Appendix C04 belonging to ref. 2020 FPL/INK 149

Programme of Requirements Pervaporation and Vapour Permeation unit

Introduction

TNO wants to have a skid mounted pervaporation (hereafter PV) and vapour permeation (hereafter VP) unit to be able to test (hybrid silica based) membranes with a membrane area of about 1 m^2 on a pilot scale at the location of end-users in the process industry. This unit shall be used in later projects for process testing on location at several potential end-users in order to demonstrate the technical feasibility of inorganic (hybrid silica) membrane PV/VP in dewatering applications on a pilot scale (100-1000 litre of feed liquid) using their process mixtures. By exchanging the membranes inside the module or by exchanging the module it shall be possible to test different membranes.

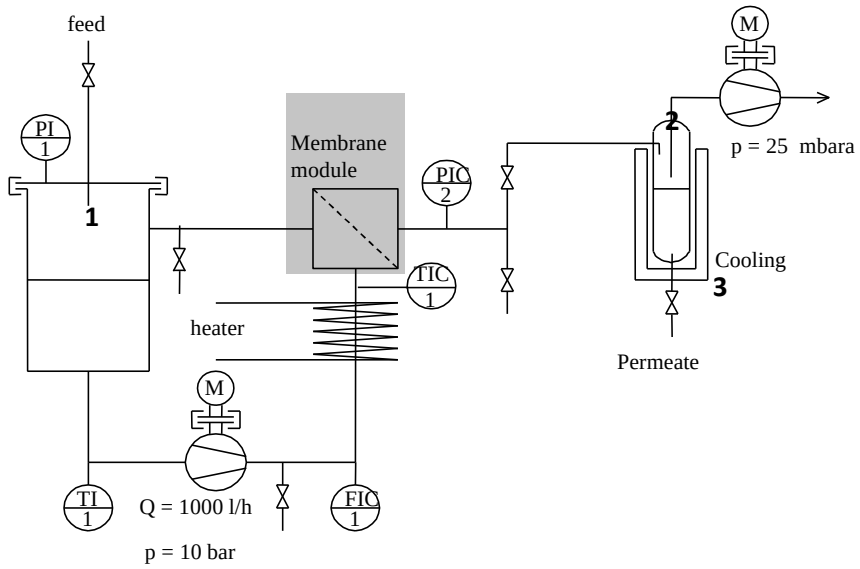
In the following sections the operation of the system, the specifications and desired operating conditions are given. These are based upon the ideas of TNO and the information obtained so far from the different end-users at which the unit is planned to be used. The information is not complete and discussions with possible vendors could lead to changes e.g. to the specifications.

Operation of the system

The pervaporation installation is to be used for the dewatering of different organic liquids/solvents at the location of several end-users (multipurpose). The operation of the PV process will be filling the feed system as a batch but after start-up the process shall run continuously without interference of an operator. Start-up, shutdown and taking samples for analysis can and will be done by an operator. In general, the system shall be able to operate up to feed temperatures of at least 180 °C. Feed mixtures are to be stored either in a feed vessel at the end-user or in a vessel that is part of the PV rig. Depending on the concentration, temperature and permeate pressure the flux through the membranes will change. Assumed is that the maximum (mainly water) flux through the membranes will be about 20 kg/m^2h.

An indicative sketch of a possible PV flow diagram of the unit is presented below (Figure 1).

Figure 1: Simple PFD of envisioned PV unit. Grey box is not in scope of delivery. The numbering of sections is used for requirements, preferences and options described in this document. 1: Feed tank, 2: Permeate tank and 3: Cooling.



The feed is pumped/recirculated over the membrane preferably with a controlled flow and definitely with a controlled temperature and linked to this a pressure. Due to a vacuum at the permeate side, water (and a small amount of organics) are transported/vapourised through the membrane, then condensed and stored in a permeate vessel. It shall be possible to take samples of feed, retentate and permeate while under operation. It shall be possible to drain the complete installation (because of use at different locations and for different applications) and flush it with e.g. ethanol or water in order to clean it. Data logging of temperature, pressure, feed flow, permeate flow (amount) as a function of time shall be possible and remote control and data acquisition shall be possible.

The test system shall have an option to run with a vapour feed as well: vapour permeation mode of operation. This vapour feed shall come from the client/the test location at which the unit is used or be made withing the PV/VP unit by vaporizing the liquid feed. Thus, either the vapour is introduced directly or an internal evaporator is required. Condensation shall be prevented in any case, though.

