Eco Process Assistance

De Prijkels • Venecoweg 19 • B-9810 Nazareth
Tel. +32 9 381.51.30
Fax +32 9 221.82.18
www.epas.be • epas@epas.be

ENGINEERING OF THE WASTE COMPARTMENT

ESA contract 15689/01/NL/ND

TECHNICAL NOTE 71.9.3

Test performance

Version : 1
Issue: 2

	Name		Signature
Prepared by:	Noëlle Michel		
Checked by:	PM	Noëlle Michel	
Approved by:	BUM	Dries Demey	

17 september 2004

DOCUMENT CHANGE LOG

Version	Issue	Date	Observation
1	0	31/08/2004	Draft
1	1	09/09/2004	Draft
1	2	17/09/2004	Final

DISTRIBUTION LIST

Quantity	Company/Department	Name
2	ESA	C. Lasseur
1	EPAS	D. Demey
		N. Michel
1	UAB	J.Albiol
		F. Godia
1	UBP	C.G. Dussap
		L. Poughon
1	VITO	H. De wever
1	LabMET	W. Verstraete
1	U. Guelph	M.A. Dixon
1	SCK	M. Mergeay
1	SHERPA	J. Brunet

CONTENT

LIST OF TABLES

1. Introduction

The liquefying compartment of the MELiSSA loop is responsible for the biodegradation of human faecal material and other wastes (inedible parts of plant material) generated by the crew. The volatile fatty acids and ammonia produced during the anaerobic fermentation process are fed to the second photoheterotrophic compartment inoculated with the bacterium *Rhodospirillum rubrum*. The produced CO_2 is supplied to the photoautotrophic compartment inoculated with the algal strain *Arthrospira platensis* and to the higher plants compartment.

At the pilot plant of the University of Barcelona, the three compartments of the MELiSSA loop (photoheterotrophic compartment CII, nitrifying compartment CIII and photoautotrophic compartment CIVa) are already connected at lab scale and will be validated at pilot scale. In order to validate the whole MELiSSA loop, it is necessary to construct the first compartment at pilot scale (fermentation reactor) for the primary degradation of the waste produced by the crew.

However, between lab and pilot scales the construction of an intermediate prototype reactor represents an important step to evaluate and improve the theoretical concepts.

Once the prototype Waste Compartment is assembled, it is necessary to perform functional tests to evaluate the hardware and the process. A first series is performed to test individually the sensors, actuators and other instruments and equipment. After these functional tests the reactor is filled with the Melissa inoculum and fed with representative substrate. The next series of tests are performed for a period of three months.

This technical note presents the results of the functional tests. The evaluation of these results together with the propositions for optimisation are presented in technical note 71.9.4.

2. Tests principles

Based on the general system requirements, a detailed list of criteria that must be satisfied by the system was established, with the general related instrumentation.

For each phase the system requirements were listed together with the related instrumentation and the basis of the associated tests (see Table 1).

Table 1. Listing of requirements

Nber	Requirements	Related instrumentation									Test principle
		Reactor, tanks	Membrane	Pumps	Mixer	Heat exchanger	Balance	Valves and connections	Sensors, transmitters	Controller	
	Hardware phase										
1	Homogeneous mixing				■					■	Check visually + analyse and compare composition of samples from bottom and top of reactor on representative period
2	Stable heating of the reactor (55°C)					■				■	Control on representative period the stability and accuracy of temperature
3	Gas tightness	■			■	■		■	■		Put reactor/system under pressure and measure on representative period the pressure stability (big leaks) or check small leaks with gas detector
4	Liquid tightness	■		■	■	■		■	■		Check visually absence of leakage
5	Running of sensors and actuators		■	■			■	■	■		Check visually running on/ off line
	Operation phase										
	Hardware evaluation										
1	Absence of clogging		■	■				■			Check regularly right flow and absence of clogging through piping
2	Absence of corrosion / fouling	■		■	■	■		■	■		Regular visual check

