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## BELISSIMA Contract No. 19297/05/NL/SFe WP80.311 Functional test plan Waste Preparation Unit

Organization Approval Loop :

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		Date :	Date :	Date :

Customer Approval :

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## 1. Scope

Within Phase 1 of the BELISSIMA contract, a Waste Preparation Unit has been designed and assembled. Its hardware functionality will be tested through this functional test plan.

## 2. Reference and applicable documents

### 2.1 *Applicable documents*

AD1 19071/05/NL/CP Memorandum of Understanding between MELiSSA partners  
Test plan template

### 2.2 *Reference documents*

RD1 TN80.241 Recommended design and integration strategy. Detailed design Waste Preparation Unit and Compartment I

## 3. Acronyms

WPU	Waste Preparation Unit
FAT	Factory Acceptance Testing
SAT	Site Acceptance Testing



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## 4. Test items

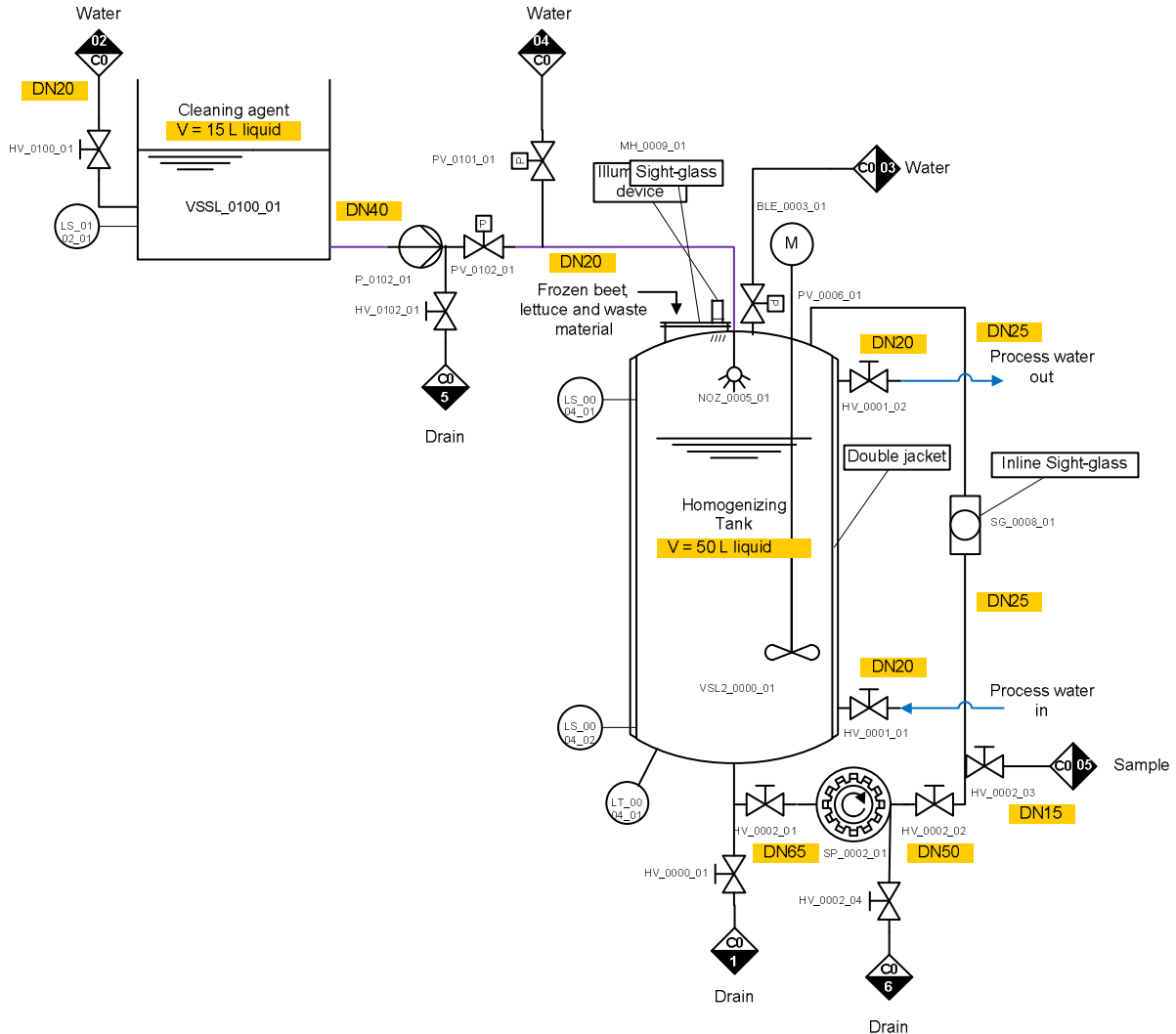
### 4.1 description

The aim of the WPU is to produce a homogeneously mixed feed for compartment I of the BELISSIMA loop. This feed will be prepared from frozen beet and lettuce, toilet paper, wheat straw, frozen urine and fecal material. The frozen beet and lettuce will be previously reduced in size in an off-line hygienic kitchen cutter (Robot Coupe, vertical cutter R30, 3 cutting blades with milled edges). The wheat straw is ground separately with two grinders from Retsch (step 1: Cutting mill SM100 at 8 mm, step 2: UltraCentrifugal Mill ZM200 with 2 mm sieve, step 3: UltraCentrifugal Mill ZM200 with 1.5 mm sieve) and sieved at 2 mm. The frozen urine and fecal material will be added directly into the WPU tank. The suspension is then diluted to the desired concentration through the addition of tap water. While the waste is circulated in a loop, further particle size reduction is achieved through an in-line pump shear pump. A sight-glass in the recirculation line allows to evaluate the mixing process.

The feed preparation unit will be cleaned after each use. To this end, an additional tank is provided from which flush water + cleaning agent can be pumped through the whole system, through a nozzles at the top of the main tank.

