light status	Off	OK	

5.6.3 MEL-TC-CIII-0603: DO and Pressure alarms

TC Identifier	**MEL-TC-CIII-0603**	**Purpose:**	Verify that DO and pressure alarms are notified	
Items Tested	CIII_PLCSW_P, MEL_CIII_Gas, MEL_CIII_Main			
Description	When pressure goes over the set point, the safety pressure valve shall be opened until the pressure returns under the set point.			
Special Requisites:	1 APS is used to simulate Pressure sensor. Check supervision values in MEL_CIII_Gas and MEL_CIII_Main displays			
Tester:	**JD**	**Date:**	**4/11/2003**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas Supervision screen set Pressure Set point to 100 mb			
2	Apply 1.95 – 2.05 V to AI 05 (CIII_MV_P)			
3	In the MEL_CIII_Gas Supervision screen check Pressure value	250±12.5 mb	OK	
4	Wait 15 minutes.			
5	Check in the Alarm Area the pressure alarm status	Alarm	OK	
6	In the MEL_CIII_Gas Supervision screen set DO set point to 80%			
7	Apply 4.65 – 4.75 V to AI 01 and AI 02 (CIII_MV_DO top/bottom)			
8	In the MEL_CIII_Gas Supervision screen check DO value	92.5±1.25 %	OK	
9	Check in the Alarm Area the DO alarm status	Alarm	OK	
10	Apply 4.15 – 4.25 V to AI 01 and AI 02 (CIII_MV_DO top/bottom)			
11	In the MEL_CIII_Gas Supervision screen check DO value	80±1.25 %	OK	
12	Check in the Alarm Area the DO alarm status	OK	OK	
13	Apply 3.65 – 3.75 V to AI 01 and AI 02 (CIII_MV_DO top/bottom)			
14	Check in the Alarm Area the DO alarm status	Alarm	OK	

5.7 MEL-CIII-TP-07 Temperature regulation

5.7.1 MEL-TC-CIII-0701: Temperature regulation

TC Identifier	MEL-TC-CIII-0701	Purpose:	Verify that when temperature goes under the set point the heater is activated with a pulse action and when is over the set point the cooling valve is opened
Items Tested	CIII_PLCSW_Temp, MEL_CIII_Temp, MEL_CIII_Main		
Description	When temperature goes under the set point, the heater is activated with a pulse action and cooling valve is opened.		
Special Requisites:	1 APS is used to simulate Temperature sensors. Check supervision values in MEL_CIII_Temp and MEL_CIII_Main displays		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Temp set control mode to AUTO			
2	Apply a light to DO 06 and DO 05 (CIII_AC_Heat, CIII_AC_CV in the CIII_AC_CP)			
3	In the MEL_CIII_Temp, set Temp ramp parameter to 30 seconds.			
4	In the MEL_CIII_Temp, check Temp set point (initial value)	28º C	OK	
5	Apply 1.70 – 1.80 V to AI 09 (Temperature bottom)			
6	In the MEL_CIII_Temp, check Temperature bottom value	27.725±1.8º C	OK	
7	Apply 1.70 – 1.80 V to AI 10 (Temperature top)			
8	In the MEL_CIII_Temp, check Temperature top value	27.725±1.8º C	OK	Fixed document
9	Apply 1.70 – 1.80 V to AI 09, AI 10 (Temperature bottom/top)			
10	In the MEL_CIII_Temp, check Temperature value	27.725±1.8º C	OK	
11	Apply 1.80 – 1.90 V to AI 09, AI 10 (Temperature bottom/top)			
12	In the MEL_CIII_Temp, check Temperature value	31.935±1.8º C	OK	
13	Check DO 05 light (CIII_AC_CV)	On	OK	
14	In the MEL_CIII_Temp check cooling valve status	Open	OK	
15	Apply 1.60 – 1.70 V to AI 09, AI 10 (Temperature bottom/top)			
16	In the MEL_CIII_Temp, check Temperature value	24.04±1.8º C	OK	
17	Check DO 05 light (CIII_AC_CV)	Off	OK	

TC Identifier	MEL-TC-CIII-0701	Purpose:	Verify that when temperature goes under the set point the heater is activated with a pulse action and when is over the set point the cooling valve is opened
Items Tested	CIII_PLCSW_Temp, MEL_CIII_Temp, MEL_CIII_Main		
Description	When temperature goes under the set point, the heater is activated with a pulse action and cooling valve is opened.		
Special Requisites:	1 APS is used to simulate Temperature sensors. Check supervision values in MEL_CIII_Temp and MEL_CIII_Main displays		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
18	Check DO 06 light (CIII_AC_Heater) status every 5 seconds (shall be 5 seconds blinking, 5 seconds off)	On	OK	
19	Apply 1.70 – 1.80 V to AI 09 (Temperature bottom)			
20	In the MEL_CIII_Temp, check Temperature bottom value	27.725±1.8º C	OK	
21	Check DO 05, DO 06 lights (CIII_AC_CV, CIII_AC_Heater)	Off	OK	

5.7.2 MEL-TC-CIII-0702: Temperature alarms

TC Identifier	**MEL-TC-CIII-0702**	**Purpose:**	Verify that when temperature goes under the set point the heater is activated with a pulse action and when is over the set point the cooling valve is opened
Items Tested	CIII_PLCSW_Temp, MEL_CIII_Temp, MEL_CIII_Main		
Description	When temperature goes under the set point, the heater is activated with a pulse action and cooling valve is opened.		
Special Requisites:	1 APS is used to simulate Temperature sensors. Check supervision values in MEL_CIII_Temp, CIII_MEL_Liquid and MEL_CIII_Main displays		
Tester:	**JD**	**Date:**	**4/11/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Temp set control mode to AUTO			
2	In the MEL_CIII_Temp, check Temp set point (initial value)	28º C	OK	
3	In the MEL_CIII_Liquid, set Liquid Input flow rate set point to 0.4 l/h			
4	Apply 1.45 – 1.55 V to AI 09 (Temperature bottom)			
5	In the MEL_CIII_Temp, check Temperature bottom value	18.55±1.8º C	OK	
6	In the MEL_CIII_Temp, check Temperature value	20.44±1.8º C	OK	
7	Check in the Alarm Area the Temperature deviation alarm status	Alarm	OK	
8	Check in the MEL_CIII_Liquid, the Liquid input flow rate	0±0.1 l/h	OK	
9	Apply 1.70 – 1.80 V to AI 09 (Temperature bottom)			
10	In the MEL_CIII_Temp, check Temperature value	27.725±1.8º C	OK	
11	Check in the Alarm Area the Temperature deviation alarm status	OK	OK	
12	Apply 2.45 – 2.55 V to AI 10 (Temperature top)			
13	In the MEL_CIII_Temp, check Temperature top value	55.25±1.8º C	OK	
14	In the MEL_CIII_Temp, check Temperature value	33.45±1.8º C	OK	
15	Check in the Alarm Area the Temperature deviation alarm status	Alarm	OK	
16	Apply 1.70 – 1.80 V to AI 10 (Temperature top)			
17	In the MEL_CIII_Temp, check Temperature value	27.725±1.8º C	OK	
18	Check in the Alarm Area the Temperature deviation alarm status	OK	OK	

5.8 MEL-CIII-TP-08: Initial Values

TC Identifier	**MEL-CIII-TP-08**	**Purpose**	**Check that correct initial values are used at PLC restart**		
Tester: JD		**Date:**	**5/11/2003**		
Variable name	**Type**	**Address**	**Init. Value**	**Description**	**OK**
CIII_CNS_CO2Kp	real	400522	5	Additional proportional constant for CO2	OK
CIII_CNS_DOBias	real	400518	0	Disturbance variable (Feed_fw) for DO PID	OK
CIII_CNS_DOKd	real	400516	0.0033	Derivative constant for DO PID	OK
CIII_CNS_DOKi	real	400514	3000	Integrative constant for DO PID	OK
CIII_CNS_DOKp	real	400512	12	Proportional constant for DO PID	OK
CIII_CNS_Doramp	real	400588	0.016	DO supervision set point ramp coefficient	OK
CIII_CNS_LinA	real	400584	73.5294	Input pump calibration constant parameter A	OK
CIII_CNS_LinB	real	400586	0.1765	Input pump calibration constant parameter B	OK
CIII_CNS_LoA	real	400598	0	Output pump calibration constant parameter A	OK
CIII_CNS_LoB	real	400600	0	Output pump calibration constant parameter B	OK
CIII_CNS_N2Kp	real	400614	0.5	Proportional constant for N2 regulation	OK
CIII_CNS_OpModeDO	int	400568	0	DO control operational mode (0=Off, 1=Auto, 2=Manual)	OK
CIII_CNS_OpModeGas	int	400566	0	Gas control operational mode (0=Off, 1=Auto, 2=Manual)	OK
CIII_CNS_OpModeL	int	400565	0	Liquid control operational mode (0=Off, 1=Auto, 2=Manual)	OK
CIII_CNS_OpModepH	int	400612	0	pH control operational mode (0=Off, 1=Auto, 2=Manual)	OK
CIII_CNS_OpModeT	int	400567	0	Temperature control operational mode (0=Off, 1=Auto, 2=Manual)	OK
CIII_CNS_pHKi	real	400510	3000	Integration constant for Acid/Base PI	OK
CIII_CNS_pHKp	real	400508	3	Proportional constant for Acid/Base PI	OK
CIII_CNS_pHMode	int	400554	1	PH regulation mode variable (1=CO2 only, 2=CO2+Base, 3=Base+Acid)	OK
CIII_CNS_pHramp	real	400560	0.005	pH supervision set point ramp coefficient	OK
CIII_CNS_Tramp	real	400556	0.0083	Temperature supervision set point ramp coefficient	OK
CIII_MAN_Ac	real	400570	0	Manual acid pump set point	OK
CIII_MAN_Bs	real	400572	0	Manual base pump set point	OK
CIII_MAN_CO2	real	400574	0	Manual CO2 flow controller set point	OK
CIII_MAN_EnAc	Bool	000190	0	Manual enable of acid pump	OK

TC Identifier	**MEL-CIII-TP-08**		**Purpose**	**Check that correct initial values are used at PLC restart**	
Tester:	**JD**		**Date:**	**5/11/2003**	
Variable name	**Type**	**Address**	**Init. Value**	**Description**	**OK**
CIII_MAN_EnBs	Bool	000191	0	Manual enable of base pump	OK
CIII_MAN_EnCV	Bool	000192	0	Manual enable of the cooling valve	OK
CIII_MAN_EnHT	Bool	000193	0	Manual enable of the heater	OK
CIII_MAN_EnLOBT	Bool	000195	0	Manual enable of buffer output pump	OK
CIII_MAN_EnP	Bool	000194	0	Manual enable of pressure safety valve	OK
CIII_MAN_Lin	real	400576	0	Manual liquid input pump set point	OK
CIII_MAN_LO	real	400578	0	Manual liquid output pump set point	OK
CIII_MAN_N2	real	400580	0	Manual N2 flow controller set point	OK
CIII_MAN_O2	real	400582	0	Manual O2 flow controller set point	OK
CIII_SSP_DO	real	400520	80	DO Supervision set point	OK
CIII_SSP_L1Lin	real	400524	0	Level 1 liquid input supervision set point	OK
CIII_SSP_L2Lin	real	400542	0	Level 2 liquid Input supervision set point	OK
CIII_SSP_P	real	400526	80	Pressure supervision set point	OK
CIII_SSP_pH	real	400504	8	pH supervision set point	OK
CIII_SSP_T	real	400500	28	Temperature supervision set point	OK

