SpiraSep 1060 Ultrafiltration Modules Product Manual

Leadership in Filtration

Table of contents

1. Technology overview

1.1 SpiraSep 1060 Ultrafiltration Module Description

SpiraSep 1060 ultrafiltration (UF) modules are submerged, vacuum-operated spiral-wound membranes complete with backwashing and aeration capabilities. SpiraSep modules are rolled with a fouling-resistant polyvinylidene fluoride (PVDF) barrier layer. Suspended solids, turbidity, viruses, bacteria, and some organic compounds are removed by the SpiraSep process.

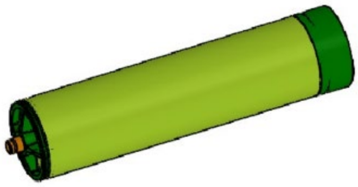

Figure 1. SpiraSep 1060 UF module

1.2 Manifold assembly

A system using SpiraSep modules consists of an array of elements submerged inside a process tank. The membrane elements are secured to the membrane frame by four bolts, and the anti-telescoping devices (ATDs) of the membrane modules have embedded screw holes for attaching the fixing bolts so that individual SpiraSep modules can be secured to the membrane frame by means of their ATDs. The permeate port is connected to the permeate header through DN40 coupling

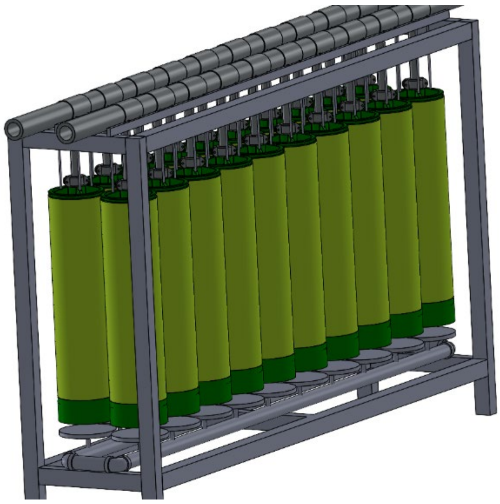

Figure 2. SpiraSep1060 membrane frame assembly

1.3 Plant configuration

A submerged UF system generally consists of the following components:

- Membrane frame assemblies submerged in a process tank
- Screws to connect the ATD and membrane frame
- Permeate pump
- Backwash pump
- Air delivery system consisting of multiple aeration headers
- Aeration blower
- Reject/concentrate pump
- Priming system
- Feed water connections
- Valves
- Instrumentations

1.4 Process overview

Feed is delivered to the system and is controlled by an automated flow control valve. Air is delivered to an array of aeration discs and is continually diffused upward through each membrane element. The convective flow of air and water actively scours the membrane surface, removing particulate matter from the element.

A self-priming centrifugal pump is used to generate a vacuum and pull water through the semi-permeable membrane. In order to prevent solids accumulation, water is continually removed from the process tank by a reject pump. Every 15 to 30 minutes, permeate production is halted and permeate water is backwashed through the membrane elements for 30 to 60 seconds. The water used for backwashing is stored in a permeate collection tank.

A chemically enhanced backwash (CEB) is performed to remove particulate matter and microbial growth from the membrane surface, which will prolong run times between membrane cleanings. Typically, a chlorine CEB is performed daily while an acid CEB is performed once every three days. The membrane tank is first drained and followed by a chemical-enhanced backwash. Permeate water, along with either sodium hypochlorite or acid, is backwashed through the system until the water level fully submerges the membrane elements. The membranes are then allowed to soak in the CEB cleaning solution for a period of 15 to 30 minutes. Following the static soak, the membranes are briefly backwashed to dislodge any additional particulate matter. Before resuming permeate production, the tank is completely drained. The CEB chemical solution is delivered to an appropriate collection system for neutralization prior to disposal.

Eventually, a full-scale clean-in-place (CIP) is performed when the trans-membrane pressure (TMP) setpoint of the UF system is reached. The maximum TMP of the submerged membrane system is 0.7 bar (10.0 psi), so the setpoint can be established anywhere at or below this pressure depending on process conditions. A CIP process consists of an extensive chemical soak using either chlorine or acid. After the feedwater is removed from the membrane tank, UF permeate and cleaning chemical is backwashed through the system until the membrane elements are fully submerged. The membranes are allowed to soak in the cleaning solution for a period of at least two hours. Additional backwashing is performed after the static soak for the purpose of removing additional solids and particulate matter. The cleaning solution is drained and delivered to an appropriate neutralization process prior to disposal.

All plant operations are controlled by a programmable logic controller (PLC).

