PermSelect®

Liquid Contacting

Operating Guidelines for *Perm*Select® Modules

_Perm_Select® PDMSXA-10 (10 cm^2)
-100 (100cm^2) and -1000 (0.1m^2)

_Perm_Select® PDMSXA-2500 (0.25 m^2)

_Perm_Select® PDMSXA-7500 (0.75 m^2)

_Perm_Select® PDMSXA-1.0 (1 m^2)

_Perm_Select® PDMSXA-2.1 (2.1 m^2)

*Perm*Select® membrane modules can be used in a variety of liquid contacting and gas separation applications. The module design allows operational flexibility to achieve targeted objectives utilizing dense PDMS hollow fiber membranes. Depending on the application of interest, please follow outlined start up and operating guidelines.

Every customer's application is different and unique. It is difficult to anticipate issues and predict performance of the membrane modules for each intended application with different fluids and operating conditions. Thus this document should only be used as an initial setup guideline, in combination with the chemical compatibility charts, to help determine if a *Perm*Select® membrane module is suitable for a specific application. It is up to each end user to determine the suitability of a *Perm*Select® membrane module in their own application by conducting their own testing and evaluation.

WARNING: While we may provide information to help our customers determine if our membrane modules are suitable for their intended application, MedArray does not represent or warrant that our products are fit or safe for a particular application. PermSelect ® membrane modules are only to be used by persons thoroughly familiar with its use in its intended application. It is the responsibility of the user to determine the suitability of membrane modules in its specific application. Membrane modules can fail, permitting fluid discharge into the environment and mixing of shell and tube side fluids. Users must take all precautions to ensure safety to people and property in case of module failure. Purchaser assumes all responsibility for the suitability and fitness for use as well as for the protection of the environment and for health and safety involving this product. Please read our Terms of Sale for further information.

Selecting Operating Mode

For liquid contacting applications, there are three modes of gas/ vacuum operation to choose from: sweep, vacuum and combination of the two. Sweep gas mode of operation is commonly used to transfer gases such as O_2, N_2 or CO_2into the liquid. Vacuum mode is most commonly used to remove dissolved gases and bubbles from the liquid. Combination mode (sweep with vacuum) is recommended to enhance degassing performance by increasing the gas transfer driving force. This mode also aids in removing condensable vapors from the module to prevent condensation. The three modes of operation are shown below:

1a. SWEEP 1b. VACUUM 1c. SWEEP w/ VACUUM

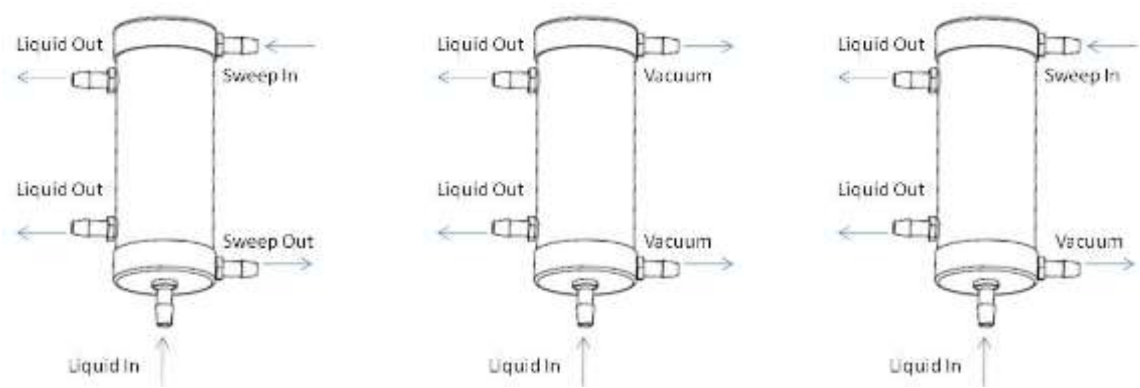


Figure 1. Liquid Contacting Operating Modes with 5 Port Modules – Liquid in the shell side

<u>Please note that the four port membrane modules (PDMSXA-10, -100, -1000) are primarily intended for degassing liquids because there is no shell side radial flow perfusing the membrane uniformly like the five port modules (PDMSXA-2500, -7500, -1.0, and -2.1). Thus the four port modules are not ideal for adding gases to liquids and are primarily intended for degassing with liquid flow in the lumen as shown in Figure 3 below.</u>

