TechnoMembranes
L'intelligence pure

Departament d'Enginyeria Química
Escola Tècnica Superior d'Enginyeries
Universitat Autònoma de Barcelona

UAB
Universitat Autònoma de Barcelona

TECHNICAL NOTE 94.43

Filtration Unit Optimisation: Hardware procurement and upgrading activities

Prepared by/Préparé par	Lasserre, J.C., Resses, L. and Peiro, E.
Reference/Réference	MELiSSA Pilot Plant Frame Contract 19445/05/NL/CP
Issue/Edition	0
Revision/Révision	0
Date of issue/Date d'édition	16/04/10
Status/Statut	Final

APPROVAL

Title Titre	**Filtration Unit Optimisation: Hardware procurement and upgrading activities**	Issue Edition	0	Revision Révision	0

Prepared by *Auteur*	Lasserre, J.C., Resses, L. and Peiro, E.	Date *Date*	16/04/10

Checked by *Verifié par*	Fossen, A.	Date *Date*	26/04/10

Approved by *Approuvé par*	Gòdia, F.	Date *Date*	26/04/10

Approved by customer *Approuvé par le client*	Lamaze, B.	Date *Date*	06/12/10

CHANGE LOG

Issue/Edition	Revision/Révision	Status/Statut	Date/Date
0	0	Final	16/04/10

Distribution List

Name/Nom	Company/Société	Quantity/Quantité
Brigitte LAMAZE	ESA	2 hardcopies + electronic version

TABLE OF CONTENT

SECTION 1

Filtration Unit Optimisation: Hardware procurement and upgrading activities

TechnoMembranes
L'intelligence pure

MELISSA Pilot Plant
Filtration Unit Optimization
Technical Note 94.43

Hardware procurement and upgrading activities

Author :
TechnoMembranes Développement
ZA les Tannes Basses
rue de l'Aramon
34800 Clermont-l'Hérault
* www.technomembranes.com
* info@technomembranes.com
& 04 67 44 91 89
🖷 04 67 44 03 52

Destine :
MELISSA Pilot Plant
Departament d'Enginyeria Quimica
Escola Técnica Superior de Enginyerá (ETSE)
Universitat Autonoma de Barcelona
Campus de Bellaterra
08193 Bellaterra (Barcelona)– Spain

Date of issue : 24th April 2009

Report TM/UAB/TN94.43/04.09/JCL

Confidential

Filtration Unit Optimization

Technical Note 94.43

Hardware procurement and upgrading activities

Distribution List

Name	Position	Company
E. Peiro	MPP	UAB
A. Fossen	MPP	UAB

Change Record

Author	Issue	Date	Change
J.C. Lasserre	1 Draft	21/04/2009	New Document
J.C. Lasserre L. Resses	1.1	21/01/2010	Updated with MPP comments
J.C. Lasserre L. Resses	1.2	31/03/2010	Updated with MPP comments
J.C. Lasserre L. Resses	1.3	16/04/2010	Updated with MPP comments

Filtration Unit Optimization

Technical Note 94.43

Hardware procurement and upgrading activities

Customer

Company : **MELISSA Pilot Plant**Departament d'Enginyeria Quimica
Escola Técnica Superior de Enginyerá (ETSE)
Universitat Autonoma de Barcelona
Adress : Campus de Bellaterra
08193 Bellaterra (Barcelona)– Spain
+34 93 586 81 01
+34 93 581 20 13
Enrique.peiro@uab.es
&
*

Contact(s) : **M. Enrique Peiro**

Document

Reference :	TM/UAB/TN94.43/04.09/jcl
Number of pages :	17
Number of appendices :	0
Separate appendices :	
Date of order :	
Date of delivery :	24/04/2009
Diffusion :	**Customer** 1 original hard copy 1 electronic copy *via* e-mail
Archives :	**TechnoMembranes** 1 hard copy 1 electronic copy on CD-R
Confidentiality :	**Normal** The data outlined in this document is strictly confidential. The technical and economical figures presented in this document are intended for the exclusive information of the customer.
Redaction :	**Jean-Christophe LASSERRE** Assay Scientist — Laurie RESSES Project Technician
Validation :	**Julien TROQUET** General Manager