1.5 Operational sequences

1.5.1 PERMEATE PRODUCTION

In a system using MANN+HUMMEL SpiraSep 1060 UF modules, an array of membrane manifold assemblies is submerged in a common process tank. Each membrane permeate port is connected to a production water line, which is connected to the permeate pump. Feed is delivered to the membrane tank, submerging the membrane elements. A vacuum is generated by the suction of a self-priming centrifugal pump, creating the necessary net drive pressure to draw water through the SpiraSep membranes. Air is diffused up through each membrane element via fine-bubble diffusers, creating tremendous shear forces on the membrane surface that remove suspended solids from the membrane surface.

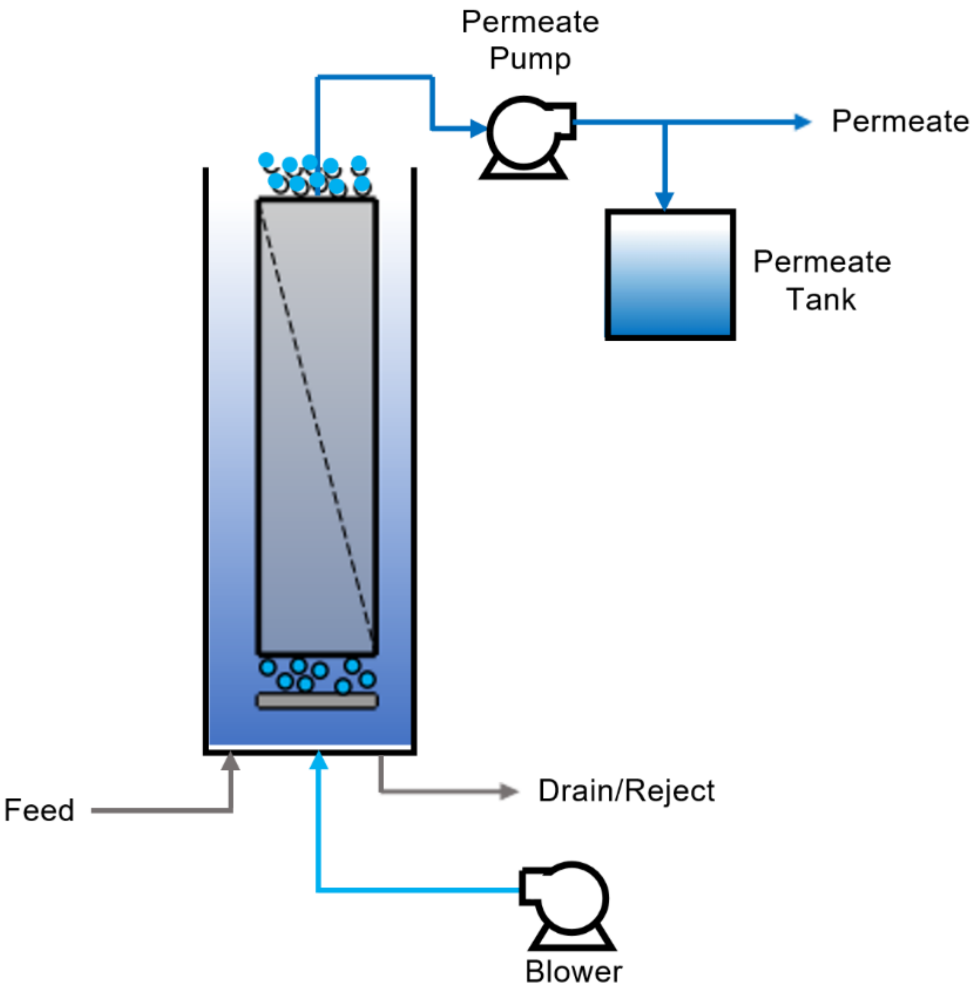

Figure 3. Permeate production

1.5.2 BACKWASH OPERATION

Periodically (on a timed basis), permeate water is reversed through the membrane (i.e., backwashed) to further remove accumulated suspended solids. This process also introduces a small amount of disinfectant (when required) to help control microbial activity on the membrane surface. Concentrate is removed from the process tank via reject pump or gravity-driven drain line and is typically less than 10% of the influent rate.