5.9 MEL-CIII-TP-09: Check Sensor / Actuator Link Errors

5.9.1 MEL-TC-CIII-0901: Check Link Errors on Analogue Inputs

TC Identifier	**MEL-TC-CIII-0901**	**Purpose:**	Verify that when a current analogue input connection is broken is notified to supervision
Functions Tested	CIII_PLCSW		
Description	Errors on sensor links are displayed in the supervision as alarms and safety values are displayed blinking in the supervision screens.		
Special Requisites:	All current inputs shall be disconnected		
Tester:		**Date:**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Temp supervision display set Temperature set point to 28			
2	In the MEL_CIII_Temp supervision display check Temperature bottom value	28 (Blinking)	OK	
3	In the MEL_CIII_Temp supervision display check Temperature top value	28 (Blinking)	OK	
4	In the MEL_CIII_Gas supervision display set DO(%) set point to 80			
5	In the MEL_CIII_Gas supervision display check DO(%) bottom value	80 (Blinking)	OK	
6	In the MEL_CIII_Gas supervision display check DO(%) top value	80 (Blinking)	OK	
7	In the MEL_CIII_Gas supervision display check Pressure value	80 (Blinking)	OK	
8	In the MEL_CIII_Liquid supervision display check NH4 value	0.0 (Blinking)	OK	
9	In the MEL_CIII_Liquid supervision display check NO3 value	0.0 (Blinking)	OK	
10	In the MEL_CIII_pH supervision display check pH bottom value	8.0 (Blinking)	OK	
11	In the MEL_CIII_pH supervision display check pH top value	8.0 (Blinking)	OK	
12	In the MEL_CIII_Main supervision display check Pressure value	80 (Blinking)	OK	
13	In the MEL_CIV_Main supervision display check DO value	640 (Blinking)	OK	Fixed doc
14	In the MEL_CIV_Main supervision display check NH4 value	0.0 (Blinking)	OK	
15	In the MEL_CIV_Main supervision display check NO3 value	0.0 (Blinking)	OK	
16	In the MEL_CIV_Main supervision display Temperature value	28.0 (Blinking)	OK	
17	In the MEL_CIV_Main supervision display pH value	8.0 (Blinking)	OK	

TC Identifier	MEL-TC-CIII-0901	Purpose:	Verify that when a current analogue input connection is broken is notified to supervision	
Functions Tested	CIII_PLCSW			
Description	Errors on sensor links are displayed in the supervision as alarms and safety values are displayed blinking in the supervision screens.			
Special Requisites:	All current inputs shall be disconnected			
18	Check following alarms are fired: - Alarm to notify Temperature sensor link error - Alarm to notify DO sensor link error - Alarm to notify NO3 sensor link error - Alarm to notify NH4 sensor link error - Alarm to notify pressure sensor link error - Alarm to notify pH sensor link error		OK	

5.9.2 MEL-TC-CIII-0802: Check Link Errors on Analogue Outputs

TC Identifier	MEL-TC-CIII-0802	Purpose:	Verify that when a current analogue output connection is broken is notified to supervision	
Functions Tested	CIII_PLCSW			
Description	Errors on actuator links are displayed in the supervision as alarms			
Special Requisites:	All current outputs shall be disconnected			
Tester:		Date:		
Course of Actions				
Step no	Description	Expected value	OK/NOK	Comments
1	Check following alarms are fired: - Alarm to notify acid pump link error - Alarm to notify base pump link error - Alarm to notify liquid input link error - Alarm to notify liquid output link error		OK	

6 HMI DISPLAYS

6.1 MEL-HMI-TP-01 Check CIII HMI Displays

6.1.1 MEL-TC-HMI-0101: Check CIII_HMI_Temp

TC Identifier	**MEL-TC-HMI-0101**	**Purpose:**	Verify that values in CIII_HMI_Te,mp are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Temp		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltages.		
Tester:	**JCM**	**Date:**	**10/11/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	Apply 2.9 – 3.1 V to AI 09 (CIII_MV_Tb) and check the displayed value Temperature in the Supervision screen CIII_HMI_Temp.	73.6±4.3 mbar	OK	
2	Apply 2.9 – 3.1 V to AI 10 (CIII_MV_Tt) and check the displayed value Temperature in the Supervision screen CIII_HMI_Temp.	73.6±4.3 mbar	OK	
3	Apply 2.9 – 3.1 V to AI 09, AI 10 (CIII_MV_Tb, CIII_MV_Tt) and check the displayed value Temperature in the Supervision screen CIII_HMI_Temp.	73.6±4.3 mbar	OK	
4	Check temperature value in the CIII_HMI_Main display.	73.6±4.3 mbar	OK	
5	In the MEL_CIII_Temp Supervision display change the temperature set point to 27 º C			
6	Check the Temperature set point in the CIII_HMI_Temp display (note ramp action)	down to 27º C	OK	
7	In the MEL_CIII_Temp Supervision display change the control mode to AUTO			
8	Check the operational mode changed accordingly in the CIII_HMI_Temp display	AUTO	OK	
9	In the MEL_CIII_Temp Supervision display change the control mode to MAN			
10	Check the operational mode changed accordingly in the CIII_HMI_Temp display	MAN	OK	
11	In the MEL_CIII_Temp Supervision display edit manual values and set: - Heater enabled. - Cooling valve enabled.			
12	Check in the CIII_HMI_Temp display status of Heater and the Cooling Valve.	Enabled	OK	

6.1.2 MEL-TC-HMI-0102: Check CIII_HMI_pH display

TC Identifier	**MEL-TC-HMI-0102**	**Purpose:**	Verify that values in CIII_HMI_pH are displayed according to specifications.	
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_pH, CIII_HMI_Gas			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:	**JCM**	**Date:**	**11/11/2003**	

Step no	**Description**	**Expected value**	**OK/NOK**	**Comments**
1	Apply 2.9 – 3.1 V to AI 06 (CIII_MV_PHb) and check the displayed value pHbot in the Supervision screen CIII_HMI_pH.	8.0±0.25 pH	OK	
2	Apply 2.9 – 3.1 V to AI 07 (CIII_MV_PHt) and check the displayed value pHtop in the Supervision screen CIII_HMI_pH.	6.5±0.25 pH	OK	
3	Apply 2.9 – 3.1 V to AI 06 and AI 07 (CIII_MV_PHb, CIII_MV_PHt) and check the displayed value pH in the HMI screen CIII_HMI_pH.	7.85±0.25 pH	OK	
4	Check pH value in the HMI screen CIII_HMI_Main	7.85±0.25 pH	OK	
5	In the MEL_CIII_pH Supervision display change the pH set point to 9			
6	Check the pH set point in the CIII_HMI_pH display (note ramp action) in 3 minutes	up to 9 pH	OK	Fixed doc.
7	In the MEL_CIII_pH Supervision display change the control mode to AUTO			
8	Check the operational mode changed accordingly in the CIII_HMI_pH display	AUTO	OK	
9	In the MEL_CIII_pH Supervision display change the pH operation mode to 2=CO2+Base			
10	Check the pH operation mode changed accordingly in the CIII_HMI_pH display	2	OK	
11	In the MEL_CIII_pH Supervision display change the pH operation mode to 3=Acid+Base			
12	Check the pH operation mode changed accordingly in the CIII_HMI_pH display	3	OK	
13	In the MEL_CIII_pH Supervision display change the control mode to MAN			
14	Check the operational mode changed accordingly in the CIII_HMI_pH display	MAN	OK	
15	In the MEL_CIII_pH Supervision display edit manual values and set: - Acid pump enabled - Acid pump control action 10%. - Base pump enabled - Base pump control action 20%. - CO2 valve at 30%			

TC Identifier	MEL-TC-HMI-0102	Purpose:	Verify that values in CIII_HMI_pH are displayed according to specifications.	
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_pH, CIII_HMI_Gas			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:	JCM	Date:	11/11/2003	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
16	Check in CIII_HMI_pH acid pump control action	10%	OK	
17	Check in CIII_HMI_pH base pump control action	20%	OK	
18	Check in CIII_HMI_pH CO2 valve control action	30%	OK	
19	Check in CIII_HMI_Gas CO2 valve control action	30%	OK	
20	Check acid and base pump status	Enabled	OK	
21	In the MEL_CIII_pH Supervision display change the control mode to OFF			
22	Check the operational mode changed accordingly in the CIII_HMI_pH display	OFF	OK	
23	Check acid, base, CO2 control actions	0.0	OK	
24	Check acid, base pumps status	Disabled	OK	

6.1.3 MEL-TC-HMI-0103: Check CIII_HMI_Liquid display

TC Identifier	**MEL-TC-HMI-0103**	**Purpose:**	Verify that values in CIII_HMI_Liquid are displayed according to specifications.	
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Liquid, MEL_HMI_Main			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:	**JCM**	**Date:**	**11/11/2003**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
	In the MEL_CIII_Liquid Supervision display change the Level 2 Liquid Input set point to 0,4			
1	Check Level 2 Liquid input set point value in the HMI screen CIII_HMI_Liquid	0,4	OK	
2	Using iFix Database Manager change the Level 1 Liquid Input set point to 0,4			
3	Check Level 1 Liquid input set point value in the HMI screen CIII_HMI_Liquid	0,4	OK	
4	Check in the CIII_HMI_Liquid display the Liquid Level Low indicator status	Enabled	OK	
5	Apply a resistance to DI 04 (Level High)			
6	Check in the CIII_HMI_Liquid display the Liquid Level High indicator status	Enabled	OK	
7	In the MEL_CIII_Liquid Supervision display change the control mode to AUTO			
8	Check in the CIII_HMI_Liquid display the control mode value	AUTO	OK	
9	Check Liquid input flow rate value in the HMI screen CIII_HMI_Liquid	0,4	OK	
10	Check Liquid input flow rate value in the HMI screen CIII_HMI_Main	0,4	OK	
11	Check Liquid input flow rate value in the HMI screen MEL_HMI_Main	0,4	OK	
12	Check Liquid input pump control action in the HMI screen CIII_HMI_Liquid	29.59%	OK	
13	Check Liquid output pump control action in the HMI screen CIII_HMI_Liquid	36.99%	OK	
14	Apply a resistance to DI 05 (CIII_MVO_Lbt)			
15	Check in the CIII_HMI_Liquid display the Buffer tank level high indicator	Enabled	OK	
16	Check in the CIII_HMI_Liquid display the Buffer tank output pump status	ON	OK	
17	In the MEL_CIII_Liquid Supervision display change the control mode to MAN			
18	Check in the CIII_HMI_Liquid display the control mode value	MAN	OK	
19	In the MEL_CIII_Liquid Supervision display edit manual values and set: - Liquid input pump control action 10% - Liquid output pump control action 20%. - Buffer output pump enabled			