In the five port modules, the most efficient mode of operation of a *Perm*Select® membrane module for liquid contacting is with the liquid on the shell side (outside the hollow fibers) as shown in the diagrams above. However, this mode of operation typically has a lower fluid pressure limitation compared to operating with the liquid on the lumen side. The trans-membrane pressure (TMP) defined as the difference in pressure between both sides of the membrane, should not exceed 15 psi (1 bar) from shell to the lumen side, and 45 psi (3 bar) from lumen to shell at ambient conditions. The reason for the lower pressure limit from shell to lumen is because the hollow fibers may collapse and be damaged if the pressure from the outside of the hollow fiber relative to the lumen side of the hollow fiber exceeds 15 psi. On the other hand, if the pressure from the lumen side relative to the outside of the hollow fiber exceeds 45 psi, the hollow fibers may over-distend and potentially be damaged.

Gas will transfer across the membrane in either mode of operation, but more efficient transfer (per unit area) is achieved with liquid flowing in the shell side because of the uniform radial flow across the fiber bundle. Thus it is important to know the fluid operating conditions before selecting the mode of operation, and depending on the operating conditions of the system, the maximum allowable trans-membrane pressure (TMP) may limit the way a module should be used.

If the liquid supply pressure is fixed and known, then subtract the sweep gas (or vacuum) pressure from this value to determine the TMP. For example suppose water is supplied from a centrifugal pump at a maximum of 30 psig. Assume the atmospheric pressure is 14.7 psia, thus the water pressure is 30 psig + 14.7 psia = 44.7 psia. In this example water can flow in the shell side provided the gas (lumen) pressure is no less than 44.7 psia – 15 psia = 29.7 psia, which is above atmospheric pressure, so this configuration would not be suitable for degassing applications. On the other hand liquid can flow in the lumen side provided the shell side pressure is no less than 44.7 psia – 45 psia = -0.3 psia which is essentially full vacuum (0 psia).

Note that the maximum TMP for each mode of operation applies whether gas or liquid is used on either side of the membrane. However in liquid contacting, it is always preferable to maintain the liquid side pressure higher that the gas pressure to prevent gas bubbles from eventually forming in the liquid.

Thus in general, with water in the lumens of the hollow fibers, full vacuum can be used with as high as 30 psig water pressure. With water flowing in the shell side and full vacuum is applied to the lumens, the maximum water pressure should not exceed 0.3 psig. This is why liquid on the shell side is more limited by maximum TMP.

Figure 1 above illustrates the module installation / operation when liquid is flowing on the shell side. Figure 2 below illustrates proper installation / operation with liquid flowing in the lumens. Table 1 below provides a fluid pressure guide for vacuum degassing applications.

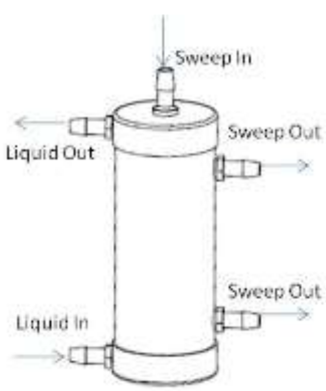
Table 1a. Vacuum Pressure Guide with Liquid on the Shell Side

Gas/ Vacuum Pressure						Maximum TMP	Maximum Liquid Pressure (gauge)			
Absolute vacuum				Relative vacuum		psi	psi	KPa	atm	mbar
Torr/mm Hg	mbar	psia	atm	% vacuum	" Hg					
760	1013	14.696	1	0.0%	0	15	15.0	103.4	1.021	1034
750	1000	14.5	0.987	1.3%	0.39	15	14.8	102.1	1.008	1021
500	667	9.7	0.658	34.2%	10.2	15	9.97	68.8	0.679	688
400	533	7.7	0.526	47.4%	14.2	15	8.04	55.4	0.547	554
300	400	5.8	0.395	60.5%	18.1	15	6.11	42.1	0.415	421
200	267	3.9	0.263	73.7%	22.0	15	4.17	28.8	0.284	288
100	133	1.9	0.132	86.8%	26.0	15	2.24	15.4	0.152	154
70	93	1.4	0.092	90.8%	27.2	15	1.66	11.4	0.113	114
50	67	1.0	0.0658	93.4%	28.0	15	1.27	8.76	0.086	88
25.4	34	0.49	0.0334	96.7%	28.9	15	0.80	5.48	0.054	55
10	13	0.19	0.0132	98.7%	29.5	15	0.50	3.43	0.034	34
1	1	0.019	0.00132	99.9%	29.88	15	0.32	2.23	0.022	22
0.1	0.13	0.002	0.00013	100.0%	29.92	15	0.31	2.11	0.021	21