3	Accuracy and repeatability of measurements											Regular calibration
4	Absence of instrument deterioration											Regular visual check
5	Absence of reactor deterioration											Regular visual check
6	Desired answer to user or controller action											Check right answer of instrument to one user/ controller action
7	Regulation of permeate production											Evaluate permeate production depending on selected program of the filtration unit
8	Regulation of gas loop											Check correct regulation of the gas loop on a representative period
9	Configuration of reactor											Evaluate general configuration of reactor
10	Configuration of filtration unit											Evaluate general configuration of filtration unit
11	Configuration of gas loop											Evaluate general configuration of gas loop
	Process evaluation											
	Biological requirement	*Expected value*	*Whole system*									
1	Optimisation of filtration process (quality of permeate, sludge concentration, technical performance)											Evaluate quality of filtration with regular analysis on reactor content and permeate; evaluate technical performance of filtration process with measuring the flow through speed
2	Optimisation of VFA production	min 3 g/L* in reactor										Measure regularly VFA concentration in reactor/ permeate
3	Optimisation of NH4+ production	min 0.27 g/L* in reactor										Measure regularly NH4+ concentration in reactor/ permeate
4	Optimisation of CO2 production											Measure regularly CO2 production
5	Optimisation of OM degradation efficiency	min 20%										Evaluate regularly OM efficiency of the prototype based on regular analysis

6	Optimisation of Nitrogen degradation efficiency	min 35%		Evaluate regularly N efficiency of the prototype based on regular analysis
7	Optimisation of Fibres degradation efficiency	min 15%		Evaluate regularly Fibres efficiency of the prototype based on regular analysis

*Expected process values are determined based on experimental data gained on Melissa lab reactors at EPAS and on model-based estimation as described in TN71.1.

3. Tests results

The following table presents the performance of the prototype reactor. The tests of operation phase were performed on a total period of 4 months. The tests of hardware phase were performed during 11 months since they could be started before nominal operation of the bioreactor.

The detailed results of the process tests are presented in TN 71.4, together with their evaluation.

Test nb	Phase	Sub-Phase	Requirement nb	Tested requirement	Sub-system	Test sub-nber	Instrument ref	Instrument description	Test performed (Y/N)	Test result	Comments
H.1.R.1	H.		1.	Homogeneous mixing	R.	1	BL-R-001	Mixer	Y	OK	
								Control	Y	OK	
H.2.R.1			2.	Stable heating of the reactor (55°C)	R.	1	HX-R-001	Heat exchanger	Y	OK	
								Control	Y	OK	
							HX-G-001	Cooler	Y	OK	
H.3.R.1			3.	Gas tightness	R.	1	R-001	Reactor	Y	OK	
							BL-R-001	Mixer for the bioreactor, equipped with LC-impeller	Y	OK	
							HX-R-001	Heat exchanger	Y	OK	
							PD-R-001	ressure transmitter	Y	OK	
							PD-R-002	Pressure transmitter	Y	OK	
							TS-R-001	Temperature sensor	Y	OK	
							pHS-R-001	pH sensor	Y	OK	
							pHT-R-001	pH transmitter	Y	OK	
								Valves, connections	Y	OK	
H.3.F.1					F.	1	R-F-001	Buffer tank	Y	NOT OK	Leakage
H.3.G.1					G.	1	R-G-001	Pressure vessel: buffer for produced gas at 4 bar	Y	OK	
							HX-G-001	Cooler	Y	OK	

						PMP-G-001	Master pump that generates air flow through gas loop	Y	OK	
						PD-G-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
						PD-G-002	Precision stainless steel pressure transmitter pressure vessel	Y	OK	
						GS-G-001	Gas analyser	Y	OK	
						GS-G-002	Gas analyser	Y	OK	
						PI-G-001	Pressure on suction side of PMP-G-001	Y	OK	
						PI-G-002	Pressure at outlet gas analyser 1	Y	OK	
						PI-G-003	Pressure at outlet gas analyser 2	Y	OK	
						PI-G-004	Controlled backpressure by PR-G-004	Y	OK	
						PI-G-005	Controlled pressure by PR-G-001	Y	OK	
						PI-G-006	Inlet pressure to PR-G-001	Y	OK	
						FI-G-001	Rotameter for flow through gas loop and analysers	Y	OK	
						PR-G-001	spring loaded, diaphragm-sensed backpressure regulator: regulates pressure in buffer vessel R-G-001, relieves net gas produced	Y	OK	
						PR-G-004	Self-contained spring loaded pressure reducing regulator with negative bias, regulates bioreactor pressure	Y	OK	