TC Identifier	MEL-TC-HMI-0103	Purpose:	Verify that values in CIII_HMI_Liquid are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Liquid, MEL_HMI_Main		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:	JCM	Date:	11/11/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
20	Check in the CIII_HMI_Liquid display the Liquid input pump control action	10%	OK	
21	Check in the CIII_HMI_Liquid display the Liquid output pump control action	20%	OK	
22	Check in the CIII_HMI_Liquid display the Buffer tank pump status	ON	OK	
23	Apply 2.9 – 3.1 V to AI 03 (CIII_MV_NH4) and check NH4 value in the HMI display CIII_HMI_Liquid	100±5 ppm	OK	
24	Check NH4 value in the HMI screen CIII_HMI_Main	100±5 ppm	OK	
25	Apply 2.9 – 3.1 V to AI 04 (CIII_MV_NO3) and check NO3 value in the HMI display CIII_HMI_Liquid	500±25 ppm	OK	
26	Check NO3 value in the HMI screen CIII_HMI_Main	500±25 ppm	OK	
27	Using iFix Data Manager set 5 to CIII_SMV_NO2	30%	OK	
28	Check in the CIII_HMI_Liquid display the NO2 value	5	OK	
29	Check in the MEL_HMI_Main display the NO2 value	5	OK	
30	Check NO2 value in the HMI screen CIII_HMI_Main	5	OK	
31	In the MEL_CIII_Liquid Supervision display change the control mode to OFF			
32	Check the operational mode changed accordingly in the CIII_HMI_Liquid display	OFF	OK	
33	Check input and output pump control action values	0.0	OK	
34	Check buffer pump status	Disabled	OK	

6.1.4 MEL-TC-HMI-0104: Check CIII_HMI_Gas display

TC Identifier	**MEL-TC-HMI-0104**	**Purpose:**	Verify that values in CIII_HMI_Gas are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Gas		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:	**JCM**	**Date:**	**11/11/2003**

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	In the MEL_CIII_Gas Supervision display change the DO set point to 85%			
2	Check in the CIII_HMI_Gas display the DO set point value (note ramp action) in 5 minutes	up to 85%	OK	
3	Apply 2.9 – 3.1 V to AI 01 (CIII_MV_Dob) and check DO bottom value in CIII_HMI_Gas display.	50±2.5%	OK	
4	Apply 2.9 – 3.1 V to AI 02 (CIII_MV_Dot) and check DO top value in CIII_HMI_Gas display.	50±2.5%	OK	
5	Apply 2.9 – 3.1 V to AI 01 and AI 02 (CIII_MV_Dob, CIII_MV_Dot) and check DO value in CIII_HMI_Gas display.	50±2.5%	OK	
6	Check in the CIII_HMI_Main display the DO value	50±2.5%	OK	
7	Check in the MEL_HMI_Main display the DO value	50±2.5%	OK	
9	In the MEL_CIII_Gas Supervision display change the DO control mode to AUTO			
10	Check in the CIII_HMI_Gas display the DO control mode value	AUTO	OK	
11	In the MEL_CIII_Gas Supervision display change the DO control mode to MAN			
12	Check in the CIII_HMI_Gas display the DO control mode value	MAN	OK	
13	In the MEL_CIII_Gas Supervision display edit manual values and set: - O2 control action to 10% - N2 Liquid output pump control action 20%.			
14	Check O2 valve control action in the HMI screen CIII_HMI_Gas	10%	OK	
15	Check N2 valve control action in the HMI screen CIII_HMI_Gas	20%	OK	
16	Apply 2.9 – 3.1 V to AI 05 (CIII_MV_P) and check P value in CIII_HMI_Gas display.	500±2.5 mbar	OK	
17	Check in the CIII_HMI_Main display the P value			
18	In the MEL_CIII_Gas Supervision display change the Gas control mode to MAN			
19	Check in the CIII_HMI_Gas display the Gas control mode value	MAN	OK	
20	In the MEL_CIII_Gas Supervision display change the Gas control mode to AUTO			

TC Identifier	MEL-TC-HMI-0104	Purpose:	Verify that values in CIII_HMI_Gas are displayed according to specifications.
Functions Tested	Interface between HMI – CIII_PLC, CIII_HMI_Main, CIII_HMI_Gas		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:	JCM	Date:	11/11/2003

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
21	Check in the CIII_HMI_Gas display the Gas control mode value	AUTO	OK	
22	In the MEL_CIII_Gas Supervision display change the P set point to 200 mbar			
23	Check in the CIII_HMI_Gas display the Pressure set point	200 mbar	OK	
24	Check in the CIII_HMI_Gas display the Safety Pressure Valve status	OPEN (green)	OK	
25	In the MEL_CIII_Gas Supervision display change the P set point to 500 mbar			
26	Check in the CIII_HMI_Gas display the Safety Pressure Valve status	CLOSED (red)	OK	

6.2 MEL-HMI-TP-02 Check CIV_HMI_Displays

DEVIATION NOTICE

A deviation on the execution of the defined test procedures was needed due to the fact that the verification of HMI displays belonging to compartment IV was performed in the Pilot Plant at UAB and the test procedures were designed to be executed in NTE premises. Therefore it was not needed to use external signals to provide meaningful values to display variables. In addition, set point values were not manipulated in order to not interfere with the process. The verification was performed checking that the values displayed in the supervision displays, which were already validated, were the same that in HMI displays. Hence, steps not executed are erased.

6.2.1 MEL-TC-HMI-0201: Check CIV_HMI_pH display

TC Identifier	**MEL-TC-HMI-0201**	**Purpose:**	Verify that values in CIV_HMI_pH are displayed according to specifications.	
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_pH, CIV_HMI_Gas			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:	**JD**	**Date:**	**14/04/2004**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	~~Apply 2.9 – 3.1 V to AI 05 (CIV_MV_pH) and check the displayed value pH in the HMI screen CIV_HMI_pH.~~	7.0±0.35 pH	N/A	See Deviation Notice above.
2	Check pH value in the HMI screen CIV_HMI_Main	7.0±0.35 pH	OK	Actual supervision value was 9.35
3	~~In the MEL_CIV_pH Supervision display change the pH set point to 9~~			See Deviation Notice above.
4	Check the pH set point in the CIV_HMI_pH display	~~9~~ 9.50	OK	Actual supervision value was 9.50
5	In the MEL_CIV_pH Supervision display change the control mode to AUTO			
6	Check the operational mode changed accordingly in the CIV_HMI_pH display	AUTO	OK	
7	In the MEL_CIV_pH Supervision display change the control mode to MAN			

TC Identifier	MEL-TC-HMI-0201	Purpose:	Verify that values in CIV_HMI_pH are displayed according to specifications.	
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_pH, CIV_HMI_Gas			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:	JD		Date:	14/04/2004

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
8	Check the operational mode changed accordingly in the CIV_HMI_pH display	MAN	OK	
9	~~In the MEL_CIV_pH Supervision display edit manual values and set:~~ ~~- Acid pump control action 10%~~ ~~- Base pump control action 20%.~~ - ~~CO2 valve control action 2,5 nLm~~		N/A	See Deviation Notice above
10	Check in CIV_HMI_pH acid pump control action	~~10~~ 0.0%	OK	Actual supervision value was 0.0%
11	Check in CIV_HMI_pH base pump control action	~~20~~ 0.0%	OK	Actual supervision value was 0.0%
12	Check in CIV_HMI_pH CO2 valve control action	~~2,5~~ 0.125 nLm	OK	Actual supervision value was 0.125 nLm
13	Check in CIV_HMI_Gas CO2 valve control action	~~2,5~~ 0.125 nLm	OK	Actual supervision value was 0.125 nLm
14	~~In the MEL_CIV_pH Supervision set CO2 offset to 1,5 nLm~~		N/A	See Deviation Notice above.
15	~~Check the CO2 offset changed accordingly in the CIV_HMI_pH display~~	1,5	N/A	See Deviation Notice above.
16	In the MEL_CIV_pH Supervision set pH control mode to 2=CO2 + Base			
17	Check the pH control mode changed accordingly in the CIV_HMI_pH display	2	OK	
18	In the MEL_CIV_pH Supervision set pH control mode to 3=Acid + Base			
19	Check the pH control mode changed accordingly in the CIV_HMI_pH display	3	OK	
20	In the MEL_CIV_pH Supervision display change the operation mode to OFF			
21	Check the operational mode changed accordingly in the CIV_HMI_pH display	OFF	OK	
22	Check acid, base and CO2 control actions	0.0	OK	

6.2.2 MEL-TC-HMI-0202: Check CIV_HMI_BP display

TC Identifier	**MEL-TC-HMI-0202**	**Purpose:**	Verify that values in CIV_HMI_BP are displayed according to specifications.	
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_BP, MEL_HMI_Main			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:	**JD**	**Date:**	**14/04/2004**	
Course of Actions				
Step no	**Description**	**Expected value**	**OK/NOK**	**Comments**
1	~~Apply 2.9 – 3.1 V to AI 02 (CIV_MV_M1) and check the displayed level for input Tank 1 in the HMI screen CIV_HMI_BP.~~	75±3.75 l	N/A	See Deviation Notice above.
2	~~Apply 2.9 – 3.1 V to AI 03 (CIV_MV_M2) and check the displayed level for input Tank 2 in the HMI screen CIV_HMI_BP.~~	75±3.75 l	N/A	See Deviation Notice above.
3	~~Apply 2.9 – 3.1 V to AI 01 (CIV_MV_CxAbs) and check the displayed value for Biomass concentration in the HMI screen CIV_HMI_BP.~~	3.0±0.5 g/l	N/A	See Deviation Notice above.
4	~~In the MEL_CIV_BP Supervision display change the Level 2 Biomass Production Set point to 1,2~~			See Deviation Notice above.
5	Check the Level 2 Biomass production set point changed accordingly in the CIV_HMI_BP display	~~1,2~~ 1.00	OK	Actual supervision value was 1.00
6	~~Using iFix Data Manager change the (CIV_SSP_L1BP) Level 1 Biomass Production Set point to 1,1~~			See Deviation Notice above.
7	Check the Level 1 Biomass production set point changed accordingly in the CIV_HMI_BP display	~~1,1~~ 1.00	OK	Actual supervision value was 1.00. Fixed variable reference since value was initially wrong.
8	In the MEL_CIV_BP Supervision display change the Level 2 Liquid input flow rate Set point to 0,7			
9	Check the Level 2 Liquid input flow rate set point changed accordingly in the CIV_HMI_BP display	~~0,7~~ 0.50	OK	Actual supervision value was 0.50
10	~~Using iFix Data Manager change the (CIV_SSP_L1LiFr) Level 1 Liquid input flow rate Set point to 0,6~~			See Deviation Notice above.
11	Check the Level 1 Liquid input flow rate set point changed accordingly in the CIV_HMI_BP display	~~0,6~~ 0.55	OK	Actual supervision value was 0.55

TC Identifier	MEL-TC-HMI-0202	Purpose:	Verify that values in CIV_HMI_BP are displayed according to specifications.	
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_BP, MEL_HMI_Main			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:	**JD**	**Date:**	**14/04/2004**	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
12	Check the Biomass production rate in the CIV_HMI_BP display	~~0,66~~ 1.00	OK	Actual supervision value was 1.00
13	Check the Biomass production rate in the CIV_HMI_Main display	~~0,66~~ 1.02	OK	Actual supervision value was 1.02
14	Check the Biomass production rate in the MEL_HMI_Main display	~~0,66~~ 1.00	OK	Actual supervision value was 1.00
15	Check the Liquid input flow rate in the CIV_HMI_BP display	~~0,6~~ 0.78	OK	Actual supervision value was 0.78
16	Check the Liquid input flow rate in the CIV_HMI_Main display	~~0,6~~ 0.78	OK	Actual supervision value was 0.78
17	Check the Liquid input flow rate in the MEL_HMI_Main display	~~0,6~~ 0.78	OK	Actual supervision value was 0.78
18	~~Using iFix Data Manager change the (CIV_SSP_LightWm) Light intensity to 150~~			See Deviation Notice above.
19	Check the Light intensity set point in the CIV_HMI_BP display	~~150~~ 40 W/m2	OK	Actual supervision value was 40
20	Check the Light intensity set point in the CIV_HMI_Main display	~~150~~ 40 W/m2	OK	Actual supervision value was 40
21	In the MEL_CIV_BP Supervision display change the operational mode to AUTO			
22	Check the operational mode in the CIV_HMI_BP display	AUTO	OK	
23	In the MEL_CIV_BP Supervision display change the operational mode to MAN			
24	~~In the MEL_CIV_BP Supervision display edit manual values and set:~~ - ~~Enable Biomass sensor aeration valve~~ - ~~Enable Liquid input pump 1~~ - ~~Enable Liquid input pump 2~~ - ~~Enable Liquid output pump~~ - ~~Set liquid input pump 1 set point to 10%~~ - ~~Set liquid input pump 2 set point to 20%~~ - ~~Set liquid output pump set point to 30%~~ - ~~Set light supply regulator set point to 40%~~			See Deviation Notice above.
25	Check in CIV_HMI_BP liquid input pump 1 control action	~~10~~ 26.00%	OK	Actual supervision value was 26.00