The membrane module is not part of the delivery of the PV/VP unit. For this system TNO has already a 1 m^2 membrane area (isothermal) module available that must fit (install but also be able to take out again) in the pilot test installation. Drawing and details of the module (which is not part of the delivery) are given below.

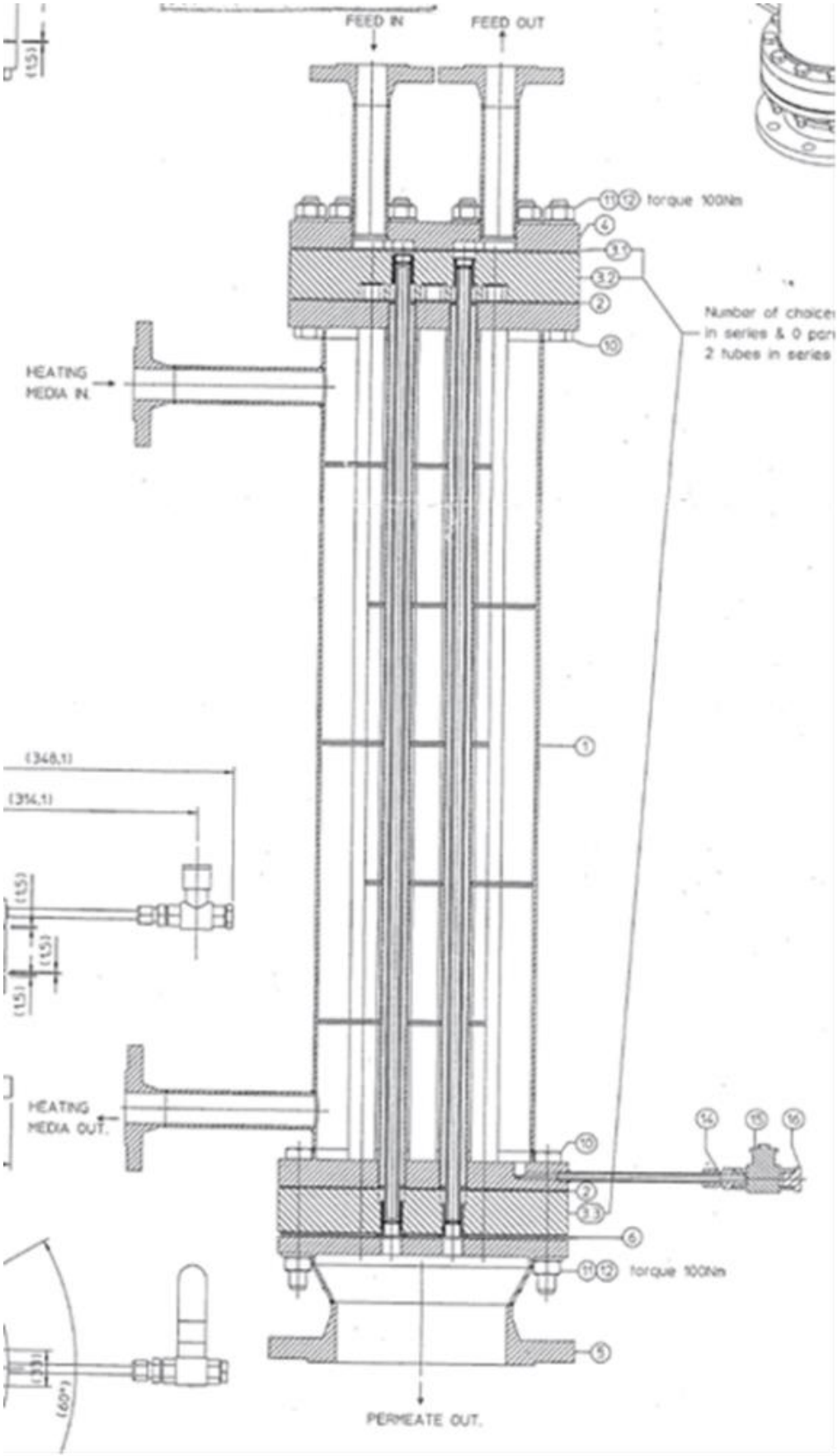
8.1: Membrane module for the PV/VP Unit

The membrane module of TNO (Grey part in Figure 1 of the PFD above) is **not** part of the delivery, but has to fit into the now tendered PV/VP unit. Description however provided for reference below.