Index

ZA Les Tannes Basses • 11 rue de l'Aramon • 34800 Clermont-L'Hérault • France
Tél. 33 (0)4 67 44 91 89 • Fax 33 (0)4 67 44 03 52 • www.technomembranes.com • info@technomer
TechnoMembranes Développement • SARL au capital de 120 000 € • RCS Montpellier B 485 007 397 • APE 7112B • TVA intracommunautaire

Applicable documents

Designation	Reference
AD1 - Proposal – MELiSSA Pilot Plant – Frame Contract 19445/05/NL/CP –"Work Order Compartment I of the MELiSSA Pilot Plant: additional characterization phase"	OFR-ESA-01/06-UAB
AD2 - TN94.42 – Filtration Unit Optimization, Trade-off and selection of the best suites membrane, Draft 01, dated 26th January 2009	TM_UAB-TN94.42_12 08_Draft_01

Acronyms and definition list

HRT	Hydraulic Retention Time
MBR	Membrane BioReactor
MPP	MELiSSA Pilot Plant
RPM	Revolution per Minute

I. Background

The MELiSSA Pilot Plant (MPP) is located within the premises of Universitat Autònoma de Barcelona (UAB), in Bellaterra (Barcelona), Spain. A new laboratory has been recently set-up at UAB to host the MELiSSA Pilot Plant. This laboratory will enable to host the different compartments, first installed and operated individually, to be completely characterized, and then, step by step, integrated at different levels: liquid, solid and gas.

The present work is presented as part of UAB's response to the ESA Call-off Order 3 related to the "Compartment I of the MELISSA Pilot Plant: additional characterization phase". Indeed, one of the hardware to be hosted at the MPP is Compartment I. This compartment has been developed during many years by the MELiSSA partners EPAS (Eco Process Assistance), a company located in Ghent (Belgium). EPAS constructed the hardware corresponding to Compartment I of the MPP, under the contract 15689/01/NL/MD, named as "Engineering Waste Compartment" (EWC).

The global study will allow the further characterisation of the Pilot Compartment I at the MPP site in UAB. The pilot reactor will be tested for approximately eighteen months. During this period, it will be operated in order to collect data for process, model and control development. The Filtration Unit will be optimised. An up-scaling of the waste preparation system used currently at EPAS will be performed.

The present Technical Note relates to the work which was carried out by TechnoMembranes as part of the global study. This Technical Note mainly involves work related to the filtration unit optimisation.

II. Objectives and program

According to the previous description, the objectives of this call off order are the installation and integration of Compartment I in the MELiSSA Pilot Plant, the performance of a long series of experiments with the proper analyses to fully characterize its operation and to provide data for mathematical model and control algorithms development, the improvement and optimization of the unit to prepare the feed to the reactor, and the optimization of the membrane unit of Compartment I. At the finalisation of the work, Compartment I should be completely operational in the MPP at the corresponding quality standards and ready to be connected to other MPP compartments.

The objective of this document is to define the characteristics of the necessary equipment for the setting up and the use of the membrane chosen during the selection tests performed on 25-litres BRM. The best suited membrane identified during the selection campaign held in TechnoMembranes is the KERASEP membrane, with 0.1µm threshold, as explained in TN94.42 (AD2).

The present TN is explaining the requirements to be fulfilled by the C1 filtration unit in order to be able to incorporate the KERASEP membranes, taking into account the characteristics of the membranes themselves and the various instruments needed for their proper operation. The hardware configuration in place in UAB is examined and the potential changes needed for the operation with KERASEP membranes are identified, in order to allow the upgrade of the filtration unit module.

As agreed with ESA and the other Call Off order partners, according to the conclusion of the meeting of March 24th, 2009, the use of these best suited membranes is planned before entering the characterization tests of the upgraded C1 .