TC Identifier	MEL-TC-HMI-0202	Purpose:	Verify that values in CIV_HMI_BP are displayed according to specifications.		
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_BP, MEL_HMI_Main				
Description	Known values applied to PLC variables shall be displayed in the display as specified.				
Special Requisites:	Use an APS to generate voltage values.				
Tester:	JD	Date:	14/04/2004		
Course of Actions					
Step no	Description	Expected value	OK/NOK	Comments	
26	Check in CIV_HMI_BP liquid input pump 2 control action	~~20~~ 0.00%	OK	Actual supervision value was 0.00	
27	Check in CIV_HMI_BP liquid output pump control action	~~30~~ 25.90%	OK	Actual supervision value was 25.90	
28	Check in CIV_HMI_BP light supply control action	~~40~~ 10%	OK	Actual supervision value was 10	
29	Check in CIV_HMI_BP liquid output flow rate	~~2,6~~ 0.59 l/h	OK	Actual supervision value was 0.59	
30	Check in CIV_HMI_Main liquid output flow rate	~~2,6~~ 0.59 l/h	OK	Actual supervision value was 0.59	
31	Check in CIV_HMI_BP liquid input pump 1 status	Enabled (green)	OK		
32	Check in CIV_HMI_BP liquid input pump 2 status	~~Enabled~~ Disabled (red)	OK	Supervision status was disabled	
33	Check in CIV_HMI_BP liquid output pump status	Enabled (green)		Supervision status was enabled	
34	Check in CIV_HMI_BP Biomass sensor aeration valve	~~Open~~ Disabled (red)		Supervision status was disabled	
35	In the MEL_CIV_BP Supervision display change the operational mode to OFF				
36	Check the operational mode in the CIV_HMI_BP display	OFF	OK		
37	Check liquid input/output, and light supply control actions	0,0	OK		

6.2.3 MEL-TC-HMI-0203: Check CIV_HMI_Gas display

TC Identifier	MEL-TC-HMI-0203	Purpose:	Verify that values in CIV_HMI_Gas are displayed according to specifications.	
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_Gas, MEL_HMI_Main			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:		Date:		

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
1	~~Apply 2.9 – 3.1 V to AI 04 (CIV_MV_P) and check the displayed pressure value in the HMI screen CIV_HMI_Gas.~~	0.75±0.375 bar	N/A	See Deviation Notice above.
2	Check in CIV_HMI_Main the pressure value	~~0.75±0.375~~ 0.07 bar	OK	Actual Supervision value was 0.07
3	~~Apply 2.9 – 3.1 V to AI 07 (CIV_MGO_O2) and check the displayed O2 flow rate value in the HMI screen CIV_HMI_Gas.~~	12.5±0.7 nLm	N/A	See Deviation Notice above.
4	Check in CIV_HMI_Main the O2 value	~~12.5±0.7~~ 21.53 nLm	OK	Actual Supervision value was 21.53
5	Check in MEL_HMI_Main the O2 value	~~12.5±0.7~~ 21.53 nLm	OK	Actual Supervision value was 21.53
6	~~Apply 2.9 – 3.1 V to AI 08 (CIV_MGO_CO2) and check the displayed CO2 at gas output value~~	250±15 ppm	N/A	See Deviation Notice above.
7	Check in CIV_HMI_Main the CO2 at output value	~~250±15~~ 0.67 % ~~ppm~~	OK	Actual Supervision value was 0.67%
8	~~Apply 2.9 – 3.1 V to AI 09 (CIV_MV_DO) and check the displayed DO concentration in the HMI screen CIV_HMI_Gas.~~	50±2.5 %	N/A	See Deviation Notice above.
9	~~Apply 2.9 – 3.1 V to AI 13 (CIV_MV_FrGas) and check the displayed gas flow at compartment input (FG-CI) in the HMI screen CIV_HMI_Gas.~~	18±0.6 nLm	N/A	See Deviation Notice above.
10	Check in CIV_HMI_Main the Gas at compartment input flow rate	~~18±0.6~~ 1.99 nLm	OK	Actual Supervision value was 1.99
11	~~Apply 2.9 – 3.1 V to AI 14 (CIV_MGO_FrGas) and check the displayed gas flow at compartment output (FG-CO) in the HMI screen CIV_HMI_Gas.~~	18±0.6 nLm	N/A	See Deviation Notice above
12	~~Apply 2.9 – 3.1 V to AI 15 (CIV_MV_FrCO2) and check the displayed CO2 flow at~~	3±0.1 nLm	N/A	See Deviation Notice above

TC Identifier	MEL-TC-HMI-0203	Purpose:	Verify that values in CIV_HMI_Gas are displayed according to specifications.	
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_Gas, MEL_HMI_Main			
Description	Known values applied to PLC variables shall be displayed in the display as specified.			
Special Requisites:	Use an APS to generate voltage values.			
Tester:		Date:		

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
	~~compartment input in the HMI screen CIV_HMI_Gas.~~			
13	Check in CIV_HMI_Main the CO2 input flow rate	~~3±0.1~~ 0.125 nLm	OK	Actual Supervision value was 0.125
14	~~Apply 2.9 – 3.1 V to AI 16 (CIV_MGI_FrGas) and check the displayed Air flow at compartment input in the HMI screen CIV_HMI_Gas.~~	18±0.6 nLm	N/A	See Deviation Notice above.
15	~~Apply 2.9 – 3.1 V to AI 06 (CIV_MV_T) and check the Temperature value in the HMI screen CIV_HMI_Main.~~	75±3.75 º C	N/A	See Deviation Notice above.
16	~~In the MEL_CIV_Gas Supervision display change the Pressure set point to 0,8~~			See Deviation Notice above.
17	Check in CIV_HMI_Gas the pressure set point	~~0,8~~ 0.025 bar	OK	Actual Supervision value was 0.025
18	~~In the MEL_CIV_Gas Supervision display change the Air input set point to 10~~			See Deviation Notice above.
19	Check in CIV_HMI_Gas the Air input set point	~~10~~ 2.00 nLm	OK	Actual Supervision value was 2,00
20	In the MEL_CIV_Gas Supervision display change the Gas at compartment input set point to 20			
21	Check in CIV_HMI_Gas the Gas at compartment input set point	~~20~~ 1,93 nLm	OK	Actual Supervision value was 1,93
22	~~In the MEL_CIV_Gas Supervision display change the Gas at output set point to 15~~			See Deviation Notice above.
23	~~Check in CIV_HMI_Gas the Gas at compartment input set point~~	15 nLm	N/A	See Deviation Notice above.
24	In the MEL_CIV_Gas Supervision display change the operational mode to AUTO			
25	Check in CIV_HMI_Gas the operational mode	AUTO	OK	
26	In the MEL_CIV_Gas Supervision display change the operational mode to MAN			
27	Check in CIV_HMI_Gas the operational mode	MAN	OK	
28	~~In the MEL_CIV_Gas Supervision display edit manual values and set:~~ - ~~Enable Safety Pressure valve~~			See Deviation Notice above.
29	Check in CIV_HMI_Gas the Safety pressure valve status	~~Open~~ Close (red)	OK	Actual Supervision status was closed
30	In the MEL_CIV_Gas Supervision display change the operational mode to OFF			
31	Check in CIV_HMI_Gas the operational mode	OFF	OK	

TC Identifier	MEL-TC-HMI-0203	Purpose:	Verify that values in CIV_HMI_Gas are displayed according to specifications.
Functions Tested	Interface between HMI – CIV_PLC, CIV_HMI_Main, CIV_HMI_Gas, MEL_HMI_Main		
Description	Known values applied to PLC variables shall be displayed in the display as specified.		
Special Requisites:	Use an APS to generate voltage values.		
Tester:		Date:	

Course of Actions

Step no	Description	Expected value	OK/NOK	Comments
32	Check in CIV_HMI_Gas the Air input, CO2 input, Gas at compartment input, Gas at output set points value	0,0	OK	
33	Check in CIV_HMI_Gas the safety pressure valve status	Closed (red)	OK	

MELISSA

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Functional Test Results and Evaluation

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Document Change Log

Version	Issue	Date	Observations
Draft	0	15 Apr '04	Reviewed. Updated with last alarm tests
1	0	20 Apr '04	First release for ESA review
1	1	28 July '04	ESA comments dates 21/07/04 implemented

TABLE OF CONTENTS

1 SCOPE

This document contains the test report resulting from the execution of the functional test procedures defined in [R7] for the MELISSA Control System Demonstrator after its connection to the MELISSA Plant at the UAB.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**.TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.
[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.
[A3] **Memorandum of Understanding between the UAB and NTE S.A.** MEL-0000-SP-007-NTE. Version 1. Issue 0. 21 January 2002.
[A4] **MELISSA Control System Architecture and Trade-off**. TN 72.3. Version 1. Issue 0. December 2002.

2.2 Reference Documents

[R1] **Definition of the control requirements for the MELISSA Loop**. TN 72.2, v. 1.2, November 2002 (MEL-3100-SP-010-NTE).
[R2] **Photoheterotrophic Compartment Set-up.** TN 37.6. UAB, February 1998.
[R3] **Nitrifying Compartment Studies.** TN 25.310. UAB, September 1996.
[R4] **Set-up of the Photosynthetic Pilot Reactor**. TN. 37.2. UAB, April 1998.
[R5] **Spirulina Controller.** TN 72.3.1, v. 1.0, ADERSA, March 2003.
[R6] **Nitrite Controller.** TN 72.3.2, v. 1.1, ADERSA, October 2003.
[R7] **Control System Demonstrator Test Plan and Procedure.** TN 72.4 VIb, v. 1.1, July 2004 (MEL-3310-PL-039-NTE).
[R8] **Nitrite Controller Test Plan and Procedure.** TN 72.3.4, v. 1.1, SHERPA, February 2004.
[R9] **Test Plan and Procedure for the Spirulina Controller.** TN 72.3.3, v. 1.0, ADERSA, October 2003.

3 INTRODUCTION

This document reports the functional tests carried out on the Control System Demonstrator after its connection to the MELISSA plant at UAB's. Tests were performed during the November 2003 – April 2004 time frame. Firstly, the Compartment IV Rack was integrated into the plant in mid November '03 and the corresponding tests were conducted and ended in mid December'03 when started integration of rack for Compartment III. Tests for Compartment III started on January and lasted until April 2004.

4 CIII FUNCTIONAL TEST RESULTS

4.1 Compartment set up

Connection of sensors and actuators were performed one by one, checking proper connectivity and measured / actuation values. Once a group of sensors and actuators corresponding to a specific loop were checked, the loop was tested end-to-end.

