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Design and Use of HYDRAcap®

Hollow Fiber Ultrafiltration Module

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ISO 9001 Quality System Certified

HYDRAcap® – Hollow Fiber Ultrafiltration Module

Hydranautics, the Membrane Technology leader, has added to its' product line the HYDRAcap® capillary ultrafiltration membrane technology. HYDRAcap is a superior treatment technology when compared to conventional treatment, offering virtually 100% colloidal removal efficiency, single step treatment, fouling resistance and chemical free operation at high recovery rates. The HYDRAcap® module has demonstrated superior performance by receiving certification from the California Department of Health Services (CADHS) for 4-Log removal of virus, Cryptosporidium and Giardia. The HYDRAcap module has also received acceptance from the NSF/EPA Environmental Technology Verification (ETV) Program, approval from the Drinking Water Inspectorate (DWI) in the United Kingdom and is ACS accredited in France. HYDRAcap offers oxidant tolerant fibers, tight membrane structure, design flexibility and is available in a variety of products. These factors contribute to make HYDRAcap® an excellent choice for treating sea water, surface water, ground water and municipal effluents as either the primary treatment method or as a pretreatment step to reverse osmosis.

Description

HYDRAcap® products contain capillary fiber membrane made from a hydrophilic polyether sulfone, with a nominal molecular weight cutoff of 150,000 Daltons. Feed water enters the center (lumen) of the fibers and permeates through the membrane radially outward, producing a filtrate turbidity typically less than 0.07 NTU. A magnified, cross sectional view of the membrane is shown in Figure 1.

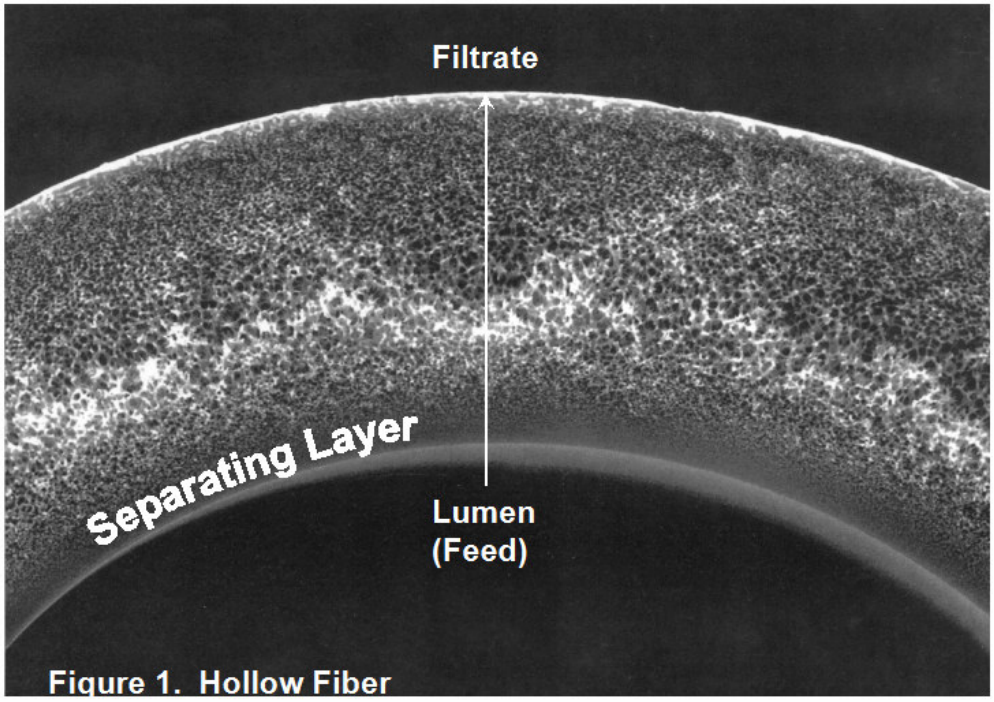


Figure 1. Hollow Fiber

The HYDRAcap® module can be operated in either direct flow ("dead-end") or crossflow. Direct flow is a mode of operation in which all feed water is converted to filtrate. For feedwater of higher turbidity or solids content, crossflow may be employed. Herein, a portion of feed is converted to filtrate and the remainder ("concentrate") flows through the lumen with sufficient velocity to minimize fouling.