						V-G-001	Valve regulating the flow through gas loop and gas analysers	Y	OK	
						V-G-002	Valve regulating the flow through gas loop and gas analyser 1	Y	OK	
						V-G-003	Valve regulating the flow through gas loop and gas analyser 2	Y	OK	
						V-G-004	Safety pressure relief valve on pressure vessel R-G-001	Y	OK	
						V-G-005	Valve regulating the flow through gas loop	Y	OK	
						V-G-006	Valve regulating the addition of N_2-gas at reactor start-up	Y	OK	
						V-G-007	Automatic liquid drain on vessel R-G-001	Y	OK	
							Connections	Y	NOT OK	Small leakage of some connections
H.4.R.1		4.	Liquid tightness	R.	1	R-001	Reactor	Y	OK	
						BL-R-001	Mixer for the bioreactor, equipped with LC-impeller	Y	OK	
						HX-R-001	Heat exchanger	Y	OK	
						PMP-R-001	Influent pump	Y	OK	
						PD-R-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
						PD-R-002	Precision stainless steel pressure transmitter bioreactor	Y	OK	
						TS-R-001	Temperature sensor	Y	OK	
						pHS-R-001	pH sensor	Y	OK	
							Valves, connections	Y	OK	
H.4.F.1				F.	1	R-F-001	Buffer tank	Y	OK	

						R-F-002	Permeate tank	Y	OK	
						PMP-F-001	Pump	Y	OK	
						PD-F-001	Pressure transducer before filtration module	Y	OK	
						PD-F-002	Pressure transducer after filtration module	Y	OK	
						PD-F-003	Pressure transducer on permeate flow	Y	OK	
						TS-F-001	Temperature sensor	Y	OK	
						FD-F-001	Flow meter	Y	OK	
						LD-F-001	Level sensor in buffer tank	Y	OK	
						SS-F-001	Turbidity sensor	Y	OK	
						NS-F-001	Ammonium analyser	Y	OK	
						V-F-001	Software controlled valve between reactor and buffer tank	Y	OK	
						V-F-006	Software controlled valve between filtration module and buffer tank	Y	OK	
						V-F-011	Software controlled valve for permeate flow back to buffer tank	Y	OK	
						V-F-013	Software controlled valve for effluent flow	Y	OK	
						V-F-002	Manual controlled valve between buffer tank and pump	Y	OK	
						V-F-003	Manual controlled valve between buffer tank and filtration module	Y	OK	
						V-F-004	Manual controlled valve before membrane module	Y	OK	

						V-F-005	Manual controlled valve after membrane module	Y	OK	
						V-F-007	Manual controlled valve between reactor and buffer tank	Y	OK	
						V-F-008	Manual controlled valve between reactor and buffer tank	Y	OK	
						V-F-009	Manual controlled valve between reactor and buffer tank	Y	OK	
						V-F-012	Manual controlled valve before permeate tank	Y	OK	
						V-F-014	Manual controlled valve between reactor and buffer tank	Y	OK	
						V-F-015	Manual controlled valve between reactor and buffer tank	Y	OK	
							Connections	Y	OK	
H.4.G.1				G.	1	V-G-007	Automatic liquid drain on gas buffer vessel R-G-001	Y	OK	
							Connections	Y	OK	
H.5.R.1		5.	Running of sensors and actuators	R.	1	PMP-R-001	Influent pump	Y	OK	
						PD-R-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
						PD-R-002	Precision stainless steel pressure transmitter bioreactor	Y	OK	
						TS-R-001	Temperature sensor	Y	OK	
						pHS-R-001	pH sensor	Y	NOT OK	Current interferences with other instruments
						pHT-R-001	pH transmitter	Y	OK	
							Control system	Y	OK	
							Valves, connections	Y	OK	

H.5.F.1				F.	1	WD-F-001	Balance	Y	OK	
						PMP-F-001	Pump	Y	OK	
						PD-F-001	Pressure transducer before filtration module	Y	OK	
						PD-F-002	Pressure transducer after filtration module	Y	OK	
						PD-F-003	Pressure transducer on permeate flow	Y	OK	
						TS-F-001	Temperature sensor	Y	OK	
						TT-F-001	Temperature transmitter	Y	OK	
						FD-F-001	Flow meter	Y	OK	
						LD-F-001	Level sensor in buffer tank	Y	OK	
						V-F-001	Software controlled valve between reactor and buffer tank	Y	OK	
						V-F-006	Software controlled valve between filtration module and buffer tank	Y	OK	
						V-F-011	Software controlled valve for permeate flow back to buffer tank	Y	OK	
						V-F-013	Software controlled valve for effluent flow	Y	OK	
						V-F-002	Manual controlled valve between buffer tank and pump	Y	OK	
						V-F-003	Manual controlled valve between buffer tank and filtration module	Y	OK	
						V-F-004	Manual controlled valve before membrane module	Y	OK	
						V-F-005	Manual controlled valve after membrane module	Y	OK	