The final P&ID of the Waste Preparation Unit is shown in Figure 1.

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**Figure 1. Final P&ID of the Waste Preparation Unit.**

A component list is provided in Table 1.



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**Table 1: Component list Waste preparation Unit.**

Tag	Purpose - Description	Supplier	Ref. / order n°
VSL2_0000_01 BLE_0003_01	Main tank, double jacket, SS316L, inside Ra < 0,8 µm, total volume 70 l, working volume 50 l Removable top with sight glass, illumination device, opening for waste material addition and spare hygienic port. Equipped with spray ball and mechanically coupled stirrer with seal containment chamber at variable frequency. Equipped with sanitary connections to instrumentation and devices for easy cleaning.	Packo  PRG: <a href="http://www.prg-gmbh.de">www.prg-gmbh.de</a>	Stirrer: R100La-4SW VITO, with frequency drive
VSSL_0100_01	Cleaning tank, SS316L, inside Ra < 0,8 µm, 15 l	Packo	
SP_0002_01	Shear pump	Fristam <a href="http://www.fristam.de">www.fristam.de</a>	FSPE 3522/145 A, rotor 145 mm, 11 kW, Cr-Ni-Mo steel 1.4404, with frequency drive
P_0102_01	Centrifugal pump with mechanical coupling	Packo	FP2 32-125 112 O-130 M08S33SES
NOZ_0005_01	Sprayball, SS316L	Alfa Laval	Toftejorg SaniMicro Rotary Spray Head, SaniMicro 360 CLIP-ON
MH_0009_01	Manhole, SS316L, Ra < 0,8 µm, and light	Papenmeier	Glass DIN 8902, light USL03
SG_0008_01	Sight glass	AWH	1", SS316L
LS_0004_01	Level switch (foam detection)	E+H <a href="http://www.endress.com">www.endress.com</a>	Liquiphant M FTL 50H 1"-1"1/2, Tri-Clamp process connection
LS_0004_02	Level switch	E+H	Liquiphant T FTL 20H 1"-1"1/2, Tri-Clamp process connection
LT_0004_01	Level transmitter	E+H	CERABAR S PMP75, Tri-Clamp process connection
LS_0102_01	Level switch	E+H	Liquiphant T FTL 20H 1"-1"1/2, Tri-Clamp process connection
HV_0000_01	Sanitary 2-way ball valve, drain buffer tank	TVC	70T 2"1/2, Tri-Clamp process connection.
HV_0002_01	Sanitary 2-way ball valve, before shear pump	TVC	70T 2"1/2, Tri-Clamp process connection.
HV_0002_02	Sanitary 2-way ball valve, after shear pump	TVC	70T 2", Tri-Clamp process connection.
PV_0102_01	Powered 2-way diaphragm valve, after centrifugal	KSB	SISTO-B DN20, Tri-Clamp process connection