4.1.1 pH control

First test run was performed with pH not in a steady state, due to the transition of the hardware. Therefore, the measured value was below the set point. The loop action was turned on and an over actuation of the base pump was detected. The conclusion was the same parameters of the old PI controller were not appropriate for the new one. A short test session with the old controller was performed to deduce the proper parameters for the new one. After updating the controller with the new parameters, pH was regulated properly.

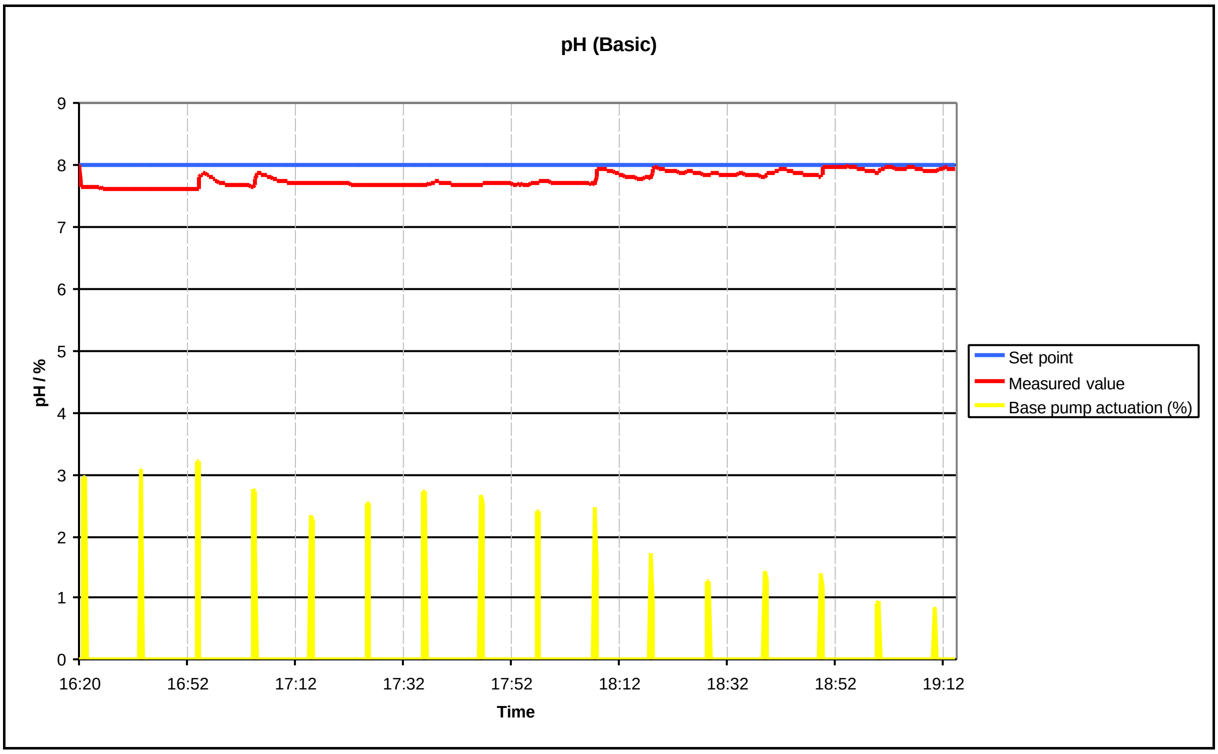

Figure 1. pH (Basic) test result (28 Jan'04)

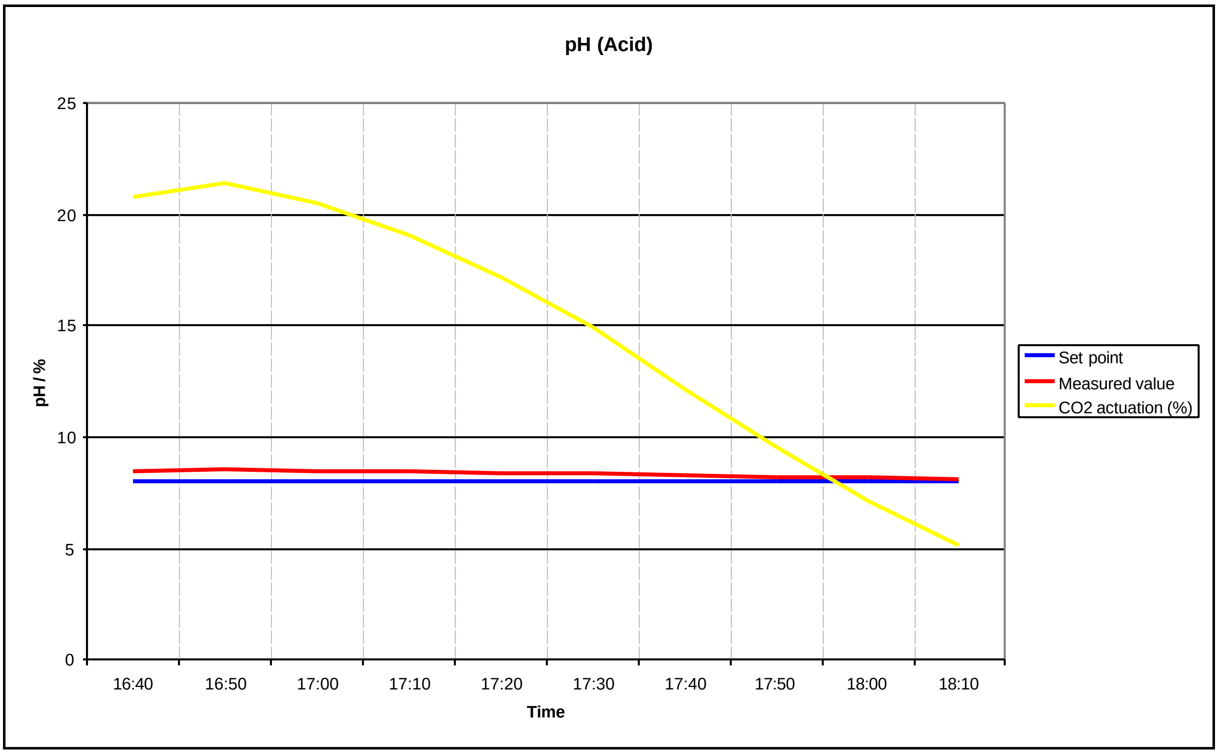

Figure 2. pH (Acid) Test result (5 Feb'2004)

In figures 1 and 2 is detailed the test result. In the figure 1 the set point was 8.0 and measured value was 7.63. The base pump was activated during the programmed periods of time and after 3 h pH finally was 7.93 and therefore inside the dead band. Figure 2 shows pH regulation using CO_2 as an acidifying medium. The pH measured value started at 8.51 and due to the addition of CO_2 after 2 h was fixed to 8.12, which is a value inside the dead band.

A specific test for the acid pump was not performed because control action is the same as for the base pump.

Test Date	**28 Jan and 5 Feb 2004**	**Test Result**	**Success**

4.1.2 Dissolved Oxygen control

The same process as in pH test was followed to determine the Dissolved Oxygen (DO) controller parameters for the new controller. The response to different inputs was measured and the results applied to set the parameters for the DO control of the new PID. When the test started the set point was fixed to 80% and DO measure was 73.89%. After turning on the control loop the system started adding oxygen, and after 1.5 h the DO measure was increased to 77.02%. Test was considered successful because the measured value's trend was correct and within the set point value +/-5%.

No specific test was performed to check the N_2 valve since the regulation is performed using a proportional control action to the O_2 PID response.

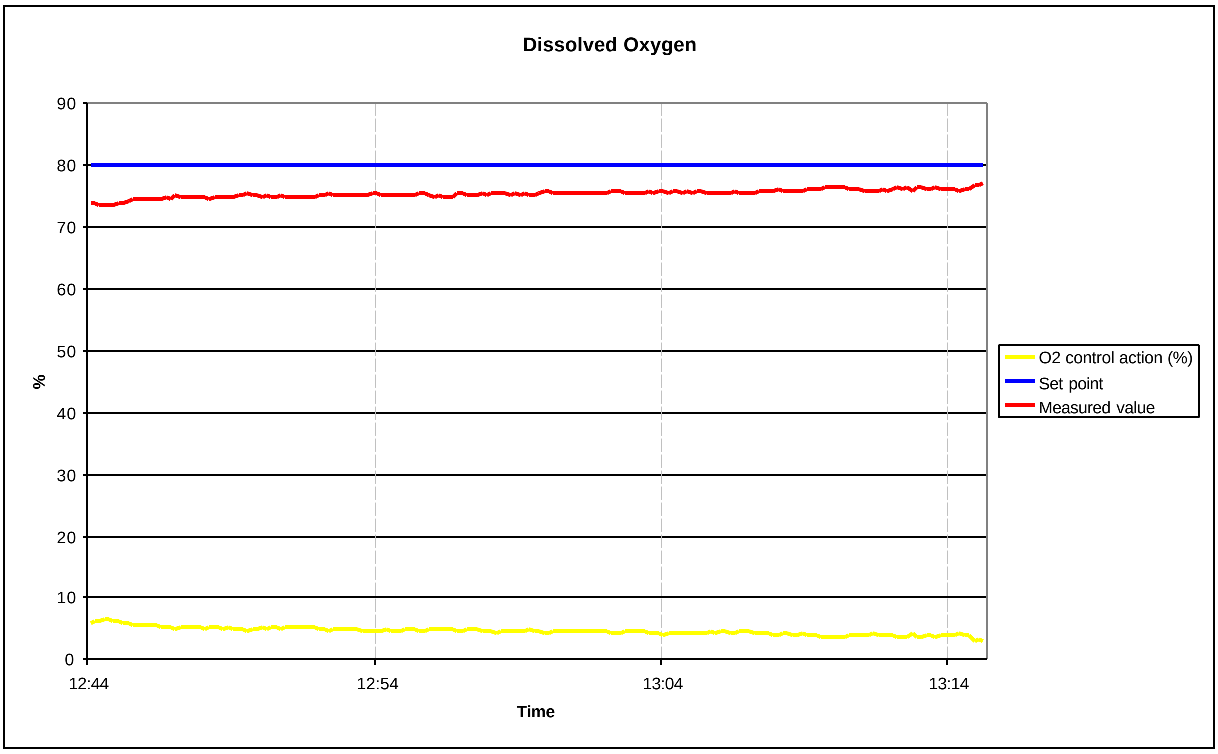

Figure 3. Dissolved Oxygen test result

Test Date	**28 Jan 2004**	**Test Result**	**Success**

4.1.3 Temperature control

Parameters were obtained from the old controller to regulate heater control action. After setting the parameters to the new controller, it was verified that the response of the new controller was equivalent to the old one. During the test preparation it was detected that the bottom temperature sensor was failing at irregular intervals, therefore only a short test was performed to check the loop control end-to-end. At test start temperature measured value was 26.97 ºC and set point was fixed to 28.0 ºC. When control loop was turned on, heater action actuated at programmed intervals and temperature was increased to 27.50 ºC after 30 minutes. Test result can be observed in figure 4. Test was considered successful because the measured value's trend was correct and within the set point value +/-5%.

No specific test was performed to verify the cooling valve since the control action is regulated by an on/off controller.

