MICRODYN SpiraSep™ 960 Ultrafiltration Modules

Product Manual

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1 Technology Overview

1.1 MICRODYN SpiraSep™ 960 ULTRAFILTRATION MODULE DESCRIPTION

MICRODYN SpiraSep™ 960 Ultrafiltration (UF) modules are immersed and vacuum-operated spiral-wound membranes complete with backwashing and aeration capabilities. SpiraSep modules are spiral-wound membrane elements with a fouling-resistant polyvinylidene fluoride (PVDF) barrier layer. Suspended solids, turbidity, viruses, bacteria and some organic compounds are removed by the SpiraSep process.

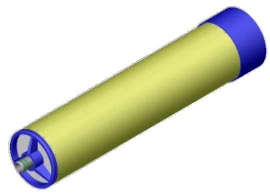

Figure 1. SpiraSep 960 UF module.

1.2 MANIFOLD ASSEMBLY

A system using SpiraSep modules consists of an array of spiral-wound elements submerged inside a process tank. The membrane elements are attached to a manifold assembly, consisting of a central permeate header with an array of membrane permeate ports, which connect to an individual SpiraSep module.

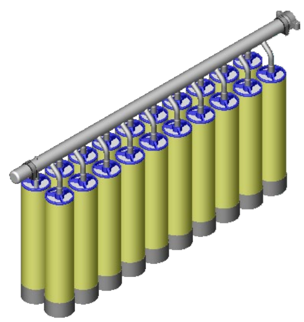

Figure 2. SpiraSep 960 manifold assembly.

1.3 PLANT CONFIGURATION

A submerged UF system generally consists of the following components:

- Multiple manifold assemblies submerged in a process tank
- Main permeate header connecting manifold assemblies
- 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 bubbled up through each membrane element. The convective flow of air and water actively scours the membrane surface, removing particulate matter from the element.

Figure 3. SpiraSep process trains.

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 – 30 minutes permeate production is halted and permeate water is backwashed through the membrane elements for 30 – 60 seconds. 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 – 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 maximum TMP of the UF system is reached. As a general guideline, the maximum TMP of 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 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 (2) hours. Additional backwashing is performed after the static soak for the purpose of removing additional solids and particulate matter. The cleaning solution is removed 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 MICRODYN SpiraSep™ 960 UF modules, an array of membrane manifold assemblies is submerged in a common process tank. Each membrane manifold assembly is connected to a main header 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 “pull” water through the SpiraSep membranes. Air is bubbled up through each membrane element via bubble diffusers, creating tremendous shear forces on the membrane surface that remove suspended solids from the membrane surface.

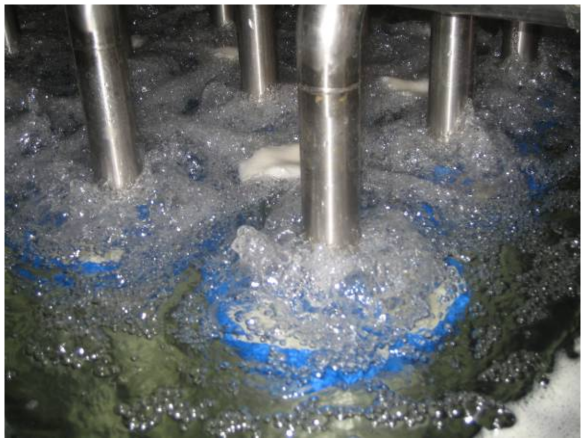

Figure 4. Membrane aeration process.