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Tag	Purpose - Description	Supplier	Ref. / order n°
	pump		
PV_0006_01	Powered 2-way diaphragm valve, inlet water to main tank	KSB	SISTO-B DN25, Tri-Clamp process connection
HV_0002_03	2-way diaphragm valve, valve to sample	KSB	SISTO-B DN15, Tri-Clamp process connection
HV_0001_01	Sanitary 2-way ball valve, inlet double jacket	TVC	70T 3/4", Tri-Clamp process connection
HV_0001_02	Sanitary 2-way ball valve, inlet double jacket	TVC	70T 3/4", Tri-Clamp process connection
PV_0101_01	Powered 2-way diaphragm valve, inlet water to sprayball	KSB	SISTO-B DN20, Tri-Clamp process connection
HV_0100_01	Sanitary 2-way ball valve, inlet water to cleaning tank	TVC	70T 3/4", Tri-Clamp process connection
HV_0102_01	Sanitary 2-way ball valve, drain after centrifugal pump	TVC	70T 3/4", Tri-Clamp process connection
HV_0002_04	Sanitary 2-way ball valve, drain after shear pump	TVC	70T 3/4", Tri-Clamp process connection



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## **4.2 hazards induced by test item and safety measures to be taken**

Fecal material and urine should be handled according to Class II Biosafety instructions.

Feed mixture with fecal material: aerosol formation should be avoided. On the open vent a single use filter (Pall, Kleenpak Capsule Filter, Emflon filter KA1PFRP1, 0.2 µm) will be mounted.

Spreading of potentially hazardous feed waste material:

- Before filling the homogenization tank, the operator has to check whether the drain and sample hand valves are closed.
- Opening the manhole will stop the shear pump immediately.
- During cleaning, opening the manhole will stop the cleaning pump and sprayball immediately.
- Inlet and outlet openings of agitator flange should be closed by connecting them with tubing.

Pressure buildup

- the unit should not operate at a pressure above 0.5 bar. At all times an open vent is necessary.
- Before starting the shear pump, the operator has to check whether the hand valves before and after the pump are in the open position.

Chemical hazards with cleaning agents: use of appropriate personnel protective equipment

## **4.3 instructions for operation**

An operating manual was provided by Packo and is provided in Appendix 1.

The instructions for operation are as follows:

- check that the installation is empty
- all pumps and stirrers shall be stopped
- check that the connections at the pumps are properly tightened after the last tests or cleanings
- an air filter shall be mounted on the open vent
- check that air filter is not clogged to avoid operation at a pressure above 0.5 bar
- all waste materials are added by hand
- avoid operating the stirrer for longer periods when there is no water in the homogenization tank

## **4.4 instructions for maintenance**

- check for the absence of leaks
- if there are leaks, tighten the connections or replace the gaskets in the Triclamp connections, the sensors, or the manhole lid
- make sure that mechanical stirrer flange is flushed by spraying with water



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## 5. Test strategy

### 5.1 Objectives of the tests

To demonstrate the basic functionalities of the hardware

### 5.2 Applicable requirements

- The WPU shall be liquid tight.
- The stirrer and pumps should induce homogeneous mixing of the substrate.
- The waste materials should be reduced to a size of 2 mm in the final waste suspension.
- The low and high level switches switch in response to low or high liquid levels.
- The high level switch in the homogenization tank (LS\_0004\_01) switches when foam occurs.
- The level transmitter measures the correct liquid volume.
- The level transmitter produces a stable signal.
- Control actions result in correct responses of components.

### 5.3 Approach followed

This test plan with its test protocols is developed based on a failure analysis.

### 5.4 Features to be tested

- Integrity of tanks, piping, and components
- Leakage of pumps, and connections
- Response of level switches to required action
- Correspondence between outgoing signal level transmitter and measured value
- Correctness of level transmitter measurement
- Correctness of control.