HYDRAcap® modules are regularly backwashed to restore permeability, which declines as solids build up on the membrane. The pH tolerance (1.5 – 13.0) of the membrane allows for the addition of chemicals for cleaning and chemically enhanced backwashing.

Product Offering

Hydranautics' HYDRAcap® ultrafiltration modules are available in two fiber diameters, the standard 0.8 mm inner diameter (I.D.) and large diameter 1.2 mm I.D. (designated as LD). All HYDRAcap® modules are available in 40 inch and 60 inch fiber lengths. The 8.9 inch diameter HYDRAcap® modules contain 13,200 and 5,600 fibers for the standard and large diameter, respectively.

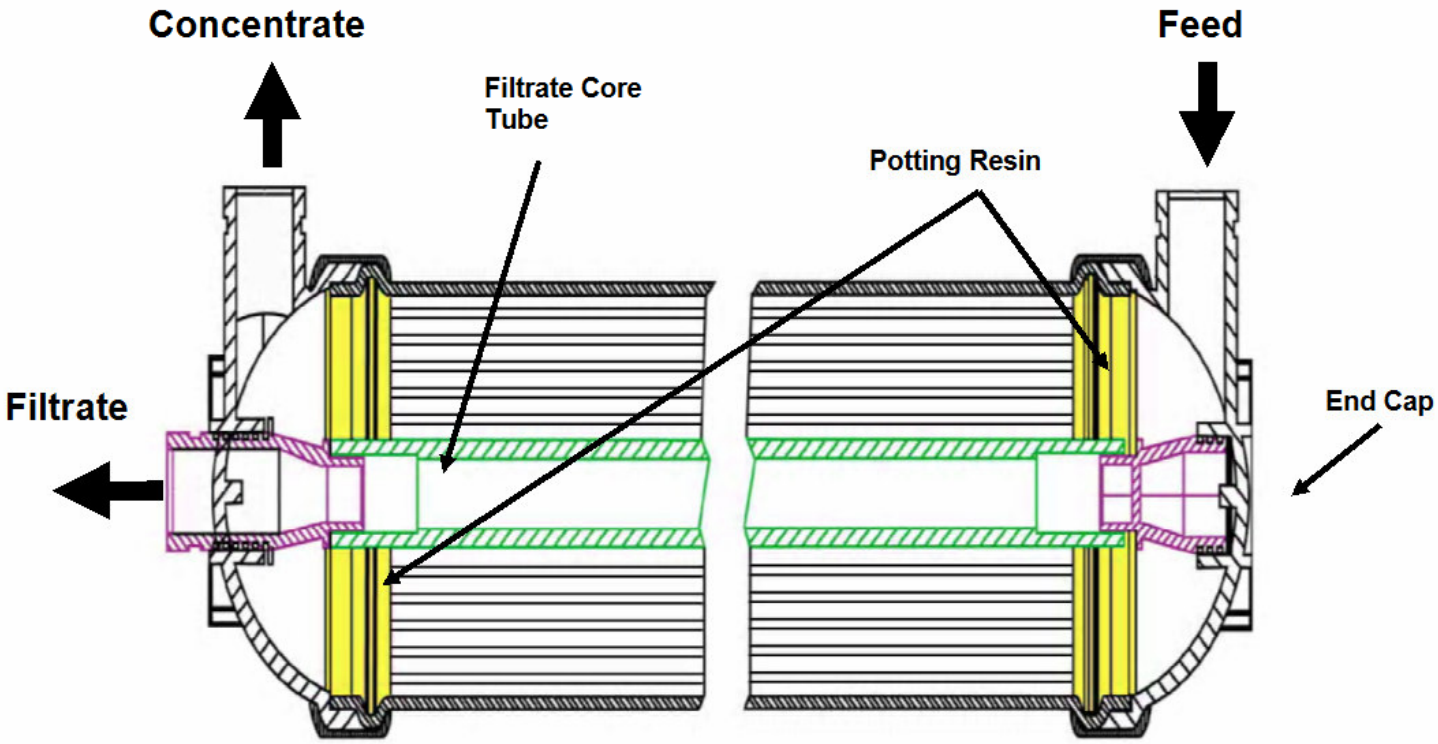


Figure 2. HYDRAcap Schematic.

The following table presents flow and area specifications for the HYDRAcap® family of products:

Table 1. HYDRAcap® Products.

HYDRAcap® Model	Area - ft^2 (m^2)	Flow - gpm (m^3/h)
60 Inch Modules		
HYDRAcap60	500 (46.5)	11 – 30 (2.7 – 6.9)
HYDRAcap60-DWI (UK)	500 (46.5)	11 – 30 (2.7 – 6.9)
HYDRAcap60-ACS (FR)	500 (46.5)	11 – 30 (2.7 – 6.9)
HYDRAcap60-LD	323 (30.0)	7.8 – 19 (1.7 – 4.3)
40 Inch Modules		
HYDRAcap40	320 (29.7)	7 – 19 (1.6 – 4.5)
HYDRAcap40-DWI (UK)	320 (29.7)	7 – 19 (1.6 – 4.5)
HYDRAcap40-LD	208 (19.3)	5 – 12.3 (1.1 – 2.8)

Figure 3. Hydracap 40 Cut Away

Selection Criteria