						V-F-007	Manual controlled valve between reactor and buffer tank	Y	OK	
						V-F-008	Manual controlled valve between reactor and buffer tank	Y	OK	
						V-F-009	Manual controlled valve between reactor and buffer tank	Y	OK	
						V-F-012	Manual controlled valve before permeate tank	Y	OK	
						V-F-014	Manual controlled valve between reactor and buffer tank	Y	OK	
						V-F-015	Manual controlled valve between reactor and buffer tank	Y	OK	
O.a.1.F.1	**O.**	**a.**	1.	Absence of clogging	R.	1	PMP-R-001	Influent pump	Y	NOT OK	Problem of selection; problem of a cleaning strategy, maintenance
								Valves, connections	Y	NOT OK	Problem of a cleaning strategy
					F.	1	M-F-001	Membrane	Y	OK	
							PMP-F-001	Pump	Y	OK	
							V-F-001	Software controlled valve between reactor and buffer tank	Y	OK	
							V-F-006	Software controlled valve between filtration module and buffer tank	Y	NOT OK	Problem of selection (internal diameter too small)
							V-F-011	Software controlled valve for permeate flow back to buffer tank	Y	OK	
							V-F-013	Software controlled valve for effluent flow	Y	OK	
							V-F-002	Manual controlled valve between buffer tank and pump	Y	OK	

							V-F-003	Manual controlled valve between buffer tank and filtration module	Y	OK	
							V-F-004	Manual controlled valve before membrane module	Y	OK	
							V-F-005	Manual controlled valve after membrane module	Y	OK	
							V-F-007	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-008	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-009	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-012	Manual controlled valve before permeate tank	Y	OK	
							V-F-014	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-015	Manual controlled valve between reactor and buffer tank	Y	OK	
								Connections, tubings	Y	NOT OK	Problem of a cleaning strategy
O.a.2.R.1			2.	Absence of corrosion / fooling	R.	1	R-001	Reactor	Y	OK	
							BL-R-001	Mixer for the bioreactor, equipped with LC-impeller	Y	OK	
							HX-R-001	Heat exchanger	Y	OK	
							PD-R-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
							PD-R-002	Precision stainless steel pressure transmitter bioreactor	Y	OK	
							TS-R-001	Temperature sensor	Y	OK	

							pHS-R-001	pH sensor	Y	OK	
								Valves, connections, tubings	Y	OK	
O.a.2.F.1					F.	1	R-F-001	Buffer tank	Y	OK	
							R-F-002	Permeate tank	Y	OK	
							PMP-F-001	Pump	Y	NOT OK	Problem of selection of housing (regarding temperature and sludge composition)
							PD-F-001	Pressure transducer before filtration module	Y	OK	
							PD-F-002	Pressure transducer after filtration module	Y	OK	
							PD-F-003	Pressure transducer on permeate flow	Y	OK	
							TS-F-001	Temperature sensor	Y	OK	
							FD-F-001	Flow meter	Y	OK	
							LD-F-001	Level sensor in buffer tank	Y	NOT OK	Some fouling: problem of a cleaning strategy
							V-F-001	Software controlled valve between reactor and buffer tank	Y	OK	
							V-F-006	Software controlled valve between filtration module and buffer tank	Y	OK	
							V-F-011	Software controlled valve for permeate flow back to buffer tank	Y	OK	
							V-F-013	Software controlled valve for effluent flow	Y	OK	
							V-F-002	Manual controlled valve between buffer tank and pump	Y	OK	
							V-F-003	Manual controlled valve between buffer tank and filtration module	Y	OK	

							V-F-004	Manual controlled valve before membrane module	Y	OK	
							V-F-005	Manual controlled valve after membrane module	Y	OK	
							V-F-007	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-008	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-009	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-012	Manual controlled valve before permeate tank	Y	OK	
							V-F-014	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-015	Manual controlled valve between reactor and buffer tank	Y	OK	
								Connections	Y	OK	
							M-F-001	Membrane	Y	NOT OK	Fouling occurs very fast: problem of selection, cleaning strategy, flux control strategy
O.a.2.G.1					G.	1	R-G-001	Pressure vessel: buffer for produced gas at 4 bar	Y	OK	
							HX-G-001	Cooler	Y	OK	
							PMP-G-001	Master pump that generates air flow through gas loop	Y	NOT OK	Condensation occurred: due to configuration problem
							PD-G-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
							PD-G-002	Precision stainless steel pressure transmitter pressure vessel	Y	OK	