### 5.5 Features not to be tested

Homogeneity of mixing cannot be tested on water and will thus be investigated during the demonstration tests.

The waste material in the Waste Preparation Unit should be reduced down to 2 mm. This requirement will be tested in the demonstration tests.

The response of the high level switch in the homogenization tank to foam will not be tested during the functional tests. A test with detergent foam could be envisaged but is not relevant because the foam consistency will be quite different from the one encountered with the real waste. This will thus form part of the demonstration tests.

The main tank of the WPU contains a double jacket, in case temperature control would need to be implemented in the future. As this feature is not installed, temperature control is not tested.



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## 5.6 Success/failure criteria

	Success/failure criteria	Related instrumentation
1	Absence of liquid leakage	Reactor/tank, pumps, valves, sensors, connections
2	Level switches respond in the correct way to low or high levels	Level switches
3	Level transmitter shows correct liquid level with a tolerance of 10%	Level transmitter
4	Level transmitter shows fluctuations below 10% of target value	Level transmitter
5	Activation of pushbuttons on control unit results in correct action	Control unit and corresponding components (valves, switches, pumps, transmitters)

## 5.7 Test sequence (Test phases/test cycles)

### Phase 1

- Checking absence of leaks
  - The tanks are filled halfway with water
  - Components under liquid level are checked for the absence of leakages
  - A recheck is performed after 24 h
  - If a leak is observed, connections have to be tightened, the component better aligned or gaskets replaced
  - The shear pump is activated and the appropriate valves opened to fill the piping with water
  - All components in the piping are visually checked for absence of leaks
  - The centrifugal pump is activated and the appropriate valves opened to fill the piping with water
  - All components in the piping are checked for absence of leaks
- Checking functionalities and responses of components
  - All valves are opened and closed to check their operability
  - All electrical instruments are switched on and checked one by one for their operation
  - The tanks and pipes are filled with water till high level
  - The response of the high level switch in the homogenizing tank is checked
  - The stirrer is switched on and off
  - Mixing of and turbulence in the water volume is checked visually
  - The nozzle is activated and the spreading of water checked visually against the tank walls and top
  - The shear pump is switched on and off, while the flow of water into the homogenizing tank is checked visually
  - The cleaning pump is switched on and off and the flow of water into the homogenizing tank checked visually
  - The homogenizing tank is emptied and the response of the low level switch checked



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- The cleaning tank is emptied and the response of the low level switch checked

#### Phase 2: Checking the level transmitter accuracy

- The level transmitter is calibrated according to the manufacturer's instructions, choosing an appropriate calibration procedure which should take into account the non-linear increase in water volume with the height of the tank (round-bottomed tank and the presence of recirculation pipe)
- The homogenizing tank is filled manually with a known amount of water between 40 and 50 l which will be the typical values used for waste preparation
- The correspondence between the outgoing signal of the level transmitter and the measured value is checked
- If they are different, connections and settings are checked and adapted
- The correspondence between the measured value and the actually added water volume is checked
- If this is different, the level transmitter is recalibrated or a different more-point calibration procedure is used
- This procedure is repeated until measured value and actually added water volume differ less than 10%
- The stability of the signal is monitored every 2 min for at least 30 min while simultaneously the stability of the water surface is checked
- Then a different volume of water is added in the lower range (10-20 l) and the procedure repeated

#### Phase 3

- Executing controller action and checking adequacy of answer under normal operation
  - The homogenization tank is filled with water to half the total volume by pushing the buttons 'Start filling CO-04' and 'Stop filling CO-04'. The opening and closing of the appropriate valve is checked.
  - The shear pump is switched on
  - The flow of water into the homogenizing tank and the opening of the associated valve is checked visually. The actual flow of the pump is not measured as not the flow but rather the mixing capacity is important and this will be verified during the demonstration tests
  - The frequency of the shear pump is varied by varying the position of the button 'speed shear pump'
  - The flow of water into the homogenizing tank is checked visually
  - The shear pump is switched off. The flow of water and closing of the associated valve is checked visually.
  - The stirrer is switched on and the response checked visually
  - Its stirring speed is varied through the button 'speed mixer' and the response checked visually
  - The stirrer is switched off
  - The cleaning tank is filled with water to half the total volume by pushing the buttons 'Start filling CO-03' and 'Stop filling CO-03'. The opening and closing of the appropriate valve is checked.



