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T E C H N I C A L   N O T E

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PILOT PLANT CONTROL SYSTEM UPGRADE

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1 INTRODUCTION

The MELISSA project is a tool for the study and development of Advanced Biological Life Support Systems. Since its initiation it was realized the necessity of a physical loop implementation to verify the successful research results, obtained by the different MELISSA partners, in a common location. This implementation will generate inestimable results and provide information for further improvements. The final goal is the experimental demonstration of the MELISSA concept by means of long-term tests on a physical implementation of the loop design. The location for those tests is known as the MELISSA Pilot Plant.

Since the beginning, a laboratory for this purpose was foreseen and was initially located in ESTEC. In this initial location it was mainly devoted to compartment IVa and its control system and later to compartment III. For those tests a control system was installed. The control system presented several levels of control. The local control was based on industrial controllers (MICON P100). Those controllers were connected to a computer station (COMPAQ 386s) using Modbus protocol. The different computer stations were interconnected using an Arcnet network. At the different stations an MS-DOS based software (INDUSTAR TOPTOOLS, FLS Automation) allowed to store and graphically display the data collected on the different compartments.

The described control system allowed to share the data among different stations on the network and more importantly allowed any station to modify the set points and local configuration of the controllers. This fact allowed the development of the so called General Purpose Station (GPS) as a station running a main control system. The main control system provided a level 2 control by means of model based predictive algorithms. A module for each compartment was progressively being developed. A higher level of control, level 3, included routines for optimisation of set points taking into account the global loop operative conditions as well as the characteristics and status of each compartment.

As mentioned before, the control system was implemented in a MS-DOS operative system environment corresponding to the state of the art systems or the year it was installed (1991). Due to its obsolescence and to upgrade it to nowadays standards a work-package was devoted to analyse and consider the different possibilities available for upgrade and selection of the most appropriated one (Technical notes TN 72.2 (Duatis 2002) and 72.3, Duatis 2003). Furthermore, once the most appropriated control system option was selected it was purchased, integrated and delivered to the Pilot Plant by the company NTE.

This technical note, performed in collaboration with NTE S.A. describes the set up, start up and initial tests of the above mentioned control system performed at the MELISSA Pilot Plant in UAB.

2 SYSTEM COMPONENTS

The system to be installed in the Pilot Plant was described in technical note 72.3 (Duatis 2003). As a summary and reference point the table below summarizes its characteristics.

Master Controller

- PC Server (Dell industrial server enclosed in a weather proof cabinet)
- O.S. Windows 2000 Server
- iFix SCADA Server
- Microsoft SQL Server 2000 (included in iFix)
- Control laws integrated by means of a software object in the server (ActiveX or DLL).

Supervision/Commanding Client

- PC Workstation
- O.S. Windows XP
- iFix SCADA Development Client
- Concept 2.5 (Quantum PLC programming tool)

Historical Database Server

- PC Server (installed in the same physical computer as the Master Controller)
- O.S. Microsoft Windows 2000 Server
- Microsoft SQL Server 2000 (additional for Historical DBMS)

Network

- Schneider Industrial Ethernet ConneXium 5x10BaseT/100BaseTX and 2x100BaseFX ports.
- Twisted pair redundant ring including 3Com Ethernet Switch.

HMI

- Mixed touch-screen / keypad Schneider Magelis

Local Controller

- Quantum PLC (CPU Ref. 140CPU43412A) with Ethernet Connection module (Ref. 140NOE77101).

3 COMPARTMENT IVa

The rack of controllers for compartment IVa (fig 1 and fig 2A) together with the two personal computers, one for the server (fig 2B) and one for the client (fig. 2C), with the iFix software and NTE-SHERPA routines installed, were delivered to UAB during the first week of October 2003. Figure 1 shows a general view of compartment IVa after its installation and during the initial operational tests.

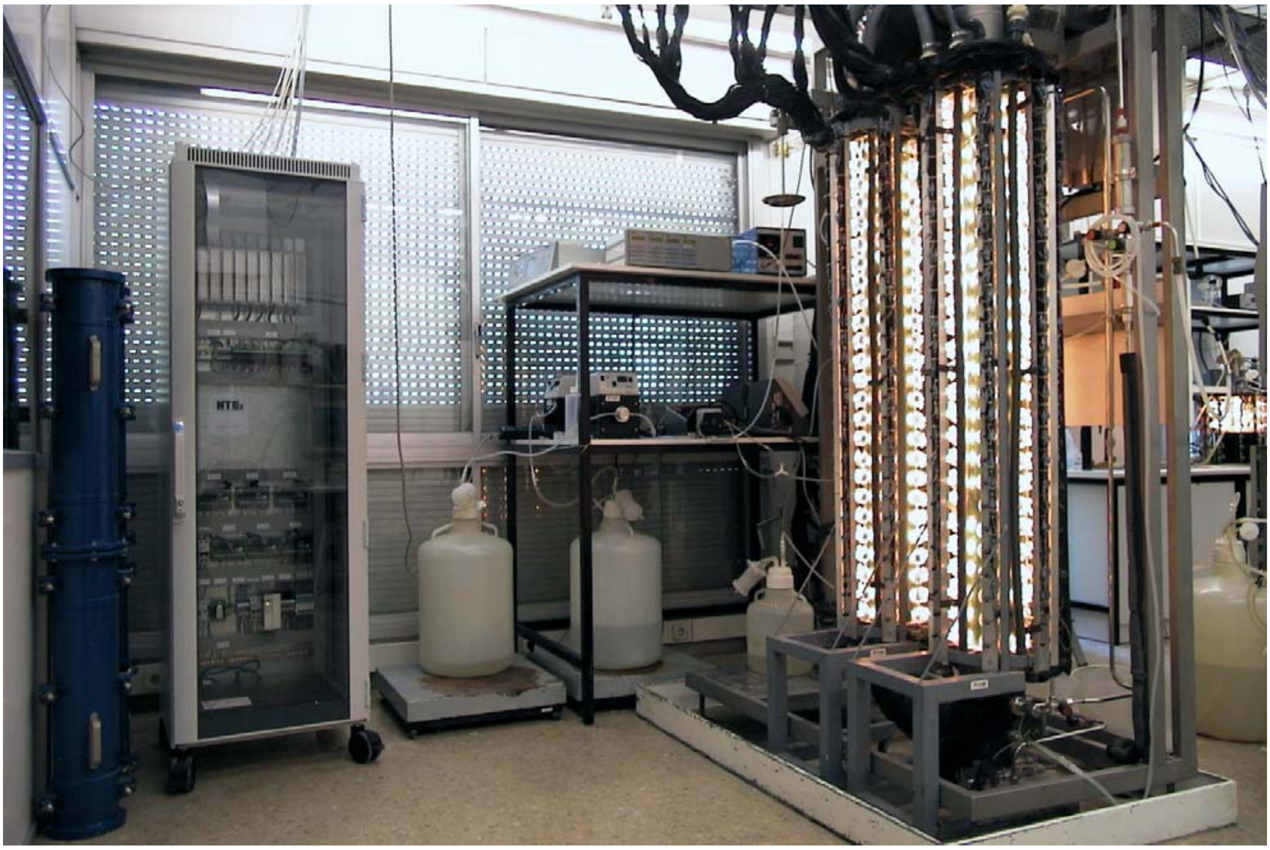


Figure 1: General view of compartment IVa bioreactor and controller's rack.

Figure 2: Close up views of compartment IVa control system. A: Controller's rack. B: Master controller and database server computer, with a 3Com Ethernet Switch. C: perspective of the user interface Dell computers.