III. Hardware definition

The scheme of the filtration unit before upgrade with KERASEP membranes is provided on Figure 4.

III.1. Membrane

The selected membrane during the test selection is the KERASEP membrane (KERMBMM1, 0.1 µm, 40 cm length).

The characteristics of this membrane are the following:

- Supplier: NOVASEP;
- Filtration threshold: 0.1 µm;
- Length: 40 cm;
- Internal channel diameter: 6 mm;
- Surface: 75 cm²;
- Layer: Zirconia;
- Support material: Al_2O_3 – TiO_2;
- Theoretical flux: >1250 L/h.m².bar (25°C);
- Circulation flow for 1 $m.s^{-1}$: 100 L/h.

The permeate flow obtained in TM during the membrane selection test being equal to 60 $L.m^{-2}.h^{-1}$, the daily volume of permeate will be 10.8 Litres (with membrane 40 cm length).

In order to increase the daily volume of permeate for the purpose of the tests included in the CI characterisation, and according to the conclusion of the meeting of March 24th, 2009, a KERASEP membrane with a 60 cm length and a 113 cm² area (instead of 40 cm and 75 cm²) has been chosen. During this meeting, it was proposed to perform trials with hydraulic retention times equal to 5 and 13 days. The change in the membrane module length (the former ATECH membrane was 1 m length) requires minor modifications in the filtrate pipelines layout of Compartment I to adapt them to the new dimensions, and some additional ones linked to the new design, as described in Section III.2.

For a hydraulic retention time of 5 days, the needed permeate flow has to be equal to 20 L/day (permeate flow= 0.83 L/h; permeate flux=73.7 L/h.m² for a 60 cm length).
For a hydraulic retention time of 13 days, the needed permeate flow has to be of 7.7 L/day (permeate flow= 0.32 L/h; permeate flux=28.4 L/h.m² for a 60 cm length).

The membrane has to be obtained from NOVASEP Company..

The address of Novasep is the following:

Novasep Process
5, chemin du Pilon
Saint-Maurice de Beynost
01708 Miribel (France)

The commercial reference of this membrane is KERMBMM1

III.2. Module

The Micro Carbosep®/Kerasep™ module is especially designed for low volume treatment by tangential ultrafiltration and microfiltration allowing feasibility trials to be performed under ideal conditions.

- stainless steel housing, clamp end-fittings,
- 2 hose liners 25 Ø,
- collars and gaskets,
- available area: 113 cm²

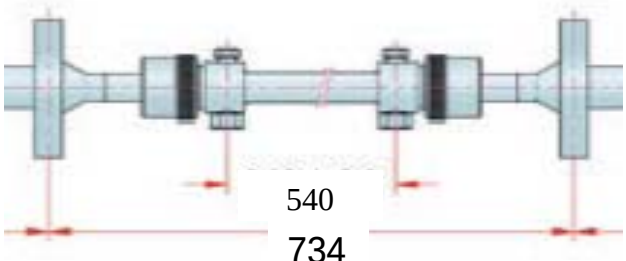

Figure 1 : Micro-module Kerasep 60 cm

Figure 2 : Micro-Module and membranes Kerasep

The module has to be obtained from Novasep Company.

The Novasep commercial reference of this module is CARMIC400004 Special

The module includes four ports on the permeate side (two on the top and two on the bottom).

The permeate outlet and the steam inlet have to be connected on the top of the module

A permeate outlet on the top of the module is preferred to be sure that the space between the membrane and the module is completely full.
The steam inlet has to be connected on the top of the module to avoid condensate accumulation on the permeate side during sterilisation step. The drain has to be connected on the bottom to evacuate the condensates.

One of the bottom ports has to be used to connect the drain. The other one has to be plugged.