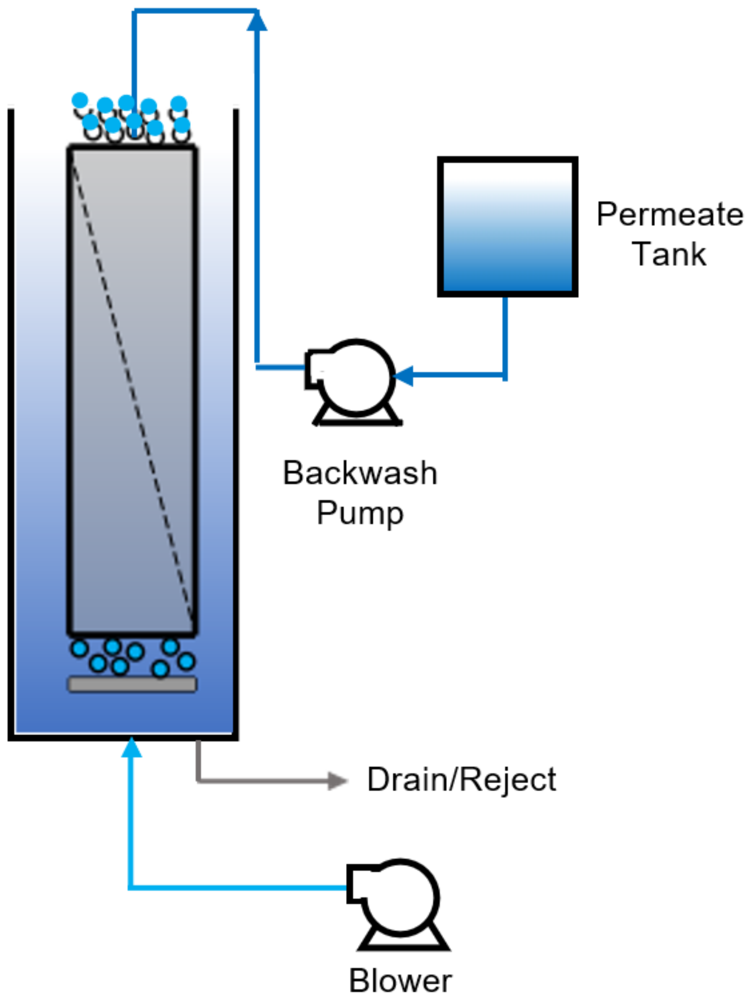

Figure 4. Backwash operation

1.5.3 CHEMICALLY ENHANCED BACKWASH (CEB)

A chemically enhanced backwash (CEB) is performed to remove particulate matter and microbial growth from the membrane surface, which will prolong run times between membrane cleanings. A chlorine CEB is typically performed daily while an acid CEB is generally performed once every three days. (Note: These CEBs may occur more or less frequently depending on the organics load and salt/mineral concentrations of the feed stream.) During a CEB, the membrane tank is first drained. Permeate water, along with either sodium hypochlorite or acid, is then backwashed through the system until the water level fully submerges the membrane elements. The membranes are then allowed to soak in the CEB cleaning solution for a period of 15 to 30 minutes. Following the static soak, the membranes are briefly backwashed to dislodge any additional particulate matter. Before resuming permeate production, the membrane tank is completely drained. The CEB chemical solution is delivered to an appropriate collection system for neutralization prior to disposal.

A CEB can also be performed in situ, where the membrane tank is not drained. For this type of procedure, the sequence of events is essentially the same, where the chemical is backwashed through the membranes followed by a soak period and additional backwashing.

TABLE 1. TYPICAL CEB SETPOINTS

CEB type	Frequency (days)	Dosage (mg/L)	CEB pH	CEB soak (min)	CEB flush (sec)
12.5% NaOCl	1–3	100–300	-	15–30	30–60
30% NaOH	1–3	250	10.5–11.0	15–30	30–60
50% Citric Acid	1–3	2,000	2.0–3.0	15–30	30–60

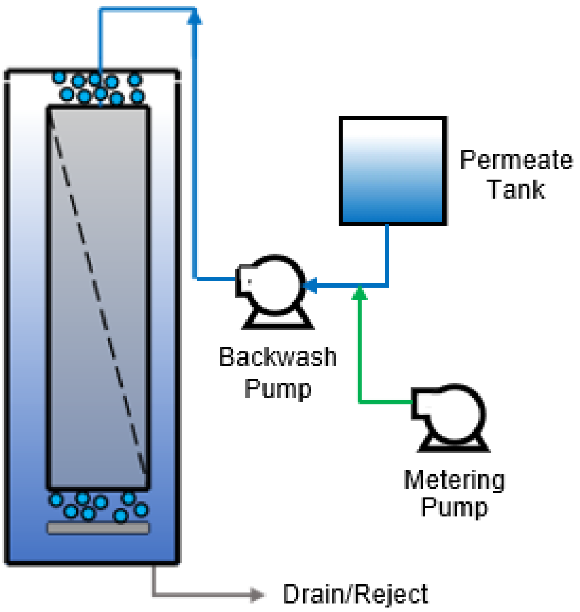

Figure 5. Periodic flux enhancement (maintenance clean)

1.5.4 RECOVERY CLEAN (CIP)

Eventually, a full-scale clean-in-place (CIP) is performed when the maximum TMP of the ultrafiltration system is reached. As a general rule, the maximum TMP of a submerged membrane system is 0.7 bar (10.0 psi). A CIP process consists of an extensive chemical soak using either chlorine or acid. After the feedwater is drained from the membrane tank, UF permeate containing cleaning chemical is backwashed through the system until the membrane elements are fully submerged. The membranes are allowed to soak in the cleaning solution for a period of at least two hours. Additional backwashing is performed after the static soak to remove additional solids and particulate matter. The cleaning solution is then drained and delivered to an appropriate neutralization process prior to disposal.