3.1 *Installation of the equipment*

As previously mentioned the company NTE was responsible for the purchase, of the different personal computers, control units and interface equipment. The control units and interface equipment were assembled in standard 2x0.5m control racks (RITTALL), and tested in their premises. At the same time the control software (iFIX + SHERPA routines) was adapted and installed in the new system. Once this step was concluded the equipment was delivered to UAB. Description of electrical interfaces and related items on the control rack can be found in TN 72.4 (Duatis 2004).

Once the equipment was received at the MELISSA Pilot Plant, its staff proceeded to its installation. To this purpose it was necessary to re-wire the measurement and actuator devices of compartment IVa.

To facilitate the connection of the measurement and actuation equipment to the control rack an auxiliary connection panel was installed in compartment IVa (fig 1).

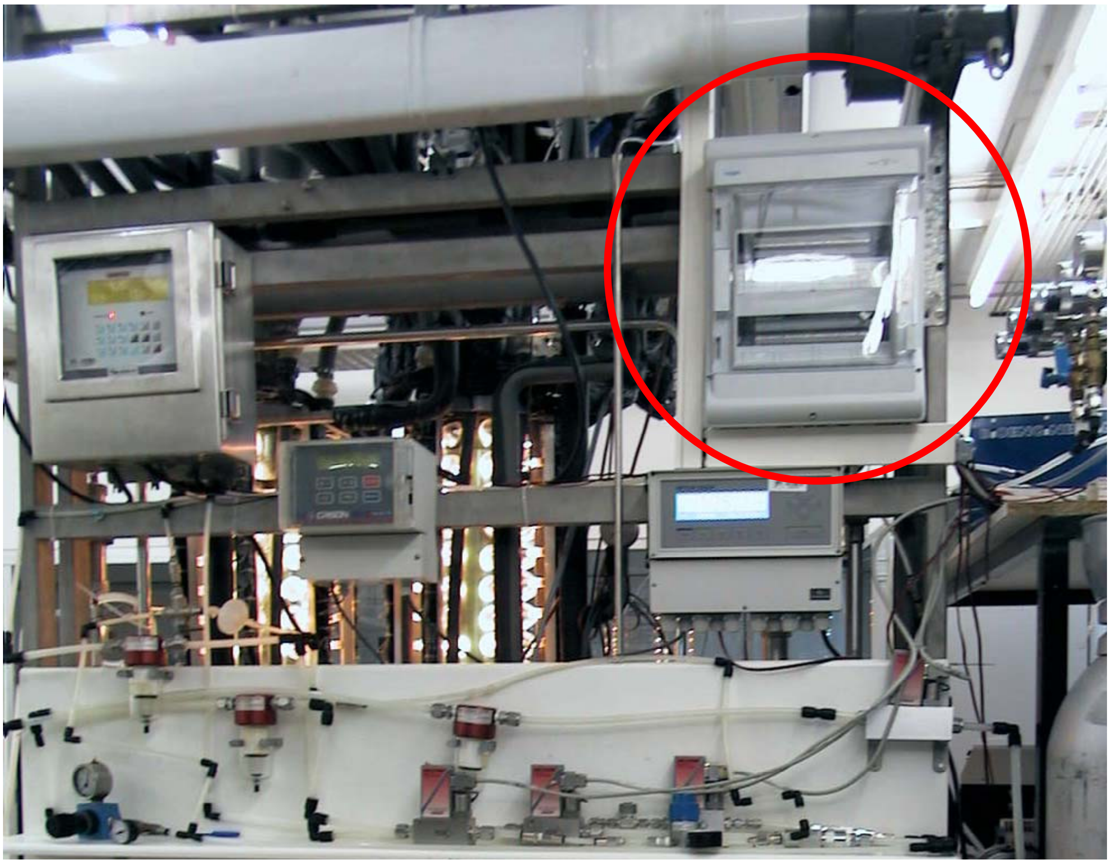


Figure 3: Close view of the location of the auxiliary connection panel (inside red circle) on the backplane of the compartment IVa bioreactor.

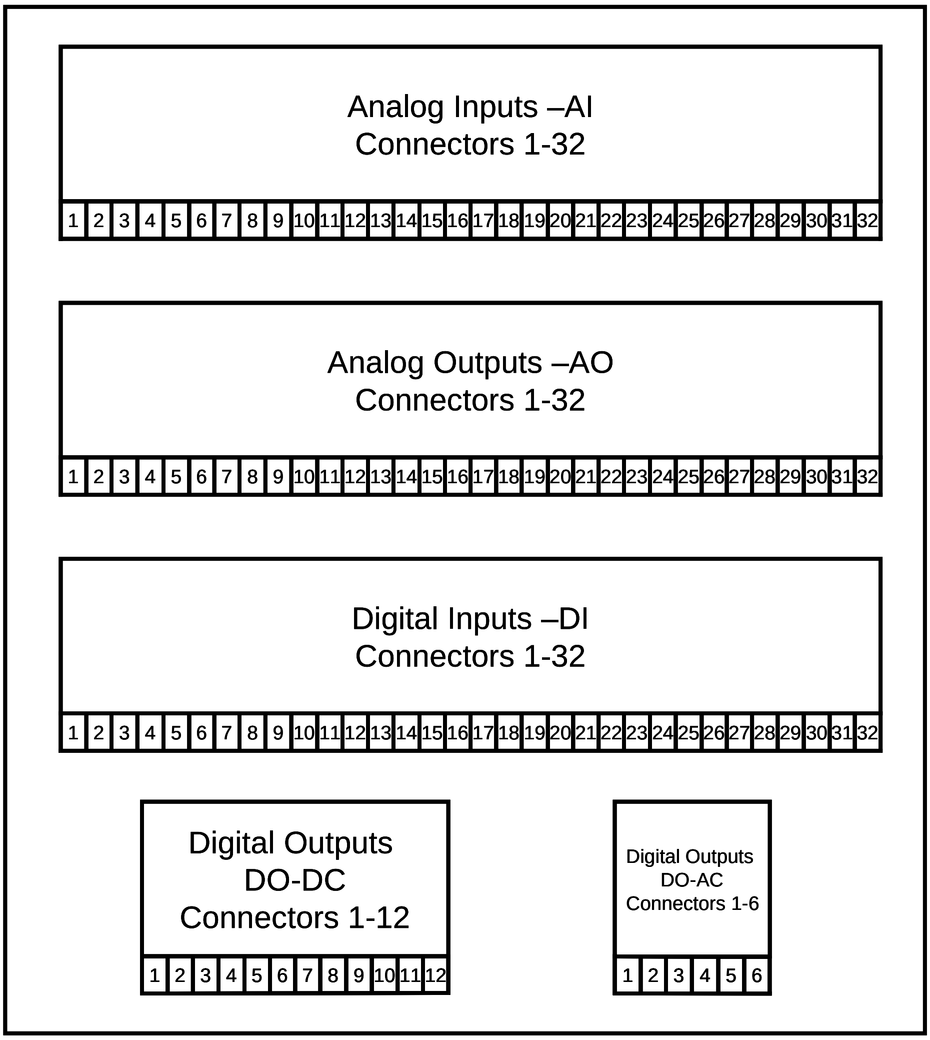


Figure 4: Scheme of the distribution of the connections inside the auxiliary connection panel for compartment IVa.

Connection between the control rack and the auxiliary connection panel was performed using multi-wire cables, each one having 16 wires of 0.22 mm section. The controllers input-output signals are mapped in the auxiliary connection panel as described in figure 4. A detailed description of the physical connection of each signal to the pins in the auxiliary connection rack can be seen in tables 1 to 5. Once the wiring was performed and the connections were verified, the system was considered ready for control testing.