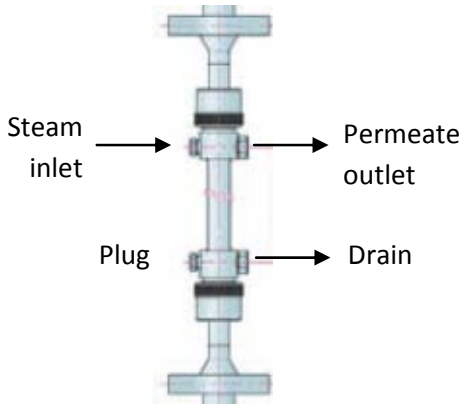

Figure 3 : Micro-Module ports

III.3. Pressure sensors

The used pressure sensors are Endress+Hausser sensors type Cerabar T

The characteristics are given in the following table:

Code	Location	Type	Range	Necessary Range	Accuracy (bar)
PT_1203_7	Downstream circulation pump	Cerabar T PMC131-A11F1A1S	-1 – 6 bar	0 – 10 bar	±0.05
PT_1203_01 to PT_1203_05	Retentate line in both membranes pipes	Cerabar T PMP135-A1G01A1Q	0 – 4 bar	0 – 4 bar	±0.02
PT_1203_03 PT_1203_06	Permeate within both membrane pipes	Cerabar T PMC45-REM1J1DL1	-1 – 4 bar	-1 – 4 bar	±0.008
PT_1203_08	Permeate final filter	Cerabar T PMP135-A1G01A1Q	0 – 4 bar	0 – 4 bar	±0.02

Table 1 : Pressure sensors specifications

All the characteristics of these pressure sensors are in accordance with the operating conditions of the Kerasep membrane 0.1 µm.

III.4. Flowmeters

The retentate flowmeter is an Endress+Hauser flowmeter, type Promag 50H DN15. Its range of measure is from 0 to 3180 L/h.
The maximum measured error is ±0.5 % of reading.

With the Kerasep membrane, a retentate flow of 100 L/h is needed to achieve a velocity of 1 m/s, calculated taking into account an internal diameter of the membrane channel equal to 6 mm. According to the results obtained during the Filtration unit optimization, this velocity is adapted to avoid particles accumulation on the membrane and to keep a stable permeate flow. This velocity also limits the energy consumption.
As the velocity should range between 1 and 2 m/s, the retentate flow should range between 100 and 200 L/h.

The range of measure is very large, but this flowmeter should be able to be used with the Kerasep membrane.

It is planned to measure the permeate flow by integration of the weight variation of the permeate tank during filtration time. A high frequency of measurement will be necessary to allow a good regulation of permeate flow.
For better accuracy it would be necessary to install a specific flowmeter on the filtration unit with a range from 0.33 to 0.83 L/h.
However to perform a test of water permeability, a flowmeter with a range up to 10 L/h would be preferable.

III.5. Permeate pump

The permeate pump is a Watson-Marlow peristaltic pump type 504 U.
For the whole foreseen range of filtration with broth a peristaltic pump with a range from 0.33 to 0.83 L/h is needed.
To perform a test of water permeability the range of the peristaltic pump has to be from 2 to 10 L/h.
Taking into account these ranges, we can conclude that the existing peristaltic pump is suitable for the nominal filtration process with the current tubing configuration (the flow range of the Watson-Marlow peristaltic pump type 504 U with 1,6 mm internal diameter tubing is 0-3,6 L/h), but it's not for the water permeability tests, where a much higher flow is needed.

III.6. Circulation pump

The circulation pump is a Seepex pump type BCSB 2-12 / J0-A7-A7-F3-GA-X

The flow range is up to 1500 L/h.
A nominal flow of 1000 L/h is obtained with a speed equal to 143 rpm and a rated frequency equal to 50 Hz.

The required flow for KERASEP membranes operation will be 100 or 200 L/h. This flow can be obtained operating the Seepex pump at a frequency of 5 or 10 Hz.
For effective cooling of the electric motor, the frequency mustn't be decreased to lower than 15 or 20 Hz.
To keep this type of pump and to run with the recommended flow it is necessary to add a fan as additional cooling.