							GS-G-001	Gas analyser	Y	NOT OK	Condensation occurred: problem of configuration
							PI-G-001	Pressure on suction side of PMP-G-001	Y	OK	
							PI-G-002	Pressure at outlet gas analyser 1	Y	OK	
							PI-G-003	Pressure at outlet gas analyser 2	Y	OK	
							PI-G-004	Controlled backpressure by PR-G-004	Y	OK	
							PI-G-005	Controlled pressure by PR-G-001	Y	OK	
							PI-G-006	Inlet pressure to PR-G-001	Y	OK	
							FI-G-001	Rotameter for flow through gas loop and analysers	Y	OK	
							PR-G-001	spring loaded, diaphragm-sensed backpressure regulator: regulates pressure in buffer vessel R-G-001, relieves net gas produced	Y	OK	
							PR-G-004	Self-contained spring loaded pressure reducing regulator with negative bias, regulates bioreactor pressure	Y	OK	
							V-G-001	Valve regulating the flow through gas loop and gas analysers	Y	OK	
							V-G-002	Valve regulating the flow through gas loop and gas analyser 1	Y	OK	
							V-G-003	Valve regulating the flow through gas loop and gas analyser 2	Y	OK	

							V-G-004	Safety pressure relief valve on pressure vessel R-G-001	Y	OK	
							V-G-005	Valve regulating the flow through gas loop	Y	OK	
							V-G-006	Valve regulating the addition of N_2-gas at reactor start-up	Y	OK	
							V-G-007	Automatic liquid drain on vessel R-G-001	Y	OK	
								Connections, tubings	Y	OK	
O.a.3.R.1			3.	Accuracy and repeatability of measurements	R.	1	PD-R-001	Precision stainless steel pressure transmitter bioreactor	Y	NOTOK	Bioreactor liquid level determination based on pressure is not accurate: due to variations of pressure in the reactor
O.a.3.R.2						2	PD-R-002	Precision stainless steel pressure transmitter bioreactor	Y	NOT OK	
O.a.3.R.3						3	TS-R-001	Temperature sensor	Y	OK	
							TT-R-001	Temperature transmitter	Y	OK	
O.a.3.R.4						4	pHS-R-001	pH sensor	Y	NOT OK	Current interference with other instruments
							pHT-R-001	pH transmitter	Y	OK	
O.a.3.F.1					F.	1	WD-F-001	Balance	Y	OK	
O.a.3.F.2						2	PD-F-001	Pressure transducer before filtration module	Y	OK	
O.a.3.F.3						3	PD-F-002	Pressure transducer after filtration module	Y	OK	
O.a.3.F.4						4	PD-F-003	Pressure transducer on permeate flow	Y	OK	
O.a.3.F.5						5	TS-F-001	Temperature sensor	Y	OK	
							TT-F-001	Temperature transmitter	Y	OK	
O.a.3.F.6						6	FD-F-001	Flow meter	Y	OK	
O.a.3.F.7						7	LD-F-001	Level sensor in buffer tank	Y	OK	

O.a.3.G.1					G.	1	PD-G-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
O.a.3.G.2						2	PD-G-002	Precision stainless steel pressure transmitter pressure vessel	Y	OK	
O.a.3.G.3						3	GS-G-001	Gas analyser	Y	OK	
O.a.3.G.5						5	PI-G-001	Pressure on suction side of PMP-G-001	Y	OK	
O.a.3.G.6						6	PI-G-002	Pressure at outlet gas analyser 1	Y	OK	
O.a.3.G.7						7	PI-G-003	Pressure at outlet gas analyser 2	Y	OK	
O.a.3.G.8						8	PI-G-004	Controlled backpressure by PR-G-004	Y	OK	
O.a.3.G.9						9	PI-G-005	Controlled pressure by PR-G-001	Y	OK	
O.a.3.G.10						10	PI-G-006	Inlet pressure to PR-G-001	Y	OK	
O.a.3.G.11						11	FI-G-001	Rotameter for flow through gas loop and analysers	Y	OK	
O.a.4.R.1			4.	Absence of instrument deterioration	R.	1	BL-R-001	Mixer for the bioreactor, equipped with LC-impeller	Y	OK	
							HX-R-001	Heat exchanger	Y	OK	
							PMP-R-001	Influent pump	Y	NOT OK	Need for a cleaning and maintenance strategy (replacing of tubing)
							PD-R-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
							PD-R-002	Precision stainless steel pressure transmitter bioreactor	Y	OK	
							TS-R-001	Temperature sensor	Y	OK	
							TT-R-001	Temperature transmitter	Y	OK	
							pHS-R-001	pH sensor	Y	OK	