Each HYDRAcap® product should be incorporated into an ultrafiltration design for which it is suited. Table 2 illustrates the uses of the various HYDRAcap® products.

Table 2. HYDRAcap® Selection Guide.

UF capacity up to 0.5 MGD (79 m^3/hr)			
Feed Source	**Water Quality (NTU)**	**HYDRAcap Model**	**Operating Mode**
Tap Water (City)	< 0.5	HYDRAcap40	Direct Mode
Well Water	0 – 5	HYDRAcap40	Direct Mode
Surface Water	0 – 2	HYDRAcap40	Direct Mode
	2 – 5	HYDRAcap40	Direct Mode
	5 – 15	HYDRAcap40/LD	Crossflow* or Direct Mode
	> 15	HYDRAcap40-LD	Direct Mode
Open Intake Seawater	< 5	HYDRAcap40	Direct Mode
Tertiary Waste Water	0 – 5	HYDRAcap40	Direct Mode
UF capacity greater than 0.5 MGD (79 m^3/hr)			
Feed Source	**Water Quality (NTU)**	**HYDRAcap Model**	**Operating Mode**
Tap Water (City)	< 0.5	HYDRAcap60	Direct Mode
Well Water	0 – 5	HYDRAcap60	Direct Mode
Surface Water	0 – 2	HYDRAcap60	Direct Mode
	2 – 5	HYDRAcap60	Direct Mode
	5 – 15	HYDRAcap60/LD	Crossflow*† or Direct Mode
	> 15	HYDRAcap60-LD	Crossflow or Direct Mode
Open Intake Seawater	< 5	HYDRAcap60	Direct Mode
Tertiary Waste Water	0 – 5	HYDRAcap60	Direct Mode

* Crossflow may not be necessary for large diameter (LD) product.

† Due to excessive pressure drop across the fibers, theHYDRAcap60 is not optimal for crossflow greater than 30 gpm.