III.7. Dimensions of pipes

The internal diameter of retentate pipes is equal to 16.5 mm.
The velocity will range between 0.130 and 0.260 m/s.
These low velocities might generate broth deposit into the pipes. A pipe with an internal diameter equal to 10 mm would be preferable.

The internal diameter of permeate pipes is equal to 3.5 mm.
This internal diameter is suitable to minimize pressure drop on the permeate side.

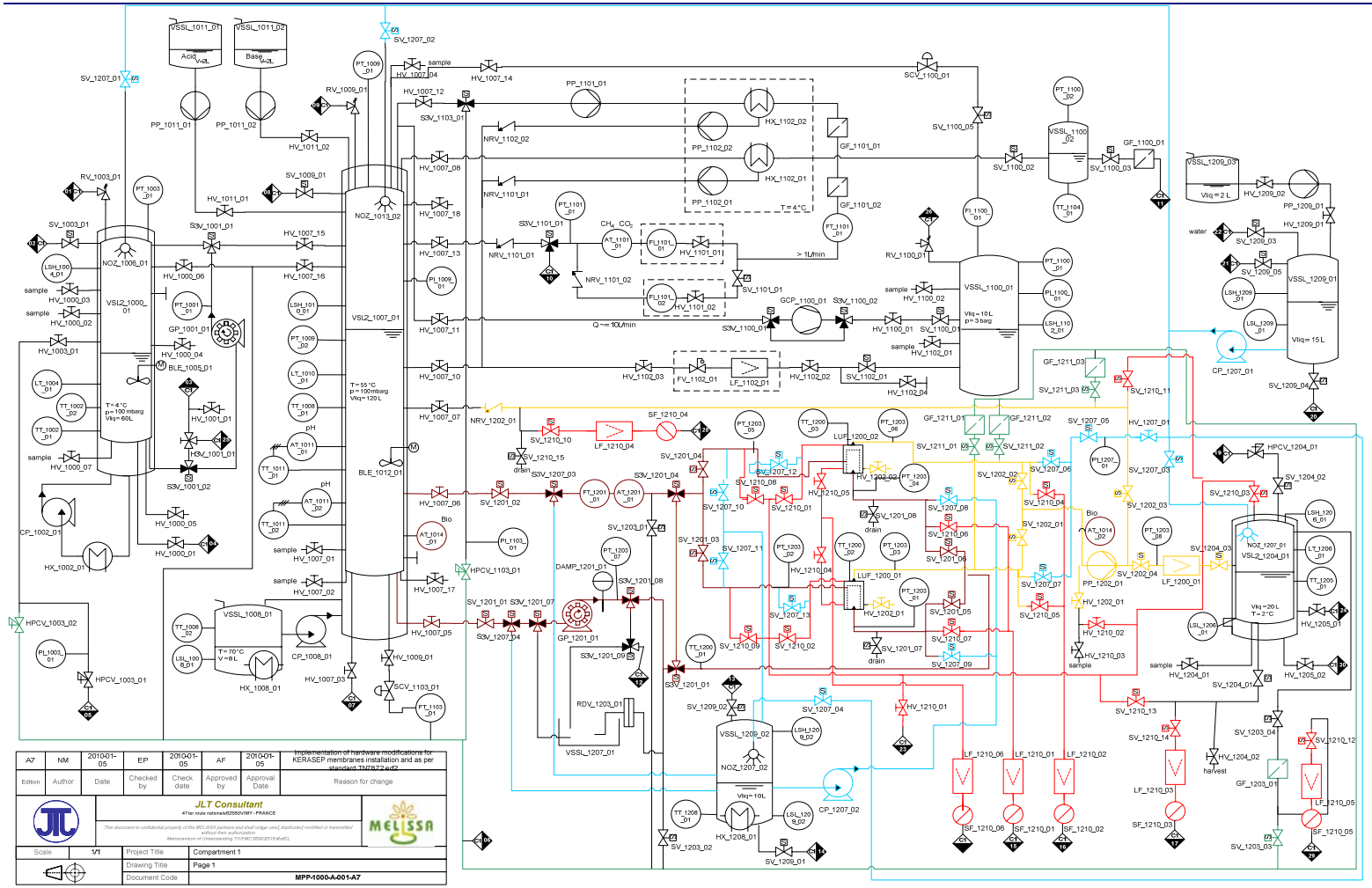

Figure 4 : Schema of filtration unit

IV. Membrane cleaning

A solution of NaOH at 10 g/L is used to clean the membrane with a circulation flow of 400 L/h.

To clean the retentate side it is preferable to work between 50 and 80°C (respecting a gradient of 10°C/minutes) during 20 minutes without filtration flow and a minimal inlet pressure. Cleaning efficiency increases when temperature increases.
The permeate side is cleaned with the CP_1207_01 pump. Ideally the applied transmembrane pressure has to be 1 bar maximum and it is better to warm as for retentate side cleaning.

The rinsing has to be performed in accordance to the gradient of temperature. For this reason it is necessary to wait at least 5 minutes before rinsing. The temperature of the decarbonised water must be over 15°C in the VSSL_1209_02 tank.

V. Conclusion

The characteristics of the pressure sensors are in accordance with the required operating conditions.
Excepted for the Seepex pump witch need an additional cooling (fan), the change of module has no impact on the instruments.

According to the low permeate flow (around 0.4 L/h for a HRT=10 days) measured and for more accuracy it is necessary to install a specific flowmeter at the inlet or outlet of the PP_1202_01 pump. This flowmeter is used:

- to measure the permeate flow during the broth filtration (filtration by only one membrane module);
- to measure the permeate flow during recycling for 5 days HRT testing (filtration potentially by both modules at the same time);
- to determine the limit flow (to research the outer limits of filtration from an intensification perspective, testing several increasing permeate flow levels).