PIN	SIGNAL	Control Rack PIN	NAME	EQUIPMENT	Electrical range	Variable Physical Range	Range Units
01	CIV_AI_01+	001	CIV_MV_CxAbs	Biomass Sensor	4-20 mA	0-3 (1)	UA
02	CIV_AI_01-	005					
03	CIV_AI_02+	009	CIV_MV_M1	Scale 1	4-20 mA	0-150	Kg
04	CIV_AI_02-	013					
05	CIV_AI_03+	017	CIV_MV_M2	Scale 2	4-20 mA	0-150	Kg
06	CIV_AI_03-	021					
07	CIV_AI_04+	025	CIV_MV_P	Pressure Sensor	4-20 mA	0-1.5	bar
08	CIV_AI_04-	029					
09	CIV_AI_05+	033	CIV_MV_pH	pH Sensor	4-20 mA	0-14	pH
10	CIV_AI_05-	037					
11	CIV_AI_06+	041	CIV_MV_T	Temp Sensor	4-20 mA	0-150	ºC
12	CIV_AI_06-	045					
13	CIV_AI_07+	049	CIV_MGO_O2	O_2-Gas Sensor	4-20 mA	[0-10]; [0-25] (1)	%
14	CIV_AI_07-	053					
15	CIV_AI_08+	057	CIV_MGO_CO2	CO_2-Gas Sensor	4-20 mA	[0-5];[0-20] (1)	%
16	CIV_AI_08-	061					
17	CIV_AI_09+	065	CIV_MV_DO	Diss. Ox. Sensor	4-20 mA	0-300 (1)	%
18	CIV_AI_09-	069					
19	CIV_AI_10+	073	Not Used				
20	CIV_AI_10-	077					
21	CIV_AI_11+	081	Not Used				
22	CIV_AI_11-	085					
23	CIV_AI_12+	089	Not Used				
24	CIV_AI_12-	093					
25	CIV_AI_13+	097	CIV_MGI_FrGas	Flow Metter Air input	0-5 V	0-30	nL/min
26	CIV_AI_13-	101					
27	CIV_AI_14+	105	CIV_MGO_FrGas	Flow Metter Gas output	0-5 V	0-30	nL/min
28	CIV_AI_14-	109					
29	CIV_AI_15+	113	CIV_MV_FrCO2	Flow Metter CO_2	0-5 V	0-5	nL/min
30	CIV_AI_15-	117					
31	CIV_AI_16+	121	CIV_MV_FrGas	Flow Metter Gas input	0-5 V	0-30	nL/min
32	CIV_AI_16-	125					

Table 1: C-IVa Analogic Input (AI) signals in compartment IVa auxiliary connection panel.

(1) Range is variable according to instrument configuration and calibration.

PIN	SIGNAL	Control Rack PIN	NAME	EQUIPMENT	Electrical range	Variable Physical Range	Range Units
01	CIV_AO_01+	129	CIV_SP_CO2	CO_2-Flow regulation	0-5 V	0-5	nL/min
02	CIV_AO_01-	133					
03	CIV_AO_02+	137	CIV_SP_Fgi	Compartment Input gas flow regulation	0-5 V	0-30	nL/min
04	CIV_AO_02-	141					
05	CIV_AO_03+	145	CIV_SP_Fgo	Compartment Output gas flow regul.	0-5 V	0-30	nL/min
06	CIV_AO_03-	149					
07	CIV_AO_04+	153	CIV_SP_Fgex	Air input flow regulator	0-5 V	0-30	nL/min
08	CIV_AO_04-	157					
09	CIV_AO_05+	161	CIV_SP_Li1	Liquid input pump 1	0-5 V	0-30 (2)	L/h
10	CIV_AO_05-	165					
11	CIV_AO_06+	169	CIV_SP_Li2	Liquid input pump 2	0-5 V	0-30 (2)	L/h
12	CIV_AO_06-	173					
13	CIV_AO_07+	177	CIV_SP_LO	Liquid output pump	0-5 V	0-30 (2)	L/h
14	CIV_AO_07-	181					
15	CIV_AO_08+	185	Not Used				
16	CIV_AO_08-	189					
17	CIV_AO_09+	193	CIV_SP_Bs	Base Pump	4-20 mA (24V)	0-100	%
18	CIV_AO_09-	197					
19	CIV_AO_10+	201	CIV_SP_Ls	Light Regulation	4-20 mA (24V)	0-220	W/m^2
20	CIV_AO_10-	205					
21	CIV_AO_11+	209	CIV_SP_Ac	Acid Pump	4-20 mA (24V)	0-100	%
22	CIV_AO_11-	213					
23	CIV_AO_12+	002	Not Used		(24V)		
24	CIV_AO_12-	006					
25	CIV_AO_13+	010	Not Used		(24V)		
26	CIV_AO_13-	014					
27	CIV_AO_14+	018	Not Used		(24V)		
28	CIV_AO_14-	022					
29	CIV_AO_15+	026	Not Used		(24V)		
30	CIV_AO_15-	030					
31	CIV_AO_16+	034	Not Used		(24V)		
32	CIV_AO_16-	038					

Table 2: C-IVa Analogic Output (AO) signals in compartment IVa auxiliary connection panel.

PIN	SIGNAL	Control Rack PIN	NAME	EQUIPMENT	Electrical range	Action	Notes
01	CIV_DI_01+	042	CIV_CAL_CO2O2	CO_2/O_2 Calibration	(24V)	ON=Calibration	Wire: BK-PK
02	CIV_DI_01-	046					
03	CIV_DI_02+	050	CIV_ERR_CO2O2	CO_2/O_2 Error	(24V)	OFF=ERROR	In error also if power off
04	CIV_DI_02-	054					
05	CIV_DI_03+	058	CIV_SCL1_CO2O2	CO_2 large scale	(24V)	ON= CO_2 large scale	Wire: W/G-BR
06	CIV_DI_03-	062					
07	CIV_DI_04+	066	CIV_SCL2_CO2O2	O_2 large scale	(24V)	ON= O_2 large scale	Wire: W/Y-GR
08	CIV_DI_04-	070					
09	CIV_DI_05+	074	Not Used		(24V)		
10	CIV_DI_05-	078					
11	CIV_DI_06+	082	Not Used		(24V)		
12	CIV_DI_06-	086					
13	CIV_DI_07+	090	Not Used		(24V)		
14	CIV_DI_07-	094					
15	CIV_DI_08+	098	Not Used		(24V)		
16	CIV_DI_08-	102					
17	CIV_DI_09+	106	Not Used		(24V)		
18	CIV_DI_09-	110					
19	CIV_DI_10+	114	Not Used		(24V)		
20	CIV_DI_10-	118					
21	CIV_DI_11+	122	Not Used		(24V)		
22	CIV_DI_11-	126					
23	CIV_DI_12+	130	Not Used		(24V)		
24	CIV_DI_12-	134					
25	CIV_DI_13+	138	Not Used		(24V)		
26	CIV_DI_13-	142					
27	CIV_DI_14+	146	Not Used		(24V)		
28	CIV_DI_14-	150					
29	CIV_DI_15+	154	Not Used		(24V)		
30	CIV_DI_15-	158					
31	CIV_DI_16+	162	Not Used		(24V)		
32	CIV_DI_16-	166					

Table 3: : C-IVa Digital Input (DI) signals in compartment IVa auxiliary connection panel. (Wire color codes: BK-PK: Black-Pink, W/G-BR: White/Green-Brown, W/Y-GR: White/Yellow-Green)

PIN	SIGNAL	Control Rack PIN	NAME	EQUIPMENT	Electrical range	Action	Notes
01	RELAY_01	170	CIV_RL_LI1	Enable Pump 1	(24V)	ON=Pump ON	
02	RELAY_01	174					
03	RELAY_02	178	CIV_RL_LI1	Enable Pump 1	(24V)	ON=Pump ON	
04	RELAY_02	182					
05	RELAY_05	186	Not Used				
06	RELAY_05	190					
07	RELAY_06	194	Not Used				
08	RELAY_06	198					
09	CIV_DO_07	202	Not Used				
10	CIV_DO_07	206					
11	CIV_DO_08	210	Not Used				
12	CIV_DO_08	214					

Table 4: C-IVa Digital Input Direct current (DI-DC) signals in compartment IVa auxiliary connection panel.