Design Considerations

HYDRAcap® modules are designed such that they can be grouped together to form a HYDRABLOC™(Figure 5.). A HYDRABLOC™ functions the same as if it were a single HYDRAcap® module except on a larger scale, with each module within the HYDRABLOC™ operating in parallel. This means each module experiences the same process conditions (i.e. turbidity, pressure and flow). Multiple HYDRABLOCs are the basis of a HYDRAcap® UF system. One benefit of using the HYDRABLOC™ design is that fewer process components are required (i.e. valves, flow meters, pressure indicators, etc.). Ideally, the larger the HYDRABLOC,™ the less the capital expenditure for the system.

In order to determine the performance of the HYDRAcap® modules each HYDRABLOC™ should have the following instrumentation:

- Feed Pressure
- Concentrate Pressure
- Filtrate Pressure
- Filtrate Flow Rate
- Concentrate Flow Rate (Crossflow)

In addition, the following instrumentation should encompass the ultrafiltration system as well:

- Feed Turbidity
- Feed Temperature
- Total Filtrate Flow Rate
- Total Filtrate Turbidity
- Backwash Pressure
- Backwash Flow Rate
- Cleaning Flow Rate
- Cleaning pH
- Cleaning Temperature

Data from the instrumentation should be analyzed continuously by the PLC. Transmembrane pressure (TMP) is a critical factor in the operation of a HYDRAcap® system. TMP is defined as average feed pressure minus filtrate pressure. An increase in TMP is indicative of solids buildup on the membrane. This is also called fouling or flux decline. Increasing TMP is normal and each system will have a different rate of fouling, but the TMP should never exceed 20 psi (1.4 bar). Though much of this fouling rate is directly dependent on feed water quality, the fouling rate can be partially controlled.

Design parameters that will effect the fouling rate are the design flux and the mode of operation. Flux is the volume of filtrate flow per unit area of the membrane. Flux is typically measured in GFD [gallons/(ft^2•day)] or lmh [Liters/(m^2•hour). Once a critical flux rate is exceeded, a more rapid flux decline will occur. Typical HYDRAcap® ultrafiltration systems will operate at a flux of 35 – 85 GFD (59 – 145 lmh).

There are three basic “processing” modes for a HYDRAcap system; “direct flow”, “crossflow” and “recycle”. For feed sources with varying turbidity or turbidity spikes, it will be necessary to automatically switch from “direct flow” to “crossflow” or “recycle”. Though “crossflow” or “recycle” will reduce flux decline, they will also have an impact on operating costs and pump size. As crossflow increases so does the energy consumption.

HYDRAcap® modules require that prefilters of 150µm, or smaller, be installed upstream of HYDRAcap® modules to prevent the fibers from plugging.

Pre-dosing of chemicals can prolong stable performance of the HYDRAcap® system. Continuous injection of free chlorine (1 ppm residual chlorine) or other approved oxidants, ahead of the HYDRAcap® system, may be recommended for raw surface water or waters with high bioactivity.

For open intake seawater, raw surface water and tertiary waste water where significant natural organic matter is present, testing has shown that continuous dosing of ferric or aluminum salts dramatically enhances performance. When dosing coagulant, backwash effluent may contain significant amounts of iron or aluminum and disposal may be an issue.

HYDRABLOC™ Operation

HYDRABLOCs are designed to produce filtrate, backwash, undergo cleaning and integrity testing. A brief summary of the HYDRABLOC operating modes will be described below.

Processing

As described in the previous section, there are two "processing" modes; "direct flow" and "crossflow". Each mode has its' trade-offs. "Direct flow" is the most economical, but is limited by the feed water quality. Crossflow reduces flux decline, but increase energy and capital costs. Table 3 lists examples of flow rate design parameters for various feed sources.