Its range should be from 0.33 to 1.32 L/h.

Due to the actual unit configuration, the measure of permeability cannot be performed after a cleaning sequence, unless the complete retentate loop is cleaned and the hoses connecting with the bioreactor are connected to a demineralised water loop, and such operation cannot be performed regularly. Therefore it would be impossible to control the cleaning efficiency and the permeability on a new membrane during permeate production sequence.
To carry out a permeability test without any modification on the unit, either the module should be disconnected from the filtration unit or the filtration loop shouldn't be running and the retentate loop conditioned as above explained.

By modifying the unit it would be possible to carry out a permeability test. Modifications should include the addition of either one flowmeter in the cleaning outlet line between PI_1207_01 and HV_1207_01 (option 1) or two flowmeters on each permeate pipe, after PT_1203_03 and PT_1203_06 (option 2). Option 2 would allow the measure of permeate production flow and permeability flow simultaneously whereas option 1 would only allow the measure of cleaning flow.

The measure of production flow would be more accurate with a flowmeter (option 2) than by integration of the weight variation of the permeate tank during filtration time.

Demineralized water (filtered 0.22 µm) used to perform the permeability test should be then stored into VSSL_1209_02 tank and an adequate sequence for the permeability test to be implemented.

The current unit presents an important dead volume. Accordingly, important rinsing will have to be performed.

Figures list

Figures list:

Tables list

Tables list:

SECTION 2

MPP Conclusions

The present TN includes the hardware procurement and upgrading proposal by TECHNOMEMBRANES for the membrane optimisation of the Compartment I Filtration Unit. The revision carried out about the suitability of the current compartment configuration for the installation and operation of the proposed KERASEP membrane reveals the following main conclusions:

a) Hardware:

- The adaptation of pipelines for the new module is feasible with minor modifications.
- The present P sensors are adequate for the new membrane.
- The existing flowmeter in the retentate side is adequate, but a flowmeter in the permeate side would be needed for an improved control of the instantaneous permeate flow and for the permeability tests.
- The existing retentate pump is considered suitable, providing the necessary additional cooling associated to the lower speed operation of the new membrane configuration.
- The existing permeate pump is suitable for the nominal filtration process with the current tubing configuration, but it is not for the water permeability tests, where a much higher flow is needed.
- The pipe dimensions are adequate in the permeate side; however, in the retentate side its internal diameter is considered higher than desired to avoid deposits into the pipes.

b) Cleaning procedures:

- The use of 10g/L NaOH is considered adequate for the cleaning of the KERASEP membranes. This composition is compatible with the current CIP procedures and hardware of CI.
- The heating of the cleaning solution is considered relevant for the cleaning of both retentate and filtrate sides of the membrane. The requirement for heating the cleaning solution in the cleaning vessel is feasible in the current configuration, but not in the cleaning buffer tank, and as a consequence it would allow to clean with hot solution the retentate side but not the permeate side of the membrane. For the last one, hardware modifications are needed.
- The recommendation for maximum 1 bar transmembrane pressure for an efficient cleaning needs to be checked during the cleaning tests of CI to check if the current configuration complies with it.

- As the current Filtration Unit presents an important dead volume, an important rinsing is needed after the cleaning sequences. This should be as well evaluated during the cleaning tests of the Compartment.

c) Permeability tests:

- Taking into account the current CI configuration, the performance of water permeability tests in the Filtration Unit is not feasible unless the filtration loop is disconnected from the bioreactor and connected to a source of demineralised water. This makes the tests on one membrane not feasible during the nominal filtration process with the other membrane, so the only feasible alternative is to carry out the water permeability tests outside of the CI hardware.

- The existing permeate pump is as well not suitable for the flow ranges needed for the water permeability test; however, in this case the range could be extended by the use of higher diameter tubing dedicated for this particular test, or performing the tests without pumping in the permeate side.

- In order to be able to perform the permeability tests and as well to obtain a better control of the instantaneous permeate flow, it is proposed to install flowmeters in the cleaning outlet line or in both filtrate lines downstream the membranes, together with a modification of the cleaning procedures to create a dedicated sequence for the membrane permeability testing. The range of flow of these flowmeters would be, however, quite large taking into account both the nominal filtration conditions (0,33-0,83 L/h) and the permeability tests ones (2-10 L/h).

All the previously described proposals involving hardware modifications should be evaluated carefully during the test performance periods of the present COO3, in order to eventually implement them, taking into account all the obtained data about the performance of the hardware in its current configuration.

In particular, the proposals regarding update of cleaning procedures and permeability tests execution should be evaluated within a global discussion of the cleaning efficiency of the existing procedures, in order to establish the optimal conditions for the maintenance of the membranes, in the frame of the cleaning and sterilisation validation process.

SECTION 3

Comments

Filtration Unit Optimization
Trade-off and selection of best suited membrane

Comments

General comments

Please introduce the MEliSSA header and footer on all pages, so that confidentiality according to the MoU is ensured.
OK, done

Detailed comments

Page/paragraph	Comment
5/ Section I, second paragraph	*"Recently, EPAS has constructed the hardware corresponding to Compartment I of the MPP, under the contract …"* Not anymore, please remove OK, removed and verb tense changed: *"EPAS constructed the hardware corresponding to Compartment I of the MPP …"*
5/ Section I, second paragraph	*"This contract will be completed soon with the functional tests of the hardware and its final delivery to the MPP."* Please remove this is not valid anymore OK, removed
7/ Section III, first paragraph	*"The simplified scheme of the filtration unit before upgrade with KERASEP membranes is provided on page 9"* Please refer to a .figure number . I don't see any scheme on page 9; if you refer to figure 4 , then I don't know if the wording "simplified" scheme is really appropriate OK, amended: *"The scheme of the filtration unit before upgrade with KERASEP membranes is provided on Figure 4"*
7/ Section III.1, second paragraph	For my understanding: is Orélis the former name of Novasep or a separate company now commercialising its products via Novasep? We understand that ORELIS is a subsidiary of NOVASEP, but we have left NOVASEP, that has been in fact the supplier for MPP membranes