PIN	SIGNAL	Control Rack PIN	NAME	EQUIPMENT	Electrical range	Action	Notes
01	AC_L	1	CIV_AC_Cx	Biomass Sensor Cleaning	(220V)	ON=Cleaning	
02	AC_N	3					
03	AC_GND	5					
04	AC_L	7	CIV_AC_Fg	Pressure safety valve	(220V)	ON=Valve Open	
05	AC_N	9					
06	AC_GND	11					

Table 5: C-IVa Digital Input alternate current (DI-AC) signals in compartment IVa auxiliary connection panel.

3.2 C-VIa running tests of the equipment

After completion of the installation and wiring, the following step was to test the operation of the control system using the control routines previously used in the 7 litres reactor and already adapted to the new system by NTE-SHERPA.

For those tests SHERPA provided the test plan (Leclercq 2003, TN 72.3.3) for two different set of conditions. The first was a short term one designed to verify the data process. In the second one a much longer test was performed in order to verify the correct operation of the control. In the following the results obtained in both kind of tests are summarized.

To perform the tests the bioreactor was filled with ZARROUCK culture medium at pH 9.5 and inoculated with the previously used *Spirulina* (*Artrospira platensis*) strain. Before initiation of the control tests a batch culture was performed using the local controllers for temperature, gas flow and pH. Once the culture had grown the continuous culture was started in order to reach the initial operating conditions for the first test.

3.2.1 TEST 1: VERIFICATION OF THE INTERNAL VARIABLES

Before the test was started the following parameters of the controller were verified:

- Control period dt= 0.5 hours
- Reference trajectory increment lambda:0.97
- Illuminated surface fraction of the bioreactor: 53/77=0.688
- Horizon of coincidence: H=5 control time periods (nhc)
- Constraints on the manipulated variable (Frmin, Frmax). Not changed.
- Constraints on the biomass concentration (cx_min, cx_max). Not changed.

Once the previous values were verified and the biomass reached a steady state the first test was initiated.

The test proposed to test the internal variables of the control was designed to last around 6 hours. The results had to be recorded either in the control system database, only for the main variables, as well as in a dedicated file (‘f_spy’) recording also the values of selected internal variables and which was used by SHERPA to verify the operation of the controller.

Initially the bioreactor reached a steady state at a dilution rate of 0.01 h^{-1} with a flow of 0.77 L/h. At this point the biomass production was of 0.7 g/h. To initiate the test the set point of biomass production was fixed at the same value actually found in the bioreactor (0.7 g/h) at the beginning of the test. Following the established protocol, after 2 hours a new set point of production of 2 g/h was established. At 4 hours after the test had been initiated, the set point was decreased to a value of 0.1 g/h. As it can be seen in figures 5 and 6 the control system responded appropriately to the different set point demands and this fact was verified by SHERPA. Therefore it was considered that the control system had passed the test and was ready for the second test.

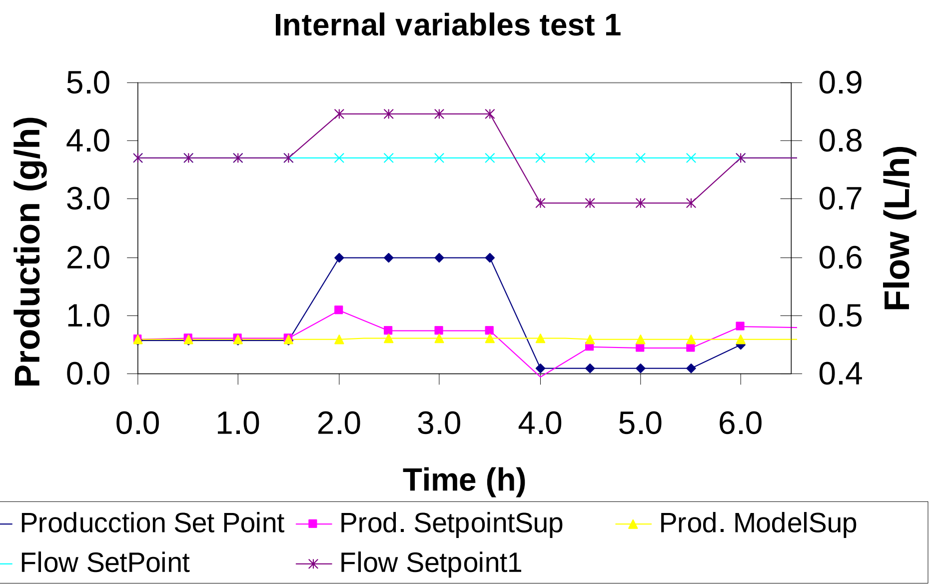


Figure 5: Evolution of variables related to biomass production and liquid flow rate during test 1.

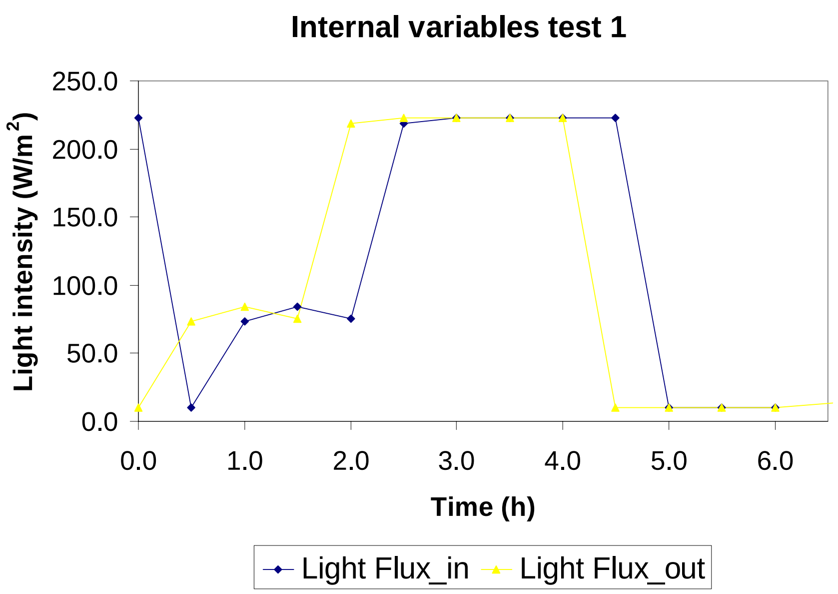


Figure 6: Evolution of variables related to light intensity during test 1

3.2.2 TEST 2: VERIFICATION OF THE CONTROLLER

Once SHERPA approved the previous test, the objective of the following test was to verify the behaviour of the controller. Therefore it was proposed to initially set a steady state condition and then move successively the set point of productivity and in a second step the flow rate (disturbance).

3.2.2.1 Part 1

To this purpose it was proposed to set the initial the conditions at a production set point of 0.7 g/h with a flow rate of 0.77. The real test had to start when this steady state was confirmed. After this steady state was sustained during more than 24 hours the test started.

To begin the test the productivity set point was increased in the client PC to the new value of 0.9 g/h as can be observed in figure 7.