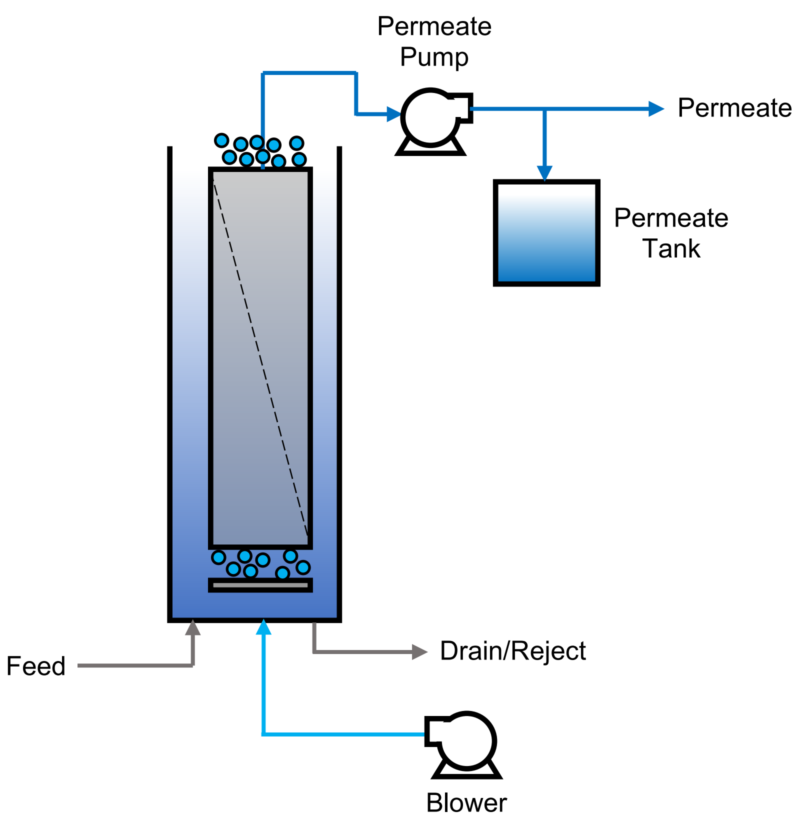

Figure 5. Permeate production.

1.5.2 Backwash Operation

Periodically (on a timed basis), permeate water is reversed through the membrane, or 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.

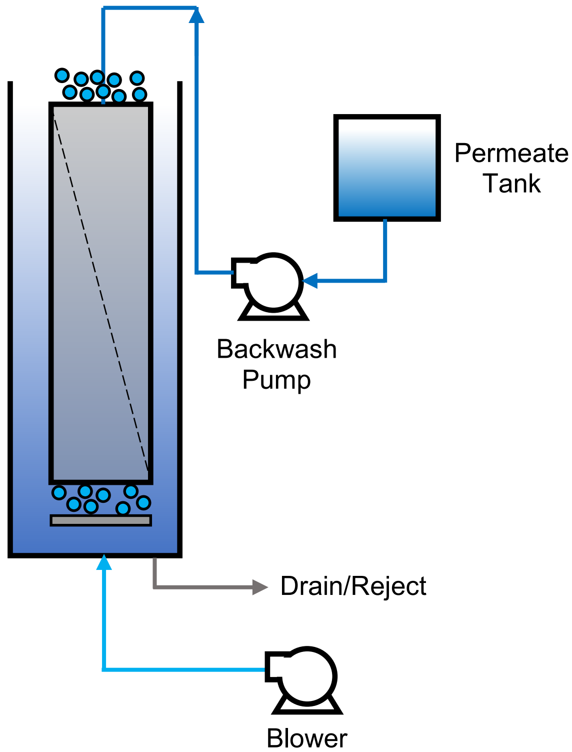

Figure 6. Backwash operation.

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 (these CEB's 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 – 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 are essentially the same, where the chemical is backwashed through the membranes followed by a soak period and additional backwashing.