Table 3. HYDRAcap Ultrafiltration System Design Parameters

Water Type	Turbidity (NTU)	TOC (mg/L)	Flux (GFD/lmh)	Crossflow (gpm/m^3hr)	Bleed (gpm/m3hr)	BW, Freq. (min)	CEB Freq. (hr/ppm Cl_2)	Cleaning Freq. (days)
City	<0.5	<1	85/145	0	0	60	24/5	90
Well	0-5	<5	75/128	0	0	30	4 to 8/5	60
Surface*	0-2 (pretrt)		70/119	0	0	30	1 to 2/10	60
	0-2 raw	~3	55/94	0	0	30	1/15	30
	2-5	~3	50/85	0	0	30	1/15	30
	5-15	~3	40/68	0	0	20	1/15	30
	15-50	<10	32/55	20-50/4.5-11.4	0	20	0.33/15-30	30
	50-100	<10	32/55	20-50/4.5-11.4	0.5-1/0.1-0.2	20	0.33/15-30	30
Seawater**	<5		60/102	0	0	20	1/5	30
Tertiary WW ***	~2	BOD <10	42/71	0	0	15	0.25/30***	30

* Continuous dosing of chlorine, or other approved oxidants, into the feed, from a raw surface water, can drastically improve the performance of the UF.

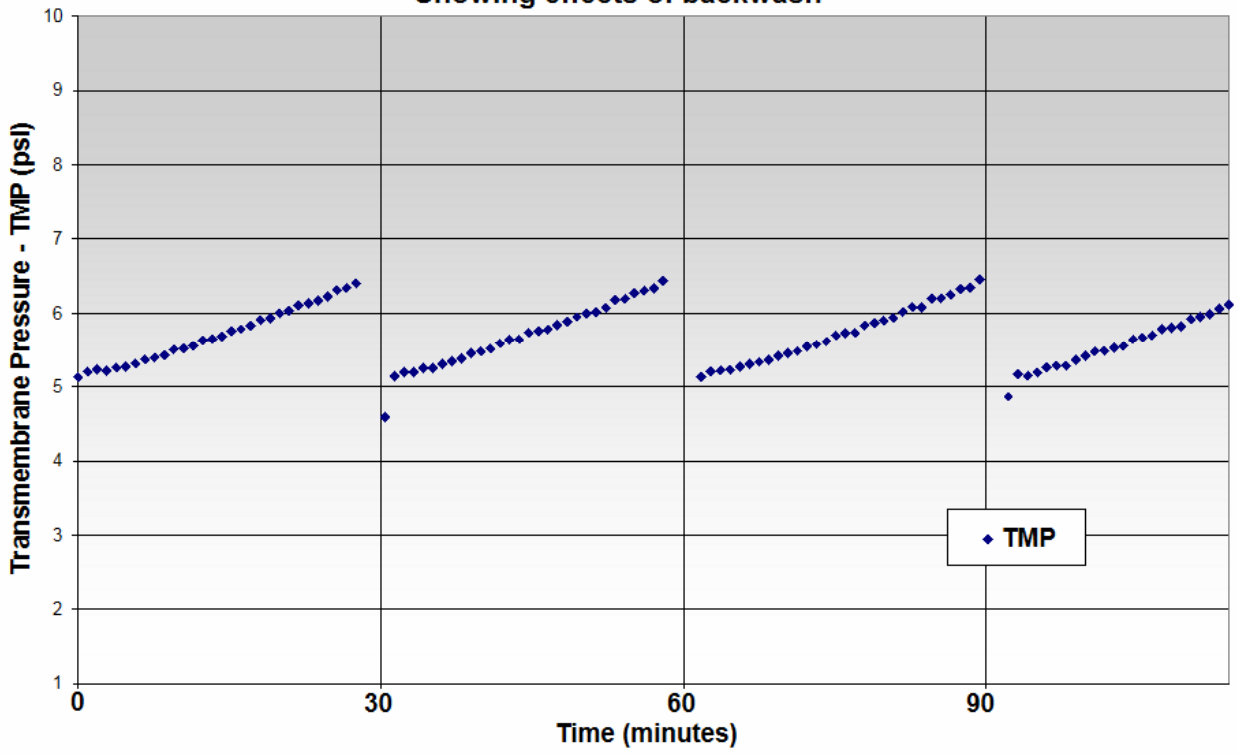
** Seawater systems should include the addition of 0.5-1.0ppm $FeCl_3$ continuously to the feed water ahead of the UF