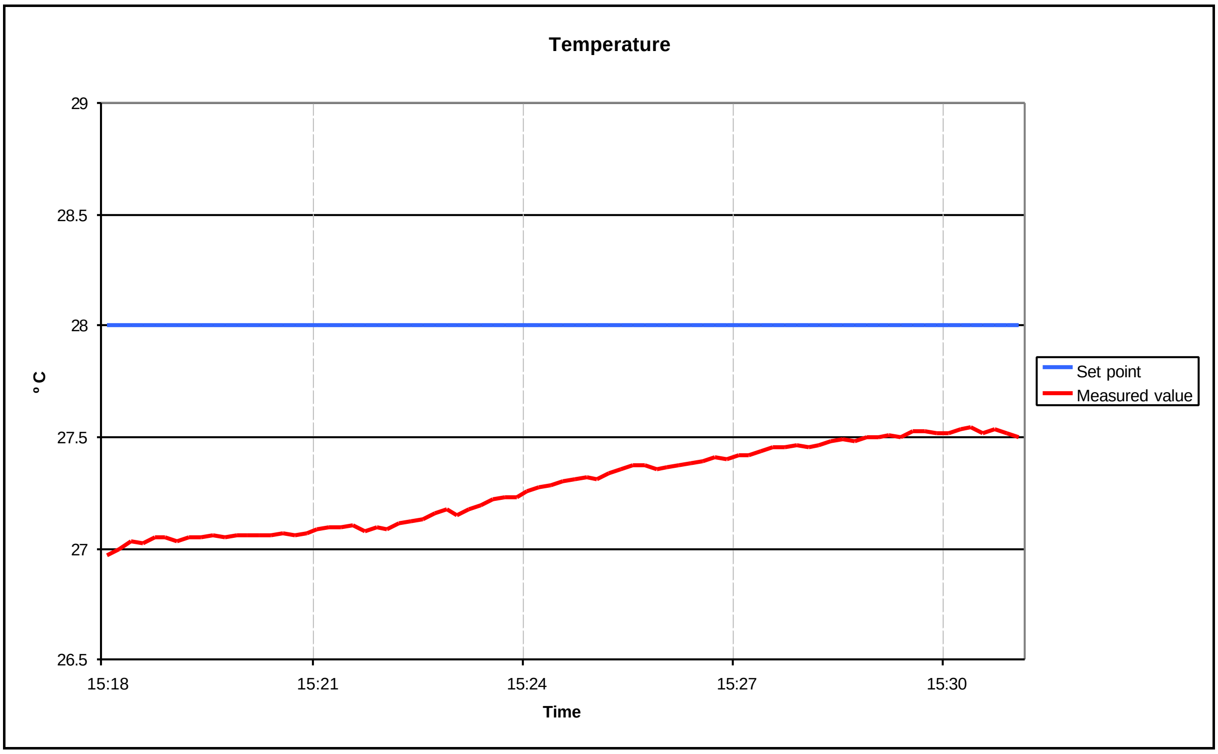

Figure 4. Temperature control test result (28 Jan'04)

Test Date	28 Jan 2004	Test Result	Success

4.1.4 Liquid Level control

To test the level sensors, the input pump was stopped manually to induce the low level signal activation, and reduction of the output pump was observed. To check the high level signal, the high level sensor was manipulated to be located more near the low level and activation was induced and the output pump flow rate was increased according to the control action.

Test Date	28 Jan 2004	Test Result	Success

4.1.5 Pressure control

To test the pressure valve, variations on the set point were performed and control action was verified checking the valve status in the compartment.

Test Date	28 Jan 2004	Test Result	Success

4.2 Alarms

4.2.1 Temperature difference alarm

Temperature difference alarm could be easily verified since the system temperature difference between the two probes was over 5 º C at test start due to the loop mode was OFF. Therefore it was verified that the liquid input pump was stopped. After the activating the loop setting the mode to AUTO it was observed that the global temperature of the reactor increased and the temperature difference between the probes decreased arriving to be less than the alarm condition, and then was verified that the input pump flow was restored.

Test Date	14 April 2004	Test Result	Success

4.2.2 Over temperature alarm

To verify this alarm the set point was decreased more than 1.5 º C under the current value. Because the variations on the set point are regulated by a ramp, the effect was not immediate and also the cooling system was activated. Therefore to have the temperature set point really 1.5 º C under the current value it is necessary to wait several minutes. After this waiting time the alarm was activated and the loop mode was set to OFF.

Test Date	14 April 2004	Test Result	Success

4.2.3 Liquid level alarm

To test the liquid level alarm a short circuit was performed to the liquid level sensor to indicate that the level is high. After waiting 15 minutes the alarm was notified and the liquid input pump was stopped.

Test Date	14 April 2004	Test Result	Success

4.3 Nitrite Estimator

4.3.1 Short Test

First short test was performed on 9th February 2004 the goal was a first checking of the data processing itself. At the end of the test, it was quickly discovered that the values of a few Internal Variables (indices 89 to 130 of vector X) were corrupted consequently to a division by zero. The bug was located in the routine 'estim_3.c' and was due to a set of safety statements put at a wrong place. A new version (Version 1.3) of the controller was sent to NTE to rebuild the controller module and repeat a new short test.

The test was therefore repeated the 16th February 2004. In this case each variable of the implemented control was exactly identical to the corresponding variable of the reference control. So the implemented control passed the short test. Plots of the 155 Internal Variables can be found in [R8].

Test Date	**6 and 9 Feb 2003**	**Test Result**	**Success**

4.3.2 Long Test

The Long test was performed on the 16th February 2004 and consisted in a step of 'requested flow rate' from 0.4 to 0.6 l/h. The 'NO2 constraint' was set to '2.86 10-4 mol/l as in the short test. Variables of the implemented control were exactly identical to the corresponding variables of the reference control. So the implemented control passed the long test and therefore validated.

Even though, it has to be noted that only the implementation (and not the control itself) was validated. As foreseen because of the measurement noise on ammonia and nitrate, the present estimator is inefficient for low concentrations of nitrite.

The Manipulated Variable (control computed flow (blue line) of the bottom graph of the figure 5) is very noisy and tends very slowly to the 'requested flow rate' (green curve).The estimator itself has to be improved.

Test Date	**16 Feb 2003**	**Test Result**	**Success**

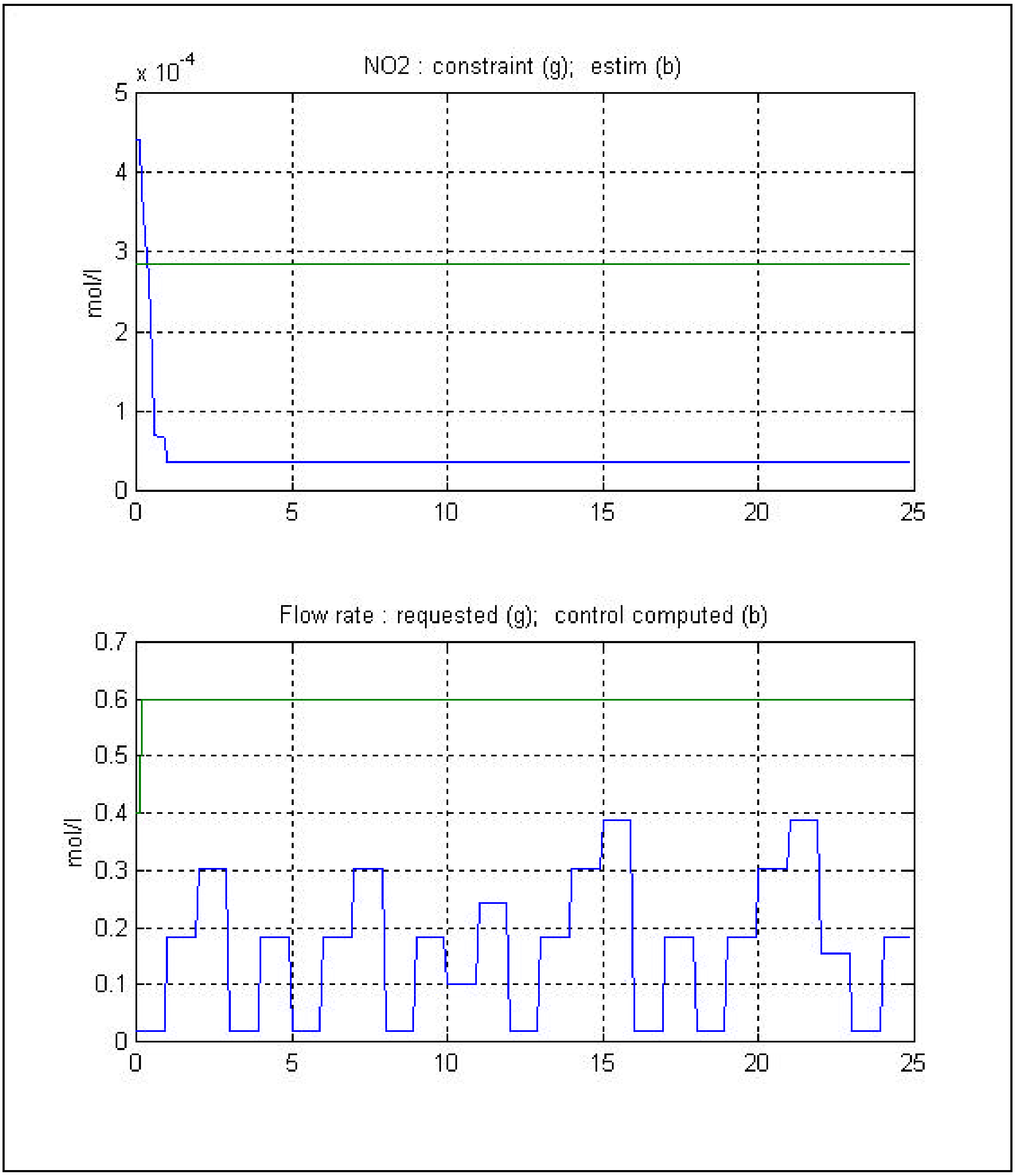

Figure 5. Nitrite Controller long test results.

5 CIV FUNCTIONAL TEST RESULTS

5.1 Set-up

Connection of sensors and actuators were performed one by one, checking proper connectivity and measured / actuation values. Once a group of sensors and actuators corresponding to a specific loop were checked, the loop was tested end-to-end. In addition, due to the compartment was stopped, as part of the set-up test the compartment was started and given to a steady state.

5.1.1 Biomass sensor

Biomass sensor cleaning operation was tested observing the acquired biomass concentration measure during the cleaning operation. No perturbations on the measure were detected. Although, it has to be noted that when air is blown into the sensor conduction, an overpressure is induced during a short period and causes the pressure regulation valve to be opened. Initially air pulse action was 5 seconds long, and due to the overpressure generated pulse was reduced to 1 second.

Test Date	**24 Nov 2003**	**Test Result**	**Success**

5.1.2 Gas flow control

Set points were set one by one to check every flow controller and actuation was measured using a manual manometer and value displayed by the sensor. Over pressure was induced closing the output gas conduct and modification of set points was verified. Similarly the gas input was closed to cause an under pressure and set points were checked as well. It has to be noted that the compartment is usually under pressure because of the gas leaks.

Test Date	**24 Nov 2003**	**Test Result**	**Success**

5.1.3 pH control

The pH control is regulated by a PI. Initially, the parameters were the same as in the old controller but an adjustment was performed to avoid a continuous offset between the set point and the measured value. Firstly, the pH regulation was tested adding CO_2 only, since the compartment behavior caused basification of the medium. The regulation in this mode was enabled during the Biomass Production test. Results can be observed in figure 6. Afterwards, two tests were performed using Acid and Base prepared media.