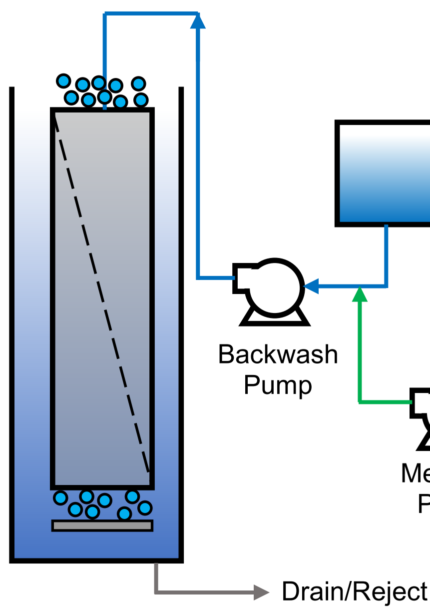

Figure 7. Periodic flux enhancement (maintenance clean).

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 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 removed 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 (2) 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.

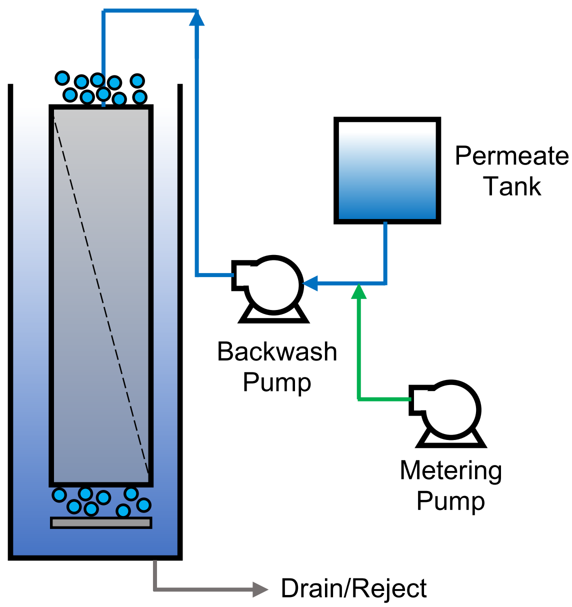

Figure 8. Recovery clean (CIP) process.

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

2 Features & Benefits

MICRODYN SpiraSep™ 960 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 microm chemistry enhances membrane fouling resistance and permeability characteristics. MICRODYN-NADIR engineers 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 backwash 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, as well as creating 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.

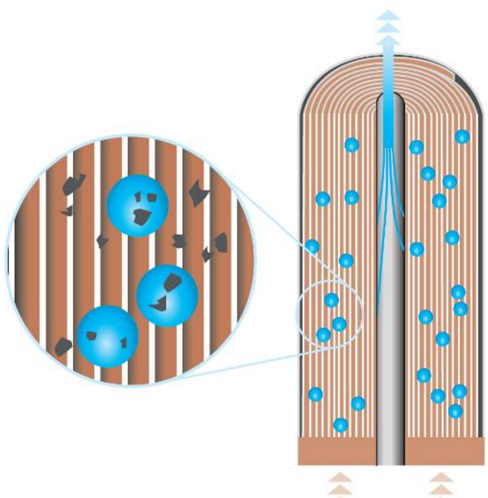

Figure 9. Membrane air scour.

2.2 OPEN FEED CHANNEL

A key feature of the MICRODYN SpiraSep™ 960 UF module is a specialized, corrugated feed spacer which creates open flow channels in the element. Conventional feed spacer materials used in RO spiral-wound membranes are unsuitable for high TSS operation. As a result, MICRODYN-NADIR engineers developed a corrugated sheet that creates a wide, open feed channel that prevents fouling. Air is able to flow upward through each individual flow channel and scrub solids from the membrane.

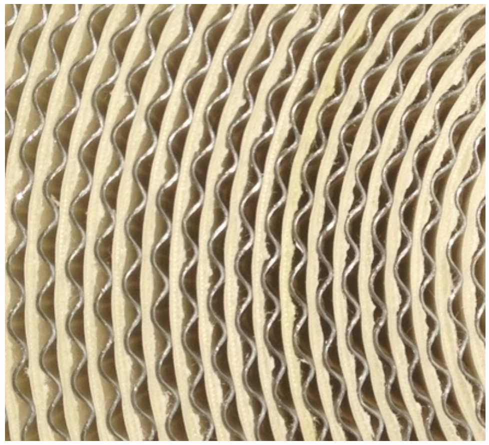

Figure 10. Corrugated flow channel spacer.