TABLE 2. TYPICAL CIP SETPOINTS

CIP type	Frequency (days)	Dosage (mg/L)	CIP pH	CIP soak (hours)	CIP flush (sec)
12.5% NaOCl	15–60	1,000/2,000	-	2–4	30–60
30% NaOH	15–60	250	PES[1]: 11.0–11.5 PVDF[1]: 10.5–11.0	2–4	30–60
50% Citric Acid	15–60	5,000	2.0–3.0	2–4	30–60

[1] Temperature, pH limits, and cleaning procedures are further detailed in the SpiraSep 1060 Product Manual.

Note: Chlorine CIP may be pH adjusted up to 10.0–11.0.

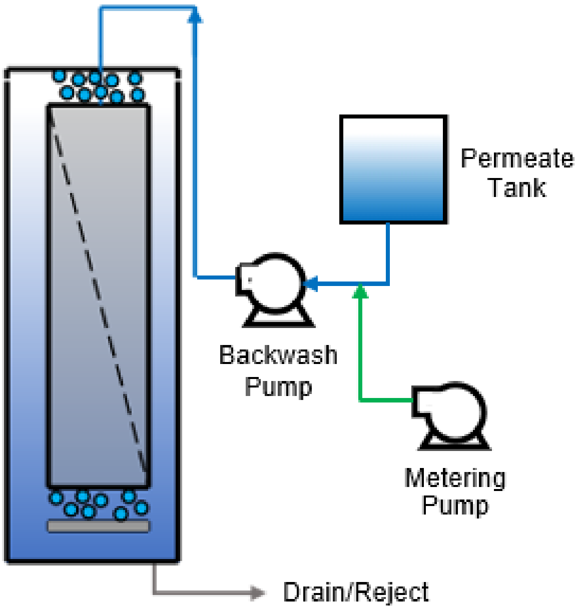

Figure 6. Recovery clean (CIP) process

2. Features and benefits

MANN+HUMMEL SpiraSep 1060 UF modules are the first to incorporate the various design features and benefits of both pressurized and submerged UF and microfiltration (MF) systems:

Membrane aeration: The open flow channels enable aggressive air scouring where bubbles “scrub” the membrane surface clean.

Open feed channel: A 90-mil corrugated feed spacer minimizes membrane fouling on feed waters with high suspended solids.

Low-fouling chemistry: The hydrophilic 0.03-micron chemistry enhances membrane fouling resistance and permeability characteristics. MANN+HUMMEL engineers have developed a specially formulated low-fouling membrane chemistry that increases permeability, reduces fouling, and lowers energy consumption.

High effluent quality: The strong, durable design of the SpiraSep UF module eliminates mechanical failures, ensuring high quality effluent throughout the life of the membrane system.

Membrane backwash: Periodic backwashing purges particulate matter from the membrane surface.

Open-ended design: SpiraSep’s open-ended design allows cake layer to exit the top and bottom of the element during backwash. It also creates uniform air flow over the entire membrane surface.

2.1 Membrane aeration

Membrane air scour is a critical operating feature of all UF/MF wastewater systems. Air bubbles generate tremendous shear forces that actively scour, or “scrub,” the membrane surface. In order to realize the benefits of air scour, the membrane design must maintain bubble-to-membrane surface contact. The corrugated feed spacer contains open flow channels, ensuring air bubbles maintain contact with the membrane surface.

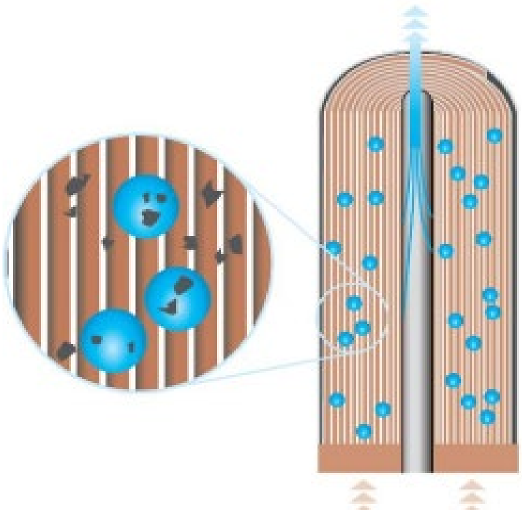

Figure 7. Membrane air scour

2.2 Open feed channel

A key feature of the MANN+HUMMEL SpiraSep 1060 UF module is a specialized corrugated feed spacer that creates open flow channels in the element. Conventional feed spacer materials used in reverse osmosis (RO) spiral-wound membranes are unsuitable for high total suspended solids (TSS) operation. As a result, MANN+HUMMEL engineers have developed a corrugated sheet that creates a wide, open feed channel, preventing fouling. Air flows upward through each individual flow channel and “scrubs” solids from the membrane.