Table 1: Specification of membrane module

8.1.1	Membranes	Maximum 1 m^2 area, tubular microporous hybrid silica from TNO inside a module as described.
8.1.2	Module	Length 1.20 m and diameter 27 cm (without taking into account the heating and drain connections), weight 120 kg. The module has different standard size flanges for permeate (DN150), feed/retentate and heating medium (DN25). See Figure 2. This module has a feed inlet, retentate outlet and permeate outlet. Furthermore, it has two connections for heat in and heat out to keep the pervaporation process isothermal. The PV/VP unit to be supplied shall be able to operate with this isothermal module concept but it shall also be possible to mount another module without this heating supply to the module.

Figure 2: Drawings and sizes of membrane module.



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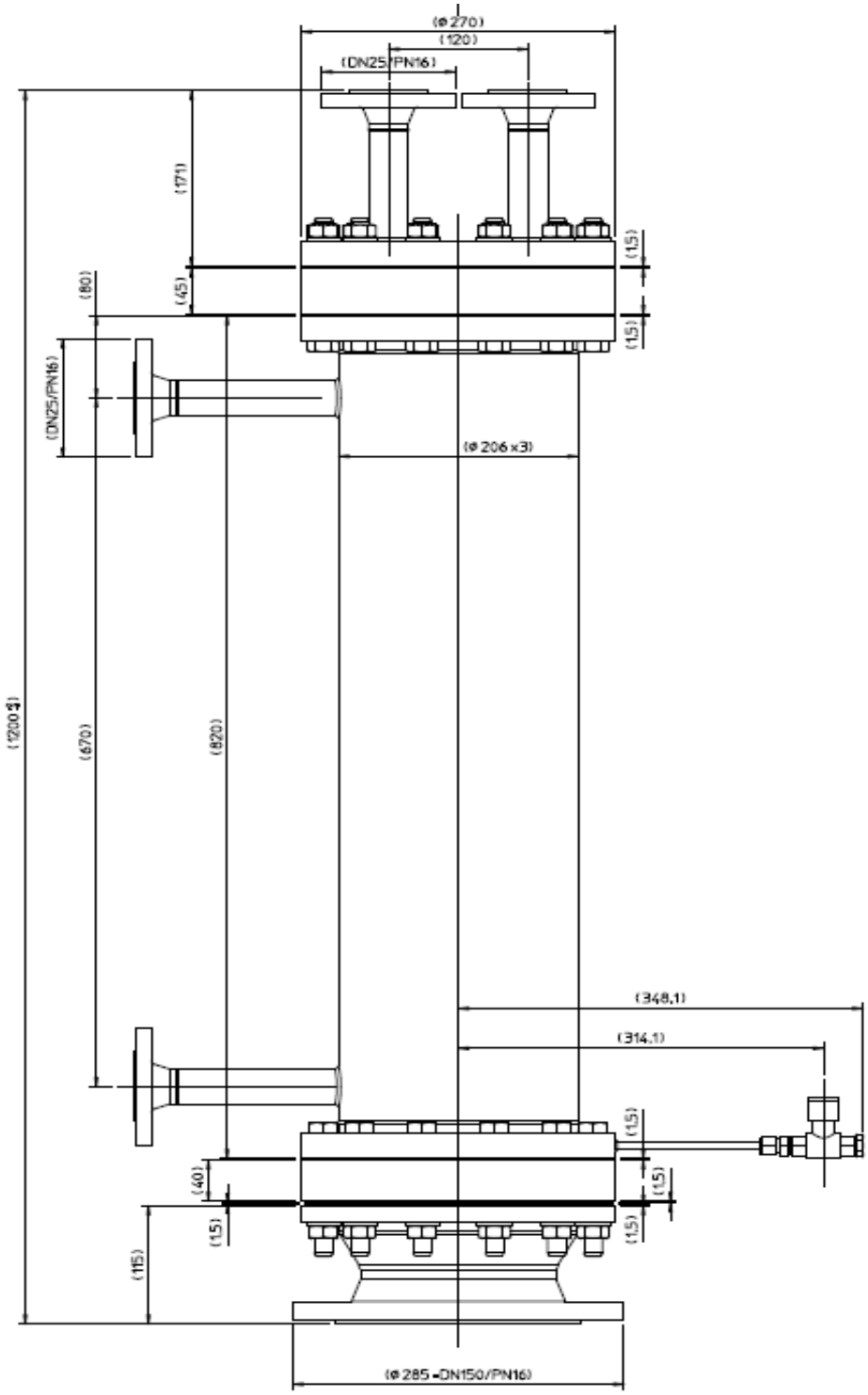