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- Extra water is added to the cleaning tank by pushing button 'Extra filling CO-03'. The response is checked visually.
- The cleaning pump is switched on and off
- The flow of water into the homogenizing tank and the opening/closing of the associated valve is checked visually.
- The homogenization tank and piping is completely emptied. The water tap is opened halfway to avoid too high water flows into the system. A predefined volume below 20 l is entered in the controller display and the button 'start filling CO-03' pushed. The amount of water entered is measured by completely emptying the tank. This procedure is repeated 3 times for the same volume, and then again 3 times for a predefined volume between 40 and 50 l.
- The homogenization tank is first filled to a predefined level of 15 l. Then an additional volume of 17 l is added by pushing the button. The total volume is measured by weighing.
- Executing controller action and checking adequacy of answer under abnormal operation
  - The homogenization tank is filled with water. The shear pump is running. The homogenization tank is emptied by opening the drain until the low level switch switches. The shear pump should then stop running.
  - The cleaning tank is filled with water. The cleaning pump is running and pumping the water to the homogenization tank. When the low level switch in the cleaning tank switches, the cleaning pump should stop running.
  - The stirrer is switched off. The manhole is opened. The stirrer is then activated through the control unit. It should not be possible to activate it.
  - The homogenization tank is filled with water. The manhole is closed and the stirrer and shear pump activated. When the manhole is opened, both compounds should stop running.
  - The manhole is closed again. The stirrer is activated. When 'Emergency stop' is pushed, the stirrer should not automatically restart after renewed power supply.
  - The system is reset. The stirrer is activated. When the power supply is interrupted and a manual restart performed, the stirrer should not automatically restart.

## **5.8 Test deliverables**

Functional test report - Functional test results

## **6. Data collection plan – Sampling plan**

### **6.1 Uncertainty acceptance level**

For the level transmitter, deviations from setpoints should be below 10%.



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## 6.2 Measurement plan

Phase 1: no measurements

Phase 2:

- Accuracy of level transmitter measurement
  - The homogenization tank and pipes are emptied completely and left overnight to dry.
  - All valves under the tank are closed.
  - The tank is open to the atmosphere.
  - A predetermined volume of water is weighed and added to the homogenization tank.
  - The measured value is noted.
- Stability of level transmitter measurement
  - After filling the homogenization tank with water and waiting for the surface to become stable, the value measured by the level transmitter is monitored every 2 min for at least 30 min
- The procedure is repeated for a different volume of water in the lower range (10-20 l)

Phase 3:

- Control of added water volumes
  - The homogenization tank and piping is completely emptied.
  - The tank is then filled with a predefined volume below 20 l.
  - The amount of water actually introduced is measured by completely emptying the tank into a preweighed reservoir.
  - The filled reservoir is weighed to determine the collected water volume.
  - This procedure is repeated 3 times for the same volume.
  - The predefined volume is set between 40 and 50 l and the above procedure is repeated.
  - The homogenization tank is first filled to a predefined level of 15 l.
  - Then the volume entered in the control unit is increased with 17 l.
  - The total volume is measured by weighing as described above.

## 6.3 Sampling techniques

Not applicable.

## 6.4 Sample size, frequency, locations

See above.

## 6.5 Analyses

Not applicable.



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## 7. Resources specification for the tests

### 7.1 Personnel : staff qualification and training needs

Engineering personnel will perform tests after consultation of the manual.

### 7.2 Hardware : instruments, specific part, hardware for software operation

WPU skid as assembled by Packo including electrical cabinet and Jumo dTRON 304/308/316 Compact Controller with program function.

### 7.3 Software : verification of software, backup needs

Not applicable.

### 7.4 Facilities : environmental needs, test conditions, interfaces needs, utilities needs

Interfaces: connection to tap water, tubing for draining

Utilities: tap water, pressurized air (6 bar), electricity (3x380VAC, 32A), drain

## 8. Responsibilities

### 8.1 Management team

Preparation test plan, supervision tests, review test results, reporting.