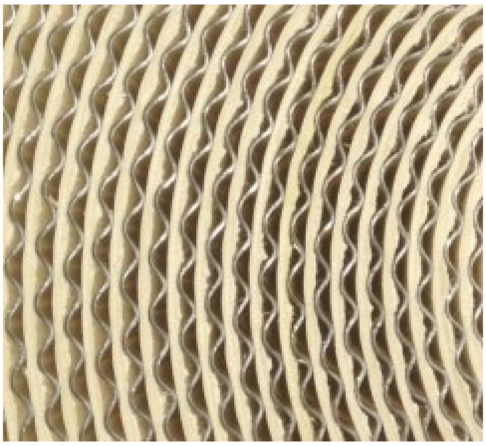

Figure 8. Corrugated flow channel spacer

2.3 Low-fouling chemistry

MANN+HUMMEL engineers have developed a specially formulated low-fouling membrane chemistry that increases permeability (i.e., membrane flux), reduces fouling, and lowers energy consumption. The small 0.03-µm pore size, when compared to other UF/MF formats, prevents solids from penetrating the inner pores of the membrane. This causes solids to reside on the surface of the membrane where it is easily removed via air scouring and/or backwashing.

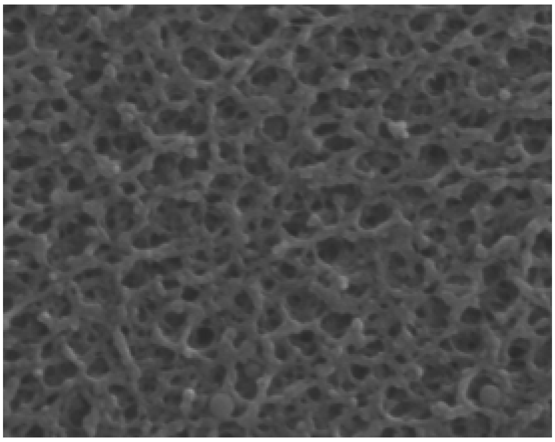

Figure 9. UF membrane surface

2.4 High effluent quality

Effluent quality is tied directly to membrane integrity and is a critical feature when operating RO pretreatment systems. The rigid, durable design of MANN+HUMMEL SpiraSep 1060 UF modules ensures that membrane integrity is not compromised. This guarantees a high effluent quality far exceeding current market standards. Typical effluent quality parameters are as follows:

- TSS < 1.0 mg/L
- Turbidity < 0.1 NTU
- SDI < 3.0

2.5 Membrane backwash

A common problem with spiral-wound membrane designs is the inability to effectively remove solids from the membrane surface and feed channels. Accumulated solids can lead to unwanted sludge layers that are easily agitated, causing TSS spikes in the system. Whereas most spiral-wound membrane elements may not be backwashed due to the danger of delaminating the membrane, SpiraSep is one of the first spiral-wound elements that is designed to handle backwashing.

With SpiraSep, the TSS concentration never reaches a steady-state value as the feed solution is completely removed and replenished with “fresh” feed after every backwash. As a result, the solids profile inside the modules follows a “saw-tooth” pattern (as shown in Figure 10). This reduces, in some cases, the average TSS concentration by 40% to–50% compared to traditional submerged membrane systems.

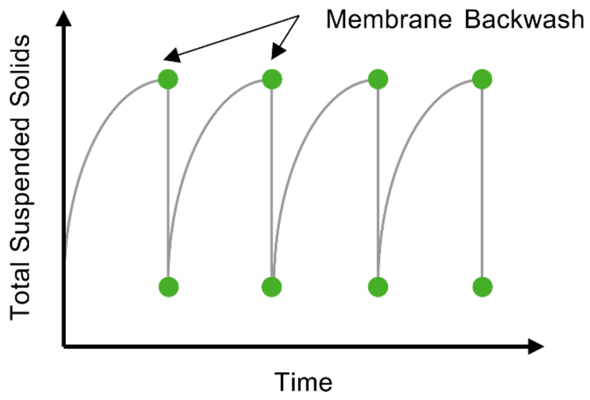

Figure 10. Total suspended solids (TSS) profile in SpiraSep UF membranes

2.6 Open-ended design

SpiraSep’s open-ended design allows cake layer to exit the top and bottom of the element during backwash. It also creates uniform air flow over the entire membrane surface. The open-ended design prevents accumulation of cake layer at the top end of the element over time. It allows for more efficient removal of fouling materials during cleanings while minimizing chemical and physical cleaning requirements.

The open-ended design also means there aren’t any element housings or pressure vessels. This means it is less susceptible to fouling and is easy to install and replace.