2.3 LOW-FOULING CHEMISTRY

MICRODYN-NADIR engineers 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.

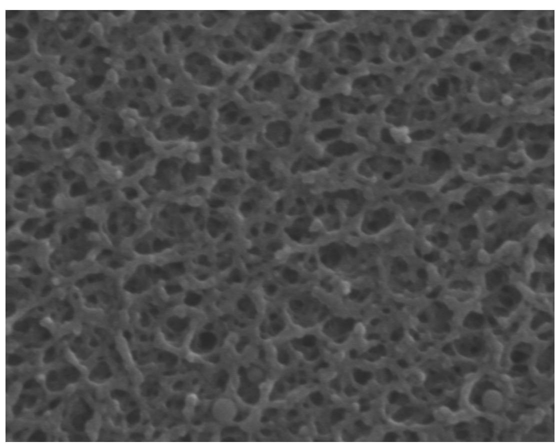

Figure 11. UF membrane surface.

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 MICRODYN SpiraSep™ 960 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:

- 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 follow a “saw-tooth” pattern (as shown in Figure 12). This reduces, in some cases, the average TSS concentration by 40 – 50% compared to traditional submerged membrane systems.

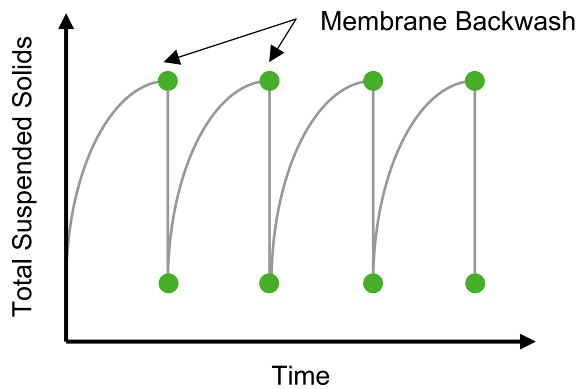

Figure 12. Total Suspended Solids (TSS) profile in SpiraSep UF membranes.

2.6 OPEN-ENDED DESIGN

SpiraSep’s open-ended design allows cake layer to exit the top and bottom of the element during backwash, as well as creating 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 corresponds to easy installation and replacement and is less susceptible to fouling.

3 Technical Specifications

3.1 ELEMENT SPECIFICATIONS

TABLE 1. MICRODYN SpiraSep™ 960 UF MODULE SPECIFICATIONS.

Parameter	Specification
Element Diameter	238 mm (9.4 inches)
Element Length	1016 mm (40.0 inches)
Element Feed Spacer	2.3 mm (0.090 inches) corrugated sheet
Active Membrane Area	20.9 mm^2 (225 ft^2)
Membrane Chemistry	Polyvinylidene fluoride (PVDF) or Polyethersulfone (PES)
Average Pore Size	0.03 micron

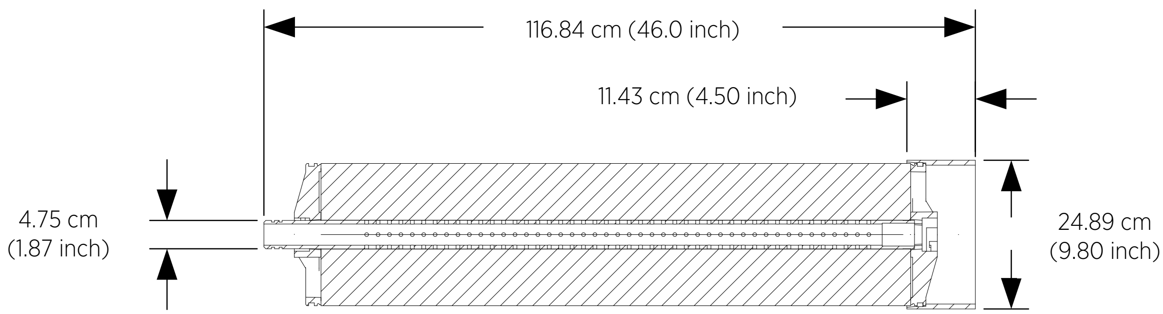

Figure 13. SpiraSep UF module dimensions.