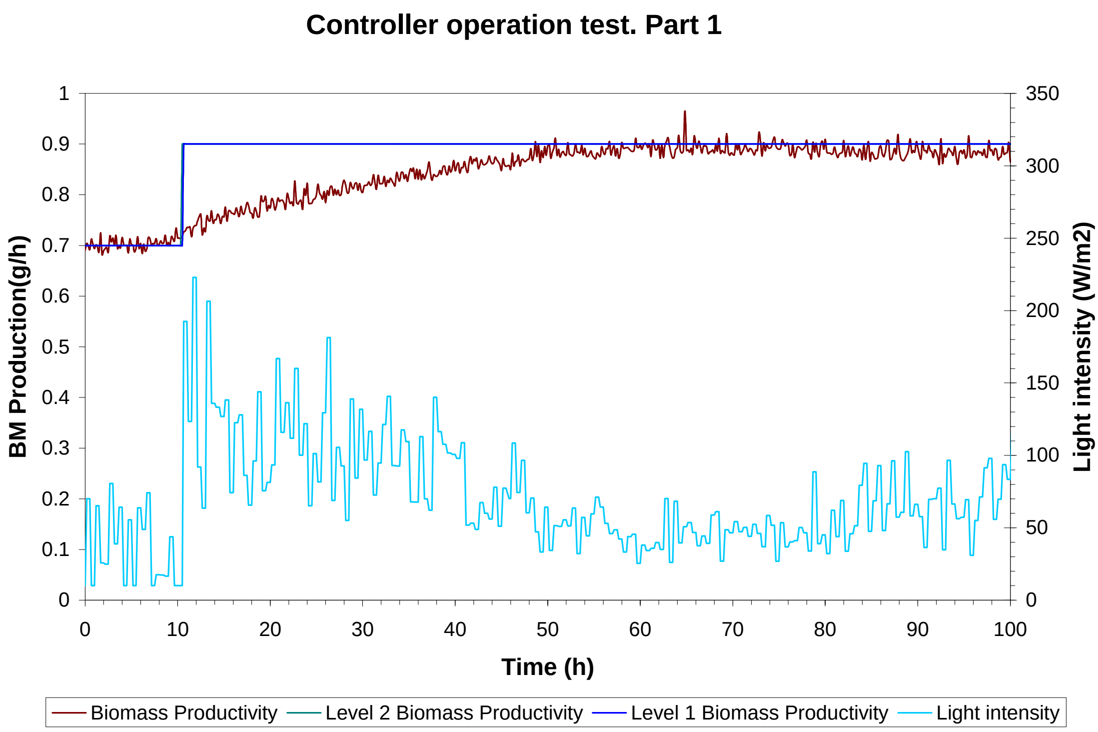


Figure 7: Evolution of biomass productivity and light intensity during the first part of the controller operation test. Controller biomass productivity level 1 and level 2 values have the same value during all the test.

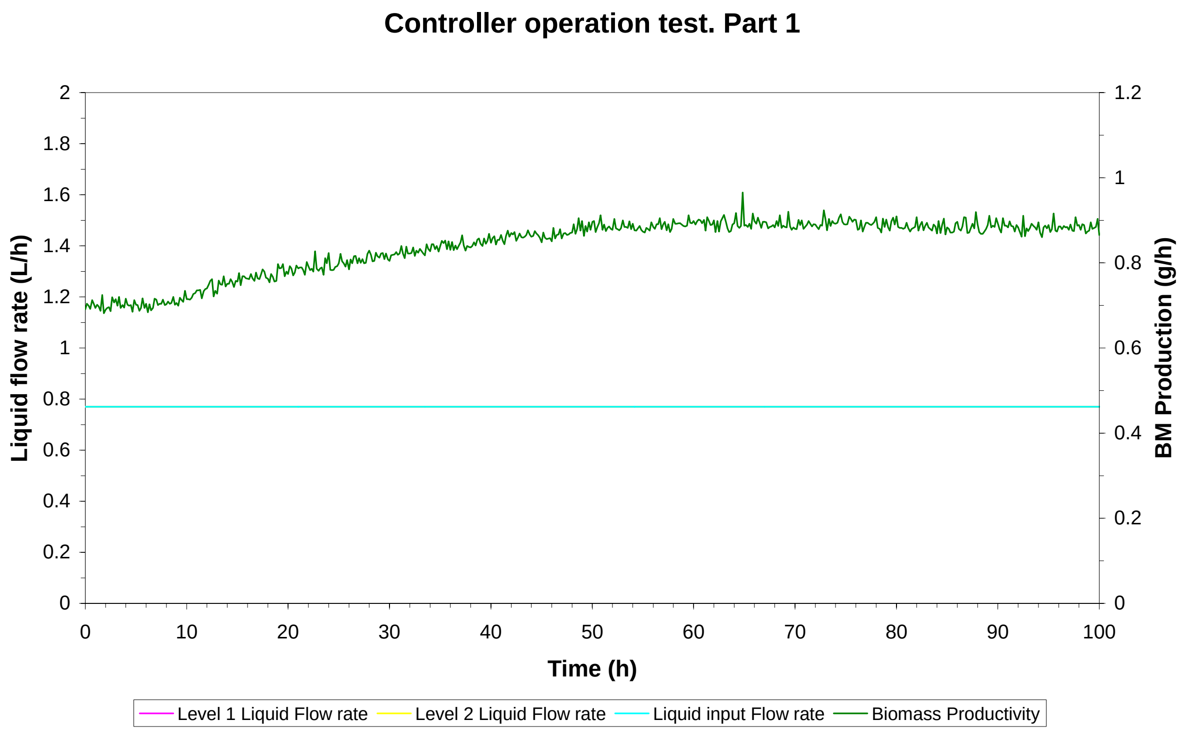


Figure 8: Values of the liquid flow rate during the first part of the controller operation test. Level 1 and level 2 controller values for the flow rate have the same value as the flow rate and therefore can not be seen. Biomass production is shown as reference with the previous figure.

As can be seen in figure 7 the controller responded appropriately by increasing the light intensity. At the same time the control considered that the demanded productivity could be reached using the same value of flow rate already used in the previous conditions and was not modified as can be seen in figure 8. As biomass level or biomass production was progressively increasing, the light intensity was gradually decreased. It can be considered that biomass reached the set point value after approximately 55 hours since the beginning of the test. No overshooting is observed. From this point onwards the controller maintained the biomass productivity close to the set point value by means of regulation of the light intensity. Once this level was reached the system was ready for the second part of the test.

3.2.2.2 Controller operation test Part 2

In this second part of the test the biomass productivity levels were chosen by SHERPA so that the control had to modify the requested set point values to the closer reachable ones according to the knowledge model. In this case the set point for the input flow rate is decreased from the 0.77 l/h to 0.5 l/h. In these conditions the control system evaluated the feasible biomass production to a lower value than in the previous case. That is, a value of 0.824 g/h instead of 0.9, as can be seen in figure 9. What is more, this production has to be reached at a flow rate of 0.55 L/h instead of the requested 0.5 L/h as can be seen in figure 10. Those values are in accordance with the expected values calculated using the knowledge model. Also, as a result of the decreased flow rate, the actual biomass production began from a lower value as can be seen in figure 9. Under those conditions the control system increased the light intensity as expected, to allow for an increased biomass production.

At around 155 h, the antivirus of another computer, which had been connected to the server in order to get a data file, identified the existence of a virus in the server computer. At that point it was not possible to unequivocally identify the contamination source. The virus could have been there even before the system reached UAB. In fact it was verified that the operative system had not been upgraded to the latest service packs and security upgrades already provided by Microsoft and that already provided protection for the type of virus found. In any case it was decided to install an antivirus and a firewall (Norton Internet Security package). When installing the security package the installer interrupted the test and reinitialized the computer. At that point it was verified that once the system was restarted not all iFix processes initialized automatically. All those minor issues mentioned above, such as automatic starting of iFix processes and correct labeling of some screen data were solved with the collaboration of NTE.