8.2: Requirements and Preferences for the PV/VP Unit

Table 2: Requirements for PV/VP unit:

8.2.1	Feed composition	Liquid water + organics or liquid MeOH + organics. Alkaline will not be used.
8.2.2	Feed pressure	1–10 bar, including pressure safety, alarm and manometer(s).
8.2.3	Feed temperature to membrane	Up to 180 °C.
8.2.4	Feed and circulation flow	Until 2000 l/h (or kg/h), based on TNO's 1 m^2 membrane module design including baffles, infinitely adjustable.
8.2.5	Feed tank (**1**)	- 1 m^3 tank of stainless steel - Feed to be kept under N_2 atmosphere, slightly (100 mbar) above atmospheric pressure in order to keep oxygen free environment. - Overpressure safety valve present. - Include measurement of amount of feed present (e.g. from the outside by a level indicator) and shut down when the feed tank is below 20% level: low level alarm action, which could also be an action of the feed pump to prevent running dry. - Possibility to fill and empty the tank easily and safely (see preferences).
8.2.6	Permeate tank (**2**)	- Size: 30 liter - Continuous operation of the unit must be possible. - Automatic emptying of the permeate vessel without interrupting the pervaporation process (see preferences). - A safety shutdown of the installation at e.g. 90% of the vessel capacity: high-high alarm action.
8.2.7	Heating	The unit must be compatible with both condensing steam and thermal oil as heating medium. Efficient use of hot retentate and cold feed streams is expected from the supplier.
8.2.8	Temp. measurement / control	On feed tank, inlet and outlet of the membrane module, 25-180 °C, including temperature control for the PV/VP process, safety and alarm.
8.2.9	Insulation	All heated elements must be properly insulated, with easy removable insulation.
8.2.10	Vacuum pressure	10-100 mbar and high pressure alarm actions.
8.2.11	Condensation / cooling system (**3**)	Both tap water / cooling water (about 20-30 °C) and glycol from an external cooler must be possible as cooling medium.
8.2.12	Skid and other materials	E.g. frame, shielding for outside operation, trace heating/insulation, piping, low temperature valves and a leak tray covering the total volume of liquid.
8.2.13	Expected maximum permeate flow	20 kg/h
8.2.14	Data acquisition and operation of the system	E.g. PC/PLC. Logging of temperatures, pressures, feed and permeate flows (weight or volume) as a function of time, possibility to indicate when a (feed and/or permeate) sample (and which sample number) has been taken, installable maximum operation time (e.g. default = 24 h). Remote operation and data acquisition must be possible, except start-up and shut down.
8.2.15	Alarms/trips	At least on: too low feed flow (leakage), maximum feed pressure, maximum temperature, too high permeate pressure, loss of cooling, feed vessel is at 20% or is empty, permeate vessel is almost full.
8.2.16	Other important specifications	- Both PV and VP operation shall be possible - Possibility to take feed, retentate and permeate samples. - Drain on system (the module has a drain on the steam heating side). - Possibility to operate at different locations. Must be transportable on a truck and able to be lifted. - All (safety) documentations, manual, operating procedures, design, component and material documentation and details, certificates, EU/PED obligatory documents, etc.
8.2.17	Miscellaneous	- ATEX design norm explosion proof. - CE certified. - Clear and simple start up and shutdown procedure. The installation must operate automatically. e.g. one button start. Operator is expected to be present for start-up, shut-down and taking of samples.