3.2 CHEMICAL COMPATIBILITY

TABLE 2. SpiraSep CHEMICAL COMPATIBILITY.

Parameter	Specification
Maximum Chlorine Exposure	2,000 mg/L [1]
Operating pH	2.0 – 11.0 [2]
Cleaning pH	2.0 – 12.0 [2]
Recommended Coagulants	Ferric sulfate, ferric chloride
Recommended Maximum Coagulant Concentration	10.0 mg/L

[1] Temperature < 40°C (104°F), pH < 11.5
[2] Temperature < 40°C (104°F)
[3] Approved coagulants are ferric chloride and ferric sulfate. For all other types of coagulants, please contact MICRODYN-NADIR.

3.3 CLEAN WATER FLUX RATES

The clean water specific flux rates for a new MICRODYN-NADIR SpiraSep™ 960 UF module as a function of transmembrane pressure (TMP) at 25°C (77°F) are:

TABLE 3. 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

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).

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

where

$$T = {}^{\circ}\mathrm{C} + 273.15$$

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 4. TEMPERATURE CORRECTION FACTORS.

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 5. 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 PARAMETERS (CEB)

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

TABLE 6. CHLORINE CEB PARAMETERS AND SPECIFICATIONS.

Parameter	Specification
Frequency	24 hours
Chlorine Concentration	100 – 1,000 mg/L
pH	9.0 – 11.5
Static Soak Length	5 – 15 minutes
Rinse Duration	1 – 5 minutes

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

TABLE 7. ACID CEB PARAMETERS AND SPECIFICATIONS.

Parameter	Specification
Frequency	1 – 3 days
pH	2.0 – 3.0
Static Soak Length	5 – 15 minutes
Rinse Duration	1 – 5 minutes

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

4 Operating Data & 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:

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

where

J = specific flux
$\mathrm{q_{TCF}}$ = temperature corrected flux
TMP = transmembrane pressure

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

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

where

$\mathrm{Q_p}$ = 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

MICRODYN SpiraSep™ 960 UF modules are connected to a permeate manifold that is positioned vertically over the membrane tank. A bayonet style fitting is utilized to connect the membranes and lock them into place. To install SpiraSep 960 elements, the permeate manifold is hoisted using an overhead crane or suitable lifting device. Once the manifold has been secured to prevent swaying or moving, the membranes can be installed. First, apply glycerin to the o-rings on the core tube to allow for easier insertion. Push the element up into the manifold permeate tube while making sure the manifold tabs are aligned with the slots on the element ATD. Once the element has been completely inserted into the manifold, twist the element in a counter clockwise direction.

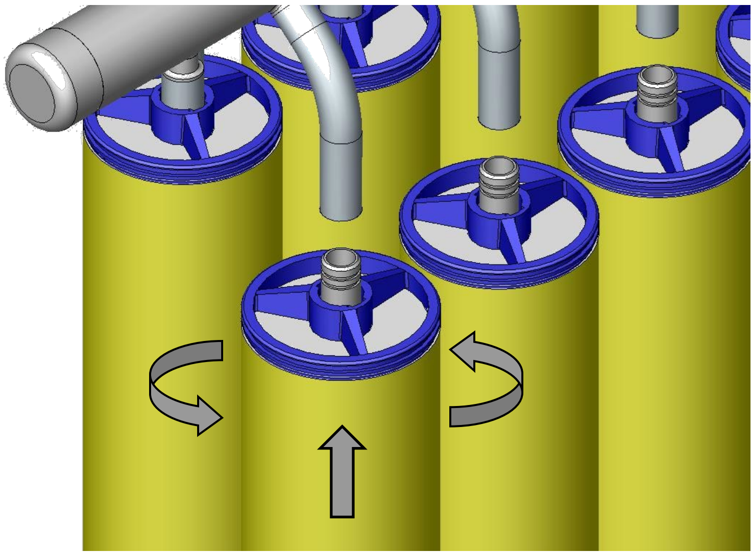

Figure 14. SpiraSep module installation.