7/ Section III.1, fourth paragraph	*"… a KERASEP membrane with a 60 cm length and a 113 cm² area (instead of 40 cm and 75 cm²) has been chosen"* Can you please precise if this new length is inducing any physical change on the hardware? OK, explained in the text: *"The change in the membrane module length (the former ATECH membrane was 1 m length) requires minor modifications in the filtrate pipelines layout of Compartment I to adapt them to the new dimensions, and some additional ones linked to the new design, as described in Section III.2."*
10/ Section III.5, first paragraph	*"The current data are not sufficient to prove the compatibility of this pump."* Can you please clarify which data is missing ? and what is the problem to get it /them? After calibrating the pump, we can conclude that it is suitable for the range of filtration, but it is not for the water permeability test proposed by TECHNOMEMBRANES, as the max. flow of the present pump is 1,2 L/h. We propose to remove the commented phrase and explain this accordingly in the text: *"Taking into account these ranges, we can conclude that the existing peristaltic pump is suitable for the nominal filtration process with the current tubing configuration (the flow range of the Watson-Marlow peristaltic pump type 504 U with 1,6 mm internal diameter tubing is 0-3,6 L/h), but it's not for the water permeability tests, where a much higher flow is needed."*
11/ Section III.6, second paragraph	*"The required flow for KERASEP membranes operation will be 100 or 200 L/h."* Do you anticipate some impact on the mixing of C1 bioreactor , basically we will empty the tank in 1 hour instead of 10 times per hour In fact, we used a flow around 400 L/h with the ATECH membrane, never 1000 L/h. So the change is not so dramatic (it's aprox. 2 times in stead of 4 times), anyway the mixing of the bioreactor should in principle rely on the agitator, not on the membrane recirculation, shouldn't it?
13/ section IV, second paragraph	Everywhere else, you use the term concentrate instead of retentate ; please update or clarify Although it's the same meaning, we consider more appropriate, speaking about the membrane, to call both sides as "retentate side" and "permeate side", so we have harmonised the doc. using the word "retentate"
13/ section IV, second	*"To clean the retentate side it is preferable to work between 50 and 80°C (respecting a gradient of 10°C/minutes)"*

paragraph	I do not see on the new module the temperature sensors which were initially present to avoid problems during sterilisation and potentially cleaning. How do you suggest to manage? Do you mean on the scheme on Fig. 3? We are maintaining this sensors in the new modules (TT_1200_02 and TT_1200_03 in the PID, page 16)
14/ Section V	We miss some information from UAB in this paragraph : TM is making recommendations in the present document, however decision on upgrading activities to be performed is not stated. This should be updated. MPP conclusion is added in page 16.
14/ Section V, second paragraph	*"Excepted for the Seepex pump witch need an additional cooling (fan), the change of module has no impact on the instruments."* Still the point of the peristaltic pump ? You mean the point mentioned in comment on Section III.5? It's clarified there.
14/ Section V, second paragraph	*"- to research the limit flow."* Do you mean 'determine' ? OK, text amended: *"- to determine the limit flow"*
14/ Section V, second paragraph	Please include or refer to a definition OK, included in the text: *"to research the outer limits of filtration from an intensification perspective, testing several increasing permeate flow levels"*
14/ Section V, second paragraph	*"Its range is from 0.33 to 0.83 L/h."* Amended to harmonise with the limit flow research test range (see TN94.66): *"Its range should be from 0.33 to 1.32 L/h."*
14/ Section V, third paragraph	*"Due to the actual unit configuration, the measure of permeability cannot be performed after a cleaning sequence"* Please detail, explain why OK, explained in the text: *"… unless the complete retentate loop is cleaned and the hoses connecting with the bioreactor are connected to a demineralised water loop, and such operation cannot be performed regularly."*