### 8.2 Testing team

Test execution and annotation test protocols.

### 8.3 Testing support team

Test performance and recording: Helmut Elslander

Reporting:

Test Phase	Author	Checked by	Approved by	Approved by customer
Functional testing	H. Elslander	H. De Wever	H. De Wever	B. Lamaze

## 9. Schedule

Tests and reporting to be finalized by end of June 2010.

## 10. Risks and contingencies

NA.





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## **11. Procedure for review and status reporting**

### **11.1 Reporting of status for a test**

The test sequence is performed as described in 5.7 by VITO personnel.

At the end of the tests, the final status (pass/fail) is decided in agreement with ESA.

### **11.2 Deviations and non conformances**

In case the test sequence cannot be performed as planned or the results are not conform the expectations, a deviation is opened and appended to the test record.

The deviation is discussed between VITO and ESA to decide on how to address it.

In any case, all deviations will be discussed before a decision is taken on the status for the test.

### **11.3 Test readiness review**

To be organized by phone when all relevant documentation has been supplied to ESA.

### **11.4 Test acceptance review**

To be organized when also demonstration tests have been performed.



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### 11.5 Records

	<b>BELISSIMA Waste Preparation Unit</b>	
	<b>Test record sheet: Functional tests: absence of leaks, functionality check</b>	Test code: T_001 Version: 01 Date: /2010 Page:

<b>Responsible person</b>	
<b>Applicable test plan and protocols</b>	

Criterion	Tag	Description	Test performed (Y/N)	Test result (C/NC)	Comments/Deviation
Absence of liquid leakage	/	/			
	VSL2_0000_01	Main tank			
	VSSL_0100_01	Cleaning tank			
	SP_0002_01	Shear pump			
	P_0102_01	Centrifugal pump with mechanical coupling			
	LS_0004_01	Level switch (foam detection main tank)			
	LS_0004_02	Level switch (main tank)			
LT_0004_01	Level transmitter				



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Criterion	Tag	Description	Test performed (Y/N)	Test result (C/NC)	Comments/Deviation
	LS_0102_01	Level switch (cleaning tank)			
	HV_0000_01	Sanitary 2-way ball valve, drain buffer tank			
	HV_0002_01	Sanitary 2-way ball valve, before shear pump			
	HV_0002_02	Sanitary 2-way ball valve, after shear pump			
	PV_0102_01	Powered 2-way diaphragm valve, after centrifugal pump			
	PV_0006_01	Powered 2-way diaphragm valve, inlet water to main tank			
	HV_0002_03	2-way diaphragm valve, valve to sample			
	HV_0001_01	Sanitary 2-way ball valve, inlet double jacket			
	HV_0001_02	Sanitary 2-way ball valve, outlet double jacket			
	PV_0101_01	Powered 2-way diaphragm valve, inlet water to sprayball			
	HV_0100_01	Sanitary 2-way ball valve, inlet water to cleaning tank			
	HV_0102_01	Sanitary 2-way ball valve, drain after centrifugal pump			
	HV_0002_04	Sanitary 2-way ball valve, drain after shear pump			
			Connections		
Functionality check	BLE_0003_01	Mechanically coupled stirrer main tank			
	NOZ_0005_01	Sprayball			
	LS_0004_01	Level switch (foam detection main tank)			
	LS_0004_02	Level switch (main tank)			
	LT_0004_01	Level transmitter			
	LS_0102_01	Level switch (cleaning tank)			
	PV_0102_01	Powered 2-way diaphragm valve, after centrifugal pump			
	PV_0006_01	Powered 2-way diaphragm valve, inlet water to main tank			
PV_0101_01	Powered 2-way diaphragm valve, inlet water to sprayball				



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Test result (pass/fail)		Number of deviations:		
Test executed by		Date	Signature	
Reviewed by		Date	Signature	

**Deviation form**

Deviation Number	Deviation:		Criticality
	Corrective action:	Responsible	Due date
	Corrective action performed and checked: Ref. of retests	Checked/ approved by	Closing date