Once all processes were restarted appropriately, the control system proceeded towards the set points specified in the test. As can be seen in figure 9 the biomass productivity evolution of the culture after the interruption progressed as foreseen which is in favor of the robustness of the control routines that actuated accordingly despite the computer reinitialization.

The Norton Internet security package was later uninstalled and the computer disconnected from UAB network following ESA request. Once the test was finished a system reinitialization was done in order to verify that all processes restarted automatically. The iFix software successfully restarted all processes required for proper operation confirming that the configuration was correct.

Once the data obtained was presented to SHERPA they verified the proper operation of the controller. Although it was considered not necessary to repeat the second part of the test in order to validate the control system, UAB decided to repeat it so that to have an undisturbed example of the proposed test. Those results are shown in figures 11 and 12 as described later.

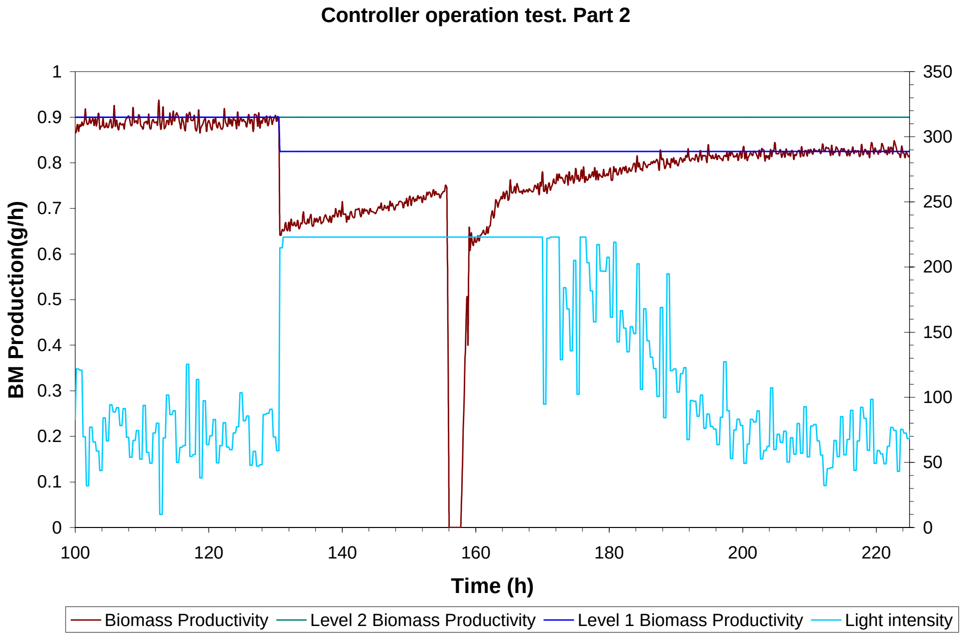


Figure 9: Evolution of biomass productivity and light intensity during the second part of the controller operation test. Discontinuity at about 156 hours is explained in the text.

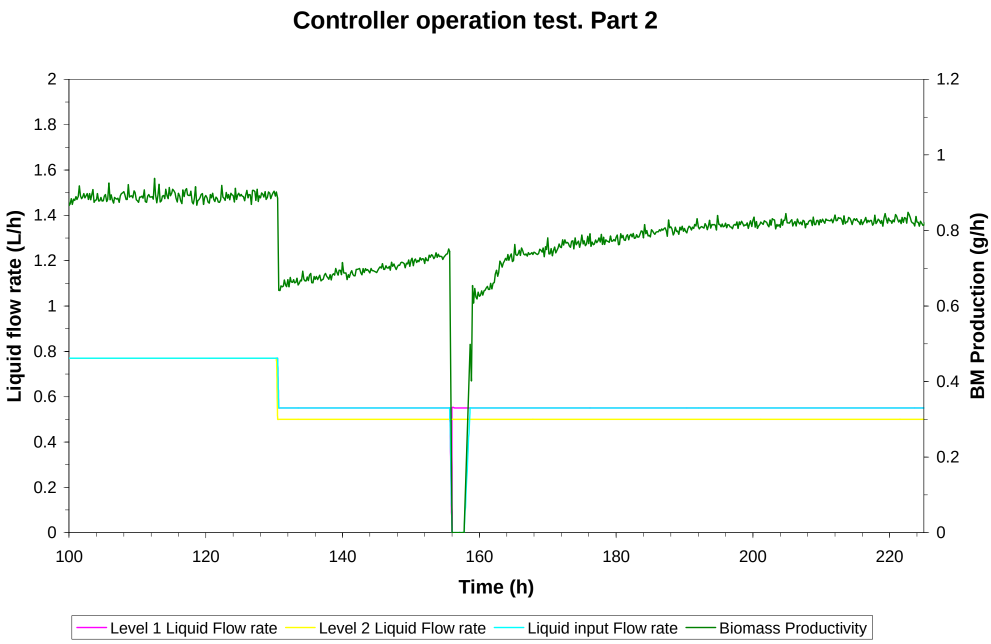


Figure 10: Values of the liquid flow rate during the first part of the controller operation test part 2. Biomass production is shown as reference with the previous figure.

3.2.2.2.1 *Repeated controller operation test part b*

As explained in the previous paragraph the second part of the performed test was interrupted by a computer re-initialization due to the installation of an antivirus and a firewall. Although the control system performed according to specifications and the test was considered valid, nevertheless the second part of test was repeated at a later time. Figures 11 and 12 show the evolution of the biomass productivity during a test started at a steady state of production of 0.9 g/h (figure 11) were the flow rate set point was decreased from 0.77 L/h to 0.5 l/h (figure 12).

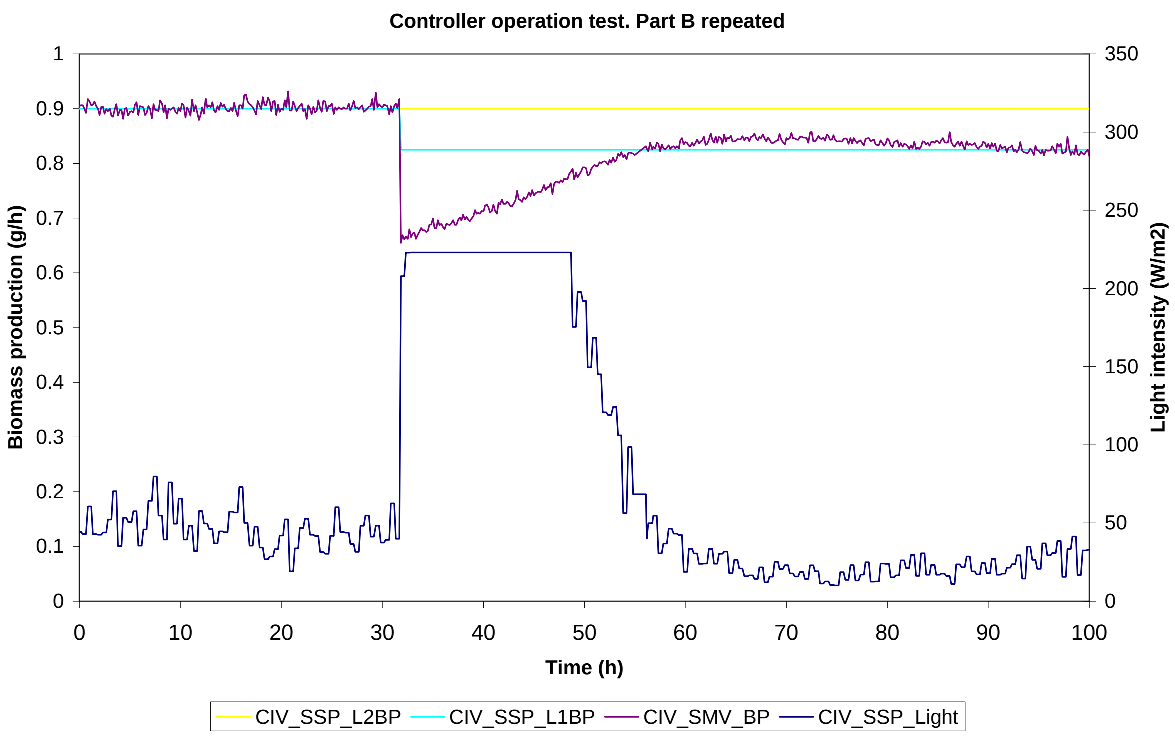


Figure 11: Evolution of biomass productivity and light intensity during the repetition of the controller operation test part B.