3. Technical specifications

3.1 Module specifications

TABLE 3. SpiraSep 1060 UF MODULE SPECIFICATIONS

Parameter	Specification
Element diameter	273 mm (10.74 inches)
Element length	1174 mm (46.2 inches)
Element feed spacer	2.3 mm (90 mil) corrugated
Active membrane area	27.4 mm^2 (295 ft^2)
Membrane chemistry	Polyvinylidene fluoride (PVDF) or polyethersulfone (PES)
Average pore size	0.06/0.03 micron

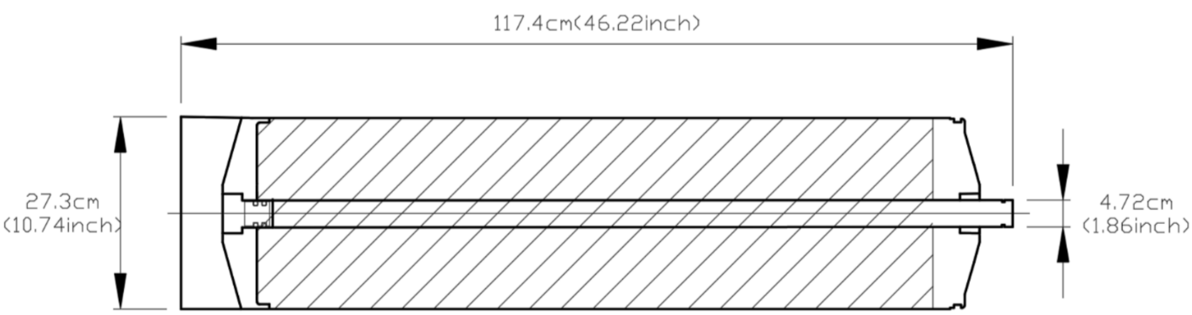

Figure 11. SpiraSep UF module dimensions

3.2 Chemical compatibility

TABLE 4. SpiraSep 1060 UF CHEMICAL COMPATIBILITY

Parameter	Specification
Maximum chlorine exposure[1]	PES: 1,000 mg/L, PVDF: 2,000 mg/L
Operating pH[2]	2.0–11.0
Cleaning pH[2]	PES: 1.0–12.0, PVDF: 2.0–11.0
Recommended coagulants	Ferric sulfate, ferric chloride
Recommended maximum coagulant concentration	10.0 mg/L

[1] Temperature < 40°C (104°F), pH < 11.0
[2] Temperature < 40°C (104°F)
[3] Approved coagulants are ferric chloride and ferric sulfate. For all other types of coagulants, please contact MANN+HUMMEL.

3.3 Clean water flux rates

The clean water specific flux rates for a new MICRODYN-NADIR SpiraSep 1060 UF module as a function of transmembrane pressure (TMP) at 25°C (77°F) are as follows:

TABLE 5. CLEAN WATER SPECIFIC FLUX AS A FUNCTION OF TMP AT 25°C (77°F)

Transmembrane pressure (TMP)		Specific flux	
bar	**psi**	**lmh/bar**	**gfd/psi**
0.03	0.5	1,278	51.1
0.07	1.0	975	39.0
0.14	2.0	698	27.9
0.21	3.0	590	23.6
0.28	4.0	520	20.8
0.34	5.0	473	18.9
0.52	7.5	395	15.8
0.69	10.0	348	13.9
0.03	0.5	1,278	51.1

3.4 Temperature correction factor (TCF)

Membrane permeate production is partially dependent on temperature. To estimate the effects of temperature alone on membrane flux, the following temperature correction factor (TCF) may be used (reference temperature is 25°C):

$$TCF = e^{1100\left(\frac{1}{298}-\frac{1}{T}\right)}$$

where:

$$T = °C + 273.15$$

The table below lists the TCF values for the temperature range of 1–30°C (33.8–86.0°F). To normalize permeate flow to 25°C (77°F), simply divide the permeate flow rate at temperature T by the corresponding TCF.

TABLE 6. SpiraSep 1060 UF MODULE SPECIFICATIONS

Temperature		Temperature correction factor (TCF)
°C	**°F**	
30	86.0	1.06
29	84.2	1.05
28	82.4	1.04
27	80.6	1.02
26	78.8	1.01
25	77.0	1.00
24	75.2	0.99

23	73.4	0.98
22	71.6	0.96
21	69.8	0.95
20	68.0	0.94
19	66.2	0.93
18	64.4	0.92
17	62.6	0.90
16	60.8	0.89
15	59.0	0.88
14	57.2	0.87
13	55.4	0.86
12	53.6	0.85
11	51.8	0.83
10	50.0	0.82
9	48.2	0.81
8	46.4	0.80
7	44.6	0.79
6	42.8	0.78
5	41.0	0.77
4	39.2	0.76
3	37.4	0.75
2	35.6	0.73
1	33.8	0.72

3.5 Backwash parameters

The following is a list of backwash parameters and specifications:

TABLE 7. BACKWASH PARAMETERS AND SPECIFICATIONS

Parameter	Specification
Typical backwash pressure	< 0.34 bar (5.0 psi)
Maximum backwash pressure	0.7 bar (10.0 psi)
Recommended backwash flux rate	68–102 lmh (40–60 gfd)
Frequency	15–30 minutes
Duration	30–60 seconds
Chlorine dosage	5.0–10.0 mg/L
Relaxation period	5–15 seconds