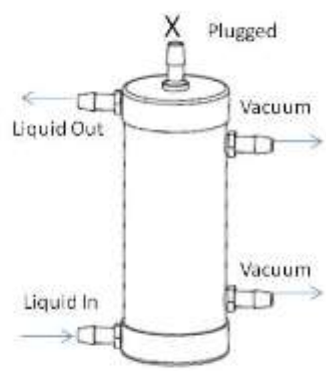
Table 1b. Vacuum Pressure Guide with Liquid in the Lumen Side

Gas/ Vacuum Pressure						Maximum TMP	Maximum Liquid Pressure (gauge)			
Absolute vacuum				Relative vacuum		psi	psi	KPa	atm	mbar
Torr/mm Hg	mbar	psia	atm	% vacuum	" Hg					
760	1013	14.696	1	0.0%	0	45	45.0	310.3	3.062	3103
750	1000	14.5	0.987	1.3%	0.39	45	44.8	308.9	3.049	3089
500	667	9.7	0.658	34.2%	10.2	45	40.0	275.6	2.720	2756
400	533	7.7	0.526	47.4%	14.2	45	38.0	262.3	2.588	2623
300	400	5.8	0.395	60.5%	18.1	45	36.1	248.9	2.457	2489
200	267	3.9	0.263	73.7%	22.0	45	34.2	235.6	2.325	2356
100	133	1.9	0.132	86.8%	26.0	45	32.2	222.3	2.194	2223
70	93	1.4	0.092	90.8%	27.2	45	31.7	218.3	2.154	2183
50	67	1.0	0.0658	93.4%	28.0	45	31.3	215.60	2.128	2156
25.4	34	0.49	0.0334	96.7%	28.9	45	30.8	212.33	2.095	2123
10	13	0.19	0.0132	98.7%	29.5	45	30.5	210.27	2.075	2103
1	1	0.019	0.00132	99.9%	29.88	45	30.3	209.07	2.063	2091
0.1	0.13	0.002	0.00013	100.0%	29.92	45	30.3	208.95	2.062	2090

2a. SWEEP



2b. VACUUM



2c. SWEEP w/ VACUUM

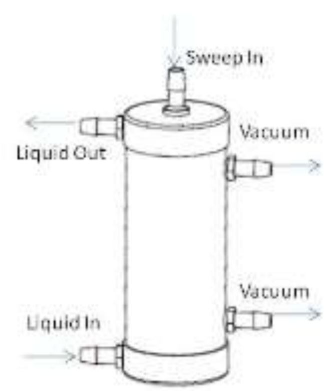


Figure 2. Liquid Contacting Operating Modes with 4 Port Modules – Liquid in the Lumens (only)

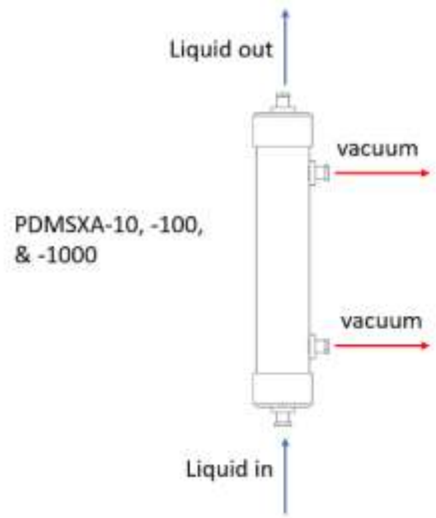


Figure 3. Liquid Degassing using Four Port Modules

General Start-Up Instructions

NOTE: Maximum TMP applies at startup also. Some users fail to ensure that the maximum TMP is not exceeded at startup when only one fluid is flowing, or if valves, flowmeters, and pumps are not set appropriately. We suggest using pressure gages wherever possible and start slowly.