							pHT-R-001	pH transmitter	Y	OK	
								Control system	Y	OK	
								Valves, connections, tubings	Y	OK	
O.a.4.F.1					F.	1	M-F-001	Membrane	Y	NOT OK	Fouling occurs very fast (problem of membrane selection, cleaning procedure, flux control strategy)
							WD-F-001	Balance	Y	OK	
							PMP-F-001	Pump	Y	OK	
							PD-F-001	Pressure transducer before filtration module	Y	OK	
							PD-F-002	Pressure transducer after filtration module	Y	OK	
							PD-F-003	Pressure transducer on permeate flow	Y	OK	
							TS-F-001	Temperature sensor	Y	OK	
							TT-F-001	Temperature transmitter	Y	OK	
							FD-F-001	Flow meter	Y	OK	
							LD-F-001	Level sensor in buffer tank	Y	OK	
							V-F-001	Software controlled valve between reactor and buffer tank	Y	OK	
							V-F-006	Software controlled valve between filtration module and buffer tank	Y	OK	
							V-F-011	Software controlled valve for permeate flow back to buffer tank	Y	OK	
							V-F-013	Software controlled valve for effluent flow	Y	OK	
							V-F-002	Manual controlled valve between buffer tank and pump	Y	OK	

							V-F-003	Manual controlled valve between buffer tank and filtration module	Y	OK	
							V-F-004	Manual controlled valve before membrane module	Y	OK	
							V-F-005	Manual controlled valve after membrane module	Y	OK	
							V-F-007	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-008	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-009	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-012	Manual controlled valve before permeate tank	Y	OK	
							V-F-014	Manual controlled valve between reactor and buffer tank	Y	OK	
							V-F-015	Manual controlled valve between reactor and buffer tank	Y	OK	
								Connections	Y	OK	
O.a.4.G.1					G.	1	R-G-001	Pressure vessel: buffer for produced gas at 4 bar	Y	OK	
							HX-G-001	Cooler	Y	OK	
							PMP-G-001	Master pump that generates air flow through gas loop	Y	NOT OK	Deterioration due to condensation
							PD-G-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
							PD-G-002	Precision stainless steel pressure transmitter pressure vessel	Y	OK	

							GS-G-001	Gas analyser	Y	NOT OK	Deterioration due to condensation and overpressure
							PI-G-001	Pressure on suction side of PMP-G-001	Y	OK	
							PI-G-002	Pressure at outlet gas analyser 1	Y	OK	
							PI-G-003	Pressure at outlet gas analyser 2	Y	OK	
							PI-G-004	Controlled backpressure by PR-G-004	Y	OK	
							PI-G-005	Controlled pressure by PR-G-001	Y	OK	
							PI-G-006	Inlet pressure to PR-G-001	Y	OK	
							FI-G-001	Rotameter for flow through gas loop and analysers	Y	OK	
							PR-G-001	spring loaded, diaphragm-sensed backpressure regulator: regulates pressure in buffer vessel R-G-001, relieves net gas produced	Y	OK	
							PR-G-004	Self-contained spring loaded pressure reducing regulator with negative bias, regulates bioreactor pressure	Y	OK	
							V-G-001	Valve regulating the flow through gas loop and gas analysers	Y	OK	
							V-G-002	Valve regulating the flow through gas loop and gas analyser 1	Y	OK	
							V-G-003	Valve regulating the flow through gas loop and gas analyser 2	Y	OK	