3.6 Chemically enhanced backwash (CEB) parameters

The following is a list of chlorine CEB parameters and specifications:

TABLE 8. CHLORINE CEB PARAMETERS AND SPECIFICATIONS

Parameter	Specification
Frequency	1–3 days
Chlorine concentration	100–300 mg/L
pH	10.5–11.0
Static soak length	15–30 minutes
Rinse duration	1–5 minutes

The following is a list of acid CEB parameters and specifications:

TABLE 9. ACID CEB PARAMETERS AND SPECIFICATIONS

Parameter	Specification
Frequency	1–3 days
pH	2.0–3.0
Static soak length	15–30 minutes
Rinse duration	1–5 minutes

WARNING: Never mix sodium hypochlorite with an acid solution as chlorine gas may be produced!

4. Operating data and normalization

It is critical in the operation of a SpiraSep system to properly monitor performance and water quality. All operating data should be normalized so that performance trends can be determined and analyzed. This will play a crucial role in determining when to clean the membranes.

The following data should be recorded for all SpiraSep systems:

Permeate, feed, and concentrate flow rates

- Transmembrane pressure (TMP)
- Feed and permeate turbidity
- Temperature
- Feed and permeate pH
- Aeration rate
- Backwash frequency and duration
- Backwash flow rate
- Backwash pressure

4.1 Data normalization

SpiraSep operating data can be normalized by calculating a temperature corrected specific flux rate. Specific flux can be calculated using the following equation:

$$J = \frac{q_{TCF}}{TMP}$$

where:

J = specific flux

q_{TCF} = temperature corrected flux

TMP = transmembrane pressure

To calculate the temperature corrected flux, use the following equation:

$$q_{TCF} = \frac{Q_p}{A \times TCF}$$

where:

Q_p = permeate flow rate

A = membrane area

TCF = temperature correction factor

The temperature correction factor (TCF) can be calculated with the following equation:

$$\mathrm{TCF} = \mathrm{e}^{1100\left(\frac{1}{298}-\frac{1}{\mathrm{T}}\right)}$$

where:

T = °C + 273.15

5. Installation procedure

MANN+HUMMEL SpiraSep 1060 UF modules are connected to a permeate line by coupling DN40. Four screws are utilized to connect the module ATD and fix them into membrane frame. To install SpiraSep 1060 elements, use the support tool to place the membrane module in a suitable position, and fix the four bolts on the bracket and the membrane module. Connect the assembly at the water inlet to the production water line using a coupling DN40 connector.