***Waste waters (all water) with greater than 2ppm NH_3 will require city or RO water as a backwash source to ensure free oxidant

Backwashing

As the permeability of the membrane declines, due to solids build-up on the membrane, it is often necessary for the HYDRAcap® to undergo a "backwash". A backwash is a way to remove solids from the membrane, and reduce the TMP, by flowing clean water (i.e., RO permeate, city/tap, or UF filtrate) from the filtrate side to the feed/concentrate side. Figure 4 illustrates typical backwash cycles and Table 3 gives typical BW frequencies. Sometimes chemical addition to the backwash is done to improve the efficacy of the backwash. This is called a chemically enhanced backwash, or CEB. This is done by a short soak during the backwash cycle.

Figure 4 - Transmembrane Pressure vs time: Showing effects of backwash



Cleaning

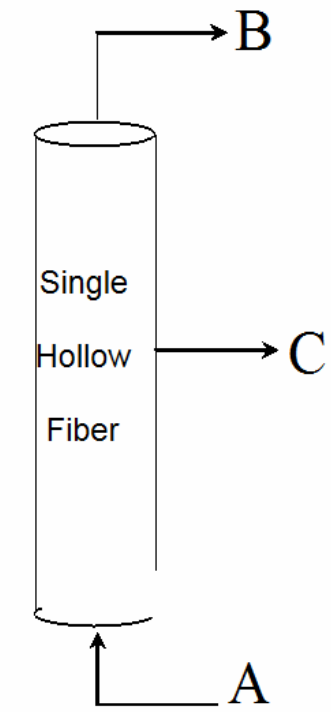
Though backwashing will reduce the TMP, it may not restore TMP to its' original start-up value. Once the TMP value shows little improvement after backwashing or when TMP reaches unacceptable levels, even after backwashing, it is necessary to perform a cleaning. The cleaning process will vary depending on the application, but generally requires a low pH and a high pH cleaning at 40ºC. Cleanings are performed by re-circulating the cleaning solution(s) through both sides of the hollow fibers. Typical frequencies are listed in Table 3.

Integrity Testing

Though the HYDRAcap® module is composed of robust fibers, which are mechanically strong and chemically stable, it is possible for fiber "breakage" to occur. Broken fibers are generally not a problem unless the filtrate turbidity is unacceptably high or the HYDRAcap® is being used for potable water as a means of microorganism reduction (i.e. Surface Water Treatment Rule). In order to determine if a HYDRAcap® module contains a broken fiber, an integrity test must be performed. An integrity test is simply a pressure hold test combined with a qualitative visual inspection of rapid bubble formation on the filtrate piping. Once a module has been identified as having a broken fiber(s), the fibers can be "repaired" or isolated.

Table 4. HYDRAcap® Single Fiber Flow Pattern

Operating Mode	Flow Direction	Flow Rate
Processing		
Direct flow	A to C	35-85 GFD (59-145 lmh)
Crossflow*	A to B & A to C	35-60 GFD (59-102 lmh) 20-60 gpm per module
Backwash		
Forward Flush	A to B	40 gpm per module
Backwash Top	C to B	85-150 GFD (145-255 lmh)
Backwash Bottom	C to A	85-150 GFD (145-255 lmh)
Soak	None	
Rinse	C to A & B	85-150 GFD (145-255 lmh)
Cleaning	A to B & A to C	10 to 20 gpm per module 30-40 GFD (51-68 lmh)
Integrity Test		
Drain	B to A (atmosphere)	
Pressurize	B to "Dead End" & C to atmosphere	



GFD=gal./ft^2/day
lmh=L/m^2/hr

Figure 5. HYDRABLOC®

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