1. Connect all the lines to the module according to the chosen mode of operation as shown in Figures 1 and 2.
2. Slowly introduce liquid into the system ensuring that the liquid pressure and flow rate do not exceed the maximum operating limits shown in Table 2.
3. Adjust the liquid inlet flow rate and pressure to targeted set points by adjusting the valves in the system.
4. Choose desired mode of operation:
    a. Sweep:
        i. Set the sweep gas pressure and flow rate entering the module to the desired levels.
    b. Vacuum only:
        i. Start vacuum pump per the manufacturer's instructions.
        ii. Open the valve connecting the module to the vacuum pump. Depending on the pressures and resulting flow configuration, the vacuum can be pulled through one or two ports. If single port operation is desirable, block one port and use the other port for the vacuum line.
        iii. Adjust vacuum pressure as necessary.

c. Sweep with vacuum:
   i. Set the sweep gas pressure at the module inlet to 1psig or less.
   ii. Set the sweep flow rate to the desired levels.
   iii. Apply vacuum as described above in section b.

Table 2. *Perm*Select® Module Operating Limits for Five Port Membrane Modules

Membrane Area Module	m^2 (ft^2)	**0.25 (2.69)** **PDMSXA-2500**	**0.75 (8.07)** **PDMSXA-7500**	**1.0 (10.76)** **PDMSXA-1.0**	**2.1 (22.6)** **PDMSXA-2.1**
Typical Liquid Flow	L/min (gpm)	0.2 – 1.9 (0.05 – 0.5)	0.5 – 6 (0.125 – 1.6)	1 – 7.5 (0.25 -2)	2.75 – 19 (0.75 -5)
Maximum Lumen to Shell TMP	bar (psi)	3 (45) @ 25 C (77 F)			
Maximum Shell to Lumen TMP	bar (psi)	1 (15) @ 25 C (77 F)			
Maximum Lumen Pressure	bar (psig)	3 (45)		2 (30)	
Maximum Shell Pressure	bar (psig)	3 (45)		2 (30)	
Sweep Flow Rate (no Vacuum)	L/min (scfm)	0.5 – 6 (0.02 -0.2)	3 – 15 (0.1 – 0.5)	3 – 23 (0.1 – 0.75)	5 – 30 (0.2 -1)
Sweep Flow with Vacuum	m^3/hr (scfm)	0.1 – 1.2 (0.004 – 0.04)	0.6 – 3 (0.02 – 0.1)	0.6 – 4.5 (0.02 – 0.15)	1 - 6 (0.04 – 0.2)

Table 3. *Perm*Select® Module Operating Limits for Four Port Membrane Modules

Membrane Area (cm^2) Module		**10** **PDMSXA-10**	**100** **PDMSXA-100**	**1000** **PDMSXA-1000**
Typical Liquid Flow	cc/min	0 - 3	0 - 30	20 - 4000
Maximum Lumen to Shell TMP	bar (psi)	3 (45)		
Maximum Shell to Lumen TMP	bar (psi)	1 (15)		
Maximum Lumen Pressure	bar (psig)	3 (45)		
Maximum Shell Pressure	bar (psig)	3 (45)		
Sweep Flow Rate (no Vacuum)	cc/min	Not recommended		
Sweep Flow with Vacuum	cc/min	Not recommended		

Other Notes

- It is highly recommended to use 10µm or smaller prefilter on the incoming liquid if particulates are present.
- Prior to use, flush and rinse all lines to and from the module before introducing the liquid inside the *Perm*Select® Module.
- Follow cleaning recommendations as necessary.
- If using compressed air for sweep, be sure it is oil free. A 3µm prefilter is recommended for any gas used inside the module.
- In some instances, a reduction in performance may be caused by condensation build up (droplets may be visible in such a case). In such an instance, remove *Perm*Select® module and dry it with sweeping air at 50°C (122°F) on both sides of the fiber, especially on the side where sweep gas is used or vacuum applied.

Technical Support

Questions related to *Perm*Select® Module use and operation? Call technical support at 734-769-1066.

Handling

Handle the module with care to avoid hits and sudden shocks from shaking or rapid movement, which can potentially cause internal damage. Careful handling will ensure optimal performance.

Storage

It is recommended to store modules in a dry, heat-sealed plastic bag at temperatures above 2°C (35°F) and below 50°C (122°F). Storing a module inside the original opaque box is important to prevent UV damage. If storing a module in the transparent plastic sealed bag outside of an opaque box, it must be away from direct sunlight. In order to avoid possible contamination, it is highly recommended for the modules to remain inside the plastic bag until use.

Shelf life

Silicone is known for its stability and if properly stored it will retain its physical properties such as tensile strength and modulus of elasticity for many years.