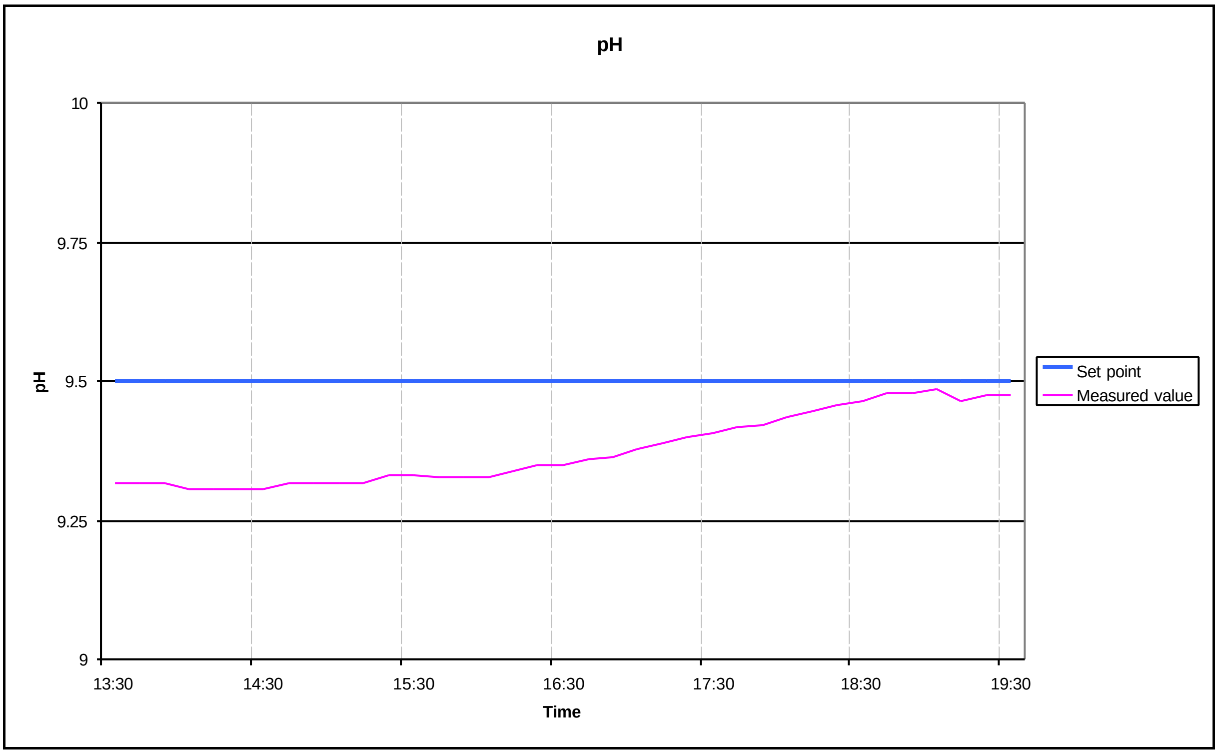

Figure 6. pH test result (27 Nov'03)

Test Date	**27 Nov 2003**	**Test Result**	**Success**

5.2 Alarms

5.2.1 Temperature alarm

Temperature alarm was tested decreasing the set point to a value under the current measure. It was observed that immediately the light was set to a very low value and the liquid input and output pumps were stopped.

Test Date	**27 Nov 2003**	**Test Result**	**Success**

5.2.2 No Gas alarm

To check this alarm gas input was disconnected and it was checked that immediately the light was set to a very low value and liquid input and output pumps were stopped.

Test Date	**5 Feb 2004**	**Test Result**	**Success**

5.3 Biomass Production

5.3.1 Short test

Short test lasted 48 hours. It can be observed in figure 6 that the Controlled Variable (blue line of upper graph of figure) was reaching its set point (red line). The Manipulated Variable (light flux on second graph) was going to its resting value, about 50 W/m^2. The biomass concentration was maintained within its constraints (third graph).
So far, the control worked as expected. After ADERSA acknowledge, test continued.

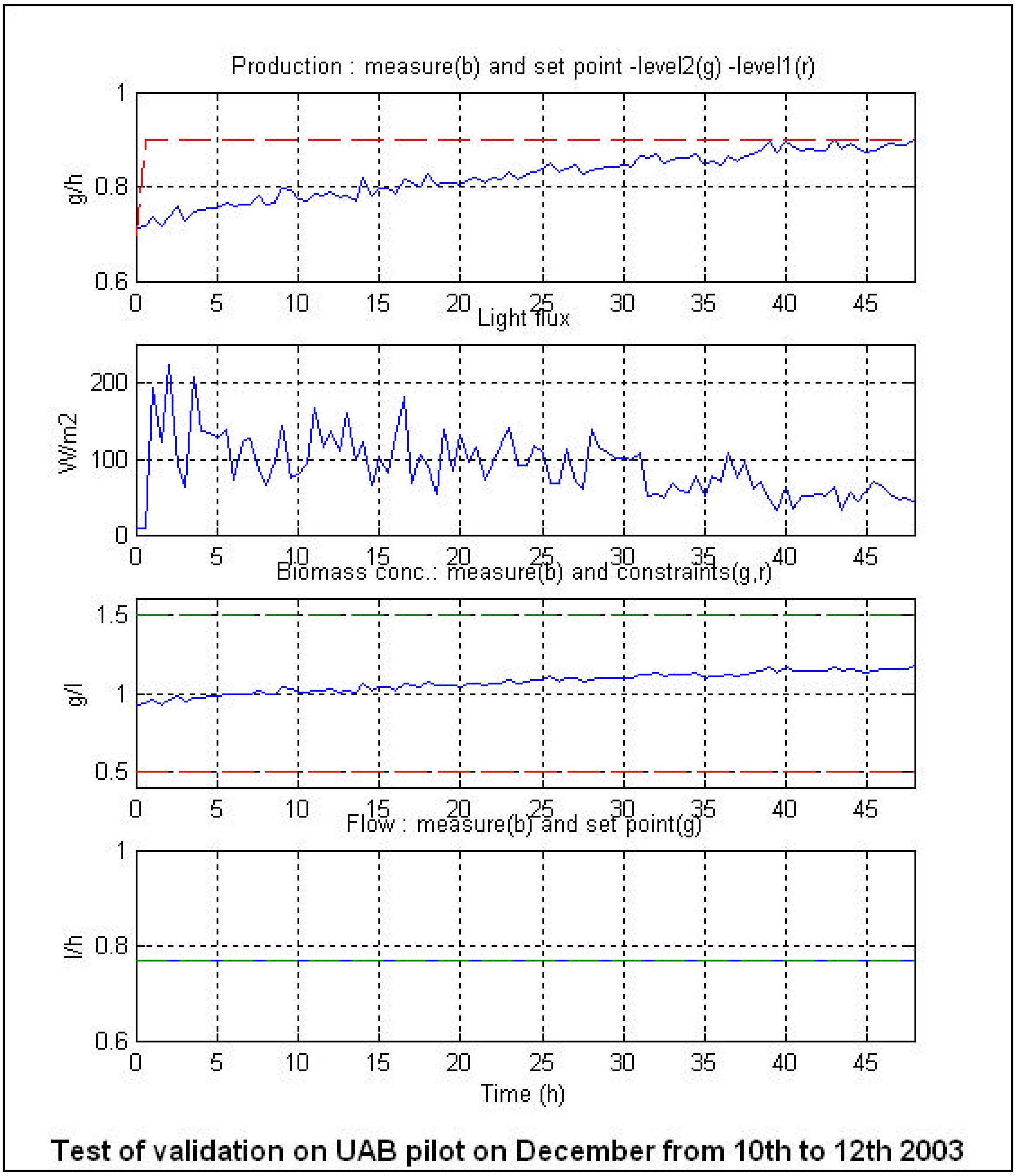

Figure 7. Biomass Production short test results

Test Date	10-12 Dec 2003	Test Result	Success

5.3.2 Long test

The long test lasted 9 days (including the two of the short test). The results can be observed in figure 7. The Controlled Variable reached its set point at time t = 45 h. When a non-measured disturbance moved the CV away at about time t = 70 h, the Manipulated Variable (light flux) increased so that the set point was reached again. No oscillation could be seen. So the control worked correctly.
Remark: a problem occurred on the pilot plant at t = 151 h (on 16^{th} December). It did not affect the control. A few hours after, the test was restarted with a re-initialization of the control. Graphs are separated due to this fact in figure 7 and figure 8.

Detailed results explanation can be found in [R9].

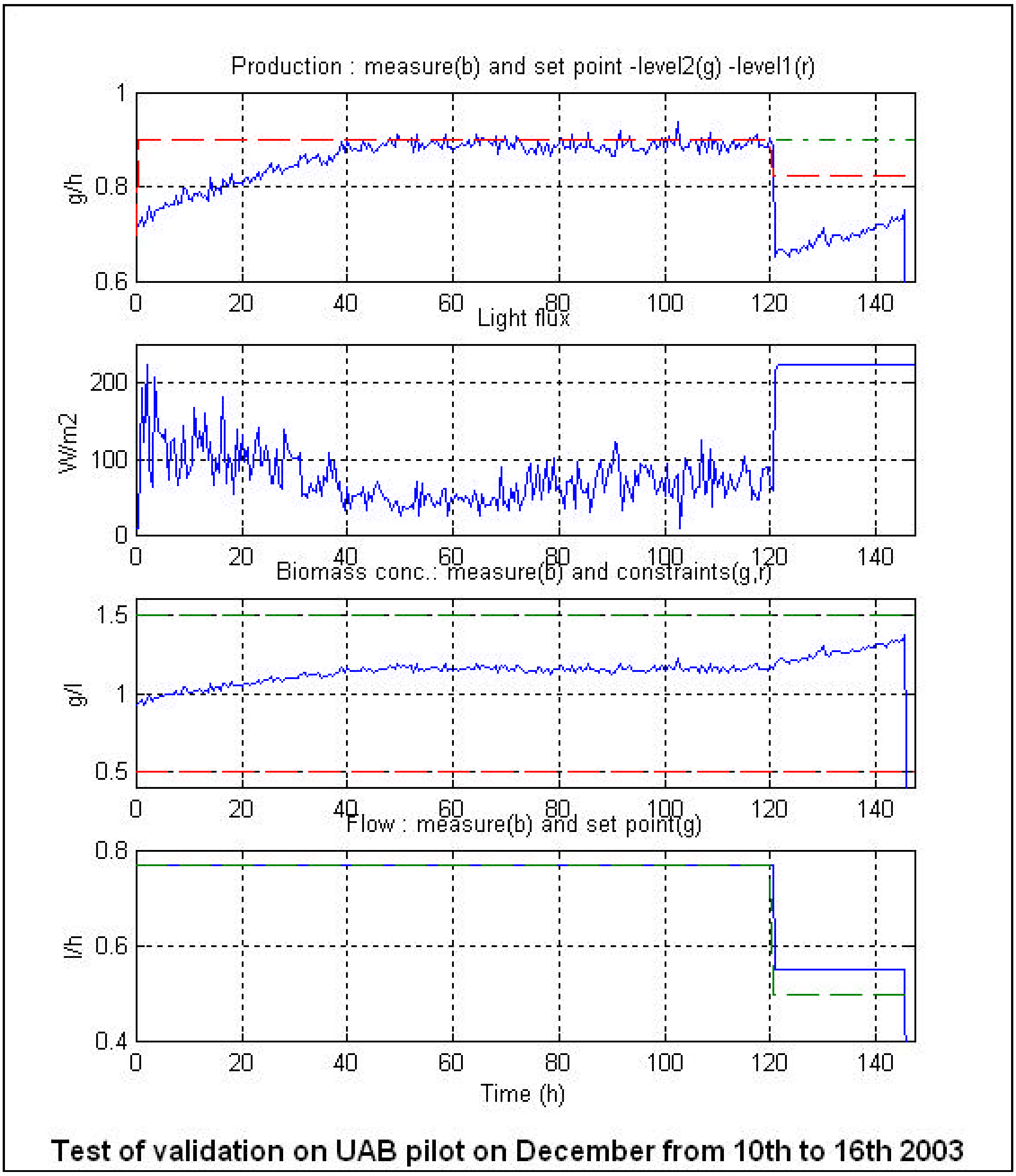

Figure 8. Biomass Production Long test result (I)

The control behaved as expected. The constraint on the concentration was not trespassed (third graph of figure 3). And the level1 production set point (red curve of the first graph) was reached without bias nor oscillation. The implementation of the control law was validated by ADERSA.