The evolution of the test is identical as the one observed in figures 9 and 10. As in the previous case the control system selected the values of 0.85 g/h and 0.55 L/h as the most appropriated ones to reach a productivity as close as possible as the requested one. The new steady state was reached at around 60 hours since the beginning of the test. Operation was considered to be within the expectations by SHERPA (Leclercq 2004 TN 72.4.1) and the tests with the control system of compartment IVa were considered finished.

At this point the installation efforts switched to compartment III as summarized in the following sections.

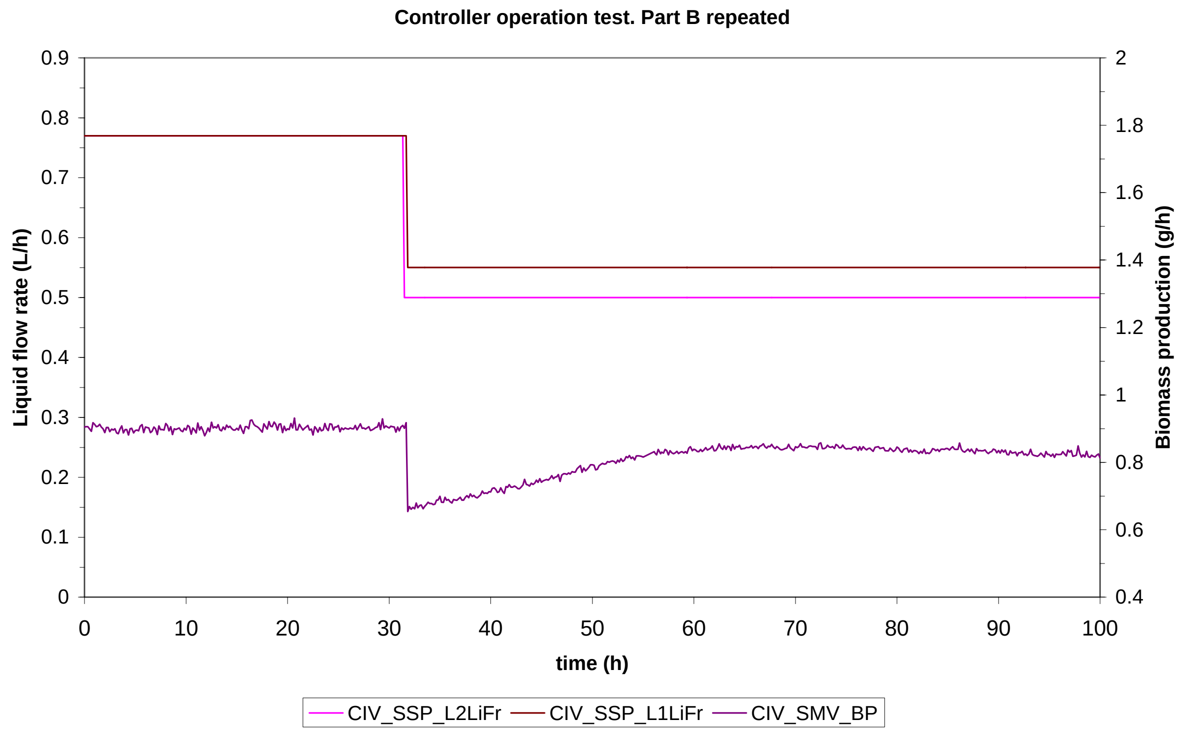


Figure 12: Values of the liquid flow rate during the repetition of the controller operation test part B. Biomass production is shown as reference with the previous figure.

4 COMPARTMENT III.

4.1 Installation of the new control hardware. Description of the procedure.

The old PLC controllers were located inside a control rack cabin (RITTAL). All analog and digital I/O in compartment III pilot reactor, as well as all power supply lines for the peripheric equipment were also centralized in that control rack. The whole control rack cabin was substituted by a bigger one (RITTAL), where the new controllers (Quantum PLC, Schneider) and internal connexions had been previously installed by NTE. UAB personnel carried out the change of all the electrical connexions (analog and digital I/O, as well as power supply lines) for the proper installation of the new hardware in the MELISSA Pilot Plant in collaboration with NTE personnel. All connexions were tested by NTE and UAB to ensure maximum reliability in the installation of the new hardware. Description of all electrical interfaces and related items of the control rack can be found in TN 72.4 (Duatis 2004).

After this first part of the installation of the control system in the laboratory, all the new equipment was connected to the reactor. It is important to outline that the main difficulty of this operation (i.e. the hardware migration) was to keep compartment III in operation during the period of time used to substitute the old hardware by the new one. Reactor load was decreased to a minimum in order to keep biofilm activity but at the same time minimize number of control loops active. In that way, only essential control loops were kept switched on (i.e. pH control loop). Relatively high aeration flow-rate (1 $L \cdot min^{-1}$) was used to avoid carrying out the hardware migration with the dissolved oxygen loop active.

Once the normal continuous nitrifying operation was stable again after the hardware migration the rest of loops were tested with specific and basic tests to assure correct performance of the new control system, including dissolved oxygen, temperature, pressure and level control loops.

4.2 Validation of the implementation of the control software.

Once all these specific tests for each basic control loop were performed specific tests of the implementation of the control software designed by SHERPA ENGINEERING (Leclercq 2004, 72.3.4) were carried out, in collaboration with NTE, to check the performance of the hardware and software installed. Two different tests were required:

a) Test 1: a short test was designed to check internal variables and data processing. The test proposed by SHERPA ENG required a step-up change in the flow-rate followed by a change in the nitrite concentration constraint.
b) Test 2: the second test is a longer one, which concerns more precisely the behaviour of the control: time response of the closed loop and oscillations. The nitrite constraint was

kept constant in the whole test and the requested flow-rate was changed to study the response of the liquid flow-rate computed.

4.2.1 TEST 1

Following SHERPA ENG requirements the short term test was carried out in the nitrifying pilot reactor. Results were stored in the hard disk of the new user's station and sent to SHERPA ENG for validation of the system implementation. An error in the software was detected by SHERPA and once it was solved the test was repeated. The results obtained in the test finally validated by SHERPA ENG are presented in figure 13. In figure 13 two graphs are shown, in the first one, the change in required liquid flow–rate (at time 0.1h) is produced and both measured and requested flow-rates are shown in the top graph of the figure. The second disturbance of the test is a step down in nitrite concentration constraint (at time 1.5h), as it is shown in the bottom graph of figure 13. On-line measurement of the effluent concentration for ammonium and nitrate is also shown in the graph. The inflow ammonium concentration was kept constant at 300 mg N / L.

After SHERPA ENG assessment of the results obtained in the short test, UAB started the second test, as it will be explained in the next section.