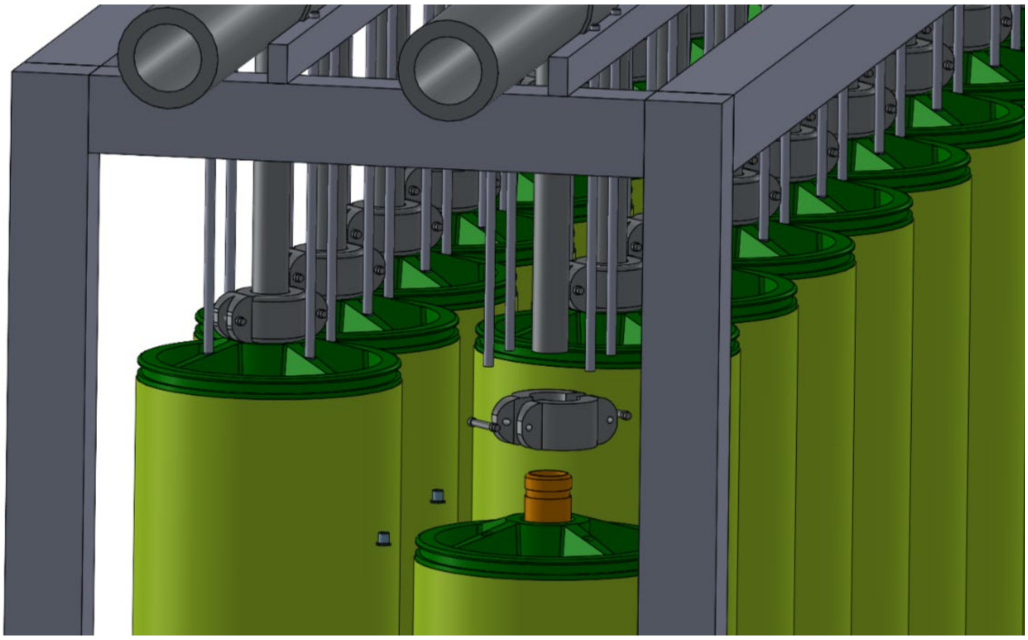

Figure 12. SpiraSep module installation

6. Cleaning procedures

6.1 Acid cleaning

1. Suitable acids for low-pH cleaning are citric, sulfuric (H_2SO_4), or hydrochloric (HCl) acids. The acid should be mixed with clean water of at least UF permeate quality. RO permeate water is preferred when available.
2. The first step in a CIP process is to drain the membrane tanks of any feed water. The purpose of this step is to purge all solids and accumulated sludge from the tank as it can decrease the cleaning strength of the CIP solution.
3. Check the water level of the UF permeate supply tank. Make sure there is enough water to fill the membrane tank.
4. Start the backwash pump. Adjust the flow rate so that the flux rate is at least 26 lmh (15 gfd) but not greater than 100 lmh (60 gfd).
5. Start the acid injection pump.
6. Check the pH of cleaning solution. The proper range is between 2.0 and 3.0 (unless otherwise specified by MANN+HUMMEL). Adjust the acid injection rate accordingly. The level of acid addition will depend on the alkalinity of the UF permeate water.
7. After the membrane tank is filled with the cleaning solution, stop the backwash and chemical metering pumps.
8. Membranes should be statically soaked in a low-pH solution for a minimum of four hours. Additional soaking time may be needed due to the type and severity of membrane fouling.
9. Start the backwash pump at a minimum flux rate of 51 lmh (30 gfd) for a period of 1 to 5 minutes. Additional backwashing may be needed depending on the type and severity of membrane fouling.
10. Drain the low-pH solution from the membrane tank. Check with local authorities on proper disposal procedures for low-pH solutions. An acid solution may need to be neutralized prior to disposal. The low pH solution should be transferred to a separate tank before neutralization.

6.2 Caustic/chlorine cleaning

1. Sodium hypochlorite (chlorine) and sodium hydroxide (caustic soda) are needed for this cleaning procedure. Chlorine and caustic should be mixed with water of at least UF permeate quality. RO permeate water is preferred, when available.
2. The first step in a CIP process is to drain the membrane tanks of any feed water. The purpose of this step is to purge all solids and accumulated sludge from the tank as it can decrease the cleaning strength of the CIP solution.
3. Check the water level of UF permeate supply tank. Make sure there is enough water to fill the membrane tank.
4. Start the backwash pump. Adjust the flow rate so that the flux rate is at least 26 lmh (15 gfd) but not greater than 100 lmh (60 gfd).
5. Start the chlorine and caustic injection pumps.
6. Adjust the chlorine injection rate to achieve a concentration no greater than 2,000 mg/L in the backwash water.
7. Check the pH of the solution. The proper pH range is between 10.5 and 11.0 (unless otherwise specified by MANN+HUMMEL). Adjust the injection rate of caustic accordingly to achieve the desired pH. The level of caustic addition will depend on the alkalinity of the UF permeate water.
8. After the membrane tank is filled with the cleaning solution, stop the backwash and chemical metering pumps.
9. Membranes should be statically soaked in a chlorine solution for a minimum of two hours. Additional soaking time may be needed due to the type and severity of membrane fouling.
10. Start the backwash pump at a minimum flux rate of 51 lmh (30 gfd) for a period of 1 to 5 minutes. Additional backwashing may be needed depending on the type and severity of membrane fouling.
11. Drain the chlorine solution from the membrane tank. Check with local authorities on proper disposal procedures for chlorine and caustic solutions. The solution may need to be neutralized prior to disposal. A chlorine solution should be transferred to a separate tank before neutralization.

7. Membrane storage

It is imperative to properly follow element storage instructions as membrane properties can be permanently compromised if not properly followed.

At all times during storage, MANN+HUMMEL SpiraSep 1060 UF modules must be fully saturated with water of UF permeate quality or better to prevent pore drying.

7.1 Short-term element storage

For systems that will be temporarily shut down for short periods of time (under three weeks), the elements should be stored in a solution of water and sodium hypochlorite at neutral pH. Water quality should be UF permeate quality or better. A free chlorine residual of 2.0 to 5.0 mg/L should be maintained within the membrane tank at all times throughout this period. This will minimize microbiological activity and reduce the chance of scaling. A new solution should be prepared weekly.

7.2 Long-term element storage

SpiraSep UF modules stored in the factory shipping solution will retain the flow/particulate retention characteristics for a period of at least 12 months from the date of shipment ex-works, or 12 months following the addition of the sanitizing/storage solution if the elements remain sealed, away from direct sunlight, and at storage temperatures between 0–25°C (32–77°F). The optimal storage temperature for periods exceeding three months is 15°C (59°F). If elements are to be stored for periods greater than 12 months, consult MANN+HUMMEL Corporation for procedures to minimize long-term effects.

For systems that will be out of service for more than three weeks, it is recommended that all elements be removed from the system and vacuum sealed in individual bags with a storage solution of 1 wt% sodium metabisulfite and 18% glycerin in RO permeate water at a pH of 3 to 4 and replaced monthly.

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