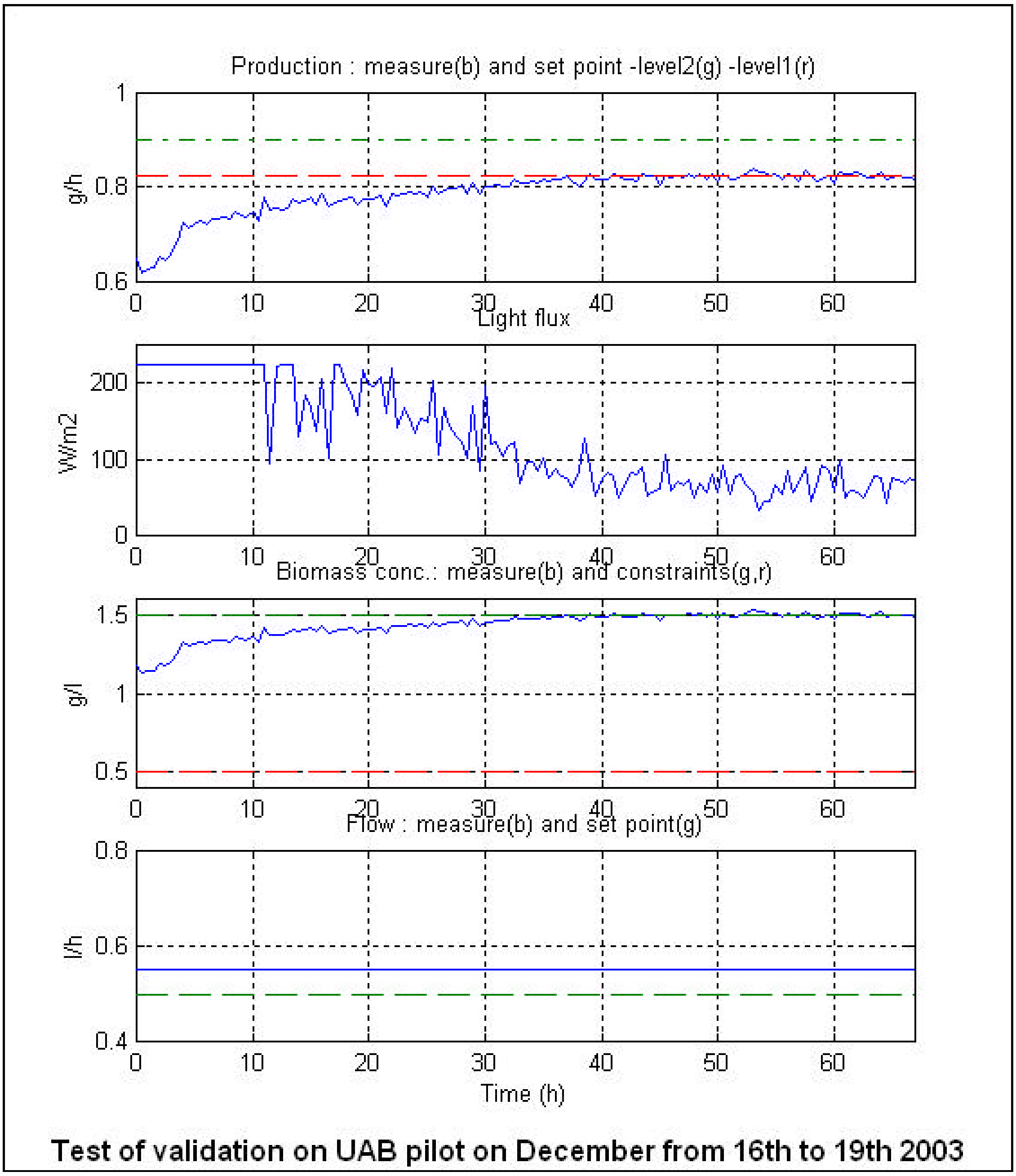

Figure 9. Biomass Production long test results (II).

Test Date	**10-16 Dec 2003**	**Test Result**	**Success**

6 TESTS RESULTS EVALUATION

6.1 Compartment IV

Transition to new compartment IV rack was very smooth. An intermediate connector panel between the compartment and the rack was prepared by the UAB and this made quite easy the connection. The fact that the compartment was stopped avoided risks. Only minor problems were found during the integration and tests performance.

Following table states the problems found and corrective actions taken during the integration of the control system to Compartment IV:

N	Date	Incidence	Corrective action	Status
1	19/11/03	Pressure sensor not measuring	Power was not correctly connected. An external power supply was provided.	Closed
2	19/11/03	Problems with CO2 and O2 gas sensors	Error signal was inverse logic Calibration and Scale1/Scale2 signals were short circuited	Closed
3	21/11/03	Supervision has CO2 and O2 sensor ranges fixed.	Modified supervision to allow two configurable ranges depending on the scale sensors are using.	Closed
4	24/11/03	Biomass conversion factor is not editable. Light intensity does not show real value when loop in manual mode. Is not possible the edition of the DO range.	Changed supervision.	Closed
5	24/11/03	Wrong biomass value when liquid input flow is 0.	Modified PLC SW to calculate production using the real flow rate.	Closed
6	25/11/03	CO2 offset does not modify CO2 input set point.	Modified PLC SW to add CO2 offset as bias of the CO2 PID.	Closed
7	25/11/03	Balance measures are needed to perform calibration of liquid input pumps.	Measures added to database.	Closed
8	2/12/03	Balances 1,2 switch even when both are full.	Changed PLC SW. Level measure is filtered with a lag filter of 10 seconds.	Closed.
9	2/12/03	pH regulation is not ok.	PID values were adjusted.	Closed
10	2/12/03	Lost initial values when PLC rebooted.	Include in the user manual procedure to follow when PLC logic needs to be updated.	Closed
11	16/12/03	Fix database damaged when updated from the client PC.	Updated MBE driver to version 7.17	Closed
12	17/12/03	Virus MSBLAS found in server computer.	Operative system was updated and a firewall was installed.	Closed.

Other modifications were performed in order to ease the utilisation of the system:

- Break down Fix tasks to allow the change of the configuration of any without affecting the others. Master Controller tasks perform database updates and execute control laws.
- Activate Fix Historical server process, which allow the visualisation of historical data into the supervision graphs. Graphs were configured to display data of two days.

Finally an additional alarm was programmed to detect when gas supply is externally interrupted.

6.2 Compartment III

Transition to the new control system was more complicated for this compartment due to fact that it had to be maintained operational during the transition phase. The first transition intent was done late in December ’03. It was not conclusive as the hardware integration took longer than expected and it was not possible to adjust the pH control parameters adequately. Therefore, the old controller was maintained connected to the reactor for the complete Christmas holiday period. Transition activities were resumed in January ’04 and finally the new rack was completely connected to the compartment.

Following table states the problems found and corrective actions taken during the Compartment III integration:

N	Date	Incidence	Corrective action	Status
1	15/12/03	Pressure sensor value was wrong.	Reported range was 4-20 mA when sensor is 0-20 mA. Configuration was updated.	Closed
2	16/12/03	Wrong pH control action.	Parameters were obtained experimentally from the old controller.	Closed.
3	16/12/03	Wrong electrical interface of acid and base pumps switches.	Switches were changed to use the two free relays.	Closed.
4	24/12/03	Supervision lost connection with PLC.	Not reproduced. Probably caused by the installation of the firewall.	Closed.
5	26/01/04	Ramps shall actuate on set-point on loop restart.	PLC software updated.	Closed.
6	28/01/04	Level 1 Liquid flow set point cannot be fixed if control law is not running.	Field made modifiable in the supervision.	Closed.
7	29/01/04	Input media pump not working.	Changed ACO 02000 cabling.	Closed.
8	14/04/04	Alarm action not performed.	Fixed PLC program to perform action even when loop mode is MAN.	Closed.

7 CONCLUSIONS

Following the successful connection of the Control System Demonstrator for Compartments III and IV to the MELISSA pant at UAB functional tests were conducted to verify the proper performance of the new controller.

In a first stage short duration checks were performed and the obtained results were analyzed and verified by SHERPA. Upon obtaining their conformity full functional procedures were run. The analysis of the test results allows drawing the following conclusions.

Four major requirements / concerns were identified in the MELISSA Control System Requirements technical note [R1], driving the design of the new Control System Architecture and, in turn, the definition and implementation of the Control System Demonstrator object of this Test report:

- Capability and performance
- Reliability
- Safety.
- Data Management.

Capability and Performance

The tests checked that the system architecture and performance is suitable for the MELISSA requirements. The implementation allowed the accommodation of control levels easily. The Supervision software provided a soft way of implementing high-level control tasks with optimal performance. The Supervision software programmability (iFix) is flexible enough to incorporate complex tasks and perform complex calculations. The tests performed confirmed that the refreshing rates of variables are fast enough, since during the test not only control law variables were monitored /manipulated but also log files were generated, database values were stored (with a maximum rate of 10 seconds), supervision displays used, historical data generated. All these actions were performed simultaneously for both compartments (CIII and CIV).

Reliability

The hardware and the software have been proven to be reliable. No problems were found that could be attributed to its reliability. Additionally, the alarm tests proved that the system is capable of controlling unexpected events and reacting in order to minimize the risk of malfunction. However, it has to be noted that alarm management could only be performed at compartment level, individually and therefore, global effects have not been assessed.

Also, additional tests should be performed on the hardware and software, especially the ones related to redundancy. On the other hand, it has to be noted that the fact of using a Windows server in the Master Control raises the problem of reboots during maintenance interventions. This problem can be minimised using a secondary backup server.

Safety

Its still too early to evaluate safety requirements. Despite of that, it is confirmed that the system has a powerful alarm management, allowing the classification of alarms, different ways of alarm reporting and the possibility of programming recovery actions that will help on implementing safety requirements.

Data Management

The tests also confirmed that the system covers widely the requirements on data management. It can be connected to Relational Database Management Systems, can generate logs, provide historical data on charts, save alarm events, etc.

It can be concluded that the tests demonstrate that the architecture concept and implementation that was chosen in the MELISSA Control System trade-off is suitable to cover the requirements stated in the TN 72.2. At this time the Control System Demonstrator is over dimensioned for the current needs, but as the Pilot Plant will increase in number of reactors, intermediate buffers, interconnections and high level control, performance requirements will need to be re-assessed accordingly.

On the other hand no potential problems are envisaged at this stage as new equipment will have to be connected to the existing control system. This is supported by the flexibility of implementing Master Control in a standard PC server.