		- The PV/VP unit shall be able to operate with the TNO isothermal module concept, but it shall also be possible to mount another module type without using this heating supply to the module.
8.2.18	Language, e.g. of system control and documentation	- English.
8.2.19	For operation at the end-users/clients the following is assumed:	Electricity: 380/400 V, 3-phase Pneumatics/air/nitrogen present: Yes Cooling water: Yes
8.2.20	Delivery	- After completion of the construction, supplier will organise a plant viewing on check of mechanical completion. TNO will travel to the construction location to check for mechanical completion. - Finally a Factory Acceptance Test (FAT) shall be conducted. The supplier will propose the elements that will be part of the FAT, which will be reviewed by TNO and must at least include the tests described below in Paragraph 8.2.21. TNO will travel to the construction location for the execution of the test. - The system will be delivered and installed at the address provided by TNO. - The system will be commissioned/started by the supplier under the supervision of TNO. It is there that the Site Acceptance Test (SAT) will be conducted, also according to 8.2.21.
8.2.21	FAT/SAT	Factory Acceptance Test (FAT) - All equipment and manufactured items shall be subjected to inspection and functional testing before release for shipment. The signed test certificates shall be submitted to TNO. - TNO or a site representative shall be present at the inspection and functional testing for the following equipment: o Visual inspection of the finally assembled skid units. o Functional test of the automated safety system with associated instrumentation and emergency shut-downs. Site Acceptance Test (SAT) - The final site integration and functionally tests of the different systems shall be conducted and witnessed by TNO and representatives from site. The signed test certificates shall be submitted to TNO.
8.2.22	Training	- Training is required for start-up and primary operation.

Table 2 continued: Preferences for PV/VP unit

8.2.23	Approach and lessons learned in design & build PV/VP installations incl. Quality and Details of PFD, following the core competencies as described in Paragraph 5.2.2.1.	- Describe your approach in producing this installation using lessons learned in previous experiences with the design & build of PV/VP installations or other similar installations. Give specific examples with pictures where appropriate and allowed. - Include a Process Flow Diagram (PFD) with all main components indicated. - Your answer is not to exceed 2 pages (excluding the PFD) as per the instructions in Paragraph 6.1.2.
8.2.24	Filling of the feed tank (**1**)	- Describe your approach on how the feed tank (**1**) will be filled/emptied safely, taking into account a.m. requirement nrs. 8.2.1 to 8.2.22. - Your answer is not to exceed 1/2 a page as per the instructions in Paragraph 6.1.2.
8.2.25	Emptying of the permeate tank (**2**)	- Describe your approach on how the permeate tank (**2**) is emptied (automatically) without interrupting the pervaporation process, taking into account a.m. requirement nrs. 8.2.1 to 8.2.22. - Your answer is not to exceed 1 page as per the instructions in Paragraph 6.1.2.
8.2.26	Vapour Permeation (VP) includes both vapour as feed and liquid evaporation:	- Describe your approach on how the use of both vapour as feed and liquid evaporation is accounted for, taking into account a.m. requirement nrs. 8.2.1 to 8.2.22 . - Your answer is not to exceed 1/2 a page as per the instructions in Paragraph 6.1.2.

8.3: Options for the PV/VP Unit

Table 3 describes optional features for the PV/VP unit that are desired by TNO and could be added at additional cost. The supplier is requested to include a description as well as price for these features in their offer.

Table 3: Optional features PV/VP unit, to be optionally prized in Appendix A04:

8.3.1	Operation in nanofiltration mode	- Describe your approach on how the pilot could also be operated in (nano)filtration mode. In this case, the feed pump shall give the flow and pressure and the permeate side is at or slightly above atmospheric. Please include PFD. - Your answer is not to exceed 1 page as per the instructions in Paragraph 6.1.2. - The offer shall indicate the incremental price if TNO would include the NF option.
8.3.2	Compatibility with acids	- Preferably, feed mixtures with acids could also be used. Describe your approach on how the use of acids in the feed would be account for. - Your answer is not to exceed 1/2 a page as per the instructions in Paragraph 6.1.2.. - The offer shall indicate the incremental price if TNO would include the acid feed option.
8.3.3	Cleaning of the membranes	- Describe your approach on how the feed side of the membranes can be washed, e.g. with (warm) water or a solvent like ethanol during several minutes to hours, taking into account a.m. requirement nrs. 8.2.1 to 8.2.22. - Your answer is not to exceed 1/2 a page as per the instructions in Paragraph 6.1.2. - The offer shall indicate the incremental price if TNO would include the cleaning/washing option.

All Tenderers answers will be evaluated according to the description in Chapter 6.1.2 of the Tender Instructions.