4.2.2 TEST 2

Following SHERPA ENG requirements the long term test was carried out in the nitrifying pilot reactor. Results were stored in the hard disk of the new user's station and sent to SHERPA ENG for validation of the system implementation. The results obtained in the test finally validated by SHERPA ENG are presented in figure 14. In figure 14 two graphs are shown, in the first one, the change (step up) in required liquid flow-rate is produced at time 0.1h, both measured and requested flow-rates are shown in the top graph of the figure. In the bottom graph (figure 14) the nitrite concentration constraint as well as ammonium concentration in the inflow and on-line measurement of the nitrate concentration is presented. In this case, no disturbance in nitrite concentration constraint is introduced in the system.

Once the experiment presented in figure 14 was finished results (raw data) were sent to SHERPA ENG for assessment, to validate the implementation of the new control system in the MELISSA Pilot Plant.

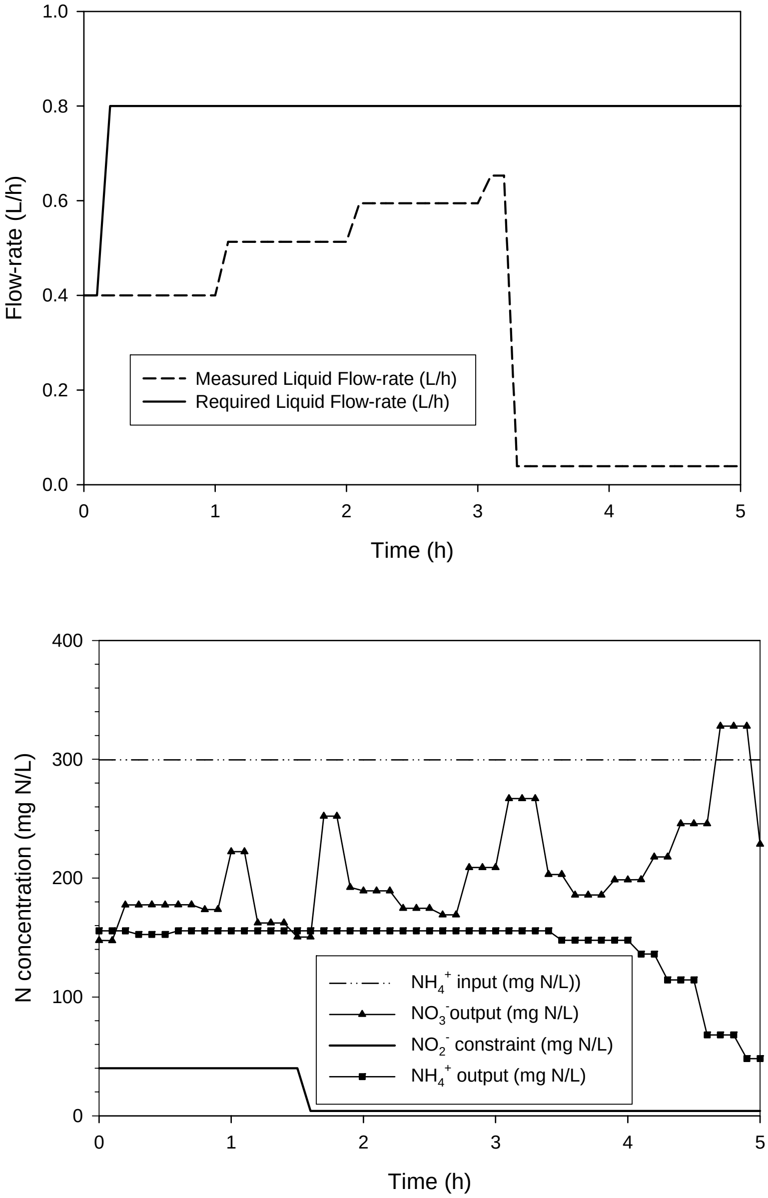
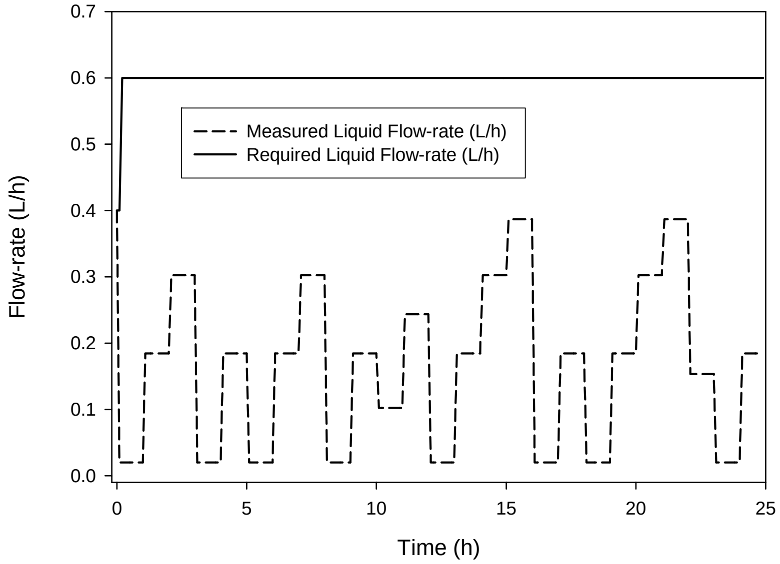


Figure 13: Short test carried-out in compartment III pilot reactor for the validation of the implementation of the new control system. Requested as well as measured liquid flow-rate are shown in the top graph. In the bottom graph the variation of the nitrite concentration constraint as well as measured ammonium and nitrate concentration in the effluent are shown.



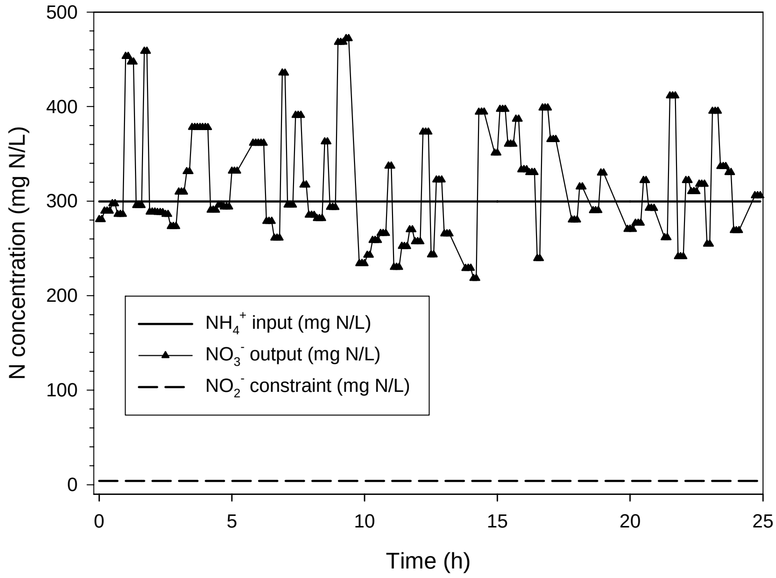


Figure 14: Long test carried-out in compartment III pilot reactor for the validation of the implementation of the new control system. Requested as well as measured liquid flow-rate are shown in the top graph. In the bottom graph the variation of the nitrite concentration constraint as well as measured nitrate concentration in the effluent are shown.

5 CONCLUSIONS

Following the assembly of the control hardware by NTE it was installed in the Pilot Plant by the MELISSA personnel. To validate the system a series of validation tests designed by SHERPA ENGINEERING were performed. As a result of the tests, the implementation and validation of the control hardware and the corresponding control law for compartment IVa has been validated and confirmed by SHERPA ENGINEERING.

In case of compartment III the implementation of validation of the hardware and control software has been validated. Nevertheless the performance of the control law for compartment III was not evaluated. The control law for compartment III is still pending to be approved by ESA. For this reason the full validation of the control law was not performed. Results of the performed tests were reviewed and approved by SHERPA ENGINEERING.

6 REFERENCES

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