							V-G-004	Safety pressure relief valve on pressure vessel R-G-001	Y	OK	
							V-G-005	Valve regulating the flow through gas loop	Y	OK	
							V-G-006	Valve regulating the addition of N_2-gas at reactor start-up	Y	OK	
							V-G-007	Automatic liquid drain on vessel R-G-001	Y	OK	
								Connections	Y	OK	
O.a.5.R.1			5.	Absence of reactor deterioration	R.	1	R-001	Reactor	Y	OK	
O.a.5.F.1					F.	1	R-F-001	Buffer tank	Y	OK	
O.a.5.F.2						2	R-F-002	Permeate tank	Y	NOT OK	Break of a top connection
O.a.5.G.1					G.	1	R-G-001	Pressure vessel: buffer for produced gas at 4 bar	Y	OK	
O.a.6.R.1			6.	Desired answer to user or controller action	R.	1	BL-R-001	Mixer for the bioreactor, equipped with LC-impeller	Y	OK	
O.a.6.R.2						2	HX-R-001	Heat exchanger	Y	OK	
O.a.6.R.3						3	PMP-R-001	Influent pump	Y	NOT OK	Tubing wearing: settings must always be manually adapted to regulate the influent flow
O.a.6.R.4						4		Valves, connections	Y	OK	
O.a.6.F.1					F.	1	WD-F-001	Balance	Y	OK	
O.a.6.F.2						2	PMP-F-001	Pump	Y	NOT OK	Unwanted stop: due to non adapted housing, electrical short cuts
O.a.6.F.5						5	V-F-001	Software controlled valve between reactor and buffer tank	Y	NOT OK	In case of underpressure in the bioreactor: sludge do not circulate to buffer, risk of emptying buffer and thus FU
O.a.6.F.6						6	V-F-006	Software controlled valve between filtration module and buffer tank	Y	OK	
O.a.6.F.7						7	V-F-011	Software controlled valve for permeate flow back to buffer tank	Y	OK	

O.a.6.F.8						8	V-F-013	Software controlled valve for effluent flow	Y	NOT OK	Occasional blockage due to electrical contact
O.a.6.F.9						9	V-F-002	Manual controlled valve between buffer tank and pump	Y	OK	
O.a.6.F.10						10	V-F-003	Manual controlled valve between buffer tank and filtration module	Y	OK	
O.a.6.F.11						11	V-F-004	Manual controlled valve before membrane module	Y	OK	
O.a.6.F.12						12	V-F-005	Manual controlled valve after membrane module	Y	OK	
O.a.6.F.13						13	V-F-007	Manual controlled valve between reactor and buffer tank	Y	OK	
O.a.6.F.14						14	V-F-008	Manual controlled valve between reactor and buffer tank	Y	OK	
O.a.6.F.15						15	V-F-009	Manual controlled valve between reactor and buffer tank	Y	OK	
O.a.6.F.16						16	V-F-012	Manual controlled valve before permeate tank	Y	OK	
O.a.6.F.17						17	V-F-014	Manual controlled valve between reactor and buffer tank	Y	OK	
O.a.6.F.18						18	V-F-015	Manual controlled valve between reactor and buffer tank	Y	OK	
O.a.6.G.1					G.	1	HX-G-001	Cooler	Y	OK	
O.a.6.G.2						2	PMP-G-001	Master pump that generates air flow through gas loop	Y	NOT OK	Difficulties at start up due to high pressure on side of the pump: problem of configuration
O.a.6.G.3						3	PI-G-004	Controlled backpressure by PR-G-004	Y	OK	
O.a.6.G.4						4	PI-G-005	Controlled pressure by PR-G-001	Y	OK	

O.a.6.G.5						5	PR-G-001	spring loaded, diaphragm-sensed backpressure regulator: regulates pressure in buffer vessel R-G-001, relieves net gas produced	Y	NOT OK	Unwanted changing of the set point due to vibrations of the racks
O.a.6.G.6						6	PR-G-004	Self-contained spring loaded pressure reducing regulator with negative bias, regulates bioreactor pressure	Y	NOT OK	Unwanted changing of the set point due to vibrations of the racks
O.a.6.G.7						7	V-G-001	Valve regulating the flow through gas loop and gas analysers	Y	OK	
O.a.6.G.8						8	V-G-002	Valve regulating the flow through gas loop and gas analyser 1	Y	OK	
O.a.6.G.10						10	V-G-004	Safety pressure relief valve on pressure vessel R-G-001	Y	OK	
O.a.6.G.11						11	V-G-005	Valve regulating the flow through gas loop	Y	OK	
O.a.6.G.12						12	V-G-006	Valve regulating the addition of N_2-gas at reactor start-up	Y	OK	
O.a.6.G.13						13	V-G-007	Automatic liquid drain on vessel R-G-001	Y	NOT OK	Blockage requiring manual shake
O.a.7.1			7.	Regulation of permeate production	R.	1		Control system	Y	OK	
					F.		WD-F-001	Balance	Y	OK	
							PMP-F-001	Pump	Y	OK	
							PD-F-001	Pressure transducer before filtration module	Y	OK	
							PD-F-002	Pressure transducer after filtration module	Y	OK	