6 Cleaning Procedures

6.1 ACID CLEANING

1. Suitable acids for low pH cleaning: citric acid, sulfuric acid (H_2SO_4), or hydrochloric (HCl). 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 water level of UF permeate supply tank. Make sure there is enough water to fill the membrane tank.
4. Start backwash pump. Adjust flow rate so that the minimum flux rate is 26 lmh (15 gfd), but not greater than 100 lmh (60 gfd).
5. Start acid injection pump.
6. Check pH of cleaning solution. Proper range is between 2.0 – 3.0, unless otherwise specified by MICRODYN-NADIR. Adjust acid injection rate accordingly. Level of acid addition will depend on the alkalinity of UF permeate water.
7. After membrane tank is filled with the cleaning solution, stop backwash and chemical metering pumps.
8. Membranes should be statically soaked in low pH solution for a minimum of four (4) hours. Additional soaking time may be needed due to type and severity of membrane fouling.
9. Start backwash pump at a minimum flux rate of 51 lmh (30 gfd) for a period of 1 – 5 minutes. Additional backwashing may be needed depneding on the type and severity of membrane fouling.
10. Drain low pH solution from membrane tank. Check with local authorities on proper disposal procedures for low pH solution. Acid solution may need to be neutralized prior to disposal. 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 water level of UF permeate supply tank. Make sure there is enough water to fill the membrane tank.
4. Start backwash pump. Adjust flow rate so that the minimum flux rate is 26 lmh (15 gfd), but not greater than 100 lmh (60 gfd).
5. Start chlorine and caustic injection pumps.
6. Adjust chlorine injection rate to achieve a concentration no greater than 2,000 mg/L in backwash water.
7. Check pH of solution. Proper pH range is 10.5 – 11.5, unless otherwise specified by MICRODYN-NADIR. Adjust injection rate of caustic accordingly to achieve desired pH. Level of caustic addition will depend on the alkalinity of the UF permeate water.
8. After membrane tank is filled with the cleaning solution, stop backwash and chemical metering pumps.
9. Membranes should be statically soaked in chlorine solution for a minimum of two (2) hours. Additional soaking time may be needed due to type and severity of membrane fouling.
10. Start backwash pump at a minimum flux rate of 51 lmh (30 gfd) for a period of 1 – 5 minutes. Additional backwashing may be needed depending on the type and severity of membrane fouling.
11. Drain chlorine solution from membrane tank. Check with local authorities on proper disposal procedures for chlorine and caustic solution. Solution may need to be neutralized prior to disposal. 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 transport properties can be permanently compromised if not properly followed.

At all times during storage, MICRODYN SpiraSep™ 960 UF modules must be fully saturated with water of UF permeate quality or better so as to prevent pore drying.

7.1 SHORT TERM ELEMENT STORAGE

Systems that will be temporarily shut down for short periods of time (less than 2 – 3 weeks), the elements should be stored in a solution of water and sodium hypochlorite at neutral pH. Water quality shall be UF permeate or better. A free chlorine residual of 2.0 – 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 twelve (12) months from date of shipment ex-works, or twelve (12) months following the addition of the sanitizing/storage solution is 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 (3) months is 15°C (59°F). If elements are to be stored for periods greater than twelve (12) months, consult TriSep Corporation for procedures to minimize long-term effects.

For systems that will be out of service for more than 2 – 3 weeks, it is recommended that all elements be removed from the system and vacuum sealed in individual bags with a storage solution of 2 wt% sodium metabisulfite and 18% glycerin in RO permeate water at a pH of 3 – 4, and replaced monthly.