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	<b>BELISSIMA Waste Preparation Unit</b>	
	<b>Test record sheet: Functional tests: Accuracy of level transmitter</b>	Test code: T_002 Version: 01 Date: /2010 Page:

<b>Responsible person</b>	
<b>Applicable test plan and protocols</b>	

Action	Expected result	Remarks	Result (C/NC)	Deviation
After proper calibration of LT_0004_01, 40 l of water is added manually to the homogenization tank	The outgoing signal of LT_0004_01 corresponds with the measured value  LT_0004_01 indicates a water volume of 40 ±4 l  LT_0004_01 shows a stable measurement			
After emptying the tank, 15 l of water is added manually to the homogenization tank	The outgoing signal of LT_0004_01 corresponds with the measured value  LT_0004_01 indicates a water volume of 15 ±1.5 l  LT_0004_01 shows a stable measurement			

<b>Test result (pass/fail)</b>		<b>Number of deviations:</b>		
<b>Test executed by</b>		<b>Date</b>		<b>Signature</b>
<b>Reviewed by</b>		<b>Date</b>		<b>Signature</b>



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Deviation Number	Deviation:		Criticality
	Corrective action:	Responsible	Due date
	Corrective action performed and checked: Ref. of retests	Checked/ approved by	Closing date



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	<b>BELISSIMA Waste Preparation Unit</b>	
	<b>Test record sheet: Functional tests: Adequacy of controller actions under normal and abnormal operation</b>	Test code: T_003 Version: 01 Date: /2010 Page:

<b>Responsible person</b>	
<b>Applicable test plan and protocols</b>	

Action	Expected result	Remarks	Result (C/NC)	Deviation
<b>Normal operation</b>				
'Start filling CO-04'	Valve PV_0101_01 opens Water added to tank VSL2_0000_01 through nozzle NOZ_0005_01			
'Stop filling CO-04'	Valve PV_0101_01 closes			
'Start shear pump'	Pump SP_0002_01 starts pumping water			
'Stop shear pump'	Pump SP_0002_01 stops			
'Speed shear pump' changed	Pump speed increases when position changed from ... to .... Pump speed decreases when position changed from ... to ...			
'Start mixer'	Agitator BLE_0003_01 starts			
'Stop mixer'	Agitator BLE_0003_01 stops			
'Speed mixer' changed	Agitator speed increases when position changed from ... to .... Agitator speed decreases when position changes from ... to ....			
'Start filling CO-03'	Valve PV_0006_01 opens			
'Stop filling CO-03'	Valve PV_0006_01 closes			
'Extra filling CO-03'	Valve PV_0006_01 opens			
'Start cleaning pump'	Pump P_0102_01 starts pumping water			
	Valve PV_0102_01 opens			
'Stop cleaning pump'	Pump P_0102_01 stops			
	Valve PV_0102_01 closes			



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Volume of 10 l is entered in controller display. Button 'Start filling CO-04' is pushed	10 l of water is added to tank VSL2_0000_01			
Volume of 40 l is entered in controller display. Button 'Start filling CO-04' is pushed	40 l of water is added to tank VSL2_0000_01			
Entered volume is first 15 l and the button 'Start filling CO-04'. Then the entered volume is set to 32 l and the button 'Extra filling CO-04' pushed.	Total added water volume to tank VSL2_0000_01 is 32 l			
<b>Abnormal operation</b>				
Empty homogenization tank until LS_0004_01 indicates low level	Pump SP_0002_01 stops running			
Empty cleaning tank until LS_0102_01 indicates low level	Pump P_0102_01 stops running			
Manhole MH_0009_01 is open and button 'start mixer' is pushed	Agitator BLE_0003_01 does not start			
Agitator BLE_0003_01 and pump SP_0002_01 are running, then manhole MH_0009_01 is opened	Agitator BLE_0003_01 and pump SP_0002_01 stop running			
Press 'Emergency stop'	No automatic restart when power supply is renewed			
Simulate power failure and manually restart	No automatic restart when power supply is renewed			

Test result (pass/fail)		Number of deviations:		
Test executed by	Date	Signature		
Reviewed by	Date	Signature		





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**Deviation form**

Deviation Number	Deviation:		Criticality
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**Appendix 1 – Manual and documentation Packo**