							PD-F-003	Pressure transducer on permeate flow	Y	OK	
							FD-F-001	Flow meter	Y	OK	
							LD-F-001	Level sensor in buffer tank	Y	OK	
							V-F-001	Software controlled valve between reactor and buffer tank	Y	OK	
							V-F-006	Software controlled valve between filtration module and buffer tank	Y	NOT OK	Internal diameter too small regarding sludge particles: frequent clogging and stopping of FU
							V-F-011	Software controlled valve for permeate flow back to buffer tank	Y	OK	
							V-F-013	Software controlled valve for effluent flow	Y	NOT OK	Occasional blocking due to electrical problem (bad contact)
O.a.8.1			8.	Regulation of gas loop	R.	1		Control system	Y	OK	
					G.		HX-G-001	Cooler	Y	OK	
							PMP-G-001	Master pump that generates air flow through gas loop	Y	OK	
							PD-G-001	Precision stainless steel pressure transmitter bioreactor	Y	OK	
							PD-G-002	Precision stainless steel pressure transmitter pressure vessel	Y	OK	
							PI-G-001	Pressure on suction side of PMP-G-001	Y	OK	
							PI-G-002	Pressure at outlet gas analyser 1	Y	OK	
							PI-G-003	Pressure at outlet gas analyser 2	Y	OK	
							PI-G-004	Controlled backpressure by PR-G-004	Y	OK	

							PI-G-005	Controlled pressure by PR-G-001	Y	OK	
							PI-G-006	Inlet pressure to PR-G-001	Y	OK	
							FI-G-001	Rotameter for flow through gas loop and analysers	Y	OK	
							PR-G-001	spring loaded, diaphragm-sensed backpressure regulator: regulates pressure in buffer vessel R-G-001, relieves net gas produced	Y	NOT OK	Problem of fixation of the set point (changes alone due to vibrations of the system)
							PR-G-004	Self-contained spring loaded pressure reducing regulator with negative bias, regulates bioreactor pressure	Y	NOT OK	Problem of fixation of the set point (changes alone due to vibrations of the system)
							V-G-001	Valve regulating the flow through gas loop and gas analysers	Y	OK	
							V-G-002	Valve regulating the flow through gas loop and gas analyser 1	Y	OK	
							V-G-003	Valve regulating the flow through gas loop and gas analyser 2	Y	OK	
							V-G-004	Safety pressure relief valve on pressure vessel R-G-001	Y	OK	
							V-G-005	Valve regulating the flow through gas loop	Y	OK	
							V-G-006	Valve regulating the addition of N_2-gas at reactor start-up	Y	OK	
							V-G-007	Automatic liquid drain on vessel R-G-001	Y	OK	
O.a.9.R.1			9.	Configuration of reactor	R.	1		all instrumentation	Y	OK	

O.a.9.F.1			10.	Configuration of filtration unit	F.	1		all instrumentation	Y	NOT OK	Cf selection of some instruments, absence of flux control strategy, location of some instruments
O.a.9.G.1			11.	Configuration of gas loop	G.	1		all instrumentation	Y	NOT OK	Cf safeties for gas analyzer, place of dryer
O.b.1.1		b.	1.	Optimisation of filtration process	F.	1		Whole system- Permeate stream	Y	NOT OK	Cf selection of membrane, absence of flux control strategy
O.b.2.1			2.	Optimisation of VFA production		1		Whole system- Permeate stream	Y	OK	
O.b.3.1			3.	Optimisation of NH4+ production		1		Whole system- Permeate stream	Y	OK	
O.b.4.1			4.	Optimisation of CO2 production		1		Whole system- Gas stream	Y	OK	
O.b.5.1			5.	Optimisation of OM degradation efficiency		1		Whole system	Y	OK	
O.b.6.1			6.	Optimisation of Nitrogen degradation efficiency		1		Whole system	Y	OK	
O.b.7.1			7	Optimisation of Fibres degradation efficiency		1		Whole system	Y	OK	

4. Conclusions

The test plan applied to the prototype compartment showed positive results on the global system. The targeted efficiencies were reached with the process. The hardware was also tested; There, some comments could be made in order to optimize the configuration of the pilot. Mainly, the filtration unit showed an unoptimal configuration. The tests results evaluation and the propositions for optimization are presented in technical note 71.9.4. Corrective actions that were tested on the prototype reactor or proposed for the pilot reactor are also described in TN 71.9.4.